Algorithms

Robert Sedgewick | Kevin Wayne

https://algs4.cs.princeton.edu

# Advanced Java

- *inheritance*
- *interfaces*
- *iterators*

Last updated on 9/16/21 7:16 AM

# Advanced Java

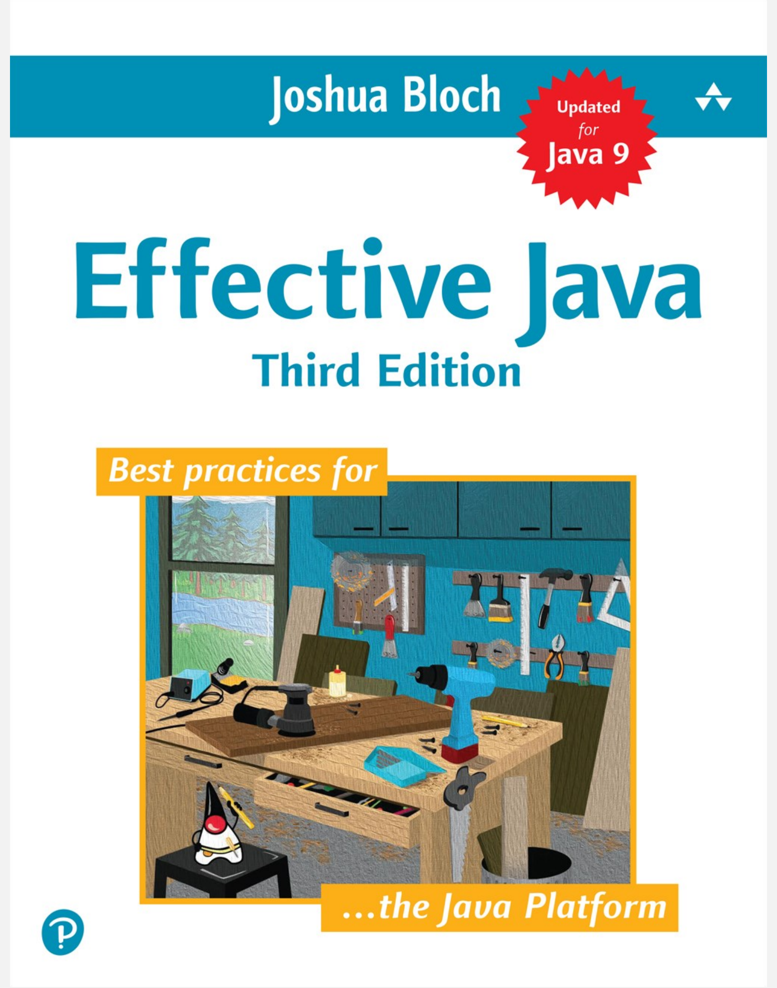
Subtitle. Java features that we (occasionally) use in this course, but don't cover (much) in COS 126.

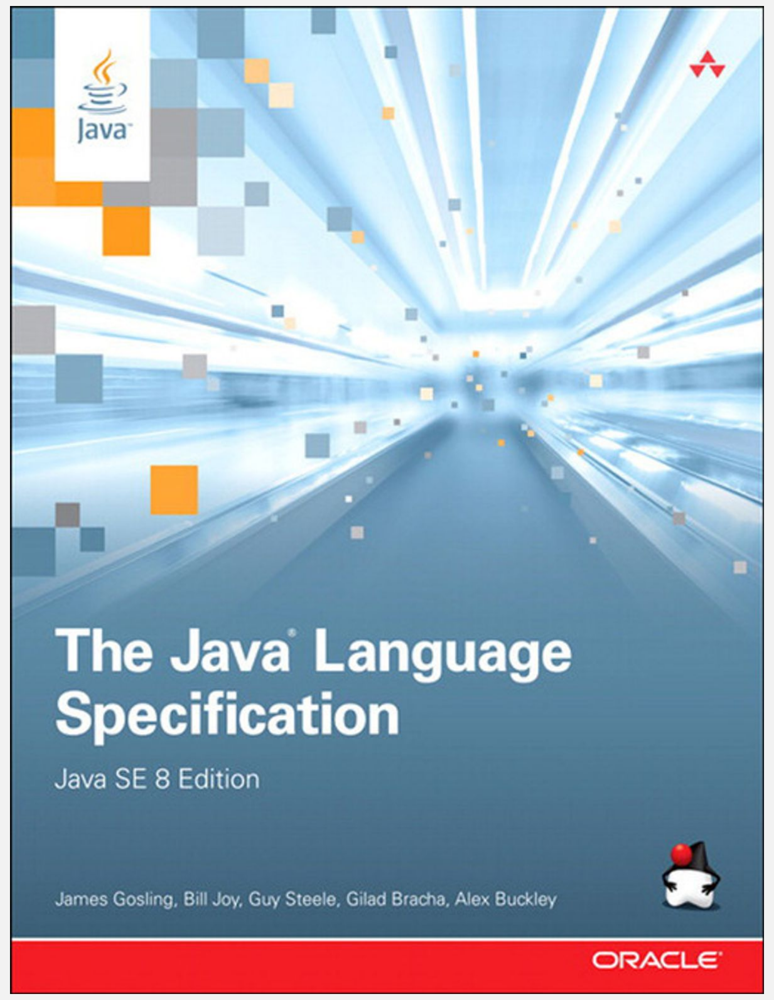
- Inheritance.
- Generics.
- Interfaces.

← common theme: promote code reuse

Q. How to take your Java to the next level?

A.




Java
The Java Language Specification
Java SE 8 Edition
James Gosling, Bill Joy, Guy Steele, Gilad Bracha, Alex Buckley
ORACLE

https://docs.oracle.com/javase/specs/jls/se8/jls8.pdf

https://algs4.cs.princeton.edu

# Advanced Java

- *inheritance*
- *interfaces*
- *iterators*

# Motivation

Q1. How did the Java architects design `System.out.println(x)` so that it works with all reference types?

