Pivotal

Testing Spring Applications

Testing in General, Spring and JUnit,
Profile-based Testing, Database Testing

Objectives

After completing this lesson, you should be able to

- Write tests using JUnit 5
- Write Integration Tests using Spring
- Configure Tests using Spring Profiles
- Extend Spring Tests to work with Databases

Agenda

- **JUnit 5**
- Integration Testing with Spring
- Testing with Profiles
- Testing with Databases
- Lab
- Appendices
  - JUnit 5, JUnit 4, Stubs & Mocks

Testing with JUnit 5

- Labs use JUnit 5 for testing
  - JUnit 5 support is a major feature of Spring 5
  - Requires Java 8+ at runtime
    - Leverages Lambdas
- Components
  - **JUnit Platform**
    - A foundation for launching testing frameworks on the JVM
  - **JUnit Jupiter**
    - An extension model for writing tests and extensions in JUnit 5
  - **JUnit Vintage**
    - A *TestEngine* for running JUnit 3 & 4 tests on the platform

JUnit 5: New Programming Models

- Replaces JUnit 4 annotations
  - `@Before` → `@BeforeEach`
  - `@BeforeClass` → `@BeforeAll`
  - `@After` → `@AfterEach`
  - `@AfterClass` → `@AfterAll`
  - `@Ignore` → `@Disabled`
- Introduces new annotations
  - `@DisplayName`
  - `@Nested`
  - `@ParameterizedTest`
  - ...

JUnit 5

- *Use right annotations from correct package*
- JUnit 5 ignores all JUnit 4 annotations

Writing Test – JUnit 5 Style

```
import static org.junit.jupiter.api.Assertions.fail;

import org.junit.jupiter.api.AfterAll;
import org.junit.jupiter.api.AfterEach;
import org.junit.jupiter.api.BeforeAll;
import org.junit.jupiter.api.BeforeEach;
import org.junit.jupiter.api.Disabled;
import org.junit.jupiter.api.Test;

class StandardTests {

    @BeforeAll
    static void initAll() {
    }

    @BeforeEach
    void init() {
    }
    …

    @Test
    void succeedingTest() {
    }

    @Test
    void failingTest() {
        fail("a failing test");
    }

    @Test
    @Disabled("for demo purposes")
    void skippedTest() {
        // not executed
    }
}
```

New package

Replaces **@BeforeClass**

Replaces **@Before**

Replaces **@Ignore**

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- **Integration Testing with Spring**
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Unit Testing

Unit Testing
Without Spring

- Unit Testing
  - Tests one unit of functionality
  - Keeps dependencies minimal
  - Isolated from the environment (including Spring)
  - Uses simplified alternatives for dependencies
    - Stubs and/or Mocks
    - *See Appendix for more details*

