ALGONQUIN COLLEGE

MODULE 08: POLYMORPHISM

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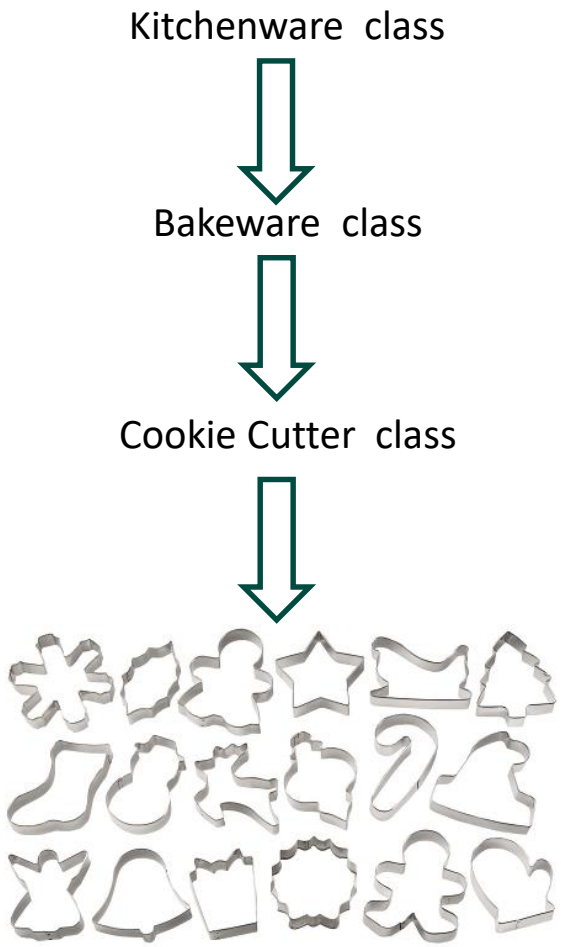
8.0 Polymorphism

Recall from Module 01 that inheritance and abstraction allow for the creation of **class hierarchies**, in which classes near the top of the hierarchy tend to be general, abstract and have few members, while those near the bottom tend to be concrete classes more richly-endowed with specialized features.

Polymorphism is a feature which allows an object of a subclass to be treated *as if* it was a member of the superclass in the same class hierarchy due to the compositional (i.e. *is a*) relationship between derived objects. For example, any object derived from a `CookieCuter` *is a* member of the `CookieCutter` class, *and* the `Bakeware` class, *and* the `Kitchenware` class—and ultimately, the `Object` class.



SnowflakeCookie class, GingerbreadManCookie class, etc.

D&D 10.2 D&D 10.3

8.0 Polymorphism

For example, consider the case in which we wish to store objects in an array declared as being of type `SnowflakeCookie`. Then, only objects instantiated directly from `new SnowflakeCookie()` will fit into the array. But if the array is declared as the superclass `CookieCutter`, then any subclass type of `CookieCutter` can be stored.

So if `CookieCutter` is a superclass (abstract or concrete) and we define an array:

```
CookieCutter[] cookieBox = new CookieCutter[35];
```

then any object derived from the `CookieCutter` superclass, i.e.

```
public class SnowflakeCookie extends CookieCutter{…}
```

can be stored into the `cookieBox` array, without casting:

```
CookieCutter[0] = new SnowflakeCookie();
```

Polymorphism allows us to do this, even though the data types on either side of the equals sign are different.

8.0 Polymorphism

Polymorphism means that a variable of a superclass type can be used to store or pass a subclass object.

For example, in the previous module, `Circle` and `Rectangle` were both declared as subclasses of `GeometricObject` via the declarations

```
public class Circle extends GeometricObject {…}
```

and

```
public class Rectangle extends GeometricObject {…}
```

8.0 Polymorphism

Polymorphism means that a variable of a superclass type can be used to store or pass a variable of one of its subclasses.

And thus,

A `Circle` object *is a* `GeometricObject`,

A `Circle` object *is a* `Object`,

and in general,

a subclass object *is an* instance of any superclass object.

8.0 Polymorphism

Recall from Module 04 that we declared classes `Circle` and `Rectangle` that extended `GeometricObject`. Every instance of a `GeometricObject` subclass is also an instance of its superclass. So if we have a method that takes as a formal parameter a `GeometricObject`:

```
public void displayObject(GeometricObject object){…}
```

Then we can then pass *any of its subclasses* into this method as the actual parameter, provided it is a subclass in the `GeometricObject`. So the above method can be used with, for example, a `Circle` object:

```
Circle circ = new Circle();
...
displayObject(circ);
```

Thus while the *formal* parameter type is a `GeometricObject`, the *actual* type passed is a subclass, `Circle`.

