Powerful Object-Oriented Programming

5th Edition
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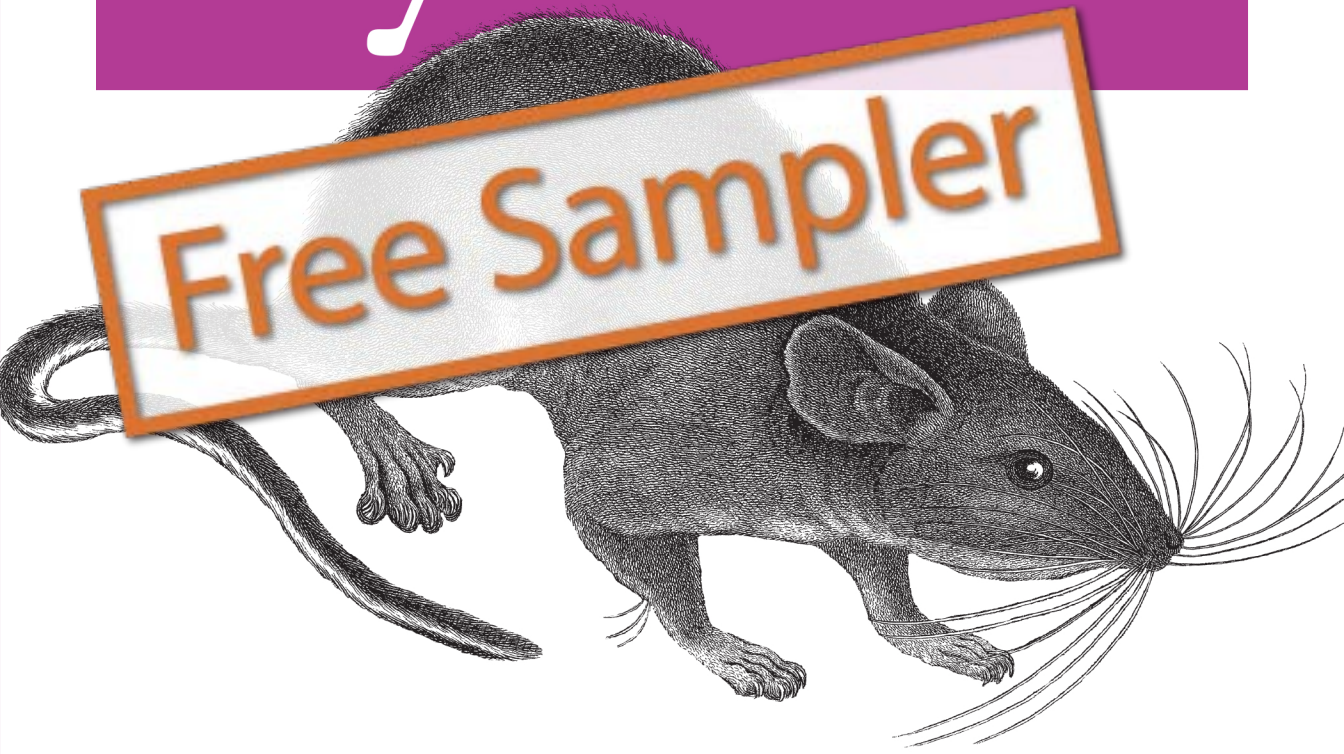
Learning

Python



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Learning Python

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Learning Python, Fifth Edition
by Mark Lutz

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (*http://my.safaribooksonline.com*). For more information, contact our corporate/institutional sales department: 800-998-9938 or *corporate@oreilly.com*.

Editor: Rachel Roumeliotis
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Indexer: Lucie Haskins
Cover Designer: Randy Comer
Interior Designer: David Futato
Illustrator: Rebecca Demarest

June 2013: Fifth Edition.

Revision History for the Fifth Edition:
2013-06-07 First release
See *http://oreilly.com/catalog/errata.csp?isbn=9781449355739* for release details.

ISBN: 978-1-449-35573-9

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PART I

Getting Started

CHAPTER 1

A Python Q&A Session

If you've bought this book, you may already know what Python is and why it's an important tool to learn. If you don't, you probably won't be sold on Python until you've learned the language by reading the rest of this book and have done a project or two. But before we jump into details, this first chapter of this book will briefly introduce some of the main reasons behind Python's popularity. To begin sculpting a definition of Python, this chapter takes the form of a question-and-answer session, which poses some of the most common questions asked by beginners.

Why Do People Use Python?

Because there are many programming languages available today, this is the usual first question of newcomers. Given that there are roughly 1 million Python users out there at the moment, there really is no way to answer this question with complete accuracy; the choice of development tools is sometimes based on unique constraints or personal preference.

But after teaching Python to roughly 260 groups and over 4,000 students during the last 16 years, I have seen some common themes emerge. The primary factors cited by Python users seem to be these:

Software quality
: For many, Python's focus on readability, coherence, and software quality in general sets it apart from other tools in the scripting world. Python code is designed to be *readable*, and hence reusable and maintainable—much more so than traditional scripting languages. The uniformity of Python code makes it easy to understand, even if you did not write it. In addition, Python has deep support for more advanced *software reuse* mechanisms, such as object-oriented (OO) and function programming.

Developer productivity
: Python boosts developer productivity many times beyond compiled or statically typed languages such as C, C++, and Java. Python code is typically *one-third to*

one-fifth the size of equivalent C++ or Java code. That means there is less to type, less to debug, and less to maintain after the fact. Python programs also run immediately, without the lengthy compile and link steps required by some other tools, further boosting programmer speed.

Program portability
: Most Python programs run unchanged on *all major computer platforms*. Porting Python code between Linux and Windows, for example, is usually just a matter of copying a script's code between machines. Moreover, Python offers multiple options for coding portable graphical user interfaces, database access programs, web-based systems, and more. Even operating system interfaces, including program launches and directory processing, are as portable in Python as they can possibly be.

Support libraries
: Python comes with a large collection of prebuilt and portable functionality, known as the *standard library*. This library supports an array of application-level programming tasks, from text pattern matching to network scripting. In addition, Python can be extended with both homegrown libraries and a vast collection of third-party application support software. Python's *third-party domain* offers tools for website construction, numeric programming, serial port access, game development, and much more (see ahead for a sampling). The NumPy extension, for instance, has been described as a free and more powerful equivalent to the Matlab numeric programming system.

