ICON
AGILITY SERVICES

Test-Driven Development Foundations v1.3

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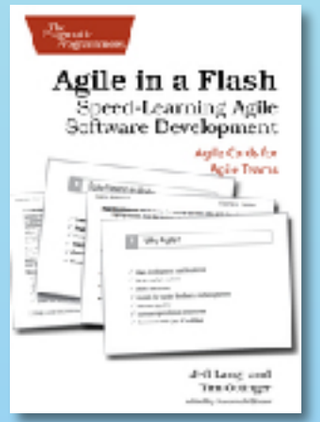

Exercise: Simple Outcomes

Flesh out the tests in ./src/misc/basics.test.js

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What's a Unit Test Look Like?

```
describe('something', () => {
  it('demonstrates some behavior', () => {
    // Arrange


    // Act


    // Assert
  })
})
```

The AAA mnemonic is courtesy of Bill Wake.

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A Sample Unit Test

```
describe('an auto', () =>
  const auto = new Auto()

  it('idles engine when started', () => {
    auto.depressBrake()

    auto.pressStartButton()

    expect(auto.RPM()).toBeWithinRange(950, 1100)
  })
})
```


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What's an Assertion Look Like?

```
expect(someCondition).toBe(true)
expect(idleSpeed).toBe(1000)
expect(alphabetizedName).toEqual('Schmoo, Kelly Loo')
expect(someArray).toEqual(['O','T','F','F','S','S'])
expect(alphabetizedName).toMatch(/^S.*,/)
expect(idleSpeed).not.toEqual(42)
expect(alphabetizedName).not.toEqual("Smelt"))))
expect(someVariable).toBeUndefined
expect(someArray).toHaveLength(3)
expect(someArray).toContain(42)
expect(someArray).toContainEqual({ name: 'Amit' })
```

See https://jest-bot.github.io/jest/docs/expect.html

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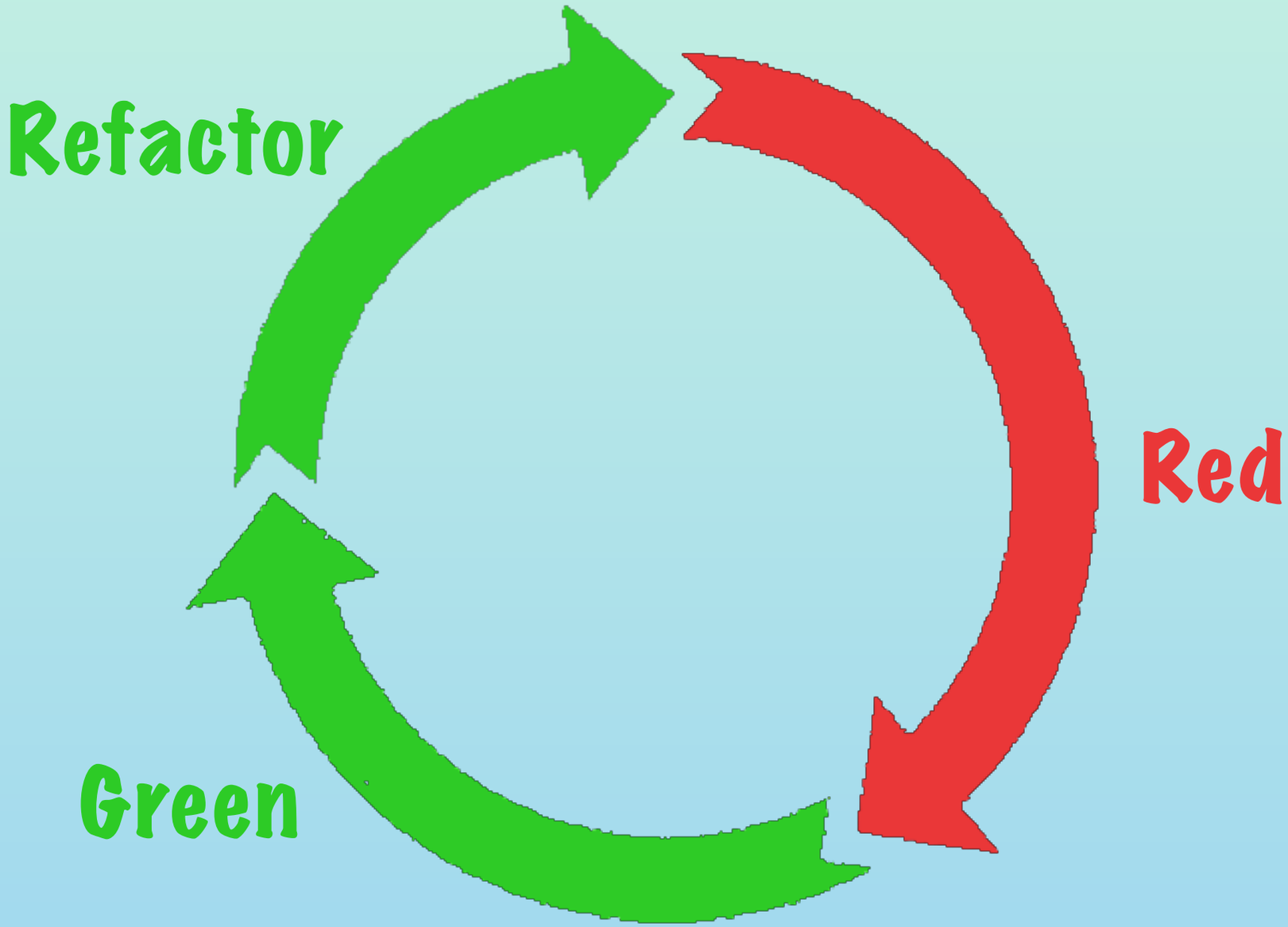
Test-Driven Development



An incremental design technique

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Exercise: (Test)-Code-Refactor

TDD Paint by Numbers

See ./src/misc/name-normalizer.test.js

npm run test:watch

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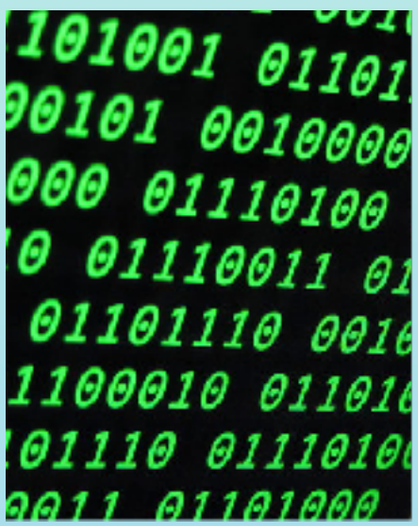
Why???



Keep yer code clean

Document choices

Gate defects

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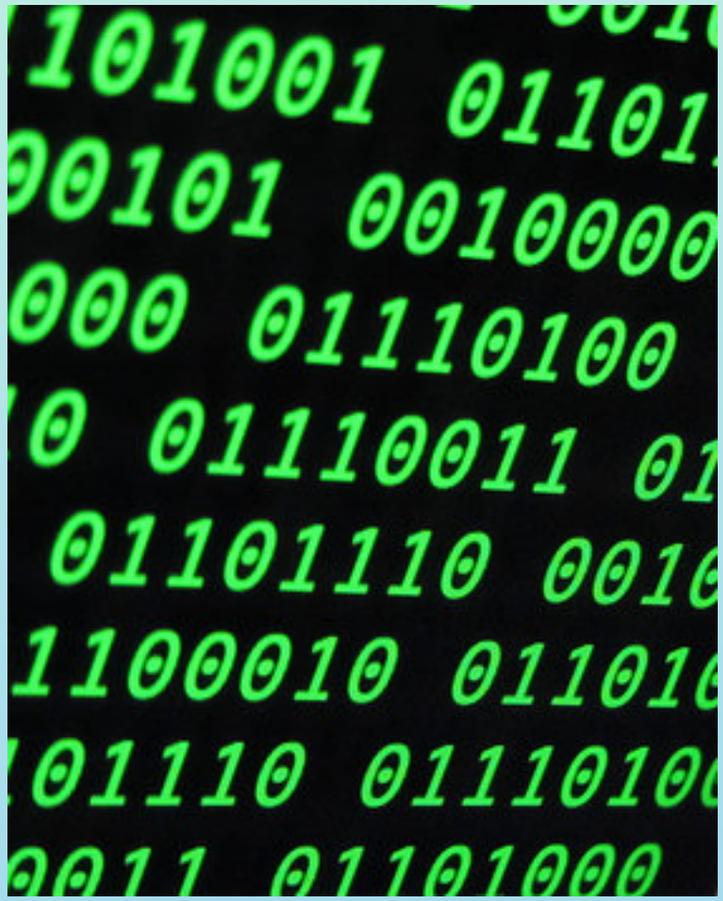
Core TDD Themes



- Drive *behavior*
- Specification by example
- Small increments
- Stick to the cycle
  - Always see red
  - Always refactor

It's just code!

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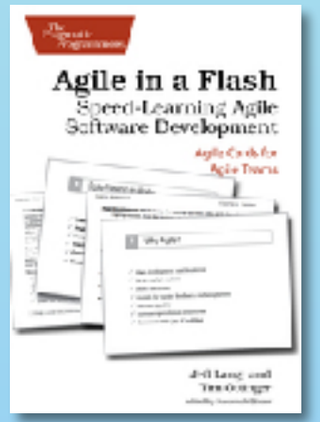
Stepping Back: Writing Tests



Recent File List

Manage a list of recently-opened files (max: 5) for use in a GUI application.

What tests do we need?

```
const recents = openFile(existingRecents, filepath)
```

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ZOMBIES!

- **Z**ero
- **O**ne
- **M**any
- **B**oundaries
- **I**nterface definition
- **E**xceptional behavior
- **S**imple Solutions & Scenarios

http://blog.wingman-sw.com/archives/677

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Test Lists

- **Z**: No files opened
- **O**: One file opened
- **M**: Multiple files opened
- **B**: One more than capacity opened
- **E**: File opened twice

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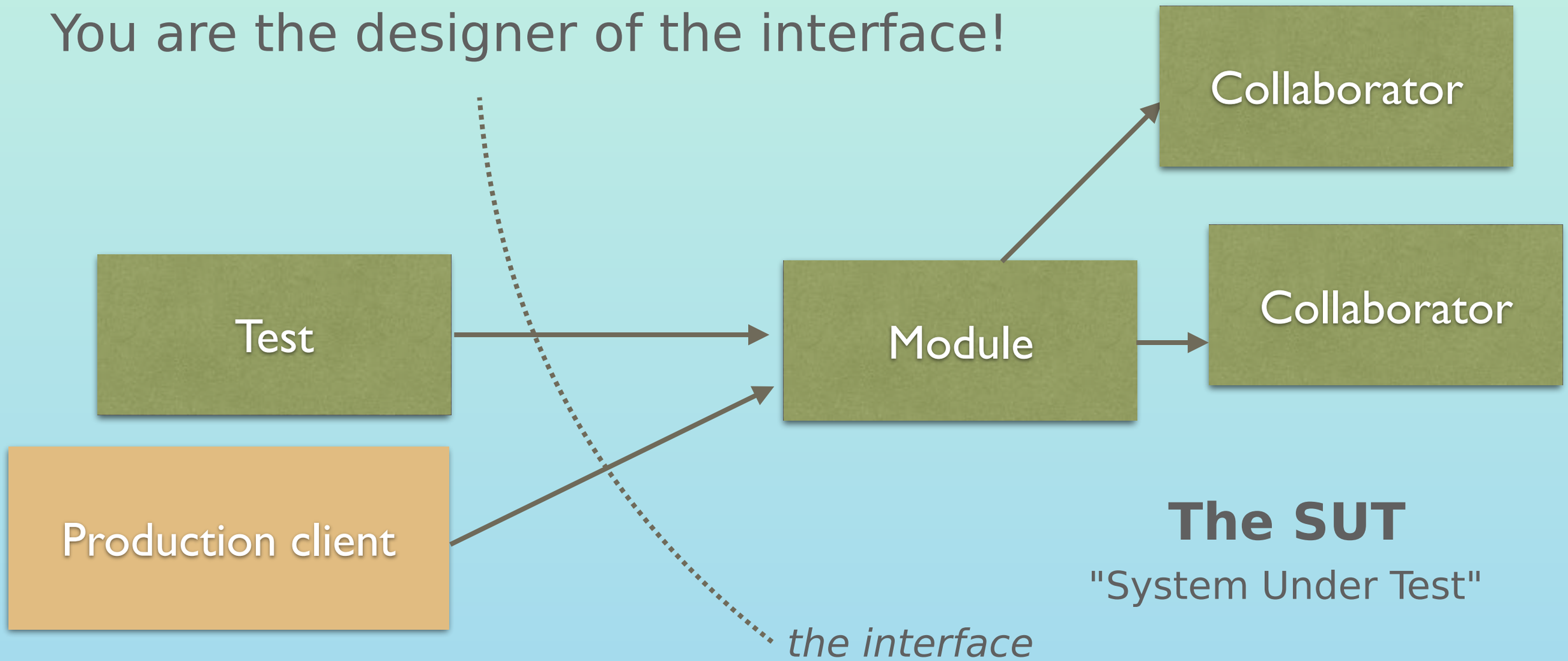
Your Test Is the First Client

You are the designer of the interface!



The SUT

"System Under Test"

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Structuring the Test

"*sifts duplicate filename to top of recently-used list*"

Arrange	Add file with name `opened-A.txt` Add file with name `opened-B.txt` Add file with name `opened-C.txt`
Act	Add file with name `opened-A.txt`

Assert	Expect recently-used list to equal:
	`opened-A.txt`
	`opened-C.txt`
	`opened-B.txt`

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Assert-First

Consider working from the outcome.

"*sifts duplicate filename to top of recently-used list*"

```
expect(recentlyUsedList).toEqual([
  duplicateOfAddedFirst, '3rd', '2nd'])
```

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Assert-First

Consider working from the outcome.

