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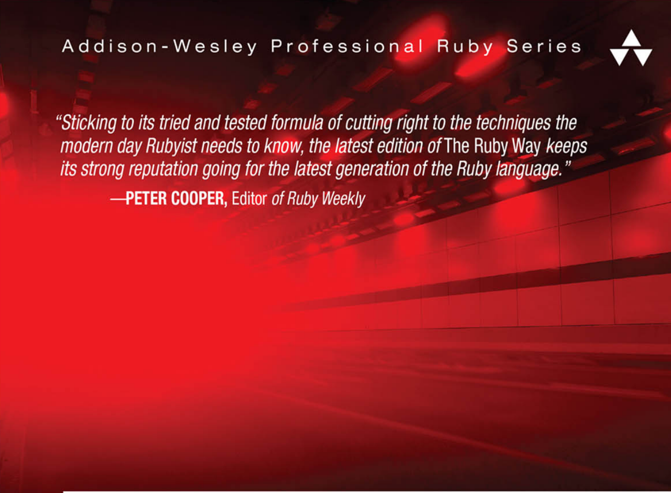

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Third Edition

Hal Fulton

with André Arko

Addison-Wesley

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To my parents, without whom I would not be possible
—Hal

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Foreword

Foreword to the Third Edition

Yesterday I was reading an article about geek fashion in `Wired.com`. According to it, wearing a Rubyconf 2012 t-shirt these days signals to people: "I work for Oracle."

Wow. How far we've come in the last 10 years!

For quite some time, using Ruby set you apart from the mainstream. Now it seems we are the mainstream. And what a long, strange journey it has been to get there.

Ruby adoption took a long time by today's standards. I read this book in 2005, and at that point, the first edition was over four years old. Ruby had just begun its second wave of adoption thanks to DHH and the start of Rails mania. It seemed like there might be a couple hundred people in the entire (English-speaking) world that used Ruby. Amazingly, at that point, the first edition of this book was already four years old. That's how ahead of its time it was.

This new edition keeps the writing style that has made the book such a hit with experienced programmers over the years. The long first chapter covers fundamental basics of object-orientation and the Ruby language. It's a must read for anyone new to the language. But it does so in concise, fast-moving narrative that assumes you already know how to create software.

From there, the chapters follow a distinctive pattern. A bit of backstory narrative, followed by rapid-fire bits of knowledge about the Ruby language. Snippets of example code are abundant and help to illuminate the concept under discussion. You can lift code samples verbatim into your programs. Especially once you get into the more practical applications chapters later in the book.

A brief bit of personal backstory seems appropriate. I owe a huge debt of gratitude to Hal for this book and the way that he wrote it. In 2005, I started work on a manuscript for Addison Wesley about the use of Ruby on Rails in the enterprise. It was my first attempt at authoring a book, and after penning about two chapters, I got stuck. Few people were using Ruby or Rails in the enterprise at that time and I had to remind myself that I was attempting to write non-fiction.

After discussing options with my editor, we determined that the best course of action might be to ditch the idea and start on a new one. *The Rails Way* was to cover the nascent Ruby on Rails framework in the style of this book. I employed terse narrative accompanying plentiful code examples. Instead of long listings, I interspersed commentary between sprinkles of code that provided just enough samples of the framework to make sense.

Like *The Ruby Way*, I aimed for breadth of coverage rather than depth. I wanted *The Rails Way* to claim permanent real estate on the desk of the serious Rails programmer. Like *The Ruby Way*, I wanted my book to be a default go-to reference. In contrast to other Rails books, I skipped tutorial material and ignored complete beginners.

And it was a huge success! Safe to say that without Hal's book, my own book would not exist and my career would have taken a less successful trajectory.

But enough congratulatory retrospective! Let's get back to the present day and the newest edition of *The Ruby Way* that you're currently reading. The immensely talented André Arko joins Hal this time around. What a great team! They deliver a painstaking revision that brings the book up to date with the latest edition of our beloved Ruby language.

My personal highlights of this edition include the following:

- A whole chapter of in-depth coverage of the new Onigmo regular expression engine. I love its beautiful and concise explanations of concepts such as positive and negative lookahead and lookbehind.
- The Internationalization chapter tackles thorny issues around String encoding and Unicode normalization. Bloggers have covered the subject in spotty fashion over the years, but having it all presented in one place is invaluable.
- The Ruby and Web Applications chapter manages to squeeze a crash-course in Rack, Sinatra, and Rails into less than 30 pages.

* Want proof of André's ingenuity? See how he cuts the load time for a real Rails app down to 500ms or less at http://andre.arko.net/2014/06/27/rails-in-05-seconds/.

I predict that this edition of *The Ruby Way* will be as successful as its predecessors. It gives me great joy to make it the latest addition to our Professional Ruby Series.

Obie Fernandez
September 15, 2014

Foreword to the Second Edition

In ancient China, people, especially philosophers, thought that something was hidden behind the world and every existence. It can never be told, nor explained, nor described in concrete words. They called it *Tao* in Chinese and *Do* in Japanese. If you translate it into English, it is the word for *Way.* It is the *Do* in Judo, Kendo, Karatedo, and Aikido. They are not only martial arts, but they also include a philosophy and a way of life.

Likewise, Ruby the programming language has its philosophy and way of thinking. It enlightens people to think differently. It helps programmers have more fun in their work. It is not because Ruby is from Japan but because programming is an important part of the human being (well, at least *some* human beings), and Ruby is designed to help people have a better life.

As always, "Tao" is difficult to describe. I feel it but have never tried to explain it in words. It's just too difficult for me, even in Japanese, my native tongue. But a guy named Hal Fulton tried, and his first try (the first edition of this book) was pretty good. This second version of his trial to describe the Tao of Ruby becomes even better with help from many people in the Ruby community. As Ruby becomes more popular (partly due to Ruby on Rails), it becomes more important to understand the secret of programmers' productivity. I hope this book helps you to become an efficient programmer.

Happy Hacking.

Yukihiro "Matz" Matsumoto
August 2006, Japan
まつもと ゆきひろ

Foreword to the First Edition

Shortly after I first met with computers in the early 80s, I became interested in programming languages. Since then I have been a "language geek." I think the reason for this interest is that programming languages are ways to express human thought. They are fundamentally human-oriented.

Despite this fact, programming languages have tended to be machine-oriented. Many languages were designed for the convenience of the computer.

But as computers became more powerful and less expensive, this situation gradually changed. For example, look at structured programming. Machines do not care whether programs are structured well; they just execute them bit by bit. Structured programming is not for machines, but for humans. This is true of object-oriented programming as well.

The time for language design focusing on humans has been coming.

In 1993, I was talking with a colleague about scripting languages, about their power and future. I felt scripting to be the way future programming should be—human-oriented.

But I was not satisfied with existing languages such as Perl and Python. I wanted a language that was more powerful than Perl and more object-oriented than Python. I couldn't find the ideal language, so I decided to make my own.

Ruby is not the simplest language, but the human soul is not simple in its natural state. It loves simplicity and complexity at the same time. It can't handle too many complex things, nor too many simple things. It's a matter of balance.

So to design a human-oriented language, Ruby, I followed the Principle of Least Surprise. I consider that everything that surprises me less is good. As a result, I feel a natural feeling, even a kind of joy, when programming in Ruby. And since the first release of Ruby in 1995, many programmers worldwide have agreed with me about the joy of Ruby programming.

As always I'd like to express my greatest appreciation to the people in the Ruby community. They are the heart of Ruby's success.

I am also thankful to the author of this book, Hal E. Fulton, for declaring the Ruby Way to help people.

This book explains the philosophy behind Ruby, distilled from my brain and the Ruby community. I wonder how it can be possible for Hal to read my mind to know and reveal this secret of the Ruby Way. I have never met him face to face; I hope to meet him soon.

I hope this book and Ruby both serve to make your programming fun and happy.

Yukihiro "Matz" Matsumoto
September 2001, Japan
まつもと ゆきひろ

Acknowledgments

Acknowledgments for the Third Edition

As can be expected by now, the process of updating this book for the third edition turned out to be somewhat monumental. Ruby has changed dramatically since the days of 1.8, and being a Ruby programmer is far more popular now than it has ever been before.

Verifying, updating, and rewriting this book took quite some time longer than expected. Ruby has progressed from 1.9 through 2.0 and 2.1, and this book has progressed through at least as many edits and rewrites along the way.

Many people contributed to making this book possible. At Addison-Wesley, Debra Williams Cauley, Songlin Qiu, Andy Beaster, and Bart Reed provided the encouragement, coordination, and editing needed to complete this edition. The contributions of Russ Olsen and André Arko were *absolutely invaluable.*

This edition was technically edited by Russ Olsen and Steve Klabnik, providing feedback and suggestions that made the book more accurate and understandable. Russ also provided the Ruby libraries and scripts that compiled the latest version of the book itself. As always, any errors are mine, not theirs.

Suggestions, code samples, or simply helpful explanations were provided by Dave Thomas, David Alan Black, Eric Hodel, Chad Fowler, Brad Ediger, Sven Fuchs, Jesse Storimer, Luke Francl, and others over the years.

Special thanks go to Paul Harrison and the rest of my colleagues at Simpli.fi for their encouragement and support.

I also wish to honor the memory of Guy Decoux and more recently Jim Weirich. Jim in particular made significant contributions to this book and to our community.

Final thanks are owed, as always, to Matz himself for creating Ruby, and to you, the reader of this book. I hope it is able to teach, inform, and maybe even amuse you.

Acknowledgments for the Second Edition

Common sense says that a second edition will only require half as much work as the first edition required. Common sense is wrong.

Even though a large part of this book came directly from the first edition, even that part had to be tweaked and tuned. Every single sentence in this book had to pass through (at the very least) a filter that asked: Is what was true in 2001 still true in 2006? And that, of course, was only the beginning.

In short, I put in many hundreds of hours of work on this second edition—nearly as much time as on the first. And yet I am "only the author."

A book is possible only through the teamwork of many people. On the publisher's side, I owe thanks to Debra Williams-Cauley, Songlin Qiu, and Mandie Frank for their hard work and infinite patience. Thanks go to Geneil Breeze for her tireless copy editing and picking bits of lint from my English. There are also others I can't name because their work was completely behind the scenes, and I never talked with them.

Technical editing was done primarily by Shashank Date and Francis Hwang. They did a great job, and I appreciate it. Errors that slipped through are my responsibility, of course.