Q2. How would an Android developer create a custom Java GUI text component, without re-implementing these 400+ required methods?

A. Inheritance.

```
action() • add() • addAncestorListener() • addCaretListener() •
addComponentListener() • addContainerListener() • addFocusListener() •
addHierarchyBoundsListener() • addHierarchyListener() • addImpl() •
addInputMethodListener() • addKeyListener() • addKeymap() • addMouseListener() •
addMouseMotionListener() • addMouseWheelListener() • addNotify() •
addPropertyChangeListener() • addVetoableChangeListener() •
applyComponentOrientation() • areFocusTraversalKeysSet() • bounds() • checkImage() •
coalesceEvents() • computeVisibleRect() • contains() • copy() • countComponents() •
createImage() • createToolTip() • createVolatileImage() • cut() • deliverEvent() •
disable() • disableEvents() • dispatchEvent() • doLayout() • enable() •
enableEvents() • enableInputMethods() • findComponentAt() • fireCaretUpdate() •
firePropertyChange() • fireVetoableChange() • getActionForKeyStroke() •
getActionMap() • getAlignmentX() • getAlignmentY() • getAncestorListeners() •
getAutoscrolls() • getBackground() • getBaseline() • getBaselineResizeBehavior() •
```

# Inheritance overview

Implementation inheritance (subclassing).

- Define a new class (subclass) from another class (parent class).
- The subclass inherits from the parent class:
  - instance variables (state)
  - instance methods (behavior)
- The subclass can override instance methods in the parent class.

  (replacing those methods with its own versions)

Main benefits.

- Facilitates code reuse.
- Enables the design of extensible libraries.

# Inheritance example

```
public class Disc {
   protected int x, y, r;

   public Disc(int x, int y, int r) {
      this.x = x;
      this.y = y;
      this.r = r;
   }

   public double area() {
      return Math.PI * r * r;
   }

   public boolean intersects(Disc that) {
      int dx = this.x - that.x;
      int dy = this.y - that.y;
      int dr = this.r + that.r;
      return dx*dx + dy*dy <= dr*dr;
   }

   public void draw() {
      StdDraw.filledCircle(x, y, r);
   }
}
```

inherited by subclass

**parent class**

```
import java.awt.Color;

public class ColoredDisc extends Disc {

   protected Color color;

   public ColoredDisc(int x, int y, int r, Color color) {
      super(x, y, r);
      this.color = color;
   }

   public Color getColor() {
      return color;
   }

   public void draw() {
      StdDraw.setPenColor(color);
      StdDraw.filledCircle(x, y, r);
   }

}
```

defines new state

calls constructor in parent class

defines new behavior

overrides method in parent class

**subclass**

# Inheritance demo (in JShell)

```
~/Desktop/advanced-java> jshell-algs4
/open Disc.java
/open ColoredDisc.java

StdDraw.setScale(0, 800);

Disc disc1 = new Disc(400, 400, 200);
disc1.area();
disc1.draw();

ColoredDisc disc2 = new ColoredDisc(225, 575, 100, StdDraw.BLUE);
ColoredDisc disc3 = new ColoredDisc(575, 575, 100, StdDraw.RED);
disc2.getColor();
disc2.draw();
disc3.draw();
disc2.area();

disc1.intersects(disc2);
disc2.intersects(disc3);

Disc disc = disc2;     // upcast from child to parent
disc.area();
```

# Advanced Java: quiz 1

**Which color will be stored in the variable `color`?**

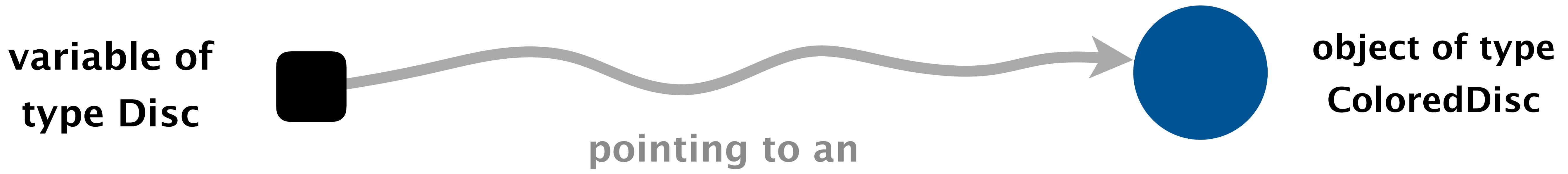
```java
Disc disc = new ColoredDisc(200, 300, 100, StdDraw.BLUE);
Color color = disc.getColor();
```

- **A.** Blue.
- **B.** Black.
- **C.** Compile-time error.
- **D.** Run-time error.
- **E.** 💣

# Polymorphism

Ex. A reference variable can refer to any object of its declared type or any of its subclasses.

```
Disc disc = new ColoredDisc(x, y, r, color);
```



```
double area = disc.area();
boolean disc.intersects(disc);
```

~~Color color = disc.getColor();~~ ← can call only Disc methods (compile-time error)

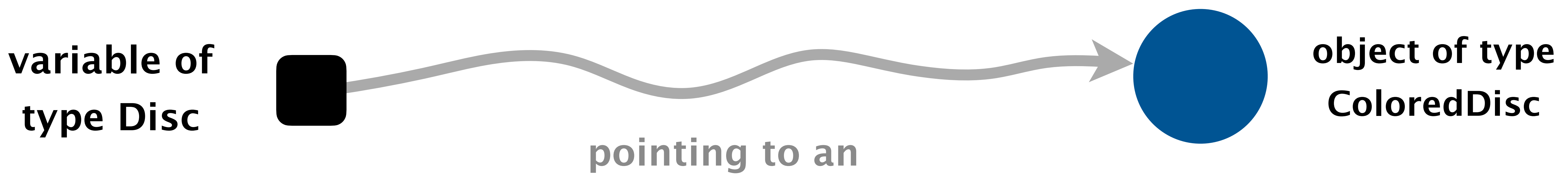
Subtype polymorphism. A subclass is a subtype of its superclass:
objects of the subtype can be used anywhere objects of the superclass are allowed.

