Software Testing Part 2
Junit Testing

AY24/25

Week 11

Outline

1. Unit Testing and JUnit
2. Assertion Methods
3. JUnit Test Cycle and Annotation

1. Unit Testing and JUnit

1.1 Review - Unit Testing

- Testing of an individual software unit
  - usually an onject class
- Focus on the functions of the unit
  - functionality, correctness, accuracy
- Usually carried out by the developers of the unit

1.2 Review - Automated Framwork

- A setup part, where you initialize the system with the test case (e.g., initialize the object under test)
- A call part, where you call the object or method to be tested.
- An assertion part where you compare the result of the call with the expected result. If the assertion evaluates to true, the test has been successful if false, then it has failed.

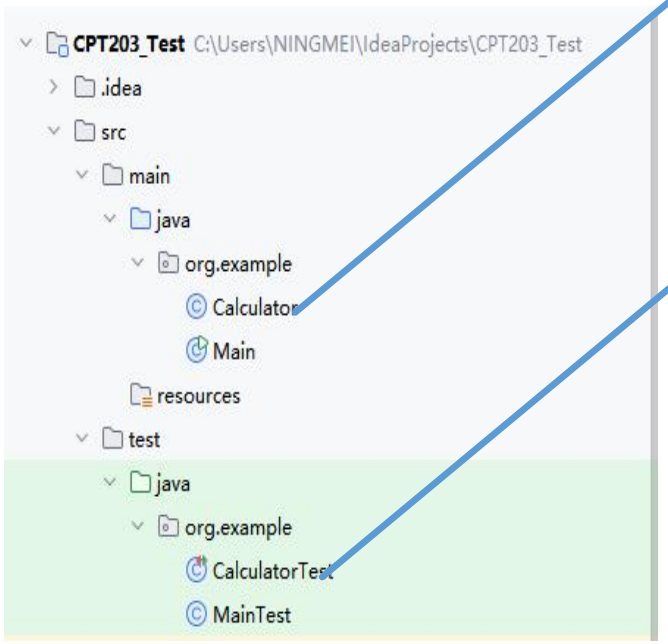
1.3 JUnit

- JUnit is a framework for writing unit tests
  - Designed for the purpose of writing and running tests on Java code
  - A unit test is a test of a single class, where a test case is a single test of a single method
  - Ensures individual test cases are executed in isolation, promoting more accurate results
- Why Junit
  - Enhanced Code Quality
  - Java-based
  - Integrates seamlessly with IDEs like Eclipse and build tools like Maven and Gradle
  - Free

1.3.1 A Junit Test Example

Formally...

Class that is being tested and its test class (where the test is implemented) are seperated




```java
public class Calculator {  no usages
    public static int add(int x, int y) {
        return x + y;
    }
}
```

Class being tested

```java
package org.example;

import org.junit.jupiter.api.Test;

import static org.junit.jupiter.api.Assertions.*;

class CalculatorTest {
    @Test // Marks the method as a test method.
    public void CalculatorTest() {
        // Setup part - Creating an instance of the class under test,
        // plus the input and expected output
        Calculator calculator = new Calculator();
        int input1 =5;
        int input2 = 3;
        int Expected = 8;

        // Call Part
        // Calling the method to be tested with some inputs.
        int ActualResult = calculator.add(input1, input2);

        // Assertion Part
        // Asserting that the method returned the expected value.
        assertEquals(Expected, ActualResult, message: "Message we want to show");
    }
}
```

A seperate test class

Anotation marking a test will be implemented

Instance creation

Define the inputs designed by us

Define the EXPECTED output

Actual output we get

method (expected (1st var), actual (2nd var), msg (optional))

1.3.1 A Junit Test Example

Sometime...

```java
import org.junit.jupiter.api.Test;
import static org.junit.jupiter.api.Assertions.*;

public class Calculator{

        public static int add(int x,int y) {
            return x + y;
        }

        // The Test class itself
    // Often named after the class it's testing
    // (e.g., CalculatorTest for Calculator class)

    @Test  // Marks the method as a test method.
    public void CalculatorTest() {
        // Setup part - Creating an instance of the class under test,
        // plus the input and expected output
        Calculator calculator = new Calculator();
        int input1 =5;
        int input2 = 3;
        int Expected = 8;

        // Call Part
        // Calling the method to be tested with some inputs.
        int ActualResult = calculator.add(input1, input2);

        // Assertion Part
        // Asserting that the method returned the expected value.
        assertEquals(Expected, ActualResult, message: "Message we want to show");
    }
}
```

Class being tested and its test class can be in the same class

```java
    @Test  // Marks the method as a test method.
    public void CalculatorTest() {
        // Setup part - Creating an instance of the class under test,
        // plus the input and expected output
        Calculator calculator = new Calculator();



        // Call Part
        // Calling the method to be tested with some inputs.
        int ActualResult = calculator.add( x: 5,  y: 3);

        // Assertion Part
        // Asserting that the method returned the expected value.
        assertEquals( expected: 8, ActualResult, message: "Message we want to show");
    }
}
```

Input directly defined in the call part

Expected output directly defined in the assertion part

1.3.2 Junit Test Verdicts

A *verdict* is the result of executing a single test case.

Pass

- The test case execution was completed
- The function being tested performed as expected

Fail

- The test case execution was completed
- The function being tested did *not* perform as expected

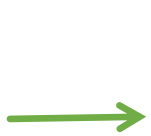
Error

- The test case execution was not completed, due to
  - an unexpected event, exceptions, or
  - improper set up of the test case, etc.

