CMPT 473
Software Testing, Reliability and Security

Unit Testing & Testability

Nick Sumner
with material from the GoogleTest documentation

Test Suite Design

- Objectives
  - Functional correctness
  - Nonfunctional attributes (performance, ...)

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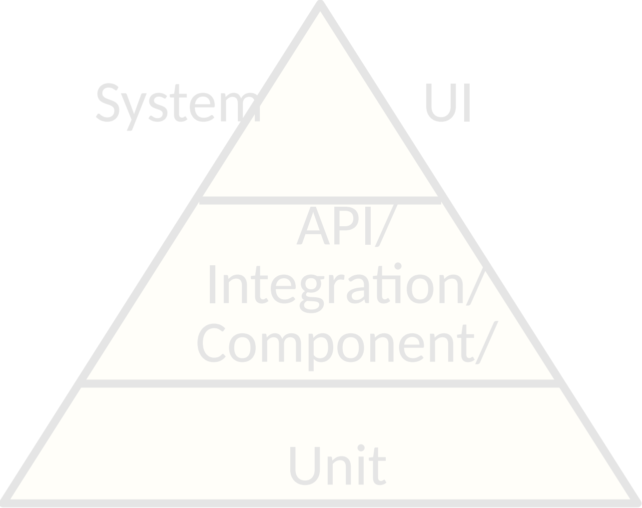

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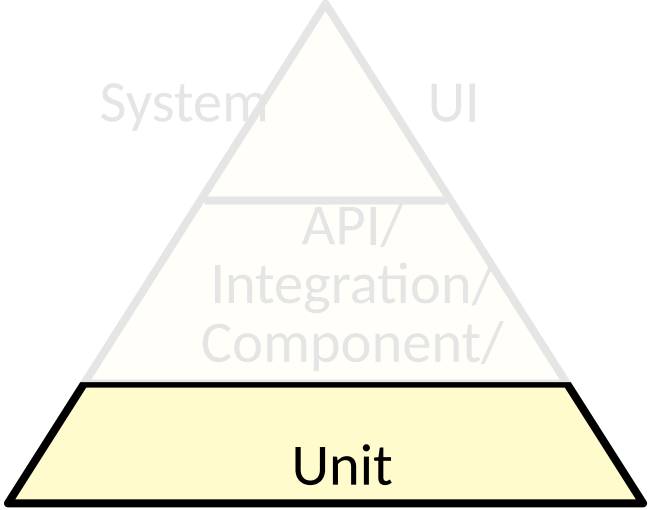

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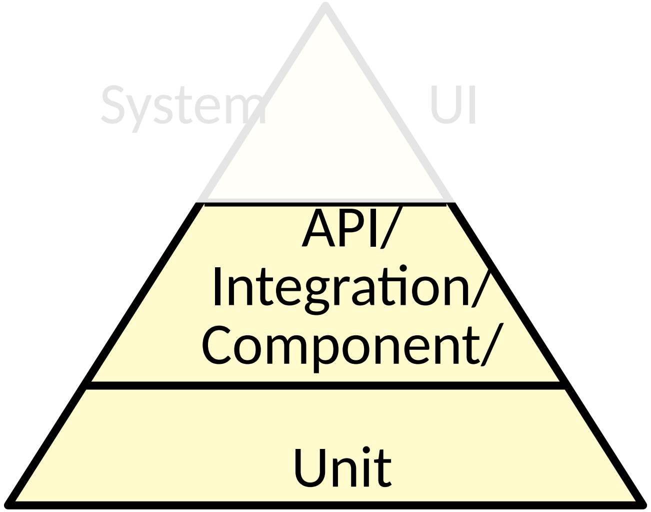

