Objects and Classes

- Functions
- Objects and Classes
- Inheritance
- Interfaces
- Packages
- Generics

Functions

Overview

- A function is a segment of code that performs a task and is extracted separately
  - Identified by a name
  - May be used (called) from different parts of the program
  - May have parameters (arguments, or inputs)
  - May return something (result, or output)
- Benefits:
  - Functions help to break down a large program into smaller problems
  - Functions reuse code
  - Functions enhance readability and maintainability
- In Java, every lines of code must be inside a class any function needs to be member of some class, and is called a *method*

Function Example

```
class FunctionExample {
    static double round2Decimals(double x) {
        double y = x * 100.;
        long z = Math.round(y);
        return z / 100.;
    }

    public static void main(String argv[]) {
        System.out.println(round2Decimals(Math.PI));    // 3.14
        System.out.println(round2Decimals(Math.E));     // 2.72
    }
}
```

- `return` statement is used to terminate a function and return a value
- Existence of parameters and local variables is limited in the scope of the function that they are declared

Void Functions

- Are functions that don’t return any result on termination
  - `return` statement has no argument
  - `return` statement at the end of function can be omitted
- Example:

```
class VoidFunctionExample {
    static void printWelcome(String name) {
        System.out.println("Hello " + name);
    }

    public static void main(String argv[]) {
        printWelcome("John");
        printWelcome("Bob");
    }
}
```

Object and Classes

Stateful Functions

- This example is about functions that change the state of the program, so that they will return a different result every time being called
  - ```
    class SingleAccountApp {
        static double balance = 0.;

        static double deposit(double amount) {
            balance += amount;
            return balance;
        }

        static double withdraw(double amount) {
            balance -= amount;
            return balance;
        }

        public static void main(String argv[]) {
            System.out.println(deposit(20.5));  // 20.5
            System.out.println(withdraw(10));   // 10.5
            System.out.println(deposit(15));    // 25.5
        }
    }
    ```
    ```

Multiple Entities?

- Now, what if we want these functions to work with multiple bank accounts?
  - We might want to bind the balance and the functions into one container this is where objects and classes come into play
  - ```
    // BankAccount.java
    class BankAccount {          // define a class; note that the members are now non-static
        double balance = 0.;

        double deposit(double amount) {
            return balance += amount;
        }

        double withdraw(double amount) {
            return balance -= amount;
        }
    }
    ```
  - ```
    // MultipleAccountApp.java
    class MultipleAccountApp {
        public static void main(String argv[]) {
            BankAccount account1 = new BankAccount(),   // create 2 instances (objects) of BankAccount
                        account2 = new BankAccount();

            System.out.println(account1.deposit(20.5)); // 20.5
            System.out.println(account1.withdraw(10));  // 10.5
            System.out.println(account2.deposit(15));   // 15 (not 25.5)
        }
    }
    ```

Object-Oriented Programming (OOP)

- From real world …
  - An *object* is thing, fact, entity,… which is characterized by its *properties* and can perform certain *operations*. Ex:
    - A student is an object characterized by: name, age, department, class, year,… and can perform: studying, doing exercises, going to class, doing tests,…
    - A cellphone is an object characterized by: SIM number, model, size,… and can perform: making call, texting, answering to calls, denying calls,…
  - A *class* is the description of properties and operations for some kind of objects
    - Simpler consideration: students are objects while the definition of students is a class, similarly for cellphones and their definition
- … to programming:
  - A *class* is a data type, which basically encapsulates its properties and methods
    - Usually defined in a `.java` file and with the same name with the class
  - An *object* is an instance created with the type of the given class

Class Properties and Methods

- Properties = member variables, methods = member functions
  - The methods can read value of the properties and update them
- Example

```
// Circle.java
class Circle {
    double radius;

    void setRadius(double newRadius) {
        radius = newRadius;
    }

    double getRadius() {
        return radius;
    }

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

    double getPerimeter() {
        return Math.PI * 2 * radius;
    }
}
```

- Using the class

```
// CircleExample.java
class CircleExample {
    public static void main(String args[]) {
        Circle c1 = new Circle();
        c1.setRadius(10);
        System.out.println(c1.getArea());