RHS of assignment statement,
method argument, return value, expression, ...

# Polymorphism

Dynamic dispatch. Java determines which version of an overridden method to call using the type of the referenced object at runtime (not necessarily the type of the variable).

```
Disc disc = new ColoredDisc(x, y, r, color);
```



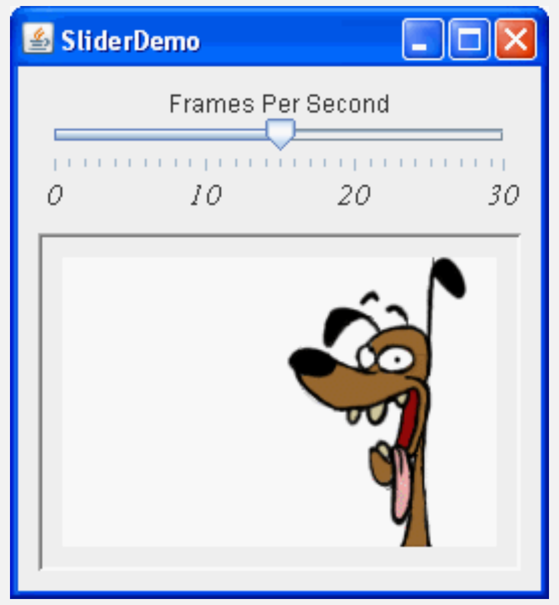
```
disc.draw();   ←——   calls ColoredDisc version of draw()
```

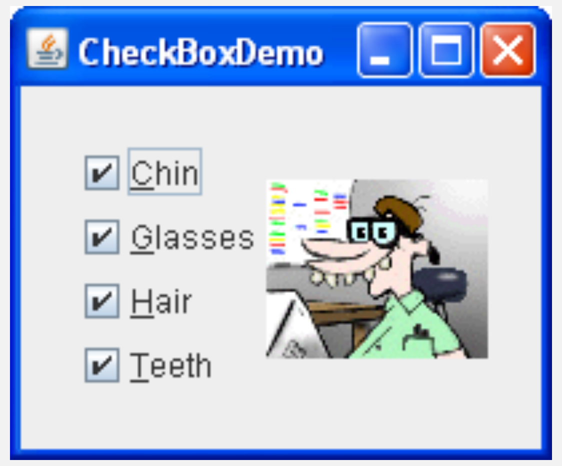
a “polymorphic” method call

# Subclass hierarchy for Java GUI components

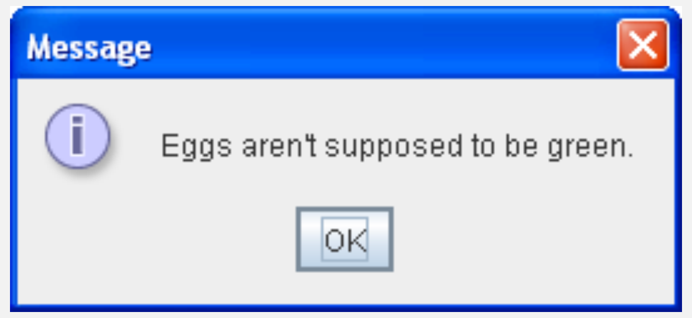
Typical use case. Design an extensible library.

Ex. Android developer design a new GUI widget for their app.

