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8. Java: Generics and Annotations

Generics and Annotations

Sources

- David Flanagan, *Java in a Nutshell*, 5th Edition, O'Reilly.
- GoF, *Design Patterns. Elements of Reusable Object-Oriented Software*, Addison Wesley,1997.
- Gilad Bracha, *Generics in the Java Programming Language, 2004*

Roadmap

> Generics
> Annotations
> Model-Driven Engineering

Roadmap

- **Generics**
- Annotations
- Model-Driven Engineering

Why do we need generics?

Generics allow you to *abstract* over *types*.
The most common examples are container types,
the collection hierarchy.

Motivating Example – Old Style

```
List stones = new LinkedList();
stones.add(new Stone(RED));
stones.add(new Stone(GREEN));
stones.add(new Stone(RED));
Stone first = (Stone) stones.get(0);
```

```
public int countStones(Color color) {
    int tally = 0;
    Iterator it = stones.iterator();
    while (it.hasNext()) {
       Stone stone = (Stone) it.next();
       if (stone.getColor() == color) {
           tally++;
       }
    }
    return tally;
}
```

The cast is annoying but essential!

Motivating example – new style using generics

List is a *generic interface* that takes a type as a *parameter*.

```
List<Stone> stones = new LinkedList<Stone>();
stones.add(new Stone(RED));
stones.add(new Stone(GREEN));
stones.add(new Stone(RED));
Stone first = /*no cast*/ stones.get(0);
```

```
public int countStones(Color color) {
    int tally = 0;
    /*no temporary*/
    for (Stone stone : stones) {
       /*no temporary, no cast*/
       if (stone.getColor() == color) {
           tally++;
       }
    }
    return tally;
}
```

Compile Time vs. Runtime Safety

Old way

```
List stones = new LinkedList();
stones.add("ceci n'est pas un stone");

...

Stone stone = (Stone) stones.get(0);
```

No check, unsafe

Runtime error

New way

```
List<Stone> stones = new LinkedList<Stone>();
stones.add("ceci n'est pas un stone");

...

Stone stone = stones.get(0);
```

Compile time check

Runtime is safe

Stack Example

```
public interface StackInterface {
   public boolean isEmpty();
   public int size();
   public void push(Object item);
   public Object top();
   public void pop();
}
```

Old way

```
public interface StackInterface<E> {
   public boolean isEmpty();
   public int size();
   public void push(E item);
   public E top();
   public void pop();
}
```

New way: we define a generic interface that takes a type parameter

Linked Stack Example

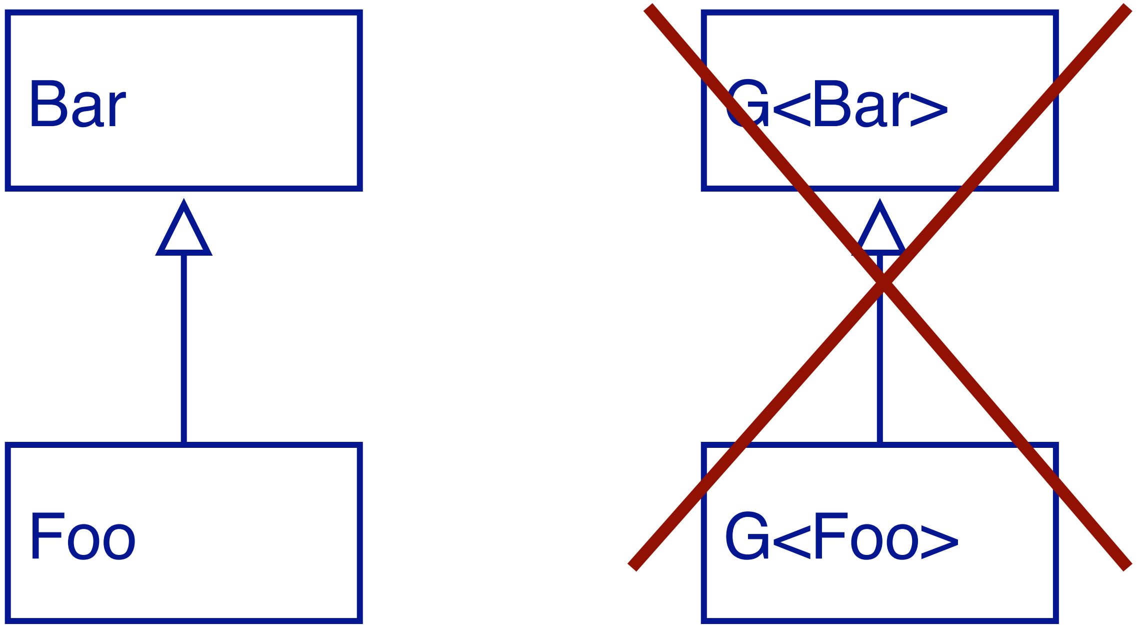
```
public class LinkStack<E> implements StackInterface<E> {
…
   public class Cell {
     public E item;
     public Cell next;
     public Cell(E item, Cell next) {
        this.item = item;
        this.next = next;
     }
   }

…
   public E top() {
     assert !this.isEmpty();
     return top.item;
   }
```

