Dealing with objects
Part III

Alexandre Bergel
abergel@dcc.uchile.cl
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Goal of this lecture

Understanding some of the *design rules* that govern *inheritance*

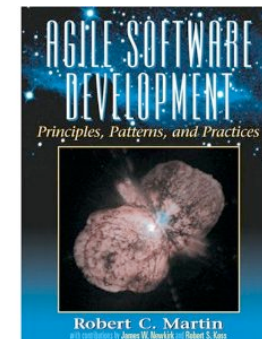*See practical problems* of class inheritance

See a *bit* of *theory*

See few *research results* in object-oriented programming languages

Recommended Texts

Agile Software Development, Principles, Patterns, and Practices

Robert C. Martin "Uncle Bob", 2002

the research icon

The *research* icon indicates topics
that are not mandatory for the controls
and the exam

Outline

1. Liskov principle

    1. theory

    2. concrete applications

2. Inheritance examples

3. Example1: Swing and AWT

4. Example2: The Smalltalk collection class hierarchy

Outline

1. Liskov principle

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Liskov substitution principle

Initially introduced in 1987 by Barbara Liskov

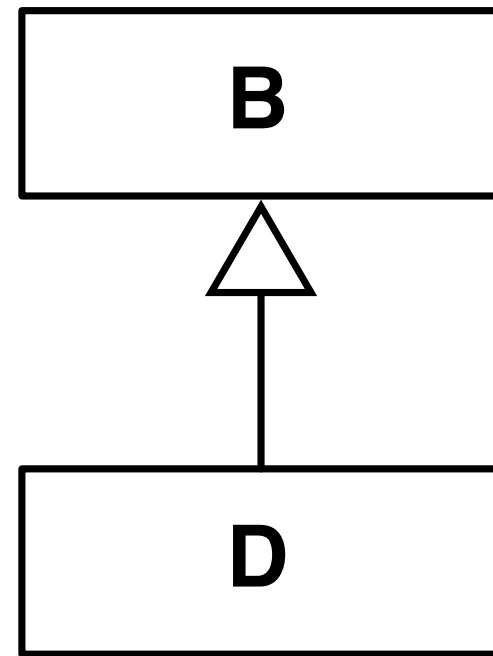Formulated in 1994 with Jeannette Wing as follows:

Let $q(x)$ be a property provable about objects x of type T. Then $q(y)$ should be true for objects y of type S where S is a subtype of T.

Liskov principle vulgarized
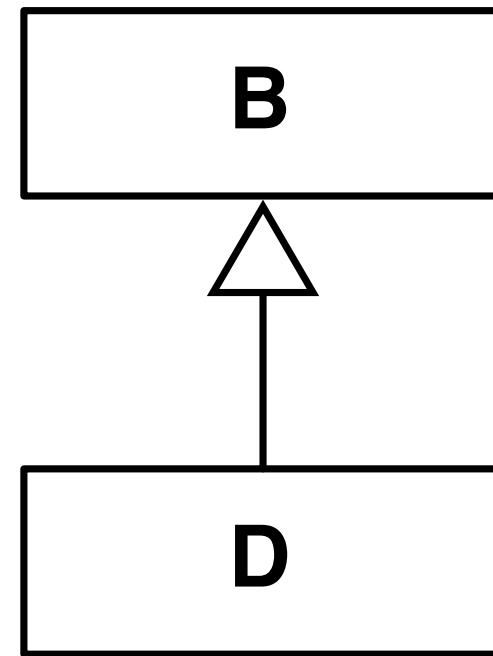
Subtypes must be substitutable for their base types

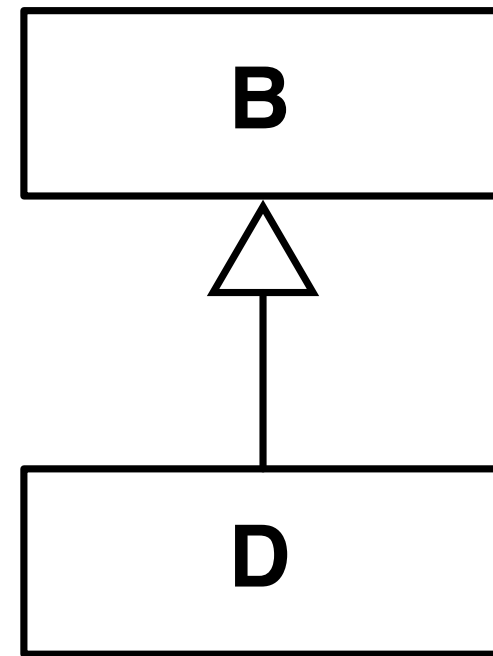# Liskov principle vulgarized

```
void f (B object) {
  ...
}
```

```
        ┌──────────┐
        │    B     │
        └────△─────┘
             │
        ┌────┴─────┐
        │    D     │
        └──────────┘
```

Liskov principle vulgarized

```
void f (B object) {
  ...
}
```

if `f(new B())` behaves correctly, `f(new D())` has to correctly behave as well

Fragile class

```
void f (B object) {
  ...
}
```

if `f(new B())` behaves correctly and `f(new D())` not, then we say that D is fragile in the presence of `f`

Some practical illustrations

Procedural coding style

Object initialization

Access privileges cannot be weakened

Procedural coding style

```java
public static long sumShapes(Shape shapes[]) {
    long sum = 0;
    for (int i=0; i<shapes.length; i++) {
        switch (shapes[i].kind()) {
        case Shape.RECTANGLE:        // a class constant
            sum += shapes[i].rectangleArea();
            break;
        case Shape.CIRCLE:
            sum += shapes[i].circleArea();
            break;
        }
    }
    return sum;
}
```

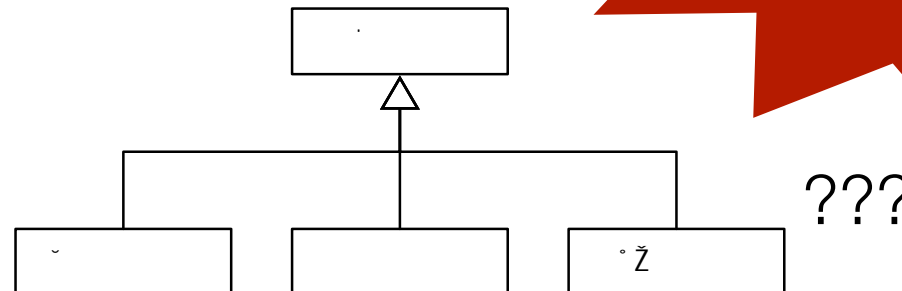???
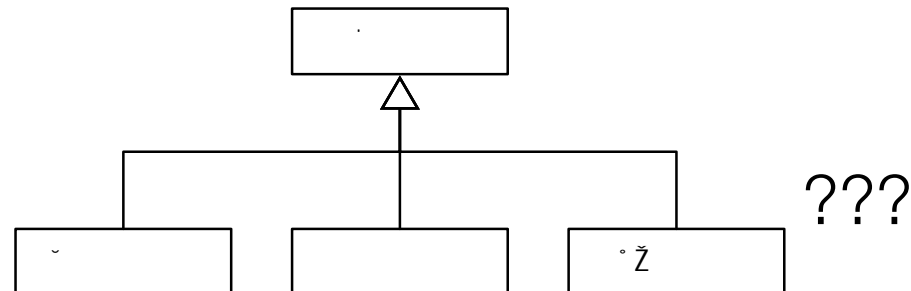
Procedural coding style