Thanks go to the people who supplied explanations, wrote sample code, and answered numerous questions for me. These include Matz himself (Yukihiro Matsumoto), Dave Thomas, Christian Neukirchen, Chad Fowler, Curt Hibbs, Daniel Berger, Armin Roehrl, Stefan Schmiedl, Jim Weirich, Ryan Davis, Jenny W., Jim Freeze, Lyle Johnson, Martin DeMello, Matt Lawrence, the infamous *why the lucky stiff,* Ron Jeffries, Tim Hunter, Chet Hendrickson, Nathaniel Talbott, and Bil Kleb.

Special thanks goes to the heavier contributors. Andrew Johnson greatly enhanced my regular expression knowledge. Paul Battley made great contributions to the internationalization chapter. Masao Mutoh added to that same chapter and also contributed material on GTK. Austin Ziegler taught me the secrets of writing PDF files. Caleb Tennis added to the Qt material. Eric Hodel added to the Rinda and Ring material, and James Britt contributed heavily to the web development chapter.

Thanks and appreciation again must go to Matz, not only for his assistance but for creating Ruby in the first place. *Domo arigato gozaimasu*!

Again I have to thank my parents. They have encouraged me without ceasing and are looking forward to seeing this book. I will make programmers of them both yet.

And once again, I have to thank all of the Ruby community for their tireless energy, productivity, and community spirit. I particularly thank the readers of this book (in both editions). I hope you find it informative, useful, and perhaps even entertaining.

Acknowledgments for the First Edition

Writing a book is truly a team effort; this is a fact I could not fully appreciate until I wrote one myself. I recommend the experience, although it is a humbling one. It is a simple truth that without the assistance of many other people, this book would not have existed.

Thanks and appreciation must first go to Matz (Yukihiro Matsumoto), who created the Ruby language in the first place. Domo arigato gozaimasu!

Thanks goes to Conrad Schneiker for conceiving the overall idea for the book and helping to create its overall structure. He also did me the service of introducing me to the Ruby language in 1999.

Several individuals have contributed material to the body of the book. The foremost of these was Guy Hurst, who wrote substantial parts of the earlier chapters as well as two of the appendices. His assistance was absolutely invaluable.

Thanks also goes to the other contributors, whom I'll name in no particular order. Kevin Smith did a great job on the GTK section of Chapter 6, saving me from a potentially steep learning curve on a tight schedule. Patrick Logan, in the same chapter, shed light on the mysteries of the FOX GUI. Chad Fowler, in Chapter 9, plumbed the depths of XML and also contributed to the CGI section.

Thanks to those who assisted in proofreading or reviewing or in other miscellaneous ways: Don Muchow, Mike Stok, Miho Ogishima, and others already mentioned. Thanks to David Eppstein, the mathematics professor, for answering questions about graph theory.

One of the great things about Ruby is the support of the community. There were many on the mailing list and the newsgroup who answered questions and gave me ideas and assistance. Again in no particular order, these are Dave Thomas, Andy Hunt, Hee-Sob Park, Mike Wilson, Avi Bryant, Yasushi Shoji ("Yashi"), Shugo Maeda, Jim Weirich, "arton," and Masaki Suketa. I'm sorry to say I have probably overlooked someone.

To state the obvious, a book would never be published without a publisher. Many people behind the scenes worked hard to produce this book; primarily I have to thank William Brown, who worked closely with me and was a constant source of encouragement; and Scott Meyer, who delved deeply into the details of putting the material together. Others I cannot even name because I have never heard of them. You know who you are.

I have to thank my parents, who watched this project from a distance, encouraged me along the way, and even bothered to learn a little bit of computer science for my sake.

A writer friend of mine once told me, “If you write a book and nobody reads it, you haven’t really written a book.” So, finally, I want to thank the reader. This book is for you. I hope it is of some value.

About the Authors

Hal Fulton first began using Ruby in 1999. In 2001, he started work on *The Ruby Way*, which was the second Ruby book published in English. Fulton was an attendee at the very first Ruby conference in 2001 and has presented at numerous other Ruby conferences on three continents, including the first European Ruby Conference in 2003. He holds two degrees in computer science from the University of Mississippi and taught computer science for four years. He has worked for more than 25 years with various forms of UNIX and Linux. He is now at Simpli.fi in Fort Worth, Texas, where he works primarily in Ruby.

André Arko first encountered Ruby as a student in 2004, and reading the first edition of this book helped him decide to pursue a career as a Ruby programmer. He is team lead of Bundler, the Ruby dependency manager, and has created or contributes to dozens of other open source projects. He works at Cloud City Development as a consultant providing team training and expertise on Ruby and Rails as well as developing web applications.

André enjoys sharing hard-won knowledge and experience with other developers, and has spoken at over a dozen Ruby conferences on four continents. He is a regular volunteer at RailsBridge and RailsGirls programming outreach events, and works to increase diversity and inclusiveness in both the Ruby community and technology as a field. He lives in San Francisco, California.

Introduction

The way that can be named is not the true Way.

—*Lao Tse,* Tao Te Ching

The title of this book is *The Ruby Way.* This is a title that begs for a disclaimer.

It has been my aim to align this book with the philosophy of Ruby as well as I could. That has also been the aim of the other contributors. Credit for success must be shared with these others, but the blame for any mistakes must rest solely with me.

Of course, I can't presume to tell you with exactness what the spirit of Ruby is all about. That is primarily for Matz to say, and I think even he would have difficulty communicating all of it in words.

In short, *The Ruby Way* is only a book, but the Ruby Way is the province of the language creator and the community as a whole. This is something difficult to capture in a book.

Still, I have tried in this introduction to pin down a little of the ineffable spirit of Ruby. The wise student of Ruby will not take it as totally authoritative.

About the Third Edition

Everything changes, and Ruby is no exception. There are many changes and much new material in this edition. In a larger sense, every single chapter in this book is "new." I have revised and updated every one of them, making hundreds of minor changes and dozens of major changes. I deleted items that were obsolete or of lesser importance; I changed material to fit changes in Ruby itself; I added examples and commentary to every chapter.

As the second Ruby book in the English language (after *Programming Ruby*, by Dave Thomas and Andy Hunt), *The Ruby Way was* designed to be complementary to that book rather than overlap with it; that is still true today.

There have been numerous changes between Ruby 1.8, covered in the second edition, and Ruby 2.1, covered here. It's important to realize, however, that these were made with great care, over several years. Ruby is still Ruby. Much of the beauty of Ruby is derived from the fact that it changes slowly and deliberately, crafted by the wisdom of Matz and the other developers.

Today we have a proliferation of books on Ruby and more articles published than we can bother to notice. Web-based tutorials and documentation resources abound.

New tools and libraries have appeared. The most common of these seem to be tools by developers for other developers: web frameworks, blogging tools, markup tools, and interfaces to exotic data stores. But there are many others, of course—GUIs, number-crunching, web services, image manipulation, source control, and more.

Ruby editor support is widespread and sophisticated. IDEs are available that are useful and mature (and which share some overlap with the GUI builders).

It's also undeniable that the community has grown and changed. Ruby is by no means a niche language today; it is used in government departments such as NASA and NOAA, enterprise companies such as IBM and Motorola, and well-known websites such as Wikipedia, GitHub, and Twitter. It is used for graphics work, database work, numerical analysis, web development, and more. In short—and I mean this in the positive sense—Ruby has gone mainstream.

Updating this book has been a labor of love. I hope it is useful to you.

How This Book Works

You probably won't learn Ruby from this book. There is relatively little in the way of introductory or tutorial information. If you are totally new to Ruby, you might want start with another book.

Having said that, programmers are a tenacious bunch, and I grant that it might be possible to learn Ruby from this book. Chapter 1, "Ruby in Review," does contain a brief introduction and some tutorial information.

Chapter 1 also contains a comprehensive "gotcha" list (which has been difficult to keep up to date). The usefulness of this list in Chapter 1 will vary widely from one reader to another because we cannot all agree on what is intuitive.

This book is largely intended to answer questions of the form "How do I…?." As such, you can expect to do a lot of skipping around. I'd be honored if everyone read every page from front to back, but I don't expect that. It's more my expectation that you will browse the table of contents in search of techniques you need or things you find interesting.

As it turns out, I have talked to many people since the first edition, and they *did* in fact read it cover to cover. What's more, I have had more than one person report to me that they did learn Ruby here. So anything is possible.

Some things this book covers may seem elementary. That is because people vary in background and experience; what is obvious to one person may not be to another. I have tried to err on the side of completeness. On the other hand, I have tried to keep the book at a reasonable size (obviously a competing goal).

This book can be viewed as a sort of "inverted reference." Rather than looking up the name of a method or a class, you will look things up by function or purpose. For example, the `String` class has several methods for manipulating case: `capitalize`, `upcase`, `casecmp`, `downcase`, and `swapcase`. In a reference work, these would quite properly be listed alphabetically, but in this book they are all listed together.

Of course, in striving for completeness, I have sometimes wandered onto the turf of the reference books. In many cases, I have tried to compensate for this by offering more unusual or diverse examples than you might find in a reference.

I have tried for a high code-to-commentary ratio. Overlooking the initial chapter, I think I've achieved this. Writers may grow chatty, but programmers always want to see the code. (If not, they *should* want to.)

The examples here are sometimes contrived, for which I must apologize. To illustrate a technique or principle *in isolation from a real-world problem* can be difficult. However, the more complex or high level the task was, the more I attempted a real-world solution. Thus, if the topic is concatenating strings, you may find an unimaginative code fragment involving `"foo"` and `"bar"`, but when the topic is something like parsing XML, you will usually find a much more meaningful and realistic piece of code.

This book has two or three small quirks to which I'll confess up front. One is the avoidance of the "ugly" Perl-like global variables such as `$_` and the others. These are present in Ruby, and they work fine; they are used daily by most or all Ruby programmers. But in nearly all cases, their use can be avoided, and I have taken the liberty of omitting them in most of the examples.

Another quirk is that I avoid using standalone expressions when they don't have side effects. Ruby is expression oriented, and that is a good thing; I have tried to take advantage of that feature. But in a code fragment, I prefer to not write expressions that merely return a value that is not usable. For example, the expression `"abc" + "def"` can illustrate string concatenation, but I would write something like `str = "abc" + "def"` instead. This may seem wordy to some, but it may seem more natural to you if you are a C programmer who really notices when functions are void or nonvoid (or an old-time Pascal programmer who thinks in procedures and functions).

My third quirk is that I don't like the "pound" notation to denote instance methods. Many Rubyists will think I am being verbose in saying "instance method `crypt` of class `String`" rather than saying `String#crypt`, but I think no one will be confused. (Actually, I am slowly being converted to this usage, as it is obvious the pound notation is not going away.)

