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Supporting

Test Suite Evolution

through Test Case Adaptation

Mehdi Mirzaaghaei

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Test Evolution

```
public final class DateTimeField{
..
```

```
public final class CopticChronology{
..

}
```

```
public class Report{
..
  addRule(int line, String file)
}
```

```
ReportTest{
 test(){
   Report r = new Report();
   r.addRule(5, file );
   assertFalse(r.isEmpty());

}
```

Test Evolution

```
public final class DateTimeField{
..
```

```
public final class CopticChronology{
..

}
```

```
public class Report{
..
  addRule(int line, Context ctx)
}
```

```
ReportTest{
 test(){
   Report r = new Report();
   r.addRule(5, file );
   assertFalse(r.isEmpty());

}
```

Test Evolution

```
public final class DateTimeField{
..
```

```
public final class CopticChronology{
..

}
```

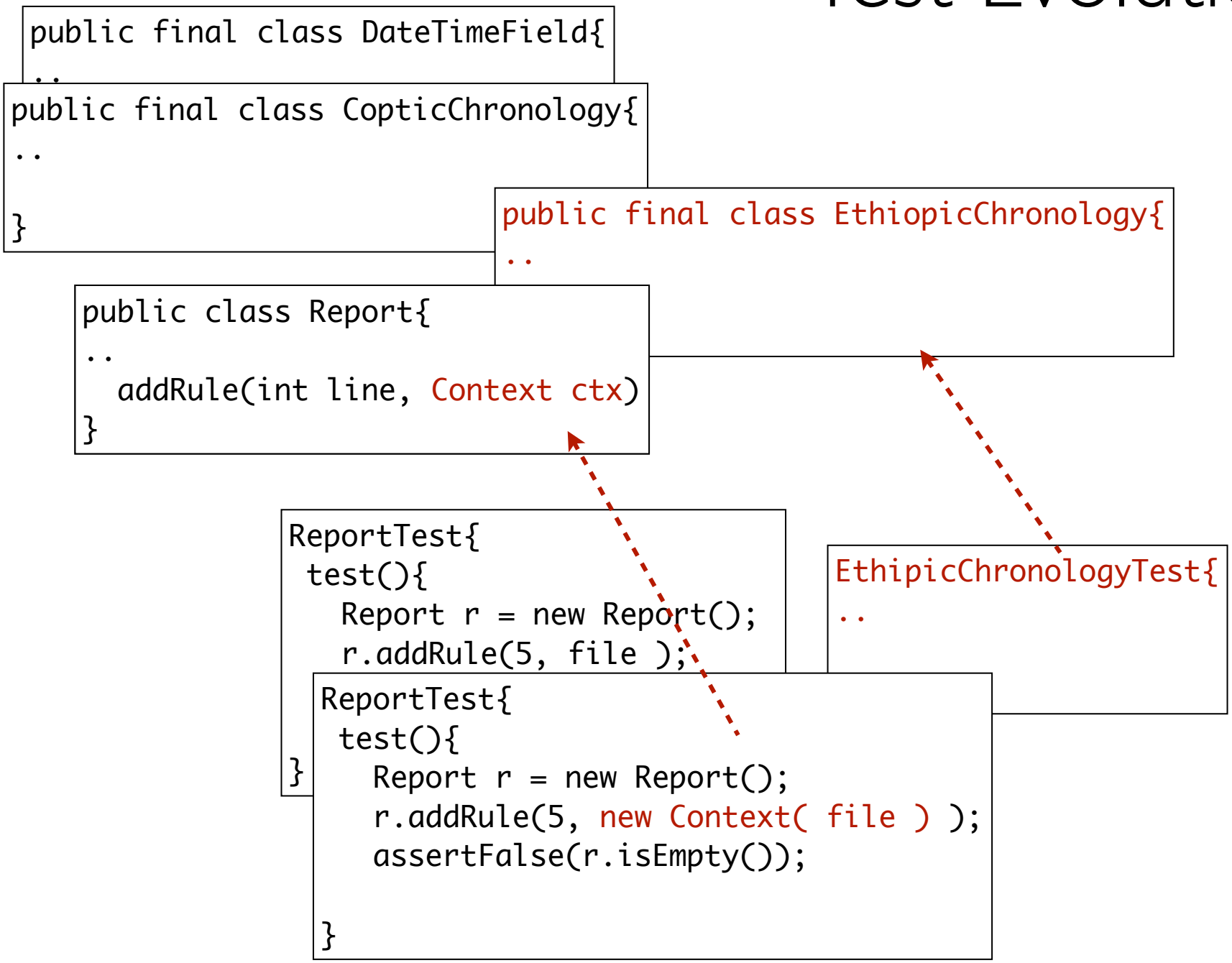
```
public class Report{
..
  addRule(int line, Context ctx)
}
```

```
ReportTest{
 test(){
   Report r = new Report();
   r.addRule(5, file );
}
```

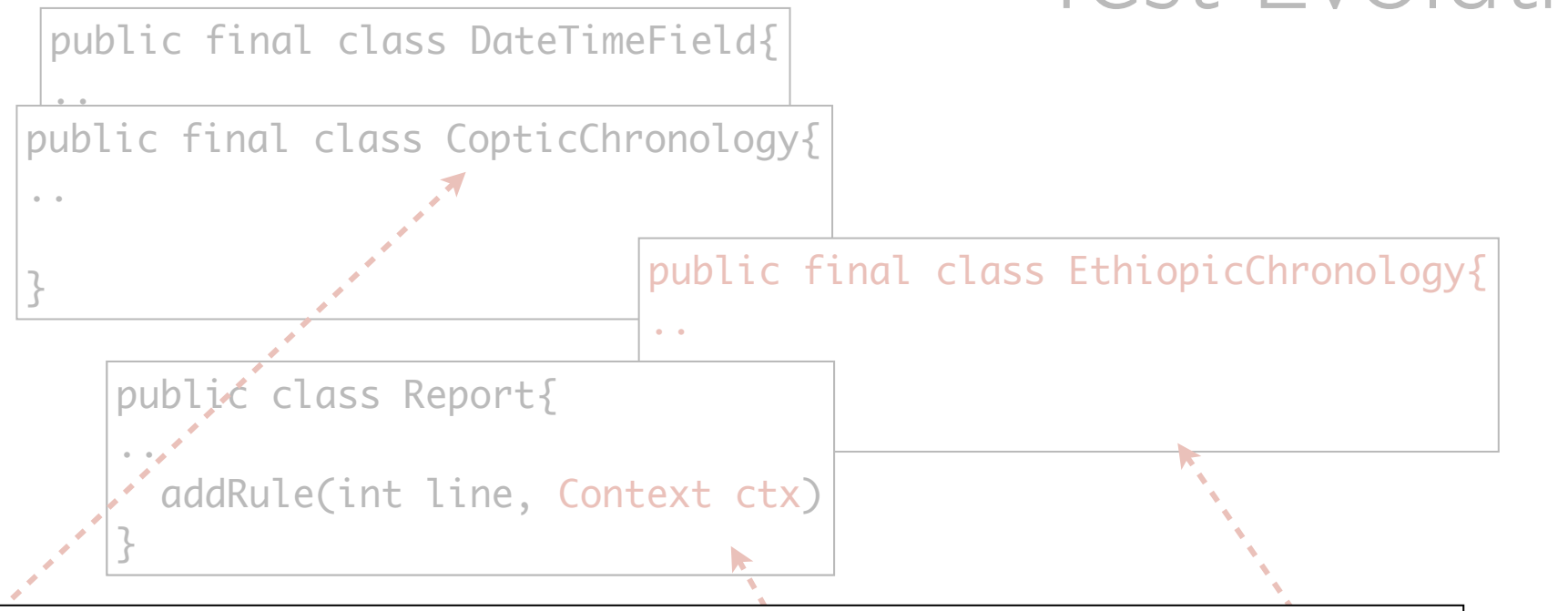
```
ReportTest{
 test(){
   Report r = new Report();
   r.addRule(5, new Context( file ) );
   assertFalse(r.isEmpty());

}
```

Test Evolution



Test Evolution

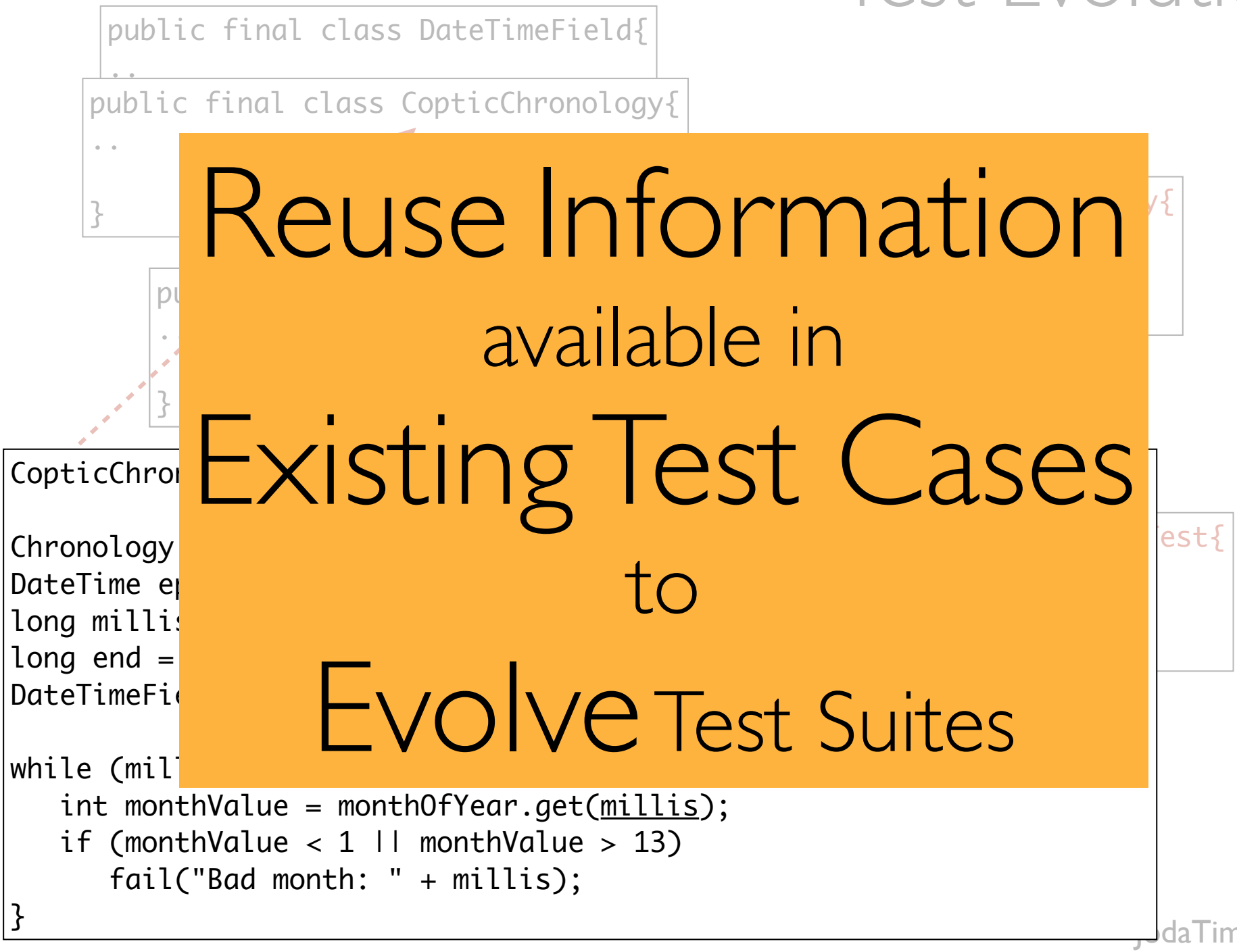



```
CopticChronologyTest{

Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, COPTIC_UTC);
long millis = epoch.getMillis();
long end = new DateTime(3000, 1, 1, 0, 0, 0, 0, ISO_UTC).getMillis();
DateTimeField monthOfYear = COPTIC_UTC.monthOfYear();

while (millis < end) {
   int monthValue = monthOfYear.get(millis);
   if (monthValue < 1 || monthValue > 13)
      fail("Bad month: " + millis);
}
```

Test Evolution



```
EthiopicChronologyTest{

Chronology ETHIOPIC_UTC = EthiopicChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, ETHIOPIC_UTC);
long millis = epoch.getMillis();
long end = new DateTime(3000, 1, 1, 0, 0, 0, 0, ISO_UTC).getMillis();
DateTimeField monthOfYear = ETHIOPIC_UTC.monthOfYear();

while (millis < end) {
   int monthValue = monthOfYear.get( new Date(millis) );
   if (monthValue < 1 || monthValue > 13)
      fail("Bad month: " + millis);
} }
```

```
CopticChronologyTest{

Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, COPTIC_UTC);
long millis = epoch.getMillis();
long end = new DateTime(3000, 1, 1, 0, 0, 0, 0, ISO_UTC).getMillis();
DateTimeField monthOfYear = COPTIC_UTC.monthOfYear();

while (millis < end) {
   int monthValue = monthOfYear.get(millis);
   if (monthValue < 1 || monthValue > 13)
      fail("Bad month: " + millis);
}
```

Test Care Assistant (TCA)

Add Test Cases for new Modules

- new Class in Hierarchy
- new Interface Implementation
- New Overloaded Method
- New Overridden Method

Repair Compilation Errors due to Signature Changes

- Parameter Addition
- Parameter Type Change
- Parameter Removal
- Return Type Change

