Module 8

Testing

Basic Concepts

- Some important terms
  - **Bug**: Error in a program. (Always expect them!)
  - **Debugging**: Process of finding & removing bugs
  - **Testing**: Process of analyzing & running a program
- Testing is a common way to search for bugs
  - However, it is not the only way
  - And it does not address how to remove them
- Good debugging starts with testing

Test Cases: Searching for Errors

- Testing is done with **test cases**
  - An input, together with an expected output
  - Input is the one (or more) argument(s)
  - Output is what is returned
  - Or what side-effect the procedure causes
- A list of test cases is **testing plan**
  - Similar to what we did when reading specs

Testing 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
    """
```

Testing Plan: A Case Study

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

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

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    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
    """
```

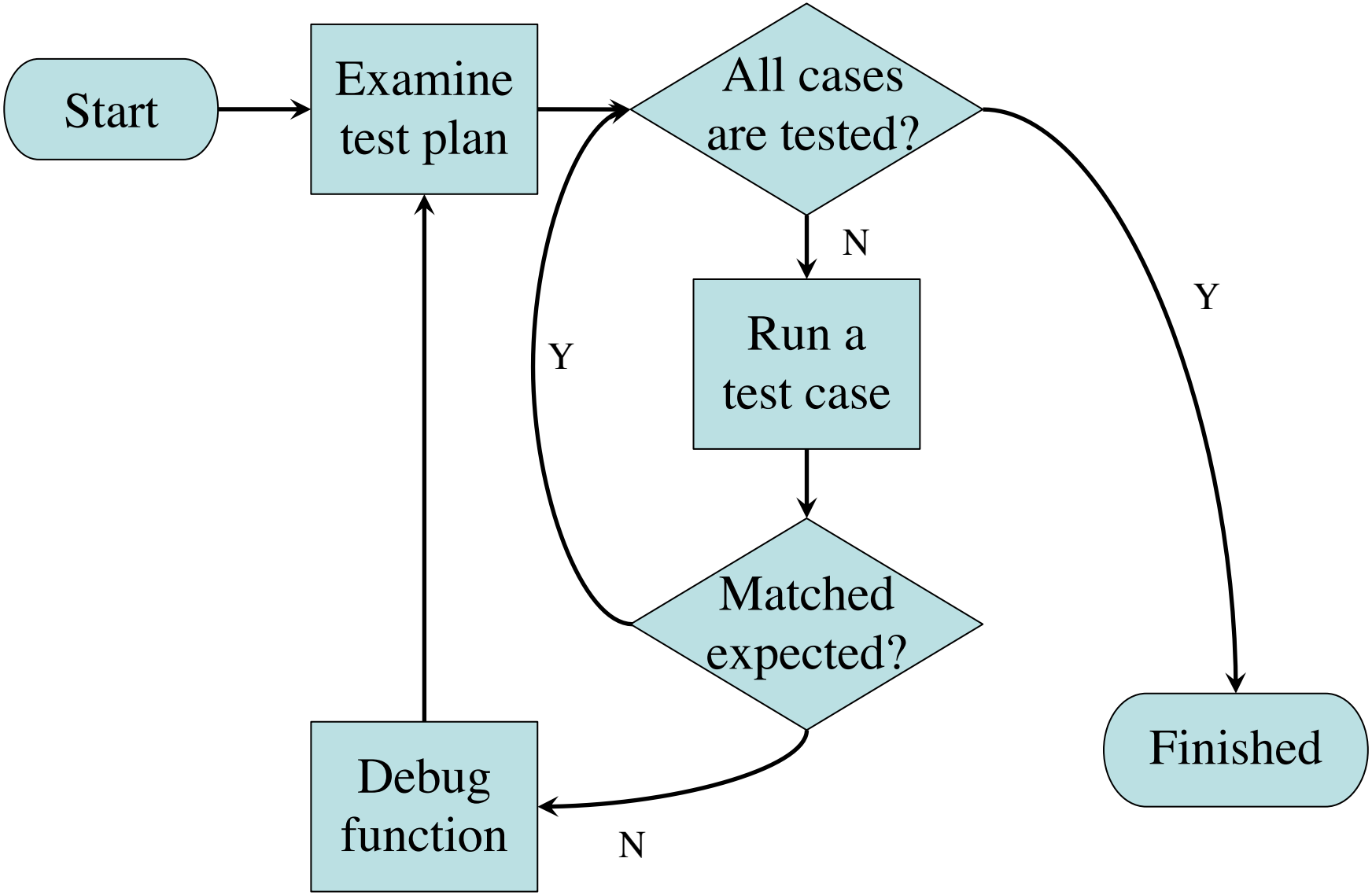
INPUT	OUTPUT
'hat'	1
'heat'	2
sky'	1
'year'	2
'xxx'	0