Liang 11.7 | D&D 10.2 | D&D 10.3

8.0 Polymorphism

Similarly, as we saw earlier (with the `CookieCutter` class) an array of objects of the superclass type may be used to store objects of the subclass type. So

```
GeometricObject[] geoObjArray = new GeometricObject[3];
...
geoObjArray[0] = new Rectangle(3,12);
geoObjArray[1] = new Circle(3);
```

We can then print out the area of each `GeometricObject` using:

```
for (GeometricObject geoObjElement: geoObjArray)
   System.out.println("Area = " + geoObjElement.getArea());
```

8.0 Polymorphism

Alternately, since every object extends from the `Object` class, we could use `Object` in place of `GeometricObject` in the declaration above (as we did when discussing the `instanceof` operation).

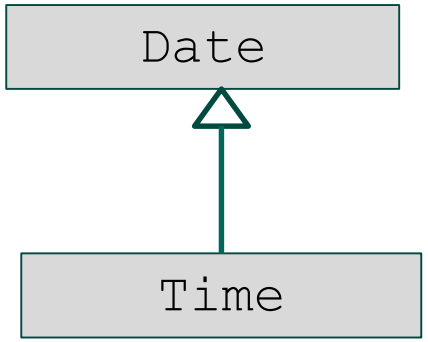
```
Object[] objArray = new GeometricObject[3];

...
objArray[0] = new Rectangle(3,12);
objArray[1] = new Circle(3);

for (Object objElement: objArray)
   System.out.println("Area = " +
                      ((GeometricObject)objElement).getArea());
```

But then any kind of object could be used in the `for` loop…until we tried to get the area of, say, a `Scanner`. This is prevented by the correct use of types (using `GeometricObject` rather than `Object`), and by the use of generic types, to which we shall return shortly.

8.0 Polymorphism

Examples of *is a* relationships (and polymorphism) can be found in `java.lang` and `java.util`. For example:

```
public class Time extends Date
```

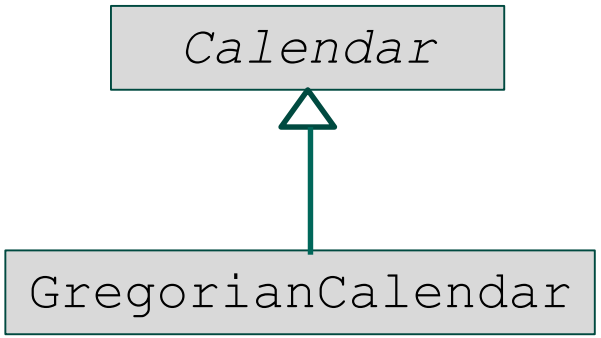


So a `Time` object *is a* `Date` object as well.

```
public class GregorianCalendar
             extends Calendar
```

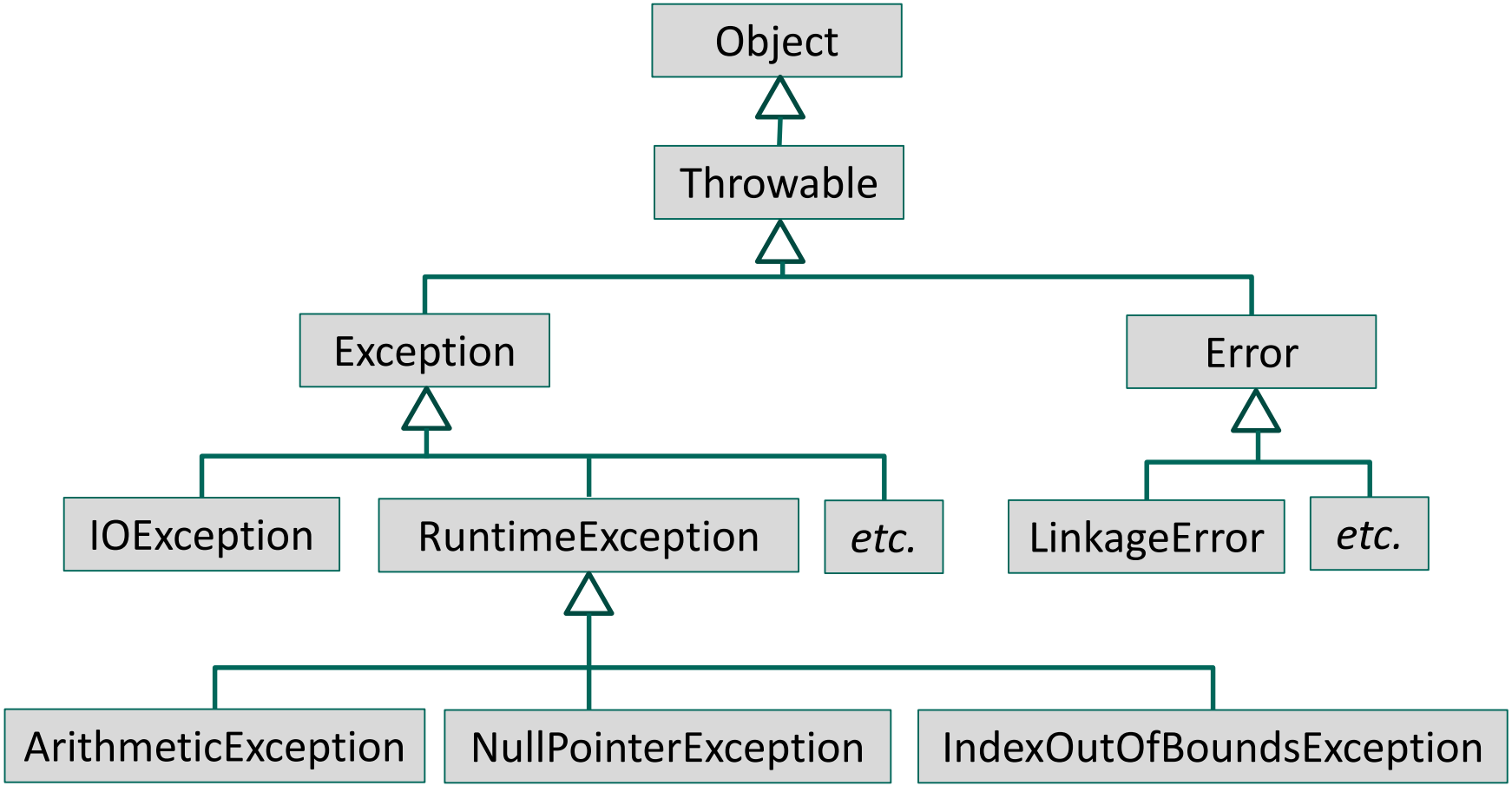
So a `GregorianCalendar` object *is a* `Calendar` object as well. We can write:

```
Calendar calendar =
          new GregorianCalendar();
```