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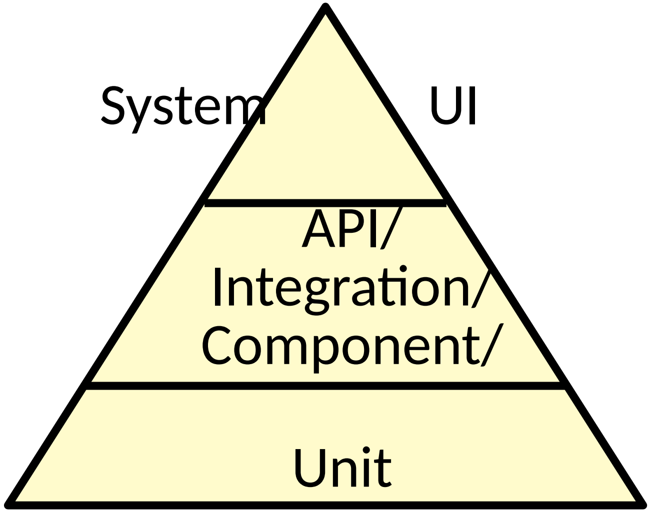

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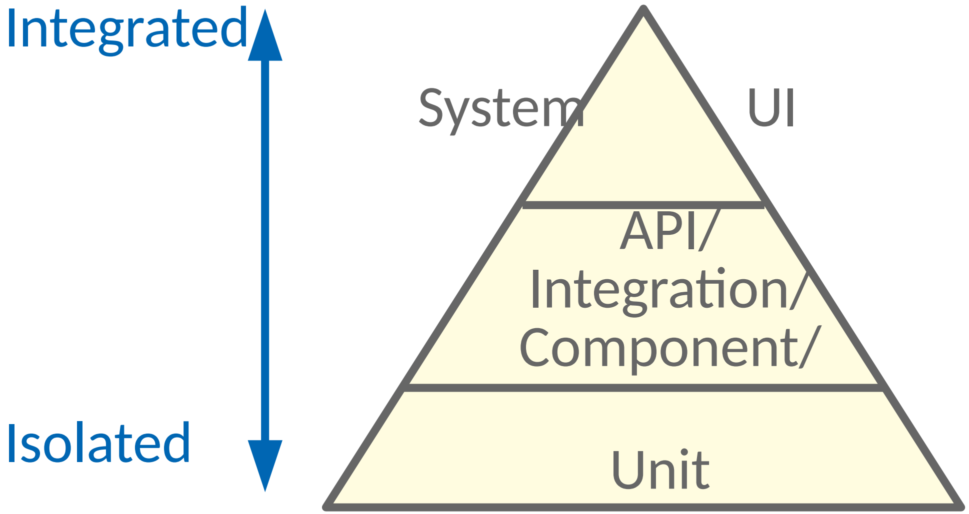

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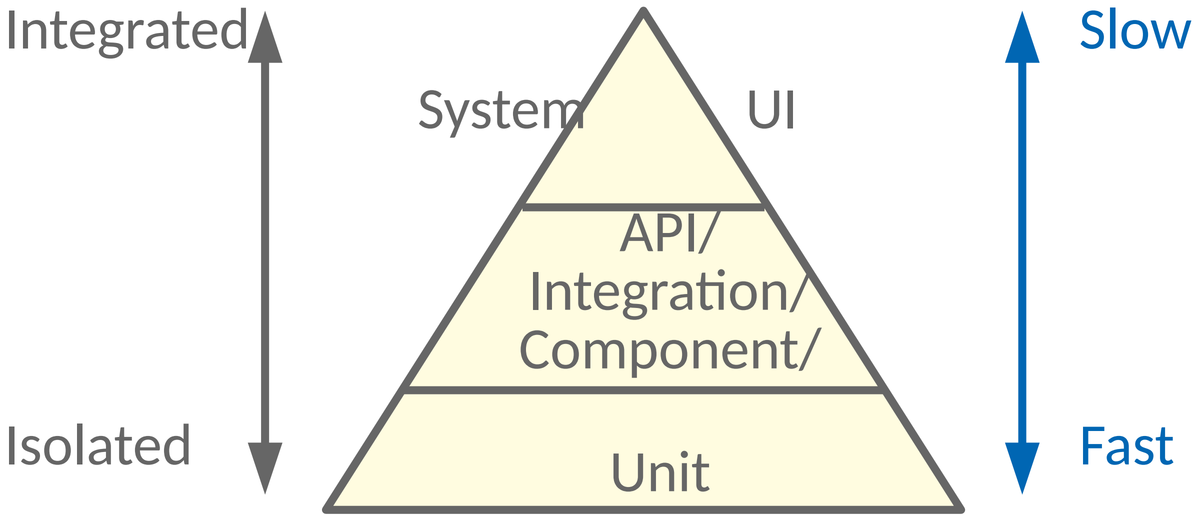

