Data Structures and Algorithms

Chapter 2

Lecture 2: Learning Objectives

- Understand and be able to implement interfaces and abstract classes into your software development
- Understand exceptions and how to adequately handle error checking within Java programs
- Understand and be able to use Java Generics to write flexible programs

Major Goals of Software Development

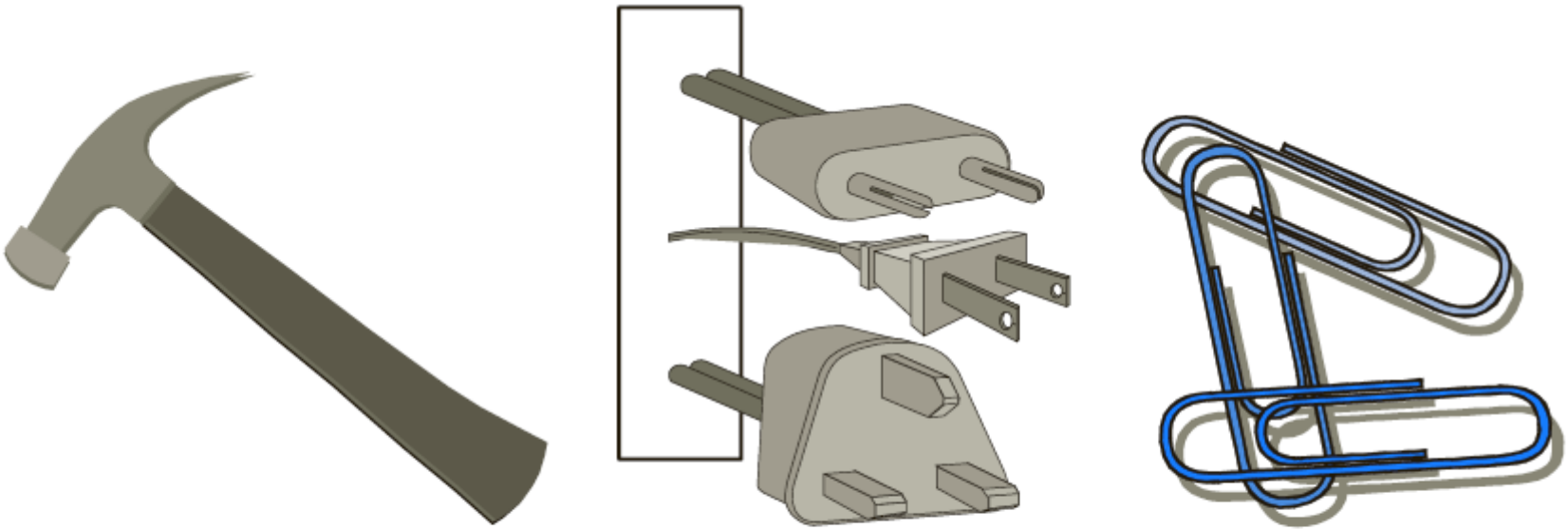


Figure 2.1: Goals of object-oriented design.