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            break;
        }
    }
    return sum;
}
```
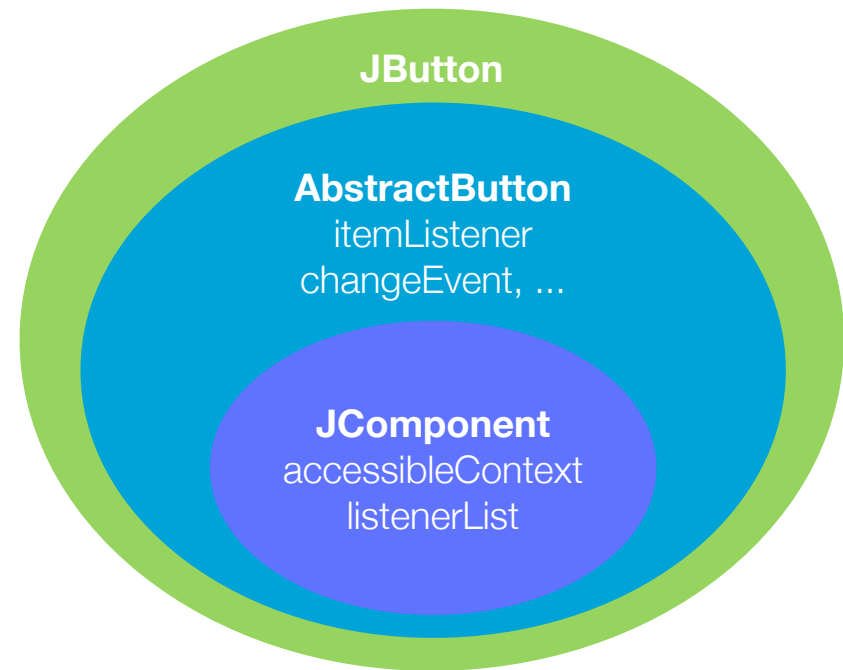
Simple violation of the Liskov principle

???

Object initialization

JComponent

accessibleContext
listenerList

...

△

AbstractButton

itemListener
changeEvent
...

...

△

JButton

...

JButton

AbstractButton
itemListener
changeEvent, ...

JComponent
accessibleContext
listenerList

Object initialization

JComponent
accessibleContext listenerList
...

AbstractButton
itemListener changeEvent ...
...

JButton
...

JButton

AbstractButton
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JComponent
accessibleContext
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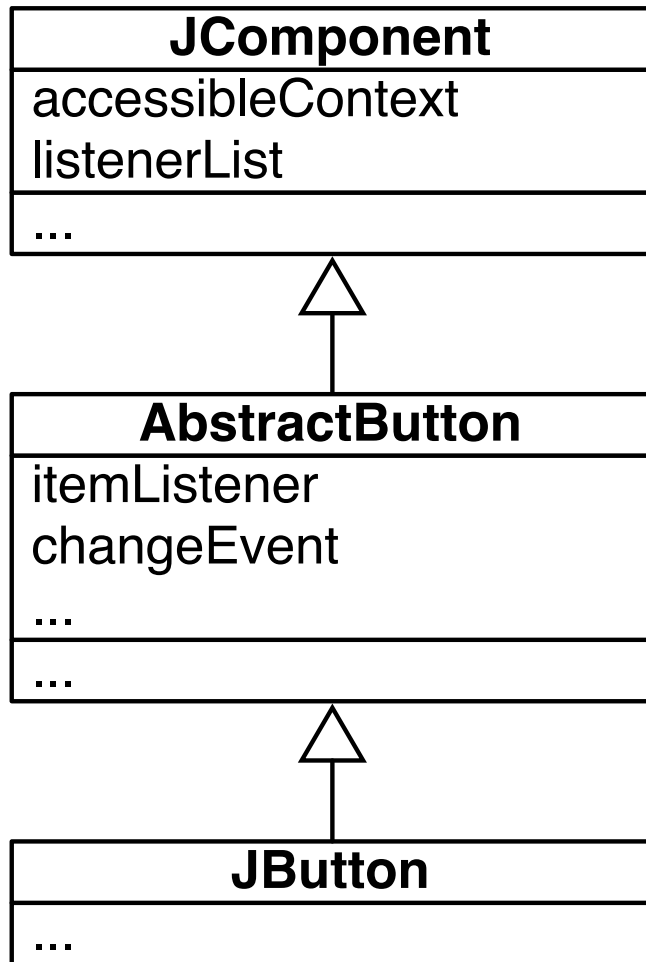
→ default order of object initialization

Object initialization

JComponent

accessibleContext
listenerList

...

AbstractButton

itemListener
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...

JButton

AbstractButton
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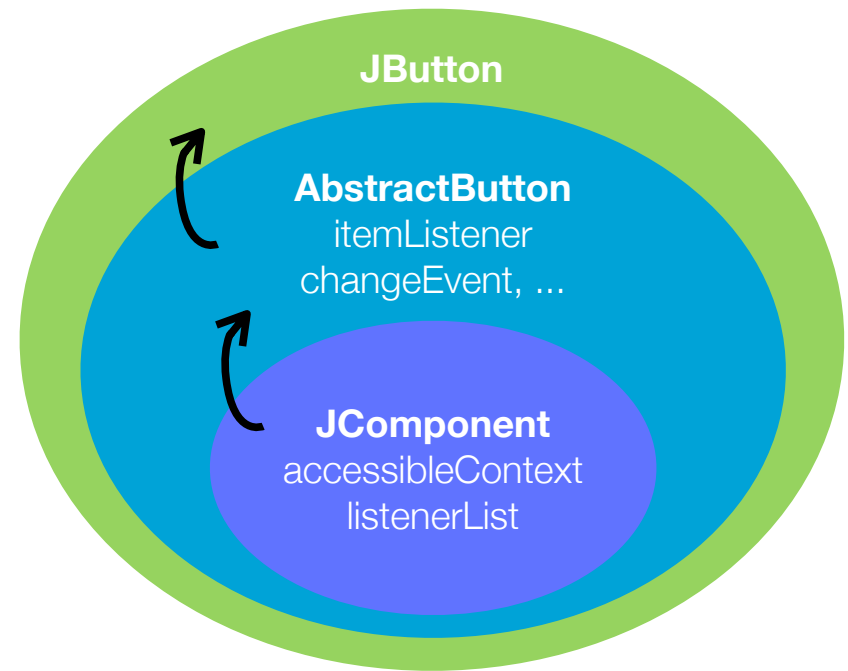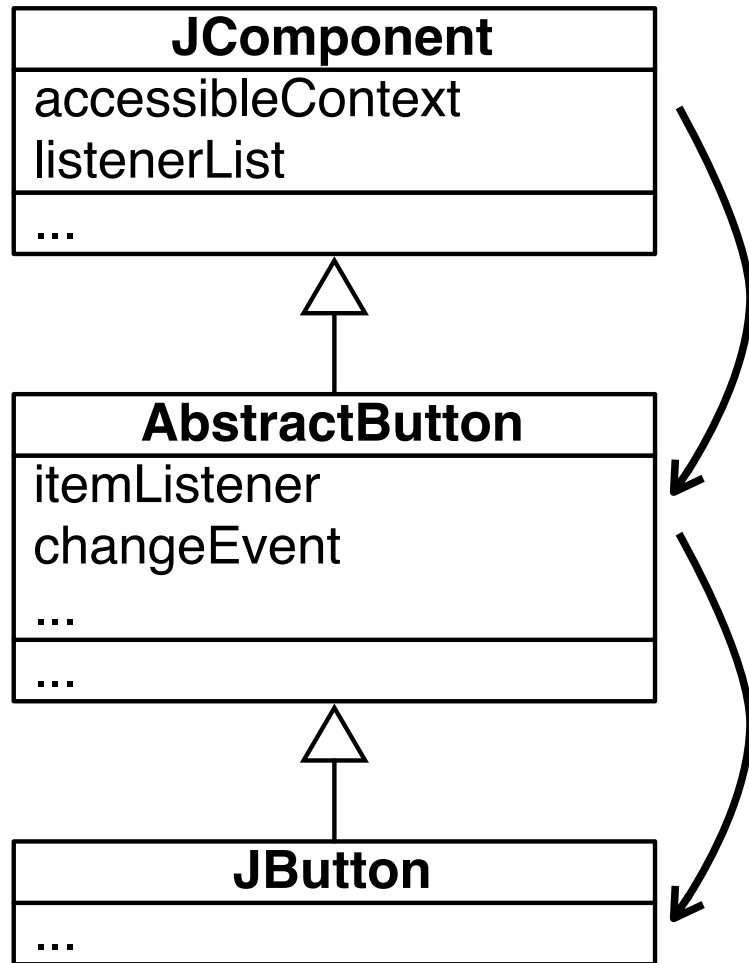
→ default order of object initialization

Access privileges can only be widened

```
class A {
    private void foo () {
    }
}

class B extends A {
    protected void foo () {

    }
}

class C extends B {
    public void foo () {

    }
}
```
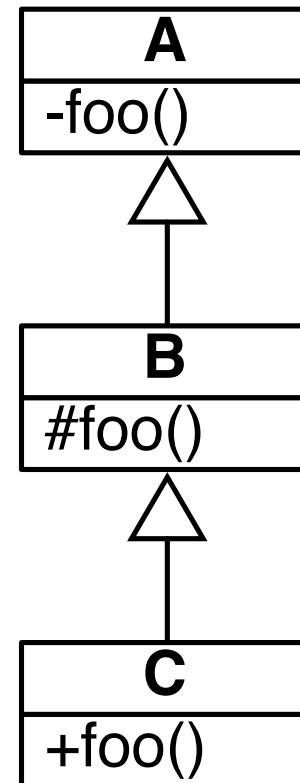
Would it be okay to have this?

```
class A {
    public void foo () {
    }
}

class B extends A {
    protected void foo () {

    }
}

class C extends B {
    private void foo () {

    }
}
```

Access privileges can only be widened

A protected method may be overridden as public

A private method cannot be overridden in Java

a private method is statically bound

a message send toward a private method is not looked up along the class hierarchy

Private methods cannot be overridden

```
class A {
    private void foo () {
    }
}

class B extends A {
    protected void foo () {
        super.foo();
    }
}

class C extends B {
    public void foo () {
        super.foo();
    }
}
```


A
-foo()

B
#foo()

C
+foo()
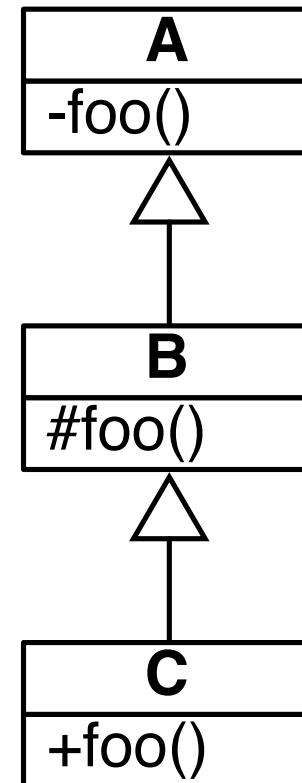
Private methods cannot be overridden

```
class A {
    private void foo () {
    }
}

class B extends A {
    protected void foo () {
        super.foo();
    }
}

class C extends B {
    public void foo () {
        super.foo();
    }
}
```

Error at compilation

A

B
#foo()

C
+foo()
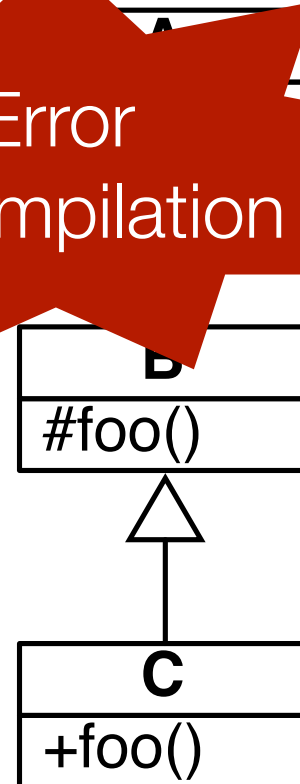
Remember that private methods are statically bound!