I have tried to include "pointers" to outside resources whenever appropriate. Time and space did not allow putting everything into this book that I wanted, but I hope I have partially made up for that by telling you where to find related materials. The ruby-doc.org and rdoc.info websites are probably the foremost of these sources; you will see them referenced many times in this book.

Here, at the front of the book, there is usually a gratuitous reference to the typefaces used for code, and how to tell code fragments from ordinary text. But I won't insult your intelligence; you've read computer books before.

I want to point out that roughly 10 percent of this book was written by other people. That does not even include tech editing and copy editing. You should read the acknowledgments in this (and every) book. Most readers skip them. Go read them now. They're good for you, like vegetables.

About the Book's Source Code

Every significant code fragment has been collected into an archive for the reader to download. Look for this archive on the informit.com site or at the book's own site, therubyway.io.

It is offered both as a `.tgz` file and as a `.zip` file. Code fragments that are very short or can't be run "out of context" will usually not appear in the archive.

What Is the "Ruby Way"?

> *Let us prepare to grapple with the ineffable itself, and see if we may not eff it after all.*
>
> —*Douglas Adams,* Dirk Gently's Holistic Detective Agency

What do we mean by the Ruby Way? My belief is that there are two related aspects: One is the philosophy of the design of Ruby; the other is the philosophy of its usage. It is natural that design and use should be interrelated, whether in software or hardware; why else should there be such a field as ergonomics? If I build a device and put a handle on it, it is because I expect someone to grab that handle.

Ruby has a nameless quality that makes it what it is. We see that quality present in the design of the syntax and semantics of the language, but it is also present in the programs written for that interpreter. Yet as soon as we make this distinction, we blur it.

Clearly Ruby is not just a tool for creating software, but it is a piece of software in its own right. Why should the workings of Ruby *programs* follow laws different from those that guide the workings of the *interpreter*? After all, Ruby is highly dynamic and extensible. There might be reasons that the two levels should differ here and there, probably for accommodating to the inconvenience of the real world. But in general, the thought processes can and should be the same. Ruby could be implemented in Ruby, in true Hofstadter-like fashion, though it is not at the time of this writing.

We don't often think of the etymology of the word *way*, but there are two important senses in which it is used. On the one hand, it means *a method or technique*, but it can also mean *a road or path*. Obviously these two meanings are interrelated, and I think when I say "the Ruby Way," I mean both of them.

So what we are talking about is a thought process, but it is also a path that we follow. Even the greatest software guru cannot claim to have reached perfection but only to follow the path. And there may be more than one path, but here I can only talk about one.

The conventional wisdom says that *form follows function*. And the conventional wisdom is, of course, conventionally correct. But Frank Lloyd Wright (speaking in his own field) once said, "Form follows function—that has been misunderstood. Form and function should be one, joined in a spiritual union."

What did Wright mean? I would say that this truth is not something you learn from a book, but from experience.

However, I would argue that Wright expressed this truth elsewhere in pieces easier to digest. He was a great proponent of simplicity, saying once, "An architect's most useful tools are an eraser at the drafting board and a wrecking bar at the site."

So, one of Ruby's virtues is simplicity. Shall I quote other thinkers on the subject? According to Antoine de St. Exupéry, "Perfection is achieved, not when there is nothing left to add, but when there is nothing left to take away."

But Ruby is a complex language. How can I say that it is simple?

If we understood the universe better, we might find a "law of conservation of complexity"—a fact of reality that disturbs our lives like entropy so that we cannot avoid it but can only redistribute it.

And that is the key. We can't avoid complexity, but we can push it around. We can bury it out of sight. This is the old "black box" principle at work; a black box performs a complex task, but it possesses simplicity *on the outside.*

If you haven't already lost patience with my quotations, a word from Albert Einstein is appropriate here: "Everything should be as simple as possible, but no simpler."

So in Ruby, we see simplicity embodied from the programmer's view (if not from the view of those maintaining the interpreter). Yet we also see the capacity for compromise. In the real world, we must bend a little. For example, every entity in a Ruby program should be a true object, but certain values such as integers are stored as immediate values. In a trade-off familiar to computer science students for decades, we have traded elegance of design for practicality of implementation. In effect, we have traded one kind of simplicity for another.

What Larry Wall said about Perl holds true: "When you say something in a small language, it comes out big. When you say something in a big language, it comes out small." The same is true for English. The reason that biologist Ernst Haeckel could say "Ontogeny recapitulates phylogeny" in only three words was that he had these powerful words with highly specific meanings at his disposal. We allow inner complexity of the language because it enables us to shift the complexity away from the individual utterance.

I would state this guideline this way: Don't write 200 lines of code when ten will do.

I'm taking it for granted that brevity is generally a good thing. A short program fragment will take up less space in the programmer's brain; it will be easier to grasp as a single entity. As a happy side effect, fewer bugs will be injected while the code is being written.

Of course, we must remember Einstein's warning about simplicity. If we put brevity too high on our list of priorities, we will end up with code that is hopelessly obfuscated. Information theory teaches us that compressed data is statistically similar to random noise; if you have looked at C or APL or regular expression notation—especially badly written—you have experienced this truth firsthand. "Simple, but not too simple"; that is the key. Embrace brevity, but do not sacrifice readability.

It is a truism that both brevity and readability are good. But there is an underlying reason for this—one so fundamental that we sometimes forget it. The reason is that computers exist for humans, not humans for computers.

In the old days, it was almost the opposite. Computers cost millions of dollars and ate electricity at the rate of many kilowatts. People acted as though the computer was a minor deity and the programmers were humble supplicants. An hour of the computer's time was more expensive than an hour of a person's time.

When computers became smaller and cheaper, high-level languages also became more popular. These were inefficient from the computer's point of view but efficient from the human perspective. Ruby is simply a later development in this line of thought. Some, in fact, have called it a *VHLL* (Very High-Level Language); though this term is not well-defined, I think its use is justified here.

The computer is supposed to be the servant, not the master, and, as Matz has said, a smart servant should do a complex task with a few short commands. This has been true through all the history of computer science. We started with machine languages and progressed to assembly language and then to high-level languages.

What we are talking about here is a shift from a *machine-centered* paradigm to a *human-centered* one. In my opinion, Ruby is an excellent example of human-centric programming.

I'll shift gears a little. There was a wonderful little book from the 1980s called *The Tao of Programming* (by Geoffrey James). Nearly every line is quotable, but I'll repeat only this: "A program should follow the 'Law of Least Astonishment.' What is this law? It is simply that the program should always respond to the user in the way that astonishes him least." (Of course, in the case of a language interpreter, the *user* is the programmer.)

I don't know whether James coined this term, but his book was my first introduction to the phrase. This is a principle that is well known and often cited in the Ruby community, though it is usually called the *Principle of Least Surprise*, or *POLS*. (I myself stubbornly prefer the acronym *LOLA*.)

Whatever you call it, this rule is a valid one, and it has been a guideline throughout the ongoing development of the Ruby language. It is also a useful guideline for those who develop libraries or user interfaces.

The only problem, of course, is that different people are surprised by different things; there is no universal agreement on how an object or method "ought" to behave. We can strive for consistency and strive to justify our design decisions, and each person can train his own intuition.

For the record, Matz has said that "least surprise" should refer to *him* as the designer. The more you think like him, the less Ruby will surprise you. And I assure you, imitating Matz is not a bad idea for most of us.

No matter how logically constructed a system may be, your intuition needs to be trained. Each programming language is a world unto itself, with its own set of assumptions, and human languages are the same. When I took German, I learned that all nouns were capitalized, but the word *deutsch* was not. I complained to my professor; after all, this was the *name* of the language, wasn't it? He smiled and said, "Don't fight it."

What he taught me was to *let German be German.* By extension, that is good advice for anyone coming to Ruby from some other language. Let Ruby be Ruby. Don't expect it to be Perl, because it isn't; don't expect it to be LISP or Smalltalk, either. On the other hand, Ruby has common elements with all three of these. Start by following your expectations, but when they are violated, don't fight it (unless Matz agrees it's a needed change).

Every programmer today knows the orthogonality principle (which would better be termed the *orthogonal completeness principle*). Suppose we have an imaginary pair of axes with a set of comparable language entities on one and a set of attributes or capabilities on the other. When we talk of "orthogonality," we usually mean that the space defined by these axes is as "full" as we can logically make it.

Part of the Ruby Way is to strive for this orthogonality. An array is in some ways similar to a hash, so the operations on each of them should be similar. The limit is reached when we enter the areas where they are different.

Matz has said that "naturalness" is to be valued over orthogonality. But to fully understand what is natural and what is not may take some thinking and some coding.

Ruby strives to be friendly to the programmer. For example, there are aliases or synonyms for many method names; `size` and `length` will both return the number of entries in an array. Some consider this sort of thing to be an annoyance or anti-feature, but I consider it a good design.

Ruby strives for consistency and regularity. There is nothing mysterious about this; in every aspect of life, we yearn for things to be regular and parallel. What makes it a little more tricky is learning when to violate this principle.

For instance, Ruby has the habit of appending a question mark (`?`) to the name of a predicate-like method. This is well and good; it clarifies the code and makes the namespace a little more manageable. But what is more controversial is the similar use of the exclamation point in marking methods that are "destructive" or "dangerous" in the sense that they modify their receivers. The controversy arises because *not all* of the destructive methods are marked in this way. Shouldn't we be consistent?

No, in fact we should not. Some of the methods by their very nature change their receiver (such as the `Array` methods `replace` and `concat`). Some of them are "writer" methods allowing assignment to a class attribute; we should *not* append an exclamation point to the attribute name or the equal sign. Some methods arguably change the state of the receiver, such as `read`; this occurs too frequently to be marked in this way. If every destructive method name ended in a `!`, our programs soon would look like sales brochures for a multilevel marketing firm.

Do you notice a kind of tension between opposing forces, a tendency for all rules to be violated? Let me state this as Fulton's Second Law: *Every rule has an exception, except Fulton's Second Law.* (Yes, there is a joke there, a very small one.)

What we see in Ruby is not a "foolish consistency" nor a rigid adherence to a set of simple rules. In fact, perhaps part of the Ruby Way is that it is *not* a rigid and inflexible approach. In language design, as Matz once said, you should "follow your heart."

Yet another aspect of the Ruby philosophy is, do *not fear change at runtime; do not fear what is dynamic.* The world is dynamic; why should a programming language be static? Ruby is one of the most dynamic languages in existence.