Creating a Stack of Integers

```java
Stack<Integer> myStack = new LinkedStack<Integer>();
myStack.push(42); // autoboxing
```

When a generic is instantiated, the *actual type parameters* are substituted for the *formal type parameters*.

Generics and Subtyping



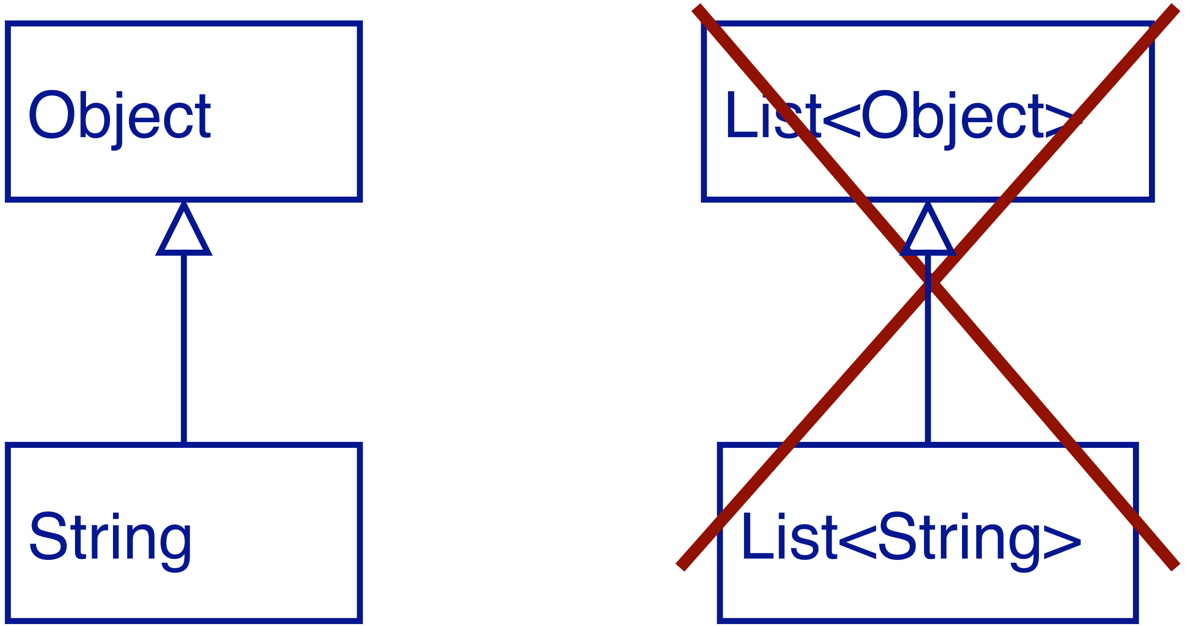
In Java, Foo is a subtype of Bar only if Foo's interface *strictly includes* Bar's interface. Instantiated generics normally have *different* interfaces. *(I.e., if the type parameters are used in the public interface.)*

Generics and Subtyping (II)

```
List<String> ls = new ArrayList<String>();

List<Object> lo = ls;

lo.add(0, new Object()); // legal?!
ls.get(0); // Not a string?!
```

Compile error as it is not type safe!

