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Programming

Perl

Tom Christiansen,
brian d foy & Larry Wall
with Jon Orwant

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Programming Perl

Adopted as the undisputed Perl bible soon after the first edition appeared in 1991, *Programming Perl* is still the go-to guide for this highly practical language. Perl began life as a super-fueled text processing utility, but quickly evolved into a general-purpose programming language that's helped hundreds of thousands of programmers, system administrators, and enthusiasts—like you—get your job done.

In this much-anticipated update to "the Camel," three renowned Perl authors cover the language up to its current version, Perl 5.14, with a preview of features in the upcoming 5.16. In a world where Unicode is increasingly essential for text processing, Perl offers the best and least painful support of any major language, smoothly integrating Unicode everywhere—including in Perl's most popular feature: regular expressions.

Important features covered by this update include:

- New keywords and syntax
- I/O layers and encodings
- New backslash escapes
- Unicode 6.0
- Unicode grapheme clusters and properties
- Named captures in regexes
- Recursive and grammatical patterns
- Expanded coverage of CPAN
- Current best practices

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Tom Christiansen, brian d foy & Larry Wall
with Jon Orwant

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by Tom Christiansen, brian d foy & Larry Wall, with Jon Orwant

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Preface

The Pursuit of Happiness

Perl is a language for getting your job done.

Of course, if your job is programming, you can get your job done with any "complete" computer language, theoretically speaking. But we know from experience that computer languages differ not so much in what they make *possible*, but in what they make *easy*. At one extreme, the so-called "fourth generation languages" make it easy to do some things, but nearly impossible to do other things. At the other extreme, so-called "industrial-strength" languages make it equally difficult to do almost everything.

Perl is different. In a nutshell, Perl is designed to make the easy jobs easy, without making the hard jobs impossible.

And what are these "easy jobs" that ought to be easy? The ones you do every day, of course. You want a language that makes it easy to manipulate numbers and text, files and directories, computers and networks, and especially programs. It should be easy to run external programs and scan their output for interesting tidbits. It should be easy to send those same tidbits off to other programs that can do special things with them. It should be easy to develop, modify, and debug your own programs, too. And, of course, it should be easy to compile and run your programs, and do it portably, on any modern operating system.

Perl does all that, and a whole lot more.

Initially designed as a glue language for Unix, Perl has long since spread to most other operating systems. Because it runs nearly everywhere, Perl is one of the most portable programming environments available today. To program C or C ++ portably, you have to put in all those strange `#ifdef` markings for different operating systems. To program Java portably, you have to understand the idiosyncrasies of each new Java implementation. To program a shell script portably, you have to remember the syntax for each operating system's version of each

command, and somehow find the common factor that (you hope) works everywhere. And to program Visual Basic portably, you just need a more flexible definition of the word "portable". :-)

Perl happily avoids such problems while retaining many of the benefits of these other languages, with some additional magic of its own. Perl's magic comes from many sources: the utility of its feature set, the inventiveness of the Perl community, and the exuberance of the open source movement in general. But much of this magic is simply hybrid vigor; Perl has a mixed heritage, and has always viewed diversity as a strength rather than a weakness. Perl is a "give me your tired, your poor" language. If you feel like a huddled mass longing to be free, then Perl is for you.

Perl reaches out across cultures. Much of the explosive growth of Perl was fueled by the hankerings of *former* Unix systems programmers who wanted to take along with them as much of the "old country" as they could. For them, Perl is the portable distillation of Unix culture, an oasis in the wilderness of "can't get there from here". On the other hand, it also works in the other direction: Windows-based web designers are often delighted to discover that they can take their Perl programs and run them unchanged on the company's Unix servers.

Although Perl is especially popular with systems programmers and web developers, that's just because they discovered it first; Perl appeals to a much broader audience. From its small start as a text-processing language, Perl has grown into a sophisticated, general-purpose programming language with a rich software development environment complete with debuggers, profilers, cross-referencers, compilers, libraries, syntax-directed editors, and all the rest of the trappings of a "real" programming language—if you want them. But those are all about making hard things possible; and lots of languages can do that. Perl is unique in that it never lost its vision for keeping easy things easy.

Because Perl is both powerful and accessible, it is being used daily in every imaginable field, from aerospace engineering to molecular biology, from mathematics to linguistics, from graphics to document processing, from database manipulation to client-server network management. Perl is used by people who are desperate to analyze or convert lots of data quickly, whether you're talking DNA sequences, web pages, or pork belly futures.

There are many reasons for the success of Perl. Perl was a successful open source project long before the open source movement got its name. Perl is free, and it will always be free. You can use Perl however you see fit, subject only to a very liberal licensing policy. If you are in business and want to use Perl, go right ahead. You can embed Perl in the commercial applications you write without fee or

restriction. And if you have a problem that the Perl community can't fix, you have the ultimate backstop: the source code itself. The Perl community is not in the business of renting you their trade secrets in the guise of "upgrades". The Perl community will never "go out of business" and leave you with an orphaned product.

It certainly helps that Perl is free software. But that's not enough to explain the Perl phenomenon, since many freeware packages fail to thrive. Perl is not just free; it's also fun. People feel like they can be creative in Perl, because they have freedom of expression: they get to choose what to optimize for, whether that's computer speed or programmer speed, verbosity or conciseness, readability or maintainability or reusability or portability or learnability or teachability. You can even optimize for obscurity, if you're entering an Obfuscated Perl Contest.

Perl can give you all these degrees of freedom because it's a language with a split personality. It's simultaneously a very simple language and a very rich language. Perl has taken good ideas from nearly everywhere, and installed them into an easy-to-use mental framework. To those who merely like it, Perl is the *Practical Extraction and Report Language*. To those who love it, Perl is the *Pathologically Eclectic Rubbish Lister*. And to the minimalists in the crowd, Perl seems like a pointless exercise in redundancy. But that's okay. The world needs a few reductionists (mainly as physicists). Reductionists like to take things apart. The rest of us are just trying to get it together.

There are many ways in which Perl is a simple language. You don't have to know many special incantations to compile a Perl program—you can just execute it like a batch file or shell script. The types and structures used by Perl are easy to use and understand. Perl doesn't impose arbitrary limitations on your data—your strings and arrays can grow as large as they like (so long as you have memory), and they're designed to scale well as they grow. Instead of forcing you to learn new syntax and semantics, Perl borrows heavily from other languages you may already be familiar with (such as C, and *awk*, and BASIC, and Python, and English, and Greek). In fact, just about any programmer can read a well-written piece of Perl code and have some idea of what it does.

Most important, you don't have to know everything there is to know about Perl before you can write useful programs. You can learn Perl "small end first". You can program in Perl Baby-Talk, and we promise not to laugh. Or more precisely, we promise not to laugh any more than we'd giggle at a child's creative way of putting things. Many of the ideas in Perl are borrowed from natural language, and one of the best ideas is that it's okay to use a subset of the language as long as you get your point across. Any level of language proficiency is acceptable in

Perl culture. We won't send the language police after you. A Perl script is "correct" if it gets the job done before your boss fires you.

Though simple in many ways, Perl is also a rich language, and there is much to be learned about it. That's the price of making hard things possible. Although it will take some time for you to absorb all that Perl can do, you will be glad to have access to Perl's extensive capabilities when the time comes that you need them.

Because of its heritage, Perl was a rich language even when it was "just" a data-reduction language designed for navigating files, scanning large amounts of text, creating and obtaining dynamic data, and printing easily formatted reports based on that data. But somewhere along the line, Perl started to blossom. It also became a language for filesystem manipulation, process management, database administration, client-server programming, secure programming, Web-based information management, and even for object-oriented and functional programming. These capabilities were not just slapped onto the side of Perl—each new capability works synergistically with the others, because Perl was designed to be a glue language from the start.

But Perl can glue together more than its own features. Perl is designed to be modularly extensible. Perl allows you to rapidly design, program, debug, and deploy applications, and it also allows you to easily extend the functionality of these applications as the need arises. You can embed Perl in other languages, and you can embed other languages in Perl. Through the module importation mechanism, you can use these external definitions as if they were built-in features of Perl. Object-oriented external libraries retain their object-orientedness in Perl.

Perl helps you in other ways, too. Unlike a strictly interpreted language such as command files or shell scripts, which compile and execute a program one command at a time, Perl first compiles your whole program quickly into an intermediate format. Like any other compiler, it performs various optimizations, and gives you instant feedback on everything from syntax and semantic errors to library binding mishaps. Once Perl's compiler frontend is happy with your program, it passes off the intermediate code to the interpreter to execute (or optionally to any of several modular backends that can emit C or bytecode). This all sounds complicated, but the compiler and interpreter are quite efficient, and most of us find that the typical compile-run-fix cycle is measured in mere seconds. Together with Perl's many fail-soft characteristics, this quick turnaround capability makes Perl a language in which you really can do rapid prototyping. Then later, as your program matures, you can tighten the screws on yourself, and make yourself program with less flair but more discipline. Perl helps you with that, too, if you ask nicely.

Perl also helps you to write programs more securely. In addition to all the typical security interfaces provided by other languages, Perl also guards against accidental security errors through a unique data tracing mechanism that automatically determines which data came from insecure sources and prevents dangerous operations before they can happen. Finally, Perl lets you set up specially protected compartments in which you can safely execute Perl code of dubious origin, masking out dangerous operations.

But, paradoxically, the way in which Perl helps you the most has almost nothing to do with Perl, and everything to do with the people who use Perl. Perl folks are, frankly, some of the most helpful folks on earth. If there's a religious quality to the Perl movement, then this is at the heart of it. Larry wanted the Perl community to function like a little bit of heaven, and by and large he seems to have gotten his wish, so far. Please do your part to keep it that way.

Whether you are learning Perl because you want to save the world, or just because you are curious, or because your boss told you to, this handbook will lead you through both the basics and the intricacies. And although we don't intend to teach you how to program, the perceptive reader will pick up some of the art, and a little of the science, of programming. We will encourage you to develop the three great virtues of a programmer: *laziness*, *impatience*, and *hubris*. Along the way, we hope you find the book mildly amusing in some spots (and wildly amusing in others). And if none of this is enough to keep you awake, just keep reminding yourself that learning Perl will increase the value of your resume. So keep reading.

What's New in This Edition

What's not new? It's been a long time since we've updated this book. Let's just say we had a couple of distractions, but we're all better now.

The third edition was published in the middle of 2000, just as Perl v5.6 was coming out. As we write this, it's 12 years later and Perl v5.16 is coming out soon. A lot has happened in those years, including several new releases of Perl 5, and a little thing we call Perl 6. That 6 is deceptive though; Perl 6 is really a "kid sister" language to Perl 5, and not just a major update to Perl 5 that version numbers have trained you to expect. This book isn't about that other language. It's still

about Perl 5, the version that most people in the world (even the Perl 6 folks!) are still using quite productively.[1]

To tell you what's new in this book is to tell you what's new in Perl. This isn't just a facelift to spike book sales. It's a long anticipated major update for a language that's been very active in the past five years. We won't list everything that's changed (you can read the *perldelta* pages), but there are some things we'd like to call out specifically.

In Perl 5, we started adding major new features, along with a way to shield older programs from new keywords. For instance, we finally relented to popular demand for a `switch`-like statement. In typical Perl fashion, though, we made it better and more fancy, giving you more control to do what you need to do. We call it `given-when`, but you only get that feature if you ask for it. Any of these statements enable the feature:

```
use v5.10;
use feature qw(switch);
use feature qw(:5.10);
```

and once enabled, you have your super-charged `switch`:

```
given ($item) {
  when (/a/)   { say "Matched an a"  }
  when (/bee/) { say "Matched a bee" }
}
```

You'll see more about that in Chapter 4, along with many of the other new features as they appear where they make the most sense.

Although Perl has had Unicode support since v5.6, that support is greatly improved in recent versions, including better regular expression support than any other language at the moment. Perl's better-and-better support is even acting as a testbed for future Unicode developments. In the previous edition of this book, we had all of that Unicode stuff in one chapter, but you'll find it throughout this book when we need it.

Regular expressions, the feature that many people associate with Perl, are even better. Other languages stole Perl's pattern language, calling it Perl Compatible Regular Expressions, but also adding some features of their own. We've stolen back some of those features, continuing Perl's tradition of taking the best ideas from everywhere and everything. You'll also find powerful new features for dealing with Unicode in patterns.

1. Since we're lazy, and since by now you already know this book is about Perl 5, we should mention that we won't always spell out "Perl v5.*n*"—for the rest of this book, if you see a bare version number that starts with "v5", just assume we're talking about that version of Perl.

Threads are much different today, too. Perl used to support two thread models: one we called `5005threads` (because that's when we added them), and interpreter threads. As of v5.10, it's just the interpreter threads. However, for various reasons, we didn't think we could do the topic justice in this edition since we dedicated our time to many of the other features. If you want to learn about threads, see the *perlthrtut* manpage, which would have been approximately the same thing our "Threads" chapter would have been. Maybe we can provide a bonus chapter later, though.

Other things have come or gone. Some experiments didn't work out and we took them out of Perl, replacing them with other experiments. Pseudohashes, for instance, were deprecated, removed, and forgotten. If you don't know what those are, don't worry about it, but don't look for them in this edition either.

And, since we last updated this book, there's been a tremendous revolution (or two) in Perl programming practice as well as its testing culture. CPAN (the Comprehensive Perl Archive Network) continues to grow exponentially, making it Perl's killer feature. This isn't a book about CPAN, though, but we tell you about those modules when they are important. Don't try to do everything with just vanilla Perl.

We've also removed two chapters, the list of modules in the Standard Library (Chapter 32 in the previous edition) and the diagnostic messages (Chapter 33 in the previous edition). Both of these will be out of date before the book even gets on your bookshelf. We'll show you how to get that list yourself. For the diagnostic messages, you can find all of them in the *perldiag* manpage, or turn warnings into longer messages with the `diagnostics` pragma.

Part I, Overview
: Getting started is always the hardest part. This part presents the fundamental ideas of Perl in an informal, curl-up-in-your-favorite-chair fashion. Not a full tutorial, it merely offers a quick jump-start, which may not serve everyone. See the section on "Offline Documentation" below for other books that might better suit your learning style.

Part II, The Gory Details
: This part consists of an in-depth, no-holds-barred discussion of the guts of the language at every level of abstraction, from data types, variables, and regular expressions, to subroutines, modules, and objects. You'll gain a good sense of how the language works, and in the process, pick up a few hints on good software design. (And if you've never used a language with pattern matching, you're in for a special treat.)

Part III, Perl As Technology
: You can do a lot with Perl all by itself, but this part will take you to a higher level of wizardry. Here you'll learn how to make Perl jump through whatever hoops your computer sets up for it, everything from dealing with Unicode, interprocess communication and multithreading, through compiling, invoking, debugging, and profiling Perl, on up to writing your own external extensions in C or C++, or interfaces to any existing API you feel like. Perl will be quite happy to talk to any interface on your computer—or, for that matter, on any other computer on the Internet, weather permitting.

Part IV, Perl As Culture
: Everyone understands that a culture must have a language, but the Perl community has always understood that a language must have a culture. This part is where we view Perl programming as a human activity, embedded in the real world of people. We'll cover how you can improve the way you deal with both good people and bad people. We'll also dispense a great deal of advice on how you can become a better person yourself, and on how to make your programs more useful to other people.

Part V, Reference Material
: Here we've put together all the chapters in which you might want to look something up alphabetically, everything from special variables and functions to standard modules and pragmas. The Glossary will be particularly helpful to those who are unfamiliar with the jargon of computer science. For example, if you don't know what the meaning of "pragma" is, you could look it up right now. (If you don't know what the meaning of "is" is, we can't help you with that.)

The Standard Distribution

The official Perl policy, as noted in *perlpolicy*, is that the last two maintenance releases are officially supported. Since the current release as we write this is v5.14, that means both v5.12 and v5.14 are officially supported. When v5.16 is released, v5.12 won't be supported anymore.

Most operating system vendors these days include Perl as a standard component of their systems, although their release cycles might not track the latest Perl. As of this writing, AIX, BeOS, BSDI, Debian, DG/UX, DYNIX/ptx, FreeBSD, IRIX, LynxOS, Mac OS X, OpenBSD, OS390, RedHat, SINIX, Slackware, Solaris, SuSE, and Tru64 all came with Perl as part of their standard distributions. Some companies provide Perl on separate CDs of contributed freeware or through their customer service groups. Third-party companies like ActiveState offer prebuilt

Perl distributions for a variety of different operating systems, including those from Microsoft.

Even if your vendor does ship Perl as standard, you'll probably eventually want to compile and install Perl on your own. That way you'll know you have the latest version, and you'll be able to choose where to install your libraries and documentation. You'll also be able to choose whether to compile Perl with support for optional extensions such as multithreading, large files, or the many low-level debugging options available through the *–D* command-line switch. (The user-level Perl debugger is always supported.)

The easiest way to download a Perl source kit is probably to point your web browser to Perl's homepage, where you'll find download information prominently featured on the start-up page, along with links to precompiled binaries for platforms that have misplaced their C compilers.

You can also head directly to CPAN, described in Chapter 19, using *http://www.cpan.org*. If those are too slow for you (and they might be, because they're *very* popular), you should find a mirror close to you. The MIRRORED.BY file there contains a list of all other CPAN sites, so you can just get that file and then pick your favorite mirror. Some of them are available through FTP, others through HTTP (which makes a difference behind some corporate firewalls). The *http://www.cpan.org* multiplexor attempts to do this selection for you. You can change your selection if you like later.

Once you've fetched the source code and unpacked it into a directory, you should read the *README* and the *INSTALL* files there to learn how to build Perl. There may also be an *INSTALL.platform* file for you to read there, where *platform* represents your operating system platform.

If your *platform* happens to be some variety of Unix, then your commands to fetch, configure, build, and install Perl might resemble what follows. First, you must choose a command to fetch the source code. You can download via the Web using a browser or a command-line tool:

```
% wget http://www.cpan.org/src/5.0/maint.tar.gz
```

Now unpack, configure, build, and install:

```
% tar zxf latest.tar.gz     # or gunzip first, then tar xf
% cd perl-5.14.2            # or 5.* for whatever number
% sh Configure -des         # assumes default answers
% make test && make install # install typically requires superuser
```

Your platform might already have packages that do this work for you (as well as providing platform-specific fixes or enhancements). Even then, many platforms already come with Perl, so you might not need to do anything.

If you already have Perl but want a different version, you can save yourself some work by using the *perlbrew* tool. It automates all of this for you and installs it where you (should) have permissions to install files so you don't need any administrator privileges. It's on CPAN as `App::perlbrew`, but you can also install it according to the documentation:

```
% curl -L http://xrl.us/perlbrewinstall | bash
```

Once installed, you can let the tool do all the work for you:

```
% ~/perl5/perlbrew/bin/perlbrew install perl-5.14.2
```

There's a lot more that perlbrew can do for you, so see its documentation.

You can also get enhanced versions of the standard Perl distribution. ActiveState offers ActivePerl for free for Windows, Mac OS X, and Linux, and for a fee for Solaris, HP-UX, and AIX.

Strawberry Perl is Windows-only, and it comes with the various tools you need to compile and install third-party Perl modules for CPAN.

Citrus Perl is a distribution for Windows, Mac OS X, and Linux that bundles wxPerl tools for creating GUIs. It's targeted at people who want to create distributed GUI applications with Perl instead of a general-purpose Perl. Its Cava Packager tool helps you do that.

Online Documentation

Perl's extensive online documentation comes as part of the standard Perl distribution. (See the next section for offline documentation.) Additional documentation shows up whenever you install a module from CPAN.

When we refer to a "Perl manpage" in this book, we're talking about this set of online Perl manual pages, sitting on your computer. The name *manpage* is purely a convention meaning a file containing documentation—you don't need a Unix-style *man* program to read one. You may even have the Perl manpages installed as HTML pages, especially on non-Unix systems.

The online manpages for Perl have been divided into separate sections so you can easily find what you are looking for without wading through hundreds of pages of text. Since the top-level manpage is simply called *perl*, the Unix command "`man perl`" should take you to it.[2] That page in turn directs you to more specific

2. If you still get a truly humongous page when you do that, you're probably picking up the ancient v4 manpage. Check your `MANPATH` for archaeological sites. (Say "`perldoc perl`" to find out how to configure your `MANPATH` based on the output of "`perl -V:man.dir`".)

pages. For example, "`man perlre`" will display the manpage for Perl's regular expressions. The *perldoc* command often works on systems when the *man* command won't. Your port may also provide the Perl manpages in HTML format or your system's native help format. Check with your local sysadmin, unless you're the local sysadmin. In which case, ask the monks at *http://perlmonks.org*.

Navigating the Standard Manpages

In the Beginning (of Perl, that is, back in 1987), the *perl* manpage was a terse document, filling about 24 pages when typeset and printed. For example, its section on regular expressions was only two paragraphs long. (That was enough, if you knew *egrep*.) In some ways, nearly everything has changed since then. Counting the standard documentation, the various utilities, the per-platform porting information, and the scads of standard modules, we now have thousands of typeset pages of documentation spread across many separate manpages. (And that's not counting any CPAN modules you install, which is likely to be quite a few.)

But in other ways, nothing has changed: there's still a *perl* manpage kicking around. And it's still the right place to start when you don't know where to start. The difference is that once you arrive, you can't just stop there. Perl documentation is no longer a cottage industry; it's a supermall with hundreds of stores. When you walk in the door, you need to find the YOU ARE HERE to figure out which shop or department store sells what you're shopping for. Of course, once you get familiar with the mall, you'll usually know right where to go.

A few of the store signs you'll see are shown in Table P-1.

Table P-1. Selected Perl manpages

Manpage	Covers
perl	What perl manpages are available
perldata	Data types
perlsyn	Syntax
perlop	Operators and precedence
perlre	Regular expressions
perlvar	Predefined variables
perlsub	Subroutines
perlfunc	Built-in functions
perlmod	How perl modules work

Manpage	Covers
perlref	References
perlobj	Objects
perlipc	Interprocess communication
perlrun	How to run Perl commands, plus switches
perldebug	Debugging
perldiag	Diagnostic messages

That's just a small excerpt, but it has the important parts. You can tell that if you want to learn about an operator, that *perlop* is apt to have what you're looking for. And if you want to find something out about predefined variables, you'd check in *perlvar*. If you got a diagnostic message you didn't understand, you'd go to *perldiag*. And so on.

Part of the standard Perl manual is the frequently asked questions (FAQ) list. It's split up into these nine different pages, as shown in Table P-2.

Table P-2. The perlfaq manpages

Manpage	Covers
perlfaq1	General questions about Perl
perlfaq2	Obtaining and learning about Perl
perlfaq3	Programming tools
perlfaq4	Data manipulation
perlfaq5	Files and formats
perlfaq6	Regular expressions
perlfaq7	General Perl language issues
perlfaq8	System interaction
perlfaq9	Networking

Some manpages contain platform-specific notes, as listed in Table P-3.

Table P-3. Platform-specific manpages

Manpage	Covers
perlamiga	The Amiga port
perlcygwin	The Cygwin port
perldos	The MS-DOS port

Manpage	Covers
perlhpux	The HP-UX port
perlmachten	The Power MachTen port
perlos2	The OS/2 port
perlos390	The OS/390 port
perlvms	The DEC VMS port
perlwin32	The MS-Windows port

(See also Chapter 22 and the CPAN ports directory described earlier for porting information.)

Non-Perl Manpages

When we refer to non-Perl documentation, as in *getitimer*(2), this refers to the *getitimer* manpage from section 2 of the Unix Programmer's Manual.[3] Manpages for syscalls such as *getitimer* may not be available on non-Unix systems, but that's probably okay, because you couldn't use the Unix syscall there anyway. If you really do need the documentation for a Unix command, syscall, or library function, many organizations have put their manpages on the Web—a quick search of Google for `crypt(3) manual` will find many copies.

Although the top-level Perl manpages are typically installed in section 1 of the standard *man* directories, we will omit appending a (1) to those manpage names in this book. You can recognize them anyway because they are all of the form "`perl`*`mumble`*".

Offline Documentation

If you'd like to learn more about Perl, here are some related publications that we recommend:

- *Perl 5 Pocket Reference*, by Johan Vromans; O'Reilly Media (5th Edition, July 2011). This small booklet serves as a convenient quick-reference for Perl.
- *Perl Cookbook*, by Tom Christiansen and Nathan Torkington; O'Reilly Media (2nd Edition, August 2003). This is the companion volume to the book you

3. Section 2 is only supposed to contain direct calls into the operating system. (These are often called "system calls", but we'll consistently call them *syscalls* in this book to avoid confusion with the `system` function, which has nothing to do with syscalls). However, systems vary somewhat in which calls are implemented as syscalls, and which are implemented as C library calls, so you could conceivably find *getitimer*(2) in section 3 instead.

have in your hands right now. This cookbook's recipes teach you how to cook with Perl.

- *Learning Perl*, by Randal Schwartz, brian d foy, and Tom Phoenix; O'Reilly Media (6th Edition, June 2011). This book teaches programmers the 30% of basic Perl they'll use 70% of the time, and it is targeted at people writing self-contained programs around a couple of hundred lines.
- *Intermediate Perl*, by Randal Schwartz, brian d foy, and Tom Phoenix; O'Reilly Media (March 2006). This book picks up where *Learning Perl* left off, introducing references, data structures, packages, objects, and modules.
- *Mastering Perl*, by brian d foy; O'Reilly Media (July 2007). This book is the final book in the trilogy along with *Learning Perl* and *Intermediate Perl*. Instead of focusing on language fundamentals, it shifts gears to teaching the Perl programmer about applying Perl to the work at hand.
- *Modern Perl*, by chromatic; Oynx Neon (October 2010). This book provides a survey of modern Perl programming practice and topics, suitable for people who know programming already but haven't paid attention to recent developments in Perl.
- *Mastering Regular Expressions*, by Jeffrey Friedl; O'Reilly Media (3rd Edition, August 2006). Although it doesn't cover the latest additions to Perl regular expressions, this book is an invaluable reference for anyone seeking to learn how regular expressions work.
- *Object Oriented Perl*, by Damian Conway; Manning (August 1999). For beginning as well as advanced OO programmers, this book explains common and esoteric techniques for writing powerful object systems in Perl.
- *Mastering Algorithms with Perl*, by Jon Orwant, Jarkko Hietaniemi, and John Macdonald; O'Reilly Media (1999). All the useful techniques from a CS algorithms course but without the painful proofs. This book covers fundamental and useful algorithms in the fields of graphs, text, sets, and more.

There are many other Perl books and publications out there, and out of senility we have undoubtedly forgotten to mention some good ones. (Out of mercy we have neglected to mention some bad ones.)

In addition to the Perl-related publications listed above, the following books aren't about Perl directly, but they still come in handy for reference, consultation, and inspiration.

- *The Art of Computer Programming*, by Donald Knuth, Volumes 1–4A: "Fundamental Algorithms," "Seminumerical Algorithms," "Sorting and Searching," and "Combinatorial Algorithms"; Addison-Wesley (2011).

- *Introduction to Algorithms*, by Thomas Cormen, Charles Leiserson, and Ronald Rivest; MIT Press and McGraw-Hill (1990).
- *Algorithms in C*, by Robert Sedgewick; Addison-Wesley (1990).
- *The Elements of Programming Style*, by Brian Kernighan and P.J. Plauger; Prentice Hall (1988).
- *The Unix Programming Environment*, by Brian Kernighan and Rob Pike; Prentice Hall (1984).
- *POSIX Programmer's Guide*, by Donald Lewine; O'Reilly Media (1991).
- *Advanced Programming in the UNIX Environment*, by W. Richard Stevens; Addison-Wesley (1–992).
- *TCP/IP Illustrated*, by W. Richard Stevens, Volumes I–III; Addison-Wesley (1992–1996).
- *The Lord of the Rings*, by J. R. R. Tolkien; Houghton Mifflin (U.S.) and Harper Collins (U.K.) (most recent printing: 2005).

Additional Resources

The Internet is a wonderful invention, and we're all still discovering how to use it to its full potential. (Of course, some people prefer to "discover" the Internet the way Tolkien discovered Middle Earth.)

Perl on the Web

Visit the Perl website. It tells what's new in the Perl world, and contains source code and ports, feature articles, documentation, conference schedules, and a lot more.

Also visit the Perl Mongers web page for a grassroots-level view of Perl's, er, grassroots, which grow quite thickly in every part of the world, except at the South Pole, where they have to be kept indoors. Local PM groups hold regular small meetings where you can exchange Perl lore with other Perl hackers who live in your part of the world.

Bug Reports

In the unlikely event that you should encounter a bug that's in Perl proper and not just in your own program, you should try to reduce it to a minimal test case and then report it with the *perlbug* program that comes with Perl. See *http://bugs.perl.org* for more info.

The *perlbug* command is really an interface to an instance of the RT bug tracking tool.[4] You can just as easily email a report to *perlbug@perl.org* without its help, but *perlbug* collects various information about your installation, such as version and compilation options, that can help the *perl* developers figure out your problem.

You can also look at the list of current issues, as someone is likely to have run into your problem before. Start at *https://rt.perl.org/* and follow the links for the *perl5* queue.

If you're dealing with a third-party module from CPAN, you'll use a different RT instance at *https://rt.cpan.org/*. Not every CPAN module makes use of its free RT account, though, so you should always check the module documentation for any extra instructions on reporting bugs.

Conventions Used in This Book

Some of our conventions get larger sections of their very own. Coding conventions are discussed in the section on "Programming with Style" in Chapter 21. In a sense, our lexical conventions are given in the Glossary.

The following typographic conventions are used in this book:

SMALL CAPITALS
: Is used mostly for the formal names of Unicode characters, and for talking about Boolean operators.

Italic
: Is used for URLs, manpages, pathnames, and programs. New terms are also italicized when they first appear in the text. Many of these terms will have alternate definitions in the Glossary, if the one in the text doesn't do it for you. It is also used for command names and command-line switches. This allows one to distinguish, for example, between the *–w* warnings switch and the `-w` filetest operator.

`Monospace Regular`
: Is used in examples to show the text that you enter literally, and in regular text to show any literal code. Data values are represented by `monospace` in roman quotes, which are not part of the value.

4. Best Practical, the creators of Request Tracker, or RT, donate their service for free for major Perl projects including *perl* itself and every CPAN distribution.

Monospace Oblique
: Is used for generic code terms for which you must substitute particular values. It's sometimes also used in examples to show output produced by a program.

Monospace Bold
: Is occasionally used for literal text that you would type into your command-line shell.

Monospace Bold Oblique
: Is used for literal output when needed to distinguish it from shell input.

We give lots of examples, most of which are pieces of code that should go into a larger program. Some examples are complete programs, which you can recognize because they begin with a `#!` line. We start nearly all of our longer programs with:

```
#!/usr/bin/perl
```

Still other examples are things to be typed on a command line. We've used `%` to indicate a generic shell prompt:

```
% perl -e 'print "Hello, world.\n"'
Hello, world.
```

This style is representative of a standard Unix command line, where single quotes represent the "most quoted" form. Quoting and wildcard conventions on other systems vary. For example, many command-line interpreters under MS-DOS and VMS require double quotes instead of single quotes when you need to group arguments with spaces or wildcards in them.

Acknowledgments

Here we say nice things in public about our kibbitzers, consultants, and reviewers to make up for all the rude things we said to them in private: Abigail, Matthew Barnett, Piers Cawley, chromatic, Damian Conway, Dave Cross, Joaquin Ferrero, Jeremiah Foster, Jeff Haemer, Yuriy Malenkiy, Nuno Mendes, Steffen Müller, Enrique Nell, David Nicol, Florian Ragwitz, Allison Randal, Chris Roeder, Keith Thompson, Leon Timmermans, Nathan Torkington, Johan Vromans, and Karl Williamson. Any technical errors are our fault, not theirs.

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We have a website for the book, where we'll list any errata and other Camel-related information:

http://shop.oreilly.com/product/9780596004927.do

Here also you'll find all the example code from the book available for download so you don't have to type it all in like we did.

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http://www.oreilly.com

PART I

Overview

CHAPTER 1

An Overview of Perl

Getting Started

We think that Perl is an easy language to learn and use, and we hope to convince you that we're right. One thing that's easy about Perl is that you don't have to say much before you say what you want to say. In many programming languages, you have to declare the types, variables, and subroutines you are going to use before you can write the first statement of executable code. And for complex problems demanding complex data structures, declarations are a good idea. But for many simple, everyday problems, you'd like a programming language in which you can simply say:

```
print "Howdy, world!\n";
```

and expect the program to do just that.

Perl is such a language. In fact, this example is a complete program,[1] and if you feed it to the Perl interpreter, it will print "`Howdy, world!`" on your screen. (The `\n` in the example produces a newline at the end of the output.)

And that's that. You don't have to say much *after* you say what you want to say, either. Unlike many languages, Perl thinks that falling off the end of your program is just a normal way to exit the program. You certainly *may* call the `exit` function explicitly if you wish, just as you *may* declare some of your variables, or even *force* yourself to declare all your variables. But it's your choice. With Perl you're free to do The Right Thing, however you care to define it.

There are many other reasons why Perl is easy to use, but it would be pointless to list them all here, because that's what the rest of the book is for. The devil may be in the details, as they say, but Perl tries to help you out down there in the hot

1. Or script, or application, or executable, or doohickey. Whatever.

place, too. At every level, Perl is about helping you get from here to there with minimum fuss and maximum enjoyment. That's why so many Perl programmers go around with a silly grin on their face.

This chapter is an overview of Perl, so we're not trying to present Perl to the rational side of your brain. Nor are we trying to be complete, or logical. That's what the following chapters are for. Vulcans, androids, and like-minded humans should skip this overview and go straight to Chapter 2 for maximum information density. If, on the other hand, you're looking for a carefully paced tutorial, you should probably get *Learning Perl*. But don't throw this book out just yet.

This chapter presents Perl to the *other* side of your brain, whether you prefer to call it associative, artistic, passionate, or merely spongy. To that end, we'll be presenting various views of Perl that will give you as clear a picture of Perl as the blind men had of the elephant. Well, okay, maybe we can do better than that. We're dealing with a camel here (see the cover). Hopefully, at least one of these views of Perl will help get you over the hump.

Natural and Artificial Languages

Languages were first invented by humans, for the benefit of humans. In the annals of computer science, this fact has occasionally been forgotten.[2] Since Perl was designed (loosely speaking) by an occasional linguist, it was designed to work smoothly in the same ways that natural language works smoothly. Naturally, there are many aspects to this, since natural language works well at many levels simultaneously. We could enumerate many of these linguistic principles here, but the most important principle of language design is that easy things should be easy, and hard things should be possible. (Actually, that's two principles.) They may seem obvious to you, but many computer languages fail at one or the other.

Natural languages are good at both because people are continually trying to express both easy things and hard things, so the language evolves to handle both. Perl was designed first of all to evolve, and indeed it has evolved. Many people have contributed to the evolution of Perl over the years. We often joke that a camel is a horse designed by a committee, but if you think about it, the camel is pretty well adapted for life in the desert. The camel has evolved to be relatively self-sufficient. (On the other hand, the camel has not evolved to smell good. Neither has Perl.) This is one of the many strange reasons we picked the camel to be Perl's mascot, but it doesn't have much to do with linguistics.

2. More precisely, this fact has occasionally been remembered.

Now when someone utters the word "linguistics", many folks focus in on one of two things. Either they think of words, or they think of sentences. But words and sentences are just two handy ways to "chunk" speech. Either may be broken down into smaller units of meaning or combined into larger units of meaning. And the meaning of any unit depends heavily on the syntactic, semantic, and pragmatic context in which the unit is located. Natural language has words of various sorts: nouns and verbs and such. If someone says "dog" in isolation, you think of it as a noun, but you can also use the word in other ways. That is, a noun can function as a verb, an adjective, or an adverb when the context demands it. If you dog a dog during the dog days of summer, you'll be a dog tired dog-catcher.[3] Perl also evaluates words differently in various contexts. We will see how it does that later. Just remember that Perl is trying to understand what you're saying, like any good listener does. Perl works pretty hard to try to keep up its end of the bargain. Just say what you mean, and Perl will usually "get it". (Unless you're talking nonsense, of course—the Perl parser understands Perl a lot better than either English or Swahili.)

But back to nouns. A noun can name a particular object, or it can name a class of objects generically without specifying which one is currently being referred to. Most computer languages make this distinction, only we call the particular one a value and the generic one a variable. A value just exists somewhere, who knows where, but a variable gets associated with one or more values over its lifetime. So whoever is interpreting the variable has to keep track of that association. That interpreter may be in your brain or in your computer.

Variable Syntax

A variable is just a handy place to keep something, a place with a name, so you know where to find your special something when you come back looking for it later. As in real life, there are various kinds of places to store things, some of them rather private, and some of them out in public. Some places are temporary, and other places are more permanent. Computer scientists love to talk about the "scope" of variables, but that's all they mean by it. Perl has various handy ways of dealing with scoping issues, which you'll be happy to learn later when the time is right. Which is not yet. (Look up the adjectives `local`, `my`, `our`, and `state` in Chapter 27, when you get curious, or see "Scoped Declarations" on page 155 in Chapter 4.)

3. And you're probably dog tired of all this linguistics claptrap. But we'd like you to understand why Perl is different from the typical computer language, doggone it!

But a more immediately useful way of classifying variables is by what sort of data they can hold. As in English, Perl's primary type distinction is between singular and plural data. Strings and numbers are singular pieces of data, while lists of strings or numbers are plural. (And when we get to object-oriented programming, you'll find that the typical object looks singular from the outside but plural from the inside, like a class of students.) We call a singular variable a *scalar*, and a plural variable an *array*. Since a string can be stored in a scalar variable, we might write a slightly longer (and commented) version of our first example like this:

```
my $phrase = "Howdy, world!\n";       # Create a variable.
print $phrase;                        # Print the variable.
```

The `my` tells Perl that `$phrase` is a brand new variable, so it shouldn't go and look for an existing one. Note that we do not have to be very specific about what kind of variable `$phrase` is. The `$` character tells Perl that `phrase` is a scalar variable; that is, one containing a singular value. An array variable, by contrast, would start with an `@` character. (It may help you to remember that a `$` is a stylized "s" for "scalar", while `@` is a stylized "a" for "array".)[4]

Perl has some other variable types, with unlikely names like "hash", "handle", and "typeglob". Like scalars and arrays, these types of variables are also preceded by funny characters, commonly known as *sigils*. For completeness, Table 1-1 lists all the sigils you'll encounter.

Table 1-1. Variable types and their uses

Type	Sigil	Example	Is a Name For
Scalar	`$`	`$cents`	An individual value (number or string)
Array	`@`	`@large`	A list of values, keyed by number
Hash	`%`	`%interest`	A group of values, keyed by string
Subroutine	`&`	`&how`	A callable chunk of Perl code
Typeglob	`*`	`*struck`	Everything named `struck`

Some language purists point to these sigils as a reason to abhor Perl. This is superficial. Sigils have many benefits, not least of which is that variables can be interpolated into strings with no additional syntax. Perl scripts are also easy to read (for people who have bothered to learn Perl!) because the nouns stand out from verbs. And new verbs can be added to the language without breaking old scripts. (We told you Perl was designed to evolve.) And the noun analogy is not

4. This is a simplification of the real story of sigils, which we'll tell you more about in Chapter 2.

frivolous—there is ample precedent in English and other languages for requiring grammatical noun markers. It's how we think! (We think.)

Singularities

From our earlier example, you can see that scalars may be assigned a new value with the = operator, just as in many other computer languages. Scalar variables can be assigned any form of scalar value: integers, floating-point numbers, strings, and even esoteric things like references to other variables, or to objects. There are many ways of generating these values for assignment.

As in the Unix[5] shell, you can use different quoting mechanisms to make different kinds of values. Double quotation marks (double quotes) do *variable interpolation*[6] and *backslash interpolation* (such as turning \n into a newline), while single quotes suppress interpolation. And backquotes (the ones leaning to the left) will execute an external program and return the output of the program, so you can capture it as a single string containing all the lines of output.

```
my $answer = 42;                # an integer
my $pi = 3.14159265;            # a "real" number
my $avocados = 6.02e23;         # scientific notation
my $pet = "Camel";              # string
my $sign = "I love my $pet";    # string with interpolation
my $cost = 'It costs $100';     # string without interpolation
my $thence = $whence;           # another variable's value
my $salsa = $moles * $avocados; # a gastrochemical expression
my $exit = system("vi $file");  # numeric status of a command
my $cwd = `pwd`;                # string output from a command
```

And while we haven't covered fancy values yet, we should point out that scalars may also hold references to other data structures, including subroutines and objects.

```
my $ary = \@myarray;              # reference to a named array
my $hsh = \%myhash;               # reference to a named hash
my $sub = \&mysub;                # reference to a named subroutine

my $ary = [1,2,3,4,5];            # reference to an unnamed array
my $hsh = {Na => 19, Cl => 35};   # reference to an unnamed hash
my $sub = sub { print $state };   # reference to an unnamed subroutine
```

5. Here and elsewhere, when we say Unix we mean any operating system resembling Unix, including BSD, Mac OS X, Linux, Solaris, AIX, and, of course, Unix.

6. Sometimes called "substitution" by shell programmers, but we prefer to reserve that word for something else in Perl. So please call it interpolation. We're using the term in the textual sense ("this passage is a Gnostic interpolation") rather than in the mathematical sense ("this point on the graph is an interpolation between two other points").

```
my $fido = Camel->new("Amelia");  # reference to an object
```

When you create a new scalar variable, but before you assign it a value, it is automatically initialized with the value we call `undef`, which as you might guess means "undefined". Depending on context, this undefined value might be interpreted as a slightly more defined null value, such as `""` or `0`. More generally, depending on how you use them, variables will be interpreted automatically as strings, as numbers, or as "true" and "false" values (commonly called *Boolean* values). Remember how important context is in human languages. In Perl, various operators expect certain kinds of singular values as parameters, so we will speak of those operators as "providing" or "supplying" scalar context to those parameters. Sometimes we'll be more specific and say it supplies a numeric context, a string context, or a Boolean context to those parameters. (Later we'll also talk about list context, which is the opposite of scalar context.) Perl will automatically convert the data into the form required by the current context, within reason. For example, suppose you said this:

```
my $camels = "123";
print $camels + 1, "\n";
```

The first assigned value of `$camels` is a string, but it is converted to a number to add `1` to it, and then converted back to a string to be printed out as `124`. The newline, represented by `"\n"`, is also in string context, but since it's already a string, no conversion is necessary. But notice that we had to use double quotes there—using single quotes to say `'\n'` would result in a two-character string consisting of a backslash followed by an "`n`", which is not a newline by anybody's definition.

So, in a sense, double quotes and single quotes are yet another way of specifying context. The interpretation of the innards of a quoted string depends on which quotes you use. (Later, we'll see some other operators that work like quotes syntactically but use the string in some special way, such as for pattern matching or substitution. These all work like double-quoted strings, too. The *double-quote* context is the "interpolative" context of Perl, and it is supplied by many operators that don't happen to resemble double quotes.)

Similarly, a reference behaves as a reference when you give it a "dereference" context, but otherwise acts like a simple scalar value. For example, we might say:

```
my $fido = Camel->new("Amelia");
if (not $fido) { die "dead camel"; }
$fido->saddle();
```

Here we create a reference to a Camel object and put it into a new variable, `$fido`. On the next line, we test `$fido` as a scalar Boolean to see if it is "true", and

we throw an exception (that is, we complain) if it is not true, which in this case would mean that the `Camel->new` constructor failed to make a proper Camel object. But on the last line, we treat `$fido` as a reference by asking it to look up the `saddle` method for the object held in `$fido`, which happens to be a Camel, so Perl looks up the `saddle` method for Camel objects. More about that later. For now, just remember that context is important in Perl because that's how Perl knows what you want without your having to say it explicitly, as many other computer languages force you to do.

Pluralities

Some kinds of variables hold multiple values that are logically tied together. Perl has two types of multivalued variables: arrays and hashes. In many ways, these behave like scalars—new ones can be declared with `my`, for instance, and they are automatically initialized to an empty state. But they are different from scalars in that, when you assign to them, they supply *list* context to the right side of the assignment rather than scalar context.

Arrays and hashes also differ from each other. You'd use an array when you want to look something up by number. You'd use a hash when you want to look something up by name. The two concepts are complementary—you'll often see people using an array to translate month numbers into month names, and a corresponding hash to translate month names back into month numbers. (Though hashes aren't limited to holding only numbers. You could have a hash that translates month names to birthstone names, for instance.)

Arrays. An *array* is an ordered list of scalars, accessed[7] by the scalar's position in the list. The list may contain numbers, strings, or a mixture of both. (It might also contain references to subarrays or subhashes.) To assign a list value to an array, simply group the values together (with a set of parentheses):

```
my @home = ("couch", "chair", "table", "stove");
```

Conversely, if you use `@home` in list context, such as on the right side of a list assignment, you get back out the same list you put in. So you could create four scalar variables from the array like this:

```
my ($potato, $lift, $tennis, $pipe) = @home;
```

These are called list assignments. They logically happen in parallel, so you can swap two existing variables by saying:

```
($alpha,$omega) = ($omega,$alpha);
```

7. Or keyed, or indexed, or subscripted, or looked up. Take your pick.

As in C, arrays are zero-based, so while you would talk about the first through fourth elements of the array, you would get to them with subscripts 0 through 3.[8] Array subscripts are enclosed in square brackets [like this], so if you want to select an individual array element, you would refer to it as `$home[`*n*`]`, where *n* is the subscript (one less than the element number) you want. See the example that follows. Since the element you are dealing with is a scalar, you always precede it with a `$`.

If you want to assign to one array element at a time, you can; the elements of the array are automatically created as needed, so you could write the earlier assignment as:

```
my @home;
$home[0] = "couch";
$home[1] = "chair";
$home[2] = "table";
$home[3] = "stove";
```

Here we see that you can create a variable with `my` without giving it an initial value. (We don't need to use `my` on the individual elements because the array already exists and knows how to create elements on demand.)

Since arrays are ordered, you can do various useful operations on them, such as the stack operations `push` and `pop`. A stack is, after all, just an ordered list with a beginning and an end. Especially an end. Perl regards the end of your array as the top of a stack. (Although most Perl programmers think of an array as horizontal, with the top of the stack on the right.)

Hashes. A *hash* is an unordered set of scalars, accessed[9] by some string value that is associated with each scalar. For this reason hashes are often called *associative arrays*. But that's too long for lazy typists, and we talk about them so often that we decided to name them something short and snappy. The other reason we picked the name "hash" is to emphasize the fact that they're disordered. (They are, coincidentally, implemented internally using a hash-table lookup, which is why hashes are so fast and stay so fast no matter how many values you put into them.) You can't `push` or `pop` a hash, though, because it doesn't make sense. A hash has no beginning or end. Nevertheless, hashes are extremely powerful and useful. Until you start thinking in terms of hashes, you aren't really thinking in Perl. Figure 1-1 shows the ordered elements of an array and the unordered (but named) elements of a hash.

8. If this seems odd to you, just think of the subscript as an offset; that is, the count of how many array elements come before it. Obviously, the first element doesn't have any elements before it, and so it has an offset of 0. This is how computers think. (We think.)

9. Or keyed, or indexed, or subscripted, or looked up. Take your pick.

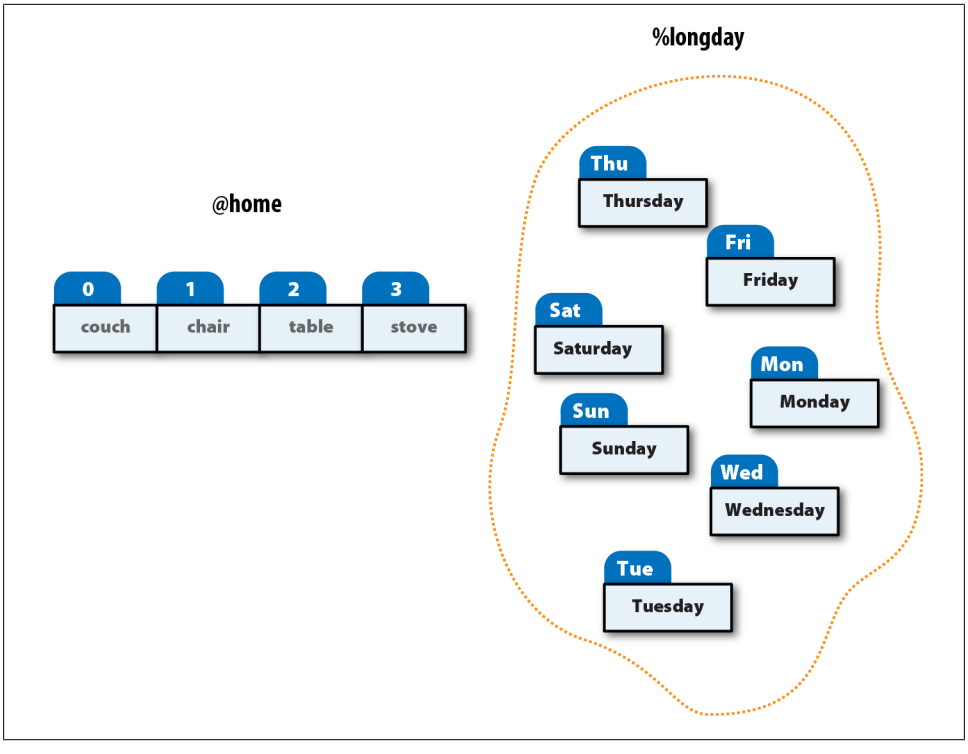


Figure 1-1. An array and a hash

Since the keys to a hash are not automatically implied by their position, you must supply the key as well as the value when populating a hash. You can still assign a list to it like an ordinary array, but each *pair* of items in the list will be interpreted as a key and a value. Since we're dealing with pairs of items, hashes use the `%` sigil to mark hash names. (If you look carefully at the `%` character, you can see the key and the value with a slash between them. It may help to squint.)

Suppose you wanted to translate abbreviated day names to the corresponding full names. You could write the following list assignment:

```
my %longday = ("Sun", "Sunday", "Mon", "Monday", "Tue", "Tuesday",
               "Wed", "Wednesday", "Thu", "Thursday", "Fri",
               "Friday", "Sat", "Saturday");
```

But that's rather difficult to read, so Perl provides the `=>` (equals sign, greater-than sign) sequence as an alternative separator to the comma. Using this syntactic sugar (and some creative formatting), it is much easier to see which strings are the keys and which strings are the associated values.

```
my %longday = (
    "Sun" => "Sunday",
    "Mon" => "Monday",
    "Tue" => "Tuesday",
    "Wed" => "Wednesday",
    "Thu" => "Thursday",
    "Fri" => "Friday",
    "Sat" => "Saturday",
);
```

Not only can you assign a list to a hash, as we did above, but if you mention a hash in list context, it'll convert the hash back to a list of key/value pairs, in a weird order. This is occasionally useful. More often people extract a list of just the keys, using the (aptly named) `keys` function. The key list is also unordered, but can easily be sorted if desired, using the (aptly named) `sort` function. Then you can use the ordered keys to pull out the corresponding values in the order you want.

Because hashes are a fancy kind of array, you select an individual hash element by enclosing the key in braces (those fancy brackets also known as "curlies"). So, for example, if you want to find out the value associated with `Wed` in the hash above, you would use `$longday{"Wed"}`. Note again that you are dealing with a scalar value, so you use `$` on the front, not `%`, which would indicate the entire hash.

Linguistically, the relationship encoded in a hash is genitive or possessive, like the word "of" in English, or like "'s". The wife *of* Adam is Eve, so we write:

```
my %wife;
$wife{"Adam"} = "Eve";
```

Complexities

Arrays and hashes are lovely, simple, flat data structures. Unfortunately, the world does not always cooperate with our attempts to oversimplify. Sometimes you need to build not-so-lovely, not-so-simple, not-so-flat data structures. Perl lets you do this by pretending that complicated values are really simple ones. To put it the other way around, Perl lets you manipulate simple scalar references that happen to refer to complicated arrays and hashes. We do this all the time in natural language when we use a simple singular noun like "government" to represent an entity that is completely convoluted and inscrutable. Among other things.

To extend our previous example, suppose we want to switch from talking about Adam's wife to Jacob's wife. Now, as it happens, Jacob had four wives. (Don't try this at home.) In trying to represent this in Perl, we find ourselves in the odd

situation where we'd like to pretend that Jacob's four wives were really one wife. (Don't try this at home, either.) You might think you could write it like this:

```
$wife{"Jacob"} = ("Leah", "Rachel", "Bilhah", "Zilpah");        # WRONG
```

But that wouldn't do what you want, because even parentheses and commas are not powerful enough to turn a list into a scalar in Perl. (Parentheses are used for syntactic grouping, and commas for syntactic separation.) Rather, you need to tell Perl explicitly that you want to pretend that a list is a scalar. It turns out that square brackets are powerful enough to do that:

```
$wife{"Jacob"} = ["Leah", "Rachel", "Bilhah", "Zilpah"];        # ok
```

That statement creates an unnamed array and puts a reference to it into the hash element `$wife{"Jacob"}`. So we have a named hash containing an unnamed array. This is how Perl deals with both multidimensional arrays and nested data structures. As with ordinary arrays and hashes, you can also assign individual elements, like this:

```
$wife{"Jacob"}[0] = "Leah";
$wife{"Jacob"}[1] = "Rachel";
$wife{"Jacob"}[2] = "Bilhah";
$wife{"Jacob"}[3] = "Zilpah";
```

You can see how that looks like a multidimensional array with one string subscript and one numeric subscript. To see something that looks more tree-structured, like a nested data structure, suppose we wanted to list not only Jacob's wives but all the sons of each of his wives. In this case we want to treat a hash as a scalar. We can use braces for that. (Inside each hash value we'll use square brackets to represent arrays, just as we did earlier. But now we have an array in a hash in a hash.)

```
my %kids_of_wife;
$kids_of_wife{"Jacob"} = {
    "Leah"   => ["Reuben", "Simeon", "Levi", "Judah", "Issachar", "Zebulun"],
    "Rachel" => ["Joseph", "Benjamin"],
    "Bilhah" => ["Dan", "Naphtali"],
    "Zilpah" => ["Gad", "Asher"],
};
```

That would be more or less equivalent to saying:

```
my %kids_of_wife;
$kids_of_wife{"Jacob"}{"Leah"}[0]   = "Reuben";
$kids_of_wife{"Jacob"}{"Leah"}[1]   = "Simeon";
$kids_of_wife{"Jacob"}{"Leah"}[2]   = "Levi";
$kids_of_wife{"Jacob"}{"Leah"}[3]   = "Judah";
$kids_of_wife{"Jacob"}{"Leah"}[4]   = "Issachar";
$kids_of_wife{"Jacob"}{"Leah"}[5]   = "Zebulun";
$kids_of_wife{"Jacob"}{"Rachel"}[0] = "Joseph";
```

```
$kids_of_wife{"Jacob"}{"Rachel"}[1] = "Benjamin";
$kids_of_wife{"Jacob"}{"Bilhah"}[0] = "Dan";
$kids_of_wife{"Jacob"}{"Bilhah"}[1] = "Naphtali";
$kids_of_wife{"Jacob"}{"Zilpah"}[0] = "Gad";
$kids_of_wife{"Jacob"}{"Zilpah"}[1] = "Asher";
```

You can see from this that adding a level to a nested data structure is like adding another dimension to a multidimensional array. Perl lets you think of it either way, but the internal representation is the same.

The important point here is that Perl lets you pretend that a complex data structure is a simple scalar. On this simple kind of encapsulation, Perl's entire object-oriented structure is built. When we earlier invoked the `Camel` constructor like this:

```
my $fido = Camel->new("Amelia");
```

we created a `Camel` object that is represented by the scalar `$fido`. But the inside of the `Camel` is more complicated. As well-behaved object-oriented programmers, we're not supposed to care about the insides of `Camel`s (unless we happen to be the people implementing the methods of the `Camel` class). But, generally, an object like a `Camel` would consist of a hash containing the particular `Camel`'s attributes, such as its name ("`Amelia`" in this case, not "`fido`"), and the number of humps (which we didn't specify, but probably defaults to 1; check the front cover).

Simplicities

If your head isn't spinning a bit from reading that last section, then you have an unusual head. People generally don't like to deal with complex data structures, whether governmental or genealogical. So, in our natural languages, we have many ways of sweeping complexity under the carpet. Many of these fall into the category of *topicalization*, which is just a fancy linguistics term for agreeing with someone about what you're going to talk about (and by exclusion, what you're probably not going to talk about). This happens on many levels in language. On a high level, we divide ourselves into various subcultures that are interested in various subtopics, and we establish sublanguages that talk primarily about those subtopics. The lingo of the doctor's office ("indissoluble asphyxiant") is different from the lingo of the chocolate factory ("everlasting gobstopper"). Most of us automatically switch contexts as we go from one lingo to another.

On a conversational level, the context switch has to be more explicit, so our language gives us many ways of saying what we're about to say. We put titles on our books and headers on our sections. On our sentences, we put quaint phrases like "In regard to your recent query" or "For all X". Usually, though, we just say

things like, "You know that dangly thingy that hangs down in the back of your throat?"

Perl also has several ways of topicalizing. One important topicalizer is the `package` declaration. Suppose you want to talk about `Camel`s in Perl. You'd likely start off your `Camel` module by saying:

```
package Camel;
```

This has several notable effects. One of them is that Perl will assume from this point on that any global verbs or nouns are about `Camel`s. It does this by automatically prefixing any global name[10] with the module name "`Camel::`". So if you say:

```
package Camel;
our $fido = &fetch();
```

then the real name of `$fido` is `$Camel::fido` (and the real name of `&fetch` is `&Camel::fetch`, but we're not talking about verbs yet). This means that if some other module says:

```
package Dog;
our $fido = &fetch();
```

Perl won't get confused, because the real name of this `$fido` is `$Dog::fido`, not `$Camel::fido`. A computer scientist would say that a package establishes a *namespace*. You can have as many namespaces as you like, but since you're only in one of them at a time, you can pretend that the other namespaces don't exist. That's how namespaces simplify reality for you. Simplification is based on pretending. (Of course, so is oversimplification, which is what we're doing in this chapter.)

Now it's important to keep your nouns straight, but it's just as important to keep your verbs straight. It's nice that `&Camel::fetch` is not confused with `&Dog::fetch` within the `Camel` and `Dog` namespaces, but the really nice thing about packages is that they classify your verbs so that *other* packages can use them. When we said:

```
my $fido = Camel->new("Amelia");
```

we were actually invoking the `&new` verb in the `Camel` package, which has the full name of `&Camel::new`. And when we said:

```
$fido->saddle();
```

10. You can declare global variables using `our`, which looks a lot like `my`, but tells people that it's a shared variable. A `my` variable is not shared and cannot be seen by anyone outside the current block. When in doubt, use `my` rather than `our` since unneeded globals just clutter up the world and confuse people.

we were invoking the `&Camel::saddle` routine, because `$fido` remembers that it is pointing to a `Camel`. This is how object-oriented programming works.

When you say `package Camel`, you're starting a new package. But sometimes you just want to borrow the nouns and verbs of an existing package. Perl lets you do that with a `use` declaration, which not only borrows verbs from another package, but also checks that the module you name is loaded in from disk. In fact, you *must* say something like:

```
use Camel;
```

before you say:

```
my $fido = Camel->new("Amelia");
```

because otherwise Perl wouldn't know what a `Camel` is.

The interesting thing is that you yourself don't really need to know what a `Camel` is, provided you can get someone else to write the `Camel` module for you. Even better would be if someone had *already* written the `Camel` module for you. It could be argued that the most powerful thing about Perl is not Perl itself, but CPAN (Comprehensive Perl Archive Network; see Chapter 19), which contains myriad modules that accomplish many different tasks that you don't have to know how to do. You just have to download whatever module you like and say:

```
use Some::Cool::Module;
```

Then you can use the verbs from that module in a manner appropriate to the topic under discussion.

So, like topicalization in a natural language, topicalization in Perl "warps" the language that you'll use from there to the end of the scope. In fact, some of the built-in modules don't actually introduce verbs at all, but simply warp the Perl language in various useful ways. We call these special modules *pragmas* (see Chapter 29). For instance, you'll often see people use the pragma `strict`, like this:

```
use strict;
```

What the `strict` module does is tighten up some of the rules so that you have to be more explicit about various things that Perl would otherwise guess about, such as how you want your variables to be scoped.[11] Making things explicit is helpful when you're working on large projects. By default, Perl is optimized for small projects, but with the `strict` pragma, Perl is also good for large projects that need to be more maintainable. Since you can add the `strict` pragma at any

11. More specifically, `use strict` requires you to use `my` , `state`, or `our` on variable declarations; otherwise, it just assumes undeclared variables are package variables, which can get you into trouble later. It also disallows various constructs that have proven to be error-prone over the years.

time, Perl is also good for evolving small projects into large ones, even when you didn't expect that to happen. Which is usually.

As Perl evolves, the Perl community also evolves, and one of the things that changes is how the community thinks Perl should behave by default. (This is in conflict with the desire for Perl to behave as it always did.) So, for instance, most Perl programmers now think that you should always put "`use strict`" at the front of your program. Over time we tend to accumulate such "culturally required" language-warping pragmas. So another built-in pragma is just the version number of Perl, which is a kind of "metapragma" that tells Perl it's okay to behave like a more modern language in all the ways it should:

```
use v5.14;
```

This particular declaration turns on several pragmas including "`use strict`";[12] it also enables new features like the `say` verb, which (unlike `print`) adds a newline for you. So we could have written our very first example above as:

```
use v5.14;
say "Howdy, world!";
```

The examples in this book all assume the v5.14 release of Perl; we will try to remember to include the `use v5.14` for you when we show you a complete program, but when we show you snippets, we will assume you've already put in that declaration yourself. (If you do not have the latest version of Perl, some of our examples may not work. In the case of `say`, you could change it back to a `print` with a newline—but it would be better to upgrade. You'll need to say at least `use v5.10` for `say` to work.)

Verbs

As is typical of your typical imperative computer language, many of the verbs in Perl are commands: they tell the Perl interpreter to do something. On the other hand, as is typical of a natural language, the meanings of Perl verbs tend to mush off in various directions depending on the context. A statement starting with a verb is generally purely imperative and evaluated entirely for its side effects. (We sometimes call these verbs *procedures*, especially when they're user-defined.) A frequently seen built-in command (in fact, you've seen it already) is the `say` command:

```
say "Adam's wife is $wife{'Adam'}.";
```

12. The implicit strictures feature was added in v5.12. Also see the `feature` pragma in Chapter 29.

This has the side effect of producing the desired output:

```
Adam's wife is Eve.
```

But there are other "moods" besides the imperative mood. Some verbs are for asking questions and are useful in conditionals such as `if` statements. Other verbs translate their input parameters into return values, just as a recipe tells you how to turn raw ingredients into something (hopefully) edible. We tend to call these verbs *functions*, in deference to generations of mathematicians who don't know what the word "functional" means in normal English.

An example of a built-in function would be the exponential function:

```
my $e = exp(1);   # 2.718281828459 or thereabouts
```

But Perl doesn't make a hard distinction between procedures and functions. You'll find the terms used interchangeably. Verbs are also sometimes called operators (when built-in), or subroutines (when user-defined).[13] But call them whatever you like—they all return a value, which may or may not be a meaningful value, which you may or may not choose to ignore.

As we go on, you'll see additional examples of how Perl behaves like a natural language. But there are other ways to look at Perl, too. We've already sneakily introduced some notions from mathematical language, such as subscripts, addition, and the exponential function. But Perl is also a control language, a glue language, a prototyping language, a text-processing language, a list-processing language, and an object-oriented language. Among other things.

But Perl is also just a plain old computer language. And that's how we'll look at it next.

An Average Example

Suppose you've been teaching a Perl class, and you're trying to figure out how to grade your students. You have a set of exam scores for each member of a class, in random order. You'd like a combined list of all the grades for each student, plus their average score. You have a text file (imaginatively named *grades*) that looks like this:

13. Historically, Perl required you to put an ampersand character (`&`) on any calls to user-defined subroutines (see `$fido = &fetch();` earlier). But with Perl v5, the ampersand became optional, so user-defined verbs can now be called with the same syntax as built-in verbs (`$fido = fetch();`). We still use the ampersand when talking about the *name* of the routine, such as when we take a reference to it (`$fetcher = \&fetch;`). Linguistically speaking, you can think of the ampersand form `&fetch` as an infinitive, "to fetch", or the similar form "do fetch". But we rarely say "do fetch" when we can just say "fetch". That's the real reason we dropped the mandatory ampersand in v5.

```
Noël 25
Ben 76
Clementine 49
Norm 66
Chris 92
Doug 42
Carol 25
Ben 12
Clementine 0
Norm 66
...
```

You can use the following script to gather all their scores together, determine each student's average, and print them all out in alphabetical order. This program assumes rather naïvely that you don't have two Carols in your class. That is, if there is a second entry for Carol, the program will assume it's just another score for the first Carol (not to be confused with the first Noël).

By the way, the line numbers are not part of the program, any other resemblances to BASIC notwithstanding.

```
 1  #!/usr/bin/perl
 2  use v5.14;
 3
 4  open(GRADES, "<:utf8", "grades")  || die "Can't open grades: $!\n";
 5  binmode(STDOUT, ':utf8');
 6
 7  my %grades;
 8  while (my $line = <GRADES>) {
 9      my ($student, $grade) = split(" ", $line);
10      $grades{$student} .= $grade . " ";
11  }
12
13  for my $student (sort keys %grades) {
14      my $scores = 0;
15      my $total = 0;
16      my @grades = split(" ", $grades{$student});
17      for my $grade (@grades) {
18          $total += $grade;
19          $scores++;
20      }
21      my $average = $total / $scores;
22      print "$student: $grades{$student}\tAverage: $average\n";
23  }
```

Now, before your eyes cross permanently, we'd better point out that this example demonstrates a lot of what we've covered so far, plus quite a bit more that we'll explain presently. But if you let your eyes go just a little out of focus, you may start to see some interesting patterns. Take some wild guesses now as to what's going on, and then later on we'll tell you if you're right.

We'd tell you to try running it, but you may not know how yet.

How to Do It

Gee, right about now you're probably wondering how to run a Perl program. The short answer is that you feed it to the Perl language interpreter program, which coincidentally happens to be named *perl*. The long answer starts out like this: There's More Than One Way To Do It.[14]

The first way to invoke *perl* (and the way most likely to work on any operating system) is to simply call *perl* explicitly from the command line.[15] If you are doing something fairly simple, you can use the *–e* switch (`%` in the following example represents a standard shell prompt, so don't type it). On Unix, you might type:

```
% perl -e 'print "Hello, world!\n";'
```

On other operating systems, you may have to fiddle with the quotes some. But the basic principle is the same: you're trying to cram everything Perl needs to know into 80 columns or so.[16]

For longer scripts, you can use your favorite text editor (or any other text editor) to put all your commands into a file and then, presuming you named the script *gradation* (not to be confused with graduation), you'd say:

```
% perl gradation
```

You're still invoking the Perl interpreter explicitly, but at least you don't have to put everything on the command line every time. And you no longer have to fiddle with quotes to keep the shell happy.

The most convenient way to invoke a script is just to name it directly (or click on it), and let the operating system find the interpreter for you. On some systems, there may be ways of associating various file extensions or directories with a particular application. On those systems, you should do whatever it is you do to associate the Perl script with the *perl* interpreter. On Unix systems that support the `#!` "shebang" notation (and most Unix systems do, nowadays), you can make the first line of your script be magical, so the operating system will know which program to run. Put a line resembling line 1 of our example into your program:

---

14. That's the Perl Slogan, and you'll get tired of hearing it, unless you're the Local Expert, in which case you'll get tired of saying it. Sometimes it's shortened to TMTOWTDI, pronounced "tim-toady". But you can pronounce it however you like. After all, TMTOWTDI.

15. Assuming that your operating system provides a command-line interface. If not, you should upgrade.

16. These types of scripts are often referred to as "one-liners". If you ever end up hanging out with other Perl programmers, you'll find that some of us are quite fond of creating intricate one-liners. Perl has occasionally been maligned as a write-only language because of these shenanigans.

```
#!/usr/bin/perl
```

(If *perl* v5.14 isn't in */usr/bin*, you'll have to change the `#!` line accordingly.[17]). Then all you have to say is:

```
% gradation
```

Of course, this didn't work because you forgot to make sure the script was executable (see the manpage for *chmod*(1)) and in your PATH. If it isn't in your PATH, you'll have to provide a complete filename so that the operating system knows how to find your script. Something like:

```
% /home/sharon/bin/gradation
```

Finally, if you are unfortunate enough to be on an ancient Unix system that doesn't support the magic `#!` line, or if the path to your interpreter is longer than 32 characters (a built-in limit on many systems), you may be able to work around it like this:

```
#!/bin/sh -- # perl, to stop looping
eval 'exec /usr/bin/perl -S $0 ${1+"$@"}'
    if 0;
```

Some operating systems may require variants of this to deal with */bin/csh*, *DCL*, *COMMAND.COM*, or whatever happens to be your default command interpreter. Ask your Local Expert.

Throughout this book, we'll just use `#!/usr/bin/perl` to represent all these notions and notations, but you'll know what we really mean by it.

A random clue: when you write a test script, don't call your script *test*. Unix systems have a built-in *test* command, which will likely be executed instead of your script. Try *try* instead.

Now that you know how to run your own Perl program (not to be confused with the *perl* program), let's get back to our example.

Filehandles

Unless you're using artificial intelligence to model a solipsistic philosopher, your program needs some way to communicate with the outside world. In lines 4 and 8 of our Average Example you'll see the word `GRADES`, which exemplifies another of Perl's data types, the *filehandle*. A filehandle is just a name you give to a file, device, socket, or pipe to help you remember which one you're talking about,

17. If your */usr/bin/perl* is an old version, you can compile a new one and put it elsewhere, such as */usr/local/bin*, as long as you fix the `#!` line to point to it.

and to hide some of the complexities of buffering and such. (Internally, filehandles are similar to streams from a language like C++ or I/O channels from BASIC.)

Filehandles make it easier for you to get input from and send output to many different places. Part of what makes Perl a good glue language is that it can talk to many files and processes at once. Having nice symbolic names for various external objects is just part of being a good glue language.[18]

You create a filehandle and attach it to a file by using `open`. The `open` function takes at least two parameters: the filehandle and filename you want to associate it with. Perl also gives you some predefined (and preopened) filehandles. `STDIN` is your program's normal input channel, while `STDOUT` is your program's normal output channel. And `STDERR` is an additional output channel that allows your program to make snide remarks off to the side while it transforms (or attempts to transform) your input into your output.[19] In lines 4 and 5 of our program, we also tell our new `GRADES` filehandle and the existing `STDOUT` filehandle to assume that text is encoded in UTF-8, a common representation of Unicode text.

Since you can use the `open` function to create filehandles for various purposes (input, output, piping), you need to be able to specify which behavior you want. As you might do on the command line, you can simply add characters to the filename:

```
open(SESAME,    "filename")           # read from existing file
open(SESAME, "<  filename")           #   (same thing, explicitly)
open(SESAME, ">  filename")           # create file and write to it
open(SESAME, ">> filename")           # append to existing file
open(SESAME, "| output-pipe-command") # set up an output filter
open(SESAME, "input-pipe-command |")  # set up an input filter
```

However, the recommended three-argument form of `open` allows you to specify the `open` mode in an argument separate from the filename itself. This is useful when you're dealing with filenames that aren't literals and so might already contain characters that look like open modes or significant whitespace.

---

18. Some of the other things that make Perl a good glue language are: it handles non-ASCII data, it's embeddable, and you can embed other things in it via extension modules. It's concise, and it "networks" easily. It's environmentally conscious, so to speak. You can invoke it in many different ways (as we saw earlier). But most of all, the language itself is not so rigidly structured that you can't get it to "flow" around your problem. It comes back to that TMTOWTDI thing again.

19. These filehandles are typically attached to your terminal, so you can type to your program and see its output, but they may also be attached to files (and such). Perl can give you these predefined handles because your operating system already provides them, one way or another. Under Unix, processes inherit standard input, output, and error from their parent process, typically a shell. One of the duties of a shell is to set up these I/O streams so that the child process doesn't need to worry about them.

```
open(SESAME, "<",  $somefile)          # read from existing file
open(SESAME, ">",  $somefile)          # create file and write to it
open(SESAME, ">>", $somefile)          # append to existing file
open(SESAME, "|-", "output-pipe-command")  # set up an output filter
open(SESAME, "-|", "input-pipe-command")   # set up an input filter
```

As we did in our program, this form of `open` also lets you specify the character encoding of the file.

```
open(SESAME, "< :encoding(UTF-8)",     $somefile)
open(SESAME, "> :crlf",                $somefile)
open(SESAME, ">> :encoding(MacRoman)", $somefile)
```

As you can see, the name you pick for the filehandle is arbitrary. Once opened, the filehandle `SESAME` can be used to access the file or pipe until it is explicitly closed (with, you guessed it, `close(SESAME)`), or until the filehandle is attached to another file by a subsequent `open` on the same filehandle. Opening an already opened filehandle implicitly closes the first file, making it inaccessible to the filehandle, and opens a different file. You must be careful that this is what you really want to do. Sometimes it happens accidentally, like when you say `open($handle,$file)`, and `$handle` happens to contain a constant string. Be sure to set `$handle` to something unique, or you'll just open a new file on the same filehandle.

A much better idea is to leave `$handle` undefined, letting Perl fill it in for you. This is handy for when you get tired of choosing your own names for filehandles: if you pass `open` an undefined variable (such as `my` creates), Perl will pick the filehandle for you and fill it in automatically:

```
open(my $handle, "< :crlf :encoding(cp1252)", $somefile)
  || die "can't open $somefile: $!";
```

If the `open` succeeds, the `$handle` variable is now defined, and you can use it wherever a filehandle is expected.

Once you've opened a filehandle for input, you can read a line using the line reading operator, `<>`. This is also known as the angle operator because it's made of angle brackets. The angle operator encloses the filehandle (`<SESAME>` if a literal handle, and `<$handle>` for an indirect one) you want to read lines from. The empty angle operator, `<>`, will read lines from all the files specified on the command line, or `STDIN` if no arguments were specified. (This is standard behavior for many filter programs.) An example using the `STDIN` filehandle to read an answer supplied by the user would look something like this:

```
print STDOUT "Enter a number: ";      # ask for a number
$number = <STDIN>;                    # input the number
say STDOUT "The number is $number.";  # print the number
```

Did you see what we just slipped by you? What's that `STDOUT` doing there in those `print` and `say` statements? Well, that's just one of the ways you can use an output filehandle. A filehandle may be supplied between the command and its argument list, and if present, tells the output where to go. In this case, the filehandle is redundant because the output would have gone to `STDOUT` anyway. Much as `STDIN` is the default for input, `STDOUT` is the default for output. (In line 22 of our Average Example, we left it out to avoid confusing you until now.)

If you try the previous example, you may notice that you get an extra blank line. This happens because the line-reading operation does not automatically remove the newline from your input line (your input would be, for example, `"9\n"`). For those times when you do want to remove the newline, Perl provides the `chop` and `chomp` functions. `chop` will indiscriminately remove (and return) the last character of the string, while `chomp` will only remove the end of record marker (generally, `"\n"`) and return the number of characters so removed. You'll often see this idiom for inputting a single line:

```
chomp($number = <STDIN>);    # input a number, then remove its newline
```

which means the same thing as:

```
$number = <STDIN>;           # input a number
chomp($number);              # remove trailing newline
```

One last thing, just because we called our variable `$number` doesn't mean it was one. Any string will do. Perl only cares whether something is a number if you try to operate on that string as though it were a number—down which road lie operators, our next topic.

Operators

As we alluded to earlier, Perl is also a mathematical language. This is true at several levels, from low-level bitwise logical operations, up through number and set manipulation, on up to larger predicates and abstractions of various sorts. And as we all know from studying math in school, mathematicians love strange symbols. What's worse, computer scientists have come up with their own versions of these strange symbols. Perl has a number of these strange symbols, too—but take heart, as most are borrowed directly from C, FORTRAN, *sed*(1) or *awk*(1), so they'll at least be familiar to users of those languages.

The rest of you can take comfort in knowing that, by learning all these strange symbols in Perl, you've given yourself a head start on all those other strange languages.

Perl's built-in operators may be classified by number of operands into unary, binary, and trinary (or ternary) operators. They may be classified by whether they're prefix operators (which go in front of their operands) or infix operators (which go in between their operands). They may also be classified by the kinds of objects they work with, such as numbers, strings, or files. Later, we'll give you a table of all the operators, but first here are some handy ones to get you started.

Some Binary Arithmetic Operators

Arithmetic operators do what you would expect from learning them in school. They perform some sort of mathematical function on numbers; see Table 1-2.

Table 1-2. Mathematical operators

Example	Name	Result
`$a + $b`	Addition	Sum of `$a` and `$b`
`$a * $b`	Multiplication	Product of `$a` and `$b`
`$a % $b`	Modulus	Remainder of `$a` divided by `$b`
`$a ** $b`	Exponentiation	`$a` to the power of `$b`

Yes, we left out subtraction and division—we suspect you can figure out how they should work. Try them and see if you're right. (Or cheat and look in Chapter 3.) Arithmetic operators are evaluated in the order your math teacher taught you (exponentiation before multiplication; multiplication before addition). You can always use parentheses to make it come out differently.

String Operators

There is also an "addition" operator for strings that performs concatenation (that is, joining strings end to end). Unlike some languages that confuse this with numeric addition, Perl defines a separate operator (`.`) for string concatenation:

```
$a = 123;
$b = 456;
say $a + $b;     # prints 579
say $a . $b;     # prints 123456
```

There's also a "multiply" operator for strings, called the *repeat* operator. Again, it's a separate operator (`x`) to keep it distinct from numeric multiplication:

```
$a = 123;
$b = 3;
say $a * $b;     # prints 369
say $a x $b;     # prints 123123123
```

These string operators bind as tightly as their corresponding arithmetic operators. The repeat operator is a bit unusual in taking a string for its left argument but a number for its right argument. Note also how Perl is automatically converting from numbers to strings. You could have put all the literal numbers above in quotes, and it would still have produced the same output. Internally, though, it would have been converting in the opposite direction (that is, from strings to numbers).

A couple more things to think about. String concatenation is also implied by the interpolation that happens in double-quoted strings. And when you print out a list of values, you're also effectively concatenating strings. So the following three statements produce the same output:

```
say $a . " is equal to " . $b . ".";    # dot operator
say $a, " is equal to ", $b, ".";       # list
say "$a is equal to $b.";               # interpolation
```

Which of these you use in any particular situation is entirely up to you. (But in our opinion interpolation is often the most readable.)

The `x` operator may seem relatively worthless at first glance, but it is quite useful at times, especially for things like this:

```
say "-" x $scrwid;
```

which draws a line across your screen, presuming `$scrwid` contains your screen width, and not your screw identifier.

Assignment Operators

Although it's not exactly a mathematical operator, we've already made extensive use of the simple assignment operator, `=` . Try to remember that `=` means "gets set to" rather than "equals". (There is also a mathematical equality operator `==` that means "equals", and if you start out thinking about the difference between them now, you'll save yourself a lot of headache later. The `==` operator is like a function that returns a Boolean value, while `=` is more like a procedure that is evaluated for the side effect of modifying a variable.)

Like the operators described earlier, assignment operators are binary infix operators, which means they have an operand on either side of the operator. The right operand can be any expression you like, but the left operand must be a valid *lvalue* (which, when translated to English, means a valid storage location like a variable, or a location in an array). The most common assignment operator is simple assignment. It determines the value of the expression on its right side, and then sets the variable on the left side to that value:

```
$a = $b;
$a = $b + 5;
$a = $a * 3;
```

Notice the last assignment refers to the same variable twice; once for the computation, once for the assignment. There's nothing wrong with that, but it's a common enough operation that there's a shortcut for it (borrowed from C). If you say:

```
lvalue operator= expression
```

it is evaluated as if it were:

```
lvalue = lvalue operator expression
```

except that the lvalue is not computed twice. (This only makes a difference if evaluation of the lvalue has side effects. But when it *does* make a difference, it usually does what you want. So don't sweat it.)

So, for example, you could write the previous example as:

```
$a *= 3;
```

which reads "multiply `$a` by 3". You can do this with almost any binary operator in Perl, even some that you can't do it with in C:

```
$line .= "\n";  # Append newline to $line.
$fill x= 80;    # Make string $fill into 80 repeats of itself.
$val ||= "2";   # Set $val to 2 if it isn't already "true".
```

Line 10 of our Average Example[20] contains two string concatenations, one of which is an assignment operator. And line 18 contains a `+=`.

Regardless of which kind of assignment operator you use, the final value of the variable on the left is returned as the value of the assignment as a whole.[21] This will not surprise C programmers, who will already know how to use this idiom to zero out variables:

```
$a = $b = $c = 0;
```

You'll also frequently see assignment used as the condition of a `while` loop, as in line 8 of our Average Example.

What *will* surprise C programmers is that assignment in Perl returns the actual variable as an lvalue, so you can modify the same variable more than once in a statement. For instance, you could say:

```
($temp -= 32) *= 5/9;
```

20. Thought we'd forgotten it, didn't you?

21. This is unlike, say, Pascal, in which assignment is a statement and returns no value. We said earlier that assignment is like a procedure, but remember that in Perl, even procedures return values.

to do an in-place conversion from Fahrenheit to Celsius. This is also why earlier in this chapter we could say:

```
chop($number = <STDIN>);
```

and have it chop the final value of `$number`. Generally speaking, you can use this feature whenever you want to copy something and at the same time do something else with it.

Unary Arithmetic Operators

As if `$variable += 1` weren't short enough, Perl borrows from C an even shorter way to increment a variable. The autoincrement (and autodecrement) operators simply add (or subtract) one from the value of the variable. They can be placed on either side of the variable, depending on when you want them to be evaluated; see Table 1-3.

Table 1-3. Increment operators

Example	Name	Result
`++$a, $a++`	Autoincrement	Add 1 to `$a`
`--$a, $a--`	Autodecrement	Subtract 1 from `$a`

If you place one of these "auto" operators before the variable, it is known as a preincremented (predecremented) variable. Its value will be changed before it is referenced. If it is placed after the variable, it is known as a postincremented (postdecremented) variable, and its value is changed after it is used. For example:

```
$a = 5;        # $a is assigned 5
$b = ++$a;     # $b is assigned the incremented value of $a, 6
$c = $a--;     # $c is assigned 6, then $a is decremented to 5
```

Line 15 of our Average Example increments the number of scores by one so that we'll know how many scores we're averaging. It uses a postincrement operator (`$scores++`), but in this case it doesn't matter since the expression is in void context, which is just a funny way of saying that the expression is being evaluated only for the side effect of incrementing the variable. The value returned is being thrown away.[22]

22. The optimizer will notice this and optimize the postincrement into a preincrement, because that's a bit faster to execute. (You didn't need to know that, but we hoped it would cheer you up.)

Logical Operators

Logical operators, also known as "short-circuit" operators, allow the program to make decisions based on multiple criteria without using nested `if` statements. They are known as short-circuit operators because they skip (short circuit) the evaluation of their right argument if they decide the left argument has already supplied enough information to decide the overall value. This is not just for efficiency. You are explicitly allowed to depend on this short-circuiting behavior to avoid evaluating code in the right argument that you know would blow up if the left argument were not "guarding" it. You can say "California or bust!" in Perl without busting (presuming you do get to California).

Perl actually has two sets of logical operators: a traditional set borrowed from C and a newer (but even more traditional) set of ultralow-precedence operators borrowed from BASIC. Both sets contribute to readability when used appropriately. C's punctuational operators work well when you want your logical operators to bind more tightly than commas, while BASIC's word-based operators work well when you want your commas to bind more tightly than your logical operators. Often they work the same, and which set you use is a matter of personal preference. (For contrastive examples, see the section "Logical and, or, not, and xor" on page 127 in Chapter 3.) Although the two sets of operators are not interchangeable due to precedence, once they're parsed, the operators themselves behave identically; precedence merely governs the extent of their arguments. Table 1-4 lists logical operators.

Table 1-4. Logical operators

Example	Name	Result
`$a && $b`	And	`$a` if `$a` is false, `$b` otherwise
`$a || $b`	Or	`$a` if `$a` is true, `$b` otherwise
`! $a`	Not	True if `$a` is not true
`$a and $b`	And	`$a` if `$a` is false, `$b` otherwise
`$a or $b`	Or	`$a` if `$a` is true, `$b` otherwise
`not $a`	Not	True if `$a` is not true
`$a xor $b`	Xor	True if `$a` or `$b` is true, but not both

Since the logical operators "short circuit" the way they do, they're often used in Perl to conditionally execute code. The following line (line 4 from our Average Example) tries to open the file *grades*:

```
open(GRADES, "<:utf8", "grades")  || die "Can't open file grades: $!\n";
```

If it opens the file, it will jump to the next line of the program. If it can't open the file, it will provide us with an error message and then stop execution.

Literally, this line means "Open *grades* or bust!" Besides being another example of natural language, the short-circuit operators preserve the visual flow. Important actions are listed down the left side of the screen, and secondary actions are hidden off to the right. (The `$!` variable contains the error message returned by the operating system—see Chapter 25.) Of course, these logical operators can also be used within the more traditional kinds of conditional constructs, such as the `if` and `while` statements.

Some Numeric and String Comparison Operators

Comparison, or relational, operators tell us how two scalar values (numbers or strings) relate to each other. There are two sets of operators: one does numeric comparison and the other does string comparison. (In either case, the arguments will be "coerced" to have the appropriate type first.) Assuming left and right arguments of `$a` and `$b`, Table 1-5 shows us what we have.

Table 1-5. Comparison operators

Comparison	Numeric	String	Return Value
Equal	`==`	`eq`	True if `$a` is equal to `$b`
Not equal	`!=`	`ne`	True if `$a` is not equal to `$b`
Less than	`<`	`lt`	True if `$a` is less than `$b`
Greater than	`>`	`gt`	True if `$a` is greater than `$b`
Less than or equal	`<=`	`le`	True if `$a` not greater than `$b`
Greater than or equal	`>=`	`ge`	True if `$a` not less than `$b`
Comparison	`<=>`	`cmp`	0 if equal, 1 if `$a` greater, –1 if `$b` greater

The last pair of operators (`<=>` and `cmp`) are entirely redundant with the earlier operators. However, they're incredibly useful in `sort` subroutines (see Chapter 27).[23]

23. Some folks feel that such redundancy is evil because it keeps a language from being minimalistic, or orthogonal. But Perl isn't an orthogonal language; it's a diagonal language. By this we mean that Perl doesn't force you to always go at right angles. Sometimes you just want to follow the hypotenuse of the triangle to get where you're going. TMTOWTDI is about shortcuts. Shortcuts are about programmer efficiency.

Some File Test Operators

The file test operators allow you to test whether certain file attributes are set before you go and blindly muck about with the files. The most basic file attribute is, of course, whether the file exists. For example, it would be very nice to know whether your mail aliases file already exists before you go and open it as a new file, wiping out everything that was in there before. Table 1-6 gives a few of the file test operators.

Table 1-6. File test operators

Example	Name	Result
`-e $a`	Exists	True if file named in `$a` exists
`-r $a`	Readable	True if file named in `$a` is readable
`-w $a`	Writable	True if file named in `$a` is writable
`-d $a`	Directory	True if file named in `$a` is a directory
`-f $a`	File	True if file named in `$a` is a regular file
`-T $a`	Text File	True if file named in `$a` is a text file

You might use them like this:

```
-e "/usr/bin/perl" or warn "Perl is improperly installed.\n";
-f "/vmlinuz" and say "I see you are a friend of Linus.";
```

Note that a regular file is not the same thing as a text file. Binary files like */vmlinuz* are regular files, but they aren't text files. Text files are the opposite of binary files, while regular files are the opposite of "irregular" files like directories and devices.

There are a lot of file test operators, many of which we didn't list. Most of the file tests are unary Boolean operators, which is to say they take only one operand (a scalar that evaluates to a filename or a filehandle), and they return either a true or false value. A few of them return something fancier, like the file's size or age, but you can look those up when you need them in the section "Named Unary and File Test Operators" on page 106 in Chapter 3.

Control Structures

So far, except for our one large example, all of our examples have been completely linear; we executed each command in order. We've seen a few examples of using the short-circuit operators to cause a single command to be (or not to be) executed. While you can write some very useful linear programs (a lot of CGI scripts

fall into this category), you can write much more powerful programs if you have conditional expressions and looping mechanisms. Collectively, these are known as control structures. So you can also think of Perl as a control language.

But to have control, you have to be able to decide things, and to decide things, you have to know the difference between what's true and what's false.

What Is Truth?

We've bandied about the term truth,[24] and we've mentioned that certain operators return a true or a false value. Before we go any further, we really ought to explain exactly what we mean by that. Perl treats truth a little differently than most computer languages, but after you've worked with it a while, it will make a lot of sense. (Actually, we hope it'll make a lot of sense after you've read the following.)

Basically, Perl holds truths to be self-evident. That's a glib way of saying that you can evaluate almost anything for its truth value. Perl uses practical definitions of truth that depend on the type of thing you're evaluating. As it happens, there are many more kinds of truth than there are of nontruth.

Truth in Perl is always evaluated in scalar context. Other than that, no type coercion is done. So here are the rules for the various kinds of values a scalar can hold:

1. Any string is true except for `""` and `"0"`.
2. Any number is true except for 0.
3. Any reference is true.
4. Any undefined value is false.

Actually, the last two rules can be derived from the first two. Any reference (rule 3) would point to something with an address and would evaluate to a number or string containing that address, which is never 0 because it's always defined. And any undefined value (rule 4) would always evaluate to 0 or the null string.

And, in a way, you can derive rule 2 from rule 1 if you pretend that everything is a string. Again, no string coercion is actually done to evaluate truth, but if the string coercion *were* done, then any numeric value of 0 would simply turn into the string `"0"` and be false. Any other number would not turn into the string `"0"`, and so would be true. Let's look at some examples so we can understand this better:

24. Strictly speaking, this is not true.

```
0          # would become the string "0", so false.
1          # would become the string "1", so true.
10 - 10    # 10 minus 10 is 0, would convert to string "0", so false.
0.00       # equals 0, would convert to string "0", so false.
"0"        # is the string "0", so false.
""         # is a null string, so false.
"0.00"     # is the string "0.00", neither "" nor "0", so true!
"0.00" + 0 # would become the number 0 (coerced by the +), so false.
\$a        # is a reference to $a, so true, even if $a is false.
undef()    # is a function returning the undefined value, so false.
```

Since we mumbled something earlier about truth being evaluated in scalar context, you might be wondering what the truth value of a list is. Well, the simple fact is none of the operations in Perl will return a list in scalar context. They'll all notice they're in scalar context and return a scalar value instead, and then you apply the rules of truth to that scalar. So there's no problem, as long as you can figure out what any given operator will return in scalar context. As it happens, both arrays and hashes return scalar values that conveniently happen to be true if the array or hash contains any elements. More on that later.

The if and unless statements

We saw earlier how a logical operator could function as a conditional. A slightly more complex form of the logical operators is the `if` statement. The `if` statement evaluates a truth condition (that is, a Boolean expression) and executes a block if the condition is true:

```
if ($debug_level > 0) {
    # Something has gone wrong.  Tell the user.
    say "Debug: Danger, Will Robinson, danger!";
    say "Debug: Answer was '54', expected '42'.";
}
```

A block is one or more statements grouped together by a set of braces. Since the `if` statement executes a block, the braces are required by definition. If you know a language like C, you'll notice that this is different. Braces are optional in C if you have a single statement, but the braces are not optional in Perl.

Sometimes just executing a block when a condition is met isn't enough. You may also want to execute a different block if that condition *isn't* met. While you could certainly use two `if` statements, one the negation of the other, Perl provides a more elegant solution. After the block, `if` can take an optional second condition, called `else`, to be executed only if the truth condition is false. (Veteran computer programmers will not be surprised at this point.)

At times you may even have more than two possible choices. In this case, you'll want to add an `elsif` truth condition for the other possible choices. (Veteran computer programmers may well be surprised by the spelling of "`elsif`", for which nobody here is going to apologize. Sorry.)

```
if ($city eq "New York") {
    say "New York is northeast of Washington, D.C.";
}
elsif ($city eq "Chicago") {
    say "Chicago is northwest of Washington, D.C.";
}
elsif ($city eq "Miami") {
    say "Miami is south of Washington, D.C.  And much warmer!";
}
else {
    say "I don't know where $city is, sorry.";
}
```

The `if` and `elsif` clauses are each computed in turn, until one is found to be true or the `else` condition is reached. When one of the conditions is found to be true, its block is executed and all remaining branches are skipped. Sometimes, you don't want to do anything if the condition is true, only if it is false. Using an empty `if` with an `else` may be messy, and a negated `if` may be illegible; it sounds weird in English to say "if not this is true, do something". In these situations, you would use the `unless` statement:

```
unless ($destination eq $home) {
    say "I'm not going home.";
}
```

There is no `elsunless` though. This is generally construed as a feature.

The given and when Statements

To test a single value for a bunch of different alternatives, recent versions of Perl have what other languages sometimes call `switch` and `case`. Because we like to make Perl work like a natural language, however, we call these `given` and `when`. (Since you're already putting `use v5.14` at the top, you should have this functionality, which was introduced in 5.10.)

```
#!/usr/bin/perl
use v5.14;

print "What is your favorite color? ";
chomp(my $answer = <STDIN>);

given ($answer) {
    when ("purple")      { say "Me too." }
```

```
        when ("green")       { say "Go!" }
        when ("yellow")      { say "Slow!" }
        when ("red")         { say "Stop!" }

        when ("blue")        { say "You may proceed." }
        when (/\w+, no \w+/) { die "AAAUUUGHHHHH!" }

        when (42)            { say "Wrong answer." }

        when (['gray','orange','brown','black','white']) {
            say "I think $answer is pretty okay too.";
        }

        default {
            say "Are you sure $answer is a real color?";
        }
    }
```

First the `given` part takes the value of its expression and makes it the topic of conversation, so the `when` statements know which value to test. The cases are then evaluated by matching the argument of each `when` against the topic to find the first `when` statement that thinks the topic's value matches. The `when` statements try to match in order, and as soon as one matches, it doesn't try any of the subsequent statements, but drops out of the whole `given` construct.

The form of each `when` argument (`"red"` vs `42` vs `/\w+, no \w+/`) determines the type of match performed, so strings match as strings, numbers match as numbers, and patterns match as, well, patterns. Lists of values match if any of them match. The `when` statement uses an underlying operation called "smartmatching" that is designed to match the way you expect most of the time, except when it doesn't. See "Smartmatch Operator" on page 112 in Chapter 3 for more on that.

Looping Constructs

These statements allow a Perl program to repeatedly execute the same code, so they are often known as *iterative* constructs. There are several kinds, which differ primarily in how you know when you're done with the loop and can go on to other things.

Conditional loops

The `while` and `until` statements test an expression for truth just as the `if` and `unless` statements do, except that they'll execute the block repeatedly as long as the condition is satisfied each time through. The condition is always checked before each iteration. If the condition is met (that is, if it is true for a `while` or false for an `until`), the block of the statement is executed.

```
print "How many tickets have we sold so far? ";
my $before = <STDIN>;

my $sold = $before;
while ($sold < 10000) {
    my $available = 10000 - $sold;
    print "$available tickets are available.  How many would you like: ";
    my $purchase = <STDIN>;
    if ($purchase > $available) {
        say "Too many! Try again.";
        $purchase = 0;
    }
    $sold += $purchase;
}

say "This show is sold out, please come back later.";
```

Note that if the original condition is never met, the loop will never be entered at all. For example, if we've already sold 10,000 tickets, we will report the show to be sold out immediately.

In our Average Example earlier, line 8 reads:

```
while (my $line = <GRADES>) {
```

This assigns the next line to the variable `$line` and, as we explained earlier, returns the value of `$line` so that the condition of the `while` statement can evaluate `$line` for truth. You might wonder whether Perl will get a false negative on blank lines and exit the loop prematurely. The answer is that it won't. The reason is clear if you think about everything we've said. The line input operator leaves the newline on the end of the string, so a blank line has the value `"\n"`. And you know that `"\n"` is not one of the canonical false values. So the condition is true, and the loop continues even on blank lines.

On the other hand, when we finally do reach the end of the file, the line input operator returns the undefined value, which always evaluates to false. And the loop terminates, just when we wanted it to. There's no need for an explicit test of the `eof` function in Perl, because the input operators are designed to work smoothly in a conditional context.

In fact, almost everything is designed to work smoothly in a conditional (Boolean) context. If you mention an array in scalar context, the length of the array is returned. So you often see command-line arguments processed like this:

```
while (@ARGV) {
    process(shift @ARGV);
}
```

The `shift` operator removes one element from the argument list each time through the loop (and returns that element). The loop automatically exits when array `@ARGV` is exhausted; that is, when its length goes to 0. And 0 is already false in Perl. In a sense, the array itself has become "false".[25]

The three-part loop

Another iterative statement is the three-part loop, also known as a C-style `for` loop. The three-part loop runs exactly like the `while` loop above, but it looks a bit different because two of the statements get moved into the official definition of the loop. (C programmers will find it very familiar though.)

```
print "How many tickets have we sold so far? ";
my $before = <STDIN>;

for (my $sold = $before; $sold < 10000; $sold += my $purchase) {
    my $available = 10000 - $sold;
    print "$available tickets are available.  How many would you like: ";
    $purchase = <STDIN>;
    if ($purchase > $available) {
        say "Too many! Try again.";
        $purchase = 0;
    }
}

say "This show is sold out, please come back later.";
```

Within the loop's parentheses, the three-part loop takes three expressions (hence the name), separated by two semicolons. The first expression sets the initial state of the loop variable. The second is a condition to test the loop variable; this works just like the `while` statement's condition. The third expression modifies the state of the loop variable; this expression is effectively executed at the end of each iteration, just as we did explicitly in the previous `while` loop.

When the three-part loop starts, the initial state is set and the truth condition is checked. If the condition is true, the block is executed. When the block finishes, the modification expression is executed, the truth condition is again checked, and, if true, the block is rerun with the next value. As long as the truth condition remains true, the block and the modification expression will continue to be executed. (Note that only the middle expression is evaluated for its value. The first

25. This is how Perl programmers think. So there's no need to compare 0 to 0 to see if it's false. Despite the fact that other languages force you to, don't go out of your way to write explicit comparisons like `while (@ARGV != 0)`. That's just inefficient for both you and the computer. And anyone who has to maintain your code.

and third expressions are evaluated only for their side effects, and the resulting values are thrown away!)

Each of the three expressions may be omitted, but the two semicolons are always required. If you leave out the middle expression, it assumes you want to loop forever, so you can write an infinite loop like this:

```
for (;;) {
    say "Take out the trash!";
    sleep(5);
}
```

The foreach loop

The last of Perl's iterative statements is known as the *foreach* loop.[26] This loop executes the same code for each of a known list of scalars, such as you might get from an array:

```
for my $user (@users) {
    if (-f "$home{$user}/.nexrc") {
        say "$user is cool... they use a perl-aware vi!";
    }
}
```

Unlike the `if` and `while` statements, which provide scalar context to a conditional expression, the foreach statement provides list context to the expression in parentheses. So the expression is evaluated to produce a list, if possible (and, if not, a single scalar value will be considered a list of one element). Then each element of the list is aliased to the loop variable in turn, and the block of code is executed once for each list element. Note that the loop variable refers to the element itself, rather than a copy of the element. Hence, modifying the loop variable also modifies the original array.

You'll find many more of these loops in the typical Perl program than traditional three-part `for` loops, because it's very easy in Perl to generate the kinds of lists that a foreach wants to iterate over. (That's partly why we stole `for`'s keyword, since we're lazy and think commonly used words should be short.) One idiom you'll often see is a loop to iterate over the sorted keys of a hash:

```
for my $key (sort keys %hash) {
```

In fact, line 13 of our Average Example does precisely that, so we can print out the students in alphabetical order.

---

26. Historically, it was written with the `foreach` keyword, hence the name. These days we tend to use the `for` keyword instead, since it reads more like English when you include a `my` declaration (and because the syntax cannot be confused with the three-part loop). So many of us never write `foreach` anymore, though you can still do that if you like.

Breaking out: next and last

The `next` and `last` operators allow you to modify the flow of your loop. It is not at all uncommon to have a special case; you may want to skip it, or you may want to quit when you encounter it. For example, if you are dealing with Unix accounts, you may want to skip the system accounts (like *root* or *lp*). The `next` operator would allow you to skip to the end of your current loop iteration and start the next iteration. The `last` operator would allow you to skip to the end of your block, as if your loop's test condition had returned false. This might be useful if, for example, you are looking for a specific account and want to quit as soon as you find it.

```
for my $user (@users) {
    if ($user eq "root" || $user eq "lp") {
        next;
    }
    if ($user eq "special") {
        print "Found the special account.\n";
        # do some processing
        last;
    }
}
```

It's possible to break out of multilevel loops by labeling your loops and specifying which loop you want to break out of. Together with statement modifiers (another form of conditional which we'll talk about later), this can make for extremely readable loop exits (if you happen to think English is readable):

```
LINE: while (my $line = <EMAIL>) {
    next LINE if $line eq "\n";   # skip blank lines
    last LINE if $line =~ /^>/;   # stop on first quoted line
    # your ad here
}
```

You may be saying, "Wait a minute, what's that funny `^>` thing there inside the leaning toothpicks? That doesn't look much like English." And you're right. That's a pattern match containing a regular expression (albeit a rather simple one). And that's what the next section is about. Perl is just about the best text-processing language in the world, and regular expressions are at the heart of Perl's text processing.

Regular Expressions

Regular expressions (a.k.a. regexes, regexps, or REs) are used by many search programs such as *grep* and *findstr*, text-munging programs like *sed* and *awk*, and editors like *vi* and *emacs*. A regular expression is a way of describing a set of strings

without having to list all the strings in your set.[27] Many other computer languages incorporate regular expressions (some of them even advertise "Perl5 regular expressions"!), but none of these languages integrates regular expressions into the language the way Perl does. Regular expressions are used several ways in Perl. First and foremost, they're used in conditionals to determine whether a string matches a particular pattern, because in a Boolean context they return true and false. So when you see something that looks like `/foo/` in a conditional, you know you're looking at an ordinary *pattern-matching* operator:

```
if (/Windows 7/) { print "Time to upgrade?\n" }
```

Second, if you can locate patterns within a string, you can replace them with something else. So when you see something that looks like `s/foo/bar/`, you know it's asking Perl to substitute "bar" for "foo", if possible. We call that the *substitution* operator. It also happens to return true or false depending on whether it succeeded, but usually it's evaluated for its side effect:

```
s/IBM/lenovo/;
```

Finally, patterns can specify not only where something is, but also where it *isn't*. So the `split` operator uses a regular expression to specify where the data isn't. That is, the regular expression defines the *separators* that delimit the fields of data. Our Average Example has a couple of trivial examples of this. Lines 9 and 16 each split strings on whitespace in order to return a list of words. But you can split on any separator you can specify with a regular expression:

```
my ($good, $bad, $ugly) = split(/,/, "vi,emacs,teco");
```

(There are various modifiers you can use in each of these situations to do exotic things like ignore case when matching alphabetic characters, but these are the sorts of gory details that we'll cover in Part II when we get to the gory details.)

The simplest use of regular expressions is to match a literal expression. In the case of the `split` above, we matched on a single comma character. But if you match on several characters in a row, they all have to match sequentially. That is, the pattern looks for a substring, much as you'd expect. Let's say we want to show all the lines of an HTML file that contain HTTP links (as opposed to FTP links). Let's imagine we're working with HTML for the first time, and we're being a little naïve. We know that these links will always have "`http:`" in them somewhere. We could loop through our file with this:

27. A good source of information on regular expression concepts is Jeffrey Friedl's book, *Mastering Regular Expressions*.

```
while (my $line = <FILE>) {
    if ($line =~ /http:/) {
        print $line;
    }
}
```

Here, the `=~` (pattern binding) is telling Perl to look for a match of the regular expression "`http:`" in the variable `$line`. If it finds the expression, the operator returns a true value and the block (a `print` statement) is executed.[28]

By the way, if you don't use the `=~` binding operator, Perl will search a default string instead of `$line`. It's like when you say, "Eek! Help me find my contact lens!" People automatically know to look around near you without your actually having to tell them that. Likewise, Perl knows that there is a default place to search for things when you don't say where to search for them. This default string is actually a special scalar variable that goes by the odd name of `$_`. In fact, it's not the default just for pattern matching; many operators in Perl default to using the `$_` variable, so a veteran Perl programmer would likely write the last example as:

```
while (<FILE>) {
    print if /http:/;
}
```

(Hmm, another one of those statement modifiers seems to have snuck in there. Insidious little beasties.)

This stuff is pretty handy, but what if we wanted to find all of the link types, not just the HTTP links? We could give a list of link types, like "`http:`", "`ftp:`", "`mailto:`", and so on. But that list could get long, and what would we do when a new kind of link was added?

```
while (<FILE>) {
    print if /http:/;
    print if /ftp:/;
    print if /mailto:/;
    # What next?
}
```

Since regular expressions are descriptive of a set of strings, we can just describe what we are looking for: a number of alphabetic characters followed by a colon. In regular expression talk (Regexese?), that would be `/[a-zA-Z]+:/`, where the brackets define a *character class*. The `a-z` and `A-Z` represent all ASCII alphabetic characters (the dash means the range of all characters between the starting and ending character, inclusive). And the `+` is a special character that says "one or more of whatever was before me". It's what we call a *quantifier*, meaning a gizmo

28. This is very similar to what the Unix command `grep 'http:' file` would do.

that says how many times something is allowed to repeat. (The slashes aren't really part of the regular expression, but rather part of the pattern-match operator. The slashes are acting like quotes that just happen to contain a regular expression.)

Because certain classes like the alphabetics are so commonly used, Perl defines shortcuts for them, as listed in Table 1-7.

Table 1-7. Shortcuts for alphabetic characters

Name	ASCII Definition	Unicode Definition	Shortcut
Whitespace	`[ \t\n\r\f]`	`\p{Whitespace}`	`\s`
Word character	`[a-zA-Z_0-9]`	`[\p{Alphabetic}\p{Digit}\p{Mark}\p{Pc}]`	`\w`
Digit	`[0-9]`	`\p{Digit}`	`\d`

Note that these match *single* characters. A `\w` will match any single word character, not an entire word. (Remember that `+` quantifier? You can say `\w+` to match a word.) Perl also provides the negation of these classes by using the uppercased character, such as `\D` for a nondigit character.

We should note that `\w` is not always equivalent to `[a-zA-Z_0-9]` (and `\d` is not always `[0-9]`). Some locales define additional alphabetic characters outside the ASCII sequence, and `\w` respects them. Versions of Perl newer than 5.8.1 also know about Unicode letter and digit properties and treat Unicode characters with those properties accordingly. (Perl also considers ideographs and combining marks to be `\w` characters.)

There is one other very special character class, written with a "`.`", that will match any character whatsoever.[29] For example, `/a./` will match any string containing an "`a`" that is not the last character in the string. Thus, it will match "`at`" or "`am`" or even "`a!`", but not "`a`", since there's nothing after the "`a`" for the dot to match. Since it's searching for the pattern anywhere in the string, it'll match "`oasis`" and "`camel`", but not "`sheba`". It matches "`caravan`" on the first "`a`". It could match on the second "`a`", but it stops after it finds the first suitable match, searching from left to right.

29. Except that it won't normally match a newline. When you think about it, a "`.`" doesn't normally match a newline in *grep*(1) either.

Quantifiers

The characters and character classes we've talked about all match single characters. We mentioned that you could match multiple "word" characters with `\w+`. The `+` is one kind of quantifier, but there are others. All of them are placed after the item being quantified.

The most general form of quantifier specifies both the minimum and maximum number of times an item can match. You put the two numbers in braces, separated by a comma. For example, if you were trying to match North American phone numbers, the sequence `\d{7,11}` would match at least seven digits, but no more than eleven digits. If you put a single number in the braces, the number specifies both the minimum and the maximum; that is, the number specifies the exact number of times the item can match. (All unquantified items have an implicit `{1}` quantifier.)

If you put the minimum and the comma but omit the maximum, then the maximum is taken to be infinity. In other words, it will match at least the minimum number of times, plus as many as it can get after that. For example, `\d{7}` will match only the first seven digits (a local North American phone number, for instance, or the first seven digits of a longer number), while `\d{7,}` will match any phone number, even an international one (unless it happens to be shorter than seven digits). There is no special way of saying "at most" a certain number of times. Just say `.{0,5}`, for example, to find at most five arbitrary characters.

Certain combinations of minimum and maximum occur frequently, so Perl defines special quantifiers for them. We've already seen `+`, which is the same as `{1,}`, or "at least one of the preceding item". There is also `*`, which is the same as `{0,}`, or "zero or more of the preceding item", and `?`, which is the same as `{0,1}`, or "zero or one of the preceding item" (that is, the preceding item is optional).

You need to be careful of a couple things about quantification. First of all, Perl quantifiers are by default *greedy*. This means that they will attempt to match as much as they can as long as the whole pattern still matches. For example, if you are matching `/\d+/` against "`1234567890`", it will match the entire string. This is something to watch out for especially when you are using "`.`", any character. Often, someone will have a string like:

```
larry:JYHtPh0./NJTU:100:10:Larry Wall:/home/larry:/bin/bash
```

and will try to match "`larry:`" with `/.+:/`. However, since the `+` quantifier is greedy, this pattern will match everything up to and including "`/home/larry:`", because it matches as much as possible before the last colon, including all the other colons. Sometimes you can avoid this by using a negated character class;

that is, by saying `/[^:]+:/`, which says to match one or more noncolon characters (as many as possible), up to the first colon. It's that little caret in there that negates the Boolean sense of the character class.[30] The other point to be careful about is that regular expressions will try to match as *early* as possible. This even takes precedence over being greedy. Since scanning happens left to right, the pattern will match as far left as possible, even if there is some other place where it could match longer. (Regular expressions may be greedy, but they aren't into delayed gratification.) For example, suppose you're using the substitution command (`s///`) on the default string (variable `$_`, that is), and you want to remove a string of x's from the middle of the string. If you say:

```
$_ = "fred xxxxxxx barney";
s/x*//;
```

it will have absolutely no effect! This is because the `x*` (meaning zero or more "`x`" characters) will be able to match the "nothing" at the beginning of the string, since the null string happens to be zero characters wide and there's a null string just sitting there plain as day before the "`f`" of "`fred`".[31] There's one other thing you need to know. By default, quantifiers apply to a single preceding character, so `/bam{2}/` will match "`bamm`" but not "`bambam`". To apply a quantifier to more than one character, use parentheses. So to match "`bambam`", use the pattern `/(bam){2}/`.

Minimal Matching

If you were using a prehistoric version of Perl and you didn't want greedy matching, you had to use a negated character class. (And, really, you were still getting greedy matching of a constrained variety.)

In modern versions of Perl, you can force nongreedy, minimal matching by placing a question mark after any quantifier. Our same username match would now be `/.*?:/`. That `.*?` will now try to match as few characters as possible, rather than as many as possible, so it stops at the first colon rather than at the last.

Nailing Things Down

Whenever you try to match a pattern, it's going to try to match in every location until it finds a match. An *anchor* allows you to restrict where the pattern can match. Essentially, an anchor is something that matches a "nothing", but a

30. Sorry, we didn't pick that notation, so don't blame us. That's just how negated character classes are customarily written in Unix culture.

31. Don't feel bad. Even the authors get caught by this from time to time.

special kind of nothing that depends on its surroundings. You could also call it a rule, a constraint, or an assertion. Whatever you care to call it, it tries to match something of zero width and either succeeds or fails. (Failure merely means that the pattern can't match that particular way. The pattern will go on trying to match some other way, if there are any other ways left to try.)

The special symbol `\b` matches at a word boundary, which is defined as the "nothing" between a word character (`\w`) and a nonword character (`\W`), in either order. (The characters that don't exist off the beginning and end of your string are considered to be nonword characters.) For example:

```
/\bFred\b/
```

would match "`Fred`" in both "`The Great Fred`" and "`Fred the Great`", but not in "`Frederick the Great`" because the "`d`" in "`Frederick`" is not followed by a nonword character.

In a similar vein, there are also anchors for the beginning and the end of the string. If it is the first character of a pattern, the caret (`^`) matches the "nothing" at the beginning of the string. Therefore, the pattern `/^Fred/` would match "`Fred`" in "Frederick the Great" but not in "The Great Fred", whereas `/Fred^/` wouldn't match either. (In fact, it doesn't even make much sense.) The dollar sign (`$`) works like the caret, except that it matches the "nothing" at the end of the string instead of the beginning.[32] So now you can probably figure out that when we said:

```
next LINE if $line =~ /^#/;
```

we meant "Go to the next iteration of `LINE` loop if this line happens to begin with a `#` character."

Earlier we said that the sequence `\d{7,11}` would match a number from seven to eleven digits long. While strictly true, the statement is misleading: when you use that sequence within a real pattern-match operator such as `/\d{7,11}/`, it does not preclude there being extra unmatched digits after the 11 matched digits! You often need to anchor quantified patterns on either or both ends to get what you expect.

Backreferences

We mentioned earlier that you can use parentheses to group things for quantifiers, but you can also use parentheses to remember bits and pieces of what you

32. This is a bit oversimplified, since we're assuming here that your string contains no newlines; `^` and `$` are actually anchors for the beginnings and endings of lines rather than strings. We'll try to straighten this all out in Chapter 5 (to the extent that it can be straightened out).

matched. A pair of parentheses around a part of a regular expression causes whatever was matched by that part to be remembered for later use. It doesn't change what the part matches, so `/\d+/` and `/(\d+)/` will still match as many digits as possible, but in the latter case they will be remembered in a special variable to be backreferenced later.

How you refer back to the remembered part of the string depends on where you want to do it from. Within the same regular expression, you use a backslash followed by an integer. The integer corresponding to a given pair of parentheses is determined by counting left parentheses from the beginning of the pattern, starting with one. So, for example, to match something similar to an HTML tag like "`<B>Bold</B>`", you might use `/<(.*?)>.*?<\/\1>/`. This forces the two parts of the pattern to match the exact same string, such as the "`B`" in this example.

Outside the regular expression itself, such as in the replacement part of a substitution, you use a `$` followed by an integer; that is, a normal scalar variable named by the integer. So if you wanted to swap the first two words of a string, for example, you could use:

```
s/(\S+)\s+(\S+)/$2 $1/
```

The right side of the substitution (between the second and third slashes) is mostly just a funny kind of double-quoted string, which is why you can interpolate variables there, including backreference variables. This is a powerful concept: interpolation (under controlled circumstances) is one of the reasons Perl is a good text-processing language. The other reason is the pattern matching, of course. Regular expressions are good for picking things apart, and interpolation is good for putting things back together again. Perhaps there's hope for Humpty Dumpty after all.

If you get tired of numbered backreferences, v5.10 or later also supports named backreferences. This is the same substitution as just given but this time using named groups:

```
s/(?<alpha>\S+)\s+(?<beta>\S+)/$+{beta} $+{alpha}/
```

Table 1-8. Regular expression backreferences

Where	Numbered Group	Named Group
Declare	`( ... )`	`(?<`*NAME*`> ... )`
Inside same regex	`\1`	`\k<`*NAME*`>`
In regular Perl code	`$1`	`$+{`*NAME*`}`

It may take longer to type in the code that way, but once your patterns grow in size and complexity, you'll be glad you can name your groups with meaningful words instead of just numbers.

List Processing

Much earlier in this chapter, we mentioned that Perl has two main contexts: scalar context (for dealing with singular things) and list context (for dealing with plural things). Many of the traditional operators we've described so far have been strictly scalar in their operation. They always take singular arguments (or pairs of singular arguments for binary operators) and always produce a singular result, even in list context. So if you write this:

```
@array = (1 + 2, 3 - 4, 5 * 6, 7 / 8);
```

you know that the list on the right side contains exactly four values, because the ordinary math operators always produce scalar values, even in the list context provided by the assignment to an array.

However, other Perl operators can produce either a scalar or a list value, depending on their context. They just "know" whether a scalar or a list is expected of them. But how will you know that? It turns out to be pretty easy to figure out, once you get your mind around a few key concepts.

First, list context has to be provided by something in the "surroundings". In the previous example, the list assignment provides it. Earlier we saw that the list of a `foreach` loop provides it. The `print` operator also provides it. But you don't have to learn these one by one.

If you look at the various syntax summaries scattered throughout the rest of the book, you'll see various operators that are defined to take a *`LIST`* as an argument. Those are the operators that *provide* list context. Throughout this book, *`LIST`* is used as a specific technical term to mean "a syntactic construct that provides list context". For example, if you look up `sort`, you'll find the syntax summary:

```
sort LIST
```

That means that `sort` provides list context to its arguments.

Second, at compile time (that is, while Perl is parsing your program and translating to internal opcodes), any operator that takes a *`LIST`* provides list context to each syntactic element of that *`LIST`*. So every top-level operator or entity in the *`LIST`* knows at compile time that it's supposed to produce the best list it knows how to produce. This means that if you say:

```
sort @dudes, @chicks, other();
```

then each of `@dudes`, `@chicks`, and `other()` knows at compile time that it's supposed to produce a list value rather than a scalar value. So the compiler generates internal opcodes that reflect this.

Later, at runtime (when the internal opcodes are actually interpreted), each of those *`LIST`* elements produces its list in turn, and then (this is important) all the separate lists are joined together, end to end, into a single list. And that squashed-flat, one-dimensional list is what is finally handed off to the function that wanted the *`LIST`* in the first place. So if `@dudes` contains `(Fred,Barney)`, `@chicks` contains `(Wilma,Betty)`, and the `other` function returns the single-element list `(Dino)`, then the *`LIST`* that `sort` sees is:

```
(Fred,Barney,Wilma,Betty,Dino)
```

and the *`LIST`* that `sort` returns is:

```
(Barney,Betty,Dino,Fred,Wilma)
```

Some operators produce lists (like `keys`), while some consume them (like `print`), and others transform lists into other lists (like `sort`). Operators in the last category can be considered filters, except that, unlike in the shell, the flow of data is from right to left, since list operators operate on arguments passed in from the right. You can stack up several list operators in a row:

```
print reverse sort map {lc} keys %hash;
```

That takes the keys of `%hash` and returns them to the `map` function, which lowercases all the keys by applying the `lc` operator to each of them, and passes them to the `sort` function, which sorts them, and passes them to the `reverse` function, which reverses the order of the list elements, and passes them to the `print` function, which prints them.

As you can see, that's much easier to describe in Perl than in English.

There are many other ways in which list processing produces more natural code. We can't enumerate all the ways here, but for an example, let's go back to regular expressions for a moment. We talked about using a pattern in scalar context to see whether it matched, but if instead you use a pattern in list context, it does something else: it pulls out all the backreferences as a list. Suppose you're searching through a log file or a mailbox, and you want to parse a string containing a time of the form "12:59:59 am". You might say this:

```
my ($hour, $min, $sec, $ampm) = /(\d+):(\d+):(\d+) *(\w+)/;
```

That's a convenient way to set several variables simultaneously. But you could just as easily say:

```
my @hmsa = /(\d+):(\d+):(\d+) *(\w+)/;
```

and put all four values into one array. Oddly, by decoupling the power of regular expressions from the power of Perl expressions, list context increases the power of the language. We don't often admit it, but Perl is actually an orthogonal language in addition to being a diagonal language. Have your cake and eat it, too.

What You Don't Know Won't Hurt You (Much)

Finally, allow us to return once more to the concept of Perl as a natural language. Speakers of a natural language are allowed to have differing skill levels, to speak different subsets of the language, to learn as they go, and, generally, to put the language to good use before they know the whole language. You don't know all of Perl yet, just as you don't know all of English. But that's Officially Okay in Perl culture. You can work with Perl usefully, even though we haven't even told you how to write your own subroutines yet. We've scarcely begun to explain how to view Perl as a system management language, or a rapid prototyping language, or a networking language, or an object-oriented language. We could write entire chapters about some of these things. (Come to think of it, we already did.)

But, in the end, you must create your own view of Perl. It's your privilege as an artist to inflict the pain of creativity on yourself. We can teach you how *we* paint, but we can't teach you how *you* paint. There's More Than One Way To Do It.

Have the appropriate amount of fun.

PART II

The Gory Details

CHAPTER 2

Bits and Pieces

We're going to start small, so this chapter is about the elements of Perl.

Since we're starting small, the progression through the next several chapters is necessarily from small to large. That is, we take a bottom-up approach, beginning with the smallest components of Perl programs and building them into more elaborate structures, much like molecules are built out of atoms. The disadvantage of this approach is that you don't necessarily get the Big Picture before getting lost in a welter of details. The advantage is that you can understand the examples as we go along. (If you're a top-down person, just turn the book over and read the chapters backward.)

Each chapter does build on the preceding chapter (or the *subsequent* chapter, if you're reading backward), so you'll need to be careful if you're the sort of person who skips around.

You're certainly welcome to peek at the reference materials toward the end of the book as we go along. (That doesn't count as skipping around.) In particular, any isolated word in `monospaced` font is likely to be found in Chapter 27. And although we've tried to stay operating-system neutral, if you are unfamiliar with Unix terminology and run into a word that doesn't seem to mean what you think it ought to mean, you should check whether the word is in the Glossary. If the Glossary doesn't work, the Index on page 1091 probably will. If that doesn't work, try your favorite search engine.

Atoms

Although there are various invisible things going on behind the scenes that we'll explain presently, the smallest things you generally work with in Perl are individual characters. And we do mean characters; historically, Perl freely confused

bytes with characters and characters with bytes, but in this new era of global networking, we must be careful to distinguish the two.

Perl may, of course, be written entirely in the 7-bit ASCII character set. For historical reasons, bytes in the range 128–255 are understood by Perl as being from the ISO-8859-1 (Latin1) character set, whose codepoints correspond to Unicode's. To tell Perl that bytes in the current source file are to be treated as Unicode encoded as UTF-8, put this declaration at the top of your file:

```
use utf8;
```

As described in Chapter 6, Perl has had Unicode support since the last millennium. This support is pervasive throughout the language: you can use Unicode characters in identifiers (variable names and such) as well as within literal strings. When you are using Unicode, you don't need to worry about how many bits or bytes it takes to represent a character. Perl just pretends all characters are the same size (that is, size 1), even though any given character might be represented by multiple bytes internally. Perl normally represents characters internally as UTF-8, a variable-length encoding. (For instance, a Unicode smiley character ☺, U+263A, would be represented internally as a three-byte sequence, but you aren't supposed to worry about that.)

If you'll let us drive our analogy of the physical elements a bit further, characters are atomic in the same sense as the individual atoms of the various elements. Yes, they're composed of smaller particles known as bits and bytes, but if you break a character apart (in a character accelerator, no doubt), the individual bits and bytes lose the distinguishing chemical properties of the character as a whole. Just as neutrons are an implementation detail of the U-238 atom, so too bytes are an implementation detail of the U+263A character.

So don't sweat the small stuff. Let's move on to bigger and better things.

Molecules

Perl is a *free-form* language, but that doesn't mean that Perl is totally free of form. As computer folks usually use the term, a free-form language is one in which you can put spaces, tabs, and newlines anywhere you like—except where you can't.

One obvious place you can't put a whitespace character is in the middle of a token. A *token* is what we call a sequence of characters with a unit of meaning, much like a simple word in natural language. But unlike the typical word, a token might contain other characters besides letters, just as long as they hang together to form a unit of meaning. (In that sense, they're more like molecules, which don't have to be composed of only one particular kind of atom.) For example, numbers and

mathematical operators are considered tokens. An *identifier* is a token that starts with an alphabetic character (typically a letter) or connector punctuation like an underscore and contains only alphabetics, combining marks, digits, and underscores. A token may not contain whitespace characters because this would split the token into two tokens, just as a space in an English word turns it into two words.[1]

Although whitespace is allowed between any two tokens, whitespace is *required* only between tokens that would otherwise be confused as a single token. All whitespace is equivalent for this purpose. Newlines are distinguished from spaces and tabs only within quoted strings, formats, and certain line-oriented forms of quoting. Specifically, newlines do not terminate statements as they do in certain other languages (such as FORTRAN or Python). Statements in Perl are terminated with semicolons, just as they are in C and various of its derivatives, like C++ and Java.

Unicode whitespace characters are allowed in a Unicode Perl program, but you need to be careful. If you use the special Unicode paragraph and line separators, be aware that Perl may count line numbers differently than your text editor does, so error messages may be more difficult to interpret. It's best to stick with good old-fashioned newlines.

Tokens are recognized greedily; if at a particular point the Perl parser has a choice between recognizing a short token or a long token, it will choose the long one. If you meant it to be two tokens, just insert some whitespace between the tokens. (We tend to put extra space around most infix operators anyway, just for readability.)

Comments are indicated by the `#` character and extend from there through the end of the line. A comment counts as whitespace for separating tokens. The Perl language attaches no special meaning to anything you might put into a comment:[2]

```
my $comet = 'Haley';  # This is a comment
```

One other oddity is that if a line begins with `=` anywhere a statement would be legal, Perl ignores everything from that line down to the next line that begins with `=cut`. The ignored text is assumed to be *pod*, or "plain old documentation". The

1. The astute reader will point out that literal strings may contain whitespace characters. But strings can get away with it only because they have quotes on both ends to keep the spaces from leaking out.

2. Actually, that's a small fib. The Perl parser does look for command-line switches on an initial `#!` line (see Chapter 17). It can also interpret the line number directives that various preprocessors produce (see the section "Generating Perl in Other Languages" on page 717 in Chapter 21). Some modules, such as `Perl::Critic` and `Smart::Comments`, also use special comments to figure out what to do.

Perl distribution has programs that will extract pod commentary from Perl modules and turn it into flat text, manpages, LaTeX, or even HTML or XML documents. In a complementary fashion, the Perl parser extracts the Perl code from Perl modules and ignores the pod. So you may consider this an alternate, multiline form of commenting. The code in this pod section isn't even compiled:

```
=pod

my $dog = 'Spot';
my $cat = 'Buster';

=cut
```

You may also consider it completely nuts, but Perl modules documented this way never lose track of their documentation. See Chapter 23 for details on pod, including a description of how to effect multiline comments in Perl.

But don't look down on the normal comment character. There's something comforting about the visual effect of a nice row of # characters down the left side of a multiline comment. It immediately tells your eyes: "This is not code." You'll note that even in languages with multiline commenting mechanisms like C, people often put a row of * characters down the left side of their comments anyway. Appearances are often more important than they appear:

```
# start of a multiline comment
# my $dog = 'Spot';
# my $cat = 'Buster';
```

In Perl, just as in chemistry and in language, you can build larger and larger structures out of the smaller ones. We already mentioned the *statement*; it's just a sequence of tokens that make up a command; that is, a sentence in the imperative mood. You can combine a sequence of statements into a *block* that is delimited by braces (also known affectionately as "curlies" by people who confuse braces with suspenders). Blocks can in turn be combined into larger blocks. Some blocks function as *subroutines*, which can be combined into *modules*, which can be combined into *programs*. But we're getting ahead of ourselves—those are subjects for coming chapters. Let's build some more tokens out of characters.

Built-in Data Types

Before we start talking about various kinds of tokens you can build from characters, we need a few more abstractions. To be specific, we need three data types.

Computer languages vary in how many and what kinds of data types they provide. Unlike some commonly used languages that provide many confusing types for similar kinds of values, Perl provides just a few built-in data types. Consider C,

in which you might run into `char`, `short`, `int`, `long`, `long long`, `bool`, `wchar_t`, `size_t`, `off_t`, `regex_t`, `uid_t`, `u_longlong_t`, `pthread_key_t`, `fp_exception_field_type`, and so on. That's just some of the integer types! Then there are floating-point numbers, and pointers, and strings.

All these complicated types correspond to just one type in Perl: the scalar. (Usually Perl's simple data types are all you need, but if not, you're free to define fancy dynamic types using Perl's object-oriented features—see Chapter 12.) Perl's three basic data types are: *scalars*, *arrays* of scalars, and *hashes* of scalars (also known as *associative arrays*). Some people may prefer to call these *data structures* rather than types. That's okay.

Scalars are the fundamental type from which more complicated structures are built. A scalar stores a single, simple value—typically a string or a number. Elements of this simple type may be combined into either of the two aggregate types. An *array* is an ordered list of scalars that you access with an integer subscript (or index). All indexing in Perl starts at 0. Unlike many programming languages, however, Perl treats negative subscripts as valid: instead of counting from the beginning, negative subscripts count back from the end of whatever it is you're indexing into. (This applies to various substring and sublist operations as well as to regular subscripting.) A *hash*, on the other hand, is an unordered set of *key/value* pairs that you access using strings (the *keys*) as subscripts to look up the scalars (the *values*) corresponding to a given key. Variables are always one of these three types. Other than variables, Perl also has other abstractions that you can think of as data types, such as filehandles, directory handles, formats, subroutines, symbol tables, and symbol table entries.

Abstractions are wonderful, and we'll collect more of them as we go along, but they're also useless in a way. You can't do anything with an abstraction directly. That's why computer languages have syntax. We need to introduce you to the various kinds of syntactic terms you can use to pull your abstract data into expressions. We like to use the technical term *term* when we want to talk in terms of these syntactic units. (Hmm, this could get terminally confusing. Just remember how your math teacher used to talk about the *terms* of an equation, and you won't go terribly wrong.)

Just like the terms in a math equation, the purpose of most terms in Perl is to produce values for operators like addition and multiplication to operate on. Unlike in a math equation, however, Perl has to *do* something with the values it calculates, not just think with a pencil in its hand about whether the two sides of the equation are equal. One of the most common things to do with a value is to store it somewhere:

```
$x = $y;
```

That's an example of the *assignment* operator (not the numeric equality operator, which is spelled `==` in Perl). The assignment gets the value from `$y` and puts it into `$x`. Notice that we aren't using the term `$x` for its value; we're using it for its location. (The old value of `$x` gets clobbered by the assignment.) We say that `$x` is an *lvalue*, meaning it's the sort of storage location we can use on the left side of an assignment. We say that `$y` is an *rvalue* because it's used on the right side.

There's also a third kind of value, called a *temporary* value, that you need to understand if you want to know what Perl is really doing with your lvalues and rvalues. If we do some actual math and say:

```
$x = $y + 1;
```

Perl takes the rvalue `$y` and adds the rvalue `1` to it, which produces a temporary value that is eventually assigned to the lvalue `$x`. It may help you to visualize what is going on if we tell you that Perl stores these temporary values in an internal structure called a *stack*.[3] The terms of an expression (the ones we're talking about in this chapter) tend to push values onto the stack, while the operators of the expression (which we'll discuss in the next chapter) tend to pop them back off the stack, perhaps leaving another temporary result on the stack for the next operator to work with. The pushes and pops all balance out—by the time the expression is done, the stack is entirely empty (or as empty as it was when we started). More about temporary values later. Some terms can only be rvalues, such as the `1` above, while others can serve as either lvalues or rvalues. In particular, as the assignments above illustrate, a variable may function as either. And that's what our next section is about.

Variables

Not surprisingly, there are three variable types corresponding to the three abstract data types we mentioned earlier. Each of these is prefixed by what we call a *sigil*.[4] Scalar variables are always named with an initial `$`, even when referring to a scalar that is part of an array or hash. It works a bit like the English word "the". See Table 2-1.

3. A stack works just like one of those spring-loaded plate dispensers you see in a buffet restaurant—you can *push* plates onto the top of the stack, or you can *pop* them off again (to use the Comp. Sci. vernacular).

4. Presumably because it takes an ordinary name and makes it more magical.

Table 2-1. Accessing scalar values

Construct	Meaning
`$days`	Simple scalar value `$days`
`$days[28]`	29th element of array `@days`
`$days{"Feb"}`	"`Feb`" value from hash `%days`

Note that we can use the same name for `$days`, `@days`, and `%days` without Perl getting confused.

There are other, fancier scalar terms that are useful in specialized situations that we won't go into yet. Table 2-2 shows what they look like.

Table 2-2. Syntax for scalar terms

Construct	Meaning
`${days}`	Same as `$days` but unambiguous before alphanumerics
`$Dog::days`	Different `$days` variable, in the `Dog` package
`$#days`	Last index of array `@days`
`$days->[28]`	29th element of array pointed to by reference `$days`
`$days[0][2]`	Multidimensional array
`$days{2000}{"Feb"}`	Multidimensional hash
`$days{2000,"Feb"}`	Multidimensional hash emulation

Entire arrays (or *slices* of arrays and hashes) are named with the sigil `@`, which works much like the words "these" or "those". Table 2-3 shows this syntax.

Table 2-3. Syntax for list terms

Construct	Meaning
`@days`	Array containing `($days[0], $days[1], ... $days[`*N*`])`
`@days[3, 4, 5]`	Array slice containing `($days[3], $days[4], $days[5])`
`@days[3..5]`	Array slice containing `($days[3], $days[4], $days[5])`
`@days{"Jan","Feb"}`	Hash slice containing `($days{"Jan"},$days{"Feb"})`

Entire hashes are named by `%`, as shown in Table 2-4.

Table 2-4. Syntax for hash terms

Construct	Meaning
`%days`	`(Jan => 31, Feb => $leap ? 29 : 28, ...)`

Any of these constructs may also serve as an lvalue, specifying a location you could assign a value to. With arrays, hashes, and slices of arrays or hashes, the lvalue provides multiple locations to assign to, so you can assign multiple values to them all at once:

```
@days = 1 .. 7;
```

Names

We've talked about storing values in variables, but the variables themselves (their names and their associated definitions) also need to be stored somewhere. In the abstract, these places are known as *namespaces*. Perl provides two kinds of namespaces, which are often called *symbol tables* and *lexical scopes*.[5] You may have an arbitrary number of symbol tables or lexical scopes, but every name you define gets stored in one or the other. We'll explain both kinds of namespaces as we go along. For now we'll just say that symbol tables are global hashes that happen to contain symbol table entries for global variables (including the hashes for other symbol tables). In contrast, lexical scopes are *unnamed* scratchpads that don't live in any symbol table but are attached to a block of code in your program. They contain variables that can only be seen by the block. (That's what we mean by a *scope*. The *lexical* part just means, "having to do with text", which is not at all what a lexicographer would mean by it. Don't blame us.)

Within any given namespace (whether global or lexical), every variable type has its own subnamespace, determined by the sigil. You can, without fear of conflict, use the same name for a scalar variable, an array, or a hash (or, for that matter, a filehandle, a subroutine name, a label, or your pet llama). This means that `$foo` and `@foo` are two different variables. Together with the previous rules, it also means that `$foo[1]` is an element of `@foo` totally unrelated to the scalar variable `$foo`. This may seem a bit weird, but that's okay, because it *is* weird.[6]

Subroutines may be named with an initial `&`, although the sigil is optional when calling the subroutine. Subroutines aren't generally considered lvalues, though you can talk Perl into allowing you to return an lvalue from a subroutine and assign to that, so it can look as though you're assigning to the subroutine.

Sometimes you just want a name for "everything named foo", regardless of its sigil. So symbol table entries can be named with an initial `*`, where the asterisk stands

5. We also call them *packages* and *pads* when we're talking about Perl's specific implementations, but those longer monikers are the generic industry terms, so we're pretty much stuck with them. Sorry.

6. In fact, it's weird enough that we decided to make it work the other way in Perl 6, which is weird in other ways instead.

for all the other sigils. These are called *typeglobs*, and they have several uses. They can also function as lvalues. Assignment to typeglobs is how Perl implements importing of symbols from one symbol table to another. More about that later.

Like most computer languages, Perl has a list of reserved words that it recognizes as special keywords. However, because variable names always start with a sigil, reserved words don't actually conflict with variable names. Certain other kinds of names don't have sigils, though, such as labels and filehandles. With these, you do have to worry (a little) about conflicting with reserved words. Since most reserved words are entirely lowercase, we recommend that you pick label and filehandle names that contain uppercase characters. For example, if you say `open(LOG, logfile)` rather than the regrettable `open(log, "logfile")`, you won't confuse Perl into thinking you're talking about the built-in `log` operator (which does logarithms, not tree trunks). Using uppercase filehandles also improves readability[7] and protects you from conflict with reserved words we might add in the future. For similar reasons, user-defined modules are typically named with initial capitals so that they'll look different from the built-in modules known as pragmas, which are named in all lowercase. And when we get to object-oriented programming, you'll notice that class names are usually capitalized for the same reason.

As you might deduce from the preceding paragraph, case is significant in identifiers—`FOO`, `Foo`, and `foo` are all different names in Perl. Identifiers start with a letter or underscore and may be of any length (for values of "any" ranging between 1 and 251, inclusive) and may contain letters, digits, and underscores. If you've declared your source code to be Unicode with `use utf8`, then the rules change a bit: now identifiers must start with either connector punctuation (like an underscore) or any character with the Unicode XID_Start (XIDS) property, and can be followed by any character with the XID_Continue (XIDC) property. This gives you access to more than 100,000 different characters[8] for your identifiers, including ideographs, which count as letters, but we don't recommend you use them unless you can read them.[9] See Chapter 6.

Names that follow sigils don't have to be identifiers, strictly speaking. They can start with a digit, in which case they may only contain more digits, as in `$123`. Names that start with anything other than an alphabetic, digit, or connector

7. One of the design principles of Perl is that different things should look different. Contrast this with languages that try to force different things to look the same, to the detriment of readability.

8. As of this writing, in Unicode v6.0.

9. As of v5.14, Perl does not normalize variable names, so even names that look the same might actually be different if one has composed characters and another decomposed characters.

punctuation are (usually) limited to that one character (like `$?` or `$$`), and generally have a predefined significance to Perl. For example, just as in the Unix shell, `$$` is the current process ID, and `$?` is the exit status of your last child process. Perl also has an extensible syntax for internal variable names. Any variable of the form `${^NAME}` is a special variable reserved for use by Perl. All these nonidentifier names are forced to be in the main symbol table. See Chapter 25 for some examples.

It's tempting to think of identifiers and names as the same thing, but when we say *name*, we usually mean a fully *qualified* name; that is, a name that says which symbol table it lives in. Such names may be formed of a sequence of identifiers separated by the `::` token:

```
$Santa::Helper::Reindeer::Rudolph::nose
```

That works just like the directories and filenames in a pathname:

```
/Santa/Helper/Reindeer/Rudolph/nose
```

In the Perl version of that notion, all the leading identifiers are the names of nested symbol tables, and the last identifier is the name of the variable within the most deeply nested symbol table. For instance, in the variable above, the symbol table is named `Santa::Helper::Reindeer::Rudolph::`, and the actual variable within that symbol table is `$nose`. (The value of that variable is, of course, "`red`".)

A symbol table in Perl is also known as a *package*, so these are often called package variables. Package variables are nominally private to the package in which they exist, but they are global in the sense that the packages themselves are global. That is, anyone can name the package to get at the variable; it's just hard to do this by accident. For instance, any program that mentions `$Dog::bert` is asking for the `$bert` variable within the `Dog::` package. That is an entirely separate variable from `$Cat::bert`. See Chapter 10.

Variables attached to a lexical scope are not in any package, so lexically scoped variable names may not contain the `::` sequence. (Lexically scoped variables are declared with a `my`, `our`, or `state` declaration.)

Name Lookups

So the question is, what's in a name? How does Perl figure out what you mean if you just say `$bert`? Glad you asked. Here are the rules the Perl parser uses while trying to understand an unqualified name in context:

1. First, Perl looks earlier in the immediately enclosing block to see whether the variable is declared in that same block with a `my`, `our`, or `state` declaration (see those entries in Chapter 27, as well as the section "Scoped Declarations" on page 155 in Chapter 4). If there is a `my` or `state` declaration, the variable is lexically scoped and doesn't exist in any package—it exists only in that lexical scope (that is, in the block's scratchpad). Because lexical scopes are unnamed, nobody outside that chunk of program can even name your variable.[10]
2. If that doesn't work, Perl looks for the block enclosing that block and tries again for a lexically scoped variable in the larger block. Again, if Perl finds one, the variable belongs only to the lexical scope from the point of declaration through the end of the block in which it is declared—including any nested blocks, like the one we just came from in step 1. If Perl doesn't find a declaration, it repeats step 2 until it runs out of enclosing blocks.
3. When Perl runs out of enclosing blocks, it examines the whole compilation unit for declarations as if it were a block. (A *compilation unit* is just the entire current file, or the string currently being compiled by an `eval` *`STRING`* operator.) If the compilation unit is a file, that's the largest possible lexical scope, and Perl will look no further for lexically scoped variables, so we go to step 4. If the compilation unit is a string, however, things get fancier. A string compiled as Perl code at runtime pretends that it's a block within the lexical scope from which the `eval` *`STRING`* is running, even though the actual boundaries of the lexical scope are the limits of the string containing the code rather than any real braces. So if Perl doesn't find the variable in the lexical scope of the string, we pretend that the `eval` *`STRING`* is a block and go back to step 2, only this time starting with the lexical scope of the `eval` *`STRING`* operator instead of the lexical scope inside its string.
4. If we get here, it means Perl didn't find any declaration (either `my` or `our`) for our variable. Perl now gives up on lexically scoped variables and assumes that our variable is a package variable. If the `strict` pragma is in effect, we will now get an error, unless the variable is one of Perl's predefined variables or has been imported into the current package. This is because that pragma disallows the use of unqualified global names. However, we aren't done with lexical scopes just yet. Perl does the same search of lexical scopes as it did in

10. If you use an `our` declaration instead of a `my` or `state` declaration, this only declares a lexically scoped *alias* (a nickname) for a package variable, rather than declaring a true lexically scoped variable the way `my` or `state` does. Outside code can still get at the real variable through its package, but in all other respects an `our` declaration behaves like a `my` declaration. This is handy when you're trying to limit your own use of globals with the `strict` pragma (which is on by default if you say `use v5.14;` for details, see the `strict` pragma in Chapter 5). But you should always prefer `my` or `state` if you don't need a global.

steps 1 through 3, only this time it searches for `package` declarations instead of variable declarations. If it finds such a package declaration, it knows that the current code is being compiled for the package in question and prepends the declared package name to the front of the variable.

5. If there is no package declaration in any surrounding lexical scope, Perl looks for the variable name in the unnamed top-level package, which happens to have the name `main` when it isn't going around without a name tag. So in the absence of any declarations to the contrary, `$bert` means the same as `$::bert`, which means the same as `$main::bert`. (But because `main` is just another package in the top-level unnamed package, it's also `$::main::bert`, and `$main::main::bert`, `$::main::main::bert`, and so on. This could be construed as a useless fact. But see "Symbol Tables" on page 389 in Chapter 10.)

There are several implications to these search rules that might not be obvious, so we'll make them explicit.

- Because the file is the largest possible lexical scope, a lexically scoped variable can never be visible outside the file in which it's declared. File scopes do not nest.
- Any particular bit of Perl is compiled in at least one lexical scope and exactly one package scope. The mandatory lexical scope is, of course, the file itself. Additional lexical scopes are provided by each enclosing block. All Perl code is also compiled in the scope of exactly one package, and although the declaration of which package you're in is lexically scoped, packages themselves are not lexically constrained. That is, they're global.
- An unqualified variable name may therefore be searched for in many lexical scopes, but only one package scope, whichever one is currently in effect (which is lexically determined).
- A variable name may only attach to one scope. Although at least two different scopes (lexical and package) are active everywhere in your program, a variable can only exist in one of those scopes.
- An unqualified variable name can therefore resolve to only a single storage location, either in the first enclosing lexical scope in which it is declared, or else in the current package—but not both. The search stops as soon as that storage location is resolved, and any storage location that it would have found had the search continued is effectively hidden.
- The location of the typical variable name can be completely determined at compile time.

Now that you know all about how the Perl compiler deals with names, you sometimes have the problem that you don't *know* the name of what you want at compile time. Sometimes you want to name something indirectly; we call this the problem of *indirection*. So Perl provides a mechanism: you can always replace an alphanumeric variable name with a block containing an expression that returns a *reference* to the real data. For instance, instead of saying:

```
$bert
```

you might say:

```
${ some_expression() }
```

and if the `some_expression()` function returns a reference to variable `$bert` (or even the string, `"bert"`), it will work just as if you'd said `$bert` in the first place. On the other hand, if the function returns a reference to `$ernie`, you'll get his variable instead. The syntax shown is the most general (and least legible) form of indirection, but we'll cover several convenient variations in Chapter 8.

Scalar Values

Whether it's named directly or indirectly, and whether it's in a variable, or an array element, or is just a temporary value, a scalar always contains a single value. This value may be a number, a string, or a reference to another piece of data. Or, there might even be no value at all, in which case the scalar is said to be *undefined*. Although we might speak of a scalar as "containing" a number or a string, scalars are typeless: you are not required to declare your scalars to be of type integer or floating point or string or whatever.

Future versions of Perl might allow you to insert `int`, `num`, and `str` type declarations. This is not to enforce strong typing, but to give the optimizer hints about things that it might not figure out for itself. Some CPAN modules already do this for you.

Perl stores strings as sequences of characters, with no arbitrary constraints on length or content. In human terms, you don't have to decide in advance how long your strings are going to get, and you can include any characters, including null bytes, within your string. Perl stores numbers as signed (or unsigned) integers if possible, or as double-precision floating-point values in the machine's native format otherwise. Floating-point values are not infinitely precise. This is important to remember because comparisons like `(10/3 == 1/3*10)` tend to fail mysteriously.

However, you can swap out Perl's normal notions of numbers using the `bigint`, `bigrat`, and `bignum` pragmas. These provide integers, rational numbers (fractions), and floating-point numbers of arbitrary precision. This can make things work more as you expect them to:

```
% perl -E 'say 10/3 == 1/3*10 ? "Yes" : "No"'
No

% perl -Mbigrat -E 'say 10/3 == 1/3*10 ? "Yes" : "No"'
Yes

% perl -E 'say 4/3 * 5/12'
0.555555555555555

% perl -Mbigrat -E 'say 4/3 * 5/12'
5/9
```

Inside your program, instead of on the command line, you'd use the declarations `use bigint`, `use bigrat`, and `use bignum` to get these fancier numbers:

```
use v5.14;
use bigrat;
say 1/3 * 6/5 * 5/4;   # prints "1/2"
```

Perl converts between the various subtypes as needed, so you can treat a number as a string or a string as a number, and Perl will do the Right Thing. To convert from string to number, Perl internally uses something like the C library's *atof*(3) function. To convert from number to string, it does the equivalent of a *sprintf*(3) with a format of `"%.14g"` on most machines. Improper conversions of a nonnumeric string like `foo` to a number count as numeric 0; these trigger warnings if you have them enabled, but are silent otherwise. See Chapter 5 for examples of detecting what sort of data a string holds.

Although strings and numbers are interchangeable for nearly all intents, references are a bit different. They're strongly typed, uncastable pointers with built-in reference-counting and destructor invocation. That is, you can use them to create complex data types, including user-defined objects. But they're still scalars, for all that, because no matter how complicated a data structure gets, you often want to treat it as a single value.

By *uncastable* we mean that you can't, for instance, convert a reference to an array into a reference to a hash. References are not castable to other pointer types. However, if you use a reference as a number or a string, you will get a numeric or string value, which is guaranteed to retain the uniqueness of the reference even though the "referenceness" of the value is lost when the value is copied from the real reference. You can compare such values or extract their type. But you can't do much else with the values, since there's no way to convert numbers or strings

back into references. Usually, this is not a problem because Perl doesn't force you to do pointer arithmetic—or even allow it. See Chapter 8 for more on references.

Numeric Literals

Numeric literals are specified in any of several customary[11] floating-point or integer formats:

```
my $x = 12345;              # integer
my $x = 12345.67;           # floating point
my $x = 6.02e23;            # scientific notation
my $x = 4_294_967_296;      # underline for legibility
my $x = 0377;               # octal
my $x = 0xffff;             # hexadecimal
my $x = 0b1100_0000;        # binary
```

Because Perl uses the comma as a list separator, you cannot use it to separate the thousands in a large number. Perl does allow you to use an underscore character instead. The underscore only works within literal numbers specified in your program, not for strings functioning as numbers or data read from somewhere else. Similarly, the leading `0x` for hexadecimal, `0b` for binary, and `0` for octal work only for literals. The automatic conversion of a string to a number does not recognize these prefixes—you must do an explicit conversion[12] with the `oct` function—which works for hex and binary numbers, too, as it happens, provided you supply the `0x` or `0b` on the front.

String Literals

String literals are usually surrounded by either single or double quotes. They work much like Unix shell quotes: double-quoted string literals are subject to backslash and variable interpolation, but single-quoted strings are not (except for `\'` and `\\` so that you can embed single quotes and backslashes into single-quoted strings). If you want to embed any other backslash sequences such as `\n` (newline), you must use the double-quoted form. (Backslash sequences are also known as *escape sequences*, because you "escape" the normal interpretation of characters temporarily.)

11. Customary in Unix culture, that is. If you're from a different culture, welcome to ours!

12. Sometimes people think Perl should convert all incoming data for them. But there are far too many decimal numbers with leading zeros in the world to make Perl do this automatically. For example, the zip code for the O'Reilly Media office in Cambridge, Massachusetts, is `02140`. The postmaster would get confused if your mailing label program turned `02140` into `1120` decimal.

A single-quoted string must be separated from a preceding word by a space because a single quote is a valid—though archaic—character in an identifier. Its use has been replaced by the more visually distinct `::` sequence. That means that `$main'var` and `$main::var` are the same thing, but the second is generally considered easier to read for people and programs.

Double-quoted strings are subject to various forms of character interpolation, as listed in Table 2-5. Many of these will be familiar to programmers of other languages.

Table 2-5. Backslashed character escapes

Code	Meaning
`\n`	Newline (usually LF)
`\r`	Carriage return (usually CR)
`\t`	Horizontal tab
`\f`	Form feed
`\b`	Backspace
`\a`	Alert (bell)
`\e`	ESC character
`\033`	ESC in octal
`\o{33}`	Also ESC in octal
`\x7f`	DEL in hexadecimal
`\x{263a}`	Character number 0x263A
`\N{LATIN SMALL LETTER E WITH ACUTE}`	The named character LATIN SMALL LETTER E WITH ACUTE, "é", which is codepoint 0xE9 in Unicode
`\N{` *`U+E9`* `}`	Character number 0xE9 again
`\cC`	Control-C

The `\N{`*`NAME`*`}` notation is usable only in conjunction with the `charnames` pragma described in Chapter 29. This allows you to specify character names symbolically, as in `\N{GREEK SMALL LETTER SIGMA}`, `\N{greek:Sigma}`, or `\N{sigma}`—depending on how you call the pragma. The notation `\N{U+`*`HEXDIGITS`*`}` does not require the `charnames` pragma, and guarantees that Unicode semantics will be used on the string or regex it appears in. See also Chapter 6.

There are also escape sequences to modify the case or "meta-ness" of subsequent characters. See Table 2-6.

Table 2-6. Translation escapes

Code	Meaning
`\u`	Force next character to titlecase[a]
`\l`	Force next character to lowercase
`\U`	Force all following characters to uppercase; ends at `\E`
`\L`	Force all following characters through `\E` to lowercase; ends at `\E`
`\F`	Force all following characters through `\E` to foldcase;[b] ends at `\E`
`\Q`	Backslash all following nonalphanumeric characters; ends at `\E`
`\E`	End `\U`, `\L`, `\F`, or `\Q`

[a] Titlecase is a Unicode case that works mostly like uppercase. See Chapter 6.

[b] `\F` is new to v5.16. The foldcase map is a special form used for case-insensitive comparison. See Chapter 5 and Chapter 6.

You may also embed newlines directly in your strings; that is, they can begin and end on different lines. This is often useful, but it also means that if you forget a trailing quote, the error will not be reported until Perl finds another line containing the quote character, which may be much further on in the script. Fortunately, this usually causes an immediate syntax error on the same line, and Perl is then smart enough to warn you that you might have a runaway string where it thought the string started.

Besides the backslash escapes listed above, double-quoted strings are subject to *variable interpolation* of scalar and list values. This means that you can insert the values of certain variables directly into a string literal. It's really just a handy form of string concatenation.[13] Variable interpolation may be done for scalar variables, entire arrays (but not hashes), single elements from an array or hash, or slices (multiple subscripts) of an array or hash. Nothing else interpolates. In other words, you may only interpolate expressions that begin with `$` or `@`, because those are the two characters (along with backslash) that the string parser looks for. Inside strings, a literal `@` that is not part of an array or slice identifier but is followed by an alphanumeric character must be escaped with a backslash (`\@`), or else a compilation error will result. Although a complete hash specified with a `%` will not be interpolated into the string, single hash values or hash slices are okay because they begin with `$` and `@`, respectively.

13. With warnings enabled, Perl may report undefined values interpolated into strings as using the concatenation or join operations, even though you don't actually use those operators there. The compiler created them for you anyway.

The following code segment prints out "`The price is $100.`":

```
my $Price = '$100';                # not interpolated
print "The price is $Price.\n";    # interpolated
```

As in some shells, you can put braces around the identifier to distinguish it from following alphanumerics: `"How ${verb}able!"`. An identifier within such braces is forced to be a string, as is any single identifier within a hash subscript. For example:

```
$days{"Feb"}
```

can be written as:

```
$days{Feb}
```

and the quotes will be assumed. Anything more complicated in the subscript is interpreted as an expression, and then you'd have to put in the quotes:

```
$days{'February 29th'}   # Ok.
$days{"February 29th"}   # Also ok. "" doesn't have to interpolate.
$days{ February 29th }   # WRONG, produces parse error.
```

In particular, you should always use quotes in slices such as:

```
@days{'Jan','Feb'}       # Ok.
@days{"Jan","Feb"}       # Also ok.
@days{ Jan,  Feb }       # Kinda wrong (breaks under use strict)
```

Apart from the subscripts of interpolated array and hash variables, there are no multiple levels of interpolation. Contrary to the expectations of shell programmers, backticks do not interpolate within double quotes, nor do single quotes impede evaluation of variables when used within double quotes. Interpolation is extremely powerful but strictly controlled in Perl. It happens only inside double quotes, and in certain other "double-quotish" operations that we'll describe in the next section:

```
print "\n";              # Ok, print a newline.
print  \n ;              # WRONG, no interpolative context.
```

Pick Your Own Quotes

Although we usually think of quotes as literal values, in Perl they function more like operators, providing various kinds of interpolating and pattern-matching capabilities. Perl provides the customary quote characters for these behaviors, but it also provides a more general way for you to choose your quote character for any of them. In Table 2-7, any nonalphanumeric, nonwhitespace delimiter may be used in place of `/`. (The newline and space characters are no longer allowed as delimiters, although prehistoric versions of Perl once allowed this.)

Table 2-7. Quote constructs

Customary	Generic	Meaning	Interpolates
''	q//	Literal string	No
""	qq//	Literal string	Yes
``	qx//	Command execution	Yes
()	qw//	Word list	No
//	m//	Pattern match	Yes
s///	s///	Pattern substitution	Yes
tr///	y///	Character translation	No
""	qr//	Regular expression	Yes

Some of these are simply forms of "syntactic sugar" to let you avoid putting too many backslashes into quoted strings, particularly into pattern matches where your regular slashes and backslashes tend to get all tangled.

If you choose single quotes for delimiters, no variable interpolation is done even on those forms that ordinarily interpolate. If the opening delimiter is an opening parenthesis, bracket, brace, or angle bracket, the closing delimiter will be the corresponding closing character. (Embedded occurrences of the delimiters must match in pairs.) Examples:

```
my $single = q!I said, "You said, 'She said it.'"!;

my $double = qq(Can't we get some "good" $variable?);

my $chunk_of_code = q {
    if ($condition) {
        print "Gotcha!";
    }
};
```

The last example demonstrates that you can use whitespace between the quote specifier and its initial bracketing character. For two-element constructs like `s///` and `tr///`, if the first pair of quotes is a bracketing pair, the second part gets its own starting quote character. In fact, the second pair needn't be the same as the first pair. So you can write things like `s<foo>(bar)` or `tr(a-f)[A-F]`. Because whitespace is also allowed between the two inner quote characters, you could even write that last one as:

```
tr (a-f)
   [A-F];
```

Whitespace is not allowed, however, when # is being used as the quoting character. q#foo# is parsed as the string 'foo', while q #foo# is parsed as the quote operator q followed by a comment. Its delimiter will be taken from the next line. Comments can also be placed in the middle of two-element constructs, which allows you to write:

```
s {foo}   # Replace foo
  {bar};  #    with bar.

tr [a-f]  # Transliterate lowercase hex
   [A-F]; #            to uppercase hex
```

Or Leave Out the Quotes Entirely

A name that has no other interpretation in the grammar will be treated as if it were a quoted string. These are known as *barewords*.[14] As with filehandles and labels, a bareword that consists entirely of lowercase ASCII letters risks conflict with future reserved words. If you have warnings enabled, Perl will warn you about barewords. For example:

```
my @days = (Mon,Tue,Wed,Thu,Fri);
print STDOUT hello, " ", world, "\n";
```

sets the array @days to the short form of the weekdays and prints "hello world" followed by a newline on STDOUT. If you leave the filehandle out, Perl tries to interpret hello as a filehandle, resulting in a syntax error. Because this is so error-prone, some people may wish to avoid barewords entirely. The quoting operators listed earlier provide many convenient forms, including the qw// "quote words" construct, which nicely quotes a list of space-separated words:

```
my @days = qw(Mon Tue Wed Thu Fri);
print STDOUT "hello world\n";
```

You can go as far as to outlaw barewords entirely. If you say:

```
use strict "subs";
```

then any bareword will produce a compile-time error. The restriction lasts through the end of the enclosing scope. An inner scope may countermand this by saying:

```
no strict "subs";
```

14. Variable names, filehandles, labels, and the like are not considered barewords because they have a meaning forced by a preceding token or a following token (or both). Predeclared names such as subroutines aren't barewords either. It's only a bareword when the parser has no clue.

Outlawing barewords is such a good idea that if you say

```
use v5.12;
```

or higher, Perl turns on all strictures for you automatically.

Note that the bare identifiers in constructs like:

```
"${verb}able"
$days{Feb}
```

are not considered barewords since they're allowed by explicit rule rather than by having "no other interpretation in the grammar".

An unquoted name with a trailing double colon, such as `main::` or `Dog::`, is always treated as the package name. Perl turns the would-be bareword `Camel::` into the string "`Camel`" at compile time, so this usage is not subject to rebuke.

Interpolating Array Values

Array variables are interpolated into double-quoted strings by joining all elements of the array with the separator specified in the `$"` variable[15] (which contains a space by default). The following are equivalent:

```
my $temp = join( $", @ARGV );
print $temp;

print "@ARGV";
```

Within search patterns, which also undergo double-quotish interpolation, there is an unfortunate ambiguity: is `/$foo[bar]/` to be interpreted as `/${foo}[bar]/` (where `[bar]` is a character class for the regular expression), or as `/${foo[bar]}/` (where `[bar]` is the subscript to array `@foo`)? If `@foo` doesn't otherwise exist, it's obviously a character class. If `@foo` exists, Perl takes a good guess about `[bar]` and is almost always right.[16] If it does guess wrong, or if you're just plain paranoid, you can force the correct interpretation with braces as shown earlier. Even if you're merely prudent, it's probably not a bad idea.

"Here" Documents

A line-oriented form of quoting is based on the Unix shell's *here-document* syntax. It's line-oriented in the sense that the delimiters are lines rather than characters.

15. `$LIST_SEPARATOR` if you use the English module bundled with Perl.

16. The guesser is too boring to describe in full, but basically takes a weighted average of all the things that look like character classes (`a-z`, `\w`, initial `^`) versus things that look like expressions (variables or reserved words).

The starting delimiter is the current line, and the terminating delimiter is a line consisting of the string you specify. Following a <<, you specify the string to terminate the quoted material, and all lines following the current line down to but not including the terminating line are part of the string. The terminating string may be either an identifier (a word) or some quoted text. If quoted, the type of quote determines the treatment of the text, just as it does in regular quoting. An unquoted identifier works as though it were in double quotes. A backslashed identifier works as though it were in single quotes (for compatibility with shell syntax). There must be no space between the << and an unquoted identifier, although whitespace is permitted if you specify a quoted string instead of the bare identifier. (If you insert a space, it will be treated as a null identifier, which is valid but deprecated, and matches the first blank line—see the first `Hurrah!` example below.) The terminating string must appear by itself, unquoted and with no extra whitespace on either side, on the terminating line.

```
print <<EOF;    # same as earlier example
The price is $Price.
EOF

print <<"EOF";  # same as above, with explicit quotes
The price is $Price.
EOF

print <<'EOF';    # single-quoted quote
All things (e.g. a camel's journey through
A needle's eye) are possible, it's true.
But picture how the camel feels, squeezed out
In one long bloody thread, from tail to snout.
                                -- C.S. Lewis
EOF

print <<\EOF;     # another single-quoted quote
I could really use $100 about now.
EOF

print << x 10;    # print next line 10 times
The camels are coming!  Hurrah!  Hurrah!

print <<"" x 10;  # the preferred way to write that
The camels are coming!  Hurrah!  Hurrah!

print <<`EOC`;    # execute commands
echo hi there
echo lo there
EOC

print <<"dromedary", <<"camelid";   # you can stack them
I said bactrian.
```

```
dromedary
She said llama.
camelid

funkshun(<<"THIS", 23, <<'THAT');   # doesn't matter if they're in parens
Here's a line
or two.
THIS
And here's another.
THAT
```

Just don't forget that you have to put a semicolon on the end to finish the statement, because Perl doesn't know you're not going to try to do this:

```
print <<"odd"
2345
odd
    + 10000;   # prints 12345
```

If you want your here docs to be indented with the rest of the code, you'll need to remove leading whitespace from each line manually:

```
(my $quote = <<'QUOTE') =~ s/^\s+//gm;
    The Road goes ever on and on,
    down from the door where it began.
QUOTE
```

You could even populate an array with the lines of a here document as follows:

```
my @sauces = <<End_Lines =~ m/(\S.*\S)/g;
   normal tomato
   spicy tomato
   green chile
   pesto
   white wine
End_Lines
```

Version Literals

A literal that begins with a `v` and is followed by one or more dot-separated decimal integers is treated as a version number:

```
use v5.14;    # turn on strict and warnings
```

(These used to be called *v-strings*, but the use of these to produce string values has been deprecated. Now you may use this notation only to produce version objects.)

Other Literal Tokens

You should consider any identifier that both begins and ends with a double underscore to be reserved for special syntactic use by Perl. Two such special literals are `__LINE__` and `__FILE__`, which represent the current line number and filename at that point in your program. They may only be used as separate tokens; they will not be interpolated into strings. Likewise, `__PACKAGE__` is the name of the package the current code is being compiled into. The token `__END__` (or, alternatively, a Control-D or Control-Z character) may be used to indicate the logical end of the script before the real end-of-file. Any following text is ignored but may be read via the `DATA` filehandle.

The `__DATA__` token functions similarly to the `__END__` token, but it opens the `DATA` filehandle within the current package's namespace, so files you `require` can each have their own `DATA` filehandles open simultaneously. For more information, see `DATA` in Chapter 25.

Context

Until now we've seen several terms that can produce scalar values. Before we can discuss terms further, though, we must come to terms with the notion of *context*.

Scalar and List Context

Every operation[17] that you invoke in a Perl script is evaluated in a specific context, and how that operation behaves may depend on the requirements of that context. There are two major contexts: scalar and list. For example, assignment to a scalar variable, or to a scalar element of an array or hash, evaluates the righthand side in a *scalar context*:

```
$x         = funkshun();  # scalar context
$x[1]      = funkshun();  # scalar context
$x{"ray"}  = funkshun();  # scalar context
```

But assignment to an array or a hash, or to a slice of either, evaluates the righthand side in a *list context*, even if the slice picks out only one element:

```
@x         = funkshun();  # list context
@x[1]      = funkshun();  # list context
@x{"ray"}  = funkshun();  # list context
%x         = funkshun();  # list context
```

17. Here we use the term "operation" loosely to mean either an operator or a term. The two concepts fuzz into each other when you start talking about functions that parse like terms but look like unary operators.

Assignment to a list of scalars also provides list context to the righthand side, even if there's only one element in the list:

```
($x,$y,$z) = funkshun();  # list context
($x)       = funkshun();  # list context
```

These rules do not change at all when you declare a variable by modifying the term with `my`, `state`, or `our`, so we have:

```
my $x      = funkshun();  # scalar context
my @x      = funkshun();  # list context
my %x      = funkshun();  # list context
my ($x)    = funkshun();  # list context
```

You will be miserable until you learn the difference between scalar and list context, because certain operators (such as our mythical `funkshun` function above) know which context they are in, and they return a list in contexts wanting a list but a scalar value in contexts wanting a scalar. (If this is true of an operation, it will be mentioned in the documentation for that operation.) In computer lingo, the operations are *overloaded* on their return type. But it's a very simple kind of overloading, based only on the distinction between singular and plural values, and nothing else.

If some operators respond to context, then obviously something around them has to supply the context. We've shown that assignment can supply a context to its right operand, but that's not terribly surprising, since all operators supply some kind of context to each of their operands. What you really want to know is *which* operators supply *which* context to their operands. As it happens, you can easily tell which ones supply list context because they all have *`LIST`* in their syntactic descriptions. Everything else supplies scalar context. Generally, it's quite intuitive.[18] If necessary, you can force scalar context onto an argument in the middle of a *`LIST`* by using the `scalar` pseudofunction. Perl provides no way to force list context in context, because anywhere you would want list context it's already provided by the *`LIST`* of some controlling function.

Scalar context can be further classified into string context, numeric context, and don't-care context. Unlike the scalar versus list distinction we just made, operations never know or care which scalar context they're in. They simply return whatever kind of scalar value they want to and let Perl lazily translate numbers to strings in string context, and strings to numbers in numeric context. Some scalar contexts don't care whether a string or a number or a reference is returned,

18. Note, however, that the list context of a *`LIST`* can propagate down through subroutine calls, so it's not always obvious from inspection whether a given statement is going to be evaluated in a scalar or list context. The program can find out its context within a subroutine by using the `wantarray` function.

so no conversion will happen. This happens, for example, when you are assigning the value to another variable. The new variable just takes on the same subtype as the old value.

Boolean Context

Another special don't-care scalar context is called *Boolean context*. Boolean context is simply any place where an expression is being evaluated to see whether it's true or false. When we say "true" and "false" in this book, we mean the technical definition that Perl uses: a scalar value is true if it is not the null string `""` or the number 0 (or its string equivalent, `"0"`). A reference is always true because it represents an address that is never 0. An undefined value (often called `undef`) is always false because it looks like either `""` or 0, depending on whether you treat it as a string or a number. (List values have no Boolean value because list values are never produced in scalar context!)

Because Boolean context is a don't-care context, it never causes any scalar conversions to happen, though of course the scalar context itself is imposed on any operand that cares. And for many operands that care, the scalar they produce in scalar context represents a reasonable Boolean value. That is, many operators that would produce a list in list context can be used for a true/false test in Boolean context. For instance, in list context such as that provided by the `unlink` operator, an array name produces the list of its values:

```
unlink @files;      # Delete all files, ignoring errors.
```

But if you use the array in a conditional (that is, in a Boolean context), the array knows it's in scalar context and returns the number of elements in the array, which conveniently is true so long as there are any elements left. So supposing you wanted to get warnings on each file that wasn't deleted properly, you might write a loop like this:

```
while (@files) {
    my $file = shift(@files);
    unlink($file) || warn "Can't delete $file: $!";
}
```

Here, `@files` is evaluated in the Boolean context supplied by the `while` statement, so Perl evaluates the array itself to see whether it's a "true array" or a "false array". It's a true array as long as there are filenames in it, but it becomes a false array as soon as the last filename is shifted out. Note that what we earlier said still holds. Despite the fact that an array contains (and can produce) a list value, we are not evaluating a list value in scalar context. We are telling the array it's a scalar and asking what it thinks of itself.

Do not be tempted to use `defined @files` for this. It doesn't work because the `defined` function is asking whether a scalar is equal to `undef`, but an array is not a scalar. The simple Boolean test suffices.

Void Context

Another peculiar kind of scalar context is *void context*. This context not only doesn't care what the return value's type is, it doesn't even *want* a return value. From the standpoint of how functions work, it's no different from an ordinary scalar context. But if you have warnings enabled, the Perl compiler will warn you if you use an expression with no side effects in a place that doesn't want a value, such as in a statement that doesn't return a value. For example, if you use a string as a statement:

```
"Camel Lot";
```

you may get a warning like this:

```
Useless use of a constant in void context in myprog line 123;
```

Interpolative Context

We mentioned earlier that double-quoted literal strings do backslash interpretation and variable interpolation, but that interpolative context (often called "double-quote context" because nobody can pronounce "interpolative") applies to more than just double-quoted strings. Some other double-quotish constructs are the generalized backtick operator, `qx//`; the pattern-match operator, `m//`; the substitution operator, `s///`; and the quote regex operator, `qr//`. The substitution operator does interpolation on its left side before doing a pattern match and then does interpolation on its right side each time the left side matches.

Interpolative context only happens inside quotes, or things that work like quotes, so perhaps it's not fair to call it a context in the same sense as scalar and list contexts. (Then again, maybe it is.)

List Values and Arrays

Now that we've talked about context, we can talk about list literals and how they behave in context. You've already seen some list literals. List literals are denoted by separating individual values by commas (and enclosing the list in parentheses where precedence requires it). Because it (almost) never hurts to use extra parentheses, the syntax diagram of a list value is usually indicated like this:

```
(LIST)
```

Earlier we said that *LIST* in a syntax description indicates something that supplies list context to its arguments. However, a bare list literal itself is the one partial exception to that rule, in that it supplies list context to its arguments only when the list as a whole is in list context. The value of a list literal in list context is just the values of the arguments in the order specified. As a fancy sort of term in an expression, a list literal merely pushes a series of temporary values onto Perl's stack, to be collected off the stack later by whatever operator wants the list. In scalar context, however, the list literal doesn't really behave like a *LIST*, in that it doesn't supply list context to its values. Instead, it merely evaluates each of its arguments in scalar context, and returns the value of the final element. That's because it's really just the C comma operator in disguise, which is a binary operator that always throws away the value on the left and returns the value on the right. In terms of what we discussed earlier, the left side of the comma operator really provides context. Because the comma operator is left associative, if you have a series of comma-separated values, you always end up with the last value because the final comma throws away whatever any previous commas produced. So, to contrast the two, the list assignment:

```
@stuff = ("one", "two", "three");
```

assigns the entire list value to array `@stuff`, but the scalar assignment:

```
$stuff = ("one", "two", "three");
```

assigns only the value "`three`" to variable `$stuff`. Like the `@files` array we mentioned earlier, the comma operator knows whether it is in a scalar or list context, and chooses its behavior accordingly.

It bears repeating that a list value is different from an array. A real array variable also knows its context, and in list context it would return its internal list of values just like a list literal. But in scalar context it returns only the length of the array. The following assigns to `$stuff` the value 3:

```
@stuff = ("one", "two", "three");
$stuff = @stuff;
```

If you expected it to get the value "`three`", you were probably making a false generalization by assuming that Perl uses the comma operator rule to throw away all but one of the temporary values that `@stuff` put on the stack. But that's not how it works. The `@stuff` array never put all its values on the stack. It never put any of its values on the stack, in fact. It only put one value, the length of the array, because it *knew* it was in scalar context. No term or operator in scalar context will ever put a list on the stack. Instead, it will put one scalar on the stack, whatever it feels like, which is unlikely to be the last value of the list it *would* have returned in list context. This is because the last value is not likely to be the most

useful value in scalar context. Got that? (If not, you'd better reread this paragraph because it's important.)

Now back to true *LIST*s, the ones that do list context. Until now we've pretended that list literals were just lists of literals. But just as a string literal might interpolate other substrings, a list literal can interpolate other sublists. Any expression that returns values may be used within a list. The values so used may be either scalar values or list values, but they all become part of the new list value because *LIST*s do automatic interpolation of sublists. That is, when a *LIST* is evaluated, each element of the list is evaluated in list context, and the resulting list value is flattened into *LIST* just as if each individual element were a member of *LIST*. Thus, arrays lose their identity in a *LIST*.[19] The list:

```
(@stuff,@nonsense,funkshun())
```

contains the elements of `@stuff`, followed by the elements of `@nonsense`, followed by whatever values the subroutine `&funkshun` decides to return when called in list context. Note that any or all of these might have interpolated a null (empty) list, in which case it's as if no array or function call had been interpolated at that point. The null list itself is represented by the literal `()`. As with a null array, which interpolates as a null list and is therefore effectively ignored, interpolating the null list into another list has no effect. Thus, `((),(),())` is equivalent to `()`.

A corollary to this rule is that you may place an optional comma at the end of any list value. This makes it easy to come back later and add more elements after the last one:

```
@releases = (
    "alpha",
    "beta",
    "gamma",
);
```

Or you can do away with the commas entirely: another way to specify a literal list is with the `qw` (quote words) syntax we mentioned earlier. This construct is equivalent to splitting a single-quoted string on whitespace. For example:

```
@froots = qw(
    apple       banana      carambola
    coconut     guava       kumquat
    mandarin    nectarine   peach
    pear        persimmon   plum
);
```

19. Some people seem to think this is a problem, but it's not. You can always interpolate a reference to an array if you do not want it to lose its identity. See Chapter 8.

(Note that those parentheses are behaving as quote characters, not ordinary parentheses. We could just as easily have picked angle brackets or braces or slashes. But parens are pretty.)

A list value may also be subscripted like a normal array. You must put the list in parentheses (real ones) to avoid ambiguity. Though it's often used to fetch a single value out of a list, it's really a slice of the list, so the syntax is:

```
(LIST)[LIST]
```

Examples:

```
# Stat returns list value.
$modification_time = (stat($file))[9];

# SYNTAX ERROR HERE.
$modification_time = stat($file)[9];  # OOPS, FORGOT PARENS

# Find a hex digit.
$hexdigit = ("a","b","c","d","e","f")[$digit-10];

# A "reverse comma operator".
return (pop(@foo),pop(@foo))[0];

# Get multiple values as a slice.
($day, $month, $year) = (localtime)[3,4,5];
```

List Assignment

A list may be assigned to only if each element of the list is itself legal to assign to:

```
($a, $b, $c) = (1, 2, 3);

($map{red}, $map{green}, $map{blue}) = (0xff0000, 0x00ff00, 0x0000ff);
```

You may assign to `undef` in a list. This is useful for throwing away some of the return values of a function:

```
($dev, $ino, undef, undef, $uid, $gid) = stat($file);
```

You can even do this on `my` declarations:

```
my ($dev, $ino, undef, undef, $uid, $gid) = stat($file);
```

The final list element may be an array or a hash:

```
($a, $b, @rest) = split;
my ($a, $b, %rest) = @arg_list;
```

You can actually put an array or hash anywhere in the list you assign to, but the first array or hash in the list will soak up all the remaining values, and anything

after it will be set to the undefined value. This may be useful in a `local` or `my`, where you probably want the arrays initialized to be empty anyway.

You can even assign to the empty list:

```
() = funkshun();
```

That ends up calling your function in list context but discarding the return values. If you had just called the function without an assignment, it would have instead been called in void context, which is a kind of scalar context, and might have caused the function to behave completely differently. List assignment in scalar context returns the number of elements produced by the expression on the *right* side of the assignment:

```
$x = ( ($a, $b) = (7,7,7) );    # set $x to 3, not 2
$x = ( ($a, $b) = funk() );     # set $x to funk()'s return count
$x = ( () = funk() );           # also set $x to funk()'s return count
```

This is handy when you want to do a list assignment in a Boolean context, because most list functions return a null list when finished, which when assigned produces a 0, which is interpreted as false. Here's how you might use it in a `while` statement:

```
while (($login, $password) = getpwent) {
    if (crypt($login, $password) eq $password) {
        print "$login has an insecure password!\n";
    }
}
```

Array Length

You may find the number of elements in the array `@days` by evaluating `@days` in scalar context, such as:

```
@days + 0;      # implicitly force @days into scalar context
scalar(@days)   # explicitly force @days into scalar context
```

Note that this only works for arrays. It does not work for list values in general. As we mentioned earlier, a comma-separated list evaluated in scalar context returns the last value, like the C comma operator. But because you almost never actually need to know the length of a list in Perl, this is not a problem.

Closely related to the scalar evaluation of `@days` is `$#days`. This will return the subscript of the last element of the array, or one less than the length, since there is a 0<th> element. Assigning to `$#days` changes the length of the array. Shortening an array by this method destroys intervening values. You can gain some measure of efficiency by preextending an array that is going to get big. (You can also extend an array by assigning to an element beyond the end of the array.) You

can truncate an array down to nothing by assigning the null list `()` to it. The following two statements are equivalent:

```
@whatever = ();
$#whatever = -1;
```

And the following is always true:

```
scalar(@whatever) == $#whatever + 1;
```

Truncating an array does not recover its memory. You have to `undef(@whatever)` (or let it go out of scope) to free its memory back to your process's memory pool. You probably can't free it all the way back to your system's memory pool because few operating systems support this.

Hashes

As we said earlier, a hash is just a funny kind of array in which you look values up using key strings instead of numbers. A hash defines associations between keys and values, so hashes are often called *associative arrays* by people who are not lazy typists.

There really isn't any such thing as a hash literal in Perl, but if you assign an ordinary list to a hash, each pair of values in the list will be taken to indicate one key/value association:

```
my %map = ("red",0xff0000,"green",0x00ff00,"blue",0x0000ff);
```

This has the same effect as:

```
my %map;        # an uninitialized hash is born empty
$map{red}   = 0xff0000;
$map{green} = 0x00ff00;
$map{blue}  = 0x0000ff;
```

It is often more readable to use the `=>` operator between key/value pairs. The `=>` operator is just a synonym for a comma, but it's more visually distinctive and also quotes any bare identifiers to the left of it (just like the identifiers in braces above), which makes it convenient for several sorts of operations, including initializing hash variables:

```
my %map = (
    red   => 0xff0000,
    green => 0x00ff00,
    blue  => 0x0000ff,
);
```

or initializing anonymous hash references to be used as records:

```
my $rec = {
    NAME  => "John Smith",
    RANK  => "Captain",
    SERNO => "951413",
};
```

or using named parameters to invoke complicated functions:

```
my $field = radio_group(
    NAME      => "animals",
    VALUES    => ["camel", "llama", "ram", "wolf"],
    DEFAULT   => "camel",
    LINEBREAK => "true",
    LABELS    => \%animal_names,
);
```

But we're getting ahead of ourselves again. Back to hashes.

You can use a hash variable (`%hash`) in list context, in which case it interpolates all its key/value pairs into the list. But just because the hash was initialized in a particular order doesn't mean that the values come back out in that order. Hashes are implemented internally using hash tables for speedy lookup, which means that the order in which entries are stored is dependent on the internal hash function used to calculate positions in the hash table, and not on anything interesting. So the entries come back in a seemingly random order. (The two elements of each key/value pair come out in the right order, of course.) For examples of how to arrange for an output ordering, see the `keys` function in Chapter 27.

When you evaluate a hash variable in scalar context, it returns a true value only if the hash contains any key/value pairs whatsoever. If there are any key/value pairs at all, the value returned is a string consisting of the number of used buckets and the number of allocated buckets, separated by a slash. This is pretty much only useful to find out whether Perl's (compiled in) hashing algorithm is performing poorly on your data set. For example, you stick 10,000 things in a hash, but evaluating `%HASH` in scalar context reveals "`1/8`", which means only one out of eight buckets has been touched. Presumably that one bucket contains all 10,000 of your items. This isn't supposed to happen.

To find the number of keys in a hash, use the `keys` function in scalar context:

```
scalar(keys(%HASH))
```

You can emulate a multidimensional hash by specifying more than one key within the braces, separated by commas. The listed keys are concatenated together, separated by the contents of `$;` (`$SUBSCRIPT_SEPARATOR`), which has a default value of `chr(28)`. The resulting string is used as the actual key to the hash. These two lines do the same thing:

```
$people{ $state, $county } = $census_results;
$people{ join $; => $state, $county } = $census_results;
```

This feature was originally implemented to support *a2p*, the *awk*-to-Perl translator. These days, you'd usually just use a real (well, realer) multidimensional array as described in Chapter 9. One place the old style may still be useful is for hashes tied to external files that don't support multidimensional keys, such as DBM files.

Don't confuse multidimensional hash emulations with slices. The one represents a scalar value, and the other represents a list value:

```
$hash{ $x, $y, $z }      # a single value
@hash{ $x, $y, $z }      # a slice of three values
```

Typeglobs and Filehandles

Perl uses a special type called a *typeglob* to hold an entire symbol table entry. The symbol table entry `*foo` contains the values of `$foo`, `@foo`, `%foo`, `&foo`, and several interpretations of plain old `foo`. The type prefix of a typeglob is a `*` because it represents all types.

One use of typeglobs (or references thereto) is for passing or storing filehandles, which was especially popular before Perl had filehandle references. If you want to save away a bareword filehandle, do it this way:

```
$fh = *STDOUT;
```

or perhaps as a real reference, like this:

```
$fh = \*STDOUT;
```

or perhaps accessing the filehandle portion in that symbol table entry:

```
$fh = *STDOUT{IO};
```

This used to be the preferred way to create a local filehandle. For example:

```
sub newopen {
    my $path = shift;
    local *FH;          # not my() nor our()
    open(FH, '<', $path) || return undef;
    return *FH;         # not \*FH!
}
$fh = newopen("/etc/passwd");
```

These days, however, it's almost always better to let Perl pick a filehandle and fill in an empty variable for you:

```
sub newopen {
    my $path = shift;
    open(my $fh, '<', $path) || return undef;
    return $fh;
}
$fh = newopen("/etc/passwd");
```

The main use of typeglobs nowadays is to alias one symbol table entry to another symbol table entry. Think of an alias as a nickname. If you say:

```
*foo = *bar;
```

it makes everything named "`foo`" a synonym for every corresponding thing named "`bar`". You can alias just one variable from a typeglob by assigning a reference instead:

```
*foo = \$bar;
```

makes `$foo` an alias for `$bar`, but doesn't make `@foo` an alias for `@bar`, or `%foo` an alias for `%bar`. All these affect global (package) variables only; lexicals cannot be accessed through symbol table entries. Aliasing global variables like this may seem like a silly thing to want to do, but it turns out that the entire module import-export mechanism is built around this feature, since there's nothing that says the symbol you're aliasing has to be in your namespace. This:

```
local *Here::blue = \$There::green;
```

temporarily makes `$Here::blue` an alias for `$There::green`, but it doesn't make `@Here::blue` an alias for `@There::green`, or `%Here::blue` an alias for `%There::green`. Fortunately, all these complicated typeglob manipulations are hidden away where you don't have to look at them. See the sections "Handle References" on page 346 and "Symbol Table References" on page 347 in Chapter 8, "Symbol Tables" on page 389 in Chapter 10, and Chapter 11 for more discussions on typeglobs and importation.

Input Operators

There are several input operators we'll discuss here because they parse as terms. Sometimes we call them pseudoliterals because they act like quoted strings in many ways. (Output operators like `print` parse as list operators and are discussed in Chapter 27.)

Command Input (Backtick) Operator

First of all, we have the command input operator, also known as the backtick operator, because it looks like this:

```
$info = `perldoc $module`;
```

A string enclosed by backticks (grave accents, technically) first undergoes variable interpolation just like a double-quoted string. The result is then interpreted as a command line by the system, and the output of that command becomes the value of the pseudoliteral. (This is modeled after a similar operator in Unix shells.) In scalar context, a single string consisting of all the output is returned. In list context, a list of values is returned, one for each line of output. (You can set `$/` to use a different line terminator.)

The command is executed each time the pseudoliteral is evaluated. The numeric status value of the command is saved in `$?` (see Chapter 25 for the interpretation of `$?`, also known as `$CHILD_ERROR`). Unlike the *csh* version of this command, no translation is done on the return data—newlines remain newlines. Unlike in any of the shells, single quotes in Perl do not hide variable names in the command from interpretation. To pass a `$` through to the shell, you need to hide it with a backslash. The `$user` in our *finger* example above is interpolated by Perl, not by the shell. (Because the command undergoes shell processing, see Chapter 20 for security concerns.)

The generalized form of backticks is `qx//` (for "quoted execution"), but the operator works exactly the same way as ordinary backticks. You just get to pick your quote characters. As with similar quoting pseudofunctions, if you happen to choose a single quote as your delimiter, the command string doesn't undergo double-quote interpolation:

```
$perl_info  = qx(ps $$);            # that's Perl's $$
$shell_info = qx'ps $$';            # that's the shell's $$
```

Line Input (Angle) Operator

The most heavily used input operator is the line input operator, also known as the angle operator or the `readline` function (since that's what it calls internally). Evaluating a filehandle in angle brackets (`STDIN`, for example) yields the next line from the associated filehandle. (The newline is included, so according to Perl's criteria for truth, a freshly read line is always true, up until end-of-file, at which point an undefined value is returned, which is conveniently false.) Ordinarily, you would assign the input value to a variable, but there is one situation where an automatic assignment happens. If and only if the line input operator is the only thing inside the conditional of a `while` loop, the value is automatically assigned to the special variable `$_`. The assigned value is then tested to see whether it is defined. (This may seem like an odd thing to you, but you'll use the construct frequently, so it's worth learning.) Anyway, the following lines are equivalent:

```
while (defined($_ = <STDIN>)) { print $_ }    # the longest way
while ($_ = <STDIN>) { print }                # explicitly to $_
while (<STDIN>) { print }                     # the short way
for (;<STDIN>;) { print }                     # while loop in disguise
print $_ while defined($_ = <STDIN>);         # long statement modifier
print while $_ = <STDIN>;                     # explicitly to $_
print while <STDIN>;                          # short statement modifier
```

Remember that this special magic requires a `while` loop. If you use the input operator anywhere else, you must assign the result explicitly if you want to keep the value:

```
while (<FH1> && <FH2>) { ... }         # WRONG: discards both inputs
if (<STDIN>)      { print }            # WRONG: prints old value of $_
if ($_ = <STDIN>) { print }            # suboptimal: doesn't test defined
if (defined($_ = <STDIN>)) { print }   # best
```

When you're implicitly assigning to `$_` in a `$_` loop, this is the global variable by that name, not one localized to the `while` loop. You can protect an existing value of `$_` this way:

```
while (local $_ = <STDIN>) { print }   # temporary value to global $_
```

or this way:

```
while (my $_ = <STDIN>) { print }      # a new, lexical $_
```

Any previous value is restored when the loop is done. Unless declared with `my` or `state`, `$_` is still a global variable, though, so functions called from inside that loop could still access it, intentionally or otherwise. You can avoid this, too, by declaring it lexical. Better yet, give your lexical variable a proper name:

```
while (my $line = <STDIN>) { print $line } # now private
```

(Both of these `while` loops still implicitly test for whether the result of the assignment is `defined`, because `my`, `state`, `local`, and `our` don't change how assignment is seen by the parser.) The filehandles `STDIN`, `STDOUT`, and `STDERR` are predefined and preopened. Additional filehandles may be created with the `open` or `sysopen` functions. See those functions' documentation in Chapter 27 for details on this.

In the `while` loops above, we were evaluating the line input operator in scalar context, so the operator returns each line separately. However, if you use the operator in list context, a list consisting of all remaining input lines is returned, one line per list element. It's easy to make a *large* data space this way, so use this feature with care:

```
$one_line = <MYFILE>;   # Get first line.
@all_lines = <MYFILE>;  # Get the rest of the lines.
```

There is no `while` magic associated with the list form of the input operator, because the condition of a `while` loop always provides scalar context (as does any conditional).

Using the null filehandle within the angle operator is special; it emulates the command-line behavior of typical Unix filter programs such as *sed* and *awk*. When you read lines from `<>`, it magically gives you all the lines from all the files mentioned on the command line. If no files were mentioned, it gives you standard input instead, so your program is easy to insert into the middle of a pipeline of processes.

Here's how it works: the first time `<>` is evaluated, the `@ARGV` array is checked. If it is null, `$ARGV[0]` is set to "-", which when opened gives you standard input. The `@ARGV` array is then processed as a list of filenames. More explicitly, the loop:

```
while (<>) {
    ...                     # code for each line
}
```

is equivalent to the following Perl-like pseudocode:

```
@ARGV = ("-") unless @ARGV;     # assume STDIN iff empty
while (@ARGV) {
    $ARGV = shift @ARGV;        # shorten @ARGV each time
    if (!open(ARGV, '<', $ARGV)) {
        warn "Can't open $ARGV: $!\n";
        next;
    }
    while (<ARGV>) {
        ...                     # code for each line
    }
}
```

except that it isn't so cumbersome to say, and will actually work. It really does shift array `@ARGV` and put the current filename into the global variable `$ARGV`. It also uses the special filehandle `ARGV` internally—`<>` is just a synonym for the more explicitly written `<ARGV>`, which is a magical filehandle. (The pseudocode above doesn't work because it treats `<ARGV>` as nonmagical.)

You can modify `@ARGV` before the first `<>` so long as the array ends up containing the list of filenames you really want. Because Perl uses its normal `open` function here, a filename of "-" counts as standard input wherever it is encountered, and the more esoteric features of `open` are automatically available to you (such as ignoring leading or trailing whitespace in the filename, or opening a "file" named "`gzip -dc < file.gz |`"). Line numbers (`$.`) continue as if the input were one big happy file. (But see the example under `eof` in Chapter 27 for how to reset line numbers on each file.)

If you want to set @ARGV to your own list of files, go right ahead:

```
# default to README file if no args given
@ARGV = ("README") unless @ARGV;
```

If you want to pass switches into your script, you can use one of the Getopt::* modules or put a loop on the front, like this:

```
while (@ARGV and $ARGV[0] =~ /^-/) {
    $_ = shift;
    last if /^--$/;
    if (/^-D(.*)/) { $debug = $1 }
    if (/^-v/)     { $verbose++  }
    ...             # other switches
}
while (<>) {
    ...             # code for each line
}
```

The <> symbol will return false only once. If you call it again after this, it will assume you are processing another @ARGV list, and if you haven't set @ARGV, it will input from STDIN.

If the string inside the angle brackets is a scalar variable (for example, <$foo>), that variable contains an *indirect filehandle*, either the name of the filehandle to input from or a reference to such a filehandle. For example:

```
$fh = \*STDIN;
$line = <$fh>;
```

or:

```
open(my $fh, '<', "data.txt");
$line = <$fh>;
```

Filename Globbing Operator

You might wonder what happens to a line input operator if you put something fancier inside the angle brackets. What happens is that it mutates into a different operator. If the string inside the angle brackets is anything other than a filehandle name or a scalar variable (even if there are just extra spaces), it is interpreted as a filename pattern to be "globbed".[20] The pattern is matched against the files in the current directory (or the directory specified as part of the fileglob pattern), and the filenames so matched are returned by the operator. As with line input,

20. Fileglobs have nothing to do with the previously mentioned typeglobs, other than that they both use the * character in a wildcard fashion. The * character has the nickname "glob" when used like this. With typeglobs, you're globbing symbols with the same name from the symbol table. With a fileglob, you're doing wildcard matching on the filenames in a directory, just as the various shells do.

names are returned one at a time in scalar context, or all at once in list context. The latter usage is more common; you often see things like:

```
@files = <*.xml>;
```

As with other kinds of pseudoliterals, one level of variable interpolation is done first, but you can't say `<$foo>` because that's an indirect filehandle as explained earlier. In older versions of Perl, programmers would insert braces to force interpretation as a fileglob: `<${foo}>`. These days, it's considered cleaner to call the internal function directly as `glob($foo)`, which is probably the right way to have invented it in the first place. So you'd write:

```
@files = glob("*.xml");
```

if you despise overloading the angle operator for this. Which you're allowed to do.

Whether you use the `glob` function or the old angle-bracket form, the fileglob operator also does `while` magic like the line input operator, assigning the result to `$_`. (That was the rationale for overloading the angle operator in the first place.) For example, if you wanted to change the permissions on all your C code files, you might say:

```
while (glob "*.c") {
    chmod 0644, $_;
}
```

which is equivalent to:

```
while (<*.c>) {
    chmod 0644, $_;
}
```

The `glob` function was originally implemented as a shell command in older versions of Perl (and in even older versions of Unix), which meant it was comparatively expensive to execute and, worse still, wouldn't work exactly the same everywhere. Nowadays it's a built-in, so it's more reliable and a lot faster.

Of course, the shortest and arguably the most readable way to do the `chmod` command above is to use the fileglob as a list operator:

```
chmod 0644, <*.c>;
```

A fileglob evaluates its (embedded) operand only when starting a new list. All values must be read before the operator will start over. In list context, this isn't important because you automatically get them all anyway. In scalar context, however, the operator returns the next value each time it is called, or a false value if you've just run out. Again, false is returned only once. So if you're expecting a single value from a fileglob, it is much better to say:

```
($file) = <blurch*>;  # list context
```

than to say:

```
$file = <blurch*>;    # scalar context
```

because the former returns all matched filenames and resets the operator, whereas the latter alternates between returning filenames and returning false.

If you're trying to do variable interpolation, it's definitely better to use the `glob` operator because the older notation can cause confusion with the indirect filehandle notation. This is where it becomes apparent that the borderline between terms and operators is a bit mushy:

```
@files = <$dir/*.[ch]>;         # Works, but avoid.
@files = glob("$dir/*.[ch]");   # Call glob as function.
@files = glob $some_pattern;    # Call glob as operator.
```

We left the parentheses off of the last example to illustrate that `glob` can be used either as a function (a term) or as a *unary operator*; that is, a prefix operator that takes a single argument. The `glob` operator is an example of a *named unary operator*, which is just one kind of operator we'll talk about in the next chapter. Later, we'll talk about pattern-matching operators, which also parse like terms but behave like operators.

CHAPTER 3

Unary and Binary Operators

In the previous chapter, we talked about the various kinds of terms you might use in an expression, but to be honest, isolated terms are a bit boring. Many terms are party animals. They like to have relationships with one another. The typical young term feels strong urges to identify with and influence other terms in various ways, but there are many different kinds of social interaction and many different levels of commitment. In Perl, these relationships are expressed using operators.

Sociology has to be good for something.

From a mathematical perspective, operators are just ordinary functions with special syntax. From a linguistic perspective, operators are just irregular verbs. But as any linguist will tell you, the irregular verbs in a language tend to be the ones you use most often. And that's important from an information theory perspective because the irregular verbs tend to be shorter and more efficient in both production and recognition.

In practical terms, operators are handy.

Operators come in various flavors, depending on their *arity* (how many operands they take), their *precedence* (how hard they try to take those operands away from surrounding operators), and their *associativity* (whether they prefer to do things right to left or left to right when associated with operators of the same precedence).

Perl operators come in three arities: *unary*, *binary*, and *trinary* (or *ternary*, if your native tongue is Shibboleth). Unary operators are always prefix operators (except for the postincrement and postdecrement operators).[1] The others are all infix operators—unless you count the list operators, which can prefix any number of

1. Though you can think of various quotes and brackets as circumfix operators that delimit terms.

arguments. But most people just think of list operators as normal functions that you can forget to put parentheses around. Here are some examples:

```
! $x                # a unary operator
$x * $y             # a binary operator
$x ? $y : $z        # a trinary operator
print $x, $y, $z    # a list operator
```

An operator's precedence controls how tightly it binds. Operators with higher precedence grab the arguments around them before operators with lower precedence. The archetypal example is straight out of elementary math, where multiplication takes precedence over addition:

```
2 + 3 * 4           # yields 14, not 20
```

The order in which two operators of the same precedence are executed depends on their associativity. These rules also follow math conventions to some extent:

```
2 * 3 * 4           # means (2 * 3) * 4, left associative
2 ** 3 ** 4         # means 2 ** (3 ** 4), right associative
2 != 3 != 4         # illegal, nonassociative
```

Table 3-1 lists the associativity and arity of the Perl operators from highest precedence to lowest.

Table 3-1. Operator precedence

Associativity	Arity	Precedence Class
None	0	Terms, and list operators (leftward)
Left	2	`->`
None	1	`++ --`
Right	2	`**`
Right	1	`! ~ \` and unary `+` and `-`
Left	2	`=~ !~`
Left	2	`* / % x`
Left	2	`+ - .`
Left	2	`<< >>`
Right	0,1	Named unary operators
None	2	`< > <= >= lt gt le ge`
None	2	`== != <=> eq ne cmp ~~`
Left	2	`&`
Left	2	`| ^`
Left	2	`&&`

Associativity	Arity	Precedence Class
Left	2	`|| //`
None	2	`.. ...`
Right	3	`?:`
Right	2	`= += -= *=` and so on
Left	2	`, =>`
Right	0+	List operators (rightward)
Right	1	`not`
Left	2	`and`
Left	2	`or xor`

It may seem to you that there are too many precedence levels to remember. Well, you're right, there are. Fortunately, you've got two things going for you here. First, the precedence levels as they're defined usually follow your intuition, presuming you're not psychotic. And, second, if you're merely neurotic, you can always put in extra parentheses to relieve your anxiety.

Another helpful hint is that any operators borrowed from C keep the same precedence relationship with one another, even where C's precedence is slightly screwy. (This makes learning Perl easier for C folks and C++ folks. Maybe even Java folks.)

The following sections cover these operators in precedence order. With very few exceptions, these all operate on scalar values only, not list values. We'll mention the exceptions as they come up.

Although references are scalar values, using most of these operators on references doesn't make much sense, because the numeric value of a reference is only meaningful to the internals of Perl. Nevertheless, if a reference points to an object of a class that allows overloading, you can call these operators on such objects, and if the class has defined an overloading for that particular operator, it will define how the object is to be treated under that operator. This is how complex numbers are implemented in Perl, for instance. For more on overloading, see Chapter 13.

Terms and List Operators (Leftward)

Any *term* is of highest precedence in Perl. Terms include variables, quote and quote-like operators, most expressions in parentheses, brackets or braces, and any function whose arguments are parenthesized. Actually, there aren't really

any functions in this sense, just list operators and unary operators behaving as functions because you put parentheses around their arguments. Nevertheless, the name of Chapter 27 is *Functions*.

Now listen carefully. Here are a couple of rules that are very important and simplify things greatly, but may occasionally produce counterintuitive results for the unwary. If any list operator (such as `print`) or any named unary operator (such as `chdir`) is followed by a left parenthesis as the next token (ignoring whitespace), the operator and its parenthesized arguments are given highest precedence, as if it were a normal function call. The rule is this: if it *looks* like a function call, it *is* a function call. You can make it look like a nonfunction by prefixing the parentheses with a unary plus, which does absolutely nothing, semantically speaking —it doesn't even coerce the argument to be numeric.

For example, since || has lower precedence than `chdir`, we get:

```
chdir $foo    || die;       # (chdir $foo) || die
chdir($foo)   || die;       # (chdir $foo) || die
chdir ($foo)  || die;       # (chdir $foo) || die
chdir +($foo) || die;       # (chdir $foo) || die
```

but because * has higher precedence than `chdir`, we get:

```
chdir $foo * 20;            # chdir ($foo * 20)
chdir($foo) * 20;           # (chdir $foo) * 20
chdir ($foo) * 20;          # (chdir $foo) * 20
chdir +($foo) * 20;         # chdir ($foo * 20)
```

Likewise for any numeric operator that happens to be a named unary operator, such as `rand`:

```
rand 10 * 20;               # rand (10 * 20)
rand(10) * 20;              # (rand 10) * 20
rand (10) * 20;             # (rand 10) * 20
rand +(10) * 20;            # rand (10 * 20)
```

In the absence of parentheses, the precedence of list operators such as `print`, `sort`, or `chmod` is either very high or very low depending on whether you look at the left side or the right side of the operator. (That's what the "Leftward" is doing in the title of this section.) For example, in:

```
my @ary = (1, 3, sort 4, 2);
print @ary;         # prints 1324
```

the commas on the right of the `sort` are evaluated before the `sort`, but the commas on the left are evaluated after. In other words, a list operator tends to gobble up all the arguments that follow it, and then act like a simple term with regard to the preceding expression. You still have to be careful with parentheses:

```
# These evaluate exit before doing the print:
print($foo, exit);  # Obviously not what you want.
print $foo, exit;   # Nor this.

# These do the print before evaluating exit:
(print $foo), exit; # This is what you want.
print($foo), exit;  # Or this.
```

The easiest place to get burned is where you're using parentheses to group mathematical arguments, and you forget that parentheses are also used to group function arguments:

```
print ($foo & 255) + 1, "\n";   # prints ($foo & 255)
```

That probably doesn't do what you expect at first glance.[2] Fortunately, mistakes of this nature generally produce warnings like "`Useless use of addition (+) in void context`" and "`print (...) interpreted as function`" when warnings are enabled. The second one is reminding you that the parentheses delimit the argument list, and that anything after it won't be part of those arguments. Write that this way instead:

```
print(($foo & 255) + 1, "\n");   # prints ($foo & 255)+1
```

Also parsed as terms are the `do {}` and `eval {}` constructs, as well as subroutine and method calls, the anonymous array and hash composers `[]` and `{}`, and the anonymous subroutine composer `sub {}`.

The Arrow Operator

Just as in C and C++, the binary `->` operator is an infix dereference operator. If the right side is a `[...]` array subscript, a `{...}` hash subscript, or a `(...)` subroutine argument list, the left side must be a reference[3] to an array, a hash, or a subroutine, respectively:

```
$aref->[42]              # an array dereference
$href->{"corned beef"}   # a hash dereference
$sref->(1,2,3)           # a subroutine dereference
```

In an lvalue (assignable) context, if the left side is not a reference, it must be a location capable of holding a hard reference, in which case such a reference will be *autovivified* for you.

2. Which is why we will be fixing it to do what you expect in Perl 6. Alas, we cannot easily retrofit this fix to Perl 5 without breaking a lot of existing code.

3. This may be a symbolic reference, but only when `no strict` is in effect. Otherwise, it must be a hard reference.

```
$aref->[42] = 'Huh!';       # autovivify an array in $aref
$href->{"corned beef"} = 0; # autovivify a hash in $href
```

In either case, it also creates the new individual array or hash element with the assigned value. For more on this (and some warnings about accidental autovivification), see Chapter 8.

If the right side of the arrow is not one of those brackets, it's a method call of some kind. The right side must be a method name (or a simple scalar variable containing the method name or a method reference), and the left side must evaluate to either an object (a blessed reference) or a class name (that is, a package name):

```
my $yogi = Bear->new("Yogi");  # a class method call
$yogi->swipe('picnic basket'); # an object method call
```

The method name may be qualified with a package name to indicate in which class to start searching for the method, or with the special package name, `SUPER::`, to indicate that the search should start in the parent class. See Chapter 12.

Autoincrement and Autodecrement

The `++` and `--` operators work as in C. That is, when placed before a variable, they increment or decrement the variable before returning the value; when placed after, they increment or decrement the variable after returning the value. For example, `$a++` increments the value of scalar variable `$a`, returning the value it had *before* the increment. Similarly, `--$b{(/(\w+)/)[0]}` decrements the element of the hash `%b` indexed by the first "word" in the default search variable (`$_`) and returns the value *after* the decrement.[4] Note that just as in C, Perl doesn't define *when* the variable is incremented or decremented. You just know it will be done sometime before or after the value is returned. This also means that modifying a variable twice in the same statement will lead to undefined behavior. Avoid statements like:

```
$i = $i++;
print ++$i + $i++;
```

Perl will not guarantee the results of such code.

4. Okay, so that wasn't exactly fair. We just wanted to make sure you were paying attention. Here's how that expression works. First, the pattern match finds the first word in `$_` using the regular expression `\w+`. The parentheses around that cause the word to be returned as a single-element list value because the pattern match is in list context. The list context is supplied by the list slice operator, `(...)[0]`, which returns the first (and only) element of the list. That value is used as the key for the hash, and then the hash value stored under that key is decremented and returned. In general, when confronted with a complex expression, analyze it from the inside out to see what order things happen in.

The autoincrement operator has a little extra built-in magic. If you increment a variable that is numeric, or that has ever been used in a numeric context, you get a normal increment. If, however, the variable has been used only in string contexts since it was set, has a value that is not the null string, and matches the pattern `/^[a-zA-Z]*[0-9]*\z/`, the increment is done as a string, preserving each character within its range, with carry:

```
my $foo;
$foo = "99"; print ++$foo;   # prints "100"
$foo = "a9"; print ++$foo;   # prints "b0"
$foo = "Az"; print ++$foo;   # prints "Ba"
$foo = "zz"; print ++$foo;   # prints "aaa"
```

The undefined value is always treated as numeric, and in particular is changed to `0` before incrementing, so that a postincrement of an undef value will return `0` rather than `undef`.

As of this writing, magical autoincrement has not been extended to Unicode letters and digits, but it might be in the future.

The autodecrement operator, however, is not magical.

Exponentiation

Binary `**` is the exponentiation operator. Note that it binds even more tightly than unary minus, so `-2**4` is `-(2**4)`, not `(-2)**4`. The operator is implemented using C's *pow*(3) function, which works with floating-point numbers internally. It calculates using logarithms, which means that it works with fractional powers, but you sometimes get results that aren't as exact as straight multiplication would produce.

Ideographic Unary Operators

Most unary operators just have names (see "Named Unary and File Test Operators" on page 106 later in this chapter), but some operators are deemed important enough to merit their own special symbolic representation. All of these operators seem to have something to do with negation. Blame the mathematicians.

Unary `!` performs logical negation; that is, "not". See `not` for a lower precedence version of logical negation. The value of a negated operand is true (1) if the operand is false (numeric 0, string `"0"`, the null string, or undefined), and false (`""`) if the operand is true.

Unary - performs arithmetic negation if the operand is numeric. If the operand is an identifier, a string consisting of a minus sign concatenated with the identifier

is returned. Otherwise, if the string starts with a plus or minus, a string starting with the opposite sign is returned. One effect of these rules is that `-bareword` is equivalent to `"-bareword"`.[5] If, however, the string begins with a nonalphabetic character (excluding "+" or "-"), Perl will attempt to convert the string to a numeric and the arithmetic negation is performed. If the string cannot be cleanly converted to a numeric, Perl will give the warning "`Argument "the string" isn't numeric in negation (-)`".

Unary ~ performs bitwise negation; that is, 1's complement. For example, `0666 & ~027` is 0640. By definition, this is somewhat nonportable when limited by the word size of your machine. For example, on a 32-bit machine, `~123` is `4294967172`, while on a 64-bit machine, it's `18446744073709551492`. But you knew that already.

What you perhaps didn't know is that if the argument to ~ happens to be a string instead of a number, a string of identical length is returned, but with all the bits of the string complemented. This is a fast way to flip a lot of bits all at once, and it's a way to flip those bits portably, since it doesn't depend on the word size of your computer. Later we'll also cover the bitwise logical operators, which have string-oriented variants as well.

When complementing strings, if all characters have ordinal values under 256, then their complements will also. But if they do not, all characters will be in either 32- or 64-bit complements, depending on your architecture. So, for example, the expression `~"\x{3B1}"` is `"\x{FFFF_FC4E}"` on 32-bit machines and `"\x{FFFF_FFFF_FFFF_FC4E}"` on 64-bit machines.

Unary + has no semantic effect whatsoever, even on strings. It is syntactically useful for separating a function name from a parenthesized expression that would otherwise be interpreted as the complete list of function arguments. (See examples under the section "Terms and List Operators (Leftward)" on page 97.) If you think about it sideways, + negates the effect that parentheses have of turning prefix operators into functions.

Unary \ creates a reference to whatever follows it. Used on a list, it creates a list of references. See the section "The Backslash Operator" on page 342 in Chapter 8 for details. Do not confuse this behavior with the behavior of backslash within a string, although both forms do convey the vaguely negational notion of protecting the next thing from interpretation. This resemblance is not entirely accidental.

5. This is most useful for Tk programmers, for whom the convention was first adopted.

Binding Operators

Binary =~ binds a string expression to a pattern match, substitution, or transliteration (loosely called translation). These operations would otherwise search or modify the string contained in $_ (the default variable). The string you want to bind is put on the left, while the operator itself is put on the right. The return value in scalar context generally indicates the success or failure of the operator on the right, since the binding operator doesn't really do anything on its own. The exception to this is when using the /r modifier with substitution (s///) or transliteration (y///, tr///), which returns a copy of the modified string. Behavior in list context depends on the particular operator.

If the right argument is an expression rather than a pattern match, substitution, or transliteration, it will be interpreted as a search pattern at runtime. That is to say, $_ =~ $pat is equivalent to $_ =~ /$pat/. This is less efficient than an explicit search, since the pattern must be checked and possibly recompiled every time the expression is evaluated. You can avoid this recompilation by precompiling the original pattern using the qr// (quote regex) operator.

Binary !~ is just like =~ except the return value is negated logically. Binary "!~" that attempts to use the /r modifier for a nondestructive substitution or transliteration is a syntax error. Apart from that, the following expressions are functionally equivalent:

```
$string !~ /pattern/
!(  $string =~ /pattern/ )
not $string =~ /pattern/
```

We said that the return value indicates success, but there are many kinds of success. Unless you use the /r modifier to make them return their results instead, substitutions return the number of successful matches, as do transliterations. (In fact, the transliteration operator is often used to count characters.) Since any nonzero result is true, it all works out. The most spectacular kind of true value is a list assignment of a pattern: in list context, pattern matches can return substrings matched by the parentheses in the pattern. But, again, according to the rules of list assignment, the list assignment itself will return true if anything matched and was assigned, and false otherwise. So you sometimes see things like:

```
if (my ($k,$v) = $string =~ m/(\w+)=(\w*)/) {
    print "KEY $k VALUE $v\n";
}
```

Let's pick that apart. The =~ has precedence over =, so =~ happens first. The =~ binds $string to the pattern match on the right, which is scanning for occurrences of things that look like *KEY=VALUE* in your string. It's in list context because it's on the right side of a list assignment. If the pattern matches, it returns a list to be assigned to $k and $v, which are new variables created by my. The list assignment itself is in scalar context, so it returns 2, the number of values on the right side of the assignment. And 2 happens to be true, since our scalar context is also a Boolean context. When the match fails, no values are assigned, which returns 0, which is false.

For more on the politics of patterns, see Chapter 5.

Multiplicative Operators

Perl provides the C-like operators * (multiply), / (divide), and % (modulo). The * and / work exactly as you would expect, multiplying or dividing their two operands. Division is done in floating point, unless you've used any of the integer, bigint, bigrat, or bignum pragmatic modules. The % operator converts its operands to integers before finding the remainder according to integer division. (However, it does this integer division in floating point if necessary, so your operands can be up to 15 digits long on most 32-bit machines.) Assume that your two operands are called $a and $b. If $b is positive, then the result of $a % $b is $a minus the largest multiple of $b that is not greater than $a (which means the result will always be in the range 0 .. $b-1). If $b is negative, then the result of $a % $b is $a minus the smallest multiple of $b that is not less than $a (which means the result will be in the range $b+1 .. 0).

When use integer is in scope, % gives you direct access to the modulus operator as implemented by your C compiler. This operator is not well defined for negative operands, but it will execute faster.

Binary x is the repetition operator. Actually, it's two operators. In scalar context, it returns a concatenated string consisting of the left operand repeated the number of times specified by the right operand. (For backward compatibility, it also does this in list context if the left argument is not in parentheses.)

```
print "-" x 80;                         # print row of dashes
print "\t" x ($tab/8), " " x ($tab%8);  # tab over
```

In list context, if the left operand is a list in parentheses or is a list formed by qw/*STRING*/, the x works as a list replicator rather than a string replicator. This is useful for initializing all the elements of an array of indeterminate length to the same value:

```
my @ones = (1) x 80;        # a list of 80 1's
@ones = (5) x @ones;        # set all elements to 5
```

Similarly, you can also use `x` to initialize array and hash slices:

```
my %hash;
my @keys = qw(perls before swine);
@hash{@keys} = ("") x @keys;
```

If this mystifies you, note that `@keys` is being used both as a list of keys on the left side of the assignment and as a scalar value (returning the array length) on the right side of the assignment. The previous example has the same effect on `%hash` as:

```
$hash{perls}  = "";
$hash{before} = "";
$hash{swine}  = "";
```

Additive Operators

Strangely enough, Perl also has the customary `+` (addition) and `-` (subtraction) operators. Both operators convert their arguments from strings to numeric values, if necessary, and return a numeric result.

Additionally, Perl provides the `.` operator, which does string concatenation. For example:

```
my $almost = "Fred" . "Flintstone";    # returns FredFlintstone
```

Note that Perl does not place a space between the strings being concatenated. If you want the space, or if you have more than two strings to concatenate, you can use the `join` operator, described in Chapter 27. Most often, though, people do their concatenation implicitly inside a double-quoted string:

```
my $fullname = "$firstname $lastname";
```

Shift Operators

The bit-shift operators (`<<` and `>>`) return the value of the left argument shifted to the left (`<<`) or to the right (`>>`) by the number of bits specified by the right argument. The arguments should be integers. For example:

```
1 << 4;     # returns 16
32 >> 4;    # returns 2
```

Be careful, though. Results on large (or negative) numbers may vary depending on the number of bits your machine uses to represent integers. You can avoid this restriction with the `bigint` pragma.

```
use v5.14;
say 500 <<  20; # prints 524288000
say 500 << 200; # prints (only) 128000

use bigint;
say 500 << 200;
803469022129495137770981046170581301261101496891396417650688000
```

Named Unary and File Test Operators

Some of the "functions" described in Chapter 27 are really unary operators. Table 3-2 lists all the named unary operators.

Table 3-2. Named unary operators

-X (file tests)	fileno	lock	setnetent
abs	getc	log	setprotoent
alarm	getgrgid	lstat	setservent
caller	getgrnam	my	shift
chdir	gethostbyname	oct	sin
chomp	getnetbyname	ord	sleep
chop	getpeername	our	sqrt
chr	getpgrp	pop	srand
chroot	getprotobyname	pos	stat
close	getpwnam	prototype	state
closedir	getpwuid	quotemeta	study
cos	getsockname	rand	tell
dbmclose	glob	readdir	telldir
defined	gmtime	readline	tied
delete	hex	readlink	uc
do	int	readpipe	ucfirst
each	keys	ref	umask
eof	lc	reset	undef
eval	lcfirst	rewinddir	untie
exists	length	rmdir	values
exit	local	scalar	write
exp	localtime	sethostent	any ($) sub
fc			

Unlike list operators, unary operators have a higher precedence than some of the binary operators. For example:

```
sleep 4 | 3;
```

does not sleep for 7 seconds. It sleeps for 4 seconds and then takes the return value of `sleep` (typically zero) and bitwise ORs that with 3, as if the expression were parenthesized as:

```
(sleep 4) | 3;
```

Compare this with:

```
print 4 | 3;
```

which *does* take the value of 4 ORed with 3 before printing it (7, in this case), as if it were written:

```
print (4 | 3);
```

This is because `print` is a list operator, not a simple unary operator. Once you've learned which operators are list operators, you'll have no trouble telling unary operators and list operators apart. When in doubt, you can always use parentheses to turn a named unary operator into a function. Remember, if it looks like a function, it is a function.

Another funny thing about named unary operators is that many of them default to `$_` if you don't supply an argument. However, if you omit the argument but the token following the named unary operator looks like it might be the start of an argument, Perl will get confused because it's expecting a term. Whenever the Perl tokener gets to one of the characters listed in Table 3-3, the tokener returns different token types depending on whether it expects a term or operator.

Table 3-3. Ambiguous characters

Character	Operator	Term
`+`	Addition	Unary plus
`-`	Subtraction	Unary minus
`*`	Multiplication	`*typeglob`
`/`	Division	`/pattern/`
`<`	Less than, left shift	`<HANDLE>, <<END`
`.`	Concatenation	`.3333`
`?`	`?:`	`?pattern?` (deprecated)
`%`	Modulo	`%hash`
`&`	`&, &&`	`&subroutine`

So a typical boo-boo is:

```
next if length < 80;
```

in which the `<` looks to the parser like the beginning of the `<>` input symbol (a term) instead of the "less than" (an operator) you were thinking of. There's really no way to fix this and still keep Perl pathologically eclectic. If you're so incredibly lazy that you cannot bring yourself to type the two characters `$_`, then use one of these instead:

```
next if length() < 80;
next if (length) < 80;
next if 80 > length;
next unless length >= 80;
```

When a term is expected, a minus sign followed by a single letter will always be interpreted as a *file test operator*. A file test operator is a unary operator that takes one argument, either a filename or a filehandle, and tests the associated file to see whether something is true about it. If the argument is omitted, it tests `$_`, except for `-t`, which tests `STDIN`. Unless otherwise documented, it returns `1` for true and `""` for false, or the undefined value if the file doesn't exist or is otherwise inaccessible. Currently implemented file test operators are listed in Table 3-4.

Table 3-4. File test operators

Operator	Meaning
`-r`	File is readable by effective UID/GID.
`-w`	File is writable by effective UID/GID.
`-x`	File is executable by effective UID/GID.
`-o`	File is owned by effective UID.
`-R`	File is readable by real UID/GID.
`-W`	File is writable by real UID/GID.
`-X`	File is executable by real UID/GID.
`-O`	File is owned by real UID.
`-e`	File exists.
`-z`	File has zero size.
`-s`	File has nonzero size (returns size).
`-f`	File is a plain file.
`-d`	File is a directory.
`-l`	File is a symbolic link.
`-p`	File is a named pipe (FIFO).

Operator	Meaning
-S	File is a socket.
-b	File is a block special file.
-c	File is a character special file.
-t	Filehandle is opened to a tty.
-u	File has setuid bit set.
-g	File has setgid bit set.
-k	File has sticky bit set.
-T	File is a text file.
-B	File is a binary file (opposite of -T).
-M	Age of file (at startup) in days since modification.
-A	Age of file (at startup) in days since last access.
-C	Age of file (at startup) in days since inode change.

These operators are exempt from the "looks like a function rule" described above. That is, an opening parenthesis after the operator does not affect how much of the following code constitutes the argument. That means, for example, that `-f($file).".bak"` is equivalent to `-f "$file.bak"`. Put the opening parentheses before the operator to separate it from code that follows (this applies only to operators with higher precedence than unary operators, of course):

```
-s($file) + 1024   # probably wrong; same as -s($file + 1024)
(-s $file) + 1024  # correct
```

Note that `-s/a/b/` does not do a negated substitution. Saying `-exp($foo)` still works as expected, however—only single letters following a minus are interpreted as file tests.

The interpretation of the file permission operators `-r`, `-R`, `-w`, `-W`, `-x`, and `-X` is based solely on the mode of the file and the user and group IDs of the user. There may be other reasons you can't actually read, write, or execute the file, such as if you are on a system that uses ACLs (Access Control Lists), and you're not on the list.[6] Also note that for the superuser, `-r`, `-R`, `-w`, and `-W` always return 1, and `-x` and `-X` return 1 if any execute bit is set in the mode. Thus, scripts run by the superuser may need to do a `stat` in order to determine the actual mode of the file, or pretend not to be superuser by temporarily setting the UID to something

6. You may, however, override the built-in semantics with the `filetest` pragma. See Chapter 29.

else. The other file test operators don't care who you are. Anybody can use the test for "regular" files:

```
while (<>) {
    chomp;
    next unless -f $_;      # ignore "special" files
    ...
}
```

The `-T` and `-B` switches work as follows. The first block or so of the file is examined for strange characters such as control codes or bytes with the high bit set (that don't look like UTF-8). If more than a third of the bytes appear to be strange, it's a binary file; otherwise, it's a text file. Also, any file containing ASCII NUL (`\0`) in the first block is considered a binary file. If `-T` or `-B` is used on a filehandle, the current input (standard I/O or "stdio") buffer is examined rather than the first block of the file. Both `-T` and `-B` return true on an empty file, or on a file at EOF (end-of-file) when testing a filehandle. Because Perl has to read a file to do the `-T` test, you don't want to use `-T` on special files that might hang or give you other kinds of grief. So on most occasions you'll want to test with a `-f` first, as in:

```
next unless -f $file && -T $file;
```

If any `stat`, `lstat`, or file-test operator is given the special filehandle consisting of a solitary underline, then the *stat* structure of the previous file test (or `stat` operator) is used, thereby saving a system call. (This doesn't work under `use filetest` or with `-t`, and you need to remember that `lstat` and `-l` will leave values in the *stat* structure for the symbolic link, not the real file. Likewise, `-l _` will always be false after a normal `stat`.)

Here are a couple of examples:

```
print "Can do.\n"    if -r $a || -w _ || -x _;

stat($filename);
print "Readable\n"   if -r _;
print "Writable\n"   if -w _;
print "Executable\n" if -x _;
print "Setuid\n"     if -u _;
print "Setgid\n"     if -g _;
print "Sticky\n"     if -k _;
print "Text\n"       if -T _;
print "Binary\n"     if -B _;
```

File ages for `-M`, `-A`, and `-C` are returned in days (including fractional days) since the script started running. This start time is stored in the special variable `$^T` (`$BASETIME`). Thus, if the file changed after the script started, you would get a negative time. Note that most time values (86,399 out of 86,400, on average) are

fractional, so testing for equality with an integer without using the `int` function is usually futile. Examples:

```
next unless -M $file > .5;      # files are older than 12 hours
&newfile if -M $file < 0;       # file is newer than process
&mailwarning if int(-A) == 90;  # file ($_) was accessed 90 days ago today
```

To reset the script's start time to the current time, say this:

```
$^T = time;
```

Starting with v5.10, as a form of purely syntactic sugar, you can stack file test operators, making `-f -w -x $file` equivalent to `-x $file && -w _ && -f _`.

Relational Operators

Perl has two classes of relational operators. One class operates on numeric values, the other on string values, as shown in Table 3-5.

Table 3-5. Relational operators

Numeric	String	Meaning
`>`	`gt`	Greater than
`>=`	`ge`	Greater than or equal to
`<`	`lt`	Less than
`<=`	`le`	Less than or equal to

These operators return `1` for true and `""` for false. Note that relational operators are nonassociating, which means that `$a < $b < $c` is a syntax error.

In the absence of locale declarations, string comparisons are based on the numeric Unicode codepoint order of each character in the string. With a locale declaration, the collation order specified by the locale is used. These legacy, locale-based collation mechanisms do not interact well with the Unicode collation mechanisms provided by the `Unicode::Collate` and `Unicode::Collate::Locale` modules. It is better to use the modules, not locales. Codepoint order is not alphabetic order except in (unicameral) ASCII, so Perl's string operators will produce alphabetic results only on legacy ASCII data, not on arbitrary text.

Equality Operators

The equality operators listed in Table 3-6 are much like the relational operators.

Table 3-6. Equality operators

Numeric	String	Meaning
`==`	`eq`	Equal to
`!=`	`ne`	Not equal to
`<=>`	`cmp`	Comparison, with signed result
`~~`	`~~`	Smartmatch

The equal and not-equal operators return `1` for true and `""` for false (just as the relational operators do). The `<=>` and `cmp` operators return `-1` if the left operand is less than the right operand, `0` if they are equal, and `+1` if the left operand is greater than the right. Although the equality operators appear to be similar to the relational operators, they do have a lower precedence level, so `$a < $b <=> $c < $d` is syntactically valid.

For reasons that are apparent to anyone who has seen *Star Wars*, the `<=>` operator is known as the "spaceship" operator.

The `~~` operator is described in the next section.

Smartmatch Operator

First available in v5.10.1,[7] binary `~~` does a "smartmatch" between its arguments. This is mostly used implicitly in the `when` construct, although not all `when` clauses call the smartmatch operator. Unique among all of Perl's operators, the smartmatch operator can recurse.

It is also unique in that all other Perl operators impose a context (usually string or numeric context) on their operands, autoconverting those operands to those imposed contexts. In contrast, smartmatch *infers* contexts from the actual types of its operands and uses that type information to select a suitable comparison mechanism.

The `~~` operator compares its operands "polymorphically", determining how to compare them according to their actual types (numeric, string, array, hash, and so on). Like the equality operators with which it shares the same precedence, `~~` returns 1 for true and `""` for false. Much like the `=~` binding operator, this operator's right argument is considered to be a pattern that either accepts or

7. The version in v5.10.0 behaved differently on fancy cases, but that's okay because you're using at least v5.14 now, right?

rejects the left argument. However, the notion of "pattern" is generalized greatly, and nearly any value can function as a pattern, or as a list of patterns.

So ~~ is often best read aloud as "matches" or "matches any of", because the left operand submits itself to be accepted or rejected by the right operand (or some part of the right operand).

The behavior of a smartmatch depends on what type of things its arguments are, as determined by Table 3-7. The first row of the table whose types apply determines the smartmatch behavior. Because what actually happens is first determined by the type of the right operand, and only later by the type of the left operand, the table is sorted on the right operand.

The smartmatch implicitly dereferences any nonblessed hash or array reference, so the *HASH* and *ARRAY* entries apply in those cases. For blessed references, the *Object* entries apply. Smartmatches involving hashes only consider hash keys, never hash values.

The "Matches" column is not always an exact rendition. For example, the smartmatch operator short circuits whenever possible, but `grep` does not. Also, `grep` in scalar context returns the number of matches, but ~~ returns only true or false.

Unlike most operators, the smartmatch operator knows to treat `undef` specially:

```
my @array = (1, 2, 3, undef, 4, 5);
say "some elements undefined" if undef ~~ @array;
```

Each operand is considered in a modified scalar context, the modification being that array and hash variables are passed by reference to the operator, which implicitly dereferences them. Both elements of each pair are the same:

```
my %hash = (red    => 1, blue   => 2, green  => 3,
            orange => 4, yellow => 5, purple => 6,
            black  => 7, grey   => 8, white  => 9);

my @array = qw(red blue green);

say "some array elements in hash keys" if  @array ~~  %hash;
say "some array elements in hash keys" if \@array ~~ \%hash;

say "red in array" if "red" ~~  @array;
say "red in array" if "red" ~~ \@array;

say "some keys end in e" if /e$/ ~~  %hash;
say "some keys end in e" if /e$/ ~~ \%hash;
```

Table 3-7. Smartmatch behavior

Left	Right	Description	Like (But Evaluated in Boolean Context)
Any	`undef`	Check whether *Any* is undefined	`!defined` *Any*
Any	*Object*	Invoke `~~` overloading on *Object*, or die	
HASH	*CODE*	Sub returns true on all *HASH* keys[a]	`!grep { !`*CODE*`->($_) } keys` *HASH*
ARRAY	*CODE*	Sub returns true on all *ARRAY* elements[a]	`!grep { !`*CODE*`->($_) }` *ARRAY*
Any	*CODE*	Sub passed *Any* returns true	*CODE*`->(`*Any*`)`
HASH1	*HASH2*	All same keys in both *HASH*es	`keys` *HASH1* `== grep { exists` *HASH2*`->{$_} } keys` *HASH1*
ARRAY	*HASH*	Any *ARRAY* elements exist as *HASH* keys	`grep { exists` *HASH*`->{$_} }` *ARRAY*
Regexp	*HASH*	Any *HASH* keys pattern match *Regexp*	`grep { /`*Regexp*`/ } keys` *HASH*
`undef`	*HASH*	Always false (`undef` can't be a key)	`0 == 1`
Any	*HASH*	*HASH* key existence	`exists` *HASH*`->{`*Any*`}`
HASH	*ARRAY*	Any *ARRAY* elements exist as *HASH* keys	`grep { exists` *HASH*`->{$_} }` *ARRAY*
ARRAY1	*ARRAY2*	Recurse on paired elements of *ARRAY1* and *ARRAY2*[b]	`(ARRAY1[0] ~~ ARRAY2[0]) && (ARRAY1[1] ~~ ARRAY2[1]) && ...`
Regexp	*ARRAY*	Any *ARRAY* elements pattern match *Regexp*	`grep { /`*Regexp*`/ }` *ARRAY*
`undef`	*ARRAY*	`undef` in *ARRAY*	`grep { !defined }` *ARRAY*
Any	*ARRAY*	Smartmatch each *ARRAY* element[c]	`grep {` *Any* `~~ $_ }` *ARRAY*

Left	Right	Description	Like (But Evaluated in Boolean Context)
HASH	*Regexp*	Any *HASH* keys match *Regexp*	`grep { /`*Regexp*`/ } keys` *HASH*
ARRAY	*Regexp*	Any *ARRAY* elements match *Regexp*	`grep { /`*Regexp*`/ }` *ARRAY*
Any	*Regexp*	Pattern match	*Any* `=~ /`*Regexp*`/`
Object	*Any*	Invoke `~~` overloading on *Object*, or fall back to:	
Any	*Num*	Numeric equality	*Any* `==` *Num*
Num	*numlike* [d]	Numeric equality	*Num* `==` *numlike*
`undef`	*Any*	Check whether undefined	`!defined(`*Any*`)`
Any	*Any*	String equality	*Any* `eq` *Any*

[a] Empty hashes or arrays match.

[b] That is, each element smart-matches the element of the same index in the other array.[c]

[c] If a circular reference is found, fall back to referential equality.

[d] Either an actual number or a string that looks like one.

Two arrays smartmatch if each element in the first array smartmatches (that is, is "in") the corresponding element in the second array, recursively:

```
my @little = qw(red blue green);
my @bigger = ("red", "blue", [ "orange", "green" ] );
if (@little ~~ @bigger) {  # true!
    say "little is contained in bigger";
}
```

Because the smartmatch operator recurses on nested arrays, this will still report that "red" is in the array:

```
my @array = qw(red blue green);
my $nested_array = [[[[[[[ @array ]]]]]]];
say "red in array" if "red" ~~ $nested_array;
```

If two arrays smartmatch each other, then they are deep copies of each other's values, as this example reports:

```
my @a = (0, 1, 2, [3, [4, 5], 6], 7);
my @b = (0, 1, 2, [3, [4, 5], 6], 7);

if (@a ~~ @b && @b ~~ @a) {
    say "a and b are deep copies of each other";
}
elsif (@a ~~ @b) {
    say "a smartmatches in b";
```

```
}
elsif (@b ~~ @a) {
    say "b smartmatches in a";
}
else {
    say "a and b don't smartmatch each other at all";
}
```

When you run this, you get:

```
a and b are deep copies of each other
```

If you were to set `$b[3] = 4`, then it would instead report that "`b smartmatches in a`", because the corresponding position in `@a` contains an array that (eventually) has a 4 in it.

Smartmatching one hash against another reports whether both contain the same keys, no more and no less. This could be used to see whether two records have the same field names, without caring what values those fields might have. For example:

```
use v5.10;
sub make_dogtag {
    state $REQUIRED_FIELDS = { name=>1, rank=>1, serial_num=>1 };

    my ($class, $init_fields) = @_;

    die "Must supply (only) name, rank, and serial number"
        unless $init_fields ~~ $REQUIRED_FIELDS;

    ...
}
```

Or, if other fields are allowed but not required, use *ARRAY* `~~` *HASH*:

```
use v5.10;
sub make_dogtag {
    state $REQUIRED_FIELDS = { name=>1, rank=>1, serial_num=>1 };

    my ($class, $init_fields) = @_;

    die "Must supply (at least) name, rank, and serial number"
        unless [keys %{$init_fields}] ~~ $REQUIRED_FIELDS;

    ...
}
```

The smartmatch operator is most often used as the implicit operator of a `when` clause. See the section "The given Statement" on page 133 in Chapter 4.

Smartmatching of Objects

To avoid relying on an object's underlying representation, if the smartmatch's right operand is an object that doesn't overload `~~`, it raises the exception, "`Smart matching a non-overloaded object breaks encapsulation`". That's because one has no business digging around to see whether something is "in" an object. These are all illegal on objects without a `~~` overload:

```
 %hash ~~ $object
    42 ~~ $object
"fred" ~~ $object
```

However, you can change the way an object is smartmatched by overloading the `~~` operator. This is allowed to extend the usual smartmatch semantics. For objects that do have an `~~` overload, see Chapter 13.

Using an object as the left operand is allowed, although it's not very useful. Smartmatching rules take precedence over overloading, so even if the object in the left operand has smartmatch overloading, this will be ignored. A left operand that is a nonoverloaded object falls back on a string or numeric comparison of whatever the `ref` operator returns. Meaning:

```
$object ~~ X
```

does *not* invoke the overload method with *X* as an argument. Instead, the above table is consulted as normal, and based on the type of *X*, overloading may or may not be invoked. For simple strings or numbers, in becomes equivalent to this:

```
$object ~~ $number          ref($object) == $number
$object ~~ $string          ref($object) eq $string
```

For example, this reports that the handle smells IOish:

```
use IO::Handle;
my $fh = IO::Handle->new();
if ($fh ~~ /\bIO\b/) {
    say "handle smells IOish";
}
```

That's because it treats `$fh` as a string like `"IO::Handle=GLOB(0x8039e0)"`, then pattern matches against that.[8]

8. But please don't do this. In the future this is likely to change to be closer to Perl 6 semantics, where the type of the right argument determines which overloading (string or number) the object on the left is supposed to behave like. So please just avoid putting objects on the left for now.

Bitwise Operators

Like C, Perl has bitwise AND, OR, XOR (exclusive OR), and NOT operators: `&`, `|`, `^`, and the previously described `~`. You'll have noticed from your painstaking examination of the table at the start of this chapter that bitwise AND has a higher precedence than the others, but we've cheated and combined them in this discussion.

These operators work differently on numeric values than they do on strings. (This is one of the few places where Perl cares about the difference.) If either operand is a number (or has been used as a number), both operands are converted to integers, and the bitwise operation is performed between the two integers. These integers are guaranteed to be at least 32 bits long, but they can be 64 bits on some machines. The point is that there's an arbitrary limit imposed by the machine's architecture. You can get around this restriction with the `bigint` pragma.

If both operands are strings (and have not been used as numbers since they were set), the operators do bitwise operations between corresponding bits from the two strings. In this case, there's no arbitrary limit, since strings aren't arbitrarily limited in size. If one string is longer than the other, the shorter string is considered to have a sufficient number of 0 bits on the end to make up the difference. Bits in each corresponding logical character in the two strings are AND'd, OR'd, or XOR'd together.

For example, if you AND together two strings:

```
"123.45" & "234.56"
```

you get another string:

```
"020.44"
```

But if you AND together a string and a number:

```
"123.45" & 234.56
```

the string is first converted to a number, giving:

```
123.45 & 234.56
```

The numbers are then converted to integers:

```
123 & 234
```

which evaluates to 106. Note that all bit strings are true (unless they result in the string "`0`"). This means if you want to see whether any byte came out to nonzero, instead of writing this:

```
if ( "fred" & "\x01\x02\x03\x04" ) { ... }
```

you need to write this:

```
if ( ("fred" & "\x01\x02\x03\x04") =~ /[^\0]/ ) { ... }
```

C-Style Logical (Short-Circuit) Operators

Like C, Perl provides the `&&` (logical AND) and `||` (logical OR) operators. Perl also provides a variant of `||`, the logical defined OR operator, `//`. These evaluate from left to right (with `&&` having slightly higher precedence than `||` or `//`), testing the truth of the statement. These operators, shown in Table 3-8, are known as short-circuit operators because they determine the truth of the statement by evaluating the fewest number of operands possible. For example, if the left operand of an `&&` operator is false, the right operand is never evaluated because the result of the operator is false regardless of the value of the right operand.

Table 3-8. Logical operators

Example	Name	Result
`$a && $b`	AND	`$a` if `$a` is false, `$b` otherwise
`$a || $b`	OR	`$a` if `$a` is true, `$b` otherwise
`$a // $b`	Defined OR	`$a` if `$a` is defined, `$b` otherwise
`$a and $b`	Low precedence AND	`$a` if `$a` is false, `$b` otherwise
`$a or $b`	Low precedence OR	`$a` if `$a` is true, `$b` otherwise
`$a xor $b`	Low precedence XOR	True is exactly one of `$a` or `$b` is true, false otherwise

Such short circuits not only save time but are also frequently used to control the flow of evaluation. For example, an oft-appearing idiom in Perl programs is:

```
open(FILE, "<", "somefile") || die "Can't open somefile: $!\n";
```

In this case, Perl first evaluates the `open` function. If the value is true (because *somefile* was successfully opened), the execution of the `die` function is unnecessary, and so it is skipped. You can read this literally as "Open some file or die!"

The `//` operator is useful for functions that indicate failure by returning `undef`. For example:

```
my $pid = fork() // die "Can't fork: $!";
if ($pid) {
    # parent code here
    ...
    wait $pid;
} else {
    # child code here
    ...
```

```
    exit;
}
```

It is also useful for detecting missing values from hashes. This returns the default if the key is not in the hash or the key has an undefined value:

```
$value = $hash{$key} // "DEFAULT";
```

The `&&` and `||` operators differ from C's in that, rather than returning 0 or 1, they return the last value evaluated. In the case of `||`, this has the delightful result that you can select the first of a series of scalar values that happens to be true. Thus, a reasonably portable way to find out the user's home directory might be:

```
my $home = $ENV{HOME}
        || $ENV{LOGDIR}
        || (getpwuid($<))[7]
        || die "You're homeless!\n";
```

On the other hand, since the left argument is always evaluated in scalar context, you can't use `||` for selecting between two aggregates for assignment:

```
@a = @b || @c;            # This doesn't do the right thing
@a = scalar(@b) || @c;    # because it really means this.
@a = @b ? @b : @c;        # This works fine, though.
```

Perl also provides lower precedence `and` and `or` operators that don't require parentheses on list operators. Some people find this more readable, although others find it less readable. These spelled-out operators also short circuit. See Table 3-8 for a complete list.

Range Operators

The `..` range operator is really two different operators depending on the context.

In scalar context, `..` returns a Boolean value. The operator is bi-stable, like an electronic flip-flop, and emulates the line-range (comma) operator of *sed*, *awk*, and various editors. Each scalar `..` operator maintains its own Boolean state. It is false as long as its left operand is false. Once the left operand is true, the range operator stays true until the right operand is true, *after* which the range operator becomes false again. The operator doesn't become false until the next time it is evaluated. It can test the right operand and become false on the same evaluation as the one where it became true (the way *awk*'s range operator behaves), but it still returns true once. If you don't want it to test the right operand until the next evaluation (which is how *sed*'s range operator works), just use three dots (`...`)

instead of two.[9] With both `..` and `...`, the right operand is not evaluated while the operator is in the false state, and the left operand is not evaluated while the operator is in the true state.

