COMP61511 (Fall 2018)

Software Engineering Concepts
In Practice

Week 2

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(bug reports welcome!)

FizzBuzz In Way Too Much Detail

The Naivest Fizzbuzz

- Any proposals?
- Let's see the **obvious**!

The Naivest Fizzbuzz (Source)

```
print("""1
2
Fizz
4
Buzz
Fizz
7
8
Fizz
Buzz
11
Fizz
13
14
FizzBuzz
16
17
Fizz
19
Buzz
Fizz
22
23
```

A Rational FizzBuzz

- Let's consider a "standard" implementation
  - Not silly
  - Not golfy
- I.e., a simple **loop oriented implementation**

A Rational FizzBuzz (Source)

```
for i in range(1,101):
    if i % 3 == 0 and i % 5 == 0:
        print('FizzBuzz')
    elif i % 3 == 0:
        print('Fizz')
    elif i % 5 == 0:
        print('Buzz')
    else:
        print(i)
```

DRY

- "Don't Repeat Yourself"
    - A fundamental principle of SE
    - It is against
        - Cut and Paste reuse
        - Not Invented Here syndrome
- Is our **current version** DRY?

A Dryer Version

- We repeat `i % 3 == 0` and `i % 5 == 0`
- Let's **abstract that out**!

A Dryer Version (Source)

```
for i in range(1,101):
    fizz = i % 3 == 0
    buzz = i % 5 == 0
    if fizz and buzz:
        print('FizzBuzz')
    elif fizz:
        print('Fizz')
    elif buzz:
        print('Buzz')
    else:
        print(i)
```

EVEN DRIER!!!

- We repeat the `_ % _ == 0` pattern!
- We say `print` a lot
- We can **fix it**!

EVEN DRIER!!! (Source)

```
FIZZ = 'Fizz'
BUZZ = 'Buzz'

def divisible_by(numerator, denominator):
    return numerator % denominator == 0

def fizzit(num):
    fizz = divisible_by(num, 3)
    buzz = divisible_by(num, 5)
    if fizz and buzz:
        return FIZZ + BUZZ
    elif fizz:
        return FIZZ
    elif buzz:
        return BUZZ
    else:
        return i

for i in range(1,101):
    print(fizzit(i))
```

Parameterization

- Basic software principle: Don't **hard code** stuff!
    - Make your code parameterisable!
- The current version hard codes a lot, e.g.,

```
FIZZ = 'Fizz'
BUZZ = 'Buzz'
```

- We have to **modify the source code** if we want to change this!
    - What else is hard coded?
    - We can **fix it**!

Parameterization (Source)

```
"""We parameterise by:
* The range of integers covered.
* The text that is output.
* The multiples that trigger text to be output

https://www.tomdalling.com/blog/software-design/fizzbuzz-

def fizzbuzz(bounds, triggers):
    for i in bounds:
        result = ''
        for text, divisor in triggers:
            result += text if i % divisor == 0 else ''
        print(result if result else i)

fizzbuzz(range(1, 101), [
    ['Fizz', 3],
    ['Buzz', 5]])
```

Still Hard Coding!

- The **kind of test** is hard coded
- We can fix **that**!

Still Hard Coding! (Source)

```
def fizzbuzz(bounds, triggers):
    for i in bounds:
        result = ''
        for text, predicate in triggers:
            result += text if predicate(i) else ''
        print(result if result else i)

fizzbuzz(range(1, 101), [
    ['Fizz', lambda i: i % 3 == 0],
    ['Buzz', lambda i: i % 5 == 0],
    ['Zazz', lambda i: i < 10]
])
```

The Path To Hell…

- …is paved with good intentions!
- Each choice was somehow **reasonable**
  - We applied good **SE principles**
  - We made choices **that are often good**
- But we ended up in **nonsense land**
  - **Local** sense led to **global** nonsense

Judgement

- Software engineers can't **just follow rules**
- Good software engineering requires **judgement**
    - **When** to apply **which** rules
    - **When** to **break** rules
    - **How* to apply or break them
    - The **reason** for each rule
        - And whether it makes sense **now**

Acknowledgement

This lecture was derived from the excellent blog post **FizzBuzz In Too Much Detail** by Tom Dalling.

Tom uses Ruby and goes a couple of steps further. Worth a read!