        Circle c2 = new Circle();
        c2.setRadius(20);
        System.out.println(c2.getPerimeter());
    }
}
```

Visibility of Members

- By default, variables and methods are accessible to other members of the class itself and to other classes in the same package
- Use a modifiers `public` and `private` to change the default behavior:

Modifier	Same class	Class in same package	Class in other packages
None (default)	✓	✓	✗
`public`	✓	✓	✓
`private`	✓	✗	✗

- From the OOP point of view, it's a good practice to declare class properties as private, and provide public setter and getter methods, for better encapsulation:
  - Possibility for read-only and write-only properties
  - Possibility for virtual properties
  - Programmer may make changes to the class in the future without affecting other parts of code

Visibility Example

```
public class Circle {
    private double radius;

    public void setRadius(double newRadius) {
        radius = newRadius;
    }

    public double getRadius() {
        return radius;
    }

    public void setDiameter(double newDiameter) {  // virtual property
        radius = newDiameter / 2.;
    }

    public double getDiameter() {
        return radius * 2.;
    }


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

    public double getPerimeter() {
        return Math.PI * 2 * radius;
    }
}
```

this

- Refers to the current object in a method or constructor
- The most common use is to eliminate the confusion between class attributes and parameters with the same name (because a class attribute is shadowed by a method or constructor parameter)
  - ```
    public class Circle {
        private double radius;

        public void setRadius(double radius) {
            this.radius = radius;
        }

        //...
    }
    ```
- Can also be used to:
  - Invoke current class constructor/method
  - Return the current class object
  - Pass an argument in the constructor/method call
    ```

`static` Members

- A `static` member belongs to the class (not to any particular object)
  - `static` variables are initialized only once at the start of the execution
  - `static` methods have access only to other `static` members, but without using the class's object (instance)
  - `this` is not defined in `static` methods
- Think about `String` class's `format()`, `split()` methods