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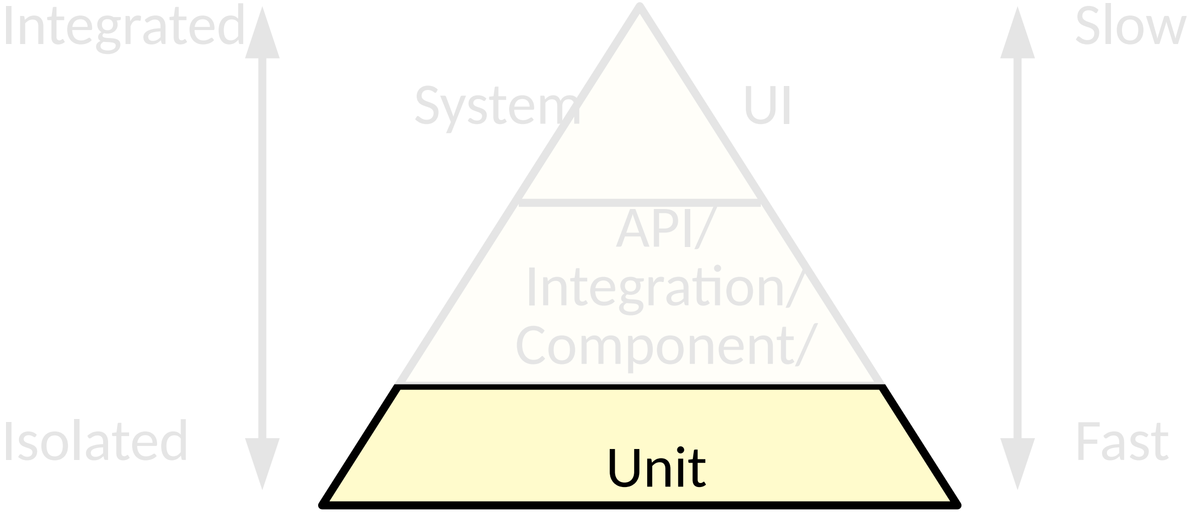

Levels of Testing

- Many different levels of testing can be considered:
  - Unit Tests
  - Integration Tests
  - System Tests
  - Acceptance Tests
  - …

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- Many different levels of testing can be considered:
  - Unit Tests
  - Integration Tests
  - System Tests
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  - …
- The simplest of these is *Unit Testing*
  - Testing the smallest possible fragments of a program

Unit Testing

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    - Unit Test a car:

      Wheels work. Steering wheel works….

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  - Degrees of isolation
  - Big & Small vs Unit & Integration

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The rapid feedback advantage
of unit tests persists for refactoring,
but there are judgement calls.

Unit Tests

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In practice, the empirical evidence is against it.

Unit Tests

- Some guiding principles:
  - *Focus* on one component *in isolation*
  - Be *simple* to set up & run
  - Be easy to *understand*

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- Some guiding principles:
  - *Focus* on one component *in isolation*
  - Be *simple* to set up & run
  - Be easy to *understand*
- Usually managed by some automating framework ….

GoogleTest

- Increasingly used framework for C++
  - Not dissimilar from JUnit, which you have already seen.

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The TEST macro defines individual test cases.

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EXPECT and ASSERT macros provide correctness oracles.