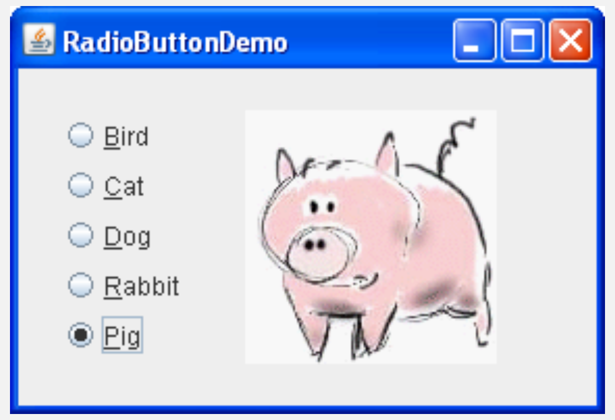




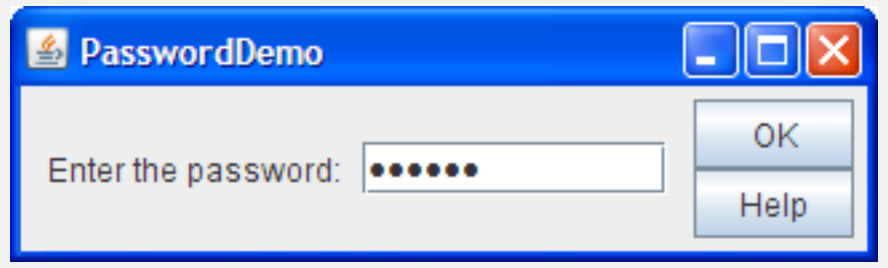
☑ Chin
☑ Glasses
☑ Hair
☑ Teeth



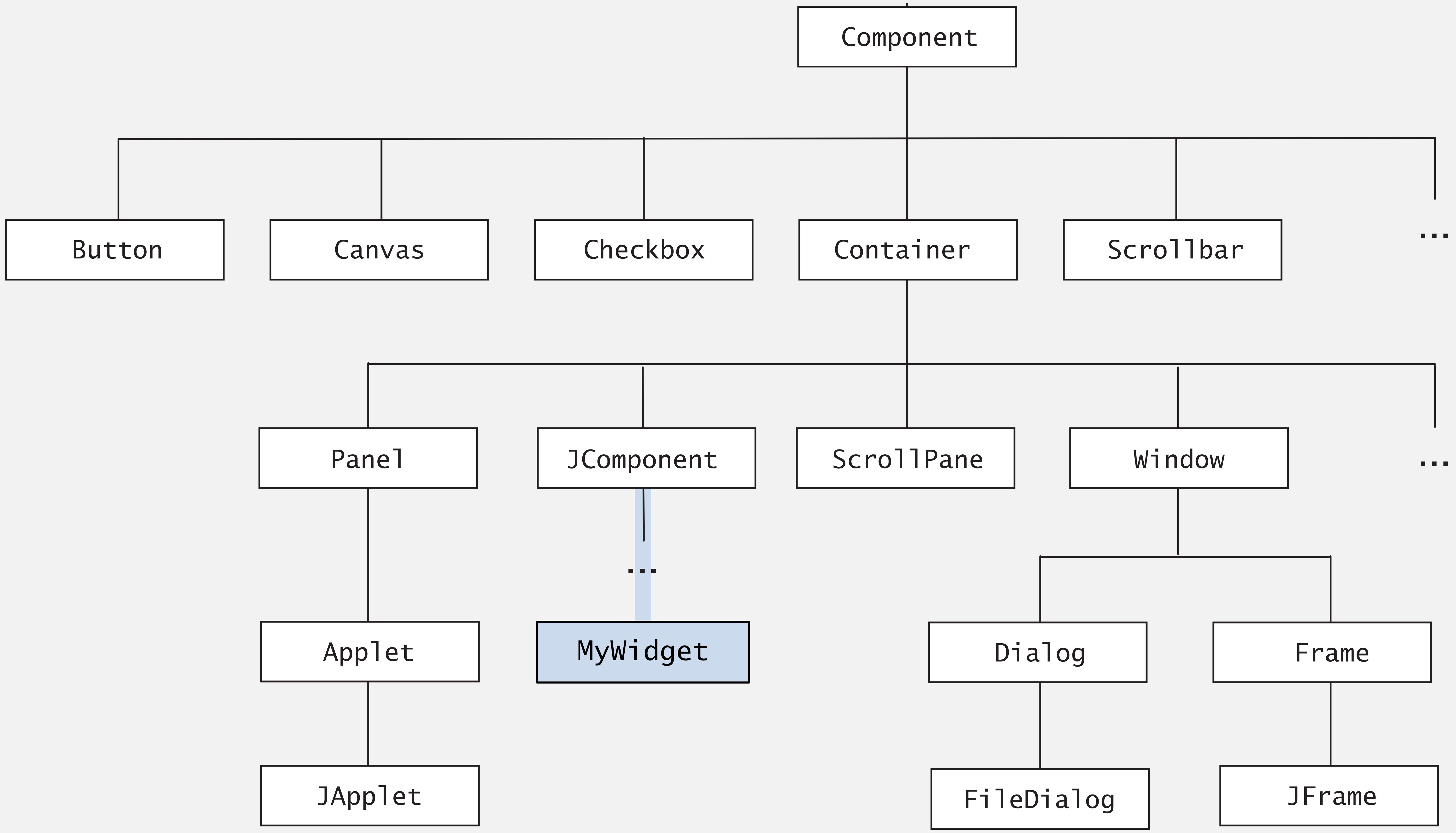
Eggs aren't supposed to be green.



○ Bird
○ Cat
○ Dog
○ Rabbit
● Pig



Enter the password: ••••••



**Java GUI class hierarchy**

# Is-A relationship

Informal rule. Inheritance should represent an Is-A relationship.

| subclass | parent class |
|---|---|
| `ColoredDisc` | `Disc` |
| `ArithmeticException` | `RuntimeException` |
| `JPasswordField` | `JTextField` |
| `Jeans` | `Clothing` |
| `SamsungGalaxyS10` | `SmartPhone` |

> “ *Objects of subtypes should behave like those of supertypes if used via supertype methods.”* — *Barbara Liskov*

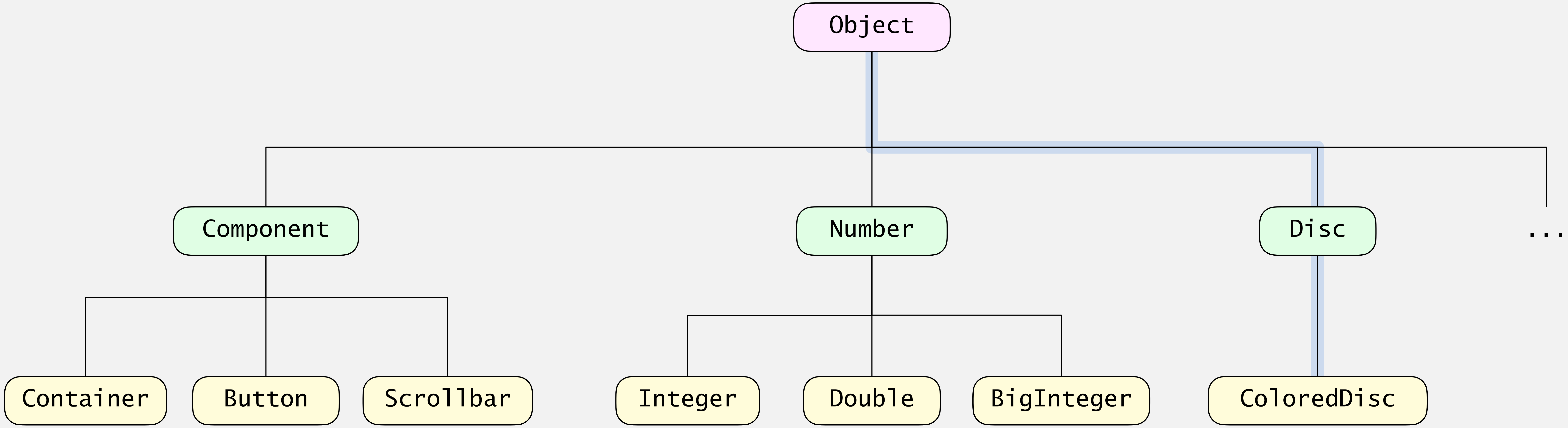
Liskov substitution principle

# Java's Object superclass

Object data type. Every class has Object as a (direct or indirect) superclass.

```
public class Disc extends Object  {
   ...


}
```

added implicitly
(if no extends clause)



