Lecture 6

Specifications & Testing

Announcements For This Lecture

Last Call

- Acad. Integrity Quiz
- Take it by tomorrow
- Also remember survey

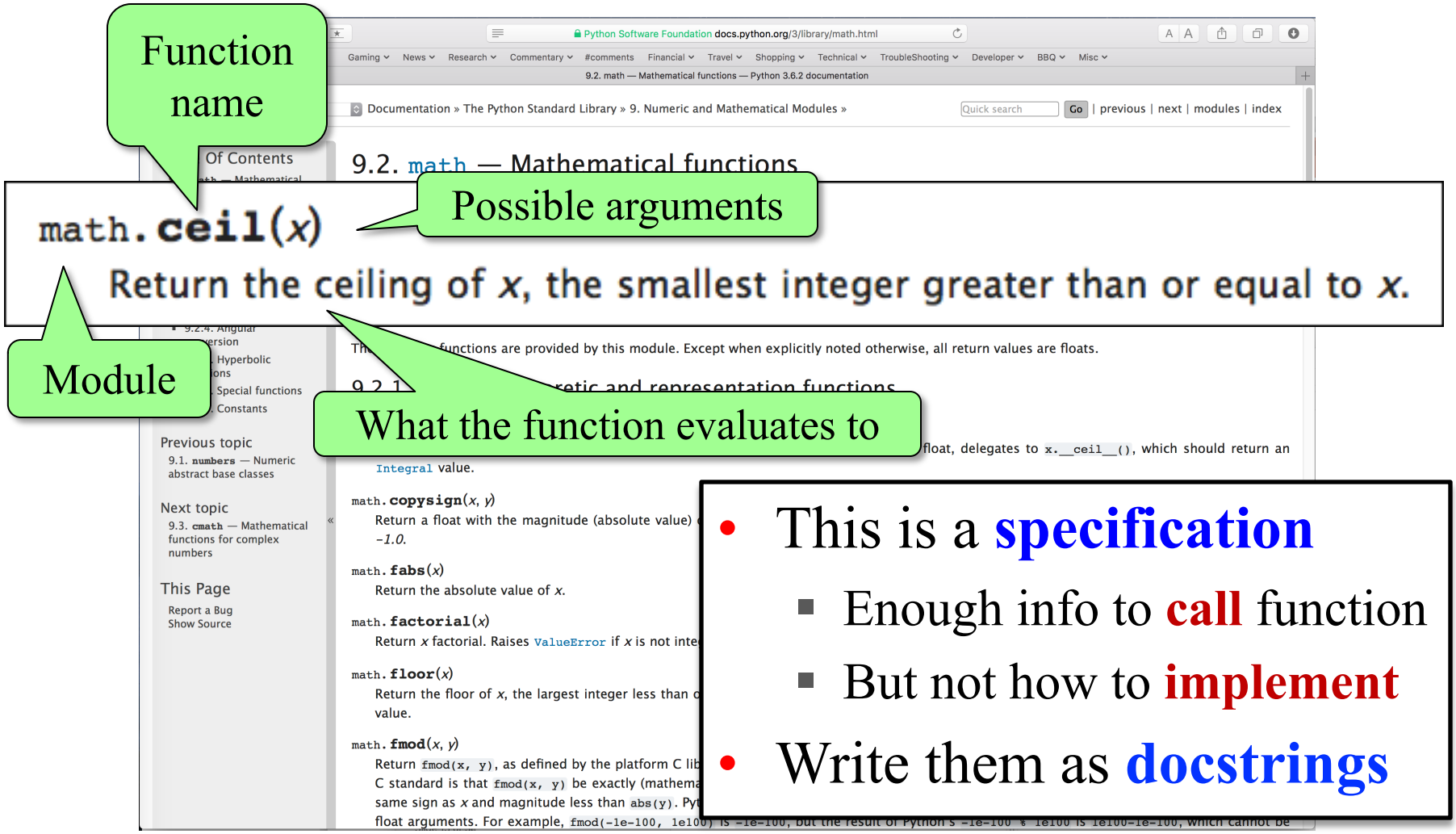
Assignment 1

- Posted on web page
  - Due Sun, Sep. 17th
  - Today's lab will help
  - Revise until correct
- Can work in pairs
  - We will pair if needed
  - Submit request tomorrow
  - One submission per pair