The value returned is either the null string for false or a sequence number (beginning with `1`) for true. The sequence number is reset for each range encountered. The final sequence number in a range has the string "`E0`" appended to it, which doesn't affect its numeric value, but gives you something to search for if you want to exclude the endpoint. You can exclude the beginning point by waiting for the sequence number to be greater than 1. If either operand of scalar `..` is a numeric literal, that operand is implicitly compared to the `$.` variable, which contains the current line number for your input file.[10]

Examples:

```
if (101 .. 200) { print }   # print 2nd hundred lines
next line if 1 .. /^$/;     # skip header lines of a message
s/^/> / if /^$/ .. eof;     # quote body of a message
```

In list context, `..` returns a list of values counting (by ones) from the left value to the right value. This is useful for writing `for (1..10)` loops and for doing slice operations on arrays:

```
for (101 .. 200) { print }  # prints 101102...199200

my @foo = getlist();
@foo = @foo[0 .. $#foo];    # an expensive no-op
@foo = @foo[ -5 .. -1 ];    # slice last 5 items
```

In the current implementation, no temporary array is created when the range operator is used as the expression in `foreach` loops, but older versions of Perl might burn a lot of memory when you write something like this:

```
for (1 .. 1_000_000) {
    # code
}
```

If the left value is greater than the right value, a null list is returned. (To produce a list in reverse order, see the `reverse` operator.)

If its operands are strings, the range operator makes use of the magical autoincrement algorithm discussed earlier. So you can say:

```
my @alphabet = ("A" .. "Z");
```

9. Do not confuse the `...` range operator with the `...` elliptical statement, which raises an "`Unimplemented`" exception when executed.

10. Technically, it contains the number of times the `readline` operator has been called on the last handle it was called on since that handle was last closed.

to get all the letters of the (modern English) alphabet, or:

```
my $hexdigit = (0 .. 9, "a" .. "f")[$num & 15];
```

to get a hexadecimal digit, or:

```
my @z2 = ("01" .. "31");
print $z2[$mday];
```

to get dates with leading zeros. You can also say:

```
my @combos = ("aa" .. "zz");
```

to get all two-letter combinations of lowercase ASCII letters. However, be careful of something like:

```
my @bigcombos = ("aaaaaaa" .. "zzzzzzz");
```

since that will require lots of memory. More precisely, it'll need space to store 8,031,810,176 scalars. Let's hope you have a 64-bit machine. With a terabyte of memory. *Fast* memory. Perhaps you should consider an iterative approach instead.

If the final value specified is not in the sequence that the magical increment would produce, the sequence goes until the next value would be longer than the final value specified. For example, `"W" .. "M"` produces `"W"`, `"X"`, `"Y"`, and `"Z"`, but then stops because the next item in the sequence, `"AA"`, is longer than the target `"M"`.

If the initial value specified isn't part of a magical increment sequence (that is, a nonempty string matching `/^[a-zA-Z]*[0-9]*\z/`), only the initial value is returned. So the following will only return an alpha:

```
use charnames "greek";
my @greek_small =  ("\N{alpha}" .. "\N{omega}");
```

To get lowercase Greek letters, you might use this instead:

```
use charnames "greek";
my @greek_small =  map { chr } (
                      ord("\N{alpha}") ..  ord("\N{omega}")
                   );
```

However, that picks up an extra letter because there are two different lowercase sigmas between rho and tau, the extra one being `"\N{final sigma}"`. In general, assuming codepoint order corresponds to alphabetic order seldom works out. See "Comparing and Sorting Unicode Text" on page 297 in Chapter 6.

Conditional Operator

As in C, `?:` is the only trinary operator. It's often called the conditional operator because it works much like an if-then-else, except that, since it's an expression and not a statement, it can be safely embedded within other expressions and functions calls. As a trinary operator, its two parts separate three expressions:

```
COND ? THEN : ELSE
```

If the condition *`COND`* is true, only the *`THEN`* expression is evaluated, and the value of that expression becomes the value of the entire expression. Otherwise, only the *`ELSE`* expression is evaluated, and its value becomes the value of the entire expression.

Scalar or list context propagates downward into the second or third argument, whichever is selected. (The first argument is always in scalar context since it's a conditional.)

```
my $a = $ok ? $b : $c;  # get a scalar
my @a = $ok ? @b : @c;  # get an array
my $a = $ok ? @b : @c;  # get a count of an array's elements
```

You'll often see the conditional operator embedded in lists of values to format with `printf`, since nobody wants to replicate the whole statement just to switch between two related values:

```
printf "I have %d camel%s.\n",
               $n,     $n == 1 ? "" : "s";
```

Conveniently, the precedence of `?:` is higher than a comma but lower than most operators you'd use inside (such as `==` in this example), so you don't usually have to parenthesize anything. But you can add parentheses for clarity if you like. For conditional operators nested within the *`THEN`* parts of other conditional operators, we suggest that you put in line breaks and indent as if they were ordinary `if` statements:

```
$leapyear =
    $year % 4 == 0
        ? $year % 100 == 0
            ? $year % 400 == 0
                ? 1
                : 0
            : 1
        : 0;
```

For conditionals nested within the *`ELSE`* parts of earlier conditionals, you can do a similar thing:

```
$leapyear =
    $year % 4
```

```
    ? 0
    : $year % 100
      ? 1
      : $year % 400
        ? 0
        : 1;
```

but it's usually better to line up all the *COND* and *THEN* parts vertically:

```
$leapyear =
    $year %   4 ? 0 :
    $year % 100 ? 1 :
    $year % 400 ? 0 : 1;
```

Lining up the question marks and colons can make sense of even fairly cluttered structures:

```
printf "Yes, I like my %s book!\n",
    $i18n eq "french"   ? "chameau"          :
    $i18n eq "german"   ? "Kamel"            :
    $i18n eq "japanese" ? "\x{99F1}\x{99DD}" :
                          "camel"
```

With the `utf8` pragma, you don't even have to escape the Unicode characters:

```
use utf8;
printf "Yes, I like my %s book!\n",
    $i18n eq "french"   ? "chameau" :
    $i18n eq "german"   ? "Kamel"   :
    $i18n eq "japanese" ? "駱駝"    :
                          "camel"
```

You can assign to the conditional operator[11] if both the second and third arguments are legal lvalues (meaning that you can assign to them), and both are scalars or both are lists (otherwise, Perl won't know which context to supply to the right side of the assignment):

```
($a_or_b ? $a : $b) = $c;  # sets either $a or $b to have the value of $c
```

Bear in mind that the conditional operator binds more tightly than the various assignment operators. Usually this is what you want (see the `$leapyear` assignments above, for example), but you can't have it the other way without using parentheses. Using embedded assignments without parentheses will get you into trouble, and you might not get a parse error because the conditional operator can be parsed as an lvalue. For example, you might write this:

```
$a % 2 ? $a += 10 : $a += 2        # WRONG
```

But that would be parsed like this:

11. This is not necessarily guaranteed to contribute to the readability of your program. But it can be used to create some cool entries in an Obfuscated Perl contest.

```
((($a % 2) ? ($a += 10) : $a) += 2
```

Assignment Operators

Perl recognizes the C assignment operators, as well as providing some of its own. There are quite a few of them:

```
=    **=    +=    *=    &=    <<=    &&=
            -=    /=    |=    >>=    ||=
            .=    %=    ^=           //=
                  x=
```

Each operator requires a target lvalue (typically a variable or array element) on the left side and an expression on the right side. For the simple assignment operator:

```
TARGET = EXPR
```

the value of the *EXPR* is stored into the variable or location designated by *TARGET*. For the other operators, Perl evaluates the expression:

```
TARGET OP= EXPR
```

as if it were written:

```
TARGET = TARGET OP EXPR
```

That's a handy mental rule, but it's misleading in two ways. First, assignment operators always parse at the precedence level of ordinary assignment, regardless of the precedence that *OP* would have by itself. Second, *TARGET* is evaluated only once. Usually that doesn't matter unless there are side effects, such as an autoincrement:

```
$var[$a++] += $value;              # $a is incremented once
$var[$a++] = $var[$a++] + $value;  # $a is incremented twice
```

Unlike in C, the assignment operator produces a valid lvalue. Modifying an assignment is equivalent to doing the assignment and then modifying the variable to which it was assigned. This is useful for modifying a copy of something, like this:

```
($tmp = $global) += $constant;
```

which is the equivalent of:

```
$tmp = $global + $constant;
```

Likewise:

```
($a += 2) *= 3;
```

is equivalent to:

```
$a += 2;
$a *= 3;
```

That's not terribly useful, but here's an idiom you see frequently:

```
(my $new = $old) =~ s/foo/bar/g;
```

That can also be written like this in v5.14 or later, using the `/r` modifier to return a copy of the changed version instead of acting on the variable that `=~` binds to:

```
my $new = ($old =~ s/foo/bar/gr);
my $new =  $old =~ s/foo/bar/gr;
```

In all cases, the value of the assignment is the new value of the variable. Since assignment operators associate right to left, this can be used to assign many variables the same value, as in:

```
$a = $b = $c = 0;
```

which assigns `0` to `$c`, and the result of that (still `0`) to `$b`, and the result of that (*still* `0`) to `$a`.

List assignment may be done only with the plain assignment operator, `=`. In list context, list assignment returns the list of new values just as scalar assignment does. In scalar context, list assignment returns the number of values that were available on the right side of the assignment, as mentioned in Chapter 2. This makes it useful for testing functions that return a null list when unsuccessful (or no longer successful), as in:

```
while (my ($key, $value) = each %gloss) { ... }

next unless my ($dev, $ino, $mode) = stat $file;
```

Comma Operators

Binary "`,`" is the comma operator. In scalar context it evaluates its left argument in void context, throws that value away, then evaluates its right argument in scalar context and returns that value. This is just like C's comma operator. For example:

```
$a = (1, 3);
```

assigns `3` to `$a`. Do not confuse the scalar context use with the list context use. In list context, a comma is just the list argument separator, and it inserts both its arguments into the *`LIST`*. It does not throw any values away.

For example, if you change the previous example to:

```
@a = (1, 3);
```

you are constructing a two-element list, while:

```
atan2(1, 3);
```

is calling the function `atan2` with two arguments.

The `=>` digraph is mostly just a synonym for the comma operator. It's useful for documenting arguments that come in pairs. It also forces any identifier to its immediate left to be interpreted as a string. This autoquoting works only on identifiers, not on numeric literals.

List Operators (Rightward)

The right side of a list operator governs all the list operator's arguments, which are comma separated, so the precedence of a list operator is lower than a comma if you're looking to the right. Once a list operator starts chewing up comma-separated arguments, the only things that will stop it are tokens that stop the entire expression (like semicolons or statement modifiers), or tokens that stop the current subexpression (like right parentheses or brackets), or the low precedence logical operators we'll talk about next.

Logical and, or, not, and xor

As lower precedence alternatives to `&&`, `||`, and `!`, Perl provides the `and`, `or`, and `not` operators. The behavior of these operators is identical—in particular, `and` and `or` short circuit like their counterparts, which makes them useful not only for logical expressions but also for control flow.

Since the precedence of these operators is much lower than the ones borrowed from C, you can safely use them after a list operator without the need for parentheses:

```
unlink "alpha", "beta", "gamma"
        or gripe(), next LINE;
```

With the C-style operators you'd have to write it like this:

```
unlink("alpha", "beta", "gamma")
        || (gripe(), next LINE);
```

But you can't just up and replace all instances of `||` with `or`. Suppose you change this:

```
$xyz = $x || $y || $z;
```

to this:

```
$xyz = $x or $y or $z;    # WRONG
```

That wouldn't do the same thing at all! The precedence of the assignment is higher than `or` but lower than `||`, so it would always assign `$x` to `$xyz` and then do the `or`s. To get the same effect as `||`, you'd have to write:

```
$xyz = ( $x or $y or $z );
```

The moral of the story is that you still must learn precedence no matter which variety of logical operators you use. We suggest you use parentheses for any such construct that might confuse the reader, even if you're not confused.[12]

There is also a logical `xor` operator that has no exact counterpart in C or Perl, since the only other exclusive OR operator (`^`) works on bits. The `xor` operator can't short circuit since both sides must be evaluated. The best equivalent for `$a xor $b` is perhaps `!$a != !$b`. One could also write `!$a ^ !$b` or even `$a ? !$b : !!$b`, of course. The point is that both `$a` and `$b` have to evaluate to true or false in a Boolean context, and the existing bitwise operator doesn't provide a Boolean context without help.

C Operators Missing from Perl

Here is what C has that Perl doesn't:

unary `&`
: The address-of operator. Perl's `\` operator (for taking a reference) fills the same ecological niche, however:

```
$ref_to_var = \$var;
```

  But Perl references are much safer than C pointers.

unary `*`
: The dereference-address operator. Since Perl doesn't have addresses, it doesn't need to dereference addresses. It does have references, though, so Perl's variable prefix characters serve as dereference operators and indicate type as well: `$`, `@`, `%`, and `&`. Oddly enough, there actually is a `*` dereference operator, but since `*` is the sigil indicating a typeglob, you wouldn't use it the same way.

`(`*TYPE*`)`
: The typecasting operator. Nobody likes to be typecast anyway.

12. Unless, of course, your intent is to *force* the reader to learn precedence, a position for which we have some sympathy.

CHAPTER 4

Statements and Declarations

A Perl program consists of a sequence of declarations and statements. A declaration may be placed anywhere a statement may be placed, but its primary effect occurs at compile time. A few declarations do double duty as ordinary statements, but most are totally transparent at runtime. After compilation, the main sequence of statements is executed just once.

In this chapter we cover statements before declarations, but we'd just like to mention a few of the more important declarations up front.

Unlike many programming languages, Perl does not (by default) require variables to be explicitly declared; they spring into existence upon their first use, whether you've declared them or not. However, if you prefer, you may declare your variables using a *declarator* such as `my`, `our`, or `state` in front of the variable name wherever it's first mentioned, and then the compiler can be pretty sure that your variable name isn't a typo when you mention it again later.

If you try to use a value from a variable that's never had a value assigned to it, it's quietly treated as `0` when used as a number, as `""` (the null string) when used as a string, or simply as false when used as a logical value. If you prefer to be warned about using undefined values as though they were real strings or numbers, the `use warnings` declaration will take care of that.

Similarly, you can use the `use strict` declaration to require yourself to declare all your variables in advance. If you use this, any unrecognized variable name will be treated as a syntax error. (Saying `use v5.12` or greater implicitly sets `strict`, but we recommend `use v5.14` so that the examples in this book compile and work.) For more on these declarations, see the section "Pragmas" on page 164 at the end of this chapter.

Simple Statements

A simple statement is an expression evaluated for its side effects. Every simple statement must end in a semicolon, unless it is the final statement in a block. In that case, the semicolon is optional—Perl knows that you must be done with the statement since you've finished the block. But put the semicolon in anyway if it's at the end of a multiline block, because you might eventually add another line.

Even though operators like `eval {}`, `do {}`, and `sub {}` all look like compound statements, they really aren't. True, they allow multiple statements on the inside, but that doesn't count. From the outside, those operators are just terms in an expression, and thus they need an explicit semicolon if used as the last item in a statement.

Any simple statement may optionally be followed by a single modifier, just before the terminating semicolon (or block ending). The possible modifiers are:

```
if EXPR
unless EXPR
while EXPR
until EXPR
for LIST
when EXPR
```

The `if` and `unless` modifiers work pretty much as they do in English:

```
$trash->take("out") if $you_love_me;
shutup() unless $you_want_me_to_leave;
```

The `while` and `until` modifiers evaluate repeatedly. As you might expect, a `while` modifier keeps executing the expression as long as its expression remains true, and an `until` modifier keeps executing only as long as it remains false:

```
$expression++ while -e "$file$expression";
kiss("me") until $I_die;
```

The `for` modifier (also spelled `foreach` if you're trying to wear out your keyboard) evaluates once for each element in its *`LIST`*, with `$_` aliased to the current element:

```
s/java/perl/ for @resumes;
say "field: $_" foreach split /:/, $dataline;
```

The `while` and `until` modifiers have the usual while-loop semantics (conditional evaluated first), except when applied to a `do` *`BLOCK`* (see Chapter 27), in which case the block executes once before the conditional is evaluated. This allows you to write loops, like this:

```
do {
    $line = <STDIN>;
    ...
} until $line eq ".\n";
```

Note that the loop-control operators described later will not work in this construct, since modifiers don't take loop labels. You can always place an extra block around it to terminate early, or inside it to iterate early, as described later in the section "Bare Blocks as Loops" on page 147. Or you could write a real loop (see next section) with multiple loop controls inside.

The `when` modifier is an experimental feature available if you say `use v5.14` (or greater). Its pattern-matching semantics are equivalent to those of the `when` statement, so see "The when Statement and Modifier" on page 137 later in this chapter.

Compound Statements

A sequence of statements within a scope[1] is called a *block*. Sometimes the scope is the entire file, such as a `require`d file or the file containing your main program. Sometimes the scope is a string being evaluated with `eval`. But, generally, a block is surrounded by braces (`{}`). When we say scope, we mean any of these three. When we mean a block with braces, we'll use the term *`BLOCK`*.

Compound statements are built out of expressions and *`BLOCK`*s. Expressions are built out of terms and operators. In our syntax descriptions, we'll use the word *`EXPR`* to indicate a place where you can use any scalar expression. To indicate an expression evaluated in list context, we'll say *`LIST`*.

The following statements may be used to control conditional and repeated execution of *`BLOCK`*s. (The *`LABEL`* portion is optional.)

```
if (EXPR) BLOCK
if (EXPR) BLOCK else BLOCK
if (EXPR) BLOCK elsif (EXPR) BLOCK ...
if (EXPR) BLOCK elsif (EXPR) BLOCK ... else BLOCK

unless (EXPR) BLOCK
unless (EXPR) BLOCK else BLOCK
unless (EXPR) BLOCK elsif (EXPR) BLOCK ...
unless (EXPR) BLOCK elsif (EXPR) BLOCK ... else BLOCK

given (EXPR) BLOCK
```

1. Scopes and namespaces are described in the section "Names" on page 60 in Chapter 2.

```
LABEL while (EXPR) BLOCK
LABEL while (EXPR) BLOCK continue BLOCK

LABEL until (EXPR) BLOCK
LABEL until (EXPR) BLOCK continue BLOCK

LABEL for (EXPR; EXPR; EXPR) BLOCK

LABEL foreach (LIST) BLOCK
LABEL foreach (LIST) BLOCK continue BLOCK
LABEL foreach VAR (LIST) BLOCK
LABEL foreach VAR (LIST) BLOCK continue BLOCK

LABEL BLOCK
LABEL BLOCK continue BLOCK
```

Note that unlike in C and Java, these are defined in terms of *BLOCK*s, not statements. This means that the braces are required—no dangling statements allowed. If you want to write conditionals without braces, there are several ways to do so. The following all do the same thing:

```
unless (open(FOO, '<', $foo)) { die "Can't open $foo: $!" }
if (!open(FOO, '<', $foo))    { die "Can't open $foo: $!" }

die "Can't open $foo: $!"     unless open(FOO, '<', $foo);
die "Can't open $foo: $!"     if !open(FOO, '<', $foo);

open(FOO, '<', $foo)          || die "Can't open $foo: $!";
open(FOO, '<', $foo)          or die "Can't open $foo: $!";
```

Under most circumstances, we tend to prefer the last pair. These forms come with less eye-clutter than the others, especially the "`or die`" version. With the `||` form, you need to get used to using parentheses religiously, but with the `or` version, it doesn't usually matter so much if you forget.

But the main reason we like the last versions better is because of how they pull the important part of the statement right up to the front of the line where you'll see it first. The error handling is shoved off to the side so that you don't have to pay attention to it unless you want to.[2] If you tab all your "`or die`" checks over to the same column on the right each time, it's even easier to read:

```
chdir($dir)                or die "chdir $dir: $!";
open(FOO, '<', $file)      or die "open $file: $!";
@lines = <FOO>             or die "$file is empty?";
close(FOO)                 or die "close $file: $!";
```

2. (Like this footnote.)

if and unless Statements

The `if` statement is straightforward. Because *`BLOCK`*s are always bounded by braces, there is never any ambiguity regarding which particular `if` an `else` or `elsif` goes with. In any given sequence of `if`/`elsif`/`else` *`BLOCK`*s, only the first one whose condition evaluates to true is executed. If none of them is true, then the `else` *`BLOCK`*, if there is one, is executed. It's usually a good idea to put an `else` at the end of a chain of `elsif`s to guard against a missed case.

If you use `unless` in place of `if`, the sense of its test is reversed. That is:

```
unless ($x == 1) ...
```

is equivalent to:

```
if ($x != 1) ...
```

or even to the unsightly:

```
if (!($x == 1)) ...
```

The scope of a variable declared in the controlling condition extends from its declaration through the rest of that conditional only, including any `elsif`s and the final `else` clause if present, but not beyond:

```
if ((my $color = <STDIN>) =~ /red/i) {
    $value = 0xFF0000;
}
elsif ($color =~ /green/i) {
    $value = 0x00FF00;
}
elsif ($color =~ /blue/i) {
    $value = 0x0000FF;
}
else {
    warn "unknown RGB component '$color', using black instead\n";
    $value = 0x000000;
}
```

After the `else`, the `$color` variable is no longer in scope. If you want the scope to extend further, declare the variable beforehand.

The given Statement

In the previous example, we kept talking about `$color`. Linguists call this a *topic*. In v5.10 or later, an alternative to the `if` structure is available, the `given` statement, which functions linguistically as a `topicalizer`. It works by setting `$_` to the current topic. You can then use `when` statements to examine the topic for various values or patterns.

This feature is enabled when you `use` a version of Perl that is at least v5.10:

```
use v5.12;              # at least v5.12, load default features
```

or when you specifically request the "`switch`" feature:

```
use feature "switch";   # just get the switch feature
```

Either of those adds several new keywords to the Perl language: `given`, `when`, `break`, `continue`, and `default`. Here is one way to recode the previous example using the new feature:

```
use v5.10;

my $value;
given (<STDIN>) {
    when (/red/i)    { $value = 0xFF0000 }
    when (/green/i)  { $value = 0x00FF00 }
    when (/blue/i)   { $value = 0x0000FF; }
    default {
        warn "unknown RGB component '$_', using black instead\n";
        $value = 0x000000;
    }
}
```

In fact, in v5.10 you *had* to write it that way since `given` couldn't return values. In v5.14 or later, you can return values, and with the statement modifier form of `when`, you may even write it this way:

```
use v5.14;

my $value = do {
    given (<STDIN>) {
        0xFF0000 when /red/i;
        0x00FF00 when /green/i;
        0x0000FF when /blue/i;
        warn "unknown RGB component '$_', using black instead\n";
        0x000000;
    }
};
```

The arguments to `given` and `when` are in scalar context; `given` binds its argument to the `$_` variable to set the topic of its *`BLOCK`*. The `when` uses its argument to pick what kind of pattern match you want done by looking at the type of the argument. The semantics of `when` are a superset of smartmatching. If the argument appears to be a Boolean expression, it is evaluated directly. If not, it is passed off to the smartmatch operator to be interpreted as `$_ ~~` *`EXPR`*. This may seem complicated, but it really isn't because the vast majority of switches are going to be of the form:

```
use v5.14;

my $n = somefunc();

given ($n) {
   when (0)       { say "zero"         }
   when (1)       { say "one"          }
   when ([3..7])  { say "many"         }
   when (/^\d+$/) { say "lots"         }
   default        { say "unwholesome"  }
}
```

In other words, the `when` args will usually be something that invokes smartmatching (or that you can pretend is invoking smartmatching).

Here is a longer example of `given`:

```
use feature ":5.10";

given ($n) {

# match if !defined($n)
    when (undef) {
        say '$n is undefined';
    }

# match if $n eq "foo"
    when ("foo") {
        say '$n is the string "foo"';
    }

# match if $n ~~ [1,3,5,7,9]
    when ([1,3,5,7,9]) {
        say '$n is an odd digit';
        continue; # Fall through!!
    }

# match if $n < 100
    when ($_ < 100) {
        say '$n is numerically less than 100';
    }

# match if complicated_check($n)
    when (\&complicated_check) {
        say 'a complicated check for $n is true';
    }

# match if no other cases match
    default {
        die q(I don't know what to do with $n);
    }
}
```

`given(`*`EXPR`*`)` assign the value of *`EXPR`* to a lexically scoped copy of `$_`, not a dynamically scoped alias the way a `foreach` without `my` does. That makes it similar to a `do` block:

```
do { my $_ = EXPR; ... }
```

except that a successful `when` (or any explicit `break`) knows how to break out of the block. Since it's lexically scoped, you can't use `given` to localize a dynamic value of `$_` as you could with an old-style `foreach`.[3]

You can use the `break` keyword to break out of the enclosing `given` block. Every `when` block is implicitly ended with a `break`.

You can use the `continue` keyword to fall through from one case to the start of the next statement, which might or might not be another `when`:

```
given($foo) {
    when (/x/) { say '$foo contains an x'; continue }
    say "I always get here.";
    when (/y/) { say '$foo contains a y'            }
    default    { say '$foo does not contain a y'    }
}
```

When a `given` statement is also a valid expression (for example, when it's the last statement of a block), it evaluates to:

- An empty list as soon as an explicit `break` is encountered.
- The value of the last evaluated expression of the successful `when`/`default` clause, if there happens to be one.
- The value of the last evaluated expression of the `given` block if no condition is true.

The last expression is evaluated in the context that was applied to the `given` block.

Note that, unlike `if` and `unless`, a failed `when` statement always evaluates to an empty list.

```
my $price = do {
    given ($item) {
        when (["pear", "apple"]) { 1 }
        break when "vote";      # My vote cannot be bought
        1e10  when /Mona Lisa/;
        "unknown";
    }
};
```

3. This omission is to be construed as a feature, since dynamically scoped `$_` is terribly error-prone as soon as you have two different pieces of code fighting over the current topic.

Note that we must use the `do` block there because `given` is recognized only as a statement, and it would be illegal after an assignment. (We might make the `do` brackets optional in some future version.)

The when Statement and Modifier

Most of the power of a `given` comes from the implicit smartmatching that various data types imply. By default, `when(`*`EXPR`*`)` is treated as an implicit smartmatch of `$_`; that is, `$_ ~~` *`EXPR`*. (See Chapter 3 for more details on smartmatching.) However, if the *`EXPR`* argument to `when` is one of the 10 exceptional forms listed below, it is evaluated directly for a Boolean result, and no smartmatching occurs:

1. A user-defined subroutine call or a method invocation.
2. A regular expression match in the form of `/`*`REGEX`*`/`, `$foo =~ /`*`REGEX`*`/`, or `$foo =~` *`EXPR`*.
3. A smartmatch that uses an explicit `~~` operator, such as *`EXPR`* `~~` *`EXPR`*. (You might, for instance, want to use an explicit smartmatch against `$_` when you need to reverse the default polymorphism of `when`'s built-in smartmatching.)
4. A relational operator such as `$_ < 10` or `$x eq "abc"` that returns a Boolean result. This includes the six numeric comparisons (`<`, `>`, `<=`, `>=`, `==`, and `!=`), and the six string comparisons (`lt`, `gt`, `le`, `ge`, `eq`, and `ne`).
5. The three built-in functions `defined`, `exists`, and `eof`.
6. A negated expression, whether `!`*`EXPR`* or `not(`*`EXPR`*`)`, or a logical exclusive OR, *`EXPR1`* `xor` *`EXPR2`*. (The bitwise versions [`~` and `^`] are not included.) Negated regular expressions also fall in this category, whichever way you write them: `!/`*`REGEX`*`/`, `$foo !~ /`*`REGEX`*`/`, or `$foo !~` *`EXPR`*.
7. A file test operator (apart from `-s`, `-M`, `-A`, and `-C`, as these return numbers, not Booleans).
8. The `..` and `...` flip-flop operators. (Note that the `...` infix operator is completely different from the `...` elliptical statement, which is recognized only where a statement is expected.)

In these first eight cases, the value of *`EXPR`* is used directly as a Boolean, so no smartmatching is done. You may think of `when` as a *smart*smartmatch.[4] To make it even smarts*marter*, Perl applies these tests recursively to the operands of logical operators (that is, "and" and "or") to decide whether to use smartmatching, as follows:

4. It may also be useful to think of Booleans as part of smartmatching because, in Perl 6, they actually are, and you might have to switch mindsets from time to time.

1. For *EXPR1*`&&`*EXPR2* or *EXPR1* `and` *EXPR2*, the test is applied *recursively* to both *EXPR1* and *EXPR2*. Only if *both* operands also pass the test will the expression be treated as Boolean. Otherwise, smartmatching is used.
2. For *EXPR1*`||`*EXPR2* or *EXPR1* `or` *EXPR2*, the test is applied *recursively* to *EXPR1* only (which might itself be a higher-precedence AND operator, for example, and thus subject to the previous rule), not to *EXPR2*. If *EXPR1* is to use smartmatching, then *EXPR2* also does so, no matter what *EXPR2* contains. But if *EXPR2* does not get to use smartmatching, then the second argument will not get to either. This is quite different from the `&&` case just described, so be careful. (Note that *EXPR1*`//`*EXPR2* is always considered Boolean because of the implied `defined` function on the left of the `//` operator.)

All those rules make things appear more complicated than they really are. They're there because Perl 5 has no built-in Boolean type.[5] The goal is for them to do what you mean. For example:

```
when (/^\d+$/ && $_ < 75) { ... }
```

will be treated as a Boolean match because the rules recognize both sides of the conjunction as Boolean matches.

Also:

```
when ([qw(foo bar)] && /baz/) { ... }
```

will use smartmatching because only the second operand looks like a Boolean. The first does not, so smartmatching wins here—or maybe everyone loses, unless you were expecting to smartmatch with the *result* of the right side, which is going to be `1` or `""`. Your `given` probably did not supply one of those.

Remember that order is important to disjunctions. If you say:

```
when ([qw(foo bar)] || /^baz/) { ... }
```

it will use smartmatching based on the first operand. However:

```
when (/^baz/ || [qw(foo bar)]) { ... }
```

has the (Boolean) regex first, which forces both operands to be treated as Boolean —and, again, everyone loses because the second argument (an array ref) is always true, so it doesn't do what you expect.

Boolean operators based on constants are still going to be optimized away. Don't be tempted to write:

```
when ("foo" or "bar") { ... }
```

5. At least, not yet. Future versions of Perl may add a Boolean type, in which case these complex rules will fall naturally out of smartmatching.

This will optimize down to "foo", so "bar" will never be considered (even though the rules say to use a smartmatch on "foo"). For an alternation like this, an array ref will work, because this will instigate smartmatching, which has its own "match any of" semantics:

```
when (['foo', 'bar']) { ... }
```

This is how you write a case with multiple "labels", since there's no equivalent in Perl to C's fall-through semantics.

`default` behaves exactly like `when(1 == 1)`, which is to say, it always matches. Because cases are evaluated in order, it must come last; like `when`, it does an implicit `break`, so you will never reach any subsequent code.

As an aid to the semantics of smartmatching, if you use a literal array or hash as the argument to `given`, it is turned into a reference, so as not to lose any information. So `given(@foo)` is the same as `given(\@foo)`, for example. If you really want to match the length of `@foo`, you need to say `given(scalar @foo)` instead.

We still consider some of the darker corners of `given` and `when` to be experimental, but please be assured that in practice most of your switch statements are likely to be based on simple string or number matches, and these will always work the way you expect.

Loop Statements

All loop statements have an optional *LABEL* in their formal syntax. (You can put a label on any statement, but it has a special meaning to a loop.[6]) If present, the label consists of an identifier followed by a colon. It's customary to make the label uppercase both to stand out visually and to avoid potential confusion with reserved words. (Perl won't get confused if you use a label that already has a meaning like `if` or `open`, but your readers might.)

while and until Statements

The `while` statement repeatedly executes the block as long as *EXPR* is true. If the word `while` is replaced by the word `until`, the sense of the test is reversed; that is, it executes the block only as long as *EXPR* remains false. The conditional is still tested before the first iteration, though.

6. Prior to v5.14, you couldn't put a label on a `package` statement.

The `while` or `until` statement can have an optional extra block: `continue`. This block is executed every time the block is continued, either by falling off the end of the first block or by an explicit `next` (a loop-control operator that goes to the next iteration). The `continue` block is not heavily used in practice, but it's in here so we can define the three-part loop rigorously in the next section.

Unlike the `foreach` loop we'll see in a moment, a `while` loop has no official "loop variable".[7] You may, however, declare variables explicitly. A variable declared in the test condition of a `while` or `until` statement is visible only in the block or blocks governed by that test. It is not part of the surrounding scope. For example:

```
while (my $line = <STDIN>) {
    $line = lc $line;
}
continue {
    print $line;   # still visible
}
# $line now out of scope here
```

Here, the scope of `$line` extends from its declaration in the control expression throughout the rest of the loop construct, including the `continue` block, but not beyond. If you want the scope to extend further, declare the variable before the loop.

Three-Part Loops

The three-part loop[8] has three semicolon-separated expressions within its parentheses. These three expressions are interpreted respectively as the initialization, the condition, and the reinitialization of the loop. The parentheses around them and the two semicolons between them are required, but the expressions themselves are optional. The initializer and reinitializer do nothing if omitted. The condition, if omitted, is considered to have a true value. (The values of the initializer and reinitializer don't matter since they are evaluated only for their side effects.)

The three-part loop can be defined in terms of the corresponding `while` loop, relocating its three expressions. When you say this:

7. A consequence of this is that a `while` never implicitly localizes any variables in its test condition. This can have "interesting" consequences when `while` loops are used in conjunction with operators that *do* implicitly know about global variables such as `$_`. In particular, see the section "Line Input (Angle) Operator" on page 88 in Chapter 2 for how implicit assignment to the global `$_` can occur in certain `while` loops, along with examples of how to deal with the problem.

8. Also known as `for` loops, but that's confusing since Perl has `for` loops that are not three-part loops, so we avoid that term.

```
LABEL:
  for (my $i = 1; $i<= 10; $i++) {
      ...
  }
```

it gets rearranged internally to work like this:

```
{
    my $i = 1;
  LABEL:
    while ($i<= 10) {
        ...
    }
    continue {
        $i++;
    }
}
```

(except that there's not really an outer block; we just put one there to show how the scope of the `my` is limited).

If you want to iterate through two variables simultaneously, just separate the parallel expressions with commas:

```
my $i;
my $bit;
for ($i = 0, $bit = 0; $i < 32; $i++, $bit <<= 1) {
    say "Bit $i is set" if $mask & $bit;
}
# the values in $i and $bit persist past the loop
```

Or to declare those variables to be visible only inside the loop:

```
for (my ($i, $bit) = (0, 1); $i< 32; $i++, $bit <<= 1) {
    say "Bit $i is set" if $mask & $bit;
}
# loop's versions of $i and $bit now out of scope
```

Besides the normal looping through array indices, the three-part loop can lend itself to many other interesting applications. It doesn't even need an explicit loop variable. Here's one example that avoids the problem you get when you explicitly test for end-of-file on an interactive file descriptor, causing your program to appear to hang:

```
$on_a_tty = -t STDIN && -t STDOUT;
sub prompt { print "yes? " if $on_a_tty }
for ( prompt(); <STDIN>; prompt() ) {
    # do something
}
```

Another traditional use of the three-part loop is the "infinite loop". Since all three expressions are optional, and the default condition is true, when you write:

```
for (;;) {
    ...
}
```

it is the same as writing:

```
while (1) {
    ...
}
```

If the notion of infinite loops bothers you, we should point out that you can always fall out of the loop at any point with an explicit loop-control operator such as `last`. Of course, if you're writing the code to control a nuclear cruise missile, you may not actually need an explicit loop exit. The loop will be terminated automatically at the appropriate moment.[9]

foreach Loops

This loop iterates over a list of values by setting the control variable (*VAR*) to each successive element of the list:

```
for my VAR (LIST) {
    ...
}
```

If "`my` *VAR*" is omitted, the global `$_` is used. You can omit the `my`, but only when `use strict` is turned off, so don't.

For historical reasons, the `foreach` keyword is a synonym for the `for` keyword, so you can use `for` and `foreach` interchangeably, whichever you think is more readable in a given situation. We tend to prefer `for` because we are lazy and because it *is* more readable, especially with the `my`. (Don't worry—Perl can easily distinguish `for (@ARGV)` from `for ($i=0; $i<$#ARGV; $i++)` because the latter contains semicolons.) Here are some examples:

```
$sum = 0;
for my $value (@array) { $sum += $value }

for my $count (10,9,8,7,6,5,4,3,2,1,"BOOM") {  # do a countdown
    say $count;
    sleep(1);
}

for (reverse "BOOM", 1 .. 10) {                # same thing
    say;
    sleep(1);
}
```

9. That is, the fallout from the loop tends to occur automatically.

```
for my $field (split /:/, $data) {            # any LIST expression
    say "Field contains: '$field'";
}

for my $key (sort keys %hash) {
    say "$key => $hash{$key}";
}
```

That last one is the canonical way to print out the values of a hash in sorted order. See the `keys` and `sort` entries in Chapter 27 for more elaborate examples.

There is no way to tell where you are in the list. You may compare adjacent elements by remembering the previous one in a variable, but sometimes you just have to break down and write a three-part loop with subscripts. That's why we have two different loops, after all.

If *`LIST`* consists of assignable values (meaning variables, generally, not enumerated constants), you can modify each of those variables by modifying *`VAR`* inside the loop. That's because the loop variable becomes an implicit alias for each item in the list that you're looping over. Not only can you modify a single array in place, you can also modify multiple arrays and hashes in a single list:

```
for my $pay (@salaries) {               # grant 8% raises
    $pay *= 1.08;
}

for (@christmas, @easter) {             # change menu
    s/ham/turkey/;
}
s/ham/turkey/ for @christmas, @easter;  # same thing

for ($scalar, @array, values %hash) {
    s/^\s+//;                           # strip leading  whitespace
    s/\s+$//;                           # strip trailing whitespace
}
```

The loop variable is valid only from within the dynamic or lexical scope of the loop and will be implicitly lexical if the variable was previously declared with `my`. This renders it invisible to any function defined outside the lexical scope of the variable, even if called from within that loop. However, if no lexical declaration is in scope, the loop variable will be a localized (dynamically scoped) global variable; this allows functions called from within the loop to access that variable. In either case, any previous value the localized variable had before the loop will be restored automatically upon loop exit.

If you prefer, you may explicitly declare which kind of variable (lexical or global) to use. This makes it easier for maintainers of your code to know what's really

going on; otherwise, they'll need to search back up through enclosing scopes for a previous declaration to figure out which kind of variable it is:

```
for my  $i    (1 .. 10) { ... }         # $i always lexical
for our $Tick (1 .. 10) { ... }         # $Tick always global
```

When a declaration accompanies the loop variable, the shorter `for` spelling is preferred over `foreach`, since it reads better in English.

Here's how a C or Java programmer might first think to code up a particular algorithm in Perl:

```
for ($i = 0; $i< @ary1; $i++) {
    for ($j = 0; $j< @ary2; $j++) {
        if ($ary1[$i] > $ary2[$j]) {
            last;         # Can't go to outer loop. :-(
        }
        $ary1[$i] += $ary2[$j];
    }
    # this is where that last takes me
}
```

But here's how a veteran Perl programmer might do it:

```
WID: for my $this (@ary1) {
    JET: for my $that (@ary2) {
        next WID if $this > $that;
        $this += $that;
    }
}
```

See how much easier that was in idiomatic Perl? It's cleaner, safer, and faster. It's cleaner because it's less noisy. It's safer because if code gets added between the inner and outer loops later on, the new code won't be accidentally executed, since `next` (explained below) explicitly iterates the outer loop rather than merely breaking out of the inner one. And it's faster than the equivalent three-part loop, since the elements are accessed directly instead of through subscripting.

But write it however you like. TMTOWTDI.

Like the `while` statement, the `foreach` statement can also take a `continue` block. This lets you execute a bit of code at the bottom of each loop iteration no matter whether you got there in the normal course of events or through a `next`.

Speaking of which, now we can finally say it: `next` is next.

Loop Control

We mentioned that you can put a *LABEL* on a loop to give it a name. The loop's *LABEL* identifies the loop for the loop-control operators `next`, `last`, and `redo`. The

LABEL names the loop as a whole, not just the top of the loop. Hence, a loop-control operator referring to the loop doesn't actually "go to" the loop label itself. As far as the computer is concerned, the label could just as easily have been placed at the end of the loop. But people like things labeled at the top, for some reason.

Loops are typically named for the item the loop is processing on each iteration. This interacts nicely with the loop-control operators, which are designed to read like English when used with an appropriate label and a statement modifier. The archetypal loop works on lines, so the archetypal loop label is `LINE:`, and the archetypal loop-control operator is something like this:

```
next LINE if /^#/;      # discard comments
```

The syntax for the loop-control operators is:

```
last LABEL
next LABEL
redo LABEL
```

The *LABEL* is optional; if omitted, the operator refers to the innermost enclosing loop. But if you want to jump past more than one level, you must use a *LABEL* to name the loop you want to affect. That *LABEL* does not have to be in your lexical scope, though it probably ought to be. But, in fact, the *LABEL* can be anywhere in your dynamic scope. If this forces you to jump out of an `eval` or subroutine, Perl issues a warning (upon request).

Just as you may have as many `return` operators in a function as you like, you may have as many loop-control operators in a loop as you like. This is not to be considered wicked or even uncool. During the early days of structured programming, some people insisted that loops and subroutines have only one entry and one exit. The one-entry notion is still a good idea, but the one-exit notion has led people to write a lot of unnatural code. Much of programming consists of traversing decision trees. A decision tree naturally starts with a single trunk but ends with many leaves. Write your code with the number of loop exits (and function returns) that is natural to the problem you're trying to solve. If you've declared your variables with reasonable scopes, everything gets automatically cleaned up at the appropriate moment, no matter how you leave the block.

The `last` operator immediately exits the loop in question. The `continue` block, if any, is not executed. The following example bombs out of the loop on the first blank line:

```
LINE: while (<STDIN>) {
    last LINE if /^$/;      # exit when done with mail header
    ...
}
```

The `next` operator skips the rest of the current iteration of the loop and starts the next one. If there is a `continue` clause on the loop, it is executed just before the condition is reevaluated, just like the third component of a three-part `for` loop. Thus, it can be used to increment a loop variable, even when a particular iteration of the loop has been interrupted by a `next`:

```
LINE: while (<STDIN>) {
    next LINE if /^#/;      # skip comments
    next LINE if /^$/;      # skip blank lines
    ...
} continue {
    $count++;
}
```

The `redo` operator restarts the loop block without evaluating the conditional again. The `continue` block, if any, is not executed. This operator is often used by programs that want to fib to themselves about what was just input. Suppose you were processing a file that sometimes had a backslash at the end of a line to continue the record on the next line. Here's how you could use `redo` for that:

```
while (<>) {
    chomp;
    if (s/\\$//) {
        $_ .= <>;
        redo unless eof;    # don't read past each file's eof
    }
    # now process $_
}
```

which is the customary Perl shorthand for the more explicitly (and tediously) written version:

```
LINE: while (defined($line = <ARGV>)) {
    chomp($line);
    if ($line =~ s/\\$//) {
        $line .= <ARGV>;
        redo LINE unless eof(ARGV);
    }
    # now process $line
}
```

Here's an example from a real program that uses all three loop-control operators. Although this particular strategy of parsing command-line arguments is less common now that we have the `Getopt::*` modules bundled with Perl,[10] it's still a nice illustration of the use of loop-control operators on named, nested loops:

10. See *Mastering Perl* for a comparison of the main command-line argument parsing modules.

```
ARG: while (@ARGV && $ARGV[0] =~ s/^-(?=.)//) {
    OPT: for (shift @ARGV) {
         m/^$/       && do {                              next ARG };
         m/^-$/      && do {                              last ARG };
         s/^d//      && do { $Debug_Level++;              redo OPT };
         s/^l//      && do { $Generate_Listing++;         redo OPT };
         s/^i(.*)//  && do { $In_Place = $1 || ".bak";    next ARG };
         say_usage("Unknown option: $_");
    }
}
```

One more point about loop-control operators. You may have noticed that we are not calling them "statements". That's because they aren't statements—although like any expression, they can be used as statements. You can almost think of them as unary operators that just happen to cause a change in control flow. So you can use them anywhere it makes sense to use them in an expression. In fact, you can even use them where it doesn't make sense. One sometimes sees this coding error:

```
open FILE, '<', $file
     or warn "Can't open $file: $!\n", next FILE;   # WRONG
```

The intent is fine, but the `next FILE` is being parsed as one of the arguments to `warn`, which is a list operator. So the `next` executes before the `warn` gets a chance to emit the warning. In this case, it's easily fixed by turning the `warn` list operator into the `warn` function call with some suitably situated parentheses:

```
open FILE, '<', $file
     or warn("Can't open $file: $!\n"), next FILE;   # okay
```

However, you might find it easier to read this:

```
unless (open FILE, '<', $file) {
     warn "Can't open $file: $!\n";
     next FILE;
}
```

Bare Blocks as Loops

A *`BLOCK`* by itself (labelled or not) is semantically equivalent to a loop that executes once. Thus, you can use `last` to leave the block or `redo` to restart the block.[11] Note that this is not true of the blocks in `eval {}`, `sub {}`, or, much to everyone's surprise, `do {}`. These three are not loop blocks because they're not *`BLOCK`*s by themselves; the keyword in front makes them mere terms in an expression that just happen to include a code block. Since they're not loop blocks, they cannot be

11. For reasons that may (or may not) become clear upon reflection, a `next` also exits the once-through block. There is a slight difference, however: a `next` will execute a `continue` block, but a `last` won't.

given a label to apply loop controls to. Loop controls may only be used on true loops, just as a `return` may only be used within a subroutine (well, or an `eval`).

Loop controls don't work in an `if` or `unless`, either, since those aren't loops. But you can always introduce an extra set of braces to give yourself a bare block, which *does* count as a loop:

```
if (/pattern/) {{
    last if /alpha/;
    last if /beta/;
    last if /gamma/;
    # do something here only if still in if()
}}
```

Here's how a block can be used to let loop-control operators work with a `do {}` construct. To `next` or `redo` a `do`, put a bare block inside:

```
do {{
    next if $x == $y;
    # do something here
}} until $x++ > $z;
```

For `last`, you have to be more elaborate:

```
{
    do {
        last if $x = $y ** 2;
        # do something here
    } while $x++ <= $z;
}
```

And if you want both loop controls available, you'll have to put a label on those blocks so you can tell them apart:

```
DO_LAST: {
             do {
DO_NEXT:           {
                     next DO_NEXT if $x == $y;
                     last DO_LAST if $x =  $y ** 2;
                     # do something here
                   }
             } while $x++ <= $z;
          }
```

But certainly by that point (if not before), you're better off using an ordinary infinite loop with `last` at the end:

```
for (;;) {
    next if $x == $y;
    last if $x =  $y ** 2;
    # do something here
    last unless $x++ <= $z;
}
```

Loopy Topicalizers

Perl has more than one topicalizer; in addition to `given`, you can also use a `foreach` loop as a topicalizer. For example, here's one way to count how many times a particular string occurs in an array:

```
use v5.10.1;
my $count = 0;
for (@array) {
    when ("FNORD") { ++$count }
}
print "\@array contains $count copies of 'FNORD'\n";
```

Or in a more recent version:

```
use v5.14;
my $count = 0;
for (@array) {
    ++$count when "FNORD";
}
print "\@array contains $count copies of 'FNORD'\n";
```

At the end of all `when` blocks inside a `foreach` loop, there is an implicit `break`, which, since you're in a loop, is equivalent to a `next`. You can override that with an explicit `last` if you're only interested in the first match.

A `when` only works if the topic is in `$_`, so you can't specify a loop variable, or if you do, it must be `$_`:

```
for my $_ (@answers) {
    say "Life, the Universe, and Everything!" when 42;
}
```

The goto Operator

Although not for the faint of heart (nor for the pure of heart), Perl does support a `goto` operator. There are three forms: `goto` *`LABEL`*, `goto` *`EXPR`*, and `goto &`*`NAME`*.

The `goto` *`LABEL`* form finds the statement labeled with *`LABEL`* and resumes execution there. It can't be used to jump into any construct that requires initialization, such as a subroutine or a `foreach` loop. It also can't be used to jump into a construct that has been optimized away (see Chapter 16). It can be used to go almost anywhere else within the current block or any block in your dynamic scope (that is, a block you were called from). You can even `goto` out of subroutines, but it's usually better to use some other construct. The author of Perl has never felt the need to use the labeled form of `goto` in Perl (except to test that it works).

The `goto` *EXPR* form is just a generalization of `goto` *LABEL*. It expects the expression to produce a label name, whose location obviously has to be resolved dynamically by the interpreter. This allows for computed gotos per FORTRAN, but isn't necessarily recommended if you're optimizing for maintainability:

```
goto(("FOO", "BAR", "GLARCH")[$i]);         # hope 0 <= i < 3

@loop_label = qw/FOO BAR GLARCH/;
goto $loop_label[rand @loop_label];         # random teleport
```

In almost all cases like this, it's usually a far, far better idea to use the structured control-flow mechanisms of `next`, `last`, or `redo` instead of resorting to a `goto`. For certain applications, a hash of references to functions or the catch-and-throw pair of `eval` and `die` for exception processing can also be prudent approaches.

The `goto &`*NAME* form is highly magical and sufficiently removed from the ordinary `goto` to exempt its users from the opprobrium to which `goto` users are customarily subjected. It substitutes a call to the named subroutine for the currently running subroutine. This behavior is used by `AUTOLOAD` subroutines to load another subroutine and then pretend that the other subroutine was called in the first place. After the `goto`, not even `caller` will be able to tell that this routine was called first. The `autouse`, `AutoLoader`, and `SelfLoader` modules all use this strategy to define functions the first time they're called, and then to jump right to them without anyone ever knowing the functions weren't there all along. It is not particularly lightweight, so don't think of it as a tailcall optimization.

Paleolithic Perl Case Structures

During its first 20 years of existence, Perl had no official switch or case statement. Prior to the appearance of `given` in the v5.10 release, people would craft their own case structures using a bare block or a once-through `foreach` loop. Here's one example:

```
SWITCH: {
    if (/^abc/) { $abc = 1; last SWITCH }
    if (/^def/) { $def = 1; last SWITCH }
    if (/^xyz/) { $xyz = 1; last SWITCH }
    $nothing = 1;
}
```

and here's another:

```
SWITCH: {
    /^abc/      && do { $abc = 1; last SWITCH };
    /^def/      && do { $def = 1; last SWITCH };
    /^xyz/      && do { $xyz = 1; last SWITCH };
```

```
    $nothing = 1;
}
```

or even just:

```
if    (/^abc/) { $abc = 1 }
elsif (/^def/) { $def = 1 }
elsif (/^xyz/) { $xyz = 1 }
else           { $nothing = 1 }
```

In this next example, notice how the `last` operators conveniently ignore the `do {}` blocks, which aren't loops, and exit the main loop instead:

```
for ($very_nasty_long_name[$i++][$j++]->method()) {
    /this pattern/      and do { push @flags, "-e"; last };
    /that one/          and do { push @flags, "-h"; last };
    /something else/    and do {                    last };
    die "unknown value: '$_'";
}
```

You'll see that idiom from time to time in older Perl code, since `for` was the only way to write a decent topicalizer until `given` showed up.

Regardless of which topicalizer you use, specifying the value only once on repeated compares is much easier to type and, therefore, harder to mistype. It avoids possible side effects from evaluating the expression again.

Cascading use of the `?:` operator can also work for simple cases. Here we again use a `for` for its aliasing property to make repeated comparisons more legible:

```
for ($user_color_preference) {
    $value = /red/      ?   0xFF0000  :
             /green/    ?   0x00FF00  :
             /blue/     ?   0x0000FF  :
                            0x000000  ;   # black if all fail
}
```

For many situations, though, it's better to build yourself a hash and quickly index into it to pull the answer out. Unlike the cascading conditionals we just looked at, a hash scales to an unlimited number of entries, and takes no more time to look up the first one than the last. You can also add cases at run time. The disadvantage is that you can only do an exact lookup, not a pattern match. If you have a hash like this:

```
%color_map = (
    azure       => 0xF0FFFF,
    chartreuse  => 0x7FFF00,
    lavender    => 0xE6E6FA,
    magenta     => 0xFF00FF,
    turquoise   => 0x40E0D0,
);
```

then exact string lookups run quickly, and you can still supply a default:

```
$value = $color_map{ lc $user_color_preference } || 0x000000;
```

Even multiway branching statements, with each case involving complicated chunks of code, can be turned into fast hash lookups. You just need to use a hash of references to functions, which are a first-class data type in Perl. See the section "Hashes of Functions" on page 381 in Chapter 9 for how to handle those.

All that being said, case structures are not always the best tool in your toolbox. The most extensible way to look up polymorphic behaviors is by using normal object dispatch instead. See Chapter 12 now if you can't wait.

One more horrific case structure you might see is this:

```
goto $data;
ABC: $foo++; goto end;
DEF: $bar++; goto end;
XYZ: $baz++; goto end;
end:
```

Yes, it works, but...it's...kinda...slow, and if none of the labels matches, it will go looking through your whole program for the missing label, and then probably blow up, if you're lucky. There are better ways to blow up, and the next section is about one of them.

The Ellipsis Statement

Beginning with v5.12, Perl accepts a bare ellipsis, "`...`", as a stub—that is, a placeholder for code that you haven't implemented yet. Do not confuse this `...` statement with the binary flip-flop `...` operator. Perl doesn't usually confuse them because Perl can tell when it is expecting statements or operators most of the time—but see below.

When Perl parses an ellipsis statement, it accepts it silently. Later, though, if you try to execute it, Perl loudly throws an exception with the text `Unimplemented`:

```
sub unimplemented { ... }
eval { unimplemented() };
if ($@ eq "Unimplemented") {
    say "Caught an Unimplemented exception!";
}
```

You may use the elliptical statement only as a complete statement (though a statement modifier is allowed). These examples are all legal examples of the ellipsis statement:

```
{ ... }
sub foo { ... }
...;
eval { ... };
... unless defined &dispatcher;
sub somemeth {
    my $self = shift;
    ...;
}
$x = do {
    my $n;
    ...;
    say "Hurrah!";
    $n;
};
```

However, `...` cannot stand in for an expression that is part of a larger statement, since `...` is also the three-dot version of the flip-flop operator (see "Range Operators" on page 120 in Chapter 3). Hence, the following are all considered syntax errors:

```
print ...;                                  # WRONG
open(my $fh, ">", "/dev/passwd") or ...;    # WRONG
if ($condition && ... ) { say "Howdy" };    # WRONG
```

There are times when Perl can't distinguish an expression from a statement. For example, a bare block and an anonymous hash composer look the same unless there's something else inside the braces to give Perl the necessary hint:

```
@transformed = map { ... } @input;  # WRONG: syntax error
```

One workaround is to use a `;` inside your block to tell Perl that the `{ ... }` is a block, not an anonymous hash composer:

```
@transformed = map {; ... } @input; # ; disambiguates ellipsis

@transformed = map { ...; } @input; # ; disambiguates ellipsis
```

Folks colloquially refer to this bit of punctuation as the "yada-yada", but you can call it by its technical name "ellipsis" when you wish to impress the impressionable. Perl does not yet accept the Unicode version, U+2026 HORIZONTAL ELLIPSIS, as an alias for `...`, but maybe someday...

Global Declarations

Subroutine and format declarations are global declarations. No matter where you place them, what they declare is global (it's local to a package, but packages are global to the program, so everything in a package is visible from anywhere). A global declaration can be put anywhere a statement can, but it has no effect on

the execution of the primary sequence of statements—the declarations take effect at compile time.

This means you can't conditionally declare subroutines or formats by hiding them from the compiler inside a runtime conditional like an `if`, since only the interpreter pays attention to those conditions. Subroutine and format declarations (and `use` and `no` declarations) are seen by the compiler no matter where they occur.

Global declarations are typically put at the beginning or the end of your program, or off in some other file. However, if you're declaring any lexically scoped variables (see the next section), you'll want to make sure your format or subroutine definition falls within the scope of the variable declarations—if you expect it to be able to access those private variables.

Note that we sneakily switched from talking about declarations to definitions. Sometimes it helps to split the *definition* of the subroutine from its *declaration*. The only syntactic difference between the two is that the definition supplies a *`BLOCK`* containing the code to be executed, while the declaration doesn't. (A subroutine definition acts as its own declaration if no declaration has been seen.) Splitting the definition from the declaration allows you to put the subroutine declaration at the front of the file and the definition at the end (with your lexically scoped variable declarations happily in the middle):

```
sub count (@);       # Compiler now knows how to call count().
my $x;               # Compiler now knows about lexical variable.
$x = count(3,2,1);   # Compiler can validate function call.
sub count (@) { @_ } # Compiler now knows what count() means.
```

As this example shows, subroutines don't actually have to be defined before calls to them can be compiled (indeed, the definition can even by delayed until first use, if you use autoloading), but declaring subroutines helps the compiler in various ways and gives you more options in how you can call them.

Declaring a subroutine allows it to be used without parentheses, as if it were a built-in operator, from that point forward in the compilation. (We used parentheses to call `count` in the last example, but we didn't actually need to.) You can declare a subroutine without defining it just by saying:

```
sub myname;
$me = myname $0   or die "can't get myname";
```

A bare declaration like that declares the function to be a list operator, not a unary operator, so be careful to use `or` there instead of `||`. The `||` operator binds too tightly to use after list operators, though you can always use parentheses around the list operator's arguments to turn the list operator back into something that

behaves more like a function call. Alternatively, you can use the prototype `($)` to turn the subroutine into a unary operator:

```
sub myname ($);
$me = myname $0   || die "can't get myname";
```

That now parses as you'd expect, but you still ought to get in the habit of using parentheses in that situation. For more on prototypes, see Chapter 7.

You *do* need to define the subroutine at some point, or you'll get an error at runtime indicating that you've called an undefined subroutine. Other than defining the subroutine yourself, there are several ways to pull in definitions from elsewhere.

You can load definitions from other files with a simple `require` statement; this was the best way to load files in Perl 4, but there are two problems with it. First, the other file will typically insert subroutine names into a package (a symbol table) of its own choosing, not into your package. Second, a `require` happens at runtime, so it occurs too late to serve as a declaration in the file invoking the `require`. There are times, however, when delayed loading is what you want.

A more useful way to pull in declarations and definitions is with the `use` declaration, which effectively `require`s the module at compile time (because `use` counts as a `BEGIN` block) and then lets you import some of the module's declarations into your own program. Thus, `use` can be considered a kind of global declaration in that it imports names at compile time into your own (global) package just as if you'd declared them yourself. See the section "Symbol Tables" on page 389 in Chapter 10 for low-level mechanics on how importation works between packages; Chapter 11, for how to set up a module's imports and exports; and Chapter 16 for an explanation of `BEGIN` and its cousins, `CHECK`, `UNITCHECK`, `INIT`, and `END`, which are also global declarations of a sort because they're dealt with at compile time and can have global effects.

Scoped Declarations

Like global declarations, lexically scoped declarations have an effect at the time of compilation. Unlike global declarations, lexically scoped declarations only apply from the point of the declaration through the end of the innermost enclosing scope (block, file, or `eval`—whichever comes first). That's why we call them lexically scoped, though perhaps "textually scoped" would be more accurate, since lexical scoping has little to do with lexicons. But computer scientists the world over know what "lexically scoped" means, so we perpetuate the usage here.

Perl also supports dynamically scoped declarations. A *dynamic scope* also extends to the end of the innermost enclosing block, but in this case, "enclosing" is defined dynamically at runtime rather than textually at compile time. To put it another way, blocks nest dynamically by invoking other blocks, not by including them. This nesting of dynamic scopes may correlate somewhat to the nesting of lexical scopes, but the two are generally not identical, especially when any subroutines have been invoked.

We mentioned that some aspects of `use` could be considered global declarations, but other aspects of `use` are lexically scoped. In particular, `use` not only imports package symbols, it also implements various magical compiler hints, known as *pragmas* (or if you're into classical Greek, *pragmata*). Most pragmas are lexically scoped, including the `strict` pragma we mention from time to time. See the later section "Pragmas" on page 164. (Hence, if it is implicitly turned on by `use v5.14` at the top of your file, it's on for the whole rest of the file, even if you switch packages.)

A `package` declaration, oddly enough, is itself lexically scoped, despite the fact that a package is a global entity. But a `package` declaration merely declares the identity of the default package for the rest of the enclosing block or, if you use the optional *`BLOCK`* after the `package` *`NAMESPACE`*, then in that specific block. Undeclared identifiers used in variable names[12] are looked up in that package. In a sense, a package is never declared at all, but springs into existence when you refer to something that belongs to that package. It's all very Perlish.

Scoped Variable Declarations

Most of the rest of this chapter is about using global variables. Or, rather, it's about *not* using global variables. There are various declarations that help you not use global variables—or, at least, not use them foolishly.

We already mentioned the `package` declaration, which was introduced into Perl long ago to allow globals to be split up into separate packages. This works pretty well for certain kinds of variables. Packages are used by libraries, modules, and classes to store their interface data (and some of their semiprivate data) to avoid conflicting with variables and functions of the same name in your main program or in other modules. If you see someone write `$Some::stuff`,[13] he's using the `$stuff` scalar variable from the package `Some`. See Chapter 10.

12. Also unqualified names of subroutines, filehandles, directory handles, and formats.

13. Or the archaic `$Some'stuff`, which probably shouldn't be encouraged outside of Perl poetry.

If this were all there were to the matter, Perl programs would quickly become unwieldy as they got longer. Fortunately, Perl's three scoping declarators make it easy to create completely private variables (using `my` or `state`), or to give selective access to global ones (using `our`). There is also a pseudodeclarator to provide temporary values to global variables (using `local`). These declarators are placed in front of the variable in question:

```
my $nose;
our $House;
state $troopers = 0;
local $TV_channel;
```

If more than one variable is to be declared, the list must be placed in parentheses:

```
my ($nose, @eyes, %teeth);
our ($House, @Autos, %Kids);
state ($name, $rank, $serno);
local (*Spouse, $phone{HOME});
```

The `my`, `state`, and `our` declarators may only declare simple scalar, array, or hash variables, while `state` may only initialize simple scalar variables (although this may contain a reference to anything else you'd like), not arrays or hashes. Since `local` is not a true declarator, the constraints are somewhat more relaxed: you may also localize, with or without initialization, entire typeglobs and individual elements or slices of arrays and hashes. Each of these modifiers offers a different sort of "confinement" to the variables they modify. To oversimplify slightly: `our` confines names to a scope, `local` confines values to a scope, and `my` confines both names and values to a scope. (And `state` is just like `my`, but it defines the scope a bit differently.) Each of these constructs may be assigned to, though they differ in what they actually do with the values since they have different mechanisms for storing values. They also differ somewhat if you *don't* (as we didn't above) assign any values to them: `my` and `local` cause the variables in question to start out with values of `undef` or `()`, as appropriate; `our`, on the other hand, leaves the current value of its associated global unchanged. And `state`, the oddball, starts with whatever value it had the last time we were here.

Syntactically, `my`, `our`, `state`, and `local` are simply modifiers (like adjectives) on an lvalue expression. When you assign to an lvalue modified by a declarator, it doesn't change whether the lvalue is viewed as a scalar or a list. To determine how the assignment will work, just pretend that the declarator isn't there. So either of:

```
my ($foo) = <STDIN>;
my @array = <STDIN>;
```

supplies list context to the righthand side, while this supplies scalar context:

```
my $foo = <STDIN>;
```

Declarators bind more tightly (with higher precedence) than the comma does. The following example erroneously declares only one variable, not two, because the list following the declarator is not enclosed in parentheses:

```
my $foo, $bar = 1;              # WRONG
```

This has the same effect as:

```
my $foo;
$bar = 1;
```

Under `strict`, you will get an error from that since `$bar` is not declared.

In general, it's best to declare a variable in the smallest possible scope that suits it. Since variables declared in a control-flow statement are visible only in the block governed by that statement, their visibility is reduced. It reads better in English this way, too:

```
sub check_warehouse {
    for my $widget (our @Current_Inventory) {
        say "I have a $widget in stock today.";
    }
}
```

By far the most frequently seen declarator is `my`, which declares lexically scoped variables for which both the names and values are stored in the current scope's temporary scratchpad; these may not be accessed from outside the lexical scope. Always use `my` unless you know why you want one of the others. Use `state` if you want the same degree of privacy but you also want the value to persist from call to call.

Closely related is the `our` declaration, which is also persistent, and also enters a lexically scoped name in the current scope, but implements its persistence by storing its value in a global variable that anyone else can access if they wish. In other words, it's a global variable masquerading as a lexical.

In addition to global scoping and lexical scoping, we also have what is known as *dynamic scoping*, implemented by `local`, which despite the word "local" really deals with global variables and has nothing to do with the local scratchpad. (It would be more aptly named `temp`, since it temporarily changes the value of an existing variable. You might even see `temp` in Perl 5 programs someday, if the keyword is borrowed back from Perl 6.)

The newly declared variable (or value, in the case of `local`) does not show up until the statement *after* the statement containing the declaration. Thus, you could mirror a variable this way:

```
my $x = $x;
```

That initializes the new inner `$x` with the current value `$x`, whether the current meaning of `$x` is global or lexical.

Declaring a lexical variable name hides any previously declared lexical of the same name, whether declared in that scope or an outer scope (although you'll get a warning if you have those enabled). It also hides any unqualified global variable of the same name, but you can always get to the global variable by explicitly qualifying it with the name of the package the global is in, for example, `$PackageName::varname`.

Lexically Scoped Variables: my

To help you avoid the maintenance headaches of global variables, Perl provides lexically scoped variables, often called *lexicals* for short. Unlike globals, lexicals guarantee you privacy. Assuming you don't hand out references to these private variables that would let them be fiddled with indirectly, you can be certain that every possible access to these private variables is restricted to code within one discrete and easily identifiable section of your program. That's why we picked the keyword `my`, after all.

A statement sequence may contain declarations of lexically scoped variables. Such declarations tend to be placed at the front of the statement sequence, but this is not a requirement; you may simply decorate the first use of a variable with a `my` declarator wherever it occurs (as long as it's in the outermost scope the variable is used). In addition to declaring variable names at compile time, the declarations act like ordinary runtime statements: each of them is executed within the sequence of statements as if it were an ordinary statement without the declarator:

```
my $name = "fred";
my @stuff = ("car", "house", "club");
my ($vehicle, $home, $tool) = @stuff;
```

These lexical variables are totally hidden from the world outside their immediately enclosing scope. Unlike the dynamic scoping effects of `local` (see below), lexicals are hidden from any subroutine called from their scope. This is true even if the same subroutine is called from itself or elsewhere—each instance of the subroutine gets its own "scratchpad" of lexical variables. Subroutines defined in the scope of a lexical variable, however, can see the variable just like any inner scope would.

Unlike block scopes, file scopes don't nest; there's no "enclosing" going on, at least not textually. If you load code from a separate file with `do`, `require`, or `use`, the code in that file cannot access your lexicals, nor can you access lexicals from that file.

However, any scope within a file (or even the file itself) is fair game. It's often useful to have scopes larger than subroutine definitions, because this lets you share private variables among a limited set of subroutines. This is one way to create variables that a C programmer would think of as "file static":

```
{
    my $state = 0;

    sub on     { $state = 1 }
    sub off    { $state = 0 }
    sub toggle { $state = !$state }
}
```

The `eval` *`STRING`* operator also works as a nested scope, since the code in the `eval` can see its caller's lexicals (as long as the names aren't hidden by identical declarations within the `eval`'s own scope). Anonymous subroutines can likewise access any lexical variables from their enclosing scopes; if they do so, they're what are known as *closures*.[14] Combining those two notions, if a block `eval`s a string that creates an anonymous subroutine, the subroutine becomes a closure with full access to the lexicals of both the `eval` and the block, even after the `eval` and the block have exited. See the section "Closures" on page 355 in Chapter 8.

Persistent Lexically Scoped Variables: state

A `state` variable is a lexically scoped variable, just like `my`. The only difference is that `state` variables will never be reinitialized, unlike `my` variables that are reinitialized each time their enclosing block is entered. This is usually so that a function can have a private variable that retains its old value between calls to that function.

`state` variables are enabled only when the `use feature "state"` pragma is in effect. This will be automatically included if you ask to `use` a version of Perl that's v5.10 or later:

```
use v5.14;
sub next_count {
```

14. As a mnemonic, note the common element between "en*clos*ing scope" and "*clos*ure". (The actual definition of closure comes from a mathematical notion concerning the completeness of sets of values and operations on those values.)

```
    state $counter = 0;  # first time through, only
    return ++$counter;
}
```

Unlike `my` variables, `state` variables are currently restricted to scalars; they cannot be arrays or hashes. This may sound like a bigger restriction than it actually is, because you can always store a reference to an array or hash in a `state` variable:

```
use v5.14;
state $bag    = { };
state $vector = [ ];

...
unless ($bag->{$item}) { $bag->{$item} = 1 }
...
push @$vector, $item;
```

Lexically Scoped Global Declarations: our

In the old days before `use strict`, Perl programs would simply access global variables directly. A better way to access globals nowadays is by the `our` declaration. This declaration is lexically scoped in that it applies only through the end of the current scope. However, unlike the lexically scoped `my` or the dynamically scoped `local`, `our` does not isolate anything to the current lexical or dynamic scope. Instead, it provides "permission" in the current lexical scope to access a variable of the declared name in the current package. Since it declares a lexical name, it hides any previous lexicals of the same name. In this respect, `our` variables act just like `my` variables.

If you place an `our` declaration outside any brace-delimited block, it lasts through the end of the current compilation unit. Often, though, people put it just inside the top of a subroutine definition to indicate that they're accessing a global variable:

```
sub check_warehouse {
    our @Current_Inventory;
    my  $widget;
    foreach $widget (@Current_Inventory) {
        say "I have a $widget in stock today.";
    }
}
```

Since global variables are longer in life and broader in visibility than private variables, we like to use longer and flashier names for them than for temporary variables. This practice alone, if studiously followed, can do nearly as much as `use strict` can toward discouraging the overuse of global variables, especially in the less prestidigitatorial typists.

Repeated `our` declarations do not meaningfully nest. Every nested `my` produces a new variable, and every nested `local` a new value. But every time you use `our`, you're talking about *the same* global variable, irrespective of nesting. When you assign to an `our` variable, the effects of that assignment persist after the scope of the declaration. That's because `our` never creates values; it just exposes a limited form of access to the global, which lives forever:

```
our $PROGRAM_NAME = "waiter";
{
    our $PROGRAM_NAME = "server";
    # Code called here sees "server".
    ...
}
# Code executed here still sees "server".
```

Contrast this with what happens under `my` or `local`, where, after the block, the outer variable or value becomes visible again:

```
my $i = 10;
{
    my $i = 99;
    ...
}
# Code compiled here sees outer 10 variable.

local $PROGRAM_NAME = "waiter";
{
    local $PROGRAM_NAME = "server";
    # Code called here sees "server".
    ...
}
# Code executed here sees restored "waiter" value.
```

It usually only makes sense to assign to an `our` declaration once, probably at the very top of the program or module, or, more rarely, when you preface the `our` with a `local` of its own:

```
{
    local our @Current_Inventory = qw(bananas);
    check_warehouse();  # no, we haven't no bananas :-)
}
```

(But why not just pass it as an argument in this case?)

Dynamically Scoped Variables: local

Using a `local` operator on a global variable gives it a temporary value each time `local` is executed, but it does not affect that variable's global visibility. When the program reaches the end of that dynamic scope, this temporary value is discarded

and the original value is restored. But it's always still a global variable that just happens to hold a temporary value while that block is executing. If you call some other function while your global contains the temporary value and that function accesses that global variable, it sees the temporary value, not the original one. In other words, that other function is in your dynamic scope, even though it's presumably not in your lexical scope.[15]

This process is called *dynamic scoping* because the current value of the global variable depends on your dynamic context; that is, it depends on which of your parents in the call chain might have called `local`. Whoever did so last before calling you controls which value you will see.

If you have a `local` that looks like this:

```
{
  local $var = $newvalue;
  some_func();
  ...
}
```

you can think of it purely in terms of runtime assignments:

```
{
  $oldvalue = $var;
  $var = $newvalue;
  some_func();
  ...
}
continue {
  $var = $oldvalue;
}
```

The difference is that with `local` the value is restored no matter how you exit the block, even if you prematurely `return` from that scope.

As with `my`, you can initialize a `local` with a copy of the same global variable. Any changes to that variable during the execution of a subroutine (and any others called from within it, which of course can still see the dynamically scoped global) will be thrown away when the subroutine returns. You'd certainly better comment what you are doing, though:

```
# WARNING: Changes are temporary to this dynamic scope.
local $Some_Global = $Some_Global;
```

15. That's why lexical scopes are sometimes called *static scopes*: to contrast them with dynamic scopes and emphasize their compile-time determinability. Don't confuse this use of the term with how `static` is used in C or C++. The term is heavily overloaded, which is why we avoid it.

A global variable then is still completely visible throughout your whole program, no matter whether it was explicitly declared with `our` or just allowed to spring into existence, or whether it's holding a `local` value destined to be discarded when the scope exits. In tiny programs, this isn't so bad, but for large ones, you'll quickly lose track of where in the code all these global variables are being used. You can forbid accidental use of globals, if you want, through the `use strict 'vars'` pragma, described in the next section.

Although both `my` and `local` confer some degree of protection, by and large you should prefer `my` over `local`. Sometimes, though, you have to use `local` so you can temporarily change the value of an existing global variable, like those listed in Chapter 25. Only alphanumeric identifiers may be lexically scoped, and many of those special variables aren't strictly alphanumeric. You also need to use `local` to make temporary changes to a package's symbol table, as shown in the section "Symbol Tables" on page 389 in Chapter 10. Finally, you can use `local` on a single element or a whole slice of an array or a hash. This even works if the array or hash happens to be a lexical variable, layering `local`'s dynamic scoping behavior on top of those lexicals. We won't talk much more about the semantics of `local` here. See the `local` entry in Chapter 27 for more information.

Pragmas

Many programming languages allow you to give hints to the compiler. In Perl, these hints are conveyed to the compiler with the `use` declaration. Some pragmas are:

```
use warnings;
use strict;
use integer;
use bytes;
use constant pi => ( 4 * atan2(1,1) );
```

Perl pragmas are all described in Chapter 29, but right now we'll just talk specifically about a couple that are most useful with the material covered in this chapter.

Although a few pragmas are global declarations that affect global variables or the current package, most are lexically scoped declarations whose effects are constrained to last only until the end of the enclosing block, file, or `eval` (whichever comes first). A lexically scoped pragma can be countermanded in an inner scope with a `no` declaration, which works just like `use` but in reverse.

Controlling Warnings

To show how this works, we'll manipulate the `warnings` pragma to tell Perl whether to issue warnings for questionable practices:

```
use warnings;       # or explicitly enable warnings
...
{
    no warnings;    # Disable warnings through end of block.
    ...
}
# Warnings are automatically enabled again here.
```

Once warnings are enabled, Perl complains about variables used only once, variable declarations that mask other declarations in the same scope, improper conversions of strings into numbers, using undefined values as legitimate strings or numbers, trying to write to files you only opened read-only (or didn't open at all), and many other conditions documented in *perldiag*.

The `warnings` pragma is the preferred way to control warnings. Old programs could only use the `-w` command-line switch or modify the global `$^W` variable:

```
{
    local $^W = 0;
    ...
}
```

It's much better to use the `use warnings` and `no warnings` pragmas. A pragma is better because it happens at compile time, because it's a lexical declaration and therefore cannot affect code it wasn't intended to affect, and because (although we haven't shown you in these simple examples) it affords fine-grained control over discrete classes of warnings. For more about the `warnings` pragma, including how to convert merely noisy warnings into fatal errors, and how to override the pragma to turn on warnings globally even if a module says not to, see "warnings" on page 1039 in Chapter 29.

Controlling the Use of Globals

Another commonly seen declaration is the `strict` pragma, which has several functions, one of which is to control the use of global variables. Normally, Perl lets you create new globals (or, all too often, step on old globals) just by mentioning them. No variable declarations are necessary—by default, that is. Because unbridled use of globals can make large programs or modules painful to maintain, you may sometimes wish to discourage their accidental use. As an aid to preventing such accidents, you can say:

```
use v5.14;           # Turn on strict implicitly.
use strict "vars";   # Turn on strict explicitly.
```

This means that any variable mentioned from here to the end of the enclosing scope must refer either to a lexical variable declared with `my`, `state`, or `our`, or to an explicitly allowed global. If it's not one of those, a compilation error results. A global is explicitly allowed if one of the following is true:

- It's one of Perl's program-wide special variables (see Chapter 25).
- It's fully qualified with its package name (see Chapter 10).
- It's imported into the current package (see Chapter 11).
- It's masquerading as a lexically scoped variable via an `our` declaration. (This is the main reason we added `our` declarations to Perl.)

Of course, there's always the fifth alternative—if the pragma proves burdensome, simply countermand it within an inner block using:

```
no strict "vars";
```

You can also turn on strict checking of symbolic dereferences and accidental use of barewords with this pragma. Normally, people just say:

```
use strict;
```

to enable all three strictures—if they haven't already implicitly enabled them via `use v5.14` or some such. See the "strict" pragma entry in Chapter 29 for more information.

CHAPTER 5
Pattern Matching

Perl's built-in support for pattern matching lets you search large amounts of data conveniently and efficiently. Whether you run a huge commercial portal site scanning every newsfeed in existence for interesting tidbits, a government organization dedicated to figuring out human demographics (or the human genome), or an educational institution just trying to get some dynamic information up on your website, Perl is the tool of choice, in part because of its database connections, but largely because of its pattern-matching capabilities. If you take "text" in the widest possible sense, perhaps 90% of what you do is 90% text processing. That's really what Perl is all about and always has been about—in fact, it's even part of Perl's name: Practical *Extraction* and Report Language. Perl's patterns provide a powerful way to scan through mountains of mere data and extract useful information from it.

You specify a pattern by creating a *regular expression* (or *regex*), and Perl's regular expression engine (the "Engine", for the rest of this chapter) then takes that expression and determines whether (and how) the pattern matches your data. While most of your data will probably be text strings, there's nothing stopping you from using regexes to search and replace any byte sequence, even what you'd normally think of as "binary" data. To Perl, bytes are just characters that happen to have an ordinal value less than 256. (More on that in Chapter 6.)

If you're acquainted with regular expressions from some other venue, we should warn you that regular expressions are a bit different in Perl. First, they aren't entirely "regular" in the theoretical sense of the word, which means they can do much more than the traditional regular expressions taught in computer science classes. Second, they are used so often in Perl that they have their own special variables, operators, and quoting conventions, which are tightly integrated into the language, not just loosely bolted on like any other library. Programmers new to Perl often look in vain for functions like these:

```
match( $string, $pattern );
subst( $string, $pattern, $replacement );
```

But matching and substituting are such fundamental tasks in Perl that they merit one-letter operators: `m/`*`PATTERN`*`/` and `s/`*`PATTERN`*`/`*`REPLACEMENT`*`/` (`m//` and `s///`, for short). Not only are they syntactically brief, they're also parsed like double-quoted strings rather than ordinary operators; nevertheless, they operate like operators, so we'll call them that. Throughout this chapter, you'll see these operators used to match patterns against a string. If some portion of the string fits the pattern, we say that the match is successful. There are lots of cool things you can do with a successful pattern match. In particular, if you are using `s///`, a successful match causes the matched portion of the string to be replaced with whatever you specified as the *`REPLACEMENT`*.

This chapter is all about how to build and use patterns. Perl's regular expressions are potent, packing a lot of meaning into a small space. They can therefore be daunting if you try to intuit the meaning of a long pattern as a whole. But if you can break it up into its parts, and if you know how the Engine interprets those parts, you can understand any regular expression. It's not unusual to see a hundred-line C or Java program expressed with a one-line regular expression in Perl. That regex may be a little harder to understand than any single line out of the longer program; on the other hand, the regex will likely be much easier to understand than the longer program taken as a whole. You just have to keep these things in perspective.

The Regular Expression Bestiary

Before we dive into the rules for interpreting regular expressions, let's see what some patterns look like. Most characters in a regular expression simply match themselves. If you string several characters in a row, they must match in order, just as you'd expect. So if you write the pattern match:

```
/Frodo/
```

you can be sure that the pattern won't match unless the string contains the substring "`Frodo`" somewhere. (A *substring* is just a part of a string.) The match could be anywhere in the string, just as long as those five characters occur somewhere, next to each other and in that order.

Other characters don't match themselves but "misbehave" in some way. We call these *metacharacters*. (All metacharacters are naughty in their own right, but some are so bad that they also cause other nearby characters to misbehave as well.)

Here are the miscreants:

```
\ | ( ) [ { ^ $ * + ? .
```

Metacharacters are actually very useful and have special meanings inside patterns; we'll tell you all those meanings as we go along. But we do want to reassure you that you can always match any of these 12 characters literally by putting a backslash in front of each. For example, backslash is itself a metacharacter, so to match a literal backslash, you'd backslash the backslash: `\\`.

You see, backslash is one of those characters that makes other characters misbehave. It just works out that when you make a misbehaving metacharacter misbehave, it ends up behaving—a double negative, as it were. So backslashing a character to get it to be taken literally works, but only on punctuational characters; backslashing an (ordinarily well-behaved) alphanumeric character does the opposite: it turns the literal character into something special. Whenever you see such a two-character sequence:

```
\b \D \t \3 \s
```

you'll know that the sequence is a *metasymbol* that matches something strange. For instance, `\b` matches a word boundary, while `\t` matches an ordinary tab character. Notice that a tab is one character wide, while a word boundary is zero characters wide because it's the spot between two characters. So we call `\b` a *zero-width* assertion. Still, `\t` and `\b` are alike in that they both assert something about a particular spot in the string. Whenever you *assert* something in a regular expression, you're just claiming that that particular something has to be true in order for the pattern to match.

Most pieces of a regular expression are some sort of assertion, including the ordinary characters that simply assert that they match themselves. To be precise, they also assert that the *next* thing will match one character later in the string, which is why we talk about the tab character being "one character wide". Some assertions (like `\t`) eat up some of the string as they match, and others (like `\b`) don't. But we usually reserve the term "assertion" for the zero-width assertions. To avoid confusion, we'll call the thing with width an *atom*. (If you're a physicist, you can think of nonzero-width atoms as massive, in contrast to the zero-width assertions, which are massless like photons.)

You'll also see some metacharacters that aren't assertions; rather, they're structural (just as braces and semicolons define the structure of ordinary Perl code but don't really do anything). These structural metacharacters are in some ways the most important ones, because the crucial first step in learning to read regular expres-

sions is to teach your eyes to pick out the structural metacharacters. Once you've learned that, reading regular expressions is a breeze.[1]

One such structural metacharacter is the vertical bar, which indicates *alternation*:

```
/Frodo|Pippin|Merry|Sam/
```

That means that any of those strings can trigger a match; this is covered in "Alternation" on page 231 later in this chapter. And in the section "Grouping and Capturing" on page 221 before that, we'll show you how to use parentheses around portions of your pattern to do *grouping*:

```
/(Frodo|Drogo|Bilbo) Baggins/
```

or even:

```
/(Frod|Drog|Bilb)o Baggins/
```

Another thing you'll see are what we call *quantifiers*, which say how many of the previous thing should match in a row. Quantifiers look like this:

```
*  +  ?  *?  *+  {3}  {2,5}
```

You'll never see them in isolation like that, though. Quantifiers only make sense when attached to atoms—that is, to assertions that have width.[2] Quantifiers attach to the previous atom only, which in human terms means they normally quantify only one character. If you want to match three copies of "`bar`" in a row, you need to group the individual characters of "`bar`" into a single "molecule" with parentheses, like this:

```
/(bar){3}/
```

That will match "`barbarbar`". If you'd said `/bar{3}/`, that would match "`barrr`"—which might qualify you as Scottish but disqualify you as barbarbaric. (Then again, maybe not. Some of our favorite metacharacters are Scottish.) For more on quantifiers, see "Quantifiers" on page 214 later in this chapter.

Now that you've seen a few of the beasties that inhabit regular expressions, you're probably anxious to start taming them. However, before we discuss regular expressions in earnest, we need to backtrack a little and talk about the pattern-matching operators that make use of regular expressions. (And if you happen to spot a few more regex beasties along the way, just leave a decent tip for the tour guide.)

---

1. Admittedly, a stiff breeze at times, but not something that will blow you away.

2. Quantifiers are a bit like the statement modifiers in Chapter 4, which can only attach to a single statement. Attaching a quantifier to a zero-width assertion would be like trying to attach a `while` modifier to a declaration—either of which makes about as much sense as asking your local apothecary for a pound of photons. Apothecaries only deal in atoms and such.

Pattern-Matching Operators

Zoologically speaking, Perl's pattern-matching operators function as a kind of cage for regular expressions, to keep them from getting out. This is by design; if we were to let the regex beasties wander throughout the language, Perl would be a total jungle. The world needs its jungles, of course—they're the engines of biodiversity, after all—but jungles should stay where they belong. Similarly, despite being the engines of combinatorial diversity, regular expressions should stay inside pattern-match operators where they belong. It's a jungle in there.

As if regular expressions weren't powerful enough, the `m//` and `s///` operators also provide the (likewise confined) power of double-quote interpolation. Since patterns are parsed like double-quoted strings, all the normal double-quote conventions will work, including variable interpolation (unless you use single quotes as the delimiter) and special characters indicated with backslash escapes. (See the section "Specific Characters" on page 199 later in this chapter.) These are applied before the string is interpreted as a regular expression. (This is one of the few places in the Perl language where a string undergoes more than one pass of processing.) The first pass is not quite normal double-quote interpolation in that it knows what it should interpolate and what it should pass on to the regular expression parser. So, for instance, any `$` immediately followed by a vertical bar, closing parenthesis, or the end of the string will be treated not as a variable interpolation, but as the traditional regex assertion meaning end-of-line. So if you say:

```
$foo = "bar";
/$foo$/;
```

the double-quote interpolation pass knows that those two `$` signs are functioning differently. It does the interpolation of `$foo`, then hands this to the regular expression parser:

```
/bar$/;
```

Another consequence of this two-pass parsing is that the ordinary Perl tokener finds the end of the regular expression first, just as if it were looking for the terminating delimiter of an ordinary string. Only after it has found the end of the string (and done any variable interpolation) is the pattern treated as a regular expression. Among other things, this means you can't "hide" the terminating delimiter of a pattern inside a regex construct (such as a bracketed character class or a regex comment, which we haven't covered yet). Perl will see the delimiter wherever it is and terminate the pattern at that point.

You should also know that interpolating variables whose values keep changing into a pattern slows down the pattern matcher, in case it has to recompile the pattern. See the section "Variable Interpolation" on page 234 later in this chapter. You can crudely suppress recompilation with the old `/o` modifier, but it's normally better to factor out the changing bits using the `qr//` construct, so that only the parts requiring recompilation have to be recompiled.

The `tr///` transliteration operator does not interpolate variables; it doesn't even use regular expressions! (In fact, it probably doesn't belong in this chapter at all, but we couldn't think of a better place to put it.) It does share one feature with `m//` and `s///`, however: it binds to variables using the `=~` and `!~` operators.

The `=~` and `!~` operators, described in Chapter 3, bind the scalar expression on their lefthand side to one of three quote-like operators on their right: `m//` for matching a pattern, `s///` for substituting some string for a substring matched by a pattern, and `tr///` (or its synonym, `y///`) for transliterating one set of characters to another set. (You may write `m//` as `//`, without the `m`, if slashes are used for the delimiter.) If the righthand side of `=~` or `!~` is none of these three, it still counts as a `m//` matching operation, but there'll be no place to put any trailing modifiers (see the next section, "Pattern Modifiers" on page 175), and you'll have to handle your own quoting:

```
say "matches" if $somestring =~ $somepattern;
```

Really, there's little reason not to spell it out explicitly:

```
say "matches" if $somestring =~ m/$somepattern/;
```

When used for a matching operation, `=~` and `!~` are sometimes pronounced "matches" and "doesn't match", respectively (although "contains" and "doesn't contain" might cause less confusion).

Apart from the `m//` and `s///` operators, regular expressions show up in two other places in Perl. The first argument to the `split` function is a special match operator specifying what *not* to return when breaking a string into multiple substrings. See the description and examples for `split` in Chapter 27. The `qr//` ("quote regex") operator also specifies a pattern via a regex, but it doesn't try to match anything (unlike `m//`, which does). Instead, the compiled form of the regex is returned for future use. See "Variable Interpolation" on page 234 for more information.

You apply one of the `m//`, `s///`, or `tr///` operators to a particular string with the `=~` binding operator (which isn't a real operator, just a kind of topicalizer, linguistically speaking). Here are some examples:

```
$haystack =~ m/needle/               # match a simple pattern
$haystack =~  /needle/               # same thing

$italiano =~ s/butter/olive oil/     # a healthy substitution

$rotate13 =~ tr/a-zA-Z/n-za-mN-ZA-M/  # easy encryption (to break)
```

Without a binding operator, `$_` is implicitly used as the "topic":

```
/new life/ and              # search in $_ and (if found)
    /new civilizations/     #    boldly search $_ again

s/sugar/aspartame/          # substitute a substitute into $_

tr/ATCG/TAGC/               # complement the DNA stranded in $_
```

Because `s///` and `tr///` change the scalar to which they're applied, you may only use them on valid lvalues:[3]

```
"onshore" =~ s/on/off/;      # WRONG: compile-time error
```

However, `m//` works on the result of any scalar expression:

```
if ((lc $magic_hat->fetch_contents->as_string) =~ /rabbit/) {
    say "Nyaa, what's up doc?";
}
else {
    say "That trick never works!";
}
```

But you have to be a wee bit careful since `=~` and `!~` have rather high precedence—in our previous example, the parentheses are necessary around the left term.[4] The `!~` binding operator works like `=~`, but it negates the logical result of the operation:

```
if ($song !~ /words/) {
    say qq/"$song" appears to be a song without words./;
}
```

Since `m//`, `s///`, and `tr///` are quote operators, you may pick your own delimiters. These work in the same way as the quoting operators `q//`, `qq//`, `qr//`, and `qw//` (see the section "Pick Your Own Quotes" on page 70 in Chapter 2).

```
$path =~ s#/tmp#/var/tmp/scratch#;

if ($dir =~ m[/bin]) {
    say "No binary directories please.";
}
```

3. Unless you use the `/r` modifier to return the mutated result as an rvalue.

4. Without the parentheses, the lower-precedence `lc` would have applied to the whole pattern match instead of just the method call on the magic hat object.

When using paired delimiters with `s///` or `tr///`, if the first part is one of the four customary ASCII bracketing pairs (angle, round, square, or curly), you may choose different delimiters for the second part than you chose for the first:

```
s(egg)<larva>;
s{larva}{pupa};
s[pupa]/imago/;
```

Whitespace is allowed in front of the opening delimiters:

```
s (egg)   <larva>;
s {larva} {pupa};
s [pupa]  /imago/;
```

Each time a pattern successfully matches, it sets the `$``, `$&`, and `$'` variables to the text left of the match, the whole match, and the text right of the match. This is useful for pulling apart strings into their components:

```
"hot cross buns" =~ /cross/;
say "Matched: <$`> $& <$'>";    # Matched: <hot > cross < buns>
say "Left:    <$`>";            # Left:    <hot >
say "Match:   <$&>";            # Match:   <cross>
say "Right:   <$'>";            # Right:   < buns>
```

For better granularity and efficiency, use parentheses to capture the particular portions that you want to keep around. Each pair of parentheses captures the substring corresponding to the *subpattern* in the parentheses. The pairs of parentheses are numbered from left to right by the positions of the left parentheses; the substrings corresponding to those subpatterns are available after the match in the numbered variables, `$1`, `$2`, `$3`, and so on:[5]

```
$_ = "Bilbo Baggins's birthday is September 22";
/(.*)'s birthday is (.*)/;
say "Person: $1";
say "Date: $2";
```

`$``, `$&`, `$'`, and the numbered variables are global variables implicitly localized to the enclosing dynamic scope. They last until the next successful pattern match or the end of the current scope, whichever comes first. More on this later, in a different scope.

Once Perl sees that you need one of `$``, `$&`, or `$'` anywhere in the program, it provides them for every pattern match. This will slow down your program a bit. Perl uses a similar mechanism to produce `$1`, `$2`, and so on, so you also pay a price for each pattern that contains capturing parentheses. (See "Grouping Without Capturing" on page 229, later in this chapter, to avoid the cost of capturing while still retaining the grouping behavior.) But if you never use `$``, `$&`, or

5. Not `$0`, though, which holds the name of your program.

`$'`, then patterns *without* capturing parentheses will not be penalized. So it's usually best to avoid `$`` , `$&`, and `$'` if you can, especially in library modules. But if you must use them once (and some algorithms really appreciate their convenience), then use them at will because you've already paid the price. `$&` is not so costly as the other two in recent versions of Perl.

A better alternative is the `/p` match modifier, discussed below. It preserves the string matched so that the `${^PREMATCH}`, `${^MATCH}`, and `${^POSTMATCH}` variables contain what `$`` , `$&`, and `$'` *would* contain, but does so without penalizing the entire program.

Pattern Modifiers

We'll discuss the individual pattern-matching operators in a moment, but first we'd like to mention another thing they all have in common, *modifiers*.

Immediately following the final delimiter of an `m//`, `s///`, `qr//`, `y///`, or `tr///` operator, you may optionally place one or more single-letter modifiers, in any order. For clarity, modifiers are usually written as "the `/i` modifier" and pronounced "the slash eye modifier", even though the final delimiter might be something other than a slash. (Sometimes people say "flag" or "option" to mean "modifier"; that's okay, too.)

Some modifiers change the behavior of the individual operator, so we'll describe those in detail later. Others change how the regex is interpreted, so we'll talk about them here. The `m//`, `s///`, and `qr//` operators[6] all accept the following modifiers after their final delimiter; see Table 5-1.

Table 5-1. Regular expression modifiers

Modifier	Meaning
`/i`	Ignore alphabetic case distinctions (case-insensitive).
`/s`	Let `.` also match newline.
`/m`	Let `^` and `$` also match next to embedded `\n`.
`/x`	Ignore (most) whitespace and permit comments in pattern.
`/o`	Compile pattern once only.
`/p`	Preserve `${^PREMATCH}`, `${^MATCH}`, and `${^POSTMATCH}` variables.
`/d`	Dual ASCII–Unicode mode charset behavior (old default).
`/a`	ASCII charset behavior.

6. The `tr///` operator does not take regexes, so these modifiers do not apply.

Modifier	Meaning
`/u`	Unicode charset behavior (new default).
`/l`	The runtime locale's charset behavior (default under *`use locale`*).

The `/i` modifier says to match a character in any possible case variation; that is, to match case-insensitively, a process also known as *casefolding*. This means to match not just uppercase and lowercase, but also titlecase characters (not used in English). Case-insensitive matching is also needed for when characters have several variants that are in the same case, like the two lowercase Greek sigmas: the lowercase of capital "`Σ`" is normally "`σ`", but becomes "`ς`" at the end of a word. For example, the Greek word *Σίσυφος* ("Sisyphus" to the rest of us) has all three sigmas in it.

Because case-insensitive matching is done according to character, not according to language,[7] it can match things whose capitalization would be considered wrong in one or another language. So `/perl/i` would not only match "`perl`" but also strings like "`proPErly`" or "`perLiter`", which aren't really correct English. Similarly, Greek /σίσυφος/i would match not just "ΣΙΣΥΦΟΣ" and "Σίσυφος", but also the malformed "ςίσυφοσ", with its outer two lowercase sigmas swapped.

That's because even though we've labelled our strings as being English or Greek, Perl doesn't really know that. It just applies its case-insensitive matching in a language-ignorant way. Because all case variants of the same letter share the same *casefold*, they all match.

Because Perl supports only 8-bit locales, locale-matching codepoints below 256 use the current locale map for determining casefolds, but larger codepoints use Unicode rules. Case-insensitive matches under locales cannot cross the 255/256 border, and other restrictions may apply.

The `/s` and `/m` modifiers don't involve anything kinky. Rather, they affect how Perl treats matches against a string that contains newlines. But they aren't about whether your string actually contains newlines; they're about whether Perl should *assume* that your string contains a single line (`/s`) or multiple lines (`/m`), because certain metacharacters work differently depending on whether they're expected to behave in a line-oriented fashion.

Ordinarily, the metacharacter "`.`" matches any one character *except* a newline, because its traditional meaning is to match characters within a line. With `/s`, however, the "`.`" metacharacter can also match a newline, because you've told

7. Well, *almost*. But we really prefer not to discuss the Turkıc İ problem, so let's just say we didn't.

Perl to ignore the fact that the string might contain multiple newlines. If you want the "not a newline" behavior under `/s`, just use `\N`, which means the same thing as `[^\n]` but is easier to type.

The `/m` modifier, on the other hand, changes the interpretation of the `^` and `$` metacharacters by letting them match next to newlines within the string instead of just at the ends of the string. (`/m` can disable optimizations that assume you are matching a single line, so don't just sprinkle it everywhere.) See the examples in the section "Positions" on page 217 later in this chapter.

The `/p` modifier preserves the text of the match itself in the special `${^MATCH}` variable, any text before the match in `${^PREMATCH}`, and any text after the match in `${^POSTMATCH}`.

The now largely obsolete `/o` modifier controls pattern recompilation. These days you need patterns more than 10k in length before this modifier has any beneficial effect, so it's something of a relic. In case you bump into it in old code, here's how it works anyway.

Unless the delimiters chosen are single quotes (`m'`*PATTERN*`'`, `s'`*PATTERN*`'`*REPLACEMENT*`'`, or `qr'`*PATTERN*`'`), any variables in the pattern are normally interpolated every time the pattern operator is evaluated. At worst, this may cause the pattern to be recompiled; at best, it costs a string comparison to see if recompilation is needed. If you want such a pattern to be compiled once and only once, use the `/o` modifier. This prevents expensive runtime recompilations; it's useful when the value you are interpolating won't change during execution. However, mentioning `/o` constitutes a promise that you won't change the variables in the pattern. If you do change them, Perl won't even notice. For better control over recompilation, use the `qr//` regex quoting operator. See "Variable Interpolation" on page 234 later in this chapter for details.

The `/x` is the *ex*pressive modifier: it allows you to *ex*ploit whitespace and *ex*planatory comments in order to *ex*pand your pattern's legibility, even *ex*tending the pattern across newline boundaries.

Er, that is to say, `/x` modifies the meaning of the whitespace characters (and the `#` character): instead of letting them do self-matching as ordinary characters do, it turns them into metacharacters that, oddly, now behave as whitespace (and comment characters) should. Hence, `/x` allows spaces, tabs, and newlines for formatting, just like regular Perl code. It also allows the `#` character, not normally special in a pattern, to introduce a comment that extends through the end of the

current line within the pattern string.[8] If you want to match a real whitespace character (or the # character), then you'll have to put it into a bracketed character class, escape it with a backslash, or encode it using an octal or hex escape. (But whitespace is normally matched with a `\s*` or `\s+` sequence, so the situation doesn't arise often in practice.)

Taken together, these features go a long way toward making traditional regular expressions a readable language. In the spirit of TMTOWTDI, there's now more than one way to write a given regular expression. In fact, there's more than two ways:

```
m/\w+:(\s+\w+)\s*\d+/;       # A word, colon, space, word, space, digits.

m/\w+: (\s+ \w+) \s* \d+/x;  # A word, colon, space, word, space, digits.

m{
    \w+:                     # Match a word and a colon.
    (                        # (begin capture group)
         \s+                 # Match one or more spaces.
         \w+                 # Match another word.
    )                        # (end capture group)
    \s*                      # Match zero or more spaces.
    \d+                      # Match some digits
}x;
```

We'll explain those new metasymbols later in the chapter. (This section was supposed to be about pattern modifiers, but we've let it get out of hand in our *ex*citement about `/x`. Ah well.) Here's a regular expression that finds duplicate words in paragraphs, stolen right out of *Perl Cookbook*. It uses the `/x` and `/i` modifiers, as well as the `/g` modifier described later.

```
# Find duplicate words in paragraphs, possibly spanning line boundaries.
#   Use /x for space and comments, /i to match both 'is'
#   in "Is is this ok?", and use /g to find all dups.
$/ = "";        # "paragrep" mode
while (<>) {
    while ( m{
                \b            # start at a word boundary
                (\w\S+)       # find a wordish chunk
                (
                    \s+       # separated by some whitespace
                    \1        # and that chunk again
                ) +           # repeat ad lib
                \b            # until another word boundary
            }xig
          )
```

8. Be careful not to include the pattern delimiter in the comment—because of its "find the end first" rule, Perl has no way of knowing you didn't intend to terminate the pattern at that point.

```
        {
            say "dup word '$1' at paragraph $.";
        }
    }
```

When run on this chapter, it produces warnings like this:

```
dup word 'that' at paragraph 150
```

As it happens, we know that that particular instance was intentional.

The `/u` modifier enables Unicode semantics for pattern matching. It is automatically set if the pattern is internally encoded in UTF-8 or was compiled within the scope of a `use feature "unicode_strings"` pragma (unless also compiled in the scope of the old `use locale` or the `use bytes` pragmas, both of which are mildly deprecated).

Under `/u`, codepoints 128–255 (that is, between 128 and 255, inclusive) take on their ISO-8859-1 (Latin-1) meanings, which are the same as Unicode's. Without `/u`, `\w` on a non-UTF-8 string matches precisely `[A-Za-z0-9_]` and nothing more. With a `/u`, using `\w` on a non-UTF-8 string also matches all Latin-1 word characters in 128–255; namely the MICRO SIGN µ, the two ordinal indicators ª and º, and the 62 Latin letters. (On UTF-8 strings, `\w` always matches all those anyway.)

The `/a` modifier changes `\d`, `\s`, `\w`, and the POSIX character classes to match codepoints within the ASCII range only.[9] These sequences normally match Unicode codepoints, not just ASCII. Under `/a`, `\d` means only the 10 ASCII digits "`0`" to "`9`", `\s` means only the 5 ASCII whitespace characters `[ \f\n\r\t]`, and `\w` means only the 63 ASCII word characters `[A-Za-z0-9_]`. (This also affects `\b` and `\B`, since they're defined in terms of `\w` transitions.) Similarly, all POSIX classes like `[[:print:]]` match ASCII characters only under `/a`.

In one regard, `/a` acts more like `/u` than you might think: it does not guarantee that ASCII characters match ASCII alone. For example, under Unicode casefolding rules, "`S`", "`s`", and "`ſ`" (U+017F LATIN SMALL LETTER LONG S) all match each other case-insensitively, as do "`K`", "`k`", and the U+212A KELVIN SIGN, "K". You can disable this fancy Unicode casefolding by doubling up the modifier, making it `/aa`.

The `/l` modifier uses the current locale's rules when pattern matching. By "current locale", we mean the one in effect when the match is executed, not whichever locale may have been in effect during its compilation. On systems that support

9. When we talk about ASCII in this platform, anyone still running on EBCDIC should make the appropriate changes in her head as she reads. Perl's online documentation discusses EBCDIC ports in more details.

it, the current locale can be changed using the `setlocale` function from the POSIX module. This modifier is the default for patterns compiled within the scope of a `"use locale"` pragma.

Perl supports single-byte locales only, not multibyte ones. This means that codepoints above 255 are treated as Unicode no matter what locale may be in effect. Under Unicode rules, case-insensitive matches can cross the single-byte boundary between 255 and 256, but these are necessarily disallowed under `/l`.

That's because under locales, the assignment of codepoints to characters is not the same as under Unicode (except for true ISO-8859-1). Therefore, the locale character 255 cannot caselessly match the character at 376, U+0178 LATIN CAPITAL LETTER Y WITH DIAERESIS (Ÿ), because 255 might not *be* U+00FF LATIN SMALL LETTER Y (ÿ) in the current locale. Perl has no way of knowing whether that character even exists in the locale, much less what its codepoint might be.

The `/u` modifier is the default if you've explicitly asked Perl to use the v5.14 feature set. If you haven't, your existing code will work as before, just as though you'd used a `/d` modifier on each pattern (or `/l` under `use locale`). This ensures backward compatibility while also providing a cleaner way to do things in the future. Traditional Perl pattern-matching behavior is dualistic; hence the name `/d`, which could also stand for "it depends". Under `/d`, Perl matches according to the platform's native character set rules *unless* there is something else indicating Unicode rules should be used. Such things include:

- Either the target string or the pattern itself is internally encoded in UTF-8
- Any codepoints above 255
- Properties specified using `\p{`*`PROP`*`}` or `\P{`*`PROP`*`}`
- Named characters, aliases, or sequences specified using `\N{`*`NAME`*`}`, or by codepoint using `\N{U+`*`HEXDIGITS`*`}`

In the absence of any declaration forcing `/u`, `/a`, or `/l` semantics, dual mode, `/d`, will be assumed. Patterns under `/d` still might have Unicode behavior—or they might not. Historically, this mixture of ASCII and Unicode semantics has caused no end of confusion, so it's no longer the default when you `use v5.14`. Or you can change to the more intuitive Unicode mode explicitly. Unicode strings can be enabled with any of:

```
use feature "unicode_strings";
use feature ":5.14";
use v5.14;
use 5.14.0;
```

Unicode strings can also be turned on using command-line options corresponding to the four pragmas given above:

```
% perl -Mfeature=unicode_strings more arguments
% perl -Mfeature=:5.14 more arguments
% perl -M5.014 more arguments
% perl -M5.14.0 more arguments
```

Because the –*E* command-line option means to use the current release's feature set, this also enables Unicode strings (in v5.14+):

```
% perl -E code to eval
```

As with most pragmas, you can also disable features on a per-scope basis, so this pragma:

```
no feature "unicode_strings";
```

disables any Unicode character-set semantics that may be declared in a surrounding lexical scope.

To make it easier to control regex behavior without adding the same pattern modifiers each time, you may now use the `re` pragma to set or clear default flags in a lexical scope.

```
# set default modifiers for all patterns
use re "/msx";    # patterns in scope have those modifiers added

# now rescind a few for an inner scope
{
    no re "/ms";  # patterns in scope have those modifiers subtracted
    ...
}
```

This is especially useful with the pattern modifiers related to charset behavior:

```
use re "/u";        # Unicode mode
use re "/d";        # dual ASCII-Unicode mode
use re "/l";        # 8-bit locale mode
use re "/a";        # ASCII mode, plus Unicode casefolding
use re "/aa";       # ASCIIer mode, without Unicode casefolding
```

With these declarations you don't have to repeat yourself to get consistent semantics, or even consistently wrong semantics.

The m// Operator (Matching)

```
m/PATTERN/modifiers
  /PATTERN/modifiers
  ?PATTERN?modifiers (deprecated)

 EXPR =~ m/PATTERN/modifiers
```

```
EXPR =~  /PATTERN/modifiers
EXPR =~  ?PATTERN?modifiers (deprecated)
```

The `m//` operator searches the string in the scalar *EXPR* for *PATTERN*. If `/` or `?` is the delimiter, the initial `m` is optional. Both `?` and `'` have special meanings as delimiters: the first is a once-only match; the second suppresses variable interpolation and the six translation escapes (`\U` and company, described later).

If *PATTERN* evaluates to a null string, either because you specified it that way using `//` or because an interpolated variable evaluated to the empty string, the last successfully executed regular expression not hidden within an inner block (or within a `split`, `grep`, or `map`) is used instead.

In scalar context, the operator returns true (`1`) if successful, false (`""`) otherwise. This form is usually seen in Boolean context:

```
if ($shire =~ m/Baggins/) { ... }  # search for Baggins in $shire
if ($shire =~ /Baggins/)  { ... }  # search for Baggins in $shire

if ( m#Baggins# )         { ... }  # search right here in $_
if ( /Baggins/ )          { ... }  # search right here in $_
```

Used in list context, `m//` returns a list of substrings matched by the capturing parentheses in the pattern (that is, `$1`, `$2`, `$3`, and so on), as described later under "Grouping and Capturing" on page 221. The numbered variables are still set even when the list is returned. If the match fails in list context, a null list is returned. If the match succeeds in list context but there were no capturing parentheses (nor `/g`), a list value of `(1)` is returned. Since it returns a null list on failure, this form of `m//` can also be used in Boolean context, but only when participating indirectly via a list assignment:

```
if (($key,$value) = /(\w+): (.*)/) { ... }
```

Valid modifiers for `m//` (in whatever guise) are shown in Table 5-2.

Table 5-2. m// modifiers

Modifier	Meaning
`/i`	Ignore alphabetic case.
`/m`	Let `^` and `$` also match next to embedded `\n`.
`/s`	Let `.` also match newline.
`/x`	Ignore (most) whitespace and permit comments in pattern.
`/o`	Compile pattern once only.
`/p`	Preserve the matched string.
`/d`	Dual ASCII–Unicode mode charset behavior (old default).

Modifier	Meaning
/u	Unicode charset behavior (new default).
/a	ASCII charset behavior.
/l	The runtime locale's charset behavior (default under *use locale*).
/g	Globally find all matches.
/cg	Allow continued search after failed /g match.

Most of these modifiers apply to the pattern and were described earlier. The last two change the behavior of the match operation itself. The /g modifier specifies global matching—that is, matching as many times as possible within the string. How it behaves depends on context. In list context, m//g returns a list of all matches found. Here we find all the places someone mentioned "perl", "Perl", "PERL", and so on:

```
if (@perls = $paragraph =~ /perl/gi) {
    printf "Perl mentioned %d times.\n", scalar @perls;
}
```

If there are no capturing parentheses within the /g pattern, then the complete matches are returned. If there are capturing parentheses, then only the strings captured are returned. Imagine a string like:

```
$string = "password=xyzzy verbose=9 score=0";
```

Also imagine you want to use that to initialize a hash, like this:

```
%hash = (password => "xyzzy", verbose => 9, score => 0);
```

Except, of course, you don't have a list—you have a string. To get the corresponding list, you can use the m//g operator in list context to capture all of the key/value pairs from the string:

```
%hash = $string =~ /(\w+)=(\w+)/g;
```

The (\w+) sequence captures an alphanumeric word. See the upcoming section "Grouping and Capturing" on page 221.

Used in scalar context, the /g modifier indicates a *progressive match*, which makes Perl start the next match on the same variable at a position just past where the last one stopped. The \G assertion represents that position in the string; see "Positions" on page 217, later in this chapter, for a description of \G. If you use the /c (for "continue") modifier in addition to /g, then when the /g runs out, the failed match doesn't reset the position pointer.

If a ? is the delimiter, as in m?*PATTERN*? (or ?*PATTERN*?, but the version without the m is deprecated), this works just like a normal /*PATTERN*/ search, except that it

matches only once between calls to the `reset` operator. This can be a convenient optimization when you want to match only the first occurrence of the pattern during the run of the program, not all occurrences. The operator runs the search every time you call it, up until it finally matches something, after which it turns itself off, returning false until you explicitly turn it back on with `reset`. Perl keeps track of the match state for you.

The `m??` operator is most useful when an ordinary pattern match would find the last rather than the first occurrence:

```
open(DICT, "/usr/dict/words")   or die "Can't open words: $!\n";
while (<DICT>) {
    $first = $1 if m? (^ neur .* ) ?x;
    $last  = $1 if m/ (^ neur .* ) /x;
}
say $first;          # prints "neurad"
say $last;           # prints "neurypnology"
```

The `reset` operator will reset only those instances of `??` compiled in the same package as the call to `reset`. Saying `m??` is equivalent to saying `??`.

The s/// Operator (Substitution)

```
s/PATTERN/REPLACEMENT/modifiers

 LVALUE =~ s/PATTERN/REPLACEMENT/modifiers
 RVALUE =~ s/PATTERN/REPLACEMENT/rmodifiers
```

This operator searches a string for *`PATTERN`* and, if found, replaces the matched substring with the *`REPLACEMENT`* text. If *`PATTERN`* is a null string, the last successfully executed regular expression is used instead.

```
$lotr = $hobbit;           # Just copy The Hobbit
$lotr =~ s/Bilbo/Frodo/g;  #   and write a sequel the easy way.
```

If the `/r` modifier is used, the return value of an `s///` operation is the result string, and the target string is left unchanged. Without the `/r` modifier, the return value of an `s///` operation (in scalar and list context alike) is the number of times it succeeded—which can be more than once if used with the `/g` modifier, as described earlier. On failure, since it substituted zero times, it returns false (`""`), which is numerically equivalent to `0`.[10]

```
if ($lotr =~ s/Bilbo/Frodo/) { say "Successfully wrote sequel." }
$change_count = $lotr =~ s/Bilbo/Frodo/g;
```

10. As with the `m//` operator and many of the more traditional operators described in Chapter 3, this is the special false value that can be safely used as the number. This is because, unlike a normal null string, this one is exempt from numeric warnings if implicitly converted to a number.

Normally, everything matched by the *PATTERN* is discarded on each substitution, but you can "keep" part of that by including `\K` in your pattern:

```
$tales_of_Rohan =~ s/Éo\Kmer/wyn/g; # rewriting history
```

The replacement portion is treated as a double-quoted string. You may use any of the dynamically scoped pattern variables described earlier (`$``, `$&`, `$'`, `$1`, `$2`, and so on) in the replacement string, as well as any other double-quote gizmos you care to employ. For instance, here's an example that finds all the strings "`revision`", "`version`", or "`release`", and replaces each with its capitalized equivalent, using the `\u` escape in the replacement portion:

```
s/revision|version|release/\u$&/g;  # Use | to mean "or" in a pattern
```

All scalar variables expand in double-quote context, not just these strange ones. Suppose you had a `%Names` hash that mapped revision numbers to internal project names; for example, `$Names{"3.0"}` might be code named "`Isengard`". You could use `s///` to find version numbers and replace them with their corresponding project names:

```
s/version ([0-9.]+)/the $Names{$1} release/g;
```

In the replacement string, `$1` returns what the first (and only) pair of parentheses captured. (You could use also `\1` as you would in the pattern, but that usage is deprecated in the replacement. In an ordinary double-quoted string, `\1` means a Control-A.)

Both *PATTERN* and *REPLACEMENT* are subject to variable interpolation, but a *PATTERN* is interpolated each time the `s///` operator is evaluated as a whole, while the *REPLACEMENT* is interpolated every time the pattern matches. (The *PATTERN* can match multiple times in one evaluation if you use the `/g` modifier.)

As before, most of the modifiers in Table 5-3 alter the behavior of the regex; they're the same as in `m//` and `qr//`. The last three alter the substitution operator itself.

Table 5-3. s/// modifiers

Modifier	Meaning
`/i`	Ignore alphabetic case (when matching).
`/m`	Let `^` and `$` also match next to embedded `\n`.
`/s`	Let `.` also match newline.
`/x`	Ignore (most) whitespace and permit comments in pattern.
`/o`	Compile pattern once only.
`/p`	Preserve the matched string.
`/d`	Dual ASCII–Unicode mode charset behavior (old default).

Modifier	Meaning
`/u`	Unicode charset behavior (new default).
`/a`	ASCII charset behavior.
`/l`	The runtime locale's charset behavior (default under *`use locale`*).
`/g`	Replace globally; that is, all occurrences.
`/r`	Return substitution and leave the original string untouched.
`/e`	Evaluate the right side as an expression.

The `/g` modifier is used with `s///` to replace every match of *`PATTERN`* with the *`REPLACEMENT`* value, not just the first one found. A `s///g` operator acts as a global search and replace, making all the changes at once, even in scalar context (unlike `m//g`, which is progressive).

The `/r` (nondestructive) modifier applies the substitution to a new copy of the string, which now no longer needs to be a variable. It returns the copy whether or not a substitution occurred; the original string always remains unchanged:

```
say "Déagol's ring!" =~ s/D/Sm/r;  # prints "Sméagol's ring!"
```

The copy will always be a plain string, even if the input is an object or a tied variable. This modifier first appeared in production release v5.14.

The `/e` modifier treats the *`REPLACEMENT`* as a chunk of Perl code rather than as an interpolated string. The result of executing that code is used as the replacement string. For example, `s/([0-9]+)/sprintf("%#x", $1)/ge` would convert all numbers into hexadecimal, changing, for example, `2581` into `0xb23`. Or suppose that, in our earlier example, you weren't sure that you had names for all the versions, so you wanted to leave any others unchanged. With a little creative `/x` formatting, you could say:

```
s{
    version
    \s+
    (
        [0-9.]+
    )
}{
    $Names{$1}
        ? "the $Names{$1} release"
        : $&
}xge;
```

The righthand side of your `s///e` (or, in this case, the lowerhand side) is syntax checked and compiled at compile time along with the rest of your program. Any syntax error is detected during compilation, and runtime exceptions are left un-

caught. Each additional `/e` after the first one (like `/ee`, `/eee`, and so on) is equivalent to calling `eval` *`STRING`* on the result of the code, once per extra `/e`. This evaluates the result of the code expression and traps exceptions in the special `$@` variable. See "Programmatic Patterns" on page 251, later in this chapter, for more details.

Modifying strings en passant

Sometimes you want a new, modified string without clobbering the old one upon which the new one was based. Instead of writing:

```
$lotr = $hobbit;
$lotr =~ s/Bilbo/Frodo/g;
```

you can combine these into one statement. Due to precedence, parentheses are required around the assignment, as they are with most combinations applying `=~` to an expression.

```
($lotr = $hobbit) =~ s/Bilbo/Frodo/g;
```

Without the parentheses around the assignment, you'd only change `$hobbit` and get the number of replacements stored into `$lotr`, which would make a rather dull sequel.

And, yes, in newer code you can just use `/r` instead:

```
$lotr = $hobbit =~ s/Bilbo/Frodo/gr;
```

But many Perlfolk still use the older idiom.

Modifying arrays en masse

You can't use a `s///` operator directly on an array. For that, you need a loop. By a lucky coincidence, the aliasing behavior of `for`/`foreach`, combined with its use of `$_` as the default loop variable, yields the standard Perl idiom to search and replace each element in an array:

```
for (@chapters) { s/Bilbo/Frodo/g }  # Do substitutions chapter by chapter.
s/Bilbo/Frodo/g for @chapters;       # Same thing.
```

As with a simple scalar variable, you can combine the substitution with an assignment if you'd like to keep the original values around, too:

```
@oldhues = ("bluebird", "bluegrass",  "bluefish", "the blues");
for (@newhues = @oldhues) { s/blue/red/ }
say "@newhues";           # prints: redbird redgrass redfish the reds
```

Another way to do the same thing is to combine the `/r` substitution modifier (new to v5.14) with a `map` operation:

```
@newhues = map { s/blue/red/r } @oldhues;
```

The idiomatic way to perform repeated substitutes on the same variable is to use a once-through loop. For example, here's how to canonicalize whitespace in a variable:

```
for ($string) {
    s/^\s+//;       # discard leading whitespace
    s/\s+$//;       # discard trailing whitespace
    s/\s+/ /g;      # collapse internal whitespace
}
```

which just happens to produce the same result as:

```
$string = join(" ", split " ", $string);
```

You can also use such a loop with an assignment, as we did in the array case:

```
for ($newshow = $oldshow) {
    s/Fred/Homer/g;
    s/Wilma/Marge/g;
    s/Pebbles/Lisa/g;
    s/Dino/Bart/g;
}
```

When a global substitution just isn't global enough

Occasionally, you can't just use a `/g` to get all the changes to occur, either because the substitutions overlap or have to happen right to left, or because you need the length of `$`` to change between matches. You can usually do what you want by calling `s///` repeatedly. However, you want the loop to stop when the `s///` finally fails, so you have to put it into the conditional, which leaves nothing to do in the main part of the loop. So we just write a `1`, which is a rather boring thing to do, but bored is the best you can hope for sometimes. Here are some examples that use a few more of those odd regex beasties that keep popping up:

```
# put commas in the right places in an integer
1 while s/(\d)(\d\d\d)(?!\d)/$1,$2/;

# expand tabs to 8-column spacing
1 while s/\t+/" " x (length($&)*8 - length($`)%8)/e;

# remove (nested (even deeply nested (like this))) remarks
1 while s/\([^()]*\)//g;

# remove duplicate words (and triplicate (and quadruplicate...))
1 while s/\b(\w+) \1\b/$1/gi;
```

That last one needs a loop because otherwise it would turn this:

```
Paris in THE THE THE THE spring.
```

into this:

```
Paris in THE THE spring.
```

which might cause someone who knows a little French to picture Paris sitting in an artesian well emitting iced tea, since "thé" is French for "tea". A Parisian is never fooled, of course.

The tr/// Operator (Transliteration)

```
tr/SEARCHLIST/REPLACEMENTLIST/cdsr

 LVALUE =~ tr/SEARCHLIST/REPLACEMENTLIST/cds
 RVALUE =~ tr/SEARCHLIST/REPLACEMENTLIST/cdsr
 RVALUE =~ tr/SEARCHLIST//c
```

For *sed* devotees, `y///` is provided as a synonym for `tr///`. This is why you can't call a function named `y`, any more than you can call a function named `q` or `m`. In all other respects, `y///` is identical to `tr///`, and we won't mention it again.

This operator might not appear to fit into a chapter on pattern matching since it doesn't use patterns. This operator scans a string, character by character, and replaces each occurrence of a character found in *`SEARCHLIST`* (which is not a regular expression) with the corresponding character from *`REPLACEMENTLIST`* (which is not a replacement string). It looks a bit like `m//` and `s///`, though, and you can even use the `=~` or `!~` binding operators on it, so we describe it here. (`qr//` and `split` are pattern-matching operators, but you don't use the binding operators on them, so they're elsewhere in the book. Go figure.)

Transliteration returns the number of characters replaced or deleted. If no string is specified via the `=~` or `!~` operator, the `$_` string is altered. The *`SEARCHLIST`* and *`REPLACEMENTLIST`* may define ranges of sequential characters with a dash:

```
$message =~ tr/A-Za-z/N-ZA-Mn-za-m/;    # rot13 encryption.
```

Note that a range like `A-Z` assumes a linear character set like ASCII. But each character set has its own ideas of how characters are ordered and thus of which characters fall in a particular range. A sound principle is to use only ranges that begin from and end at either alphabetics of equal case (`a-e`, `A-E`), or digits (`0-4`). Anything else is suspect. When in doubt, spell out the character sets in full: `ABCDE`. Even something as easy as `[A-E]` fails, but `[ABCDE]` works because the Latin small capital letters' codepoints are scattered all over the place; see Table 5-4.

Table 5-4. Small capitals and their codepoints

Glyph	Code	Category	Script	Name
ᴀ	U+1D00	GC=Ll	SC=Latin	LATIN LETTER SMALL CAPITAL A
ʙ	U+0299	GC=Ll	SC=Latin	LATIN LETTER SMALL CAPITAL B
ᴄ	U+1D04	GC=Ll	SC=Latin	LATIN LETTER SMALL CAPITAL C
ᴅ	U+1D05	GC=Ll	SC=Latin	LATIN LETTER SMALL CAPITAL D
ᴇ	U+1D07	GC=Ll	SC=Latin	LATIN LETTER SMALL CAPITAL E

The *SEARCHLIST* and *REPLACEMENTLIST* are not variable interpolated as double-quoted strings; you may, however, use those backslash sequences that map to a specific character, such as `\n` or `\015`.

Table 5-5 lists the modifiers applicable to the `tr///` operator. They're completely different from those you apply to `m//`, `s///`, or `qr//`, even if some look the same.

Table 5-5. tr/// modifiers

Modifier	Meaning
`/c`	Complement *SEARCHLIST*.
`/d`	Delete found but unreplaced characters.
`/s`	Squash duplicate replaced characters.
`/r`	Return transliteration and leave the original string untouched.

If the `/r` modifier is used, the transliteration is on a new copy of the string, which is returned. It need not be an *LVALUE*.

```
say "Drogo" =~ tr/Dg/Fd/r;   # Drogo -> Frodo
```

If the `/c` modifier is specified, the character set in *SEARCHLIST* is complemented; that is, the effective search list consists of all the characters *not* in *SEARCHLIST*. In the case of Unicode, this can represent a *lot* of characters, but since they're stored logically, not physically, you don't need to worry about running out of memory.

The `/d` modifier turns `tr///` into what might be called the "transobliteration" operator: any characters specified by *SEARCHLIST* but not given a replacement in *REPLACEMENTLIST* are deleted. (This is slightly more flexible than the `-d` behavior of some *tr*(1) programs, which delete anything they find in *SEARCHLIST*, period.)

If the `/s` modifier is specified, sequences of characters converted to the same character are squashed down to a single instance of the character.

If the /d modifier is used, *REPLACEMENTLIST* is always interpreted exactly as specified. Otherwise, if *REPLACEMENTLIST* is shorter than *SEARCHLIST*, the final character is replicated until it is long enough. If *REPLACEMENTLIST* is null, the *SEARCHLIST* is replicated, which is surprisingly useful if you just want to count characters, not change them. It's also useful for squashing characters using /s. If you're only counting characters, you may use any *RVALUE*, not just an *LVALUE*.

```
tr/aeiou/!/;                # change any vowel into !
tr{/\\\r\n\b\f. }{_};       # change strange chars into an underscore

$count = ($para =~ tr/\n//); # count the newlines in $para
$count = tr/0-9//;           # count the digits in $_

tr/@$%*//d;                  # delete any of those

# change en passant
($HOST = $host) =~ tr/a-z/A-Z/;

# same end result, but as an rvalue
$HOST = ($host =~ tr/a-z/A-Z/r);

$pathname =~ tr/a-zA-Z/_/cs; # change all but ASCII alphas
                             # to single underbar
```

If the same character occurs more than once in *SEARCHLIST*, only the first is used. Therefore, this:

```
tr/AAA/XYZ/
```

will change any single character A to an X (in $_).

Although variables aren't interpolated into tr///, you can still get the same effect by using eval *EXPR*:

```
$count = eval "tr/$oldlist/$newlist/";
die if $@;  # propagates exception from illegal eval contents
```

One more note: if you want to change your text to uppercase or lowercase, don't use tr///. Use the \U or \L sequences in a double-quoted string (or the equivalent uc and lc functions) since they will pay attention to locale or Unicode information and tr/a-z/A-Z/ won't. Additionally, in Unicode strings, the \u sequence and its corresponding ucfirst function understand the notion of titlecase, which for some characters may be distinct from simply converting to uppercase.

The `\F` sequence corresponds to the `fc` function; see the `fc` description in Chapter 27. New to v5.16, these are used for simple case-insensitive comparisons, as in `"\F$a" eq "\F$b"` or the equivalent `fc($a) eq fc($b)`. The `/i` modifier has always used casefolding internally for case-insensitive matching; `\F` and `fc` now provide easier access. See also "Comparing and Sorting Unicode Text" on page 297 in Chapter 6.

Metacharacters and Metasymbols

Now that we've admired all the fancy cages, we can go back to looking at the critters in the cages—those funny-looking symbols you put inside the patterns. By now you'll have cottoned to the fact that these symbols aren't regular Perl code like function calls or arithmetic operators. Regular expressions are their own little language nestled inside of Perl. (There's a bit of the jungle in all of us.)

For all their power and expressivity, patterns in Perl recognize the same 12 traditional metacharacters (the Dirty Dozen, as it were) found in many other regular expression packages:

```
\ | ( ) [ { ^ $ * + ? .
```

Some of those bend the rules, making otherwise normal characters that follow them special. We don't like to call the longer sequences "characters", so when they make longer sequences, we call them *metasymbols* (or sometimes just "symbols"). But at the top level, those 12 metacharacters are all you (and Perl) need to think about. Everything else proceeds from there.

Some simple metacharacters stand by themselves, like `.` and `^` and `$`. They don't directly affect anything around them. Some metacharacters work like prefix operators, governing what follows them, like `\`. Others work like postfix operators, governing what immediately precedes them, like `*`, `+`, and `?`. One metacharacter, `|`, acts like an infix operator, standing between the operands it governs. There are even bracketing metacharacters that work like circumfix operators, governing something contained inside them, like `(...)` and `[...]`. Parentheses are particularly important, because they specify the bounds of `|` on the inside, and of `*`, `+`, and `?` on the outside.

If you learn only one of the 12 metacharacters, choose the backslash. (Er...and the parentheses.) That's because backslash disables the others. When a backslash precedes a nonalphanumeric character in a Perl pattern, it always makes that next character a literal. If you need to match one of the 12 metacharacters in a pattern literally, you write them with a backslash in front. Thus, `\.` matches a real dot, `\$` a real dollar sign, `\\` a real backslash, and so on. This is known as

"escaping" the metacharacter, or "quoting it", or sometimes just "backslashing" it. (Of course, you already know that backslash is used to suppress variable interpolation in double-quoted strings.)

Although a backslash turns a metacharacter into a literal character, its effect upon a following alphanumeric character goes the other direction. It takes something that was regular and makes it special. That is, together they make a metasymbol. An alphabetical list of these metasymbols can be found below in Table 5-3.

Metasymbol Tables

In the following tables, the Atomic column says "yes" if the given metasymbol is quantifiable (if it can match something with width, more or less). Also, we've used "`...`" to represent "something else". (Please see the later discussion to find out what "`...`" means, if it is not clear from the one-line gloss in the table.)

Table 5-6 shows the basic traditional metasymbols. The first four of these are the structural metasymbols we mentioned earlier, while the last three are simple metacharacters. The `.` metacharacter is an example of an atom because it matches something with width (the width of a character, in this case); `^` and `$` are examples of assertions, because they match something of zero width, and because they are only evaluated to see whether they're true.

Table 5-6. General regex metacharacters

Symbol	Atomic	Meaning
`\...`	Varies	(De)meta next (non)alphanumeric character alphanumeric character (maybe)
`...|...`	No	Alternation (match one or the other)
`(...)`	Yes	Grouping (treat as a unit)
`[...]`	Yes	Character class (match one character from a set)
`^`	No	True at beginning of string (or after any newline, maybe)
`.`	Yes	Match one character (except newline, normally)
`$`	No	True at end of string (or before any newline, maybe)

The quantifiers, which are further described in their own section, indicate how many times the preceding atom (that is, single character or grouping) should match. These are listed in Table 5-7.

Table 5-7. Regex quantifiers

Maximal	Minimal	Possessive	Allowed Range
{*MIN*,*MAX*}	{*MIN*,*MAX*}?	{*MIN*,*MAX*}?+	Must occur at least *MIN* times but no more than *MAX* times
{*MIN*,}	{*MIN*,}?	{*MIN*,}?+	Must occur at least *MIN* times
{*COUNT*}	{*COUNT*}?	{*COUNT*}?+	Must match exactly *COUNT* times
*	*?	*+	0 or more times (same as {0,})
+	+?	++	1 or more times (same as {1,})
?	??	?+	0 or 1 time (same as {0,1})

A minimal quantifier tries to match as *few* characters as possible within its allowed range. A maximal quantifier tries to match as *many* characters as possible within its allowed range.

For instance, `.+` is guaranteed to match at least one character of the string, but it will match all of them given the opportunity. The opportunities are discussed later in this chapter in "The Little Engine That /Could(n't)?/" on page 241.

A possessive quantifier is just like a maximal one, except under backtracking, during which it never gives up anything it's already grabbed, whereas minimal and maximal quantifiers can change how much they match during backtracking.

You'll note that quantifiers may never be quantified. Things like `??` and `++` are quantifiers in their own right, respectively minimal and possessive, not a normal one-character quantifier that has itself been quantified. One can only quantify a thing marked atomic, and the quantifiers are not atoms.

We wanted to provide an extensible syntax for new kinds of metasymbols. Given that we only had a dozen metacharacters to work with, we chose a formerly illegal regex sequence to use for arbitrary syntactic extensions. Except for the last one, these metasymbols are all of the form `(?`*KEY*`...)`; that is, a (balanced) parenthesis followed by a question mark, followed by a *KEY* and the rest of the subpattern. The *KEY* character indicates which particular regex extension it is. See Table 5-8 for a list of these. Most of them behave structurally since they're based on parentheses, but they also have additional meanings. Again, only atoms may be quantified because they represent something that's really there (potentially).

Table 5-8. Extended regex sequences

Extension	Atomic	Meaning
`(?#...)`	No	Comment, discard.
`(?:...)`	Yes	Noncapturing group.
`(?>...)`	Yes	Possessive group, no capturing or backtracking.
`(?adlupimsx-imsx)`	No	Enable/disable pattern modifiers.
`(?^alupimsx)`	No	Reset and enable pattern modifiers.
`(?adlupimsx-imsx:...)`	Yes	Group-only parentheses plus enable/disable modifiers.
`(?^alupimsx:...)`	Yes	Group-only parentheses plus reset and enable modifiers.
`(?=...)`	No	True if lookahead assertion succeeds.
`(?!...)`	No	True if lookahead assertion fails.
`(?<=...)`	No	True if lookbehind assertion succeeds.
`(?<!...)`	No	True if lookbehind assertion fails.
`(?|...|...|...)`	Yes	Branch reset for numbered groups.
`(?<NAME>...)`	Yes	Named capture group; also `(?'NAME'...)`. See `\k<NAME>` below.
`(?{...})`	No	Execute embedded Perl code.
`(??{...})`	Yes	Match regex from embedded Perl code.
`(?NUMBER)`	Yes	Call the independent subexpression in group *NUMBER*; also `(?+NUMBER)`, `(?-NUMBER)`, `(?0)`, and `(?R)`. Make sure *not* to use an ampersand here.
`(?&NAME)`	Yes	Recurse on group *NAME*; make sure you *do* use an ampersand here. Also `(?P>NAME)`.
`(?(COND)...|...)`	Yes	Match with if-then-else pattern.
`(?(COND)...)`	Yes	Match with if-then pattern.
`(?(DEFINE)...)`	No	Define named groups for later "regex subroutine" invocation as `(?&NAME)`.
`(*VERB)`	No	Backtracking control verb; also `(*VERB:NAME)`.

Backtracking control verbs are still highly experimental and so are not discussed here. Nevertheless, you may run into them from time to time if you're meddling in the affairs of wizards. So please check the *perlre* manpage if you see any of these:

```
(*ACCEPT)
(*COMMIT)
(*FAIL)       (*F)
(*MARK:NAME)  (*:NAME)
(*PRUNE)      (*PRUNE:NAME)
(*SKIP)       (*SKIP:NAME)
(*THEN)       (*THEN:NAME)
```

Or just run like heck.

And, finally, Table 5-9 shows all of your favorite alphanumeric metasymbols. (Symbols that are processed by the variable interpolation pass are marked with a dash in the Atomic column, since the Engine never even sees them.)

Table 5-9. Alphanumeric regex metasymbols

Symbol	Atomic	Meaning
`\0`	Yes	Match character number zero (U+0000, NULL, NUL).
`\` *NNN*	Yes	Match the character given in octal, up to `\377`.
`\` *n*	Yes	Match n^{th} capture group (decimal).
`\a`	Yes	Match the alert character (ALERT, BEL).
`\A`	No	True at the beginning of a string.
`\b`	Yes	Match the backspace char (BACKSPACE, BS) (only in char class).
`\b`	No	True at word boundary.
`\B`	No	True when not at word boundary.
`\c` *X*	Yes	Match the control character Control-*X* (`\cZ`, `\c[`, etc.).
`\C`	Yes	Match one byte (C `char`) even in UTF-8 (dangerous!).
`\d`	Yes	Match any digit character.
`\D`	Yes	Match any nondigit character.
`\e`	Yes	Match the escape character (ESCAPE, ESC, not backslash).
`\E`	—	End case (`\F`, `\L`, `\U`) or quotemeta (`\Q`) translation.
`\f`	Yes	Match the form feed character (FORM FEED, FF).
`\F`	—	Foldcase (not lowercase) until `\E`.[a]
`\g{`*GROUP*`}`	Yes	Match the named or numbered capture group.
`\G`	No	True at end-of-match position of prior `m//g`.
`\h`	Yes	Match any horizontal whitespace character.
`\H`	Yes	Match any character except horizontal whitespace.
`\k<`*GROUP*`>`	Yes	Match the named capture group; also `\k'`*NAME*`'`.
`\K`	No	Keep text to the left of `\K` out of match.

Symbol	Atomic	Meaning
\l	—	Lowercase (not foldcase) next character only.
\L	—	Lowercase (not foldcase) until \E.
\n	Yes	Match the newline character (usually LINE FEED, LF).
\N	Yes	Match any character except newline.
\N{*NAME*}	Yes	Match the named character, alias, or sequence, like \N{greek:Sigma} for "Σ".
\o{*NNNN*}	Yes	Match the character give in octal.
\p{*PROP*}	Yes	Match any character with the named property.
\P{*PROP*}	Yes	Match any character without the named property.
\Q	—	Quote (de-meta) metacharacters until \E.
\r	Yes	Match the return character (usually CARRIAGE RETURN, CR).
\R	Yes	Match any linebreak grapheme (not in char classes).
\s	Yes	Match any whitespace character.
\S	Yes	Match any nonwhitespace character.
\t	Yes	Match the tab character (CHARACTER TABULATION, HT).
\u	—	Titlecase (not uppercase) next character only.
\U	—	Uppercase (not titlecase) until \E.
\v	Yes	Match any vertical whitespace character.
\V	Yes	Match any character except vertical whitespace.
\w	Yes	Match any "word" character (alphabetics, digits, combining marks, and connector punctuation).
\W	Yes	Match any nonword character.
\x{*abcd*}	Yes	Match the character given in hexadecimal.
\X	Yes	Match grapheme (not in char classes).
\z	No	True at end of string only.
\Z	No	True at end of string or before optional newline.

[a] \F and the corresponding fc function are new to v5.16.

The braces are optional on \p and \P if the property name is one character. The braces are optional on \x if the hexadecimal number is two digits or less. Leaving the braces off \N means a non-newline instead of a named character. The braces are optional on \g if the referenced capture group is numeric (but please use them anyway).

The `\R` matches either a CARRIAGE RETURN followed by a LINE FEED (possessively), or else any one vertical whitespace character. It is equivalent to `(?>\r\n|\v)`. The possessive group means that `"\r\n" =~ /\R\n/` can never match; once it's seen the two-character CRLF, it will never later change that to just the CARRIAGE RETURN alone, even if something later in the pattern needs the LINE FEED for the overall pattern to succeed.

Only metasymbols with "Match the..." or "Match any..." descriptions may be used within character classes (square brackets), and then only if they match one character, so `\R` and `\X` are not allowed. That is, character classes can only match one character at a time, so they are limited to containing specific sets of single characters; within them you may only use metasymbols that describe other specific sets of single characters, or that describe specific individual characters. Of course, these metasymbols may also be used outside character classes, along with all the other nonclassificatory metasymbols. But note that `\b` is two entirely different beasties: it's the backspace character inside a character class, but a word boundary assertion outside.

The `\K` (mnemonic: "Keep" what you've already matched) does not match anything. Rather, it tells the engine to reset anything it's treasuring up as part of the match proper, like the `$&` or `${^MATCH}` variables, or of the lefthand side of a substitution. See the examples in the `s///` operator.

There is some amount of overlap between the characters that a pattern can match and the characters an ordinary double-quoted string can interpolate. Since regexes undergo two passes, it is sometimes ambiguous which pass should process a given character. When there is ambiguity, the variable interpolation pass defers the interpretation of such characters to the regular expression parser.

But the variable interpolation pass can only defer to the regex parser when it knows it is parsing a regex. You can specify regular expressions as ordinary double-quoted strings, but then you must follow normal double-quote rules. Any of the previous metasymbols that happen to map to actual characters will still work, even though they're not being deferred to the regex parser. But you can't use any of the other metasymbols in ordinary double quotes (or indeed in any double-quote context such as `` `...` ``, `qq(...)`, `qx(...)`, or an interpolative here document). If you want your string to be parsed as a regular expression without doing any matching (yet), you should be using the `qr//` (quote regex) operator.

On the other hand, the case and quotemeta translation escapes (`\U` and friends) *must* be processed during the variable interpolation pass because the very purpose of those metasymbols is to influence how variables are interpolated. If you suppress variable interpolation with single quotes, you won't get the translation

escapes either. Neither variables nor translation escapes (`\U`, etc.) are expanded in any single-quoted string, nor in single-quoted `m'...'` or `qr'...'` operators. Even when you do interpolation, these translation escapes are ignored if they show up as the *result* of variable interpolation, since by then it's too late to influence variable interpolation.

Although the transliteration operator doesn't take regular expressions, any metasymbol we've discussed that matches a single specific character also works in a `tr///` operation. The rest do not (except for backslash, which continues to work in the backward way it always works).

Specific Characters

As mentioned before, everything that's not special in a pattern matches itself. That means an `/a/` matches an "`a`", an `/=/` matches an "`=`", and so on. Some characters, though, aren't very easy to type in—and even if you manage that, they'll just mess up your screen formatting. (If you're lucky. Control characters are notorious for being out-of-control.) To fix that, regexes recognize the double-quotish character aliases listed in Table 5-10.

Table 5-10. Double-quotish character aliases

Escape	Meaning
`\0`	Null character (NUL, NULL)
`\a`	Alarm (BEL, ALERT)
`\e`	Escape (ESC, ESCAPE)
`\f`	Form feed (FF, FORM FEED)
`\n`	Newline (LF, LINE FEED)
`\r`	Return (CR, CARRIAGE RETURN)
`\t`	Tab (HT, HORIZONTAL TAB)

Just as in double-quoted strings, patterns also honor the following five metasymbols:

`\c`*`X`*
: A named ASCII control character, like `\cC` for Control-C, `\cZ` for Control-Z, `\c[` for ESC, and `\c?` for DEL. The resulting ordinal must be 0–31 or 127.

`\`*`NNN`*
: A character specified using its two- or three-digit octal code. The leading `0` is optional, except for values less than `010` (8 decimal) since (unlike in double-quoted strings) the single-digit versions are always considered to be

references to strings captured by that numbered capture group within a pattern. Multiple digits are interpreted as the *n*th reference if you've captured at least *n* substrings earlier in the pattern (where *n* is considered as a decimal number). Otherwise, they are interpreted as a character specified in octal.

`\x{`*`HEXDIGITS`*`}`
: A codepoint (character number) specified as one or two hex digits (`[0-9a-fA-F]`), as in `\x1B`. The one-digit form is usable only if the character following it is not a hex digit. If braces are used, you may use as many digits as you'd like. For example, `\x{262f}` matches a Unicode U+262F YIN YANG (☯).

`\N{`*`NAME`*`}`
: A named character, alias, or sequence, such as `\N{GREEK SMALL LETTER EPSILON}`, `\N{greek:epsilon}`, or `\N{epsilon}`. This requires the `charnames` pragma described in Chapter 29, which also determines which flavors of those names you may use (`":full"` corresponding to the first style just shown, and `":short"` corresponding to the other two).

  You may also specify the character using the `\N{U+`*`NUMBER`*`}` notation. For example, `\N{U+263B}` means ☻, the BLACK SMILING FACE character. This usage does not require the `charnames` pragma.

  A list of all Unicode character names can be found in your closest Unicode standards document, or generated by iterating through `charnames::viacode(`*`N`*`)` for *`N`* running from `0` through `0x10_FFFF`, remembering to skip the surrogates.

`\o{`*`NUMBER`*`}`
: A character specified using its octal code. Unlike the ambiguous `\`*`NNN`* notation, this can be any number of octal digits and will never be confused for a capture reference.

Wildcard Metasymbols

Three special metasymbols serve as generic wildcards, each of them matching "any" character (for certain values of "any"). These are the dot ("`.`"), `\C`, and `\X`. None of these may be used in a bracketed character class. You can't use the dot there because it would match (nearly) any character in existence, so it's something of a universal character class in its own right. If you're going to include or exclude everything, there's not much point in having a bracketed character class. The special wildcards `\C` and `\X` have special structural meanings that don't map well to the notion of choosing a single Unicode character, which is the level at which bracketed character classes work.

The dot metacharacter matches any one character other than a newline. (And with the `/s` modifier, it matches that, too. In which case use `\N` to match a non-newline.) Like any of the dozen special characters in a pattern, to match a dot literally, you must escape it with a backslash. For example, this checks whether a filename ends with a dot followed by a one-character extension:

```
if ($pathname =~ /\.(.)\z/s) {
    say "Ends in $1";
}
```

The first dot, the escaped one, is the literal character, and the second says "match any character". The `\z` says to match only at the end of the string, and the `/s` modifier lets the dot match a newline as well. (Yes, using a newline as a file extension Isn't Very Nice, but that doesn't mean it can't happen.)

The dot metacharacter is most often used with a quantifier. A `.*` matches a maximal number of characters, while a `.*?` matches a minimal number of characters. But it's also sometimes used without a quantifier for its width: `/(..):(..):(..)/` matches three colon-separated fields, each of which is two characters long.

Do not confuse characters with bytes. Back in the day, dot only matched a single byte, but now it matches Unicode characters, many of which cannot be encoded in a single byte:

```
use charnames qw[ :full ];
$BWV[887] = "G\N{MUSIC SHARP SIGN} minor";
my ($note, $black, $mode) = $BWV[887] =~ /^([A-G])(.)\s+(\S+)/;
say "That's lookin' sharp!" if $black eq chr 0x266f;  # ♯
```

The `\X` metasymbol matches a character in a more extended sense. It matches a string of one or more Unicode characters known as a "grapheme cluster". It's meant to grab several characters in a row that together represent a single glyph to the user. Typically it's a base character followed by combining diacritics like cedillas or diaereses that combine with that base character to form one logical unit. It can also be any Unicode linebreak sequence including `"\r\n"`, and, because one doesn't apply marks to linebreaks, it can even be a lone mark at the start of the string or line.

Perl's original `\X` worked mostly like `(?\PM\pM*)>`, but that doesn't work out so well, so Unicode refined its notion of grapheme clusters. The exact definition is complicated, but this is close enough:

```
(?> \R
  | \p{Grapheme_Base}   \p{Grapheme_Extend}*
  | \p{Grapheme_Extend}
)
```

The point is that `\X` matches one user-visible character (grapheme), even if it takes several programmer-visible characters (codepoints) to do so. The length of the string matched by `/\X/` could exceed one character if the `\R` in the pseudoexpansion above matched a CRLF pair, or if a grapheme base character were followed by one or more grapheme extend characters.[11] The possessive group means `\X` can't change its mind once it's found a base character with any extend characters after it. For example, `/\X.\z/` can never match "`cafe\x{301}`", where U+0301 is COMBINING ACUTE ACCENT, because `\X` cannot be backtracked into.

If you are using Unicode and really want to get at a single byte instead of a single character, you *could* use the `\C` metasymbol. This will always match one byte (specifically, one C language `char` type), even if this gets you out of sync with your Unicode character stream. See the appropriate warnings about doing this in Chapter 6. This is probably the wrong way to go about it, though. Instead, you should probably decode the string as bytes (that is, characters whose codepoints are under 256) using the `Encode` module.

Character Classes

In a pattern match, you may match any character that has—or that does not have—a particular property. There are four ways to specify character classes. You may specify a character class in the traditional way, using square brackets and enumerating the possible characters, or you may use any of three mnemonic shortcuts: classic Perl classes like `\w`, using properties like `\p{word}`, or using legacy POSIX classes like `[:word:]`. Each of these shortcuts matches only one character from its set. Quantify them to match larger expanses, such as `\d+` to match one or more digits. (An easy mistake is to think that `\w` matches a word. Use `\w+` to match a word — provided by "word" you mean a programming language identifier with underscores and digits and such, not an English-language word.)

Bracketed Character Classes

An enumerated list of characters in square brackets is called a *bracketed character class* and matches any one of the characters in the list. For example, `[aeiouy]` matches a letter that can be a vowel in English. To match a right square bracket, either backslash it or place it first in the list.

11. Usually combining marks; currently the only nonmark grapheme extend characters are ZERO WIDTH NON-JOINER, ZERO WIDTH JOINER, HALFWIDTH KATAKANA VOICED SOUND MARK, and HALFWIDTH KATAKANA SEMI-VOICED SOUND MARK.

Character ranges may be indicated using a hyphen[12] and the `a-z` notation. Multiple ranges may be combined; for example, `[0-9a-fA-F]` matches one hex "digit". You may use a backslash to protect a hyphen that would otherwise be interpreted as a range separator, or just put it at the beginning or end of the class (a practice which is arguably less readable but more traditional).

A caret (or circumflex, or hat, or up arrow) at the front of the bracketed character class inverts the class, causing it to match any single character *not* in the list. (To match a caret, either *don't* put it first or, better, escape it with a backslash.) For example, `[^aeiouy]` matches any character that isn't a vowel. Be careful with character class negation, though, because the universe of characters is expanding. For example, that bracketed character class matches consonants—and also matches spaces, newlines, and anything (including vowels) in Cyrillic, Greek, or nearly any other script, not to mention every ideograph in Chinese, Japanese, and Korean. And someday maybe even Cirth and Tengwar. (Linear B and Etruscan, for sure.) So it might be better to specify your consonants explicitly, such as `[cbdfghjklmnpqrstvwxyz]`, or `[b-df-hj-np-tv-z]` for short. (This also solves the issue of "`y`" needing to be in two places at once, which a set complement would preclude.)

Normal character metasymbols that represent a specific character are allowed, such as `\n`, `\t`, `\c`*X*, `\x`*NN*, `\`*NNN* (meaning the octal number, *not* the backreference), `\p{`*YESPROP*`}`, and `\N{`*NAME*`}`. Additionally, you may use `\b` within a character class to mean a backspace, just as it does in a double-quoted string. Normally, in a pattern match, it means a word boundary. But zero-width assertions don't make any sense in character classes, so here `\b` returns to its normal meaning in strings. Any single character can be used as the endpoint of a range, whether used as a literal, a classic backslash escape like `\t`, as its hex or octal codepoint, or using named characters.

A character class also allows any metasymbol representing a specific set of characters, including negated classes like `\P{`*NOPROP*`}`, `\N`, `\S`, and `\D`, as well as predefined character classes described later in the chapter (classic, Unicode, or POSIX). But don't try to use any of these as endpoints of a range—that doesn't make sense, so the "`-`" will be interpreted literally. It also doesn't make sense to use something that could be more than one character long. That rules out `\R` since that can match both a carriage return and a line feed, `\X` since that can match multiple codepoints in a row, or certain named sequences via `\N{`*NAME*`}` that expand to multiple codepoints.

12. Actually, by U+002D, HYPHEN-MINUS not by U+2010, HYPHEN.

All other metasymbols lose their special meaning inside square brackets. In particular, you can't use any of the three generic wildcards: "`.`", `\X`, or `\C`. The first often surprises people, but it doesn't make much sense to use the universal character class within a restricted one, and you often want to match a literal dot as part of a character class—when you're matching filenames, for instance. It's also meaningless to specify quantifiers, assertions, or alternation inside a bracketed character class, since the characters are interpreted individually. For example, `[fee|fie|foe|foo]` means the same thing as `[feio|]`.

A bracketed character class normally matches only one character. For this reason, Unicode names sequences cannot be (usefully) used in bracketed character classes in v5.14. These look like named characters, but are really several characters long. For example, LATIN CAPITAL LETTER A WITH MACRON AND GRAVE can be used in the `\N{...}` construct, but that actually expands into U+0100 followed by U+0300. Inside brackets, that named sequence would look like `[\x{100}\x{300}]`, which is unlikely to be what you want.

However, under `/i`, a bracketed character class can sometimes match more than one character. This is because under full casefolding, a single character in the string can match several in the pattern, or vice versa. For example, this is true:

```
"SS" =~ /^[\xDF]$/iu
```

That's because the casefold of U+00DF is "`ss`", and the casefold of "`SS`" is also "`ss`". Since the casefolds are the same, the match succeeds. However, full casefolding is downgraded to simple casefolding under inverted character classes such as `[^\xDF]`, because this would otherwise lead to logical contradictions. This is the only time Perl ever uses simple casefolding; normally, all casefolding and casemapping in Perl is full, not simple.

Classic Perl Character Class Shortcuts

Since the beginning, Perl has provided a number of character class shortcuts. These are listed in Table 5-11. All of them are backslashed alphabetic metasymbols, and, in each case, the uppercase version is the negation of the lowercase version.

These match much more than you might think, because they normally work on the full Unicode range not on ASCII alone (and for negated classes, even beyond Unicode). In any case, the normal meanings are a superset of the old ASCII or locale meanings. For explanations of the properties and the legacy POSIX forms, see "POSIX-Style Character Classes" on page 210 later in this chapter. To keep the old ASCII meanings, you can always `use re "/a"` for that scope, or put a `/a` or two on an individual pattern.

Table 5-11. Classic character classes

Symbol	Meaning	Normal Property	/a Property	/a Enumerated	Legacy [:POSIX:]
\d	Digit	\p{X_POSIX_Digit}	\p{POSIX_Digit}	[0-9]	[:digit:]
\D	Nondigit	\P{X_POSIX_Digit}	\P{POSIX_Digit}	[^0-9]	[:^digit:]
\w	Word character	\p{X_POSIX_Word}	\p{POSIX_Word}	[_A-Za-z0-9]	[:word:]
\W	Non-(word character)	\P{X_POSIX_Word}	\P{POSIX_Word}	[^_A-Za-z0-9]	[:^word:]
\s	Whitespace	\p{X_Perl_Space}	\p{Perl_Space}	[\t\n\f\r]	[:space:] [a]
\S	Nonwhitespace	\P{X_Perl_Space}	\P{Perl_Space}	[^\t\n\f\r]	[:^space:]
\h	Horizontal whitespace character	\p{Horiz_Space}	\p{Horiz_Space}	Many	[:blank:]
\H	Non-(Horizontal whitespace character)	\P{Horiz_Space}	\P{Horiz_Space}	Many	[:^blank:]
\v	Vertical whitespace character	\p{Vert_Space}	\p{Vert_Space}	Many	—
\V	Non-(Vertical whitespace character)	\P{Vert_Space}	\P{Vert_Space}	Many	—

[a] But without VTAB.

(Yes, we know most words don't have numbers or underscores in them; `\w` is for matching "words" in the sense of tokens in a typical programming language. Or Perl, for that matter.)

These metasymbols may be used either outside or inside square brackets—that is, either standalone or as part of a constructed bracketed character class:

```
if ($var =~ /\D/)        { warn "contains a nondigit" }
if ($var =~ /[^\w\s.]/)  { warn "contains non-(word, space, dot)" }
```

Most of these have definitions that follow the Unicode Standard. Although Perl uses Unicode internally, many old programs exist that don't realize this, which can lead to surprises. So the traditional character class abbreviations in Perl all suffer from a sort of multiple-personality disorder in which sometimes they mean one thing and sometimes another. Under the `/u` flag, that dual mode goes away, and strings are always given Unicode semantics. Since this is the path toward sanity, it is the default under `use v5.14` or better. (The `unicode_strings` feature also sets this default.)

For traditional reasons, `\s` is not the same as `[\h\v]`, because `\v` includes `\cK`, the rarely used vertical tab character. That is why Perl's `\s` isn't exactly equal to Unicode's `\p{Whitespace}` property.

If you use legacy locales (because of `use locale` or `use re "/l"`), then you get the locale's sense of these for codepoints below 256, but still get the normal sense for codepoints of 256 and above.

On codepoints larger that 255, Perl normally switches to a purely character interpretation. That means a codepoint like U+0389, GREEK CAPITAL LETTER OMEGA, is *always* a `\w` character.

However, under the `/a` or `/aa` modifiers, it no longer is. Usually, one uses these ASCII-only modifiers to enforce an ASCII-only interpretation of old patterns that were designed before Unicode existed. Instead of putting a `/a` on every pattern that needs it, you can use the following lexically scoped pragma, and the `/a` will be automatically assumed:

```
use re "/a";
```

This rules out, for example, certain whitespace characters. It also means that the non-ASCII letters from ISO-8859-1 will no longer count as letters for `\w` characters.

Character Properties

Character properties are available using `\p{`*PROP*`}` and its set complement, `\P{`*PROP*`}`. For the seven major Unicode General Category properties of just one letter, the braces on the `\p` and `\P` are optional. So you may write `\pL` for any letter or `\pN` for any number, but you must use braces for anything longer, like `\p{Lm}` or `\p{Nl}`.

Most properties are directly defined in the Unicode Standard, but some, usually composites built out of the standard properties, are peculiar to Perl. For example `Nl` and `Mn` are standard Unicode General Categories representing letter-numbers and nonspacing combining marks, while `Perl_Space` is of Perl's own devising.

Properties may be used by themselves or combined in a constructed character class:

```
if ($var =~ /^\p{alpha}+$/)   { say "all alphabetic" }
if ($var =~ s/[^\pL\N]//g)    { say "deleted all nonalphanumerics" }
```

There are a great many properties, and some of those commonly used ones each cover more characters than many people imagine. For example, the `alpha` and `word` properties each cover over 100,000 characters, with `word` necessarily being the larger of the two as it is a proper superset of `alpha`.

The current list of properties supported by your release of Perl can be found in the *perluniprops* manpage, including how many characters each property matches. Perl closely tracks the Unicode Standard, so as new properties are added to Unicode, they are also added to Perl. For official Unicode properties, see UAX #44: Unicode Character Database, plus the Compatibility Properties from Annex C of UTS #18: Unicode Regular Expressions. As if all those weren't enough, you can even define your own properties; see Chapter 6 for how to do that.

Among the most commonly used properties are the Unicode General Categories. Table 5-12 shows all seven one-character categories, including their long forms and meanings.

Table 5-12. Unicode General Categories (major)

Short Property	Long Property	Meaning
`C`	`Other`	Crazy control codes and such
`L`	`Letter`	Letters and ideographs
`M`	`Mark`	Combining marks
`N`	`Number`	Numbers
`P`	`Punctuation`	Punctuation marks

Short Property	Long Property	Meaning
S	Symbol	Symbols, signs, and sigils
Z	Separator	Separators (Zeparators?)

Each of those seven is really an alias for all two-character General Categories that start with that letter. Table 5-13 gives the complete (and closed) set of all General Categories. All characters, even those currently unassigned, belong to exactly one of the following General Categories.

Table 5-13. Unicode General Categories (all)

Short Name	Long Name	Meaning
Cc	Control	The C0 and C1 control codes from ASCII and Latin-1
Cf	Format	Invisible characters for fancy text
Cn	Unassigned	Codepoints not yet assigned a character
Co	Private Use	Make up your own meanings for these
Cs	Surrogate	noncharacters reserved for UTF-16
Ll	Lowercase_Letter	Minuscule letters
Lm	Modifier_Letter	Superscript letters and spacing diacritics
Lo	Other_Letter	Unicameral letters and ideographs
Lt	Titlecase_Letter	Initial-only capitals, like the first word of a sentence
Lu	Uppercase_Letter	Majuscule letters, capitals used in all-cap text
Mc	Spacing_Mark	Little combining pieces that take up a print column
Me	Enclosing_Mark	Combining marks that surround another character
Mn	Nonspacing_Mark	Little combining pieces that don't take up a print column
Nd	Decimal_Number	A digit meaning 0–9 for use in bigendian base10 numbers
Nl	Letter_Number	Letters serving as numbers, like Roman numerals
No	Other_Number	Any other sort of number, like fractions
Pc	Connector_Punctuation	Joining punctuation an like underscore

Short Name	Long Name	Meaning
Pd	Dash_Punctuation	Any sort of dash or hyphen (but not minus)
Pe	Close_Punctuation	Punctuation like closing brackets
Pf	Final_Punctuation	Punctuation like right quotation marks
Pi	Initial_Punctuation	Punctuation like left quotation marks
Po	Other_Punctuation	All other punctuation
Ps	Open_Punctuation	Punctuation like opening brackets
Sc	Currency_Symbol	Symbols used with currency
Sk	Modifier_Symbol	Mostly diacritics
Sm	Math_Symbol	Symbols used with math
So	Other_Symbol	All other symbols
Zl	Line_Separator	Just U+2028
Zp	Paragraph_Separator	Just U+2029
Zs	Space_Separator	All other noncontrol whitespace

All standard Unicode properties are actually composed of two parts, as in `\p{`*NAME*`=`*VALUE*`}`. All one-part properties are therefore additions to official Unicode properties. Boolean properties whose values are true can always be abbreviated as one-part properties, which allows you to write `\p{Lowercase}` for `\p{Lowercase=True}`. Other types of properties besides Boolean properties take string, numeric, or enumerated values. Perl also provides one-part aliases for all general category, script, and block properties, plus the level-one recommendations from Unicode Technical Standard #18 on Regular Expressions (version 13, from 2008-08), such as `\p{Any}`.

For example, `\p{Armenian}`, `\p{IsArmenian}`, and `\p{Script=Armenian}` all represent the same property, as do `\p{Lu}`, `\p{GC=Lu}`, `\p{Uppercase_Letter}`, and `\p{General_Category=Uppercase_Letter}`. Other examples of binary properties (those whose values are implicitly true) include `\p{Whitespace}`, `\p{Alphabetic}`, `\p{Math}`, and `\p{Dash}`. Examples of properties that aren't binary properties include `\p{Bidi_Class=Right_to_Left}`, `\p{Word_Break=A_Letter}`, and `\p{Numeric_Value=10}`. The *perluniprops* manpage lists all properties and their aliases that Perl supports, both standard Unicode properties and the Perl specials, too.

The result is undefined if you try to match a non-Unicode codepoint (that is, one above 0x10FFFF) against a Unicode property. Currently, a warning is raised by

default and the match will fail. In some cases, this is counterintuitive, as both these fail:

```
chr(0x110000) =~ \p{ahex=true}      # false
chr(0x110000) =~ \p{ahex=false}     # false!

chr(0x110000) =~ \P{ahex=true}      # true
chr(0x110000) =~ \P{ahex=false}     # true!
```

User-defined properties can behave however they please, though. See the "Building Character" section in `15`.

POSIX-Style Character Classes

Unlike Perl's other character class shortcuts, the legacy POSIX-style character-class syntax notation, `[:CLASS:]`, is available for use *only* when constructing other character classes—that is, inside an additional pair of square brackets. For example, `/[.,[:alpha:][:digit:]]/` will search for one character that is either a literal dot (because it's in a bracketed character class), a comma, an alphabetic character, or a digit. All may be used as character properties of the same name; for example, `[.,\p{alpha}\p{digit}]`.

Except for "`punct`", explained immediately below, the POSIX character class names can be used as properties with `\p{}` or `\P{}` with the same meanings. This has two advantages: it is easier to type because you don't need to surround them with extra brackets; and, perhaps more importantly, because as properties their definitions are no longer affected by charset modifiers—they always match as Unicode. In contrast, using the `[[:...:]]` notation, the POSIX classes *are* affected by modifier flags.

The `\p{punct}` property differs from the `[[:punct:]]` POSIX class in that `\p{punct}` never matches nonpunctuation, but `[[:punct:]]` (and `\p{POSIX_Punct}` and `\p{X_POSIX_Punct}`) will. This is because Unicode splits what POSIX considers punctuation into two categories: Punctuation and Symbols. Unlike `\p{punct}`, the others just mentioned also will match the characters shown in Table 5-14.

Table 5-14. ASCII symbols that count as punctuation

Glyph	Code	Category	Script	Name
$	U+0024	GC=Sc	SC=Common	DOLLAR SIGN
+	U+002B	GC=Sm	SC=Common	PLUS SIGN
<	U+003C	GC=Sm	SC=Common	LESS-THAN SIGN
=	U+003D	GC=Sm	SC=Common	EQUALS SIGN

Glyph	Code	Category	Script	Name
>	U+003E	GC=Sm	SC=Common	GREATER-THAN SIGN
^	U+005E	GC=Sk	SC=Common	CIRCUMFLEX ACCENT
`	U+0060	GC=Sk	SC=Common	GRAVE ACCENT
|	U+007C	GC=Sm	SC=Common	VERTICAL LINE
~	U+007E	GC=Sm	SC=Common	TILDE

Another way to think of it is that `[[:punct:]]` matches all characters that Unicode considers punctuation (unless Unicode rules are not in effect), plus those nine characters in the ASCII range that Unicode considers symbols.

The second column in Table 5-15 shows the POSIX classes available as of v5.14.

Table 5-15. POSIX character classes

Class	Normal Meaning	With `/a`[*]
`alnum`	Any alphanumeric character; that is, any `alpha` or `digit`. This includes many nonletters; see next entry. Equivalent to `\p{X_POSIX_Alnum}`.	Only `[A-Za-z0-9]`. Equivalent to `\p{POSIX_Alnum}`.[*]
`alpha`	Any alphabetic character at all, including all letters plus any nonletter character with the property `Other_Alphabetic`, like Roman numerals, circled letter symbols, and the Greek combining iota mark. Equivalent to `\p{X_POSIX_Alpha}`.	Only the 52 ASCII characters `[A-Za-z]`. Equivalent to `\p{POSIX_Alpha}`.[*]
`ascii`	Any character with an ordinal value of 0–127. Equivalent to `\p{ASCII}`.	Any character with an ordinal value of 0–127. Equivalent to `\p{ASCII}`.[*]
`blank`	Any horizontal whitespace. Equivalent to `\p{X_POSIX_Blank}`, `\p{HorizSpace}`, or `\h`.	Only a space or a tab. Equivalent to `\p{POSIX_Blank}`.
`cntrl`	Any character with the property `Control`. Usually characters that don't produce output as such, but instead control the terminal somehow; for example, newline, form feed, and backspace are all control characters. This set currently includes any character with an ordinal value of 0–31, or 127–159. Equivalent to `\p{X_POSIX_Cntrl}`.	Any character with an ordinal value of 0–31, or 127. Equivalent to `\p{POSIX_Cntrl}`.

Class	Normal Meaning	With /a⁂
digit	Any character with the Digit property. More formally, characters with the property Numeric_Type=Decimal occurring contiguous ranges of 10 characters and whose ascending numeric values range from 0 to 9 (Numeric_Value=0..9). Equivalent to \p{X_POSIX_Digit} or \d.	The 10 characters "0" through "9". Equivalent to \p{POSIX_Digit}, or \d under /a.
graph	Any non-Whitespace character whose General Category is neither Control, Surrogate, nor Unassigned. Equivalent to \p{X_POSIX_Graph}.	The ASCII character set minus whitespace and control, so any character whose ordinal is 33–126. Equivalent to \p{POSIX_Graph}.⁂
lower	Any lowercase character, not necessarily letters only. Includes all codepoints of General Category Lowercase_Letter, plus those with the property Other_Lowercase. Equivalent to \p{X_POSIX_Lower} or \p{Lowercase}. Under /i, also matches any character with GC=LC, an abbreviation for any of GC=Lu, GC=Lt, and GC=Ll.	Only the 26 ASCII lowercase letters [a-z]. Under /i, also includes [A-Z]. Equivalent to \p{POSIX_Lower}.⁂
print	Any graph or non-cntrl blank character. Equivalent to \p{X_POSIX_Print}.	Any graph or non-cntrl blank character. Equivalent to \p{POSIX_Print}.⁂
punct	Any character whose General Category is Punctuation, plus those nine ASCII characters in the Symbol General Category. Equivalent to \p{X_POSIX_Punct} or \pP.	Any ASCII character whose General Category is either Punctuation or Symbol. Equivalent to \p{POSIX_Punct}.
space	Any character with the Whitespace property, including tab, line feed, vertical tab, form feed, carriage return, space, nonbreaking space, next line, thin space, hair space, the Unicode paragraph separator, and a whole lot more. Equivalent to \p{X_POSIX_Space}, [\v\h], or [\s\cK]; \s alone is instead equivalent to \p{X_Perl_Space}, which is missing \cK, the vertical tab.	Any ASCII Whitespace character, so tab, line feed, vertical tab, form feed, carriage return, and space. Equivalent to \p{POSIX_Space}; \s alone is missing the vertical tab.
upper	Any uppercase (but not titlecase) character, not necessarily letters only. Includes all codepoints of General Category Upper	Only the 26 uppercase ASCII letters [A-Z]. Under /i, also in-

Class	Normal Meaning	With /a⁂
	case_Letter plus those with the property Other_Uppercase. Under /i, also includes any character sharing a casefold with any uppercase character. Equivalent to \p{X_POSIX_Upper} or \p{Uppercase}.	cludes [a-z]. Equivalent to \p{POSIX_Upper}.⁂
word	Any character that is an alnum or whose General Category is Mark or Connector_Punctuation. Equivalent to \p{X_POSIX_Word} or \w. Note that Unicode identifiers, including Perl's, follow their own rules: the first character has the ID_Start property, and subsequent characters have the ID_Continue property. (Perl also allows Connector_Punctuation at the start.)	Any ASCII letter, digit, or underscore. Equivalent to \p{POSIX_Word}, or to \w under /a.⁂
xdigit	Any hexadecimal digit, either narrow ASCII characters or the corresponding full-width characters. Equivalent to \p{X_POSIX_XDigit}, \p{Hex_Digit}, or \p{hex}.	Any hexadecimal digit in the ASCII range. Equivalent to [0-9A-Fa-f], \p{POSIX_XDigit}, \p{ASCII_Hex_Digit}, or \p{ahex}.

Anything in the above table marked with ⁂ can also match certain non-ASCII characters under /ai. This presently means:

```
ſ  U+017F GC=Ll SC=Latin        LATIN SMALL LETTER LONG S
K  U+212A GC=Lu SC=Latin        KELVIN SIGN
```

because the first casefolds to a normal lowercase s, and the second to a normal lowercase k. You can suppress this by doubling the /a to make /aai.

You can negate the POSIX character classes by prefixing the class name with a ^ following the [:. (This is a Perl extension.) See Table 5-16.

Table 5-16. POSIX character classes and their Perl equivalents

POSIX	Classic
[^:digit:]	\D
[^:space:]	\S
[^:word:]	\W

The brackets are part of the POSIX-style [::] construct, not part of the whole character class. This leads to writing patterns like /^[[:lower:][:digit:]]+$/ to

match a string consisting entirely of lowercase characters or digits (plus an optional trailing newline). In particular, this does not work:

```
42 =~ /^[:digit:]$/         # WRONG
```

That's because it's not inside a character class. Rather, it *is* a character class, the one representing the characters "`:`", "`i`", "`t`", "`g`", and "`d`". Perl doesn't care that you specified "`:`" twice.

Here's what you need instead:

```
42 =~ /^[[:digit:]]+$/
```

The POSIX character classes `[.cc.]` and `[=cc=]` are recognized but produce an error indicating they are not supported.

Quantifiers

Unless you say otherwise, each item in a regular expression matches just once. With a pattern like `/nop/`, each of those characters must match, each right after the other. Words like "`panoply`" or "`xenophobia`" are fine, because *where* the match occurs doesn't matter.

If you wanted to match both "`xenophobia`" and "`Snoopy`", you couldn't use the `/nop/` pattern, since that requires just one "`o`" between the "`n`" and the "`p`", and Snoopy has two. This is where *quantifiers* come in handy: they say how many times something may match, instead of the default of matching just once. Quantifiers in a regular expression are like loops in a program; in fact, if you think of a regex as a program, then they *are* loops. Some loops are exact, like "repeat this match only five times" (`{5}`). Others give both lower and upper bounds on the match count, like "repeat this match at least twice but no more than four times" (`{2,4}`). Others have no closed upper bound at all, like "match this at least twice, but as many times as you'd like" (`{2,}`).

Table 5-17 shows the quantifiers that Perl recognizes in a pattern.

Table 5-17. Regex quantifiers compared

Maximal	Minimal	Possessive	Allowed Range
{*MIN*,*MAX*}	{*MIN*,*MAX*}?	{*MIN*,*MAX*}?+	Must occur at least *MIN* times but no more than *MAX* times
{*MIN*,}	{*MIN*,}?	{*MIN*,}?+	Must occur at least *MIN* times
{*COUNT*}	{*COUNT*}?	{*COUNT*}?+	Must match exactly *COUNT* times
*	*?	*+	0 or more times (same as {0,})
+	+?	++	1 or more times (same as {1,})

Maximal	Minimal	Possessive	Allowed Range
`?`	`??`	`?+`	0 or 1 time (same as `{0,1}`)

Something with a `*` or a `?` doesn't actually have to match. That's because it can match 0 times and still be considered a success. A `+` may often be a better fit, since it has to be there at least once.

Don't be confused by the use of "exactly" in the previous table. It refers only to the repeat count, not the overall string. For example, `$n =~ /\d{3}/` doesn't say "is this string exactly three digits long?" It asks whether there's any point within `$n` at which three digits occur in a row. Strings like "`101 Morris Street`" test true, but so do strings like "`95472`" or "`1-800-555-1212`". All *contain* three digits at one or more points, which is all you asked about. See the section "Positions" later in this chapter for how to use positional assertions (as in `/^\d{3}$/`) to nail this down.

Given the opportunity to match something a variable number of times, maximal quantifiers will elect to maximize the repeat count. So when we say "as many times as you'd like", the greedy quantifier interprets this to mean "as many times as you can possibly get away with", constrained only by the requirement that this not cause specifications later in the match to fail. If a pattern contains two open-ended quantifiers, then obviously both cannot consume the entire string: characters used by one part of the match are no longer available to a later part. Each quantifier is greedy at the expense of those that follow it, reading the pattern left to right.

That's the traditional behavior of quantifiers in regular expressions. However, Perl permits you to reform the behavior of its quantifiers: by placing a `?` after that quantifier, you change it from maximal to minimal. That doesn't mean that a minimal quantifier will always match the smallest number of repetitions allowed by its range any more than a maximal quantifier must always match the greatest number allowed in its range. The overall match must still succeed, and the minimal match will take as much as it needs to succeed, and no more. (Minimal quantifiers value contentment over greed.)

For example, in the match:

```
"exasperate" =~ /e(.*)e/    #  $1 now "xasperat"
```

the `.*` matches "`xasperat`", the longest possible string for it to match. (It also stores that value in `$1`, as described in the section "Grouping and Capturing" on page 221, later in the chapter.) Although a shorter match was available, a greedy match doesn't care. Given two choices at the same starting point, it always returns the *longer* of the two.

Contrast this with this:

```
"exasperate" =~ /e(.*?)e/   #  $1 now "xasp"
```

Here, the minimal matching version, `.*?`, is used. Adding the `?` to `*` makes `*?` take on the opposite behavior: now given two choices at the same starting point, it always returns the *shorter* of the two.

Although you could read `*?` as saying to match zero or more of something but preferring zero, that doesn't mean it will always match zero characters. If it did so here, for example, and left `$1` set to `""`, then the second "`e`" wouldn't be found, since it doesn't immediately follow the first one.

You might also wonder why, in minimally matching `/e(.*?)e/`, Perl didn't stick "`rat`" into `$1`. After all, "`rat`" also falls between two `e`s, and it is shorter than "`xasp`". In Perl, the minimal/maximal choice applies only when selecting the shortest or longest from among several matches that all have the same starting point. If two possible matches exist, but these start at different offsets in the string, then their lengths don't matter—nor does it matter whether you've used a minimal quantifier or a maximal one. The earliest of several valid matches always wins out over all latecomers. It's only when multiple possible matches start at the same point that you use minimal or maximal matching to break the tie. If the starting points differ, there's no tie to break. Perl's matching is normally *leftmost longest*; with minimal matching, it becomes *leftmost shortest*. But the "leftmost" part never varies and is the dominant criterion.[13]

There are two ways to defeat the leftward leanings of the pattern matcher. First, you can use an earlier greedy quantifier (typically `.*`) to try to slurp earlier parts of the string. In searching for a match for a greedy quantifier, it tries for the longest match first, which effectively searches the rest of the string right to left:

```
"exasperate" =~ /.*e(.*?)e/   #  $1 now "rat"
```

But be careful with that, since the overall match now includes the entire string up to that point.

13. Not all regex engines work this way. Some believe in overall greed, in which the longest match always wins, even if it shows up later. Perl isn't that way. You might say that eagerness holds priority over greed (or thrift). For a more formal discussion of this principle and many others, see the section "The Little Engine That /Could(n't)?/" on page 241.

The second way to defeat leftmostness is to use positional assertions, discussed in the next section.

Just as you can change any maximal quantifier to a minimal one by adding a `?` afterwards, you can also change any maximal quantifier to a possessive one by adding a `+` afterwards. Possessive matches are a way to control backtracking. Both minimal and maximal quantifiers always try all possible combinations looking for a match. A possessive quantifier will never be backtracked into trying to find another possibility, which can improve performance tremendously.

This isn't often a problem with simple matches, but as soon as you have multiple and especially nested quantifiers, it can matter a great deal. It won't usually change the overall success of a match, but it can make it fail much, much faster. For example:

```
("a" x 20 . "b") =~ /(a*a*a*a*a*a*a*a*a*a*a*)*[^Bb]$/
```

will fail—eventually. The regex engine is hard at work, futilely trying all possible combinations of allocating `a`s to star groups. It doesn't realize it's doomed to fail. By changing one or more of those variable `*` quantifiers to an invariant `*+` quantifier, you can make it fail a lot faster. In this case, changing the last, other star from maximal to possessive gains a couple orders of magnitude in performance, which is nothing to laugh at.

Sure, this is a contrived example, but when building complex patterns, this sort of thing can crop up before you know. It turns out that possessive quantifiers work exactly like the nonbacktracking groups we'll meet later. The possessive match `a*+` is the same as `(?>a*)`. Possessive groups are a bit more flexible than possessive quantifiers, because you can group together more things as a unit that will be invisible to backtracking. But possessive quantifiers are a lot easier to type, and they are often all you need to avoid catastrophic backtracking.

Positions

Some regex constructs represent *positions* in the string to be matched, which is a location just to the left or right of a real character. These metasymbols are examples of *zero-width* assertions because they do not correspond to actual characters in the string. We often just call them "assertions". (They're also known as "anchors" because they tie some part of the pattern to a particular position, while the rest of the pattern is free to drift with the tide.)

You can always manipulate positions in a string without using patterns. The built-in `substr` function lets you extract and assign to substrings, measured from the beginning of the string, the end of the string, or from a particular numeric offset.

This might be all you need if you were working with fixed-length records, for instance. Patterns are only necessary when a numeric offset isn't sufficient. But, most of the time, `substr` isn't sufficient—or at least not sufficiently convenient, compared to patterns.

Beginnings: The \A and ^ Assertions

The `\A` assertion matches only at the beginning of the string, no matter what. In contrast, though, the `^` assertion always matches at the beginning of string; it can also match with the more traditional meaning of beginning of line: if the pattern uses the `/m` modifier and the string has embedded newlines, `^` also matches anywhere inside the string immediately following a newline character:

```
/\Abar/      # Matches "bar" and "barstool"
/^bar/       # Matches "bar" and "barstool"
/^bar/m      # Matches "bar" and "barstool" and "sand\nbar"
```

Used in conjunction with `/g`, the `/m` modifier lets `^` match many times in the same string:

```
s/^\s+//gm;             # Trim leading whitespace on each line
$total++ while /^./mg;  # Count nonblank lines
```

Endings: The \z, \Z, and $ Assertions

The `\z` metasymbol matches at the end of the string, no matter what's inside. `\Z` matches right before the newline at the end of the string if there is a newline, or at the end if there isn't. The `$` metacharacter usually means the same as `\Z`. However, if the `/m` modifier was specified and the string has embedded newlines, then `$` can also match anywhere inside the string right in front of a newline:

```
/bot\z/      # Matches "robot"
/bot\Z/      # Matches "robot" and "abbot\n"
/bot$/       # Matches "robot" and "abbot\n"
/bot$/m      # Matches "robot" and "abbot\n" and "robot\nrules"

/^robot$/    # Matches "robot" and "robot\n"
/^robot$/m   # Matches "robot" and "robot\n" and "this\nrobot\n"
/\Arobot\Z/  # Matches "robot" and "robot\n"
/\Arobot\z/  # Matches only "robot" — but why didn't you use eq?
```

As with `^`, the `/m` modifier lets `$` match many times in the same string when used with `/g`. (These examples assume that you've read a multiline record into `$_`, perhaps by setting `$/` to `""` before reading.)

```
s/\s*$//gm;   # Trim trailing whitespace on each line in paragraph

while (/^([^:]+):\s*(.*)/gm ) {  # get mail header
```

```
        $headers{$1} = $2;
    }
```

In "Variable Interpolation" on page 234, later in this chapter, we'll discuss how you can interpolate variables into patterns: if `$foo` is "`bc`", then `/a$foo/` is equivalent to `/abc/`. Here, the `$` does not match the end of the string. For a `$` to match the end of the string, it must be at the end of the pattern or immediately be followed by a vertical bar or closing parenthesis.

Boundaries: The \b and \B Assertions

The `\b` assertion matches at any word boundary, defined as the position between a `\w` character and a `\W` character, in either order. If the order is `\W\w`, it's a beginning-of-word boundary, and if the order is `\w\W`, it's an end-of-word boundary. (The ends of the string count as `\W` characters here.) The `\B` assertion matches any position that is *not* a word boundary—that is, the middle of either `\w\w` or `\W\W`.

```
/\bis\b/   # matches "what it is" and "that is it"
/\Bis\B/   # matches "thistle" and "artist"
/\bis\B/   # matches "istanbul" and "so—isn't that butter?"
/\Bis\b/   # matches "confutatis" and "metropolis near you"
```

Because `\W` includes all punctuation characters (except the underscore), there are `\b` boundaries in the middle of strings like "`isn't`", "`booktech@oreilly.com`", "`M.I.T.`", and "`key/value`".

Inside a bracketed character class (`[\b]`), a `\b` represents a backspace rather than a word boundary.

Progressive Matching

When used with the `/g` modifier, the `pos` function allows you to read or set the offset where the next progressive match will start:

```
$burglar = "Bilbo Baggins";
while ($burglar =~ /b/gi) {
    printf "Found a B at %d\n", pos($burglar)-1;
}
```

(We subtract one from the position because that was the length of the string we were looking for, and `pos` is always the position just past the match.)

The code above prints:

```
Found a B at 0
Found a B at 3
Found a B at 6
```

After a failure, the match position normally resets back to the start. If you also apply the /c (for "continue") modifier, then when the /g runs out, the failed match doesn't reset the position pointer. This lets you continue your search past that point without starting over at the very beginning.

```
$burglar = "Bilbo Baggins";
while ($burglar =~ /b/gci) {        # ADD /c
    printf "Found a B at %d\n", pos($burglar)-1;
}
while ($burglar =~ /i/gi) {
    printf "Found an I at %d\n", pos($burglar)-1;
}
```

Besides the three Bs it found earlier, Perl now reports finding an i at position 10. Without the /c, the second loop's match would have restarted from the beginning and found another i at position 1 first.

Where You Left Off: The \G Assertion

Whenever you start thinking in terms of the pos function, it's tempting to start carving your string up with substr, but this is rarely the right thing to do. More often, if you started with pattern matching, you should continue with pattern matching. However, if you're looking for a positional assertion, you're probably looking for \G.

The \G assertion represents within the pattern the same point that pos represents outside of it. When you're progressively matching a string with the /g modifier (or you've used the pos function to directly select the starting point), you can use \G to specify the position just after the previous match. That is, it matches the location immediately before whatever character would be identified by pos. This allows you to remember where you left off:

```
($recipe = <<'DISH') =~ s/^\s+//gm;
    Preheat oven to 451 deg. Fahrenheit.
    Mix 1 ml. dilithium with 3 oz. NaCl and
    stir in 4 anchovies.  Glaze with 1 g.
    mercury.  Heat for 4 hours and let cool
    for 3 seconds.  Serves 10 aliens.
DISH

$recipe =~ /\d+ /g;
$recipe =~ /\G(\w+)/;           # $1 is now "deg"
$recipe =~ /\d+ /g;
$recipe =~ /\G(\w+)/;           # $1 is now "ml"
$recipe =~ /\d+ /g;
$recipe =~ /\G(\w+)/;           # $1 is now "oz"
```

The \G metasymbol is often used in a loop, as we demonstrate in our next example. We "pause" after every digit sequence, and, at that position, we test whether there's an abbreviation. If so, we grab the next two words. Otherwise, we just grab the next word:

```
pos($recipe) = 0;                 # Just to be safe, reset \G to 0
while ( $recipe =~ /(\d+) /g ) {
    my $amount = $1;
    if ($recipe =~ / \G (\w{0,3}) \. \s+ (\w+) /x) {  # abbrev. + word
        say "$amount $1 of $2";
    } else {
        $recipe =~ / \G (\w+) /x;                     # just a word
        say "$amount $1";
    }
}
```

That produces:

```
451 deg of Fahrenheit
1 ml of dilithium
3 oz of NaCl
4 anchovies
1 g of mercury
4 hours
3 seconds
10 aliens
```

Grouping and Capturing

Patterns allow you to group portions of your pattern together into subpatterns and to remember the strings matched by those subpatterns. We call the first behavior *grouping* and the second one *capturing*. It is also possible to group without capturing. More on that later.

Capturing

To capture a substring for later use, put parentheses around the subpattern that matches it. The first pair of parentheses stores its substring in $1, the second pair in $2, and so on. You may use as many parentheses as you like; Perl just keeps defining more numbered variables for you to represent these captured strings.

Some examples:

```
/(\d)(\d)/  # Match two digits, capturing them into $1 and $2
/(\d+)/     # Match one or more digits, capturing them all into $1
/(\d)+/     # Match a digit one or more times, capturing the last into $1
```

Note the difference between the second and third patterns. The second form is usually what you want. The third form does *not* create multiple variables for multiple digits. Parentheses are numbered when the pattern is compiled, not when it is matched.

Captured strings are often called *group references* because they refer back to parts of the captured text. Historical pattern-matching engines restricted group references to *backreferences* only, but Perl allows references to any group, whether back, forward, or the one you're in the middle of solving.

There are actually two ways to get at these capture groups. The numbered variables you've seen are how you get at backreferences outside of a pattern, but that doesn't work inside the pattern. You have to use backreference notation, so either `\1`, `\2`, `\g{1}`, `\g{2}`, `\k<some_group>`, `\k<other_group>`, etc.

You can't use `$1` for a group reference within the pattern because that would already have been interpolated as an ordinary variable back when the regex was compiled. So we use the traditional `\1` group reference notation inside patterns. For two- and three-digit backreference numbers, there is some ambiguity with octal character notation, but that is neatly solved by considering how many captured patterns are available. For instance, if Perl sees a `\11` metasymbol, it's equivalent to `$11` only if there are at least 11 substrings captured earlier in the pattern. Otherwise, it's equivalent to `\011`—that is, a tab character. To avoid this ambiguity, refer to a capture group by its number using `\g{`*`NUMBER`*`}`, and to an octal character by number using `\o{`*`OCTNUM`*`}`. So `\g{11}` is always the 11th capture group, and `\o{11}` is always the character whose codepoint is octal 11. An even better idea than racking up 11 capture groups is to use named groups, described below.

So to find doubled words like "`the the`" or "`had had`", you might use this pattern:

```
/\b(\w+) \1\b/i
```

But most often you'll be using the `$1` form, because you'll usually apply a pattern and then do something with the substrings. Suppose you have some text (a mail header) that looks like this:

```
From: gnat@perl.com
To: camelot@oreilly.com
Date: Mon, 17 Jul 2011 09:00:00 -1000
Subject: Eye of the needle
```

and you want to construct a hash that maps the text before each colon to the text afterward. If you were looping through this text line by line (say, because you were reading it from a file), you could do that as follows:

```
while (<>) {
    /^(.*?): (.*)$/;    # Pre-colon text into $1, post-colon into $2
    $fields{$1} = $2;
}
```

Like `$``, `$&`, and `$'`, these numbered variables are dynamically scoped through the end of the enclosing block or `eval` string, or to the next successful pattern match, whichever comes first. You can use them in the righthand side (the replacement part) of a substitute, too:

```
s/^(\S+) (\S+)/$2 $1/;  # Swap first two words
```

Groupings can nest and, when they do, the groupings are counted by the location of the left parenthesis. So given the string "Primula Brandybuck", the pattern:

```
/^((\w+) (\w+))$/
```

would capture "`Primula Brandybuck`" into `$1`, "`Primula`" into `$2`, and "`Brandy buck`" into `$3`. This is depicted in Figure 5-1.

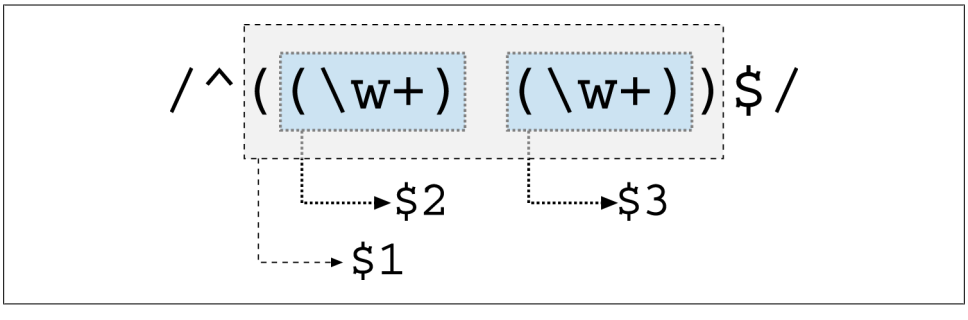


Figure 5-1. Creating group references with parentheses

As we mentioned earlier, not all group references need to be backreferences. You are allowed to refer to any group the pattern knows about, even if you haven't quite gotten around to filling it out yet. This is only useful if you're in some repetition where you'll revisit the same group ref again. The first time you encounter these non-backref group references, they fail because they haven't happened yet. But by the time the later visit happens, that group has something more interesting in it.

Here are the three types of references to capture groups. The first is a traditional backreference, because it has already been completed by the time it is first needed:

```
"foofoobar" =~ /^(foo)\1bar$/              # backref
```

This, though, is a forward reference:

```
"foofoobar" =~ /^((\3bar)|(foo))+$/        # forwref
```

We haven't even begun the third group the first time through the + quantifiers' repetitions, so \3 fails and we skip to the other alternative, which fills in the third group with the string's first "foo". On the next repetition of the + quantifier, \3 contains "foo", and we finish up with bar and we're done.

This third example is neither a backreference nor a forward reference, because it's within the very group it's referring to, making it something of a circumref:

```
"foofoobar" =~ /^(\1bar|(foo))+/           # circumref
```

Patterns with captures are often used in list context to populate a list of values, since the pattern is smart enough to return the captured substrings as a list:

```
($first, $last)        =  /^(\w+) (\w+)$/;
($full, $first, $last) =  /^((\w+) (\w+))$/;
```

With the /g modifier, a pattern can return multiple substrings from multiple matches, all in one list. Suppose you had the mail header we saw earlier all in one string (in $_, say). You could do the same thing as our line-by-line loop, but with one statement:

```
%fields = /^(.*?): (.*)$/gm;
```

The pattern matches four times; each time it matches, it finds two substrings. The /gm match returns all of these as a flat list of eight strings, which the list assignment to %fields will conveniently interpret as four key/value pairs, thus restoring harmony to the universe.

Several other special variables deal with text captured in pattern matches. $& contains the entire matched string, $` everything to the left of the match, $' everything to the right. $+ contains the contents of the last capture group.

```
$_ = "Speak, <EM>friend</EM>, and enter.";
m[ (<.*?>) (.*?) (</.*?>) ]x; # A tag, then chars, then an end tag
say "prematch: $`";           # Speak,
say "match: $&";              # <EM>friend</EM>
say "postmatch: $'";          # , and enter.
say "lastmatch: $+";          # </EM>
```

For more explanation of these magical Elvish variables (and for a way to write them in English), see Chapter 25.

The @- (@LAST_MATCH_START) array holds the offsets of the beginnings of any submatches, and @+ (@LAST_MATCH_END) holds the offsets of the ends:

```
#!/usr/bin/perl
$alphabet = "abcdefghijklmnopqrstuvwxyz";
$alphabet =~ /(hi).*(stu)/;

say "The entire match began at $-[0] and ended at $+[0]";
```

```
say "The first  match began at $-[1] and ended at $+[1]";
say "The second match began at $-[2] and ended at $+[2]";
```

If you really want to match a literal parenthesis character instead of having it interpreted as a metacharacter, backslash it:

```
/\(e.g., .*?\)/
```

This matches a parenthesized example (*e.g.*, this statement). But since dot is a wildcard, this also matches any parenthetical statement with the first letter `e` and third letter `g` (ergo, this statement, too).

Numbered capture groups are inherently fragile. Imagine you use something like this to match a sequence of duplicated words:

```
$dupword = qr/ \b (?: ( \w+ ) (?: \s+ \1 )+ ) \b /xi;
```

If you embed that in a larger pattern that itself has capture groups earlier than where your duplicate word pattern appears, then that `\1` will be wrong. For example, this won't work:

```
$quoted  = qr{ ( ["'] ) $dupword  \1 }x;
```

because `$dupword` *should* be using `\2` there if it's going to wind up embedded in `$quoted`. But you can't do that because while `$dupword` is being compiled, there's *not yet* a second capture group to refer back to, so it won't even compile.

A solution that works in this situation is to use relatively numbered capture groups. To access them, you need to use the `\g{`*`NUMBER`*`}` notation, which is a numbered reference that refers to capture group *`NUMBER`*. When *`NUMBER`* is positive, it's the same as `\`*`NUMBER`*. But when *`NUMBER`* is negative, it's that many previous capture groups earlier. So `\g{-1}` is the last capture group, `\g{-2}` is the second to the last one, etc.

A better definition then for the duplicate-word pattern, defined in a way that allows it to be more freely embedded in a larger pattern, is:

```
$dupword = qr/ \b (?: (\w+) (?: \s+ \g{-1} )+ ) \b /xi;
```

Here's a simple program for finding duplicate word sequences paragraph by paragraph in the input stream:

```
#!/usr/bin/env perl
use v5.14;

my $dupword = qr{ \b (?: ( \w+ ) (?: \s+ \g{-1} )+ ) \b }xi;
my $quoted  = qr{ ( ["'] ) $dupword  \1 }x;
$/ = q();  # cross paragraphs

while (<>) {
    while (/$quoted/pg) {
```

```
            printf "%s %d: %s\n", $ARGV, $., ${^MATCH};
        }
    } continue {
        close ARGV if eof;
    }
```

Although that program works fine by itself, there's still a serious issue. If `$quoted` is used in a still larger pattern, its use of `\1` will become wrong. Yet it can't know how many to count back, because it shouldn't have to know how many the unrelated pattern in `$dupword` has used.

Named capture groups

The only way to resolve the last conundrum requires a new strategy, one that doesn't use numbered capture groups at all. For this (and much more) were named capture groups invented. To declare a named capture group inside your pattern, use `(?<`*`NAME`*`>...)`. This is still a capture group just like a regular parenthesized grouping, but its name is *`NAME`*.

Or, rather, its name is *also* *`NAME`*, because a named capture group is still a numbered one, too, just as though it sat in the same spot but without a name. This is the same way that named groups behave with respect to numbered ones in the most commonly used regular expression libraries for Java and Python. However, it's different from how named groups work in the .NET Framework like C♯, where named captures are assigned numbers only after all numbered groups. (And in that other weird language Perl 6, a capture is given a number for its name *only* if it has no other name. Go figure.)

To refer back to a named capture group in the same pattern, the way you used to use `\1` or `\g{1}` with numbered groups, use `\k<`*`NAME`*`>`. We can now address the somewhat problematic definition with `$quoted` in the previous problem to enable its use in larger patterns:

```
$quoted = qr{ (?<quote> ["'] ) $dupword  \k<quote>  }x;
```

That's fine for within the pattern, but just as group `\1` during pattern matching is accessible as `$1` afterwards, you will sometimes want to access named capture groups' contents after the pattern has run. That's what the built-in hash variable `%+` is for. Its keys are whatever names you've given your capture groups, and the values are what those groups have captured. So given the previous definition of `$quoted` and of `$dupword`, you could pull out all the quoted duplicate word sequences this way:

```
say $+{quote} while /$quoted/g;
```

Here's another example:

```
$word = "bookkeeper";
$word =~ s/ (?<letter> \p{alpha} ) \k<letter> /$+{letter}/gix;
#  $word is now "bokeper"
```

(We used the `/x` modifier just so we could put some whitespace into the pattern to make it easier to read. Nobodylikesreadingthiskindofthing.)

If you happen to have more than one group by the same *NAME* in the same pattern, then `%+` holds only the last string captured, but each entry in the `%-` hash holds a reference to an array of them. Given several groups of the same *NAME*, use `@{$-{`*NAME*`}}` for all of them, `$-{`*NAME*`}[0]` for the first, `$-{`*NAME*`}[1]` for the next, and so on, up to `$-{`*NAME*`}[-1]` for the last one.

Imagine you wanted to match either a name then a number, or a number then a name. If you had used numbered capture groups, you would have a problem knowing which was which:

```
/ (\d+) \s+ (\pL+) | (\pL+) \s+ (\d+) /x
```

Because now you don't know which branch was taken, you don't know whether to grab `$1` and `$2` or `$3` and `$4`. Here's where the `(?|...)` branch-reset construct comes in handy:

```
m{
    (?| (\d+)  \s+ (\pL+)   # these are $1 and $2
      | (\pL+) \s+ (\d+)    # and so is this pair!
    )
}x
```

At each alternative, group numbers reset back to whatever they were when the branch-reset was entered. This way, no matter which half matches, you know the data is in `$1` and `$2`.

That's okay for simpler patterns, but using named capture groups will work out better in the long run, and for more complex patterns. By giving them names like this:

```
m{
    (?<name>   \pL+ ) \s+ (?<number> \d+  )
       |
    (?<number> \d+  ) \s+ (?<name>   \pL+ )
}x
```

it now doesn't matter which branch of the alternation was taken. Access the contents of the match groups after the match like so:

```
$+{name}
$+{number}
```

However, without the alternation, both captures will be loaded twice:

```
m{
    (?<name>   \pL+ ) \s+ (?<number> \d+  )
    \W+
    (?<number> \d+  ) \s+ (?<name>   \pL+ )
}x
```

So, if the pattern matches, there will be two values each for both the `<name>` and `<number>` groups. When you have the same named group loaded more than once, the previous contents in the `%+` variable are overwritten, just like assigning to a scalar more than once. However, the `%-` variable holds an array of values for each name in the hash, so this time new contents are pushed onto the end of the anonymous array associated with the named key.

Because the values in `%-` are array references not strings the way they are in `%+`, you could get at the entire set of matches like this:

```
@{ $-{name}   }
@{ $-{number} }
```

or at individual scalars like this:

```
$-{name}[0]
$-{name}[1]
$-{number}[0]
$-{number}[1]
```

Which makes `$+{name}` the same as `$-{name}[-1]`. It's also the same as `$-{name}[$#{$-{name}}]`, but that's getting a mite punctual.

Speaking of which, if you don't much like having variables whose names are single punctuation marks, the standard `Tie:Hash::NamedCapture` module lets you use whatever name you'd like for these two built-in hashes. Pass an extra argument of `all => 1` if you want the version that acts like the `%-` variable; otherwise, the tied hash acts like the `%+` variable.

```
use Tie::Hash::NamedCapture;
tie my %last_captured, "Tie::Hash::NamedCapture";
tie my %all_captured,  "Tie::Hash::NamedCapture", all => 1;
```

Now access your named captures through those variables, just as you did with `$+` and `%+`, but using your own names.

```
$last_captured{name}
$last_captured{number}

@{ $all_captured{name}   }
@{ $all_captured{number} }

$all_captured{name}[0]
$all_captured{name}[1]
```

```
$all_captured{number}[0]
$all_captured{number}[1]
```

These uses of named captures should already have you convinced to prefer them over numbered groups in all but the simplest of patterns (and some would say even then). But named captures really start to shine when you write recursive patterns and grammars, described in the upcoming section "Fancy Patterns" on page 247.

Grouping Without Capturing

Bare parentheses both group and capture. But sometimes you don't want that. Sometimes you just want to group portions of the pattern without capturing the string for later use. An extended form of parentheses, the `(?:`*PATTERN*`)` notation, will do that.

There are at least three reasons you might want to group without capturing:

1. To quantify something.
2. To limit the scope of interior alternation; for example, `/^cat|cow|dog$/` needs to be `/^(?:cat|cow|dog)$/` so that the cat doesn't run away with the `^`.
3. To limit the scope of an embedded pattern modifier to a particular subpattern, such as in `/foo(?-i:Case_Matters)bar/i`. (See the next section, "Scoped Pattern Modifiers" on page 230.)

In addition, it's more efficient to suppress the capture of something you're not going to use. On the minus side, the notation is a little noisier, visually speaking.

In a pattern, a left parenthesis immediately followed by a question mark denotes a regex *extension*. The current regular expression bestiary is relatively fixed—we don't dare create a new metacharacter for fear of breaking old Perl programs. Instead, the extension syntax is used to add new features to the bestiary.

In the remainder of this chapter we'll see many more regex extensions, all of which group without capturing, as well as doing something else. The `(?:`*PATTERN*`)` extension is just special in that it does nothing else. So if you say:

```
@fields = split(/\b(?:a|b|c)\b/)
```

it's like:

```
@fields = split(/\b(a|b|c)\b/)
```

but doesn't spit out extra fields. (The `split` operator is a bit like `m//g` in that it will emit extra fields for all the captured substrings within the pattern. Ordinarily, `split` only returns what it *didn't* match. For more on `split`, see Chapter 27.)

Scoped Pattern Modifiers

You may *lexically scope* the `/i`, `/m`, `/s`, `/x`, `/d`, `/u`, `/a`, `/l`, and `/p` modifiers within a portion of your pattern by inserting them (without the slash) between the `?` and `:` of the grouping notation. If you say:

```
/Harry (?i:s) Truman/
```

it matches both "`Harry S Truman`" and "`Harry s Truman`", whereas:

```
/Harry (?x: [A-Z] \.? \s )?Truman/
```

matches both "`Harry S Truman`" and "`Harry S. Truman`", as well as "`Harry Tru man`"; and:

```
/Harry (?ix: [A-Z] \.? \s )?Truman/
```

matches all five, by combining the `/i` and `/x` within the group.

You can also subtract modifiers from a scope with a minus sign:

```
/Harry (?x-i: [A-Z] \.? \s )?Truman/i
```

This matches any capitalization of the name—but if the middle initial is provided, it must be capitalized, since the `/i` applied to the overall pattern is suspended inside the scope.

When subtracting, you may only subtract `/i`, `/m`, `/s`, or `/x`. The other modifiers `/d`, `/u`, `/a`, `/l`, and `/p` modifiers may only be added.

By omitting both colon and *`PATTERN`*, you can export modifier settings to an outer group, turning it into a scope. That is, you can selectively turn modifiers on and off for the grouping construct one level outside the modifiers' parentheses, like so:

```
/(?i)foo/           # Equivalent to /foo/i
/foo((?-i)bar)/i    # "bar" must be lower case
/foo((?x-i) bar)/   # Enables /x and disables /i for "bar"
```

Note that the second and third examples create capture groups. If that wasn't what you wanted, then you should have been using `(?-i:bar)` and `(?x-i: bar)`, respectively.

Setting modifiers on a portion of your pattern is particularly useful when you want "`.`" to match newlines in part of your pattern but not in the rest of it. Setting `/s` on the whole pattern doesn't help you there (unless you use `\N` to match non-newlines).

Alternation

Inside a pattern or subpattern, use the `|` metacharacter to specify a set of possibilities, any one of which could match. For instance:

```
/Gandalf|Saruman|Radagast/
```

matches `Gandalf` or `Saruman` or `Radagast`. The alternation extends only as far as the innermost enclosing parentheses (whether capturing or not):

```
/prob|n|r|l|ate/    # Match prob, n, r, l, or ate
/pro(b|n|r|l)ate/   # Match probate, pronate, prorate, or prolate
/pro(?:b|n|r|l)ate/ # Match probate, pronate, prorate, or prolate
```

The second and third forms match the same strings, but the second form captures the variant character in `$1` and the third form does not.

At any given position, the Engine tries to match the first alternative, and then the second, and so on. The relative length of the alternatives does not matter, which means that in this pattern:

```
/(Sam|Samwise)/
```

`$1` will never be set to `Samwise`, no matter what string it's matched against, because `Sam` will always match first. When you have overlapping matches like this, put the longer ones at the beginning.

But the ordering of the alternatives only matters at a given position. The outer loop of the Engine does left-to-right matching, so the following always matches the first `Sam`:

```
"'Sam I am,' said Samwise" =~ /(Samwise|Sam)/;   # $1 eq "Sam"
```

To force right-to-left scanning, use greedy quantifiers:

```
"'Sam I am,' said Samwise" =~ /.*(Samwise|Sam)/; # $1 eq "Samwise"
```

You can defeat left-to-right (or right-to-left) matching by including any of the various positional assertions we saw earlier, such as `\G`, `^`, and `$`. Here we anchor the pattern to the end of the string:

```
"'Sam I am,' said Samwise" =~ /(Samwise|Sam)$/;  # $1 eq "Samwise"
```

Notice how we've factored the `$` out of the alternation (since we already had a handy pair of parentheses to put it after), but in the absence of such parentheses, you could also distribute the assertions to any or all of the individual alternatives, depending on how you want them to match. This little program displays lines that begin with either a `__DATA__` or `__END__` token:

```
#!/usr/bin/perl
while (<>) {
```

```
    print if /^__DATA__|^__END__/;
}
```

But be careful with that. Remember that the first and last alternatives (before the first `|` and after the last one) tend to gobble up the other elements of the regular expression on either side, out to the ends of the expression, unless there are enclosing parentheses. A common mistake is to ask for:

```
/^cat|dog|cow$/
```

when you really mean:

```
/^(cat|dog|cow)$/
```

The first matches "`cat`" at the beginning of the string, or "`dog`" anywhere, or "`cow`" at the end of the string. The second matches any string consisting solely of "`cat`" or "`dog`" or "`cow`". It also captures `$1`, which you may not want. Suppress that with one of:

```
/^cat$|^dog$|^cow$/
/^(?:cat|dog|cow)$/
```

An alternative can be empty, in which case it always matches.

```
/com(pound|)/;      # Matches "compound" or "com"
/com(pound(s|)|)/;  # Matches "compounds", "compound", or "com"
```

This is much like using the `?` quantifier, which matches 0 times or 1 time:

```
/com(pound)?/;      # Matches "compound" or "com"
/com(pound(s?))?/;  # Matches "compounds", "compound", or "com"
/com(pounds?)?/;    # Same, but doesn't use $2
```

There is one difference, though. When you apply the `?` to a subpattern that captures into a numbered variable, that variable will be undefined if there's no string to go there. If you used an empty alternative, it would still be false, but it would be a defined null string instead.

Staying in Control

As any good manager knows, you shouldn't micromanage your employees. Just tell them what you want, and let them figure out the best way of doing it. Similarly, it's often best to think of a regular expression as a kind of specification: "Here's what I want; go find a string that fits the bill."

On the other hand, the best managers also understand the job their employees are trying to do. The same is true of pattern matching in Perl. The more thoroughly you understand how Perl goes about the task of matching any particular

pattern, the more wisely you'll be able to make use of Perl's pattern-matching capabilities.

One of the most important things to understand about Perl's pattern matching is when *not* to use it.

Letting Perl Do the Work

When people of a certain temperament first learn regular expressions, they're often tempted to see everything as a problem in pattern matching. And while that may even be true in the larger sense, pattern matching is about more than just evaluating regular expressions. It's partly about looking for your car keys where you dropped them, not just under the streetlamp where you can see better. In real life, we all know that it's a lot more efficient to look in the right places than the wrong ones.

Similarly, you should use Perl's control flow to decide which patterns to execute and which ones to skip. A regular expression is pretty smart, but it's smart like a horse. It can get distracted if it sees too much at once. So sometimes you have to put blinders onto it. For example, you'll recall our earlier example of alternation:

```
/Gandalf|Saruman|Radagast/
```

That works as advertised, but not as well as it might, because it searches every position in the string for every name before it moves on to the next position. Astute readers of *The Lord of the Rings* will recall that, of the three wizards named above, Gandalf is mentioned much more frequently than Saruman, and Saruman is mentioned much more frequently than Radagast. So it's generally more efficient to use Perl's logical operators to do the alternation:

```
/Gandalf/ || /Saruman/ || /Radagast/
```

This is yet another way of defeating the "leftmost" policy of the Engine. It only searches for `Saruman` if `Gandalf` is nowhere to be seen. And it only searches for `Radagast` if `Saruman` is also absent.

Not only does this change the order in which things are searched, it sometimes allows the regular expression optimizer to work better. It's generally easier to optimize searching for a single string than for several strings simultaneously. Similarly, anchored searches can often be optimized if they're not too complicated.

You don't have to limit your control of the control flow to the `||` operator. Often you can control things at the statement level. You should always think about weeding out the common cases first. Suppose you're writing a loop to process a

configuration file. Many configuration files are mostly comments. It's often best to discard comments and blank lines early before doing any heavy-duty processing, even if the heavy-duty processing would throw out the comments and blank lines in the course of things:

```
while (<CONF>) {
    next if /^#/;
    next if /^\s*(#|$)/;
    chomp;
    munchabunch($_);
}
```

Even if you're not trying to be efficient, you often need to alternate ordinary Perl expressions with regular expressions simply because you want to take some action that is not possible (or very difficult) from within the regular expression, such as printing things out. Here's a useful number classifier:

```
warn "has nondigits"        if     /\D/;
warn "not a natural number" unless /^\d+$/;             # rejects -3
warn "not an integer"       unless /^-?\d+$/;           # rejects +3
warn "not an integer"       unless /^[+-]?\d+$/;
warn "not a decimal number" unless /^-?\d+\.?\d*$/;     # rejects .2
warn "not a decimal number" unless /^-?(?:\d+(?:\.\d*)?|\.\d+)$/;
warn "not a C float"
       unless /^([+-]?)(?=\d|\.\d)\d*(\.\d*)?([Ee]([+-]?\d+))?$/;
```

We could stretch this section out a lot longer, but really, that sort of thing is what this whole book is about. You'll see many more examples of the interplay of Perl code and pattern matching as we go along. In particular, see the later section"Programmatic Patterns" on page 251. (It's okay to read the intervening material first, of course.)

Variable Interpolation

Using Perl's control-flow mechanisms to control pattern matching has its limits. The main difficulty is that it's an "all or nothing" approach—either you run the pattern, or you don't. Sometimes you know the general outlines of the pattern you want, but you'd like to have the capability of parameterizing it. Variable interpolation provides that capability, much like parameterizing a subroutine lets you have more influence over its behavior than just deciding whether to call it or not. (More about subroutines in the next chapter.)

One nice use of interpolation is to provide a little abstraction, along with a little readability. With regular expressions you may certainly write things concisely:

```
if ($num =~ /^[-+]?\d+\.?\d*$/) { ... }
```

But what you mean is more apparent when you write:

```
$sign        = '[-+]?';
$digits      = '\d+';
$decimal     = '\.?';
$more_digits = '\d*';
$number = "$sign$digits$decimal$more_digits";
...
if ($num =~ /^$number$/o) { ... }
```

We'll cover this use of interpolation more under "Generated patterns" on page 252 later in this chapter. We'll just point out that we used the `/o` modifier to suppress recompilation because we don't expect `$number` to change its value over the course of the program. This is no longer necessary because Perl has gotten smarter about such things, but you may see it in older code.

Another cute trick is to turn your tests inside out and use the variable string to pattern match against a set of known strings:

```
chomp($answer = <STDIN>);
if    ("SEND"  =~ /^\Q$answer/i) { say "Action is send"  }
elsif ("STOP"  =~ /^\Q$answer/i) { say "Action is stop"  }
elsif ("ABORT" =~ /^\Q$answer/i) { say "Action is abort" }
elsif ("LIST"  =~ /^\Q$answer/i) { say "Action is list"  }
elsif ("EDIT"  =~ /^\Q$answer/i) { say "Action is edit"  }
```

This lets your user perform the "send" action by typing any of `S`, `SE`, `SEN`, or `SEND` (in any mixture of upper- and lowercase). To "stop", he'd have to type at least `ST` (or `St`, or `sT`, or `st`).

When backslashes happen

When you think of double-quote interpolation, you usually think of both variable and backslash interpolation. But as we mentioned earlier, for regular expressions there are two passes, and the interpolation pass defers most of the backslash interpretation to the regular expression parser (which we discuss later). Ordinarily, you don't notice the difference because Perl takes pains to hide the difference.

It's actually fairly important that the regex parser handle the backslashes, because only the regex parser knows which `\b` means a word boundary and which `\b` means a backspace. Or suppose you're searching for tab characters in a pattern with a `/x` modifier:

```
($col1, $col2) = /(.*?) \t+ (.*?)/x;
```

If Perl didn't defer the interpretation of `\t` to the regex parser, the `\t` would have turned into whitespace, which the regex parser would have ignorantly ignored because of the `/x`. But Perl is not so ignoble, or tricky.

You can trick yourself, though. Suppose you abstracted out the column separator like this:

```
$colsep = "\t+";                        # (double quotes)
($col1, $col2) = /(.*?) $colsep (.*?)/x;
```

Now you've just blown it because the `\t` turns into a real tab before it gets to the regex parser, which will think you said `/(.*?)+(.*?)/` after it discards the whitespace. Oops. To fix, avoid `/x`, or use single quotes. Or better, use `qr//`. (See the next section.)

The only double-quote escapes that are processed as such are named characters and the six translation escapes: `\N{`*CHARNAME*`}`, `\U`, `\u`, `\L`, `\l`, `\F`, `\Q`, and `\E`. If you ever look into the inner workings of the Perl regular expression compiler, you'll find code for handling escapes like `\t` for tab, `\n` for newline, and so on. But you won't find code for those six translation escapes. (We only listed them in Table 5-3 because people expect to find them there.) If you somehow manage to sneak any of them into the pattern without going through double-quotish evaluation, they won't be recognized. If you sneak a named character in, it will generate an error because the charmap that was active when the string was created needs to be the one to resolve what codepoint a name goes to. (This is because Perl allows you to create custom character name aliases, so it isn't always the standard set. See "charnames" on page 1008 in Chapter 29.)

How could they find their way in? Well, you can defeat interpolation by using single quotes as your pattern delimiter. In `m'...'`, `qr'...'`, and `s'...'...'`, the single quotes suppress variable interpolation and the processing of translation escapes, just as they would in a single-quoted string. Saying `m'\ufrodo'` won't find a capitalized version of poor frodo. However, since the "normal" backslash characters aren't really processed on that level anyway, `m'\t\d'` still matches a real tab followed by any digit.

Another way to defeat interpolation is through interpolation itself. If you say:

```
$var = '\U';
/${var}frodo/;
```

poor frodo remains uncapitalized. Perl won't redo the interpolation pass for you just because you interpolated something that looks like it might want to be reinterpolated. You can't expect that to work any more than you'd expect this double interpolation to work:

```
$hobbit = "Frodo";
$var = '$hobbit';           # (single quotes)
/$var/;                     # means m'$hobbit', not m'Frodo'.
```

Here's another example that shows how most backslashes are interpreted by the regex parser, not by variable interpolation. Imagine you have a simple little *grep*-style program written in Perl:[14]

```
#!/usr/bin/perl
$pattern = shift;
while (<>) {
    print if /$pattern/;
}
```

If you name that program *pgrep* and call it this way:

```
% pgrep '\t\d' *.c
```

then you'll find that it prints out all lines of all your C source files in which a digit follows a tab. You didn't have to do anything special to get Perl to realize that `\t` was a tab. If Perl's patterns *were* just double-quote interpolated, you would have; fortunately, they aren't. They're recognized directly by the regex parser.

The real *grep* program has a `-i` switch that turns off case-sensitive matching. You don't have to add such a switch to your *pgrep* program; it can already handle that without modification. You just pass it a slightly fancier pattern, with an embedded `/i` modifier:

```
% pgrep '(?i)ring' LotR*.pod
```

That now searches for any of "`Ring`", "`ring`", "`RING`", and so on. You don't see this feature too much in literal patterns, since you can always just write `/ring/i`. But for patterns passed in on the command line, in web search forms, or embedded in configuration files, it can be a lifesaver. (Speaking of rings.)

The qr/PATTERN/modifiers quote regex operator

Variables that interpolate into patterns necessarily do so at runtime, not compile time. This used to noticeably slow down execution because Perl had to check whether you'd changed the contents of the variable; if so, it would have to recompile the regular expression. These days, Perl is a lot smarter, and you'd need to be interpolating patterns that were more than 10k longer before you noticed any benefit from the nearly extinct `/o` option, which tells Perl to interpolate and compile only once:

```
print if /$pattern/o;
```

14. If you didn't know what a *grep* program was before, you will now. No system should be without *grep*—we believe *grep* is the most useful small program ever invented. (It logically follows that we don't believe Perl is a small program.)

Although that works fine in our *pgrep* program, in the general case, it doesn't. Imagine you have a slew of patterns, and you want to match each of them in a loop, perhaps like this:

```
for my $item (@data) {
    for my $pat (@patterns) {
        if ($item =~ /$pat/) { ... }
    }
}
```

You couldn't write `/$pat/o` because the meaning of `$pat` varies each time through the inner loop.

The solution to this is the `qr/`*PATTERN*`/msixpodual` operator, which is usually just pronounced `qr//`, for obvious reasons. This operator quotes—and compiles—its *PATTERN* as a regular expression. *PATTERN* is interpolated the same way as in `m/`*PATTERN*`/`. If `'` is used as the delimiter, no interpolation of variables (or the seven translation escapes) is done. The operator returns a special value that may be used instead of the equivalent literal in a corresponding pattern match or substitute. For example:

```
$regex = qr/my.STRING/is;
s/$regex/something else/;
```

is equivalent to:

```
s/my.STRING/something else/is;
```

So for our nested loop problem above, preprocess your pattern first using a separate loop:

```
@regexes = ();
for my $pat (@patterns) {
    push @regexes, qr/$pat/;
}
```

or all at once using Perl's `map` operator:

```
@regexes = map { qr/$_/ } @patterns;
```

And then change the loop to use those precompiled regexes:

```
for my $item (@data) {
    foreach $re (@regexes) {
        if ($item =~ /$re/) { ... }
    }
}
```

Now when you run the match, Perl doesn't have to create a compiled regular expression on each `if` test, because it sees that it already has one.

The result of a `qr//` may even be interpolated into a larger match, as though it were a simple string:

```
$regex = qr/$pattern/;
$string =~ /foo${regex}bar/;   # interpolate into larger patterns
```

This time, Perl does recompile the pattern, but you could always chain several `qr//` operators together into one.

The reason this works is because the `qr//` operator returns a special kind of object that has a stringification overload as described in Chapter 13. If you print out the return value, you'll see the equivalent string:

```
use v5.14;
$re = qr/my.STRING/is;
say $re;                 # prints (?^usi:my.STRING) in v5.14
```

The `^` says to start with the default option set. The `/u` is there because the "`unicode_strings`" feature is in scope, because you said `use v5.14`. The `/s` and `/i` modifiers were enabled in the pattern because they were supplied to `qr//`. The `/x` and `/m` are not mentioned because they are already disabled in the default environment specified by the caret at the start, which says to start over with the original modifiers, not the current ones.

Anytime you interpolate strings of unknown provenance into a pattern, you should be prepared to handle any exceptions thrown by the regex compiler, in case someone fed you a string containing untamable beasties:

```
$re = qr/$pat/is;                    # might escape and eat you
$re = eval { qr/$pat/is } || warn ...  # caught it in an outer cage
```

For more on the `eval` operator, see Chapter 27.

The Regex Compiler

After the variable interpolation pass has had its way with the string, the regex parser finally gets a shot at trying to understand your regular expression. There's not actually a great deal that can go wrong at this point, apart from messing up the parentheses or using a sequence of metacharacters that doesn't mean anything. The parser does a recursive-descent analysis of your regular expression and, if it parses, turns it into a form suitable for interpretation by the Engine (see the next section). Most of the interesting stuff that goes on in the parser involves optimizing your regular expression to run as fast as possible. We're not going to explain that part. It's a trade secret. (Rumors that looking at the regular expression code will drive you insane are greatly exaggerated. We hope.)

But you might like to know what the parser actually thought of your regular expression, and if you ask it politely, it will tell you. By saying `use re "debug"`, you can examine how the regex parser processes your pattern. (You can also see the same information by using the `-Dr` command-line switch, which is available to you if your Perl was compiled with the `-DDEBUGGING` flag during installation.)

```
#!/usr/bin/perl
use re "debug";
"Smeagol" =~ /^Sm(.*)[aeiou]l$/;
```

The output is below. You can see that prior to execution Perl compiles the regex and assigns meaning to the components of the pattern: `BOL` for the beginning of line (`^`), `REG_ANY` for the dot, and so on:

```
Compiling REx "^Sm(.*)[aeiou]l$"
Final program:
   1: BOL (2)
   2: EXACT <Sm> (4)
   4: OPEN1 (6)
   6:   STAR (8)
   7:     REG_ANY (0)
   8: CLOSE1 (10)
  10: ANYOF[aeiou][] (21)
  21: EXACT <l> (23)
  23: EOL (24)
  24: END (0)
anchored "Sm" at 0 floating "l"$ at 3..2147483647 (checking anchored)
anchored(BOL) minlen 4
```

Some of the lines summarize the conclusions of the regex optimizer. It knows that the string must start with "`Sm`", and that therefore there's no reason to do the ordinary left-to-right scan. It knows that the string must end with an "`l`", so it can reject out of hand any string that doesn't. It knows that the string must be at least four characters long, so it can ignore any string shorter than that right off the bat. It also knows what the rarest character in each constant string is, which can help in searching "studied" strings. (See the `study` entry in Chapter 27.)

It then goes on to trace how it executes the pattern:

```
Guessing start of match in sv for REx "^Sm(.*)[aeiou]l$" against "Smeagol"
Guessed: match at offset 0
Matching REx "^Sm(.*)[aeiou]l$" against "Smeagol"
   0 <> <Smeagol>            |  1:BOL(2)
   0 <> <Smeagol>            |  2:EXACT <Sm>(4)
   2 <Sm> <eagol>            |  4:OPEN1(6)
   2 <Sm> <eagol>            |  6:STAR(8)
                                 REG_ANY can match 5 times
                                 out of 2147483647...
   7 <Smeagol> <>            |  8:  CLOSE1(10)
   7 <Smeagol> <>            | 10:  ANYOF[aeiou][](21)
```

```
                                    failed...
   6 <Smeago> <l>            |  8:  CLOSE1(10)
   6 <Smeago> <l>            | 10:  ANYOF[aeiou][](21)
                                    failed...
   5 <Smeag> <ol>            |  8:  CLOSE1(10)
   5 <Smeag> <ol>            | 10:  ANYOF[aeiou][](21)
   6 <Smeago> <l>            | 21:  EXACT <l>(23)
   7 <Smeagol> <>            | 23:  EOL(24)
   7 <Smeagol> <>            | 24:  END(0)
Match successful!
Freeing REx: "^Sm(.*)[aeiou]l$"
```

If you follow the stream of whitespace down the middle of `Smeagol`, you can actually see how the Engine overshoots to let the `.*` be as greedy as possible, then backtracks on that until it finds a way for the rest of the pattern to match. But that's what the next section is about.

The Little Engine That /Could(n't)?/

And now we'd like to tell you the story of the Little Regex Engine that says, "I think I can. I think I can. I think I can."

In this section, we lay out the rules used by Perl's regular expression engine to match your pattern against a string. The Engine is extremely persistent and hard-working. It's quite capable of working even after you think it should quit. The Engine doesn't give up until it's certain there's no way to match the pattern against the string. The Rules below explain how the Engine "thinks it can" for as long as possible, until it *knows* it can or can't. The problem for our Engine is that its task is not merely to pull a train over a hill. It has to search a (potentially) very complicated space of possibilities, keeping track of where it has been and where it hasn't.

The Engine uses a nondeterministic finite-state automaton (NFA, not to be confused with NFL, a nondeterministic football league) to find a match. That just means that it keeps track of what it has tried and what it hasn't, and when something doesn't pan out, it backs up and tries something else. This is known as *backtracking*. (Er, sorry—we didn't invent that term. Really.) The Engine is capable of trying a million subpatterns at one spot, then giving up on all those, backing up to within one choice of the beginning, and trying the million subpatterns again at a different spot. The Engine is not terribly intelligent—just persistent, and thorough. If you're cagey, you can give the Engine an efficient pattern that doesn't let it do a lot of silly backtracking.

When someone trots out a phrase like "Regexes choose the leftmost, longest match", that means that Perl generally prefers the leftmost match over the longest

match. But the Engine doesn't realize it's "preferring" anything, and it's not really thinking at all, just gutting it out. The overall preferences are an emergent behavior resulting from many individual and unrelated choices. Here are those choices:[15]

Rule 1

The Engine tries to match as far left in the string as it can, such that the entire regular expression matches under Rule 2.

The Engine starts just before the first character and tries to match the entire pattern starting there. The entire pattern matches if and only if the Engine reaches the end of the pattern before it runs off the end of the string. If it matches, it quits immediately—it doesn't keep looking for a "better" match, even though the pattern might match in many different ways.

If it is unable to match the pattern at the first position in the string, it admits temporary defeat and moves to the next position in the string, between the first and second characters, and tries all the possibilities again. If it succeeds, it stops. If it fails, it continues on down the string. The pattern match as a whole doesn't fail until it has tried to match the entire regular expression at every position in the string, including after the last character.

A string of *n* characters actually provides *n* `+ 1` positions to match at. That's because the beginnings and the ends of matches are *between* the characters of the string (or at either end). This rule sometimes surprises people when they write a pattern like `/x*/` that can match zero or more "`x`" characters. If you try that pattern on a string like "`fox`", it won't find the "`x`". Instead, it will immediately match the null string before the "`f`" and never look further. If you want it to match one or more `x` characters, you need to use `/x+/` instead. See the quantifiers under Rule 5.

A corollary to this rule is that any pattern matching the null string is guaranteed to match at the leftmost position in the string (in the absence of any zero-width assertions to the contrary).

Rule 2

When the Engine encounters a set of alternatives (separated by `|` symbols), either at the top level or at the current grouping level, it tries them left to right, stopping on the first successful match that allows successful completion of the entire pattern.

15. Some of these choices may be skipped if the regex optimizer has any say, which is equivalent to the Little Engine simply jumping through the hill via quantum tunnelling. But for this discussion we're pretending the optimizer doesn't exist.

A set of alternatives matches a string if any of the alternatives match under Rule 3. If none of the alternatives matches, it backtracks to the rule that invoked this rule, which is usually Rule 1, but could be Rule 4 or 6, if we're within a group. That rule will then look for a new position at which to apply Rule 2.

If there's only one alternative, then either it matches or it doesn't, and Rule 2 still applies. (There's no such thing as zero alternatives because a null string always matches.)

Rule 3

Any particular alternative matches if every *item* listed in the alternative matches sequentially according to Rules 4 and 5 (such that the entire regular expression can be satisfied).

An item consists of either an *assertion*, which is covered in Rule 4, or a *quantified atom*, covered by Rule 5. Items that have choices on how to match are given a "pecking order" from left to right. If the items cannot be matched in order, the Engine backtracks to the next alternative under Rule 2.

Items that must be matched sequentially aren't separated in the regular expression by anything syntactic—they're merely juxtaposed in the order they must match. When you ask to match `/^foo/`, you're actually asking for four items to be matched one after the other. The first is a zero-width assertion, matched under Rule 4, and the other three are ordinary characters that must match themselves, one after the other, under Rule 5.

The left-to-right pecking order means that in a pattern like:

```
/x*y*/
```

`x*` gets to pick one way to match, and then `y*` tries all its ways. If that fails, then `x*` gets to pick its second choice and make `y*` try all of its ways again. And so on. The items to the right "vary faster", to borrow a phrase from multidimensional arrays.

Rule 4

If an assertion does not match at the current position, the Engine backtracks to Rule 3 and retries higher-pecking-order items with different choices.

Some assertions are fancier than others. Perl supports many regex extensions, some of which are zero-width assertions. For example, the positive lookahead `(?=...)` and the negative lookahead `(?!...)` don't actually match any characters but merely assert that the regular expression represented by `...`

would (or would not) match at this point, were we to attempt it, hypothetically speaking.[16]

Rule 5

A quantified atom matches only if the atom itself matches some number of times that is allowed by the quantifier. (The atom itself is matched according to Rule 6.)

Different quantifiers require different numbers of matches, and most of them allow a range of numbers of matches. Multiple matches must all match in a row; that is, they must be adjacent within the string. An unquantified atom is assumed to have a quantifier requiring exactly one match (that is, `/x/` is the same as `/x{1}/`). If no match can be found at the current position for any allowed quantity of the atom in question, the Engine backtracks to Rule 3 and retries higher-pecking-order items with different choices.

The quantifiers are `*`, `+`, `?`, `*?`, `+?`, `??`, `*+`, `++`, `?+`, and the various brace forms. If you use the `{`*`COUNT`*`}` form, then there is no choice, and the atom must match exactly that number of times or not at all. Otherwise, the atom can match over a range of quantities, and the Engine keeps track of all the choices so that it can backtrack if necessary. But then the question arises as to which of these choices to try first. One could start with the maximal number of matches and work down, or the minimal number of matches and work up.

The traditional quantifiers (without a trailing question mark) specify *greedy* matching; that is, they attempt to match as many characters as possible. To find the greediest match, the Engine has to be a little bit careful. Bad guesses are potentially rather expensive, so the Engine doesn't actually count down from the maximum value, which after all could be Very Large and cause millions of bad guesses. What the Engine actually does is a little bit smarter: it first counts *up* to find out how many matching atoms (in a row) are really there in the string, and then it uses *that* actual maximum as its first choice. (It also remembers all the shorter choices in case the longest one doesn't pan out.) It then (at long last) tries to match the rest of the pattern, assuming the longest choice to be the best. If the longest choice fails to produce a match for the rest of the pattern, it backtracks and tries the next longest.

If you say `/.*foo/`, for example, it will try to match the maximal number of "any" characters (represented by the dot) clear out to the end of the line

16. In actual fact, the Engine *does* attempt it. The Engine goes back to Rule 2 to test the subpattern, and then wipes out any record of how much string was eaten, returning only the success or failure of the subpattern as the value of the assertion. (It does, however, remember any captured substrings.)

before it ever tries looking for "`foo`"; and then when the "`foo`" doesn't match there (and it can't, because there's not enough room for it at the end of the string), the Engine will back off one character at a time until it finds a "`foo`". If there is more than one "`foo`" in the line, it'll stop on the last one, since that will really be the *first* one it encounters as it backtracks. When the entire pattern succeeds using some particular length of `.*`, the Engine knows it can throw away all the other shorter choices for `.*` (the ones it would have used had the current "`foo`" not panned out).

By placing a question mark after any greedy quantifier, you turn it into a frugal quantifier that chooses the smallest quantity for the first try. So if you say `/.*?foo/`, the `.*?` first tries to match 0 characters, then 1 character, then 2, and so on, until it can match the "`foo`". Instead of backtracking backward, it backtracks forward, so to speak, and ends up finding the first "`foo`" on the line instead of the last.

Rule 6

Each atom matches according to the designated semantics of its type. If the atom doesn't match (or does match, but doesn't allow a match of the rest of the pattern), the Engine backtracks to Rule 5 and tries the next choice for the atom's quantity.

Atoms match according to the following types:

- A regular expression in parentheses, `(...)`, matches whatever the regular expression (represented by `...`) matches according to Rule 2. Parentheses therefore serve as a grouping operator for quantification. Bare parentheses also have the side effect of capturing the matched substring for later use in a *group reference*, often known as a *backreference*. This side effect can be suppressed by using `(?:...)` instead, which has only the grouping semantics—it doesn't store anything in `$1`, `$2`, and so on. Other forms of parenthetical atoms (and assertions) are possible—see the rest of this chapter.
- A dot matches any character, except maybe newline.
- A list of characters in square brackets (a *bracketed character class*) matches any one of the characters specified by the list.
- A backslashed letter matches an abstract sequence, typically either a particular character or one of a set of characters, as listed in Table 5-3.
- Any other backslashed character matches that character.
- Any character not mentioned above matches itself.

That all sounds rather complicated, but the upshot of it is that, for each set of choices given by a quantifier or alternation, the Engine has a knob it can twiddle.

It will twiddle those knobs until the entire pattern matches. The Rules just say in which order the Engine is allowed to twiddle those knobs. Saying the Engine prefers the leftmost match merely means it twiddles the start position knob the slowest. And backtracking is just the process of untwiddling the knob you just twiddled in order to try twiddling a knob higher in the pecking order—that is, one that varies slower.

Here's a more concrete example. This program detects when two consecutive words share a common ending and beginning:

```
$a = "nobody";
$b = "bodysnatcher";
if ("$a $b" =~ /^(\w+)(\w+) \2(\w+)$/) {
    say "$2 overlaps in $1-$2-$3";
}
```

This prints:

```
body overlaps in no-body-snatcher
```

You might think that `$1` would first grab up all of "`nobody`" due to greediness. And, in fact, it does—at first. But once it's done so, there aren't any further characters to put in `$2`, which needs characters put into it because of the `+` quantifier. So the Engine backs up and `$1` begrudgingly gives up one character to `$2`. This time the space character matches successfully, but then it sees `\2`, which represents a measly "`y`". The next character in the string is not a "`y`", but a "`b`". This makes the Engine back up character by character all the way, eventually forcing `$1` to surrender the body to `$2`. Habeas corpus, as it were.

Actually, that won't quite work out if the overlap is itself the product of a doubling, as in the two words "`rococo`" and "`cocoon`". The algorithm above would have decided that the overlapping string, `$2`, must be just "`co`" rather than "`coco`". But we don't want a "`rococococoon`"; we want a "`rococoon`". Here's one of those places you can outsmart the Engine. Adding a minimal matching quantifier to the `$1` part gives the much better pattern `/^(\w+?)(\w+) \2(\w+)$/`, which does exactly what we want.

For a much more detailed discussion of the pros and cons of various kinds of regular expression engines, see Jeffrey Friedl's book, *Mastering Regular Expressions*. Perl's regular expression Engine works very well for many of the everyday problems you want to solve with Perl, and it even works okay for those not-so-everyday problems—if you give it a little respect and understanding.

Fancy Patterns

Lookaround Assertions

Sometimes you just need to sneak a peek. There are four regex extensions that help you do just that, and we call them *lookaround* assertions because they let you scout around in a hypothetical sort of way, without committing to matching any characters. What these assertions assert is that some pattern would (or would not) match if we were to try it. The Engine works it all out for us by actually trying to match the hypothetical pattern, and then pretending that it didn't match (if it did).

When the Engine peeks ahead from its current position in the string, we call it a *lookahead* assertion. If it peeks backward, we call it a *lookbehind* assertion. The lookahead patterns can be any regular expression, but the lookbehind patterns may only be fixed width, since they have to know from where to start the hypothetical match.

While these four extensions are all zero-width assertions, and hence do not consume characters (at least, not officially), you can in fact capture substrings within them if you supply extra levels of capturing parentheses.

`(?=`*`PATTERN`*`)` *(positive lookahead)*

When the Engine encounters `(?=`*`PATTERN`*`)`, it looks ahead in the string to ensure that *`PATTERN`* occurs. If you'll recall, in our earlier duplicate word remover, we had to write a loop because the pattern ate too much each time through:

```
$_ = "Paris in THE THE THE THE spring.";

# remove duplicate words (and triplicate (and quadruplicate...))
1 while s/\b(\w+) \1\b/$1/gi;
```

Whenever you hear the phrase "ate too much", you should always think "lookahead assertion" (well, almost always). By peeking ahead instead of gobbling up the second word, you can write a one-pass duplicate word remover like this:

```
s/ \b(\w+) \s (?= \1\b ) //gxi;
```

Of course, this isn't quite right, since it will mess up valid phrases like "`The clothes you DON DON't fit.`"

Lookahead assertions can be used to implement overlapping matches. For example,

```
"0123456789" =~ /(\d{3})/g
```

returns only three strings: `012`, `345`, and `678`. By wrapping the capture group with a lookahead assertion:

```
"0123456789" =~ /(?:(\d{3}))/g
```

you now retrieve all of `012`, `123`, `234`, `345`, `456`, `567`, `678`, and `789`. This works because this tricky assertion does a stealthy sneakahead to run up and grab what's there and stuff its capture group with it, but being a lookahead, it reneges and doesn't technically consume any of it. When the engine sees that it should try again because of the `/g`, it steps one character past where last it tried.

`(?!`*PATTERN*`)` *(negative lookahead)*

When the Engine encounters `(?!`*PATTERN*`)`, it looks ahead in the string to ensure that *PATTERN* does *not* occur. To fix our previous example, we can add a negative lookahead assertion after the positive assertion to weed out the case of contractions:

```
s/ \b(\w+) \s (?= \1\b (?! '\w))//xgi;
```

That final `\w` is necessary to avoid confusing contractions with words at the ends of single-quoted strings. We can take this one step further, since earlier in this chapter we intentionally used "that that particular", and we'd like our program to not "fix" that for us. So we can add an alternative to the negative lookahead in order to pre-unfix that "`that`" (thereby demonstrating that any pair of parentheses can be used to group alternatives):

```
s/ \b(\w+) \s (?= \1\b (?! '\w | \s particular))//gix;
```

Now we know that that particular phrase is safe. Unfortunately, the Gettysburg Address is still broken. So we add another exception:

```
s/ \b(\w+) \s (?= \1\b (?! '\w | \s particular | \s nation))//igx;
```

This is just starting to get out of hand. So let's do an Official List of Exceptions, using a cute interpolation trick with the `$"` variable to separate the alternatives with the `|` character:

```
@thatthat = qw(particular nation);
local $" = '|';
s/ \b(\w+) \s (?= \1\b (?! '\w | \s (?: @thatthat ))//xig;
```

`(?<=`*PATTERN*`)` *(positive lookbehind)*

When the Engine encounters `(?<=` *PATTERN*`)`, it looks backward in the string to ensure that *PATTERN* already occurred.

Our example still has a problem. Although it now lets Honest Abe say things like "`that that nation`", it also allows "`Paris, in the the nation of France`". We can add a positive lookbehind assertion in front of our exception list to make sure that we apply our `@thatthat` exceptions only to a real "`that that`".

```
s/ \b(\w+) \s (?= \1\b (?! '\w | (?<= that) \s (?: @thatthat ))//ixg;
```

Yes, it's getting terribly complicated, but that's why this section is called "Fancy Patterns", after all. If you need to complicate the pattern any more than we've done so far, judicious use of comments and `qr//` will help keep you sane. Or at least saner.

Or consider using `\K` to lie to the Engine about where the official match started. The preceding pattern will then function as a kind of lookbehind to the official part of the pattern, but it will be scanned for left to right. This is especially useful if you find yourself wanting a variable-width lookbehind, which is something the Engine can't. Or at least won't.

`(?<!`*`PATTERN`*`)` *(negative lookbehind)*

When the Engine encounters `(?<!` *`PATTERN`*`)`, it looks backward in the string to ensure that *`PATTERN`* did not occur.

Let's go for a really simple example this time. How about the easy version of that old spelling rule, "I before E except after C"? In Perl, you spell it:

```
s/(?<!c)ei/ie/g
```

You'll have to weigh for yourself whether you want to handle any of the exceptions. (For example, "`weird`" is spelled weird, especially when you spell it "`wierd`".)