1.3.2 Junit Test Verdicts (cont.)

- If the tests run correctly, a test method does nothing but shows the results in Green

```
int input1 =5;
int input2 = 3;
int Expected = 8;
```



1.3.2 Junit Test Verdicts (cont.)

- If a test fails

```
int input1 =5;
int input2 = 3;
int Expected = 9;
```

1.3.2 Junit Test Verdicts (cont.)

- If an error happens

```
Calculator calculator = new Calculatorsss();
int input1 =5;
int input2 = 3;
int Expected = 8;
```

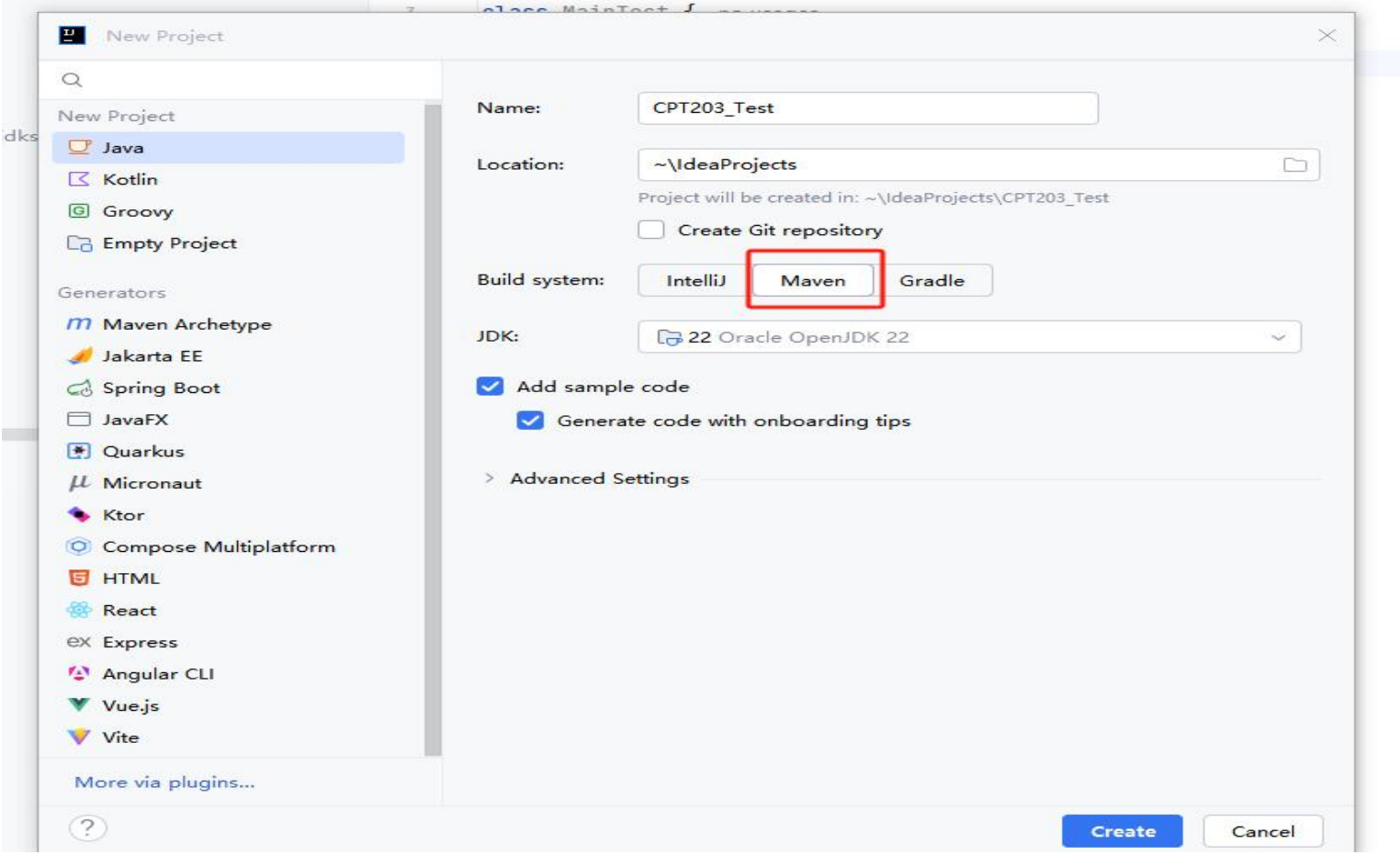
```
C:\Users\NINGMEI\IdeaProjects\123123\src\Calculator.java:19:37
java: 找不到符号
  符号:   类 Calculatorsss
  位置: 类 Calculator
```

1.4 JUnit Best Practices

- Tests need *failure atomically* (ability to know exactly what failed).
  - Each test should have a clear, long, descriptive name.
  - Assertions should always have clear messages to know what failed.
  - Write many small tests, not one big test.
    - Each test should have roughly just 1 assertion at its end.
- Test for expected errors / exceptions.
- Choose a descriptive assert method, not always `assertTrue`.
- Choose representative test cases from equivalent input classes.
- Avoid complex logic in test methods if possible.