Java class hierarchy

# Java’s Object superclass

Object data type. Every class has `Object` as a (direct or indirect) superclass.

| public class Object | | |
|---|---|---|
| String | toString() | *string representation* |
| boolean | equals(Object x) | *is this object equal to x ?* |
| int | hashCode() | *hash code of this object* |
| Class | getClass() | *runtime class of this object* |
| | ... | *copying, garbage collection, concurrency* |

Inherited methods. Inherited behavior is often not what you want ⇒ override them.

- Equals: reference equality (same as ==).
- Hash code: memory address of object (or random number).
- String representation: name of class, followed by `@`, followed by hash code.

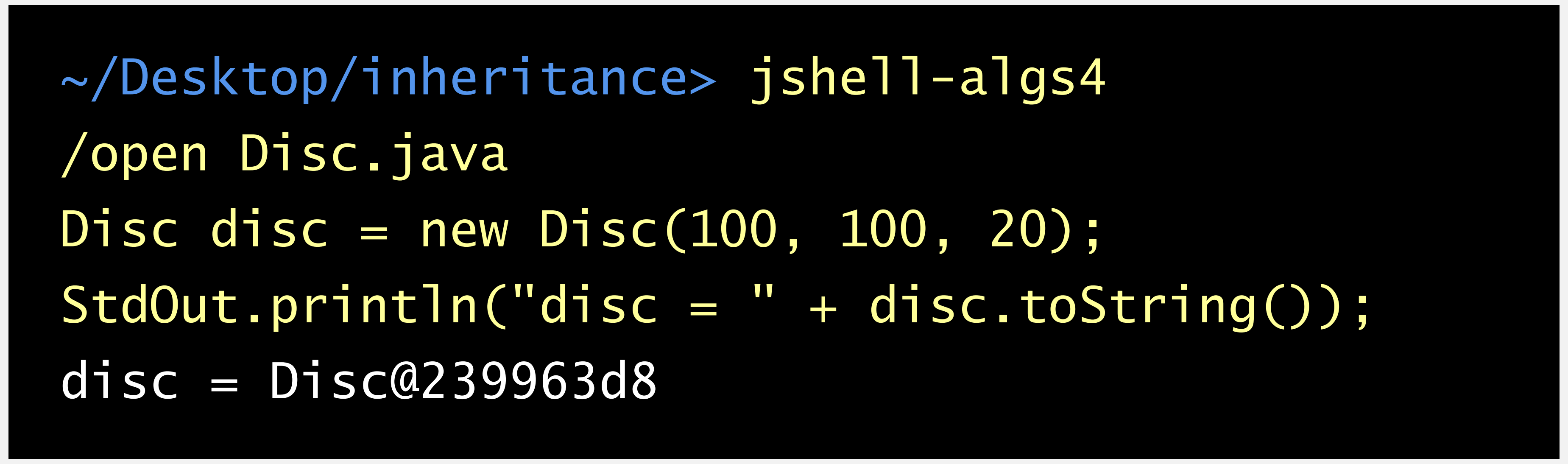
# The toString() method

Best practice. Override the `toString()` method.

```
public class Disc {
   protected int x, y, r;

   ...

   public String toString() {
     return String.format("(%d, %d, %d)", x, y, r);
   }

}
```

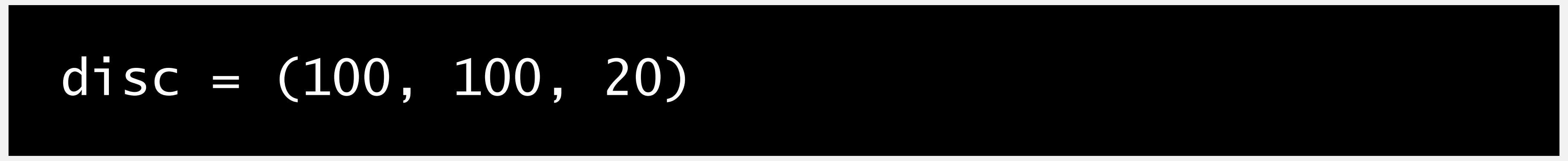
works like `printf()` but returns string (instead of printing it)

**without overriding toString() method**



```
~/Desktop/inheritance> jshell-algs4
/open Disc.java
Disc disc = new Disc(100, 100, 20);
StdOut.println("disc = " + disc.toString());
disc = Disc@239963d8
```

**after overriding toString() method**



```
disc = (100, 100, 20)
```

String concatenation operator. Java implicitly calls object's `toString()` method.

```
StdOut.println("disc = " + disc);
```