Product Qualities

Qualities (Or "Properties")

- Software has a variety of **characteristics**
  - Size, implementation language, license…
  - User base, user satisfaction, market share…
  - Crashingness, bugginess, performance, functions…
  - Usability, prettiness, slickness…

"Quality" Of Success

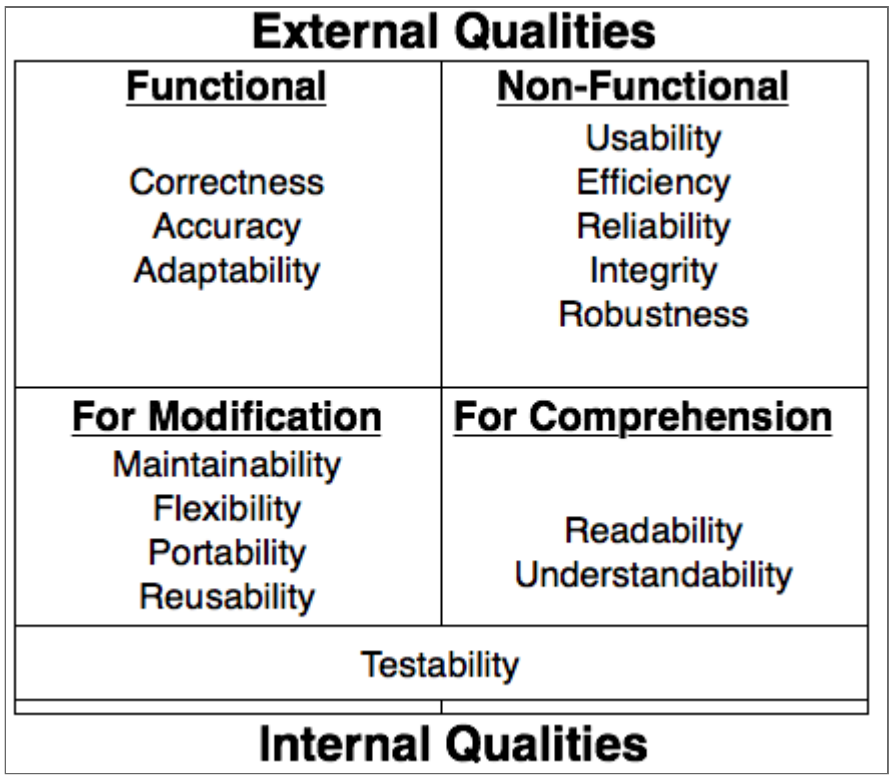
- Success is determined by
  - the **success criteria**
    - i.e., the nature and degree of **desired** characteristics
  - whether the software **fulfils** those criteria
    - i.e., possesses the desired characteristics to the desired degree

Inducing Success

- While success is **determined** by qualities
  - the determination isn't **straightforward**
  - the determination isn't **strict**
    - for example, **luck** plays a role!
  - it depends on how you **specify** the critical success factors

Software Quality Landscape

20.1. Characteristics of Software Quality



External Vs. Internal (Rough Thought)

- **External** qualities:
  - McConnell: those "that a user of the software product is aware of"
- **Internal** qualities:
  - "non-external characterisitcs that a **developer directly experiences while working on that software**"
- Boundary varies with the kind of user!

External Definition

- **External** qualities:
  - McConnell: those "that a user of the software product is **aware of**"
  - This isn't quite right!
    - A user might be **aware of** the implementation langauge
  - "characteristics of software that a **user** directly experiences in the normal use of that software"?

Internal Definition

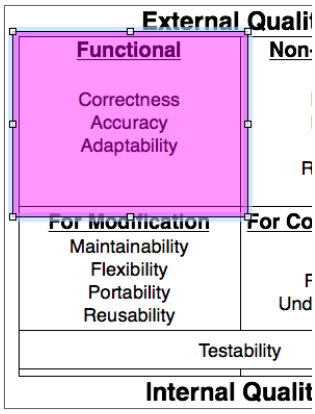
- **Internal** qualities:
  - "non-external characterisitcs that a **developer directly experiences while working on that software**"
  - Intuitively, "under the hood"

External: Functional Vs. Non-Functional

- Functional ≈ **What** the software does
    - Behavioural
    - What does it accomplish for the user
    - Primary requirements
- Non-functional ≈ **How** it does it
    - Quality of service
        - There can be requirements here!
    - Ecological features

Key Functional: Correctness

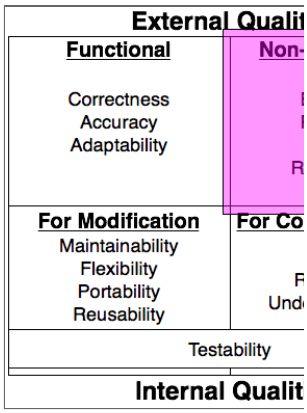
- **Correctness**
  - **Freedom from faults** in
    - spec,
    - design,
    - implementation
  - **Does the job**
  - Fulfills all the **use cases** or **user stories**



Implementation and design could be perfect, but if there was a spec misunderstanding, ambiguity, or change, the software will not be correct!

External: "Qualities Of Service"

- **Usability** — can the user make it go
- **Efficiency** — wrt time & space
- **Reliability** — long MTBF
- **Integrity**
  - Corruption/loss free
  - Attack resistance/secure
- **Robustness** — behaves well on strange input



All these contribute to the **user experience** (UX)!

