Comp 311
Functional Programming

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September 6, 2018

Announcements

- Homework 0 is "due" today.
  (You should now know how to use the SVN repo.)

- Homework 1 assignment has been moved to Tuesday, and the due date will shift likewise.

Class Methods

- Methods are functions defined in the body of a class definition. They have direct access to the members of a class instance

- Syntactically, they are placed between braces, after the class parameters

Class Methods

```
case class C(field1: Type1, ..., fieldN: TypeN) {
def m1(x11: TypeP11, ..., xK1: TypePk1): TypeR11 =
    expr
...
def mJ(x1J: TypeP1J, ..., xKJ: TypePkJ): TypeR1J =
    expr
}
```

Method Definitions

```
case class Coordinate(x: Int, y: Int) {
  def magnitude() = x*x + y*y
}
```

Applying a Class Method

- Given a class definition:

```
class C(p₁: T₁, ..., pₖ: Tₖ) { ...
    def m(param₁: T₁₁, paramₙ: T₁ₙ): T = e
    ...
}
```

- To reduce the application of a method:

$$\texttt{C}(v_1, \ldots, v_k).\texttt{m}(arg_1, \ldots, arg_N)$$

  - Reduce the receiver and arguments, left to right
  - Reduce the body of `m`, replacing constructor parameters with constructor arguments and method parameters with method arguments

Applying a Class Method

```
Coordinate(5,3).magnitude() ↦

5*5 + 3*3 ↦

25 + 9 ↦

34
```

Compound Value Patterns

```
def dotProduct(c1: Coordinate, c2: Coordinate) = {
  (c1, c2) match {
    case (Coordinate(x1,y1), Coordinate(x2,y2)) =>
      x1*x2 + y1*y2
  }
}
```

Patterns in Assignments

Patterns in Scala may also be used for destructuring assignments:

```
def dotProduct(c1: Coordinate, c2: Coordinate) = {
  val Coordinate(x1, y1) = c1
  val Coordinate(x2, y2) = c2
  x1*x2 + y1*y2
}
```

Symbols in Patterns: Binding or Constant?

- A symbol with a *lower-case* first character is a binding symbol
- A character with an *upper-case* first character is a value
- You can make a variable a constant using `backticks`

```
val pi = 3.14
val One = 1.0
expr match {
  case pi => "Pi"
  case One => "One"
}
```

Singleton Objects

Singleton Objects

- Also, we often would like to organize identifiers and functions together into a single entity

- When *compiling* a Scala file, it is *required* that all constant and function definitions are placed inside a class or object

- For this purpose, we can make use of *singleton objects*

Singleton Objects

```
object IncomeTax {

  val cutoff0 = 0
  val bracket0 = 0

  val bracket1 = 100
  val cutoff1 = 9075
  ...

  def incomeTaxForBracket(income: Int, cutoff: Int, bracket: Int) = {
    require(income >= 0)
    (income - cutoff) * bracket / divisor + incomeTax(cutoff)
  } ensuring (_ >= 0)
}
```

Syntax for Singleton Objects

```
object Name {

  valDefs*
  functionDefs*
}
```

We Can Refer to the Constants and Functions in the Object Using Dot Notation

```
IncomeTax.bracket1
↦
100
```

We Can Refer to the Constants and Functions in the Object Using Dot Notation

```
IncomeTax.incomeTax(100000)
```

↦

21174

Case Objects

- Declaring a *case object* denotes your intent:
  You will use this object as a *value* and use it as a pattern in *match* expressions.

- Using a normal *object* denotes a container for “static” methods declarations, or a value that won’t be *matched*.

```
case object Name {

  valDefs*

  functionDefs*
}
```

Homework

Homework Grading Criteria

- Style: 50%

- Correctness: 50%

Style of Program Code and Test Code

- Clarity
- Comments
- Contracts
- Design Principles

Clarity: Is the Program Easy to Read?

- Is the program concise?

  "Make every word say."
  (Strunk and White, *The Elements of Style*)

- Are functions kept relatively small, with sub-parts broken up according to the problem domain?

  Think of the *profit*, *revenue*, and *cost* example from Lecture 2

Clarity: Is the Program Easy to Read?

- Are the names of functions and variables syntactically consistent?

- For instance, do they all use `camelCase`?

- Are similar functions given names of similar length?

Clarity: Is the Program Easy to Read?

- Are names adequately descriptive and appropriate?
  - For example, using single letter names for public functions is not appropriate
  - Are consistent metaphors used for functions that work together?

Clarity: Is the Program Easy to Read?

- Is the program consistent in its indentation and whitespace?
    - This can affect readability
- Is there appropriate spacing?
    - Code that is too close together can be hard to read

Comments

- Does each function include a statement of purpose?
- Are the comments excessive?
- Comments embedded in program should be used only for cases where it is not clear locally why the program is doing what it does
- The reader should be expected to know the language the text is written in

Contracts

- Do the parameter types and return types of all functions and variables make sense?
- Are `require` and `ensuring` clauses included when necessary?
- Are the included `require` and `ensuring` clauses defined appropriately?
- Are requirements that cannot be expressed in `require` and `ensuring` clauses defined as documentation?

Design Principles

- Does the program stick to the constructs covered in class so far?

- Is the program purely functional?

Design Principles

- Does the program follow templates provided in class when appropriate?
    - For instance, is the function body a simple algebraic expression?
- Is it a series of `if-else` expressions breaking up sub-ranges?
- Is it a `match` expression breaking up an abstract datatype?

Design Principles

- Does the program include abstractions to factor out common code? (DRY)
  - Copy-and-paste coding should be strongly avoided
- Does the program avoid unnecessary complexity? (KISS)

Correctness

- Does the program compile?
- Do all student submitted tests pass?
- Does the program include all entry points required by the assignment?
- Are all tests automated? Tests should indicate on their own that either they pass or fail

Correctness

- Example Tests: Are simple examples included in the tests showing how the function behaves under usually circumstances?
- Stress Tests: Are there additional tests ensuring that the function behaves appropriately when given extreme data values

`0, 1, -1, PositiveInfinity, NegativeInfinity, NaN, etc.`

Correctness

- Persuasive Tests: Is there adequate coverage to convince the reader that the program behaves as expected?

- Does the program perform correctly when subjected to additional testing provided by the course staff?

Expected Test Structure

- All tests in a program should be captured in a *test suite*
- For each component of a program, there should be a corresponding test class
- For each function, there should be a corresponding test function
- For each test function, there should be multiple tests, checking both common and extreme cases

Example: Testing Our Theater Profit Calculator

```
class TheaterProfitTest(name: String) extends TestCase(name) {

  def testAttendance() = {
     ...
  }
  def testCost() = {
     ...
  }
  def testProfit() = {
     ...
  }
  def testRevenue() = {
     ...
  }
  def testMax() = {
      ...
  }
}
```

Example: Testing Our Theater Profit Calculator

```
class TheaterProfitTest(name: String) extends TestCase(name) {

  def testAttendance() {
    assertEquals(120, attendance(500))
    assertEquals(135, attendance(490))
    assertEquals(165, attendance(470))
    assertEquals(0, attendance(1000))
    assertEquals(0, attendance(580))
    assertEquals(2, attendance(579))
    assertEquals(870, attendance(0))
  }
  ...
}
```

Example: Testing Our Theater Profit Calculator

```
class TheaterProfitTest(name: String) extends TestCase(name) {
  ...
  def testRevenue() {
    assertEquals(0, revenue(0))
    assertEquals(0, revenue(1000))
    assertEquals(53550, revenue(510))
  }
  ...
}
```

Using DrScala

DrScala

- Available from the course homepage:

