Lecture 5

Visualizing Functions

Announcements For This Lecture

Readings

- See link on website:
  - Docstrings in Python
  - Material is not in Text

Today's Lab

- Practice today's lecture
- **Highly recommend doing optional part**

Assignment 1

- Posted on web page
  - Due Wed, Sep. 18th
  - Revise until correct
- Can work in pairs
  - One submission for pair
  - Link up on Piazza
- **Consultants can help**

One-on-One Sessions

- Starting tomorrow: 1/2-hour one-on-one sessions
  - Bring computer to work with instructor, TA or consultant
  - Hands on, dedicated help with Lab 2 and/or Lab 3
  - To prepare for assignment, **not for help on assignment**
- **Limited availability: we cannot get to everyone**
  - Students with experience or confidence should hold back
- Sign up online in CMS: first come, first served
  - Choose assignment One-on-One
  - Pick a time that works for you; will add slots as possible
  - Can sign up starting at 1pm **TODAY**

Anatomy of a Specification

```
def greet(n):
    """Prints a greeting to the name n

    Greeting has format 'Hello <n>!'
    Followed by a conversation starter.

    Precondition: n is a string
    representing a person's name"""
    print 'Hello '+n+'!'
    print 'How are you?'
```

One line description, followed by blank line

More detail about the function. It may be many paragraphs.

Precondition specifies assumptions we make about the arguments

Anatomy of a Specification

```
def to_centigrade(x):
    """Returns: x converted to centigrade

    Value returned has type float.

    Precondition: x is a float measuring
    temperature in fahrenheit"""
    return 5*(x-32)/9.0
```

"Returns" indicates a fruitful function

More detail about the function. It may be many paragraphs.

Precondition specifies assumptions we make about the arguments

Preconditions

- Precondition is a promise
  - If precondition is true, the function works
  - If precondition is false, no guarantees at all
- Get **software bugs** when
  - Function precondition is not documented properly
  - Function is used in ways that violates precondition

```
>>> to_centigrade(32)
0.0
>>> to_centigrade(212)
100.0
>>> to_centigrade('32')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "temperature.py", line 19 ...
TypeError: unsupported operand type(s)
for -: 'str' and 'int'
```

Precondition violated

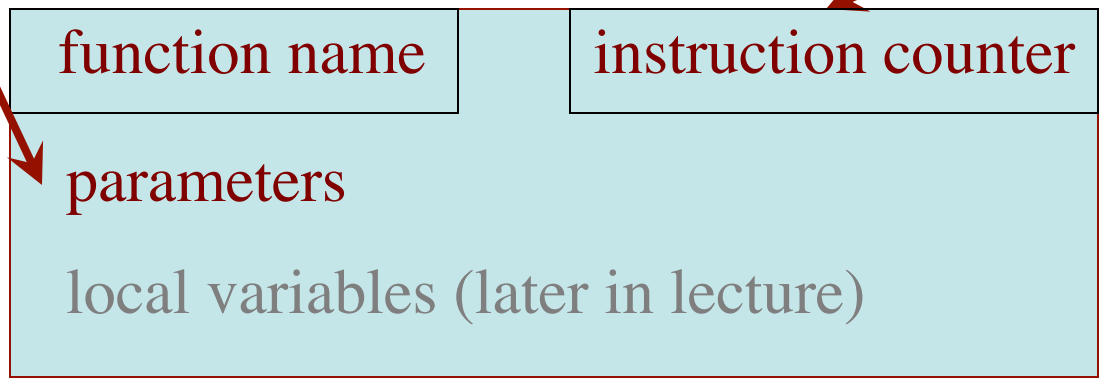
How Do Functions Work?