Component integration
: Python scripts can easily communicate with other parts of an application, using a variety of integration mechanisms. Such integrations allow Python to be used as a product *customization and extension* tool. Today, Python code can invoke C and C++ libraries, can be called from C and C++ programs, can integrate with Java and .NET components, can communicate over frameworks such as COM and Silverlight, can interface with devices over serial ports, and can interact over networks with interfaces like SOAP, XML-RPC, and CORBA. It is not a standalone tool.

Enjoyment
: Because of Python's ease of use and built-in toolset, it can make the act of programming *more pleasure than chore*. Although this may be an intangible benefit, its effect on productivity is an important asset.

Of these factors, the first two (quality and productivity) are probably the most compelling benefits to most Python users, and merit a fuller description.

Software Quality

By design, Python implements a deliberately simple and readable syntax and a highly coherent programming model. As a slogan at a past Python conference attests, the net result is that Python seems to "fit your brain"—that is, features of the language interact

in consistent and limited ways and follow naturally from a small set of core concepts. This makes the language easier to learn, understand, and remember. In practice, Python programmers do not need to constantly refer to manuals when reading or writing code; it's a consistently designed system that many find yields surprisingly uniform code.

By philosophy, Python adopts a somewhat minimalist approach. This means that although there are usually multiple ways to accomplish a coding task, there is usually just one obvious way, a few less obvious alternatives, and a small set of coherent interactions everywhere in the language. Moreover, Python doesn't make arbitrary decisions for you; when interactions are ambiguous, explicit intervention is preferred over "magic." In the Python way of thinking, explicit is better than implicit, and simple is better than complex.[1]

Beyond such design themes, Python includes tools such as modules and OOP that naturally promote code reusability. And because Python is focused on quality, so too, naturally, are Python programmers.

Developer Productivity

During the great Internet boom of the mid-to-late 1990s, it was difficult to find enough programmers to implement software projects; developers were asked to implement systems as fast as the Internet evolved. In later eras of layoffs and economic recession, the picture shifted. Programming staffs were often asked to accomplish the same tasks with even fewer people.

In both of these scenarios, Python has shined as a tool that allows programmers to get more done with less effort. It is deliberately optimized for *speed of development*—its simple syntax, dynamic typing, lack of compile steps, and built-in toolset allow programmers to develop programs in a fraction of the time needed when using some other tools. The net effect is that Python typically boosts developer productivity many times beyond the levels supported by traditional languages. That's good news in both boom and bust times, and everywhere the software industry goes in between.

Is Python a "Scripting Language"?

Python is a general-purpose programming language that is often applied in scripting roles. It is commonly defined as an *object-oriented scripting language*—a definition that blends support for OOP with an overall orientation toward scripting roles. If pressed for a one-liner, I'd say that Python is probably better known as a *general-purpose pro-*

1. For a more complete look at the Python philosophy, type the command `import this` at any Python interactive prompt (you'll see how in Chapter 3). This invokes an "Easter egg" hidden in Python—a collection of design principles underlying Python that permeate both the language and its user community. Among them, the acronym EIBTI is now fashionable jargon for the "explicit is better than implicit" rule. These principles are not religion, but are close enough to qualify as a Python motto and creed, which we'll be quoting from often in this book.

gramming language that blends procedural, functional, and object-oriented paradigms—a statement that captures the richness and scope of today's Python.

Still, the term "scripting" seems to have stuck to Python like glue, perhaps as a contrast with larger programming effort required by some other tools. For example, people often use the word "script" instead of "program" to describe a Python code file. In keeping with this tradition, this book uses the terms "script" and "program" interchangeably, with a slight preference for "script" to describe a simpler top-level file and "program" to refer to a more sophisticated multifile application.

Because the term "scripting language" has so many different meanings to different observers, though, some would prefer that it not be applied to Python at all. In fact, people tend to make three very different associations, some of which are more useful than others, when they hear Python labeled as such:

Shell tools
: Sometimes when people hear Python described as a scripting language, they think it means that Python is a tool for coding operating-system-oriented scripts. Such programs are often launched from console command lines and perform tasks such as processing text files and launching other programs.

  Python programs can and do serve such roles, but this is just one of dozens of common Python application domains. It is not just a better shell-script language.

Control language
: To others, scripting refers to a "glue" layer used to control and direct (i.e., script) other application components. Python programs are indeed often deployed in the context of larger applications. For instance, to test hardware devices, Python programs may call out to components that give low-level access to a device. Similarly, programs may run bits of Python code at strategic points to support end-user product customization without the need to ship and recompile the entire system's source code.

  Python's simplicity makes it a naturally flexible control tool. Technically, though, this is also just a common Python role; many (perhaps most) Python programmers code standalone scripts without ever using or knowing about any integrated components. It is not just a control language.

Ease of use
: Probably the best way to think of the term "scripting language" is that it refers to a simple language used for quickly coding tasks. This is especially true when the term is applied to Python, which allows much faster program development than compiled languages like C++. Its rapid development cycle fosters an exploratory, incremental mode of programming that has to be experienced to be appreciated.

  Don't be fooled, though—Python is not just for simple tasks. Rather, it makes tasks simple by its ease of use and flexibility. Python has a simple feature set, but it allows programs to scale up in sophistication as needed. Because of that, it is commonly used for quick tactical tasks and longer-term strategic development.

So, is Python a scripting language or not? It depends on whom you ask. In general, the term "scripting" is probably best used to describe the rapid and flexible mode of development that Python supports, rather than a particular application domain.

OK, but What's the Downside?

After using it for 21 years, writing about it for 18, and teaching it for 16, I've found that the only significant universal downside to Python is that, as currently implemented, its *execution speed* may not always be as fast as that of fully compiled and lower-level languages such as C and C++. Though relatively rare today, for some tasks you may still occasionally need to get "closer to the iron" by using lower-level languages such as these that are more directly mapped to the underlying hardware architecture.

We'll talk about implementation concepts in detail later in this book. In short, the standard implementations of Python today compile (i.e., translate) source code statements to an intermediate format known as *byte code* and then interpret the byte code. Byte code provides portability, as it is a platform-independent format. However, because Python is not normally compiled all the way down to binary machine code (e.g., instructions for an Intel chip), some programs will run more slowly in Python than in a fully compiled language like C. The *PyPy* system discussed in the next chapter can achieve a 10X to 100X speedup on some code by compiling further as your program runs, but it's a separate, alternative implementation.