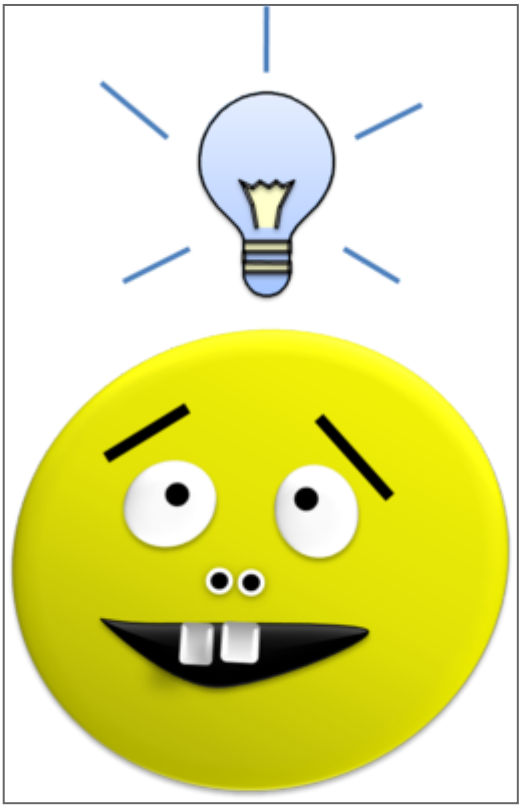
Internal: Testability

- A critical property!
  - Relative to a **target quality**
    - A system could be
      - highly testable for **correctenss**
      - lowly testable for **efficiency**
  - Partly determined by test infrastructure
    - Having **great hooks** for tests pointless without **tests**

Internal: Testability

- Practically speaking
  - Low testability blocks **knowing** qualities
  - Test-based evidence is essential

Comprehending Product Qualities



Comprehension?

- We can distinguish two forms:
  - Know-**that**
    - You believe a **true** claim about the software
    - …with appropriate evidence
  - Know-**how**
    - You have a **competancy** with respect to the software
    - E.g., you know-how to recompile it for a different platform
- Both require significant effort!

Quality Levels

- We talked about different **kinds** of quality
  - Coming in degrees or **amounts**
  - "Easy" example: Good vs. poor performance
- Most qualities in principle are **quantifiable**
  - Most things are quantifiable
- But reasonable quantification isn't always **possible**
  - Or **worth it**

Defects As Quality Lacks

> *A **defect** in a software system is a **quality level** (for some quality) that is **not acceptable**.*

- Quality levels need to be elicited and negotiated
    - All parties must agree on
        - **what** they are,
        - their **operational definition**
        - their **significance**

What **counts** as a defect is often determined late in the game!

Question

If your program crashes then it

1. definitely has a bug.
2. is highly likely to have a bug.
3. may or may not have a bug.

