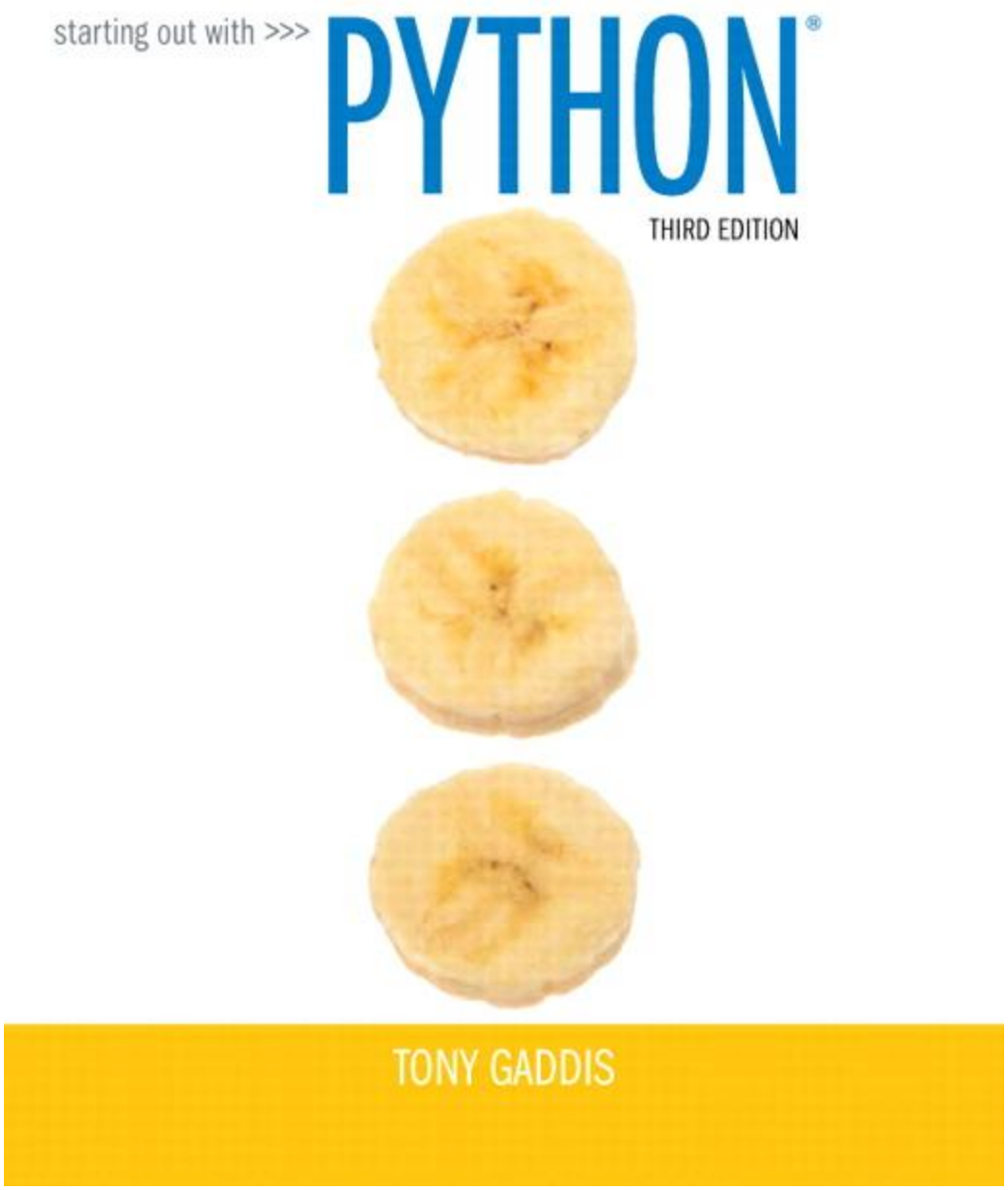
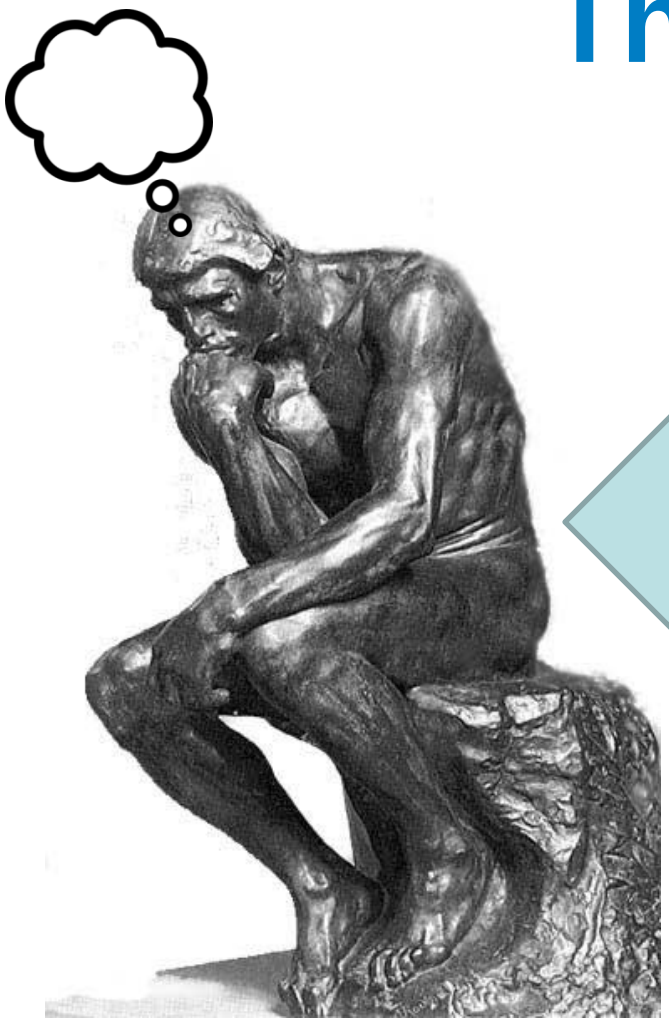
DEBUGGING