One-on-One Sessions

- Starts Monday: 1/2-hour one-on-one sessions
  - Bring computer to work with instructor, TA or consultant
  - Hands on, dedicated help with Labs 6 (and related)
  - 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 5pm **TODAY**

Recall: The Python API



- This is a **specification**
  - Enough info to **call** function
  - But not how to **implement**
- Write them as **docstrings**

Anatomy of a Specification

One line description, followed by blank line

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

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

    Parameter n: person to greet
    Precondition: n is a string"""
    print('Hello '+n+'!')
    print('How are you?')
```

Anatomy of a Specification

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

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Parameter description

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Parameter description

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.

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

One line description, followed by blank line

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

Parameter description

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Anatomy of a Specification

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    return 5*(x-32)/9.0
```

"Returns" indicates a fruitful function

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

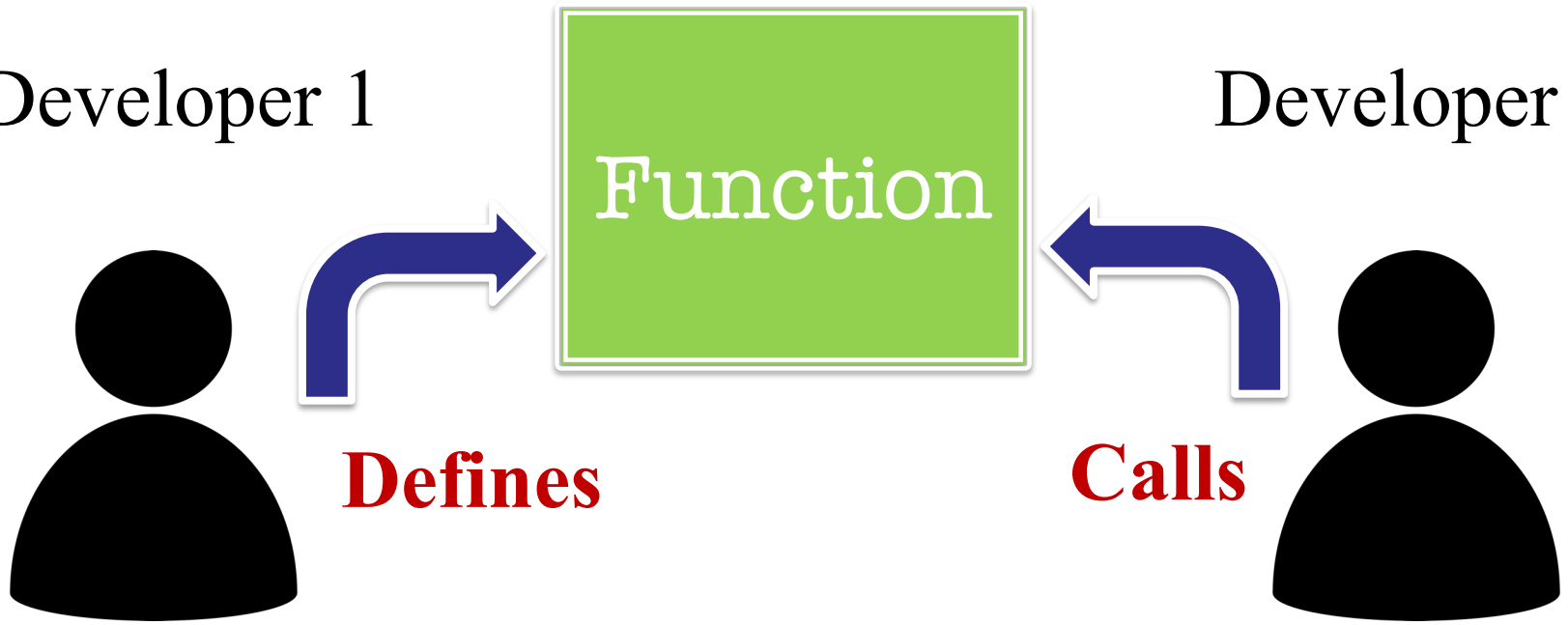
Parameter description

Precondition specifies assumptions we make about the arguments

What Makes a Specification "Good"?