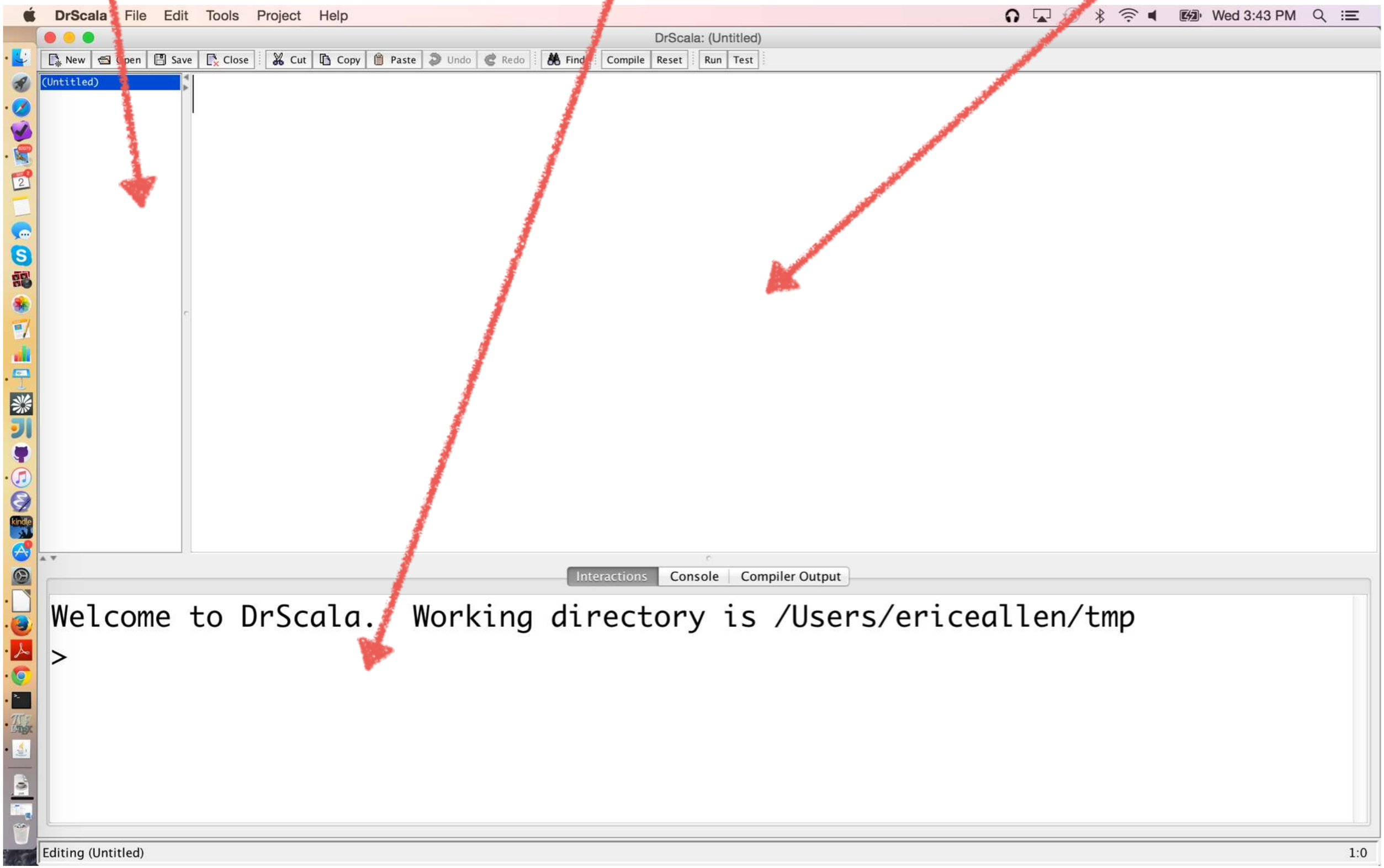
  https://comp311.rice.edu

- A lightweight development environment well-suited to the exercises we will do in this class

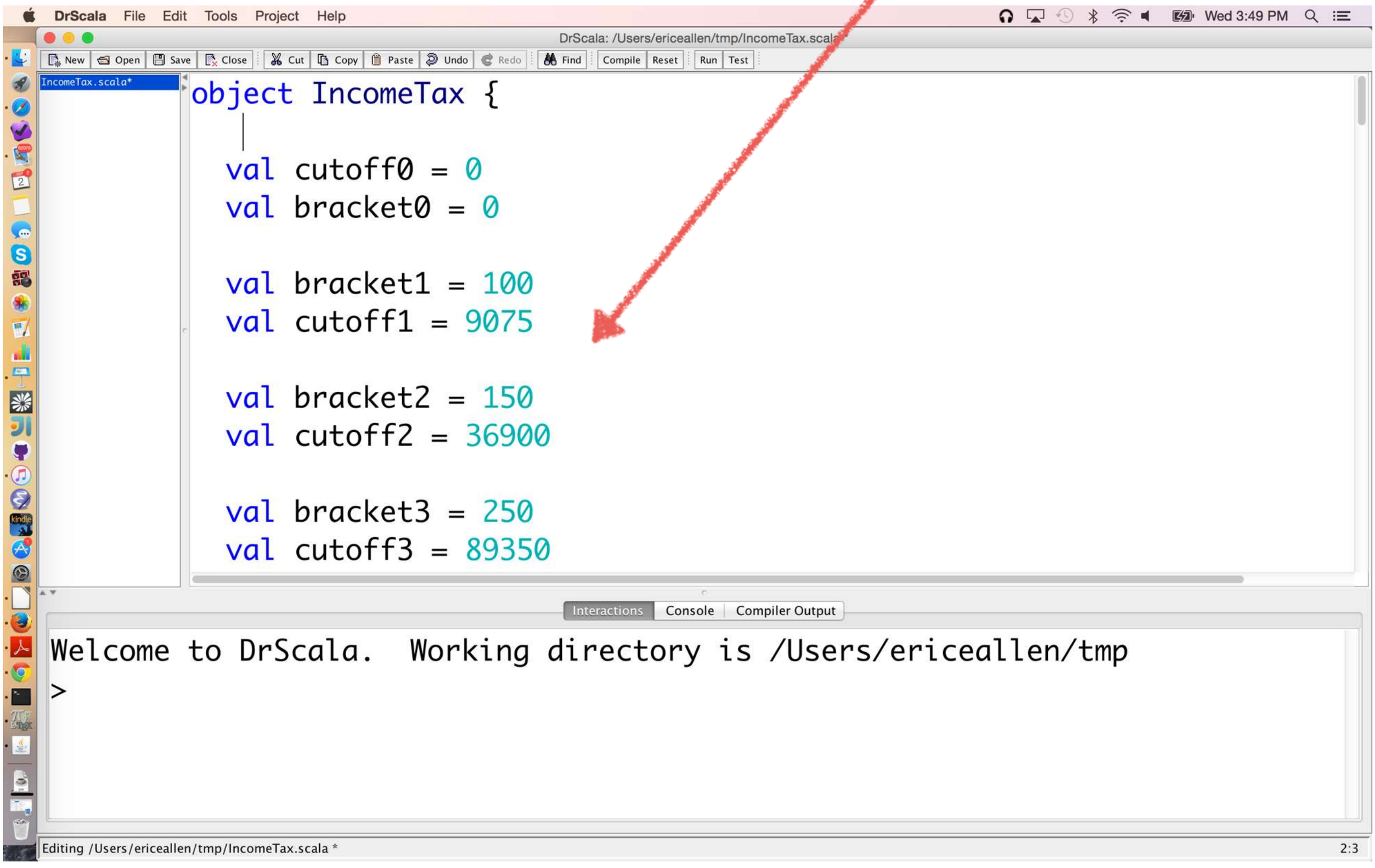
Open Files

Interactions Pane

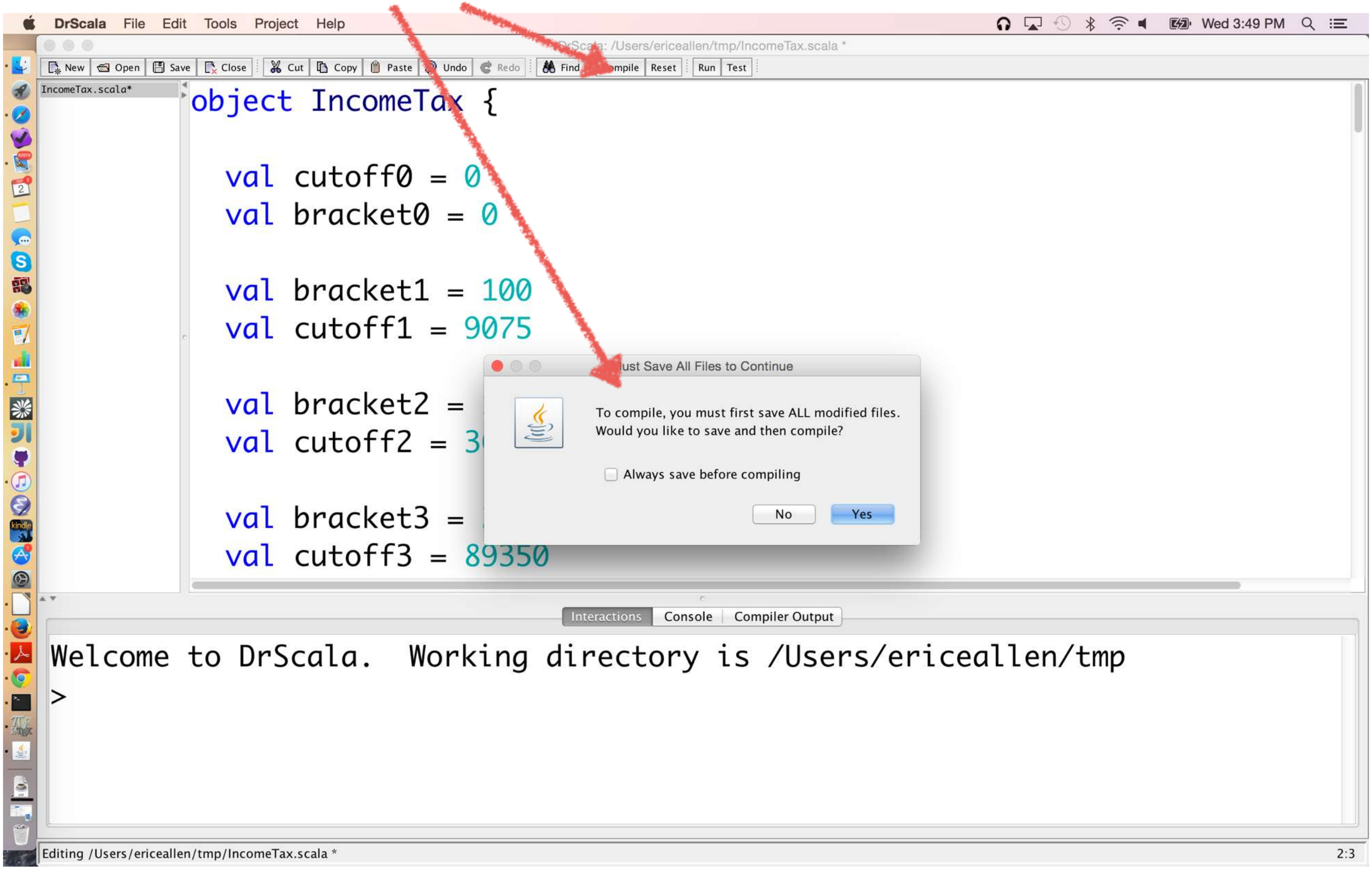
Definitions Pane



Define your program in the definitions pane



A prompt to save your program after hitting the Compile button



DrScala File Edit Tools Project Help — Wed 3:49 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