I would also argue that another aspect is, do not be a slave to performance issues. When performance is unacceptable, the issue must be addressed, but it should normally not be the first thing you think about. Prefer elegance over efficiency where efficiency is less than critical. Then again, if you are writing a library that may be used in unforeseen ways, performance may be critical from the start.

When I look at Ruby, I perceive a balance between different design goals, a complex interaction reminiscent of the *n*-body problem in physics. I can imagine it might be modeled as an Alexander Calder mobile. It is perhaps this interaction itself, the harmony, that embodies Ruby's philosophy rather than just the individual parts. Programmers know that their craft is not just science and technology but art. I hesitate to say that there is a spiritual aspect to computer science, but just between you and me, there certainly is. (If you have not read Robert Pirsig's *Zen and the Art of Motorcycle Maintenance*, I recommend that you do so.)

Ruby arose from the human urge to create things that are useful and beautiful. Programs written in Ruby should spring from the same source. That, to me, is the essence of the Ruby Way.

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CHAPTER 2

Working with Strings

Atoms were once thought to be fundamental, elementary building blocks of nature; protons were then thought to be fundamental, then quarks. Now we say the string is fundamental.

—David Gross, professor of theoretical physics, Princeton University

A computer science professor in the early 1980s started out his data structures class with a single question. He didn't introduce himself or state the name of the course; he didn't hand out a syllabus or give the name of the textbook. He walked to the front of the class and asked, "What is the most important data type?"

There were one or two guesses. Someone guessed "pointers," and he brightened but said no, that wasn't it. Then he offered his opinion: The most important data type was *character* data.

He had a valid point. Computers are supposed to be our servants, not our masters, and character data has the distinction of being human readable. (Some humans can read binary data easily, but we will ignore them.) The existence of characters (and therefore strings) enables communication between humans and computers. Every kind of information we can imagine, including natural language text, can be encoded in character strings.

A *string* is simply a sequence of characters. Like most entities in Ruby, strings are first-class objects. In everyday programming, we need to manipulate strings in many ways. We want to concatenate strings, tokenize them, analyze them, perform searches and substitutions, and more. Ruby makes most of these tasks easy.

For much of the history of Ruby, a single byte was considered a character. That is not true of special characters, emoji, and most non-Latin scripts. For a more detailed discussion of the ways that bytes and characters are often not the same, refer to Chapter 4, "Internationalization in Ruby."

2.1 Representing Ordinary Strings

A string in Ruby is composed simply of a sequence of 8-bit bytes. It is not null terminated as in C, so it may contain null characters. Strings containing bytes above 0xFF are always legal, but are only meaningful in non-ASCII encodings. Strings are assumed to use the UTF-8 encoding. Before Ruby 2.0, they were assumed to be simple ASCII. (For more information on encodings, refer to Chapter 4.)

The simplest string in Ruby is single quoted. Such a string is taken absolutely literally; the only escape sequences recognized are the single quote (`\'`) and the escaped backslash itself (`\\`). Here are some examples:

```
s1 = 'This is a string'    # This is a string
s2 = 'Mrs. O\'Leary'       # Mrs. O'Leary
s3 = 'Look in C:\\TEMP'    # Look in C:\TEMP
```

A double-quoted string is more versatile. It allows many more escape sequences, such as backspace, tab, carriage return, and linefeed. It allows control characters to be embedded as octal numbers, and Unicode code points to be embedded via their hexadecimal reference number. Consider these examples:

```
s1 = "This is a tab: (\t)"
s2 = "Some backspaces: xyz\b\b\b"
s3 = "This is also a tab: \011"
s4 = "And these are both bells: \a \007"
s5 = "This is the unicode snowman: \u2603"
```

Non-ASCII characters will be shown "backslash escaped" when their string is inspected, but will print normally. Double-quoted strings also allow expressions to be embedded inside them. See Section 2.21, "Embedding Expressions within Strings."

2.2 Representing Strings with Alternate Notations

Sometimes we want to represent strings that are rich in metacharacters, such as single quotes, double quotes, and more. For these situations, we have the %q and %Q notations. Following either of these is a string within a pair of delimiters; I personally favor square brackets ([ ]).

The difference between the %q and %Q variants is that the former acts like a single-quoted string, and the latter like a double-quoted string:

```
S1 = %q[As Magritte said, "Ceci n'est pas une pipe."]
s2 = %q[This is not a tab: (\t)]  # same as: 'This is not a tab: \t'
s3 = %Q[This IS a tab: (\t)]      # same as: "This IS a tab: \t"
```

Both kinds of notation can be used with different delimiters. Besides brackets, there are other paired delimiters (parentheses, braces, and angle brackets):

```
s1 = %q(Bill said, "Bob said, 'This is a string.'")
s2 = %q{Another string.}
s3 = %q<Special characters '"[](){} in this string.>
```

There are also “nonpaired” delimiters. Basically any character may be used that is printable, but not alphanumeric, not whitespace, and not a paired character:

```
s1 = %q:"I think Mrs. O'Leary's cow did it," he said.:
s2 = %q*\r is a control-M and \n is a control-J.*
```

2.3 Using Here-Documents

If you want to represent a long string spanning multiple lines, you can certainly use a regular quoted string:

```
str = "Once upon a midnight dreary,
       While I pondered, weak and weary..."
```

However, the indentation will be part of the string.

Another way is to use a *here-document,* a string that is inherently multiline. (This concept and term are borrowed from older languages and contexts.) The syntax is the << symbol, followed by an end marker, then zero or more lines of text, and finally the same end marker on a line by itself:

```
str = <<EOF
Once upon a midnight dreary,
While I pondered weak and weary,...
EOF
```

Be careful about things such as trailing spaces on the final end marker line. Current versions of Ruby will fail to recognize the end marker in those situations.

Note that here-documents may be "stacked"; for example, here is a method call with three such strings passed to it:

```
some_method(<<STR1, <<STR2, <<STR3)
first piece
of text...
STR1
second piece...
STR2
third piece
of text.
STR3
```

By default, a here-document is like a double-quoted string—that is, its contents are subject to interpretation of escape sequences and interpolation of embedded expressions. But if the end marker is single-quoted, the here-document behaves like a single-quoted string:

```
str = <<'EOF'
This isn't a tab: \t
and this isn't a newline: \n
EOF
```

If a here-document's end marker is preceded by a hyphen, the end marker may be indented. *Only* the spaces before the end marker are deleted from the string, not those on previous lines:

```
str = <<-EOF
  Each of these lines
  starts with a pair
  of blank spaces.
  EOF
```

To delete the spaces from the beginning of each line, we need another method. The `ActiveSupport` gem (included in Rails) defines a `strip_heredoc` method that works similarly to this one:

```
class String
  def strip_heredoc
    # Find the margin whitespace on the first line
    margin = self[/\A\s*/]
    # Remove margin-sized whitespace from each line
    gsub(/\s{#{margin.size}}/,"")
  end
end
```

The amount of whitespace before the start of the first line is detected, and that amount of whitespace is then stripped off of each line. It's used in this way:

```
str = <<end.strip_heredoc
  This here-document has a "left margin"
  set by the whitespace on the first line.

  We can do inset quotations here,
  hanging indentions, and so on.
end
```

The word *end* is used naturally enough as an end marker. (This, of course, is a matter of taste. It looks like the reserved word `end` but is really just an arbitrary marker.) Many text editors use the end marker as a hint for syntax highlighting. As a result, using `<<SQL` or `<<RUBY` can make it dramatically easier to read blocks of code inside here-docs in those editors.

2.4 Finding the Length of a String

The method `length` can be used to find a string's length. A synonym is `size`:

```
str1 = "Carl"
x = str1.length     # 4
str2 = "Doyle"
x = str2.size       # 5
```

2.5 Processing a Line at a Time

A Ruby string can contain newlines. For example, a file can be read into memory and stored in a single string. Strings provide an iterator, `each_line`, to process a string one line at a time:

```
str = "Once upon\na time...\nThe End\n"
num = 0
str.each_line do |line|
  num += 1
  print "Line #{num}: #{line}"
end
```

The preceding code produces three lines of output:

```
Line 1: Once upon
Line 2: a time...
Line 3: The End
```

Iterators (such as `each_line`) can be chained together with other iterators (such as `with_index`). Connecting function outputs and inputs in a line like this is a technique sometimes called *function composition* (or *method chaining*). Instead of tracking the line number manually, `with_index` can be *composed* with `each_line` to produce the exact same output:

```
str = "Once upon\na time...\nThe End\n"
str.each_line.with_index do |line, num|
  print "Line #{num + 1}: #{line}"
end
```

2.6 Processing a Character or Byte at a Time

Ruby used to treat each byte as a character, but that is no longer the case. The bytes in a string are available as an array via the `bytes` method. To process the bytes, one at a time, use the `each_byte` iterator:

```
str = "ABC"
str.each_byte {|byte| print byte, " " }
puts
# Produces output: 65 66 67
```

A character is essentially the same as a one-character string. In multibyte encodings, a one-character string may be more than one byte:

```
str = "ABC"
str.each_char {|char| print char, " " }
puts
# Produces output: A B C
```

In any version of Ruby, you can break a string into an array of one-character strings by using scan with a simple wildcard regular expression matching a single character:

```
str = "ABC"
chars = str.scan(/./)
chars.each {|char| print char, " " }
puts
# Produces output: A B C
```

2.7 Performing Specialized String Comparisons

Ruby has built-in ideas about comparing strings; comparisons are done lexicographically, as we have come to expect (that is, based on character set order). But if we want, we can introduce rules of our own for string comparisons, and these can be of arbitrary complexity.

For example, suppose that we want to ignore the English articles *a*, *an*, and *the* at the front of a string, and we also want to ignore most common punctuation marks. We can do this by overriding the built-in method <=> (which is called for <, <=, >, and >=). Listing 2.1 shows how we do this.

Listing 2.1 Specialized String Comparisons

```
class String

  alias old_compare <=>

  def <=>(other)
    a = self.dup
    b = other.dup
    # Remove punctuation
    a.gsub!(/[\,\.\?\!\:\;]/, "")
    b.gsub!(/[\,\.\?\!\:\;]/, "")
    # Remove initial articles
    a.gsub!(/^(a |an |the )/i, "")
    b.gsub!(/^(a |an |the )/i, "")
    # Remove leading/trailing whitespace
    a.strip!
    b.strip!
    # Use the old <=>
    a.old_compare(b)
  end

end


title1 = "Calling All Cars"
title2 = "The Call of the Wild"

# Ordinarily this would print "yes"

if title1 < title2
  puts "yes"
else
  puts "no"         # But now it prints "no"
end
```

Note that we "save" the old <=> with an alias and then call it at the end. This is because if we tried to use the < method, it would call the new <=> rather than the old one, resulting in infinite recursion and a program crash.

