Object-Oriented Programming Concept

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Outline

- Part I – Encapsulation
- Part II – Call by Reference
- Part III – Inheritance
- Part IV – Abstract Class and Interface
- Part V – Polymorphism

OOP Concept Part I
Encapsulation

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Introduction

- Classes are the most important language feature that make *object-oriented programming* (*OOP*) possible
- Programming in Java consists of defining a number of classes
  - Every program is a class
  - All helping software consists of classes
  - All programmer-defined types are classes
- Classes are central to Java

A Class Is a Type

- A class is a special kind of programmer-defined type, and variables can be declared of a class type
- A value of a class type is called an object or *an instance of the class*
  - If Cat is a class, then the phrases “cat is of type Cat," “cat is an object of the class Cat," and “cat is an instance of the class Cat" mean the same thing
- A class determines the types of data that an object can contain, as well as the actions it can perform

Primitive Type Values vs. Class Type Values

- A primitive type value is a **single piece of data**
- A class type value or object can have **multiple pieces of data**, as well as actions called ***methods***
  - All objects of a class have the same methods
  - All objects of a class have the same pieces of data (i.e., name, type, and number)
  - For a given object, each piece of data can hold a different value

The Contents of a Class Definition

- A class definition specifies the data items and methods that all of its objects will have
- These data items and methods are sometimes called ***members*** of the object
- **Data items are called *fields* or *instance variables***
- Instance variable declarations and method definitions can be placed in any order within the class definition

Lab

```java
public class Duck {

  public boolean canfly = false;

  public void quack(){
    System.out.println("Quack!!");
  }

}
```

The `new` Operator

- An object of a class is named or declared by a variable of the class type:

  ```
  ClassName  classVar;
  ```

- The **`new`** operator must then be used to create the object and associate it with its variable name:

  ```
  classVar = new ClassName();
  ```

- These can be combined as follows:

  ```
  ClassName classVar = new ClassName();
  ```

Lab

```java
public class Farm {

  public static void main(String[] args) {
    Duck duck = new Duck();
  }

}
```

Instance Variables and Methods

- Instance variables can be defined as in the following two examples
  - Note the `public` modifier (for now):

```
public String  instanceVar1;
public int  instanceVar2;
```

- In order to refer to a particular instance variable, preface it with its object name as follows:

```
objectName.instanceVar1
objectName.instanceVar2
```

Instance Variables and Methods

- Method definitions are divided into two parts: a *heading* and a *method body:*

```
public void myMethod()        ← Heading
{
      code to perform some action   } Body
      and/or compute a value        }
}
```

- Methods are invoked using the name of the calling object and the method name as follows:

```
classVar.myMethod();
```

- Invoking a method is equivalent to executing the method body

Lab

```java
public class Farm {

public static void main(String[] args) {

  Duck duck = new Duck();

  boolean canTheDuckFly = duck.canfly;
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  duck.quack();
}
}
```

Local Variables

- A variable declared within a method definition is called a *local variable*
  - All variables declared in a method are local variables
  - All method parameters are local variables
- If two methods each have a local variable of the same name, they are still two entirely different variables

instance variable

```
public class Duck {

  public boolean canfly = false;

  public String eat(String food){
    String message = "Thank you! The " + food +" is good!";
    return message;
  }
}
```

local variable

Parameters of a Method

- A parameter list provides a description of the data required by a method

```
public double myMethod(int p1, int p2, double p3){
      double sum = p1 + p2 +p3;
      return sum;
}
```

Arguments

- When a method is invoked, the type of each argument must be compatible with the type of the corresponding parameter

```
int    a=1;
int    b=2;
double c=3.0;
double result = myMethod(a,b,c);
```

Automatic Upper Casting

- A primitive argument can be automatically type cast from any of the following types, to any of the types that appear to its right:

```
byte→short→int→long→float→double
Char ──────────┘
```

For example:

```
int    a=1;
int    b=2;
int    c=3;
double result = myMethod(a,b,c);
```

Enum

- The **Enum** is a data type which contains a fixed set of constants.

```
public enum Class {
        ENGLISH, MATH
}
```

```
public class Demo {

  public static void main(String args[]) {
    for (Class s : Class.values()) {
      System.out.println(s);
    }
  }
}
```

Enum can have fields, constructors and methods

```java
public enum Grade {
  A(90, "Excellent"), B(80,
"Good"), C(70, "Average");

  private int score;
  private String description;

  Grade(int score, String desc) {
    this.score = score;
    this.description = desc;
  }

  public int getScore() {
    return score;
  }

  public String getDescription() {
    return description;
  }
}
```

```java
public class Student {

  Grade grade;

  public void assignGrade(Grade assignedgrade) {
    grade = assignedgrade;

    switch (grade) {
      case A:
        System.out.print("Ya!" + grade.getDescription());
        break;
      default:
        break;
    }
  }

  public static void main(String args[]) {
    Student s = new Student();
    s.assignGrade(Grade.A);
  }
}
```