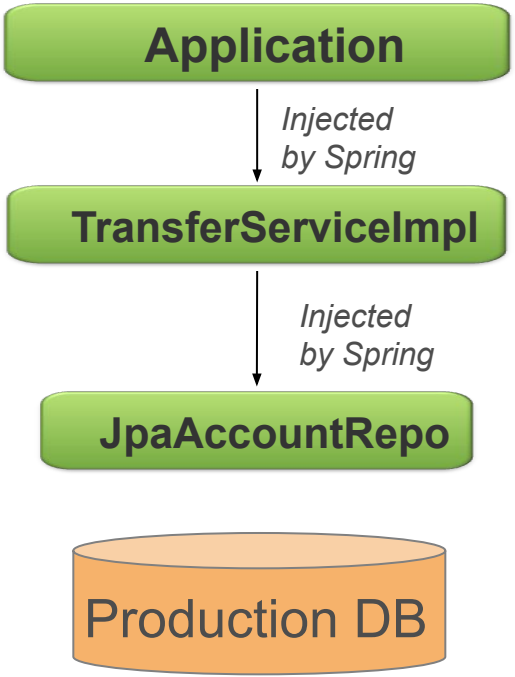
Integration Testing

Integration Testing
With Spring

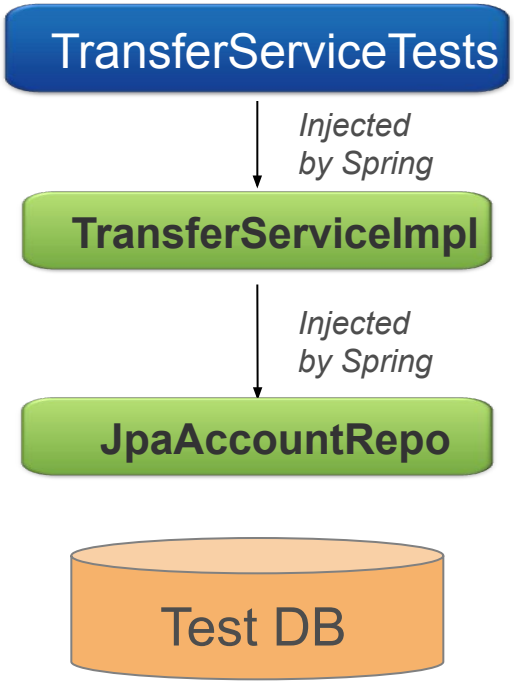
- Integration Testing
  - Tests the interaction of multiple units working together
    - All should work individually (unit tests showed this)
- Tests application classes in context of their surrounding infrastructure
  - Out-of-container testing, no need to run up full App. Server
  - Infrastructure may be “scaled down”
    - Use Apache DBCP connection pool instead of container-provider pool obtained through JNDI
    - Use ActiveMQ to save expensive commercial messaging server licenses

Integration Test Example

- Production mode



- Integration test



Spring Support for Testing

- Spring has rich testing support
  - Based on **`TestContext`** framework
    - Defines an **`ApplicationContext`** for your tests
  - **`@ContextConfiguration`**
    - Defines the Spring configuration to use
- Packaged as a separate module
  - **`spring-test.jar`**

https://docs.spring.io/spring/docs/current/spring-framework-reference/testing.html#integration-testing
https://docs.spring.io/spring/docs/current/spring-framework-reference/testing.html#testcontext-framework

`@ExtendWith` in JUnit 5

- JUnit 5 has extensible architecture via **`@ExtendWith`**
  - Replaces JUnit 4's **`@RunWith`**
  - JUnit 5 supports *multiple* extensions - hence the name

- Spring's extension point is the **`SpringExtension`** class
  - A Spring aware test-runner

See *Appendix* (end of this section) for Spring's JUnit 4 support.

Using Spring's Test Support

```
@ExtendWith(SpringExtension.class)
@ContextConfiguration(classes=SystemTestConfig.class)

public class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void shouldTransferMoneySuccessfully() {
        TransferConfirmation conf = transferService.transfer(...);
        ...
    }
}
```

Run with Spring support

Point to system test configuration file(s)

Inject bean to test

Test the system as normal

No need for *@BeforeEach* method for creating TransferService

`@SpringJUnitConfig`

- **`@SpringJUnitConfig`** is a "*composed*" annotation that combines
  - **`@ExtendWith(SpringExtension.class)`** from JUnit 5
  - **`@ContextConfiguration`** from Spring

Recommended: Use *composed* annotation

```
@SpringJUnitConfig(SystemTestConfig.class)
public class TransferServiceTests {
  ...
}
```

Alternative Autowiring for Tests

```
@SpringJUnitConfig(SystemTestConfig.class)
public class TransferServiceTests {
    // @Autowired
    // private TransferService transferService;

    @Test
    public void shouldTransferMoneySuccessfully
                (@Autowired TransferService transferService) {
        TransferConfirmation conf = transferService.transfer(...);
        ...
    }

}
```

No longer required – dependency injected as test method *argument*

NOTES:

- Test works either way – your choice
- This use of Autowired *unique to tests*

Including Configuration as an Inner Class

```
@SpringJUnitConfig
public class JdbcAccountRepoTest {

  @Test
  public void shouldUpdateDatabaseSuccessfully() {...}

  @Configuration
  @Import(SystemTestConfig.class)
  static  class TestConfiguration {
    @Bean public DataSource dataSource() { … }
  }
}
```

Don't specify any config classes

Looks for configuration *embedded* in test class

Override a bean with a test alternative

Multiple Test Methods

```
@SpringJUnitConfig(classes=SystemTestConfig.class)
public class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void successfulTransfer() { … }

    @Test
    public void failedTransfer() { … }
}
```

ApplicationContext instantiated only *once*

Both tests share *same* cached **`ApplicationContext`** & use *same* **`TransferService`** bean

Most Spring Beans are *stateless/immutable* singletons, never modified during any test. No need for a new context for each test.