Constructors

- A constructor is a special method and is used to initialize new objects when being created
  - Is usually used to set initial values for objects properties
  - Has the same name of the class, does not have a return type, and can be overloaded
  - When no constructor is defined, the compiler automatically creates a default one (which is empty and takes no parameter)
- Example:
  - ```
    public class BankAccount {
        private String name;
        private double balance;

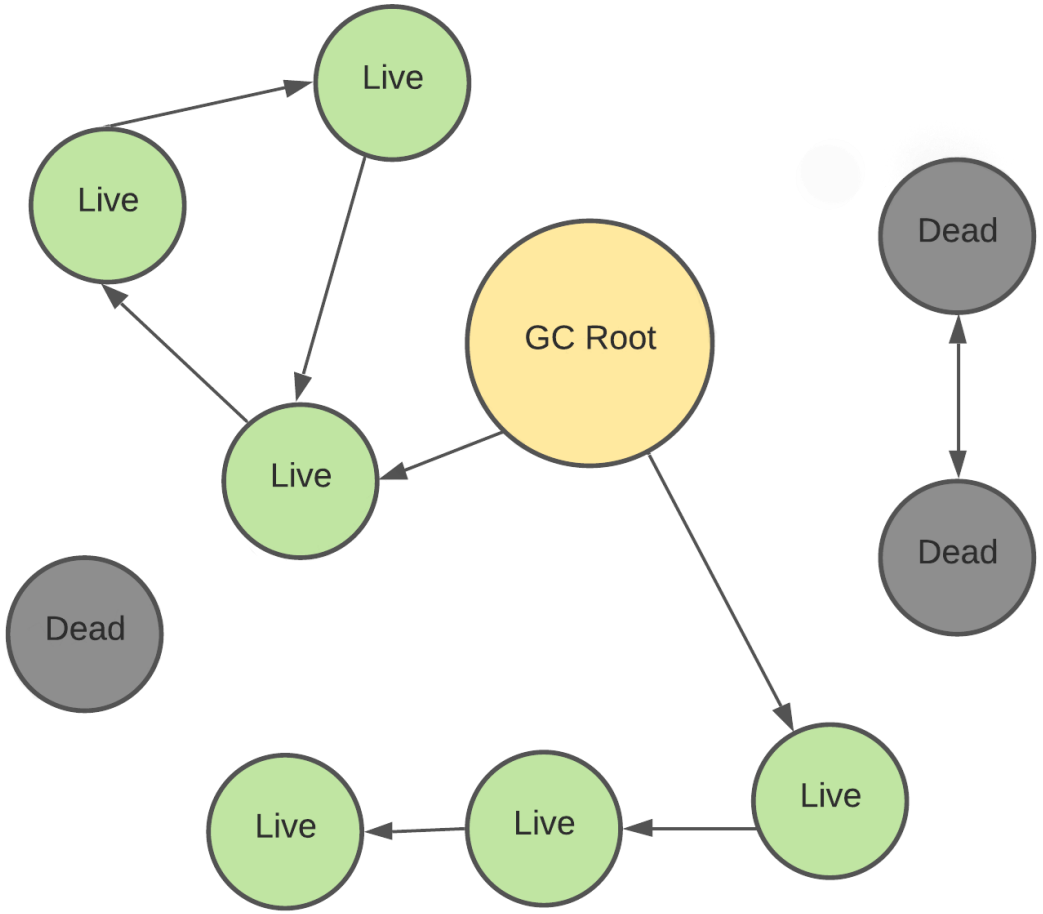
        public BankAccount(String firstName) {
            name = firstName;
            balance = 0.;
        }

        public BankAccount(String firstName, double firstBalance) {
            name = firstName;
            balance = firstBalance;
        }

        // ...
    }
    ```
    ```

Garbage Collector (GC)

- GC is a background process for reclaiming the runtime unused memory by destroying the unused objects
  - Automatic detection of unused objects based on number of references to them (objects with circular references are also detected)
  - Programmers don’t need to take care of destroying unused objects
  - GC is non-deterministic



`finalize()` Method

- Is a special method that is called by the GC before destroying the object from memory
- Is usually used to perform cleanup activity
- Is also non-deterministic
- Is *deprecated in Java 9*, because:
  - It's difficult to handle correct finalization for a group of related objects, since there is no ordering among `finalize()` methods; sometimes this may cause deadlocks
  - There are no guarantees about the timeliness of finalization
  - There is no explicit registration/deregistration mechanism
  - Alternatives: `java.lang.ref.Cleaner`, `java.lang.ref.PhantomReference`

`null` Value

- When an object variable does not reference any object, it holds a special literal value `null`

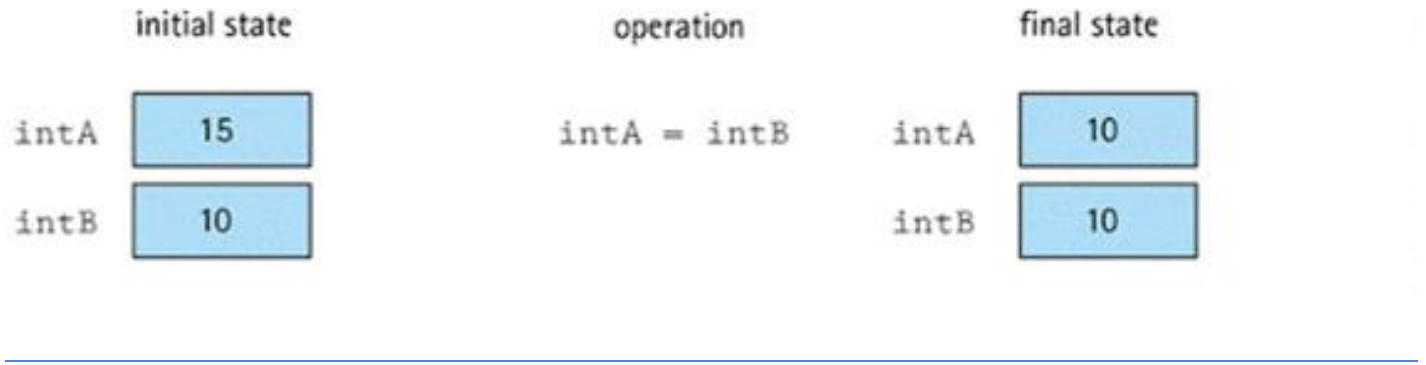
- Example:
  - ```
    Student s1, s2 = new Student(); // s1 is null, s2 is not null

    s1 = new Student(); // s1 now is not null

    s2 = null;  // s2 now is null,
                // the created object is left unreferenced
    ```
    ```