Possessive Groups

As described in "The Little Engine That /Could(n't)?/" on page 241, the Engine often backtracks as it proceeds through the pattern. You can block the Engine from backtracking back through a particular set of choices by creating a *nonbacktracking subpattern*. A possessive group looks like `(?>`*`PATTERN`*`)`, and it works exactly like a simple noncapturing group `(?:`*`PATTERN`*`)`, except that once *`PATTERN`* has found a match, it suppresses backtracking on any of the quantifiers or alternatives inside the subpattern. (Hence, it is meaningless to use this on a *`PATTERN`* that doesn't contain quantifiers or alternatives.) The only way to get it to change its mind is to backtrack to something before the subpattern and reenter the subpattern from the left.

It's like going into a car dealership. After a certain amount of haggling over the price, you deliver an ultimatum: "Here's my best offer; take it or leave it." If they don't take it, you don't go back to haggling again. Instead, you backtrack clear out the door. Maybe you go to another dealership and start haggling again. You're allowed to haggle again, but only because you reentered the nonbacktracking pattern again in a different context.

For devotees of Prolog or SNOBOL, you can think of this as a scoped cut or fence operator.

Consider how in `"aaab" =~ /(?:a*)ab/`, the `a*` first matches three `a`s, but then gives up one of them because the last `a` is needed later. The subgroup sacrifices some of what it wants in order for the whole match to succeed. (Which is like letting the car salesman talk you into giving him more of your money because you're afraid to walk away from the deal.) In contrast, the subpattern in `"aaab" =~ /(?>a*)ab/` will never give up what it grabs, even though this behavior causes the whole match to fail. (As the song says, you have to know when to hold 'em, when to fold 'em, and when to walk away.)

Although `(?>` *`PATTERN`*`)` is useful for changing the behavior of a pattern, it's mostly used for speeding up the failure of certain matches that you know will fail anyway (unless they succeed outright). The Engine can take a spectacularly long time to fail, particularly with nested quantifiers. The following pattern will succeed almost instantly:

```
$_ = "aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaab";
/a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*[Bb]/;
```

But success is not the problem. Failure is. If you remove that final "`b`" from the string, the pattern will probably run for many, many years before failing. Many, many millennia. Actually, billions and billions of years.[17] You can see by inspection that the pattern can't succeed if there's no "`b`" on the end of the string, but the regex optimizer is not smart enough (as of this writing) to figure out that `/[Bb]/` will never match some other way. But if you give it a hint, you can get it to fail quickly while still letting it succeed where it can:

```
/(?>a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*a*)[Bb]/;
```

For a (hopefully) more realistic example, imagine a program that's supposed to read in a paragraph at a time and show just the lines that are continued, where

17. Actually, it's more on the order of septillions and septillions. We don't know exactly how long it would take. We didn't care to wait around watching it not fail. In any event, your computer is likely to crash before the heat death of the universe, and this regular expression takes longer than either of those.

continuation lines are specified with trailing backslashes. Here's a sample from Perl's *Makefile* that uses this line-continuation convention:

```
# Files to be built with variable substitution before miniperl
# is available.
sh = Makefile.SH cflags.SH config_h.SH makeaperl.SH makedepend.SH \
        makedir.SH myconfig.SH writemain.SH
```

You could write your simple program this way:

```
#!/usr/bin/perl -00p
while ( /( (.+) ( (?<=\\) \n .* )+ ) /gx) {
    say "GOT $.: $1\n";
}
```

That works, but it's really quite slow. That's because the Engine backtracks a character at a time from the end of the line, shrinking what's in `$1`. This is pointless. And writing it without the extraneous captures doesn't help much. Using:

```
(.+(?:(?<=\\)\n.*)+)
```

for a pattern is somewhat faster, but not much. This is where a nonbacktracking subpattern helps a lot. The pattern:

```
((?>.+)(?:(?<=\\)\n.*)+)
```

does the same thing, but more than an order of magnitude faster because it doesn't waste time backtracking in search of something that isn't there.

You'll never get a success with `(?>...)` that you wouldn't get with `(?:...)`, or even a simple `(...)`. But if you're going to fail, it's best to fail quickly and get on with your life.

By the way, since our example contains only a single quantifier, `(?>.+)` may be more succinctly written as `.++`.

Programmatic Patterns

Most Perl programs tend to follow an imperative (also called procedural) programming style, like a series of discrete commands laid out in a readily observable order: "Preheat oven, mix, glaze, heat, cool, serve to aliens." Sometimes into this mix you toss a few dollops of functional programming ("use a little more glaze than you think you need, even after taking this into account, recursively"), or sprinkle it with bits of object-oriented techniques ("but please hold the anchovy objects"). Often it's a combination of all of these.

But the regular expression Engine takes a completely different approach to problem solving, more of a declarative approach. You describe goals in the language of regular expressions, and the Engine implements whatever logic is needed to

solve your goals. Logic programming languages (such as Prolog) don't always get as much exposure as the other three styles, but they're more common than you'd think. Perl couldn't even be built without *make*(1) or *yacc*(1), both of which could be considered—if not purely declarative languages—at least hybrids that blend imperative and logic programming together.

You can do this sort of thing in Perl, too, by blending goal declarations and imperative code together more miscibly than we've done so far, drawing upon the strengths of both. You can programmatically build up the string you'll eventually present to the regex Engine, in a sense creating a program that writes a new program on the fly.

You can also supply ordinary Perl expressions as the replacement part of `s///` via the `/e` modifier. This allows you to dynamically generate the replacement string by executing a bit of code every time the pattern matches.

Even more elaborately, you can interject bits of code wherever you'd like in the middle of a pattern using the `(?{ CODE })` extension, and that code will be executed every time the Engine encounters that code as it advances and recedes in its intricate backtracking dance.

Finally, you can use `s///ee` or `(??{ CODE })` to add another level of indirection: the *results* of executing those code snippets will themselves be reevaluated for further use, creating bits of program and pattern on the fly, just in time.

Generated patterns

It has been said[18] that programs that write programs are the happiest programs in the world. In Jeffrey Friedl's book *Mastering Regular Expressions*, the final tour de force demonstrates how to write a program that produces a regular expression to determine whether a string conforms to the RFC 822 standard; that is, whether it contains a standards-compliant, valid mail header. The pattern produced is several thousand characters long, and it's about as easy to read as a crash dump in pure binary. But Perl's pattern matcher doesn't care about that; it just compiles up the pattern without a hitch and, even more interestingly, executes the match very quickly—much more quickly, in fact, than many short patterns with complex backtracking requirements.

That's a very complicated example. Earlier we showed you a very simple example of the same technique when we built up a `$number` pattern out of its components (see the earlier section "Variable Interpolation" on page 234). But to show you the

18. By Andrew Hume, the famous Unix philosopher.

power of this programmatic approach to producing a pattern, let's work out a problem of medium complexity.

Suppose you wanted to pull out all the words with a certain vowel-consonant sequence; for example, "`audio`" and "`eerie`" both follow a VVCVV pattern. Although describing what counts as a consonant or a vowel is easy, you wouldn't ever want to type that in more than once. Even for our simple VVCVV case, you'd need to type in a pattern that looked something like this:

```
^[aeiouy][aeiouy][cbdfghjklmnpqrstvwxzy][aeiouy][aeiouy]$
```

A more general-purpose program would accept a string like "`VVCVV`" and programmatically generate that pattern for you. For even more flexibility, it could accept a word like "`audio`" as input and use that as a template to infer "`VVCVV`" and, from that, the long pattern above. It sounds complicated, but it really isn't because we'll let the program generate the pattern for us. Here's a simple *cvmap* program that does all of that:

```
#!/usr/bin/perl
$vowels = "aeiouy";
$cons   = "cbdfghjklmnpqrstvwxzy";
%map = (C => $cons, V => $vowels);  # init map for C and V

for $class ($vowels, $cons) {       # now for each type
    for (split //, $class) {        # get each letter of that type
        $map{$_} .= $class;         # and map the letter back to the type
    }
}

for $char (split //, shift) {       # for each letter in template word
    $pat .= "[$map{$char}]";        # add appropriate character class
}

$re = qr/^${pat}$/i;                # compile the pattern
say "REGEX is $re\n";              # debugging output
@ARGV = ("/usr/share/dict/words")   # pick a default dictionary
    if -t && !@ARGV;

while (<>) {                        # and now blaze through the input
    print if /$re/;                 # printing any line that matches
}
```

The `%map` variable holds all the interesting bits. Its keys are each letter of the alphabet, and the corresponding value is all the letters of its type. We throw in C and V, too, so you can specify either "`VVCVV`" or "`audio`", and still get out "`eerie`". Each character in the argument supplied to the program is used to pull out the right character class to add to the pattern. Once the pattern is created

and compiled up with `qr//`, the match (even a very long one) will run quickly. Here's what you might get if you run this program on "`fortuitously`":

```
% cvmap fortuitously /usr/dict/words
  REGEX is (?i-xsm:^[cbdfghjklmnpqrstvwxzy][aeiouy][cbdfghjklmnpqrstvw
  xzy][cbdfghjklmnpqrstvwxzy][aeiouy][aeiouy][cbdfghjklmnpqrstvwxzy][a
  eiouy][aeiouy][cbdfghjklmnpqrstvwxzy][cbdfghjklmnpqrstvwxzy][aeiouyc
  bdfghjklmnpqrstvwxzy]$)
  carriageable
  circuitously
  fortuitously
  languorously
  marriageable
  milquetoasts
  sesquiquarta
  sesquiquinta
  villainously
```

Looking at that `REGEX`, you can see just how much villainous typing you saved by programming languorously, albeit circuitously.

Substitution evaluations

When the `/e` modifier ("e" is for expression evaluation) is used on an `s/`*`PATTERN`*`/`*`CODE`*`/e` expression, the replacement portion is interpreted as a Perl expression, not just as a double-quoted string. It's like an embedded `do { `*`CODE`*` }`. Even though it looks like a string, it's really just a code block that gets compiled at the same time as the rest of your program, long before the substitution actually happens.

You can use the `/e` modifier to build replacement strings with fancier logic than double-quote interpolation allows. This shows the difference:

```
s/(\d+)/$1 * 2/;     # Replaces "42" with "42 * 2"
s/(\d+)/$1 * 2/e;    # Replaces "42" with "84"
```

And this converts Celsius temperatures into Fahrenheit:

```
$_ = "Preheat oven to 233C.\n";
s/\b(\d+\.?\d*)C\b/int($1 * 1.8 + 32) . "F"/e;   # convert to 451F
```

Applications of this technique are limitless. Here's a filter that modifies its files in place (like an editor) by adding 100 to every number that starts a line (and that is followed by a colon, which we only peek at but don't actually match or replace):

```
% perl -pi -e 's/^(\d+)(?=:)/100 + $1/e' filename
```

Now and then you want to do more than just use the string you matched in another computation. Sometimes you want that string to *be* a computation, whose own evaluation you'll use for the replacement value. Each additional `/e`

modifier after the first wraps an `eval` around the code to execute. The following two lines do the same thing, but the first one is easier to read:

```
s/PATTERN/CODE/ee
s/PATTERN/eval(CODE)/e
```

You could use this technique to replace mentions of simple scalar variables with their values:

```
s/(\$\w+)/$1/eeg;       # Interpolate most scalars' values
```

Because it's really an `eval`, the `/ee` even finds lexical variables. A slightly more elaborate example calculates a replacement for simple arithmetical expressions on (nonnegative) integers:

```
$_ = "I have 4 + 19 dollars and 8/2 cents.\n";
s{ (
        \d+ \s*         # find an integer
        [+*/-]          # and an arithmetical operator
        \s* \d+         # and another integer
   )
}{ $1 }eegx;            # then expand $1 and run that code
print;                  # "I have 23 dollars and 4 cents."
```

Like any other `eval` *`STRING`*, compile-time errors (like syntax problems) and run-time exceptions (like dividing by zero) are trapped. If so, the `$@` (`$EVAL_ERROR`) variable says what went wrong.

Match-time code evaluation

In most programs that use regular expressions, the surrounding program's run-time control structure drives the logical execution flow. You write `if` or `while` loops, or make function or method calls, that wind up calling a pattern-matching operation now and then. Even with `s///e`, it's the substitution operator that is in control, executing the replacement code only after a successful match.

With *code subpatterns*, the normal relationship between regular expression and program code is inverted. As the Engine is applying its Rules to your pattern at match time, it may come across a regex extension of the form `(?{ CODE })`. When triggered, this subpattern doesn't do any matching or any looking about. It's a zero-width assertion that always "succeeds", evaluated only for its side effects. Whenever the Engine needs to progress over the code subpattern as it executes the pattern, it runs that code.

```
"glyph" =~ /.+ (?{ say "hi" }) ./x;  # Prints "hi" twice.
```

As the Engine tries to match `glyph` against this pattern, it first lets the `.+` eat up all five letters. Then it prints "`hi`". When it finds that final dot, all five letters have been eaten, so it needs to backtrack back to the `.+` and make it give up one of the

letters. Then it moves forward through the pattern again, stopping to print "`hi`" again before assigning `h` to the final dot and completing the match successfully.

The braces around the *`CODE`* fragment are intended to remind you that it is a block of Perl code, and it certainly behaves like a block in the lexical sense. That is, if you use `my` to declare a lexically scoped variable in it, it is private to the block. But if you use `local` to localize a dynamically scoped variable, it may not do what you expect. A `(?{ CODE })` subpattern creates an implicit dynamic scope that is valid throughout the rest of the pattern, until it either succeeds or backtracks through the code subpattern. One way to think of it is that the block doesn't actually return when it gets to the end. Instead, it makes an invisible recursive call to the Engine to try to match the rest of the pattern. Only when that recursive call is finished does it return from the block, delocalizing the localized variables.[19] In the next example, we initialize `$i` to `0` by including a code subpattern at the beginning of the pattern. Then, we match any number of characters with `.*`—but we place another code subpattern in between the `.` and the `*` so we can count how many times `.` matches.

```
$_ = "lothlorien";
m/  (?{ $i = 0 })                   # Set $i to 0
    (.    (?{ $i++ })    )*         # Update $i, even after backtracking
    lori                            # Forces a backtrack
 /x;
```

The Engine merrily goes along, setting `$i` to `0` and letting the `.*` gobble up all 10 characters in the string. When it encounters the literal `lori` in the pattern, it backtracks and gives up those four characters from the `.*`. After the match, `$i` will still be `10`.

If you wanted `$i` to reflect how many characters the `.*` actually ended up with, you could make use of the dynamic scope within the pattern:

19. People who are familiar with recursive descent parsers may find this behavior confusing because such compilers return from a recursive function call whenever they figure something out. The Engine doesn't do that—when it figures something out, it goes *deeper* into recursion (even when exiting a parenthetical group!). A recursive descent parser is at a minimum of recursion when it succeeds at the end, but the Engine is at a local *maximum* of recursion when it succeeds at the end of the pattern. You might find it helpful to dangle the pattern from its left end and think of it as a skinny representation of a call graph tree. If you can get that picture into your head, the dynamic scoping of local variables will make more sense. (And if you can't, you're no worse off than before.)

```
$_ = "lothlorien";
m/  (?{ $i = 0 })
    (. (?{ local $i = $i + 1; }) )*  # Update $i, backtracking-safe.
    lori
    (?{ $result = $i })              # Copy to non-local()ized location.
 /x;
```

Here we use `local` to ensure that `$i` contains the number of characters matched by `.*`, regardless of backtracking. `$i` will be forgotten after the regular expression ends, so the code subpattern, `(?{ $result = $i })`, ensures that the count will live on in `$result`.

The special variable `$^R` (described in Chapter 25) holds the result of the last `(?{ CODE })` that was executed as part of a successful match.

You can use a `(?{ CODE })` extension as the *COND* of a `(?(COND)IFTRUE|IFFALSE)`. If you do this, `$^R` will not be set, and you may omit the parentheses around the conditional:

```
"glyph" =~ /.+(?(?{ $foo{bar} gt "symbol" }).|signet)./;
```

Here we test whether `$foo{bar}` is greater than `symbol`. If so, we include `.` in the pattern; if not, we include `signet` in the pattern. Stretched out a bit, it might be construed as more readable:

```
"glyph" =~ m{
    .+                              # some anythings
    (?(?{                           # if
            $foo{bar} gt "symbol"   # this is true
        })
            .                       # match another anything
        |                           # else
            signet                  # match signet
    )
    .                               # and one more anything
}x;
```

When `use re "eval"` is in effect, a regex is allowed to contain `(?{ CODE })` subpatterns even if the regular expression interpolates variables:

```
/(.*?) (?{length($1) < 3 && warn}) $suffix/;  # Error without
                                              # use re "eval"
```

This is normally disallowed since it is a potential security risk. Even though the pattern above may be innocuous because `$suffix` is innocuous, the regex parser can't tell which parts of the string were interpolated and which ones weren't, so it just disallows code subpatterns entirely if there were any interpolations.

If the pattern is obtained from tainted data, even `use re "eval"` won't allow the pattern match to proceed.

When `use re "taint"` is in effect and a tainted string is the target of a regex, the captured subpatterns (either in the numbered variables or in the list of values returned by `m//` in list context) are tainted. This is useful when regex operations on tainted data are meant not to extract safe substrings, but merely to perform other transformations. See Chapter 20 for more on tainting. For the purpose of this pragma, precompiled regular expressions (usually obtained from `qr//`) are not considered to be interpolated:

```
/foo${pat}bar/
```

This is allowed if `$pat` is a precompiled regular expression, even if `$pat` contains `(?{ CODE })` subpatterns.

Earlier we showed you a bit of what `use re 'debug'` prints out. A more primitive debugging solution is to use `(?{ CODE })` subpatterns to print out what's been matched so far during the match:

```
"abcdef" =~ / .+ (?{say "Matched so far: $&"}) bcdef $/x;
```

This prints:

```
Matched so far: abcdef
Matched so far: abcde
Matched so far: abcd
Matched so far: abc
Matched so far: ab
Matched so far: a
```

showing the `.+` grabbing all the letters and giving them up one by one as the Engine backtracks.

Match-time pattern interpolation

You can build parts of your pattern from within the pattern itself. The `(??{ CODE })` extension allows you to insert code that evaluates to a valid pattern. It's like saying `/$pattern/`, except that you can generate `$pattern` at runtime—more specifically, at match time. For instance:

```
/\w (??{ if ($threshold > 1) { "red" } else { "blue" } }) \d/x;
```

This is equivalent to `/\wred\d/` if `$threshold` is greater than 1, and `/\wblue\d/` otherwise.

You can include group references inside the evaluated code to derive patterns from just-matched substrings (even if they will later become unmatched through backtracking). For instance, this matches all strings that read the same backward as forward (known as palindromedaries, phrases with a hump in the middle):

```
/^ (.+) .? (??{quotemeta reverse $1}) $/xi;
```

You can balance parentheses like so:

```
$text =~ /( \(+ ) (.*?) (??{ "\)" x length $1 })/x;
```

This matches strings of the form `(shazam!)` and `(((shazam!)))`, sticking `shazam!` into `$2`. Unfortunately, it doesn't notice whether the parentheses in the middle are balanced. For that we need recursion.

Fortunately, you can do recursive patterns, too. One way is to have a compiled pattern that uses `(??{ CODE })` to refer to itself. Recursive matching is pretty irregular, as regular expressions go. Any text on regular expressions will tell you that a standard regex can't match nested parentheses correctly. And that's correct. It's also correct that Perl's regexes aren't standard. The following pattern[20] matches a set of nested parentheses, however deep they go:

```
$np = qr{
           \(
           (?:
              (?> [^()]+ )    # Non-parens without backtracking
            |
              (??{ $np })     # Group with matching parens
           )*
           \)
         }x;
```

You could use it like this to match a function call:

```
$funpat = qr/\w+$np/;
"myfunfun(1,(2*(3+4)),5)" =~ /^$funpat$/;   # Matches!
```

Conditional interpolation

The `(?(`*`COND`*`)`*`IFTRUE`*`|`*`IFFALSE`*`)` regex extension is similar to Perl's `?:` operator. If *`COND`* is true, the *`IFTRUE`* pattern is used; otherwise, the *`IFFALSE`* pattern is used. The *`COND`* can be a group reference (expressed as a bare integer, without the `\` or `$`), a lookaround assertion, or a code subpattern. (See the sections "Lookaround Assertions" on page 247 and "Match-time code evaluation" on page 255, earlier in this chapter.)

If the *`COND`* is an integer, it is treated as a group reference. For instance, consider:

```
#!/usr/bin/perl
$x = "Perl is free.";
$y = 'ManagerWare costs $99.95.';

foreach ($x, $y) {
    /^(\w+) (?:is|(costs)) (?(2)(\$\d+)|\w+)/;  # Either (\$\d+) or \w+
```

20. Note that you can't declare the variable in the same statement in which you're going to use it. You can always declare it earlier, of course.

```
    if ($3) {
        say "$1 costs money.";         # ManagerWare costs money.
    } else {
        say "$1 doesn't cost money.";  # Perl doesn't cost money.
    }
}
```

Here, the *COND* is `(2)`, which is true if a second group reference exists. If that's the case, `(\$\d+)` is included in the pattern at that point (creating the `$3` capture variable); otherwise, `\w+` is used.

If the *COND* is a lookaround or code subpattern, the truth of the assertion is used to determine whether to include *IFTRUE* or *IFFALSE*:

```
/[ATGC]+(?(?<=AA)G|C)$/;
```

This uses a lookbehind assertion as the *COND* to match a DNA sequence that ends in either `AAG`, or some other base combination and `C`.

You can omit the `|`*IFFALSE* alternative. If you do, the *IFTRUE* pattern will be included in the pattern as usual if the *COND* is true; but if the condition isn't true, the Engine will move on to the next portion of the pattern.

Recursive Patterns

When you reference a capture group from within the pattern, whatever was actually captured by that group is what gets used for the backreference.

```
/\b (        \p{alpha}+ ) \s+    \1    \b /x   # numbered backref
/\b (        \p{alpha}+ ) \s+  \g{1}   \b /x   # alternate syntax
/\b (        \p{alpha}+ ) \s+ \g{-1}   \b /x   # relative backref
/\b (?<word> \p{alpha}+ ) \s+ \k<word> \b /x   # named    backref
```

Those four examples all use backreferences to match the same word twice in a row. But sometimes you want to match two different words with the same pattern.

For that, a different syntax is used: `(?`*NUMBER*`)` calls back into the pattern of a numbered group, whereas `(?&`*NAME*`)` does so for a named group. (The latter is reminiscent of the `&` form of subroutine calls.)

```
/\b (        \p{alpha}+ ) \s+ (?-1)    \b /x   # "call" numbered group
/\b (?<word> \p{alpha}+ ) \s+ (?&word) \b /x   # "call" named group
```

With the *NUMBER* form, a leading minus sign counts groups right to left from the current location, so `-1` means to call the previous group; you don't have to know the absolute position of it. On the other hand, if the number has a plus sign in front, `(?+`*NUMBER*`)`, you count forward that many groups to the right of where you are.

You are even allowed to call a group that you're already in the middle of, causing the matching engine to recurse on itself. This is a normal thing to want to do. Here's one way to match balanced parentheses:

```
/ ( \( (?: [^()]++ | (?1) )*+ \) )/x
```

Because the entire pattern is enclosed by capture parentheses, you can omit them altogether and use `(?0)` to call "group zero", which means the whole pattern:

```
/ \( (?: [^()]++ | (?0) )*+ \) /x
```

That works fine here, but it may not do what you expect when you write a `qr//` that gets used in some other pattern. In that case, you should stick with a relatively numbered group. Here we define a regex that matches an identifier followed by balanced parentheses:

```
$funcall = qr/\w+ ( \( (?: [^()]++ | (?-1) )*+ \) )/x
```

Then we call it like this:

```
while (<>) {
    say $1 if /^ \s* ( $funcall ) \s* ; \s* $/x;
}
```

This conveniently leaves only the desired result in `$1`. The subrule is an example of Position Independent Code: it doesn't care about its absolute position in the overall scheme of things.

Numbered groups are okay for simple patterns, but for anything more complicated, you'll find named groups to be more readable:

```
$funcall = qr/\w+ (?<paren> \( (?: [^()]++ | (?&paren) )*+ \) )/x
while (<>) {
    say $+{func} if /^ \s* (?<func> $funcall ) \s* ; \s* $/x;
}
```

In fact, named groups are the only way to retain sanity as you scale up the size of your parsing problem.

Note that a subcall does not return its captures to the outer pattern; it only returns its final match position. Often this is what you want because it controls side effects, but sometimes you'll want to keep around pieces of whatever it is you're parsing. More on that in just a moment.

Speaking of parsing, you may by now have realized that you have almost everything you need for real parsing. By real parsing we don't mean the simple state machines that NFAs and DFAs are good for, but actual recursive descent parsing. With the features explained in this section and the next, a Perl pattern becomes fully equivalent to a recursive descent parser. With just a few more bells and

whistles, you'll be able to easily write full grammars that look a lot like a *yacc* file or a grammar in Backus–Naur Form.

Grammatical Patterns

Grammars work by parsing subpatterns recursively. Since capture groups can work as subpatterns, they can be used as productions in a grammar. What you haven't seen yet is a way to define all your productions separate from calling them.

Obviously, if we're just using a capture group as a subpattern, it doesn't matter whether it has actually been used to match anything yet. In fact, when you're writing a grammar, you generally *don't* want your subpatterns called the first time you define them; you'd just like to define them all and then start using them later. What you really want is a way to wall off a part of your pattern for definitions alone, not for execution.

The `(?(DEFINE)...)` block does just that. Technically, it's really just a conditional, like the `(?(`*`COND`*`)...)` conditional we saw earlier. Here, the condition is `DEFINE`, which turns out to always be false.[21] So anything you put in a `DEFINE` block is guaranteed not to be executed.

The smart-aleck in the class will now point out that the compiler is free to discard any unused code in a conditional that is always false. The teacher will point out, however, that this policy applies only to executable code, not to declarations. And it happens that groups within the `DEFINE` block are considered declarative, so they are not thrown away. They remain quite callable as subpatterns from elsewhere within the same pattern.

So that's where we'll put our grammar. You can put your `DEFINE` block anywhere you'd like, but usually people put it either before the main pattern or afterwards. Within the block, the order of definition doesn't matter either. So all your patterns end up looking pretty much like this:

```
qr{
    (?&abstract_description_of_what_is_being_matched)

    (?(DEFINE)
        (?<abstract_description_of_what_is_being_matched>
            (?&component1)
            (?&component2)
            (?&component3)
            ...
```

21. Yes, it's a hack, but it's a neat hack. Otherwise, we'd be forced to use a postfix `{0}` quantifier as Ruby does, to the detriment of readability.

```
        )
        (?<component1> ... )
        (?<component2> ... )
        (?<component3> ... )
        ...
    )
}x;
```

The only executable portion of that pattern is the part outside the `DEFINE` block, which calls the top rule that calls all the others.

This starts to look like not just a conventional grammar, but also a conventional program. Unlike the left-to-right processing of a normal pattern, this one now has the general form of top-down programming, full of subroutines calling each other iteratively and recursively. The importance of this development model cannot be overstated, because giving good names to your abstractions is the single most important thing you can do toward making your pattern matching easy to develop, debug, and maintain. It's no different from normal programming that way.

And it's easy to recognize where you are missing an abstraction; if you're repeating yourself somewhere, that repeated functionality probably needs to be factored out and named. And if you give it a memorable name that tells what it's for, this helps you organize and maintain your code. If you later want to modify that code, you only have to do so in one place; subroutine calls were the original code-reuse paradigm. Subpatterns are just subroutine calls in disguise.

This style of pattern matching is completely addictive, once you get the hang of it: nontrivial patterns will stop looking like classic regular expressions and start looking like their powerful cousins, grammars. You will no longer put up with having to write:

```
/\b(?=(?=[\p{Alphabetic}\p{Digit}])\X)(?:(?=[\p{Alphabetic}\p{Digit}])\X
|['\x{2019}]|(?=[^\x{2014}])\p{dash})+(?!(?=[\p{Alphabetic}\p{Digit}])\X|)/
```

Instead, here's how you'll *prefer* to write it, as a grammatical pattern for pulling words out:

```
$word_rx = qr{    (?&one_word)
  (?(DEFINE)
    (?<a_letter>        (?= [\p{Alphabetic}\p{Digit}] ) \X          )
    (?<some_letters>    (?: (?&a_letter) | (?&tick) | (?&dash) ) +  )
    (?<tick>            ['\N{RIGHT SINGLE QUOTATION MARK}]          )
    (?<dash>            (?= [^\N{EM DASH}] ) \p{dash}               )
    (?<one_word>
        \b
        (?= (?&a_letter) )
        (?&some_letters)
        (?! (?&a_letter)
```

```
            | (?&dash)
          )
      )
    ) # end define block
}x;
```

The top-level pattern merely calls the `one_word` regex subroutine, which does all the work. You could use that pattern to print out all words in a file, one per line, like this:

```
while (/($word_rx)/) {
    say $1;
}
```

As those examples show, sometimes you can write a grammatical pattern as an old-fashioned, ungrammatical one that doesn't have any regex subroutines in it. But you really don't want to do that because it's too hard to read, write, debug, and maintain a complicated pattern all jammed together like that. But beyond that, you just get a lot more power with grammars. Many interesting problems lie beyond the reach of classic regexes. Let's look at an example of something easily matched by Perl patterns but which no classic regex could ever solve. (Two such examples, as it turns out, one balanced and the other mirrored.)

This book is itself written in pod, Perl's lightweight documentation system. You can read more about it in Chapter 23, but in some ways pod looks a bit like any other SGML-derived markup language. It has tags and pointy brackets. And just like most other markup languages, these tags can nest in a way that completely defeats any attempt to search or manipulate them using a simple-minded, old-school regex tool like the venerable *grep*. That's because they're nested structures, which means your searches and manipulators on these also need to have nested structure. And nesting is something that your textbook regular expressions just don't do. Fortunately for you, Perl's regexes are not textbook, so they can be used to parse fancy markup languages like XML and HTML. And pod.

Pod tags always begin with a single capital letter immediately followed by one or more opening left-angle brackets. That much is easy. The hard part is finding the closer, the right-angle bracket (or brackets) to end the tag. And there are two ways to do that, depending on whether the opener is followed by whitespace.

```
X<stuff>       # balanced style
X<< stuff >>   # mirrored style
```

Without whitespace, you are dealing with a balanced tag, where the number of close brackets must balance the number of open brackets seen before, including any brackets in the "stuff".

With whitespace, your tag is not balanced but mirrored: it ends when you come to whitespace followed by the same number of closing brackets as there were opening ones. Within that, you may have whatever you like for angle brackets, whether open or close, and they do not have to nest because they are not counted.

Here are a few of the hairier examples in actual use in this book:

```
B<-0xR<HHH...>>
C<<< >>= >>>
C<0..(2Y<R<BITS>>)-1>
C<< BZ<><touch> SZ<><BZ<><-t> IZ<><time>> IZ<><file> >>
C<(?E<lt>!...)>
C<< !grep { !R<CODE>->($_) } keys R<HASH> >>
C<<< <HANDLE>, <<END >>>
C<(?(R<COND>)R<IFTRUE>|R<IFFALSE>)>
C<<< << R<EXPR> >>>
C<s/R<PATTERN>/R<REPLACEMENT>/>
I<Santa MarE<iacute>a>
X<<< < (left angle bracket);<< (left-shift) operator:@leftleft >>>
```

Here is the start of a grammar to do this:

```
podtag::        capital either
capital::       uppercase_letter
either::        < balanced | mirrored >
```

These translate directly into subpatterns:

```
(?<podtag>      (?&capital) (?&either)        )
(?<capital>     \p{uppercase_letter}          )
(?<either>      (?&balanced) | (?&mirrored)   )
```

A balanced angle group is just text surrounded by properly nested angle brackets, such as with `B<-0xR<HHHH>>`. Balanced things we already know how to do, because it works just like the earlier problem to find balanced parentheses.

```
(?<balanced> < ( [^<>]++ | (?&balanced) )* >  )
```

That brings us to the last piece of our grammar, the mirrored tag. Mirrored tags are the ones that look like `C<<< << R<EXPR> >>>`. We have to look for as many closing brackets as we saw opening ones, but we don't need to worry about counting opening and closing brackets in between there. Well, almost.

```
(?<mirrored>    (?<open> <{2,}+  ) \s++
                   \s+
                     (?: (?&podtag) | \p{Any} ) *?
                   \s+
                \s++ (??{ ">" x length $MATCH{open} })
)
```

The start of <mirrored> grabs up two or more open brackets, possessively, and stores them in the <open> group so we can later use them as a backreference when we need to count them. Note that we are merely using <open> as a named capture, not a named subrule, since a named rule would hide its internal captures.

The middle part pulls in the tag contents. Here we have to be careful, because those guts can contain other pod tags, and *those* tags may be of the balanced sort. But if it's anything else but a mirrored tag, it doesn't count. We use the \p{Any}, which is Unicode-speak for what Perl calls (?s:.); in other words, match any character at all, even a newline.[22]

The last line interpolates the result of that expression to generate as many closing angle brackets as we'd seen at line 1.

Here then is the whole program.

```
#!/usr/bin/env perl
# demo-podtags-core
use v5.14;
use strict;
use warnings;
use open qw(:std :utf8);       # an all-UTF-8 workflow
use warnings FATAL => "utf8";  # in case there are input encoding errors
use re "/x";                   # always want legible patterns
our %MATCH; *MATCH = \%+;      # alias %MATCH to %+ for legibility

my $RX = qr{
     (?(DEFINE)
         (?<podtag>         (?&capital) (?&either)          )
         (?<capital>        \p{upper}                       )
         (?<either>         (?&mirrored) | (?&balanced)     )
         (?<balanced>       < (?&contents) >                )
         (?<contents>       (?: (?&podtag) | (?&unangle) )* )
         (?<unangle>        [^<>]++                         )
         (?<mirrored>       (?<open> <{2,}+  ) \s++
                              \s+
                                (?: (?&podtag) | \p{Any} ) *?
                              \s+
                            \s++ (??{ ">" x length $MATCH{open} })
         )
     )
};

@ARGV = glob("*.pod")           if @ARGV == 0 && -t STDIN;
die "usage: $0 [pods]\n"        if @ARGV == 0 && -t STDIN;
```

22. This isn't technically true. At higher levels of conformance than Perl provides, \p{Any} could match locale-specific linguistic elements like digraphs and trigraphs.

```
$/ = "";  # paragraph mode, since tags can cross \n but not \n\n
$| = 1;   # faster output for the impatient

while (<>) {
    while (/ (?<TAG> (?&podtag) ) $RX /g) {
         say $MATCH{TAG};
    }
}
```

A few things to notice. To print out our match, we had to explicitly save it into something in our own scope, the group named `<TAG>`. Sure, we could have used `$&` or `${^MATCH}` or such, but the point is that anything that was saved in capture groups *within* the call to `<podtag>` is lost upon its return.

So while you can use this technique to validate input, it has its points of frustration when it comes to pulling out the pieces you that you've just worked so hard to parse. While you could pepper your code with `(?{ CODE })` inserts to do something to save pieces of the parse on the way through, that gets tedious fast. A better solution is to use the helper module described in the next section.

Grammars

Damian Conway's `Regexp::Grammars` CPAN module was designed to address this, and quite a bit more. It makes writing grammars in Perl even easier than what we went through in the previous example. This module is a truly fantastic tool, and it is much too fancy for us to explain here; look to its manpage for details. But this should whet your appetite.

`Regexp::Grammars` is really a grammar compiler, much in the way that *yacc* is. Except instead of spitting out a C program the way *yacc* does, `Regexp::Grammars` spits out a pattern that you can use just as you would any other pattern. It does this using a trick we'll talk about in the next section: it overloads the `qr//` operator and rewrites the pattern you give it into a different one that does the dirty work.

Here we've rewritten the previous program to use Damian's module.

```
#!/usr/bin/env perl
# demo-podtags-grammar
use v5.14;
use strict;
use warnings;
use open qw(:std :utf8);         # an all-UTF-8 workflow
use warnings FATAL => "utf8";    # in case there are input encoding errors
use re "/x";                     # always want legible patterns

my $podtag = do { use Regexp::Grammars; qr{
    <podtag>
```

```
    <token: podtag>         <capital> <either>
    <token: capital>        \p{upper}
    <token: either>         <mirrored> | <balanced>
    <token: balanced>       \< <contents> \>
    <token: contents>       (?: <[podtag]> | <[unangle]> ) *
    <token: unangle>        [^<>]++
    <token: mirrored>       <open=( \< {2,} )>
                                \s+
                                    (?: <podtag> | \p{Any} ) *?
                                \s+
                            </open>
    }xms;
};

@ARGV = glob("*.pod")           if @ARGV == 0 && -t STDIN;
die "usage: $0 [pods]\n"        if @ARGV == 0 && -t STDIN;

$/ = "";  # paragraph mode, since tags can cross \n but not \n\n
$| = 1;   # faster output for the impatient

while (<>) {
    while (/$podtag/g) {
      say $/{podtag}{capital},
          $/{podtag}{either}{""};
    }
}
```

This program parses the same input as the previous one; the grammar looks almost the same. But it's better in many ways. It was easier to write, and we think it's easier to read, too. It also does things the other version could not do. Look at the `<mirrored>` subroutine. Here we use a feature of `Regexp::Grammars` that allows us to capture the opening left-angle brackets to the group named `<open>`, then implicitly match the corresponding number of closing right-angle brackets just by saying `</open>`.

Perhaps more important, our pattern match and output statement are a bit different. The match is simpler, and the print is fancier. The hash variable named `%/` holds the nested data structure created by any successful match of a grammar regex.

What you don't see here with just this printout is that the `%/` variable is structured. It exactly matches the parse taken. Suppose you feed the program input like "Left C<B<nested>> an I<< N<inside>un>tag >> gets X<indexed> right". After the parse, we'll use the `Data::Dump` module to show you what you'll find in `%/`.

```
use Data::Dump;  # from CPAN
# do the match, then
dd \%/;  # pass ref to results hash
```

And you'll get this output:

```
{
  "" => "C<B<nested>>",
  "podtag" => {
    "" => "C<B<nested>>",
    "capital" => "C",
    "either" => {
      "" => "<B<nested>>",
      "balanced" => {
        "" => "<B<nested>>",
        "contents" => {
          "" => "B<nested>",
          "podtag" => [
            {
              "" => "B<nested>",
              "capital" => "B",
              "either" => {
                "" => "<nested>",
                "balanced" => {
                  "" => "<nested>",
                  "contents" => { "" => "nested", "unangle" => ["nested"] },
                },
              },
            },
          ],
        },
      },
    },
  },
}
{
  "" => "I<< N<inside>un>tag >>",
  "podtag" => {
    "" => "I<< N<inside>un>tag >>",
    "capital" => "I",
    "either" => {
      "" => "<< N<inside>un>tag >>",
      "mirrored" => {
        "" => "<< N<inside>un>tag >>",
        "open" => "<<",
        "podtag" => {
          "" => "N<inside>",
          "capital" => "N",
          "either" => {
            "" => "<inside>",
            "balanced" => {
              "" => "<inside>",
```

```
                "contents" => { "" => "inside", "unangle" => ["inside"] },
              },
            },
          },
        },
      },
    },
  }
```

As you see, inside the hash is essentially a trace of every production the grammar executed in running the parse, including nested tags. `Regexp::Grammars` is a lot more sophisticated than we can show here. Plus, once you've gone to so much trouble to set up your grammars, your grammars can even share each other's regex subroutines if you'd like. That's a lot more sharing than you get in the simpler grammars shown in the previous section, which had none at all. It's worth taking a serious look at if you have complicated parsing to do.

Defining Your Own Assertions

You can't (easily: see next section) change how Perl's Engine works, but if you're sufficiently warped, you can change how it sees your pattern. Since Perl interprets your pattern similarly to double-quoted strings, you can use the wonder of overloaded string constants to see to it that text sequences of your choosing are automatically translated into other text sequences.

In the example below, we specify two transformations to occur when Perl encounters a pattern. First, we define `\tag` so that, when it appears in a pattern, it's automatically translated to `(?:<.*?>)`, which matches most HTML and XML tags. Second, we "redefine" the `\w` metasymbol so that it handles only English letters.

We'll define a package called `Tagger` that hides the overloading from our main program. Once we do that, we'll be able to say:

```
use Tagger;
$_ = "<I>camel</I>";
say "Tagged camel found" if /\tag\w+\tag/;
```

Here's *Tagger.pm*, couched in the form of a Perl module (see Chapter 11):

```
package Tagger;
use overload;

sub import { overload::constant "qr" => \&convert }

sub convert {
    my $re = shift;
    $re =~ s/ \\tag  /<.*?>/xg;
```

```
    $re =~ s/ \\w    /[A-Za-z]/xg;
    return $re;
}

1;
```

The `Tagger` module is handed the pattern immediately before interpolation, so you can bypass the overloading by bypassing interpolation, as follows:

```
$re = '\tag\w+\tag';   # This string begins with \t, a tab
print if /$re/;        # Matches a tab, followed by an "a"...
```

If you wanted the interpolated variable to be customized, call the `convert` function directly:

```
$re = '\tag\w+\tag';         # This string begins with \t, a tab
$re = Tagger::convert $re;   # expand \tag and \w
print if /$re/;              # $re becomes <.*?>[A-Za-z]+<.*?>
```

Now if you're still wondering what those `sub` thingies are in the `Tagger` module, you'll find out soon enough because that's what Chapter 6 is all about.

Alternate Engines

Starting with v5.10, you can even swap out Perl's entire regex engine and replace it with an alternate pattern-matching library. The underlying mechanics that make this possible are documented in the *perlreapi* manpage. It's pretty tough reading, meant for seriously hardcore hackers only.

But you may be in luck. Thanks to CPAN, Perl plug-ins for the alternate regex engine of your choice may already exist. When you use these, you write your patterns normally and, come time to execute them, the alternate engine takes charge. Table 5-18 shows some CPAN modules that let you use other languages' regex engines in your Perl code (as they exist on CPAN in autumn 2011). There may be more by the time you read this, so look around.

Table 5-18. Alternate regex engines

Module	Description	Version	Updated	Current Maintainer
`re::engine::LPEG`	The LPEG regex engine	0.05	2010-07-09	François Perrad
`re::engine::RE2`	Russ Cox's RE2 regex engine	0.08	2011-04-22	David Leadbeater
`re::engine::Plugin`	General API for writing custom	0.09	2011-04-05	Vincent Pit

Module	Description	Version	Updated	Current Maintainer
	regex engines			
`re::engine::Plan9`	Regexes from Plan9!	0.16	2010-03-31	Ævar Arnfjörð Bjarmason
`re::engine::Oniguruma`	Ruby's Oniguruma regex engine	0.05	2011-07-10	藤吾郎
`re::engine::Lua`	Lua's regex engine	0.06	2008-12-20	François Perrad
`re::engine::PCRE`	Phil Hazel's Perl-Compatible RegEx engine	0.17	2011-Jan-29	Ævar Arnfjörð Bjarmason

(Notice anything about those authors? More than two-thirds of them have names you can't even *talk* about in ASCII. Welcome to the global 21st century!)

One engine of special note is Russ Cox's RE2 library. It's a C and C++ library that's used in the Go programming language, among many other places. The interesting thing is that it maintains a high level Perl compatibility, including good UTF-8 support, while avoiding the potential pitfalls of catastrophic backtracking. It does this because unlike Perl, whose engine is a recursive backtracker, RE2 uses a hybrid NFA/DFA approach that never gets bogged down in pathological cases.

This can be critical in time-sensitive applications where you want to let users provide their own pattern, but you cannot risk letting their search take forever. First written for Google's Code Search, where time is of the essence, RE2 is also used via its Perl interface at *http://grep.cpan.me*. This site lets you enter a search pattern that runs over everything in CPAN.

Once you've installed `re::engine::RE2`,[23] using it is as easy as putting a `use re::engine::RE2` in the lexical scope whose regexes you want to use RE2's engine instead of the native Perl one. That's all.

Here's an example of the kind of place where RE2 blows the socks off any recursive backtracker. First, timings running regular Perl:

23. See the directions in Chapter 19 if you don't already know how.

```
% time perl -E 'say (("a" x 17) =~ /a*a*a*a*a*a*a*a*a*a*[Bb]/i || 0)'
>/dev/null
  1.564u 0.005s 0:01.57
% time perl -E 'say (("a" x 23) =~ /a*a*a*a*a*a*a*a*a*a*[Bb]/i || 0)'
>/dev/null
  17.757u 0.025s 0:17.84
% time perl -E 'say (("a" x 29) =~ /a*a*a*a*a*a*a*a*a*a*[Bb]/i || 0)'
>/dev/null
  127.965u 0.180s 2:09.20
```

Now again but using the RE2 engine instead:

```
% time perl -Mre::engine::RE2 -E 'say (("a" x 500) =~
  /a*a*a*a*a*a*a*a*a*a*[Bb]/i || 0)'
  /dev/null
  0.004u 0.002s 0:00.00
% time perl -Mre::engine::RE2 -E 'say (("a" x 5000) =~
  /a*a*a*a*a*a*a*a*a*a*[Bb]/i || 0)'
  /dev/null
  0.004u 0.002s 0:00.00
% time perl -Mre::engine::RE2 -E 'say (("a" x 50000) =~
  /a*a*a*a*a*a*a*a*a*a*[Bb]/i || 0)'
  /dev/null
  0.004u 0.002s 0:00.00
```

As you see, with RE2, the run time no longer grows proportionately to the input size, but only to the regex size. When your input string is as large as all of CPAN, this can matter a great deal. Yes, it's something of a contrived demo, but patterns that show the same sort of issue come up surprisingly frequently.

You can configure `re::engine::RE2` to use RE2 for patterns it can handle and to fall back to native Perl for those it can't, which makes it 100% compatible. Or, if you're providing an external service, you can configure it to use only RE2 without a fallback, and that way never risk falling into a denial-of-service situation in your server.

For more about the design of RE2 and about finite automata in general, see Russ Cox's three-paper series "Regular Expression Matching Can Be Simple and Fast", "Regular Expression Matching: The Virtual Machine Approach", and "Regular Expression Matching in the Wild".

CHAPTER 6
Unicode

If you've never heard of Unicode, you must have been living on a desert island with nothing but a manual typewriter for the last 20 years. Unicode celebrated its 20th birthday back in early 2010. Even if you have heard of it, you may not really know what it is, or how to work with it. This is not something to be embarrassed about; the fact of the matter is that *everyone* is still learning about Unicode, including its inventors. Although we can't hope to cover all the nuanced intricacies of Unicode in this chapter or even this book, we can certainly get you started using Unicode in Perl.

Working with Unicode these days isn't an option: it's a necessity. The majority of the Web is in Unicode,[1] and many large corpora are 100% Unicode. Because web browsers do their best to make do with whatever character set web servers give them, you probably haven't noticed how much Unicode is really out there now. Programming languages without solid Unicode support are decades behind the curve, as are programs written in those languages. They might have worked okay in the 1980s, even the 1990s, but today we need the real thing.

So how did we get here?

Computers store characters as numbers. In the early days these were small integers, 5, 6, 7, or 8 bits long. EBCDIC used 8 bits and was based on punch cards. ASCII used up only 7 bits, leaving precisely 1 bit in each byte for other purposes —many, many other purposes, all contradictory, as it turned out.

So, in those days, pretty much everyone in western lands confused characters with small numbers in the range 0 to 127, or 0 to 255. Even though that's more characters than you likely have keys on your keyboard, it really wasn't very many,

1. In the UTF-8 encoding of Unicode, to be precise.

and people in different parts of the world had their own ideas of which particular character each of those numbers represented.

That might be enough to send off a telegram in simple English, but it isn't enough to handle all the characters needed by the Latin, Greek, and Cyrillic alphabets, let alone the many Asian ones. The Asians were forced to develop various mutually incompatible 16-bit codes. It was extremely difficult, and often impossible, to include text from several alphabets in the same text document, since the same number meant one letter in one alphabet but a different letter in a different alphabet.

Historically, people made up character sets to reflect what they needed to do in the context of their own culture. Since people of all cultures are naturally lazy, they've tended to include only the symbols they needed, excluding the ones they didn't need. That worked fine as long as we were all isolationists communicating only with other people of our own culture. But now that we're starting to use the Internet for cross-cultural communication, we're running into problems with the exclusive approach. It's hard enough to figure out how to use an American keyboard to type basic Latin characters with accent marks on them, let alone some of the more exotic characters.

So along came the idea of Unicode: a single system of characters that everyone can use interchangeably for nearly every textual purpose. Unicode covers not just all modern writing systems plus most of the ancient ones we know much about, it also includes specialist characters used in typesetting, mathematics, linguistics, and many other fields, including even the emoticons used on cell phones. See Table 6-1.

Table 6-1. Sample Unicode characters

Latin Letters	Å æ ç ð é ffi ï İ ñ ø œ š ſ ß ʒ þ
Greek Letters	ɑ ά β Γ γ Δ δ ϝ θ λ Ξ ξ π Σ σ ς φ χ Ψ Ώ ᾠ
Cyrillic Letters	а Б б Д ж з И и к Л с т У у Ф ф Ш ь Э Ю я
Math Letters	𝒜 𝒟 𝔅 ℜ 𝔼 𝔽 𝔵 𝔶 𝔩 ξ ς **Θ Ψ Ω**
Math Symbols	÷ × ± ≤ ≠ ≈ ≡ ∅ ∈ ∛ Δ Ω ⊆ ∞ ∫ ∂ ∴ $\aleph_0$
Currency Symbols	¢ $ £ ₤ € ₡ ₢ ₣ ƒ ₱ ₩ ¥
Dots	. · ‥ ○ ∘ • ¨ .. ... ⋯ ⋱ ⋰ ⋮
Dashes	- ‐ ▪ ─ – ‑ ‒ —
Quotation Marks	‘ “ ‹ ’ ” ‹ › « » 「 」

As you can see, some of those look rather similar. Unicode distinguishes characters not by how they look, but what they do. It's a semantic code, really, and only secondarily a glyph code, and that's only because representing glyphs is a part of its semantics. Unlike ASCII, which is just a small set of characters with few properties defined for those characters, Unicode is much more than that. It's too easy to think of Unicode as just an overgrown form of ASCII, with a bunch more characters. But Unicode is more than just more characters—it's also all the rules for categorizing and handling that bunch of characters.

Along with the characters and properties, Unicode also defines how to deal with casemapping and casefolding; combining characters; grapheme clusters; normalization forms; collation; character properties for use in pattern matching, including character names, categories, and scripts; numeric equivalences (*e.g.*, telling you that U+216B, "Ⅻ", has the value 12); print widths; bidirectionality; rules for word- and linebreaking; and glyph variations. Just to name a few...

Perl first introduced tentative support for Unicode in v5.6, although it wasn't until v5.8 that we finally managed to resolve the important I/O issues. By v5.12, most of the remaining kinks were worked out, and as of v5.14 Perl—coincident with v6.0 of the Unicode Standard—you should be able to use Unicode and Perl together seamlessly. Mostly. Well, better than other languages do it, anyway.

What we mean is that we've made the easy things easy without forbidding the possibility of tackling hard things, too. The first easy thing to notice is that Perl lets your strings contain characters of arbitrarily large ordinal values. ASCII limits characters to 7-bit ordinals, Latin-1 to 8-bit ordinals, and Unicode to 21-bit ordinals.[2] But Perl's characters are not limited to such tiny numbers. Currently, Perl's characters are limited to 64 bits on 64-bit machines, but that's still 18,446,744,073,708,437,504 more codepoints than Unicode itself provides. (Well, we did say "arbitrarily large", and that's pretty arbitrary.)

In Unicode, every character has its own unique number, called its *codepoint*. That's why it's called Unicode: a unique, universal code for every different character. For example, the character named LATIN CAPITAL LETTER A has the character number 65 decimal, 0x41 hex. This is often written U+0041; the "U+" prefix is a convention that says it's not just any old number, but a number that represents a Unicode codepoint.

If you've ever mistaken an "`l`" for a "`1`", an "`O`" for a "`0`", or a "`,`" for a "`.`", you know how easy it is for a human to get characters mixed up. You also know that the computer is never fooled. It doesn't matter what the character might look

2. Strictly speaking, they're only 20.087463 bits, since Unicode has only 0x110000 codepoints, not 0x200000.

like in one or another font. All that matters is what it does. For example, the characters shown in Table 6-2 usually all look mostly alike in most fonts.

Table 6-2. Unicode confusables for capital A

Glyph	Code	Category	Script	Name
A	U+00041	Lu	Latin	LATIN CAPITAL LETTER A
A	U+0FF21	Lu	Latin	FULLWIDTH LATIN CAPITAL LETTER A
A	U+00391	Lu	Greek	GREEK CAPITAL LETTER ALPHA
A	U+00410	Lu	Cyrillic	CYRILLIC CAPITAL LETTER A
A	U+1D5A0	Lu	Common	MATHEMATICAL SANS-SERIF CAPITAL A
A	U+1D670	Lu	Common	MATHEMATICAL MONOSPACE CAPITAL A

The first column in the table is the glyph for the character. You can use Unicode literals like those in your own code only if you've said `use utf8` in the current lexical scope. Most mainstream editors and windowing systems will have various ways of entering such characters, though they may not be turned on by default, so a little research may be in order—if you're not too lazy. But hey, that's okay, too: if you don't know how to type in a character, you can always find one somewhere else, grab it with your mouse, and paste it in.

Outside of looking at it, the glyph is in some ways the least useful aspect of a character, because you cannot know how or even whether it will display in anyone else's font but your own. A glyph may look okay to you, but never trust your eyes—trust the numbers. The second column is the standard Unicode notation for a character's numeric code. Here are some ways of talking about codepoints in Perl:

```
if (ord($somechar) == 0x0391) { .... }
$alpha = "\x{391}";
$alpha = "\N{U+391}";
$alpha = chr(0x391);
```

After the codepoint comes two of the codepoints' most important properties: its General Category property, listed as *`CATEGORY`*, and its Script property, listed as *`SCRIPT`*. Codepoint properties are most often used as named character classes in patterns, where a `\p{`*`PROPERTY`*`}` matches any codepoint with that property, and `\P{`*`PROPERTY`*`}` matches any codepoint without that property.

```
/^\p{GC=Lu}+$/                      # all capital letters
/^\p{script=Greek}+$/               # it's greek to me
/[\P{script=Latin}\P{script=Common}]/   # not intersection
```

The last one is true for strings that contain any codepoint that's either non-Latin or non-Common. Because case, whitespace, and underscore don't count in property names, you can format them however you like. So if you think it's more readable to write `\p{gc=modifier_letter}` in all lowercase and `\P{SC=INHERITED}` in all uppercase, go right ahead: Perl won't care. Or do the opposite, if you like it that way.

Besides two-part properties like those above, Perl also provides one-element aliases for all general categories and scripts, so you can just use `\p{Lu}` and `\p{Greek}` if you'd like. For example, if you wanted to make sure your string only had Latin and Greek characters in it, you could do this:

```
$mylang = qr/[\p{Latin}\p{Greek}\p{Common}\p{Inherited}]/;
if ($string =~ /\A$mylang+\z/) { ... }
```

We added Common for things that are common to more than one script, like digits and punctuation, and Inherited for things like combining marks (usually diacritics) that take on the script of whatever base codepoint they're attached to. Combining codepoints are completely unlike anything in ASCII, so they're something that ASCII-speakers first coming to Unicode may find confusing. Perhaps the nearest concept in ASCII is overstriking using backspace, except that in Unicode combining codepoints automatically apply to the previous codepoint, so no backspace is necessary. We talk all about them in the upcoming section "Graphemes and Normalization" on page 290.

You'll note that we've started differentiating the term "codepoint" from the term "character" in this chapter. In other places (including other chapters in this book), they are often used interchangeably, and character is also used sometimes to mean "grapheme", but here we need to be just a bit more precise. A codepoint is specifically one of the individual integers that make up the string when seen as a list of integers, while a character can fuzzily mean either codepoint or a grapheme in its human context. More generally, you should be aware that people might mean three or four different things when they say "character".

The last field in our table is the character's name. Er, the codepoint's name. To specify the names of codepoints in your code, you first have to load them in with the `charnames` module, after which you may refer to them using `\N{...}` like this:

```
use charnames qw(:full);

$alpha      =     "\N{GREEK CAPITAL LETTER ALPHA}";
$alpha_code = ord "\N{GREEK CAPITAL LETTER ALPHA}";
if ($string =~ /\N{GREEK CAPITAL LETTER ALPHA}/) { ... }
```

Talking about codepoints by name is a lot better than talking about them by number. It makes your code more understandable.

For other nifty things you can do with `\N{...}`, see "charnames" on page 1008 in Chapter 29.

Show, Don't Tell

If a picture is worth a thousand words, putting the actual characters you want into your program has to be worth at least fifty or so. So you'll want to start off by telling Perl that your source code really is in Unicode characters, not just in bytes.[3] You don't have to do this, but it makes some things easier if you can enter real Unicode into your source.

So far, Perl assumes every source unit is in ASCII unless you tell it otherwise (though, arguably, the default should change to Unicode someday). You can always specify Unicode codepoints through the circumlocutions we mentioned above, but literals will be treated as separate bytes. If Perl sees a literal UTF-8 character, it won't realize it should treat it as one logical character, and it will show up as one, two, three, or even four separate Perl characters, all with ordinals under 256. You don't want that to happen, so use these declarations:

```
use v5.14;          # includes the unicode_strings feature
use utf8;           # handles UTF-8 literals
```

The first makes sure that codepoints with ordinals in the tricky range of 128–255 are treated as Unicode strings, while the second tells the Perl compiler that this entire source file is in the UTF-8 encoding of Unicode. Under the `utf8` pragma, you can now use Unicode in your string and regex literals.

```
my $dwarf   = "Þórinn Eikinskjaldi";
my $search  = "búsqueda";
my $measure = "Ångström";
my $how     = "à contre-cœur";
my $motto   = "👪💗🐪";
```

That's a lot easier to read, although maybe not as easy to type as writing:

```
use charnames qw(:full);

my $dwarf   = "\N{LATIN CAPITAL LETTER THORN}\N{LATIN SMALL LETTER
               O WITH ACUTE}rinn Eikinskjaldi";
my $search  = "b\N{LATIN SMALL LETTER U WITH ACUTE}squeda";
my $measure = "A\N{COMBINING RING ABOVE}ngstro\N{COMBINING DIAERESIS}m";
my $how     = "\N{LATIN SMALL LETTER A WITH GRAVE} contre-c\N{LATIN
               SMALL LIGATURE OE}ur";
my $motto   = "\N{FAMILY} \N{GROWING HEART} \N{DROMEDARY CAMEL}";
```

3. You may prefer to call them "octets"; that's okay, but we think the two words are pretty much synonymous these days, so we'll stick with the blue-collar word.

Which in turn are both preferable to putting secret magic numbers in code, like this:

```
my $dwarf   = "\x{DE}\x{F3}rinn Eikinskjaldi";
my $search  = "b\x{FA}squeda";
my $measure = "\x{C5}ngstr\x{F6}m";
my $how     = "\x{E0} contre-c\x{153}ur";
my $motto   = "\x{1F46A} \x{1F497} \x{1F42A}";
```

But that's not all. Under `utf8`, you can now use Unicode in Perl identifiers.

```
# a few character sets
my @ɪso     = qw( Latin1 Latin2 Latin15 );
my @μsoft   = qw( cp852  cp1251 cp1252  );
my @鯉      = qw( koi8-f koi8-u koi8-r  );

# whether to include answers that return no results
my $INCLUÍR_NINGUNOS               = 0;

# whether diacritics matter
my $SI_IMPORTAN_MARCAS_DIACRÍTICAS = 0;

# think of << as the "hasta" operator :)
my @ciudades_españolas = ordenar_a_la_española(<<'LA_ÚLTIMA' =~ /\S.*\S/g);
.....
.....
LA_ÚLTIMA

my $déjà_imprimée;   # le nom d'une ville

# Greek hypermegas
my @ὑπέρμεγας = ( );

# Ok, now we're just showing off  :-)
my $ʇndʇno = uɯopəpʅsdn($input);
```

In practice, if you're using non-English names for your identifiers, you'll probably want your comments in the corresponding language. All this makes it easier for people all over the world to write Perl in their own language, instead of forcing them all to learn English.

Currently, you should limit Unicode identifiers to private variables only. This is because of how global variables are stored, and also because of how module names map to the local filesystem. The first of these restrictions is expected to be removed in the near future, although the second one is still a matter for research.

Getting at Unicode Data

Internally, Perl keeps all codepoints in a format that's compatible with Unicode, meaning that the bottom 21 bits are the same as Unicode's, just as Unicode's bottom 8 bits are the same as Latin-1's. How these codepoints are actually stored internally is not something average Perl users should ever have to worry about.

However, as soon as you have to interact with the outside world, you are going to have to interpret the input data being fed to you and, in turn, generate output data that's in a format the receiving program finds palatable. Characters inside Perl have been *decoded* from their external format into abstract characters, but when you need to emit those characters, you'll have to *encode* them into whatever format is expected of you. If you forget to do this, you're liable to generate mutterings about "wide character" or "Malformed UTF-8 character".

Perl has two main ways to mark the encoding of an entire stream, plus various shortcuts to make this even easier. If your stream is already opened, you can set its encoding by passing a second argument to the `binmode` function:

```
binmode(STDIN,  ":encoding(CP1252)")
    || die "can't binmode to cp1252: $!";
binmode STDOUT, ":encoding(UTF-8)"
    || die "can't binmode to UTF-8: $!";
```

If you haven't opened the file yet, then you can use the mode argument in a call to `open` to specify the encoding right there.

```
open(OUTPUT, "> :raw :encoding(UTF-16LE) :crlf", $filename)
             or die "can't open $filename: $!";
print OUTPUT for @stuff;
close(OUTPUT) or die "couldn't close $filename: $!";
```

On input, the `:crlf` layer translates `\n` into `\r\n`; on output, it does the opposite. This layer is enabled by default under Windows when opening files in "text" mode, but you must specify it explicitly on Unix if you want that behavior. See the *PerlIO* manpage for more about I/O layers.

But `\n` and `\r\n` aren't the only possible line terminators under Unicode. Currently, Unicode recognizes eight different linebreak sequences—these seven codepoints plus the two-codepoint `\r\n` grapheme:

```
U+000A LINE FEED (LF)
U+000B LINE TABULATION
U+000C FORM FEED (FF)
U+000D CARRIAGE RETURN (CR)
U+0085 NEXT LINE (NEL)
U+2028 LINE SEPARATOR
U+2029 PARAGRAPH SEPARATOR
```

There is no special layer for handling Unicode linebreak sequences generically, but if you can afford to read the entire file into memory, it is easy to convert them all into newlines:

```
$complete_file =~ s/\R/\n/g;
```

Or split them into a list of lines, all without their line terminator:

```
@lines = split(/\R/, $complete_file);
```

The `open` pragma can be used to set the encoding on all newly opened filehandles. For example, to say that any `open` without a specified encoding will default to UTF-8, as will `STDIN`, `STDOUT`, and `STDERR`:

```
use open qw( :encoding(UTF-8) :std );
```

If you just want your standard streams set to UTF-8 instead of binary, you can use the *–CS* command-line option on a per-execution basis, or you can set the `PERL_UNICODE` environment variable to "`S`". If you set them to "`D`", then all handles that are not opened with an encoding layer default to UTF-8 text instead of binary byte data. See `19`.

Using either the `-C` command-line option or the `PERL_UNICODE` environment variable makes calling `binmode` even on Unix programs necessary for binary streams, something normally only Windows users—or people writing portable programs—have to do. It will break existing Unix programs that assume if they say nothing, they get binary not text. But it will unbreak existing programs that don't know to decode their UTF-8 text.

Ranked from highest to lowest (such that anything occurring higher in the list always overrides any settings from something that comes lower down), the precedence of the various mechanisms to set the stream encoding is as follows:

1. Explicitly calling `binmode` on an already-open filehandle.
2. Including a layer in the second out of three or more arguments to `open`.
3. The `open` pragma.
4. The *–C* command-line switch.
5. The `PERL_UNICODE` environment variable.

One exception to all this is the `DATA` handle. It isn't covered either by the `use utf8` or the `open` pragmas, so you'll still need to set its encoding yourself:

```
binmode(DATA, ":encoding(UTF-8)");
```

Because of the way the `utf8` and `UTF-8` encoding layers are implemented, they do not normally throw exceptions on malformed input. Add this to your code to make them do so:

```
use warnings FATAL => "utf8";
```

As of v5.14, Perl has three subwarnings that are part of the "`utf8`" warning group, which you may at times wish to distinguish. These are:

nonchar
: Unicode sets aside 66 codepoints as noncharacter codepoints. These all have the Unassigned (Cn) General Category, and they will never be assigned. They may not be used in open interchange so that code can mix them in with character data as internal sentinels, and they will always be distinguishable from that data. The noncharacter codepoints are the 32 from U+FDD0 to U+FDEF, and 34 codepoints comprising the last two codepoints from each plane (whose hex codes therefore end with FFFE or FFFF). Under some circumstances you may wish to permit these codepoints, such as between two cooperating processes that are using them for shared sentinels. If so, you would want to say:

```
no warnings "nonchar";
```

surrogate
: These codepoints are reserved for use by UTF-16. There is really never any reason to enable these, and no conformant processes can interchange them because UTF-16 agents would be unable to process them (though UTF-8 and UTF-32 agents could do so, were they so inclined).

non_unicode
: The maximum Unicode codepoint is U+10FFFF, but Perl knows how to accept codepoints up to the maximum permissible unsigned number available on the platform. Depending on various settings and the phase of the moon, Perl may warn (using the warning category "non_unicode", which is a subcategory of "utf8") if an attempt is made to operate on or output codes larger than normal. For example, "`uc(0x11_0000)`" will generate this warning, returning the input parameter as its result, as the uppercase of every non-Unicode codepoint is the codepoint itself.

Of those, the non-Unicode codepoints are by far the most useful, and you quite probably want to allow them for your own internal use.

```
no warnings "non_unicode";
```

Here is just one possible use for them. What this does for ASCII:

```
tr[\x00-\x7F][\x80-\xFF];
```

this does for Unicode:

```
tr[\x{00_0000}-\x{10_FFFF}][\x{20_0000}-\x{30_FFFF}];
```

That is, they remap all codepoints from the legal range of their respective character sets into an illegal range. Why would you do that? It's one way to mark text that you never want to match again. Just make sure to put them back when you're done.

The Encode Module

The standard `Encode` module is most often used implicitly, not explicitly. It's loaded automatically whenever you pass an `:encoding(`*`ENC`*`)` argument to `binmode` or to `open`.

However, you'll sometimes find yourself with a bit of encoded data that didn't come from a stream whose encoding you've set, so you'll have to decode it manually before you can work with it. These encoded strings might come from anywhere outside your program, like an environment variable, a program argument, a CGI parameter, or a database field. Alas, you'll even seen "text" files where some lines have one encoding but other lines have different encodings. You are guaranteed to see *mojibake*.

In all these situations, you'll need to turn to the `Encode` module to manage encoding and decoding more explicitly. The functions you'll most often use from it are, surprise, `encode` and `decode`. If you have raw external data that's still in some encoded form stored as bytes, call `decode` to turn that into abstract internal characters. On the flip side, if you have abstract internal characters and you want to convert them to some particular encoding scheme, you call `encode`.

```
use Encode qw(encode decode);
$chars = decode("shiftjis", $bytes);
$bytes = encode("MIME-Header-ISO_2022_JP", $chars);
```

For example, if you knew for sure that your terminal encoding was set to UTF-8, you could decode `@ARGV` this way:

```
# this works just like perl -CA
if (grep /\P{ASCII}/ => @ARGV) {
   @ARGV = map { decode("UTF-8", $_) } @ARGV;
}
```

For people who don't run an all-UTF-8 environment, it's not a good idea to assume the terminal is always in UTF-8. It may be in a locale encoding. Although the standard `Encode` module doesn't support locale-sensitive operations, the CPAN `Encode::Locale` module does. Use it like this:

```
use Encode;
use Encode::Locale;

# use "locale" as an arg to encode/decode
@ARGV = map { decode(locale =>  $_) } @ARGV;

# or as a stream for binmode or open
binmode $some_fh, ":encoding(locale)";

binmode STDIN,  ":encoding(console_in)"   if -t STDIN;
binmode STDOUT, ":encoding(console_out)"  if -t STDOUT;
binmode STDERR, ":encoding(console_out)"  if -t STDERR;
```

Databases are one area where you may have to deal with manual encoding and decoding. It depends on the database system. With simple DBM files, the underlying library expects bytes not codepoint strings, so you cannot directly use regular Unicode text on DBM files. If you try, you will get a `Wide character in subroutine` exception. To store a Unicode key-data pair in a `%dbhash` DBM hash, encode them to UTF-8 first:

```
use Encode qw(encode decode);

# assuming $uni_key and $uni_value are abstract Unicode strings

$enc_key   = encode("UTF-8", $uni_key);
$enc_value = encode("UTF-8", $uni_value);
$dbhash{$enc_key} = $enc_value;
```

The reciprocal action to retrieve a Unicode value, therefore, requires first encoding the key before you use it, then decoding the value returned after you fetch it:

```
use DB_File;
use Encode qw(encode decode);

tie %dbhash, "DB_File", "pathname";

# $uni_key holds a normal Perl string (abstract Unicode)
$enc_key   = encode("UTF-8", $uni_key);

$enc_value = $dbhash{$enc_key};
$uni_value = decode("UTF-8", $enc_key);
```

Now you can work with the returned `$uni_value` as with any other Perl string. Before that, it just has bytes, which are nothing but integers under 256 stored in string form. (And those integers are very much *not* Unicode codepoints.)

Alternately, starting with v5.8.4, you can use the standard `DBM_Filter` module to transparently handle the encoding and decoding for you.

```
use DB_File;
use DBM_Filter;

use Encode qw(encode decode);

$dbobj = tie %dbhash, "DB_File", "pathname";
$dbobj->Filter_Value("utf8");

# $uni_key holds a normal Perl string (abstract Unicode)
$uni_value  = $dbhash{$uni_key};
```

A Case of Mistaken Identity

If you only know ASCII, nearly all your assumptions about how text behaves with respect to case will be invalid in Unicode. In ASCII, there are uppercase letters and lowercase letters, but in Unicode, there is also a third sort of case, called titlecase. This isn't something we make much use of in English, but it does occur in various other writing systems derived from Latin or Greek.

Usually titlecase is the same as uppercase, but not always. It's used when only the first letter should be capitalized but not the rest. Some Unicode codepoints look like two letters printed side by side, but they are really just one codepoint. When used on a word that's supposed to have only its first part capitalized but not the rest, the titlecase version only capitalizes the appropriate part. These mostly exist to support legacy encodings, and today it is more common to use codepoints whose titlecase map produces two separate codepoints, one each in uppercase and lowercase. Here's an example of one of the legacy characters:

```
use v5.14;
use charnames qw(:full);
my $beast = "\N{LATIN SMALL LETTER DZ}ur";
say for $beast, ucfirst($beast), uc($beast);
```

That prints out "dzur", "Dzur", and "DZUR", each of which is only three codepoints long.

Some letters have no case, and some nonletters do have case. Lettercase is comparatively rare in the world's writing systems. Only eight out of Unicode v6.0's nearly 100 supported scripts have cased characters in them: Armenian, Coptic, Cyrillic, Deseret, Georgian, Glagolitic, Greek, and Latin scripts, plus some from Common and Inherited. None of the rest do.

A string can change length when casemapped. Under *simple casemapping*, the casemap of a string is always the same length as the original, but under *full casemapping*, it need not be. For example, the uppercase of "tschüß" is "TSCHÜSS", one character longer.

Different strings in one case can map to the same string in another case. Both lowercase Greek sigmas, "σ" and "ς", have the same uppercase form, "Σ", and that's just a simple example. To address all these variations sanely (or less insanely), a fourth casemap called foldcase is required for case-insensitive comparisons. Strings with the same foldcase are *by definition* case-insensitive equivalent.

Perl has always supported case-insensitive matching using the `/i` pattern modifier, which compares their *casefolds*. Starting with v5.16, the `fc` function is supported directly, allowing you to compare the foldcase of two string to decide whether they are case variants of each other. Before v5.16, you can get the `fc` function from the `Unicode::CaseFold` CPAN module.

Check your copy of the *perlfunc* manpage and your release notes in *perldelta* to see whether this feature exists yet in your release. If so, it will probably have an interpolated translation escape called `\F` that works like `\L` and `\U`, but for foldcase instead.

Another un-ASCII surprise is that casemapping is not guaranteed to be a reversible operation. For example, `lc("ß")` is `"ß"`, but `uc("ß")` is "SS" and `lc("SS")` is "ss", which is not at all where we started from. It doesn't take exotic two-character combinations to show that you cannot guarantee a round trip back to where you started. Remember our Greek sigmas: "σ" is the normal form, but "ς" is used at the end of the word, and both of those have the same uppercase form, "Σ". The round trip fails in that `lc(uc("ς"))` does not bring you back to the "ς" you started with, but only to "σ".

Not all cased characters change when casemapped. In Unicode, just because something is (say) lowercase doesn't mean that it even *has* a casemap for uppercase or titlecase. For example, `uc("McKinley")` is "`MCKINLEY`", because that MODIFIER LETTER SMALL C is lowercase but doesn't change case when casemapped—it wouldn't look right. Similarly, the small capitals are actually lowercase letters because they all fit within the x-height of the font. In "BOULDER CAMERA", the first letter of each word is in uppercase and the rest in lowercase.

Not all characters considered lowercase are even letters. Case is a property distinct from the General Categories. Roman numerals are cased numbers—for example, "Ⅷ" vs "viii". There are even letters that are considered lowercase but are `GC=Lm` not `GC=Ll`.

The typical ASCII strategy of putting a word into "headline" case using `ucfirst(lc($s))` is not guaranteed to work correctly in Unicode, because titlecasing the lowercase version is not always the same as titlecasing the original. This is also true of the other combinations. The correct way is to titlecase the first letter by itself and lowercase the remainder, either by calling the functions explicitly or with a regex substitution:

```
$tc = ucfirst(substr($s, 0, 1)) .  lc(substr($s, 1));

s/(\w)(\w*)/\u$1\L$2/g;
```

Apart from the General Categories, Unicode has quite a few other properties related to lettercase. Table 6-3 shows the ones available in Unicode v6.0. They're all binary properties, so you can just use their one-element form if you'd like. So instead of saying `\p{CWCM=Yes}` and `\p{CWCM=No}`, you can write `\p{CWCM}` for any codepoint that has that property, and `\P{CWCM}` for any codepoint that lacks it.

Table 6-3. Case-related properties

Short	Long
Cased	Cased
Lower	Lowercase
Title	Titlecase
Upper	Uppercase
CWL	Changes_When_Lowercased
CWT	Changes_When_Titlecased
CWU	Changes_When_Uppercased
CWCM	Changes_When_Casemapped
CWCF	Changes_When_Casefolded
CWKCF	Changes_When_NFKC_Casefolded
CI	Case_Ignorable
SD	Soft_Dotted

The `Lower` and `Upper` properties match all codepoints with the appropriate property, not letters alone. There are currently no nonletter titlecase codepoints, so `Title` is (for now) the same as `gc=Lt`. However, under `/i`, all three of them are the same as the `Cased` property, which is not letter-specific. Using `gc=Lt` case-insensitively is only the same as `Case_Letter`.

Graphemes and Normalization

We already mentioned characters like LATIN SMALL LETTER DZ that occupy one codepoint but that may look like two characters to the end user. The opposite situation also exists and is much more common. That is, a single user-visible character (a *grapheme*) can require more than a single codepoint to represent. Think of a letter plus one or more diacritics, like both és in "résumé". Those might each be one codepoint, or two. It's even possible that one é of them is a letter codepoint but the other is a letter followed by a combining mark. By design, you can never tell the difference just by looking at them because they are considered canonically equivalent. This has serious ramifications for almost all text handling, and it very nearly contradicts what we said earlier about glyphs not being important. In this particular sense they are the most important.

Combining characters are used to change an "n" into an "ñ", a "c" into a "ç", an "o" into an "ô", or a "u" into a "ű". The first three transformations require one combining mark, while the last one requires two combining marks. In fact, there's no limit to these. You can keep piling them on as long as you'd like, and you can create things people have never seen before.

All this requires quite a bit of serious rethinking and rewriting of all kinds of software. Just think about what the font system has to do. (No, giving up is not a valid option.) Your own programs that process text may need serious overhauling. Even something as simple in concept as reversing a string goes awry, because if you reverse by codepoint instead of grapheme, you'll move the combining characters from one base to another. Niño, María, and François become õniN, áiraM, and siǫcnarF.

Consider a grapheme made up of a base alphabetic codepoint, A, followed by two combining marks, call them X and Y. Does the order those marks get applied matter? Are AXY and AYX the same? Sometimes they are, sometimes they aren't. With a grapheme like "ō̱" it doesn't matter, since one mark goes on the top and the other on the bottom. Since it doesn't matter, your program needs to treat a grapheme that shows up as a LATIN LETTER SMALL O followed by a COMBINING OGONEK and then a COMBINING MACRON the same way as it treats one where the combining marks come in the opposite order. But with something where both marks go on the same part of the letter, order *does* matter. More on that in a moment.

It gets harder. Unicode has certain characters that are precomposed to allow round trip translation from legacy character sets to Unicode and back. Latin has around 500 of these, and Greek has around 250. There are lots more, too.

For example, an "é" could be codepoint U+00E9, a LATIN LETTER SMALL E WITH ACUTE. That's just a single codepoint. But here's the thing: it needs to be treated just as you would if the grapheme showed up as a LATIN LETTER SMALL E followed by a COMBINING ACUTE ACCENT.

With graphemes that logically have more than one mark, you could have even more variation, as some of them may start with one or another precomposed character that already has a mark built right into it, and then adds the other one.

To help cope with all this, Unicode has a well-defined procedure called *normalization*. Per the Unicode Glossary at *http://unicode.org/glossary/*, normalization "removes alternate representations of equivalent sequences from textual data, to convert the data into a form that can be binary-compared for equivalence." In other words, it gives a single, unique identity to each semantic entity that needs one, so all the one-to-many mappings go away.

Here are the four Unicode normalization forms:

- Normalization Form D (NFD) is formed by canonical decomposition.
- Normalization Form C (NFC) is formed by canonical decomposition followed by canonical composition.
- Normalization Form KD (NFKD) is formed by compatibility decomposition.
- Normalization Form KC (NFKC) is formed by compatibility decomposition followed by canonical composition.

Normally you want to use the canonical forms, because normalizing to the compatibility forms loses information. For example, `NFKD("™")` returns the regular, two-character string "`TM`". This may be want you want in searching and related applications, but canonical decomposition normally works better than compatibility decomposition for most applications.

Unless you normalize it yourself, a string does not necessarily show up to your program in either NFD or NFC; there are strings that are in neither. Consider something like "ō̵", which is just a letter Latin small letter "o" with a tilde and a macron (as opposed to a macron and tilde) over it. That particular grapheme takes anywhere from 1–3 codepoints, depending on normalization: `"\x{22D}"` in NFC, `"\x{6F}\x{303}\x{304}"` in NFD, or `"\x{F5}\x{304}"`, which is neither. Table 6-4 shows seven variants of a Latin small letter "o" with a tilde and sometimes a macron.

Table 6-4. Canonical conundra

N	Glyph	NFC?	NFD?	Literal	Codepoints
1	õ	✓	—	`"\x{F5}"`	LATIN SMALL LETTER O WITH TILDE
2	õ	—	✓	`"o\x{303}"`	LATIN SMALL LETTER O, COMBINING TILDE
3	o͞	✓	—	`"\x{22D}"`	LATIN SMALL LETTER O WITH TILDE AND MACRON
4	o͞	—	—	`"\x{F5}\x{304}"`	LATIN SMALL LETTER O WITH TILDE, COMBINING MACRON
5	o͞	—	✓	`"o\x{303}\x{304}"`	LATIN SMALL LETTER O, COMBINING TILDE, COMBINING MACRON
6	o̱	—	✓	`"o\x{304}\x{303}"`	LATIN SMALL LETTER O, COMBINING MACRON, COMBINING TILDE
7	o̱	✓	—	`"\x{14D}\x{303}"`	LATIN SMALL LETTER O WITH MACRON, COMBINING TILDE

In Perl, the standard `Unicode::Normalize` module handles normalization functions for you. A good rule of thumb is to run all Unicode input through NFD as the first thing you do to it, and all Unicode output through NFC as the last thing you do with it. In other words, like this:

```
use v5.14;
use strict;
use warnings;
use warnings FATAL => "utf8";  # throw encoding error exceptions
use open qw(:std :utf8);

use Unicode::Normalize qw(NFD NFC);

while (my $line = <>) {
    $line = NFD($line);
    ...
} continue {
    print NFC($line);
}
```

That reads in UTF-8 input and automatically decodes it, throwing an exception if there is a problem with malformed UTF-8. The first thing it does inside the loop is normalize the input string into its canonically decomposed form. In other words, it breaks apart all precomposed characters completely, to the delight of reductionists everywhere. It also reorders all marks that attach to different points on the base codepoint[4] into a reliable ordering.

4. The fancy term is that they are reordered according to their canonical combining classes.

Unless you normalize, you cannot even begin to deal with combining character issues. Consider the different graphemes we presented in Table 6-4.

- Number 4 is in *neither* NFC *nor* NFD. These things happen.
- Assuming you enforce NFD, 1 turns into 2, both 3 and 4 turn into 5, and 7 turns into 6.
- Assuming you enforce NFC, 2 turns into 1, both 4 and 5 turn into 3, and 6 turns into 7.
- That means that by normalizing to *either* NFD *or* NFC, you can do a simple `eq` to get 1–2, 3–5, and 6–7 to each respectively test equal to one another.
- Notice, however, that it's three different sets. ☹

One piece of good news is that Perl patterns have pretty good support for graphemes, provided you know how to use it. A `\X` in a regex matches a single user-visible character, which in Unicode-speak is called a grapheme cluster.[5]

Not all grapheme clusters are a base codepoint plus zero or more combining codepoints, but most are. One extremely common two-character grapheme that has no combining characters is `"\r\n"`, commonly called CRLF. `\X` matches a CRLF as a single grapheme cluster because it is just one user-perceived character. Japanese also has two grapheme extenders that are not combining marks, HALFWIDTH KATAKANA VOICED SOUND MARK and HALFWIDTH KATAKANA SEMI-VOICED SOUND MARK.

But, for the most part, you can think of a grapheme cluster as a base character (`\p{Grapheme_Base}`) with any number of combining characters variation selectors, Japanese voice marks, or zero-width joiners or nonjoiners (`\p{Grapheme_Extend}*`) immediately following it, with an exception made for the CRLF pair.

Actually, you can probably just think of a grapheme cluster as a grapheme.[6]

A `\X` in a Perl pattern matches any of those seven cases above indiscriminately, and it doesn't even need them in canonical form. Yes, but now what? This is where it stops being easy. Because if you want to know about more the grapheme than that it *is* a grapheme, you have to be moderately clever with your pattern matching. NFD is assumed *and required* for the following to work:

5. *Very* technically speaking, Perl's `\X` matches what the Unicode Standard refers to as an *extended* grapheme cluster. Standards writers apparently get paid by the word.

6. That's what we do. We aren't getting paid by the word.

- `/^o/` reports that all seven start with an "o".
- `/^o\x{COMBINING TILDE}/` reports that 1–5 start with an "o" and a tilde, but that misses 6 and 7.
- You'd need `/^o\pM*?\x{COMBINING TILDE}/` to get all seven matching.

And here is a stab at a solution to match a complete character, with various issues still unresolved, like whether to use `\p{Grapheme_Extend}` instead of `\pM` and `\p{Grapheme_Base}` (were there any) instead of `\PM`:

```
$o_tilde_rx = qr{ o \pM *? \x{COMBINING TILDE} \pM* }x;
```

For a much easier approach to accent-insensitive strings comparisons, see the next section, "Comparing and Sorting Unicode Text" on page 297.

The only thing in the Perl core that knows about graphemes is `\X` in a pattern. Built-in functions like `substr`, `length`, `index`, `rindex`, and `pos` access strings at the granularity of the codepoint, not of the grapheme. So `\X` is your hammer, and all of Unicode starts to look like nails. A lot of nails.

Imagine reversing "crème brûlée" codepoint by codepoint. Assuming normalization to NFD, you'd end up with "éêlurb emèrc" when you really want "eélûrb emèrc". Instead, use `\X` to extract a list of graphemes, then reverse that.

```
use v5.14;
use utf8;
my $cb = "crème brûlée";
my $bc = join("" => reverse($cb =~ /\X/g));
say $bc;    # "eélûrb emèrc"
```

Assuming `$cb` below is always "`crème brûlée`", contrast operating on codepoints compared with operating on graphemes:

```
my $char_length = length($cb);       # 15 or 12
my $graph_count = 0;
$graph_count++ while $cb =~ /\X/g;   # 12
```

You could pull out the first bit this way:

```
my $piece  = substr($cb, 0, 5);    # "crèm" or "crème"
my($piece) = $cb =~ /(\X{5})/;     # "crème"
```

And change the last bit this way:

```
substr($cb, -6) = "fraîche";       # "crème brfraîche" or "crème fraîche"
$cb =~ s/\X{6}$/fraîche/;          # "crème brûlée"
```

While this inserts "` bien`":

```
substr($cb, 5, 0) = " bien";       # "crèm biene brûlée" or "crème bien brûlée"
$cb =~ s/^\X{5}\K/ bien/;          # "crème bien brûlée"
```

Notice how the codepoint-based approach is unreliable. The first answer is when the string is in NFD, and the second in NFC. You might think keeping or putting it in NFC will somehow solve all your problems, but it won't. For one thing, there are infinitely more graphemes without a precomposed form than those that have one, so NFC by no means guarantees you won't have any combining marks.

Furthermore, NFC is actually harder to work with, which is why we recommend always normalizing to NFD on input. Consider how you'd spot a word with two `e`s in it, like "`crème`" and "`brûlée`". The simplest and only reliable way to do it:

```
/ e .*? e /x
```

will work only in NFD, not NFC. And while you might think that if you could instead guarantee NFC, that you could write:

```
/ [eéè] .*? [eéè] /x
```

But that breaks when the crêpes show up. Adding an `ê` only appears to help, because pretty soon you end up with crazy things like this:

```
/ [èéêëēĕėęḙḛḝ] [èéêëēĕėęḙḛḝ] /x   # two e's in a row
```

which won't work if someone gives you an underlined `e`, since there is no precomposed character for that. If (but only if) your strings are in NFD, then this always works:

```
/ (?: (?=e) \X ){2} /x
```

This provides a reliable and nondestructive way to do accent-insensitive matching: match a grapheme with `\X` and impose a restriction that it must be one that starts with the grapheme base character you're looking for. The only sort of thing you can't get at this way by first running everything through NFD (or maybe NFKD) are the letters that don't decompose, because they are considered letters in their own right.

So, for example, you won't find any `o`s in "`smørrebrød`", because LATIN SMALL LETTER O WITH STROKE has no decomposition that separates out the `o`s. And while you would find two `o`s in the decomposition of "`Ævar Arnfjörð Bjarmason`", you wouldn't find any `e`s or `d`s, because LATIN CAPITAL LETTER AE doesn't break up into an `a` plus an `e`, and LATIN SMALL LETTER ETH doesn't ever turn into a `d`.

Not under decomposition, at least. However, a comparison using a collator object from `Unicode::Collate` set to check only the primary strength would indeed find all three of those. In the following section, "Comparing and Sorting Unicode Text" on page 297, we show you how to do that.

Having to recast Perl's built-in string functions in terms of `\X` every time is a bit clunky. An alternate approach is to use the `Unicode::GCString` CPAN module.

Regular Perl strings are always codepoint oriented, but this object-oriented module lets you access Unicode Grapheme Cluster Strings as graphemes instead. Here's how you'd use its methods to manipulate a string of graphemes in the same ways we did earlier:

```
my $gs = Unicode::GCString("crème brûlée");

say $gs->length();
say $gs->substr(0,5);
$gs->substr(-6, 6, "fraîche");
$gs->substr( 5, 0, " bien");
```

Now normalization forms don't matter anymore, so the `length` method returns an answer in graphemes, the `substr` method operates on graphemes, and you can even use `index` and `rindex` method to search for literal substrings, getting back integer offsets in graphemes, not codepoints.

Possibly this module's most useful method is `columns`. Imagine you wanted to print out some menu items like this:

```
crème brûlée         £5.00
trifle               £4.00
toffee ice cream     £4.00
```

How do you get everything to line up? Even assuming your are using a fixed-width font, you can't use:

```
printf("%-25s £%.2f\n", $item, $price);
```

because Perl will assume every codepoint is exactly one column, which just isn't true.

The `columns` method tells you how many print columns a string would occupy if printed. Often this is the same as a string's length in graphemes, but often it is not. Unicode considers some characters to be "wide" in that they take up two columns when printed. These are so common in East Asian scripts that Unicode has properties like `East_Asian_Width=Wide` and `East_Asian_Width=Full`, indicating characters that take up two print columns.

Other characters take up none at all, and not just because they're combining marks: they might be control or format characters. Plus, some combining marks are considered spacing marks, which actually do take up print columns. About the only thing you can generally rely on is that in a fixed-width font, each character's width will be some integer multiple of the width of a column.

One approach, then, for printing a string padded to a certain width would be something along these lines:

```
sub pad {
    my($s, $width) = @_;
    my $gs = Unicode::GCString->new($s);
    return $gs . (" " x ($width - $gs->columns));
}

printf("%s £%.2f\n", pad($item, 25), $price);
```

Now your columns will align even if your strings have formatting characters, combining marks, or wide characters in them.

Interesting and useful as it is, the `Unicode::GCString` is really just a helper module for a larger module that tackles a much harder problem: the `Unicode::LineBreak` module from CPAN. This module implements the Unicode Line Breaking Algorithm from UAX#14. It's what you have to use if you want to format your Unicode text into paragraphs like the Unix *fmt*(1) program of the `Text::Autoformat` module. The *unifmt* program from the CPAN `Unicode::Tussle` suite is an example of this. It does the Right Thing even in the face of East Asian wide characters, tabs, combining characters, and invisible formatting codes.

Comparing and Sorting Unicode Text

When you use Perl's built-in `sort` or `cmp` operators, strings are not compared alphabetically. Instead, the numeric codepoint of each character in one string is compared with the numeric codepoint of the corresponding character in the other string. This doesn't work so well on text where some letters are shared between languages and other letters are peculiar to each language. It's not just letters that have misordered codepoints—numbers and other supposedly contiguous sequences can do that, too, because some were added to the character sets when they were small, and others were added after the character sets grew, like Topsy. For instance, squares and cubes were added to Latin-1 early on. Notice how they sort early, too:

```
use v5.14;
use utf8;
my @exes = qw( x⁷ x⁰ x⁸ x³ x⁶ x⁵ x⁴ x² x⁹ x¹ );
@exes = sort @exes;
say "@exes";

# prints: x² x³ x¹ x⁰ x⁴ x⁵ x⁶ x⁷ x⁸ x⁹
```

Because codepoint order does not correspond to alphabetic order, your data will come out in an order that, while not exactly random, isn't what someone looking for a lexicographic sort wants. The default `sort` is good mostly for providing fast access to an ordering that will be the same every time, even though it isn't usefully

alphabetic. It's just deterministic. Sometimes that's good enough, but other times...

Enter the standard `Unicode::Collate` module, which implements the Unicode Collation Algorithm (UCA), a highly customizable, multilevel sort specifically designed for Unicode data. The module has a lot of fancy features, but often you can just call its default `sort` method:

```
use v5.14;
use utf8;
use Unicode::Collate;
my @exes = qw( x⁷ x⁰ x⁸ x³ x⁶ x⁵ x⁴ x² x⁹ x¹ );
@exes = Unicode::Collate->new->sort(@exes);
say "@exes";

# prints: x⁰ x¹ x² x³ x⁴ x⁵ x⁶ x⁷ x⁸ x⁹
```

By default, the module provides an alphanumeric sort. To a first approximation, it's like first throwing out all nonalphanumerics and then sorting whatever's left case-insensitively, not according to numeric codepoint order, but in sequential order of the alphabetics in the string. This is the kind of sort that dictionaries use, which is why it's sometimes called a dictionary sort or a lexicographic sort.

Before everyone got used to computers that didn't understand how to sort text, this was how everything was expected to be sorted, and often still is. A book title with a comma after the first word should not suddenly hare off to a completely different place than the same title without the comma. Commas shouldn't matter, at least not unless everything else is tried. Commas are not part of any natural sequence like an alphabet or the integers.

Consider what happens with Perl's built-in `sort` (which is the same as the default string sort found in the shell command and most programming languages):

```
% perl -e 'print sort <>' little-reds
Little Red Mushrooms
Little Red Riding Hood
Little Red Tent
Little Red, More Blue
Little, Red Rider
```

What kind of nonsense is that? "`More`" should come before "`Mushrooms`", "`Rider`", and "`Riding`" should go together, and "`Tent`" should go at the end. Even on pure ASCII, that isn't an alphabetic sort; this is:

```
% perl -MUnicode::Collate -e '
    print for Unicode::Collate->new->sort(<>)' little-reds
Little Red, More Blue
Little Red Mushrooms
Little, Red Rider
Little Red Riding Hood
Little Red Tent
```

We think you'll like Unicode's sort so much that you'll want to keep a little script around to sort your regular text. This one assumes UTF-8 input and produces UTF-8 output:

```
#!/usr/bin/perl
use warnings;
use open qw(:std :utf8);
use warnings qw(FATAL utf8);
use Unicode::Collate;
print for Unicode::Collate->new->sort(<>);
```

A more featureful version of that program can be found in the *ucsort* program, part of the CPAN `Unicode::Tussle` suite.

Most people find that, left to its defaults, the module's sort produces aesthetically pleasing results. It already knows how to order letters and numbers, plus all the weirdnesses of Unicode that mess up ASCII sorts, like letters that aren't numerically close to each other needing to sort together, all the fancy Unicode casing rules, canonically equivalent strings, and quite a bit more.

Plus, if it isn't quite to your liking, its potential for customization is unbounded. Here's a simple tweak that works well on English-language book or movie titles. This time we'll sort uppercase before lowercase, remove leading articles before sorting, and zero-pad numbers on the left so that *101 Dalmations* sorts after *7 Brides for 7 Brothers*.[7]

```
my $collator = Unicode::Collate->new(
    --upper_before_lower => 1,
    --preprocess => {
        local $_ = shift;
        s/^ (?: The | An? ) \h+ //x;  # strip articles
        s/ ( \d+ ) / sprintf "%020d", $1 /g;
        return $_;
    };
);
```

We've already shown how an alphabetic sort looks better than a codepoint sort on ASCII. On non-ASCII Unicode, it's even more dramatic. Even if you are "only"

7. The padding is needed because although Unicode knows an individual numeric codepoint's numeric value, it doesn't know that "9" should come before "10"—unless you do something like this.

using English, you still need to deal with more than ASCII. What if your data has a 10¢ stamp or a £5 note? Even in purely English text you encounter curly quotes, fancy dashes, and all kinds of specialists symbols that ASCII doesn't handle. Even if we're only talking about words such as you'd find in the English dictionary, that doesn't let you off the hook. Here are just a few of the non-ASCII entries from the *Oxford English Dictionary*, sorted (column-major) with the UCA in default mode:

Allerød	fête	Niçoise	smørrebrød
après-ski	feuilleté	piñon	soirée
Bokmål	flügelhorn	plaçage	tapénade
brassière	Gödelian	prêt-à-porter	vicuña
caña	jalapeño	Provençal	vis-à-vis
crème	Madrileño	quinceañera	Zuñi
crêpe	Möbius	Ragnarök	α-ketoisovaleric acid
désœuvrement	Mohorovičić discontinuity	résumé	(α-)lipoic acid
Fabergé	moiré	Schrödinger	(β-)nornicotine
façade	naïve	Shijō	ψ-ionone

You don't want to see what happens if you sort those next to similar words that are only in ASCII. It is not a pretty picture. And that's just Latin text. Consider these figures from Greek mythology, sorted using the default codepoint sort:

Δύσις	Ἄσβολος	Διόνυσος	Φάντασος	Μεγαλήσιος
Ασβετος	Αγχίσης	Ἑσπερίς	Ἄγδιστις	Τελεσφόρος
Ασωπός	Λάχεσις	Ἕσπερος	Ἀστραῖος	Χρυσόθεμις
Θράσος	Νέμεσις	Εύνοστος	Ασκληπιός	Ἀριστόδημος
Ιάσιος	Περσεύς	Ἡφαιστος	Ἥφαιστος	Ἀριστόμαχος
Νέσσος	Ἄδραστος	Ηωσφόρος	Ἀρισταῖος	Λαιστρυγόνες
Πέρσης	Ἄλκηστις	Θρασκίας	Ἀσκάλαφος	
Πίστις	Αίγισθος	Πάσσαλος	Βορυσθενίς	
Χρύσος	Αργέστης	Πρόφασις	Ἑσπερίδες	

Even if you can't read the Greek alphabet, you can tell how seriously broken sorting by codepoint is: just scan down the first letter in each column. See how they jump around? Under a default UCA sort, they now come right:

Ἄγδιστις	Ασβετος	Ἑσπερίδες	Ιάσιος	Πίστις
Αγχίσης	Ἄσβολος	Ἑσπερίς	Λαιστρυγόνες	Πρόφασις
Ἄδραστος	Ἀσκάλαφος	Ἕσπερος	Λάχεσις	Τελεσφόρος
Αἴγισθος	Ασκληπιός	Εύνοστος	Μεγαλήσιος	Φάντασος
Ἄλκηστις	Ἀστραῖος	Ἥφαιστος	Νέμεσις	Χρυσόθεμις
Αργέστης	Ασωπός	Ήφαιστος	Νέσσος	Χρύσος
Ἀρισταῖος	Βορυσθενίς	Ηωσφόρος	Πάσσαλος	
Ἀριστόδημος	Διόνυσος	Θρασκίας	Περσεύς	
Ἀριστόμαχος	Δύσις	Θράσος	Πέρσης	

Convinced? Let's first look at how the UCA really works, and then how to configure it a bit.

The Unicode Collation Algorithm is a multilevel sort. You've seen these before. Imagine you were writing your comparison function to pass to the built-in `sort` that looked like this:

```
@collated_text = sort {

    primary($a)    <=>   primary($b)
                    ||
    secondary($a)  <=>   secondary($b)
                    ||
    tertiary($a)   <=>   tertiary($b)
                    ||
    quaternary($a) <=>   quaternary($b)

} @random_text;
```

That's a multilevel sort, and at a certain level of simplification, that's pretty much what the UCA is doing. Each of those four functions returns a number that represents the sort weight at that strength. Only when primary strengths differ does it fall through to compare secondary strengths, and so on down the levels.

This is a little bit of a simplification, but it works essentially this way:

Primary strength: compare letters
: Compare whether the basic letters[8] are the same. Ignore nonletters at this stage; just skip ahead until you find a letter. If the letters aren't the same for the same relative position, there is an established dictionary order about what goes first.

8. And digits, and a few things you might not realize are letters; just pretend we said all those things when we say letter here.

If you are a user of the Latin alphabet sorting Latin text, this will be in the order of the abcs you learned in school, so "`Fred`" comes before "`freedom`", as does "`free beer`". The reason it put "`free beer`" in front of "`freedom`" is because the fifth letter in the first string is "`b`", and that comes before the fifth letter in the second string, which is "`d`". See how that works? That's dictionary order. We aren't doing a field sort here.

Secondary strength: compare diacritics
: If the letters are the same, then check whether the diacritics (technically, the combining marks; diacritics and marks mostly overlap, but not completely) are the same. By default we resolve ties by looking at the diacritics reading left to right, but this can be flipped to do so right to left, as is needed in French. (The classic demo is that normal LTR tie-breaking order sorts `cote < coté < côte < côté`, whereas the French RTL tie-breaking order for diacritics sorts `cote < côte < coté < côté`; in other words, the middle two words exchange positions in French ordering. It has to do with their inflectional morphology, which is tail-based.)

Tertiary strength: compare case
: If the letters and the diacritics are the same, then check whether the case is the same. By default, lowercase precedes uppercase, but this is easy to flip using the `upper_before_lower => 1` option when you construct your collator object.

Quaternary strength: compare everything else
: If the letters, the diacritics, and the case are all the same for a given position, now you go back and reconsider any nonletters, like punctuation and symbols and whitespace, that you temporarily ignored at earlier levels. Here, everything counts.

You don't have to do all those if you don't want. You can, for example, tell it to use only the primary strength, which only considers basic letters and absolutely nothing else.

That's how you do an "accent-insensitive" string comparison, using your collator object's `eq` method.

Normalization won't always help you enough. For example, you can't use it to get "`o`", "`o̵`", and "`ø`" to look the same, because LATIN SMALL LETTER O WITH STROKE has no decomposition to something with an "`o`" in it. On the other hand, when comparing whether letters are the same, `Unicode::Collate` *does* count "`o`", "`o̵`", and "`ø`" as the same letter—normally. Not in Swedish or Hungarian, though.

Similarly, with "`d`" and "`ð`" — you can't decompose LATIN SMALL LETTER ETH to anything with a "`d`" in it, but the UCA treats them as the same letter. Er, except

in Icelandic (the "is" locale), where "d" and "ð" are now different letters in their own right.

If you wanted your collator object to ignore case but consider accents for level one ties, you'd set it to do only the first two stages and skip the rest by passing the constructor an option pair of `level => 2`.

Here's the full syntax for all the optional configuration parameters in the constructor as of its v0.81 release:

```
$Collator = Unicode::Collate->new(
   UCA_Version => $UCA_Version,
   alternate => $alternate, # alias for 'variable'
   backwards => $levelNumber, # or \@levelNumbers
   entry => $element,
   hangul_terminator => $term_primary_weight,
   ignoreName => qr/$ignoreName/,
   ignoreChar => qr/$ignoreChar/,
   ignore_level2 => $bool,
   katakana_before_hiragana => $bool,
   level => $collationLevel,
   normalization  => $normalization_form,
   overrideCJK => \&overrideCJK,
   overrideHangul => \&overrideHangul,
   preprocess => \&preprocess,
   rearrange => \@charList,
   rewrite => \&rewrite,
   suppress => \@charList,
   table => $filename,
   undefName => qr/$undefName/,
   undefChar => qr/$undefChar/,
   upper_before_lower => $bool,
   variable => $variable,
);
```

Consult the module's manpage for the sort of arguments its constructor accepts. Although the module is bundled with Perl, it is also available as a dual-lived CPAN module. That way it can get updated independently from the Perl core. The version released with Perl v5.14 shipped with v0.73 of `Unicode::Collate`, so it's obviously been updated since then. You don't have to have a cutting-edge release of Perl to run the latest version of the module. It supports Perl releases dating back to v5.6, and has built-in forwards compatibility with later Unicode releases via its `UCA_Version` constructor argument.

Using the UCA with Perl's sort

In real code, the `sort` built-in is usually called in one of two ways. Either it's called with no sort routine at all, or it's called with a block argument that serves as the

custom comparison function. The `Unicode::Collate`'s `sort` method is a fine substitute for the first flavor, but not the second. For that, you'd use a different method from your collator object, called `getSortKey`.

Suppose you have a program that uses the built-in `sort`, like this:

```
@srecs = sort {
    $b->{AGE}   <=>  $a->{AGE}
                ||
    $a->{NAME}  cmp  $b->{NAME}
} @recs;
```

But then you decide you want the text to sort alphabetically on your `NAME` fields, not just by numeric codepoints. To do this, just ask the collator object to give you back the binary sort key for each text string you will eventually wish to sort. Unlike the regular text, if you pass this binary sort key to the `cmp` operator, it will magically sort in the order you want.

The block you pass to `sort` now looks like this:

```
my $collator = Unicode::Collate->new();
for my $rec (@recs) {
    $rec->{NAME_key} = $collator->getSortKey( $rec->{NAME} );
}
@srecs = sort {
    $b->{AGE}       <=>  $a->{AGE}
                    ||
    $a->{NAME_key}  cmp  $b->{NAME_key}
} @recs;
```

You can pass the constructor any optional arguments to do anything special, including preprocessing.

Another thing you can do with collator objects is use them to do simple accent- and case-insensitive matching. It makes sense; if you have the ability to tell when things are ordered, you also have the ability to tell when they are equivalent in a given ordering. So you just have to pick the right ordering semantics. For example, if you set the collation level to 1, it only considers whether things are the same letter, diacritics and case notwithstanding. Your collator object has methods on it like `eq`, `substr`, and `index` to help with this. (You have to set it not to normalize, though, because otherwise your codepoint offsets will be wrong.) Here's an example:

```
use v5.14;
use utf8;
use Unicode::Collate;
my $Collator = Unicode::Collate->new(
                  level  => 1,
                  normalization => undef,
```

```
                );

my $full = "Gabriel García Márquez";
for my $sub (qw[MAR CIA]) {
    if (my($pos,$len) = $Collator->index($full, $sub)) {
        my $match = substr($full, $pos, $len);
        say "Found match of literal ‹$sub› in ‹$full› as ‹$match›";
    }
}
```

When run, that prints out:

```
Found match of literal ‹MAR› in ‹Gabriel García Márquez› as ‹Már›
Found match of literal ‹CIA› in ‹Gabriel García Márquez› as ‹cía›
```

Please don't tell the CIA.

Locale Sorting

Although the default UCA works well for English and a lot of other languages—including Irish Gaelic, Indonesian, Italian, Georgian, Dutch, Portuguese, and German (except in phonebooks!)—it needs some modification to work the way speakers of many other languages expect their alphabets to sort. Or nonalphabets, as the case may be.

For example, the Nordic languages place some of their letters with diacritics after *z* instead of next to the regular letters. Even Spanish does things a little differently: the *ñ* isn't considered a regular *n* with a tilde on it the way *ã* and *õ* are in Portuguese. Instead, it's its own letter (named *eñe*, of course) that falls after *n* and before *o* in the Spanish alphabet. That means these words should sort in this order in Spanish: *radio, ráfaga, ranúnculo, raña, rápido, rastrillo*. Notice how *ranúnculo* comes before *raña* instead of after it.

The way to address locale-specific sorting of Unicode data is to use the `Unicode::Collate::Locale` module. It's part of the `Unicode::Collate` distribution, so it comes standard with v5.14 and is included with its companion module if you separately install either from CPAN.

The only difference in the two modules' APIs is that the `Unicode::Collate::Locale` takes an extra parameter to the constructor: the locale. As of this writing, 70 different locales are supported, including variants like German phonebook (umlauted vowels collate as though they were the regular vowel plus an *e* following them), traditional Spanish (*ch* and *ll* count as graphemes with their own ordering in the alphabet), Japanese, and five different ways of sorting Chinese.

Using these locales is really easy:

```
use Unicode::Collate::Locale;

$coll = Unicode::Collate::Locale->new(locale => "fr");

@french_text = $coll->sort(@french_text);
```

Because `Unicode::Collate::Locale` is a subclass of `Unicode::Collate`, its constructor accepts the same optional arguments that its superclass's does, and its objects support the same methods, so you can use these objects for locale-sensitive searches the same way as before. Here we select the "German phonebook" locale, where (for example) *ae* and *ä* count as the same letter. You can just compare them outright like this:

```
state $coll = new Unicode::Collate::Locale::
              locale => "de__phonebook",
          ;

if ($coll->eq($a, $b)) { ... }
```

And here's a way to search:

```
use Unicode::Collate::Locale;
my $Collator = new Unicode::Collate::Locale::
               locale => "de__phonebook",
               level  => 1,
               normalization => undef,
              ;

my $full = "Ich müß Perl studieren.";
my $sub = "MUESS";
if (my ($pos,$len) = $Collator->index($full, $sub)) {
    my $match = substr($full, $pos, $len);
    say "Found match of literal ‹$sub› in ‹$full› as ‹$match›";
}
```

When run, that says:

```
Found match of literal ‹MUESS› in ‹Ich müß Perl studieren.› as ‹müß›
```

More Goodies

One thing to always be aware of is that, by default, the Perl shortcuts like `\w`, `\s`, and even `\d` match many Unicode characters based on particular character properties. These are described in Table 5-6, and are intended to match the formal definitions given in Annex C: Compatibility Properties from Unicode Technical Standard #18, "Unicode Regular Expressions", version 13, from August 2008.

If you are used to matching `(\d+)` to grab a whole number and use it like a number, that will not always work correctly with Unicode data. As of Unicode v6.0, 420

codepoints are matched by `\d`. If you don't want that, you may specify `/\d/a` or `/(?a:\d)/`, or you may use the more particular property, `\p{POSIX_Digit}`.

However, if you mean to match any run of decimal digits in any one script and need to use that match as a number in Perl, the `Unicode::UCD` module's `num` function will help you do that.

```
use v5.14;
use utf8;
use Unicode::UCD qw(num);
my $num;
if ("৪৸৬৯" =~ /(\d+)/) {
    $num = num($1);
    printf "Your number is %d\n", $num;
    # Your number is 4567
}
```

Although regexes can ask whether a character has some property, they can't tell you what properties the character has (at least, not without testing all of them). And sometimes you really do want to know that. For example, suppose you want to know what Script a codepoint has been assigned, or what its General Category is. To do that, you use the same `Unicode::UCD` module again. Here is a program to print out useful properties you can use in pattern matching.

```
use v5.14;
use utf8;
use warnings;

use Unicode::UCD       qw( charinfo );
use Unicode::Normalize qw( NFD );

## uncomment next line for decomposed forms
my $mystery = ## NFD
                "৪৸৬৯";

for my $chr (split //, $mystery) {
    my $ci = charinfo(ord $chr);
    print "U+", $$ci{code};
    printf ' \N{%s}'."\n\t",  $$ci{name};
    print  " gc=",            $$ci{category};
    print  " script=",        $$ci{script};
    print  " BC=",            $$ci{bidi};
    print  " mirrored=",      $$ci{bidi};
    print  " ccc=",           $$ci{combining};
    print  " nv=",            $$ci{numeric};
    print  "\n";
}
```

When run, that program prints out:

```
U+096D \N{DEVANAGARI DIGIT SEVEN} gc=Nd script=Devanagari
       BC=L mirrored=L ccc=0 nv=7
U+00BE \N{VULGAR FRACTION THREE QUARTERS} gc=No script=Common A
       BC=ON mirrored=ON ccc=0 nv=3/4
U+00E7 \N{LATIN SMALL LETTER C WITH CEDILLA} gc=Ll script=Latin
       BC=L mirrored=L ccc=0 nv=
U+1F6F \N{GREEK CAPITAL LETTER OMEGA WITH DASIA AND PERISPOMENI}
       gc=Lu script=Greek BC=L mirrored=L ccc=0 nv=
```

However, if you remove the comment blocking `NFD` from running, you get:

```
U+096D \N{DEVANAGARI DIGIT SEVEN} gc=Nd script=Devanagari
       BC=L mirrored=L ccc=0 nv=7
U+00BE \N{VULGAR FRACTION THREE QUARTERS} gc=No script=Common
       BC=ON mirrored=ON ccc=0 nv=3/4
U+0063 \N{LATIN SMALL LETTER C} gc=Ll script=Latin
       BC=L mirrored=L ccc=0 nv=
U+0327 \N{COMBINING CEDILLA} gc=Mn script=Inherited
       BC=NSM mirrored=NSM ccc=202 nv=
U+03A9 \N{GREEK CAPITAL LETTER OMEGA} gc=Lu script=Greek
       BC=L mirrored=L ccc=0 nv=
U+0314 \N{COMBINING REVERSED COMMA ABOVE} gc=Mn script=Inherited
       BC=NSM mirrored=NSM ccc=230 nv=
U+0342 \N{COMBINING GREEK PERISPOMENI} gc=Mn script=Inherited
       BC=NSM mirrored=NSM ccc=230 nv=
```

Custom Regex Boundaries

A `\b` for a word boundary and `\B` for a non-(word boundary) both rely on your current definition of `\w` (meaning that they change right along with `\w` if you switch to ASCII semantics with the `/a` or `/aa` modifier).

If those aren't quite the kind of boundaries you're looking for, you can always write your own boundary assertions based on arbitrary edge conditions, like script boundaries. Here is the definition of `\b`:

```
(?(?<=      \w)     # if there is a word character to the left
      (?!   \w)     #    then there must be no word character to the right
  |   (?=   \w)     #    else there must be a  word character to the right
)
```

And here is the definition of `\B`:

```
(?(?<=      \w)     # if there is a word character to the left
      (?=   \w)     #    then there must be a  word character to the right
  |   (?!   \w)     #    else there must be no word character to the right
)
```

Now that you know exactly how word boundaries and nonboundaries work, you can craft your own boundaries by swapping in your own condition wherever you see `\w` in the patterns above. You just need to be careful to specify a fixed-width

condition so that it can be used in a lookbehind. That means you can't use things like `\X` or `\R`, which are variable width. The easiest way to do that is to use a property or other character class. For example, you could use `\p{Greek}` for characters in the Greek script—but best add Inherited so you don't miss the combining characters, so use `[\p{Greek}\p{Inherited}]` instead.

For example, this might provide regex subroutines suitable for that kind of work:

```
(?(DEFINE)
    (?<greeklish>           [\p{Greek}\p{Inherited}]   )
    (?<ungreeklish>         [^\p{Greek}\p{Inherited}]  )
    (?<greek_boundary>
        (?(?<=      (?&greeklish))
              (?!   (?&greeklish))
          |   (?=   (?&greeklish))
        )
    )
    (?<greek_nonboundary>
        (?(?<=      (?&greeklish))
              (?=   (?&greeklish))
          |   (?!   (?&greeklish))
        )
    )
)
```

For character classes that are the result of adding, subtracting, negating, and intersecting existing Unicode properties, like the `<greeklish>` regex subroutine is above, you might prefer to implement these as custom properties. Custom properties look just like normal properties. For example:

```
sub IsGreeklish {
    return <<'END';
+utf8::IsGreek
+utf8::IsInherited
END
}
```

Now you may use `\p{IsGreeklish}` and `\P{IsGreeklish}` in patterns compiled in the same package as that subroutine. See the next section for how to put these together.

Building Character

To define your own property, you need to write a subroutine with the name of the property you want (see Chapter 7). For security reasons, this subroutine's (unqualified) name must begin with either `Is` or `In`. The subroutine should be defined in the package that needs the property (see Chapter 10), which means that if you want to use it in multiple packages, you'll either have to import it from a

module (see Chapter 11), or inherit it as a class method from the package in which it is defined (see Chapter 12).

Once you've got that all settled, the subroutine should return data in the same format as the files in *PATH_TO_PERLLIB/unicode/Is* directory. That is, just return a list of characters or character ranges in hexadecimal, one per line. If there is a range, the two numbers are separated by a tab. Suppose you wanted a property that would be true if your character is in the range of either of the Japanese syllabaries, known as hiragana and katakana (together they're known as kana). You can just put in the two ranges like this:

```
sub InKana {
    return <<'END';
3040    309F
30A0    30FF
END
}
```

Alternatively, you could define it in terms of existing property names:

```
sub InKana {
    return <<'END';
+utf8::InHiragana
+utf8::InKatakana
END
}
```

You can also do set subtraction using a "-" prefix. Suppose you only wanted the actual characters, not just the block ranges of characters. You could weed out all the undefined ones like this:

```
sub IsKana {
    return <<'END';
+utf8::InHiragana
+utf8::InKatakana
-utf8::IsCn
END
}
```

You can also start with a complemented character set using the "`!`" prefix:

```
sub IsNotKana {
    return <<'END';
!utf8::InHiragana
-utf8::InKatakana
+utf8::IsCn
END
}
```

Intersection, specified with the "`&`" prefix, is useful for getting the common characters matched by two (or more) classes.

```
sub IsGraecoRomanTitle {<<'END_OF_SET'}
+utf8::IsLatin
+utf8::IsGreek
&utf8::IsTitle
END_OF_SET

sub IsGreekTitle {<<'END_OF_SET'}
+main::IsGraecoRomanTitle
-utf8::IsLatin
END_OF_SET
```

It's important to remember not to use "&" for the first set; that would be intersecting with nothing, resulting in an empty set.

Perl itself uses exactly the same tricks to define the meanings of its "classic" character classes (like `\w`) when you include them in your own custom character classes (like `[-.\w\s]`). You might think that the more complicated you get with your rules, the slower they will run. But, in fact, once Perl has calculated the bit pattern for a particular 64-bit swatch of your property, it caches it so it never has to recalculate the pattern again. (It does it in 64-bit swatches so that it doesn't even have to decode your UTF-8 to do its lookups.) Thus, all character classes, built-in or custom, run at essentially the same speed (fast) once they get going.

For a different take on customization just by changing the syntax of square-bracketed character classes, check out the CPAN `Unicode::Regex::Set` module.

Together with custom names, custom properties can make even private-use codepoints manageable without having to resort to ugly numbers. For example, Unicode hasn't yet incorporated Tengwar (an elvish script) into its official repertoire (although it's on the roadmap—there are, after all, many maps of Middle Earth). That doesn't stop font designers from creating beautiful and useful Tengwar fonts. Although some fonts do use the block of codepoints that Unicode has reserved for eventually putting Tengwar into, most use codepoints from a private use area. Either way, however, those codepoints do not yet have assigned names or properties.

This is no barrier to Perl, because it's easy to create your own names for characters and properties. One existing Tengwar module in Perl provides for named characters like:

```
TENGWAR LETTER TINCO        TENGWAR DIGIT ZERO
TENGWAR LETTER PARMA        TENGWAR DIGIT ONE
TENGWAR LETTER CALMA        TENGWAR DIGIT TWO
TENGWAR LETTER QUESSE       TENGWAR DIGIT THREE
```

This lets you write things like:

```
if ($elvish =~ /\N{TENGWAR LETTER SILME NUQUERNA}/) {...}
```

without a hitch. You can even use `charnames::viacode` on a Tengwar codepoint to get back its custom name. Even better, it provides Tengwar character properties like:

```
In_Tengwar                  In_Tengwar_Numerals
In_Tengwar_Consonants       Is_Tengwar_Decimal
In_Tengwar_Vowels           Is_Tengwar_Duodecimal
In_Tengwar_Alphabetics      In_Tengwar_Marks
In_Tengwar_Punctuation      In_Tengwar_Alphanumerics
```

which leads to Perl code that looks like:

```
print "W" if /\p{In_Tengwar_Alphanumerics}/;
print "A" if /\p{In_Tengwar_Alphabetics}/;
print "C" if /\p{In_Tengwar_Consonants}/;
print "V" if /\p{In_Tengwar_Vowels}/;
```

or even:

```
$TENGWAR_GRAPHEME = qr{
    (?>
        (?= \p{In_Tengwar} ) \P{In_Tengwar_Marks}
        \p{In_Tengwar_Marks} *
    ) | \p{In_Tengwar_Marks}
}x;
```

Trying to write that sort of code without being able to name your abstractions, both characters and properties, is a bit like trying to program a computer with only numeric memory addresses and no variable names. Sure, you can do it if you want to badly enough, but it won't fit in smoothly with existing facilities, and it probably won't be readable or maintainable. By letting you craft your own special-purpose language even for such custom applications as private use areas, Perl helps you write code that's simple and clear.

References

Perl closely tracks the published Unicode Standard wherever possible. That Standard includes various annexes and technical reports. Some of those applicable to material discussed in this chapter include:

UAX #44: Unicode Character Database

UTS #18: Unicode Regular Expressions

UAX #15: Unicode Normalization Forms

UTS #10: Unicode Collation Algorithm

UAX #29: Unicode Text Segmentation

UAX #14: Unicode Line Breaking Algorithm

UAX #11: East Asian Width

CHAPTER 7
Subroutines

Like many languages, Perl provides for user-defined subroutines.[1] These subroutines may be defined anywhere in the main program, loaded in from other files via the `do`, `require`, or `use` keywords, or generated at runtime using `eval`. You can even load them at runtime with the mechanism described in the section "Autoloading" on page 397 in Chapter 10. You can call a subroutine indirectly, using a variable containing either its name or a reference to the routine, or through an object, letting the object determine which subroutine should really be called. You can generate anonymous subroutines, accessible only through references, and if you want, use these to clone new, nearly identical functions via *closures* (which are covered in the section by that name in Chapter 8).

Syntax

To declare a named subroutine without defining it, use one of these forms:

```
sub NAME
sub NAME PROTO
sub NAME       ATTRS
sub NAME PROTO ATTRS
```

To declare and define a named subroutine, add a *BLOCK*:

```
sub NAME              BLOCK
sub NAME PROTO        BLOCK
sub NAME       ATTRS  BLOCK
sub NAME PROTO ATTRS  BLOCK
```

1. We'll also call them *functions*, but functions are the same thing as subroutines in Perl. Sometimes we'll even call them *methods*, which are defined the same way, but called differently.

To create an anonymous subroutine or closure, leave out the *NAME*:

```
sub                  BLOCK
sub       PROTO      BLOCK
sub            ATTRS BLOCK
sub       PROTO ATTRS BLOCK
```

PROTO and *ATTRS* stand for the prototype and attributes, each of which is discussed in its own section later in this chapter. They're not so important—the *NAME* and the *BLOCK* are the essential parts, even when they're missing.

For the forms without a *NAME*, you still have to provide some way of calling the subroutine. So be sure to save the return value since this form of `sub` declaration is not only compiled at compile time as you would expect, but also produces a runtime return value:

```
$subref = sub BLOCK;
```

To import subroutines defined in another module, say:

```
use MODULE qw(NAME1 NAME2 NAME3 ...);
```

To call subroutines directly, say:

```
NAME(LIST)          # & is optional with parentheses.
NAME LIST           # Parens optional if sub predeclared/imported.
&NAME               # Exposes current @_ to that subroutine,
                    # (and circumvents prototypes).
```

To call subroutines indirectly (by name or by reference), use any of these:

```
&$subref(LIST)      # The & is not optional on indirect call
$subref->(LIST)     # (unless using infix notation).
&$subref            # Exposes current @_ to that subroutine.
```

The official name of a subroutine includes the `&` prefix. A subroutine may be called using the prefix, but the `&` is usually optional, and so are the parentheses if the subroutine has been predeclared. However, the `&` is not optional when you're just naming the subroutine, such as when it's used as an argument to `defined` or `undef`, or when you want to generate a reference to a named subroutine by saying `$subref = \&name`. Nor is the `&` optional when you want to make an indirect subroutine call using the `&$subref()` or `&{$subref}()` constructs. However, the more convenient `$subref->()` notation does not require it. See Chapter 8 for more about references to subroutines.

Perl doesn't force a particular capitalization style on your subroutine names. However, one loosely held convention is that functions called indirectly by Perl's runtime system (like `BEGIN`, `UNITCHECK`, `CHECK`, `INIT`, `END`, `AUTOLOAD`, `DESTROY`, and all the functions mentioned in Chapter 14) are in all capitals, so you might want

to avoid using that style. (But subroutines used for constant values are customarily named with all caps, too. That's okay. We hope...)

Semantics

Before you get too worked up over all that syntax, just remember that the normal way to define a simple subroutine ends up looking like this:

```
sub razzle {
    print "Ok, you've been razzled.\n";
}
```

and the normal way to call it is simply:

```
razzle();
```

In this case, we ignored inputs (arguments) and outputs (return values). But the Perl model for passing data into and out of a subroutine is really quite simple: all function parameters are passed as one single, flat list of scalars, and multiple return values are likewise returned to the caller as one single, flat list of scalars. As with any *LIST*, any arrays or hashes passed in these lists will interpolate their values into the flattened list, losing their identities—but there are several ways to get around this, and the automatic list interpolation is frequently quite useful. Both parameter lists and return lists may contain as many or as few scalar elements as you'd like (though you may put constraints on the parameter list by using prototypes). Indeed, Perl is designed around this notion of *variadic* functions (those taking any number of arguments), unlike C, where they're sort of grudgingly kludged in so that you can call *printf*(3).

Now, if you're going to design a language around the notion of passing varying numbers of arbitrary arguments, you'd better make it easy to process those arbitrary lists of arguments. Any arguments passed to a Perl routine come in as the array `@_`. If you call a function with two arguments, they are accessible inside the function as the first two elements of that array: `$_[0]` and `$_[1]`. Since `@_` is just a regular array with an irregular name, you can do anything to it you'd normally do to an array.[2] The array `@_` is a local array, but its values are aliases to the actual scalar parameters. (This is known as pass-by-reference semantics.) Thus, you can modify the actual parameters if you modify the corresponding element of `@_`. (This is rarely done, however, since it's so easy to return interesting values in Perl.)

2. This is an area where Perl is *more* orthogonal than the typical programming language.

The return value of the subroutine (or of any other block, for that matter) is the value of the last expression evaluated. Or, you may use an explicit `return` statement to specify the return value and exit the subroutine from any point in the subroutine. Either way, as the subroutine is called in a scalar or list context, so also is the final expression of the routine evaluated in that same scalar or list context.

Tricks with Parameter Lists

Perl does not yet have named formal parameters, but in practice all you do is copy the values of `@_` to a `my` list, which serves nicely for a list of formal parameters. (Not coincidentally, copying the values changes the pass-by-reference semantics into pass by value, which is how people usually expect parameters to work anyway, even if they don't know the fancy computer science terms for it.) Here's a typical example:

```
sub maysetenv {
    my($key, $value) = @_;
    $ENV{$key} = $value unless $ENV{$key};
}
```

But you aren't required to name your parameters, which is the whole point of the `@_` array. For example, to calculate a maximum, you can just iterate over `@_` directly:

```
sub max {
    my $max = shift(@_);
    for my $item (@_) {
        $max = $item if $max < $item;
    }
    return $max;
}

$bestday = max($mon,$tue,$wed,$thu,$fri);
```

Positional parameters work well for functions with short argument lists, but as the number of parameters increases, it becomes awkward to remember which argument does what, make some of them optional, or have default values. A more flexible approach that addresses all these issues has the caller supply arguments using pairs of parameter names and values. The first element of each pair is the argument name; the second, its value. This makes for self-documenting code because you can see the parameters' intended meanings without having to read the full function definition. Even better, programmers using your function no longer have to remember the argument order, and they can leave unspecified any extraneous, unused arguments. We strongly recommend this style of using named parameters.

The trick is to assign the `@_` argument list to a hash.

```
configuration(PASSWORD => "xyzzy", VERBOSE => 9, SCORE => 0);

sub configuration {
    my %options = @_;
    print "Maximum verbosity.\n" if $options{VERBOSE} == 9;
}
```

To show you how flexible this is, here is an example from *Perl Cookbook*'s recipe on "Passing by Named Parameter" from its "Subroutines" chapter.

```
thefunc(INCREMENT => "20s", START => "+5m", FINISH => "+30m");
thefunc(START => "+5m", FINISH => "+30m");
thefunc(FINISH => "+30m");
thefunc(START => "+5m", INCREMENT => "15s");
```

Then, in the subroutine, create a hash loaded up with default values plus the array of named pairs.

```
sub thefunc {
    my %args = (
        INCREMENT   => "10s",
        FINISH      => 0,
        START       => 0,
        @_,         # actual args override defaults
    );
    if ($args{INCREMENT} =~ /m$/ ) { ... }
    ...
}
```

By giving each argument value a name and then assigning `@_` to the `%args` hash, you no longer have to remember any required ordering, and you can omit whichever of them you please to have them assume some default value.

On the other hand, here's an example of not naming your formal arguments so that you can modify your actual arguments:

```
upcase_in($v1, $v2);  # this changes $v1 and $v2
sub upcase_in {
    for (@_) { $_ = uc($_) }
}
```

You aren't allowed to modify constants in this way, of course. If an argument were actually a scalar literal like `"hobbit"` or read-only scalar variable like `$1`, and you tried to change it, Perl would raise an exception (presumably fatal, possibly career-threatening). For example, this won't work:

```
upcase_in("frederick");
```

It would be much safer if the `upcase_in` function were written to return a copy of its parameters instead of changing them in place:

```
($v3, $v4) = upcase($v1, $v2);
sub upcase {
    my @parms = map { uc } @_;
    # Check whether we were called in list context.
    return wantarray ? @parms : $parms[0];
}
```

Notice how this (unprototyped) function doesn't care whether it was passed real scalars or arrays. Perl will smash everything into one big, long, flat `@_` parameter list. This is one of the places where Perl's simple argument-passing style shines. The `upcase` function will work perfectly well without changing the `upcase` definition, even if we feed it things like this:

```
@newlist = upcase(@list1, @list2);
@newlist = upcase( split /:/, $var );
```

Do not, however, be tempted to do this:

```
(@a, @b) = upcase(@list1, @list2);   # WRONG
```

Why not? Because, like the flat incoming parameter list in `@_`, the return list is also flat. So this stores everything in `@a` and empties out `@b` by storing the null list there. See the later section "Passing References" on page 324 for alternatives.

Error Indications

If you want your function to return in such a way that the caller will realize there's been an error, the most natural way to do this in Perl is to use a bare `return` statement without an argument. That way when the function is used in scalar context, the caller gets `undef`; when used in list context, the caller gets a null list.

Under extraordinary circumstances, you might choose to raise an exception to indicate an error. Use this measure sparingly, though; otherwise, your whole program will be littered with exception handlers. For example, failing to open a file in a generic file-opening function is hardly an exceptional event. However, ignoring that failure might well be. The `wantarray` built-in returns `undef` if your function was called in void context, so you can tell if you're being ignored:

```
if ($something_went_awry) {
     return if defined wantarray;  # good, not void context.
     die "Pay attention to my error, you danglesocket!!!\n";
 }
```

Scoping Issues

Subroutines may be called recursively because each call gets its own argument array, even when the routine calls itself. If a subroutine is called using the `&` form, the argument list is optional. If the `&` is used but the argument list is omitted, something special happens: the `@_` array of the calling routine is supplied implicitly. This is an efficiency mechanism that new users may wish to avoid.

```
&foo(1,2,3);    # pass three arguments
foo(1,2,3);     # the same

foo();          # pass a null list
&foo();         # the same

&foo;           # foo() gets current args, like foo(@_), but faster!
foo;            # like foo() if sub foo predeclared, else bareword "foo"
```

Not only does the `&` form make the argument list optional, but it also disables any prototype checking on the arguments you do provide. This is partly for historical reasons and partly to provide a convenient way to cheat if you know what you're doing. See the section "Prototypes" on page 326 later in this chapter.

Variables you access from inside a function that haven't been declared private to that function are not necessarily global variables; they still follow the normal block-scoping rules of Perl. As explained in the "Names" section of Chapter 2, this means they look first in the surrounding lexical scope (or scopes) for resolution, then on to the single package scope. From the viewpoint of a subroutine, then, any `my` or `state` variables from an enclosing lexical scope are still perfectly visible.

For example, the `bumpx` function below has access to the file-scoped `$x` lexical variable because the scope where the `my` was declared—the file itself—hasn't been closed off before the subroutine is defined:

```
# top of file
my $x = 10;         # declare and initialize variable
sub bumpx { $x++ }  # function can see outer lexical variable
```

C and C++ programmers would probably think of `$x` as a "file static" variable. It's private as far as functions in other files are concerned, but global from the perspective of functions declared after the `my`. C programmers who come to Perl looking for what they would call "static variables" for files or functions find no such keyword in Perl. Perl programmers generally avoid the word "static" because static systems are dead and boring, and because the word is so muddled in historical usage.

Although Perl doesn't include the word "static" in its lexicon, Perl programmers have no problem creating variables that are private to a function and persist across function calls using the similar concept of `state` variables, explained below. But that's not the only way to do it. Perl's richer scoping primitives combine with automatic memory management in ways that someone looking for a "static" keyword might never think of trying.

Lexical variables don't get automatically garbage collected just because their scope has exited; they wait to get recycled until they're no longer *used*, which is much more important. To create private variables that aren't automatically reset across function calls, enclose the whole function in an extra block and put both the `my` declaration and the function definition within that block. You can even put more than one function there for shared access to an otherwise private variable:

```
{
    my $counter = 0;
    sub next_counter { return ++$counter }
    sub prev_counter { return --$counter }
}
```

As always, access to the lexical variable is limited to code within the same lexical scope. The names of the two functions, on the other hand, are globally accessible (within the package), and, since they were defined inside `$counter`'s scope, they can still access that variable even though no one else can.

If this function is loaded via `require` or `use`, then this is probably just fine. If it's all in the main program, you'll need to make sure any runtime assignment to `my` is executed early enough, either by putting the whole block before your main program or, alternatively, by placing a `BEGIN` or `INIT` block around it to make sure it gets executed before your program starts:

```
BEGIN {
    my @scale = ("A" .. "G");
    my $note  = -1;
    sub next_pitch { return $scale[ ($note += 1) %= @scale ] };
}
```

The `BEGIN` doesn't affect the subroutine definition, nor does it affect the persistence of any lexicals used by the subroutine. It's just there to ensure the variables get initialized before the subroutine is ever called. For more on declaring private and global variables, see the sections "my" on page 897, "state" on page 957, and "our" on page 911, respectively, in Chapter 27. The `BEGIN` and `INIT` constructs are explained in Chapter 16.

To make it easier to keep a variable's declaration close to its use, the "`state`" feature allows for a variant of the `my` keyword. To enable them, declare that you're using a version of Perl that's at least v5.10.

Now you can use the `state` keyword to declare a lexical variable that will be initialized only the first time through:

```
use v5.14;

sub bumpx {
    state $x = 10;         # init only 1st time through
    return $x++;
}
```

That function will now behave just like the previous one, returning first 10, then 11, then 12, and so on. Here's a function that has a persistent, private hash for keeping track of how many times something has been seen:

```
sub seen_count {
  state %count;
  my $item = shift();
  return ++$count{$item};
}
```

Unlike other variable declarations, initialization of `state` variables is restricted to simple scalar variables only. You can still use arrays and hashes as `state` variables, but you can't magically initialize them the way you can with scalars. This isn't actually the limitation it might appear to be, because you can always store a reference to the type you want, and that *is* a scalar. For example, instead of:

```
# can't use state %hash = (....)
my %hash = (
  READY   => 1,
  WILLING => 1,
  ABLE    => 1,
);
```

as a `state` variable, you would use:

```
state $hashref = {
  READY   => 1,
  WILLING => 1,
  ABLE    => 1,
};
```

To implement the `next_pitch` function described above using `state` variables, you'd do this:

```
sub next_pitch {
    state $scale = ["A" .. "G"];
    state $note  = -1;
    return $scale->[ ($note += 1) %= @$scale ];
}
```

The main point with `state` variables is that you don't have to use a `BEGIN` (or `UNITCHECK`) block to make sure the initialization happens before the function is called.

Finally, when we say that a `state` variable is initialized only once, we don't mean to imply that `state` variables in separate closures are the same variables. They aren't, so each gets its own initialization. This is how `state` variables differ from `static` variables in other languages.

For example, in both versions of the code below, `$epoch` is a lexical that's private to the closure that's returned. However, in `timer_then`, it's initialized before that closure is returned, while in `timer_now`, initialization of `$epoch` is delayed until the closure that's returned is first called:

```
sub timer_then {
  my $epoch = time();
  return sub {
      ...
  };
}

sub timer_now {
  return sub {
      state $epoch = time();
      ...
  };
}
```

Passing References

If you want to pass more than one array or hash into or out of a function, and you want them to maintain their integrity, then you'll need to use an explicit pass-by-reference mechanism. Before you do that, you need to understand references as detailed in Chapter 8. This section may not make much sense to you otherwise. But, hey, you can always look at the pictures...

Here are a few simple examples. First, let's define a function that expects a reference to an array. When the array is large, it's much faster to pass it in as a single reference than a long list of values:

```
$total = sum ( \@a );

sub sum {
    my ($aref)  = @_;
    my ($total) = 0;
    for (@$aref) { $total += $_ }
    return $total;
}
```

Let's pass in several arrays to a function and have it `pop` each of them, returning a new list of all their former last elements:

```
@tailings = popmany ( \@a, \@b, \@c, \@d );

sub popmany {
    my @retlist = ();
    for my $aref (@_) {
        push @retlist, pop @$aref;
    }
    return @retlist;
}
```

Here's how you might write a function that does a kind of set intersection by returning a list of keys occurring in all the hashes passed to it:

```
@common = inter( \%foo, \%bar, \%joe );
sub inter {
    my %seen;
    for my $href (@_) {
        while (my $k = each %$href) {
            $seen{$k}++;
        }
    }
    return grep { $seen{$_} == @_ } keys %seen;
}
```

So far, we're just using the normal list return mechanism. What happens if you want to pass or return a hash? Well, if you're only using one of them, or you don't mind them concatenating, then the normal calling convention is okay, although a little expensive.

As we explained earlier, where people get into trouble is here:

```
(@a, @b) = func(@c, @d);
```

or here:

```
(%a, %b) = func(%c, %d);
```

That syntax simply won't work. It just sets `@a` or `%a` and clears `@b` or `%b`. Plus, the function doesn't get two separate arrays or hashes as arguments: it gets one long list in `@_`, as always.

You may want to arrange for your functions to use references for both input and output. Here's a function that takes two array references as arguments and returns the two array references ordered by the number of elements they have in them:

```
($aref, $bref) = func(\@c, \@d);
print "@$aref has more than @$bref\n";
sub func {
    my ($cref, $dref) = @_;
    if (@$cref > @$dref) {
        return ($cref, $dref);
    } else {
        return ($dref, $cref);
    }
}
```

For passing filehandles or directory handles into or out of functions, see the sections "Handle References" and "Symbol Table References" in Chapter 8.

Prototypes

Perl lets you define your own functions to be called like Perl's built-in functions. Consider `push(@array, $item)`, which must tacitly receive a reference to `@array`, not just the list values held in `@array`, so that the array can be modified. *Prototypes* let you declare subroutines to take arguments just like many of the built-ins—that is, with certain constraints on the number and types of arguments. We call them "prototypes", but they work more like automatic templates for the calling context than like what C or Java programmers would think of as prototypes. With these templates, Perl will automatically add implicit backslashes, or calls to `scalar`, or whatever else it takes to get things to show up in a way that matches the template. For instance, if you declare:

```
sub mypush (+@);
```

then `mypush` takes arguments exactly like `push` does. For this to work, the declaration of the function to be called must be visible at compile time. The prototype only affects the interpretation of function calls when the `&` character is omitted. In other words, if you call it like a built-in function, it behaves like a built-in function. If you call it like an old-fashioned subroutine, then it behaves like an old-fashioned subroutine. The `&` suppresses prototype checks and associated contextual effects.

Because prototypes are taken into consideration only at compile time, it naturally falls out that they have no influence on subroutine references like `\&foo` or on indirect subroutine calls like `&{$subref}` or `$subref->()`. Method calls are not influenced by prototypes, either. That's because the actual function to be called is indeterminate at compile time, depending as it does on inheritance, which is dynamically determined in Perl.

Since the intent is primarily to let you define subroutines that work like built-in functions, Table 7-1 gives some prototypes you might use to emulate the corresponding built-ins.

Table 7-1. Prototypes to emulate built-ins

Declared As	Called As
`sub mylink ($$)`	`mylink $old, $new`
`sub myreverse (@)`	`myreverse $a,$b,$c`
`sub myjoin ($@)`	`myjoin ":",$a,$b,$c`
`sub mypop (;+)`	`mypop @array`
`sub mysplice (+;$$@)`	`mysplice @array,@array,0,@pushme`
`sub mykeys (+)`	`mykeys %{$hashref}`
`sub mypipe (**)`	`mypipe READHANDLE, WRITEHANDLE`
`sub myindex ($$;$)`	`myindex &getstring, "substr"`
	`myindex &getstring, "substr", $start`
`sub mysyswrite (*$;$$)`	`mysyswrite OUTF, $buf`
	`mysyswrite OUTF, $buf, length($buf)-$off, $off`
`sub myopen (*;$@)`	`myopen HANDLE`
	`myopen HANDLE, $name`
	`myopen HANDLE, "-|", @cmd`
`sub mysin (_)`	`mysyn $a`
	`mysyn`
`sub mygrep (&@)`	`mygrep { /foo/ } $a,$b,$c`
`sub myrand ($)`	`myrand 42`
`sub mytime ()`	`mytime`

Any backslashed prototype character (shown between parentheses in the left column above) represents an actual argument (exemplified in the right column), which absolutely must start with that character. Just as the first argument to

`keys` must start with `%` or `$`, so too must the first argument to `mykeys`. The special `+` prototype takes care of this for you as a shortcut for `\[@%]`.[3]

You can use the backslash group notation, `\[]`, to specify more than one allowed backslashed argument type. For example:

```
sub myref (\[$@%&*])
```

allows calling `myref` as any of these, where Perl will arrange that the function receives a reference to the indicated argument:

```
myref $var
myref @array
myref %hash
myref &sub
myref *glob
```

A semicolon separates mandatory arguments from optional arguments. (It would be redundant before `@` or `%`, since lists can be null.) Unbackslashed prototype characters have special meanings. Any unbackslashed `@` or `%` eats all the rest of the actual arguments and forces list context. (It's equivalent to *`LIST`* in a syntax description.) An argument represented by `$` has scalar context forced on it. An `&` requires a reference to a named or anonymous subroutine.

As the last character of a prototype, or just before a semicolon, you can use `_` in place of `$`. If this argument is not provided, the current `$_` variable will be used instead. For example:

```
sub mymkdir(_;$) {
  my $dirname   = shift();
  my $mask = @_ ? shift() : 0777;
  my $mode = $mask &~ umask();
  ...
}

mymkdir($path, 01750);
mymkdir($path);
mymkdir();    # passes in $_
```

The `+` prototype is a special alternative to `$` that acts like `\[@%]` when passed a literal array or hash variable, but it will otherwise force scalar context on the argument. This is useful for functions that take for an argument not only a literal array (or hash) but also a reference to one:

3. The prototype for the hash operators have changed over the years. In v5.8 it was `\%`, in v5.12 it was `\[@%]`, and in v5.14 it's `+`.

```
sub mypush (+@) {
  my $aref = shift;
  die "Not an array or arrayref" unless ref($aref) eq "ARRAY";
  push @$aref, @_;
}
```

When using the + prototype, your function should always test that the argument is of an acceptable type. (We've intentionally written this in a way that doesn't work on objects because doing so would encourage violation of the object's encapsulation.)

A * allows the subroutine to accept anything in that slot that would be accepted by a built-in as a filehandle: a bare name, a constant, a scalar expression, a typeglob, or a reference to a typeglob. The value will be available to the subroutine either as a simple scalar or (in the latter two cases) as a reference to the typeglob. If you wish to always convert such arguments to a typeglob reference, use `Symbol::qualify_to_ref` as follows:

```
use Symbol "qualify_to_ref";

sub myfileno (*) {
    my $fh = qualify_to_ref(shift, caller);
    ...
}
```

Note how the last three examples in the table are treated specially by the parser. `mygrep` is parsed as a true list operator, `myrand` is parsed as a true unary operator with unary precedence the same as `rand`, and `mytime` is truly argumentless, just like `time`.

That is, if you say:

```
mytime +2;
```

you'll get `mytime() + 2`, not `mytime(2)`, which is how it would be parsed without the prototype, or with a unary prototype.

The `mygrep` example also illustrates how `&` is treated specially when it is the first argument. Ordinarily, an `&` prototype would demand an argument like `\&foo` or `sub{}`. When it is the first argument, however, you can leave off the `sub` of your anonymous subroutine and just pass a bare block in the "indirect object" slot (with no comma after it). So one nifty thing about the `&` prototype is that you can generate new syntax with it, provided the `&` is in the initial position:

```
sub try (&$) {
    my ($try, $catch) = @_;
    eval { &$try };
    if ($@) {
        local $_ = $@;
```

```
        &$catch;
    }
}
sub catch (&) { $_[0] }

try {
    die "phooey";
}  # not the end of the function call!
catch {
    /phooey/  &&  print "unphooey\n";
};
```

This prints "`unphooey`". What happens is that `try` is called with two arguments: the anonymous function `{die "phooey";}` and the return value of the `catch` function, which in this case is nothing but its own argument—the entire block of yet another anonymous function. Within `try`, the first function argument is called while protected within an `eval` block to trap anything that blows up. If something does blow up, the second function is called with a local version of the global `$_` variable set to the raised exception.[4] If this all sounds like pure gobbledygook, you'll have to read about `die` and `eval` in Chapter 27, and then go check out anonymous functions and closures in Chapter 8. On the other hand, if it intrigues you, you might check out the `Try::Tiny` module on CPAN, which uses this to implement elaborately structured exception handling with `try`, `catch`, and `finally` clauses.

Here's a reimplementation of the `grep` *`BLOCK`* operator[5] (the built-in one is more efficient, of course):

```
sub mygrep (&@) {
    my $coderef = shift;
    my @result;
    for my $_ (@_) {
        push(@result, $_) if &$coderef;
    }
    return @result;
}
```

Some folks would prefer to see full alphanumeric prototypes. Alphanumerics have been intentionally left out of prototypes for the express purpose of someday adding named, formal parameters. (Maybe.) The current mechanism's main goal is to let module writers enforce a certain amount of compile-time checking on module users.

4. Yes, there are still unresolved issues having to do with the visibility of `@_`. We're ignoring that question for the moment.

5. It's not possible to reimplement the `grep` *`EXPR`* form.

The built-in function `prototype` retrieves the prototype of user-defined and built-in functions; see Chapter 27. To change a function's prototype on the fly, use the `set_prototype` function from the standard `Scalar::Util` module. For example, if you wanted the `NFD` and `NFC` functions from `Unicode::Normalize` to act like they have a prototype of "_", you could do this:

```
use Unicode::Normalize qw(NFD NFC);

BEGIN {
    use Scalar::Util "set_prototype";
    set_prototype(\&NFD => "_");
    set_prototype(\&NFC => "_");
}
```

Inlining Constant Functions

Functions prototyped with `()`, meaning that they take no arguments at all, are parsed like the `time` built-in. More interestingly, the compiler treats such functions as potential candidates for inlining. If the result of that function, after Perl's optimization and constant-folding pass, is either a constant or a lexically scoped scalar with no other references, then that value will be used in place of calls to that function. Calls made using `&`*`NAME`* are never inlined, however, just as they are not subject to any other prototype effects. (See the `constant` pragma in Chapter 29 for an easy way to declare such constants.)

Both versions of these functions to compute π will be inlined by the compiler:

```
sub pi ()           { 3.14159 }             # Not exact, but close
sub PI ()           { 4 * atan2(1, 1) }     # As good as it gets
```

In fact, all of the following functions are inlined because Perl can determine everything at compile time:

```
sub FLAG_FOO ()     { 1 << 8 }
sub FLAG_BAR ()     { 1 << 9 }
sub FLAG_MASK ()    { FLAG_FOO | FLAG_BAR }

sub OPT_GLARCH ()   { (0x1B58 & FLAG_MASK) == 0 }
sub GLARCH_VAL ()   {
    if (OPT_GLARCH) { return 23 }
    else            { return 42 }
}

sub N () { int(GLARCH_VAL) / 3 }
BEGIN {                 # compiler runs this block at compile time
    my $prod = 1;       # persistent, private variable
    for (1 .. N) { $prod *= $_ }
    sub NFACT () { $prod }
}
```

In the last example, the NFACT function is inlined because it has a void prototype and the variable it returns is not changed by that function; furthermore, it can't be changed by anyone else since it's in a lexical scope. So the compiler replaces uses of NFACT with that value, which was precomputed at compile time because of the surrounding BEGIN.

If you redefine a subroutine that was eligible for inlining, you'll get a mandatory warning. (You can use this warning to tell whether the compiler inlined a particular subroutine.) The warning is considered severe enough not to be optional, because previously compiled invocations of the function will still use the old value of the function. If you need to redefine the subroutine, ensure that it isn't inlined either by dropping the () prototype (which changes calling semantics, so beware) or by thwarting the inlining mechanism in some other way, such as:

```
sub not_inlined () {
    return 23 if $$;
}
```

See Chapter 16 for more about what happens during the compilation and execution phases of your program's life.

Care with Prototypes

It's probably best to put prototypes on new functions, not retrofit prototypes onto older ones. These are context templates, not ANSI C prototypes, so you must be especially careful about silently imposing a different context. Suppose, for example, you decide that a function should take just one parameter, like this:

```
sub func ($) {
    my $n = shift;
    print "you gave me $n\n";
}
```

That makes it a unary operator (like the rand built-in) and changes how the compiler determines the function's arguments. With the new prototype, the function consumes just one scalar-context argument instead of many arguments in list context. If someone has been calling it with an array or list expression, even if that array or list contained just a single element, where before it worked, now you've got something completely different:

```
func @foo;                  # counts @foo elements
func split /:/;             # counts number of fields returned
func "a", "b", "c";         # passes "a" only, discards "b" and "c"
func("a", "b", "c");        # suddenly, a compiler error!
```

You've just supplied an implicit `scalar` in front of the argument list, which can be more than a bit surprising. The old `@foo` that used to hold one thing doesn't get passed in. Instead, 1 (the number of elements in `@foo`) is now passed to `func`. And the `split`, being called in scalar context, scribbles all over your `@_` parameter list. In the third example, because `func` has been prototyped as a unary operator, only "`a`" is passed in; then the return value from `func` is discarded as the comma operator goes on to evaluate the next two items and return "`c`." In the final example, the user now gets a syntax error at compile time on code that used to compile and run just fine.

If you're writing new code and would like a unary operator that takes only a scalar variable, not any old scalar expression, you could prototype it to take a scalar *reference*:

```
sub func (\$) {
    my $nref = shift;
    print "you gave me $$nref\n";
}
```

Now the compiler won't let anything by that doesn't start with a dollar sign:

```
func @foo;              # compiler error, saw @, want $
func split/:/;          # compiler error, saw function, want $
func $s;                # this one is ok -- got real $ symbol
func $a[3];             # and this one
func $h{stuff}[-1];     # or even this
func 2+5;               # scalar expr still a compiler error
func ${ \(2+5) };       # ok, but is the cure worse than the disease?
```

If you aren't careful, you can get yourself into trouble with prototypes. But if you are careful, you can do a lot of neat things with them. This is all very powerful, of course, and should only be used in moderation to make the world a better place.

Prototypes of Built-in Functions

For reference, Table 7-2 lists the actual prototypes of the overridable built-ins as of v5.14.

Table 7-2. Prototypes for built-in functions

Prototype	Keywords
()	and, break, continue, dump, endgrent, endhostent, endnetent, endprotoent, endpwent, endservent, fork, getgrent, gethostent, getlogin, getnetent, getppid, getprotoent, getpwent, getservent, or, setgrent, setpwent, time, times, wait, wantarray
(_)	abs, alarm, chr, chroot, cos, exp, fc, hex, int, lc, lcfirst, length, log, oct, ord, quotemeta, readlink, readpipe, ref, rmdir, sin, sqrt, uc, ucfirst
(;$)	caller, chdir, exit, getpgrp, gmtime, localtime, rand, reset, sleep, srand, umask,
(;*)	close, eof, getc, readline, select, tell, write
(;+)	pop, shift
(@)	chmod, chown, die, kill, reverse, unlink, utime, warn
(_;$)	mkdir
(;$$)	setpgrp
($)	getgrgid, getgrnam, gethostbyname, getnetbyname, getprotobyname, getprotobynumber, getpwnam, getpwuid, sethostent, setnetent, setprotoent, setservent
(*)	closedir, fileno, getpeername, getsockname, lstat, readdir, rewinddir, stat, telldir
(+)	each, keys, values
(\$)	lock
(\%)	dbmclose
(\[$@%*])	tied, untie
($;$)	bless, unpack
(*;$)	binmode
(*;$@)	open
(+;$$@)	splice
($$)	atan2, crypt, gethostbyaddr, getnetbyaddr, getpriority, getservbyname, getservbyport, link, msgget, rename, semop, symlink, truncate, waitpid
($@)	formline, join, pack, sprintf, syscall
(+@)	push, unshift
(*$)	bind, connect, flock, listen, opendir, seekdir, shutdown
(**)	accept, pipe

Prototype	Keywords
($$;$)	index, rindex
($$;$$)	substr
(*$;$$)	syswrite
(\[$@%*]$@)	tie
($$$)	msgctl, msgsnd, semget, setpriority, shmctl, shmget, vec
(*$$)	fcntl, getsockopt, ioctl, seek, sysseek
(\%$$)	dbmopen
(*$$;$)	send, sysopen
(*\$$;$)	read, sysread
($$$$)	semctl, shmread, shmwrite
(*$$$)	setsockopt, socket
(*\$$$)	recv
($$$$$)	msgrcv
(**$$$)	socketpair

Subroutine Attributes

A subroutine declaration or definition may have a list of attributes associated with it. If such an attribute list is present, it is broken up at whitespace or colon boundaries and treated as though a `use attributes` had been seen. See the `attributes` pragma in Chapter 29 for internal details. There are two standard attributes for subroutines: `method` and `lvalue`.

The method Attribute

The `method` attribute can be used by itself:

```
sub afunc : method { ... }
```

Currently, this only has the effect of marking the subroutine so as not to trigger the "`Ambiguous call resolved as CORE::%s`" warning. (We may make it mean more someday.)

The attribute system is user-extensible, letting you create your own attribute names. These new attributes must be valid as simple identifier names (without any punctuation other than the "_" character). They may have a parameter list appended, which is currently only checked for whether its parentheses nest properly.

Here are examples of valid syntax (even though the attributes are unknown):

```
sub fnord (&\%) : switch(10,foo(7,3))  :  expensive;
sub plugh () : Ugly('\(") :Bad;
sub xyzzy : _5x5 { ... }
```

Here are examples of invalid syntax:

```
sub fnord : switch(10,foo();  # ()-string not balanced
sub snoid : Ugly("(");        # ()-string not balanced
sub xyzzy : 5x5;              # "5x5" not a valid identifier
sub plugh : Y2::north;        # "Y2::north" not a simple identifier
sub snurt : foo + bar;        # "+" not a colon or space
```

The attribute list is passed as a list of constant strings to the code that associates them with the subroutine. Exactly how this works (or doesn't) is highly experimental. Check *attributes*(3) for current details on attribute lists and their manipulation.

The lvalue Attribute

It is possible to return a modifiable scalar value from a subroutine, but only if you declare the subroutine to return an lvalue:

```
my $val;
sub canmod : lvalue {
    $val;
}
sub nomod {
    $val;
}

canmod() = 5;   # Assigns to $val.
nomod()  = 5;   # ERROR
```

If you're passing parameters to an lvalued subroutine, you'll usually want parentheses to disambiguate what's being assigned:

```
canmod $x  = 5;     # assigns 5 to $x first!
canmod 42  = 5;     # can't change a constant; compile-time error
canmod($x) = 5;     # this is ok
canmod(42) = 5;     # and so is this
```

If you want to be sneaky, you can get around this in the particular case of a subroutine that takes one argument. Declaring the function with a prototype of `($)` causes the function to be parsed with the precedence of a named unary operator. Since named unaries have higher precedence than assignment, you no longer need the parentheses. (Whether this is desirable or not is left up to the style police.)

You don't have to be sneaky in the particular case of a subroutine that allows zero arguments (that is, with a `()` prototype). Without ambiguity, you can say this:

```
canmod = 5;
```

That works because no valid term begins with `=`. Similarly, lvalued method calls can omit the parentheses when you don't pass any arguments:

```
$obj->canmod = 5;
```

We promise not to break those two constructs in future versions of Perl 5. They're handy when you want to wrap object attributes in method calls (so that they can be inherited like method calls but accessed like variables).

The scalar or list context of both the lvalue subroutine and the righthand side of an assignment to that subroutine is determined as if the subroutine call were replaced by a scalar. For example, consider:

```
data(2,3) = get_data(3,4);
```

Both subroutines here are called in scalar context, while in:

```
(data(2,3)) = get_data(3,4);
```

and in:

```
(data(2),data(3)) = get_data(3,4);
```

all the subroutines are called in list context.

The current implementation does not allow arrays and hashes to be returned from lvalue subroutines directly. You can always return a reference instead.

CHAPTER 8

References

For both practical and philosophical reasons, Perl has always been biased in favor of flat, linear data structures. And for many problems, this is just what you want.

Suppose you wanted to build a simple table (two-dimensional array) showing vital statistics—age, eye color, and weight—for a group of people. You could do this by first creating an array for each individual:

```
@john = (47, "brown", 186);
@mary = (23, "hazel", 128);
@bill = (35, "blue",  157);
```

You could then construct a single, additional array consisting of the names of the other arrays:

```
@vitals = ("john", "mary", "bill");
```

To change John's eyes to "red" after a night on the town, we want a way to change the contents of the `@john` array given only the simple string "`john`". This is the basic problem of *indirection*, which various languages solve in various ways. In C, the most common form of indirection is the pointer, which lets one variable hold the memory address of another variable. In Perl, the most common form of indirection is the *reference*.

What Is a Reference?

In our example, `$vitals[0]` has the value "`john`". That is, it contains a string that happens to be the name of another (global) variable. We say that the first variable *refers* to the second, and this sort of reference is called a *symbolic* reference, since Perl has to look up `@john` in a symbol table to find it. (You might think of symbolic references as analogous to symbolic links in the filesystem.) We'll talk about symbolic references later in this chapter.

The other kind of reference is a *hard* reference, and this is what most Perl programmers use to accomplish their indirections (if not their indiscretions). We call them hard references not because they're difficult, but because they're real and solid. If you like, think of hard references as real references and symbolic references as fake references. It's like the difference between true friendship and mere name-dropping. When we don't specify which type of reference we mean, it's a hard reference. Figure 8-1 depicts a variable named `$bar` referring to the contents of a scalar named `$foo`, which has the value "`bot`".

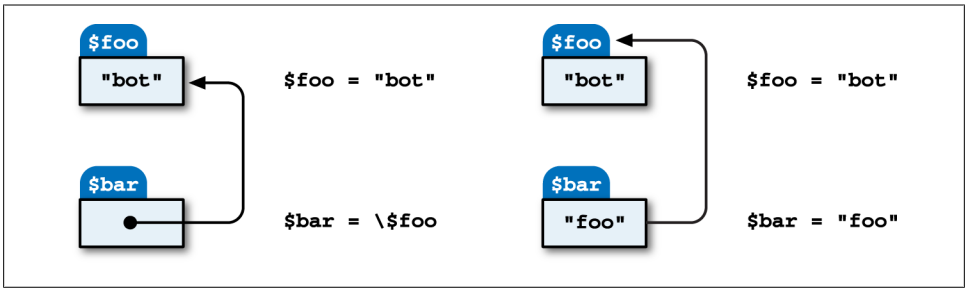


Figure 8-1. A hard reference and a symbolic reference

Unlike a symbolic reference, a real reference refers not to the name of another variable (which is just a container for a value) but to an actual value itself, some internal glob of data. There's no good word for that thing, but when we have to, we'll call it a *referent*. Suppose, for example, that you create a hard reference to a lexically scoped array named `@array`. This hard reference, and the referent it refers to, will continue to exist even after `@array` goes out of scope. A referent is only destroyed when all the references to it are eliminated.

A referent doesn't really have a name of its own, apart from the references to it. To put it another way, every Perl variable name lives in some kind of symbol table, holding one hard reference to its underlying (otherwise nameless) referent. That referent might be simple, like a number or string, or complex, like an array or hash. Either way, there's still exactly one reference from the variable to its value. You might create additional hard references to the same referent but, if so, the variable doesn't know (or care) about them.[1]

A symbolic reference is just a string that happens to name something in a package symbol table. It's not so much a distinct type as it is something you do with a string. But a hard reference is a different beast entirely. It is the third of the three

1. If you're curious, you can determine the underlying refcount with the `Devel::Peek` module, bundled with Perl.

kinds of fundamental scalar data types—the other two being strings and numbers. A hard reference doesn't know something's name just to refer to it, and it's actually completely normal for there to *be* no name to use in the first place. Such totally nameless referents are called *anonymous*; we discuss them in "Anonymous Data" on page 342, later in this chapter.

To *reference* a value, in the terminology of this chapter, is to create a hard reference to it. (There's a special operator for this creative act.) The reference so created is simply a scalar, which behaves in all familiar contexts just like any other scalar. To *dereference* this scalar means to use the reference to get at the referent. Both referencing and dereferencing occur only when you invoke certain explicit mechanisms; implicit referencing or dereferencing never occurs in Perl 5. Well, almost never.[2]

A function call *can* use implicit pass-by-reference semantics—if it has a prototype declaring it that way. If so, the caller of the function doesn't explicitly pass a reference, although you still have to dereference it explicitly within the function. See the section "Prototypes" on page 326 in Chapter 7. And to be perfectly honest, there's also some behind-the-scenes dereferencing happening when you use certain kinds of filehandles, but that's for backward compatibility and is transparent to the casual user. Two built-in functions, `bless` and `lock`, each take a reference for their argument but implicitly dereference it to work their magic on what lies behind. Finally, as of the v5.14 release, built-in functions that specifically operate on arrays and hashes[3] now accept a reference to the correct type and dereference it as needed. But those confessions aside, the basic principle still holds that Perl isn't interested in muddling your levels of indirection.

A reference can point to any data structure. Since references are scalars, you can store them in arrays and hashes, and thus build arrays of arrays, arrays of hashes, hashes of arrays, arrays of hashes and functions, and so on. There are examples of these in Chapter 9.

Keep in mind, though, that Perl arrays and hashes are internally one-dimensional. That is, their elements can hold only scalar values (strings, numbers, and references). When we use a phrase like "array of arrays", we really mean "array of references to arrays", just as when we say "hash of functions", we really mean "hash of references to subroutines". But since references are the only way to implement such structures in Perl, it follows that the shorter, less accurate phrase

2. And in Perl 6, it's almost always, just to keep you confused.

3. `keys`, `values`, `each`, `pop`, `push`, `shift`, `unshift`, and `splice`.

is not so inaccurate as to be false; therefore, it should not be totally despised, unless you're into that sort of thing.

Creating References

There are several ways to create references, most of which we will describe before explaining how to use (dereference) the resulting references.

The Backslash Operator

You can create a reference to any named variable or subroutine with a backslash. (You may also use it on an anonymous scalar value like `7` or `"camel"`, although you won't often need to.) This operator works like the `&` (address-of) operator in C—at least at first glance.

Here are some examples:

```
$scalarref = \$foo;
$constref  = \186_282.42;
$arrayref  = \@ARGV;
$hashref   = \%ENV;
$coderef   = \&handler;
$globref   = \*STDOUT;
```

The backslash operator can do more than produce a single reference. It will generate a whole list of references if applied to a list. See the upcoming section "Other Tricks You Can Do with Hard References" on page 353 for details.

Anonymous Data

In the examples just shown, the backslash operator merely makes a duplicate of a reference that is already held in a variable name—with one exception. The `186_282.42` isn't referenced by a named variable—it's just a value. It's one of those *anonymous* referents we mentioned earlier. Anonymous referents are accessed only through references. This one happens to be a number, but you can create anonymous arrays, hashes, and subroutines as well.

The anonymous array composer

You can create a reference to an anonymous array with square brackets:

```
$arrayref = [1, 2, ["a", "b", "c", "d"]];
```

Here we've composed an anonymous array of three elements, whose final element is a reference to an anonymous array of four elements (depicted in Figure 8-2).

(The multidimensional syntax described later can be used to access this. For example, `$arrayref->[2][1]` would have the value "`b`".)

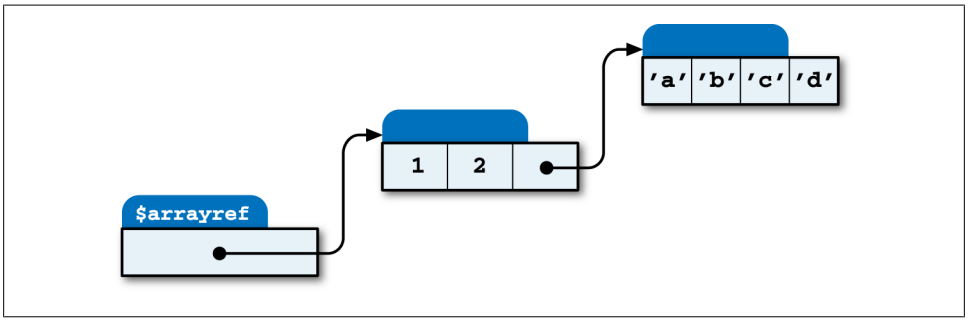


Figure 8-2. A reference to an array, whose third element is itself an array reference

We now have one way to represent the table at the beginning of the chapter:

```
$table = [ [ "john", 47, "brown", 186],
           [ "mary", 23, "hazel", 128],
           [ "bill", 35, "blue",  157] ];
```

Square brackets work like this only where the Perl parser is expecting a term in an expression. They should not be confused with the brackets in an expression like `$array[6]`—although the mnemonic association with arrays is intentional. Inside a quoted string, square brackets don't compose anonymous arrays; instead, they become literal characters in the string. (Square brackets do still work for subscripting in strings, or you wouldn't be able to print string values like `"VAL=$array[6]\n"`. And to be totally honest, you can in fact sneak anonymous array composers into strings, but only when embedded in a larger expression that is being interpolated. We'll talk about this cool feature later in the chapter because it involves dereferencing as well as referencing.)

The anonymous hash composer

You can create a reference to an anonymous hash with braces:

```
$hashref = {
    "Adam"   => "Eve",
    "Clyde"  => $bonnie,
    "Antony" => "Cleo" . "patra",
};
```

For the values (but not the keys) of the hash, you can freely mix other anonymous array, hash, and subroutine composers to produce as complicated a structure as you like.

We now have another way to represent the table at the beginning of the chapter:

```
$table = {
            "john" => [ 47, "brown", 186 ],
            "mary" => [ 23, "hazel", 128 ],
            "bill" => [ 35, "blue",  157 ],
};
```

That's a hash of arrays. Choosing the best data structure is a tricky business, and the next chapter is devoted to it. But, as a teaser, we could even use a hash of hashes for our table:

```
$table = {
           "john" => { age    => 47,
                       eyes   => "brown",
                       weight => 186,
                     },
           "mary" => { age    => 23,
                       eyes   => "hazel",
                       weight => 128,
                     },
           "bill" => { age    => 35,
                       eyes   => "blue",
                       weight => 157,
                     },
 };
```

As with square brackets, braces work like this only where the Perl parser is expecting a term in an expression. They should not be confused with the braces in an expression like `$hash{key}`—although the mnemonic association with hashes is (again) intentional. The same caveats apply to the use of braces within strings.

There is one additional caveat that didn't apply to square brackets. Since braces are also used for several other things (including blocks), you may occasionally have to disambiguate braces at the beginning of a statement by putting a `+` or a `return` in front, so that Perl realizes the opening brace isn't starting a block. For example, if you want a function to make a new hash and return a reference to it, you have these options:

```
sub hashem {        { @_ } }   # Silently WRONG — returns @_.
sub hashem {       +{ @_ } }   # Ok.
sub hashem { return { @_ } }   # Ok.
```

The anonymous subroutine composer

You can create a reference to an anonymous subroutine by using `sub` without a subroutine name:

```
$coderef = sub { print "Boink!\n" };  # Now &$coderef prints "Boink!"
```

Note the presence of the semicolon, required here to terminate the expression. (It isn't required after the more common usage of `sub` *NAME* `{}` that declares and

defines a named subroutine.) A nameless `sub {}` is not so much a declaration as it is an operator—like `do {}` or `eval {}`—except that the code inside isn't executed immediately. Instead, it just generates a reference to the code, which in our example is stored in `$coderef`. However, no matter how many times you execute the line shown above, `$coderef` will still refer to the same anonymous subroutine.[4]

Object Constructors

Subroutines can also return references. That may sound trite, but sometimes you are *supposed* to use a subroutine to create a reference rather than creating the reference yourself. In particular, special subroutines called *constructors* create and return references to objects. An object is simply a special kind of reference that happens to know which class it's associated with, and constructors know how to create that association. They do so by taking an ordinary referent and turning it into an object with the `bless` operator, so we can speak of an object as a blessed reference. There's nothing religious going on here; since a class acts as a user-defined type, blessing a referent simply makes it a user-defined type in addition to a built-in one. Constructors are often named `new`—especially by C++ and Java programmers—but they can be named anything in Perl.

Constructors can be called in any of these ways:

```
$objref = Doggie::->new(Tail => "short", Ears => "long");  #1
$objref = new Doggie:: Tail => "short", Ears => "long";    #2
$objref = Doggie->new(Tail => "short", Ears => "long");    #3
$objref = new Doggie Tail => "short", Ears => "long";      #4
```

The first and second invocations are the same. They both call a function named `new` that is supplied by the `Doggie` module. The third and fourth invocations are the same as the first two, but are slightly more ambiguous: the parser will get confused if you define your own subroutine named `Doggie`. (Which is why people typically stick with lowercase names for subroutines and uppercase for modules.) The fourth invocation can also get confused if you've defined your own `new` subroutine and don't happen to have done either a `require` or a `use` of the `Doggie` module, either of which has the effect of declaring the module. Always declare your modules if you want to use #4. (And watch out for stray `Doggie` subroutines.)

See Chapter 12 for a discussion of Perl objects.

4. But even though there's only one anonymous subroutine, there may be several copies of the lexical variables in use by the subroutine, depending on when the subroutine reference was generated. These are discussed later in the section "Closures" on page 355.

Handle References

References to filehandles or directory handles can be created by referencing the typeglob of the same name:

```
splutter(\*STDOUT);

sub splutter {
    my $fh = shift;
    say $fh "her um well a hmmm";
}

$rec = get_rec(\*STDIN);
sub get_rec {
    my $fh = shift;
    return scalar <$fh>;
}
```

If you're passing around filehandles, you can also use the bare typeglob to do so: in the example above, you could have used `*STDOUT` or `*STDIN` instead of `\*STDOUT` and `\*STDIN`.

Although you can usually use typeglob and references to typeglobs interchangeably, there are a few places where you can't. Simple typeglobs can't be `bless`ed into objectdom, and typeglob references can't be passed back out of the scope of a localized typeglob.

When generating new filehandles, older code would often do something like this to open a list of files:

```
for $file (@names) {
    local *FH;
    open(*FH, $file) || next;
    $handle{$file} = *FH;
}
```

That still works, but it's often preferable to let an undefined variable autovivify an anonymous typeglob:

```
for $file (@names) {
    my $fh;
    open($fh, $file) || next;
    $handle{$file} = $fh;
}
```

Anytime you have a variable that contains a filehandle instead of a bareword handle, you have an indirect filehandles. It doesn't matter whether you use strings, typeglobs, references to typeglobs, or one of the more exotic I/O objects. You just use a scalar that—one way or another—gets interpreted as a filehandle. For most purposes, you can use either a typeglob or a typeglob reference almost

indiscriminately. As we admitted earlier, there is some implicit dereferencing magic going on here.

Symbol Table References

In unusual circumstances, you might not know what type of reference you need when your program is written. A reference can be created by using a special syntax, affectionately known as the *foo{*THING*} syntax. *foo{*THING*} returns a reference to the *THING* slot in *foo, which is the symbol table entry holding the values of $foo, @foo, %foo, and friends.

```
$scalarref = *foo{SCALAR};   # Same as \$foo
$arrayref  = *ARGV{ARRAY};   # Same as \@ARGV
$hashref   = *ENV{HASH};     # Same as \%ENV
$coderef   = *handler{CODE}; # Same as \&handler
$globref   = *foo{GLOB};     # Same as \*foo
$ioref     = *STDIN{IO};     # Er...
$formatref = *foo{FORMAT};   # More er...
```

All of these are self-explanatory except for the last two. *foo{FORMAT} is how to get at the object that was declared using the format statement. There isn't much you can do with one of those that's very interesting.

On the other hand, *STDIN{IO} yields the actual internal IO::Handle object that the typeglob contains; that is, the part of the typeglob that the various I/O functions are actually interested in. For compatibility with old versions of Perl, *foo{FILEHANDLE} was once a synonym for the hipper *foo{IO} notation, but that use is now deprecated.

In theory, you can use a *HANDLE{IO} anywhere you'd use a *HANDLE or a *HANDLE, such as for passing handles into or out of subroutines, or storing them in larger data structures. (In practice, there are still some wrinkles to be ironed out.) The advantage of them is that they access only the real I/O object you want, not the whole typeglob, so you run no risk of clobbering more than you want to through a typeglob assignment (although if you always assign to a scalar variable instead of to a typeglob, you'll be okay). One disadvantage is that there's no way to autovivify one as of yet:[5]

```
splutter(*STDOUT); splutter(*STDOUT{IO});

sub splutter {
    my $fh = shift; print $fh "her um well a hmmm\n";
}
```

5. Currently, open my $fh autovivifies a typeglob instead of an IO::Handle object, but someday we may fix that, so you shouldn't rely on the typeglobbedess of what open currently autovivifies.

Both invocations of `splutter` print "`her um well a hmmm`".

The `*foo{`*`THING`*`}` thing returns `undef` if that particular *`THING`* hasn't been seen by the compiler yet, except when *`THING`* is `SCALAR`. It so happens that `*foo{SCALAR}` returns a reference to an anonymous scalar even if `$foo` hasn't been seen yet. (Perl always adds a scalar to any typeglob as an optimization to save a bit of code elsewhere. But don't depend on it to stay that way in future releases.)

Implicit Creation of References

You've seen some sly references to *autovivifying*, which is our final method for creating references—though it's not really a method at all. References of an appropriate type simply spring into existence if you dereference them in an lvalue context that assumes they exist. This is extremely useful and is also What You Expect. This topic is covered later in this chapter, where we'll discuss how to dereference all of the references we've created so far. Oh, hey, we're already there.

Using Hard References

Just as there are numerous ways to create references, there are also several ways to use, or *dereference*, a reference. There is just one overriding principle: Perl does no implicit referencing or dereferencing.[6] When a scalar is holding a reference, it always behaves like a simple scalar. It doesn't magically start being an array or hash or subroutine; you have to tell it explicitly to do so, by dereferencing it.

Using a Variable As a Variable Name

When you encounter a scalar like `$foo`, you should be thinking "the scalar value of `foo`." That is, there's a `foo` entry in the symbol table, and the `$` funny character, known as a *sigil*, is a way of looking at whatever scalar value might be inside. If what's inside is a reference, you can look inside *that* (dereferencing `$foo`) by prepending another sigil. Or, looking at it the other way around, you can replace the literal `foo` in `$foo` with a scalar variable that points to the actual referent. This is true of any variable type, so not only is `$$foo` the scalar value of whatever `$foo` refers to, but `@$bar` is the array value of whatever `$bar` refers to, `%$glarch` is the hash value of whatever `$glarch` refers to, and so on. The upshot is that you can put an extra sigil on the front of any simple scalar variable to dereference it:

6. We already confessed that this was a small fib. We're not about to do so again.

```
$foo         = "three humps";
$scalarref   = \$foo;         # $scalarref is now a reference to $foo
$camel_model = $$scalarref;   # $camel_model is now "three humps"
```

Here are some other dereferences:

```
$bar = $$scalarref;

push(@$arrayref, $filename);
$$arrayref[0] = "January";            # Set the first element of @$arrayref
@$arrayref[4..6] = qw/May June July/; # Set several elements of @$arrayref

%$hashref = (KEY => "RING", BIRD => "SING");  # Initialize whole hash
$$hashref{KEY} = "VALUE";                     # Set one key/value pair
@$hashref{"KEY1","KEY2"} = ("VAL1","VAL2");   # Set two more pairs

&$coderef(1,2,3);

say $handleref "output";
```

This form of dereferencing can only make use of a simple scalar variable (one without a subscript). That is, dereferencing happens *before* (or binds tighter than) any array or hash lookups. Let's use some braces to clarify what we mean: an expression like `$$arrayref[0]` is equivalent to `${$arrayref}[0]` and means the first element of the array referred to by `$arrayref`. That is not at all the same as `${$arrayref[0]}`, which is dereferencing the first element of the (probably nonexistent) array named `@arrayref`. Likewise, `$$hashref{KEY}` is the same as `${$hashref}{KEY}`, and has nothing to do with `${$hashref{KEY}}`, which would be dereferencing an entry in the (probably nonexistent) hash named `%hashref`. You will be miserable until you understand this.

You can achieve multiple levels of referencing and dereferencing by concatenating the appropriate sigils. The following prints "`howdy`":

```
$refrefref = \\\"howdy";
print $$$$refrefref;
```

You can think of the dollar signs as operating right to left. But the beginning of the chain must still be a simple, unsubscripted scalar variable. There is, however, a way to get fancier, which we already sneakily used earlier, and which we'll explain in the next section.

Using a BLOCK As a Variable Name

Not only can you dereference a simple variable name, you can also dereference the contents of a *`BLOCK`*. Anywhere you'd put an alphanumeric identifier as part of a variable or subroutine name, you can replace the identifier with a *`BLOCK`*

returning a reference of the correct type. In other words, the earlier examples could all be disambiguated like this:

```
$bar = ${$scalarref};
push(@{$arrayref}, $filename);
${$arrayref}[0] = "January";
@{$arrayref}[4..6] = qw/May June July/;
${$hashref}{"KEY"} = "VALUE";
@{$hashref}{"KEY1","KEY2"} = ("VAL1","VAL2");
&{$coderef}(1,2,3);
```

not to mention:

```
$refrefref = \\\"howdy";
print ${${${$refrefref}}};
```

Admittedly, it's silly to use the braces in these simple cases, but the *BLOCK* can contain any arbitrary expression. In particular, it can contain subscripted expressions. In the following example, `$dispatch{$index}` is assumed to contain a reference to a subroutine (sometimes called a "coderef"). The example invokes the subroutine with three arguments:

```
&{ $dispatch{$index} }(1, 2, 3);
```

Here, the *BLOCK* is necessary. Without that outer pair of braces, Perl would have treated `$dispatch` as the coderef instead of `$dispatch{$index}`.

Using the Arrow Operator

For references to arrays, hashes, or subroutines, a third method of dereferencing involves the use of the `->` infix operator. This form of syntactic sugar makes it easier to get at individual array or hash elements, or to call a subroutine indirectly.

The type of the dereference is determined by the right operand—that is, by what follows directly after the arrow. If the next thing after the arrow is a bracket or brace, the left operand is treated as a reference to an array or a hash, respectively, to be subscripted by the expression on the right. If the next thing is a left parenthesis, the left operand is treated as a reference to a subroutine, to be called with whatever parameters you supply in the parentheses on the right.

Each of these next trios is equivalent, corresponding to the three notations we've introduced. (We've inserted some spaces to line up equivalent elements.)

```
$  $arrayref  [2] = "Dorian";         #1
${ $arrayref }[2] = "Dorian";         #2
   $arrayref->[2] = "Dorian";         #3

$  $hashref  {KEY} = "F#major";       #1
${ $hashref }{KEY} = "F#major";       #2
```

```
    $hashref->{KEY} = "F#major";       #3

&   $coderef  (Presto => 192);         #1
&{  $coderef }(Presto => 192);         #2
    $coderef->(Presto => 192);         #3
```

You can see that the initial sigil is missing from the third notation in each trio. The sigil is guessed at by Perl, which is why it can't be used to dereference complete arrays, complete hashes, or slices of either. As long as you stick with scalar values, though, you can use any expression to the left of the `->`, including another dereference, because multiple arrow operators associate left to right:

```
print $array[3]->{"English"}->[0];
```

You can deduce from this expression that the fourth element of `@array` is intended to be a hash reference, and the value of the "`English`" entry in that hash is intended to be an array reference.

Note that `$array[3]` and `$array->[3]` are not the same. The first is talking about the fourth element of `@array`, while the second one is talking about the fourth element of the (possibly anonymous) array whose reference is contained in `$array`.

Suppose now that `$array[3]` is undefined. The following statement is still legal:

```
$array[3]->{"English"}->[0] = "January";
```

This is one of those cases mentioned earlier in which references spring into existence (or "autovivify") when used as an lvalue (that is, when a value is being assigned to it). If `$array[3]` was undefined, it's automatically defined as a hash reference so that we can set a value for `$array[3]->{"English"}` in it. Once that's done, `$array[3]->{"English"}` is automatically defined as an array reference so that we can assign something to the first element in that array. Note that rvalues are a little different: `print $array[3]->{"English"}->[0]` only defines `$array[3]` and `$array[3]->{"English"}`, not `$array[3]->{"English"}->[0]`, since the final element is not an lvalue. (The fact that it defines the first two at all in an rvalue context could be considered a bug. We may fix that someday.)

The arrow is optional between brackets or braces, or between a closing bracket or brace and a parenthesis for an indirect function call. So you can shrink the previous code down to:

```
$dispatch{$index}(1, 2, 3);
$array[3]{"English"}[0] = "January";
```

In the case of ordinary arrays, this gives you multidimensional arrays that are just like C's array:

```
$answer[$x][$y][$z] += 42;
```

Well, okay, not *entirely* like C's arrays. For one thing, C doesn't know how to grow its arrays on demand, while Perl does. Also, some constructs that are similar in the two languages parse differently. In Perl, the following two statements do the same thing:

```
$listref->[2][2] = "hello";    # Pretty clear
$$listref[2][2]  = "hello";    # A bit confusing
```

This second of these statements may disconcert the C programmer, who is accustomed to using `*a[i]` to mean "what's pointed to by the i^{th} element of `a`". But in Perl, the five characters (`$ @ * % &`) effectively bind more tightly than braces or brackets.[7] Therefore, it is `$$listref` and not `$listref[2]` that is taken to be a reference to an array. If you want the C behavior, either you have to write `${$listref[2]}` to force the `$listref[2]` to get evaluated before the leading `$` dereferencer, or you have to use the `->` notation:

```
$listref[2]->[$greeting] = "hello";
```

Using Object Methods

If a reference happens to be a reference to an object, then the class that defines that object probably provides methods to access the innards of the object, and you should generally stick to those methods if you're merely using the class (as opposed to implementing it). In other words, be nice and don't treat an object like a regular reference, even though Perl lets you when you really need to. Perl does not enforce encapsulation. We are not totalitarians here. We do expect some basic civility, however.

In return for this civility, you get complete orthogonality between objects and data structures. Any data structure can behave as an object when you want it to—or not, when you don't.

Pseudohashes

A *pseudohash* used to be a way to treat an array as though it were a hash so you could fake an ordered hash. Pseudohashes were an experiment that turned out to be not such a great idea, so they have been removed from Perl as of v5.10, but some people are stuck on even earlier versions, so we'll leave in a note, even though you shouldn't use them. If you used them, you should have used the `fields` module's `phash` and `new` functions.

7. But not because of operator precedence. The sigils in Perl are not operators in that sense. Perl's grammar simply prohibits anything more complicated than a simple variable or block from following the initial sigil.

The `fields::phash` interface is no longer available as of v5.10, although `fields::new` still works. Nonetheless, you should consider using restricted hashes from the standard `Hash::Util` module instead.

Other Tricks You Can Do with Hard References

As mentioned earlier, the backslash operator is usually used on a single referent to generate a single reference, but it doesn't have to be. When used on a list of referents, it produces a list of corresponding references. The second line of the following example does the same thing as the first line, since the backslash is automatically distributed throughout the whole list:

```
@reflist = (\$s, \@a, \%h, \&f);     # List of four references
@reflist = \($s,  @a   %h,  &f);     # Same thing
```

If a parenthesized list contains exactly one array or hash, then all of its values are interpolated, and references to each are returned:

```
@reflist = \(@x);                    # Interpolate array, then get refs
@reflist = map { \$_ } @x;           # Same thing
```

This also occurs when there are internal parentheses:

```
@reflist = \(@x, (@y));              # But only single aggregates expand
@reflist = (\@x, map { \$_ } @y);    # Same thing
```

If you try this with a hash, the result will contain references to the values (as you'd expect), but also references to *copies* of the keys (as you might not expect).

Since array and hash slices are really just lists, you can backslash a slice of either of these to get a list of references. Each of the next three lines does exactly the same thing:

```
@envrefs = \@ENV{"HOME", "TERM"};         # Backslashing a slice
@envrefs = \( $ENV{HOME},  $ENV{TERM} );  # Backslashing a list
@envrefs = ( \$ENV{HOME}, \$ENV{TERM} );  # A list of two references
```

Since functions can return lists, you can apply a backslash to them. If you have more than one function to call, first interpolate each function's return values into a larger list, and then backslash the whole thing:

```
@reflist = \fx();
@reflist = map { \$_ } fx();               # Same thing

@reflist = \( fx(), fy(), fz() );
@reflist = ( \fx(), \fy(), \fz() );        # Same thing
@reflist = map { \$_ } fx(), fy(), fz();   # Same thing
```

The backslash operator always supplies list context to its operand, so those functions are all called in list context. If the backslash is itself in scalar context, you'll end up with a reference to the last value of the list returned by the function:

```
@reflist = \localtime();      # Ref to each of nine time elements
$lastref = \localtime();      # Ref to whether it's daylight savings time
```

In this regard, the backslash behaves like the named Perl list operators, such as `print`, `reverse`, and `sort`, which always supply list context on their right no matter what might be happening on their left. As with named list operators, use an explicit `scalar` to force what follows into scalar context:

```
$dateref = \scalar localtime();    # \"Tue Oct 18 07:23:50 2011"
```

You can use the `ref` operator to determine what a reference is pointing to. Think of `ref` as a "typeof" operator that returns true if its argument is a reference and false otherwise. The value returned depends on the type of thing referenced. Built-in types include `SCALAR`, `ARRAY`, `HASH`, `CODE`, `GLOB`, `REF`, `VSTRING`, `IO`, `LVALUE`, `FORMAT`, and `REGEXP`, plus the classes `version`, `Regexp`, and `IO::Handle`. Here we use the `ref` operator to check subroutine arguments:

```
sub sum {
     my $arrayref = shift;
     warn "Not an array reference" if ref($arrayref) ne "ARRAY";
     return eval join("+", @$arrayref);
 }

 say sum([1..100]);  #  5050, by Euler's trick
```

If you use a hard reference in a string context, it'll be converted to a string containing both the type and the address: `SCALAR(0x1fc0e)`. (The reverse conversion cannot be done since reference count information is lost during stringification—and also because it would be dangerous to let programs access a memory address named by an arbitrary string.)

You can use the `bless` operator to associate a referent with a package functioning as an object class. When you do this, `ref` returns the class name instead of the internal type. An object reference used in a string context returns a string with the external and internal types, as well as the address in memory: `MyType=HASH(0x20d10)` or `IO::Handle=IO(0x186904)`. See Chapter 12 for more details about objects.

Since the way in which you dereference something always indicates what sort of referent you're looking for, a typeglob can be used the same way a reference can, despite the fact that a typeglob contains multiple referents of various types. So `${*main::foo}` and `${\$main::foo}` both access the same scalar variable, although the latter is more efficient.

Here's a trick for interpolating the return value of a subroutine call into a string:

```
say "My sub returned @{[ mysub(1,2,3) ]} that time.";
```

It works like this. At compile time, when the `@{...}` is seen within the double-quoted string, it's parsed as a block that returns a reference. Within the block, there are square brackets that create a reference to an anonymous array from whatever is in the brackets. So at runtime, `mysub(1,2,3)` is called in list context, and the results are loaded into an anonymous array, a reference to which is then returned within the block. That array reference is then immediately dereferenced by the surrounding `@{...}`, and the array value is interpolated into the double-quoted string just as an ordinary array would be. This chicanery is also useful for arbitrary expressions, such as:

```
say "We need @{ [$n + 5] } widgets!";
```

Be careful though: square brackets supply list context to their expression. In this case it doesn't matter, although the earlier call to `mysub` might care. When it does matter, use an explicit `scalar` to force the context:

```
say "mysub returns @{ [scalar mysub(1,2,3)] } now.";
```

Closures

Earlier we talked about creating anonymous subroutines with a nameless `sub {}`. You can think of those subroutines as defined at runtime, which means that they have a time of generation as well as a location of definition. Some variables might be in scope when the subroutine is created, and different variables might be in scope when the subroutine is called.

Forgetting about subroutines for a moment, consider a reference that refers to a lexical variable:

```
{
    my $critter = "camel";
    $critterref = \$critter;
}
```

The value of `$$critterref` will remain "`camel`" even though `$critter` disappears after the closing curly brace. But `$critterref` could just as well have referred to a subroutine that refers to `$critter`:

```
{
    my $critter = "camel";
    $critterref = sub { return $critter };
}
```

This is a *closure*, which is a notion out of the functional programming world of LISP and Scheme.[8] It means that when you define an anonymous function in a particular lexical scope at a particular moment, it pretends to run in that scope even when later called from outside that scope. (A purist would say it doesn't have to pretend—it actually *does* run in that scope.)

In other words, you are guaranteed to get the same copy of a lexical variable each time, even if other instances of that lexical variable have been created before or since for other instances of that closure. This gives you a way to set values used in a subroutine when you define it, not just when you call it.

You can also think of closures as a way to write a subroutine template without using `eval`. The lexical variables act as parameters for filling in the template, which is useful for setting up little bits of code to run later. These are commonly called *callbacks* in event-based programming, where you associate a bit of code with a keypress, mouse click, window exposure, and so on. When used as callbacks, closures do exactly what you expect, even if you don't know the first thing about functional programming. (Note that this closure business only applies to `my` variables. Global variables work as they've always worked, since they're neither created nor destroyed the way lexical variables are.)

Another use for closures is within *function generators*; that is, functions that create and return brand new functions. Here's an example of a function generator implemented with closures:

```
sub make_saying  {
    my $salute = shift;
    my $newfunc = sub {
        my $target = shift;
        say "$salute, $target!";
    };
    return $newfunc;            # Return a closure
}

$f = make_saying("Howdy");      # Create a closure
$g = make_saying("Greetings");  # Create another closure

# Time passes...

$f->("world");
$g->("earthlings");
```

This prints:

```
Howdy, world!
Greetings, earthlings!
```

8. In this context, the word "functional" should not be construed as an antonym of "dysfunctional".

Note in particular how `$salute` continues to refer to the actual value passed into `make_saying`, despite the fact that the `my $salute` has gone out of scope by the time the anonymous subroutine runs. That's what closures are all about. Since `$f` and `$g` hold references to functions that, when called, still need access to the distinct versions of `$salute`, those versions automatically stick around. If you now overwrite `$f`, *its* version of `$salute` would automatically disappear. (Perl only cleans up when you're not looking.)

Perl doesn't provide references to object methods (described in Chapter 12), but you can get a similar effect using a closure. Suppose you want a reference not just to the subroutine the method represents, but one which, when invoked, would call that method on a particular object. You can conveniently remember both the object and the method as lexical variables bound up inside a closure:

```
sub get_method_ref {
    my ($self, $methodname) = @_;
    my $methref = sub {
        # the @_ below is not the same as the one above!
        return $self->$methodname(@_);
    };
    return $methref;
}

my $dog = new Doggie::
            Name => "Lucky",
            Legs => 3,
            Tail => "clipped";

our $wagger = get_method_ref($dog, "wag");
$wagger->("tail");        # Calls $dog->wag("tail").
```

Not only can you get Lucky to wag what's left of his tail now, even once the lexical `$dog` variable has gone out of scope and Lucky is nowhere to be seen, the global `$wagger` variable can still get him to wag his tail, wherever he is.

Closures as function templates

Using a closure as a function template allows you to generate many functions that act similarly. Suppose you want a suite of functions that generate HTML font changes for various colors:

```
print "Be ", red("careful"), "with that ", green("light"), "!!!";
```

The `red` and `green` functions would be very similar. We'd like to name our functions, but closures don't have names since they're just anonymous subroutines with an attitude. To get around that, we'll perform the cute trick of naming our anonymous subroutines. You can bind a coderef to an existing name by assigning

it to a typeglob of the name of the function you want. (See the section "Symbol Tables" on page 389 in Chapter 10.) In this case, we'll bind it to two different names, one uppercase and one lowercase:

```
@colors = qw(red blue green yellow orange purple violet);
for my $name (@colors) {
    no strict "refs";       # Allow symbolic references
    *$name = *{uc $name} = sub { "<FONT COLOR='$name'>;@_</FONT>" };
}
```

Now you can call functions named `red`, `RED`, `blue`, `BLUE`, and so on, and the appropriate closure will be invoked. This technique reduces compile time and conserves memory, and is less error-prone as well, since syntax checks happen during compilation. It's critical that any variables in the anonymous subroutine be lexicals in order to create a closure. That's the reason for the `my` above.

This is one of the few places where giving a prototype to a closure makes sense. If you wanted to impose scalar context on the arguments of these functions (probably not a wise idea for this example), you could have written it this way instead:

```
*$name = sub ($) { "<FONT COLOR='$name'>$_[0]</FONT>" };
```

That's almost good enough. However, since prototype checking happens during compile time, the runtime assignment above happens too late to be of much use. You could fix this by putting the whole loop of assignments within a `BEGIN` block, forcing it to occur during compilation. (More likely, you'd put it out in a module that you `use` at compile time.) Then the prototypes will be visible during the rest of the compilation.

Nested subroutines

If you are accustomed (from other programming languages) to using subroutines nested within other subroutines, each with their own private variables, you'll have to work at it a bit in Perl. Named subroutines do not nest properly, although anonymous ones do.[9] Anyway, we can emulate nested, lexically scoped subroutines using closures. Here's an example:

```
sub outer {
    my $x = $_[0] + 35;
    local *inner = sub { return $x * 19 };
    return $x + inner();
}
```

9. To be more precise, globally *named* subroutines don't nest. Unfortunately, that's the only kind of named subroutine declaration we have. We haven't yet implemented lexically scoped, named subroutines (known as `my subs`), but when we do, they should nest correctly.

Now, `inner` can only be called from within `outer` because of the temporary assignments of the closure. But when it is, it has normal access to the lexical variable `$x` from the scope of `outer`.

This has the interesting effect of creating a function local to another function, something not normally supported in Perl. Because `local` is dynamically scoped, and because function names are global to their package, any other function that `outer` called could also call the temporary version of `inner`. To prevent that, you'd need an extra level of indirection:

```
sub outer {
    my $x = $_[0] + 35;
    my $inner = sub { return $x * 19 };
    return $x + $inner->();
}
```

Symbolic References

What happens if you try to dereference a value that is not a hard reference? The value is then treated as a *symbolic reference*. That is, the reference is interpreted as a string representing the *name* of a global variable.

Here is how this works:

```
$name = "bam";
$$name = 1;                # Sets $bam
$name->[0] = 4;            # Sets the first element of @bam
$name->{X} = "Y";          # Sets the X element of %bam to Y
@$name = ();               # Clears @bam
keys %$name;               # Yields the keys of %bam
&$name;                    # Calls &bam
```

This is very powerful, and slightly dangerous, in that it's possible to intend (with the utmost sincerity) to use a hard reference, but to accidentally use a symbolic reference instead. To protect against that, you can say:

```
use strict "refs";
```

and then only hard references will be allowed for the rest of the enclosing block. An inner block may countermand the decree with:

```
no strict "refs";
```

It is also important to understand the difference between the following two lines of code:

```
${identifier};    # Same as $identifier.
${"identifier"};  # Also $identifier, but a symbolic reference.
```

Because the second form is quoted, it is treated as a symbolic reference and will generate an error if `use strict "refs"` is in effect. Even if `strict "refs"` is not in effect, it can only refer to a package variable. But the first form is identical to the unbracketed form, and it will refer to even a lexically scoped variable if one is declared. The next example shows this (and the next section discusses it).

Only package variables are accessible through symbolic references, because symbolic references always go through the package symbol table. Since lexical variables aren't in a package symbol table, they are therefore invisible to this mechanism. For example:

```
our $value  = "global";
{
    my $value = "private";
    print "Inside, mine is ${value}, ";
    say "but ours is ${"value"}.";
}
say "Outside, ${value} is again ${"value"}.";
```

which prints:

```
Inside, mine is private, but ours is global.
Outside, global is again global.
```

Braces, Brackets, and Quoting

In the previous section, we pointed out that `${identifier}` is not treated as a symbolic reference. You might wonder how this interacts with reserved words, and the short answer is that it doesn't. Despite the fact that `push` is a reserved word, these two statements print "`pop on over`":

```
$push = "pop on ";
print "${push}over";
```

The reason is that, historically, this use of braces is how Unix shells have isolated a variable name from subsequent alphanumeric text that would otherwise be interpreted as part of the name. It's how many people expect variable interpolation to work, so we made it work the same way in Perl. But with Perl, the notion extends further and applies to any braces used in generating references, whether or not they're inside quotes. This means that:

```
print ${push} . "over";
```

or even (since spaces never matter):

```
print ${ push } . "over";
```

both print "`pop on over`", even though the braces are outside of double quotes. The same rule applies to any identifier used for subscripting a hash. So instead of writing:

```
$hash{ "aaa" }{ "bbb" }{ "ccc" }
```

you can just write:

```
$hash{ aaa }{ bbb }{ ccc }
```

or:

```
$hash{aaa}{bbb}{ccc}
```

and not worry about whether the subscripts are reserved words. So this:

```
$hash{ shift }
```

is interpreted as `$hash{"shift"}`. You can force interpretation as a reserved word by adding anything that makes it more than a mere identifier:

```
$hash{  shift()  }
$hash{ +shift   }
$hash{  shift @_ }
```

References Don't Work As Hash Keys

Hash keys are stored internally as strings.[10] If you try to store a reference as a key in a hash, the key value will be converted into a string:

```
$x{ \$a } = $a;
($key, $value) = each %x;
print $$key;                # WRONG
```

We mentioned earlier that you can't convert a string back to a hard reference. So if you try to dereference `$key`, which contains a mere string, it won't return a hard dereference, but rather a symbolic dereference—and since you probably don't have a variable named `SCALAR(0x1fc0e)`, you won't accomplish what you're attempting. You might want to do something more like:

```
$r = \@a;
$x{ $r } = $r;
```

Then at least you can use the hash *value*, which will be a hard reference, instead of the key, which won't.

Although you can't store a reference as a key, if (as in the earlier example) you use a hard reference in a string context, it *is* guaranteed to produce a unique string.

10. They're also stored *externally* as strings, such as when you put them into a DBM file. In fact, DBM files *require* that their keys (and values) be strings.

This is because the address of the reference is included as part of the resulting string. So you can in fact use a reference as a unique hash key; you just can't dereference it later.

There is one special kind of hash in which you *are* able to use references as keys. Through the magic[11] of the `Tie::RefHash` module bundled with Perl, the thing we just said you couldn't do, you can do:

```
use Tie::RefHash;
tie my %h, "Tie::RefHash";
%h = (
    ["this", "here"]   => "at home",
    ["that", "there"]  => "elsewhere",
);
while ( my($keyref, $value) = each %h ) {
    say "@$keyref is $value";
}
```

In fact, by tying different implementations to the built-in types, you can make scalars, hashes, and arrays behave in many of the ways we've said you can't. That'll show us! Stupid authors...

For more about tying, see Chapter 14.

Garbage Collection, Circular References, and Weak References

High-level languages typically allow programmers not to worry about deallocating memory when they're done using it. This automatic reclamation process is known as *garbage collection*. For most purposes, Perl uses a fast and simple reference-based garbage collector.

When a block is exited, its locally scoped variables are normally freed up, but it is possible to hide your garbage so that Perl's garbage collector can't find it. One serious concern is that unreachable memory with a nonzero reference count will normally not get freed. Therefore, circular references are a bad idea:

```
{               # make $a and $b point to each other
    my ($a, $b);
    $a = \$b;
    $b = \$a;
}
```

11. Yes, that *is* a technical term, as you'll notice if you muddle through the *mg.c* file in the Perl source distribution.

or more simply:

```
{               # make $a point to itself
    my $a;
    $a = \$a;
}
```

Even though `$a` should be deallocated at the end of the block, it isn't. When building recursive data structures, you'll have to break (or weaken; see below) the self-reference yourself if you want to reclaim the memory before your program (or thread) exits. (Upon exit, the memory will be reclaimed for you automatically via a costly but complete mark-and-sweep garbage collection.) If the data structure is an object, you can use a `DESTROY` method to break the reference automatically; see "Garbage Collection with DESTROY Methods" on page 441 in Chapter 12.

A similar situation can occur with *caches*—repositories of data designed for faster-than-normal retrieval. Outside the cache there are references to data inside the cache. The problem occurs when all of those references are deleted, but the cache data with its internal reference remains. The existence of any reference prevents the referent from being reclaimed by Perl, even though we want cache data to disappear as soon as it's no longer needed. As with circular references, we want a reference that doesn't affect the reference count, and therefore doesn't delay garbage collection.

Here's another example, this time of an explicitly circular double-linked list:

```
$ring = {
  VALUE => undef,
  NEXT  => undef,
  PREV  => undef,
};
$ring->{NEXT} = $ring;
$ring->{PREV} = $ring;
```

The underlying hash has an underlying refcount of three, and `undef`fing `$ring` or letting it go out of scope will only decrement that count by one, resulting in a whole hashfull of memory irrecoverable by Perl.

To address this situation, Perl introduced the concept of *weak references*. A weak reference is just like any other regular reference (meaning a "hard" reference, not a "symbolic" one) except for two critical properties: it no longer contributes to the reference count on its referent, and when its referent is garbage collected, the weak reference itself becomes undefined. These properties make weak references perfect for data structures that hold internal references to themselves. That way, those internal references do not count toward the structure's reference count, but external ones still do.

Although Perl supported weak reference starting in v5.6, there was no standard `weaken` function to access them from Perl itself until the v5.8.1 release, when the `weaken` function was first included standard with the `Scalar::Util` module. That module also provides an `is_weak` function that reports whether its reference argument has been weakened or not.

Here's how you would use it on the ring example just given:

```
use Scalar::Util qw(weaken);

$ring = {
  VALUE => undef,
  NEXT  => undef,
  PREV  => undef,
};
$ring->{NEXT} = $ring;
$ring->{PREV} = $ring;
weaken($ring->{NEXT});
weaken($ring->{PREV});
```

Weak references work like normal (hard) references as far as the `ref` operator is concerned: it reports the type of referent. However, when a weak reference's referent gets garbage collected, the variable holding that weak reference will suddenly become undefined, since it no longer refers to something that exists.

Copying a weak reference creates a regular reference. If you need another weak reference, you'll have to weaken the copy afterwards.

For a longer example of managing weak references, see Recipe 11.15, "Coping with Circular Data Structures using Weak References," in *Perl Cookbook*.

CHAPTER 9

Data Structures

Perl provides for free many of the data structures that you have to build yourself in other programming languages. The stacks and queues that budding computer scientists learn about are both just arrays in Perl. When you `push` and `pop` (or `unshift` and `shift`) an array, it's a stack; when you `push` and `shift` (or `unshift` and `pop`) an array, it's a queue. And many of the tree structures in the world are built only to provide fast, dynamic access to a conceptually flat lookup table. Hashes, of course, are built into Perl, and they provide fast, dynamic access to a conceptually flat lookup table, only without the mind-numbingly recursive data structures that are claimed to be beautiful by people whose minds have been suitably numbed already.

But sometimes you want nested data structures because they most naturally model the problem you're trying to solve. So Perl lets you combine and nest arrays and hashes to create arbitrarily complex data structures. Properly applied, they can be used to create linked lists, binary trees, heaps, B-trees, sets, graphs, and anything else you can devise. See *Mastering Algorithms with Perl*, *Perl Cookbook*, the "Data Structure Cookbook" in *perldsc*, or CPAN, the central repository for all such modules. But simple combinations of arrays and hashes may be all you ever need, so they're what we'll talk about in this chapter.

Arrays of Arrays

There are many kinds of nested data structures. The simplest kind to build is an array of arrays, also called a two-dimensional array or a matrix. (The obvious generalization applies: an array of arrays of arrays is a three-dimensional array, and so on for higher dimensions.) It's reasonably easy to understand, and nearly everything that applies here will also be applicable to the fancier data structures we'll explore in subsequent sections.

Creating and Accessing a Two-Dimensional Array

Here's how to put together a two-dimensional array:

```
# Assign a list of array references to an array.
@AoA = (
         [ "fred", "barney" ],
         [ "george", "jane", "elroy" ],
         [ "homer", "marge", "bart" ],
);

print $AoA[2][1];   # prints "marge"
```

The overall list is enclosed by parentheses, not brackets, because you're assigning a list and not a reference. If you wanted a reference to an array instead, you'd use brackets:

```
# Create a reference to an array of array references.
$ref_to_AoA = [
    [ "fred", "barney", "pebbles", "bamm bamm", "dino", ],
    [ "homer", "bart", "marge", "maggie", ],
    [ "george", "jane", "elroy", "judy", ],
];

print $ref_to_AoA->[2][3];   # prints "judy"
```

Remember that there is an implied `->` between every pair of adjacent braces or brackets. Therefore, these two lines:

```
$AoA[2][3]
$ref_to_AoA->[2][3]
```

are equivalent to these two lines:

```
$AoA[2]->[3]
$ref_to_AoA->[2]->[3]
```

There is, however, no implied `->` before the first pair of brackets, which is why the dereference of `$ref_to_AoA` requires the initial `->`. Also remember that you can count backward from the end of an array with a negative index, so:

```
$AoA[0][-2]
```

is the next-to-last element of the first row.

Growing Your Own

Those big list assignments are well and good for creating a fixed data structure, but what if you want to calculate each element on the fly, or otherwise build the structure piecemeal?

Let's read in a data structure from a file. We'll assume that it's a plain text file, where each line is a row of the structure, and each line consists of elements delimited by whitespace. Here's how to proceed:[1]

```
while (<>) {
    @tmp = split;           # Split elements into an array.
    push @AoA, [ @tmp ];    # Add an anonymous array reference to @AoA.
}
```

Of course, you don't need to name the temporary array, so you could also say:

```
while (<>) {
    push @AoA, [ split ];
}
```

If you want a reference to an array of arrays, you can do this:

```
while (<>) {
    push @$ref_to_AoA, [ split ];
}
```

Both of those examples add new rows to the array of arrays. What about adding new columns? If you're just dealing with two-dimensional arrays, it's often easiest to use simple assignment:[2]

```
for $x (0 .. 9) {                       # For each row...
    for $y (0 .. 9) {                   # For each column...
        $AoA[$x][$y] = func($x, $y);    # ...set that cell
    }
}

for $x ( 0..9 ) {                       # For each row...
    $ref_to_AoA->[$x][3] = func2($x);   # ...set the fourth column
}
```

It doesn't matter in what order you assign the elements, nor does it matter whether the subscripted elements of `@AoA` are already there or not; Perl will gladly create them for you, setting intervening elements to the undefined value as need be. Perl will even create the original reference in `$ref_to_AoA` for you if it needs to in the code above. If you just want to append to a row, you have to do something a bit funnier:

```
# Append new columns to an existing row.
push @{ $AoA[0] }, "wilma", "betty";
```

1. Here, as in other chapters, we omit (for clarity) the `my` declarations that you would ordinarily put in. In this example, you'd normally write `my @tmp = split`.

2. As with the temp assignment earlier, we've simplified; the loops in this chapter would likely be written `for my $x` in real code.

You might be wondering whether you could get away with skipping that dereference and just write:

```
push $AoA[0], "wilma", "betty";  # compiler error < v5.14
```

We were wondering the same thing ourselves. For the longest time that wouldn't even compile, because the argument to `push` must be a real array, not just a reference to an array. Therefore, its first argument always had to begin with an `@` character, but what came after the `@` was somewhat negotiable.

As of v5.14, you can *sometimes* get away with omitting an explicit dereference when calling certain built-in functions. Those functions are `pop`, `push`, `shift`, `unshift`, and `splice` for arrays, and `keys`, `values`, and `each` for hashes. These no longer require their first argument to begin with a literal `@` or `%`. If passed a valid reference to the appropriate type of aggregate, they dereference it as needed; unlike explicit dereferencing, this implicit dereferencing never triggers autovivification. If passed an invalid reference, a runtime exception is raised. Since running your spiffy new code on older releases causes those venerable compilers to choke, you should notify users that your code is of a new vintage by putting a `use` *`VERSION`* pragma at the top of the file:

```
use 5.014;     # no new wine in old bottles
use v5.14;     # no new patches on old cloth
```

Access and Printing

Now let's print the data structure. If you only want one element, this is sufficient:

```
print $AoA[3][2];
```

But if you want to print the whole thing, you can't just say:

```
print @AoA;         # WRONG
```

It's wrong because you'll see stringified references instead of your data. Perl never automatically dereferences for you. Instead, you have to roll yourself a loop or two. The following code prints the whole structure, looping through the elements of `@AoA` and dereferencing each inside the `print` statement:

```
for $row ( @AoA ) {
    say "@$row";
}
```

If you want to keep track of subscripts, you might do this:

```
for $i ( 0 .. $#AoA ) {
    say "row $i is: @{$AoA[$i]}";
}
```

or maybe even this (notice the inner loop):

```
for $i ( 0 .. $#AoA ) {
    for $j ( 0 .. $#{$AoA[$i]} ) {
        say "element $i $j is $AoA[$i][$j]";
    }
}
```

As you can see, things are getting a bit complicated. That's why sometimes it's easier to use a temporary variable on your way through:

```
for $i ( 0 .. $#AoA ) {
    $row = $AoA[$i];
    for $j ( 0 .. $#{$row} ) {
        say "element $i $j is $row->[$j]";
    }
}
```

When you get tired of writing a custom print for your data structures, you might look at the standard `Dumpvalue` or `Data::Dumper` modules. The former is what the Perl debugger uses, while the latter generates parsable Perl code. For example:

```
use v5.14;     # using the + prototype, new to v5.14

sub show(+) {
    require Dumpvalue;
    state $prettily = new Dumpvalue::
                        tick        => q("),
                        compactDump => 1,  # comment these two lines out
                        veryCompact => 1,  # if you want a bigger dump
                    ;
    dumpValue $prettily @_;
}

# Assign a list of array references to an array.
my @AoA = (
       [ "fred", "barney" ],
       [ "george", "jane", "elroy" ],
       [ "homer", "marge", "bart" ],
);
push $AoA[0], "wilma", "betty";
show @AoA;
```

will print out:

```
0  0..3  "fred" "barney" "wilma" "betty"
1  0..2  "george" "jane" "elroy"
2  0..2  "homer" "marge" "bart"
```

Whereas if you comment out the two lines we said you might wish to, then it shows you the array contents this way instead:

```
0  ARRAY(0x8031d0)
   0  "fred"
   1  "barney"
   2  "wilma"
   3  "betty"
1  ARRAY(0x803d40)
   0  "george"
   1  "jane"
   2  "elroy"
2  ARRAY(0x803e10)
   0  "homer"
   1  "marge"
   2  "bart"
```

A CPAN module that we like to use for displaying our data dumps is `Data::Dump`. Here's what it looks like:

```
use v5.14;                  # for push on scalars
use Data::Dump qw(dump);    # CPAN module

my @AoA = (
       [ "fred", "barney" ],
       [ "george", "jane", "elroy" ],
       [ "homer", "marge", "bart" ],
);
push $AoA[0], "wilma", "betty";
dump \@AoA;
```

That produces this output:

```
[
  ["fred", "barney", "wilma", "betty"],
  ["george", "jane", "elroy"],
  ["homer", "marge", "bart"],
]
```

Slices

If you want to access a slice (part of a row) of a multidimensional array, you're going to have to do some fancy subscripting. The pointer arrows give us a nice way to access a single element, but no such convenience exists for slices. You can always use a loop to extract the elements of your slice one by one:

```
@part = ();
for ($y = 7; $y< 13; $y++) {
    push @part, $AoA[4][$y];
}
```

This particular loop could be replaced with an array slice:

```
@part = @{ $AoA[4] } [ 7..12 ];
```

If you want a *two-dimensional slice*, say, with `$x` running from `4..8` and `$y` from `7..12`, here's one way to do it:

```
@newAoA = ();
for ($startx = $x = 4; $x<= 8; $x++) {
    for ($starty = $y = 7; $y<= 12; $y++) {
        $newAoA[$x - $startx][$y - $starty] = $AoA[$x][$y];
    }
}
```

In this example, the individual values within our destination two-dimensional array, `@newAoA`, are assigned one by one, taken from a two-dimensional subarray of `@AoA`. An alternative is to create anonymous arrays, each consisting of a desired slice of an `@AoA` subarray, and then put references to these anonymous arrays into `@newAoA`. We would then be writing references into `@newAoA` (subscripted once, so to speak) instead of subarray values into a twice-subscripted `@newAoA`. This method eliminates the innermost loop:

```
for ($x = 4; $x<= 8; $x++) {
    push @newAoA, [ @{ $AoA[$x] } [ 7..12 ] ];
}
```

Of course, if you do this often, you should probably write a subroutine called something like `extract_rectangle`. And if you do it very often with large collections of multidimensional data, you should probably use the `PDL` (Perl Data Language) module, available from CPAN.

Common Mistakes

As mentioned earlier, Perl arrays and hashes are one-dimensional. In Perl, even "multidimensional" arrays are actually one-dimensional, but the values along that dimension are references to other arrays, which collapse many elements into one. If you print these values out without dereferencing them, you will get the stringified references rather than the data you want. For example, these two lines:

```
@AoA = ( [2, 3], [4, 5, 7], [0] );
print "@AoA";
```

result in something like:

```
ARRAY(0x83c38) ARRAY(0x8b194) ARRAY(0x8b1d0)
```

On the other hand, this line displays `7`:

```
print $AoA[1][2];
```

When constructing an array of arrays, remember to compose new references for the subarrays. Otherwise, you will just create an array containing the element counts of the subarrays, like this:

```
for $i (1..10) {
    @array = somefunc($i);
    $AoA[$i] = @array;       # WRONG!
}
```

Here, `@array` is being accessed in scalar context, and therefore yields the count of its elements, which is dutifully assigned to `$AoA[$i]`. The proper way to assign the reference will be shown in a moment.

After making the previous mistake people realize they need to assign a reference, so the next mistake people naturally make involves taking a reference to the same memory location over and over again:

```
for $i (1..10) {
    @array = somefunc($i);
    $AoA[$i] = \@array;      # WRONG AGAIN!
}
```

Every reference generated by the second line of the `for` loop is the same, namely, a reference to the single array `@array`. Yes, this array changes on each pass through the loop, but when everything is said and done, `$AoA` contains 10 references to the same array, which now holds the last set of values assigned to it. `print @{$AoA[1]}` will reveal the same values as `print @{$AoA[2]}`.

Here's a more successful approach:

```
for $i (1..10) {
    @array = somefunc($i);
    $AoA[$i] = [ @array ];   # RIGHT!
}
```

The brackets around `@array` create a new anonymous array, into which the elements of `@array` are copied. We then store a reference to that new array.

A similar result—though more difficult to read—would be produced by:

```
for $i (1..10) {
    @array = somefunc($i);
    @{$AoA[$i]} = @array;
}
```

Since `$AoA[$i]` needs to be a new reference, the reference springs into existence. Then, the preceding `@` dereferences this new reference, with the result that the values of `@array` are assigned (in list context) to the array referenced by `$AoA[$i]`. You might wish to avoid this construct for clarity's sake.

But there *is* a situation in which you might use it. Suppose `@AoA` is already an array of references to arrays. That is, you've made assignments like:

```
$AoA[3] = \@original_array;
```

And now suppose that you want to change `@original_array` (that is, you want to change the fourth row of `$AoA`) so that it refers to the elements of `@array`. This code will work:

```
@{$AoA[3]} = @array;
```

In this case, the reference itself does not change, but the elements of the referenced array do. This overwrites the values of `@original_array`.

Finally, the following dangerous-looking code actually works fine:

```
for $i (1..10) {
    my @array = somefunc($i);
    $AoA[$i] = \@array;
}
```

That's because the lexically scoped `my @array` variable is created afresh on each pass through the loop. So even though it looks as though you've stored the same variable reference each time, you haven't. This is a subtle distinction, but the technique can produce more efficient code—at the risk of misleading less-enlightened programmers. (It's more efficient because there's no copy in the final assignment.) On the other hand, if you have to copy the values anyway (which the first assignment in the loop is doing), then you might as well use the copy implied by the brackets and avoid the temporary variable:

```
for $i (1..10) {
    $AoA[$i] = [ somefunc($i) ];
}
```

In summary:

```
$AoA[$i] = [ @array ];   # Safest, sometimes fastest
$AoA[$i] = \@array;      # Fast but risky, depends on my-ness of array
@{ $AoA[$i] } = @array;  # A bit tricky
```

Once you've mastered arrays of arrays, you'll want to tackle more complex data structures. If you're looking for C structures or Pascal records, you won't find any special reserved words in Perl to set these up for you. What you get instead is a more flexible system. If your idea of a record structure is less flexible than this, or if you'd like to provide your users with something more opaque and rigid, then you can use the object-oriented features detailed in Chapter 12.

Perl has just two ways of organizing data: as ordered lists stored in arrays and accessed by position, or as unordered key/value pairs stored in hashes and accessed by name. The best way to represent a record in Perl is with a hash reference, but how you choose to organize such records will vary. You might want to keep an ordered list of these records that you can look up by number, in which case you'd use an array of hash references to store the records. Or, you might wish to

look up the records by name, in which case you'd maintain a hash of hash references.

In the following sections, you will find code examples detailing how to compose (from scratch), generate (from other sources), access, and display several different data structures. We first demonstrate three straightforward combinations of arrays and hashes, followed by a hash of functions and more irregular data structures. We end with a demonstration of how these data structures can be saved. These examples assume that you have already familiarized yourself with the explanations set forth earlier in this chapter.

Hashes of Arrays

Use a hash of arrays when you want to look up each array by a particular string rather than merely by an index number. In our example of television characters, instead of looking up the list of names by the zeroth show, the first show, and so on, we'll set it up so we can look up the cast list given the name of the show.

Because our outer data structure is a hash, we can't order the contents, but we can use the `sort` function to specify a particular output order.

Composition of a Hash of Arrays

You can create a hash of anonymous arrays as follows:

```
# We customarily omit quotes when the keys are identifiers.
%HoA = (
    flintstones    => [ "fred", "barney" ],
    jetsons        => [ "george", "jane", "elroy" ],
    simpsons       => [ "homer", "marge", "bart" ],
);
```

To add another array to the hash, you can simply say:

```
$HoA{teletubbies} = [ "tinky winky", "dipsy", "laa-laa", "po" ];
```

Generation of a Hash of Arrays

Here are some techniques for populating a hash of arrays. To read from a file with the following format:

```
flintstones: fred barney wilma dino
jetsons:     george jane elroy
simpsons:    homer marge bart
```

you could use either of the following two loops:

```
while ( <> ) {
     next unless s/^(.*?):\s*//;
     $HoA{$1} = [ split ];
 }

 while ( $line = <> ) {
     ($who, $rest) = split /:\s*/, $line, 2;
     @fields = split " ", $rest;
     $HoA{$who} = [ @fields ];
 }
```

If you have a subroutine `get_family` that returns an array, you can use it to stuff `%HoA` with either of these two loops:

```
for $group ( "simpsons", "jetsons", "flintstones" ) {
    $HoA{$group} = [ get_family($group) ];
}

for $group ( "simpsons", "jetsons", "flintstones" ) {
    @members = get_family($group);
    $HoA{$group} = [ @members ];
}
```

You can append new members to an existing array like so:

```
push @{ $HoA{flintstones} }, "wilma", "pebbles";
```

Access and Printing of a Hash of Arrays

You can set the first element of a particular array as follows:

```
$HoA{flintstones}[0] = "Fred";
```

To capitalize the second Simpson, apply a substitution to the appropriate array element:

```
$HoA{simpsons}[1] =~ s/(\w)/\u$1/;
```

You can print all of the families by looping through the keys of the hash:

```
for $family ( keys %HoA ) {
    say "$family: @{ $HoA{$family} }";
}
```

With a little extra effort, you can add array indices as well:

```
for $family ( keys %HoA ) {
    print "$family: ";
    for $i ( 0 .. $#{ $HoA{$family} } ) {
        print " $i = $HoA{$family}[$i]";
    }
    print "\n";
}
```

Or sort the arrays by how many elements they have:

```
for $family ( sort { @{$HoA{$b}} <=> @{$HoA{$a}} } keys %HoA ) {
    say "$family: @{ $HoA{$family} }"
}
```

Or even sort the arrays by the number of elements and then order the elements ASCIIbetically (or, to be precise, utf8ically):

```
# Print the whole thing sorted by number of members and name.
for $family ( sort { @{$HoA{$b}} <=> @{$HoA{$a}} } keys %HoA ) {
    say "$family: ", join(", " => sort @{ $HoA{$family} });
}
```

If you have non-ASCII Unicode or even just punctuation of any sort in your family names, then sorting by codepoint order won't produce an alphabetic sort. Instead, do this:

```
use Unicode::Collate;
my $sorter = Unicode::Collate->new();  # normal alphabetic sort
say "$family: ",
    join ", " => $sorter->sort( @{ $HoA{$family} } );
```

Arrays of Hashes

An array of hashes is useful when you have a bunch of records that you'd like to access sequentially, and each record itself contains key/value pairs. Arrays of hashes are used less frequently than the other structures in this chapter.

Composition of an Array of Hashes

You can create an array of anonymous hashes as follows:

```
@AoH = (
    {
       husband  => "barney",
       wife     => "betty",
       son      => "bamm bamm",
    },
    {
       husband => "george",
       wife    => "jane",
       son     => "elroy",
    },
    {
       husband => "homer",
       wife    => "marge",
       son     => "bart",
    },
  );
```

To add another hash to the array, you can simply say:

```
push @AoH, { husband => "fred", wife => "wilma", daughter => "pebbles" };
```

Generation of an Array of Hashes

Here are some techniques for populating an array of hashes. To read from a file with the following format:

```
husband=fred friend=barney
```

you could use either of the following two loops:

```
while ( <> ) {
    $rec = {};
    for $field ( split ) {
        ($key, $value) = split /=/, $field;
        $rec->{$key} = $value;
    }
    push @AoH, $rec;
}

while ( <> ) {
    push @AoH, { split /[\s=]+/ };
}
```

If you have a subroutine `get_next_pair` that returns key/value pairs, you can use it to stuff `@AoH` with either of these two loops:

```
while ( @fields = get_next_pair() ) {
    push @AoH, { @fields };
}

while (<>) {
    push @AoH, { get_next_pair($_) };
}
```

You can append new members to an existing hash like so:

```
$AoH[0]{pet} = "dino";
$AoH[2]{pet} = "santa's little helper";
```

Access and Printing of an Array of Hashes

You can set a key/value pair of a particular hash as follows:

```
$AoH[0]{husband} = "fred";
```

To capitalize the husband of the second array, apply a substitution:

```
$AoH[1]{husband} =~ s/(\w)/\u$1/;
```

You can print all of the data as follows:

```
for $href ( @AoH ) {
    print "{ ";
    for $role ( keys %$href ) {
         print "$role=$href->{$role} ";
    }
    print "}\n";
}
```

and with indices:

```
for $i ( 0 .. $#AoH ) {
    print "$i is { ";
    for $role ( keys %{ $AoH[$i] } ) {
         print "$role=$AoH[$i]{$role} ";
    }
    print "}\n";
}
```

Hashes of Hashes

A multidimensional hash is the most flexible of Perl's nested structures. It's like building up a record that itself contains other records. At each level, you index into the hash with a string (quoted when necessary). Remember, however, that the key/value pairs in the hash won't come out in any particular order; you can use the `sort` function to retrieve the pairs in whatever order you like.

Composition of a Hash of Hashes

You can create a hash of anonymous hashes as follows:

```
%HoH = (
    flintstones => {
        husband   => "fred",
        pal       => "barney",
    },
    jetsons => {
        husband   => "george",
        wife      => "jane",
        "his boy" => "elroy",  # Key quotes needed.
    },
    simpsons => {
        husband   => "homer",
        wife      => "marge",
        kid       => "bart",
    },
);
```

To add another anonymous hash to `%HoH`, you can simply say:

```
$HoH{ mash } = {
     captain  => "pierce",
     major    => "burns",
     corporal => "radar",
 };
```

Generation of a Hash of Hashes

Here are some techniques for populating a hash of hashes. To read from a file with the following format:

```
flintstones: husband=fred pal=barney wife=wilma pet=dino
```

you could use either of the following two loops:

```
while ( <> ) {
    next unless s/^(.*?):\s*//;
    $who = $1;
    for $field ( split ) {
        ($key, $value) = split /=/, $field;
        $HoH{$who}{$key} = $value;
    }
}

while ( <> ) {
    next unless s/^(.*?):\s*//;
    $who = $1;
    $rec = {};
    $HoH{$who} = $rec;
    for $field ( split ) {
        ($key, $value) = split /=/, $field;
        $rec->{$key} = $value;
    }
}
```

If you have a subroutine `get_family` that returns a list of key/value pairs, you can use it to stuff `%HoH` with either of these three snippets:

```
for $group ( "simpsons", "jetsons", "flintstones" ) {
    $HoH{$group} = { get_family($group) };
}

for $group ( "simpsons", "jetsons", "flintstones" ) {
    @members = get_family($group);
    $HoH{$group} = { @members };
}

sub hash_families {
    my @ret;
    for $group ( @_ ) {
        push @ret, $group, { get_family($group) };
    }
```

```
    return @ret;
}
%HoH = hash_families( "simpsons", "jetsons", "flintstones" );
```

You can append new members to an existing hash like so:

```
%new_folks = (
    wife => "wilma",
    pet  => "dino";
);
for $what (keys %new_folks) {
    $HoH{flintstones}{$what} = $new_folks{$what};
}
```

Access and Printing of a Hash of Hashes

You can set a key/value pair of a particular hash as follows:

```
$HoH{flintstones}{wife} = "wilma";
```

To capitalize a particular key/value pair, apply a substitution to an element:

```
$HoH{jetsons}{"his boy"} =~ s/(\w)/\u$1/;
```

You can print all the families by looping through the keys of the outer hash and then looping through the keys of the inner hash:

```
for $family ( keys %HoH ) {
    print "$family: ";
    for $role ( keys %{ $HoH{$family} } ) {
         print "$role=$HoH{$family}{$role} ";
    }
    print "\n";
}
```

In very large hashes, it may be slightly faster to retrieve both keys and values at the same time using `each` (which precludes sorting):

```
while ( ($family, $roles) = each %HoH ) {
    print "$family: ";
    while ( ($role, $person) = each %$roles ) {
        print "$role=$person ";
    }
    print "\n";
}
```

(Unfortunately, it's the large hashes that really need to be sorted, or you'll never find what you're looking for in the printout.) You can sort the families and then the roles as follows:

```
for $family ( sort keys %HoH ) {
    print "$family: ";
    for $role ( sort keys %{ $HoH{$family} } ) {
         print "$role=$HoH{$family}{$role} ";
    }
    print "\n";
}
```

To sort the families by the number of members (instead of ASCIIbetically [or utf8ically]), you can use `keys` in scalar context:

```
for $family ( sort { keys %{$HoH{$a}} <=> keys %{$HoH{$b}} } keys %HoH ) {
    print "$family: ";
    for $role ( sort keys %{ $HoH{$family} } ) {
         print "$role=$HoH{$family}{$role} ";
    }
    print "\n";
}
```

To sort the members of a family in some fixed order, you can assign ranks to each:

```
$i = 0;
for ( qw(husband wife son daughter pal pet) ) { $rank{$_} = ++$i }

for $family ( sort { keys %{$HoH{$a}} <=> keys %{$HoH{$b}} } keys %HoH ) {
    print "$family: ";
    for $role ( sort { $rank{$a} <=> $rank{$b} } keys %{ $HoH{$family} } ) {
        print "$role=$HoH{$family}{$role} ";
    }
    print "\n";
}
```

Hashes of Functions

When writing a complex application or network service in Perl, you might want to make a large number of commands available to your users. Such a program might have code like this to examine the user's selection and take appropriate action:

```
if    ($cmd =~ /^exit$/i)     { exit }
elsif ($cmd =~ /^help$/i)     { show_help() }
elsif ($cmd =~ /^watch$/i)    { $watch = 1 }
elsif ($cmd =~ /^mail$/i)     { mail_msg($msg) }
elsif ($cmd =~ /^edit$/i)     { $edited++; editmsg($msg); }
elsif ($cmd =~ /^delete$/i)   { confirm_kill() }
else {
    warn "Unknown command: '$cmd'; Try 'help' next time\n";
}
```

You can also store references to functions in your data structures, just as you can store references to arrays or hashes:

```
%HoF = (                            # Compose a hash of functions
    exit    =>  sub { exit },
    help    =>  \&show_help,
    watch   =>  sub { $watch = 1 },
    mail    =>  sub { mail_msg($msg) },
    edit    =>  sub { $edited++; editmsg($msg); },
    delete  =>  \&confirm_kill,
);

if   ($HoF{lc $cmd}) { $HoF{lc $cmd}->() }   # Call function
else { warn "Unknown command: '$cmd'; Try 'help' next time\n" }
```

In the second to last line, we check whether the specified command name (in lowercase) exists in our "dispatch table", `%HoF`. If so, we invoke the appropriate command by dereferencing the hash value as a function, and then pass that function an empty argument list. We could also have dereferenced it as `&{ $HoF{lc $cmd} }()`, or, as of the v5.6 release of Perl, simply `$HoF{lc $cmd}()`.

More Elaborate Records

So far, what we've seen in this chapter are simple, two-level, homogeneous data structures: each element contains the same kind of referent as all the other elements at that level. It certainly doesn't have to be that way. Any element can hold any kind of scalar, which means that it could be a string, a number, or a reference to anything at all. The reference could be an array or hash reference, or a reference to a named or anonymous function, or an object. The only thing you can't do is stuff multiple referents into one scalar. If you find yourself trying to do that, it's a sign that you need an array or hash reference to collapse multiple values into one.

In the sections that follow, you will find code examples designed to illustrate many of the possible types of data you might want to store in a record, which we'll implement using a hash reference. The keys are uppercase strings, a convention sometimes employed (and occasionally unemployed, but only briefly) when the hash is being used as a specific record type.

Composition, Access, and Printing of More Elaborate Records

Here is a record with six disparate fields:

```
$rec = {
    TEXT      => $string,
    SEQUENCE  => [ @old_values ],
```

```
    LOOKUP    => { %some_table },
    THATCODE  => \&some_function,
    THISCODE  => sub { $_[0] ** $_[1] },
    HANDLE    => \*STDOUT,
};
```

The *TEXT* field is a simple string, so you can just print it:

```
print $rec->{TEXT};
```

SEQUENCE and *LOOKUP* are regular array and hash references:

```
print $rec->{SEQUENCE}[0];
$last = pop @{ $rec->{SEQUENCE} };

print $rec->{LOOKUP}{"key"};
($first_k, $first_v) = each %{ $rec->{LOOKUP} };
```

THATCODE is a named subroutine and *THISCODE* is an anonymous subroutine, but they're invoked identically:

```
$that_answer = $rec->{THATCODE}->($arg1, $arg2);
$this_answer = $rec->{THISCODE}->($arg1, $arg2);
```

With an extra pair of braces, you can treat `$rec->{`*HANDLE*`}` as an indirect object:

```
print { $rec->{HANDLE} } "a string\n";
```

If you're using the `IO::Handle` module, you can even treat the handle as a regular object:

```
use IO::Handle;
$rec->{HANDLE}->autoflush(1);
$rec->{HANDLE}->print("a string\n");
```

Composition, Access, and Printing of Even More Elaborate Records

Naturally, the fields of your data structures can themselves be arbitrarily complex data structures in their own right:

```
%TV = (
    flintstones => {
        series   => "flintstones",
        nights   => [ "monday", "thursday", "friday" ],
        members  => [
            { name => "fred",    role => "husband", age  => 36, },
            { name => "wilma",   role => "wife",    age  => 31, },
            { name => "pebbles", role => "kid",     age  =>  4, },
        ],
    },

    jetsons     => {
        series   => "jetsons",
        nights   => [ "wednesday", "saturday" ],
```

```
        members  => [
            { name => "george",  role => "husband", age  => 41, },
            { name => "jane",    role => "wife",    age  => 39, },
            { name => "elroy",   role => "kid",     age  =>  9, },
        ],
    },

    simpsons    => {
        series   => "simpsons",
        nights   => [ "monday" ],
        members  => [
            { name => "homer", role => "husband", age => 34, },
            { name => "marge", role => "wife",    age => 37, },
            { name => "bart",  role => "kid",     age => 11, },
        ],
    },
);
```

Generation of a Hash of Complex Records

Because Perl is quite good at parsing complex data structures, you might just put your data declarations in a separate file as regular Perl code, and then load them in with the `do` or `require` built-in functions. Another popular approach is to use a CPAN module (such as `XML::Parser`) to load in arbitrary data structures expressed in some other language (such as XML).

You can build data structures piecemeal:

```
$rec = {};
$rec->{series} = "flintstones";
$rec->{nights} = [ find_days() ];
```

Or read them in from a file (here, assumed to be in `field=value` syntax):

```
@members = ();
while (<>) {
     %fields = split /[\s=]+/;
     push @members, { %fields };
}
$rec->{members} = [ @members ];
```

And fold them into larger data structures keyed by one of the subfields:

```
$TV{ $rec->{series} } = $rec;
```

You can use extra pointer fields to avoid duplicate data. For example, you might want a `"kids"` field included in a person's record, which might be a reference to an array containing references to the kids' own records. By having parts of your data structure refer to other parts, you avoid the data skew that would result from updating the data in one place but not in another:

```
for $family (keys %TV) {
    my $rec = $TV{$family};   # temporary pointer
    @kids = ();
    for $person ( @{$rec->{members}} ) {
        if ($person->{role} =~ /kid|son|daughter/) {
            push @kids, $person;
        }
    }
    # $rec and $TV{$family} point to same data!
    $rec->{kids} = [ @kids ];
}
```

The `$rec->{kids} = [ @kids ]` assignment copies the array contents—but they are merely references to uncopied data. This means that if you age Bart as follows:

```
$TV{simpsons}{kids}[0]{age}++;            # increments to 12
```

then you'll see the following result, because `$TV{simpsons}{kids}[0]` and `$TV{simpsons}{members}[2]` both point to the same underlying anonymous hash table:

```
print $TV{simpsons}{members}[2]{age};     # also prints 12
```

Now to print the entire `%TV` structure:

```
for $family ( keys %TV ) {
    print "the $family";
    print " is on ", join (" and ", @{ $TV{$family}{nights} }), "\n";
    print "its members are:\n";
    for $who ( @{ $TV{$family}{members} } ) {
        print " $who->{name} ($who->{role}), age $who->{age}\n";
    }
    print "children: ";
    print join (", ", map { $_->{name} } @{ $TV{$family}{kids} } );
    print "\n\n";
}
```

Saving Data Structures

If you want to save your data structures for use by another program later, there are many ways to do it. The easiest way is to use Perl's `Data::Dumper` module, which turns a (possibly self-referential) data structure into a string that can be saved externally and later reconstituted with `eval` or `do`.

```
use Data::Dumper;
$Data::Dumper::Purity = 1;       # since %TV is self-referential
open (FILE, "> tvinfo.perldata") || die "can't open tvinfo: $!";
print FILE Data::Dumper->Dump([\%TV], ['*TV']);
close(FILE)                      || die "can't close tvinfo: $!";
```

A separate program (or the same program) can then read in the file later:

```
open (FILE, "< tvinfo.perldata") || die "can't open tvinfo: $!";
undef $/;                        # read in file all at once
eval <FILE>;                     # recreate %TV
die "can't recreate tv data from tvinfo.perldata: $@" if $@;
close(FILE)                      || die "can't close tvinfo: $!";
print $TV{simpsons}{members}[2]{age};
```

or simply:

```
do "tvinfo.perldata"           || die "can't recreate tvinfo: $! $@";
print $TV{simpsons}{members}[2]{age};
```

`Storable`, another standard module, writes out data structures in very fast, packed binary format. It also supports automatic file locking (provided your system implements the `flock` function), and it even has fancy hooks so object classes can handle their own serialization. Here's how you might save that same structure using `Storable`:

```
use Storable qw(lock_nstore);
lock_nstore(\%TV, "tvdata.storable");
```

And here's how to restore it into a variable that will hold a reference to the retrieved hash:

```
use Storable qw(lock_retrieve);
$TV_ref = lock_retrieve("tvdata.storable");
```

`Storable` also provides a `dclone` function that creates a "deep" copy of a multilevel data structure, which is usually easier than writing your own version.

```
use Storable qw(dclone);
%TV_copy = % { dclone \%TV };
```

For other tricks you can do with `Data::Dumper` and `Storable`, consult their documentation.

Many other solutions are available, with storage formats ranging from packed binary (very fast) to XML (very interoperable). YAML is a good intermediate choice that is actually quite readable. Check out a CPAN mirror near you today!

CHAPTER 10
Packages

In this chapter, we get to start having fun, because we get to start talking about software design. If we're going to talk about good software design, we have to talk about Laziness, Impatience, and Hubris, the basis of good software design.

We've all fallen into the trap of using cut and paste when we should have defined a higher-level abstraction, if only just a loop or subroutine.[1] To be sure, some folks have gone to the opposite extreme of defining ever-growing mounds of higher-level abstractions when they should have used cut and paste.[2] Generally, though, most of us need to think about using more abstraction rather than less.

Caught somewhere in the middle are the people who have a balanced view of how much abstraction is good, but who jump the gun on writing their own abstractions when they should be reusing existing code.[3] Whenever you're tempted to do any of these things, you need to sit back and think about what will do the most good for you and your neighbor over the long haul. If you're going to pour your creative energies into a lump of code, why not make the world a better place while you're at it? (Even if you're only aiming for the program to *succeed*, you need to make sure it fits the right ecological niche.)

The first step toward ecologically sustainable programming is simply this: don't litter in the park. When you write a chunk of code, think about giving the code its own namespace so that your variables and functions don't clobber anyone else's, or vice versa. A namespace is a bit like your home, where you're allowed to be as messy as you like, so long as you keep your external interface to other citizens moderately civil. In Perl, a namespace is called a *package*. Packages

1. This is a form of False *Laziness*.
2. This is a form of False *Hubris*.
3. You guessed it—this is False *Impatience*. But if you're determined to reinvent the wheel, at least try to invent a better one.

provide the fundamental building block upon which the higher-level concepts of modules and classes are constructed.

Like the notion of "home", the notion of "package" is a bit nebulous. Packages are independent of files. You can have many packages in a single file, or a single package that spans several files, just as your home could be one small garret in a larger building (if you're a starving artist), or it could comprise several buildings (if your name happens to be Queen Elizabeth). But the usual size of a home is one building, and the usual size of a package is one file. Perl provides some special help for people who want to put one package in one file, as long as you're willing to give the file the same name as the package and use an extension of *.pm*, which is short for "perl module". The *module* is the fundamental unit of reusability in Perl. Indeed, the way you use a module is with the `use` command, which is a compiler directive that controls the importation of subroutines and variables from a module. Every example of `use` you've seen until now has been an example of module reuse.

The Comprehensive Perl Archive Network, or CPAN, is where you should put your modules if other people might find them useful. Perl has thrived because of the willingness of programmers to share the fruits of their labor with the community. Naturally, CPAN is also where you can find modules that others have thoughtfully uploaded for everyone to use. See Chapter 19 and *http://www.cpan.org* for details.