In other words…



Wildcards

```
void printCollection(Collection c) {
   Iterator i = c.iterator();
   while (i.hasNext()) {
     System.out.println(i.next());
   }
}
```

We want a method that prints our all the elements of a collection

```
void printCollection(Collection<Object> c) {
   for (Object e: c){
     System.out.println(e);
   }
}
```

Here is a naïve attempt at writing it using generics

```
printCollection(stones);
```

Won’t compile!

What type matches all kinds of collections?

```
Collection<?>
```

“collection of unknown” is a collection whose element type matches anything — **a wildcard type**

```
void printCollection(Collection<?> c) {
    for (Object e: c){
      System.out.println(e);
    }
}
```

```
printCollection(stones);
```

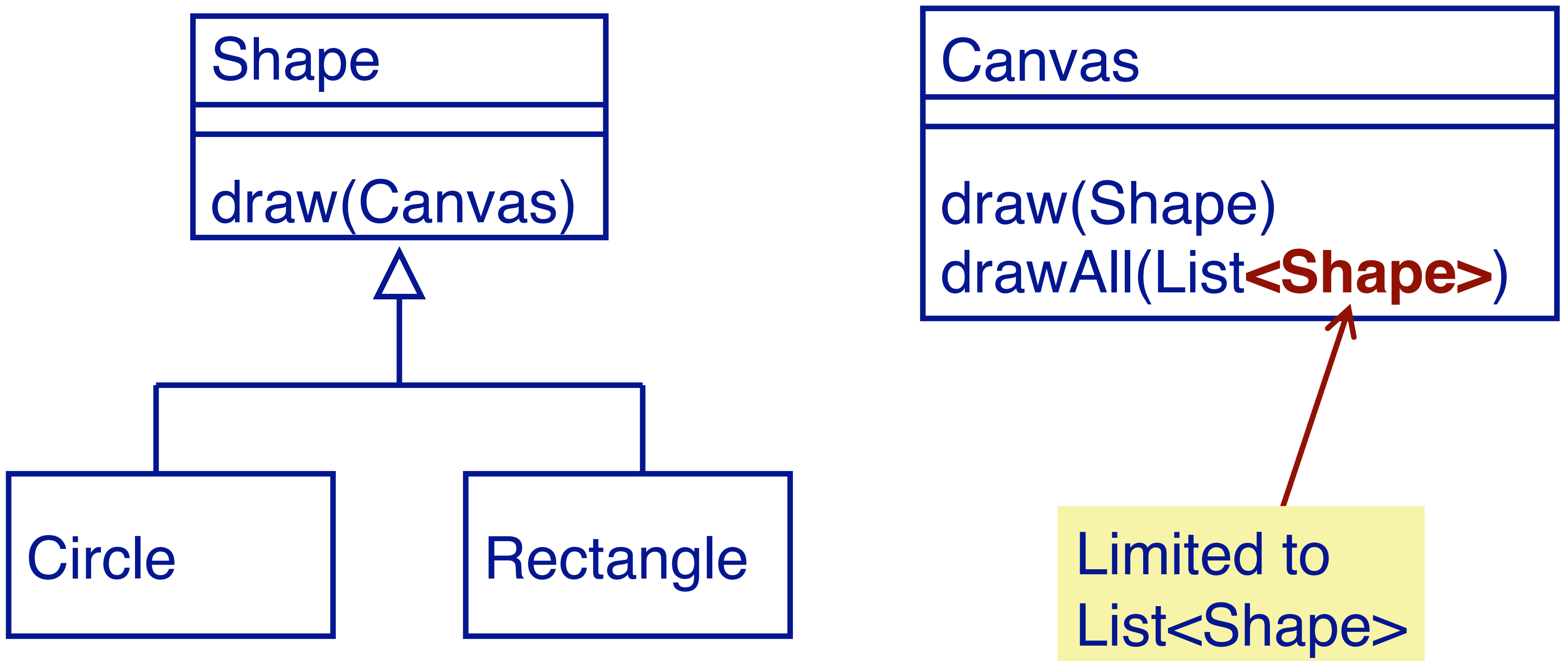
```
stone(java.awt.Color[r=255,g=0,b=0])
stone(java.awt.Color[r=0,g=255,b=0])
stone(java.awt.Color[r=0,g=255,b=0])
```