IncomeTax.scala

```
object IncomeTax {

  val cutoff0 = 0
  val bracket0 = 0

  val bracket1 = 100
  val cutoff1 = 9075

  val bracket2 = 150
  val cutoff2 = 36900

  val bracket3 = 250
  val cutoff3 = 89350
```

Successful compilation reported in the Compiler Output tab

Interactions | Console | Compiler Output

```
Compilation completed.  Output directory is:
/Users/ericeallen/tmp
```

Compiler

Scala version 2.12.0-M2

Highlight source

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 3:49 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

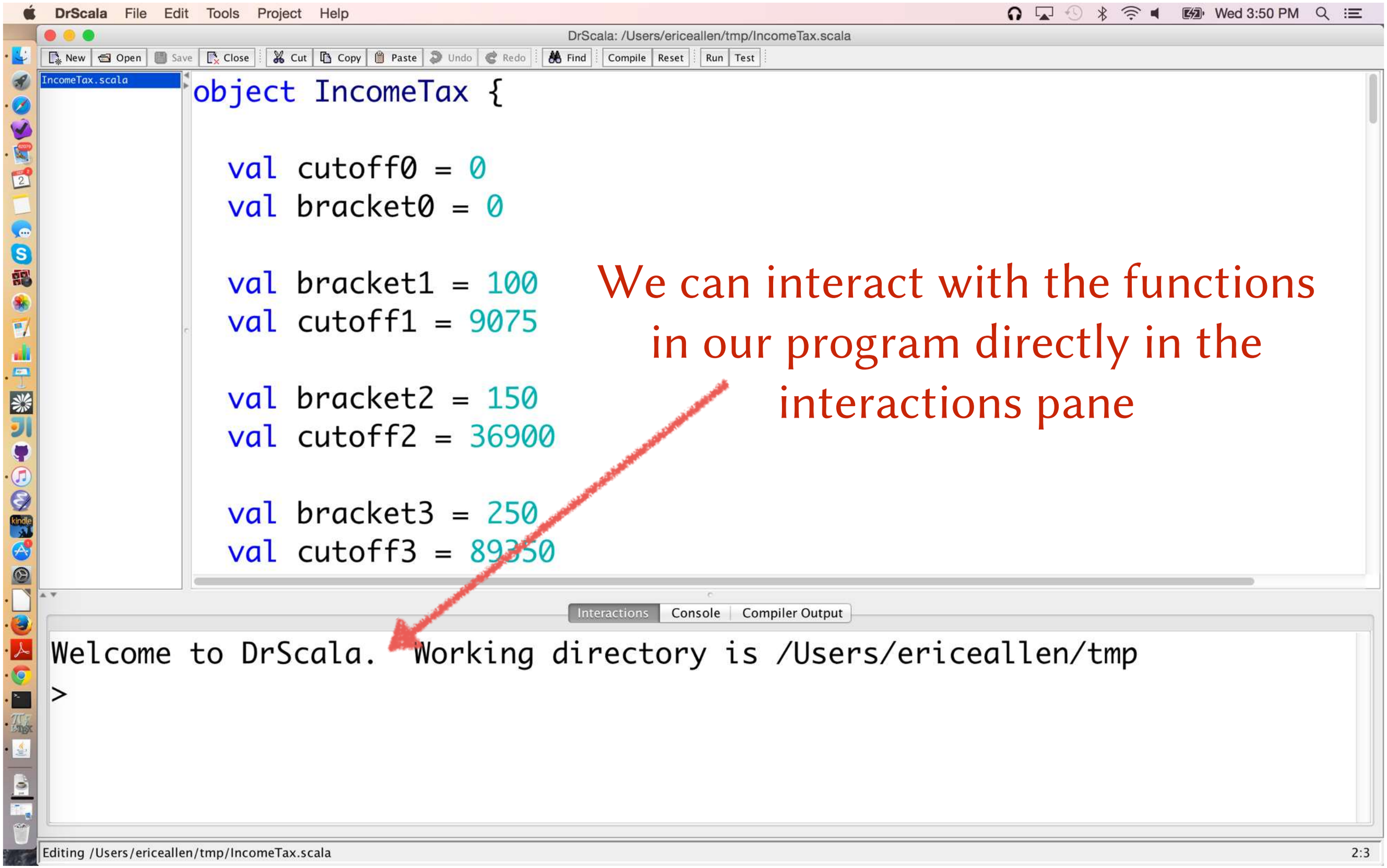
IncomeTax.scala

```
object IncomeTax {

  val cutoff0 = 0
  val bracket0 = 0

  val bracket1 = 100
  val cutoff1 = 9075

  val bracket2 = 150
  val cutoff2 = 36900

  val bracket3 = 250
  val cutoff3 = 89350
```

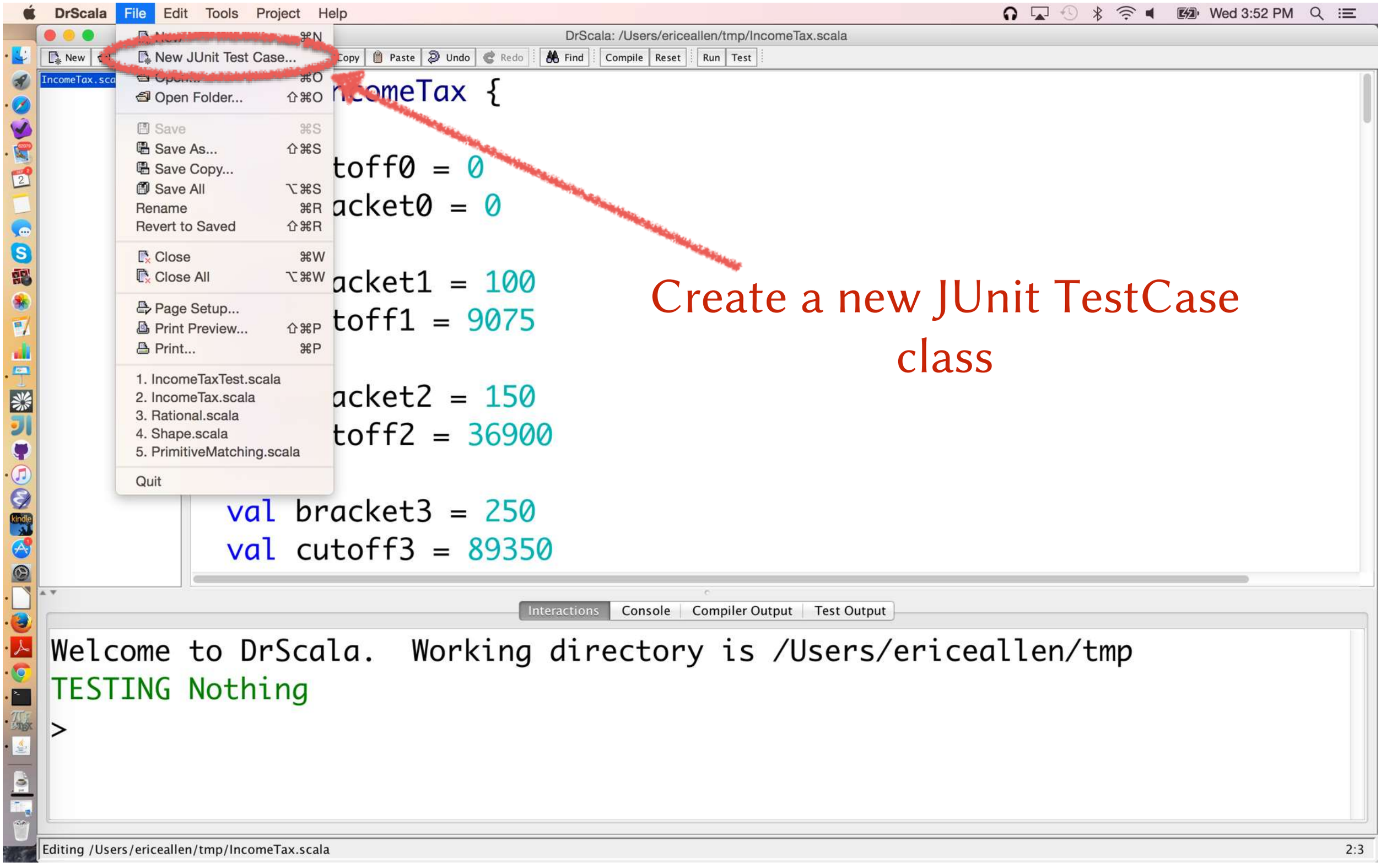
Console output from running a program printed here

Interactions | Console | Compiler Output

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3



We can interact with the functions in our program directly in the interactions pane