1.5 Configure JUnit in IntelliJ

- Create a New Poject (e.g., Maven)

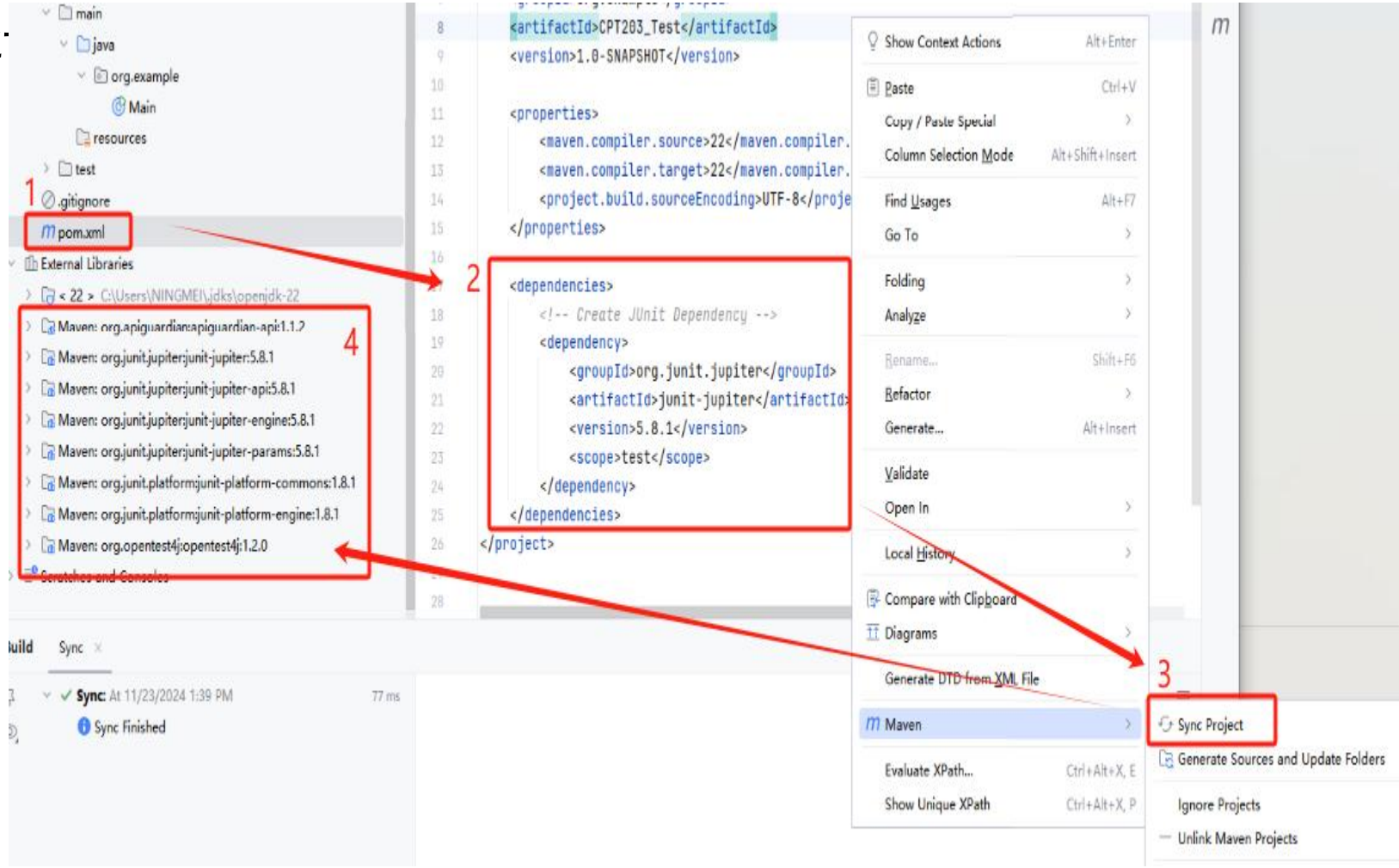


1.5 Run JUnit in IntelliJ (cont.)

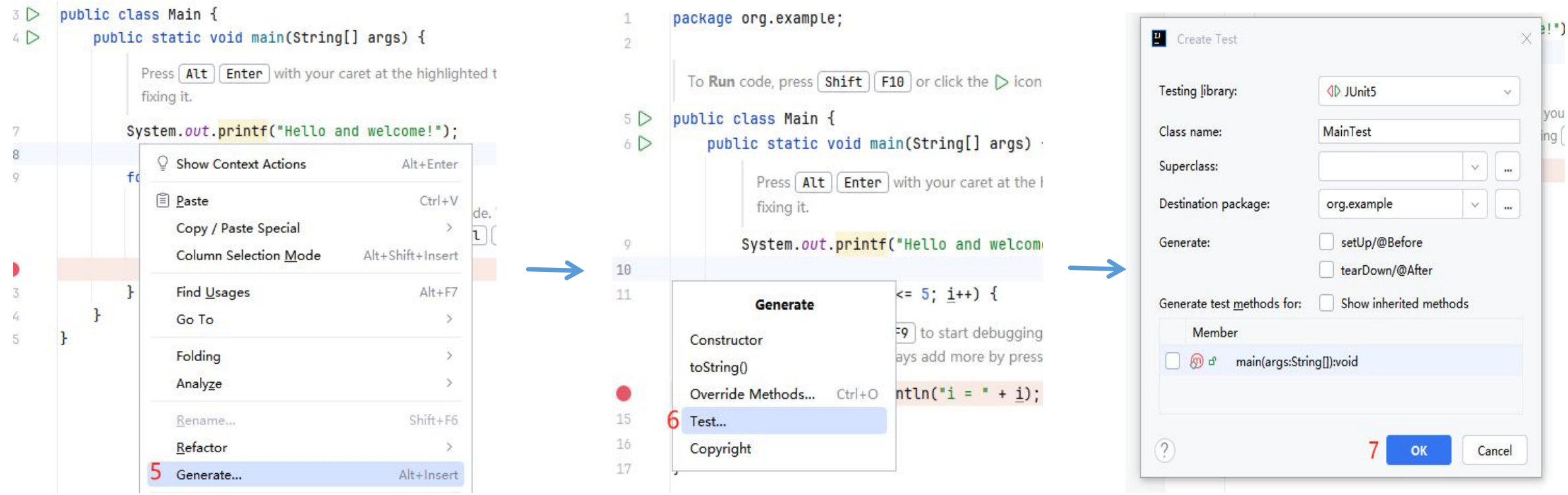
1. Click “pom.xml” in the project root directory
2. Add dependcy

```
<dependencies>
  <dependency>
    <groupId>org.junit.jupiter</groupId>
    <artifactId>junit-jupiter</artifactId>
    <version>5.8.1</version>
    <scope>test</scope>
  </dependency>
</dependencies>
```