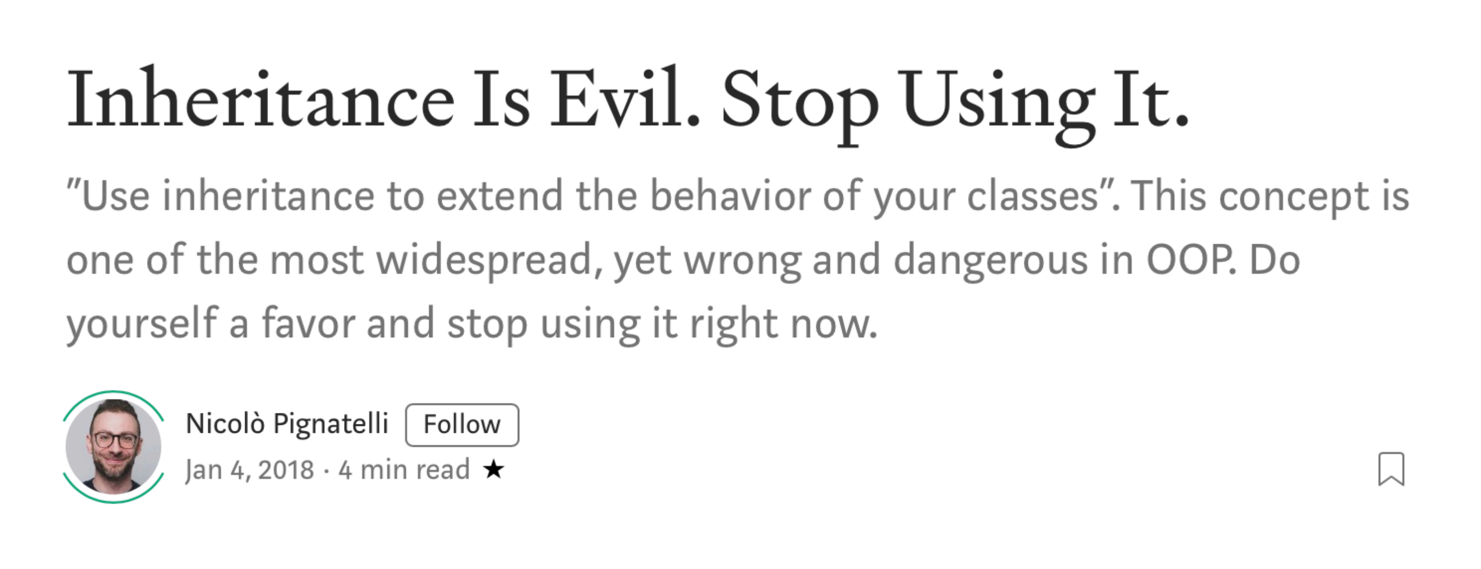
string concatenation operator

# Inheritance summary

Subclassing. Powerful OOP mechanism for code reuse.

Limitations.

- Violates encapsulation.
- Stuck with inherited instance variables and methods forever.
- Subclasses may break with seemingly innocuous change to superclass.



Inheritance Is Evil. Stop Using It.

"Use inheritance to extend the behavior of your classes". This concept is one of the most widespread, yet wrong and dangerous in OOP. Do yourself a favor and stop using it right now.

Nicolò Pignatelli

Jan 4, 2018 · 4 min read ★

Best practices.

- Use with extreme care.
- Favor composition (or interfaces) over subclassing.

This course.

- Yes: override inherited methods: `toString()`, `hashCode()`, and `equals()`.
- No: define subclass hierarchies.

Algorithms

Robert Sedgewick | Kevin Wayne

https://algs4.cs.princeton.edu

## Advanced Java

- *inheritance*
- *interfaces*
- *iterators*

# Motivation

Q1. How to design a single method that can sort arrays of strings, integers, or dates?

Q2. How to iterate over a collection without knowing the underlying representation?

Q3. How to intercept and process mouse clicks in a Java app?

A. Java interfaces.

```
String[] a = { "Apple", "Orange", "Banana" };
Arrays.sort(a);

Integer[] b = { 3, 1, 2 };
Arrays.sort(b);
```

**sort arrays**

```
Stack<String> = new Stack<>();
stack.push("First");
stack.push("Whitman");
stack.push("Mathey");

for (String s : stack)
   StdOut.println(s);
```

**iterate over a collection**

# Java interfaces overview

Interface. A set of methods that define some behavior (partial API) for a class.

```
public interface Shape2D {
   void draw();
   boolean contains(int x0, int y0);
}
```

the contract: methods with these signatures
(and prescribed behaviors)

class promises to
honor the contract

```
public class Disc implements Shape2D {
   protected int x, y, r;

   public Disc(double x, double y, double r) {
      this.x = x;
      this.y = y;
      this.r = r;
   }

   public void draw() {
      StdDraw.filledCircle(x, y, r);
   }

   public boolean contains(int x0, int y0) {
      int dx = x - x0;
      int dy = y - y0;
      return dx*dx + dy*dy <= r*r;
   }

   public boolean intersects(Disc that) {
      ...
   }
}
```

class abides by
the contract

class can define
additional methods

# Java interfaces overview

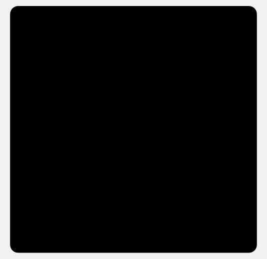
Interface. A set of methods that define some behavior (partial API) for a class.

```
public interface Shape2D {
   void draw();
   boolean contains(int x0, int y0);
}
```

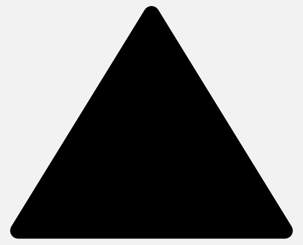
the contract: methods with these signatures
(and prescribed behaviors)

Many classes can implement the same interface.

```
public class Square implements Shape2D {
   ...
}
```



```
public class Triangle implements Shape2D {
   ...
}
```



```
public class Star implements Shape2D {
   ...
}
```

```
public class Heart implements Shape2D {
   ...
}
```

# Java interfaces demo (in JShell)

```
~/Desktop/inheritance> jshell-algs4
/open Shape2D.java
/open Disc.java
/open Square.java
/open Heart.java

Square square = new Square(400, 400, 200);
Shape2D disc = new Disc(400, 700, 100);
Shape2D heart = new Heart(400, 400, 100);

~~Shape2D s = "Hello, World";~~       // compile-time error (incompatible types)

square.area();
square.contains(400, 300);
disc.contains(400, 300);
~~disc.area();~~                      // compile-time error (not a Shape2D method)

StdDraw.setScale(0, 800);
Shape2D[] shapes = { disc, square, heart };
for (int i = 0; i < shapes.length; i++)
    shapes[i].draw();
```

implicit type conversion
(upcasting)

# Java interface properties

Interfaces are reference types. Can use interface name anywhere you can use a data type name.

variable declarations, argument types, return types

Subtype polymorphism. A class that implements an interface is a subtype of that interface: objects of the subtype can be used anywhere objects of the interface are allowed.