Draw template on a piece of paper

- **Function Frame**: Representation of function call
- A **conceptual model** of Python

Draw parameters as variables (named boxes)

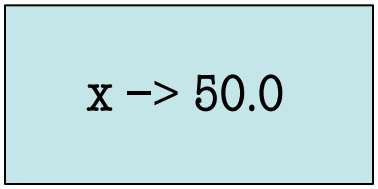
- Number of statement in the function body to execute next
- **Starts with 1**



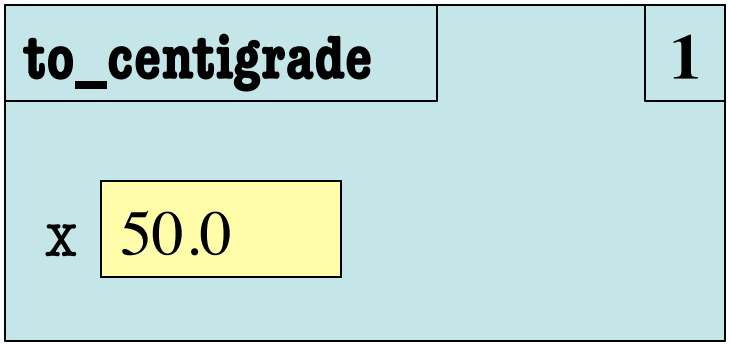
Text (Section 3.10) vs. Class

Textbook

to_centigrade



This Class



Definition:

```
def to_centigrade(x):
    return 5*(x-32)/9.0
```

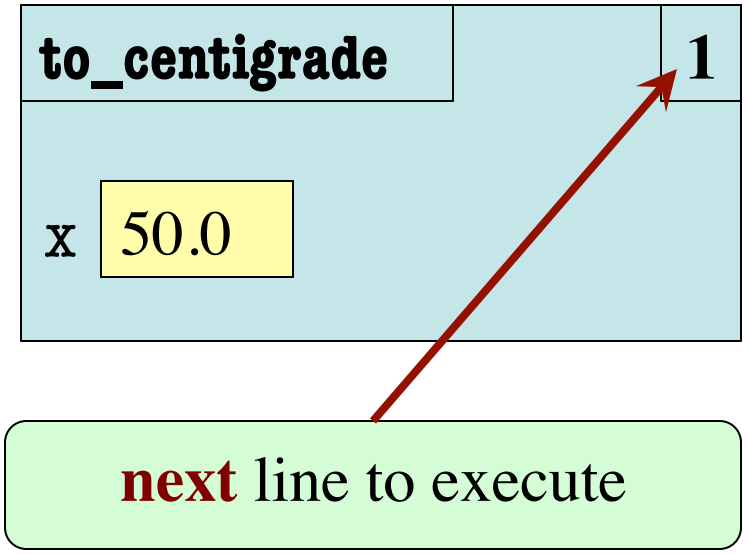
Call: to_centigrade(50.0)

Example: to_centigrade(50.0)

1. Draw a frame for the call
2. Assign the argument value to the parameter (in frame)
3. Execute the function body
   - Look for variables in the frame
   - If not there, look for global variables with that name
4. Erase the frame for the call

```
1  def to_centigrade(x):
       return 5*(x-32)/9.0
```

Initial call frame (before exec body)



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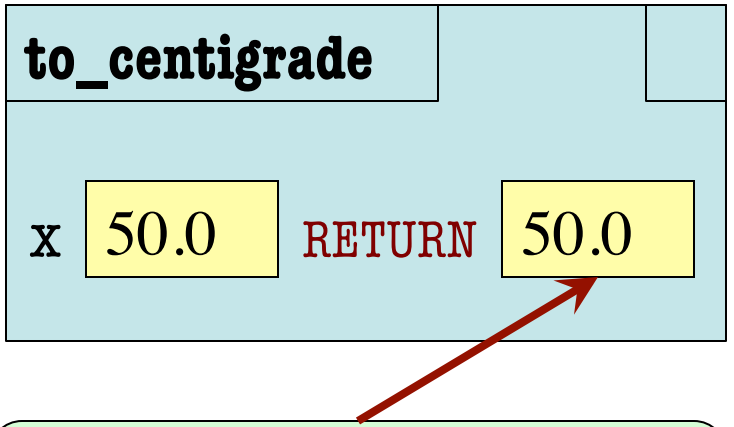
Executing the return statement