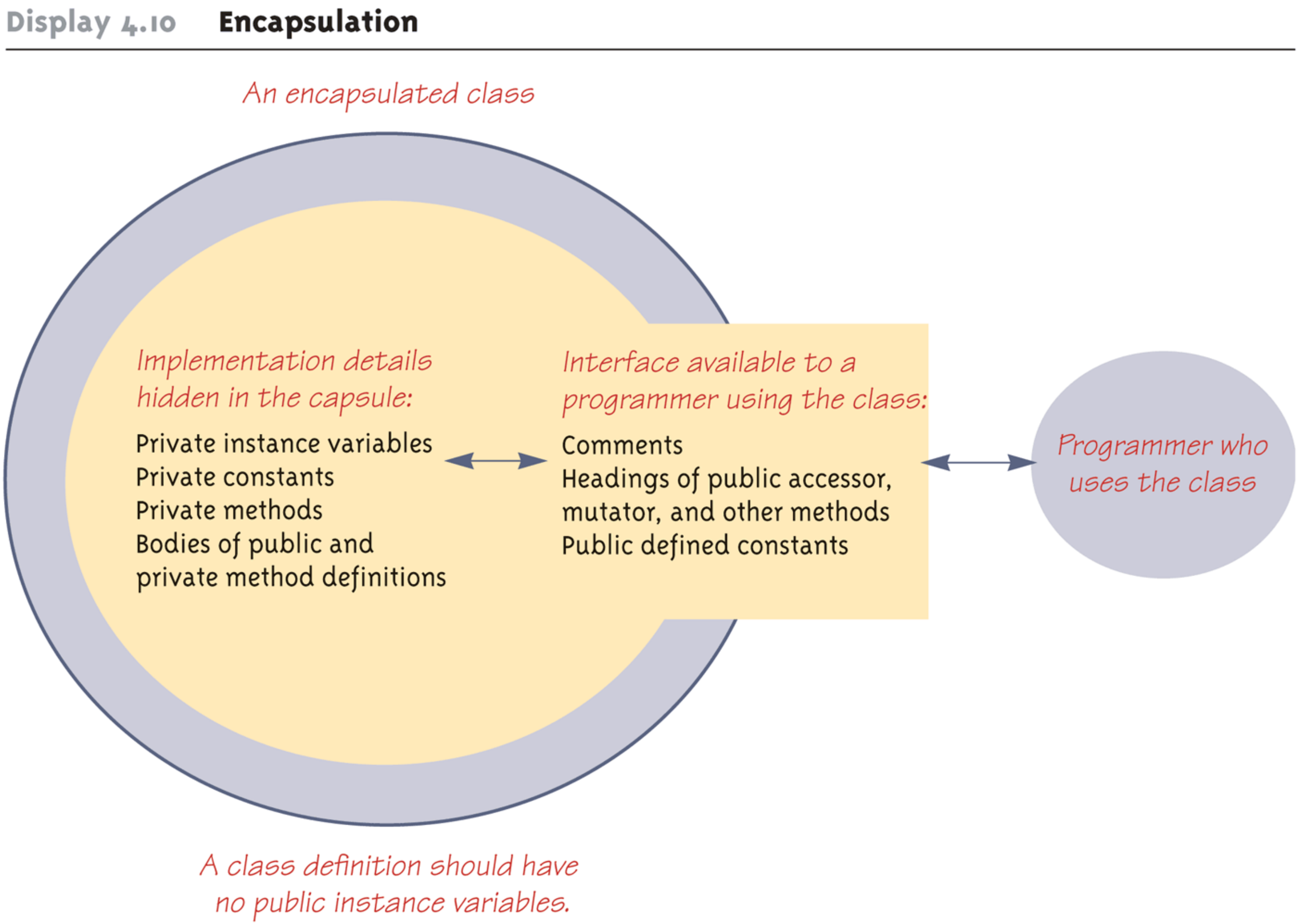
Encapsulation

- *Encapsulation* means that the data and methods of a class are combined into a single unit (i.e., a class object), which hides the implementation details
  - Knowing the details is unnecessary because interaction with the object occurs via a well-defined and simple interface
  - In Java, hiding details is done by marking them **`private`**

`public` and `private` Modifiers

- The modifier **`public`** means that there are no restrictions on where an instance variable or method can be used
- The modifier **`private`** means that an instance variable or method cannot be accessed by name outside of the class
  - It is considered good programming practice to make **all** instance variables **`private`**
  - Most methods are **`public`**, and thus provide controlled access to the object
  - Usually, methods are **`private`** only if used as helping methods for other methods in the class

Encapsulation



Lab

```
public class Duck {

  private boolean canfly = false;

  public boolean getCanfly(){
    return canfly;
  }

  …

}
```

Lab

```
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck(true);

  boolean canTheDuckFly = duck.getCanfly();
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  …

}

}
```

Overloading

- *Overloading* is when two or more methods *in the same class* have the same method name
- To be valid, any two definitions of the method name must have different *signatures*
  - A signature consists of the name of a method together with its parameter list
  - Differing signatures must have different numbers and/or types of parameters

Lab

```java
public class Duck {
  …
  public void quack(){
    System.out.println("Quack!!");
  }
  public void quack(String sound){
    System.out.println(sound);
  }
  …
}
```

```java
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck(true);
  …
  duck.quack();
  duck.quack("Ga Ga Ga");
}
}
```