"*sifts duplicate filename to top of recently-used list*"

```
add(recentlyUsedList, duplicateOfAddedFirst)

expect(recentlyUsedList)
  .toEqual([duplicateOfAddedFirst, '3rd', '2nd'])
```

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Assert-First

Consider working from the outcome.

"*sifts duplicate filename to top of recently-used list*"

```
add(recentlyUsedList, '1st')
add(recentlyUsedList, '2nd')
add(recentlyUsedList, '3rd')
const duplicateOfAddedFirst = '1st'

add(recentlyUsedList, duplicateOfAddedFirst)

expect(recentlyUsedList)
  .toEqual([duplicateOfAddedFirst, '3rd', '2nd'])
```


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Exercise: Stock Portfolio Module

In-memory only

- is it empty or not?
- what is the count of unique symbols?
- given a symbol and # of shares, make a purchase
- how many shares exist for a given symbol?
- throw a RangeError when buying non-positive shares

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***** Remember! *****

Red: Ensure test fails

Green: Implement no more code than necessary

Refactor: Clarify and eliminate all duplication

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A Functional Implementation

Store portfolio info in a state object:

```
{
  holdings:
  {
    IBM: 20,
    BAYN: 10
  }
}
```

Pass state to each function, return updated state:

```
const create = () => ({ isEmpty: true })

const portfolio = create()
const newPortfolio = purchase(portfolio, 'BAYN', 42)
```

Ensure your function creates no side-effects!

I.e., **portfolio** should not change

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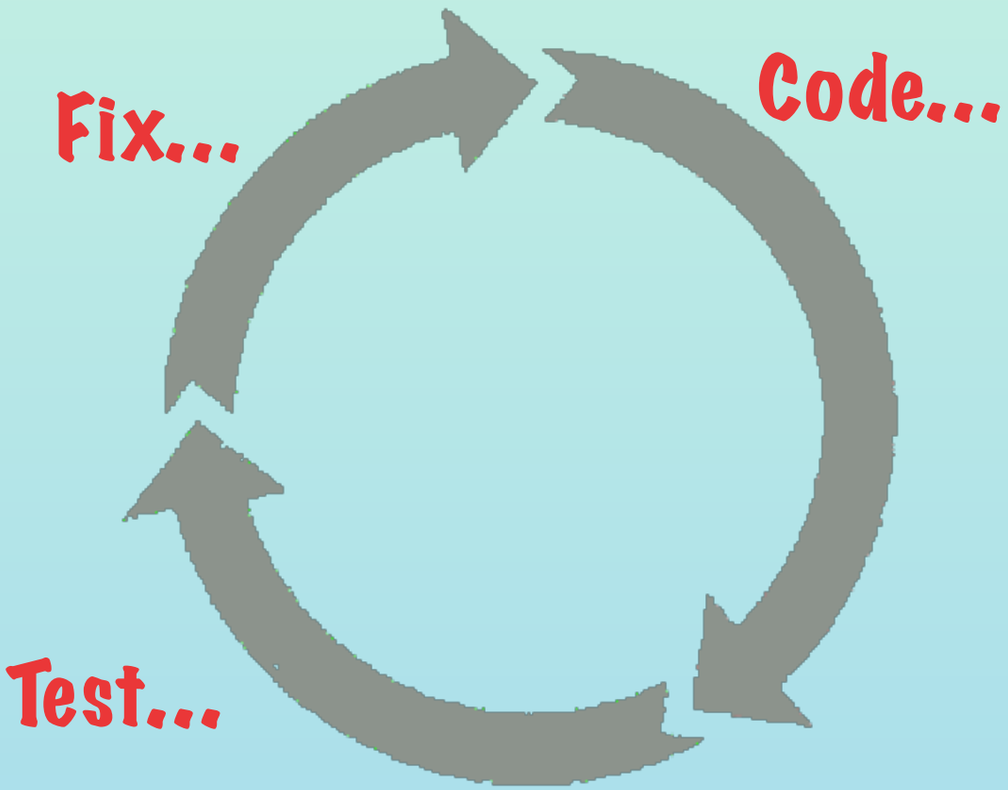
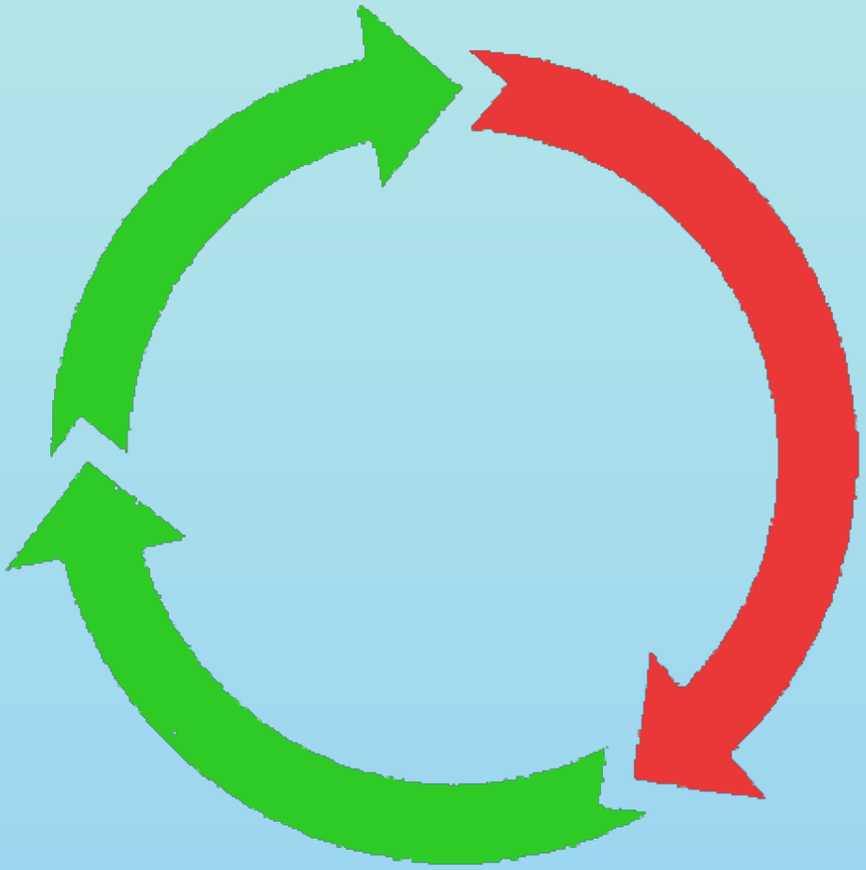
TAD** and TDD: What's the Difference?





"Test-After Development"

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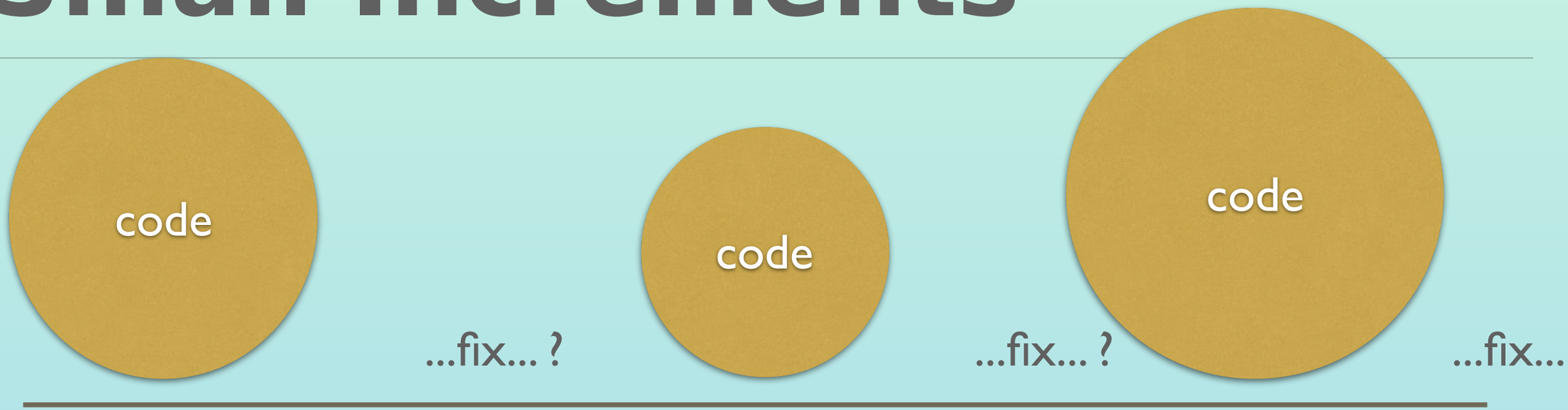
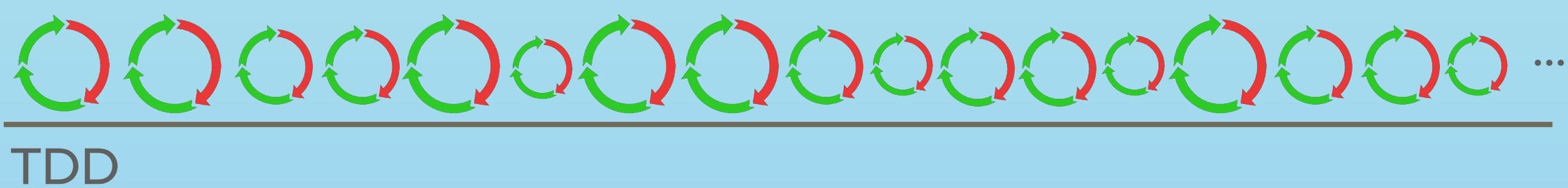
Small Increments



vs.



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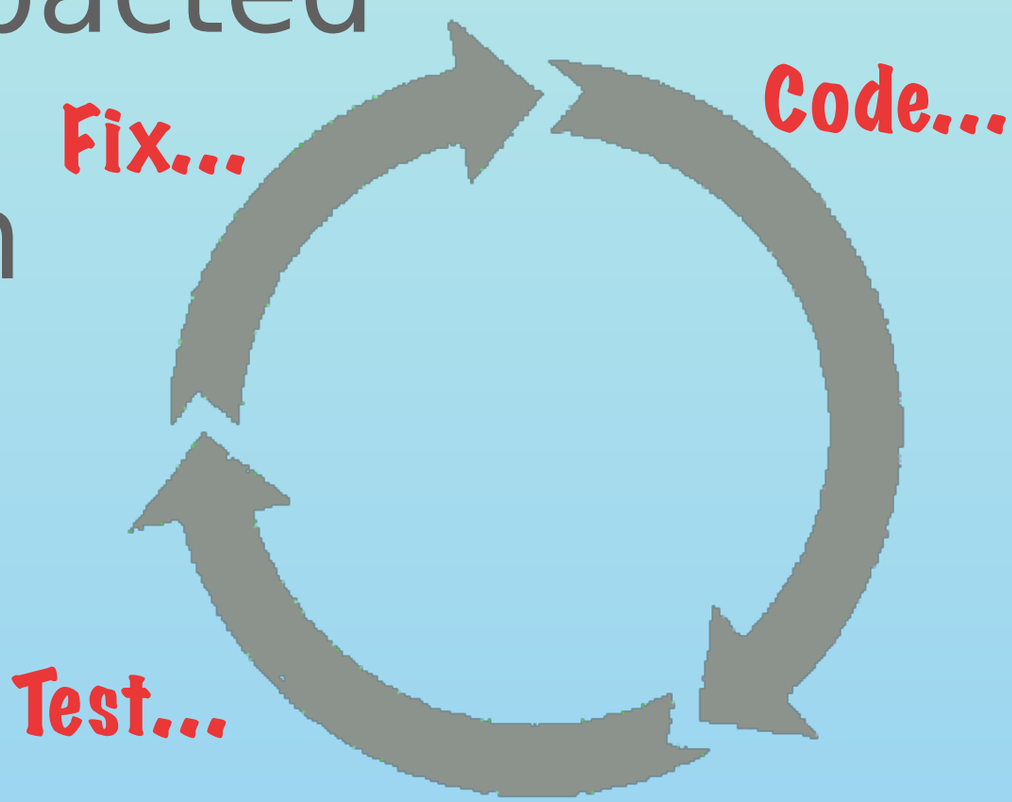
Test-After Development (TAD)

- Some refactoring accommodated
- Coverage: ~70%
- Design not usually impacted
- Some defect reduction
- Separate task?