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ASSERT oracles terminate the program when they fail.
EXPECT oracles allow the program to continue running.

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  - Group them into ***test fixtures***
  - A fresh fixture is created for each test

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  - Group them into ***test fixtures***
  - A fresh fixture is created for each test
  - Fixtures enable using the same configuration for multiple tests

GoogleTest - Fixtures

```
class StackTest : public ::testing::Test {
 protected:
  void SetUp() override {
    s1.push(1);
    s2.push(2);
    s2.push(3);
  }

  void TearDown() override { }

  Stack<int> s1;
  Stack<int> s2;
};
```

Derive from the fixture base class

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SetUp() will be called ***before*** all tests using the fixture

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};
```

TearDown() will be called ***after*** all tests using the fixture

GoogleTest - Fixtures

Use the fixture in test cases defined with TEST_F:

```
TEST_F(StackTest, popOfOneIsEmpty) {
  s1.pop();
  EXPECT_EQ(0, s1.size());
}
```

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```

Behaves like

```
{
  StackTest t;
  t.SetUp();
  t.popOfOneIsEmpty();
  t.TearDown();
}
```

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A different expectation than before!

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expected value

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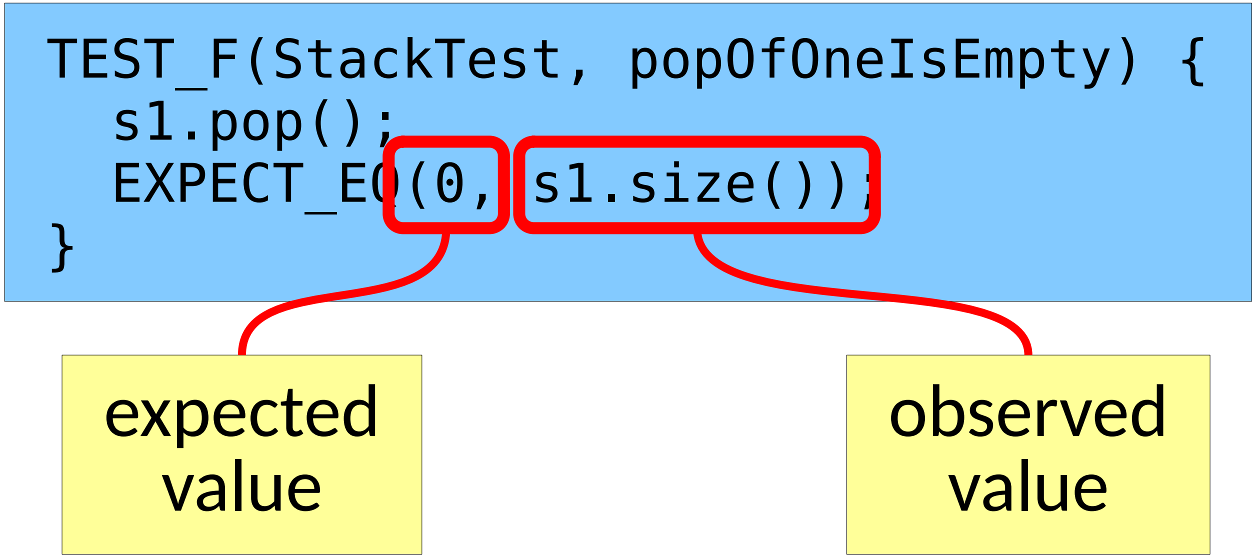

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observed value

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- Some tests require common setUp & tearDown
- Many different assertions and expectations available

```
ASSERT_TRUE(condition);          EXPECT_TRUE(condition);
ASSERT_FALSE(condition);         EXPECT_FALSE(condition);
ASSERT_EQ(expected,actual);      EXPECT_EQ(expected,actual);
ASSERT_NE(val1,val2);            EXPECT_NE(val1,val2);           …
ASSERT_LT(val1,val2);            EXPECT_LT(val1,val2);
ASSERT_LE(val1,val2);            EXPECT_LE(val1,val2);
ASSERT_GT(val1,val2);            EXPECT_GT(val1,val2);
ASSERT_GE(val1,val2);            EXPECT_GE(val1,val2);
```

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- More information available online
  - github.com/google/googletest/blob/master/googletest/docs/Primer.md
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Designing a Unit Test

- Common structure

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```
TEST_CASE("empty") {
  Environment env;
  ExprTree tree;

  auto result = evaluate(tree, env);

  CHECK(!result.has_value());
}
```