PYTHON

CODE



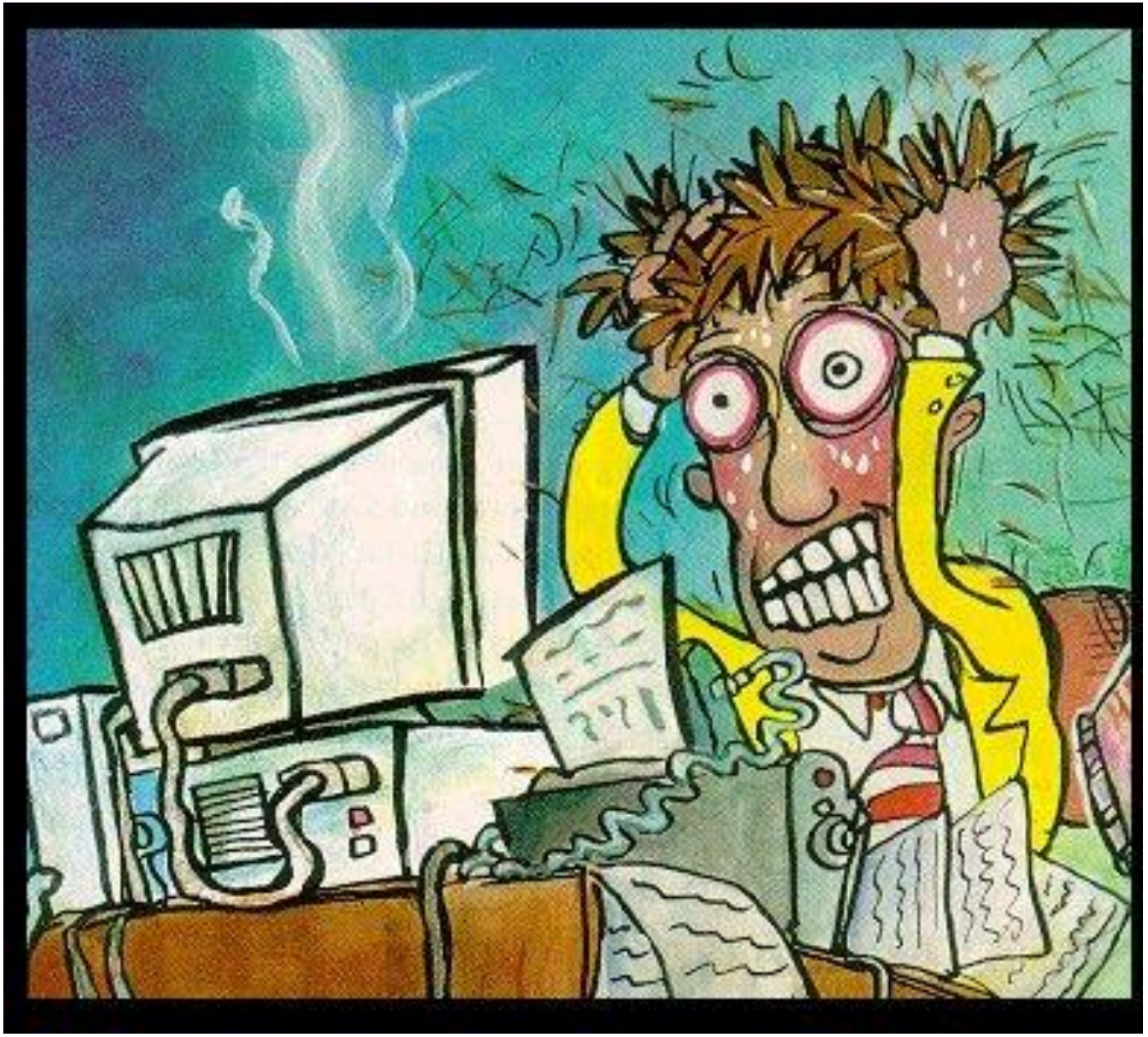
The problem

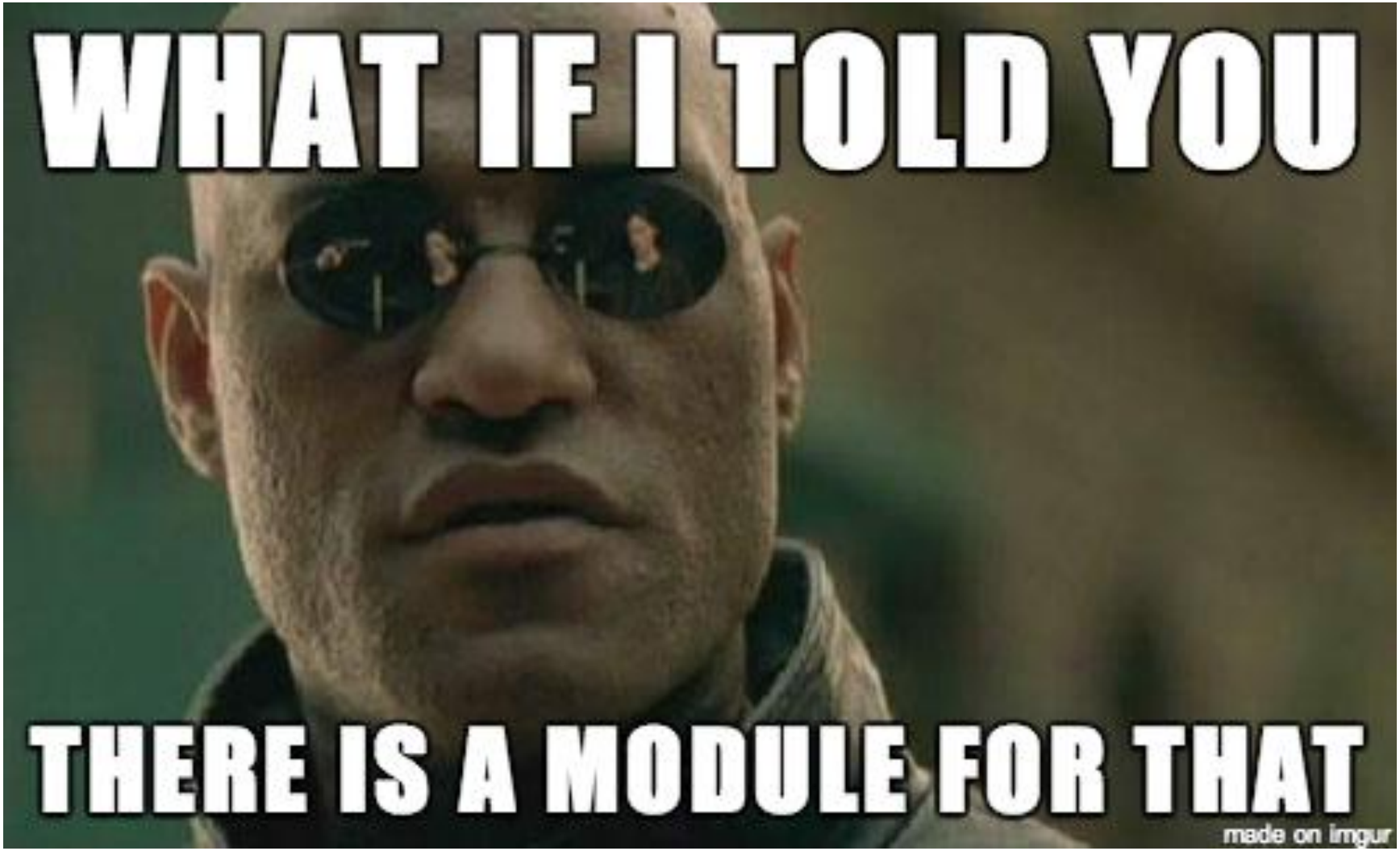


Not the same!

What you want
your program to do

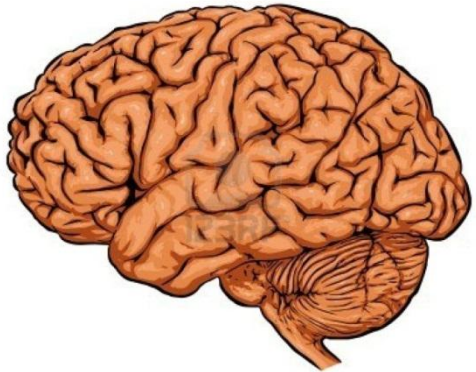
What your
program does




WHAT IF I TOLD YOU
THERE IS A MODULE FOR THAT
made on imgur

Debugging tools

- **Python Interpreter**
  - Python error message
- **`print`**
- **`assert`**
- **Python Tutor (http://pythontutor.com)**
- **IDE Debugging Tools**
- **Best tool:**



Two key ideas

1. **The scientific method**
2. **Divide and conquer**

If you master those, you will find debugging easy, and possibly “enjoyable”

The scientific method

1. **Create a hypothesis**
2. **Design an experiment to test that hypothesis**
   - Ensure that it yields insight
3. **Understand the result of your experiment**
   - If you don’t understand, then possibly suspend your main line of work to understand that

Tips:

- **Be systematic**
  - Never do anything if you don't have a reason