OOP Concept Part II
Call by Reference

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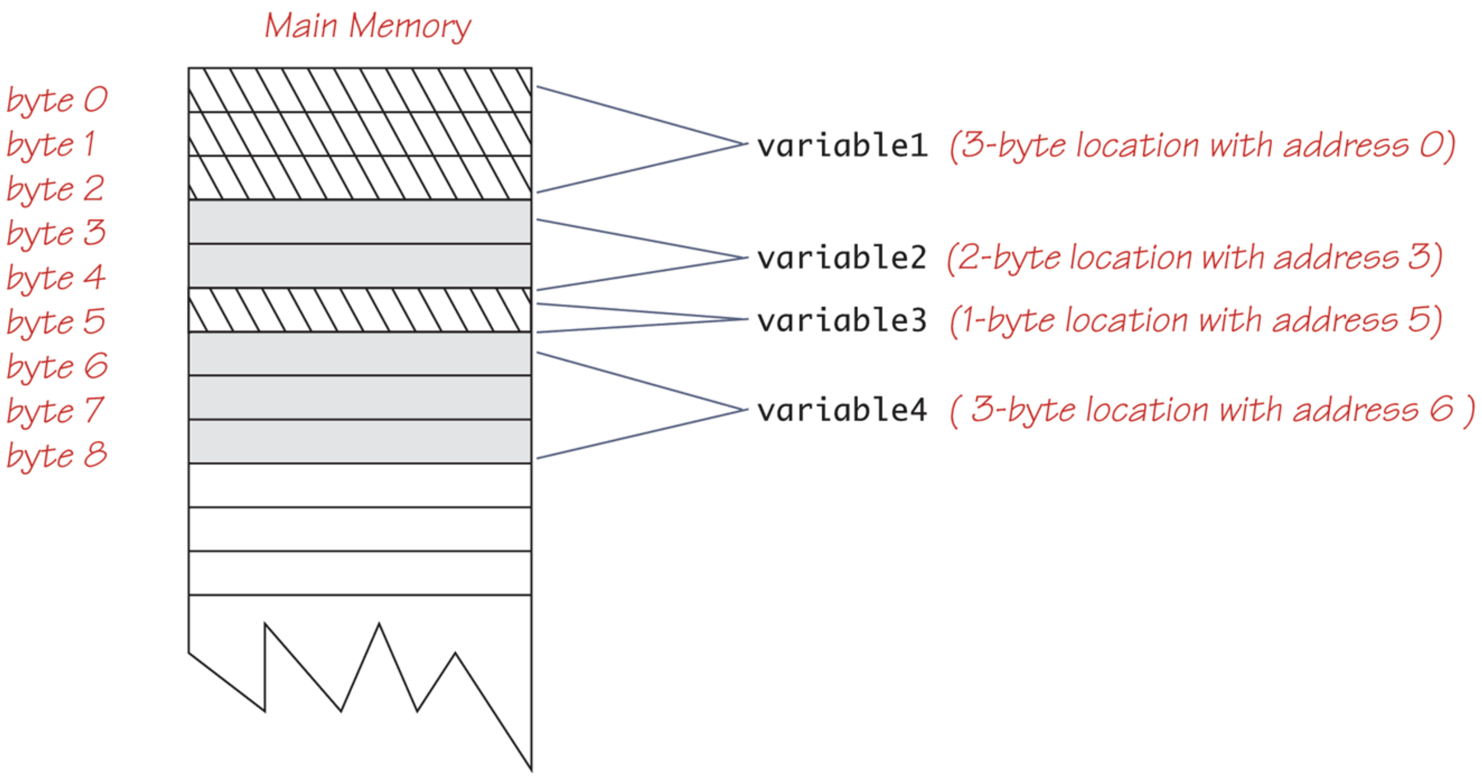
Variables and Memory

- Values of most data types require more than one byte of storage
  - Several **adjacent bytes** are then used to hold the data item
  - The entire **chunk of memory** that holds the data is called its ***memory location***
  - The address of the **first byte** of this memory location is used as the **address** for the data item
- A computer's main memory can be thought of as a long list of memory locations of *varying sizes*

Variables in Memory

Display 5.10 **Variables in Memory**



References

- Every variable is implemented as a location in computer memory
- When the variable is a **primitive type, the value of the variable is stored in the memory location** assigned to the variable
  - Each primitive type always require the same amount of memory to store its values

References

- When the variable is **a class type**, **only the memory address (or *reference*)** where its object is located is stored in the memory location assigned to the variable
  - The object named by the variable is stored in some other location in memory
  - Like primitives, the value of a class variable is a fixed size
  - Unlike primitives, the value of a class variable is a memory address or reference
  - The object, whose address is stored in the variable, can be of any size

Class Type Variables Store a Reference (Part 1 of 2)

Display 5.12 **Class Type Variables Store a Reference**

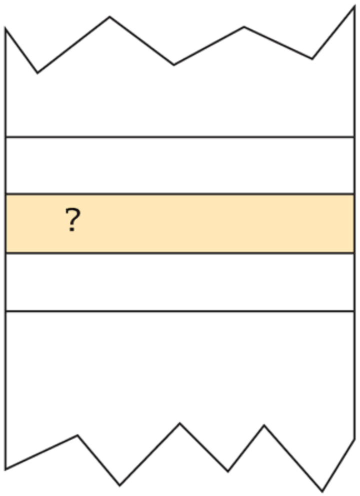
```
public class ToyClass
{
     private String name;
     private int number;
```

The complete definition of the class `ToyClass` *is given in Display 5.11.*

```
ToyClass sampleVariable;
```