```
class A {
    public String callFoo (){
        return this.foo();
    }
    private String foo () {
        return "A";
    }
}


class B extends A {
    protected String foo () {
        return "B";
    }
}

class C extends B {
    public String foo () {
        return "C";
    }
}
```

new C().callFoo() returns "A"

What happens if A.foo is turned as public?

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1. Liskov principle

    1. theory

    2. concrete applications

2. **Inheritance examples**

3. Example1: Swing and AWT

4. Example2: The Smalltalk collection class hierarchy

Virtual Classes
A powerful mechanism in object-oriented programming

Ole Lehrmann Madsen
Computer Science Department, Aarhus University
Ny Munkegade, DK-8000 Aarhus C, Denmark
Tlf.: +45 6 12 71 88 - E-mail: olmadsen@daimi.dk

Birger Møller-Pedersen
Norwegian Computing Center
P.O. Box 114, Blindern, N-0314 Oslo 3, Norway
Tlf.: +47 2 45 35 00 - E-mail: birger@nz.uninett.no

Abstract

The notions of class, subclass and virtual procedure are fairly well understood and recognized as some of the key concepts in object-oriented programming. The possibility of modifying a virtual procedure in a subclass is a powerful technique for specializing the general properties of the superclass.

In most object-oriented languages, the attributes of an object may be references to objects and (virtual) procedures. In Simula and BETA it is also possible to have class attributes. The power of class attributes has not yet been widely recognized. In BETA a class may also have *virtual class attributes*. This makes it possible to defer part of the specification of a class attribute to a subclass. In this sense virtual classes are analogous to virtual procedures. Virtual classes are mainly interesting within strongly typed languages where they provide a mechanism for defining general parameterized classes such as set, vector and list. In this sense they provide an alternative to generics.

Although the notion of virtual class originates from BETA, it is presented as a general language mechanism.

Keywords: languages, virtual procedure, virtual class, strong typing, parameterized class, generics, BETA, Simula, Eiffel, C++, Smalltalk

1 Introduction

The notions of class and subclass are some of the key language concepts associated with object-oriented programming. Classes support the classification of objects with the same properties, and subclassing supports the specialization of the general properties. A class defines a set of attributes associated with each instance of the class. An attribute may be either an object reference (or just reference for short) or a procedure.

In a subclass it is possible to specialize the general properties defined in the superclass. This can be done by adding references and/or procedures. However, it is also possible to modify the procedures defined in the superclass. Modification can take place in different ways. In Simula 67 [4] a procedure attribute may be declared virtual. A virtual procedure may then be redefined in a subclass. A non-virtual procedure cannot be redefined[1]. This is essentially the same scheme adapted by C++ [16] and Eiffel [13]. In Smalltalk [6] any procedure is virtual in the sense that it can be redefined in a subclass, and even the parameters of a procedure may be redefined.

In BETA [8] a virtual procedure cannot be redefined in a subclass, but it may be further defined by an *extended* definition. The extended procedure is a "subprocedure" (in the same way as for subclass) of the procedure defined in the superclass. This implies that the actions of a virtual procedure definition are automatically combined with the actions of the extended procedure in a subclass. This is the case for all levels of subclasses that further defines a virtual procedure. In Smalltalk and C++ it is the responsibility of the programmer to combine a redefined virtual procedure with the corresponding virtual procedure of the superclass. This is of course more flexible, since the programmer can ignore the procedure in the superclass. However, it is also a potential source of error since the programmer may forget to execute the virtual procedure from the superclass.

Using the terminology from [18] a class in BETA

---

[1] In Simula a subclass may declare a new procedure with the same name as a procedure defined in a superclass. This does not have the effect of a redefinition as in Smalltalk.

@OOPSLA'89

```
Window: class Stream
    (# UpperLeft,LowerRight: @ Point;
       Label: ^ Text;
       Move: proc (# ... #);
       Display: virtual proc (# ... #);
    #)
```

Figure 2: Example of class declaration

"In Figure 2 an example of a class is given. Class Window is described as a subclass of class Stream. ..."