Return statement creates a special variable for result

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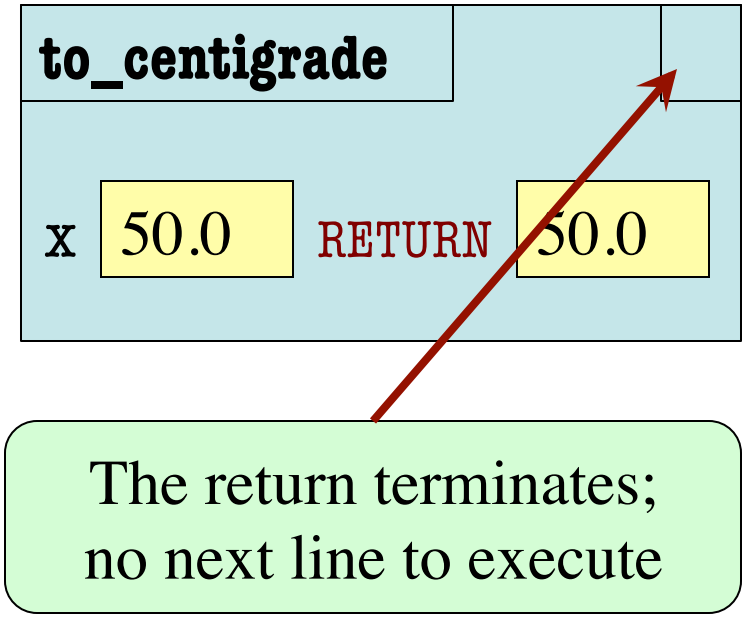

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ERASE WHOLE FRAME

```
1  def to_centigrade(x):
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```

But don't actually erase on an exam

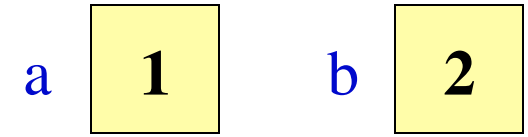
Call Frames vs. Global Variables

- This does not work:

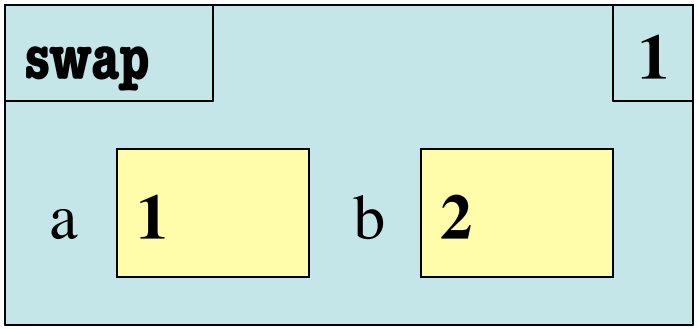
```
def swap(a,b):
    """Swap vars a & b"""
1   tmp = a
2   a = b
3   b = tmp
```