Dirties Context

- Forces context to be closed at end of test method
  - Allows testing of **`@PreDestroy`** behavior
- Next test gets a *new* Application Context
  - Cached context destroyed, new context cached instead

```
@Test
@DirtiesContext
public void testTransferLimitExceeded() {
    transferService.setMaxTransfers(0);
    …  // Do a transfer, expect a failure

}
```

Context closed and destroyed at end of test

Test Property Sources

- Custom properties *just* for testing
  - Specify one or more properties
    - Has higher precedence than sources
  - Specify location of one or more properties files to load
    - Defaults to looking for ***[classname].properties***

```
@SpringJUnitConfig(SystemTestConfig.class)
@TestPropertySource(properties = { "username=foo", "password=bar" }
                    locations = "classpath:/transfer-test.properties")
public class TransferServiceTests {
    ...
}
```

Benefits of Testing with Spring

- No need to deploy to an external container to test application functionality
  - Run everything quickly inside your IDE
  - Supports *Continuous Integration* testing

- Allows reuse of your configuration between test and production environments
  - Application configuration logic is typically reused
  - Infrastructure configuration is environment-specific
    - DataSources
    - JMS Queues

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- **Testing with Profiles**
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Activating Profiles For a Test

- @ActiveProfiles inside the test class
  - Define one or more profiles
  - Beans associated with that profile are instantiated
  - Also beans not associated with *any* profile

- Example: Two profiles activated – *jdbc* **and** *dev*

```
@SpringJUnitConfig(DevConfig.class)
@ActiveProfiles( { "jdbc", "dev" } )

public  class TransferServiceTests  { … }
```

Profiles Activation with JavaConfig

- @Profile on @*Configuration* class or any of its @*Bean* methods

```
@SpringJUnitConfig(DevConfig.class)
@ActiveProfiles("jdbc")
public  class TransferServiceTests
{...}
```

```
@Configuration
@Profile("jdbc")
public class DevConfig {

    @Bean
     public ... {...}
}
```

```
@Configuration
public class DevConfig {

    @Profile("jdbc")
    @Bean
    public ... {...}
}
```

Only beans matching an active profile or with *no* profile are loaded

Profiles Activation with Annotations

- @Profile on a *Component* class

```
@SpringJUnitConfig(DevConfig.class)
@ActiveProfiles("jdbc")
public  class TransferServiceTests {
    …
}
```

```
@Repository
@Profile("jdbc")
public class
JdbcAccountRepository {
    …
}
```

Only beans with current profile / no profile are component-scanned

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Testing with Databases

- Integration testing against SQL database is common
- In-memory databases useful for this kind of testing
  - No prior install needed
- Common requirement: populate DB before test runs
  - Use the **`@Sql`** annotation:

```
@Test
@Sql ( "/testfiles/test-data.sql" )
public void successfulTransfer() {
    ...
}
```

Run this SQL script *before* this test method executes.

@Sql Examples

Run these scripts before *each* **@Test** method *unless* a method is annotated with its own **@Sql**

```
@SpringJUnitConfig(...)
@Sql( { "/testfiles/schema.sql", "/testfiles/load-data.sql" } )
public class MainTests {

    // schema.sql and load-data.sql only run before this test
    @Test
    public void success() {  …  }

    @Test // Overrides to use own scripts
    @Sql ( scripts="/testfiles/setupBadTransfer.sql" )
    @Sql ( scripts="/testfiles/cleanup.sql",
            executionPhase=Sql.ExecutionPhase.AFTER_TEST_METHOD  )
    public void transferError() { …  }
}
```