Creates the variable `sampleVariable` *in memory but assigns it no value.*

`sampleVariable`



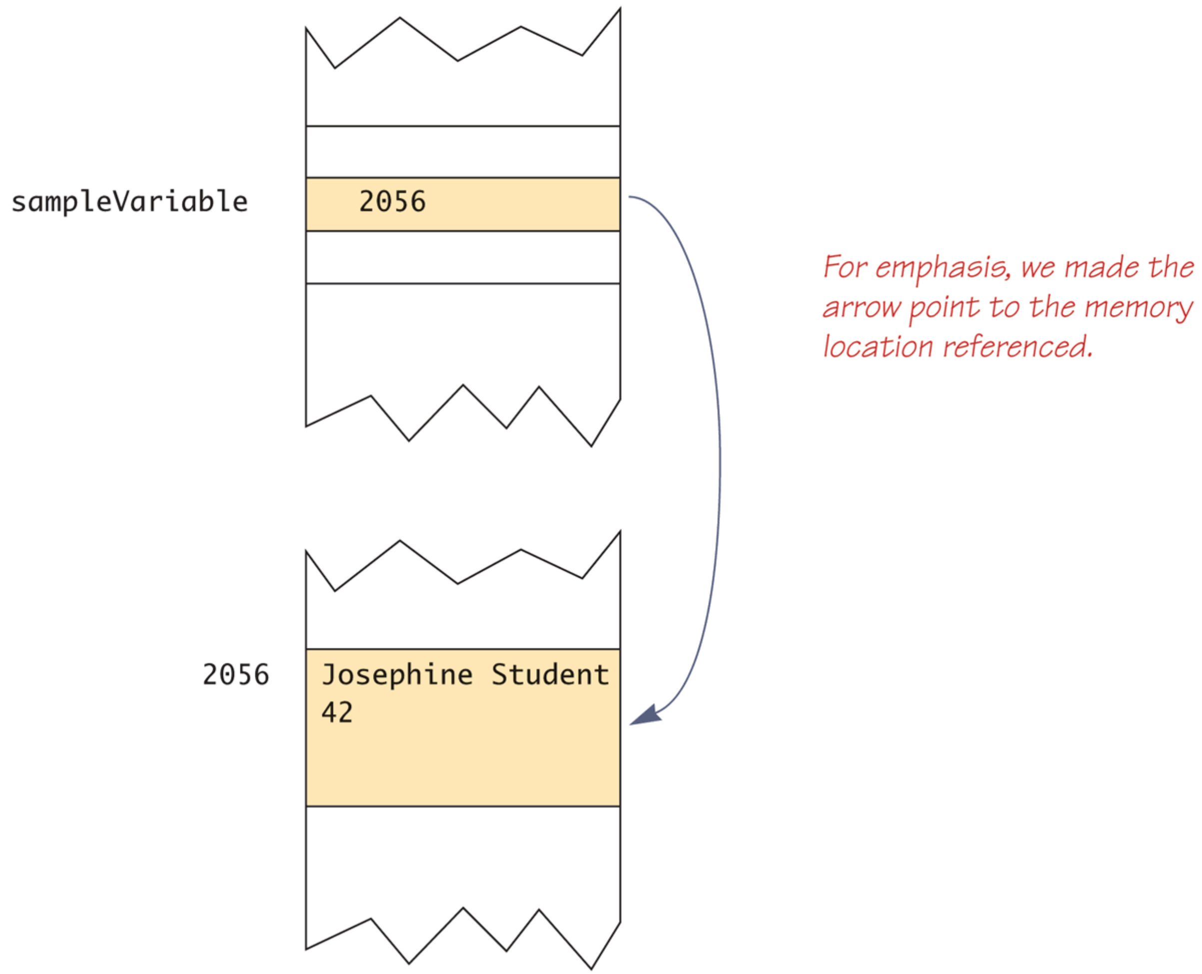

```
sampleVariable =
new ToyClass("Josephine Student", 42);
```

Creates an object, places the object someplace in memory, and then places the address of the object in the variable `sampleVariable`*. We do not know what the address of the object is, but let's assume it is* `2056`*. The exact number does not matter.*

(continued)

Class Type Variables Store a Reference (Part 2 of 2)

Display 5.12 **Class Type Variables Store a Reference**



References

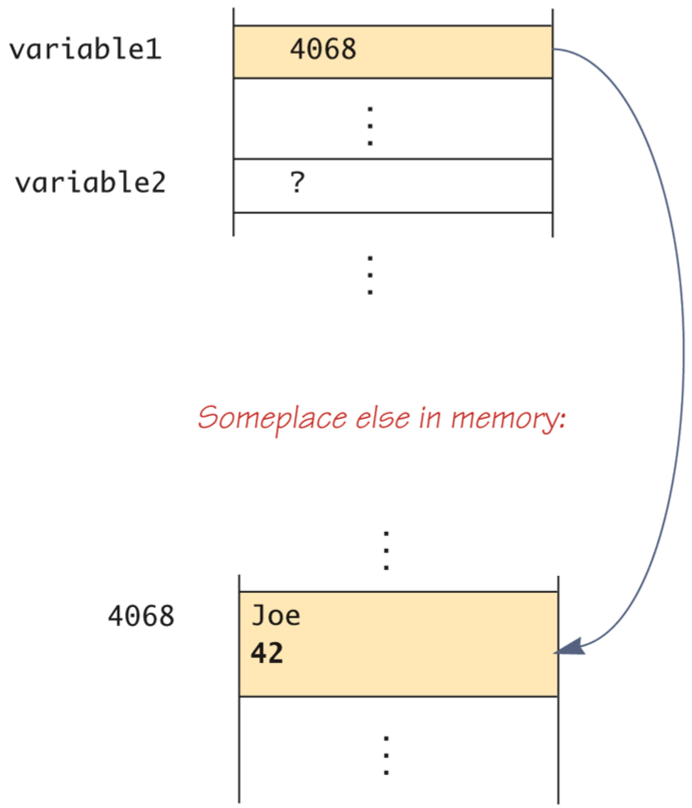
- **Two reference variables can contain the same reference**, and therefore name the same object
  - The assignment operator sets the reference (memory address) of one class type variable equal to that of another
  - Any change to the object named by one of theses variables will produce a change to the object named by the other variable, since they are the same object

```
variable2 = variable1;
```

Assignment Operator with Class Type Variables (Part 1 of 3)

Display 5.13 Assignment Operator with Class Type Variables

```
ToyClass variable1 = new ToyClass("Joe", 42);
ToyClass variable2;
```



We do not know what memory address (reference) is stored in the variable `variable1`*. Let's say it is* `4068`*. The exact number does not matter.*