3. Right click -> Maven -> Sync Project
4. You see the dependencies

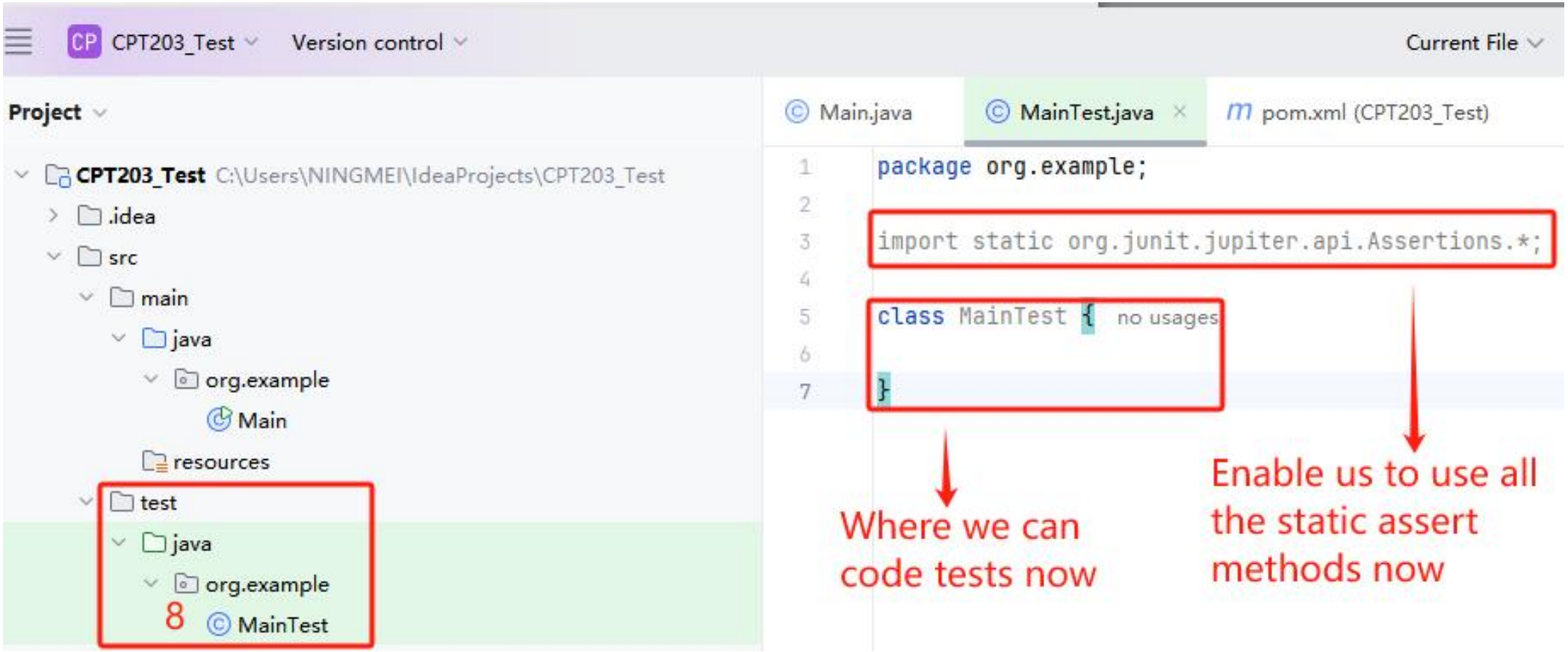


1.5 Run JUnit in IntelliJ (cont.)



5. To verify we can use Junit now, reight click in the Main class, and select **Generate**
6. Select **Test**
7. Select **OK**