Difference in Usage of Primitive and Object Types

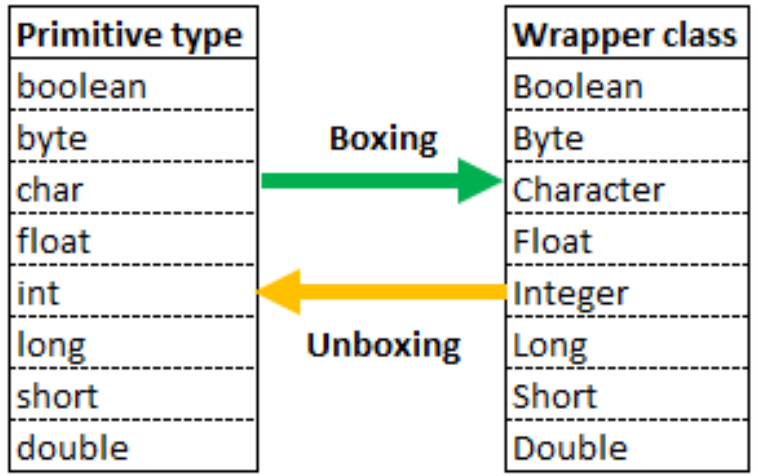
- Primitive types:
  - Variables always have a value
  - Assignment, comparison, parameter passing are done using value
- Object types (including strings, arrays):
  - Variables may be `null`
  - Assignment, comparison, parameter passing are done using reference



Wrapper Classes for Primitive Types

- Wrapper classes provide a way to use primitive types as objects, that is useful in
  - Passing parameters by reference
  - Working with `Collection` objects
- Example
  - ```
    Integer myInt = 5;       // boxing
    Double myDouble = 5.99;
    Character myChar = 'A';
    System.out.println(myInt.intValue());
    System.out.println(myDouble.doubleValue());
    System.out.println(myChar.charValue());

    int i = myInt;           // unboxing
    ```
  - ```
    ArrayList<int> myNumbers = new ArrayList<int>();   // Compile error
    ```
  - ```
    ArrayList<Integer> myNumbers = new ArrayList<Integer>(); // Ok!
    ```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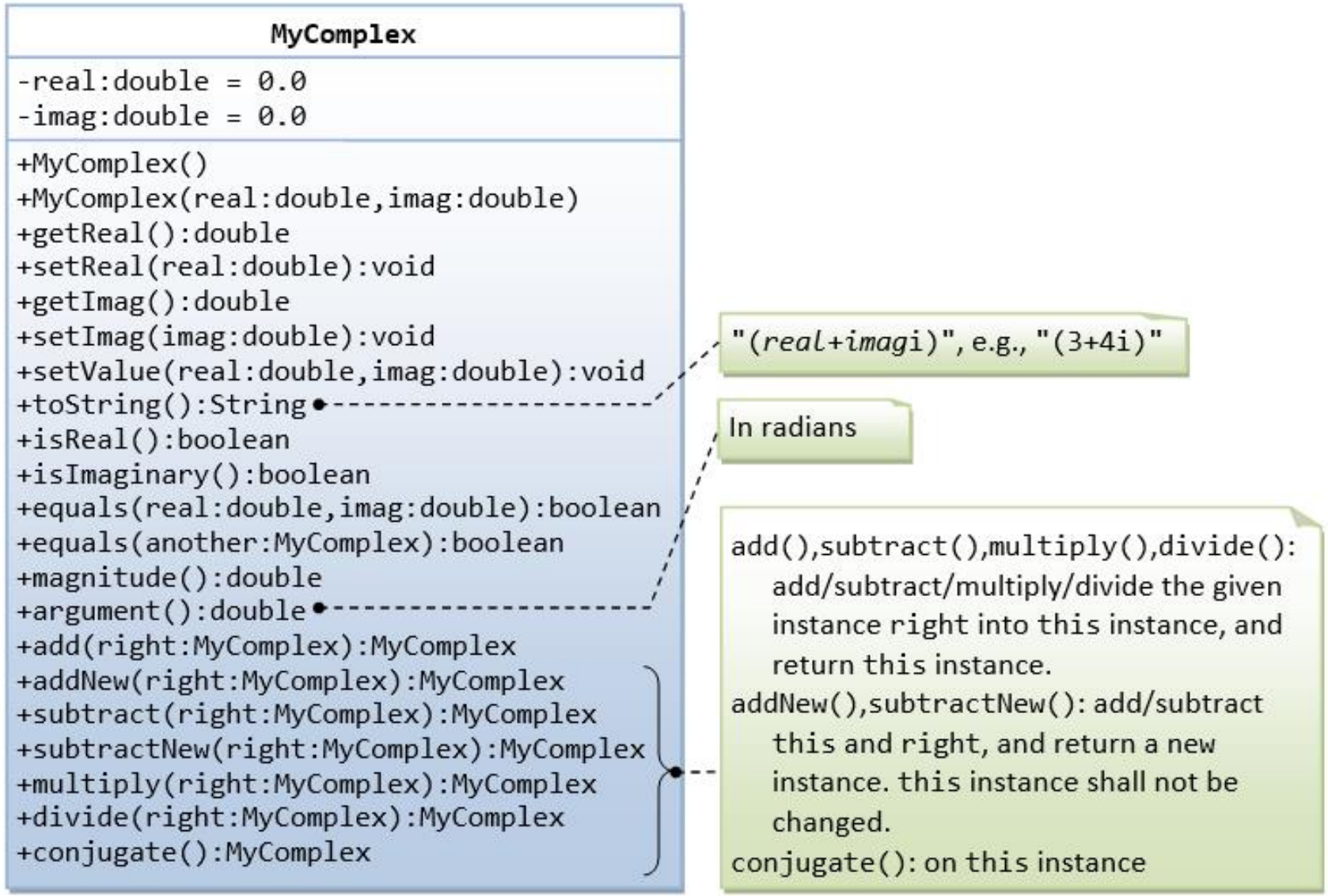
Exercise

- Write a class allowing to work with complex numbers



Inheritance

Initial Example

- To manage the personnel of a company, we need to define classes corresponding to the posts:

```
class Worker {
    private String name;
    private float salary;
    private int level;

    String getName() {...}
    void getPaid() {...}
    void doWork() {...}
    ...
}
```

```
class Manager {
    private String name;
    private float salary;
    private int dept;

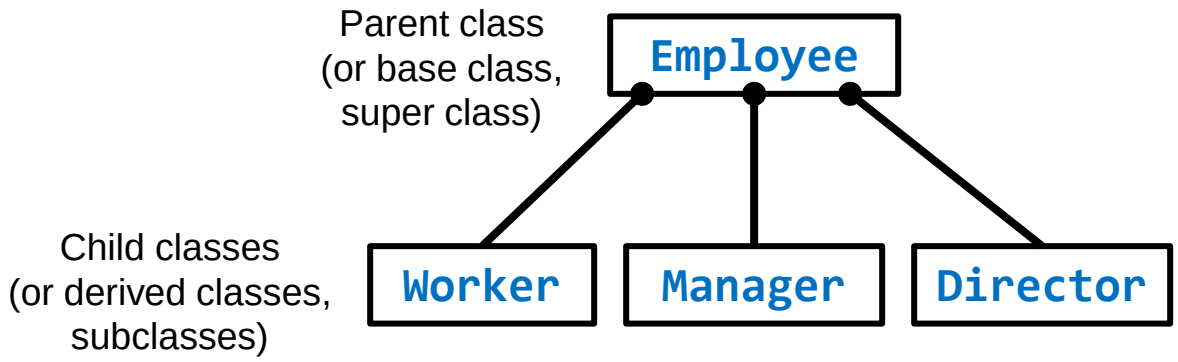
    String getName() {...}
    void getPaid() {...}
    void doWork() {...}
    ...
}
```

```
class Director {
    private String name;
    private float salary;

    String getName() {...}
    void getPaid() {...}
    void doWork() {...}
    void assignWork() {...}
    ...
}
```

- All 3 above classes have common members that are the same By defining an `Employee` class for those things and then we can:
  - Reuse code
  - Reduce written code
  - Facilitate the maintenance, modifications in the future
  - Clarify the logic in the software design

Redesigned Classes



- Child classes have access to all the members of its parent class, like if they were their own members, *except the private members*
- Only the parts that are different from the parent class need to be added to the child classes
- Objects of a child classes can be implicitly casted to parent class, but not inverse:
  - ```
    Employee e = new Worker();  // Ok
    Worker w = new Employee();  // Error
    ```

```
class Employee {
    private String name;
    private float salary;

    String getName() {...}
    void getPaid() {...}
    void doWork() {...}
}

class Worker extends Employee {
    private int level;
    ...
}

class Manager extends Employee {
    private int dept;
    ...
}

class Director extends Employee {
    void assignWork() {...}
    ...
}
```
```

Constructors in Inheritance (1/2)

- Constructors are not inherited by child classes
  - ```
    class Pet {
        Pet() { ... }
        Pet(String name) { ... }
    }

    class Dog extends Pet {
        // ...
    }

    public class Hello {
        public static void main(String argv[]) {
            Dog d1 = new Dog();          // Ok!
            Dog d2 = new Dog("Max");     // Error!
        }
    }
    ```
    ```