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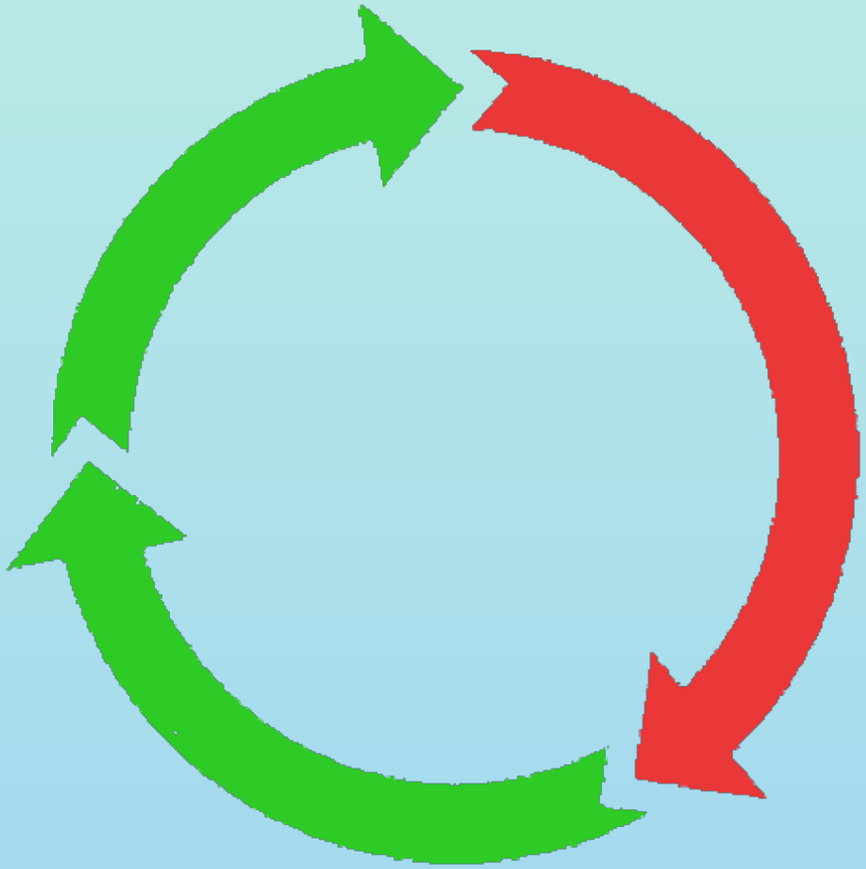
Test-Driven Development (TDD)

- Continual refactoring
- Coverage for all intended features
- Incremental design shaping
- Significant defect reduction
- Minimized debugging
- Integral part of coding process
- Clarify / document needs / choices
- Continual forward progress
- Consistent pacing
- Continual feedback / learning
- Sustainable



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Katas

http://codekata.com

Other sites:

https://exercism.io

http://cyber-dojo.org

https://sites.google.com/site/tddproblems/

https://www.codewars.com

https://github.com/jlangr/name-normalizer

https://github.com/emilybache

https://projecteuler.net/archives

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Roman Numeral Converter

Given a positive integer
from 1 up to 4000,
answer its Roman equivalent

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Quick Feedback

How do you feel?

5 Great

4 Good

3 Whatever

2 Eh

1 WTF

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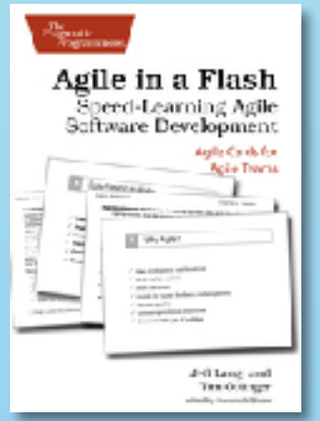
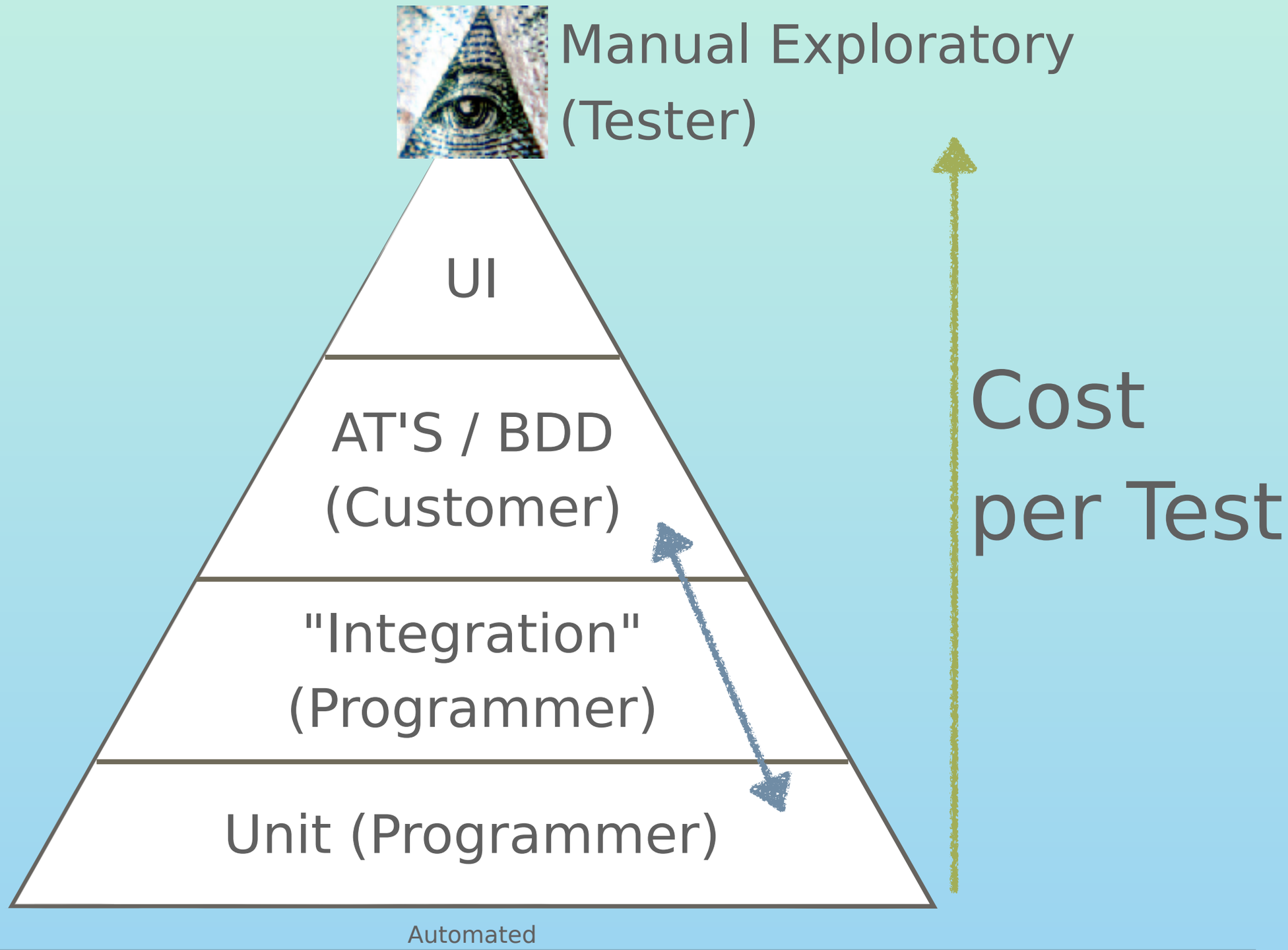
Where Does TDD Fit?



Unit Testing: Insufficient!



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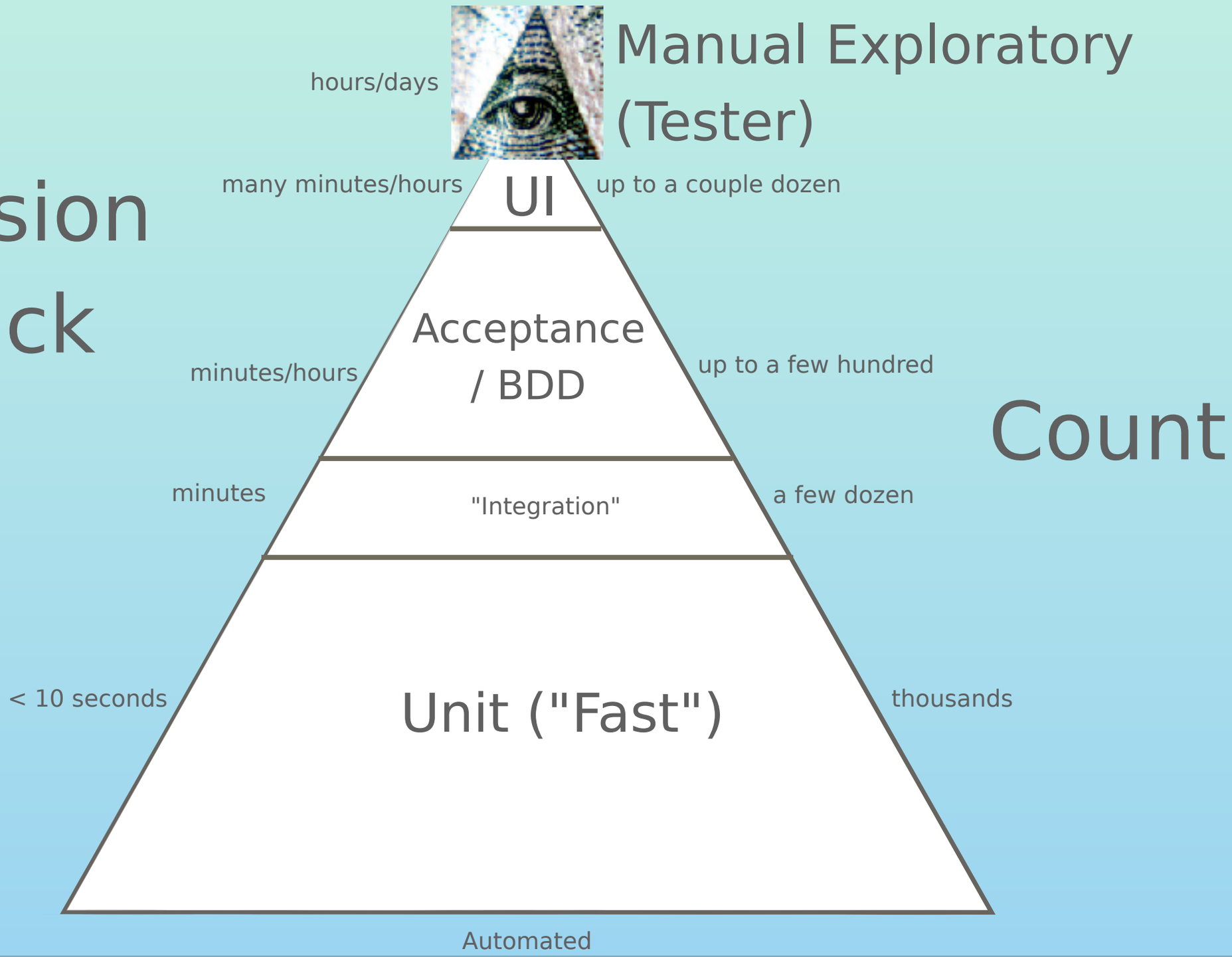
A Re-leveled Pyramid



Regression Feedback

Count

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Feedback Q's

:-)	What have I learned of value?
%-|	What, if anything, am I unclear about regarding the discussion / exercises?
?:-/	What, if anything, did I find disturbing / disconcerting?

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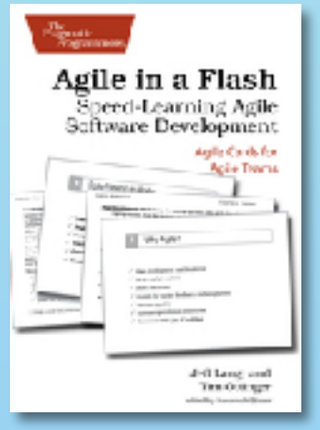
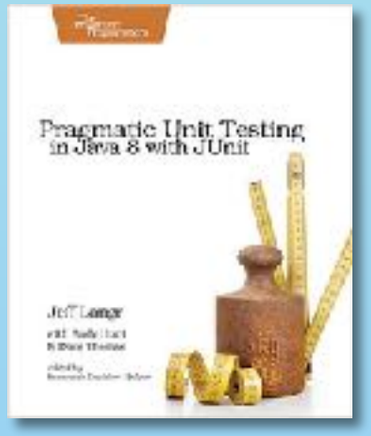
Documentation





Tests as Documents

what we're describing

the generalized behavior it supports

```
describe('an unstarted auto', () => {
  let auto
  beforeEach(() => { auto = new Au
  it('idles engine when started', () => {
    auto.depressBrake()

    auto.pressStartButton()

    expect(auto.RPM()).
      toBeWithinRange(950, 1100)
  })
})
```

an example of that behavior

Seek to first understand through the tests.

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Behavior-Driven Structuring

```
describe('given some context', () => {
  describe('when some event occurs', () => {
    it('then can be verified', () => {


    })
  })
})
```


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BDD Structuring Example

```
describe('given a checked-out material', () => {
  let dueDate

  beforeEach(() => {
   dueDate = borrow(AgileJava, PatronId)
  })

  describe('when returned late', () => {
    let daysLate
    beforeEach(() => {
      daysLate = returnMaterial(AgileJava)
    })

    it('is marked as available', () => {})
    it('generates a late fine', () => {})
    it('notifies patrons with hold', () => {})
  })
})
```


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Iterative Naming

- Re-consider name continually

```
it('x', …

it('verifies engine start', …

it('verifies engine start idle speed', …

it('has low idle on engine start', …
```

- Review often and holistically!

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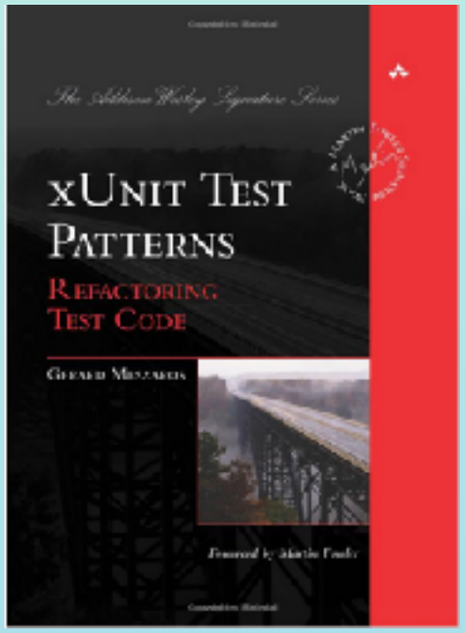
Sustainable Tests

The long answer:



A quicker route:

- Single behavior tests
- AAA
- Correlate result with context
- Test abstraction

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Exercise: Test Smells

Find and fix test smells.
Paraphrase cleaned tests
to your pair.