1.5 Run JUnit in IntelliJ (cont.)

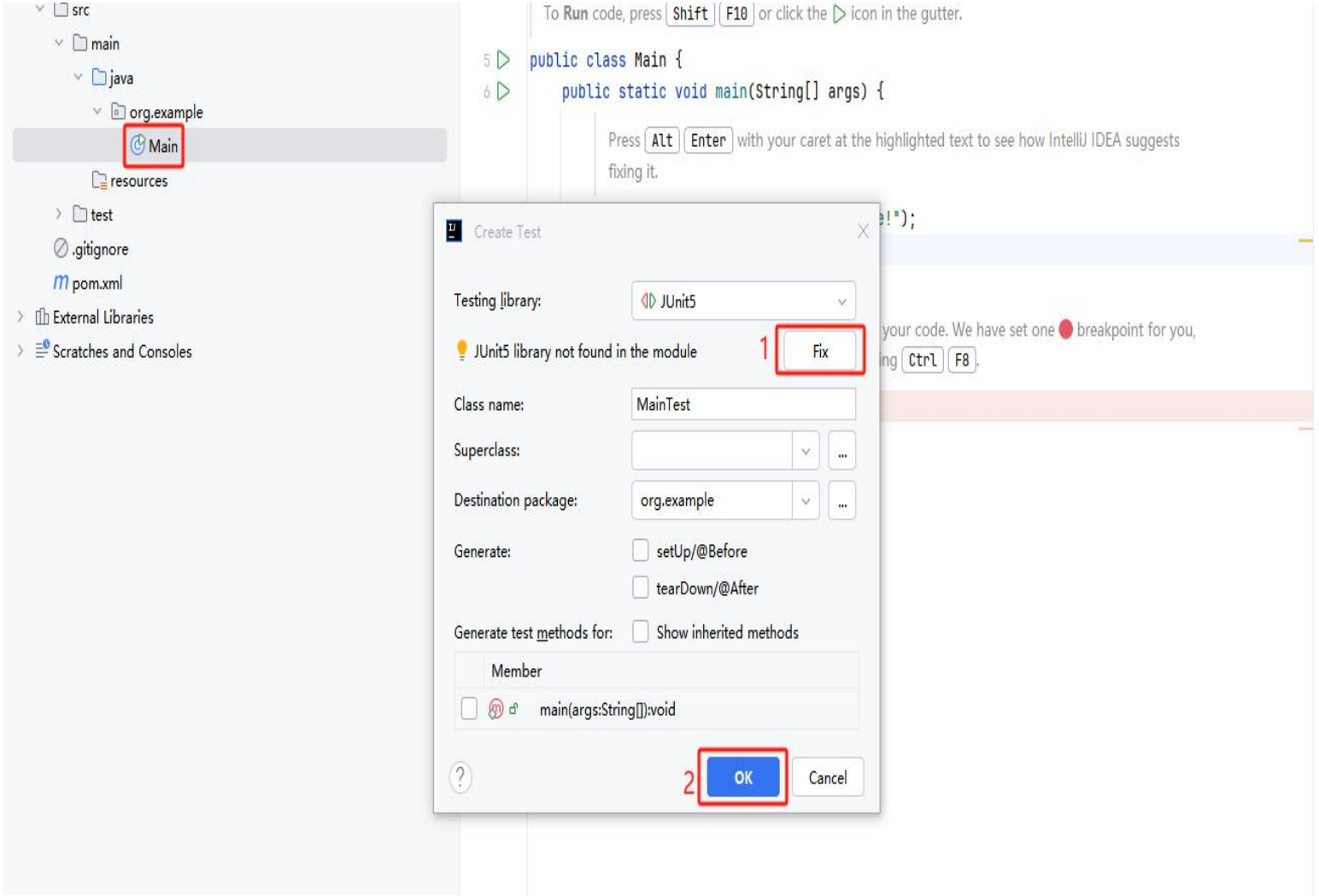


8. A test class named MainTest is generated under test file (becasue we were generating test in the Main class)

1.5 Run JUnit in IntelliJ (cont.)

Or a much quicker way

- Create a Maven Project
- Right click in Main class -> Generate -> Test
- At the window poped up, click Fix and then OK
- Done :)



2. Assertion Methods

2.1 AssertTrue/AssertFlase

- Assert a Boolean condition is true or false

  assertTrue(*condition*)
  assertFalse(*condition*)

- Optionally, include a failure message

  assertTrue(*condition, message*)
  assertFalse(*condition, message*)

```
public class NumberChecker {  2 usages
    public boolean isPositive(int number) {  1 usage
        return number > 0;
    }
}
```

```
package org.example;

import org.junit.jupiter.api.Test;

import static org.junit.jupiter.api.Assertions.*;

class NumberCheckerTest {

    @Test
    public void testIsPositive() {
        NumberChecker checker = new NumberChecker();
        boolean isPositive = checker.isPositive( number: 5);
        assertTrue(isPositive);
        assertFalse(isPositive,  message: "This failure message is optional");
    }
}
```

2.2 AssertSame/AssertNotSame

- Assert two object references are identical

  assertSame(*expected, actual*)

  - True if: expected == actual

  assertNotSame(*expected, actual*)

  - True if: expected != actual

- With a failure message

  assertSame(*expected, actual, (optional) message*)
  assertNotSame(*expected, actual, (optional) message*)

- Note: Compare if two objects are exactly the same one, NOT the value

2.2 AssertSame/AssertNotSame (cont.)

```java
package org.example;

import org.junit.jupiter.api.Assertions;
import org.junit.jupiter.api.Test;

public class assertSame {
    @Test
    public void assertSameShowcase() {
        String s1 = new String( original: "Hello");
        String s2 = new String( original: "Hello");
        Assertions.assertSame(s1, s2);
    }
}
```

```
Tests failed: 1 of 1 test – 15 ms

C:\Users\NINGMEI\.jdks\openjdk-22\bin\java.exe ...

org.opentest4j.AssertionFailedError: expected: java.lang.String@491666ad<Hello> but was: java.lang.String@176d53b2<Hello>
Expected :Hello
Actual   :Hello
<Click to see difference>

<5 internal lines>
    at org.example.assertSame.assertSameShowcase(assertSame.java:11) <29 internal lines>
    at java.base/java.util.ArrayList.forEach(ArrayList.java:1597) <9 internal lines>
    at java.base/java.util.ArrayList.forEach(ArrayList.java:1597) <27 internal lines>


Process finished with exit code -1
```

2 object references (in hash code) are different, indicating they are stored in different memory location in Java

2.3 AssertEquals/AssertNotEquals

- Assert two objects are equal to each regarding value/content
- It doesn't matter if expected and actual are the same object or different object; as long as their content is equal, the test will pass.

  assertEquals(expected, actual, *(optional) message*)
- Not only for int type, but also for other values (e.g., string, float, ...)

```java
package org.example;

public class StringCase {  2 usages
    public String combining(String one, String two) {  1 usage
        return one + two;
    }
}
```

```java
package org.example;

import org.junit.jupiter.api.Test;

import static org.junit.jupiter.api.Assertions.assertEquals;

public class assertEquals {

@Test
public void testCombining() {
    StringCase SC = new StringCase();

    String expected = "HelloWorld";
    String actual = SC.combining( one: "Hello",  two: "World");

    assertEquals(expected, actual);
  }
}
```