```
Window: class Stream
   (# UpperLeft,LowerRight: @ Point;
      Label: ^ Text;
      Move: proc (# ... #);
      Display: virtual proc (# ... #);
   #)
```

Figure 2: Example of class declaration

"In Figure 2 an example of a class is given. Class Window is described as a subclass of class Stream. ..."

Do you think a window can be considered as a stream?
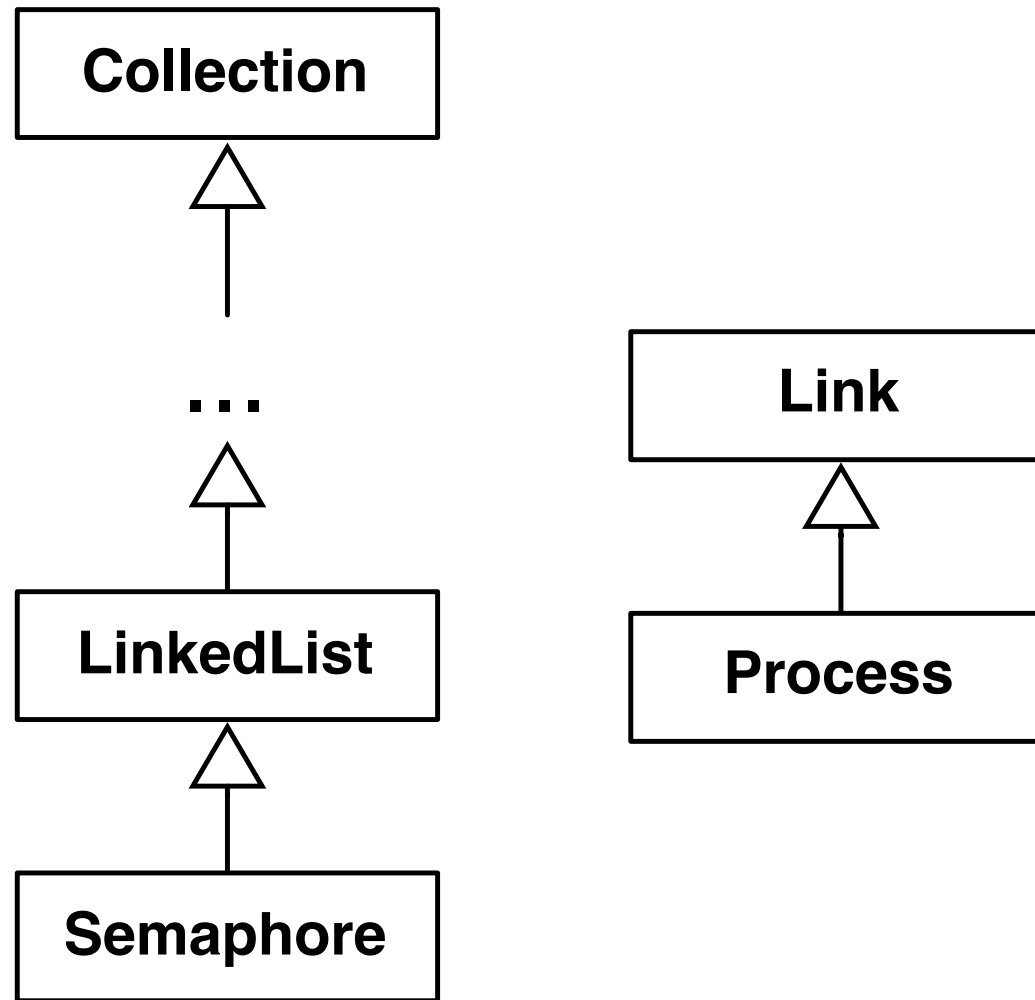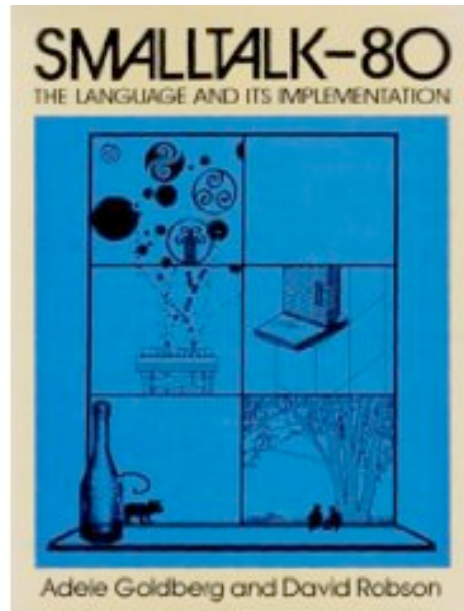
Probably a semaphore can be seen as a collection, but is it worth subclassing LinkedList in that case?

Outline

Presentation of AWT
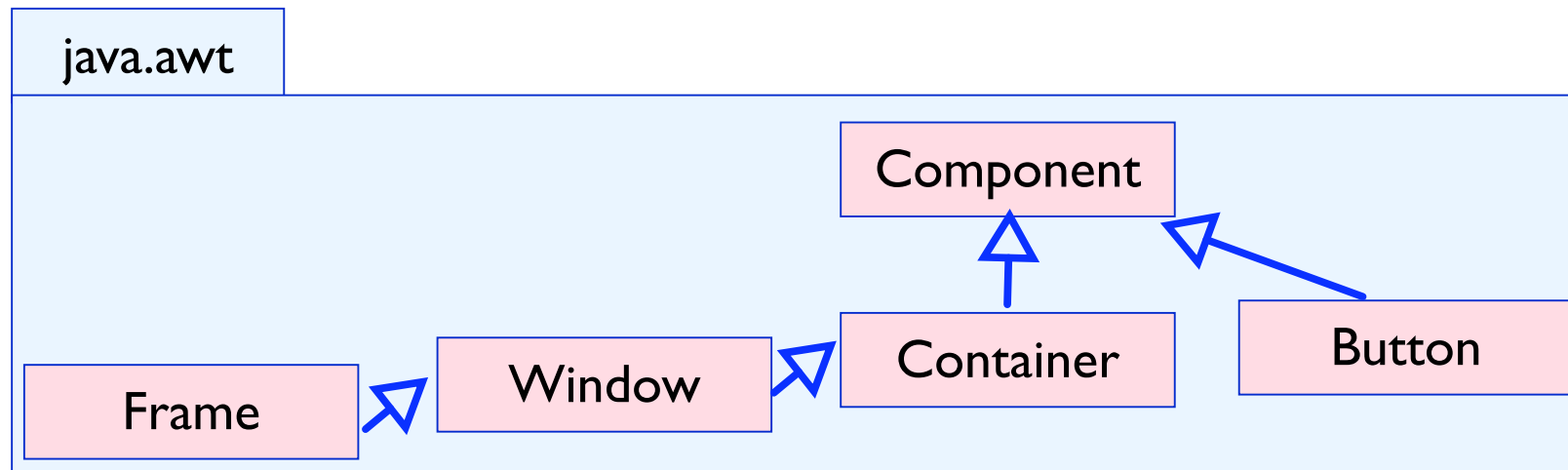
In the AWT framework:

Widgets are components (i.e., inherit from Component)

A frame is a window (Frame is a subclass of Window)

Swing at the top of AWT
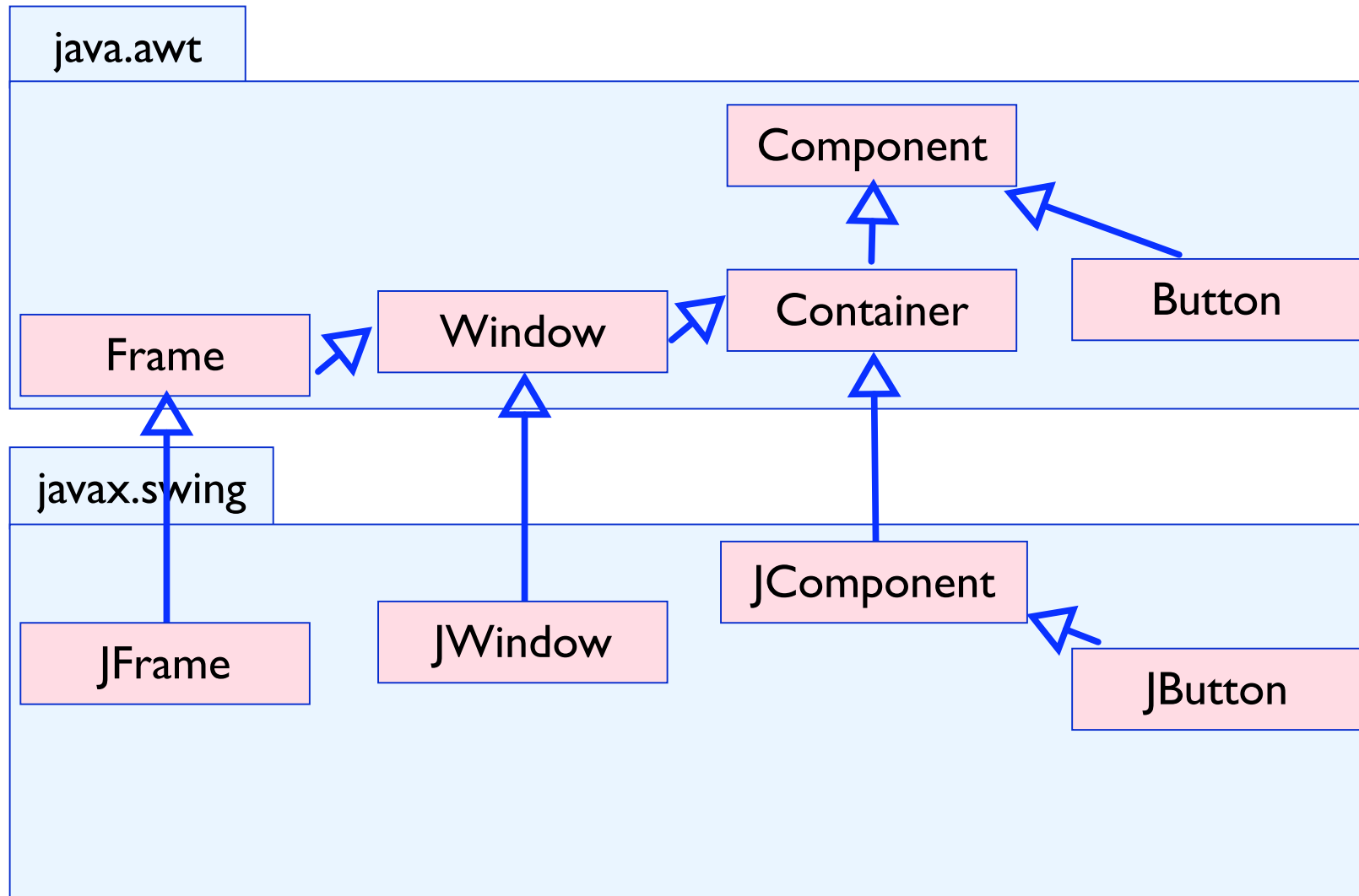
Problem #1: Brocken Inheritance

Problem #1: Brocken Inheritance

java.awt

Component

Frame → Window → Container   Button

javax.swing

                        JComponent

JFrame → JWindow   JButton
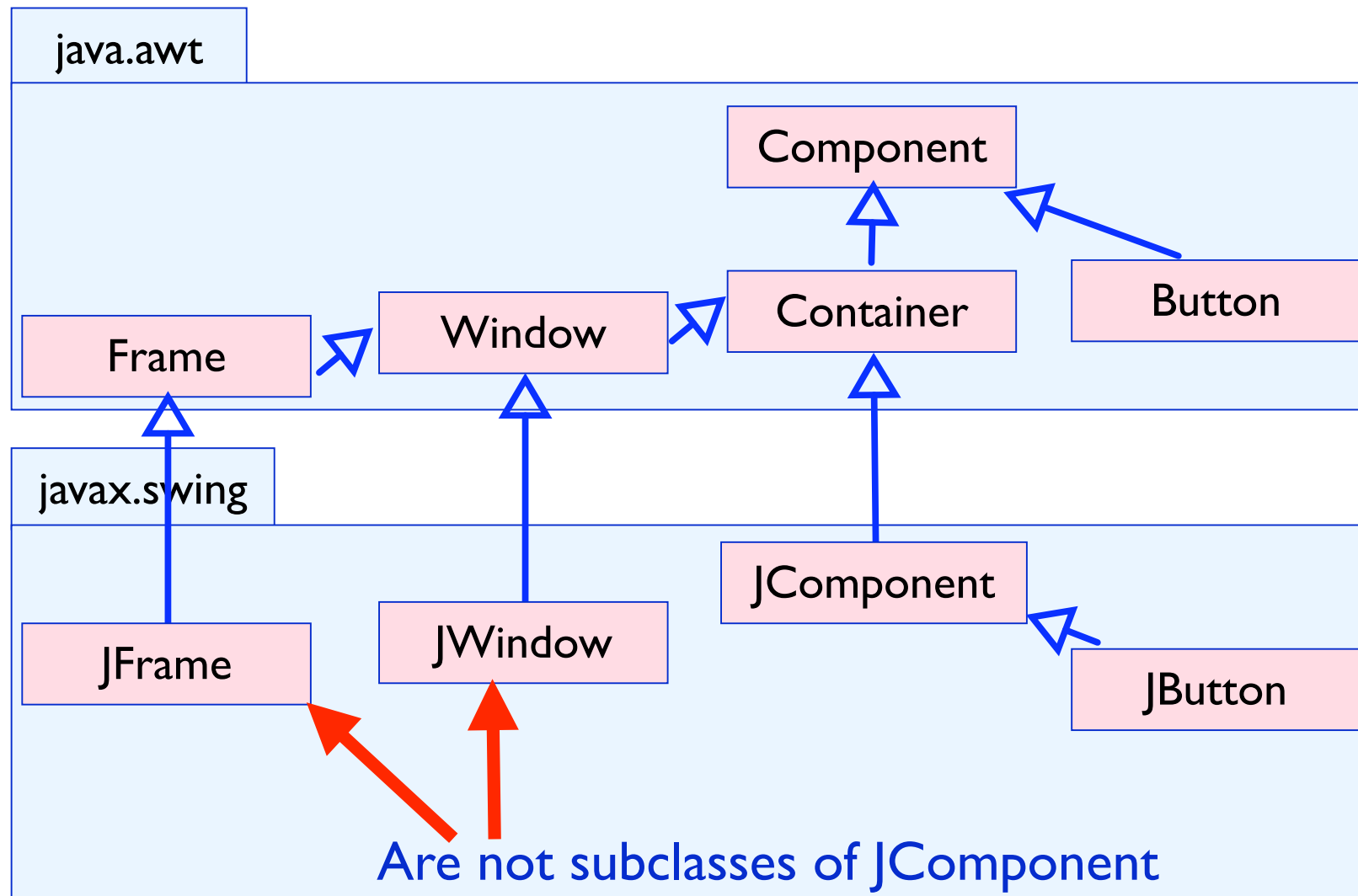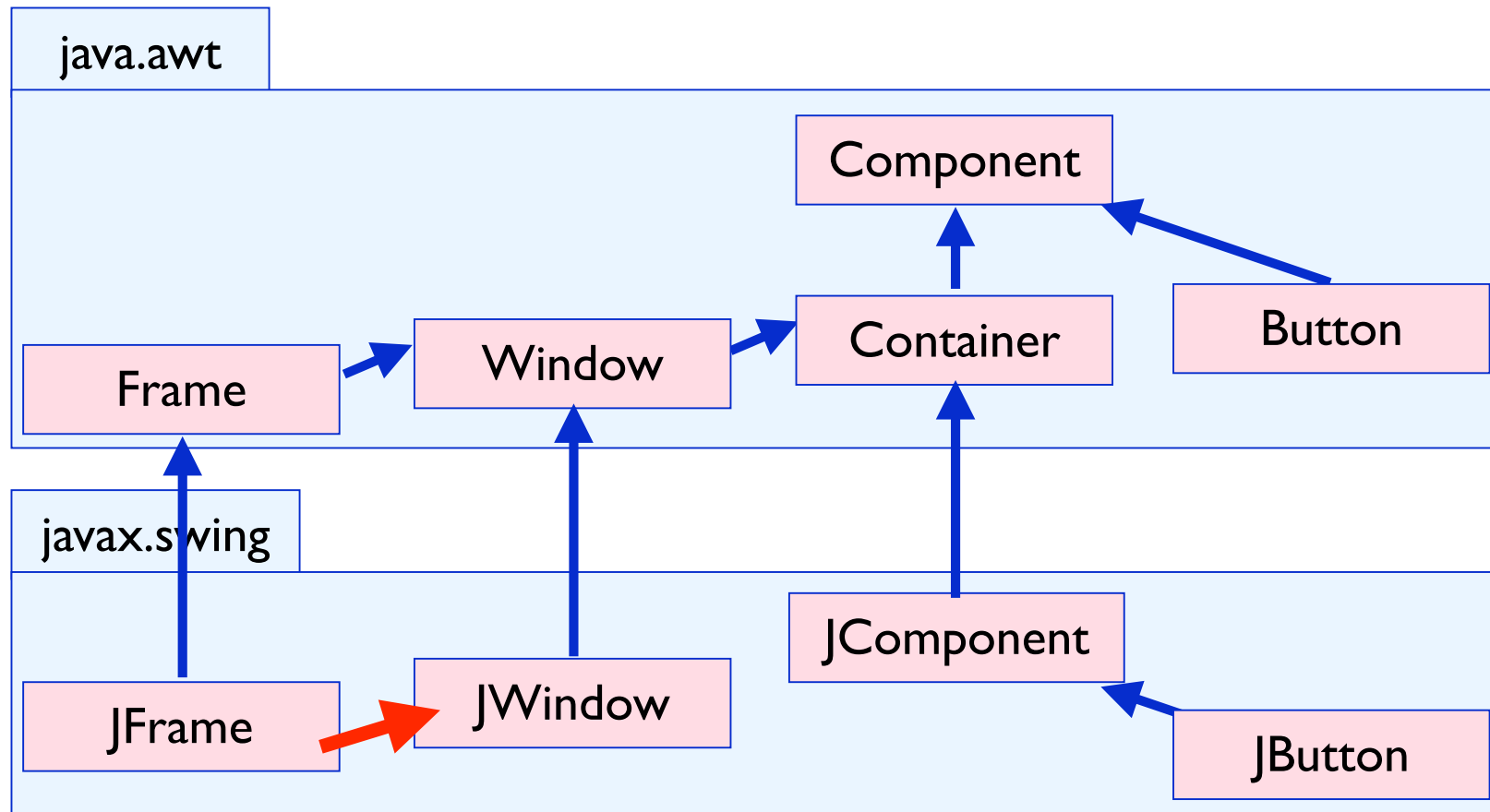
Missing inheritance link between JFrame and JWindow

Problem #2: Code Duplication
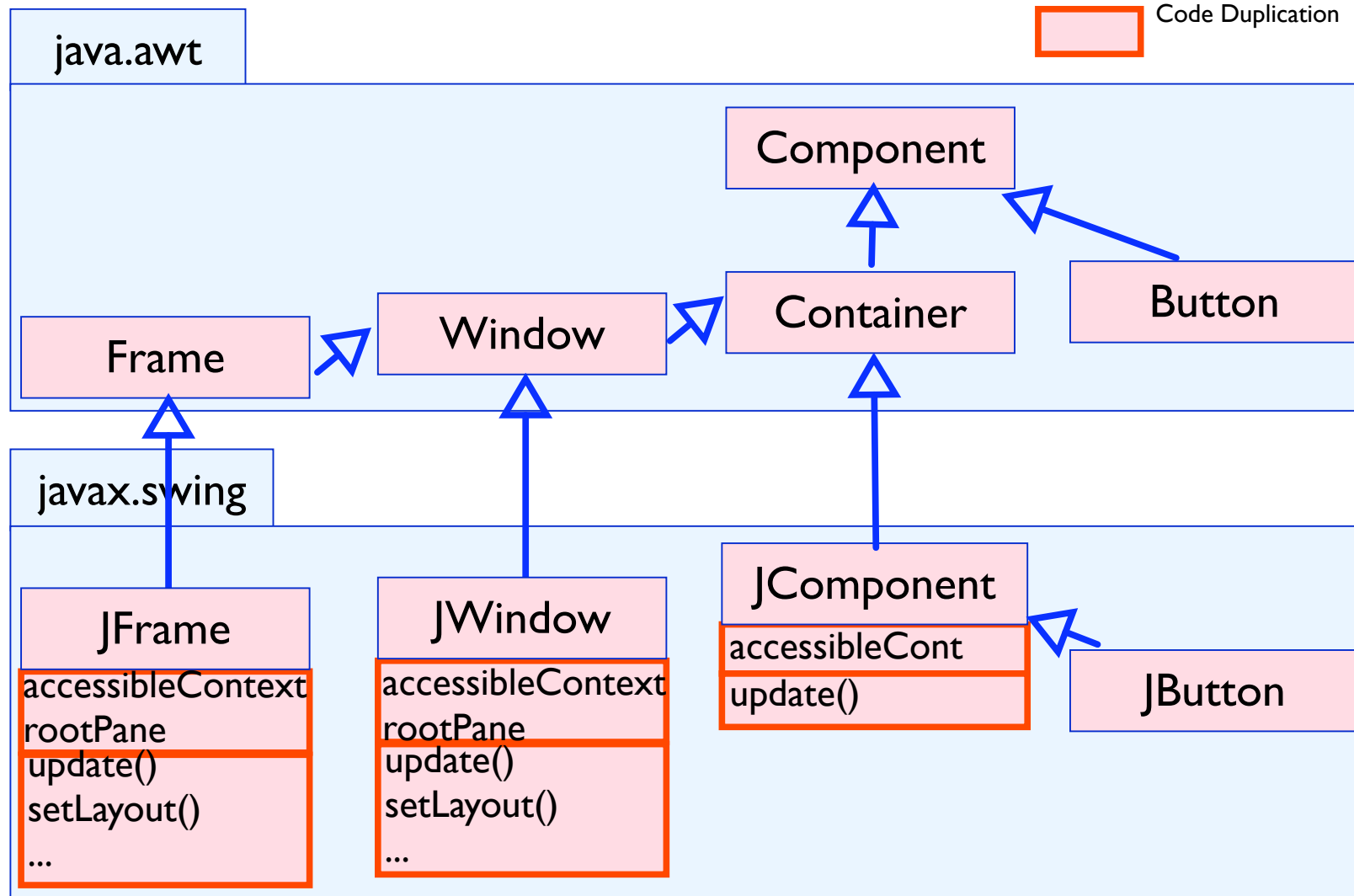
Problem #3: Explicit Type Checks and Casts