Questions:

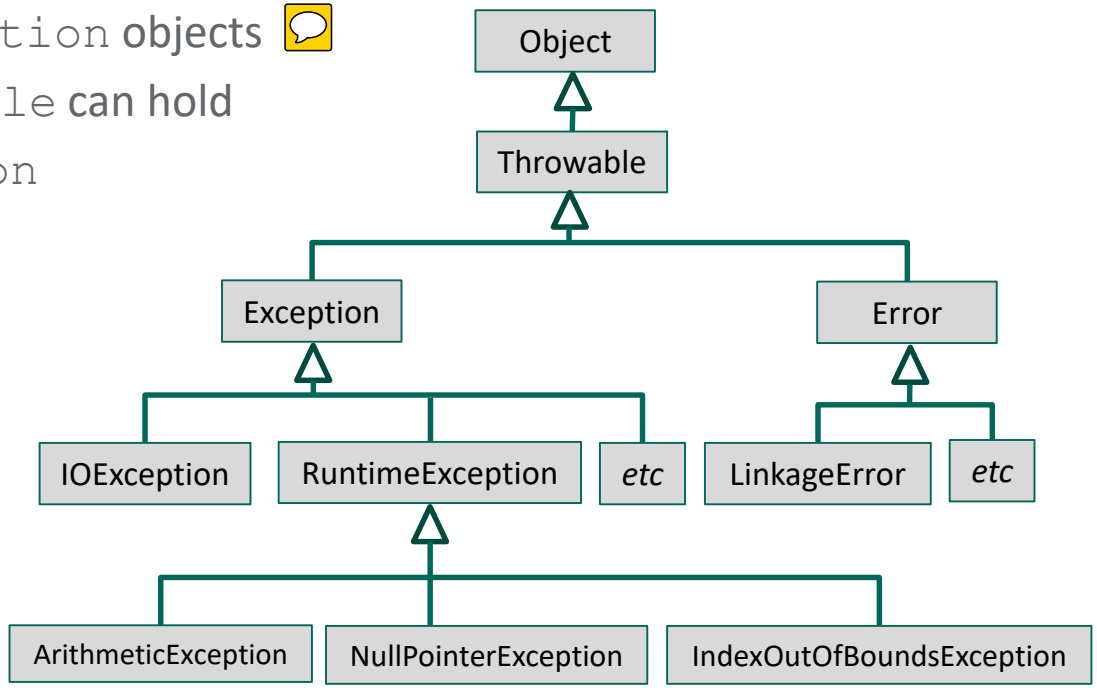
The `Throwable` class has a rich object hierarchy:



Questions:

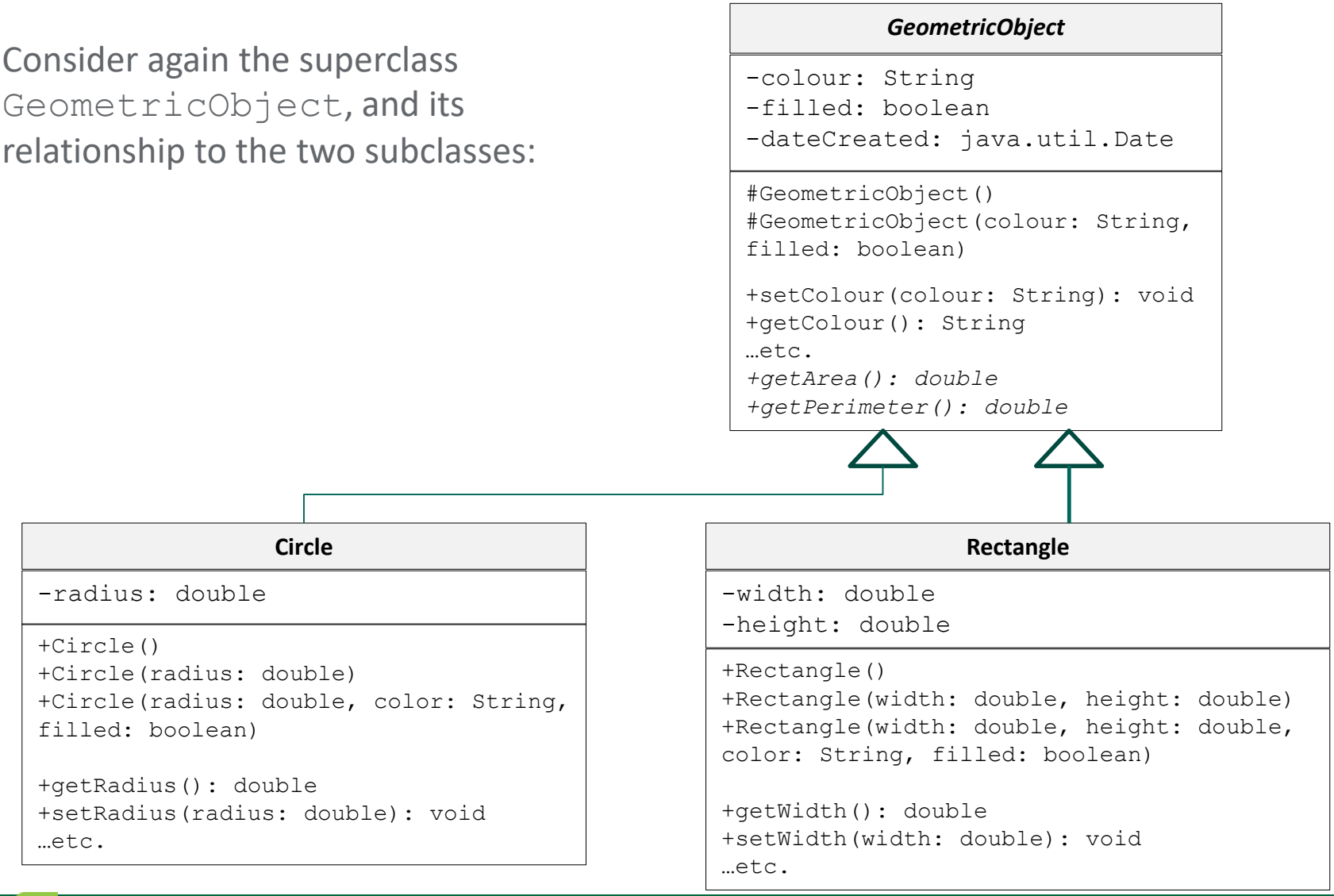
Answer true or false for each of the following:

1. An `IOException` object is an instance of `Throwable`
2. A `LinkageError` object is an instance of `Error`
3. A `LinkageError` object is an instance of Exception
4. An array of type `RuntimeException` can hold `ArithmeticException` objects
5. An array of type `Throwable` can hold `NullPointerException` objects



8.1 Polymorphism in action

Consider again the superclass `GeometricObject`, and its relationship to the two subclasses:



8.1 Polymorphism in action

Recall that the `GeometricObject` declared two abstract methods…

```
public abstract class GeometricObject
  private String colour = "white";
  private boolean filled;
  private java.util.Date dateCreated;

  protected GeometricObject(){
    dateCreated =new java.util.Date();
  }

  protected GeometricObject(
        String colour, boolean filled)
    dateCreated =new java.util.Date();
    this.colour = colour;
    this.filled = filled;
  }

  public void setColour(String colour){
    return colour;
  }
```

```
  public String getColour(){
    return colour;
  }

  …etc.

  public abstract double getArea();

  public abstract double getPerimeter();
}
```

abstract methods

8.1 Polymorphism in action

…and because they were abstract, they *had* to be overridden in their subclasses:

```
public class Rectangle
    extends GeometricObject{
    …
    public double getPerimeter(){
      return (2 * (width + height));
    }

    public double getArea(){
      return (width * height);
    }
}
```

```
public class Circle
    extends GeometricObject{
    …
    public double getPerimeter(){
      return (2 * Math.PI * radius);
    }

    public double getArea(){
      return (Math.PI * radius * radius);
    }
}
```

8.1 Polymorphism in action

To actually put these classes to use, we'll need a test class in `main()`:

```
public static TestGeometricObject {
  public static void main(String[] args){
    GeometricObject circ1 = new Circle(5);
    GeometricObject rect1 = new Rectangle(5, 3);
    System.out("Same area? " +
            equalArea(circ1, rect1));
  }

  private static boolean equalArea(GeometricObject obj1,
                                   GeometricObject obj2){
    return obj1.getArea() == obj2.getArea();
  }
}
```

8.1 Polymorphism in action

Polymorphism allows us to pass the two instantiated objects as special subclass objects of the `GeometricObject` type. If we'd declared the `equalArea()` method with two *specific* parameters, say a `Circle` and a `Rectangle`, like this…

```
    ...
    private static boolean equalArea(Circle obj1,
                                     Rectangle obj2){
      return (obj1.getArea() == obj2.getArea());
    }
}
```

…the code still works (since both object have a `getArea()` method) but then we could *only* pass a `Circle` object *and* a `Rectangle` object into our method (in that order)…*and nothing else*.