Note that you can think of

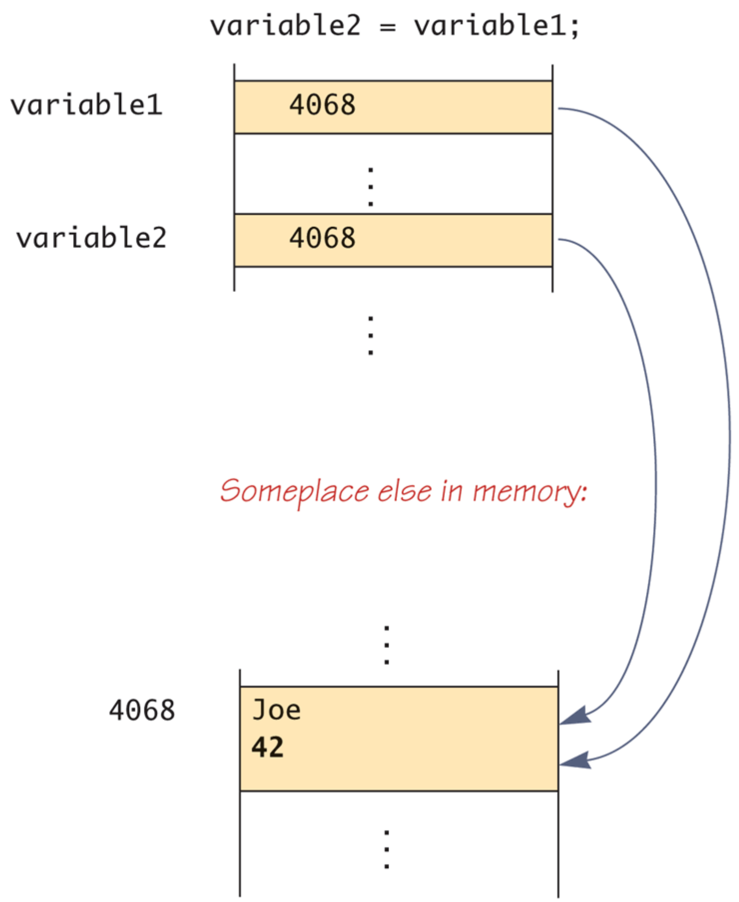
```
new ToyClass("Joe", 42)
```

as returning a reference.

(continued)

Assignment Operator with Class Type Variables (Part 2 of 3)

Display 5.13 **Assignment Operator with Class Type Variables**



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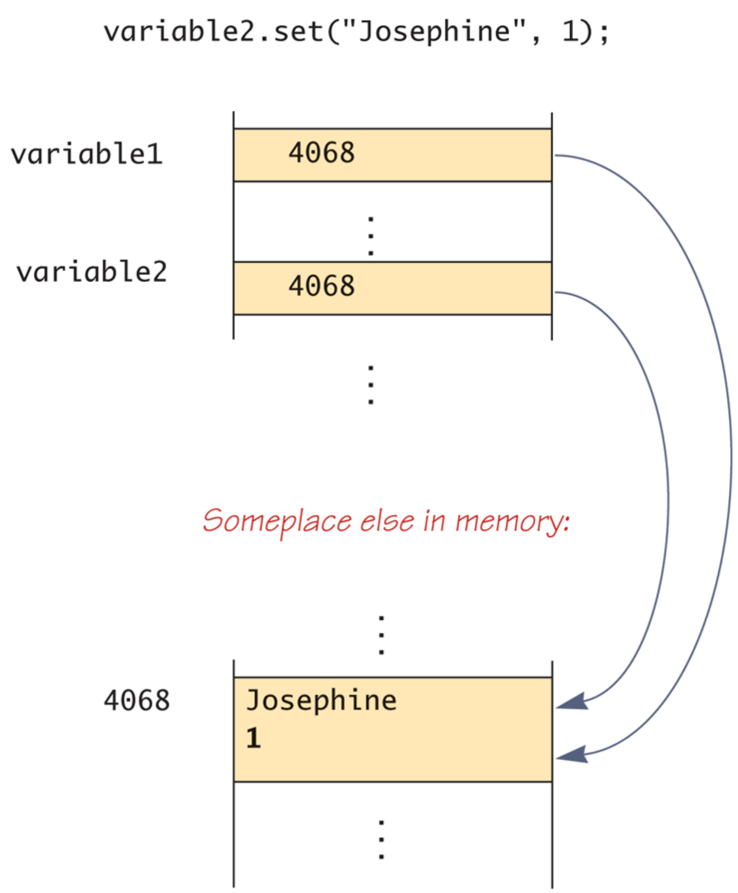
Assignment Operator with Class Type Variables (Part 3 of 3)

Display 5.13 Assignment Operator with Class Type Variables



Lab

```
public class Cat {

    int age = 1;

    public static void main(String[] args)
    {
        Cat cat1 = new Cat();
        Cat cat2 = cat1;

        cat1.age = 2;
        System.out.println(cat2.age);

     }

}
```

Class Parameters

- **Primitive type parameters** in Java are ***call-by-value*** parameters
  - A parameter is a *local variable* that is set equal to the value of its argument
  - Therefore, any change to the value of the parameter cannot change the value of its argument
- **Class type parameters** appear to behave differently from primitive type parameters
  - They appear to behave in a way similar to parameters in languages that have the ***call-by-reference*** parameter passing mechanism

Differences Between Primitive and Class-Type Parameters

- A method **cannot change the value of a variable of a primitive type** that is an argument to the method
- In contrast, a method **can change the values of the instance variables of a class type** that is an argument to the method

Lab (Call by Value)

```java
public class PrimitiveParameterDemo {

    public static void main(String[] args)
    {
        int speed = 50;
        System.out.println("argument value:" + speed);

        changer(speed);

        System.out.println("argument value:" + speed);
     }

    public static void changer(int speed)
    {
    speed = 100;
    System.out.println("parameter value:" + speed);
    }

}
```