```
public class Container extends Component {
   Component components[] = new Component [0];
   public Component add (Component comp) {...}
}

public class JComponent extends Container {
   public void paintChildren (Graphics g) {
      for (; i>=0 ; i--) {
         Component comp = getComponent (i);
         isJComponent = (comp instanceof JComponent);
         ...
         ((JComponent) comp).getBounds();
      }
   }}
```

Supporting Unanticipated Changes

AWT couldn't *be enhanced* without risk of *breaking* existing code

Swing is, therefore, *built on the top* of AWT using *subclassing*

As a result, *Swing is a big mess internally*!

Why do we care to have a messy Swing ?

Swing appeared in 1998, and *has not evolved since*!

Swing is too heavy to be ported to PDA, cellphones, ...

SWT is *becoming* a *new standard*.

Either a system evolves, or it is dead. [Lehmans74]

Classbox/J

Alexandre Bergel, Stéphane Ducasse, and Oscar Nierstrasz, *Classbox/J: Controlling the Scope of Change in Java*, In **Proceedings of Object-Oriented Programming, Systems, Languages, and Applications (OOPSLA'05)**, New York, NY, USA, ACM Press, pp. 177-189, 2005

Alexandre Bergel, Stéphane Ducasse, Oscar Nierstrasz, and Roel Wuyts, *Classboxes: Controlling Visibility of Class Extensions*, In **Computer Languages, Systems and Structures**, Volume 31, Number 3-4, pp. 107-126, May, 2005, Impact Factor 0.467 (2005)
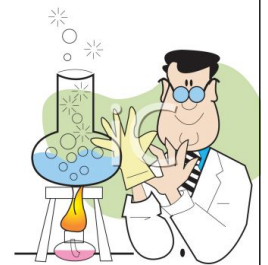
Refining Classes (1 / 2)

A classbox widgetsCB