  - Random guessing is likely to dig you into a deeper hole
- **Don’t make assumptions (verify them)**

Example experiments

1. **An alternate implementation of a function**
   - Run all your test cases afterward
2. **A new, simpler test case**
   - Examples: smaller input, or test a function in isolation
   - Can help you understand the reason for a failure

Example experiments

Keep track of everything you do

- **Specific inputs and outputs (both expected and actual)**
- **Specific versions of the program**
  - If you get stuck, you can return to something that works
  - You can write multiple implementations of a function
- **What you have already tried**
- **What you are in the middle of doing now**
  - This may look like a stack!
- **What you are sure of, and why**

Have a notebook or paper handy to write down various results

Read the error message

```
Traceback (most recent call last):
  File "nx_error.py", line 41, in <module>
    print friends_of_friends(rj, myval)
  File "nx_error.py", line 30, in friends_of_friends
    f = friends(graph, user)
  File "nx_error.py", line 25, in friends
    return set(graph.neighbors(user))#
  File "/Library/Frameworks/…/graph.py", line 978, in neighbors
     return list(self.adj[n])
TypeError: unhashable type: 'list'
```

First function that was called (**<module>** means the interpreter)

Second function that was called

Call stack or traceback

Last function that was called (this one suffered an error)

The error message: daunting but useful.
You need to understand:

- the literal meaning of the error
- the underlying problems certain errors tend to suggest

List of all exceptions (errors):
http://docs.python.org/2/library/exceptions.html#bltin-exceptions
Two other resources, with more details about a few of the errors:
http://inventwithpython.com/appendixd.html
http://www.cs.arizona.edu/people/mccann/errors-python