Run *before* **@Test** method

… run *after* **@Test** method

@Sql Options

- When/how does the SQL run?
  - *executionPhase:* before (default) or after test method
  - *config:* Options to control SQL scripts
    - What to do if script fails? **`FAIL_ON_ERROR`**, **`CONTINUE_ON_ERROR`**, **`IGNORE_FAILED_DROPS`**, **`DEFAULT*`**
    - SQL syntax control: comments, statement separator

```
@Sql(  scripts = "/test-user-data.sql",
       config = @SqlConfig(errorMode = ErrorMode.FAIL_ON_ERROR,
                           commentPrefix = "//", separator = "@@")  )
```

`*DEFAULT` = whatever @Sql defines at class level, otherwise **`FAIL_ON_ERROR`**

Summary

- Testing is an *essential* part of any development
- Unit testing tests a class in isolation
  - External dependencies should be minimized
  - Consider creating stubs or mocks to unit test
  - *You don't need Spring to unit test*
- Integration testing tests the interaction of multiple units working together
  - Spring provides good integration testing support
  - Profiles for different test & deployment configurations
  - Built-in support for testing with Databases

Lab: Integration Testing

Lab project:
24-test

Anticipated Lab time:
30 Minutes

Optional Topics: Appendices on JUnit 5, JUnit 4, Unit testing using Stubs and Mocks

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- JUnit 5
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- **Appendices**
  - **More on JUnit 5**
  - JUnit 4 Support
  - Unit Testing (Stubs & Mocks)

JUnit 4 vs JUnit 5

- JUnit 5 enhances JUnit framework
  - New features are added over JUnit 4
- JUnit 5 supports multiple extensions
  - Solves “single Runner limitation” of JUnit 4

JUnit 5: New Assertions – 1

- Introduces new assertions
  - `assertThrows`
    `(<exception.class>, <lambda-expression>)`
  - `assertTimeout`
    `(<duration>, <lambda-expression>)`
  - `assertAll`
    `(<description>, <multiple-assertions>)`
- Improves assumptions
  - Uses lambda expression
    - The code to be tested

JUnit 5: New Assertions – 2

`assertThrows(..)` & `assertTimeout(..)`

```
@Test
void exceptionTesting() {
    Throwable exception = assertThrows(IllegalArgumentException.class,
            () -> { /* Perform task that throws illegal argument exception */ }
    );
    assertEquals("some error message", exception.getMessage());
}

@Test
void timeoutNotExceeded() {
    // The following assertion succeeds.
    assertTimeout(ofMinutes(2), () -> {
        // Perform task that takes less than 2 minutes.
    });
}
```

No need to specify expected attribute

No need to specify timeout attribute

JUnit 5: New Assertions – 3

```
@Test
void standardAssertions() {
    assertEquals(2, 2);
    assertEquals(4, 4, "Optional assertion message is now last parameter.");
    assertTrue(2 == 2, () -> "Assertion messages can be lazily evaluated -- "
            + "to avoid constructing complex messages unnecessarily.");
}

@Test
void groupedAssertions() {
    // In a grouped assertion all assertions are executed, and any
    // failures will be reported together.
    assertAll("person",
        () -> assertEquals("John", person.getFirstName()),
        () -> assertEquals("Doe", person.getLastName())
    );
}
```

JUnit 5: Assumptions – 1

- Run test only if a condition is true
  - Typically in a particular environment/platform/operating system

```
@Test  void testOnlyOnCiServer() {
    assumeTrue("CI".equals(System.getenv("ENV")));
    // Remainder of this test
}

@Test  void testOnlyOnDeveloperWorkstation() {
    assumeTrue("DEV".equals(System.getenv("ENV")),
        () -> "Aborting test: not on developer workstation");
    // Remainder of test
}
```

Only run test in Continuous Integration environment

Only run test in Dev, return an error message otherwise

JUnit 5: Assumptions – 2

- Only run test code if a condition is true

```
@Test  void testInAllEnvironments() {
    assumingThat("CI".equals(System.getenv("ENV")),
        () -> {
            // perform these assertions only on the CI server
            assertEquals(2, 2);
        });

    // perform these assertions in all environments
    assertEquals("a string", "a string");
}
```