Pitfalls of wildcards

```
String myString;
Object myObject;
List<?> c = new ArrayList<String>();

// c.add("hello world");                // compile error
// c.add(new Object());                 // compile error
((List<String>) c).add("hello world");
((List<Object>) c).add(new Object());   // no compile error!

// String myString = c.get(0);          // compile error
myString = (String) c.get(0);
myObject = c.get(0);
myString = (String) c.get(1);           // run-time error!
```

Bounded Wildcards

Consider a simple drawing application to draw shapes (circles, rectangles,…)



Limited to List<Shape>

A Method that accepts a List of any kind of Shape...

```
public void drawAll(List<? extends Shape>) {…}
```

a bounded wildcard

Shape is the ***upper bound*** of the wildcard

More fun with generics

```
import java.util.*;
 …

   public void pushAll(Collection<? extends E> collection) {
     for (E element : collection) {
        this.push(element);
     }
   }

   public List<E> sort(Comparator<? super E> comp) {
     List<E> list = this.asList();
     Collections.sort(list, comp);
     return list;
   }
```

All elements must be *at least* an E

The comparison method must require *at most* an E

Roadmap

- Generics
- **Annotations**
- Model-Driven Engineering

Annotations

> Annotations are a *special kind of comment*

— As with comments, annotations do not change or affect the semantics of the program, i.e. the runtime behavior.

> Annotations are *meta-descriptions*

— Unlike comments, annotations can be accessed and used by third-party tools (e.g. JUnit) or even your program itself.