Create a new JUnit TestCase class

DrScala File Edit Tools Project Help — Wed 3:53 PM

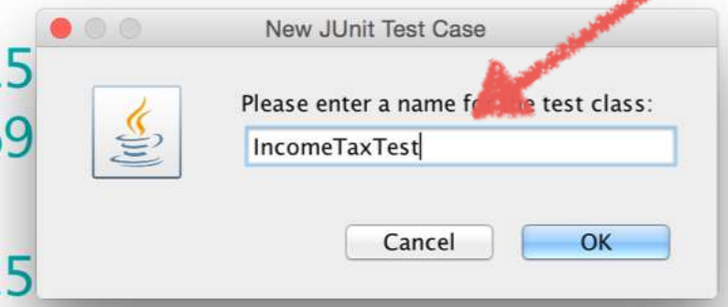
DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

IncomeTax.scala

```
object IncomeTax {

  val cutoff0 = 0
  val bracket0 = 0

  val bracket1 = 100
  val cutoff1 = 9075

  val bracket2 = 15
  val cutoff2 = 369

  val bracket3 = 25
  val cutoff3 = 89350
```

We are prompted for a name. Let's call it IncomeTaxTest



Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

```
import junit.framework.TestCase
import junit.framework.Assert._

/**
 * A JUnit test case class.
 * Every method starting with the word "test" will be called when ru
 * the test with JUnit.
 */
class IncomeTaxTest(name: String) extends TestCase(name) {


  /**
   * A test method.
   * (Replace "X" with a name describing the test.  You may write as
```

A new test class is created

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

```
import junit.framework.TestCase
import junit.framework.Assert._

/**
 * A JUnit test case class.
 * Every method starting with the word "test" will be called when ru
 * the test with JUnit.
 */
class IncomeTaxTest(name: String) extends TestCase(name) {

  /**
   * A test method.
   * (Replace "X" with a name describing the test.  You may write as
```

Note that this is *not* a case class

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

```
import junit.framework.TestCase
import junit.framework.Assert._

/**
 * A JUnit test case class.
 * Every method starting with the word "test" will be called when ru
 * the test with JUnit.
 */
class IncomeTaxTest(name: String) extends TestCase(name) {


  /**
   * A test method.
   * (Replace "X" with a name describing the test.  You may write as
```

Ignore the extends clause for now

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

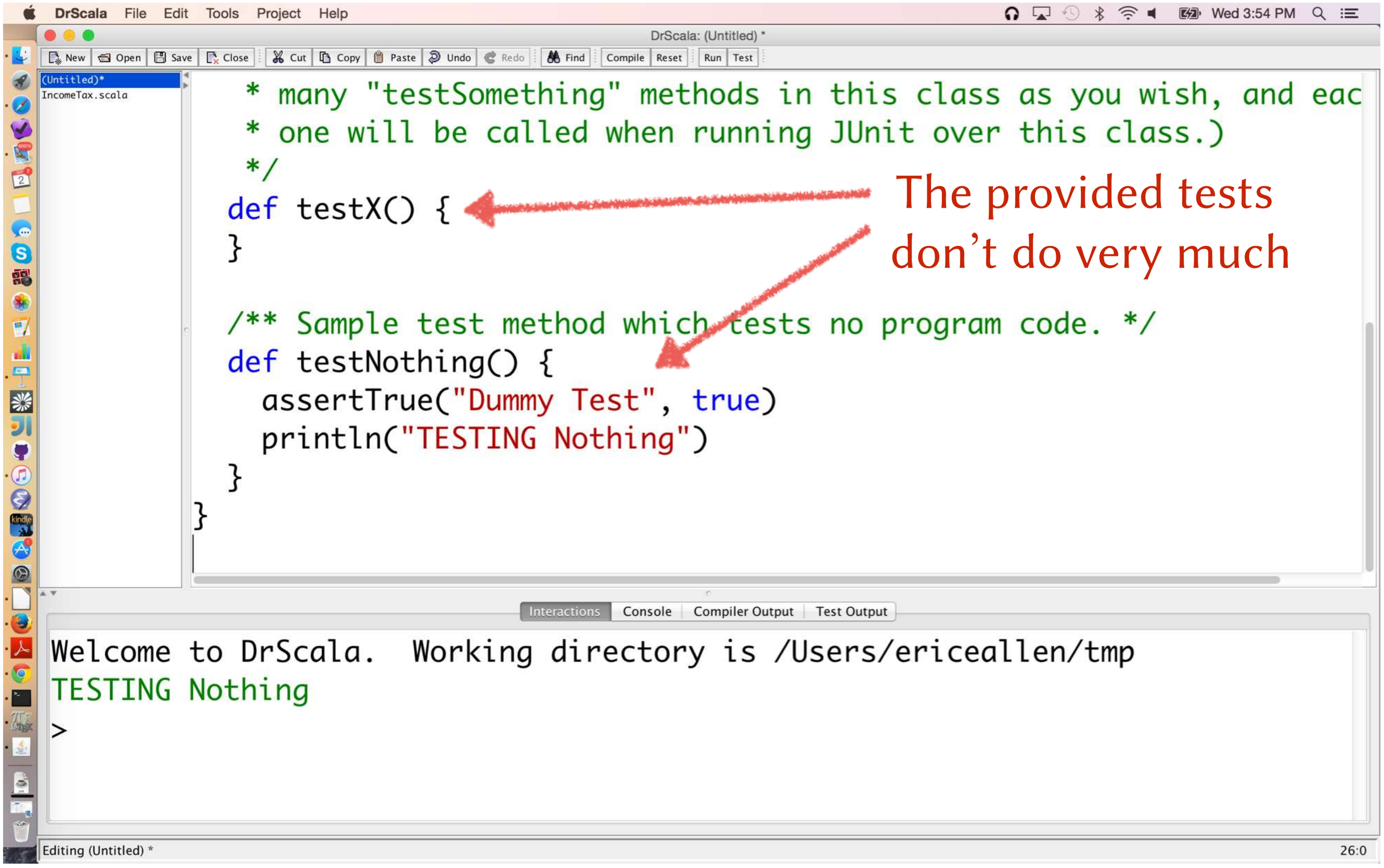
```
import junit.framework.TestCase
import junit.framework.Assert._

/**
 * A JUnit test case class.
 * Every method starting with the word "test" will be called when ru
 * the test with JUnit.
 */
class IncomeTaxTest(name: String) extends TestCase(name) {

  /**
   * A test method.
   * (Replace "X" with a name describing the test.  You may write as
```

Ignore the import statements for now

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0


DrScala File Edit Tools Project Help
Wed 3:54 PM
DrScala: (Untitled) *
New Open Save Close Cut Copy Paste Undo Redo Find Compile Reset Run Test
(Untitled)*
IncomeTax.scala
* many "testSomething" methods in this class as you wish, and eac
* one will be called when running JUnit over this class.)
*/
def testX() {
}
/** Sample test method which tests no program code. */
def testNothing() {
assertTrue("Dummy Test", true)
println("TESTING Nothing")
}
}
The provided tests don't do very much
Interactions Console Compiler Output Test Output
Welcome to DrScala. Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
Editing (Untitled) *
26:0

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

```
   * many "testSomething" methods in this class as you wish, and eac
   * one will be called when running JUnit over this class.)
   */
  def testX() {
  }

  /** Sample test method which tests no program code. */
  def testNothing() {
    assertTrue("Dummy Test", true)
    println("TESTING Nothing")
  }
}
```

All functions with names starting with "test" are treated as tests

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

```
   * many "testSomething" methods in this class as you wish, and eac
   * one will be called when running JUnit over this class.)
   */
  def testX() {
  }

  /** Sample test method which tests no program code. */
  def testNothing() {
    assertTrue("Dummy Test", true)
    println("TESTING Nothing")
  }
}
```

The assertTrue function is available to us in our tests.