Polymorphism allows us to reuse the same code using generalized parameters, i.e. it promotes *code reuse*.

8.1 Polymorphism in action

Declaring the `equalArea()` method with the two superclass parameters ensures that we can pass *any* `GeometricObject`-derived subclass object into this method, e.g.

```
  public class Circle extends GeometricObject {…}
  public class Rectangle extends GeometricObject {…}
  public class Ellipse extends GeometricObject {…}
  public class Triangle extends GeometricObject {…}
  public class Polygon extends GeometricObject {…}

System.out("Same area? " +
  equalArea(new Circle(3), new Triangle (3, 4, 5));
System.out("Same area? " +
  equalArea(new Ellipse(12,2), new Polygon());
System.out("Same area? " +
  equalArea(new Ellipse(5, 12), new Ellipse(12, 5));
```

8.2 Generic Methods and Polymorphism

As we've already seen, generic methods can be used inside classes to help eliminate the need for overloading. Similarly, we can eliminate the need for `instanceOf()` by the thoughtful use of generics:

```
public class BoundedTypeDemo {
   public static <T extends GeometricObject>
                  boolean equalArea ( T obj1, T obj2 ){
      return (obj1.getArea() == obj2.getArea());
   }

   public static void main(String[] args){
      Rectangle rect = new Rectangle(2,2);
      Circle circle = new Circle(2);

      System.out.println("Same area? " +
                         = equalArea(rect, circle));
   }
}
```

This example is taken from: Liang D. Y. (2014). *Introduction to Java Programming, Comprehensive Version, 10th Ed*. Toronto, ON: Pearson. pg. 743

8.2 Generic Methods and Polymorphism

Note that the format of the generic type is the same as we saw in Module 07:

Formal Type: the declaration goes in front of the return type

How its going to be used

```
public static <T extends GeometricObject>
                    boolean equalArea ( T obj1, T obj2){
```

Here, the generic type is said to be **bounded**. That is, `T` is bounded to being either a `GeometricObject` or one of its subclasses.

As with all generic declarations, this helps ensure that we catch errors at compile-time rather than run-time. (This is what happens, for example, when we use `instanceof` to determine the type of an object. We don't know what the object is an instance of until runtime, at which point it may be too late to avoid a runtime error) Therefore,

```
<T extends GeometricObject>
```

specifies that `equalArea`'s two parameters *must* both be instances of the `GeometricObject` class. And it requires this information at compile time.

8.2 Generic Methods and Polymorphism

Note that whenever a formal type, say `T`, appears inside the `<>`, this is to alert the compiler that `T` stands for the class used to parameterize the class. If `T` is unbounded, then any class can be used in an expression. So, for example, the definition of ArrayList is:

```
ArrayList<T> list = new ArrayList<>();
```

This effectively says that `list` can be an `ArrayList` of *any* type; `T` extends from `Object`.

8.2 Generic Methods and Polymorphism

In many simple cases it is possible to use the wildcard ? equivalently with T. For example, both of the following methods print out the contents of an ArrayList of Numbers (where `Number` is an `Integer`, `Float`, `Double`, etc.):

```
static void printList(ArrayList<? extends Number> list) {
    for (Number num : list) {
        System.out.println(num);
    }
}

static <T extends Number> void printList(ArrayList<T> list) {
    for (Number num : list) {
        System.out.println(num);
    }
}
```

Both methods operate equivalently. That's because we don't actually need to specify what type of Number we're using one we're in either method.

*Example adapted rom: https://stackoverflow.com/questions/11497020/java-generics-wildcard-extends-number-vs-t-extends-number

8.2 Generic Methods and Polymorphism

What happens if we need to know the type of the object inside the method. Then the wildcard won't distinguish between different types. The following method attempts to add the numbers in two arraylists:

```
public void addAll(ArrayList<? extends Number> num1,
                        ArrayList<? extends Number> num2) {
    for (Number n: num1) {num2.add(num1);
    }
}
```

Mixed data types

This fails, because the data type must be the same between the two lists. And the ? Indicates that the two types allow different types of Numbers to be passed. But if we specify