Lab (Call by Reference)

```java
public class ToyClass
{
    private String name;
    private int number;

    public ToyClass(String initialName, int initialNumber)
    {
        name = initialName;
        number = initialNumber;
    }

    public String toString( )
    {
        return (name + " " + number);
    }


    public void set(String newName, int newNumber)
    {
        name = newName;
        number = newNumber;
    }
}
```

Lab (Call by Reference)

```
public class ClassParameterDemo
{
    public static void main(String[] args)
    {
        ToyClass anObject = new ToyClass("Robot Dog", 10);
        System.out.println(anObject);

        changer(anObject);
        System.out.println(anObject);
     }

    public static void changer(ToyClass aParameter)
    {
    aParameter.set("Robot Cat",20);
    }

}
```

OOP Concept Part III
Inheritance

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Inheritance

- The sharing of attributes and operations among classes based on a hierarchical relationship
  - It allows code to be *reused*, without having to copy it into the definitions of the derived classes

- Each subclass inherits all of the properties of its superclass and adds its own unique properties (called extension)

- **Is-a** relationship

Introduction to Inheritance

- The original class is called the *base class*

- The new class is called a *derived class*
  - A derived class automatically has all the instance variables and methods that the base class has, and it can have additional methods and/or instance variables as well

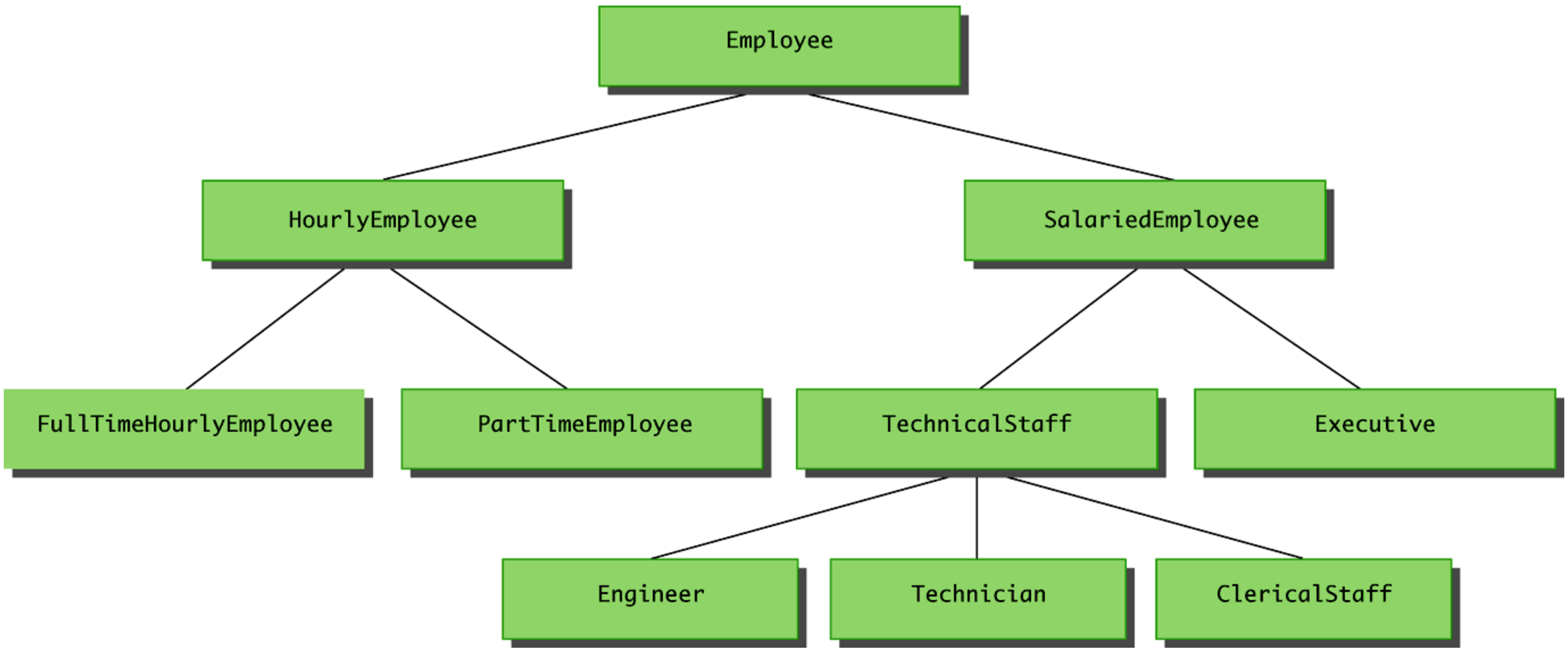
Examples of Derived Classes

- Within Java, a class called **`Employee`** can be defined that includes all employees
- This class can then be used to define classes for hourly employees and salaried employees
  - In turn, the **`HourlyEmployee`** class can be used to define a **`PartTimeHourlyEmployee`** class, and so forth

```
public class HourlyEmployee extends Employee
```

A Class Hierarchy

Display 7.1 A Class Hierarchy



Derived Class (Subclass)

- Members of a class that are declared **private** are not inherited by subclasses of that class.

- Only members of a class that are declared **protected** or **public** are inherited by subclasses declared in a package other than the one in which the class is declared.

