Debugging Logical Errors

Debug Logical Errors By Checking Inputs and Outputs

When your code generates a logical error, the best thing to do is **compare the expected output to the actual output**.

1. Copy the function call from the `assert` that is failing into the interpreter. Compare the actual output to the expected output.
    - `assert` functions work buy throwing an assertion error if the expression inside them is false
2. If the **expected** output seems incorrect, re-read the problem prompt.
3. If you're not sure why the actual output is produced, use a **debugging process** to investigate.

If you've written the test set yourself, you should also take a moment to make sure the test itself is not incorrect.

example.py

```
1  def findAverage(total, n):
2      if n <= 0:
3          return "Cannot compute the average"
4      return total // n
5
6  def testFindAverage():
7      print("Testing findAverage()...", end="")
8      assert(findAverage(20, 4) == 5)
9      assert(findAverage(13, 2) == 6.5)
10     assert(findAverage(10, 0) == "Cannot compute the average")
11     print("... done!")
12
13 testFindAverage()
```

```
Running script: "C:\Users\river\Downloads\example.py"
Testing findAverage()...Traceback (most recent call last):
  File "C:\Users\river\Downloads\example.py", line 13, in
<module>
    testFindAverage()
  File "C:\Users\river\Downloads\example.py", line 9, in t
estFindAverage
    assert(findAverage(13, 2) == 6.5)
AssertionError

>>>
```

function call

expected output

Ways to Debug

There are many approaches you can take towards debugging code effectively. Let's highlight three.

- **Rubber Duck Debugging:** talking through your code
- **Printing and Experimenting:** visualizing what's in your code
- **Thorough Tracing:** checking each part of the code line-by-line

Sidebar: Clean Up Top-Level Testing

Some students like to test their code by adding print statements and function calls at the top level of the code (not inside a function).

This is fine, but if you do this, **remove the top-level code** before you submit on Gradescope. Otherwise, the tool might mark your entire submission as incorrect instead of only marking the single broken function.

Alternative approach: do testing in the interpreter! After you 'Run File as Script', all of your functions are available there to be tested.

Rubber Duck Debugging

If you find yourself getting stuck, try **rubber duck debugging**. Explain what your code is supposed to do and what is going wrong out loud to an inanimate object, like a rubber duck.

In the process of explaining your code out loud to someone else, you may find that a piece of your code does not match your intentions, or that you missed a step. You can then make the fix easily. This works more often than you might think!

Print and Experiment

If rubber duck debugging doesn't work, try **printing and experimenting** to determine where in your code the problem is.

Add print statements around where you think the error occurs that display relevant values in the code. Run the code again and check whether the printed values match what you think they should be at that stage in the code.

Each print call should also include a brief string that gives context to what is being printed. Here is an example of a piece of code that could have a logical error, and how we could use print statements to see what's going wrong:

```
# f is some function
def foo():
    x = f(1)
    y = f(2)

    print(“Before if x=”, x, “y=”, y”)
    if x < 10:
        y += 100
        print(“In if y=”, y)
        elif y < 10:
                x += 100
                print(“In elif x=”, x)
        else:
                x += y
                print(“In else x=”, x)
        print(x, y)
        return x + y
```

Understanding the Prompt

When something goes wrong with your code, before rushing to change the code itself, you should make sure you understand **conceptually** what your code does.

First- make sure you're solving the right problem! Re-read the problem prompt to check that you're doing the right task.

It can often help to analyze the **test cases** to make sure you understand why each input results in each output.

Making Hypotheses

If something looks wrong in the printed results, make a hypothesis about what the problem is and adjust your code accordingly. Then run the code again and see if the values change. Repeat this as much as necessary until your code works as expected.

An important part of this process is that you have to be intentional about the changes you make. Don't just change parts of the code haphazardly - have a theory for why each change might fix your problem.

Thorough Tracing

If you can't find the problem through printing and experimenting, you may have to resort to **thorough tracing** to determine what's going wrong.

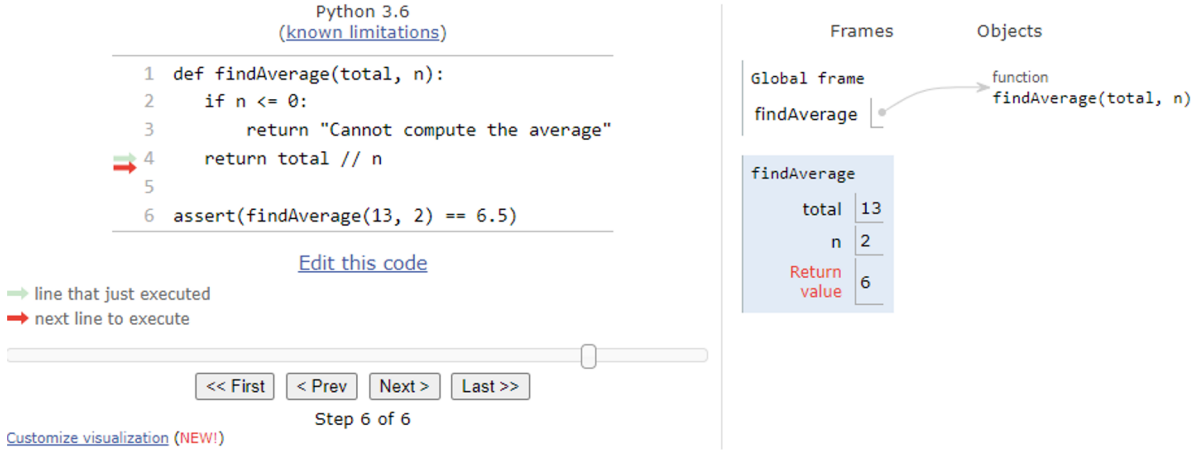
Step through your code line by line and track **on paper** what values should be held in each of your variables at each step of the process.

Compare your traced values with what you would create step-by-step if you were solving the problem by hand. This might help you identify where the problem is occurring.

Tracing with Tools

Learning how to trace code by hand is a useful skill, but there are also **tools** that can help support you during debugging. Start with the website http://pythontutor.com/ .

If you paste your code into the editor and click 'Visualize Execution', you can step through your code line by line. The tool will visualize the **state** of the program on the right as you step through it. This can be very helpful!



Debugging is Hard

Finally, remember that debugging is hard! If you've spent more than **15 minutes stuck on an error**, more effort is not the solution. Get a friend or TA to help (or Piazza!), or take a break and come back to the problem later. A fresh mindset will make finding your bug much easier.