Object-Oriented Design Principles to meet Goals

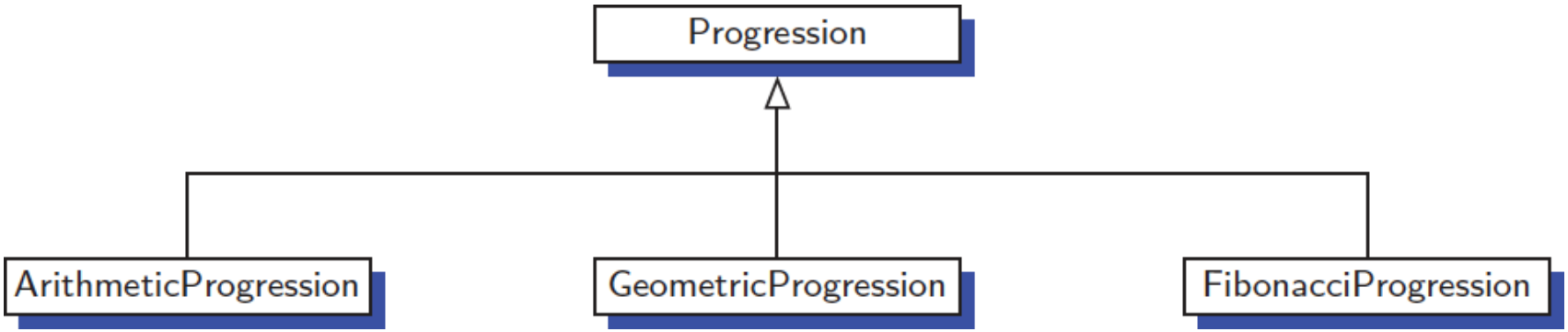
- **Abstraction** – distill a complicated system to its most fundamental parts
  - **Done using interfaces/abstract classes**

- **Encapsulation** – Components of a software system should not reveal the internal details of their implementation

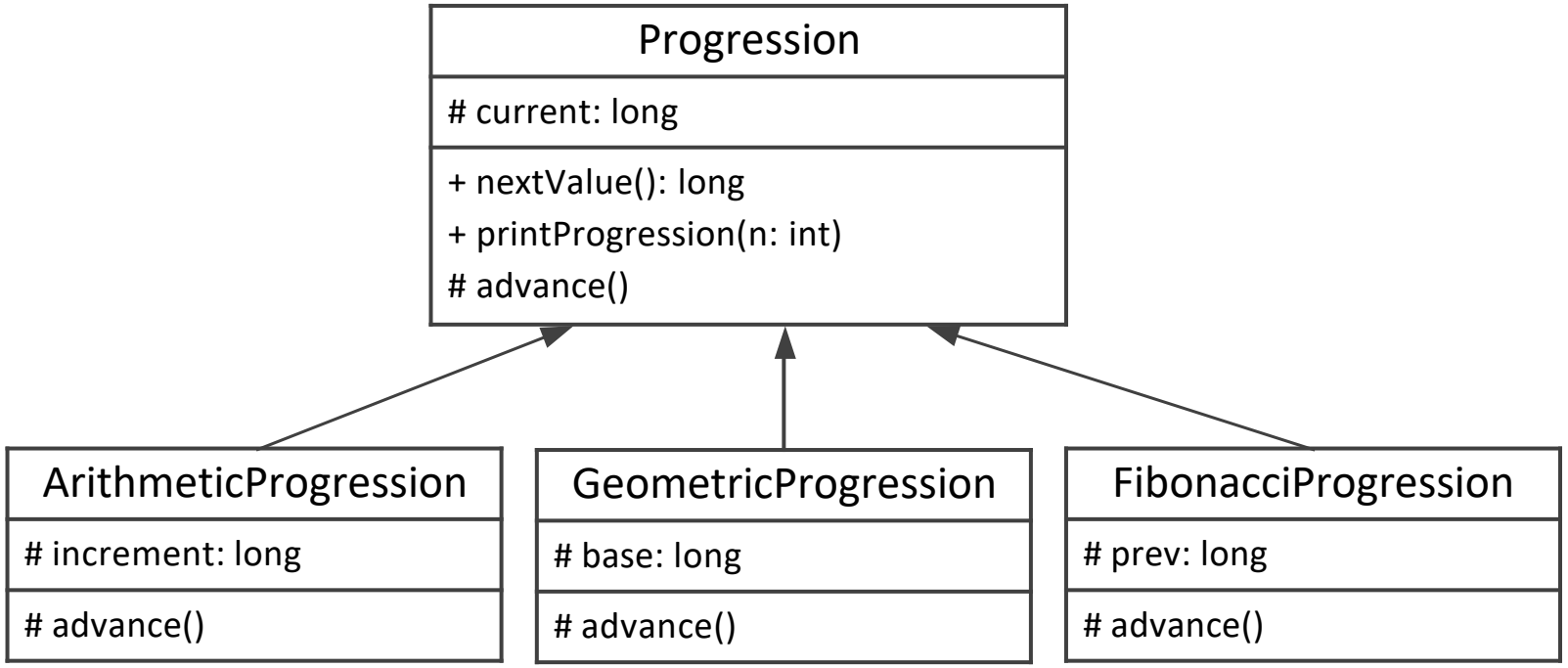
- **Modularity** - Different components of a software system should be organized into separate functional units