Whether you will ever *care* about the execution speed difference depends on what kinds of programs you write. Python has been optimized numerous times, and Python code runs fast enough by itself in most application domains. Furthermore, whenever you do something "real" in a Python script, like processing a file or constructing a graphical user interface (GUI), your program will actually run at C speed, since such tasks are immediately dispatched to compiled C code inside the Python interpreter. More fundamentally, Python's speed-of-development gain is often far more important than any speed-of-execution loss, especially given modern computer speeds.

Even at today's CPU speeds, though, there still are some domains that do require optimal execution speeds. Numeric programming and animation, for example, often need at least their core number-crunching components to run at C speed (or better). If you work in such a domain, you can still use Python—simply split off the parts of the application that require optimal speed into *compiled extensions*, and link those into your system for use in Python scripts.

We won't talk about extensions much in this text, but this is really just an instance of the Python-as-control-language role we discussed earlier. A prime example of this dual language strategy is the *NumPy* numeric programming extension for Python; by combining compiled and optimized numeric extension libraries with the Python language, NumPy turns Python into a numeric programming tool that is simultaneously efficient and easy to use. When needed, such extensions provide a powerful optimization tool.

Other Python Tradeoffs: The Intangible Bits

I mentioned that execution speed is the only major downside to Python. That's indeed the case for most Python users, and especially for newcomers. Most people find Python to be easy to learn and fun to use, especially when compared with its contemporaries like Java, C#, and C++. In the interest of full disclosure, though, I should also note up front some more abstract tradeoffs I've observed in my two decades in the Python world—both as an educator and developer.

As an educator, I've sometimes found the *rate of change* in Python and its libraries to be a negative, and have on occasion lamented its *growth* over the years. This is partly because trainers and book authors live on the front lines of such things—it's been my job to teach the language despite its constant change, a task at times akin to chronicling the herding of cats! Still, it's a broadly shared concern. As we'll see in this book, Python's original "keep it simple" motif is today often subsumed by a trend toward more sophisticated solutions at the expense of the learning curve of newcomers. This book's size is indirect evidence of this trend.

On the other hand, by most measures Python is still much simpler than its alternatives, and perhaps only as complex as it needs to be given the many roles it serves today. Its overall coherence and open nature remain compelling features to most. Moreover, not everyone needs to stay up to date with the cutting edge—as Python 2.X's ongoing popularity clearly shows.

As a developer, I also at times question the tradeoffs inherent in Python's *"batteries included" approach* to development. Its emphasis on prebuilt tools can add dependencies (what if a battery you use is changed, broken, or deprecated?), and encourage special-case solutions over general principles that may serve users better in the long run (how can you evaluate or use a tool well if you don't understand its purpose?). We'll see examples of both of these concerns in this book.

For typical users, and especially for hobbyists and beginners, Python's toolset approach is a major asset. But you shouldn't be surprised when you outgrow precoded tools, and can benefit from the sorts of skills this book aims to impart. Or, to paraphrase a proverb: give people a tool, and they'll code for a day; teach them how to build tools, and they'll code for a lifetime. This book's job is more the latter than the former.

As mentioned elsewhere in this chapter, both Python and its toolbox model are also susceptible to downsides common to *open source* projects in general—the potential triumph of the *personal preference* of the few over common usage of the many, and the occasional appearance of *anarchy* and even *elitism*—though these tend to be most grievous on the leading edge of new releases.

We'll return to some of these tradeoffs at the end of the book, after you've learned Python well enough to draw your own conclusions. As an open source system, what Python "is" is up to its users to define. In the end, Python is more popular today than ever, and its growth shows no signs of abating. To some, that may be a more telling metric than individual opinions, both pro and con.

Who Uses Python Today?

At this writing, the best estimate anyone can seem to make of the size of the Python user base is that there are roughly 1 million Python users around the world today (plus or minus a few). This estimate is based on various statistics, like download rates, web statistics, and developer surveys. Because Python is open source, a more exact count is difficult—there are no license registrations to tally. Moreover, Python is automatically included with Linux distributions, Macintosh computers, and a wide range of products and hardware, further clouding the user-base picture.

In general, though, Python enjoys a large user base and a very active developer community. It is generally considered to be in *the top 5 or top 10* most widely used programming languages in the world today (its exact ranking varies per source and date). Because Python has been around for *over two decades* and has been widely used, it is also very stable and robust.

Besides being leveraged by individual users, Python is also being applied in real revenue-generating products by real companies. For instance, among the generally known Python user base:

- *Google* makes extensive use of Python in its web search systems.
- The popular *YouTube* video sharing service is largely written in Python.
- The *Dropbox* storage service codes both its server and desktop client software primarily in Python.
- The *Raspberry Pi* single-board computer promotes Python as its educational language.
- *EVE Online*, a massively multiplayer online game (MMOG) by CCP Games, uses Python broadly.
- The widespread *BitTorrent* peer-to-peer file sharing system began its life as a Python program.
- *Industrial Light & Magic*, *Pixar*, and others use Python in the production of animated movies.
- *ESRI* uses Python as an end-user customization tool for its popular GIS mapping products.
- Google's *App Engine* web development framework uses Python as an application language.
- The *IronPort* email server product uses more than 1 million lines of Python code to do its job.
- *Maya*, a powerful integrated 3D modeling and animation system, provides a Python scripting API.
- The *NSA* uses Python for cryptography and intelligence analysis.
- *iRobot* uses Python to develop commercial and military robotic devices.

- The *Civilization IV* game's customizable scripted events are written entirely in Python.
- The One Laptop Per Child (*OLPC*) project built its user interface and activity model in Python.
- *Netflix* and *Yelp* have both documented the role of Python in their software infrastructures.
- *Intel*, *Cisco*, *Hewlett-Packard*, *Seagate*, *Qualcomm*, and *IBM* use Python for hardware testing.
- *JPMorgan Chase*, *UBS*, *Getco*, and *Citadel* apply Python to financial market forecasting.
- *NASA*, *Los Alamos*, *Fermilab*, *JPL*, and others use Python for scientific programming tasks.