2.4 AssertArrayEquals

- Assert two arrays are equal:

  assertArrayEquals(expected, actual, *(optinal) message*)

  - arrays must have same length
  - Recursively check for each valid index i,

```
public class Array {  1 usage

    public static int[] generateArray() {  1 usage
        return new int[] {1,2,3};
    }
}
```

```
package org.example;

import org.junit.jupiter.api.Test;

import static org.junit.jupiter.api.Assertions.*;

class ArrayTest {
@Test
    public void testArray() {
    int[] expectedArray = new int[] {3, 2, 1};
    int[] actualArray = Array.generateArray();
    assertArrayEquals(expectedArray, actualArray);}
}
```

2.5 AssertThrows

- Used to test that a specific type of exception is thrown during the execution of a block of code
- assertThrows(expectedExceptionClass, executable)
  - expectedExceptionClass is the type of exception you expect
  - executable is a *lambda expression* or a method reference that executes the code under test
- Particularly useful for negative test cases where you want to ensure that your code fails under certain conditions

2.5 AssertThrows (cont.)

```java
package org.example;


public class AssertThrowsCalCase { no usages
    public double divide(int numerator, int denominator) { no usages
        if (denominator == 0) {
            throw new ArithmeticException("Division by zero is not allowed");
        }
        return (double) numerator / denominator;
    }

}
```

```java
class AssertThrowsCalCaseTest {
    @Test
    public void testDivisionByZeroThrowsException() {
        // Create an instance of the AssertThrowsCalCase class.
        // This class contains the 'divide' method we want to test.
        AssertThrowsCalCase calculator = new AssertThrowsCalCase();

        // Use assertThrows to test that an ArithmeticException is thrown.
        // assertThrows takes two main parameters:
        // 1. The class of the exception we expect to be thrown.
        // 2. A lambda expression that executes the code we're testing.
        assertThrows(
                //The expected exception type.
                //Here, we expect an ArithmeticException.
                ArithmeticException.class,
                // This is the lambda expression.
                // It is used to execute the 'divide' method of the calculator object.
                // The 'divide' method is called with arguments 10 and 0.
                () -> calculator.divide( numerator: 10,  denominator: 0));
    }
}
```

1

2

3

1. Parameter List 2. operator 3. Body: method being tested with the case (10 and 0)

2.5 AssertThrows (cont.)

Why use Lambda (Correct Approach):

- *assertThrows(ArithmeticException.class, () -> calculator.divide(10, 0));*

- This approach delays the execution of divide until assertThrows can catch the exception.

Otherwise (Problematic):

- *assertThrows(ArithmeticException.class, calculator.divide(10, 0));*
- In this case, divide is executed immediately, and if it throws an exception, it happens before assertThrows can catch it, leading to a test error.

3. JUnit Test Cycle and Annotation

3.1 Life Cycle

- Normally, a test class contains multiple test methods. JUnit manages the execution of each test method in form of a lifecycle.

- The complete lifecycle of a test case can be seen in three phases with the help of annotations.

3.2 Life Cycle Phases

1. **Setup**: This phase puts the test infrastructure in place. JUnit provides class level setup *(@BeforeAll)* and method level setup *(@BeforeEach)*. Generally, heavy objects like databse comnections are created in class level setup while lightweight objects like test objects are reset in the method level setup.

2. **Test Execution**: In this phase, the test execution and assertion happen. The execution result will signify a success or failure.

3. **Cleanup**: This phase is used to cleanup the test infrastructure setup in the first phase. Just like setup, teardown also happen at class level *(@AfterAll)* and method level *(@AfterEach).*

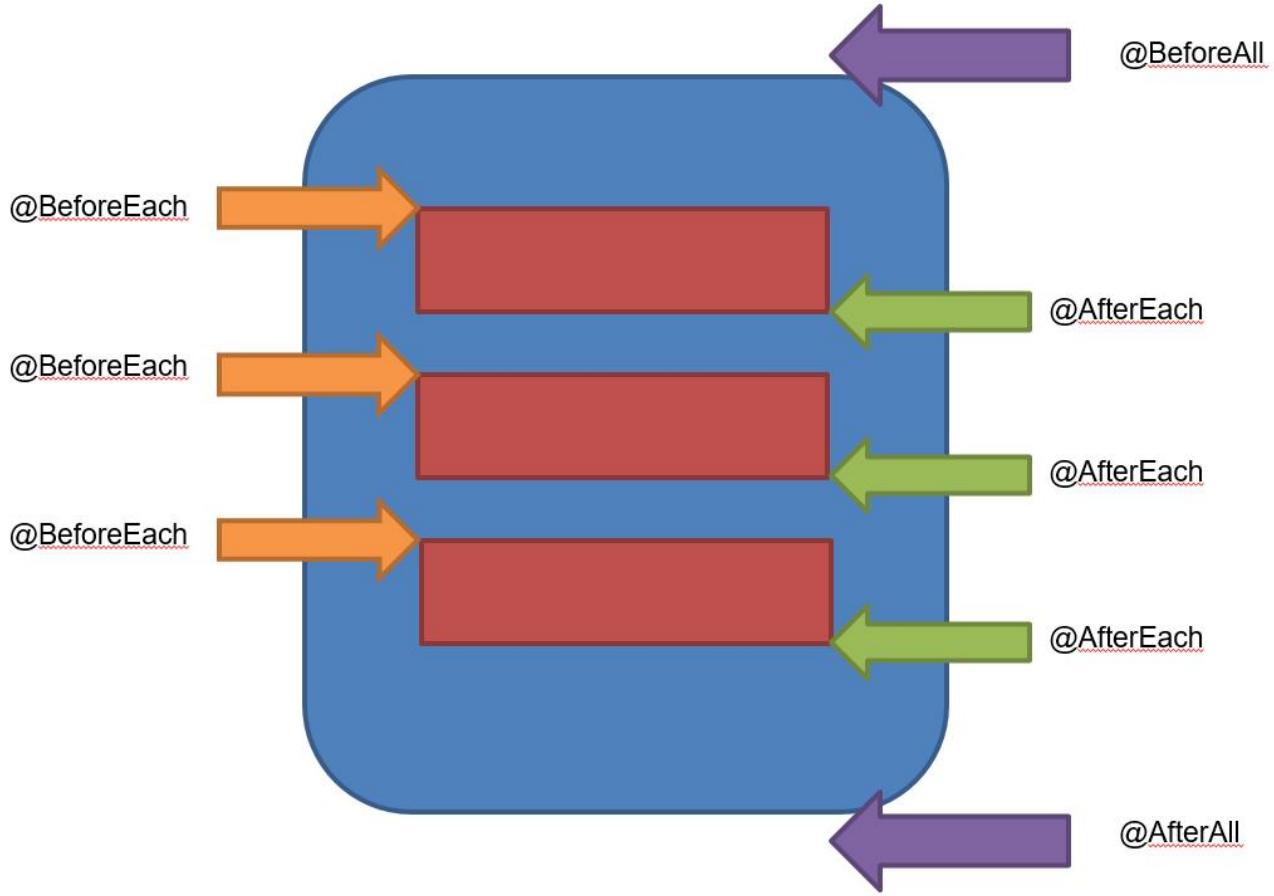
3.2 Life Cycle Phases (cont.)