Further instructions: ./src/pos/routes/checkout.test.js

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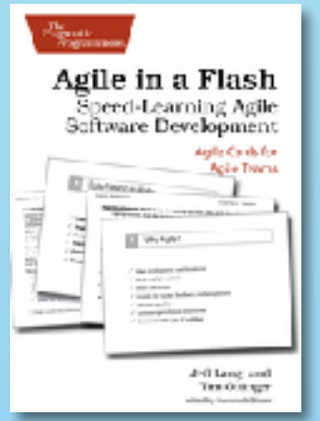
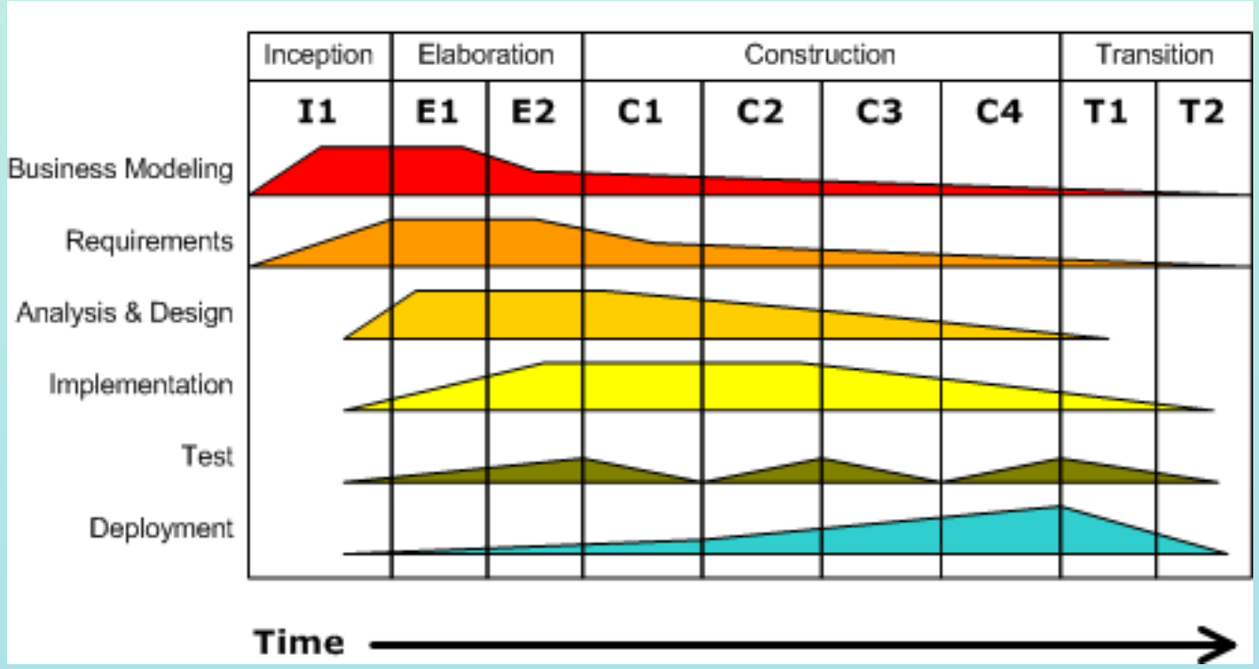
Continual Design



Software Development

- Activities:
  - Analysis, design, coding, testing, review, documentation, planning, deployment, ...



- Agile:
  - *All activities all the time*

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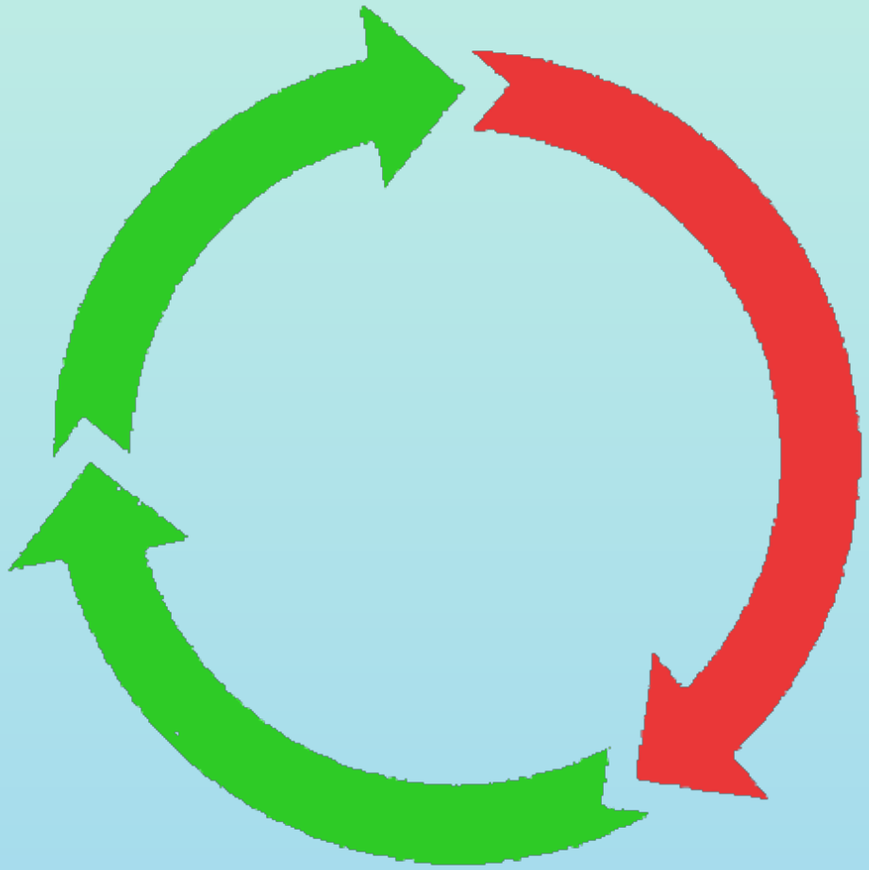
TDD: Continual ...

- Testing
- Coding
- Design
- Documentation
- Review



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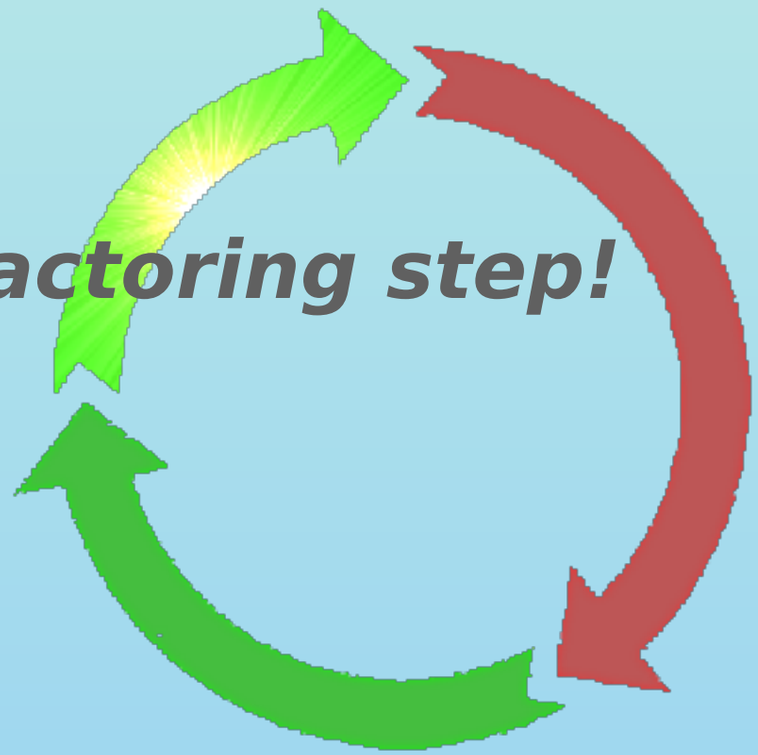
Continual Design

- Always retain an optimal design
- Entropy is unavoidable

Never skimp on the refactoring step!



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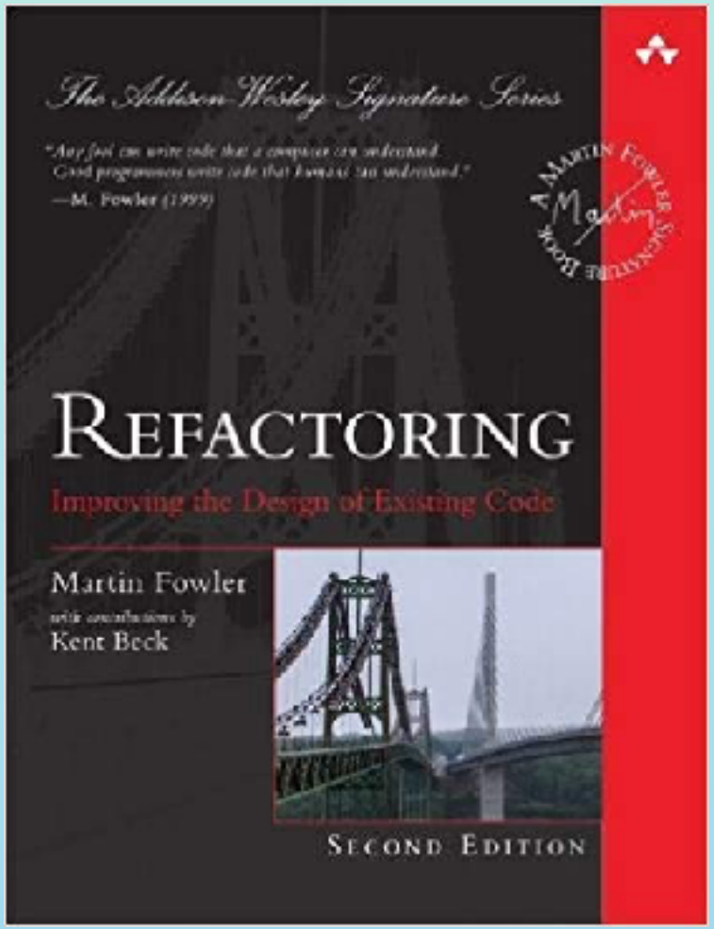
Refactoring



Same "*externally recognized*" behavior

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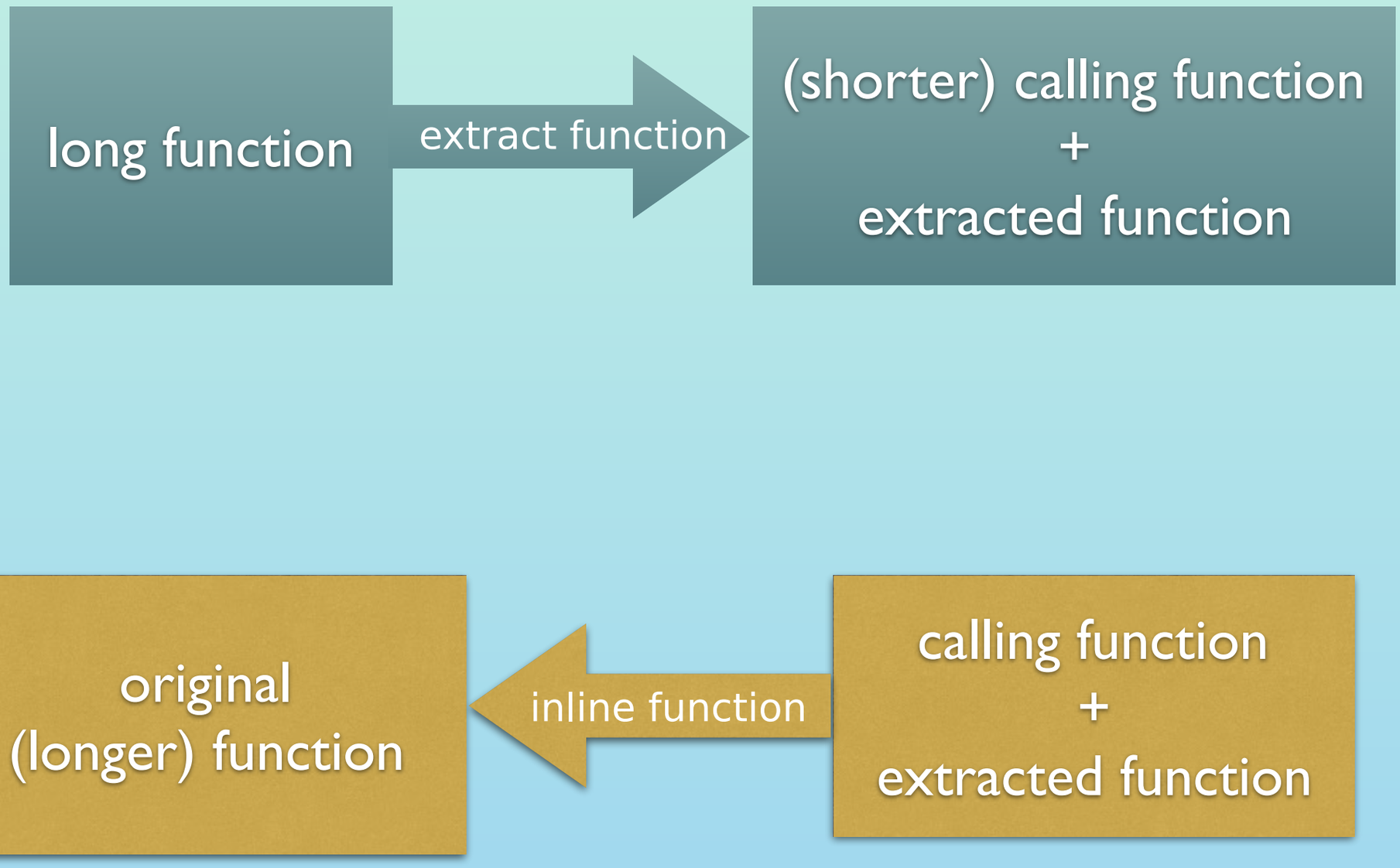
For *(almost)* Every Transform…



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Code Smells

- Comments
- Duplicate Code
- Feature Envy
- Large Module
- Long Function
- Long Parameter List
- Primitive Obsession
- Shotgun Surgery
- Speculative Generality
- Switch Statements
- **. . . and many more**

"*a complete code smells reference:*"
https://github.com/lee-dohm/code-smells

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The Nature of the Smell

Aroma?