Question

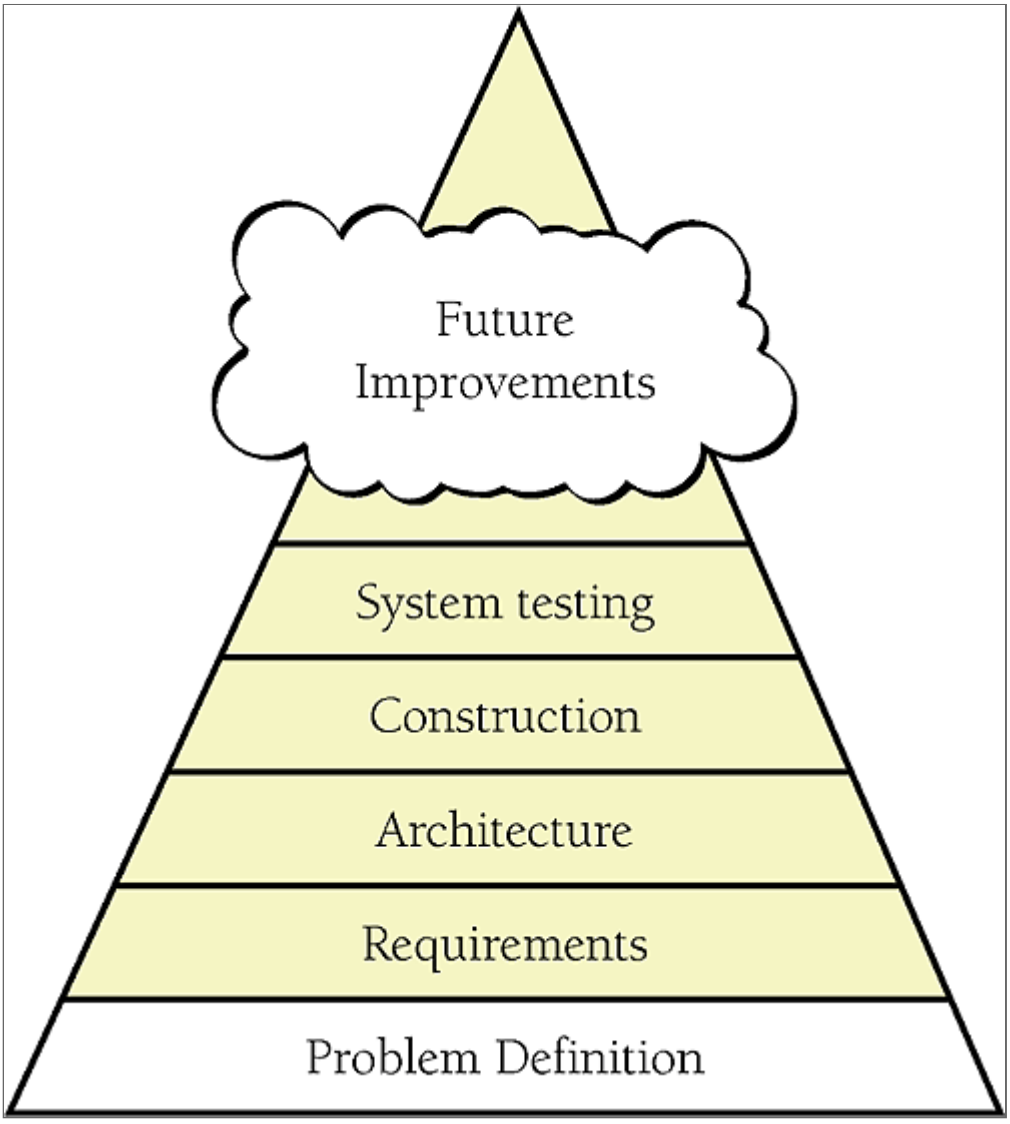
1. definitely has a bug.
2. is highly likely to have a bug.
3. may or may not have a bug.

Bug Or Feature?

(**Does QA hate you?** — scroll for the cartoons as well as the wisdom.)

- Even a **crashing code path** can be a **feature**!
- Contention arises when the stakes are high
    - and sometime the stakes can seem high to some people!
    - defect rectification costs the same
        - whether the defect is **detected**...
        - ...or a feature is **redefined**
- Defects (even redefined features) aren't personal

Problem Definition



This is a logical, not temporal, order.

Problem Definition

The penalty for failing to define the problem is that you can waste a lot of time solving the wrong problem. This is a double-barreled penalty because you also don't solve the right problem.
*—**McConnell**, 3.3*

Quality Assurance

- Defect **Avoidance** or **Prevention**
    - "Prerequisite" work can help
        - Requirement negotiation
        - Design
        - Tech choice
    - Methodology
- Defect **Detection** & Rectification
    - If a defect exists,
        - Find it
        - Fix it

The Points Of Quality

1. Defect **prevention**
    - Design care, code reviews, etc.
2. Defect **appraisal**
    - Detection, triaging, etc.
3. **Internal** rectification
    - We fix/mitigate before shipping
4. **External** rectification
    - We cope after shipping