Lab

```java
import java.util.Date;

public class Employee {

  protected String name;
  protected Date hireDate;

  public Employee(){}

  public Employee(String theName, Date theDate){
        name = theName;
        hireDate = theDate;
  }
  public Date getHireDate(){
        return hireDate;
  }

  public String getName(){
        return name;
  }

}
```

Lab

```java
import java.util.Date;

public class HourlyEmployee extends Employee{
 private double wageRate;

 public HourlyEmployee(String theName, Date theDate, double rate){
        name = theName;
        hireDate = theDate;
        wageRate = rate;
 }

}
```

Lab

```java
import java.util.Date;

public class Company {

  public static void main(String[] args){

    HourlyEmployee hourlyEmployee = new HourlyEmployee("Josephine",
          new Date(114,0,1), 100);

    System.out.println(hourlyEmployee.getName());

  }
}
```

Parent and Child Classes

- A base class is often called the *parent class*
  - A derived class is then called a *child class*
- These relationships are often extended such that a class that is a parent of a parent . . . of another class is called an *ancestor class*
  - If class **`A`** is an ancestor of class **`B`**, then class **`B`** can be called a *descendent* of class **`A`**

Overriding a Method Definition

- Although a derived class inherits methods from the base class, it can **change** or ***override*** an inherited method if necessary
  - In order to override a method definition, a new definition of the method is simply placed in the class definition

Lab

```
import java.util.Date;

public class HourlyEmployee extends Employee{
 private double wageRate;

 public HourlyEmployee(String theName, Date theDate, double rate){
        name = theName;
        hireDate = theDate;
        wageRate = rate;
 }
 public String getName(){
        return "Hourly Employee:" + name;
 }
}
```

Then run Company again!

Pitfall: Overriding Versus Overloading

- When a method is **overridden**, the new method definition given in the derived class has the **exact same number and types of parameters** as in the base class

- When a method in a derived class has a **different signature** from the method in the base class, that is **overloading**

OOP Concept Part IV
Abstract Class & Interface

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Introduction to Abstract Classes

- In order to postpone the definition of a method, Java allows an *abstract method* to be declared
  - An abstract method has a heading, but no method body
  - The body of the method is defined in the derived classes
- The class that contains an abstract method is called an *abstract class*

Abstract Method

- An abstract method is like a placeholder for a method that will be fully defined in a descendent class
- It has a complete method heading, to which has been added the modifier `abstract`
- **It cannot be private**
- It has no method body, and ends with a semicolon in place of its body

```
public abstract double getPay();
public abstract void doIt(int count);
```

Abstract Class

- A class that has at least one abstract method is called an *abstract class*
  - An abstract class must have the modifier **`abstract`** included in its class heading:

```
public abstract class Employee
{
  private instanceVariables;
  . . .
  public abstract double getPay();
  . . .
}
```

Abstract Class

- An abstract class can have any number of abstract and/or fully defined methods
- If a derived class of an abstract class adds to or does not define all of the abstract methods, then it is abstract also, and must add **`abstract`** to its modifier

- A class that has no abstract methods is called a *concrete class*

Pitfall: You Cannot Create Instances of an Abstract Class

- An abstract class can only be used to derive more specialized classes
  - While it may be useful to discuss employees in general, in reality an employee must be a salaried worker or an hourly worker
- **An abstract class constructor cannot be used to create an object of the abstract class**

Lab

```java
public abstract class Animal {
  public abstract void run();
  public void sit(){ System.out.println(“Sit down…”); }
}
```

```java
public class Dog extends Animal {
  public void run(){
    System.out.println("The dog is running");
  }
}
```

```java
public class Cat extends Animal{
  public void run(){
    System.out.println("The cat is running");
  }
}
```

Lab

```java
public class House {

  public static void main(String[] args) {
    Animal dog = new Dog();
    Animal cat = new Cat();

    playWith(dog);
    playWith(cat);

    dog.sit();
    cat.sit();
  }

  public static void playWith(Animal animal){
    animal.run();

  }

}
```

Interfaces

- An *interface* is something like an extreme case of an abstract class
  - However, *an interface is not a class*
  - *It is a type that can be satisfied by any class that implements the interface*
- The syntax for defining an interface is similar to that of defining a class
  - Except the word **`interface`** is used in place of **`class`**

Interfaces

- An interface specifies a set of methods that any class that implements the interface must have
  - It contains **method headings** and **constant definitions** only
    - Any variables defined in an interface must be public, static, and final
  - It contains **no instance variables nor any complete method definitions**

Lab (Constants)

```
public interface Shape {
  int color = 1; // => public static final int color = 1;
}
```

```
public class Paint {
  public static void main(String[] args) {
    System.out.println(Shape.color);
  }
}
```

Interfaces

- All methods in an interface are **implicitly public and abstract**, so you can omit the public modifier.
  - They cannot be given private or protected

```
public interface ISpec1 {
        private void run(); //Not allowed
        protected void run(); //Not allowed

        void run(); // Allowed. Equal to the following definition
        public abstract void run(); //Allowed

}
```

Lab

```java
public interface Shape {

  int color = 1; // => public static final int color = 1;

  public abstract double area(); //=> double area();
}
```

Interfaces

- *Multiple inheritance* is not allowed in Java
- Instead, Java's way of approximating multiple inheritance is through interfaces

```
public class ConcreteClass implements ISpec1, ISpec2, ISpec3{
        …
}
```

Interfaces

- To *implement an interface*, a concrete class must do two things:

  1. `implements` ***`Interface_Name`***

  1. The class must implement *all* the method headings listed in the definition(s) of the interface(s)

Lab

```
public class Rectangle implements Shape{
  int x1=0;
  int y1=0;
  int x2=10;
  int y2=10;
  public double area(){
    return (x2-x1)*(y2-y1);
  }
}


public class Circle implements Shape{

  double radius = 3;
  public double area(){
    return radius*radius*3.14;
  }
}
```