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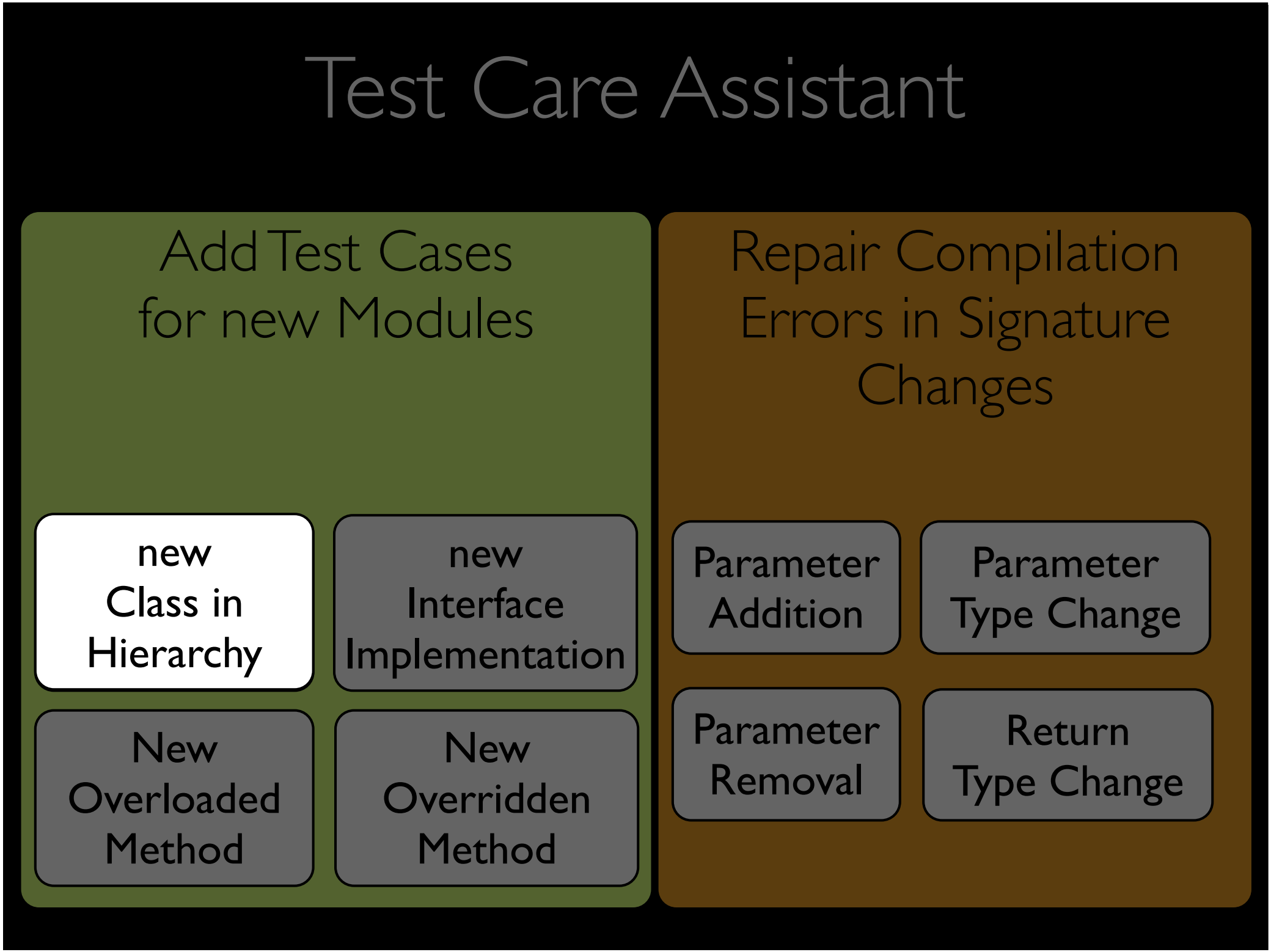
Test Care Assistant
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new Class in Hierarchy
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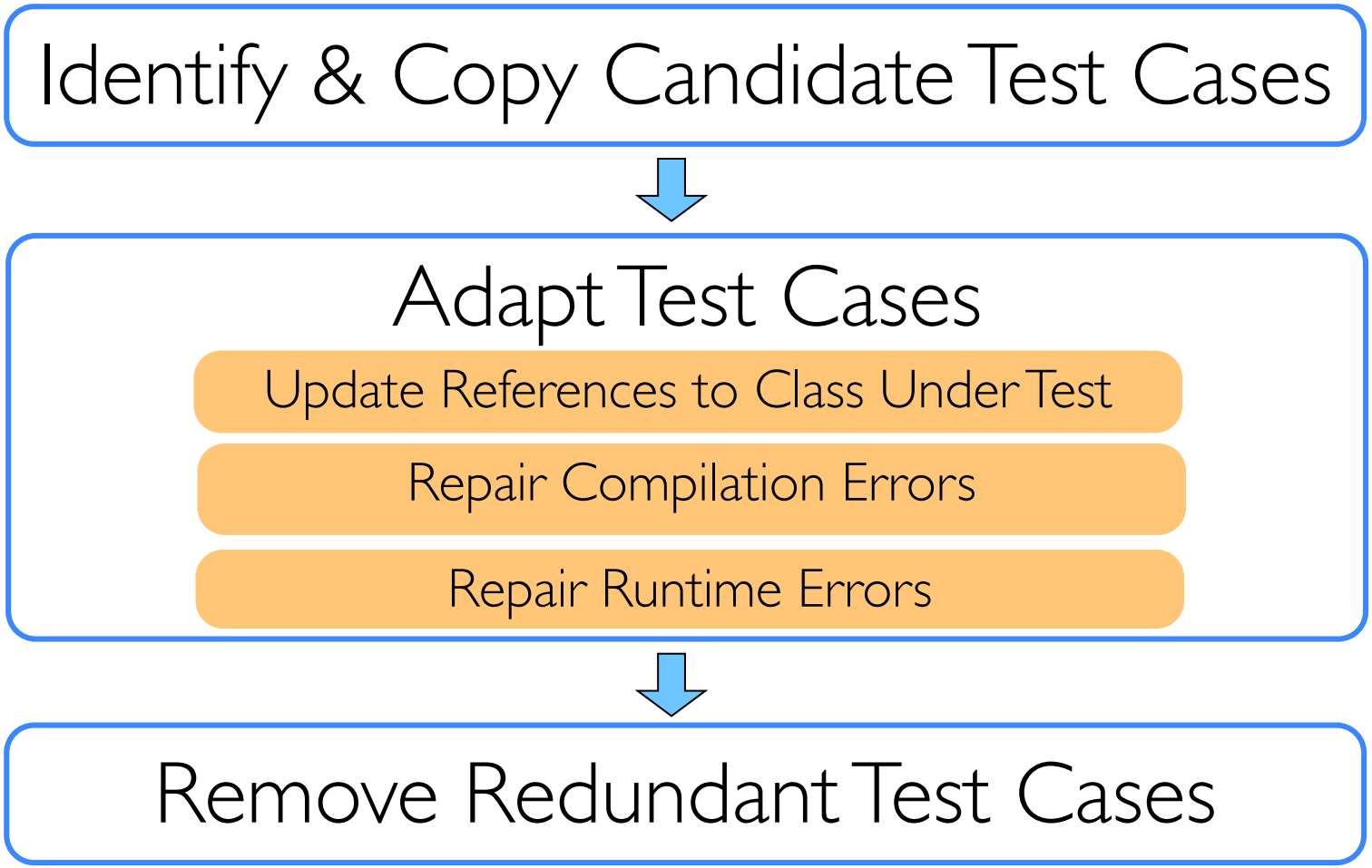
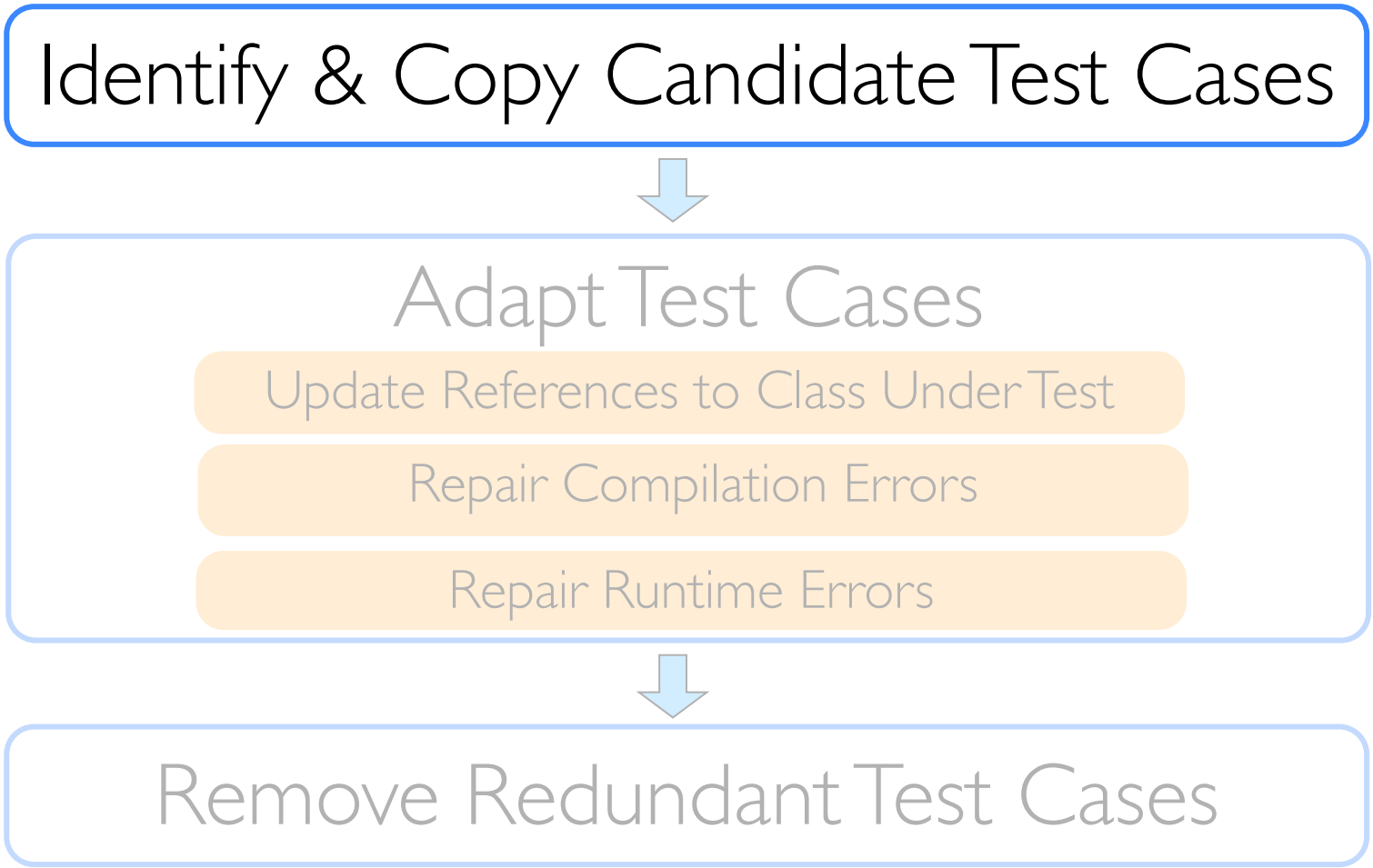
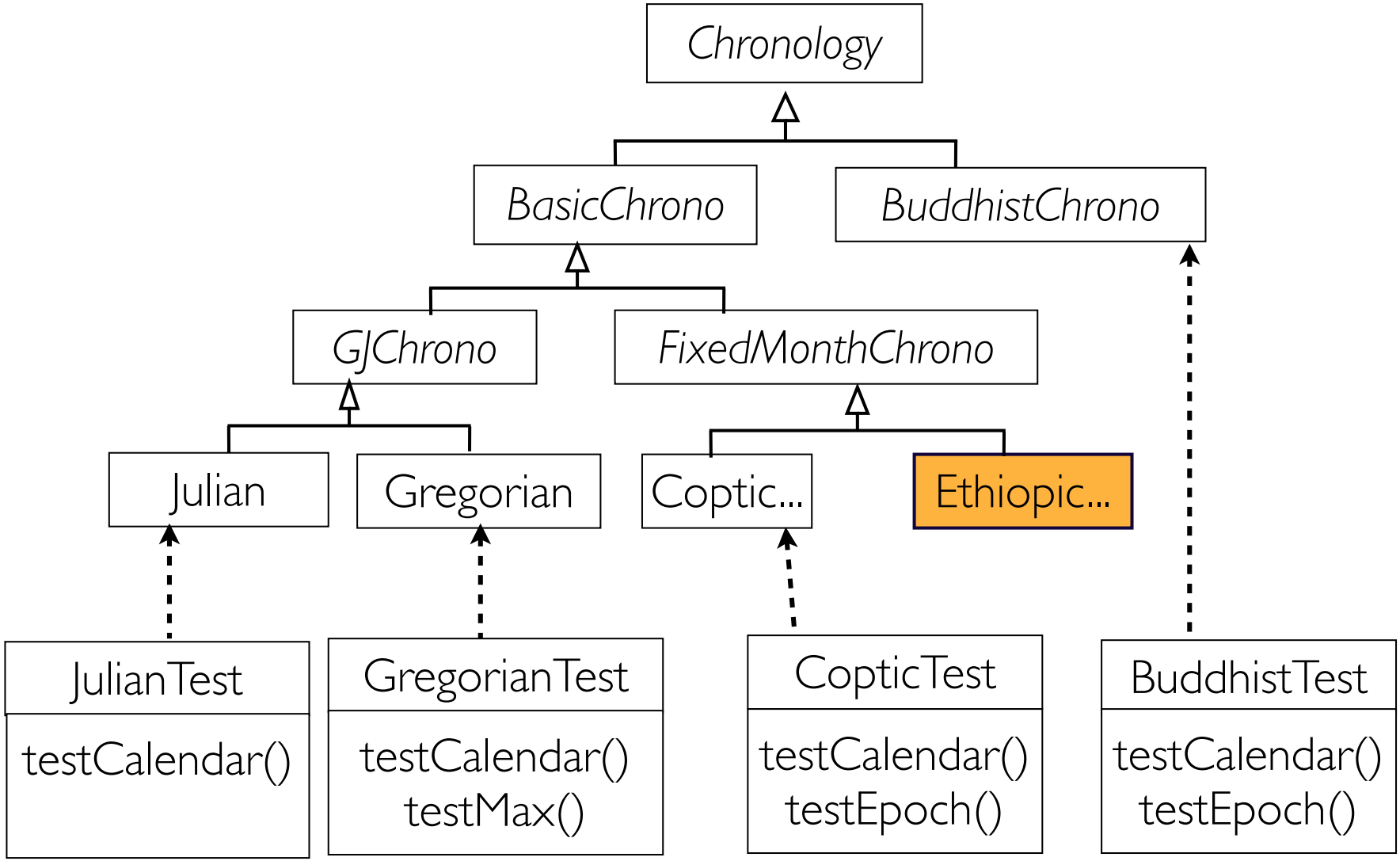
Generate Test Cases for Classes added to a Hierarchy



Generate Test Cases for Classes added to a Hierarchy



Identify & Copy Candidate Test Cases



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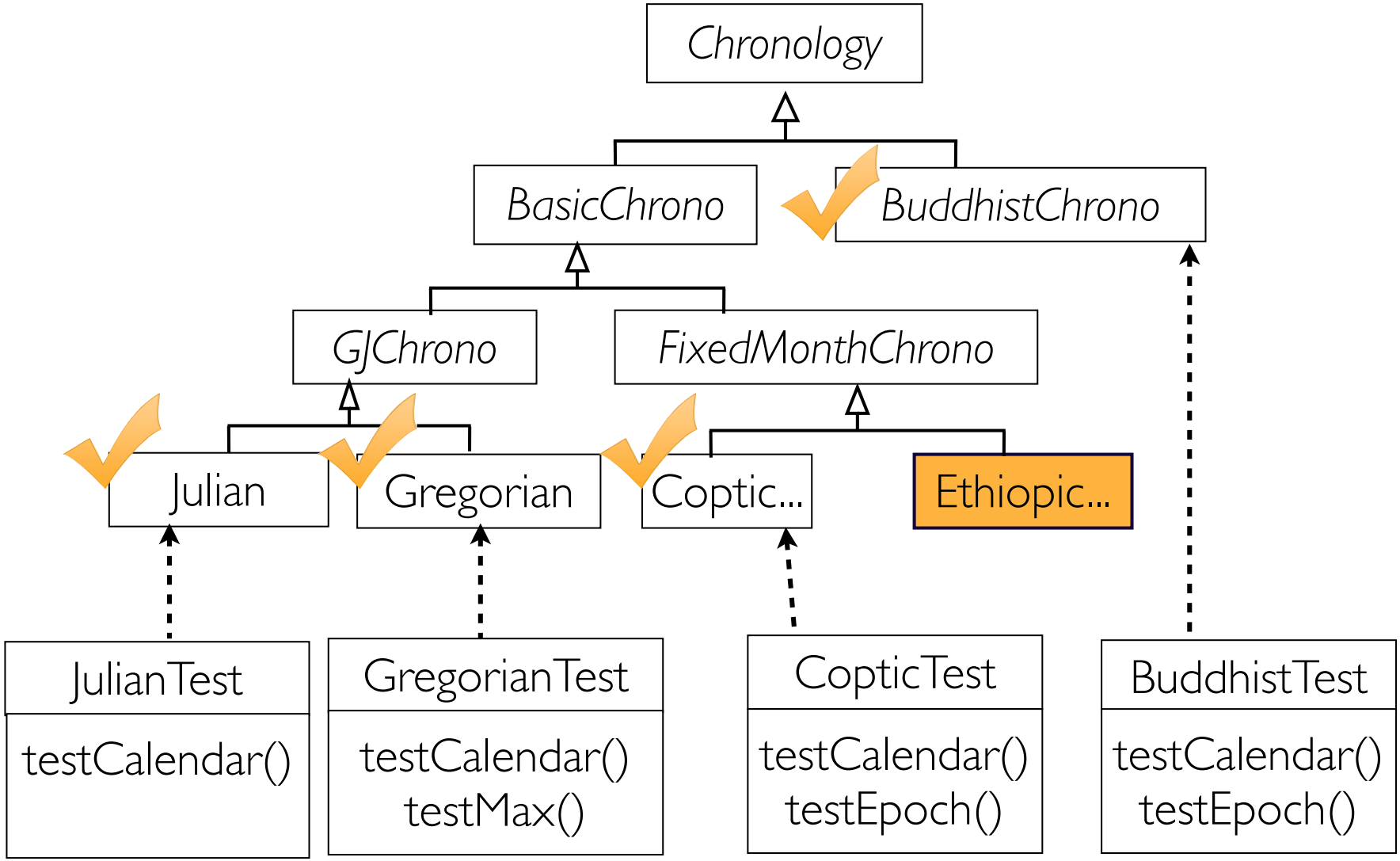