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0

DrScala File Edit Tools Project Help — Wed 3:54 PM

DrScala: (Untitled) *

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala

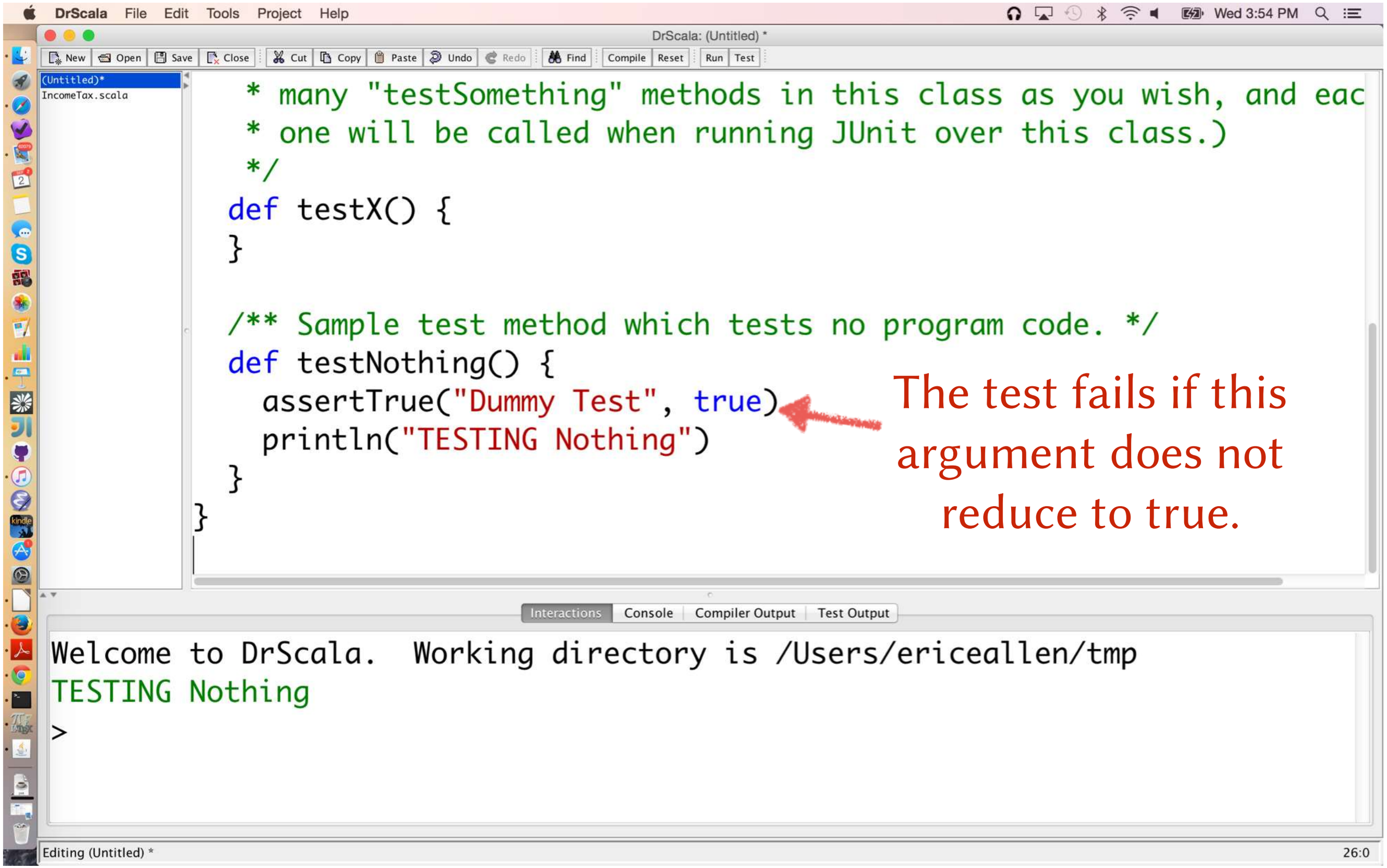
```
   * many "testSomething" methods in this class as you wish, and eac
   * one will be called when running JUnit over this class.)
   */
  def testX() {
  }

  /** Sample test method which tests no program code. */
  def testNothing() {
    assertTrue("Dummy Test", true)
    println("TESTING Nothing")
  }
}
```

The optional String is printed if the test fails.

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Editing (Untitled) * 26:0


DrScala File Edit Tools Project Help
Wed 3:54 PM
DrScala: (Untitled) *
New Open Save Close Cut Copy Paste Undo Redo Find Compile Reset Run Test
(Untitled)*
IncomeTax.scala
* many "testSomething" methods in this class as you wish, and eac
* one will be called when running JUnit over this class.)
*/
def testX() {
}
/** Sample test method which tests no program code. */
def testNothing() {
assertTrue("Dummy Test", true)
println("TESTING Nothing")
}
}
The test fails if this argument does not reduce to true.
Interactions Console Compiler Output Test Output
Welcome to DrScala. Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
Editing (Untitled) *
26:0

assertEquals fails if its two arguments are not equal

Add many more test functions

DrScala File Edit Tools Project Help — Wed 8:35 PM

DrScala: /Users/ericeallen/tmp/IncomeTaxTest.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

IncomeTax.scala
IncomeTaxTest.scala

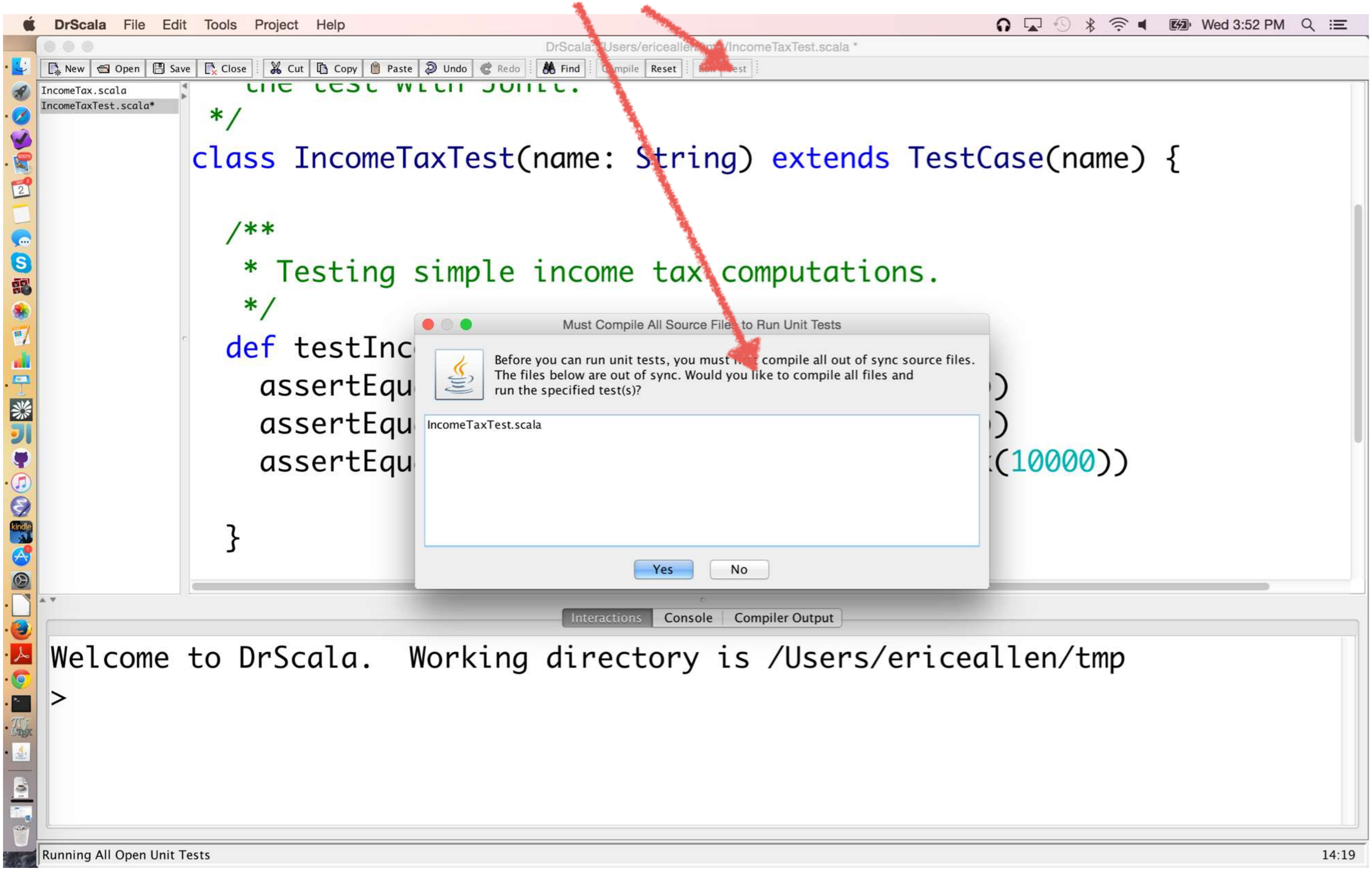
```
/**
 * Testing simple income tax computations.
 */
def testIncomeTax() {
  assertEquals(100, IncomeTax.incomeTax(1000))
  assertEquals(907, IncomeTax.incomeTax(9075))
  assertEquals(907 + 138, IncomeTax.incomeTax(10000))
}

/** Sample test method which tests no program code. */
def testNothing() {
  assertTrue("Dummy Test", true)
  println("TESTING Nothing")
```