Recall: Workflow for this Course

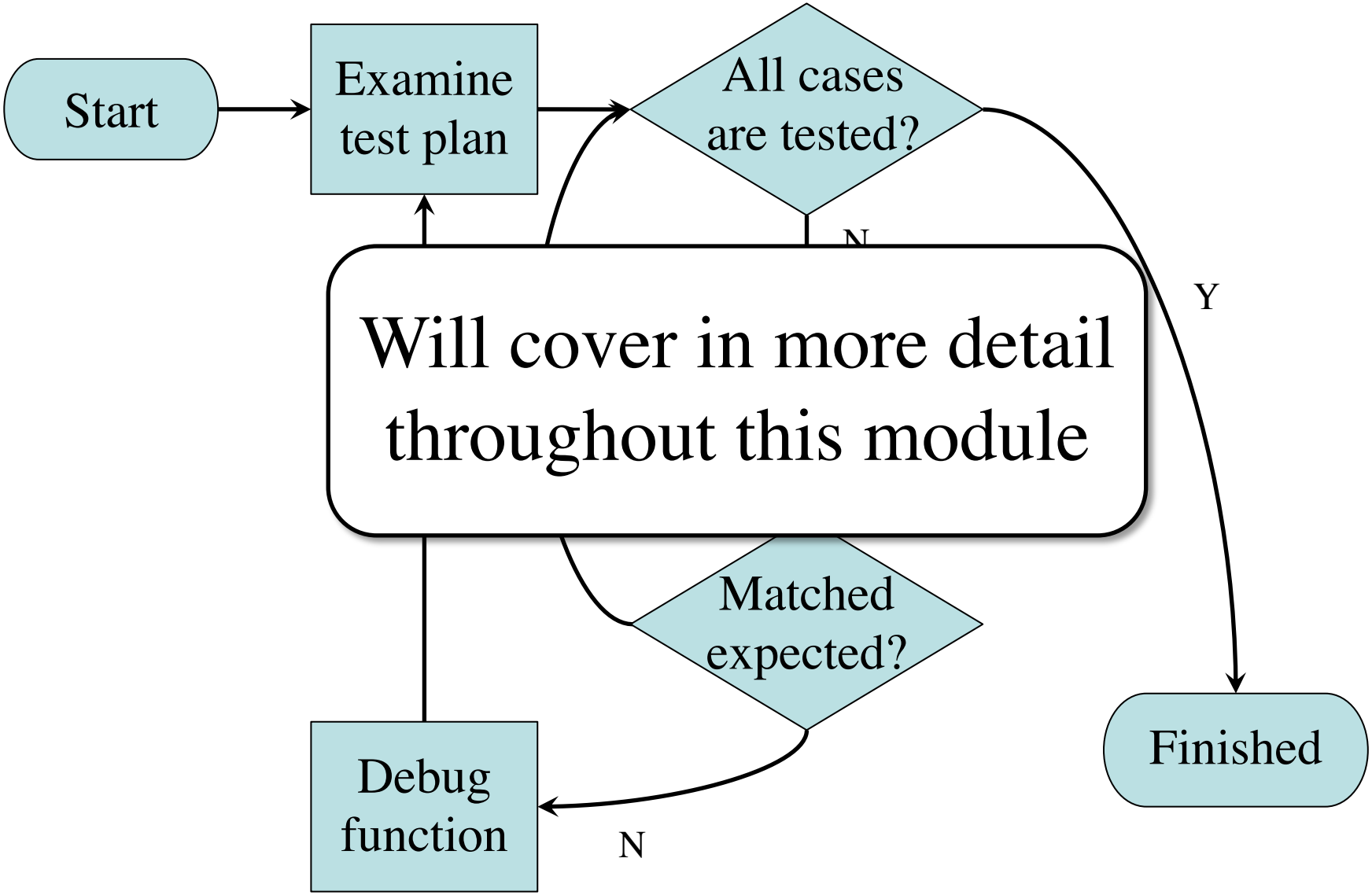
1. Write a procedure (function) in a module
2. Open up the Terminal
3. Move to the directory with this file
4. Start Python (type `python`)
5. Import the module
6. **Call the procedure (function)**

Testing!