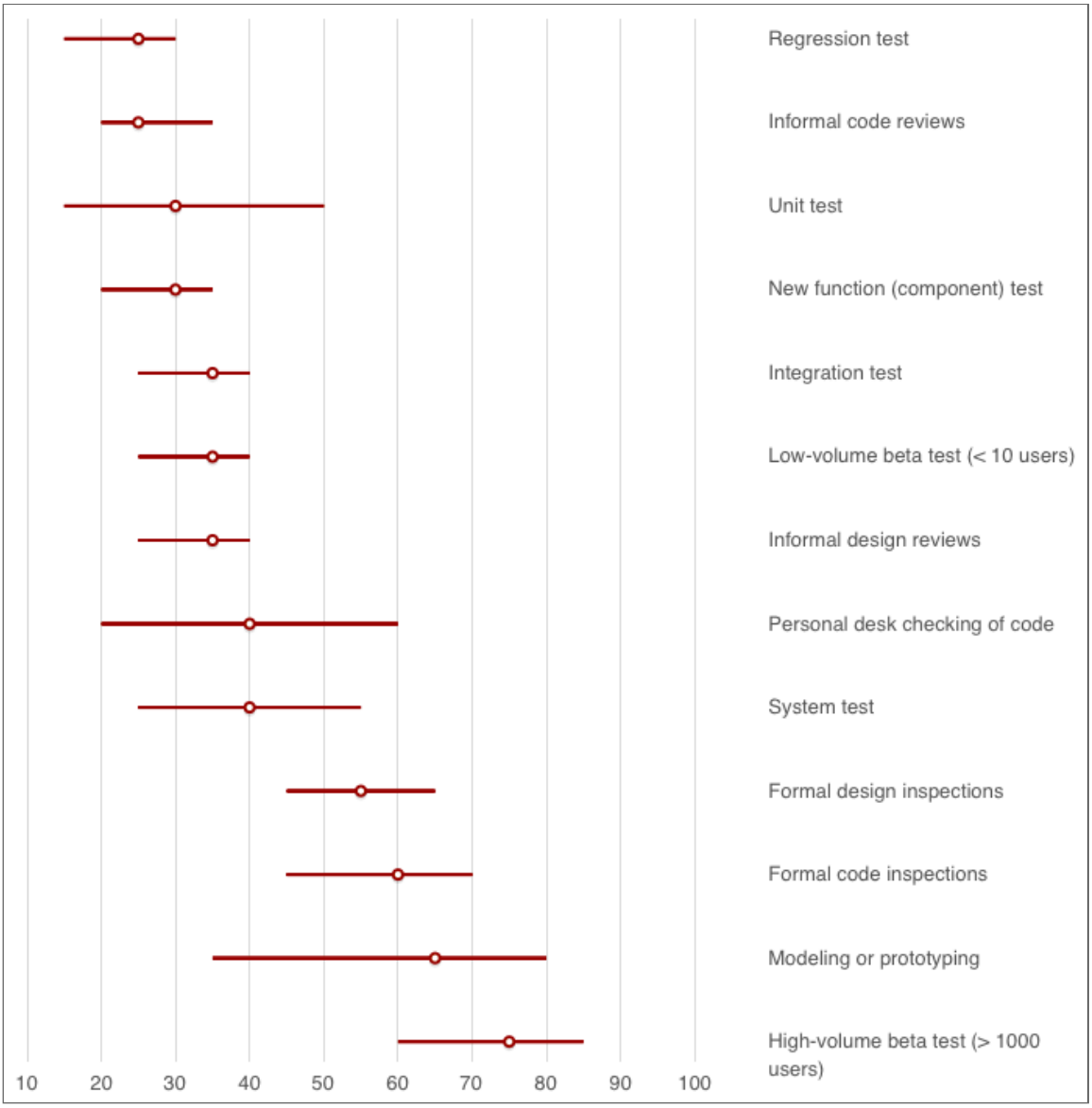
Defect Detection Techniques

Table 20-2. Defect-Detection Rates

Removal Step	Lowest Rate	Modal Rate	Highest Rate
Informal design reviews	25%	35%	40%
Formal design inspections	45%	55%	65%
Informal code reviews	20%	25%	35%
Formal code inspections	45%	60%	70%
Modeling or prototyping	35%	65%	80%
Personal desk-checking of code	20%	40%	60%
Unit test	15%	30%	50%
New function (component) test	20%	30%	35%
Integration test	25%	35%	40%
Regression test	15%	25%	30%
System test	25%	40%	55%
Low-volume beta test (<10 sites)	25%	35%	40%
High-volume beta test (>1,000 sites)	60%	75%	85%

Source: Adapted from *Programming Productivity* (Jones 1986a), "Software Defect-Removal Efficiency" (Jones 1996), and "What We Have Learned About Fighting Defects" (Shull et al. 2002).

Defect Detection Techniques



Experiencing Software

- It's one to know that there are bugs
    - **All** software has bugs!
- It's another to be able to **trigger** a bug
    - Not just a specific bug!
    - If you understand the software
        - You know how to break it.
- Similarly, for **making changes**
    - tweaks, extensions, adaptions, etc.
- The more command, the more modalities of mastery

Lab!

Revisiting Rainfall

We're going to look at your rainfalls before discussing it in detail.

We're going to do a **code review**!

You're going to work in 2-person teams!

Three Tasks

1. Do a code review!
2. Write some tests based on your code review!
3. Do an essay review!

To the lab! Material in the usual place.

Testing Rainfall

Rainfail

- 14 out of 29 students submitted
- Key point: *1 out of 15 programs passed all 13 tests*
    - 1 program passed ALL tests1
    - 1 passed 9
    - 6 passed 8
    - 3 passed 6
    - 1 passed 4
    - 1 passed 0
    - 2 "We could not compile your code."

The rainfall problem is still a challenge!

