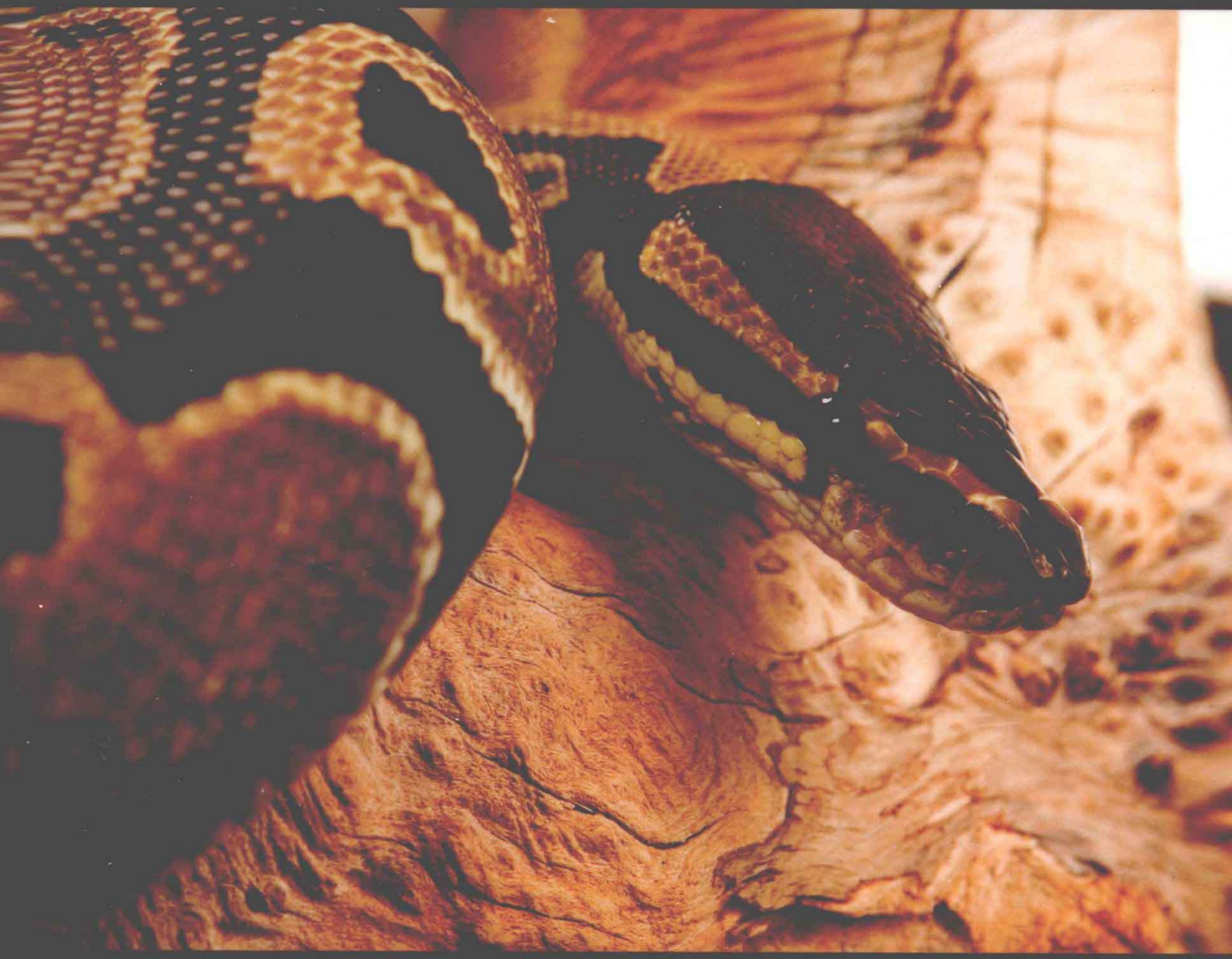
ALLEN B. DOWNEY

PYTHON
FOR SOFTWARE DESIGN



HOW TO THINK LIKE A COMPUTER SCIENTIST

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Olin College of Engineering

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Python for Software Design

Python for Software Design is a concise introduction to software design using the Python programming language. Intended for people with no programming experience, this book starts with the most basic concepts and gradually adds new material. Some of the ideas students find most challenging, like recursion and object-oriented programming, are divided into a sequence of smaller steps and introduced over the course of several chapters. The focus is on the programming process, with special emphasis on debugging. The book includes a wide range of exercises, from short examples to substantial projects, so that students have ample opportunity to practice each new concept.

Exercise solutions and code examples along with Swampy, a suite of Python programs that is used in some of the exercises, are available from thinkpython.com.

Allen B. Downey, Ph.D., is an Associate Professor of Computer Science at the Olin College of Engineering in Needham, Massachusetts. He has taught at Wellesley College, Colby College, and UC Berkeley. He has a doctorate in computer science from UC Berkeley and a master's degree from MIT. Professor Downey is the author of a previous version of this book, titled *How to Think Like a Computer Scientist: Learning with Python*, which he self-published in 2001.