The trend over the last 25 years or so has been to design computer languages that enforce a state of paranoia. You're expected to program every module as if it were in a state of siege. Certainly there are some feudal cultures where this is appropriate, but not all cultures are like this. In Perl culture, for instance, you're expected to stay out of someone's home because you weren't invited in, not because there are bars on the windows.[4]

This is not a book about object-oriented methodology, and we're not here to convert you into a raving object-oriented zealot, even if you want to be converted. There are already plenty of books out there for that. Perl's philosophy of object-oriented design fits right in with Perl's philosophy of everything else: use object-oriented design where it makes sense, and avoid it where it doesn't. Your call.

In OO-speak, every object belongs to a grouping called a *class*. In Perl, classes and packages and modules are all so closely related that novices can often think of them as being interchangeable. The typical class is implemented by a module

4. But Perl provides some bars if you want them, too. See "Handling Insecure Code" on page 668 in Chapter 20.

that defines a package with the same name as the class. We'll explain all of this in the next few chapters.

When you `use` a module, you benefit from direct software reuse. With classes, you benefit from indirect software reuse when one class uses another through inheritance. And with classes, you get something more: a clean interface to another namespace. Everything in a class is accessed indirectly, insulating the class from the outside world.

As we mentioned in Chapter 8, object-oriented programming in Perl is implemented using references whose referents know to which class they belong. In fact, now that you know references, you know almost everything difficult about objects. The rest of it just "lays under the fingers", as a pianist would say. You will need to practice a little, though.

One of your basic finger exercises consists of learning how to protect different chunks of code from inadvertently tampering with one another's variables. Every chunk of code belongs to a particular *package*, which determines what variables and subroutines are available to it. As Perl encounters a chunk of code, it is compiled into what we call the *current package*. The initial current package is called "`main`", but you can switch the current package to another one at any time with the `package` declaration. The current package determines which symbol table is used to find your variables, subroutines, I/O handles, and formats.

Symbol Tables

The contents of a package are collectively called a *symbol table*. Symbol tables are stored in a hash whose name is the same as the package, but with two colons appended. The `main` symbol table's name is thus `%main::`. Since `main` also happens to be the default package, Perl provides `%::` as an abbreviation for `%main::`.

Likewise, the symbol table for the `Red::Blue` package is named `%Red::Blue::`. As it happens, the `main` symbol table contains all other top-level symbol tables, including itself, so `%Red::Blue::` is also `%main::Red::Blue::`.

When we say that a symbol table "contains" another symbol table, we mean that it contains a reference to the other symbol table. Since `main` is the top-level package, it contains a reference to itself, making `%main::` the same as `%main::main::`, and `%main::main::main::`, and so on, ad infinitum. It's important to check for this special case if you write code that traverses all symbol tables.

Inside a symbol table's hash, each key/value pair matches a variable name to its value. The keys are the symbol identifiers, and the values are the corresponding typeglobs. So when you use the `*`*`NAME`* typeglob notation, you're really just

accessing a value in the hash that holds the current package's symbol table. In fact, the following have (nearly) the same effect:

```
*sym = *main::variable;
*sym = $main::{"variable"};
```

The first is more efficient because the `main` symbol table is accessed at compile time. It will also create a new typeglob by that name if none previously exists, whereas the second form will not.

Since a package is a hash, you can look up the keys of the package and get to all the variables of the package. Since the values of the hash are typeglobs, you can dereference them in several ways. Try this:

```
foreach $symname (sort keys %main::) {
    local *sym = $main::{$symname};
    print "\$$symname is defined\n" if defined $sym;
    print "\@$symname is nonnull\n" if         @sym;
    print "\%$symname is nonnull\n" if         %sym;
}
```

Since all packages are accessible (directly or indirectly) through the `main` package, you can write Perl code to visit every package variable in your program. The Perl debugger does precisely that when you ask it to dump all your variables with the `V` command. Note that if you do this, you won't see variables declared with `my` since those are independent of packages, although you will see variables declared with `our`. See Chapter 18.

Earlier we said that only identifiers are stored in packages other than `main`. That was a bit of a fib: you can use any string you want as the key in a symbol table hash—it's just that it wouldn't be valid Perl if you tried to use a non-identifier directly:

```
$!@#$%           = 0;         # WRONG, syntax error.
${'!@#$%'}       = 1;         # Ok, though unqualified.

${'main::!@#$%'} = 2;         # Can qualify within the string.
print ${ $main::{'!@#$%'} }   # Ok, prints 2!
```

Assignment to a typeglob is an aliasing operation; that is,

```
*dick = *richard;
```

causes variables, subroutines, formats, and file and directory handles accessible via the identifier `richard` to also be accessible via the symbol `dick`. If you want to alias only a particular variable or subroutine, assign a reference instead:

```
*dick = \$richard;
```

That makes $richard and $dick the same variable, but leaves @richard and @dick as separate arrays. Tricky, eh?

This is how the Exporter works when importing symbols from one package to another. For example:

```
*SomePack::dick = \&OtherPack::richard;
```

imports the &richard function from package OtherPack into SomePack, making it available as the &dick function. (The Exporter module is described in the next chapter.) If you precede the assignment with a local, the aliasing will only last as long as the current dynamic scope.

This mechanism may be used to retrieve a reference from a subroutine, making the referent available as the appropriate data type:

```
*units = populate() ;          # Assign \%newhash to the typeglob
print $units{kg};              # Prints 70; no dereferencing needed!

sub populate {
    my %newhash = (km => 10, kg => 70);
    return \%newhash;
}
```

Likewise, you can pass a reference into a subroutine and use it without dereferencing:

```
%units = (miles => 6, stones => 11);
fillerup( \%units );           # Pass in a reference
print $units{quarts};          # Prints 4

sub fillerup {
    local *hashsym = shift;    # Assign \%units to the typeglob
    $hashsym{quarts} = 4;      # Affects %units; no dereferencing needed!
}
```

These are tricky ways to pass around references cheaply when you don't want to have to explicitly dereference them. Note that both techniques only work with package variables; they would not have worked had we declared %units with my.

Another use of symbol tables is for making "constant" scalars:

```
*PI = \3.14159265358979;
```

Now you cannot alter $PI, which is probably a good thing, all in all. This isn't the same as a constant subroutine, which is optimized at compile time. A constant subroutine is one prototyped to take no arguments and to return a constant expression; see the section "Inlining Constant Functions" in Chapter 7, for details. The use constant pragma (see Chapter 29) is a convenient shorthand:

```
use constant PI => 3.14159;
```

Under the hood, this uses the subroutine slot of *PI, instead of the scalar slot used earlier. It's equivalent to the more compact (but less readable):

```
*PI = sub () { 3.14159 };
```

That's a handy idiom to know anyway—assigning a sub {} to a typeglob is the way to give a name to an anonymous subroutine at run time.

Assigning a typeglob reference to another typeglob (*sym = *oldvar) is the same as assigning the entire typeglob, because Perl automatically dereferences the typeglob reference for you. And when you set a typeglob to a simple string, you get the entire typeglob named by that string, because Perl looks up the string in the current symbol table. The following are all equivalent to one another, though the first two compute the symbol table entry at compile time, while the last two do so at run time:

```
*sym =   *oldvar;
*sym =  \*oldvar;       # autodereference
*sym = *{"oldvar"};     # explicit symbol table lookup
*sym =   "oldvar";      # implicit symbol table lookup
```

When you make any of the following assignments, you're replacing just one of the references within the typeglob:

```
*sym = \$frodo;
*sym = \@sam;
*sym = \%merry;
*sym = \&pippin;
```

If you think about it sideways, the typeglob itself can be viewed as a kind of hash, with entries for the different variable types in it. In this case, the keys are fixed, since a typeglob can contain exactly one scalar, one array, one hash, and so on. But you can pull out the individual references, like this:

```
*pkg::sym{SCALAR}      # same as \$pkg::sym
*pkg::sym{ARRAY}       # same as \@pkg::sym
*pkg::sym{HASH}        # same as \%pkg::sym
*pkg::sym{CODE}        # same as \&pkg::sym
*pkg::sym{GLOB}        # same as \*pkg::sym
*pkg::sym{IO}          # internal file/dir handle, no direct equivalent
*pkg::sym{NAME}        # "sym" (not a reference)
*pkg::sym{PACKAGE}     # "pkg" (not a reference)
```

You can say *foo{PACKAGE} and *foo{NAME} to find out what name and package the *foo symbol table entry comes from. This may be useful in a subroutine that is passed typeglobs as arguments:

```
sub identify_typeglob {
    my $glob = shift;
    print "You gave me ", *{$glob}{PACKAGE}, "::", *{$glob}{NAME}, "\n";
}
```

```
identify_typeglob(*foo);
identify_typeglob(*bar::glarch);
```

This prints:

```
You gave me main::foo
You gave me bar::glarch
```

The `*foo{`*`THING`*`}` notation can be used to obtain references to individual elements of `*foo`. See the section "Symbol Table References" in Chapter 8 for details.

This syntax is primarily used to get at the internal filehandle or directory handle reference, because the other internal references are already accessible in other ways. (The old `*foo{FILEHANDLE}` is no longer supported to mean `*foo{IO}`.) But we thought we'd generalize it because it looks kind of pretty. Sort of. You probably don't need to remember all this unless you're planning to write another Perl debugger.

Qualified Names

You can refer to *identifiers*[5] in other packages by prefixing ("*qualifying*") the identifier with the package name and a double colon: `$Package::Variable`. If the package name is null, the `main` package is assumed. That is, `$::sail` is equivalent to `$main::sail`.[6]

The old package delimiter was a single quote, so in very old Perl programs you'll see variables like `$main'sail` and `$somepack'horse`. But the double colon is now the preferred delimiter, in part because it's more readable to humans, and in part because it's more readable to *emacs* macros. It also makes C++ programmers feel like they know what was going on—as opposed to using the single quote as the separator, which was there to make Ada programmers feel like they knew what's going on. Because the old-fashioned syntax is still supported for backward compatibility, if you try to use a string like `"This is $owner's house"`, you'll be accessing `$owner::s`; that is, the `$s` variable in package `owner`, which is probably not what you meant. Use braces to disambiguate, as in `"This is ${owner}'s house"`.

5. By identifiers, we mean the names used as symbol table keys for accessing scalar variables, array variables, hash variables, subroutines, file or directory handles, and formats. Syntactically speaking, labels are also identifiers, but they aren't put into a particular symbol table; rather, they are attached directly to the statements in your program. Labels cannot be package-qualified.

6. To clear up another bit of potential confusion, in a variable name like `$main::sail`, we use the term "identifier" to talk about `main` and `sail`, but not `main::sail` together. We call that a variable name instead, because identifiers cannot contain colons.

The double colon can be used to chain together identifiers in a package name: `$Red::Blue::var`. This means the `$var` belonging to the `Red::Blue` package. The `Red::Blue` package has nothing to do with any `Red` or `Blue` packages that might happen to exist. That is, a relationship between `Red::Blue` and `Red` or `Blue` may have meaning to the person writing or using the program, but it means nothing to Perl. (Well, other than the fact that, in the current implementation, the symbol table `Red::Blue` happens to be stored in the symbol table `Red`. But the Perl language makes no use of that directly.)

Long ago, variables beginning with an underscore were forced into the `main` package, but we decided it was more useful for package writers to be able to use a leading underscore to indicate semiprivate identifiers meant for internal use by that package only. (Truly private variables can be declared as file-scoped lexicals, but that works best when the package and module have a one-to-one relationship, which is common but not required.)

The `%SIG` hash (which is for trapping signals; see Chapter 15) is also special. If you define a signal handler as a string, it's assumed to refer to a subroutine in the `main` package unless another package name is explicitly used. Use a fully qualified signal handler name if you want to specify a particular package, or avoid strings entirely by assigning a typeglob or a function reference instead:

```
$SIG{QUIT} = "Pkg::quit_catcher"; # fully qualified handler name
$SIG{QUIT} = "quit_catcher";      # implies "main::quit_catcher"
$SIG{QUIT} = *quit_catcher;       # forces current package's sub
$SIG{QUIT} = \&quit_catcher;      # forces current package's sub
$SIG{QUIT} = sub { print "Caught SIGQUIT\n" };   # anonymous sub
```

The Default Package

The default package is `main`, just like the top-level subroutine name in C. Unless you say otherwise (coming up), all variables are in this package. These are the same:

```
#!/usr/bin/perl

$name       = 'Amelia';
$main::name = 'Amelia';

$type       = 'Camel';
$main::type = 'Camel';
```

Under `strict`, you have to say otherwise because that pragma doesn't let you use undeclared variables:

```
#!/usr/bin/perl

use v5.12;

$name       = 'Amelia';  # compile-time error
$main::name = 'Amelia';

$type       = 'Camel';   # compile-time error
$main::type = 'Camel';
```

Only identifiers (names starting with letters or an underscore) are stored in a package's symbol table. All other symbols are kept in the `main` package, including the nonalphabetic variables, like `$!`, `$?`, and `$_`.[7] In addition, when unqualified, the identifiers `STDIN`, `STDOUT`, `STDERR`, `ARGV`, `ARGVOUT`, `ENV`, `INC`, and `SIG` are forced to be in package `main`, even when used for other purposes than their built-in ones. Don't name your package `m`, `s`, `y`, `tr`, `q`, `qq`, `qr`, `qw`, or `qx` unless you're looking for a lot of trouble. For instance, you won't be able to use the qualified form of an identifier as a filehandle because it will be interpreted instead as a pattern match, a substitution, or a transliteration.

Changing the Package

The notion of "current package" is both a compile-time and runtime concept. Most variable name lookups happen at compile time, but runtime lookups happen when symbolic references are dereferenced, and also when new bits of code are parsed under `eval`. In particular, when you `eval` a string, Perl knows which package the `eval` was invoked in and propagates that package inward when evaluating the string. (You can always switch to a different package inside the `eval` string, of course, since an `eval` string counts as a block, just like a file loaded in with `do`, `require`, or `use`.)

For this reason, every `package` declaration must declare a complete package name. No package name ever assumes any kind of implied "prefix", even if (seemingly) it is declared within the scope of some other package declaration.

Alternatively, if an `eval` wants to find out what package it's in, the special symbol `__PACKAGE__` contains the current package name. Since you can treat it as a string, you could use it in a symbolic reference to access a package variable. But if you

7. You can have a lexical `$_` in v5.10, though.

were doing that, chances are you should have declared the variable with `our` instead so it could be accessed as if it were a lexical.

Any variable not declared with `my` is associated with a package—even seemingly omnipresent variables like `$_` and `%SIG`. Other variables use the current package, unless they are qualified:

```
$name = 'Amelia';           # name in current package

$Animal::name = 'Camelia';  # name in Animal package
```

The `package` declaration changes the default package for the rest of the scope (block, file, or `eval`—whichever comes first) or until another `package` declaration at the same level, which supersedes the earlier one (this is a common practice):

```
package Animal;

$name = 'Camelia';          # $Animal::name
```

It's important to note, and to repeat, that the `package` does not create a scope, so it cannot hide lexical variables in the same scope:

```
my $type = 'Camel';

package Animal;

print "Type is $type\n";    # the lexical $type, so, "Camel"
$type = 'Ram';

package Zoo;

print "Type is $type\n";    # the lexical $type, so, "Ram"
```

To preferentially use the package version of a variable with the same name as a lexical variable in the same scope, use `our`. Beware, though. This makes the version for the current package the default for the rest of the scope, even if the default package changes:

```
my $type = 'Camel';

package Animal;

our $type = 'Ram';
print "Type is $type\n";    # the package $type, so, "Ram"

package Zoo;

print "Type is $type\n";    # the Animal $type, so, "Ram"
```

In package `Zoo`, `$type` is still the `$Animal::type` version. The `our` applies for the rest of the scope, not the rest of the package declaration. This can be slightly

confusing. Remember, the `package` only changes the default package name; it does not end or begin scopes. Once you change the package, all subsequent undeclared identifiers are placed in the symbol table belonging to the current package. That's it.

Typically, a `package` declaration will be the first statement of a file meant to be included by `require` or `use`. But again, that's by convention. You can put a `package` declaration anywhere you can put a statement. You could even put it at the end of a block, in which case it would have no effect whatsoever. You can switch into a package in more than one place; a package declaration merely selects the symbol table to be used by the compiler for the rest of that block. This is how a given package can span more than one file.

As of recent versions, the version of a package may be specified on the package declaration line:

```
package Zoo v3.1.4;
```

Additionally, a bracketed form that looks more like standard blocks is available in v5.14 and later. This limits the package's scope to the inside of the block. We could avoid the problem of name spillage mentioned earlier by using this feature:

```
my $type = 'Camel';

package Animal {
    our $type = 'Ram';
    print "Type is $type\n";    # the package $type, so, "Ram"
}

package Zoo v3.1.4 {
    print "Type is $type\n";    # the outer $type, so, "Camel"
}
```

Autoloading

Normally, you can't call a subroutine that isn't defined. However, if there is a subroutine named `AUTOLOAD` in the undefined subroutine's package (or in the case of an object method, in the package of any of the object's base classes), then the `AUTOLOAD` subroutine is called with the same arguments that would have been passed to the original subroutine. You can define the `AUTOLOAD` subroutine to return values just like a regular subroutine, or you can make it define the routine that didn't exist and then call that as if it'd been there all along.

The fully qualified name of the original subroutine magically appears in the package-global `$AUTOLOAD` variable, in the same package as the `AUTOLOAD` routine.

Here's a simple example that gently warns you about undefined subroutine invocations instead of exiting:

```
sub AUTOLOAD {
    our $AUTOLOAD;
    warn "Attempt to call $AUTOLOAD failed.\n";
}

blarg(10);              # our $AUTOLOAD will be set to main::blarg
print "Still alive!\n";
```

Or, you can return a value on behalf of the undefined subroutine:

```
sub AUTOLOAD {
    our $AUTOLOAD;
    return "I see $AUTOLOAD(@_)\n";
}

print blarg(20);        # prints: I see main::blarg(20)
```

Your `AUTOLOAD` subroutine might load a definition for the undefined subroutine using `eval` or `require`, or use the glob assignment trick discussed earlier, and then execute that subroutine using the special form of `goto` that can erase the stack frame of the `AUTOLOAD` routine without a trace. Here we define the subroutine by assigning a closure to the glob:

```
sub AUTOLOAD {
    my $name = our $AUTOLOAD;
    *$AUTOLOAD = sub { print "I see $name(@_)\n" };
    goto &$AUTOLOAD;    # Restart the new routine.
}

blarg(30);              # prints: I see main::blarg(30)
glarb(40);              # prints: I see main::glarb(40)
blarg(50);              # prints: I see main::blarg(50)
```

The standard `AutoSplit` module is used by module writers to split their modules into separate files (with filenames ending in *.al*), each holding one routine. The files are placed in the *auto/* directory of your system's Perl library, after which the files can be autoloaded on demand by the standard `AutoLoader` module.

A similar approach is taken by the `SelfLoader` module, except that it autoloads functions from the file's own `DATA` area, which is less efficient in some ways and more efficient in others. Autoloading of Perl functions by `AutoLoader` and `SelfLoader` is analogous to dynamic loading of compiled C functions by `DynaLoader`, except that autoloading is done at the granularity of the function call, whereas dynamic loading is done at the granularity of the complete module, and will usually link in many C or C++ functions all at once. (Note that many Perl programmers get along just fine without the `AutoSplit`, `AutoLoader`, `SelfLoader`, or

DynaLoader modules. You just need to know that they're there in case you *can't* get along just fine without them.)

One can have great fun with AUTOLOAD routines that serve as wrappers to other interfaces. For example, let's pretend that any function that isn't defined should just call system with its arguments. All you'd do is this:

```
sub AUTOLOAD {
    my $program = our $AUTOLOAD;
    $program =~ s/.*::///;  # trim package name
    system($program, @_);
}
```

(Congratulations, you've now implemented a rudimentary form of the Shell module that comes standard with Perl.) You can call your autoloader (on Unix) like this:

```
date();
who("am", "i");
ls("-l");
echo("Abadugabudabuda...");
```

In fact, if you predeclare the functions you want to call that way, you can pretend they're built-ins and omit the parentheses on the call:

```
sub date (;$$);       # Allow zero to two arguments.
sub who (;$$$$);      # Allow zero to four args.
sub ls;               # Allow any number of args.
sub echo ($@);        # Allow at least one arg.

date;
who "am", "i";
ls "-l";
echo "That's all, folks!";
```

As of v5.8, AUTOLOAD can have an :lvalue attribute.

```
package Chameau;
use v5.14;

sub new { bless {}, $_[0] }

sub AUTOLOAD :lvalue {
    our $AUTOLOAD;
    my $method = $AUTOLOAD =~ s/.*::///r;
    $_[0]->{$method};
}

1;
```

With that method, you can access it or assign to it:

```
use v5.14;
use Chameau;

my $chameau = Chameau->new;

$chameau->awake = 'yes';

say $chameau->awake;
```

Or, you can make the last value a symbolic reference:

```
package Trampeltier;

sub new { bless {}, $_[0] }
sub AUTOLOAD :lvalue { no strict 'refs'; *{$AUTOLOAD} }

1;
```

so you can define the method by assigning to it:

```
use Trampeltier;

my $trampeltier = Trampeltier->new;

$trampeltier->name = sub { 'Amelia' };
```

We're not sure that you'd ever want to do that, though.

CHAPTER 11
Modules

The module is the fundamental unit of code reuse in Perl. Under the hood, it's just a package defined in a file of the same name (with *.pm* on the end). In this chapter, we'll explore how you can use other people's modules and create your own.

Perl comes bundled with hundreds of useful modules, which you can find in the *lib* directory of your Perl distribution, which are decided at the time you (or someone) built *perl*. You can see where these directories are with the *–V* switch:

```
% perl -V
Summary of my perl5 (revision 5 version 14 subversion 1) configuration:

...
Built under darwin
Compiled at Jul  5 2011 21:43:59
@INC:
  /usr/local/perl/lib/site_perl/5.14.2/darwin-2level
  /usr/local/perl/lib/site_perl/5.14.2
  /usr/local/perl/lib/5.14.2/darwin-2level
  /usr/local/perl/lib/5.14.2
  .
```

You can see all of the modules that come with *perl* with *corelist*, which also comes with *perl*:

```
% corelist -v 5.014
```

All standard modules also have extensive online documentation, which (horrors) will most likely be more up to date than this book. Try the *perldoc* command to read the documentation:

```
% perldoc Digest::MD5
```

The Comprehensive Perl Archive Network (CPAN) contains a worldwide repository of modules contributed by the Perl community, and is discussed in Chapter 19. See also *http://www.cpan.org*.

Loading Modules

Modules come in two flavors: traditional and object-oriented. Traditional modules define subroutines and variables for the caller to import and use. Object-oriented modules function as class definitions and are accessed through method calls, described in Chapter 12. Some modules do both.

Perl modules are typically included in your program by saying:

```
use MODULE;
```

This is equivalent to:

```
BEGIN {
  require MODULE;
  MODULE->import();
}
```

This happens during the compile phase, so any code in the module runs during the compile phase. This usually isn't a problem since most code in modules lives in subroutines or methods. Some modules may load additional modules, XS code, and other code components. Since Perl handles a `use` when it runs into it, any modifications to `@INC` need to happen before the `use`. You probably want the `lib` pragma (see Chapter 29), which you also load with `use`.

If you want to load the module during the run phase, perhaps delaying its inclusion until you run a subroutine that needs it, you can use `require`:

```
require MODULE;
```

MODULE must be a package name that translates to the module's file. The `use` translates `::` to `/` and then appends a *.pm* to the end. It looks for that name in `@INC`. If your module is named `Animal::Mammal::HoneyBadger`, this will look for *Animal/Mammal/HoneyBadger.pm*. Once loaded, the path where Perl found the file shows up in `%INC`. Perl loads a file once. Before it tries to load a file, it looks in `%INC` to see whether it is already loaded. If so, it can reuse the result.

You can load files directly with `require`, using the right path separator (which may not be portable):

```
require FILE;
require 'Animal/Mammal/HoneyBadger.pm';
```

In general, however, `use` is preferred over `require` because it looks for modules during compilation, so you learn about any mistakes sooner.

Some modules offer additional functionality in its import list. This list becomes the argument list for `import`:

```
use MODULE LIST;
```

like this:

```
BEGIN {
  require MODULE;
  MODULE->import(LIST);
}
```

A module's `import` can do whatever it likes, but most modules stick with a version they inherit from `Exporter`, which we'll talk more about later. Typically, the `import` puts symbols (subroutines and variables) in the current namespace so they are available for the rest of the compilation unit. Some modules have a default import list.

For example, the `Hash::Util` module exports several symbols for special hash action. The `use` pulls in the `lock_keys` symbol, which is then available for the rest of the compilation unit:

```
use Hash::Util qw(lock_keys);

lock_keys( my %hash, qw(name location) );
```

Even without a *LIST*, it might import some symbols based on the module's default list.[1] The `File::Basename` module automatically imports a `basename`, `dirname`, and `fileparse`:

```
use File::Basename;

say basename($ARGV[0]);
```

If you want absolutely no imports, you can supply an explicit empty list:

```
use MODULE ();
```

Sometimes you want to use a specific version (or later) of a module, usually to avoid known issues in an earlier version or to use a newer, nonbackward-compatible API:

```
use MODULE VERSION LIST;
```

1. This is generally considered impolite now. Making people specify what they want helps to head off conflicts in two different modules importing the same thing.

Normally, any version greater than or equal to *VERSION* is fine. You can't specify exactly a version or a range of versions. However, the module might decide to do something different, since it's really the `VERSION` method that decides what to do.

Unloading Modules

The opposite of `use` is `no`. Instead of calling `import`, it calls `unimport`. That method can do whatever it likes. The syntax is the same:

```
no MODULE;
no MODULE LIST;
no MODULE VERSION;
no MODULE VERSION LIST;
```

You may only want some symbols available for a short time. For instance, the `Moose` module, an object system built on top of Perl's built-in features, imports many convenience methods. The `has` method declares attributes, but once you are done with those names, they don't need to stick around. At the end of the section that needs them, you can unimport them with `no`:

```
package Person;
use Moose;

has "first_name" => (is => "rw", isa => "Str");
has "last_name"  => (is => "rw", isa => "Str");

sub full_name {
    my $self = shift;
    $self->first_name . " " . $self->last_name
}

no Moose; # keywords are removed from the Person package
```

To temporarily turn off a strict feature, unimport the feature that's in the way. Use the smallest scope possible so you don't miss other problems:

```
my $value = do {
  no strict "refs";

  ${ "${{class}::name}" }; # symbolic reference
};
```

Similarly, you might need to temporarily turn off a type of warning, so you unimport that type of warning:

```
use warnings;
{
    no warnings 'redefine';
    local *badger = sub { ... };
    ...;
}
```

Creating Modules

In this chapter, we'll merely show you the code portion of a module. There's a lot more to creating a *distribution*, which we cover in Chapter 19.

Naming Modules

A good name is one of the most important parts of creating a module. Once you choose a name and people start using your module, you have to live with that name virtually forever as your users refuse to update their code. If you are uploading your module to CPAN, you want people to be able to find it easily, too. You can read some naming guidelines at PAUSE.

Module names should be capitalized unless they're functioning as pragmas. Pragmas (see Chapter 29) are in effect compiler directives (hints for the compiler), so we reserve the lowercase pragma names for future use.

If you want to make a private module whose name should never conflict with a module in the Standard Library or on CPAN, you can use the `Local` namespace. It's not forbidden from CPAN, but by convention it's not used.

A Sample Module

Earlier, we said that there are two ways for a module: traditional or object-oriented. We'll show you the shortest examples of each.

An object-oriented module is the easy one to show since it doesn't need much infrastructure to communicate with its user. Everything happens through methods:

```
package Bestiary::OO 1.001;

sub new {
    my( $class, @args ) = @_;
    bless {}, $class;
}

sub camel  { "one-hump dromedary" }
sub weight { 1024 }
```

```
### more methods here

1;
```

A program that uses it does all its work through methods:

```
use v5.10;
use Bestiary::OO;

my $bestiary = Bestiary::OO->new;   # class method

say "Animal is ",   $bestiary->camel(),
    " has weight ", $bestiary->weight();
```

To construct a traditional module called `Bestiary`, create a file called *Bestiary.pm* that looks like this:

```
package Bestiary 1.001;
use parent qw(Exporter);

our @EXPORT    = qw(camel);    # Symbols to be exported by default
our @EXPORT_OK = qw($weight);  # Symbols to be exported on request

### Include your variables and functions here

sub camel { "one-hump dromedary" }

$weight = 1024;

1; # end with an expression that evaluates to true
```

A program can now say `use Bestiary` to be able to access the `camel` function (but not the `$weight` variable), and `use Bestiary qw(camel $weight)` to access both the function and the variable:

```
use v5.10;

use Bestiary qw(camel $weight);

say "Animal is ", camel(), " has weight $weight";
```

You can also create modules that dynamically load code written in C, although we don't cover that here.

Module Privacy and the Exporter

Perl does not automatically patrol private/public borders within its modules—unlike languages such as C++, Java, and Ada, Perl isn't obsessed with enforced privacy. A Perl module would prefer that you stay out of its living room because you weren't invited, not because it has a shotgun.

The module and its user have a contract, part of which is common law and part of which is written. Part of the common law contract is that a module refrain from changing any namespace it wasn't asked to change. The written contract for the module (that is, the documentation) may make other provisions. But then, having read the contract, you presumably know that when you say `use RedefineTheWorld` you're redefining the world, and you're willing to risk the consequences. The most common way to redefine worlds is to use the `Exporter` module. As we'll see later in this chapter, you can even redefine built-ins with this module.

When you `use` a module, the module typically makes some variables or functions available to your program or, more specifically, to your program's current package. This act of exporting symbols from the module (and thus importing them into your program) is sometimes called *polluting* your namespace. Most modules use `Exporter` to do this; that's why near the top most modules say something like one of these:

```
use parent qw(Exporter);

require Exporter;
our @ISA = ("Exporter");
```

These two lines make the module inherit from the `Exporter` class. Inheritance is described in the next chapter, but all you need to know is our `Bestiary` module can now export symbols into other packages with lines like these:

```
our @EXPORT    = qw($camel %wolf ram);              # Export by default
our @EXPORT_OK = qw(leopard @llama $emu);           # Export by request
our %EXPORT_TAGS = (                               # Export as group
                    camelids => [qw($camel @llama)],
                    critters => [qw(ram $camel %wolf)],
                   );
```

From the viewpoint of the exporting module, the `@EXPORT` array contains the names of variables and functions to be exported by default: what your program gets when it says `use Bestiary`. Variables and functions in `@EXPORT_OK` are exported only when the program specifically requests them in the `use` statement. Finally, the key/value pairs in `%EXPORT_TAGS` allow the program to include particular groups of the symbols listed in `@EXPORT` and `@EXPORT_OK`.

From the viewpoint of the importing package, the `use` statement specifies a list of symbols to import, a group named in `%EXPORT_TAGS`, a pattern of symbols, or nothing at all, in which case the symbols in `@EXPORT` would be imported from the module into your program.

You can include any of these statements to import symbols from the `Bestiary` module:

```
use Bestiary;                   # Import @EXPORT symbols
use Bestiary ();                # Import nothing
use Bestiary qw(ram @llama);    # Import the ram function and @llama array
use Bestiary qw(:camelids);     # Import $camel and @llama
use Bestiary qw(:DEFAULT);      # Import @EXPORT symbols
use Bestiary qw(/am/);          # Import $camel, @llama, and ram
use Bestiary qw(/^\$/);         # Import all scalars
use Bestiary qw(:critters !ram); # Import the critters, but exclude ram
use Bestiary qw(:critters !:camelids);
                                # Import critters, but no camelids
```

Leaving a symbol off the export lists (or removing it explicitly from the import list with the exclamation point) does not render it inaccessible to the program using the module. The program can always access the contents of the module's package by fully qualifying the package name, like `%Bestiary::gecko`. (Because lexical variables do not belong to packages, privacy is still possible; see "Private Methods" on page 440 in the next chapter.)

You can say `BEGIN { $Exporter::Verbose=1 }` to see how the specifications are being processed and what is actually being imported into your package.

The `Exporter` is itself a Perl module, and, if you're curious, you can see the typeglob trickery it uses to export symbols from one package into another. Inside the `Exporter` module, the key function is named `import`, which performs the necessary aliasing to make a symbol in one package appear to be in another. In fact, a `use Bestiary` *`LIST`* statement is exactly equivalent to:

```
BEGIN {
    require Bestiary;
    import Bestiary LIST;
}
```

This means that your modules don't have to use the `Exporter`. A module can do anything it jolly well pleases when it's used, since `use` just calls the ordinary `import` method for the module, and you can define that method to do anything you like.

Exporting without using Exporter's import method

The `Exporter` defines a method called `export_to_level`, used when (for some reason) you can't directly call `Exporter`'s `import` method. The `export_to_level` method is invoked like this:

```
MODULE->export_to_level($where_to_export, @what_to_export);
```

where $where_to_export is an integer indicating how far up the calling stack to export your symbols, and @what_to_export is an array listing the symbols to export (usually @_).

For example, suppose our Bestiary had an import function of its own:

```
package Bestiary;
@ISA = qw(Exporter);
@EXPORT_OK = qw ($zoo);

sub import {
    $Bestiary::zoo = "menagerie";
}
```

The presence of this import function prevents Exporter's import function from being inherited. If you want Bestiary's import function to behave just like Exporter's import function once it sets $Bestiary::zoo, you'd define it as follows:

```
sub import {
    $Bestiary::zoo = "menagerie";
    Bestiary->export_to_level(1, @_);
}
```

This exports symbols to the package one level "above" the current package. That is, to whatever program or module is using the Bestiary.

If this is all you need, however, you probably don't want to inherit from Exporter. You can import the import method:

```
package Bestiary;
use Exporter qw(import);    # v5.8.3 and later
```

Version checking

If your module defines a $VERSION variable, a program using your module can ensure that the module is sufficiently recent. For example:

```
use Bestiary 3.14;   # The Bestiary must be version 3.14 or later
use Bestiary v1.0.4; # The Bestiary must be version 1.0.4 or later
```

These are converted into calls to Bestiary->VERSION, which you inherit from UNIVERSAL (see Chapter 12).

If you use require, you can still check the version by calling VERSION directly:

```
require Bestiary;
Bestiary->VERSION( '2.71828' );
```

Now, module versions are a more complicated thing than they should be, and some of that is inescapable history. Versions started off as whatever Perl would find in $VERSION in the module's package. That could be a number, a string, or the result of an operation. For many years, there was no standardization of version

strings, so people would make exotic versions like "`1.23alpha`".[2] These turn out to be the same thing:

```
our $VERSION = 1.002003;
our $VERSION = '1.002003';
our $VERSION = v1.2.3;

use version;
our $VERSION = version->new( "v1.2.3" );
```

That was fine for awhile, but then Perl changed its own version number scheme between 5.005 and v5.6, just like that. Now that was a *v-string*, a special sort of literal that represented a version and could contain as many dots as you liked. These v-strings were really integers packed as characters. Next, Perl got the idea of the version object and the `version` module. If you have to support truly ancient versions of Perl (first, we're sorry: v5.6 came out last millennium already), best stick to simple strings.

Perl assumes that the part after the decimal point is three places, which makes comparisons odd. So version `1.9` comes before version `1.10`, even though the `.9` sorts after the `.1` lexicographically. Perl sees those each as `1.009` and `1.010`. Do you have to like that? No. Do you have to live with it? Yes. (But, by all means, use the `v1.9` form everywhere you can get away with it, since that will be future compatible.)

In addition to all of that, a convention for developmental, nonreleased versions developed. Putting a `_` or `-TRIAL` in your version, many of the CPAN tools won't consider it a stable release. This lets authors upload to CPAN with the benefit of CPAN Testers and prerelease user testing without forcing everyone else to use the potentially broken release (see Chapter 19).

```
our $VERSION = '1.234_001';
```

The quotes are necessary there to preserve the underscore, which would otherwise be parsed away, because the compiler permits them in numeric literals.

David Golden says more about this in "Version numbers should be boring" (*http://www.dagolden.com/index.php/369/version-numbers-should-be-boring/*).

Note that in very recent Perls you can get rid of the `our` declaration entirely, and just write:

```
package Bestiary v1.2.3;
```

2. For a sampling of some of the nonsense, see the work that the `CPAN:DistnameInfo` module does to recognize a version.

Managing unknown symbols

In some situations, you may want to *prevent* certain symbols from being exported. Typically, this applies to modules that have functions or constants that might not make sense on some systems. You can prevent the `Exporter` from exporting those symbols by placing them in the `@EXPORT_FAIL` array.

If a program tries to import any of these symbols, the `Exporter` gives the module an opportunity to respond in some way before generating an error. It does this by calling an `export_fail` method with a list of the failed symbols, which you might define as follows (assuming your module uses the `Carp` module):

```
use Carp;
sub export_fail {
    my $class = shift;
    carp "Sorry, these symbols are unavailable: @_";
    return @_;
}
```

The `Exporter` provides a default `export_fail` method, which simply returns the list unchanged and makes the `use` fail with an exception raised for each symbol. If `export_fail` returns an empty list, no error is recorded and all requested symbols are exported.

Tag-handling utility functions

Since the symbols listed within `%EXPORT_TAGS` must also appear in either `@EXPORT` or `@EXPORT_OK`, the `Exporter` provides two functions to let you add those tagged sets of symbols:

```
%EXPORT_TAGS = (foo => [qw(aa bb cc)], bar => [qw(aa cc dd)]);

Exporter::export_tags("foo");     # add aa, bb and cc to @EXPORT
Exporter::export_ok_tags("bar");  # add aa, cc and dd to @EXPORT_OK
```

Specifying names that are not tags is erroneous.

Overriding Built-in Functions

Many built-in functions may be *overridden*, although (like knocking holes in your walls) you should do this only occasionally and for good reason. Typically, this might be done by a package attempting to emulate missing built-in functionality on a non-Unix system. (Do not confuse overriding with *overloading*, which adds additional object-oriented meanings to built-in operators, but doesn't override much of anything. See the discussion of the `overload` module in Chapter 13 for more on that.)

Overriding may be done only by importing the name from a module—ordinary predeclaration isn't good enough. To be perfectly forthcoming, it's the assignment of a code reference to a typeglob that triggers the override, as in `*open = \&myopen`. Furthermore, the assignment must occur in some other package; this makes accidental overriding through typeglob aliasing intentionally difficult. However, if you really want to do your own overriding, don't despair, because the `subs` pragma lets you predeclare subroutines via the import syntax, so those names then override the built-in ones:

```
use subs qw(chdir chroot chmod chown);
chdir $somewhere;
sub chdir { ... }
```

In general, modules should not export built-in names like `open` or `chdir` as part of their default `@EXPORT` list, since these names may sneak into someone else's namespace and change the semantics unexpectedly. If the module includes the name in the `@EXPORT_OK` list instead, importers will be forced to explicitly request that the built-in name be overridden, thus keeping everyone honest.

The original versions of the built-in functions are always accessible via the `CORE` pseudopackage. Therefore, `CORE::chdir` will always be the version originally compiled into Perl, even if the `chdir` keyword has been overridden.

Well, almost always. The foregoing mechanism for overriding built-in functions is restricted, quite deliberately, to the package that requests the import. But there is a more sweeping mechanism you can use when you wish to override a built-in function everywhere, without regard to namespace boundaries. This is achieved by defining the function in the `CORE::GLOBAL` pseudopackage. Below is an example that replaces the `glob` operator with something that understands regular expressions. (Note that this example does not implement everything needed to cleanly override Perl's built-in `glob`, which behaves differently depending on whether it appears in a scalar or list context. Indeed, many Perl built-ins have such context-sensitive behaviors, and any properly written override should adequately support these. For a fully functional example of glob overriding, study the `File::Glob` module bundled with Perl.) Anyway, here's the antisocial version:

```
*CORE::GLOBAL::glob = sub {
     my $pat = shift;
     my @got;
     local *D;
     if (opendir D, ".") {
         @got = grep /$pat/, readdir D;
         closedir D;
     }
     return @got;
 }

 package Whatever;

 print <^[a-z_]+\.pm\$>;       # show all pragmas in the current directory
```

By overriding `glob` globally, this preemptively forces a new (and subversive) behavior for the `glob` operator in *every* namespace, without the cognizance or cooperation of modules that own those namespaces. Naturally, this must be done with extreme caution—if it must be done at all. And it probably mustn't.

Our overriding philosophy is: it's nice to be important, but it's more important to be nice.

CHAPTER 12
Objects

First of all, you need to understand packages and modules; see Chapter 10 and Chapter 11. You also need to know about references and data structures; see Chapter 8 and Chapter 9. It's also helpful to understand a little about object-oriented programming (OOP), so in the next section we'll give you a little course on OOL (object-oriented lingo).

Perl's object-oriented model is probably a lot different than any you have used from other languages. As you go through this chapter, it's best to forget anything you know from those languages.

Brief Refresher on Object-Oriented Lingo

An *object* is a data structure with a collection of behaviors. We generally speak of the behaviors as acted out by the object directly, sometimes to the point of anthropomorphizing the object. For example, we might say that a rectangle "knows" how to display itself on the screen, or that it "knows" how to compute its own area.

Every object gets its behaviors by virtue of being an *instance* of a *class*. The class defines *methods*: behaviors that apply to the class and its instances. When the distinction matters, we refer to methods that apply only to a particular object as *instance methods*, and those that apply to the entire class as *class methods*. But this is only a convention—to Perl, a method is just a method, distinguished only by the type of its first argument.

You can think of an instance method as some action performed by a particular object, such as printing itself out, copying itself, or altering one or more of its properties ("set this sword's name to Andúril"). Class methods might perform operations on many objects collectively ("display all swords") or provide other operations that aren't dependent on any particular object ("from now on,

whenever a new sword is forged, register its owner in this database"). Methods that generate instances (objects) of a class are called *constructor methods* ("create a sword with a gem-studded hilt and a secret inscription"). These are usually class methods ("make me a new sword") but can also be instance methods ("make a copy just like this sword here").

A class may *inherit* methods from *parent classes*, also known as *base classes* or *superclasses*. If it does, it's known as a *derived class* or a *subclass*. (Confusing the issue further, some literature uses "base class" to mean a "most super" superclass. That's not what we mean by it.) Inheritance makes a new class that behaves just like an existing one but also allows for altered or added behaviors not found in its parents. When you invoke a method whose definition is not found in the class, Perl automatically consults the parent classes for a definition. For example, a sword class might inherit its `attack` method from a generic blade class. Parents can themselves have parents, and Perl will search those classes as well when it needs to. The blade class might in turn inherit its `attack` method from an even more generic weapon class.

When the `attack` method is invoked on an object, the resulting behavior may depend on whether that object is a sword or an arrow. Perhaps there wouldn't be any difference at all, which would be the case if both swords and arrows inherited their attacking behavior from the generic weapon class. But if there were a difference in behaviors, the method dispatch mechanism would always select the `attack` method suitable for the object in question. The useful property of always selecting the most appropriate behavior for a particular type of object is known as *polymorphism*. It's an important form of not caring.

You have to care about the innards of your objects when you're implementing a class, but when you *use* a class, you should be thinking of its objects as black boxes. You can't see what's inside, you shouldn't need to know how it works, and you interact with the box only on its terms—via the methods provided by the class. Even if you know what those methods do to the object, you should resist the urge to fiddle around with it yourself. It's like the remote control for your television set: even if you know what's going on inside it, you shouldn't monkey with its innards without good reason.

Perl lets you peer inside the object from outside the class when you need to. But doing so breaks its *encapsulation*, the principle that all access to an object should be through methods alone. Encapsulation decouples the published interface (how an object should be used) from the implementation (how it actually works). Perl does not have an explicit interface facility apart from this unwritten contract between designer and user. Both parties are expected to exercise common sense

and common decency: the user by relying only upon the documented interface, the designer by not breaking that interface.

Perl doesn't force a particular style of programming on you, and it doesn't have the obsession with privacy that some other object-oriented languages do. Perl does have an obsession with freedom, however, and one of the freedoms you have as a Perl programmer is the right to select as much or as little privacy as you like. In fact, Perl can have stronger privacy in its classes and objects than C++. That is, Perl does not restrict you from anything, and, in particular, it doesn't restrict you from restricting yourself—if you're into that kind of thing. The sections "Private Methods" on page 440 and "Closures as Objects" later in this chapter demonstrate how you can increase your dosage of discipline.

Admittedly, there's a lot more to objects than this, as well as a lot of ways to find out more about object-oriented design. But that's not our purpose here. So, on we go.

Perl's Object System

Perl doesn't provide any special syntax for defining objects, classes, or methods. Instead, it reuses existing constructs to implement these three concepts.[1] Here are some simple definitions that you may find reassuring:

An object is simply a reference…er, a referent.
: Since references let individual scalars represent larger collections of data, it shouldn't be a surprise that references are used for all objects. Technically, an object isn't the reference proper—it's really the referent that the reference points at. This distinction is frequently blurred by Perl programmers, however, and since we feel it's a lovely metonymy, we will perpetuate the usage here when it suits us.[2]

A class is simply a package.
: A package serves as a class by using the package's subroutines to execute the class's methods, and by using the package's variables to hold the class's global data. Often, a module is used to hold one or more classes.

A method is simply a subroutine.
: You just declare subroutines in the package you're using as the class; these will then be used as the class's methods. Method invocation, a new way to

1. Now *there's* an example of software reuse for you!
2. We prefer linguistic vigor over mathematical rigor. Either you will agree or you won't.

call subroutines, passes an extra argument: the object or package used for invoking the method.

Method Invocation

If you were to boil down all of object-oriented programming into one quintessential notion, it would be *abstraction*. It's the single underlying theme you'll find running through all those 10-dollar words that OO enthusiasts like to bandy about, like polymorphism and inheritance and encapsulation. We believe in those fancy words, but we'll address them from the practical viewpoint of what it means to invoke methods. Methods lie at the heart of the object system because they provide the abstraction layer needed to implement all these fancy terms. Instead of directly accessing a piece of data sitting in an object, you invoke an instance method. Instead of directly calling a subroutine in some package, you invoke a class method. By interposing this level of indirection between class use and class implementation, the program designer remains free to tinker with the internal workings of the class, with little risk of breaking programs that use it.

Perl supports two different syntactic forms for invoking methods. One uses a familiar style you've already seen elsewhere in Perl, and the second is a form you may recognize from other programming languages. No matter which form of method invocation is used, the subroutine constituting the method is always passed an extra initial argument. If a class is used to invoke the method, that argument will be the name of the class. If an object is used to invoke the method, that argument will be the reference to the object. Whichever it is, we'll call it the method's *invocant*. For a class method, the invocant is the name of a package. For an instance method, the invocant is a reference that specifies an object.

In other words, the invocant is whatever the method was invoked *with*. Some OO literature calls this the method's *agent* or its *actor*. Grammatically, the invocant is neither the subject of the action nor the receiver of that action. It's more like an indirect object, the beneficiary on whose behalf the action is performed—just like the word "me" in the command, "Forge me a sword!" Semantically, you can think of the invocant as either an invoker or an invokee, whichever fits better into your mental apparatus. We're not going to tell you how to think. (Well, not about that.)

Most methods are invoked explicitly, but methods may also be invoked implicitly when triggered by object destructors, overloaded operators, or tied variables. Properly speaking, these are not regular subroutine calls, but rather method invocations automatically triggered by Perl on behalf of an object. Destructors are

described later in this chapter, overloading is described in Chapter 13, and ties are described in Chapter 14.

One difference between methods and regular subroutines is when their packages are resolved—that is, how early (or late) Perl decides which code should be executed for the method or subroutine. A subroutine's package is resolved during compilation, before your program begins to run.[3] In contrast, a method's package isn't resolved until it is actually invoked. (Prototypes are checked at compile time, which is why regular subroutines can use them but methods can't.)

The reason a method's package can't be resolved earlier is relatively straightforward: the package is determined by the class of the invocant, and the invocant isn't known until the method is actually invoked. At the heart of OO is this simple chain of logic: once the invocant is known, the invocant's class is known, and once the class is known, the class's inheritance is known, and once the class's inheritance is known, the actual subroutine to call is known.

The logic of abstraction comes at a price. Because of the late resolution of methods, an object-oriented solution in Perl is likely to run slower than the corresponding non-OO solution. For some of the fancier techniques described later, it could be a *lot* slower. However, many common problems are solved not by working faster, but by working smarter. That's where OO shines.

Method Invocation Using the Arrow Operator

We mentioned that there are two styles of method invocation. The first style for invoking a method looks like this:

```
INVOCANT->METHOD(LIST)
INVOCANT->METHOD
```

For obvious reasons, this style is usually called the arrow form of invocation. (Do not confuse `->` with `=>`, the "double-barrelled" arrow used as a fancy comma.) Parentheses are required if there are any arguments. When executed, the invocation first locates the subroutine determined jointly by the class of the *INVOCANT* and the *METHOD* name, and then calls that subroutine, passing *INVOCANT* as its first argument.

When *INVOCANT* is a reference, we say that *METHOD* is invoked as an instance method; when *INVOCANT* is a package name, we say that *METHOD* is invoked as a class method.

3. More precisely, the subroutine call is resolved down to a particular typeglob, a reference to which is stuffed into the compiled opcode tree. The meaning of that typeglob is negotiable even at runtime—this is how `AUTOLOAD` can autoload a subroutine for you. Normally, however, the meaning of the typeglob is also resolved at compile time by the definition of an appropriately named subroutine.

There really is no difference between the two, other than that the package name is more obviously associated with the class itself than with the objects of the class. You'll have to take our word for it that the objects also know their class. We'll tell you in a bit how to associate an object with a class name, but you can use objects without knowing that.

For example, to construct an object using the class method `summon` and then invoke the instance method `speak` on the resulting object, you might say this:

```
$mage = Wizard->summon("Gandalf");  # class method
$mage->speak("friend");             # instance method
```

The `summon` and `speak` methods are defined by the `Wizard` class—or one of the classes from which it inherits. But you shouldn't worry about that. Do not meddle in the affairs of Wizards.

Since the arrow operator is left associative (see Chapter 3), you can even combine the two statements into one:

```
Wizard->summon("Gandalf")->speak("friend");
```

Sometimes you want to invoke a method without knowing its name ahead of time. You can use the arrow form of method invocation and replace the method name with a simple scalar variable:

```
$method = "summon";
$mage = Wizard->$method("Gandalf");  # Invoke Wizard->summon

$travel = $companion eq "Shadowfax" ? "ride" : "walk";
$mage->$travel("seven leagues");     # Invoke $mage->ride or $mage->walk
```

Although you're using the name of the method to invoke it indirectly, this usage is not forbidden by `use strict 'refs'`, since *all* method calls are in fact looked up symbolically at the time they're resolved.

In our example, we stored the name of a subroutine in `$travel`, but you could also store a subroutine reference. This bypasses the method lookup algorithm, but sometimes that's exactly what you want to do. See both the section "Private Methods" on page 440 and the discussion of the `can` method in the section "UNIVERSAL: The Ultimate Ancestor Class" on page 435. To create a reference to a particular method being called on a particular instance, see the section "Closures" on page 355 in Chapter 8.

Method Invocation Using Indirect Objects

The second style of method invocation looks like this:

```
METHOD INVOCANT (LIST)
METHOD INVOCANT LIST
METHOD INVOCANT
```

The parentheses around *LIST* are optional; if omitted, the method acts as a list operator. So you can have statements like the following, all of which use this style of method call. Notice the lack of a semicolon after the class name or instance:

```
no feature "switch"; # for given forgiveness (see below)
$mage = summon Wizard "Gandalf";
$nemesis = summon Balrog home => "Moria", weapon => "whip";
move $nemesis "bridge";
speak $mage "You cannot pass";
break $staff;               # safer to use: break $staff ();
```

The list operator syntax should be familiar to you; it's the same style used for passing filehandles to `print` or `printf`:

```
print STDERR "help!!!\n";
```

It's also similar to English sentences like "Give Gollum the Preciousss", so we call it the *indirect object* form. The invocant is expected in the *indirect object slot*. When you read about passing a built-in function like `system` or `exec` something in its "indirect object slot", this means that you're supplying this extra, comma-less argument in the same place you would when you invoke a method using the indirect object syntax.

The indirect object form even permits you to specify the *INVOCANT* as a *BLOCK* that evaluates to an object (reference) or class (package). This lets you combine those two invocations into one statement this way:

```
speak { summon Wizard "Gandalf" } "friend";
```

Syntactic Snafus with Indirect Objects

One syntax will often be more readable than the other. The indirect object syntax is less cluttered but suffers from several forms of syntactic ambiguity. The first is that the *LIST* part of an indirect object invocation is parsed the same as any other list operator. Thus, the parentheses of:

```
enchant $sword ($pips + 2) * $cost;
```

are assumed to surround all the arguments, regardless of what comes afterward. It would therefore be equivalent to this:

```
($sword->enchant($pips + 2)) * $cost;
```

That's unlikely to do what you want: `enchant` is only being called with `$pips + 2`, and the method's return value is then multiplied by `$cost`. As with other list operators, you must also be careful of the precedence of `&&` and `||` versus `and` and `or`—if you disdain parentheses.

For example, this:

```
name $sword $oldname || "Glamdring";   # can't use "or" here!
```

becomes the intended:

```
$sword->name($oldname || "Glamdring");
```

but this:

```
speak $mage "friend" && enter();        # should've been "and" here!
```

becomes the dubious:

```
$mage->speak("friend" && enter());
```

which could be fixed by rewriting into one of these equivalent forms:

```
enter() if $mage->speak("friend");
$mage->speak("friend") && enter();
speak $mage "friend" and enter();
```

The second syntactic infelicity of the indirect object form is that its *INVOCANT* is limited to a name, an unsubscripted scalar variable, or a block.[4] As soon as the parser sees one of these, it has its *INVOCANT*, so it starts looking for its *LIST*. So these invocations:

```
move $party->{LEADER};              # probably wrong!
move $riders[$i];                   # probably wrong!
```

actually parse as these:

```
$party->move->{LEADER};
$riders->move([$i]);
```

rather than what you probably wanted:

```
$party->{LEADER}->move;
$riders[$i]->move;
```

The parser only looks a little ways ahead to find the invocant for an indirect object, not even as far as it would look for a unary operator. This oddity does not arise with the first notation, so you might wish to stick with the arrow as your weapon of choice.

4. Attentive readers will recall that this is precisely the same list of syntactic items that are allowed after a funny character to indicate a variable dereference—for example, `@ary`, `@$aryref`, or `@{$aryref}`.

Even English has a similar issue here. Think about the command, "Throw your cat out the window a toy mouse to play with." If you parse that sentence too quickly, you'll end up throwing the cat, not the mouse (unless you notice that the cat is already out the window). Like Perl, English has two different syntaxes for expressing the agent: "Throw your cat the mouse" and "Throw the mouse to your cat." Sometimes the longer form is clearer and more natural, and sometimes the shorter one is. At least in Perl you're required to use braces around any complicated indirect object.

Package-Quoted Classes

The final syntactic ambiguity with the indirect object style of method invocation is that it may not be parsed as a method call at all, because the current package may have a subroutine of the same name as the method. When using a class method with a literal package name as the invocant, there is a way to resolve this ambiguity while still keeping the indirect object syntax: package-quote the classname by appending a double colon to it.

```
$obj = method CLASS::;   # forced to be "CLASS"->method
```

This is important because the commonly seen notation:

```
$obj = new CLASS;        # might not parse as method
```

will not always behave properly if the current package has a subroutine named `new` or *`CLASS`*. Even if you studiously use the arrow form instead of the indirect object form to invoke methods, this can, on rare occasion, still be a problem. At the cost of extra punctuation noise, the *`CLASS`*`::` notation guarantees how Perl will parse your method invocation. The first two examples below do not always parse the same way, but the second two do:

```
$obj = new ElvenRing;               # could be new("ElvenRing")
                                    # or even new(ElvenRing())
$obj = ElvenRing->new;              # could be ElvenRing()->new()

$obj = new ElvenRing::;             # always "ElvenRing"->new()
$obj = ElvenRing::->new;            # always "ElvenRing"->new()
```

This package-quoting notation can be made prettier with some creative alignment:

```
$obj = new ElvenRing::
            name    => "Narya",
            owner   => "Gandalf",
            domain  => "fire",
            stone   => "ruby";
```

Still, you may say, "Oh, ugh!" at that double colon, so we'll tell you that you can almost always get away with a bare class name, provided two things are true. First, there is no subroutine of the same name as the class. (If you follow the convention that subroutine names like `new` start lowercase and class names like `ElvenRing` start uppercase, this is never a problem.) Second, the class has been loaded with one of:

```
use ElvenRing;
require ElvenRing;
```

Either of these declarations ensures that Perl knows `ElvenRing` is a module name, which forces any bare name like `new` before the class name `ElvenRing` to be interpreted as a method call, even if you happen to have declared a `new` subroutine of your own in the current package. People don't generally get into trouble with indirect objects unless they start cramming multiple classes into the same file, in which case Perl might not know that a particular package name was supposed to be a class name. People who name subroutines with names that look like `ModuleNames` also come to grief eventually.

This is (almost) what happened to us where we said:

```
no feature "switch";
```

Assuming you'd used the recommended `use v5.14` or so, anything v5.10 or over pulls in `break` as a keyword to help with the `given` construct. We turned off the "`switch`" feature because otherwise the compiler thinks that `break` might be a keyword. Adding the parentheses at the end doesn't even help here, even though that's what you normally do—or *should* do—to make method calls safe using this syntax. The compiler doesn't actually know *what* to make of it, but it isn't letting it slide.

Object Construction

All objects are references, but not all references are objects. A reference won't work as an object unless its referent is specially marked to tell Perl to what package it belongs. The act of marking a referent with a package name—and, therefore, its class, since a class is just a package—is known as *blessing*. You can think of the blessing as turning a reference into an object, although it's more accurate to say that it turns the reference into an object reference.

The `bless` function takes either one or two arguments. The first argument is a reference and the second is the package to bless the referent into. If the second argument is omitted, the current package is used.

```
$obj = { };                # Get reference to anonymous hash.
bless($obj);               # Bless hash into current package.
bless($obj, "Critter");    # Bless hash into class Critter.
```

Here we've used a reference to an anonymous hash, which is what people usually use as the data structure for their objects. Hashes are extremely flexible, after all. But allow us to emphasize that you can bless a reference to anything you can make a reference to in Perl, including scalars, arrays, subroutines, and typeglobs. You can even bless a reference to a package's symbol table hash if you can think of a good reason to. (Or even if you can't.) Object orientation in Perl is completely orthogonal to data structure.

Once the referent has been blessed, calling the built-in `ref` function on its reference returns the name of the blessed class instead of the built-in type, such as `HASH`. If you want the built-in type, use the `reftype` function from the `attributes` module. See the section "attributes" on page 1002 in Chapter 29.

And that's how to make an object. Just take a reference to something, give it a class by blessing it into a package, and you're done. That's all there is to it if you're designing a minimal class. If you're using a class, there's even less to it, because the author of a class will have hidden the `bless` inside a method called a *constructor*, which creates and returns instances of the class. Because `bless` returns its first argument, a typical constructor can be as simple as this:

```
package Critter;
sub spawn { bless {} }
```

Or, spelled out slightly more explicitly:

```
package Critter;
sub spawn {
    my     $self = {};       # Reference to an empty anonymous hash
    bless  $self, "Critter"; # Make that hash a Critter object
    return $self;            # Return the freshly generated Critter
}
```

With that definition in hand, here's how one might create a `Critter` object:

```
$pet = Critter->spawn;
```

Inheritable Constructors

Like all methods, a constructor is just a subroutine, but we don't call it as a subroutine. We always invoke it as a method—a class method, in this particular case, because the invocant is a package name. Method invocations differ from regular subroutine calls in two ways. First, they get the extra argument we discussed earlier. Second, they obey inheritance, allowing one class to use another's methods.

We'll describe the underlying mechanics of inheritance more rigorously in the next section, but, for now, some simple examples of its effects should help you design your constructors. For instance, suppose we have a `Spider` class that inherits methods from the `Critter` class. In particular, suppose the `Spider` class doesn't have its own `spawn` method. The correspondences shown in Table 12-1 apply:

Table 12-1. Mapping methods to subroutines

Method Call	Resulting Subroutine Call
`Critter->spawn()`	`Critter::spawn("Critter")`
`Spider->spawn()`	`Critter::spawn("Spider")`

The subroutine called is the same in both cases, but the argument differs. Note that our `spawn` constructor above completely ignored its argument, which means our `Spider` object was incorrectly blessed into class `Critter`. A better constructor would provide the package name (passed in as the first argument) to `bless`:

```
sub spawn {
    my $class =  shift;       # Store the package name
    my $self  =  { };
    bless($self, $class);     # Bless the reference into that package
    return $self;
}
```

Now you could use the same subroutine for both these cases:

```
$vermin = Critter->spawn;
$shelob = Spider->spawn;
```

And each object would be of the proper class. This even works indirectly, as in:

```
$type  = "Spider";
$shelob = $type->spawn;         # same as "Spider"->spawn
```

That's still a class method, not an instance method, because its invocant holds a string and not a reference.

If `$type` were an object instead of a class name, the previous constructor definition wouldn't have worked because `bless` needs a class name. But, for many classes, it makes sense to use an existing object as the template from which to create another. In these cases, you can design your constructors so that they work with either objects or class names:

```
sub spawn {
    my $invocant = shift;
    my $class    = ref($invocant) || $invocant;  # Object or class name
    my $self     = { };
```

```
    bless($self, $class);
    return $self;
}
```

Initializers

Most objects maintain internal information that is indirectly manipulated by the object's methods. All our constructors so far have created empty hashes, but there's no reason to leave them empty. For instance, we could have the constructor accept extra arguments to store into the hash as key/value pairs. The OO literature often refers to such data as *properties*, *attributes*, *accessors, accessor method*, *member data*, *instance data*, or *instance variables*. The section "Instance Variables", later in this chapter, discusses attributes in more detail.

Imagine a `Horse` class with instance attributes like "name" and "color":

```
$steed = Horse->new(name => "Shadowfax", color => "white");
```

If the object is implemented as a hash reference, the key/value pairs can be interpolated directly into the hash once the invocant is removed from the argument list:

```
sub new {
    my $invocant = shift;
    my $class = ref($invocant) || $invocant;
    my $self = { @_ };          # Remaining args become attributes
    bless($self, $class);       # Bestow objecthood
    return $self;
}
```

This time we used a method named `new` for the class's constructor, which just might lull C++ programmers into thinking they know what's going on. But Perl doesn't consider "`new`" to be anything special; you may name your constructors whatever you like. Any method that happens to create and return an object is a de facto constructor. In general, we recommend that you name your constructors whatever makes sense in the context of the problem you're solving. For example, constructors in the `Tk` module are named after the widgets they create. In the `DBI` module, a constructor named `connect` returns a database handle object, and another constructor named `prepare` is invoked as an instance method and returns a statement handle object. But if there is no suitable context-specific constructor name, `new` is perhaps not a terrible choice. Then again, maybe it's not such a bad thing to pick a random name to force people to read the interface contract (meaning the class documentation) before they use its constructors.

Elaborating further, you can set up your constructor with default key/value pairs, which the user could later override by supplying them as arguments:

```
sub new {
    my $invocant = shift;
    my $class   = ref($invocant) || $invocant;
    my $self = {
        color  => "bay",
        legs   => 4,
        owner  => undef,
        @_,                 # Override previous attributes
    };
    return bless $self, $class;
}

$ed       = Horse->new;                     # A 4-legged bay horse
$stallion = Horse->new(color => "black");  # A 4-legged black horse
```

This `Horse` constructor ignores its invocant's existing attributes when used as an instance method. You could create a second constructor designed to be called as an instance method, and, if designed properly, you could use the values from the invoking object as defaults for the new one:

```
$steed  = Horse->new(color => "dun");
$foal   = $steed->clone(owner => "EquuGen Guild, Ltd.");

sub clone {
    my $model = shift;
    my $self  = $model->new(%$model, @_);
    return $self;     # Previously blessed by ->new
}
```

(You could also have rolled this functionality directly into `new`, but then the name wouldn't quite fit the function.)

Notice how even in the `clone` constructor we don't hardcode the name of the `Horse` class. We have the original object invoke its own `new` method, whatever that may be. If we had written that as `Horse->new` instead of `$model->new`, then the class wouldn't have facilitated inheritance by a `Zebra` or `Unicorn` class. You wouldn't want to clone Pegasus and suddenly find yourself with a horse of a different color.

Sometimes, however, you have the opposite problem: rather than trying to share one constructor among several classes, you're trying to have several constructors share one class's object. This happens whenever a constructor wants to call a base class's constructor to do part of the construction work. Perl doesn't do hierarchical construction for you. That is, Perl does not automatically call the constructors (or the destructors) for any base classes of the class requested, so your constructor will have to do that itself and then add any additional attributes the derived class needs. So the situation is not unlike the `clone` routine, except that instead of copying an existing object into the new object, you want to call

your base class's constructor and then transmogrify the new base object into your new derived object.

Class Inheritance

As with the rest of Perl's object system, inheritance of one class by another requires no special syntax to be added to the language. When you invoke a method for which Perl finds no subroutine in the invocant's package, that package's `@ISA` array[5] is examined. This is how Perl implements inheritance: each element of a given package's `@ISA` array holds the name of another package, which is searched when methods are missing. For example, the following makes the `Horse` class a subclass of the `Critter` class. (We declare `@ISA` with `our` because it has to be a package variable, not a lexical declared with `my`.)

```
package Horse;
our @ISA = "Critter";
```

You might see this with the `parent` pragma, which handles `@ISA` for you and loads the parent class at the same time:

```
package Horse;
use parent qw(Critter);
```

The `parent` pragma replaces the older `base` pragma, which did the same thing but threw in some `fields` magic if it thought the superclasses used them. If you don't know what that is, don't worry about it (just use `parent`):

```
package Horse;
use base qw(Critter).
```

You should now be able to use a `Horse` class or object everywhere that a `Critter` was previously used. If your new class passes this *empty subclass test*, you know that `Critter` is a proper base class, fit for inheritance.

Suppose you have a `Horse` object in `$steed` and invoke a `move` method on it:

```
$steed->move(10);
```

Because `$steed` is a `Horse`, Perl's first choice for that method is the `Horse::move` subroutine. If there isn't one, instead of raising a runtime exception, Perl consults the first element of `@Horse::ISA`, which directs it to look in the `Critter` package for `Critter::move`. If this subroutine isn't found either, and `Critter` has *its* own `@Critter::ISA` array, then that too will be consulted for the name of an ancestral package that might supply a `move` method, and so on, back up the inheritance hierarchy until we come to a package without an `@ISA`.

5. Pronounced "is a", as in "A horse is a critter."

The situation we just described is *single inheritance*, where each class has only one parent. Such inheritance is like a linked list of related packages. Perl also supports *multiple inheritance*; just add more packages to the class's `@ISA`. This kind of inheritance works more like a tree data structure, because every package can have more than one immediate parent. Some people find this to be sexier.

When you invoke a method *`methname`* on an invocant of type *`classname`*, Perl tries six different ways to find a subroutine to use:

1. First, Perl looks in the invocant's own package for a subroutine named *`classname`*`::`*`methname`*. If that fails, inheritance kicks in, and we go to step 2.
2. Next, Perl checks for methods inherited from base classes by looking in all *`parent`* packages listed in `@`*`classname`*`::ISA` for a *`parent`*`::`*`methname`* subroutine. The search is left to right, recursive, and depth-first. The recursion assures that grandparent classes, great-grandparent classes, great-great-grandparent classes, and so on, are all searched.
3. If that fails, Perl looks for a subroutine named `UNIVERSAL::`*`methname`*.
4. At this point, Perl gives up on *`methname`* and starts looking for an `AUTOLOAD`. First, it looks for a subroutine named *`classname`*`::AUTOLOAD`.
5. Failing that, Perl searches all *`parent`* packages listed in `@`*`classname`*`::ISA` for any *`parent`*`::AUTOLOAD` subroutine. The search is again left to right, recursive, and depth-first.
6. Finally, Perl looks for a subroutine named `UNIVERSAL::AUTOLOAD`.

Perl stops after the first successful attempt and invokes that subroutine. If no subroutine is found, an exception is raised, one that you'll see frequently:

```
Can't locate object method "methname" via package "classname"
```

If you've built a debugging version of Perl using the `-DDEBUGGING` option to your C compiler, by using Perl's `-Do` switch, you can watch it go through each of these steps when it resolves method invocation.

We will discuss the inheritance mechanism in more detail as we go along.

Inheritance Through @ISA

If `@ISA` contains more than one package name, the packages are all searched in left-to-right order by default. The search is depth-first, so if you have a `Mule` class set up for inheritance this way:

```
package Mule;
our @ISA = ("Horse", "Donkey");
```

Perl looks for any methods missing from `Mule` first in `Horse` (and any of its ancestors, like `Critter`) before going on to search through `Donkey` and its ancestors.

If a missing method is found in a base class, Perl internally caches that location in the current class for efficiency, so the next time it has to find the method, it doesn't have to look as far. Changing `@ISA` or defining new methods invalidates the cache and causes Perl to perform the lookup again.

When Perl searches for a method, it makes sure that you haven't created a circular inheritance hierarchy. This could happen if two classes inherit from one another, even indirectly through other classes. Trying to be your own great-grandfather is too paradoxical even for Perl, so the attempt raises an exception. However, Perl does not consider it an error to inherit from more than one class sharing a common ancestry, which is rather like cousins marrying. Your inheritance hierarchy just stops looking like a tree and starts to look like a directed acyclic graph. This doesn't bother Perl—so long as the graph really is acyclic.

When you set `@ISA`, the assignment normally happens at runtime, so unless you take precautions, code in `BEGIN`, `CHECK`, `UNITCHECK`, or `INIT` blocks won't be able to use the inheritance hierarchy. One precaution (or convenience) is the `parent` pragma, which lets you `require` classes and add them to `@ISA` at compile time. Here's how you might use it:

```
package Mule;
use parent ("Horse", "Donkey");   # declare superclasses
```

This is a shorthand for:

```
package Mule;
BEGIN {
    our @ISA = ("Horse", "Donkey");
    require Horse;
    require Donkey;
}
```

Sometimes folks are surprised that including a class in `@ISA` doesn't `require` the appropriate module for you. That's because Perl's class system is largely orthogonal to its module system. One file can hold many classes (since they're just packages), and one package may be mentioned in many files. But in the most common situation, where one package and one class and one module and one file all end up being pretty interchangeable if you squint enough, the `parent` pragma offers a declarative syntax that establishes inheritance and loads in module files. It's one of those convenient diagonals we keep mentioning.

See the descriptions of `use parent` in Chapter 29 for further details. Also see the older `base` pragma, which performs extra `fields` magic (which has fallen out of favor with Perl programmers).

Alternate Method Searching

With multiple inheritance, the default traversal of `@INC` to find the right method might not work for you, because a method in a far away superclass might hide a better method in a closer superclass. Consider the inheritance shown in Figure 12-1, where `Mule` inherits from two classes, `Donkey` and `Horse`, which both inherit from `Equine`. The `Equine` has a `color` method, which `Donkey` inherits. `Horse` provides its own `color`, though. Using the default traversal, you don't know which `color` you'll get unless you know the order of the parent classes:

```
use parent qw(Horse Donkey);   # finds Horse::Color first
use parent qw(Donkey Horse);   # finds Equine::Color first
```

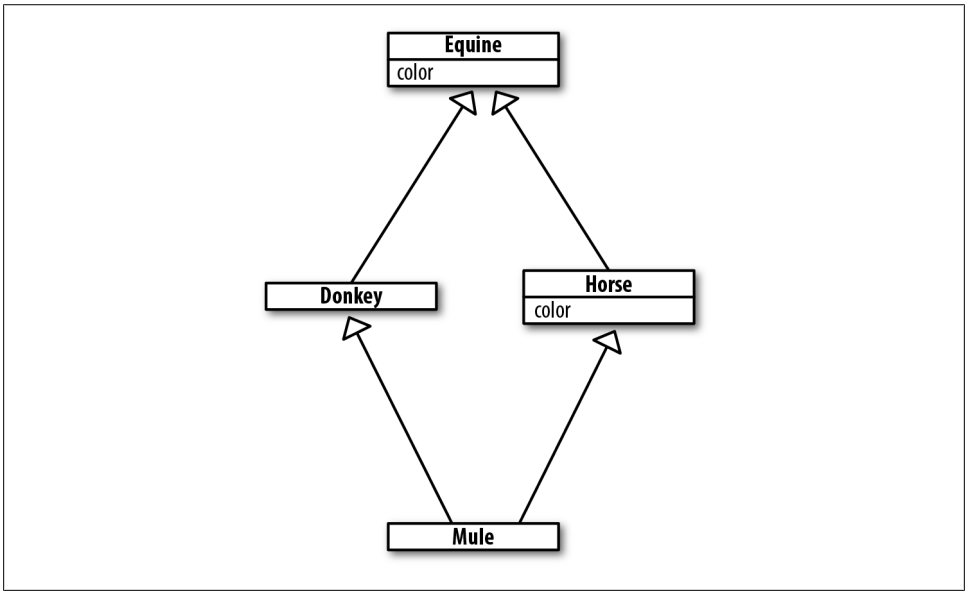


Figure 12-1. Multiple inheritance graph

As of v5.10, the traversal is configurable. In fancy terms, this is the *method resolution order*, which you select with the `mro` pragma (see Chapter 29):

```
package Mule;
use mro 'c3';
use parent qw(Donkey Horse);
```

The C3 algorithm traverses `@INC` so it finds inherited methods that are closer in the inheritance graph. Said another way, that means that no superclass will be searched before one of its subclasses. Perl will not look in `Equine` before it looks in `Horse`.

If your Perl does not support the `mro` pragma, you might be able to use the `MRO::Compat` CPAN module.

Accessing Overridden Methods

When a class defines a method, that subroutine overrides methods of the same name in any base classes. You have the `Mule` object (which is derived from class `Horse` and class `Donkey`), and you decide to invoke your object's `breed` method. Although the parent classes have their own `breed` methods, the designer of the `Mule` class overrode those by supplying the `Mule` class with its own `breed` method. That means the following cross is unlikely to be productive:

```
$stallion = Horse->new(gender => "male");
$molly = Mule->new(gender => "female");
$colt = $molly->breed($stallion);
```

Now, suppose that through the miracle of genetic engineering, you find some way around a mule's notorious sterility problem, so you want to skip over the nonviable `Mule::breed` method. You *could* call your method as an ordinary subroutine, being sure to pass the invocant explicitly:

```
$colt = Horse::breed($molly, $stallion);
```

However, this sidesteps inheritance, which is nearly always the wrong thing to do. It's perfectly imaginable that no `Horse::breed` subroutine exists because both `Horse`s and `Donkey`s derive that behavior from a common parent class called `Equine`. If, on the other hand, you want to specify that Perl should *start* searching for a method in a particular class, just use ordinary method invocation but qualify the method name with the class:

```
$colt = $molly->Horse::breed($stallion);
```

Occasionally, you'll want a method in a derived class to act as a wrapper around some method in a base class. The method in the derived class can itself invoke the method in the base class, adding its own actions before or after that invocation. You *could* use the notation just demonstrated to specify at which class to start the search. But in most cases of overridden methods, you don't want to have to know or specify which parent class's overridden method to execute.

That's where the `SUPER` pseudoclass comes in handy. It lets you invoke an overridden base class method without having to specify which class defined that

method.[6] The following subroutine looks in the current package's `@ISA` without making you specify particular classes:

```
package Mule;
our @ISA = qw(Horse Donkey);
sub kick {
    my $self = shift;
    print "The mule kicks!\n";
    $self->SUPER::kick(@_);
}
```

The `SUPER` pseudopackage is meaningful only when used *inside* a method. Although the implementer of a class can employ `SUPER` in her own code, someone who merely uses a class's objects cannot.

If you are using C3 method resolution order, then instead of `SUPER::`*`METHNAME`* you use `next::method`, which is loaded by the `use mro "c3"` pragma. Unlike with `SUPER`, with `next::method`, you don't specify the method name because it figures it out for you:

```
use v5.14;
package Mule;
use mro 'c3';
use parent qw(Horse Donkey);
sub kick {
    my $self = shift;
    say "The mule kicks!";
    $self->next::method(@_);
}
```

Every bit of code in Perl knows what its current package is, as determined by the last `package` statement. A `SUPER` method looks only in the `@ISA` of the current package from when the call to `SUPER` was compiled. It doesn't care about the class of the invocant, nor about the package of the subroutine that was called. This can cause problems if you try to define methods in another class by merely playing tricks with the method name:

```
package Bird;
use Dragonfly;
sub Dragonfly::divebomb { shift->SUPER::divebomb(@_) }
```

Unfortunately, this invokes `Bird`'s superclass, not `Dragonfly`'s. To do what you're trying to do, you need to explicitly switch into the appropriate package for the compilation of `SUPER` as well:

6. This is not to be confused with the mechanism mentioned in Chapter 11 for overriding Perl's built-in functions, which aren't object methods and so aren't overridden by inheritance. You call overridden built-ins via the `CORE` pseudopackage, not the `SUPER` pseudopackage.

```
package Bird;
use Dragonfly;
{
    package Dragonfly;
    sub divebomb { shift->SUPER::divebomb(@_) }
}
```

The `next::method` has a similar problems because it uses the package of its `caller` to figure out what class to look at. If you define a method in `Donkey` from another package, `next::method` will break:

```
package main;
*Donkey::sound = sub { (shift)->next::method(@_) };
```

The anonymous subroutine shows up in the stack with as `__ANON__`, so `next::method` doesn't know which package it is in. You can use the `Sub::Name` CPAN module to make it work out, though:

```
use Sub::Name qw(subname);
*Donkey::sound =
    subname 'Donkey::sound' => sub { (shift)->next::method(@_) };
```

As these examples illustrate, you don't need to edit a module file just to add methods to an existing class. Since a class is just a package, and a method just a subroutine, all you have to do is define a function in that package as we've done here, and the class suddenly has a new method. No inheritance required. Only the package matters, and since packages are global, any package can be accessed from anywhere in the program. (Did we mention we're going to install a jacuzzi in your living room next week?)

UNIVERSAL: The Ultimate Ancestor Class

If no method definition with the right name is found after searching the invocant's class and all its ancestor classes recursively, one more check for a method of that name is made in the special predefined class called `UNIVERSAL`. This package never appears in an `@ISA`, but it is always consulted when an `@ISA` check fails. You can think of `UNIVERSAL` as the ultimate ancestor from which all classes implicitly derive, making it work like class `Object` does in Java or class `object` in Python's new-style classes.

The following predefined methods are available in class `UNIVERSAL`, and thus in all classes. These all work regardless of whether they are invoked as class methods or object methods.

`INVOCANT``->isa(`*`CLASS`*`)`

> The `isa` method returns true if *`INVOCANT`*'s class is *`CLASS`* or any class inheriting from *`CLASS`*. Instead of a package name, *`CLASS`* may also be one of the

built-in types, such as "HASH" or "ARRAY". (Checking for an exact type does not bode well for encapsulation or polymorphism, though. You should be relying on method dispatch to give you the right method.)

```
use IO::Handle;
if (IO::Handle->isa("Exporter")) {
    print "IO::Handle is an Exporter.\n";
}

$fh = IO::Handle->new();
if ($fh->isa("IO::Handle")) {
    print "\$fh is some sort of IOish object.\n";
}
if ($fh->isa("GLOB")) {
    print "\$fh is really a GLOB reference.\n";
}
```

INVOCANT->DOES(*ROLE*)

Perl v5.10 added the idea of *roles*, a way that a class can include external methods without necessarily inheriting them, as `isa` requires. A role specifies a set of behavior but doesn't care how a class does it. It might inherit the methods, mock them, delegate them, or something else.

By default, `DOES` is identical to `isa`, and you can use `DOES` instead of `isa` in all cases. If your class does something fancy to include methods without inheritance, though, you'd want to define `DOES` to return the right answer.

Roles are a Perl 6 thing, and the truth is that Perl 5 doesn't do anything at all with them. The `UNIVERSAL DOES` method exists so cooperating classes could, were they so included, build something where `DOES` matters. Perl itself doesn't pay any attention to it at all.

INVOCANT->can(*METHOD*)

The `can` method returns a reference to the subroutine that would be called if *METHOD* were applied to *INVOCANT*. If no such subroutine is found, `can` returns `undef`.

```
if ($invocant->can("copy")) {
    print "Our invocant can copy.\n";
}
```

This could be used to conditionally invoke a method only if one exists:

```
$obj->snarl if $obj->can("snarl");
```

Under multiple inheritance, this allows a method to invoke all overridden base class methods, not just the leftmost one:

```
sub snarl {
    my $self = shift;
    print "Snarling: @_\n";
    my %seen;
    for my $parent (@ISA) {
        if (my $code = $parent->can("snarl")) {
            $self->$code(@_) unless $seen{$code}++;
        }
    }
}
```

We use the `%seen` hash to keep track of which subroutines we've already called, so we can avoid calling the same subroutine more than once. This could happen if several parent classes shared a common ancestor.

Methods that would trigger an `AUTOLOAD` (described in the next section) will not be accurately reported unless the package has declared (but not defined) the subroutines it wishes to have autoloaded.

If you are using the `mro` pragma, you probably want the `next::can` method instead of this one.

INVOCANT`->VERSION(`*NEED*`)`

The `VERSION` method returns the version number of *INVOCANT*'s class, as stored in the package's `$VERSION` variable. If the *NEED* argument is provided, it verifies that the current version isn't less than *NEED* and raises an exception if it is. This is the method that `use` invokes to determine whether a module is sufficiently recent.

```
use Thread 1.0;   # calls Thread->VERSION(1.0)
print "Running version ", Thread->VERSION, " of Thread.\n";
```

You may supply your own `VERSION` method to override the method in `UNIVERSAL`. However, this will cause any classes derived from your class to use the overridden method, too. If you don't want that to happen, you should design your method to delegate other classes' version requests back up to `UNIVERSAL`.

The methods in `UNIVERSAL` are built-in Perl subroutines, which you may call if you fully qualify them and pass two arguments, as in `UNIVERSAL::isa($formobj, "HASH")`. However, this bypasses some sanity checking since `$formobj` could be any value, not just a reference. You might trap that in `eval`:

```
eval { UNIVERSAL::isa($formobj, "HASH") }
```

This is not recommended, though, because `can` usually has the answer you're really looking for:

```
eval { UNIVERSAL::can($formobj, $method) }
```

But, if you're worried about `$formobj` being an object and want to wrap it in an `eval`, you might as well use it as an object anyway since the answer is the same (you can't call that method on `$formobj`):

```
eval { $formobj->can( $method ) }
```

You're free to add your own methods to class `UNIVERSAL`. (You should be careful, of course; you could really mess someone up who is expecting *not* to find the method name you're defining, perhaps so that he can autoload it from somewhere else.) Here we create a `copy` method that objects of all classes can use if they've not defined their own. We fail spectacularly if invoked on a class instead of an object:

```
use Data::Dumper;
use Carp;
sub UNIVERSAL::copy {
    my $self = shift;
    if (ref $self) {
        return eval Dumper($self);  # no CODE refs
    } else {
        confess "UNIVERSAL::copy can't copy class $self";
    }
}
```

This `Data::Dumper` strategy doesn't work if the object contains any references to subroutines, because they cannot be properly reproduced. Even if the source were available, the lexical bindings would be lost.

Method Autoloading

Normally, when you call an undefined subroutine in a package that defines an `AUTOLOAD` subroutine, the `AUTOLOAD` subroutine is called in lieu of raising an exception (see the section "Autoloading" on page 397 in Chapter 10). With methods, this works a little differently. If the regular method search (through the class, its ancestors, and finally `UNIVERSAL`) fails to find a match, the same sequence is run again, this time looking for an `AUTOLOAD` subroutine. If found, this subroutine is called as a method, with the package's `$AUTOLOAD` variable set to the fully qualified name of the subroutine on whose behalf `AUTOLOAD` was called.

You need to be a bit cautious when autoloading methods. First, the `AUTOLOAD` subroutine should return immediately if it's being called on behalf of a method named `DESTROY`, unless your goal was to simulate `DESTROY`, which has a special meaning to Perl (see the section "Instance Destructors" on page 440 later in this chapter).

```
sub AUTOLOAD {
    return if our $AUTOLOAD =~ /::DESTROY$/;
    ...
}
```

Second, if the class is providing an AUTOLOAD safety net, you won't be able to use UNIVERSAL::can on a method name to check whether it's safe to invoke. You have to check for AUTOLOAD separately:

```
if ($obj->can("methname") || $obj->can("AUTOLOAD")) {
    $obj->methname();
}
```

Finally, under multiple inheritance, if a class inherits from two or more classes—each of which has an AUTOLOAD—only the leftmost will ever be triggered, since Perl stops as soon as it finds the first AUTOLOAD.

The last two quirks are easily circumvented by declaring the subroutines in the package whose AUTOLOAD is supposed to manage those methods. You can do this either with individual declarations:

```
package Goblin;
sub kick;
sub bite;
sub scratch;
```

or with the subs pragma, which is more convenient if you have many methods to declare:

```
package Goblin;
use subs qw(kick bite scratch);
```

Even though you've only declared these subroutines and not defined them, this is enough for the system to think they're real. They show up in a UNIVERSAL::can check, and, more importantly, they show up in step 2 of the search for a method, which will never progress to step 3, let alone step 4.

"But, but," you exclaim, "they invoke AUTOLOAD, don't they?" Well, yes, they do eventually, but the mechanism is different. Having found the method stub via step 2, Perl tries to call it. When it is discovered that the method isn't all it was cracked up to be, the AUTOLOAD method search kicks in again. But, this time, it starts its search in the class containing the stub, which restricts the method search to that class and its ancestors (and UNIVERSAL). That's how Perl finds the correct AUTOLOAD to run and knows to ignore AUTOLOADs from the wrong part of the original inheritance tree.

Private Methods

There is one way to invoke a method so that Perl ignores inheritance altogether. If instead of a literal method name you specify a simple scalar variable containing a reference to a subroutine, then the subroutine is called immediately. In the description of `UNIVERSAL->can` in the previous section, the last example invokes all overridden methods using the subroutine's reference, not its name.

An intriguing aspect of this behavior is that it can be used to implement private method calls. If you put your class in a module, you can make use of the file's lexical scope for privacy. First, store an anonymous subroutine in a file-scoped lexical:

```
# declare private method
my $secret_door = sub {
    my $self = shift;
    ...
};
```

Later on in the file you can use that variable as though it held a method name. The closure will be called directly, without regard to inheritance. As with any other method, the invocant is passed as an extra argument.

```
sub knock {
    my $self = shift;
    if ($self->{knocked}++ > 5) {
        $self->$secret_door();
    }
}
```

This enables the file's own subroutines (the class methods) to invoke a method that code outside that lexical scope cannot access.

Instance Destructors

As with any other referent in Perl, when the last reference to an object goes away, its memory is implicitly recycled. With an object, you have the opportunity to capture control just as this is about to happen by defining a `DESTROY` subroutine in the class's package. This method is triggered automatically at the appropriate moment, with the about-to-be-recycled object as its only argument.

Destructors are rarely needed in Perl because memory management is handled automatically for you. Some objects, though, may have state outside the memory system that you'd like to attend to, such as filehandles or database connections.

```
package MailNotify;
sub DESTROY {
    my $self = shift;
```

```
    my $fh   = $self->{mailhandle};
    my $id   = $self->{name};
    print $fh "\n$id is signing off at " . localtime() . "\n";
    close $fh;  # close pipe to mailer
}
```

Just as Perl uses only a single method to construct an object, even when the constructor's class inherits from one or more other classes, Perl also uses only one `DESTROY` method per object destroyed regardless of inheritance. In other words, Perl does not do hierarchical destruction for you. If your class overrides a superclass's destructor, then your `DESTROY` method may need to invoke the `DESTROY` method for any applicable base classes:

```
sub DESTROY {
    my $self = shift;
    # check for an overridden destructor...
    $self->SUPER::DESTROY if $self->can("SUPER::DESTROY");
    # now do your own thing before or after
}
```

This only applies to inherited classes; an object that is simply *contained* within the current object—as, for example, one value in a larger hash—will be freed and destroyed automatically. This is one reason why containership via mere aggregation (sometimes called a "has-a" relationship) is often cleaner and clearer than inheritance (an "is-a" relationship). In other words, often you really need to store only one object inside another directly, instead of through inheritance, which can add unnecessary complexity. Sometimes when users reach for multiple inheritance, single inheritance will suffice.

Explicitly calling `DESTROY` is possible but seldom needed. It might even be harmful since running the destructor more than once on the same object could prove unpleasant.

Garbage Collection with DESTROY Methods

As described in the section "Garbage Collection, Circular References, and Weak References" on page 362 in Chapter 8, a variable that refers to itself (or multiple variables that refer to one another indirectly) will not be freed until the program (or embedded interpreter) is about to exit. If you want to reclaim the memory any earlier, you usually have to explicitly break the reference or weaken it using the `Scalar::Util` module.

With objects, an alternative solution is to create a container class that holds a pointer to the self-referential data structure. Define a `DESTROY` method for the containing object's class that manually breaks the circularities in the self-refer-

ential structure. You can find an example of this in Recipe 13.13, "Coping with Circular Data Structures Using Weak References" of *Perl Cookbook*.

When an interpreter shuts down, all its objects are destroyed, which is important for multithreaded or embedded Perl applications. Objects are always destroyed in a separate pass before ordinary references. This is to prevent `DESTROY` methods from using references that have themselves been destroyed. (And also because plain references are only garbage collected in embedded interpreters, since exiting a process is a very *fast* way of reclaiming references. But exiting won't run the object destructors, so Perl does that first.)

Managing Instance Data

Most classes create objects that are essentially just data structures with several internal data fields (instance variables), plus methods to manipulate them.

Perl classes inherit methods, not data, but as long as all access to the object is through method calls anyway, this works out fine. If you want data inheritance, you have to effect it through method inheritance. By and large, this is not a necessity in Perl, because most classes store the attributes of their object in an anonymous hash. The object's instance data is contained within this hash, which serves as its own little namespace to be carved up by whatever classes do something with the object. For example, if you want an object called `$city` to have a data field named `elevation`, you can simply access `$city->{elevation}`. No declarations are necessary. But method wrappers have their uses.

Suppose you want to implement a `Person` object. You decide to have a data field called "name", which by a strange coincidence you'll store under the key `name` in the anonymous hash that will serve as the object. But you don't want users touching the data directly. To reap the rewards of encapsulation, users need methods to access that instance variable without lifting the veil of abstraction.

For example, you might make a pair of accessor methods:

```
sub get_name {
    my $self = shift;
    return $self->{name};
}

sub set_name {
    my $self      = shift;
    $self->{name} = shift;
}
```

which leads to code like this:

```
$him = Person->new();
$him->set_name("Frodo");
$him->set_name( ucfirst($him->get_name) );
```

You could even combine both methods into one:

```
sub name {
    my $self = shift;
    if (@_) { $self->{name} = shift }
    return $self->{name};
}
```

which would then lead to code like this:

```
$him = Person->new();
$him->name("Frodo");
$him->name( ucfirst($him->name) );
```

The advantage of writing a separate function for each instance variable (which for our `Person` class might be name, age, height, and so on) is that it is direct, obvious, and flexible. The drawback is that every time you want a new class, you end up defining one or two nearly identical methods per instance variable. This isn't too bad for the first few, and you're certainly welcome to do it that way if you'd like. But when convenience is preferred over flexibility, you might prefer one of the techniques described in the following sections.

Note that we will be varying the implementation, not the interface. If users of your class respect the encapsulation, you'll be able to transparently swap one implementation for another without the users noticing. (Family members in your inheritance tree using your class for a subclass or superclass might not be so forgiving, since they know you far better than strangers do.) If your users have been peeking and poking into the private affairs of your class, the inevitable disaster is their own fault and none of your concern. All you can do is live up to your end of the contract by maintaining the interface. Trying to stop everyone else in the world from ever doing something slightly wicked will take up all your time and energy—and, in the end, fail anyway.

Dealing with family members is more challenging. If a subclass overrides a superclass's attribute accessor, should it access the same field in the hash or not? An argument can be made either way, depending on the nature of the attribute. For the sake of safety in the general case, each accessor can prefix the name of the hash field with its own classname, so that subclass and superclass can both have their own version. Several of the examples below, including the standard `Struct::Class` module, use this subclass-safe strategy. You'll see accessors resembling this:

```
sub name {
    my $self = shift;
    my $field = __PACKAGE__ . "::name";
    if (@_) { $self->{$field} = shift }
    return $self->{$field};
}
```

In each of the following examples, we create a simple `Person` class with fields `name`, `race`, and `aliases`, each with an identical interface but a completely different implementation. We're not going to tell you which one we like the best, because we like them all the best, depending on the occasion. And tastes differ. Some folks prefer stewed conies; others prefer fissssh.

Generating Accessors with Autoloading

As we mentioned earlier, when you invoke a nonexistent method, Perl has two different ways to look for an `AUTOLOAD` method, depending on whether you declared a stub method. You can use this property to provide access to the object's instance data without writing a separate function for each instance. Inside the `AUTOLOAD` routine, the name of the method actually invoked can be retrieved from the `$AUTOLOAD` variable. Consider the following code:

```
use Person;
$him = Person->new;
$him->name("Aragorn");
$him->race("Man");
$him->aliases( ["Strider", "Estel", "Elessar"] );
printf "%s is of the race of %s.\n", $him->name, $him->race;
print "His aliases are: ", join(", ", @{$him->aliases}), ".\n";
```

As before, this version of the `Person` class implements a data structure with three fields: `name`, `race`, and `aliases`:

```
package Person;
use Carp;

my %Fields = (
    "Person::name"  => "unnamed",
    "Person::race"   => "unknown",
    "Person::aliases"  => [],
);

# The next declaration guarantees we get our own autoloader.
use subs qw(name race aliases);

sub new {
    my $invocant = shift;
    my $class = ref($invocant) || $invocant;
    my $self  = { %Fields, @_ };    # clone like Class::Struct
```

```
    bless $self, $class;
    return $self;
}

sub AUTOLOAD {
    my $self = shift;
    # only handle instance methods, not class methods
    croak "$self not an object" unless ref($invocant);
    my $name = our $AUTOLOAD;
    return if $name =~ /::DESTROY$/;
    unless (exists $self->{$name}) {
        croak "Can't access '$name' field in $self";
    }
    if (@_) { return $self->{$name} = shift }
    else    { return $self->{$name} }
}
```

As you see, there are no methods named `name`, `race`, or `aliases` anywhere to be found. The `AUTOLOAD` routine takes care of all that. When someone uses `$him->name("Aragorn")`, the `AUTOLOAD` subroutine is called with `$AUTOLOAD` set to "`Person::name`". Conveniently, by leaving it fully qualified, it's in exactly the right form for accessing fields of the object hash. That way, if you use this class as part of a larger class hierarchy, you don't conflict with uses of the same name in other classes.

Generating Accessors with Closures

Most accessor methods do essentially the same thing: they simply fetch or store a value from that instance variable. In Perl, the most natural way to create a family of near-duplicate functions is looping around a closure. But closures are anonymous functions lacking names, and methods need to be named subroutines in the class's package symbol table so that they can be called by name. This is no problem—just assign the closure reference to a typeglob of the appropriate name.

```
package Person;

sub new {
    my $invocant = shift;
    my $self = bless({}, ref $invocant || $invocant);
    $self->init();
    return $self;
}

sub init {
    my $self = shift;
    $self->name("unnamed");
    $self->race("unknown");
    $self->aliases([]);
```

```
}

for my $field (qw(name race aliases)) {
    my $slot = __PACKAGE__ . "::$field";
    no strict "refs";          # So symbolic ref to typeglob works.
    *$slot = sub {
        my $self = shift;
        $self->{$field} = shift if @_;
        return $self->{$field};
    };
}
```

Closures are the cleanest hand-rolled way to create a multitude of accessor methods for your instance data. It's efficient for both the computer and you. Not only do all the accessors share the same bit of code (they only need their own lexical pads), but later if you decide to add another attribute, the changes required are minimal: just add one more word to the `for` loop's list, and perhaps something to the `init` method.

Using Closures for Private Objects

So far, these techniques for managing instance data have offered no mechanism for "protection" from external access. Anyone outside the class can open up the object's black box and poke about inside—if she doesn't mind voiding the warranty. Enforced privacy tends to get in the way of people trying to get their jobs done. Perl's philosophy is that it's better to encapsulate one's data with a sign that says:

```
IN CASE OF FIRE
  BREAK GLASS
```

You should respect such encapsulation when possible, but still have easy access to the contents in an emergency situation, like for debugging.

But if you do want to enforce privacy, Perl isn't about to get in your way. Perl offers low-level building blocks that you can use to surround your class and its objects with an impenetrable privacy shield—one stronger, in fact, than that found in many popular object-oriented languages. Lexical scopes and the lexical variables inside them are the key components here, and closures play a pivotal role.

In the earlier section "Private Methods" on page 440, we saw how a class can use closures to implement methods that are invisible outside the module file. Later, we'll look at accessor methods that regulate class data that are so private not even the rest of the class has unrestricted access. Those are still fairly traditional uses of closures. The truly interesting approach is to use a closure as the very object itself. The object's instance variables are locked up inside a scope to which the

object alone—that is, the closure—has free access. This is a very strong form of encapsulation; not only is it proof against external tampering, even other methods in the same class must use the proper access methods to get at the object's instance data.

Here's an example of how this might work. We'll use closures both for the objects themselves and for the generated accessors:

```
package Person;
sub new {
    my $invocant  = shift;
    my $class = ref($invocant) || $invocant;
    my $data = {
       NAME     => "unnamed",
       RACE     => "unknown",
       ALIASES  => [],
    };
    my $self = sub {
       my $field = shift;
       ############################
       ### ACCESS CHECKS GO HERE ###
       ############################
       if (@_) { $data->{$field} = shift }
       return    $data->{$field};
    };
    bless($self, $class);
    return $self;
}
# generate method names
for my $field (qw(name race aliases)) {
    no strict "refs";  # for access to the symbol table
    *$field = sub {
        my $self = shift;
        return $self->(uc $field, @_);
    };
}
```

The object created and returned by the `new` method is no longer a hash, as it was in other constructors we've looked at. It's a closure with unique access to the attribute data stored in the hash referred to by `$data`. Once the constructor call is finished, the only access to `$data` (and hence to the attributes) is via the closure.

In a call like `$him->name("Bombadil")`, the invoking object stored in `$self` is the closure that was blessed and returned by the constructor. There's not a lot one can do with a closure beyond calling it, so we do just that with `$self->(uc $field, @_)`. Don't be fooled by the arrow; this is just a regular indirect function call, not a method invocation. The initial argument is the string "`name`", and any

remaining arguments are whatever else was passed in.[7] Once we're executing inside the closure, the hash reference inside `$data` is again accessible. The closure is then free to permit or deny access to whatever it pleases.

No one outside the closure object has unmediated access to this very private instance data, not even other methods in the class. They could try to call the closure the way the methods generated by the `for` loop do, perhaps setting an instance variable the class never heard of. But this approach is easily blocked by inserting various bits of code in the constructor where you see the comment about access checks. First, we need a common preamble:

```
use Carp;
local $Carp::CarpLevel = 1;  # Keeps croak messages short
my ($cpack, $cfile) = caller();
```

Now for each of the checks. The first one makes sure the specified attribute name exists:

```
croak "No valid field '$field' in object"
    unless exists $data->{$field};
```

This one allows access only by callers from the same file:

```
carp "Unmediated access denied to foreign file"
    unless $cfile eq __FILE__;
```

This one allows access only by callers from the same package:

```
carp "Unmediated access denied to foreign package ${cpack}::"
    unless $cpack eq __PACKAGE__;
```

And this one allows access only by callers whose classes inherit ours:

```
carp "Unmediated access denied to unfriendly class ${cpack}::"
    unless $cpack->isa(__PACKAGE__);
```

All these checks block unmediated access only. Users of the class who politely use the class's designated methods are under no such restriction. Perl gives you the tools to be just as persnickety as you want to be. Fortunately, not many people want to be.

But some people ought to be. Persnickety is good when you're writing flight-control software. If you either want or ought to be one of those people, and you prefer using working code over reinventing everything on your own, check out Damian Conway's `Tie::SecureHash` module on CPAN. It implements restricted hashes with support for public, protected, and private persnicketations. It also copes with the inheritance issues that we've ignored in the previous example.

7. Sure, the double-function call is slow, but if you wanted fast, would you really be using objects in the first place?

Damian has also written an even more ambitious module, `Class::Contract`, that imposes a formal software engineering regimen over Perl's flexible object system. This module's feature list reads like a checklist from a computer science professor's software engineering textbook,[8] including enforced encapsulation, static inheritance, and design-by-contract condition checking for object-oriented Perl, along with a declarative syntax for attribute, method, constructor, and destructor definitions at both the object and class level, and preconditions, postconditions, and class invariants. Whew!

New Tricks

As of v5.6, you can also declare a method to indicate that it returns an lvalue. This is done with the lvalue subroutine attribute (not to be confused with object attributes). This experimental feature allows you to treat the method as something that would appear on the lefthand side of an equals sign:

```
package Critter;

sub new {
    my $class = shift;
    my $self = { pups => 0, @_ };    # Override default.
    bless $self, $class;
}

sub pups : lvalue {                  # We'll assign to pups() later.
    my $self = shift;
    $self->{pups};
}

package main;
$varmint = Critter->new(pups => 4);
$varmint->pups *= 2;                 # Assign to $varmint->pups!
$varmint->pups =~ s/(.)/$1$1/;       # Modify $varmint->pups in place!
print $varmint->pups;                # Now we have 88 pups.
```

This lets you pretend `$varmint->pups` is a variable while still obeying encapsulation. See the section "The lvalue Attribute" on page 336 in Chapter 7.

If you're running a threaded version of Perl and want to ensure that only one thread can call a particular method on an object, you can use the `locked` and `method` attributes to do that:

8. Can you guess what Damian's job is? By the way, we highly recommend his book, *Object Oriented Perl* (Manning).

```
sub pups : locked method {
    ...
}
```

When any thread invokes the `pups` method on an object, Perl locks the object before execution, preventing other threads from doing the same. See the section "The method Attribute" on page 335 in Chapter 7.

Managing Class Data

We've looked at several approaches to accessing per-object data values. Sometimes, though, you want some common state shared by all objects of a class. Instead of being an attribute of just one instance of the class, these variables are global to the entire class, no matter which class instance (object) you use to access them through. (C++ programmers would think of these as static member data.) Here are some situations where class variables might come in handy:

- To keep a count of all objects ever created, or how many are still kicking around.
- To keep a list of all objects over which you can iterate.
- To store the name or file descriptor of a log file used by a class-wide debugging method.
- To keep collective data, like the total amount of cash dispensed by all ATMs in a network in a given day.
- To track the last object created by a class, or the most accessed object.
- To keep a cache of in-memory objects that have already been reconstituted from persistent memory.
- To provide an inverted lookup table so you can find an object based on the value of one of its attributes.

The question comes down to deciding where to store the state for those shared attributes. Perl has no particular syntactic mechanism to declare class attributes any more than it has for instance attributes. Perl provides the developer with a broad set of powerful but flexible features that can be uniquely crafted to the particular demands of the situation. You can then select the mechanism that makes the most sense for the given situation instead of having to live with someone else's design decisions. Alternatively, you can live with the design decisions someone else has packaged up and put onto CPAN. Again, TMTOWTDI.

Like anything else pertaining to a class, class data shouldn't be accessed directly, especially from outside the implementation of the class itself. It doesn't say much for encapsulation to set up carefully controlled accessor methods for instance

variables but then invite the public in to diddle your class variables directly, such as by setting `$SomeClass::Debug = 1`. To establish a clear firewall between interface and implementation, you can create accessor methods to manipulate class data similar to those you use for instance data.

Imagine we want to keep track of the total world population of `Critter` objects. We'll store that number in a package variable, but provide a method called `population` so that users of the class don't have to know about the implementation.

```
Critter->population()       # Access via class name
$gollum->population()       # Access via instance
```

Since a class in Perl is just a package, the most natural place to store class data is in a package variable. Here's a simple implementation of such a class. The `population` method ignores its invocant and just returns the current value of the package variable, `$Population`. (Some programmers like to capitalize their globals.)

```
package Critter;
our $Population = 0;
sub population { return $Population }
sub DESTROY { $Population-- }
sub spawn {
    my $invocant = shift;
    my $class = ref($invocant) || $invocant;
    $Population++;
    return bless { name => shift || "anon" }, $class;
}
sub name {
    my $self = shift;
    $self->{name} = shift if @_;
    return $self->{name};
}
```

If you want to make class data methods that work like accessors for instance data, do this:

```
our $Debugging = 0;     # class datum
sub debug {
    shift;              # intentionally ignore invocant
    $Debugging = shift if @_;
    return $Debugging;
}
```

Now you can set the overall debug level through the class or through any of its instances.

Because it's a package variable, `$Debugging` is globally accessible. But if you change the `our` variable to `my`, then only code later in that same file can see it. You can go still further—you can restrict unfettered access to class attributes even from the rest of the class itself. Wrap the variable declaration in a block scope:

```
{
    my $Debugging = 0;          # lexically scoped class datum
    sub debug {
        shift;                  # intentionally ignore invocant
        $Debugging = shift if @_;
        return $Debugging;
    }
}
```

Now, no one is allowed to read or write the class attributes without using the accessor method, since only that subroutine is in the same scope as the variable and has access to it.

If a derived class inherits these class accessors, then these still access the original data, no matter whether the variables were declared with `our` or `my`. The data isn't package relative. You might look at it as methods executing in the class in which they were originally defined, not in the class that invoked them.

For some kinds of class data, this approach works fine; for others, it doesn't. Suppose we create a `Warg` subclass of `Critter`. If we want to keep our populations separate, `Warg` can't inherit `Critter`'s population method because that method as written always returns the value of `$Critter::Population`.

You'll have to decide on a case-by-case basis whether it makes any sense for class attributes to be package relative. If you want package-relative attributes, use the invocant's class to locate the package holding the class data:

```
sub debug {
    my $invocant = shift;
    my $class   = ref($invocant) || $invocant;
    my $varname = $class . "::Debugging";
    no strict "refs";       # to access package data symbolically
    $$varname = shift if @_;
    return $$varname;
}
```

We temporarily rescind strict references because otherwise we couldn't use the fully qualified symbolic name for the package global. This is perfectly reasonable: since all package variables by definition live in a package, there's nothing wrong with accessing them via that package's symbol table.

Another approach is to make everything an object needs—even its global class data—available via that object (or passed in as parameters). To do this, you'll often have to make a dedicated constructor for each class, or at least have a dedicated initialization routine to be called by the constructor. In the constructor or initializer, you store references to any class data directly in the object itself, so nothing ever has to go looking for it. The accessor methods use the object to find a reference to the data.

Rather than put the complexity of locating the class data in each method, just let the object tell the method where the data is located. This approach only works well when the class data accessor methods are invoked as instance methods, because the class data could be in unreachable lexicals you couldn't get at using a package name.

No matter how you roll it, package-relative class data is always a bit awkward. It's really a lot cleaner if, when you inherit a class data accessor method, you effectively inherit the state data that it's accessing as well. See the *perltoot* manpage for numerous, more elaborate approaches to creative management of class data. You may have to hunt around for it, though.

The Moose in the Room

We've told you about Perl's built-in object system, but there's another object system that Perl programmers like. The `Moose` module uses metaobject programming to do a lot of fancy things for you. There's a lot more to `Moose` than we can tell you about in this book (and it really deserves its own book anyway), but here's a taste:

```
use v5.14;

package Stables 1.01 {
    use Moose;

    has "animals" => (
        traits  => ["Array"],
        is      => "rw",
        isa     => "ArrayRef[Animal]",
        default => sub { [] },
        handles => {
            add_animal  => "push",
            add_animals => "push",
        },
    );

    sub roll_call {
        my($self) = @_;

        for my $animal ($self->animals) {
            say "Some ", $animal->type,
                " named ", $animal->name,
                " is in the stable";
        }
    }

}
```

```
package Animal 1.01 {
    use Moose;

    has "name" => (
        is       => "rw",
        isa      => "Str",
        required => 1,
    );

    has "type" => (
        is      => "rw",
        isa     => "Str",
        default => "animal",
    );

}

my $stables = Stables->new;

$stables->add_animal(
    Animal->new(name => "Mr. Ed", type => "horse")
);

$stables->add_animals(
    Animal->new(name => "Donkey",   type => "donkey"),
    Animal->new(name => "Lampwick", type => "donkey"),
    Animal->new(name => "Trigger",  type => "horse" ),
);

$stables->roll_call;
```

`Moose` does many things to simplify your life as a class designer. In the `Stables` package, Moose provides features that would otherwise be boring work if you had to implement them yourself. Calling `has` defines accessors with particular properties.

default constructor with default arguments

There's no explicit constructor in `Stables` or `Animal`. `Moose` takes care of all that for you. If you need something special, you can still provide your own. In `Animal`, the `name` attribute is required, but the `type` attribute has a default value.

parameter checking

In the `has animals` line in `Stables`, the type of value is declared as an `ArrayRef` that contains `Animal` objects. The `default` specifies what to do if the constructor has no arguments (since `required` is `0`). `Moose` will check that anything you give to `add_animals` is an `Animal` object.

traits

: The `traits` key gives behavior to the accessor. Since the value is an array reference, you'll probably want to do array-like operations on it. The `handles` hash reference map the names that you want to use to the method names the trait provides. The `add_animal` and `add_animals` methods dispatch to the `Array` trait's `push`.

This is just a simple example. `Moose` can do much more powerful and helpful things. To learn more about `Moose`, start at its website.

Other modules provide `Moose`-like interfaces. The `Mouse` framework is a stripped down version of `Moose` that aims to mitigate the performance issues by not including features you probably don't want. `Moo` is also a stripped down `Moose` without XS prerequisites for easier deployment. The `Mo` framework is even smaller than that.

Summary

That's about all there is to it, except for everything else. Now you just need to go off and buy a book about object-oriented design methodology and bang your forehead with it for the next six months or so.

CHAPTER 13
Overloading

Objects are cool, but sometimes they're just a little *too* cool. Sometimes you would rather they behaved a little less like objects and a little more like regular data types. But there's a problem: objects are referents represented by references, and references aren't terribly useful except as references. You can't add references, or print them, or (usefully) apply many of Perl's built-in operators. The only thing you can do is dereference them. So you find yourself writing many explicit method invocations, like this:

```
print $object->as_string;
$new_object = $subject->add($object);
```

Such explicit dereferencing is in general a good thing; you should never confuse your references with your referents, except when you want to confuse them. Now would be one of those times. If you design your class with *overloading*, you can pretend the references aren't there and simply say:

```
print $object;
$new_object = $subject + $object;
```

When you overload one of Perl's built-in operators, you define how it behaves when it's applied to objects of a particular class. A number of standard Perl modules use overloading, such as `Math::BigInt`, which lets you create `Math::BigInt` objects that behave just like regular integers but have no size limits. You can add them with `+`, divide them with `/`, compare them with `<=>`, and print them with `print`.

Note that overloading is not the same as autoloading, which is loading a missing function or method on demand. Neither is it the same as overriding, which is one function or method masking another. Overloading hides nothing; it adds meaning to an operation that would have been nonsense on a mere reference.

The overload Pragma

The `overload` pragma implements operator overloading. You provide it with a key/value list of operators and their associated behaviors:

```
package MyClass;

use overload   "+" => \&myadd,            # coderef
               "<" => "less_than",        # named method
             "abs" => sub { return @_ };  # anonymous subroutine
```

Now when you try to add two `MyClass` objects, the `myadd` subroutine will be called to create the result.

When you try to compare two `MyClass` objects with the `<` operator, Perl notices that the behavior is specified as a string and interprets the string as a method name and not simply as a subroutine name. In the example above, the `less_than` method might be supplied by the `MyClass` package itself or inherited from a base class of `MyClass`, but the `myadd` subroutine must be supplied by the current package. The anonymous subroutine for `abs` supplies itself even more directly. However these routines are supplied, we'll call them *handlers*.

For unary operators (those taking only one operand, like `abs`), the handler specified for the class is invoked whenever the operator is applied to an object of that class.

For binary operators like `+` or `<`, the handler is invoked whenever the first operand is an object of the class *or* when the second operand is an object of the class and the first operand has no overloading behavior. That's so you can say either:

```
$object + 6
```

or:

```
6 + $object
```

without having to worry about the order of operands. (In the second case, the operands will be *swapped* when passed to the handler.) If our expression was:

```
$animal + $vegetable
```

and `$animal` and `$vegetable` were objects of different classes, both of which used overloading, then the overloading behavior of `$animal` would be triggered. (We'll hope the animal likes vegetables.)

There is only one trinary (ternary) operator in Perl, `?:`, and you can't overload it. Fortunately.

Overload Handlers

When an overloaded operator is, er, operated, the corresponding handler is invoked with three arguments. The first two arguments are the two operands. If the operator only uses one operand, the second argument is `undef`.

The third argument indicates whether the first two arguments were swapped. Even under the rules of normal arithmetic some operations, like addition or multiplication, don't usually care about the order of their arguments, but others, like subtraction and division, do.[1] Consider the difference between:

```
$object - 6
```

and:

```
6 - $object
```

If the first two arguments to a handler have been swapped, the third argument will be true. Otherwise, the third argument will be false, in which case there is a finer distinction as well: if the handler has been triggered by another handler involving assignment (as in `+=` using `+` to figure out how to add), then the third argument is not merely false, but `undef`. This distinction enables some optimizations.

As an example, here is a class that lets you manipulate a bounded range of numbers. It overloads both `+` and `-` so that the result of adding or subtracting objects constrains the values within the range 0 and 255:

```
package ClipByte;

 use overload "+" => \&clip_add,
              "-" => \&clip_sub;

 sub new {
     my $class = shift;
     my $value = shift;
     return bless \$value => $class;
 }

 sub clip_add {
     my ($x, $y) = @_;
     my ($value) = ref($x) ? $$x : $x;
     $value     += ref($y) ? $$y : $y;
     $value = 255 if $value > 255;
     $value =   0 if $value < 0;
```

1. Your overloaded objects are not required to respect the rules of normal arithmetic, of course, but it's usually best not to surprise people. Oddly, many languages make the mistake of overloading `+` with string concatenation, which is not commutative and only vaguely additive. For a different approach, see Perl.

```
    return bless \$value => ref($x);
}

sub clip_sub {
    my ($x, $y, $swap) = @_;
    my ($value) = (ref $x) ? $$x : $x;
    $value     -= (ref $y) ? $$y : $y;
    if ($swap) { $value = -$value }
    $value = 255 if $value > 255;
    $value =   0 if $value < 0;
    return bless \$value => ref($x);
}

package main;

$byte1 = ClipByte->new(200);
$byte2 = ClipByte->new(100);

$byte3 = $byte1 + $byte2;    # 255
$byte4 = $byte1 - $byte2;    # 100
$byte5 = 150 - $byte2;       # 50
```

You'll note that every function here is by necessity a constructor, so each one takes care to `bless` its new object back into the current class, whatever that is; we assume our class might be inherited. We also assume that if `$y` is a reference, it's a reference to an object of our own type. Instead of testing `ref($y)`, we could have called `$y->isa("ClipByte")` if we wanted to be more thorough (and run slower).

Overloadable Operators

You can only overload certain operators, which are shown in Table 13-1. The operators are also listed in the `%overload::ops` hash made available when you `use overload`, though the categorization is a little different there.

Table 13-1. Overloadable operators

Category	Operators
Conversion	`"" 0+ bool qr`
Arithmetic	`+ - * / % ** x . neg`
Logical	`!`
Bitwise	`& | ~ ^ ! << >>`
Assignment	`+= -= *= /= %= **= x= .= <<= >>= ++ --`
Comparison	`== < <= > >= != <=> lt le gt ge eq ne cmp`
Mathematical	`atan2 cos sin exp abs log sqrt int`

Category	Operators
Iterative	`<>`
Filetest	`-X`
Dereference	`${} @{} %{} &{} *{}`
Matching	`~~`
Pseudo	`nomethod fallback =`

Note that `neg`, `bool`, `nomethod`, and `fallback` are not actual Perl operators. The five dereferencers, `qr`, `""`, and `0+` probably don't *seem* like operators either. Nevertheless, they are all valid keys for the parameter list you provide to `use overload`. This is not really a problem. We'll let you in on a little secret: it's a bit of a fib to say that the `overload` pragma overloads operators. It overloads the underlying operations, whether invoked explicitly via their "official" operators or implicitly via some related operator. (The pseudo-operators we mentioned can only be invoked implicitly.) In other words, overloading happens not at the syntactic level, but at the semantic level. The point is not to look good. The point is to do the right thing. Feel free to generalize.

Note also that `=` does *not* overload Perl's assignment operator as you might expect. That would not do the right thing. More on that later.

We'll start by discussing the conversion operators, not because they're the most obvious (they aren't), but because they're the most useful. Many classes overload nothing but stringification, specified by the `""` key. (Yes, that really is two double quotes in a row.)

Conversion operators: `""`, `0+`, `bool`, `qr`

The first three keys let you provide behaviors for Perl's automatic conversions to strings, numbers, and Boolean values, respectively.

The fourth key is used whenever the object is interpolated into or used as a regex, including when it appears as the right operand of an `=~` or `!~` operator. The `qr` subroutine must return a compiled regex, or a ref to a compiled regex such as the real `qr` returns, and any further overloading on the return value will be ignored.

We say that *stringification* occurs when any nonstring variable is used as a string. It's what happens when you convert a variable into a string via printing, interpolation, concatenation, or even by using it as a hash key. Stringification is also why you see something like `SCALAR(0xba5fe0)` when you try to `print` an object.

We say that *numification* (pronounced like *mummification*) occurs when a nonnumeric variable is converted into a number in any numeric context, such as any mathematical expression, array index, or even as an operand of the `..` range operator.

Finally, while nobody here quite has the nerve to call it *boolification*, you can define how an object should be interpreted in a Boolean context (such as `if`, `unless`, `while`, `for`, `and`, `or`, `&&`, `||`, `?:`, or the block of a `grep` expression) by creating a `bool` handler.

Any of the three conversion operators can be *autogenerated* if you have any one of them (we'll explain autogeneration later). Your handlers can return any value you like. Note that if the operation that triggered the conversion is also overloaded, *that* overloading will occur immediately afterward.

Here's a demonstration of `""` that invokes an object's `as_string` handler upon stringification. Don't forget to quote the quotes:

```
package Person;

use overload q("") => \&as_string;

sub new {
    my $class = shift;
    return bless { @_ } => $class;
}

sub as_string {
    my $self = shift;
    my ($key, $value, $result);
    while (($key, $value) = each %$self) {
        $result .= "$key => $value\n";
    }
    return $result;
}

$obj = Person->new(height => 72, weight => 165, eyes => "brown");

print $obj;
```

Instead of something like `Person=HASH(0xba1350)`, this prints (in hash order):

```
weight => 165
height => 72
eyes => brown
```

(We sincerely hope this person was not measured in kg and cm.)

Arithmetic operators: `+`, `-`, `*`, `/`, `%`, `**`, `x`, `.`, `neg`

These should all be familiar except for `neg`, which is a special overloading key for the unary minus: the `-` in `-123`. The distinction between the `neg` and

- keys allows you to specify different behaviors for unary minus and binary minus, more commonly known as subtraction.

If you overload - but not `neg`, and then try to use a unary minus, Perl will emulate a `neg` handler for you. This is known as *autogeneration*, where certain operators can be reasonably deduced from other operators (on the assumption that the overloaded operators will have the same relationships as the regular operators). Since unary minus can be expressed as a function of binary minus (that is, `-123` is equivalent to `0 - 123`), Perl doesn't force you to overload `neg` when - will do. (Of course, if you've arbitrarily defined binary minus to divide the second argument by the first, unary minus will be a fine way to throw a divide-by-0 exception.)

Concatenation via the `.` operator can be autogenerated via the stringification handler (see `""` under "Conversion operators" above).

Logical operator: `!`

If a handler for `!` is not specified, it can be autogenerated using the `bool`, `""`, or `0+` handler. If you overload the `!` operator, the `not` operator will also trigger whatever behavior you requested. (Remember our little secret?)

You may be surprised at the absence of the other logical operators, but most logical operators can't be overloaded because they short circuit. They're really control-flow operators that need to be able to delay evaluation of some of their arguments. That's also the reason the `?:` operator isn't overloaded.

Bitwise operators: `&`, `|`, `~`, `^`, `<<`, `>>`

The `~` operator is a unary operator; all the others are binary. Here's how we could overload `>>` to do something like `chop`:

```
package ShiftString;

use overload
    ">>"   => \&right_shift,
    q("")  => sub { ${ $_[0] } };

sub new {
    my $class = shift;
    my $value = shift;
    return bless \$value => $class;
}

sub right_shift {
    my ($x, $y) = @_;
    my $value = $$x;
    substr($value, -$y) = "";
    return bless \$value => ref($x);
}
```

```
$camel = ShiftString->new("Camel");
$ram = $camel >> 2;
print $ram;            # Cam
```

Assignment operators: `+=`, `-=`, `*=`, `/=`, `%=`, `**=`, `x=`, `.=`, `<<=`, `>>=`, `++`, `--`

These assignment operators might change the value of their arguments or leave them as is. The result is assigned to the lefthand operand only if the new value differs from the old one. This allows the same handler to be used to overload both `+=` and `+`. Although this is permitted, it is seldom recommended, since by the semantics described later under "When an Overload Handler Is Missing (nomethod and fallback)" on page 469, Perl will invoke the handler for `+` anyway, assuming `+=` hasn't been overloaded directly.

Concatenation (`.=`) can be autogenerated using stringification followed by ordinary string concatenation. The `++` and `--` operators can be autogenerated from `+` and `-` (or `+=` and `-=`).

Handlers implementing `++` and `--` are expected to *mutate* (alter) their arguments. If you wanted autodecrement to work on letters as well as numbers, you could do that with a handler as follows:

```
package MagicDec;

use overload
    q(--) => \&decrement,
    q("") => sub { ${ $_[0] } };

sub new {
    my $class = shift;
    my $value = shift;
    bless \$value => $class;
}

sub decrement {
    my @string = reverse split(//, ${ $_[0] } );
    my $i;
    for ($i = 0; $i< @string; $i++ ) {
        last unless $string[$i] =~ /a/i;
        $string[$i] = chr( ord($string[$i]) + 25 );
    }
    $string[$i] = chr( ord($string[$i]) - 1 );
    my $result = join("" => reverse @string);
    $_[0] = bless \$result => ref($_[0]);
}

package main;

for $normal (qw/perl NZ Pa/) {
```

```
    $magic = MagicDec->new($normal);
    $magic--;
    print "$normal goes to $magic\n";
}
```

That prints out:

```
perl goes to perk
NZ goes to NY
Pa goes to Oz
```

exactly reversing Perl's magical string autoincrement operator.

The `++$a` operation can be autogenerated using `$a += 1` or `$a = $a + 1`, and `$a--` using `$a -= 1` or `$a = $a - 1`. However, this does not trigger the copying behavior that a real `++` operator would. See the section "The Copy Constructor (=)" on page 468 later in this chapter.

Comparison operators: `==`, `<`, `<=`, `>`, `>=`, `!=`, `<=>`, `lt`, `le`, `gt`, `ge`, `eq`, `ne`, `cmp`

If `<=>` is overloaded, it can be used to autogenerate behaviors for `<`, `<=`, `>`, `>=`, `==`, and `!=`. Similarly, if `cmp` is overloaded, it can be used to autogenerate behaviors for `lt`, `le`, `gt`, `ge`, `eq`, and `ne`.

Note that overloading `cmp` won't let you sort objects as easily as you'd like, because what will be compared are the stringified versions of the objects instead of the objects themselves. If that was your goal, you'd want to overload `""` as well.

Mathematical functions: `atan2`, `cos`, `sin`, `exp`, `abs`, `log`, `sqrt`, `int`

If `abs` is unavailable, it can be autogenerated from `<` or `<=>` combined with either unary minus or subtraction.

An overloaded `-` can be used to autogenerate missing handlers for unary minus or for the `abs` function, which may also be overloaded . (Yes, we know that `abs` looks like a function, whereas unary minus looks like an operator, but they aren't all that different as far as Perl's concerned.)

Traditionally, the Perl function `int` rounds toward 0 (see the `int` entry in Chapter 27), and so for objects acting like floating-point types, one should probably do the same thing to avoid surprising people.

Iterative operator: `<>`

The `<>` handler can be triggered by using either `readline` (when it reads from a filehandle, as in `while (<FH>)`) or `glob` (when it is used for fileglobbing, as in `@files = <*.*>`).

```
package LuckyDraw;

use overload
    "<>" => sub {
```

```
        my $self = shift;
        return splice @$self, rand @$self, 1;
    };

sub new {
    my $class = shift;
    return bless [@_] => $class;
}

package main;

$lotto = new LuckyDraw 1 .. 51;

for (qw(1st 2nd 3rd 4th 5th 6th)) {
    $lucky_number = <$lotto>;
    print "The $_ lucky number is: $lucky_number.\n";
}

$lucky_number = <$lotto>;
print "\nAnd the bonus number is: $lucky_number.\n";
```

In California, this prints:

```
The 1st lucky number is: 18
The 2nd lucky number is: 11
The 3rd lucky number is: 40
The 4th lucky number is: 7
The 5th lucky number is: 51
The 6th lucky number is: 33

And the bonus number is: 5
```

File test operators

The key `-X` is used to specify a subroutine to handle all the filetest operators, like `-f`, `-x`, and so on. See Table 3-4 in the section "Named Unary and File Test Operators" on page 106 in Chapter 3.

It is not possible to overload any filetest operator individually. To distinguish them, the letter following the – is passed as the second argument (that is, in the slot that for binary operators is used to pass the second operand).

Calling an overloaded filetest operator does not affect the stat value associated with the special filehandle `_`. It still refers to the result of the last `stat`, `lstat`, or unoverloaded filetest.

This overload was introduced in v5.12.

Dereference operators: `${}`, `@{}`, `%{}`, `&{}`, `*{}`

Attempts to dereference scalar, array, hash, subroutine, and glob references can be intercepted by overloading these five symbols.

The online Perl documentation for `overload` demonstrates how you can use this operator to simulate your own pseudohashes. Here's a simpler example that implements an object as an anonymous array but permits hash referencing. Don't try to treat it as a real hash; you won't be able to `delete` key/value pairs from the object. If you want to combine array and hash notations, use a real pseudohash (as it were).

```
package PsychoHash;

use overload "%{}" => \&as_hash;

sub as_hash {
    my ($x) = shift;
    return { @$x };
}

sub new {
    my $class = shift;
    return bless [ @_ ] => $class;
}

$critter = new PsychoHash( height => 72, weight => 365, type => "camel" );

print $critter->{weight};   # prints 365
```

Also see Chapter 14 for a mechanism to let you redefine basic operations on hashes, arrays, and scalars.

When overloading an operator, try not to create objects with references to themselves. For instance:

```
use overload "+" => sub { bless [ \$_[0], \$_[1] ] };
```

This is asking for trouble because if you say `$animal += $vegetable`, the result will make

`$animal` a reference to a blessed array reference whose first element is `$animal`. This is a *circular reference*, which means that even if you destroy `$animal`, its memory won't be freed until your process (or interpreter) terminates. See "Garbage Collection, Circular References, and Weak References" on page 362 in Chapter 8.

Smartmatching

The key ~~ allows you to override the smartmatching logic used by the ~~ operator and the given construct. See the section "Smartmatch Operator" on page 112 in Chapter 3 and "The given Statement" on page 133 in Chapter 4.

Unusually, the overloaded implementation of the smartmatch operator does not get full control of the smartmatch behavior. In particular, in the following code:

```
package Foo;
use overload "~~" => "match";

my $obj =  Foo->new();
$obj ~~ [ 1,2,3 ];
```

the smartmatch does not invoke the method call like this:

```
$obj->match([1,2,3],0);     # WRONG INVOCATION
```

but rather, the smartmatch distributive rule takes precedence, so `$obj` is smartmatched against each array element in turn until a match is found, and so you may therefore see between one and three of these calls instead:

```
$obj->match(1,0);
$obj->match(2,0);
$obj->match(3,0);
```

Consult Table 3-7 in Chapter 3 for details of when overloading is invoked on the smartmatch operator.

The Copy Constructor (=)

Although it looks like a regular operator, `=` has a special and slightly subintuitive meaning as an overload key. It does *not* overload the Perl assignment operator. It can't, because that operator has to be reserved for assigning references, or everything breaks.

The handler for `=` is used in situations where a mutator (such as `++`, `--`, or any of the assignment operators) is applied to a reference that shares its object with another reference. The `=` handler lets you intercept the mutator and copy the object yourself so that the copy alone is mutated. Otherwise, you'd clobber the original.

```
$copy = $original;   # copies only the reference
++$copy;             # changes underlying shared object
```

Now bear with us. Suppose that `$original` is a reference to an object. To make `++$copy` modify only `$copy` and not `$original`, a copy of `$copy` is first made, and `$copy` is assigned a reference to this new object. This operation is not performed until `++$copy` is executed, so `$copy` coincides with `$original` before the increment —but not afterward. In other words, it's the `++` that recognizes the need for the copy and calls out to your copy constructor.

The need for copying is recognized only by mutators such as ++ or +=, or by nomethod, which is described later. If the operation is autogenerated via +, as in:

```
$copy = $original;
$copy = $copy + 1;
```

then no copying occurs because + doesn't know it's being used as a mutator.

If the copy constructor is required during the execution of some mutator, but a handler for = was not specified, it can be autogenerated as a string copy provided the object is a plain scalar and not something fancier.

For example, the code actually executed for the sequence:

```
$copy = $original;
...
++$copy;
```

might end up as something like this:

```
$copy = $original;
...
$copy = $copy->clone(undef, "");
$copy->incr(undef, "");
```

This assumes $original points to an overloaded object, ++ was overloaded with \&incr, and = was overloaded with \&clone.

Similar behavior is triggered by $copy = $original++, which is interpreted as $copy = $original; ++$original.

When an Overload Handler Is Missing (nomethod and fallback)

If you apply an unoverloaded operator to an object, Perl first tries to autogenerate a behavior from other overloaded operators using the rules described earlier. If that fails, Perl looks for an overloading behavior for nomethod and uses that if available. That handler is to operators what an AUTOLOAD subroutine is to subroutines: it's what you do when you can't think of what else to do.

If used, the nomethod key should be followed by a reference to a handler that accepts four arguments (not three as all the other handlers expect). The first three arguments are no different than in any other handler; the fourth is a string corresponding to the operator whose handler is missing. This serves the same purpose as the $AUTOLOAD variable does in AUTOLOAD subroutines.

If Perl has to look for a nomethod handler but can't find one, an exception is raised.

If you want to prevent autogeneration from occurring, or you want a failed autogeneration attempt to result in no overloading at all, you can define the special `fallback` overloading key. It has three useful states:

`undef`
: If `fallback` is not set, or is explicitly set to `undef`, the sequence of overloading events is unaffected: handlers are sought, autogeneration is attempted, and finally the `nomethod` handler is invoked. If that fails, an exception is raised.

`false`
: If `fallback` is set to a defined but false value (like `0`), autogeneration is never attempted. Perl will call the `nomethod` handler if one exists, but raise an exception otherwise.

`true`
: This is nearly the same behavior as for `undef`, but no exception is raised if an appropriate handler cannot be synthesized via autogeneration. Instead, Perl reverts to following the unoverloaded behavior for that operator, as though there were no `use overload` pragma in the class at all.

Overloading Constants

You can change how constants are interpreted by Perl with `overload::constant`, which is most usefully placed in a package's `import` method. (If you do this, you should properly invoke `overload::remove_constant` in the package's `unimport` method so that the package can clean up after itself when you ask it to.)

Both `overload::constant` and `overload::remove_constant` expect a list of key/value pairs. The keys should be any of `integer`, `float`, `binary`, `q`, and `qr`, and each value should be the name of a subroutine, an anonymous subroutine, or a code reference that will handle the constants.

```
sub import { overload::constant ( integer => \&integer_handler,
                                  float   => \&float_handler,
                                  binary  => \&base_handler,
                                  q       => \&string_handler,
                                  qr      => \&regex_handler ) }
```

Any handlers you provide for `integer` and `float` will be invoked whenever the Perl tokener encounters a constant number. This is independent of the `constant` pragma; simple statements such as:

```
$year = cube(12) + 1;        # integer
$pi   = 3.14159265358979;    # float
```

will trigger whatever handler you requested.

The `binary` key lets you intercept binary, octal, and hexadecimal constants. `q` handles single-quoted strings (including strings introduced with `q`) and constant substrings within `qq`- and `qx`-quoted strings and here documents. Finally, `qr` handles constant pieces within regular expressions, as described at the end of Chapter 5.

The handler will be passed three arguments. The first argument is the original constant, in whatever form it was provided to Perl. The second argument is how Perl actually interpreted the constant; for instance, `123_456` will appear as `123456`.

The third argument is defined only for strings handled by the `q` and `qr` handlers, and will be one of `qq`, `q`, `s`, or `tr`, depending on how the string is to be used. `qq` means that the string is from an interpolated context, such as double quotes, backticks, an `m//` match, or the pattern of an `s///` substitution. `q` means that the string is from an uninterpolated context, `s` means that the constant is a replacement string in an `s///` substitution, and `tr` means that it's a component of a `tr///` or `y///` expression.

The handler should return a scalar, which will be used in place of the constant. Often, that scalar will be a reference to an overloaded object, but there's nothing preventing you from doing something more dastardly:

```
package DigitDoubler;    # A module to be placed in DigitDoubler.pm
use overload;

sub import { overload::constant ( integer => \&handler,
                                  float   => \&handler ) }

sub handler {
    my ($orig, $interp, $context) = @_;
    return $interp * 2;          # double all constants
}

1;
```

Note that `handler` is shared by both keys, which works okay in this case. Now when you say:

```
use DigitDoubler;

$trouble = 123;      # trouble is now 246
$jeopardy = 3.21;    # jeopardy is now 6.42
```

you redefine the world.

If you intercept string constants, it is recommended that you provide a concatenation operator ("`.`") as well, since an interpolated expression like `"ab$cd!!"` is merely a shortcut for the longer `'ab' . $cd . '!!'`. Similarly, negative numbers

are considered negations of positive constants, so you should provide a handler for `neg` when you intercept integers or floats. (We didn't need to do that earlier because we're returning actual numbers, not overloaded object references.)

Note that `overload::constant` does not propagate into runtime compilation inside `eval`, which can be either a bug or a feature, depending on how you look at it.

Public Overload Functions

As of the v5.6 release of Perl, the `overload` pragma provides the following functions for public consumption.

`overload::StrVal(OBJ)`
: This function returns the string value that *`OBJ`* would have in absence of stringification overloading (`""`).

`overload::Overloaded(OBJ)`
: This function returns a true value if *`OBJ`* is subject to any operator overloading at all, and false otherwise.

`overload::Method(OBJ, OPERATOR)`
: This function returns a reference to whatever code implements the overloading for *`OPERATOR`* when it operates on *`OBJ`*, or `undef` if no such overloading exists.

Inheritance and Overloading

Inheritance interacts with overloading in two ways. The first occurs when a handler is named as a string rather than provided as a code reference or anonymous subroutine. When named as a string, the handler is interpreted as a method, and can therefore be inherited from superclasses.

The second interaction between inheritance and overloading is that any class derived from a overloaded class is itself subject to that overloading. In other words, overloading is itself inherited. The set of handlers in a class is the union of handlers of all that class's ancestors, recursively. If a handler can be found in several different ancestors, the handler actually used is governed by the usual rules for method inheritance. For example, if class `Alpha` inherits from classes `Beta` and `Gamma`, in that order, and class `Beta` overloads `+` with `\&Beta::plus_sub`, but class `Gamma` overloads `+` with the string `"plus_meth"`, then `Beta::plus_sub` will be called when you try to apply `+` to an `Alpha` object.

Since the value of the `fallback` key is not a handler, its inheritance is not governed by the rules given above. In the current implementation, the `fallback` value from the first overloaded ancestor is used, but this is accidental and subject to change without notice (well, without much notice).

Runtime Overloading

Since `use` statements are executed at compile time, the only way to change overloading during runtime is:

```
eval " use overload '+' => \&my_add ";
```

You can also say:

```
eval " no overload '+', '--', '<=' ";
```

although the use of these constructs during runtime is questionable.

Overloading Diagnostics

If your Perl was compiled with `-DDEBUGGING`, you can view diagnostic messages for overloading when you run a program with the *–Do* switch or its equivalent. You can also deduce which operations are overloaded using the `m` command of Perl's built-in debugger.

If you're feeling overloaded now, maybe the next chapter will tie things back together for you.

CHAPTER 14
Tied Variables

Some human endeavors require a disguise. Sometimes the intent is to deceive, but more often the intent is to communicate something true at a deeper level. For instance, many job interviewers expect you to dress up in a tie to indicate that you're seriously interested in fitting in, even though both of you know you'll never wear a tie on the job. It's odd when you think about it: tying a piece of cloth around your neck can magically get you a job. In Perl culture, the `tie` operator plays a similar role: it lets you create a seemingly normal variable that, behind the disguise, is actually a full-fledged Perl object that is expected to have an interesting personality of its own. It's just an odd bit of magic, like pulling Bugs Bunny out of a hat.

Put another way, the funny characters `$`, `@`, `%`, or `*` in front of a variable name tell Perl and its programmers a great deal—they each imply a particular set of archetypal behaviors. You can warp those behaviors in various useful ways with `tie`, by associating the variable with a class that implements a new set of behaviors. For instance, you can create a regular Perl hash, and then `tie` it to a class that makes the hash into a database, so that when you read values from the hash, Perl magically fetches data from an external database file, and when you set values in the hash, Perl magically stores data in the external database file. In this case, "magically" means "transparently doing something very complicated". You know the old saying: any technology sufficiently advanced is indistinguishable from a Perl script. (Seriously, people who play with the guts of Perl use *magic* as a technical term referring to any extra semantics attached to variables such as `%ENV` or `%SIG`. Tied variables are just an extension of that.)

Perl already has built-in `dbmopen` and `dbmclose` functions that magically tie hash variables to databases, but those functions date back to the days when Perl had no `tie`. Now, `tie` provides a more general mechanism. In fact, Perl itself implements `dbmopen` and `dbmclose` in terms of `tie`.

You can `tie` a scalar, array, hash, or filehandle (via its typeglob) to any class that provides appropriately named methods to intercept and emulate normal accesses to those variables. The first of those methods is invoked at the point of the `tie` itself: tying a variable always invokes a constructor, which, if successful, returns an object that Perl squirrels away where you don't see it, down inside the "normal" variable. You can always retrieve that object later using the `tied` function on the normal variable:

```
tie VARIABLE, CLASSNAME, LIST;  # binds VARIABLE to CLASSNAME
$object = tied VARIABLE;
```

Those two lines are equivalent to:

```
$object = tie VARIABLE, CLASSNAME, LIST;
```

Once it's tied, you treat the normal variable normally, but each access automatically invokes methods on the underlying object; all the complexity of the class is hidden behind those method invocations. If later you want to break the association between the variable and the class, you can `untie` the variable:

```
untie VARIABLE;
```

You can almost think of `tie` as a funny kind of `bless`, except that it blesses a bare variable instead of an object reference. It also can take extra parameters, just as a constructor can—which is not terribly surprising, since it actually does invoke a constructor internally, whose name depends on which type of variable you're tying: either `TIESCALAR`, `TIEARRAY`, `TIEHASH`, or `TIEHANDLE`.[1] These constructors are invoked as class methods with the specified *`CLASSNAME`* as their invocant, plus any additional arguments you supplied in *`LIST`*. (The *`VARIABLE`* is not passed to the constructor.)

These four constructors each return an object in the customary fashion. They don't really care whether they were invoked from `tie`, nor do any of the other methods in the class, since you can always invoke them directly if you'd like. In one sense, all the magic is in the `tie`, not in the class implementing the `tie`. It's just an ordinary class with funny method names, as far as the class is concerned. (Indeed, some tied modules provide extra methods that aren't visible through the tied variable; these methods must be called explicitly as you would any other object method. Such extra methods might provide services like file locking, transaction protection, or anything else an instance method might do.)

1. Since the constructors have separate names, you could even provide a single class that implements all of them. That would allow you to tie scalars, arrays, hashes, and filehandles all to the same class, although this is not generally done, since it would make the other magical methods tricky to write.

So these constructors `bless` and return an object reference just as any other constructor would. That reference need not refer to the same type of variable as the one being tied; it just has to be blessed, so that the tied variable can find its way back to your class for succor. For instance, our long `TIEARRAY` example will use a hash-based object, so it can conveniently hold additional information about the array it's emulating.

The `tie` function will not `use` or `require` a module for you—you must do that yourself explicitly, if necessary, before calling the `tie`. (On the other hand, the `dbmopen` function will, for backward compatibility, attempt to `use` one or another DBM implementation. But you can preempt its selection with an explicit `use`, provided the module you `use` is one of the modules in `dbmopen`'s list of modules to try. See the online docs for the `AnyDBM_File` module for a fuller explanation.)

The methods called by a tied variable have predetermined names like `FETCH` and `STORE`, since they're invoked implicitly (that is, triggered by particular events) from within the innards of Perl. These names are in `ALLCAPS`, a convention we often follow for such implicitly called routines. (Other special names that follow this convention include `BEGIN`, `CHECK`, `UNITCHECK`, `INIT`, `END`, `DESTROY`, and `AUTOLOAD`, not to mention `UNIVERSAL->VERSION`. In fact, nearly all of Perl's predefined packages, variables, and filehandles are in uppercase: `STDIN`, `SUPER`, `CORE`, `CORE::GLOBAL`, `DATA`, `@EXPORT`, `@INC`, `@ISA`, `@ARGV`, and `%ENV`. Of course, built-in functions, operators, and pragmas go to the opposite extreme and have no capitals at all.)

The first thing we'll cover is extremely simple: how to tie a scalar variable.

Tying Scalars

To implement a tied scalar, a class must define the following methods: `TIESCALAR`, `FETCH`, and `STORE` (and possibly `UNTIE` and `DESTROY`). When you `tie` a scalar variable, Perl calls `TIESCALAR`. When you read the tied variable, it calls `FETCH`, and when you assign a value to the variable, it calls `STORE`. If you've kept the object returned by the initial `tie` (or if you retrieve it later using `tied`), you can access the underlying object yourself—this does not trigger its `FETCH` or `STORE` methods. As an object it's not magical at all, but rather quite objective.

Perl calls `UNTIE`, if you've defined it, when it unties the variable. This gives you a chance to do any bookkeeping or clean-up before the association disappears and the variable is no longer special.

If a `DESTROY` method exists, Perl invokes it when the last reference to the tied object disappears, just as for any other object. That happens when your program ends or when you call `untie`, which eliminates the reference used by the tie. However,

`untie` doesn't eliminate any outstanding references you might have stored elsewhere; `DESTROY` is deferred until those references are gone, too.

The `Tie::Scalar` and `Tie::StdScalar` packages, both found in the standard `Tie::Scalar` module, provide some simple base class definitions if you don't want to define all of these methods yourself. `Tie::Scalar` provides elemental methods that do very little, and `Tie::StdScalar` provides methods that make a tied scalar behave like a regular Perl scalar. (Which seems singularly useless, but sometimes you just want a bit of a wrapper around the ordinary scalar semantics, for example, to count the number of times a particular variable is set.)

Before we show you our elaborate example and complete description of all the mechanics, here's a taste just to whet your appetite—and to show you how easy it really is. Here's a complete program:

```
#!/usr/bin/perl
package Centsible;
sub TIESCALAR { bless \my $self, shift }
sub STORE { ${ $_[0] } = $_[1] }  # do the default thing
sub FETCH { sprintf "%.02f", ${ my $self = shift } } # round value

package main;
tie $bucks, "Centsible";
$bucks = 45.00;
$bucks *= 1.0715; # tax
$bucks *= 1.0715; # and double tax!
print "That will be $bucks, please.\n";
```

When run, that program produces:

```
That will be 51.67, please.
```

To see the difference it makes, comment out the call to `tie`; then you'll get:

```
That will be 51.66505125, please.
```

Admittedly, that's more work than you'd normally go through to round numbers.

Scalar-Tying Methods

Now that you've seen a sample of what's to come, let's develop a more elaborate scalar-tying class. Instead of using any canned package for the base class (especially since scalars are so simple), we'll look at each of the four methods in turn, building an example class named `ScalarFile`. Scalars tied to this class contain regular strings, and each such variable is implicitly associated with a file where that string is stored. (You might name your variables to remind you to which file you're referring.) Variables are tied to the class this way:

```
use ScalarFile;       # load ScalarFile.pm
tie $camel, "ScalarFile", "/tmp/camel.lot";
```

Once the variable has been tied, its previous contents are clobbered, and the internal connection between the variable and its object overrides the variable's normal semantics. When you ask for the value of `$camel`, it now reads the contents of */tmp/camel.lot*, and when you assign a value to `$camel`, it writes the new contents out to */tmp/camel.lot*, obliterating any previous occupants.

The tie is on the variable, not the value, so the tied nature of a variable does not propagate across assignment. For example, let's say you copy a variable that's been tied:

```
$dromedary = $camel;
```

Instead of reading the value in the ordinary fashion from the `$camel` scalar variable, Perl invokes the `FETCH` method on the associated underlying object. It's as though you'd written this:

```
$dromedary = (tied $camel)->FETCH():
```

Or if you remember the object returned by `tie`, you could use that reference directly, as in the following sample code:

```
$clot = tie $camel, "ScalarFile", "/tmp/camel.lot";
$dromedary = $camel;          # through the implicit interface
$dromedary = $clot->FETCH();  # same thing, but explicitly
```

If the class provides methods besides `TIESCALAR`, `FETCH`, `STORE`, and `DESTROY`, you could use `$clot` to invoke them manually. However, one normally minds one's own business and leaves the underlying object alone, which is why you often see the return value from `tie` ignored. You can still get at the object via `tied` if you need it later (for example, if the class happens to document any extra methods you need). Ignoring the returned object also eliminates certain kinds of errors, which we'll cover later.

Here's the preamble of our class, which we will put into *ScalarFile.pm*:

```
package ScalarFile;
use Carp;                # Propagate error messages nicely.
use strict;              # Enforce some discipline on ourselves.
use warnings;            # Turn on lexically scoped warnings.
use warnings::register;  # Allow user to say "use warnings 'ScalarFile'".
my $count = 0;           # Internal count of tied ScalarFiles.
```

The standard `Carp` module exports the `carp`, `croak`, and `confess` subroutines, which we'll use in the code later in this section. As usual, see the docs for more about `Carp`.

The following methods are defined by the class.

CLASSNAME->TIESCALAR(*LIST*)

The TIESCALAR method of the class is triggered whenever you `tie` a scalar variable. The optional *LIST* contains any parameters needed to initialize the object properly. (In our example, there is only one parameter: the name of the file.) The method should return an object, but this doesn't have to be a reference to a scalar. In our example, though, it is:

```
sub TIESCALAR {           # in ScalarFile.pm
    my $class    = shift;
    my $filename = shift;
    $count++;             # A file-scoped lexical, private to class
    return bless \$filename, $class;
}
```

Since there's no scalar equivalent to the anonymous array and hash composers, `[]` and `{}`, we merely bless a lexical variable's referent, which effectively becomes anonymous as soon as the name goes out of scope. This works fine (you could do the same thing with arrays and hashes) as long as the variable really is lexical. If you try this trick on a global, you might think you're getting away with it, until you try to create another *camel.lot*. Don't be tempted to write something like this:

```
sub TIESCALAR { bless \$_[1], $_[0] }    # WRONG,
                                         # could refer to global.
```

A more robustly written constructor might check that the filename is accessible. We check first to see whether the file is readable, since we don't want to clobber the existing value. (In other words, we shouldn't assume the user is going to write first. He might be treasuring his old Camel Lot file from a previous run of the program.) If we can't open or create the filename specified, we'll indicate the error gently by returning `undef` and optionally printing a warning via `carp`. (We could just `croak` instead—it's a matter of taste whether you prefer fish or frogs.) We'll use the `warnings` pragma to determine whether the user is interested in our warning:

```
sub TIESCALAR {           # in ScalarFile.pm
    my $class    = shift;
    my $filename = shift;
    my $fh;
    if ( -r -w $filename ) {
        close $fh;
        $count++;
        return bless \$filename, $class;
    }
    carp "Can't tie $filename: $!" if warnings::enabled();
    return;
}
```

Given such a constructor, we can now associate the scalar `$string` with the file *camel.lot*:

```
tie ($string, "ScalarFile", "camel.lot") || die;
```

(We're still assuming some things we shouldn't. In a production version of this, we'd probably open the filehandle once and remember the filehandle as well as the filename for the duration of the tie, keeping the handle exclusively locked with `flock` the whole time. Otherwise, we're open to race conditions—see "Handling Timing Glitches" on page 661 in Chapter 20.)

SELF`->FETCH`

This method is invoked whenever you access the tied variable (that is, read its value). It takes no arguments beyond the object tied to the variable. In our example, that object contains the filename.

```
sub FETCH {
     my $self  = shift;
     confess "I am not a class method" unless ref $self;
     return unless open my $fh, $$self;
     read($fh, my $value, -s $fh);  # NB: don't use -s on pipes!
     return $value;
 }
```

This time we've decided to blow up (raise an exception) if `FETCH` gets something other than a reference. (Either it was invoked as a class method, or someone miscalled it as a subroutine.) There's no other way for us to return an error, so it's probably the right thing to do. In fact, Perl would have raised an exception in any event as soon as we tried to dereference `$self`; we're just being polite and using `confess` to spew a complete stack backtrace onto the user's screen. (If that can be considered polite.)

We can now see the contents of *camel.lot* when we say this:

```
tie($string, "ScalarFile", "camel.lot");
print $string;
```

SELF`->STORE(`*VALUE*`)`

This method is run when the tied variable is set (assigned). The first argument, *SELF*, is as always the object associated with the variable; *VALUE* is whatever was assigned to the variable. (We use the term "assigned" loosely—any operation that modifies the variable can call `STORE`.)

```
sub STORE {
    my($self,$value) = @_;
    ref($self)                  || confess "not a class method";
    open(my $fh, ">", $$self)   || croak "can't clobber $$self: $!";
    syswrite($fh, $value) == length $value
                                || croak "can't write to $$self: $!";
```

```
    close($fh)                  || croak "can't close $$self: $!";
    return $value;
}
```

After "assigning" it, we return the new value—because that's what assignment does. If the assignment wasn't successful, we `croak` out the error. Possible causes might be that we didn't have permission to write to the associated file, or the disk filled up, or gremlins infested the disk controller. Sometimes you control the magic, and sometimes the magic controls you.

We can now write to *camel.lot* when we say this:

```
tie($string, "ScalarFile", "camel.lot");
$string  = "Here is the first line of camel.lot\n";
$string .= "And here is another line, automatically appended.\n";
```

SELF`->UNTIE`

This method is triggered by `untie`, and only by `untie`. In this example, there's not much use for it, so it just notes that it was called:

```
sub UNTIE {
    my $self = shift;
    confess "Untying!";
}
```

See the caution in "A Subtle Untying Trap" on page 510 later in this chapter.

SELF`->DESTROY`

This method is triggered when the object associated with the tied variable is about to be garbage collected, in case it needs to do something special to clean up after itself. As with other classes, such a method is seldom necessary, since Perl deallocates the moribund object's memory for you automatically. Here we'll define a `DESTROY` method that decrements our count of tied files:

```
sub DESTROY {
    my $self = shift;
    confess "This is not a class method!" unless ref $self;
    $count--;
}
```

We might then also supply an extra class method to retrieve the current count. Actually, it doesn't care whether it's called as a class method or an object method, but you don't have an object anymore after the `DESTROY`, now do you?

```
sub count {
    ### my $invocant = shift;
    $count;
}
```

You can call this as a class method at any time, like this:

```
if (ScalarFile->count) {
    warn "Still some tied ScalarFiles sitting around somewhere...\n";
}
```

That's about all there is to it. Actually, it's more than all there is to it, since we've done a few nice things here for the sake of completeness, robustness, and general aesthetics (or lack thereof). Simpler `TIESCALAR` classes are certainly possible.

Magical Counter Variables

Here's a simple `Tie::Counter` class, inspired by the CPAN module of the same name. Variables tied to this class increment themselves by 1 every time they're used. For example:

```
tie my $counter, "Tie::Counter", 100;
@array = qw /Red Green Blue/;
for my $color (@array) {              # Prints:
    print "  $counter  $color\n";      #   100  Red
}                                     #   101  Green
                                      #   102  Blue
```

The constructor takes as an optional extra argument the first value of the counter, which defaults to 0. Assigning to the counter will set a new value. Here's the class:

```
package Tie::Counter;
sub FETCH     { ++ ${ $_[0] } }
sub STORE     { ${ $_[0] } = $_[1] }
sub TIESCALAR {
    my ($class, $value) = @_;
    $value = 0 unless defined $value;
    bless \$value => $class;
}
1;  # if in module
```

See how small that is? It doesn't take much code to put together a class like this.

Cycling Through Values

Through the magic of `tie`, an array can act as a scalar. The `tie` interface can convert the scalar interface to the array interface. The `Tie::Cycle` CPAN module uses a scalar to cycle through the values in an array. The object keeps track of a cursor and advances it on each access. When it gets to the end, it goes back to the start:

```
package Tie::Cycle;

sub TIESCALAR {
```

```
    my $class    = shift;
    my $list_ref = shift;
    return unless ref $list_ref eq ref [];
    my @shallow_copy = map { $_ } @$list_ref;
    my $self = [ 0, scalar @shallow_copy, \@shallow_copy ];
    bless $self, $class;
}

sub FETCH {
    my $self = shift;
    my $index = $$self[0]++;
    $$self[0] %= $self->[1];
    return $self->[2]->[ $index ];
}

sub STORE {
    my $self     = shift;
    my $list_ref = shift;
    return unless ref $list_ref eq ref [];
    $self = [ 0, scalar @$list_ref, $list_ref ];
}
```

This is handy for giving different CSS classes to alternate rows in an HTML table without complicating the code:

```
tie my $row_class, "Tie::Cycle", [ qw(odd even) ];

for my $item (@items) {
    print qq(<tr class="$row_class">...</tr>);
}
```

This makes it easy to add even more CSS classes without changing the code:

```
tie my $row_class, "Tie::Cycle", [ qw(red green blue) ];
```

Magically Banishing $_

This curiously exotic `underscore` tie class[2] is used to outlaw unlocalized uses of `$_`. Instead of pulling in the module with `use`, which invokes the class's `import` method, this module should be loaded with `no` to call the seldom-used `unimport` method (see Chapter 11). The user says:

```
no underscore;
```

And then all uses of `$_` as an unlocalized global raise an exception.

2. Curiously, the `underscore` came from an example in an earlier edition of this book, which then made it into *Perl Cookbook*, which motivated Dan Kogai to create a CPAN module for it.

Here's a little test suite for the module:

```
#!/usr/bin/perl
no underscore;
@tests = (
    "Assignment"  => sub { $_ = "Bad" },
    "Reading"     => sub { print },
    "Matching"    => sub { $x = /badness/ },
    "Chop"        => sub { chop },
    "Filetest"    => sub { -x },
    "Nesting"     => sub { for (1..3) { print } },
);

while ( ($name, $code) = splice(@tests, 0, 2) ) {
    print "Testing $name: ";
    eval { &$code };
    print $@ ? "detected" : " missed!";
    print "\n";
}
```

which prints out the following:

```
Testing Assignment: detected
Testing Reading: detected
Testing Matching: detected
Testing Chop: detected
Testing Filetest: detected
Testing Nesting: 123 missed!
```

The last one was "missed" because it was properly localized by the `for` loop and thus safe to access.

Here's the curiously exotic `underscore` module itself. (Did we mention that it's curiously exotic?) It works because tied magic is effectively hidden by a `local`. The module does the `tie` in its own initialization code so that a `require` also works:

```
package underscore;
use warnings;
use strict;
use Carp ();
our $VERSION = sprintf "%d.%02d", q$Revision: 0.1 $ =~ /(\d+)/g;

sub TIESCALAR{
    my ($pkg, $code, $msg) = @_;
    bless [$code, $msg], $pkg;
}

sub unimport {
    my $pkg    = shift;
    my $action = shift;
    no strict "refs";
```

```
    my $code = ref $action
                ? $action
                : ($action
                    ? \&{ "Carp::" . $action }
                    : \&Carp::croak
                  );
    my $msg = shift || '$_ is forbidden';
    untie $_ if tied $_;
    tie $_, __PACKAGE__, $code, $msg;
}

sub import{  untie $_ }

sub FETCH{ $_[0]->[0]($_[0]->[1]) }
sub STORE{ $_[0]->[0]($_[0]->[1]) }

1; # End of underscore
```

It's hard to usefully mix calls to `use` and `no` for this class in your program because they all happen at compile time, not runtime. You could call `Underscore->import` and `Underscore->unimport` directly, just as `use` and `no` do. Normally, though, to renege and let yourself freely use `$_` again, you'd just use `local` on it, which is the whole point.

Tying Arrays

A class implementing a tied array must define at least the methods `TIEARRAY`, `FETCH`, and `STORE`. There are many optional methods: the ubiquitous `UNTIE` and `DESTROY` methods, of course, but also the `STORESIZE` and `FETCHSIZE` methods used to provide `$#array` and `scalar(@array)` access. In addition, `CLEAR` is triggered when Perl needs to empty the array, and `EXTEND` when Perl would have preextended allocation in a real array.

You may also define the `POP`, `PUSH`, `SHIFT`, `UNSHIFT`, `SPLICE`, `DELETE`, and `EXISTS` methods if you want the corresponding Perl functions to work on the tied array. The `Tie::Array` class can serve as a base class to implement the first five of those functions in terms of `FETCH` and `STORE`. (`Tie::Array`'s default implementation of `DELETE` and `EXISTS` simply calls `croak`.) As long as you define `FETCH` and `STORE`, it doesn't matter what kind of data structure your object contains.

On the other hand, the `Tie::StdArray` class (defined in the standard `Tie::Array` module) provides a base class with default methods that assume the object contains a regular array. Here's a simple array-tying class that makes use of this. Because it uses `Tie::StdArray` as its base class, it only needs to define the methods that should be treated in a nonstandard way:

```
#!/usr/bin/perl
package ClockArray;
use Tie::Array;
our @ISA = "Tie::StdArray";
sub FETCH {
    my($self,$place) = @_;
    $self->[ $place % 12 ];
}
sub STORE {
    my($self,$place,$value) = @_;
    $self->[ $place % 12 ] = $value;
}

package main;
tie my @array, "ClockArray";
@array = ( "a" ... "z" );
print "@array\n";
```

When run, the program prints out "`y z o p q r s t u v w x`". This class provides an array with only a dozen slots, like hours of a clock, numbered 0 through 11. If you ask for the 15th array index, you really get the 3rd one. Think of it as a travel aid for people who haven't learned how to read 24-hour clocks.

Array-Tying Methods

That's the simple way. Now for some nitty-gritty details. To demonstrate, we'll implement an array whose bounds are fixed at its creation. If you try to access anything beyond those bounds, an exception is raised. For example:

```
use BoundedArray;
tie @array, "BoundedArray", 2;

$array[0] = "fine";
$array[1] = "good";
$array[2] = "great";
$array[3] = "whoa";   # Prohibited; displays an error message.
```

The preamble code for the class is as follows:

```
package BoundedArray;
use Carp;
use strict;
```

To avoid having to define `SPLICE` later, we'll inherit from the `Tie::Array` class:

```
use Tie::Array;
our @ISA = ("Tie::Array");
```

CLASSNAME`->TIEARRAY(`*LIST*`)`

> As the constructor for the class, `TIEARRAY` should return a blessed reference through which the tied array will be emulated.

In this next example, just to show you that you don't *really* have to return an array reference, we'll choose a hash reference to represent our object. A hash works out well as a generic record type: the value in the hash's "BOUND" key will store the maximum bound allowed, and its "DATA" value will hold the actual data. If someone outside the class tries to dereference the object returned (doubtless thinking it an array reference), an exception is raised.

```
sub TIEARRAY {
    my $class = shift;
    my $bound = shift;
    confess "usage: tie(\@ary, 'BoundedArray', max_subscript)"
        if @_ || $bound =~ /\D/;
    return bless { BOUND => $bound, DATA => [] }, $class;
}
```

We can now say:

```
tie(@array, "BoundedArray", 3);  # maximum allowable index is 3
```

to ensure that the array will never have more than four elements. Whenever an individual element of the array is accessed or stored, FETCH and STORE will be called just as they were for scalars, but with an extra index argument.

SELF->FETCH(INDEX)

This method is run whenever an individual element in the tied array is accessed. It receives one argument after the object: the index of the value we're trying to fetch.

```
sub FETCH {
    my ($self, $index) = @_;
    if ($index > $self->{BOUND}) {
        confess "Array OOB: $index > $self->{BOUND}";
    }
    return $self->{DATA}[$index];
}
```

SELF->STORE(*INDEX*, *VALUE*)

This method is invoked whenever an element in the tied array is set. It takes two arguments after the object: the index at which we're trying to store something and the value we're trying to put there. For example:

```
sub STORE {
    my($self, $index, $value) = @_;
    if ($index > $self->{BOUND} ) {
        confess "Array OOB: $index > $self->{BOUND}";
    }
    return $self->{DATA}[$index] = $value;
}
```

SELF->UNTIE

This method is triggered by `untie`. We don't need it for this example. See the caution in "A Subtle Untying Trap" on page 510 later in this chapter.

SELF->DESTROY

Perl calls this method when the tied variable needs to be destroyed and its memory reclaimed. This is almost never needed in a language with garbage collection, so for this example we'll just leave it out.

SELF->FETCHSIZE

The `FETCHSIZE` method should return the total number of items in the tied array associated with *SELF*. It's equivalent to `scalar(@array)`, which is usually equal to `$#array + 1`.

```
sub FETCHSIZE {
    my $self = shift;
    return scalar @{$self->{DATA}};
}
```

SELF->STORESIZE(*COUNT*)

This method sets the total number of items in the tied array associated with *SELF* to be *COUNT*. If the array shrinks, you should remove entries beyond *COUNT*. If the array grows, you should make sure the new positions are undefined. For our `BoundedArray` class, we also ensure that the array doesn't grow beyond the limit initially set.

```
sub STORESIZE {
    my ($self, $count) = @_;
    if ($count > $self->{BOUND}) {
        confess "Array OOB: $count > $self->{BOUND}";
    }
    $#{$self->{DATA}} = $count;
}
```

SELF->EXTEND(*COUNT*)

Perl uses the `EXTEND` method to indicate that the array is likely to expand to hold *COUNT* entries. That way you can allocate memory in one big chunk instead of in many successive calls later on. Since our `BoundedArray`s have fixed upper bounds, we won't define this method.

SELF->EXISTS(*INDEX*)

This method verifies that the element at *INDEX* exists in the tied array. For our `BoundedArray`, we just employ Perl's built-in `exists` after verifying that it's not an attempt to look past the fixed upper bound.

```
sub EXISTS  {
    my ($self, $index) = @_;
    if ($index > $self->{BOUND}) {
```

```
            confess "Array OOB: $index > $self->{BOUND}";
        }
        exists $self->{DATA}[$index];
    }
```

SELF->DELETE(*INDEX*)

The DELETE method removes the element at *INDEX* from the tied array *SELF*. For our BoundedArray class, the method looks nearly identical to EXISTS, but this is not the norm.

```
sub DELETE {
    my ($self, $index) = @_;
    print STDERR "deleting!\n";
    if ($index > $self->{BOUND}) {
        confess "Array OOB: $index > $self->{BOUND}";
    }
    delete $self->{DATA}[$index];
}
```

SELF->CLEAR

This method is called whenever the array has to be emptied. That happens when the array is set to a list of new values (or an empty list), but not when it's provided to the undef function. Since a cleared BoundedArray always satisfies the upper bound, we don't need to check anything here:

```
sub CLEAR {
    my $self = shift;
    $self->{DATA} = [];
}
```

If you set the array to a list, CLEAR will trigger but won't see the list values. So if you violate the upper bound like so:

```
tie(@array, "BoundedArray", 2);
@array = (1, 2, 3, 4);
```

the CLEAR method will still return successfully. The exception will only be raised on the subsequent STORE. The assignment triggers one CLEAR and four STOREs.

SELF->PUSH(*LIST*)

This method appends the elements of *LIST* to the array. Here's how it might look for our BoundedArray class:

```
sub PUSH    {
    my $self = shift;
    if (@_ + $#{$self->{DATA}} > $self->{BOUND}) {
        confess "Attempt to push too many elements";
    }
    push @{$self->{DATA}}, @_;
}
```

SELF->UNSHIFT(*LIST*)
: This method prepends the elements of *LIST* to the array. For our BoundedArray class, the subroutine would be similar to PUSH.

SELF->POP
: The POP method removes the last element of the array and returns it. For BoundedArray, it's a one-liner:

```
sub POP { my $self = shift; pop @{$self->{DATA}} }
```

SELF->SHIFT
: The SHIFT method removes the first element of the array and returns it. For BoundedArray, it's similar to POP.

SELF->SPLICE(*OFFSET, LENGTH, LIST*)
: This method lets you splice the *SELF* array. To mimic Perl's built-in splice, *OFFSET* should be optional and default to zero, with negative values counting back from the end of the array. *LENGTH* should also be optional, defaulting to the rest of the array. *LIST* can be empty. If it's properly mimicking the built-in, the method will return a list of the original *LENGTH* elements at *OFFSET* (that is, the list of elements to be replaced by LIST).

  Since splicing is a somewhat complicated operation, we won't define it at all; we'll just use the SPLICE subroutine from the Tie::Array module that we got for free when we inherited from Tie::Array. This way we define SPLICE in terms of other BoundedArray methods so the bounds checking will still occur.

That completes our BoundedArray class. It warps the semantics of arrays just a little. But we can do better—and in much less space.

Notational Convenience

One of the nice things about variables is that they interpolate. One of the not-so-nice things about functions is that they don't. You can use a tied array to make a function that can be interpolated. Suppose you want to interpolate random integers in a string. You can just say:

```
#!/usr/bin/perl
package RandInterp;
sub TIEARRAY { bless \my $self };
sub FETCH { int rand $_[1] };

package main;
tie @rand, "RandInterp";
for (1,10,100,1000) {
    print "A random integer less than $_ would be $rand[$_]\n";
}
$rand[32] = 5;    # Will this reformat our system disk?
```

When run, this prints:

```
A random integer less than 1 would be 0
A random integer less than 10 would be 3
A random integer less than 100 would be 46
A random integer less than 1000 would be 755
Can't locate object method "STORE" via package "RandInterp" at foo line 10.
```

As you can see, it's no big deal that we didn't even implement `STORE`. It just blows up like normal.

Tying Hashes

A class implementing a tied hash should define eight methods. `TIEHASH` constructs new objects. `FETCH` and `STORE` access the key/value pairs. `EXISTS` reports whether a key is present in the hash, and `DELETE` removes a key along with its associated value.[3] `CLEAR` empties the hash by deleting all key/value pairs. `FIRSTKEY` and `NEXTKEY` iterate over the key/value pairs when you call `keys`, `values`, or `each`. And, as usual, if you want to perform particular actions when the object is deallocated, you may define a `DESTROY` method. (If this seems like a lot of methods, you didn't read the last section on arrays attentively. In any event, feel free to inherit the default methods from the standard `Tie::Hash` module, redefining only the interesting ones. Again, `Tie::StdHash` assumes the implementation is also a hash.)

For example, suppose you want to create a hash where every time you assign a value to a key, instead of overwriting the previous contents, the new value is appended to an array of values. That way when you say:

```
$h{$k} = "one";
$h{$k} = "two";
```

It really does:

```
push @{ $h{$k} }, "one";
push @{ $h{$k} }, "two";
```

That's not a very complicated idea, so you should be able to use a pretty simple module. Using `Tie::StdHash` as a base class, it is. Here's a `Tie::AppendHash` that does just that:

```
package Tie::AppendHash;
use Tie::Hash;
our @ISA = ("Tie::StdHash");
sub STORE {
```

3. Remember that Perl distinguishes between a key not existing in the hash and a key existing in the hash but having a corresponding value of `undef`. The two possibilities can be tested with `exists` and `defined`, respectively.

```
    my ($self, $key, $value) = @_;
    push @{$self->{key}}, $value;
}
1;
```

Hash-Tying Methods

Here's an example of an interesting tied-hash class: it gives you a hash representing a particular user's dot files (that is, files whose names begin with a period, which is a naming convention for initialization files under Unix). You index into the hash with the name of the file (minus the period) and get back that dot file's contents. For example:

```
use DotFiles;
tie %dot, "DotFiles";
if ( $dot{profile} =~ /MANPATH/ ||
     $dot{login}   =~ /MANPATH/ ||
     $dot{cshrc}   =~ /MANPATH/    ) {
    print "you seem to set your MANPATH\n";
}
```

Here's another way to use our tied class:

```
# Third argument is the name of a user whose dot files we will tie to.
tie %him, "DotFiles", "daemon";
foreach $f (keys %him) {
    printf "daemon dot file %s is size %d\n", $f, length $him{$f};
}
```

In our `DotFiles` example we implement the object as a regular hash containing several important fields, of which only the `{CONTENTS}` field will contain what the user thinks of as the hash. Table 14-1 gives the object's actual fields.

Table 14-1. Object fields in DotFiles

Field	Contents
`USER`	Whose dot files this object represents
`HOME`	Where those dot files live
`CLOBBER`	Whether we are allowed to change or remove those dot files
`CONTENTS`	The hash of dot file names and content mappings

Here's the start of *DotFiles.pm*:

```
package DotFiles;
use Carp;
sub whowasi { (caller(1))[3] . "()" }
my $DEBUG = 0;
sub debug { $DEBUG = @_ ? shift : 1 }
```

For our example we want to be able to turn on debugging output to help in tracing during development, so we set up `$DEBUG`. We also keep one convenience function around internally to help print out warnings: `whowasi` returns the name of the function that called the current function (`whowasi`'s "grandparent" function).

Here are the methods for the `DotFiles` tied hash:

CLASSNAME`->TIEHASH(`*LIST*`)`

Here's the `DotFiles` constructor:

```
sub TIEHASH {
     my $self   = shift;
     my $user   = shift || $>;
     my $dotdir = shift || "";

     croak "usage: @{[ &whowasi ]} [USER [DOTDIR]]" if @_;

     $user = getpwuid($user) if $user =~ /^\d+$/;
     my $dir = (getpwnam($user))[7]
             || croak "@{ [&whowasi] }: no user $user";
     $dir .= "/$dotdir" if $dotdir;

     my $node = {
         USER        => $user,
         HOME        => $dir,
         CONTENTS    => {},
         CLOBBER     => 0,
     };

     opendir(DIR, $dir)
             || croak "@{[&whowasi]}: can't opendir $dir: $!";
     for my $dot (grep /^\./ && -f "$dir/$_", readdir(DIR)) {
         $dot =~ s/^\.//;
         $node->{CONTENTS}{$dot} = undef;
     }
     closedir DIR;

     return bless $node, $self;
 }
```

It's probably worth mentioning that if you're going to apply file tests to the values returned by the above `readdir`, you'd better prepend the directory in question (as we do). Otherwise, since no `chdir` was done, you'd likely be testing the wrong file.

SELF->FETCH(*KEY*)

This method implements reading an element from the tied hash. It takes one argument after the object: the key whose value we're trying to fetch. The key is a string, and you can do anything you like with it (consistent with its being a string).

Here's the fetch for our `DotFiles` example:

```
sub FETCH {
    carp &whowasi if $DEBUG;
    my $self = shift;
    my $dot = shift;
    my $dir = $self->{HOME};
    my $file = "$dir/.$dot";

    unless (exists $self->{CONTENTS}->{$dot} || -f $file) {
        carp "@{[&whowasi]}: no $dot file" if $DEBUG;
        return undef;
    }

    # Implement a cache.
    if (defined $self->{CONTENTS}->{$dot}) {
        return $self->{CONTENTS}->{$dot};
    } else {
        return $self->{CONTENTS}->{$dot} = `cat $dir/.$dot`;
    }
}
```

We cheated a little by running the Unix *cat*(1) command, but it would be more portable (and more efficient) to open the file ourselves. On the other hand, since dot files are a Unixy concept, we're not that concerned. Or shouldn't be. Or something...

SELF->STORE(*KEY*, *VALUE*)

This method does the dirty work whenever an element in the tied hash is set (written). It takes two arguments after the object: the key under which we're storing the new value and the value itself.

For our `DotFiles` example, we won't let users overwrite a file without first invoking the `clobber` method on the original object returned by `tie`:

```
sub STORE {
    carp &whowasi if $DEBUG;
    my $self  = shift;
    my $dot   = shift;
    my $value = shift;
    my $file  = $self->{HOME} . "/.$dot";

    croak "@{[&whowasi]}: $file not clobberable"
        unless $self->{CLOBBER};
```

```
        open(F, "> $file") || croak "can't open $file: $!";
        print F $value;
        close(F)           || croak "can't close $file: $!";
    }
```

If someone wants to clobber something, she can say:

```
$ob = tie %daemon_dots, "daemon";
$ob->clobber(1);
$daemon_dots{signature} = "A true daemon\n";
```

But they could alternatively set `{CLOBBER}` with `tied`:

```
tie %daemon_dots, "DotFiles", "daemon";
tied(%daemon_dots)->clobber(1);
```

or as one statement:

```
(tie %daemon_dots, "DotFiles", "daemon")->clobber(1);
```

The `clobber` method is simply:

```
sub clobber {
    my $self = shift;
    $self->{CLOBBER} = @_ ? shift : 1;
}
```

SELF->DELETE(*KEY*)

This method handles requests to remove an element from the hash. If your emulated hash uses a real hash somewhere, you can just call the real `delete`. Again, we'll be careful to check whether the user really wants to clobber files:

```
sub DELETE   {
    carp &whowasi if $DEBUG;
    my $self = shift;
    my $dot = shift;
    my $file = $self->{HOME} . "/.$dot";
    croak "@{[&whowasi]}: won't remove file $file"
        unless $self->{CLOBBER};
    delete $self->{CONTENTS}->{$dot};
    unlink($file)|| carp "@{[&whowasi]}: can't unlink $file: $!";
}
```

SELF->CLEAR

This method is run when the whole hash needs to be cleared, usually by assigning the empty list to it. In our example, that would remove all the user's dot files! It's such a dangerous thing that we'll require `CLOBBER` to be set higher than `1` before this can happen:

```
sub CLEAR {
    carp &whowasi if $DEBUG;
    my $self = shift;
    croak "@{[&whowasi]}: won't remove all dotfiles for $self->{USER}"
        unless $self->{CLOBBER} > 1;
    for my $dot ( keys %{$self->{CONTENTS}}) {
        $self->DELETE($dot);
    }
}
```

SELF->EXISTS(*KEY*)

This method runs when the user invokes the `exists` function on a particular hash. In our example, we'll look at the `{CONTENTS}` hash element to find the answer:

```
sub EXISTS   {
    carp &whowasi if $DEBUG;
    my $self = shift;
    my $dot  = shift;
    return exists $self->{CONTENTS}->{$dot};
}
```

SELF->FIRSTKEY

This method is called when the user begins to iterate through the hash, such as with a `keys`, `values`, or `each` call. By calling `keys` in scalar context, we reset its internal state to ensure that the next `each` used in the `return` statement will get the first key.

```
sub FIRSTKEY {
    carp &whowasi if $DEBUG;
    my $self = shift;
    my $temp = keys %{$self->{CONTENTS}};
    return scalar each %{$self->{CONTENTS}};
}
```

SELF->NEXTKEY(*PREVKEY*)

This method is the iterator for a `keys`, `values`, or `each` function. *PREVKEY* is the last key accessed, which Perl knows to supply. This is useful if the `NEXTKEY` method needs to know its previous state to calculate the next state.

For our example, we are using a real hash to represent the tied hash's data, except that this hash is stored in the hash's `CONTENTS` field instead of in the hash itself. So we can just rely on Perl's `each` iterator:

```
sub NEXTKEY  {
    carp &whowasi if $DEBUG;
    my $self = shift;
    return scalar each %{ $self->{CONTENTS} }
}
```

SELF->UNTIE
: This method is triggered by `untie`. We don't need it for this example. See the caution in "A Subtle Untying Trap" on page 510 later in this chapter.

SELF->DESTROY
: This method is triggered when a tied hash's object is about to be deallocated. You don't really need it except for debugging and extra cleanup. Here's a very simple version:

```
sub DESTROY  {
    carp &whowasi if $DEBUG;
}
```

Now that we've given you all those methods, your homework is to go back and find the places we interpolated `@{[&whowasi]}` and replace them with a simple tied scalar named `$whowasi` that does the same thing.

Tying Filehandles

A class implementing a tied filehandle should define the following methods: `TIEHANDLE` and at least one of `PRINT`, `PRINTF`, `WRITE`, `READLINE`, `GETC`, and `READ`. The class can also provide a `DESTROY` method, as well as `BINMODE`, `OPEN`, `CLOSE`, `EOF`, `FILENO`, `SEEK`, `TELL`, `READ`, and `WRITE` methods to enable the corresponding Perl built-ins for the tied filehandle. (Well, that isn't quite true: `WRITE` corresponds to `syswrite` and has nothing to do with Perl's built-in `write` function for printing with `format` declarations.)

Tied filehandles are especially useful when Perl is embedded in another program (such as Apache or *vi*) and output to `STDOUT` or `STDERR` needs to be redirected in some special way.

But filehandles don't actually have to be tied to a file at all. You can use output statements to build up an in-memory data structure and input statements to read them back in. Here's an easy way to reverse a sequence of `print` and `printf` statements without reversing the individual lines:

```
package ReversePrint 0.01 {
    use strict;
    sub TIEHANDLE {
        my $class = shift;
        bless [], $class;
    }
    sub PRINT {
        my $self = shift;
        push @$self, join("" => @_);
    }
    sub PRINTF {
```

```
        my $self = shift;
        my $fmt = shift;
        push @$self, sprintf($fmt, @_);
    }
    sub READLINE {
        my $self = shift;
        pop @$self;
    }
}

my $m = "--MORE--\n";
tie *REV, "ReversePrint";

# Do some prints and printfs.
print REV "The fox is now dead.$m";

printf REV <<"END", int rand 10000000;
The quick brown fox jumps
over the lazy dog %d times!
END

print REV <<"END";
The quick brown fox jumps
over the lazy dog.
END

# Now read back from the same handle.
print while <REV>;
```

This prints:

```
The quick brown fox jumps
over the lazy dog.
The quick brown fox jumps
over the lazy dog 3179357 times!
The fox is now dead.--MORE--
```

Filehandle-Tying Methods

For our extended example, we'll create a filehandle that uppercases strings that are printed to it. Just for kicks, we'll begin the file with `<SHOUT>` when it's opened and end with `</SHOUT>` when it's closed. That way we can rant in well-formed XML.

Here's the top of our *Shout.pm* file that will implement the class:

```
package Shout;
use Carp;               # So we can croak our errors
```

We'll now list the method definitions in *Shout.pm*.

CLASSNAME->TIEHANDLE(*LIST*)

This is the constructor for the class, which as usual should return a blessed reference.

```
sub TIEHANDLE {
    my $class = shift;
    my $form = shift;
    open(my $self, $form, @_)  || croak "can't open $form@_: $!";
    if ($form =~ />/) {
        print $self  "<SHOUT>\n";
        $$self->{WRITING} = 1;     # Remember to do end tag
    }
    return bless $self, $class;    # $self is a glob ref
}
```

Here we open a new filehandle according to the mode and filename passed to the `tie` operator, write `<SHOUT>` to the file, and return a blessed reference to it. There's a lot of stuff going on in that `open` statement, but we'll just point out that, in addition to the usual "open or die" idiom, the `my $self` furnishes an undefined scalar to `open`, which knows to autovivify it into a typeglob. The fact that it's a typeglob is also significant, because not only does the typeglob contain the real I/O object of the file, it also contains various other handy data structures that come along for free, like a scalar (`$$$self`), an array (`@$$self`), and a hash (`%$$self`). (We won't mention the subroutine, `&$$self`.)

The `$form` is the filename-or-mode argument. If it's a filename, `@_` is empty, so it behaves as a two-argument open. Otherwise, `$form` is the mode for the rest of the arguments.

After the open, we test to see whether we should write the beginning tag. If so, we do. And right away we use one of those glob data structures we mentioned. That `$$self->{WRITING}` is an example of using the glob to store interesting information. In this case, we remember whether we did the beginning tag so we know whether to do the corresponding end tag. We're using the `%$$self` hash, so we can give the field a decent name. We could have used the scalar as `$$$self`, but that wouldn't be self-documenting. (Or it would *only* be self-documenting, depending on how you look at it.)

SELF->PRINT(*LIST*)

This method implements a `print` to the tied handle. The *LIST* is whatever was passed to `print`. Our method below uppercases each element of *LIST*:

```
sub PRINT {
     my $self = shift;
     print $self map {uc} @_;
 }
```

SELF->READLINE

This method supplies the data when the filehandle is read from the angle operator (<FH>) or `readline`. The method should return `undef` when there is no more data.

```
sub READLINE {
    my $self = shift;
    return <$self>;
}
```

Here we simply `return <$self>` so that the method will behave appropriately depending on whether it was called in scalar or list context.

SELF->GETC

This method runs whenever `getc` is used on the tied filehandle.

```
sub GETC {
    my $self = shift;
    return getc($self);
}
```

Like several of the methods in our `Shout` class, the `GETC` method simply calls its corresponding Perl built-in and returns the result.

SELF->OPEN(*LIST*)

Our `TIEHANDLE` method itself opens a file, but a program using the `Shout` class that calls `open` afterward triggers this method.

```
sub OPEN {
    my $self = shift;
    my $form = shift;
    my $name = "$form@_";
    $self->CLOSE;
    open($self, $form, @_)         || croak "can't reopen $name: $!";
    if ($form =~ />/) {
        (print $self "<SHOUT>\n")  || croak "can't start print: $!";
        $$self->{WRITING} = 1;     # Remember to do end tag
    }
    else {
        $$self->{WRITING} = 0;     # Remember not to do end tag
    }
    return 1;
}
```

We invoke our own `CLOSE` method to explicitly close the file in case the user didn't bother to. Then we open a new file with whatever filename was specified in the `open` and shout at it.

SELF->CLOSE

This method deals with the request to close the handle. Here we seek to the end of the file and, if that was successful, print `</SHOUT>` before using Perl's built-in `close`.

```
sub CLOSE {
    my $self = shift;
    if ($$self->{WRITING}) {
        $self->SEEK(0, 2)             || return;
        $self->PRINT("</SHOUT>\n")    || return;
    }
    return close $self;
}
```

SELF->SEEK(*LIST*)

When you `seek` on a tied filehandle, the `SEEK` method gets called.

```
sub SEEK {
    my $self = shift;
    my ($offset, $whence) = @_;
    return seek($self, $offset, $whence);
}
```

SELF->TELL

This method is invoked when `tell` is used on the tied handle.

```
sub TELL {
    my $self = shift;
    return tell $self;
}
```

SELF->PRINTF(*LIST*)

This method is run whenever `printf` is used on the tied handle. The *LIST* will contain the format and the items to be printed.

```
sub PRINTF {
    my $self = shift;
    my $template = shift;
    return $self->PRINT(sprintf $template, @_);
}
```

Here we use `sprintf` to generate the formatted string and pass it to `PRINT` for uppercasing. There's nothing that requires you to use the built-in `sprintf` function, though. You could interpret the percent escapes to suit your own purpose.

SELF->READ(*LIST*)

This method responds when the handle is read using `read` or `sysread`. Note that we modify the first argument of *LIST* "in-place", mimicking `read`'s ability to fill in the scalar passed in as its second argument.

```
sub READ {
    my ($self, undef, $length, $offset) = @_;
    my $bufref = \$_[1];
    return read($self, $$bufref, $length, $offset);
}
```

SELF->WRITE(*LIST*)

This method gets invoked when the handle is written to with `syswrite`. Here we uppercase the string to be written.

```
sub WRITE {
    my $self = shift;
    my $string = uc(shift);
    my $length = shift || length $string;
    my $offset = shift || 0;
    return syswrite $self, $string, $length, $offset;
}
```

SELF->EOF

This method returns a Boolean value when a filehandle tied to the `Shout` class is tested for its end-of-file status using `eof`.

```
sub EOF {
    my $self = shift;
    return eof $self;
}
```

SELF->BINMODE(*IOLAYER*)

This method specifies the I/O layer to be used on the filehandle. If none is specified, it puts the tied filehandle into binary mode (the `:raw` layer) for filesystems that distinguish between text and binary files.

```
sub BINMODE {
    my $self = shift;
    my $disc = shift || ":raw";
    return binmode $self, $disc;
}
```

That's how you'd write it, but it's actually useless in our case because the `open` already wrote on the handle. So in our case we should probably make it say:

```
sub BINMODE { croak("Too late to use binmode") }
```

SELF->FILENO

This method should return the file descriptor (`fileno`) associated with the tied filehandle by the operating system.

```
sub FILENO {
    my $self = shift;
    return fileno $self;
}
```

SELF->UNTIE
: This method is triggered by `untie`. We don't need it for this example. See the caution in "A Subtle Untying Trap" on page 510 later in this chapter.

SELF->DESTROY
: As with the other types of ties, this method is triggered when the tied object is about to be destroyed. This is useful for letting the object clean up after itself. Here we make sure that the file is closed, in case the program forgot to call `close`. We could just say `close $self`, but it's better to invoke the `CLOSE` method of the class. That way if the designer of the class decides to change how files are closed, this `DESTROY` method won't have to be modified.

```
sub DESTROY {
    my $self = shift;
    $self->CLOSE;      # Close the file using Shout's CLOSE method.
}
```

Here's a demonstration of our `Shout` class:

```
#!/usr/bin/perl
use Shout;
tie(*FOO, Shout::, ">filename");
print FOO "hello\n";            # Prints HELLO.
seek FOO, 0, 0;                 # Rewind to beginning.
@lines = <FOO>;                 # Calls the READLINE method.
close FOO;                      # Close file explicitly.
open(FOO, "+<", "filename");    # Reopen FOO, calling OPEN.
seek(FOO, 8, 0);                # Skip the "<SHOUT>\n".
sysread(FOO, $inbuf, 5);        # Read 5 bytes from FOO into $inbuf.
print "found $inbuf\n";         # Should print "hello".
seek(FOO, -5, 1);               # Back up over the "hello".
syswrite(FOO, "ciao!\n", 6);    # Write 6 bytes into FOO.
untie(*FOO);                    # Calls the CLOSE method implicitly.
```

After running this, the file contains:

```
<SHOUT>
CIAO!
</SHOUT>
```

Here are some more strange and wonderful things to do with that internal glob. We use the same hash as before but with new keys `PATHNAME` and `DEBUG`. First, we install a stringify overloading so that printing one of our objects reveals the pathname (see Chapter 13):

```
# This is just so totally cool!
use overload q("") => sub { $_[0]->pathname };

# This is the stub to put in each function you want to trace.
sub trace {
    my $self = shift;
    local $Carp::CarpLevel = 1;
    Carp::cluck("\ntrace magical method") if $self->debug;
}

# Overload handler to print out our path.
sub pathname {
    my $self = shift;
    confess "i am not a class method" unless ref $self;
    $$self->{PATHNAME} = shift if @_;
    return $$self->{PATHNAME};
}
# Dual moded.
sub debug {
    my $self = shift;
    my $var = ref $self ? \$$self->{DEBUG} : \our $Debug;
    $$var = shift if @_;
    return ref $self ? $$self->{DEBUG} || $Debug : $Debug;
}
```

And then we call `trace` on entry to all our ordinary methods like this:

```
sub GETC { $_[0]->trace;           # NEW
    my($self) = @_;
    getc($self);
}
```

And also set the pathname in `TIEHANDLE` and `OPEN`:

```
sub TIEHANDLE {
    my $class    = shift;
    my $form = shift;
    my $name = "$form@_";          # NEW
    open(my $self, $form, @_)   || croak "can't open $name: $!";
    if ($form =~ />/) {
        print $self  "<SHOUT>\n";
        $$self->{WRITING} = 1;     # Remember to do end tag
    }
    bless $self, $class;           # $fh is a glob ref
    $self->pathname($name);        # NEW
    return $self;
}

sub OPEN { $_[0]->trace;           # NEW
    my $self = shift;
    my $form = shift;
    my $name = "$form@_";
    $self->CLOSE;
```

```
    open($self, $form, @_)      || croak "can't reopen $name: $!";
    $self->pathname($name);        # NEW
    if ($form =~ />/) {
        (print $self "<SHOUT>\n") || croak "can't start print: $!";
        $$self->{WRITING} = 1;     # Remember to do end tag
    }
    else {
        $$self->{WRITING} = 0;     # Remember not to do end tag
    }
    return 1;
}
```

Somewhere, we also have to call `$self->debug(1)` to turn debugging on. When we do that, all our `Carp::cluck` calls will produce meaningful messages. Here's one that we get while doing the reopen above. It shows us three deep in method calls, as we're closing down the old file in preparation for opening the new one:

```
trace magical method at foo line 87
    Shout::SEEK('>filename', '>filename', 0, 2) called at foo line 81
    Shout::CLOSE('>filename') called at foo line 65
    Shout::OPEN('>filename', '+<', 'filename') called at foo line 141
```

Creative Filehandles

You can `tie` the same filehandle to both the input and the output of a two-ended pipe. Suppose you wanted to run the *bc*(1) (arbitrary precision calculator) program this way:

```
use Tie::Open2;

tie *CALC, "Tie::Open2", "bc -l";
$sum = 2;
for (1 .. 7) {
    print CALC "$sum * $sum\n";
    $sum = <CALC>;
    print "$_: $sum";
    chomp $sum;
}
close CALC;
```

One would expect it to print this:

```
1: 4
2: 16
3: 256
4: 65536
5: 4294967296
6: 18446744073709551616
7: 340282366920938463463374607431768211456
```

One's expectations would be correct if one had the *bc*(1) program on one's computer, and one also had `Tie::Open2` defined as follows. This time we'll use a blessed array for our internal object. It contains our two actual filehandles for reading and writing. (The dirty work of opening a double-ended pipe is done by `IPC::Open2`; we're just doing the fun part.)

```
package Tie::Open2;
use strict;
use Carp;
use Tie::Handle;  # do not inherit from this!
use IPC::Open2;

sub TIEHANDLE {
    my ($class, @cmd) = @_;
    no warnings "once";
    my @fhpair = \do { local(*RDR, *WTR) };
    bless $_, "Tie::StdHandle" for @fhpair;
    bless(\@fhpair => $class)->OPEN(@cmd) || die;
    return \@fhpair;
}

sub OPEN {
    my ($self, @cmd) = @_;
    $self->CLOSE if grep {defined} @{ $self->FILENO };
    open2(@$self, @cmd);
}

sub FILENO {
    my $self = shift;
    [ map { fileno $self->[$_] } 0,1 ];
}

for my $outmeth ( qw(PRINT PRINTF WRITE) ) {
    no strict "refs";
    *$outmeth = sub {
        my $self = shift;
        $self->[1]->$outmeth(@_);
    };
}
for my $inmeth ( qw(READ READLINE GETC) ) {
    no strict "refs";
    *$inmeth = sub {
        my $self = shift;
        $self->[0]->$inmeth(@_);
    };
}
for my $doppelmeth ( qw(BINMODE CLOSE EOF)) {
    no strict "refs";
    *$doppelmeth = sub {
        my $self = shift;
```

```
        $self->[0]->$doppelmeth(@_) && $self->[1]->$doppelmeth(@_);
    };
}
for my $deadmeth ( qw(SEEK TELL)) {
    no strict "refs";
    *$deadmeth = sub {
        croak("can't $deadmeth a pipe");
    };
}
1;
```

The final four loops are just incredibly snazzy, in our opinion. For an explanation of what's going on, look back at the section "Closures as Function Templates" in Chapter 8.

Here's an even wackier set of classes. The package names should give you a clue as to what they do.

```
use strict;
package Tie::DevNull;

    sub TIEHANDLE {
        my $class = shift;
        my $fh = local *FH;
        bless \$fh, $class;
    }
    for (qw(READ READLINE GETC PRINT PRINTF WRITE)) {
        no strict "refs";
        *$_  = sub { return };
    }

package Tie::DevRandom;

    sub READLINE { rand() . "\n" }
    sub TIEHANDLE {
        my $class = shift;
        my $fh = local *FH;
        bless \$fh, $class;
    }

    sub FETCH { rand() }
    sub TIESCALAR {
        my $class = shift;
        bless \my $self, $class;
    }

package Tie::Tee;

    sub TIEHANDLE {
        my $class = shift;
        my @handles;
```

```
        for my $path (@_) {
            open(my $fh, ">$path") || die "can't write $path";
            push @handles, $fh;
        }
        bless \@handles, $class;
    }

    sub PRINT {
        my $self = shift;
        my $ok = 0;
        for my $fh (@$self) {
            $ok += print $fh @_;
        }
        return $ok == @$self;
    }
```

The `Tie::Tee` class emulates the standard Unix *tee*(1) program, which sends one stream of output to multiple different destinations. The `Tie::DevNull` class emulates the null device, */dev/null* on Unix systems. And the `Tie::DevRandom` class produces random numbers either as a handle or as a scalar, depending on whether you call `TIEHANDLE` or `TIESCALAR`! Here's how you call them:

```
package main;

tie *SCATTER,   "Tie::Tee", qw(tmp1 - tmp2 >tmp3 tmp4);
tie *RANDOM,    "Tie::DevRandom";
tie *NULL,      "Tie::DevNull";
tie my $randy,  "Tie::DevRandom";

for my $i (1..10) {
    my $line = <RANDOM>;
    chomp $line;
    for my $fh (*NULL, *SCATTER) {
        print $fh "$i: $line $randy\n";
    }
}
```

This produces something like the following on your screen:

```
1: 0.124115571686165 0.20872819474074
2: 0.156618299751194 0.678171662366353
3: 0.799749050426126 0.300184963960792
4: 0.599474551447884 0.213935286029916
5: 0.700232143543861 0.800773751296671
6: 0.201203608274334 0.0654303290639575
7: 0.605381294683365 0.718162304090487
8: 0.452976481105495 0.574026269121667
9: 0.736819876983848 0.391737610662044
10: 0.518606540417331 0.381805078272308
```

But that's not all! It wrote to your screen because of the - in the `*SCATTER` `tie` above. But that line also told it to create files *tmp1*, *tmp2*, and *tmp4*, as well as to append to file *tmp3*. (We also wrote to the `*NULL` filehandle in the loop, though of course that didn't show up anywhere interesting—unless you're interested in black holes.)

A Subtle Untying Trap

If you intend to make use of the object returned from `tie` or `tied`, and the class defines a destructor, there is a subtle trap you must guard against. Consider this (admittedly contrived) example of a class that uses a file to log all values assigned to a scalar:

```
package Remember;

sub TIESCALAR {
    my $class = shift;
    my $filename = shift;
    open(my $handle, ">", $filename)
         || die "Cannot open $filename: $!\n";
    print $handle "The Start\n";
    bless {FH => $handle, VALUE => 0}, $class;
}

sub FETCH {
    my $self = shift;
    return $self->{VALUE};
}

sub STORE {
    my $self = shift;
    my $value = shift;
    my $handle = $self->{FH};
    print $handle "$value\n";
    $self->{VALUE} = $value;
}

sub DESTROY {
    my $self = shift;
    my $handle = $self->{FH};
    print $handle "The End\n";
    close $handle;
}

1;
```

Here is an example that makes use of our `Remember` class:

```
use strict;
use Remember;

my $fred;
$x = tie $fred, "Remember", "camel.log";
$fred = 1;
$fred = 4;
$fred = 5;
untie $fred;
system "cat camel.log";
```

This is the output when it is executed:

```
The Start
1
4
5
The End
```

So far, so good. Let's add an extra method to the `Remember` class that allows comments in the file—say, something like this:

```
sub comment {
    my $self = shift;
    my $message = shift;
    print { $self->{FH} } $handle $message, "\n";
}
```

And here is the previous example, modified to use the `comment` method:

```
use strict;
use Remember;

my ($fred, $x);
$x = tie $fred, "Remember", "camel.log";
$fred = 1;
$fred = 4;
comment $x "changing...";
$fred = 5;
untie $fred;
system "cat camel.log";
```

Now the file will be empty, which probably wasn't what you intended. Here's why. Tying a variable associates it with the object returned by the constructor. This object normally has only one reference: the one hidden behind the tied variable itself. Calling "`untie`" breaks the association and eliminates that reference. Since there are no remaining references to the object, the `DESTROY` method is triggered.

However, in the example above we stored a second reference to the object tied to `$x`. That means that after the `untie` there will still be a valid reference to the object. `DESTROY` won't get triggered, and the file won't get flushed and closed. That's why there was no output: the filehandle's buffer was still in memory. It won't hit the disk until the program exits.

To detect this, you could use the *–w* command-line flag, or include the `use warnings "untie"` pragma in the current lexical scope. Either technique would identify a call to `untie` while there were still references to the tied object remaining. If so, Perl prints this warning:

```
untie attempted while 1 inner references still exist
```

To get the program to work properly and silence the warning, eliminate any extra references to the tied object *before* calling `untie`. You can do that explicitly:

```
undef $x;
untie $fred;
```

Often, though, you can solve the problem simply by making sure your variables go out of scope at the appropriate time.

Tie Modules on CPAN

Before you get all inspired to write your own tie module, you should check to see whether someone's already done it. There are lots of tie modules on CPAN, with more every day. (Well, every month, anyway.) Table 14-2 lists some of them.

Table 14-2. Tie modules on CPAN

Module	Description
`IO::WrapTie`	Wraps tied objects in an `IO::Handle` interface.
`MLDBM`	Transparently stores complex data values, not just flat strings, in a DBM file.
`Tie::Cache::LRU`	Implements a least-recently used cache.
`Tie::Const`	Provides constant scalars and hashes.
`Tie::Counter`	Enchants a scalar variable to increment upon each access.
`Tie::CPHash`	Implements a case-preserving but case-insensitive hash.
`Tie::Cycle`	Cycles through a list of values via a scalar.
`Tie::DBI`	Ties hashes to DBI relational databases.
`Tie::Dict`	Ties a hash to an RPC dict server.
`Tie::DictFile`	Ties a hash to a local dictionary file.

Module	Description
`Tie::DNS`	Ties interface to Net::DNS.
`Tie::EncryptedHash`	Hashes (and objects based on hashes) with encrypting fields.
`Tie::FileLRUCache`	Implements a lightweight, filesystem-based, persistent LRU cache.
`Tie::FlipFlop`	Implements a tie that alternates between two values.
`Tie::HashDefaults`	Lets a hash have default values.
`Tie::HashHistory`	Tracks history of all changes to a hash.
`Tie::iCal`	Ties iCal files to Perl hashes.
`Tie::IxHash`	Provides ordered associative arrays for Perl.
`Tie::LDAP`	Implements an interface to an LDAP database.
`Tie::Persistent`	Provides persistent data structures via `tie`.
`Tie::Pick`	Randomly picks (and removes) an element from a set.
`Tie::RDBM`	Ties hashes to relational databases.
`Tie::STDERR`	Sends output of your `STDERR` to another process such as a mailer.
`Tie::Syslog`	Ties a filehandle to automatically syslog its output.
`Tie::TextDir`	Ties a directory of files.
`Tie::Toggle`	False and true, alternately, ad infinitum.
`Tie::TZ`	Ties `$TZ`, setting `%ENV` and calling `tzset(3)`.
`Tie::VecArray`	Provides an array interface to a bit vector.
`Tie::Watch`	Places watch points on Perl variables.
`Win32::TieRegistry`	Provides powerful and easy ways to manipulate a Microsoft Windows registry.

PART III

Perl as Technology

CHAPTER 15

Interprocess Communication

Computer processes have almost as many ways of communicating as people do. The difficulties of interprocess communication should not be underestimated. It doesn't do you any good to listen for verbal cues when your friend is only using body language. Likewise, two processes can communicate only when they agree on the means of communication, and on the conventions built on top of that. As with any kind of communication, the conventions to be agreed upon range from lexical to pragmatic: everything from which lingo you'll use up to whose turn it is to talk. These conventions are necessary because it's very difficult to communicate bare semantics in the absence of context.

In our lingo, interprocess communication is usually pronounced IPC. The IPC facilities of Perl range from the very simple to the very complex. Which facility you should use depends on the complexity of the information to be communicated. The simplest kind of information is almost no information at all: just the awareness that a particular event has happened at a particular point in time. In Perl, these events are communicated via a signal mechanism modelled on the Unix signal system.

At the other extreme, the socket facilities of Perl allow you to communicate with any other process on the Internet using any mutually supported protocol you like. Naturally, this freedom comes at a price: you have to go through a number of steps to set up the connections and make sure you're talking the same language as the process on the other end. This may in turn require you to adhere to any number of other strange customs, depending on local conventions. To be protocoligorically correct, you might even be required to speak a language like XML, Java, or Perl. Horrors.

Sandwiched in between are some facilities intended primarily for communicating with processes on the same machine. These include good old-fashioned files, pipes, FIFOs, and the various System V IPC syscalls. Support for these facilities

varies across platforms; modern Unix systems (including Apple's Mac OS X) should support all of them, and, except for signals and SysV IPC, most of the rest are supported on any recent Microsoft operating systems, including pipes, forking, file locking, and sockets.[1]

More information about porting in general can be found in the standard Perl documentation set (in whatever format your system displays it) under *perlport*. Microsoft-specific information can be found under *perlwin32* and *perlfork*, which are installed even on non-Microsoft systems. For textbooks, we suggest the following:

- *Perl Cookbook*, Second Edition, by Tom Christiansen and Nathan Torkington (O'Reilly), Chapters 16 through 18.
- *Advanced Programming in the UNIX Environment*, by W. Richard Stevens (Addison-Wesley).
- *TCP/IP Illustrated*, by W. Richard Stevens, Volumes I–III (Addison-Wesley).

Signals

Perl uses a simple signal-handling model: the `%SIG` hash contains references (either symbolic or hard) to user-defined signal handlers. Certain events cause the operating system to deliver a signal to the affected process. The handler corresponding to that event is called with one argument containing the name of the signal that triggered it. To send a signal to another process, use the `kill` function. Think of it as sending a one-bit piece of information to the other process.[2] If that process has installed a signal handler for that signal, it can execute code when it receives the signal. But there's no way for the sending process to get any sort of return value, other than knowing that the signal was legally sent. The sender receives no feedback saying what, if anything, the receiving process did with the signal.

We've classified this facility as a form of IPC, but, in fact, signals can come from various sources, not just other processes. A signal might also come from your own process, or it might be generated when the user at the keyboard types a particular sequence like Control-C or Control-Z, or it might be manufactured by the kernel when a special event transpires, such as when a child process exits, or when your process runs out of stack space or hits a file size or memory limit. But

1. Well, except for `AF_UNIX` sockets.

2. Actually, it's more like five or six bits, depending on how many signals your OS defines, and on whether the other process makes use of the fact that you *didn't* send a different signal.

your own process can't easily distinguish among these cases. A signal is like a package that arrives mysteriously on your doorstep with no return address. You'd best open it carefully.

Since entries in the `%SIG` array can be hard references, it's common practice to use anonymous functions for simple signal handlers:

```
$SIG{INT}  = sub { die "\nOutta here!\n" };
$SIG{ALRM} = sub { die "Your alarm clock went off" };
```

Or, you could create a named function and assign its name or reference to the appropriate slot in the hash. For example, to intercept interrupt and quit signals (often bound to Control-C and Control-\ on your keyboard), set up a handler like this:

```
sub catch_zap {
    my $signame = shift();
    our $shucks++;
    die "Somebody sent me a SIG$signame!";
}
$shucks = 0;
$SIG{INT}  = "catch_zap";   # always means &main::catch_zap
$SIG{INT}  = \&catch_zap;   # best strategy
$SIG{QUIT} = \&catch_zap;   # catch another, too
```

Notice how all we do in the signal handler is set a global variable and then raise an exception with `die`. This was important back before Perl had safe signals because on most systems the C library is not reentrant, and signals were delivered asynchronously. This could cause core dumps in even the best behaving of Perl code. Under safe signals, the problem goes away.

An even easier way to trap signals is to use the `sigtrap` pragma to install simple, default signal handlers:

```
use sigtrap qw(die INT QUIT);
use sigtrap qw(die untrapped normal-signals
   stack-trace any error-signals);
```

The pragma is useful when you don't want to bother writing your own handler, but you still want to catch dangerous signals and perform an orderly shutdown. By default, some of these signals are so fatal to your process that your program will just stop in its tracks when it receives one. Unfortunately, that means that any `END` functions for at-exit handling and `DESTROY` methods for object finalization are not called. But they *are* called on ordinary Perl exceptions (such as when you call `die`), so you can use this pragma to painlessly convert the signals into exceptions. Even though you aren't dealing with the signals yourself, your program still behaves correctly. See the description of `use sigtrap` in Chapter 29 for many more features of this pragma.

You may also set the %SIG handler to either of the strings "IGNORE" or "DEFAULT", in which case Perl will try to discard the signal or allow the default action for that signal to occur (though some signals can be neither trapped nor ignored, such as the KILL and STOP signals; see *signal*(3), if you have it, for a list of signals available on your system and their default behaviors).

The operating system thinks of signals as numbers rather than names, but Perl, like most people, prefers symbolic names to magic numbers. To find the names of the signals, list out the keys of the %SIG hash, or use the *kill –l* command if you have one on your system. You can also use Perl's standard Config module to determine your operating system's mapping between signal names and signal numbers. See *Config*(3) for an example of this.

Because %SIG is a global hash, assignments to it affect your entire program. It's often more considerate to the rest of your program to confine your signal catching to a restricted scope. Do this with a local signal handler assignment, which goes out of effect once the enclosing block is exited. (But remember that local values are visible in functions called from within that block.)

```
{
    local $SIG{INT} = "IGNORE";
    ...     # Do whatever you want here, ignoring all SIGINTs.
    fn();   # SIGINTs ignored inside fn() too!
    ...     # And here.
}           # Block exit restores previous $SIG{INT} value.

fn();       # SIGINTs not ignored inside fn() (presumably).
```

Signalling Process Groups

Processes (under Unix, at least) are organized into process groups, generally corresponding to an entire job. For example, when you fire off a single shell command that consists of a series of filter commands that pipe data from one to the other, those processes (and their child processes) all belong to the same process group. That process group has a number corresponding to the process number of the process group leader. If you send a signal to a positive process number, it just sends the signal to the process. But if you send a signal to a negative number, it sends that signal to every process whose process group number is the corresponding positive number—that is, the process number of the process group leader. (Conveniently for the process group leader, the process group ID is just $$.)

Suppose your program wants to send a hang-up signal to all child processes it started directly, plus any grandchildren started by those children, plus any great-grandchildren started by those grandchildren, and so on. To do this, your

program first calls `setpgrp(0,0)` to become the leader of a new process group, and any processes it creates will be part of the new group. It doesn't matter whether these processes were started manually via `fork`, automatically via piped `open`s, or as backgrounded jobs with `system("cmd &")`. Even if those processes had children of their own, sending a hang-up signal to your entire process group will find them all (except for processes that have set their own process group or changed their saved or effective UID so that it no longer matches your real or effective UID, to give themselves diplomatic immunity to your signals).

```
{
    local $SIG{HUP} = "IGNORE";   # exempt myself
    kill(HUP, -$$);               # signal my own process group
}
```

Another interesting signal is signal number `0`. This doesn't actually affect the target process, but instead checks that it's alive and hasn't changed its UIDs. That is, it checks whether it's legal to send a signal, without actually sending one.

```
unless (kill 0 => $kid_pid) {
    warn "something wicked happened to $kid_pid";
}
```

Signal number `0` is the only signal that works the same under Microsoft ports of Perl as it does in Unix. On Microsoft systems, `kill` does not actually deliver a signal. Instead, it forces the target process to exit with the status indicated by the signal number. This may be fixed someday. The magic `0` signal, however, still behaves in the standard, nondestructive fashion.

Reaping Zombies

When a process exits, its parent is sent a `CHLD` signal by the kernel, and the process becomes a zombie[3] until the parent calls `wait` or `waitpid`. If you start another process in Perl using anything except `fork`, Perl takes care of reaping your zombied children; but if you use a raw `fork`, you're expected to clean up after yourself. On many but not all kernels, a simple hack for autoreaping zombies is to set `$SIG{CHLD}` to `"IGNORE"`. A more flexible (but tedious) approach is to reap them yourself. Because more than one child may have died before you get around to dealing with them, you must gather your zombies in a loop until there aren't any more:

```
use POSIX ":sys_wait_h";
sub REAPER { 1 until waitpid(-1, WNOHANG) == -1 }
```

3. Yes, that really is the technical term.

To run this code as needed, you can either set a CHLD signal handler for it:

```
$SIG{CHLD} = \&REAPER;
```

or, if you're running in a loop, just arrange to call the reaper every so often.

Timing Out Slow Operations

A common use for signals is to impose time limits on long-running operations. If you're on a Unix system (or any other POSIX-conforming system that supports the ALRM signal), you can ask the kernel to send your process an ALRM at some point in the future:

```
use Fcntl ":flock";
eval {
    local $SIG{ALRM} = sub { die "alarm clock restart" };
    alarm 10;               # schedule alarm in 10 seconds
    eval {
        flock(FH, LOCK_EX)  # a blocking, exclusive lock
            || die "can't flock: $!";
    };
    alarm 0;                # cancel the alarm
};
alarm 0;               # race condition protection
die if $@ && $@ !~ /alarm clock restart/; # reraise
```

If the alarm hits while you're waiting for the lock, and you simply catch the signal and return, you'll go right back into the flock because Perl automatically restarts syscalls where it can. The only way out is to raise an exception through die and then let eval catch it. (This works because the exception winds up calling the C library's *longjmp*(3) function, which is what really gets you out of the restarting syscall.)

The nested exception trap is included because calling flock would raise an exception if flock is not implemented on your platform, and you need to make sure to clear the alarm anyway. The second alarm 0 is provided in case the signal comes in after running the flock but before getting to the first alarm 0. Without the second alarm, you would risk a tiny race condition—but size doesn't matter in race conditions; they either exist or they don't. And we prefer that they don't.

Blocking Signals

Now and then, you'd like to delay receipt of a signal during some critical section of code. You don't want to blindly ignore the signal, but what you're doing is too important to interrupt. Perl's %SIG hash doesn't implement signal blocking, but the POSIX module does, through its interface to the *sigprocmask*(2) syscall:

```
use POSIX qw(:signal_h);
$sigset   = POSIX::SigSet->new;
$blockset = POSIX::SigSet->new(SIGINT, SIGQUIT, SIGCHLD);
sigprocmask(SIG_BLOCK, $blockset, $sigset)
    || die "Could not block INT,QUIT,CHLD signals: $!\n";
```

Once the three signals are all blocked, you can do whatever you want without fear of being bothered. When you're done with your critical section, unblock the signals by restoring the old signal mask:

```
sigprocmask(SIG_SETMASK, $sigset)
    || die "Could not restore INT,QUIT,CHLD signals: $!\n";
```

If any of the three signals came in while blocked, they are delivered immediately. If two or more different signals are pending, the order of delivery is not defined. Additionally, no distinction is made between having received a particular signal once while blocked and having received it many times.[4] For example, if nine child processes exited while you were blocking `CHLD` signals, your handler (if you had one) would still be called only once after you unblocked. That's why, when you reap zombies, you should always loop until they're all gone.

Signal Safety

Before v5.8, Perl attempted to treat signals like an interrupt and handle them immediately, no matter what state the interpreter was in. This was inherently unreliable because of reentrancy issues. Perl's own memory could become corrupted and your process could crash, or worse.

Today, when a signal arrives for your process, Perl just marks a bit that says it's pending. Then at the next safe point in the interpreter loop, all pending signals are processed. This is all safe and orderly and reliable, but it is not necessarily timely. Some of Perl's opcodes can take a long time to execute, such as calling `sort` on an extremely large list.

To get Perl to return to handling (or mishandling) signals the old, unreliable way, set your `PERL_SIGNALS` environment variable to "`unsafe`". You had best read the section on "Deferred Signals" in the *perlipc* manpage first, though.

Files

Perhaps you've never thought about files as an IPC mechanism before, but they shoulder the lion's share of interprocess communication—far more than all other

4. Traditionally, that is. Countable signals may be implemented on some real-time systems according to the latest specs, but we haven't seen these yet.

means combined. When one process deposits its precious data in a file and another process later retrieves that data, those processes have communicated. Files offer something unique among all forms of IPC covered here: like a papyrus scroll unearthed after millennia buried in the desert, a file can be unearthed and read long after its writer's personal end.[5] Factoring in persistence with comparative ease of use, it's no wonder that files remain popular.

Using files to transmit information from the dead past to some unknown future poses few surprises. You write the file to some permanent medium like a disk, and that's about it. (You might tell a web server where to find it, if it contains HTML.) The interesting challenge is when all parties are still alive and trying to communicate with one another. Without some agreement about whose turn it is to have their say, reliable communication is impossible; agreement may be achieved through file locking, which is covered in the next section. In the section after that, we discuss the special relationship that exists between a parent process and its children, which allows related parties to exchange information through inherited access to the same files.

Files certainly have their limitations when it comes to things like remote access, synchronization, reliability, and session management. Other sections of this chapter cover various IPC mechanisms invented to address such limitations.

File Locking

In a multitasking environment, you need to be careful not to collide with other processes that are trying to use the same file you're using. As long as all processes are just reading, there's no problem; however, as soon as even one process needs to write to the file, complete chaos ensues unless some sort of locking mechanism acts as traffic cop.

Never use the mere existence of a filename (that is, `-e $file`) as a locking indication, because a race condition exists between the test for existence of that filename and whatever you plan to do with it (like create it, open it, or unlink it). See the section "Handling Race Conditions" on page 663 in Chapter 20 for more about this.

Perl's portable locking interface is the `flock`(*HANDLE*,*FLAGS*) function, described in Chapter 27. Perl maximizes portability by using only the simplest and most widespread locking features found on the broadest range of platforms. These semantics are simple enough that they can be emulated on most systems, including those that don't support the traditional syscall of that name, such as

5. Presuming that a process can have a personal end.

System V or Windows NT. (If you're running a Microsoft system earlier than NT, though, you're probably out of luck, as you would be if you're running a system from Apple before Mac OS X.)

Locks come in two varieties: shared (the `LOCK_SH` flag) and exclusive (the `LOCK_EX` flag). Despite the suggestive sound of "exclusive", processes aren't required to obey locks on files. That is, `flock` only implements *advisory locking*, which means that locking a file does not stop another process from reading or even writing to the file. Requesting an exclusive lock is just a way for a process to let the operating system suspend it until all current lockers, whether shared or exclusive, are finished with it. Similarly, when a process asks for a shared lock, it is just suspending itself until there is no exclusive locker. Only when all parties use the file-locking mechanism can a contended file be accessed safely.

Therefore, `flock` is a blocking operation by default. That is, if you can't get the lock you want immediately, the operating system suspends your process until you can. Here's how to get a blocking, shared lock, typically used for reading a file:

```
use Fcntl qw(:DEFAULT :flock);
open(FH, "< filename")  || die "can't open filename: $!";
flock(FH, LOCK_SH)      || die "can't lock filename: $!";
# now read from FH
```

You can try to acquire a lock in a nonblocking fashion by including the `LOCK_NB` flag in the `flock` request. If you can't be given the lock right away, the function fails and immediately returns false. Here's an example:

```
flock(FH, LOCK_SH | LOCK_NB)
    || die "can't lock filename: $!";
```

You may wish to do something besides raising an exception as we did here, but you certainly don't dare do any I/O on the file. If you are refused a lock, you shouldn't access the file until you can get the lock. Who knows what scrambled state you might find the file in? The main purpose of the nonblocking mode is to let you go off and do something else while you wait. But it can also be useful for producing friendlier interactions by warning users that it might take a while to get the lock (so they don't feel abandoned):

```
use Fcntl qw(:DEFAULT :flock);
open(FH, "< filename")  || die "can't open filename: $!";
unless (flock(FH, LOCK_SH | LOCK_NB)) {
    local $| = 1;
    print "Waiting for lock on filename...";
    flock(FH, LOCK_SH)  || die "can't lock filename: $!";
    print "got it.\n"
}
# now read from FH
```

Some people will be tempted to put that nonblocking lock into a loop. The main problem with nonblocking mode is that, by the time you get back to checking again, someone else may have grabbed the lock because you abandoned your place in line. Sometimes you just have to get in line and wait. If you're lucky there will be some magazines to read.

Locks are on filehandles, not on filenames.[6] When you close the file, the lock dissolves automatically, whether you close the file explicitly by calling `close` or implicitly by reopening the handle or by exiting your process.

To get an exclusive lock, typically used for writing, you have to be more careful. You cannot use a regular `open` for this; if you use an open mode of `<`, it will fail on files that don't exist yet, and if you use `>`, it will clobber any files that do. Instead, use `sysopen` on the file so it can be locked before getting overwritten. Once you've safely opened the file for writing but haven't yet touched it, successfully acquire the exclusive lock and only *then* truncate the file. Now you may overwrite it with the new data.

```
use Fcntl qw(:DEFAULT :flock);
 sysopen(FH, "filename", O_WRONLY | O_CREAT)
     || die "can't open filename: $!";
 flock(FH, LOCK_EX)
     || die "can't lock filename: $!";
 truncate(FH, 0)
     || die "can't truncate filename: $!";
 # now write to FH
```

If you want to modify the contents of a file in place, use `sysopen` again. This time you ask for both read and write access, creating the file if needed. Once the file is opened, but before you've done any reading or writing, get the exclusive lock and keep it around your entire transaction. It's often best to release the lock by closing the file because that guarantees all buffers are written before the lock is released.

An update involves reading in old values and writing out new ones. You must do both operations under a single exclusive lock, lest another process read the (imminently incorrect) value after (or even before) you do, but before you write. (We'll revisit this situation when we cover shared memory later in this chapter.)

6. Actually, locks aren't on filehandles—they're on the file descriptors associated with the filehandles since the operating system doesn't know about filehandles. That means that all our `die` messages about failing to get a lock on filenames are technically inaccurate. But error messages of the form "I can't get a lock on the file represented by the file descriptor associated with the filehandle originally opened to the path *filename*, although by now *filename* may represent a different file entirely than our handle does" would just confuse the user (not to mention the reader).

```
use Fcntl qw(:DEFAULT :flock);

sysopen(FH, "counterfile", O_RDWR | O_CREAT)
    || die "can't open counterfile: $!";
flock(FH, LOCK_EX)
    || die "can't write-lock counterfile: $!";
$counter = <FH> || 0;  # first time would be undef
seek(FH, 0, 0)
    || die "can't rewind counterfile : $!";
print FH $counter+1, "\n"
    || die "can't write counterfile: $!";

# next line technically superfluous in this program, but
# a good idea in the general case
truncate(FH, tell(FH))
    || die "can't truncate counterfile: $!";
close(FH)
    || die "can't close counterfile: $!";
```

You can't lock a file you haven't opened yet, and you can't have a single lock that applies to more than one file. What you can do, though, is use a completely separate file to act as a sort of semaphore, like a traffic light, to provide controlled access to something else through regular shared and exclusive locks on the semaphore file. This approach has several advantages. You can have one lockfile that controls access to multiple files, avoiding the kind of deadlock that occurs when one process tries to lock those files in one order while another process is trying to lock them in a different order. You can use a semaphore file to lock an entire directory of files. You can even control access to something that's not even in the filesystem, like a shared memory object or the socket upon which several preforked servers would like to call `accept`.

If you have a DBM file that doesn't provide its own explicit locking mechanism, an auxiliary lockfile is the best way to control concurrent access by multiple agents. Otherwise, your DBM library's internal caching can get out of sync with the file on disk. Before calling `dbmopen` or `tie`, open and lock the semaphore file. If you open the database with `O_RDONLY`, you'll want to use `LOCK_SH` for the lock. Otherwise, use `LOCK_EX` for exclusive access to updating the database. (Again, this only works if all participants agree to pay attention to the semaphore.)

```
use Fcntl qw(:DEFAULT :flock);
use DB_File;  # demo purposes only; any db is fine

$DBNAME  = "/path/to/database";
$LCK     = $DBNAME . ".lockfile";

# use O_RDWR if you expect to put data in the lockfile
sysopen(DBLOCK, $LCK, O_RDONLY | O_CREAT)
    || die "can't open $LCK: $!";
```

```
# must get lock before opening database
flock(DBLOCK, LOCK_SH)
    || die "can't LOCK_SH $LCK: $!";

tie(%hash, "DB_File", $DBNAME, O_RDWR | O_CREAT)
    || die "can't tie $DBNAME: $!";
```

Now you can safely do whatever you'd like with the tied `%hash`. When you're done with your database, make sure you explicitly release those resources, and in the opposite order that you acquired them:

```
untie %hash;    # must close database before lockfile
close DBLOCK;   # safe to let go of lock now
```

If you have the GNU DBM library installed, you can use the standard `GDBM_File` module's implicit locking. Unless the initial `tie` contains the `GDBM_NOLOCK` flag, the library makes sure that only one writer may open a GDBM file at a time, and that readers and writers do not have the database open at the same time.

Passing Filehandles

Whenever you create a child process using `fork`, that new process inherits all its parent's open filehandles. Using filehandles for interprocess communication is easiest to illustrate by using plain files first. Understanding how this works is essential for mastering the fancier mechanisms of pipes and sockets described later in this chapter.

The simplest example opens a file and starts up a child process. The child then uses the filehandle already opened for it:

```
open(INPUT, "< /etc/motd")      || die "/etc/motd: $!";
 if ($pid = fork) { waitpid($pid,0) }
 else {
     defined($pid)         || die "fork: $!";
     while (<INPUT>) { print "$.: $_" }
     exit;  # don't let child fall back into main code
 }
 # INPUT handle now at EOF in parent
```

Once access to a file has been granted by `open`, it stays granted until the filehandle is closed; changes to the file's permissions or to the owner's access privileges have no effect on accessibility. Even if the process later alters its user or group IDs, or the file has its ownership changed to a different user or group, that doesn't affect filehandles that are already open. Programs running under increased permissions (like set-id programs or systems daemons) often open a file under their increased

rights and then hand off the filehandle to a child process that could not have opened the file on its own.

Although this feature is of great convenience when used intentionally, it can also create security issues if filehandles accidentally leak from one program to the next. To avoid granting implicit access to all possible filehandles, Perl automatically closes any filehandles it has opened (including pipes and sockets) whenever you explicitly `exec` a new program or implicitly execute one through a call to a piped `open`, `system`, or `qx//` (backticks). The system filehandles `STDIN`, `STDOUT`, and `STDERR` are exempt from this because their main purpose is to provide communications linkage between programs. So one way of passing a filehandle to a new program is to copy the filehandle to one of the standard filehandles:

```
open(INPUT, "< /etc/motd")      || die "/etc/motd: $!";
 if ($pid = fork) { wait }
 else {
     defined($pid)               || die "fork: $!";
     open(STDIN, "<&INPUT")      || die "dup: $!";
     exec("cat", "-n")           || die "exec cat: $!";
 }
```

If you really want the new program to gain access to a filehandle other than these three, you can, but you have to do one of two things. When Perl opens a new file (or pipe or socket), it checks the current setting of the `$^F` (`$SYSTEM_FD_MAX`) variable. If the numeric file descriptor used by that new filehandle is greater than `$^F`, the descriptor is marked as one to close. Otherwise, Perl leaves it alone, and new programs you `exec` will inherit access.

It's not always easy to predict what file descriptor your newly opened filehandle will have, but you can temporarily set your maximum system file descriptor to some outrageously high number for the duration of the `open`:

```
# open file and mark INPUT to be left open across execs
{
    local $^F = 10_000;
    open(INPUT, "< /etc/motd")   || die "/etc/motd: $!";
} # old value of $^F restored on scope exit
```

Now all you have to do is get the new program to pay attention to the descriptor number of the filehandle you just opened. The cleanest solution (on systems that support this) is to pass a special filename that equates to a file descriptor. If your system has a directory called */dev/fd* or */proc/$$/fd* containing files numbered from 0 through the maximum number of supported descriptors, you can probably use this strategy. (Many Linux operating systems have both, but only the */proc* version tends to be correctly populated. BSD and Solaris prefer */dev/fd*. You'll have to poke around at your system to see which looks better for you.)

First, open and mark your filehandle as one to be left open across execs, as shown in the previous code, then fork it like this:

```
if ($pid = fork) { wait }
else {
    defined($pid)                || die "fork: $!";
    $fdfile = "/dev/fd/" . fileno(INPUT);
    exec("cat", "-n", $fdfile)   || die "exec cat: $!";
}
```

Using the fcntl syscall, you may diddle the filehandle's close-on-exec flag manually. This is convenient for those times when you didn't realize back when you created the filehandle that you would want to share it with your children.

```
use Fcntl qw/F_SETFD/;

fcntl(INPUT, F_SETFD, 0)
    || die "Can't clear close-on-exec flag on INPUT: $!\n";
```

You can also force a filehandle to close:

```
fcntl(INPUT, F_SETFD, 1)
    || die "Can't set close-on-exec flag on INPUT: $!\n";
```

You can also query the current status:

```
use Fcntl qw/F_SETFD F_GETFD/;

printf("INPUT will be %s across execs\n",
    fcntl(INPUT, F_GETFD, 1) ? "closed" : "left open");
```

If your system doesn't support file descriptors named in the filesystem, and you want to pass a filehandle other than STDIN, STDOUT, or STDERR, you can still do so, but you'll have to make special arrangements with that program. Common strategies for this are to pass the descriptor number through an environment variable or a command-line option.

If the executed program is in Perl, you can use open to convert a file descriptor into a filehandle. Instead of specifying a filename, use "&=" followed by the descriptor number.

```
if (($ENV{input_fdno} // "") =~ /^\d$/) {
    open(INPUT, "<&=$ENV{input_fdno}")
        || die "can't fdopen $ENV{input_fdno} for input: $!";
}
```

It gets even easier than that if you're going to be running a Perl subroutine or program that expects a filename argument. You can use the descriptor-opening feature of Perl's regular open function (but not sysopen or three-argument open) to make this happen automatically. Imagine you have a simple Perl program like this:

```
#!/usr/bin/perl -p
# nl - number input lines
printf "%6d  ", $.;
```

Presuming you've arranged for the `INPUT` handle to stay open across `exec`s, you can call that program this way:

```
$fdspec = "<&=" . fileno(INPUT);
system("nl", $fdspec);
```

or to catch the output:

```
@lines = `nl '$fdspec'`;  # single quotes protect spec from shell
```

Whether or not you `exec` another program, if you use file descriptors inherited across `fork`, there's one small gotcha. Unlike variables copied across a `fork`, which actually get duplicate but independent copies, file descriptors really *are* the same in both processes. If one process reads data from the handle, the seek pointer (file position) advances in the other process, too, and that data is no longer available to either process. If they take turns reading, they'll leapfrog over each other in the file. This makes intuitive sense for handles attached to serial devices, pipes, or sockets, since those tend to be read-only devices with ephemeral data. But this behavior may surprise you with disk files. If this is a problem, reopen any files that need separate tracking after the fork.

The `fork` operator is a concept derived from Unix, which means it might not be implemented correctly on all non-Unix/non-POSIX platforms. Notably, `fork` works on Microsoft systems only if you're running Perl v5.6 (or better) on Windows 98 (or later). Although `fork` is implemented via multiple concurrent execution streams within the same program on these systems, these aren't the sort of threads where all data is shared by default; here, only file descriptors are.

Pipes

A *pipe* is a unidirectional I/O channel that can transfer a stream of bytes from one process to another. Pipes come in both named and nameless varieties. You may be more familiar with nameless pipes, so we'll talk about those first.

Anonymous Pipes

Perl's `open` function opens a pipe instead of a file when you append or prepend a pipe symbol to the second argument to `open`. This turns the rest of the arguments into a command, which will be interpreted as a process (or set of processes) that you want to pipe a stream of data either into or out of. Here's how to start up a child process that you intend to write to:

```
open SPOOLER, "| cat -v | lpr -h 2>/dev/null"
     || die "can't fork: $!";
 local $SIG{PIPE} = sub { die "spooler pipe broke" };
 print SPOOLER "stuff\n";
 close SPOOLER || die "bad spool: $! $?";
```

This example actually starts up two processes, the first of which (running *cat*) we print to directly. The second process (running *lpr*) then receives the output of the first process. In shell programming, this is often called a *pipeline*. A pipeline can have as many processes in a row as you like, as long as the ones in the middle know how to behave like *filters*; that is, they read standard input and write standard output.

Perl uses your default system shell (*/bin/sh* on Unix) whenever a pipe command contains special characters that the shell cares about. If you're only starting one command, and you don't need—or don't want—to use the shell, you can use the multiargument form of a piped open instead:

```
open SPOOLER, "|-", "lpr", "-h"    # requires 5.6.1
    || die "can't run lpr: $!";
```

If you reopen your program's standard output as a pipe to another program, anything you subsequently `print` to `STDOUT` will be standard input for the new program. So to page your program's output,[7] you'd use:

```
if (-t STDOUT) {            # only if stdout is a terminal
    my $pager = $ENV{PAGER} || "more";
    open(STDOUT, "| $pager")    || die "can't fork a pager: $!";
}
END {
    close(STDOUT)               || die "can't close STDOUT: $!"
}
```

When you're writing to a filehandle connected to a pipe, always explicitly `close` that handle when you're done with it. That way your main program doesn't exit before its offspring.

Here's how to start up a child process that you intend to read from:

```
open STATUS, "netstat -an 2>/dev/null |"
    || die "can't fork: $!";
while (<STATUS>) {
    next if /^(tcp|udp)/;
    print;
}
close STATUS || die "bad netstat: $! $?";
```

7. That is, let them view it one screenful at a time, not set off random bird calls.

You can open a multistage pipeline for input just as you can for output. And, as before, you can avoid the shell by using an alternate form of `open`:

```
open STATUS, "-|", "netstat", "-an"      # requires 5.6.1
    || die "can't run netstat: $!";
```

But then you don't get I/O redirection, wildcard expansion, or multistage pipes, since Perl relies on your shell to do those.

You might have noticed that you can use backticks to accomplish the same effect as opening a pipe for reading:

```
print grep { !/^(tcp|udp)/ } `netstat -an 2>&1`;
die "bad netstat" if $?;
```

While backticks are extremely handy, they have to read the whole thing into memory at once, so it's often more efficient to open your own piped filehandle and process the file one line or record at a time. This gives you finer control over the whole operation, letting you kill off the child process early if you like. You can also be more efficient by processing the input as it's coming in, since computers can interleave various operations when two or more processes are running at the same time. (Even on a single-CPU machine, input and output operations can happen while the CPU is doing something else.)

Because you're running two or more processes concurrently, disaster can strike the child process any time between the `open` and the `close`. This means that the parent must check the return values of both `open` and `close`. Checking the `open` isn't good enough, since that will only tell you whether the fork was successful, and possibly whether the subsequent command was successfully launched. (It can tell you this only in recent versions of Perl, and only if the command is executed directly by the forked child, not via the shell.) Any disaster that happens after that is reported from the child to the parent as a nonzero exit status. When the `close` function sees that, it knows to return a false value, indicating that the actual status value should be read from the `$?` (`$CHILD_ERROR`) variable. So checking the return value of `close` is just as important as checking `open`. If you're writing to a pipe, you should also be prepared to handle the `PIPE` signal, which is sent to you if the process on the other end dies before you're done sending to it.

Talking to Yourself

Another approach to IPC is to make your program talk to itself, in a manner of speaking. Actually, your process talks over pipes to a forked copy of itself. It works much like the piped open we talked about in the last section, except that the child process continues executing your script instead of some other command.

To represent this to the `open` function, you use a pseudocommand consisting of a minus. So the second argument to `open` looks like either "`-|`" or "`|-`", depending on whether you want to pipe from yourself or to yourself. As with an ordinary `fork` command, the `open` function returns the child's process ID in the parent process but `0` in the child process. Another asymmetry is that the filehandle named by the `open` is used only in the parent process. The child's end of the pipe is hooked to either `STDIN` or `STDOUT` as appropriate. That is, if you open a pipe *to* minus with `|-`, you can write to the filehandle you opened, and your kid will find this in `STDIN`:

```
if (open(TO, "|-")) {
    print TO $fromparent;
}
else {
    $tochild = <STDIN>;
    exit;
}
```

If you open a pipe *from* minus with `-|`, you can read from the filehandle you opened, which will return whatever your kid writes to `STDOUT`:

```
if (open(FROM, "-|")) {
    $toparent = <FROM>;
}
else {
    print STDOUT $fromchild;
    exit;
}
```

One common application of this construct is to bypass the shell when you want to open a pipe from a command. You might want to do this because you don't want the shell to interpret any possible metacharacters in the filenames you're trying to pass to the command. If you're running v5.6.1 or later, you can use the multiargument form of `open` to get the same result.

Another use of a forking open is to safely open a file or command even while you're running under an assumed UID or GID. The child you `fork` drops any special access rights, then safely opens the file or command and acts as an intermediary, passing data between its more powerful parent and the file or command it opened. Examples can be found in the section "Accessing Commands and Files Under Reduced Privileges" on page 657 in Chapter 20.

One creative use of a forking open is to filter your own output. Some algorithms are much easier to implement in two separate passes than they are in just one pass. Here's a simple example in which we emulate the Unix *tee*(1) program by sending our normal output down a pipe. The agent on the other end of the pipe (one of our own subroutines) distributes our output to all the files specified:

```
tee("/tmp/foo", "/tmp/bar", "/tmp/glarch");

while (<>) {
    print "$ARGV at line $. => $_";
}
close(STDOUT)  || die "can't close STDOUT: $!";

sub tee {
    my @output = @_;
    my @handles = ();
    for my $path (@output) {
        my $fh;  # open will fill this in
        unless (open ($fh, ">", $path)) {
            warn "cannot write to $path: $!";
            next;
        }
        push @handles, $fh;
    }

    # reopen STDOUT in parent and return
    return if my $pid = open(STDOUT, "|-");
    die "cannot fork: $!" unless defined $pid;

    # process STDIN in child
    while (<STDIN>) {
        for my $fh (@handles) {
            print $fh $_ || die "tee output failed: $!";
        }
    }
    for my $fh (@handles) {
        close($fh) || die "tee closing failed: $!";
    }
    exit;  # don't let the child return to main!
}
```

This technique can be applied repeatedly to push as many filters on your output stream as you wish. Just keep calling functions that fork-open `STDOUT`, and have the child read from its parent (which it sees as `STDIN`) and pass the massaged output along to the next function in the stream.

Another interesting application of talking to yourself with fork-open is to capture the output from an ill-mannered function that always splats its results to `STDOUT`. Imagine if Perl only had `printf` and no `sprintf`. What you'd need would be something that worked like backticks, but with Perl functions instead of external commands:

```
badfunc("arg");                      # drat, escaped!
$string = forksub(\&badfunc, "arg");  # caught it as string
@lines  = forksub(\&badfunc, "arg");  # as separate lines
```

```
sub forksub {
    my $kidpid = open my $self, "-|";
    defined $kidpid         || die "cannot fork: $!";
    shift->(@_), exit       unless $kidpid;
    local $/                unless wantarray;
    return <$self>;         # closes on scope exit
}
```

We're not claiming this is efficient; a tied filehandle would probably be a good bit faster. But it's a lot easier to code up if you're in more of a hurry than your computer is.

Bidirectional Communication

Although using `open` to connect to another command over a pipe works reasonably well for unidirectional communication, what about bidirectional communication? The obvious approach doesn't actually work:

```
open(PROG_TO_READ_AND_WRITE, "| some program |")  # WRONG!
```

and if you forget to enable warnings, then you'll miss out entirely on the diagnostic message:

```
Can't do bidirectional pipe at myprog line 3.
```

The `open` function doesn't allow this because it's rather prone to deadlock unless you're quite careful. But if you're determined, you can use the standard `IPC::Open2` library module to attach two pipes to a subprocess's `STDIN` and `STDOUT`. There's also an `IPC::Open3` module for tridirectional I/O (allowing you to also catch your child's `STDERR`), but this requires either an awkward `select` loop or the somewhat more convenient `IO::Select` module. But then you'll have to avoid Perl's buffered input operations like `<>` (`readline`).

Here's an example using `open2`:

```
use IPC::Open2;
local (*Reader, *Writer);
$pid = open2(\*Reader, \*Writer, "bc -l");
$sum = 2;
for (1 .. 5) {
    print Writer "$sum * $sum\n";
    chomp($sum = <Reader>);
}
close Writer;
close Reader;
waitpid($pid, 0);
print "sum is $sum\n";
```

You can also autovivify lexical filehandles:

```
my ($fhread, $fhwrite);
$pid = open2($fhread, $fhwrite, "cat -u -n");
```

The problem with this in general is that standard I/O buffering is really going to ruin your day. Even though your output filehandle is autoflushed (the library does this for you) so that the process on the other end will get your data in a timely manner, you can't usually do anything to force it to return the favor. In this particular case, we were lucky: *bc* expects to operate over a pipe and knows to flush each output line. But few commands are so designed, so this seldom works out unless you yourself wrote the program on the other end of the double-ended pipe. Even simple, apparently interactive programs like *ftp* fail here because they won't do line buffering on a pipe. They'll only do it on a tty device.

The `IO::Pty` and `Expect` modules from CPAN can help with this because they provide a real tty (actually, a real pseudo-tty, but it acts like a real one). This gets you line buffering in the other process without modifying its program.