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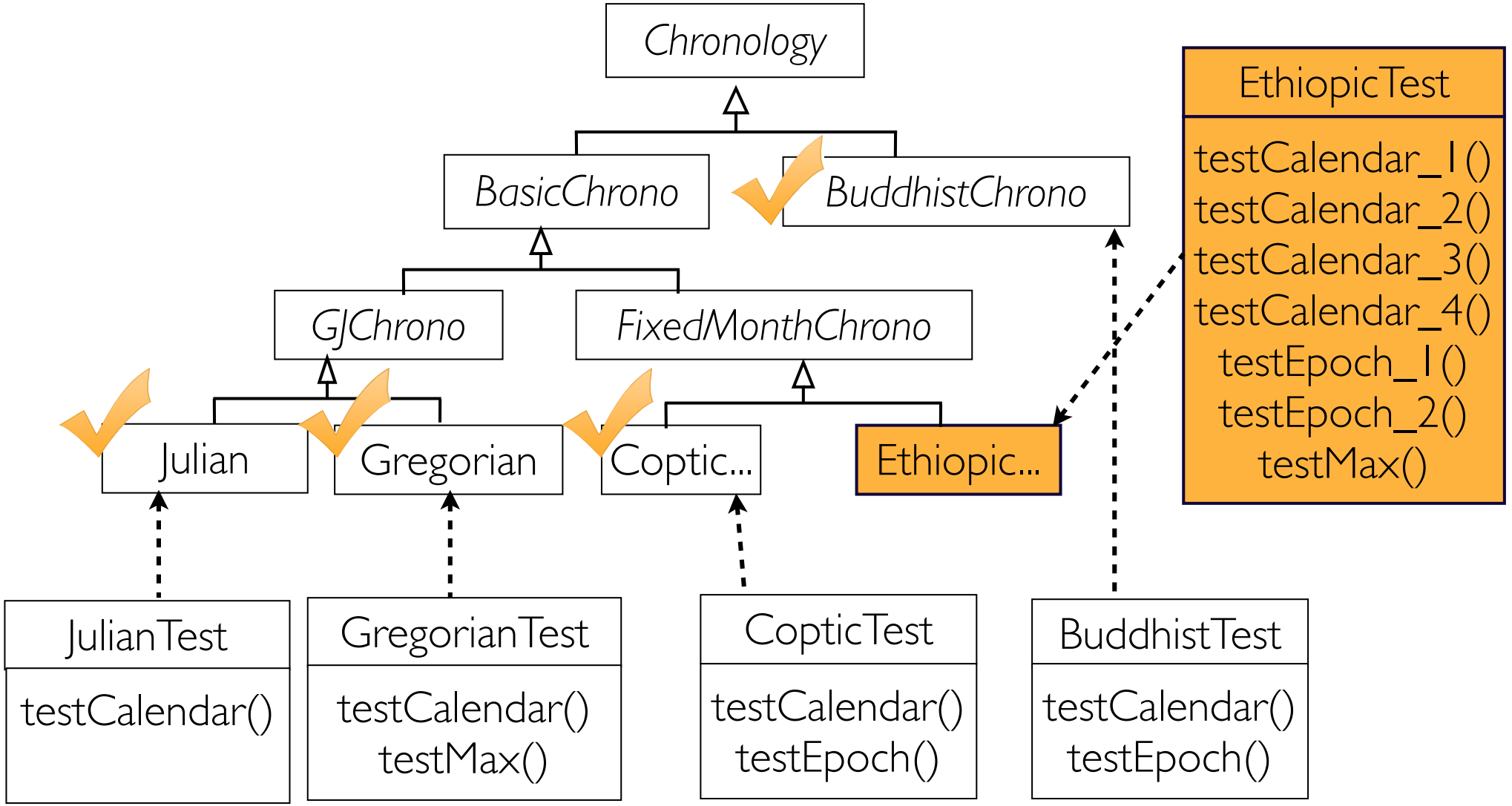
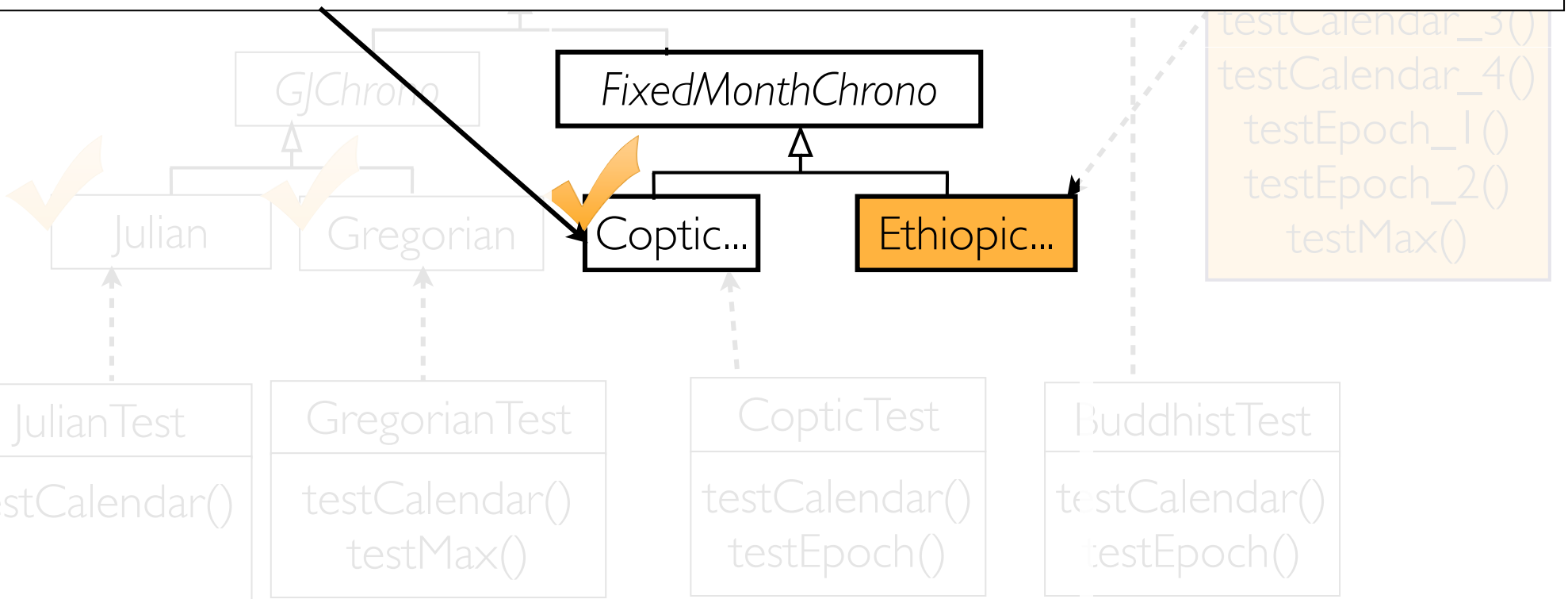


Identify & Copy Candidate Test Cases

```
Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, COPTIC_UTC);
assertEquals( CopticChronology.AM, epoch.getEra() )
...
```



Update References to Class Under Test

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Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
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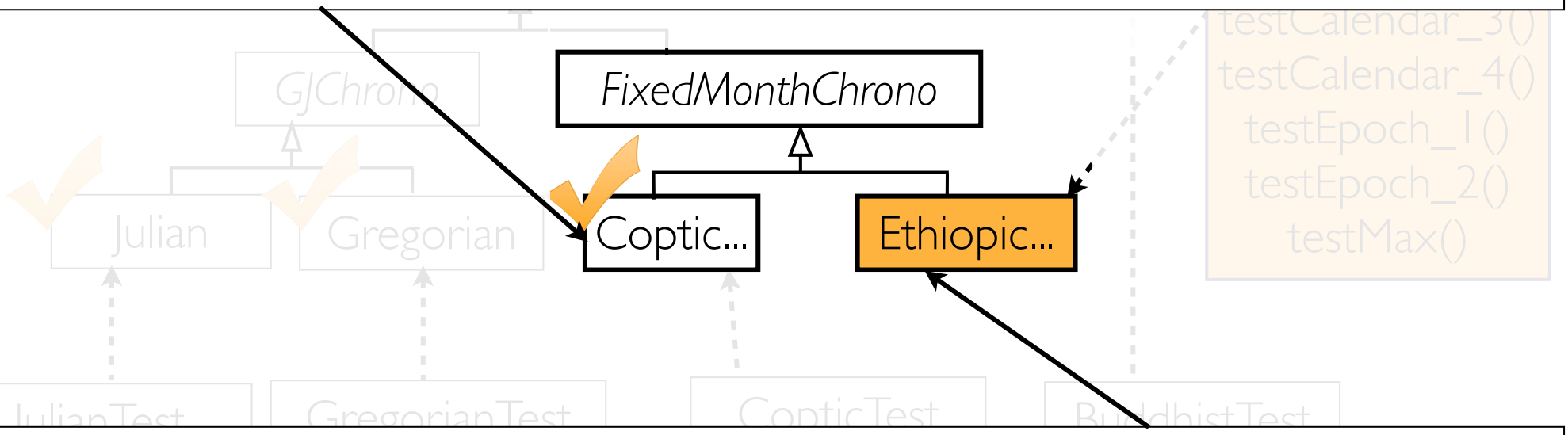


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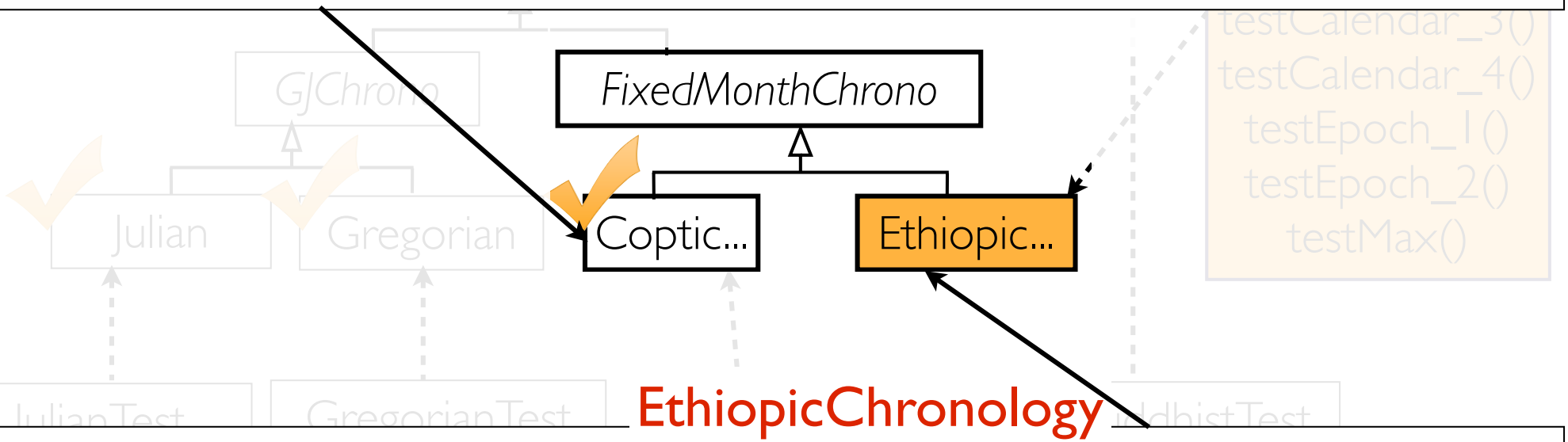


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DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, COPTIC_UTC);
assertEquals( CopticChronology.AM, epoch.getEra() )
...
```

EthiopicChronology

Update References to Class Under Test

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Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, COPTIC_UTC);
assertEquals( CopticChronology.AM, epoch.getEra() )
...
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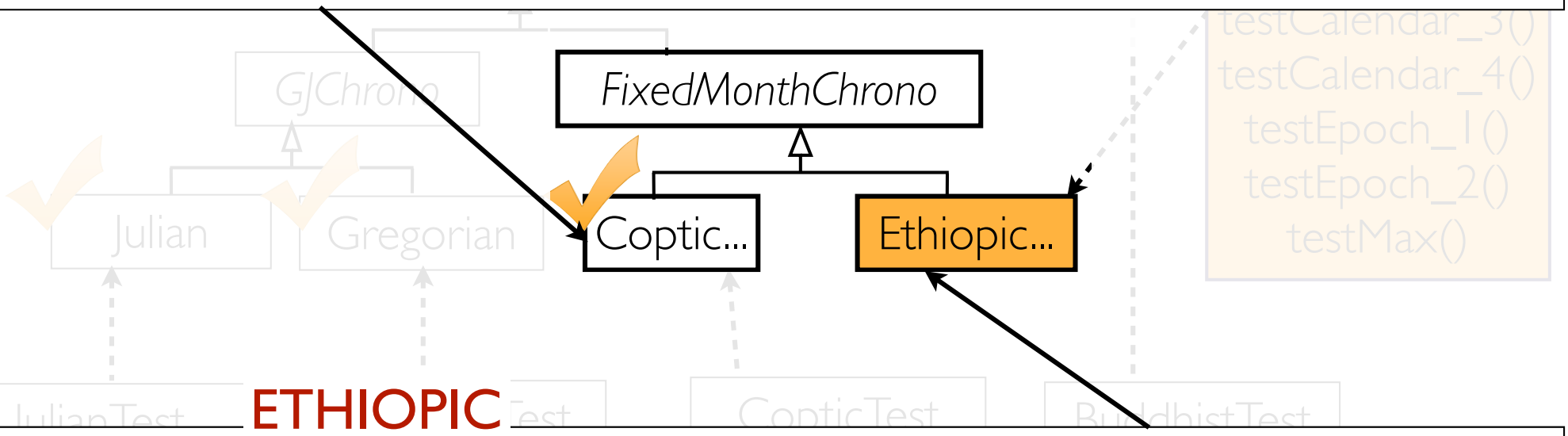


ETHIOPIC