Constructors in Inheritance (2/2)

- Each constructor of child class must call one of the parent's constructors, or the constructor with no parameter is implicitly used if it exists
  - ```
    class Dog extends Pet {
        Dog() {
            super();        // call Pet(), may be omitted
            // ...
        }

        Dog(String name) {
            super(name);    // call Pet(name)
            // ...
        }
    }

    public class Hello {
        public static void main(String argv[]) {
            Dog d1 = new Dog();          // Ok!
            Dog d2 = new Dog("Max");     // Now ok!
        }
    }
    ```
    ```

Method Overriding

- A method in a child class will override the one in the parent class, if it is declared to be the same (same name, same parameters)
  - The new implementation will replace the old one from the parent class for objects of the child class
  - `@Override` annotation can be optionally used for automatic detection of mismatches
  - Used for runtime polymorphism

```
class Pet {
  private String name;

  Pet(String name) {
    this.name = name;
  }

  void eat(String food) {
    System.out.printf("Pet %s is eating %s...%n", name, food);
  }
}



class Dog extends Pet {
  Dog(String name) {
    super(name);
  }


  @Override
  void eat(String food) {
    System.out.printf("Dog %s is eating %s...%n", name, food);
  }
}
```

Overridden Method Test

- Let's determine the output:
  - ```
    Dog a1 = new Dog("Max");
    a1.eat("noodle");   // ?

    Pet a2 = a1;
    a2.eat("rice");     // ?

    Dog a3 = (Dog)a2;
    a3.eat("bone");     // ?

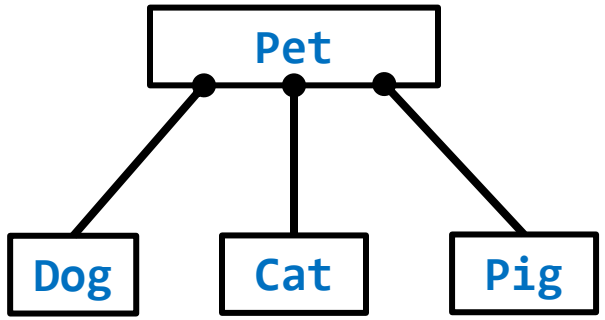
    Pet b1 = new Pet("Daisy");
    b1.eat("milk");     // ?

    Dog b2 = (Dog)b1;   // ?
    ```
    ```

Polymorphism

- Done by dynamically binding the method from the subclass in response to a method call from a subclass object referenced by superclass type
- Example: Let's add 2 more child classes `Cat` and `Pig`, then consider the following code
  - ```
    Pet pets[] = {
        new Cat("Garfield"),
        new Dog("Max"),
        new Cat("Lucky"),
        new Pig("Lazy"),
        new Dog("Quick")
    };

    for (Pet p : pets)
        p.eat("rice");
    ```


    ```

Methods that Cannot be Overridden

- The following methods cannot be overridden:
  - `final` methods
  - `static` methods
  - `private` methods
  - Constructors

`protected` Members

- The `protected` access modifier is used for members to make them accessible in the same package and subclasses
- Example: Change `private` members of `Employee` class to `protected`, to make them accessible by the subclasses when necessary
  - ```
    class Employee {
        protected String name;
        protected float salary;

        String getName() {...}
        void getPaid() {...}
        void doWork() {...}
    }
    ```
    ```

`Object` Class

- The `Object` class is the parent class of all the classes, i.e, it is the topmost class
  - No need to explicitly inherit the `Object` class
  - It provides some common behaviors to all the objects

Method	Description
`public final Class getClass()`	Returns the `Class` class object of this object, which can further be used to get the metadata of this class
`public boolean equals(Object obj)`	Compares the given object to this object
`protected Object clone()`	Creates and returns the exact copy (clone) of this object
`public String toString()`	Returns the string representation of this object
`public int hashCode()`	Returns the hashcode number for this object