If you split your program into several processes and want these to all have a conversation that goes both ways, you can't use Perl's high-level pipe interfaces, because these are all unidirectional. You'll need to use two low-level `pipe` function calls, each handling one direction of the conversation:

```
pipe(FROM_PARENT, TO_CHILD)     || die "pipe: $!";
pipe(FROM_CHILD,  TO_PARENT)    || die "pipe: $!";
select(((select(TO_CHILD), $| = 1))[0]);   # autoflush
select(((select(TO_PARENT), $| = 1))[0]);  # autoflush

if ($pid = fork) {
    close FROM_PARENT; close TO_PARENT;
    print TO_CHILD "Parent Pid $$ is sending this\n";
    chomp($line = <FROM_CHILD>);
    print "Parent Pid $$ just read this: '$line'\n";
    close FROM_CHILD; close TO_CHILD;
    waitpid($pid,0);
} else {
    die "cannot fork: $!" unless defined $pid;
    close FROM_CHILD; close TO_CHILD;
    chomp($line = <FROM_PARENT>);
    print "Child Pid $$ just read this: '$line'\n";
    print TO_PARENT "Child Pid $$ is sending this\n";
    close FROM_PARENT; close TO_PARENT;
    exit;
}
```

On many Unix systems, you don't actually have to make two separate `pipe` calls to achieve full duplex communication between parent and child. The `socketpair` syscall provides bidirectional connections between related processes on the same machine. So instead of two `pipe`s, you only need one `socketpair`.

```
use Socket;
socketpair(Child, Parent, AF_UNIX, SOCK_STREAM, PF_UNSPEC)
    || die "socketpair: $!";

# or letting perl pick filehandles for you
my ($kidfh, $dadfh);
socketpair($kidfh, $dadfh, AF_UNIX, SOCK_STREAM, PF_UNSPEC)
    || die "socketpair: $!";
```

After the `fork`, the parent closes the `Parent` handle, then reads and writes via the `Child` handle. Meanwhile, the child closes the `Child` handle, then reads and writes via the `Parent` handle.

If you're looking into bidirectional communications because the process you'd like to talk to implements a standard Internet service, you should usually just skip the middleman and use a CPAN module designed for that exact purpose. (See the section "Sockets" on page 543 later in this chapter for a list of some of these.)

Named Pipes

A named pipe (often called a FIFO) is a mechanism for setting up a conversation between unrelated processes on the same machine. The names in a "named" pipe exist in the filesystem, which is just a funny way to say that you can put a special file in the filesystem namespace that has another process behind it instead of a disk.[8] A FIFO is convenient when you want to connect a process to an unrelated one. When you open a FIFO, your process will block until there's a process on the other end. So if a reader opens the FIFO first, it blocks until the writer shows up—and vice versa.

To create a named pipe, use the POSIX `mkfifo` function—if you're on a POSIX system, that is. On Microsoft systems, you'll instead want to look into the `Win32::Pipe` module, which, despite its possible appearance to the contrary, creates named pipes. (Win32 users create anonymous pipes using `pipe` just like the rest of us.)

For example, let's say you'd like to have your *.signature* file produce a different answer each time it's read. Just make it a named pipe with a Perl program on the other end that spits out random quips. Now every time any program (like a mailer, newsreader, finger program, and so on) tries to read from that file, that program will connect to your program and read in a dynamic signature.

8. You can do the same thing with Unix-domain sockets, but you can't use `open` on those.

In the following example, we use the rarely seen -p file test operator to determine whether anyone (or anything) has accidentally removed our FIFO.[9] If they have, there's no reason to try to open it, so we treat this as a request to exit. If we'd used a simple open function with a mode of "> $fpath", there would have been a tiny race condition that would have risked accidentally creating the signature as a plain file if it disappeared between the -p test and the open. We couldn't use a "+< $fpath" mode, either, because opening a FIFO for read-write is a nonblocking open (this is only true of FIFOs). By using sysopen and omitting the O_CREAT flag, we avoid this problem by never creating a file by accident.

```
use Fcntl;              # for sysopen
chdir;                  # go home
$fpath = ".signature";
$ENV{PATH} .= ":/usr/games";

unless (-p $fpath) {    # not a pipe
    if (-e _) {         # but a something else
        die "$0: won't overwrite .signature\n";
    } else {
        require POSIX;
        POSIX::mkfifo($fpath, 0666) || die "can't mknod $fpath: $!";
        warn "$0: created $fpath as a named pipe\n";
    }
}

while (1) {
    # exit if signature file manually removed
    die "Pipe file disappeared" unless -p $fpath;
    # next line blocks until there's a reader
    sysopen(FIFO, $fpath, O_WRONLY)
        || die "can't write $fpath: $!";
    print FIFO "John Smith (smith\@host.org)\n", `fortune -s`;
    close FIFO;
    select(undef, undef, undef, 0.2);  # sleep 1/5th of a second
}
```

The short sleep after the close is needed to give the reader a chance to read what was written. If we just immediately loop back up around and open the FIFO again before our reader has finished reading the data we just sent, then no end-of-file is seen because there's once again a writer. We'll both go round and round until, during one iteration, the writer falls a little behind and the reader finally sees that elusive end-of-file. (And we were worried about race conditions?)

9. Another use is to see whether a filehandle is connected to a pipe, named or anonymous, as in -p STDIN.

System V IPC

Everyone hates System V IPC. It's slower than paper tape, carves out insidious little namespaces completely unrelated to the filesystem, uses human-hostile numbers to name its objects, and is constantly losing track of its own mind. Every so often, your sysadmin has to go on a search-and-destroy mission to hunt down these lost SysV IPC objects with *ipcs*(1) and kill them with *ipcrm*(1), hopefully before the system runs out of memory.

Despite all this pain, ancient SysV IPC still has a few valid uses. The three kinds of IPC objects are shared memory, semaphores, and messages. For message passing, sockets are the preferred mechanisms these days, and they're a lot more portable, too. For simple uses of semaphores, the filesystem tends to get used. As for shared memory—well, now there's a problem for you. If you have it, the more modern *mmap*(2) syscall fits the bill, but the quality of the implementation varies from system to system. It also requires a bit of care to avoid letting Perl reallocate your strings from where *mmap*(2) put them.

The `File::Map` CPAN module makes this a lot easier. It still requires some care in handling, but if you mess things up it just warns you instead of dumping core with a segmentation violation.

Here's a little program that demonstrates controlled access to a shared memory buffer by a brood of sibling processes. SysV IPC objects can also be shared among *unrelated* processes on the same computer, but then you have to figure out how they're going to find each other. To mediate safe access, we'll create a semaphore per piece.[10]

Every time you want to get or put a new value into the shared memory, you have to go through the semaphore first. This can get pretty tedious, so we'll wrap access in an object class. `IPC::Shareable` goes one step further, wrapping its object class in a `tie` interface.

This program runs until you interrupt it with a Control-C or equivalent:

```
#!/usr/bin/perl -w
use v5.6.0;   # or better
use strict;
use sigtrap qw(die INT TERM HUP QUIT);
my $PROGENY = shift(@ARGV) || 3;
```

10. It would be more realistic to create a pair of semaphores for each bit of shared memory, one for reading and the other for writing; in fact, that's what the `IPC::Shareable` module on CPAN does. But we're trying to keep things simple here. It's worth admitting, though, that with a couple of semaphores, you could then make use of pretty much the only redeeming feature of SysV IPC: performing atomic operations on entire sets of semaphores as one unit, which is occasionally useful.

```
eval { main() };   # see DESTROY below for why
die if $@ && $@ !~ /^Caught a SIG/;
print "\nDone.\n";
exit;

sub main {
    my $mem = ShMem->alloc("Original Creation at " . localtime);
    my(@kids, $child);
    $SIG{CHLD} = "IGNORE";
    for (my $unborn = $PROGENY; $unborn > 0; $unborn--) {
        if ($child = fork) {
            print "$$ begat $child\n";
            next;
        }
        die "cannot fork: $!" unless defined $child;
        eval {
            while (1) {
                $mem->lock();
                $mem->poke("$$ " . localtime)
                    unless $mem->peek =~ /^$$\b/o;
                $mem->unlock();
            }
        };
        die if $@ && $@ !~ /^Caught a SIG/;
        exit;  # child death

    }
    while (1) {
        print "Buffer is ", $mem->get, "\n";
        sleep 1;
    }
}
```

And here's the `ShMem` package, which that program uses. You can just tack it on to the end of the program, or put it in its own file (with a "`1;`" at the end) and `require` it from the main program. (The two IPC modules it uses in turn are found in the standard Perl distribution.)

```
package ShMem;
 use IPC::SysV qw(IPC_PRIVATE IPC_RMID IPC_CREAT S_IRWXU);
 use IPC::Semaphore;
 sub MAXBUF() { 2000 }

 sub alloc {    # constructor method
     my $class = shift();
     my $value = @_ ? shift() : "";

     my $key = shmget(IPC_PRIVATE, MAXBUF, S_IRWXU) || die "shmget: $!";
     my $sem = IPC::Semaphore->new(IPC_PRIVATE, 1, S_IRWXU | IPC_CREAT)
                          or die "IPC::Semaphore->new: $!";
     $sem->setval(0,1)    or die "sem setval: $!";
```

```
        my $self = bless {
            OWNER   => $$,
            SHMKEY  => $key,
            SEMA    => $sem,
        } => $class;

        $self->put($value);
        return $self;
    }
```

Now for the fetch and store methods. The `get` and `put` methods lock the buffer, but `peek` and `poke` don't, so the latter two should be used only while the object is manually locked—which you have to do when you want to retrieve an old value and store back a modified version, all under the same lock. The demo program does this in its `while (1)` loop. The entire transaction must occur under the same lock, or the testing and setting wouldn't be atomic and might bomb.

```
sub get {
    my $self = shift();
    $self->lock;
    my $value = $self->peek(@_);
    $self->unlock;
    return $value;
}
sub peek {
    my $self = shift();
    shmread($self->{SHMKEY}, my $buff=q(), 0, MAXBUF) || die "shmread: $!";
    substr($buff, index($buff, "\0")) = q();
    return $buff;
}
sub put {
    my $self = shift();
    $self->lock;
    $self->poke(@_);
    $self->unlock;
}
sub poke {
    my($self,$msg) = @_;
    shmwrite($self->{SHMKEY}, $msg, 0, MAXBUF) || die "shmwrite: $!";
}
sub lock {
    my $self = shift();
    $self->{SEMA}->op(0,-1,0) || die "semop: $!";
}
sub unlock {
    my $self = shift();
    $self->{SEMA}->op(0,1,0) || die "semop: $!";
}
```

Finally, the class needs a destructor so that when the object goes away, we can manually deallocate the shared memory and the semaphore stored inside the object. Otherwise, they'll outlive their creator, and you'll have to resort to *ipcs* and *ipcrm* (or a sysadmin) to get rid of them. That's why we went through the elaborate wrappers in the main program to convert signals into exceptions: so that all destructors get run, SysV IPC objects get deallocated, and sysadmins get off our case.

```
sub DESTROY {
    my $self = shift();
    return unless $self->{OWNER} == $$;  # avoid dup dealloc
    shmctl($self->{SHMKEY}, IPC_RMID, 0)    || warn "shmctl RMID: $!";
    $self->{SEMA}->remove()                  || warn "sema->remove: $!";
}
```

Sockets

The IPC mechanisms discussed earlier all have one severe restriction: they're designed for communication between processes running on the same computer. (Even though files can sometimes be shared across machines through mechanisms like NFS, locking fails miserably on many NFS implementations, which takes away most of the fun of concurrent access.) For general-purpose networking, sockets are the way to go. Although sockets were invented under BSD, they quickly spread to other forms of Unix, and nowadays you can find a socket interface on nearly every viable operating system out there. If you don't have sockets on your machine, you're going to have tremendous difficulty using the Internet.

With sockets, you can do both virtual circuits (as TCP streams) and datagrams (as **UDP** packets). You may be able to do even more, depending on your system. But the most common sort of socket programming uses TCP over Internet-domain sockets, so that's the kind we cover here. Such sockets provide reliable connections that work a little bit like bidirectional pipes that aren't restricted to the local machine. The two killer apps of the Internet, email and web browsing, both rely almost exclusively on TCP sockets.

You also use UDP heavily without knowing it. Every time your machine tries to find a site on the Internet, it sends UDP packets to your DNS server asking it for the actual IP address. You might use UDP yourself when you want to send and receive datagrams. Datagrams are cheaper than TCP connections precisely because they aren't connection-oriented; that is, they're less like making a telephone call and more like dropping a letter in the mailbox. But UDP also lacks the reliability that TCP provides, making it more suitable for situations where you

don't care whether a packet or two gets folded, spindled, or mutilated. Or for when you know that a higher-level protocol will enforce some degree of redundancy or fail-softness (which is what DNS does).

Other choices are available but far less common. You can use Unix-domain sockets, but they only work for local communication. Various systems support various other non-IP-based protocols. Doubtless these are somewhat interesting to someone somewhere, but we'll restrain ourselves from talking about them somehow.

The Perl functions that deal with sockets have the same names as the corresponding syscalls in C, but their arguments tend to differ for two reasons: first, Perl filehandles work differently from C file descriptors; and second, Perl already knows the length of its strings, so you don't need to pass that information. See Chapter 27 for details on each socket-related syscall.

One problem with ancient socket code in Perl was that people would use hardcoded values for constants passed into socket functions, which destroys portability. Like most syscalls, the socket-related ones quietly but politely return `undef` when they fail, instead of raising an exception. It is therefore essential to check these functions' return values, since if you pass them garbage, they aren't going to be very noisy about it. If you ever see code that does anything like explicitly setting `$AF_INET = 2`, you know you're in for big trouble. An immeasurably superior approach is to use the `Socket` module or the even friendlier `IO::Socket` module, both of which are standard. These modules provide various constants and helper functions you'll need for setting up clients and servers. For optimal success, your socket programs should always start out like this (and don't forget to add the *–T* taint-checking switch to the shebang line for servers):

```
#!/usr/bin/perl
use v5.14;
use warnings;
use autodie;

# or IO::Socket::IP from CPAN for IPv6
use IO::Socket;
```

As noted elsewhere, Perl is at the mercy of your C libraries for much of its system behavior, and not all systems support all sorts of sockets. It's probably safest to stick with normal TCP and UDP socket operations. For example, if you want your code to stand a chance of being portable to systems you haven't thought of, don't expect there to be support for a reliable sequenced-packet protocol. Nor should you expect to pass open file descriptors between unrelated processes over a local Unix-domain socket. (Yes, you can really do that on many Unix machines —see your local *recvmsg*(2) manpage.)

If you just want to use a standard Internet service like mail, news, domain name service, FTP, Telnet, the Web, and so on, then instead of starting from scratch, try using existing CPAN modules for these. Prepackaged modules designed for these include `Net::SMTP` (or `Mail::Mailer`), `Net::NNTP`, `Net::DNS`, `Net::FTP`, `Net::Telnet`, and the various HTTP-related modules. The `libnet` and `libwww` module suites both comprise many individual networking modules.

In the sections that follow, we present several sample clients and servers without a great deal of explanation of each function used, as that would mostly duplicate the descriptions we've already provided in Chapter 27.

Networking Clients

Use Internet-domain sockets when you want reliable client-server communication between potentially different machines.

To create a TCP client that connects to a server somewhere, it's usually easiest to use the standard `IO::Socket::INET` module:

```
#!/usr/bin/env perl
use v5.14;
use warnings;
use autodie;
use IO::Socket::INET;

my $remote_host = "localhost";  # replace with real remote host
my $remote_port = "daytime";    # replace with service name or portnumber

my $socket = IO::Socket::INET->new(
                PeerAddr => $remote_host,
                PeerPort => $remote_port,
                Type     => SOCK_STREAM,
            );

# send something over the socket; netstuff likes CRLFs
# daytime doesn't take input, but use on other servers
print $socket "Why don't you call me anymore?\r\n";

# read the remote answer,
my $answer = <$socket> =~ s/\R\z//r;

say "Got answer: $answer";

# and terminate the connection when we're done.
close($socket);
```

A shorthand form of the call is good enough when you just have a host and port combination to connect to, and are willing to use defaults for all other fields:

```
$socket = IO::Socket::INET->new("www.yahoo.com:80")
    or die "Couldn't connect to port 80 of yahoo: $!";
```

For IPv6, it's easiest if you get the `IO::Socket::IP` module from CPAN. If you have a release of Perl later than v5.14, it may even be on our system already. Once you've done that, all you do is change the name of the class in the code above from `IO::Socket::INET` to `IO::Socket::IP`, and it will work for IPv6, too. That class is an extra `sockdomain` method that you can test to see which flavor of IP you got:

```
#!/usr/bin/env perl
use v5.14;
use warnings;
use autodie;
use IO::Socket::IP;

my $remote_host = "localhost";
my $remote_port = "daytime";

my $socket = IO::Socket::IP->new(
                PeerAddr => $remote_host,
                PeerPort => $remote_port,
                Type     => SOCK_STREAM,
            );

my $familyname = ( $socket->sockdomain == AF_INET6 ) ? "IPv6" :
                 ( $socket->sockdomain == AF_INET  ) ? "IPv4" :
                                                       "unknown";

say "Connected to $remote_host:$remote_port via ", $familyname;

# send something over the socket: networks like CRLFs
print $socket "Why don't you call me anymore?\r\n";

# read the remote answer,
my $answer = <$socket> =~ s/\R\z//r;

say "Got answer: $answer";

# and terminate the connection when we're done.
close($socket);
```

To connect using the basic `Socket` module:

```
use v5.14;
use warnings;
use autodie;
use Socket;
```

```
my $remote_host = "localhost";
my $remote_port = 13;  # daytime service port

socket(my $socket, PF_INET, SOCK_STREAM, getprotobyname("tcp"));
my $internet_addr = inet_aton($remote_host);
my $paddr = sockaddr_in($remote_port, $internet_addr);

connect($socket, $paddr);
$socket->autoflush(1);

print $socket "Why don't you call me anymore?\r\n";
my $answer = <$socket> =~ s/\R\z//r;

say "Answer was: ", $answer;
```

You may use IPv6 with the standard `Socket` module in v5.14, but the function calls and API are a tiny bit different from what is shown above, which is IPv4 only. See the *Socket* manpage for details.

If you want to close only your side of the connection so that the remote end gets an end-of-file, but you can still read data coming from the server, use the `shutdown` syscall for a half-close:

```
# no more writing to server
shutdown(Server, 1);    # Socket::SHUT_WR constant in v5.6
```

Networking Servers

Here's a corresponding server to go along with it. It's pretty easy with the standard `IO::Socket::INET` class:

```
use IO::Socket::INET;

$server = IO::Socket::INET->new(LocalPort => $server_port,
                                Type      => SOCK_STREAM,
                                Reuse     => 1,
                                Listen    => 10 )   # or SOMAXCONN
    || die "Couldn't be a tcp server on port $server_port: $!\n";

while ($client = $server->accept()) {
    # $client is the new connection
}

close($server);
```

You can also write that using the lower-level `Socket` module:

```
#!/usr/bin/env perl

use v5.14;
```

```
use warnings;
use autodie;
use Socket;

my $server_port = 12345;  # pick a number

# make the socket
socket(my $server, PF_INET, SOCK_STREAM, getprotobyname("tcp"));

# so we can restart our server quickly
setsockopt($server, SOL_SOCKET, SO_REUSEADDR, 1);

# build up my socket address
my $own_addr = sockaddr_in($server_port, INADDR_ANY);
bind($server, $own_addr);

# establish a queue for incoming connections
listen($server, SOMAXCONN);

# accept and process connections
while (accept(my $client, $server)) {
    # do something with new client connection in $client
} continue {
    close $client;
}

close($server);
```

The client doesn't need to `bind` to any address, but the server does. We've specified its address as `INADDR_ANY`, which means that clients can connect from any available network interface. If you want to sit on a particular interface (like the external side of a gateway or firewall machine), use that interface's real address instead. (Clients can also do this, but they rarely need to.)

If you want to know which machine connected to you, call `getpeername` on the client connection. This returns an IP address, which you'll have to translate into a name on your own (if you can):

```
use Socket;
$other_end = getpeername($client)
    || die "Couldn't identify other end: $!\n";
($port, $iaddr) = unpack_sockaddr_in($other_end);
$actual_ip = inet_ntoa($iaddr);
$claimed_hostname = gethostbyaddr($iaddr, AF_INET);
```

This is trivially spoofable because the owner of that IP address can set up her reverse tables to say anything she wants. For a small measure of additional confidence, translate back the other way again:

```
@name_lookup = gethostbyname($claimed_hostname)
    || die "Could not reverse $claimed_hostname: $!\n";
@resolved_ips = map { inet_ntoa($_) } @name_lookup[ 4 .. $#name_lookup ];
$might_spoof = !grep { $actual_ip eq $_ } @resolved_ips;
```

Once a client connects to your server, your server can do I/O both to and from that client handle. But while the server is so engaged, it can't service any further incoming requests from other clients. To avoid getting locked down to just one client at a time, many servers immediately `fork` a clone of themselves to handle each incoming connection. (Others `fork` in advance, or multiplex I/O between several clients using the `select` syscall.)

```
REQUEST:
 while (accept(my $client => $server)) {
     if ($kidpid = fork) {
         close $client;         # parent closes unused handle
         next REQUEST;
     }
     defined($kidpid)   || die "cannot fork: $!";

     close $server;             # child closes unused handle

     $client->autoflush(1);

     # per-connection child code does I/O with Client handle
     $input = <$client>;
     print $client "output\n";  # or STDOUT, same thing

     open(STDIN,  "<&", $client)    || die "can't dup client: $!";
     open(STDOUT, ">&", $client)    || die "can't dup client: $!";
     open(STDERR, ">&", $client)    || die "can't dup client: $!";

     # run the calculator, just as an example
     system("bc -l");     # or whatever you'd like, so long as
                          # it doesn't have shell escapes!
     print "done\n";      # still to client

     close $client;
     exit;  # don't let the child back to accept!
 }
```

This server clones off a child with `fork` for each incoming request. That way it can handle many requests at once, as long as you can create more processes. (You might want to limit this.) Even if you don't `fork`, the `listen` will allow up to `SOMAXCONN` (usually five or more) pending connections. Each connection uses up some resources, although not as much as a process. Forking servers have to be careful about cleaning up after their expired children (called "zombies" in Unix-speak) because otherwise they'd quickly fill up your process table. The `REAPER`

code discussed in the earlier section "Signals" on page 518 will take care of that for you, or you may be able to assign `$SIG{CHLD} = "IGNORE"`.

Before running another command, we connect the standard input and output (and error) up to the client connection. This way any command that reads from `STDIN` and writes to `STDOUT` can also talk to the remote machine. Without the reassignment, the command couldn't find the client handle—which by default gets closed across the `exec` boundary, anyway.

When you write a networking server, we strongly suggest that you use the *–T* switch to enable taint checking even if you aren't running setuid or setgid. This is always a good idea for servers and any other program that runs on behalf of someone else (like all CGI scripts), because it lessens the chances that people from the outside will be able to compromise your system. See the section "Handling Insecure Data" on page 648 in Chapter 20 for much more about all this.

One additional consideration when writing Internet programs: many protocols specify that the line terminator should be `CRLF`, which can be specified various ways: `"\r\n"`,[11] `"\015\12"`, or `"\xd\xa"`, or even `chr(13).chr(10)`. Many Internet programs will in fact accept a bare `"\012"` as a line terminator, but that's because Internet programs usually try to be liberal in what they accept and strict in what they emit. (Now if only we could get people to do the same...)

Message Passing

As we mentioned earlier, UDP communication involves much lower overhead but provides no reliability, since there are no promises that messages will arrive in a proper order—or even that they will arrive at all. UDP is often said to stand for Unreliable Datagram Protocol.

Still, UDP offers some advantages over TCP, including the ability to broadcast or multicast to a whole bunch of destination hosts at once (usually on your local subnet). If you find yourself getting overly concerned about reliability and starting to build checks into your message system, then you probably should just use TCP to start with. True, it costs more to set up and tear down a TCP connection, but if you can amortize that over many messages (or one long message), it doesn't much matter.

11. Except on prehistoric, pre-Unix Macs that nobody we know of still uses.

Anyway, here's an example of a UDP program. It contacts the UDP time port of the machines given on the command line, or everybody it can find using the universal broadcast address if no arguments were supplied.[12] Not all machines have a time server enabled, especially across firewall boundaries, but those that do will send you back a 4-byte integer packed in network byte order that represents what time that machine thinks it is. The time returned, however, is in the number of seconds since 1900. You have to subtract the number of seconds between 1900 and 1970 to feed that time to the `localtime` or `gmtime` conversion functions.

```
#!/usr/bin/perl
# clockdrift - compare other systems' clocks with this one
#              without arguments, broadcast to anyone listening.
#              wait one-half second for an answer.

use v5.14;
use warnings;
use strict;
use Socket;

unshift(@ARGV, inet_ntoa(INADDR_BROADCAST))
    unless @ARGV;

socket(my $msgsock, PF_INET, SOCK_DGRAM, getprotobyname("udp"))
    || die "socket: $!";

# Some borked machines need this.  Shouldn't hurt anyone else.
setsockopt($msgsock, SOL_SOCKET, SO_BROADCAST, 1)
    || die "setsockopt: $!";

my $portno = getservbyname("time", "udp")
    || die "no udp time port";

for my $target (@ARGV) {
    print "Sending to $target:$portno\n";
    my $destpaddr = sockaddr_in($portno, inet_aton($target));
    send($msgsock, "x", 0, $destpaddr)
        || die "send: $!";
}

# daytime service returns 32-bit time in seconds since 1900
my $FROM_1900_TO_EPOCH = 2_208_988_800;
my $time_fmt = "N";   # and it does so in this binary format
my $time_len = length(pack($time_fmt, 1));  # any number's fine

my $inmask = q();  # string to store the fileno bits for select
vec($inmask, fileno($msgsock), 1) = 1;
```

12. If that doesn't work, run *ifconfig –a* to find the proper local broadcast address.

```
# wait only half a second for input to show up
while (select(my $outmask = $inmask, undef, undef, 0.5)) {
    defined(my $srcpaddr = recv($msgsock, my $bintime, $time_len, 0))
        || die "recv: $!";
    my($port, $ipaddr) = sockaddr_in($srcpaddr);
    my $sendhost = sprintf "%s [%s]",
                   gethostbyaddr($ipaddr, AF_INET) || "UNKNOWN",
                   inet_ntoa($ipaddr);
    my $delta = unpack($time_fmt, $bintime) -
                     $FROM_1900_TO_EPOCH - time();
    print "Clock on $sendhost is $delta seconds ahead of this one.\n";
}
```

CHAPTER 16
Compiling

If you came here looking for a Perl compiler, you may be surprised to discover that you already have one—your *perl* program (typically */usr/bin/perl*) already contains a Perl compiler. That might not be what you were thinking, and if it wasn't, you may be pleased to know that we do also provide *code generators* (which some well-meaning folks call "compilers"), and we'll discuss those toward the end of this chapter. But first we want to talk about what we think of as The Compiler. Inevitably there's going to be a certain amount of low-level detail in this chapter that some people will be interested in and some people will not. If you find that you're not, think of it as an opportunity to practice your speed-reading skills.

Imagine that you're a conductor who's ordered the score for a large orchestral work. When the box of music arrives, you find several dozen booklets, one for each member of the orchestra with just his part in it. But, curiously, your master copy with all the parts is missing. Even more curiously, the parts you *do* have are written out using plain English instead of musical notation. Before you can put together a program for performance, or even give the music to your orchestra to play, you'll first have to translate the prose descriptions into the normal system of notes and bars. Then you'll need to compile the individual parts into one giant score so that you can get an idea of the overall program.

Similarly, when you hand the source code of your Perl script over to *perl* to execute, it is no more useful to the computer than the English description of the symphony was to the musicians. Before your program can run, Perl needs to compile[1] these English-looking directions into a special symbolic representation. Your program still isn't running, though, because the compiler only compiles. Like the conductor's score, even after your program has been converted to an instruction

1. Or translate, or transform, or transfigure, or transmute, or transmogrify.

format suitable for interpretation, it still needs an active agent to interpret those instructions.

The Life Cycle of a Perl Program

You can break up the life cycle of a Perl program into four distinct phases, each with separate stages of its own. The first and the last are the most interesting and the middle two are optional. The stages are depicted in Figure 16-1.

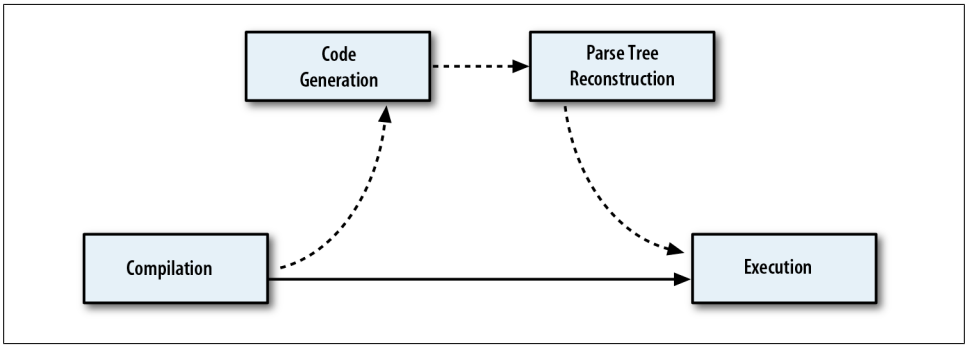


Figure 16-1. The life cycle of a Perl program

1. The Compilation Phase

During phase 1, the *compile phase*, the Perl compiler converts your program into a data structure called a *parse tree*. Along with the standard parsing techniques, Perl employs a much more powerful one: it uses `BEGIN` blocks to guide further compilation. `BEGIN` blocks are handed off to the interpreter to be run as soon as they are parsed, which effectively runs them in *FIFO* order (first in, first out). This includes any `use` and `no` declarations; these are really just `BEGIN` blocks in disguise. `UNITCHECK` blocks are executed as soon as their compilation unit is finished being compiled; these are used for per-unit initialization. Any `CHECK`, `INIT`, and `END` blocks are scheduled by the compiler for delayed execution.

Lexical declarations are noted, but assignments to them are not executed. All `eval` *`BLOCK`*s, `s///e` constructs, and noninterpolated regular expressions are compiled here, and constant expressions are preevaluated. The compiler is now done, unless it gets called back into service later. At the end of this phase, the interpreter is again called up to execute any scheduled `CHECK` blocks in LIFO order (last in, first out). The presence or absence of a `CHECK` block determines whether we next go to phase 2 or skip over to phase 4.

2. *The Code Generation Phase (optional)*

   `CHECK` blocks are installed by code generators, so this optional phase occurs when you explicitly use one of the code generators (described later in "Code Generators" on page 565). These convert the compiled (but not yet run) program into either C source code or serialized Perl *bytecodes*—a sequence of values expressing internal Perl instructions. If you choose to generate C source code, it can eventually produce a file called an *executable image* in native machine language.[2] At this point, your program goes into suspended animation. If you made an executable image, you can go directly to phase 4; otherwise, you need to reconstitute the freeze-dried bytecodes in phase 3.

3. *The Parse Tree Reconstruction Phase (optional)*

   To reanimate the program, its parse tree must be reconstructed. This phase exists only if code generation occurred and you chose to generate bytecode. Perl must first reconstitute its parse trees from that bytecode sequence before the program can run. Perl does not run directly from the bytecodes; that would be slow.

4. *The Execution Phase*

   Finally, what you've all been waiting for: running your program. Hence, this is also called the *run phase*. The interpreter takes the parse tree (which it got either directly from the compiler or indirectly from code generation and subsequent parse tree reconstruction) and executes it. (Or, if you generated an executable image file, it can be run as a standalone program since it contains an embedded Perl interpreter.)

   At the start of this phase, before your main program gets to run, all scheduled `INIT` blocks are executed in FIFO order. Then your main program is run. The interpreter can call back into the compiler as needed upon encountering an `eval` *`STRING`*, a `do` *`FILE`* or `require` statement, an `s///ee` construct, or a pattern match with an interpolated variable that is found to contain a legal code assertion.

   When your main program finishes, any delayed `END` blocks are finally executed, this time in LIFO order. The very first one seen will execute last, and then you're done. `END` blocks are skipped only if you `exec` or your process is blown away by an uncaught catastrophic error. Ordinary exceptions are not considered catastrophic.

Now we'll discuss these phases in greater detail, and in a different order.

---

2. Your original script is an *executable file*, too, but it's not machine language, so we don't call it an image. An image file is called that because it's a verbatim copy of the machine codes your CPU knows how to execute directly.

Compiling Your Code

Perl is always in one of two modes of operation: either it is compiling your program, or it is executing it—never both at the same time. Throughout this book, we refer to certain events as happening at compile time, or we say that "the Perl *compiler* does this and that". At other points, we mention that something else occurs at runtime, or that "the Perl *interpreter* does this and that". Although you can get by with thinking of both the compiler and interpreter as simply "Perl", understanding which of these two roles Perl is playing at any given point is essential to understanding why many things happen as they do. The *perl* executable implements both roles: first the compiler, then the interpreter. (Other roles are possible, too; *perl* is also an optimizer and a code generator. Occasionally, it's even a trickster—but all in good fun.)

It's also important to understand the distinction between compile phase and compile time, and between run phase and runtime. A typical Perl program gets one compile phase and then one run phase. A "phase" is a large-scale concept. But compile time and runtime are small-scale concepts. A given compile phase does mostly compile-time stuff, but it also does some runtime stuff via `BEGIN` blocks. A given run phase does mostly runtime stuff, but it can do compile-time stuff through operators like `eval` *`STRING`*.

In the typical course of events, the Perl compiler reads through your entire program source before execution starts. This is when Perl parses the declarations, statements, and expressions to make sure they're syntactically legal.[3] If it finds a syntax error, the compiler attempts to recover from the error so it can report any other errors later in the source. Sometimes this works, and sometimes it doesn't; syntax errors have a noisy tendency to trigger a cascade of false alarms. Perl bails out in frustration after about 10 errors.

In addition to the interpreter that processes the `BEGIN` blocks, the compiler processes your program with the connivance of three notional agents. The *lexer* scans for each minimal unit of meaning in your program. These are sometimes called *lexemes*, but you'll more often hear them referred to as *tokens* in texts about programming languages. The lexer is sometimes called a tokener or a scanner, and what it does is sometimes called lexing or tokenizing. The *parser* then tries to make sense out of groups of these tokens by assembling them into larger constructs, such as expressions and statements, based on the grammar of the Perl language. The *optimizer* rearranges and reduces these larger groupings into more

3. No, there's no formal syntax diagram like a BNF, but you're welcome to peruse the *perly.y* file in the Perl source tree, which contains the *yacc*(1) grammar Perl uses. We recommend that you stay out of the lexer, which has been known to induce eating disorders in lab rats.

efficient sequences. It picks its optimizations carefully, not wasting time on marginal optimizations, because the Perl compiler has to be blazing fast when used as a load-and-go compiler.

This doesn't happen in independent stages but all at once with a lot of cross talk between the agents. The lexer occasionally needs hints from the parser to know which of several possible token types it's looking at. (Oddly, lexical scope is one of the things the lexical analyzer *doesn't* understand, because that's the other meaning of "lexical".) The optimizer also needs to keep track of what the parser is doing, because some optimizations can't happen until the parse has reached a certain point, like finishing an expression, statement, block, or subroutine.

You may think it odd that the Perl compiler does all these things at once instead of one after another. However, it's really just the same messy process you go through to understand natural language on the fly, while you're listening to it or reading it. You don't wait until the end of a chapter to figure out what the first sentence meant. Consider the correspondences listed in Table 16-1.

Table 16-1. Corresponding terms in computer languages and natural languages

Computer Language	Natural Language
Character	Letter
Token	Morpheme
Term	Word
Expression	Phrase
Statement	Sentence
Block	Paragraph
File	Chapter
Program	Story

Assuming the parse goes well, the compiler deems your input a valid story, er, program. If you use the *–c* switch when running your program, it prints out a "syntax OK" message and exits. Otherwise, the compiler passes the fruits of its efforts on to other agents. These "fruits" come in the form of a *parse tree*. Each fruit on the tree—or *node*, as it's called—represents one of Perl's internal *opcodes*, and the branches on the tree represent that tree's historical growth pattern. Eventually, the nodes will be strung together linearly, one after another, to indicate the execution order in which the runtime system will visit those nodes.

Each opcode is the smallest unit of executable instruction that Perl can think about. You might see an expression like `$a = -($b + $c)` as one statement, but

Perl thinks of it as six separate opcodes. Laid out in a simplified format, the parse tree for that expression would look like Figure 16-2. The numbers represent the visitation order that the Perl runtime system will eventually follow.

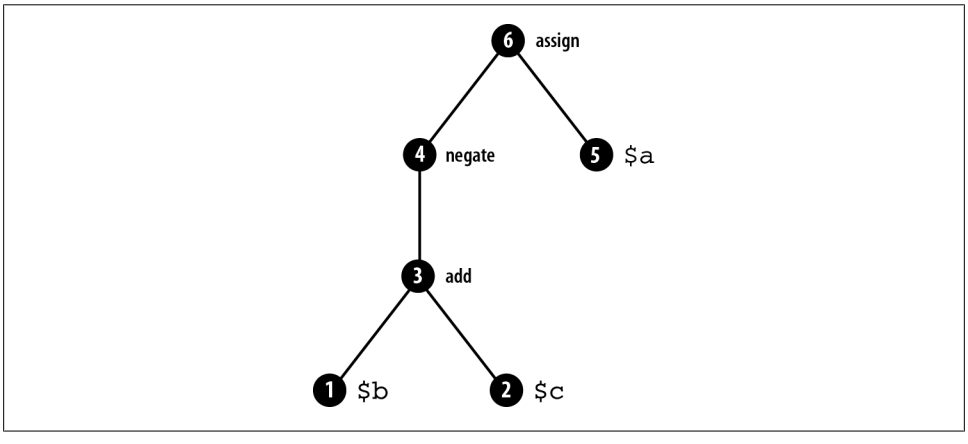


Figure 16-2. Opcode visitation order of $a = -($b + $c)

Perl isn't a one-pass compiler as some might imagine. (One-pass compilers are great at making things easy for the computer and hard for the programmer.) It's really a multipass, optimizing compiler consisting of at least three different logical passes that are interleaved in practice. Passes 1 and 2 run alternately as the compiler repeatedly scurries up and down the parse tree during its construction; pass 3 happens whenever a subroutine or file is completely parsed. Here are those passes:

Pass 1: Bottom-up Parsing

During this pass, the parse tree is built up by the *yacc*(1) parser using the tokens it's fed from the underlying lexer (which could be considered another logical pass in its own right). Bottom-up just means that the parser knows about the leaves of the tree before it knows about its branches and root. It really does figure things out from bottom to top in Figure 16-2, since we drew the root at the top, in the idiosyncratic fashion of computer scientists (and linguists).

As each opcode node is constructed, per-opcode sanity checks verify correct semantics, such as the correct number and types of arguments used to call built-in functions. As each subsection of the tree takes shape, the optimizer considers what transformations it can apply to the entire subtree now beneath it. For instance, once it knows that a list of values is being fed to a function that takes a specific number of arguments, it can throw away the

opcode that records the number of arguments for functions that take a varying number of arguments. A more important optimization, known as *constant folding*, is described later in this section.

This pass also constructs the node visitation order used later for execution, which is a really neat trick because the first place to visit is almost never the top node. The compiler makes a temporary loop of opcodes, with the top node pointing to the first opcode to visit. When the top-level opcode is incorporated into something bigger, that loop of opcodes is broken, only to make a bigger loop with the new top node. Eventually the loop is broken for good when the start opcode gets poked into some other structure such as a subroutine descriptor. The subroutine caller can still find that first opcode despite its being way down at the bottom of the tree, as it is in Figure 16-2. There's no need for the interpreter to recurse back down the parse tree to figure out where to start.

Pass 2: Top-down Optimizer

A person reading a snippet of Perl code (or of English code, for that matter) cannot determine the context without examining the surrounding lexical elements. Sometimes you can't decide what's really going on until you have more information. Don't feel bad, though, because you're not alone: neither can the compiler. In this pass, the compiler descends back down the subtree it's just built to apply local optimizations, the most notable of which is *context propagation*. The compiler marks subjacent nodes with the appropriate contexts (void, scalar, list, reference, or lvalue) imposed by the current node. Unwanted opcodes are nulled out but not deleted, because it's now too late to reconstruct the execution order. We'll rely on the third pass to remove them from the provisional execution order determined by the first pass.

Pass 3: Peephole Optimizer

Certain units of code have their own storage space in which they keep lexically scoped variables. (Such a space is called a *scratchpad* in Perl lingo.) These units include `eval` *`STRING`*s, subroutines, and entire files. More importantly from the standpoint of the optimizer, they each have their own entry point, which means that while we know the execution order from here on, we can't know what happened before because the construct could have been called from anywhere. So when one of these units is done being parsed, Perl runs a peephole optimizer on that code. Unlike the previous two passes, which walked the branch structure of the parse tree, this pass traverses the code in linear execution order, since this is basically the last opportunity to

do so before we cut the opcode list off from the parser. Most optimizations were already performed in the first two passes, but some can't be.

Assorted late-term optimizations happen here, including stitching together the final execution order by skipping over nulled out opcodes, and recognizing when various opcode juxtapositions can be reduced to something simpler. The recognition of chained string concatenations is one important optimization, since you'd really like to avoid copying a string back and forth each time you add a little bit to the end. This pass doesn't just optimize; it also does a great deal of "real" work: trapping barewords, generating warnings on questionable constructs, checking for code unlikely to be reached, resolving pseudohash keys, and looking for subroutines called before their prototypes had been compiled.

Pass 4: Code Generation

This pass is optional; it isn't used in the normal scheme of things. But if any of the three code generators—`B::Bytecode`, `B::C`, and `B::CC`—are invoked, the parse tree is accessed one final time. The code generators emit either serialized Perl bytecodes used to reconstruct the parse tree later or literal C code representing the state of the compile-time parse tree.

Generation of C code comes in two different flavors. `B::C` simply reconstructs the parse tree and runs it using the usual `runops` loop that Perl itself uses during execution. `B::CC` produces a linearized and optimized C equivalent of the runtime code path (which resembles a giant jump table) and executes that instead.

During compilation, Perl optimizes your code in many, many ways. It rearranges code to make it more efficient at execution time. It deletes code that can never be reached during execution, like an `if (0)` block, or the `elsif`s and the `else` in an `if (1)` block. If you use lexically typed variables declared with `my ClassName $var` or `our ClassName $var`, and the `ClassName` package was set up with the `fields` pragma, accesses to constant fields from the underlying pseudohash are typo-checked at compile time and converted into array accesses instead. If you supply the `sort` operator with a simple enough comparison routine, such as `{$a <=> $b}` or `{$b cmp $a}`, this is replaced by a call to compiled C code.

Perl's most dramatic optimization is probably the way it resolves constant expressions as soon as possible. For example, consider the parse tree shown in Figure 16-2. If nodes 1 and 2 had both been literals or constant functions, nodes 1 through 4 would have been replaced by the result of that computation, which would look something like Figure 16-3.

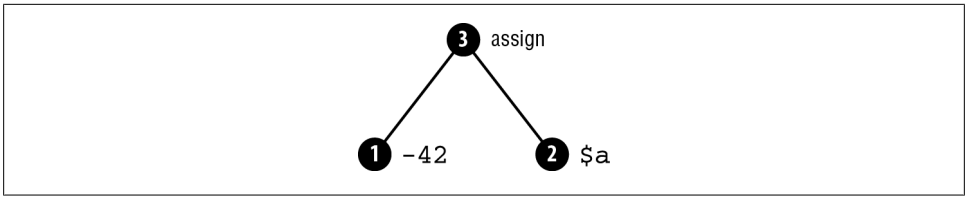


Figure 16-3. Constant folding

This is called *constant folding*. Constant folding isn't limited to simple cases such as turning `2**10` into `1024` at compile time. It also resolves function calls—both built-ins and user-declared subroutines that meet the criteria from the section "Inlining Constant Functions" in Chapter 7. Reminiscent of FORTRAN compilers' notorious knowledge of their own intrinsic functions, Perl also knows which of its own built-ins to call during compilation. That's why if you try to take the `log` of `0.0` or the `sqrt` of a negative constant, you'll incur a compilation error, not a runtime error, and the interpreter is never run at all.[4] Even arbitrarily complicated expressions are resolved early, sometimes triggering the deletion of complete blocks such as the one here:

```
if (2 * sin(1)/cos(1) < 3 && somefn()) { whatever() }
```

No code is generated for what can never be evaluated. Because the first part is always false, neither `somefn` nor `whatever` can ever be called. (So don't expect to `goto` labels inside that block, because it won't even exist at runtime.) If `somefn` were an inlinable constant function, then even switching the evaluation order like this:

```
if (somefn() && 2 * sin(1)/cos(1) < 3) { whatever() }
```

wouldn't change the outcome, since the entire expression still resolves at compile time. If `whatever` were inlinable, it wouldn't be called at runtime, nor even during compilation; its value would just be inserted as though it were a literal constant. You would then incur a warning about a "Useless use of a constant in void context". This might surprise you if you didn't realize it was a constant. However, if `whatever` were the last statement evaluated in a function called in a nonvoid context (as determined by the optimizer), you wouldn't see the warning.

You can see the final result of the constructed parse tree after all optimization stages with *perl –Dx*. (The *–D* switch requires a special debugging-enabled build of Perl). Also see the `B::Deparse` module in the section "Code Development Tools" on page 567.

4. Actually, we're oversimplifying here. The interpreter does get run, because that's how the constant folder is implemented. But it is run immediately at compile time, similar to how `BEGIN` blocks are executed.

All in all, the Perl compiler works hard (but not *too* hard) to optimize code so that, come runtime, overall execution is sped up. It's about time to get your program running, so let's do that now.

Executing Your Code

To the first approximation, SPARC programs only run on SPARC machines, Intel programs only run on Intel machines, and Perl programs only run on Perl machines. A Perl machine possesses those attributes that a Perl program would find ideal in a computer: memory that is automatically allocated and deallocated; fundamental data types that are dynamic strings, arrays, and hashes, and have no size limits; and systems that all behave pretty much the same way. The job of the Perl interpreter is to make whatever computer it happens to be running on appear to be one of these idealistic Perl machines.

This fictitious machine presents the illusion of a computer specially designed to do nothing but run Perl programs. Each opcode produced by the compiler is a fundamental command in this emulated instruction set. Instead of a hardware program counter, the interpreter just keeps track of the current opcode to execute. Instead of a hardware stack pointer, the interpreter has its own virtual stack. This stack is very important because the Perl virtual machine (which we refuse to call a PVM) is a stack-based machine. Perl opcodes are internally called *PP codes* (short for "push-pop codes") because they manipulate the interpreter's virtual stack to find all operands, process temporary values, and store all results.

If you've ever programmed in Forth or PostScript, or used an HP scientific calculator with RPN ("Reverse Polish Notation") entry, you know how a stack machine works. Even if you haven't, the concept is simple: to add 3 and 4, you do things in the order `3 4 +` instead of the more conventional `3 + 4`. What this means in terms of the stack is that you push `3` and then `4` onto the stack, and `+` then pops both arguments off the stack, adds them, and pushes `7` back onto the stack, where it will sit until you do something else with it.

Compared with the Perl compiler, the Perl interpreter is a straightforward, almost boring program. All it does is step through the compiled opcodes, one at a time, and dispatch them to the Perl runtime environment—that is, the Perl virtual machine. It's just a wad of C code, right?

Actually, it's not boring at all. A Perl virtual machine keeps track of a great deal of dynamic context on your behalf so that you don't have to. Perl maintains quite a few stacks, which you don't have to understand, but which we'll list here anyway just to impress you:

operand stack
: That's the stack we already talked about.

save stack
: Where localized values are saved pending restoration. Many internal routines also localize values without your knowing it.

scope stack
: The lightweight dynamic context that controls when the save stack should be "popped".

context stack
: The heavyweight dynamic context; who called whom to get where you are now. The `caller` function traverses this stack. Loop-control functions scan this stack to find out which loop to control. When you peel back the context stack, the scope stack gets peeled back appropriately, which restores all your local variables from the save stack, even if you left the earlier context by nefarious methods such as raising an exception and *longjmp*(3)ing out.

jumpenv stack
: The stack of *longjmp*(3) contexts that allows us to raise exceptions or exit expeditiously.

return stack
: Where we came from when we entered this subroutine.

mark stack
: Where the current variadic argument list on the operand stack starts.

recursive lexical pad stacks
: Where the lexical variables and other "scratch register" storage is kept when subroutines are called recursively.

And, of course, there's the C stack on which all the C variables are stored. Perl actually tries to avoid relying on C's stack for the storage of saved values, since *longjmp*(3) bypasses the proper restoration of such values.

All this is to say that the usual view of an interpreter, a program that interprets another program, is really woefully inadequate to describe what's going on here. Yes, there's some C code implementing some opcodes, but when we say "interpreter", we mean something more than that, in the same way that when we say "musician", we mean something more than a set of DNA instructions for turning notes into sounds. Musicians are real, live organisms and have "state". So do interpreters.

Specifically, all this dynamic and lexical context, along with the global symbol tables, plus the parse trees, plus a thread of execution, is what we call an interpreter. As a context for execution, an interpreter really starts its existence even before the compiler starts, and it can run in rudimentary form even as the compiler is building up the interpreter's context. In fact, that's precisely what's happening when the compiler calls into the interpreter to execute `BEGIN` blocks and such. And the interpreter can turn around and use the compiler to build itself up further. Every time you define another subroutine or load another module, the particular virtual Perl machine that we call an interpreter is redefining itself. You can't really say that either the compiler or the interpreter is in control, because they're cooperating to control the bootstrap process we commonly call "running a Perl script". It's like bootstrapping a child's brain. Is it the DNA doing it or is it the neurons? A little of both, we think, with some input from external programmers.

It's possible to run multiple interpreters in the same process; they may or may not share parse trees, depending on whether they were started by cloning an existing interpreter or by building a new interpreter from scratch. It's also possible to run multiple threads in a single interpreter, in which case they share not only parse trees but also global symbols.

But most Perl programs use only a single Perl interpreter to execute their compiled code. And while you can run multiple, independent Perl interpreters within one process, the current API for this is only accessible from C. Each individual Perl interpreter serves the role of a completely separate process, but doesn't cost as much to create as a whole new process does. That's how Apache's `mod_perl` extension gets such great performance: when you launch a CGI script under `mod_perl`, that script has already been compiled into Perl opcodes, eliminating the need for recompilation—but, more importantly, eliminating the need to start a new process, which is the real bottleneck. Apache initializes a new Perl interpreter in an existing process and hands that interpreter the previously compiled code to execute. Of course, there's much more to it than that—there always is.

Many other applications such as *nvi*, *vim*, and *innd* can embed Perl interpreters; we can't hope to list them all here. There are a number of commercial products that don't even advertise that they have embedded Perl engines. They just use it internally because it gets their job done in style.

Compiler Backends

So if Apache can compile a Perl program now and execute it later, why can't you? Apache and other programs that contain embedded Perl interpreters have it easy

—they never store the parse tree to an external file. If you're content with that approach, and don't mind using the C API to get at it, you can do the same thing.

If you don't want to go that route, or have other needs, then there are a few options available. Instead of feeding the opcode output from the Perl compiler immediately into a Perl interpreter, you can invoke any of several alternative backends instead. These backends can serialize and store the compiled opcodes to an external file or even convert them into a couple different flavors of C code.

Please be aware that the code generators are all extremely experimental utilities that shouldn't be expected to work in a production environment. In fact, they shouldn't even be expected to work in a nonproduction environment except maybe once in a blue moon. Now that we've set your expectations low enough that any success at all will necessarily surpass them, it's safe to tell you how the backends work.

Some of the backend modules are code generators, like `B::Bytecode`, `B::C`, and `B::CC`. Others are really code-analysis and debugging tools, like `B::Deparse`, `B::Lint`, and `B::Xref`. Beyond those backends, the standard release includes several other low-level modules of potential interest to would-be authors of Perl code-development tools. Other backend modules can be found on CPAN, including (as of this writing) `B::Fathom`, `B::Graph`, and `B::Size`.

When you're using the Perl compiler for anything other than feeding the interpreter, the `O` module (that is, using the *O.pm* file) stands between the compiler and assorted backend modules. You don't call the backends directly; instead, you call the middle end, which in turn calls the designated backend. So if you had a module called `B::Backend`, you would invoke it on a given script this way:

```
% perl -MO=Backend SCRIPTNAME
```

Some backends take options, specified as:

```
% perl -MO=Backend,OPTS SCRIPTNAME
```

Some backends already have their own frontends to invoke their middle ends for you so you don't have to remember their M.O. In particular, *perlcc*(1) invokes that code generator, which can be cumbersome to fire up.

Code Generators

The three current backends that convert Perl opcodes into some other format are all emphatically experimental. (Yes, we said this before, but we don't want you to forget.) Even when they happen to produce output that runs correctly, the resulting programs may take more disk space, more memory, and more CPU

time than they would ordinarily. This is an area of ongoing research and development. Things will get better.

The Bytecode Generator

The `B::Bytecode` module writes the parse tree's opcodes out in a platform-independent encoding. You can take a Perl script compiled down to bytecodes and copy that to any other machine with Perl installed on it.

The standard but currently experimental *perlcc*(1) command knows how to convert Perl source code into a byte-compiled Perl program. All you have to do is:

```
% perlcc -B -o pbyscript srcscript
```

And now you should be able to directly "execute" the resulting *pbyscript*. The start of that file looks somewhat like this:

```
#!/usr/bin/perl
use ByteLoader 0.03;
^C^@^E^A^C^@^@^@^A^F^@^C^@^@^@^B^F^@^C^@^@^@^C^F^@^C^@^@^@
B^@^@^@^H9^A8M-^?M-^?M-^?M-^?7M-^?M-^?M-^?M-^?6^@^@^@^A6^@
^G^D^D^@^@^@^KR^@^@^@^HS^@^@^@^HV^@M-2<W^FU^@^@^@^@X^Y@Z^@
...
```

There you find a small script header followed by purely binary data. This may seem like deep magic, but its dweomer, er, dwimmer is at most a minor one. The `ByteLoader` module uses a technique called a *source filter* to alter the source code before Perl gets a chance to see it. A source filter is a kind of preprocessor that applies to everything below it in the current file. Instead of being limited to simplistic transformations the way macro processors like *cpp*(1) and *m4*(1) are, here there are no constraints. Source filters have been used to augment Perl's syntax, to compress or encrypt source code, even to write Perl programs in Latin. E perlibus unicode; cogito, ergo substr; carp dbm, et al. Er, caveat scriptor.

The `ByteLoader` module is a source filter that knows how to disassemble the serialized opcodes produced by `B::Bytecode` to reconstruct the original parse tree. The reconstituted Perl code is spliced into the current parse tree without using the compiler. When the interpreter hits those opcodes, it just executes them as though they'd been there waiting for it all along.

The C Code Generators

The remaining code generators, `B::C` and `B::CC`, both produce C code instead of serialized Perl opcodes. The code they generate is far from readable, and if you try to read it you'll just go blind. It's not something you can use to plug little translated Perl-to-C bits into a larger C program.

The B::C module just writes out the C data structures needed to recreate the entire Perl runtime environment. You get a dedicated interpreter with all the compiler-built data structures preinitialized. In some senses, the code generated is like what B::Bytecode produces. Both are a straight translation of the opcode trees that the compiler built, but where B::Bytecode lays them out in symbolic form to be recreated later and plugged into a running Perl interpreter, B::C lays those opcodes down in C. When you compile this C code with your C compiler and link in the Perl library, the resulting program won't need a Perl interpreter installed on the target system. (It might need some shared libraries, though, if you didn't link everything statically.) However, this program isn't really any different than the regular Perl interpreter that runs your script. It's just precompiled into a standalone executable image.

The B::CC module, however, tries to do more than that. The beginning of the C source file it generates looks pretty much like what B::C produced[5] but, eventually, any similarity ends. In the B::C code, you have a big opcode table in C that's manipulated just as the interpreter would do on its own, whereas the C code generated by B::CC is laid out in the order corresponding to the runtime flow of your program. It even has a C function corresponding to each function in your program. Some amount of optimization based on variable types is done; a few benchmarks can run twice as fast as in the standard interpreter. This is the most ambitious of the current code generators, the one that holds the greatest promise for the future. By no coincidence, it is also the least stable of the three.

Computer science students looking for graduate thesis projects need look no further. There are plenty of diamonds in the rough waiting to be polished off here.

Code Development Tools

The O module has many interesting Modi Operandi beyond feeding the exasperatingly experimental code generators. By providing relatively painless access to the Perl compiler's output, this module makes it easy to build other tools that need to know everything about a Perl program.

The B::Lint module is named after *lint*(1), the C program verifier. It inspects programs for questionable constructs that often trip up beginners but don't normally trigger warnings. Call the module directly:

```
% perl -MO=Lint,all myprog
```

5. But, then, so does everything once you've gone blind. Didn't we warn you not to peek?

Only a few checks are currently defined, such as using an array in an implicit scalar context, relying on default variables, and accessing another package's (nominally private) identifiers that start with _. See *B::Lint*(3) for details. You'll probably find that most Perlers who lint their programs use `Perl::Critic` instead. It's a static analysis tool built on top of `PPI`, and it does a pretty good job.

The `B::Xref` module generates cross-reference listings of the declaration and use of all variables (both global and lexically scoped), subroutines, and formats in a program, broken down by file and subroutine. Call the module this way:

```
% perl -MO=Xref myprog  > myprog.pxref
```

For instance, here's a partial report:

```
Subroutine parse_argv
  Package (lexical)
    $on               i113, 114
    $opt              i113, 114
    %getopt_cfg       i107, 113
    @cfg_args         i112, 114, 116, 116
  Package Getopt::Long
    $ignorecase       101
    &GetOptions       &124
  Package main
    $Options          123, 124, 141, 150, 165, 169
    %$Options         141, 150, 165, 169
    &check_read       &167
    @ARGV             121, 157, 157, 162, 166, 166
```

This shows that the `parse_argv` subroutine had four lexical variables of its own; it also accessed global identifiers from both the `main` package and from `Getopt::Long`. The numbers are the lines where that item was used: a leading `i` indicates that the item was first introduced at the following line number, and a leading `&` means a subroutine was called there. Dereferences are listed separately, which is why both `$Options` and `%$Options` are shown.

The `B::Deparse` is a pretty printer that can demystify Perl code and help you understand what transformations the optimizer has taken with your code. For example, this shows what defaults Perl uses for various constructs:

```
% perl -MO=Deparse -ne 'for (1 .. 10) { print if -t }'
LINE: while (defined($_ = <ARGV>)) {
    foreach $_ (1 .. 10) {
        print $_ if -t STDIN;
    }
}
```

The *–p* switch adds parentheses so you can see Perl's idea of precedence:

```
% perl -MO=Deparse,-p -e 'print $a ** 3 + sqrt(2) / 10 ** -2 ** $c'
print((($a ** 3) + (1.4142135623731 / (10 ** (-(2 ** $c))))));
```

You can use *–q* to see what primitives interpolated strings are compiled into:

```
% perl -MO=Deparse,-q -e '"A $name and some @ARGV\n"'
'A ' . $name . ' and some ' . join($", @ARGV) . "\n";
```

And this shows how Perl really compiles a three-part `for` loop into a `while` loop:

```
% perl -MO=Deparse -e 'for ($i=0;$i<10;$i++) { $x++ }'
$i = 0;
while ($i< 10) {
    ++$x;
}
continue {
    ++$i
}
```

You could even call `B::Deparse` on a Perl bytecode file produced by *perlcc –b*, and have it decompile that binary file for you. Serialized Perl opcodes may be a tad tough to read, but strong encryption they are not.

Avant-Garde Compiler, Retro Interpreter

There's a right time to think about everything; sometimes that time is beforehand, and sometimes it's after. Sometimes it's somewhere in the middle. Perl doesn't presume to know when it's the right time to think, so it gives the programmer a number of options for telling it when to think. Other times it knows that some sort of thinking is necessary but doesn't have any idea what it ought to think, so it needs ways of asking your program. Your program answers these kinds of questions by defining subroutines with names appropriate to what Perl is trying to find out.

Not only can the compiler call into the interpreter when it wants to be forward thinking, but the interpreter can also call back to the compiler when it wants to revise history. Your program can use several operators to call back into the compiler. Like the compiler, the interpreter can also call into named subroutines when it wants to find things out. Because of all this give and take between the compiler, the interpreter, and your program, you need to be aware of what things happen when. First we'll talk about when these named subroutines are triggered.

In Chapter 10 we saw how a package's `AUTOLOAD` subroutine is triggered when an undefined function in that package is called. In Chapter 12 we met the `DESTROY` method, which is invoked when an object's memory is about to be automatically reclaimed by Perl. And in Chapter 14 we encountered the many functions implicitly called when a tied variable is accessed.

These subroutines all follow the convention that if a subroutine is triggered automatically by either the compiler or the interpreter, we write its name in uppercase. Associated with the different stages of your program's lifetime are four other such subroutines named `BEGIN`, `UNITCHECK`, `CHECK`, `INIT`, and `END`. The `sub` keyword is optional before their declarations. Perhaps they are better called "blocks", because they're in some ways more like named blocks than real subroutines.

For instance, unlike regular subroutines, there's no harm in declaring these blocks multiple times, since Perl keeps track of when to call them, so you never have to call them by name. (They are also unlike regular subroutines in that `shift` and `pop` act as though you were in the main program, and so they act on `@ARGV` by default, not `@_`.)

These five block types run in this order:

`BEGIN`
: Runs ASAP (as soon as parsed) whenever encountered during compilation, before compiling the rest of the file.

`UNITCHECK`
: Runs just after the unit that defined them has been compiled. The main program file and each module it loads are compilation units, as are string `eval`s, code compiled using the `(?{ })` and `(??{ })` constructs in a regex, calls to `do` *`FILE`* and `require` *`FILE`*, and code after the *–e* switch on the command line. This rather than `INIT` is what you want to use to run initialization code.

`CHECK`
: Runs when compilation is complete but before the program starts. (`CHECK` can mean "checkpoint" or "double-check" or even just "stop".)

`INIT`
: Runs at the beginning of execution right before the main flow of your program starts.

`END`
: Runs at the end of execution right after the program finishes.

If you declare more than one of these by the same name, even in separate modules, the `BEGIN`s all run before any `CHECK`s, which all run before any `INIT`s, which all run before any `END`s—which all run dead last, after your main program has finished. Multiple `BEGIN`s and `INIT`s run in declaration order (FIFO), and the `CHECK`s and `END`s run in inverse declaration order (LIFO).

This is probably easiest to see in a demo:

```
use v5.10;
say         "start main running here";
die         "main now dying here\n";
die         "XXX: not reached\n";
UNITCHECK   { say "1st UNITCHECK: done compiling" }
END         { say "1st END: done running"         }
CHECK       { say "1st CHECK: done compiling"     }
INIT        { say "1st INIT: started running"     }
END         { say "2nd END: done running"         }
BEGIN       { say "1st BEGIN: still compiling"    }
INIT        { say "2nd INIT: started running"     }
BEGIN       { say "2nd BEGIN: still compiling"    }
CHECK       { say "2nd CHECK: done compiling"     }
END         { say "3rd END: done running"         }
```

When run, that demo program produces this output:

```
1st BEGIN: still compiling
2nd BEGIN: still compiling
1st UNITCHECK: done compiling
2nd CHECK: done compiling
1st CHECK: done compiling
1st INIT: started running
2nd INIT: started running
start main running here
main now dying here
3rd END: done running
2nd END: done running
1st END: done running
```

Because a `BEGIN` block executes immediately, it can pull in subroutine declarations, definitions, and importations before the rest of the file is even compiled. These can alter how the compiler parses the rest of the current file, particularly if you import subroutine definitions. At the very least, declaring a subroutine lets it be used as a list operator, making parentheses optional. If the imported subroutine is declared with a prototype, calls to it can be parsed like built-ins and can even override built-ins of the same name in order to give them different semantics. The `use` declaration is just a `BEGIN` block with an attitude.

`END` blocks, by contrast, are executed as *late* as possible: when your program exits the Perl interpreter, even if as a result of an untrapped `die` or other fatal exception. There are two situations in which an `END` block (or a `DESTROY` method) is skipped. It isn't run if, instead of exiting, the current process just morphs itself from one program to another via `exec`. A process blown out of the water by an uncaught signal also skips its `END` routines. (See the `sigtrap` pragma described in Chapter 29 for an easy way to convert catchable signals into exceptions. For general information on signal handling, see "Signals" on page 518 in Chapter 15.) To avoid

all END processing, you can call POSIX::_exit, say *kill –9, $$*, or just exec any innocuous program, such as */bin/true* on Unix systems.

Inside an END block, $? contains the status the program is going to exit with. You can modify $? from within the END block to change the exit value of the program. Beware of changing $? accidentally by running another program with system or backticks.

If you have several END blocks within a file, they execute in *reverse* order of their definition. That is, the last END block defined is the first one executed when your program finishes. This reversal enables related BEGIN and END blocks to nest the way you'd expect, if you pair them up. For example, if the main program and a module it loads both have their own paired BEGIN and END subroutines, like so:

```
BEGIN { print "main begun" }
END { print "main ended" }
use Module;
```

and in that module, these declarations:

```
BEGIN { print "module begun" }
END { print "module ended" }
```

then the main program knows that its BEGIN will always happen first, and its END will always happen last. (Yes, BEGIN is really a compile-time block, but similar arguments apply to paired INIT and END blocks at runtime.) This principle is recursively true for any file that includes another when both have declarations like these. This nesting property makes these blocks work well as package constructors and destructors. Each module can have its own set-up and tear-down functions that Perl will call automatically. This way the programmer doesn't have to remember that if a particular library is used, what special initialization or clean-up code ought to be invoked, and when. The module's declarations assure these events.

If you think of an eval *STRING* as a call *back* from the interpreter to the compiler, then you might think of a BEGIN as a call *forward* from the compiler into the interpreter. Both temporarily put the current activity on hold and switch modes of operation. When we say that a BEGIN block is executed as early as possible, we mean it's executed just as soon as it is completely defined, even before the rest of the containing file is parsed. BEGIN blocks are therefore executed during compile time, never during runtime. Once a BEGIN block has run, it is immediately undefined and any code it used is returned to Perl's memory pool. You couldn't call a BEGIN block as a subroutine even if you tried, because by the time it's there, it's already gone.

Similar to `BEGIN` blocks, `INIT` blocks are run just before the Perl runtime begins execution in "first in, first out" (FIFO) order. For example, the code generators documented in *perlcc* make use of `INIT` blocks to initialize and resolve pointers to XSUBs. `INIT` blocks are really just like `BEGIN` blocks, except they let the programmer distinguish construction that must happen at compile phase from construction that must happen at run phase. When you're running a script directly, that's not terribly important because the compiler gets invoked every time anyway; but when compilation is separate from execution, the distinction can be crucial. The compiler may be invoked only once, and the resulting executable may be invoked many times.

Similar to `END` blocks, `CHECK` blocks are run just after the Perl compile phase ends but before run phase begins, in LIFO order. `CHECK` blocks are useful for "winding down" the compiler just as `END` blocks are useful for winding down your program. In particular, the backends all use `CHECK` blocks as the hook from which to invoke their respective code generators. All they need to do is put a `CHECK` block into their own module, and it will run at the right time, so you don't have to install a `CHECK` into your program. For this reason, you'll rarely write a `CHECK` block yourself, unless you're writing such a module.

Putting it all together, Table 16-2 lists various constructs with details on when they compile and when they run the code represented by "...".

Table 16-2. What happens when

Block or Expression	Compiles During Phase	Traps Compile Errors	Runs During Phase	Traps Run Errors	Call Trigger Policy
`use ...`	C	No	C	No	Now
`no ...`	C	No	C	No	Now
`BEGIN {...}`	C	No	C	No	Now
`UNITCHECK {...}`	C	No	C	No	Late
`CHECK {...}`	C	No	C	No	Late
`INIT {...}`	C	No	R	No	Early
`END {...}`	C	No	R	No	Late
`eval {...}`	C	No	R	Yes	Inline
`eval "..."`	R	Yes	R	Yes	Inline
`foo(...)`	C	No	R	No	Inline
`sub foo {...}`	C	No	R	No	Call anytime
`eval "sub {...}"`	R	Yes	R	No	Call later
`s/pat/.../e`	C	No	R	No	Inline
`s/pat/"..."/ee`	R	Yes	R	Yes	Inline

Now that you know the score, we hope you'll be able to compose and perform your Perl pieces with greater confidence.

CHAPTER 17

The Command-Line Interface

This chapter is about aiming Perl in the right direction before you fire it off. There are various ways to aim Perl, but the two primary ways are through switches on the command line and through environment variables. Switches are the more immediate and precise way to aim a particular command. Environment variables are more often used to set general policy.

Command Processing

It is fortunate that Perl grew up in the Unix world, because that means its invocation syntax works pretty well under the command interpreters of other operating systems, too. Most command interpreters know how to deal with a list of words as arguments and don't care if an argument starts with a minus sign. There are, of course, some sticky spots where you'll get fouled up if you move from one system to another. You can't use single quotes under MS-DOS as you do under Unix, for instance. And on systems like VMS, some wrapper code has to jump through hoops to emulate Unix I/O redirection. Wildcard interpretation is a wildcard. Once you get past those issues, however, Perl treats its switches and arguments much the same on any operating system.

Even when you don't have a command interpreter per se, it's easy to execute a Perl program from another program written in any language. Not only can the calling program pass arguments in the ordinary way, it can also pass information via environment variables and, if your operating system supports them, inherited file descriptors (see "Passing Filehandles" in Chapter 15). Even exotic argument-passing mechanisms can easily be encapsulated in a module, then brought into your Perl program via a simple `use` directive.

Perl parses command-line switches in the standard fashion.[1] That is, it expects any switches (words beginning with a minus) to come first on the command line. After that usually comes the name of the script, followed by any additional arguments to be passed into the script. Some of these additional arguments may themselves look like switches, but if so, they must be processed by the script, because Perl quits parsing switches once it sees a nonswitch, or the special "--" switch that says, "I am the last switch."

Perl gives you some flexibility in where you place the source code for your program. For small, quick-and-dirty jobs, you can program Perl entirely from the command line. For larger, more permanent jobs, you can supply a Perl script as a separate file. Perl looks for a script to compile and run in any one of these three ways:

1. Specified line by line via *–e* or *–E* switches on the command line. For example:

```
% perl -e "print 'Hello, World.'"
Hello, World.

% perl -E "say 'Howdy y\\'all!'"
Howdy y'all!
```

2. Contained in the file specified by the first filename on the command line. Systems supporting the `#!` notation on the first line of an executable script invoke interpreters this way on your behalf.
3. Passed in implicitly via standard input. This method works only when there are no filename arguments; to pass arguments to a standard-input script you must use method 2, explicitly specifying a "–" for the script name. For example:

```
% echo "print qq(Hello, @ARGV.)" | perl - World
Hello, World.
```

With methods 2 and 3, Perl starts parsing the input file from the beginning—unless you've specified a *–x* switch, in which case it scans for the first line starting with `#!` and containing the word "`perl`", and starts there instead. This is useful for running a script embedded in a larger message. If so, you might indicate the end of the script using the `__END__` token.

Whether or not you use *–x*, the `#!` line is always examined for switches when the line is parsed. That way, if you're on a platform that permits only one argument with the `#!` line, or worse, doesn't even recognize the `#!` line as special, you can

1. Presuming you agree that Unix is both standard and fashionable.

still get consistent switch behavior no matter how Perl was invoked, even if *–x* was used to find the beginning of the script.

Warning: because older versions of Unix silently chop off kernel interpretation of the `#!` line after 32 characters, some switches may get to your program intact, and others not; you could even get a "–" without its letter, if you're not careful. You probably want to make sure that all your switches fall either before or after that 32-character boundary. Most switches don't care whether they're processed redundantly, but getting a "–" instead of a complete switch would cause Perl to try to read its source code from the standard input instead of from your script. And a partial *–I* switch could also cause odd results. However, some switches do care if they are processed twice, like combinations of *–l* and *–0*. Either put all switches after the 32-character boundary (if applicable), or replace the use of *–0DIGITS* with `BEGIN{ $/ = "\0DIGITS"; }`. Of course, if you're not on a Unix system, you're guaranteed not to have this particular problem.

Parsing of `#!` switches starts from where "`perl`" is first mentioned in the line. The sequences "–*" and "– " are specifically ignored for the benefit of *emacs* users so that, if you're so inclined, you can say:

```
#!/bin/sh -- # -*- perl -*- -p
eval 'exec perl -S $0 ${1+"$@"}'
    if 0;
```

and Perl will see only the *–p* switch. The fancy "*–*– *perl –*–*" gizmo tells *emacs* to start up in Perl mode; you don't need it if you don't use *emacs*. The *–S* mess is explained later under the description of that switch.

A similar trick involves the *env*(1) program, if you have it:

```
#!/usr/bin/env perl
```

The previous examples use a relative path to the Perl interpreter, getting whatever version is first in the user's path. If you want a specific version of Perl, say, *perl5.14.0*, place it directly in the `#!` line's path, whether with the *env* program, with the *–S* mess, or with a regular `#!` processing.

If the `#!` line does *not* contain the word "`perl`", the program named after the `#!` is executed instead of the Perl interpreter. For example, suppose you have an ordinary Bourne shell script out there that says:

```
#!/bin/sh
echo "I am a shell script"
```

If you feed that file to Perl, then Perl will run */bin/sh* for you. This is slightly bizarre, but it helps people on machines that don't recognize `#!`, because—by setting their `SHELL` environment variable—they can tell a program (such as a mailer) that

their shell is */usr/bin/perl*. Perl will then dispatch the program to the correct interpreter for them, even though their kernel is too stupid to do so.

But back to Perl scripts that are really Perl scripts. After locating your script, Perl compiles the entire program into an internal form (see Chapter 16). If any compilation errors arise, execution does not even begin. (This is unlike the typical shell script or command file, which might run part-way through before finding a syntax error.) If the script is syntactically correct, it is executed. If the script runs off the end without hitting an `exit` or `die` operator, an implicit `exit(0)` is supplied by Perl to indicate successful completion to your caller. (This is unlike the typical C program, where you're likely to get a random exit status if your program just terminates in the normal way.)

#! and Quoting on Non-Unix Systems

Unix's `#!` technique can be simulated on other systems:

MS-DOS
: Create a batch file to run your program, and codify it in `ALTERNATIVE_SHEBANG`. See the *dosish.h* file in the top level of the Perl source distribution for more information about this.

OS/2
: Put this line:

```
extproc perl -S -your_switches
```

: as the first line in **.cmd* file (*–S* works around a bug in *cmd.exe*'s "`extproc`" handling).

VMS
: Put these lines:

```
% perl -mysw 'f$env("procedure")' 'p1' 'p2' 'p3' 'p4' 'p5' 'p6' 'p7' 'p8' !
$exit++ + ++$status != 0 and $exit = $status = undef;
```

: at the top of your program, where *-mysw* are any command-line switches you want to pass to Perl. You can now invoke the program directly by typing `perl program`, as a DCL procedure by saying `@program`, or implicitly via `DCL $PATH` by using just the name of the program. This incantation is a bit much to remember, but Perl will display it for you if you type in `perl "-V:start perl"`. If you can't remember that—well, that's why you bought this book.

Windows
: When using the ActiveState distribution of Perl under some variant of Microsoft's Windows suite of operating systems (that is, Win95, Win98,

Win00,[2] WinNT, but not Win3.1), the installation procedure for Perl modifies the Windows Registry to associate the *.pl* extension with the Perl interpreter.

If you install another port of Perl, including the one in the Win32 directory of the Perl distribution, then you'll have to modify the Windows Registry yourself.

Note that using a *.pl* extension means you can no longer tell the difference between an executable Perl program and a "perl library" file. You could use *.plx* for a Perl program instead to avoid this. This is less of an issue these days, as Perl modules live in *.pm* files, and people don't write as many `.pl` files.

Command interpreters on non-Unix systems often have extraordinarily different ideas about quoting than Unix shells have. You'll need to learn the special characters in your command interpreter (`*`, `\`, and `"` are common) and how to protect whitespace and these special characters to run one-liners via the *–e* switch. You might also have to change a single `%` to a `%%`, or otherwise escape it, if that's a special character for your shell.

On some systems you may have to change single quotes to double quotes. But don't do that on Unix or Plan9 systems, or on anything running a Unix-style shell, such as systems from the MKS Toolkit or from the Cygwin package produced by the Cygnus folks, now at Redhat. Microsoft's new Unix emulator called Interix is also starting to look, ahem, interixing.

For example, on Unix (including Linux and Mac OS X), use:

```
% perl -e 'print "Hello world\n"'
```

On VMS, use:

```
$ perl -e "print ""Hello world\n"""
```

or again with `qq//`:

```
$ perl -e "print qq(Hello world\n)"
```

And on MS-DOS et al., use:

```
A: perl -e "print \"Hello world\n\""
```

or use `qq//` to pick your own quotes:

```
A: perl -e "print qq(Hello world\n)"
```

The problem is that neither of those is reliable: it depends on the command interpreter you're using there. There is no general solution to all of this. It's just a

2. Er, pardon the technical difficulties...

mess. If you aren't on a Unix system but want to do command-line things, your best bet is to acquire a better command interpreter than the one your vendor supplied you, which shouldn't be too hard.

Or, just write it all in Perl and forget the one-liners.

Location of Perl

Although this may seem obvious, Perl is useful only when users can find it easily. When possible, it's good for both */usr/bin/perl* and */usr/local/bin/perl* to be symlinks to the actual binary. If that can't be done, system administrators are strongly encouraged to put Perl and its accompanying utilities into a directory typically found along a user's standard `PATH`, or in some other obvious and convenient place.

In this book, we use the standard `#!/usr/bin/perl` notation on the first line of the program to mean whatever particular mechanism works on your system. If you care about running a specific version of Perl, use a specific path:

```
#!/usr/local/bin/perl5.14.0
```

If you just want to be running *at least* some version number but don't mind higher ones, place a statement like this near the top of your program:

```
use v5.14;
```

(Note: Ancient versions of Perl used numbers like "`5.005`" or "`5.004_05`". Nowadays we would think of those as v5.5.0 and v5.4.5, but versions of Perl older than v5.6.0 won't understand that notation. The `use 5.`*`NNN`* form is safest to ensure backward compatibility stretching back into the previous millennium.)

Switches

A single-character command-line *switch* without its own argument may always be combined (bundled) with a switch following it.

```
#!/usr/bin/perl -spi.bak    # same as -s -p -i.bak
```

Switches are also known as options or flags. Whatever you call them, here are the ones Perl recognizes:

`--` Terminates switch processing, even if the next argument starts with a minus. It has no other effect.

`-0DIGITS`
: Specifies the input record separator (`$/`) as an octal number or hexadecimal number representing that single character's codepoint. If no digits are

specified, the null character (that's U+0000, Perl's `"\0"`) is the separator. Other switches may precede or follow the digits. For example, if you have a version of *find*(1) that can print filenames terminated by the null character, you can say this to delete a bunch of them:

```
% find . -name '*.bak' -print0 | perl -n0e unlink
```

The special value `00` makes Perl read files in paragraph mode, equivalent to setting the `$/` variable to `""`. Any value `0400` or above `0777` makes Perl slurp in whole files at once, but, by convention, the value `0777` is normally used for this. This is equivalent to undefining the `$/` variable. We use `0777` since there is no ASCII character with that value. (Unfortunately, there *is* a Unicode character with that value, LATIN SMALL LETTER O WITH STROKE AND ACUTE, but something tells us you won't be delimiting your records with that. But if you really want to, just specify its codepoint in hex: *–0x1FF*.)

You can also specify the separator character using hexadecimal notation: *–0xHHH...*, where the "H" are valid hexadecimal digits. Unlike the octal form, this one may be used to specify any Unicode character, even those beyond 0xFF. (This means that you cannot use the *–x* switch with a directory name that consists of hexadecimal digits alone.)

–a Turns on autosplit mode, but only when used with *–n* or *–p*. An implicit `split` command to the `@F` array is done as the first thing inside the implicit `while` loop produced by the *–n* and *–p* switches. So:

```
% perl -ane 'print pop(@F), "\n";'
```

is equivalent to:

```
LINE: while (<>) {
    @F = split(' ');
    print pop(@F), "\n";
}
```

A different field separator may be specified by passing a regular expression for `split` to the *–F* switch. For example, these two calls are equivalent:

```
% awk -F: '$7 && $7 !~ /^\/bin/' /etc/passwd
% perl -F: -lane 'print if $F[6] && $F[6] !~ m(^/bin)' /etc/passwd
```

–c Causes Perl to check the syntax of the script and then exit without executing what it's just compiled. Technically, it does a bit more than that: it will execute any `BEGIN`, `UNITCHECK`, and `CHECK` blocks, as well as any `use` or `no` directives, since these are all considered to occur before the execution of your program. It no longer executes any `INIT` or `END` blocks, however. The older but rarely useful behavior may still be obtained by putting:

```
BEGIN { $^C = 0; exit; }
```

at the end of your main script. That's because the `$^C` variable reflects the value of the *–c* switch.

–C [number/list]

The *–C* flag controls certain of Perl's Unicode features. The *–C* can be followed either by a number or a list of option letters. The letters, their numeric values, and effects are shown in Table 17-1; listing the letters is equal to summing the numbers.

Table 17-1. Values for the -C switch

Letter	Hex Number	Meaning
I	`0x1`	`STDIN` is assumed to be in UTF-8.
O	`0x2`	`STDOUT` will be in UTF-8.
E	`0x4`	`STDERR` will be in UTF-8.
S	`0x7`	I + O + E
i	`0x8`	UTF-8 is the default `PerlIO` layer for input streams.
o	`0x10`	UTF-8 is the default `PerlIO` layer for output streams.
D	`0x18`	i + o
A	`0x20`	The `@ARGV` elements are expected to be strings encoded in UTF-8.
L	`0x40`	Normally the "*IOEioA*" are unconditional; the *L* makes them conditional on the locale environment variables (the `LC_ALL`, `LC_TYPE`, and `LANG`, in order of decreasing precedence)—if the variables indicate UTF-8, then the selected "*IOEioA*" are in effect.
a	`0x100`	Set `${^UTF8CACHE}` to `-1` to run the UTF-8 caching code in debugging mode. Probably meaningless unless you're trying to debug or rewrite Perl's internals.

For example, *–COE* and its numeric equivalent, *–C6*, enable utf8ness on both `STDOUT` and `STDERR`. Repeating letters is just redundant, not cumulative nor toggling.

The *io* options mean that any subsequent `open` (or similar I/O operations) in the current file scope will have the `:utf8` `PerlIO` layer implicitly applied to them; in other words, UTF-8 is expected from any input stream, and UTF-8 is produced to any output stream. This is just the default, with explicit layers in `open` and with `binmode` one can manipulate streams as usual.

–C on its own (not followed by any number or option list), or the empty string `""` for the `PERL_UNICODE` environment variable, has the same effect as

–CSDL. In other words, the standard I/O handles and the default `open` layer are utf8ified *but* only if the locale-related environment variables indicate a UTF-8 locale. This behavior follows the *implicit* UTF-8 behavior of v5.8.0 and should not be used today.

You can use *–C0* (or `"0"` for the `PERL_UNICODE` environment variable) to explicitly disable the above Unicode features.

The magic variable `${^UNICODE}` reflects the numeric value of this setting. This variable is set during Perl startup and is thereafter read-only. If you want runtime effects, either use the `open` pragma or one of the three-argument form of `open` or the two-argument form of `binmode`.

(In releases earlier than v5.8.1, the *–C* switch was a Win32-only switch that enabled the use of Unicode-aware "wide system call" Win32 APIs. This feature was practically unused, so the command-line switch was therefore "recycled".)

Note: since the v5.10.1 release, if the *–C* option is used on the `#!` line, it must be specified on the command line as well. This is because the standard streams are already set up at this point in the execution of the Perl interpreter. You can also use `binmode` to set the encoding of an I/O stream.

–d

–dt Runs the program under the Perl debugger. See Chapter 18. If *t* is specified, it indicates to the debugger that threads will be used in the code being debugged.

–d: MODULE[=ARG1,ARG2]

–dt: MODULE[=ARG1,ARG2]

Runs the program under the control of a debugging, profiling, or tracing module installed as `Devel::`*`MODULE`*. For example, *–d:DProf* executes the program using the `Devel::DProf` profiler. As with the *–M* flag, options may be passed to the `Devel::`*`MODULE`* package where they will be received and interpreted by the `Devel::`*`MODULE`*`::import` routine. Again, like *–M*, use *–d:–MODULE* to call `Devel::`*`MODULE`*`::unimport` instead of import. The comma-separated list of options must follow a = character. If *t* is specified, it indicates to the debugger that threads will be used in the code being debugged.

–D LETTERS

–D NUMBERS

Sets debugging flags. (This only works if debugging is compiled into your version of Perl as described below.) You may specify either a *`NUMBER`* that is the sum of the bits you want or a list of *`LETTERS`*. To see how it executes your

script, for instance, use *–D14* or *–Dslt*. Another useful value is *–D1024* or *–Dx*, which lists your compiled syntax tree. And *–D512* or *–Dr* displays compiled regular expressions. The numeric value is available internally as the special variable `$^D`. Table 17-2 lists the assigned bit values. The numbers below are given in hex to make them easy to read, but you must supply them in decimal if you're using the *–NUMBER* format. We strongly recommend that the letters be used instead.

Table 17-2. -D options

Bit	Letter	Meaning
`0x0400000`	*A*	consistency checks on internal structures ("*A*ll clear?")
`0x2000000`	*B*	dump su*B*routine definitions, including special *B*locks like `BEGIN`
`0x0200000`	*C*	*C*opy-on-write
`0x0000020`	*c*	string–numeric *c*onversions
`0x0008000`	*D*	cleaning up once program's all *D*one
`0x0000100`	*f*	*f*ormat processing
`0x0002000`	*H*	*H*ash dump: usurps `values`
`0x0080000`	*J*	show `s,t,P-debug` on (*i.e.*, don't *J*ump over) opcodes in package `DB::`
`0x0000004`	*l*	*l*oop and context stack processing
`0x1000000`	*M*	trace smart-*M*atch resolution
`0x0000080`	*m*	*m*emory and SV allocation
`0x0000010`	*o*	method and *o*verloading resolution
`0x0000040`	*P*	print *P*rofiling info, source file input state
`0x0000001`	*p*	tokenizing and *p*arsing (with *v*, displays parse stack)
`0x0800000`	*q*	*q*uiet; currently suppresses only the "`EXECUTING`" message
`0x0040000`	*R*	include *R*eference counts of dumped variables (*e.g.*, when using *–Ds*)
`0x0000200`	*r*	*r*egex parsing and execution
`0x0000002`	*s*	*s*tack snapshots (with *v*, displays all stacks)
`0x0020000`	*T*	*T*okenizing
`0x0000008`	*t*	*t*race execution
`0x0001000`	*U*	*U*nofficial, *U*ser hacking (reserved for private, unreleased use)
`0x0000800`	*u*	tainting checks on *u*nsafe external data

Bit	Letter	Meaning
0x0100000	*v*	*v*erbose: use in conjunction with other flags
0x0004000	*X*	scratchpad allocation ("*X*ratchpad")
0x0000400	*x*	syntax-tree dump

These flags all require a Perl executable specially built for debugging. However, because this is not the default, you won't be able to use the *–D* switch at all unless you or your sysadmin built this special debugging version of Perl. See the *INSTALL* file in the Perl source directory for details, but the short story is that you need to pass *–DDEBUGGING* to your C compiler when compiling Perl itself. This flag is automatically set if you include the *–g* option when *Configure* asks you about optimizer and debugger flags.

If you're just trying to get a printout of each line of Perl code as it executes (the way that *sh –x* provides for shell scripts), you can't use Perl's *–D* switch. Instead, do this:

```
# Bourne shell syntax
$ PERLDB_OPTS="NonStop=1 AutoTrace=1 frame=2" perl -dS program

# csh syntax
% (setenv PERLDB_OPTS "NonStop=1 AutoTrace=1 frame=2"; perl -dS program)
```

See Chapter 18 for details and variations.

–e PERLCODE

May be used to enter one or more lines of script. When the *–e* option is given, Perl will not look for the program's filename in the argument list. The *PERLCODE* argument is treated as if it ended with a newline, so multiple *–e* commands may be given to build up a multiline program. (Make sure to use semicolons where you would in a normal program stored in a file.) Just because *–e* supplies a newline on each argument doesn't imply that you must use multiple *–e* switches; if your shell supports multiline quoting like *sh*, *ksh*, or *bash*, you may pass a multiline script as one *–e* argument:

```
$ perl -e 'print "Howdy, ";print "@ARGV!\n";' world
Howdy, world!
```

With *csh* it's probably better to use multiple *–e* switches:

```
% perl -e 'print "Howdy, ";' \
       -e 'print "@ARGV!\n";' world
Howdy, world!
```

Both implicit and explicit newlines count in the line numbering, so the second print is on line 2 of the *–e* script in either case.

–E PERLCODE

Behaves just like *–e*, except it implicitly enables all optional features (in the main compilation unit). As for the v5.14 release, those features are `say`, `state`, `switch`, and `unicode_strings`. See the `feature` pragma in Chapter 29.

–f Disables executing *$Config{sitelib}/sitecustomize.pl* at startup.

Perl can be built so that it by default will try to execute *$Config{sitelib}/sitecustomize.pl* at startup (in a `BEGIN` block). This is a hook that lets the sysadmin customize how Perl behaves. For instance, it can be used to add entries to the `@INC` array to make Perl find modules in nonstandard locations.

Perl actually inserts the following code:

```
BEGIN {
    do {
            local $!;
            -f "$Config{sitelib}/sitecustomize.pl";
    } &&    do "$Config{sitelib}/sitecustomize.pl";
}
```

Since it is an actual `do` (not a `require`), *sitecustomize.pl* doesn't need to return a true value. The code is run in package `main`, in its own lexical scope. However, if the script dies, `$@` will not be set.

The value of `$Config{sitelib}` is also determined in C code and not read from *Config.pm*, which is not loaded.

The code is executed *very* early. For example, any changes made to `@INC` will show up in the output of *perl -V*. Of course, likewise `END` blocks will be executed very late.

To determine at runtime if this capability has been compiled in your Perl, you can check the value of `$Config{usesitecustomize}`:

```
% perl -V:usesitecustomize
usesitecustomize='undef';
```

–F PATTERN

Specifies the pattern to `split` on when autosplitting via the *–a* switch (has no effect otherwise). The pattern may be surrounded by slashes (`//`), double quotes (`""`), or single quotes (`''`). Otherwise, it will be put in single quotes automatically. Remember that to pass quotes through a shell, you'll have to quote your quotes, and how you can do that depends on the shell.

–h Prints a summary of Perl's command-line options.

–i

–i EXTENSION

Specifies that files processed by the `<>` construct are to be edited in place. It does this by renaming the input file, opening the output file by the original name, and selecting that output file as the default for calls to `print`, `printf`, and `write`.[3] The *`EXTENSION`* is used to modify the name of the old file to make a backup copy. If no *`EXTENSION`* is supplied, no backup is made and the current file is overwritten. If the *`EXTENSION`* doesn't contain a `*`, then that string is appended to the end of the current filename. If the *`EXTENSION`* does contain one or more `*` characters, then each `*` is replaced by the filename currently being processed. In Perl terms, you could think of this as:

```
($backup = $extension) =~ s/\*/$file_name/g;
```

This lets you use a prefix for the backup file instead of—or even in addition to—a suffix:

```
% perl -pi'orig_*' -e 's/foo/bar/' xyx     # backup to 'orig_xyx'
```

You can even put backup copies of the original files into another directory (provided that the directory already exists):

```
% perl -pi'old/*.orig' -e 's/foo/bar/' xyx # backup to 'old/xyx.orig'
```

These pairs of one-liners are equivalent:

```
% perl -pi -e 's/foo/bar/' xyx             # overwrite current file
% perl -pi'*' -e 's/foo/bar/' xyx          # overwrite current file

% perl -pi'.orig' -e 's/foo/bar/' xyx      # backup to 'xyx.orig'
% perl -pi'*.orig' -e 's/foo/bar/' xyx     # backup to 'xyx.orig'
```

From the shell, saying:

```
% perl -p -i.orig -e "s/foo/bar/;"
```

is the same as using the program:

```
#!/usr/bin/perl -pi.orig
s/foo/bar/;
```

which is convenient shorthand for the remarkably longer:

```
#!/usr/bin/perl
$extension = '.orig';
LINE: while (<>) {
    if ($ARGV ne $oldargv) {
        if ($extension !~ /\*/) {
            $backup = $ARGV . $extension;
        }
```

3. Technically, this isn't really "in place". It's the same filename but a different physical file.

```
            else {
                ($backup = $extension) =~ s/\*/$ARGV/g;
            }
            unless (rename($ARGV, $backup)) {
                warn "cannot rename $ARGV to $backup: $!\n";
                close ARGV;
                next;
            }
            open(ARGVOUT, ">$ARGV");
            select(ARGVOUT);
            $oldargv = $ARGV;
        }
        s/foo/bar/;
    }
    continue {
        print;  # this prints to original filename
    }
    select(STDOUT);
```

This long code is virtually identical to the simple one-liner with the *–i* switch, except the *–i* form doesn't need to compare `$ARGV` to `$oldargv` to know when the filename has changed. It does, however, use `ARGVOUT` for the selected filehandle and restore the old `STDOUT` as the default output filehandle after the loop. Like the code above, Perl creates the backup file irrespective of whether any output has truly changed. See the description of the `eof` function for examples of how to use `eof` without parentheses to locate the end of each input file, in case you want to append to each file or to reset line numbering.

If, for a given file, Perl is unable to create the backup file as specified in the *`EXTENSION`*, it will issue a warning to that effect and continue processing any other remaining files listed.

You cannot use *–i* to create directories or to strip extensions from files. Nor can you use it with a `~` to indicate a home directory—which is just as well, since some folks like to use that character for their backup files:

```
% perl -pi~ -e 's/foo/bar/' file1 file2 file3...
```

Finally, the *–i* switch does not stop Perl from running if no filenames are given on the command line. When this happens, no backup is made since the original file cannot be determined, and processing proceeds from `STDIN` to `STDOUT` as might be expected.

–I DIRECTORY

Directories specified by *–I* are prepended to `@INC`, which holds the search path for modules. Like `use lib`, the *–I* switch implicitly adds platform-specific directories. See `use lib` in Chapter 29, for details.

–l

–l OCTNUM

Enables automatic line-end processing. It has two effects: first, it automatically `chomp`s the line terminator when used with *–n* or *–p*; second, it sets `$\` to the value of *OCTNUM* so that any print statements will have a line terminator of ASCII value *OCTNUM* added back on. If *OCTNUM* is omitted, *–l* sets `$\` to the current value of `$/`, typically newline. So to trim lines to 80 columns, say this:

```
% perl -lpe 'substr($_, 80) = ""'
```

Note that the assignment `$\ = $/` is done when the switch is processed, so the input record separator can be different from the output record separator if the *–l* switch is followed by a *–0* switch:

```
% gnufind / -print0 | perl -ln0e 'print "found $_" if -p'
```

This sets `$\` to newline and later sets `$/` to the null character. (Note that `0` would have been interpreted as part of the *–l* switch had it followed the *–l* directly. That's why we bundled the *–n* switch between them.)

–m and –M

These switches load a *MODULE* as if you'd executed a `use`, unless you specify *–MODULE* instead of *MODULE*, in which case they invoke `no`. For example, *–Mstrict* is like `use strict`, while *–M–strict* is like `no strict`.

–m MODULE

Executes `use` *MODULE* `()` before executing your script.

–M MODULE

Executes `use` *MODULE* before executing your script. The command is formed by mere interpolation of the rest of the argument after the *–M*, so you can use quotes to add extra code after the module name—for example, *–M'MODULE qw(foo bar)'*. If the first character after the *–M* or *–m* is a dash (*–*), then the `use` is replaced with `no`. To use this to assert a minimal version number of the running Perl, use *–Mv5.14*, for example, to make sure you're running at least v5.14 or better.

–M MODULE=ARG1,ARG2…

A little built-in syntactic sugar means you can also say *–Mmodule=foo,bar* as a shortcut for *–M'module qw(foo bar)'*. This avoids the need to use quotes when importing symbols. The actual code generated by *–Mmodule=foo,bar* is:

```
use module split(/,/, q{foo,bar})
```

Note that the `=` form removes the distinction between *–m* and *–M*, but it's better to use the uppercase form to avoid confusion.

You may only use the *–M* and *–m* switches from a real command-line invocation of Perl, not as options picked up on the `#!` line. (Hey, if you're gonna put it in the file, why not just write the equivalent `use` or `no` instead?)

–P Removed in v5.12 due to portability concerns. Use the `Text::CPP` module from CPAN instead.

–n Causes Perl to assume the following loop around your script, which makes it iterate over filename arguments much as *sed –n* or *awk* do:

```
LINE:
while (<>) {
    ...                # your script goes here
}
```

You may use `LINE` as a loop label from within your script, even though you can't see the actual label in your file.

Note that the lines are not printed by default. See *–p* to have lines printed. Here is an efficient way to delete all files older than a week:

```
find . -mtime +7 -print | perl -nle unlink
```

This is faster than using the *–exec* switch of the *find* program because you don't have to start a process on every filename found. It does suffer from the bug of mishandling newlines in pathnames, which you can fix if you follow the example under *–0*. By an amazing coincidence, `BEGIN` and `END` blocks may be used to capture control before or after the implicit loop, just as in *awk*.

–p Causes Perl to assume the following loop around your script, which makes it iterate over filename arguments much as *sed* does:

```
LINE:
while (<>) {
    ...         # your script goes here
}
continue {
    (print) || die "-p destination: $!\n";
}
```

You may use `LINE` as a loop label from within your script, even though you can't see the actual label in your file.

If a file named by an argument cannot be opened for some reason, Perl warns you about it and moves on to the next file. Note that the lines are printed automatically. An error occurring during printing is treated as fatal. By yet another amazing coincidence, `BEGIN` and `END` blocks may be used to capture control before or after the implicit loop, just as in *awk*.

–s Enables rudimentary switch parsing for switches on the command line after the script name but before any filename arguments or a "`--`" switch-processing terminator. Any switch found is removed from `@ARGV`, and a variable by the same name as the switch is set in Perl. Switch bundling is not allowed, because multicharacter switches are permitted.

The following script prints "`true`" only when the script is invoked with a *–foo* switch.

```
#!/usr/bin/perl -s
if ($foo) { print "true\n" }
```

If the switch is of the form *–xxx=yyy*, the `$xxx` variable is set to whatever follows the equals sign in that argument ("`yyy`" in this case). The following script prints "`true`" if and only if the script is invoked with a *–foo=bar* switch.

```
#!/usr/bin/perl -s
if ($foo eq 'bar') { print "true\n" }
```

Do note that a switch like *--help* creates the variable `${-help}`, which is not compliant with `strict refs`. Also, using this option on a script with warnings enabled may generate spurious "used only once" warnings.

–S Makes Perl use the `PATH` environment variable to search for the script (unless the name of the script contains directory separators).

Typically, this switch is used to help emulate `#!` startup on platforms that don't support `#!`. On many platforms that have a shell compatible with Bourne or C shell, you can use this:

```
#!/usr/bin/perl
eval "exec /usr/bin/perl -S $0 $*"
        if $running_under_some_shell;
```

The system ignores the first line and feeds the script to */bin/sh*, which proceeds to try to execute the Perl script as a shell script. The shell executes the second line as a normal shell command and thus starts up the Perl interpreter. On some systems `$0` doesn't always contain the full pathname, so *–S* tells Perl to search for the script if necessary. After Perl locates the script, it parses the lines and ignores them because the variable `$running_under_some_shell` is never true. A better construct than `$*` would be `${1+"$@"}`, which handles embedded spaces and such in the filenames but doesn't work if the script is being interpreted by *csh*. To start up *sh* instead of *csh*, some systems have to replace the `#!` line with a line containing just a colon, which Perl will ignore politely. Other systems can't control that and need a totally devious construct that will work under any of *csh*, *sh*, or *perl*, such as the following:

```
eval '(exit $?0)' && eval 'exec /usr/bin/perl -S $0 ${1+"$@"}'
    & eval 'exec /usr/bin/perl -S $0 $argv:q'
                 if 0;
```

Yes, it's ugly, but so are the systems that work[4] this way.

On some platforms, the *–S* switch also makes Perl append suffixes to the filename while searching for it. For example, on Win32 platforms, the *.bat* and *.cmd* suffixes are appended if a lookup for the original name fails and the name does not already end in one of those suffixes. If your Perl was built with debugging enabled, you can use Perl's *–Dp* switch to watch how the search progresses.

If the filename supplied contains directory separators (even as just a relative pathname, not an absolute one), and if the file is not found, those platforms that implicitly append file extensions (not Unix) will do so and look for the file with those extensions added, one by one.

On DOS-like platforms, if the script does not contain directory separators, it will first be searched for in the current directory before being searched for in the `PATH`. On Unix platforms, the script will be searched for strictly on the `PATH`, due to security concerns about accidentally executing something in the current working directory without explicitly requesting this.

–t Like *–T*, but taint checks will issue warnings rather than fatal errors. These warnings can be controlled normally with `no warnings qw(taint)`.

Note: *this is not a substitute for –T!* This is meant to be used *only* as a temporary development aid while securing legacy code: for real production code and for new secure code written from scratch, always use the real *–T*.

–T Forces "taint" checks to be turned on so you can test them. Ordinarily these checks are done only when running setuid or setgid. It's a good idea to turn them on explicitly for programs run on another's behalf, such as CGI programs. See Chapter 20.

For security reasons, Perl must see this option quite early; usually this means it must appear early on the command line or in the `#!` line. If it's not early enough, Perl complains.

–u Causes Perl to dump core after compiling your script. In theory, you can then take this core dump and turn it into an executable file by using the *undump* program (not supplied). This speeds startup at the expense of some disk space (which you can minimize by stripping the executable). If you want to execute a portion of your script before dumping, use Perl's `dump` operator

4. We use the term advisedly.

instead. Note: availability of *undump* is platform specific; it may not be available for a specific port of Perl. It has been superseded by the new Perl-to-C code generator, which is much more portable (but still experimental).

–U Allows Perl to do unsafe operations. Currently the only "unsafe" operations are unlinking directories while running as superuser, and running setuid programs with fatal taint checks turned into warnings. Note that warnings must be enabled to actually produce the taint-check warnings.

–v Prints the version and patch level of your Perl executable, along with a bit of extra information.

–V Prints a summary of the major Perl configuration values and the current value of `@INC`.

–V: NAME

Prints to `STDOUT` the value of the named configuration variable. The *NAME* may contain regex characters, like "`.`" to match any character, or "`.*`" to match any optional sequence of characters.

```
% perl -V:man.dir
man1dir='/usr/local/man/man1'
man3dir='/usr/local/man/man3'

% perl -V:'.*threads'
d_oldpthreads='undef'
use5005threads='define'
useithreads='undef'
usethreads='define'
```

If you ask for a configuration variable that doesn't exist, its value will be reported as "`UNKNOWN`". Configuration information is available from within a program using the `Config` module, although patterns are not supported for the hash subscripts:

```
% perl -MConfig -le 'print $Config{man1dir}'
/usr/local/man/man1
```

See the `Config` module for more details.

–w Prints warnings about variables that are mentioned only once and scalar values that are used before being set. Also warns about redefined subroutines, and references to undefined filehandles or filehandles opened read-only that you are attempting to write on. Also warns you if you use values as numbers that don't look like numbers, if you use an array as though it were a scalar, if your subroutines recurse more than 100 deep, and innumerable other things. See every entry labelled "(W)" in *perldiag*.

This switch just sets the global `$^W` variable. It has no effect on lexical warnings—see the *–W* and *–X* switches for that. You can enable or disable specific warnings via the `warnings` (or `no warnings`) pragma, described in Chapter 29.

–W Enables all warnings unconditionally and permanently throughout the program, even if warnings were disabled locally using `no warnings` or `$^W = 0`. This includes all files loaded via `use`, `require`, or `do`. Think of it as the Perl equivalent of the *lint*(1) command.

–x

–x DIRECTORY
Tells Perl to extract a script that is embedded in a message. Leading garbage will be discarded until the first line that starts with `#!` and contains the string "`perl`". Any meaningful switches on that line after the word "`perl`" will be applied. If a directory name is specified, Perl will switch to that directory before running the script. The *–x* switch controls the disposal of leading garbage only, not trailing garbage. The script must be terminated with `__END__` or `__DATA__` if there is trailing garbage to be ignored. (The script can process any or all of the trailing garbage via the `DATA` filehandle if desired. In theory, it could even `seek` to the beginning of the file and process the leading garbage.)

–X Disables all warnings unconditionally and permanently, the exact opposite of what the *–W* flag does.

Environment Variables

In addition to the various switches that explicitly modify Perl's behavior, you can set various environment variables to influence various underlying behaviors. How you set up these environment variables is system dependent, but one trick you should know if you use *sh*, *ksh*, or *bash* is that you can temporarily set an environment variable for a single command, as if it were a funny kind of switch. It has to be set in front of the command:

```
$ PATH='/bin:/usr/bin' perl myproggie
```

You can do something similar with a subshell in *csh* and *tcsh*:

```
% (setenv PATH "/bin:/usr/bin"; perl myproggie)
```

Otherwise, you'd typically set environment variables in some file with a name resembling *.cshrc* or *.profile* in your home directory. Under *csh* and *tcsh* you'd say:

```
% setenv PATH '/bin:/usr/bin'
```

And under *sh*, *ksh*, and *bash* you'd say:

```
$ PATH='/bin:/usr/bin'; export PATH
```

Other systems will have other ways of setting these on a semipermanent basis. Here are the environment variables Perl pays attention to:

`HOME`
: Used if `chdir` is called without an argument.

`LC_ALL`, `LC_CTYPE`, `LC_COLLATE`, `LC_NUMERIC`, `PERL_BADLANG`
: Environment variables that control how Perl handles data specific to particular natural languages. See the online docs for *perllocale*.

`LOGDIR`
: Used if `chdir` has no argument but `HOME` is not set.

`PATH`
: Used in executing subprocesses and for finding the program if the *–S* switch is used.

`PERL5DB`
: The command used to load the debugger code. The default is:

```
BEGIN { require "perl5db.pl" }
```

: See Chapter 18 for more uses of this variable.

`PERL5DB_THREADED`
: If set to a true value, indicates to the debugger that the code being debugged uses threads.

`PERL_ALLOW_NON_IFS_LSP` *(specific to the Win32 port)*
: Set to 1 to allow the use of non-IFS compatible LSPs. Perl normally searches for an IFS-compatible LSP because this is required for its emulation of Windows sockets as real filehandles. However, this may cause problems if you have a firewall such as *McAfee Guardian*, which requires all applications to use its LSP and which is not IFS-compatible, because clearly Perl will normally avoid using such an LSP.

: Setting this environment variable to 1 means that Perl will simply use the first suitable LSP enumerated in the catalog, which keeps *McAfee Guardian* happy (and in that particular case Perl still works, too, because *McAfee Guardian*'s LSP actually plays some other games that allow applications requiring IFS compatibility to work).

`PERL_DEBUG_MSTATS`
: Relevant only if Perl is compiled with the malloc included with the Perl distribution (that is, if `perl -V:d_mymalloc` is `define`). If set, this dumps out memory statistics after execution. If set to an integer greater than one, also dumps out memory statistics after compilation.

PERL_DESTRUCT_LEVEL
: Relevant only if your Perl executable was built with -DDEBUGGING, this variable controls the behavior of global destruction of objects and other references. See "PERL_DESTRUCT_LEVEL" in *perlhacktips* for more information.

PERL_DL_NONLAZY
: Set to one to have Perl resolve *all* undefined symbols when it loads a dynamic library. The default behavior is to resolve symbols when they are used. Setting this variable is useful during testing of extensions as it ensures that you get an error on misspelled function names, even if the test suite doesn't call it.

PERL_ENCODING
: Don't use this. It relies on the `encoding` pragma, which doesn't work.

PERL_HASH_SEED
: (Since v5.8.1.) Used to randomize Perl's internal hash function. To emulate the pre-5.8.1 behavior, set to an integer (zero means the same order as v5.8.0). "Pre-5.8.1" means, among other things, that hash keys will always have the same ordering between different runs of Perl.

  Most hashes return elements in the same order as v5.8.0 by default. On a hash-by-hash basis, if pathological data is detected during a hash key insertion, then that hash will switch to an alternative random hash seed.

  The default behavior is to randomize, unless the PERL_HASH_SEED is set. If Perl has been compiled with -DUSE_HASH_SEED_EXPLICIT, the default behavior is *not* to randomize—unless the PERL_HASH_SEED is set.

  If PERL_HASH_SEED is unset or set to a nonnumeric string, Perl uses the pseudorandom seed supplied by the operating system and libraries.

  Please note that the hash seed is sensitive information. Hashes are randomized to protect against local and remote attacks against Perl code. By manually setting a seed, this protection may be partially or completely lost.

  See "Algorithmic Complexity Attacks" in *perlsec* and "ENVIRONMENT" in *perlrun* for more information.

PERL_HASH_SEED_DEBUG
: (Since v5.8.1.) Set to one to display (to STDERR) the value of the hash seed at the beginning of execution. This, combined with PERL_HASH_SEED [see "PERL_HASH_SEED" in *perlrun*] is intended to aid in debugging nondeterministic behavior caused by hash randomization.

  Note that the hash seed is sensitive information: by knowing it you can craft a denial-of-service attack against Perl code, even remotely; see "Algorithmic

Complexity Attacks" in *perlsec* for more information. *Do not disclose the hash seed* to people who don't need to know it. See also `hash_seed()` of `Hash::Util`.

`PERL_MEM_LOG`
: If your Perl was configured with `-Accflags=-DPERL_MEM_LOG`, setting the environment variable `PERL_MEM_LOG` enables logging debug messages. The value has the form *`number`*`[m][s][t]`, where *`number`* is the file descriptor number you want to write to (2 is default), and the combination of letters specifies that you want information about (m)emory and/or (s)v, optionally with (t)imestamps. For example `PERL_MEM_LOG=1mst` will log all information to stdout. You can also write to other opened file descriptors, in a variety of ways:

```
bash$ 3>foo3 PERL_MEM_LOG=3m perl ...
```

`PERL_ROOT` *(specific to the VMS port)*
: A translation concealed rooted logical name that contains Perl and the logical device for the `@INC` path on VMS only. Other logical names that affect Perl on VMS include `PERLSHR`, `PERL_ENV_TABLES`, and `SYS$TIMEZONE_DIFFERENTIAL`, but these are optional and discussed further in *perlvms* and in *README.vms* in the Perl source distribution.

`PERL_SIGNALS`
: In v5.8.1 and later. If set to `unsafe`, the pre-Perl-5.8.0 behavior (immediate but unsafe signals) is restored. If set to `safe`, the safe (or deferred) signals are used. See "Deferred Signals (Safe Signals)" in *perlipc*.

`PERL5SHELL` *(Microsoft ports only)*
: May be set to an alternative shell that Perl must use internally for executing commands via backticks or `system`. Default is *cmd.exe /x/c* on WinNT and *command.com /c* on Win95. The value is considered to be space-separated. Precede any character that needs to be protected (like a space or backslash) with a backslash.

  Note that Perl doesn't use `COMSPEC` for this purpose because `COMSPEC` has a high degree of variability among users, leading to portability concerns. Besides, Perl can use a shell that may not be fit for interactive use, and setting `COMSPEC` to such a shell may interfere with the proper functioning of other programs (which usually look in `COMSPEC` to find a shell fit for interactive use).

`PERL5LIB`
: A colon-separated[5] list of directories in which to look for Perl library files before looking in the standard library and the current directory. Any archi-

5. On Unix and its derivatives. On Microsoft systems, it's semicolon-separated.

tecture-specific directories under the specified locations are automatically included if they exist. If `PERL5LIB` is not defined, `PERLLIB` is consulted for backward compatibility with older releases.

When running taint checks (either because the program was running setuid or setgid, or the *–T* switch was used), neither of these library variables is used. Such programs must employ an explicit `lib` pragma for that purpose.

`PERL5OPT`
: Default command-line switches. Switches in this variable are taken as if they were on every Perl command line. Only the *–[DIMUdmw]* switches are allowed. When running taint checks (because the program was running setuid or setgid, or the *–T* switch was used), this variable is ignored. If `PERL5OPT` begins with *–T*, tainting will be enabled, causing any subsequent options to be ignored.

`PERLIO`
: A space- (or colon-) separated list of `PerlIO` layers. If Perl is built to use `PerlIO` system for IO (the default), these layers affect Perl's IO.

  It is conventional to start layer names with a colon (for example, `:perlio`) to emphasize their similarity to variable "attributes". But the code that parses layer specification strings (which is also used to decode the PERLIO environment variable) treats the colon as a separator.

  An unset or empty PERLIO is equivalent to the default set of layers for your platform—for example, `:unix:perlio` on Unix-like systems, and `:unix:crlf` on Windows and other DOS-like systems.

  The list becomes the default for *all* Perl's IO. Consequently, only built-in layers can appear in this list, because external layers such as `:encoding(`*`LAYER`*`)` need IO in order to load them. See the `open` pragma in Chapter 29 for how to add external encodings as defaults.

  It makes sense to include some layers in the `PerlIO` environment variable; these are briefly summarized below.

  `:bytes`
  : A pseudolayer that turns *off* the `:utf8` flag for the layer below. It is unlikely to be useful on its own in the global `PERLIO` environment variable. You perhaps were thinking of `:crlf:bytes` or `:perlio:bytes`.

  `:crlf`
  : A layer that does CRLF to `"\n"` translation, distinguishing "text" and "binary" files in the manner of MS-DOS and similar operating systems. (It currently does *not* mimic MS-DOS as far as treating of Control-Z as being an end-of-file marker.)

`:mmap`
: A layer that implements "reading" of files by using `mmap` to make a (whole) file appear in the process's address space, and then using that as `PerlIO`'s "buffer".

`:perlio`
: This is a reimplementation of "stdio-like" buffering written as a `PerlIO` "layer". As such, it will call whatever layer is below it for its operations (typically `:unix`).

`:pop`
: An experimental pseudolayer that removes the topmost layer. Use with the same care as is reserved for nitroglycerin.

`:raw`
: A pseudolayer that manipulates other layers. Applying the `:raw` layer is equivalent to calling `binmode($fh)`. It makes the stream pass each byte as is, without any decoding. In particular, CRLF translation and intuiting `:utf8` from locale environment variables are both disabled.

  Unlike in the earlier versions of Perl, `:raw` is *not* just the inverse of `:crlf`. Other layers that5 would affect the binary nature of the stream are also removed or disabled.

`:stdio`
: This layer provides `PerlIO` interface by wrapping the system's ANSI C "stdio" library calls. The layer provides both buffering and IO. Note that `:stdio` layer does *not* do CRLF translation, even if that is the platform's normal behavior. You will need a `:crlf` layer above it to do that.

`:unix`
: Low-level layer that calls `read`, `write`, `lseek`, etc.

`:utf8`
: A pseudolayer that enables a flag on the layer below to tell Perl that output should be in UTF-8, and that input should be regarded as already in valid UTF-8 form. It does not check for validity and, as such, should be handled with caution for input. If you use this layer on input, always enable (preferably fatal) UTF-8 warnings. Otherwise, you should use `:encoding(UTF-8)` when reading UTF-8 encoded data.

`:win32`
: On Win32 platforms this *experimental* layer uses native "handle" IO rather than a Unix-like numeric file descriptor layer. Known to be buggy in the v5.14 release.

The default set of layers should give acceptable results on all platforms

For Unix platforms, that will be the equivalent of "unix perlio" or "stdio". Configure is set up to prefer the "stdio" implementation if the system library provides fast access to the buffer; otherwise, it uses the "unix perlio" implementation.

On Win32, the default in the v5.14 release is "unix crlf". Win32's "stdio" has several bugs—or, more charitably, misfeatures—for Perl IO that are somewhat dependent on which version and vendor supplied the C compiler. Using our own `crlf` layer as the buffer avoids those issues and makes things more uniform. The `crlf` layer provides CRLF `"\n"` conversion as well as buffering.

Perl v5.14 uses `unix` as the bottom layer on Win32 and so still uses the C compiler's numeric file descriptor routines. There is an experimental native `win32` layer, which is expected to be enhanced in the future and should eventually become the default under Win32.

The `PERLIO` environment variable is completely ignored when Perl is run in taint mode.

`PERLIO_DEBUG`

If set to the name of a file or device, certain operations of `PerlIO`'s subsystem will be logged to that file, opened in append mode. Typical uses are this in Unix:

```
% env PERLIO_DEBUG=/dev/tty perl script ...
```

Whereas in Win32, the approximate equivalent is:

```
> set PERLIO_DEBUG=CON
> perl script ...
```

This functionality is disabled for setuid scripts and for scripts run with *–T*.

`PERLLIB`

A colon-separated list of directories in which to look for Perl library files before looking in the standard library and the current directory. If `PERL5LIB` is defined, `PERLLIB` is not used.

`PERL_UNICODE`

Equivalent to the *–C* command-line switch. Note that this is not a Boolean variable. Setting this to `"1"` is not the right way to "enable Unicode" (whatever that would mean). However, you can use `"0"` to "disable Unicode" (or, alternatively, unset `PERL_UNICODE` in your shell before starting Perl).

Setting this variable to `"AS"` is generally useful in most situations involving text not binary: it implicitly decodes `@ARGV` from UTF-8, and it `binmode`s all three of the `STDIN`, `STDOUT`, and `STDERR` handles to the built-in `:utf8` layer. Use

when these are intended to be UTF-8 text, not just binary streams of bytes. Setting this variable to `"ASD"` may be even more useful for some cases, but because it also changes the default encoding of all filehandles from binary to `:utf8`, it breaks many old programs that assume binary (or on Windows, text) streams and so don't bother to call `binmode` themselves. Unix programs are notorious for this. Therefore, it is best to use the `"D"` setting only for temporary runs.

Because the built-in `:utf8` layer does not by default raise exceptions or even warn of malformed UTF-8 in input streams, for correct behavior it is imperative that you also enable "`utf8`" warnings if you use the `:utf8` layer on input streams. From the command line, use *–Mwarnings=utf8* for warnings, or *–Mwarnings=FATAL,utf8* for exceptions. Those correspond to `use warnings "utf8"` and `use warnings FATAL => "utf8"` from within the program. See the section "Getting at Unicode Data" on page 282 in Chapter 6.

`SYS$LOGIN` *(specific to the VMS port)*
: Used if `chdir` has no argument, and HOME and LOGDIR are not set.

Apart from these, Perl itself uses no other environment variables, except to make them available to the program being executed and to any child processes that program launches. Some modules, standard or otherwise, may care about other environment variables. For example, the `re` pragma uses `PERL_RE_TC` and `PERL_RE_COLORS`, the `Cwd` module uses `PWD`, and the `CGI` module uses the many environment variables set by your HTTP daemon (that is, your web server) to pass information to the CGI script.

Programs running setuid would do well to execute the following lines before doing anything else, just to keep people honest:

```
$ENV{PATH}  = '/bin:/usr/bin';    # or whatever you need
$ENV{SHELL} = '/bin/sh' if exists $ENV{SHELL};
delete @ENV{qw(IFS CDPATH ENV BASH_ENV)};
```

See Chapter 20 for details.

CHAPTER 18
The Perl Debugger

First of all, have you tried the `warnings` pragma?

If you invoke Perl with the `-d` switch, your program will be run inside the Perl debugger. This works like an interactive Perl environment, prompting for debugger commands that let you examine source code, set breakpoints, dump out your function-call stack, change the values of variables, and so on. Any command not recognized by the debugger is executed directly (using `eval`) as Perl code in the package of the code currently being debugged. (The debugger uses the `DB` package for its own state information, to avoid trampling yours.) This is so wonderfully convenient that people often fire up the debugger just to test out Perl constructs interactively. In that case, it doesn't matter what program you tell Perl to debug, so we'll choose one without much meaning:

```
% perl -de 42
```

In Perl, the debugger is not a program completely separate from the one being debugged the way it usually is in a typical programming environment. Instead, the `-d` flag tells the compiler to insert source information into the parse trees it's about to hand off to the interpreter. That means your code must first compile correctly for the debugger to work on it. If that is successful, the interpreter preloads a special Perl library file containing the debugger itself.

```
% perl -d /path/to/program
```

The program will halt immediately before the first runtime executable statement (but see the next section, "Using the Debugger" on page 604, regarding compile-time statements) and ask you to enter a debugger command. Whenever the debugger halts and shows you a line of code, it displays the line that it's *about* to execute, not the one just executed.

As the debugger encounters a line, it first checks for a breakpoint, prints it (if the debugger is in trace mode), performs any actions (created with the `a` command described later in "Debugger Commands" on page 606), and finally prompts the user if a breakpoint is present or if the debugger is in single-step mode. If not, it evaluates the line normally and continues to the next line.

Using the Debugger

The debugger prompt is something like:

```
DB<8>
```

or even:

```
DB<<17>>
```

where the number shows how many commands you've executed. A *csh*-like history mechanism allows you to access previous commands by number. For example, `!17` would repeat command number 17. The number of angle brackets indicates the depth of the debugger. For example, you get more than one set of brackets if you're already at a breakpoint and then print out the result of a function call that itself also has a breakpoint.

If you want to enter a multiline command, such as a subroutine definition with several statements, you may escape the newline that would normally end the debugger command with a backslash. Here's an example:

```
DB<1> for (1..3) {         \
  cont:     print "ok\n";    \
  cont: }
  ok
  ok
  ok
```

Let's say you want to fire up the debugger on a little program of yours (let's call it *camel_flea*) and stop it as soon as it gets down to a function named `infested`. Here's how you'd do that:

```
% perl -d camel_flea
  Loading DB routines from perl5db.pl version 1.07
  Editor support available.

  Enter h or `h h' for help, or `man perldebug' for more help.

  main::(camel_flea:2):     pests('bactrian', 4);
DB<1>
```

The debugger halts your program right before the first runtime executable statement (but see below about compile-time statements) and asks you to enter a

command. Again, whenever the debugger stops to show you a line of code, it displays the line it's *about* to execute, not the one it just executed. The line displayed may not look exactly like it did in your source file, particularly if you've run it through any kind of preprocessor.

Now, you'd like to stop as soon as your program gets to the `infested` function, so you establish a breakpoint there, like so:

```
DB<1> b infested
DB<2> c
```

The debugger now continues until it hits that function, at which point it says this:

```
main::infested(camel_flea:8):       my $bugs = int rand(3);
```

To look at a "window" of source code around the breakpoint, use the `w` command:

```
DB<2> w
5     }
6
7       sub infested {
8==>b       my $bugs = int rand(3);
9:          our $Master;
10:         contaminate($Master);
11:         warn "needs wash"
12              if $Master && $Master->isa("Human");
13
14:         print "got $bugs\n";

DB<2>
```

As you see by the `==>` marker, your current line is line 8, and by the `b` there, you know it has a breakpoint on it. If you had set an action, there also would have been an `a` there. The line numbers with colons are breakable; the rest are not.

To see who called whom, ask for a stack backtrace using the *T* command:

```
DB<2> T
$ = main::infested called from file `Ambulation.pm' line 4
@ = Ambulation::legs(1, 2, 3, 4) called from file `camel_flea' line 5
. = main::pests('bactrian', 4) called from file `camel_flea' line 2
```

The initial character (`$`, `@`, or `.`) tells whether the function was called in a scalar, list, or void context, respectively. There are three lines because you were three functions deep when you ran the stack backtrace. Here's what each line means:

- The first line says you were in the function `main::infested` when you ran the stack trace. It tells you the function was called in scalar context from line 4 of the file *Ambulation.pm*. It also shows that it was called without any arguments whatsoever, meaning it was called as `&infested` instead of the normal way, as `infested()`.

- The second line shows that the function `Ambulation::legs` was called in list context from line number 5 of the *camel_flea* file, with those four arguments.
- The third line shows that `main::pests` was called in void context from line 2 of *camel_flea*.

If you have compile-phase executable statements, such as code from `BEGIN` and `CHECK` blocks or `use` statements, these will *not* ordinarily be stopped by the debugger, although `require`s and `INIT` blocks will, since they happen after the transition to run phase (see Chapter 16). Compile-phase statements can be traced with the `AutoTrace` option set in `PERLDB_OPTS`.

You can exert a little control over the Perl debugger from within your Perl program itself. You might do this, for example, to set an automatic breakpoint at a certain subroutine whenever a particular program is run under the debugger. From your own Perl code, however, you can transfer control back to the debugger using the following statement, which is harmless if the debugger is not running:

```
$DB::single = 1;
```

If you set `$DB::single` to 2, it's equivalent to the `n` command, whereas a value of 1 emulates the `s` command. The `$DB::trace` variable should be set to 1 to simulate the `t` command.

Another way to debug a module is to set a breakpoint on *load*ing:

```
DB<7> b load c:/perl/lib/Carp.pm
Will stop on load of `c:/perl/lib/Carp.pm'.
```

and then restart the debugger using the `R` command. For finer control, you can use the `b compile subname` to stop as soon as possible after a particular subroutine is compiled.

Debugger Commands

When you type commands into the debugger, you don't need to terminate them with a semicolon. Use a backslash to continue lines (but only in the debugger).

Since the debugger uses `eval` to execute commands, `my` and `local` settings will disappear once the command returns. If a debugger command coincides with some function in your own program, simply precede the function call with anything that doesn't look like a debugger command, such as a leading `;` or a `+`.

If the output of a debugger built-in command scrolls past your screen, just precede the command with a leading pipe symbol so it's run through your pager:

```
DB<1> |h
```

The debugger has plenty of commands, and we divide them (somewhat arbitrarily) into stepping and running, breakpoints, tracing, display, locating code, automatic command execution, and, of course, miscellaneous.

Perhaps the most important command is `h`, which provides help. If you type `h h` at the debugger prompt, you'll get a compact help listing designed to fit on one screen. If you type `h` *`COMMAND`*, you'll get help on that debugger command.

Stepping and Running

The debugger operates by *stepping* through your program line by line. The following commands let you control what you skip over and where you stop.

`s` [*`EXPR`*]
: The `s` debugger command single-steps through the program. That is, the debugger will execute the next line of your program until another statement is reached, descending into subroutine calls as necessary. If the next line to execute involves a function call, then the debugger stops at the first line inside that function. If an *`EXPR`* is supplied that includes function calls, these will be single-stepped, too.

`n` [*`EXPR`*]
: The `n` command executes subroutine calls, without stepping through them, until the beginning of the next statement at this same level (or higher). If an *`EXPR`* is supplied that includes function calls, those functions will be executed with stops before each statement.

`<ENTER>`
: If you just hit enter at the debugger prompt, the previous `n` or `s` command is repeated.

`.`
: The `.` command returns the internal debugger pointer to the line last executed and prints out that line.

`r`
: This command continues until the currently executing subroutine returns. It displays the return value if the `PrintRet` option is set, which it is by default.

Breakpoints

`b`

`b` *`LINE`*

`b` *`CONDITION`*

`b` *`LINE CONDITION`*

`b` *`SUBNAME`*

`b` *`SUBNAME CONDITION`*

`b postpone` *`SUBNAME`*

`b postpone` *`SUBNAME CONDITION`*

`b compile` *`SUBNAME`*

`b load` *`FILENAME`*

The `b` debugger command sets a *breakpoint* before *`LINE`*, telling the debugger to stop the program at that point so that you can poke around. If *`LINE`* is omitted, it sets a breakpoint on the line that's about to execute. If *`CONDITION`* is specified, it's evaluated each time the statement is reached: a breakpoint is triggered only if *`CONDITION`* is true. Breakpoints may only be set on lines that begin an executable statement. Note that conditions don't use `if`:

```
b 237 $x > 30
b 237 ++$count237 < 11
b 33 /pattern/i
```

The `b` *`SUBNAME`* form sets a (possibly conditional) breakpoint before the first line of the named subroutine. *`SUBNAME`* may be a variable containing a code reference; if so, *`CONDITION`* is not supported.

There are several ways to set a breakpoint on code that hasn't even been compiled yet. The `b postpone` form sets a (possibly conditional) breakpoint at the first line of *`SUBNAME`* after it is compiled.

The `b compile` form sets a breakpoint on the first statement to be executed after *`SUBNAME`* is compiled. Note that, unlike the `postpone` form, this statement is outside the subroutine in question because the subroutine hasn't been called yet, only compiled.

The `b load` form sets a breakpoint on the first executed line of the file. The *`FILENAME`* should be a full pathname as found in the `%INC` values.

`d`

`d` *`LINE`*

This command deletes the breakpoint at *`LINE`*; if omitted, it deletes the breakpoint on the line about to execute.

`D` This command deletes all breakpoints.

`L` This command lists all the breakpoints and actions.

`c`

`c` *`LINE`*
: This command continues execution, optionally inserting a one-time-only breakpoint at the specified *`LINE`*.

Tracing

`T`
: This command produces a stack backtrace.

`t`

`t` *`EXPR`*
: This command toggles trace mode, which prints out every line in your program as it is evaluated. See also the `AutoTrace` option discussed later in this chapter. If an *`EXPR`* is provided, the debugger will trace through its execution. See also the later section "Unattended Execution" on page 619.

`W`

`W` *`EXPR`*
: This command adds *`EXPR`* as a global *watch expression*. (A watch expression is an expression that will cause a breakpoint when its value changes.) If no *`EXPR`* is provided, all watch expressions are deleted.

Display

Perl's debugger has several commands for examining data structures while your program is stopped at a breakpoint.

`p`

`p` *`EXPR`*
: This command is the same as `print DB::OUT` *`EXPR`* in the current package. In particular, since this is just Perl's own `print` function, nested data structures and objects are not shown—use the `x` command for that. The `DB::OUT` handle prints to your terminal (or perhaps an editor window) no matter where standard output may have been redirected.

`x`

`x` *`EXPR`*
: The `x` command evaluates its expression in list context and displays the result, pretty printed. That is, nested data structures are printed out recursively and with unviewable characters suitably encoded.

`V`

`V` *`PKG`*

`V` *`PKG VARS`*

This command displays all (or when you specify *`VARS`*, some) variables in the specified *`PKG`* (defaulting to the `main` package) using a pretty printer. Hashes show their keys and values, control characters are rendered legibly, nested data structures print out in a legible fashion, and so on. This is similar to calling the `x` command on each applicable variable, except that `x` works with lexical variables, too. Also, here you type the identifiers *without* a type specifier such as `$` or `@`, like this:

```
V Pet::Camel SPOT FIDO
```

In place of a variable name in *`VARS`*, you can use *`~PATTERN`* or *`!PATTERN`* to print existing variables whose names either match or don't match the specified pattern.

`X`

`X` *`VARS`*

This command is the same as `V` *`CURRENTPACKAGE`*, where *`CURRENTPACKAGE`* is the package into which the current line was compiled.

`H`

`H` *`-NUMBER`*

This command displays the last *`NUMBER`* commands. Only commands longer than one character are stored in the history. (Most of them would be `s` or `n`, otherwise.) If *`NUMBER`* is omitted, all commands are listed.

Locating Code

Inside the debugger, you can extract and display parts of your program with these commands.

`l`

`l` *`LINE`*

`l` *`SUBNAME`*

`l` *`MIN+INCR`*

`l` *`MIN-MAX`*

The `l` command lists the next few lines of your program, or the specified *`LINE`* if provided, or the first few lines of the *`SUBNAME`* subroutine or code reference.

The `l` *`MIN+INCR`* form lists *`INCR`*`+1` lines, starting at *`MIN`*. The `l` *`MIN-MAX`* form lists lines *`MIN`* through *`MAX`*.

`-` This command lists the previous few lines of your program.

`w` *`[LINE]`*
: Lists a window (a few lines) around the given source *`LINE`*, or the current line if no *`LINE`* is supplied.

`f` *`FILENAME`*
: This command lets you view a different program or `eval` statement. If the *`FILENAME`* is not a full pathname as found in the values of `%INC`, it is interpreted as a regular expression to find the filename you mean.

`/PATTERN/`
: This command searches forward in the program for *`PATTERN`*; the final `/` is optional. The entire *`PATTERN`* is optional, too; if omitted, it repeats the previous search.

`?PATTERN?`
: This command searches backward for *`PATTERN`*; the final `?` is optional. It repeats the previous search if *`PATTERN`* is omitted.

`S`

`S` *`PATTERN`*

`S !`*`PATTERN`*
: The `S` command lists those subroutine names matching (or, with `!`, those not matching) *`PATTERN`*. If no *`PATTERN`* is provided, all subroutines are listed.

Actions and Command Execution

From inside the debugger, you can specify actions to be taken at particular times. You can also launch external programs.

`a`

`a` *`COMMAND`*

`a` *`LINE`*

`a` *`LINE COMMAND`*
: This command sets an action to take before *`LINE`* executes, or the current line if *`LINE`* is omitted. For example, this prints out `$foo` every time line 53 is reached:

```
a 53 print "DB FOUND $foo\n"
```

: If no `COMMAND` is specified, the action on the specified *`LINE`* is deleted. With neither *`LINE`* nor *`COMMAND`*, the action on the current line is deleted.

`A`
: The `A` debugger command deletes all actions.

`<`

`< ?`

`< EXPR`

`<< EXPR`

The `< EXPR` form specifies a Perl expression to be evaluated before every debugger prompt. You can add another expression with the `<< EXPR` form, list them with `< ?`, and delete them all with a plain `<`.

`>`

`> ?`

`> EXPR`

`>> EXPR`

The `>` commands behave just like their `<` cousins but are executed after the debugger prompt instead of before.

`{`

`{ ?`

`{ COMMAND`

`{{ COMMAND`

The `{` debugger commands behave just like `<` but specify a debugger command to be executed before the debugger prompt instead of a Perl expression. A warning is issued if you appear to have accidentally entered a block of code instead. If that's what you really mean to do, write it with `; { ... }` or even `do { ... }`.

`!`

`! NUMBER`

`! -NUMBER`

`!PATTERN`

A lone `!` repeats the previous command. The *`NUMBER`* specifies which command from the history to execute; for instance, `! 3` executes the third command typed into the debugger. If a minus sign precedes the *`NUMBER`*, the commands are counted backward: `! -3` executes the third-to-last command. If a *`PATTERN`* (no slashes) is provided instead of a *`NUMBER`*, the last command that began with *`PATTERN`* is executed. See also the `recallCommand` debugger option.

`!! CMD`

This debugger command runs the external command *`CMD`* in a subprocess, which will read from `DB::IN` and write to `DB::OUT`. See also the `shellBang` debugger option. This command uses whatever shell is named in `$ENV{SHELL}`, which can sometimes interfere with proper interpretation of

status, signal, and core dump information. If you want a consistent exit value from the command, set `$ENV{SHELL}` to `/bin/sh`.

`|`

`! NUMBER`

`! -NUMBER`

`!PATTERN`

The `|DBCMD` command runs the debugger command *DBCMD*, piping `DB::OUT` to `$ENV{PAGER}`. This is often used with commands that would otherwise produce long output, such as:

```
DB<1> |V main
```

Note that this is for debugger commands, not commands you'd type from your shell. If you wanted to pipe the external command *who* through your pager, you could do something like this:

```
DB<1> !!who | more
```

The `||PERL CMD` command is like `|DBCMD`, but `DB::OUT` is temporarily `select`ed as well, so any commands that call `print`, `printf`, or `write` without a filehandle will also be sent down the pipe. For example, if you had a function that generated loads of output by calling `print`, you'd use this command instead of the previous one to page through that output:

```
DB<1> sub saywho { print "Users: ", `who` }
DB<2> ||saywho()
```

Miscellaneous Commands

`q` *and* `^D`

These commands quit the debugger. This is the recommended way to exit, although typing `exit` twice sometimes works. Set the `inhibit_exit` option to `0` if you want to be able to step off the end of the program and remain in the debugger anyway. You may also need to set `$DB::finished` to `0` if you want to step through global destruction.

`R` Restart the debugger by `exec`ing a new session. The debugger tries to maintain your history across sessions, but some internal settings and command-line options may be lost. The following settings are currently preserved: history, breakpoints, actions, debugger options, and the Perl command-line options *–w*, *–I*, and *–e*.

`=`

`= ALIAS`

`= ALIAS VALUE`

This command prints out the current value of *ALIAS* if no *VALUE* is given. With a *VALUE*, it defines a new debugger command with the name *ALIAS*. If both *ALIAS* and *VALUE* are omitted, all current aliases are listed. For example:

```
= quit q
```

An *ALIAS* should be a simple identifier and should translate to a simple identifier as well. You can do more sophisticated aliasing by adding your own entries to `%DB::aliases` directly. See the following section, "Debugger Customization" on page 615.

`man`

`man MANPAGE`

This command calls your system's default documentation viewer on the given page or on the viewer itself if *MANPAGE* is omitted. If that viewer is *man*, the current `%Config` information is used to invoke it. The "`perl`" prefix will be automatically supplied for you when necessary; this lets you type `man debug` and `man op` from the debugger.

On systems that do not normally have the *man* utility, the debugger invokes *perldoc*; if you want to change that behavior, set `$DB::doccmd` to whatever viewer you like. This may be set in an *rc* file or through direct assignment.

`O`

`O OPTION ...`

`O OPTION? ...`

`O OPTION=VALUE ...`

The `O` command lets you manipulate debugger options, which are listed in "Debugger Options" on page 616 later in this chapter. The `O OPTION` form sets each of the listed debugger options to `1`. If a question mark follows an *OPTION*, its current value is displayed.

The `O OPTION=VALUE` form sets the values; if *VALUE* has internal whitespace, it should be quoted. For example, you could set `O pager="less -MQeicsNfr"` to use *less* with those specific flags. You may use either single or double quotes, but if you do, you must escape embedded instances of the same sort of quote that you began with. You must also escape any backslash that immediately precedes the quote but is not meant to escape the quote itself. In other words, just follow single-quoting rules irrespective of the quote actually used. The debugger responds by showing you the value of the option just set, always using single-quoted notation for its output:

```
DB<1> O OPTION='this isn\'t bad'
                OPTION = 'this isn\'t bad'
```

```
DB<2> O   OPTION="She said, \"Isn't it?\""
               OPTION = 'She said, "Isn\'t it?"'
```

For historical reasons, the `=`*`VALUE`* is optional but defaults to `1` only where safe to do so—that is, mostly for Boolean options. It is better to assign a specific *`VALUE`* using `=`. The *`OPTION`* can be abbreviated, but unless you're trying to be intentionally cryptic, it probably should not be. Several options can be set together. See the upcoming section "Debugger Options" on page 616 later in the chapter for a list of these.

Debugger Customization

The debugger probably contains enough configuration hooks that you'll never have to modify it yourself. You may change debugger behavior from within the debugger using its `O` command, from the command line via the `PERLDB_OPTS` environment variable, and by running any preset commands stored in *rc* files.

Editor Support for Debugging

The debugger's command-line history mechanism doesn't provide command-line editing like many shells do: you can't retrieve previous lines with `^p`, or move to the beginning of the line with `^a`, although you can execute previous lines with the exclamation point syntax familiar to shell users. However, if you install the `Term::ReadKey` and `Term::ReadLine` modules from CPAN, you will have full editing capabilities similar to what GNU *readline*(3) provides.

If you have *emacs* installed on your system, it can interact with the Perl debugger to provide an integrated software development environment reminiscent of its interactions with C debuggers. Perl comes with a start file for making *emacs* act like a syntax-directed editor that understands (some of) Perl's syntax. Look in the *emacs* directory of the Perl source distribution. Users of *vi* should also look into *vim* (and *gvim*, the mousey and windy version) for coloring of Perl keywords.

A similar setup by one of us (Tom) for interacting with any vendor-shipped *vi* and the X11 window system is also available. This works similarly to the integrated multiwindow support that *emacs* provides, where the debugger drives the editor. However, at the time of this writing, its eventual location in the Perl distribution is uncertain. But we thought you should know of the possibility.

Customizing with Init Files

You can do some customization by setting up either a *.perldb* or *perldb.ini* file (depending on your operating system), which contains initialization code. This init file holds Perl code, not debugger commands, and it is processed before the `PERLDB_OPTS` environment variable is looked at. For instance, you could make aliases by adding entries to the `%DB::alias` hash this way:

```
$alias{len}  = 's/^len(.*)/p length($1)/';
$alias{stop} = 's/^stop (at|in)/b/';
$alias{ps}   = 's/^ps\b/p scalar /';
$alias{quit} = 's/^quit(\s*)/exit/';
$alias{help} = 's/^help\s*$/|h/';
```

You can change options from within your init file using function calls into the debugger's internal API:

```
parse_options("NonStop=1 LineInfo=db.out AutoTrace=1 frame=2");
```

If your init file defines the subroutine `afterinit`, that function is called after debugger initialization ends. The init file may be located in the current directory or in the home directory. Because this file contains arbitrary Perl commands, for security reasons, it must be owned by the superuser or the current user, and writable by no one but its owner.

If you want to modify the debugger, copy *perl5db.pl* from the Perl library to another name and hack it to your heart's content. You'll then want to set your `PERL5DB` environment variable to say something like this:

```
BEGIN { require "myperl5db.pl" }
```

As a last resort, you could also use `PERL5DB` to customize the debugger by directly setting internal variables or calling internal debugger functions. Be aware, though, that any variables and functions not documented either here or in the online *perldebug*, *perldebguts*, or `DB` manpages are considered to be for internal use only and are subject to change without notice.

Debugger Options

The debugger has numerous options that you can set with the `O` command, either interactively, from the environment, or from an init file.

`recallCommand, ShellBang`
: The characters used to recall a command or spawn a shell. By default, both are set to `!`.

`pager`
: Program to use for output of pager-piped commands (those beginning with a `|` character). By default, `$ENV{PAGER}` will be used. Because the debugger uses your current terminal characteristics for bold and underlining, if the chosen pager does not pass escape sequences through unchanged, the output of some debugger commands will not be readable when sent through the pager.

`tkRunning`
: Runs under the `Tk` module while prompting (with `ReadLine`).

`signalLevel, warnLevel, dieLevel`
: Set the level of verbosity. By default, the debugger leaves your exceptions and warnings alone because altering them can break correctly running programs.

  To disable this default safe mode, set these values to something higher than 0. At a level of 1, you get backtraces upon receiving any kind of warning (this is often annoying) or exception (this is often valuable). Unfortunately, the debugger cannot distinguish fatal exceptions from nonfatal ones. If `dieLevel` is 1, then your nonfatal exceptions are also traced and unceremoniously altered if they came from `eval`ed strings or from any kind of `eval` within modules you're attempting to load. If `dieLevel` is 2, the debugger doesn't care where they came from: it usurps your exception handler and prints out a trace, and then modifies all exceptions with its own embellishments. This may perhaps be useful for some tracing purposes, but it tends to hopelessly confuse any program that takes its exception handling seriously.

  The debugger will attempt to print a message when any uncaught `INT`, `BUS`, or `SEGV` signal arrives. If you're in a slow syscall (like a `wait` or an `accept`, or a `read` from your keyboard or a socket) and haven't set up your own `$SIG{INT}` handler, then you won't be able to Control-C your way back to the debugger, because the debugger's own `$SIG{INT}` handler doesn't understand that it needs to raise an exception to *longjmp*(3) out of slow syscalls.

`AutoTrace`
: Sets the trace mode (similar to `t` command, but can be put into `PERLDB_OPTS`).

`LineInfo`
: Assigns the file or pipe to print line number info to. If it is a pipe (say, `| visual_perl_db`), then a short message is used. This is the mechanism used to interact with a slave editor or visual debugger, such as the special *vi* or *emacs* hooks, or the *ddd* graphical debugger.

`inhibit_exit`
: If 0, allows stepping off the end of the program.

`PrintRet`
: Prints return value after `r` command if set (default).

`ornaments`
: Affects screen appearance of the command line (see the online docs for `Term::ReadLine`). There is currently no way to disable ornaments, which can render some output illegible on some displays or with some pagers. This is considered a bug.

`frame`
: Affects printing of messages on entry and exit from subroutines. If `frame & 2` is false, messages are printed on entry only. (Printing on exit might be useful if interspersed with other messages.)

  If `frame & 4`, arguments to functions are printed, plus context and caller info. If `frame & 8`, overloaded `stringify` and `tie`d `FETCH` are enabled on the printed arguments. If `frame & 16`, the return value from the subroutine is printed.

  The length at which the argument list is truncated is governed by the next option.

`maxTraceLen`
: Length to truncate the argument list when the `frame` option's bit 4 is set.

The following options affect what happens with the `V`, `X`, and `x` commands:

`arrayDepth, hashDepth`
: Print only the first *n* elements. If *n* is omitted, all of the elements will be printed.

`compactDump, veryCompact`
: Change the style of array and hash output. If `compactDump` is enabled, short arrays may be printed on one line.

`globPrint`
: Prints contents of typeglobs.

`DumpDBFiles`
: Displays arrays holding debugged files.

`DumpPackages`
: Displays symbol tables of packages.

`DumpReused`
: Displays contents of "reused" addresses.

`quote, HighBit, undefPrint`
: Change the style of string display. The default value for `quote` is `auto`; you can enable double-quotish or single-quotish format by setting it to `"` or `'`, respectively. By default, characters with their high bit set are printed verbatim.

`UsageOnly`
: Instead of showing the contents of a package's variables, with this option enabled, you get a rudimentary per-package memory usage dump based on the total size of the strings found in package variables. Because the package symbol table is used, lexical variables are ignored.

Unattended Execution

During startup, options are initialized from `$ENV{PERLDB_OPTS}`. You may place the initialization options `TTY`, `noTTY`, `ReadLine`, and `NonStop` there.

If your init file contains:

```
parse_options("NonStop=1 LineInfo=tperl.out AutoTrace");
```

then your program will run without human intervention, putting trace information into the file *db.out*. (If you interrupt it, you'd better reset `LineInfo` to */dev/tty* if you expect to see anything.)

The following options can be specified only at startup. To set them in your init file, call `parse_options("`*`OPT=VAL`*`")`.

`TTY`
: The terminal to use for debugging I/O.

`noTTY`
: If set, the debugger goes into `NonStop` mode and will not connect to a terminal. If interrupted (or if control goes to the debugger via explicit setting of `$DB::signal` or `$DB::single` from the Perl program), it connects to a terminal specified in the `TTY` option at startup, or to a terminal found at runtime using the `Term::Rendezvous` module of your choice.

  This module should implement a method named `new` that returns an object with two methods: `IN` and `OUT`. These should return filehandles for the debugger to use as input and output. The `new` method should inspect an argument containing the value of `$ENV{PERLDB_NOTTY}` at startup, or */tmp/perldbtty$$* otherwise. This file is not inspected for proper ownership or wide-open write access, so security hazards are theoretically possible.

`ReadLine`
: If false, `ReadLine` support in the debugger is disabled in order to debug applications that themselves use a `ReadLine` module.

`NonStop`
: If set, the debugger goes into noninteractive mode until interrupted, or your program sets `$DB::signal` or `$DB::single`.

Options can sometimes be uniquely abbreviated by the first letter, but we recommend that you always spell them out in full, for legibility and future compatibility.

Here's an example of using the `PERLDB_OPTS` environment variable to set options automatically.[1] It runs your program noninteractively, printing information on each entry into a subroutine and for each line executed. Output from the debugger's trace are placed into the *tperl.out* file. This lets your program still use its regular standard input and output, without the trace information getting in the way.

```
$ PERLDB_OPTS="NonStop frame=1 AutoTrace LineInfo=tperl.out" perl -d myprog
```

If you interrupt the program, you'll need to quickly reset to `O LineInfo=/dev/tty`, or whatever makes sense on your platform. Otherwise, you won't see the debugger's prompting.

Debugger Support

Perl provides special debugging hooks at both compile time and runtime for creating debugging environments such as the standard debugger. These hooks are not to be confused with the *perl –D* options, which are usable only if your Perl was built with *–DDEBUGGING* support.

For example, whenever you call Perl's built-in `caller` function from the package `DB`, the arguments that the corresponding stack frame was called with are copied to the `@DB::args` array. When you invoke Perl with the `-d` switch, the following additional features are enabled:

- Perl inserts the contents of `$ENV{PERL5DB}` (or `BEGIN {require 'perl5db.pl'}` if not present) before the first line of your program.
- The array `@{"_<$filename"}` holds the lines of `$filename` for all files compiled by Perl, as well as for `eval`ed strings that contain subroutines or are currently

1. We're using *sh* shell syntax to show environment variable settings. Users of other shells should adjust accordingly.

being executed. The `$filename` for `eval`ed strings looks like `(eval 34)`. Code assertions in regular expressions look like `(re_eval 19)`.

- The hash `%{"_<$filename"}` contains breakpoints and actions keyed by line number. You can set individual entries as opposed to the whole hash. Perl only cares about Boolean truth here, although the values used by *perl5db.pl* have the form `"$break_condition\0$action"`. Values in this hash are magical in numeric context: they are zeros if the line is not breakable.

  The same holds for evaluated strings that contain subroutines or are currently being executed. The `$filename` for `eval`ed strings looks like `(eval 34)` or `(re_eval 19)`.
- The scalar `${"_<$filename"}` contains `"_<$filename"`. This is also the case for evaluated strings that contain subroutines or are currently being executed. The `$filename` for `eval`ed strings looks like `(eval 34)` or `(re_eval 19)`.
- After each `require`d file is compiled, but before it is executed, `DB::postponed(*{"_<$filename"})` is called if the subroutine `DB::postponed` exists. Here, the `$filename` is the expanded name of the `require`d file, as found in the values of `%INC`.
- After each subroutine *`subname`* is compiled, the existence of `$DB::postponed{`*`subname`*`}` is checked. If this key exists, `DB::postponed(`*`subname`*`)` is called if the `DB::postponed` subroutine also exists.
- A hash `%DB::sub` is maintained, whose keys are subroutine names and whose values have the form *`filename`*`:`*`startline-endline`*. *`filename`* has the form `(eval 34)` for subroutines defined inside `eval`s, or `(re_eval 19)` for those within regular expression code assertions.
- When the execution of your program reaches a point that might hold a breakpoint, the `DB::DB` subroutine is called if any of the variables `$DB::trace`, `$DB::single`, or `$DB::signal` is true. These variables are not `local`izable. This feature is disabled when executing inside `DB::DB`, including functions called from it, unless `$^D & (1<<30)` holds true.
- When execution of the program reaches a subroutine call, a call to `&DB::sub(`*`args`*`)` is made instead, with `$DB::sub` holding the name of the called subroutine. This doesn't happen if the subroutine was compiled in the `DB` package.

Note that if `&DB::sub` needs external data for it to work, no subroutine call is possible until this is done. For the standard debugger, the `$DB::deep` variable (how many levels of recursion deep into the debugger you can go before a mandatory break) gives an example of such a dependency.

Writing Your Own Debugger

The minimal working debugger consists of one line:

```
sub DB::DB {}
```

which, since it does nothing whatsoever, can easily be defined via the `PERL5DB` environment variable:

```
$ PERL5DB="sub DB::DB {}" perl -d your-program
```

Another tiny, slightly more useful debugger could be created like this:

```
sub DB::DB {print ++$i; scalar <STDIN>}
```

This little debugger would print the sequential number of each encountered statement and would wait for you to hit a newline before continuing.

The following debugger, small though it may appear, is really quite functional:

```
{
    package DB;
    sub DB  {}
    sub sub {print ++$i, " $sub\n"; &$sub}
}
```

It prints the sequential number of the subroutine call and the name of the called subroutine. Note that `&DB::sub` must be compiled from the package `DB`, as we've done here.

If you base your new debugger on the current debugger, there are some hooks that can help you customize it. At startup, the debugger reads your init file from the current directory or your home directory. After the file is read, the debugger reads the `PERLDB_OPTS` environment variable and parses this as the remainder of an `O ...` line such as you might enter at the debugger prompt.

The debugger also maintains magical internal variables, such as `@DB::dbline` and `%DB::dbline`, which are aliases for `@{"::_<`*`current_file`*`"}` `%{"::_<`*`current_file`*`"}`. Here, *`current_file`* is the currently selected file, either explicitly chosen with the debugger's `f` command or implicitly by flow of execution.

Some functions can help with customization. `DB::parse_options(`*`STRING`*`)` parses a line like the `O` option. `DB::dump_trace(`*`SKIP`*`[, `*`COUNT`*`])` skips the specified number of frames and returns a list containing information about the calling frames (all of them, if *`COUNT`* is missing). Each entry is a reference to a hash with keys "`context`" (either `.`, `$`, or `@`), "`sub`" (subroutine name or info about `eval`), "`args`" (`undef` or a reference to an array), "`file`", and "`line`". `DB::print_trace(`*`FH, SKIP`*`[, `*`COUNT`*`[, `*`SHORT`*`]])` prints formatted info about caller frames to the supplied

filehandle. The last two functions may be convenient as arguments to the debugger's `<` and `<<` commands.

You don't need to learn all that—most of us haven't. In fact, when we need to debug a program, we usually just insert a few `print` statements here and there and rerun the program.

On our better days, we'll even remember to turn on warnings first. That often spotlights the problem right away, thus saving a great deal of wear and tear on our hair (what's left of it). But when that doesn't work, it's nice to know that, waiting for you patiently behind that `-d` switch, there is a lovely debugger that can do darn near anything *except* find your bug for you.

But if you're going to remember one thing about customizing the debugger, perhaps it is this: don't limit your notion of bugs to things that make Perl unhappy. It's also a bug if your program makes *you* unhappy. Earlier, we showed you a couple of really simple custom debuggers. In the next section, we'll show you an example of a different sort of custom debugger, one that may (or may not) help you debug the bug known as "Is this thing ever gonna finish?"

Profiling Perl

As we write this, Perl comes with a profiler called `Devel::DProf`. However, by the time you read this, it might be gone. Perl v5.16, which is scheduled for release around the same time this book hits the shelves, removes this old profiler. Most people using a profiler have moved on to another profiler, `Devel::NYTProf`. We'll tell you about `Devel::DProf` since it's still in Perl, but we'll also tell you about the new one, which doesn't come with Perl.

These profilers are not lightweight, and they aren't your only options for a profiler. CPAN also holds `Devel::SmallProf`, which reports the time spent in each line of your program. That can help you figure out if you're using some particular Perl construct that is being surprisingly expensive. Most of the built-in functions are pretty efficient, but it's easy to accidentally write a regular expression whose overhead increases exponentially with the size of the input. See also the section "Efficiency" on page 691 in Chapter 21 for other helpful hints.

Devel::DProf

Do you want to make your program faster? Well, of course you do. But first you should stop and ask yourself, "Do I really need to spend time making this

program faster?" Recreational optimization can be fun,[2] but normally there are better uses for your time. Sometimes you just need to plan ahead and start the program when you're going on a coffee break (or use it as an excuse for one). But if your program absolutely must run faster, you should begin by profiling it. A profiler can tell you which parts of your program take the most time to execute, so you won't waste time optimizing a subroutine that has an insignificant effect on the overall execution time.

Perl comes with a profiler, the `Devel::DProf` module. You can use it to profile the Perl program in *mycode.pl* by typing:

```
% perl -d:DProf mycode.pl
```

Even though we've called it a profiler—since that's what it does—the mechanism `DProf` employs is the very same one we discussed earlier in this chapter. `DProf` is just a debugger that records the time Perl entered and left each subroutine.

When your profiled script terminates, `DProf` will dump the timing information to a file called *tmon.out*. The *dprofpp* program that came with Perl knows how to analyze *tmon.out* and produce a report. You may also use *dprofpp* as a frontend for the whole process with the `-p` switch (described later).

Given this program:

```
outer();

sub outer {
  for (my $i=0; $i< 100; $i++) { inner() }
}

sub inner {
  my $total = 0;
  for (my $i=0; $i< 1000; $i++) { $total += $i }
}

inner();
```

the output of *dprofpp* is:

```
Total Elapsed Time = 0.537654 Seconds
  User+System Time = 0.317552 Seconds
Exclusive Times
%Time ExclSec CumulS #Calls sec/call Csec/c  Name
 85.0   0.270  0.269    101   0.0027 0.0027  main::inner
 2.83   0.009  0.279      1   0.0094 0.2788  main::outer
```

2. Or so says Nathan Torkington, who contributed this section of the book.

Note that the percentage numbers don't add up to 100. In fact, in this case, they're pretty far off, which should tip you off that you need to run the program longer. As a general rule, the more profiling data you can collect, the better your statistical sample. If we increase the outer loop to run 1,000 times instead of 100 times, we'll get more accurate results:

```
Total Elapsed Time = 2.875946 Seconds
  User+System Time = 2.855946 Seconds
Exclusive Times
%Time ExclSec CumulS #Calls sec/call Csec/c  Name
 99.3   2.838  2.834   1001   0.0028 0.0028  main::inner
 0.14   0.004  2.828      1   0.0040 2.8280  main::outer
```

The first line reports how long the program took to run, from start to finish. The second line displays the total of two different numbers: the time spent executing your code ("user") and the time spent in the operating system executing system calls made by your code ("system"). (We'll have to forgive a bit of false precision in these numbers—the computer's clock almost certainly does not tick every millionth of a second. It might tick every hundredth of a second if you're lucky.)

The "user+system" times can be changed with command-line options to *dprofpp*. `-r` displays elapsed time, `-s` displays system time only, and `-u` displays user time only.

The rest of the report is a breakdown of the time spent in each subroutine. The "Exclusive Times" line indicates that when subroutine `outer` called subroutine `inner`, the time spent in `inner` didn't count toward `outer`'s time. To change this, causing `inner`'s time to be counted toward `outer`'s, give the `-I` option to *dprofpp*.

For each subroutine, the following is reported: `%Time`, the percentage of time spent in this subroutine call; `ExclSec`, the time in seconds spent in this subroutine not including those subroutines called from it; `CumulS`, the time in seconds spent in this subroutine and those called from it; `#Calls`, the number of calls to the subroutine; `sec/call`, the average time in seconds of each call to the subroutine not including those called from it; `Csec/c`, the average time in seconds of each call to the subroutine and those called from it.

Of those, the most useful figure is `%Time`, which will tell you where your time goes. In our case, the `inner` subroutine takes the most time, so we should try to optimize that subroutine or find an algorithm that will call it less. `:-)` Options to *dprofpp* provide access to other information or vary the way the times are calculated. You can also make *dprofpp* run the script for you in the first place, so you don't have to remember the *–d:DProf* switch:

–p SCRIPT
: Tells *dprofpp* that it should profile the given *SCRIPT* and then interpret its profile data. See also `-Q`.

–Q
: Used with `-p` to tell *dprofpp* to quit after profiling the script, without interpreting the data.

–a
: Sorts output alphabetically by subroutine name rather than by decreasing percentage of time.

–R
: Counts anonymous subroutines defined in the same package separately. The default behavior is to count all anonymous subroutines as one, named `main::__ANON__`.

–I
: Displays all subroutine times inclusive of child subroutine times.

–l
: Sorts by number of calls to the subroutines. This may help identify candidates for inlining.

–O COUNT
: Shows only the top *COUNT* subroutines. The default is 15.

–q
: Does not display column headers.

–T
: Displays the subroutine call tree to standard output. Subroutine statistics are not displayed.

–t
: Displays the subroutine call tree to standard output. Subroutine statistics are not displayed. A function called multiple (consecutive) times at the same calling level is displayed once, with a repeat count.

–S
: Produces output structured by the way your subroutines call one another:

```
main::inner x 1         0.008s
main::outer x 1         0.467s = (0.000 + 0.468)s
  main::inner x 100     0.468s
```

  Read this as follows: the top level of your program called `inner` once, and it ran for 0.008s elapsed time; the top level called `outer` once, and it ran for 0.467s inclusively (0s in `outer` itself; 0.468s in the subroutines called from `outer`), calling `inner` 100 times (which ran for 0.468s). Whew, got that?

  Branches at the same level (for example, `inner` called once and `outer` called once) are sorted by inclusive time.

–U
: Does not sort. Displays in the order found in the raw profile.

–v
: Sorts by average time spent in subroutines during each call. This may help identify candidates for hand optimization by inlining subroutine bodies.

–g subroutine
: Ignores subroutines except *subroutine* and whatever is called from it.

Other options are described in *dprofpp*(1), its standard manpage.

Devel::NYTProf

The `Devel::NYTProf` module started at the *New York Times* by Adam Kaplan, although it's currently maintained outside the *Times* now. It's fast (written in C), it's powerful, and it makes nice reports. It's the fastest statement and subroutine profiler available, and we don't have enough room to tell you all of the wonderful things about it. Download it from CPAN, and then use it just like the other debuggers:

```
% perl -d:NYTProf your_program
```

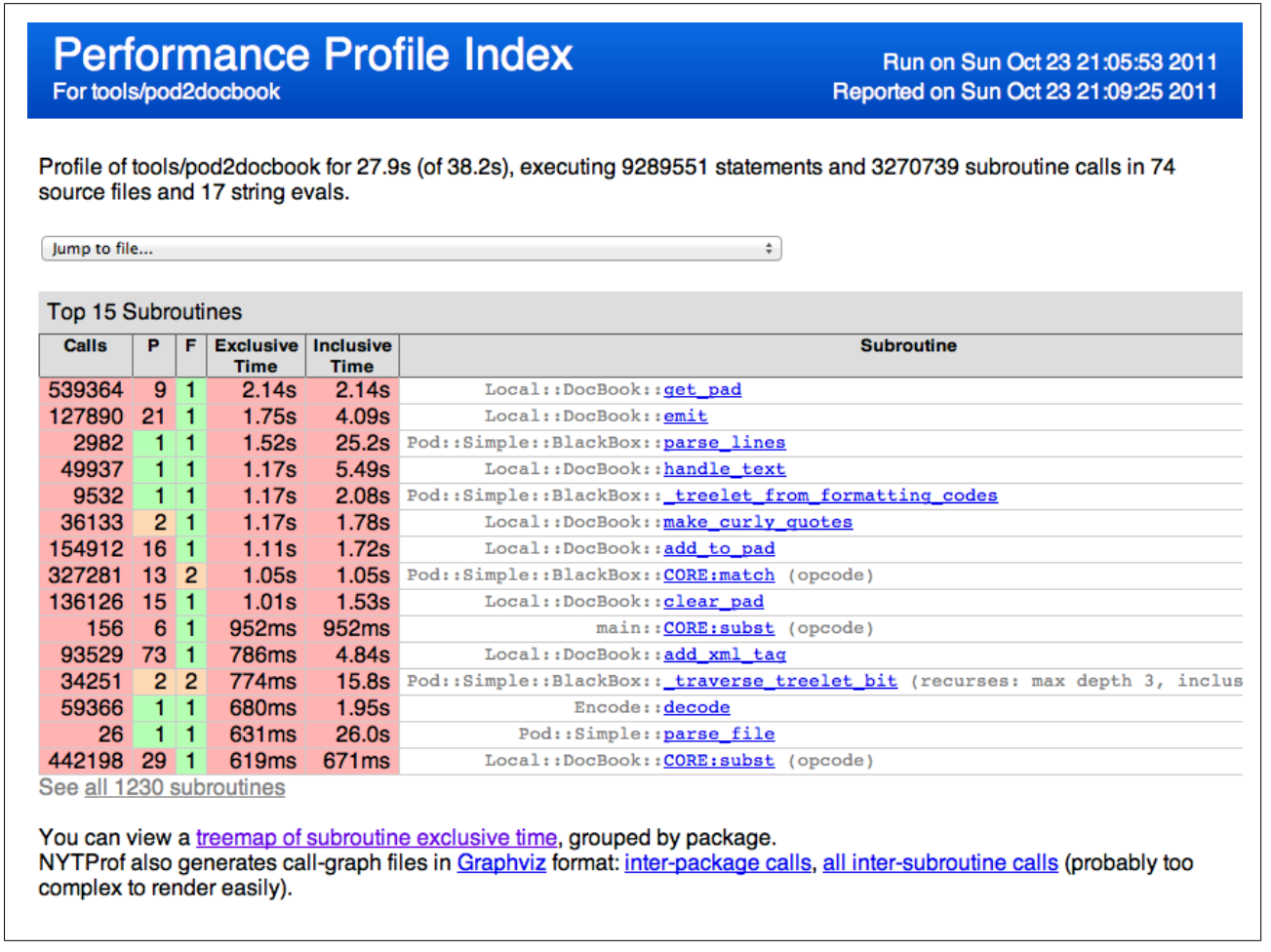
Once finished, you can inspect the results as HTML files. The first HTML file (Figure 18-1) is the summary:

```
% nytprofhtml --open
```

You can set various options in the `NYTPROF` environment variable. For instance, you can tell the profiler when to start: right away, at the `INIT` phase, or at the beginning of the `END`:

```
% env NYTPROF=start=init perl -d:NYTProf your_program
```

See the module documentation for more details. Now go take that coffee break. You'll need it for the next chapter.



Performance Profile Index

For tools/pod2docbook

Run on Sun Oct 23 21:05:53 2011
Reported on Sun Oct 23 21:09:25 2011

Profile of tools/pod2docbook for 27.9s (of 38.2s), executing 9289551 statements and 3270739 subroutine calls in 74 source files and 17 string evals.

Jump to file...

Top 15 Subroutines

Calls	P	F	Exclusive Time	Inclusive Time	Subroutine
539364	9	1	2.14s	2.14s	Local::DocBook::get_pad
127890	21	1	1.75s	4.09s	Local::DocBook::emit
2982	1	1	1.52s	25.2s	Pod::Simple::BlackBox::parse_lines
49937	1	1	1.17s	5.49s	Local::DocBook::handle_text
9532	1	1	1.17s	2.08s	Pod::Simple::BlackBox::_treelet_from_formatting_codes
36133	2	1	1.17s	1.78s	Local::DocBook::make_curly_quotes
154912	16	1	1.11s	1.72s	Local::DocBook::add_to_pad
327281	13	2	1.05s	1.05s	Pod::Simple::BlackBox::CORE:match (opcode)
136126	15	1	1.01s	1.53s	Local::DocBook::clear_pad
156	6	1	952ms	952ms	main::CORE:subst (opcode)
93529	73	1	786ms	4.84s	Local::DocBook::add_xml_tag
34251	2	2	774ms	15.8s	Pod::Simple::BlackBox::_traverse_treelet_bit (recurses: max depth 3, inclus
59366	1	1	680ms	1.95s	Encode::decode
26	1	1	631ms	26.0s	Pod::Simple::parse_file
442198	29	1	619ms	671ms	Local::DocBook::CORE:subst (opcode)

See all 1230 subroutines

You can view a treemap of subroutine exclusive time, grouped by package.
NYTProf also generates call-graph files in Graphviz format: inter-package calls, all inter-subroutine calls (probably too complex to render easily).

Figure 18-1. The starting page for the HTML view of NYTProf

CHAPTER 19
CPAN

CPAN started as a repository of Perl software and has turned into a loose collection of services built around that repository. When people say "CPAN", they might be talking about any one of these things since people conflate anything that connects to this central repository.

History

Toward the end of 1993, Tim Bunce, Jarkko Hietaniemi, and Andreas König set up the perl-packrats mailing list to discuss the idea of an archive for all the Perl 4 stuff floating around the Internet. Perl 5 development had started that year, and one of its main features would be an extensible module system that would allow people to extend the language without changing *perl*. Jared Rhine suggested the idea of a central repository, but nothing much happened. His idea had come from CTAN, the Comprehensive TeX Archive Network.

A couple of years later, Jarkko resurrected the idea and set up an FTP archive at *ftp://ftp.cpan.org*. Soon after, Andreas König set up PAUSE, the Perl Authors Upload Server, to provide a way for people to contribute to this repository. The parts that most people think of as "CPAN", the modules, are really just two directories that CPAN mirrors from PAUSE. There's a lot more to CPAN though.

Other services mirrored the master CPAN site to provide quick and easy access across the globe. There are now about 300 public mirrors across six continents. Anyone can mirror all of CPAN to create a new public mirror, or even create a private mirror for their own use.[1]

As CPAN became popular, other projects developed around it. Graham Barr added a search interface at *http://search.cpan.org*. Barbie built up the idea of CPAN

1. See "How to mirror CPAN" at *http://www.cpan.org/misc/how-to-mirror.html*.

Testers to test every distribution on CPAN. David Cantrell developed CPANdeps to combine the test results of a distribution with all of its dependencies. Moritz Onken created a second-generation search and aggregation site with MetaCPAN as part of a Google Summer of Code project. There are many other services built around the actual CPAN, which is just that central repository.

A Tour of the Repository

Most files on CPAN come from PAUSE, which provides the *authors* and *modules* directories. There's more to CPAN than just the modules. Here's a short tour of the more interesting parts.

authors
: This directory, mirrored from PAUSE, contains numerous subdirectories, arranged by the author ID of the contributor under the id subdirectory. The first level of directories is the first letter in the author ID, the second level is the first two letters, and the final level is the full author ID. For instance, for the author NANIS (Sinan Ünür), the path under *authors* is *id/N/NA/NANIS*. Under that directory is everything Sinan has uploaded—but not removed; see BackPAN.

  Some authors have a directory with their full name, such as *Hugo_van_der_Sanden*. The *authors* directory had a flatter structure when there weren't that many authors. As CPAN became more popular—there are now over 9,000 registered authors—PAUSE partitioned the author names into the three-level structure.

doc
: This directory is used to hold the Perl documentation, as well as various commentary on it, but it is no longer maintained. There's still some interesting material in there, but it's no longer the main source of Perl information. For online documentation, use *http://perldoc.perl.org* for the core Perl information or one of the Perl module sites for module documentation.

modules
: Curiously, this directory is not where you find the module, but all of the special index files that the CPAN clients use to turn a package name, such as `Mojolicious`, into its path under *authors*—in this case, *authors/id/S/SR/SRI/Mojolicious-1.99.tar.gz* (or wherever the latest `Mojolicious` distribution is).

  There are also subdirectories, like *by-module*, that organize the distributions by name instead of author. These are symlinks into the *authors* directory where the actual files are.

There is also a *by-category* directory, which is not of much use these days. Before CPAN had so many thousands of distributions, the CPAN librarians wanted to categorize every module so you could navigate through categories[2] to find the module that you'd want. Searching directly turned out to be much more popular than roaming the virtual stacks of CPAN, so the "Module List" fell into disrepair and went out of date quickly. Part of this relied on authors registering and categorizing their contributions to PAUSE, but not so many people do that anymore.

ports

This directory contains the source code and sometimes also precompiled executable images of Perl ports to operating systems that are not directly supported in the standard distribution, or for which compilers are mercilessly hard to come by. These ports are the individual efforts of their respective authors, and they may not all function precisely as described in this book. These days, few systems should require special ports. The index document of this directory is interesting to look through anyway, because it includes information detailing when each system vendor began shipping Perl as part of their standard installation.

scripts

This directory contains a small collection of diverse Perl programs, largely a hold-over from the time when people distributed standalone programs. Authors included their programs in the *scripts* section by including special pod headings in their program documentation. Alas, almost no one does this anymore. Now people upload programs as part of a normal Perl module distribution, commonly in the `App::` namespace. CPAN is not particularly script-friendly; it's more module-friendly.

src This is where you will find the source code for the standard Perl distribution. Actually, for two standard Perl distributions—one is marked *maint* and the other *devel*. There are two tracks of Perl development. One, *maint*, is the one you should use for real work. The *devel* branch is experimental, where the Perl developers try out new features, new code, and other things that might be too broken for stable use.

To know which is which, look at the version number, such as 5.14.2. The first number is the major version, meaning Perl v5. The second number is the minor version.[3] If that minor number is even, it's a maintenance version. So

2. Does anyone remember Yahoo! before search was the big thing?

3. This is not *minor* in scope. This is the number for the big releases. One way to think about this is to consider "Perl 5" is the language, and the next number is the major release.

distributions with 5.10.1, 5.12.4, and 5.14.2 are stable releases because 10, 12, and 14 are even numbers. If the minor number is odd, like 5.15.3, it's an experimental version because 15 is odd.

There are two links in this directory that will always produce the latest versions despite the actual versions. The latest.tar.gz and maint.tar.gz point to the most recent release in the most recent maintenance branch.[4] The CPAN maintainers discourage the use of these terms because some people don't understand what they point to.

Creating a MiniCPAN

You can mirror CPAN yourself, but as we write this, you'd have to sync 24,000 distributions taking up 13 GB of disk space. Since PAUSE only indexes the latest distributions, you probably won't need most of those distributions. For most uses, you'll probably only ever install the latest versions. Because of this, in 2002, Randal Schwartz created *minicpan* and wrote about it in *Linux Magazine*.[5]. He reduced his local CPAN footprint by 80%, and brian d foy coined the term Schwartz Factor to measure that reduction.

The `CPAN::Mini` distribution has the tools you need. This module is not part of the Standard Library, so you have to install it yourself (see later in this chapter).

First, set up your configuration, noting from where you want to fetch new data and where you want to store it:

```
local: /Users/Amelia/MINICPAN
remote: http://cpan.example.com/
```

Running *minicpan* creates the slim repository:

```
% minicpan
Using config from /Users/Amelia/.minicpanrc
Updating /Users/Amelia/MINICPAN
Mirroring from http://cpan.example.com/
============================================================
authors/01mailrc.txt.gz ... updated
modules/02packages.details.txt.gz ... updated
modules/03modlist.data.gz ... updated
authors/id/A/AA/AAR/Math-Clipper-1.01.tar.gz ... updated
authors/id/A/AA/AAR/CHECKSUMS ... updated
```

4. The Perl developers officially support the last two maintenance versions. If the current release is Perl v5.16, that means v5.14 is officially supported but v5.12 has no official support. See *perlpolicy* for the details.

5. See *http://www.stonehenge.com/merlyn/LinuxMag/col42.html*.

Point your CPAN clients at this repository, and you can now install modules even if you are on a train, plane, or automobile, in the middle of the Black Rock Desert, or even in a power outage. Well, until your battery runs out.

You can minutely control what you sync, although you need to write your own *minicpan* program to use these controls. The `module_filters` and `path_filters` let you use regular expressions or subroutine references to note which modules or authors to skip. A matched pattern or a subroutine that returns true makes `CPAN::Mini` skip that distribution:

```
use CPAN::Mini;

CPAN::Mini->update_mirror(
    remote         => "http://cpan.mirrors.comintern.su",
    local          => "/usr/share/mirrors/cpan",
    force          => 0,
    module_filters => [ qr/Acme/i ],
    path_filters   => [
        qr/RJBS/,
        sub { $_[0] =~ /SUNGO/ }
    ],
);
```

The CPAN Ecosystem

CPAN really is a network of services, with several steps between the person who uploads the distribution to the person who installs it. This chapter doesn't go through everything out there; it merely highlights the main parts.

PAUSE

PAUSE is the gateway to CPAN for contributors. Before you can upload anything, you need an account. It's free and easy. One of the PAUSE administrators will check your application, mostly as just a check against bots, and then set up the account.

Once you have the account, you can upload your work to PAUSE. You can upload almost anything that you like. PAUSE doesn't care about what you are doing or how well you do it.

When you upload a distribution, the PAUSE indexer looks through your archive for any Perl namespaces that you might have used. There are no restrictions on which namespaces you can use, but PAUSE keeps a list of people it thinks are authorized to modify a namespace.

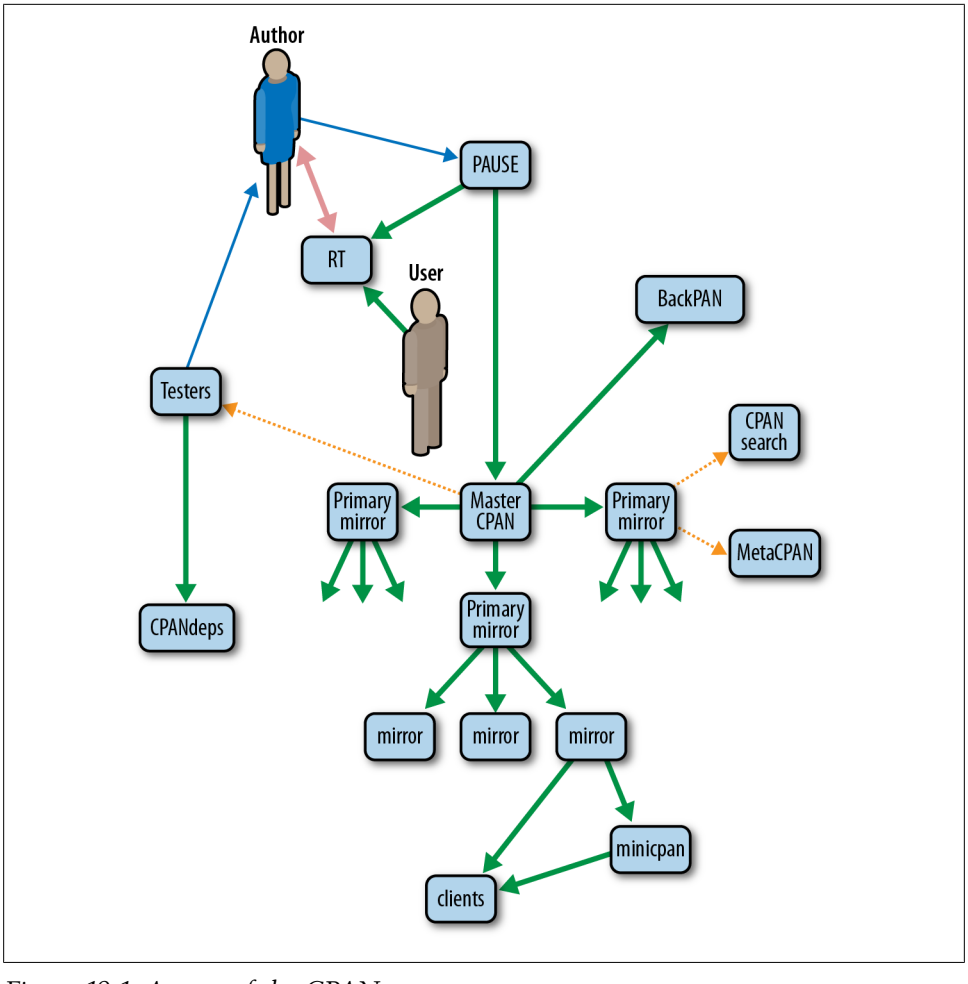


Figure 19-1. A map of the CPAN ecosystem

- The first author to use a namespace gets *first-come* permissions and becomes the *primary maintainer*.
- The *primary maintainer* can assign *co-maintainer* permissions to another author (or many authors).
- The primary maintainer can give up that status to another author.

If you upload a distribution that uses a namespace for which you don't have one of these permissions, the PAUSE indexer refuses to index the module and sends you an error. It still accepts your upload, however, and it will still show up on CPAN. People will be able to download it. However, since the indexer did not index it, your distribution will not show up in the database PAUSE creates. If

your module doesn't show up in the database, the CPAN clients won't know about it and won't be able to install it. PAUSE just skips your distribution, and so does the world.

Searching CPAN

There are two major search sites for CPAN, and both provide similar functionality. These two sites aggregate distribution-specific links to other CPAN projects:

- CPAN Search (*http://search.cpan.org*)
- MetaCPAN (*https://www.metacpan.org*)

Testing

Perl has a great testing culture. As soon as someone uploads a new distribution to PAUSE, a loose confederation of machines of different shapes and sizes known as CPAN Testers (*http://testers.cpan.org*) downloads, builds, and runs their test suites. This group aims to test as many modules as possible on as many possible platforms and versions of Perl as it can find.

This way, the solitary Perl author can develop on a single architecture and, by the mere act of uploading, get results for other architectures and across several versions of Perl. And it's free! Authors can get detailed instructions on making their distribution "Testers-friendly" by reading the CPAN Testers wiki (*http://wiki.cpantesters.org*).

This works out for the users of CPAN modules, too. People can inspect the test reports to see how a particular module fares. David Cantrell's CPANdeps (*http://deps.cpantesters.org*) presents the test reports in a matrix of platforms and Perl versions, and also provides a summary of the test reports for all module dependencies as a "probability of success" for installation.

Bug Tracking

Since Perl and CPAN aren't a single, centralized project, there's no one place to report or read about bugs. Although many people report bugs directly in private email, that doesn't create a public record that everyone can work from, comment on, and potentially fix. Open source can only work if it's open access, and dropping messages into a single person's email isn't open to the whole world to review and inspect.

rt.cpan.org

CPAN, the repository of contributions from thousands of authors all working on their own projects, has a bug tracker, too. Each distribution gets its own queue in the Request Tracker instance at *https://rt.cpan.org*. This is the default way to report a problem with a module.

Other bug tracking

Some module authors prefer to use something other than *https://rt.cpan.org*. Find out what they want by looking in the distribution's documentation. Module authors sometimes include instructions in their module's documentation, but sometimes they don't. Since files such as *README* and *META.yml* are left behind at installation time, looking at those files at one of the CPAN Search sites might help.

perlbug

If you need to report a bug in a module that comes with *perl* itself, you can use the *perlbug* tool. This collects information about your platform and interpreter so the people who diagnose the bugs have the information they'll need to do so. It's really an interface that sends a specially formatted email message to *perlbug@perl.org*, an address you can also mail directly if you'd like. These reports automatically go to Perl 5 Porters. Some modules are *dual-lived*, living both in the *Standard Library* and on CPAN, so it might be a bit tricky to figure out the right place. Don't let that stop you from reporting the problem, though. We'll sort it out.

rt.perl.org

perlbug sends its report to the Request Tracker instance at *https://rt.perl.org*, the same place you'd go to read about existing bugs, including those in modules in the Standard Library. You should also check this site if you don't find anything in *https://rt.cpan.org*.

Installing CPAN Modules

There are two major build systems people use in their CPAN distributions. One is built around the common *make* tool, while the other is pure Perl.

By Hand

People don't often install CPAN distributions by hand since they would have to handle all of the dependencies themselves, which is too much work. You can do it, though, and it's useful to know how.

When you look inside the distribution, you'll probably find a *Makefile.PL* or a *Build.PL*. You use them in the same way, as shown in Table 19-1.

Table 19-1. Build commands for the two major build tools

Makefile.PL	Build.PL
`% perl Makefile.PL`	`% perl Build.PL`
`% make`	`% ./Build`
`% make test`	`% ./Build test`
`% make install`	`% ./Build install`

With the defaults, both build systems try to install the distribution in the library paths you (or someone) set up when they built and installed the *perl* binary you used to run the build file. You can see those directories at the end of the output of *perl –V*.

You may not have permission to write into those directories, but you can install modules in any directory you please by telling build file where to install them. Build files change their behavior based on command-line options or environment variables.

```
% perl Makefile.PL INSTALL_BASE=/some/other/directory

% perl Build.PL --install_base /some/other/directory
```

You don't have to specify the options every time if you set them in the right environment variables. Each build system has an environment variable to hold default command-line options. Here's how you'd do it in a */bin/sh* environment:

```
% export PERL_MM_OPT='INSTALL_BASE=/some/other/directory'
% export PERL_MB_OPT='--install_base /some/other/directory'
```

And here's how to do it using a shell that expects *csh* syntax:

```
% setenv PERL_MM_OPT 'INSTALL_BASE=/some/other/directory'
% setenv PERL_MB_OPT '--install_base /some/other/directory'
```

No matter which method you use to tell the build file where you want everything installed, it attaches *lib/perl5*[6] to the end of whatever path you gave. You need to remember this for the next part.

6. This is really the default. You can change this with *Configure*'s `-Dinstallstyle` when you compile *perl*.

If you install your modules in a different directory, you must remember to tell your programs where to find them, either by using the *–I* switch:

```
% perl -I/some/other/directory/lib/perl5 program.pl
```

or by using the `PERL5LIB` environment variable:

```
% export PERL5LIB=/some/other/directory/lib/perl5
% perl program.pl
```

You can also use the `lib` pragma in your program:

```
use lib qw(/some/other/directory/lib/perl5);
```

If you don't remember these paths, you can use the `local::lib` module from CPAN (it doesn't ship with the standard Perl distribution). Loaded by itself, it tells you which values to use. By default, it uses subdirectories under your home directory:

```
% perl -Mlocal::lib
export PERL_LOCAL_LIB_ROOT="/home/amelia";
export PERL_MB_OPT="--install_base /home/amelia/perl5";
export PERL_MM_OPT="INSTALL_BASE=/home/amelia/perl5";
export PERL5LIB="/home/amelia/perl5/lib/perl5/darwin-2level:/home/amelia/perl5/
lib/perl5";
export PATH="/Users/amelia/perl5/bin:$PATH";
```

Or you can specify another directory:

```
% perl -Mlocal::lib=/some/other/directory
export PERL_LOCAL_LIB_ROOT="/some/other/directory";
export PERL_MB_OPT="--install_base /some/other/directory";
export PERL_MM_OPT="INSTALL_BASE=/some/other/directory";
export PERL5LIB="/some/other/directory/lib/perl5/darwin-2level:/some/other/
directory/lib/perl5";
export PATH="/some/other/directory/bin:$PATH";
```

You must still set up this environment yourself, although simply using `local::lib` in your program will set it up for you:

```
use local::lib;

use local::lib qw(/some/other/directory);
```

CPAN Clients

Most people install their modules with a client.[7] There are three popular CPAN clients, each designed to appeal to different audiences with different needs. You don't have to use the same one all the time or make a lifelong choice.

7. Or they use a package manager that their operating system provides.

cpan

The *cpan* command, which comes with the Standard Library and the `CPAN.pm` module, provides a quick way to install modules. Just specify the modules you want on the command line:

```
% cpan IO::Interactive AnyEvent
```

To install the modules in a different directory, you can configure that. With no arguments, *cpan* drops you into the `CPAN.pm` shell:

```
% cpan
cpan> o conf makepl_arg INSTALL_BASE=/some/other/directory
cpan> o conf mbuild_arg "--install_base /some/other/directory"
cpan> o conf commit
```

You can also start the `CPAN.pm` shell:

```
% perl -MCPAN -e shell
cpan> install POE
```

or use it with `local::lib`:

```
% perl -MCPAN -Mlocal::lib -e shell
cpan> install Set::CrossProduct
```

cpanp

Perl also comes with another CPAN interface, `CPANPLUS`. This project wanted to take the lessons from the development of `CPAN.pm` and start over:

```
% cpanp -i IO::Interactive AnyEvent
```

You can also start the `CPANPLUS` shell:

```
% perl -MCPANPLUS -e shell
CPAN Terminal> install POE
```

`CPANPLUS` uses a menu-driven configuration system, so once you enter its shell, just follow its prompts.

cpanminus

A third popular client that you might like if you like its defaults is *cpanminus*, or just *cpanm*. This is a minimal client that strives to do the right thing for most people. It also uses `local::lib` by default. Most people like this client, and it's a good one to use until you need something fancier.

Since *cpanm* wants to be easy to use, it doesn't require you to install other modules to use it.[8] You just download it and start using it. The cpanm docs demonstrate this using *curl*,[9] then pipe that directory to *perl* to turn it into *cpanm*. This is the preferred way because *cpanm* can pick up the configuration from the *perl* binary you actually use:

```
% curl -L http://cpanmin.us | perl - App::cpanminus
```

Or you can download it, save it as *cpanm*, and run it. On Unix, that's (essentially) the same as saving the result and making it executable, although in this case it uses */usr/bin/env* to find the first *perl* in your path:

```
% cd ~/bin
% curl -LO http://xrl.us/cpanm
% chmod +x cpanm
```

Once you have *cpanm*, tell it to install modules, like this:

```
% cpanm HTML::Barcode
```

Creating CPAN Distributions

This is a short introduction for creating CPAN distributions. Entire books can be written on this.[10] *Intermediate Perl*, one of the O'Reilly tutorial books for Perl, covers this topic in much more detail.

Starting Your Distribution

Since the start of CPAN long ago, best practices and standard conventions in using CPAN have settled, so now pretty much everyone agrees on what a good distribution needs to have. You don't have to start from scratch if you use tools to create the distribution skeleton for you.

h2xs

The canonical distribution creation tool isn't really a distribution-creation tool. By its name, it's designed to convert C header files into XS files, the glue language that connects Perl to C. It's grown since then, even to the point that most people use it without its main feature:

8. Some people think the Standard Library is really just a starter kit so you can run *cpan* or *cpanp*. We'll see how it turns out in future versions, and this is one of the topics that will liven up any dull meeting of Perl mongers. Mention it and step back to watch the carnage.

9. curl is a command-line tool for transferring data (*http://curl.haxx.se*).

10. And an entire book has been written on creating CPAN modules: Sam Tregar's *Writing Perl Modules for CPAN*, published by Apress.

```
% h2xs -XAn Some::Module
Defaulting to backward compatibility with perl 5.14.2

Writing Some-Module/lib/Some/Module.pm
Writing Some-Module/Makefile.PL
Writing Some-Module/README
Writing Some-Module/t/Some-Module.t
Writing Some-Module/Changes
Writing Some-Module/MANIFEST
```

Distribution::Cooker

`Distribution::Cooker` module is the least sophisticated of the distribution-creation tools, designed for the people who don't need much.[11] It cooks a directory of templates, meaning you can design your distribution any way you like and then replicate it. Once you get things the way you like, you don't need to modify the other tools' output each time. Indeed, the best way to use this tool is to start with another tool, modify the output until you like what you have, then design a corresponding template.

Module::Starter

`Module::Starter` is the best tool for people who don't know what they want yet. You start with a configuration file in *${HOME}/.module-starter/config* so you don't have to type as much:

```
author: Amelia Camel
email: amelia@example.com
builder: Module::Build
verbose: 1
```

Then, when you run *module–starter*, you get a basic distribution structure:

```
% module-starter --module=Some::Module2
Created Some-Module
Created Some-Module/lib/Some
Created Some-Module/lib/Some/Module2.pm
Created Some-Module/t
Created Some-Module/t/pod-coverage.t
Created Some-Module/t/pod.t
Created Some-Module/t/manifest.t
Created Some-Module/t/boilerplate.t
Created Some-Module/t/00-load.t
Created Some-Module/ignore.txt
Created Some-Module/Build.PL
Created Some-Module/Changes
Created Some-Module/README
```

11. `Distribution::Cooker` only makes it into this book because one of this book's authors wrote it and uses it.

```
Created Some-Module/MANIFEST
Created starter directories and files
```

Notice the test file *Some-Module/t/boilerplate.t*. That's there to check that you changed some of the defaults, such as the description of the module.

Dist::Zilla

`Dist::Zilla` is a sophisticated tools that does much more than merely create the initial distribution. It manages the entire life cycle of your module from the moment of conception through release, testing, bug fixing, and rereleasing. It's much more complicated than we have time to explain, but many people like it.

Testing Your Modules

Perl's testing culture is one of its most compelling features. We've already told you about CPAN Testers, the people who test all CPAN distributions on a variety of platforms. As an author, it's up to you to create your own tests. We're not going to tell you everything involved with that, because it's already extensively covered in other titles such as *Intermediate Perl* and *Perl Testing: A Developer's Notebook*.

Internal testing

If you are using either of the two standard distribution build tools, you already have a test harness in place. You run the *test* target:

```
% make test

% ./Build test
```

Those both do the same thing: they look for either a *test.pl* file or a *t/* directory. Using a *test.pl* file is the old way, in which just one file holds all tests. Using a *t/* subdirectory is a better approach because it can hold multiple test files, each one ending with *.t*, and the test harness runs all of the subtests.

Each test file is just a Perl program, most likely using `Test::More` to do the work. Here's an example test file that loads your `Math::MySum` module and tests its `my_sum` method:

```
use strict;
use warnings;
use Test::More;

BEGIN { use_ok( "Math::MySum" ) }
can_ok( "Math::MySum", "my_sum" );

my($i, $j) = (1, 3);
my $string = "Amelia";
```

```
is($i + $j, Math::MySum->my_sum( $i, $j ),
    "Sum of $i and $j is 4");

like($string, qr/mel/, "String has mel in it");

done_testing;
```

These programs output TAP (Test Anywhere Protocol), a simple format that Larry invented and others extended.[12] The TAP output for this program looks like:

```
ok 1 - use Math::MySum;
ok 2 - Math::MySum->can('my_sum')
ok 3 - Sum of 1 and 3 is 4
ok 4 - String has mel in it
1..4
```

You can also run tests individually using the `blib` module to automatically add the build libraries to `@INC`:

```
% perl -Mblib t/failingtest.t
```

You can also use the *prove* tool:

```
% prove -vb t/failingtest.t
```

The trick with any test suite is testing all code. Since you're the author of both the module and its tests, you could easily pass your tests by not covering the hard parts. To check that, the `Devel::Cover` module provides a *cover* program you can use to measure your test coverage:

```
% cover -test
```

The *cover* command runs the test suite for you, collects statistics, and produces a report:

```
Reading database from ./cover_db

---------------------------- ------ ------ ------ ------ ------ ------
File                          stmt   bran   cond    sub   time  total
---------------------------- ------ ------ ------ ------ ------ ------
blib/lib/Some/Module.pm       82.9   50.0   27.3   92.3   83.0   72.7
---------------------------- ------ ------ ------ ------ ------ ------

Writing HTML output to ./cover_db/coverage.html ...
done.
```

12. Many other languages have embraced TAP, too. The TAP *producer* doesn't have to be in the same language as the TAP *consumer*.

It measures four sorts of coverage:

statement
: Runs every statement.

branch
: Tests each branch such as in an `if` with several `elsif` blocks, each of which counts as a separate branch.

condition
: Tests each combination of conditions whenever there are multiple possible conditions. For instance, here's such a condition in an `if`:

```
if ($m && $n) { ... }
```

That `if` has three testable combinations: both `$m` and `$n` can each be true; `$m` can be false, in which case it doesn't matter what `$n` is; `$m` can be true, and `$n` can be either true or false. You should test each of those.

subroutine
: Runs every subroutine, which is also part of testing every statement.

External testing

If you upload your distribution to PAUSE, the CPAN Testers will automatically download it, test it, and send you the results. This is handy for testing on platforms and Perl versions you don't have. You don't have to do anything special for this.

That only works for public distributions, though. If you don't plan to release your work to CPAN, you can still do some external testing by setting up your own CPAN Testers system and your own farm of test machines. You use the same tools as the regular CPAN Testers, but you draw your distributions from your private sources.

You can also integrate Perl testing into many continuous integration-testing frameworks, such as *smolder* (especially made for Perl but not limited to it), Hudson, Jenkins, or TeamCity. Any tool that understands TAP, and there are now several, can analyze your test output.

PART IV

Perl as Culture

CHAPTER 20
Security

Whether you're dealing with a user sitting at the keyboard typing commands or someone sending information across the network, you need to be careful about the data coming into your programs. The other person may, either maliciously or accidentally, send you data that will do more harm than good. Perl provides a special security-checking mechanism called *taint mode*, whose purpose is to isolate tainted data so that you won't use it to do something you didn't intend to do. For instance, if you mistakenly trust a tainted filename, you might end up appending an entry to your password file when you thought you were appending to a log file. The mechanism of tainting is covered in the next section, "Handling Insecure Data" on page 648.

In multitasking environments, offstage actions by unseen actors can affect the security of your own program. If you presume exclusive ownership of external objects (especially files) as though yours were the only process on the system, you expose yourself to errors substantially subtler than those that come from directly handling data or code of dubious provenance. Perl helps you out a little here by detecting some situations that are beyond your control; but for those that you can control, the key is understanding which approaches are proof against unseen meddlers. The upcoming section "Handling Timing Glitches" on page 661 discusses these matters.

If the data you get from a stranger happens to be a bit of source code to execute, you need to be even more careful than you would with her data. Perl provides checks to intercept stealthy code masquerading as data so you don't execute it unintentionally. If you do want to execute foreign code, though, the `Safe` module lets you quarantine suspect code where it can't do any harm and might possibly do some good. These are the topics of the section "Handling Insecure Code" on page 668 later in this chapter.

Handling Insecure Data

Perl makes it easy to program securely, even when your program is being used by someone less trustworthy than the program itself. That is, some programs need to grant limited privileges to their users without giving away other privileges. Setuid and setgid programs fall into this category on Unix, as do programs running in various privileged modes on other operating systems that support such notions. Even on systems that don't, the same principle applies to network servers and to any programs run by those servers (such as CGI scripts, mailing list processors, and daemons listed in */etc/inetd.conf*). All such programs require a higher level of scrutiny than normal.

Even programs run from the command line are sometimes good candidates for taint mode, especially if they're meant to be run by a privileged user. Programs that act upon untrusted data, like those that generate statistics from log files or use `LWP::*` or `Net::*` to fetch remote data, should probably run with tainting explicitly turned on; programs that are not prudent risk being turned into "Trojan horses". Since programs don't get any kind of thrill out of risk taking, there's no particular reason for them not to be careful.

Compared with Unix command-line shells, which are really just frameworks for calling other programs, Perl is easy to program securely because it's straightforward and self-contained. Unlike most shell programming languages, which are based on multiple, mysterious substitution passes on each line of the script, Perl uses a more conventional evaluation scheme with fewer hidden snags. Additionally, because the language has more built-in functionality, it can rely less upon external (and possibly untrustworthy) programs to accomplish its purposes.

Under Unix, Perl's hometown, the preferred way to compromise system security was to cajole a privileged program into doing something it wasn't supposed to do. To stave off such attacks, Perl developed a unique approach for coping with hostile environments. Perl automatically enables taint mode whenever it detects its program running with differing real and effective user or group IDs.[1] Even if the file containing your Perl script doesn't have the setuid or setgid bits turned on, that script can still find itself executing in taint mode. This happens if your script was invoked by another program that was *itself* running under differing IDs. Perl programs that weren't designed to operate under taint mode tend to expire prematurely when caught violating safe tainting policy. This is just as well,

1. The setuid bit in Unix permissions is mode 04000, and the setgid bit is 02000; either or both may be set to grant the user of the program some of the privileges of the owner (or owners) of the program. (These are collectively known as set-id programs.) Other operating systems may confer special privileges on programs in other ways, but the principle is the same.

since these are the sorts of shenanigans that were historically perpetrated on shell scripts to compromise system security. Perl isn't that gullible.

You can also enable taint mode explicitly with the `-T` command-line switch. You should do this for daemons, servers, and any programs that run on behalf of someone else, such as CGI scripts. Programs that can be run remotely and anonymously by anyone on the Net are executing in the most hostile of environments. You should not be afraid to say "No!" occasionally. Contrary to popular belief, you can exercise a great deal of prudence without dehydrating into a wrinkled prude.

On the more security-conscious sites, running all CGI scripts under the `-T` flag isn't just a good idea: it's the law. We're not claiming that running in taint mode is sufficient to make your script secure. It's not, and it would take a whole book just to mention everything that would. But if you aren't executing your CGI scripts under taint mode, you've needlessly abandoned the strongest protection Perl can give you.

While in taint mode, Perl takes special precautions called *taint checks* to prevent traps both obvious and subtle. Some of these checks are reasonably simple, such as verifying that dangerous environment variables aren't set and that directories in your path aren't writable by others; careful programmers have always used checks like these. Other checks, however, are best supported by the language itself, and it is these checks especially that contribute to making a privileged Perl program more secure than the corresponding C program, or a Perl CGI script more secure than one written in any language without taint checks. (Which, as far as we know, is any language other than Perl.)

The principle is simple: you may not use data derived from outside your program to affect something else outside your program—at least, not by accident. Anything that comes from outside your program is marked as tainted, including all command-line arguments, environment variables, and file input. Tainted data may not be used directly or indirectly in any operation that invokes a subshell, nor in any operation that modifies files, directories, or processes. Any variable set within an expression that has previously referenced a tainted value becomes tainted itself, even if it is logically impossible for the tainted value to influence the variable. However, using a tainted variable to choose an untainted value does not taint the result. For instance, `$value` is not tainted here:

```
my $value = $tainted ? 'Amelia' : 'Camelia'; # $value is not tainted.
```

or even here:

```
my $value = do {
    if( $tainted ) { 'Amelia'  }
```

```
    else           { 'Camelia' }
};
```

Because taintedness is associated with each scalar, some individual values in an array or hash might be tainted and others might not. (Only the values in a hash can be tainted, though, not the keys. More on that in a moment.)

The following code illustrates how tainting would work if you executed all these statements in order. Statements marked "Insecure" will trigger an exception, whereas those that are "OK" will not.

```
$arg = shift(@ARGV);          # $arg is now tainted (due to @ARGV).
$hid = "$arg, 'bar'";         # $hid also tainted (due to $arg).
$line = <>;                   # Tainted (reading from external file).
$path = $ENV{PATH};           # Tainted due to %ENV, but see below.
$mine = "abc";                # Not tainted.

system "echo $mine";          # Insecure until PATH set.
system "echo $arg";           # Insecure: uses sh with tainted $arg.
system "echo", $arg;          # OK once PATH set (doesn't use sh).
system "echo $hid";           # Insecure two ways: taint, PATH.

$oldpath = $ENV{PATH};        # $oldpath is tainted (due to %ENV).
$ENV{PATH} = "/bin:/usr/bin"; # (Makes it OK to execute other programs.)
$newpath = $ENV{PATH};        # $newpath is NOT tainted.

delete @ENV{qw{IFS
               CDPATH
               ENV
               BASH_ENV}};    # Makes %ENV safer.

system "echo $mine";          # OK, is secure once path is reset.
system "echo $hid";           # Insecure via tainted $hid.

open(OOF, "< $arg");          # OK (read-only opens not checked).
open(OOF, "> $arg");          # Insecure (trying to write to tainted arg).

open(OOF, "echo $arg|")       # Insecure due to tainted $arg, but...
    || die "can't pipe from echo: $!";

open(OOF,"-|")                # Considered OK: see below for taint
    || exec "echo", $arg      #   exemption on exec'ing a list.
    || die "can't exec echo: $!";

open(OOF,"-|", "echo", $arg)  # Same as previous, likewise OKish.
    || die "can't pipe from echo: $!";

$shout = `echo $arg`;         # Insecure via tainted $arg.
$shout = `echo abc`;          # $shout is tainted due to backticks.
$shout2 = `echo $shout`;      # Insecure via tainted $shout.
```

```
unlink $mine, $arg;           # Insecure via tainted $arg.
umask $arg;                   # Insecure via tainted $arg.

exec "echo $arg";             # Insecure via tainted $arg passed to shell.
exec "echo", $arg;            # Considered OK! (But see below.)
exec "sh", "-c", $arg;        # Considered OK, but isn"t really!
```

If you try to do something insecure, you get an exception (which, unless trapped, becomes a fatal error) such as "`Insecure dependency`" or "`Insecure $ENV{PATH}`". See the section "Cleaning Up Your Environment" on page 656 later in this chapter.

If you pass a *`LIST`* to a `system`, `exec`, or pipe `open`, the arguments are not inspected for taintedness, because with a *`LIST`* of arguments, Perl doesn't need to invoke the potentially dangerous shell to run the command. You can still easily write an insecure `system`, `exec`, or pipe `open` using the *`LIST`* form, as demonstrated in the final example above. These forms are exempt from checking because you are presumed to know what you're doing when you use them.

Sometimes, though, you can't tell how many arguments you're passing. If you supply these functions with an array[2] that contains just one element, then it's just as though you passed one string in the first place, so the shell might be used. The solution is to pass an explicit path in the indirect-object slot:

```
system @args;              # Won't call the shell unless @args == 1.
system { $args[0] } @args; # Bypasses shell even with one-argument list.
```

Detecting and Laundering Tainted Data

To test whether a scalar variable contains tainted data, you can use the following `is_tainted` function. It makes use of the fact that `eval` *`STRING`* raises an exception if you try to compile tainted data. It doesn't matter that the `$nada` variable used in the expression to compile will always be empty; it will still be tainted if `$arg` is tainted. The outer `eval` *`BLOCK`* isn't doing any compilation. It's just there to catch the exception raised if the inner `eval` is given tainted data. Since the `$@` variable is guaranteed to be nonempty after each `eval` if an exception was raised and empty otherwise, we return the result of testing whether its length was zero:

```
sub is_tainted {
    my $arg = shift;
    my $nada = substr($arg, 0, 0);  # zero-length
    local $@;  # preserve caller's version
    eval { eval "# $nada" };
    return length($@) != 0;
}
```

2. Or a function that produces a list.

The `Scalar::Util` module, which comes with Perl, already does this for you with `tainted`:

```
use Scalar::Util qw(tainted);

print "Tainted!" if tainted( $ARGV[0] );
```

The `Taint::Util` CPAN module goes one better. It has a `tainted` function that does the same thing, but it also has a `taint` function that will make any data tainted:

```
use Taint::Util qw(tainted taint);

my $scalar = 'This is untainted'; # untainted
taint( $scalar );                 # now tainted
```

This is handy for test scripts when you want to test with tainted data:

```
use Test::More;
use Taint::Util qw(tainted taint);

my $tainted = 'This is untainted'; # untainted
taint( $tainted );                  # now tainted

ok( tainted( $tainted ), 'Data are tainted' );
is( refuse_to_work( $tainted ), undef, 'Returns undef with tainted data' );

done_testing();
```

But testing for taintedness only gets you so far. Usually you know perfectly well which variables contain tainted data, you just have to clear the data's taintedness. The only official way to bypass the tainting mechanism is by referencing submatches returned by an earlier regular expression match.[3] When you write a pattern that contains capturing parentheses, you can access the captured substrings through match variables like `$1`, `$2`, and `$+`, or by evaluating the pattern in list context. Either way, the presumption is that you knew what you were doing when you wrote the pattern to weed out anything dangerous. So you need to give it some real thought—never blindly untaint, or else you defeat the entire mechanism.

It's better to verify that the variable contains only good characters than to check whether it contains any bad characters. That's because it's far too easy to miss bad characters that you never thought of. For example, here's a test to make sure

3. An unofficial way is by storing the tainted string as the key to a hash and fetching back that key. Because keys aren't really full SVs (internal name scalar values), they don't carry the taint property. This behavior may be changed someday, so don't rely on it. Be careful when handling keys, lest you unintentionally untaint your data and do something unsafe with them.

$string contains nothing but "word" characters (alphabetics, numerics, and underscores), hyphens, at signs, and dots:

```
if ($string =~ /^([-\@\w.]+)$/) {
    $string = $1;                       # $string now untainted.
}
else {
    die "Bad data in $string";          # Log this somewhere.
}
```

This renders $string fairly secure to use later in an external command, since /\w+/ doesn't normally match shell metacharacters, nor are those other characters going to mean anything special to the shell.[4] Had we used /(.+)/s instead, it would have been unsafe because that pattern lets everything through. But Perl doesn't check for that. When untainting, be exceedingly careful with your patterns. Laundering data by using regular expressions is the *only* approved internal mechanism for untainting dirty data. And sometimes it's the wrong approach entirely. If you're in taint mode because you're running set-id and not because you intentionally turned on -T, you can reduce your risk by forking a child of lesser privilege; see the section "Cleaning Up Your Environment" later in this chapter.

The use re 'taint' pragma disables the implicit untainting of any pattern matches through the end of the current lexical scope. You might use this pragma if you just want to extract a few substrings from some potentially tainted data, but since you aren't being mindful of security, you'd prefer to leave the substrings tainted to guard against unfortunate accidents later.

Imagine you're matching something like this, where $fullpath is tainted:

```
($dir, $file) = $fullpath =~ m!(.*/)(.*)!s;
```

By default, $dir and $file would now be untainted. But you probably didn't want to do that so cavalierly, because you never really thought about the security issues. For example, you might not be terribly happy if $file contained the string "; rm -rf * ;", just to name one rather egregious example. The following code leaves the two result variables tainted if $fullpath was tainted:

```
{
    use re "taint";
    ($dir, $file) = $fullpath =~ m!(.*/)(.*)!s;
}
```

4. Unless you were using an intentionally broken locale. Perl assumes that your system's locale definitions are potentially compromised. Hence, when running under the locale pragma, patterns with a symbolic character class in them, such as \w or [[:alpha:]], produce tainted results.

A good strategy is to leave submatches tainted by default over the whole source file and only selectively permit untainting in nested scopes as needed:

```
use re "taint";
# remainder of file now leaves $1 etc tainted
{
    no re "taint";
    # this block now untaints re matches
    if ($num =~ /^(\d+)$/) {
        $num = $1;
    }
}
```

Input from a filehandle or a directory handle is automatically tainted, except when it comes from the special filehandle, `DATA`. If you want to, you can mark other handles as trusted sources via the `IO::Handle` module's `untaint` function:

```
use IO::Handle;

IO::Handle::untaint(*SOME_FH);          # Either procedurally
SOME_FH->untaint();                     # or using the OO style.
```

Turning off tainting on an entire filehandle is a risky move. How do you *really* know it's safe? If you're going to do this, you should at least verify that nobody but the owner can write to the file.[5] If you're on a Unix filesystem (and one that prudently restricts *chown*(2) to the superuser), the following code works:

```
use File::stat;
use Symbol "qualify_to_ref";
sub handle_looks_safe(*) {
    my $fh = qualify_to_ref(shift, caller);
    my $info = stat($fh);
    return unless $info;

    # owner neither superuser nor "me", whose
    # real uid is in the $< variable
    if ($info->uid != 0 && $info->uid != $<) {
        return 0;
    }

    # check whether group or other can write file.
    # use 066 to detect for readability also
    if ($info->mode & 022) {
        return 0;
    }
    return 1;
}
```

5. Although you can untaint a directory handle, too, this function only works on a filehandle. That's because given a directory handle, there's no portable way to extract its file descriptor to `stat`.

```
use IO::Handle;
SOME_FH->untaint() if handle_looks_safe(*SOME_FH);
```

We called `stat` on the filehandle, not the filename, to avoid a dangerous race condition. See the section "Handling Race Conditions" on page 663 later in this chapter.

Note that this routine is only a good start. A slightly more paranoid version would check all parent directories as well, even though you can't reliably `stat` a directory handle. But if any parent directory is world-writable, you know you're in trouble whether or not there are race conditions.

Perl has its own notion of which operations are dangerous, but it's still possible to get into trouble with other operations that don't care whether they use tainted values. It's not always enough to be careful of input. Perl output functions don't test whether their arguments are tainted, but in some environments, this matters. If you aren't careful of what you output, you might just end up spitting out strings that have unexpected meanings to whoever is processing the output. If you're running on a terminal, special escape and control codes could cause the viewer's terminal to act strangely. If you're in a web environment and you blindly spit back data that was given to you, you could unknowingly produce HTML tags that would drastically alter the page's appearance. Worse still, some markup tags can even execute code back on the browser.

Imagine the common case of a guest book where visitors enter their own messages to be displayed when others come calling. A malicious guest could supply unsightly HTML tags or put in `<SCRIPT>...</SCRIPT>` sequences that execute code (like JavaScript) back in the browsers of subsequent guests.

Just as you should carefully check for only good characters when inspecting tainted data that accesses resources on your own system, you should apply the same care in a web environment when presenting data supplied by a user. For example, to strip the data of any character not in the specified list of good characters, try something like this:

```
$new_guestbook_entry =~ tr[_a-zA-Z0-9 ,./!?()@+*-][]dc;
```

You certainly wouldn't use that to clean up a filename, since you probably don't want filenames with spaces or slashes, just for starters. But it's enough to keep your guest book free of sneaky HTML tags and entities. Each data-laundering case is a little bit different, so always spend time deciding what is and isn't permitted. The tainting mechanism is intended to catch stupid mistakes, not to remove the need for thought.

Cleaning Up Your Environment

When you execute another program from within your Perl script, no matter how, Perl checks to make sure your PATH environment variable is secure. Since it came from your environment, your PATH starts out tainted; so, if you try to run another program, Perl raises an "`Insecure $ENV{PATH}`" exception. When you set it to a known, untainted value, Perl makes sure that each directory in that path is nonwritable by anyone other than the directory's owner and group; otherwise, it raises an "`Insecure directory`" exception.

You may be surprised to find that Perl cares about your PATH even when you specify the full pathname of the command you want to execute. It's true that with an absolute filename, the PATH isn't used to find the executable to run. But there's no reason to trust the program you're running not to turn right around and execute some *other* program and get into trouble because of the insecure PATH. So Perl forces you to set a secure PATH before you call any program, no matter how you say to call it.

The PATH isn't the only environment variable that can bring grief. Because some shells use the variables IFS, CDPATH, ENV, and BASH_ENV, Perl makes sure that those are all either empty or untainted before it will run another command. Either set these variables to something known to be safe or delete them from the environment altogether:

```
delete @ENV{qw(IFS CDPATH ENV BASH_ENV)};   # Make %ENV safer
```

Features convenient in a normal environment can become security concerns in a hostile one. Even if you remember to disallow filenames containing newlines, it's important to understand that open accesses more than just named files. Given appropriate ornamentation on the filename argument, one- or two-argument calls to open can also run arbitrary external commands via pipes, fork extra copies of the current process, duplicate file descriptors, and interpret the special filename "-" as an alias for standard input or output. It can also ignore leading and trailing whitespace that might disguise such fancy arguments from your check patterns. While it's true that Perl's taint checking will catch tainted arguments used for pipe opens (unless you use a separated argument list) and any file opens that aren't read-only, the exception this raises is still likely to make your program misbehave.

If you intend to use any externally derived data as part of a filename to open, at least include an explicit mode separated by a space. It's probably safest, though, to use either the low-level sysopen or the three-argument form of open:

```
# Magic open—could be anything
open(FH, $file)             || die "can't magic open $file: $!";

# Guaranteed to be a read-only file open and not a pipe
# or fork, but still groks file descriptors and "-",
# and ignores whitespace at either end of name.
open(FH, "< $file")         || die "can't open $file: $!";

# WYSIWYG open: disables all convenience features.
open(FH, "<", $file)        || die "can't open $file: $!";

# Same properties as WYSIWYG 3-arg version.
require Fcntl;
sysopen(FH, $file, O_RDONLY)        || die "can't sysopen $file: $!";
```

Even these steps aren't quite good enough. Perl doesn't prevent you from opening tainted filenames for reading, so you need to be careful of what you show people. A program that opens an arbitrary, user-supplied filename for reading—and then reveals that file's contents—is still a security problem. What if it's a private letter? What if it's your system password file? What if it's salary information or your stock portfolio?

Look closely at filenames provided by a potentially hostile user[6] before opening them. For example, you might want to verify that there are no sneaky directory components in the path. Names like "*../../../../../../../etc/passwd*" are notorious tricks of this sort. You can protect yourself by making sure there are no slashes in the pathname (assuming that's your system's directory separator). Another common trick is to put newlines or semicolons into filenames that will later be interpreted by some poor, witless command-line interpreter that can be fooled into starting a new command in the middle of the filename. This is why taint mode discourages uninspected external commands.

Accessing Commands and Files Under Reduced Privileges

The following discussion pertains to some nifty security facilities of Unix-like systems. Users of other systems may safely (or rather, unsafely) skip this section.

If you're running set-id, whenever possible, try to arrange that you do dangerous operations with the privileges of the user, not the privileges of the program. That is, whenever you're going to call `open`, `sysopen`, `system`, backticks, and any other file or process operations, you can protect yourself by setting your effective UID or GID back to the real UID or GID. In Perl, you can do this for setuid scripts by

6. And on the Net, the only users you can trust not to be potentially hostile are the ones who are being *actively* hostile instead.

saying `$> = $<` (or `$EUID = $UID` if you `use English`) and for setgid scripts by saying `$) = $(` (`$EGID = $GID`). If both IDs are set, you should reset both. However, sometimes this isn't feasible because you might still need those increased privileges later in your program.

For those cases, Perl provides a reasonably safe way to open a file or pipe from within a set-id program. First, fork a child using the special `open` syntax that connects the parent and child by a pipe. In the child, reset the user and group IDs back to their original or known safe values. You also get to modify any of the child's per-process attributes without affecting the parent, letting you change the working directory, set the file creation mask, or fiddle with environment variables. No longer executing under extra privileges, the child process at last calls `open` and passes whatever data it manages to access on behalf of the mundane but demented user back up to its powerful but justly paranoid parent.

Even though `system` and `exec` don't use the shell when you supply them with more than one argument, the backtick operator admits no such alternative calling convention. Using the forking technique, we easily emulate backticks without fear of shell escapes, and with reduced (and therefore safer) privileges:

```
use English;   # to use $UID, etc
die "Can't fork open: $!"   unless defined($pid = open(FROMKID, "-|"));
if ($pid) {           # parent
    while (<FROMKID>) {
        # do something
    }
    close FROMKID;
}
else {
    $EUID = $UID;  # setuid(getuid())
    $EGID = $GID;  # setgid(getgid()), and initgroups(2) on getgroups(2)
    chdir("/")      || die "can't chdir to /: $!";
    umask(077);
    $ENV{PATH} = "/bin:/usr/bin";
    exec "myprog", "arg1", "arg2";
    die "can't exec myprog: $!";
}
```

This is by far the best way to call other programs from a set-id script. You make sure never to use the shell to execute anything, and you drop your privileges before you yourself `exec` the program. (But because the list forms of `system`, `exec`, and pipe `open` are specifically exempted from taint checks on their arguments, you must still be careful of what you pass in.)

If you don't need to drop privileges and just want to implement backticks or a pipe `open` without risking the shell intercepting your arguments, you could use this:

```
open(FROMKID, "-|") || exec("myprog", "arg1", "arg2")
    || die "can't run myprog: $!";
```

and then just read from FROMKID in the parent. As of the v5.6.1 release of Perl, you can write that as:

```
open(FROMKID, "-|", "myprog", "arg1", "arg2");
```

The forking technique is useful for more than just running commands from a set-id program. It's also good for opening files under the ID of whoever ran the program. Suppose you had a setuid program that needed to open a file for writing. You don't want to run the open under your extra privileges, but you can't permanently drop them, either. So arrange for a forked copy that's dropped its privileges to do the open for you. When you want to write to the file, write to the child, and it will then write to the file for you.

```
use English;

defined ($pid = open(SAFE_WRITER, "|-"))
    || die "Can't fork: $!";

if ($pid) {
    # you're the parent. write data to SAFE_WRITER child
    print SAFE_WRITER "@output_data\n";
    close SAFE_WRITER
        || die $! ? "Syserr closing SAFE_WRITER writer: $!"
                  : "Wait status $? from SAFE_WRITER writer";
}
else {
    # you're the child, so drop extra privileges
    ($EUID, $EGID) = ($UID, $GID);

    # open the file under original user's rights
    open(FH, "> /some/file/path")
        || die "can't open /some/file/path for writing: $!";

    # copy from parent (now stdin) into the file
    while (<STDIN>) {
        print FH $_;
    }
    close(FH)   || die "close failed: $!";
    exit;       # Don't forget to make the SAFE_WRITER disappear.
}
```

Upon failing to open the file, the child prints an error message and exits. When the parent writes to the now-defunct child's filehandle, it triggers a broken pipe signal (SIGPIPE), which is fatal unless trapped or ignored. See the section on "Signals" in Chapter 15.

Defeating Taint Checking

Taint mode is a development tool to help you find where you need to cleanse data. It's not a guarantee that nothing bad will happen with your program, so bad things can still happen. It's very easy to get around it, in fact.

The *–T* command-line switch forces taint checking, and you can put that on your shebang line:

```
#!/usr/bin/perl -T

system 'echo', $ARGV[0];
```

If run from the command line with *perl* and no *–T*, it fails:

```
% perl echo.pl
"-T" is on the #! line, it must also be used on the command line
```

The crafty user can turn on taint mode but turn the normally fatal messages into warnings. The *–t* switch turns on taint mode but only warns about violations. The `system` still accepts tainted data:

```
% perl -t echo.pl Amelia
Insecure $ENV{PATH} while running with -t switch
Insecure dependency in system while running with -t switch
Insecure $ENV{PATH} while running with -t switch
Amelia
```

Running as setuid, where taint mode is automatically on, is similarly defeated with *–u*:

```
% perl -t echo.pl Amelia
Insecure $ENV{PATH} while running with -t switch
Insecure dependency in system while running with -t switch
Insecure $ENV{PATH} while running with -t switch
Amelia
```

Similarly, the *–U* switch allows *perl* to run "unsafe" operations, but you still need to specify *–T*:

```
% perl -TU echo.pl Amelia
Amelia
```

If you want the warnings back, use *–w*:

```
% perl -TU -w echo.pl Amelia
Insecure $ENV{PATH} while running with -t switch
Insecure dependency in system while running with -t switch
Insecure $ENV{PATH} while running with -t switch
Amelia
```

Programmers can defeat taint mode by not cleansing data properly, some of which we already showed. For instance, there's the shortcut of simply matching everything:

```
my $untainted = $tainted =~ m/(.*)/;
```

You might recognize that in code reviews, so a crafty shirker might pass the data through a hash. Since taint applies to scalar *variables*, hash keys aren't tainted. Using a scalar variable as a hash key dumps all the *magic* it carries:

```
my (untainted) = keys %{ { $untainted => 1 } };
```

There's even more to think about. For more tricksiness, see the chapter "Secure Programming Techniques" in *Mastering Perl*.

Handling Timing Glitches

Sometimes your program's behavior is exquisitely sensitive to the timing of external events beyond your control. This is always a concern when other programs, particularly inimical ones, might be vying with your program for the same resources (such as files or devices). In a multitasking environment, you cannot predict the order in which processes waiting to run will be granted access to the processor. Instruction streams among all eligible processes are interleaved, so first one process gets some CPU, and then another process, and so on. Whose turn it is to run, and how long they're allowed to run, appears to be random. With just one program that's not a problem. However, it can be a problem when several programs share common resources.

Thread programmers are especially sensitive to these issues. They quickly learn not to say:

```
$var++ if $var == 0;
```

when they should say:

```
{
    lock($var);
    $var++ if $var == 0;
}
```

The former produces unpredictable results when multiple execution threads attempt to run this code at the same time. If you think of files as shared objects, and processes as threads contending for access to those shared objects, you can see how the same issues arise. A process, after all, is really just a thread with an attitude. Or vice versa.

Timing unpredictabilities affect both privileged and nonprivileged situations. We'll first describe how to cope with a long-standing bug in old Unix kernels that affects any set-id program. Then we'll move on to discuss race conditions in general, how they can turn into security holes, and steps you can take to avoid falling into these holes.

Unix Kernel Security Bugs

Beyond the obvious problems that stem from giving special privileges to interpreters as flexible and inscrutable as shells, older versions of Unix have a kernel bug that makes any set-id script insecure before it ever gets to the interpreter. The problem is not the script itself, but a race condition in what the kernel does when it finds a set-id executable script. (The bug doesn't exist on machines that don't recognize `#!` in the kernel.) When a kernel opens such a file to see which interpreter to run, there's a delay before the (now set-id) interpreter starts up and reopens the file. That delay gives malicious entities a chance to change the file, especially if your system supports symbolic links.

Fortunately, sometimes this kernel "feature" can be disabled. Unfortunately, there are a couple of different ways to disable it. The system can outlaw scripts with the set-id bits set, which doesn't help much. Alternatively, it can ignore the set-id bits on scripts. In the latter case, Perl can emulate the setuid and setgid mechanism when it notices the (otherwise useless) set-id bits on Perl scripts. It does this via a special executable called *suidperl*, which is automatically invoked for you if it's needed.[7] However, if the kernel set-id script feature *isn't* disabled, Perl will complain loudly that your setuid script is insecure. You'll either need to disable the kernel set-id script "feature" or put a C wrapper around the script. A C wrapper is just a compiled program that does nothing except call your Perl program. Compiled programs are not subject to the kernel bug that plagues set-id scripts.

Here's a simple wrapper, written in C:

```
#define REAL_FILE "/path/to/script"
main(ac, av)
    char **av;
{
    execv(REAL_FILE, av);
}
```

7. Needed *and* permitted—if Perl detects that the filesystem on which the script resides was mounted with the `nosuid` option, that option will still be honored. You can't use Perl to sneak around your sysadmin's security policy this way.

Compile this wrapper into an executable image and then make *it* rather than your script set-id. Be sure to use an absolute filename, since C isn't smart enough to do taint checking on your `PATH`.

Another possible approach is to use the experimental C code generator for the Perl compiler. A compiled image of your script will not have the race condition (see Chapter 16).

Vendors in recent years have finally started to provide systems free of the set-id bug. On such systems, when the kernel gives the name of the set-id script to the interpreter, it no longer uses a filename subject to meddling, but instead passes a special file representing the file descriptor, like */dev/fd/3*. This special file is already opened on the script so that there can be no race condition for evil scripts to exploit.[8] Most modern versions of Unix use this approach to avoid the race condition inherent in opening the same filename twice.

Handling Race Conditions

Which runs us right into the topic of *race conditions*. What are they really? Race conditions turn up frequently in security discussions. (Although less often than they turn up in insecure programs. Unfortunately.) That's because they're a fertile source of subtle programming errors, and such errors can often be turned into security *exploits* (the polite term for screwing up someone's security). A race condition exists when the result of several interrelated events depends on the ordering of those events, but that order cannot be guaranteed due to nondeterministic timing effects. Each event races to be the first one done, and the final state of the system is anybody's guess.

Imagine you have one process overwriting an existing file and another process reading that same file. You can't predict whether you read in old data, new data, or a haphazard mixture of the two. You can't even know whether you've read all the data. The reader could have won the race to the end of the file and quit. Meanwhile, if the writer kept going after the reader hit end-of-file, the file would grow past where the reader stopped reading, and the reader would never know it.

Here the solution is simple: just have both parties `flock` the file. The reader typically requests a shared lock, and the writer typically requests an exclusive one. So long as all parties request and respect these advisory locks, reads and writes

8. On these systems, Perl should be compiled with *–DSETUID_SCRIPTS_ARE_SECURE_NOW*. The *Configure* program that builds Perl tries to figure this out for itself, so you should never have to specify this explicitly.

cannot be interleaved, and there's no chance of mutilated data. See the section on "File Locking" on page 524 in Chapter 15.

You risk a far less obvious form of race condition every time you let operations on a filename govern subsequent operations on that file. When used on filenames rather than filehandles, the file test operators represent something of a garden path leading straight into a race condition. Consider this code:

```
if (-e $file) {
    open(FH, "<", $file)
        || die "can't open $file for reading: $!";
}
else {
    open(FH, ">", $file)
        || die "can't open $file for writing: $!";
}
```

The code looks just about as straightforward as it gets, but it's still subject to races. There's no guarantee that the answer returned by the `-e` test will still be valid by the time either `open` is called. In the `if` block, another process could have removed the file before it could be opened, and you wouldn't find the file you thought was going to be there. In the `else` block, another process could have created the file before the second `open` could get its turn to create the file, so the file that you thought would not be there, would be. The simple `open` function creates new files but overwrites existing ones. You may think you want to overwrite any existing file, but consider that the existing file might be a newly created alias or symbolic link to a file elsewhere on the system that you very much don't want to overwrite. You may think you know what a filename means at any particular instant, but you can never really be sure as long as any other processes with access to the file's directory are running on the same system.

To fix this problem of overwriting, you'll need to use `sysopen`, which provides individual controls over whether to create a new file or clobber an existing one. And we'll ditch that `-e` file existence test since it serves no useful purpose here and only increases our exposure to race conditions.

```
use Fcntl qw/O_WRONLY O_CREAT O_EXCL/;
open(FH, "<", $file)
    || sysopen(FH, $file, O_WRONLY | O_CREAT | O_EXCL)
    || die "can't create new file $file: $!";
```

Now even if the file somehow springs into existence between when `open` fails and when `sysopen` tries to open a new file for writing, no harm is done, because with the flags provided, `sysopen` will refuse to open a file that already exists.

If someone is trying to trick your program into misbehaving, there's a good chance he'll go about it by having files appear and disappear when you're not expecting.

One way to reduce the risk of deception is by promising to never operate on a filename more than once. As soon as you have the file opened, forget about the filename (except maybe for error messages), and operate only on the handle representing the file. This is much safer because, even though someone could play with your filenames, he can't play with your filehandles. (Or if he can, it's because you let him—see "Passing Filehandles" on page 528 in Chapter 15.)

Earlier in this chapter, we showed a `handle_looks_safe` function that called Perl's `stat` function on a filehandle (not a filename) to check its ownership and permissions. Using the filehandle is critical to correctness—if we had used the name of the file, there would have been no guarantee that the file whose attributes we were inspecting was the same one we just opened (or were about to open). Some pesky evildoer could have deleted our file and quickly replaced it with a file of nefarious design, sometime between the `stat` and the `open`. It wouldn't matter which was called first; there'd still be the opportunity for foul play between the two. You may think that the risk is very small because the window is very short, but there are many cracking scripts out in the world that will be perfectly happy to run your program thousands of times to catch it the one time it wasn't careful enough. A smart cracking script can even lower the priority of your program so it gets interrupted more often than usual, just to speed things up a little. People work hard on these things—that's why they're called *exploits*.

By calling `stat` on a filehandle that's already open, we only access the filename once and so avoid the race condition. A good strategy for avoiding races between two events is to somehow combine both into one, making the operation atomic.[9] Since we access the file by name only once, there can't be any race condition between multiple accesses, so it doesn't matter whether the name changes. Even if our cracker deletes the file we opened (yes, that can happen) and puts a different one there to trick us with, we still have a handle to the real, original file.

Temporary Files

Apart from allowing buffer overruns (which Perl scripts are virtually immune to) and trusting untrustworthy input data (which taint mode guards against), creating temporary files improperly is one of the most frequently exploited security holes. Fortunately, temp file attacks usually require crackers to have a valid user

9. Yes, you may still perform atomic operations in a nuclear-free zone. When Democritus gave the word "atom" to the indivisible bits of matter, he meant literally something that could not be cut: *ἀ-* (not) + *-τομος* (cuttable). An atomic operation is an action that can't be interrupted (just try interrupting an atomic bomb sometime).

account on the system they're trying to crack, which drastically reduces the number of potential bad guys.

Careless or casual programs use temporary files in all kinds of unsafe ways, like placing them in world-writable directories, using predictable filenames, and not making sure the file doesn't already exist. Whenever you find a program with code like this:

```
open(TMP, "> /tmp/foo.$$")
    || die "can't open /tmp/foo.$$: $!";
```

you've just found all three of those errors at once. That program is an accident waiting to happen.

The way the exploit plays out is that the cracker first plants a file with the same name as the one you'll use. Appending the PID isn't enough for uniqueness; surprising though it may sound, guessing PIDs really isn't difficult.[10] Now along comes the program with the careless `open` call, and instead of creating a new temporary file for its own purposes, it overwrites the cracker's file instead.

So what harm can that do? A lot. The cracker's file isn't really a plain file, you see. It's a symbolic link (or sometimes a hard link), probably pointing to some critical file that crackers couldn't normally write to on their own, such as */etc/passwd*. The program thought it opened a brand new file in */tmp*, but it clobbered an existing file somewhere else instead.

Perl provides two functions that address this issue, if properly used. The first is `POSIX::tmpnam`, which just returns a filename that you're expected to open for yourself:

```
# Keep trying names until we get one that's brand new.
use POSIX;
do {
    $name = tmpnam();
} until sysopen(TMP, $name, O_RDWR | O_CREAT | O_EXCL, 0600);
# Now do I/O using TMP handle.
```

The second is `IO::File::new_tmpfile`, which gives you back an already opened handle:

```
# Or else let the module do that for us.
use IO::File;
my $fh = IO::File::new_tmpfile();  # this is POSIX's tmpfile(3)
# Now do I/O using $fh handle.
```

Neither approach is perfect, but, of the two, the first is the better approach. The major problem with the second one is that Perl is subject to the foibles of whatever

10. Unless you're on a system like OpenBSD, which randomizes new PID assignments.

implementation of *tmpfile*(3) happens to be in your system's C library, and you have no guarantee that this function doesn't do something just as dangerous as the `open` we're trying to fix. (And some, sadly enough, do.) A minor problem is that it doesn't give you the name of the file at all. Although it's better if you can handle a temp file without a name—because that way you'll never provoke a race condition by trying to open it again—often you can't.

The major problem with the first approach is that you have no control over the location of the pathname as you do with the C library's *mkstemp*(3) function. For one thing, you never want to put the file on an NFS-mounted filesystem. The `O_EXCL` flag is not guaranteed to work correctly under NFS, so multiple processes that request an exclusive create at nearly the same time might all succeed. For another, because the path returned is probably in a directory others can write to, someone could plant a symbolic link pointing to a nonexistent file, forcing you to create your file in a location she prefers.[11] If you have any say in it, don't put temp files in a directory that anyone else can write to. If you must, make sure to use the `O_EXCL` flag to `sysopen`, and try to use directories with the owner-delete-only flag (the sticky bit) set on them.

As of v5.6.1, there is a third way. The standard `File::Temp` module takes into account all the difficulties we've mentioned. You might use the default options, like this:

```
use File::Temp "tempfile";
$handle = tempfile();
```

Or you might specify some of the options, like this:

```
use File::Temp "tempfile";
($handle, $filename) = tempfile("plughXXXXXX",
                                DIR => "/var/spool/adventure",
                                SUFFIX = ".dat");
```

The `File::Temp` module also provides security-conscious emulations of the other functions we've mentioned (though the native interface is better because it gives you an opened filehandle, not just a filename, which is subject to race conditions). See the documentation for a longer description of the options and semantics of this module.

Once you have your filehandle, you can do whatever you want with it. It's open for both reading and writing, so you can write to the handle, `seek` back to the beginning, and then, if you want, overwrite what you'd just put there or read it back again. The thing you really, *really* want to avoid doing is ever opening that

11. A solution to this, which only works under some operating systems, is to call `sysopen` and OR in the `O_NOFOLLOW` flag. This makes the function fail if the final component of the path is a symbolic link.

filename again, because you can't know for sure that it's really the same file you opened the first time around.[12]

When you launch another program from within your script, Perl normally closes all filehandles for you to avoid another vulnerability. If you use `fcntl` to clear your close-on-exec flag (as demonstrated at the end of the entry on `open` in Chapter 27), other programs you call will inherit this new, open file descriptor. On systems that support the */dev/fd/* directory, you could provide another program with a filename that really means the file descriptor by constructing it this way:

```
$virtname = "/dev/fd/" . fileno(TMP);
```

If you only needed to call a Perl subroutine or program that's expecting a filename as an argument, and you knew that subroutine or program used regular `open` for it, you could pass the handle using Perl's notation for indicating a filehandle:

```
$virtname = "=&" . fileno(TMP);
```

When that file "name" is passed with a regular Perl `open` of one or two arguments (not three, which would dispel this useful magic), you gain access to the duplicated descriptor. In some ways, this is more portable than passing a file from */dev/fd/*, because it works everywhere that Perl works; not all systems have a */dev/fd/* directory. On the other hand, the special Perl `open` syntax for accessing file descriptors by number works only with Perl programs, not with programs written in other languages.

Handling Insecure Code

Taint checking is just the sort of security blanket you need if you want to catch bogus data you ought to have caught yourself, but didn't think to catch before passing off to the system. It's a bit like the optional warnings Perl can give you —they may not indicate a real problem, but on average the pain of dealing with the false positives is less than the pain of not dealing with the false negatives. With tainting, the latter pain is even more insistent, because using bogus data doesn't just give the wrong answers; it can blow your system right out of the water, along with your last two years of work. (And maybe your next two, if you didn't make good backups.) Taint mode is useful when you trust yourself to write honest code but don't necessarily trust whoever is feeding you data not to try to trick you into doing something regrettable.

12. Except afterwards by doing a `stat` on both filehandles and comparing the first two return values of each (the device/inode pair). But it's too late by then, because the damage is already done. All you can do is detect the damage and abort (and maybe sneakily send email to the system administrator).

Data is one thing. It's quite another matter when you don't even trust the code you're running. What if you fetch an applet off the Net and it contains a virus, a time bomb, or a Trojan horse? Taint checking is useless here because the data you're feeding the program may be fine—it's the code that's untrustworthy. You're placing yourself in the position of someone who receives a mysterious device from a stranger, with a note that says, "Just hold this to your head and pull the trigger." Maybe you think it will dry your hair, but you might not think so for very long.

In this realm, prudence is synonymous with paranoia. What you want is a system that lets you impose a quarantine on suspicious code. The code can continue to exist, and even perform certain functions, but you don't let it wander around doing just anything it feels like. In Perl, you can impose a kind of quarantine using the `Safe` module.

Changing Root

Perl's `chroot` works just like the *chroot*(2) system call. It changes the root directory, so your program can't access any files outside of the section of the filesystem that you intend to use. However, only the root user gets to do this, so already that's a security issue:

```
chroot( '/usr/local/apache/data' );
chdir( '/' );   # now in /usr/local/apache/data
```

This doesn't actually prevent access outside of the new root. A directory handle opened prior to the `chroot` can crawl back up to the real root, even though you can't use a filename:

```
use v5.14;
use warnings;

say "Here I am";

opendir my $rootdh, '/';

chroot( '/Users/Amelia' );
opendir my $dh, '/';  # /Users/Amelia
say for readdir($dh);

chdir( $rootdh );     # oops, back to the real '/'
opendir my $dh, '.';
say for readdir($dh);
```

This relies on you, or someone else, allowing this situation to happen. If someone can edit the program to insert this naughtiness, no level of Perl security is going to help. Use any trick you can find to avoid a root user Perl program.

Safe Compartments

The `Safe` module lets you set up a *sandbox*, a special compartment in which all system operations are trapped, and namespace access is carefully controlled. The low-level, technical details of this module are in a state of flux, so here we'll take a more philosophical approach.

Restricting namespace access

At the most basic level, a `Safe` object is like a safe, except the idea is to keep the bad people in, not out. In the Unix world, there is a syscall known as *chroot*(2) that can permanently consign a process to running only in a subdirectory of the directory structure—in its own private little hell, if you will. Once the process is put there, there is no way for it to reach files outside, because there's no way for it to *name* files outside.[13]

A `Safe` object is a little like *chroot*(2), except that instead of being restricted to a subset of the filesystem's directory structure, it's restricted to a subset of Perl's package structure, which is hierarchical just as the filesystem is.

Another way to look at it is that the `Safe` object is like one of those observation rooms with one-way mirrors where the police put suspicious characters. People on the outside can look into the room, but those inside can't see out.

When you create a `Safe` object, you may give it a package name if you want. If you don't, a new one will be chosen for you:

```
use Safe;
my $sandbox = Safe->new("Dungeon");
$Dungeon::foo = 1;  # Direct access is discouraged, though.
```

If you fully qualify variables and functions using the package name supplied to the `new` method, you can access them in that package from the outside, at least in the current implementation.

Slightly more upward compatible might be to set things up first before creating the `Safe`, as shown below. This is likely to continue working and is a handy way to set up a `Safe` that has to start off with a lot of "state". (Admittedly, `$Dungeon::foo` isn't a lot of state.)

```
use Safe;
$Dungeon::master = 'Gary Gygax';  # Still direct access, still discouraged.
my $sandbox = Safe->new("Dungeon");
```

13. Some sites do this for executing all CGI scripts using loopback, read-only mounts. It's something of a pain to set up, but if someone ever escapes, they'll find there's nowhere to go.

But `Safe` also provides a way to access the compartment's globals, even if you don't know the name of the compartment's package. So for maximal upward compatibility (though less than maximal speed), we suggest you use the `reval` method:

```
use Safe;
my $sandbox = Safe->new();
$sandbox->reval( q($master = 'Gary Gygax') );
```

(In fact, that's the same method you'll use to run suspicious code.) When you pass code into the compartment to compile and run, that code thinks that it's really living in the `main` package. What the outside world calls `$Dungeon::master`, the code inside thinks of it as `$main::master`, `$::master`, or just `$master` (if you aren't running under `use strict`). It won't work to say `$Dungeon::master` inside the compartment because that would really access `$Dungeon::Dungeon::master`. By giving the `Safe` object its own notion of `main`, variables and subroutines in the rest of your program are protected.