```
Chronology ~~COPTIC~~_UTC = EthiopicChronology.ETHIOPIC_UTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, ~~COPTIC~~_UTC);
assertEquals( EthiopicChronology.AM, epoch.getEra() )
...
```

Adapt Candidate Test Cases

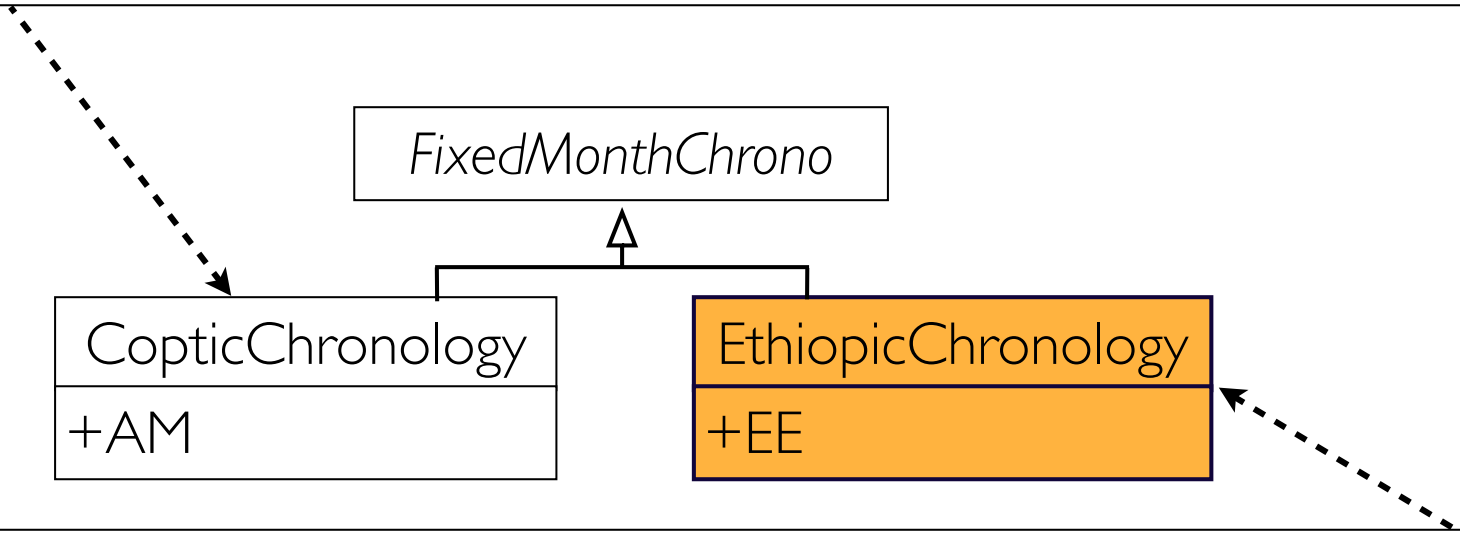
Undefined Fields

Missing Constructors

Missing Methods

Adapting Undefined Fields

```
Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, COPTIC_UTC);
assertEquals( CopticChronology.AM, epoch.getEra() )
...
```




```
Chronology ETHIOPIC_UTC = EthiopicChronology.getInstanceUTC();
DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, ETHIOPIC_UTC);
assertEquals( EthiopicChronology.AM, epoch.getEra() )
```

Adapting Undefined Fields

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Chronology COPTIC_UTC = CopticChronology.getInstanceUTC();
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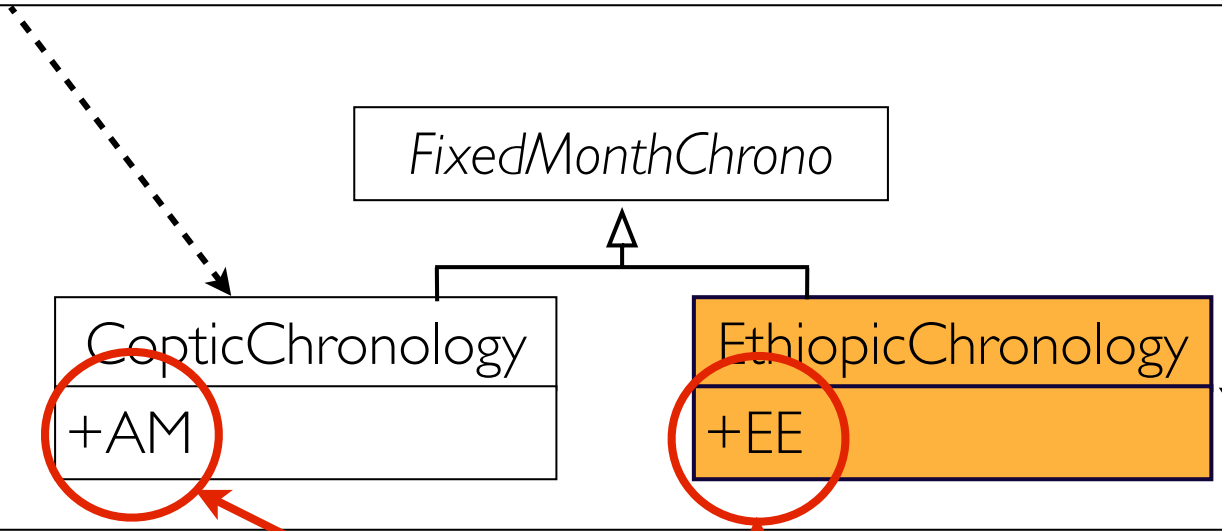


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DateTime epoch = new DateTime(1, 1, 1, 0, 0, 0, 0, ETHIOPIC_UTC);
assertEquals( EthiopicChronology.AM, epoch.getEra() )
```

```
class CopticChronology {

    /** Serialization lock */
 long serialVersionUID = -59L;

 /**
 * Constant value for ...
 */
 public static final int AM =
  DateTimeConstants.CE;

 /** A singleton era field. */
 private DateTimeField
  ERA_FIELD = new
  SingleEraDateTimeField("AM");
```

```
class EthiopicChronology {

 /** Serialization lock */
 long serialVersionUID = -59L;

 /**
 * Constant value for ...
 */
 public static final int EE =
  DateTimeConstants.CE;

 /** A singleton era field. */
 private ateTimeField
  ERA_FIELD = new
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```

+AM

+EE

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+EE

```
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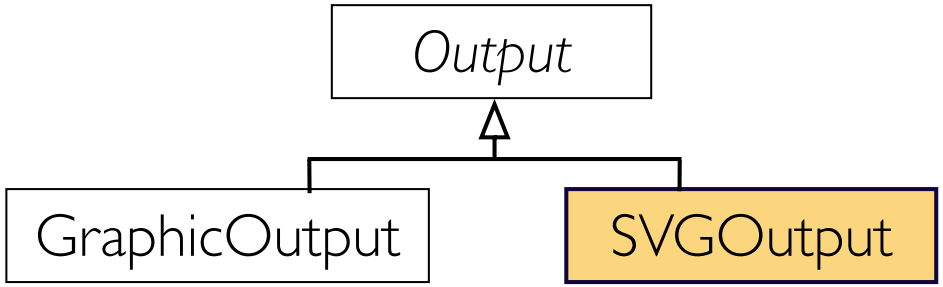
assertEquals( EthiopicChronology.AM, epoch.getEra() )
```

EE

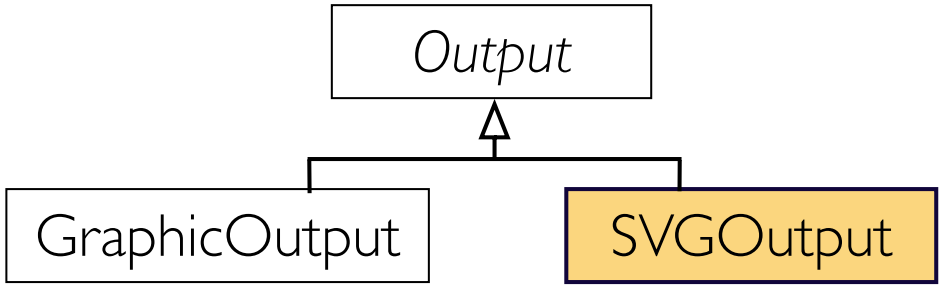
Adapting Undefined Constructors




```
public void testDefaultFont() {
 g = new GraphicsMock();
 output = new GraphicsOutput(
      g,
      DefaultEnv.DEFAULT_FONT,
      fgColour,
      bgColour);
 [..]
 assertEquals("graphicsOutput",
output.toString());
}
```

```
public void testDefaultFont() {
 g = new GraphicsMock();
 output = new SVGOutput(
      g,
      DefaultEnv.DEFAULT_FONT,
      fgColour,
      bgColour);
 [..]
 assertEquals("graphicsOutput",
output.toString());
}
```

Adapting Undefined Constructors

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}
```

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public void testDefaultFont() {
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 output = new SVGOutput(
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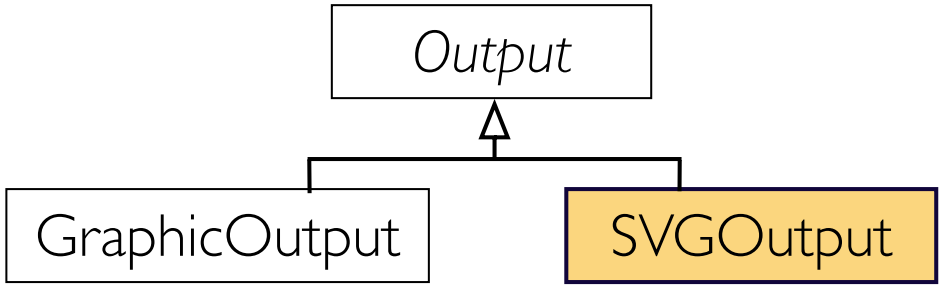
      DefaultEnv.DEFAULT_FONT,
      fgColour,
      bgColour);

 ertEquals("graphicsOutput",
 ut.toString());
```

Compilation error:
The constructor SVGOutput(Graphics2D, Font, Color, Color) is undefined

Adapting Undefined Constructors




```
public void testDefaultFont() {
 g = new GraphicsMock();
 ou                    GraphicsOutput(

                                    DEFAULT_FONT,

 [
 g                                   LA",
ou                                  ));
}
```

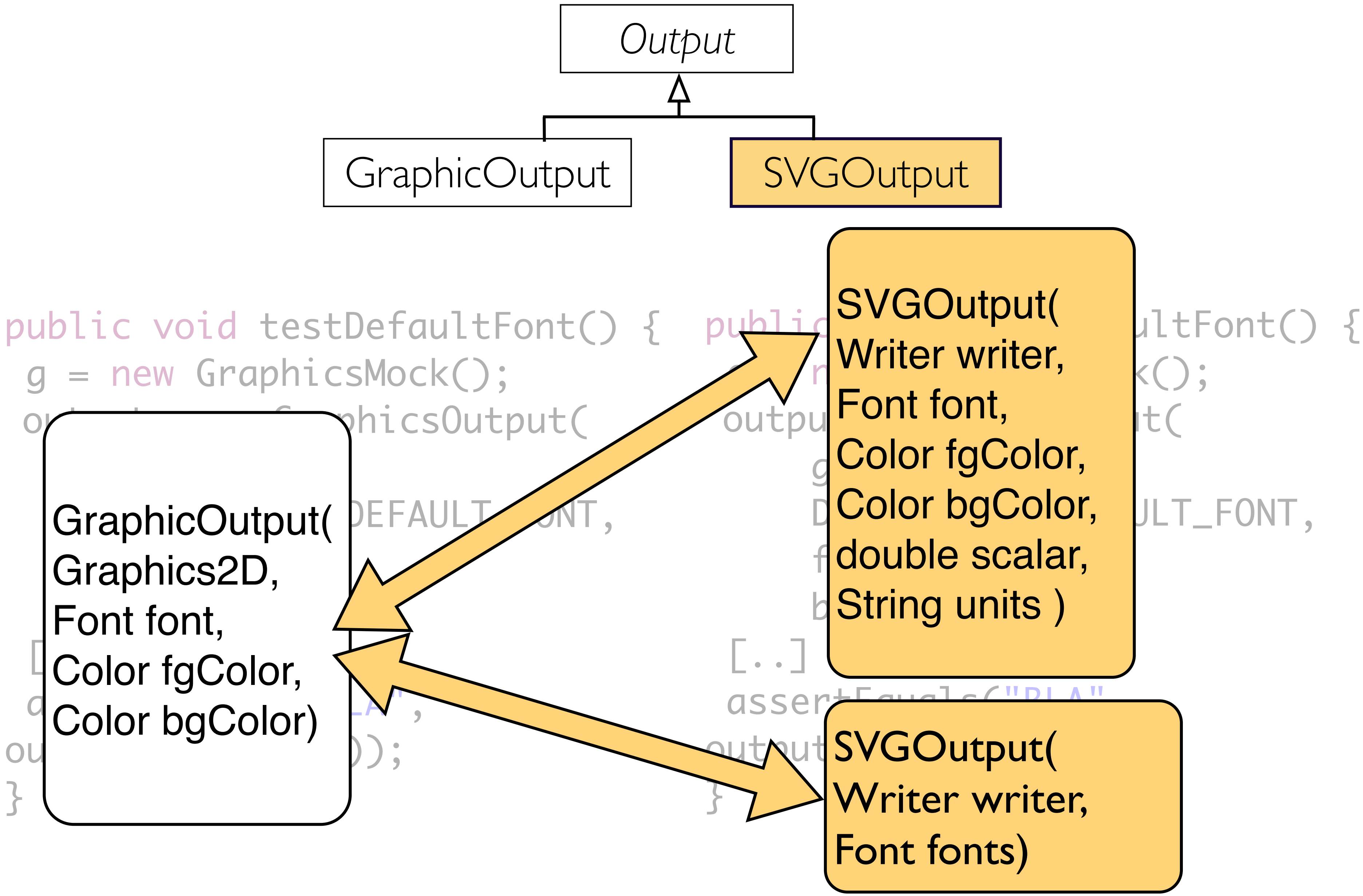
GraphicOutput(
Graphics2D,
Font font,
Color fgColor,
Color bgColor)