JUnit uses annotations

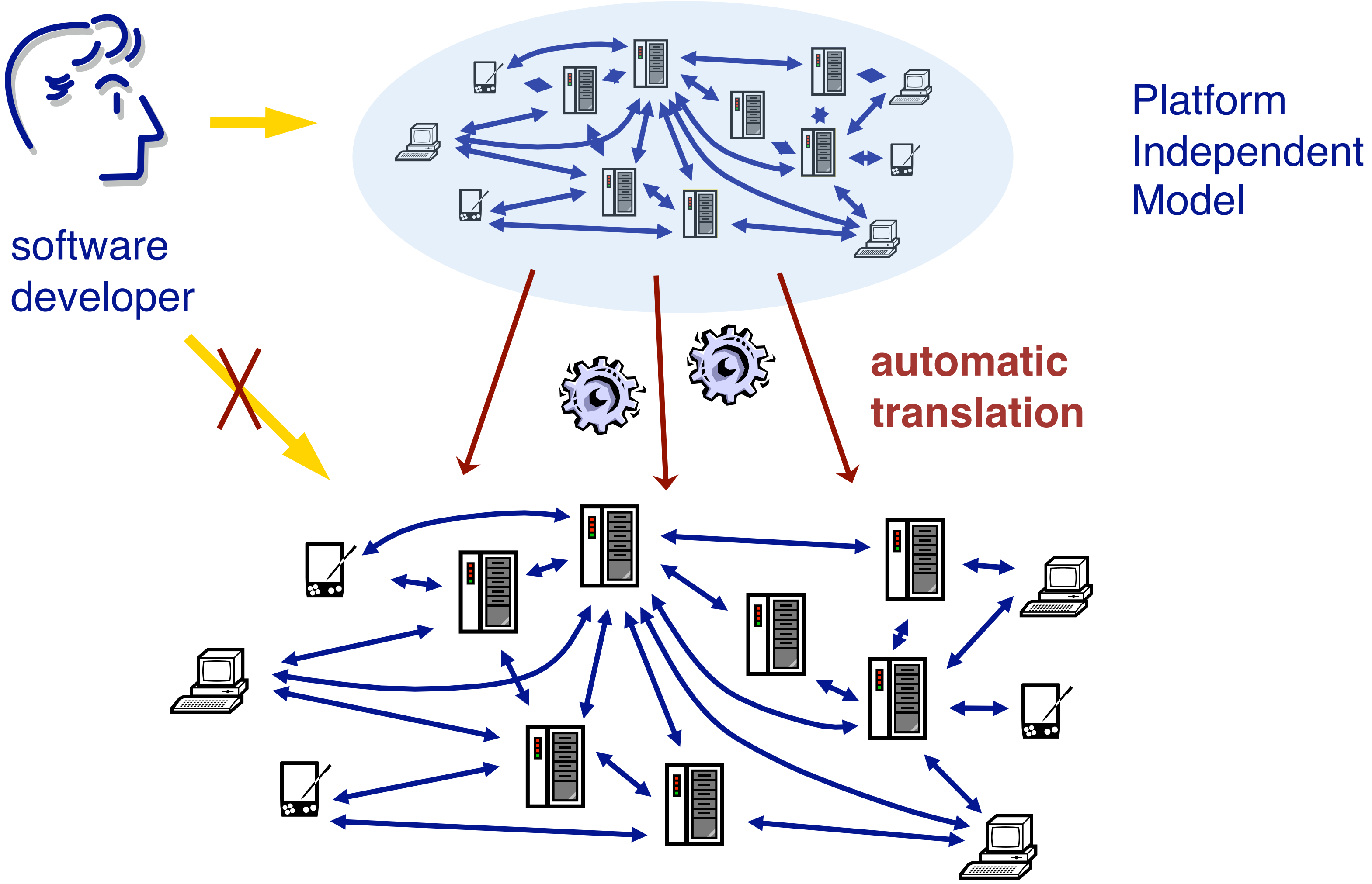
```
@Before
public void setup() { …

@Test
public void someTest() { …

@Test(expected=IOException.class)
public void anotherTest() { …
```

JUnit uses annotations to find out which methods are test methods, and which are part of the setup. You may even pass parameters to the annotations.

Roadmap

- > Generics
- > Annotations
- > **Model-Driven Engineering**

The Vision of MDE

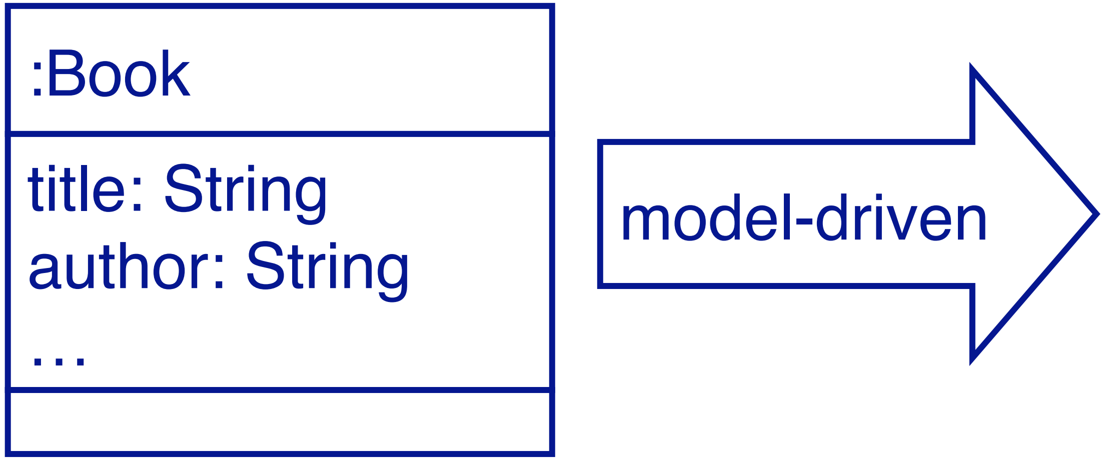


Example: a model-driven UI

- We want a UI to edit any kind of object with any kind of properties (i.e. Model-driven Engineering)