Interactions | Console | Compiler Output | Test Output

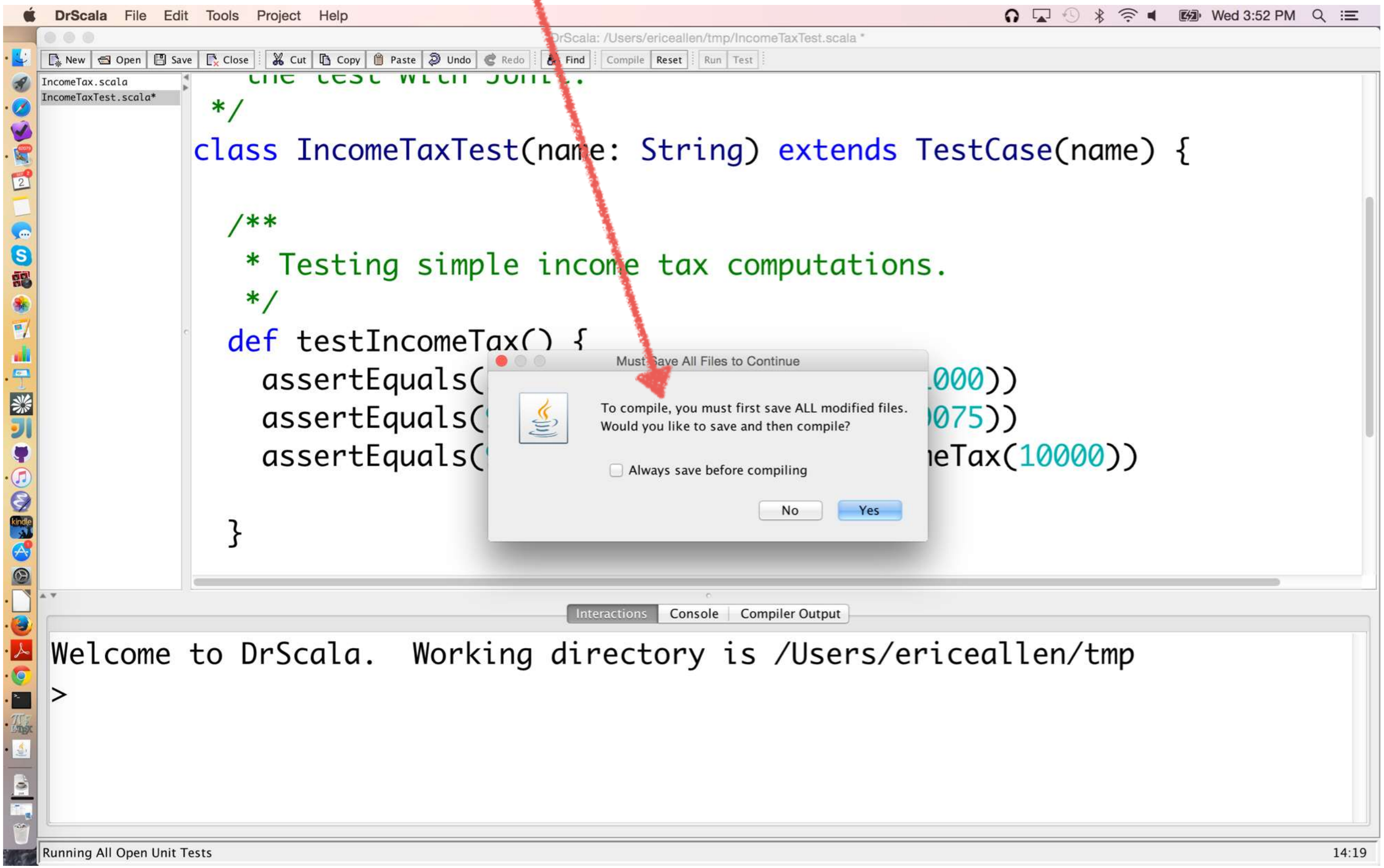
```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
TESTING Nothing
>
```

Bracket matches: def testIncomeTax() { — 18:3

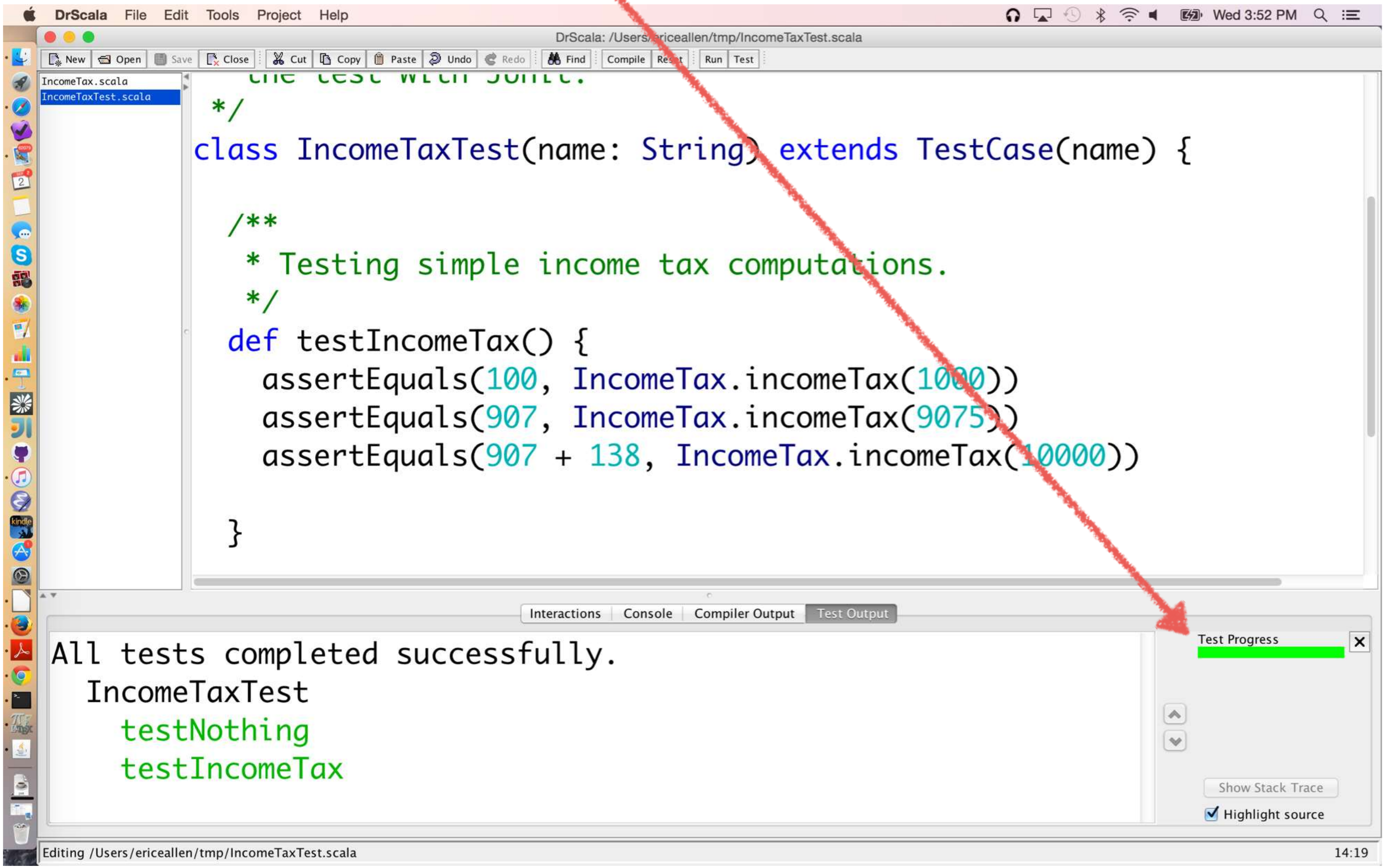
Hitting the Test button prompts us to compile



Agreeing to compile prompts us to save



A green bar indicates that all tests passed



DrScala File Edit Tools Project Help — Wed 8:15 PM

DrScala: /Users/ericeallen/tmp/IncomeTaxTest.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

IncomeTax.scala
IncomeTaxTest.scala

```
  def testIncomeTax() {
    assertEquals(100, IncomeTax.incomeTax(1000))
    assertEquals(907, IncomeTax.incomeTax(9075))
    assertEquals(907 + 138, IncomeTax.incomeTax(10000)
  }

  def testThatFails() {
    assertTrue(false)
  }

  /** Sample test method which tests no program code.
  def testNothing() {
    assertTrue("Dummy Test", true)
    println("TESTING Nothing")
```

A red bar indicates a test failure

Interactions | Console | Compiler Output | Test Output

```
IncomeTaxTest
  testIncomeTax
  testThatFails
  testNothing
```

Test Progress

Show Stack Trace

Highlight source

Editing /Users/ericeallen/tmp/IncomeTaxTest.scala 21:0

DrScala File Edit Tools Project Help — Wed 8:15 PM

DrScala: /Users/ericeallen/tmp/IncomeTaxTest.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

IncomeTax.scala
IncomeTaxTest.scala

```
  def testIncomeTax() {
    assertEquals(100, IncomeTax.incomeTax(1000))
    assertEquals(907, IncomeTax.incomeTax(9075))
    assertEquals(907 + 138, IncomeTax.incomeTax(10000)
  }

  def testThatFails() {
    assertTrue(false)
  }

/** Sample test method which tests no program code.
def testNothing() {
  assertTrue("Dummy Test", true)
  println("TESTING Nothing")
```

The failing test is highlighted in yellow

Interactions | Console | Compiler Output | Test Output

```
IncomeTaxTest
  testIncomeTax
  testThatFails
  testNothing
```