```
public                              ultFont() {
 g = n                              k();
 outpu                              t(
      g
      D                             ULT_FONT,
      f
      b
 [..]
 assert
output
}
```

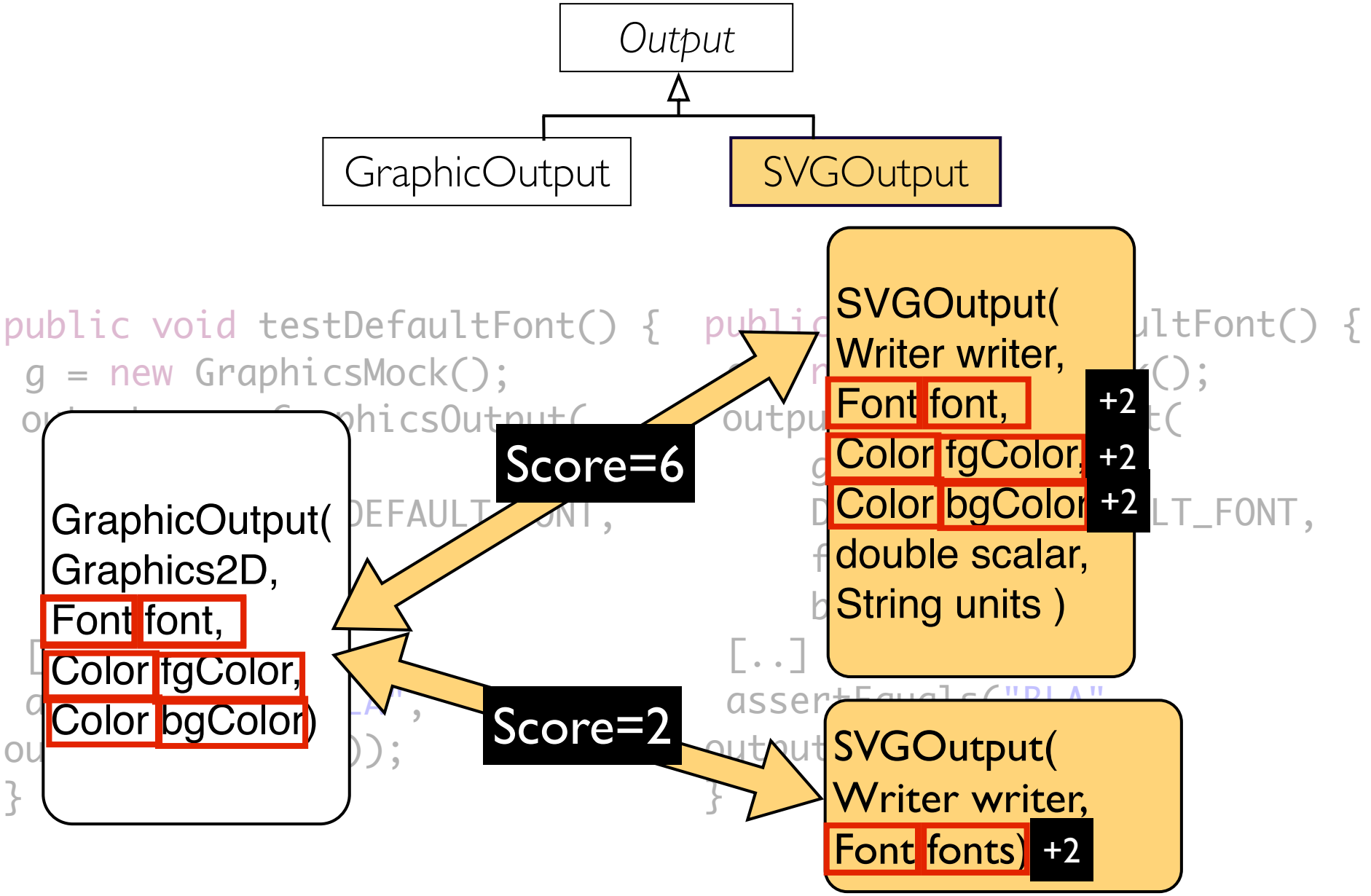
SVGOutput(
Writer writer,
Font font,
Color fgColor,
Color bgColor,
double scalar,
String units)

SVGOutput(
Writer writer,
Font fonts)

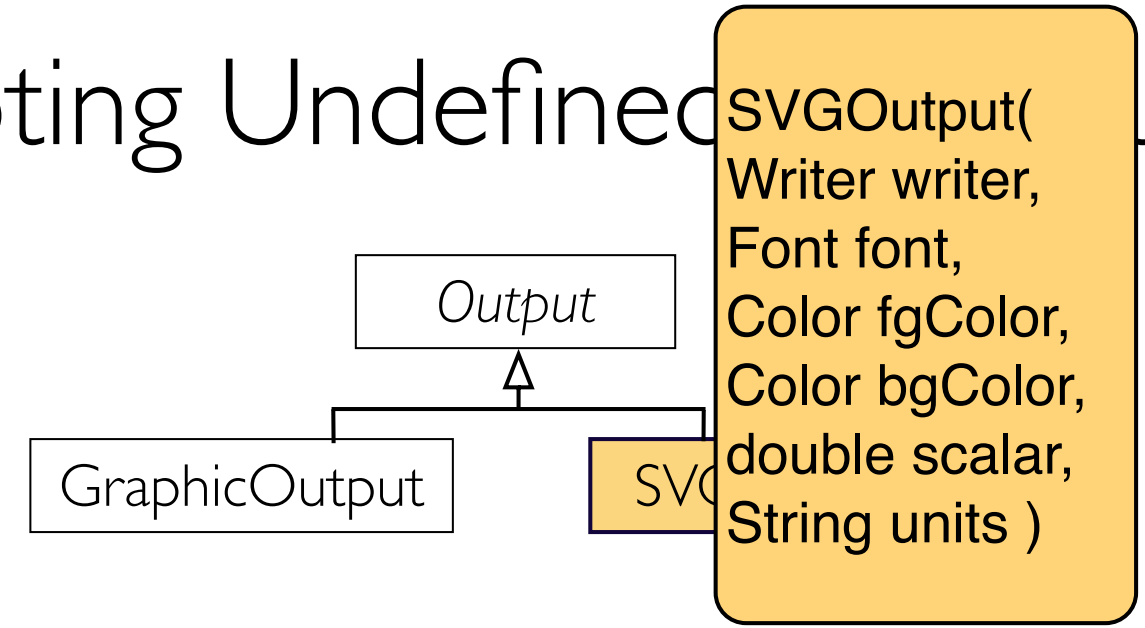
Adapting Undefined Constructors



Adapting Undefined Constructors



Adapting Undefined uctors

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 output = new GraphicsOutput(
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      bgColour);
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 assertEquals("graphicsOutput",
output.toString());
}
```

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      fgColour,
      bgColour,
       ...,
        ...;
 [..]
 assertEquals("graphicsOutput",
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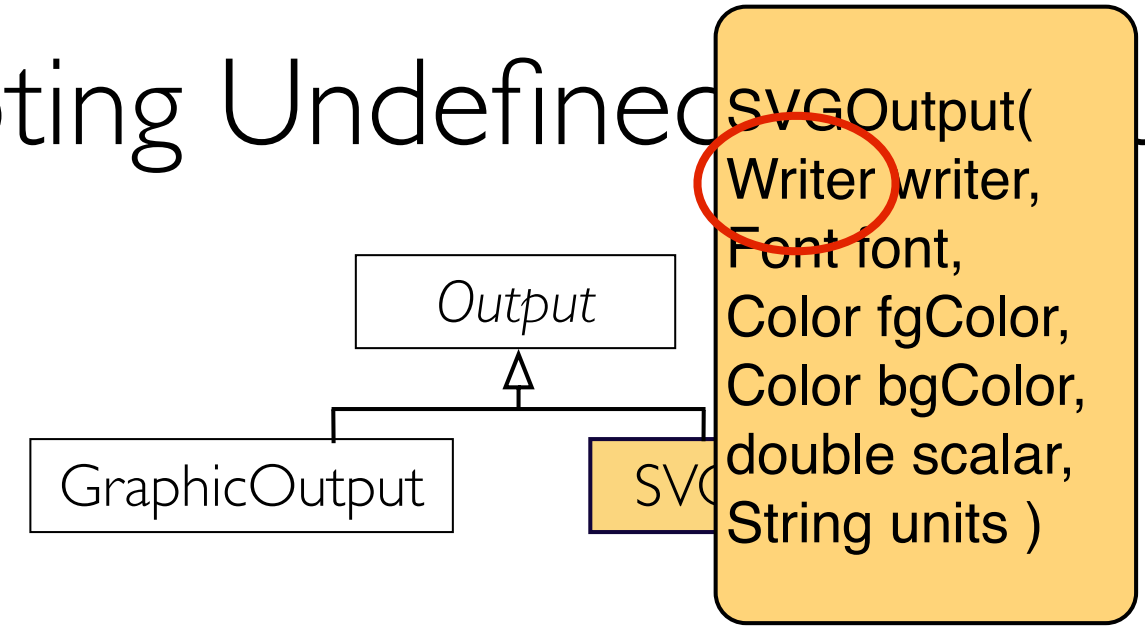
}
```

Adapting Undefined uctors

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      DefaultEnv.DEFAULT_FONT,
      fgColour,
      bgColour);
 [..]
 assertEquals("graphicsOutput",
output.toString());
}
```

```
public void testDefaultFont() {
 g = new GraphicsMock();
 output = new SVGOutput(
      new StringWriter( EasyMock(Writer)),
      DefaultEnv.DEFAULT_FONT,
      fgColour,
      bgColour,
        ...,
         ...;
 [..]
 assertEquals("graphicsOutput",
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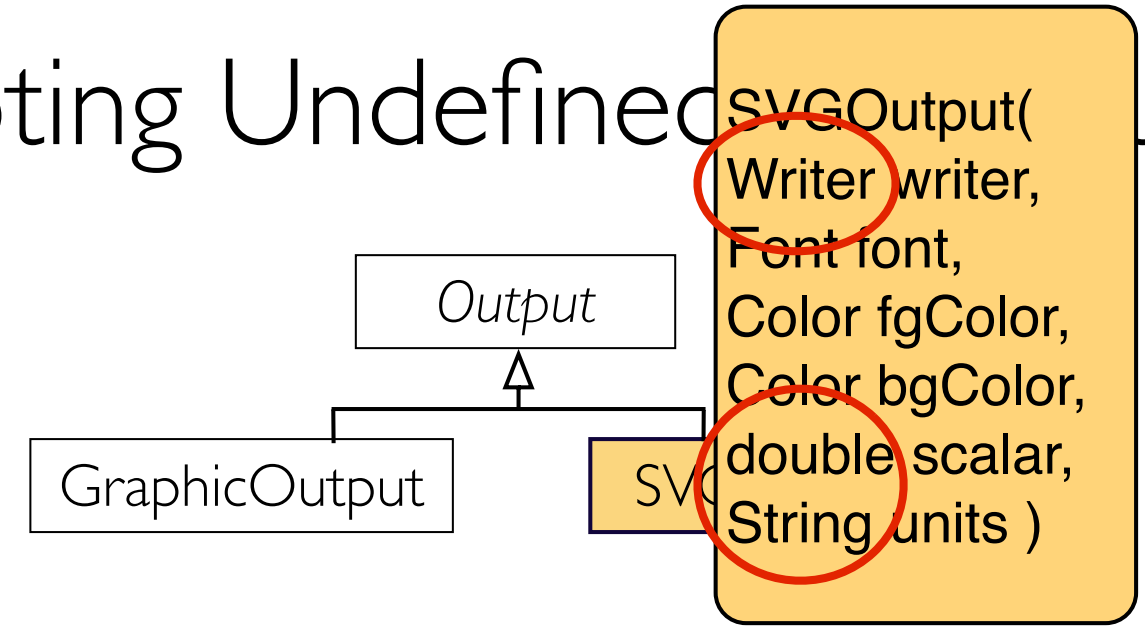
}
```

Adapting Undefined uctors

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Barbecue 1.5b1

Adapting Runtime Failures

Test Failures: apply ReAssert

Daniel et. al.[ASE09,ISSTA10]

```
public void testDefaultFont() {
 g = new GraphicsMock();
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}
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Daniel et. al.[ASE09,ISSTA10]

```
public void testDefaultFont() {
 g = new Graphi
 output = new SV
      new String
      DefaultEnv
      fgColour,
      bgColour,
      0,
      “”;
 [..]
 assertEquals("graphicsOutput", output.toString());
}
```

junit.framework.AssertionFailedError:
expected:<SVGOutput> but
was:<graphicsOutput>

Adapting Runtime Failures

Test Failures: apply ReAssert

Daniel et. al.[ASE09,ISSTA10]

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public void testDefaultFont() {
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      bgColour,
      0,
      “”;
 [..]
 assertEquals("graphicsOutput", output.toString());
}
```

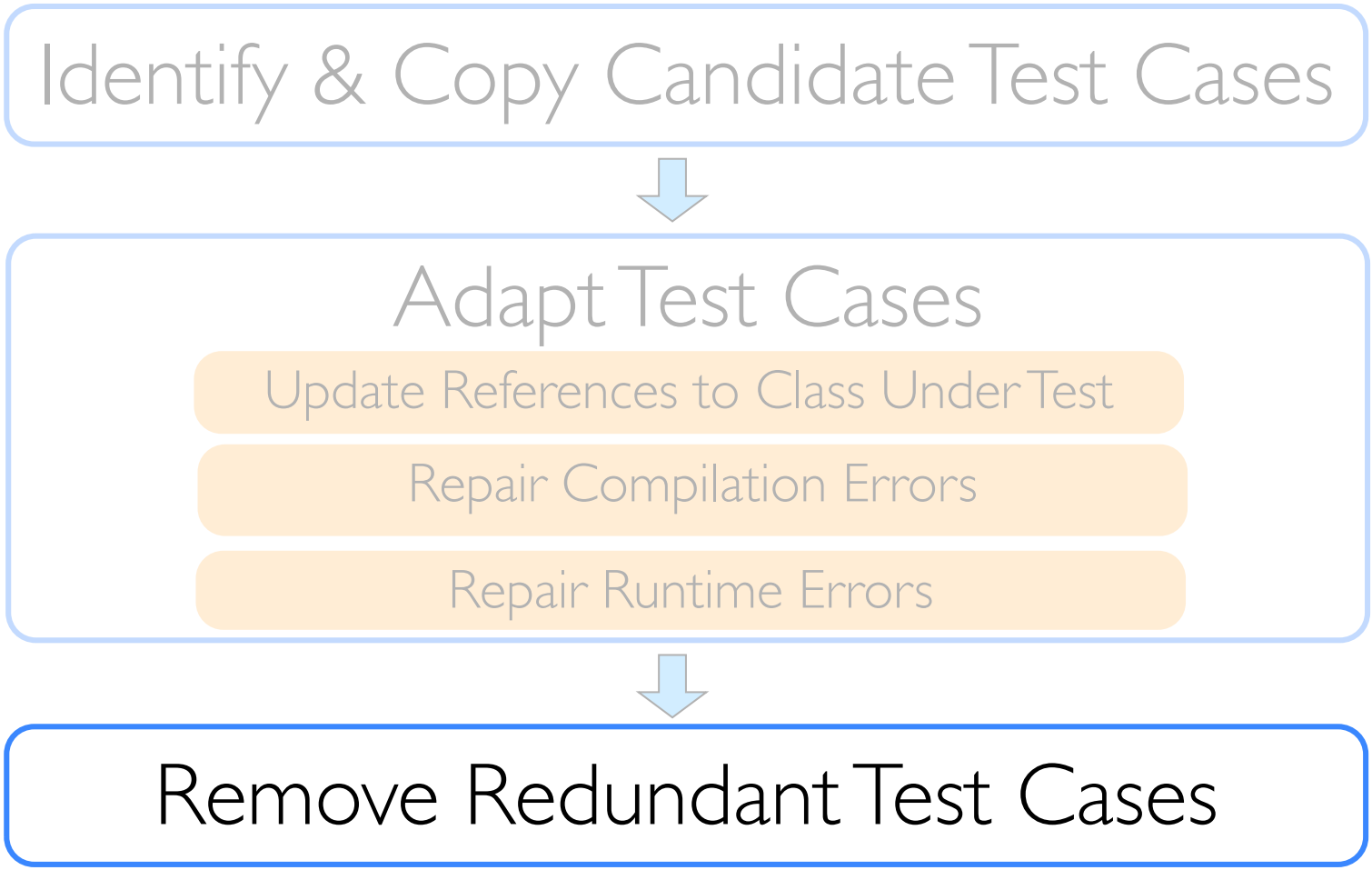
"SVGOutput"

Adapting Runtime Failures

Uncaught Exceptions:

involve users

Add Test Cases



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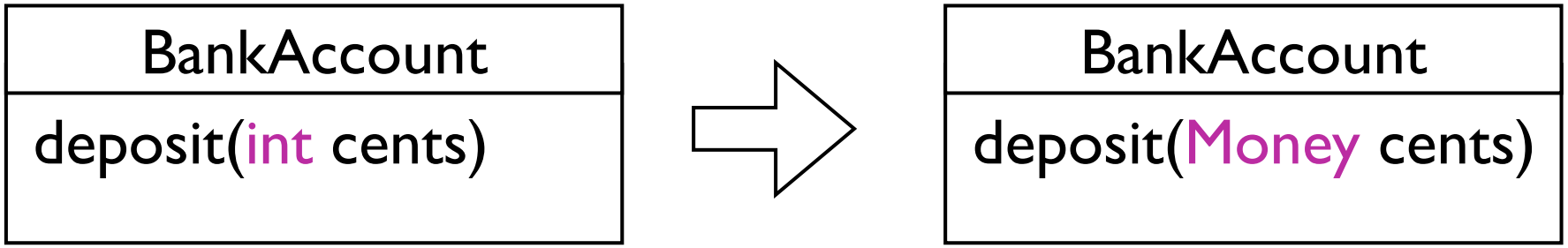
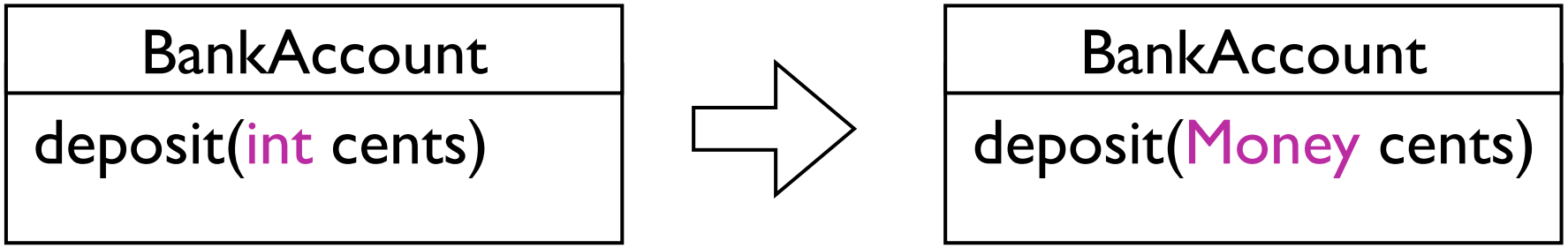
- Return Type Change