```
package widgetsCB;


public class Component {
    public void update() {this.paint();}
    public void paint () {/*Old code*/}
}

public class Button extends Component {
    ...
}
```

Refining Classes (2 / 2)

Widget enhancements defined in NewWidgetsCB:

```
package NewWidgetsCB;

import widgetsCB.Component;
import widgetsCB.Button;

refine Component {
   /* Variable addition */
   private ComponentUI lookAndFeel;

   /* Redefinition of paint() */
   public void paint() {
      /* Code that uses lookAndFeel*/ }
}
```
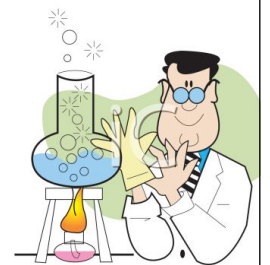
Multiple Versions of Classes

Import

C class refinement

widgetsCB

Component

paint()
update()

Button

new Button("Ok").update()

OK

NewWidgetsCB

Component
lookAndFeel
paint()

Button

new Button("Ok").update()

MacOS Button!

Swing Refactored as a Classbox

AwtCB

Component

Container

Window

Frame

Button

javax.swing

JFrame
- accessibleContext
- rootPane
- update()
- setLayout()
- ...

JWindow
- accessibleContext
- rootPane
- update()
- setLayout()
- ...

JComponent
- accessibleContext
- update()

JButton
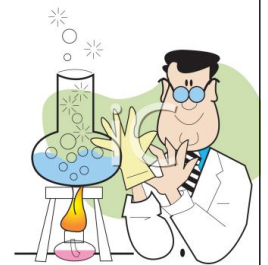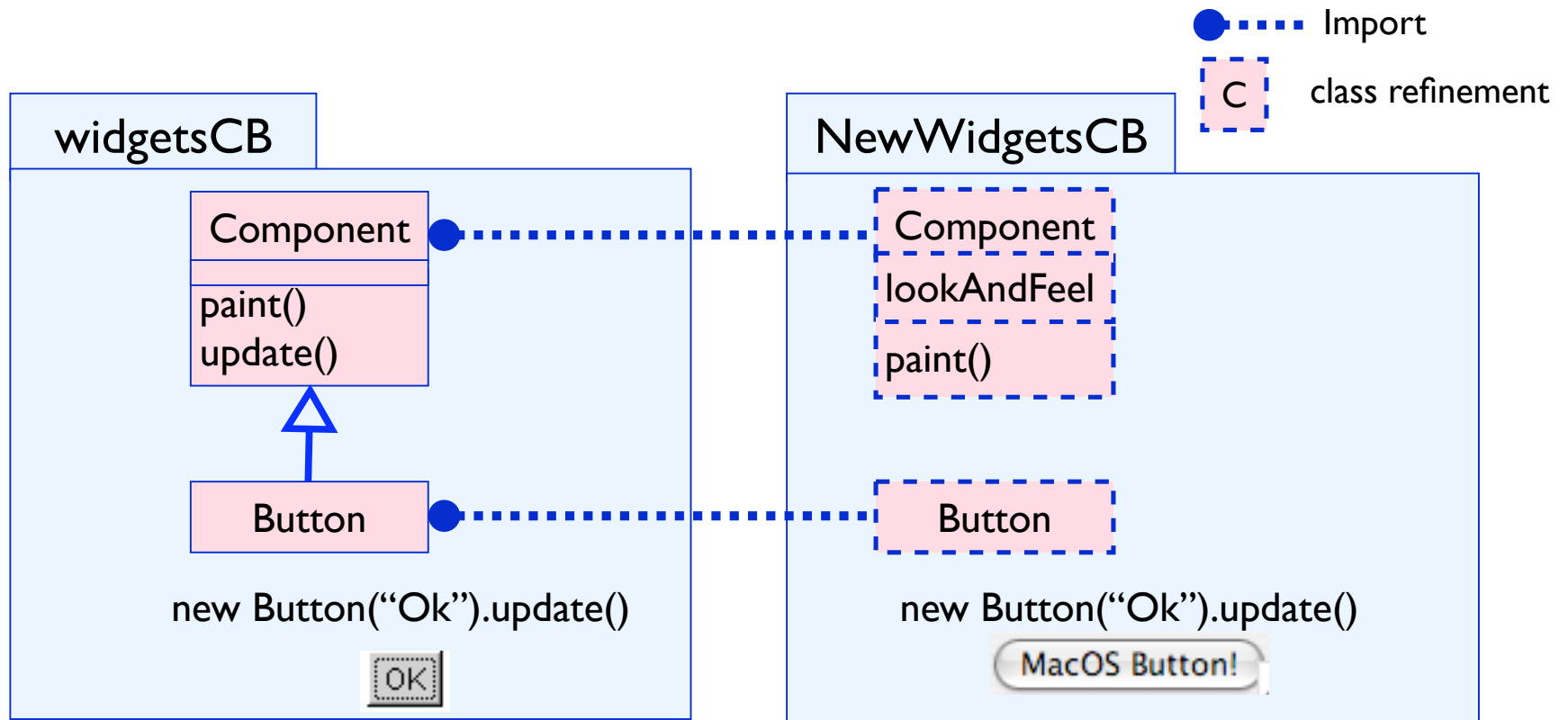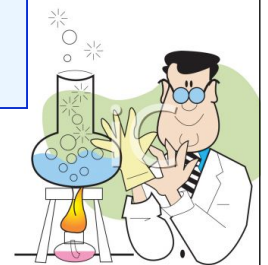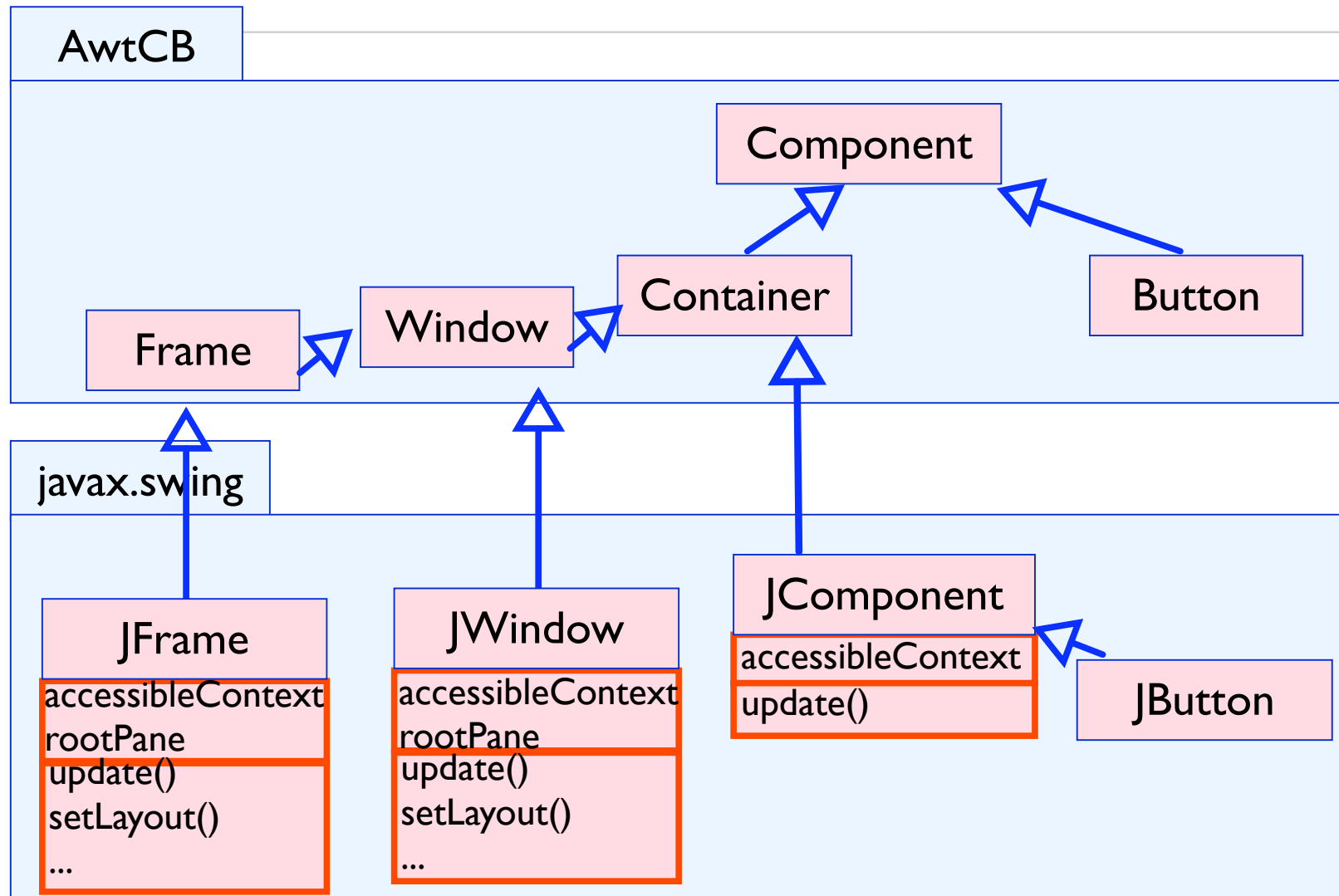
Swing Refactored as a Classbox

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3. Example1: Swing and AWT

4. **Example2: The Smalltalk collection class hierarchy**

the Stream framework in Squeak

Example of a library that has been in use for almost 20 years

Contains many flaws in its design

the Stream framework in Squeak

Stream

atEnd
close
contents
do:
flush
next
next:
next:put:
nextPut:
nextPutAll:
upToEnd

Positionable Stream

collection
position
readLimit

atEnd
contents
isEmpty
next:
peek
position
position:
reset
setToEnd
skip:
skipTo:
upTo:
upToEnd

ReadStream

next
next:
~~nextPut:~~
size
upTo:
upToEnd

WriteStream

writeLimit

contents
flush
~~next~~
nextPut:
nextPutAll:
position:
reset
setToEnd
size
space
cr

ReadWriteStream

close
contents
next
next:

FileStream

rwmode
name
fileID
buffer1

atEnd
close
flush
fullName
next
next:
nextPut:
nextPutAll:
peek
position
position:
reset
setToEnd
size
skip:
upTo:
upToEnd

Methods too high

Stream
- *atEnd*
- close
- *contents*
- do:
- flush
- *next*
- next:
- nextput:
- *nextPut:*
- nextPutAll:
- upToEnd

Positionable Stream
- collection
- position
- readLimit
- atEnd
- contents
- isEmpty
- next:
- peek
- position
- position:
- reset
- setToEnd
- skip:
- skipTo:
- upTo:

ReadStream
- next
- next:
- ~~nextPut:~~
- size
- upTo:

WriteStream
- writeLimit
- contents
- flush
- ~~next~~
- nextPut:
- nextPutAll:
- position:
- reset
- setToEnd
- size
- space
- cr

ReadWriteStream
- close
- contents

FileStream
- rwmode
- name
- fileID
- buffer1
- atEnd
- close
- flush
- fullName
- next
- next:
- nextPut:
- nextPutAll:
- peek
- position
- position:
- reset
- setToEnd
- size
- skip:
- upTo:
- upToEnd

nextPutAll: aCollection
    aCollection do: [:v| self nextPut: v].
    ^ aCollection

Methods too high

The nextPut: method defined in Stream allows for element addition

The ReadStream class is read-only

It therefore needs to "cancel" this method by redefining it and throwing an exception

Unused state

Stream
- *atEnd*
- close
- *contents*
- do:
- flush
- *next*
- next:
- next:put:
- *nextPut:*
- nextPutAll:
- upToEnd

Positionable Stream
- collection
- position
- readLimit
- atEnd
- contents
- isEmpty
- next:
- peek
- position
- position:
- reset
- setToEnd
- skip:
- skipTo:
- upTo:
- upToEnd

ReadStream
- next
- next:
- ~~nextPut:~~
- size
- upTo:
- upToEnd

WriteStream