In the test life cycle, we will primarily need to have some annotated methods to setup and cleanup the test environment or test data on which the tests run.

In JUnit, by default, for each test method – a new instance of test is created.

1. @BeforeAll and @AfterAll annotations – clear by their name – should be called only once in the entire tests execution cycle. So they must be declared **static**.
2. @BeforeEach and @AfterEach are invoked for each instance of test so they should not be static.

3.2 Life Cycle Phases (cont.)



3.2 Life Cycle Phases (cont.)

```java
import static org.junit.jupiter.api.Assertions.assertEquals;


    public class JunitLifeCycle {

        // Class level setup - runs once before all tests
        @BeforeAll e.g., link to the whole database
        static void setupClass() {
            // Code to set up database connections or other heavy resources
        }

        // Method level setup - runs before each test
        @BeforeEach e.g., select a specific dataset for the test below
        void setupTest() {
            // Code to initialize or reset test objects
        }

        // Actual test case
        @Test Test implementation
        void testExample() {
            // Test execution and assertions
            assertEquals( expected: 2,  actual: 1 + 1);
        }

        // Method level cleanup - runs after each test
        @AfterEach e.g., clean up the spefici dataset for next round of test
        void tearDownTest() {
            // Code to reset or clean up after each test
        }

        // Class level cleanup - runs once after all tests
        @AfterAll e.g., Disconnect the whole databased and end test
        static void tearDownClass() {
            // Code to clean up database connections or other heavy resources
        }
}
```