To compile and run code inside the compartment, use the `reval` ("restricted `eval`") method, passing the code string as its argument. Just as with any other `eval` *`STRING`* construct, compilation errors and runtime exceptions in `reval` don't kill your program. They just abort the `reval` and leave the exception in `$@`, so make sure to check it after every `reval` call.

Using the initializations given earlier, this code will print out that "`master is now Dave Arneson`", but only after you allow `print` (see the next section):

```
$sandbox->permit( qw(print) );
$sandbox->reval(
    q($master = 'Dave Arneson'; print "master is now $main::master\n";)
);
if ($@) {
    die "Couldn't compile code in box: $@";
}
```

If you just want to compile code and not run it, wrap your string in a subroutine declaration:

```
$sandbox->reval(q{
    our $master;
    sub say_master {
        print "master is now $main::master\n";
    }
}, 1);
die if $@;      # check compilation
```

This time we passed `reval` a second argument, which, since it's true, tells `reval` to compile the code under the `strict` pragma. From within the code string you can't disable strictness, either, because importing and unimporting are just two

of the things you can't normally do in a `Safe` compartment. There are a lot of things you can't normally do in a `Safe` compartment—see the next section.

Once you've created the `say_master` function in the compartment, these are pretty much the same:

```
$sandbox->reval("say_master()");     # Best way.
die if $@;

$sandbox->varglob("say_master")->(); # Call through anonymous glob.

Dungeon::say_master();               # Direct call, strongly discouraged.
```

Restricting operator access

The other important thing about a `Safe` object is that Perl limits the available operations within the sandbox. (You might let your kid take a bucket and shovel into the sandbox, but you'd probably draw the line at a bazooka.) It's not enough to protect just the rest of your program; you need to protect the rest of your computer, too.

When you compile Perl code in a `Safe` object, either with `reval` or `rdo` (the restricted version of the `do` *`FILE`* operator), the compiler consults a special, per-compartment access-control list to decide whether each individual operation is deemed safe to compile. This way you don't have to stress out (much) worrying about unforeseen shell escapes, opening files when you didn't mean to, strange code assertions in regular expressions, or most of the external access problems folks normally fret about (or ought to).

If you want to change what's denied or allowed, you can do that by telling the compartment what to restrict or permit:

```
use v5.10;

$time = $sandbox->reval( q(time) );  # works fine

$sandbox->deny( qw(time) );
$time = $sandbox->reval( q(time) );  # fails
```

You can restrict entire sets of op codes, as specified in the `Opcode` module (see Table 20-1), although this requires some knowledge of *perl*'s internals:

```
$sandbox->deny( qw(:base_math) );
my $time = $sandbox->reval( 'log(10)' );  # fails
```

The trick, however, is protecting `Opcode` so that its export tags actually are what you expect. If you don't trust the tags, you can specify individual opcodes, which are also in the `Opcode` module's documentation. Never trust anybody.

Table 20-1. Selected opcode tags from Opcode

Opcode	Includes
`:base_io`	Filehandle-based input and output
`:dangerous`	A dumping ground tag for various dangerous things
`:filesys`	Input and output
`:load`	Load external files or get caller information
`:sys_db`	Access to system databases, such as */etc/passwd*
`:subprocess`	Creation of child processes

The `Safe` module doesn't offer complete protection against *denial-of-service attacks*, especially when used in its more permissive modes. Denial-of-service attacks consume all available system resources of some type, denying other processes access to essential system facilities. Examples of such attacks include filling up the kernel process table, dominating the CPU by running forever in a tight loop, exhausting available memory, and filling up a filesystem. These problems are very difficult to solve, especially portably. See the end of the section "Code Masquerading As Data" on page 675, later in this chapter, for more discussion of denial-of-service attacks.

Safe examples

Imagine you've got a CGI program that manages a form into which the user may enter an arbitrary Perl expression and get back the evaluated result.[14] Like all external input, the string comes in tainted, so Perl won't let you `eval` it yet—you'll first have to untaint it with a pattern match. The problem is that you'll never be able to devise a pattern that can detect all possible threats. And you don't dare just untaint whatever you get and send it through the built-in `eval`. (If you do that, *we* will be tempted to break into your system and delete the script.)

That's where `reval` comes in. Here's a CGI script that processes a form with a single form field, evaluates (in scalar context) whatever string it finds there, and prints out the formatted result:

```
#!/usr/bin/perl -lTw
use strict;
use CGI::Carp "fatalsToBrowser";
use CGI qw/:standard escapeHTML/;
use Safe;
```

14. Please don't laugh. We really have seen web pages that do this. Without a `Safe`!

```
print header(-type => "text/html;charset=UTF-8"),
      start_html("Perl Expression Results");
my $expr = param("EXPR") =~ /^([^;]+)/
            ? $1 # return the now-taintless portion
            : croak("no valid EXPR field in form");
my $answer = Safe->new->reval($expr);
die if $@;

print p("Result of", tt(escapeHTML($expr)),
               "is", tt(escapeHTML($answer)));
```

Imagine some evil user feeding you "`print `cat /etc/passwd`` " (or worse) as the input string. Thanks to the restricted environment that disallows backticks, Perl catches the problem during compilation and returns immediately. The string in `$@` is "`quoted execution (``, qx) trapped by operation mask`", plus the customary trailing information identifying where the problem happened.

Because we didn't say otherwise, the compartments we've been creating all used the default set of allowable operations. How you go about declaring specific operations permitted or forbidden isn't important here. What is important is that this is completely under the control of your program. And since you can create multiple `Safe` objects in your program, you can confer various degrees of trust upon various chunks of code, depending on where you got them from.

If you'd like to play around with `Safe`, here's a little interactive Perl calculator. It's a calculator in that you can feed it numeric expressions and see their results immediately. But it's not limited to numbers alone. It's more like the looping example under `eval` in Chapter 27, where you can take whatever they give you, evaluate it, and give them back the result. The difference is that the `Safe` version doesn't execute just anything you feel like. You can run this calculator interactively at your terminal, typing in little bits of Perl code and checking the answers, to get a feel for what sorts of protection `Safe` provides.

```
#!/usr/bin/perl -w
# safecalc - demo program for playing with Safe
use strict;
use Safe;
my $sandbox = Safe->new();
while (1) {
    print "Input: ";
    my $expr = <STDIN>;
    exit unless defined $expr;
    chomp($expr);
    print "$expr produces ";
    local $SIG{__WARN__} = sub { die @_ };
    my $result = $sandbox->reval($expr, 1);
    if ($@ =~ s/at \(eval \d+\).*//) {
```

```
            printf "[%s]: %s", $@ =~
                /trapped by operation mask/
                ? "Security Violation" : "Exception", $@;
        }
        else {
            print "[Normal Result] $result\n";
        }
    }
```

When you give it the normal algebraic expressions, it computes and returns the result. If you try to do something such as run backticks or load a module, it doesn't let you:

```
Input: 2+2
2+2 produces [Normal Result] 4
Input: `ls -l`
`ls -l` produces [Security Violation]: 'quoted execution (``, qx)'
trapped by operation mask
Input: use LWP::Simple; getprint('http://www.perl.org')
use LWP::Simple; getprint('http://www.perl.org') produces [Security Violation]:
'require' trapped by operation mask
Input: 1/137
1/137 produces [Normal Result] 0.0072992700729927
```

Code Masquerading As Data

`Safe` compartments are available for when the really scary stuff is going down, but that doesn't mean you should let down your guard totally when you're doing the everyday stuff around home. You need to cultivate an awareness of your surroundings and look at things from the point of view of someone wanting to break in. You need to take proactive steps like keeping things well lit and trimming the bushes where various lurking problems can hide.

Perl tries to help you in this area, too. Perl's conventional parsing and execution scheme avoids the pitfalls to which shell programming languages often fall prey. There are many extremely powerful features in the language, but by design they're syntactically and semantically bounded in ways that keep things under the programmer's control. With few exceptions, Perl evaluates each token only once. Something that looks like it's being used as a simple data variable won't suddenly go rooting around in your filesystem.

Unfortunately, that sort of thing can happen if you call out to the shell to run other programs for you, because then you're running under the shell's rules instead of Perl's. The shell is easy to avoid, though—just use the list-argument forms of the `system`, `exec`, or piped `open` functions. Although backticks don't have a list-argument form that is proof against the shell, you can always emulate them as described in the section "Accessing Commands and Files Under Reduced Priv-

ileges" on page 657, earlier in this chapter. (While there's no syntactic way to make backticks take an argument list, a multiargument form of the underlying `read pipe` operator is in development; but as of this writing, it isn't quite ready for prime time.)

When you use a variable in an expression (including when you interpolate it into a double-quoted string), there's No Chance that the variable will contain Perl code that does something you aren't intending.[15] Unlike the shell, Perl never needs defensive quotes around variables, no matter what might be in them.

```
$new = $old;                # No quoting needed.
print "$new items\n";       # $new can't hurt you.

$phrase = "$new items\n";   # Nor here, neither.
print $phrase;              # Still perfectly ok.
```

Perl takes a "what you see is what you get" approach. If you don't see an extra level of interpolation, then it doesn't happen. It *is* possible to interpolate arbitrary Perl expressions into strings, but only if you specifically ask Perl to do that. (Even so, the contents are still subject to taint checking if you're in taint mode.)

```
$phrase = "You lost @{[ 1 + int rand(6) ]} hit points\n";
```

Interpolation is not recursive, however. You can't just hide an arbitrary expression in a string:

```
$count = "1 + int rand(6)";             # Some random code.
$saying = "$count hit points";          # Merely a literal.
$saying = "@{[$count]} hit points";     # Also a literal.
```

Both assignments to `$saying` would produce "`1 + int rand(6) hit points`", without evaluating the interpolated contents of `$count` as code. To get Perl to do that, you have to call `eval` *`STRING`* explicitly:

```
$code = "1 + int rand(6)";
$die_roll = eval $code;
die if $@;
```

If `$code` were tainted, that `eval` *`STRING`* would raise its own exception. Of course, you almost never want to evaluate random user code—but if you did, you should look into using the `Safe` module. You may have heard of it.

There is one place where Perl can sometimes treat data as code; namely, when the pattern in a `qr//`, `m//`, or `s///` operator contains either of the new regular expression assertions: `(?{` *`CODE`* `})` or `(??{` *`CODE`* `})`. These pose no security issues when used as literals in pattern matches:

15. Although if you're generating a web page, it's possible to emit HTML tags, including JavaScript code, that might do something that the remote browser isn't expecting.

```
$cnt = $n = 0;
while ($data =~ /( \d+ (?{ $n++ }) | \w+ )/gx) {
    $cnt++;
}
print "Got $cnt words, $n of which were digits.\n";
```

But existing code that interpolates variables into matches was written with the assumption that the data is data, not code. The new constructs might have introduced a security hole into previously secure programs. Therefore, Perl refuses to evaluate a pattern if an interpolated string contains a code assertion, and it raises an exception instead. If you really need that functionality, you can always enable it with the lexically scoped `use re 'eval'` pragma. (You still can't use tainted data for an interpolated code assertion, though.)

A completely different sort of security concern that can come up with regular expressions is denial-of-service problems. These can make your program quit too early, run too long, or exhaust all available memory—and sometimes even dump core, depending on the phase of the moon.

When you process user-supplied patterns, you don't have to worry about interpreting random Perl code. However, the regular expression engine has its own little compiler and interpreter, and the user-supplied pattern is capable of giving the regular expression compiler heartburn. If an interpolated pattern is not a valid pattern, a runtime exception is raised, which is fatal unless trapped. If you do try to trap it, make sure to use only `eval` *`BLOCK`*, not `eval` *`STRING`*, because the extra evaluation level of the latter would in fact allow the execution of random Perl code. Instead, do something like this:

```
if (not eval { "" =~ /$match/; 1 }) {
    # (Now do whatever you want for a bad pattern.)
}
else {
    # We know pattern is at least safe to compile.
    if ($data =~ /$match/) { ... }
}
```

A more troubling denial-of-service problem is that given the right data and the right search pattern, your program can appear to hang forever. That's because some pattern matches require exponential time to compute, and this can easily exceed the MTBF rating on our solar system. If you're especially lucky, these computationally intensive patterns will also require exponential storage. If so, your program will exhaust all available virtual memory, bog down the rest of the system, annoy your users, and either `die` with an orderly "`Out of memory!`" error or leave behind a really big core dump file (though perhaps not as large as the solar system).

Like most denial-of-service attacks, this one is not easy to solve. If your platform supports the `alarm` function, you could time out the pattern match. Unfortunately, Perl cannot (currently) guarantee that the mere act of handling a signal won't ever trigger a core dump. (This is scheduled to be fixed in a future release.) You can always try it, though, and even if the signal isn't handled gracefully, at least the program won't run forever.

If your system supports per-process resource limits, you could set these in your shell before calling the Perl program, or use the `BSD::Resource` module from CPAN to do so directly from Perl. The Apache web server allows you to set time, memory, and file size limits on CGI scripts it launches.

Finally, we hope we've left you with some unresolved feelings of insecurity. Remember, just because you're paranoid doesn't mean they're not out to get you. So you might as well enjoy it.

CHAPTER 21

Common Practices

Almost any Perl programmer will be glad to give you reams of advice on how to program. We're no different (in case you hadn't noticed). In this chapter, rather than trying to tell you about specific features of Perl, we'll go at it from the other direction and use a more scattergun approach to describe idiomatic Perl. Our hope is that, by putting together various bits of things that seemingly aren't related, you can soak up some of the feeling of what it's like to actually "think Perl". After all, when you're programming, you don't write a bunch of expressions, then a bunch of subroutines, then a bunch of objects. You have to go at everything all at once, more or less. So this chapter is a bit like that.

There is, however, a rudimentary organization to the chapter in that we'll start with the negative advice and work our way toward the positive advice. We don't know if that will make you feel any better, but it makes us feel better. Besides, for most of your programming career, you'll spend your time learning what not to do before you figure out what to do, so get used to it early.

Common Goofs for Novices

The biggest goof of all is forgetting to `use warnings`, which identifies many errors. The second biggest goof is forgetting to `use strict` when it's appropriate. These two pragmas can save you hours of head-banging when your program starts getting bigger. (And it will.) Yet another faux pas is to forget to consult the online *perlfaq*. Suppose you want to find out if Perl has a `round` function. You might try searching the FAQ first by searching with *perldoc*:

```
% perldoc -q round
```

Apart from those "metagoofs", there are several kinds of programming traps. Some traps almost everyone falls into, and other traps you'll fall into only if you come from a particular culture that does things differently. We've separated these out in the following sections.

Universal Blunders

- Putting a comma after the filehandle in a `print` statement. Although it looks extremely regular and pretty to say:

  ```
  print STDOUT, "goodbye", $adj, "world!\n";    # WRONG
  ```

  this is nonetheless incorrect because of that first comma. What you want instead is the indirect object syntax:

  ```
  print STDOUT "goodbye", $adj, "world!\n";     # ok
  ```

  The syntax works this way so that you can say:

  ```
  print $filehandle "goodbye", $adj, "world!\n";
  ```

  where `$filehandle` is a scalar holding the name of a filehandle at runtime. This is distinct from:

  ```
  print $notafilehandle, "goodbye", $adj, "world!\n";
  ```

  where `$notafilehandle` is simply a string that is part of the list of things to be printed. In that case, you might see something like `GLOB(0xDEADBEEF)` on the terminal, because the output went to standard output and the filehandle reference stringified itself.

  See *indirect object* in the Glossary.

- Using `==` instead of `eq` and `!=` instead of `ne`. The `==` and `!=` operators are *numeric* tests. The other two are *string* tests. The strings `"123"` and `"123.00"` are equal as numbers but not equal as strings. Also, most nonnumeric strings are numerically equal to zero, and some of them, such as `"123xyz"`, probably aren't what you want in a numeric context. Unless you are dealing with numbers, you almost always want the string-comparison operators instead. The `warnings` pragma will tell you when these operators use nonnumeric data.
- Forgetting the trailing semicolon. Every statement in Perl is terminated by a semicolon or the end of a block. Newlines aren't statement terminators as they are in *awk*, Python, or FORTRAN. Remember that Perl is like C.

  A statement containing a here document is particularly prone to losing its semicolon. It ought to look like this:

```
print <<"FINIS";
A foolish consistency is the hobgoblin of little minds,
adored by little statesmen and philosophers and divines.
                                        --Ralph Waldo Emerson
FINIS
```

- Forgetting that a *BLOCK* requires braces. Naked statements are not *BLOCK*s. If you are creating a control structure such as a `while` or an `if` that requires one or more *BLOCK*s, you *must* use braces around each *BLOCK*. Remember that Perl is *not* like C.
- Not saving `$1`, `$2`, and so on across regular expressions. Remember that every successful `m/atch/` or `s/ubsti/tution/` will set (or clear, or mangle) your `$1`, `$2`...variables. One way to save them right away is to evaluate the match within list context, as in:

  ```
  my ($one, $two) = /(\w+) (\w+)/;
  ```

- Not realizing that a `local` also changes the variable's value as seen by other subroutines called within the scope of the local. It's easy to forget that `local` is a runtime statement that does dynamic scoping, because there's no equivalent in languages like C. See the section "Scoped Declarations" in Chapter 4. Usually you want a `my` anyway.
- Losing track of brace pairings. A good text editor will help you find the pairs. Get one (or two). And it helps to have a consistent style so you know where to expect a brace, even if people debate those positions just for the blood sport. Tools such as `Perl::Tidy` can beautify code for you.
- Using loop control statements in `do {} while`. Although the braces in this control structure look suspiciously like part of a loop *BLOCK*, they aren't.
- Using `$foo[1]` when you mean `$foo[0]`. Perl arrays begin at zero by default. In the olden days, Perl tried to be flexible by allowing you to set the starting index through the `$[` special variable, but v5.12 deprecated that.
- Saying `@foo[0]` when you mean `$foo[0]`. The `@foo[0]` reference is an array *slice*, meaning an array consisting of the single element `$foo[0]`. Sometimes this doesn't make any difference, as in:

  ```
  print "the answer is @foo[0]\n";
  ```

  but it makes a big difference for things like:

  ```
  @foo[0] = <STDIN>;
  ```

  which will slurp up all the rest of `STDIN`, assign the *first* line to `$foo[1]`, and discard everything else. This is probably not what you intended. Get into the habit of thinking that `$` means a single value, while `@` means a list of values, and you'll do okay.

- Forgetting the parentheses of a list operator like `my`, which makes one variable lexical and the other global:

```
my  $x, $y  = (4, 8);     # WRONG
my ($x, $y) = (4, 8);     # ok
```

- Forgetting to select the right filehandle before setting the format variables `$^`, `$~`, or the buffering variable `$|`. These variables depend on the currently selected filehandle, as determined by `select(`*`FILEHANDLE`*`)`. The initial filehandle so selected is `STDOUT`. You should really be using the filehandle methods from the `IO::Handle` module instead. See Chapter 25.
- Forgetting to set the encoding on every text stream you read or write. There is no such thing as a generic "textfile". The *–C* command-line option, the `PERL_UNICODE` environment variable, and the `open` pragma can set this implicitly for convenience, and the `binmode` and `open` functions can set it explicitly for precision. If you do not somehow specify the encoding either implicitly or explicitly, you do not have text data. Encoding cannot be guessed. They must be specified.

Frequently Ignored Advice

Practicing Perl Programmers should take note of the following:

- Remember that many operations behave differently in list context than they do in a scalar one, or that a list and an array are not the same thing. For instance:

```
($x) = (4, 5, 6); # List context; $x is set to 4
 $x  = (4, 5, 6); # Scalar context; $x is set to 6

 @a  = (4, 5, 6);
 $x  = @a;        # Scalar context; $x is set to 3 (the array length)
```

- Avoid barewords if you can, especially all lowercase ones. You can't tell just by looking at it whether a word is a function or a bareword string. By using quotes on strings and parentheses around function call arguments, you won't ever get them confused. In fact, the pragma `use strict` at the beginning of your program makes barewords a compile-time error—probably a good thing.
- You can't tell just by looking which built-in functions are unary operators (like `chop` and `chdir`), which are list operators (like `print` and `unlink`), and which are argumentless (like `time`). You'll want to learn them by reading Chapter 27. As always, use parentheses if you aren't sure—or even if you aren't sure you're sure. Note also that user-defined subroutines are by default list

operators, but they can be declared as unary operators with a prototype of `($)` or argumentless with a prototype of `()`.

- People have a hard time remembering that some functions default to `$_`, `@ARGV`, or whatever, while others do not. Take the time to learn which are which or avoid default arguments.
- `<FH>` is not the name of a filehandle; it is an angle operator that does a line-input operation on the handle. This confusion usually manifests itself when people try to `print` to the angle operator:

```
print <FH> "hi";    # WRONG, omit angles
```

- Remember also that data read by the angle operator is assigned to `$_` only when the file read is the sole condition in a `while` loop:

```
while (<FH>) { }   # Data assigned to $_
<FH>;              # Data read and discarded!
```

- Don't use `=` when you need `=~`; the two constructs are quite different:

```
$x =  /foo/;  # Searches $_ for "foo", puts result in $x
$x =~ /foo/;  # Searches $x for "foo", discards result
```

- Use `/r` on your substitutions to return the result.

```
@new = map { s/old/new/r } @old;
```

- Use `my` for local variables whenever you can get away with it. Using `local` merely gives a temporary value to a global variable, which leaves you open to unforeseen side effects of dynamic scoping.
- Don't use `local` on a module's exported variables. If you localize an exported variable, its exported value will not change. The local name becomes an alias to a new value, but the external name is still an alias for the original.

C Traps

Cerebral C programmers should take note of the following:

- Curlies are required for `if` and `while` blocks.
- You must use `elsif` rather than "else if" or "elif". Syntax like this:

```
if (expression) {
    block;
}
else if (another_expression) {      # WRONG
    another_block;
}
```

  is illegal. The `else` part is always a block, and a naked `if` is not a block. You mustn't expect Perl to be exactly the same as C. What you want instead is:

```
if (expression) {
    block;
}
elsif (another_expression) {
    another_block;
}
```

Note also that "elif" is "file" spelled backward. Only Algol-ers would want a keyword that was the same as another word spelled backward.

- The `break` and `continue` keywords from C become in Perl `last` and `next`, respectively. Unlike in C, these do *not* work within a `do {} while` construct.
- For a long time Perl had no equivalent to C's `switch` statement. Perl v5.10 introduced a "switch on steroids" with the fancy name `given-when` (since it's a fancier construct). See Chapter 4. It's easy to build your own, too; see "Bare Blocks as Loops" and "The given Statement" in Chapter 4.
- Variables begin with `$`, `@`, or `%` in Perl.
- Comments begin with `#`, not `/*`. Use pod for multiline comments.
- You can't take the address of anything, although a similar operator in Perl is the backslash, which creates a reference. You get something that looks like an address when you stringify a reference, but you can't really use it for anything.
- `ARGV` must be capitalized. `$ARGV[0]` is C's `argv[1]`, and C's `argv[0]` ends up in `$0`. See Chapter 25.
- Syscalls such as `link`, `unlink`, and `rename` return true for success, not `0`.
- The signal handlers in `%SIG` deal with signal names, not numbers.

Shell Traps

Sharp shell programmers should take note of the following:

- Variables are prefixed with `$`, `@`, or `%` on the left side of the assignment as well as the right. A shellish assignment like:

```
camel="dromedary";      # WRONG
```

won't be parsed the way you expect. You need:

```
$camel="dromedary";     # ok
```

- The loop variable of a `foreach` also requires a `$`. Although *csh* likes:

```
foreach hump (one two)
    stuff_it $hump
end
```

In Perl, this is written as:

```
foreach $hump ("one", "two") {
    stuff_it($hump);
}
```

- The backtick operator does variable interpolation without regard to the presence of single quotes in the command.
- The backtick operator does no translation of the return value. In Perl, you have to trim the newline explicitly, like this:

```
chomp($thishost = `hostname`);
```

- Shells (especially *csh*) do several levels of substitution on each command line. Perl does interpolation only within certain constructs such as double quotes, backticks, angle brackets, and search patterns.
- Shells tend to interpret scripts a little bit at a time. Perl compiles the entire program before executing it (except for `BEGIN` blocks, which execute before the compilation is done).
- Program arguments are available via `@ARGV`, not `$1`, `$2`, and so on.
- The environment is not automatically made available as individual scalar variables. Use the standard `Env` module if you want that to happen.

Python Traps

Perl and Python are both dynamic languages that share some common ancestors and appeared within five years of each other (1987 and 1991). Perl 4 even stole Python's object system for Perl 5. Although the two languages are more alike than their superficial syntax would suggest, they also see many of the same things from different perspectives.

- Python and Perl sometimes use different words for the same concepts, and sometimes they use the same words for different concepts; see Table 21-1.

Table 21-1. A mapping of Python to Perl jargon

Python	Perl
Tuple	List
List	Array
Dictionary	Hash

- Variables begin with `$`, `@`, or `%` in Perl. Using sigils like `$str` lets Perl keep its nouns and its verbs separate, so you never have to worry about accidentally overwriting some important built-in the way you do in Python if you use `str` for your purposes. You *can* override built-ins in Perl, but never accidentally the way you can in Python.

- Don't forget to `use warnings` so Perl notices things that in Python give you exceptions. Otherwise in Perl you only learn about these things if you test for them, so if you forget, you never know. See also `warnings` and `autodie` in Chapter 27.
- Many built-in functions take default arguments or have default behavior for their most common cases. See Chapter 27.
- Python's methods take explicit parameter lists. In Perl, you unpack the arguments to your function, which gives you great flexibility in the number and order of the arguments your function takes. We consider this a feature, but if you find yourself writing lots of boilerplate to unpack your function arguments, you might consider the `Method::Signatures` module from CPAN.
- Perl knows about patterns and compiles them for you at compile time along with the rest of your program.
- Perl's `\N{`*`NAME`*`}` construct allows shortcuts, aliases, and custom names (which can even be different in different lexical scopes); Python's `\N{`*`NAME`*`}` doesn't.
- Perl characters are abstract code points, not low-level code units as in Python.
- Perl pattern matching uses Unicode rules for case-insensitivity, but Python uses only ASCII casefolding rules, so (for example) all three Greek sigmas match case-insensitively in Perl.
- Perl's casemapping functions like `uc` and `lc` follow Unicode rules, so they work on all cased codepoints, not just on letters.
- Perl understands (potentially nested) lexical scope, and so it is completely comfortable with full lexical closures. Python doesn't and isn't.
- Perl uses full Unicode casing, so the casemap of a string can be longer than the original. Python uses only simple Unicode casing (when it bothers to use it at all), which doesn't give as good results on strings.
- Any subroutine that returns a blessed reference is a Perl constructor. There's no special name for a constructor method.
- Perl methods are just methods, and they always receive their invocant as a bonus, initial argument. Perl as a language makes no distinction between object methods, class methods, or static methods in the Python sense of these things.
- Perl's object-orientation is optional, not mandatory. Perl doesn't enforce pervasive object-orientation on its built-in types unless you ask it to—not everything has methods. You might like `autobox`, though.
- In Perl, you call a function with arguments:

```
my $string = join("|", qw(Python Perl Ruby) );
```

In Python, there's likely a main argument with a method to do it:

```
new = "|".join(["Python", "Perl", "Ruby"])
```

- Perl pattern matches float unless you anchor your pattern explicitly, like Python's `re.search()` method but unlike its `re.match()`, which can only match at the beginning of a line.
- Perl's strings aren't arrays of characters, so you can't use array operators on them. On strings you use string operators, natch.
- Except for a backslash itself or a backslashed delimiter, Perl never expands backslash escapes in single-quoted strings, but Python does. Perl's singled-quoted strings like `'\t'` are more like Python's raw strings like `r'\t'`.
- Perl uses backticks to quote literals to execute arbitrary system commands and return their output, as in `$file = `cat foo.c`.`
- You don't have to preallocate memory in Perl the way you do in Python, because arrays and other data structures grow on demand, sometimes via *autovivification*. In Python, you have to explicitly grow your lists and explicitly allocate new lists and dictionaries to grow them.
- Python throws exceptions for normal operations like `open` failures, while Perl uses special return values, usually `undef`. That means if you forget to check for that error return, you will miss it. You can use `autodie` to make failed system calls raise exceptions.
- Perl does not by default throw exceptions on failed or partial numeric conversions from strings, nor on treating `undef` as a defined value. You can make it do so with:

```
use warnings FATAL => q(numeric uninitialized);
```

- Perl lists never nest, even if you add extra parens. Use square brackets to make nested arrays (of array references) instead.
- Perl's range operator is inclusive on both sides, so `0..9` includes `0` and `9`.
- Perl's interactive shell is its debugger (Chapter 17), but `Devel::REPL` is good, too. Calling Perl without arguments does not drop you into an interactive read-eval-print loop as it does in Python. Use `perl -de0` for that.

Ruby Traps

Matz, the creator of Ruby, stole heavily from Perl (and we think he chose a pretty good starting point). Actually, he put a Perl and a Smalltalk in a room and let them breed.

- There's no *irb*. See the Python section.

- Perl just has numbers. It doesn't care whether they have fractional portions or not.
- You don't need to surround variables with `{}` (`#{}` in Ruby) to interpolate them, unless you need to disambiguate the identifier from the string around it:

```
"My favorite language is $lang"
```

- Perl interpolated strings don't have to be double-quoted: they can use `qq` with arbitrary delimiters. Similarly, generic uninterpolated strings don't have to use single quotes: they can use a `q` with arbitrary delimiters.

```
q/That's all, folks/
q(No interpolation for $100)
qq(Interpolation for $animal)
```

- You need to separate all Perl statements with a `;`, even if they are on different lines. The final statement in a block doesn't need a final `;`.
- The case of variable names in Perl don't mean anything to *perl*.
- The sigils don't denote variable scope, nor even type. A `$` in Perl is a single item, like `$scalar`, `$array[0]`, or `$hash{$key}`.
- Perl compares strings with `lt`, `le`, `eq`, `ne`, `ge`, and `gt`.
- No magic blocks, but see `PerlX::MethodCallWithBlock`.
- Perl's subroutine definitions are compile-phase. So:

```
use v5.10;
sub foo { say "Camelia" }
foo();
sub foo { say "Amelia" };
foo();
```

  This prints `Amelia` twice, because the last definition is in place before the run-phase statements execute. This also means that the call to a subroutine can appear earlier in the file than the subroutine's definition.
- Perl doesn't have class variables, but people try to fake them with lexical variables.
- The range operator in Perl returns a list, but see `PerlX::Range`.
- The `/s` pattern modifier makes Perl's `.` match a newline, whereas Ruby uses the `/m` for the same thing. The `/m` in Perl makes the `^` and `$` anchors match at the beginning and end of logical lines.
- Perl flattens lists.
- Perl's `=>` can stand in almost anywhere you can use a comma, so you'll often see Perlers use the arrow to indicate direction:

```
rename $old => $new;
```

- In Perl, `0`, `"0"`, `""`, `()`, and `undef` are false in Boolean contexts. Basic Perl doesn't require a special Boolean value. You might want the `boolean` module.
- Perl often fakes the job of `nil` with an `undef`.
- Perl allows you to be a bit sloppier because some of the characters aren't that special. A `?` after a variable doesn't do anything to the variable, for instance:

```
my $flag = $foo? 0 :1;
```

Java Traps

- There is no `main` in Perl or, rather, no:

```
public static void main(String[ ] argv) throws IOException
```

- Perl allocates memory for you as you need it by growing its arrays and hashes on demand. Autovivification means that if you assign to it, there'll be room for it.
- Perl doesn't make you declare your variables in advance unless you `use strict`.
- In Perl, there is a difference between a thing and a reference to a thing, so you (usually) have to explicitly dereference the latter.
- Not all functions need to be methods in Perl.
- String and numeric literals aren't usually objects in Perl—but they can be.
- Java programmers looking to define a data structure using a class may be surprised that Perl builds these up out of simple data declarations mixing anonymous hashes and arrays. See Chapter 9.
- Instance data on a Perl object is (usually) just a value in the hash used for the object, where the name of that hash field corresponds to the name of instance data in Java.
- Privacy is optional in Perl.
- The function that a method invocation ends up calling is not determined until runtime, and any object or class with a method by that name is just fine by Perl. Only the interface matters.
- Perl supports operator overloading.
- Perl does not support function overloading by signature. See the `Class::Multimethod` module on CPAN.
- Perl allows multiple inheritance, although this more corresponds to multiple interfaces in Java, since Perl classes inherit only methods, not data.

- A Java `char` is not an abstract Unicode codepoint; it is a UTF-16 code unit, which means it takes two of Java `char`s, as well as special coding, to work outside the Basic Multilingual Plane in Java. In contrast, a Perl character *is* an abstract codepoint whose underlying implementation is intentionally hidden from the programmer. Perl code automatically works on the full range of Unicode—and beyond.
- Unlike in Java, Perl's string literals can have literal newlines in them. It's still usually better to use a "here" document, though.
- Functions typically indicate failure by returning `undef`, not by raising an exception. Use the `autodie` pragma if you like the other way.
- Perl does not use named parameters; arguments to a program show up in each function's `@_` array. They're typically given names right away, though. You might check out the `Methods::Signatures` module from CPAN if you'd like a more formal way to declare named parameters.
- The things Perl refers to as function prototypes work nothing at all like Java's.
- Perl supports pass by named parameter, allowing optional arguments to be omitted and the argument order to be freely rearranged.
- Perl's garbage-collection system is based on reference counting, so it is possible to write a destructor to automatically clean up resources like open file descriptors, database connections, file locks, etc.
- Perl regexes don't need extra backslashes.
- Perl has regex literals, which the compiler compiles, syntax checks at compile time, and stores for efficiency.
- Pattern matches in Perl do not silently impose anchors on your patterns the way Java's `match` method does. Perl's matching works more like Java's `find` method.
- A Perl pattern can have more than one capture group by the same name.
- Perl patterns can recurse.
- Java patterns need a special option to make them use Unicode casefolding for case-insensitive matches, but Perl patterns use Unicode casefolding by default. When doing so, Perl uses full casefolding, but Java uses only simple casefolding.
- In Java patterns, classic character classes like `\w` and `\s` are by default ASCII-only, and it takes a special option to upgrade them to understand Unicode. Perl patterns are Unicode-aware by default, so it instead takes a special option to downgrade classic character classes (or POSIX classes) back to working only on legacy ASCII.

- Java's JNI corresponds to Perl's XS, at least in spirit. Perl modules often have compiled C/C++ components, but Java's rarely do.
- Not everything needs to be rewritten in Perl; Perl makes it easy to call your system's native programs using backticks, `system`, and pipe `opens`.

Efficiency

While most of the work of programming may simply be getting your program working properly, you may find yourself wanting more bang for the buck out of your Perl program. Perl's rich set of operators, data types, and control constructs are not necessarily intuitive when it comes to speed and space optimization. Many trade-offs were made during Perl's design, and such decisions are buried in the guts of the code. In general, the shorter and simpler your code is, the faster it runs, but there are exceptions. This section attempts to help you make it work just a wee bit better.

If you want it to work a lot faster, you can play with the Perl compiler backend described in Chapter 16, or rewrite your inner loop as a C extension (which we don't cover in this book). However, before you do any work, you should profile your program (see Chapter 17) to see whether there's something simple you can adjust first.

Note that optimizing for time may sometimes cost you in space or programmer efficiency (indicated by conflicting hints below). Them's the breaks. If programming was easy, they wouldn't need something as complicated as a human being to do it, now would they?

Time Efficiency

- Use hashes instead of linear searches. For example, instead of searching through `@keywords` to see whether `$_` is a keyword, construct a hash with:

  ```
  my %keywords;
  for (@keywords) {
      $keywords{$_}++;
  }
  ```

  Then you can quickly tell if `$_` contains a keyword by testing `$keyword{$_}` for a nonzero value.
- Avoid subscripting when a `foreach` or list operator will do. Not only is subscripting an extra operation, but if your subscript variable happens to be in floating point because you did arithmetic, an extra conversion from floating point back to integer is necessary. There's often a better way to do it. Con-

sider using `foreach`, `shift`, and `splice` operations. Consider saying `use integer`.

- Avoid `goto`. It scans outward from your current location for the indicated label.
- Avoid `printf` when `print` will do.
- Avoid `$&` and its two buddies, `$`` and `$'`. Any occurrence in your program causes all matches to save the searched string for possible future reference. However, once you've blown it, it doesn't hurt to have more of them. Perl v5.10 introduced the per-match variables with the `/p` (see Chapter 5), so you don't have to either suffer or give up features.
- Avoid using `eval` on a string. An `eval` of a string (although not of a *`BLOCK`*) forces recompilation every time through. The Perl parser is pretty fast for a parser, but that's not saying much. Nowadays there's almost always a better way to do what you want anyway. In particular, any code that uses `eval` merely to construct variable names is obsolete since you can now do the same using symbolic references directly:

```
no strict "refs";
$name = "variable";
$$name = 7;          # Sets $variable to 7
```

  Not that we recommend that, but if you can't find any other way to do it, trying this is slightly less bad than the string `eval`.
- Short-circuit alternation is often faster than the corresponding regex. So:

```
print if /one-hump/ || /two/;
```

  is likely to be faster than:

```
print if /one-hump|two/;
```

  at least for certain values of `one-hump` and `two`. This is because the optimizer likes to hoist certain simple matching operations up into higher parts of the syntax tree and do very fast matching with a Boyer–Moore algorithm. A complicated pattern tends to defeat this.
- Reject common cases early with `next if`. As with simple regular expressions, the optimizer likes this. And it just makes sense to avoid unnecessary work. You can typically discard comment lines and blank lines even before you do a `split` or `chop`:

```
while (<>) {
    next if /^#/;
    next if /^$/;
    chop;
    @piggies = split(/,/);
```

```
    ...
}
```

- Avoid regular expressions with many quantifiers or with big `{MIN,MAX}` numbers on parenthesized expressions. Such patterns can result in exponentially slow backtracking behavior unless the quantified subpatterns match on their first "pass". You can also use the `(?>...)` construct to force a subpattern to either match completely or fail without backtracking.
- Try to maximize the length of any nonoptional literal strings in regular expressions. This is counterintuitive, but longer patterns often match faster than shorter patterns. That's because the optimizer looks for constant strings and hands them off to a Boyer–Moore search, which benefits from longer strings. Compile your pattern with Perl's `-Dr` debugging switch to see what Dr. Perl thinks the longest literal string is.
- Avoid expensive subroutine calls in tight loops. There is overhead associated with calling subroutines, especially when you pass lengthy parameter lists or return lengthy values. In order of increasing desperation, try passing values by reference, passing values as dynamically scoped globals, inlining the subroutine, or rewriting the whole loop in C. (Better than all of those solutions is if you can define the subroutine out of existence by using a smarter algorithm.)
- Avoid calling the same subroutine over and over if you know that you'll get the same answer each time. Modules such as `Memoize` can help with that, or you can construct your own cache once you have the answer (and you know it won't change).
- Avoid `getc` for anything but single-character terminal I/O. In fact, don't use it for that either. Use `sysread`.
- Avoid frequent `substr`s on long strings, especially if the string contains UTF-8. It's okay to use `substr` at the front of a string. For some tasks you can keep the `substr` at the front by "chewing up" the string as you go with a four-argument `substr`, replacing the part you grabbed with `""`:

```
while ($buffer) {
    process(substr($buffer, 0, 10, ""));
}
```

- If you can, use `pack` and `unpack` instead of multiple `substr` invocations.
- Use `substr` as an lvalue rather than concatenating substrings. For example, to replace the fourth through seventh characters of `$foo` with the contents of the variable `$bar`, don't do this:

```
$foo = substr($foo,0,3) . $bar . substr($foo,7);
```

Instead, simply identify the part of the string to be replaced and assign into it, as in:

```
substr($foo, 3, 4) = $bar;
```

But be aware that if `$foo` is a huge string and `$bar` isn't exactly the length of the "hole", this can do a lot of copying, too. Perl tries to minimize that by copying from either the front or the back, but there's only so much it can do if the `substr` is in the middle.

- Use `s///` rather than concatenating substrings. This is especially true if you can replace one constant with another of the same size. This results in an in-place substitution.
- Use statement modifiers and equivalent `and` and `or` operators instead of full-blown conditionals. Statement modifiers (like `$ring = 0 unless $engaged`) and logical operators avoid the overhead of entering and leaving a block. They can often be more readable, too.
- Use `$foo = $a || $b || $c`. This is much faster (and shorter to say) than:

```
if ($a) {
    $foo = $a;
}
elsif ($b) {
    $foo = $b;
}
elsif ($c) {
    $foo = $c;
}
```

Similarly, set default values with:

```
$pi ||= 3;
```

- Group together any tests that want the same initial string. When testing a string for various prefixes in anything resembling a switch structure, put together all the `/^a/` patterns, all the `/^b/` patterns, and so on.
- Don't test things you know won't match. Use `last` or `elsif` to avoid falling through to the next case in your switch statement.
- Use special operators like `study`, logical string operations, and `pack "u"` and `unpack "%"` formats.
- Beware of the tail wagging the dog. Misstatements resembling `(<STDIN>)[0]` can cause Perl much unnecessary work. In accordance with Unix philosophy, Perl gives you enough rope to hang yourself.
- Factor operations out of loops. The Perl optimizer does not attempt to remove invariant code from loops. It expects you to exercise some sense.

- Strings can be faster than arrays.
- Arrays can be faster than strings. It all depends on whether you're going to reuse the strings or arrays and which operations you're going to perform. Heavy modification of each element implies that arrays will be better, and occasional modification of some elements implies that strings will be better. But you just have to try it and see.
- `my` variables are faster than `local` variables.
- Sorting on a manufactured key array may be faster than using a fancy sort subroutine. A given array value will usually be compared multiple times, so if the sort subroutine has to do much recalculation, it's better to factor out that calculation to a separate pass before the actual sort.
- If you're deleting characters, `tr/abc//d` is faster than `s/[abc]//g`.
- `print` with a comma separator may be faster than concatenating strings. For example:

```
print $fullname{$name} . " has a new home directory " .
    $home{$name} . "\n";
```

  has to glue together the two hashes and the two fixed strings before passing them to the low-level print routines, whereas:

```
print $fullname{$name}, " has a new home directory ",
    $home{$name}, "\n";
```

  doesn't. On the other hand, depending on the values and the architecture, the concatenation may be faster. Try it.
- Prefer `join("", ...)` to a series of concatenated strings. Multiple concatenations may cause strings to be copied back and forth multiple times. The `join` operator avoids this.
- `split` on a fixed string is generally faster than `split` on a pattern. That is, use `split(/ /, ...)` rather than `split(/ +/, ...)` if you know there will only be one space. However, the patterns `/\s+/`, `/^/`, `//`, and `/ /` are specially optimized, as is the special `split` on whitespace.
- Preextending an array or string can save some time. As strings and arrays grow, Perl extends them by allocating a new copy with some room for growth and copying in the old value. Pre-extending a string with the `x` operator or an array by setting `$#array` can prevent this occasional overhead and reduce memory fragmentation.
- Don't `undef` long strings and arrays if they'll be reused for the same purpose. This helps prevent reallocation when the string or array must be reextended.
- Prefer `"\0" x 8192` over `unpack("x8192",())`.

- `system("mkdir ...")` may be faster on multiple directories if the *mkdir* syscall isn't available.
- Avoid using `eof` if return values will already indicate it.
- Cache entries from files (like *passwd* and *group* files) that are apt to be reused. It's particularly important to cache entries from the network. For example, to cache the return value from `gethostbyaddr` when you are converting numeric addresses (like `204.148.40.9`) to names (like "`www.oreilly.com`"), you can use something like:

```
sub numtoname {
    local ($_) = @_;
    unless (defined $numtoname{$_}) {
        my(@a) = gethostbyaddr(pack("C4", split(/\./)),2);
        $numtoname{$_} = @a > 0 ? $a[0] : $_;
    }
    return $numtoname{$_};
}
```

- Avoid unnecessary syscalls. Operating system calls tend to be rather expensive. So, for example, don't call the `time` operator when a cached value of `$now` would do. Use the special _ filehandle to avoid unnecessary *stat*(2) calls. On some systems, even a minimal syscall may execute a thousand instructions.
- Avoid unnecessary `system` calls. The `system` function has to fork a subprocess in order to execute the program you specify—or worse, execute a shell to execute the program. This can easily execute a million instructions.
- Worry about starting subprocesses, but only if they're frequent. Starting a single *pwd*, *hostname*, or *find* process isn't going to hurt you much—after all, a shell starts subprocesses all day long. We do occasionally encourage the toolbox approach, believe it or not.
- Keep track of your working directory yourself rather than calling *pwd* repeatedly. (A standard module is provided for this; see `Cwd` in Chapter 28.)
- Avoid shell metacharacters in commands—pass lists to `system` and `exec` where appropriate.
- Set the sticky bit on the Perl interpreter on machines without demand paging:

```
% chmod +t /usr/bin/perl
```

- Replace `system` calls with nonblocking pipe `open`s. Read the input as it comes in instead of waiting for the entire program to complete.
- Use asynchronous event processing (`AnyEvent`, `Coro`, `POE`, `Gearman`, and so on) to do more than one thing at once. With modern machines, you probably have more than one CPU, and those CPUs are probably multicore. Some of

these events might just sit there waiting for a network response, blocking your program from doing other things. Some of these can take the place of blocking `system` calls.

Space Efficiency

- Give variables the shortest scope possible so they don't take up space when they aren't needed.
- Use `vec` for compact integer array storage if the integers are of fixed width. (Integers of variable width can be stored in a UTF-8 string.)
- Prefer numeric values over equivalent string values; they require less memory.
- Use `substr` to store constant-length strings in a longer string.
- Use the `Tie::SubstrHash` module for very compact storage of a hash array if the key and value lengths are fixed.
- Use `__END__` and the `DATA` filehandle to avoid storing program data as both a string and an array.
- Prefer `each` to `keys` where order doesn't matter.
- Delete or `undef` globals that are no longer in use.
- Use some kind of DBM to store hashes on disk instead of inside the program.
- Use temp files to store arrays.
- Use pipes to offload processing to other tools. They clean up their memory use when they exit.
- Avoid list operations and entire file slurps.
- Avoid using `tr///`. Each `tr///` expression must store a sizable translation table.
- Don't unroll your loops or inline your subroutines.
- Use `File::Mmap` to read files if you don't need to modify the data (and sometimes even if you do).
- Avoid recursion. Perl doesn't have tail-call optimization since it's a dynamic language. You should be able to convert those to an iterative approach, which is how languages with tail-call optimize recursion.

Programmer Efficiency

The half-perfect program that you can run today is better than the fully perfect and pure program that you can run next month. Deal with some temporary ugliness.[1] Some of these are the antithesis of our advice so far.

- Look on CPAN before you write your own code.
- Look on CPAN again. You probably missed the module you need. Ask around.
- Use defaults.
- Use funky shortcut command-line switches like `-a`, `-n`, `-p`, `-s`, and `-i`.
- Use `for` to mean `foreach`.
- Run system commands with backticks.
- Use `<*>` and such.
- Use patterns created at runtime.
- Use `*`, `+`, and `{}` liberally in your patterns.
- Process whole arrays and slurp entire files.
- Use `getc`.
- Use `$``, `$&`, and `$'`.
- Don't check error values on `open`, since `<`*`HANDLE`*`>` and `print` *`HANDLE`* will simply behave as no-ops when given an invalid handle.
- Don't `close` your files—they'll be closed on the next `open`.
- Don't pass subroutine arguments. Use globals.
- Don't name your subroutine parameters. You can access them directly as `$_[`*`EXPR`*`]`.
- Use whatever you think of first.
- Get someone else to do the work for you by programming half an implementation and putting it on Github.

Maintainer Efficiency

Code that you (or your friends) are going to use and work on for a long time into the future deserves more attention. Substitute some short-term gains for much better long-term benefits.

- Don't use defaults.

1. This is also called "technical debt", but it's not always a bad thing.

- Use `foreach` to mean `foreach`.
- Use meaningful loop labels with `next` and `last`.
- Use meaningful variable names.
- Use meaningful subroutine names.
- Put the important thing first on the line using `and`, `or`, and statement modifiers (like `exit if $done`).
- Close your files as soon as you're done with them.
- Use packages, modules, and classes to hide your implementation details.
- Make a sensible API.
- Pass arguments as subroutine parameters.
- Name your subroutine parameters using `my`.
- Parenthesize for clarity.
- Put in lots of (useful) comments.
- Include embedded pod documentation.
- `use warnings`.
- `use strict`.
- Write tests and get good test coverage (see Chapter 19).

Porter Efficiency

- Wave a handsome tip under his nose.
- Avoid functions that aren't implemented everywhere. You can use `eval` tests to see what's available.
- Use the `Config` module or the `$^O` variable to find out what kind of machine you're running on.
- Put in `use v5.xx` statements in to denote the Perl you need.
- Don't use new features just to play with shiny things.
- Don't expect native float and double to `pack` and `unpack` on foreign machines.
- Use network byte order (the "`n`" and "`N`" formats for `pack`) when sending binary data over the network.
- Don't send binary data over the network. Send ASCII. Better, send UTF-8. Better yet, send money.
- Use standard or common formats, such as JSON or YAML, for language- or service-agnostic data exchange.

- Check `$]` or `$^V` to see whether the current version supports all the features you use.
- Don't use `$]` or `$^V`. Use `require` or `use` with a version number.
- Put in the `eval exec` hack, even if you don't use it, so your program will run on those few systems that have Unix-like shells but don't recognize the `#!` notation.
- Put the `#!/usr/bin/perl` line in even if you don't use it.
- Test for variants of Unix commands. Some *find* programs can't handle the *–xdev* switch, for example.
- Avoid variant Unix commands if you can do it internally. Unix commands don't work too well on MS-DOS or VMS.
- Put all your scripts and manpages into a single network filesystem that's mounted on all your machines.
- Publish your module on CPAN. You'll get lots of feedback if it's not portable.
- Make it easy for people to contribute to your work by using public source control, such as Github.

User Efficiency

Making other people's lives easier is a lot more work than making stuff easy for you.

- Instead of making users enter data line by line, pop users into their favorite editor.
- Better yet, use a GUI like the Perl `/Tk` or `Wx` modules, where users can control the order of events.
- Put up something for users to read while you continue doing work.
- Use autoloading so that the program *appears* to run faster.
- Give the option of helpful messages at every prompt.
- Give a helpful usage message if users don't give correct input.
- Include extended examples in the documentation, and complete example programs in the distribution.
- Display the default action at every prompt, and maybe a few alternatives.
- Choose defaults for beginners. Allow experts to change the defaults.
- Use single-character input where it makes sense.
- Pattern the interaction after other things the user is familiar with.

- Make error messages clear about what needs fixing. Include all pertinent information such as filename and error code, like this:

```
open(FILE, $file) || die "$0: Can't open $file for reading: $!\n";
```

- Use `fork && exit` to detach from the terminal when the rest of the script is just batch processing.
- Allow arguments to come from either the command line or standard input.
- Use configuration files with a simple text format. There are many modules for this already on CPAN.
- Don't put arbitrary limitations into your program.
- Prefer variable-length fields over fixed-length fields.
- Use text-oriented network protocols.
- Tell everyone else to use text-oriented network protocols!
- Tell everyone else to tell everyone else to use text-oriented network protocols!!!
- Be vicariously lazy.
- Be nice.

Programming with Style

You'll certainly have your own preferences in regard to formatting, but there are some general guidelines that will make your programs easier to read, understand, and maintain. Larry made some general recommendations in *perlstyle*, but they are just recommendations. You might also like *Perl Best Practices* or *Modern Perl*.

The most important thing is to run your programs under `strict` and `warnings` pragmas, unless you have a good reason not to. If you need to turn them off, use `no` in the smallest scope possible. The `sigtrap` and even the `diagnostics` pragmas may also be beneficial.

Regarding aesthetics of code layout, about the only thing Larry cares strongly about is that the closing brace of a multiline *`BLOCK`* should be "outdented" to line up with the keyword that started the construct. Beyond that, he has other preferences that aren't so strong. Examples in this book (should) all follow these coding conventions:

- Use four-column indents.
- Put an opening brace on the same line as its preceding keyword, if possible; otherwise, line them up vertically:

```
while ($condition) {        # for short ones, align with keywords
    # do something
}

# if the condition wraps, line up the braces with each other
while ($this_condition and $that_condition
       and $this_other_long_condition)
{
    # do something
}
```

- Put space before the opening brace of a multiline *BLOCK*.
- A short *BLOCK* may be put on one line, including braces.
- Omit the semicolon in a short, one-line *BLOCK*.
- Surround most operators with space.
- Surround a "complex" subscript (inside brackets) with space.
- Put blank lines between chunks of code that do different things.
- Put a newline between a closing brace and `else`.
- Do not put space between a function name and its opening parenthesis.
- Do not put space before a semicolon.
- Put space after each comma.
- Break long lines after an operator (but before `and` and `or`, even when spelled `&&` and `||`).
- Line up corresponding items vertically.
- Omit redundant punctuation so long as clarity doesn't suffer.

Larry has his reasons for each of these things, but he doesn't claim that everyone else's mind works the same as his does (or doesn't).

Here are some other, more substantive style issues to think about:

- Just because you *can* do something a particular way doesn't mean you *should* do it that way. Perl is designed to give you several ways to do anything, so consider picking the most readable one. For instance:

  ```
  open(FOO,$foo)  || die "Can't open $foo: $!";
  ```

  is better than:

  ```
  die "Can't open $foo: $!"   unless open(FOO,$foo);
  ```

  because the second way hides the main point of the statement in a modifier. On the other hand:

  ```
  print "Starting analysis\n" if $verbose;
  ```

is better than:

```
$verbose and print "Starting analysis\n";
```

since the main point isn't whether the user typed `-v` or not.

- Similarly, just because an operator lets you assume default arguments doesn't mean that you have to make use of the defaults. The defaults are there for lazy programmers writing one-shot programs. If you want your program to be readable, consider supplying the argument.
- Along the same lines, just because you *can* omit parentheses in many places doesn't mean that you ought to:

```
return print reverse sort num values %array;
return print(reverse(sort num (values(%array))));
```

When in doubt, parenthesize. At the very least, it will let some poor schmuck bounce on the `%` key in *vi*.

Even if *you* aren't in doubt, consider the mental welfare of the person who has to maintain the code after you and who will probably put parentheses in the wrong place.

- Don't go through silly contortions to exit a loop at the top or the bottom. Perl provides the `last` operator so you can exit in the middle. You can optionally "outdent" it to make it more visible:

```
LINE:
    for (;;) {
        statements;
      last LINE if $foo;
        next LINE if /^#/;
        statements;
    }
```

- Don't be afraid to use loop labels—they're there to enhance readability as well as to allow multilevel loop breaks. See the example just given.
- Avoid using `grep`, `map`, or backticks in void context; that is, when you just throw away their return values. Those functions all have return values, so use them. Otherwise, use a `foreach` loop or the `system` function.
- For portability, when using features that may not be implemented on every machine, test the construct in an `eval` to see whether it fails. If you know the version or patch level of a particular feature, you can test `$]` (`$PERL_VERSION` in the English module) to see whether the feature is there. The `Config` module will also let you interrogate values determined by the *Configure* program when Perl was installed.

- Choose mnemonic identifiers. If you can't remember what mnemonic means, you've got a problem.
- Although short identifiers like `$gotit` are probably okay, use underscores to separate words. It is generally much easier to read `$var_names_like_this` than `$VarNamesLikeThis`, especially for nonnative speakers of English. Besides, the same rule works for `$VAR_NAMES_LIKE_THIS`.

  Package names are sometimes an exception to this rule. Perl informally reserves lowercase module names for pragmatic modules like `integer` and `strict`. Other modules should begin with a capital letter and use mixed case, but they should probably omit underscores due to name-length limitations on certain primitive filesystems.
- You may find it helpful to use letter case to indicate the scope or nature of a variable. For example:

```
$ALL_CAPS_HERE   # constants only (beware clashes with Perl vars!)
$Some_Caps_Here  # package-wide global/static
$no_caps_here    # function scope my() or local() variables
```

  For various vague reasons, function and method names seem to work best as all lowercase. For example, `$obj->as_string()`.

  You can use a leading underscore to indicate that a variable or function should not be used outside the package that defined it. (Perl does not enforce this; it's just a form of documentation.)
- If you have a really hairy regular expression, use the `/x` modifier and put in some whitespace to make it look a little less like line noise.
- Don't use slash as a delimiter when your regular expression already has too many slashes or backslashes.
- Don't use quotes as delimiters when your string contains the same kind of quote. Use the `q//`, `qq//`, or `qx//` pseudofunctions instead.
- Use the `and` and `or` operators to avoid having to parenthesize list operators so much and to reduce the incidence of punctuational operators like `&&` and `||`. Call your subroutines as if they were functions or list operators to avoid excessive ampersands and parentheses.
- Use here documents instead of repeated `print` statements.
- Line up corresponding things vertically, especially if they're too long to fit on one line anyway:

```
$IDX = $ST_MTIME;
$IDX = $ST_ATIME       if $opt_u;
$IDX = $ST_CTIME       if $opt_c;
$IDX = $ST_SIZE        if $opt_s;
```

```
mkdir($tmpdir, 0700) || die "can't mkdir $tmpdir: $!";
chdir($tmpdir)       || die "can't chdir $tmpdir: $!";
mkdir("tmp",   0777) || die "can't mkdir $tmpdir/tmp: $!";
```

- That which we tell you three times is true:

  Always check the return codes of system calls.

  Always check the return codes of system calls.

  ALWAYS CHECK THE RETURN CODES OF SYSTEM CALLS!

  Error messages should go to `STDERR` and should say which program caused the problem and what the failed call and its arguments were. Most importantly, for failed syscalls, messages should contain the standard system error message for what went wrong. Here's a simple but sufficient example:

  ```
  opendir(D, $dir)  || die "Can't opendir $dir: $!";
  ```

  Remember to check the return code, always.

- Line up your transliterations when it makes sense:

  ```
  tr [abc]
     [xyz];
  ```

- Think about reusability. Why waste brainpower on a one-shot script when you might want to do something like it again? Consider generalizing your code. Consider writing a module or object class. Consider making your code run cleanly with `use strict` and `-w` in effect. Consider giving away your code. Consider changing your whole world view. Consider ... oh, nevermind.
- Use `Perl::Tidy` to beautify code, and use `Perl::Critic` to catch possible programming problems.
- Be consistent.
- Be nice.

Fluent Perl

We've touched on a few idioms in the preceding sections (not to mention the preceding chapters), but there are many other idioms you'll commonly see when you read programs by accomplished Perl programmers. When we speak of idiomatic Perl in this context, we don't just mean a set of arbitrary Perl expressions with fossilized meanings. Rather, we mean Perl code that shows an understanding of the flow of the language, what you can get away with when, and what that buys you. And when to buy it.

We can't hope to list all the idioms you might see—that would take a book as big as this one. Maybe two. (See *Perl Cookbook*, for instance.) But here are some of the important idioms, where "important" might be defined as "that which induces hissy fits in people who think they already know just how computer languages ought to work".

- Use `=>` in place of a comma anywhere you think it improves readability:

  ```
  return bless $mess => $class;
  ```

  This reads, "Bless this mess into the specified class." Just be careful not to use it after a word that you don't want autoquoted:

  ```
  sub foo () { "FOO" }
  sub bar () { "BAR" }
  print foo => bar;   # prints fooBAR, not FOOBAR;
  ```

  Another good place to use `=>` is near a literal comma that might get confused visually:

  ```
  join(", " => @array);
  ```

  Perl provides you with more than one way to do things so that you can exercise your ability to be creative. Exercise it!

- Use the singular pronoun to increase readability:

  ```
  for (@lines) {
      $_ .= "\n";
  }
  ```

  The `$_` variable is Perl's version of a pronoun, and it essentially means "it". So the code above means "for each line, append a newline to *it*." Nowadays you might even spell that:

  ```
  $_ .= "\n" for @lines;
  ```

  The `$_` pronoun is so important to Perl that its use is mandatory in `grep` and `map`. Here is one way to set up a cache of common results of an expensive function:

  ```
  %cache = map { $_ => expensive($_) } @common_args;
  $xval = $cache{$x} || expensive($x);
  ```

- Omit the pronoun to increase readability even further.[2]
- Use loop controls with statement modifiers.

2. In this section, multiple bullet items in a row all refer to the subsequent example, since some of our examples illustrate more than one idiom.

```
while (<>) {
     next if /^=for\s+(index|later)/;
     $chars += length;
     $words += split;
     $lines += y/\n//;
 }
```

This is a fragment of code we used to do page counts for this book. When you're going to be doing a lot of work with the same variable, it's often more readable to leave out the pronouns entirely, contrary to common belief.

The fragment also demonstrates the idiomatic use of `next` with a statement modifier to short circuit a loop.

The `$_` variable is always the loop-control variable in `grep` and `map`, but the program's reference to it is often implicit:

```
@haslen = grep { length } @random;
```

Here we take a list of random scalars and only pick the ones that have a length greater than `0`.

- Use `for` to set the antecedent for a pronoun:

```
for ($episode) {
    s/fred/barney/g;
    s/wilma/betty/g;
    s/pebbles/bambam/g;
}
```

So what if there's only one element in the loop? It's a convenient way to set up "it"—that is, `$_`. Linguistically, this is known as topicalization. It's not cheating, it's communicating.

- Implicitly reference the plural pronoun, `@_`.
- Use control flow operators to set defaults:

```
sub bark {
    my Dog $spot = shift;
    my $quality  = shift || "yapping";
    my $quantity = shift || "nonstop";
    ...
}
```

Here we're implicitly using the other Perl pronoun, `@_`, which means "them". The arguments to a function always come in as "them". The `shift` operator knows to operate on `@_` if you omit it, just as the ride operator at Disneyland might call out "Next!" without specifying which queue is supposed to shift. (There's no point in specifying because there's only one queue that matters.)

The `||` can be used to set defaults despite its origins as a Boolean operator, since Perl returns the first true value. Perl programmers often manifest a cavalier attitude toward the truth; the line above would break if, for instance, you tried to specify a quantity of 0. But as long as you never want to set either `$quality` or `$quantity` to a false value, the idiom works great. There's no point in getting all superstitious and throwing in calls to `defined` and `exists` all over the place. You just have to understand what it's doing. As long as it won't accidentally be false, you're fine.

If you think it will accidentally be false, you can use the defined-OR operator, `//`, instead:

```
use v5.10;

sub bark {
    my Dog $spot = shift;
    my $quality  = shift // "yapping";
    my $quantity = shift // "nonstop";
    ...
}
```

- Use assignment forms of operators, including control-flow operators:

```
$xval = $cache{$x} ||= expensive($x);
```

Here we don't initialize our cache at all. We just rely on the `||=` operator to call `expensive($x)` and assign it to `$cache{$x}` only if `$cache{$x}` is false. The result of that is whatever the new value of `$cache{$x}` is. Again, we take the cavalier approach toward truth in that if we cache a false value, `expensive($x)` will get called again. Maybe the programmer knows that's okay, because `expensive($x)` isn't expensive when it returns false. Or maybe the programmer knows that `expensive($x)` never returns a false value at all. Or maybe the programmer is just being sloppy. Sloppiness can be construed as a form of creativity.

- Use loop controls as operators, not just as statements. And...
- Use commas like small semicolons:

```
while (<>) {
    $comments++, next if /^#/;
    $blank++, next    if /^\s*$/;
    last              if /^__END__/;
    $code++;
}
print "comment = $comments\nblank = $blank\ncode = $code\n";
```

This shows an understanding that statement modifiers modify statements, while `next` is a mere operator. It also shows the comma being idiomatically used to separate expressions much like you'd ordinarily use a semicolon.

(The difference being that the comma keeps the two expressions as part of the same statement, under the control of the single statement modifier.)

- Use flow control to your advantage:

```
while (<>) {
    /^#/       and $comments++, next;
    /^\s*$/    and $blank++, next;
    /^__END__/ and last;
    $code++;
}
print "comment = $comments\nblank = $blank\ncode = $code\n";
```

  Here's the exact same loop again, only this time with the patterns out in front. The perspicacious Perl programmer understands that it compiles down to exactly the same internal codes as the previous example. The `if` modifier is just a backward `and` (or `&&`) conjunction, and the `unless` modifier is just a backward `or` (or `||`) conjunction.

- Use the implicit loops provided by the *–n* and *–p* switches.
- Don't put a semicolon at the end of a one-line block:

```
#!/usr/bin/perl -n
$comments++, next LINE if /#/;
$blank++, next LINE    if /^\s*$/;
last LINE              if /^__END__/;
$code++;

END { print "comment = $comments\nblank = $blank\ncode = $code\n" }
```

  This is essentially the same program as before. We put an explicit `LINE` label on the loop-control operators because we felt like it, but we didn't really need to since the implicit `LINE` loop supplied by *–n* is the innermost enclosing loop. We used an `END` to get the final print statement outside the implicit main loop, just as in *awk*.

- Use here docs when the printing gets ferocious.
- Use a meaningful delimiter on the here doc:

```
END { print <<"COUNTS" }
comment = $comments
blank = $blank
code = $code
COUNTS
```

  Rather than using multiple prints, the fluent Perl programmer uses a multiline string with interpolation. And despite our calling it a Common Goof earlier, we've brazenly left off the trailing semicolon because it's not necessary at the

end of the `END` block. (If we ever turn it into a multiline block, we'll put the semicolon back in.)

- Do substitutions and translations en passant on a scalar:

```
($new = $old) =~ s/bad/good/g;
```

  or use the `/r` modifier to return the result instead:

```
$new = $old =~ s/bad/good/gr;
```

  Since lvalues are lvaluable, so to speak, you'll often see people changing a value "in passing" while it's being assigned. This could actually save a string copy internally (if we ever get around to implementing the optimization):

```
chomp($answer = <STDIN>);
```

  Any function that modifies an argument in place can do the en passant trick. But wait, there's more!

- Don't limit yourself to changing scalars en passant:

```
for (@new = @old) { s/bad/good/g }
```

  Here we copy `@old` into `@new`, changing everything in passing (not all at once, of course—the block is executed repeatedly, one "it" at a time).

- Pass named parameters using the fancy `=>` comma operator.
- Rely on assignment to a hash to do even/odd argument processing:

```
sub bark {
    my DOG $spot = shift;
    my %parm = @_;
    my $quality  = $parm{QUALITY}  || "yapping";
    my $quantity = $parm{QUANTITY} || "nonstop";
    ...
}

$fido->bark( QUANTITY => "once",
             QUALITY => "woof" );
```

  Named parameters are often an affordable luxury. And with Perl, you get them for free—if you don't count the cost of the hash assignment.

- Repeat Boolean expressions until false.
- Use minimal matching when appropriate.
- Use the `/e` modifier to evaluate a replacement expression:

```
#!/usr/bin/perl -p
1 while s/^(.*?)(\t+)/$1 . " " x (length($2) * 4 - length($1) % 4)/e;
```

  This program fixes any file you receive from someone who mistakenly thinks he can redefine hardware tabs to occupy four spaces instead of eight. It makes

use of several important idioms. First, the `1 while` idiom is handy when all the work you want to do in the loop is actually done by the conditional. (Perl is smart enough not to warn you that you're using `1` in void context.) We have to repeat this substitution because each time we substitute some number of spaces in for tabs, we have to recalculate the column position of the next tab from the beginning.

The `(.*?)` matches the smallest string it can up until the first tab, using the minimal matching modifier (the question mark). In this case, we could have used an ordinary greedy `*` like this: `([^\t]*)`. But that only works because a tab is a single character, so we can use a negated character class to avoid running past the first tab. In general, the minimal matcher is much more elegant, and it doesn't break if the next thing that must match happens to be longer than one character.

The `/e` modifier does a substitution using an expression rather than a mere string. This lets us do the calculations we need right when we need them.

- Use creative formatting and comments on complex substitutions:

```
#!/usr/bin/perl -p
1 while s{
    ^               # anchor to beginning
    (               # start first subgroup
        .*?         # match minimal number of characters
    )               # end first subgroup
    (               # start second subgroup
        \t+         # match one or more tabs
    )               # end second subgroup
}
{
    my $spacelen = length($2) * 4;  # account for full tabs
    $spacelen -= length($1) % 4;    # account for the uneven tab
    $1 . " " x $spacelen;           # make correct number of spaces
}ex;
```

This is probably overkill, but some people find it more impressive than the previous one-liner. Go figure.

- Go ahead and use `$`` if you feel like it:

```
1 while s/(\t+)/" " x (length($1) * 4 - length($`) % 4)/e;
```

Here's the shorter version, which uses `$``, which is known to impact performance. Except that we're only using the length of it, so it doesn't really count as bad.

- Use the offsets directly from the `@-` (`@LAST_MATCH_START`) and `@+` (`@LAST_MATCH_END`) arrays:

```
1 while s/\t+/" " x (($+[0] - $-[0]) * 4 - $-[0] % 4)/e;
```

This one's even shorter. (If you don't see any arrays there, try looking for array elements instead.) See `@-` and `@+` in Chapter 25.

- Use `eval` with a constant return value:

```
sub is_valid_pattern {
    my $pat = shift;
    return eval { "" =~ /$pat/; 1 } || 0;
}
```

You don't have to use the `eval {}` operator to return a real value. Here we always return `1` if it gets to the end. However, if the pattern contained in `$pat` blows up, the `eval` catches it and returns `undef` to the Boolean conditional of the `||` operator, which turns it into a defined `0` (just to be polite, since `undef` is also false but might lead someone to believe that the `is_valid_pattern` subroutine is misbehaving, and we wouldn't want that, now would we?).

- Use modules to do all the dirty work.
- Use object factories.
- Use callbacks.
- Use stacks to keep track of context.
- Use negative subscripts to access the end of an array or string:

```
use XML::Parser;

$p = XML::Parser->new( Style => "subs" );
setHandlers $p Char => sub { $out[-1] .= $_[1] };

push @out, "";

sub literal {
    $out[-1] .= "C<";
    push @out, "";
}

sub literal_ {
    my $text = pop @out;
    $out[-1] .= $text . ">";
}
...
```

This is a snippet from the 250-line program we used to translate the XML version of the old Camel book back into pod format, so we could edit it for this edition with a Real Text Editor before we translated it back to DocBook.

The first thing you'll notice is that we rely on the `XML::Parser` module (from CPAN) to parse our XML correctly, so we don't have to figure out how. That

cuts a few thousand lines out of our program right there (presuming we're reimplementing in Perl everything `XML::Parser` does for us,[3] including translation from almost any character set into UTF-8).

`XML::Parser` uses a high-level idiom called an *object factory*. In this case, it's a parser factory. When we create an `XML::Parser` object, we tell it which style of parser interface we want, and it creates one for us. This is an excellent way to build a testbed application when you're not sure which kind of interface will turn out to be the best in the long run. The `subs` style is just one of `XML::Parser`'s interfaces. In fact, it's one of the oldest interfaces, and it's probably not even the most popular one these days.

The `setHandlers` line shows a method call on the parser, not in arrow notation, but in "indirect object" notation, which lets you omit the parens on the arguments, among other things. The line also uses the named parameter idiom we saw earlier.

The line also shows another powerful concept, the notion of a callback. Instead of us calling the parser to get the next item, we tell it to call us. For named XML tags like `<literal>`, this interface style will automatically call a subroutine of that name (or the name with an underline on the end for the corresponding end tag). But the data between tags doesn't have a name, so we set up a `Char` callback with the `setHandlers` method.

Next we initialize the `@out` array, which is a stack of outputs. We put a null string into it to represent that we haven't collected any text at the current tag embedding level (0 initially).

Now is when that callback comes back in. Whenever we see text, it automatically gets appended to the final element of the array via the `$out[-1]` idiom in the callback. At the outer tag level, `$out[-1]` is the same as `$out[0]`, so `$out[0]` ends up with our whole output. (Eventually. But first we have to deal with tags.)

Suppose we see a `<literal>` tag. The `literal` subroutine gets called, appends some text to the current output and then pushes a new context onto the `@out` stack. Now any text up until the closing tag gets appended to that new end of the stack. When we hit the closing tag, we pop the `$text` we've collected back off the `@out` stack, and append the rest of the transmogrified data to the new (that is, the old) end of stack, the result of which is to translate the XML string, `<literal>`*text*`</literal>`, into the corresponding pod string, `C<`*text*`>`.

The subroutines for the other tags are just the same, only different.

3. Actually, `XML::Parser` is just a fancy wrapper around James Clark's expat XML parser.

- Use `my` without assignment to create an empty array or hash.
- Split the default string on whitespace.
- Assign to lists of variables to collect however many you want.
- Use autovivification of undefined references to create them.
- Autoincrement undefined array and hash elements to create them.
- Use autoincrement of a `%seen` hash to determine uniqueness.
- Assign to a handy `my` temporary in the conditional.
- Use the autoquoting behavior of braces.
- Use an alternate quoting mechanism to interpolate double quotes.
- Use the `?:` operator to switch between two arguments to a `printf`.
- Line up `printf` args with their `%` field:

```
my %seen;
while (<>) {
    my ($a, $b, $c, $d) = split;
    print unless $seen{$a}{$b}{$c}{$d}++;
}
if (my $tmp = $seen{fee}{fie}{foe}{foo}) {
    printf qq(Saw "fee fie foe foo" [sic] %d time%s.\n),
                                          $tmp,  $tmp == 1 ? "" : "s";
}
```

These nine lines are just chock full of idioms. The first line makes an empty hash because we don't assign anything to it. We iterate over input lines setting "it"—that is, `$_`—implicitly, then using an argumentless `split`, which splits "it" on whitespace. Then we pick off the four first words with a list assignment, throwing any subsequent words away. Then we remember the first four words in a four-dimensional hash, which automatically creates (if necessary) the first three reference elements and final count element for the autoincrement to increment. (Under `warnings`, the autoincrement will never warn that you're using undefined values, because autoincrement is an accepted way to define undefined values.) We then print out the line if we've never seen a line starting with these four words before. This is because the autoincrement is a postincrement, which, in addition to incrementing the hash value, will return the old true value if there was one.

After the loop, we test `%seen` again to see whether a particular combination of four words was seen. We make use of the fact that we can put a literal identifier into braces and it will be autoquoted. Otherwise, we'd have to say `$seen{"fee"}{"fie"}{"foe"}{"foo"}`, which is a drag—even when you're not running from a giant.

We assign the result of `$seen{fee}{fie}{foe}{foo}` to a temporary variable even before testing it in the Boolean context provided by the `if`. Because assignment returns its left value, we can still test the value to see whether it was true. The `my` tells your eye that it's a new variable, and we're not testing for equality but doing an assignment. It would also work fine without the `my`, and an expert Perl programmer would still immediately notice that we used one `=` instead of two `==`. (A semiskilled Perl programmer might be fooled, however. Pascal programmers of any skill level will foam at the mouth.)

Moving on to the `printf` statement, you can see the `qq()` form of double quotes we used so that we could interpolate ordinary double quotes as well as a newline. We could've directly interpolated `$tmp` there as well, since it's effectively a double-quoted string, but we chose to do further interpolation via `printf`. Our temporary `$tmp` variable is now quite handy, particularly since we don't just want to interpolate it, but also to test it in the conditional of a `?:` operator to see whether we should pluralize the word "time". Finally, note that we lined up the two fields with their corresponding `%` markers in the `printf` format. If an argument is too long to fit, you can always go to the next line for the next argument, though we didn't have to in this case.

Whew! Had enough? There are many more idioms we could discuss, but this book is already sufficiently heavy. However, we'd like to talk about one more idiomatic use of Perl: the writing of program generators.

Program Generation

Almost from the time people first figured out that they could write programs, they started writing programs that write other programs. We often call these *program generators*. (If you're a history buff, you might know that RPG stood for Report Program Generator long before it stood for Role-Playing Game.) Nowadays they'd probably be called "program factories", but the generator people got there first, so they got to name it.

Now anyone who has written a program generator knows that it can make your eyes go crossed even when you're wide awake. The problem is simply that much of your program's data looks like real code, but it isn't (at least not yet). The same text file contains both stuff that does something and similar-looking stuff that doesn't. Perl has various features that make it easy to mix Perl together with other languages, textually speaking.

(Of course, these features also make it easier to write Perl in Perl, but that's rather to be expected by now, we should think.)

Generating Other Languages in Perl

Perl is (among other things) a text-processing language, and most computer languages are textual. Beyond that, Perl's lack of arbitrary limits, together with the various quoting and interpolation mechanisms, make it easy to visually isolate the code of the other language you're spitting out. For example, here is a small chunk of *s2p*, the *sed*-to-*perl* translator:

```
print &q(<<"EOT");
:       #!$bin/perl
:       eval 'exec $bin/perl -S \$0 \${1+"\$@"}'
:               if \$running_under_some_shell;
:
EOT
```

Here the enclosed text happens to be legal in two languages, Perl and *sh*. We've used an idiom right off the bat that will preserve your sanity in the writing of a program generator: the trick of putting a "noise" character and a tab on the front of every quoted line, which visually isolates the enclosed code, so you can tell at a glance that it's not the code that is actually being executed. One variable, `$bin`, is interpolated in the multiline quote in two places, and then the string is passed through a function to strip the colon and tab.

Of course, you aren't required to use multiline quotes. One often sees CGI scripts containing millions of `print` statements, one per line. It seems a bit like driving to church in a Formula 1 car, but hey, if it gets you there... (We will admit that a column of `print` statements has its own form of visual distinctiveness.)

When you are embedding a large, multiline quote containing some other language (such as HTML), it's often helpful to pretend you're programming inside-out, enclosing Perl into the other language instead, much as you might do with overtly everted languages such as PHP:

```
print <<"XML";
    <stuff>
    <nonsense>
    blah blah blah @{[ scalar EXPR ]} blah blah blah
    blah blah blah @{[ LIST ]} blah blah blah
    </nonsense>
    </stuff>
XML
```

You can use either of those two tricks to interpolate the values of arbitrarily complicated expressions into the long string.

Some program generators don't look much like program generators, depending on how much of their work they hide from you. In Chapter 19 we saw how a small *Makefile.PL* program could be used to write a *Makefile*. The *Makefile* can

easily be 100 times bigger than the *Makefile.PL* that produced it. Think how much wear and tear that saves your fingers. Or don't think about it—that's the point, after all.

Generating Perl in Other Languages

It's easy to generate other languages in Perl, but the converse is also true. Perl can easily be generated in other languages because it's both concise and malleable. You can pick your quotes not to interfere with the other language's quoting mechanisms. You don't have to worry about indentation, or where you put your line breaks, or whether to backslash your backslashes Yet Again. You aren't forced to define a package as a single string in advance, since you can slide into your package's namespace repeatedly, whenever you want to evaluate more code in that package.

Another thing that makes it easy to write Perl in other languages (including Perl) is the `#line` directive. Perl knows how to process these as special directives that reconfigure its idea of the current filename and line number. This can be useful in error or warning messages, especially for strings processed with `eval` (which, when you think about it, is just Perl writing Perl). The syntax for this mechanism is the one used by the C preprocessor: when Perl encounters a `#` symbol and the word `line`, followed by a number and a filename, it sets `__LINE__` to the number and `__FILE__` to the filename.[4]

Here are some examples that you can test by typing into *perl* directly. We've used a Control-D to indicate end-of-file, which is typical on Unix. DOS/Windows and VMS users can type Control-Z. If your shell uses something else, you'll have to use that to tell *perl* you're done. Alternatively, you can always type in `__END__` to tell the compiler there's nothing left to parse.

Here, Perl's built-in `warn` function prints out the new filename and line number:

```
% perl
# line 2000 "Odyssey"
# the "#" on the previous line must be the first char on line
warn "pod bay doors";  # or die
^D
pod bay doors at Odyssey line 2001.
```

And here, the exception raised by `die` within the `eval` found its way into the `$@` (`$EVAL_ERROR`) variable, along with the temporary new filename and line:

4. Technically, it matches the pattern `/^#\s*line\s+(\d+)\s*(?:\s"([^"]+)")?\s*$/`, with `$1` providing the line number for the next line and `$2` providing the optional filename specified within quotes. (A null filename leaves `__FILE__` unchanged.)

```
# line 1996 "Odyssey"
eval qq{
#line 2025 "Hal"
    die "pod bay doors";
};
print "Problem with $@";
warn "I'm afraid I can't do that";
^D
Problem with pod bay doors at Hal line 2025.
I'm afraid I can't do that at Odyssey line 2001.
```

This shows how a `#line` directive affects only the current compilation unit (file or `eval` *`STRING`*), and that when that unit is done being compiled, the previous settings are automatically restored. This way you can set up your own messages inside an `eval` *`STRING`* or `do` *`FILE`* without affecting the rest of your program.

One of the very first Perl preprocessors was the *sed*-to-*perl* translator, *s2p*. In fact, Larry delayed the initial release of Perl in order to complete *s2p* and *awk*-to-*perl* (*a2p*), because he thought they'd improve the acceptance of Perl. Hmm, maybe they did.

See the online docs for more on these, as well as the *find2perl* translator.

Source Filters

If you can write a program to translate random stuff into Perl, then why not have a way of invoking that translator from within Perl?

The notion of a source filter started with the idea that a script or module should be able to decrypt itself on the fly, like this:

```
#!/usr/bin/perl
use MyDecryptFilter;
@*x$]`0uN&k^Zx02jZ^X{.?s!(f;9Q/^A^@~~8H]|,%@^P:q-=
...
```

But the idea grew from there, and now a source filter can be defined to do any transformation on the input text you like. Put that together with the notion of the *–x* switch mentioned in Chapter 17, and you have a general mechanism for pulling any chunk of program out of a message and executing it, regardless of whether it's written in Perl.

Using the `Filter` module from CPAN, one can now even do things like programming Perl in *awk*:

```
#!/usr/bin/perl
use Filter::exec "a2p";         # the awk-to-perl translator
1,30 { print $1 }
```

Now that's definitely what you might call idiomatic. But we won't pretend for a moment that it's common practice.

CHAPTER 22
Portable Perl

A world with only one operating system makes portability easy and life boring. We prefer a larger genetic pool of operating systems, as long as the ecosystem doesn't divide too cleanly into predators and prey. Perl runs on dozens of operating systems, and because Perl programs aren't platform dependent, the same program can run on all of those systems without modification.

Well, almost. Perl tries to give the programmer as many features as possible, but if you make use of features particular to a certain operating system, you'll necessarily reduce the portability of your program to other systems. In this section we'll provide some guidelines for writing portable Perl code. Once you make a decision about how portable you want to be, you'll know where the lines are drawn, and you can stay within them.

Looking at it another way, writing portable code is usually about willfully limiting your available choices. Naturally, it takes discipline and sacrifice to do that, two traits that Perl programmers might be unaccustomed to.

The *perlport* manpage lists the platforms that Perl no longer supports, such as Mac OS 9 (Classic) and Windows 95, 98, ME, and NT4. Not only are they unsupported, but the code that formerly supported them has disappeared from the codebase. So, depending on your Perl, you may not have to support those anymore. Supported systems with deviations or special cases get their own manpage, as listed in Table 22-1.

Table 22-1. System-specific manpages

Manpage			
perlaix	*perlfreebsd*	*perlnetware*	*perlsymbian*
perlamiga	*perlhaiku*	*perlopenbsd*	*perltru64*
perlbeos	*perlhpux*	*perlos2*	*perluts*

Manpage			
perlbs2000	*perlhurd*	*perlos390*	*perlvmesa*
perlce	*perlirix*	*perlos400*	*perlvms*
perlcygwin	*perllinux*	*perlplan9*	*perlvos*
perldgux	*perlmacos*	*perlqnx*	*perlwin32*
perldos	*perlmacosx*	*perlriscos*	
perlepoc	*perlmpeix*	*perlsolaris*	

Not all Perl programs have to be portable. There is no reason not to use Perl to glue Unix tools together, prototype a Macintosh application, or manage the Windows registry. If it makes sense to sacrifice portability, go ahead.[1] In general, note that the notions of a user ID, a "home" directory, and even the state of being logged in will exist only on multiuser platforms.[2]

The special `$^O` variable tells you what operating system your Perl was built on. This is provided to speed up code that would otherwise have to load `Config` to get the same information via `$Config{osname}`. Even if you've pulled in `Config` for other reasons, it still saves you the price of a tied-hash lookup. You can also use the `Devel::AssertOS` or `Devel::CheckOS` CPAN modules for fancier control.

To get more detailed information about the platform, you can look at the rest of the information in the `%Config` hash, which is made available by the standard `Config` module. For example, to check whether the platform has the `lstat` call, you can check `$Config{d_lstat}`. See `Config`'s online documentation for a full description of available variables, and see the *perlport* manpage for a listing of the behavior of Perl built-in functions on different platforms. Here are the Perl functions whose behavior varies the most across platforms (see *perlport* for more details):

`-X` (file tests), `accept`, `alarm`, `bind`, `binmode`, `chmod`, `chown`, `chroot`, `connect`, `crypt`, `dbmclose`, `dbmopen`, `dump`, `endgrent`, `endhostent`, `endnetent`, `endprotoent`, `endpwent`, `endservent`, `exec`, `fcntl`, `fileno`, `flock`, `fork`, `getgrent`, `getgrgid`, `getgrnam`, `gethostbyaddr`, `gethostbyname`, `gethostent`, `getlogin`, `getnetbyaddr`, `getnetbyname`, `getnetent`, `getpeername`, `getpgrp`, `getppid`, `getpriority`, `getprotobyname`, `getprotobynumber`, `getprotoent`, `getpwent`, `getpwnam`, `getpwuid`, `getservbyport`,

1. Not every conversation has to be cross-culturally correct. Perl tries to give you at least one way to do the Right Thing, but it doesn't try to force it on you rigidly. In this respect, Perl more closely resembles your mother tongue than a nanny's tongue.

2. Although a "user" is a bit of an odd concept now, because even a system designed for one person might have many "users".

getservent, getservbyname, getsockname, getsockopt, glob, ioctl, kill, link, listen, lstat, msgctl, msgget, msgrcv, msgsnd, open, pipe, qx, readlink, readpipe, recv, select, semctl, semget, semop, send, sethostent, setgrent, setnetent, setpgrp, setpriority, setprotoent, setpwent, setservent, setsockopt, shmctl, shmget, shmread, shmwrite, shutdown, socket, socketpair, stat, symlink, syscall, sysopen, system, times, truncate, umask, utime, wait, waitpid

Newlines

On most operating systems, lines in files are terminated by one or two characters that signal the end of the line. The characters vary from system to system. Unix traditionally uses `\012` (that is, the octal 12 character in ASCII), one type of DOSish I/O uses `\015\012`, and the pre-Unix Macs used to use `\015`. Perl uses `\n` to represent a "logical" newline, regardless of platform. In DOSish Perls, `\n` usually means `\012`, but when accessing a file in "text mode", it is translated to (or from) `\015\012`, depending on whether you're reading or writing. Unix does the same thing on terminals in canonical mode. `\015\012` is commonly referred to as CRLF.

Because DOS distinguishes between text files and binary files, DOSish Perls have limitations when using `seek` and `tell` on a file in "text mode". For best results, only `seek` to locations obtained from `tell`. If you use Perl's built-in `binmode` function on the filehandle, however, you can usually `seek` and `tell` with impunity.

A common misconception in socket programming is that `\n` will be `\012` everywhere. In many common Internet protocols, `\012` and `\015` are specified, and the values of Perl's `\n` and `\r` are not reliable since they vary from system to system:

```
print SOCKET "Hi there, client!\015\012";  # right
print SOCKET "Hi there, client!\r\n";      # wrong
```

However, using `\015\012` (or `\cM\cJ`, or `\x0D\x0A`, or even `v13.10`) can be tedious and unsightly, as well as confusing to those maintaining the code. The `Socket` module supplies some Right Things for those who want them:

```
use Socket qw(:DEFAULT :crlf);
print SOCKET "Hi there, client!$CRLF"      # right
```

When reading from a socket, remember that the default input record separator `$/` is `\n`, which means you have to do some extra work if you're not sure what you'll be seeing across the socket. Robust socket code should recognize either `\012` or `\015\012` as end of line:

```
use Socket qw(:DEFAULT :crlf);
local ($/) = LF;     # not needed if $/ is already \012

while (<SOCKET>) {
    s/$CR?$LF/\n/;   # replace LF or CRLF with logical newline
}
```

Similarly, code that returns text data—such as a subroutine that fetches a web page—should often translate newlines. A single line of code will often suffice:

```
$data =~ s/\015?\012/\n/g;
return $data;
```

Endianness and Number Width

Computers store integers and floating-point numbers in different orders (*big-endian* or *little-endian*) and different widths (32-bit and 64-bit being the most common today). Normally, you won't have to think about this. But if your program sends binary data across a network connection, or onto disk to be read by a different computer, you may need to take precautions.

Conflicting orders can make an utter mess out of numbers. If a little-endian host (such as an Intel CPU) stores 0x12345678 (305,419,896 in decimal), a big-endian host (such as a Motorola CPU) will read it as 0x78563412 (2,018,915,346 in decimal). To avoid this problem in network (socket) connections, use the `pack` and `unpack` formats `n` and `N`, which write unsigned short and long numbers in big-endian order (also called "network" order), regardless of the platform.

You can explore the endianness of your platform by unpacking a data structure packed in native format, such as:

```
say unpack("h*", pack("s2", 1, 2));
# '10002000' on e.g. Intel x86 or Alpha 21064 in little-endian mode
# '00100020' on e.g. Motorola 68040
```

To determine your endianness, you could use either of these statements:

```
$is_big_endian    = unpack("h*", pack("s", 1)) =~ /01/;
$is_little_endian = unpack("h*", pack("s", 1)) =~ /^1/;
```

Even if two systems have the same endianness, there can still be problems when transferring data between 32-bit and 64-bit platforms. There is no good solution other than to avoid transferring or storing raw binary numbers. Either transfer and store numbers as text instead of binary, or use modules like `Data::Dumper` or `Storable` to do this for you. You really want to be using text-oriented protocols in any event—they're more robust, more maintainable, and more extensible than binary protocols.

Of course, with the advent of XML and Unicode, our definition of text is getting more flexible. For instance, between two systems running Perl v5.6 or newer, you can transport a sequence of integers encoded as characters in `utf8` (Perl's version of UTF-8). If both ends are running on an architecture with 64-bit integers, you can exchange 64-bit integers. Otherwise, you're limited to 32-bit integers. Use `pack` with a `U*` template to send, and `unpack` with a `U*` template to receive (see Chapter 26).

Files and Filesystems

File path components are separated with `/` on Unix, with `\` on Windows, and with `:` on the old pre-Unix Macs. Some systems support neither hard links (`link`) nor symbolic links (`symlink`, `readlink`, `lstat`). Some systems pay attention to capitalization of filenames, some don't, and some pay attention when creating files but not when reading them. Different systems use different character repertoires.

Here are some tips for writing portable file-manipulating Perl programs:

- The `File::Basename` module, another platform-tolerant module bundled with Perl, splits a pathname into its components: the base filename, the full path to the directory, and the file suffix:

```
use File::Basename;

my $name = basename( $ARGV[0] );
my $dir  = dirname( $ARGV[0] );

my( $base, $dir, $suffix ) = fileparse( $ARGV[0], qr/\.[^.]+\z/ );
```

- The standard `File::Spec` modules provide functions to move around a file system and put path components together properly. Don't hardcode paths, but construct them:

```
use File::Spec::Functions;
chdir( updir() );        # go up one directory
$file = catfile( curdir(), "temp", "file.txt" );
```

  That last line reads in *./temp/file.txt* on Unix and Windows or *[.temp]file.txt* on VMS, and stores the file's contents in `$file`.

- The `File::HomeDir` module from CPAN locates special user directories by detecting your operating system and constructing the right paths for you.
- Use the `Path::Class` CPAN module for an object-oriented interface to `File::Spec` that easily allows reading a path from one sort of system and translating it to an equivalent path for another system.

- Use the `File::Temp` module, which comes with Perl, to create a temporary file or a file with a name so far unused.
- Don't use two files of the same name with different case, like *test.pl* and *Test.pl*, since some platforms ignore capitalization. Some ignore it, but preserve it anyway.
- Constrain filenames to the 8.3 convention (eight-letter names and three-letter extensions) where possible. You can often get away with longer filenames as long as you make sure the filenames will remain unique when shoved through an 8.3-sized hole in the wall. (Hey, it's gotta be easier than shoving a camel through the eye of a needle.)
- Minimize nonalphanumeric characters in filenames. Using underscores is often okay, but it wastes a character that could be better used for uniqueness on 8.3 systems. (Remember, that's why we don't usually put underscores into module names.)
- Normalize your filenames or avoid using non-ASCII characters. Support for Unicode filenames varies among systems, and no common API works across all systems. Some characters may work on some systems but fail completely on others.
- Likewise, when using the `AutoSplit` module, try to constrain your subroutine names to eight characters or less, and don't give two subroutines the same name with different case. If you need longer subroutine names, make the first eight characters of each unique.
- Always use `<` explicitly to open a file for reading; otherwise, on systems that allow punctuation in filenames, a file prefixed with a `>` character could result in a file being wiped out, and a file prefixed with a `|` character could result in a pipe `open`. That's because the two-argument form of `open` is magical and will interpret characters like `>`, `<`, and `|`, which may be the wrong thing to do. (Except when it's right.)

```
open(FILE,      $existing_file)  || die $!;  # wrongish
open(FILE,    "<$existing_file") || die $!;  # righter
open(FILE, "<", $existing_file)  || die $!;  # righterer
```

- Choose your input and output encoding, and document what it is. Better yet, give people a way to choose the encodings they want. If you don't know what you want, use UTF-8. Avoid UTF-16, which may have endian issues.
- Don't assume text files will end with a newline. They should, but sometimes people forget, especially when their text editor helps them forget.

System Interaction

Platforms that rely on a graphical user interface sometimes lack command lines, so programs requiring a command-line interface might not work everywhere. You can't do much about this except upgrade.

Some other tips:

- Some platforms can't delete or rename files that are in use, so remember to `close` files when you are done with them. Don't `unlink` or `rename` an open file. Don't `tie` or `open` a file already tied or opened; `untie` or `close` it first.
- Don't open the same file more than once at a time for writing, since some operating systems put mandatory locks on such files.
- Don't depend on a specific environment variable existing in `%ENV`, and don't assume that anything in `%ENV` will be case-sensitive or case-preserving. Don't assume Unix inheritance semantics for environment variables; on some systems, they may be visible to all other processes.
- Don't use signals or `%SIG`.
- Avoid filename globbing. Use `opendir`, `readdir`, and `closedir` instead. (As of v5.6, basic filename globbing is much more portable than it was, but some systems may still chafe under the Unixisms of the default interface if you try to get fancy.)
- Don't assume specific values of the error numbers or strings stored in `$!`.

Interprocess Communication (IPC)

To maximize portability, don't try to launch new processes. That means you should avoid `system`, `exec`, `fork`, `pipe`, ``` `` ```, `qx//`, or `open` with a `|`.

The main problem is not the operators themselves; commands that launch external processes are generally supported on most platforms (though some do not support any type of forking). Problems are more likely to arise when you invoke external programs that have names, locations, output, or argument semantics that vary across platforms.

One especially popular bit of Perl code is opening a pipe to *sendmail* so that your programs can send mail:

```
open(MAIL, "|/usr/lib/sendmail -t") || die "cannot fork sendmail: $!";
```

This won't work on platforms without *sendmail*. For a portable solution, use one of the CPAN modules to send your mail, such as `Mail::Mailer` and `Mail::Send` in the MailTools distribution, or `Mail::Sendmail`.

The Unix System V IPC functions (`msg*(), sem*(), shm*()`) are not always available, even on some Unix platforms.

The `IPC::Run`, `IPC::System::Simple`, and `Capture::Tiny` CPAN modules can help manage some cross-platform issues with external commands.

External Subroutines (XS)

XS code can usually be made to work with any platform, but libraries and header files might not be readily available, or the XS code itself might be platform specific. If the libraries and headers are portable, then it's a reasonable guess that the XS code can be made portable as well.

A different type of portability issue arises when writing XS code: the availability of a C compiler on the end user's platform. C brings with it its own portability issues, and writing XS code will expose you to some of those. Writing in pure Perl is an easier way to achieve portability, because Perl's configuration process goes through extreme agonies to hide C's portability blemishes from you.[3]

Standard Modules

In general, the standard modules (modules bundled with Perl) work on all platforms. Notable exceptions are the `CPAN.pm` module (which currently makes connections to external programs that may not be available), platform-specific modules (such as `ExtUtils::MM_VMS`), and DBM modules.

There is no single DBM module available on all platforms. `SDBM_File` and the others are generally available on all Unix and DOSish ports.

The good news is that at least one DBM module should be available, and `AnyDBM_File` will use whichever module it can find. With such uncertainty, you should use only the features common to all DBM implementations. For instance, keep your records to no more than 1K bytes. See the `AnyDBM_File` module documentation for more details.

A bit fancier than DBMs is SQLite, which comes with the `DBD::SQLite` driver for `DBI`. It's a minimal and embeddable relational database that's in the public domain (so you can distribute it with your code). It runs on the common operating systems.

3. Some people on the margins of society run Perl's *Configure* script as a cheap form of entertainment. People have even been known to stage "Configure races" between competing systems and wager large sums on them. This practice is now outlawed in most of the civilized world.

Dates and Times

Where possible, use the ISO-8601 standard ("*YYYY-MM-DD*") to represent dates. Strings like "`1987-12-18`" can be easily converted into a system-specific value with a module like `Date::Parse`. A list of time and date values (such as that returned by the built-in `localtime` function) can be converted to a system-specific representation using `Time::Local`.

The built-in `time` function will always return the number of seconds since the beginning of the "epoch", but operating systems differ in their opinions of when that was. On many systems, the epoch began on January 1, 1970, at 00:00:00 UTC, but on VMS it began on November 17, 1858, at 00:00:00. So for portable times you may want to calculate an offset for the epoch:

```
require Time::Local;
$offset = Time::Local::timegm(0, 0, 0, 1, 0, 70);
```

The value for `$offset` in Unix and Windows will always be `0`, but on other systems it may be some large number. `$offset` can then be added to a Unix time value to get what should be the same value on any system.

A system's representation of the time of day and the calendar date can be controlled in widely different ways. Don't assume the time zone is stored in `$ENV{TZ}`. Even if it is, don't assume that you can control the time zone through that variable.

If you need exceedingly precise date and time control, get the `DateTime` module from CPAN.

Internationalization

Don't assume anything about the encoding or the environment. You and everyone you know might use the same setup, but once you distribute your work you're likely to find a world of differences.

Use Unicode inside your program. Do any translation to and from other character sets at your interfaces to the outside world. See Chapter 6.

Outside the world of Unicode, you should assume little about character sets and nothing about the `ord` values of characters. Do not assume that the alphabetic characters have sequential `ord` values. The lowercase letters may come before or after the uppercase letters; the lowercase and uppercase may be interlaced so that both `a` and `A` come before `b`; the accented and other international characters may be interlaced so that `ä` comes before `b`.

Even within Unicode, most of those warnings hold. There are many sequences of alphabetic characters in the same sequence whose codepoint order has nothing to do with their alphabetic order.

If your program is to operate on a POSIX system (a rather large assumption), consult the *perllocale* manpage for more information about POSIX locales. Locales affect character sets and encodings, and date and time formatting, among other things. Proper use of locales will make your program a little bit more portable, or at least more convenient and native-friendly for non-English users. But be aware that locales and Unicode don't mix well yet.

Style

When it is necessary to have platform-specific code, consider keeping it in one place to ease porting to other platforms. Use the `Config` module and the special variable `$^O` to differentiate between platforms.

Be careful in the tests you supply with your module or programs. A module's code may be fully portable, but its tests may well not be. This often happens when tests spawn other processes or call external programs to aid in the testing, or when (as noted above) the tests assume certain things about the filesystem and paths. Be careful not to depend on a specific output style for errors, even when checking `$!` for "standard" errors after a syscall. Use the `Errno` module instead.

Remember that good style transcends both time and culture, so for maximum portability you must seek to understand the universal amidst the exigencies of your existence. The coolest people are not prisoners of the latest cool fad; they don't have to be, because they are not worried about being "in" with respect to their own culture, programmatically or otherwise. Fashion is a variable, but style is a constant.

CHAPTER 23

Plain Old Documentation

One of the principles underlying Perl's design is that simple things should be simple, and hard things should be possible. Documentation should be simple.

Perl supports a simple text markup format called *pod* that can stand on its own or be freely intermixed with your source code to create embedded documentation. Pod can be converted to many other formats for printing or viewing, or you can just read it directly, because it's plain.

Pod is not as expressive as languages like XML, LaTeX, *troff*(1), or even HTML. This is intentional: we sacrificed that expressiveness for simplicity and convenience. Some text markup languages make authors write more markup than text, which makes writing harder than it has to be and reading next to impossible. A good format, like a good movie score, stays in the background without causing distraction.

Getting programmers to write documentation is almost as hard as getting them to wear ties. Pod was designed to be so easy to write that even a programmer could do it—and would. We don't claim that pod is sufficient for writing a book, although it was sufficient for writing this one.

Pod in a Nutshell

Most document formats require the entire document to be in that format. Pod is more forgiving: you can embed pod in any sort of file, relying on *pod translators* to extract the pod. Some files consist entirely of 100% pure pod. But other files, notably Perl programs and modules, may contain dollops of pod sprinkled about wherever the author feels like it. Perl simply skips over the pod text when parsing the file for execution.

The Perl lexer knows to begin skipping when, at a spot where it would ordinarily find a statement, it instead encounters a line beginning with an equals sign and an identifier, like this:

```
=head1 Here There Be Pods!
```

That text, along with all remaining text up through and including a line beginning with `=cut`, will be ignored. This allows you to intermix your source code and your documentation freely, as in:

```
=item snazzle

The snazzle() function will behave in the most spectacular
form that you can possibly imagine, not even excepting
cybernetic pyrotechnics.

=cut

sub snazzle {
    my $arg = shift;
    ....
}

=item razzle

The razzle() function enables autodidactic epistemology generation.

=cut

sub razzle {
    print "Epistemology generation unimplemented on this platform.\n";
}
```

For more examples, look at any standard or CPAN Perl module. They're all supposed to come with pod, and nearly all do, except for the ones that don't.

Since pod is recognized by the Perl lexer and thrown out, you may also use an appropriate pod directive to quickly comment out an arbitrarily large section of code. Use a `=for` pod block to comment out one paragraph, or a `=begin`/`=end` pair for a larger section. We'll cover the syntax of those pod directives later. Remember, though, that in both cases you're still in pod mode afterwards, so you need to `=cut` back to the compiler:

```
print "got 1\n";

=for commentary
This paragraph alone is ignored by anyone except the
mythical "commentary" translator.  When it's over, you're
still in pod mode, not program mode.
print "got 2\n";
```

```
=cut

# ok, real program again
print "got 3\n";

=begin comment

print "got 4\n";

all of this stuff
here will be ignored
by everyone

print "got 5\n";

=end comment

=cut

print "got 6\n";
```

This will print out that it got `1`, `3`, and `6`. Remember that these pod directives can't go just anywhere. You have to put them only where the parser is expecting to see a new statement, not just in the middle of an expression or at other arbitrary locations.

From the viewpoint of Perl, all pod markup is thrown out. But from the viewpoint of pod translators, it's the code that is thrown out. Pod translators view the remaining text as a sequence of paragraphs separated by blank lines.

There are three kinds of paragraphs: verbatim paragraphs, command paragraphs, and prose paragraphs.

Verbatim Paragraphs

Verbatim paragraphs are used for literal text that you want to appear as is, such as snippets of code. A verbatim paragraph must be indented; that is, it must begin with a space or tab character. The translator should reproduce it exactly, typically in a monospace font, with tabs assumed to be on eight-column boundaries. There are no special formatting escapes, so you can't play font games to italicize or embolden. A `<` character means a literal `<`, and nothing else.

Command Paragraphs

All pod directives start with `=` followed by an identifier. This may be followed by any amount of arbitrary text that the directive can use however it pleases. The

only syntactic requirement is that the text must all be one paragraph. Currently recognized directives (sometimes called *pod commands*) are:

`=encoding`
: By default, the Pod translators assume that your Pod source is either ASCII or Latin-1. You can change this by specifying the encoding with this command, probably to UTF-8:

```
=encoding uft8
```

`=head1`

`=head2`
: The `=head1`, `=head2`,... directives produce headings at the level specified. The rest of the text in the paragraph is treated as the heading description. These are similar to the `.SH` and `.SS` section and subsection headers in *man*(7), or to `<H1>...</H1>` and `<H2>...</H2>` tags in HTML. In fact, that's exactly what those translators convert these directives into for those formats.

`=cut`
: The `=cut` directive indicates the end of a stretch of pod. (There might be more pod later in the document, but if so it will be introduced with another pod directive.)

`=pod`
: The `=pod` directive does nothing beyond telling the compiler to lay off parsing code through the next `=cut`. It's useful for adding another paragraph to the document if you're mixing up code and pod a lot.

`=over` *`NUMBER`*

`=item` *`SYMBOL`*

`=back`
: The `=over` directive starts a section specifically for the generation of a list using the `=item` directive. At the end of your list, use `=back` to end it. The *`NUMBER`*, if provided, hints to the formatter how many spaces to indent. Some formatters aren't rich enough to respect the hint, while others are *too* rich to respect it, insofar as it's difficult when working with proportional fonts to make anything line up merely by counting spaces. (However, four spaces is generally construed as enough room for bullets or numbers.)

  The actual type of the list is indicated by the *`SYMBOL`* on the individual items. Here is a bulleted list:

```
=over 4

=item *
```

```
Mithril armor

=item *

Elven cloak

=back
```

And a numbered list:

```
=over 4

=item 1.

First, speak "friend".

=item 2.

Second, enter Moria.

=back
```

And a named list:

```
=over 4

=item armor()

Description of the armor() function

=item chant()

Description of the chant() function

=back
```

You may nest lists of the same or different types, but some basic rules apply: don't use `=item` outside an `=over`/`=back` block; use at least one `=item` inside an `=over`/`=back` block; and, perhaps most importantly, keep the type of the items consistent within a given list. Use `=item *` for each item to produce a bulleted list; `=item 1.`, `=item 2.`, and so on to produce a numbered list; or use `=item foo`, `=item bar`, and so on to produce a named list. If you start with bullets or numbers, stick with them, since formatters are allowed to use the first `=item` type to decide how to format the list.

As with everything in pod, the result is only as good as the translator. Some translators pay attention to the particular numbers (or letters, or Roman numerals) following the `=item`, and others don't. The current *pod2html* translator, for instance, is quite cavalier: it strips out the sequence indicators entirely without looking at them to infer what sequence you're using, then

wraps the entire list inside `<OL>` and `</OL>` tags so that the browser can display it as an ordered list in HTML. This is not to be construed a feature; it may be fixed eventually.

`=for` *`TRANSLATOR`*

`=begin` *`TRANSLATOR`*

`=end` *`TRANSLATOR`*

`=for`, `=begin`, and `=end` let you include special sections to be passed through unaltered, but only to particular formatters. Formatters that recognize their own names, or aliases for their names, in *`TRANSLATOR`* pay attention to that directive; any others completely ignore them. The directive `=for` specifies that just the rest of this paragraph is destined *for* a particular translator:

```
=for html
<p> This is a<flash>raw</flash> <small>HTML</small> paragraph </p>
```

The paired `=begin` and `=end` directives work similarly to `=for`, but instead of accepting only a single paragraph, they treat all text between matched `=begin` and `=end` as destined for a particular translator. Some examples:

```
=begin html

<br>Figure 1.<IMG SRC="figure1.png"><br>

=end html

=begin text

  ---------------
  |  foo        |
  |        bar  |
  ---------------

^^^^ Figure 1. ^^^^

=end text
```

Values of *`TRANSLATOR`* commonly accepted by formatters include `roff`, `man`, `troff`, `nroff`, `tbl`, `eqn`, `latex`, `tex`, `html`, and `text`. Some formatters will accept some of these as synonyms. No translator accepts `comment`—that's just the customary word for something to be ignored by everybody. Any unrecognized word would serve the same purpose. While writing this book, we often left notes for ourselves under the directive `=for later`.[1]

1. We actually created our own pod translator to convert our pod source to DocBook using a custom subclass of `Pod::PseudoPod`.

Note that `=begin` and `=end` do nest, but only in the sense that the outermost matched set causes everything in the middle to be treated as nonpod, even if it happens to contain other *`=word`* directives. That is, as soon as any translator sees `=begin foo`, it will either ignore or process *everything* down to the corresponding `=end foo`.

Flowed Text

The third type of paragraph is simply "flowed" text. That is, if a paragraph doesn't start with either whitespace or an equals sign, it's taken as a plain paragraph: regular text that's typed in with as few frills as possible. Newlines are treated as equivalent to spaces. It's largely up to the translator to make it look nice, because programmers have more important things to do. It is assumed that translators will apply certain common heuristics—see the section "Pod Translators and Modules" on page 740 later in this chapter.

You can do some things explicitly, however. Inside either ordinary paragraphs or heading/item directives (but not in verbatim paragraphs) you may use special sequences to adjust the formatting. These sequences always start with a single capital letter followed by a left-angle bracket, and extend through the matching (not necessarily the next) right-angle bracket. Sequences may contain other sequences.

Here are the sequences defined by pod:

`I<`*`text`*`>`
: Italicized text, used for emphasis, book titles, names of ships, and manpage references such as "*perlpod*(1)".

`B<`*`text`*`>`
: Emboldened text, used almost exclusively for command-line switches and sometimes for names of programs.

`C<`*`text`*`>`
: Literal code, probably in a fixed-width font like Courier. Not needed on simple items that the translator should be able to infer as code, but you should put it anyway.

`S<`*`text`*`>`
: Text with nonbreaking spaces. Often surrounds other sequences.

`L<`*`name`*`>`
: A cross reference (link) to a name:

  `L<`*`name`*`>`
  : Manual page

`L<name/ident>`
: Item in manual page

`L<name/"sec">`
: Section in other manual page

`L</"sec">`
: Ditto

These next five are the same as those above, but the output will be only *`text`*, with the link information hidden as in HTML:

`L<text|name>`

`L<text|name/ident>`

`L<text|name/"sec">`

`L<text|"sec">`

`L<text|/"sec">`

The *`text`* cannot contain the characters "`/`" and "`|`", and it should contain matched "`<`" or "`>`".

`F<pathname>`
: Used for filenames. This is traditionally the same as `I`.

`X<entry>`
: An index entry of some sort. As always, it's up to the translator what to do. The pod specification doesn't dictate that.

`E<escape>`
: A named character, similar to HTML escapes:

  `E<lt>`
  : A literal `<` (optional except in other interior sequences and when preceded by a capital letter)

  `E<gt>`
  : A literal `>` (optional except in other interior sequences)

  `E<sol>`
  : A literal `/` (needed in `L<>` only)

  `E<verbar>`
  : A literal `|` (needed in `L<>` only)

  `E<NNN>`

  `E<0x`*`XXXXXX`*`>`
  : Character number (*i.e.*, codepoint) *`NNN`* or `0x`*`XXXXXX`* in Unicode

  `E<entity>`
  : Some nonnumeric HTML entity, such as `E<Agrave>`

`Z<>`

A zero-width character. This is nice for putting in front of sequences that might confuse something. For example, if you had a line in regular prose that had to start with an equals, you could write that as:

```
Z<>=can you see
```

or for something with a "From" in it, so the mailer doesn't add a greater than:

```
Z<>From here on out...
```

Most of the time, you will need but a single set of angle brackets to delimit a pod sequence. Sometimes, however, you will want to put a `<` or `>` inside a sequence. (This is particularly common when using a `C<>` sequence to provide a monospace font for a snippet of code.) As with all things in Perl, there is more than one way to do it. One way is to simply represent the closing bracket with an `E<`*`ENTITY`*`>` sequence:

```
C<$a E<lt>=E<gt> $b>
```

This produces "`$a <=> $b`".

A more readable, and perhaps more "plain", way is to use an alternate set of delimiters that doesn't require the angle brackets to be escaped. Doubled angle brackets (`C<<` *`stuff`* `>>`) may be used, provided there is whitespace immediately following the opening delimiter and immediately preceding the closing one. For example, the following will work:

```
C<< $a <=> $b >>
```

You may use as many repeated angle brackets as you like as long as you have the same number of them on both sides. Also, you must make sure that whitespace immediately follows the last `<` of the left side and immediately precedes the first `>` of the right side. So the following will also work:

```
C<<< $a <=> $b >>>
C<<<< $a <=> $b >>>>
```

All these end up spitting out `$a <=> $b` in a monospace font.

The extra whitespace inside on either end goes away, so you should leave whitespace on the outside if you want it. Also, the two inside chunks of extra whitespace don't overlap, so if the first thing being quoted is `>>`, it isn't taken as the closing delimiter:

```
The C<< >> >> right shift operator.
```

This produces: "The `>>` right shift operator."

Note that pod sequences *do* nest. That means you can write "`The I<Santa MarE<iacute>a> left port already`" to produce "The *Santa María* left port already", or "`B<touch> S<B<-t> I<time>> I<file>`" to produce "*touch –t time file*", and expect this to work properly.

Pod Translators and Modules

Perl is bundled with several pod translators that convert pod documents (or the embedded pod in other types of documents) into various formats. All should be 8-bit clean.

pod2text
: Converts pod into text. Normally, this text will be 7-bit ASCII, but it will be 8-bit if it had 8-bit input, or specifically ISO-8859-1 (or Unicode) if you use sequences like `LE<uacute>thien` for *Lúthien* or `EE<auml>rendil` for *Eärendil*.

  If you have a file with pod in it, the easiest (although perhaps not the prettiest) way to view just the formatted pod would be:

```
% pod2text File.pm | more
```

  Then again, pod is supposed to be human readable without formatting.

pod2man
: Converts pod into Unix manpage format suitable for viewing through *nroff*(1) or creating typeset copies via *troff*(1). For example:

```
% pod2man File.pm | nroff -man | more
```

  or:

```
% pod2man File.pm | troff -man -Tps -t > tmppage.ps
% ghostview tmppage.ps
```

  and to print:

```
% lpr -Ppostscript tmppage.ps
```

pod2html
: Converts pod into HTML for use with your favorite viewer (maybe that's *lynx*):

```
% pod2man File.pm | troff -man -Tps -t > tmppage.ps
% lynx tmppage.html
```

pod2latex
: Converts pod into the LaTeX format, which you can then typeset with that tool.

Additional translators for other formats are available on CPAN.

You should write your pod as close to plain text as you possibly can, with as few explicit markups as you can get away with. It is up to the individual translator to decide how things in your text should be represented. That means letting the translator figure out how to create paired quotes, how to fill and adjust text, how to find a smaller font for words in all capitals, etc. Since these were written to process Perl documentation, most translators[2] should also recognize unadorned items like these and render them appropriately:

- `FILEHANDLE`
- `$scalar`
- `@array`
- `function()`
- `manpage(3r)`
- `somebody@someplace.com`
- `http://foo.com/`

Perl also comes with several standard modules for parsing and converting pod, including `Pod::Checker` (and the associated *podchecker* utility) for checking the syntax of pod documents, `Pod::Find` for finding pod documents in directory trees, and `Pod::Simple` for creating your own pod utilities. Inside a CPAN distribution, you can use the `Test::Pod` module to check the format of your documentation and the `Test::Pod::Coverage` module to check that all of the interface is documented.

Note that pod translators should only look at paragraphs beginning with a pod directive (this makes parsing easier), whereas the compiler actually knows to look for pod escapes, even in the middle of a paragraph. This means that the following secret stuff will be ignored by both the compiler and the translators.

```
$a=3;
=secret stuff
warn "Neither POD nor CODE!?"
=cut back
print "got $a\n";
```

You probably shouldn't rely upon the `warn` being podded out forever. Not all pod translators are well behaved in this regard, and the compiler may someday become pickier.

2. If you're designing a general-purpose pod translator, not one for Perl code, your criteria may vary.

Writing Your Own Pod Tools

Pod was designed first and foremost to be easy to write. As an added benefit, pod's simplicity also lends itself to writing simple tools for processing pod. If you're looking for pod directives, just set your input record separator to paragraph mode (perhaps with the *–00* switch), and only pay attention to paragraphs that look poddish.

For example, here's a simple *olpod* program to produce a pod outline:

```
#!/usr/bin/perl -l00n
# olpod - outline pod
next unless /^=head/;
s/^=head(\d)\s+/ " " x ($1 * 4 - 4)/e;
print $_, "\n";
```

If you run that on the current chapter of this book, you'll get something like this:

```
Plain Old Documentation
  Pod in a Nutshell
    Verbatim Paragraphs
    Command Paragraphs
    Flowed Text
  Pod Translators and Modules
  Writing Your Own Pod Tools
  Pod Pitfalls
  Documenting Your Perl Programs
```

That pod outliner didn't really pay attention to whether it was in a valid pod block or not. Since pod and nonpod can intermingle in the same file, running general-purpose tools to search or analyze the whole file doesn't always make sense. But that's no problem given how easy it is to write tools for pod. Here's a tool that *is* aware of the difference between pod and nonpod, and produces only the pod:

```
#!/usr/bin/perl -00
# catpod - cat out just the pods
while (<>) {
    if (! $inpod) { $inpod = /^=/            }
    if ($inpod)   { $inpod = !/^=cut/; print }
} continue {
    if (eof)      {  close ARGV; $inpod = "" }
}
```

You could use that program on another Perl program or module, then pipe the output along to another tool. For example, if you have the *wc*(1) program[3] to count lines, words, and characters, you could feed it *catpod* output to consider only pod in its counting:

3. And if you don't, get the Perl Power Tools version from CPAN.

```
% catpod MyModule.pm | wc
```

There are plenty of places where pod allows you to write primitive tools trivially using plain, straightforward Perl. Now that you have *catpod* to use as a component, here's another tool to show just the indented code:

```
#!/usr/bin/perl -n00
# podlit - print the indented literal blocks from pod input
print if /^\s/;
```

What would you do with that? Well, you might want to do *perl –wc* checks on the code in the document, for one thing. Or maybe you want a flavor of *grep*(1)[4] that only looks at the code examples:

```
% catpod MyModule.pm | podlit | grep funcname
```

This tool-and-filter philosophy of interchangeable (and separately testable) parts is a sublimely simple and powerful approach to designing reusable software components. It's a form of laziness to just put together a minimal solution that gets the job done today—for certain kinds of jobs, at least.

For other tasks, though, this can even be counterproductive. Sometimes it's more work to write a tool from scratch, sometimes less. For those we showed you earlier, Perl's native text-processing prowess makes it expedient to use brute force. But not everything works that way. As you play with pod, you might notice that although its directives are simple to parse, its sequences can get a little dicey. Although some, um, subcorrect translators don't accommodate this, sequences can nest within other sequences and can have variable-length delimiters.

Instead of coding up all that parsing code on your own, laziness looks for another solution. The standard `Pod::Simple` module fits that bill. It's especially useful for complicated tasks, like those that require real parsing of the internal bits of the paragraphs, conversion into alternative output formats, and so on. It's easier to use the module for complicated cases because the amount of code you end up writing is smaller. It's also better because the tricky parsing is already worked out for you. It's really the same principle as using *catpod* in a pipeline.

The `Pod::Simple` module takes an interesting approach to its job. It's an object-oriented module of a different flavor than most you've seen in this book. Its primary goal isn't so much to provide objects for direct manipulation as it is to provide a base class upon which other classes can be built.

You create your own class and inherit from `Pod::Simple` (or one of its interfaces), which provides all the methods to parse the pod. Your subclass overrides the

4. And if you don't have *grep*, see previous footnote.

appropriate methods to turn the things the parser finds into the output you want. You only have to override the parts that you want to change. You probably want to start with a translator that is close to what you want. Here's a short subclass of `Pod::Simple::Text` that finds instances of the Perl documentation in `L<>` and makes endnotes for each link. You have to know about the innards of the base class, a violation of encapsulation, which we are merely demonstrating instead of endorsing:

```
use v5.14;

package Local::MyText 0.01 {
    use parent "Pod::Simple::Text";
    use Data::Dumper;
    my @links;

    sub links {
        $_[0]->{"".__PACKAGE__}{links} //= [];
    }

    sub start_L {
        my($self, $link) = @_;
        push $self->links, $link->{to}[2];
    }

    sub end_L {
        my($self) = @_;
        my $count = @{$self->links};
        $self->{Thispara} .= "[" . $count . "]";
    }

    sub end_Document {
        my($self) = shift;
        while (my($index, $text) = each $self->links) {
            $self->{Thispara} .=
                "$index http://perldoc.perl.org/$text.html\n";
        }
        $self->emit_par;
    }
}

1;
```

You could write your own version of *pod2text* that loads a file and invokes your subclass, but *perldoc* will load an alternate formatting class with the *–M* switch:[5]

```
% perldoc -MLocal::MyText some_pod.pod
```

5. This is not the same `-M` switch for *perl*. There has to be a space between the `-M` and the name of the class. Sadly, *perldoc* does not warn you about these sorts of problems if you get it wrong.

For this pod:

```
=pod

If you want to read about the Perl pod specification, see
the LZ<><perlpod> or LZ<><perlpodspec> documentation.

=cut
```

you get this output:

```
If you want to read about the Perl pod specification, see the
perlpod[1] or perlpodspec[2] documentation.

0 http://perldoc.perl.org/perlpod.html
1 http://perldoc.perl.org/perlpodspec.html
```

That example merely changes how the formatter interprets the pod specification. Here's another example that overrides the handling of the verbatim paragraphs to reformat them with `Perl::Tidy`:

```
use v5.14;

package Local::MyTidy 0.01 {
    use parent "Pod::Simple::Text";
    use Perl::Tidy;

    sub end_Verbatim  {
        my($self) = @_;
        Perl::Tidy::perltidy(
            source      => \ $self->{Thispara},
            destination => \ my $out,
            argv        => [qw/-gnu/],
        );
        $self->{Thispara} = $out =~ s/^/    /gmr;
        say { $self->{output_fh} } "", $self->{Thispara};
        return;
    }

}

1;
```

This formatter turns poorly formatted code like this:

```
=encoding utf8

=pod

This is a regular paragraph.

#!/usr/bin/perl
for (@ARGV){
```

```
    my $count = 0;
    say $count++, " ", $_;
}

This is another regular paragraph.

=cut
```

into something like this:[6]

```
This is a regular paragraph

#!/usr/bin/perl
for (@ARGV) {
    my $count = 0;
    say $count++, " ", $_;
}

This is another regular paragraph
```

You may want to define new pod things. For instance, if you want to define a new command, it's easy to do that even if it takes a little fiddling. You have to tell the parser that your new command is valid. In this example, a new `V<>` command translates its text into a list of codepoints. Instead of seeing *é*, you might see (U+00E9). It does this by setting a flag when it enters the `V<>` so it knows to do something different in `handle_text`:

```
use v5.14;
package Local::MyCodePoint 0.01 {
    use parent "Pod::Simple::Text";
    use Data::Dumper;

    sub new {
        my $self = shift;
        my $new = $self->SUPER::new;
        $new->accept_codes("V");
        return $new;
    }
    sub handle_text {
        my($self, $text) = @_;
        $self->{Thispara} .=
        $self->{""._PACKAGE_}{in_V}
            ?  $self->make_codepoints($text)
            : $text;
    }
    sub make_codepoints {
        $_[1] =~ s/(.)/ sprintf "(U+%04X)", ord($1) /ger;
    }
```

6. The `Perl::Tidy` module accepts many different options, so you can adjust the knobs and dials to choose any style decisions you like.

```
    sub start_V {
        my($self, $text) = @_;
        $self->{"".__PACKAGE__}{in_V} = 1;
    }
    sub end_V {
        my($self, $text) = @_;
        $self->{"".__PACKAGE__}{in_V} = 0;
    }
}

1;
```

With this new command, this pod:

```
=encoding utf8

=pod

V<À> la recherche du temps perdu

=cut
```

turns into this text:

```
(U+00C0) la recherche du temps perdu
```

Pod Pitfalls

Pod is fairly straightforward, but it's still possible to flub a few things that can confuse some translators:

- It's really easy to leave out the trailing angle bracket.
- It's really easy to leave out the trailing `=back` directive.
- It's easy to accidentally put a blank line into the middle of a long `=for` *`comment`* directive. Consider using `=begin`/`=end` instead.
- If you mistype one of the tags on a `=begin`/`=end` pair, it'll eat the rest of your file (podwise). Consider using `=for` instead.
- Pod translators require paragraphs to be separated by completely empty lines—that is, by two or more consecutive newline (`\n`) characters. If you have a line with spaces or tabs on it, it will not be treated as a blank line. This can cause two or more paragraphs to be treated as one.
- The meaning of a "link" is not defined by pod, and it's up to each translator to decide what to do with it. (If you're starting to get the idea that most decisions have been deferred to the translators, not pod, you're right.) Translators will often add wording around a `L<>` link, so that "`L<foo(1)>`" becomes "the *foo*(1) manpage", for example. So you shouldn't write things like "`the`

`L<foo> manpage`" if you want the translated document to read sensibly; that would end up saying "the the *foo*(1) manpage manpage".

If you need total control of the text used for a link, use the form `L<show this text|foo>` instead.

The standard *podchecker* program checks pod syntax for errors and warnings. For example, it checks for unknown pod sequences and for seemingly blank lines containing whitespace. It is still advisable to pass your document through two or more different pod translators and proofread the results. Some of the problems you find may be idiosyncrasies of the particular translators, which you may or may not wish to work around. Here's a bit of pod with some problems:

```
=encoding utf8

=pod

This is a D<para>.

=item * This is an item

=cut
```

Using *podchecker* catches two errors and gives you a warning about the whitespace you can't see in the blank line:

```
% podchecker broken.pod
*** ERROR: Unknown interior-sequence 'D' at line 5 in file broken.pod
*** ERROR: =item without previous =over at line 7 in file broken.pod
*** WARNING: line containing nothing but whitespace in paragraph at line 8
in file broken.pod
broken.pod has 2 pod syntax errors.
```

And, as always, Everything is Subject To Change at the Whim of the Random Hacker.

Documenting Your Perl Programs

We hope you document your code whether or not you're a Random Hacker. If you do, you may wish to include the following sections in your pod:

`=head1 NAME`
: The name of your program or module.

`=head1 SYNOPSIS`
: A summary of the module's use.

`=head1 DESCRIPTION`
: The bulk of your documentation. (Bulk is good in this context.)

`=head1 AUTHOR`
: Who you are. (Or an alias, if you are ashamed of your program.)

`=head1 BUGS`
: What you did wrong (and why it wasn't really your fault).

`=head1 SEE ALSO`
: Where people can find related information (so they can work around your bugs).

`=head1 COPYRIGHT`
: The copyright statement. If you wish to assert an explicit copyright, you should say something like:

```
Copyright 2013, Randy Waterhouse.  All Rights Reserved.
```

  Many modules also add:

```
This program is free software.  You may copy or
redistribute it under the same terms as Perl itself.
```

One caveat: if you're going to put your pod at the end of the file, and you're using an `__END__` or `__DATA__` token, make sure to put an empty line before the first pod directive:

```
__END__

=head1 NAME

Modern - I am the very model of a modern major module
```

Without the empty line before the `=head1`, the pod translators will ignore the start of your (extensive, accurate, cultured) documentation.

CHAPTER 24
Perl Culture

This book is a part of Perl culture, so we can't hope to put everything we know about Perl culture in here. We can only whet your appetite with a little history, a little art—some would say "very little art"—and some highlights from the Perl community. For a much larger dose of Perl culture, see *http://www.perl.org*. Or just get acquainted with some other Perl programmers. We can't tell you what sort of people they'll be—about the only personality trait Perl programmers have in common is that they're all pathologically helpful.

History Made Practical

In order to understand why Perl is defined the way it is (or isn't), one must first understand why Perl even exists. So let's drag out the old dusty history book...

Way back in 1986, Larry was a systems programmer on a project developing multilevel-secure wide area networks. He was in charge of an installation consisting of three VAXen and three Suns on the West Coast, connected over an encrypted, 1200-baud serial line to a similar configuration on the East Coast. Since Larry's primary job was support (he wasn't a programmer on the project, just the system guru), he was able to exploit his three virtues (*Laziness*, *Impatience*, and *Hubris*) to develop and enhance all sorts of useful tools—such as *rn*, *patch*, and *warp*.[1] One day, after Larry had just finished ripping *rn* to shreds, leaving it in pieces on the floor of his directory, the great Manager came to him and said, "Larry, we need a configuration management and control system for all six VAXen and all six Suns. We need it in a month. Go to it!"

1. It was at about this time that Larry latched onto the phrase *feeping creaturism* in a desperate attempt to justify on the basis of biological necessity his overwhelming urge to add "just one more feature". After all, if Life Is Simply Too Complicated, why not programs, too? Especially programs like *rn* that really ought to be treated as advanced Artificial Intelligence projects so that they can read your news for you. Of course, some people say that the *patch* program is already *too* smart.

So, Larry—never being one to shirk work—asked himself what was the best way to have a bicoastal CM system, without writing it from scratch, that would allow viewing of problem reports on both coasts, with approvals and control. The answer came to him in one word: B-news.[2] Larry went off and installed news on these machines and added two control commands: an "append" command to append to an existing article, and a "synchronize" command to keep the article numbers the same on both coasts. CM would be done using RCS (Revision Control System), and approvals and submissions would be done using news and *rn*. Fine so far.

Then the great Manager asked him to produce reports. News was maintained in separate files on a master machine, with lots of cross-references between files. Larry's first thought was, "Let's use *awk*." Unfortunately, the *awk* of that day couldn't handle opening and closing of multiple files based on information in the files. Larry didn't want to have to code a special-purpose tool. As a result, a new language was born.

This new tool wasn't originally called Perl. Larry bandied about a number of names with his officemates and cohorts (Dan Faigin, who wrote this history, and Mark Biggar, his brother-in-law, who also helped greatly with the initial design). Larry actually considered and rejected every three- or four-letter word in the dictionary. One of the earliest names was "Gloria", after his sweetheart (and wife). He soon decided that this would cause too much domestic confusion.

The name then became "Pearl", which mutated into our present-day "Perl", partly because Larry saw a reference to another language called PEARL, but mostly because he's too lazy to type five letters all the time. And, of course, so that Perl could be used as a four-letter word. (You'll note, however, the vestiges of the former spelling in the acronym's gloss: "Practical Extraction *And* Report Language".[3])

This early Perl lacked many of the features of today's Perl. Pattern matching and filehandles were there, scalars were there, and formats were there, but there were very few functions, no associative arrays, and only a crippled implementation of regular expressions, borrowed from *rn*. The manpage was only 15 pages long. But Perl was faster than *sed* and *awk*, and it began to be used on other applications on the project.

But Larry was needed elsewhere. Another great Manager came over one day and said, "Larry, support R&D." And Larry said, okay. He took Perl with him and

2. That is, the second implementation of Usenet transport software.

3. This is sometimes called a *backronym* since the name came first and the expansion later.

discovered that it was turning into a good tool for system administration. He borrowed Henry Spencer's beautiful regular expression package and butchered it into something Henry would prefer not to think about during dinner. Then Larry added most of the goodies he wanted, as well as a few goodies other people wanted. He released it on the network.[4] The rest, as they say, is history.[5] Which goes something like this: Perl 1.0 was released on December 18, 1987; some people still take Perl's Birthday seriously. Perl 2.0 follows in June 1988, and Randal Schwartz created the legendary "Just Another Perl Hacker" (*JAPH*) signature. In 1989, Tom Christiansen presented the first public Perl tutorial at the Baltimore Usenix. With Perl 3.0 in October 1989, the language was released and distributed for the first time under the terms of the GNU Public License.

In March 1990, Larry wrote the first Perl Poem (see the following section). Then he and Randal wrote the first edition of this book, The Pink Camel; it was published in early 1991.[6] Perl 4.0 was released simultaneously; it included an Artistic License as well as the GPL. After Perl 4, Larry conceived a new and improved Perl; in 1994, the Perl 5 Porters, or just p5p, was established to port *perl* to almost every system it could get its hands on. This group, fluid in membership, is still responsible for Perl's development and support.

The unveiling of the much anticipated Perl 5 occurred in October 1994. A complete rewrite of Perl, it included objects and modules. The advent of Perl 5 even merited coverage by *The Economist*.[7] In 1995, CPAN was officially introduced to the Perl community. Jon Orwant began publishing *The Perl Journal* in 1996. After a long gestation, the second edition of this book, The Blue Camel, appeared that fall. In 1997, a group of notable Perl hackers founded The Perl Institute to organize advocacy and support for Perl.

The first O'Reilly Perl Conference (TPC) was held in San Jose, California, in the summer of 1997. During this conference, a group of New Yorkers formed the first Perl users group, which they called `/New York Perl M((o|u)ngers|aniacs)*/`, although that was a bit unwieldy, so it turned into NY.pm, setting the pattern for most future Perl user group names. That turned into Perl mongers the

4. More astonishingly, he kept on releasing it as he went to work at Jet Propulsion Lab, then at NetLabs and Seagate, and then at O'Reilly & Associates (a small company that publishes pamphlets about computers and stuff, now called O'Reilly Media).

5. And this, so to speak, is a footnote to history. When Perl was started, *rn* had just been ripped to pieces in anticipation of a major rewrite. Since he started work on Perl, Larry hasn't touched *rn*. It is still in pieces. Occasionally, Larry threatens to rewrite *rn* in Perl (but never seriously).

6. Its title was *Programming perl*, with an all-lowercase "perl".

7. "Unlike lots of other freely available software, Perl is useful, and it works."—"Electric metre", *The Economist*, July 1, 1995.

next year when that same group helped people start their own user groups. Perl mongers took over for The Perl Institute.

In 1999, Kevin Lenzo organized Yet Another Perl Conference (YAPC) at Carnegie Mellon in Pittsburgh. The tech conferences were mostly held on the West Coast of the United States, close to Silicon Valley. That wasn't convenient for the East Coasters. This is the same year that Chris Nandor wrote a Perl script to submit 25,000 All-Star votes for Boston Red Sox shortstop Nomar Garciaparra,[8] earning him mentions in many All-Star stories for several years after that, and what some people believe motivated a single episode subplot in the TV show *Sports Night*.[9]

The next year, the London Perl mongers organized YAPC::EU (although that wasn't the first European Perl event; the first German Perl Workshop predated even The Perl Conference). Those conferences were so successful that they turned into the Yet Another Foundation (also known as The Perl Foundation) in the U.S. and the YAPC Europe Foundation in Europe. Soon there were YAPCs in Asia and South America, too, although the different conferences really only share the name. Now it's tough to find a week where there isn't a Perl event somewhere, which makes for a very close-knit community of people who mostly work apart from one another but get together often.

The Perl Conference expanded into other subjects. It turned into The Open Source Conference, or just OSCON, where Larry regularly gives his "State of the Onion" address and Damian Conway wows audiences with "The Conway Channel". At the 2000 edition of OSCON, Larry announced Perl 6—decidedly not the subject of this book—as an ambitious project to start from scratch. For this book, we'll just say that Perl 6 is a lot of fun, it revitalized Perl 5 development, and it only shares a name with the Perl we're writing about here. It's really a completely different language, stealing from Perl just like Perl stole from other languages.

For more Perl history, at least up to 2002, check out the Perl Timeline on CPAST, the Comprehensive Perl Arcana Society Tapestry (*http://history.perl.org*).

Perl Poetry

Perl assumes that any *bareword* it runs into will eventually be the name of a defined subroutine, even if you haven't defined it yet. This is sometimes called "Perl poetry mode". This allows people to write poetry in Perl, such as this monstrosity:

8. "Cyber-stuffing remains threat to All-Star voting," ESPN.com.

9. In the "Louise Revisited" episode, which aired on October 26, 1999, Jeremy used a Perl script to stuff the ballot box for Casey, one of the anchors.

```
BEFOREHAND: close door, each window & exit; wait until time.
    open spellbook, study, read (scan, select, tell us);
write it, print the hex while each watches,
    reverse its length, write again;
    kill spiders, pop them, chop, split, kill them.
        unlink arms, shift, wait & listen (listening, wait),
sort the flock (then, warn the "goats" & kill the "sheep");
    kill them, dump qualms, shift moralities,
    values aside, each one;
        die sheep! die to reverse the system
        you accept (reject, respect);
next step,
    kill the next sacrifice, each sacrifice,
    wait, redo ritual until "all the spirits are pleased";
    do it ("as they say").
do it(*everyone***must***participate***in***forbidden**s*e*x*).
return last victim; package body;
    exit crypt (time, times & "half a time") & close it,
    select (quickly) & warn your next victim;
AFTERWORDS: tell nobody.
    wait, wait until time;
    wait until next year, next decade;
        sleep, sleep, die yourself,
        die at last
```

Larry wrote this poem and sent it to *news.groups* to support his request for the creation of a *comp.lang.perl.poems* group. Most people probably noticed that it was April 1, but that didn't deter people from writing more Perl poetry.

Sharon Hopkins wrote quite a few Perl poems, as well as a paper on Perl poetry that she presented at the Usenix Winter 1992 Technical Conference, entitled "Camels and Needles: Computer Poetry Meets the Perl Programming Language". Besides being the most prolific Perl poet, Sharon is also the most widely published, having had the following poem published in both *The Economist* and *The Guardian*:

```
#!/usr/bin/perl

APPEAL:

listen (please, please);

open yourself, wide;
    join (you, me),
connect (us,together),

tell me.

do something if distressed;
```

```
    @dawn, dance;
    @evening, sing;
    read (books,$poems,stories) until peaceful;
    study if able;

    write me if-you-please;

sort your feelings, reset goals, seek (friends, family, anyone);

        do*not*die (like this)
        if sin abounds;

keys (hidden), open (locks, doors), tell secrets;
do not, I-beg-you, close them, yet.

                            accept (yourself, changes),
                            bind (grief, despair);

require truth, goodness if-you-will, each moment;

select (always), length(of-days)

# listen (a perl poem)
# Sharon Hopkins
# rev. June 19, 1995
```

Virtues of the Perl Programmer

Laziness
: *Laziness* sounds like the vice of the same name, but there's a difference. The vice is about the avoidance of immediate work. The virtue is about the avoidance of future work. Programmers with the power of Perl at their fingertips create the tools that make the same tasks easier the more they are done. Perl is a great language of automating tasks, and the more it automates today, the less work programmers do manually later.

Impatience
: *Impatience* is that nasty feeling you get when the computer is doing what it wants instead of what you want. Or, more correctly, when the programmer on the other side of the software chose the wrong default settings, made a poor GUI, or doesn't give you access to this data. You've experienced it enough to not inflict the same pain on other programmers, turning your frustration with your wasted time into a benefit for other people.

Hubris
: *Hubris* is the sense that, with the right tools, you can do just about anything. It's all a Simple Matter of Programming, right? It's also the thing that's likely to make you fly too close to the Sun.

Events

Almost every week of the year has some Perl event. Here are some of the main ones. Most are listed in *The Perl Review* Community Calendar (*http://theperlreview.com/community_calendar*).

The Perl Conference, OSCON
: O'Reilly & Associates' The Perl Conference in 1997 wasn't the first Perl event, but it might have been the most important, historically. At this event, a small group of New Yorkers formed the first Perl users group, NY.pm. This led to the creation of several other Perl mongers groups that year; within a couple of years, there were hundreds of groups. The Perl Conference expanded to become The Open Source Conference, or just OSCON.

YAPC
: YAPC, or Yet Another Perl Conference, comes in many forms and is on at least four continents. Every year, one of these low cost, grass roots, mostly noncommercial conferences is held in Asia, Europe, North America, and South America. Although they share the same name, each is organized by a different group.

Perl Workshops
: Whereas YAPC runs over several days, a Perl workshop is usually a one- or two-day event dedicated to a particular subject, such as the Perl QA Workshop, which focuses on issues of CPAN infrastructure and Perl testing. Not many people know that the German Perl Workshop was the first organized Perl event, even before there were Perl mongers or The Perl Conference.

Hackathons
: The least structured of all Perl events are hackathons, where Perl people assemble to do work in the same place. Sometimes the hackathon focuses on a particular topic, and sometimes it's just a bunch of people working on their own projects in the same room.

Getting Help

Perl people are some of the most helpful people around, and even the people who don't like Perl tend to realize that. We think Perl's roots in so many different kinds of languages attract the sort of people who like different kinds of languages rather than just the one they know. Perhaps they find a little good in everything.

If you need to find help, there are many people waiting to help you in almost any Internet-type discussion thingy that exists. Here are several notable ones:

http://perldoc.perl.org
: All of the Perl documentation is online, so you never have to live without it—despite what your platform and packaging system think. Yes, some vendors give you *perl* with no manuals.

Learn Perl
: This website is your starting point for many of the beginner resources available, including many that we list here.

Perl beginners mailing list
: Casey West started this mailing list as a safe place for absolute beginners to ask the most basic questions in a safe environment. Other fora may be much more, well, unregulated, and a bit more discouraging for the new Perl programmer.

Perlmonks
: Perlmonks is a web bulletin board dedicated to Perl. It's not specifically a help desk, but if you've done your homework and ask a good question, you're likely to get top-notch help very quickly. You might want to read "brian's Guide to Solving Any Perl Problem" first.[10]

Stackoverflow
: Stackoverflow is a question-and-answer site for general programming. Even though it is not dedicated to Perl, there are several Perl experts who frequent the site and answer questions.

Your local Perl mongers group
: There are hundreds of Perl mongers groups across the world. Although each has its particular flavor, it's a good way for you to find and interact with Perl users near you (or not so near you). Many of these groups put on workshops and other events. Find the mongers nearest you at *http://www.pm.org*, and if you don't find one, start one!

10. This guide also appears in *Mastering Perl*.

Usenet newsgroups

The Perl newsgroups are a great, if sometimes cluttered, source of information about Perl. Your first stop might be *news:comp.lang.perl.moderated*, a moderated, low-traffic newsgroup that includes announcements and technical discussion. Because of the moderation, the newsgroup is quite readable.

The high-traffic *news:comp.lang.perl.misc* group discusses everything from technical issues to Perl philosophy to Perl games and Perl poetry. Like Perl itself, *news:comp.lang.perl.misc* is meant to be useful, and no question is too silly to ask.[11]

If you're using a web browser to access Usenet instead of a regular newsreader, prepend *news:* to the newsgroup name to get at one of these named newsgroups. (This only works if you have a news server.) Alternately, if you use a Usenet searching service like Google Groups, specify `*perl*` as the newsgroups to search for.

Mailing lists

Many topics, both general and specific, have dedicated mailing lists. Many of those are listed on *http://lists.perl.org*. You can find others directly from project websites. You can also use sites such as *http://markmail.org* to search the archives across many Perl lists.

IRC

Internet Relay Chat (IRC) is another favorite medium for Perl programmers, and, if you like that sort of thing, you'll find plenty of people to talk to. These chat rooms don't see themselves primarily as a help desk, so dropping by just to ask a question without introducing yourself is a bit like crashing a party. However, some, like `#perl-help` and `#win32`, are specifically help channels. Find many IRC channels at *http://www.irc.perl.org/*.

11. Of course, some questions are too silly to answer. (Especially those already answered in the online manpages and FAQs. Why ask for help on a newsgroup when you could find the same answer yourself in less time than it takes to type in the question?)

PART V

Reference Material

CHAPTER 25

Special Names

This chapter is about variables that have special meanings to Perl. Most of the punctuational names have reasonable mnemonics or analogs in one of the shells (or both). But if you want to use long variable names as synonyms, just say:

```
use English "-no_match_vars";
```

at the top of your program. This aliases all the short names to long names in the current package. Some of these variables even have medium names, generally borrowed from *awk*. Most people eventually settle on using the short names, at least for the more commonly used variables. Throughout this book, we consistently refer to the short names, but we also often mention the long names (in parentheses) so that you can look them up easily in this chapter.

The semantics of these variables can be quite magical. (To create your own magic, see Chapter 14.) A few of these variables are read-only. If you try to assign values to them, an exception will be raised.

In what follows, we'll first provide a concise listing of the variables and functions for which Perl assigns a special meaning, grouped by type, so you can look up variables when you're not sure of the proper name. Then we'll explain all of the variables alphabetically under their proper name (or their least improper name).

Special Names Grouped by Type

We used the word "type" loosely—the sections here actually group variables more by their scope—that is, from where they're visible.

Regular Expression Special Variables

The following special variables related to pattern matching are visible throughout the dynamic scope in which the pattern match occurred. In other words, they

behave as though they were declared with `local`, so you needn't declare them that way yourself. See Chapter 5.

```
$digits

$& ($MATCH)
$' ($POSTMATCH)
$` ($PREMATCH)

${^MATCH}
${^POSTMATCH}
${^PREMATCH}

$+ ($LAST_PAREN_MATCH)
%+ (%LAST_PAREN_MATCH)
@+ (@LAST_MATCH_END)

@-
%-

$^R ($LAST_REGEXP_CODE_RESULT)
$^N ($LAST_SUBMATCH_RESULT)
```

Per-Filehandle Variables

These special variables never need to be mentioned in a `local`, because they always refer to some value pertaining to the currently selected output filehandle—each filehandle keeps its own set of values. When you `select` another filehandle, the old filehandle remembers the values it had for these variables, and the variables now reflect the values of the new filehandle. See also the `IO::Handle` module.

```
$| ($AUTOFLUSH, $OUTPUT_AUTOFLUSH)
$- ($FORMAT_LINES_LEFT)
$= ($FORMAT_LINES_PER_PAGE)
$~ ($FORMAT_NAME)
$% ($FORMAT_PAGE_NUMBER)
$^ ($FORMAT_TOP_NAME)
```

Per-Package Special Variables

These special variables exist separately in each package. There should be no need to localize them, since `sort` automatically does so on `$a` and `$b`, and the rest are probably best left alone (though you will need to declare them with `our` if you `use strict`).

```
$a
$AUTOLOAD
$b
@EXPORT
```

```
@EXPORT_OK
%EXPORT_TAGS
%FIELDS
@ISA
%OVERLOAD
$VERSION
```

Program-Wide Special Variables

These variables are truly global in the fullest sense—they mean the same thing in every package, because they're all forced into package `main` when unqualified (except for `@F`, which is special in `main`, but not forced). If you want a temporary copy of one of these, you must localize it in the current dynamic scope.

```
%ENV
%! (%ERRNO, %OS_ERROR)
%INC
%SIG
%^H

@_
@ARGV
@INC

$_
$0 ($PROGRAM_NAME)
$ARGV

$! ($ERRNO, $OS_ERROR)
$" ($LIST_SEPARATOR)
$$ ($PID, $PROCESS_ID)
$( ($GID, $REAL_GROUP_ID)
$) ($EGID, $EFFECTIVE_GROUP_ID)
$, ($OFS, $OUTPUT_FIELD_SEPARATOR)
$. ($NR, $INPUT_LINE_NUMBER)
$/ ($RS, $INPUT_RECORD_SEPARATOR)
$: ($FORMAT_LINE_BREAK_CHARACTERS)
$; ($SUBSEP, $SUBSCRIPT_SEPARATOR)
$< ($UID, $REAL_USER_ID)
$> ($EUID, $EFFECTIVE_USER_ID)
$? ($CHILD_ERROR)
$@ ($EVAL_ERROR)
$[
$\ ($ORS, $OUTPUT_RECORD_SEPARATOR)
$]
$^A ($ACCUMULATOR)
$^C ($COMPILING)
$^D ($DEBUGGING)
${^ENCODING}
$^E ($EXTENDED_OS_ERROR)
```

```
${^GLOBAL_PHASE}
$^F ($SYSTEM_FD_MAX)
$^H
$^I ($INPLACE_EDIT)
$^L ($FORMAT_FORMFEED)
$^M
$^O ($OSNAME)
${^OPEN}
$^P ($PERLDB)
$^R ($LAST_REGEXP_CODE_RESULT)
${^RE_DEBUG_FLAGS}
${^RE_TRIE_MAXBUF}
$^S (EXCEPTIONS_BEING_CAUGHT)
$^T ($BASETIME)
${^TAINT}
${^UNICODE}
${^UTF8CACHE}
${^UTF8LOCALE}
$^V ($PERL_VERSION)
$^W ($WARNING)
${^WARNING_BITS}
${^WIDE_SYSTEM_CALLS}
${^WIN32_SLOPPY_STAT}
$^X ($EXECUTABLE_NAME)
```

Per-Package Special Filehandles

Except for `DATA`, which is always per-package, the following filehandles are always assumed to be in `main` when not fully qualified with another package name:

```
_ # (underline)
ARGV
ARGVOUT
DATA
STDIN
STDOUT
STDERR
```

Per-Package Special Functions

The following subroutine names have a special meaning to Perl. They're always called implicitly because of some event, such as accessing a tied variable or trying to call an undefined function. We don't describe them in this chapter since they all receive heavy-duty coverage elsewhere in the book.

Undefined function call interceptor (see Chapter 10):

```
AUTOLOAD
```

Moribund objects' finalization (see Chapter 12):

```
DESTROY
```

Exception objects (see `die` in Chapter 27):

```
PROPAGATE
```

Auto-init and auto-cleanup functions (see Chapter 16):

```
BEGIN, CHECK, UNITCHECK, INIT, END
```

Threading support:

```
CLONE, CLONE_SKIP
```

Tie methods (see Chapter 14):

```
BINMODE, CLEAR, CLOSE, DELETE, DESTROY, EOF, EXISTS, EXTEND,
FETCH, FETCHSIZE, FILENO, FIRSTKEY, GETC, NEXTKEY, OPEN, POP,
PRINT, PRINTF, PUSH, READ, READLINE, SCALAR, SEEK, SHIFT,
SPLICE, STORE, STORESIZE, TELL, TIEARRAY, TIEHANDLE, TIEHASH,
TIESCALAR, UNSHIFT, and WRITE.
```

Special Variables in Alphabetical Order

We've alphabetized these entries according to the long variable name. If you don't know the long name of a variable, you can find it in the previous section. (Variables without alphabetical names are sorted to the front.)

So that we don't have to keep repeating ourselves, each variable description in Table 25-1 starts with one or more of these annotations.

Table 25-1. Annotations for special variables

Annotation	Meaning
XXX	Deprecated, *do not use* in anything new.
NOT	Not Officially There (internal use only).
RMV	Removed from Perl.
ALL	Truly global, shared by all packages.
PKG	Package global; each package can have its own.
FHA	Filehandle attribute; one per I/O object.
DYN	Dynamically scoped automatically (implies ALL).
LEX	Lexically scoped at compile time.
RO	Read only; raises an exception if you modify.

When more than one variable name or symbol is listed, only the short one is available by default. Using the `English` module makes the longer synonyms available to the current package, and only to the current package, even if the variable is marked [ALL].

Entries of the form *`method HANDLE EXPR`* show object-oriented interfaces to the per-filehandle variables provided by the `IO::Handle` module. As of v5.14, this module is loaded on demand. (You may also use the *`HANDLE->method(EXPR)`* notation if you prefer.) These let you avoid having to call `select` to change the default output handle before examining or changing that variable. Each such method returns the old value of the attribute; a new value is set if the *`EXPR`* argument is supplied. If not supplied, most of the methods do nothing to the current value, except for `autoflush`, which assumes an argument of `1`, just to be different.

`$_` [ALL] The default input and pattern-search space. These pairs are equivalent:

```
while (<>) {...}    # equivalent only in unadorned while test
while (defined($_ = <>)) {...}

chomp
chomp($_)

/^Subject:/
$_ =~ /^Subject:/

tr/a-z/A-Z/
$_ =~ tr/a-z/A-Z/
```

Here are the places where Perl will assume `$_` if you don't specify something to operate on:

- List functions like `print` and `unlink`, and unary functions like `ord`, `pos`, and `int`, as well as all the file tests, except for `-t`, which defaults to `STDIN`. All functions that default to `$_` are so marked in Chapter 27.
- The pattern-matching operations `m//` and `s///`, and the transliteration operations `y///` and `tr///`, when used without an `=~` operator.
- The iterator variable in a `foreach` loop (even when spelled `for` or when used as a statement modifier) if no other variable is supplied.
- The implicit iterator variable in the `grep` and `map` functions. (There is no way to specify a different variable for these.)
- The default place to put an input record when a `<FH>`, `readline`, or `glob` operation's result is tested by itself as the sole criterion of a `while` test. This assignment does not occur outside of a `while` test or if any additional elements are included in the `while` expression.

Because `$_` is a global variable, this may sometimes lead to unwanted side effects. As of v5.10, you may use a private (lexical) version of `$_` by declaring it with `my`. Moreover, declaring `our $_` restores the global `$_` in the current scope.

(Mnemonic: underline is the underlying operand in certain operations.)

`@_` [ALL] Within a subroutine, this array holds the argument list passed to that subroutine. See Chapter 7.

`_ (underline)`
[ALL] This is the special filehandle used to cache the information from the last successful `stat`, `lstat`, or file test operator (like `-w $file` or `-d $file`).

`$`*`digits`*
[DYN,RO] The numbered variables `$1`, `$2`, and so on (up just as high as you want)[1] contain the text matched by the corresponding set of parentheses in the last matched pattern within the currently active dynamic scope. (Mnemonic: like `\`*`digits`*.)

`$]` [ALL] Returns the version + patchlevel/1000. It can be used at the beginning of a script to determine whether the Perl interpreter executing the script is in the right range of versions. (Mnemonic: is this version of Perl in the right bracket?) Example:

```
warn "No checksumming!\n" if $] < 3.019;
die "Must have prototyping available\n" if $] < 5.003;
```

See also the documentation of `use` *`VERSION`* and `require` *`VERSION`* for a convenient way to fail if the Perl interpreter is too old. See `$^V` for a more flexible representation of the Perl version.

`$[` [XXX,LEX] The index of the first element in an array and of the first character in a substring. Default is 0, but we used to set it to 1 to make Perl behave more like *awk* (or FORTRAN) when subscripting and when evaluating the `index` and `substr` functions. Because it was found to be so dangerous, assignment to `$[` is now treated as a lexically scoped compiler directive, and it cannot influence the behavior of any other file. (Mnemonic: `[` begins subscripts.)

`$#` [RMV,ALL] Removed in the v5.10 release. Don't use this; use `printf` instead. `$#` once contained the output format for printed numbers, in a half-hearted attempt to emulate *awk*'s `OFMT` variable. (Mnemonic: `#` is the number sign,

1. Although many regular expression engines only support up to nine backreferences, Perl has no such limit. So if you go around writing `$768`, Perl won't mind, although maintainers of your code might.

but if you're sharp, you'll just forget it so you don't make a hash of your program and get pounded for it.)

This is not the sigil you use in front of an array name to get the last index, like `$#ARRAY`. That's still how you get the last index of an array in Perl. The two have nothing to do with each other.

`$*` [RMV,ALL] This defunct variable could once upon a time be set to true to get Perl to assume `/m` on every pattern match that doesn't have an explicit `/s`. It was removed in the v5.10 release. (Mnemonic: `*` matches multiple things.)

`%-` [DYN,RO] Like `%+` (%LAST_PAREN_MATCH), this variable allows access to the named capture groups in the last successful pattern match in the currently active dynamic scope. Its keys are the names of the capture groups, and its values are array references. Each contains the values matched by all groups of that same name, should there be several of them, in the order in which those names appeared in the pattern.

Do not mix calls to `each` on this hash while also doing pattern matching in the loop itself, or things will change out from under you.

If you don't like writing `$-{NAME}[0]` and such, use the standard `Tie::Hash::NamedCapture` module to give `%-` an aliased name of your own choosing.

`$a` [PKG] This variable is used by the `sort` function to hold the first of each pair of values to be compared (`$b` is the second of each pair). The package for `$a` is the same one that the `sort` operator was compiled in, which is not necessarily the same as the one its comparison function was compiled into. This variable is implicitly localized within the `sort` comparison block. Because it is a global, it is exempt from `use strict` complaints. Because it is an alias for the actual array value, you might think you can modify it, but you shouldn't. See the `sort` function.

`$ACCUMULATOR`

`$^A` [ALL] The current value of the `write` accumulator for `format` lines. A format contains `formline` commands that put their result into `$^A`. After calling its format, `write` prints out the contents of `$^A` and empties it. So you never actually see the contents of `$^A` unless you call `formline` yourself and then look at it. See the `formline` function.

`ARGV`

[ALL] The special filehandle that iterates over command-line filenames in `@ARGV`. Usually written as the null filehandle in the angle operator: `<>`.

`$ARGV`
: [ALL] Contains the name of the current file when reading from the `ARGV` handle using the `<>` or `readline` operators.

`@ARGV`
: [ALL] The array containing the command-line arguments intended for the script. Note that `$#ARGV` is generally the number of arguments minus one, since `$ARGV[0]` is the first argument, not the command name; use `scalar @ARGV` for the number of program arguments. See `$0` for the program name.

`ARGVOUT`
: [ALL] The special filehandle used while processing the `ARGV` handle under the *–i* switch or the `$^I` variable. See the *–i* switch in Chapter 17.

`$AUTOLOAD`
: [PKG] During the execution of an `AUTOLOAD` method, this per-package variable contains the fully qualified name of the function on whose behalf the `AUTOLOAD` method is running. See Chapter 25.

`$b`
: [PKG] The variable, companion to `$a`, used in `sort` comparisons. See `$a` and the `sort` function for details.

`$BASETIME`

`$^T`
: [ALL] The time at which the script began running, in seconds, since the epoch (the beginning of 1970 for Unix systems). The values returned by the `-M`, `-A`, and `-C` file tests are relative to this moment.

`$CHILD_ERROR`

`$?`
: [ALL] The status returned by the last pipe close, backtick (``` `` ```) command, or `wait`, `waitpid`, or `system` functions. Note that this is not just the simple exit code, but the entire 16-bit status word returned by the underlying *wait*(2) or *waitpid*(2) syscall (or equivalent). Thus, the exit value of the subprocess is in the high byte—that is, `$? >> 8`. In the low byte, `$? & 127` says which signal (if any) the process died from, while `$? & 128` reports whether its demise produced a core dump. (Mnemonic: similar to `$?` in the *sh* and its offspring.)

  Inside an `END` block, `$?` contains the value that is going to be given to `exit`. You can modify `$?` in an `END` to change the exit status of the script. For example:

```
END {
    $? = 1 if $? == 255;  # die would make it 255
}
```

Under VMS, the pragma `use vmsish "status"` makes `$?` reflect the true VMS exit status instead of the default emulation of POSIX status.

If the `h_errno` variable is supported in C, its numeric value is returned via `$?` if any of the `gethost*()` functions fail.

`$COMPILING`

`$^C` [ALL] The current value of the internal flag associated with the `-c` switch, mainly of use with *–MO=…* to let code alter its behavior. For example, you might want to `AUTOLOAD` at compile time instead of using the normal, deferred loading so that code can be generated right away. Setting `$^C = 1` is similar to calling `B::minus_c`. See Chapter 16.

`DATA`

[PKG] This special filehandle refers to anything following either the `__END__` token or the `__DATA__` token in the current file. The `__END__` token always opens the `main::DATA` filehandle, and so it is used in the main program. The `__DATA__` token opens the `DATA` handle in whichever package is in effect at the time, so different modules can each have their own `DATA` filehandle, since they (presumably) have different package names.

`$DEBUGGING`

`$^D` [ALL] The current value of the internal debugging flags, set from the *–D* switch on the command line; see the section "Switches" on page 580 in Chapter 17 for the values. Like its command-line equivalent, you can use numeric or symbolic values—for example, `$^D = 10` or `$^D = "st"`.

(Mnemonic: value of the *–D* switch.)

`${^ENCODING}`

[XXX,ALL] The *object reference* to the `Encode` object that is used to convert the source code to Unicode. Thanks to this variable, your Perl script does not have to be written in UTF-8. Default is *undef*. The direct manipulation of this variable is highly discouraged.

This variable was added in v5.8.2.

`$EFFECTIVE_GROUP_ID`

`$)` [ALL] The effective GID (group ID) of this process. If you are on a machine that supports membership in multiple groups simultaneously, `$)` gives a space-separated list of groups you are in. The first number is the one returned by *getegid*(2), and the subsequent ones by *getgroups*(2), one of which may be the same as the first number.

Similarly, a value assigned to `$)` must also be a space-separated list of numbers. The first number is used to set the effective GID, and the rest (if any) are passed to the *setgroups*(2) syscall. To get the effect of an empty list for `setgroups`, just repeat the new effective GID; for example, to force an effective GID of 5 and an effectively empty `setgroups` list, say:

```
$) = "5 5";
```

(Mnemonic: parentheses are used to *group* things. The effective GID is the group that's *right* for you, if you're running setgid.) Note: `$<`, `$>`, `$(`, and `$)` can only be set on machines that support the corresponding system set-id routine. `$(` and `$)` can be swapped only on machines supporting *setregid*(2).

`$EFFECTIVE_USER_ID`

`$>` [ALL] The effective UID of this process as returned by the *geteuid*(2) syscall. Example:

```
$< = $>;            # set real to effective uid
($<,$>) = ($>,$<);  # swap real and effective uid
```

You can change both the effective uid and the real uid at the same time using `POSIX::setuid`. Changes to `$>` require a check to `$!` to detect any possible errors after an attempted change.

(Mnemonic: it's the UID you went *to*, if you're running setuid.) Note: `$<` and `$>` can only be swapped on machines supporting *setreuid*(2). And sometimes not even then.

`%ENV` [ALL] The hash containing your current environment variables. Setting a value in `%ENV` changes the environment for both your process and child processes launched after the assignment. (It cannot change a parent process's environment on any system resembling Unix.)

```
$ENV{PATH}  = "/bin:/usr/bin";
$ENV{PAGER} = "less";
$ENV{LESS}  = "MQeicsnf";  # our favorite switches to less(1)
system "man perl";         # picks up new settings
```

To remove something from your environment, make sure to use the `delete` function instead of `undef` on the hash value.

Note that processes running as *crontab*(5) entries inherit a particularly impoverished set of environment variables. (If your program runs fine from the command line but not under *cron*, this is probably why.) Also note that you should set `$ENV{PATH}`, `$ENV{SHELL}`, `$ENV{BASH_ENV}`, and `$ENV{IFS}` if you are running as a setuid script. See Chapter 20.

`$EVAL_ERROR`

`$@` [ALL] The currently raised exception or the Perl syntax error message from the last `eval` operation. (Mnemonic: where was the syntax error "at"?) Unlike `$!` (`$OS_ERROR`), which is set on failure but not cleared on success, `$@` is guaranteed to be set (to a true value) if the last `eval` had a compilation error or runtime exception, and guaranteed to be cleared (to a false value) if no such problem occurred.

Warning messages are not collected in this variable. You can, however, set up a routine to process warnings by setting `$SIG{__WARN__}`, as described later in this section.

Note that the value of `$@` may be an exception object rather than a string. If so, you can still probably treat it as a string if the exception object has stringification overloading defined for its class. If you propagate an exception by saying:

```
die if $@;
```

then an exception object will call `$@->PROPAGATE` to see what to do. (A string exception merely adds a "propagated at" line to the string.)

`$EXCEPTIONS_BEING_CAUGHT`

`$^S` [ALL] This variable reflects the current state of the interpreter, returning true if inside an `eval` and false otherwise. It's undefined if parsing of the current compilation unit hasn't finished yet, which may be the case in `$SIG{__DIE__}` and `$SIG{__WARN__}` handlers. (Mnemonic: state of `eval`.)

`$EXECUTABLE_NAME`

`$^X` [ALL] The name that the *perl* binary itself was executed as, from C's `argv[0]`.

`@EXPORT`

[PKG] This array variable is consulted by the `Exporter` module's `import` method to find the list of other package variables and subroutines to be exported by default when the module is `use`d, or when the `:DEFAULT` import tag is used. It is not exempt from `use strict` complaints, so it must be declared with `our` or fully qualified by package name if you've enabled that pragma. However, all variables whose names begin with the string "`EXPORT`" are exempt from warnings about being used only once. See Chapter 11.

`@EXPORT_OK`

[PKG] This array variable is consulted by the `Exporter` module's `import` method to determine whether a requested import is legal. It is not exempt from `use strict`. See Chapter 11.

`%EXPORT_TAGS`

: [PKG] This hash variable is consulted by the `Exporter` module's `import` method when an import symbol with a leading colon is requested, as in `use POSIX ":sys_wait_h"`. The keys are the colon tags, but without the leading colon. The values should be references to arrays containing symbols to import when the colon tag is requested, all of which must also appear in either `@EXPORT` or `@EXPORT_OK`. It is not exempt from `use strict`. See Chapter 11.

`$EXTENDED_OS_ERROR`

`$^E` [ALL] Error information specific to the current operating system. Under Unix, `$^E` is identical to `$!` (`$OS_ERROR`), but it differs under OS/2, VMS, and Microsoft systems and on MacPerl. See your port's information for specifics. Caveats mentioned in the description of `$!` generally apply to `$^E` as well. (Mnemonic: extra error explanation.)

`@F` [PKG] The array into which the input line's fields are split when the *–a* command-line switch is given. If the *–a* option is not used, this array has no special meaning. (This array is actually only `@main::F`, and not in all packages at once.)

`%FIELDS`

: [XXX,PKG] This hash is for internal use by the `fields` pragma to determine the current legal fields in an object hash.

`format_formfeed` *`HANDLE EXPR`*

`$FORMAT_FORMFEED`

`$^L` [ALL] What a `write` function implicitly outputs to perform a form feed before it emits a top of form header. Default is `"\f"`.

`format_lines_left` *`HANDLE EXPR`*

: [FHA] The number of lines left on the page of the currently selected output handle, for use with the `format` declaration and the `write` function. (Mnemonic: `lines_on_page - lines_printed`.)

`format_lines_per_page` *`HANDLE EXPR`*

`$FORMAT_LINES_PER_PAGE`

`$=` [FHA] The current page length (printable lines) of the currently selected output handle, for use with `format` and `write`. Default is 60. (Mnemonic: `=` has horizontal lines.)

`format_line_break_characters` *`HANDLE EXPR`*

`$FORMAT_LINE_BREAK_CHARACTERS`

`$:` [ALL] The current set of characters after which a string may be broken to fill continuation fields (starting with `^`) in a format. Default is `" \n-"` to break on whitespace or hyphens. (Mnemonic: a colon is a technical word meaning part of a line in poetry. Now you just have to remember the mnemonic...)

`format_name` *`HANDLE EXPR`*

`$FORMAT_NAME`

`$~` [FHA] The name of the current report format for the currently selected output handle. Default is the filehandle's name. (Mnemonic: takes a turn after `$^`.)

`format_page_number` *`HANDLE EXPR`*

`$FORMAT_PAGE_NUMBER`

`$%` [FHA] The current page number of the currently selected output handle, for use with `format` and `write`. (Mnemonic: `%` is the page number register in *troff*(1). What, you don't know what *troff* is?)

`format_top_name` *`HANDLE EXPR`*

`$FORMAT_TOP_NAME`

`$^` [FHA] The name of the current top-of-page format for the currently selected output handle. Default is the name of the filehandle with `_TOP` appended. (Mnemonic: points to top of page.)

`$^H` [NOT,LEX] This variable contains lexically scoped status bits (a.k.a. hints) for the Perl parser. This variable is strictly for internal use only. Its availability, behavior, and contents are subject to change without notice. If you touch it, you will undoubtedly die a horrible death of some loathsome tropical disease unknown to science. (Mnemonic: we won't give you a hint.)

`%^H` [NOT,LEX] The `%^H` hash provides the same lexical scoping semantics as `$^H`, making it useful for implementation of lexically scoped pragmas. Read the dire warnings listed under `$^H`, and then add to them the fact that this variable is still experimental.

`%INC`

[ALL] The hash containing entries for the filename of each Perl file loaded via `do` *`FILE`*, `require`, or `use`. The key is the filename you specified, and the value is the location of the file actually found. The `require` operator uses this array to determine whether a given file has already been loaded. For example:

```
% perl -MLWP::Simple -le 'print $INC{"LWP/Simple.pm"}'
/opt/perl/5.6.0/lib/site_perl/LWP/Simple.pm
```

`@INC`

[ALL] The array containing the list of directories where Perl modules may be found by `do` *`FILE`*, `require`, or `use`. It initially consists of the arguments to any *–I* command-line switches and directories in the `PERL5LIB` environment variable, followed by the default Perl libraries, such as:

```
/usr/local/lib/perl5/site_perl/5.14.2/darwin-2level
/usr/local/lib/perl5/site_perl/5.14.2
/usr/local/lib/perl5/5.14.2/darwin-2level
/usr/local/lib/perl5/5.14.2
/usr/local/lib/perl5/site_perl
.
```

followed by "`.`" to represent the current directory. If you need to modify this list from within your program, try the `lib` pragma, which not only modifies the variable at compile time, but also adds in any related architecture-dependent directories (such as those that contain the shared libraries used by XS modules):

```
use lib "/mypath/libdir/";
use SomeMod;
```

`$INPLACE_EDIT`

`$^I` [ALL] The current value of the inplace-edit extension. Use `undef` to disable inplace editing. You can use this from within your program to get the same behavior as the *–i* switch provides. For example, to do the equivalent of this command:

```
% perl -i.orig -pe 's/foo/bar/g' *.c
```

you can use the following equivalent code in your program:

```
local $^I   = ".orig";
local @ARGV = glob("*.c");
while (<>) {
    s/foo/bar/g;
    print;
}
```

(Mnemonic: value of the *–i* switch.)

`$INPUT_LINE_NUMBER`

`$.` [ALL] The current record number (usually line number) for the last filehandle you read from (or called `seek` or `tell` on). The value may be different from the actual physical line number in the file, depending on what notion of "line" is in effect—see `$/` (`$INPUT_RECORD_SEPARATOR`) on how to affect that. An explicit close on a filehandle resets the line number. Because `<>` never

does an explicit close, line numbers increase across ARGV files (but see examples under eof). Localizing $. also localizes Perl's notion of "the last read filehandle". (Mnemonic: many programs use "." to mean the current line number.)

$INPUT_RECORD_SEPARATOR

$/ [ALL] The input record separator, newline by default, which is consulted by the readline function, the <FH> operator, and the chomp function. It works like *awk*'s RS variable and, if set to the null string, treats one or more empty lines as a record terminator. (But an empty line must contain no hidden spaces or tabs.) You may set it to a multicharacter string to match a multicharacter terminator, but you may not set it to a pattern—*awk* has to be better at something.

Note that setting $/ to "\n\n" means something slightly different than setting it to "", if the file contains consecutive empty lines. Setting it to "" will treat two or *more* consecutive empty lines as a single empty line. Setting it to "\n\n" means Perl will blindly assume that a third newline belongs to the next paragraph.

Entirely undefining $/ makes the next line input operation slurp in the remainder of the file as one scalar value:

```
undef $/;           # enable whole-file mode
$_ = <FH>;          # whole file now here
s/\n[ \t]+/ /g;     # fold indented lines
```

If you're using the while (<>) construct to access the ARGV handle while $/ is undefined, each read gets the next file:

```
undef $/;
while (<>) {        # $_ has the whole next file in it
    ...
}
```

Although we used undef above, it's safer to undefine $/ using local:

```
{
    local $/;
    $_ = <FH>;
}
```

Setting $/ to a reference to either an integer, a scalar containing an integer, or a scalar that's convertible to an integer will make readline and <FH> operations read in fixed-length records (with the maximum record size being the referenced integer) instead of variable-length records terminated by a particular string. So this:

```
$/ = \32768; # or \"32768" or \$scalar_var_containing_32768
open(FILE, $myfile);
$record = <FILE>;
```

will read a record of no more than 32,768 bytes from the `FILE` handle. If you're not reading from a record-oriented file (or your operating system doesn't have record-oriented files), then you'll likely get a full chunk of data with every read. If a record is larger than the record size you've set, you'll get the record back in pieces. Record mode mixes well with line mode only on systems where standard I/O supplies a *read*(3) function; VMS is a notable exception.

Calling `chomp` when `$/` is set to enable record mode—or when it is undefined—has no effect. See also the *–0* (the digit) and the *–l* (the letter) command-line switches in Chapter 17. (Mnemonic: `/` is used to separate lines when quoting poetry.)

`@ISA`

[PKG] This array contains names of other packages to look through when a method call cannot be found in the current package. That is, it contains the base classes of the package. The `base` pragma sets this implicitly. It is not exempt from `strict`. See Chapter 12.

`@LAST_MATCH_END`

`@+` [DYN,RO] This array holds the offsets of the ends of the last successful submatches in the currently active dynamic scope. `$+[0]` is the offset of the end of the entire match. This is the same value the `pos` function returns when called on the variable that it was matched against. (When we say "offset of the end", we really mean the offset to the first character *following* the end of whatever matched, so that we can subtract beginning offsets from end offsets and arrive at the length.) The n^{th} element of this array holds the offset of the n^{th} submatch, so `$+[1]` is the offset where `$1` ends, `$+[2]` the offset where `$2` ends, and so on. You can use `$#+` to determine how many subgroups were in the last successful match. See also `@-` (`@LAST_MATCH_START`).

After a successful match against some variable `$var`:

- `$`` is the same as `substr($var, 0, $-[0])`
- `$&` is the same as `substr($var, $-[0], $+[0] - $-[0])`
- `$'` is the same as `substr($var, $+[0])`
- `$1` is the same as `substr($var, $-[1], $+[1] - $-[1])`
- `$2` is the same as `substr($var, $-[2], $+[2] - $-[2])`
- `$3` is the same as `substr($var, $-[3], $+[3] - $-[3])`, and so on

`@LAST_MATCH_START`

`@-` [DYN,RO] This array holds the offsets of the beginnings of the last successful submatches in the currently active dynamic scope. `$-[0]` is the offset of the beginning of the entire match. The n^{th} element of this array holds the offset of the n^{th} submatch, so `$-[1]` is the offset where `$1` begins, `$-[2]` the offset where `$2` begins, and so on. You can use `$#-` to determine how many subgroups were in the last successful match. See also `@+` (`@LAST_MATCH_END`).

`$LAST_PAREN_MATCH`

`$+` [DYN,RO] This returns the last parenthesized submatch from the last successful pattern in the currently active dynamic scope. This is useful when you don't know (or care) which of a set of alternative patterns matched. (Mnemonic: be positive and forward looking.) Example:

```
$rev = $+   if /Version: (.*)|Revision: (.*)/;
```

`%LAST_PAREN_MATCH`

`%+` [DYN,RO] Like `%-`, this variable allows access to the named capture groups in the last successful pattern match in the currently active dynamic scope. Its keys are the names of the capture groups, and its values are the string matched by that name or, in the event that you have more than one group by one name, the last such match. Use `%-` to find all of them.

Do not mix calls to `each` on this hash while also doing pattern matching in the loop itself, or things will change out from under you.

If you don't like writing `$+{`*NAME*`}` and such, use the standard `Tie::Hash::NamedCapture` module to give `%+` an aliased name of your own choosing.

`$LAST_REGEXP_CODE_RESULT`

`$^R` [DYN] This contains the result of the last snippet of code executed inside a successful pattern with the `(?{ `*CODE*` })` construct. `$^R` gives you a way to execute code and remember the result for use later in the pattern, or even afterward.

As the Perl regular expression engine moves through the pattern, it may encounter multiple `(?{ `*CODE*` })` expressions. As it does, it remembers each value of `$^R` so that if it later has to backtrack past an expression, it restores the previous value of `$^R`. In other words, `$^R` has a dynamic scope within the pattern, much like `$1` and friends.

So `$^R` is not simply the result of the last snippet of code executed inside a pattern. It's the result of the last snippet of code *leading to a successful*

match. A corollary is that if the match was not successful, `$^R` will be restored to whatever value it had before the match occurred.

If the `(?{ CODE })` pattern is functioning directly as the conditional of a `(?(COND)IFTRUE|IFFALSE)` subpattern, `$^R` is not set.

`$LAST_SUBMATCH_RESULT`

`$^N` The text matched by the used group most-recently closed (*i.e.*, the group with the rightmost closing parenthesis) of the last successful search pattern.

This is mainly used from inside `(?{...})` blocks to examine text just matched. For example, to effectively capture text to a variable (in addition to `$1`, `$2`, etc.), replace `(...)` with:

```
(?:(PATTERN)(?{ $var = $^N }))
```

Setting and then using `$var` in this way relieves you from having to worry about exactly which set of parentheses they are.

This variable was added in v5.8.

Mnemonic: the (possibly) Nested parenthesis that most recently closed.

`$LIST_SEPARATOR`

`$"` [ALL] When an array or slice is interpolated into a double-quoted string (or the like), this variable specifies the string to put between individual elements. Default is a space. (Mnemonic: obvious, one hopes.)

`$^M` [ALL] By default, running out of memory is not trappable. However, if your *perl* was compiled to take advantage of `$^M`, you may use it as an emergency memory pool. If your Perl is compiled with *-DPERL_EMERGENCY_SBRK* and uses Perl's `malloc`, then:

```
$^M = "a" x (1 << 16);
```

would allocate a 64K buffer for emergency use. See the *INSTALL* file in the Perl source distribution directory for information on how to enable this option. As a disincentive to casual use of this advanced feature, there is no `use English` long name for this variable (and we won't tell you what the mnemonic is).

`$MATCH`

`$&` [DYN,RO] The string matched by the last successful pattern match in the currently active dynamic scope. (Mnemonic: like `&` in some editors.)

The use of this variable anywhere in a program imposes a considerable performance penalty on all regular expression matches. To avoid this penalty, you can extract the same substring by using `@-`. Starting with v5.10, you can

use the /p match flag and the ${^MATCH} variable to do the same thing for particular match operations.

${^MATCH}
: [DYN,RO] This variable is just like $& ($MATCH) except that it does not incur the performance penalty associated with that variable, and it is only guaranteed to contain a defined value when the pattern was compiled or executed with the /p modifier.

  This variable was added in v5.10.

$OSNAME

$^O
: [ALL] This variable contains the name of the platform (usually the operating system) for which the current *perl* binary was compiled. It's a cheap alternative to pulling it out of the Config module.

$OS_ERROR

$ERRNO

$!
: [ALL] If used in a numeric context, yields the current value of the last syscall error, with all the usual caveats. (This means that you shouldn't depend on the value of $! to be anything in particular, unless you've gotten a specific error return indicating a system error.) If used in a string context, $! yields the corresponding system error string. You can assign an error number to $! if, for instance, you want $! to return the string for that particular error, or you want to set the exit value for die. See also the Errno. (Mnemonic: what just went bang?)

%OS_ERROR

%ERRNO

%!
: [ALL] Each element of %! has a true value only if $! is set to that value. For example, $!{ENOENT} is true if and only if the current value of $! is ENOENT; that is, if the most recent error was "No such file or directory" (or its moral equivalent: not all operating systems, and certainly not all languages, give that exact error). To check for whether a particular key is meaningful on your system, use exists $!{*SOMEKEY*}; for a list of legal keys, use keys %!. See the documentation for the Errno module for more information, and see also $! above.

  This variable was added in v5.005.

  [ALL] This hash is defined only if you've loaded the standard Errno module. Once you've done this, you can subscript into %! using a particular error string, and its value is true only if that's the current error. For example, $!

`{ENOENT}` is true only if the C `errno` variable is currently set to the C `#define` value, `ENOENT`. This is convenient for accessing vendor-specific symbols.

`autoflush` *`HANDLE EXPR`*

`$AUTOFLUSH`

`$|` [FHA] If set to true, forces a buffer flush after every `print`, `printf`, and `write` on the currently selected output handle. (We call this *command buffering*. Contrary to popular belief, setting this variable does not turn off buffering.) The default is false, which on many systems means that `STDOUT` will be line buffered if output is to the terminal, and block buffered otherwise, even on pipes and sockets. Setting this variable is useful when you are outputting to a pipe, such as when you are running a Perl script under *rsh*(1) and want to see the output as it's happening. If you have pending, unflushed data in the currently selected filehandle's output buffer when this variable is set to true, that buffer will be immediately flushed as a side effect of assignment. See the one-argument form of `select` for examples of controlling buffering on filehandles other than `STDOUT`. (Mnemonic: when you want your pipes to be piping hot.)

This variable has no effect on input buffering; for that, see `getc` in Chapter 27 or the example in the `POSIX` module.

`$OUTPUT_FIELD_SEPARATOR`

`$/` [ALL] The output field separator (terminator, actually) for `print`. Ordinarily, `print` simply prints out the list elements you specify without anything between them. Set this variable as you would set *awk*'s `OFS` variable to specify what is printed between fields. (Mnemonic: what is printed when there is a "`,`" in your `print` statement.)

`$OUTPUT_RECORD_SEPARATOR`

`$\` [ALL] The output record separator (terminator, actually) for `print`. Ordinarily, `print` simply prints out the comma-separated fields you specify, with no trailing newline or record separator assumed. Set this variable as you would set *awk*'s `ORS` variable to specify what is printed at the end of the `print`. (Mnemonic: you set `$\` instead of adding `"\n"` at the end of the print. Also, it's just like `/`, but it's what you get "back" from Perl.) See also the *–l* (for "line") command-line switch in Chapter 17.

%OVERLOAD

[NOT,PKG] This hash's entries are set internally by the `use overload` pragma to implement operator overloading for objects of the current package's class. See Chapter 13.

$PERLDB

$^P [NOT,ALL] The internal variable for enabling the Perl debugger (*perl –d*).

$PERL_VERSION

$^V [ALL] The revision, version, and subversion of the Perl interpreter. This variable first appeared in v5.6.0; earlier versions of perl will see an undefined value. Before v5.10.0, `$^V` was represented as a v-string.

`$^V` can be used to determine whether the Perl interpreter executing a script is in the right range of versions. For example:

```
warn "Hashes not randomized!\n" unless $^V && $^V gt v5.8;
```

To convert `$^V` into its string representation, use `sprintf`'s `"%vd"` conversion:

```
printf "version is v%vd\n", $^V;  # Perl's version
```

Newer versions of Perl will do this automatically:

```
$ perl -E 'say $^V'
v5.14.0

$ perl -E 'say $^V  5.10.1'
1
```

See the documentation of `use` *VERSION* and `require` *VERSION* for a convenient way to fail if the running Perl interpreter is older than you were hoping. See also `$]` for the original representation of the Perl version.

Mnemonic: use ^V for Version Control.

$POSTMATCH

$' [DYN,RO] The string following whatever was matched by the last successful pattern in the currently active dynamic scope. (Mnemonic: ' often follows a quoted string.) Example:

```
$_ = "abcdefghi";
/def/;
print "$`:$&:$'\n";         # prints abc:def:ghi
```

Thanks to dynamic scope, Perl can't know which patterns will need their results saved away into these variables, so mentioning `$`` or `$'` anywhere in a program incurs a performance penalty on all pattern matches throughout the program. This isn't much of an issue in small programs, but you prob-

ably should avoid this pair when you're writing reusable module code. The example above can be equivalently recoded like this, but without the global performance hit:

```
$_ = "abcdefghi";
/(.*?)(def)(.*)/s;          # /s in case $1 contains newlines
print "$1:$2:$3\n";         # prints abc:def:ghi
```

`${^POSTMATCH}`

[DYN,RO] This variable is just like `$'` (`$POSTMATCH`) except that it does not incur the performance penalty associated with that variable, and it is only guaranteed to contain a defined value when the pattern was compiled or executed with the `/p` modifier.

This variable was added in v5.10.

`$PREMATCH`

`$`` [DYN,RO] The string preceding whatever was matched by the last successful pattern in the currently active dynamic scope. (Mnemonic: ` often precedes a quoted string.) See the performance note under `$'`, previously.

`${^PREMATCH}`

This is just like `$`` (`$PREMATCH`) except that it does not incur the performance penalty associated with that variable, and it is only guaranteed to contain a defined value when the pattern was compiled or executed with the `/p` modifier.

This variable was added in v5.10.

`$PROCESS_ID`

`$$` [ALL] The process number (PID) of the Perl running this script. This variable is automatically updated upon a `fork`. In fact, you can even set `$$` yourself; this will not, however, change your PID. That would be a neat trick. (Mnemonic: same as in the various shells.)

You need to be careful not to use `$$` anywhere it might be misinterpreted as a dereference: `$$alphanum`. In this situation, write `${$}alphanum` to distinguish it from `${$alphanum}`.

`$PROGRAM_NAME`

`$0` [ALL] Contains the name of the file containing the Perl script being executed. Assignment to `$0` is magical: it attempts to modify the argument area that the *ps*(1) program normally reports on. This is more useful as a way of indicating the current program state than it is for hiding the program you're

running. But it doesn't work on all systems. (Mnemonic: same as *sh*, *ksh*, *bash*, etc.)

In multithreaded scripts, Perl coordinates the threads so that any thread may modify its copy of the `$0`, and the change becomes visible to *ps* (assuming the operating system plays along). Note that the view other threads have of `$0` will not change, since they have their own copies of it.

If the program has been given to Perl via the switches *–e* or *–E*, `$0` will contain the string `"-e"`.

`$REAL_GROUP_ID`

`$(` [ALL] The real group ID (GID) of this process. If you are on a platform that supports simultaneous membership in multiple groups, `$(` gives a space-separated list of groups you are in. The first number is the one returned by *getgid*(2), and the subsequent ones by *getgroups*(2), one of which may be the same as the first number.

However, a value assigned to `$(` must be a single number used to set the real GID. So the value given by `$(` should *not* be assigned back to `$(` without being forced to be numeric, such as by adding zero. This is because you can have only one real group. See `$)` (`$EFFECTIVE_GROUP_ID`) instead, which allows you to set multiple effective groups.

(Mnemonic: parentheses are used to *group* things. The real GID is the group you *left*, if you're running setgid.)

`$REAL_USER_ID`

`$<` [ALL] The real user ID (UID) of this process as returned by the *getuid*(2) syscall. Whether and how you can modify this is subject to the vagaries of your system's implementation—see examples under `$>` (`$EFFECTIVE_USER_ID`). Because changes to `$<` require a system call, check `$!` after a change attempt to detect possible errors. (Mnemonic: it's the UID you came *from*, if you're running setuid.)

`%SIG`

[ALL] The hash used to set signal handlers for various signals. (See the section "Signals" on page 518 in Chapter 15.) For example:

```
sub handler {
    my $sig = shift;   # 1st argument is signal name
    syswrite STDERR, "Caught a SIG$sig--shutting down\n";
                       # Avoid standard I/O in async handlers
                       # to suppress core dumpage. (Even that
                       # string concat is risky.)
    close LOG;         # This calls standard I/O, so
```

```
                        # may dump core anyway!
    exit 1;             # But since we're exiting, no
                        # harm in trying
}

$SIG{INT}  = \&handler;
$SIG{QUIT} = \&handler;
...
$SIG{INT}  = "DEFAULT";    # restore default action
$SIG{QUIT} = "IGNORE";     # ignore SIGQUIT
```

The `%SIG` hash contains undefined values corresponding to those signals for which no handler has been set. A handler may be specified as a subroutine reference or as a string. A string value that is not one of the two special actions "`DEFAULT`" or "`IGNORE`" is the name of a function that, if unqualified by package, is interpreted to be the `main` package. Here are some other examples:

```
$SIG{PIPE} = "Plumber";   # okay, assumes main::Plumber
$SIG{PIPE} = \&Plumber;   # fine, use Plumber from current package
```

Certain internal hooks can also be set using the `%SIG` hash. The routine indicated by `$SIG{__WARN__}` is called when a warning message is about to be printed. The warning message is passed as the first argument. The presence of a `__WARN__` hook causes the ordinary printing of warnings to `STDERR` to be suppressed. You can use this to save warnings in a variable or to turn warnings into fatal errors, like this:

```
local $SIG{__WARN__} = sub { die $_[0] };
eval $proggie;
```

This is similar to saying:

```
use warnings qw/FATAL all/;
eval $proggie;
```

except that the first has dynamic scope, whereas the second has lexical scope.

The routine indicated by `$SIG{__DIE__}` provides a way to turn a frog exception into a prince exception with a magical kiss, which often doesn't work. The best use is for a moribund program that's about to die of an untrapped exception to do some last-moment processing on its way out. You can't save yourself this way, but you can give one last hurrah.

The exception message is passed as the first argument. When a `__DIE__` hook routine returns, exception processing continues as it would have in the absence of the hook, unless the hook routine itself exits via a `goto`, a loop exit, or a `die`. The `__DIE__` handler is explicitly disabled during the call so that you yourself can then call the real `die` from a `__DIE__` handler. (If it weren't

disabled, the handler would call itself recursively forever.) The handler for `$SIG{__WARN__}` works similarly.

Only the main program should set `$SIG{__DIE__}`, not modules. That's because, currently, even exceptions that are being trapped still trigger a `$SIG{__DIE__}` handler. This is strongly discouraged because of its potential for breaking innocent modules who aren't expecting their predicted exceptions to be mysteriously altered. Use this feature only as a last resort, and, if you must, always put a `local` on the front to limit the period of danger.

If you're used to programming languages that react to uncaught exceptions by providing a messy stack dump all over the screen, you can get Perl to do much the same thing by putting this in your main program:

```
use Carp;
$SIG{__DIE__} = sub { confess "$0: UNCAUGHT EXCEPTION: @_" unless $^S };
```

Do not attempt to build an exception-handling mechanism on this feature. Use `eval {}` to trap exceptions instead. For example, instead of using a `__DIE__` hook, it's cleaner to arrange for your entire main program to be in a subroutine and wrap that with a standard exception catcher—a regular `eval` *BLOCK*:

```
use Carp;
eval {
    function_that_does_everything();
    1;
} || confess "$0: Caught unexpected exception: $@";
```

`STDERR`
: [ALL] The special filehandle for standard error in any package.

`STDIN`
: [ALL] The special filehandle for standard input in any package.

`STDOUT`
: [ALL] The special filehandle for standard output in any package.

`$SUBSCRIPT_SEPARATOR`

`$;` [ALL] The subscript separator for multidimensional hash emulation. If you refer to a hash element as:

```
$foo{$a,$b,$c}
```

it really means:

```
$foo{join($;, $a, $b, $c)}
```

But don't put:

```
@foo{$a,$b,$c}      # a slice--note the @
```

which means:

```
($foo{$a},$foo{$b},$foo{$c})
```

The default is `"\034"`, the same as `SUBSEP` in *awk*. Note that if your keys contain binary data, there might not be any safe value for `$;`. (Mnemonic: comma—the syntactic subscript separator—is a semi-semicolon. Yeah, we know it's pretty lame, but `$,` is already taken for something more important.)

Although we haven't deprecated this feature, you should instead consider using "real" multidimensional hashes now, such as `$foo{$a}{$b}{$c}` instead of `$foo{$a,$b,$c}`. The fake ones may be easier to sort, however, and they are much more amenable to use as simple DBM files.

`$SYSTEM_FD_MAX`

`$^F` [ALL] The maximum "system" file descriptor, ordinarily 2. System file descriptors are passed to new programs during an `exec`, while higher file descriptors are not. Also, during an `open`, system file descriptors are preserved even if the `open` fails. (Ordinary file descriptors are closed before the `open` is attempted and stay closed if the `open` fails.) Note that the close-on-exec status of a file descriptor will be decided according to the value of `$^F` at the time of the `open`, not the time of the `exec`. Avoid this by temporarily jacking `$^F` through the roof first:

```
{
    local $^F = 10_000;
    pipe(HITHER,THITHER) || die "can't pipe: $!";
}
```

`${^TAINT}`

[ALL,RO] This read-only variable reflects whether taint mode is on, off, or just giving warnings:

0	Taint mode is off (the default).
1	Taint mode is on, usually because the program was run with the **`-T`** command-line switch.
-1	Taint warnings only, enabled by the **`-t`** or **`-TU`** command-line switches.

This variable was added in v5.8.

`${^UNICODE}`

[XXX,ALL] This variable reflects certain internal Unicode settings of Perl. This variable is set to a numeric value during Perl startup by the *–C* command-line switch or the `PERL_UNICODE` environment variable; thereafter, it is read-only.

This variable was added in v5.8.2.

`${^UTF8CACHE}`

[NOT, ALL] Internal variable that controls the state of the internal UTF-8 offset caching code:

1	For on (the default)
0	For off
-1	To debug the caching code by checking all its results against linear scans and panicking on any discrepancy. Set by the *-Ca* command-line switch.

This variable was added in v5.8.9.

`${^UTF8LOCALE}`

[NOT,ALL] This variable indicates whether a UTF-8 locale was detected by Perl at startup. This information is used by Perl when in its "adjust utf8ness to locale" mode, set by the *–CL* command-line switch.

This variable was added in v5.8.8.

`$VERSION`

[PKG] This variable is accessed whenever a minimum acceptable version of a module is specified, as in `use SomeMod 2.5`. If `$SomeMod::VERSION` is less than that, an exception is raised. Technically, it's the `UNIVERSAL->VERSION` method that looks at this variable, so you could define your own `VERSION` function in the current package if you want something other than the default behavior. See Chapter 12.

`$WARNING`

`$^W` [ALL] The current Boolean value of the global warning switch (not to be confused with the global warming switch, about which we hear many global warnings). See also the `warnings` pragma in Chapter 29, and the *–W* and *–X* command-line switches for lexically scoped warnings, which are unaffected by this variable. (Mnemonic: the value is related to the *–w* switch.)

`${^WARNING_BITS}`

[NOT,ALL] The current set of warning checks enabled by the `use warnings` pragma. See `use warnings` in Chapter 29 for more details.

`${^WIDE_SYSTEM_CALLS}`

[ALL] Global flag that enables all syscalls made by Perl to use wide-character APIs native to the system, if available. This can also be enabled from the command line using the *–C* command-line switch. The initial value is typically `0` for compatibility with Perl versions earlier than v5.6, but Perl may automatically set it to `1` if the system provides a user-settable default (such

as via `$ENV{LC_CTYPE}`). The `bytes` pragma always overrides the effect of this flag in the current lexical scope.

`${^WIN32_SLOPPY_STAT}`

[ALL] If this variable is set to a true value, then `stat` on Windows will not try to open the file. This means that the link count cannot be determined and file attributes may be out of date if additional hardlinks to the file exist. On the other hand, not opening the file is considerably faster, especially for files on network drives.

This variable could be set in the *sitecustomize.pl* file to configure the local Perl installation to use "sloppy" `stat` by default. See the documentation for *–f* in *"Command Switches"* in *perlrun* for more information about site customization.

This variable was added in v5.10.

CHAPTER 26
Formats

Perl is known for its ability to tear apart text in many different ways—that's the Extraction part that made it popular. Perl also makes it easy to create formatted strings for its Report job. This chapter covers the `printf` and `sprintf` functions, the `pack` and `unpack` functions, and formats, historically intended for printing nicely formatted reports on your line-printer, but still useful from time to time in this millennium.

String Formats

Perl can create a string formatted by the usual `printf` conventions of the C library function *sprintf*. The `sprintf` version returns a string, and the `printf` version outputs either to the default or supplied filehandle:

```
sprintf FORMAT, LIST
printf FORMAT, LIST
printf FILEHANDLE FORMAT, LIST
```

The `sprintf` argument handling is a bit special. Its first argument is always taken as a scalar, even if it's an array. This is probably not what you want since it uses `@array` in scalar context and only prints the number of elements in the array:

```
my @array = ( '%d %d %d', 1, 2, 3 );
sprintf @array;
```

The arguments for `printf` are different since it handles an optional *FILEHANDLE* argument.

The *FORMAT* string contains text with embedded field specifiers into which the elements of *LIST* are substituted, one per field. This feature is one of the things that Perl stole from C, so look at the *sprintf*(3) or *printf*(3) on your system for an explanation of the general principles.

Perl does its own `sprintf` formatting—it emulates the C function *sprintf*, but it doesn't use it.[1] As a result, any nonstandard extensions in your local *sprintf*(3) function are not available from Perl.

Perl's `sprintf` permits the universally known conversions shown in Table 26-1.

Table 26-1. Formats for sprintf

Field	Meaning
`%%`	A literal percent sign
`%b`	An unsigned integer, in binary
`%B`	Like `%b`, but using an uppercase "B" with the `#` flag
`%c`	A character with the given ordinal value
`%d`	A signed integer, in decimal
`%e`	A floating-point number, in scientific notation, with a lowercase "e"
`%E`	Like `%e`, but using an uppercase "E"
`%f`	A floating-point number, in fixed decimal notation
`%g`	A floating-point number, in `%e` or `%f` notation
`%G`	Like `%g`, but with an uppercase "E" (if applicable)
`%h`	A C short or unsigned short, depending on the compiler that built *perl*
`%n`	Stores the number of C `chars` output so far into the next argument
`%o`	An unsigned integer, in octal
`%p`	A pointer (outputs the Perl value's address in hexadecimal)
`%s`	A string of unspecified width
`%u`	An unsigned integer, in decimal
`%x`	An unsigned integer, in hexadecimal, using lowercase letters
`%X`	An unsigned integer, in hexadecimal, using uppercase letters

You might instead want Table 26-2 to see those conversions by the type of value they expect.

1. Except for floating-point numbers, and even then only the standard modifiers are allowed.

Table 26-2. Formats by value type

Type	Format
Integers	`%b %B %d %h %o %p %u`
Floating point	`%e %E %f %g %G`
Strings	`%c %s`

For some numeric conversions, you can specify how the `sprintf` should interpret the number instead of relying on the sizes that your compiler supplies. See Table 26-3.

Table 26-3. sprintf numeric conversions

Field	Meaning
hh	C `char` or `unsigned char` (v5.14 and later)
h	C `short` or `unsigned short` (v5.14 and later)
j	C type `intmax_t` (v5.14 or later, with a C99 compiler)
l	C `long` or `unsigned long`
q, L, ll	C `long long`, `unsigned long long`, or `quad` (compiler must support quads)
t	C `ptrdiff_t` (v5.14 or later)
v	Interpret string as a vector of integers, output as numbers separated either by dots or by an arbitrary string received from the argument list when the flag is preceded by `*`
z	C `size_t` (v5.14 or later)

For backward (and we do mean "backward") compatibility, Perl permits these unnecessary but widely supported conversions in Table 26-4. We segregate these from Table 26-1 in the hopes that you won't use them.

Table 26-4. Backward compatible synonyms for numeric conversions

Field	Meaning
`%i`	A synonym for `%d`
`%D`	A synonym for `%ld`
`%U`	A synonym for `%lu`
`%O`	A synonym for `%lo`
`%F`	A synonym for `%f`

Between the % and the format letter, you may specify several additional attributes controlling the interpretation of the format, as listed in Table 26-5.

Table 26-5. Format modifiers for sprintf

Flag	Meaning
space	Prefix positive number with a space
+	Prefix positive number with a plus sign
-	Left-justify within the field
0	Use zeros, not spaces, to right-justify
#	Prefix nonzero octal with "0", nonzero hex with "0x"
*	Use the value of the next argument as the field width
number$	Use the value of the argument at position *number*
**number*$	Use the value of the argument at position *number* as the field width
number	Minimum field width (there is no maximum width equivalent)
. *number*	"Precision": digits after decimal point for floating-point numbers, maximum length for string, minimum length for integer

Here are some examples. Putting a space in front of the specifier puts exactly one space in front of the number, no matter its size:

```
printf "<% d>",  1;   # "< 1>"
```

Using a + appends a positive sign to the number, even if it is 0:[2]

```
printf "<%+d>",  1;   # "<+1>"
printf "<%+d>",  2;   # "<+2>"
```

Using a space and a + together, in any order, always puts a + in front of the positive number:

```
printf "<%+ d>", 3;   # "<+3>"
printf "<% +d>", 5;   # "<+5>"
```

Specifying a precision for an integer will zero pad it. The + doesn't count against the precision:

```
printf "<%.5d>",   8;   # "<00008>"
printf "<%+.5d>", 13;   # "<+00013>"
```

If the width is larger, though, it only zero pads to the width of the precision. You can left or right justify the values:

2. This is different from the concept of 0^+ and 0^-, the limit of 0 approached from different sides.

```
printf "<%-10.6d>", 21;  # "<000021    >"
printf "<%10.6d>",  34;  # "<    000034>"
printf "<%010.6d>", 55;  # "<    000055>"
printf "<%+10.6d>", 89;  # "<   +000089>"
```

Those work for any of the integer formats.

Strings by default align to the right, although a minus aligns the string to the left:

```
printf "<%6s>",  144;   # "<   144>"
printf "<%-6s>", 233;   # "<233   >"
```

A leading `0` pads the blank positions with zeros, but only to the left, even if the value isn't a number:

```
printf "<%06s>",  377;    # "<000377>"
printf "<%-06s>", 610;    # "<610   >" - no zeroes
printf "<%06s>", "Perl";  # "<00Perl>"
```

The width is handy to align strings in a fixed column format. However, `printf` uses the width only for the minimum. It does not truncate strings:

```
printf "<%5s>", "Amelia"; # "<Amelia>", with all six characters
```

If you want to truncate the string should it overflow, you can use *`.number`* after the field width:

```
printf "<%5.5s>", "Camelia"; # "<Camel>", with only five characters
```

The width of the field and the number of characters you take don't have to match up. If you take more characters than the width, the string still overflows:

```
printf "<%3.5s>\n", "Camelia"; # "<Camel>"
```

Normally, `printf` fills in the specifiers with the next unused argument, but you can tell it explicitly which argument to use with *`number`*`$`. When you use *`number`* `$`, you must be careful to use uninterpolated strings or escape the dollar sign, or else Perl will think you want a variable interpolated there.

```
printf '%2$d %1$d', 12, 34;      # "34 12"
printf '%3$d %d %1$d', 1, 2, 3;  # "3 1 1"
```

This also allows you to reuse arguments, too:

```
printf '%2$d %1$d %2$d', 12, 34; # "34 12 34"
```

Sometimes you don't know the width ahead of time, so you can specify it as an argument and take the value from the next argument with `*`. This takes an argument for the width before it takes an argument for the string:

```
printf "<%*s>", 6, "Perl";   # "<  Perl>"
```

If the argument's value is negative, it's left-justified:

```
printf "<%*s>", -6, "Perl";   # "<Perl  >"
```

If you don't want to use the next argument, you can use *number*$ to specify the width argument by its position:

```
printf '<%*2$s>', "a", 6; # "<     a>"
```

If you want to take the field width and the maximum number of characters in the string from the argument list, you can use * in both places:

```
printf "<%*.*s>\n", 10, 5, "Camelia"; # "<     Camel>"
```

but you can only use an argument for the width:

```
printf '<%*2$.*s>', "Camelia", 10, 5; # "<   Camelia>"
printf '<%*.*2$s>', "Camelia", 10, 5; # "<%*.*2$s>"
```

A # adds extra characters to the front of a number to denote its base, but only when the value is not 0 (in which case it doesn't matter):

```
printf "<%#o>",  37;   # "<045>"

printf "<%#x>",  42;   # "<0x2a>"
printf "<%#X>",  42;   # "<0X2A>"

printf "<%#b>", 137;   # "<0b10001001>"
printf "<%#B>", 137;   # "<0B10001001>"
```

When the # flag and a precision are given in the %o conversion, the precision won't count the leading "0":

```
printf "<%#.5o>",   0377;   # "<00377>"
printf "<%#.5o>", 010755;   # "<010755>"
printf "<%#.0o>",      0;   # "<0>"
```

For floating-point values (%e, %f, and %g), you can specify the number of places after the decimal point with *.number*. If you are using a width, this goes after the width. Notice that this specifier rounds the number:

```
printf "<%f>",   3.14159265;   # "<3.141593>"
printf "<%.1f>", 3.14159265;   # "<3.1>"
printf "<%.0f>", 3.14159265;   # "<3>"

printf "<%e>",   6.62606857e-34;   # "<6.626069e-34>"
printf "<%.1e>", 1.05457148e-34;   # "<1.1e-34>"
```

If `use locale` (see Chapter 29) is in effect and you called `POSIX::setlocale`, the format uses the decimal separator for that locale:

```
use POSIX;
use locale;

POSIX::setlocale(LC_NUMERIC, "fr_FR");
printf "<%f>", 3.1415926; # "<3,141593>"
```

The %g specifier uses your system preferences, so you might get slightly different results:

```
printf "<%g>",    1 << 31;  # "<2.14748e+09>"
printf "<%.5g>",  1 << 31;  # "<2.1475e+09>"
printf "<%.10g>", 1 << 31;  # "<2147483648>"
```

The number of digits used for exponents less than 100 depends on your system; some may zero pad them:

```
printf "<%g>",    1 << 31;  # "<2.14748e+009>" maybe
```

The v modifier is different than the other ones. It breaks apart its string argument, considering each character to be an integer that it formats as you tell it. It joins the integers with a dot. Used with a hex format specifier, this is convenient for printing out sequences of codepoints in a "Unicode-like" notation:

```
printf "<%vd>", "\x5\xE\x2";  # "5.14.2"

use utf8;
printf "<%vd>", "À%{";  # "<65.758.37.123>"
printf "<%vX>", "À%{";  # "<41.300.25.7B>"
printf "U+v%04x", "À%{";  # "U+0041.0300.0025.007B"
```

(Notice how the "À" grapheme above requires two separate codepoints.)

If you don't want to use a dot to join the numbers, you can specify your separator as an argument:

```
printf "<%*vX>", ":", "À%{";   # "<41:300:325:7B>"
printf "<%*2$vX>", "À%{", ":"; # "<41:300:25:7B>"
```

Graphemes, in particular multicodepoint grapheme clusters, are an issue here. As we'll see with the other two types of formats described in this chapter, Perl gives the wrong answer when calculating widths for Unicode data that contains non-printing characters, combining marks, and wide characters. The same is also true of field widths in format strings for printf and sprintf. There is an example in the section "Graphemes and Normalization" on page 290 in Chapter 6 showing how to use the columns method from the Unicode::GCString module to trick printf into doing the right thing with all these, despite itself. The basic strategy is to prepad to the correct width beforehand using the smarter columns method instead of expecting simpleminded printf to suss out something so sophisticated.

Binary Formats

If you're familiar with more traditional languages, you may have come across the concept of records or struct types. In contrast to sprintf, which is primarily oriented toward human-readable output, the pack and unpack functions are

useful for low-level, repetitive conversion and formatting of basic datatypes into (and back out of) string representations of these struct or record types. The two functions share a template language, with minor differences, described in the next section.

pack

```
pack TEMPLATE, LIST
```

This function takes a *LIST* of ordinary Perl values, converts them into a string of bytes according to the *TEMPLATE*, and returns this string. The argument list will be padded or truncated as necessary. That is, if you provide fewer arguments than the *TEMPLATE* requires, `pack` assumes additional null arguments. If you provide more arguments than the *TEMPLATE* requires, the extra arguments are ignored. Unrecognized format elements in *TEMPLATE* will raise an exception.

The template describes the structure of the string as a sequence of fields. Each field is represented by a single character that describes the type of the value and its encoding. For instance, a format character of `N` specifies an unsigned four-byte integer in big-endian byte order.

Fields are packed in the order given in the template. For example, to pack an unsigned one-byte integer and a single-precision floating-point value into a string, you'd say:

```
$string = pack("Cf", 244, 3.14);
```

The first byte of the returned string has the value 244. The remaining bytes are the encoding of 3.14 as a single-precision float. The particular encoding of the floating-point number depends on your computer's hardware.

Some important things to consider when packing are:

- The type of data (such as integer or float or string)
- The range of values (such as whether your integers will fit into one, two, four, or maybe even eight bytes; or whether you're packing 8-bit or Unicode characters)
- Whether your integers are signed or unsigned
- The encoding to use (such as native, little-endian, or big-endian packing of bits and bytes)

Table 26-6 lists the format characters and their meanings. (Other characters can occur in formats as well; these are described later.)

Table 26-6. Template characters for pack/unpack

Character	Meaning
`a`	A null-padded string of bytes
`A`	A space-padded string of bytes
`b`	A bit string, in ascending bit order inside each byte (like `vec`)
`B`	A bit string, in descending bit order inside each byte
`c`	A signed char (8-bit integer) value
`C`	An unsigned char (8-bit integer) value; see `U` for Unicode
`d`	A double-precision floating-point number in native format
`D`	A float or long-double floating-point number in native format; long doubles are available only if your system supports them and you compiled *perl* for them
`f`	A single-precision floating-point number in native format
`F`	A Perl internal floating-point number (NV) in native format
`h`	A hexadecimal string, low nybble first
`H`	A hexadecimal string, high nybble first
`i`	A signed integer value, native format; this is at least 32 bits, but depends on the C compiler you used
`I`	An unsigned integer value, native format; this is at least 32 bits, but depends on the C compiler you used
`j`	A Perl-internal signed integer (IV)
`J`	A Perl-internal unsigned integer (UV)
`l`	A signed long value, always 32 bits
`L`	An unsigned long value, always 32 bits
`n`	A 16-bit short in "network" (big-endian) order
`N`	A 32-bit long in "network" (big-endian) order
`p`	A pointer to a structure (null-terminated string)
`P`	A pointer to a fixed-length string
`q`	A signed quad (64-bit integer) value
`Q`	An unsigned quad (64-bit integer) value (only if your system supports 64-bits and you compiled your *perl* for them)
`s`	A signed short value, always 16 bits
`S`	An unsigned short value, always 16 bits
`u`	A uuencoded string

Character	Meaning
U	A Unicode character number; this converts to a character in character mode and a UTF-8 encoded character in byte mode
v	A 16-bit short in "VAX" (little-endian) order
V	A 32-bit long in "VAX" (little-endian) order
w	A BER compressed integer
W	An unsigned char value
x	A null byte (skip forward a byte)
X	Back up a byte
Z	A null-terminated (and null-padded) string of bytes
@	Null-fill to absolute position
.	Null-fill or truncate to absolute position
(	Start a group
)	End a group

Table 26-7. Template modifiers for pack/unpack

Modifier	Applied to	Effect
!	iIlLsS	Forces native sizes
!	xX	Makes x and X act as alignment characters
!	nNvV	Treats as signed instead of unsigned integers
!	@.	Specifies the position as the byte offset in the internal representation of the packed string—danger!
>	dDfFiIjJlLpPqQsS	Forces big-endian byte order; can apply to groups and subgroups
<	dDfFiIjJlLpPqQsS	Forces little-endian byte order; can apply to groups and subgroups

You may freely place whitespace and comments in your *TEMPLATE*s. Comments start with the customary # symbol and extend up through the first newline (if any) in the *TEMPLATE*.

Repetition

Each letter in the template may be followed by a number indicating the *count*, interpreted as a repeat count or length of some sort, depending on the format. We'll start with those that repeat, the ones that pack as characters or numbers: c, C, d, D, f, F, i, I, j, J, l, L, n, N, p, q, Q, s, S, U, v, V, w, and W.

A number after these fields represents repetition, so that field will be repeated in the string, taking as many arguments as is specified:

```
$out = pack 'C4', 192, 168, 1, 1;    # \xC0\xA8\01\01
```

The repeat can optionally go in brackets:

```
$out = pack 'C[4]', 192, 168, 1, 1;  # \xC0\xA8\01\01
```

Another letter in the brackets uses the length of that format for the count:

```
$out = pack 'C[N]', 192, 168, 1, 1;  # \xC0\xA8\01\01
$out = pack 'C[s]', 192, 168, 1, 1;  # \xC0\xA8
```

If there aren't enough arguments, `pack` fills in the remaining arguments with nulls:

```
$out = pack 'C4', 192, 168;          # \xC0\xA8\00\00
```

Using a `*` takes up the remaining arguments:

```
$out = pack 'C*', 192, 168, 1, 1;    # \xC0\xA8\01\01
```

The other letters do other things with a repeat. A number after `a`, `A`, or `Z` specifies the length of the field to be padded:

```
$out = pack 'A10', 192, 168, 1, 1;    # \xC0\xA8\01\01
```

If the number is less than the string width, `a` and `A` truncate:

```
$out = pack 'A4', 'Amelia';    # "Amel"
$out = pack 'a4', 'Amelia';    # "Amel"
```

With the `*`, `a` and `A` produce a field as long as its argument:

```
$out = pack 'A*', 'Amelia';    # "Amelia"
$out = pack 'a*', 'Amelia';    # "Amelia"
```

The `Z`, however, reserves the final position for the terminating null byte:

```
$out = pack 'Z4', 'Amelia';    # "Ame\000"
```

as long as the number is not `0`, in which case there is no null byte:

```
$out = pack 'Z0', 'Amelia';    # ""
```

A `Z*` takes the entire string, no matter how long, and still ends it with a null:

```
$out = pack 'Z*', 'Amelia';    # "Amelia\000"
```

For `b` and `B`, the count is the number of bits you want in the output. Each `b` and `B` uses only one bit, the least significant one, from each character in the input, and each sets only one bit, whatever its length:

```
$out = pack 'B8', '10011101';  # 0b10011101
$out = pack 'b8', '10011101';  # 0b10111001
```

The `h` and `H` do something similar using the count as the number of nybbles to produce. These are special, though, since they interpret characters that look like a hexadecimal digit as that number:

```
$out = pack 'h1', 'a';         # 0x0a
$out = pack 'H1', 'a';         # 0xa0
$out = pack 'H8', 'deadbeef';  # 0xdeadbeef
```

Otherwise, it uses the low nybble:

```
$out = pack 'h2', '1';         # 0x01
$out = pack 'h2', 'one';       # 0x08
$out = pack 'H2', 'one';       # 0x80
```

A `*` with `h` or `H` pads the string with nulls to get an even number of nybbles:

```
$out = pack 'H*', 'deadbee';  # 0xdeadbee0
```

For `P`, the count specifies the size of the struct to pack.

With `u`, the count is the line length for the uuencoded string. A count less than 3 (or is `*`) is treated as 45. This format:

```
$out = pack "u30", $some_string;
```

takes one line:

```
93VYE(')I;F<@=&\@<G5L92!T:&5M(&%L;```
```

But with the same string and a shorter line length:

```
$out = pack "u15", $some_string;
```

wraps the string:

```
/3VYE(')I;F<@=&\@<G5L
*92!T:&5M(&%L;```
```

An `x` consumes no arguments, but inserts as many nulls as specified. A `*` is the same as 0:

```
$out = pack "H2 x h2", "dead", "beef";   # 0xde00eb
$out = pack "H2 x3 h2", "dead", "beef";  # 0xde000000eb
$out = pack "H2 x* h2", "dead", "beef";  # 0xdeeb
```

The `X` consumes no arguments. It backs up the number of bytes specified, as long as it does not go past the beginning of the string packed so far. A `*` is the same as 0:

```
$out = pack "H2 X h2",  "dead", "beef";  # 0xeb
$out = pack "H2 X3 h2", "dead", "beef";  # 0xde000000eb
$out = pack "H2 X* h2", "dead", "beef";  # 0xdeeb
```

An `@` truncates or fills to the position relative to the innermost group (or the entire string if there is no group). If the packed string so far is longer than the count,

its length is reduced to count. If the packed string so far is shorter than count, it's padded with nulls. In each case, the rest of the template picks up from the new position:

```
$out = pack 'A*', 'Amelia';              # Amelia
$out = pack 'A*@3', 'Amelia';            # Ame
$out = pack 'A*@3A*', 'Amelia', 'Camel'; # AmeCamel

$out = pack 'c@5', 137;                  # 0x8900000000
```

A `*` is the same as `0`, so it truncates everything done so far:

```
$out = pack 'A*@*A*', 'Amelia', 'Camel'; # Camel
```

Within a group, the truncation or padding only applies to that part of the group:

```
$out = pack 'A(A@4A)A', 'A', 'B', 'C', 'D';  # "AB\000\000\000CD
$out = pack 'A(A@*A)A', 'A', 'B', 'C', 'D';  # "ACD
```

The `.` also truncates or pads, but it takes the position from the list. The repeat count specifies the start of the effect: 0 to start from the current position, a number to specify the group to start from, or a `*` to specify the beginning of the string:

```
# truncate from the beginning of the string
$out = pack 'A(A.*A)A', 'A', 'B', 1, 'C', 'D';  # 'ACD'

# pad from the beginning of the string
$out = pack 'A(A.*A)A', 'A', 'B', 5, 'C', 'D';  # "AB\000\000\000CD"

# truncate from the beginning of the string
$out = pack 'A(A.1A)A', 'A', 'B', 1, 'C', 'D';  # "ABCD"

# pad from the beginning of the string
$out = pack 'A(A.1A)A', 'A', 'B', 3, 'C', 'D';  # "AB\000\000\000\000CD"

# pad from the current position
$out = pack 'A(A.0A)A', 'A', 'B', 0, 'C', 'D';  # "ABCD"
$out = pack 'A(A.0A)A', 'A', 'B', 2, 'C', 'D';  # "AB\000\000CD"
```

Other modifiers

The `/` character allows packing and unpacking of strings where the packed structure contains a byte count followed by the string itself. You write *`length-item/string-item`*. The *`length-item`* can be any `pack` template letter, and it describes how the length value is packed. The ones likely to be of most use are integer-packing ones like `n` (for Java strings), `w` (for ASN.1 or SNMP), and `N` (for Sun XDR). The *`string-item`* must, at present, be `A*`, `a*`, or `Z*`. For `unpack`, the length of the string is obtained from the *`length-item`*, but if you put in the `*`, it will be ignored:

```
unpack "C/a", "\04Gurusamy";        # gives "Guru"
unpack "a3/A* A*", "007 Bond  J ";  # gives (" Bond","J")
pack "n/a* w/a*","hello,","world";  # gives "\000\006hello,\005world"
```

The *length-item* is not returned explicitly from `unpack`. Adding a *count* to the *length-item* letter is unlikely to do anything useful unless that letter is `A`, `a`, or `Z`. Packing with a *length-item* of `a` or `Z` may introduce null (`\0`) characters, which Perl does not regard as legal in numeric strings.

The integer formats `s`, `S`, `l`, and `L` may be immediately followed by a `!` to signify native shorts or longs instead of exactly 16 or 32 bits, respectively. Today, this is an issue mainly in 64-bit platforms, where the native shorts and longs as seen by the local C compiler can be different than these values. (`i!` and `I!` also work but only because of completeness; they are identical to `i` and `I`.)

The actual sizes (in bytes) of native shorts, ints, longs, and long longs on the platform where Perl was built are also available via the `Config` module:

```
use Config;
say $Config{shortsize};
say $Config{intsize};
say $Config{longsize};
say $Config{longlongsize};
```

Just because *Configure* knows the size of a long long doesn't necessarily imply that you have `q` or `Q` formats available to you. (Some systems do, but you may or may not be running one. Yet.)

Integer formats of greater than one byte in length (`s`, `S`, `i`, `I`, `l`, and `L`) are inherently nonportable between processors, because they obey the native byte order and endianness. If you want portable packed integers, use the formats `n`, `N`, `v`, and `V`; their byte endianness and size are known.

Floating-point numbers are only in the native machine format. Because of the variety of floating formats and the lack of a standard "network" representation, no facility for interchange has been made. This means that packed floating-point data written on one machine may not be readable on another. This is a problem even when both machines use IEEE floating-point arithmetic, because the endianness of the memory representation is not part of the IEEE spec.

Perl internally uses doubles for all floating-point calculations, so converting from double into float, then back again to double, will lose precision. This means that `unpack("f", pack("f", $foo))` will not generally equal `$foo`.

You are responsible for any alignment or padding considerations expected by other programs, particularly those programs that were created by a C compiler with its own idiosyncratic notions of how to lay out a C `struct` on the particular

architecture in question. You'll have to add enough xs while packing to make up for this. For example, a C declaration of:

```
struct foo {
    unsigned char c;
    float f;
};
```

might be written out in a "`C x f`" format, a "`C x3 f`" format, or even an "`f C`" format—just to name a few. The `pack` and `unpack` functions handle their input and output as flat sequences of bytes, because there is no way for them to know where the bytes are going to or coming from.

The `!` applied to the `@` or `.` makes those positions use the byte offset in the packed strings. This can be very efficient, but you have to think much harder about the string and know the sizes for the other formats.

The `<` and `>` for endianness on the specifier on `d`, `D`, `f`, `F`, `i`, `I`, `j`, `J`, `l`, `L`, `p`, `P`, `q`, `Q`, `s`, and `S`. These are the specifiers that pack integers, save for those that already specify endianness. The `<` forces little-endian semantics, and the `>` forces big-endian semantics:

```
$out = pack 'L>', 0xDEADBEEF;  # "\xDE\xAD\xBE\xEF"
$out = pack 'L<', 0xDEADBEEF;  # "\xEF\xBE\xAD\xDE"
```

More examples

Let's look at some more examples. This first pair packs numeric values into bytes:

```
$out = pack "CCCC", 65, 66, 67, 68;      # $out eq "ABCD"
$out = pack "C4", 65, 66, 67, 68;        # same thing
```

This one does the same thing with Unicode circled letters:

```
$foo = pack("U4",0x24b6,0x24b7,0x24b8,0x24b9);
```

This does a similar thing, with a couple of nulls thrown in:

```
$out = pack "CCxxCC", 65, 66, 67, 68;    # $out eq "AB\0\0CD"
```

Packing your shorts doesn't imply that you're portable:

```
$out = pack "s2", 1, 2;    # "\1\0\2\0" on little-endian
                           # "\0\1\0\2" on big-endian
```

On binary and hex packs, the *count* refers to the number of bits or nybbles, not the number of bytes produced:

```
$out = pack "B32", "01010000011001010111001001101100";
$out = pack "H8", "5065726c";    # both produce "Perl"
```

The length on an `a` field applies only to one string:

```
$out = pack "a4", "abcd", "x", "y", "z";      # "abcd"
```

To get around that limitation, use multiple specifiers:

```
$out = pack "aaaa",  "abcd", "x", "y", "z";   # "axyz"
$out = pack "a" x 4, "abcd", "x", "y", "z";   # "axyz"
```

The `a` format does null filling:

```
$out = pack "a14", "abcdefg";   # "abcdefg\0\0\0\0\0\0\0"
```

This template packs a C `struct tm` record (at least on some systems):

```
$out = pack "i9pl", gmtime(), $tz, $toff;
```

Generally, the same template may also be used in the `unpack` function, although some formats act differently, notably `a`, `A`, and `Z`.

If you want to join fixed-width text fields together, use `pack` with a *`TEMPLATE`* of several `A` or `a` formats:

```
$string = pack("A10" x 10, @data);
```

Don't say that "A" too seriously: it works on Perl's internal Unicode just fine. But it's pad by codepoint, not by logical print column. If you need to work on your résumé, you would get this:

```
pack("(A10)2", "re\x{301}sume\x{301}", "work")'
"résumé  work      "
```

But if you need to start working again, you would get this:

```
say pack("(A10)2", "resume", "work")'
resume    work
```

See the discussion on "Graphemes and Normalization" on page 290 in Chapter 6 for how to use the `columns` method from `Unicode::GCString`to pad correctly in the face of control characters, combining marks, and wide (two-column) characters like those found in many East Asian scripts.

If you want to join variable-width text fields with a separator, use the `join` function instead:

```
$string = join(" and ", @data);
$string = join("", @data);            # null separator
```

Although all of our examples used literal strings as templates, there is no reason you couldn't pull in your templates from a disk file. You could build an entire relational database system around this function. (What that would prove about you we won't get into.)

unpack

```
unpack TEMPLATE, EXPR
```

This function does the reverse of `pack`: it expands a string (*`EXPR`*) representing a data structure into a list of values according to the *`TEMPLATE`* and returns those values. In scalar context, it can be used to unpack a single value. The *`TEMPLATE`* here has much the same format as it has in the `pack` function—it specifies the order and type of the values to be unpacked. See `pack` for a detailed description of *`TEMPLATE`*. An invalid element in the *`TEMPLATE`*, or an attempt to move outside the string with the `x`, `X`, or `@` formats, raises an exception.

The string is broken into chunks described by the *`TEMPLATE`*. Each chunk is separately converted to a value. Typically, the bytes of the string either are the result of a `pack` or represent a C structure of some kind.

If the repeat count of a field is larger than the remainder of the input string allows, the repeat count is silently decreased. (Normally, you'd use a repeat count of `*` here, anyway.) If the input string is longer than what *`TEMPLATE`* describes, the rest of the string is ignored.

The `unpack` function is also useful for plain text data, too, not just binary data. Imagine that you had a data file that contained records that looked like this:

```
2009 The Graveyard Book                    Neil Gaiman
2008 The Yiddish Policemen's Union         Michael Chabon
2007 Rainbows End                          Vernor Vinge
2006 Spin                                  Robert Charles Wilson
2005 Jonathan Strange & Mr Norrell         Susanna Clarke
2004 Paladin of Souls                      Lois McMaster Bujold
2003 Hominids                              Robert J. Sawyer
2002 American Gods                         Neil Gaiman
2001 Harry Potter and the Goblet of Fire   J. K. Rowling
```

Such a file might have been produced either by `printf`, described earlier in this chapter, or by formats, described in the next section. Or it could have been produced externally. In any case, you can't use `split` to parse out the fields because they have no distinct separator. Instead, fields are determined by their byte offset into the record. So even though this is a regular text record, because it's in a fixed format, you want to use `unpack` to pull it apart:

```
use v5.14;
while (<>) {
    my($year, $title, $author) = unpack("A4 x A39 A*", $_);
    say "$author won ${year}'s Hugo for $title.";
}
```

(The reason we wrote `${year}'s` there is because Perl would have treated `$year's` as meaning `$year::s`. If you were using UTF-8 in your source code via `use utf8`, you could have used `$year's` safely enough, though.)

In addition to fields allowed in `pack`, you may prefix a field with *`%number`* to produce a simple *`number`*-bit additive checksum of the items instead of the items themselves. Default is a 16-bit checksum. The checksum is calculated by summing numeric values of expanded values (for string fields, the sum of `ord($char)` is taken; for bit fields, it's the sum of zeros and ones). For example, the following computes the same number as the SysV *sum*(1) program:

```
undef $/;
$checksum = unpack ("%32C*", <>) % 65535;
```

The following efficiently counts the number of set bits in a bitstring:

```
$setbits = unpack "%32b*", $selectmask;
```

Here's a simple Base64 decoder:

```
while (<>) {
    tr#A-Za-z0-9+/##cd;                 # remove non-base64 chars
    tr#A-Za-z0-9+/# -_#;                # convert to uuencoded format
    $len = pack("c", 32 + 0.75*length); # compute length byte
    print unpack("u", $len . $_);       # uudecode and print
}
```

The `p` and `P` formats should be used with care. Since Perl has no way of checking whether the value passed to `unpack` corresponds to a valid memory location, passing a pointer value that's not known to be valid is likely to have disastrous consequences.

If there are more pack codes or if the repeat count of a field or a group is larger than what the remainder of the input string allows, the result is not well defined: the repeat count may be decreased; or `unpack` may produce empty strings or zeros, or it may raise an exception. If the input string is longer than one described by the *`TEMPLATE`*, the remainder of that input string is ignored.

Picture Formats

Perl has a mechanism to help you generate simple reports of the kind you often see coming out of your mainframe's line printer. (What, you don't have one of those?) To facilitate this, Perl helps you code up your output page close to how it will look when it's printed. It can keep track of things like how many lines are on a page, the current page number, when to print page headers, and so on. Keywords are borrowed from FORTRAN: `format` to declare and `write` to execute; see the relevant entries in Chapter 27. Fortunately, the layout is much more legi-

ble, more like the `PRINT USING` statement of BASIC. Think of it as a poor man's *nroff*(1). (If you know *nroff*, that may not sound like a recommendation.)

Formats, like packages and subroutines, are declared rather than executed, so they may occur at any point in your program. (Usually it's best to keep them all together.) They have their own namespace apart from all the other types in Perl. This means that if you have a function named "`Foo`", it is not the same thing as a format named "`Foo`". However, the default name for the format associated with a given filehandle is the same as the name of that filehandle. Thus, the default format for `STDOUT` is named "`STDOUT`", and the default format for filehandle `TEMP` is named "`TEMP`". They just look the same. They aren't.

Output record formats are declared as follows:

```
format NAME =
FORMLIST
.
```

If *`NAME`* is omitted, format `STDOUT` is defined. *`FORMLIST`* consists of a sequence of lines, each of which may be of one of three types:

- A comment, indicated by putting a `#` in the first column.
- A "picture" line giving the format for one output line.
- An argument line supplying values to plug into the previous picture line.

Picture lines are printed exactly as they look, except for certain fields that substitute values into the line.[3] Each substitution field in a picture line starts with either `@` (at) or `^` (caret). These lines do not undergo any kind of variable interpolation. The `@` field (not to be confused with the array marker `@`) is the normal kind of field; the other kind, the `^` field, is used to do rudimentary multiline text-block filling. The length of the field is supplied by padding out the field with multiple `<`, `>`, or `|` characters to specify, respectively, left justification, right justification, or centering. If the variable exceeds the width specified, it is truncated.

Be warned that all this talk of widths and justification breaks down miserably once you bring "interesting" Unicode characters into the picture for interesting values of "interesting". It doesn't even work with nonprinting ASCII. Picture formats assume every codepoint takes up exactly one column. In Unicode, this is not true, as many codepoints occupy zero print columns, and some occupy two of them. See the discussion on ^"Graphemes and Normaliza-

3. Even those fields maintain the integrity of the columns you put them in, however. There is nothing in a picture line that can cause fields to grow or shrink or shift back and forth. The columns you see are sacred in a WYSIWYG sense—assuming you're using a fixed-width font. Even control characters are assumed to have a width of one.

tion" on page 290 in Chapter 6 for how to use the `columns` method from `Unicode::GCString` to get the true print columns of a Unicode string.

As an alternate form of right justification, you may also use `#` characters (after an initial `@` or `^`) to specify a numeric field. You can insert a `.` in place of one of the `#` characters to line up the decimal points. If any value supplied for these fields contains a newline, only the text up to the newline is printed. Finally, the special field `@*` can be used for printing multiline, nontruncated values; it should generally appear on a picture line by itself.

The values are specified on the following line in the same order as the picture fields. The expressions providing the values should be separated by commas. The expressions are all evaluated in list context before the line is processed, so a single list expression could produce multiple list elements. The expressions may be spread out to more than one line if enclosed in braces. (If so, the opening brace must be the first token on the first line.) This lets you line up the values under their respective format fields for easier reading.

If an expression evaluates to a number with a decimal part, and if the corresponding picture specifies that the decimal part should appear in the output (that is, any picture except multiple `#` characters without an embedded `.`), the character used for the decimal point is always determined by the current `LC_NUMERIC` locale. This means that if, for example, the runtime environment happens to specify a German locale, a comma will be used instead of a period. See the *perllocale* manpage for more information.

Inside an expression, the whitespace characters `\n`, `\t`, and `\f` are all considered equivalent to a single space. Thus, you could think of this filter as being applied to each value in the format:

```
$value =~ tr/\n\t\f/ /;
```

The remaining whitespace character, `\r`, forces the printing of a newline if the picture line allows it.

Picture fields that begin with `^` rather than `@` are treated specially. With a `#` field, the field is blanked out if the value is undefined. For other field types, the caret enables a kind of fill mode. Instead of an arbitrary expression, the value supplied must be a scalar variable name that contains a text string. Perl puts as much text as it can into the field, and then chops off the front of the string so that the next time the variable is referenced, more of the text can be printed. (Yes, this means that the variable itself is altered during execution of the `write` call and is not preserved. Use a scratch variable if you want to preserve the original value.) Normally, you would use a sequence of fields lined up vertically to print out a block of text. You might wish to end the final field with the text "`...`", which will

appear in the output if the text was too long to appear in its entirety. You can change which characters are legal to "break" on (or after) by changing the variable `$:` (that's `$FORMAT_LINE_BREAK_CHARACTERS` if you're using the `English` module) to a list of the desired characters.

Understand that this simplistic type of linebreaking has nothing to do with the sophisticated linebreaking required by UAX #14: Unicode Line Breaking Algorithm. With Unicode text, the `Line_Break=`*VALUE* (abbreviation `LB`) property of each codepoint must be used, in conjunction with fancy tables, to figure out where breaks are permitted. To give you an idea of how complicated this is, here are the possible property values for *VALUE* in `\p{LB=`*VALUE*`}`:

```
Ambiguous           Contingent_Break    Ideographic         Postfix_Numeric
Alphabetic          Close_Punctuation   Inseparable         Prefix_Numeric
Break_Both          Close_Parenthesis   Infix_Numeric       Quotation
Break_After         Combining_Mark      Line_Feed           Space
Break_Before        Complex_Context     Next_Line           Unknown
Mandatory_Break     Exclamation         Nonstarter          Word_Joiner
Break_Symbols       Glue                Numeric             ZWSpace
Carriage_Return     Hyphen              Open_Punctuation
```

Scripts normally written without whitespace or dashes are especially challenging to linebreak, so this is really the only way to do it. The `Unicode::LineBreak` module from CPAN, which includes the popular `Unicode::GCString` module in its distribution, fully implements UAX #14, including handling East Asian scripts. You'll want to use this module for anything fancier than simplistic ASCII.

Using `^` fields can produce variable-length records. If the text to be formatted is short, just repeat the format line with the `^` field in it a few times. If you just do this for short data, you'd end up getting a few blank lines. To suppress lines that would end up blank, put a `~` (tilde) character anywhere in the line. (The tilde itself will be translated to a space upon output.) If you put a second tilde next to the first, the line will be repeated until all the text in the fields on that line are exhausted. (This works because the `^` fields chew up the strings they print. But if you use a field of the `@` variety in conjunction with two tildes, the expression you supply had better not give the same value every time forever! Use a `shift` or some other operator with a side effect that exhausts the set of values.)

Top-of-form processing is by default handled by a format with the same name as the current filehandle with `_TOP` concatenated to it. It's triggered at the top of each page. See the `write` entry in Chapter 27.

Here are some examples:

```
# a report on the /etc/passwd file
format STDOUT_TOP =
                         Passwd File
```

```
Name                Login    Office   Uid   Gid Home
------------------------------------------------------------------
.
format STDOUT =
@<<<<<<<<<<<<<<<<<< @|||||||| @<<<<<<@>>>> @>>>> @<<<<<<<<<<<<<<<<<
$name,              $login,  $office,$uid,$gid, $home
.

# a report from a bug report form
format STDOUT_TOP =
                           Bug Reports
@<<<<<<<<<<<<<<<<<<<<<<<     @|||         @>>>>>>>>>>>>>>>>>>>>>>>
$system,                      $%,         $date
------------------------------------------------------------------
.
format STDOUT =
Subject: @<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
         $subject
Index: @<<<<<<<<<<<<<<<<<<<<<<<<<<<< ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
       $index,                        $description
Priority: @<<<<<<<<<< Date: @<<<<<<< ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
          $priority,        $date,    $description
From: @<<<<<<<<<<<<<<<<<<<<<<<<<<<<< ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
      $from,                         $description
Assigned to: @<<<<<<<<<<<<<<<<<<<<<< ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
             $programmer,            $description
~                                    ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
                                     $description
~                                    ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
                                     $description
~                                    ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
                                     $description
~                                    ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
                                     $description
~                                    ^<<<<<<<<<<<<<<<<<<<<<<<<...
                                     $description
.
```

Lexical variables are not visible within a format unless the format is declared within the scope of the lexical variable.

It is possible to intermix `print`s with `write`s on the same output channel, but you'll have to handle the `$-` special variable (`$FORMAT_LINES_LEFT` if you're using the `English` module) yourself.

Format Variables

The current format name is stored in the variable `$~` (`$FORMAT_NAME`), and the current top-of-form format name is in `$^` (`$FORMAT_TOP_NAME`). The current output page number is stored in `$%` (`$FORMAT_PAGE_NUMBER`), and the number of lines on

the page is in $= ($FORMAT_LINES_PER_PAGE). Whether to flush the output buffer on this handle automatically is stored in $| ($OUTPUT_AUTOFLUSH). The string to be output before each top of page (except the first) is stored in $^L ($FORMAT_FORMFEED). These variables are set on a per-filehandle basis, so you'll need to select the filehandle associated with a format in order to affect its format variables:

```
select((select(OUTF),
        $~ = "My_Other_Format",
        $^ = "My_Top_Format"
       )[0]);
```

Pretty ugly, eh? It's a common idiom, though, so don't be too surprised when you see it. You can at least use a temporary variable to hold the previous filehandle:

```
$ofh = select(OUTF);
$~ = "My_Other_Format";
$^ = "My_Top_Format";
select($ofh);
```

This is a much better approach in general because not only does legibility improve, but you now have an intermediary statement in the code to stop on when you're single-stepping in the debugger. If you use the English module, you can even read the variable names:

```
use English;
$ofh = select(OUTF);
$FORMAT_NAME     = "My_Other_Format";
$FORMAT_TOP_NAME = "My_Top_Format";
select($ofh);
```

But you still have those funny calls to select. If you want to avoid them, use the IO::Handle module bundled with Perl. Now you can access these special variables using lowercase method names instead:

```
use IO::Handle;
OUTF->format_name("My_Other_Format");
OUTF->format_top_name("My_Top_Format");
```

Much better!

Since the values line following your picture line may contain arbitrary expressions (for @ fields, not ^ fields), you can farm out more sophisticated processing to other functions, like sprintf or one of your own. For example, to insert commas into a number:

```
format Ident =
    @<<<<<<<<<<<<<<
    commify($n)
.
```

To get a real @, ~, or ^ into the field, do this:

```
format Ident =
I have an @ here.
         "@"
.
```

To center a whole line of text, do something like this:

```
format Ident =
@||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
                           "Some text line"
.
```

The `>` field-length indicator ensures that the text will be right-justified within the field, but the field as a whole occurs exactly where you show it occurring. There is no built-in way to say "float this field to the righthand side of the page, however wide it is." You have to specify where it goes relative to the left margin. The truly desperate can generate their own format on the fly, based on the current number of columns (not supplied), and then `eval` it:

```
$format  = "format STDOUT = \n"
         . "^" . "<" x $cols . "\n"
         . '$entry' . "\n"
         . "\t^" . "<" x ($cols-8) . "~~\n"
         . '$entry' . "\n"
         . ".\n";
print $format if $Debugging;
eval $format;
die $@ if $@;
```

The most important line there is probably the `print`. What the `print` would print out looks something like this:

```
format STDOUT =
^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
$entry
    ^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<~~
$entry
.
```

Here's a little program that behaves like the *fmt*(1) Unix utility:

```
format =
^<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< ~~
$_

.

$/ = "";
while (<>) {
    s/\s*\n\s*/ /g;
    write;
}
```

Footers

While `$^` (`$FORMAT_TOP_NAME`) contains the name of the current header format, there is no corresponding mechanism to do the same thing automatically for a footer. Not knowing how big a format is going to be until you evaluate it is one of the major problems. It's on the to-do list.[4]

Here's one strategy: if you have a fixed-size footer, you can get footers by checking `$-` (`$FORMAT_LINES_LEFT`) before each `write`, and then print the footer yourself if necessary.

Here's another strategy: open a pipe to yourself using `open(MESELF, "|-")` (see the `open` entry in Chapter 27), and always `write` to `MESELF` instead of `STDOUT`. Have your child process postprocess its `STDIN` to rearrange headers and footers however you like. Not very convenient, but it's doable.