And so on—though this list is representative, a full accounting is beyond this book's scope, and is almost guaranteed to change over time. For an up-to-date sampling of additional Python users, applications, and software, try the following pages currently at Python's site and Wikipedia, as well as a search in your favorite web browser:

- Success stories: *http://www.python.org/about/success*
- Application domains: *http://www.python.org/about/apps*
- User quotes: *http://www.python.org/about/quotes*
- Wikipedia page: *http://en.wikipedia.org/wiki/List_of_Python_software*

Probably the only common thread among the companies using Python today is that Python is used all over the map, in terms of application domains. Its general-purpose nature makes it applicable to almost all fields, not just one. In fact, it's safe to say that virtually every substantial organization writing software is using Python, whether for short-term tactical tasks, such as testing and administration, or for long-term strategic product development. Python has proven to work well in both modes.

What Can I Do with Python?

In addition to being a well-designed programming language, Python is useful for accomplishing real-world tasks—the sorts of things developers do day in and day out. It's commonly used in a variety of domains, as a tool for scripting other components and implementing standalone programs. In fact, as a general-purpose language, Python's roles are virtually unlimited: you can use it for everything from website development and gaming to robotics and spacecraft control.

However, the most common Python roles currently seem to fall into a few broad categories. The next few sections describe some of Python's most common applications today, as well as tools used in each domain. We won't be able to explore the tools

mentioned here in any depth—if you are interested in any of these topics, see the Python website or other resources for more details.

Systems Programming

Python's built-in interfaces to operating-system services make it ideal for writing portable, maintainable system-administration tools and utilities (sometimes called *shell tools*). Python programs can search files and directory trees, launch other programs, do parallel processing with processes and threads, and so on.

Python's standard library comes with POSIX bindings and support for all the usual OS tools: environment variables, files, sockets, pipes, processes, multiple threads, regular expression pattern matching, command-line arguments, standard stream interfaces, shell-command launchers, filename expansion, zip file utilities, XML and JSON parsers, CSV file handlers, and more. In addition, the bulk of Python's system interfaces are designed to be portable; for example, a script that copies directory trees typically runs unchanged on all major Python platforms. The *Stackless* Python implementation, described in Chapter 2 and used by *EVE Online*, also offers advanced solutions to multiprocessing requirements.

GUIs

Python's simplicity and rapid turnaround also make it a good match for graphical user interface programming on the desktop. Python comes with a standard object-oriented interface to the Tk GUI API called *tkinter* (*Tkinter* in 2.X) that allows Python programs to implement portable GUIs with a native look and feel. Python/tkinter GUIs run unchanged on Microsoft Windows, X Windows (on Unix and Linux), and the Mac OS (both Classic and OS X). A free extension package, *PMW*, adds advanced widgets to the tkinter toolkit. In addition, the *wxPython* GUI API, based on a C++ library, offers an alternative toolkit for constructing portable GUIs in Python.

Higher-level toolkits such as *Dabo* are built on top of base APIs such as wxPython and tkinter. With the proper library, you can also use GUI support in other toolkits in Python, such as *Qt* with PyQt, *GTK* with PyGTK, *MFC* with PyWin32, *.NET* with IronPython, and *Swing* with Jython (the Java version of Python, described in Chapter 2) or JPype. For applications that run in web browsers or have simple interface requirements, both Jython and Python web frameworks and server-side CGI scripts, described in the next section, provide additional user interface options.

Internet Scripting

Python comes with standard Internet modules that allow Python programs to perform a wide variety of networking tasks, in client and server modes. Scripts can communicate over sockets; extract form information sent to server-side CGI scripts; transfer files by FTP; parse and generate XML and JSON documents; send, receive, compose, and parse

email; fetch web pages by URLs; parse the HTML of fetched web pages; communicate over XML-RPC, SOAP, and Telnet; and more. Python's libraries make these tasks remarkably simple.

In addition, a large collection of third-party tools are available on the Web for doing Internet programming in Python. For instance, the *HTMLGen* system generates HTML files from Python class-based descriptions, the *mod_python* package runs Python efficiently within the Apache web server and supports server-side templating with its Python Server Pages, and the Jython system provides for seamless Python/Java integration and supports coding of server-side applets that run on clients.

In addition, full-blown web development framework packages for Python, such as *Django*, *TurboGears*, *web2py*, *Pylons*, *Zope*, and *WebWare*, support quick construction of full-featured and production-quality websites with Python. Many of these include features such as object-relational mappers, a Model/View/Controller architecture, server-side scripting and templating, and AJAX support, to provide complete and enterprise-level web development solutions.

More recently, Python has expanded into rich Internet applications (RIAs), with tools such as *Silverlight* in *IronPython*, and *pyjs* (a.k.a. *pyjamas*) and its Python-to-JavaScript compiler, AJAX framework, and widget set. Python also has moved into cloud computing, with *App Engine*, and others described in the database section ahead. Where the Web leads, Python quickly follows.

Component Integration

We discussed the component integration role earlier when describing Python as a control language. Python's ability to be extended by and embedded in C and C++ systems makes it useful as a flexible glue language for scripting the behavior of other systems and components. For instance, integrating a C library into Python enables Python to test and launch the library's components, and embedding Python in a product enables onsite customizations to be coded without having to recompile the entire product (or ship its source code at all).

Tools such as the *SWIG* and *SIP* code generators can automate much of the work needed to link compiled components into Python for use in scripts, and the *Cython* system allows coders to mix Python and C-like code. Larger frameworks, such as Python's *COM* support on Windows, the Jython *Java*-based implementation, and the IronPython .NET-based implementation provide alternative ways to script components. On Windows, for example, Python scripts can use frameworks to script Word and Excel, access *Silverlight*, and much more.

Database Programming

For traditional database demands, there are Python interfaces to all commonly used relational database systems—Sybase, Oracle, Informix, ODBC, MySQL, PostgreSQL,

SQLite, and more. The Python world has also defined a *portable database API* for accessing SQL database systems from Python scripts, which looks the same on a variety of underlying database systems. For instance, because the vendor interfaces implement the portable API, a script written to work with the free MySQL system will work largely unchanged on other systems (such as Oracle); all you generally have to do is replace the underlying vendor interface. The in-process *SQLite* embedded SQL database engine is a standard part of Python itself since 2.5, supporting both prototyping and basic program storage needs.

In the non-SQL department, Python's standard `pickle` module provides a simple object persistence system—it allows programs to easily save and restore entire Python objects to files and file-like objects. On the Web, you'll also find third-party open source systems named *ZODB* and *Durus* that provide complete object-oriented database systems for Python scripts; others, such as *SQLObject* and *SQLAlchemy*, that implement object relational mappers (ORMs), which graft Python's class model onto relational tables; and *PyMongo*, an interface to *MongoDB*, a high-performance, non-SQL, open source *JSON*-style document database, which stores data in structures very similar to Python's own lists and dictionaries, and whose text may be parsed and created with Python's own standard library `json` module.