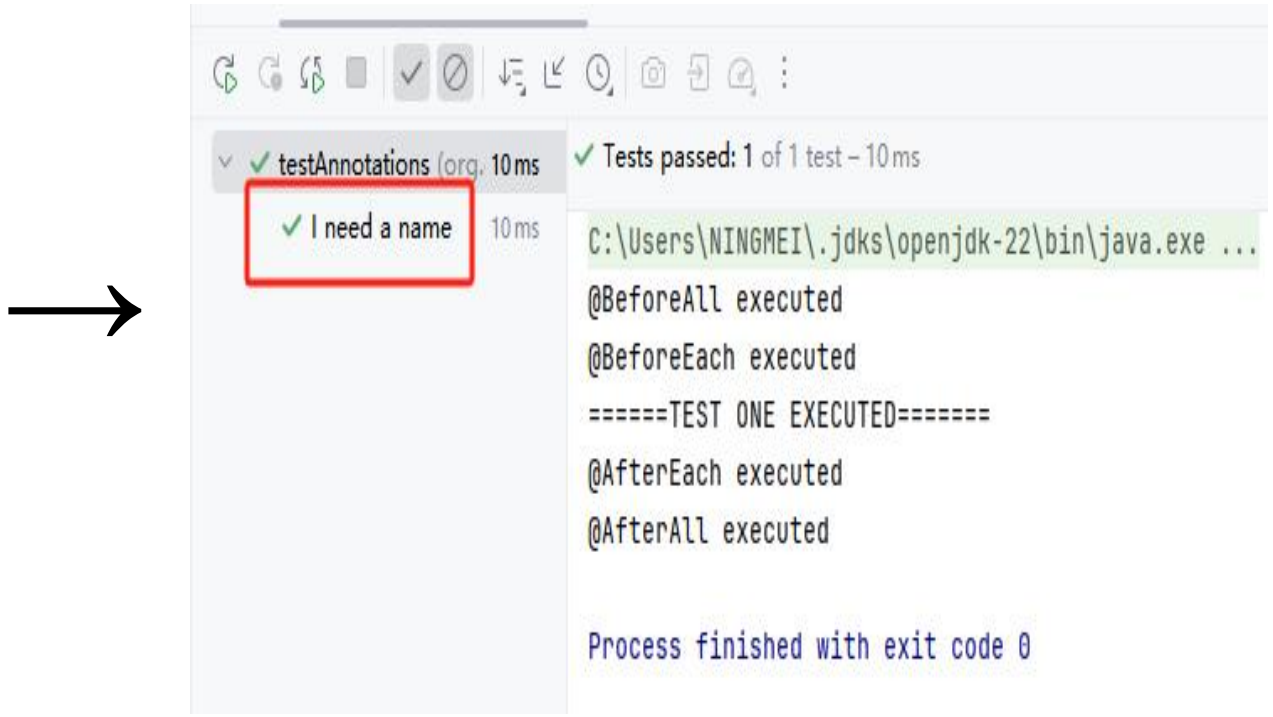
3.3 Junit 5 Annotations

Annotation	Description
`@BeforeEach`	The annotated method will be run before each test method in the test class.
`@AfterEach`	The annotated method will be run after each test method in the test class.
`@BeforeAll`	The annotated method will be run before all test methods in the test class. This method must be static.
`@AfterAll`	The annotated method will be run after all test methods in the test class. This method must be static.
`@Test`	It is used to mark a method as a junit test.
`@DisplayName`	Used to provide any custom display name for a test class or test method
`@Disable`	It is used to disable or ignore a test class or test method from the test suite.
`@Nested`	Used to create nested test classes
`@Tag`	Mark test methods or test classes with tags for test discovering and filtering
`@TestFactory`	Mark a method is a test factory for dynamic tests.

3.3.1 @DisplayName

- @DisplayName // to display meaningful name appear in the test report

```java
@DisplayName("I need a name")
//@RepeatedTest(3)
@Test
void test1()
{
    System.out.println("======TEST ONE EXECUTED=======");
    assertEquals( expected: 4 , Calculator.add( x: 2,  y: 2));
}
```



3.3.2 @Timeout

- Useful for simple performance test
  - Network communication
  - Complex computation
- The @Timeout annotation
  - Time unit defaults to seconds (@Timeout (1)) but is configurable

```
@DisplayName("I need a name")
//@RepeatedTest(3)
@Timeout(value = 1, unit= TimeUnit.MILLISECONDS)
@Test
void test1()
{
    System.out.println("======TEST ONE EXECUTED=======");
    assertEquals( expected: 4 , Calculator.add( x: 2,  y: 2));
}
```

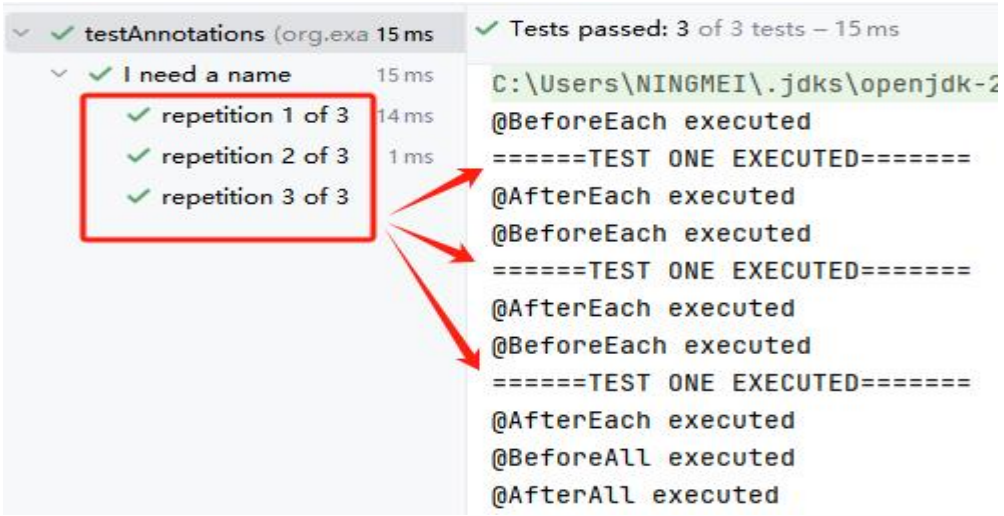
```
Tests failed: 1 of 1 test – 16 ms
C:\Users\NINGMEI\.jdks\openjdk-22\bin\java.exe ...
@BeforeAll executed
@BeforeEach executed
======TEST ONE EXECUTED=======
@AfterEach executed

java.util.concurrent.TimeoutException: test1() timed out after 1 millisecond
> <26 internal lines>
>     at java.base/java.util.ArrayList.forEach(ArrayList.java:1597) <9 internal lines>
>     at java.base/java.util.ArrayList.forEach(ArrayList.java:1597) <27 internal lines>
```

16ms > 1ms, so failed

3.3.3 @RepeatedTest

- *@RepeatedTest* is used to mark a test method that should repeat a specified number of times with a configurable display name.
- In the given example, the test method uses @RepeatedTest(3) annotation. It means that the test will be executed 3 times.
- *@Test* would **NOT** be needed if we are using *@RepeatedTest*

```
@DisplayName("I need a name")
@RepeatedTest(3)
//@Test
void test1()
{
    System.out.println("======TEST ONE EXECUTED=======");
    assertEquals( expected: 4 , Calculator.add( x: 2,  y: 2));
}
```



3.3.3 @RepeatedTest (cont.)

- *@RepeatedTest* is used to mark a test method that should repeat a specified number of times with a configurable display name.
- In the given example, the test method uses @RepeatedTest(3) annotation. It means that the test will be executed 3 times.
- *@Test* would **NOT** be needed if we are using *@RepeatedTest*

```
@DisplayName("I need a name")
@RepeatedTest(3)
//@Test
void test1()
{
    System.out.println("======TEST ONE EXECUTED=======");
    assertEquals( expected: 4 , Calculator.add( x: 2,  y: 2));
}
```

Otherwise, output:

...[A Warning Message (not an error)]... +
This is typically the result of annotating a method with multiple competing annotations such as @Test, @RepeatedTest, @ParameterizedTest, @TestFactory, etc