RHS of assignment statements, method arguments, return types, ...

Key differences with inheritance.

- Uses keyword `implements` instead of `extends`.
- No instance variables or instance methods inherited.
- Multiple inheritance: a class can implement many interfaces (but extend only one class).

```
public class MovableDisc extends Disc implements Shape2D, Movable {
   ...
}
```

# Advanced Java: quiz 2

**Which of the following statements leads to a compile-time error?**

**A.** `Shape2D shape = new Shape2D();`

**B.** `Shape2D[] shapes = new Shape2D[10];`

**C.** Both A and B.

**D.** Neither A nor B.

# Java interfaces in the wild

Interfaces are essential for industrial-strength programming in Java.

| purpose | built-in interfaces |
|---|---|
| sorting | java.lang.Comparable<br>java.util.Comparator |
| iteration | java.lang.Iterable<br>java.util.Iterator |
| collections | java.util.List<br>java.util.Map<br>java.util.Set |
| GUI events | java.awt.event.MouseListener<br>java.awt.event.KeyListener<br>java.awt.event.MenuListener |
| lambda expressions | java.util.function.Consumer<br>java.util.function.Supplier<br>java.util.function.BinaryOperator |
| concurrency | java.lang.Runnable<br>java.lang.Callable |

this course

# Java interfaces summary

Java interface. A set of methods that define some behavior (partial API) for a class.

Design benefits.

- Enables callbacks, which promotes code reuse.
- Facilitates lambda expressions for functional programming.

This course.

- Yes: use interfaces built into Java (for sorting and iteration).
- No: define our own interfaces; lambda expressions.

https://algs4.cs.princeton.edu

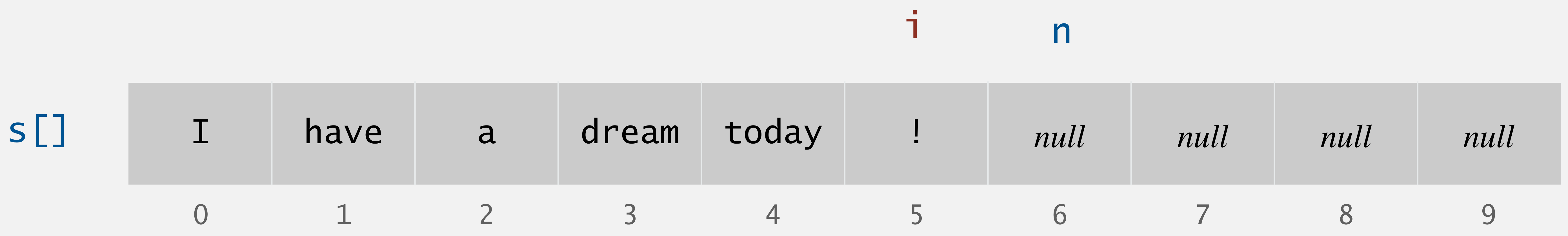
# Advanced Java

- *inheritance*
- *interfaces*
- *iterators*

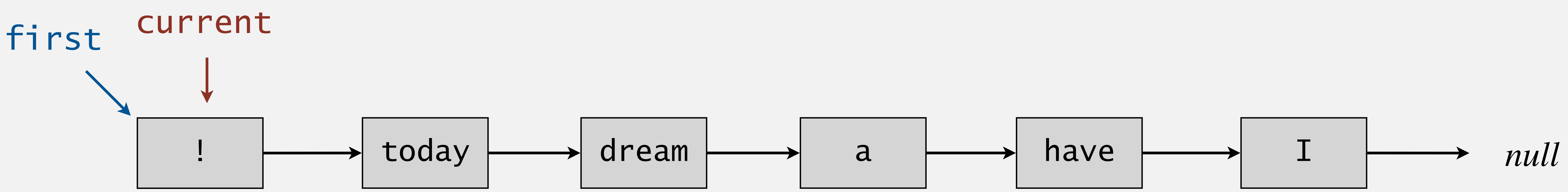
# Iteration

Design challenge. Allow client to iterate over items in a collection (e.g., a stack), without exposing its internal representation.

stack (resizing-array representation)



stack (linked-list representation)



Java solution. Use a foreach loop.

# Foreach loop

Java provides elegant syntax for iterating over items in a collection.

**“foreach” loop (shorthand)**

```
Stack<String> stack = new Stack<>();
...

for (String s : stack) {
    ...
}
```

**equivalent code (longhand)**

```
Stack<String> stack = new Stack<>();
...

Iterator<String> iterator = stack.iterator();
while (iterator.hasNext()) {
   String s = iterator.next();
   ...
}
```

## To make user-defined collection support foreach loop:

- Data type must have a method named `iterator()`.
- The `iterator()` method returns an `Iterator` object that has two core method:
  - the `hasNext()` methods returns `false` when there are no more items
  - the `next()` method returns the next item in the collection

# Iterator and Iterable interfaces

Java defines two interfaces that facilitate foreach loops.