Still other systems offer more specialized ways to store data, including the datastore in Google's *App Engine*, which models data with Python classes and provides extensive scalability, as well as additional emerging cloud storage options such as *Azure*, *PiCloud*, *OpenStack*, and *Stackato*.

Rapid Prototyping

To Python programs, components written in Python and C look the same. Because of this, it's possible to prototype systems in Python initially, and then move selected components to a compiled language such as C or C++ for delivery. Unlike some prototyping tools, Python doesn't require a complete rewrite once the prototype has solidified. Parts of the system that don't require the efficiency of a language such as C++ can remain coded in Python for ease of maintenance and use.

Numeric and Scientific Programming

Python is also heavily used in numeric programming—a domain that would not traditionally have been considered to be in the scope of scripting languages, but has grown to become one of Python's most compelling use cases. Prominent here, the *NumPy* high-performance numeric programming extension for Python mentioned earlier includes such advanced tools as an array object, interfaces to standard mathematical libraries, and much more. By integrating Python with numeric routines coded in a compiled language for speed, NumPy turns Python into a sophisticated yet easy-to-use numeric programming tool that can often replace existing code written in traditional compiled languages such as FORTRAN or C++.

Additional numeric tools for Python support animation, 3D visualization, parallel processing, and so on. The popular *SciPy* and *ScientificPython* extensions, for example, provide additional libraries of scientific programming tools and use NumPy as a core component. The *PyPy* implementation of Python (discussed in Chapter 2) has also gained traction in the numeric domain, in part because heavily algorithmic code of the sort that's common in this domain can run dramatically faster in PyPy—often 10X to 100X quicker.

And More: Gaming, Images, Data Mining, Robots, Excel...

Python is commonly applied in more domains than can be covered here. For example, you'll find tools that allow you to use Python to do:

- Game programming and multimedia with *pygame*, *cgkit*, *pyglet*, *PySoy*, *Panda3D*, and others
- Serial port communication on Windows, Linux, and more with the *PySerial* extension
- Image processing with *PIL* and its newer *Pillow* fork, *PyOpenGL*, *Blender*, *Maya*, and more
- Robot control programming with the *PyRo* toolkit
- Natural language analysis with the *NLTK* package
- Instrumentation on the *Raspberry Pi* and *Arduino* boards
- Mobile computing with ports of Python to the Google *Android* and Apple *iOS* platforms
- Excel spreadsheet function and macro programming with the *PyXLL* or *DataNitro* add-ins
- Media file content and metadata tag processing with *PyMedia*, *ID3*, *PIL/Pillow*, and more
- Artificial intelligence with the *PyBrain* neural net library and the *Milk* machine learning toolkit
- Expert system programming with *PyCLIPS*, *Pyke*, *Pyrolog*, and *pyDatalog*
- Network monitoring with *zenoss*, written in and customized with Python
- Python-scripted design and modeling with *PythonCAD*, *PythonOCC*, *FreeCAD*, and others
- Document processing and generation with *ReportLab*, *Sphinx*, *Cheetah*, *PyPDF*, and so on
- Data visualization with *Mayavi, matplotlib*, *VTK*, *VPython*, and more
- XML parsing with the `xml` library package, the `xmlrpclib` module, and third-party extensions
- JSON and CSV file processing with the `json` and `csv` modules

- Data mining with the *Orange* framework, the *Pattern* bundle, *Scrapy*, and custom code

You can even play solitaire with the *PySolFC* program. And of course, you can always code custom Python scripts in less buzzword-laden domains to perform day-to-day system administration, process your email, manage your document and media libraries, and so on. You'll find links to the support in many fields at the PyPI website, and via web searches (search Google or *http://www.python.org* for links).

Though of broad practical use, many of these specific domains are largely just instances of Python's component integration role in action again. Adding it as a frontend to libraries of components written in a compiled language such as C makes Python useful for scripting in a wide variety of domains. As a general-purpose language that supports integration, Python is widely applicable.

How Is Python Developed and Supported?

As a popular open source system, Python enjoys a large and active development community that responds to issues and develops enhancements with a speed that many commercial software developers might find remarkable. Python developers coordinate work online with a source-control system. Changes are developed per a formal protocol, which includes writing a *PEP* (Python Enhancement Proposal) or other document, and extensions to Python's regression testing system. In fact, modifying Python today is roughly as involved as changing commercial software—a far cry from Python's early days, when an email to its creator would suffice, but a good thing given its large user base today.

The *PSF* (Python Software Foundation), a formal nonprofit group, organizes conferences and deals with intellectual property issues. Numerous Python conferences are held around the world; O'Reilly's *OSCON* and the PSF's *PyCon* are the largest. The former of these addresses multiple open source projects, and the latter is a Python-only event that has experienced strong growth in recent years. PyCon 2012 and 2013 reached *2,500 attendees* each; in fact, PyCon 2013 had to cap its limit at this level after a surprise sell-out in 2012 (and managed to grab wide attention on both technical and nontechnical grounds that I won't chronicle here). Earlier years often saw attendance double—from 586 attendees in 2007 to over 1,000 in 2008, for example—indicative of Python's growth in general, and impressive to those who remember early conferences whose attendees could largely be served around a single restaurant table.

Open Source Tradeoffs

Having said that, it's important to note that while Python enjoys a vigorous development community, this comes with inherent tradeoffs. Open source software can also appear chaotic and even resemble *anarchy* at times, and may not always be as smoothly implemented as the prior paragraphs might imply. Some changes may still manage to

defy official protocols, and as in all human endeavors, mistakes still happen despite the process controls (Python 3.2.0, for instance, came with a broken console `input` function on Windows).

Moreover, open source projects exchange commercial interests for the *personal preferences* of a current set of developers, which may or may not be the same as yours—you are not held hostage by a company, but you are at the mercy of those with spare time to change the system. The net effect is that open source software evolution is often driven by the few, but imposed on the many.