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This specific test uses
another framework
called Doctest

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Set up a scenario

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Run the scenario

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Check the outcome

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This is sometimes known as AAA:

Arrange
Act
Assert

Designing a Unit Test

- Common structure
- Tests should run in isolation

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struct Frob {
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      { }
  DBConnection conn;
};
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TEST_CASE("bad test 1") {
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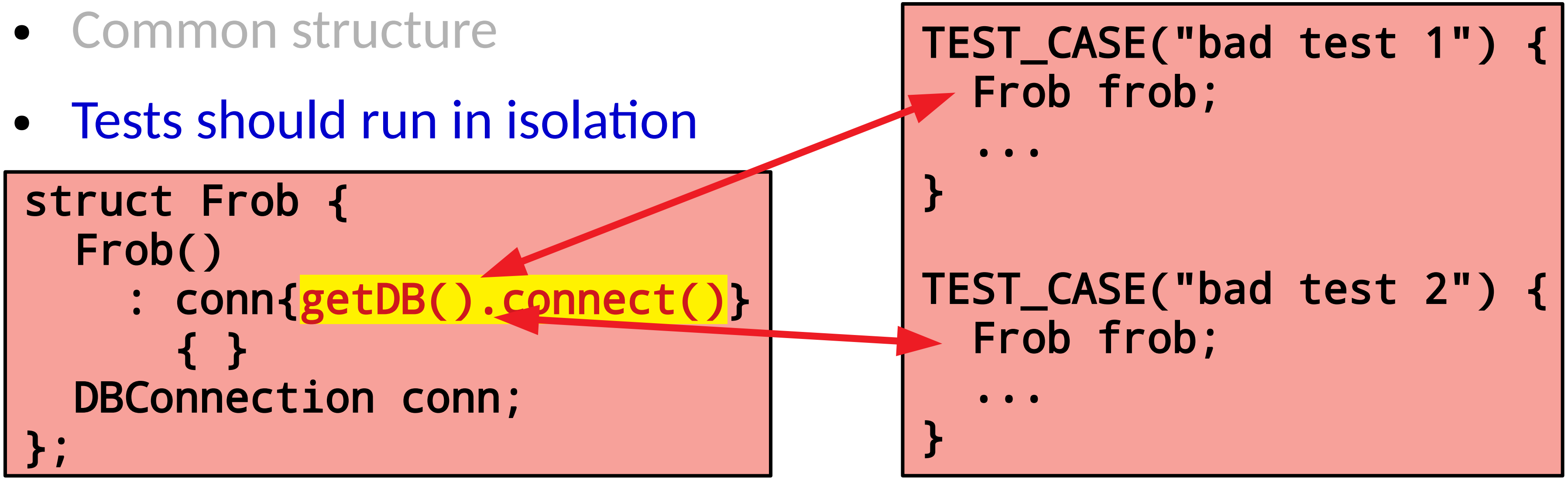