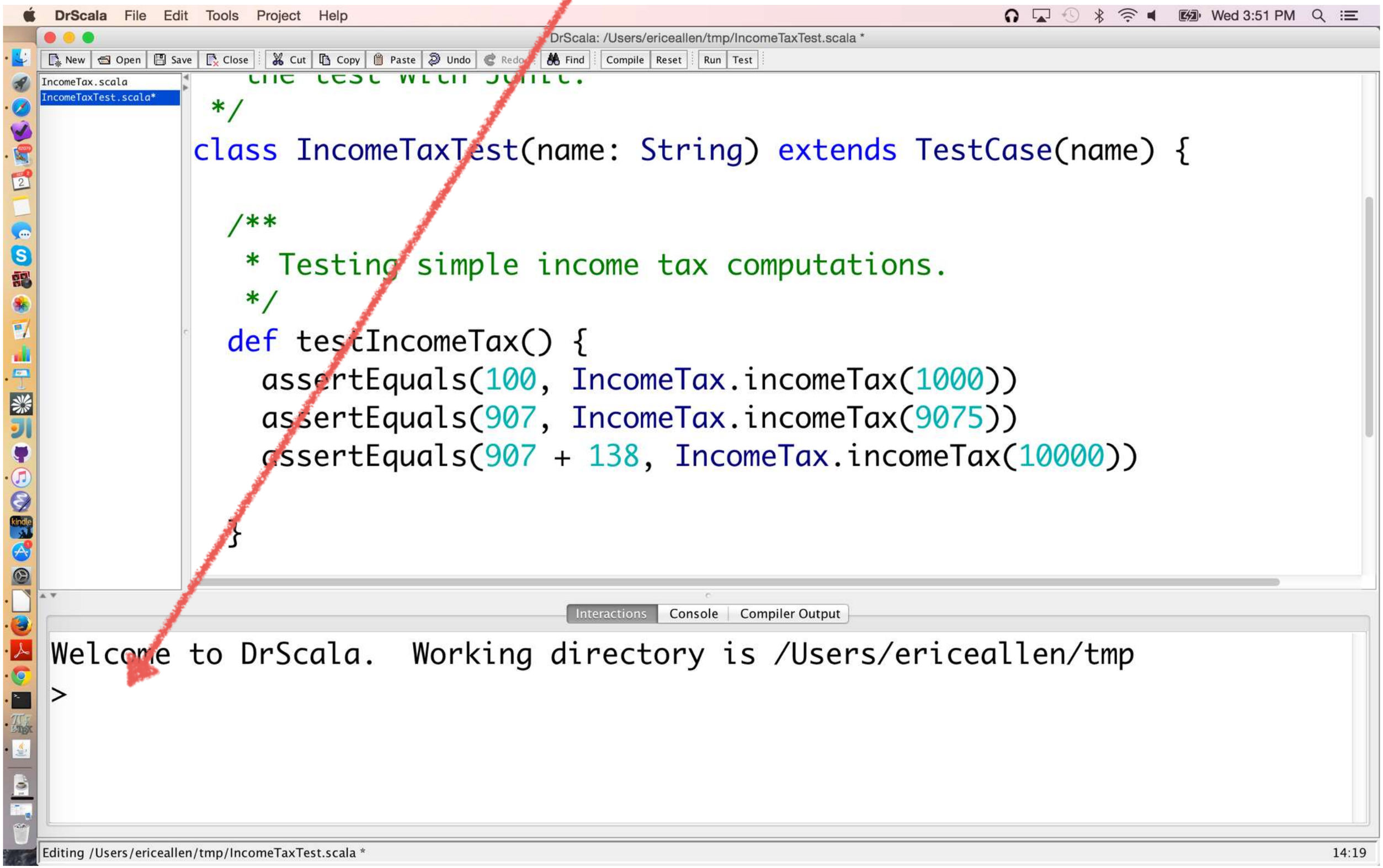
Test Progress

Show Stack Trace

Highlight source

Editing /Users/ericeallen/tmp/IncomeTaxTest.scala 21:0

To interact with our program, we use the Interactions Pane



DrScala File Edit Tools Project Help — Wed 5:02 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> 2 + 2
res0: Int = 4
>
```

We can enter arbitrary Scala expressions

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:02 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
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res0: Int = 4
>
```

The value our expression reduces to is displayed

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DrScala File Edit Tools Project Help — Wed 5:02 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

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IncomeTaxTest.scala*

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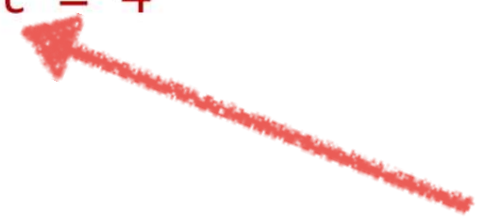
```

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> 2 + 2
res0: Int = 4
>
```



As is its type

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:02 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
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   * owed for a single tax payer, using
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    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> 2 + 2
res0: Int = 4
>
```

And the value is bound to a fresh identifier

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:03 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> 2 + 2
res0: Int = 4
> IncomeTax.incomeTax(100000)
res1: Int = 21174
>
```

The classes we have compiled in Definitions are in scope in Interactions

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:03 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> 2 + 2
res0: Int = 4
> IncomeTax.incomeTax(100000)
res1: Int = 21174
> res0 * res1
res2: Int = 84696
>
```

We can refer to previously bound identifiers in subsequent expressions

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:04 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
res0: Int = 4
> IncomeTax.incomeTax(100000)
res1: Int = 21174
> res0 * res1
res2: Int = 84696
> val pi = 3.14
pi: Double = 3.14
>
```

We can also bind new identifiers directly

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:04 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
res1: Int = 21174
> res0 * res1
res2: Int = 84696
> val pi = 3.14
pi: Double = 3.14
> res1 * pi
res3: Double = 66486.36
>
```

And compute with them

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:04 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
res2: Int = 84696
> val pi = 3.14
pi: Double = 3.14
> res1 * pi
res3: Double = 66486.36
> def square(x: Double) = x * x
square: (x: Double)Double
>
```

We can also define new functions

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:05 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
  /
   * Given an income in U.S. Dollars,
   * returns the dollar value of tax
   * owed for a single tax payer, using
   * 2014-2015 IRS tax brackets.
   */
  def incomeTax(income: Int): Int = {
    require(income >= 0)

    if (income <= cutoff0) {
      bracket0
```

Interactions | Console | Compiler Output | Test Output

```
> val pi = 3.14
pi: Double = 3.14
> res1 * pi
res3: Double = 66486.36
> def square(x: Double) = x * x
square: (x: Double)Double
> def abs(x: Double) =
      |
```

For definitions that are not syntactically complete, we are given a new line, indicated by a vertical bar

Editing /Users/ericeallen/tmp/IncomeTax.scala 2:3

DrScala File Edit Tools Project Help — Wed 5:07 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
/**
 * Given an income in U.S. Dollars,
 * returns the dollar value of tax
 * owed for a single tax payer, using
 * 2014-2015 IRS tax brackets.
 */
def incomeTax(income: Int): Int = {
  require(income >= 0)

  if (income <= cutoff0) {
    bracket0
```

Interactions | Console | Compiler Output | Test Output

```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> def abs(x: Double) =
      | if (x < 0) -x else
      | x
abs: (x: Double)Double
>
```

The function is bound and an arrow type is displayed

Resetting Interactions 2:3

DrScala File Edit Tools Project Help — Wed 5:07 PM

DrScala: /Users/ericeallen/tmp/IncomeTax.scala

New | Open | Save | Close | Cut | Copy | Paste | Undo | Redo | Find | Compile | Reset | Run | Test

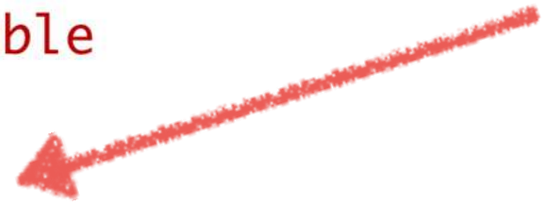
(Untitled)*
IncomeTax.scala
IncomeTaxTest.scala*

```
/**
 * Given an income in U.S. Dollars,
 * returns the dollar value of tax
 * owed for a single tax payer, using
 * 2014-2015 IRS tax brackets.
 */
def incomeTax(income: Int): Int = {
  require(income >= 0)

  if (income <= cutoff0) {
    bracket0
```

Interactions | Console | Compiler Output | Test Output

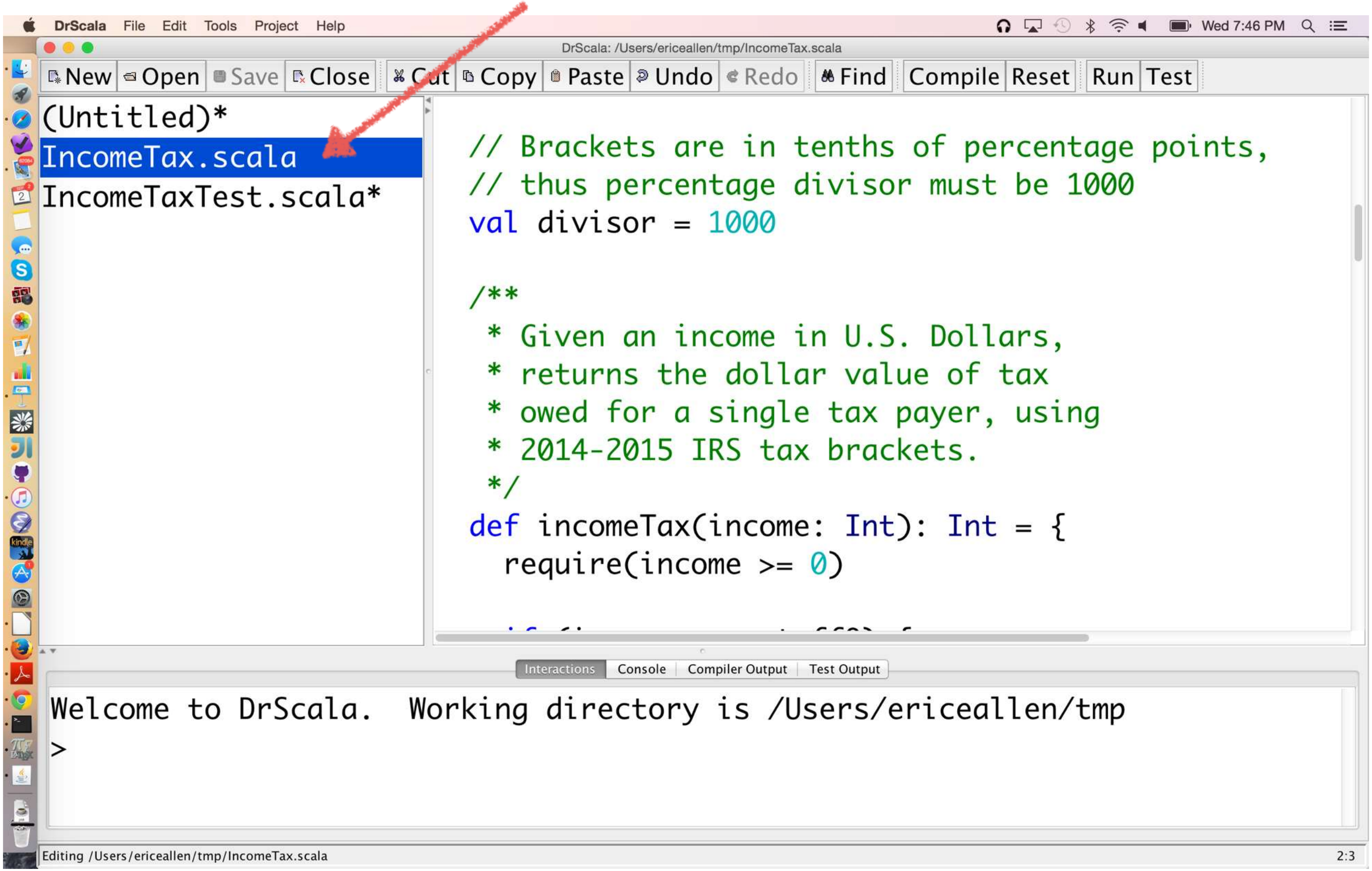
```
Welcome to DrScala.  Working directory is /Users/ericeallen/tmp
> def abs(x: Double) =
      | if (x < 0) -x else
      | x
abs: (x: Double)Double
> abs(-5.0)
res0: Double = 5.0
>
```