Accessing Formatting Internals

For low-level access to the internal formatting mechanism, you may use the built-in `formline` operator and access `$^A` (the `$ACCUMULATOR` variable) directly. (Formats essentially compile into a sequence of calls to `formline`.) For example:

```
$str = formline <<'END', 1,2,3;
@<<<  @|||  @>>>
END

say "Wow, I just stored '$^A' in the accumulator!";
```

Or to create an `swrite` subroutine that is to `write` as `sprintf` is to `printf`, do this:

```
use Carp;
sub swrite {
    croak "usage: swrite PICTURE ARGS" unless @_;
    my $format = shift;
    $^A = "";
    formline($format, @_);
    return $^A;
}

$string = swrite(<<'END', 1, 2, 3);
Check me out
@<<<  @|||  @>>>
END
print $string;
```

4. That doesn't guarantee we'll ever do it, of course. Formats are somewhat passé in this age of WWW, Unicode, XML, XSLT, and whatever the next few things after that are.

If you were using the `IO::Handle` module, you could use `formline` as follows to wrap a block of text at column 72:

```
use IO::Handle;
STDOUT->formline("^" . ("<" x 72) . "~~\n", $long_text);
```

Now brace yourself for a *big* chapter...

CHAPTER 27
Functions

This chapter describes the built-in Perl functions in alphabetical order[1] for convenient reference. Each function description begins with a brief summary of the syntax for that function. Parameter names like *THIS* represent placeholders for actual expressions, and the text following the syntax summary will describe the semantics of supplying (or omitting) the actual arguments.

You can think of functions as terms in an expression, along with literals and variables. Or you can think of them as prefix operators that process the arguments after them. We call them operators half the time anyway.

Some of these operators, er, functions take a *LIST* as an argument. Elements of the *LIST* should be separated by commas (or by `=>`, which is just a funny kind of comma). The elements of the *LIST* are evaluated in list context, so each element will return either a scalar or a list value, depending on its sensitivity to list context. Each returned value, whether scalar or list, will be interpolated as part of the overall sequence of scalar values. That is, all the lists get flattened into one list. From the point of view of the function receiving the arguments, the overall argument *LIST* is always a single-dimensional list value. (To interpolate an array as a single element, you must explicitly create and interpolate a reference to the array instead.)

Predefined Perl functions may be used either with or without parentheses around their arguments; the syntax summaries in this chapter omit the parentheses. If you do use parentheses, the simple but occasionally surprising rule is this: if it looks like a function, then it *is* a function, so precedence doesn't matter. Otherwise, it's a list operator or unary operator, and precedence does matter. Be

1. Sometimes tightly related functions are grouped together in the system manpages, so we respect that grouping here. To find the description of `endpwent`, for instance, you'll have to look under `getpwent`.

careful, because even if you put whitespace between the keyword and its left parenthesis, that doesn't keep it from being a function:

```
print 1+2*4;       # Prints 9
print(1+2) * 4;    # Prints 3!
print (1+2)*4;     # Also prints 3!
print +(1+2)*4;    # Prints 12
print ((1+2)*4);   # Prints 12
```

If you run Perl with the *–w* switch, it will warn you about this. For example, the second and third lines above produce messages like this:

```
print (...) interpreted as function at - line 2.
Useless use of integer multiplication in void context at - line 2.
```

Given the simple definition of some functions, you have considerable latitude in how you pass arguments. For instance, the most common way to use `chmod` is to pass the file permissions (the mode) as the first:

```
chmod 0644, @array;
```

but the definition of `chmod` just says:

```
chmod LIST
```

so you could just as well say:

```
unshift @array, 0644;
chmod @array;
```

If the first argument of the list is not a valid mode, `chmod` will fail, but that's a runtime semantic problem unrelated to the syntax of the call. If the semantics require any special arguments to be passed first, the text will describe these restrictions.

In contrast to the simple *`LIST`* functions, other functions impose additional syntactic constraints. For instance, `push` has a syntax summary that looks like this:

```
push ARRAY, LIST
```

This means that `push` requires a proper array as its first argument, but doesn't care about its remaining arguments. That's what the *`LIST`* at the end means. (*`LIST`*s always come at the end, since they gobble up all remaining values.) Whenever a syntax summary contains any arguments before the *`LIST`*, those arguments are syntactically distinguished by the compiler, not just semantically distinguished by the interpreter when it runs later. Such arguments are never evaluated in list context. They may be evaluated in scalar context, or they may be special referential arguments such as the array in `push`. (The description will tell you which is which.)

For operations based directly on the C library's functions, we do not try to duplicate your system's documentation. When a `function` description says to see *function*(2), that means you should look up the corresponding C version of that function to learn more about its semantics. The number in parentheses indicates the section of the system programmer's manual in which you will find the manpage, if you have the manpages installed. (And in which you won't, if you don't.)

These manpages may document system-dependent behavior like shadow password files, access control lists, and so forth. Many Perl functions that derive from C library functions in Unix are emulated even on non-Unix platforms. For example, although your operating system might not support the *flock*(2) or *fork*(2) syscalls, Perl will do its best to emulate them anyway by using whatever native facilities your platform provides.

Occasionally, you'll find that the documented C function has more arguments than the corresponding Perl function. Generally, the missing arguments are things that Perl knows already, such as the length of the previous argument, so you needn't supply them in Perl. Any remaining disparities are caused by the different ways Perl and C specify filehandles and success/failure values.

In general, functions in Perl that serve as wrappers for syscalls of the same name (like *chown*(2), *fork*(2), *closedir*(2), etc.) all return true when they succeed, and `undef` otherwise, as mentioned in the descriptions that follow. This is different from the C library's interfaces to these operations, which all return `-1` on failure. Exceptions to this rule are `wait`, `waitpid`, and `syscall`. Syscalls also set the special `$!` (`$OS_ERROR`) variable on failure. Other functions do not, except accidentally.

For functions that can be used in either scalar or list context, failure is generally indicated in scalar context by returning a false value (usually `undef`) and in list context by returning the null list. Successful execution is generally indicated by returning a value that will evaluate to true (in context).

Remember the following rule: there is *no* rule that relates the behavior of a function in list context to its behavior in scalar context, or vice versa. It might do two totally different things.

Each function knows the context in which it was called. The same function that returns a list when called in list context will, when called in scalar context, return whichever kind of value would be most appropriate. Some functions return the length of the list that would have been returned in list context. Some operators return the first value in the list. Some functions return the last value in the list. Some functions return the "other" value, when something can be looked up either by number or by name. Some functions return a count of successful

operations. In general, Perl functions do exactly what you want—unless you want consistency.

One final note: we've tried to be very consistent in our use of the terms "byte" and "character". Historically, these terms have been confused with each other (and with themselves). But when we say "byte", we mean a character whose ordinal value fits into 8 bits. When we say "character", we usually mean an abstract Unicode codepoint. This is the kind of thing C programmers used to stick in their `char` variables until they outgrew them. Today, `int` is the new `char`. A codepoint is a *programmer-visible character*, a nonnegative integer that corresponds to a single Unicode entity, sometimes informally called a character.

Currently, few of Perl's functions outside its regex library have much to do with graphemes, but they're the next layer of abstraction up from codepoints. These are *user-visible characters*, which may in turn comprise several programmer-visible ones. A CR+LF is one examples of a grapheme that occupies two codepoints. Another good one is o̅, which may occupy anywhere from 1–3 codepoints, depending on normalization: "`\x{22D}`" in NFC, "`\x{6F}\x{303}\x{304}`" in NFD, or "`\x{F5}\x{304}`", which is neither. In this chapter, if you catch us talking about characters, we really mean codepoints, and if we talk about bytes, we just mean *undecoded* ordinals smaller than 256.

Perl Functions by Category

Here are Perl's functions and function-like keywords, arranged by category. Some functions appear under more than one heading.

Scalar manipulation

`chomp`, `chop`, `chr`, `crypt`, `fc`, `hex`, `index`, `lc`, `lcfirst`, `length`, `oct`, `ord`, `pack`, `q//`, `qq//`, `reverse`, `rindex`, `sprintf`, `substr`, `tr///`, `uc`, `ucfirst`, `y///`

Regular expressions and pattern matching

`m//`, `pos`, `qr//`, `quotemeta`, `s///`, `split`, `study`

Numeric functions

`abs`, `atan2`, `cos`, `exp`, `hex`, `int`, `log`, `oct`, `rand`, `sin`, `sqrt`, `srand`

Array processing

`pop`, `push`, `shift`, `splice`, `unshift`

As of v5.12, you may also use `each`, `keys`, and `values` on arrays, if you really feel you must.

List processing

`grep`, `join`, `map`, `qw//`, `reverse`, `sort`, `unpack`

Hash processing

`delete`, `each`, `exists`, `keys`, `values`

Input and output

`binmode`, `close`, `closedir`, `dbmclose`, `dbmopen`, `die`, `eof`, `fileno`, `flock`, `format`, `getc`, `print`, `printf`, `read`, `readdir`, `readpipe`, `rewinddir`, `say`, `seek`, `seekdir`, `select` (ready file descriptors), `syscall`, `sysread`, `sysseek`, `syswrite`, `tell`, `telldir`, `truncate`, `warn`, `write`

Fixed-length data and records

`pack`, `read`, `syscall`, `sysread`, `sysseek`, `syswrite`, `unpack`, `vec`

Filehandles, files, and directories

`-X`, `chdir`, `chmod`, `chown`, `chroot`, `fcntl`, `glob`, `ioctl`, `link`, `lstat`, `mkdir`, `open`, `opendir`, `readlink`, `rename`, `rmdir`, `select` (ready file descriptors), `select` (output filehandle), `stat`, `symlink`, `sysopen`, `umask`, `unlink`, `utime`

Flow of program control

`caller`, `continue`, `die`, `do`, `dump`, `eval`, `exit`, `__FILE__`, `goto`, `last`, `__LINE__`, `next`, `__PACKAGE__`, `redo`, `return`, `sub`, `wantarray`

Scoping

`caller`, `import`, `local`, `my`, `no`, `our`, `package`, `state`, `use`

`state` is available only if the "`state`" feature is enabled or if it is prefixed with `CORE::`. See `feature`. Alternately, include a `use v5.10` or later to the current scope.

The switch feature

`break`, `continue`, `default`, `given`, `when`

Except for `continue` as an expression not a block, these are available only if you enable the "`switch`" feature. Alternately, include a `use v5.10` or later to the current scope. See "The given Statement" on page 133 in Chapter 4.

Miscellaneous

`defined`, `dump`, `eval`, `formline`, `lock`, `prototype`, `reset`, `scalar`, `undef`, `wantarray`

Processes and process groups

`alarm`, `exec`, `fork`, `getpgrp`, `getppid`, `getpriority`, `kill`, `pipe`, `qx//`, `setpgrp`, `setpriority`, `sleep`, `system`, `times`, `wait`, `waitpid`

Library modules

`do`, `import`, `no`, `package`, `require`, `use`

Classes and objects

`bless`, `dbmclose`, `dbmopen`, `package`, `ref`, `tie`, `tied`, `untie`, `use`

Low-level socket access

`accept`, `bind`, `connect`, `getpeername`, `getsockname`, `getsockopt`, `listen`, `recv`, `send`, `setsockopt`, `shutdown`, `socket`, `socketpair`

System V interprocess communication

`msgctl`, `msgget`, `msgrcv`, `msgsnd`, `semctl`, `semget`, `semop`, `shmctl`, `shmget`, `shmread`, `shmwrite`

Fetching user and group information

`endgrent`, `endhostent`, `endnetent`, `endpwent`, `getgrent`, `getgrgid`, `getgrnam`, `getlogin`, `getpwent`, `getpwnam`, `getpwuid`, `setgrent`, `setpwent`

Fetching network information

`endprotoent`, `endservent`, `gethostbyaddr`, `gethostbyname`, `gethostent`, `getnetbyaddr`, `getnetbyname`, `getnetent`, `getprotobyname`, `getprotobynumber`, `getprotoent`, `getservbyname`, `getservbyport`, `getservent`, `sethostent`, `setnetent`, `setprotoent`, `setservent`

Time

`gmtime`, `localtime`, `time`, `times`

Functions related to Unicode

`binmode`, `chomp`, `chop`, `chr`, `dbmopen`, `fc`, `getc`, `index`, `lc`, `lcfirst`, `length`, `m//`, `my`, `open`, `ord`, `our`, `pack`, `package`, `pos`, `print`, `printf`, `quotemeta`, `read`, `readline`, `reverse`, `rindex`, `s///`, `seek`, `sort`, `split`, `sprintf`, `state`, `substr`, `sysopen`, `sysread`, `sysseek`, `syswrite`, `tell`, `tr///`, `truncate`, `uc`, `ucfirst`, `unpack`, `write`, `y///`

Perl Functions in Alphabetical Order

Many of the following function names are annotated with, um, annotations. Here are their meanings:

- 

Uses `$_` (`$ARG`) as a default variable.
- 

Sets `$!` (`$OS_ERROR`) on syscall errors.
- 

Raises exceptions; uses `eval` to trap `$@` (`$EVAL_ERROR`).
- 

Sets `$?` (`$CHILD_ERROR`) when child process exits.
- 

Taints returned data.
- 

Taints returned data under some system, locale, or handle settings.
- 

Raises an exception if given an argument of inappropriate type.
- 

Raises an exception if modifying a read-only target.
- 

Raises an exception if fed tainted data.

- X U Raises an exception if unimplemented on current platform.
- X WIDE Raises an exception if passed a string containing characters with ordinals higher than 255.

Functions that return tainted data when fed tainted data are not marked, since that's most of them. In particular, if you use any function on `%ENV` or `@ARGV`, you'll get tainted data.

Functions marked with X ARG raise an exception when they require, but do not receive, an argument of a particular type (such as filehandles for I/O operations, references for `bless`ing, etc.).

Functions marked with X RO sometimes need to alter their arguments. If they can't modify the argument because it's marked read-only, they'll raise an exception. Examples of read-only variables are the special variables containing data captured during a pattern match and variables that are really aliases to constants.

Functions marked with X U may not be implemented on all platforms. Although many of these are named after functions in the Unix C library, don't assume that just because you aren't running Unix, you can't call any of them. Many are emulated, even those you might never expect to see—such as `fork` on Win32 systems. For more information about the portability and behavior of system-specific functions, see the *perlport* manpage, plus any platform-specific documentation that came with your Perl port.

Functions marked with X WIDE raise an exception when they are passed an undecoded string with any characters that are too big to fit into a byte value.

Functions that raise other miscellaneous exceptions are marked with $@, including math functions that throw range errors, such as `sqrt(-1)`.

abs

$_

```
abs VALUE
abs
```

This function returns the absolute value of its argument.

```
$diff = abs($first - $second);
```

Here and in the examples following, good style (and the `strict` pragma) would dictate that you add a `my` modifier to declare a new lexically scoped variable, like this:

```
my $diff = abs($first - $second);
```

However, we've omitted `my` from most of our examples for clarity. Just assume that any such variable was declared earlier.

accept

```
accept SOCKET, PROTOSOCKET
```

This function is used by server processes that wish to listen for socket connections from clients. *PROTOSOCKET* must be a filehandle already opened via the `socket` operator and bound to one of the server's network addresses or to `INADDR_ANY`. Execution is suspended until a connection is made, at which point the *SOCKET* filehandle is opened and attached to the newly made connection. The original *PROTOSOCKET* remains unchanged; its sole purpose is to be cloned into a real socket. The function returns the connected address if the call succeeds, false otherwise. For example:

```
unless ($peer = accept(SOCKET, PROTOSOCK)) {
    die "Can't accept a connection: $!";
}
```

On systems that support it, the close-on-exec flag will be set for the newly opened file descriptor, as determined by the value of `$^F` (`$SYSTEM_FD_MAX`).

See *accept*(2). See also the example in the section "Sockets" on page 543 in Chapter 15.

alarm

```
alarm EXPR
alarm
```

This function tells the operating system to send a `SIGALRM` signal to the current process after *EXPR* wallclock seconds have elapsed.

Only one timer may be active at once. Each call disables the previous timer, and an *EXPR* of 0 cancels the previous timer without starting a new one. The return value is the amount of time remaining on the previous timer.

```
print "Answer me within one minute, or die: ";
alarm(60);              # kill program in one minute
$answer = <STDIN>;
$timeleft = alarm(0);  # clear alarm
say "You had $timeleft seconds remaining";
```

It is usually a mistake to intermix `alarm` and `sleep` calls, because many systems use the *alarm*(2) syscall mechanism to implement *sleep*(3). Historically, the elapsed time may be up to one second less than you specified because of how

seconds are counted. Additionally, a busy system may not get around to running your process immediately. See Chapter 15 for information on signal handling, such as how to use alarms to time out slow operations.

For alarms of finer granularity than one second, the `Time::HiRes` module provides functions for this purpose. For a hackier approach, use the four-argument version of `select` (leaving the first three arguments undefined), or Perl's `syscall` function to access *setitimer*(2) (if your system supports it).

atan2

```
atan2 Y, X
```

This function returns the principal value of the arc tangent of *Y*/*X* in the range -π to +π. A quick way to get an approximate value of π is to say:

```
$pi = atan2(1,1) * 4;
```

For the tangent operation, you may use the `tan` function from the `Math::Trig` or the `POSIX` modules, or just use the familiar relation:

```
sub tan { sin($_[0]) / cos($_[0]) }
```

If either or both arguments are 0, the return value is implementation defined; see your *atan2*(3) manpage for more information.

bind


```
bind SOCKET, NAME
```

This function assigns a name to an unnamed but already-opened socket specified by the *SOCKET* filehandle so that other processes can find it. The function returns true if it succeeded, false otherwise. *NAME* should be a packed address of the proper type for the socket.

```
use Socket;
$port_number = 80;      # pretend we want to be a web server
$sockaddr = sockaddr_in($port_number, INADDR_ANY);
bind(SOCK, $sockaddr) || die "Can't bind $port_number: $!";
```

See *bind*(2). See also the examples in the section "Sockets" in Chapter 15. Normally, you should be using the higher-level interface to sockets provided by the standard `IO::Socket` module.

binmode

```
binmode FILEHANDLE, IOLAYER
binmode FILEHANDLE
```

This function arranges for the *FILEHANDLE* to have the semantics specified by the *IOLAYER* argument. If *IOLAYER* is omitted, binary (or "raw") semantics are applied to the filehandle. If *FILEHANDLE* is an expression, the value is taken as the name of the filehandle or a reference to a filehandle, as appropriate. The function returns true if it succeeded, false otherwise.

The `binmode` function should be called after the `open` but before any I/O is done on the filehandle. The only way to reset the mode on a filehandle is to reopen the file, since the various layers may have treasured up various bits and pieces of data in various buffers. This restriction may be relaxed in the future.

In olden days, `binmode` was used primarily on operating systems whose runtime libraries distinguished text from binary files. On those systems, the purpose of `binmode` was to turn off the default text semantics. However, with the advent of Unicode and its many different storage encodings, programs on all systems must take some cognizance of the distinction.

These days there is only one kind of binary file (as far as Perl is concerned), but there are many kinds of text files, which Perl would also like to treat in a single way. So Perl has a single internal format for Unicode text, UTF-8.

Since there are many kinds of text files, text files often need to be translated on input into UTF-8, and then back into some legacy character set or some other representation of Unicode on output.

You can use I/O layers to tell Perl how exactly (or inexactly) to do these translations. For example, a layer of "`:text`" tells Perl to do generic text processing without telling Perl which kind of text processing to do.

But I/O layers like "`:utf8`" and "`:encoding(Latin1)`" tell Perl which text format to read and write.

On the other hand, the "`:raw`" I/O layer tells Perl to keep its cotton-pickin' hands off the data.

For more on how I/O layers work, see the `open` function. The rest of this discussion describes what `binmode` does without the *IOLAYER* argument; that is, the historical meaning of `binmode`, which is equivalent to:

```
binmode FILEHANDLE, ":raw";
```

Unless instructed otherwise, Perl assumes your freshly opened file should be read or written in text mode. Text mode means that `\n` (newline) will be your internal line terminator. All systems use `\n` as the internal line terminator, but what that really represents varies from system to system, device to device, and even file to file, depending on how you access the file. In such legacy systems (including MS-DOS and VMS), what your program sees as a `\n` may not be what's physically stored on disk. The operating system might, for example, store text files with `\cM\cJ` sequences that are translated on input to appear as `\n` to your program, then on output translate `\n` from your program back to `\cM\cJ`. The `binmode` function disables this automatic translation on such systems.

In the absence of an *`IOLAYER`* argument, `binmode` has no effect under Unix (including Mac OS X), both of which use `\n` to end each line and represent that as a single character. (It may, however, be a different character: Unix uses `\cJ` and pre-Unix Macs used `\cM`. Doesn't matter.)

The following example shows how a Perl script might read a GIF image from a file and print it to the standard output. On systems that would otherwise alter the literal data into something other than its exact physical representation, you must prepare both handles. While you could use a "`:raw`" layer directly in the GIF open, you can't do that so easily with preopened filehandles like `STDOUT`:

```
binmode(STDOUT, ":raw")
  || die "couldn't binmode STDOUT to raw: $!";
open(GIF, "< :raw", "vim-power.gif")
  || die "Can't open vim-power.gif: $!";
while (read(GIF, $buf, 1024)) {  # now bytes, not chars
    print STDOUT $buf;
}
```

Note that if you use the built-in UTF-8 layer, like this:

```
binmode(HANDLE, ":utf8");
```

then if it is an input handle, you must be prepared to deal with encoding errors yourself, because as of v5.14, the default is too lenient with malformed UTF-8. The quickest and also perhaps the best way to handle encoding errors is not to allow them at all.

```
use warnings FATAL => "utf8";
```

Even if you implement the `Encode` module using something like:

```
binmode(HANDLE, ":encoding(utf8)")
```

you should still fatalize UTF-8 warnings as shown above, because otherwise you will not take an exception when there is an error. (Always assuming you prefer exceptions to mangled text. Neither is designed to make you happy.)

bless

```
bless REF, CLASSNAME
bless REF
```

This function tells the referent pointed to by reference *REF* that it is now an object in the *CLASSNAME* package—or the current package if no *CLASSNAME* is specified. If *REF* is not a valid reference, an exception is raised. For convenience, `bless` returns the reference, since it's often the last function in a constructor subroutine. For example:

```
$pet = Beast->new(TYPE => "cougar", NAME => "Clyde");

# then in Beast.pm:
sub new {
    my $class  = shift;
    my %attrs = @_;
    my $self   = { %attrs };
    return bless($self, $class);
}
```

You should generally bless objects into *CLASSNAME*s that are mixed case. Name spaces with all lowercase names are reserved for internal use as Perl pragmata (compiler directives). Built-in types (such as "`SCALAR`", "`ARRAY`", "`HASH`", "`UNIVERSAL`", etc.) all have uppercase names, so you may wish to avoid such package names as well.

Make sure that *CLASSNAME* is not false; blessing into false packages is not supported and may result in unpredictable behavior.

It is not a bug that there is no corresponding `curse` operator. (But there is a `sin` operator.) See also Chapter 12 for more about the blessing (and blessings) of objects.

break

```
break
```

Exit from a `given` block earlier than normal (before the end of a `when` clause). This keyword is enabled by the `switch` feature; see the `feature` pragma in Chapter 29 for more information.

caller

```
caller EXPR
caller
```

This function returns information about the stack of current subroutine calls and such. Without an argument, it returns the package name, filename, and line number from which the currently executing subroutine was called:

```
($package, $filename, $line) = caller;
```

Here's an example of an exceedingly picky function, making use of the special tokens `__PACKAGE__` and `__FILE__` described in Chapter 2:

```
sub careful {
    my ($package, $filename) = caller;
    unless ($package  eq __PACKAGE__ && $filename eq __FILE__) {
        die "You weren't supposed to call me, $package!";
    }
    say "called me safely";
}

sub safecall {
    careful();
}
```

When called with an argument, `caller` evaluates *`EXPR`* as the number of stack frames to go back before the current one. For example, an argument of 0 means the current stack frame, 1 means the caller, 2 means the caller's caller, and so on. The function also reports additional information, as shown here:

```
my $i = 0;
while (my ($package, $filename, $line, $subroutine,
           $hasargs, $wantarray, $evaltext, $is_require,
           $hints, $bitmask, $hinthash) = caller($i++) )
{
    ...
}
```

If the frame is a subroutine call, `$hasargs` is true if it has its own `@_` array (not one borrowed from its caller). Otherwise, `$subroutine` may be "`(eval)`" if the frame is not a subroutine call but an `eval`. If so, additional elements `$evaltext` and `$is_require` are set: `$is_require` is true if the frame is created by a `require` or `use` statement, and `$evaltext` contains the text of the `eval` *`EXPR`* statement. In particular, for a `eval` *`BLOCK`* statement, `$filename` is "`(eval)`", but `$evaltext` is undefined. (Note also that each `use` statement creates a `require` frame inside an `eval` *`EXPR`* frame.) The `$hints`, `$bitmask`, and `$histhash` are internal values; please ignore them unless you're a member of the thaumatocracy.[2]

In a fit of even deeper magic, `caller` also sets the array `@DB::args` to the arguments passed in the given stack frame—but only when called from within the `DB` package. See Chapter 18.

2. `$hinthash` is a reference to a hash containing the value of `%^H` when the caller was compiled, or `undef` if `%^H` was empty. Do not modify the values of this hash, as they are the actual values stored in the optree.

Be aware that the optimizer might have optimized call frames away before `caller` had a chance to get the information. That means that `caller(`*`N`*`)` might not return information about the call frame you expect for *`N`* `> 1`. In particular, `@DB::args` might have information from the previous time `caller` was called.

Also understand that setting `@DB::args` is *best effort*, intended for debugging or generating backtraces, and should not be relied on. In particular, `@_` contains aliases to the caller's current `@_` array. Perl does not take a snapshot of `@_` at subroutine entry, so `@DB::args` will reflect any modifications the subroutine made to `@_` subsequent to its call. In addition, `@DB::args`, like `@_`, does not hold explicit references to its elements, so in certain cases its elements may have become freed and reallocated for other variables or temporary values. Finally, a side effect of the current implementation is that the effects of only `shift @_` can be undone (but not `pop` or `splice`), and if a reference to `@_` has been taken, you're probably just hosed. So `@DB::args` is actually a hybrid of the current and initial states of `@_`. Buyer beware.

chdir

```
chdir EXPR
chdir
```

This function changes the current process's working directory to *`EXPR`*, if possible. If *`EXPR`* is omitted, `$ENV{HOME}` is used if set, and `$ENV{LOGDIR}` otherwise; these are usually the process's home directory. The function returns true on success, false otherwise.

```
chdir("$prefix/lib") || die "Can't cd to $prefix/lib: $!";
```

See also the `Cwd` module, which lets you keep track of your current directory automatically.

On systems that support *fchdir*(2), you may pass a filehandle or directory handle as *`EXPR`*. On systems that don't support *fchdir*(2), passing handles raises a runtime exception.

chmod

```
chmod LIST
```

This function changes the permissions of a list of files. The first element of the list must be the numerical mode, as in the *chmod*(2) syscall. The function returns the number of files successfully changed. For example:

```
$cnt = chmod 0755, "file1", "file2";
```

will set `$cnt` to `0`, `1`, or `2`, depending on how many files were changed. Success is measured by lack of error, not by an actual change, because a file may have had the same mode before the operation. An error probably means you lacked sufficient privileges to change its mode because you were neither the file's owner nor the superuser. Check `$!` to find the actual reason for failure.

Here's a more typical usage:

```
chmod(0755, @executables) == @executables
        || die "couldn't chmod some of @executables: $!";
```

If you need to know which files didn't allow the change, use something like this:

```
@cannot = grep {not chmod(0755, $_) } "file1", "file2", "file3";
die "$0: could not chmod @cannot" if @cannot;
```

This idiom uses the `grep` function to select only those elements of the list for which the `chmod` function failed.

On systems that support *fchmod*(2), you may also pass filehandles in the argument list. On systems without *fchmod*(2) support, passing filehandles raises a runtime exception. To be recognized, filehandles must be passed as typeglobs or references to typeglobs: strings are considered filenames.

When using nonliteral mode data, you may need to convert an octal string to a number using the `oct` function. That's because Perl doesn't automatically assume a string contains an octal number just because it happens to have a leading "`0`".

```
$DEF_MODE = 0644;   # Can't use quotes here!
PROMPT: {
    print "New mode? ";
    $strmode = <STDIN>;
    exit unless defined $strmode;       # test for eof
    if ($strmode =~ /^\s*$/) {          # test for blank line
        $mode = $DEF_MODE;
    }
    elsif ($strmode !~ /^\d+$/) {
        say "Want numeric mode, not $strmode";
        redo PROMPT;
    }
    else {
        $mode = oct($strmode);          # converts "755" to 0755
    }
    chmod $mode, @files;
}
```

This function works with numeric modes much like the Unix *chmod*(2) syscall. If you want a symbolic interface like the one the *chmod*(1) command provides, see the `File::chmod` module on CPAN.

You can also import the symbolic `S_I*` constants from the `Fcntl` module:

```
use Fcntl ":mode";
chmod S_IRWXU | S_IRGRP | S_IXGRP | S_IROTH | S_IXOTH, @executables;
```

Some people consider that more readable than `0755`. Go figure.

chomp

```
chomp VARIABLE
chomp LIST
chomp
```

This function (normally) deletes a trailing newline from the end of a string contained in a variable. This is a slightly safer version of `chop` (described next) in that it has no effect on a string that doesn't end in a newline. More specifically, it deletes the terminating string corresponding to the current value of `$/`, and not just any last character.

Unlike `chop`, `chomp` returns the number of characters deleted. If `$/` is `""` (in paragraph mode), `chomp` removes all trailing newlines from the selected string (or strings, if chomping a *LIST*). When in slurp mode (`$/ = undef`) or fixed-length record mode (`$/` is a reference to an integer), `chomp` does nothing. You cannot `chomp` a literal, only a variable. Chomping a hash `chomp`s only the values, not the keys.

For example:

```
while (<PASSWD>) {
    chomp;   # avoid \n on last field
    @array = split /:/;
    ...
}
```

I/O layers are allowed to override the value of the `$/` variable and mark how strings should be `chomp`ed. This has the advantage that an I/O layer can recognize more than one variety of line terminator (like the Unicode paragraph and line separators), but still safely `chomp` whatever terminates the current line.

The `chomp` function is not currently smart enough to handle Unicode linebreak sequences, whose regex metacharacter is `\R`. To do so on your own:

```
s/\R/\n/g;    # convert all Unicode linebreaks to \n
```

Or, sometimes, perhaps like this:

```
my @paras = split /\R+/, our $file_contents;
```

However, if you want to preserve the linebreak sequence, you'd best do this:

```
our $line =~ s/(\R?)\z//;
my  $terminator = $1;
```

chop

```
chop VARIABLE
chop LIST
chop
```

This function chops off the last character of a string variable and returns the character chopped. The `chop` function is used primarily to remove the newline from the end of an input record, and it is more efficient than using a substitution. If that's all you're doing, then it would be safer to use `chomp`, since `chop` always shortens the string no matter what's there, and `chomp` is more selective.

You cannot `chop` a literal, only a variable. If you `chop` a *LIST* of variables, each string in the list is chopped:

```
@lines = `cat myfile`;
chop @lines;
```

You can `chop` anything that is an lvalue, including an assignment:

```
chop($cwd = `pwd`);
chop($answer = <STDIN>);
```

This is different from:

```
$answer = chop($tmp = <STDIN>);  # WRONG
```

which puts a newline into `$answer` because `chop` returns the character chopped, not the remaining string (which is in `$tmp`). One way to get the result intended here is with `substr`:

```
$answer = substr <STDIN>, 0, -1;
```

But this is more commonly written as:

```
chop($answer = <STDIN>);
```

In the most general case, `chop` can be expressed using `substr`:

```
$last_char = chop($var);
$last_char = substr($var, -1, 1, "");   # same thing
```

Once you understand this equivalence, you can use it to do bigger chops. To chop more than one character, use `substr` as an lvalue, assigning a null string. The following removes the last five characters of `$caravan`:

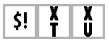
```
substr($caravan, -5) = "";
```

The negative subscript causes `substr` to count from the end of the string instead of the beginning. To save the removed characters, you could use the four-argument form of `substr`, creating something of a quintuple chop:

```
$tail = substr($caravan, -5, 5, "");
```

This is all dangerous business dealing with codepoints instead of graphemes. Perl doesn't really have a grapheme mode, so you have to deal with them yourself. Consider a word like *naïveté*, which is really `nai\x{308}vete\x{301}` in NFD. If you use `chop`, you won't get *naïvet*; you'll get *naïvete*. You have need to use `s/\X\z//` to chop a grapheme instead of a codepoint. The CPAN `Unicode::GCString` module is a tremendous help with all this.

chown



```
chown LIST
```

This function changes the owner and group of a list of files. The first two elements of the list must be the *numeric* UID and GID, in that order. A value of `-1` in either position is interpreted by most systems to leave that value unchanged. The function returns the number of files successfully changed. For example:

```
chown($uidnum, $gidnum, "file1", "file2") == 2
        || die "can't chown file1 || file2: $!";
```

will set `$cnt` to `0`, `1`, or `2`, depending on how many files got changed (in the sense that the operation succeeded, not in the sense that the owner was different afterward). Here's a more typical usage:

```
chown($uidnum, $gidnum, @filenames) == @filenames
        || die "can't chown @filenames: $!";
```

Here's a subroutine that accepts a username, looks up the user and group IDs for you, and does the `chown`:

```
sub chown_by_name {
    my($user, @files) = @_;
    chown((getpwnam($user))[2,3], @files) == @files
            || die "can't chown @files: $!";
}

chown_by_name("fred", glob("*.c"));
```

However, you may not want the group changed as the previous function does, because the */etc/passwd* file associates each user with a single group even though that user may be a member of many secondary groups according to */etc/group*. An alternative is to pass a `-1` for the GID, which leaves the group of the file unchanged. If you pass a `-1` as the UID and a valid GID, you can set the group without altering the owner.

On systems that support *fchown*(2), you may also pass filehandles in the argument list. On systems without *fchown*(2) support, passing filehandles raises a runtime

exception. To be recognized, filehandles must be passed as typeglobs or references to typeglobs: strings are considered filenames.

On most systems, you are not allowed to change the ownership of the file unless you're the superuser, although you should be able to change the group to any of your secondary groups. On insecure systems, these restrictions may be relaxed, but this is not a portable assumption. On POSIX systems, you can detect which rule applies like this:

```
use POSIX qw(sysconf _PC_CHOWN_RESTRICTED);
# only try if we're the superuser or on a permissive system
if ($> == 0 || !sysconf(_PC_CHOWN_RESTRICTED) ) {
    chown($uidnum, -1, $filename)
        || die "can't chown $filename to $uidnum: $!";
}
```

chr

```
chr NUMBER
chr
```

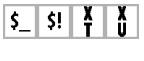
This function returns the character represented by *NUMBER* (truncated to an integer) in the Unicode character set. For example, `chr(65)` is "A", LATIN SMALL LETTER A, and `chr(0x2122)` is "™", TRADE MARK SIGN. For the reverse of `chr`, use `ord`.

If *NUMBER* is negative, this function produces the Unicode REPLACEMENT CHARACTER, U+FFFD.[3]

(Note that characters with codepoints between 128 and 255 are by default internally not encoded as UTF-8 for backward-compatibility reasons. You shouldn't ever notice this, but if you do, that's why.)

If you'd rather specify your characters by name than by number (for example, "`\N{WHITE SMILING FACE}`" for a Unicode smiley, "☺"), see the section "charnames" on page 1008 in Chapter 29. To convert a character number to its official name instead of to the character itself, see that pragma's `charnames::viacode` function.

chroot



```
chroot FILENAME
chroot
```

If successful, *FILENAME* becomes the new root directory for the current process—the starting point for pathnames beginning with "`/`". This directory is inherited

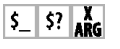
3. Except under the `bytes` pragma, where the low eight bits of the value are used.

across `exec` calls and by all subprocesses `fork`ed after the `chroot` call. There is no way to undo a `chroot`. For security reasons, only the superuser can use this function. Here's some code that approximates what many FTP servers do:

```
chroot((getpwnam("ftp"))[7])
    || die "can't do anonymous ftp: $!";
```

This function is unlikely to work on non-Unix systems. See *chroot*(2).

close




```
close FILEHANDLE
close
```

This function closes the file, socket, or pipe associated with *FILEHANDLE* after flushing any IO buffers. It closes the currently selected filehandle if the argument is omitted. It returns true if the close is successful, false otherwise. You don't have to close *FILEHANDLE* if you are immediately going to do another `open` on it, since the next `open` will close it for you, but then you would miss any error that occurred. (See `open`.) However, an explicit `close` on an input file resets the line counter (`$.`); the implicit close done by `open` does not.

FILEHANDLE may be an expression whose value can be used as an indirect filehandle (either the real filehandle name or a reference to anything that can be interpreted as a filehandle object).

If the filehandle came from a piped open, `close` returns false if any underlying syscall fails or if the program at the other end of the pipe exited with nonzero status. In the latter case, the `close` forces `$!` (`$OS_ERROR`) to zero. So if a `close` on a pipe returns a nonzero status, check `$!` to determine whether the problem was with the pipe itself (nonzero value) or with the program at the other end (zero value). In either event, `$?` (`$CHILD_ERROR`) and `${^CHILD_ERROR_NATIVE}` contain the wait status value (see its interpretation under `system`) of the command associated with the other end of the pipe. For example:

```
open(OUTPUT, "| sort -rn | lpr -p") # pipe to sort and lpr
    || die "Can't start sortlpr pipe: $!";
print OUTPUT @lines;                # print stuff to output
close(OUTPUT)                       # wait for sort to finish
    || warn $! ? "Syserr closing sortlpr pipe: $!"
               : "Wait status $? from sortlpr pipe";
```

A filehandle produced by *dup*(2)ing a pipe is treated as an ordinary filehandle, so `close` will not wait for the child on that filehandle. You have to wait for the child by closing the original filehandle. For example:

```
open(NETSTAT, "netstat -rn |")
    || die "can't run netstat: $!";
open(STDIN, "<&NETSTAT")
    || die "can't dup to stdin: $!";
```

If you close `STDIN` above, there is no wait; if you close `NETSTAT`, there is.

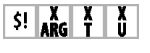
If you somehow manage to reap an exited pipe child on your own, the close will fail. This could happen if you had a `$SIG{CHLD}` handler of your own that got triggered when the pipe child exited, or if you intentionally called `waitpid` on the process ID returned from the `open` call.

closedir


```
closedir DIRHANDLE
```

This function closes a directory opened by `opendir` and returns the success of that operation. See the examples under `readdir`. *`DIRHANDLE`* may be an expression whose value can be used as an indirect dirhandle, usually the real dirhandle name or an autovivified handle object.

connect




```
connect SOCKET, NAME
```

This function initiates a connection with another process that is waiting at an `accept`. The function returns true if it succeeded, false otherwise. *`NAME`* should be a packed network address of the proper type for the socket. For example, assuming `SOCK` is a previously created socket:

```
use Socket;

my ($remote, $port) = ("www.perl.com", 80);
my $destaddr = sockaddr_in($port, inet_aton($remote));
connect(SOCK, $destaddr)
    || die "Can't connect to $remote at port $port: $!";
```

To disconnect a socket, use either `close` or `shutdown`. See also the examples in the section "Sockets" on page 543 in Chapter 15. See *connect*(2). For most socket operations, the higher-level interface provided by the standard `IO::Socket` module is preferred.

continue

This is usually a flow-control statement rather than a function. If there is a `continue` attached to a *`BLOCK`* (typically in a `while` or `foreach`), it is always executed

just before the conditional is about to be evaluated again, just like the third part of a `for(;;)` loop. Thus it can be used to increment a loop variable, even when the loop has been continued via the `next` statement (which is similar to the C `continue` statement).

`last`, `next`, or `redo` may appear within a `continue` block; `last` and `redo` behave as if they had been executed within the main block. So will `next`, but since it will execute a `continue` block, it may be more entertaining.

```
while (EXPR) {
    ### redo always comes here
    do_something;
} continue {
    ### next always comes here
    do_something_else;
    # then back the top to re-check EXPR
}
### last always comes here
```

Omitting the `continue` section is equivalent to using an empty one, logically enough, so `next` goes directly back to check the condition at the top of the loop. See the section "Loop Control" on page 144 in Chapter 4.

However, if the "switch" feature is enabled, `continue` is also an operator that exits the current `when` or `default` block and, by default, falls through to the next one. See the section "The given Statement" on page 133 in Chapter 4.

cos


```
cos EXPR
cos
```

This function returns the cosine of *EXPR* (expressed in radians). For example, the following script will print a cosine table of angles measured in degrees:

```
# Here's the lazy way of getting degrees-to-radians

$pi = atan2(1,1) * 4;
$pi_over_180 = $pi/180;

# Print table
for ($deg = 0; $deg <= 90; $deg++) {
    printf "%3d %7.5f\n", $deg, cos($deg * $pi_over_180);
}
```

For the inverse cosine operation, use the `acos` function from the `Math::Trig` or `POSIX` modules, or else use this relation:

```
sub acos { atan2( sqrt(1 - $_[0] * $_[0]), $_[0] ) }
```

crypt

```
crypt PLAINTEXT, SALT
```

This function computes a one-way hash of a string exactly in the manner of *crypt*(3). This is somewhat useful for checking the password file for lousy passwords,[4] although what you really want to do is prevent people from adding the bad passwords in the first place.

`crypt` is intended to be a one-way function, much like breaking eggs to make an omelette. There is no (known) way to decrypt an encrypted password apart from exhaustive, brute-force guessing.

When verifying an existing encrypted string, you should use the encrypted text as the *SALT* (like `crypt($plain, $crypted) eq $crypted`). This lets your code work with the standard `crypt` (and with more exotic implementations, too).

When choosing a new *SALT*, you minimally need to create a random two-character string whose characters come from the set `[./0-9A-Za-z]` (like `join "", (".", "/", 0..9, "A".."Z", "a".."z")[rand 64, rand 64]`). Older implementations of `crypt` needed only the first two characters of the *SALT*, but code that gives only the first two characters is now considered nonportable. See your local *crypt*(3) manpage for details.

Here's an example that makes sure that whoever runs this program knows his own password:

```
$pwd = (getpwuid ($<))[1];    # Assumes we're on Unix

system "stty -echo";   # or look into Term::ReadKey on CPAN
print "Password: ";
chomp($word = <STDIN>);
print "\n";
system "stty echo";

if (crypt($word, $pwd) ne $pwd) {
    die "Sorry...\n";
} else {
    say "ok";
}
```

Of course, typing in your own password to whoever asks for it is unwise.

Shadow password files are slightly more secure than traditional password files, and you might have to be a superuser to access them. Because few programs should run under such powerful privileges, you might have the program maintain

4. Only people with honorable intentions are allowed to do this.

its own independent authentication system by storing the `crypt` strings in a different file than */etc/passwd* or */etc/shadow*.

The `crypt` function is unsuitable for encrypting large quantities of data, not least of all because you can't get the information back. Look at the `Crypt::*`, `Digest::*`, and `PGP::*` directories on your favorite CPAN mirror for a slew of potentially useful modules.

If using `crypt` on a Unicode string, which may have characters with codepoints above 255, Perl tries copying the string to an 8-bit byte string before calling `crypt` on the copy. If that works, good. If not, `crypt` raises an exception.

dbmclose

```
dbmclose HASH
```

This function breaks the binding between a DBM (database management) file and a hash.

`dbmclose` is really just a call to `untie` with the proper arguments, provided for backward compatibility with ancient versions of Perl.

dbmopen

```
dbmopen HASH, DBNAME, MODE
```

This binds a DBM file to a hash (that is, an associative array). (A DBM consists of a set of C library routines that allow random access to records via a hashing algorithm.) *`HASH`* is the name of the hash (including the `%`). *`DBNAME`* is the name of the database (without any *.dir* or *.pag* extension). If the database does not exist and a valid *`MODE`* is specified, the database is created with the protection specified by *`MODE`*, as modified by the umask. To prevent creation of the database if it doesn't exist, you may specify a *`MODE`* of `undef`, and the function will return false if it can't find an existing database. Values assigned to the hash before the `dbmopen` are not accessible.

The `dbmopen` function is really just a call to `tie` with the proper arguments, provided for backward compatibility with ancient versions of Perl. The return value from `dbmopen` is the same as it would be if you had called `tie` yourself: the tied object on success, or false on failure. You can control which DBM library you use by using the `tie` interface directly or by loading the appropriate module before you call `dbmopen`. Here's an example that works on some systems for versions of `DB_File` similar to the version in your Netscape browser:

```
use DB_File;
dbmopen(%NS_Hist, "$ENV{HOME}/.netscape/history.dat", undef)
    || die "Can't open netscape history file: $!";

while (($url, $when) = each %NS_Hist) {
    next unless defined($when);
    chop ($url, $when);        # kill trailing null bytes
    printf "Visited %s at %s.\n", $url,
        scalar(localtime(unpack("V",$when)));
}
```

If you don't have write access to the DBM file, you can only read the hash variables, not set them. If you want to test whether you can write, either use a file test like `-w $file`, or try setting a dummy hash entry inside an `eval {}`, which will trap the exception.

Functions such as `keys` and `values` may return huge list values when used on large DBM files. You may prefer to use the `each` function to iterate over large DBM files so that you don't load the whole thing in memory at once.

Hashes bound to DBM files have the same limitations as the type of DBM package you're using, including restrictions on how much data you can put into a bucket. If you stick to short keys and values, it's rarely a problem. See also the `DB_File`.

Another thing you should bear in mind is that many existing DBM databases contain null-terminated keys and values because they were set up with C programs in mind. The Netscape history file and the old *sendmail* aliases file are examples. Just use `"$key\0"` when pulling out a value, and remove the null from the value.

```
$alias = $aliases{"postmaster\0"};
$alias =~ s/\0\z//;   # kill the null
```

Starting with v5.8.4, the standard `DBM_Filter` module can handle the business of having null-terminated strings for you automatically.

```
use DB_File;
$db = dbmopen(%aliases, "/etc/mail/aliases", undef)
  || die "can't dbmopen /etc/mail/aliases: $!";
$db->Filter_Push("null");
$alias = $aliases{"postmaster"};
print "postmaster is aliased to $alias\n";
```

The same strategy is useful for pushing a `utf8` filter on the handle. See Chapter 6 for an example of how to use Unicode as keys and values of DBM files.

There is currently no built-in way to lock a generic DBM file. Some would consider this a bug. The `GDBM_File` module does try to provide locking at the granularity of the entire file. When in doubt, your best bet is to use a separate lock file.

defined

```
defined EXPR
defined
```

This function returns a Boolean value saying whether *EXPR* is a defined value. Most data you deal with is defined, but a scalar that contains no valid string, numeric, or reference value is said to contain the undefined value, or `undef` for short. Initializing a scalar variable to a particular value defines it, and it stays defined until you assign an undefined value to it or explicitly call the `undef` function on that variable.

Many operations return `undef` under exceptional conditions, such as at end-of-file, when using an uninitialized variable's value, an operating system error, etc. Since `undef` is just one kind of false value, a simple Boolean test does not distinguish between `undef`, numeric zero, the null string, and the one-character string, "`0`"—all of which are equally false. The `defined` function lets you distinguish between an undefined null string and a defined null string when using operators that might return a real null string.

Here is a fragment that tests a scalar value from a hash:

```
print if defined $switch{D};
```

When used on a hash element like this, `defined` tells only whether the value is defined, not whether the key has an entry in the hash. It's possible to have a key whose value is undefined; the key itself, however, still exists. Use `exists` to determine whether the hash key exists.

In the next example, we exploit the convention that some operations return the undefined value when you run out of data (this presumes there are no elements that contain `undef`):

```
print "$val\n" while defined($val = pop(@ary));
```

In this one, we do the same thing with the `getpwent` function for retrieving information about the system's users.

```
setpwent();
while (defined($name = getpwent())) {
    say "<<$name>>";
}
endpwent();
```

The same thing goes for error returns from syscalls that could validly return a false value:

```
die "Can't readlink $sym: $!"
    unless defined($value = readlink $sym);
```

You may also use `defined` to see whether a subroutine has been defined yet. This makes it possible to avoid blowing up on nonexistent subroutines (or subroutines that have been declared but never given a definition):

```
indir("funcname", @arglist);
sub indir {
    my $subname = shift;
    no strict "refs";  # so we can use subname indirectly
    if (defined &$subname) {
        &$subname(@_);    # or $subname->(@_);
    }
    else {
        warn "Ignoring call to invalid function $subname";
    }
}
```

However, even an undefined subroutine might still be callable, in that its package may have an `AUTOLOAD` function that handles calls to undefined functions in that package.

Use of `defined` on aggregates (hashes and arrays) is deprecated. It used to report whether memory for that aggregate had ever been allocated. Instead, use a simple Boolean test to see whether the array or hash has any elements:

```
if (@an_array) { print "has array elements\n" }
if (%a_hash)   { print "has hash members\n"   }
```

When used on a hash element, it tells you whether the value is defined, not whether the key exists in the hash. Use `exists` for the latter purpose.

See also `undef` and `exists`.

delete

```
delete EXPR
```

This function deletes an element (or a slice of elements) from the specified hash or array. (See `unlink` if you want to delete a file.) Deleted elements are normally returned in the order specified, although this behavior is not guaranteed for tied variables such as DBM files. After the delete operation, the `exists` function returns false on any deleted key or index. (In contrast, after the `undef` function, the `exists` function continues to return true, because the `undef` function only undefines the value of the element, but doesn't delete the element itself.)

Deleting from the `%ENV` hash modifies the environment. Deleting from a hash tied to a (writable) DBM file deletes the entry from that DBM file.

Deleting from an array causes the element at the specified position to revert to a completely uninitialized state, but it doesn't close up the gap, since that would

change the positions of all subsequent entries. Use a `splice` for that. However, if you delete the final element in an array, the array size does shrink by one or more, depending on the position of the next largest existing element, if any.

Calling `delete` on array values is deprecated and likely to be removed in some future version of Perl.

EXPR can be arbitrarily complicated if the final operation is a hash or array lookup:

```
# set up array of array of hash
$dungeon[$x][$y] = \%properties;

# delete one property from hash
delete $dungeon[$x][$y]{"OCCUPIED"};

# delete three properties all at once from hash
delete @{ $dungeon[$x][$y] }{ "OCCUPIED", "DAMP", "LIGHTED" };

# delete reference to %properties from array
delete $dungeon[$x][$y];
```

The following naïve example inefficiently deletes all values from a `%hash`:

```
for my $key (keys %hash) {
    delete $hash{$key};
}
```

As does this:

```
delete @hash{keys %hash};
```

Both are slower than assigning the empty list or undefining it:

```
%hash = ();         # completely empty %hash
undef %hash;        # forget %hash ever existed
```

Likewise for arrays:

```
for my $index (0 .. $#array) {
    delete $array[$index];
}
```

and:

```
delete @array[0 .. $#array];
```

are less efficient than either of:

```
@array = ();         # completely empty @array
undef @array;        # forget @array ever existed
```

The `delete local` *EXPR* construct can also be used to localize the deletion of array or hash elements to the current block. Until the block exits, elements locally deleted temporarily no longer exist.

die

$@

```
die LIST
die
```

Outside an `eval`, this function prints the concatenated value of *LIST* to `STDERR` and exits with the current value of `$!` (the C library's `errno` variable). If `$!` is 0, it exits with the value of `($? >> 8)`, the status of the last reaped child from a `system`, `wait`, `close` on a pipe, or `` `command` ``. If `($? >> 8)` is 0, it exits with 255.

Within an `eval`, the function sets the `$@` variable to the error message that would have otherwise been produced, then aborts the `eval`, which returns `undef`. The `die` function can thus be used to raise named exceptions that can be caught at a higher level in the program. See `eval` later in this chapter.

If *LIST* is a single object reference, that object is assumed to be an exception object and is returned unmodified as the exception in `$@` (described below).

If *LIST* is empty and `$@` already contains a string value (typically from a previous `eval`) that value is reused after appending "`\t...propagated`". This is useful for propagating (reraising) exceptions:

```
eval { ... };
die unless $@ =~ /Expected exception/;
```

If *LIST* is empty and `$@` already contains an exception object, that object's `$@->PROPAGATE` method is invoked with additional file and line number parameters to determine how the exception should propagate, with its return value replacing the value in `$@`. That is, it's as if `$@ = eval { $@->PROPAGATE(__FILE__, __LINE__) }` were called.

If *LIST* is empty and `$@` is empty, then the string "`Died`" is used. If an uncaught exception results in an interpreter exit, the exit code is determined from the values of `$!` and `$?` with this pseudocode:

```
exit $! if $!;              # errno
exit $? >> 8 if $? >> 8;    # child exit status
exit 255;                   # last resort
```

The intent is to squeeze as much possible information about the likely cause into the limited space of the system exit code. However, because `$!` can be set by any syscall, the value of the exit code used by `die` can be unpredictable, so it should not be relied on other than being nonzero.

If the final value of *LIST* does not end in a newline (and you're not passing an exception object), the current script filename, line number, and input line number (if any) are appended to the message, as well as a newline. Hint: sometimes appending "`, stopped`" to your message will cause it to make better sense when

the string "`at scriptname line 123`" is appended. Suppose you are running script *canasta*; consider the difference between the following two ways of dying:

```
die "/usr/games is no good";
die "/usr/games is no good, stopped";
```

which produce, respectively:

```
/usr/games is no good at canasta line 123.
/usr/games is no good, stopped at canasta line 123.
```

If you want your own error messages reporting the filename and line number, use the `__FILE__` and `__LINE__` special tokens (which don't interpolate within strings):

```
die sprintf qq("%s" line "%s", phooey on you!\n),
    __FILE__, __LINE__;
```

This produces output like:

```
"canasta", line 38, phooey on you!
```

One other style issue—consider the following equivalent examples:

```
die "Can"t cd to spool: $!"   unless chdir "/usr/spool/news";

chdir("/usr/spool/news")        || die "Can't cd to spool: $!"
```

Because the important part is the `chdir`, the second form is generally preferred.

You can also call `die` with a reference argument, and if this is trapped within an `eval`, `$@` contains that reference. This permits more elaborate exception handling using objects that maintain arbitrary state about the exception. Such a scheme is sometimes preferable to matching particular string values of `$@` with regular expressions. Because `$@` is a global variable and `eval` may be used within object implementations, be careful that analyzing the error object doesn't replace the reference in the global variable. It's easiest to make a local copy of the reference before any manipulations. Here's an example:

```
use Scalar::Util "blessed";

eval { WHATEVER; die Some::Module::Exception->new( FOO => "bar" ) };
if (my $eval_err = $@) {
    if (blessed($eval_err) && $eval_err->isa("Some::Module::Exception")) {
        # handle Some::Module::Exception
    }
    else {
        # handle all other exceptions
    }
}
```

Because Perl stringifies uncaught exception messages before display, you'll probably want to overload stringification operations on exception objects. See Chapter 13 for details about that.

You can arrange for a function to be run just before `die` by setting `$SIG{__DIE__}` to the function to run. The associated handler is called with the error text, and it can change the error message (if it wants to) by calling `die` again. Only the most accomplished and desperate wizards ever attempt such feats of magic, and fewer still survive.

See also `eval`, `exit`, `warn`, `%SIG`, the `warnings` pragma, and the `Carp` module.

do (block)

```
do BLOCK
```

The `do` *`BLOCK`* form executes the sequence of statements in the *`BLOCK`* and returns the value of the last expression evaluated in the block. When modified by a `while` or `until` statement modifier, Perl executes the *`BLOCK`* once before testing the loop condition. (On other statements, the loop modifiers test the conditional first.) The `do` *`BLOCK`* itself does *not* count as a loop, so the loop control statements `next`, `last`, or `redo` cannot be used to leave or restart the block. See the section "Bare Blocks as Loops" on page 147 in Chapter 4 for workarounds.

do (file)

```
do FILE
```

The `do` *`FILE`* form uses the value of *`FILE`* as a filename and executes the contents of the file as a Perl script. Its primary use is (or rather was) to include subroutines from a Perl subroutine library, so that:

```
do "stat.pl";
```

is rather like:

```
scalar eval `cat stat.pl`;   # `type stat.pl` on Windows
```

except that `do` is more efficient, more concise, keeps track of the current filename for error messages, searches the directories listed in the `@INC` array, and updates `%INC` if the file is found. (See Chapter 25.) It also differs in that code evaluated with `do` *`FILE`* cannot see lexicals in the enclosing scope, whereas code in `eval` *`FILE`* does. It's the same, however, in that it reparses the file every time you call it —so you might not want to do this inside a loop unless the filename itself changes at each loop iteration.

If do can't read the file, it returns undef and sets $! to the error. If do can read the file but can't compile it, it returns undef and sets an error message in $@. If the file is successfully compiled, do returns the value of the last expression evaluated.

Inclusion of library modules (which have a mandatory *.pm* suffix) is better done with the use and require operators, which also do error checking and raise an exception if there's a problem. They also offer other benefits: they avoid duplicate loading, help with object-oriented programming, and provide hints to the compiler on function prototypes.

But do *FILE* is still useful for such things as reading program configuration files. Manual error checking can be done this way:

```
# read in config files: system first, then user
for $file ("/usr/share/proggie/defaults.rc",
           "$ENV{HOME}/.someprogrc")
{
    unless ($return = do $file) {
        warn "couldn't parse $file: $@" if $@;
        warn "couldn't do $file: $!"    unless defined $return;
        warn "couldn't run $file"       unless $return;
    }
}
```

A long-running daemon could periodically examine the timestamp on its configuration file, and if the file has changed since it was last read in, the daemon could use do to reload that file. This is more tidily accomplished with do than with require or use.

do (subroutine)

$@

```
do SUBROUTINE(LIST)
```

The do *SUBROUTINE*(*LIST*) is a deprecated form of a subroutine call. An exception is raised if the *SUBROUTINE* is undefined. See Chapter 7.

dump

```
dump LABEL
dump
```

This function causes an immediate core dump. Primarily this is so that you can use the *undump* program (not supplied) to turn your core dump into an executable binary after having initialized all your variables at the beginning of the program. When the new binary is executed it will begin by executing a goto *LABEL* (with all the restrictions that goto suffers). Think of it as a goto with an intervening core dump and reincarnation. If *LABEL* is omitted, the program is

restarted from the top. Warning: any files opened at the time of the dump will *not* be open any more when the program is reincarnated, with possible resulting confusion on the part of Perl. See also the *–u* command-line option in Chapter 17.

This function is now largely obsolete, partly because it's difficult to convert a core file into an executable in the general case, and partly because various compiler backends for generating portable bytecode and compilable C code have superseded it. However, the people managing the Perl compiler project (meaning *perlcc* and friends), hosted on CPAN, report that `dump` and *undump* support may soon be resurrected.

If you're looking to use `dump` to speed up your program, check out the discussion of efficiency matters in Chapter 21, as well the Perl native-code generator in Chapter 16. You might also consider autoloading or selfloading, which at least make your program *appear* to run faster.

each

```
each HASH
each ARRAY
each EXPR
```

This function steps through a hash one key/value pair at a time. When called in list context, `each` returns a two-element list consisting of the key and value for the next element of a hash so that you can iterate over it. When called in scalar context, `each` returns just the key for the next element in the hash. When the hash is entirely read, the empty list is returned, which when assigned produces a false value in scalar context, such as a loop test. The next call to `each` after that will start iterating again. The typical use is as follows, using predefined `%ENV` hash:

```
while (($key,$value) = each %ENV) {
    say "$key=$value";
}
```

Internally, a hash maintains its own entries in an apparently random order. The `each` function iterates through this sequence because every hash remembers which entry was last returned. The actual ordering of this sequence is subject to change in future versions of Perl, but is guaranteed to be in the same order as the `keys` (or `values`) function would produce on the same (unmodified) hash. For security reasons, this ordering can vary between different runs of the same program.

Perl maintains a single iterator for each hash, shared by all `each`, `keys`, and `values` function calls in the program; it can be reset by reading all the elements from the hash, or by evaluating `keys %hash` or `values %hash`. If you add or delete ele-

ments of a hash while iterating over it, the result is not well defined: entries may be skipped or duplicated.

Starting with v5.12, `each` can also take an array argument. The keys of the array are its indices. Unlike with a hash, pairs are returned in ascending order by key (array index).

Starting with v5.14, `each` can take a reference to an unblessed hash or array, which will be dereferenced automatically. This aspect of `each` is considered experimental. The exact behavior may change in a future version of Perl.

```
while (($key,$value) = each $hashref) { ... }
```

See also `keys`, `values`, and `sort`.

eof


```
eof FILEHANDLE
eof()
eof
```

This function returns true if the next read on *FILEHANDLE* would return end-of-file or if *FILEHANDLE* is not open. *FILEHANDLE* may be an expression whose value gives the real filehandle or a reference to a filehandle object of some sort. An `eof` without an argument returns the end-of-file status for the last file read. An `eof()` with empty parentheses `()` tests the `ARGV` filehandle (most commonly seen as the null filehandle in `<>`). Therefore, inside a `while (<>)` loop, an `eof()` with parentheses will detect the end of only the last of a group of files. Use `eof` (without parentheses) to test *each* file in a `while (<>)` loop. For example, the following code inserts dashes just before the last line of the *last* file:

```
while (<>) {
    if (eof()) {
        say "-" x 30;
    }
    print;
}
```

On the other hand, this script resets line numbering on *each* input file:

```
# reset line numbering on each input file
while (<>) {
    next if /^\s*#/;        # skip comments
    print "$.\t$_";
} continue {
    close ARGV if eof;      # Not eof()!
}
```

Like "$" in a *sed* program, eof tends to show up in line number ranges. Here's a script that prints lines from /pattern/ to the end of each input file:

```
while (<>) {
    print if /pattern/ .. eof;
}
```

Here, the flip-flop operator (..) evaluates the pattern match for each line. Until the pattern matches, the operator returns false. When it finally matches, the operator starts returning true, causing the lines to be printed. When the eof operator finally returns true (at the end of the file being examined), the flip-flop operator resets and starts returning false again for the next file in @ARGV.

Warning: the eof function reads a byte and then pushes it back on the input stream with *ungetc*(3), so it is not useful in an interactive context. Experienced Perl programmers rarely use eof, since the various input operators already behave politely in while-loop conditionals. See the example in the description of foreach in Chapter 4.

eval

```
eval BLOCK
eval EXPR
eval
```

The eval keyword serves two distinct but related purposes in Perl. These purposes are represented by two forms of syntax, eval *BLOCK* and eval *EXPR*. The first form traps runtime exceptions (errors) that would otherwise prove fatal, similar to the "try block" construct in C++ or Java. The second form compiles and executes little bits of code on the fly at runtime, and also (conveniently) traps any exceptions just like the first form. But the second form runs much slower than the first form, since it must parse the string every time. On the other hand, it is also more general. Whichever form you use, eval is the preferred way to do all exception handling in Perl.

For either form of eval, the value returned from an eval is the value of the last expression evaluated, just as with subroutines. Similarly, you may use the return operator to return a value from the middle of the eval. The expression providing the return value is evaluated in void, scalar, or list context, depending on the context of the eval itself. See wantarray for more on how the evaluation context can be determined.

If there is a trappable error (including any produced by the die operator), eval returns undef and puts the error message (or object) in $@. If there is no error,

`$@` is guaranteed to be set to the null string, so you can test it reliably afterward for errors. A simple Boolean test suffices:

```
eval { ... };    # trap runtime errors
if ($@) { ... }  # handle error
```

The `eval` *`BLOCK`* form is syntax checked and compiled at compile time, so it is just as efficient at runtime as any other block. (People familiar with the slow `eval` *`EXPR`* form are occasionally confused on this issue.) Because the *`BLOCK`* is compiled when the surrounding code is, this form of `eval` cannot trap syntax errors.

The `eval` *`EXPR`* form can trap syntax errors because it parses the code at runtime. (If the parse is unsuccessful, it places the parse error in `$@`, as usual.) Otherwise, it executes the value of *`EXPR`* as though it were a little Perl program. The code is executed in the context of the current Perl program, which means that it can see any enclosing lexicals from a surrounding scope, and that any nonlocal variable settings remain in effect after the `eval` is complete, as do any subroutine or format definitions. The code of the `eval` is treated as a block, so any locally scoped variables declared within the `eval` last only until the `eval` is done. (See `my` and `local`.) As with any code in a block, a final semicolon is not required.

Here is a simple Perl shell. It prompts the user to enter a string of arbitrary Perl code, compiles and executes that string, and prints whatever error occurred:

```
print "\nEnter some Perl code: ";

while (<STDIN>) {
    eval;
    print $@;
    print "\nEnter some more Perl code: ";
}
```

Here is a *rename* program to do a mass renaming of files using a Perl expression:

```
#!/usr/bin/perl
# rename - change filenames
$op = shift;
for (@ARGV) {
    $was = $_;
    eval $op;
    die if $@;
    # next line calls the built-in function, not
    # the script by the same name
    rename($was,$_) unless $was eq $_;
}
```

You'd use that program like this:

```
% rename 's/\.orig$//'               *.orig
% rename 'y/A-Z/a-z/ unless /^Make/' *
% rename '$_ .= ".bad"'              *.f
```

Since `eval` traps errors that would otherwise prove fatal, it is useful for determining whether particular features (such as `fork` or `symlink`) are implemented.

Because `eval` *`BLOCK`* is syntax checked at compile time, any syntax error is reported earlier. Therefore, if your code is invariant and both `eval` *`EXPR`* and `eval` *`BLOCK`* will suit your purposes equally well, the *`BLOCK`* form is preferred. For example:

```
# make divide-by-zero nonfatal
eval { $answer = $a / $b };     warn $@ if $@;

# same thing, but less efficient if run multiple times
eval '$answer = $a / $b';       warn $@ if $@;

# a compile-time syntax error (not trapped)
eval { $answer = };             # WRONG

# a runtime syntax error
eval '$answer =';               # sets $@
```

Here, the code in the *`BLOCK`* has to be valid Perl code to make it past the compile phase. The code in the *`EXPR`* doesn't get examined until runtime, so it doesn't cause an error until runtime.

The block of `eval` *`BLOCK`* does *not* count as a loop, so the loop control statements `next`, `last`, or `redo` cannot be used to leave or restart the block.

An `eval` *`STRING`* executed within the `DB` package doesn't see the usual surrounding lexical scope, but rather the scope of the first non-DB piece of code that called it. You don't normally need to worry about this unless you are writing a Perl debugger.

exec

```
exec PATHNAME LIST
exec LIST
```

The `exec` function terminates the current program and executes an external command *and never returns!!!* Use `system` instead of `exec` to return to your program after the commands complete. The `exec` function fails and returns false only if the command does not exist *and* if it is executed directly instead of via your system's command shell, discussed below.

If there is only one scalar argument, the argument is checked for shell metacharacters. If metacharacters are found, the entire argument is passed to the system's

standard command interpreter (*/bin/sh* under Unix). If there are no metacharacters, the argument is split into words and executed directly, since in the interests of efficiency this bypasses the overhead of shell processing. It also gives you more control of error recovery should the program not exist.

If there is more than one argument in *LIST*, or if *LIST* is an array with more than one value, the system shell will never be used. This also bypasses any shell processing of the command. The presence or absence of metacharacters in the arguments doesn't affect this list-triggered behavior, which makes it the preferred form in security-conscious programs that do not wish to expose themselves to injection attacks via shell escapes.

This example causes the currently running Perl program to replace itself with the *echo* program, which then prints out the current argument list:

```
exec "echo", "Your arguments are: ", @ARGV;
```

This example shows that you can `exec` a pipeline, not just a single program.

```
exec "sort $outfile | uniq"
    || die "Can't do sort/uniq: $!";
```

Ordinarily, `exec` never returns—if it does return, it always returns false, and you should check `$!` to find out what went wrong. In very old releases of Perl (before v5.6), `exec` (and `system`) did not flush your output buffer, so you needed to enable command buffering by setting `$|` on one or more filehandles to avoid lost output with `exec` or misordered output with `system`.

When you ask the operating system to execute a new program within an existing process (as Perl's `exec` function does), you tell the system the location of the program to execute, but you also tell the new program (through its first argument) the name under which the program was invoked. Customarily, the name you tell it is just a copy of the location of the program, but it doesn't necessarily have to be, since there are two separate arguments at the level of the C language. When it is not a copy, you have the odd result that the new program thinks it's running under a name that may be totally different from the actual pathname where the program resides. Often this doesn't matter to the program in question, but some programs do care and adopt a different persona depending on what they think their name is. For example, the *vi* editor looks to see whether it was called as "`vi`" or as "`view`". If invoked as "`view`", it automatically enables read-only mode, just as though it were called with the *–R* command-line option.

This is where `exec`'s optional *PATHNAME* parameter comes into play. Syntactically, it goes in the indirect-object slot like the filehandle for `print` or `printf`. It therefore doesn't take a comma afterwards, because it's not exactly part of the argument list. (In a sense, Perl takes the opposite approach from the operating system in

that it assumes the first argument is the important one, and lets you modify the pathname if it differs.) For example:

```
$editor = "/usr/bin/vi";
exec $editor "view", @files      # trigger read-only mode
    || die "Couldn't execute $editor: $!";
```

As with any other indirect object, you can also replace the simple scalar holding the program name with a block containing arbitrary code, which simplifies the previous example to:

```
exec { "/usr/bin/vi" } "view", @files      # trigger read-only mode
    || die "Couldn't execute /usr/bin/vi: $!";
```

As we mentioned earlier, `exec` treats a discrete list of arguments as a directive to bypass shell processing. However, there is one place where you might still get tripped up. The `exec` call (and `system`, too) cannot distinguish between a single scalar argument and an array containing only one element.

```
@args = ("echo surprise");  # just one element in list
exec @args                  # still subject to shell escapes
     || die "exec: $!";     #   because @args == 1
```

To avoid this, use the *PATHNAME* syntax, explicitly duplicating the first argument as the pathname, which forces the rest of the arguments to be interpreted as a list, even if there is only one of them:

```
exec { $args[0] } @args   # safe even with one-argument list
    || die "can't exec @args: $!";
```

The first version, the one without the curlies, runs the *echo* program, passing "`surprise`" as an argument. The second version doesn't; it tries to run a program literally called *echo surprise*, doesn't find it (we hope), and sets `$!` to a nonzero value indicating failure.

Because the `exec` function is most often used shortly after a `fork`, it is assumed that anything that normally happens when a Perl process terminates should be skipped. On an `exec`, Perl does not call your `END` blocks, nor will it call any `DESTROY` methods associated with any objects. Otherwise, your child process would end up doing the cleanup you expected the parent process to do. (We wish that were the case in real life.)

Because it's such a common mistake to use `exec` instead of `system`, Perl warns you if there is a following statement that isn't `die`, `warn`, or `exit`, provided you have warnings enabled. (You *do* have warnings enabled, right?) If you really want to follow an `exec` with some other statement, you can use either of these styles to avoid the warning:

```
exec ("foo")   || print STDERR "couldn't exec foo: $!";
{ exec ("foo") }; print STDERR "couldn't exec foo: $!";
```

As the second line above shows, a call to `exec` that is the last statement in a block is exempt from this warning.

Perl attempts to flush all files opened for output before the exec, but this may not be supported on some platforms. To be safe, you may need to set `$|` (`$AUTOFLUSH` in English) or call the `autoflush` method of `IO::Handle` on any open handles to avoid lost output.

Note that on an `exec`, `END` blocks are not called and `DESTROY` methods are not invoked on your objects.

See also `system`.

exists

```
exists EXPR
```

Given an expression that specifies an element of a hash, this function returns true if the specified element in the hash has ever been initialized, even if the corresponding value is undefined.

```
print "True\n"      if         $hash{$key};
print "Exists\n"    if exists  $hash{$key};
print "Defined\n"   if defined $hash{$key};
```

Historically, `exists` may also be called on array elements, but its behavior is less obvious and is strongly tied to the use of `delete` on arrays. However, calling `exists` on array values is deprecated and likely to be removed in a future version of Perl.

```
print "True\n"      if         $array[$index];
print "Exists\n"    if exists  $array[$index];
print "Defined\n"   if defined $array[$index];
```

An element can be true only if it's defined, and it can be defined only if it exists, but the reverse doesn't necessarily hold.

EXPR can be arbitrarily complicated, provided the final operation is a hash key or array index lookup:

```
if (exists $hash{A}{B}{$key}) { ... }
```

Although the last element does not spring into existence just because its existence was tested, intervening ones do. Thus, `$$hash{"A"}` and `$hash{"A"}->{"B"}` both spring into existence. This is not a function of `exists`, *per se*; it happens anywhere the arrow operator is used (explicitly or implicitly):

```
undef $ref;
if (exists $ref->{"Some key"}) { }
print $ref;   # prints HASH(0x80d3d5c)
```

Even though the "`Some key`" element didn't spring into existence, the previously undefined `$ref` variable did suddenly come to hold an anonymous hash. This is a surprising instance of *autovivification* in what does not at first—or even second—glance appear to be an lvalue context. This behavior is likely to be fixed in a future release. As a workaround, you can nest your calls:

```
if (       $ref                &&
     exists $ref->[$x]          &&
     exists $ref->[$x][$y]      &&
     exists $ref->[$x][$y]{$key} &&
     exists $ref->[$x][$y]{$key}[2] ) { ... }
```

If *EXPR* is the name of a subroutine, the `exists` function returns true if that subroutine has been declared, even if it has not yet been defined. The following prints "`Exists`" only:

```
sub flub;
print "Exists\n"     if exists  &flub;
print "Defined\n"    if defined &flub;
```

Using `exists` on a subroutine name can be useful for an `AUTOLOAD` subroutine that needs to know whether a particular package wants a particular subroutine to be defined. The package can indicate this by declaring a stub `sub` like `flub`, as shown above.

Accidentally using the return value of a subroutine *call*, rather than a subroutine *name*, as an argument to `exists` is an error.

```
exists &sub;    # OK
exists &sub();  # Error: the parens would call the function
```

exit

```
exit EXPR
exit
```

This function evaluates *EXPR* as an integer and exits immediately with that value as the final error status of the program. If *EXPR* is omitted, the function exits with `0` status (meaning "no error"). Here's a fragment that lets a user exit the program by typing `x` or `X`:

```
$ans = <STDIN>;
exit if $ans =~ /^[Xx]/;
```

You shouldn't use `exit` to abort a subroutine if there's any chance that someone might want to trap whatever error happened. Use `die` instead, which can be

trapped by an `eval`. Or use one of `die`'s wrappers from the `Carp` module, like `croak` or `confess`.

We said that the `exit` function exits immediately, but that was a bald-faced lie. It exits as soon as possible, but first it calls any defined `END` routines for at-exit handling. These routines cannot abort the exit, although they can change the eventual exit value by setting the `$?` variable. Likewise, any class that defines a `DESTROY` method will invoke that method on behalf of all its objects before the real program exits. If you really need to bypass exit processing, you can call the `POSIX` module's `_exit` function to avoid all `END` and destructor processing. And if `POSIX` isn't available, you can `exec "/bin/false"` or some such.

exp

```
exp EXPR
exp
```

This function returns *e*, the natural logarithm base, to the power of *EXPR*. To get the value of *e*, use `exp(1)`. For general exponentiation of different bases, use the `**` operator we stole from FORTRAN:

```
use Math::Complex;
print -exp(1) ** (i * pi);   # prints 1(ish)
```

__FILE__

A special token that returns the name of the file in which it occurs. See "Generating Perl in Other Languages" on page 717 in Chapter 21.

fc

```
fc EXPR
fc
```

New to v5.16, this function returns the full Unicode casefold of *EXPR*. This is the internal function implementing the `\F` escape in casefolded strings. Just as titlecase is based on uppercase but different, foldcase is based on lowercase but different. In ASCII there is a one-to-one mapping between only two cases, but in Unicode there is a one-to-many mapping and between three cases. Because that's too many combinations to check manually each time, a fourth casemap called foldcase was invented as a common intermediary for the other three. It is not a case itself, but it *is* a casemap.

To compare whether two strings are the same without regard to case, do this:

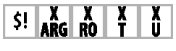
```
fc($a) eq fc($b)
```

Prior to v5.16, the only reliable way to compare strings case-insensitively was with the `/i` pattern modifier, because Perl has always used casefolding semantics for case-insensitive pattern matches. Knowing this, you can emulate equality comparisons like this:

```
sub fc_eq($$) {
    my($a, $b) = @_;
    return $a =~ /\A\Q$b\E\z/i;
}
```

For earlier releases than v5.16, the `fc` function can be found in the `Unicode::CaseFold` module on CPAN. For comparisons that are both accent- and case-insensitive, use the `eq` or `cmp` methods with a `Unicode::Collate` collator object that was passed `level=>1` in its constructor, or with a `Unicode::Collate::Locale` object similarly constructed for locale-specific equality and ordering. See "A Case of Mistaken Identity" and "Comparing and Sorting Unicode Text" in Chapter 6.

fcntl




```
fcntl FILEHANDLE, FUNCTION, SCALAR
```

This function calls your operating system's file control functions, as documented in the *fcntl*(2) manpage. Before you call `fcntl`, you'll probably first have to say:

```
use Fcntl;
```

to load the correct constant definitions.

`SCALAR` will be read or written (or both) depending on the *`FUNCTION`*. A pointer to the string value of *`SCALAR`* will be passed as the third argument of the actual *fcntl* call. (If *`SCALAR`* has no string value but does have a numeric value, that value will be passed directly rather than passing a pointer to the string value.) See the `Fcntl` module for a description of the more common permissible values for *`FUNCTION`*.

The `fcntl` function will raise an exception if used on a system that doesn't implement *fcntl*(2). On systems that do implement it, you can do such things as modify the close-on-exec flags (if you don't want to play with the `$^F` (`$SYSTEM_FD_MAX`) variable), modify the nonblocking I/O flags, emulate the *lockf*(3) function, and arrange to receive the `SIGIO` signal when I/O is pending.

Here's an example of setting a filehandle named `REMOTE` to be nonblocking at the system level. This makes any input operation return immediately if nothing is available when reading from a pipe, socket, or serial line that would otherwise block. It also works to cause output operations that normally would block to

return a failure status instead. (For those, you'll likely have to negotiate `$|` as well.)

```
use Fcntl qw(F_GETFL F_SETFL O_NONBLOCK);

$flags = fcntl(REMOTE, F_GETFL, 0)
            || die "Can't get flags for the socket: $!";

$flags = fcntl(REMOTE, F_SETFL, $flags | O_NONBLOCK)
            || die "Can't set flags for the socket: $!";
```

The return value of `fcntl` (and `ioctl`) is shown in Table 27-1.

Table 27-1. Return values for fcntl

Syscall Returns	Perl Returns
`-1`	`undef`
`0`	String "`0 but true`"
Anything else	That number

Thus, Perl returns true on success and false on failure, yet you can still easily determine the actual value returned by the operating system:

```
$retval = fcntl(...) || -1;
printf "fcntl actually returned %d\n", $retval;
```

Here, even the string "`0 but true`" prints as 0, thanks to the `%d` format. This string is true in Boolean context and `0` in numeric context. This lets you use a simple `|| die` test on the return value instead of the skewed version, `// die`. (It is also happily exempt from the normal warnings on improper numeric conversions.)

fileno

```
fileno FILEHANDLE
```

This function returns the file descriptor underlying a filehandle. If the filehandle is not open, `fileno` returns `undef`. If there is no real file descriptor at the OS level, as can happen with filehandles connected to memory objects via `open` with a reference for the third argument, `-1` is returned.

A *file descriptor* is a small, nonnegative integer like 0 or 1, in contrast to filehandles like `STDIN` and `STDOUT`, which are symbols. Unfortunately, the operating system doesn't know about your cool symbols. It only thinks of open files using these small file numbers, and although Perl will usually do the translations for you automatically, occasionally you have to know the actual file descriptor.

So, for example, the `fileno` function is useful for constructing bitmaps for `select` and for passing to certain obscure system calls if *syscall*(2) is implemented. It's also useful for double checking that the `open` function gave you the file descriptor you wanted and for determining whether two filehandles use the same system file descriptor.

```
if (fileno(THIS) == fileno(THAT)) {
    say "THIS and THAT are dups";
}
```

If *`FILEHANDLE`* is an expression, the value is taken as an indirect filehandle, generally its name or a reference to something resembling a filehandle object.

Don't count on the association of a Perl filehandle and a numeric file descriptor throughout the life of the program. If a file has been closed and reopened, the file descriptor may change. Perl takes a bit of trouble to try to ensure that certain file descriptors won't be lost if an `open` on them fails, but it only does this for file descriptors that don't exceed the current value of the special `$^F` (`$SYSTEM_FD_MAX`) variable (by default, 2). Although filehandles `STDIN`, `STDOUT`, and `STDERR` start out with file descriptors of 0, 1, and 2 (the Unix standard convention), even they can change if you start closing and opening them with wild abandon. You can't get into trouble with 0, 1, and 2 so long as you always reopen immediately after closing. The basic rule on Unix systems is to pick the lowest available descriptor, and that'll be the one you just closed.

flock


```
flock FILEHANDLE, OPERATION
```

The `flock` function is Perl's portable file-locking interface. It locks only entire files, not individual records. The function manages locks on the file associated with *`FILEHANDLE`*, returning true for success and false otherwise. To avoid the possibility of lost data, Perl flushes your *`FILEHANDLE`* before locking or unlocking it. Perl might implement its `flock` using *flock*(2), *fcntl*(2), *lockf*(3), or some other platform-specific lock mechanism; if none of these is available, calling `flock` raises an exception. See the section "File Locking" on page 524 in Chapter 15.

`OPERATION` is one of `LOCK_SH`, `LOCK_EX`, or `LOCK_UN`, possibly OR'd with `LOCK_NB`. These constants are traditionally valued `1`, `2`, `8`, and `4`, but you can use the symbolic names if you import them from the `Fcntl` module, either individually or as a group using the `:flock` tag.

`LOCK_SH` requests a shared lock, so it's typically used for reading. `LOCK_EX` requests an exclusive lock, so it's typically used for writing. `LOCK_UN` releases a previously requested lock; closing the file also releases any locks. If the `LOCK_NB` bit is used

with LOCK_SH or LOCK_EX, flock returns immediately rather than waiting for an unavailable lock. Check the return status to see whether you got the lock you asked for. If you don't use LOCK_NB, you might wait indefinitely for the lock to be granted.

Another nonobvious but traditional aspect of flock is that its locks are *merely advisory*. Discretionary locks are more flexible but offer fewer guarantees than mandatory ones. This means that files locked with flock may be modified by programs that do not also use flock. Cars that stop for red lights get on well with one another, but not with cars that don't stop for red lights. Drive defensively.

Some implementations of flock cannot lock things over the network. While you could in theory use the more system-specific fcntl for that, the jury (having sequestered itself on the case for the last couple of decades or so) is still out on whether this is (or even can be) reliable.

Here's a mailbox appender for Unix systems that use *flock*(2) to lock mailboxes:

```
use Fcntl qw/:flock/;       # import LOCK_* constants
sub mylock {
    flock(MBOX, LOCK_EX)
        || die "can't lock mailbox: $!";
    # in case someone appended while we were waiting
    # and our stdio buffer is out of sync
    seek(MBOX, 0, 2)
        || die "can't seek to the end of mailbox: $!";
}

open(MBOX, ">> /usr/spool/mail/$ENV{USER}")
    || die "can't open mailbox: $!";

mylock();
say MBOX $msg, "\n";
close MBOX
    || die "can't close mailbox: $!";
```

On systems that support a real *flock*(2) syscall, locks are inherited across fork calls. Other implementations are not so lucky and are likely to lose the locks across forks. See also the section "File Locking" on page 524 in Chapter 15 for other flock examples.

fork

```
fork
```

This function creates two processes out of one by invoking the *fork*(2) syscall. If it succeeds, the function returns the new child process's ID to the parent process

and 0 to the child process. If the system doesn't have sufficient resources to allocate a new process, the call fails and returns `undef`. File descriptors (and sometimes locks on those descriptors) are shared, while everything else is copied —or at least made to look that way.

In ancient versions, unflushed buffers remain unflushed in both processes, which means you might need to set `$|` on one or more filehandles earlier in the program to avoid duplicate output.

A nearly bulletproof way to launch a child process while checking for "cannot fork" errors would be:

```
use Errno qw(EAGAIN);
FORK: {
    if ($pid = fork) {
        # parent here
        # child process pid is available in $pid
    }
    elsif (defined $pid) { # $pid is zero here if defined
        # child here
        # parent process pid is available with getppid
    }
    elsif ($! == EAGAIN) {
        # EAGAIN is the supposedly recoverable fork error
        sleep 5;
        redo FORK;
    }
    else {
        # weird fork error
        die "Can't fork: $!";
    }
}
```

These precautions are not necessary on operations that do an implicit *fork*(2)—such as `system`, backticks, or opening a process as a filehandle—because Perl automatically retries a fork on a temporary failure when it's doing the `fork` for you. Be careful to end the child code with an `exit`; otherwise, your child will inadvertently leave the conditional block and start executing code intended only for the parent process.

If you `fork` without ever waiting on your children, you will accumulate zombies (exited processes whose parents haven't waited on them yet). On some systems, you can avoid this by setting `$SIG{CHLD}` to "`IGNORE`"; on most, you must `wait` for your moribund children. See "wait" in this chapter for examples of doing this, or see the section "Signals" on page 518 in Chapter 15 for more on `SIGCHLD`.

If a forked child inherits system file descriptors like `STDIN` and `STDOUT` that are connected to a remote pipe or socket, you may have to reopen these in the child

to */dev/null*. That's because even when the parent process exits, the child will live on with its copies of those filehandles. The remote server (such as, say, a CGI script or a background job launched from a remote shell) will appear to hang because it's still waiting for all copies to be closed. Reopening the system filehandles to something else fixes this.

On most systems supporting *fork*(2), great care has gone into making it extremely efficient (for example, using copy-on-write technology on data pages), making it the dominant paradigm for multitasking over the last few decades. The `fork` function is unlikely to be implemented efficiently (or perhaps at all) on systems that don't resemble Unix. For example, Perl emulates a proper `fork` even on Microsoft systems, but no assurances are made on performance. You might have more luck there with the `Win32::Process` module.

Perl attempts to flush all files opened for output before forking the child process, but this may not be supported on some platforms. To be safe, you may need to set `$|` (`$AUTOFLUSH` in English) or call the `autoflush` method from `IO::Handle` on any open handles to avoid duplicate output.

If you `fork` without ever waiting on your children, you will accumulate zombies. On some systems, you can avoid this by setting `$SIG{CHLD}` to "`IGNORE`". See also Chapter 15 for more examples of forking and reaping moribund children.

Note that if your forked child inherits system file descriptors like `STDIN` and `STDOUT` that are actually connected by a pipe or socket, then the remote server (such as, say, a CGI script or a backgrounded job launched from a remote shell) won't think you're done, even if you exit the parent process. You should reopen those to */dev/null* if this is an issue.

format

```
format NAME =
     picture line
     value list
     ...
 .
```

This function declares a named sequence of picture lines (with associated values) for use by the `write` function. If *NAME* is omitted, the name defaults to `STDOUT`, which happens to be the default format name for the `STDOUT` filehandle. Since, like a `sub` declaration, this is a package-global declaration that happens at compile time, any variables used in the value list need to be visible at the point of the format's declaration. That is, lexically scoped variables must be declared earlier in the file, while dynamically scoped variables merely need to be set at the time

write is called. Here's an example (which assumes we've already calculated $cost and $quantity):

```
my $str = "widget";               # Lexically scoped variable

format Nice_Output =
Test: @<<<<<<<< @||||| @>>>>>
      $str,     $%,    '$' . int($num)
.

local $~ = "Nice_Output";         # Select our format
local $num = $cost * $quantity;   # Dynamically scoped variable

write;
```

Like filehandles, format names are identifiers that exist in a symbol table (package) and may be fully qualified by package name. Within the typeglobs of a symbol table's entries, formats reside in their own namespace, which is distinct from filehandles, directory handles, scalars, arrays, hashes, and subroutines. Like those other six types, however, a format named Whatever would also be affected by a local on the *Whatever typeglob. In other words, a format is just another gadget contained in a typeglob, independent of the other gadgets.

The section "Picture Formats" on page 810 in Chapter 26 contains numerous details and examples of their use. Chapter 25 describes the internal format-specific variables, and the English and IO::Handle modules provide easier access to them.

formline

```
formline PICTURE, LIST
```

This is an internal function used by formats, although you may also call it yourself. It always returns true. It formats a list of values according to the contents of *PICTURE*, placing the output into the format output accumulator, $^A (or $ACCUMULATOR if you use the English module). Eventually, when a write is done, the contents of $^A are written to some filehandle, but you could also read $^A yourself and then set $^A back to "". A format typically does one formline per line of form, but the formline function itself doesn't care how many newlines are embedded in the *PICTURE*. This means that the ~ and ~~ tokens will treat the entire *PICTURE* as a single line. You may therefore need to use multiple formlines to implement a single record format, just as the format compiler does internally.

Be careful if you put double quotes around the picture, since an @ character may be taken to mean the beginning of an array name. See the section "Picture Formats" on page 810 in Chapter 26 for example uses.

```
getc FILEHANDLE
getc
```

This function returns the next character from the input file attached to *FILEHANDLE*. It returns `undef` at end-of-file or if an I/O error was encountered. If *FILEHANDLE* is omitted, the function reads from `STDIN`.

This function is somewhat slow, but it's occasionally useful for single-character input from the keyboard—provided you manage to get your keyboard input unbuffered. This function requests unbuffered input from the standard I/O library. Unfortunately, the standard I/O library is not so standard as to provide a portable way to tell the underlying operating system to supply unbuffered keyboard input to the standard I/O system. To do that, you have to be slightly more clever, and in an operating-system-dependent fashion. Under Unix you might say this:

```
if ($BSD_STYLE) {
    system "stty cbreak </dev/tty >/dev/tty 2>&1";
} else {
    system "stty", "-icanon", "eol", "\001";
}

$key = getc;

if ($BSD_STYLE) {
    system "stty -cbreak </dev/tty >/dev/tty 2>&1";
} else {
    system "stty", "icanon", "eol", "^@"; # ASCII NUL
}
print "\n";
```

This code puts the next character typed on the terminal in the string `$key`. If your *stty* program has options like `cbreak`, you'll need to use the code where `$BSD_STYLE` is true. Otherwise, you'll need to use the code where it is false. Determining the options for *stty*(1) is left as an exercise to the reader.

The `POSIX` module provides a more portable version of this using the `POSIX::getattr` function on systems purporting POSIX compliance. See also the `Term::ReadKey` module from your nearest CPAN site for a more portable and flexible approach. For the `ungetc` function, use the method in the `IO::Handle` class.

getgrent

```
getgrent
setgrent
endgrent
```

These routines iterate through your */etc/group* file (or maybe someone else's */etc/group* file, if it's coming from a server somewhere). The return value from `getgrent` in list context is:

```
#  0      1        2     3
($name, $passwd, $gid, $members) = getgrent();
```

where `$members` contains a space-separated list of the login names of the members of the group. To set up a hash for translating group names to GIDs, say this:

```
while (($name, $passwd, $gid) = getgrent()) {
    $gid{$name} = $gid;
}
```

In scalar context, `getgrent` returns only the group name. The standard `User::grent` module supports a by-name interface to this function. See *getgrent*(3).

getgrgid

```
getgrgid GID
```

This function looks up a group file entry by group number. The return value in list context is:

```
#  0      1        2     3
($name, $passwd, $gid, $members)
    = getgrgid(0);
```

where `$members` contains a space-separated list of the login names of the members of the group. If you want to do this repeatedly, consider caching the data in a hash using `getgrent`.

In scalar context, `getgrgid` returns only the group name. The `User::grent` module supports a by-name interface to this function. See *getgrgid*(3).

getgrnam

```
getgrnam NAME
```

This function looks up a group file entry by group name. The return value in list context is:

```
#  0      1        2     3
($name, $passwd, $gid, $members) =
    getgrnam("wheel");
```

where `$members` contains a space-separated list of login names that are members of the group. If you want to do this repeatedly, consider caching the data in a hash using `getgrent`.

In scalar context, `getgrnam` returns only the numeric group ID. The `User::grent` module supports a by-name interface to this function. See *getgrnam*(3).

gethostbyaddr


```
gethostbyaddr ADDR, ADDRTYPE
```

This function translates addresses into names (and alternate addresses). *`ADDR`* should be a packed binary network address, and *`ADDRTYPE`* should in practice usually be `AF_INET` (from the `Socket` module). The return value in list context is:

```
#  0      1         2          3       4 ...
($name, $aliases, $addrtype, $length, @addrs) =
    gethostbyaddr($packed_binary_address, $addrtype);
```

where `@addrs` is a list of packed binary addresses. In the Internet domain, each address is (historically) four bytes long and can be unpacked by saying something like:

```
($a, $b, $c, $d) = unpack("C4", $addrs[0]);
```

Alternatively, you can convert directly to dot-vector notation with the `v` modifier to `sprintf`:

```
$dots = sprintf "%vd", $addrs[0];
```

The `inet_ntoa` function from the `Socket` module is useful for producing a printable version. This approach will become important if and when we all ever manage to switch over to IPv6.

```
use Socket;
$printable_address = inet_ntoa($addrs[0]);
```

In scalar context, `gethostbyaddr` returns only the hostname.

To produce an *`ADDR`* from a dot vector, say this:

```
use Socket;
$ipaddr = inet_aton("127.0.0.1");       # localhost
$claimed_hostname = gethostbyaddr($ipaddr, AF_INET);
```

See the section "Sockets" on page 543 in Chapter 15 for more examples. The `Net::hostent` module supports a by-name interface to this function. See *gethostbyaddr*(3).

The `Socket` module is a `gethostinfo` function that works for addresses in all common forms, including IPv6.

The `getaddrinfo` function is used to get a list of IP addresses and port numbers for a given host (and possibly service), and it provides more flexibility than the *gethostbyname*(3) and *getservbyname*(3) functions.

```
use Socket qw(:all);
@addr_structs = getaddrinfo("127.0.0.1");   # IPv4 loopback
@addr_structs = getaddrinfo("207.171.7.72");

@addr_structs = getaddrinfo("::1");         # IPv6 loopback
@addr_structs = getaddrinfo("e80::223:12ff:fe58:714c");
```

gethostbyname


```
gethostbyname NAME
```

This function translates a network hostname to its corresponding addresses (and other names). The return value in list context is:

```
#  0      1         2          3       4 ...
($name, $aliases, $addrtype, $length, @addrs) =
    gethostbyname($remote_hostname);
```

where `@addrs` is a list of raw addresses. In the Internet domain, each address is (historically) four bytes long and can be unpacked by saying something like:

```
($a, $b, $c, $d) = unpack("C4", $addrs[0]);
```

You can convert directly to dot-vector notation with the `v` modifier to `sprintf`:

```
$dots = sprintf "%vd", $addrs[0];
```

In scalar context, `gethostbyname` returns only the host address:

```
use Socket;
$ipaddr = gethostbyname($remote_host);
printf "%s has address %s\n",
    $remote_host, inet_ntoa($ipaddr);
```

See "Sockets" on page 543 in Chapter 15 for another approach. The `Net::hostent` module supports a by-name interface to this function. See also *gethostbyname*(3).

gethostent

```
gethostent
sethostent STAYOPEN
endhostent
```

These functions iterate through your */etc/hosts* file and return each entry one at a time. The return value from `gethostent` is:

```
($name, $aliases, $addrtype, $length, @addrs)
```

where `@addrs` is a list of raw addresses. In the Internet domain, each address is four bytes long and can be unpacked by saying something like:

```
($a, $b, $c, $d) = unpack("C4", $addrs[0]);
```

Scripts that use `gethostent` should not be considered portable. If a machine uses a name server, it would have to interrogate most of the Internet to try to satisfy a request for all the addresses of every machine on the planet. So `gethostent` is unimplemented on such machines. See *gethostent*(3) for other details.

The `Net::hostent` module supports a by-name interface to this function.

getlogin

```
getlogin
```

This function returns the current login name if found. On Unix systems, this is read from the *utmp*(5) file. If it returns false, use `getpwuid` instead. For example:

```
$login = getlogin() || (getpwuid($<))[0] || "Intruder!!";
```

getnetbyaddr

```
getnetbyaddr ADDR, ADDRTYPE
```

This function translates a network address to the corresponding network name or names. The return value in list context is:

```
use Socket;
($name, $aliases, $addrtype, $net) = getnetbyaddr(127, AF_INET);
```

In scalar context, `getnetbyaddr` returns only the network name. The `Net::netent` module supports a by-name interface to this function. See *getnetbyaddr*(3).

getnetbyname

```
getnetbyname NAME
```

This function translates a network name to its corresponding network address. The return value in list context is:

```
($name, $aliases, $addrtype, $net) = getnetbyname("loopback");
```

In scalar context, `getnetbyname` returns only the network address. The `Net::netent` module supports a by-name interface to this function. See *getnetbyname*(3).

getnetent

```
getnetent
setnetent STAYOPEN
endnetent
```

These functions iterate through your */etc/networks* file. The return value in list context is:

```
($name, $aliases, $addrtype, $net) = getnetent();
```

In scalar context, `getnetent` returns only the network name. The `Net::netent` module supports a by-name interface to this function. See *getnetent*(3).

The concept of network names seems rather quaint these days; most IP addresses are on unnamed (and unnameable) subnets.

getpeername

```
getpeername SOCKET
```

This function returns the packed socket address of the other end of the *SOCKET* connection. For example:

```
use Socket;
$hersockaddr      = getpeername SOCK;
($port, $heraddr) = sockaddr_in($hersockaddr);
$herhostname      = gethostbyaddr($heraddr, AF_INET);
$herstraddr       = inet_ntoa($heraddr);
```

getpgrp

```
getpgrp PID
```

This function returns the current process group for the specified *PID* (use a *PID* of `0` for the current process). Invoking `getpgrp` will raise an exception if used on a machine that doesn't implement *getpgrp*(2). If *PID* is omitted, the function returns the process group of the current process (the same as using a *PID* of `0`). On systems implementing this operator with the POSIX *getpgrp*(2) syscall, *PID* must be omitted or, if supplied, it must be `0`.

getppid

```
getppid
```

This function returns the process ID of the parent process. On the typical Unix system, if your parent process ID changes to 1, it means your parent process has died and you've been adopted by the *init*(8) program.

getpriority

```
getpriority WHICH, WHO
```

This function returns the current priority for a process, a process group, or a user. See *getpriority*(2). Invoking `getpriority` will raise an exception if used on a machine that doesn't implement *getpriority*(2).

The `BSD::Resource` module from CPAN provides a more convenient interface, including the `PRIO_PROCESS`, `PRIO_PGRP`, and `PRIO_USER` symbolic constants to supply for the *WHICH* argument. Although these are traditionally set to `0`, `1`, and `2`, respectively, you really never know what may happen within the dark confines of C's `#include` files.

A value of `0` for *WHO* means the current process, process group, or user. So to get the priority of the current process, use:

```
$curprio = getpriority(0, 0);
```

getprotobyname

```
getprotobyname NAME
```

This function translates a protocol name to its corresponding number. The return value in list context is:

```
($name, $aliases, $protocol_number) = getprotobyname("tcp");
```

When called in scalar context, `getprotobyname` returns only the protocol number. The `Net::proto` module supports a by-name interface to this function. See *getprotobyname*(3).

getprotobynumber

```
getprotobynumber NUMBER
```

This function translates a protocol number to its corresponding name. The return value in list context is:

```
#  1      2         3
($name, $aliases, $protocol_number) = getprotobynumber(6);
```

When called in scalar context, `getprotobynumber` returns only the protocol name. The `Net::proto` module supports a by-name interface to this function. See *getprotobynumber*(3).

getprotoent

```
getprotoent
setprotoent STAYOPEN
endprotoent
```

These functions iterate through the */etc/protocols* file. In list context, the return value from `getprotoent` is:

```
#  1      2         3
($name, $aliases, $protocol_number) = getprotoent();
```

When called in scalar context, `getprotoent` returns only the protocol name. The `Net::proto` module supports a by-name interface to this function. See *getprotent*(3).

getpwent

```
getpwent
setpwent
endpwent
```

These functions conceptually iterate through your */etc/passwd* file, though this may involve the */etc/shadow* file if you're the superuser and are using shadow passwords; it may get a lot fancier than that if you're using some database- or network-based login system. The return value in list context is:

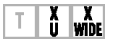
```
#  0     1       2    3    4      5        6     7    8
($name,$passwd,$uid,$gid,$quota,$comment,$gcos,$dir,$shell) = getpwent();
```

Some machines may use the quota and comment fields for purposes other than their named purposes, but the remaining fields will always be the same. To set up a hash for translating login names to UIDs, say this:

```
while (($name, $passwd, $uid) = getpwent()) {
    $uid{$name} = $uid;
}
```

In scalar context, `getpwent` returns only the username. The `User::pwent` module supports a by-name interface to this function. See *getpwent*(3).

getpwnam



```
getpwnam NAME
```

This function translates a username to the corresponding */etc/passwd* file entry. The return value in list context is:

```
#  0     1       2    3    4      5        6     7    8
($name,$passwd,$uid,$gid,$quota,$comment,$gcos,$dir,$shell) = getpwnam("daemon");
```

On systems that support shadow passwords, you will have to be the superuser to retrieve the actual password. Your C library should notice that you're suitably empowered and open the */etc/shadow* file (or wherever it keeps the shadow file). At least, that's how it's supposed to work.

For repeated lookups, consider caching the data in a hash using `getpwent`.

In scalar context, `getpwnam` returns only the numeric user ID. The `User::pwent` module supports a by-name interface to this function. See *getpwnam*(3) and *passwd*(5).

getpwuid

```
getpwuid UID
```

This function translates a numeric user ID to the corresponding */etc/passwd* file entry. The return value in list context is:

```
#  0     1       2    3    4      5        6     7    8
($name,$passwd,$uid,$gid,$quota,$comment,$gcos,$dir,$shell) = getpwuid(2);
```

For repeated lookups, consider caching the data in a hash using `getpwent`.

In scalar context, `getpwuid` returns the username. The `User::pwent` module supports a by-name interface to this function. See *getpwnam*(3) and *passwd*(5).

getservbyname

```
getservbyname NAME, PROTO
```

This function translates a service (port) name to its corresponding port number. *PROTO* is a protocol name such as "`tcp`". The return value in list context is:

```
#  0      1         2             3
($name, $aliases, $port_number, $protocol_name) = getservbyname("www", "tcp");
```

In scalar context, `getservbyname` returns only the service port number. The `Net::servent` module supports a by-name interface to this function. See *getservbyname*(3).

getservbyport

```
getservbyport PORT, PROTO
```

This function translates a service (port) number to its corresponding names. *PROTO* is a protocol name such as "`tcp`". The return value in list context is:

```
#  0      1         2             3
($name, $aliases, $port_number, $protocol_name) = getservbyport(80, "tcp");
```

In scalar context, `getservbyport` returns only the service name. The `Net::servent` module supports a by-name interface to this function. See *getservbyport*(3).

getservent

```
getservent
setservent STAYOPEN
endservent
```

This function iterates through the */etc/services* file or its equivalent. The return value in list context is:

```
#  0      1         2             3
($name, $aliases, $port_number, $protocol_name) = getservent();
```

In scalar context, `getservent` returns only the service port name. The `Net::servent` module supports a by-name interface to this function. See *getservent*(3).

getsockname

```
getsockname SOCKET
```

This function returns the packed socket address of this end of the *SOCKET* connection. (And why wouldn't you know your own address already? Maybe because you bound an address containing wildcards to the server socket before

doing an `accept`, and now you need to know what interface someone used to connect to you. Or you were passed a socket by your parent process—*inetd*, for example.)

```
use Socket;
# assume that SOCK is a connected socket
$mysockaddr = getsockname(SOCK);
($port, $myaddr) = sockaddr_in($mysockaddr);
$myname = gethostbyaddr($myaddr, AF_INET);
printf "I am %s [%vd]\n", $myname, $myaddr;
```

getsockopt


```
getsockopt SOCKET, LEVEL, OPTNAME
```

This function queries the option named *OPTNAME* associated with *SOCKET* at a given *LEVEL*. Options may exist at multiple protocol levels depending on socket type, but at least the uppermost socket level `SOL_SOCKET` (defined in the `Socket` module) will exist. To query options at another level the protocol number of the appropriate protocol controlling the option should be supplied. For example, to indicate that an option is to be interpreted by the TCP protocol, *LEVEL* should be set to the protocol number for TCP, which you can get using `getprotobyname`.

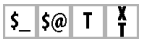
The function returns a packed string representing the requested socket option, or `undef` if there is an error with the reason for that error in `$!`. Just what is in the packed string depends on the *LEVEL* and *OPTNAME*; see *getsockopt*(2) for details. But often the option is an integer, in which case the result is a packed integer, which you can `unpack` with the "`i`" (or `I`) format.

For example, to test whether Nagle's algorithm is enabled on a socket:

```
use Socket qw(:all);

# assume that $socket hold the handle of a connected socket
$tcp = IPPROTO_TCP;
$packed = getsockopt($socket, $tcp, TCP_NODELAY)
    || die "getsockopt: $!";
$nodelay = unpack("I", $packed);
printf "Nagle's algorithm is o%s.\n", $nodelay ? "ff" : "n";
```

See `setsockopt` for more information.

glob



```
glob EXPR
glob
```

This function returns the value of *EXPR* with filename expansions the way a shell would expand them. This is the internal function implementing the `<*>` operator.

For historical reasons, the algorithm matches the *csh*(1)'s style of expansion, not the Bourne shell's. Files whose first character is a dot ("`.`") are ignored unless this character is explicitly matched first. An asterisk ("`*`") matches any sequence of any character (including none). A question mark ("`?`") matches any one character. A square bracket sequence ("`[...]`") specifies a simple character class, like "`[chy0-9]`". Character classes may be negated with a circumflex, as in "`*.[^oa]`", which matches any file with an extension consisting of a period followed by one character that is neither an "a" nor an "o". A tilde ("`~`") expands to a home directory, as in "`~/.*rc`" for all the current user's "rc" files, or "`~jane/Mail/*`" for all of Jane's mail files. Braces may be used for alternation, as in "`~/.{mail,ex,csh,twm,}rc`" to get those particular rc files.

The `glob` function grandfathers the use of whitespace to separate multiple patterns such as `<*.c *.h>`. If you want to glob filenames that might contain whitespace, you'll have to use extra quotes around the spacy filename to protect it. For example, to glob filenames that have an "`e`" followed by a space followed by an "`f`", use either of:

```
@spacies = <"*e f*">;
@spacies = glob  '"*e f*"';
@spacies = glob q("*e f*");
```

If you had to get a variable through, you could do this:

```
@spacies = glob   "'*${var}e f*'";
@spacies = glob qq("*${var}e f*");
```

Alternately, you can use the `File::Glob` module directly; for details, see its manpage. Calling `glob` or the `<*>` operator automatically `use`s that module, so if the module mysteriously vaporizes from your library, an exception is raised.

When you call `open`, Perl does not expand wildcards, even tildes. You need to `glob` the result first:

```
open(MAILRC, "~/.mailrc")               # WRONG: tilde is a shell thing
    || die "can't open ~/.mailrc: $!";

open(MAILRC, <~/.mailrc>)               # expand tilde first
    || die "can't open ~/.mailrc: $!";
```

```
open(MAILRC, (glob("~/.mailrc"))[0])     # same, but more
    || die "can't open ~/.mailrc: $!";   # careful of list return
```

If nonempty braces are the only wildcard characters used in the `glob`, no filenames are matched, but potentially many strings are returned. For example, this produces nine strings, one for each pairing of fruits and colors:

```
@many =  glob "{apple,tomato,cherry}={green,yellow,red}";
```

The `glob` function is not related to the Perl notion of typeglobs, other than that they both use a `*` to represent multiple items.

See also the section "Filename Globbing Operator" on page 91 in Chapter 2.

gmtime

```
gmtime EXPR
gmtime
```

This function converts a time as returned by the `time` function to a nine-element list with the time correct for what was historically called Greenwich Mean Time (GMT), but which is now known as Coordinated Universal Time (UTC). It's typically used as follows:

```
#  0    1    2     3     4    5     6     7     8
($sec,$min,$hour,$mday,$mon,$year,$wday,$yday,$isdst) = gmtime;
```

If as here the *EXPR* is omitted, it does `gmtime(time())`. The Perl library module `Time::Local` contains a subroutine, `timegm`, that can convert the list back into a time value.

All list elements are numeric and come straight out of a `struct tm` (that's a C programming structure—don't sweat it). In particular, this means that `$mon` has the range `0..11`, with January as month 0, and `$wday` has the range `0..6`, with Sunday as day `0`. You can remember which ones are zero-based because those are the ones you're always using as subscripts into zero-based arrays containing month and day names.

For example, to get the current month in London, you might say:

```
$london_month = (qw(Jan Feb Mar Apr May Jun
                    Jul Aug Sep Oct Nov Dec))[(gmtime)[4]];
```

`$year` is the number of years since 1900; that is, in year 2023, `$year` is `123`, *not* simply `23`. To get the four-digit year, just say `$year + 1900`. To get the two-digit year (for example "01" in 2001), use `sprintf("%02d", $year % 100)`.

In scalar context, `gmtime` returns a *ctime*(3)-like string based on the GMT time value. The `Time::gmtime` module supports a by-name interface to this function. See also `POSIX::strftime` for a more fine-grained approach to formatting times.

This scalar value is *not* locale dependent but is instead a Perl built-in. Also see the `Time::Local` module and the *strftime*(3) and *mktime*(3) functions available via the `POSIX` module. To get somewhat similar but locale-dependent date strings, set up your locale environment variables appropriately (please see the *perllocale* manpage), and try:

```
use POSIX qw(strftime);
$now_string = strftime "%a %b %e %H:%M:%S %Y", gmtime;
```

The `%a` and `%b` escapes, which represent the short forms of the day of the week and the month of the year, may not necessarily be three characters wide in all locales.

goto

`$@`

```
goto LABEL
goto EXPR
goto &NAME
```

`goto` *`LABEL`* finds the statement labelled with *`LABEL`* and resumes execution there. If the *`LABEL`* cannot be found, an exception is raised. It cannot be used to go into any construct that requires initialization, such as a subroutine or a `foreach` loop. It also can't be used to go into a construct that is optimized away. It can be used to go almost anywhere else within the dynamic scope,[5] including out of subroutines; however, for that purpose, it's usually better to use some other construct such as `last` or `die`. The author of Perl has never felt the need to use this form of `goto` (in Perl, that is—C is another matter).

Going to even greater heights of orthogonality (and depths of idiocy), Perl allows `goto` *`EXPR`*, which expects *`EXPR`* to evaluate to a label name, whose location is *guaranteed* to be unresolvable until runtime since the label is unknown when the statement is compiled. This allows for computed `goto`s per FORTRAN, but isn't recommended if you're optimizing for maintainability:

```
goto +("FOO", "BAR", "GLARCH")[$i];
```

The unrelated `goto &`*`NAME`* is highly magical, substituting a call to the named subroutine for the currently running subroutine. This construct may be used without shame by `AUTOLOAD` subroutines that wish to load another subroutine and then

5. This means that if it doesn't find the label in the current routine, it looks back through the routines that called the current routine for the label, thus making it nearly impossible to maintain your program.

pretend that this new subroutine—and not the original one—had been called in the first place (except that any modifications to `@_` in the original subroutine are propagated to the replacement subroutine). After the `goto`, not even `caller` will be able to tell that the original `AUTOLOAD` routine was called first.

grep

```
grep EXPR, LIST
grep BLOCK LIST
```

This function evaluates *EXPR* or *BLOCK* in Boolean context for each element of *LIST*, temporarily setting `$_` to each element in turn, much like the `foreach` construct. In list context, it returns a list of those elements for which the expression is true. (The operator is named after a beloved Unix program that extracts lines out of a file that match a particular pattern. In Perl, the expression is often a pattern, but it doesn't have to be.) In scalar context, `grep` returns the number of times the expression was true.

If `@all_lines` contains lines of code, this example weeds out comment lines:

```
@code_lines = grep !/^\s*#/, @all_lines;
```

Because `$_` is an implicit alias to each list value, altering `$_` modifies the elements of the original list. While this is useful and supported, it can occasionally cause bizarre results if you aren't expecting it. For example:

```
@list = qw(barney fred dino wilma);
@greplist = grep { s/^[bfd]// } @list;
```

`@greplist` is now "`arney`", "`red`", "`ino`", but `@list` is now "`arney`", "`red`", "`ino`", "`wilma`"! Ergo, Caveat Programmor.

See also `map`. The following two statements are functionally equivalent:

```
@out = grep { EXPR } @in;
@out = map { EXPR ? $_ : () } @in
```

For a version of `grep` that short circuits, see the `first` function from the standard `List::Util` module. Instead of returning a list of all elements for which the *EXPR* was true, it returns only the first such, or `undef` if none were. As always, `$_` is set to each element:

```
use List::Util qw(first);

$first_over_100  = first { $_ > 100 } @list;
$first_with_foo  = first { /foo/ } @list;
```

And here's a function that takes a single character and reports which release of the Unicode Standard it premièred in:

```
use v5.14;
use List::Util qw(first);
sub getage(_) {
    my $one_char = shift;
    die unless length($one_char) == 1;
    state $ages = [reverse qw(1.1 2.0 2.1 3.0 3.1 3.2
                              4.0 4.1 5.0 5.1 5.2 6.0
                             )];
    return first { $one_char =~ /\p{Age=$_}/ } @$ages;
}
```

hex

$_

```
hex EXPR
hex
```

This function interprets *EXPR* as a hexadecimal string and returns the equivalent decimal value. A leading "`0x`" is ignored, if present. To interpret strings that might start with any of `0`, `0b`, or `0x`, see `oct`. The following code sets `$number` to 4,294,906,560:

```
$number = hex("ffff12c0");
```

To do the inverse function, use `sprintf`:

```
sprintf "%lx", $number;        # (That's an ell, not a one.)
```

Hex strings may represent integers only. Strings that would cause integer overflow trigger a warning. Unlike `oct`, leading whitespace is not stripped.

import

```
import CLASSNAME LIST
import CLASSNAME
```

There is no built-in `import` function. It is merely an ordinary class method defined (or inherited) by modules that wish to export names to another module through the `use` operator. See `use` for details.

index

```
index STR, SUBSTR, OFFSET
index STR, SUBSTR
```

This function searches for one literal string within another. It returns the position of the first occurrence of *SUBSTR* in *STR*. The *OFFSET*, if specified, says how many characters from the start to skip before beginning to look. Positions are based at

0. If the substring is not found, the function returns one less than the base, ordinarily -1. To work your way through a string, you might say:

```
$pos = -1;
while (($pos = index($string, $lookfor, $pos)) > -1) {
    say "Found at $pos"; $pos++;
}
```

Offsets are always by programmer-visible characters (*i.e.*, codepoints), not by user-visible characters (graphemes). The offset is in bytes only if you have already decoded from abstract characters into some serialization scheme, like UTF-8 or UTF-16. See Chapter 6.

To work with strings as sequences of graphemes instead of codepoints, see the `index`, `rindex`, and `pos` methods for the CPAN `Unicode::GCString` module.

int

```
int EXPR
int
```

This function returns the integer portion of *EXPR*. If you're a C programmer, you're apt to forget to use `int` with division, which is a floating-point operation in Perl:

```
$average_age = 939/16;      # yields 58.6875 (58 in C)
$average_age = int 939/16;  # yields 58
```

You should not use this function for generic rounding, because it truncates toward 0 and because machine representations of floating-point numbers can produce counterintuitive results. For example, `int(-6.725/0.025)` produces `-268` rather than the correct `-269`; that's because the value is really more like `-268.99999999999994315658`. Usually, the `sprintf`, `printf`, or the `POSIX::floor` and `POSIX::ceil` functions will serve you better than will `int`.

```
$n = sprintf("%.0f", $f);   # round (not trunc) to nearest integer
```

To compensate for the inherent bias that always rounding a 5 up would cause, IEEE specifies that rounding be toward the nearest even number on a 5. Therefore, this:

```
for (-3 ... 3) { printf "%.0f\n", $_ + 0.5 }
```

Prints the sequence -2, -2, -0, 0, 2, 2, and 4.

ioctl

$! X ARG X RO X T X U

```
ioctl FILEHANDLE, FUNCTION, SCALAR
```

This function implements the *ioctl*(2) syscall, which controls I/O. To get the correct function definitions, first you'll probably have to say:

```
require "sys/ioctl.ph";     # perhaps /usr/local/lib/perl/sys/ioctl.ph
```

If *sys/ioctl.ph* doesn't exist or doesn't have the correct definitions, you'll have to roll your own based on your C header files such as *sys/ioctl.h*. (The Perl distribution includes a script called *h2ph* to help you do this, but running it is nontrivial.) *SCALAR* will be read or written (or both) depending on the *FUNCTION*—a pointer to the string value of *SCALAR* will be passed as the third argument of the actual *ioctl*(2) call. If *SCALAR* has no string value but does have a numeric value, that value will be passed directly rather than a pointer to the string value. The `pack` and `unpack` functions are useful for manipulating the values of structures used by `ioctl`. If the `ioctl` needs to write data into your *SCALAR*, it is up to you to ensure that the string is long enough to hold what needs to be written, often by initializing it to a dummy value of the correct size using `pack`. The following example determines how many bytes (not characters) are available for reading using the `FIONREAD` `ioctl`:

```
require "sys/ioctl.ph";

# pre-allocate the right size buffer:
$size = pack("L", 0);
ioctl(FH, FIONREAD(), $size)
    || die "Couldn't call ioctl: $!";
$size = unpack("L", $size);
```

Here is how to detect the current window size[6] in rows and columns:

```
require "sys/ioctl.ph";

# four unsigned shorts of the native size
$template = "S!4";
# pre-allocate the right size buffer:
my $ws = pack($template, ());
ioctl(STDOUT, TIOCGWINSZ(), $ws)
    || die "Couldn't call ioctl: $!";
($rows, $cols, $xpix, $ypix) = unpack($template, $ws);
```

If *h2ph* wasn't installed or doesn't work for you, you can *grep* the include files by hand or write a small C program to print out the value. You may also have to

6. Or, rather, how to get the window size associated with the `STDOUT` filehandle.

look at C code to determine the structure template layout and size needed for your system.

The return value of `ioctl` (and `fcntl`) is as shown in Table 27-2.

Table 27-2. Return values for ioctl

Syscall Returns	Perl Returns
`-1`	`undef`
`0`	String "`0 but true`"
Anything else	That number

Thus, Perl returns true on success and false on failure, yet you can still easily determine the actual value returned by the operating system:

```
$retval = ioctl(...) || -1;
printf "ioctl actually returned %d\n", $retval;
```

The special string "`0 but true`" is exempt from warnings from the *–w* command-line flag or the `warnings` pragma about improper numeric conversions.

Calls to `ioctl` should not be considered portable. If, say, you're merely turning off echo once for the whole script, it's more portable to say:

```
system "stty -echo";   # Works on most Unix boxen
```

Just because you *can* do something in Perl doesn't mean you *ought* to. For still better portability, you might look at the `Term::ReadKey` module from CPAN. Almost anything you might want to use `ioctl` for, there probably exists a CPAN module that already does that, and more portably, too, because they usually rope your system's C compiler into doing the heavy lifting for you.

join

```
join EXPR, LIST
```

This function joins the separate strings of *`LIST`* into a single string with fields separated by the value of *`EXPR`*, and returns the string. For example:

```
$rec = join ":", $login,$passwd,$uid,$gid,$gcos,$home,$shell;
```

To do the opposite, see `split`. To join things together into fixed-position fields, see `pack`. The most efficient way to concatenate many strings together is to `join` them with a null string:

```
$string = join "", @array;
```

Unlike `split`, `join` doesn't take a pattern as its first argument and will produce a warning if you try.

keys

```
keys HASH
keys ARRAY
keys EXPR
```

This function returns a list consisting of all keys in the indicated *HASH*. The keys are returned in an apparently random order, but it is the same order produced by either the `values` or `each` function (assuming the hash has not been modified between calls). As a side effect, it resets *HASH*'s iterator. Here is a (rather cork-brained) way to print your environment:

```
@keys   = keys   %ENV;    # keys are in the same order as
@values = values %ENV;    # values, as this demonstrates
while (@keys) {
    say pop(@keys), "=", pop(@values);
}
```

You're more likely to want to see the environment sorted by keys:

```
for my $key (sort keys %ENV) {
    say $key, "=", $ENV{$key};
}
```

You can sort the values of a hash directly, but that's somewhat useless in the absence of any way to map values back to keys. To sort a hash by value, you generally need to sort the `keys` by providing a comparison function that accesses the values based on the keys. Here's a descending numeric sort of a hash by its values:

```
for my $key (sort { $hash{$b} <=> $hash{$a} } keys %hash) {
    printf "%4d %s\n", $hash{$key}, $key;
}
```

Using `keys` on a hash bound to a largish DBM file will produce a largish list, causing you to have a largish process. You might prefer to use the `each` function here, which will iterate over the hash entries one by one without slurping them all into a single gargantuan list.

In scalar context, `keys` returns the number of elements of the hash (and resets the `each` iterator). However, to get this information for tied hashes, including DBM files, Perl must walk the entire hash, so it's not efficient then. Calling `keys` in void context helps with that.

Used as an lvalue, `keys` increases the number of hash buckets allocated for the given hash. (This is similar to preextending an array by assigning a larger number

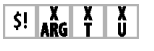
to `$#array`.) Preextending your hash can gain a measure of efficiency, if you happen to know the hash is going to get big, and how big it's going to get. If you say:

```
keys %hash = 1000;
```

then `%hash` will have at least 1,000 buckets allocated for it (you get 1,024 buckets, in fact, since it rounds up to the next power of two). You can't shrink the number of buckets allocated for the hash using `keys` in this way (but you needn't worry about doing this by accident, as trying has no effect). The buckets will be retained even if you do `%hash = ()`. Use `undef %hash` if you want to free the storage while `%hash` is still in scope.

See also `each`, `values`, and `sort`.

kill




```
kill SIGNAL, LIST
```

This function sends a signal to a list of processes. For *`SIGNAL`*, you may use either an integer or a quoted signal name (without a "`SIG`" on the front). Trying to use an unrecognized *`SIGNAL`* name raises an exception. The function returns the number of processes successfully signalled. If *`SIGNAL`* is negative, the function kills process groups instead of processes. (On Unix systems derived from SysV, a negative process number will also kill process groups, but that's not portable.) A PID of zero sends the signal to all processes of the same group ID as the sender. For example:

```
$cnt = kill 1, $child1, $child2;
kill 9, @goners;
kill "STOP", getppid       # Can *so* suspend my login shell...
        unless getppid == 1;    # (But don't taunt init(8).)
```

A *`SIGNAL`* of `0` tests whether a process is still alive and that you still have permission to signal it. No signal is sent. This way you can check whether the process is still alive and hasn't changed its UID.

```
use Errno qw(ESRCH EPERM);
if (kill 0 => $minion) {
    say "$minion is alive!";
} elsif ($! == EPERM) {             # changed UID
    say "$minion has escaped my control!";
} elsif ($! == ESRCH) {
    say "$minion is deceased.";  # or zombied
} else {
    warn "Odd; I couldn't check on the status of $minion: $!\n";
}
```

See the section "Signals" on page 518 in Chapter 15.

last

$@

```
last LABEL
last
```

The `last` operator immediately exits the loop in question, just like the `break` statement in C or Java (as used in loops). If *LABEL* is omitted, the operator refers to the innermost enclosing loop. The `continue` block, if any, is not executed.

```
LINE: while (<MAILMSG>) {
    last LINE if /^$/; # exit when done with header
    # rest of loop here
}
```

`last` cannot be used to exit a block that returns a value, such as `eval {}`, `sub {}`, or `do {}`, and it should not be used to exit a `grep` or `map` operation. With warnings enabled, Perl warns if you `last` out of a loop that's not in your current lexical scope, such as a loop in a calling subroutine.

A block by itself is semantically identical to a loop that executes once. Thus, `last` can be used to effect an early exit out of such a block. See also Chapter 4 for illustrations of how `last`, `next`, `redo`, and `continue` work.

lc

$_ T

```
lc EXPR
lc
```

This function returns a lowercased version of *EXPR*. This is the internal function implementing the `\L` escape in double-quoted strings.

Do not use `lc` for case-insensitive comparisons the way you may have once done in ASCII, because it gives the wrong answer for Unicode. Instead, use the `fc` (foldcase) function, either from the CPAN `Unicode::CaseFold` module, or via `use feature "fc"` in v5.16 or later. See the section "A Case of Mistaken Identity" in Chapter 6 for more information.

Codepoints in the 128–256 range are ignored by `lc` if the string does not have Unicode semantics (and locale mode is not in effect), which can be difficult to guess. The `unicode_strings` feature guarantees Unicode semantics even on those codepoints. See Chapter 6.

Your current `LC_CTYPE` locale is respected if `use locale` is in effect, though how locales interact with Unicode is still a topic of ongoing research, as they say. See the *perllocale*, *perlunicode*, and LIperlfunc> manpages for the most recent results.

lcfirst

```
lcfirst EXPR
lcfirst
```

This function returns a version of *EXPR* with the first character lowercased. This is the internal function implementing the `\l` escape in double-quoted strings. See the previous entry regarding Unicode casemapping.

length

```
length EXPR
length
```

This function returns the length in codepoints (programmer-visible characters) of the scalar value *EXPR*. If *EXPR* is omitted, it returns the length of `$_`. (But be careful that the next thing doesn't look like the start of an *EXPR*, or Perl's lexer will get confused. For example, `length < 10` won't compile. When in doubt, use parentheses.)

Do not try to use `length` to find the size of an array or hash. Use `scalar @array` for the size of an array, and `scalar keys %hash` for the number of key/value pairs in a hash. (The `scalar` is typically omitted when redundant.)

To find the number of graphemes (user-visible characters) in a string, either count them:

```
my $count = 0;
$count++ while our $string =~ /\X/g;
```

or use the CPAN `Unicode::GCString` module, which lets you work with a string as a sequence of graphemes instead of as a sequence of codepoints. That module also tells you how long a string is in print columns. That way you can still use `printf` justification and, if you're creative, maybe even `format` and `write`, even though some codepoints occupy 0 columns, others 1 column, and still others 2 columns when printed.

__LINE__

A special token that compiles to the current line number. See "Generating Perl in Other Languages" on page 717 in Chapter 21.

link

```
link OLDFILE, NEWFILE
```

This function creates a new filename linked to the old filename. The function returns true for success, false otherwise. See also `symlink` later in this chapter. This function is unlikely to be implemented on non-Unix-style filesystems.

listen

```
listen SOCKET, QUEUESIZE
```

Thisfunction tells the system that you're going to be accepting connections on this *SOCKET* and that the system can queue the number of waiting connections specified by *QUEUESIZE*. Imagine having call-waiting on your phone, with up to 17 callers queued. (Gives me the willies!) The function returns true if it succeeds, false otherwise.

```
use Socket;
listen(PROTOSOCK, SOMAXCONN)
    || die "cannot set listen queue on PROTOSOCK: $!";
```

See `accept`. See also the section "Sockets" on page 543 in Chapter 15. See *listen*(2).

local

```
local EXPR
```

This operator does not create a local variable; use `my` for that. Instead, it localizes existing variables; that is, it causes one or more global variables to have locally scoped values within the innermost enclosing block, `eval`, or file. If more than one variable is listed, the list must be placed in parentheses because the operator binds more tightly than commas. All listed variables must be legal lvalues—that is, something you could assign to; this can include individual elements of arrays or hashes.

This operator works by saving the current values of the specified variables on a hidden stack and restoring them on exiting the block, subroutine, `eval`, or file. After the `local` is executed, but before the scope is exited, any subroutines and executed formats will see the local, inner value, instead of the previous, outer value, because the variable is still a global variable, despite having a localized value. The technical term for this is *dynamic scoping*. See the section "Scoped Declarations" on page 155 in Chapter 4.

The *EXPR* may be assigned to if desired, which lets you initialize your variables as you localize them. If no initializer is given, all scalars are initialized to `undef`, and

all arrays and hashes to `()`. As with ordinary assignment, if you use parentheses around the variables on the left (or if the variable is an array or hash), the expression on the right is evaluated in list context. Otherwise, the expression on the right is evaluated in scalar context.

In any event, the expression on the right is evaluated before the localization, but the initialization happens after localization, so you can initialize a localized variable with its nonlocalized value. For instance, this code demonstrates how to make a temporary change to a global array:

```
if ($sw eq "-v") {
    # init local array with global array
    local @ARGV = @ARGV;
    unshift(@ARGV, "echo");
    system @ARGV;
}
# @ARGV restored
```

You can also temporarily modify global hashes:

```
# temporarily add a couple of entries to the %digits hash
if ($base12) {
    # (NOTE: We're not claiming this is efficient!)
    local(%digits) = (%digits, T => 10, E => 11);
    parse_num();
}
```

You can use `local` to give temporary values to individual elements of arrays and hashes, even lexically scoped ones:

```
if ($protected) {
    local $SIG{INT} = "IGNORE";
    precious();     # no interrupts during this function
}                   # previous handler (if any) restored
```

You can also use `local` on typeglobs to create local filehandles without loading any bulky object modules:

```
local *MOTD;                # protect any global MOTD handle
my $fh = do { local *FH };  # create new indirect filehandle
```

Although you may see localized typeglobs used in old code that needed to generate new filehandles, these days a plain `my $fh` is good enough. That's because if you give an undefined variable as the filehandle argument to a function that initializes a filehandle (such as the first argument to `open` or `socket`), Perl autovivifies a brand new filehandle for you.

In general, you usually want to use `my` instead of `local`, because `local` isn't really what most people think of as "local", or even "lo-cal". See `my`.

The `delete local EXPR` construct can also be used to localize the deletion of array or hash elements to the current block.

localtime

```
localtime EXPR
localtime
```

This function converts the value returned by `time` to a nine-element list with the time corrected for the local time zone. It's typically used as follows:

```
#  0    1    2     3     4    5     6     7     8
($sec,$min,$hour,$mday,$mon,$year,$wday,$yday,$isdst) = localtime;
```

If, as here, *EXPR* is omitted, it does `localtime(time())`.

All list elements are numeric and come straight out of a `struct tm`. (That's a bit of C programming lingo—don't worry about it.) In particular, this means that `$mon` has the range `0..11` with January as month 0, and `$wday` has the range `0..6` with Sunday as day `0`. You can remember which ones are zero-based because those are the ones you're always using as subscripts into zero-based arrays containing month and day names.

For example, to get the name of the current day of the week:

```
$thisday = (Sun,Mon,Tue,Wed,Thu,Fri,Sat)[(localtime)[6]];
```

`$year` is the number of years since 1900; that is, in year 2023, `$year` is `123`, *not* simply `23`. To get the four-digit year, just say `$year + 1900`. To get the two-digit year (for example, "01" in 2001), use `sprintf("%02d", $year % 100)`.

The Perl library module `Time::Local` contains a subroutine, `timelocal`, that can convert in the opposite direction.

In scalar context, `localtime` returns a *ctime*(3)-like string. For example, the *date*(1) command can be (almost)[7] emulated with:

```
perl -le 'print scalar localtime()'
```

See also the standard `POSIX` module's `strftime` function for a more fine-grained approach to formatting times. The `Time::localtime` module supports a by-name interface to this function.

lock

```
lock THING
```

7. *date*(1) prints the timezone, whereas scalar `localtime` does not.

The `lock` function places a lock on a variable, subroutine, or object referenced by *`THING`* until the lock goes out of scope. For backward compatibility, this function is a built-in only if your version of Perl was compiled with threading enabled, and if you've said `use Threads`. Otherwise, Perl will assume this is a user-defined function.

log

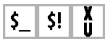
```
log EXPR
log
```

This function returns the natural logarithm (that is, base *e*) of *`EXPR`*. If *`EXPR`* is negative, it raises an exception. To get the log of another base, use basic algebra: the base-*N* log of a number is equal to the natural log of that number divided by the natural log of *N*. For example:

```
sub log10 {
    my $n = shift;
    return log($n)/log(10);
}
```

For the inverse of `log`, see `exp`.

lstat



```
lstat EXPR
lstat
```

This function does the same thing as Perl's `stat` function (including setting the special _ filehandle), but if the last component of the filename is a symbolic link, it `stat`s the symbolic link itself instead of the file to which the symbolic link points. If symbolic links are unimplemented on your system, a normal `stat` is done instead.

m//

```
/PATTERN/
m/PATTERN/
```

This is the match operator, which interprets *`PATTERN`* as a regular expression. The operator is parsed as a double-quoted string rather than as a function. See Chapter 5.

map

```
map BLOCK LIST
map EXPR, LIST
```

This function evaluates the *BLOCK* or *EXPR* for each element of *LIST* (locally setting `$_` to each element) and returns the list comprising the results of each such evaluation. It evaluates *BLOCK* or *EXPR* in list context, so each element of *LIST* may map to zero, one, or more elements in the returned value. These are all flattened into one list. For instance:

```
@words = map { split " " } @lines;
```

splits a list of lines into a list of words. But often there is a one-to-one mapping between input values and output values:

```
@chars = map chr, @nums;
```

translates a list of numbers to the corresponding characters. And here's an example of a one-to-two mapping:

```
%hash = map { genkey($_) => $_ } @array;
```

which is just a funny functional way to write this:

```
%hash = ();
for my $_ (@array) {
    $hash{genkey($_)} = $_;
}
```

Because `$_` is an alias (implicit reference) into the list's values, this variable can be used to modify the elements of the array. This is useful and supported, although it can cause bizarre results if the *LIST* is not a named array. Using a regular `foreach` loop for this purpose may be clearer. See also `grep`; `map` differs from `grep` in that `map` returns a list consisting of the results of each successive evaluation of *EXPR*, whereas `grep` returns a list consisting of each value of *LIST* for which *EXPR* evaluates to true.

mkdir

```
mkdir FILENAME, MASK
mkdir FILENAME
```

This function creates the directory specified by *FILENAME*, giving it permissions specified by the numeric *MASK* as modified by the current `umask`. If the operation succeeds, it returns true; otherwise, it returns false.

If *MASK* is omitted, a mask of `0777` is assumed, which is almost always what you want anyway. In general, creating directories with permissive *MASK*s (like `0777`)

and letting the user modify that with her `umask` is better than supplying a restrictive *`MASK`* and giving the user no way to be more permissive. The exception to this rule is when the file or directory should be kept private (mail files, for instance). See `umask`.

If the *mkdir*(2) syscall is not built into your C library, Perl emulates it by calling the *mkdir*(1) program for each directory. If you are creating a long list of directories on such a system, it'll be more efficient to call the *mkdir* program yourself with the list of directories than to start zillions of subprocesses.

msgctl

```
msgctl ID, CMD, ARG
```

This function calls the System V IPC *msgctl*(2) syscall; see *msgctl*(2) for more details. You may have to `use IPC::SysV` first to get the correct constant definitions. If *`CMD`* is `IPC_STAT`, then *`ARG`* must be a variable that will hold the returned `msqid_ds` C structure. Return values are like `ioctl` and `fcntl`: `undef` for error, "`0 but true`" for zero, or the actual return value otherwise.

This function is available only on machines supporting System V IPC, which turns out to be far fewer than those supporting sockets.

msgget

```
msgget KEY, FLAGS
```

This function calls the System V IPC *msgget*(2) syscall. See *msgget*(2) for details. The function returns the message queue ID, or `undef` if there is an error. Before calling, you should use `IPC::SysV`.

This function is available only on machines supporting System V IPC.

msgrcv

```
msgrcv ID, VAR, SIZE, TYPE, FLAGS
```

This function calls the *msgrcv*(2) syscall to receive a message from message queue *`ID`* into variable *`VAR`* with a maximum message size of *`SIZE`*. See *msgrcv*(2) for details. When a message is received, the message type will be the first thing in *`VAR`*, and the maximum length of *`VAR`* is *`SIZE`* plus the size of the message type. Decode this with `unpack("l! a*")`. The function returns true if successful, or false if there is an error. Before calling, you should `use IPC::SysV`.

This function is available only on machines supporting System V IPC.

msgsnd

```
msgsnd ID, MSG, FLAGS
```

This function calls the *msgsnd*(2) syscall to send the message `MSG` to the message queue `ID`. See *msgsnd*(2) for details. `MSG` must begin with the long integer message type. You can create a message like this:

```
$msg = pack "l! a*", $type, $text_of_message;
```

The function returns true if successful, or false if there is an error. Before calling, `use IPC::SysV`.

This function is available only on machines supporting System V IPC.

my

```
my TYPE EXPR : ATTRIBUTES
my EXPR : ATTRIBUTES
my TYPE EXPR
my EXPR
```

This operator declares one or more private variables to exist only within the innermost enclosing block, subroutine, `eval`, or file. If more than one variable is listed, the list must be placed in parentheses because the operator binds more tightly than commas. Only simple scalars or complete arrays and hashes may be declared this way.

The variable name cannot be package qualified, because package variables are all globally accessible through their corresponding symbol table, and lexical variables are unrelated to any symbol table. Unlike `local`, then, this operator has nothing to do with global variables, other than hiding any other variable of the same name from view within its scope (that is, where the private variable exists). A global variable can always be accessed through its package-qualified form, however, or through a symbolic reference.

A private variable's scope does not start until the statement *after* its declaration. The variable's scope extends into any enclosed blocks thereafter, up to the end of the scope of the variable itself.

However, this means that any subroutines you call from within the scope of a private variable cannot see the private variable unless the block that defines the subroutine itself is also textually enclosed within the scope of that variable. That sounds complicated, but it's not once you get the hang of it. The technical term for this is *lexical scoping*, so we often call these *lexical variables*. In C culture,

they're sometimes called "auto" variables, since they're automatically allocated and deallocated at scope entry and exit.

The *EXPR* may be assigned to if desired, which lets you initialize your lexical variables. (If no initializer is given, all scalars are initialized to the undefined value and all arrays and hashes to the empty list.) As with ordinary assignment, if you use parentheses around the variables on the left (or if the variable is an array or hash), the expression on the right is evaluated in list context. Otherwise, the expression on the right is evaluated in scalar context. For example, you can name your formal subroutine parameters with a list assignment, like this:

```
my ($friends, $romans, $countrymen) = @_;
```

But be careful not to omit the parentheses indicating list assignment, like this:

```
my $country = @_;  # right or wrong?
```

This assigns the length of the array (that is, the number of the subroutine's arguments) to the variable, since the array is being evaluated in scalar context. You can profitably use scalar assignment for a formal parameter, though, as long as you use the `shift` operator. In fact, since object methods are passed the object as the first argument, many method subroutines start off by "stealing" the first argument:

```
sub simple_as {
    my $self = shift;   # scalar assignment
    my ($a,$b,$c) = @_; # list assignment
    ...
}
```

If you try to declare a lexically scoped subroutine with `my sub`, Perl will die with the message that this feature has not been implemented yet. (Unless, of course, this feature *has* been implemented yet.[8])

The *TYPE* and *ATTRIBUTES* are optional. Here's what a declaration that uses them might look like:

```
my Dog $spot :ears(short) :tail(long);
```

The *TYPE*, if specified, indicates what kind of scalar or scalars are declared in *EXPR*, either directly as one or more scalar variables, or indirectly through an array or hash. If *TYPE* is the name of the class, the scalars will be assumed to contain references to objects of that type, or to objects compatible with that type. In particular, derived classes are considered compatible. That is, assuming `Collie` is derived from `Dog`, you might declare:

8. There's some hope of this, as Perl 6 has demonstrated that subroutines can be lexically scoped by default and still be easy to use.

```
my Dog $lassie = new Collie;
```

Your declaration claims that you will use the `$lassie` object consistently with its being a `Dog` object. The fact that it's actually a `Collie` object shouldn't matter as long as you only try to do `Dog` things. Through the magic of virtual methods, the implementation of those `Dog` methods might well be in the `Collie` class, but the declaration above is only talking about the interface, not the implementation. In theory.

In fact, Perl doesn't actually make much use of the type information yet, but it's available for future improvements. (It was historically used by pseudohashes, but those are dead now.) The *`TYPE`* declaration should be considered a generic type interface that might someday be instantiated in various ways depending on the class. In fact, the *`TYPE`* might not even be an official class name. We're reserving the lowercase type names for Perl, because one way we'd like to extend the type interface is to allow optional low-level type declarations such as `int`, `num`, and `str`.[9] These declarations will not be for the purpose of strong typing; rather, they'll be hints to the compiler telling it to optimize the storage of the variable with the assumption that the variable will be used mostly as declared. The semantics of scalars will stay pretty much the same—you'll still be able to add two `str` scalars, or print an `int` scalar, just as though they were the ordinary polymorphic scalars you're familiar with. But, with an `int` declaration, Perl might decide to store only the integer value and forget about caching the resulting string as it currently does. Loops with `int` loop variables might run faster, particularly in code compiled down to C. In particular, arrays of numbers could be stored much more compactly. As a limiting case, the built-in `vec` function might even become obsolete when we can write declarations such as:

```
my bit @bitstring;
```

The *`ATTRIBUTES`* declaration is used more often than types are; see the `attributes` pragma in Chapter 29 for more on that. One attribute we'll likely implement someday is `constant`:

```
my num $PI : constant = atan2(1,1) * 4;
```

But there are many other possibilities, such as establishing default values for arrays and hashes, or letting variables be shared among cooperating interpreters. Like the type interface, the attribute interface should be considered a generic interface, a kind of workbench for inventing new syntax and semantics. We do

9. In fact, such native types are currently being prototyped in Perl 6 with just this syntax, so the Perl 5 folks might well borrow back all the good bits once the Perl 6 folks have discovered all the bad bits. `:-)`

not know how Perl will evolve in the next 10 years. We only know that we can make it easier on ourselves by planning for that in advance.

See also `local`, `our`, and `state`, and the section "Scoped Declarations" in Chapter 4.

new

```
new CLASSNAME LIST
new CLASSNAME
```

There is no built-in `new` function. It is merely an ordinary constructor method (that is, a user-defined subroutine) that is defined or inherited by the *CLASSNAME* class (that is, package) to let you construct objects of type *CLASSNAME*. Many constructors are named "new", but only by convention, just to trick C++ programmers into thinking they know what's going on. Always read the documentation of the class in question so you know how to call its constructors; for example, the constructor that creates a list box in the Tk widget set is just called `Listbox`. See Chapter 12.

next


```
next LABEL
next
```

The `next` operator is like the `continue` statement in C: it starts the next iteration of the loop designated by *LABEL*:

```
LINE: while (<STDIN>) {
    next LINE if /^#/;     # discard comments
    ...
}
```

If there were a `continue` block in this example, it would be executed immediately following the invocation of `next`. When *LABEL* is omitted, the operator refers to the innermost enclosing loop.

A block by itself is semantically identical to a loop that executes once. Thus, `next` will exit such a block early (via the `continue` block, if there is one).

`next` cannot be used to exit a block that returns a value, such as `eval {}`, `sub {}`, or `do {}`, and it should not be used to exit a `grep` or `map` operation. With warnings enabled, Perl warns you if you `next` out of a loop not in your current lexical scope, such as a loop in a calling subroutine. See the section "Loop Statements" on page 139 in Chapter 4.

no

```
no MODULE VERSION LIST
no MODULE VERSION
no MODULE LIST
no MODULE
no VERSION
```

See the `use` operator, which is the opposite of `no`, kind of. Most standard modules do not unimport anything, making `no` a no-op, as it were. The pragmatic modules tend to be more obliging here. If *`MODULE`* cannot be found, an exception is raised.

oct

```
oct EXPR
oct
```

This function interprets *`EXPR`* as an octal string and returns the equivalent decimal value. If *`EXPR`* happens to start with "`0x`", it is interpreted as a hexadecimal string instead. If *`EXPR`* starts off with "`0b`", it is interpreted as a string of binary digits. The following will properly convert to whole numbers input strings in decimal, binary, octal, and hex bases using standard Perl notation:

```
$val = oct $val if $val =~ /^0/;
```

For the inverse function, use `sprintf` with an appropriate format:

```
$dec_perms = (stat("filename"))[2] & 07777;
$oct_perm_str = sprintf "%o", $perms;
```

The `oct` function is commonly used when a data string such as "`644`" needs to be converted into a file mode, for example. Although Perl automatically converts strings into numbers as needed, this automatic conversion assumes base 10.

Leading whitespace is ignored without warning, as are any trailing nondigits, such as a decimal point (`oct` only handles nonnegative integers, not negative integers or floating point).

open

```
open FILEHANDLE, MODE, EXPR, LIST
open FILEHANDLE, MODE, EXPR
open FILEHANDLE, MODE, REFERENCE
open FILEHANDLE, EXPR
```

The `open` function associates an internal *`FILEHANDLE`* with an external file specification given by *`EXPR`* or *`LIST`*. It may be called with two or three arguments (or more if the third argument is a command). When three or more arguments are

present, the second argument specifies the access *MODE* in which the file should be opened, and the remaining argument supplies the actual filename or the command to execute, depending on the mode. In the case of a command, additional arguments may be supplied if you wish to invoke the command directly without involving a shell, much like `system` or `exec`. Or the command may be supplied as a single argument (the third one), in which case the decision to invoke the shell depends on whether the command contains shell metacharacters. (Don't use more than three arguments if the arguments are ordinary filenames; it won't work.) If the *MODE* is not recognized, `open` raises an exception.

As a special case, the three-argument form with a read/write mode and the third argument being `undef`:

```
open(my $tmp, "+>", undef) or die ...
```

opens a filehandle to an anonymous temporary file. Using "`+<`" also works for symmetry, but you really should consider writing something to the temporary file first. You will need to `seek` to do the reading.

You may use the three-argument form of `open` to specify I/O layers (sometimes called "disciplines") to apply to the handle that affect how the input and output are processed (see the `PerlIO` module for more details). For example:

```
open(my $fh, "< :encoding(UTF-8)", "filename")
    || die "can't open UTF-8 encoded filename: $!";
```

opens a UTF-8-encoded file (that is, a file containing Unicode characters). As of v5.14, the default behavior on UTF-8 input streams does *not* throw an exception on an encoding error. If you use any sort of UTF-8 layer, consider adding:

```
use warnings FATAL => "utf8";
```

so that you can catch the exception. See Chapter 6.

Note that if layers are specified in the three-argument form, then default layers stored in `${^OPEN}` are ignored. (See Chapter 25; default layers are set by the `open` pragma or the switch *–CioD*.)

If your Perl was built using `PerlIO`,[10] you can open filehandles directly to Perl scalars by passing a reference to that scalar as the *EXPR* argument in the three-argument form:

```
open($fh, ">", \$variable) || ...
```

To reopen `STDOUT` or `STDERR` as an in-memory file, close it first:

10. The default build configuration since the v5.8 release in 2002.

```
close(STDOUT)   || die "can't close STDOUT: $!";
open(STDOUT, ">", \$variable)   || die "can't memopen STDOUT: $!";
```

If only two arguments are present, the mode and filename/command are assumed to be combined in the second argument. (And if you don't specify a mode in the second argument, just a filename, then the file is opened read-only to be on the safe side.)

```
open(LOG, "> logfile")    or die "Can't create logfile: $!"; # ok
open(LOG, ">", "logfile") or die "Can't create logfile: $!"; # better
```

The `open` function returns true when it succeeds and `undef` otherwise. If the `open` starts up a pipe to a child process, the return value will be the process ID of that new process. As with any syscall, always check the return value of `open` to make sure it worked.[11] But this isn't C or Java, so don't use an `if` statement when the `||` operator will do. You can also use `or`, and if you do, you may omit parentheses on the `open`. If you choose to omit parentheses on a function call to turn it into a list operator, be careful to use "`or die`" after the list rather than "`|| die`". That's because the precedence of `||` is higher than list operators like `open`, with the unexpected result that the `||` will bind to your last argument, not the whole `open`:

```
open LOG, ">", "logfile" || die "Can't create logfile: $!";  # WRONG
open LOG, ">", "logfile" or die "Can't create logfile: $!";  # ok
```

That looks rather intense, so you may wish to use parentheses to tell your eye where the list operator ends:

```
open(LOG, ">", "logfile") or die "Can't create logfile: $!";  # good
open(LOG, ">", "logfile") || die "Can't create logfile: $!";  # good
```

Or just put the `or` on another line:

```
open LOG, ">", "logfile"
    or die "Can't create logfile: $!";
```

As that example shows, the *`FILEHANDLE`* argument is often just a simple identifier (normally uppercase), but it may also be an expression whose value provides a reference to the actual filehandle. (The reference may be either a symbolic reference to the filehandle name or a hard reference to any object that can be interpreted as a filehandle.) This is called an *indirect filehandle*, and any function that takes a *`FILEHANDLE`* as its first argument can handle indirect filehandles as well as direct ones. But `open` is special: if you supply it with an undefined variable for the indirect filehandle, Perl will automatically define that variable for you—that is, autovivifying it to contain a proper filehandle reference. One advantage

11. Unless you used the `autodie` pragma, which takes care of checking for you.

of this is that the filehandle will be closed automatically when there are no further references to it, typically when the variable goes out of scope:

```
{
    my $fh;                   # (uninitialized)
    open $fh, ">", "logfile"  # $fh is autovivified
        or die "Can't create logfile: $!";
    ...                       # do stuff with $fh
}                             # $fh closed here
```

The `my $fh` declaration can be readably incorporated into the `open`:

```
open(my $fh, ">", "logfile") || die ...
```

The `>` symbol you've been seeing in front of the filename is an example of a mode, whether part of the filename argument or as a preceding argument. Historically, the two-argument form of `open` came first. The recent addition of the three-argument form lets you separate the mode from the filename, which has the advantage of avoiding any possible confusion between the two. In the following example, we know that the user is not trying to open a filename that happens to start with ">". We can be sure that he's specifying a *`MODE`* of ">", which opens the file named in *`EXPR`* for writing, creating the file if it doesn't exist and truncating the file down to nothing if it does already exist:

```
open(LOG, ">", "logfile")  || die "Can't create logfile: $!";
```

In the shorter forms, the filename and mode are in the same string. The string is parsed much as the typical shell processes file and pipe redirections. First, any leading and trailing whitespace is removed from the string. Then the string is examined, on either end if need be, for characters specifying how the file is to be opened. Whitespace is allowed between the mode and the filename.

The modes that indicate how to open a file are shell-like redirection symbols. A list of these symbols is provided in Table 27-3. To access a file with combinations of open modes not covered by this table, see the low-level `sysopen` function.

Table 27-3. Modes for open

	Read Mode	Write Access	Append Access	Create Nonexisting	Clobber Existing
< *PATH*	Y	N	N	N	N
> *PATH*	N	Y	N	Y	Y
>> *PATH*	N	Y	Y	Y	N
+< *PATH*	Y	Y	N	N	N
+> *PATH*	Y	Y	N	Y	Y
+>> *PATH*	Y	Y	Y	Y	N

	Read Mode	Write Access	Append Access	Create Nonexisting	Clobber Existing
`| COMMAND`	N	Y	n/a	n/a	n/a
`COMMAND |`	Y	N	n/a	n/a	n/a

If the mode is "`<`" or nothing, an existing file is opened for input. If the mode is "`>`", the file is opened for output, which truncates existing files and creates nonexistent ones. If the mode is "`>>`", the file is created if needed and opened for appending, and all output is automatically placed at the end of the file. If a new file must be created because you used a mode of "`>`" or "`>>`", access permissions on the new file will depend on the process's current `umask` under the rules described for that function.

Here are common examples:

```
open(INFO,      "datafile")  || die("can't open datafile: $!");
open(INFO,    "< datafile")  || die("can't open datafile: $!");
open(RESULTS, "> runstats")  || die("can't open runstats: $!");
open(LOG,    ">> logfile ")  || die("can't open logfile:  $!");
```

If you prefer the low-punctuation version, you can write:

```
open(INFO,      "datafile")  or die "can't open datafile: $!";
open(INFO,    "< datafile")  or die "can't open datafile: $!";
open(RESULTS, "> runstats")  or die "can't open runstats: $!";
open(LOG,    ">> logfile ")  or die "can't open logfile:  $!";
```

When opened for reading, the special filename "`-`" refers to `STDIN`. When opened for writing, the same special filename refers to `STDOUT`. Normally, these are specified as "`<-`" and "`>-`", respectively.

```
open(INPUT,  "-" ) || die;     # re-open standard input for reading
open(INPUT,  "<-") || die;     # same thing, but explicit
open(OUTPUT, ">-") || die;     # re-open standard output for writing
```

This way the user can supply a program with a filename that will use the standard input or the standard output, but the author of the program doesn't have to write special code to know about this.

You may also place a "`+`" in front of any of these three modes to request simultaneous read and write. However, whether the file is clobbered or created and whether it must already exist is still governed by your choice of less-than or greater-than signs. This means that "`+<`" is almost always preferred for read/write updates, as the dubious "`+>`" mode would first clobber the file before you could ever read anything from it. (Only use that mode if you want to reread only what you only just wrote.)

```
open(DBASE, "+< database")
    || die "can't open existing database in update mode: $!";
```

You can treat a file opened for update as a random-access database and use `seek` to move to a particular byte number, but the variable-length records of regular text files usually make it impractical to use read-write mode to update such files. See the *–i* command-line option in Chapter 17 for a different approach to updating.

If the leading character in *EXPR* is a pipe symbol, `open` fires up a new process and connects a write-only filehandle to the command. This way you can write into that handle, and what you write will show up on that command's standard input. For example:

```
open(PRINTER, "| lpr -Plp1")    || die "can't fork: $!";
say PRINTER "stuff";
close(PRINTER)                  || die "lpr/close failed: $?/$!";
```

If the trailing character in *EXPR* is a pipe symbol, `open` again launches a new process, but this time with a read-only filehandle connected to it. This lets whatever the command writes to its standard output show up on your handle for reading. For example:

```
open(NET, "netstat -i -n |")    || die "can't fork: $!";
while (<NET>) { ... }
close(NET)                      || die "can't close netstat: $!/$?";
```

Explicitly closing any piped filehandle causes the parent process to wait for the child to finish and returns the status code in `$?` (`$CHILD_ERROR`). It's also possible for `close` to set `$!` (`$OS_ERROR`). See the examples under `close` and `system` for how to interpret these error codes.

Any pipe command containing shell metacharacters (such as wildcards or I/O redirections) is passed to your system's canonical shell (*/bin/sh* on Unix), so those shell-specific constructs can be processed first. If no metacharacters are found, Perl launches the new process itself without calling the shell.

You may also use the three-argument form to start up pipes. Using that style, the equivalent of the previous pipe opens would be:

```
open(PRINTER, "|-", "lpr -Plp1")    || die "can't fork: $!";
open(NET, "-|", "netstat -i -n")    || die "can't fork: $!";
```

Here, the minus in the second argument represents the command in the third argument. These commands don't happen to invoke the shell, but if you want to guarantee no shell processing occurs, new versions of Perl let you say:

```
open(PRINTER, "|-", "lpr", "-Plp1")    || die "can't fork: $!";
open(NET, "-|", "netstat", "-i", "-n") || die "can't fork: $!";
```

If you use the two-argument form to open a pipe to or from the special command "-",[12] an implicit `fork` is done first. (On systems that can't `fork`, this raises an exception. Microsoft systems did not support `fork` during most of the 20th century, but they have since.) Here, the minus represents your new child process, which is a copy of the parent. The return value from this forking `open` depends on who is looking at it; it is the process ID of the child when examined from the parent process, `0` when examined from the child process, and the undefined value `undef` if the `fork` fails—in which case, there is no child. For example:

```
my $pid = open(FROM_CHILD, "-|") // die "can't fork: $!";

if ($pid) {
    @parent_lines = <FROM_CHILD>;  # parent code
}
else {
    print STDOUT @child_lines;     # child code
    exit;
}
```

The filehandle behaves normally for the parent, but for the child process, the parent's input (or output) is piped from (or to) the child's `STDOUT` (or `STDIN`). The child process does not see the parent's filehandle opened. (This is conveniently indicated by the `0` PID.)

Typically, you'd use this construct instead of the normal piped `open` when you want to exercise more control over just how the pipe command gets executed (such as when you are running setuid) and don't want to have to scan shell commands for metacharacters. The following piped opens are roughly equivalent:

```
open(FH,             "| tr   'a-z'  'A-Z'");         # pipe to shell
                                                     # command
open(FH, "|-",         "tr", "a-z", "A-Z" );         # pipe to bare
                                                     # command
open(FH, "|-") || exec("tr", "a-z", "A-Z") || die;   # pipe to child
open(FOO, "|-",        "tr", "a-z", "A-Z") || die;   # pipe to child
```

as are these:

```
open(FH,              "cat    -n   'file' |");      # pipe from shell
                                                    # command
open(FH, "-|",        "cat", "-n", "file");         # pipe from bare
                                                    # command
open(FH, "-|") || exec("cat", "-n", "file") || die; # pipe from child
open(FOO, "-|", "cat", "-n", $file) || die;         # pipe from child
```

12. Or you can think of it as leaving the command off of the three-argument forms above.

The last two examples in each block shows the pipe as "list form", which is not yet supported on all platforms. A good rule of thumb is that if your platform has true `fork` (in other words, if your platform is Unix) you can use the list form.

See "Anonymous Pipes" in Chapter 15 for more examples of this. For more elaborate uses of fork open, see the sections "Talking to Yourself" on page 533 in Chapter 15 and "Cleaning Up Your Environment" on page 656 in Chapter 20.

Perl tries to flush all files opened for output before any operation that may do a fork, but this may not be supported on some platforms. To be safe, you may need to set `$|` (`$AUTOFLUSH` in `English`) or call the `autoflush` method of `IO::Handle` on any open handles.

On systems that support a close-on-exec flag on files, the flag will be set for the newly opened file descriptor as determined by the value of `$^F` (`$SYSTEM_FD_MAX`).

Closing any piped filehandle causes the parent process to wait for the child to finish and then returns the status value in `$?` and `${^CHILD_ERROR_NATIVE}`.

The filename passed to the two-argument form of `open` has any leading and trailing whitespace deleted and the normal redirection characters honored. This property, known as "magic open", can often be used to good effect. A user could specify a filename of "`rsh cat file |`", or you could change certain filenames as needed:

```
$filename =~ s/(.*\.gz)\s*$/gzip -dc < $1|/;
open(FH, $filename)   || die "Can't open $filename: $!";
```

When starting a command with `open`, you must choose either input or output: "`cmd|`" for reading or "`|cmd`" for writing. You may not use `open` to start a command that pipes both in and out, as the (currently) illegal notation, "`|cmd|`", might appear to indicate. However, the standard `IPC::Open2` and `IPC::Open3` library routines give you a close equivalent. For details on double-ended pipes, see the section "Bidirectional Communication" on page 536 in Chapter 15.

You may also, in the Bourne shell tradition, specify an *EXPR* beginning with `>&`, in which case the rest of the string is interpreted as the name of a filehandle (or file descriptor, if numeric) to be duplicated using the *dup2*(2) syscall.[13] You may use `&` after `>`, `>>`, `<`, `+>`, `+>>`, and `+<`. (The specified mode should match the mode of the original filehandle.)

One reason you might want to do this would be if you already had a filehandle open and wanted to make another handle that's really a duplicate of the first one.

13. This doesn't (currently) work with anonymous handles created by filehandle autovivification, but you can always use `fileno` to fetch the file descriptor and dup that.

```
open(SAVEOUT, ">&SAVEERR") || die "couldn't dup SAVEERR: $!";
open(MHCONTEXT, "<&4")     || die "couldn't dup fd4: $!";
```

That means that if a function is expecting a filename, but you don't want to give it a filename because you already have the file open, you can just pass the filehandle with a leading ampersand. It's best to use a fully qualified handle though, just in case the function happens to be in a different package:

```
somefunction("&main::LOGFILE");
```

Another reason to "dup" filehandles is to temporarily redirect an existing filehandle without losing track of the original destination. Here is a script that saves, redirects, and restores `STDOUT` and `STDERR`:

```
#!/usr/bin/perl
open SAVEOUT, ">&STDOUT";
open SAVEERR, ">&STDERR";

open(STDOUT, "> foo.out") || die "Can't redirect stdout";
open(STDERR, ">&STDOUT")  || die "Can't dup stdout";

select STDERR; $| = 1;         # enable autoflush
select STDOUT; $| = 1;         # enable autoflush

say STDOUT "stdout 1";     # these I/O streams propagate to
say STDERR "stderr 1";     # subprocesses too

system("some command");        # uses new stdout/stderr

close STDOUT;
close STDERR;

open STDOUT, ">&SAVEOUT";
open STDERR, ">&SAVEERR";

say STDOUT "stdout 2";
say STDERR "stderr 2";
```

If the filehandle or descriptor number is preceded by a `&=` combination instead of a simple `&`, then instead of creating a completely new file descriptor, Perl makes the *`FILEHANDLE`* an alias for the existing descriptor using the *fdopen*(3) C library call. This is slightly more parsimonious of systems resources, although that's less of a concern these days.

```
$fd = $ENV{"MHCONTEXTFD"};
open(MHCONTEXT, "<&=$fdnum")
        || die "couldn't fdopen descriptor $fdnum: $!";
```

Filehandles STDIN, STDOUT, and STDERR always remain open across an exec. Other filehandles, by default, do not. On systems supporting the fcntl function, you may modify the close-on-exec flag for a filehandle.

```
use Fcntl qw(F_GETFD F_SETFD);
$flags = fcntl(FH, F_SETFD, 0)
        || die "Can't clear close-on-exec flag on FH: $!";
```

See also the special $^F ($SYSTEM_FD_MAX) variable in Chapter 25.

With the two-argument form of open, you have to be careful when you use a string variable as a filename, since the variable may contain arbitrarily weird characters (particularly when the filename has been supplied by arbitrarily weird characters on the Internet). If you're not careful, parts of the filename might get interpreted as a *MODE* string, ignorable whitespace, a dup specification, or a minus. Here's one historically interesting way to insulate yourself:

```
$path =~ s#^(\s)#./$1#;
open(FH, "< $path\0") || die "can't open $path: $!";
```

But that's still broken in several ways. Instead, just use the three-argument form of open to open any arbitrary filename cleanly and without any (extra) security risks:

```
open(FH, "<", $path) || die "can't open $path: $!";
```

On the other hand, if what you're looking for is a true, C-style *open*(2) syscall with all its attendant belfries and whistle-stops, then check out sysopen:

```
use Fcntl;
sysopen(FH, $path, O_RDONLY) || die "can't open $path: $!";
```

If you're running on a system that distinguishes between text and binary files, you may need to put your filehandle into binary mode—or forgo doing so, as the case may be—to avoid mutilating your files. On such systems, if you use text mode on a binary file, or binary mode on a text file, you probably won't like the results.

Systems that need the binmode function are distinguished from those that don't by the format used for text files. Those that don't need it terminate each line with a single character that corresponds to what C thinks is a newline, \n. Unix, including modern versions of Mac OS, falls into this category. VMS, MVS, MS-whatever, and S&M operating systems of other varieties treat I/O on text files and binary files differently, so they need binmode.

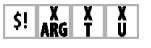
Or its equivalent. You can specify binary mode in the open function without a separate call to binmode. As part of the *MODE* argument (but only in the three-argument form), you may specify various input and output layers. To do the

equivalent of a `binmode`, use the three-argument form of `open` and stuff a layer of `:raw` in after the other *MODE* characters:

```
open(FH, "< :raw", $path) || die "can't open $path: $!";
```

See the `Encode` module in Chapter 6 for details about what other sorts of things you can put there, including handling of Windows text files.

opendir




```
opendir DIRHANDLE, EXPR
```

This function opens a directory named *EXPR* for processing by `readdir`, `telldir`, `seekdir`, `rewinddir`, and `closedir`. The function returns true if successful. Directory handles have their own namespace separate from filehandles.

See the example at `readdir`.

ord


```
ord EXPR
ord
```

This function returns the numeric value (codepoint) of the first character of *EXPR*. The return value is always unsigned. If you want a signed value, use `unpack("c", EXPR)`. If you want the characters in the string converted to a list of numbers, use `unpack("U*", EXPR)` instead. To find the codepoint for a character gives it name as a string, use the `charnames::vianame` functions from the `charnames` pragma.

our

```
our TYPE EXPR : ATTRIBUTES
our EXPR : ATTRIBUTES
our TYPE EXPR
our EXPR
```

An `our` declares one or more variables to be valid globals within the enclosing block, file, or `eval`. That is, `our` has the same rules as a `my` declaration for determination of visibility, but does not create a new private variable; it merely allows unfettered access to the existing package global. If more than one value is listed, the list must be placed in parentheses.

The primary use of an `our` declaration is to hide the variable from the effects of a `use strict "vars"` declaration; since the variable is masquerading as a `my` variable, you are permitted to use the declared global variable without qualifying it with

its package. However, just like the `my` variable, this only works within the lexical scope of the `our` declaration. In this respect, it differs from `use vars`, which affects the entire package and is not lexically scoped.

`our` is also like `my` in that you are allowed to declare variables with a *`TYPE`* and with *`ATTRIBUTES`*. Here is the syntax:

```
our Dog $spot :ears(short) :tail(long);
```

As of this writing, it's not entirely clear what that will mean. Attributes could affect either the global or the local interpretation of `$spot`. On the one hand, it would be most like `my` variables for attributes to warp the current local view of `$spot` without interfering with other views of the global in other places. On the other hand, if one module declares `$spot` to be a `Dog`, and another declares `$spot` to be a `Cat`, you could end up with meowing dogs or barking cats. This is a subject of ongoing research, which is a fancy way to say we don't know what we're talking about yet.

Another way in which `our` is like `my` is in its visibility. An `our` declaration declares a global variable that will be visible across its entire lexical scope, even across package boundaries. The package in which the variable is located is determined at the point of the declaration, not at the point of use. This means the following behavior holds and is deemed to be a feature:

```
package Foo;
our $bar;      # $bar is $Foo::bar for rest of lexical scope
$bar = 582;

package Bar;
print $bar;    # prints 582, just as if "our" had been "my"
```

However, the distinction between `my` creating a new, private variable and `our` exposing an existing, global variable is important, especially in assignments. If you combine a runtime assignment with an `our` declaration, the value of the global variable does not disappear once the `our` goes out of scope. For that, you need `local`:

```
($x, $y) = ("one", "two");
say "before block, x is $x, y is $y";
{
    our $x = 10;
    local our $y = 20;
    say "in block, x is $x, y is $y";
}
say "past block, x is $x, y is $y";
```

That prints out:

```
before block, x is one, y is two
in block, x is 10, y is 20
past block, x is 10, y is two
```

Multiple `our` declarations in the same lexical scope are allowed if they are in different packages. If they happen to be in the same package, Perl will emit warnings if you ask it to.

```
use warnings;
package Foo;
our $bar;          # declares $Foo::bar for rest of lexical scope
$bar = 20;

package Bar;
our $bar = 30;     # declares $Bar::bar for rest of lexical scope
print $bar;        # prints 30

our $bar;          # emits warning
```

See also `local`, `our`, and `state`, as well as the section "Scoped Declarations" on page 155 in Chapter 4.

pack

```
pack TEMPLATE, LIST
```

This function takes a *LIST* of ordinary Perl values, converts them into a string of bytes according to the *TEMPLATE*, and returns this string. Templates for `pack` and `unpack` are described in Chapter 26.

package

```
package NAMESPACE VERSION BLOCK
package NAMESPACE VERSION
package NAMESPACE BLOCK
package NAMESPACE
```

This is not really a function but a declaration that says that the *BLOCK*, or the rest of the innermost enclosing scope, belongs to the indicated symbol table or namespace. (The scope of a `package` declaration is thus the same as the scope of a `my`, `state`, or `our` declaration.) Within its scope, the declaration causes the compiler to resolve all unqualified global identifiers by looking them up in the declared package's symbol table.

A `package` declaration affects only global variables—including those on which you've used `local`—not lexical variables created with `my`, `state`, or `our`. It only affects unqualified global variables; global variables that are qualified with a package name of their own ignore the current declared package. Global variables

declared with `our` are unqualified and therefore respect the current package, but only at the point of declaration, after which they behave like `my` variables. That is, for the rest of their lexical scope, `our` variables are "nailed" to the package in use at the point of declaration, even if a subsequent package declaration intervenes.

Typically, you would put a `package` declaration as the first thing in a file that is to be included by the `require` or `use` operator, but you can put one anywhere a statement would be legal. When creating a traditional or object-oriented module file, it is customary to name the package the same name as the file to avoid confusion. (It's also customary to name such packages beginning with a capital letter, because lowercase modules are by convention interpreted as pragmatic modules.)

You can switch into a given package in more than one place; it merely influences which symbol table is used by the compiler for the rest of that block. (If the compiler sees another `package` declaration at the same level, the new declaration overrides the previous one.) Your main program is assumed to start with an invisible `package main` declaration.

If *`VERSION`* is provided, `package` sets the `$VERSION` variable in the given namespace to a `version` object with the VERSION provided. *`VERSION`* must be a "strict" style version number as defined by the `version` pragma: a positive decimal number (integer or decimal-fraction) without exponentiation, or else a dotted-decimal v-string with a leading `v` character and at least three components. (This may be relaxed to two in the future as people become used to version objects.) You should set `$VERSION` only once per package.

You can refer to variables, subroutines, handles, and formats in other packages by qualifying the identifier with the package name and a double colon: `$Package::Variable`. If the package name is null, the main package is assumed. That is, `$::sail` is equivalent to `$main::sail`, as well as to `$main'sail`, which is still occasionally seen in older code.

Here's an example:

```
package main;       $sail = "hale and hearty";
package Mizzen;     $sail = "tattered";
package Whatever;
say "My main sail is $main::sail.";
say "My mizzen sail is $Mizzen::sail.";
```

This prints:

```
My main sail is hale and hearty.
My mizzen sail is tattered.
```

The symbol table for a package is stored in a hash with a name ending in a double colon. The main package's symbol table is named `%main::`, for example. So the existing package symbol `*main::sail` can also be accessed as `$main::{"sail"}`.

See Chapter 10 for more information about packages. See `my` earlier in this chapter for other scoping issues.

__PACKAGE__

A special token that returns the name of the package in which it occurs. See Chapter 10.

pipe


```
pipe READHANDLE, WRITEHANDLE
```

Like the corresponding syscall, this function opens a pair of connected pipes—see *pipe*(2). This call is usually used right before a `fork`, after which the pipe's reader should close *`WRITEHANDLE`*, and the writer close *`READHANDLE`*. (Otherwise, the pipe won't indicate EOF to the reader when the writer closes it.) If you set up a loop of piped processes, deadlock can occur unless you are remarkably careful. In addition, note that Perl's pipes use standard I/O buffering, so you may need to set `$|` (`$OUTPUT_AUTOFLUSH`) on your *`WRITEHANDLE`* to flush after each output operation, depending on the application—see `select` (output filehandle).

(As with `open`, if either filehandle is undefined, it will be autovivified.)

Here's a small example:

```
pipe(README, WRITEME);
unless ($pid = fork) {  #              child
    defined($pid) || die "can't fork: $!";
    close(README);
    for $i (1..5) { print WRITEME "line $i\n" }
    exit;
}
$SIG{CHLD} = sub { waitpid($pid, 0) };
close(WRITEME);
@strings = <README>;
close(README);
print "Got:\n", @strings;
```

Notice how the writer closes the read end and the reader closes the write end. You can't use one pipe for two-way communication. Either use two different pipes or the `socketpair` syscall for that. See the section "Pipes" on page 531 in Chapter 15.

pop

```
pop ARRAY
pop
```

This function treats an array like a stack—it pops (removes) and returns the last value of the array, shortening the array by one element. If *ARRAY* is omitted, the function pops `@_` within the lexical scope of subroutines and formats; it pops `@ARGV` at file scopes (typically the main program) or within the lexical scopes established by the `eval` *STRING*, `BEGIN {}`, `CHECK {}`, `UNITCHECKINIT {}`, and `END {}` constructs. It has the same effect as:

```
$tmp = $ARRAY[$#ARRAY--];
```

or:

```
$tmp = splice @ARRAY, -1;
```

If there are no elements in the array, `pop` returns `undef`. (But don't depend on that to tell you when the array is empty if your array contains `undef` values!) See also `push` and `shift`. If you want to pop more than one element, use `splice`.

The `pop` requires its first argument to be an array, not a list. If you just want the last element of a list, use this:

```
( LIST )[-1]
```

Starting with v5.14, `pop` can take a reference to an unblessed array, which will be dereferenced automatically. This aspect of `pop` is considered experimental. The exact behavior may change in a future version of Perl.

pos

```
pos SCALAR
pos
```

This function returns the location in *SCALAR* where the last `m//g` search over *SCALAR* left off.

It returns the offset of the character (codepoint) *after* the last one matched. (That is, it's equivalent to `length($`) + length($&)`.) This is the offset where the next `m//g` search on that string will start. Remember that the offset of the beginning of the string is `0`. Note that 0 is a valid match offset. `undef` indicates that the search position is reset (usually due to match failure, but it can also be because no match has been run on the scalar yet).

For example:

```
$graffito = "fee fie foe foo";
while ($graffito =~ m/e/g) {
    say pos $graffito;
}
```

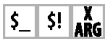
prints `2`, `3`, `7`, and `11`, the offsets of each of the codepoints following an "`e`". The `pos` function may be assigned a value to tell the next `m//g` where to start:

```
$graffito = "fee fie foe foo";
pos $graffito = 4;  # Skip the fee, start at fie
while ($graffito =~ m/e/g) {
    say pos $graffito;
}
```

This prints only `7` and `11`. The regular expression assertion `\G` matches only at the location currently specified by `pos` for the string being searched. See the section "Positions" on page 217 in Chapter 5.

Note that we said codepoints, not characters. We didn't want to confuse you. Codepoints are programmer-visible characters, some of which may even be invisible to users. A user-visible character, usually called graphemes or grapheme clusters, may well comprise multiple codepoints. For example, a "`\r\n`" is one user character but two programmer characters. See the CPAN `Unicode::GCString` module if you would like a flavor of `pos` that works with graphemes instead of codepoints.

print




```
print FILEHANDLE LIST
print FILEHANDLE
print LIST
print
```

This function prints a string or a comma-separated list of strings. If set, the contents of the `$\` (`$OUTPUT_RECORD_SEPARATOR`) variable will be implicitly printed at the end of the list. The function returns true if successful, false otherwise. The current value of `$,` (if any) is printed between each *`LIST`* item. The current value of `$\` (if any) is printed after the entire *`LIST`* has been printed.

To use *`FILEHANDLE`* alone to print the content of `$_` to it, you must use a real filehandle like `FH`, not an indirect one like `$fh`. *`FILEHANDLE`* may be a scalar variable name (unsubscripted), in which case the variable contains either the name of the actual filehandle or a reference to a filehandle object of some sort. As with any other indirect object, *`FILEHANDLE`* may also be a block that returns such a value:

```
print { $OK ? "STDOUT" : "STDERR" } "stuff\n";
print { $iohandle[$i] } "stuff\n";
```

If *FILEHANDLE* is a variable and the next token is a term, it may be misinterpreted as an operator unless you interpose a + or put parentheses around the arguments. For example:

```
print $a - 2;   # prints $a - 2 to default filehandle (usually STDOUT)
print $a (- 2); # prints -2 to filehandle specified in $a
print $a -2;    # also prints -2 (weird parsing rules :-)
```

If *FILEHANDLE* is omitted, the function prints to the currently selected output filehandle, initially `STDOUT`. To set the default output filehandle to something other than `STDOUT`, use the `select` *FILEHANDLE* operation.[14] If *LIST* is also omitted, the function prints `$_`. Because `print` takes a *LIST*, anything in the *LIST* is evaluated in list context. Thus, when you say:

```
print OUT <STDIN>;
```

it is not going to print the next line from standard input, but all remaining lines from standard input up to end-of-file, since that's what `<STDIN>` returns in list context. If you want the other thing, say:

```
print OUT scalar <STDIN>;
```

Also, remembering the if-it-looks-like-a-function-it-is-a-function rule, be careful not to follow the `print` keyword with a left parenthesis unless you want the corresponding right parenthesis to terminate the arguments to the `print`. Instead, interpose a + or put parens around all the arguments:

```
print  (1+2)*3, "\n";       # WRONG
print +(1+2)*3, "\n";       # ok
print ((1+2)*3, "\n");      # ok
```

If you specify a *FILEHANDLE*, you may omit the *LIST* only if the *FILEHANDLE* is a regular bareword filehandle, not a block or indirect filehandle.

```
$_ = "stuff\n";
*NEWOUT = *STDOUT;
print NEWOUT;   # ok: prints "stuff\n"

$fh = *NEWOUT;
print $fh;      # WRONG: prints STDOUT "*main::STDOUT"
```

Printing Unicode data to a filehandle that doesn't have an I/O layer specifying how to encode it will trigger a mandatory warning, "Wide character in print". To fix this, specify an encoding via `binmode` or as the second argument in a three-or-more-argument `open`.

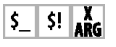
```
binmode(STDOUT, ":utf8") || die "Can't binmode: $!";
```

14. Thus, `STDOUT` isn't really the default filehandle for `print`. It's merely the *default* default filehandle.

```
open(HANDLE, "> :encoding(UTF-16)", $file)
    || die "Can't open $file: $!";
```

Printing to a closed pipe or socket will generate a `SIGPIPE` signal. See the section "Signals" on page 518 in Chapter 15.

printf




```
printf FILEHANDLE FORMAT, LIST
printf FORMAT, LIST
printf FILEHANDLE
printf LIST
printf
```

This function prints a formatted string to *`FILEHANDLE`* or, if omitted, the currently selected output filehandle, initially `STDOUT`. The first item in the *`LIST`* must be a string that says how to format the rest of the items. This is similar to the C library's *printf*(3) and *fprintf*(3) functions. The function is equivalent to:

```
print FILEHANDLE sprintf FORMAT, LIST
```

except that `$\` (`$OUTPUT_RECORD_SEPARATOR`) is not appended.

See Chapter 26 for how formats are interpreted. We'd duplicate all that here, but this book is already an ecological disaster.

An exception is raised only if an invalid reference type is used as the *`FILEHANDLE`* argument.

If you omit both the *`FORMAT`* and the *`LIST`*, `$_` is used—but, in that case, you should have been using `print`. Don't fall into the trap of using a `printf` when a simple `print` would do. The `print` function is more efficient and less error prone.

prototype


```
prototype FUNCTION
```

This function returns the prototype of a function as a string (or `undef` if the function has no prototype). *`FUNCTION`* is a reference to, or the name of, the function whose prototype you want to retrieve.

If *`FUNCTION`* is a string starting with `CORE::`, the rest is taken as a name for a Perl built-in, and an exception is raised if there is no such built-in. If the built-in is not *overridable* (such as `qw//`) or its arguments cannot be expressed by a prototype (such as `system`), the function returns `undef` because the built-in does not really behave like a Perl function. Otherwise, the string describing the equivalent prototype is returned.

push

```
push ARRAY, LIST
```

This function treats *ARRAY* as a stack and pushes the values of *LIST* onto the end of *ARRAY*. The length of *ARRAY* increases by the length of *LIST*. The function returns this new length. The `push` function has the same effect as:

```
for my $value (listfunc()) {
    $array[++$#array] = $value;
}
```

or:

```
splice @array, @array, 0, listfunc();
```

but it is more efficient (for both you and your computer). You can use `push` in combination with `shift` to make a fairly time-efficient shift register or queue:

```
for (;;) {
    push @array, shift @array;
    ...
}
```

See also `pop` and `unshift`.

Starting with v5.14, `push` can take a reference to an unblessed array, which will be dereferenced automatically. This aspect of `push` is considered experimental. The exact behavior may change in a future version of Perl.

q/STRING/

```
q/STRING/
qq/STRING/
qr/STRING/
qw/STRING/
qx/STRING/
```

Generalized quotes. See the section "Pick Your Own Quotes" on page 70 in Chapter 2. For status annotations on `qx//`, see `readpipe`. For status annotations on `qr//`, see `m//`. See also "Staying in Control" on page 232 in Chapter 5.

quotemeta

```
quotemeta EXPR
quotemeta
```

This function returns the value of *EXPR* with all nonalphanumeric characters backslashed. (That is, all characters not matching `/[A-Za-z_0-9]/` will be preceded by a backslash in the returned string, regardless of locale settings.) This is

the internal function implementing the `\Q` escape in interpolative contexts (including double-quoted strings, backticks, and patterns).

rand

```
rand EXPR
rand
```

This function returns a pseudorandom floating-point number greater than or equal to 0 and less than the value of *EXPR*. (*EXPR* should be positive.) If *EXPR* is omitted, the function returns a floating-point number between 0 and 1 (including 0, but excluding 1). `rand` automatically calls `srand` unless `srand` has already been called. See also `srand`.

To get an integral value, such as for a die roll, combine this with `int`, as in:

```
$roll = int(rand 6) + 1;       # $roll now a number between 1 and 6
```

Because Perl uses your own C library's pseudorandom number function, like *random*(3) or *drand48*(3), the quality of the distribution is not guaranteed. If you need stronger randomness, such as for cryptographic purposes, you might consult instead the documentation on *random*(4) if your system has a */dev/random* or */dev/urandom* device; the CPAN modules `Math::Random::Secure`, `Math::Random::MT::Perl`, and `Math::TrulyRandom`; or a good textbook on computational generation of pseudorandom numbers, such as the second volume of Knuth.[15]

read


```
read FILEHANDLE, SCALAR, LENGTH, OFFSET
read FILEHANDLE, SCALAR, LENGTH
```

This function tries to read *LENGTH characters* (meaning codepoints, not graphemes) of data into variable *SCALAR* from the specified *FILEHANDLE*. The function returns the number of characters read or 0 at end-of-file. It returns `undef` on error. *SCALAR* will grow or shrink to the length actually read. The *OFFSET*, if specified, determines where in the variable to start putting characters so that you can read into the middle of a string.

To copy data from filehandle `FROM` into filehandle `TO`, you could say:

```
while (read(FROM, $buf, 16384)) {
    print TO $buf;
}
```

15. Knuth, D.E. *The Art of Computer Programming, Seminumerical Algorithms*, vol. 2, 3rd ed. (Reading, Mass.: Addison–Wesley, 1997).

Note the *characters*: depending on the status of the filehandle, either (8-bit) bytes or characters are read. A byte is just Perl's way of talking about undecoded codepoints with small values. By default, all filehandles operate on bytes. But, for example, if the filehandle has been opened with the `:utf8` I/O layer, the I/O will operate on UTF-8-encoded Unicode characters, not bytes. Similarly for the two-argument form of `binmode`, the middle argument to `open`, or via the `open` pragma: in those cases, pretty much any characters can be read.

The opposite of a `read` is simply a `print`, which already knows the length of the string you want to write and can write a string of any length. Don't make the mistake of using `write`, which is solely used with `format`s.

Perl's `read` function is implemented using standard I/O's *fread*(3) function, so the actual *read*(2) syscall may read more than *`LENGTH`* bytes to fill the input buffer, and *fread*(3) may do more than one *read*(2) syscall to fill the buffer. To gain greater control, specify the real syscall using `sysread`. Calls to `read` and `sysread` should not be intermixed unless you are into heavy wizardry (or pain).

readdir


```
readdir DIRHANDLE
```

This function reads directory entries (which are simple filenames) from a directory handle opened by `opendir`. In scalar context, this function returns the next directory entry, if any; otherwise, it returns `undef`. In list context, it returns all the rest of the entries in the directory, which will be a null list if there are no entries. For example:

```
opendir(THISDIR, ".") || die "serious dainbramage: $!";
@allfiles = readdir THISDIR;
closedir THISDIR;
say "@allfiles";
```

That prints all files in the current directory on one line. If you want to avoid the "`.`" and "`..`" entries, incant one of these (whichever you think is least unreadable):

```
@allfiles = grep { $_ ne "." && $_ ne ".." } readdir THISDIR;
@allfiles = grep { ! /^[.][.]?\z/ } readdir THISDIR;
@allfiles = grep { ! /^\.{1,2}\z/ } readdir THISDIR;
@allfiles = grep !/^\.\.?\z/, readdir THISDIR;
```

And to avoid all `.*` files (like the *ls* program):

```
@allfiles = grep !/^\./, readdir THISDIR;
```

To get just text files, say this:

```
@textfiles = grep -T, readdir THISDIR;
```

But watch out on that last one because the result of `readdir` needs to have the directory part glued back on if it's not the current directory—like this:

```
opendir(THATDIR, $path) || die "can't opendir $path: $!";
@dotfiles = grep { /^\./ && -f } map { "$path/$_" } readdir(THATDIR);
closedir THATDIR;
```

As of v5.12 you can use a bare `readdir` in a `while` loop, which will set `$_` on every iteration. You may also use an undefined scalar variable, which will be autovivified with an anonymous directory handle.

```
my $dh;  # make sure it's new
opendir($dh, $somedir) || die "can't opendir $somedir: $!";
while (readdir($dh)) {
    print "$somedir/$_\n";
}
closedir $dh;
```

readline


```
readline FILEHANDLE
readline
```

This is the internal function implementing the `<FILEHANDLE>` operator, but you can use it directly. The function reads the next record from *FILEHANDLE*, which may be a filehandle name or an indirect filehandle expression that returns either the name of the actual filehandle or a reference to anything resembling a filehandle object, such as a typeglob. In scalar context, each call reads and returns the next record until end-of-file is reached, whereupon the next call returns `undef`. In list context, `readline` reads records until end-of-file is reached and then returns a list of records. By "record", we normally mean a line of text, but changing the value of `$/` (`$INPUT_RECORD_SEPARATOR`) from its default value causes this operator to "chunk" the text differently. Undefining `$/` makes the chunk size entire files (slurp mode).

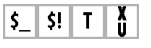
When slurping files in scalar context, if you happen to slurp an empty file, `readline` returns `""` the first time, and `undef` each subsequent time. When slurping from the magical `ARGV` filehandle, each file returns one chunk (again, null files return as `""`), followed by a single `undef` when the files are exhausted. If *FILEHANDLE* is omitted, the `ARGV` filehandle is assumed.

The `<FILEHANDLE>` operator is discussed in more detail in the section "Input Operators" on page 87 in Chapter 2.

```
$line = <STDIN>;
$line = readline(STDIN);          # same thing
$line = readline(*STDIN);         # same thing
```

```
$line = readline(\*STDIN);        # same thing

open(my $fh, "<&=STDIN") || die;
bless($fh => "AnyOldClass");
$line = readline($fh);            # same thing
```

readlink




```
readlink EXPR
readlink
```

This function returns the filename pointed to by a symbolic link. *EXPR* should evaluate to a filename, the last component of which is a symbolic link. If it is not a symbolic link, or if symbolic links are not implemented on the filesystem, or if some system error occurs, `undef` is returned, and you should check the error code in `$!`.

Be aware that the returned symlink may be relative to the location you specified. For instance, you may say:

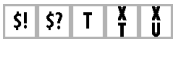
```
$link_contents = readlink("/usr/local/src/express/yourself.h");
```

and `readlink` might return:

```
../express.1.23/includes/yourself.h
```

which is not directly usable as a filename unless your current directory happens to be */usr/local/src/express*.

readpipe




```
readpipe scalar EXPR
readpipe LIST # (proposed)
```

This is the internal function implementing the `qx//` quote construct (also known as the backticks operator). It is occasionally handy when you need to specify your *EXPR* in a way that wouldn't be handy using the quoted form. Be aware that we may change this interface in the future to support a *LIST* argument to make it more like the `exec` function, so don't assume that it will continue to provide scalar context for *EXPR*. Supply the `scalar` yourself, or try the *LIST* form. Who knows, it might work by the time you read this.

recv

$! T X ARG X RO X U

```
recv SOCKET, SCALAR, LEN, FLAGS
```

This function receives a message on a socket. It attempts to receive *LENGTH* characters (codepoints) of data into variable *SCALAR* from the specified *SOCKET* filehandle. The function returns the address of the sender or `undef` if there's an error. *SCALAR* will grow or shrink to the length actually read. The function takes the same flags as *recv*(2), and it is actually implemented using the *recvfrom*(2). See the section "Sockets" on page 543 in Chapter 15.

Note the *characters*: depending on the status of the socket, either undecoded (8-bit) bytes or fully decoded characters are received. By default, all sockets operate on bytes. But, for example, if the socket has been changed using `binmode` to operate with the `:encoding(utf8)` I/O layer, the I/O will operate on UTF-8-encoded Unicode characters, not bytes.

redo

$@

```
redo LABEL
redo
```

The `redo` operator restarts a loop block without reevaluating the conditional. The `continue` block, if any, is not executed. If the *LABEL* is omitted, the operator refers to the innermost enclosing loop. This operator is normally used by programs that wish to deceive themselves about what was just input:

```
# A loop that joins lines continued with a backslash
while (<STDIN>) {
    if (s/\\\n$// && defined($nextline = <STDIN>)) {
        $_ .= $nextline;
        redo;
    }
    print;  # or whatever...
}
```

`redo` cannot be used to exit a block that returns a value such as `eval {}`, `sub {}`, or `do {}`, and it should not be used to exit a `grep` or `map` operation. With warnings enabled, Perl will warn you if you `redo` a loop not in your current lexical scope.

A block by itself is semantically identical to a loop that executes once. Thus, `redo` inside such a block will effectively turn it into a looping construct. See the section "Loop Control" on page 144 in Chapter 4.

ref

```
ref EXPR
ref
```

The `ref` operator returns a true value if *EXPR* is a reference, and false otherwise. The value returned depends on the type of thing the reference refers to. Built-in types include:

```
SCALAR
ARRAY
HASH
CODE
REF
GLOB
LVALUE
FORMAT
IO
VSTRING
Regexp
```

The return value `LVALUE` indicates a reference to an lvalue that is not a variable. You get this from taking the reference of function calls like `pos` or `substr`. `VSTRING` is returned if the reference points to a version string.

The result `Regexp` indicates that the argument is a regular expression resulting from `qr//`.

If the referenced object has been blessed into a package, then that package name is returned instead. You can think of `ref` as a "typeof" operator.

```
if (ref($r) eq "HASH") {
    say "r is a reference to a hash.";
}
elsif (ref($r) eq "Hump") {    # Naughty—see below
    say "r is a reference to a Hump object.";
}
elsif (not ref $r) {
    say "r is not a reference at all.";
}
```

It's considered bad OO style to test your object's class for equality to any particular class name, since a derived class will have a different name but should be allowed access to the base class's methods, according to the Liskov Substitution Principle. It's better to use the `UNIVERSAL` method `isa`, as follows:

```
if ($r->isa("Hump")) {
    say "r is a reference to a Hump object, || subclass.";
}
```

It's usually best not to test at all, since the OO mechanism won't send the object to your method unless it thinks it's appropriate in the first place. See Chapter 8 and Chapter 12 for more details. See also the `reftype` function under the section "attributes" on page 1002 in Chapter 29.

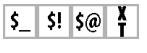
rename

```
rename OLDNAME, NEWNAME
```

This function changes the name of a file. It returns true for success, and false otherwise. It will not (usually) work across filesystem boundaries, although on a Unix system the *mv* command can sometimes be used to compensate for this. If a file named *NEWNAME* already exists, it will be destroyed. Non-Unix systems might have additional restrictions.

See the standard `File::Copy` module for cross-filesystem renames using a platform-independent `move` function.

require



```
require VERSION
require EXPR
require
```

This function asserts a dependency of some kind on its argument.

If the argument is a string, `require` loads and executes the Perl code found in the separate file whose name is given by the string. This is similar to using a `do` on a file, except that `require` checks to see whether the library file has been loaded already and raises an exception if any difficulties are encountered. (It can thus be used to express file dependencies without worrying about duplicate compilation.) Like its cousins `do` and `use`, `require` knows how to search the include path stored in the `@INC` array and to update `%INC` on success. See Chapter 25.

The file must return true as the last value to indicate successful execution of any initialization code, so it's customary to end such a file with `1` unless you're sure it'll return true otherwise. (This requirement may be relaxed in the future.)

If `require`'s argument is a version number of the form v5.6.2, `require` demands that the currently executing version of Perl be at least that version. (Perl also accepts a floating-point number such as 5.005_03 for compatibility with older versions of Perl, but that form is now discouraged because folks from other cultures don't understand it.) Thus, a script that requires v5.14 can put as its first line:

```
require 5.014_001;  # preferred for (ancient) backward compatibility
require 5.14.1;     # ditto
require v5.14.1;    # runtime version check
```

and earlier versions of Perl will abort. Like all `require`s, however, this is done at runtime. You might prefer to say `use 5.14.0` for a compile-time check. See also `$PERL_VERSION` in Chapter 25.

If `require`'s argument is a bare package name (see `package`), `require` assumes an automatic *.pm* suffix, making it easy to load standard modules. This behavior is like `use`, except that it happens at runtime rather than compile time, and the `import` method is not called. For example, to pull in *Socket.pm* without introducing any symbols into the current package, say this:

```
require Socket;           # instead of "use Socket;"
```

However, you can get the same effect with the following, which has the advantage of giving a compile-time warning if *Socket.pm* can't be located:

```
use Socket ();
```

Using `require` on a bare name also replaces any `::` in the package name with your system's directory separator, traditionally `/`. In other words, if you try this:

```
require Foo::Bar;         # a splendid bare name
```

The require function looks for the *Foo/Bar.pm* file in the directories specified in the `@INC` array. But if you try this:

```
$class = "Foo::Bar";
require $class;           # $class is not a bare name
```

or this:

```
require "Foo::Bar";       # quoted literal not a bare name
```

the require function will look for the *Foo::Bar* file in the `@INC` array and will complain about not finding `Foo::Bar` there. If so, you can do this:

```
eval "require $class";
```

Now that you understand how `require` looks for files with a bareword argument, there is a little extra functionality going on behind the scenes. Before `require` looks for a "*.pm*" extension, it will first look for a similar filename with a "*.pmc*" extension. If this file is found, it will be loaded in place of any file ending in a "*.pm*" extension.

The `@INC` array contains a list of scalars that determine how a module is loaded. The `require` function walks through this list until it finds a scalar entry that leads to loadable source code, then loads that code.

Each element of `@INC` must be either a string (which is treated as the name of a directory in which to look for the required file) or some form of "code-like entity" (which is used to generate the contents of the required file).

A "code-like entity" can be a subroutine reference, an array containing a subroutine reference (plus some optional arguments for the subroutine), or an object with an `INC` method. Whichever form of the "code-like entity" is encountered, the code is invoked and passed two arguments: the entity itself and the file that is being looked for. That is:

```
Sub ref:      $sub_ref->($sub_ref, $required_file)
Array ref:    $arr_ref->[0]->($arr_ref, $required_file)
Object:       $object->INC($required_file)
```

No matter which form is being invoked, the subroutine or method is always expected to return a list of up to three values, which are interpreted as shown in Table 27-4.

Table 27-4. Expected return values for coderefs in @INC

Arguments	Action
(*HANDLE*)	Read source in from this handle
(*HANDLE, CODEREF*)	Read source in from handle and filter through subroutine
(*HANDLE, CODEREF, REF*)	As above, but pass *REF* to subroutine as well
(undef, *CODEREF*)	Call subroutine repeatedly to return source lines
(undef, *CODEREF, REF*)	As above, but pass *REF* to subroutine as well
Anything else	Fail and try the next entry in `@INC`

These hooks are also permitted to set the `%INC` entry corresponding to the files they have loaded. See the `%INC` variable in Chapter 25.

See also `do` *FILE*, the `use` command, the `lib` pragma, and the standard `FindBin` module.

reset

```
reset EXPR
reset
```

This function is generally used (or abused) at the top of a loop or in a `continue` block at the end of a loop to clear global variables or reset `m??` searches so that they work again. The expression is interpreted as a list of single characters (hyphens are allowed for ranges). All scalar variables, arrays, and hashes beginning with one of those letters are reset to their pristine state. If the expression is omit-

ted, one-match searches (`m?PATTERN?`) are reset to match again. The function resets variables or searches for only the current package. It always returns true.

To reset all "X" variables, say this:

```
reset "X";
```

To reset all lowercase variables, say this:

```
reset "a-z";
```

Lastly, to just reset `??` searches, say:

```
reset;
```

Resetting "A-Z" in package `main` is not recommended since you'll wipe out your global `ARGV`, `INC`, `ENV`, and `SIG` arrays and hashes.

Lexical variables (created by `my`) are not affected. Use of `reset` is vaguely deprecated because it easily clears out entire namespaces, and because the `??` operator is itself vaguely deprecated; please use `m??` instead.

See also the `delete_package` function from the standard `Symbol` module, and the whole issue of Safe compartments documented in the section "Safe Compartments" on page 670 in Chapter 20.

return


```
return EXPR
return
```

This operator causes the current subroutine, `eval`, or `do FILE` to return immediately with the specified value or values. Attempting to use `return` outside these three places raises an exception. Note also that an `eval` cannot do a `return` on behalf of the subroutine that called the `eval`.

EXPR will be evaluated in list, scalar, or void context, depending on how the return value will be used, which may vary from one execution to the next. That is, the supplied expression will be evaluated with the same context as the subroutine was called in. If the subroutine was called in scalar context, *EXPR* is also evaluated in scalar context and so returns a single scalar value. If the subroutine was invoked in list context, then *EXPR* is also evaluated in list context and so returns a list of values. A `return` with no argument returns the scalar value `undef` in scalar context, an empty list `()` in list context, and (naturally) nothing at all in void context. The context of the subroutine call can be determined from within the subroutine by using the (misnamed) `wantarray` function.

reverse

```
reverse LIST
```

In list context, this function returns a list value consisting of the elements of *LIST* in the opposite order. The function can be used to create descending sequences:

```
for (reverse 1 .. 10) { ... }
```

Because of the way hashes flatten into lists when passed as a *LIST*, `reverse` can also be used to invert a hash, presuming the values are unique:

```
%barfoo = reverse %foobar;
```

In scalar context, the function concatenates all the elements of *LIST* and then returns the reverse of that resulting string, character by character. By character we mean codepoint, not grapheme. That means you will inappropriately reverse the pieces of "`\r\n`" into "`\n\r`", causing combining characters to accidentally apply to the wrong base character. To do a reverse on graphemes instead of by codepoint, do this:

```
$codeuni = join "" => reverse $unicode =~ /\X/g;
```

A small hint: reversing a list sorted earlier by a user-defined function can often be achieved more easily by sorting the list in the opposite direction in the first place.

rewinddir


```
rewinddir DIRHANDLE
```

This function sets the current position to the beginning of the directory for the `readdir` routine on *DIRHANDLE*. The function may not be available on all machines that support `readdir`—`rewinddir` dies if unimplemented. It returns true on success, and false otherwise.

rindex

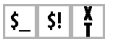
```
rindex STR, SUBSTR, POSITION
rindex STR, SUBSTR
```

This function works just like `index` except that it returns the position of the *last* occurrence of *SUBSTR* in *STR* (a reverse `index`). The function returns `-1` if *SUBSTR* is not found. *POSITION*, if specified, is the rightmost position that may be returned. To work your way through a string backward, say:

```
$pos = length $string;
while (($pos = rindex $string, $lookfor, $pos) >= 0) {
    say "Found at $pos";
    $pos--;
}
```

Note that like `index`, this works by character (codepoint) position, not by grapheme position. To work with strings as sequences of graphemes instead of codepoints, see the `index`, `rindex`, and `pos` methods for the CPAN `Unicode::GCString` module.

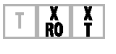
rmdir



```
rmdir FILENAME
rmdir
```

This function deletes the directory specified by *`FILENAME`* if that directory is empty. If the function succeeds, it returns true; otherwise, it returns false. See also the `File::Path` module if you want to remove the contents of the directory first and don't care to shell out to call *rm –r* for some reason (such as not having a shell or an *rm* command).

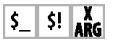
s///



```
s///
```

The substitution operator. See the section "Pattern-Matching Operators" in Chapter 5.

say



```
say FILEHANDLE LIST
say FILEHANDLE
say LIST
say
```

Just like `print`, but implicitly appends a newline. `say` *`LIST`* is simply an abbreviation for `{ local $\ = "\n"; print LIST }`. To use *`FILEHANDLE`* without a *`LIST`* to print the contents of `$_` to it, you must use a real filehandle like `FH`, not an indirect one like `$fh`.

This keyword is available only when the "`say`" feature is enabled; see the section "Terms and List Operators (Leftward)" on page 97 in Chapter 3.

scalar

```
scalar EXPR
```

This pseudofunction may be used within a *LIST* to force *EXPR* to be evaluated in scalar context when evaluation in list context would produce a different result. For example:

```
my($nextvar) = scalar <STDIN>;
```

prevents `<STDIN>` from reading all the lines from standard input before doing the assignment, since assignment to a list (even a `my` list) provides list context. Without the `scalar` in this example, the first line from `<STDIN>` would still be assigned to `$nextvar`, but subsequent lines would be read and thrown away, since the list we're assigning to is only able to receive a single scalar value.

Of course, a simpler, less-cluttered way would be to just leave the parentheses off, thereby changing the list context to a scalar one:

```
my $nextvar = <STDIN>;
```

Since a `print` function is a *LIST* operator, you have to say:

```
say "Length is ", scalar(@ARRAY);
```

if you want the length of `@ARRAY` to be printed out.

There's no "`list`" function corresponding to `scalar` since, in practice, one never needs to force evaluation in list context. That's because any operation that wants *LIST* already provides list context to its list arguments for free.

Because `scalar` is a unary operator, if you accidentally use a parenthesized list for the *EXPR*, this behaves as a scalar comma expression, evaluating all but the last element in void context and returning the final element evaluated in scalar context. This is seldom what you want. The following single statement:

```
print uc(scalar(&foo,$bar)),$baz;
```

is the (im)moral equivalent of these two:

```
&foo;
print(uc($bar),$baz);
```

See Chapter 2 for more details on the comma operator. See "Prototypes" in Chapter 7 for more on unary operators.

seek

```
seek FILEHANDLE, OFFSET, WHENCE
```

This function positions the file pointer for *FILEHANDLE*, just like the *fseek*(3) call of standard I/O. The first position in a file is at offset 0, not offset 1. Also, offsets refer to byte positions, not character positions or line numbers. In general, since line lengths vary, it's not possible to access a particular line number without examining the whole file up to that point, unless all your lines are known to be of a particular length, or you've built an index that translates line numbers into byte offsets. (The same restrictions apply to character positions in files with variable-length character encodings like UTF-8 and UTF-16: the operating system doesn't know what characters are, only bytes.)

FILEHANDLE can be an expression whose value gives either the name of the actual filehandle, a typeglob, or a reference to anything resembling a filehandle object. The function returns true on success, and false otherwise. For handiness, the function can calculate offsets from various file positions for you. The value of *WHENCE* specifies which file position your *OFFSET* uses for its starting point: `0`, the beginning of the file; `1`, the current position in the file; or `2`, the end of the file. The *OFFSET* can be negative for a *WHENCE* of `1` or `2`. If you'd like to use symbolic values for *WHENCE*, you may use `SEEK_SET`, `SEEK_CUR`, and `SEEK_END` from either the `IO::Seekable` or the `POSIX` module, or the `Fcntl` module.

If you want to position the file for `sysread` or `syswrite`, don't use `seek`; standard I/O buffering makes its effect on the file's system position unpredictable and nonportable. Use `sysseek` instead.

Because of the rules and rigors of ANSI C, on some systems you have to do a seek whenever you switch between reading and writing. Among other things, this may have the effect of calling the standard I/O library's *clearerr*(3) function. A *WHENCE* of `1` (`SEEK_CUR`) with an `OFFSET` 0 is useful for not moving the file position:

```
seek(TEST, 0, 1);
```

One interesting use for this function is to allow you to follow growing files, like this:

```
for (;;) {
    while (<LOG>) {
        grok($_);          # Process current line
    }
    sleep 15;
    seek LOG, 0, 1;        # Reset end-of-file error
}
```

The final `seek` clears the end-of-file error without moving the pointer. Depending on how standard your C library's standard I/O implementation happens to be, you may need something more like this:

```
for (;;) {
    for ($curpos = tell FILE; <FILE>; $curpos = tell FILE) {
        grok($_);          # Process current line
    }
    sleep $for_a_while;
    seek FILE, $curpos, 0; # Reset end-of-file error
}
```

Similar strategies can be used to remember the `seek` addresses of each line in an array.

Warning: *`POSITION`* is in bytes not characters, no matter whether there should happen to be any encoding layer on the filehandle. However, all functions in Perl that read from files *do* go through any encoding layer, and you can therefore read a partial "character" and wind up with an invalid Perl string. Avoid mixing calls to `sysseek` or `seek` with I/O functions on filehandle with a multibyte encoding layer.

seekdir


```
seekdir DIRHANDLE, POS
```

This function sets the current position for the next call to `readdir` on *`DIRHANDLE`*. *`POS`* must be a value returned by `telldir`. This function has the same caveats about possible directory compaction as the corresponding system library routine. The function may not be implemented everywhere that `readdir` is. It's certainly not implemented anywhere `readdir` isn't.

select (output filehandle)


```
select FILEHANDLE
select
```

For historical reasons, there are two `select` operators that are totally unrelated to each other. (See the next section for the other one.) This version of the `select` operator returns the currently selected output filehandle and, if *`FILEHANDLE`* is supplied, sets the current default filehandle for output. This has two effects: first, a `write` or a `print` without a filehandle will default to this *`FILEHANDLE`*; second, special variables related to output will refer to this output filehandle. For example, if you have to set the same top-of-form format for more than one output filehandle, you might do the following:

```
select REPORT1;
$^ = "MyTop";
select REPORT2;
$^ = "MyTop";
```

But note that this leaves `REPORT2` as the currently selected filehandle. This could be construed as antisocial, since it could really foul up some other routine's `print` or `write` statements. Properly written library routines leave the currently selected filehandle the same on exit as it was on entry. To support this, *`FILEHANDLE`* may be an expression whose value gives the name of the actual filehandle. Thus, you can save and restore the currently selected filehandle like this:

```
my $oldfh = select STDERR;
$| = 1;
select $oldfh;
```

or idiomatically but somewhat obscurely like this:

```
select((select(STDERR), $| = 1)[0])
```

This example works by building a list consisting of the returned value from `select(STDERR)` (which selects `STDERR` as a side effect) and `$| = 1` (which is always 1), but sets autoflushing on the now-selected `STDERR` as a side effect. The first element of that list (the previously selected filehandle) is now used as an argument to the outer `select`. Bizarre, right? That's what you get for knowing just enough Lisp to be dangerous.

You can also use the standard `SelectSaver` module to automatically restore the previous `select` on scope exit.

However, now that we've explained all that, we should point out that you rarely need to use this form of `select` nowadays, because most special variables you would want to set have object-oriented wrapper methods to do it for you. So instead of setting `$|` directly, you might say:

```
use IO::Handle;             # Unfortunately, this is *not* a small module
STDOUT->autoflush(1);
```

And the earlier format example might be coded as:

```
use IO::Handle;
REPORT1->format_top_name("MyTop");
REPORT2->format_top_name("MyTop");
```

select (ready file descriptors)

```
select RBITS, WBITS, EBITS, TIMEOUT
```

The four-argument `select` operator is totally unrelated to the previously described `select` operator. This operator is used to discover which (if any) of your file descriptors are ready to do input or output, or to report an exceptional condition. (This helps you avoid having to do polling.) It calls the *select*(2) syscall with the bit masks you've specified, which you can construct using `fileno` and `vec`, like this:

```
$rin = $win = $ein = "";
vec($rin, fileno(STDIN), 1)  = 1;
vec($win, fileno(STDOUT), 1) = 1;
$ein = $rin | $win;
```

If you want to `select` on many filehandles, you might wish to write a subroutine:

```
sub fhbits {
    my @fhlist = @_;
    my $bits;
    for my $fh (@fhlist) {
        vec($bits, fileno($fh), 1) = 1;
    }
    return $bits;
}
$rin = fhbits(*STDIN, *TTY, *MYSOCK);
```

Notice we passed in the filehandles using their typeglobs, because passing them in as strings is a bad idea. If you are using autovivified filehandles, you don't have to do this.

If you wish to use the same bit masks repeatedly (and it's more efficient if you do), the usual idiom is:

```
($nfound, $timeleft) =
    select($rout=$rin, $wout=$win, $eout=$ein, $timeout);
```

Or to block until any file descriptor becomes ready:

```
$nfound = select($rout=$rin, $wout=$win, $eout=$ein, undef);
```

As you can see, calling `select` in scalar context just returns `$nfound`, the number of ready descriptors found.

The `$wout=$win` trick works because the value of an assignment is its left side, so `$wout` gets clobbered first by the assignment and then by the `select`, while `$win` remains unchanged.

Any of the arguments can also be `undef`, in which case they're ignored. The *`TIMEOUT`*, if not `undef`, is in seconds, which may be fractional. (A timeout of `0` affects

a poll.) Not many implementations are capable of returning `$timeleft`. If not, they always return `$timeleft` equal to the supplied `$timeout`.

The standard `IO::Select` module provides a user-friendlier interface to `select`, mostly because it does all the bit-mask work for you.

One use for `select` is to sleep with a finer resolution than `sleep` allows. To do this, specify `undef` for all the bitmasks. So to sleep for (at least) 4.75 seconds, use:

```
select undef, undef, undef, 4.75;
```

(On some non-Unix systems the triple `undef` may not work, and you may need to fake up at least one bitmask for a valid descriptor that won't ever be ready.)

These days, importing a special version of `sleep` from the standard `Time::HiRes` module is probably the more portable way to do this:

```
use Time::HiRes qw(sleep);
sleep 4.75;    # not the normal sleep
```

One should probably not (attempt to) mix buffered I/O (like `read` or `<HANDLE>`) with `select`, except as permitted by POSIX, and even then only on truly POSIX .systems. Use `sysread` instead

semctl

```
semctl ID, SEMNUM, CMD, ARG
```

This function calls the System V IPC function *semctl*(2). You'll probably have to say `use IPC::SysV` first to get the correct constant definitions. If *`CMD`* is `IPC_STAT` or `GETALL`, then *`ARG`* must be a variable that will hold the returned `semid_ds` structure or semaphore value array. As with `ioctl` and `fcntl`, return values are `undef` for error, "`0 but true`" for zero, and the actual return value otherwise.

See also the `IPC::Semaphore` module. This function is available only on machines supporting System V IPC.

semget

```
semget KEY, NSEMS, FLAGS
```

This function calls the System V IPC syscall *semget*(2). Before calling, you should `use IPC::SysV` to get the correct constant definitions. The function returns the semaphore ID, or `undef` if there is an error.

See also the `IPC::Semaphore` module. This function is available only on machines supporting System V IPC.'

semop

```
semop KEY, OPSTRING
```

This function calls the System V IPC syscall *semop*(2) to do semaphore operations such as signalling and waiting. Before calling, you should `use IPC::SysV` to get the correct constant definitions.

`OPSTRING` must be a packed array of `semop` structures. You can make each `semop` structure by saying `pack("s*", $semnum, $semop, $semflag)`. The number of semaphore operations is implied by the length of *`OPSTRING`*. The function returns true if successful, or false if there is an error.

The following code waits on semaphore `$semnum` of semaphore id `$semid`:

```
$semop = pack "s*", $semnum, -1, 0;
semop($semid, $semop)     || die "Semaphore trouble: $!";
```

To signal the semaphore, simply replace `-1` with `1`.

See the section "System V IPC" on page 540 in Chapter 15. See also the `IPC::Semaphore` module. This function is available only on machines supporting System V IPC.

send

```
send SOCKET, MSG, FLAGS, TO
send SOCKET, MSG, FLAGS
```

This function sends a message on a socket. It takes the same flags as the syscall of the same name—see *send*(2). On unconnected sockets, you must specify a destination to send *`TO`*, which then makes Perl's `send` work like *sendto*(2). The C syscall *sendmsg*(2) is currently unimplemented in standard Perl. The `send` function returns the number of characters sent, or `undef` if there is an error.

Note the *characters*: depending on the status of the socket, either (8-bit) bytes or characters are sent. By default, all sockets operate on bytes. But if, for example, the socket has been changed using `binmode` to operate with the `:encoding(utf8)` I/O layer, then its I/O will operate on UTF-8-encoded Unicode characters, not bytes.

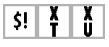
(Some non-Unix systems improperly treat sockets as different from ordinary file descriptors, with the result that you must always use `send` and `recv` on sockets rather than the handier standard I/O operators.)

One error that at least one of us makes frequently is to confuse Perl's `send` with C's `send` and write:

```
send SOCK, $buffer, length $buffer;      # WRONG
```

This will mysteriously fail depending on the relationship of the string length to the *FLAGS* bits expected by the system. See "Message Passing" on page 550 in Chapter 15 for examples.

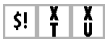
setpgrp



```
setpgrp PID, PGRP
```

This function sets the current process group (*PGRP*) for the specified *PID* (use a *PID* of 0 for the current process). Invoking `setpgrp` will raise an exception if used on a machine that doesn't implement *setpgrp*(2). Beware: some systems will ignore the arguments you provide and always do `setpgrp(0, $$)`. Fortunately, those are the arguments one usually wants to provide. If the arguments are omitted, they default to `0,0`. The BSD 4.2 version of `setpgrp` did not accept any arguments, but in BSD 4.4, it is a synonym for the `setpgid` function. For better portability (by some definition), use the `setpgid` function in the `POSIX` module directly. If what you're really trying to do is daemonize your script, consider the `POSIX::setsid` function as well. Note that the POSIX version of `setpgrp` does not accept arguments, so only `setpgrp(0,0)` is truly portable.

setpriority



```
setpriority WHICH, WHO, PRIORITY
```

This function sets the current *PRIORITY* for a process, a process group, or a user, as specified by the *WHICH* and *WHO*. See *setpriority*(2). Invoking `setpriority` will raise an exception if used on a machine that doesn't implement *setpriority*(2). To "nice" your process down by four units (the same as executing your program with *nice*(1)), try:

```
setpriority 0, 0, getpriority(0, 0) + 4;
```

The interpretation of a given priority may vary from one operating system to the next. Some priorities may be unavailable to nonprivileged users.

See also the `BSD::Resource` module from CPAN.

setsockopt

```
setsockopt SOCKET, LEVEL, OPTNAME, OPTVAL
```

This function sets the socket option requested. The function returns `undef` on error. The `Socket` module provides the needed constants for *LEVEL* and *OPNAME*,

although those for *LEVEL* can all be obtained from `getprotobyname`. *LEVEL* specifies which protocol layer you're aiming the call at, or `SOL_SOCKET` for the socket itself at the top of all the layers. *OPTVAL* might either be a packed string or an integer. An integer *OPTVAL* is shorthand for `pack("i", OPTVAL)`. *OPTVAL* may be specified as `undef` if you don't want to pass an argument.

One common option to set on a socket is `SO_REUSEADDR`, which gets around the problem of not being able to bind to a particular address while the previous TCP connection on that port is still making up its mind to shut down. That would look like this:

```
use Socket;
socket(SOCK, ...) || die "Can't make socket: $!";
setsockopt(SOCK, SOL_SOCKET, SO_REUSEADDR, 1)
        || warn "Can't do setsockopt: $!\n";
```

Another common option is to disable Nagle's algorithm on a socket:

```
use Socket qw(IPPROTO_TCP TCP_NODELAY);
setsockopt($socket, IPPROTO_TCP, TCP_NODELAY, 1);
```

See *setsockopt*(2) for other possible values.

shift X ARG

```
shift ARRAY
shift
```

This function shifts the first value of the array off and returns it, shortening the array by one and moving everything down. (Or up, or left, depending on how you visualize the array list. We like left.) If there are no elements in the array, the function returns `undef`.

If *ARRAY* is omitted, the function shifts `@_` within the lexical scope of subroutines and formats; it shifts `@ARGV` at file scopes (typically the main program) or within the lexical scopes established by the `eval` *STRING*, `BEGIN {}`, `CHECK {}`, `UNITCHECK {}`, `INIT {}`, and `END {}` constructs.

Subroutines often start by copying their arguments into lexical variables, and `shift` can be used for this:

```
sub marine {
    my $fathoms = shift;  # depth
    my $fishies = shift;  # number of fish
    my $o2      = shift;  # oxygen concentration
    # ...
}
```

`shift` is also used to process arguments at the front of your program:

```
while (defined($_ = shift)) {
    /^[^-]/     && do { unshift @ARGV, $_; last };
    /^-w/       && do { $WARN = 1;         next };
    /^-r/       && do { $RECURSE = 1;      next };
    die "Unknown argument $_";
}
```

You should consider the standard `Getopt::Std` and `Getopt::Long` modules for processing program arguments.

Starting with v5.14, `shift` can take a reference to an unblessed array, which will be dereferenced automatically. This aspect of `shift` is considered experimental. The exact behavior may change in a future version of Perl.

See also `unshift`, `push`, `pop`, and `splice`. The `shift` and `unshift` functions do the same thing to the left end of an array that `pop` and `push` do to the right end.

shmctl

```
shmctl ID, CMD, ARG
```

This function calls the System V IPC syscall, *shmctl*(2). Before calling, you should `use IPC::SysV` to get the correct constant definitions.

If *`CMD`* is `IPC_STAT`, then *`ARG`* must be a variable that will hold the returned `shmid_ds` structure. Like `ioctl` and `fcntl`, the function returns `undef` for error, "`0 but true`" for zero, and the actual return value otherwise.

This function is available only on machines supporting System V IPC.

shmget

```
shmget KEY, SIZE, FLAGS
```

This function calls the System V IPC syscall, *shmget*(2). The function returns the shared memory segment ID, or `undef` if there is an error. Before calling, `use SysV::IPC`.

This function is available only on machines supporting System V IPC.

shmread

```
shmread ID, VAR, POS, SIZE
```

This function reads from the shared memory segment *`ID`* starting at position *`POS`* for size *`SIZE`* (by attaching to it, copying out, and detaching from it). *`VAR`* must

be a variable that will hold the data read. The function returns true if successful, or false if there is an error.

This function is available only on machines supporting System V IPC.

shmwrite

```
shmwrite ID, STRING, POS, SIZE
```

This function writes to the shared memory segment *ID* starting at position *POS* for size *SIZE* (by attaching to it, copying in, and detaching from it). If *STRING* is too long, only *SIZE* bytes are used; if *STRING* is too short, nulls are written to fill out *SIZE* bytes. The function returns true if successful, or false if there is an error.

This function is available only on machines supporting System V IPC. (You're probably tired of reading that—we're getting tired of saying it.)

shutdown

```
shutdown SOCKET, HOW
```

This function shuts down a socket connection in the manner indicated by *HOW*. If *HOW* is 0, further receives are disallowed. If *HOW* is 1, further sends are disallowed. If *HOW* is 2, everything is disallowed.

```
shutdown(SOCK, 0);    # no more reading
shutdown(SOCK, 1);    # no more writing
shutdown(SOCK, 2);    # no more I/O at all
```

This is useful with sockets when you want to tell the other side you're done writing but not done reading, or vice versa. It's also a more insistent form of close because it disables any copies of those file descriptors held in forked processes.

Imagine a server that wants to read its client's request until end-of-file, then send an answer. If the client calls `close`, that socket is now invalid for I/O, so no answer would ever come back. Instead, the client should use `shutdown` to half-close the connection:

```
say SERVER "my request";          # send some data
shutdown(SERVER, 1);              # send eof; no more writing
$answer = <SERVER>;               # but you can still read
```

(If you came here trying to figure out how to shut down your system, you'll have to execute an external program to do that. See `system`.)

sin

```
sin EXPR
sin
```

Sorry, there's nothing wicked about this operator. It merely returns the sine of *EXPR* (expressed in radians).

For the inverse sine operation, you may use `Math::Trig` or the `POSIX` module's `asin` function, or use this relation:

```
sub asin { atan2($_[0], sqrt(1 - $_[0] * $_[0])) }
```

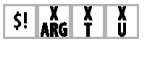
sleep

```
sleep EXPR
sleep
```

This function causes the script to sleep for *EXPR* (integer) seconds, or forever if no *EXPR*, and returns the number of seconds slept. It may be interrupted by sending the process a `SIGALRM`. On some older systems, it may sleep up to a full second less than what you requested, depending on how it counts seconds. Most modern systems always sleep the full amount. They may appear to sleep longer than that, however, because your process might not be scheduled right away in a busy multitasking system. For delays of finer granularity than one second, the standard `Time::HiRes` module provides a `usleep` function. If available, the `select` (ready file descriptors) call can also give you better resolution. You may be able to use `syscall` to call the *getitimer*(2) and *setitimer*(2) routines that some Unix systems support. You probably cannot mix `alarm` and `sleep` calls because `sleep` is often implemented using `alarm`.

See also the `POSIX` module's `pause` function.

socket



```
socket SOCKET, DOMAIN, TYPE, PROTOCOL
```

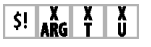
This function opens a socket of the specified kind and attaches it to filehandle *SOCKET*. *DOMAIN*, *TYPE*, and *PROTOCOL* are specified the same as for *socket*(2). If undefined, *SOCKET* will be autovivified. Before using this function, your program should contain the line:

```
use Socket;
```

This gives you the proper constants. The function returns true if successful. See the examples in the section "Sockets" on page 543 in Chapter 15.

On systems that support a close-on-exec flag on files, the flag will be set for the newly opened file descriptor, as determined by the value of $^F. See the $^F ($SYSTEM_FD_MAX) variable in Chapter 25.

socketpair




```
socketpair SOCKET1, SOCKET2, DOMAIN, TYPE, PROTOCOL
```

This function creates an unnamed pair of sockets in the specified domain of the specified type. *DOMAIN*, *TYPE*, and *PROTOCOL* are specified the same as for *socketpair*(2). You will need to `use Socket` to get the required constants. If either socket argument is undefined, it will be autovivified. The function returns true if successful, and false otherwise. On a system where *socketpair*(2) is unimplemented, calling this function raises an exception.

This function is typically used just before a `fork`. One of the resulting processes should close *SOCKET1*, and the other should close *SOCKET2*. You can use these sockets bidirectionally, unlike the filehandles created by the `pipe` function. Some systems define `pipe` using `socketpair`, in which a call to `pipe(Rdr, Wtr)` is essentially:

```
use Socket;
socketpair(Rdr, Wtr, AF_UNIX, SOCK_STREAM, PF_UNSPEC);
shutdown(Rdr, 1);        # no more writing for reader
shutdown(Wtr, 0);        # no more reading for writer
```

Perl v5.8 and later will emulate socketpair using IP sockets to localhost if your system implements sockets but not `socketpair`. On systems that support a close-on-exec flag on files, the flag will be set for the newly opened file descriptors, as determined by the value of $^F. See the $^F ($SYSTEM_FD_MAX) variable in Chapter 25. See also the example at the end of the section "Bidirectional Communication" on page 536 in Chapter 15.

sort


```
sort USERSUB LIST
sort BLOCK LIST
sort LIST
```

This function sorts the *LIST* and returns the sorted list value. Undefined values sort before defined null strings, which sort before everything else. By default, it sorts in simple numeric codepoint order (or whatever the `cmp` operator returns in case of overloading). For a true lexicographic sort, you must use the `Unicode::Collate` module; see "Comparing and Sorting Unicode Text" on page 297 in Chapter 6. The short story is that the easiest way to get a good alphabetic sort is like this:

```
use Unicode::Collate;
@alphabetized_list = Unicode::Collate->new->sort(@list);
```

When the `locale` pragma is in effect, `sort` *`LIST`* sorts *`LIST`* according to the current collation locale. Even if such a locale exists, Perl does not support multibyte locales, so this is unlikely to do what you want. See instead the `Unicode::Collate::Locale` module if you want reliable locale sorting.

`USERSUB`, if given, is the name of a subroutine that returns an integer less than, equal to, or greater than 0, depending on how the elements of the list are to be ordered. (The handy `<=>` and `cmp` operators can be used to do three-way numeric and string comparisons.) If a *`USERSUB`* is given but that function is undefined, `sort` raises an exception.

In the interests of efficiency, the normal calling code for subroutines is bypassed, with the following effects: the subroutine may not be a recursive subroutine (nor may you exit the block or routine with a loop-control operator), and the two elements to be compared are not passed into the subroutine via `@_`, but rather by temporarily setting the global variables `$a` and `$b` in the package in which the `sort` was compiled (see the examples that follow). The variables `$a` and `$b` are aliases to the real values, so don't modify them in the subroutine.

The comparison subroutine is required to behave. If it returns inconsistent results (sometimes saying `$x[1]` is less than `$x[2]` and sometimes saying the opposite, for example), the results are not well defined. (That's another reason you shouldn't modify `$a` and `$b`.)

`USERSUB` may be a scalar variable name (unsubscripted), in which case the value provides either a symbolic or a hard reference to the actual subroutine to use. (A symbolic name rather than a hard reference is allowed even when the `use strict 'refs'` pragma is in effect.) In place of a *`USERSUB`*, you can provide a *`BLOCK`* as an anonymous, inline sort subroutine.

To do an ordinary numeric sort, say this:

```
sub numerically { $a <=> $b }
@sortedbynumber = sort numerically 53,29,11,32,7;
```

To sort in descending order, you could simply apply `reverse` after the `sort`, or you could reverse the order of `$a` and `$b` in the sort routine:

```
@descending = reverse sort numerically 53,29,11,32,7;

sub reverse_numerically { $b <=> $a }
@descending = sort reverse_numerically 53,29,11,32,7;
```

To sort ASCII strings by codepoint order except without regard to case, run `$a` and `$b` through `lc` before comparing:

```
@unsorted = qw/sparrow Ostrich LARK catbird blueJAY/;
@sorted = sort { lc($a) cmp lc($b) } @unsorted;
```

Unlike with ASCII, under Unicode neither `lc` nor `uc` works for case canonicalization, because the mapping between cases is more complex than those two functions can express. There are now three cases, not two, and there is no longer a one-to-one mapping between cases; *i.e.*, some uppercase characters have multiple lowercase variants and vice versa. To address all this, Perl is expected to someday support an `fc` function, named so because it produces a string's "case-fold", which is what the `/i` pattern modifier uses. Look for `fc` to appear around v5.16 or so, perhaps as `use feature "fc"`. If an `fc` function *is* available, you can use that instead of `lc` in your sort comparisons that use `cmp`, provided your text isn't too fancy and you don't mind sorting (mostly) by numeric codepoint. If you don't have an `fc`, or to sort text alphabetically instead of by codepoint, see the section "Comparing and Sorting Unicode Text" on page 297 in Chapter 6.

Sorting hashes by value is a common use of the `sort` function. For example, if a `%sales_amount` hash records department sales, doing a hash lookup in the sort routine lets hash keys be sorted according to their corresponding values:

```
# sort from highest to lowest department sales
sub bysales { $sales_amount{$b} <=> $sales_amount{$a} }

for $dept (sort bysales keys %sale_amount) {
    say "$dept => $sales_amount{$dept}";
}
```

You can apply additional levels of sorting by cascading multiple comparisons using the `||` or `or` operators. This works nicely because the comparison operators conveniently return `0` for equivalence, causing them to fall through to the next comparison. Here, the hash keys are sorted first by their associated sales amounts and then by the keys themselves (in case two or more departments have the same sales amount):

```
sub by_sales_then_dept {
    $sales_amount{$b} <=> $sales_amount{$a}
                      ||
                $a cmp $b
}

for $dept (sort by_sales_then_dept keys %sale_amount) {
    say "$dept => $sales_amount{$dept}";
}
```

Assume that `@recs` is an array of hash references, where each hash contains fields such as `FIRSTNAME`, `LASTNAME`, `AGE`, `HEIGHT`, and `SALARY`. The following routine sorts

to the front of the list those records for people who are first richer, then taller, then younger, then less alphabetically challenged:

```
sub prospects {
    $b->{SALARY}    <=>  $a->{SALARY}
        ||
    $b->{HEIGHT}    <=>  $a->{HEIGHT}
        ||
    $a->{AGE}       <=>  $b->{AGE}
        ||
    $a->{LASTNAME}  cmp  $b->{LASTNAME}
        ||
    $a->{FIRSTNAME} cmp  $b->{FIRSTNAME}
}

@sorted = sort prospects @recs;
```

Any useful information that can be derived from `$a` and `$b` can serve as the basis of a comparison in a sort routine. For example, if lines of text are to be sorted according to specific fields, `split` could be used within the sort routine to derive the fields.

```
@sorted_lines = sort {
    @a_fields = split /:/, $a;     # colon-separated fields
    @b_fields = split /:/, $b;

    $a_fields[3] <=> $b_fields[3]  # numeric sort on 4th field, then
        ||
    $a_fields[0] cmp $b_fields[0]  # string sort on 1st field, then
        ||
    $b_fields[2] <=> $a_fields[2]  # reverse numeric sort on 3rd field
        ||
    ...                            # etc.

} @lines;
```

However, because `sort` calls the sort routine many times using different pairings of values for `$a` and `$b`, the previous example will resplit each line more often than needed.

To avoid the expense of repeated derivations such as the splitting of lines to compare their fields, run the derivation once per value prior to the sort and save the derived information. Here, anonymous arrays are created to encapsulate each line along with the results of splitting the line:

```
@temp = map { [$_, split /:/] } @lines;
```

Next, the array references are sorted:

```
@temp = sort {
    @a_fields = @$a[1..$#$a];
```

```
    @b_fields = @$b[1..$#$b];

    $a_fields[3] <=> $b_fields[3]  # numeric sort on 4th field, then
        ||
    $a_fields[0] cmp $b_fields[0]  # string sort on 1st field, then
        ||
    $b_fields[2] <=> $a_fields[2]  # reverse numeric sort on 3rd field
        ||
    ...                            # etc.

} @temp;
```

Now that the array references are sorted, the original lines can be retrieved from the anonymous arrays:

```
@sorted_lines = map { $_->[0] } @temp;
```

Putting it all together, this `map-sort-map` technique[16] can be executed in one statement:

```
@sorted_lines = map { $_->[0] }
                sort {
                   $a->[4] <=> $b->[4] # beware: indices really
                                       # appear to start at 1
                           ||
                   $a->[1] cmp $b->[1]
                           ||
                   $a->[3] <=> $b->[3]
                           ||
                   ...
                }
                map { [$_, split /:/] } @lines;
```

Do not declare `$a` and `$b` as lexical variables (with `my`). They are package globals (though they're exempt from the usual restrictions on globals when you're using `use strict`). You do need to make sure your sort routine is in the same package, though, or else qualify `$a` and `$b` with the package name of the caller.

You *can* write sort subroutines with the standard argument passing method (and, not coincidentally, use XS subroutines as sort subroutines), provided you declare the sort subroutine with a prototype of `($$)`. And if you do that, then you can in fact declare `$a` and `$b` as lexicals:

```
sub numerically ($$) {
        my ($a, $b) = @_;
        $a <=> $b;
}
```

And, someday, when full prototypes are implemented, you'll just say:

16. Sometimes called the Schwartzian Transform.

```
sub numerically ($a, $b) { $a <=> $b }
```

and then we'll be back where we started, more or less.

Perl v5.6 and earlier used a quicksort algorithm to implement sort. That algorithm was not stable and *could* go quadratic. (A *stable* sort preserves the input order of elements that compare equal. Although quicksort's runtime is O(N·logN) when averaged over all arrays of length N, the time can be $O(N^2)$, *quadratic* behavior, for some inputs.) In the experimental v5.7 release, the quicksort implementation was replaced with a stable mergesort algorithm whose worst-case behavior is O(N·logN). But benchmarks indicated that for some inputs, on some platforms, the original quicksort was faster. Perl v5.8 has a `sort` pragma for limited control of the sort. Its rather blunt control of the underlying algorithm may not persist into future Perls, but the ability to characterize the input or output in implementation independent ways quite probably will. See the section "sort" on page 1032 in Chapter 29.

splice


```
splice ARRAY, OFFSET, LENGTH, LIST
splice ARRAY, OFFSET, LENGTH
splice ARRAY, OFFSET
splice ARRAY
```

This function removes the elements designated by *OFFSET* and *LENGTH* from an *ARRAY*, and replaces them with the elements of *LIST*, if any. If *OFFSET* is negative, the function counts backward from the end of the array, but if that would land before the beginning of the array, an exception is raised. If *LENGTH* is negative, it removes the elements from *OFFSET* onward except for *-LENGTH* elements at the end of the array. If both *OFFSET* and *LENGTH* are in list context, `splice` returns the elements removed from the array. In scalar context, it returns the last element removed, or `undef` if there was none. If the number of new elements doesn't equal the number of old elements, the array grows or shrinks as necessary, and elements after the splice change their position correspondingly. If *LENGTH* is omitted, the function removes everything from *OFFSET* onward. If *OFFSET* is omitted, the array is cleared as it is read. If both *OFFSET* and *LENGTH* are omitted, removes everything. If *OFFSET* is past the end of the *ARRAY*, Perl issues a warning, and splices at the end of the *ARRAY*.

The equivalents listed in Table 27-5 hold.

Table 27-5. Splice equivalents for array operations

Direct Method	Splice Equivalent
`push(@a, $x, $y)`	`splice(@a, @a, 0, $x, $y)`
`pop(@a)`	`splice(@a, -1)`
`shift(@a)`	`splice(@a, 0, 1)`
`unshift(@a, $x, $y)`	`splice(@a, 0, 0, $x, $y)`
`$a[$x] = $y`	`splice(@a, $x, 1, $y)`
`(@a, @a = ())`	`splice(@a)`

The `splice` function is also handy for carving up the argument list passed to a subroutine. For example, assuming list lengths are passed before lists:

```
sub list_eq {       # compare two list values
    my @a = splice(@_, 0, shift);
    my @b = splice(@_, 0, shift);
    return 0 unless @a == @b;       # same length?
    while (@a) {
        return 0 if pop(@a) ne pop(@b);
    }
    return 1;
}
if (list_eq($len, @foo[1..$len], scalar(@bar), @bar)) { ... }
```

It would be cleaner to use array references for this, however.

Starting with v5.14, `splice` can take a reference to an unblessed array, which will be dereferenced automatically. This aspect of `splice` is considered experimental. The exact behavior may change in a future version of Perl.

split

`$_` T

```
split /PATTERN/, EXPR, LIMIT
split /PATTERN/, EXPR
split /PATTERN/
split
```

This function scans a string given by *EXPR* for separators, and splits the string into a list of substrings, returning the resulting list value in list context or the count of substrings in scalar context.[17] The separators are determined by repeated pattern matching, using the regular expression given in *PATTERN*, so the separators may be of any size and need not be the same string on every match. (The sepa-

17. Scalar context also causes `split` to write its result to `@_`, but this usage is deprecated.

rators are not ordinarily returned; exceptions are discussed later in this section.) If the *PATTERN* doesn't match the string at all, `split` returns the original string as a single substring. If it matches once, you get two substrings, and so on. You may supply regular expression modifiers to the *PATTERN*, like `/`*PATTERN*`/i`, `/`*PATTERN*`/x`, etc. The `//m` modifier is assumed when you split on the pattern `/^/`.

If *LIMIT* is specified and positive, the function splits into no more than that many fields (though it may split into fewer if it runs out of separators). If *LIMIT* is negative, it is treated as if an arbitrarily large *LIMIT* has been specified. If *LIMIT* is omitted or zero, trailing null fields are stripped from the result (which potential users of `pop` would do well to remember). If *EXPR* is omitted, the function splits the `$_` string. If *PATTERN* is also omitted or is the literal space, `" "`, the function splits on whitespace, `/\s+/`, after skipping any leading whitespace.

A *PATTERN* of `/^/` is secretly treated as if it were `/^/m`, since it isn't much use otherwise.

Strings of any length can be split:

```
@chars  = split //,   $word;
@fields = split /:/,  $line;
@words  = split " ",  $paragraph;
@lines  = split /^/,  $buffer;
```

Using `split` to break up a string into a sequence of graphemes is possible, but using a straight pattern match for this is more straightforward:

```
@graphs = grep { length } split /(\X)/, $word;
@graphs = $word =~ /\X/g;
```

A pattern capable of matching either the null string or something longer than the null string (for instance, a pattern consisting of any single character modified by a `*` or `?`) will split the value of *EXPR* into separate characters wherever it matches the null string between characters; nonnull matches will skip over the matched separator characters in the usual fashion. (In other words, a pattern won't match in one spot more than once, even if it matched with a zero width.) For example:

```
print join(":" => split / */, "hi there");
```

produces the output "`h:i:t:h:e:r:e`". The space disappears because it matches as part of the separator. As a trivial case, the null pattern `//` simply splits into separate characters, and spaces do not disappear. (For normal pattern matches, a `//` pattern would repeat the last successfully matched pattern, but `split`'s pattern is exempt from that wrinkle.)

The *LIMIT* parameter splits only part of a string:

```
my ($login, $passwd, $remainder) = split /:/, $_, 3;
```

We encourage you to split to lists of names like this to make your code self-documenting. (For purposes of error checking, note that `$remainder` would be undefined if there were fewer than three fields.) When assigning to a list, if *`LIMIT`* is omitted, Perl supplies a *`LIMIT`* one larger than the number of variables in the list, to avoid unnecessary work. For the split above, *`LIMIT`* would have been 4 by default, and `$remainder` would have received only the third field, not all the rest of the fields. In time-critical applications, it behooves you not to split into more fields than you really need. (The trouble with powerful languages is that they let you be powerfully stupid at times.)

We said earlier that the separators are not returned, but if the *`PATTERN`* contains parentheses, then the substring matched by each pair of parentheses is included in the resulting list, interspersed with the fields that are ordinarily returned. Here's a simple example:

```
split /([-,])/, "1-10,20";
```

which produces the list value:

```
(1, "-", 10, ",", 20)
```

With more parentheses, a field is returned for each pair, even if some pairs don't match, in which case undefined values are returned in those positions. So if you say:

```
split /(-)|(,)/, "1-10,20";
```

you get the value:

```
(1, "-", undef, 10, undef, ",", 20)
```

The */PATTERN/* argument may be replaced with an expression to specify patterns that vary at runtime.