Run this part *only* in a CI environment

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  - More on JUnit 5
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  - Unit Testing (Stubs & Mocks)

Spring's JUnit 4 Support

- Packaged as a separate module
  - **`spring-test.jar`**
- Consists of several JUnit test support classes
- Central support class is *SpringJUnit4ClassRunner*
  - Caches a *shared* ApplicationContext across test methods

See: Spring Framework Reference – Integration Testing
https://docs.spring.io/spring/docs/4.3.x/spring-framework-reference/htmlsingle/#integration-testing

Using Spring with JUnit 4

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes=SystemTestConfig.class)

public class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void shouldTransferMoneySuccessfully() {
        TransferConfirmation conf = transferService.transfer(...);
        ...
    }

}
```

Run with Spring support

Point to system test configuration file

Inject bean to test

Test the system as normal

No need for @Before method

Including Configuration as an Inner Class

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration
public class JdbcAccountRepoTest {

  private JdbcAccountRepo repo = ...;

  @Test
  public void shouldUpdateDatabaseSuccessfully() {...}

  @Configuration
  @Import(SystemTestConfig.class)
  static  class TestConfiguration {
     @Bean public DataSource dataSource() { … }
  }
}
```

Don't specify any config classes

Looks for configuration *embedded* in test class

Override a bean with an alternative for testing

Multiple Test Methods

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(classes=SystemTestConfig.class)
public class TransferServiceTests {
    @Autowired
    private TransferService transferService;

    @Test
    public void successfulTransfer() {  … }

    @Test
    public void failedTransfer()  {  … }
}
```

ApplicationContext instantiated only *once*

Both tests share *same* cached ApplicationContext - use *same* transferService bean

Add `@DirtiesContext` to test method - forces *new* context for next test

Alternative Runner Class

- Can use **`SpringRunner`** as an alternative to the **`SpringJUnit4ClassRunner`**
  - Simply a sub-class with a nicer name
  - Available from Spring 4.3