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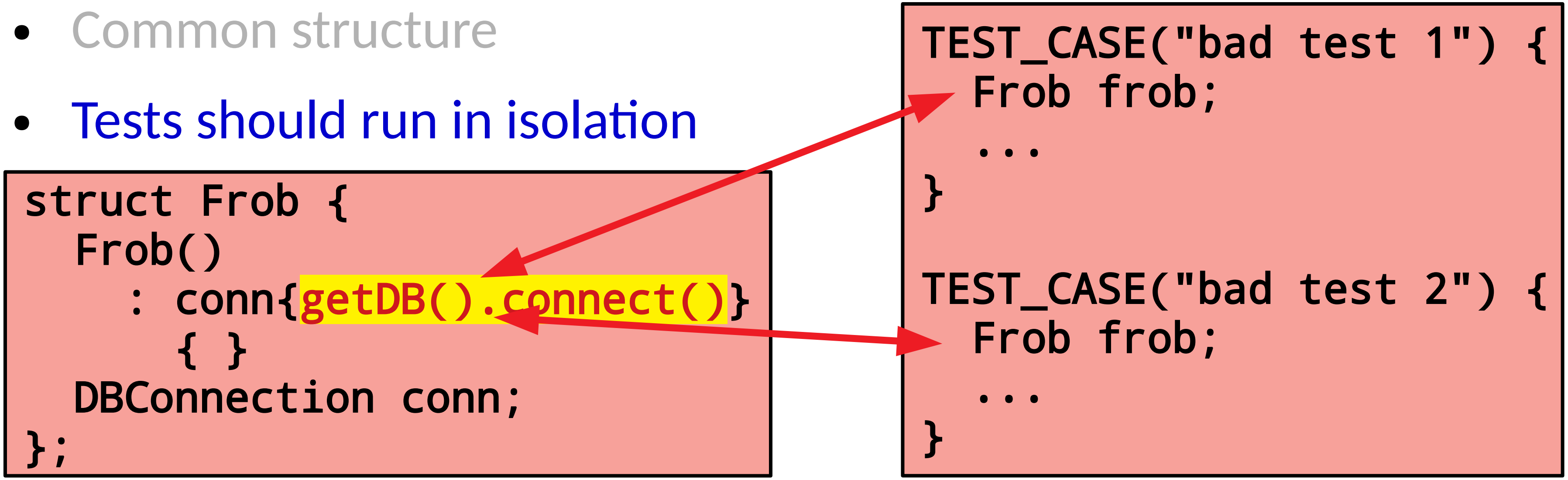

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A flaky DB can affect results!

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- Common structure
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```
struct Frob {
  Frob(Connection& inConn)
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Dependency injection allows the user of a class to control its behavior

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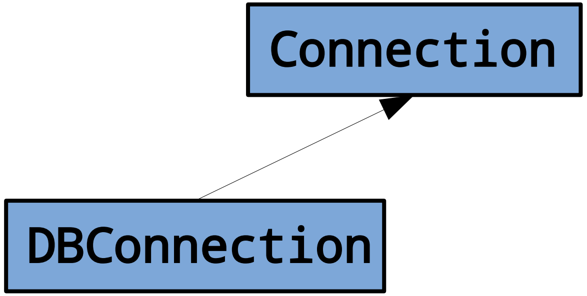

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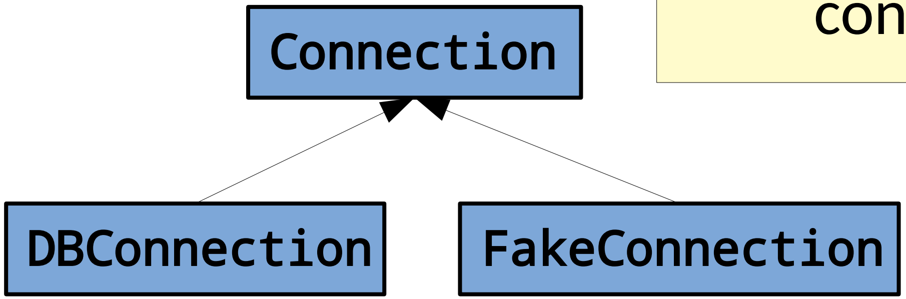