Let's Talk Testing

- You had *limited time*
    - So test generation had to be quick!
    - Typically ad hoc
        - Can we do better?
- How testable is `rainfall.py`?
    - You were responsible *only* for `average_rainfall(input_list)`
        - Only this *unit*! Can ignore all else!
            - *Perfect* for `doctest`

Problem Statement

*Design a program called **rainfall** that consumes a **list of numbers** representing daily rainfall amounts as entered by a user. The list may contain the number **-999 indicating the end** of the data of interest. Produce the **average of the non-negative** values in the list up to the first -999 (if it shows up). There may be negative numbers other than -999 in the list.*

Set Up

```
def average_rainfall(input_list):
    """>>> average_rainfall(<<FIRST TEST INPUT>>)
    <<FIRST EXPECTED RESULT>>
    """
    # Here is where your code should go
    return "Your computed average" #<-- change this!
```

```
$ python 1setup.py
Your computed average
```

First Test Run

```
$ python -m doctest 1setup.py
**********************************************************
File "/Users/bparsia/Documents/2018/Teaching/COMP61511/la
Failed example:
    average_rainfall(<<FIRST TEST INPUT>>)
Exception raised:
    Traceback (most recent call last):
      File "//anaconda/lib/python3.5/doctest.py", line 13
        compileflags, 1), test.globs)
      File "<doctest 1setup.average_rainfall[0]>", line 1
        average_rainfall(<<FIRST TEST INPUT>>)
                         ^
    SyntaxError: invalid syntax
**********************************************************
1 items had failures:
   1 of   1 in 1setup.average_rainfall
***Test Failed*** 1 failures.
```

First Test

- Where do we get our first real test?
  - Hint: Read the docs:

But that's clearly not a correct solution. When fully implemented, we'd expect to see something like:

```
$ python rainfall.py 2 3 4 67 -999
19.0
```

Convert To Appropriate `doctest`

- For a *system* test, we'd need to use `subproce` etc.
    - But we can just test our unit!
        - `average_rainfall(input_l`
        - But it takes a *list* not a *string* as input!
    - `'2 3 4 67 -999'` ==> `[2, 3, 4, -999]`
        - We had to *massage* the input to our test!

Tested `average_rainfall` V 2

```
def average_rainfall(input_list):
    """>>> average_rainfall([2,3,4,67, -999])
    19.0
    """
    # Here is where your code should go
    return "Your computed average" #<-- change this!
```

```
$ python 1setup.py
Your computed average
```

Second Test Run

```
$ python -m doctest 2firstfull.py
**********************************************************
File "/Users/bparsia/Documents/2018/Teaching/COMP61511/la
Failed example:
    average_rainfall([2,3,4,67, -999])
Expected:
        19.0
Got:
    'Your computed average'
**********************************************************
1 items had failures:
   1 of   1 in 2firstfull.average_rainfall
***Test Failed*** 1 failures.
```

Yay!

- We have a **real** and **reasonable** test!
    - And a clear **format** for subsequent tests
    - And an **infrastructure** that makes it easy to run tests
- We have a **broken implementation**
    - As witnessed by a test!
- We Can Fix It!

Rosie Sez

First Implementation

```
def average_rainfall(input_list):
    """>>> average_rainfall([2,3,4,67, -999])
    19.0
    """
    # Here is where your code should go
    return sum(input_list)/len(input_list)
```

- Will this fail this test?
- Is there a test that it will pass?

First Implementation With Tests

```
def average_rainfall(input_list):
    """>>> average_rainfall([2,3,4,67, -999])
    19.0
    >>> average_rainfall([2,3,4,67, -999])
    19.0
    """
    # Here is where your code should go
    return sum(input_list)/len(input_list)
```

Third Test Run

```
$ python -m doctest 4firstimpl2.py
**********************************************************
File "/Users/bparsia/Documents/2018/Teaching/COMP61511/la
Failed example:
    average_rainfall([2,3,4,67, -999])
Expected:
        19.0
Got:
    -184.6
**********************************************************
1 items had failures:
   1 of   2 in 4firstimpl2.average_rainfall
***Test Failed*** 1 failures.
```

Second Implementation

```
def average_rainfall(input_list):
    """>>> average_rainfall([2,3,4,67, -999])
    19.0
    >>> average_rainfall([2,3,4,67 -999])
    19.0
    """
    # Here is where your code should go
    return sum(input_list[:-1])/len(input_list[:-1])
```

- Fixes one test but not the other!
- Tests **work together**

Third Implementation

```
def average_rainfall(input_list):
    """>>> average_rainfall([2, 3, 4, 67, -999])
    19.0
    >>> average_rainfall([2, 3, 4, 67, -999])
    19.0
    """
    rainfall_sum = 0
    count = 0
    for i in input_list:
        if i == -999:
            break
        else:
            rainfall_sum += i
            count += 1
    # Here is where your code should go
    return rainfall_sum/count
```

Fourth Test Run

```
$ python -m doctest 5secondimpl.py
**********************************************************
File "/Users/bparsia/Documents/2018/Teaching/COMP61511/la
Failed example:
    average_rainfall([2,3,4,67, -999])
Expected:
        19.0
Got:
    19.0
**********************************************************
1 items had failures:
   1 of   2 in 5secondimpl.average_rainfall
***Test Failed*** 1 failures.
```

Whaaaaaaaaaaaaaaaaaat?!