Note also that the == operator does not call the <=> method (mixed in from `Comparable`). This means that if we need to check equality in some specialized way, we will have to override the == method separately. But in this case, == works as we want it to anyhow.

Suppose that we wanted to do case-insensitive string comparisons. The built-in method `casecmp` will do this; we just have to make sure that it is used instead of the usual comparison.

Here is one way:

```
class String
  def <=>(other)
    casecmp(other)
  end
end
```

But there is a slightly easier way:

```
class String
  alias <=> casecmp
end
```

However, we haven't finished. We need to redefine == so that it will behave in the same way:

```
class String
  def ==(other)
    casecmp(other) == 0
  end
end
```

Now all string comparisons will be strictly case insensitive. Any sorting operation that depends on <=> will likewise be case insensitive.

2.8 Tokenizing a String

The `split` method parses a string and returns an array of tokenized strings. It accepts two parameters: a delimiter and a field limit (which is an integer).

The delimiter defaults to whitespace. Actually, it uses `$;` or the English equivalent `$FIELD_SEPARATOR`. If the delimiter is a string, the explicit value of that string is used as a token separator:

```
s1 = "It was a dark and stormy night."
words = s1.split          # ["It", "was", "a", "dark", "and",
                          #  "stormy", "night"]
s2 = "apples, pears, and peaches"
list = s2.split(", ")     # ["apples", "pears", "and peaches"]

s3 = "lions and tigers and bears"
zoo = s3.split(/ and /)   # ["lions", "tigers", "bears"]
```

The `limit` parameter places an upper limit on the number of fields returned, according to these rules:

- If it is omitted, trailing null entries are suppressed.
- If it is a positive number, the number of entries will be limited to that number (stuffing the rest of the string into the last field as needed). Trailing null entries are retained.

- If it is a negative number, there is no limit to the number of fields, and trailing null entries are retained.

These three rules are illustrated here:

```
str = "alpha,beta,gamma,,"
list1 = str.split(",")     # ["alpha","beta","gamma"]
list2 = str.split(",",2)   # ["alpha", "beta,gamma,,"]
list3 = str.split(",",4)   # ["alpha", "beta", "gamma", ","]
list4 = str.split(",",8)   # ["alpha", "beta", "gamma", "", ""]
list5 = str.split(",",-1)  # ["alpha", "beta", "gamma", "", ""]
```

Similarly, the `scan` method can be used to match regular expressions or strings against a target string:

```
str = "I am a leaf on the wind..."

# A string is interpreted literally, not as a regex
arr = str.scan("a")   # ["a","a","a"]

# A regex will return all matches
arr = str.scan(/\w+/)
# ["I", "am", "a", "leaf", "on", "the", "wind"]

# A block will be passed each match, one at a time
str.scan(/\w+/) {|x| puts x }
```

The `StringScanner` class, from the standard library, is different in that it maintains state for the scan rather than doing it all at once:

```
require 'strscan'
str = "Watch how I soar!"
ss = StringScanner.new(str)
loop do
  word = ss.scan(/\w+/)    # Grab a word at a time
  break if word.nil?
  puts word
  sep = ss.scan(/\W+/)     # Grab next non-word piece
  break if sep.nil?
end
```

2.9 Formatting a String

Formatting a string is done in Ruby as it is in C: with the sprintf method. It takes a string and a list of expressions as parameters and returns a string. The format string contains essentially the same set of specifiers available with C's sprintf (or printf):

```
name = "Bob"
age = 28
str = sprintf("Hi, %s... I see you're %d years old.", name, age)
```

You might ask why we would use this instead of simply interpolating values into a string using the #{expr} notation. The answer is that sprintf makes it possible to do extra formatting, such as specifying a maximum width, specifying a maximum number of decimal places, adding or suppressing leading zeroes, left-justifying, right-justifying, and more:

```
str = sprintf("%-20s  %3d", name, age)
```

The String class has the method %, which does much the same thing. It takes a single value or an array of values of any type:

```
str = "%-20s  %3d" % [name, age]  # Same as previous example
```

We also have the methods ljust, rjust, and center; these take a length for the destination string and pad with spaces as needed:

```
str = "Moby-Dick"
s1 = str.ljust(13)           # "Moby-Dick"
s2 = str.center(13)          # "  Moby-Dick  "
s3 = str.rjust(13)           # "    Moby-Dick"
```

If a second parameter is specified, it is used as the pad string (which may possibly be truncated as needed):

```
str = "Captain Ahab"
s1 = str.ljust(20,"+")       # "Captain Ahab++++++++"
s2 = str.center(20,"-")      # "----Captain Ahab----"
s3 = str.rjust(20,"123")     # "12312312Captain Ahab"
```

2.10 Using Strings as IO Objects

Besides `sprintf` and `scanf`, there is another way to fake input/output to a string—the `StringIO` class.

Because this is a very IO-like object, we cover it in a later chapter. See Section 10.1.24, "Treating a String as a File."

2.11 Controlling Uppercase and Lowercase

Ruby's `String` class offers a rich set of methods for controlling case. This section offers an overview of these.

The `downcase` method converts a string to all lowercase. Likewise, `upcase` converts it to all uppercase. Here is an example each:

```
s1 = "Boston Tea Party"
s2 = s1.downcase              # "boston tea party"
s3 = s2.upcase                # "BOSTON TEA PARTY"
```

The `capitalize` method capitalizes the first character of a string while forcing all the remaining characters to lowercase:

```
s4 = s1.capitalize            # "Boston tea party"
s5 = s2.capitalize            # "Boston tea party"
s6 = s3.capitalize            # "Boston tea party"
```

The `swapcase` method exchanges the case of each letter in a string:

```
s7 = "THIS IS AN ex-parrot."
s8 = s7.swapcase              # "this is an EX-PARROT."
```

There is also the `casecmp` method, which acts like the `<=>` method but ignores case:

```
n1 = "abc".casecmp("xyz")     # -1
n2 = "abc".casecmp("XYZ")     # -1
n3 = "ABC".casecmp("xyz")     # -1
n4 = "ABC".casecmp("abc")     # 0
n5 = "xyz".casecmp("abc")     # 1
```

Each of these also has an in-place equivalent (upcase!, downcase!, capitalize!, and swapcase!).

There are no built-in methods for detecting case, but this is easy to do with regular expressions, as shown in the following example:

```
if string =~ /[a-z]/
  puts "string contains lowercase characters"
end

if string =~ /[A-Z]/
  puts "string contains uppercase characters"
end

if string =~ /[A-Z]/ and string =~ /a-z/
  puts "string contains mixed case"
end

if string[0..0] =~ /[A-Z]/
  puts "string starts with a capital letter"
end
```

Regular expressions of this sort will only match ASCII characters. To match Unicode uppercase or lowercase characters, use a named character class, as shown here:

```
if string =~ /\p{Upper}/
  puts "string contains uppercase Unicode characters like Ü"
end
```

For more information about regular expressions, see Chapter 3, "Working with Regular Expressions."

2.12 Accessing and Assigning Substrings

In Ruby, substrings may be accessed in several different ways. Normally the bracket notation is used, as for an array, but the brackets may contain a pair of Fixnums, a range, a regex, or a string. Each case is discussed in turn.

If a pair of Fixnum values is specified, they are treated as an offset and a length, and the corresponding substring is returned:

```
str = "Humpty Dumpty"
sub1 = str[7,4]         # "Dump"
sub2 = str[7,99]        # "Dumpty" (overrunning is OK)
sub3 = str[10,-4]       # nil (length is negative)
```

It is important to remember that these are an offset and a length (number of characters), not beginning and ending offsets.

A negative index counts backward from the end of the string. In this case, the index is one based, not zero based, but the length is still added in the forward direction:

```
str1 = "Alice"
sub1 = str1[-3,3]   # "ice"
str2 = "Through the Looking-Glass"
sub3 = str2[-13,4]  # "Look"
```

A range may be specified. In this case, the range is taken as a range of indices into the string. Ranges may have negative numbers, but the numerically lower number must still be first in the range. If the range is "backward" or if the initial value is outside the string, `nil` is returned, as shown here:

```
str = "Winston Churchill"
sub1 = str[8..13]    # "Church"
sub2 = str[-4..-1]   # "hill"
sub3 = str[-1..-4]   # nil
sub4 = str[25..30]   # nil
```

If a regular expression is specified, the string matching that pattern will be returned. If there is no match, `nil` will be returned:

```
str = "Alistair Cooke"
sub1 = str[/l..t/]   # "list"
sub2 = str[/s.*r/]   # "stair"
sub3 = str[/foo/]    # nil
```

If a string is specified, that string will be returned if it appears as a substring (or `nil` if it does not):

```
str = "theater"
sub1 = str["heat"]  # "heat"
sub2 = str["eat"]   # "eat"
```

```
sub3 = str["ate"]   # "ate"
sub4 = str["beat"]  # nil
sub5 = str["cheat"] # nil
```

Finally, in the trivial case, using a `Fixnum` as the index will yield a single character (or `nil` if out of range):

```
str = "Aaron Burr"
ch1 = str[0]     # "A"
ch1 = str[1]     # "a"
ch3 = str[99]    # nil
```

It is important to realize that the notations described here will serve for assigning values as well as for accessing them:

```
str1 = "Humpty Dumpty"
str1[7,4] = "Moriar"     # "Humpty Moriarty"

str2 = "Alice"
str2[-3,3] = "exandra"   # "Alexandra"

str3 = "Through the Looking-Glass"
str3[-13,13]  = "Mirror" # "Through the Mirror"

str4 = "Winston Churchill"
str4[8..13] = "H"        # "Winston Hill"

str5 = "Alistair Cooke"
str5[/e$/] ="ie Monster" # "Alistair Cookie Monster"

str6 = "theater"
str6["er"] = "re"        # "theatre"

str7 = "Aaron Burr"
str7[0] = "B"            # "Baron Burr"
```

Assigning to an expression evaluating to `nil` will have no effect.

2.13 Substituting in Strings

We've already seen how to perform simple substitutions in strings. The sub and gsub methods provide more advanced pattern-based capabilities. There are also sub! and gsub!, their in-place counterparts.