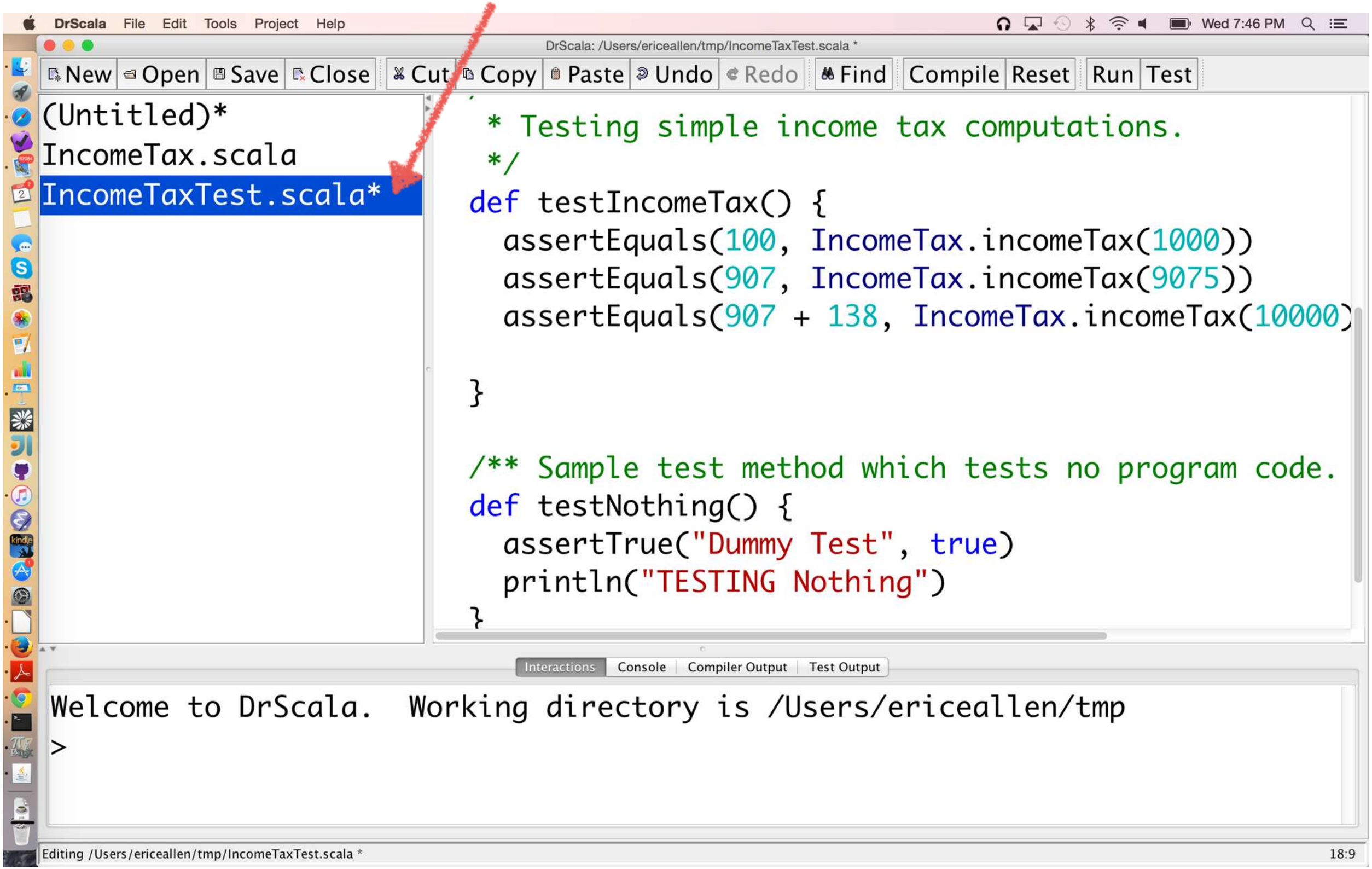
And we can refer to this function in subsequent expressions

Resetting Interactions 2:3

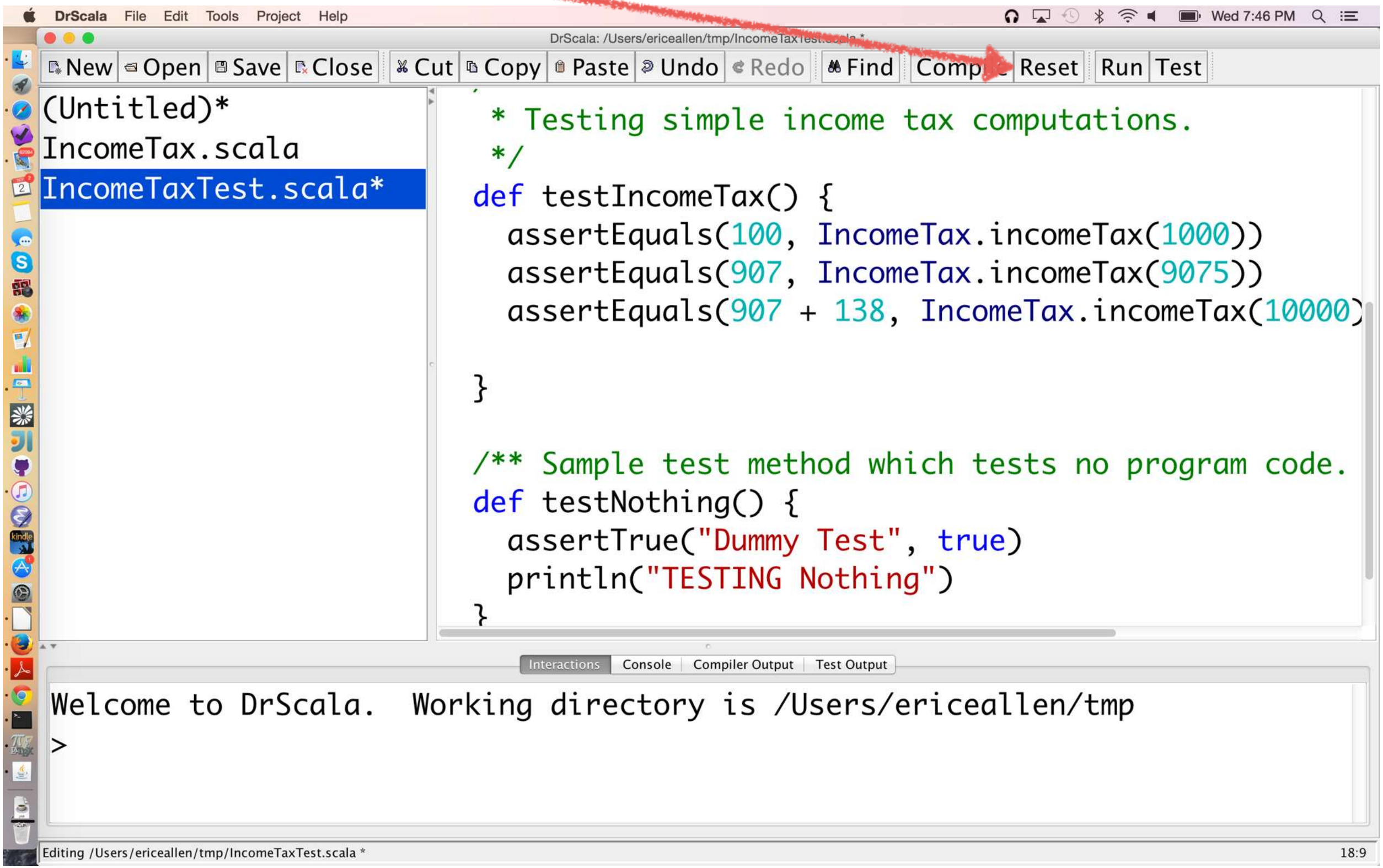
We can click on the file to appear in Definitions



Files that have not been saved include an asterisk



Reset resets the Interactions session



Run executes Definitions