As a special case, if the expression is a single space (" "), the function splits on whitespace just as `split` with no arguments does. Thus, `split(" ")` can be used to emulate *awk*'s default behavior. In contrast, `split(/ /)` will give you as many null initial fields as there are leading spaces. (Other than this special case, if you supply a string instead of a regular expression, it'll be interpreted as a regular expression anyway.) You can use this property to remove leading and trailing whitespace from a string and to collapse intervening stretches of whitespace into a single space:

```
$string = join(" ", split(" ", $string));
```

The following example splits an RFC 822 message header into a hash containing `$head{Date}`, `$head{Subject}`, and so on. It uses the trick of assigning a list of pairs to a hash, because separators alternate with separated fields. It uses parentheses

to return part of each separator as part of the returned list value. Since the `split` pattern is guaranteed to return things in pairs by virtue of containing one set of parentheses, the hash assignment is guaranteed to receive a list consisting of key/value pairs, where each key is the name of a header field. (Unfortunately, this technique loses information for multiple lines with the same key field, such as Received-By lines. Ah, well)

```
$header =~ s/\n\s+/ /g;      # Merge continuation lines.
%head = ("FRONTSTUFF", split /^(\S*?):\s*/m, $header);
```

The following example processes the entries in a Unix *passwd*(5) file. You could leave out the `chomp`, in which case `$shell` would have a newline on the end of it.

```
open(PASSWD, "/etc/passwd");
while (<PASSWD>) {
    chomp;        # remove trailing newline
    ($login, $passwd, $uid, $gid, $gcos, $home, $shell) =
            split /:/;
    ...
}
```

Here's how to process each word of each line of each file of input to create a word-frequency hash.

```
while (<>) {
    for my $word (split) {
        $count{$word}++;
    }
}
```

The inverse of `split` is `join`, except that `join` can only join with the same separator between all fields. To break apart a string with fixed-position fields, use `unpack`.

sprintf

```
sprintf FORMAT, LIST
```

This function returns a string formatted by the usual `printf` conventions of the C library function *sprintf*. See *sprintf*(3) or *printf*(3) on your system for an explanation of the general principles. The *`FORMAT`* string contains text with embedded field specifiers into which the elements of *`LIST`* are substituted, one per field. For an explanation of the fields, see the section "String Formats" on page 793 in Chapter 26.

sqrt

$_ $@

```
sqrt EXPR
sqrt
```

This function returns the square root of *EXPR*. For other roots such as cube roots, you can use the `**` operator to raise something to a fractional power. Don't try either of these approaches with negative numbers, as that poses a slightly more complex problem (and raises an exception). But there's a standard module to take care of even that:

```
use Math::Complex;
print sqrt(-2);    # prints 1.4142135623731i
```

srand

```
srand EXPR
srand
```

This function sets the random number seed for the `rand` operator. If *EXPR* is omitted, it uses a semirandom value supplied by the kernel (if it supports the */dev/urandom* device) or based on the current time and process ID, among other things. In either case, starting with v5.14, it returns the seed. It's usually not necessary to call `srand` at all, because if it is not called explicitly, it is called implicitly at the first use of the `rand` operator. However, this was not true in versions of Perl before v5.004 (1997), so if your script needs to run under older Perl versions, it should call `srand`.

Frequently called programs (like CGI scripts) that simply use `time ^ $$` for a seed can fall prey to the mathematical property that `a^b == (a+1)^(b+1)` one-third of the time. So don't do that. Use this instead:

```
srand( time() ^ ($$ + ($$ << 15)) );
```

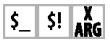
You'll need something much more random than the default seed for cryptographic purposes. On some systems, the */dev/random* device is suitable. Otherwise, checksumming the compressed output of one or more rapidly changing operating system status programs is the usual method. For example:

```
srand (time ^ $$ ^ unpack "%32L*", `ps wwaxl | gzip`);
```

If you're particularly concerned with this, see the `Math::TrulyRandom` module in CPAN.

Do *not* call `srand` multiple times in your program unless you know exactly what you're doing and why you're doing it. The point of the function is to "seed" the `rand` function so that `rand` can produce a different sequence each time you run your program. Just do it once at the top of your program, or you *won't* get random numbers out of `rand`!

stat



```
stat FILEHANDLE
stat DIRHANDLE
stat EXPR
stat
```

In scalar context, this function returns a Boolean value that indicates whether the call succeeded. In list context, it returns a 13-element list giving the statistics for a file, either the file opened via *FILEHANDLE* or DIRHANDLE, or named by *EXPR*. It's typically used as follows:

```
($dev,$ino,$mode,$nlink,$uid,$gid,$rdev,$size,
    $atime,$mtime,$ctime,$blksize,$blocks)
            = stat $filename;
```

Not all fields are supported on all filesystem types; unsupported fields return 0. Table 27-6 lists the meanings of the fields.

Table 27-6. Fields returned by stat

Index	Field	Meaning
0	$dev	Device number of filesystem
1	$ino	Inode number
2	$mode	File mode (type and permissions)
3	$nlink	Number of (hard) links to the file
4	$uid	Numeric user ID of file's owner
5	$gid	Numeric group ID of file's designated group
6	$rdev	The device identifier (special files only)
7	$size	Total size of file, in bytes
8	$atime	Last access time in seconds since the epoch
9	$mtime	Last modify time in seconds since the epoch
10	$ctime	Inode change time (*not* creation time!) in seconds since the epoch
11	$blksize	Preferred blocksize for file system I/O
12	$blocks	Actual number of blocks allocated

$dev and $ino, taken together, uniquely identify a file on the same system. The $blksize and $blocks are likely defined only on BSD-derived filesystems. The $blocks field (if defined) is reported in 512-byte blocks. The value of $blocks*512 can differ greatly from $size for files containing unallocated blocks, or "holes", which aren't counted in $blocks.

If `stat` is passed the special filehandle consisting of an underline, no actual *stat*(2) is done, but the current contents of the stat structure from the last `stat`, `lstat`, or `stat`-based file test operator (such as `-r`, `-w`, and `-x`) are returned.

Because the mode contains both the file type and its permissions, you should mask off the file type portion and `printf` or `sprintf` using a "`%o`" if you want to see the real permissions:

```
$mode = (stat($filename))[2];
printf "Permissions are %04o\n", $mode & 07777;
```

The `File::stat` module provides a convenient, by-name access mechanism:

```
use File::stat;
$sb = stat($filename);
printf "File is %s, size is %s, perm %04o, mtime %s\n",
   $filename, $sb->size, $sb->mode & 07777,
   scalar localtime $sb->mtime;
```

You can also import symbolic definitions of the various mode bits from the `Fcntl` module.

```
use Fcntl ':mode';

$mode = (stat($filename))[2];

$user_rwx      = ($mode & S_IRWXU) >> 6;
$group_read    = ($mode & S_IRGRP) >> 3;
$other_execute =  $mode & S_IXOTH;

printf "Permissions are %04o\n", S_IMODE($mode), "\n";

$is_setuid     =  $mode & S_ISUID;
$is_directory  =  S_ISDIR($mode);
```

You could write the last two using the `-u` and `-d` operators. See *stat*(2) for more details.

Hint: if you need only the size of the file, check out the `-s` file test operator, which returns the size in bytes directly. There are also file tests that return the ages of files in days.

state

```
state EXPR
state TYPE EXPR
state EXPR : ATTRS
state TYPE EXPR : ATTRS
```

The `state` declarator introduces a lexically scoped variable, just as `my` does. However, the contents of state variables persist across calls to the same routine; such

variables can only be initialized once the first time the scope is entered and will never be reinitialized, unlike lexical variables, which are reinitialized each time their enclosing scope is entered.

When a closure is cloned, it is considered a new subroutine, so any state variables will be initialized in the new clone on first call. State variables are not static in the sense a C programmer would think of it, unless the routine itself is static.

State variables are enabled only when the `use feature "state"` pragma is in effect. See the section "feature" on page 1017 in Chapter 29. Only initialization of scalar state variables is fully supported at this time, though you may always use a scalar reference to an array or hash.

study

```
study SCALAR
study
```

This function takes extra time to study *SCALAR* in anticipation of doing many pattern matches on the string before it is next modified. This may or may not save time, depending on the nature and number of patterns you are searching on, and on the distribution of character frequencies in the string to be searched—you probably want to compare runtimes with and without it to see which runs faster. Those loops that scan for many short constant strings (including the constant parts of more complex patterns) will benefit most from `study`. If all your pattern matches are constant strings anchored at the front, `study` won't help at all because no scanning is done. You may have only one `study` active at a time—if you study a different scalar, the first is "unstudied".

The way `study` works is this: a linked list of every character in the string to be searched is made, so we know, for example, where all the "`k`" characters are. From each search string, the rarest character is selected, based on some static frequency tables constructed from some C programs and English text. Only those places that contain this rarest character are examined.

For example, here is a loop that inserts index-producing entries before any line containing a certain pattern:

```
while (<>) {
    study;
    print ".IX foo\n"       if /\bfoo\b/;
    print ".IX bar\n"       if /\bbar\b/;
    print ".IX blurfl\n"    if /\bglarch\b/;
    ...
    print;
}
```

In searching for `/\bfoo\b/`, only locations in `$_` that contain "`f`" will be looked at, because "`f`" is rarer than "`o`". This is a big win except in pathological cases. The only question is whether it saves you more time than it took to build the linked list in the first place.

If you have to look for strings that you don't know until runtime, you can build an entire loop as a string and `eval` that to avoid recompiling all your patterns all the time. Together with setting `$/` to input entire files as one record, this can be very fast, often faster than specialized programs like *fgrep*(1). The following scans a list of files (`@files`) for a list of words (`@words`), and prints out the names of those files that contain a case-insensitive match:

```
$search = "while (<>) { study;";
for my $word (@words) {
    $search .= "++\$seen{\$ARGV} if /\\b$word\\b/i;\n";
}
$search .= "}";
@ARGV = @files;
undef $/;               # slurp each entire file
eval $search;           # this screams
die $@ if $@;           # in case eval failed
$/ = "\n";              # restore normal input terminator
for my $file (sort keys(%seen)) {
    say $file";
}
```

Now that we have the `qr//` operator, complicated runtime `eval`s as seen above are less necessary. This does the same thing:

```
@pats = ();
for my $word (@words) {
    push @pats, qr/\b${word}\b/i;
}
@ARGV = @files;
undef $/;               # slurp each entire file
while (<>) {
    for $pat (@pats) {
        $seen{$ARGV}++ if /$pat/;
    }
}
$/ = "\n";              # restore normal input terminator
for my $file (sort keys(%seen)) {
    say $file";
}
```

sub

Named declarations:

```
sub NAME PROTO ATTRS
sub NAME ATTRS
sub NAME PROTO
sub NAME
```

Named definitions:

```
sub NAME PROTO ATTRS BLOCK
sub NAME ATTRS BLOCK
sub NAME PROTO BLOCK
sub NAME BLOCK
```

Unnamed definitions:

```
sub PROTO ATTRS BLOCK
sub ATTRS BLOCK
sub PROTO BLOCK
sub BLOCK
```

The syntax of subroutine declarations and definitions looks complicated, but it is actually pretty simple in practice. Everything is based on the syntax:

```
sub NAME PROTO ATTRS BLOCK
```

All four fields are optional; the only restrictions are that the fields that do occur must occur in that order, and that you must use at least one of *NAME* or *BLOCK*. For the moment, we'll ignore the *PROTO* and *ATTRS*; they're just modifiers on the basic syntax. The *NAME* and the *BLOCK* are the important parts to get straight:

- If you have just a *NAME* and no *BLOCK*, it's a predeclaration of that name (but if you ever want to call the subroutine, you'll have to supply a definition with both a *NAME* and a *BLOCK* later). Named declarations are useful because the parser treats a name specially if it knows it's a user-defined subroutine. You can call such a subroutine either as a function or as an operator, just like built-in functions. These are sometimes called *forward* declarations.
- If you have both a *NAME* and a *BLOCK*, it's a standard named subroutine definition (and a declaration, too, if you didn't declare the name previously). Named definitions are useful because the *BLOCK* associates an actual meaning (the body of the subroutine) with the declaration. That's all we mean when we say it defines the subroutine rather than just declaring it. The definition is like the declaration, however, in that the surrounding code doesn't see it, and it returns no inline value by which you could reference the subroutine.
- If you have just a *BLOCK* without a *NAME*, it's a nameless definition—that is, an anonymous subroutine. Since it doesn't have a name, it's not a declaration at all, but a real operator that returns a reference to the anonymous subroutine body at runtime. This is extremely useful for treating code as data. It lets you pass odd chunks of code around to be used as callbacks, and maybe even

as closures if the `sub` definition operator refers to any lexical variables outside of itself. That means that different calls to the same `sub` operator will do the bookkeeping necessary to keep the correct "version" of each such lexical variable in sight for the life of the closure, even if the original scope of the lexical variable has been destroyed.

In any of these three cases, either one or both of the *PROTO* and *ATTRS* may occur after the *NAME*, before the *BLOCK*, or both. A prototype is a list of characters in parentheses that tell the parser how to treat arguments to the function. Attributes are introduced by a colon and supply additional information to the parser about the function. Here's a typical definition that includes all four fields:

```
sub numstrcmp ($$) : locked {
    my ($a, $b) = @_;
    return $a <=> $b || $a cmp $b;
}
```

For details on attribute lists and their manipulation, see the section "attributes" on page 1002 in Chapter 29. See also Chapter 7 and "The anonymous subroutine composer" on page 344 in Chapter 8.

substr


```
substr EXPR, OFFSET, LENGTH, REPLACEMENT
substr EXPR, OFFSET, LENGTH
substr EXPR, OFFSET
```

This function extracts a substring out of the string given by *EXPR* and returns it. The substring is extracted starting at *OFFSET* characters from the front of the string. If *OFFSET* is negative, the substring starts that far from the end of the string instead. If *LENGTH* is omitted, everything to the end of the string is returned. If *LENGTH* is negative, the length is calculated to leave that many characters off the end of the string. Otherwise, *LENGTH* indicates the length of the substring to extract, which is sort of what you'd expect.

Notice we said characters, by which we mean codepoints, not bytes or graphemes. For bytes, encode into UTF-8 first and try again. For graphemes, use the `substr` method from the CPAN `Unicode::GCString` module.

You may use `substr` as an lvalue (something to assign to), in which case *EXPR* must also be a legal lvalue. If you assign something shorter than the length of your substring, the string will shrink, and if you assign something longer than the length, the string will grow to accommodate it. To keep the string the same length, you may need to pad or chop your value using `sprintf` or the `x` operator.

If you try to assign to an unallocated area past the end of the string, `substr` raises an exception.

To prepend the string "`Larry`" to the current value of `$_`, use:

```
substr($var, 0, 0) = "Larry";
```

To instead replace the first character of `$_` with "`Moe`", use:

```
substr($var, 0, 1) = "Moe";
```

And, finally, to replace the last character of `$var` with "`Curly`", use:

```
substr($var, -1) = "Curly";
```

An alternative to using `substr` as an lvalue is to specify the *`REPLACEMENT`* string as the fourth argument. This lets you replace parts of the *`EXPR`* and return what was there before in one operation, just as you can with `splice`. The next example also replaces the last character of `$var` with "`Curly`" and puts that replaced character into `$oldstr`:

```
$oldstr = substr($var, -1, 1, "Curly");
```

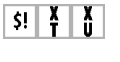
You don't have to use lvalue `substr` only with assignment. This replaces any spaces with dots, but only in the last 10 characters in the string:

```
substr($var, -10) =~ s/ /./g;
```

Note that we keep talking about characters. As elsewhere in this book, we mean codepoints, the programmer view of characters, and not graphemes, the user view of characters; graphemes can and often do span multiple codepoints. The CPAN `Unicode::GCString` module provides replacement functions for `substr`, `index`, `pos`, and many others, so you operate on your strings in logical glyphs instead of in fiddly little codepoints.

If you were going to use `substr` instead of regexes because you think that surely `substr` must be faster, you might be surprised. Often, regexes are faster than `substr`, even for fixed-width fields.

symlink




```
symlink OLDNAME, NEWNAME
```

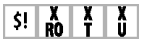
This function creates a new filename symbolically linked to the old filename. The function returns true for success, and false otherwise. On systems that don't support symbolic links, it raises an exception at runtime. To check for that, use `eval` to trap the potential error:

```
$can_symlink = eval { symlink("",""); 1 };
```

Or use the `Config` module. Be careful if you supply a relative symbolic link, since it'll be interpreted relative to the location of the symbolic link itself, not to your current working directory.

See also `link` and `readlink` earlier in this chapter.

syscall




```
syscall LIST
```

This function calls the system call (meaning a syscall, not a shell command) specified as the first element of the list passes the remaining elements as arguments to the system call. (Many of these calls are now more readily available through modules like `POSIX`.) The function raises an exception if *syscall*(2) is unimplemented.

The arguments are interpreted as follows: if a given argument is numeric, the argument is passed as a C integer. If not, a pointer to the string value is passed. You are responsible for making sure the string is long enough to receive any result that might be written into it; otherwise, you're looking at a core dump. You can't use a string literal (or other read-only string) as an argument to `syscall` because Perl has to assume that any string pointer might be written through. If your integer arguments are not literals and have never been interpreted in a numeric context, you may need to add 0 to them to force them to look like numbers.

`syscall` returns whatever value was returned by the system call invoked. By C coding conventions, if that system call fails, `syscall` returns `-1` and sets `$!` (errno). Some system calls legitimately return `-1` if successful. The proper way to handle such calls is to assign `$!=0` before the call, and check the value of `$!` if `syscall` returns `-1`.

Not all system calls can be accessed this way. For example, Perl supports passing up to 14 arguments to your system call, which in practice should usually suffice. However, there's a problem with syscalls that return multiple values. Consider `syscall(&SYS_pipe)`: it returns the file number of the read end of the pipe it creates. There is no way to retrieve the file number of the other end. You can avoid this instance of the problem by using `pipe` instead. To solve the generic problem, write XSUBs (external subroutine modules, a dialect of C) to access the system calls directly. Then put your new module onto CPAN and become wildly popular.

The following subroutine returns the current time as a floating-point number rather than as integer seconds as `time` returns. (It will only work on machines that support the *gettimeofday*(2) syscall.)

```
sub finetime() {
    package main;   # for next require
    require "syscall.ph";
    # presize buffer to two 32-bit longs...
    my $tv = pack("LL", ());
    syscall(&SYS_gettimeofday, $tv, undef) >= 0
        || die "gettimeofday: $!";
    my($seconds, $microseconds) = unpack("LL", $tv);
    return $seconds + ($microseconds / 1_000_000);
}
```

Suppose Perl didn't support the *setgroups*(2) syscall,[18] but your kernel did. You could still get at it this way:

```
require "syscall.ph";
syscall(&SYS_setgroups, scalar @newgids, pack("i*", @newgids))
        || die "setgroups: $!";
```

You may have to run *h2ph* as indicated in the Perl installation instructions for *syscall.ph* to exist. Some systems may require a `pack` template of "`II`" instead. Even more disturbing, `syscall` assumes the size equivalence of the C types `int`, `long`, and `char*`. Try not to think of `syscall` as the epitome of portability.

See the `Time::HiRes` module from CPAN for a more rigorous approach to fine-grained timing issues.

sysopen


```
sysopen FILEHANDLE, FILENAME, MODE, MASK
sysopen FILEHANDLE, FILENAME, MODE
```

The `sysopen` function opens the file whose filename is given by *`FILENAME`* and associates it with *`FILEHANDLE`*. If *`FILEHANDLE`* is an expression, its value is used as the name of, or reference to, the filehandle. If *`FILEHANDLE`* is a variable whose value is undefined, a value will be created for you. The return value is true if the call succeeds, and false otherwise.

This function is a direct interface to your operating system's *open*(2) syscall followed by an *fdopen*(3) library call. As such, you'll need to pretend you're a C programmer for a bit here. The possible values and flag bits of the *`MODE`* parameter are available through the `Fcntl` module. Because different systems support different flags, don't count on all of them being available on your system. Consult your *open*(2) manpage or its local equivalent for details. Nevertheless, the flags listed in Table 27-7 should be present on any system with a reasonably standard C library.

18. Although through `$(`, it does.

Table 27-7. Flags for sysopen

Flag	Meaning
O_RDONLY	Read only.
O_WRONLY	Write only.
O_RDWR	Read and write.
O_CREAT	Create the file if it doesn't exist.
O_EXCL	Fail if the file already exists.
O_APPEND	Append to the file.
O_TRUNC	Truncate the file.
O_NONBLOCK	Nonblocking access.

Many other options are possible, however. Table 27-8 lists some less common flags.

Table 27-8. Less common flags for sysopen

Flag	Meaning
O_NDELAY	Old synonym for O_NONBLOCK.
O_SYNC	Writes block until data is physically written to the underlying hardware. O_ASYNC, O_DSYNC, and O_RSYNC may also be seen.
O_EXLOCK	flock with LOCK_EX (advisory only).
O_SHLOCK	flock with LOCK_SH (advisory only).
O_DIRECTORY	Fail if the file is *not* a directory.
O_NOFOLLOW	Fail if the last path component is a symbolic link.
O_BINARY	binmode the handle for Microsoft systems. An O_TEXT may also sometimes exist to get the opposite behavior.
O_LARGEFILE	Some systems need this for files over 2 GB.
O_NOCTTY	Opening a terminal file won't make that terminal become the process's controlling terminal if you don't have one yet. Usually no longer needed.

The O_EXCL flag is *not* for locking: here, exclusiveness means that if the file already exists, sysopen fails.

If the file named by *FILENAME* does not exist and the *MODE* includes the O_CREAT flag, then sysopen creates the file with initial permissions determined by the *MASK* argument (or 0666 if omitted), as modified by your process's current umask. This default is reasonable: see the umask entry for an explanation.

Filehandles opened with `open` and `sysopen` may be used interchangeably. You do not need to use `sysread` and friends just because you happened to open the file with `sysopen`, nor are you precluded from doing so if you opened it with `open`. Each can do things that the other can't. Regular `open` can open pipes, fork processes, set layers, duplicate file handles, and convert a file descriptor number into a filehandle. It also ignores leading and trailing whitespace in filenames and respects "-" as a special filename. But when it comes to opening actual files, `sysopen` can do anything that `open` can.

The following examples show equivalent calls to both functions. We omit the `or die $!` checks for clarity, but make sure to always check return values in your programs. We'll restrict ourselves to using only flags available on virtually all operating systems. It's just a matter of controlling the values that you OR together using the bitwise `|` operator to pass in *`MODE`* argument.

- Open a file for reading:

```
open(FH, "<", $path);
sysopen(FH, $path, O_RDONLY);
```

- Open a file for writing, creating a new file if needed, or truncating an old file:

```
open(FH, ">", $path);
sysopen(FH, $path, O_WRONLY | O_TRUNC | O_CREAT);
```

- Open a file for appending, creating one if necessary:

```
open(FH, ">>", $path);
sysopen(FH, $path, O_WRONLY | O_APPEND | O_CREAT);
```

- Open a file for update, where the file must already exist:

```
open(FH, "+<", $path);
sysopen(FH, $path, O_RDWR);
```

And here are things you can do with `sysopen` but *not* with regular `open`:

- Open and create a file for writing, which must not previously exist:

```
sysopen(FH, $path, O_WRONLY | O_EXCL | O_CREAT);
```

- Open a file for appending, which must already exist:

```
sysopen(FH, $path, O_WRONLY | O_APPEND);
```

- Open a file for update, creating a new file if necessary:

```
sysopen(FH, $path, O_RDWR | O_CREAT);
```

- Open a file for update, which must not already exist:

```
sysopen(FH, $path, O_RDWR | O_EXCL | O_CREAT);
```

- Open a write-only file without blocking, but not creating it if it doesn't exist:

```
sysopen(FH, $path, O_WRONLY | O_NONBLOCK);
```

The `IO::File` module provides a set of object-oriented synonyms (plus a small bit of new functionality) for opening files. You are welcome to call the appropriate `IO::File` or `IO::Handle` methods on any handle created with `open`, `sysopen`, `pipe`, `socket`, or `accept`, even if you didn't use the module to initialize those handles. In fact, Perl will now load those modules implicitly as needed to make sure those methods are available to you.

sysread


```
sysread FILEHANDLE, SCALAR, LENGTH, OFFSET
sysread FILEHANDLE, SCALAR, LENGTH
```

This function tries to read *`LENGTH`* characters of data into variable *`SCALAR`* from the specified *`FILEHANDLE`* using a low-level syscall, *read*(2). The function returns the number of characters read, or 0 at EOF.[19] The `sysread` function returns `undef` on error. *`SCALAR`* will grow or shrink to the length actually read. The *`OFFSET`*, if specified, says where in the string to start putting the characters so that you can read into the middle of a string that's being used as a buffer. For an example of using *`OFFSET`*, see `syswrite`. An exception is raised if *`LENGTH`* is negative or if *`OFFSET`* points outside the string.

If the filehandle has no encoding layer, then the characters read in are no larger than 255, so they are effectively bytes.

Be prepared to handle the problems (like interrupted syscalls) that standard I/O normally handles for you. Because it bypasses standard I/O, do not mix `sysread` with other kinds of reads, `print`, `printf`, `write`, `seek`, `tell`, or `eof` on the same filehandle unless you are into heavy wizardry (and/or pain). Also, when reading characters from a file containing UTF-8, UTF-16, or any other multibyte encoding, the buffer boundary may fall in the middle of a character. It is therefore best to set the encoding and read characters instead of bytes.

Note that if the filehandle has been marked as `:utf8`, Unicode characters are read instead of bytes (*`LENGTH`*, *`OFFSET`*, and the return value of `sysread` are in Unicode characters). The `:encoding(...)` layer implicitly introduces the `:utf8` layer.

19. There is no `syseof` function, which is okay, since `eof` doesn't work well on device files (like terminals) anyway. Use `sysread` and check for a return value of 0 to decide whether you're done.

sysseek

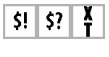
```
sysseek FILEHANDLE, POSITION, WHENCE
```

This function sets *FILEHANDLE*'s system position using the syscall *lseek*(2). It bypasses standard I/O, so mixing this with reads (other than `sysread`), `print`, `write`, `seek`, `tell`, or `eof` may (and probably shall) cause confusion. *FILEHANDLE* may be an expression whose value gives the name of the filehandle. The values for *WHENCE* are `0` to set the new position to *POSITION* bytes into the file, `1` to set it to the current position plus *POSITION*, and `2` to set it to EOF plus *POSITION* bytes (typically negative). For *WHENCE*, you may use the constants `SEEK_SET`, `SEEK_CUR`, and `SEEK_END` from the standard `IO::Seekable` and `POSIX` modules, or from the `Fcntl` module, which is more portable and convenient.

This function returns the new position in bytes, or `undef` on failure. A position of zero is returned as the special string "`0 but true`", which can be used numerically without producing warnings or having to mess around with `// die` instead of the more customary `|| die`.

Warning: `POSITION` is in bytes not characters, no matter whether there should happen to be any encoding layer on the filehandle. However, all functions in Perl that read from files *do* go through any encoding layer, and you can therefore read a partial "character" and wind up with an invalid Perl string. Avoid mixing calls to `sysseek` or `seek` with I/O functions on filehandle with a multibyte encoding layer.

system



```
system PATHNAME LIST
system LIST
```

This function executes any program on the system for you and returns that program's exit status—not its output. To capture the output from a command, use backticks or `qx//` instead. The `system` function works exactly like `exec`, except that `system` does a `fork` first and then, after the `exec`, waits for the executed program to complete. That is, it runs the program for you and returns when it's done, whereas `exec` *replaces* your running program with the new one, so it never returns if the replacement succeeds.

Argument processing varies depending on the number of arguments, as described under `exec`, including determining whether the shell will be called and whether you've lied to the program about its name by specifying a separate *PATHNAME*.

Because `system` and backticks block `SIGINT` and `SIGQUIT`, sending one of those signals (such as from a Control-C) to the program being run doesn't interrupt your main program. But the other program you're running *does* get the signal. Check the return value from `system` to see whether the program you were running exited properly.

```
@args = ("command", "arg1", "arg2");
system(@args) == 0
     || die "system @args failed: $?"
```

The return value is the exit status of the program as returned through the *wait*(2) syscall. Under traditional semantics, to get the real exit value, divide by 256 or shift right by 8 bits. That's because the lower byte has something else in it. (Two somethings, really.) The lowest seven bits indicate the signal number that killed the process (if any), and the eighth bit indicates whether the process dumped core. You can check all failure possibilities, including signals and core dumps, by inspecting `$?` (`$CHILD_ERROR`):

```
$exit_value  = $? >> 8;
$signal_num  = $? & 127;    # or 0x7f, or 0177, or 0b0111_1111
$dumped_core = $? & 128;    # or 0x80, or 0200, or 0b1000_0000
```

If the program has to be run via the system shell[20] because you had only one argument and that argument had shell metacharacters in it, normal return codes are subject to that shell's additional quirks and capabilities. In other words, under those circumstances, you may be unable to recover the detailed information described earlier.

syswrite


```
syswrite FILEHANDLE, SCALAR, LENGTH, OFFSET
syswrite FILEHANDLE, SCALAR, LENGTH
syswrite FILEHANDLE, SCALAR
```

This function tries to write *`LENGTH`* bytes of data from variable *`SCALAR`* to the specified *`FILEHANDLE`* using the *write*(2) syscall. The function returns the number of bytes written, or `undef` on error. The *`OFFSET`*, if specified, says from where in the string to start writing. (You might do this if you were using the string as a buffer, for instance, or if you needed to recover from a partial write.) A negative *`OFFSET`* specifies that writing should start that many bytes backward from the end of the string. If *`SCALAR`* is empty, the only *`OFFSET`* permitted is 0. An exception is raised if *`LENGTH`* is negative or if *`OFFSET`* points outside the string.

20. That's */bin/sh* by definition, or whatever makes sense on your platform, but not whatever shell the user just happens to be using at the time.

To copy data from filehandle `FROM` into filehandle `TO`, you can use something like:

```
use Errno qw/EINTR/;
$blksize = (stat FROM)[11] || 16384;  # preferred block size?
while ($len = sysread FROM, $buf, $blksize) {
    if (!defined $len) {
        next if $! == EINTR;
        die "System read error: $!";
    }
    $offset = 0;
    while ($len) {          # Handle partial writes
        $written = syswrite TO, $buf, $len, $offset;
        die "System write error: $!" unless defined $written;
        $offset += $written;
        $len    -= $written;
    }
}
```

You must be prepared to handle the problems that standard I/O normally handles for you, such as partial writes. Because `syswrite` bypasses the C standard I/O library, do not mix calls to it with reads (other than `sysread`), writes (like `print`, `printf`, or `write`), or other stdio functions like `seek`, `tell`, or `eof` unless you are into heavy wizardry.[21]

If the filehandle is marked `:utf8`, Unicode characters encoded in UTF-8 are written instead of bytes, and the *`LENGTH`*, *`OFFSET`*, and return value of `syswrite` are in (UTF-8-encoded Unicode) characters. The `:encoding(...)` layer implicitly introduces the `:utf8` layer.

tell

```
tell FILEHANDLE
tell
```

This function returns the current file position (in bytes, zero-based) for *`FILEHANDLE`*. Typically, this value will be fed to the `seek` function at some future time to get back to the current position. *`FILEHANDLE`* may be an expression giving the name of the actual filehandle or a reference to a filehandle object. If *`FILEHANDLE`* is omitted, the function returns the position of the file last read. File positions are meaningful only on regular files. Devices, pipes, and sockets have no file position.

Note the *in bytes*: even if the filehandle has been set to operate on characters (for example, by using the `:encoding(utf8)` open layer), `tell` still always returns byte offsets, not character offsets (because that would render `seek` and `tell` rather slow).

21. Or pain.

There is no `systell` function. Use `sysseek(FH, 0, 1)` for that. Seek `seek` for an example telling how to use `tell`.

Do not use `tell` (or other buffered I/O operations) on a filehandle that has been manipulated by `sysread`, `syswrite`, or `sysseek`. Those functions ignore the buffering, while `tell` does not.

telldir


```
telldir DIRHANDLE
```

This function returns the current position of the `readdir` routines on *`DIRHANDLE`*. This value may be given to `seekdir` to access a particular location in a directory. The function has the same caveats about possible directory compaction as the corresponding system library routine. This function might not be implemented everywhere that `readdir` is. Even if it is, no calculation may be done with the return value. It's just an opaque value, meaningful only to `seekdir`.

tie


```
tie VARIABLE, CLASSNAME, LIST
```

This function binds a variable to a package class that will provide the implementation for the variable. *`VARIABLE`* is the variable (scalar, array, or hash) or typeglob (representing a filehandle) to be tied. *`CLASSNAME`* is the name of a class implementing objects of an appropriate type.

Any additional arguments are passed to the appropriate constructor method of the class, meaning one of `TIESCALAR`, `TIEARRAY`, `TIEHASH`, or `TIEHANDLE`. (If the appropriate method is not found, an exception is raised.) Typically, these are arguments such as might be passed to the *dbm_open*(3) function of C, but their meaning is package dependent. The object returned by the constructor is in turn returned by the `tie` function, which can be useful if you want to access other methods in *`CLASSNAME`*. (The object can also be accessed through the `tied` function.) So a class for tying a hash to an I SAM implementation might provide an extra method to traverse a set of keys sequentially (the "S" of I SAM), since your typical DBM implementation can't do that.

Functions such as `keys` and `values` may return huge list values when used on large objects like DBM files. You may prefer to use the `each` function to iterate over such. For example:

```
use NDBM_File;
tie(%ALIASES, "NDBM_File", "/etc/aliases", 1, 0)
    || die "Can't open aliases: $!";
while (($key,$val) = each %ALIASES) {
    say "$key = $val";
}
untie %ALIASES;
```

A class implementing a hash should provide the following methods:

```
TIEHASH CLASS, LIST
FETCH SELF, KEY
STORE SELF, KEY, VALUE
DELETE SELF, KEY
CLEAR SELF
EXISTS SELF, KEY
FIRSTKEY SELF
NEXTKEY SELF, LASTKEY
SCALAR SELF
DESTROY SELF
UNTIE SELF
```

A class implementing an array should provide the following methods:

```
TIEARRAY CLASS, LIST
FETCH SELF, KEY
STORE SELF, KEY, VALUE
FETCHSIZE SELF
STORESIZE SELF, COUNT
CLEAR SELF
PUSH SELF, LIST
POP SELF
SHIFT SELF
UNSHIFT SELF, LIST
SPLICE SELF, OFFSET, LENGTH, LIST
EXTEND SELF, COUNT
DESTROY SELF
UNTIE SELF
```

A class implementing a scalar should provide the following methods:

```
TIESCALAR CLASS, LIST
FETCH SELF,
STORE SELF, VALUE
DESTROY SELF
UNTIE SELF
```

A class implementing a filehandle should provide the following methods:

```
TIEHANDLE CLASS, LIST
READ SELF, SCALAR, LENGTH, OFFSET
READLINE SELF
GETC SELF
WRITE SELF, SCALAR, LENGTH, OFFSET
```

```
PRINT SELF, LIST
PRINTF SELF, FORMAT, LIST
BINMODE SELF
EOF SELF
FILENO SELF
SEEK SELF, POSITION, WHENCE
TELL SELF
OPEN SELF, MODE, LIST
CLOSE SELF
DESTROY SELF
UNTIE SELF
```

Not all methods indicated above need to be implemented: the `Tie::Hash`, `Tie::Array`, `Tie::Scalar`, and `Tie::Handle` modules provide base classes that have reasonable defaults. See Chapter 14 for a detailed discussion of these methods. Unlike `dbmopen`, the `tie` function will not `use` or `require` a module for you—you need to do that explicitly yourself. See the `DB_File` and `Config` modules for interesting `tie` implementations.

tied

```
tied VARIABLE
```

This function returns a reference to the object underlying the scalar, array, hash, or typeglob contained in *VARIABLE* (the same value that was originally returned by the `tie` call that bound the variable to a package). It returns the undefined value if *VARIABLE* isn't tied to a package. So, for example, you can use:

```
ref tied %hash
```

to find out to which package your hash is tied. (Presuming you've forgotten.)

time

```
time
```

This function returns the number of nonleap seconds since "the epoch", traditionally 00:00:00 on January 1, 1970, UTC.[22] The returned value is suitable for feeding to `gmtime` and `localtime`, for comparison with file modification and access times returned by `stat`, and for feeding to `utime`.

```
$start = time();
system("some slow command");
$end   = time();
if ($end - $start > 1) {
```

22. Not to be confused with the "epic", which is about the making of Unix. (Other operating systems may have a different epoch, not to mention a different epic.)

```
    say "Program started: ", scalar localtime($start);
    say "Program ended:   ", scalar localtime($end);
}
```

For measuring time in finer granularity than integer seconds, use the `Time::HiRes` module, included with Perl since the v5.8 release and available from CPAN earlier than that.

times

```
times
```

In list context, this function returns a four-element list giving the user and system CPU times, in seconds (probably fractional), for this process and terminated children of this process.

```
($user, $system, $cuser, $csystem) = times();
printf "This pid and its kids have consumed %.3f seconds\n",
            $user + $system + $cuser + $csystem;
```

In scalar context, returns just the user time. For example, to time the execution speed of a section of Perl code:

```
$start = times();
...
$end = times();
printf "that took %.2f CPU seconds of user time\n",
        $end - $start;
```

tr///

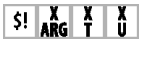
```
tr///
y///
```

This is the transliteration (sometimes erroneously called translation) operator, which is like the `y///` operator in the Unix *sed* program, only better, in everybody's humble opinion. See Chapter 5.

To use with a read-only value without raising an exception, use the `/r` modifier, first available in v5.14.

```
say "bookkeeper" =~ tr/boep/peob/r; # prints "peekkoobor"
```

truncate



```
truncate FILEHANDLE, LENGTH
truncate EXPR, LENGTH
```

This function truncates the file opened on *FILEHANDLE*, or named by *EXPR*, to the specified length in bytes, *not* characters. The function raises an exception if *ftruncate*(2) or an equivalent isn't implemented on your system. (You can always truncate a file by copying the front of it, if you have the disk space.) The function returns true on success, and `undef` otherwise.

The behavior is undefined if *LENGTH* is greater than the current file length. However, on traditional Unix filesystems, it sets the length of the file past the old end, and the kernel returns an intervening, never-written-to data as all zero bytes.

The position in the file of *FILEHANDLE* is left unchanged. You may wish to call `seek` before writing to the file after calling `truncate` on it.

uc

```
uc EXPR
uc
```

This function returns an uppercased version of *EXPR*. This is the internal function implementing the `\U` escape in interpolated strings. For titlecase, use `ucfirst` instead.

Do not use `uc` for case-insensitive comparisons the way you may have once done in ASCII, because it gives the wrong answer for Unicode. Instead, use the `fc` (foldcase) function, either from the CPAN `Unicode::CaseFold` module or via `use feature "fc"` in v5.16 or later. See the section "A Case of Mistaken Identity" on page 287 in Chapter 6 for more information.

Codepoints in the 128–256 range are ignored by `uc` if the string does not have Unicode semantics (and locale mode is not in effect), which can be difficult to guess. The `unicode_strings` feature guarantees Unicode semantics even on those codepoints. See Chapter 6.

ucfirst

```
ucfirst EXPR
ucfirst
```

This function returns a version of *EXPR* with the first character *titlecased* and other characters left alone. *Titlecase* is "Unicodese" for an initial capital that has (or expects to have) lowercase characters following it, not uppercase ones. Examples are the first letter of a sentence, of a person's name, of a newspaper headline, or of most words in a title. Characters with no titlecase mapping return the uppercase mapping instead. This is the internal function implementing the `\u` escape in double-quoted strings.

For example, if someone used U+FB02 LATIN SMALL LIGATURE FL at the start of "flower" (that is, "\x{FB02}ower"), and you want to use it as the first word of a sentence, its titlecase mapping is "Flower", not "FLower". Its uppercase is still "FLOWER", though.

To capitalize a string by mapping its first character to titlecase and the rest to lowercase, use:

```
ucfirst(substr($word, 0, 1)) . lc(substr($word, 1))
```

Do not (unless you're into cultural imperialism) use:

```
ucfirst lc $word
```

or "\u\L$word", because that can produce a different and incorrect answer with certain characters. The titlecase of something that's been lowercased doesn't always produce the same thing titlecasing the original produces.

Because titlecasing only makes sense at the start of a string that's followed by lowercase characters, we can't think of any reason you might want to titlecase *every* character in a string. But here's how to do that anyway, just in case:

```
$string =~ s/ ( (?= \p{CWT} ) \X ) /\u$1/gx;
```

The full name of the shortcut CWT property we used there is Changes_When_Titlecased=True, but that's much too long to type, and the official abbreviation works perfectly well.

See uc regarding the unicode_strings feature.

umask

```
umask EXPR
umask
```

This function sets the umask for the process and returns the old one using the *umask*(2) syscall. Your umask tells the operating system which permission bits to *disallow* when creating a new file, including files that happen to be directories. If *EXPR* is omitted, the function merely returns the current umask. For example, to ensure that the "user" bits are allowed and the "other" bits disallowed, try something like:

```
umask((umask() & 077) | 7);   # don't change the group bits
```

Remember that a umask is a number, usually given in octal; it is *not* a string of octal digits. See also oct, if all you have is a string. Remember also that the umask's bits are complemented compared to ordinary permissions.

The Unix permission `rwxr-x---` is represented as three sets of three bits, or three octal digits: `0750` (the leading 0 indicates octal and doesn't count as one of the three digits). Since the umask's bits are flipped, it represents disabled permissions bits. The permission (or "mode") values you supply to `mkdir` or `sysopen` are modified by your umask, so even if you tell `sysopen` to create a file with permissions `0777`, if your umask is `0022`, the file is created with permissions `0755`. If your `umask` were `0027` (group can't write; others can't read, write, or execute), then passing `sysopen` a *`MASK`* of `0666` would create a file with mode `0640` (since `0666 & ~0027` is `0640`).

Here's some advice: supply a creation mode of `0666` for regular files (in `sysopen`) and one of `0777` both for directories (in `mkdir`) and for executable files. This gives users the freedom of choice: if they want protected files, they choose process umasks of `022`, `027`, or even the particularly antisocial mask of `077`. Programs should rarely if ever make policy decisions better left to the user. The exception to this rule is programs that write files that should be kept private: mail files, web browser cookies, *.rhosts* files, and so on.

If *umask*(2) is not implemented on your system and you are trying to restrict your *own* access (that is, if `(`*`EXPR`*` & 0700) > 0`), you'll trigger a runtime exception. If *umask*(2) is not implemented and you are not trying to restrict your own access, the function simply returns `undef`.

undef

```
undef EXPR
undef
```

`undef` is the name by which we refer to the abstraction known as "the undefined value". Conveniently, it also happens to be the name of a function that always returns the undefined value. We happily confuse the two.[23]

Coincidentally, the `undef` function can also explicitly undefine an entity if you supply its name as an argument. The *`EXPR`* argument, if specified, must be an lvalue. Hence, you may only use this on a scalar value, an entire array or hash, a subroutine name (using the `&` prefix), or a typeglob. Any storage associated with the object will be recovered for reuse (though not returned to the system, for most operating systems). The `undef` function will probably not do what you expect on most special variables. Using it on a read-only variable like `$1` raises an exception.

23. On the other hand, Perl 6 happily chooses to unconfuse undef and confuse other things instead.

The undef function is a unary operator, not a list operator, so you can only undefine one thing at a time. Here are some uses of undef as a unary operator:

```
undef $foo;
undef $bar{"blurfl"};   # Different from delete $bar{"blurfl"};
undef @ary;
undef %hash;
undef &mysub;
undef *xyz;             # destroys $xyz, @xyz, %xyz, &xyz, etc.
```

Without an argument, undef is just used for its value:

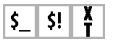
```
select(undef, undef, undef, $naptime);

return (wantarray ? () : undef) if $they_blew_it;
return if $they_blew_it;  # same thing
```

You may use undef as a placeholder on the left side of a list assignment, in which case the corresponding value from the right side is simply discarded. Apart from that, you may not use undef as an lvalue.

```
($a, $b, undef, $c) = &foo;       # Ignore third value returned
```

Also, do not try to compare anything to undef—it doesn't do what you think. All it does is compare against 0 or the null string. Use the defined function or the // operator to test whether a value is defined.

unlink




```
unlink LIST
unlink
```

This function deletes a list of files.[24] The function returns the number of filenames successfully deleted. Here are some examples:

```
$count = unlink("a", "b", "c");
unlink @goners;
unlink glob("*.orig");
```

The unlink function will not delete directories unless you are the superuser and the supply *–U* command-line option to Perl. Even if these conditions are met, be warned that unlinking a directory can inflict Serious Damage on your filesystem. Use rmdir instead.

Here's a simple *rm* command with very simple error checking:

24. Actually, under a POSIX filesystem, it removes the directory entries (filenames) that refer to the real files. Since a file may be referenced (linked) from more than one directory, the file isn't removed until the last reference to it is removed.

```
#!/usr/bin/perl
@cannot = grep {not unlink} @ARGV;
die "$0: could not unlink all of @cannot" if @cannot;
```

unpack

```
unpack TEMPLATE, EXPR
```

This function does the reverse of `pack`: it expands a string (*`EXPR`*) representing a data structure into a list of values according to the *`TEMPLATE`* and returns those values. Templates for `pack` and `unpack` are described in Chapter 26.

unshift

```
unshift ARRAY, LIST
```

This function does the opposite of `shift`. (Or the opposite of `push`, depending on how you look at it.) It prepends *`LIST`* to the front of the array and returns the new number of elements in the array:

```
unshift(@ARGV, "-e", $cmd) unless $ARGV[0] =~ /^-/;
```

Note the *`LIST`* is prepended whole, not one element at a time, so the prepended elements stay in the same order. Use `reverse` to do the reverse.

Starting with v5.14, `unshift` can take a reference to an unblessed array, which will be dereferenced automatically. This aspect of `unshift` is considered experimental. The exact behavior may change in a future version of Perl.

untie

```
untie VARIABLE
```

Breaks the binding between the variable or typeglob contained in *`VARIABLE`* and the package that it's tied to. See `tie`, and all of Chapter 14, but especially the section "A Subtle Untying Trap" on page 510.

use

```
use MODULE VERSION LIST
use MODULE VERSION ()
use MODULE VERSION
use MODULE LIST
use MODULE ()
use MODULE
use VERSION
```

The `use` declaration loads in a module, if it hasn't been loaded before, and imports subroutines and variables into the current package from the named module. (Technically speaking, it imports some semantics into the current package from the named module, generally by aliasing certain subroutine or variable names into your package.) Most `use` declarations look like this:

```
use MODULE LIST;
```

That is exactly equivalent to saying:

```
BEGIN { require MODULE; import MODULE LIST }
```

The `BEGIN` forces the `require` and `import` to happen at compile time. The `require` makes sure the module is loaded into memory if it hasn't been yet. The `import` is not a built-in—it's just an ordinary class method call into the package named by *`MODULE`* to tell that module to pull the list of features back into the current package. The module can implement its import method any way it likes, though most modules just choose to derive their import method via inheritance from the Exporter class that is defined in the `Exporter` module. See Chapter 11 and the `Exporter` module for more information. If no `import` method can be found, then the call is skipped without murmur.

If you don't want your namespace altered, supply an empty list explicitly:

```
use MODULE ();
```

That is exactly equivalent to the following:

```
BEGIN { require MODULE }
```

If the first argument to `use` is a version number like v5.12.3, the currently executing version of Perl must be at least as modern as the version specified. If the current version of Perl is less than *`VERSION`*, an error message is printed and Perl exits immediately. This is useful for checking the current Perl version before loading library modules that depend on newer versions, since occasionally we have to "break" the misfeatures of older versions of Perl. (We try not to break things any more than we have to. In fact, we often try to break things less than we have to.)

Speaking of not breaking things, Perl still accepts antemillennial version numbers of the form:

```
use 5.005_03;
```

However, to align better with industry standards, all versions of Perl released this millennium accept (and we prefer to see) the three-tuple form:

```
use 5.12.0;    # That's version 5, subversion 12, patchlevel 0.
use v5.12.0;   # same
use v5.12;     # same, but be sure to put the v!
```

```
use 5.012;     # same, for compatibility with very old perls
use 5.12;      # WRONG!
```

If the *VERSION* argument is present after *MODULE*, then the `use` will call the `VERSION` method in class *MODULE* with the given *VERSION* as an argument. Note that there is no comma after *VERSION*! The default `VERSION` method, which is inherited from the `UNIVERSAL` class, croaks if the given version is larger than the value of the variable `$Module::VERSION`.

Also, starting in production-release v5.10, `use VERSION` will also load the `feature` pragma and enable all features available in the requested version. See the section "feature" on page 1017 in Chapter 29. Similarly, if the specified Perl version is production-release v5.12 or higher, strictures are enabled lexically as with `use strict` (except that the *strict.pm* file is not actually loaded).

Because `use` provides a wide-open interface, pragmas (compiler directives) are also implemented via modules. Examples of currently implemented pragmas include:

```
use autouse "Carp" => qw(carp croak);
use bignum;
use constant PI => 4 * atan2(1,1);
use diagnostics;
use integer;
use lib "/opt/projects/spectre/lib";
use locale;
use sigtrap qw(die INT QUIT);
use sort qw(stable _quicksort _mergesort);
use strict  qw(subs vars refs);
use threads;
use warnings qw(numeric uninitialized);
use warnings qw(FATAL all);
```

Many of these pragmatic modules import semantics into the current lexical scope. (This is unlike ordinary modules, which only import symbols into the current package, which has little relation to the current lexical scope other than that the lexical scope is being compiled with that package in mind. That is to say... oh, never mind, see Chapter 11.)

Because `use` takes effect at compile time, it doesn't respect the ordinary flow control of the code being compiled. In particular, putting a `use` inside the false branch of a conditional doesn't prevent it from being processed. If a module or pragma needs to be loaded only conditionally, this can be done using the `if` pragma:

```
use if $] < 5.008, "utf8";
use if WANT_WARNINGS, warnings => qw(all);
```

There's a corresponding declaration, `no`, which "unimports" any meanings originally imported by `use` that have since become, er, unimportant:

```
no integer;
no strict qw(refs);
no warnings qw(deprecated);
```

Care should be taken when using the `no VERSION` form of `no`. It is *only* meant to be used to assert that the running Perl is of an earlier version than its argument, *not* to undo the feature-enabling side effects of `use VERSION`.

See Chapter 29 for a list of standard pragmas.

utime

```
utime LIST
```

This function changes the access and modification times on each file of a list of files. The first two elements of the list must be the *numerical* access and modification times, in that order. The function returns the number of files successfully changed. The inode change time of each file is set to the current time. Here's an example of a *touch* command that sets the modification date of the file (assuming you're the owner) to about a month in the future:

```
#!/usr/bin/perl
# montouch - post-date files now + 1 month
$day = 24 * 60 * 60;            # 24 hours of seconds
$later = time() + 30 * $day;    # 30 days is about a month
utime $later, $later, @ARGV;
```

and here's a more sophisticated *touch*-like command with a smattering of error checking:

```
#!/usr/bin/perl
# montouch - post-date files now + 1 month
$later = time() + 30 * 24 * 60 * 60;
@cannot = grep {not utime $later, $later, $_} @ARGV;
die "$0: Could not touch @cannot." if @cannot;
```

To read the times from existing files, use `stat` and then pass the appropriate fields through `localtime` or `gmtime` for printing.

Under NFS this will use the time of the NFS server, not the time of the local machine. If there is a time synchronization problem, the NFS server and local machine will have different times. The Unix *touch*(1) command will in fact normally use this form instead of the one shown in the first example.

Passing only one of the first two elements as `undef` is equivalent to passing a 0, so it will not have the effect described when both are `undef`. This also triggers an uninitialized warning.

On systems that support *futimes*(2), you may pass filehandles among the files. On systems that don't support the *futimes*(2) syscall, passing filehandles raises an exception. To be recognized, filehandles must be passed as globs or glob references; barewords are considered filenames.

```
utime($then, $then, $then, *SOME_HANDLE);
```

values

```
values HASH
values ARRAY
```

This function returns a list consisting of all the values in the indicated *HASH*. The values are returned in an apparently random order, but it is the same order as either the `keys` or `each` function would produce on the same hash. Oddly, to sort a hash by its values, you usually need to use the `keys` function, so see the example under `keys` for that.

You can modify the values of a hash using this function because the returned list contains aliases of the values, not just copies. (In earlier versions, you needed to use a hash slice for that.)

```
for (@hash{keys %hash}) { s/foo/bar/g }   # old way
for (values %hash)      { s/foo/bar/g }   # now changes values
```

Using `values` on a hash that is bound to a humongous DBM file is bound to produce a humongous list, causing you to have a humongous process. You might prefer to use the `each` function, which will iterate over the hash entries one by one without slurping them all into a single gargantuan, er, humongous list.

vec

```
vec EXPR, OFFSET, BITS
```

The `vec` function provides compact storage of lists of unsigned integers. These integers are packed as tightly as possible within an ordinary Perl string. The string in *EXPR* is treated as a bit string made up of some arbitrary number of elements, depending on the length of the string.

OFFSET specifies the index of the particular element you're interested in. The syntaxes for reading and writing the element are the same, since `vec` stores or returns the value of the element depending on whether you use it in an lvalue or an rvalue context.

BITS specifies how wide each element is in bits, which must be a power of two: `1`, `2`, `4`, `8`, `16`, or `32` (and also `64` on some platforms). (An exception is raised if any

other value is used.) Each element can therefore contain an integer in the range `0..(2^BITS)-1`. For the smaller sizes, as many elements as possible are packed into each byte. When *`BITS`* is `1`, there are eight elements per byte. When *`BITS`* is `2`, there are four elements per byte. When *`BITS`* is `4`, there are two elements (traditionally called nybbles) per byte. And so on. Integers larger than a byte are stored in big-endian order.

A list of unsigned integers can be stored in a single scalar variable by assigning them individually to the `vec` function. (If *`EXPR`* is not a valid lvalue, an exception is raised.) In the following example, the elements are each 4 bits wide:

```
$bitstring = "";
$offset = 0;

for my $num (0, 5, 5, 6, 2, 7, 12, 6) {
    vec($bitstring, $offset++, 4) = $num;
}
```

If an element off the end of the string is written to, Perl will first extend the string with sufficiently many zero bytes.

The vectors stored in the scalar variable can be subsequently retrieved by specifying the correct *`OFFSET`*.

```
$num_elements = length($bitstring)*2;  # 2 elements per byte

for my $offset (0 .. $num_elements-1) {
    say vec($bitstring, $offset, 4);
}
```

If the selected element is off the end of the string, a value of `0` is returned.

Strings created with `vec` can also be manipulated with the logical operators `|`, `&`, `^`, and `~`. These operators will assume that a bit string operation is desired when both operands are strings. See the examples of this in the section "Bitwise Operators" on page 118 in Chapter 3.

If *`BITS`* `== 1`, a bitstring can be created to store a series of bits all in one scalar. The ordering is such that `vec($bitstring,0,1)` is guaranteed to go into the lowest bit of the first byte of the string.

```
@bits = (0,0,1,0, 1,0,1,0, 1,1,0,0, 0,0,1,0);

$bitstring = "";
$offset = 0;

for my $bit (@bits) {
    vec($bitstring, $offset++, 1) = $bit;
}
```

```
say $bitstring";        # "TC", ie. '0x54', '0x43'
```

A bit string can be translated to or from a string of 1s and 0s by supplying a "b*" template to pack or unpack. Alternatively, pack can be used with a "b*" template to create the bit string from a string of 1s and 0s. The ordering is compatible with that expected by vec.

```
$bitstring = pack "b*", join(q(), @bits);
say $bitstring";   # "TC", same as before
```

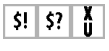
unpack can be used to extract the list of 0s and 1s from the bit string.

```
@bits = split(//, unpack("b*", $bitstring));
say "@bits";        # 0 0 1 0 1 0 1 0 1 1 0 0 0 0 1 0
```

If you know the exact length in bits, it can be used in place of the "*".

See select for additional examples of using bitmaps generated with vec. See pack and unpack for higher-level manipulation of binary data.

wait

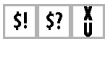



```
wait
```

This function waits for a child process to terminate and returns the PID of the deceased process, or -1 if there are no child processes (or, on some systems, if child processes are being automatically reaped). The status is returned in $?, as described under system. If you get zombie child processes, you should be calling this function, or waitpid.

If you expected a child and didn't find it with wait, you probably had a call to system, a close on a pipe, or backticks between the fork and the wait. These constructs also do a *wait*(2) and may have harvested your child process. Use waitpid to avoid this problem.

waitpid




```
waitpid PID, FLAGS
```

This function waits for a particular child process to terminate and returns the PID when the process is dead, -1 if there are no child processes, or 0 if the *FLAGS* specify nonblocking and the process isn't quite dead yet. The status of any dead process is returned in $?, as described under system. To get valid flag values, you'll need to import the ":sys_wait_h" import tag group from the POSIX module. Here's an example that does a nonblocking wait for all pending zombie processes.

```
use POSIX ":sys_wait_h";
do {
    $kid = waitpid(-1,&WNOHANG);
} until $kid == -1;
```

On systems that implement neither the *waitpid*(2) nor *wait4*(2) syscall, *FLAGS* may be specified only as `0`. In other words, you can wait for a specific *PID* there, but you can't do so in nonblocking mode.

On some systems, a return value of `-1` could mean that child processes are being automatically reaped because you set `$SIG{CHLD} = "IGNORE"`.

wantarray

```
wantarray
```

This function returns true if the context of the currently executing subroutine is looking for a list value, and false otherwise. The function returns a defined false value (`""`) if the calling context is looking for a scalar, and the undefined false value (`undef`) if the calling context isn't looking for anything; that is, if it's in void context.

Here are examples of typical usage:

```
return unless defined wantarray;    # don't bother doing more
my @a = complex_calculation();
return wantarray ? @a : \@a;
```

See also `caller`. This function should really have been named "`wantlist`", but we named it back when list contexts were still called array contexts.

warn


```
warn LIST
warn
```

This function produces an error message, printing *LIST* to `STDERR` just like `die`, but it doesn't try to exit or throw an exception. For example:

```
warn "Debug enabled" if $debug;
```

If *LIST* is empty and `$@` already contains a value (typically from a previous `eval`), the string "`\t...caught`" is appended following `$@` on `STDERR`. (This is similar to the way `die` propagates errors, except that `warn` doesn't propagate [reraise] the exception.) If the message string supplied is empty, the message "`Warning: Some thing's wrong`" is used.

As with `die`, if the strings supplied don't end in a newline, file and line number information is automatically appended. The `warn` function is unrelated to Perl's `-w` command-line option, but can be used in conjunction with it, such as when you wish to emulate built-ins:

```
warn "Something wicked\n" if $^W;
```

No message is printed if there is a `$SIG{__WARN__}` handler installed. It is the handler's responsibility to deal with the message as it sees fit. One thing you might want to do is promote a mere warning into an exception:

```
local $SIG{__WARN__} = sub {
    my $msg = shift;
    die $msg if $msg =~ /isn't numeric/;
};
```

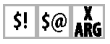
Most handlers must therefore make arrangements to display the warnings that they are not prepared to deal with, by calling `warn` again in the handler. This is perfectly safe; it won't produce an endless loop because `__WARN__` hooks are not called from inside `__WARN__` hooks. This behavior differs slightly from that of `$SIG{__DIE__}` handlers (which don't suppress the error text but can instead call `die` again to change it).

Using a `__WARN__` handler provides a powerful way to silence all warnings, even the so-called mandatory ones. Sometimes you need to wrap this in a `BEGIN{}` block so that it can happen at compile time:

```
# wipe out *all* compile-time warnings
BEGIN { $SIG{__WARN__} = sub { warn $_[0] if $DOWARN } }
my $foo = 10;
my $foo = 20;          # no warning about duplicate my $foo,
                       # but hey, you asked for it!

# no compile-time or runtime warnings before here
$DOWARN = 1;           # *not* a built-in variable

# runtime warnings enabled after here
warn "\$foo is alive and $foo!";     # does show up
```

See the `warnings` pragma for lexically scoped control of warnings. See the `Carp` module's `carp` and `cluck` functions for other ways to produce warning messages.

write



```
write FILEHANDLE
write
```

This function writes a formatted record (possibly multiline) to the specified filehandle, using the format associated with that filehandle—see the section "Format Variables" on page 814 in Chapter 26. By default, the format associated with a filehandle is the one having the same name as the filehandle. However, the format for a filehandle may be changed by altering the `$~` variable after you `select` that handle:

```
$old_fh = select(HANDLE);
$~ = "NEWNAME";
select($old_fh);
```

or by saying:

```
use IO::Handle;
HANDLE->format_name("NEWNAME");
```

Since formats are put into a package namespace, you may have to fully qualify the format name if the `format` was declared in a different package:

```
$~ = "OtherPack::NEWNAME";
```

Top-of-form processing is handled automatically. If there is insufficient room on the current page for the formatted record, the page is advanced by writing a form feed, a special top-of-page format is used for the new page header, and then the record is written. The number of lines remaining on the current page is in the variable `$-`, which can be set to 0 to force a new page on the next `write`. (You may need to `select` the filehandle first.) By default, the name of the top-of-page format is the name of the filehandle with "`_TOP`" appended, but the format for a filehandle may be changed, altering the `$^` variable after `select`ing that handle or by saying:

```
use IO::Handle;
HANDLE->format_top_name("NEWNAME_TOP");
```

If *`FILEHANDLE`* is unspecified, output goes to the current default output filehandle, which starts out as `STDOUT` but may be changed by the single-argument form of the `select` operator. If the *`FILEHANDLE`* is an expression, then the expression is evaluated to determine the actual *`FILEHANDLE`* at runtime.

If a specified `format` or the current top-of-page `format` does not exist, an exception is raised.

The `write` function is *not* the opposite of `read`. Unfortunately. Use `print` for simple string output. If you looked up this entry because you wanted to bypass standard I/O, see `syswrite`.

y//

```
y///
```

The transliteration (historically, but imprecisely, also called translation) operator, also known as `tr///`. See Chapter 5.

CHAPTER 28

The Standard Perl Library

The standard Perl distribution contains much more than just the *perl* executable that runs your scripts. It also includes hundreds of modules filled with reusable code, which we call *Standard Perl Library*. Because the standard modules are available everywhere, if you use one of them in your program, you can run your program anywhere Perl is installed, without any extra installation steps.

But we should tell you that not everywhere you find *perl* has the Standard Perl Library. Since Perl comes with some many different platforms, you might run into some vendors who change the Perl. Some vendors augment Perl by adding extra modules or tools. Some might update some modules to work better with their platforms (and we hope they pass their patches upstream). Others, however, remove parts. If you find part of the Standard Library missing, complain to your vendor or install your own Perl.

In previous editions of this book, we listed every module in the Standard Library and told you a little about each one. We took that out of this edition, and instead we'll show you how to do this for yourself. Chapter 29 still goes through all of the pragmas.

Library Science

Let's review a bit of the terminology we've been splattering about. We, and the rest of the community, tend to use it loosely because the concepts overlap or coexist, but sometimes precision matters.

namespace

A *namespace* is a place to keep names so they won't be confused with names in other namespaces. This leaves you with the simpler problem of not confusing the namespaces themselves. There are two ways to avoid confusing namespaces with one another: give them unique names, or give them unique

locations. Perl lets you do both: named namespaces are called *packages*, and unnamed namespaces are called *lexical scopes*. Since lexical scopes can be no larger than a file, and since the standard modules are file-sized (at minimum), it follows that all module interfaces must make use of named namespaces (packages) if they're to be used by anyone outside the file.

package

A *package* is Perl's standard mechanism for declaring a named namespace. It's a simple mechanism for grouping together related functions and variables. Just as two directories can both contain a (different) file named *Amelia*, two different parts of a Perl program can each have its own `$Amelia` variable or `&Amelia` function. Even though these variables or functions seem to have the same name as one another, those names reside in distinct namespaces managed by the `package` declaration. Package names are used to identify both modules and classes, as described in Chapter 11 and Chapter 12.

library

The term *library* is unfortunately rather overloaded in Perl culture. These days we normally use the term to mean the entire set of Perl modules installed on your system.

Historically, a Perl library was also a single file containing a collection of subroutines sharing some common purpose. Such a file often has the file extension *.pl*,[1] short for "perl library". We still use that extension for random bits of Perl code that you pull in with `do` *`FILE`* or with `require`. Although it's not a full-fledged module, a library file typically declares itself to be in a distinct package so related variables and subroutines can be kept together and don't accidentally interfere with other variables in your program. There is no mandatory extension; others besides *.pl* sometimes occur, as explained later in this chapter. These simple, unstructured library files have been largely superseded by the concept of the module.

module

A Perl *module* is a library file that conforms to certain specific conventions that allow one or more files implementing that module to be brought in with a single `use` declaration at compile time. Module filenames must always end in *.pm* because the `use` declaration assumes it. The `use` declaration will also translate the package separator `::` to whatever your directory separator is, so the directory structure in your Perl library can match your package structure. Chapter 11 describes how to create your own Perl modules.

1. Yes, people tend to use this extension for programs, too. We guess that's okay if you're into that sort of thing, or your operating system forces it on you to make fancy icons.

class
: A *class* is just a module that implements methods for objects associated with the module's package name. If you're interested in object-oriented modules, see Chapter 12.

pragma
: A *pragma* is just a special module that twiddles Perl's internal knobs, often to change how the compiler interprets something or to add special behavior. See Chapter 29 for the pragmas in the Standard Library.

extension
: An *extension* is a Perl module that, in addition to loading a *.pm* file, also loads a shared library implementing the module's semantics in C or C++.

program
: A Perl *program* is code designed to be run as an independent entity. It's also known as a *script* when you don't want anyone to expect much from it, an *application* when it's big and complicated, an *executable* when its caller doesn't care what language it was written in, or an *enterprise solution* when it costs a fortune. Perl programs might exist as source code, bytecode, or native machine code. If it's something you might run from the command line, we'll call it a program.

distribution
: A *distribution* is an archive of *scripts*, *libraries*, or *modules* along with a test suite, documentation, and installation scripts. When people talk about "getting a module from CPAN", they really mean a distribution. See Chapter 19.

A Tour of the Perl Library

You'll save an enormous amount of time if you make the effort to familiarize yourself with the Standard Library, because there's no reason to reinvent those particular wheels. You should be aware, however, that this collection contains a wide range of material. Although some libraries may be extremely helpful, others might be completely irrelevant to your needs. For example, if you're only writing in 100% pure Perl, those modules that support the dynamic loading of C and C ++ extensions aren't going to help you much.

Perl expects to find library modules somewhere in its library "include" path, `@INC`. This array specifies the ordered list of directories Perl searches when you load in some library code using the keywords `do`, `require`, or `use`. You can easily list out those directories by calling Perl with the *–V* switch for Very Verbose Version information, or with this simple code:

```
% perl -le "print for @INC"
/usr/local/lib/perl5/site_perl/5.14.2/darwin-2level
/usr/local/lib/perl5/site_perl/5.14.2
/usr/local/lib/perl5/5.14.2/darwin-2level
/usr/local/lib/perl5/5.14.2
.
```

That's only one sample of possible output. Every installation of Perl uses its own paths. The important thing is that, although contents will vary depending upon your vendor's and your site's installation policy, you can rely upon all standard libraries being installed with Perl. That one is from a Perl installed manually. Another Perl on the same system can give a different answer.

```
% /usr/bin/perl -le "print for @INC"
/Library/Perl/5.12/darwin-thread-multi-2level
/Library/Perl/5.12
/Network/Library/Perl/5.12/darwin-thread-multi-2level
/Network/Library/Perl/5.12
/Library/Perl/Updates/5.12.3
/System/Library/Perl/5.12/darwin-thread-multi-2level
/System/Library/Perl/5.12
/System/Library/Perl/Extras/5.12/darwin-thread-multi-2level
/System/Library/Perl/Extras/5.12
.
```

This output, from Mac OS X.7, is much different and illustrates some different locations for modules. There's the Standard Library under */System*, but then updates go into a directory closer to the front of `@INC`. When you update Mac OS X, instead of overwriting the Standard Library, it puts its updates into a different vendor-specific directory. The modules you install go into the */Library*, so the operating system updates never overwrite your changes. Unless you say otherwise when you install modules (see Chapter 19), that's where they go.

If you look through the directories for this Perl, you might find the same modules but different versions, but also additional modules. Some vendors apply their own patches to the Standard Library. Maybe they update the version and maybe they don't. If you don't think that your Perl is acting like everyone else's, you might check whether you actually have the same thing everyone else has.

The *perldoc* command's *–l* reports the location of a module:

```
% perldoc -l MODULE
/usr/local/lib/perl5/site_perl/5.14.2/MODULE
```

Inside a program, the `%INC` variable keeps track of what it has already loaded and where it found it. The keys are the namespace translated to a file path, such as *Unicode/UCD.pm*, and the value is the path to the module. See Chapter 25 for more details.

This brings up one of the problems of module loading. Perl uses the first matching file it finds in `@INC`. It does not find the latest or best version if it exists later, and there isn't a good way to make *perl* keep looking, aside from reimplementing the whole process in a code reference that you put at the front of `@INC`,[2] or creating a new library path that links to the "best" versions of the modules in all of the other directories. Those are clunky and take a lot of care and feeding. For instance, if someone sets `PERL5LIB`, should you choose the versions that you find there instead of looking in later directories?

Roll Call

In previous editions we included a list of all modules in the Standard Library, but this book is already too long to devote tens of pages to that, especially considering that you can just look in *perlmodlib* to see the list for your version of Perl. If you don't like that, you can make this list yourself by looking for all *.pm* files, then extracting the nonblank line after `=head1 NAME`:

```
use v5.10;

use File::Find;

my %names;
my $wanted = sub {
    return unless /\.pm\z/;
    open(my $fh, "<", $File::Find::name)
        || die "can't open $File::Find::name: $!";
    OUTER: while( <$fh> ) {
        next unless /\A =head1 \s+ NAME/x;
        while( <$fh> ) {
            next if /\A \s* \z/x;
            / (?<name>\S+) \s* -+ \s* (?<desc>.*) /x;
            $names{ $+{name} } = $+{desc};
            last OUTER;
        }
     }
  };

find($wanted, @INC);

for my $name (sort keys %names) {
    printf "%-25s - %s\n", $name, $names{$name};
}
```

With v5.14, that finds about 500 namespaces:

2. The `inc::latest` module provides a code reference that does this.

```
AnyDBM_File             - provide framework for multiple DBMs
App::Cpan               - easily interact with CPAN from
                        - the command line
App::Prove              - Implements the C<prove> command.
... many others ...
warnings                - Perl pragma to control optional warnings
warnings::register      - warnings import function
writemain               - write the C code for perlmain.c
```

There's another way to get this. The `Module::CoreList` module, part of the Standard Perl Library, knows what came with which Perl. Its *corelist* module is the interface. To find the versions it knows about, use the *–v* switch:

```
% corelist -v
5
5.000
5.001
5.002
...
v5.14.0
v5.14.1
```

With a version, *–v* reports all the modules and versions that came with that version of Perl:

```
% corelist -v 5.14.1

The following modules were in perl 5.14.1 CORE
AnyDBM_File                                     1.00
App::Cpan                                       1.5701
App::Prove                                      3.23
...many more...
version                                         0.88
vmsish                                          1.02
warnings                                        1.12
warnings::register                              1.02
```

It can also report a module's history with the *–a* switch:

```
% corelist -a Archive::Extract
Archive::Extract was first released with perl v5.9.5
  v5.9.5     0.22_01
  v5.10.0    0.24
  v5.10.1    0.34
  ...
  v5.14.0    0.48
  v5.14.1    0.48
```

If you want to know the earliest Perl version that contains that module, don't use any switch:

```
% corelist Module::CoreList
Module::CoreList was first released with perl v5.8.9
```

The *–d* switch reports the earliest version of Perl to include the module. For example, `Module::CoreList` didn't join the Standard Perl Library until v5.9.2:

```
% corelist -d Module::CoreList
Module::CoreList was first released with perl v5.9.2
```

The *–d* stands for "date", so don't be confused. Perl v5.9.2 was released temporally before v5.8.9, which is why the results seem odd.

The Future of the Standard Perl Library

Two schools of thought are battling for the future of the Standard Perl Library. One school would like to have as much as possible in the Standard Perl Library, so they can create applications using the modules they like and be able to distribute them easily without requiring people to install additional modules. The other school wants a minimal distribution with just the right number of modules to allow the later installation from CPAN of additional modules.

Each school has merit. A bigger Library benefits users. They don't have to bother their system administrators and lawyers to allow them to install additional modules once they have Perl. A smaller library makes it easier for the Perl 5 Porters, who have less of a distraction handling modules and can spend more time working on other tasks.

Some modules are *dual-lived*, meaning they have two tracks of development. One is in the Perl repository itself and the other is on CPAN. This allows the modules to patch problems more quickly than the Perl release cycle. When it's time for a new release of Perl, the maintainers merge the changes from the CPAN version into the Perl sources. Sometimes the version in the Perl repository gets fixed first. In that case, the CPAN developers merge the changes at their leisure.

For many years, this process was cumbersome because the layout of the CPAN version and the Standard Library version was very different, making the merge a tedious, hard-to-automate process. Besides patching the modules, the maintainers had to merge the tests into the rest of the Perl test suite, place ancillary files in the right places, and so on. It wasn't a task that anyone looked forward to. The trend now is to put the CPAN distribution completely in its own directory in the *perl* repository to make it easy to drop in the changes to a module—and that may be completely done by the time you read this book. Maintaining dual-lived modules has improved greatly over the past few years. This makes it easy for vendors to include additional modules in their customized distribution of Perl.

Wandering the Stacks

If you look through the directories in `@INC` and their subdirectories, you'll find several different kinds of files installed. Most have names ending in *.pm*, but some end in *.pl*, *.ph*, *.al*, or *.so*. The ones that most interest you are the first set, because a suffix of *.pm* indicates that the file is a proper Perl module. More on those in a minute.

The few files you see there ending in *.pl* are those old Perl libraries we mentioned earlier. They are included for compatibility with ancient releases of Perl from the '80s and early '90s. Because of this, Perl code that worked back in, say, 1990 should continue to behave properly without any fuss, even if you have a modern version of Perl installed. When writing new code that makes use of the standard Perl library, you should always elect to use the *.pm* version over any *.pl*, where possible. That's because modules don't pollute your namespace the way many of the old *.pl* files do. As Perl has evolved, though, the Perl 5 Porters have been removing some of those files, either delegating those tasks to modules or making you go to CPAN to get them.

One note on the use of the *.pl* extension: it means Perl library, not Perl program. Although *.pl* is sometimes used to identify Perl programs on web servers that need to distinguish executable programs from static content in the same directory or by some systems to associate a file with a program to open it, we suggest that you use a suffix of *.plx* instead to indicate an executable Perl program. (Similar advice holds for operating systems that choose interpreters based on filename extensions.) Or don't use an extension at all since *perl* doesn't care what you call it. It will happily run *hello.rb* as long as the text in it is a Perl program.[3]

Files with extensions of *.al* are small pieces of larger modules that will be automatically loaded when you use their parent *.pm* file. If you build your module layout using the standard *h2xs* tool (see Chapter 19) that comes with Perl (and if you haven't used Perl's *–A* flag), the `make install` procedure will use the `AutoLoader` module (hence the *a* and the *l*) to create these little *.al* files for you.

The *.ph* files were made by the standard *h2ph* program, a somewhat aging but still occasionally necessary tool that does its best to translate C preprocessor directives into Perl. The resulting *.ph* files contain constants sometimes needed by low-level functions like `ioctl`, `fcntl`, or `syscall`. (Nowadays most of these values are more conveniently and portably available in standard modules such

3. One of the goals of the Parrot interpreter is to be able to load and run a *hello.rb*—even if it contains Ruby code.

as the `POSIX`, `Errno`, `Fcntl`, or `Socket` modules.) See *perlinstall* for how to install these optional but sometimes important components.

One last file extension you might encounter while poking around is *.so* (or whatever your system uses for shared libraries). These *.so* files are platform-dependent portions of extension modules. Originally written in C or C++, these modules have been compiled into dynamically relocatable object code. The end user doesn't need to be aware of their existence, however, because the module interface hides them. When the user code says `require Module` or `use Module`, Perl loads *Module.pm* and executes it, which lets the module pull in any other necessary pieces, such as *Module.so* or any autoloaded *.al* components. In fact, the module could load anything it jolly well pleases, including 582 other modules, and all of those modules could load another 582 modules each. It could download all of CPAN if it felt like it, and maybe the last two years of *freshmeat.net* archives.

A module is not just a static chunk of code in Perl. It's an active agent that figures out how to implement an interface on your behalf. It may follow all the standard conventions, or it may not. It's allowed to do anything to warp the meaning of the rest of your program, up to and including translating the rest of your program into SPITBOL. This sort of chicanery is considered perfectly fair as long as it's well documented. When you use such a Perl module, you're agreeing to *its* contract, not a standard contract written by Perl.

So you'd best read the fine print.

CHAPTER 29

Pragmatic Modules

A *pragma* is a special kind of module that affects the compilation phase of your program. Some pragmatic modules (or *pragmata*, for short [or *pragmas*, for shorter]) may also affect the execution phase of your program. Think of these as hints to the compiler. Because they need to be seen at compile time, they'll work only when invoked by a `use` or a `no`, because by the time a `require` or a `do` runs, compilation is long since over.

By convention, pragma names are written all in lowercase, because lowercase module names are reserved for the Perl distribution itself. When writing your own modules, use at least one upper- or titlecase character in the module name to avoid conflict with pragma names.

Unlike regular modules, most pragmas limit their effects to the rest of the innermost enclosing block from which they were invoked. In other words, they're lexically scoped, just like `my` variables. Ordinarily, the lexical scope of an outer block covers any inner block embedded within it, but an inner block may countermand a lexically scoped pragma from an outer block by using the `no` statement:

```
use strict;
use integer;
{
    no strict "refs";       # allow symbolic references
    no integer;             # resume floating-point arithmetic
    # ....
}
```

More so than the other modules Perl ships with, the pragmas form an integral and essential part of the Perl compilation environment. It's hard to use the compiler well if you don't know how to pass hints to it, so we'll put some extra effort into describing pragmas.

Another thing to be aware of is that we often use pragmas to prototype features that later get implemented as "real" syntax. So in some programs you'll see deprecated pragmas like `use attrs`, whose functionality is now supported directly by subroutine declaration syntax, or `use vars`, which we replaced with `our` declarations. We're not in a terrible hurry to break the old ways of doing things, but we do think the new ways are nicer to look at.

Finally, at the end of this chapter, we'll show how to create your own pragmas that act just like those that come with Perl.

attributes

```
sub afunc : method;
my $closure = sub : method { ... };

use attributes;
@attrlist = attributes::get(\&afunc);
```

The `attributes` pragma has two purposes. The first is to provide an internal mechanism for declaring *attribute lists*, which are optional properties associated with subroutine declarations and (someday soon) variable declarations. (Since it's an internal mechanism, you don't generally use this pragma directly.) The second purpose is to provide a way to retrieve those attribute lists at runtime using the `attributes::get` function call. In this capacity, `attributes` is just a standard module, not a pragma.

Only a few built-in attributes are currently handled by Perl. Package-specific attributes are allowed by an experimental extension mechanism described in the section "Package-specific Attribute Handling" of the *attributes*(3) manpage.

Attribute setting occurs at compile time; attempting to set an unrecognized attribute is a compilation error. (The error is trappable by `eval`, but it still stops the compilation within that `eval` block.)

Only three built-in attributes for subroutines are currently implemented: `locked`, `method`, and `lvalue`. See Chapter 7 for further discussion of these. There are currently no built-in attributes for variables as there are for subroutines, but we can think of several we might like, such as `constant`.

The `attributes` pragma provides two subroutines for general use. They may be imported if you ask for them.

`get`
: This function returns a (possibly empty) list of attributes given a single input parameter that's a reference to a subroutine or variable. The function raises an exception by invoking `Carp::croak` if passed invalid arguments.

`reftype`
: This function acts somewhat like the built-in `ref` function, but it always returns the underlying, built-in Perl data type of the referenced value, ignoring any package into which it might have been blessed.

Precise details of attribute handling remain in flux, so you'd best check out the online documentation included with your Perl release to see what state it's all in.

autodie

```
use autodie;
```

This pragma turns failures of Perl function calls into fatal errors, but only in its lexical scope. It replaces the standard Perl functions that return false on failure with versions that throw exceptions on failure. The exception message in `$@` lets you know which sort you encountered:

```
eval {
    use autodie;
    open my $fh, "<:encoding(UTF-8)", $filename;
    my @lines = <$fh>;
    close $fh;
}

for ($@) {
    when (undef)   { }
    when ("open")  { say "Open failed";             }
    when (":io")   { say "Some other IO error";     }
    when (":all")  { say "Some other autodie error" }
    default        { say "Non-autodie error"        }
  }
```

The pragma can replace related sets of functions, too, such as just the ones that deal with input and output:

```
use autodie qw(:io);
```

If you don't want this feature for an inner scope, turn it off:

```
no autodie;
```

autouse

```
use autouse "Carp" => qw(carp croak);
carp "this carp was predeclared and autoused";
```

This pragma provides a mechanism for runtime demand loading of a particular module only when a function from that module really gets called. It does this by providing a stub function that replaces itself with the real call once triggered. This is similar in spirit to the way the standard `AutoLoader` and `SelfLoader` modules behave. In short, it's a performance hack to help make your Perl program start up faster (on average) by avoiding compilation of modules that might never ever be called during a given execution run.

How `autouse` behaves depends on whether the module is already loaded. For example, if the module `Module` is already loaded, then the declaration:

```
use autouse "Module" => qw(func1 func2($;$) Module::func3);
```

is equivalent to the simple import of two functions:

```
use Module qw(func1 func2);
```

This assumes that `Module` defines `func2` with prototype `($;$)`, and that `func1` and `func3` have no prototypes. (More generally, this also assumes that `Module` uses `Exporter`'s standard `import` method; otherwise, a fatal error is raised.) In any event, it completely ignores `Module::func3` since that is presumably already declared.

If, on the other hand, `Module` has not yet been loaded when the `autouse` pragma is parsed, the pragma declares functions `func1` and `func2` to be in the current package. It also declares a function `Module::func3` (which could be construed as mildly antisocial, were it not for the fact that the nonexistence of the `Module` module has even more antisocial consequences). When these functions are called, they make sure the `Module` in question is loaded and then replace themselves with calls to the real functions just loaded.

Because the `autouse` pragma moves portions of your program's execution from compile time to runtime, this can have unpleasant ramifications. For example, if the module you `autouse` has some initialization that is expected to be done early, this may not happen early enough. Autousing can also hide bugs in your code when important checks are moved from compile time to runtime.

In particular, if the prototype you've specified on `autouse` line is wrong, you will not find out about it until the corresponding function is executed (which may be months or years later for a rarely called function). To partially alleviate this problem, you could write your code like this during code development:

```
use Chase;
use autouse Chase => qw[ hue($) cry(&$) ];
cry "this cry was predeclared and autoused";
```

The first line ensures that errors in your argument specification will be found early. When your program graduates from development into production mode, you can comment out the regular loading of the `Chase` module and leave just the autousing call in place. That way you get safety during development and performance during production.

base

```
use base qw(Mother Father);
```

This pragma lets a programmer conveniently declare a derived class based on the listed parent classes. This pragma has mostly fallen out of favor, and most people prefer to use the `parent` pragma.

The declaration above is roughly equivalent to:

```
BEGIN {
    require Mother;
    require Father;
    push @ISA, qw(Mother Father);
}
```

The `base` pragma takes care of any `require` needed. When the `strict "vars"` pragma is in scope, `use base` lets you (in effect) assign to `@ISA` without first having to declare `our @ISA`. (Since the `base` pragma happens at compile time, it's best to avoid diddling `@ISA` on your own at runtime.)

But beyond this, `base` has another property. If any named base class use fields facility under `fields` (mentioned later in this chapter), then the pragma initializes the package's special field attributes from the base class. (Multiple inheritance of field classes is *not* supported. The `base` pragma raises an exception if more than one named base class has fields.)

Any base class not yet loaded will be loaded automatically via `require`. However, whether to `require` a base class package is determined not by the customary inspection of `%INC`, but by the absence of a global `$VERSION` in the base package. This hack keeps Perl from repeatedly trying (and failing) to load a base class that isn't in its own requirable file (because, for example, it's loaded as part of some other module's file). If `$VERSION` is not detected after successfully loading a file, `base` will define `$VERSION` in the base package, setting it to the string `"-1, defined by base.pm"`. This string might change in later versions of the pragma.

bigint

```
use bigint;
```

This pragma bypasses the architecture-dependent treatment of integer operations to work with very large numbers, as well as handling the special value `NaN` (for not a number):

```
use bigint;
say 2 ** 512;
```

This pragma works by overloading the numeric operators to use `Math::BigInt` to compute values. As such, it can be considerably slower than built-in operations. Still, slow right answers are always better than fast wrong ones.

You can load different implementing libraries, which may vary in performance. By default, `bigint` uses a pure Perl implementation, but you can load a faster library if you have it:

```
use bigint lib => 'GMP';
```

You can set the accuracy, which determines the number of significant digits in the answer:

```
use bigint a => 2;
```

Or, you can set the precision, which specifies the magnitude of the answer. A precision less than 0 is ignored:

```
use bigint p => -2;   # to the hundredths place (ignored)
use bigint p =>  1;   # rounded to 10
```

bignum

```
use bignum;
```

This pragma bypasses the architecture-dependent treatment of numeric operations to work with very large numbers (or numbers with more decimal places), as well as handling the special value `NaN` (for not a number):

```
use bignum;
say sqrt(2);
```

This pragma works by overloading the numeric operators to use `Math::BigInt` and `Math::BigFloat` to compute values. See `bigint`.

bigrat

```
use bigrat;
```

This pragma bypasses the architecture-dependent treatment of numeric operations to work with rational numbers (that is, fractions) and keep them as rational numbers so you lose no precision (at least until you are ready for that):

```
use bigrat;
say 1/2 + 1/3;   # 5/6
```

This pragma works by overloading the numeric operators to use `Math::BigInt` and `Math::BigRat` to compute values. See `bigint`.

blib

From the command line:

```
% perl -Mblib program [args...]
% perl -Mblib=DIR program [args...]
```

From your Perl program:

```
use blib;
use blib DIR;
```

This pragma is primarily intended as a way to test arbitrary Perl programs against an uninstalled version of a package using Perl's *–M* command-line switch. It assumes your directory structure was produced by the standard `ExtUtils::MakeMaker` or `Module::Build` modules.

The pragma looks for a *blib* directory structure starting in the directory named *`DIR`* (or current directory if none was specified), and if it doesn't find a *blib* directory there, works its way back up through your .. directories, scanning up to five levels of parent directory.

bytes

```
use bytes;
no bytes;
```

The `bytes` pragma disables character semantics for the rest of the lexical scope in which it appears. The `no bytes` pragma can be used to reverse the effect of `use bytes` within the current lexical scope.

Perl normally assumes character semantics in the presence of character data (that is, data from a source marked as being of a particular character encoding).

To understand the implications and differences between character semantics and byte semantics, see Chapter 6. A visit to Tokyo might also help.

You probably don't want to use this pragma, and it's likely to disappear in later versions of Perl. In v5.14, the `bytes` pragma's documentation strongly discourages its use. If you have a string, treat it as a character string without worrying about its underlying encoding.

charnames

```
use charnames HOW;
print "\N{CHARNAME} is a funny character";

use charnames ();  # no compile-time \N{}, just run-time functions
```

All forms other than `use charnames ()` enable interpolation of named characters into strings and regexes using the `\N{`*`CHARNAME`*`}` notation:

```
use charnames ":full";
print "\N{GREEK SMALL LETTER SIGMA} is called sigma.\n";

use charnames ":short";
print "\N{greek:Sigma} is an uppercase sigma.\n";

use charnames qw(cyrillic greek);
print "\N{sigma} is Greek sigma, and \N{be} is Cyrillic b.\n";

use charnames ":full", ":alias" => {
    "WRY CAT" => "CAT FACE WITH WRY SMILE",
    "AMELIA"  => "DROMEDARY CAMEL",
    "s with comma" => 0x0219,
};

# ":loose" supported on v5.16 and later only
use charnames ":loose";
```

If `:full` is present, then `\N{`*`CHARNAME`*`}` is expanded by looking first in the list of standard Unicode character names. If `:short` is present, and *`CHARNAME`* has the form *`SCRIPT:CNAME`*, then *`CNAME`* is looked up as a letter in script *`SCRIPT`*. If `:loose` is present (and you are running v5.16 or better), it works just like `:full` except names are looked up without regard to case, whitespace, or underscores, just as in Unicode property names in regexes.

Used with one or more Unicode script name arguments,[1] *`CHARNAME`* is looked up as a letter in the given scripts, first looking in the first listed script, then the next

1. You can find the current list of scripts recognized by Unicode in the *perluniprops* manpage.

one if any, and so on. For lookup of *CHARNAME* inside a given script *SCRIPTNAME*, it looks for the names:

```
SCRIPTNAME CAPITAL LETTER CHARNAME
SCRIPTNAME SMALL LETTER CHARNAME
SCRIPTNAME LETTER CHARNAME
```

If *CHARNAME* is entirely lowercase, the `CAPITAL` variant is ignored. Otherwise, the `SMALL` variant is ignored.

```
use charnames "Greek";
print "\N{Sigma} \N{sigma} \N{final sigma}\n"; # Σ σ ς

use charnames "Latin";
print "\N{DZ} \N{D with small letter z} \N{dz}\n"; # DZ Dz dz
```

`\N{`*NAME*`}` operates only at compile time as a special form of string constant used inside double-quotish strings. *NAME* must be a literal; you cannot use variables inside the `\N{`*NAME*`}`. For similar runtime functionality, use `charnames::string_via name`, described below.

The notation `\N{U+`*HEXDIGITS*`}`, where the *HEXDIGITS* is a hexadecimal number, also inserts a Unicode character into a string, but alone of all `\N{...}` uses, this one doesn't require the `charnames` pragma. The character inserted is the one whose codepoint (ordinal value) is equal to the hex number. For example, `\N{U+263A}` is the Unicode (white background, black foreground) smiley face. That notation doesn't require this pragma, whereas the equivalent using character names, `\N{WHITE SMILING FACE}`, does.

Any string that includes a `\N{`*CHARNAME*`}` or `\N{U+`*HEXDIGITS*`}` automatically has Unicode semantics, even if you haven't used the Unicode strings feature.

For the C0 and C1 control characters (U+0000..U+001F, U+0080..U+009F) there are no official Unicode names, but you can instead use the ISO 6429 names: LINE FEED, ESCAPE, and so forth, and their abbreviations, LF, ESC, etc. See the *charnames* manpage for other commonly used aliases.

If the input name is unknown, `\N{`*NAME*`}` raises a warning and substitutes the Unicode REPLACEMENT CHARACTER (U+FFFD).

For `\N{`*NAME*`}`, it is a fatal error if the `bytes` is in effect and the input name is that of a character that won't fit into a byte (that is, whose ordinal is above 255).

Custom Character Names

You can create custom character names to allow for more convenient typing or to give names to codepoints Unicode hasn't assigned a name to. Aliases are added either using anonymous hashes:

```
use charnames ":alias" => {
    e_ACUTE      => "LATIN SMALL LETTER E WITH ACUTE",
    "APPLE LOGO" => 0xF8FF,  # private-use codepoint
};
my $str = "\N{APPLE LOGO}";
```

or using a file containing a list of key/value pairs:

```
use charnames ":alias" => "pro";  # look in unicore/pro_alias.pl
```

The specified file should be under a *unicore/* subdirectory somewhere in the `@INC` path, and it should be named using a trailing *_alias.pl* at the end. So, for example, the file looked for above will be *unicore/pro_alias.pl*. This file should return a list in plain Perl:

```
(
    A_grave    => "LATIN CAPITAL LETTER A WITH GRAVE",
    A_circ     => "LATIN CAPITAL LETTER A WITH CIRCUMFLEX",
    A_diaer    => "LATIN CAPITAL LETTER A WITH DIAERESIS",
    A_dier     => "LATIN CAPITAL LETTER A WITH DIAERESIS",
    A_uml      => "LATIN CAPITAL LETTER A WITH DIAERESIS",
    A_tilde    => "LATIN CAPITAL LETTER A WITH TILDE",
    A_macron   => "LATIN CAPITAL LETTER A WITH MACRON",
);
```

Both these methods insert `:full` automatically as the first argument if no other argument is given; you can also give the `:full` explicitly:

```
use charnames ":full", ":alias" => "pro";
```

Even private-use characters can gain names. For example, after:

```
use charnames ":full", ":alias" => {
    "TENGWAR LETTER TINCO"    =>   0xE000,
    "TENGWAR LETTER PARMA"    =>   0xE001,
    "TENGWAR LETTER CALMA"    =>   0xE002,
    "TENGWAR LETTER QUESSE"   =>   0xE003,
    "TENGWAR LETTER ANDO"     =>   0xE004,
    ...
}
```

then string and regex constants in that lexical scope can refer to those named characters:

```
if (/\N{TENGWAR LETTER TINCO}/) { ... }
```

Runtime Lookups

This pragma also provides three functions for converting between character names and numbers at runtime, rather than at compile time the way `\N{`*CHAR NAME*`}` interpolation works. These are:

`charnames::vianame`
: Takes an official name, official alias, or custom alias and returns a single integer codepoint. For example, it converts the string `"LATIN SMALL LETTER A"` into 0x61.

`charnames::string_vianame`
: Takes a string that can be an official name, an official alias, or a named sequence and gives back a string. For example, this converts `"LATIN SMALL LETTER A"` into `"a"`. Because of named sequences, the string returned may (rarely) be longer than length 1.

`charnames::viacode`
: Takes an integer and returns the official alias if there is one, and the official name if there is not. For example, this converts 0x61 into the string `"LATIN SMALL LETTER A"`. Will return custom names only if no official name exists, such as for private-use area codepoints.

These functions are not exported, so you must fully qualify them to use them. They also provide runtime access to any custom aliases you may have created. This shows how each works:

```
use v5.14;
use warnings;
use warnings FATAL => "utf8";
use open qw(:std :utf8);

use charnames ":full", ":alias" => {
    ecute         => "LATIN SMALL LETTER E WITH ACUTE",
    "APPLE LOGO"  => 0xF8FF,  # private use character
};

printf "U+%04X is named '%s'.\n",  0xE9  => charnames::viacode(0xE9);
printf "%s is code U+%04X.\n",     ecute => charnames::vianame("ecute");
printf "%s is string '%s'.\n",     ecute => charnames::string_vianame("ecute");

printf "U+%04X is named '%s'.\n",    0xF8FF => charnames::viacode(0xF8FF);
printf "%s is code U+%04X.\n", "APPLE LOGO" => charnames::vianame("APPLE LOGO");
printf "%s is string '%s'.\n", "APPLE LOGO" => charnames::string_vianame("APPLE LOGO");
```

Here's the output it produces:

```
U+00E9 is named 'LATIN SMALL LETTER E WITH ACUTE'.
ecute is code U+00E9.
ecute is string 'é'.

U+F8FF is named 'APPLE LOGO'.
APPLE LOGO is code U+F8FF.
APPLE LOGO is string ''.
```

You can even write your own module that works like the `charnames` pragma but defines character names differently. However, the interface to that is still experimental, so see the manpage for the latest.

constant

```
use constant BUFFER_SIZE    => 4096;
use constant ONE_YEAR       => 365.2425 * 24 * 60 * 60;
use constant PI             => 4 * atan2 1, 1;
use constant DEBUGGING      => 0;
use constant ORACLE         => 'oracle@cs.indiana.edu';
use constant USERNAME       => scalar getpwuid($<);
use constant USERINFO       => getpwuid($<);

use constant {
    BUFFER_SIZE    => 4096,
    ONE_YEAR       => 365.2425 * 24 * 60 * 60,
    PI             => 4 * atan2( 1, 1 ),
    DEBUGGING      => 0,
    ORACLE         => 'oracle@cs.indiana.edu',
    USERNAME       => scalar getpwuid($<),
    USERINFO       => getpwuid($<),
};

sub deg2rad { PI * $_[0] / 180 }

print "This line does nothing"      unless DEBUGGING;

# references can be declared constant
use constant CHASH          => { foo => 42 };
use constant CARRAY         => [ 1,2,3,4 ];
use constant CCODE          => sub { "bite $_[0]\n" };

print CHASH->{foo};
print CARRAY->[$i];
print CCODE->("me");
print CHASH->[10];                          # compile-time error
```

This pragma declares the named symbol to be an immutable constant[2] with the given scalar or list value. Values are evaluated in list context. You may override this with `scalar` as we did above. Giving it a hash reference declares many constants at once with only one `use` statement.

Since these constants don't have a `$` on the front, you can't interpolate them directly into double-quotish strings, although you may do so indirectly:

```
print "The value of PI is @{[ PI ]}.\n";
```

2. Implemented as a subroutine taking no arguments and returning the same constant each time.

Because list constants are returned as lists, not as arrays, you must subscript a list-valued constant using extra parentheses as you would any other list expression:

```
$homedir = USERINFO[7];             # WRONG
$homedir = (USERINFO)[7];           # ok
```

Although using all capital letters (plus underscores between words) for constants is generally recommended to help them stand out and to avoid potential collisions with other keywords and subroutine names, this is merely a convention. Constant names must begin with an alphabetic character or an underscore, but (if alphabetic) it need not be an upper- or titlecase one.

Constants are not private to the lexical scope in which they occur. Instead, they are simply argumentless subroutines in the symbol table of the package issuing the declaration. You may refer to a constant *`CONST`* from package `Other` as `Other::`*`CONST`*. Read more about compile-time inlining of such subroutines in the section "Inlining Constant Functions" on page 331 in Chapter 7.

As with all `use` directives, `use constant` happens at compile time. It's therefore misleading at best to place a constant declaration inside a conditional statement, such as `if ($foo) { use constant ... }`. Since this happens at compile time, Perl can replace constant expressions with their value as it runs into them.

Omitting the value for a symbol gives it the value of `undef` in scalar context or the empty list, `()`, in list context. But it is probably best to declare these explicitly:

```
use constant CAMELIDS       => ();
use constant CAMEL_HOME     => undef;
```

Restrictions on constant

List constants are not currently inlined the way scalar constants are. And it is not possible to have a subroutine or keyword with the same name as a constant. This is probably a Good Thing.

You cannot declare more than one named constant at a time as a list:

```
use constant FOO => 4, BAR => 5;    # WRONG
```

That defines a constant named `FOO` whose return list is `(4, "BAR", 5)`. You need this instead:

```
use constant FOO => 4
use constant BAR => 5;
```

or even:

```
use constant {
    FOO => 4,
    BAR => 5,
};
```

You can get yourself into trouble if you use a constant in a context that automatically quotes bare names. (This is true for any subroutine call, not just constants.) For example, you can't say `$hash{CONSTANT}` because *CONSTANT* will be interpreted as a string. Use `$hash{CONSTANT()}` or `$hash{+CONSTANT}` to prevent the quoting mechanism from kicking in. Similarly, since the `=>` operator quotes its left operand if that operand is a bare name, you must say `CONSTANT() => "value"` instead of `CONSTANT=> "value"` .

deprecate

```
use deprecate;
```

Core modules that have been marked for removal from the Standard Library use this pragma to issue a warning that you should use the CPAN version instead. If your module is not in the Standard Library, this pragma does nothing.

diagnostics

```
use diagnostics;            # compile-time enable
use diagnostics -verbose;

enable  diagnostics;        # runtime enable
disable diagnostics;        # runtime disable
```

This pragma expands the normal terse diagnostics and suppresses duplicate warnings. It augments the short versions with the more explicative and endearing descriptions found in *perldiag*. Like other pragmas, it also affects the compilation phase of your program, not just the run phase.

When you `use diagnostics` at the start of your program, this automatically enables Perl's *–w* command-line switch by setting `$^W` to 1. The remainder of your whole compilation will then be subject to enhanced diagnostics. These still go out on `STDERR`.

Because of the interaction between runtime and compile-time issues, and because it's probably not a good idea anyway, you may not use `no diagnostics` to turn them off at compile time. However, you may control their behavior at runtime using the `disable` and `enable` methods. (Make sure you do the `use` first or else you won't be able to get at the methods.)

The -verbose flag first prints out the *perldiag* manpage's introduction before any other diagnostics are issued. The $diagnostics::PRETTY variable can be set (before the use) to generate nicer escape sequences for pagers like *less*(1) or *more*(1):

```
BEGIN { $diagnostics::PRETTY = 1 }
use diagnostics;
```

Warnings dispatched from Perl and detected by this pragma are each displayed only once. This is useful when you're caught in a loop that's generating the same warning (like uninitialized value) over and over again. Manually generated warnings, such as those stemming from calls to warn or carp, are unaffected by this duplicate detection mechanism.

Here are some examples of using the diagnostics pragma. The following file is certain to trigger a few errors at both runtime and compile time:

```
use diagnostics;
print NOWHERE "nothing\n";
print STDERR "\n\tThis message should be unadorned.\n";
warn "\tThis is a user warning";
print "\nDIAGNOSTIC TESTER: Please enter a<CR> here: ";
my $a, $b = scalar <STDIN>;
print "\n";
print $x/$y;
```

Here's the output:

```
Parentheses missing around "my" list at diag.pl line 6 (#1)
    (W parenthesis) You said something like

        my $foo, $bar = @_;

    when you meant

        my ($foo, $bar) = @_;

    Remember that "my", "our", "local" and "state" bind
    tighter than comma.

Name "main::y" used only once: possible typo at diag.pl line 8 (#2)
    (W once) Typographical errors often show up as unique variable names.
    If you had a good reason for having a unique name, then just mention
    it again somehow to suppress the message.  The our declaration is
    provided for this purpose.

    NOTE: This warning detects symbols that have been used only once so
    $c, @c, %c, *c, &c, sub c{}, c(), and c (the filehandle or format)
    are considered the same; if a program uses $c only once but also uses
    any of the others it will not trigger this warning.

Name "main::b" used only once: possible typo at diag.pl line 6 (#2)
```

```
Name "main::NOWHERE" used only once: possible typo at diag.pl line 2 (#2)
Name "main::x" used only once: possible typo at diag.pl line 8 (#2)

print() on unopened filehandle NOWHERE at diag.pl line 2 (#3)
    (W unopened) An I/O operation was attempted on a filehandle that was
    never initialized.  You need to do an open(), a sysopen(), or a socket()
    call, or call a constructor from the FileHandle package.

  This message should be unadorned.
  This is a user warning at diag.pl line 4.

DIAGNOSTIC TESTER: Please enter a<CR> here:

Use of uninitialized value $y in division (/) at diag.pl line 8, <STDIN>
    line 1 (#4) (W uninitialized) An undefined value was used as if it
    were already defined.  It was interpreted as a "" or a 0, but maybe
    it was a mistake. To suppress this warning assign a defined value to
    your variables.

    To help you figure out what was undefined, perl will try to tell you
    the name of the variable (if any) that was undefined. In some cases
    it cannot do this, so it also tells you what operation you used the
    undefined value in.  Note, however, that perl optimizes your program
    and the operation displayed in the warning may not necessarily appear
    literally in your program.  For example, "that $foo" is usually
    optimized into "that ". $foo, and the warning will refer to the
    concatenation (.) operator, even though there is no . in your program.

Use of uninitialized value $x in division (/) at diag.pl line 8,
    <STDIN> line 1 (#4)

Illegal division by zero at diag.pl line 8, <STDIN> line 1 (#5)
    (F) You tried to divide a number by 0.  Either something was wrong in
    your logic, or you need to put a conditional in to guard against
    meaningless input.

Uncaught exception from user code:
  Illegal division by zero at diag.pl line 8, <STDIN> line 1.
 at diag.pl line 8
```

Diagnostic messages come from the *perldiag* manpage. If an extant `$SIG{__WARN__}` handler is discovered, this will still be honored, but only after the `diagnostics::splainthis` function (the pragma's `$SIG{__WARN__}` interceptor) has had its way with your warnings. Perl does not currently support stacked handlers, so this is the best we can do for now. There is a `$diagnostics::DEBUG` variable you may set if you're desperately curious about what sorts of things are being intercepted:

```
BEGIN { $diagnostics::DEBUG = 1 }
use diagnostics;
```

encoding

```
use encoding ENCODING;
use encoding "euc-jp";
```

This pragma was supposed to let you write Perl source in any *ENCODING* that you like and have Perl convert your character strings correctly as well as to convert standard output and error to the specified encoding. However, it has never worked correctly and probably never can. Instead, convert your source code from whatever legacy encoding you were using into UTF-8, and put a `use utf8` declaration at the top of the file. Set your standard I/O streams using the `open` pragma or with `binmode`.

feature

```
use feature ":5.10";  # this is a "feature bundle"
use feature qw(say state switch unicode_strings);

{
    no feature qw(say);
    ...;
}
```

Perl future-proofs itself by introducing new keywords and features through the `feature` pragma. This pragma enables or disables features in the lexical scope. Specify the ones you want to turn on or off either by a version tag or the feature name.

`say`
: Enables the `say` keyword, which is like `print` but with a free newline.

`state`
: Enables `state`, which allows persistent subroutine variables.

`switch`
: Enables Perl's super-charged switch structure, called `given-when`.

`unicode_strings`
: This feature isn't a keyword. Instead, it causes all string operations within the lexical scope to use Unicode semantics. This also applies to regexes compiled within the scope, even if they should eventually be executed outside of it. See "The Unicode Bug" in *perlunicode*. This feature is the only one not in the `:v5.10` bundle, although it is in the `:v5.12` and later bundles.

fields

This pragma was deprecated in v5.10, so we're not going to encourage you to use it by telling you much about it. It was designed as a way to declare class fields that would be type checked at compile time. To do this, it relied on the (since-removed) pseudohash feature. If you're stuck with `fields` in your legacy code, you can still read about it in its own documentation, which is still in v5.14 (at least).

filetest

```
$can_perhaps_read = -r "file";      # use the mode bits
{
    use filetest "access";          # intuit harder
    $can_really_read = -r "file";
}
$can_perhaps_read = -r "file";      # use the mode bits again
```

This lexically scoped pragma tells the compiler to change the behavior of the unary file test operators `-r`, `-w`, `-x`, `-R`, `-W`, and `-X`, documented in Chapter 3. The default behavior for these file tests is to use the mode bits returned by the `stat` family of calls. However, this may not always be the right thing to do, such as when a filesystem understands ACLs (access control lists). In environments such as AFS where this matters, the `filetest` pragma may help the permission operators to return results more consistent with other tools.

There may be a slight performance decrease in the affected file test operators under `filetest`, since on some systems the extended functionality needs to be emulated.

Warning: any notion of using file tests for security purposes is a lost cause from the start. There is a window open for race conditions, because there's no way to guarantee that the permissions will not change between the test and the real operation. If you are the least bit serious about security, you won't use file test operators to decide whether something *will* work. Instead, just go ahead and try the real operation, then test for whether that operation succeeded. (You should be doing that anyway.) See the section "Handling Timing Glitches" on page 661 in Chapter 20.

if

```
use if CONDITION, MODULE => IMPORTS;

use if $^O =~ /MSWin/, "Win32::File";

use if $^V >= 5.010, parent => qw(Mojolicious::UserAgent);
use if $^V <  5.010, base   => qw(LWP::UserAgent);
```

The `if` pragma controls the loading of a module based on some condition. This pragma doesn't handle loading modules with a minimum version. Specify an import list after the module name.

inc::latest

```
use inc::latest "Module::Build";
```

Some module authors started distributing their dependencies inside their distributions in an *inc* directory. They wanted to use a particular version of `Module::Build`, for instance, so they'd install that module in `inc` in their distribution and prefer it to any installed version. Before the Perl tool chain understood `configure_requires`, this was a hack to start the build process with modules within the distribution.

The `inc::latest` module tells perl to load a version in *inc*, but only if its version is greater than the one installed in the rest of `@INC`.

integer

```
use integer;
$x = 10/3;
# $x is now 3, not 3.33333333333333333
```

This lexically scoped pragma tells the compiler to use integer operations from here through the end of the enclosing block. On many machines, this doesn't matter a great deal for most computations, but on those few remaining architectures without floating-point hardware, it can amount to a dramatic performance difference.

Note that this pragma affects certain numeric operations, not the numbers themselves. For example, if you run this code:

```
use integer;
$x = 1.8;
$y = $x + 1;
$z = -1.8;
```

you'll be left with `$x == 1.8`, `$y == 2`, and `$z == -1`. The `$z` case happens because unary - counts as an operation, so the value `1.8` is truncated to `1` before its sign bit is flipped. Likewise, functions that expect floating-point numbers, such as `sqrt` or the trig functions, still receive and return floats even under `use integer`. So `sqrt(1.44)` is `1.2`, but `0 + sqrt(1.44)` is now just `1`.

Native integer arithmetic as provided by your C compiler is used. This means that Perl's own semantics for arithmetic operations might not be preserved. One common source of trouble is the modulus of negative numbers. Perl may do it one way, but your hardware may do it another:

```
% perl -le "print (4 % -3)"
-2

% perl -Minteger -le "print (4 % -3)"
1
```

Additionally, integer arithmetic causes the bit operators to treat their operands as signed values instead of unsigned values:

```
% perl -le "print ~0"
18446744073709551615

% perl -Minteger -le "print ~0"
-1
```

less

```
use less;

use less "CPU";
use less "memory";
use less "time";
use less "disk";
use less "fat";         # great with "use locale";
```

Implemented in v5.10 and later, this pragma is intended to someday give hints to the compiler, code-generator, or interpreter to enable certain trade-offs by using the new hints hash reference that `caller` now returns.

This module has always been part of the Perl distribution (as a joke), but it didn't do anything until v5.10. Even then, hints are available only in their lexical scope, so although the pragma documentation makes it sound as though another module can easily find out what you want less of, this is still only a demonstration of the new `caller` feature.

It is not an error to ask to use less of something that Perl doesn't know how to make less of right now.

lib

```
use lib "$ENV{HOME}/libperl";   # add ~/libperl
no lib ".";                     # remove cwd
```

This pragma simplifies the manipulation of `@INC` at compile time. It is typically used to add extra directories to Perl's search path so that later `do`, `require`, and `use` statements will find library files that aren't located in Perl's default search path. It's especially important with `use`, since that happens at compile time, too, and setting `@INC` normally (that is, at runtime) would be too late.

Parameters to `use lib` are prepended to the beginning of Perl's search path. Saying `use lib` *`LIST`* is *almost* the same as saying `BEGIN { unshift(@INC,` *`LIST`*`) }`, but `use lib` *`LIST`* includes support for platform-specific directories. For each given directory `$dir` in its argument list, the `lib` pragma also checks to see whether a directory named *$dir/$archname/auto* exists. If so, the *$dir/$archname* directory is assumed to be a corresponding platform-specific directory, so it is added to `@INC` (in front of `$dir`).

To avoid redundant additions that slow access time and waste a small amount of memory, trailing duplicate entries in `@INC` are removed when entries are added.

Normally, you should only *add* directories to `@INC`. If you do need to delete directories from `@INC`, take care to delete only those that you yourself added, or those you're somehow certain aren't needed by other modules in your program. Other modules may have added directories to your `@INC` that they need for correct operation.

The `no lib` pragma deletes all instances of each named directory from `@INC`. It also deletes any corresponding platform-specific directory as described earlier.

When the `lib` pragma is loaded, it saves the current value of `@INC` to the array `@lib::ORIG_INC`. So to restore the original, just copy that array to the real `@INC`.

Even though `@INC` typically includes dot (.), the current directory, this really isn't as useful as you'd think. For one thing, the dot entry comes at the end, not the start, so that modules installed in the current directory don't suddenly override system versions. You could say `use lib "."` if that's what you really want. More annoyingly, it's the current directory of the Perl process, not the directory that the script was installed into, which makes it completely unreliable. If you create a program plus some modules for that program to use, it will work while you're developing, but it won't work when you aren't running in the directory the files live in.

One solution for this is to use the standard `FindBin` module:

```
use FindBin;               # where was script installed?
use lib $FindBin::Bin;     # use that dir for libs, too
```

The `FindBin` module tries to guess the full path to the directory in which the running process's program was installed. Don't use this for security purposes, because malicious programs can usually deceive it if they try hard enough. But unless you're intentionally trying to break the module, it should work as intended. The module provides a `$FindBin::Bin` variable (which you may import) that contains the module's guess of where the program was installed. You can then use the `lib` pragma to add that directory to your `@INC`, thus producing an executable-relative path.

Some programs expect to be installed in a *bin* directory and then find their library modules in "cousin" files installed in a *lib* directory at the same level as *bin*. For example, programs might go in */usr/local/apache/bin* or */opt/perl/bin*, and libraries go in */usr/local/apache/lib* and */opt/perl/lib*. This code takes care of that neatly:

```
use FindBin qw($Bin);
use lib "$Bin/../lib";
```

If you find yourself specifying the same `use lib` in several unrelated programs, you might consider setting the `PERL5LIB` environment variable instead. See the description of the `PERL5LIB` environment variable in Chapter 17.

```
# syntax for sh, bash, ksh, or zsh
$ PERL5LIB=$HOME/perllib; export PERL5LIB

# syntax for csh or tcsh
% setenv PERL5LIB ~/perllib
```

If you want to use optional directories on just this program without changing its source, look into the *–I* command-line switch:

```
% perl -I ~/perllib program-path args
```

See Chapter 17 for more about using the *–I* switch on the command line.

locale

```
@x = sort @y;       # ASCII sorting order
{
    use locale;
    @x = sort @y;   # Locale-defined sorting order
}
@x = sort @y;       # ASCII sorting order again
```

This lexically scoped pragma tells the compiler to enable (or disable, under `no locale`) POSIX locales for built-in operations. Enabling locales tells Perl's string comparison and case-related functionality to be respectful of your POSIX

language environment. If this pragma is in effect and your C library knows about POSIX locales, Perl looks to your `LC_CTYPE` setting for regular expressions and to your `LC_COLLATE` setting for string comparisons like those in `sort`.

Since locales are more a form of nationalization than of internationalization, the use of locales may interact oddly with Unicode. It's more portable and more reliable to use Perl's native Unicode facilities for matters of casing and comparison, which are standard across all installations, instead of relying on possibly dodgy vendor locales. See the sections "Comparing and Sorting Unicode Text" and "Locale Sorting" in Chapter 6.

mro

```
use mro;       # enables next::method and friends globally

use mro "dfs"; # enable DFS MRO for this class (Perl default)
use mro "c3";  # enable C3 MRO for this class
```

By default, Perl searches for methods with a depth-first search through the classes (package names) in `@INC`. The `mro` pragma changes that method resolution order. Specifying `dfs` uses the default depth-first search, while specifying `c3` uses the C3 algorithm to resolve certain ambiguities in multiple inheritance. Without an import list, keeps the default method resolution order by enabling features that interact with C3 method resolution (see Chapter 12).

open

```
use open IN  => ":crlf", OUT => ":raw";
use open OUT => ":utf8";
use open IO  => ":encoding(iso-8859-7)";

use open IO  => ":locale";

use open ":encoding(utf8)";
use open ":locale";
use open ":encoding(iso-8859-7)";

use open ":std";
```

The `open` pragma declares one or more default layers (formerly called *disciplines*) for I/O operations, but only if your Perl binary was built with PerlIO. Any `open` and `readpipe` (that is, `qx//` or backticks) operators found within the lexical scope of this pragma that do not specify their own layers will use the declared defaults. Neither `open` with an explicit set of layers, nor `sysopen` under any circumstances, is influenced by this pragma.

There are several layers to choose from:

`:bytes`
: This layer treats the data as characters with codepoints in the range 0 to 255. This is the inverse of the `:utf8` layer. This is not the same thing as `:raw`, though, since this still may do CRLF processing under Windows systems.

`:crlf`
: This layer corresponds to the text mode, in which line endings are translated to or from the native line endings. This is a no-op on a platform where `binmode` is a no-op. This layer is available without PerlIO.

`:encoding(`*ENCODING*`)`
: This layer specifies any encoding supported by the `Encode` module, directly or indirectly.

`:locale`
: This layer decodes or encodes its data according to the locale settings.

`:raw`
: This pseudolayer turns off any layer below it that would interpret the data as other than binary data. This is a no-op on a platform where `binmode` is a no-op. This layer is available without PerlIO.

`:std`
: The `:std` layer isn't really a layer. Importing it applies the other specified layers to the standard filehandles. With `OUT`, it sets layers on the standard output and error. With `IN`, it sets layers on standard input.

`:utf8`
: This layer decodes or encodes its data as UTF-8, treating the data as character strings. The inverse of this layer is `:bytes`.

If you use the built-in `utf8` layer on input streams, it is very important that you be prepared to handle encoding errors. This is the best way:

```
use warnings FATAL => "utf8";    # in case there are input encoding errors
```

That way you take an exception if there is a problem. Recovering from encoding errors is possible, but challenging.

ops

```
perl -M-ops=system ... # disable the "system" opcode
```

The `ops` pragma disables certain opcodes, with irreversible global effect. The Perl interpreter always compiles Perl source into an internal representation of opcodes before it runs it. By default, there are no restrictions on which opcodes Perl

will run. Disabling opcodes restricts what Perl will compile; any code that would use a disable opcode causes a compilation error. Don't think that this provides robust security, though. The `Opcode` module has more details about opcodes. Also see the `Safe` module (Chapter 20), which might be a better choice for you.

overload

In the `Number` module:

```
package Number;
use overload "+" => \&myadd,
             "-" => \&mysub,
            "*=" => "multiply_by";
```

In your program:

```
use Number;
$a = Number->new( 57 );
$b = $a + 5;
```

The built-in operators work well on strings and numbers, but make little sense when applied to object references (since, unlike C or C++, Perl doesn't allow pointer arithmetic). The `overload` pragma lets you redefine the meanings of these built-in operations when applied to objects of your own design. In the previous example, the call to the pragma redefines three operations on `Number` objects: addition will call the `Number::myadd` function, subtraction will call the `Number::mysub` function, and the multiplicative assignment operator will call the `multiply_by` method in class `Number` (or one of its base classes). We say of these operators that they are now *overloaded* because they have additional meanings overlaid on them (and not because they have too many meanings—though that may also be the case).

For much more on overloading, see Chapter 13.

overloading

```
no overloading;
```

This is one of the few pragmas mostly used to turn something off instead of turning something on. On its own, it turns off all overloaded operations, returning them to their normal behavior for the rest of the lexical scope.

To disable particular overloaded operations, specify the same keys that `overload` uses:

```
no overloading qw("");   # no stringification overloading
```

To reenable overloading, do it in reverse:

```
use overloading;         # all back on

use overloading @ops;    # reenable only some of them
```

parent

```
use parent qw(Mother Father);
```

The `parent` pragma supersedes the `base` pragma. It loads modules and sets up inheritance relationships without the `%FIELDS` hash magic, and it provides a way to set up inheritance without loading files.

The following example is equivalent to loading both parent modules and adding them to `@INC` without declaring `@INC` explicitly:

```
BEGIN {
    require Mother;
    require Father;
    push @ISA, qw(Mother Father);
}
```

This assumes each parent module lives in its own file. If the parent classes do not live in separate files, perhaps because you've defined them in the same file or already loaded them from a file as part of another class, you can use the `-norequire` option to merely set up the inheritance relationship:

```
use parent qw(-norequire Mother Father);
```

This is equivalent to adding those classes to `@INC`:

```
BEGIN {
    push @ISA, qw(Mother Father);
}
```

re

This pragma controls the use of regular expressions. It has five possible invocations: `taint`; `eval` and `/flags` mode, which are lexically scoped; and `debug` and `debugcolor`, which aren't.

```
use re "taint";
# Contents of $match are tainted if $dirty was also tainted
($match) = ($dirty =~ /^(.*)$/s);

# Allow code interpolation:
use re "eval";
$pat = '(?{ $var = 1 })';      # embedded code execution
/alpha${pat}omega/;            # won't fail unless under -T
```

```
                                # and $pat is tainted

use re "/a";                    # by default, every pattern
                                #     has the /a flag
use re "/msx";                  # by default, every pattern
                                #     has the /msx flags

use re "debug";                 # like "perl -Dr"
/^(.*)$/s;                      # output debugging info during
                                #     compile time and runtime

use re "debugcolor";            # same as "debug",
                                #    but with colored output

use re qw(Debug LIST);          # fine control of debugging output
```

When `use re "taint"` is in effect and a tainted string is the target of a regex, the numbered regex variables and values returned by the `m//` operator in list context are all tainted. This is useful when regex operations on tainted data aren't meant to extract safe substrings, but are meant to do other transformations instead. See the discussion on tainting in Chapter 20.

When `use re "eval"` is in effect, a regex is allowed to contain assertions that execute Perl code, which are of the form `(?{ ... })`, even when the regex contains interpolated variables. Execution of code segments resulting from variable interpolation into a regex is normally disallowed for security reasons: you don't want programs that read patterns from config files, command-line arguments, or CGI form fields to suddenly start executing arbitrary code if they weren't designed to expect this possibility. This pragma allows only untainted strings to be interpolated; tainted data will still raise an exception (if you're running with taint checks enabled). See also Chapter 5 and Chapter 20.

For purposes of this pragma, interpolation of precompiled regular expressions (produced by the `qr//` operator) is not considered variable interpolation. Nevertheless, when you build the `qr//` pattern, it needs to have `use re "eval"` in effect if any of its interpolated strings contain code assertions. For example:

```
$code = '(?{ $n++ })';      # code assertion
$str  = '\b\w+\b' . $code;  # build string to interpolate

$line =~ /$str/;    # this needs use re 'eval'

$pat = qr/$str/;    # this also needs use re 'eval'
$line =~ /$pat/;    # but this doesn't need use re 'eval'
```

The flags mode, `use re "/flags"`, enables default pattern modifiers for the match, substitution, and regular expression quoting operators in its lexical scope. For

instance, if you want all patterns in your file to use ASCII semantics for its character classes (`\d`, `\w`, and `\s`):

```
while (<>) {
    use re "/a";
    if (/\d/) {    # only 0 .. 9
        print "Found an ASCII digit: $_";
    }
}
```

Turning on one of the pattern modifiers that affects classic and POSIX character classes (`/adlu`) overrides any settings from the `locale` pragma or the `unicode_strings` feature.

To turn on multiline string mode so that `^` and `$` match near newlines, not just at the ends of the string (`/m`), `.` matches newline (`/s`), and extended patterns (`/x`), use:

```
use re "/msx";
```

Under `use re "debug"`, Perl emits debugging messages when compiling and when executing regular expressions. The output is the same as that obtained by running a "debugging Perl" (one compiled with `-DDEBUGGING` passed to the C compiler) and then executing your Perl program under Perl's `-Dr` command-line switch. Depending on how complicated your pattern is, the resulting output can be overwhelming. Calling `use re "debugcolor"` enables more colorful output that can be useful, provided your terminal understands color sequences. Set your `PERL_RE_TC` environment variable to a comma-separated list of relevant *termcap*(5) properties for highlighting. For more details, see Chapter 18.

To get more control of the debugging output, use the `Debug` (capital D) and a list of things to debug. `All` is equivalent to `use re "debug"`:

```
{
    use re qw(Debug All);      # just like "use re 'debug'"

    ...;
}
```

To get finer-grained control of the debugging, try other options. For example, the `COMPILE` option outputs only debugging statements related to pattern compilation:

```
{
    use re qw(Debug COMPILE);  # just like 'use re "debug"'

    ...;
}
```

Many other options are listed in the `re` documentation.

sigtrap

```
use sigtrap;
use sigtrap qw(stack-trace old-interface-signals);  # same thing

use sigtrap qw(BUS SEGV PIPE ABRT);
use sigtrap qw(die INT QUIT);
use sigtrap qw(die normal-signals);
use sigtrap qw(die untrapped normal-signals);
use sigtrap qw(die untrapped normal-signals
               stack-trace any error-signals);

use sigtrap "handler" => \&my_handler, "normal-signals";
use sigtrap qw(handler my_handler normal-signals stack-trace error-signals);
```

The `sigtrap` pragma installs some simple signal handlers on your behalf so that you don't have to worry about them. This is useful in situations where an untrapped signal would cause your program to misbehave, like when you have `END {}` blocks, object destructors, or other at-exit processing that needs to be run no matter how your program happens to terminate.

When your program dies of an uncaught signal, the program exits immediately without cleanup. If instead you catch and convert such signals into fatal exceptions, good things happen: all scopes are exited, their resources are relinquished, and any END blocks are processed.

The `sigtrap` pragma provides two simple signal handlers for your use. One gives a Perl stack trace, and the other throws an exception via `die`. Alternately, you can supply your own handler for the pragma to install. You may specify predefined sets of signals to trap; you can also supply your own explicit list of signals. The pragma can optionally install handlers for only those signals that have not been otherwise handled.

Arguments passed to `use sigtrap` are processed in order. When a user-supplied signal name or the name of one of `sigtrap`'s predefined signal lists is encountered, a handler is immediately installed. When an option is encountered, this affects only those handlers installed later in processing the argument list.

Signal Handlers

These options affect which handler will be used for signals installed later:

`stack-trace`
: This pragma-supplied handler outputs a Perl stack trace to `STDERR` and then tries to dump core. This is the default signal handler.

`die`
: This pragma-supplied handler calls `die` via `Carp::croak` with a message indicating the signal caught.

`handler` *YOURHANDLER*
: *YOURHANDLER* will be used as the handler for signals installed later. *YOURHANDLER* can be any value valid for assignment into `%SIG`. Remember that the proper functioning of many C library calls (particularly standard I/O calls) cannot be guaranteed within a signal handler. Worse, it's hard to guess which bits of C library code are called from which bits of Perl code. (On the other hand, many signals that `sigtrap` traps are pretty vile—they're gonna take you down anyway, so there's not much harm in *trying* to do something, now is there?)

Predefined Signal Lists

The `sigtrap` pragma has a few built-in lists of signals to trap:

`normal-signals`
: These are the signals a program might normally expect to encounter, which, by default, cause it to terminate. They are the `HUP`, `INT`, `PIPE`, and `TERM` signals.

`error-signals`
: These are the signals that usually reflect a serious problem with the Perl interpreter or with your program. They are the `ABRT`, `BUS`, `EMT`, `FPE`, `ILL`, `QUIT`, `SEGV`, `SYS`, and `TRAP` signals.

`old-interface-signals`
: These are the signals that were trapped by default under an older version of `sigtrap`'s interface. They are `ABRT`, `BUS`, `EMT`, `FPE`, `ILL`, `PIPE`, `QUIT`, `SEGV`, `SYS`, `TERM`, and `TRAP`. If no signals or signals lists are passed to `use sigtrap`, this list is used.

If your platform does not implement a particular signal named in the predefined lists, that signal name will be silently ignored. (The signal itself can't be ignored because it doesn't exist.)

Other Arguments to sigtrap

`untrapped`
: This token suppresses the installation of handlers for subsequently listed signals if they've already been trapped or ignored.

`any`
: This token installs handlers for all subsequently listed signals. This is the default behavior.

`signal`
: Any argument that looks like a signal name (that is, one matching the pattern `/^[A-Z][A-Z0-9]*$/`) requests `sigtrap` to handle that signal.

`number`
: A numeric argument that requires the version number of the `sigtrap` pragma to be at least *number*. This works just like most regular modules that have a `$VERSION` package variable:

```
% perl -Msigtrap -le 'print $sigtrap::VERSION'
1.02
```

Examples of sigtrap

Provide a stack trace for the old interface signals:

```
use sigtrap;
```

Same thing, but more explicitly:

```
use sigtrap qw(stack-trace old-interface-signals);
```

Provide a stack trace only on the four listed signals:

```
use sigtrap qw(BUS SEGV PIPE ABRT);
```

Die on an `INT` or a `QUIT` signal:

```
use sigtrap qw(die INT QUIT);
```

Die on any of `HUP`, `INT`, `PIPE`, or `TERM`:

```
use sigtrap qw(die normal-signals);
```

Die on `HUP`, `INT`, `PIPE`, or `TERM`—except don't change the behavior for signals that have already been trapped or ignored elsewhere in the program:

```
use sigtrap qw(die untrapped normal-signals);
```

Die on receipt of any currently untrapped `normal-signals`; additionally, provide a stack backtrace on receipt of any of the `error-signals`:

```
use sigtrap qw(die untrapped normal-signals
               stack-trace any error-signals);
```

Install the routine `my_handler` as the handler for the `normal-signals`:

```
use sigtrap "handler" => \&my_handler, "normal-signals";
```

Install `my_handler` as the handler for the `normal-signals`; provide a Perl stack backtrace on receipt of any of the `error-signals`:

```
use sigtrap qw(handler my_handler normal-signals
               stack-trace error-signals);
```

sort

Before v5.8, quicksort was the default algorithm for Perl's built-in `sort` function. The quicksort algorithm has at its worst quadratic behavior, and it doesn't necessarily preserve the order of elements that sort the same (so it's *unstable*). Perl v5.8 changed the default to a merge sort, which at its worst has *O(N log N)* behavior and preserves the order of equal elements (so it's *stable*).

The `sort` pragma lets you choose which algorithm to use. And in case the default might someday change from a mergesort, you can choose a `stable` sort without picking the particular algorithm:

```
use sort "stable";          # guarantee stability
use sort "_quicksort";      # use a quicksort algorithm
use sort "_mergesort";      # use a mergesort algorithm
use sort "defaults";        # revert to default behavior
no  sort "stable";          # stability not important

use sort "_qsort";          # alias for quicksort

my $current;
BEGIN {
   $current = sort::current();     # identify prevailing algorithm
}
```

strict

```
use strict;         # Install all three strictures.

use strict "vars";  # Variables must be predeclared
use strict "refs";  # Can't use symbolic references
use strict "subs";  # Bareword strings must be quoted

use strict;         # Install all...
no strict "vars";   # ...then renege on one

use v5.12;          # by default with v5.12.0 or later
```

This lexically scoped pragma changes some basic rules about what Perl considers to be legal code. Sometimes these restrictions seem too strict for casual programming, such as when you're just trying to whip up a five-line filter program. The larger your program, the stricter you need to be about it. If you declare a minimum version of perl with `use`, and that minimum version is v5.12 or later, you get strictures implicitly.

Currently, there are three possible things to be strict about: `subs`, `vars`, and `refs`. If no import list is supplied, all three restrictions are assumed.

strict "refs"

This generates a runtime error if you try to dereference a string instead of a reference, whether intentionally or otherwise.

See Chapter 8 for more about these.

```
use strict "refs";

$ref = \$foo;       # Store "real" (hard) reference
print $$ref;        # Dereferencing is ok

$ref = "foo";       # Store name of global (package) variable
print $$ref;        # WRONG, runtime error under strict refs
```

Symbolic references are suspect for various reasons. It's surprisingly easy for even well-meaning programmers to invoke them accidentally; `strict "refs"` guards against that. Unlike real references, symbolic references can refer only to package variables. They aren't reference counted. And there's often a better way to do what you're doing: instead of referencing a symbol in a global symbol table, use a hash as its own mini symbol table. It's more efficient, more readable, and less error prone.

Nevertheless, some sorts of valid manipulation really do require direct access to the package's global symbol table of variables and function names. For example, you might want to examine the `@EXPORT` list or the `@ISA` superclass of a given package whose name you don't know in advance. Or you might want to install a whole slew of function calls that are all aliases to the same closure. This is just what symbolic references are best at, but to use them while `use strict` is in effect, you must first undo the `refs` stricture:

```
# make a bunch of attribute accessors
for my $methname (qw/name rank serno/) {
    no strict "refs";
    *$methname = sub { $_[0]->{ __PACKAGE__ . $methname } };
}
```

strict "vars"

Under this stricture, a compile-time error is triggered if you try to access a variable that hasn't met at least one of the following criteria:

- Predefined by Perl itself, such as `@ARGV`, `%ENV`, and global punctuation variables like `$.` or `$_`.
- Declared with `our` (for a global) or `my` or `state` (for a lexical).
- Imported from another package. (The `vars` pragma fakes up an import, but use `our` instead.)

- Fully qualified using its package name and the double-colon package separator.

The `local` operator by itself isn't good enough to keep `use strict "vars"` happy because, despite its name, that operator doesn't change whether the named variable is globally visible. Instead, it gives the variable (or individual element of an array or hash) a new, temporary value for the duration of the block at runtime. You still need to use `our` to declare a global variable, or `my` or `state` to declare a lexical variable. You can, however, localize an `our`:

```
local our $law = "martial";
```

Globals predefined by Perl are exempt from these requirements. This applies to program-wide globals (those forced into package `main` like `@ARGV` or `$_`) and to per-package variables like `$a` and `$b`, which are normally used by the `sort` function. Per-package variables used by modules like `Exporter` must still be declared using `our`:

```
our @EXPORT_OK = qw(name rank serno);
```

strict "subs"

This stricture makes Perl treat all barewords as syntax errors. A *bareword* ("bearword" in ursine dialects) is any bare name or identifier that has no other interpretation forced by context. (Context is often forced by a nearby keyword or token, or by predeclaration of the word in question.) Historically, barewords were interpreted as unquoted strings. This stricture outlaws that interpretation. If you mean to use it as a string, quote it. If you mean to use it as a function call, predeclare it or use parentheses.

As a particular case of forced context, remember that a bareword that appears by itself in curly braces or on the lefthand side of the `=>` operator counts as being quoted, and so is not subject to this restriction.

```
use strict "subs";

$x = whatever;      # WRONG: bareword error!
$x = whatever();    # This always works, though.

sub whatever;       # Predeclare function.
$x = whatever;      # Now it's ok.

# These uses are permitted, because the => quotes:
%hash = (red => 1, blue => 2, green => 3);

$rednum =  $hash{red};              # Ok, braces quote here
```

```
# But not this one:
@coolnums = @hash{blue, green};     # WRONG: bareword error
@coolnums = @hash{"blue", "green"}; # Ok, words now quoted
@coolnums = @hash{qw/blue green/};  # Likewise
```

subs

```
use subs qw/winken blinken nod/;
@x = winken 3..10;
@x = nod blinken @x;
```

This pragma predeclares as standard subroutines the names in the argument list. The advantage is that you may now use those functions without parentheses as list operators, just as if you'd declared them yourself. This is not necessarily as useful as full declarations, because it doesn't allow prototypes or attributes, such as:

```
sub winken(@);
sub blinken(\@) : locked;
sub nod($) : lvalue;
```

Because it is based on the standard import mechanism, the `use subs` pragma is not lexically scoped but package scoped. That is, the declarations are operative for the entire file in which they appear, but only in the current package. You may not rescind such declarations with `no subs`.

threads

Perl has used a couple of different threading models in its time. There were the old v5.005 threads through the `Threads` module, but those were removed in v5.10. The second way, introduced in v5.8, are "interpreter threads" (or "ithreads") that give each new thread its own Perl interpreter. If you know about threads from some other language, forget all that for Perl's threads because they are the same in name only.

To use `threads`, you need a *perl* compiled with threads support. You can check the output of `perl -V` and look for something like `USE_ITHREADS` in the compile-time options. You can also check the `Config` module, which lets you inspect the compile-time options inside your program:

```
use Config;
$Config{useithreads}
or die("Recompile Perl with threads to run this program.");
```

Many perls distributed with operating systems have a thread-enabled Perl already since it's easier to turn it on for everyone than have it off for everyone, making a

few people complain (which means you might squeeze extra performance out of your Perl binary by recompiling it without thread support).

Here's a short example that starts some threads, detaches them, and starts a final thread and joins it. The program doesn't wait for the detached threads to finish, but it will wait for the joined thread to complete. You can create threads with a code reference or a subroutine name, or using the `async` function from `threads`:

```
#!/usr/bin/perl
use v5.10;

use Config;
$Config{useithreads}        || die "You need thread support to run this";

use threads;

threads->create(sub {
    my $id = threads->tid;
    foreach (0 .. 10) {
        sleep rand 5;
        say "Meow from cat $id ($_)";
    }
})->detach;

for (0 .. 4) {
    my $t = async {
        my $id = threads->tid;
        foreach (0 .. 10) {
            sleep rand 5;
            say "Bow wow from dog $id ($_)";
        }
    };
    $t->detach;
    return $t;
};

threads->create("bird")->join;
sub bird {
    my $id = threads->tid;
    for (0 .. 10) {
        sleep rand 5;
        say "Chirp from bird $id ($_)";
    }
}
```

You can read more about threads in *perlthrtut*, the Perl thread tutorial. Perl has a way to share variables among threads with `thread::shared` and a way to set up a shared queue with the `Threads::Queue` module.

utf8

```
use utf8;
```

The `utf8` pragma declares that the Perl source for the rest of the lexical scope is encoded as UTF-8. This lets you use Unicode string literals and identifiers.

```
use utf8;
my $résumé_name = "Björk Guðmundsdóttir";
{
    no utf8;
    my $mojibake = '文字化け';  # probably erroneous
}
```

There are other features that the `utf8` provides, but they are deprecated in favor of the `Encode` module.

Note that as of v5.14, the compiler does not normalize identifiers, so you can't tell the difference between different ways to form the same glyphs (using composed or decomposed characters). See Chapter 6 for details on normalization. We recommend that you normalize all of your Perl identifiers into NFC (or NFKC) to avoid situations where you have two different variables that look the same.

vars

```
use vars qw($frobbed @munge %seen);
```

This pragma, once used to declare a global variable, is now unofficially deprecated in favor of the `our` modifier. The previous declaration is better accomplished using:

```
our($frobbed, @munge, %seen);
```

or even:

```
our $frobbed = "F";
our @munge = "A" .. $frobbed;
our %seen = ();
```

No matter which of these you use, remember that they're talking about package globals, not file-scoped lexicals.

version

```
use version 0.77;

my $version = version->parse($version_string);
my $qversion = qv($other_version_string);
```

```
if ($version > $qversion) {
    say "Version is greater!";
}
```

The `version` module isn't really a pragma, but it looks like one since its name is all lowercase. Before v5.10, `version` provided a way to quote version with `qv()` and compare version numbers. It sounds simple, but when you get down to the hairy task it actually is, you might doubt your commitment to programming. For instance, how do you order the versions 1.02, 1.2, and v1.2.0? Now Perl can do that internally. It's still a mess, though.[3]

vmsish

```
use vmsish;        # all features

use vmsish "exit";
use vmsish "hushed";
use vmsish "status";
use vmsish "time";

no vmsish "hushed";
vmsish::hushed($hush);

use vmsish;        # all features
no vmsish "time";  # but turn off 'time'
```

The `vmsish` pragma controls various features of Perl on VMS so your program acts less like a Unix program and more like a VMS program. These features are lexically scoped, so you can enable and disable them as you need them.

exit

Under `exit`, using `exit 1` and `exit 0` both map to `SS$_NORMAL`, indicating a successful exit. Under Unix emulation, `exit 1` indicates an error.

hushed

Under `hushed`, a Perl program run from DCL does not print messages to `SYS$OUTPUT` or `SYS$ERROR` on an unsuccessful exit. This does not suppress any messages from the Perl program itself. This affects only the `exit` and `die` statements in its lexical scope, and only those that Perl compiles after it encounters this pragma.

3. You might like David Golden's "Version numbers should be boring".

status

Under `status`, the `system` return value and the value of `$?` use the VMS exit status rather than emulate the POSIX exit status.

time

With this feature, all times are relative to the local time zone instead of the default Universal Time.

warnings

```
use warnings;   # same as importing "all"
no warnings;    # same as unimporting "all"

use warnings::register;
if (warnings::enabled()) {
    warnings::warn("some warning");
}

if (warnings::enabled("void")) {
    warnings::warn("void", "some warning");
}

warnings::warnif("Warnings are on");
warnings::warnif("number", "Something is wrong with a number");
```

This lexically scoped pragma permits flexible control over Perl's built-in warnings, both those emitted by the compiler as well as those from the runtime system.

Once upon a time, the only control you had in Perl over the treatment of warnings in your program was through either the *–w* command-line option or the `$^W` variable. Although useful, these tend to be all-or-nothing affairs. The *–w* option ends up enabling warnings in pieces of module code that you may not have written, which is occasionally problematic for you and embarrassing for the original author. Using `$^W` to either disable or enable blocks of code can be less than optimal because it works only during execution time, not during compile time.[4] Another issue is that this program-wide global variable is scoped dynamically, not lexically. That means that if you enable it in a block and then from there call other code, you again risk enabling warnings in code not developed with such exacting standards in mind.

4. In the absence of `BEGIN` blocks, of course.

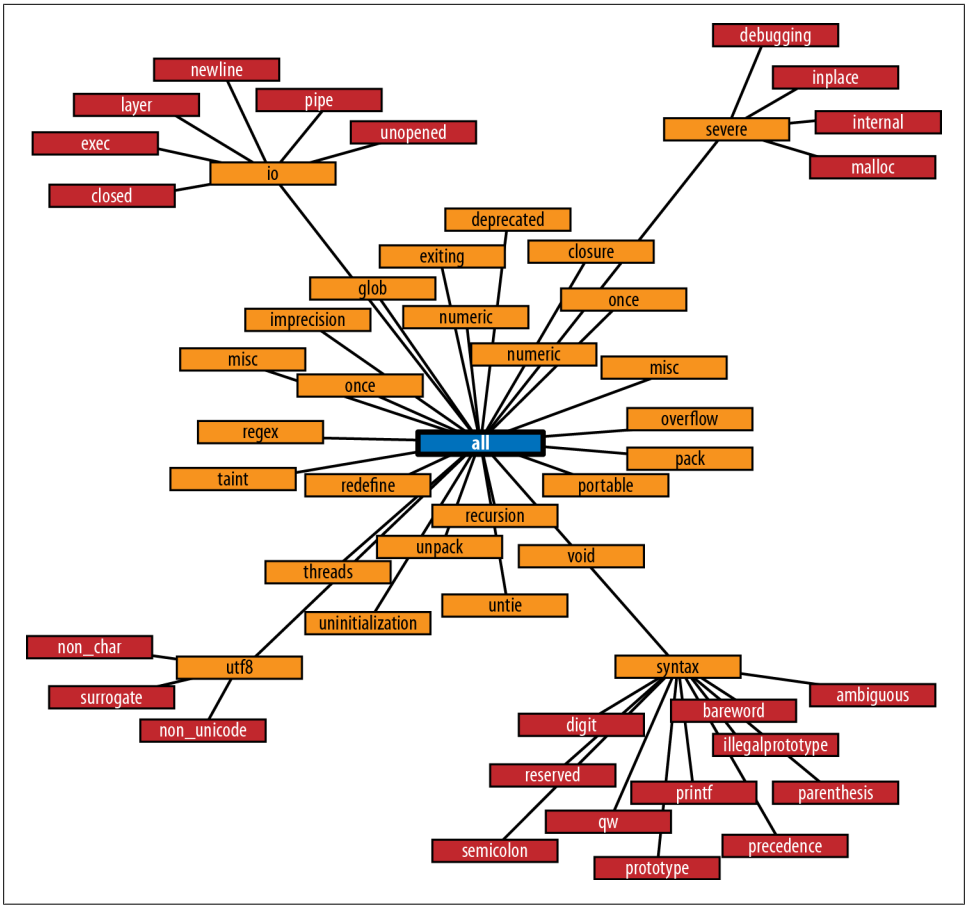


Figure 29-1. Perl's warning categories

The `warnings` pragma circumvents these limitations by being a lexically scoped, compile-time mechanism that permits finer control over where warnings can or can't be triggered. A hierarchy of warning categories (see Figure 29-1) has been defined to allow groups of warnings to be enabled or disabled in isolation from one another. (The exact categorization is experimental and subject to change.) These categories can be combined by passing multiple arguments to `use` or `no`:

```
use warnings qw(void redefine);
no  warnings qw(io syntax untie);
```

If multiple instances of the `warnings` pragma are active for a given scope, their effects are cumulative:

```
use warnings "void"; # Only "void" warnings enabled.
...
use warnings "io";   # Both "void" and "io" warnings now enabled
```

```
...
no warnings "void";  # Only "io" warnings now enabled
```

To make fatal errors of all warnings enabled by a particular `warnings` pragma, use the word `FATAL` at the front of the import list. This is useful when you would prefer a certain condition that normally causes only a warning to abort your program. Suppose, for example, that you considered it so improper to use an invalid string as a number (which normally produces a value of 0) that you want this brazen act to kill your program. While you're at it, you decide that using uninitialized values in places where real string or numeric values are expected should also be cause for immediate suicide:

```
{
    use warnings FATAL => qw(numeric uninitialized);
    $x = $y + $z;
}
```

Now if either `$y` or `$z` is uninitialized (that is, holds the special scalar value, `undef`), or if either contains a string that doesn't cleanly convert into a numeric value, your program will become suicidal; that is, instead of going merrily on its way, or at most issuing a small complaint if you had warnings enabled, your program will now raise an exception. (Think of this as Perl running in Python mode.) If you aren't trapping exceptions, that makes it a fatal error. The exception text is the same as would normally appear in the warning message.

Fatalizing all warnings at the top of your program with:

```
use warnings FATAL => "all";
```

doesn't work very well, because it doesn't distinguish between compile-time warnings and runtime warnings. The first message from the compiler is often not the one you need to see, but with compile-time fatalized warnings, it's the one you'll want to see. A better approach is to delay making them fatal until runtime.

```
use Carp qw(carp croak confess cluck);
use warnings;   # compile-time warnings

# at runtime, before you do anything else
$SIG{__WARN__} = sub { confess "FATALIZED WARNING: @_" };
```

An alternate application of this idea is to use `cluck` instead of `confess`. That way you still get a stack dump, but your program continues. This can be helpful in figuring the code path that leads to a warning. See the explanation of the `%SIG` hash in `28` for other related examples.

The `warnings` pragma ignores the *–w* command-line switch and the value of the `$^W` variable; the pragma's settings take precedence. However, the *–W* command-line flag overrides the pragma, enabling full warnings in all code within your

program, even code loaded with `do`, `require`, or `use`. In other words, with *–W*, Perl pretends that every block in your program has a `use warnings "all"` pragma. Think of it as a *lint*(1) for Perl programs. (But see also the online documentation for the `B::Lint` module.) The *–X* command-line flag works the other way around. It pretends that every block has `no warnings "all"` in effect.

Several functions are provided to help module authors make their module's functions behave like built-in functions with respect to the lexical scoping of the caller (that is, so that users of the module can lexically enable or disable warnings the module might issue):

`warnings::register`
: Registers the current module name as a new category of warnings, so users of your module can turn off its warnings.

`warnings::enabled(`*`CATEGORY`*`)`
: Returns true if the warnings category *`CATEGORY`* is enabled in the lexical scope of the calling module. Otherwise, it returns false. If *`CATEGORY`* is not supplied, the current package name is used.

`warnings::warn(`*`CATEGORY, MESSAGE`*`)`
: If the calling module has *not* set *`CATEGORY`* to `FATAL`, prints *`MESSAGE`* to `STDERR`. If the calling module has set *`CATEGORY`* to `FATAL`, prints *`MESSAGE`* to `STDERR`, then dies. If *`CATEGORY`* is not supplied, the current package name is used.

`warnings::warnif(`*`CATEGORY, MESSAGE`*`)`
: Like `warnings::warn`, but only if *`CATEGORY`* is enabled.

User-Defined Pragmas

Perl v5.10 added a way to easily create your own lexically scoped pragmata. The `%^H` hash contains information other code can inspect to get hints about what you'd like to do, and `caller` has a reference to the version of that hash in effect for the level you request:

```
my $hints = ( caller(1) )[10];
```

This is a simple hash with simple values. Without getting into the gory details, this hash may be shared between threads so the internals store it in a compact form that precludes any values other than integers, strings, and undef. That's okay, because you really only need it to denote whether your pragma's feature is on or off. This hash is also lexically scoped, so each lexical scope gets its own version.

To create your own pragma, define the three subroutines `import`, `unimport`, and `in_effect`. The first two are invoked implicitly by `use` and `no`. Typically, `use` turns on a feature by calling `import`, while `no` turns off that feature by calling `unimport`. Aside from any special processing you'd like, your `import` and `unimport` set a flag in `%H`. Outside your pragma, other code can call `in_effect` to find out whether your pragma is enabled, which you'll handle by looking in `%H` for the value you set.

There are no rules on what you can put in `%H`, but remember that other pragmas also use this hash for their own work, so choose a key other code is unlikely to use, such as your package name.

Here's a short pragma that replaces the built-in `sqrt` function with one that can handle negative numbers (crudely). A `use complex` calls an `import` method, which sets the `complex` key in `%^H` to 1 and creates a subroutine called `sqrt` that uses the same definition as `complex::complex_sqrt`. The `complex_sqrt` uses `in_effect` to see whether it should use a negative number. If so, it takes the square root of the absolute value and, if the square is less than 0, appends "`i`" to the result:

```
use utf8;
use v5.10;

package complex;
use strict;
use warnings;
use Carp;

sub complex_sqrt {
    my $number = shift;
    if (complex::in_effect()) {
        my $root = CORE::sqrt(abs($number));
        $root .= "i" if $number < 0;
        return $root;
    }
    else {
        croak("Can't take sqrt of $number") if $number < 0;
        CORE::sqrt($number)
    }
}

sub import {
    $^H{complex} = 1;
    my($package) = (caller(1))[0];
    no strict "refs";
    *{ "${package}::sqrt" } = \&complex::complex_sqrt;
}

sub unimport {
```

```
    $^H{complex} = 0;
}

sub in_effect {
    my $hints = (caller(1))[10];
    return $hints->{complex};
}

1;
```

Now parts of your program can create imaginary numbers:

```
use utf8;
use v5.10;
use complex;

say "1. √-25 is " => sqrt(-25);
say "2. √36 is "  => sqrt( 36);

eval {
    no complex;

    say "3. √-25 is " => sqrt(-25);
    say "4. √36 is "  => sqrt( 36);
} or say "Error: $@";
```

A `no complex` unsets `$^H{complex}`, disallowing negative arguments to `complex` for the rest of the scope. The `%^H` hash is lexically scoped, so its previous value is restored on scope exit. Inside the `eval`, the `no complex` turns off the special handling, so `sqrt(-25)` causes an error:

```
1. √-25 is 5i
2. √36 is 6
Error: Can't take sqrt of -25 at sqrt.pl line 10
```

Although this is a toy example, using and returning `Math::Complex` would do a better job, even if you use it directly instead of hiding it behind a pragma.

Glossary

When we italicize a word or phrase in here, it usually means you can find it defined elsewhere in the glossary. Think of them as hyperlinks.

accessor methods
A *method* used to indirectly inspect or update an *object*'s state (its *instance variables*).

actual arguments
The *scalar values* that you supply to a *function* or *subroutine* when you call it. For instance, when you call `power("puff")`, the string `"puff"` is the actual argument. See also *argument* and *formal arguments*.

address operator
Some languages work directly with the memory addresses of values, but this can be like playing with fire. Perl provides a set of asbestos gloves for handling all memory management. The closest to an address operator in Perl is the backslash operator, but it gives you a *hard reference*, which is much safer than a memory address.

algorithm
A well-defined sequence of steps, explained clearly enough that even a computer could do them.

alias
A nickname for something, which behaves in all ways as though you'd used the original name instead of the nickname. Temporary aliases are implicitly created in the loop variable for `foreach` loops, in the `$_` variable for `map` or `grep` operators, in `$a` and `$b` during `sort`'s comparison function, and in each element of `@_` for the *actual arguments* of a subroutine call. Permanent aliases are explicitly created in *packages* by *importing* symbols or by assignment to *typeglobs*. Lexically scoped aliases for package variables are explicitly created by the `our` declaration.

alphabetic
The sort of characters we put into words. In Unicode, this is all letters including all ideographs and certain diacritics, letter numbers like Roman numerals, and various combining marks.

alternatives
A list of possible choices from which you may select only one, as in, "Would you like door A, B, or C?" Alternatives in regular expressions are separated with a single vertical bar: `|`. Alternatives in normal Perl expressions are separated with a double vertical bar: `||`. Logical alternatives in *Boolean* expressions are separated with either `||` or `or`.

anonymous
Used to describe a *referent* that is not directly accessible through a named *variable*. Such a referent must be indirectly accessible through at least one *hard reference*. When the last hard reference goes away, the anonymous referent is destroyed without pity.

application
: A bigger, fancier sort of *program* with a fancier name so people don't realize they are using a program.

architecture
: The kind of computer you're working on, where one "kind" of computer means all those computers sharing a compatible machine language. Since Perl programs are (typically) simple text files, not executable images, a Perl program is much less sensitive to the architecture it's running on than programs in other languages, such as C, that are *compiled* into machine code. See also *platform* and *operating system*.

argument
: A piece of data supplied to a *program*, *subroutine*, *function*, or *method* to tell it what it's supposed to do. Also called a "parameter".

ARGV
: The name of the array containing the *argument vector* from the command line. If you use the empty `<>` operator, `ARGV` is the name of both the *filehandle* used to traverse the arguments and the *scalar* containing the name of the current input file.

arithmetical operator
: A *symbol* such as `+` or `/` that tells Perl to do the arithmetic you were supposed to learn in grade school.

array
: An ordered sequence of *values*, stored such that you can easily access any of the values using an *integer* ***subscript*** that specifies the value's *offset* in the sequence.

array context
: An archaic expression for what is more correctly referred to as *list context*.

Artistic License
: The open source license that Larry Wall created for Perl, maximizing Perl's usefulness, availability, and modifiability. The current version is 2.0 (*http://www.opensource.org/licenses/artistic-license.php*).

ASCII
: The American Standard Code for Information Interchange (a 7-bit character set adequate only for poorly representing English text). Often used loosely to describe the lowest 128 values of the various ISO-8859-X character sets, a bunch of mutually incompatible 8-bit codes best described as half ASCII. See also *Unicode*.

assertion
: A component of a *regular expression* that must be true for the pattern to match but does not necessarily match any characters itself. Often used specifically to mean a *zero-width* assertion.

assignment
: An *operator* whose assigned mission in life is to change the value of a *variable*.

assignment operator
: Either a regular *assignment* or a compound *operator* composed of an ordinary assignment and some other operator, that changes the value of a variable in place; that is, relative to its old value. For example, `$a += 2` adds `2` to `$a`.

associative array
: See *hash*. Please. The term associative array is the old Perl 4 term for a *hash*. Some languages call it a dictionary.

associativity
: Determines whether you do the left *operator* first or the right *operator* first when you have "A *operator* B *operator* C", and the two operators are of the same precedence. Operators like `+` are left associative, while operators like `**` are right associative. See Chapter 3 for a list of operators and their associativity.

asynchronous
: Said of events or activities whose relative temporal ordering is indeterminate because too many things are going on at once. Hence, an asynchronous event is one you didn't know when to expect.

atom

A *regular expression* component potentially matching a *substring* containing one or more characters and treated as an indivisible syntactic unit by any following *quantifier*. (Contrast with an *assertion* that matches something of *zero width* and may not be quantified.)

atomic operation

When Democritus gave the word "atom" to the indivisible bits of matter, he meant literally something that could not be cut: *ἀ-* (not) + *-τομος* (cuttable). An atomic operation is an action that can't be interrupted, not one forbidden in a nuclear-free zone.

attribute

A new feature that allows the declaration of *variables* and *subroutines* with modifiers, as in `sub foo : locked method`. Also another name for an *instance variable* of an *object*.

autogeneration

A feature of *operator overloading* of *objects*, whereby the behavior of certain *operators* can be reasonably deduced using more fundamental operators. This assumes that the overloaded operators will often have the same relationships as the regular operators. See Chapter 13.

autoincrement

To add one to something automatically, hence the name of the `++` operator. To instead subtract one from something automatically is known as an "autodecrement".

autoload

To load on demand. (Also called "lazy" loading.) Specifically, to call an `AUTOLOAD` subroutine on behalf of an undefined subroutine.

autosplit

To split a string automatically, as the `-a` *switch* does when running under `-p` or `-n` in order to emulate *awk*. (See also the `AutoSplit` module, which has nothing to do with the `-a` switch but a lot to do with autoloading.)

autovivification

A Graeco-Roman word meaning "to bring oneself to life". In Perl, storage locations (*lvalues*) spontaneously generate themselves as needed, including the creation of any *hard reference* values to point to the next level of storage. The assignment `$a[5][5][5][5][5] = "quintet"` potentially creates five scalar storage locations, plus four references (in the first four scalar locations) pointing to four new anonymous arrays (to hold the last four scalar locations). But the point of autovivification is that you don't have to worry about it.

AV

Short for "array value", which refers to one of Perl's internal data types that holds an *array*. The `AV` type is a subclass of *SV*.

awk

Descriptive editing term—short for "awkward". Also coincidentally refers to a venerable text-processing language from which Perl derived some of its high-level ideas.

backreference

A substring *captured* by a subpattern within unadorned parentheses in a *regex*. Backslashed decimal numbers (`\1`, `\2`, etc.) later in the same pattern refer back to the corresponding subpattern in the current match. Outside the pattern, the numbered variables (`$1`, `$2`, etc.) continue to refer to these same values, as long as the pattern was the last successful match of the current *dynamic scope*.

backtracking

The practice of saying, "If I had to do it all over, I'd do it differently," and then actually going back and doing it all over differently. Mathematically speaking, it's returning from an unsuccessful recursion on a tree of possibilities. Perl backtracks when it attempts to match patterns with a *regular expression*, and its earlier attempts don't pan out. See the section "The Little Engine That /Could(n't)?/" on page 241 in Chapter 5.

backward compatibility
: Means you can still run your old program because we didn't break any of the features or bugs it was relying on.

bareword
: A word sufficiently ambiguous to be deemed illegal under `use strict 'subs'`. In the absence of that stricture, a bareword is treated as if quotes were around it.

base class
: A generic *object* type; that is, a *class* from which other, more specific classes are derived genetically by *inheritance*. Also called a "superclass" by people who respect their ancestors.

big-endian
: From Swift: someone who eats eggs big end first. Also used of computers that store the most significant *byte* of a word at a lower byte address than the least significant byte. Often considered superior to little-endian machines. See also *little-endian*.

binary
: Having to do with numbers represented in base 2. That means there's basically two numbers: 0 and 1. Also used to describe a file of "nontext", presumably because such a file makes full use of all the binary bits in its bytes. With the advent of *Unicode*, this distinction, already suspect, loses even more of its meaning.

binary operator
: An *operator* that takes two *operands*.

bind
: To assign a specific *network address* to a *socket*.

bit
: An integer in the range from 0 to 1, inclusive. The smallest possible unit of information storage. An eighth of a *byte* or of a dollar. (The term "Pieces of Eight" comes from being able to split the old Spanish dollar into 8 bits, each of which still counted for money. That's why a 25-cent piece today is still "two bits".)

bit shift
: The movement of bits left or right in a computer word, which has the effect of multiplying or dividing by a power of 2.

bit string
: A sequence of *bits* that is actually being thought of as a sequence of bits, for once.

bless
: In corporate life, to grant official approval to a thing, as in, "The VP of Engineering has blessed our WebCruncher project." Similarly, in Perl, to grant official approval to a *referent* so that it can function as an *object*, such as a WebCruncher object. See the `bless` function in Chapter 27.

block
: What a *process* does when it has to wait for something: "My process blocked waiting for the disk." As an unrelated noun, it refers to a large chunk of data, of a size that the *operating system* likes to deal with (normally a power of 2 such as 512 or 8192). Typically refers to a chunk of data that's coming from or going to a disk file.

BLOCK
: A syntactic construct consisting of a sequence of Perl *statements* that is delimited by braces. The `if` and `while` statements are defined in terms of ***BLOCK***s, for instance. Sometimes we also say "block" to mean a lexical scope; that is, a sequence of statements that acts like a ***BLOCK***, such as within an `eval` or a file, even though the statements aren't delimited by braces.

block buffering
: A method of making input and output efficient by passing one *block* at a time. By default, Perl does block buffering to disk files. See *buffer* and *command buffering*.

Boolean
: A value that is either *true* or *false*.

Boolean context
: A special kind of *scalar context* used in conditionals to decide whether the *scalar value* returned by an expression is *true* or *false*. Does not evaluate as either a string or a number. See *context*.

breakpoint
: A spot in your program where you've told the debugger to stop *execution* so you can poke around and see whether anything is wrong yet.

broadcast
: To send a *datagram* to multiple destinations simultaneously.

BSD
: A psychoactive drug, popular in the '80s, probably developed at UC Berkeley or thereabouts. Similar in many ways to the prescription-only medication called "System V", but infinitely more useful. (Or, at least, more fun.) The full chemical name is "Berkeley Standard Distribution".

bucket
: A location in a *hash table* containing (potentially) multiple entries whose keys "hash" to the same hash value according to its hash function. (As internal policy, you don't have to worry about it unless you're into internals, or policy.)

buffer
: A temporary holding location for data. Data that are *Block buffering* means that the data is passed on to its destination whenever the buffer is full. *Line buffering* means that it's passed on whenever a complete line is received. *Command buffering* means that it's passed every time you do a `print` command (or equivalent). If your output is unbuffered, the system processes it one byte at a time without the use of a holding area. This can be rather inefficient.

built-in
: A *function* that is predefined in the language. Even when hidden by *overriding*, you can always get at a built-in function by *qualifying* its name with the `CORE::` pseudopackage.

bundle
: A group of related modules on *CPAN*. (Also sometimes refers to a group of command-line switches grouped into one *switch cluster*.)

byte
: A piece of data worth eight *bits* in most places.

bytecode
: A pidgin-like lingo spoken among 'droids when they don't wish to reveal their orientation (see *endian*). Named after some similar languages spoken (for similar reasons) between compilers and interpreters in the late 20th century. These languages are characterized by representing everything as a nonarchitecture-dependent sequence of bytes.

C
: A language beloved by many for its inside-out *type* definitions, inscrutable *precedence* rules, and heavy *overloading* of the function-call mechanism. (Well, actually, people first switched to C because they found lowercase identifiers easier to read than upper.) Perl is written in C, so it's not surprising that Perl borrowed a few ideas from it.

cache
: A data repository. Instead of computing expensive answers several times, compute it once and save the result.

callback
: A *handler* that you register with some other part of your program in the hope that the other part of your program will *trigger* your handler when some event of interest transpires.

call by reference
: An *argument*-passing mechanism in which the *formal arguments* refer directly to the *actual arguments*, and the *subroutine* can change the actual arguments by changing

the formal arguments. That is, the formal argument is an *alias* for the actual argument. See also *call by value*.

call by value
An *argument*-passing mechanism in which the *formal arguments* refer to a copy of the *actual arguments*, and the *subroutine* cannot change the actual arguments by changing the formal arguments. See also *call by reference*.

canonical
Reduced to a standard form to facilitate comparison.

capture variables
The variables—such as `$1` and `$2`, and `%+` and `%-`—that hold the text remembered in a pattern match. See Chapter 5.

capturing
The use of parentheses around a *subpattern* in a *regular expression* to store the matched *substring* as a *backreference*. (Captured strings are also returned as a list in *list context*.) See Chapter 5.

cargo cult
Copying and pasting code without understanding it, while superstitiously believing in its value. This term originated from preindustrial cultures dealing with the detritus of explorers and colonizers of technologically advanced cultures. See *The Gods Must Be Crazy*.

case
A property of certain characters. Originally, typesetter stored capital letters in the upper of two cases and small letters in the lower one. Unicode recognizes three cases: *lowercase* (*character property* `\p{lower}`), *titlecase* (`\p{title}`), and *uppercase* (`\p{upper}`). A fourth casemapping called *foldcase* is not itself a distinct case, but it is used internally to implement *casefolding*. Not all letters have case, and some nonletters have case.

casefolding
Comparing or matching a string case-insensitively. In Perl, it is implemented with the `/i` pattern modifier, the `fc` function, and the `\F` double-quote translation escape.

casemapping
The process of converting a string to one of the four Unicode *casemaps*; in Perl, it is implemented with the `fc`, `lc`, `ucfirst`, and `uc` functions.

character
The smallest individual element of a string. Computers store characters as integers, but Perl lets you operate on them as text. The integer used to represent a particular character is called that character's *codepoint*.

character class
A square-bracketed list of characters used in a *regular expression* to indicate that any character of the set may occur at a given point. Loosely, any predefined set of characters so used.

character property
A predefined *character class* matchable by the `\p` or `\P` *metasymbol*. *Unicode* defines hundreds of standard properties for every possible codepoint, and Perl defines a few of its own, too.

circumfix operator
An *operator* that surrounds its *operand*, like the angle operator, or parentheses, or a hug.

class
A user-defined *type*, implemented in Perl via a *package* that provides (either directly or by inheritance) *methods* (that is, *subroutines*) to handle *instances* of the class (its *objects*). See also *inheritance*.

class method
A *method* whose *invocant* is a *package* name, not an *object* reference. A method associated with the class as a whole. Also see *instance method*.

client
: In networking, a *process* that initiates contact with a *server* process in order to exchange data and perhaps receive a service.

closure
: An *anonymous* subroutine that, when a reference to it is generated at runtime, keeps track of the identities of externally visible *lexical variables*, even after those lexical variables have supposedly gone out of *scope*. They're called "closures" because this sort of behavior gives mathematicians a sense of closure.

cluster
: A parenthesized *subpattern* used to group parts of a *regular expression* into a single *atom*.

CODE
: The word returned by the `ref` function when you apply it to a reference to a subroutine. See also *CV*.

code generator
: A system that writes code for you in a low-level language, such as code to implement the backend of a compiler. See *program generator*.

codepoint
: The integer a computer uses to represent a given character. ASCII codepoints are in the range 0 to 127; Unicode codepoints are in the range 0 to 0x1F_FFFF; and Perl codepoints are in the range 0 to $2^{32}-1$ or 0 to $2^{64}-1$, depending on your native integer size. In Perl Culture, sometimes called *ordinals*.

code subpattern
: A *regular expression* subpattern whose real purpose is to execute some Perl code—for example, the `(?{...})` and `(??{...})` subpatterns.

collating sequence
: The order into which *characters* sort. This is used by *string* comparison routines to decide, for example, where in this glossary to put "collating sequence".

co-maintainer
: A person with permissions to index a *namespace* in *PAUSE*. Anyone can upload any namespace, but only primary and co-maintainers get their contributions indexed.

combining character
: Any character with the General Category of Combining Mark (`\p{GC=M}`), which may be spacing or nonspacing. Some are even invisible. A sequence of combining characters following a grapheme base character together make up a single user-visible character called a *grapheme*. Most but not all diacritics are combining characters, and vice versa.

command
: In *shell* programming, the syntactic combination of a program name and its arguments. More loosely, anything you type to a shell (a command interpreter) that starts it doing something. Even more loosely, a Perl *statement*, which might start with a *label* and typically ends with a semicolon.

command buffering
: A mechanism in Perl that lets you store up the output of each Perl *command* and then flush it out as a single request to the *operating system*. It's enabled by setting the `$|` (`$AUTOFLUSH`) variable to a true value. It's used when you don't want data sitting around, not going where it's supposed to, which may happen because the default on a *file* or *pipe* is to use *block buffering*.

command-line arguments
: The *values* you supply along with a program name when you tell a *shell* to execute a *command*. These values are passed to a Perl program through `@ARGV`.

command name
: The name of the program currently executing, as typed on the command line. In C, the *command* name is passed to the program as the first command-line argument. In Perl, it comes in separately as `$0`.

comment
A remark that doesn't affect the meaning of the program. In Perl, a comment is introduced by a `#` character and continues to the end of the line.

compilation unit
The *file* (or *string*, in the case of `eval`) that is currently being *compiled*.

compile
The process of turning source code into a machine-usable form. See *compile phase*.

compile phase
Any time before Perl starts running your main program. See also *run phase*. Compile phase is mostly spent in *compile time*, but may also be spent in *runtime* when `BEGIN` blocks, `use` declarations, or constant subexpressions are being evaluated. The startup and import code of any `use` declaration is also run during compile phase.

compiler
Strictly speaking, a program that munches up another program and spits out yet another file containing the program in a "more executable" form, typically containing native machine instructions. The *perl* program is not a compiler by this definition, but it does contain a kind of compiler that takes a program and turns it into a more executable form (*syntax trees*) within the *perl* process itself, which the *interpreter* then interprets. There are, however, extension *modules* to get Perl to act more like a "real" compiler. See Chapter 16.

compile time
The time when Perl is trying to make sense of your code, as opposed to when it thinks it knows what your code means and is merely trying to do what it thinks your code says to do, which is *runtime*.

composer
A "constructor" for a *referent* that isn't really an *object*, like an anonymous array or a hash (or a sonata, for that matter). For example, a pair of braces acts as a composer for a hash, and a pair of brackets acts as a composer for an array. See the section "Creating References" on page 342 in Chapter 8.

concatenation
The process of gluing one cat's nose to another cat's tail. Also a similar operation on two *strings*.

conditional
Something "iffy". See *Boolean context*.

connection
In telephony, the temporary electrical circuit between the caller's and the callee's phone. In networking, the same kind of temporary circuit between a *client* and a *server*.

construct
As a noun, a piece of syntax made up of smaller pieces. As a transitive verb, to create an *object* using a *constructor*.

constructor
Any *class method*, *instance method*, or *subroutine* that composes, initializes, blesses, and returns an *object*. Sometimes we use the term loosely to mean a *composer*.

context
The surroundings or environment. The context given by the surrounding code determines what kind of data a particular *expression* is expected to return. The three primary contexts are *list context*, *scalar context*, and *void context*. Scalar context is sometimes subdivided into *Boolean context*, *numeric context*, *string context*, and *void context*. There's also a "don't care" context (which is dealt with in Chapter 2, if you care).

continuation
The treatment of more than one physical *line* as a single logical line. *Makefile* lines are continued by putting a backslash before the *newline*. Mail headers, as defined by RFC 822, are continued by putting a space or tab *after* the newline. In general, lines in Perl do not need any form of continuation mark, because *whitespace* (including newlines) is gleefully ignored. Usually.

core dump
: The corpse of a *process*, in the form of a file left in the *working directory* of the process, usually as a result of certain kinds of fatal errors.

CPAN
: The Comprehensive Perl Archive Network. (See the Preface and Chapter 19 for details.)

C preprocessor
: The typical C compiler's first pass, which processes lines beginning with `#` for conditional compilation and macro definition, and does various manipulations of the program text based on the current definitions. Also known as *cpp*(1).

cracker
: Someone who breaks security on computer systems. A cracker may be a true *hacker* or only a *script kiddie*.

currently selected output channel
: The last *filehandle* that was designated with `select(FILEHANDLE)`; `STDOUT`, if no filehandle has been selected.

current package
: The *package* in which the current statement is *compiled*. Scan backward in the text of your program through the current *lexical scope* or any enclosing lexical scopes until you find a package declaration. That's your current package name.

current working directory
: See *working directory*.

CV
: In academia, a curriculum vitæ, a fancy kind of résumé. In Perl, an internal "code value" typedef holding a *subroutine*. The `CV` type is a subclass of *SV*.

dangling statement
: A bare, single *statement*, without any braces, hanging off an `if` or `while` conditional. C allows them. Perl doesn't.

datagram
: A packet of data, such as a *UDP* message, that (from the viewpoint of the programs involved) can be sent independently over the network. (In fact, all packets are sent independently at the *IP* level, but *stream* protocols such as *TCP* hide this from your program.)

data structure
: How your various pieces of data relate to each other and what shape they make when you put them all together, as in a rectangular table or a triangular tree.

data type
: A set of possible values, together with all the operations that know how to deal with those values. For example, a numeric data type has a certain set of numbers that you can work with, as well as various mathematical operations that you can do on the numbers, but would make little sense on, say, a string such as `"Kilroy"`. Strings have their own operations, such as *concatenation*. Compound types made of a number of smaller pieces generally have operations to compose and decompose them, and perhaps to rearrange them. *Objects* that model things in the real world often have operations that correspond to real activities. For instance, if you model an elevator, your elevator object might have an `open_door` *method*.

DBM
: Stands for "Database Management" routines, a set of routines that emulate an *associative array* using disk files. The routines use a dynamic hashing scheme to locate any entry with only two disk accesses. DBM files allow a Perl program to keep a persistent *hash* across multiple invocations. You can `tie` your hash variables to various DBM implementations.

declaration
: An *assertion* that states something exists and perhaps describes what it's like, without giving any commitment as to how or where you'll use it. A declaration is like the part of

your recipe that says, "two cups flour, one large egg, four or five tadpoles..." See *statement* for its opposite. Note that some declarations also function as statements. Subroutine declarations also act as definitions if a body is supplied.

declarator
Something that tells your program what sort of variable you'd like. Perl doesn't require you to declare variables, but you can use `my`, `our`, or `state` to denote that you want something other than the default.

decrement
To subtract a value from a variable, as in "decrement `$x`" (meaning to remove 1 from its value) or "decrement `$x` by 3".

default
A *value* chosen for you if you don't supply a value of your own.

defined
Having a meaning. Perl thinks that some of the things people try to do are devoid of meaning; in particular, making use of variables that have never been given a *value* and performing certain operations on data that isn't there. For example, if you try to read data past the end of a file, Perl will hand you back an undefined value. See also *false* and the `defined` entry in Chapter 27.

delimiter
A *character* or *string* that sets bounds to an arbitrarily sized textual object, not to be confused with a *separator* or *terminator*. "To delimit" really just means "to surround" or "to enclose" (like these parentheses are doing).

dereference
A fancy computer science term meaning "to follow a *reference* to what it points to". The "de" part of it refers to the fact that you're taking away one level of *indirection*.

derived class
A *class* that defines some of its *methods* in terms of a more generic class, called a *base class*. Note that classes aren't classified exclusively into base classes or derived classes: a class can function as both a derived class and a base class simultaneously, which is kind of classy.

descriptor
See *file descriptor*.

destroy
To deallocate the memory of a *referent* (first triggering its `DESTROY` method, if it has one).

destructor
A special *method* that is called when an *object* is thinking about *destroying* itself. A Perl program's `DESTROY` method doesn't do the actual destruction; Perl just *triggers* the method in case the *class* wants to do any associated cleanup.

device
A whiz-bang hardware gizmo (like a disk or tape drive or a modem or a joystick or a mouse) attached to your computer, which the *operating system* tries to make look like a *file* (or a bunch of files). Under Unix, these fake files tend to live in the */dev* directory.

directive
A *pod* directive. See Chapter 23.

directory
A special file that contains other files. Some *operating systems* call these "folders", "drawers", "catalogues", or "catalogs".

directory handle
A name that represents a particular instance of opening a directory to read it, until you close it. See the `opendir` function.

discipline
Some people need this and some people avoid it. For Perl, it's an old way to say *I/O layer*.

dispatch
To send something to its correct destination. Often used metaphorically to indicate a transfer of programmatic control to a destination selected algorithmically, often by

lookup in a table of function *references* or, in the case of object *methods*, by traversing the inheritance tree looking for the most specific definition for the method.

distribution
: A standard, bundled release of a system of software. The default usage implies source code is included. If that is not the case, it will be called a "binary-only" distribution.

dual-lived
: Some modules live both in the *Standard Library* and on *CPAN*. These modules might be developed on two tracks as people modify either version. The trend currently is to untangle these situations.

dweomer
: An enchantment, illusion, phantasm, or jugglery. Said when Perl's magical *dwimmer* effects don't do what you expect, but rather seem to be the product of arcane *dweomercraft*, sorcery, or wonder working. [From Middle English.]

dwimmer
: DWIM is an acronym for "Do What I Mean", the principle that something should just do what you want it to do without an undue amount of fuss. A bit of code that does "dwimming" is a "dwimmer". Dwimming can require a great deal of behind-the-scenes magic, which (if it doesn't stay properly behind the scenes) is called a *dweomer* instead.

dynamic scoping
: Dynamic scoping works over a *dynamic scope*, making variables visible throughout the rest of the *block* in which they are first used and in any *subroutines* that are called by the rest of the block. Dynamically scoped variables can have their values temporarily changed (and implicitly restored later) by a `local` operator. (Compare *lexical scoping*.) Used more loosely to mean how a subroutine that is in the middle of calling another subroutine "contains" that subroutine at *runtime*.

eclectic
: Derived from many sources. Some would say *too* many.

element
: A basic building block. When you're talking about an *array*, it's one of the items that make up the array.

embedding
: When something is contained in something else, particularly when that might be considered surprising: "I've embedded a complete Perl interpreter in my editor!"

empty subclass test
: The notion that an empty *derived class* should behave exactly like its *base class*.

encapsulation
: The veil of abstraction separating the *interface* from the *implementation* (whether enforced or not), which mandates that all access to an *object*'s state be through *methods* alone.

endian
: See *little-endian* and *big-endian*.

en passant
: When you change a *value* as it is being copied. [From French "in passing", as in the exotic pawn-capturing maneuver in chess.]

environment
: The collective set of *environment variables* your *process* inherits from its parent. Accessed via `%ENV`.

environment variable
: A mechanism by which some high-level agent such as a user can pass its preferences down to its future offspring (child *processes*, grandchild processes, great-grandchild processes, and so on). Each environment variable is a *key/value* pair, like one entry in a *hash*.

EOF
: End of File. Sometimes used metaphorically as the terminating string of a *here document*.

errno
The error number returned by a *syscall* when it fails. Perl refers to the error by the name `$!` (or `$OS_ERROR` if you use the English module).

error
See *exception* or *fatal error*.

escape sequence
See *metasymbol*.

exception
A fancy term for an error. See *fatal error*.

exception handling
The way a program responds to an error. The exception-handling mechanism in Perl is the `eval` operator.

exec
To throw away the current *process*'s program and replace it with another, without exiting the process or relinquishing any resources held (apart from the old memory image).

executable file
A *file* that is specially marked to tell the *operating system* that it's okay to run this file as a program. Usually shortened to "executable".

execute
To run a *program* or *subroutine*. (Has nothing to do with the `kill` built-in, unless you're trying to run a *signal handler*.)

execute bit
The special mark that tells the operating system it can run this program. There are actually three execute bits under Unix, and which bit gets used depends on whether you own the file singularly, collectively, or not at all.

exit status
See *status*.

exploit
Used as a noun in this case, this refers to a known way to compromise a program to get it to do something the author didn't intend. Your task is to write unexploitable programs.

export
To make symbols from a *module* available for *import* by other modules.

expression
Anything you can legally say in a spot where a *value* is required. Typically composed of *literals*, *variables*, *operators*, *functions*, and *subroutine* calls, not necessarily in that order.

extension
A Perl module that also pulls in *compiled* C or C++ code. More generally, any experimental option that can be *compiled* into Perl, such as multithreading.

false
In Perl, any value that would look like `""` or `"0"` if evaluated in a string context. Since undefined values evaluate to `""`, all undefined values are false, but not all false values are undefined.

FAQ
Frequently Asked Question (although not necessarily frequently answered, especially if the answer appears in the Perl FAQ shipped standard with Perl).

fatal error
An uncaught *exception*, which causes termination of the *process* after printing a message on your *standard error* stream. Errors that happen inside an `eval` are not fatal. Instead, the `eval` terminates after placing the exception message in the `$@` (`$EVAL_ERROR`) variable. You can try to provoke a fatal error with the `die` operator (known as throwing or raising an exception), but this may be caught by a dynamically enclosing `eval`. If not caught, the `die` becomes a fatal error.

feeping creaturism
A spoonerism of "creeping featurism", noting the biological urge to add just one more feature to a program.

field
: A single piece of numeric or string data that is part of a longer *string*, *record*, or *line*. Variable-width fields are usually split up by *separators* (so use `split` to extract the fields), while fixed-width fields are usually at fixed positions (so use `unpack`). *Instance variables* are also known as "fields".

FIFO
: First In, First Out. See also *LIFO*. Also a nickname for a *named pipe*.

file
: A named collection of data, usually stored on disk in a *directory* in a *filesystem*. Roughly like a document, if you're into office metaphors. In modern filesystems, you can actually give a file more than one name. Some files have special properties, like directories and devices.

file descriptor
: The little number the *operating system* uses to keep track of which opened *file* you're talking about. Perl hides the file descriptor inside a *standard I/O* stream and then attaches the stream to a *filehandle*.

fileglob
: A "wildcard" match on *filenames*. See the `glob` function.

filehandle
: An identifier (not necessarily related to the real name of a file) that represents a particular instance of opening a file, until you close it. If you're going to open and close several different files in succession, it's fine to open each of them with the same filehandle, so you don't have to write out separate code to process each file.

filename
: One name for a file. This name is listed in a *directory*. You can use it in an `open` to tell the *operating system* exactly which file you want to open, and associate the file with a *filehandle*, which will carry the subsequent identity of that file in your program, until you close it.

filesystem
: A set of *directories* and *files* residing on a partition of the disk. Sometimes known as a "partition". You can change the file's name or even move a file around from directory to directory within a filesystem without actually moving the file itself, at least under Unix.

file test operator
: A built-in unary operator that you use to determine whether something is *true* about a file, such as `-o $filename` to test whether you're the owner of the file.

filter
: A program designed to take a *stream* of input and transform it into a stream of output.

first-come
: The first *PAUSE* author to upload a *namespace* automatically becomes the *primary maintainer* for that namespace. The "first come" permissions distinguish a *primary maintainer* who was assigned that role from one who received it automatically.

flag
: We tend to avoid this term because it means so many things. It may mean a command-line *switch* that takes no argument itself (such as Perl's `-n` and `-p` flags) or, less frequently, a single-bit indicator (such as the `O_CREAT` and `O_EXCL` flags used in `sysopen`). Sometimes informally used to refer to certain regex modifiers.

floating point
: A method of storing numbers in "scientific notation", such that the precision of the number is independent of its magnitude (the decimal point "floats"). Perl does its numeric work with floating-point numbers (sometimes called "floats") when it can't get away with using *integers*. Floating-point numbers are mere approximations of real numbers.

flush
: The act of emptying a *buffer*, often before it's full.

FMTEYEWTK
: Far More Than Everything You Ever Wanted To Know. An exhaustive treatise on one narrow topic, something of a super-*FAQ*. See Tom for far more.

foldcase
: The casemap used in Unicode when comparing or matching without regard to case. Comparing lower-, title-, or uppercase are all unreliable due to Unicode's complex, one-to-many case mappings. Foldcase is a *lowercase* variant (using a partially decomposed *normalization* form for certain codepoints) created specifically to resolve this.

fork
: To create a child *process* identical to the parent process at its moment of conception, at least until it gets ideas of its own. A thread with protected memory.

formal arguments
: The generic names by which a *subroutine* knows its *arguments*. In many languages, formal arguments are always given individual names; in Perl, the formal arguments are just the elements of an array. The formal arguments to a Perl program are `$ARGV[0]`, `$ARGV[1]`, and so on. Similarly, the formal arguments to a Perl subroutine are `$_[0]`, `$_[1]`, and so on. You may give the arguments individual names by assigning the values to a `my` list. See also *actual arguments*.

format
: A specification of how many spaces and digits and things to put somewhere so that whatever you're printing comes out nice and pretty.

freely available
: Means you don't have to pay money to get it, but the copyright on it may still belong to someone else (like Larry).

freely redistributable
: Means you're not in legal trouble if you give a bootleg copy of it to your friends and we find out about it. In fact, we'd rather you gave a copy to all your friends.

freeware
: Historically, any software that you give away, particularly if you make the source code available as well. Now often called *open source software*. Recently there has been a trend to use the term in contradistinction to *open source software*, to refer only to free software released under the Free Software Foundation's GPL (General Public License), but this is difficult to justify etymologically.

function
: Mathematically, a mapping of each of a set of input values to a particular output value. In computers, refers to a *subroutine* or *operator* that returns a *value*. It may or may not have input values (called *arguments*).

funny character
: Someone like Larry, or one of his peculiar friends. Also refers to the strange prefixes that Perl requires as noun markers on its variables.

garbage collection
: A misnamed feature—it should be called, "expecting your mother to pick up after you". Strictly speaking, Perl doesn't do this, but it relies on a reference-counting mechanism to keep things tidy. However, we rarely speak strictly and will often refer to the reference-counting scheme as a form of garbage collection. (If it's any comfort, when your interpreter exits, a "real" garbage collector runs to make sure everything is cleaned up if you've been messy with circular references and such.)

GID
: Group ID—in Unix, the numeric group ID that the *operating system* uses to identify you and members of your *group*.

glob
: Strictly, the shell's `*` character, which will match a "glob" of characters when you're trying to generate a list of filenames. Loosely, the act of using globs and similar symbols to do pattern matching. See also *fileglob* and *typeglob*.

global

Something you can see from anywhere, usually used of *variables* and *subroutines* that are visible everywhere in your program. In Perl, only certain special variables are truly global—most variables (and all subroutines) exist only in the current *package*. Global variables can be declared with `our`. See "Global Declarations" on page 153 in Chapter 4.

global destruction

The *garbage collection* of globals (and the running of any associated object destructors) that takes place when a Perl *interpreter* is being shut down. Global destruction should not be confused with the Apocalypse, except perhaps when it should.

glue language

A language such as Perl that is good at hooking things together that weren't intended to be hooked together.

granularity

The size of the pieces you're dealing with, mentally speaking.

grapheme

A graphene is an allotrope of carbon arranged in a hexagonal crystal lattice one atom thick. A *grapheme*, or more fully, a *grapheme cluster string* is a single user-visible *character*, which may in turn be several characters (*codepoints*) long. For example, a carriage return plus a line feed is a single grapheme but two characters, while a "ō" is a single grapheme but one, two, or even three characters, depending on *normalization*.

greedy

A *subpattern* whose *quantifier* wants to match as many things as possible.

grep

Originally from the old Unix editor command for "Globally search for a Regular Expression and Print it", now used in the general sense of any kind of search, especially text searches. Perl has a built-in `grep` function that searches a list for elements matching any given criterion, whereas the *grep*(1) program searches for lines matching a *regular expression* in one or more files.

group

A set of users of which you are a member. In some operating systems (like Unix), you can give certain file access permissions to other members of your group.

GV

An internal "glob value" typedef, holding a *typeglob*. The `GV` type is a subclass of *SV*.

hacker

Someone who is brilliantly persistent in solving technical problems, whether these involve golfing, fighting orcs, or programming. Hacker is a neutral term, morally speaking. Good hackers are not to be confused with evil *crackers* or clueless *script kiddies*. If you confuse them, we will presume that you are either evil or clueless.

handler

A *subroutine* or *method* that Perl calls when your program needs to respond to some internal event, such as a *signal*, or an encounter with an operator subject to *operator overloading*. See also *callback*.

hard reference

A *scalar value* containing the actual address of a *referent*, such that the referent's *reference* count accounts for it. (Some hard references are held internally, such as the implicit reference from one of a *typeglob*'s variable slots to its corresponding referent.) A hard reference is different from a *symbolic reference*.

hash

An unordered association of *key*/*value* pairs, stored such that you can easily use a string *key* to look up its associated data *value*. This glossary is like a hash, where the word to be defined is the key and the definition is the value. A hash is also sometimes septisyllabically called an "associative array", which is a pretty good reason for simply calling it a "hash" instead.

hash table
: A data structure used internally by Perl for implementing associative arrays (hashes) efficiently. See also *bucket*.

header file
: A file containing certain required definitions that you must include "ahead" of the rest of your program to do certain obscure operations. A C header file has a *.h* extension. Perl doesn't really have header files, though historically Perl has sometimes used translated *.h* files with a *.ph* extension. See `require` in Chapter 27. (Header files have been superseded by the *module* mechanism.)

here document
: So called because of a similar construct in *shells* that pretends that the *lines* following the *command* are a separate *file* to be fed to the command, up to some terminating string. In Perl, however, it's just a fancy form of quoting.

hexadecimal
: A number in base 16, "hex" for short. The digits for 10 through 16 are customarily represented by the letters `a` through `f`. Hexadecimal constants in Perl start with `0x`. See also the `hex` function in Chapter 27.

home directory
: The directory you are put into when you log in. On a Unix system, the name is often placed into `$ENV{HOME}` or `$ENV{LOGDIR}` by *login*, but you can also find it with `(get pwuid($<))[7]`. (Some platforms do not have a concept of a home directory.)

host
: The computer on which a program or other data resides.

hubris
: Excessive pride, the sort of thing for which Zeus zaps you. Also the quality that makes you write (and maintain) programs that other people won't want to say bad things about. Hence, the third great virtue of a programmer. See also *laziness* and *impatience*.

HV
: Short for a "hash value" typedef, which holds Perl's internal representation of a hash. The `HV` type is a subclass of *SV*.

identifier
: A legally formed name for most anything in which a computer program might be interested. Many languages (including Perl) allow identifiers to start with an alphabetic character, and then contain alphabetics and digits. Perl also allows connector punctuation like the underscore character wherever it allows alphabetics. (Perl also has more complicated names, like *qualified* names.)

impatience
: The anger you feel when the computer is being lazy. This makes you write programs that don't just react to your needs, but actually anticipate them. Or at least that pretend to. Hence, the second great virtue of a programmer. See also *laziness* and *hubris*.

implementation
: How a piece of code actually goes about doing its job. Users of the code should not count on implementation details staying the same unless they are part of the published *interface*.

import
: To gain access to symbols that are exported from another module. See `use` in Chapter 27.

increment
: To increase the value of something by 1 (or by some other number, if so specified).

indexing
: In olden days, the act of looking up a *key* in an actual index (such as a phone book). But now it's merely the act of using any kind of key or position to find the corresponding *value*, even if no index is involved. Things have degenerated to the point that Perl's `index` function merely locates the position (index) of one string in another.

indirect filehandle

An *expression* that evaluates to something that can be used as a *filehandle*: a *string* (filehandle name), a *typeglob*, a typeglob *reference*, or a low-level *IO* object.

indirection

If something in a program isn't the value you're looking for but indicates where the value is, that's indirection. This can be done with either *symbolic references* or *hard references*.

indirect object

In English grammar, a short noun phrase between a verb and its direct object indicating the beneficiary or recipient of the action. In Perl, `print STDOUT "$foo\n";` can be understood as "verb indirect-object object", where `STDOUT` is the recipient of the `print` action, and `"$foo"` is the object being printed. Similarly, when invoking a *method*, you might place the invocant in the dative slot between the method and its arguments:

```
$gollum = new Pathetic::Creature "Sméagol";
give $gollum "Fisssssh!";
give $gollum "Precious!";
```

indirect object slot

The syntactic position falling between a method call and its arguments when using the indirect object invocation syntax. (The slot is distinguished by the absence of a comma between it and the next argument.) `STDERR` is in the indirect object slot here:

```
print STDERR "Awake!  Awake!  Fear, Fire,
    Foes!  Awake!\n";
```

infix

An *operator* that comes in between its *operands*, such as multiplication in `24 * 7`.

inheritance

What you get from your ancestors, genetically or otherwise. If you happen to be a *class*, your ancestors are called *base classes* and your descendants are called *derived classes*. See *single inheritance* and *multiple inheritance*.

instance

Short for "an instance of a class", meaning an *object* of that *class*.

instance data

See *instance variable*.

instance method

A *method* of an *object*, as opposed to a *class method*.

A *method* whose *invocant* is an *object*, not a *package* name. Every object of a class shares all the methods of that class, so an instance method applies to all instances of the class, rather than applying to a particular instance. Also see *class method*.

instance variable

An *attribute* of an *object*; data stored with the particular object rather than with the class as a whole.

integer

A number with no fractional (decimal) part. A counting number, like 1, 2, 3, and so on, but including 0 and the negatives.

interface

The services a piece of code promises to provide forever, in contrast to its *implementation*, which it should feel free to change whenever it likes.

interpolation

The insertion of a scalar or list value somewhere in the middle of another value, such that it appears to have been there all along. In Perl, variable interpolation happens in double-quoted strings and patterns, and list interpolation occurs when constructing the list of values to pass to a list operator or other such construct that takes a *`LIST`*.

interpreter

Strictly speaking, a program that reads a second program and does what the second program says directly without turning the program into a different form first, which is what *compilers* do. Perl is not an interpreter by this definition, because it contains a kind of compiler that takes a program and turns

it into a more executable form (*syntax trees*) within the *perl* process itself, which the Perl *runtime* system then interprets.

invocant
The agent on whose behalf a *method* is invoked. In a *class* method, the invocant is a package name. In an *instance* method, the invocant is an object reference.

invocation
The act of calling up a deity, daemon, program, method, subroutine, or function to get it to do what you think it's supposed to do. We usually "call" subroutines but "invoke" methods, since it sounds cooler.

I/O
Input from, or output to, a *file* or *device*.

IO
An internal I/O object. Can also mean *indirect object*.

I/O layer
One of the filters between the data and what you get as input or what you end up with as output.

IPA
India Pale Ale. Also the International Phonetic Alphabet, the standard alphabet used for phonetic notation worldwide. Draws heavily on Unicode, including many combining characters.

IP
Internet Protocol, or Intellectual Property.

IPC
Interprocess Communication.

is-a
A relationship between two *objects* in which one object is considered to be a more specific version of the other, generic object: "A camel is a mammal." Since the generic object really only exists in a Platonic sense, we usually add a little abstraction to the notion of objects and think of the relationship as being between a generic *base class* and a specific *derived class*. Oddly enough, Platonic classes don't always have Platonic relationships—see *inheritance*.

iteration
Doing something repeatedly.

iterator
A special programming gizmo that keeps track of where you are in something that you're trying to iterate over. The `foreach` loop in Perl contains an iterator; so does a hash, allowing you to `each` through it.

IV
The integer four, not to be confused with six, Tom's favorite editor. IV also means an internal Integer Value of the type a *scalar* can hold, not to be confused with an *NV*.

JAPH
"Just Another Perl Hacker", a clever but cryptic bit of Perl code that, when executed, evaluates to that string. Often used to illustrate a particular Perl feature, and something of an ongoing Obfuscated Perl Contest seen in USENET signatures.

key
The string index to a *hash*, used to look up the *value* associated with that key.

keyword
See *reserved words*.

label
A name you give to a *statement* so that you can talk about that statement elsewhere in the program.

laziness
The quality that makes you go to great effort to reduce overall energy expenditure. It makes you write labor-saving programs that other people will find useful, and then document what you wrote so you don't have to answer so many questions about it. Hence, the first great virtue of a programmer. Also hence, this book. See also *impatience* and *hubris*.

leftmost longest
: The preference of the *regular expression* engine to match the leftmost occurrence of a *pattern*, then given a position at which a match will occur, the preference for the longest match (presuming the use of a *greedy* quantifier). See Chapter 5 for *much* more on this subject.

left shift
: A *bit shift* that multiplies the number by some power of 2.

lexeme
: Fancy term for a *token*.

lexer
: Fancy term for a *tokener*.

lexical analysis
: Fancy term for *tokenizing*.

lexical scoping
: Looking at your *Oxford English Dictionary* through a microscope. (Also known as *static scoping*, because dictionaries don't change very fast.) Similarly, looking at variables stored in a private dictionary (namespace) for each scope, which are visible only from their point of declaration down to the end of the lexical scope in which they are declared. —Syn. *static scoping*. —Ant. *dynamic scoping*.

lexical variable
: A *variable* subject to *lexical scoping*, declared by `my`. Often just called a "lexical". (The `our` declaration declares a lexically scoped name for a global variable, which is not itself a lexical variable.)

library
: Generally, a collection of procedures. In ancient days, referred to a collection of subroutines in a *.pl* file. In modern times, refers more often to the entire collection of Perl *modules* on your system.

LIFO
: Last In, First Out. See also *FIFO*. A LIFO is usually called a *stack*.

line
: In Unix, a sequence of zero or more nonnewline characters terminated with a *newline* character. On non-Unix machines, this is emulated by the C library even if the underlying *operating system* has different ideas.

linebreak
: A *grapheme* consisting of either a carriage return followed by a line feed or any character with the Unicode Vertical Space *character property*.

line buffering
: Used by a *standard I/O* output stream that flushes its *buffer* after every *newline*. Many standard I/O libraries automatically set up line buffering on output that is going to the terminal.

line number
: The number of lines read previous to this one, plus 1. Perl keeps a separate line number for each source or input file it opens. The current source file's line number is represented by `__LINE__`. The current input line number (for the file that was most recently read via `<FH>`) is represented by the `$.` (`$INPUT_LINE_NUMBER`) variable. Many error messages report both values, if available.

link
: Used as a noun, a name in a *directory* that represents a *file*. A given file can have multiple links to it. It's like having the same phone number listed in the phone directory under different names. As a verb, to resolve a partially *compiled* file's unresolved symbols into a (nearly) executable image. Linking can generally be static or dynamic, which has nothing to do with static or dynamic scoping.

LIST
: A syntactic construct representing a comma-separated list of expressions, evaluated to produce a *list value*. Each *expression* in a *`LIST`* is evaluated in *list context* and interpolated into the list value.

list
: An ordered set of scalar values.

list context
: The situation in which an *expression* is expected by its surroundings (the code calling it) to return a list of values rather than a single value. Functions that want a `LIST` of arguments tell those arguments that they should produce a list value. See also *context*.

list operator
: An *operator* that does something with a list of values, such as `join` or `grep`. Usually used for named built-in operators (such as `print`, `unlink`, and `system`) that do not require parentheses around their *argument* list.

list value
: An unnamed list of temporary scalar values that may be passed around within a program from any list-generating function to any function or construct that provides a *list context*.

literal
: A token in a programming language, such as a number or *string*, that gives you an actual *value* instead of merely representing possible values as a *variable* does.

little-endian
: From Swift: someone who eats eggs little end first. Also used of computers that store the least significant *byte* of a word at a lower byte address than the most significant byte. Often considered superior to big-endian machines. See also *big-endian*.

local
: Not meaning the same thing everywhere. A global variable in Perl can be localized inside a *dynamic scope* via the `local` operator.

logical operator
: Symbols representing the concepts "and", "or", "xor", and "not".

lookahead
: An *assertion* that peeks at the string to the right of the current match location.

lookbehind
: An *assertion* that peeks at the string to the left of the current match location.

loop
: A construct that performs something repeatedly, like a roller coaster.

loop control statement
: Any statement within the body of a loop that can make a loop prematurely stop looping or skip an *iteration*. Generally, you shouldn't try this on roller coasters.

loop label
: A kind of key or name attached to a loop (or roller coaster) so that loop control statements can talk about which loop they want to control.

lowercase
: In Unicode, not just characters with the General Category of Lowercase Letter, but any character with the Lowercase property, including Modifier Letters, Letter Numbers, some Other Symbols, and one Combining Mark.

lvaluable
: Able to serve as an *lvalue*.

lvalue
: Term used by language lawyers for a storage location you can assign a new *value* to, such as a *variable* or an element of an *array*. The "l" is short for "left", as in the left side of an assignment, a typical place for lvalues. An *lvaluable* function or expression is one to which a value may be assigned, as in `pos($x) = 10`.

lvalue modifier
: An adjectival pseudofunction that warps the meaning of an *lvalue* in some declarative fashion. Currently there are three lvalue modifiers: `my`, `our`, and `local`.

magic
: Technically speaking, any extra semantics attached to a variable such as `$!`, `$0`, `%ENV`, or

`%SIG`, or to any tied variable. Magical things happen when you diddle those variables.

magical increment
: An *increment* operator that knows how to bump up ASCII alphabetics as well as numbers.

magical variables
: Special variables that have side effects when you access them or assign to them. For example, in Perl, changing elements of the `%ENV` array also changes the corresponding environment variables that subprocesses will use. Reading the `$!` variable gives you the current system error number or message.

Makefile
: A file that controls the compilation of a program. Perl programs don't usually need a *Makefile* because the Perl compiler has plenty of self-control.

man
: The Unix program that displays online documentation (manual pages) for you.

manpage
: A "page" from the manuals, typically accessed via the *man*(1) command. A manpage contains a SYNOPSIS, a DESCRIPTION, a list of BUGS, and so on, and is typically longer than a page. There are manpages documenting *commands*, *syscalls*, *library functions*, *devices*, *protocols*, *files*, and such. In this book, we call any piece of standard Perl documentation (like perlop or perldelta) a manpage, no matter what format it's installed in on your system.

matching
: See *pattern matching*.

member data
: See *instance variable*.

memory
: This always means your main memory, not your disk. Clouding the issue is the fact that your machine may implement *virtual* memory; that is, it will pretend that it has more memory than it really does, and it'll use disk space to hold inactive bits. This can make it seem like you have a little more memory than you really do, but it's not a substitute for real memory. The best thing that can be said about virtual memory is that it lets your performance degrade gradually rather than suddenly when you run out of real memory. But your program can die when you run out of virtual memory, too—if you haven't thrashed your disk to death first.

metacharacter
: A *character* that is *not* supposed to be treated normally. Which characters are to be treated specially as metacharacters varies greatly from context to context. Your *shell* will have certain metacharacters, double-quoted Perl *strings* have other metacharacters, and *regular expression* patterns have all the double-quote metacharacters plus some extra ones of their own.

metasymbol
: Something we'd call a *metacharacter* except that it's a sequence of more than one character. Generally, the first character in the sequence must be a true metacharacter to get the other characters in the metasymbol to misbehave along with it.

method
: A kind of action that an *object* can take if you tell it to. See Chapter 12.

method resolution order
: The path Perl takes through `@INC`. By default, this is a double depth first search, once looking for defined methods and once for `AUTOLOAD`. However, Perl lets you configure this with `mro`.

minicpan
: A CPAN mirror that includes just the latest versions for each distribution, probably created with `CPAN::Mini`. See Chapter 19.

minimalism
: The belief that "small is beautiful". Paradoxically, if you say something in a small lan-

guage, it turns out big, and if you say it in a big language, it turns out small. Go figure.

mode
In the context of the *stat*(2) syscall, refers to the field holding the *permission bits* and the type of the *file*.

modifier
See *statement modifier*, *regular expression modifier*, and *lvalue modifier*, not necessarily in that order.

module
A *file* that defines a *package* of (almost) the same name, which can either *export* symbols or function as an *object* class. (A module's main *.pm* file may also load in other files in support of the module.) See the `use` built-in.

modulus
An integer divisor when you're interested in the remainder instead of the quotient.

mojibake
When you speak one language and the computer thinks you're speaking another. You'll see odd translations when you send UTF 8, for instance, but the computer thinks you sent Latin-1, showing all sorts of weird characters instead. The term is written 「文字化け」 in Japanese and means "character rot", an apt description. Pronounced [modʒibake] in standard *IPA* phonetics, or approximately "moh-jee-bah-keh".

monger
Short for one member of *Perl mongers*, a purveyor of Perl.

mortal
A temporary value scheduled to die when the current statement finishes.

mro
See *method resolution order*.

multidimensional array
An array with multiple subscripts for finding a single element. Perl implements these using *references*—see Chapter 9.

multiple inheritance
The features you got from your mother and father, mixed together unpredictably. (See also *inheritance* and *single inheritance*.) In computer languages (including Perl), it is the notion that a given class may have multiple direct ancestors or *base classes*.

named pipe
A *pipe* with a name embedded in the *filesystem* so that it can be accessed by two unrelated *processes*.

namespace
A domain of names. You needn't worry about whether the names in one such domain have been used in another. See *package*.

NaN
Not a number. The value Perl uses for certain invalid or inexpressible floating-point operations.

network address
The most important attribute of a socket, like your telephone's telephone number. Typically an IP address. See also *port*.

newline
A single character that represents the end of a line, with the ASCII value of 012 octal under Unix (but 015 on a Mac), and represented by `\n` in Perl strings. For Windows machines writing text files, and for certain physical devices like terminals, the single newline gets automatically translated by your C library into a line feed and a carriage return, but normally, no translation is done.

NFS
Network File System, which allows you to mount a remote filesystem as if it were local.

normalization
Converting a text string into an alternate but equivalent *canonical* (or compatible) representation that can then be compared for equivalence. Unicode recognizes four different normalization forms: NFD, NFC, NFKD, and NFKC.

null character
: A character with the numeric value of zero. It's used by C to terminate strings, but Perl allows strings to contain a null.

null list
: A *list value* with zero elements, represented in Perl by `()`.

null string
: A *string* containing no characters, not to be confused with a string containing a *null character*, which has a positive length and is *true*.

numeric context
: The situation in which an expression is expected by its surroundings (the code calling it) to return a number. See also *context* and *string context*.

numification
: (Sometimes spelled *nummification* and *nummify*.) Perl lingo for implicit conversion into a number; the related verb is *numify*. *Numification* is intended to rhyme with *mummification*, and *numify* with *mummify*. It is unrelated to English *numen*, *numina*, *numinous*. We originally forgot the extra *m* a long time ago, and some people got used to our funny spelling, and so just as with `HTTP_REFERER`'s own missing letter, our weird spelling has stuck around.

NV
: Short for Nevada, no part of which will ever be confused with civilization. NV also means an internal floating-point Numeric Value of the type a *scalar* can hold, not to be confused with an *IV*.

nybble
: Half a *byte*, equivalent to one *hexadecimal* digit, and worth four *bits*.

object
: An *instance* of a *class*. Something that "knows" what user-defined type (class) it is, and what it can do because of what class it is. Your program can request an object to do things, but the object gets to decide whether it wants to do them or not. Some objects are more accommodating than others.

octal
: A number in base 8. Only the digits 0 through 7 are allowed. Octal constants in Perl start with 0, as in 013. See also the `oct` function.

offset
: How many things you have to skip over when moving from the beginning of a string or array to a specific position within it. Thus, the minimum offset is zero, not one, because you don't skip anything to get to the first item.

one-liner
: An entire computer program crammed into one line of text.

open source software
: Programs for which the source code is freely available and freely redistributable, with no commercial strings attached. For a more detailed definition, see *http://www.opensource.org/osd.html*.

operand
: An *expression* that yields a *value* that an *operator* operates on. See also *precedence*.

operating system
: A special program that runs on the bare machine and hides the gory details of managing *processes* and *devices*. Usually used in a looser sense to indicate a particular culture of programming. The loose sense can be used at varying levels of specificity. At one extreme, you might say that all versions of Unix and Unix-lookalikes are the same operating system (upsetting many people, especially lawyers and other advocates). At the other extreme, you could say this particular version of this particular vendor's operating system is different from any other version of this or any other vendor's operating system. Perl is much more portable across operating systems than many other languages. See also *architecture* and *platform*.

operator
: A gizmo that transforms some number of input values to some number of output values, often built into a language with a special syntax or symbol. A given operator may have specific expectations about what *types* of data you give as its arguments (*operands*) and what type of data you want back from it.

operator overloading
: A kind of *overloading* that you can do on built-in *operators* to make them work on *objects* as if the objects were ordinary scalar values, but with the actual semantics supplied by the object class. This is set up with the overload *pragma*—see Chapter 13.

options
: See either *switches* or *regular expression modifiers*.

ordinal
: An abstract character's integer value. Same thing as *codepoint*.

overloading
: Giving additional meanings to a symbol or construct. Actually, all languages do overloading to one extent or another, since people are good at figuring out things from *context*.

overriding
: Hiding or invalidating some other definition of the same name. (Not to be confused with *overloading*, which adds definitions that must be disambiguated some other way.) To confuse the issue further, we use the word with two overloaded definitions: to describe how you can define your own *subroutine* to hide a built-in *function* of the same name (see the section "Overriding Built-in Functions" on page 411 in Chapter 11), and to describe how you can define a replacement *method* in a *derived class* to hide a *base class*'s method of the same name (see Chapter 12).

owner
: The one user (apart from the superuser) who has absolute control over a *file*. A file may also have a *group* of users who may exercise joint ownership if the real owner permits it. See *permission bits*.

package
: A *namespace* for global *variables*, *subroutines*, and the like, such that they can be kept separate from like-named *symbols* in other namespaces. In a sense, only the package is global, since the symbols in the package's symbol table are only accessible from code *compiled* outside the package by naming the package. But in another sense, all package symbols are also globals—they're just well-organized globals.

pad
: Short for *scratchpad*.

parameter
: See *argument*.

parent class
: See *base class*.

parse tree
: See *syntax tree*.

parsing
: The subtle but sometimes brutal art of attempting to turn your possibly malformed program into a valid *syntax tree*.

patch
: To fix by applying one, as it were. In the realm of hackerdom, a listing of the differences between two versions of a program as might be applied by the *patch*(1) program when you want to fix a bug or upgrade your old version.

PATH
: The list of *directories* the system searches to find a program you want to *execute*. The list is stored as one of your *environment variables*, accessible in Perl as `$ENV{PATH}`.

pathname
A fully qualified filename such as */usr/bin/perl*. Sometimes confused with `PATH`.

pattern
A template used in *pattern matching*.

pattern matching
Taking a pattern, usually a *regular expression*, and trying the pattern various ways on a string to see whether there's any way to make it fit. Often used to pick interesting tidbits out of a file.

PAUSE
The Perl Authors Upload SErver (*http://pause.perl.org*), the gateway for *modules* on their way to *CPAN*.

Perl mongers
A Perl user group, taking the form of its name from the New York Perl mongers, the first Perl user group. Find one near you at *http://www.pm.org*.

permission bits
Bits that the *owner* of a file sets or unsets to allow or disallow access to other people. These flag bits are part of the *mode* word returned by the `stat` built-in when you ask about a file. On Unix systems, you can check the *ls*(1) manpage for more information.

Pern
What you get when you do `Perl++` twice. Doing it only once will curl your hair. You have to increment it eight times to shampoo your hair. Lather, rinse, iterate.

pipe
A direct *connection* that carries the output of one *process* to the input of another without an intermediate temporary file. Once the pipe is set up, the two processes in question can read and write as if they were talking to a normal file, with some caveats.

pipeline
A series of *processes* all in a row, linked by *pipes*, where each passes its output stream to the next.

platform
The entire hardware and software context in which a program runs. A program written in a platform-dependent language might break if you change any of the following: machine, operating system, libraries, compiler, or system configuration. The *perl* interpreter has to be *compiled* differently for each platform because it is implemented in C, but programs written in the Perl language are largely platform independent.

pod
The markup used to embed documentation into your Perl code. Pod stands for "Plain old documentation". See Chapter 23.

pod command
A sequence, such as `=head1`, that denotes the start of a *pod* section.

pointer
A *variable* in a language like C that contains the exact memory location of some other item. Perl handles pointers internally so you don't have to worry about them. Instead, you just use symbolic pointers in the form of *keys* and *variable* names, or *hard references*, which aren't pointers (but act like pointers and do in fact contain pointers).

polymorphism
The notion that you can tell an *object* to do something generic, and the object will interpret the command in different ways depending on its type. [< Greek πολυ- + μορφή, many forms.]

port
The part of the address of a TCP or UDP socket that directs packets to the correct process after finding the right machine, something like the phone extension you give when you reach the company operator. Also the result of converting code to run on a different platform than originally intended, or the verb denoting this conversion.

portable
Once upon a time, C code compilable under both BSD and SysV. In general, code that

can be easily converted to run on another *platform*, where "easily" can be defined however you like, and usually is. Anything may be considered portable if you try hard enough, such as a mobile home or London Bridge.

porter
Someone who "carries" software from one *platform* to another. Porting programs written in platform-dependent languages such as C can be difficult work, but porting programs like Perl is very much worth the agony.

possessive
Said of quantifiers and groups in patterns that refuse to give up anything once they've gotten their mitts on it. Catchier and easier to say than the even more formal *nonbacktrackable*.

POSIX
The Portable Operating System Interface specification.

postfix
An *operator* that follows its *operand*, as in `$x++`.

pp
An internal shorthand for a "push-pop" code; that is, C code implementing Perl's stack machine.

pragma
A standard module whose practical hints and suggestions are received (and possibly ignored) at compile time. Pragmas are named in all lowercase.

precedence
The rules of conduct that, in the absence of other guidance, determine what should happen first. For example, in the absence of parentheses, you always do multiplication before addition.

prefix
An *operator* that precedes its *operand*, as in `++$x`.

preprocessing
What some helper *process* did to transform the incoming data into a form more suitable for the current process. Often done with an incoming *pipe*. See also *C preprocessor*.

primary maintainer
The author that PAUSE allows to assign *comaintainer* permissions to a *namespace*. A primary maintainer can give up this distinction by assigning it to another PAUSE author. See Chapter 19.

procedure
A *subroutine*.

process
An instance of a running program. Under multitasking systems like Unix, two or more separate processes could be running the same program independently at the same time—in fact, the `fork` function is designed to bring about this happy state of affairs. Under other operating systems, processes are sometimes called "threads", "tasks", or "jobs", often with slight nuances in meaning.

program
See *script*.

program generator
A system that algorithmically writes code for you in a high-level language. See also *code generator*.

progressive matching
Pattern matching that picks up where it left off before.

property
See either *instance variable* or *character property*.

protocol
In networking, an agreed-upon way of sending messages back and forth so that neither correspondent will get too confused.

prototype
An optional part of a *subroutine* declaration telling the Perl compiler how many and

what flavor of arguments may be passed as *actual arguments*, so you can write subroutine calls that parse much like built-in functions. (Or don't parse, as the case may be.)

pseudofunction
A construct that sometimes looks like a function but really isn't. Usually reserved for *lvalue* modifiers like `my`, for *context* modifiers like `scalar`, and for the pick-your-own-quotes constructs, `q//`, `qq//`, `qx//`, `qw//`, `qr//`, `m//`, `s///`, `y///`, and `tr///`.

pseudohash
Formerly, a reference to an array whose initial element happens to hold a reference to a hash. You used to be able to treat a pseudohash reference as either an array reference or a hash reference. Pseduohashes are no longer supported.

pseudoliteral
An *operator* that looks something like a *literal*, such as the output-grabbing operator, `` `command` ``.

public domain
Something not owned by anybody. Perl is copyrighted and is thus *not* in the public domain—it's just *freely available* and *freely redistributable*.

pumpkin
A notional "baton" handed around the Perl community indicating who is the lead integrator in some arena of development.

pumpking
A *pumpkin* holder, the person in charge of pumping the pump, or at least priming it. Must be willing to play the part of the Great Pumpkin now and then.

PV
A "pointer value", which is Perl Internals Talk for a `char*`.

qualified
Possessing a complete name. The symbol `$Ent::moot` is qualified; `$moot` is unqualified. A fully qualified filename is specified from the top-level directory.

quantifier
A component of a *regular expression* specifying how many times the foregoing *atom* may occur.

race condition
A race condition exists when the result of several interrelated events depends on the ordering of those events, but that order cannot be guaranteed due to nondeterministic timing effects. If two or more programs, or parts of the same program, try to go through the same series of events, one might interrupt the work of the other. This is a good way to find an *exploit*.

readable
With respect to files, one that has the proper permission bit set to let you access the file. With respect to computer programs, one that's written well enough that someone has a chance of figuring out what it's trying to do.

reaping
The last rites performed by a parent *process* on behalf of a deceased child process so that it doesn't remain a *zombie*. See the `wait` and `waitpid` function calls.

record
A set of related data values in a *file* or *stream*, often associated with a unique *key* field. In Unix, often commensurate with a *line*, or a blank-line–terminated set of lines (a "paragraph"). Each line of the */etc/passwd* file is a record, keyed on login name, containing information about that user.

recursion
The art of defining something (at least partly) in terms of itself, which is a naughty no-no in dictionaries but often works out okay in computer programs if you're careful not to recurse forever (which is like an infinite loop with more spectacular failure modes).

reference
Where you look to find a pointer to information somewhere else. (See *indirection*.)

References come in two flavors: *symbolic references* and *hard references*.

referent
Whatever a reference refers to, which may or may not have a name. Common types of referents include scalars, arrays, hashes, and subroutines.

regex
See *regular expression*.

regular expression
A single entity with various interpretations, like an elephant. To a computer scientist, it's a grammar for a little language in which some strings are legal and others aren't. To normal people, it's a pattern you can use to find what you're looking for when it varies from case to case. Perl's regular expressions are far from regular in the theoretical sense, but in regular use they work quite well. Here's a regular expression: `/Oh s.*t./`. This will match strings like "`Oh say can you see by the dawn's early light`" and "`Oh sit!`". See Chapter 5.

regular expression modifier
An option on a pattern or substitution, such as `/i` to render the pattern case-insensitive.

regular file
A *file* that's not a *directory*, a *device*, a named *pipe* or *socket*, or a *symbolic link*. Perl uses the `-f` file test operator to identify regular files. Sometimes called a "plain" file.

relational operator
An *operator* that says whether a particular ordering relationship is *true* about a pair of *operands*. Perl has both numeric and string relational operators. See *collating sequence*.

reserved words
A word with a specific, built-in meaning to a *compiler*, such as `if` or `delete`. In many languages (not Perl), it's illegal to use reserved words to name anything else. (Which is why they're reserved, after all.) In Perl, you just can't use them to name *labels* or *filehandles*. Also called "keywords".

return value
The *value* produced by a *subroutine* or *expression* when evaluated. In Perl, a return value may be either a *list* or a *scalar*.

RFC
Request For Comment, which despite the timid connotations is the name of a series of important standards documents.

right shift
A *bit shift* that divides a number by some power of 2.

role
A name for a concrete set of behaviors. A role is a way to add behavior to a class without inheritance.

root
The superuser (`UID` == 0). Also the top-level directory of the filesystem.

RTFM
What you are told when someone thinks you should Read The Fine Manual.

run phase
Any time after Perl starts running your main program. See also *compile phase*. Run phase is mostly spent in *runtime* but may also be spent in *compile time* when `require`, `do` *`FILE`*, or `eval` *`STRING`* operators are executed, or when a substitution uses the `/ee` modifier.

runtime
The time when Perl is actually doing what your code says to do, as opposed to the earlier period of time when it was trying to figure out whether what you said made any sense whatsoever, which is *compile time*.

runtime pattern
A pattern that contains one or more variables to be interpolated before parsing the pattern as a *regular expression*, and that therefore cannot be analyzed at compile time, but must be reanalyzed each time the pattern match operator is evaluated. Runtime patterns are useful but expensive.

RV

A recreational vehicle, not to be confused with vehicular recreation. RV also means an internal Reference Value of the type a *scalar* can hold. See also *IV* and *NV* if you're not confused yet.

rvalue

A *value* that you might find on the right side of an *assignment*. See also *lvalue*.

sandbox

A walled off area that's not supposed to affect beyond its walls. You let kids play in the sandbox instead of running in the road. See Chapter 20.

scalar

A simple, singular value; a number, *string*, or *reference*.

scalar context

The situation in which an *expression* is expected by its surroundings (the code calling it) to return a single *value* rather than a *list* of values. See also *context* and *list context*. A scalar context sometimes imposes additional constraints on the return value—see *string context* and *numeric context*. Sometimes we talk about a *Boolean context* inside conditionals, but this imposes no additional constraints, since any scalar value, whether numeric or *string*, is already true or false.

scalar literal

A number or quoted *string*—an actual *value* in the text of your program, as opposed to a *variable*.

scalar value

A value that happens to be a *scalar* as opposed to a *list*.

scalar variable

A *variable* prefixed with `$` that holds a single value.

scope

From how far away you can see a variable, looking through one. Perl has two visibility mechanisms. It does *dynamic scoping* of `local` *variables*, meaning that the rest of the *block*, and any *subroutines* that are called by the rest of the block, can see the variables that are local to the block. Perl does *lexical scoping* of `my` variables, meaning that the rest of the block can see the variable, but other subroutines called by the block *cannot* see the variable.

scratchpad

The area in which a particular invocation of a particular file or subroutine keeps some of its temporary values, including any lexically scoped variables.

script

A text *file* that is a program intended to be *executed* directly rather than *compiled* to another form of file before *execution*.

Also, in the context of *Unicode*, a writing system for a particular language or group of languages, such as Greek, Bengali, or Tengwar.

script kiddie

A *cracker* who is not a *hacker* but knows just enough to run canned scripts. A *cargo-cult* programmer.

sed

A venerable Stream EDitor from which Perl derives some of its ideas.

semaphore

A fancy kind of interlock that prevents multiple *threads* or *processes* from using up the same resources simultaneously.

separator

A *character* or *string* that keeps two surrounding strings from being confused with each other. The `split` function works on separators. Not to be confused with *delimiters* or *terminators*. The "or" in the previous sentence separated the two alternatives.

serialization

Putting a fancy *data structure* into linear order so that it can be stored as a *string* in a disk file or database, or sent through a *pipe*. Also called marshalling.

server
: In networking, a *process* that either advertises a *service* or just hangs around at a known location and waits for *clients* who need service to get in touch with it.

service
: Something you do for someone else to make them happy, like giving them the time of day (or of their life). On some machines, well-known services are listed by the `getservent` function.

setgid
: Same as *setuid*, only having to do with giving away *group* privileges.

setuid
: Said of a program that runs with the privileges of its *owner* rather than (as is usually the case) the privileges of whoever is running it. Also describes the bit in the mode word (*permission bits*) that controls the feature. This bit must be explicitly set by the owner to enable this feature, and the program must be carefully written not to give away more privileges than it ought to.

shared memory
: A piece of *memory* accessible by two different *processes* who otherwise would not see each other's memory.

shebang
: Irish for the whole McGillicuddy. In Perl culture, a portmanteau of "sharp" and "bang", meaning the `#!` sequence that tells the system where to find the interpreter.

shell
: A *command*-line *interpreter*. The program that interactively gives you a prompt, accepts one or more *lines* of input, and executes the programs you mentioned, feeding each of them their proper *arguments* and input data. Shells can also execute scripts containing such commands. Under Unix, typical shells include the Bourne shell (*/bin/sh*), the C shell (*/bin/csh*), and the Korn shell (*/bin/ksh*). Perl is not strictly a shell because it's not interactive (although Perl programs can be interactive).

side effects
: Something extra that happens when you evaluate an *expression*. Nowadays it can refer to almost anything. For example, evaluating a simple assignment statement typically has the "side effect" of assigning a value to a variable. (And you thought assigning the value was your primary intent in the first place!) Likewise, assigning a value to the special variable `$|` (`$AUTOFLUSH`) has the side effect of forcing a flush after every `write` or `print` on the currently selected filehandle.

sigil
: A glyph used in magic. Or, for Perl, the symbol in front of a variable name, such as `$`, `@`, and `%`.

signal
: A bolt out of the blue; that is, an event triggered by the *operating system*, probably when you're least expecting it.

signal handler
: A *subroutine* that, instead of being content to be called in the normal fashion, sits around waiting for a bolt out of the blue before it will deign to *execute*. Under Perl, bolts out of the blue are called signals, and you send them with the `kill` built-in. See the `%SIG` hash in Chapter 25 and the section "Signals" on page 518 in Chapter 15.

single inheritance
: The features you got from your mother, if she told you that you don't have a father. (See also *inheritance* and *multiple inheritance*.) In computer languages, the idea that *classes* reproduce asexually so that a given class can only have one direct ancestor or *base class*. Perl supplies no such restriction, though you may certainly program Perl that way if you like.

slice
: A selection of any number of *elements* from a *list*, *array*, or *hash*.

slurp
: To read an entire *file* into a *string* in one operation.

socket
: An endpoint for network communication among multiple *processes* that works much like a telephone or a post office box. The most important thing about a socket is its *network address* (like a phone number). Different kinds of sockets have different kinds of addresses—some look like filenames, and some don't.

soft reference
: See *symbolic reference*.

source filter
: A special kind of *module* that does *preprocessing* on your script just before it gets to the *tokener*.

stack
: A device you can put things on the top of, and later take them back off in the opposite order in which you put them on. See *LIFO*.

standard
: Included in the official Perl distribution, as in a standard module, a standard tool, or a standard Perl *manpage*.

standard error
: The default output *stream* for nasty remarks that don't belong in *standard output*. Represented within a Perl program by the *filehandle* `STDERR`. You can use this stream explicitly, but the `die` and `warn` built-ins write to your standard error stream automatically (unless trapped or otherwise intercepted).

standard input
: The default input *stream* for your program, which if possible shouldn't care where its data is coming from. Represented within a Perl program by the *filehandle* `STDIN`.

standard I/O
: A standard C library for doing *buffered* input and output to the *operating system*. (The "standard" of standard I/O is at most marginally related to the "standard" of standard input and output.) In general, Perl relies on whatever implementation of standard I/O a given operating system supplies, so the buffering characteristics of a Perl program on one machine may not exactly match those on another machine. Normally this only influences efficiency, not semantics. If your standard I/O package is doing block buffering and you want it to *flush* the buffer more often, just set the `$|` variable to a true value.

Standard Library
: Everything that comes with the official *perl* distribution. Some vendor versions of *perl* change their distributions, leaving out some parts or including extras. See also *dual-lived*.

standard output
: The default output *stream* for your program, which if possible shouldn't care where its data is going. Represented within a Perl program by the *filehandle* `STDOUT`.

statement
: A *command* to the computer about what to do next, like a step in a recipe: "Add marmalade to batter and mix until mixed." A statement is distinguished from a *declaration*, which doesn't tell the computer to do anything, but just to learn something.

statement modifier
: A *conditional* or *loop* that you put after the *statement* instead of before, if you know what we mean.

static
: Varying slowly compared to something else. (Unfortunately, everything is relatively stable compared to something else, except for certain elementary particles, and we're not so sure about them.) In computers, where things are supposed to vary rapidly, "static" has a derogatory connotation, indicating a slightly dysfunctional *variable*, *subroutine*, or *method*. In Perl culture, the word is politely avoided.

If you're a C or C++ programmer, you might be looking for Perl's `state` keyword.

static method
No such thing. See *class method*.

static scoping
No such thing. See *lexical scoping*.

static variable
No such thing. Just use a *lexical variable* in a scope larger than your *subroutine*, or declare it with `state` instead of with `my`.

stat structure
A special internal spot in which Perl keeps the information about the last *file* on which you requested information.

status
The *value* returned to the parent *process* when one of its child processes dies. This value is placed in the special variable `$?`. Its upper eight *bits* are the exit status of the defunct process, and its lower eight bits identify the signal (if any) that the process died from. On Unix systems, this status value is the same as the status word returned by *wait*(2). See `system` in Chapter 27.

STDERR
See *standard error*.

STDIN
See *standard input*.

STDIO
See *standard I/O*.

STDOUT
See *standard output*.

stream
A flow of data into or out of a process as a steady sequence of bytes or characters, without the appearance of being broken up into packets. This is a kind of *interface*—the underlying *implementation* may well break your data up into separate packets for delivery, but this is hidden from you.

string
A sequence of characters such as "He said !@#*&%@#*?!". A string does not have to be entirely printable.

string context
The situation in which an expression is expected by its surroundings (the code calling it) to return a *string*. See also *context* and *numeric context*.

stringification
The process of producing a *string* representation of an abstract object.

struct
C keyword introducing a structure definition or name.

structure
See *data structure*.

subclass
See *derived class*.

subpattern
A component of a *regular expression* pattern.

subroutine
A named or otherwise accessible piece of program that can be invoked from elsewhere in the program in order to accomplish some subgoal of the program. A subroutine is often parameterized to accomplish different but related things depending on its input *arguments*. If the subroutine returns a meaningful *value*, it is also called a *function*.

subscript
A *value* that indicates the position of a particular *array element* in an array.

substitution
Changing parts of a string via the `s///` operator. (We avoid use of this term to mean *variable interpolation*.)

substring
A portion of a *string*, starting at a certain *character* position (*offset*) and proceeding for a certain number of characters.

superclass
See *base class*.

superuser
The person whom the *operating system* will let do almost anything. Typically your system administrator or someone pretending to be your system administrator. On Unix systems, the *root* user. On Windows systems, usually the Administrator user.

SV
Short for "scalar value". But within the Perl interpreter, every *referent* is treated as a member of a class derived from SV, in an object-oriented sort of way. Every *value* inside Perl is passed around as a C language `SV*` pointer. The SV *struct* knows its own "referent type", and the code is smart enough (we hope) not to try to call a *hash* function on a *subroutine*.

switch
An option you give on a command line to influence the way your program works, usually introduced with a minus sign. The word is also used as a nickname for a *switch statement*.

switch cluster
The combination of multiple command-line switches (*e.g.*, `-a -b -c`) into one switch (*e.g.*, `-abc`). Any switch with an additional *argument* must be the last switch in a cluster.

switch statement
A program technique that lets you evaluate an *expression* and then, based on the value of the expression, do a multiway branch to the appropriate piece of code for that value. Also called a "case structure", named after the similar Pascal construct. Most switch statements in Perl are spelled `given`. See "The given Statement" on page 133 in Chapter 4.

symbol
Generally, any *token* or *metasymbol*. Often used more specifically to mean the sort of name you might find in a *symbol table*.

symbolic debugger
A program that lets you step through the *execution* of your program, stopping or printing things out here and there to see whether anything has gone wrong, and, if so, what. The "symbolic" part just means that you can talk to the debugger using the same symbols with which your program is written.

symbolic link
An alternate filename that points to the real *filename*, which in turn points to the real *file*. Whenever the *operating system* is trying to parse a *pathname* containing a symbolic link, it merely substitutes the new name and continues parsing.

symbolic reference
A variable whose value is the name of another variable or subroutine. By *dereferencing* the first variable, you can get at the second one. Symbolic references are illegal under `use strict "refs"`.

symbol table
Where a *compiler* remembers symbols. A program like Perl must somehow remember all the names of all the *variables*, *filehandles*, and *subroutines* you've used. It does this by placing the names in a symbol table, which is implemented in Perl using a *hash table*. There is a separate symbol table for each *package* to give each package its own *namespace*.

synchronous
Programming in which the orderly sequence of events can be determined; that is, when things happen one after the other, not at the same time.

syntactic sugar
An alternative way of writing something more easily; a shortcut.

syntax
From Greek σύνταξις, "with-arrangement". How things (particularly symbols) are put together with each other.

syntax tree
: An internal representation of your program wherein lower-level *constructs* dangle off the higher-level constructs enclosing them.

syscall
: A *function* call directly to the *operating system*. Many of the important subroutines and functions you use aren't direct system calls, but are built up in one or more layers above the system call level. In general, Perl programmers don't need to worry about the distinction. However, if you do happen to know which Perl functions are really syscalls, you can predict which of these will set the `$!` (`$ERRNO`) variable on failure. Unfortunately, beginning programmers often confusingly employ the term "system call" to mean what happens when you call the Perl `system` function, which actually involves many syscalls. To avoid any confusion, we nearly always say "syscall" for something you could call indirectly via Perl's `syscall` function, and never for something you would call with Perl's `system` function.

taint checks
: The special bookkeeping Perl does to track the flow of external data through your program and disallow their use in system commands.

tainted
: Said of data derived from the grubby hands of a user, and thus unsafe for a secure program to rely on. Perl does taint checks if you run a *setuid* (or *setgid*) program, or if you use the `-T` switch.

taint mode
: Running under the `-T` switch, marking all external data as suspect and refusing to use it with system commands. See Chapter 20.

TCP
: Short for Transmission Control Protocol. A protocol wrapped around the Internet Protocol to make an unreliable packet transmission mechanism appear to the application program to be a reliable *stream* of bytes. (Usually.)

term
: Short for a "terminal"—that is, a leaf node of a *syntax tree*. A thing that functions grammatically as an *operand* for the operators in an expression.

terminator
: A *character* or *string* that marks the end of another string. The `$/` variable contains the string that terminates a `readline` operation, which `chomp` deletes from the end. Not to be confused with *delimiters* or *separators*. The period at the end of this sentence is a terminator.

ternary
: An *operator* taking three *operands*. Sometimes pronounced *trinary*.

text
: A *string* or *file* containing primarily printable characters.

thread
: Like a forked process, but without *fork*'s inherent memory protection. A thread is lighter weight than a full process, in that a process could have multiple threads running around in it, all fighting over the same process's memory space unless steps are taken to protect threads from one another.

tie
: The bond between a magical variable and its implementation class. See the `tie` function in Chapter 27 and Chapter 14.

titlecase
: The case used for capitals that are followed by lowercase characters instead of by more capitals. Sometimes called sentence case or headline case. English doesn't use Unicode titlecase, but casing rules for English titles are more complicated than simply capitalizing each word's first character.

TMTOWTDI
: There's More Than One Way To Do It, the Perl Motto. The notion that there can be

more than one valid path to solving a programming problem in context. (This doesn't mean that more ways are always better or that all possible paths are equally desirable—just that there need not be One True Way.)

token
A morpheme in a programming language, the smallest unit of text with semantic significance.

tokener
A module that breaks a program text into a sequence of *tokens* for later analysis by a parser.

tokenizing
Splitting up a program text into *tokens*. Also known as "lexing", in which case you get "lexemes" instead of tokens.

toolbox approach
The notion that, with a complete set of simple tools that work well together, you can build almost anything you want. Which is fine if you're assembling a tricycle, but if you're building a defranishizing comboflux regurgalator, you really want your own machine shop in which to build special tools. Perl is sort of a machine shop.

topic
The thing you're working on. Structures like `while(<>)`, `for`, `foreach`, and `given` set the topic for you by assigning to `$_`, the default (*topic*) variable.

transliterate
To turn one string representation into another by mapping each character of the source string to its corresponding character in the result string. Not to be confused with translation: for example, Greek *πολύχρωμος* transliterates into *polychromos* but translates into *many-colored*. See the `tr///` operator in Chapter 5.

trigger
An event that causes a *handler* to be run.

trinary
Not a stellar system with three stars, but an *operator* taking three *operands*. Sometimes pronounced *ternary*.

troff
A venerable typesetting language from which Perl derives the name of its `$%` variable and which is secretly used in the production of Camel books.

true
Any scalar value that doesn't evaluate to 0 or `""`.

truncating
Emptying a file of existing contents, either automatically when opening a file for writing or explicitly via the `truncate` function.

type
See *data type* and *class*.

type casting
Converting data from one type to another. C permits this. Perl does not need it. Nor want it.

typedef
A type definition in the C and C++ languages.

typed lexical
A *lexical variable* that is declared with a *class* type: `my Pony $bill`.

typeglob
Use of a single identifier, prefixed with `*`. For example, `*name` stands for any or all of `$name`, `@name`, `%name`, `&name`, or just `name`. How you use it determines whether it is interpreted as all or only one of them. See "Typeglobs and Filehandles" on page 86 in Chapter 2.

typemap
A description of how C types may be transformed to and from Perl types within an *extension* module written in *XS*.

UDP
User Datagram Protocol, the typical way to send *datagrams* over the Internet.

UID
: A user ID. Often used in the context of *file* or *process* ownership.

umask
: A mask of those *permission bits* that should be forced off when creating files or directories, in order to establish a policy of whom you'll ordinarily deny access to. See the `umask` function.

unary operator
: An operator with only one *operand*, like `!` or `chdir`. Unary operators are usually prefix operators; that is, they precede their operand. The `++` and `--` operators can be either prefix or postfix. (Their position *does* change their meanings.)

Unicode
: A character set comprising all the major character sets of the world, more or less. See *http://www.unicode.org*.

Unix
: A very large and constantly evolving language with several alternative and largely incompatible syntaxes, in which anyone can define anything any way they choose, and usually do. Speakers of this language think it's easy to learn because it's so easily twisted to one's own ends, but dialectical differences make tribal intercommunication nearly impossible, and travelers are often reduced to a pidgin-like subset of the language. To be universally understood, a Unix shell programmer must spend years of study in the art. Many have abandoned this discipline and now communicate via an Esperanto-like language called Perl.

  In ancient times, Unix was also used to refer to some code that a couple of people at Bell Labs wrote to make use of a PDP-7 computer that wasn't doing much of anything else at the time.

uppercase
: In Unicode, not just characters with the General Category of Uppercase Letter, but any character with the Uppercase property, including some Letter Numbers and Symbols. Not to be confused with *titlecase*.

value
: An actual piece of data, in contrast to all the variables, references, keys, indices, operators, and whatnot that you need to access the value.

variable
: A named storage location that can hold any of various kinds of *value*, as your program sees fit.

variable interpolation
: The *interpolation* of a scalar or array variable into a string.

variadic
: Said of a *function* that happily receives an indeterminate number of *actual arguments*.

vector
: Mathematical jargon for a list of *scalar values*.

virtual
: Providing the appearance of something without the reality, as in: virtual memory is not real memory. (See also *memory*.) The opposite of "virtual" is "transparent", which means providing the reality of something without the appearance, as in: Perl handles the variable-length UTF 8 character encoding transparently.

void context
: A form of *scalar context* in which an *expression* is not expected to return any *value* at all and is evaluated for its *side effects* alone.

v-string
: A "version" or "vector" *string* specified with a `v` followed by a series of decimal integers in dot notation, for instance, `v1.20.300.4000`. Each number turns into a *character* with the specified ordinal value. (The `v` is optional when there are at least three integers.)

warning
: A message printed to the `STDERR` stream to the effect that something might be wrong

but isn't worth blowing up over. See `warn` in Chapter 27 and the `warnings` pragma in Chapter 29.

watch expression
: An expression which, when its value changes, causes a breakpoint in the Perl debugger.

weak reference
: A reference that doesn't get counted normally. When all the normal references to data disappear, the data disappears. These are useful for circular references that would never disappear otherwise.

whitespace
: A *character* that moves your cursor but doesn't otherwise put anything on your screen. Typically refers to any of: space, tab, line feed, carriage return, or form feed. In Unicode, matches many other characters that Unicode considers whitespace, including the NO-BREAK SPACE.

word
: In normal "computerese", the piece of data of the size most efficiently handled by your computer, typically 32 bits or so, give or take a few powers of 2. In Perl culture, it more often refers to an alphanumeric *identifier* (including underscores), or to a string of nonwhitespace *characters* bounded by whitespace or string boundaries.

working directory
: Your current *directory*, from which relative pathnames are interpreted by the *operating system*. The operating system knows your current directory because you told it with a `chdir`, or because you started out in the place where your parent *process* was when you were born.

wrapper
: A program or subroutine that runs some other program or subroutine for you, modifying some of its input or output to better suit your purposes.

WYSIWYG
: What You See Is What You Get. Usually used when something that appears on the screen matches how it will eventually look, like Perl's `format` declarations. Also used to mean the opposite of magic because everything works exactly as it appears, as in the three-argument form of `open`.

XS
: An extraordinarily exported, expeditiously excellent, expressly eXternal Subroutine, executed in existing C or C++ or in an exciting extension language called (exasperatingly) XS.

XSUB
: An external *subroutine* defined in *XS*.

yacc
: Yet Another Compiler Compiler. A parser generator without which Perl probably would not have existed. See the file *perly.y* in the Perl source distribution.

zero width
: A subpattern *assertion* matching the *null string* between *characters*.

zombie
: A process that has died (exited) but whose parent has not yet received proper notification of its demise by virtue of having called `wait` or `waitpid`. If you `fork`, you must clean up after your child processes when they exit; otherwise, the process table will fill up and your system administrator will Not Be Happy with you.

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Colophon

The animal on the cover of *Programming Perl* is a dromedary camel.

The dromedary camel (*Camelus dromedarius*), also known as the "Arabian camel," is a one-humped, even-toed ungulate, or hooved animal. Dromedaries are the largest members of the camel family. They have been domesticated for 3,500 years, and thanks to the many adaptations that allow them to thrive in the desert, they're valued as beasts of burden.

The world's dromedary camel population is mostly domesticated, with just one known wild population, located in Australia. Domesticated dromedaries inhabit the Middle East and North Africa, where they live in herds consisting of many females among a dominant male. The dromedary's hump can store up to 80 pounds of fat, which can be broken down into water and energy, allowing it to travel in desert conditions for 100 miles without water. In addition to their ability to travel long distances in arid conditions without sustenance, dromedaries have double rows of eyelashes that keep sand out of their eyes, the ability to close their nostrils during a sandstorm, and unlike horses, they kneel for the loading of cargo and passengers. Their typical lifespan is 40 to 50 years.

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