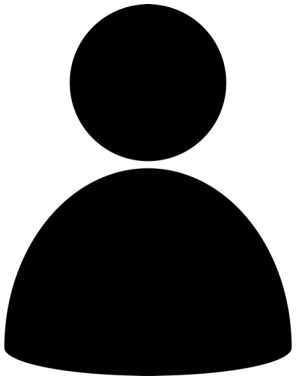
- Software development is a **business**
  - Not just about coding – **business processes**
  - Processes enable better code development
- Complex projects need **multi-person** teams
  - Lone programmers do simple contract work
  - Teams must have people working separately
- Processes are about how to **break-up** the work
  - What pieces to give each team member?
  - How can we fit these pieces back together?

Functions as a Way to Separate Work

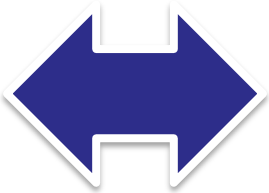


Working on Complicated Software

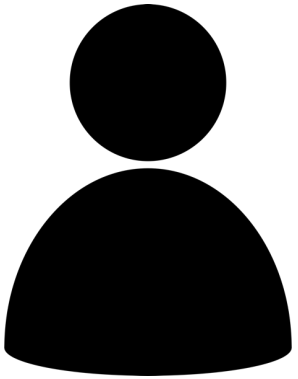
Developer 1



Calls