```
@RunWith(SpringRunner.class)
@ContextConfiguration(SystemTestConfig.class)
public class TransferServiceTests {
    ...
}
```

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Unit Testing vs. Integration Testing

- Unit Testing
  - Tests one unit of functionality
  - Keeps dependencies minimal
  - Isolated from the environment (including Spring)
- Integration Testing
  - Tests the interaction of multiple units working together
  - Integrates infrastructure
- Discussed Integration Testing earlier
  - Let's discuss Unit Testing here
  - Remember: *Unit Testing does not use Spring*

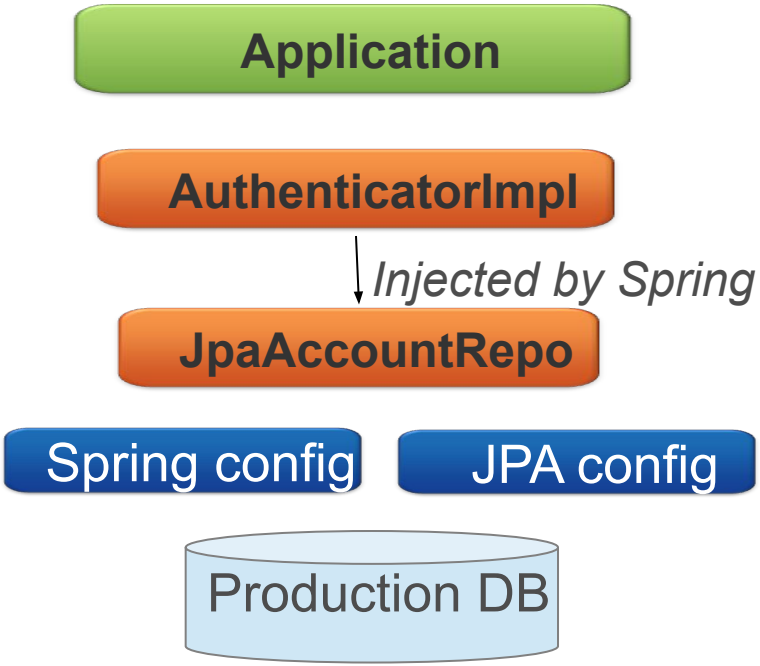
Unit Testing

- Remove links with dependencies
  - The test shouldn't fail because of external dependencies
  - Spring is also considered as a dependency

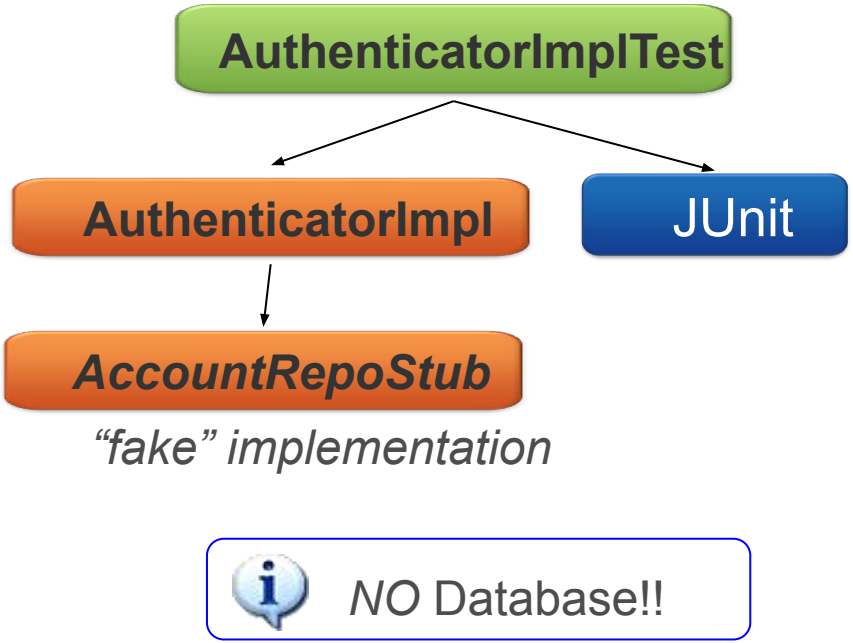
- 2 ways to create a “testing-purpose” implementation of your dependencies:
  - Stubs Create a simple test implementation
  - Mocks Dependency class generated at startup-time using a “Mocking framework”

Unit Testing example

- Production mode



- Unit test with Stubs



Example Unit to be Tested

Note: Validation failure paths ignored for simplicity

```
public class AuthenticatorImpl implements Authenticator {
  private AccountRepository accountRepository;

  public AuthenticatorImpl(AccountRepository accountRepository) {
    this.accountRepository = accountRepository;
  }

  public boolean authenticate(String username, String password) {
      Account account = accountRepository.getAccount(username);

      return account.getPassword().equals(password);
  }
}
```

External dependency

Unit *business* logic
– 2 paths: success or fail

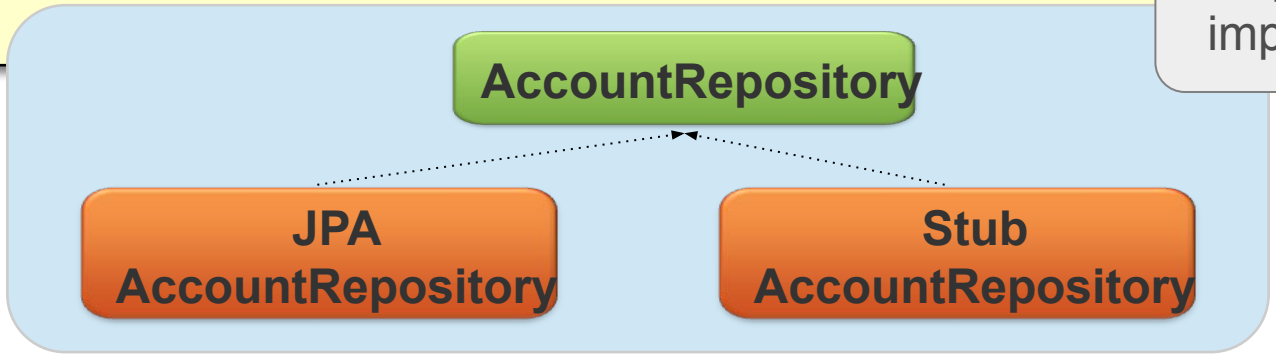
Implementing a Stub

- Only need *one* Account for testing
- Test *must only* use valid data (can only use "lisa")

- Class created manually
  - Implements Business interface