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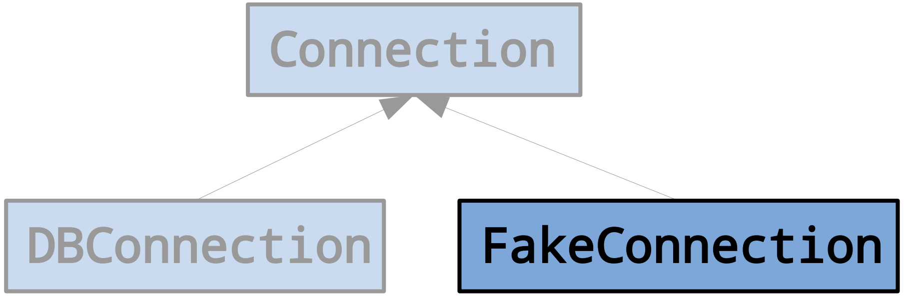

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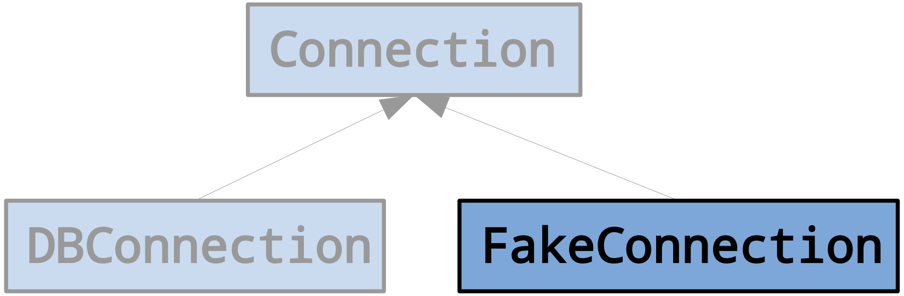

More on this later!

Common Patterns (Ammonn & Offutt)

- Checking State
  - Final State
    - Prepare initial state
    - Run test
    - Check final state

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These have become fundamental for testing hard software

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    - Testing 'fakes' that verify expected interactions
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The FakeConnection could check that DB interactions are correct.

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NOTE: Test doubles for isolation are good, but mocks should be used sparingly.

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  - Not just difficult to get adequacy
  - What makes it difficult to *write* tests?

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  - Static binding (mitigated by parametric polymorphism)

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- Dependencies
  - Connections between classes
  - Singletons
  - Nondeterminism
  - Static binding
  - Mixing construction & application logic
  - …

Testability

- What makes testing hard?
  - Not just difficult to get adequacy
  - What makes it difficult to *write* tests?
- Dependencies
  - Connections between classes
  - Singletons
  - Nondeterminism
  - Static binding
  - Mixing construction & application logic
  - …

But solutions exist!
You can *design* code to be testable!

Testability (by example)

- Next week (?) we will work together to improve some difficult to test code….

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How might we mitigate
boilerplate issues?

Mocking Framework Example

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  - Mocking
    - e.g. GoogleMock, Mockito, etc.
  - Dependency Injection

      e.g. Google Guice, Pico Container, etc.

Using GoogleMock

- Steps:
  1) Derive a mock class from the class you wish to fake

Using GoogleMock

```
class Thing {
 public:
  virtual int foo(int x);
  virtual void bar(int y);
};
```

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class MockThing : public Thing {
 public:
  ...


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  virtual int foo(int x);
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- Steps:
  1) Derive a mock class from the class you wish to fake
  2) Replace *virtual* calls with uses of `MOCK_METHOD()`.

```
class MockThing : public Thing {
 public:
  ...
  MOCK_METHOD(int, foo, (int x), (override));
  MOCK_METHOD(void, bar, (int y), (override));
};
```

Using GoogleMock

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     - What arguments? How many times? In what order?

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InSequence dummy;
EXPECT_CALL(mockThing, foo(Ge(20)))
    .Times(2)
    .WillOnce(Return(100))
    .WillOnce(Return(200));
EXPECT_CALL(mockThing, bar(Lt(5)));
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This is part of the Arrange in AAA.

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  4) Specify expectations before use via `EXPECT_CALL()`.
     - What arguments? How many times? In what order?
  5) Expectations are automatically checked in the destructor of the mock.