Lab

```
public class Paint {

  public static void main(String[] args) {
    System.out.println(Shape.color);

    Shape shape1 = new Rectangle();
    printArea(shape1);

    Shape shape2 = new Circle();
    printArea(shape2);
  }

  public static void printArea(Shape shape){
    System.out.println(shape.area());
  }
}
```

Abstract Classes Implementing Interfaces

- Abstract classes may implement one or more interfaces
  - Any method headings given in the interface that are not given definitions are made into abstract methods
- A concrete class must give definitions for all the method headings given in the abstract class *and the interface*

Abstract Class vs. Interface

```
public abstract class Animal {
  public abstract void run();
  public void sit(){ System.out.println(“Sit down…”); }
}
```

vs.

```
public interface Shape {

  int color = 1; // => public static final int color = 1;

  public abstract double area(); //=> double area();
}
```

Derived Interfaces

- Like classes, an interface may be derived from a base interface
  - This is called *extending* the interface
  - The derived interface must include the phrase

    `extends BaseInterfaceName`
- A concrete class that implements a derived interface must have definitions for any methods in the derived interface as well as any methods in the base interface

Lab

```java
public interface Drawing {

  public abstract void drawBorder();
}
```

```java
public interface Shape extends Drawing{

  int color = 1; // => public static final int color = 1;

  public abstract double area();
}
```

Lab

```
public class Rectangle implements Shape{

  int x1=0;
  int y1=0;
  int x2=10;
  int y2=10;

  public double area(){
    return (x2-x1)*(y2-y1);
  }
  public void drawBorder(){
    System.out.println("Drawing the border of the rectangle...");
  }
}
```

Lab

```
public class Circle implements Shape{

  double radius = 3;
  public double area(){
    return radius*radius*3.14;
  }

  public void drawBorder(){
    System.out.println("Drawing the border of the circle...");
  }
}
```

OOP Concept Part V
Polymorphism

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Late Binding

- ***Early binding*** or ***static binding***
  - **which method is to be called** is decided at compile-time
    - ***Overloading****: an invocation can be operated on arguments of more than one type*

- ***Late binding*** or ***dynamic binding***
  - **which method is to be called** is decided at runtime
    - ***Overriding***: a derived class inherits methods from the base class, it can change or override an inherited method

Lab: Early binding (through overloading)

```
public class SayHello {

  public String sayHello(String name){
    return "Hello! "+ name;
  }

  public String sayHello(String name, String gender){
    if(gender.equals("boy")){
      return "Hello! Mr. "+ name;
    }
    else if(gender.equals("girl")){
      return "Hello! Miss. "+ name;
    }else{
      return "Hello! "+ name;
    }
  }

  public static void main(String[] args){
    SayHello hello = new SayHello();
    System.out.println(hello.sayHello("S.J.")); //decided at compile time
    System.out.println(hello.sayHello("S.J.","boy")); //decided at compile time
  }
}
```

Lab: Late binding (through overriding)

```java
public class Payment {
  public void pay(){
    System.out.println("Pay in cash");
  }
  public void checkout(){
    pay();
  }
}
```

```java
public class Store {
  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();
  }
}
```

Lab: Late binding (through overriding)

```
public class CreditCardPayment extends Payment{
  public void pay() {
    System.out.println("Pay with credit card");
  }
}
```

```
public class Store {
  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();

    Payment p2 = new CreditCardPayment();
    p2.checkout();
  }
}
```

Pitfall: No Late Binding for Static Methods

- Java uses **static binding** with **private**, **`final`**, and **static** methods
  - In the case of `private` and `final` methods, late binding would serve no purpose
  - However, in the case of a static method invoked using a calling object, it does make a difference

Lab

```java
public class Payment {
  public static void pay(){
    System.out.println("Pay in cash");
  }
  public void checkout(){
    pay();
  }
}
```

```java
public class CreditCardPayment extends Payment{
  public static void pay() {
    System.out.println("Pay with credit card");
  }
}
```

Then run Store again!

Lab

```
public class Store {
  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();

    Payment p2 = new CreditCardPayment();
    p2.checkout();
  }
}
```

the type of `p2` is determined by its variable name, not the object that it references

Upcasting and Downcasting

- *Upcasting* is when an object of a derived class is assigned to a variable of a base class (or any ancestor class)

```
Payment p2 = new CreditCardPayment();
p2.checkout();
```

Upcasting and Downcasting

- *Downcasting* is when a type cast is performed from a base class to a derived class (or from any ancestor class to any descendent class)
  - Downcasting has to be done very carefully
  - In many cases it doesn't make sense, or is illegal:

```
Payment p1 = new Payment();
CreditCardPayment p2 = (CreditCardPayment)p1; //runtime error
```

Tip: Checking to See if Downcasting is Legitimate

- Downcasting to a specific type is only sensible if the object being cast is an instance of that type
  - This is exactly what the **`instanceof`** operator tests for:

    `object instanceof ClassName`
  - It will return true if ***`object`*** is of type ***`ClassName`***
  - In particular, it will return true if ***`object`*** is an instance of any descendent class of ***`ClassName`***

Lab (Downcasting)

Step1: Remove “static” in **CreditCardPayment and Payment**

Step2

```
public class CreditCardPayment extends Payment{
  public void pay() {
    System.out.println("Pay with credit card");
  }
  public void sign(){
    System.out.println("Signing...");
  }
}
```

Lab (Downcasting)

```
public class Store {

  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();
    payProcess(p1);

    Payment p2 = new CreditCardPayment();
    p2.checkout();
    payProcess(p2);
  }

  public static void payProcess(Payment p){
    if(p instanceof CreditCardPayment){
      ((CreditCardPayment)p).sign();
    }
  }
}
```