```
>>> a = 1
>>> b = 2
>>> swap(a,b)
```

Global Variables



Call Frame



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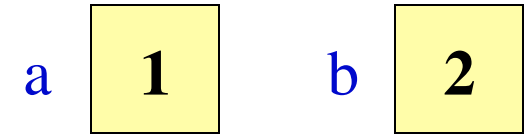

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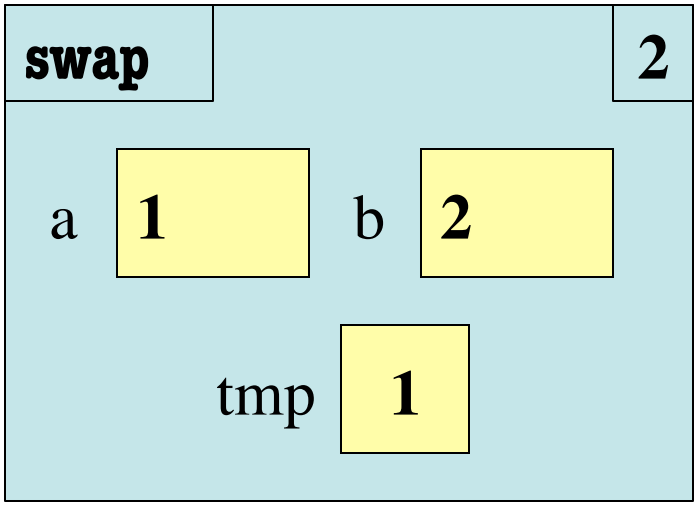

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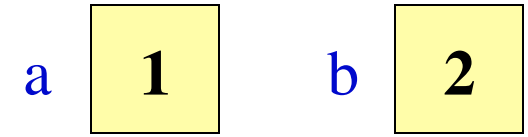

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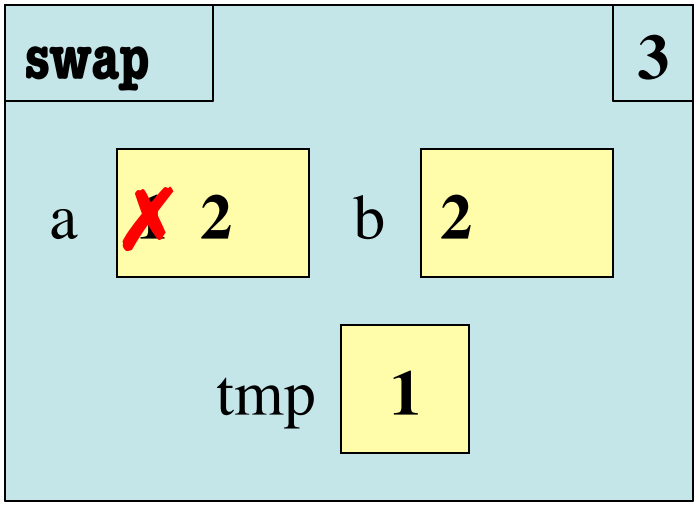

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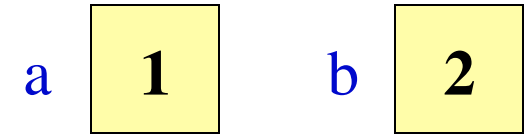

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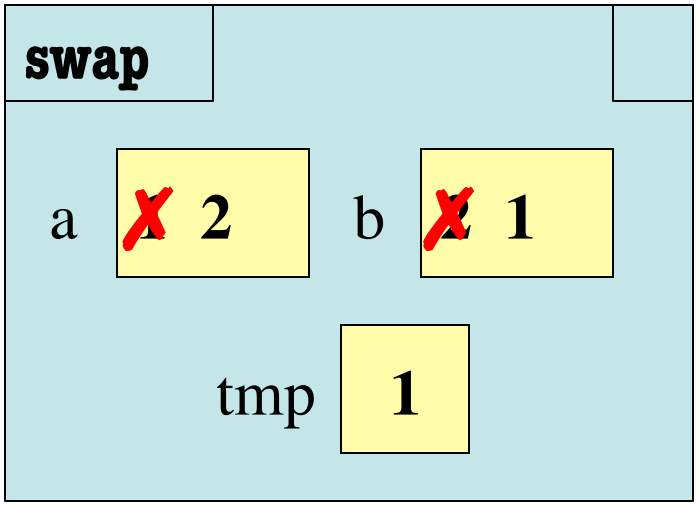

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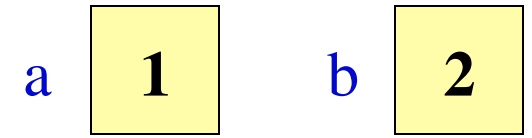