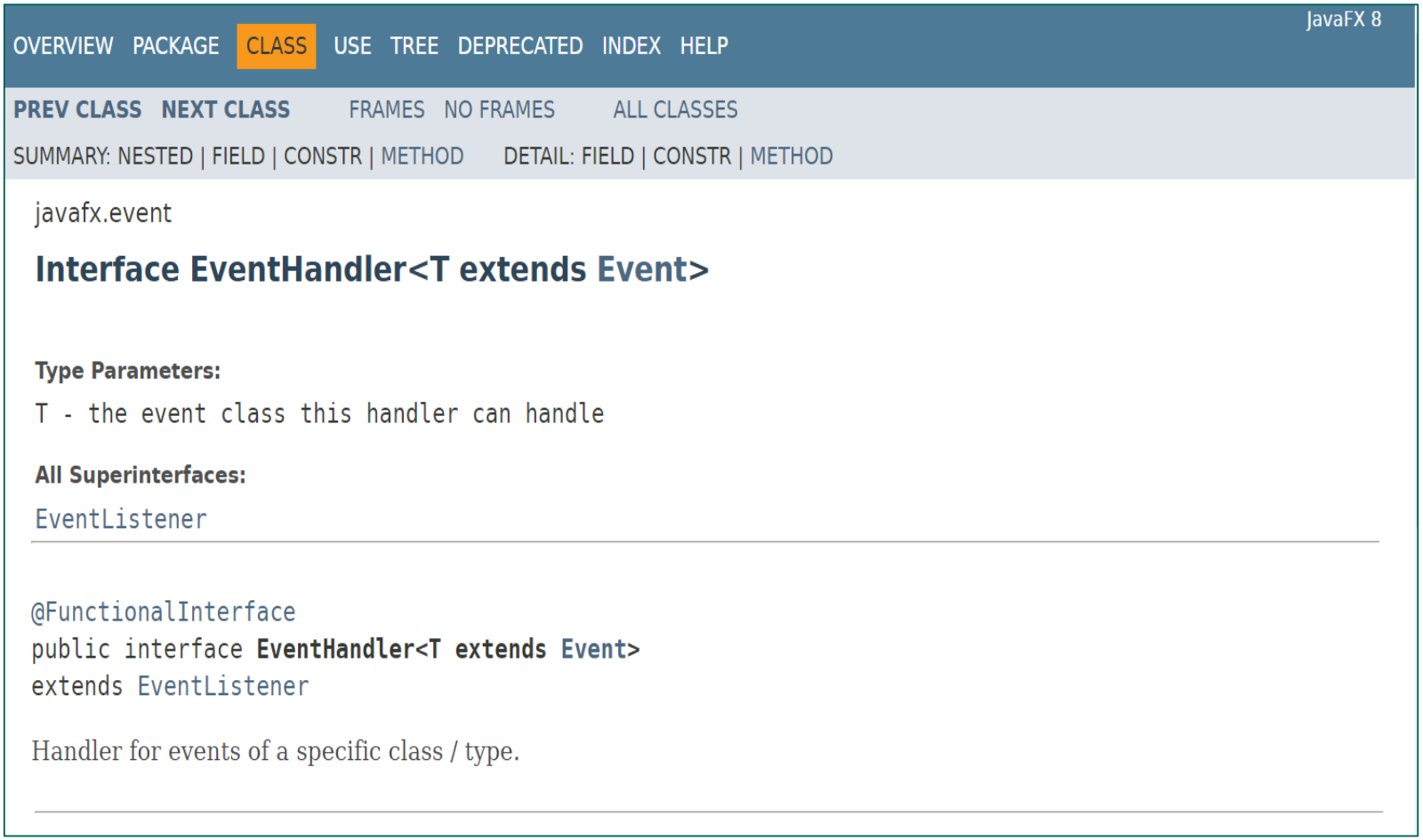
```
public <T> void addAll(ArrayList<T extends Number> num1,
                ArrayList<T extends Number> num2) {
    for (T n: num1) {num2.add(num1);
    }
}
```

then this works, since the two numbers are guaranteed to be of the same type.

*Example adapted rom: https://stackoverflow.com/questions/18187005/java-generic-type-difference-between-list-extends-number-and-list-t-exten

8.2 Generic Methods and Polymorphism

You've seen bounded types in use in an earlier example. The declaration for an `EventHandler` is parameterized to only use `Event` and its subclasses:



OVERVIEW PACKAGE CLASS USE TREE DEPRECATED INDEX HELP

JavaFX 8

PREV CLASS NEXT CLASS FRAMES NO FRAMES ALL CLASSES

SUMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD

javafx.event

Interface EventHandler<T extends Event>

Type Parameters:

T - the event class this handler can handle

All Superinterfaces:

EventListener

```
@FunctionalInterface
public interface EventHandler<T extends Event>
extends EventListener
```

Handler for events of a specific class / type.

8.2 Generic Methods and Polymorphism

Thus the `EventHandler` may *only* be parameterized with `Event` objects, where the event type `T` is passed to the `handler()` method as shown below:

Method Summary

All Methods	Instance Methods	Abstract Methods

Modifier and Type	Method and Description
void	**handle**(T event) Invoked when a specific event of the type for which this handler is registered happens.