Developer 2



Func 1

Func 2

Func 3

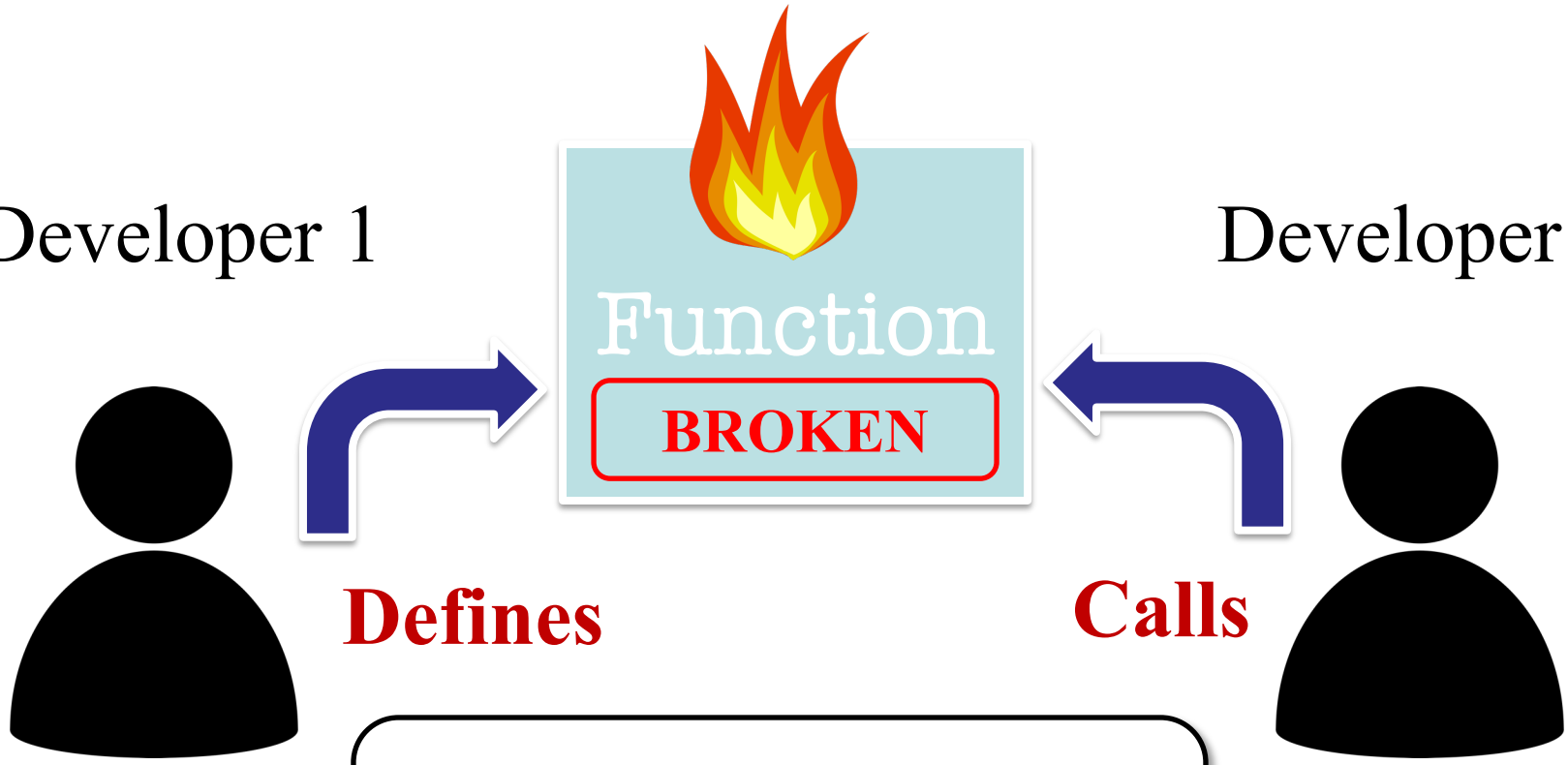
Architect plans the separation

Func 4

Func 5

Func 6

What Happens When Code Breaks?



Whose fault is it?
Who must fix it?

Purpose of a Specification

- To clearly layout **responsibility**
  - What does the function promise to do?
  - What is the allowable use of the function?
- From this responsibility we determine
  - If definer implemented function properly
  - If caller uses the function in a way allowed
- A specification is a **business contract**
  - Requires a formal documentation style
  - Rules for modifying contract *beyond course scope*