Stench?

"beagle smelling roses," courtesy Grangernite, https://www.flickr.com/photos/ldoty/2573672102 https://creativecommons.org/licenses/by/2.0/

adapted from "Yum, that smells good!", courtesy Tankboy, https://www.flickr.com/photos/tankboy/284958387; https://creativecommons.org/licenses/by-sa/2.0/

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Exercise: Code Smells

Identify test smells.

See ./src/pos/routes/checkout.test.js

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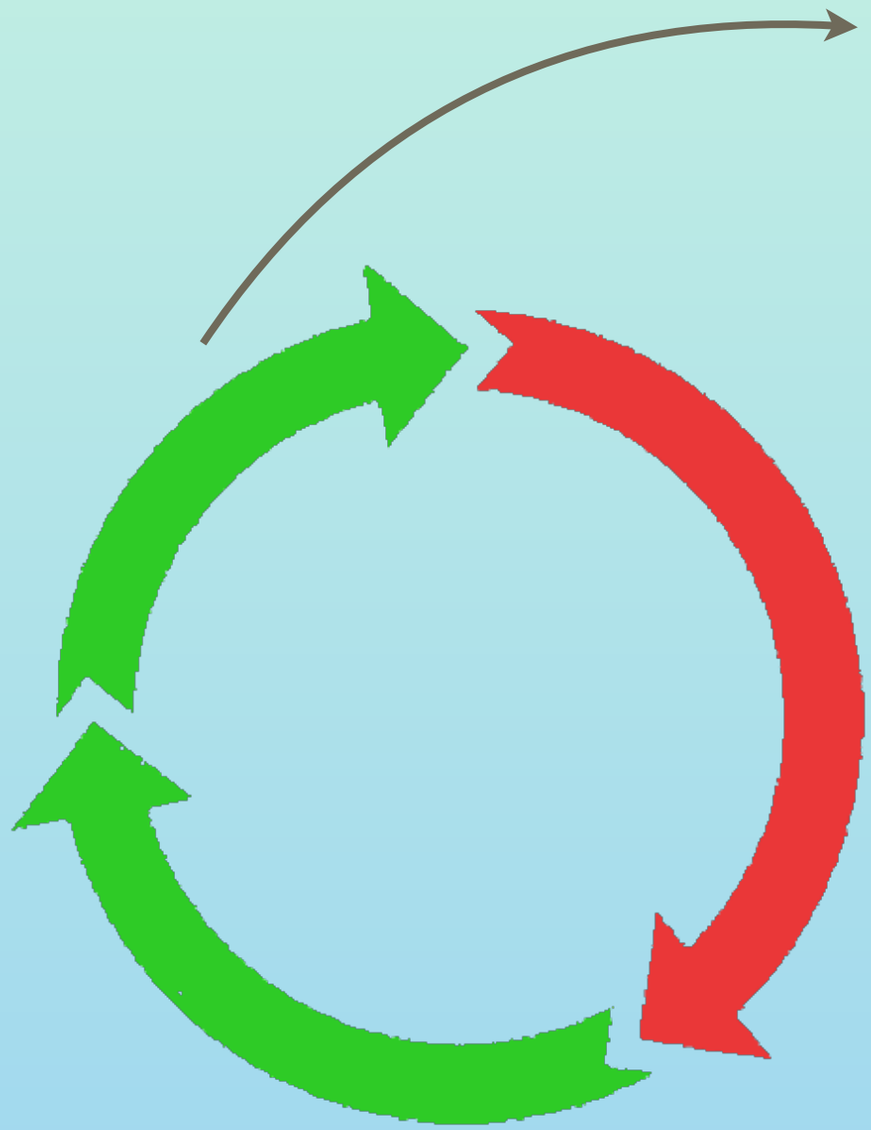
Refactoring Opportunities



small cleanup
verify
small cleanup
verify
...

One thing at a time!

Break things once in a while.

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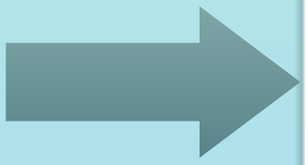
Refactoring: Extract Function

```
const uglyFunction = () => {
   // stuff a
   ...
   // stuff b
   ...
   // some smaller behavior
   doSomething()
   doSomethingElse()
   // ...
   // stuff c
   // ...
}
```



```
const uglyFunction = () => {
   // stuff a   ...
   // stuff b
   ...
   someSmallerBehavior()
   // ...
   // stuff c
   // ...
}

const someSmallerBehavior = () => {
   doSomething()
   doSomethingElse()
}
```

Why?

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Single-Line Extract?

```
catch(err) {
  const { sev, system, module, msg } = err
  const errMsg = `${new Date()}: ${system}-${module} ${sev} ${trunc(msg, 80)}`
  log(errMsg)
  throw new Error(errMsg, err)
}
```

```
  catch(err) {
    const { sev, system, module, msg } = err
    const errMsg = formatErrorMessage(sev, system, module, msg)
    log(errMsg)
    throw new Error(errMsg, err)
  }

const formatErrorMessage = (sev, system, module, msg) =>
  `${new Date()}: ${system}-${module} ${sev} ${trunc(msg, 80)}`
```


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Exercise: Extract Function

- In ./src/pos/routes/checkout.js
  - Do a single-line function extract on `postCheckoutTotal`
  - Otherwise focus on renaming and eliminating lies

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Refactoring-Inhibiting Temp

```
checkout.items.forEach(item => {
  let price = item.price;
  const isExempt = item.exempt;
  if (!isExempt && discount > 0) {
    const discountAmount = discount * price;
    const discountedPrice = price * (1.0 - discount);

    // add into total
    totalOfDiscountedItems += discountedPrice;

    let text = item.description;
    // format percent
    const amount = parseFloat(Math.round(price * 100) / 100).toFixed(2)
    const amountWidth = amount.length;

    let textWidth = LineWidth - amountWidth;
    messages.push(pad(text, textWidth) + amount);

    total += discountedPrice;

    // discount line
    const discountFormatted = '-' + parseFloat(Math.round(discountAmount * 100) / 100).toFixed(2)
    textWidth = LineWidth - discountFormatted.length;
    text = `   ${discount * 100}% mbr disc`;
    messages.push(`${pad(text, textWidth)}${discountFormatted}`);

    totalSaved += discountAmount;
  }
```

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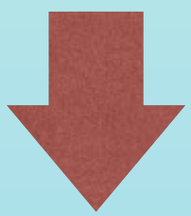
Refactoring: Replace Temp With Query

```
const discountAmount = discount * price;
// . . .

// discount line
const discountFormatted = '-' + parseFloat(Math.round(discountAmount * 100) / 100).toFixed(2)
textWidth = LineWidth - discountFormatted.length;
text = `   ${discount * 100}% mbr disc`;
messages.push(`${pad(text, textWidth)}${discountFormatted}`);

totalSaved += discountAmount;
```



```
  // discount line
  const discountFormatted =
    '-' + parseFloat(Math.round(discountAmount(discount, price) * 100) / 100).toFixed(2)
  textWidth = LineWidth - discountFormatted.length;
  text = `   ${discount * 100}% mbr disc`;
  messages.push(`${pad(text, textWidth)}${discountFormatted}`);

  totalSaved += discountAmount(discount, price);
  // …
});

const discountAmount = (discount, price) => discount * price;
// . . . . . . . .
```

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Replace Temp With Query

Steps:

- Make temp `const`
- Extract Function on the rhs
- Replace temp references with the query
- Remove temp

Why?

Concerns?

Can we go the other way?

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Exercise: Replace Temp with Query

- In ./src/pos/routes/checkout.js
  - Apply Replace Temp with Query in `postCheckoutTotal` as appropriate
  - Extract as many additional functions as you can

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TODO Code Smell: Feature Envy

```
class WrongPlace {
   client() {
      const x = enviousFunction()
      ...
   }

   enviousFunction() {
      const there = new GreenerGrass()
      const result = there.doStuff(this.someValue)
      there.doMoreStuff(result)
      return there.answer()
   }
}
```

Why is this a problem?

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TODO Refactoring: Move Function

```
class WrongPlace {
   client() {
      const x = new GreenerGrass().homebodyMethod(this.someValue)
      ...
   }
}

class GreenerGrass {
   homebodyMethod(someValue) {
      var result = doStuff(someValue)
      doMoreStuff(result)
      return answer()
   }
   ...
}
```

What must you also do when you move a function?

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Exercise: Move Function

- In ./src/pos/routes/checkout.js
- Move at least 2 envious functions to better (or new!) homes
- Ensure you've added documentation (i.e tests)!

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Planning: Up-Front Design

- Not just once!
  - Planning: project, release, iteration, day, task, test
  - Any estimation
- **Minimal**: sketches & conversations
  - Not detailed specs

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Premature Generalization

- Need might never materialize
- Details might change
- Interim complexity $

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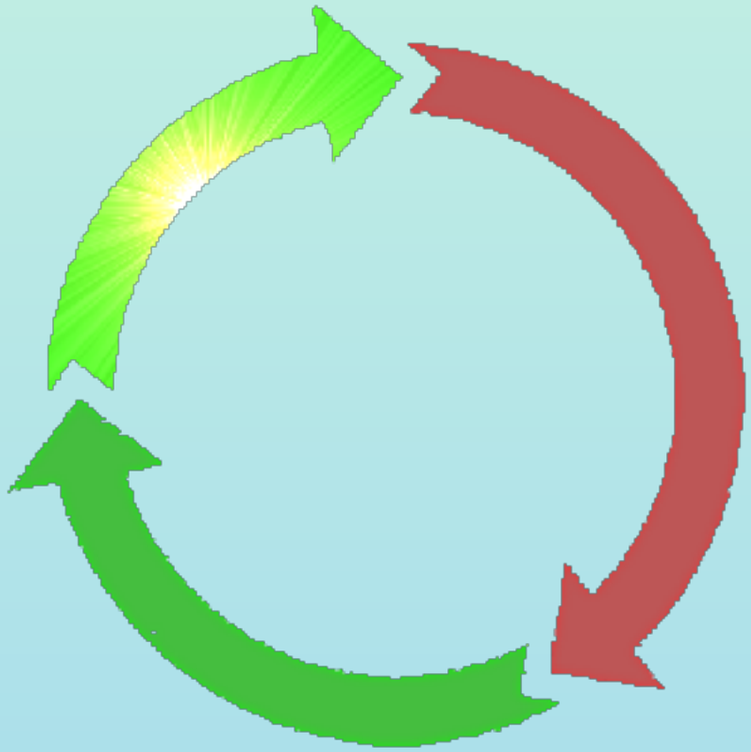
Refactoring Guidelines



Never skip!

Single-goal

Run *all* tests

It's your responsibility

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Design Drivers / Guidelines

- Code smells
- SOLID
- Design patterns
- GRASP
- Simple design
- DRY
- ...

It's all good!

Does everything point to the same place?

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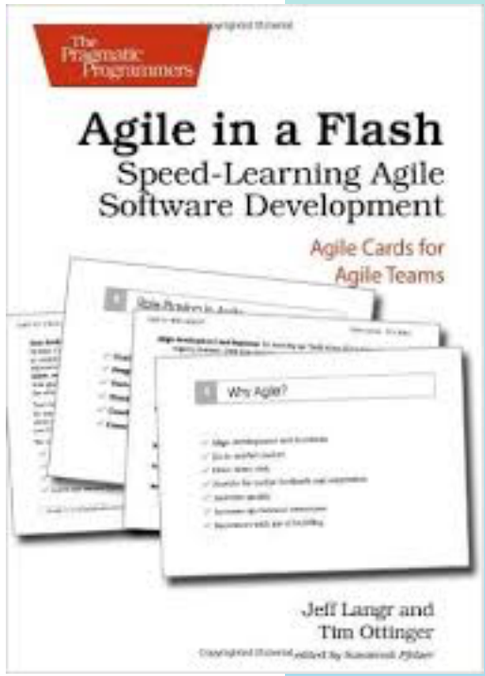
41 Build Superior Systems with Simple Design

- All tests must pass
- No code is duplicated
- Code is self-explanatory
- No superfluous parts exist



Kent Beck's (ordered) rules for emergent design

Exercise: Simple Design Rules

- In ./src/pos/routes/checkout.js
  - Stamp out duplication!
  - Strive for rapid readability
  - Have you gone too far?

