



# Think Python

HOW TO THINK LIKE A COMPUTER SCIENTIST

Allen B. Downey



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Second Edition

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## **Think Python**

by Allen B. Downey

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# Preface

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## The Strange History of This Book

In January 1999 I was preparing to teach an introductory programming class in Java. I had taught it three times and I was getting frustrated. The failure rate in the class was too high and, even for students who succeeded, the overall level of achievement was too low.

One of the problems I saw was the books. They were too big, with too much unnecessary detail about Java, and not enough high-level guidance about how to program. And they all suffered from the trapdoor effect: they would start out easy, proceed gradually, and then somewhere around Chapter 5 the bottom would fall out. The students would get too much new material, too fast, and I would spend the rest of the semester picking up the pieces.

Two weeks before the first day of classes, I decided to write my own book. My goals were:

- Keep it short. It is better for students to read 10 pages than not read 50 pages.
- Be careful with vocabulary. I tried to minimize jargon and define each term at first use.
- Build gradually. To avoid trapdoors, I took the most difficult topics and split them into a series of small steps.
- Focus on programming, not the programming language. I included the minimum useful subset of Java and left out the rest.

I needed a title, so on a whim I chose *How to Think Like a Computer Scientist*.

My first version was rough, but it worked. Students did the reading, and they understood enough that I could spend class time on the hard topics, the interesting topics and (most important) letting the students practice.

I released the book under the GNU Free Documentation License, which allows users to copy, modify, and distribute the book.

What happened next is the cool part. Jeff Elkner, a high school teacher in Virginia, adopted my book and translated it into Python. He sent me a copy of his translation, and I had the unusual experience of learning Python by reading my own book. As Green Tea Press, I published the first Python version in 2001.

In 2003 I started teaching at Olin College and I got to teach Python for the first time. The contrast with Java was striking. Students struggled less, learned more, worked on more interesting projects, and generally had a lot more fun.

Since then I've continued to develop the book, correcting errors, improving some of the examples and adding material, especially exercises.

The result is this book, now with the less grandiose title *Think Python*. Some of the changes are:

- I added a section about debugging at the end of each chapter. These sections present

general techniques for finding and avoiding bugs, and warnings about Python pitfalls.

- I added more exercises, ranging from short tests of understanding to a few substantial projects. Most exercises include a link to my solution.
- I added a series of case studies — longer examples with exercises, solutions, and discussion.
- I expanded the discussion of program development plans and basic design patterns.
- I added appendices about debugging and analysis of algorithms.

The second edition of *Think Python* has these new features:

- The book and all supporting code have been updated to Python 3.
- I added a few sections, and more details on the Web, to help beginners get started running Python in a browser, so you don't have to deal with installing Python until you want to.
- For “**The turtle Module**” I switched from my own turtle graphics package, called Swampy, to a more standard Python module, `turtle`, which is easier to install and more powerful.
- I added a new chapter called “The Goodies”, which introduces some additional Python features that are not strictly necessary, but sometimes handy.

I hope you enjoy working with this book, and that it helps you learn to program and think like a computer scientist, at least a little bit.

— Allen B. Downey  
Olin College

## Conventions Used in This Book

The following typographical conventions are used in this book:

### *Italic*

Indicates new terms, URLs, email addresses, filenames, and file extensions.

### **Bold**

Indicates terms defined in the Glossary.

### *Constant width*

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

### ***Constant width bold***

Shows commands or other text that should be typed literally by the user.

### *Constant width italic*

Shows text that should be replaced with user-supplied values or by values determined by context.

## Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at <http://www.greenteapress.com/thinkpython2/code>.

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Thanks to the Free Software Foundation for developing the GNU Free Documentation License, which helped make my collaboration with Jeff and Chris possible, and Creative Commons for the license I am using now.

Thanks to the editors at Lulu who worked on *How to Think Like a Computer Scientist*.

Thanks to the editors at O'Reilly Media who worked on *Think Python*.

Thanks to all the students who worked with earlier versions of this book and all the contributors (listed below) who sent in corrections and suggestions.

## Contributor List

More than 100 sharp-eyed and thoughtful readers have sent in suggestions and corrections over the past few years. Their contributions, and enthusiasm for this project, have been a huge help.

If you have a suggestion or correction, please send email to [feedback@thinkpython.com](mailto:feedback@thinkpython.com). If I make a change based on your feedback, I will add you to the contributor list (unless you ask to be omitted).

If you include at least part of the sentence the error appears in, that makes it easy for me to search. Page and section numbers are fine, too, but not quite as easy to work with. Thanks!