`abstract` Classes

- An `abstract` method is a method declared without implementation
  - need to be overridden by the subclasses
- An `abstract` class is a class having at least one `abstract` method
  - An `abstract` class cannot be instantiated
- Example:

```
abstract class Shape {
    abstract double getArea();
    abstract void draw();
    abstract void erase();

    void redraw() {
        erase();
        draw();
    }
};
```

```
class Circle extends Shape {
    // ...

    @Override
    double getArea() { //... }

    @Override
    void draw() { //... }

    @Override
    void erase() { // ... }
}
```

Interfaces

- An interface:
  - Is a blueprint to implement a class
  - Cannot be instantiated
  - Has no concrete methods, i.e., all methods are abstract
  - Has no instance variables, but may have `public static final` ones
  - Has no constructors
- A class may inherit multiple interfaces, but can inherit only one class

- Example:

```
interface Drawable {
    void draw();
}

interface Erasable {
    void erase();
}

abstract class Shape
implements Drawable, Erasable {
    abstract double getArea();

    void redraw() {
        draw();
        erase();
    }
}
```

Anonymous Classes

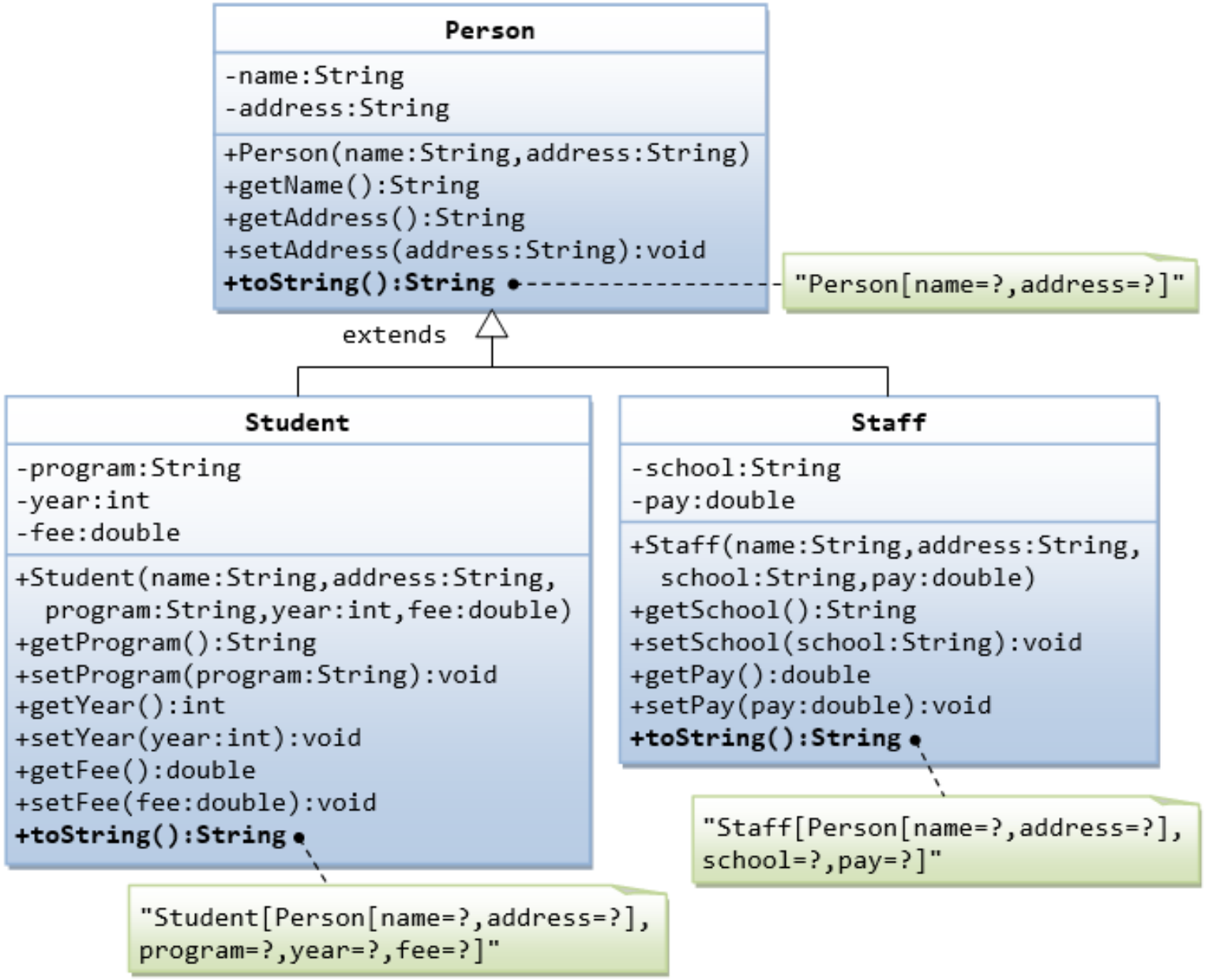
- Anonymous classes enable programmers to declare and instantiate a class at the same time in the code
  - They are like any other classes except that don't have a name
  - Use them if one needs to use the class only once
- Example:

```
Pet aVerySpecialPet = new Pet("Unique") {
        void sleep() { // ... }
        void walk()  { // ... }
        void swim()  { // ... }

        @Override
        void eat(String food) { // ... }
};
```