The sub method substitutes the first occurrence of a pattern with the given substitute-string or the given block:

```
s1 = "spam, spam, and eggs"
s2 = s1.sub(/spam/,"bacon")
# "bacon, spam, and eggs"

s3 = s2.sub(/(\w+), (\w+),/,'\2, \1,')
# "spam, bacon, and eggs"

s4 = "Don't forget the spam."
s5 = s4.sub(/spam/) { |m| m.reverse }
# "Don't forget the maps."

s4.sub!(/spam/) { |m| m.reverse }
# s4 is now "Don't forget the maps."
```

As this example shows, the special symbols \1, \2, and so on may be used in a substitute string. However, special variables (such as $& or its English equivalent $MATCH) may not.

If the block form is used, the special variables may be used. However, if all you need is the matched string, it will be passed into the block as a parameter. If it is not needed at all, the parameter can of course be omitted.

The gsub method (global substitution) is essentially the same except that all matches are substituted rather than just the first:

```
s5 = "alfalfa abracadabra"
s6 = s5.gsub(/a[bl]/,"xx")     # "xxfxxfa xxracadxxra"
s5.gsub!(/[lfdbr]/) { |m| m.upcase + "-" }
# s5 is now "aL-F-aL-F-a aB-R-acaD-aB-R-a"
```

The method Regexp.last_match is essentially identical to $& or $MATCH.

2.14 Searching a String

Besides the techniques for accessing substrings, there are other ways of searching within strings. The index method returns the starting location of the specified substring, character, or regex. If the item is not found, the result is nil:

```
str = "Albert Einstein"
pos1 = str.index(?E)        # 7
pos2 = str.index("bert")    # 2
pos3 = str.index(/in/)      # 8
pos4 = str.index(?W)        # nil
pos5 = str.index("bart")    # nil
pos6 = str.index(/wein/)    # nil
```

The method rindex (right index) starts from the right side of the string (that is, from the end). The numbering, however, proceeds from the beginning, as usual:

```
str = "Albert Einstein"
pos1 = str.rindex(?E)       # 7
pos2 = str.rindex("bert")   # 2
pos3 = str.rindex(/in/)     # 13 (finds rightmost match)
pos4 = str.rindex(?W)       # nil
pos5 = str.rindex("bart")   # nil
pos6 = str.rindex(/wein/)   # nil
```

The include? method, shown next, simply tells whether the specified substring or character occurs within the string:

```
str1 = "mathematics"
flag1 = str1.include? ?e         # true
flag2 = str1.include? "math"     # true
str2 = "Daylight Saving Time"
flag3 = str2.include? ?s         # false
flag4 = str2.include? "Savings"  # false
```

The scan method repeatedly scans for occurrences of a pattern. If called without a block, it returns an array. If the pattern has more than one (parenthesized) group, the array will be nested:

```
str1 = "abracadabra"
sub1 = str1.scan(/a./)
# sub1 now is ["ab","ac","ad","ab"]
```

```
str2 = "Acapulco, Mexico"
sub2 = str2.scan(/(.)(c.)/)
# sub2 now is [ ["A","ca"], ["l","co"], ["i","co"] ]
```

If a block is specified, the method passes the successive values to the block, as shown here:

```
str3 = "Kobayashi"
str3.scan(/[^aeiou]+[aeiou]/) do |x|
  print "Syllable: #{x}\n"
end
```

This code produces the following output:

```
Syllable: Ko
Syllable: ba
Syllable: ya
Syllable: shi
```

2.15 Converting Between Characters and ASCII Codes

Single characters in Ruby are returned as one-character strings. Here is an example:

```
str = "Martin"
print str[0]        # "M"
```

The `Integer` class has a method called `chr` that will convert an integer to a character. By default, integers will be interpreted as ASCII, but other encodings may be specified for values greater than 127. The `String` class has an `ord` method that is in effect an inverse:

```
str = 77.chr            # "M"
s2  = 233.chr("UTF-8")  # "é"
num = "M".ord           # 77
```

2.16 Implicit and Explicit Conversion

At first glance, the `to_s` and `to_str` methods seem confusing. They both convert an object into a string representation, don't they?

There are several differences, however. First, *any* object can in principle be converted to some kind of string representation; that is why nearly every core class has a `to_s` method. But the `to_str` method is never implemented in the core.

As a rule, `to_str` is for objects that are really very much like strings—that can "masquerade" as strings. Better yet, think of the short name `to_s` as being *explicit conversion* and the longer name `to_str` as being *implicit conversion.*

You see, the core does not *define* any `to_str` methods. But core methods do *call* `to_str` sometimes (if it exists for a given class).

The first case we might think of is a *subclass* of `String`; but, in reality, any object of a subclass of `String` already "is a" `String`, so `to_str` is unnecessary there.

In real life, `to_s` and `to_str` usually return the same value, but they don't have to do so. The implicit conversion should result in the "real string value" of the object; the explicit conversion can be thought of as a "forced" conversion.

The `puts` method calls an object's `to_s` method in order to find a string representation. This behavior might be thought of as an implicit call of an explicit conversion. The same is true for string interpolation. Here's a crude example:

```
class Helium
  def to_s
    "He"
  end

  def to_str
    "helium"
  end
end

e = Helium.new
print "Element is "
puts e                    # Element is He
puts "Element is " + e    # Element is helium
puts "Element is #{e}"    # Element is He
```

So you can see how defining these appropriately in your own classes can give you a little extra flexibility. But what about honoring the definitions of the objects passed into your methods?

For example, suppose that you have a method that is "supposed" to take a `String` as a parameter. Despite our "duck typing" philosophy, this is frequently done and is often completely appropriate. For example, the first parameter of `File.new` is "expected" to be a string.

The way to handle this is simple. When you expect a string, check for the existence of to_str and call it as needed:

```
def set_title(title)
  if title.respond_to? :to_str
    title = title.to_str
  end
  # ...
end
```

Now, what if an object *doesn't* respond to to_str? We could do several things. We could force a call to to_s, we could check the class to see whether it is a String or a subclass thereof, or we could simply keep going, knowing that if we apply some meaningless operation to this object, we will eventually get an ArgumentError anyway.

A shorter way to do this is

```
title = title.to_str if title.respond_to?(:to_str)
```

which replaces the value of title only if it has a to_str method.

Double-quoted string interpolation will implicitly call to_s, and is usually the easiest way to turn multiple objects into strings at once:

```
e = Helium.new
str = "Pi #{3.14} and element #{e}
# str is now "3.14 and element He"
```

Implicit conversion *would* allow you to make strings and numbers essentially equivalent. You could, for example, do this:

```
class Fixnum
  def to_str
    self.to_s
  end
end

str = "The number is " + 345     # The number is 345
```

However, I don't recommend this sort of thing. There is such a thing as "too much magic"; Ruby, like most languages, considers strings and numbers to be different, and I believe that most conversions should be explicit for the sake of clarity.

There is nothing *magical* about the `to_str` method. It is intended to return a string, but if you code your own, it is your responsibility to see that it does.

2.17 Appending an Item onto a String

The append operator (<<) can be used to append a string onto another string. It is "stackable" in that multiple operations can be performed in sequence on a given receiver:

```
str = "A"
str << [1,2,3].to_s << " " << (3.14).to_s
# str is now "A123 3.14"
```

2.18 Removing Trailing Newlines and Other Characters

Often we want to remove extraneous characters from the end of a string. The prime example is a newline on a string read from input.

The `chop` method removes the last character of the string (typically a trailing newline character). If the character before the newline is a carriage return (`\r`), it will be removed also. The reason for this behavior is the discrepancy between different systems' conceptions of what a newline is. On systems such as UNIX, the newline character is represented internally as a linefeed (`\n`). On others, such as Windows, it is stored as a carriage return followed by a linefeed (`\r\n`):

```
str = gets.chop         # Read string, remove newline
s2 = "Some string\n"    # "Some string" (no newline)
s3 = s2.chop!           # s2 is now "Some string" also
s4 = "Other string\r\n"
s4.chop!                # "Other string" (again no newline)
```

Note that the "in-place" version of the method (`chop!`) will modify its receiver.

It is also important to note that in the absence of a trailing newline, the last character will be removed anyway:

```
str = "abcxyz"
s1 = str.chop           # "abcxy"
```

Because a newline may not always be present, the chomp method may be a better alternative:

```
str = "abcxyz"
str2 = "123\n"
str3 = "123\r"
str4 = "123\r\n"
s1 = str.chomp          # "abcxyz"
s2 = str2.chomp         # "123"
# With the default record separator, \r and \r\n are removed
# as well as \n
s3 = str3.chomp         # "123"
s4 = str4.chomp         # "123"
```

There is also a chomp! method, as we would expect.

If a parameter is specified for chomp, it will remove the set of characters specified from the end of the string rather than the default record separator. Note that if the record separator appears in the middle of the string, it is ignored, as shown here:

```
str1 = "abcxyz"
str2 = "abcxyz"
s1 = str1.chomp("yz")   # "abcx"
s2 = str2.chomp("x")    # "abcxyz"
```

2.19 Trimming Whitespace from a String

The strip method removes whitespace from the beginning and end of a string, whereas its counterpart, strip!, modifies the receiver in place:

```
str1 = "\t  \nabc  \t\n"
str2 = str1.strip         # "abc"
str3 = str1.strip!        # "abc"
# str1 is now "abc" also
```

Whitespace, of course, consists mostly of blanks, tabs, and end-of-line characters.

If we want to remove whitespace only from the beginning or end of a string, we can use the lstrip and rstrip methods:

```
str = "  abc  "
s2 = str.lstrip       # "abc  "
s3 = str.rstrip       # "  abc"
```

There are in-place variants (`rstrip!` and `lstrip!`) also.

2.20 Repeating Strings

In Ruby, the multiplication operator (or method) is overloaded to enable repetition of strings. If a string is multiplied by *n,* the result is *n* copies of the original string concatenated together. Here is an example:

```
etc = "Etc. "*3                       # "Etc. Etc. Etc. "
ruler = "+" + ("."*4+"5"+"."*4+"+")*3
# "+....5....+....5....+....5....+"
```

2.21 Embedding Expressions within Strings

The `#{}` notation makes embedding expressions within strings easy. We need not worry about converting, appending, and concatenating; we can interpolate a variable value or other expression at any point in a string:

```
puts "#{temp_f} Fahrenheit is #{temp_c} Celsius"
puts "The discriminant has the value #{b*b - 4*a*c}."
puts "#{word} is #{word.reverse} spelled backward."
```

Bear in mind that full statements can also be used inside the braces. The last evaluated expression will be the one returned:

```
str = "The answer is #{ def factorial(n)
                          n==0 ? 1 : n*factorial(n-1)
                        end

                        answer = factorial(3) * 7}, of course."
# The answer is 42, of course.
```

There are some shortcuts for global, class, and instance variables, in which case the braces can be dispensed with:

```
puts "$gvar = #$gvar and ivar = #@ivar."
```

Note that this technique is not applicable for single-quoted strings (because their contents are not expanded), but it does work for double-quoted here-documents and regular expressions.