- Lloyd Hugh Allen sent in a correction to Section 8.4.
- Yvon Boulianne sent in a correction of a semantic error in Chapter 5.
- Fred Bremmer submitted a correction in Section 2.1.
- Jonah Cohen wrote the Perl scripts to convert the LaTeX source for this book into beautiful HTML.
- Michael Conlon sent in a grammar correction in Chapter 2 and an improvement in style in Chapter 1, and he initiated discussion on the technical aspects of interpreters.
- Benoit Girard sent in a correction to a humorous mistake in Section 5.6.
- Courtney Gleason and Katherine Smith wrote `horsebet.py`, which was used as a case study in an earlier version of the book. Their program can now be found on the website.
- Lee Harr submitted more corrections than we have room to list here, and indeed he should be listed as one of the principal editors of the text.
- James Kaylin is a student using the text. He has submitted numerous corrections.
- David Kershaw fixed the broken `catTwice` function in Section 3.10.
- Eddie Lam has sent in numerous corrections to Chapters 1, 2, and 3. He also fixed the Makefile so that it creates an index the first time it is run and helped us set up a versioning scheme.
- Man-Yong Lee sent in a correction to the example code in Section 2.4.
- David Mayo pointed out that the word “unconsciously” in Chapter 1 needed to be changed to “subconsciously”.
- Chris McAloon sent in several corrections to Sections 3.9 and 3.10.



- Matthew J. Moelter has been a long-time contributor who sent in numerous corrections and suggestions to the book.
- Simon Dicon Montford reported a missing function definition and several typos in Chapter 3. He also found errors in the `increment` function in Chapter 13.
- John Ouzts corrected the definition of “return value” in Chapter 3.
- Kevin Parks sent in valuable comments and suggestions as to how to improve the distribution of the book.
- David Pool sent in a typo in the glossary of Chapter 1, as well as kind words of encouragement.
- Michael Schmitt sent in a correction to the chapter on files and exceptions.
- Robin Shaw pointed out an error in Section 13.1, where the `printTime` function was used in an example without being defined.
- Paul Sleight found an error in Chapter 7 and a bug in Jonah Cohen’s Perl script that generates HTML from LaTeX.
- Craig T. Snyder is testing the text in a course at Drew University. He has contributed several valuable suggestions and corrections.
- Ian Thomas and his students are using the text in a programming course. They are the first ones to test the chapters in the latter half of the book, and they have made numerous corrections and suggestions.
- Keith Verheyden sent in a correction in Chapter 3.
- Peter Winstanley let us know about a longstanding error in our Latin in Chapter 3.
- Chris Wrobel made corrections to the code in the chapter on file I/O and exceptions.
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- Christoph Zwerschke sent several corrections and pedagogic suggestions, and explained the difference between *gleich* and *selbe*.
- James Mayer sent us a whole slew of spelling and typographical errors, including two in the contributor list.
- Hayden McAfee caught a potentially confusing inconsistency between two examples.
- Angel Arnal is part of an international team of translators working on the Spanish

version of the text. He has also found several errors in the English version.

- Tauhidul Hoque and Lex Berezhny created the illustrations in Chapter 1 and improved many of the other illustrations.
- Dr. Michele Alzetta caught an error in Chapter 8 and sent some interesting pedagogic comments and suggestions about Fibonacci and Old Maid.
- Andy Mitchell caught a typo in Chapter 1 and a broken example in Chapter 2.
- Kalin Harvey suggested a clarification in Chapter 7 and caught some typos.
- Christopher P. Smith caught several typos and helped us update the book for Python 2.2.
- David Hutchins caught a typo in the Foreword.
- Gregor Lingl is teaching Python at a high school in Vienna, Austria. He is working on a German translation of the book, and he caught a couple of bad errors in Chapter 5.
- Julie Peters caught a typo in the Preface.
- Florin Oprina sent in an improvement in `makeTime`, a correction in `printTime`, and a nice typo.
- D. J. Webre suggested a clarification in Chapter 3.
- Ken found a fistful of errors in Chapters 8, 9 and 11.
- Ivo Wever caught a typo in Chapter 5 and suggested a clarification in Chapter 3.
- Curtis Yanko suggested a clarification in Chapter 2.
- Ben Logan sent in a number of typos and problems with translating the book into HTML.
- Jason Armstrong saw the missing word in Chapter 2.
- Louis Cordier noticed a spot in Chapter 16 where the code didn't match the text.
- Brian Cain suggested several clarifications in Chapters 2 and 3.
- Rob Black sent in a passel of corrections, including some changes for Python 2.2.
- Jean-Philippe Rey at Ecole Centrale Paris sent a number of patches, including some updates for Python 2.2 and other thoughtful improvements.
- Jason Mader at George Washington University made a number of useful suggestions and corrections.

- Jan Gundtofte-Bruun reminded us that “a error” is an error.
- Abel David and Alexis Dinno reminded us that the plural of “matrix” is “matrices”, not “matrixes”. This error was in the book for years, but two readers with the same initials reported it on the same day. Weird.
- Charles Thayer encouraged us to get rid of the semicolons we had put at the ends of some statements and to clean up our use of “argument” and “parameter”.
- Roger Sperberg pointed out a twisted piece of logic in Chapter 3.
- Sam Bull pointed out a confusing paragraph in Chapter 2.
- Andrew Cheung pointed out two instances of “use before def”.
- C. Corey Capel spotted a missing word and a typo in Chapter 4.
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- Jared Spindor found some jetsam at the end of a sentence.
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- Adam Hobart fixed a problem with floor division in `arc`.
- Daryl Hammond and Sarah Zimmerman pointed out that I served up `math.pi` too early. And Zim spotted a typo.
- George Sass found a bug in a Debugging section.

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