Exercise

- Write the classes as shown in the class diagram



Packages

General

- A package is used to group related classes, and is organized as a folder in the file system
  - Better encapsulation to avoid name conflicts
  - Better maintainability
- A package may contain sub-packages □ leading to a hierarchy of packages
- Categories
  - Built-in packages (from the Java API)
  - User-defined packages (your own)
  - Third-party packages (found on the Internet or given by someone else)

Built-in Packages

- The JDK provides a number of ready-to-use and useful packages

Package	Description
`java.lang`	Classes and interfaces that are fundamental to the design of the Java programming language, like `String`, `StringBuffer`, `System`, `Math`, `Integer`,… This package is imported by default, there is no need to explicitly do that.
`java.util`	The collections framework, some internationalization support classes, properties, random number generation classes
`java.io`	Classes for system input/output operations
`java.awt`	Classes for creating user interfaces and for painting graphics and images
`java.net`	Classes for implementing networking applications
`java.sql`	Classes for accessing and processing data stored in a database

Using a Package

- Using a class without importing the package
  - `java.util.Scanner in = new java.util.Scanner(System.in);`
- Import a class from a package
  - ```
    // on top of the file
    import java.util.Scanner;
    ```
  - ```
    // in the code
    Scanner in = new Scanner(System.in);
    ```
- Import a whole package
  - ```
    // on top of the file
    import java.util.*;
    ```
  - ```
    // in the code
    Scanner in = new Scanner(System.in);
    ```

User-defined Package Example

- Folders and files:

```
root
└── mypack
    ├── MyClass1.java
    └── MyClass2.java
```

- MyClass1.java
  - ```
    package mypack;

    class MyClass1 { ... }
    ```
- MyClass2.java
  - ```
    package mypack;

    class MyClass2 { ... }
    ```

Generics

General

- Sometimes, one needs to parameterize types, i.e., allow types to be parameters to methods, classes and interfaces and obtain their different versions
  - Parameters are limited to object types, it’s not possible to use primitive types
- Two types:
  - Generic methods
  - Generic classes, interfaces

Generic Classes

- Example:
  - ```
    class Pair<K, V> {
        private K key;
        private V value;

        Pair(K key, V value) {
            this.key = key;
            this.value = value;
        }

        void setKey(K key)     { this.key = key; }
        void setValue(V value) { this.value = value; }
        K getKey()             { return key; }
        V getValue()           { return value; }
    }
    ```
    ```

Generic Methods

- Example:
  - ```
    class MyMath {
      static <K, V> boolean compare(Pair<K, V> p1, Pair<K, V> p2) {
        return p1.getKey().equals(p2.getKey()) &&
               p1.getValue().equals(p2.getValue());
      }
    }
    ```
- Usage:
  - ```
    Pair<Integer, String> p1 = new Pair<>(1, "apple");
    Pair<Integer, String> p2 = new Pair<>(2, "pear");

    // explicit parameters:
    boolean same1 = MyMath.<Integer, String>compare(p1, p2);

    // implicit parameters:
    boolean same2 = MyMath.compare(p1, p2);
    ```

Bounded Type Parameters

- One might want to restrict the types that can be used as type arguments in a parameterized type
  - Use the `extends` keyword, but it has a general sense to mean either `extends` or `implements`
- Examples:
  - ```
    class Polynomial<T extends Number> {
        // ...
    }
    ```
  - ```
    <T extends B & A & C> void func1(T t) {
        //...
    }
    ```

Exercises

1. Complete the company personnel management classes
2. Complete the class hierarchy for basic shapes: circles, rectangles, squares
3. Implement the `toString()`, `clone()`, `equals()` methods for the shape classes