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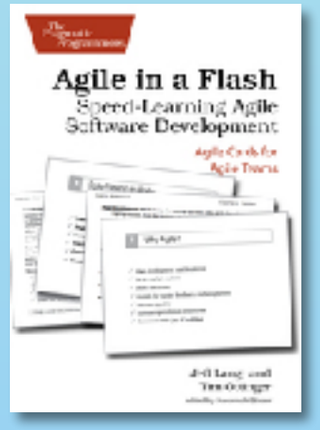
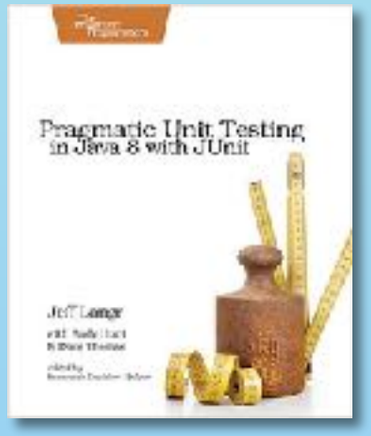
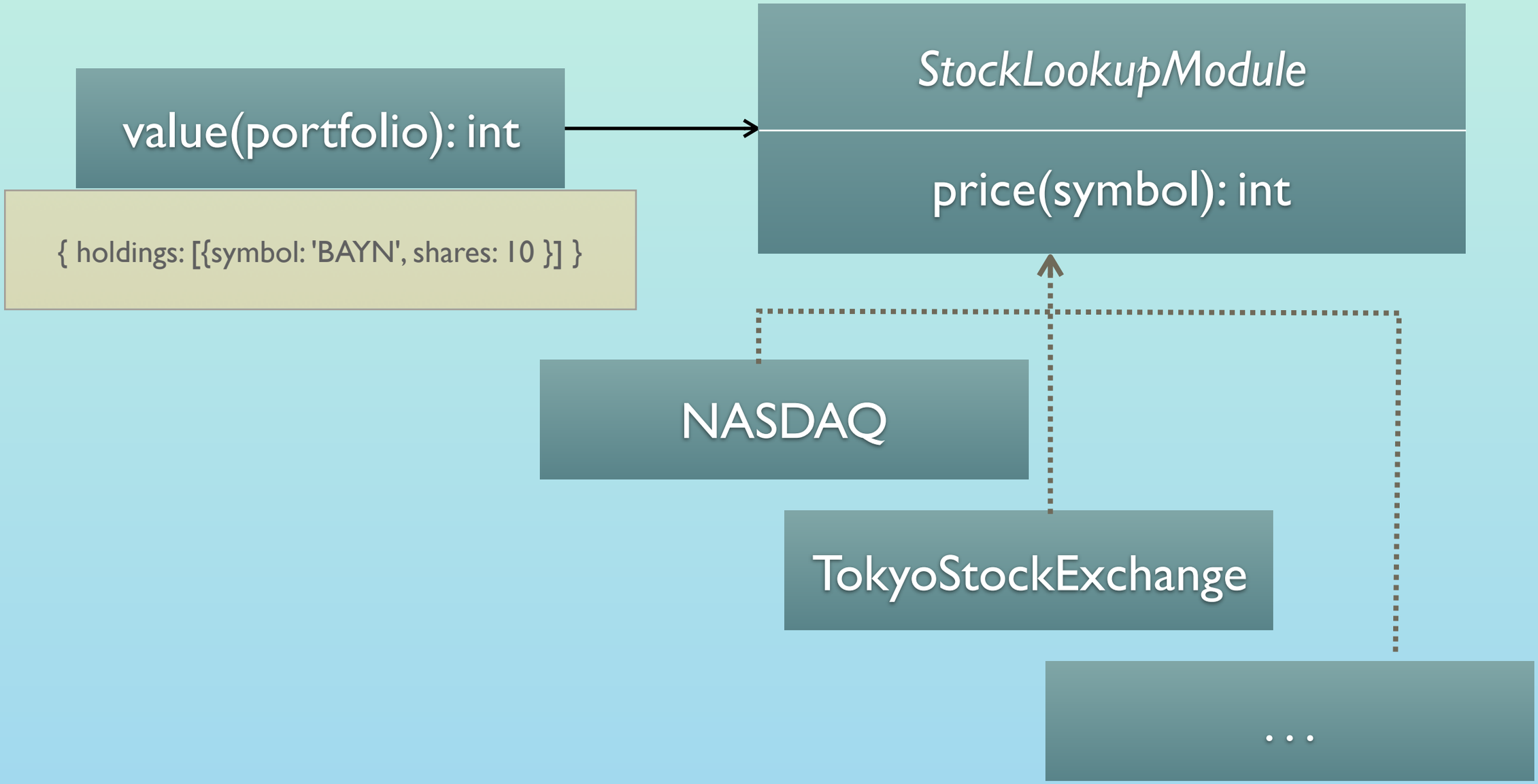
Test Doubles





Testing Challenge: Portfolio



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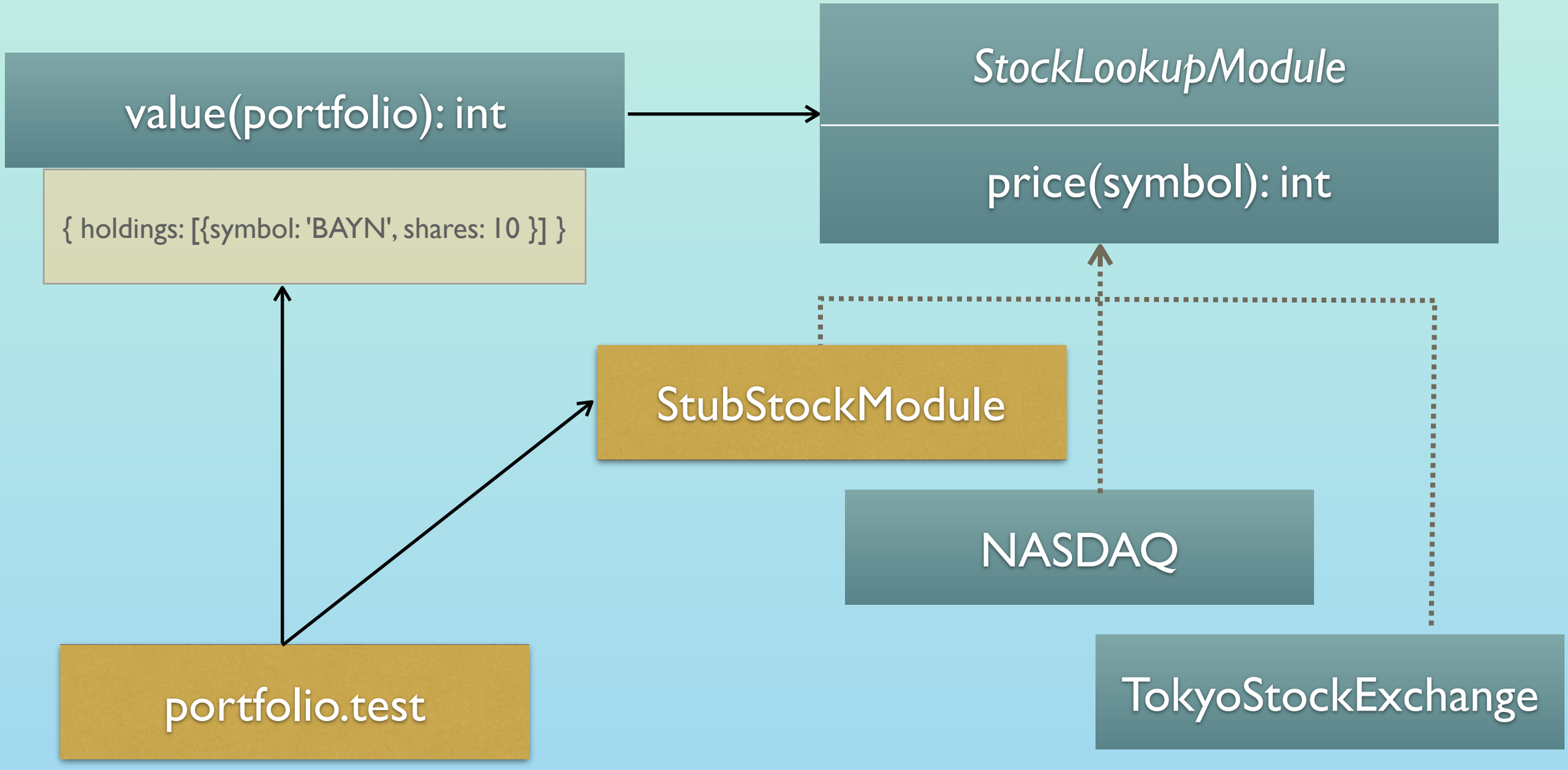
Using a Test Double



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Portfolio Code

Test-Driving from portfolio.test.js:

```
import * as StockLookupService from './stock-lookup-service'

describe('portfolio value with stub', () => {
  it('is symbol price for single-share purchase', () => {
    portfolio = purchase(portfolio, 'IBM', 1)
    expect(value(portfolio)).to.equal(42) // how to make this work?
  })
})
```

Some notion of an implementation in portfolio.js:

```
import { symbolLookup } from './stock-lookup-service'
export const value =
  portfolio => symbolLookup(Object.keys(portfolio.holdings)[0])
```

The troublesome dependency in stock-lookup-service.js:

```
export let symbolLookup = _symbol => { /* prod code */ }
```


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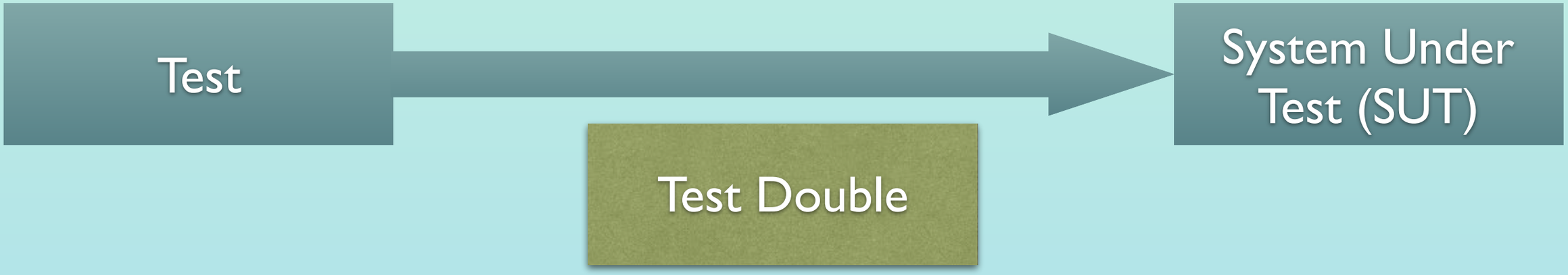
Test Double Injection Techniques



<u>Functional</u>

Function argument

import * Function Override

exports injection

<u>OO</u>

Constructor / setter

Prototype

Method override

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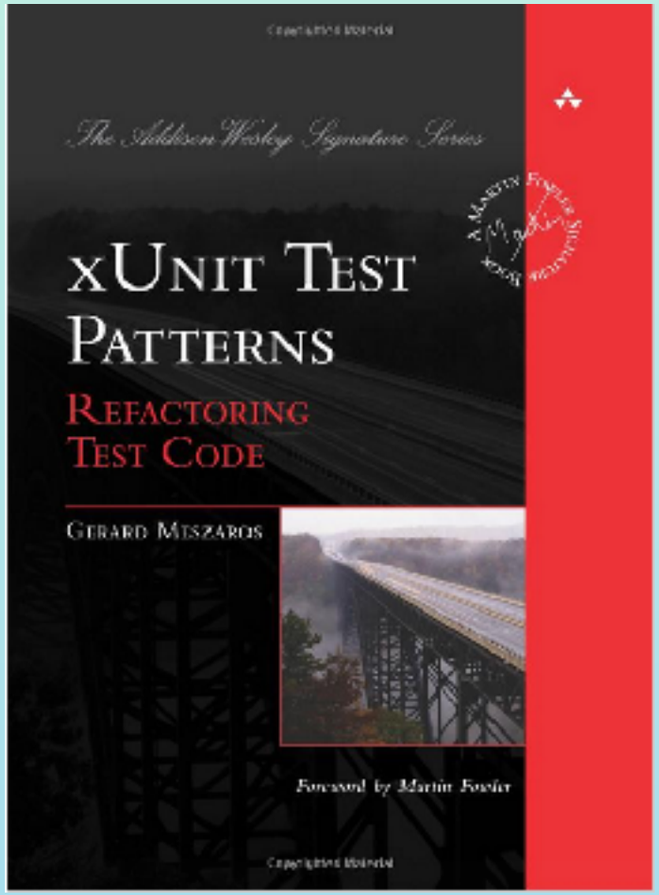
Test Double Terms

Stub: dumb emulation

Spy: captures values to verify

Mock: self-verifies

Fake: whole collaborator emulation



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Mock Tools

JsMock

JSmockito

td
test double

Jack

History suggests more & changes coming!

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Jest: A Simple Stub

https://jestjs.io

What if the cities are ordered differently?

```
const temperatureServerStub = jest.fn()
temperatureServerStub.mockReturnValueOnce(96)
temperatureServerStub.mockReturnValueOnce(88)

const result = averageTemp(['Miami', 'St. Louis'], temperatureServerStub)

expect(result).toEqual(92)
```

```
export const currentTemperature = _city => {
  throw Error('server down')
}

export const averageTemp = (cities, currentTemperature) => {
  return cities
    .map(city => currentTemperature(city))
    .reduce((sum, temp) => sum + temp, 0) / cities.length
}
```


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jest-when

https://github.com/timkindberg/jest-when

```
import { when } from 'jest-when'
// ...
const temperatureServerStub = jest.fn()
when(temperatureServerStub).calledWith('Miami').mockReturnValueOnce(96)
when(temperatureServerStub).calledWith('St. Louis').mockReturnValueOnce(88)

const result = averageTemp(['Miami', 'St. Louis'], temperatureServerStub)

expect(result).toEqual(92)
```

npm install --save-dev jest-when

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Mocks Are Trackers

https://jestjs.io/docs/en/mock-function-api.html

`mockFn.mock.calls`: list of arguments for all calls to `mockFn`

`mockFn.mock.results`: list of results for all calls to `mockFn`

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jest.fn() shorthand

```
jest.fn(() => doSomething())
```

is equivalent to:

```
jest.fn().mockImplementation(() => doSomething())
```


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Exercise: Jest Stubs

Test-drive the `value()` function for your Portfolio solution, using Jest for stubs.

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Jest: Exceptions

```
it('answers 0 when price retrieval throws', () => {
  const portfolio = {}
  purchase(portfolio, "BAYN", 1)

  const priceRetrieveStub =
    jest.fn(() => { throw new Error() })
  const result = value(portfolio, priceRetrieveStub)

  expect(result).toEqual(0)
})
```


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Exercise: Jest Exceptions

When calculating the portfolio value,
use zero dollars for the current stock price
if the symbol lookup throws an error.