Inheritance

- Inheritance hierarchy example



Inheritance



Inheritance

```
/* not a complete code */
public class Progression {

    protected long current;
    public Progression( ) { this(0); }
    public Progression(long start) { current = start; }
    public long nextValue( ) {
    }
    protected void advance( ) {
    }
    public void printProgression(int n) {
    }
}
```

Inheritance

```
/* not a complete code */
public class ArithmeticProgression extends Progression {

    protected long increment;
    public ArithmeticProgression( ) { this(0); }
    public ArithmeticProgression(long stepsize) {
    }
    public ArithmeticProgression(long stepsize, long start) {
    }
    protected void advance( ) {
    }
}
```

Interface

- Used to specify a “contract” between different programs.
- No data
- Methods do not have implementation.
- Cannot be instantiated.
- Can be used for multiple inheritance.
- A class implementing an interface must implements all methods.

Interface

```
1  /** Interface for objects that can be sold. */
2  public interface Sellable {
3    /** Returns a description of the object. */
4    public String description( );
5    /** Returns the list price in cents. */
6    public int listPrice( );
7    /** Returns the lowest price in cents we will accept. */
8    public int lowestPrice( );
   }
```

Interface

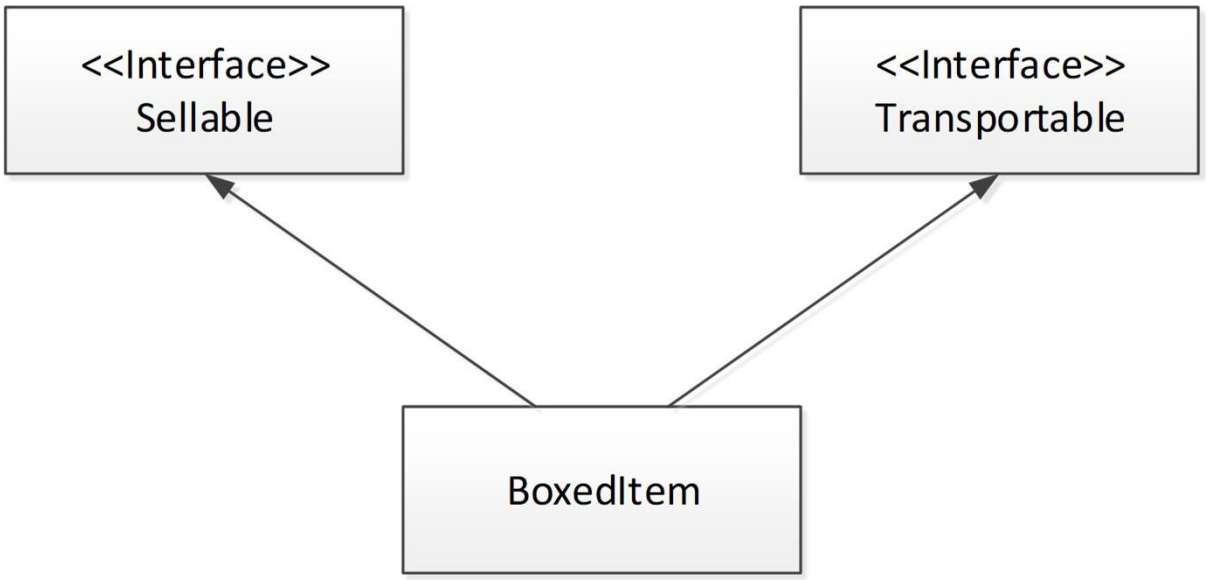
```
1  /** Class for photographs that can be sold. */
2  public class Photograph implements Sellable {
3    private String descript;                    // description of this photo
4    private int price;                          // the price we are setting
5    private boolean color;                      // true if photo is in color
6    public Photograph(String desc, int p, boolean c) {   // constructor
7      descript = desc;
8      price = p;
9      color = c;
10   }
11   public String description( ) { return descript; }
12   public int listPrice( ) { return price; }
13   public int lowestPrice( ) { return price/2; }
14   public boolean isColor( ) { return color; }
15 }
```