A Bug!

- There was a bug in our tests
    - All along!

```
def average_rainfall(input_list):
"""">>> average_rainfall([2, 3, 4, 67, -999])
19.0
```

vs.

```
def average_rainfall(input_list):
"""    >>> average_rainfall([2, 3, 4, 67, -99
19.0
```

- Earlier tests failed for *two reasons*!
- One bug *concealed* the other!!!

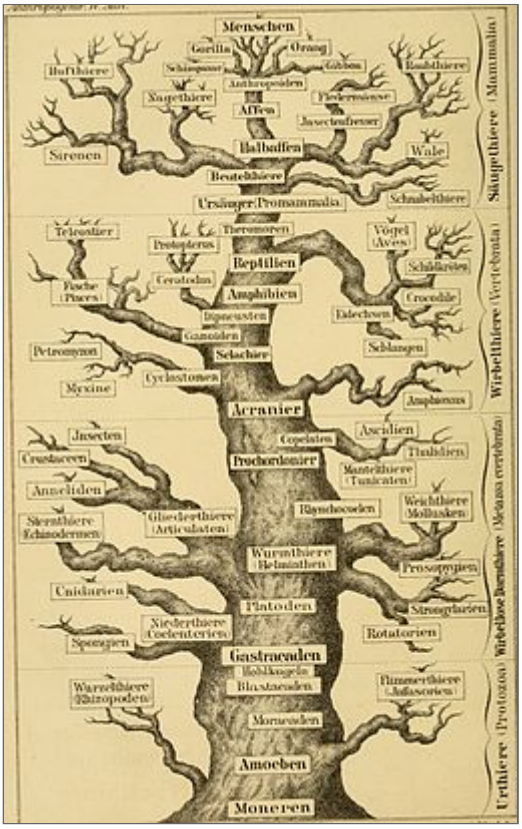
Yay!

```
$ python -m doctest 6secondimpl2.py
$
$ python -m doctest -v 6secondimpl2.py
Trying:
    average_rainfall([2,3,4,67, -999])
Expecting:
    19.0
ok
Trying:
    average_rainfall([2,3,4,67, -999])
Expecting:
    19.0
ok
1 items had no tests:
    6secondimpl2
1 items passed all tests:
   2 tests in 6secondimpl2.average_rainfall
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

Next Tests?

- These tests clearly aren't enough
- What next?
    - Look for boundary conditions (`[-999]`)
    - Look for "odd equivalents"
        - Is `[-999, 1]` the same as `[-999]`?
        - How about `[]` and `[-999]`?
        - How about `[-999]` and `[-999, 0]`
    - Look for *normal* cases you haven't covered
        - `[-1 0 10, -999]`
        - For each new feature iterate the earlier moves!
            - e.g., is `[-1 -2 -3 -999 1]` the same as `[]`?

A Classification Of Tests



A Classification Of Tests

- Based on a 5W+H approach by **Ray Sinnema** (archived)
    - **Who** (Programmer vs. customer vs. manager vs…)
    - **What** (Correctness vs. Performance vs. Useability vs…)
    - **When** (Before writing code or after)
        - Or even before architecting!
    - **Where** (Unit vs. Component vs. Integration vs. System)
        - Or lab vs. field
    - **Why** (Verification vs. specification vs. design)
    - **How** (Manual vs. automated)
        - On demand vs. continuous

Who?

- Sinnema: Tests give **confidence** in the system
    - I.e., they are **evidence** of a **quality**
    - **Who** is **getting** the evidence?
        - **Users?** Tests focus on **external** qualities
            - Can I **accept** this software?
        - **Programmers?** Tests focus on **internal** qualities
            - Can I **check in** this code?
        - **Managers?** Both?
            - Are we **ready to release**
- But also, **who** is **writing** the test?
    - A bug report is a (typically partial) test case!

What?

- Which **qualities** am I trying to show?
  - Internal vs. external
  - Functional vs. non-functional?
  - Most **developer testing** is functional (i.e., correctness)
    - And at the unit level
    - Does this class **behave as designed**

When?

- **When** is the test written?
  - **Before** the code is written?
  - **After** the code is written?
- Perhaps a better distinction
  - Tests written with **existing code/design in mind**
  - Test written **without regard** for existing code/design
  - This is related to white vs. black box testing
    - Main difference is whether you **respect the existing API**

Where?

- **Unit**
  - Smallest "chunk" of coherent code
  - Method, routine, sometimes a class
  - **McConnell**: "the execution of a **complete class, routine, or small program** that has been written by a **single programmer or team of programmers**, which is tested **in isolation** from the more complete system"
- **Component** (McConnell specific, I think)
  - "work of **multiple programmers or programming teams**" and **in isolation**

Where? (Ctnd)

- **Integration**
  - Testing the **interaction** of two or more units/components
- **System**
  - Testing the system as a whole
  - In the lab
    - I.e., in a controlled setting
  - In the field
    - I.e., in "natural", uncontrolled settings

Where? (Ctnd Encore)

- **Regression**
  - A bit of a funny one
  - **Backward looking** and **change oriented**
    - Ensure a change **hasn't broken anything**
    - Esp previous fixes.

Why?

- Three big reasons
    1. **Verification** (or validation)
        - Does the system possess a quality to a certain degree?
    2. **Design**
        - Impose constraints on the design space
            - Both structure and function
    3. **Comprehension**
        - How does the system work?
            - Reverse engineering
        - How do I work with the system?

How?

- **Manual**
  - Typically interactive