Repair Signature Changes




```
BankAccount account = new BankAccount();
int amount = 500;
account.deposit(amount);
assertEquals( 500, account.getBalance());
```

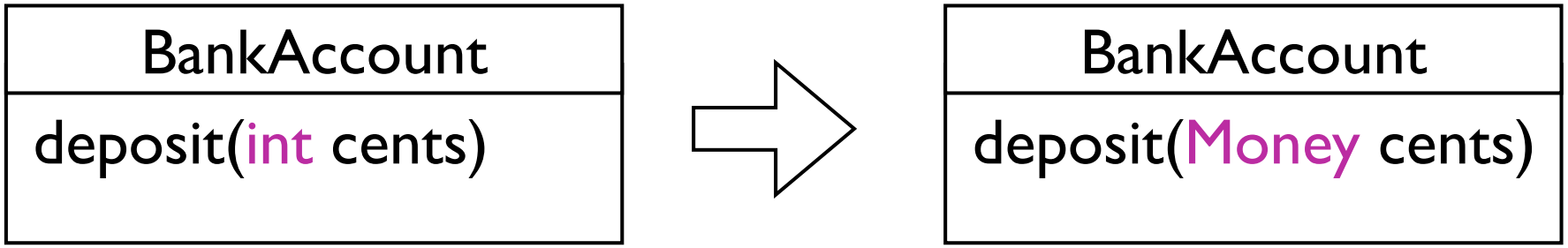
Repair Signature Changes



Compilation error:
Method *deposit(Money)* in the type BankAccount is not applicable for the arguments (int)

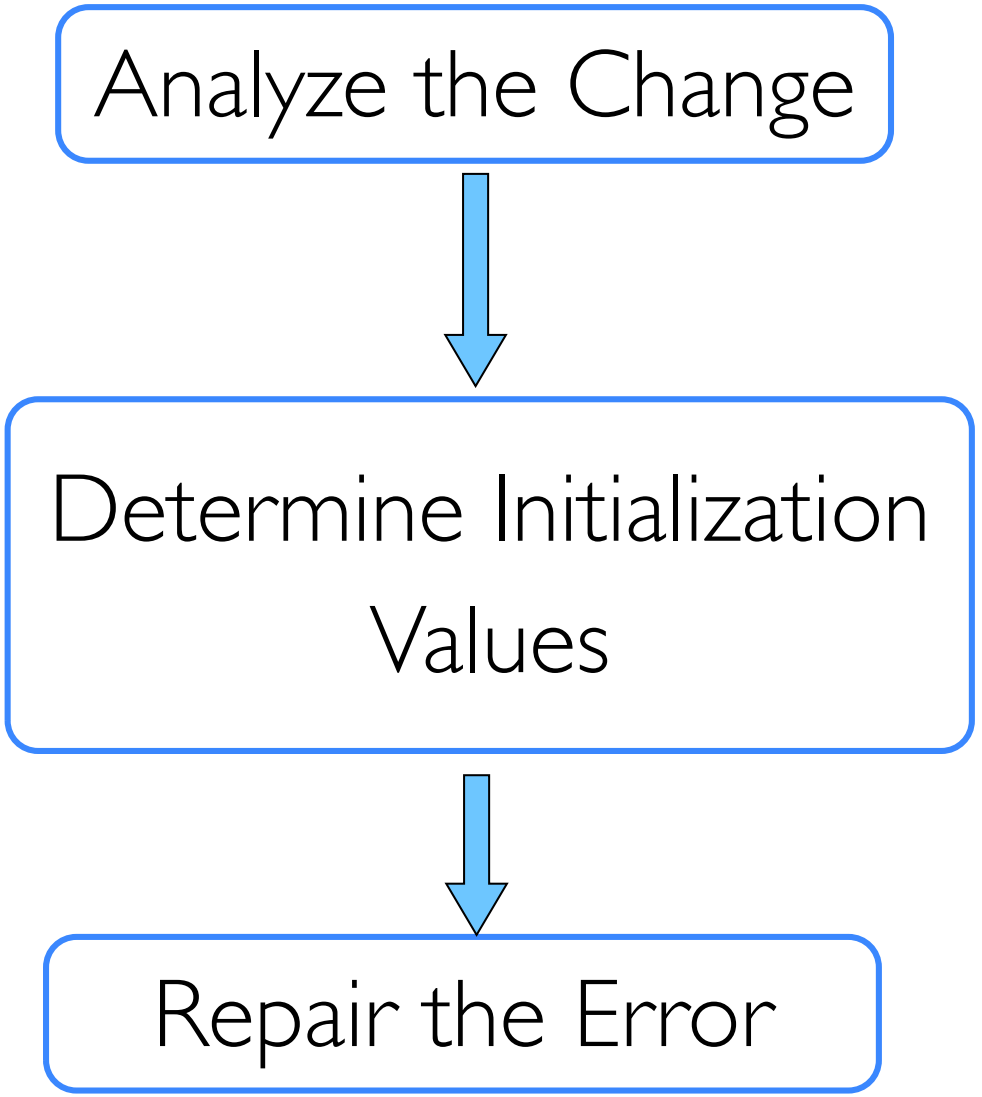
```
BankAccount account = new BankAccount();
int amount = 500;
account.deposit(amount);
assertEquals( 500, account.getBalance());
```

Repair Signature Changes

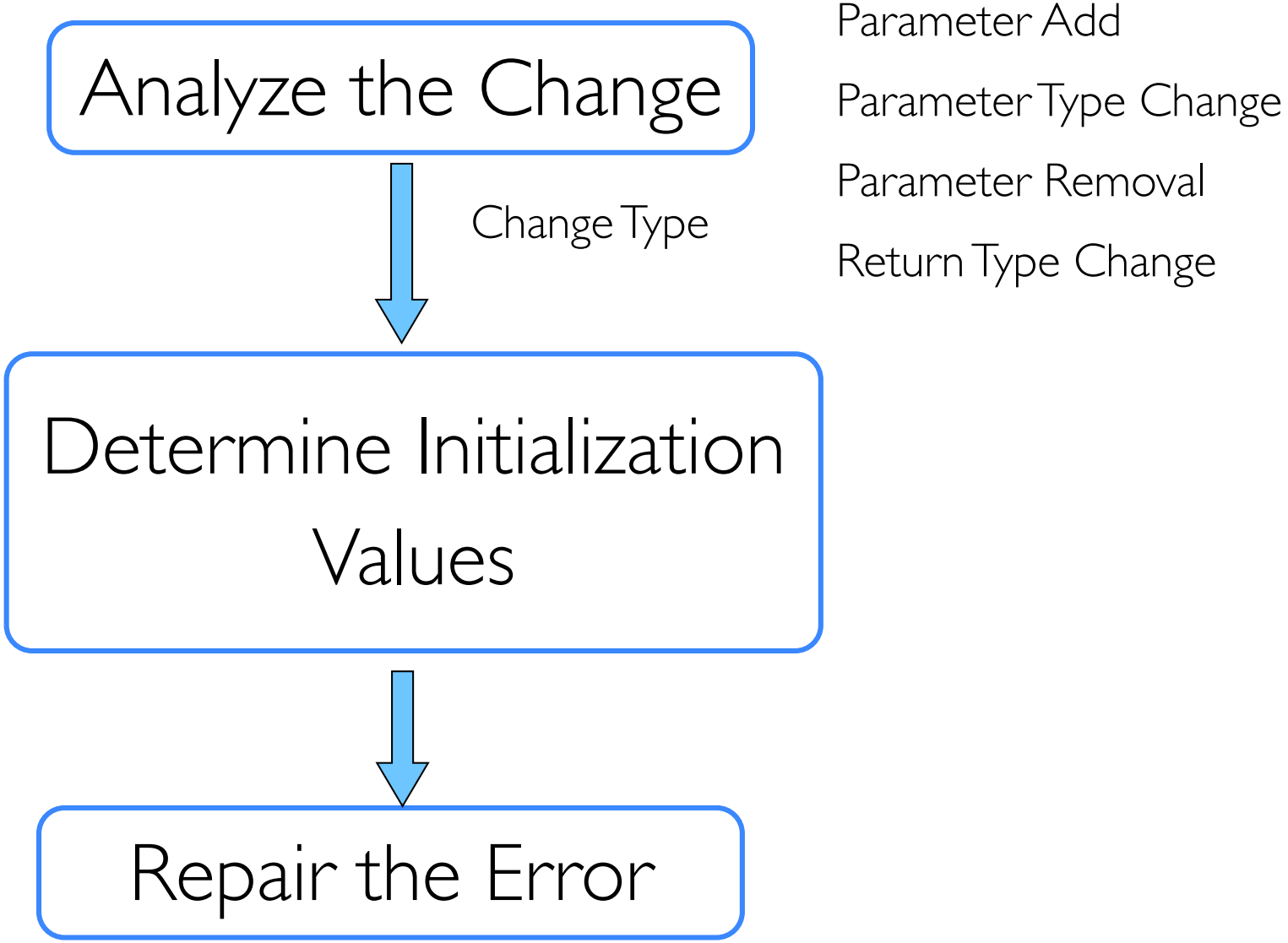



```
BankAccount account = new BankAccount();
Money money = new Money(500);
account.deposit(money);
assertEquals(500, account.getBalance());
```