- writeLimit
- ~~contents~~
- flush
- ~~next~~
- nextPut:
- nextPutAll:
- position:
- reset
- setToEnd
- size
- space
- cr

ReadWriteStream
- close
- contents
- next
- next:

FileStream
- rwmode
- name
- fileID
- buffer1
- atEnd
- close
- flush
- fullName
- next
- next:
- nextPut:
- nextPutAll:
- peek
- position
- position:
- reset
- setToEnd
- size
- skip:
- upTo:
- upToEnd

Unused state

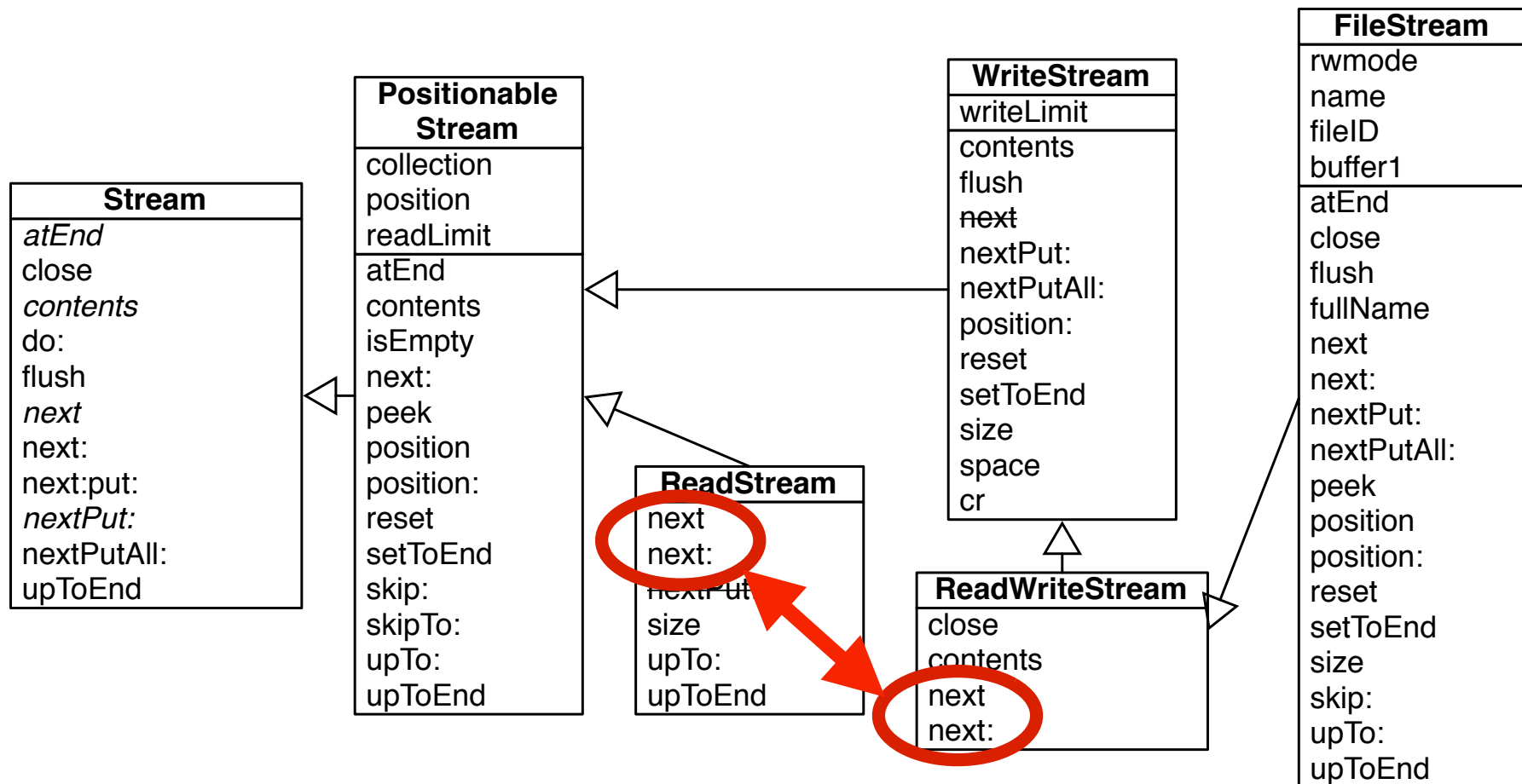State defined in the super classes are becoming irrelevant in subclasses

FileStream does not use inherited variables

Multiple Inheritance Simulation

Stream

atEnd
close
contents
do:
flush
next
next:
next:put:
nextPut:
nextPutAll:
upToEnd

Positionable Stream

collection
position
readLimit

atEnd
contents
isEmpty
next:
peek
position
position:
reset
setToEnd
skip:
skipTo:
upTo:
upToEnd

WriteStream

writeLimit

contents
flush
next
nextPut:
nextPutAll:
position:
reset
setToEnd
size
space
cr

ReadStream

next
next:
nextPut
size
upTo:
upToEnd

ReadWriteStream

close
contents
next
next:

FileStream

rwmode
name
fileID
buffer1

atEnd
close
flush
fullName
next
next:
nextPut:
nextPutAll:
peek
position
position:
reset
setToEnd
size
skip:
upTo:
upToEnd

Multiple Inheritance Simulation

Methods are duplicated among different class hierarchies

Class schizophrenia?

Too many responsibilities for classes

object factories

group methods when subclassing

Class schizophrenia?

Too many responsibilities for classes

object factories => *need for completeness*

group methods when subclassing => *need to incorporate incomplete fragments*
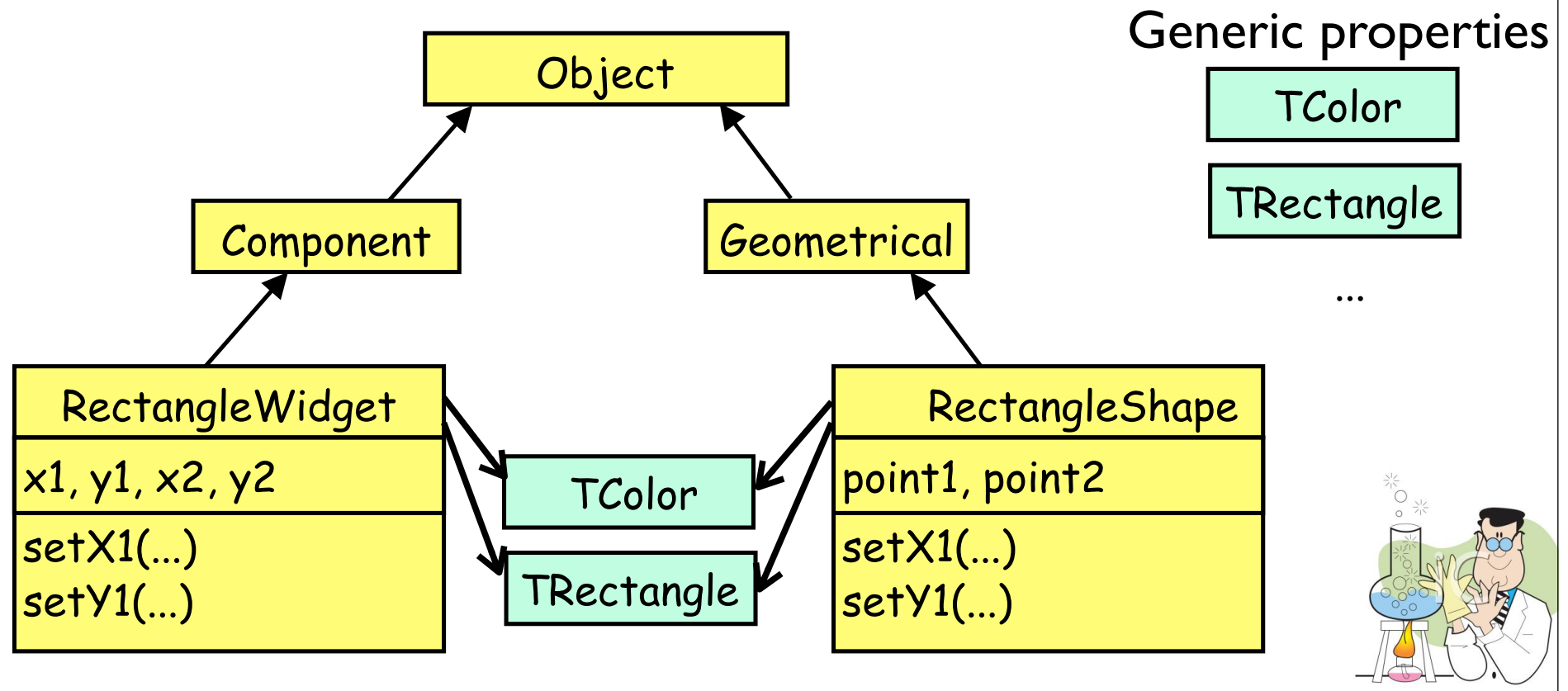
Traits

Stéphane Ducasse, Oscar Nierstrasz, Nathanael Schärli, Roel Wuyts, and Andrew P. Black. **Traits: A Mechanism for fine-grained Reuse**. In ACM Transactions on Programming Languages and Systems (TOPLAS) 28(2) p. 331—388, March 2006

Nathanael Schärli, Stéphane Ducasse, Oscar Nierstrasz, and Andrew P. Black. **Traits: Composable Units of Behavior**. In Proceedings of European Conference on Object-Oriented Programming (ECOOP'03), LNCS 2743 p. 248—274, Springer Verlag, July 2003
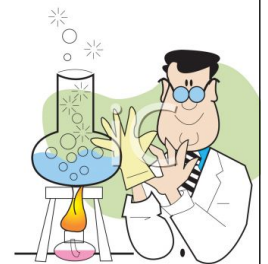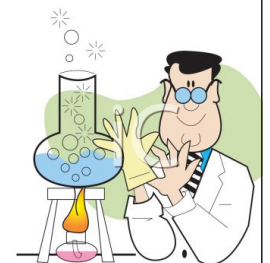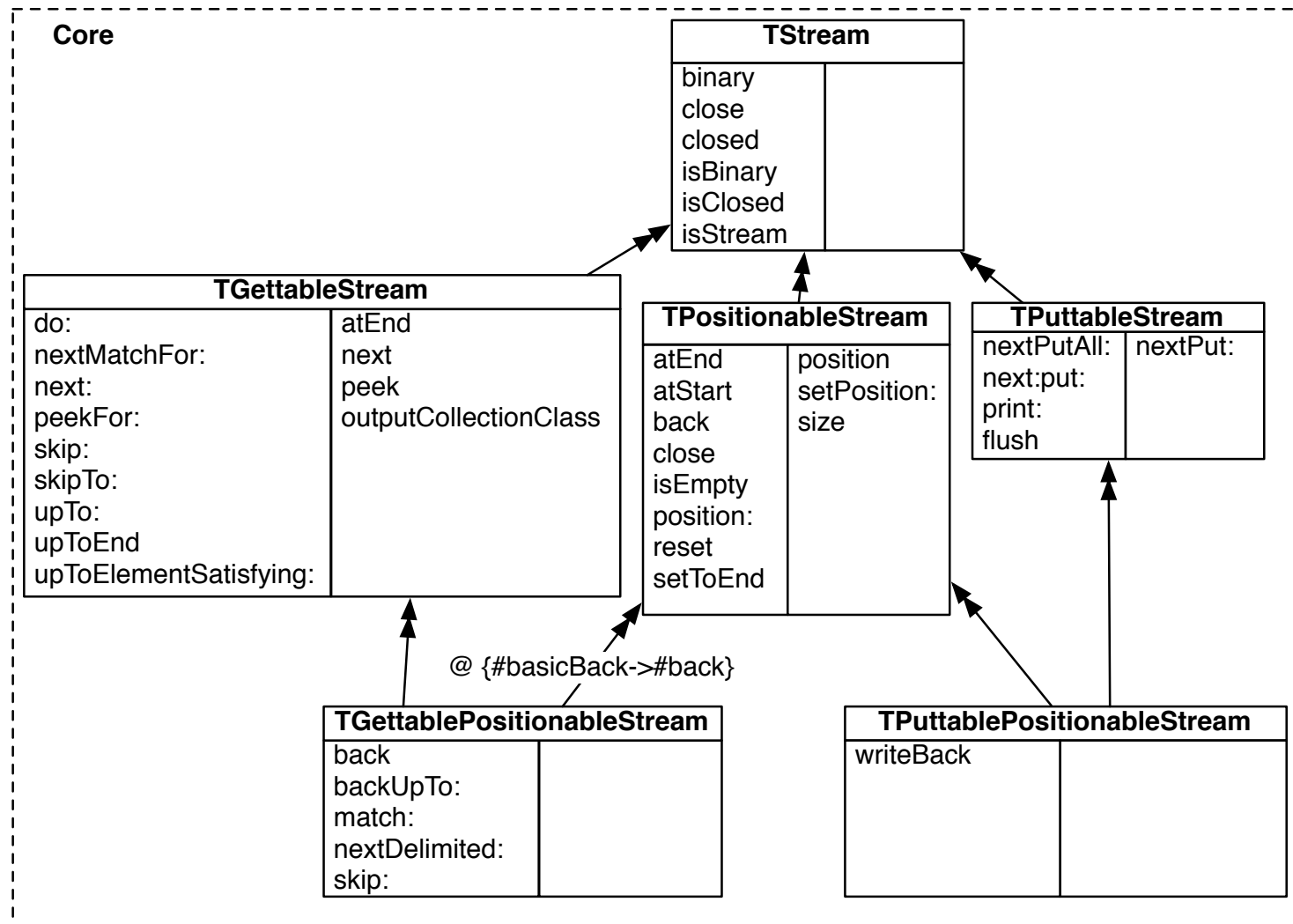
Class = Superclass + State + Traits + Glue Methods

Traits are the behavioral building blocks of classes

Generic properties

TColor

TRectangle

...

Object

Component

Geometrical

RectangleWidget

x1, y1, x2, y2

setX1(...)
setY1(...)

TColor

TRectangle

RectangleShape

point1, point2

setX1(...)
setY1(...)

Stream revisited

Core

TStream

binary
close
closed
isBinary
isClosed
isStream

TGettableStream

do:	atEnd
nextMatchFor:	next
next:	peek
peekFor:	outputCollectionClass
skip:	
skipTo:	
upTo:	
upToEnd	
upToElementSatisfying:	

TPositionableStream

atEnd	position
atStart	setPosition:
back	size
close	
isEmpty	
position:	
reset	
setToEnd	

TPuttableStream

nextPutAll:	nextPut:
next:put:	
print:	
flush	

@ {#basicBack->#back}

TGettablePositionableStream

back	
backUpTo:	
match:	
nextDelimited:	
skip:	

TPuttablePositionableStream

writeBack	

What you should know!

What is the Liskov principle?

How the Liskov principle affects the design of a programming language

Why a good class hierarchy is not easy to obtain and requires experience

Defining a subclass should be driven by the IS-A relation

Can you answer to these questions?

Why a class Window should not be defined as a subclass of Stream?

What makes class inheritance so difficult to use?

Is there a definitive answer on what a good class hierarchy is?

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