Using GoogleMock

- Precisely specifying mock behavior

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InSequence dummy;
EXPECT_CALL(mockThing, foo(Ge(20)))
    .Times(2) // Can be omitted here
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Complex behaviors can be checked using these basic pieces.

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- A *mock* will check that a function is called in the right ways.
- A *stub* will prevent interaction with external resources and possibly return fake data.

What might this imply about where you use mocks vs where you use stubs?

Using GoogleMock

- How would I stub out a database connection?

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```
struct Frob {
  Frob(Connection& inConn)
    : conn{inConn}
      { }
  Connection& conn;

  int doThing() {
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    x = conn.readValue();
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  }
};
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Using GoogleMock

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```

```
TEST(FrobTests, doesThing) {
  FakeDBConnection conn;
  EXPECT_CALL(conn, readValue())
    .WillOnce(Return(5));

  Frob frob{conn};
  auto result = frob.doThing();

  ASSERT(42, result);
}
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Using GoogleMock

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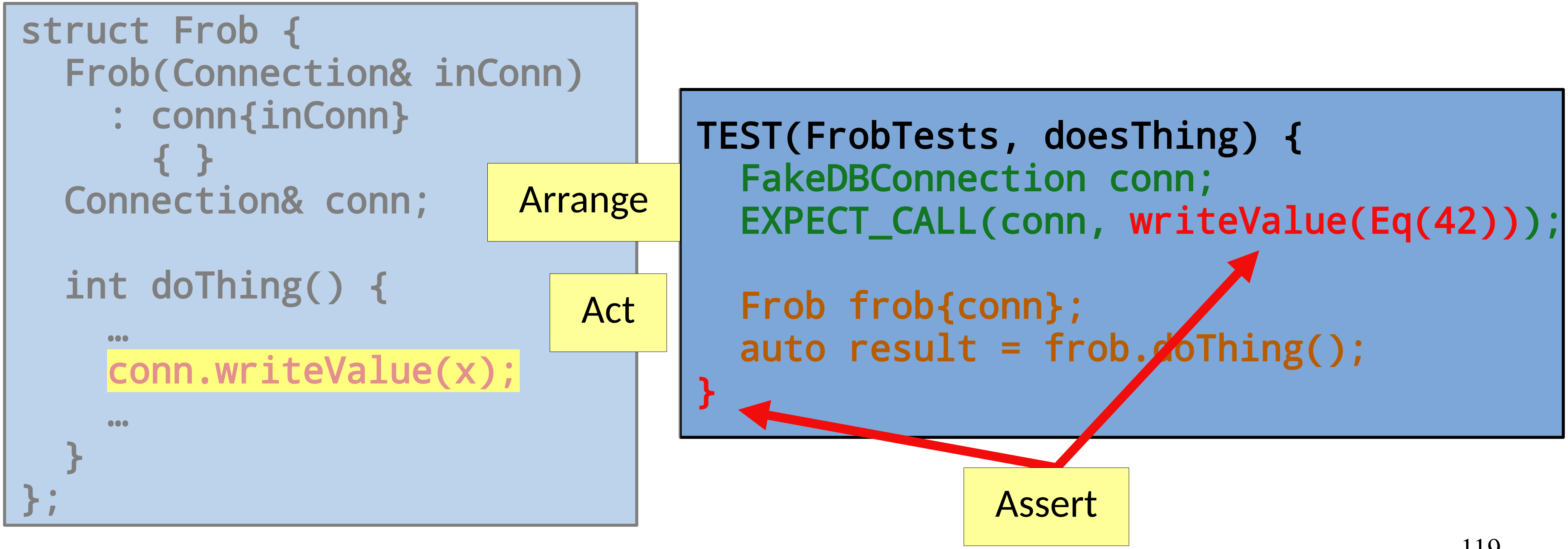

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- Testing small components ***bootstraps confidence*** in the system on confidence in its constituents.
- Tests can verify ***state*** or ***behaviors***.
- Software must be ***designed for testing*** (or designed by testing)