Interface

```
1  /** Interface for objects that can be transported. */
2  public interface Transportable {
3    /** Returns the weight in grams. */
4    public int weight();
5    /** Returns whether the object is hazardous. */
6public boolean isHazardous(); 7
   }
```

Interface

- Multiple inheritance



Interface

```
1  public class BoxedItem implements Sellable, Transportable {
2    private String descript;       // description of this item
3    private int price;              // list price in cents
4    private int weight;             // weight in grams
5    private boolean haz;            // true if object is hazardous
6    private int height=0;           // box height in centimeters
7    private int width=0;            // box width in centimeters
8    private int depth=0;            // box depth in centimeters
9   public BoxedItem(String desc, int p, int w, boolean h) {
10      descript = desc;
11      price = p;
12      weight = w;
13      haz = h;
14   }
/* continue to the next slide */
```

Interface

```
15   public String description() { return descript; }
16   public int listPrice() { return price; }
17   public int lowestPrice() { return price/2;  }
18   public int weight() { return weight; }
19   public boolean isHazardous() { return haz; }
20   public int insuredValue() { return price*2; }
21   public void setBox(int h, int w, int d) {
22     height = h;
23     width = w;
24     depth = d;
25   }
26 }
```

Why Interfaces?

- Imagine you were in charge of tracking inventory/transactions at a store
- The “sellable” interface would allow you to create a method like below:

```
public boolean sell(Sellable s)
{
   //Can use methods here which objects that implement “Sellable” have
  //Like s.listPrice()
}
```

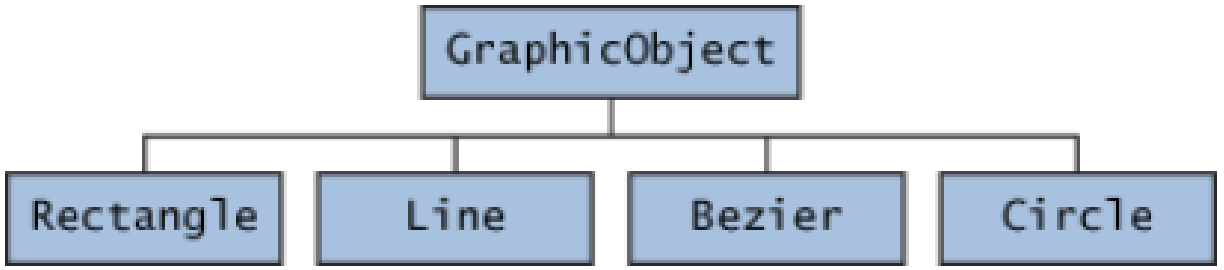
Abstract Class

- An abstract method: a method without implementation.
- A concrete method: a method with implementation.

- Abstract class:
  - Declared with *abstract* keyword.
  - May or may not have abstract method.
  - A class with an abstract method must be an abstract class.
  - Used when subclasses share many common variables and methods.
  - Cannot be instantiated.