In practice, though, these tradeoffs impact those on the "bleeding" edge of new releases much more than those using established versions of the system, including prior releases in both Python 3.X and 2.X. If you kept using classic classes in Python 2.X, for example, you were largely immune to the *explosion* of class functionality and change in new-style classes that occurred in the early-to-mid 2000s. Though these become mandatory in 3.X (along with much more), many 2.X users today still happily skirt the issue.

What Are Python's Technical Strengths?

Naturally, this is a developer's question. If you don't already have a programming background, the language in the next few sections may be a bit baffling—don't worry, we'll explore all of these terms in more detail as we proceed through this book. For developers, though, here is a quick introduction to some of Python's top technical features.

It's Object-Oriented and Functional

Python is an object-oriented language, from the ground up. Its *class model* supports advanced notions such as polymorphism, operator overloading, and multiple inheritance; yet, in the context of Python's simple syntax and typing, OOP is remarkably easy to apply. In fact, if you don't understand these terms, you'll find they are much easier to learn with Python than with just about any other OOP language available.

Besides serving as a powerful code structuring and reuse device, Python's OOP nature makes it ideal as a *scripting tool* for other object-oriented systems languages. For example, with the appropriate glue code, Python programs can subclass (specialize) classes implemented in C++, Java, and C#.

Of equal significance, OOP is an *option* in Python; you can go far without having to become an object guru all at once. Much like C++, Python supports both procedural and object-oriented programming modes. Its object-oriented tools can be applied if and when constraints allow. This is especially useful in tactical development modes, which preclude design phases.

In addition to its original *procedural* (statement-based) and *object-oriented* (class-based) paradigms, Python in recent years has acquired built-in support for *functional*

programming—a set that by most measures includes generators, comprehensions, closures, maps, decorators, anonymous function lambdas, and first-class function objects. These can serve as both complement and alternative to its OOP tools.

It's Free

Python is completely free to use and distribute. As with other open source software, such as Tcl, Perl, Linux, and Apache, you can fetch the entire Python system's source code for free on the Internet. There are no restrictions on copying it, embedding it in your systems, or shipping it with your products. In fact, you can even sell Python's source code, if you are so inclined.

But don't get the wrong idea: "free" doesn't mean "unsupported." On the contrary, the Python online community responds to user queries with a speed that most commercial software help desks would do well to try to emulate. Moreover, because Python comes with complete source code, it empowers developers, leading to the creation of a large team of implementation experts. Although studying or changing a programming language's implementation isn't everyone's idea of fun, it's comforting to know that you can do so if you need to. You're not dependent on the whims of a commercial vendor, because the ultimate documentation—*source code*—is at your disposal as a last resort.

As mentioned earlier, Python development is performed by a community that largely coordinates its efforts over the Internet. It consists of Python's original creator—*Guido van Rossum*, the officially anointed Benevolent Dictator for Life (*BDFL*) of Python—plus a supporting cast of thousands. Language changes must follow a formal enhancement procedure and be scrutinized by both other developers and the BDFL. This tends to make Python more conservative with changes than some other languages and systems. While the Python 3.X/2.X split broke with this tradition soundly and deliberately, it still holds generally true within each Python line.

It's Portable

The standard implementation of Python is written in portable ANSI C, and it compiles and runs on virtually every major platform currently in use. For example, Python programs run today on everything from PDAs to supercomputers. As a partial list, Python is available on:

- Linux and Unix systems
- Microsoft Windows (all modern flavors)
- Mac OS (both OS X and Classic)
- BeOS, OS/2, VMS, and QNX
- Real-time systems such as VxWorks
- Cray supercomputers and IBM mainframes

- PDAs running Palm OS, PocketPC, and Linux
- Cell phones running Symbian OS, and Windows Mobile
- Gaming consoles and iPods
- Tablets and smartphones running Google's Android and Apple's iOS
- And more

Like the language interpreter itself, the standard library modules that ship with Python are implemented to be as portable across platform boundaries as possible. Further, Python programs are automatically compiled to portable byte code, which runs the same on any platform with a compatible version of Python installed (more on this in the next chapter).

What that means is that Python programs using the core language and standard libraries run the same on Linux, Windows, and most other systems with a Python interpreter. Most Python ports also contain platform-specific extensions (e.g., COM support on Windows), but the core Python language and libraries work the same everywhere. As mentioned earlier, Python also includes an interface to the Tk GUI toolkit called tkinter (Tkinter in 2.X), which allows Python programs to implement full-featured graphical user interfaces that run on all major GUI desktop platforms without program changes.

It's Powerful

From a features perspective, Python is something of a hybrid. Its toolset places it between traditional scripting languages (such as Tcl, Scheme, and Perl) and systems development languages (such as C, C++, and Java). Python provides all the simplicity and ease of use of a scripting language, along with more advanced software-engineering tools typically found in compiled languages. Unlike some scripting languages, this combination makes Python useful for large-scale development projects. As a preview, here are some of the main things you'll find in Python's toolbox:

Dynamic typing
: Python keeps track of the kinds of objects your program uses when it runs; it doesn't require complicated type and size declarations in your code. In fact, as you'll see in Chapter 6, there is no such thing as a type or variable declaration anywhere in Python. Because Python code does not constrain data types, it is also usually automatically applicable to a whole range of objects.

Automatic memory management
: Python automatically allocates objects and reclaims ("garbage collects") them when they are no longer used, and most can grow and shrink on demand. As you'll learn, Python keeps track of low-level memory details so you don't have to.

Programming-in-the-large support
: For building larger systems, Python includes tools such as modules, classes, and exceptions. These tools allow you to organize systems into components, use OOP

to reuse and customize code, and handle events and errors gracefully. Python's functional programming tools, described earlier, provide additional ways to meet many of the same goals.

Built-in object types
: Python provides commonly used data structures such as lists, dictionaries, and strings as intrinsic parts of the language; as you'll see, they're both flexible and easy to use. For instance, built-in objects can grow and shrink on demand, can be arbitrarily nested to represent complex information, and more.

Built-in tools
: To process all those object types, Python comes with powerful and standard operations, including concatenation (joining collections), slicing (extracting sections), sorting, mapping, and more.

Library utilities
: For more specific tasks, Python also comes with a large collection of precoded library tools that support everything from regular expression matching to networking. Once you learn the language itself, Python's library tools are where much of the application-level action occurs.

Third-party utilities
: Because Python is open source, developers are encouraged to contribute precoded tools that support tasks beyond those supported by its built-ins; on the Web, you'll find free support for COM, imaging, numeric programming, XML, database access, and much more.