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Verifying a "Tell" (*aka* Spying)

How to test-drive?

```
const sell = (portfolio, symbol, shares, auditor) {
  portfolio[symbol] -= shares
  auditor('sell made')
}
```

```
const portfolio = {}
purchase(portfolio, "BAYN", 10)
const auditorSpy = jest.fn()

sell(portfolio, "BAYN", 3, auditorSpy)

expect(auditorSpy).toHaveBeenCalled()
```


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Jest: Was It Called?

```
expect(mock).toHaveBeenCalled()

expect(mock).toHaveBeenCalledTimes(2)

expect(mock).toHaveBeenCalledWith(arg1, arg2, ...)

expect(mock).toHaveBeenCalledWith(1, arg1, arg2, ...)
expect(mock).toHaveBeenCalledWith(2, arg1, arg2, ...)

expect(mock).toHaveReturned() // i.e. did not throw error
expect(mock).toHaveReturnedWith('some value')

expect(mock).toHaveLastReturnedWith('...')
...
```

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Jest Spying: Verifying Arguments

```
expect(auditorStub)
  .toHaveBeenCalledWith('sold shares of BAYN', 3)
```

```
const sell = (portfolio, symbol, shares, auditor) => {
  portfolio[symbol] -= shares
  auditor(`sold shares of ${symbol}`, shares)
}
```


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Jest Argument Matching

How to verify the date?

```
auditor(`sold shares of ${symbol}`, shares, Date.now())
```

Use `expect.any(constructor)`:

```
expect(auditorStub)
  .toHaveBeenCalledWith(
    'sold shares of BAYN',
    3,
    expect.any(Number))
```

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Spy Exercise

Verify that the portfolio sends an appropriate audit message on all buy & sell transactions.

The audit function should take on a description,
the current timestamp,
and the number of shares involved.

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Jest: Replace a Module Function

```
import * as TemperatureServer from './temperature-server'

TemperatureServer.currentTemperature = jest.fn()

it('calculates average temperature', () => {
  TemperatureServer.currentTemperature.mockReturnValueOnce(83)
  TemperatureServer.currentTemperature.mockReturnValueOnce(52)

  const result = averageTemperature(['Miami', 'St. Louis'])

  expect(result).toEqual(67)
})
```

Not as common as mocking a module (next!)

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Mocking a Module

```
import { currentTemperature} from './temperature-server'

jest.mock('./temperature-server.js')

it('calculates average temperature', () => {
  currentTemperature.mockReturnValueOnce(82)
  currentTemperature.mockReturnValueOnce(52)

  const result = averageTemperature(['Miami', 'St. Louis'])

  expect(result).toEqual(67)
})
```

All *exports in a module are initialized to jest.fn()*

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Jest: Is That All?

No.

- Manual mocks
- Alternate ways to create an ES6 class mock
- Partial module mocks ("bypassing module mocks")
- Fake timers (`setTimeout`, `setInterval`, etc.)

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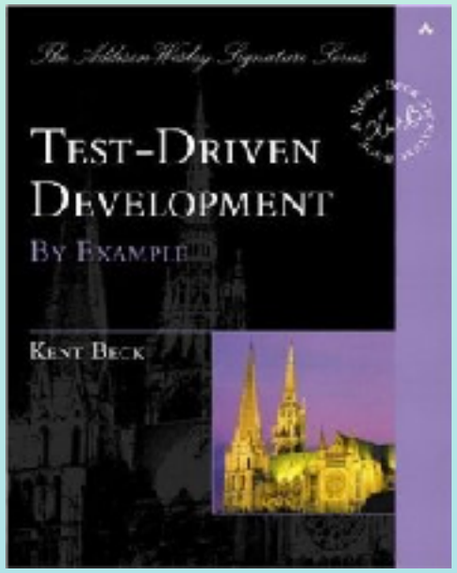
Schools of Mock

Classic ("Detroit")

algorithmic approach

verification of state

tests drive code from specific to general

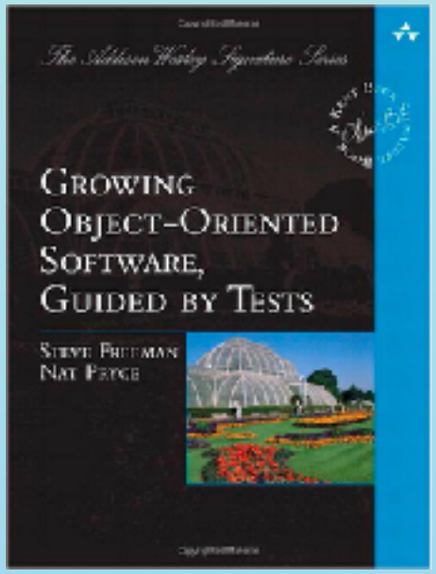


London

roles, responsibilities, and interactions

"Fake it until you make it"

drive incrementally from the outside in



Read Martin Fowler's "Mocks Aren't Stubs"

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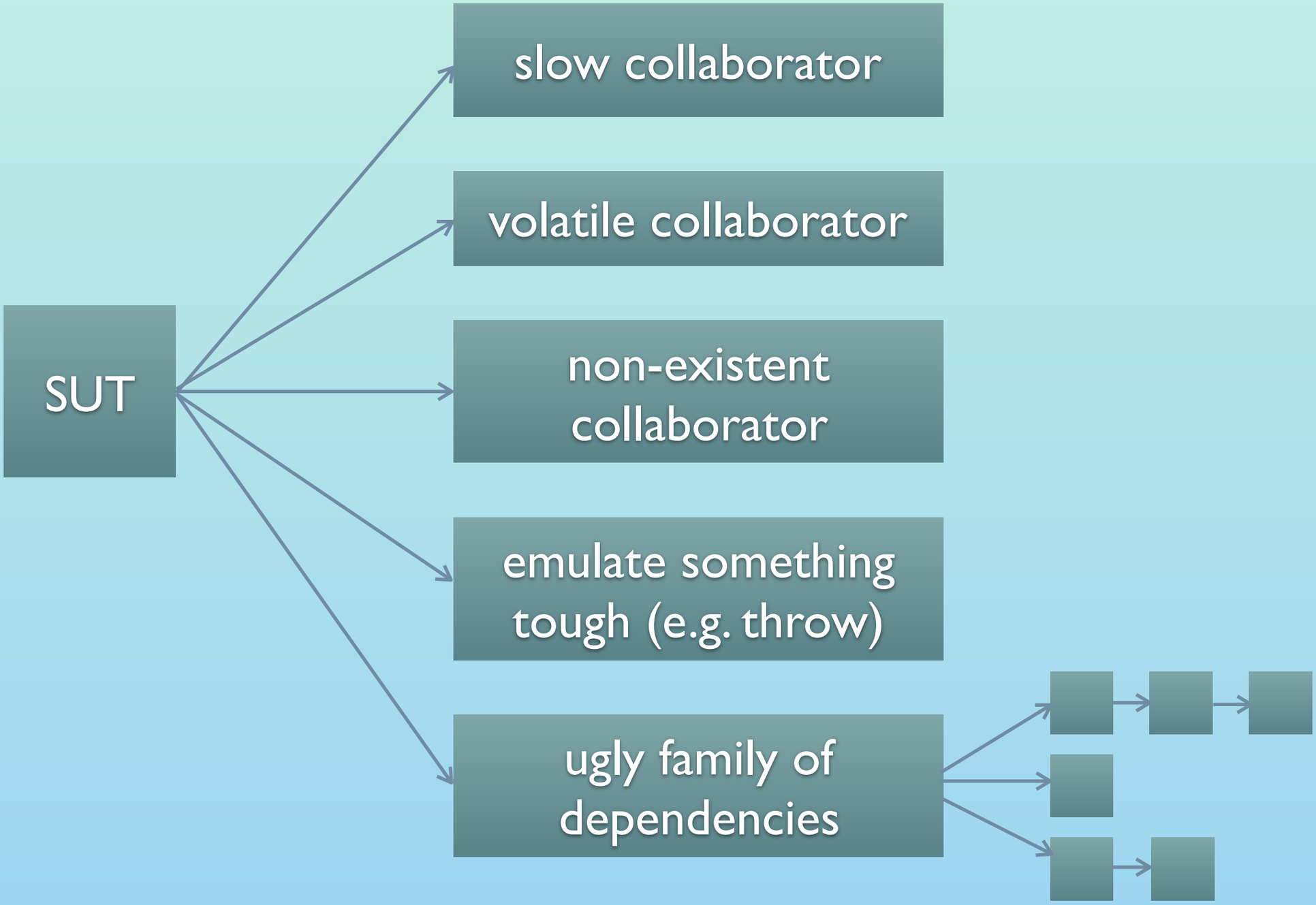
Classic School: When to Mock



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When *Not* to Mock?

Can you inject the data or a generator instead?

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The Pragmatic Mocker

- Writes integration tests where mocks are used
- Watches coupling between tests & implementation
- Seeks to mock only direct collaborators
- Avoids mocking what they don't own
- Avoids fakes (and if necessary, test-drives 'em!)
- Isolates, minimizes the use of test doubles
  - But prefers testability

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Wrap-Up Exercise

- Support voids on checkout

Work outside in:

- Stub collaborators until ready to build them out

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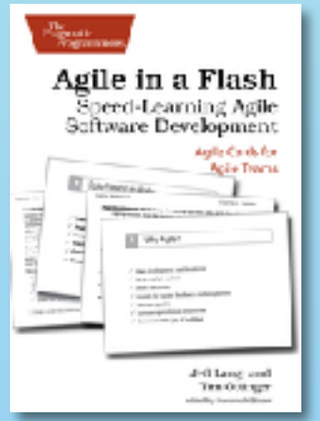
Growing & Sustaining TDD



Next Week

- Establish team policies & standards around TDD
- Ensure your build pipeline supports it
- Reviews must include the tests
- Consider pairing / mobbing

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Growing TDD

- Sharing sessions
- Challenges / contests
- Coaches & champions
- "Stop the line" mentality
- Changing metrics
- Three+ sets of eyes!

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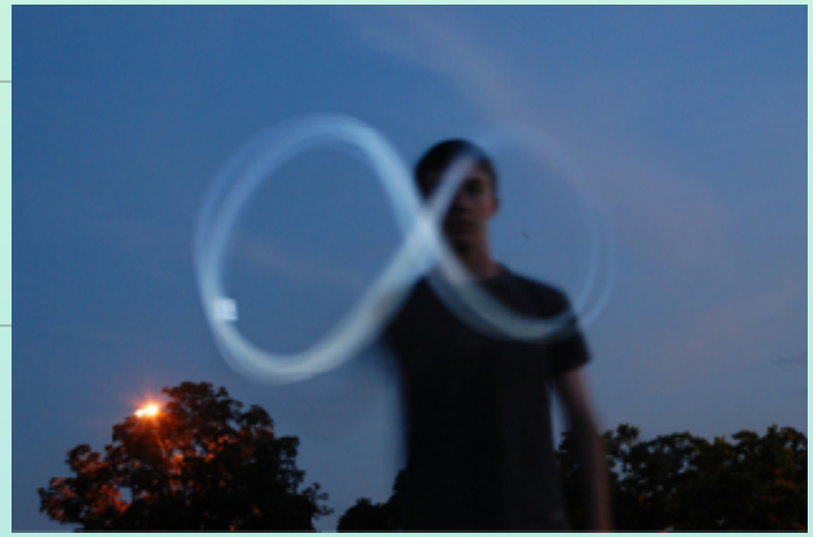
Sustaining TDD



Everything under "Growing TDD," plus:

- TDD-specific retrospectives
- Daily stand-down
- "Why" reminders
- Review standards regularly
- Keep the tests fast
- Always use tests as an entry point
- Refactor, refactor, refactor
  - Tests too!

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Mastering TDD

TDD is a skill.

Practice, practice, practice.

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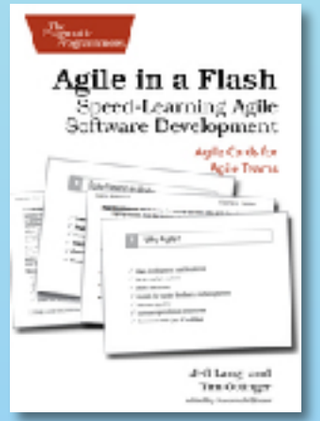
Miscellaneous Topics



Testing With Promises: ES6

```
const funcReturningPromise = () =>
  new Promise((resolve, _reject) => setTimeout(resolve, 500, 42))
```

Nope:

```
describe('testing promises', () => { // doesn't work!
  const x = funcReturningPromise()
  expect(x).to.equal(41)
})
```

ES6: await

```
describe('testing promises', async () => {
  const x = await funcReturningPromise()
  expect(x).to.equal(41)
})
```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Testing With Promises: Old School

```
it('is worth share price for single share purchase', done => {
  portfolio.retrievePrice = () => Promise.resolve({ symbol: IBM, price: 100 });
  portfolio.purchase(IBM, 1);

  portfolio.value()
    .then(result => {
      expect(result).to.equal(IBM);
      done();
    });
});
```

If that doesn't work:

```
it('is worth share price for single share purchase', done => {
  portfolio.retrievePrice = () => Promise.resolve({ symbol: IBM, price: 100 });
  portfolio.purchase(IBM, 1);

  portfolio.value()
    .then(result => { expect(result).to.equal(100); })
    .then(done, done);
});
```