How to Test a Function



How to Test a Function



Testing Plan: A Case Study

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    Parameter w: The text to check for vowels
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    """
```

How many tests is enough?

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 **CORRECT(ISH)**
C: 4
D: 5
E: I do not know

- If in doubt, just add more tests
- You are (rarely) 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

HOWEVER

- **NEVER** test a violation of precondition
  - Why? You have no idea what happens
  - Unspecified means no guarantees at all
  - So you have no correct answer to compare
- **Example**: `'bcd'` okay, but `'12a'` is bad.
- This can effect the rule of 1, 2, and 0
  - Precondition may disallow the rule
  - **Example**: a string with at least one value

Test Script: A Special Kind of Script

- Right now to test a function we 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 module/script?
  - This module/script tests the first one

Test Script: A Special Kind of Script

- A test script is designed to test another module
  - It imports the other module (so it can access it)
  - It defines one or more test cases
  - It calls the function on each input
  - It compares the result to an expected output
- Doesn't do much if everything is fine
- If wrong, it prints out helpful information
  - What was the case that failed?
  - What was the wrong answer given?

Testing with assert_equals

- Testing uses a special function:

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

- Provided by the introcs module
  - Special module used for this course
  - Documentation is on course web page
  - Also contains useful string functions
  - And other functions beyond course scope

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'

Testing last_name_first(n)

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

# First test case
result = name.last_name_first('Walker White')
introcs.assert_equals('White, Walker', result)

# Second test case
result = name.last_name_first('Walker          White')
introcs.assert_equals('White, Walker', result)

print('Module name is working correctly')
```

Testing last_name_first(n)

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import name                    # The module we want to test
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# First test case
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Actual Output

Input

Expected Output

Testing last_name_first(n)

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

# First test case
result = name.last_name_first('Walker White')
introcs.assert_equals('White, Walker', result)

# Second test case
result = name.last_name_first('Walker          White')
introcs.assert_equals('White, Walker', result)

print('Module name is working correctly')
```

Quits Python if not equal

Message will print out only if no errors.

Testing last_name_first(n)

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

# First test case
result = name
introcs.asser

# Second test
result = name.
introcs.assert_equals( White, Walker', result)

print('Module name is working correctly')
```

Finish example with number_of_vowels

Using Test Procedures

- In the real world, we have a lot of test cases
  - I wrote 20000+ test cases for a C++ game library
  - This is not all one function!
  - You need a way to cleanly organize them
- **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)

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'

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 is working correctly')
```

Actual file has 2 funcs

Test Procedure

```
def test_last_name_first():
    """Test procedure for last_name_first(n)"""
    print('Testing function last_name_first')
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# Execution of the testing code
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```

Actual file has 2 funcs

No tests happen if you forget this

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')
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# Execution of the testing code
# test_last_name_first()
print('Module name is working correctly')
```

Actual file has 2 funcs

Can remove to disable test

Testing last_name_first(n)

```
# test procedure
def test_last_name_first():
    """Test procedure for last_name_first(n)"""
    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)
```

Call function on test input

Compare to expected output

```
# Script code
test_last_name_first()
print('Module name is working correctly')
```

Call test procedure to activate the test

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

Types of Testing

Black Box Testing

- Function is "opaque"
  - Test looks at what it does
  - rns
  - nges
- **Ex**
- **Problems**:
  - Are the tests everything?
  - What caused the error?

Works on functions you did not define

White Box Testing

- Function is "transparent"
  - es
  - on
  - or is
- **Ex** nt
- **Problems**:
  - Much harder to do
  - Must remove when done

Can actually find the bug in function

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(str(first))
    last  = n[end_first+1:]
    print(str(last))
    return last+', '+first
```

Print variable after each assignment

Run Demo

How to Use the Results

- Goal of **white box testing** is error location
  - Want to identify the **exact line** with the error
  - Then you look real hard at line to find error
  - What you did in earlier assessment
- But similar approach to **black box testing**
  - At each line you have **expected** print result
  - Compare it to the **received** print result
  - Line before first mistake is *likely* the error

Finding the Error

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- Idea: "Visualize" the program with print statements

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

Do as little as possible on each line of code

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('space at '+end_first)
    first = n[:end_first]
    print('first is '+str(first))
    last  = n[end_first+1:]
    print('last is '+str(last))
    return last+', '+first
```

Print variable after each assignment

Optional: Annotate value to make it easier to identify

Warning About Print Statements

- Must remove them when you are done
  - Not part of the specification (violation)
  - Slow everything down unnecessarily
  - App Store will reject an app with prints
- But you might want them again later
  - **Solution**: “comment them out”
  - Can uncomment later if need them