2.22 Delayed Interpolation of Strings

Sometimes we might want to delay the interpolation of values into a string. There is no perfect way to do this.

A naive approach is to store a single-quoted string and then evaluate it:

```
str = '#{name} is my name, and #{nation} is my nation.'
name, nation = "Stephen Dedalus", "Ireland"
s1  = eval('"' + str + '"')
# Stephen Dedalus is my name, and Ireland is my nation.
```

However, using `eval` is almost always the worst option. Any time you use `eval`, you are opening yourself up to many problems, including extremely slow execution and unexpected security vulnerabilities, so it should be avoided if at all possible.

A much less dangerous way is to use a block:

```
str = proc do |name, nation|
 "#{name} is my name, and #{nation} is my nation."
end
s2 = str.call("Gulliver Foyle", "Terra")
# Gulliver Foyle is my name, and Terra is my nation.
```

2.23 Parsing Comma-Separated Data

The use of comma-delimited data is common in computing. It is a kind of "lowest common denominator" of data interchange used (for example) to transfer information between incompatible databases or applications that know no other common format.

We assume here that we have a mixture of strings and numbers and that all strings are enclosed in quotes. We further assume that all characters are escaped as necessary (commas and quotes inside strings, for example).

The problem becomes simple because this data format looks suspiciously like a Ruby array of mixed types. In fact, we can simply add brackets to enclose the whole expression, and we have an array of items:

```
string = gets.chop!
# Suppose we read in a string like this one:
# "Doe, John", 35, 225, "5'10\"", "555-0123"
data = eval("[" + string + "]")   # Convert to array
data.each {|x| puts "Value = #{x}"}
```

This fragment produces the following output:

```
Value = Doe, John
Value = 35
Value = 225
Value = 5' 10"
Value = 555-0123
```

For a more heavy-duty solution, refer to the CSV library (which is a standard library).

2.24 Converting Strings to Numbers (Decimal and Otherwise)

Basically there are two ways to convert strings to numbers: the `Kernel` method `Integer` and `Float` and the `to_i` and `to_f` methods of `String`. (Capitalized method names such as `Integer` are usually reserved for special data conversion functions like this.)

The simple case is trivial, and these are equivalent:

```
x = "123".to_i          # 123
y = Integer("123")      # 123
```

When a string is not a valid number, however, their behaviors differ:

```
x = "junk".to_i         # silently returns 0
y = Integer("junk")     # error
```

`to_i` stops converting when it reaches a non-numeric character, but `Integer` raises an error:

```
x = "123junk".to_i      # 123
y = Integer("123junk")  # error
```

Both allow leading and trailing whitespace:

```
x = " 123 ".to_i        # 123
y = Integer(" 123 ")    # 123
```

Floating point conversion works much the same way:

```
x = "3.1416".to_f      # 3.1416
y = Float("2.718")     # 2.718
```

Both conversion methods honor scientific notation:

```
x = Float("6.02e23")   # 6.02e23
y = "2.9979246e5".to_f # 299792.46
```

`to_i` and `Integer` also differ in how they handle different bases. The default, of course, is decimal or base ten; but we can work in other bases also. (The same is not true for floating point.)

When talking about converting between numeric bases, strings always are involved. After all, an integer is an integer, and they are all stored in binary.

Base conversion, therefore, always means converting to or from some kind of string. Here, we're looking at converting *from* a string. (For the reverse, see Section 5.18, "Performing Base Conversions," and Section 5.5, "Formatting Numbers for Output.")

When a number appears in program text as a literal numeric constant, it may have a "tag" in front of it to indicate base. These tags are 0b for binary, a simple 0 for octal, and 0x for hexadecimal.

These tags are honored by the `Integer` method but *not* by the `to_i` method, as demonstrated here:

```
x = Integer("0b111")     # binary      - returns 7
y = Integer("0111")      # octal       - returns 73
z = Integer("0x111")     # hexadecimal - returns 291

x = "0b111".to_i         # 0
y = "0111".to_i          # 0
z = "0x111".to_i         # 0
```

`to_i`, however, allows an optional parameter to indicate the base. Typically, the only meaningful values are 2, 8, 10 (the default), and 16. However, tags are not recognized even with the base parameter:

```
x = "111".to_i(2)         # 7
y = "111".to_i(8)         # octal       - returns 73
z = "111".to_i(16)        # hexadecimal - returns 291

x = "0b111".to_i          # 0
y = "0111".to_i           # 0
z = "0x111".to_i          # 0
```

Because of the "standard" behavior of these methods, a digit that is inappropriate for the given base will be treated differently:

```
x = "12389".to_i(8)       # 123    (8 is ignored)
y = Integer("012389")     # error  (8 is illegal)
```

Although it might be of limited usefulness, `to_i` handles bases up to 36, using all letters of the alphabet. (This may remind you of the Base64 encoding; for information on that, see Section 2.37, "Encoding and Decoding Base64 Strings.")

```
x = "123".to_i(5)         # 66
y = "ruby".to_i(36)       # 1299022
```

It's also possible to use the `scanf` standard library to convert character strings to numbers. This library adds a `scanf` method to `Kernel`, to `IO`, and to `String`:

```
str = "234 234 234"
x, y, z = str.scanf("%d %o %x")    # 234, 156, 564
```

The `scanf` methods implement all the meaningful functionality of their C counterparts: `scanf`, `sscanf`, and `fscanf`. However, `scanf` does not handle binary.

2.25 Encoding and Decoding `rot13` Text

The `rot13` method is perhaps the weakest form of encryption known to humankind. Its historical use is simply to prevent people from "accidentally" reading a piece of text. It was commonly seen in Usenet posts; for example, a joke that might be considered offensive might be encoded in `rot13`, or you could post the entire plot of *Star Wars: Episode 12* on the day before the premiere.

The encoding method consists simply of "rotating" a string through the alphabet, so that *A* becomes *N*, *B* becomes *O*, and so on. Lowercase letters are rotated in the same way; digits, punctuation, and other characters are ignored. Because 13 is half of

26 (the size of our alphabet), the function is its own inverse; applying it a second time will "decrypt" it.

The following example is an implementation as a method added to the `String` class. We present it without further comment:

```
class String

  def rot13
    self.tr("A-Ma-mN-Zn-z","N-Zn-zA-Ma-m")
  end

end

joke = "Y2K bug"
joke13 = joke.rot13    # "L2X oht"

episode2 = "Fcbvyre: Naanxva qbrfa'g trg xvyyrq."
puts episode2.rot13
```

2.26 Encrypting Strings

There are times when we don't want strings to be immediately legible. For example, passwords should not be stored in plaintext, no matter how tight the file permissions are.

The standard method `crypt` uses the standard function of the same name to DES-encrypt a string. It takes a "salt" value as a parameter (similar to the seed value for a random number generator). On non-UNIX platforms, this parameter may be different.

A trivial application for this follows, where we ask for a password that Tolkien fans should know:

```
coded = "hfCghHIE5LAM."

puts "Speak, friend, and enter!"

print "Password: "
password = gets.chop

if password.crypt("hf") == coded
  puts "Welcome!"
```

```
else
  puts "What are you, an orc?"
end
```

It is worth noting that you should never use encryption to store passwords. Instead, employ *password hashing* using a hashing algorithm designed specifically for passwords, such as bcrypt. Additionally, never rely on encryption of this nature for communications with a server-side web application. To secure web applications, use the HTTPS protocol and Secure Sockets Layer (SSL) to encrypt all traffic. Of course, you could still use encryption on the server side, but for a different reason—to protect the data as it is stored rather than during transmission.

2.27 Compressing Strings

The `Zlib` library provides a way of compressing and decompressing strings and files.

Why might we want to compress strings in this way? Possibly to make database I/O faster, to optimize network usage, or even to obscure stored strings so that they are not easily read.

The `Deflate` and `Inflate` classes have class methods named `deflate` and `inflate`, respectively. The `deflate` method (which obviously compresses) has an extra parameter to specify the style of compression. The styles show a typical trade-off between compression quality and speed; `BEST_COMPRESSION` results in a smaller compressed string, but compression is relatively slow; `BEST_SPEED` compresses faster but does not compress as much. The default (`DEFAULT_COMPRESSION`) is typically somewhere in between in both size and speed.

```
require 'zlib'
include Zlib

long_string = ("abcde"*71 + "defghi"*79 + "ghijkl"*113)*371
# long_string has 559097 characters

s1 = Deflate.deflate(long_string,BEST_SPEED)        # 4188 chars
s2 = Deflate.deflate(long_string)                   # 3568 chars
s3 = Deflate.deflate(long_string,BEST_COMPRESSION)  # 2120 chars
```

Informal experiments suggest that the speeds vary by a factor of two, and the compression amounts vary inversely by the same amount. Speed and compression are greatly dependent on the contents of the string. Speed, of course, also is affected by hardware.

Be aware that there is a "break-even" point below which it is essentially useless to compress a string (unless you are trying to make the string unreadable). Below this point, the overhead of compression may actually result in a *longer* string.

2.28 Counting Characters in Strings

The `count` method counts the number of occurrences of any of a set of specified characters:

```
s1 = "abracadabra"
a  = s1.count("c")      # 1
b  = s1.count("bdr")    # 5
```

The string parameter is like a simple regular expression. If it starts with a caret, the list is negated:

```
c = s1.count("^a")      # 6
d = s1.count("^bdr")    # 6
```

A hyphen indicates a range of characters:

```
e = s1.count("a-d")     # 9
f = s1.count("^a-d")    # 2
```

2.29 Reversing a String

A string may be reversed simply by using the `reverse` method (or its in-place counterpart `reverse!`):

```
s1 = "Star Trek"
s2 = s1.reverse         # "kerT ratS"
s1.reverse!             # s1 is now "kerT ratS"
```

Suppose that you want to reverse the word order (rather than character order). You can use `String#split`, which gives you an array of words. The `Array` class also has a `reverse` method, so you can then reverse the array and join to make a new string:

```
phrase = "Now here's a sentence"
phrase.split(" ").reverse.join(" ") # "sentence a here's Now"
```

2.30 Removing Duplicate Characters

Runs of duplicate characters may be removed using the `squeeze` method. If a parameter is specified, only those characters will be squeezed.

```
s1 = "bookkeeper"
s2 = s1.squeeze         # "bokeper"
s3 = "Hello..."
s4 = s3.squeeze         # "Helo."
```

If a parameter is specified, only those characters will be squeezed.

```
s5 = s3.squeeze(".")    # "Hello."
```

This parameter follows the same rules as the one for the `count` method (see Section 2.28, "Counting Characters in Strings," earlier in this chapter); that is, it understands the hyphen and the caret.