Abstract Class

- An example from Oracle documentation (https://docs.oracle.com/javase/tutorial/java/IandI/abstract.html)



Classes Rectangle, Line, Bezier, and Circle Inherit from GraphicObject

Abstract Class

```
abstract class GraphicObject {
    int x, y;
    . . .
    void moveTo(int newX, int newt) {
        . . .
    }
    abstract void draw();
    abstract void resize();
}
```

Abstract Class

```
class Rectangle extends GraphicObject {
    void draw() {
        // implementation
        . . .
    }
    void resize() {
        // implementation
        . . .
    }
}
```

Interface and Abstract Class

- Consider using **interface** if any of these statements apply to your situation:
  - You expect that unrelated classes would implement your interface.
  - You want to specify the behavior of a particular data type, but not concerned about who implements its behavior.
  - You want to take advantage of multiple inheritance of type.

Interface and Abstract Class

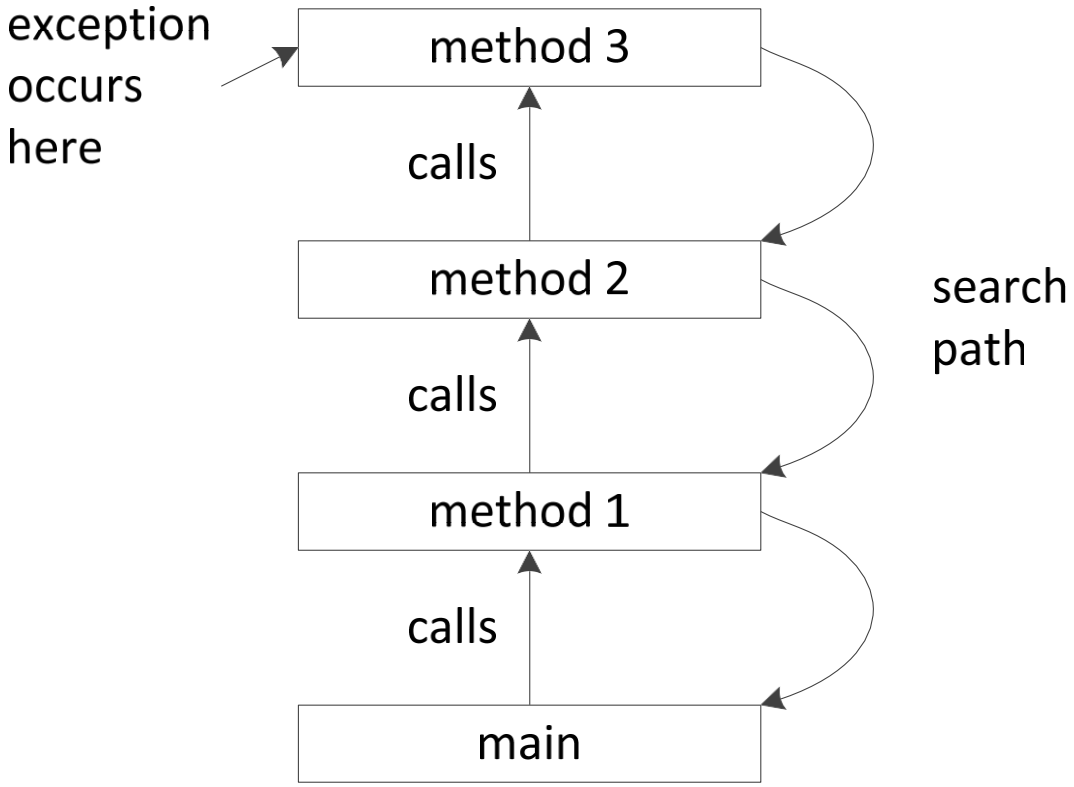
- Consider using **abstract classes** if any of these statements apply to your situation:
  - You want to share code among several closely related classes.
  - You expect that classes that extend your abstract class have many common methods or fields.