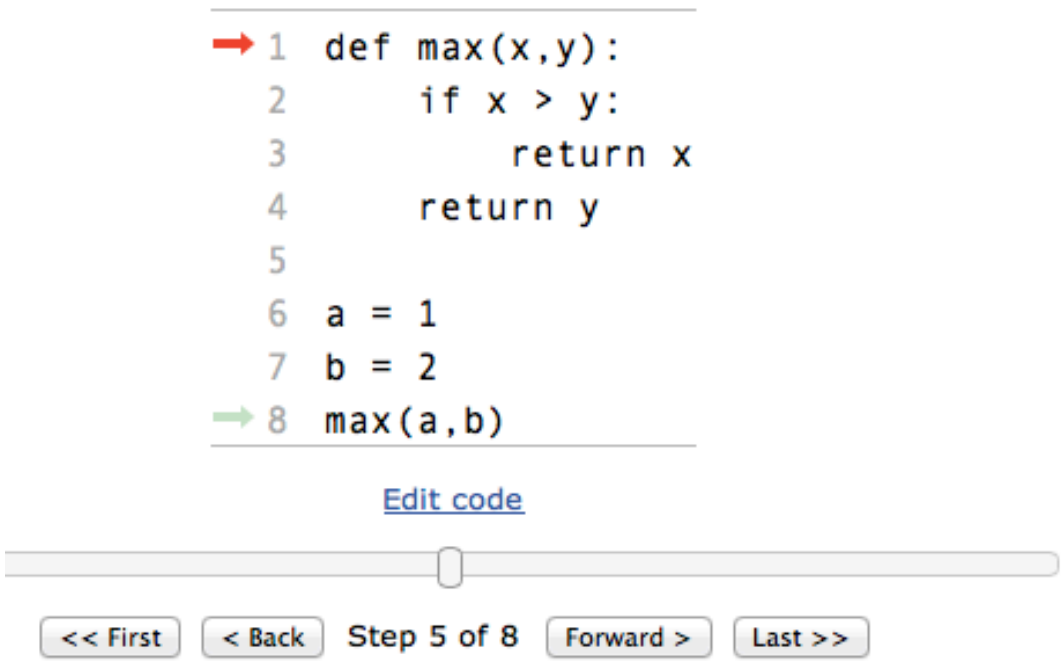
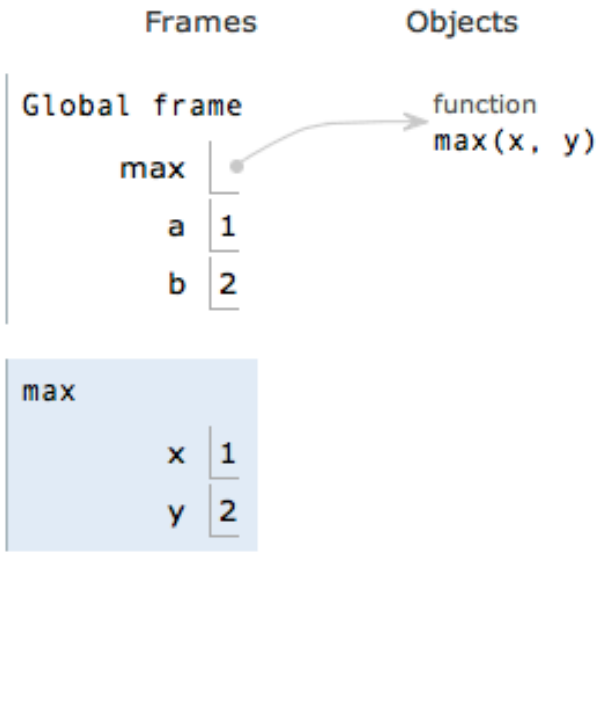


Call Frame

Visualizing Frames: The Python Tutor





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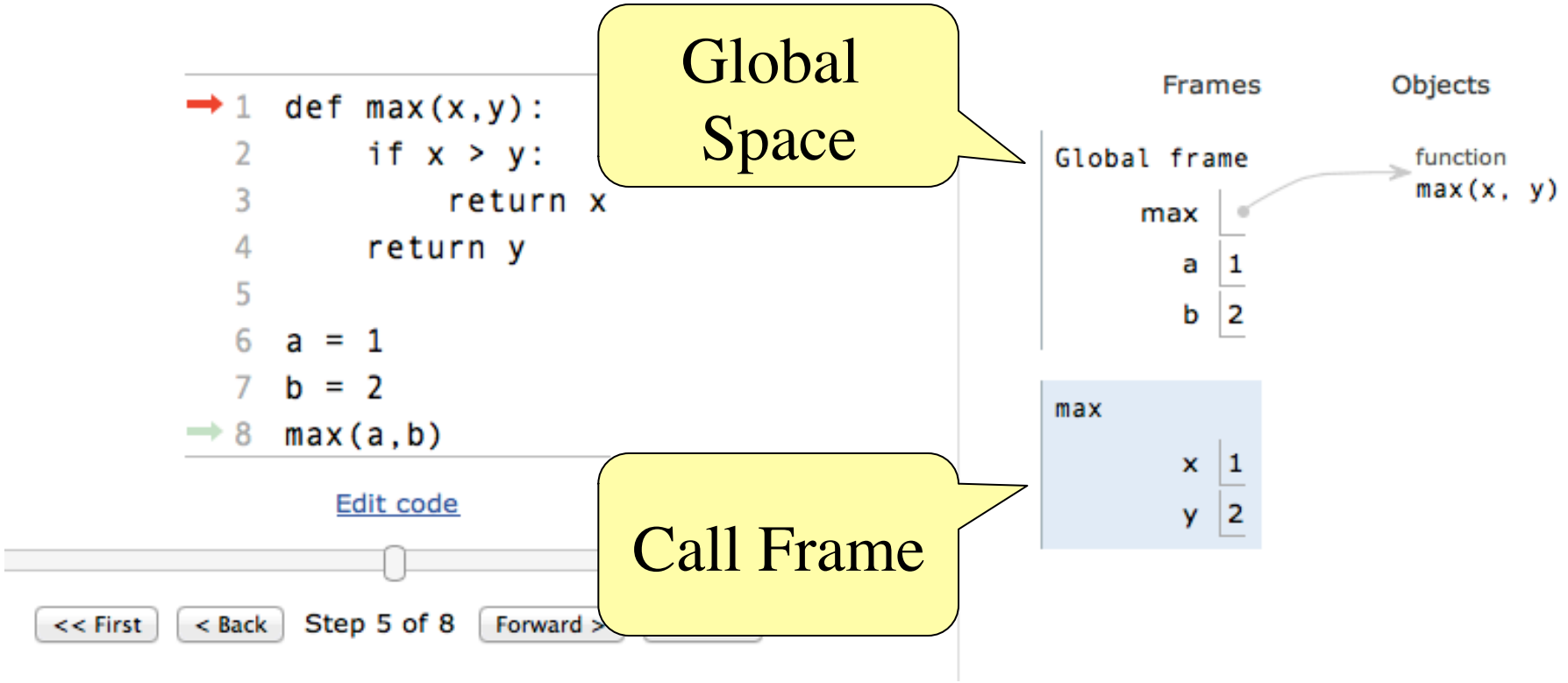

Limitations of the Python Tutor

- The Python Tutor is extremely useful
  - You can see exactly what Python is doing
  - You could use it to find errors in your code!
- However, the Python tutor is very *limited*
  - You can only import the most basic modules
  - You cannot import user-defined modules
- We need some other way to search for errors
  - This is the motivation for **code testing**

Limitations of the Python Tutor

- The Python Tutor is extremely useful
  - You
  - You code!
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- We need some other way to search for errors
  - This is the motivation for **code testing**

Many professional software development tools do this too.

Test Cases: Finding Errors

- **Bug**: Error in a program. (Always expect them!)
- **Debugging**: Process of finding bugs and removing them.
- **Testing**: Process of analyzing, running program, looking for bugs.
- **Test case**: A set of input values, together with the expected output.

Get in the habit of writing test cases for a function from the function's specification —even *before* writing the function's body.