There is also a `squeeze!` method.

2.31 Removing Specific Characters

The `delete` method removes characters from a string if they appear in the list of characters passed as a parameter:

```
s1 = "To be, or not to be"
s2 = s1.delete("b")            # "To e, or not to e"
s3 = "Veni, vidi, vici!"
s4 = s3.delete(",!")           # "Veni vidi vici"
```

This parameter follows the same rules as the one for the `count` method (see Section 2.28, "Counting Characters in Strings," earlier in this chapter); that is, it understands the hyphen and the caret.

There is also a `delete!` method.

2.32 Printing Special Characters

The `dump` method (like `inspect`) provides explicit printable representations of characters that may ordinarily be invisible or print differently. Here is an example:

```
s1 = "Listen" << “\007\007\007” # Add three ASCII BEL characters
puts s1.dump                      # Prints: Listen\007\007\007
s2 = "abc\t\tdef\tghi\n\n"
puts s2.dump                      # Prints: abc\t\tdef\tghi\n\n
s3 = "Double quote: \""
puts s3.dump                      # Prints: Double quote: \"
```

2.33 Generating Successive Strings

On rare occasions, we may want to find the "successor" value for a string; for example, the successor for "aaa" is "aab" (then "aad", "aae", and so on).

Ruby provides the method succ (successor) for this purpose:

```
droid = "R2D2"
improved  = droid.succ         # "R2D3"
pill  = "Vitamin B"
pill2 = pill.succ              # "Vitamin C"
```

We don't recommend the use of this feature unless the values are predictable and reasonable. If you start with a string that is esoteric enough, you will eventually get strange and surprising results.

There is also an upto method that applies succ repeatedly in a loop until the desired final value is reached:

```
"Files, A".upto "Files, X" do |letter|
  puts "Opening: #{letter}"
end

# Produces 24 lines of output
```

Again, we stress that this is not used frequently, and you use it at your own risk. In addition, there is no corresponding "predecessor" function.

2.34 Calculating a 32-Bit CRC

The Cyclic Redundancy Check (CRC) is a well-known way of obtaining a "signature" for a file or other collection of bytes. The CRC has the property that the chance of data being changed and keeping the same CRC is 1 in 2***N*, where *N* is the number of bits in the result (most often 32 bits).

The zlib library, created by Ueno Katsuhiro, enables you to do this.

The method crc32 computes a CRC given a string as a parameter:

```
require 'zlib'
include Zlib
crc = crc32("Hello")            # 4157704578
crc = crc32(" world!",crc)      # 461707669
crc = crc32("Hello world!")     # 461707669 (same as above)
```

A previous CRC can be specified as an optional second parameter; the result will be as if the strings were concatenated and a single CRC was computed. This can be used, for example, to compute the checksum of a file so large that we can only read it in chunks.

2.35 Calculating the SHA-256 Hash of a String

The `Digest::SHA256` class produces a 256-bit *hash* or *message digest* of a string of arbitrary length. This hashing function is one-way, and does not allow for the discovery of the original message from the digest. There are also `MD5`, `SHA384`, and `SHA512` classes inside `Digest` for each of those algorithms.

The most commonly used class method is `hexdigest`, but there are also `digest` and `base64digest`. They all accept a string containing the message and return the digest as a string, as shown here:

```
require 'digest'
Digest::SHA256.hexdigest("foo")[0..20]    # "2c26b46b68f"
Digest::SHA256.base64digest("foo")[0..20] # "LCa0a2j/xo/"
Digest::SHA256.digest(“foo")[0..5]        # ",&\xB4kh\xFF"
```

Although the `digest` method provides a 64-byte string containing the 512-bit digest, the `hexdigest` method is actually the most useful. It provides the digest as an ASCII string of 64 hex characters representing the 64 bytes.

Instances and the `update` method allow the hash to be built incrementally, perhaps because the data is coming from a streaming source:

```
secret = Digest::SHA256.new
source.each { |chunk| secret.update(chunk) }
```

Repeated calls are equivalent to a single call with concatenated arguments:

```
# These two statements...
cryptic.update("Data...")
cryptic.update(" and more data.")

# ...are equivalent to this one.
cryptic.update("Data... and more data.”)

cryptic.hexdigest[0..20] # "50605ba0a90"
```

2.36 Calculating the Levenshtein Distance Between Two Strings

The concept of distance between strings is important in inductive learning (AI), cryptography, proteins research, and in other areas.

The Levenshtein distance is the minimum number of modifications needed to change one string into another, using three basic modification operations: *del*(-etion), *ins*(-ertion), and *sub*(-stitution). A substitution is also considered to be a combination of a deletion and insertion (*indel*).

There are various approaches to this, but we will avoid getting too technical. Suffice it to say that this Ruby implementation (shown in Listing 2.2) allows you to provide optional parameters to set the cost for the three types of modification operations and defaults to a single indel cost basis (cost of insertion = cost of deletion).

Listing 2.2 The Levenshtein distance

```
class String

  def levenshtein(other, ins=2, del=2, sub=1)
    # ins, del, sub are weighted costs
    return nil if self.nil?
    return nil if other.nil?
    dm = []        # distance matrix

    # Initialize first row values
    dm[0] = (0..self.length).collect { |i| i * ins }
    fill = [0] * (self.length - 1)

    # Initialize first column values
    for i in 1..other.length
      dm[i] = [i * del, fill.flatten]
    end

    # populate matrix
    for i in 1..other.length
      for j in 1..self.length
    # critical comparison
        dm[i][j] = [
             dm[i-1][j-1] +
               (self[j-1] == other[i-1] ? 0 : sub),
                 dm[i][j-1] + ins,
             dm[i-1][j] + del
     ].min
      end
    end
    # The last value in matrix is the
    # Levenshtein distance between the strings
    dm[other.length][self.length]
  end

end


s1 = "ACUGAUGUGA"
s2 = "AUGGAA"
d1 = s1.levenshtein(s2)    # 9


s3 = "pennsylvania"
s4 = "pencilvaneya"
d2 = s3.levenshtein(s4)    # 7


s5 = "abcd"
s6 = "abcd"
d3 = s5.levenshtein(s6)    # 0
```

Now that we have the Levenshtein distance defined, it's conceivable that we could define a similar? method, giving it a threshold for similarity. Here is an example:

```
class String

  def similar?(other, thresh=2)
    self.levenshtein(other) < thresh
  end

end


if "polarity".similar?("hilarity")
  puts "Electricity is funny!"
end
```

Of course, it would also be possible to pass in the three weighted costs to the similar? method so that they could in turn be passed into the levenshtein method. We have omitted these for simplicity.

2.37 Encoding and Decoding Base64 Strings

Base64 is frequently used to convert machine-readable data into a text form with no special characters in it. For example, images and fonts stored inline inside CSS files are encoded with Base64.

The easiest way to do a Base64 encode/decode is to use the built-in `Base64` module. The `Base64` class has an `encode64` method that returns a Base64 string (with a newline appended). It also has the method `decode64`, which changes the string back to its original bytes, as shown here:

```
require "base64"
str = "\xAB\xBA\x02abdce"
encoded  = Base64.encode64(str)     # "q7oCYWJkY2U=\n"
original = Base64.decode64(encoded) # "\xAB\xBA\x02abdce"
```

2.38 Expanding and Compressing Tab Characters

Occasionally we have a string with tabs in it and we want to convert them to spaces (or vice versa). The two methods shown here do these operations:

```
class String

  def detab(ts=8)
    str = self.dup
    while (leftmost = str.index("\t")) != nil
      space = " "*(ts-(leftmost%ts))
      str[leftmost]=space
    end
    str
  end

  def entab(ts=8)
    str = self.detab
    areas = str.length/ts
    newstr = ""
    for a in 0..areas
      temp = str[a*ts..a*ts+ts-1]
      if temp.size==ts
        if temp =~ / +/
          match=Regexp.last_match[0]
          endmatch = Regexp.new(match+"$")
          if match.length>1
            temp.sub!(endmatch,"\t")
          end
        end
      end
      newstr += temp
    end
    newstr
  end

end

foo = "This       is        only   a     test.          "

puts foo
puts foo.entab(4)
puts foo.entab(4).dump
```

Note that this code is not smart enough to handle backspaces.

2.39 Wrapping Lines of Text

Occasionally we may want to take long text lines and print them within margins of our own choosing. The code fragment shown here accomplishes this, splitting only on word boundaries and honoring tabs (but not honoring backspaces or preserving tabs):

```
str = <<-EOF
  When in the Course of human events it becomes necessary
  for one people to dissolve the political bands which have
  connected them with another, and to assume among the powers
  of the earth the separate and equal station to which the Laws
  of Nature and of Nature's God entitle them, a decent respect
  for the opinions of mankind requires that they should declare
  the causes which impel them to the separation.
EOF

max = 20

line = 0
out = [""]
```

```
input = str.gsub(/\n/," ")
words = input.split(" ")

while input != ""
  word = words.shift
  break if not word
  if out[line].length + word.length > max
    out[line].squeeze!(" ")
    line += 1
    out[line] = ""
  end
  out[line] << word + " "
end

out.each {|line| puts line}  # Prints 24 very short lines
```

The `ActiveSupport` gem includes similar functionality in a method named `word_wrap`, along with many other string manipulation helpers. Search for it online.

2.40 Conclusion

In this chapter, we have seen the basics of representing strings (both single-quoted strings and double-quoted strings). We've seen how to interpolate expressions into double-quoted strings, and how the double quotes also allow certain special characters to be inserted with escape sequences. We've seen the `%q` and `%Q` forms, which permit us to choose our own delimiters for convenience. Finally, we've seen the here-document syntax, carried over from older contexts such as UNIX shells.

This chapter has demonstrated all the important operations a programmer wants to perform on a string, including concatenation, searching, extracting substrings, tokenizing, and much more. We have seen how to iterate over a string by line or by byte. We have seen how to transform a string to and from a coded form such as Base64 or compressed form.

It's time now to move on to a related topic—regular expressions. Regular expressions are a powerful tool for detecting patterns in strings. We'll cover this topic in the next chapter.

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