Despite the array of tools in Python, it retains a remarkably simple syntax and design. The result is a powerful programming tool with all the usability of a scripting language.

It's Mixable

Python programs can easily be "glued" to components written in other languages in a variety of ways. For example, Python's C API lets C programs call and be called by Python programs flexibly. That means you can add functionality to the Python system as needed, and use Python programs within other environments or systems.

Mixing Python with libraries coded in languages such as C or C++, for instance, makes it an easy-to-use frontend language and customization tool. As mentioned earlier, this also makes Python good at rapid prototyping—systems may be implemented in Python first, to leverage its speed of development, and later moved to C for delivery, one piece at a time, according to performance demands.

It's Relatively Easy to Use

Compared to alternatives like C++, Java, and C#, Python programming seems astonishingly simple to most observers. To run a Python program, you simply type it and run it. There are no intermediate compile and link steps, like there are for languages

such as C or C++. Python executes programs immediately, which makes for an interactive programming experience and *rapid turnaround* after program changes—in many cases, you can witness the effect of a program change nearly as fast as you can type it.

Of course, development cycle turnaround is only one aspect of Python's ease of use. It also provides a deliberately simple syntax and powerful built-in tools. In fact, some have gone so far as to call Python *executable pseudocode*. Because it eliminates much of the complexity in other tools, Python programs are simpler, smaller, and more flexible than equivalent programs in other popular languages.

It's Relatively Easy to Learn

This brings us to the point of this book: especially when compared to other widely used programming languages, the core Python language is remarkably easy to learn. In fact, if you're an experienced programmer, you can expect to be coding small-scale Python programs in a matter of days, and may be able to pick up some limited portions of the language in just hours—though you shouldn't expect to become an expert quite that fast (despite what you may have heard from marketing departments!).

Naturally, mastering any topic as substantial as today's Python is not trivial, and we'll devote the rest of this book to this task. But the true investment required to master Python is worthwhile—in the end, you'll gain programming skills that apply to nearly every computer application domain. Moreover, most find Python's learning curve to be much gentler than that of other programming tools.

That's good news for professional developers seeking to learn the language to use on the job, as well as for end users of systems that expose a Python layer for customization or control. Today, many systems rely on the fact that end users can learn enough Python to tailor their Python customization code onsite, with little or no support. Moreover, Python has spawned a large group of users who program for fun instead of career, and may never need full-scale software development skills. Although Python does have advanced programming tools, its core language essentials will still seem relatively simple to beginners and gurus alike.

It's Named After Monty Python

OK, this isn't quite a technical strength, but it does seem to be a surprisingly well-kept secret in the Python world that I wish to expose up front. Despite all the reptiles on Python books and icons, the truth is that Python is named after the British comedy group *Monty Python*—makers of the 1970s BBC comedy series *Monty Python's Flying Circus* and a handful of later full-length films, including *Monty Python and the Holy Grail*, that are still widely popular today. Python's original creator was a fan of Monty Python, as are many software developers (indeed, there seems to be a sort of symmetry between the two fields...).

This legacy inevitably adds a humorous quality to Python code examples. For instance, the traditional "foo" and "bar" for generic variable names become "spam" and "eggs" in the Python world. The occasional "Brian," "ni," and "shrubbery" likewise owe their appearances to this namesake. It even impacts the Python community at large: some events at Python conferences are regularly billed as "The Spanish Inquisition."

All of this is, of course, very funny if you are familiar with the shows, but less so otherwise. You don't need to be familiar with Monty Python's work to make sense of examples that borrow references from it, including many you will see in this book, but at least you now know their root. (Hey—I've warned you.)

How Does Python Stack Up to Language X?

Finally, to place it in the context of what you may already know, people sometimes compare Python to languages such as Perl, Tcl, and Java. This section summarizes common consensus in this department.

I want to note up front that I'm not a fan of winning by disparaging the competition—it doesn't work in the long run, and that's not the goal here. Moreover, this is not a zero sum game—most programmers will use many languages over their careers. Nevertheless, programming tools present choices and tradeoffs that merit consideration. After all, if Python didn't offer something over its alternatives, it would never have been used in the first place.

We talked about performance tradeoffs earlier, so here we'll focus on functionality. While other languages are also useful tools to know and use, many people find that Python:

- Is more powerful than *Tcl*. Python's strong support for "programming in the large" makes it applicable to the development of larger systems, and its library of application tools is broader.
- Is more readable than *Perl*. Python has a clear syntax and a simple, coherent design. This in turn makes Python more reusable and maintainable, and helps reduce program bugs.
- Is simpler and easier to use than *Java* and *C#*. Python is a scripting language, but Java and C# both inherit much of the complexity and syntax of larger OOP systems languages like C++.
- Is simpler and easier to use than *C++*. Python code is simpler than the equivalent C++ and often one-third to one-fifth as large, though as a scripting language, Python sometimes serves different roles.
- Is simpler and higher-level than *C*. Python's detachment from underlying hardware architecture makes code less complex, better structured, and more approachable than C, C++'s progenitor.

- Is more powerful, general-purpose, and cross-platform than *Visual Basic*. Python is a richer language that is used more widely, and its open source nature means it is not controlled by a single company.
- Is more readable and general-purpose than *PHP*. Python is used to construct websites too, but it is also applied to nearly every other computer domain, from robotics to movie animation and gaming.
- Is more powerful and general-purpose than *JavaScript*. Python has a larger toolset, and is not as tightly bound to web development. It's also used for scientific modeling, instrumentation, and more.
- Is more readable and established than *Ruby*. Python syntax is less cluttered, especially in nontrivial code, and its OOP is fully optional for users and projects to which it may not apply.
- Is more mature and broadly focused than *Lua*. Python's larger feature set and more extensive library support give it a wider scope than Lua, an embedded "glue" language like Tcl.
- Is less esoteric than *Smalltalk*, *Lisp*, and *Prolog*. Python has the dynamic flavor of languages like these, but also has a traditional syntax accessible to both developers and end users of customizable systems.

Especially for programs that do more than scan text files, and that might have to be read in the future by others (or by you!), many people find that Python fits the bill better than any other scripting or programming language available today. Furthermore, unless your application requires peak performance, Python is often a viable alternative to systems development languages such as C, C++, and Java: Python code can often achieve the same goals, but will be much less difficult to write, debug, and maintain.