- The example requires these steps
  - Define custom annotations for getters and setters.
  - Annotate our classes with these annotations
  - Write a UI class that access these annotations at runtime to create a custom UI

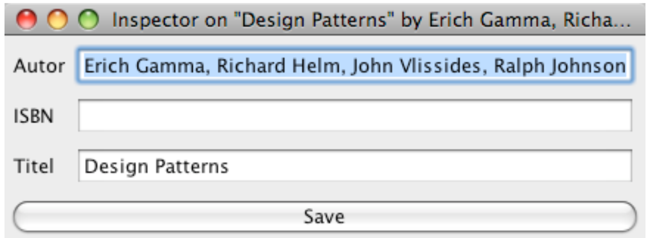
Model-driven Engineering



:Book

title: String
author: String
…

model-driven

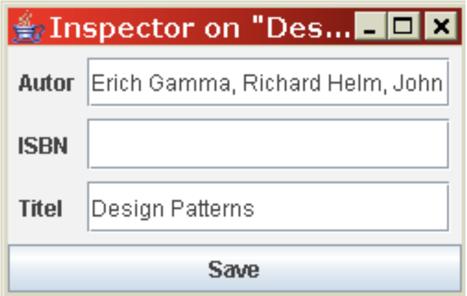


Inspector on "Design Patterns" by Erich Gamma, Richa…

Autor: Erich Gamma, Richard Helm, John Vlissides, Ralph Johnson

ISBN:

Titel: Design Patterns



Inspector on "Des…

Autor: Erich Gamma, Richard Helm, John

ISBN:

Titel: Design Patterns

Model
can be any kind of object
with any kind of properties

Model-driven UI
labels and field are automatically
created based on the model

Defining our custom annotations

```
import java.lang.annotation.*;

@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.METHOD)
public @interface GetProperty {


   public String value();

}
```

This defines a **`@GetProperty`** annotation for methods. The annotation is accessible at runtime.

Annotating our domain classes

```
@GetProperty(“Titel”)
public void getTitle() {
   return title;
}

@GetProperty(“Autor”)
public void getAuthor() {
   return author;
}


…
```

Use reflection to access the annotations of any object

```
import java.reflect.Method;

public void printAnnotatedMethods(Object obj) {
   for (Method m : obj.getClass().getMethods()) {
     if (m.isAnnotationPresent(GetProperty.class)) {
        this.processProperty(obj, m);
     }
   }
}
```

The for loop iterates over all methods of obj’s Class.
The if block is only entered for annotated methods.

Use reflection to call any method of any object

```
import java.reflect.Method;

public void processProperty(Object obj, Method m)
     throws Exception {
   GetProperty g = m.getAnnotation(GetProperty.class);
   this.add(new Jlabel(g.value()));
   String value = (String) m.invoke(obj);
   this.add(new JTextField(value));
}
```

We use reflection to invoke the method **`m`** on the object **`obj`**.

What you should know!

- ✎ *Why do I need generics?*
- ✎ *Why is casting dangerous?*
- ✎ *How do I use generics?*
- ✎ *Can I subtype a generic type?*
- ✎ *When is the Abstract Factory pattern useful?*
- ✎ *Some uses of Annotations?*
- ✎ *A Model-Driven Engineering Example*

Can you answer these questions?

- ✎ *Why is List<Object> not the supertype of List<String>?*
- ✎ *Which pattern could we use to implement a Windowing Toolkit that supports multiple "look-and-feel" user interfaces?*
- ✎ *What are the advantages and disadvantages of using the Abstract Factory Pattern?*

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