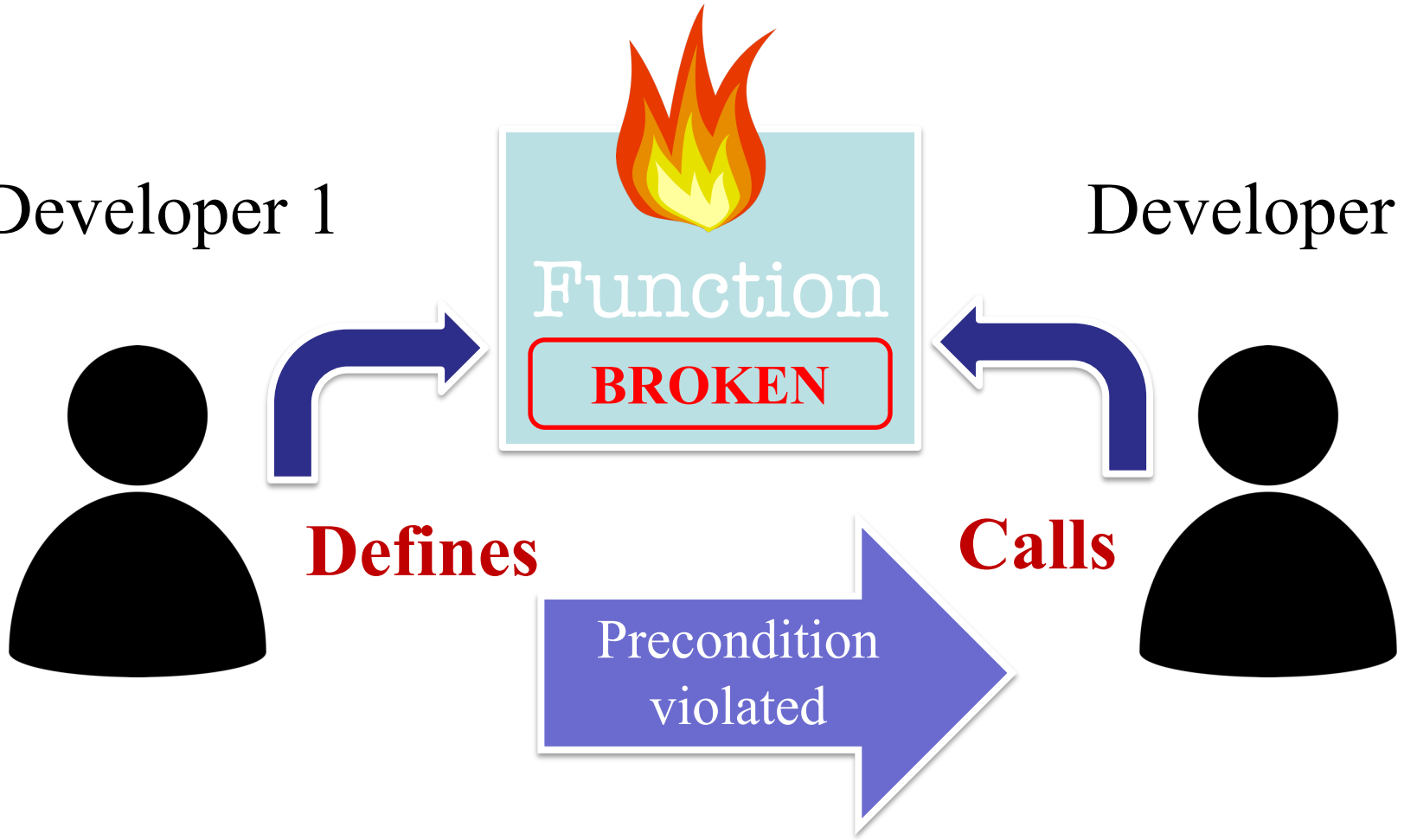
Preconditions are a Promise

- If precondition true
  - Function must work
- If precondition false
  - Function might work
  - Function might not
- Assigns responsibility
  - How to tell fault?