Of course, your author has been a card-carrying Python evangelist since 1992, so take these comments as you may (and other languages' advocates' mileage may vary arbitrarily). They do, however, reflect the common experience of many developers who have taken time to explore what Python has to offer.

Chapter Summary

And that concludes the "hype" portion of this book. In this chapter, we've explored some of the reasons that people pick Python for their programming tasks. We've also seen how it is applied and looked at a representative sample of who is using it today. My goal is to teach Python, though, not to sell it. The best way to judge a language is to see it in action, so the rest of this book focuses entirely on the language details we've glossed over here.

The next two chapters begin our technical introduction to the language. In them, we'll explore ways to run Python programs, peek at Python's byte code execution model, and introduce the basics of module files for saving code. The goal will be to give you

just enough information to run the examples and exercises in the rest of the book. You won't really start programming per se until Chapter 4, but make sure you have a handle on the startup details before moving on.

Test Your Knowledge: Quiz

In this edition of the book, we will be closing each chapter with a quick open-book quiz about the material presented herein to help you review the key concepts. The answers for these quizzes appear immediately after the questions, and you are encouraged to read the answers once you've taken a crack at the questions yourself, as they sometimes give useful context.

In addition to these end-of-chapter quizzes, you'll find lab *exercises* at the end of each part of the book, designed to help you start coding Python on your own. For now, here's your first quiz. Good luck, and be sure to refer back to this chapter's material as needed.

1. What are the six main reasons that people choose to use Python?
2. Name four notable companies or organizations using Python today.
3. Why might you *not* want to use Python in an application?
4. What can you do with Python?
5. What's the significance of the Python `import this` statement?
6. Why does "spam" show up in so many Python examples in books and on the Web?
7. What is your favorite color?

Test Your Knowledge: Answers

How did you do? Here are the answers I came up with, though there may be multiple solutions to some quiz questions. Again, even if you're sure of your answer, I encourage you to look at mine for additional context. See the chapter's text for more details if any of these responses don't make sense to you.

1. Software quality, developer productivity, program portability, support libraries, component integration, and simple enjoyment. Of these, the quality and productivity themes seem to be the main reasons that people choose to use Python.
2. Google, Industrial Light & Magic, CCP Games, Jet Propulsion Labs, Maya, ESRI, and many more. Almost every organization doing software development uses Python in some fashion, whether for long-term strategic product development or for short-term tactical tasks such as testing and system administration.
3. Python's main downside is performance: it won't run as quickly as fully compiled languages like C and C++. On the other hand, it's quick enough for most applications, and typical Python code runs at close to C speed anyhow because it invokes

linked-in C code in the interpreter. If speed is critical, compiled extensions are available for number-crunching parts of an application.

4. You can use Python for nearly anything you can do with a computer, from website development and gaming to robotics and spacecraft control.
5. This was mentioned in a footnote: `import this` triggers an Easter egg inside Python that displays some of the design philosophies underlying the language. You'll learn how to run this statement in the next chapter.
6. "Spam" is a reference from a famous Monty Python skit in which people trying to order food in a cafeteria are drowned out by a chorus of Vikings singing about spam. Oh, and it's also a common variable name in Python scripts...
7. Blue. No, yellow! (See the prior answer.)

Python Is Engineering, Not Art

When Python first emerged on the software scene in the early 1990s, it spawned what is now something of a classic conflict between its proponents and those of another popular scripting language, Perl. Personally, I think the debate is tired and unwarranted today—developers are smart enough to draw their own conclusions. Still, this is one of the most common topics I'm asked about on the training road, and underscores one of the main reasons people choose to use Python; it seems fitting to say a few brief words about it here.

The short story is this: *you can do everything in Python that you can in Perl, but you can read your code after you do it*. That's it—their domains largely overlap, but Python is more focused on producing readable code. For many, the enhanced readability of Python translates to better code reusability and maintainability, making Python a better choice for programs that will not be written once and thrown away. Perl code is easy to write, but can be difficult to read. Given that most software has a lifespan much longer than its initial creation, many see Python as the more effective tool.

The somewhat longer story reflects the backgrounds of the designers of the two languages. *Python* originated with a mathematician by training, who seems to have naturally produced an orthogonal language with a high degree of uniformity and coherence. *Perl* was spawned by a linguist, who created a programming tool closer to natural language, with its context sensitivities and wide variability. As a well-known Perl motto states, *there's more than one way to do it*. Given this mindset, both the Perl language and its user community have historically encouraged untethered freedom of expression when writing code. One person's Perl code can be radically different from another's. In fact, writing unique, tricky code is often a source of pride among Perl users.

But as anyone who has done any substantial code maintenance should be able to attest, *freedom of expression is great for art, but lousy for engineering*. In engineering, we need a minimal feature set and predictability. In engineering, freedom of expression can lead to maintenance nightmares. As more than one Perl user has confided to me, the result of too much freedom is often code that is much easier to rewrite from scratch than to modify. This is clearly less than ideal.

Consider this: when people create a painting or a sculpture, they do so largely for themselves; the prospect of someone else changing their work later doesn't enter into it. This is a critical difference between art and engineering. When people write *software*, they are not writing it for themselves. In fact, they are not even writing primarily for the computer. Rather, good programmers know that code is written for the next human being who has to read it in order to maintain or reuse it. If that person cannot understand the code, it's all but useless in a realistic development scenario. In other words, programming is not about being clever and obscure—*it's about how clearly your program communicates its purpose*.

This readability focus is where many people find that Python most clearly differentiates itself from other scripting languages. Because Python's syntax model almost *forces* the creation of readable code, Python programs lend themselves more directly to the full software development cycle. And because Python emphasizes ideas such as limited interactions, code uniformity, and feature consistency, it more directly fosters code that can be used long after it is first written.

In the long run, Python's focus on *code quality* in itself boosts programmer productivity, as well as programmer satisfaction. Python programmers can be wildly creative, too, of course, and as we'll see, the language does offer multiple solutions for some tasks—sometimes even more than it should today, an issue we'll confront head-on in this book too. In fact, this sidebar can also be read as a *cautionary tale*: quality turns out to be a fragile state, one that depends as much on *people* as on technology. Python has historically encouraged good engineering in ways that other scripting languages often did not, but the rest of the quality story is up to you.

At least, that's some of the common consensus among many people who have adopted Python. You should judge such claims for yourself, of course, by learning what Python has to offer. To help you get started, let's move on to the next chapter.