Preface

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. I had tried three different books (and had read a dozen more), and they all had the same problems. 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 trap door effect: they would start out easy, proceed gradually, and then somewhere around Chapter 4 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. I wrote one 10-page chapter a day for 13 days. I made some revisions on Day 14 and then sent it out to be photocopied.

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 the jargon and define each term at first use.
- Build gradually. To avoid trap doors, 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.

Jeff and I revised the book, incorporated a case study by Chris Meyers, and in 2001 we released *How to Think Like a Computer Scientist: Learning with Python*, also under the GNU Free Documentation License. As Green Tea Press, I published the book and started selling hard copies through Amazon.com and college book stores. Other books from Green Tea Press are available at `greenteapress.com`.

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.

Over the last five years I have continued to develop the book, correcting errors, improving some of the examples, and adding material, especially exercises. In 2008, I started work on a major revision of the book – at the same time, I was contacted by an editor at Cambridge University Press who was interested in publishing the next edition. Good timing!

The result is this book, now with the less grandiose title *Python for Software Design*. 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 removed the material in the last few chapters about the implementation of lists and trees. I still love those topics, but I thought they were incongruent with the rest of the book.
- I added more exercises, ranging from short tests of understanding to a few substantial projects.
- I added a series of case studies – longer examples with exercises, solutions, and discussion. Some of them are based on Swampy, a suite of Python programs I wrote for use in my classes. Swampy, code examples, and some solutions are available from `thinkpython.com`.
- I expanded the discussion of program development plans and basic design patterns.
- The use of Python is more idiomatic. The book is still about programming, not Python, but now I think the book gets more leverage from the language.

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

ACKNOWLEDGMENTS

First and most importantly, I thank Jeff Elkner, who translated my Java book into Python, which got this project started and introduced me to what has turned out to be my favorite language.

I also thank Chris Meyers, who contributed several sections to *How to Think Like a Computer Scientist*.

And I thank the Free Software Foundation for developing the GNU Free Documentation License, which helped make my collaboration with Jeff and Chris possible.

I also thank the editors at Lulu who worked on *How to Think Like a Computer Scientist* and the editors at Cambridge University Press who worked on this edition.

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

And I thank my wife, Lisa, for her work on this book, and Green Tea Press, and everything else, too.

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`. 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, it will be easier for me to search for it. 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 to and suggestions for 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 Sleigh found an error in Chapter 7 and a bug in Jonah Cohen's Perl script that generates HTML from LaTeX.
- Craig T. Snydal 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.
- Moshe Zadka has made invaluable contributions to this project. In addition to writing the first draft of the chapter on dictionaries, he provided continual guidance in the early stages of the book.
- 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 is helping us prepare to update the book for Python 2.2.
- David Hutchins caught a typo in the Preface.
- 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 a 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 semi-colons 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 in the Third Theorem of Debugging and a typo in Chapter 4.
- Alessandra helped clear up some Turtle confusion.
- Wim Champagne found a brain-o in a dictionary example.
- Douglas Wright pointed out a problem with floor division in `arc`.
- Jared Spindor found some jetsam at the end of a sentence.
- Lin Peiheng sent a number of very helpful suggestions.

- Ray Hagtvedt sent in two errors and a not-quite-error.
- Torsten Hübsch pointed out an inconsistency in Swampy.
- Inga Petuhhov corrected an example in Chapter 14.
- Arne Babenhauserheide sent several helpful corrections.
- Mark E. Casida is is good at spotting repeated words.
- Scott Tyler filled in a that was missing. And then sent in a heap of corrections.
- Gordon Shephard sent in several corrections, all in separate emails.
- Andrew Turner spotted an error in Chapter 8.
- 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.
- Brian Bingham suggested Exercise 11.9.
- Leah Engelbert-Fenton pointed out that I used `tuple` as a variable name, contrary to my own advice. And then found a bunch of typos and a "use before def."
- Joe Funke spotted a typo.
- Chao-chao Chen found an inconsistency in the Fibonacci example.
- Jeff Paine knows the difference between space and spam.
- Lubos Pintes sent in a typo.
- Gregg Lind and Abigail Heithoff suggested Exercise 14.6.
- Max Hailperin has sent in a number of corrections and suggestions. Max is one of the authors of the extraordinary *Concrete Abstractions*, which you might want to read when you are done with this book.
- Chotipat Pornavalai found an error in an error message.
- Stanislaw Antol sent a list of very helpful suggestions.
- Eric Pashman sent a number of corrections for Chapters 4–11.
- Miguel Azevedo found some typos.
- Jianhua Liu sent in a long list of corrections.
- Nick King found a missing word.
- Martin Zuther sent a long list of suggestions.
- Adam Zimmerman found an inconsistency in my instance of an "instance" and several other errors.
- Ratnakar Tiwari suggested a footnote explaining degenerate triangles.
- Anurag Goel suggested another solution for `is_abecedarian` and sent some additional corrections. And he knows how to spell Jane Austen.
- Kelli Kratzer spotted one of they typos.
- Mark Griffiths pointed out a confusing example in Chapter 3.
- Roydan Ongie found an error in my Newton's method.
- Patryk Wolowiec helped me with a problem in the HTML version.

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