    - Human intervation for more than initiation
  - Expectations **flexible**
- **Automated**
  - The test executes and evaluates on initiation
  - Automatically run (i.e., continuously)

Test Coverage(S)

Coverage

> *QA Engineer walks into a bar. Orders a beer. Orders 0 beers. Orders 999999999 beers. Orders a lizard. Orders -1 beers. Orders a sfdeljknesv.*
>
> *— Bill Sempf (@sempf)* ***September 23, 2014***

- Esp. for **fine grained** tests, generality is a problem
- We want a **set** of tests that
    - determines some property
    - at a reasonable level of confidence
- This typically requires **coverage**

Coverage And Requirements

- Consider **acceptance** testing
  - For a test suite to **support** acceptance
    - It needs to provide information about all the critical requirements
- Consider **test driven development**
  - Where tests drive design
  - What happens without requirements coverage?

Code Coverage

- A test case (or suite) **covers a line of code**
    - if the running of the test executes the LOC
- Code coverage is a minimal sort of completeness
    - See McConnell on "basis" testing
        - Aim for **minimal** test suite with full code coverage
    - See **coverage.py**
    - Tricky bit typically involves **branches**
        - The more branches, the harder to achieve code coverage

Input Coverage

- Input spaces are (typically) too large to cover directly
    - So we need a **sample**
    - Pure **sample** probably inadequate
        - Space too large and uninteresting
    - We want a **biased** sample
        - E.g., **where the bugs are**
            - Hence, attention to boundary cases
        - E.g., **common inputs**
            - That is, what's *likely* to be seen

Situation/Scenario Coverage

- Inputs aren't everything
    - Machine configuration
    - History of use
    - Interaction patterns
- Field testing helps
    - Hence alpha plus narrow and wide beta testing
- **System tests** answer to this!

Limits Of (Developer) Testing

- Testing always has **limits**
  - Tests are **wrong**
  - Tests are **buggy**
  - Tests are **incomplete**
- "Self" Testing subject to cognitive biases
  - **Confirmation bias**: We interpret wrongly
  - **Observer-expectancy effect/Experimenter bias**: We influence others to interpret incorrectly
  - **Congruence bias**: We look in the wrong place

Developing Test Strategies

- Have one! However preliminary
    - Ad hoc testing rarely works out well
- Review it regularly
    - You may need adjustements based on
        - Individual or team psychology
        - Situation
- The McConnell **basic strategy** (22.2) is a good default

Developer Test Strategies

McConnell: **22.2 Recommended Approach to Developer Testing**

- "**Test for each relevant requirement** to make sure that the requirements have been implemented."
- "**Test for each relevant design concern** to make sure that the design has been implemented... as early as possible"
- "**Use "basis testing"** ...At a minimum, you should **test every line of code.**"
- "**Use a checklist** of the kinds of errors you've made on the project to date or have made on previous projects."
- **Design the test cases along with the product.**

What About Input Coverage In WC?

- By reverse engineering **wc** we aim for an alternative python implementation
- With a clear **spec** according to CW1
- How can we achieve functional correctness of **miniwc**?
    - By achieving **100%** input coverage to satisfy the specification
    - Let's see some examples...

Empty Text File

Common Case: 1 Line

```
[bash-3.2$ echo "This is common text in one line" > common_1line_file.txt
[bash-3.2$ wc common_1line_file.txt
       1       7      32 common_1line_file.txt
```

Common Case: 2 Lines

```
[bash-3.2$ echo -e "This is common text in \n two lines" > common_2line_file.txt
[bash-3.2$ wc common_2line_file.txt
       2       7      35 common_2line_file.txt
```

Visualising Potential Errors

- Guard against program **input**
  - What kind of file? Different types, wrong names…
  - Contents of file?
- Provide input coverage for every output **dimension**
  - Number of lines (single, multiple)
  - Number of characters (common case, large, small)
  - Number of words (how are words counted?)
  - Number of bytes (encoding?)