Note that the declaration of `handle()` does *NOT* need to be written as:

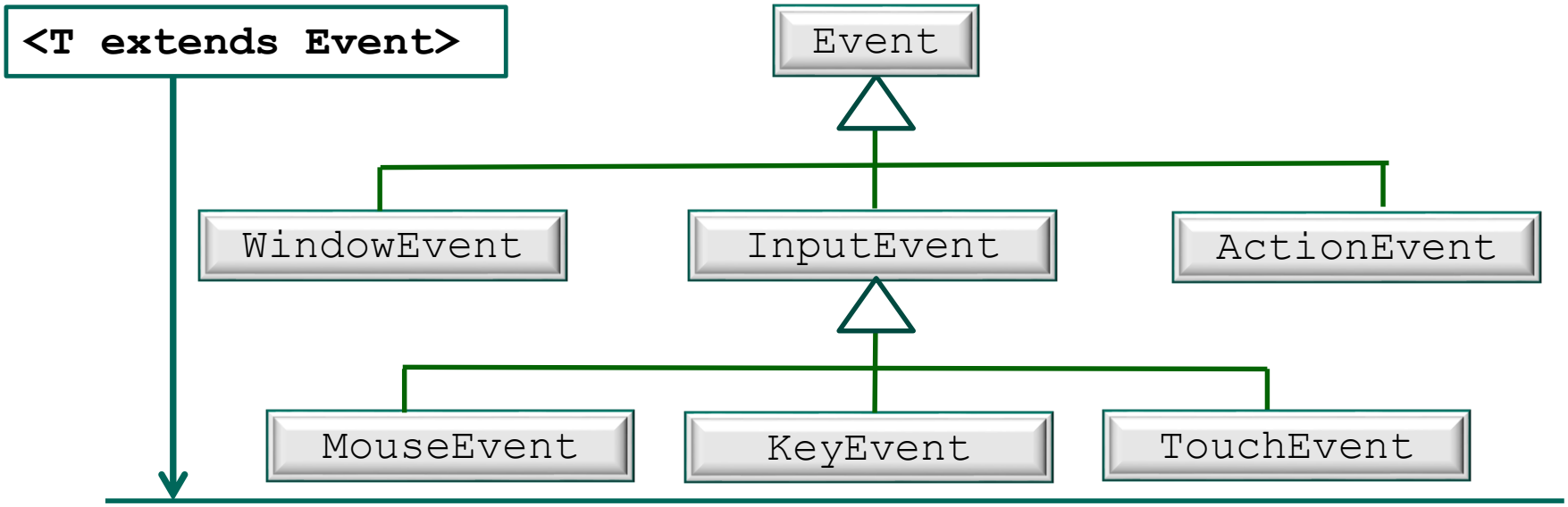
```
void handle(<T extends Event> event)
```

`T` already bounded

since `T` has already been bounded in the class declaration as a subclass of `Event`.

8.2 Generic Methods and Polymorphism

Finally, recall again the `Event` object hierarchy:



Thus an `Event`, or any of its subclasses (including `ActionEvent`) can be passed to the `EventHandler`; the notation `<T extends Event>` guarantees that only objects that are polymorphically related to `Event` as subclasses can be passed to the `EventHandler` at compile-time.

8.2 Generic Methods and Polymorphism

Consider the following example, which uses an `ArrayList` as a **stack** of objects of type `E`. A stack is a type of **data structure**, a specialized program designed to organize and manage data. A typical data structure consists of both an array of some type, and a set of related methods designed to manipulate this information.

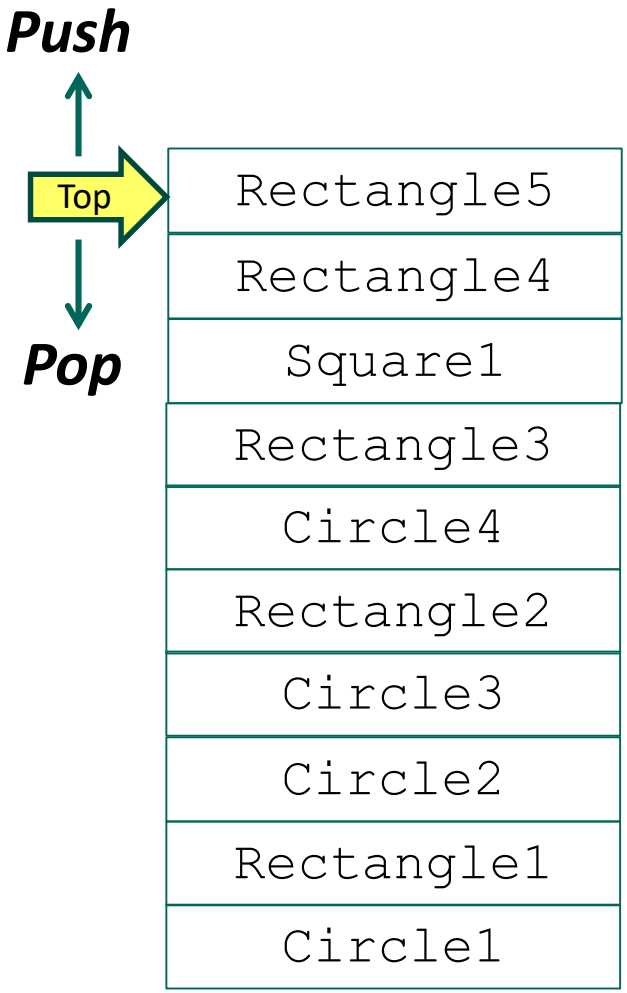
The standard analogy for a stack is of a stack of cafeteria plates. Plates may be **push**ed onto the top of the stack, or **pop**ped off the top. (Other operations, like removing a plate from the middle of the pile without disrupting the order, require more sophisticated data structures.)