- `Iterable` interface: `iterator()` method that returns an `Iterator`. ← "I am a collection that can be traversed with a foreach loop"
- `Iterator` interface: `next()` and `hasNext()` methods. ← "I represent the state of one traversal" (supports multiple iterators over the same collection)
- Each interface is generic.

**java.lang.Iterable interface**

```
public interface Iterable<Item>
{
   Iterator<Item> iterator();
}
```

**java.util.Iterator interface**

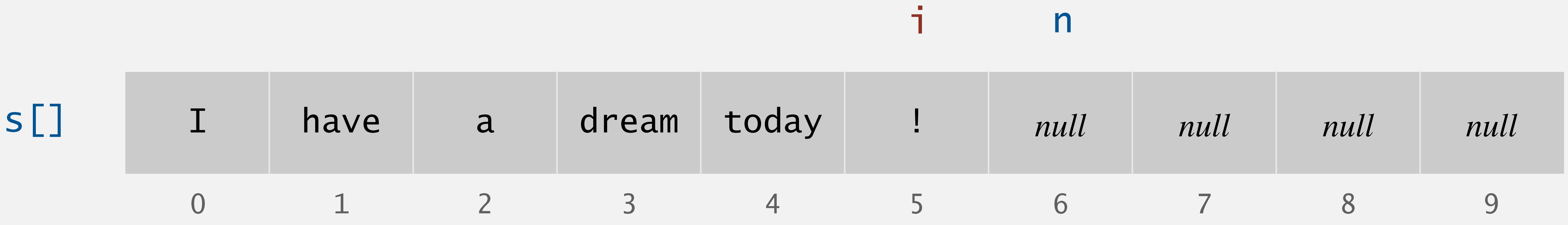
```
public interface Iterator<Item>
{
   boolean hasNext();
   Item next();
}
```

Type safety. Foreach loop won't compile unless collection is `Iterable` (or an array).

# Stack iterator:  array implementation

```
import java.util.Iterator;

public class ResizingArrayStack<Item> implements Iterable<Item>
{
    ...

   public Iterator<Item> iterator() { return new ReverseArrayIterator(); }

   private class ReverseArrayIterator implements Iterator<Item>
   {
      private int i = n-1;    // index of next item to return

      public boolean hasNext() {  return i >= 0;    }
      public Item next()       {  return s[i--];    }
   }

}
```

Note: next() must throw a NoSuchElementException if called when no more items in iteration

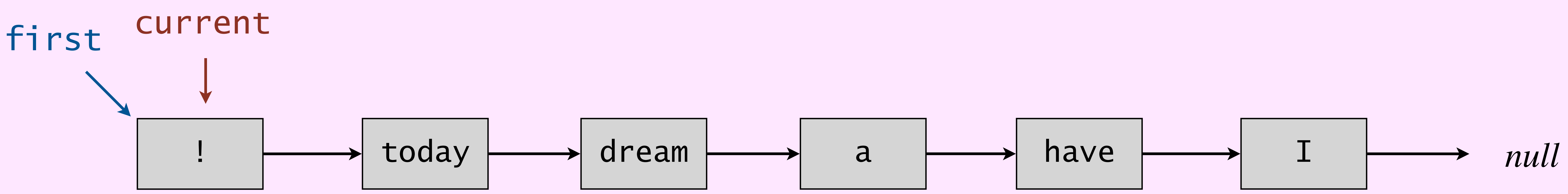


| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | i | n | | | |
| s[] | I | have | a | dream | today | ! | *null* | *null* | *null* | *null* |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

# Stack iterator: linked-list implementation (in IntelliJ)

```
import java.util.Iterator;

public class LinkedStack<Item>  implements Iterable<Item>
{
   ...
   public Iterator<Item> iterator() { return new LinkedIterator(); }

   private class LinkedIterator implements Iterator<Item>
   {
      private Node current = first;

      public boolean hasNext() {  return current != null;  }

      public Item next()
      {
         Item item = current.item;
         current   = current.next;
         return item;
      }
   }
}
```

Note: next() must throw a NoSuchElementException when called with no more items in iteration



# Advanced Java: quiz 3

**Suppose that you add A, B, and C to a stack (linked list or resizing array), in that order.**

**What does the following code fragment do?**

```
for (String s : stack)
   for (String t : stack)
      StdOut.println(s + "-" + t);
```

**A.** Prints `A-A A-B A-C B-A B-B B-C C-A C-B C-C`

**B.** Prints `C-C B-B A-A`

**C.** Prints `C-C C-B C-A`

**D.** Prints `C-C C-B C-A B-C B-B B-A A-C A-B A-A`

**E.** Depends upon implementation.

# Advanced Java: quiz 4

**Suppose that you add A, B, and C to a stack (linked list or resizing array), in that order.**

**What does the following code fragment do?**

```
for (String s : stack)
{
   StdOut.println(s);
   StdOut.println(stack.pop());
   stack.push(s);
}
```

**A.** Prints A A B B C C

**B.** Prints C C B B A A

**C.** Prints C C B C A B

**D.** Prints C C C C C C C C . . .

**E.** Depends on implementation.

# ITERATION: CONCURRENT MODIFICATION

Q. What should happen if a client modifies a collection while iterating over it?

A. A fail-fast iterator throws a `java.util.ConcurrentModificationException`.

concurrent modification

```
for (String s : stack)
   stack.push(s);
```

Q. How to detect concurrent modification?

A.

# Java iterators summary

Iterator and Iterable. Two Java interfaces that allow a client to iterate over items in a collection without exposing its internal representation.

```
Stack<String> stack = new Stack<>();
...

for (String s : stack) {
  ...
}
```

This course.

- Yes: use iterators in client code.
- Yes: implement iterators (Assignment 2 only).

> *“ I was interested in doing it, there was an opportunity,*
> *so I just did it. ”* — *Barbara Liskov*