Exceptions

- An *exception*, shorthand for *exceptional event*, is an event that occurs during the execution of a program
- When an exception occurs
  - an exception is *thrown*
  - the runtime system finds an *exception handler*
  - the code in the handler is executed

Exceptions

- Call stack and exception handler search path



Exceptions

- Try-catch statement

try {

guardedBody

} catch (*exceptionType*$_1$ *variable*$_1$) {

remedyBody$_1$

} catch (*exceptionType*$_2$ *variable*$_2$) {

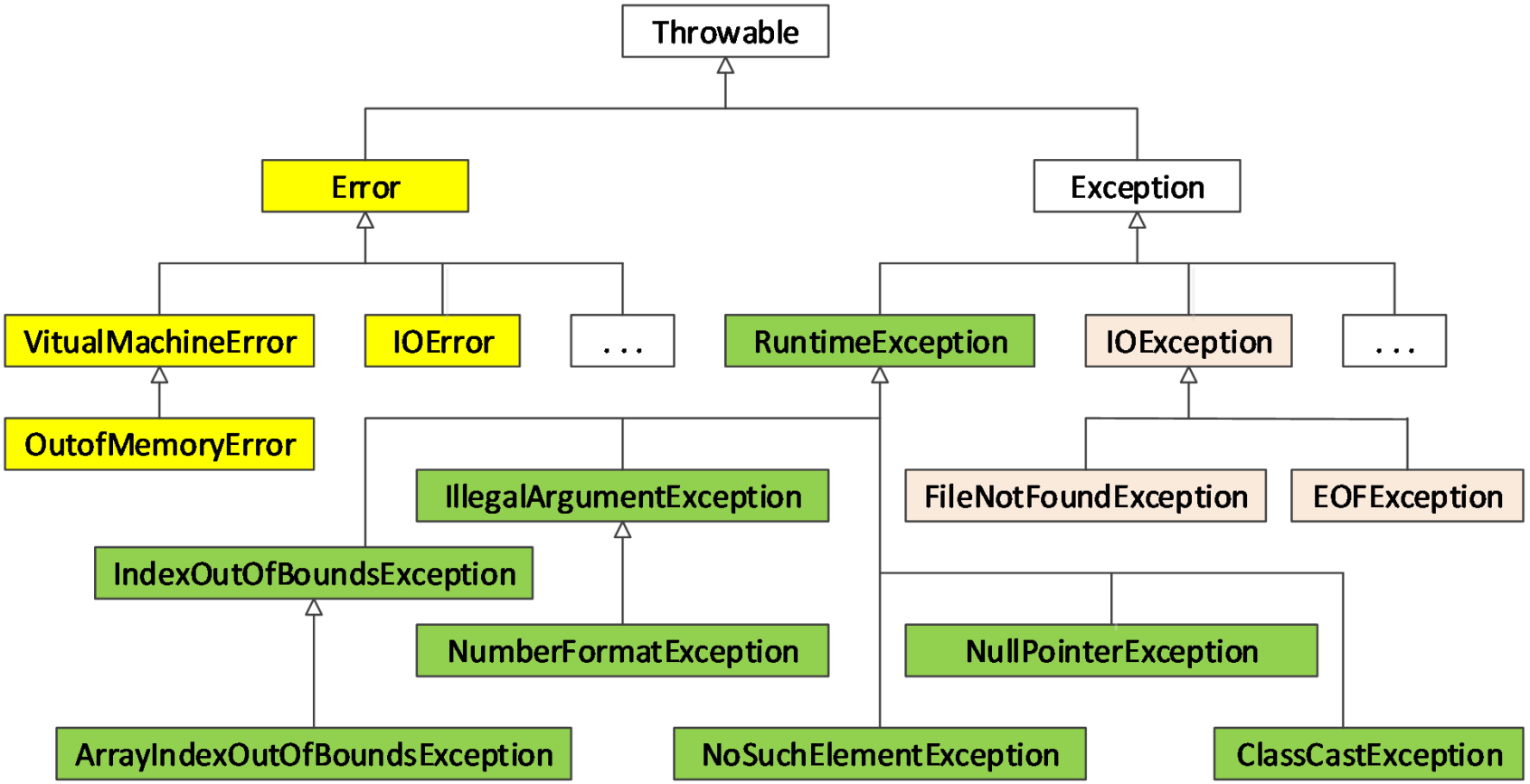
remedyBody$_2$

} . . .