Divide and conquer

- **Where is the defect (or “bug”)?**
- **Your goal is to find the one place that it is**
- **Finding a defect is often harder than fixing it**

- **Initially, the defect might be anywhere in your program**
  - It is impractical to find it if you have to look everywhere
- **Idea: bit by bit reduce the scope of your search**
- **Eventually, the defect is localized to a few lines or one line**
  - Then you can understand and fix it

- **4 ways to divide and conquer:**
  - In the program code
  - In test cases
  - During the program execution
  - During the development history

Divide and conquer in the program code

- **Localize the defect to part of the program**
  - e.g., one function, or one part of a function
- **Code that isn't executed cannot contain the defect**

3 approaches:

- **Test one function at a time**
- **Add assertions or print statements**
  - The defect is executed before the failing assertion (and maybe after a succeeding assertion)
- **Split complex expressions into simpler ones**

  Example: Failure in

```
result = set({graph.neighbors(user)})
```

  Change it to

```
nbors = graph.neighbors(user)
nbors_set = {nbors}
result = set(nbors_set)
```

  The error occurs on the "nbors_set = {nbors}" line

Divide and conquer in test cases

- **Your program fails when run on some large input**
  - It's hard to comprehend the error message
  - The log of print statement output is overwhelming
- **Try a smaller input**
  - Choose an input with some but not all characteristics of the large input
  - Example: Unicode characters, duplicates, zeroes in data, …

Divide and conquer in execution time via `print` statements

- **A sequence of `print` statements is a record of the execution of your program**
- **The `print` statements let you see and search multiple moments in time**
- **Print statements are a useful technique, in moderation**
- **Be disciplined**
  - Print results, sub- results, types, lists …
  - Too much output is overwhelming rather than informative
  - Remember the scientific method: have a reason (a hypothesis to be tested) for each print statement
  - Don't *only* use print statements

Divide and conquer in development history

- **The code used to work (for some test case)**
- **The code now fails**
- **The defect is related to some line you changed**

- **This is useful only if you kept a version of the code that worked (use good names!)**
- **This is most useful if you have made few changes**
- **Moral: test often!**
  - Fewer lines to compare
  - You remember what you were thinking/doing recently

A metaphor about debugging

If your code doesn't work as expected, then by definition you don't understand what is going on.

- **You're lost in the woods.**
- **All bets are off.**
- **Don't trust anyone or anything.**

Don't press on into unexplored territory -- go back the way you came!
(and leave breadcrumbs!)

You're trying to "advance the front lines," not "trailblaze"

Time-Saving Trick: Make Sure you're Debugging the Right Problem

- **The game is to go from "working to working"**
- **When something doesn't work, STOP!**
  - It's wild out there!
- **FIRST: go back to the last situation that worked properly.**
  - Rollback your recent changes and verify that everything still works as expected.
  - Don't make assumptions – by definition, you don't understand the code when something goes wrong, so you can't trust your assumptions.
  - You may find that even what previously worked now doesn't
  - Perhaps you forgot to consider some "innocent" or unintentional change, and now even tested code is broken

A bad timeline

- A works, so celebrate a little
- Now try B
- B doesn’t work
- Change B and try again
- Change B and try again
- Change B and try again

…

A better timeline

- **A works, so celebrate a little**
- **Now try B**
- **B doesn't work**
- ***Rollback to A***
- **Does A still work?**
  - Yes: Find A' that is somewhere between A and B
  - No: You have unintentionally changed something else, and there's no point futzing with B at all!

These "innocent" and unnoticed changes happen more than you would think!

- You add a comment, and the indentation changes.
- You add a print statement, and a function is evaluated twice.
- You move a file, and the wrong one is being read
- You're on a different computer, and the library is a different version

Once on solid ground, you can set out again

- Once you have something that works and something that doesn't work, it's only a matter of time
- You just need to incrementally change the working code into the non-working code, and the problem will reveal itself.
- Variation: Perhaps your code works with one input, but fails with another. Incrementally change the good input into the bad input to expose the problem.

Simple Debugging Tools

print

- shows what's happening whether there's a problem or not
- does not stop execution

assert

- Raises an exception if some condition is not met
- Does nothing if everything works
- Example: `assert len(myList) == 16`
- Use this liberally! Not just for debugging!