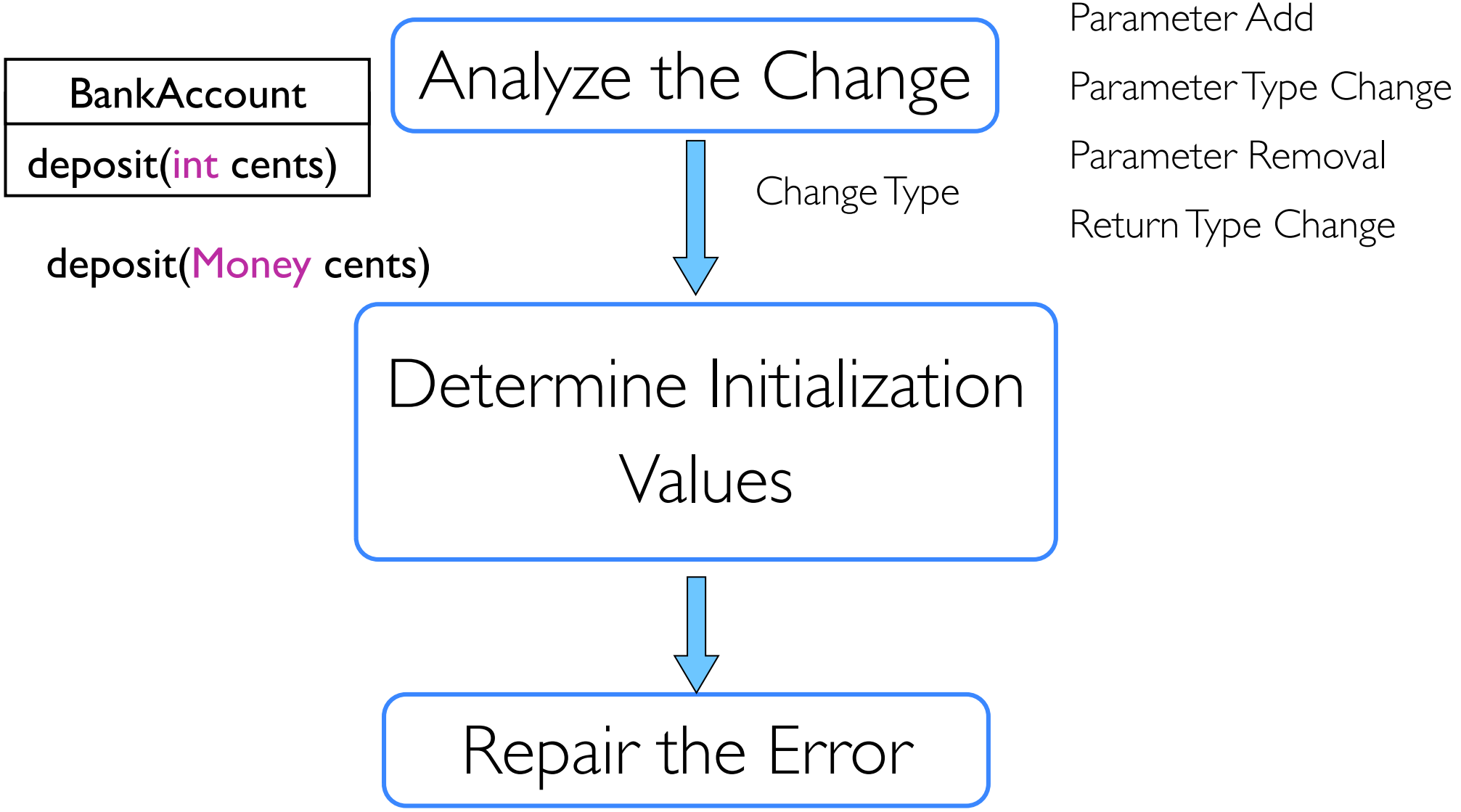
Repair Signature Changes



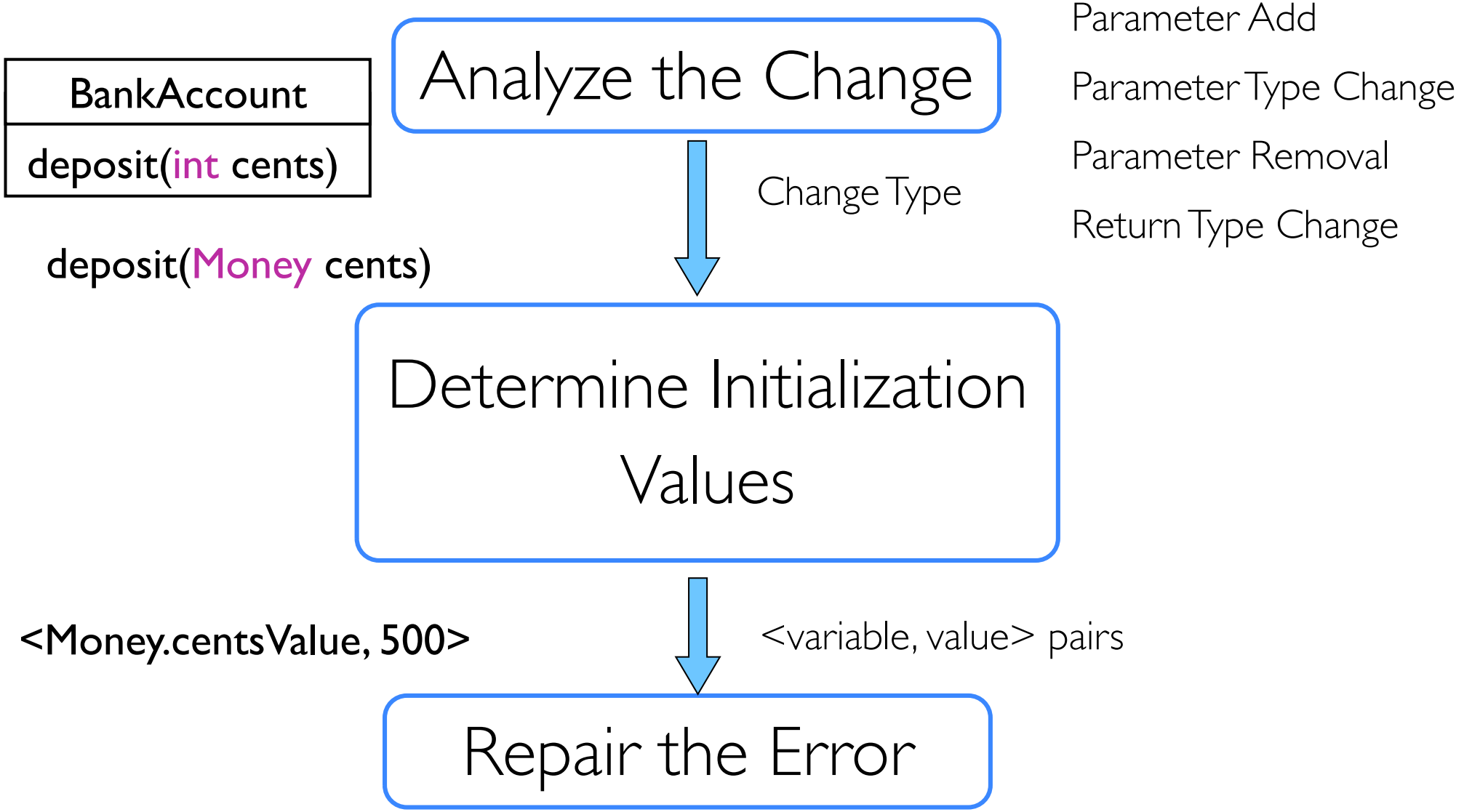
Repair Signature Changes



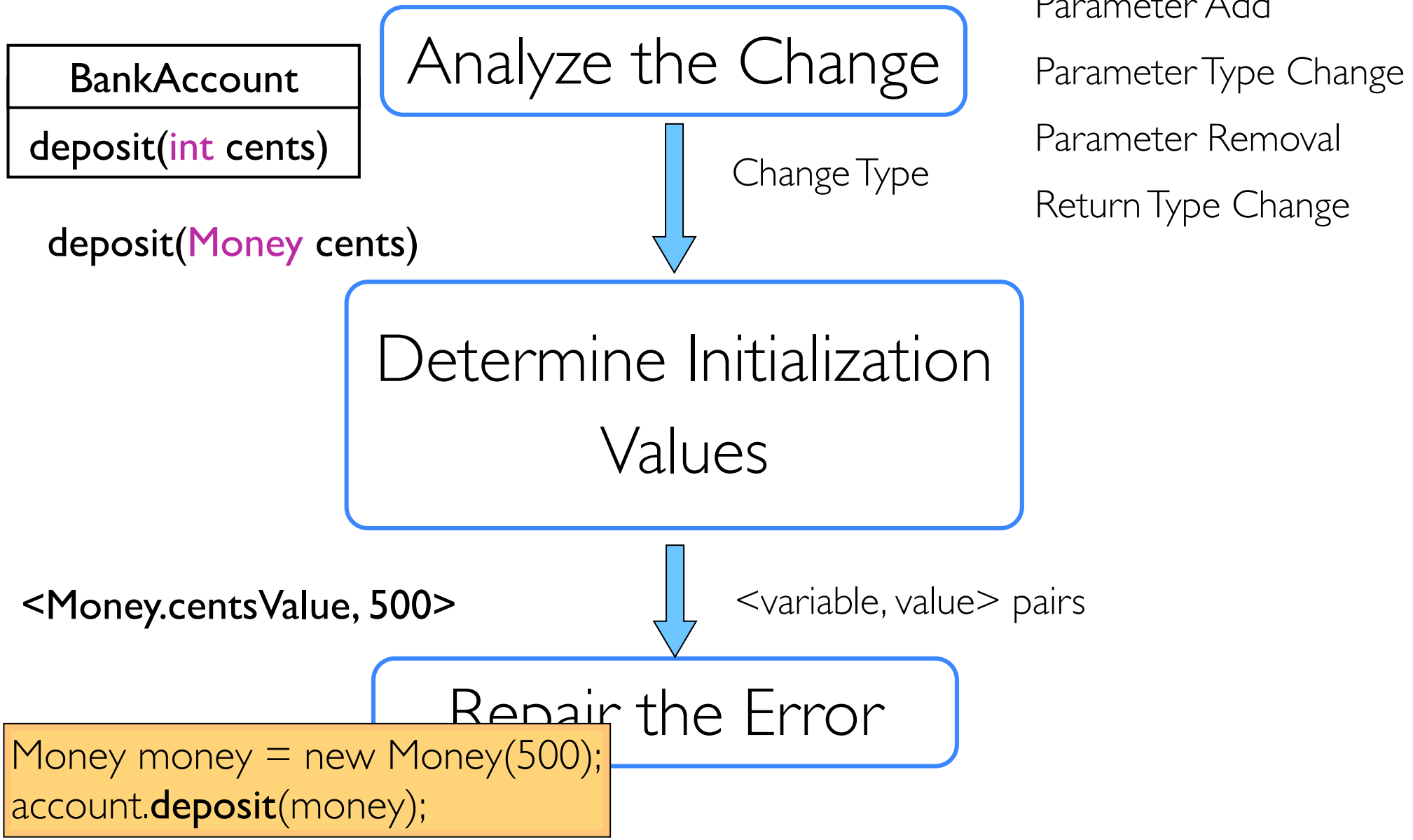
Repair Signature Changes



Repair Signature Changes



Repair Signature Changes



EVALUATION

Q1: APPLICABILITY

Q2: EFFECTIVENESS

Test Care Assistant

Add Test Cases for new Modules

- new Class in Hierarchy
- new Interface Implementation
- New Overloaded Method
- New Overridden Method

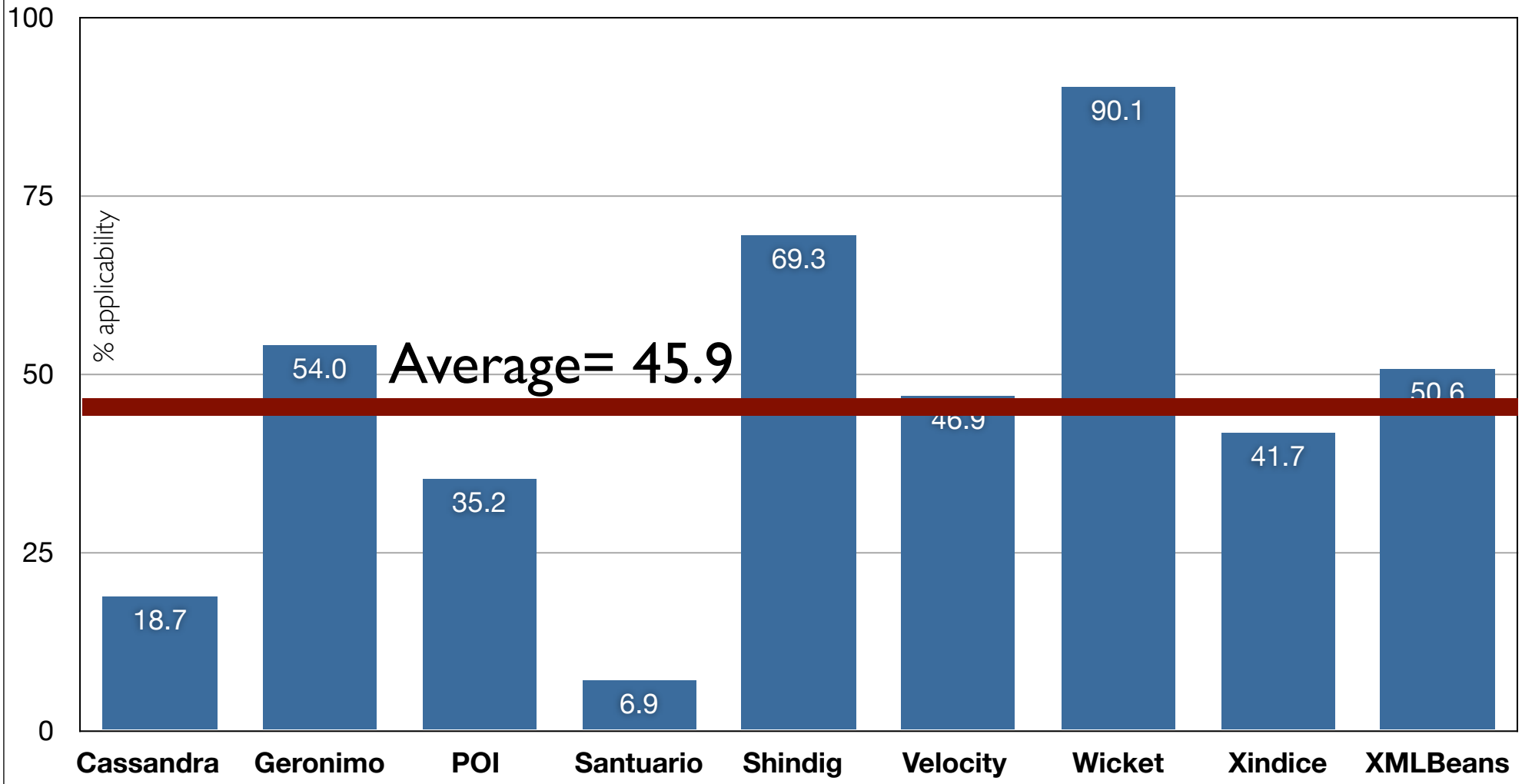
Repair Compilation Errors due to Signature Changes

- Parameter Addition
- Parameter Type Change
- Parameter Removal
- Return Type Change

Repair Signature Changes Applicability

Subject	# versions
Cassandra	19
Geronimo	4
POI	6
Santuario	4
Shindig	6
Velocity	15
Wicket	7
Xindice	9
XMLBeans	7

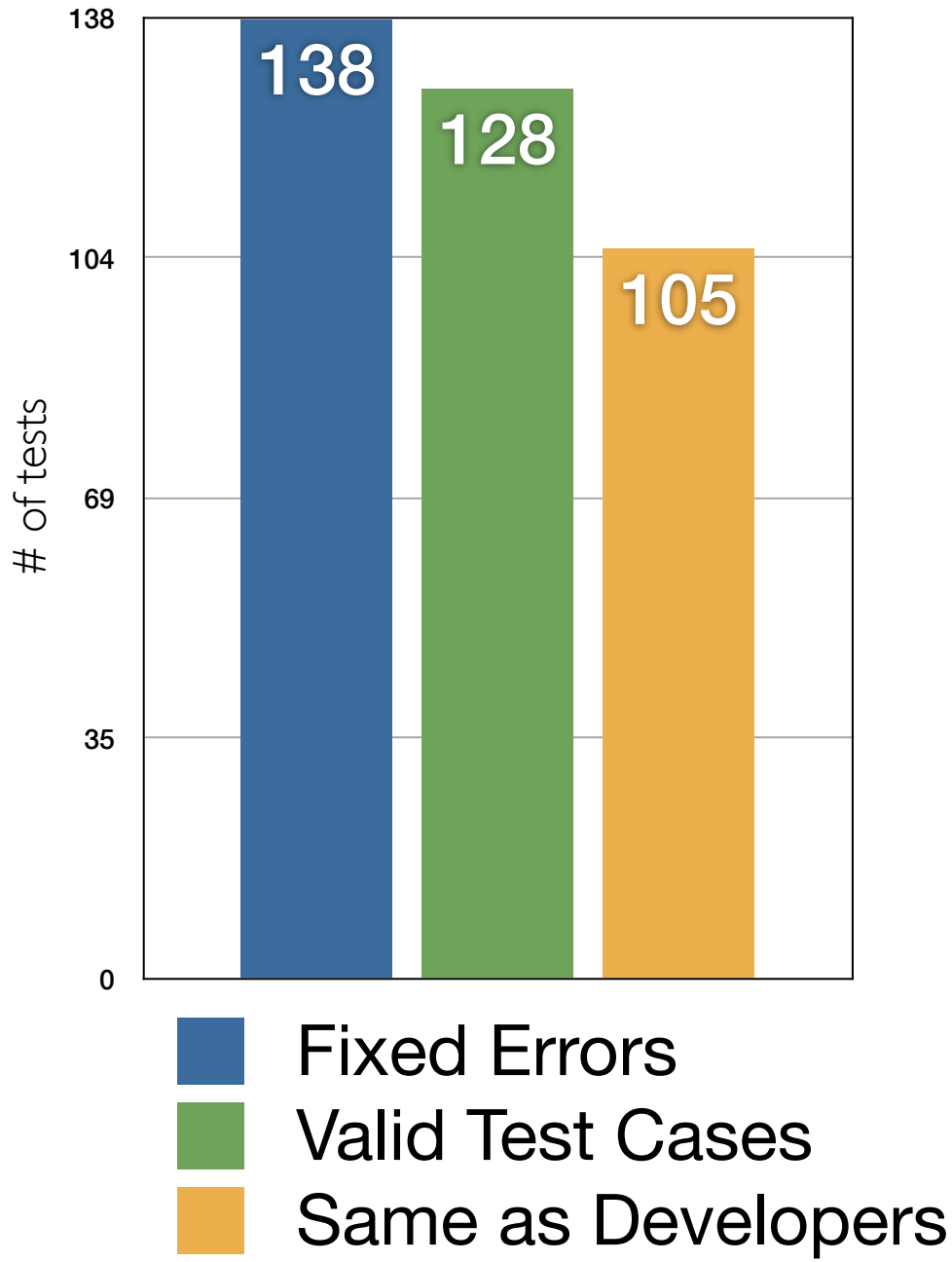
Repair Signature Changes Applicability



Repair Signature Changes Effectiveness

Project	# Versions	# Tests
PMD	13	**99**
JodaTime	2	**19**
JFreeChart	6	**21**
	21	**138**

Repair Signature Changes Effectiveness



Test Care Assistant

Add Test Cases for new Modules

- new Class in Hierarchy
- new Interface Implementation
- New Overloaded Method
- New Overridden Method