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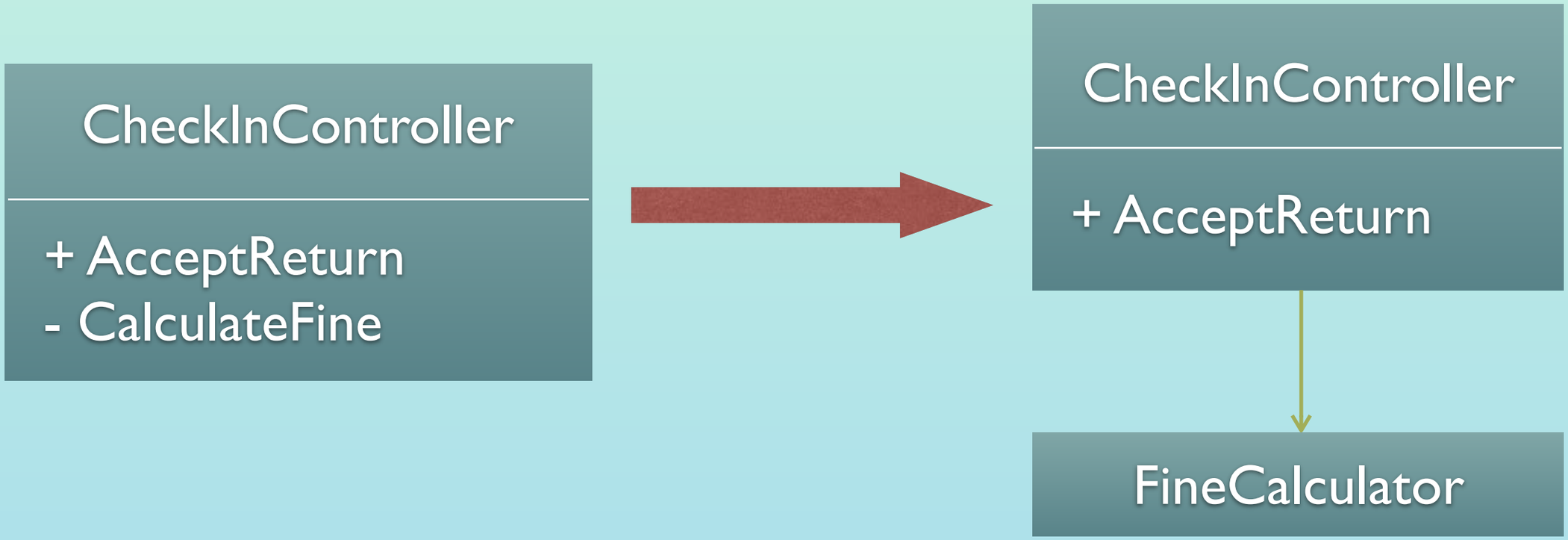
Testing Non-Public Behavior?



Or simply relax access.

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Rules of Ten

Green & clean in < 10 (minutes)

Delete and repeat if you're late!

... taking smaller steps this time.

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Rules of Ten

Debate stops at 10 (minutes)

"Show me."

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Rules of Ten

All unit tests run in < 10 (seconds).

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Fixing a Slow Test Run

Warn on tests < ***n*** *ms*

Fail on tests > ***n*** ms

Running a subset of tests increases risk.

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Uncle Bob's TPP

Transformations have a preferred ordering, which if maintained by ordering of tests, prevents "long outages" in TDD.

The Priority List

(**{}->nil)** no code at all->code that employs nil
(nil->constant)
(constant->constant+) a simple constant to a more complex constant
(constant->scalar) replacing a const. with a variable or an argument
(statement->statements) adding more unconditional statements.
(unconditional->if) splitting the execution path
(scalar->array)
(array->container)
(statement->tail-recursion)
(if->while)
(statement->recursion)
(expression->function) replacing expression w/ a function or algorithm
(variable->assignment) replacing the value of a variable.
(case) adding a case (or else) to an existing switch or if

"As the tests get more specific, the code gets more generic."

http://thecleancoder.blogspot.com/2011/02/fib-t-p-premise.html
https://8thlight.com/blog/uncle-bob/2013/05/27/TheTransformationPriorityPremise.html

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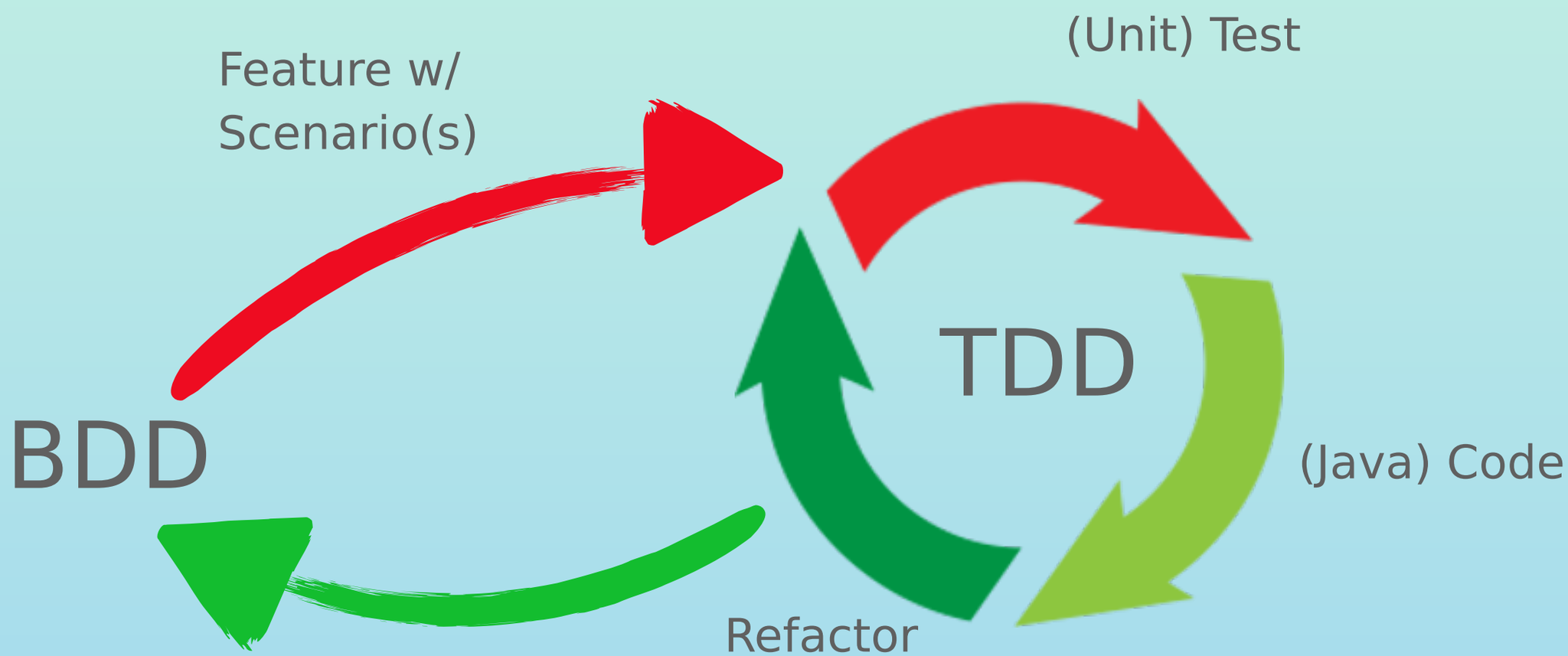
Per and updated by Uncle Bob.

Behavior-Driven Development (BDD)



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Terminology

TDD = test-driven development

Usually: **"driving code units by describing examples"**

also ...

"driving a system guided by examples"

BDD = behavior-driven development

Usually: **"driving a system by describing examples"**

also ...

"driving code units guided by examples"

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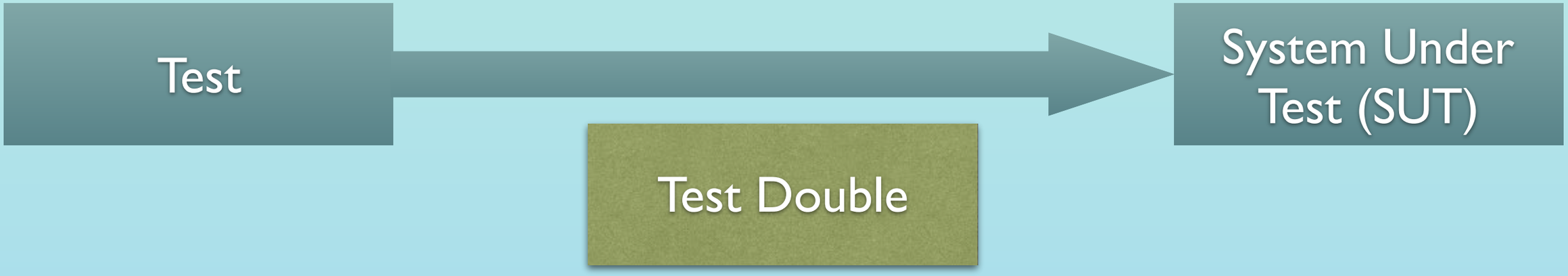
Alternate Test Double Injection Techniques



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ES6: Function Override

(using **`import * as`**)

portfolio.test.js

```
import * as StockLookupService from './stock-lookup-service'

describe('portfolio value with stub', () => {
  it('is symbol price for single-share purchase', () => {
    StockLookupService.symbolLookupStub(_ => 42)
    portfolio = purchase(portfolio, 'IBM', 1)
    expect(value(portfolio)).to.equal(42)
  })
})
```

stock-lookup-service.js

```
export let symbolLookup = _symbol => { /* prod code */ }
export const symbolLookupStub = stub => symbolLookup = stub
```

portfolio.js

```
import { symbolLookup } from './stock-lookup-service'
export const value =
  portfolio => symbolLookup(Object.keys(portfolio.holdings)[0])
```


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Exercise: Function Override using `import * as`

Prototype Injection

```
PortfolioObj.prototype.value = function() {
  if (this.size() === 0) return 0
  return this.lookupPrice('BAYN')
    .then(function({_symbol, price
      return price
    })
}

PortfolioObj.prototype.lookupPrice
  return ax.get(`http://localhost
    .then(function(response) {
      return { symbol: symbol, pr
    })
}
```

```
let realLookupPrice

beforeEach(() => {
  realLookupPrice = PortfolioObj.prototype.lookupPrice
  PortfolioObj.prototype.lookupPrice =
    function() {
      return Promise.resolve(
        { symbol: Monsanto, price: MonsantoValue })
    }
})

afterEach(() => {
  PortfolioObj.prototype.lookupPrice = realLookupPrice
})

it('...', async () => {
  portfolio.purchase(Monsanto, 1)
  const result = await portfolio.value()
  expect(result).to.equal(MonsantoValue)
})
```


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Exercise: Prototype Injection

Flesh out the portfolio value function, using TDD, starting with `./src/misc/portfolio-obj.test.js` and `./src/misc/portfolio/portfolio-obj.js`

Start simple! Add in small increments!

You should end up with at least three tests, perhaps four.

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Jest: Method Dependency

https://jestjs.io/docs/en/es6-class-mocks

```
class TemperatureService {
  currentTemperature(_city) {
    throw Error('server *really* down')
  }
}

const averageTemperature = (cities, temperatureService)  => {
  return cities
    .map(city => temperatureService.currentTemperature(city))
    .reduce((sum, temp) => sum + temp, 0) / cities.length
};
```


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Jest Method Stub

```
class TemperatureService {
  currentTemperature(_city) {
    // ...
  }}
```

```
import TemperatureService from './temperature-class'
import { when } from 'jest-when'

const mockCurrentTemperature = jest.fn()
jest.mock('./temperature-class', () =>
  jest.fn().mockImplementation(() => ({ currentTemperature: mockCurrentTemperature }))
)

  TemperatureService.mockClear() // in beforeEach
  mockCurrentTemperature.mockClear() // in beforeEach

  const temperatureService = new TemperatureService()
  when(mockCurrentTemperature).calledWith('Miami').mockReturnValueOnce(82)
  when(mockCurrentTemperature).calledWith('St. Louis').mockReturnValueOnce(52)

  const result =  averageTemperature(['Miami', 'St. Louis'], temperatureService)

  expect(result).toEqual(67)
```


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require() Dependency Challenge

portfolio.js

```
var symbolLookup = require('./stock-lookup-service').symbolLookup

// ... other funcs ...

var value = function(portfolio) {
  var sumValues = function(totalValue, symbol) {
    return totalValue + symbolLookup(symbol) * sharesOf(portfolio, symbol)
  }
  return empty(portfolio) ? 0 :
    Object.keys(portfolio.holdings).reduce(sumValues, 0)
}

module.exports = { /* ... */, value: value }
```

stock-lookup-service.js

```
module.exports = {
  symbolLookup: function(symbol) { /* ... */ }
}
```


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Exports Injection: Old School

portfolio.js

```
var value = function(symbolLookup, portfolio) {
  var sumValues = function(totalValue, symbol) {
    return totalValue + symbolLookup(symbol) * sharesOf(portfolio, symbol)
  }
  return empty(portfolio)
    ? 0
    : Object.keys(portfolio.holdings).reduce(sumValues, 0)
}

module.exports = function(symbolLookup) {
  return {
    // ... other funcs ...
    value: value.bind(null, symbolLookup)
  }
}
```


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Injecting Via Exports

portfolio.test.js

```
var stubSymbolLookup = jest.fn()
var Portfolio = require('./portfolio')(stubSymbolLookup)

describe('portfolio value', function() {
  it('is symbol price for single-share purchase', function() {
    stubSymbolLookup.mockReturnValueOnce(IBMPrice)
    var portfolio = createPortfolio()

    portfolio = purchase(portfolio, 'IBM', 1)

    expect(value(portfolio)).toEqual(IBMPrice)
  })
})
```


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References / Reading List

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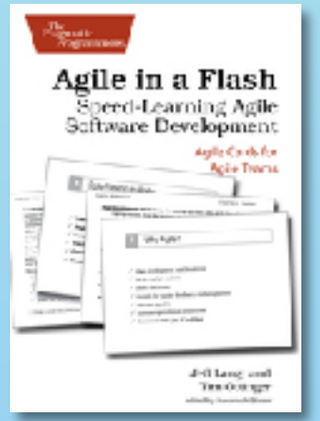
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