. . .

Exceptions

- Java Exception Hierarchy (part)



Exceptions

- *Errors*:
  - exception objects of the *Error* class and all of its subclasses.
  - external to the application and they are thrown by JVM.
- *Runtime exceptions* (unchecked exceptions):
  - exception objects of the *RuntimeException* class and all of its subclasses.
  - exceptional events internal to the application, and occur due to mistakes in programming logic
- *Other exceptions* (checked exceptions):
  - all other exceptions
  - If a code may throw a *checked exception*, then it must be in a *try-catch* statement or it must be in a method which is declared with a *throws* clause.
- Example: CheckedExceptionDemo.java

Generics

- **Generics** are classes and methods that can operate on a variety of data types

- An example, we want a “Pair” class that can hold pairs of any types of objects, can we write a single class that works for (int, String) pairs as well as (Book, int) pairs?

```
public class Pair<A,B> {
  A first;
  B second;
  public Pair(A a, B b) {
    first = a;
    second = b;
  }
  public A getFirst( ) { return first; }
  public B getSecond( ) { return second;}
}
```

Generics

- Types are declared using generic names:

```
public class GenericQueue<E> {
    private java.util.ArrayList<E> list = new java.util.ArrayList<>();
    public void enqueue(E e){
    }
    public E dequeue(){
    }
    . . .
}
```

- Instantiated using actual types:

```
GenericQueue<Integer> integerQueue = new GenericQueue<>();
GenericQueue<String> stringQueue = new GenericQueue<>();
```

Generics

- Generic class definition

```
1  public class Pair<A,B> {
2      A first;
3      B second;
4      public Pair(A a, B b) {              // constructor
5          first = a;
6second = b; 7     }
8      public A getFirst() { return first; }
9public B getSecond() { return second;} 10
}
```

- Instantiation

```
Pair<String, Double> bid;          // declare
bid = new Pair<>("pi", 3.14);      // instantiate
```

Generics

- Generic method

```
1  public class GenericDemo {
2      public static <T> void reverse(T[ ] data) {
3int low = 0, high = data.length - 1; 4
5          while (low < high) {          // swap data[low] and data[high]
6              T temp = data[low];
7              data[low++] = data[high];       // post-increment of low
8              data[high--] = temp;            // post-decrement of high
9    }     }

10 }
```

Generics

- Generic method

```
String[ ] names = new String[ ]{"john", "susan", "molly"};
GenericDemo.reverse(names);

Integer[ ] integers = new Integer[ ]{10, 20, 30, 40, 50};
GenericDemo.reverse(integers);

Character[ ] chars = new Character[ ]{'a', 'b', 'c', 'd', 'e'};
GenericDemo.reverse(chars);
```

Generics

- Demonstration
  - GenericQueue.java
  - GenericDemo1.java
  - GenericDemo2.java
  - GenericDemo3.java

Nested Class

```
class OuterClass {
    ...
    class NestedClass {
        ...
    }
}
```

Nested Class

- We use nested classes for the following reasons:
  - *NestedClass* is used only for the *OuterClass*.
  - We want to declare members of the *OuterClass* as private but, at the same time, we want *a* smaller class to be able to access members of the *OuterClass*.
  - We want to implement a data structure which has another smaller data structure as its member.

- The code becomes more readable and it is easy to maintain.
- Nested classes also help reduce name conflict.

References

- M.T. Goodrich, R. Tamassia, and M.H. Goldwasser, “Data Structures and Algorithms in Java,” Sixth Edition, Wiley, 2014.
- Oracle documentation (https://docs.oracle.com/javase/tutorial/java/IandI/abstract.html)