```
class StubAccountRepository implements AccountRepository {
  public Account getAccount(String user) {
    return "lisa".equals(user) ? new Account("lisa", "secret") : null;
  }
}
```

Simplest *minimal* implementation



Unit Test using a Stub

Lisa is the *only* test user

```
public class AuthenticatorImplTests {
  private AuthenticatorImpl authenticator;

  @BeforeEach public void setUp() {
     authenticator = new AuthenticatorImpl( new StubAccountRepository() );
  }

  @Test public void successfulAuthentication() {
     assertTrue(authenticator.authenticate("lisa", "secret"));
  }

  @Test public void invalidPassword() {
     assertFalse(authenticator.authenticate("lisa", "invalid"));
  }
```

Spring **not** in charge of injecting dependencies

OK scenario

KO scenario

Unit Testing with Stubs

- Advantages
  - Easy to implement and understand
  - Reusable
- Disadvantages
  - Change to an interface requires change to stub
  - Your stub must implement all methods
    - even those not used by a specific scenario
  - If a stub is reused refactoring can break other tests

Steps to Testing with a Mock

1. Use a mocking library to generate a mock object
   - Implements the dependent interface on-the-fly
2. Record the mock with expectations of how it will be used for a scenario
   - What methods will be called
   - What values to return
3. Exercise the scenario
4. Verify mock expectations were met

Example: Using a Mock - I

EasyMock

- Setup
  - A Mock class is created at startup time

```
import static org.easymock.classextensions.EasyMock.*;

public class AuthenticatorImplTests  {
    private AccountRepository accountRepository
                    = createMock(AccountRepository.class);

    private AuthenticatorImpl authenticator
                = new AuthenticatorImpl(accountRepository);

     // continued on next slide ...
```

Static import

Creates an implementation of interface *AccountRepository*

Example: Using a Mock - II

EasyMock

```
// … continued from previous slide
 @Test public void validUserWithCorrectPassword() {
   expect(accountRepository.getAccount("lisa")).
       andReturn(new Account("lisa", "secret"));

   replay(accountRepository);

   assertTrue( authenticator.
             authenticate("lisa", "secret") );

    verify(accountRepository);
   }
}
```

Recording

What behavior to expect?

Recording → Playback

Playback mode - run test

Mock now fully available

Verification

No planned method call has been omitted

Same Example using Mockito

Mockito

```
import static org.mockito.Mockito.*;

public class AuthenticatorImplTests  {
    private AccountRepository accountRepository
            = mock( AccountRepository.class );              // Create a mock object
    private AuthenticatorImpl authenticator
        = new AuthenticatorImpl(accountRepository);      // Inject the mock object

    @Test public void validUserWithCorrectPassword() {
        when(accountRepository.getAccount("lisa")).                  // Train the mock
            thenReturn(new Account("lisa", "secret"));

        assertTrue( authenticator.authenticate("lisa", "secret") );          // Run test
        verify(accountRepository);                                  // Verify getAccount() was
    }                                                              // invoked on the mock
```

No *replay* step with Mockito

Mock Considerations

- Several mocking libraries available
  - Mockito, JMock, EasyMock
- Advantages
  - No additional class to maintain
  - You only need to setup what is necessary for the scenario you are testing
  - Test behavior as well as state
    - Were all mocked methods used? If not, why not?
- Disadvantages
  - A little harder to understand at first

Mocks or Stubs?

- You will probably use both
- General recommendations
  - Favor mocks for non-trivial interfaces
  - Use stubs when you have simple interfaces with repeated functionality
  - Always consider the specific situation
- Read “Mocks Aren’t Stubs” by Martin Fowler
  - http://www.martinfowler.com/articles/mocksArentStubs.html