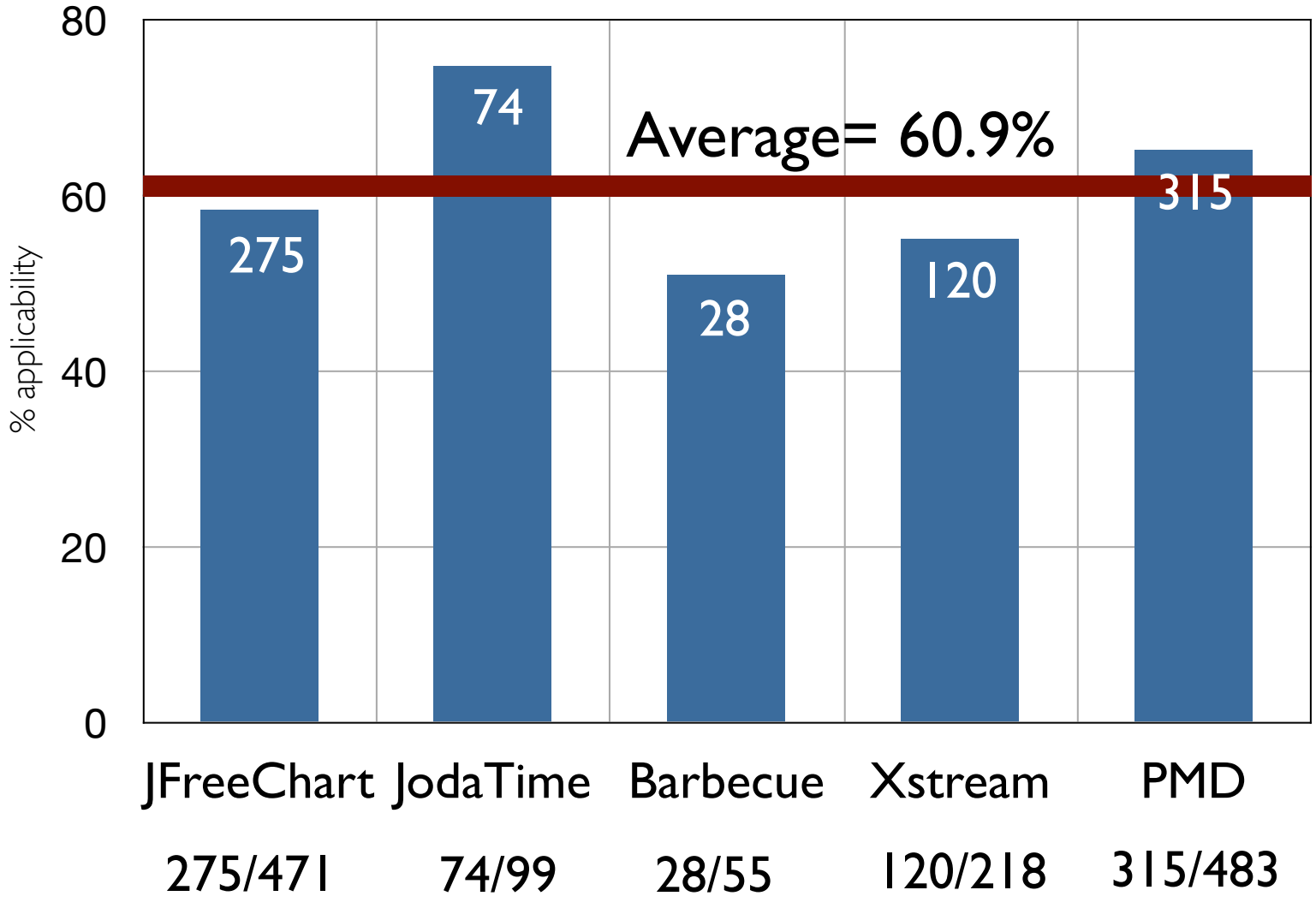
Repair Compilation Errors in Signature Changes

- Parameter Addition
- Parameter Type Change
- Parameter Removal
- Return Type Change

Applicability

Software	version	KLOC	classes
JFreeChart	0.96	217	471
JodaTime	1.62	64	99
Barbecue	1.5	9	55
Xstream	1.31	25	218
PMD	4.2	65	483

Applicability



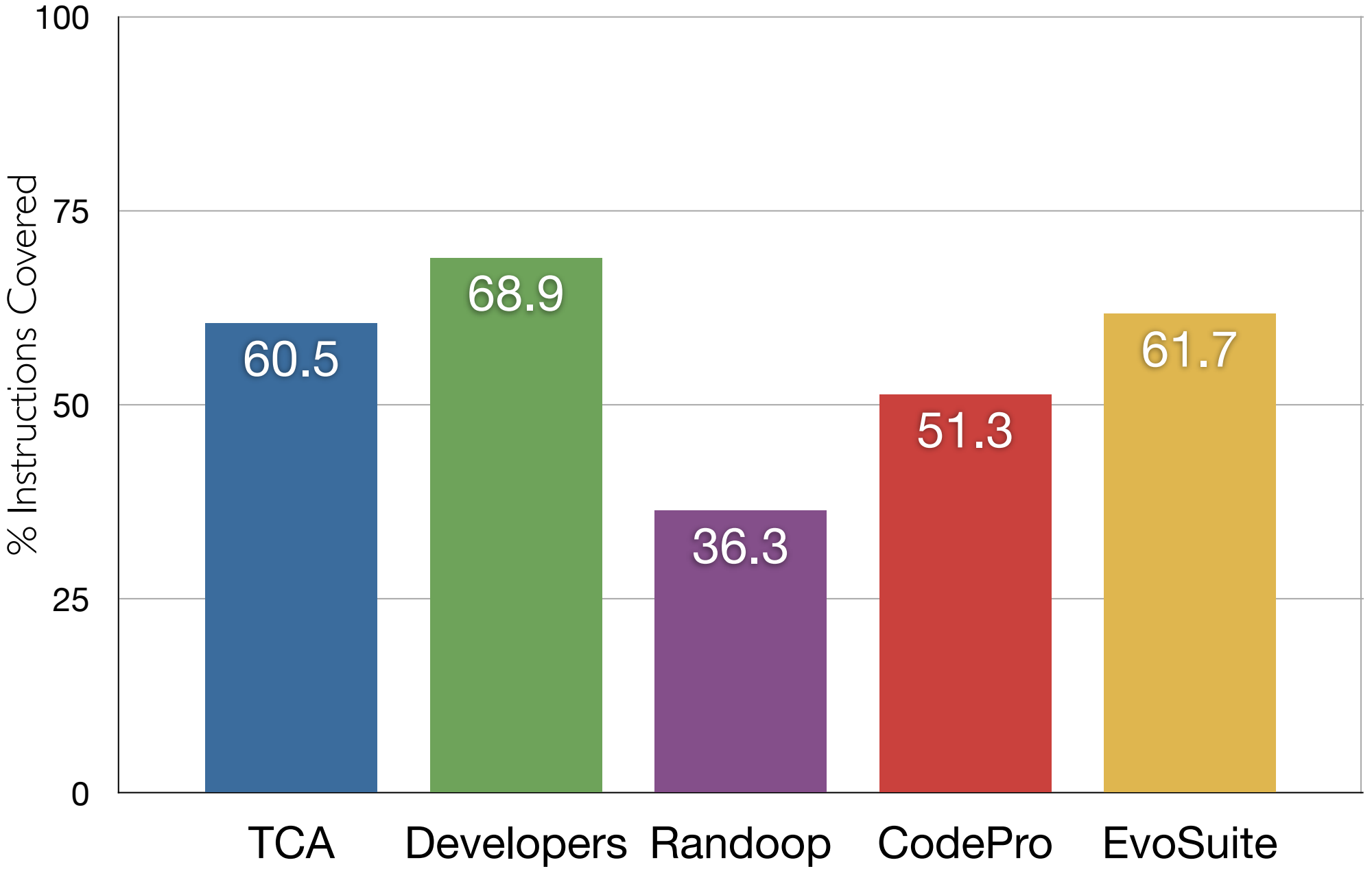
% classes for which TCA can generate tests

Effectiveness

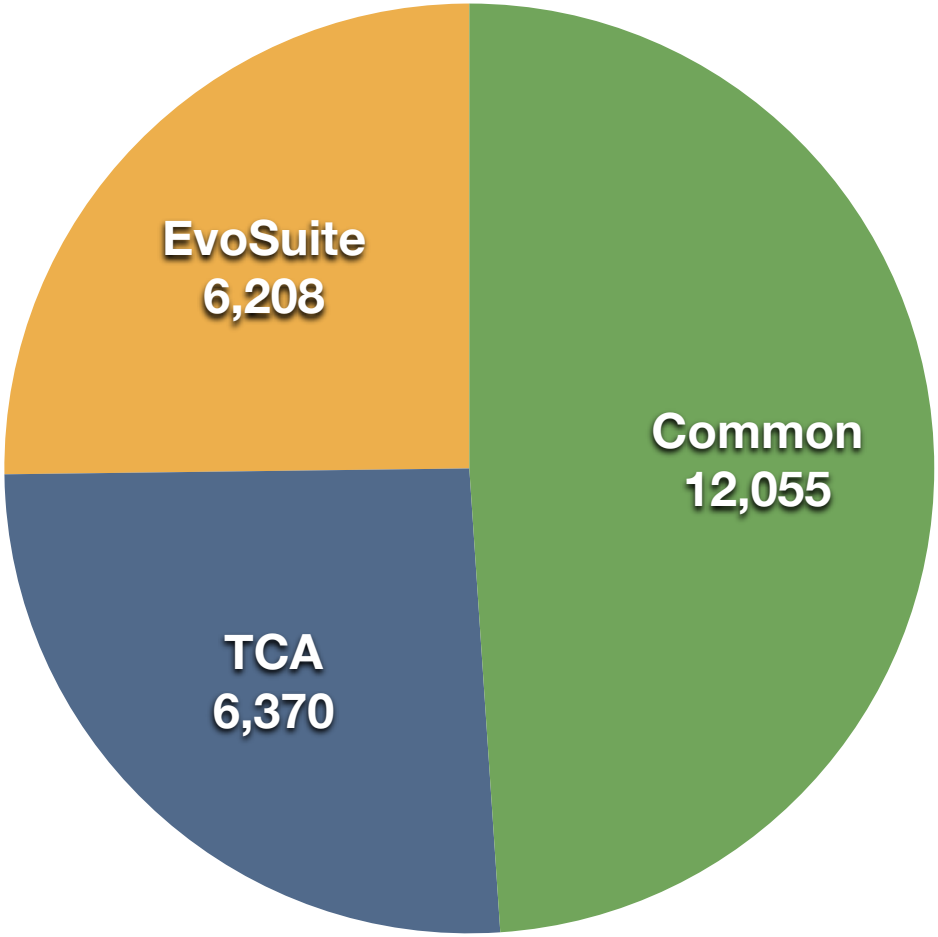
TCA	Developer's	Test Generation Tools
 Randoop	Google CodePro AnalytiX™ 	
• random test generation • run for 50 sec on each class	• industrial, coverage based • run for each classes	• search-based testing • run with assertion generation

Subjects	classes
Xstream 1.31	36
PMD 4.2	56
Barbecue 1.5b1	12
JodaTime 1.62	32
JfreeChart 1.013	204
Total	**340**

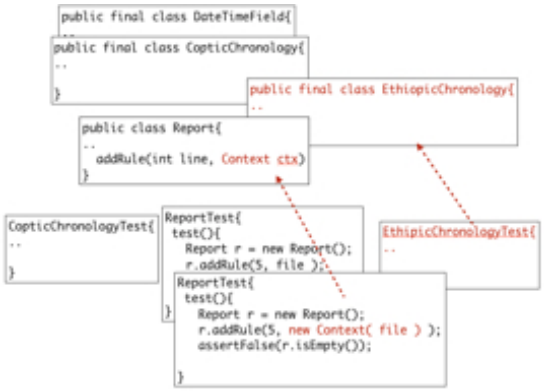
Coverage Results



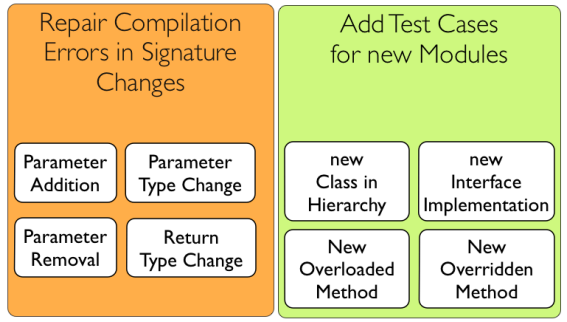
TCA and Evosuite are Complementary



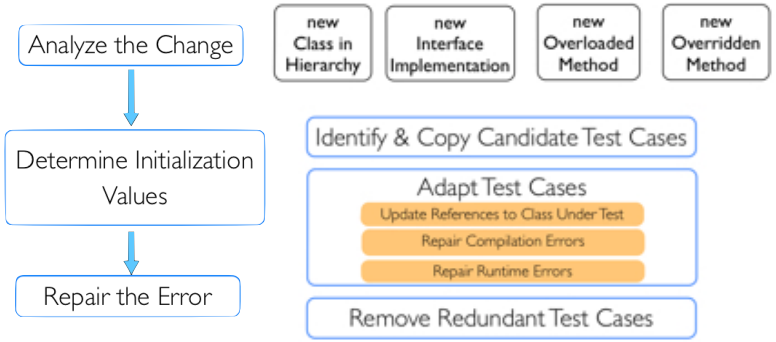
Covered Statements



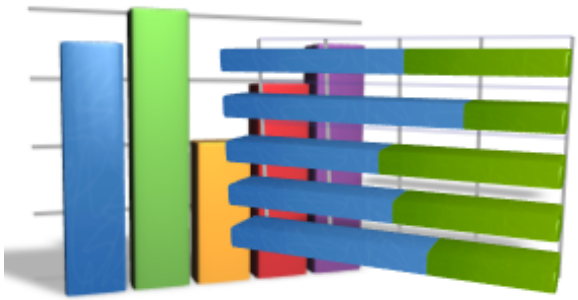
Test Evolution



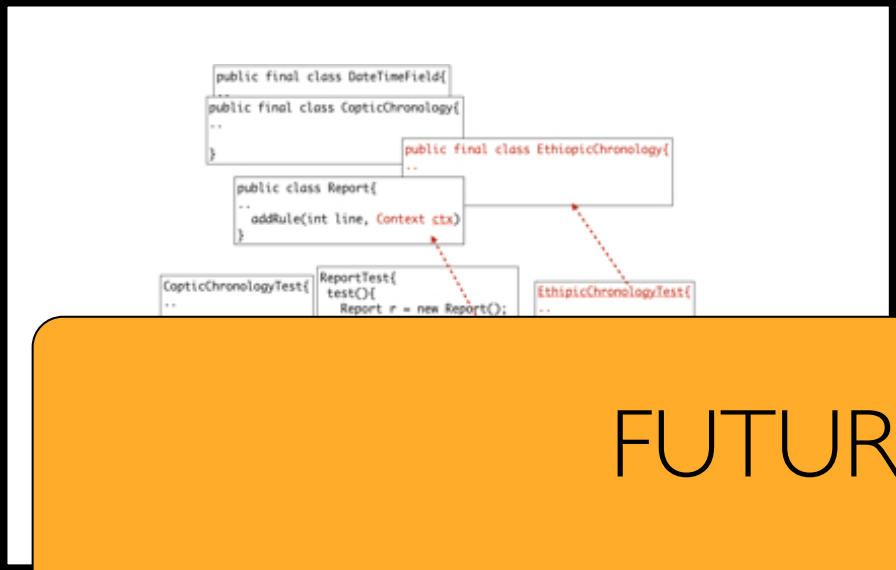
Test Reuse Algorithms

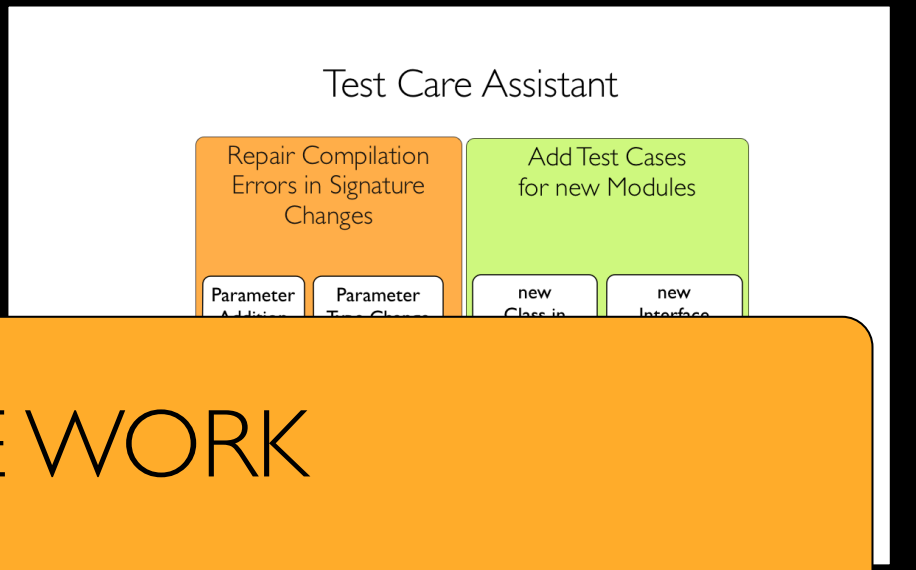


Test Care Assistant



Evaluation





FUTURE WORK

- Evaluate other Test Reuse Algorithms
- User study on readability of generated tests

Test Care Assistant

Evaluation