```
def number_vowels(w):
    """Returns: number of vowels in word w.

    Precondition: w string w/ at least one letter and only letters"""
    pass  # nothing here yet!
```

Test Cases: Finding Errors

- **Bug**: Error in a program. (Always
- **Debugging**: Process of finding bug
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- **Test case**: A set of input values, to

Get in the habit of writing test case
function's specification —even *bef*

Some Test Cases

- number_vowels('Bob')
  Answer should be 1
- number_vowels('Aeiuo')
  Answer should be 5
- number_vowels('Grrr')
  Answer should be 0

```
def number_vowels(w):
    """Returns: number of vowels in word w.

    Precondition: w string w/ at least one letter and only letters"""
    pass  # nothing here yet!
```

Representative Tests

- Cannot test all inputs
  - "Infinite" possibilities
- Limit ourselves to tests that are **representative**
  - Each test is a significantly different input
  - Every possible input is similar to one chosen
- An art, not a science
  - If easy, never have bugs
  - Learn with much practice

Representative Tests for `number_vowels(w)`

- Word with just one vowel
  - For each possible vowel!
- Word with multiple vowels
  - Of the same vowel
  - Of different vowels
- Word with only vowels
- Word with no vowels

Running Example

- The following function has a bug:

```
def last_name_first(n):
    """Returns: copy of <n> but in the form <last-name>, <first-name>

    Precondition: <n> is in the form <first-name> <last-name>
    with one or more blanks between the two names"""
    end_first = n.find(' ')
    first = n[:end_first]
    last  = n[end_first+1:]
    return last+', '+first
```

Look at precondition when choosing tests

- Representative Tests:
  - last_name_first('Walker White') give 'White, Walker'
  - last_name_first('Walker White') gives 'White, Walker'

Unit Test: A Special Kind of Module

- A unit test is a module that tests another module
  - It **imports the other module** (so it can access it)
  - It **imports the cornelltest module** (for testing)
  - It **defines one or more test procedures**
    - Evaluate the function(s) on the test cases
    - Compare the result to the expected value
  - It has special code that **calls the test procedures**
- The test procedures use the cornelltest function

```
def assert_equals(expected,received):
    """Quit program if expected and received differ"""
```

Modules vs. Scripts

Module

- Provides functions, constants
  - **Example**: temperature.py
- `import` it into Python
  - In interactive shell…
  - or other module
- All code is either
  - In a function definition, or
  - A variable assignment

Script

- Behaves like an application
  - **Example**: helloApp.py
- Run it from command line
  - `python helloApp.y`
  - No interactive shell
  - `import` acts "weird"
- Commands *outside* functions
  - Does each one in order

Combining Modules and Scripts

- Scripts often have functions in them
  - Can we `import` them without "running" script?
  - Want to separate script part from module part
- New feature: `if __name__ == '__main__':`
  - Put all "script code" underneath this line
  - Also, indent all the code underneath
  - Prevents code from running if imported
  - **Example**: `bettertemp.py`

Modules/Scripts in this Course

- Our modules consist of
  - Function definitions
  - "Constants" (global vars)
  - **Optional** script code to call/test the functions
- All **statements** must
  - be inside of a function or
  - assign a constant or
  - be in the application code
- import should only pull in definitions, not app code

```
# temperature.py
...
# Functions
def to_centigrade(x):
    """Returns: x converted to C"""
...
# Constants
FREEZING_C = 0.0   # temp. water freezes
...
# Application code
if __name__ == '__main__':
    assert_floats_equal(0.0,to_centigrade(32.0))
    assert_floats_equal(100,to_centigrade(212))
    assert_floats_equal(32.0,to_fahrenheit(0.0))
    assert_floats_equal(212.0,to_fahrenheit(100.0))
```

Testing last_name_first(n)

```
# test procedure
def test_last_name_first():
    """Test procedure for last_name_first(n)"""
    cornelltest.assert_equals('White, Walker',
                              last_name_first('Walker White'))
    cornelltest.assert_equals('White, Walker',
                              last_name_first('Walker     White'))
```

Expected is the literal value.

Received is the expression.

Quits Python if not equal

```
# Application code
if __name__ == '__main__':
    test_last_name_first()
    print 'Module name is working correctly'
```

Message will print out only if no errors.

Testing last_name_first(n)

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```

Expressions inside of () can be split over several lines.

Quits Python if not equal

```
# Application code
if __name__ == '__main__':
    test_last_name_first()
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```

Message will print out only if no errors.

Finding the Error

- Unit tests cannot find the source of an error
- Idea: "Visualize" the program with print statements

```
def last_name_first(n):
    """Returns: copy of <n> in form <last>, <first>"""
    end_first = n.find(' ')
    print end_first
    first = n[:end_first]
    print 'first is '+`first`
    last  = n[end_first+1:]
    print 'last is '+`last`
    return last+', '+first
```

Print variable after each assignment

Optional: Annotate value to make it easier to identify

Types of Testing

Black Box Testing

- Function is "opaque"
  - Test looks at what it does
  - **Fruitful**: what it returns
  - **Procedure**: what changes
- **Example**: Unit tests
- **Problems**:
  - Are the tests everything?
  - What caused the error?

White Box Testing

- Function is "transparent"
  - Tests/debugging takes place inside of function
  - Focuses on where error is
- **Example**: Use of `print`
- **Problems**:
  - Much harder to do
  - Must remove when done