Liang 19.3 | D&D 20.6

8.2 Generic Methods and Polymorphism

Each time we push an object on to the stack, the stack grows; each time we pop an object off the stack, the stack shrinks. The yellow arrow at right indicates the top of the stack.

The code below* uses an `ArrayList` to support a generic stack of objects.



* Taken, with modifications, from Liang D. Y. (2014). *Introduction to Java Programming, Comprehensive Version, 10th Ed*. Toronto, ON: Pearson. pp. 741-742.

8.2 Generic Methods and Polymorphism

```
import java.util.ArrayList;

public class GenericStack<E> {
   private ArrayList<E> list = new ArrayList<>();

   public void push(E o) {
      list.add(o);
   }

   public E pop() {
      E o = list.get(getSize() - 1);
      list.remove(getSize() - 1);
      return o;
   }

   public boolean isEmpty() {
      return list.isEmpty();
   }
```

8.2 Generic Methods and Polymorphism

```
    //… continued

    public int getSize() {
        return list.size();
    }

    public E getTop() {
        return list.get(getSize() - 1);

    @Override
    public String toString(){
        return "Stack: " + list.toString();}
    }
}
```

8.2 Generic Methods and Polymorphism

We can parameterize a `GenericStack` with the `String` type by calling

```
GenericStack<String> stack1 = new GenericStack<>();
```

and then adding `String` objects to the stack

```
stack1.push("London");
stack1.push("Paris");
stack1.push("Rome");
```

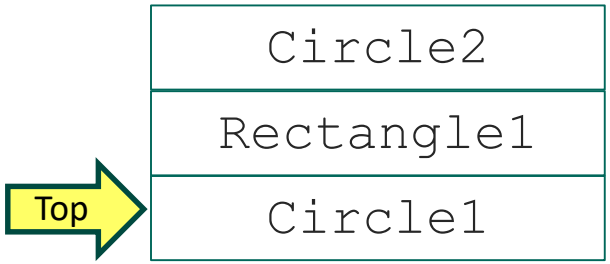
8.2 Generic Methods and Polymorphism

We can parameterize a `GenericStack` with `GeometricObjects` by calling

```
GenericStack<GeometricObject> stack2 =
                              new GenericStack<>();
```

and then adding `GeometricObjects` to the stack

```
stack2.push(Circle1);
stack2.push(Rectangle1);
stack2.push(Circle2);
```



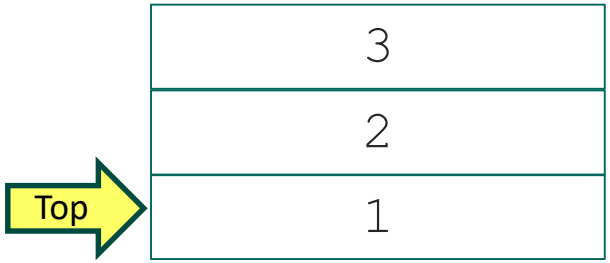
8.2 Generic Methods and Polymorphism

We can even use primitive numeric types like `int`s in our stack, provided we parameterize it with its numeric object equivalent:

```
GenericStack<Integer> stack3 =
                        new GenericStack<>();
```

and then adding `GeometricObjects` to the stack

```
stack3.push(1);
stack3.push(2);
stack3.push(3);
```



This feature, in which Java automatically wraps a primitive data type in its class equivalent, is called **autoboxing**. Thus a primitive `int` is converted to an `Integer`, a `double` is converted to a `Double`, and a `boolean` is converted to `Boolean`. (Note that `Integer`, `Double`, `Byte`, `Float`, `Boolean`, `Long`…etc. are subclasses of the `Number` type)

8.2 Generic Methods and Polymorphism

Generic classes *may* be used without specifying a type. For example, the `GenericStack` may be called using

```
GenericStack stack = new GenericStack();
```

This is equivalent to

```
GenericStack<Object> stack = new GenericStack<>();
```

This says we have a `GenericStack` of *any* type, since every type is a subclass of `Object`.

When used in this way, without a *specific* type, a generic class is called a **raw type**. Raw types allow for backward compatibility with earlier versions of Java. But whenever possible you should *avoid using raw types*, since they are considered *unsafe*. *Always use parameterized types, wherever possible*.

Liang 19.6 | D&D 20.7