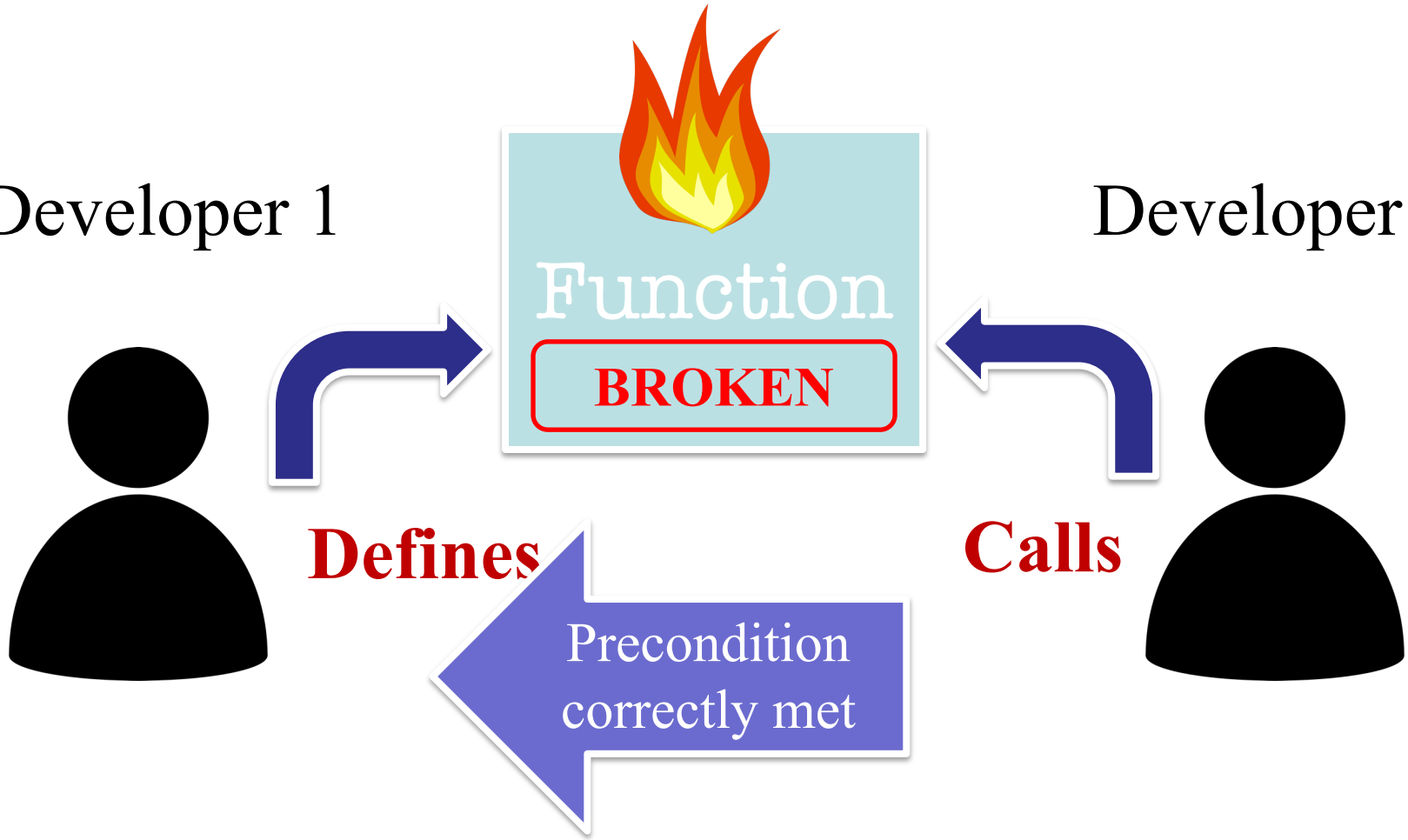
```
>>> to_centigrade(32.0)
0.0
>>> to_centigrade('32')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "temperature.py", line 19 ...
TypeError: unsupported operand type(s)
for -: 'str' and 'int'
```

Precondition violated

Assigning Responsibility



Assigning Responsibility



What if it Just Works?

- Violation != crash
  - Sometimes works anyway
  - *Undocumented* behavior
- But is **bad practice**
  - Definer may change the definition at any time
  - Can do anything so long as specification met
  - Caller code breaks
- Hits Microsoft devs a lot

```
>>> to_centigrade(32.0)
0.0
>>> to_centigrade(212)
100.0
```

Precondition violated

Precondition violations are unspecified!

Testing Software

- You are **responsible** for your function definition
  - You must ensure it meets the specification
  - May even need to prove it to your boss
- **Testing**: Analyzing & running a program
  - Part of, but not the same as, **debugging**
  - Finds **bugs** (errors), but does not remove them
- To test your function, you create a **test plan**
  - A test plan is made up of several **test cases**
  - Each is an **input** (argument), and its expected **output**

Test Plan: A Case Study

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

    Parameter w: The text to check for vowels
    Precondition: w string w/ at least one letter and only letters
    """
    ...
```

Brainstorm some test cases

Test Plan: A Case Study

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

    Parameter w: The text to check for vowels
    Precondition: w string w/ at least one letter and only letters
    """
    ...
```

rhythm?
crwth?

Surprise!
Bad Specification

Test Plan: A Case Study

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

    Vowels are defined to be 'a','e','i','o', and 'u'. 'y' is a vowel if it is
    not at the start of the word.

    Repeated vowels are counted separately.  Both upper case and
    lower case vowels are counted.

    Examples: ....

    Parameter w: The text to check for vowels
    Precondition: w string w/ at least one letter and only letters
    """
```

Test Plan: A Case Study

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

    Vowels are defined to be 'a'
    not at the start of the word

    Repeated vowels are counted separately.  Both upper case and
    lower case vowels are counted.

    Examples: ....

    Parameter w: The text to check for vowels
    Precondition: w string w/ at least one letter and only letters
    """
```

Some Test Cases

INPUT	OUTPUT
'hat'	1
'aeiou'	5
'grrr'	0

Representative Tests

- We cannot test all possible inputs
  - "Infinite" possibilities (strings arbitrary length)
  - Even if finite, way too many to test
- Limit to tests that are **representative**
  - Each test is a significantly different input
  - Every possible input is similar to one chosen
- This is an art, not a science
  - If easy, no one would ever have bugs
  - Learn with much practice (and why teach early)

Representative Tests

Simplest case first!

A little complex

"Weird" cases

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

How Many "Different" Tests Are Here?

number_vowels(w)

INPUT	OUTPUT
'hat'	1
'charm'	1
'bet'	1
'beet'	2
'beetle'	3

A: 2
B: 3
C: 4
D: 5
E: I do not know

How Many "Different" Tests Are Here?

```
number_vowels(w)
```

INPUT	OUTPUT
'hat'	1
'charm'	1
'bet'	1
'beet'	2
'beetle'	3

A: 2
B: 3 **CORRECT(ISH)**
C: 4
D: 5
E: I do not know

- If in doubt, just add more tests
- You are never penalized for too many tests

The Rule of Numbers

- When testing the numbers are 1, 2, and 0
- **Number 1**: The simplest test possible
  - If a complex test fails, what was the problem?
  - **Example**: Word with just one vowels
- **Number 2**: Add more than was expected
  - **Example**: Multiple vowels (all ways)
- **Number 0**: Make something missing
  - **Example**: Words with no vowels

Running Example

- The following function has a bug:

```
def last_name_first(n):
    """Returns a copy of n in the form 'last-name, first-name'

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

Precondition **forbids** a 0^{th} test

- Representative Tests:
  - last_name_first('Walker White') returns 'White, Walker'
  - last_name_first('Walker White') returns 'White, Walker'

Test Scripts: Automating Testing

- To test a function we have to do the following
  - **Start** the Python interactive shell
  - **Import** the module with the function
  - **Call** the function several times to see if it is okay
- But this is incredibly time consuming!
  - Have to **quit** Python if we change module
  - Have to retype everything each time
- What if we made a **second** Python file?
  - This file is a **script** to test the **module**

Unit Test: An Automated Test Script

- A **unit test** is a script to test a **single function**
  - Imports the function module (so it can access it)
  - Imports the introcs module (for testing)
  - Implements one or more test cases
    - A representative input
    - The expected output
- The test cases use the introcs function

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

Testing last_name_first(n)

```
import name                 # The module we want to test
import introcs              # Includes the test procedures

# Test one space between names
result = name.last_name_first('Walker White')
introcs.assert_equals('White, Walker', result)

# Test multiple spaces between names
result = name.last_name_first('Walker          White')
introcs.assert_equals('White, Walker', result)

print('Module name passed all tests.')
```

Testing last_name_first(n)

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```

Comment describing test

Actual Output

Input

Expected Output

Testing last_name_first(n)

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# Test multiple spaces between names
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introcs.assert_equals('White, Walker', result)


print('Module name passed all tests.')
```

Quits Python if not equal

Message will print out only if no errors.

Testing Multiple Functions

- Unit test is for a **single function**
  - But you are often testing many functions
  - Do not want to write a test script for each
- **Idea**: Put test cases inside another procedure
  - Each function tested gets its own procedure
  - Procedure has test cases for that function
  - Also some print statements (to verify tests work)
- Turn tests on/off by calling the test procedure

Test Procedure

```
def test_last_name_first():
    """Test procedure for last_name_first(n)"""
    print('Testing function last_name_first')
    result = name.last_name_first('Walker White')
    introcs.assert_equals('White, Walker', result)
    result = name.last_name_first('Walker          White')
    introcs.assert_equals('White, Walker', result)


# Execution of the testing code
test_last_name_first()
print('Module name passed all tests.')
```

Test Procedure

```
def test_last_name_first():
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    print('Testing function last_name_first')
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# Execution of the testing code
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print('Module name passed all tests.')
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No tests happen if you forget this