

# Chapter 7: Introduction to Classes and Objects

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# Objectives

- ▶ Understand **classes**, **objects**, **instance variables**
- ▶ Learn to **declare** a class and use it to create an object
- ▶ Learn to declare **instance methods** to implement **class behavior**
- ▶ Learn to declare **instance variables** to implement **class attributes**
- ▶ Learn to use a **constructor** to initialize an object when it is created

# Object-Oriented Programming

- ▶ Each Java program consists of one or more classes
- ▶ Each class represents **a type of objects** (e.g., those in the physical world such as a car and a printer)
- ▶ Objects interact with each other for computation using methods.
- ▶ Three key concepts: **class, object, method**

# The Car Driving Analogy

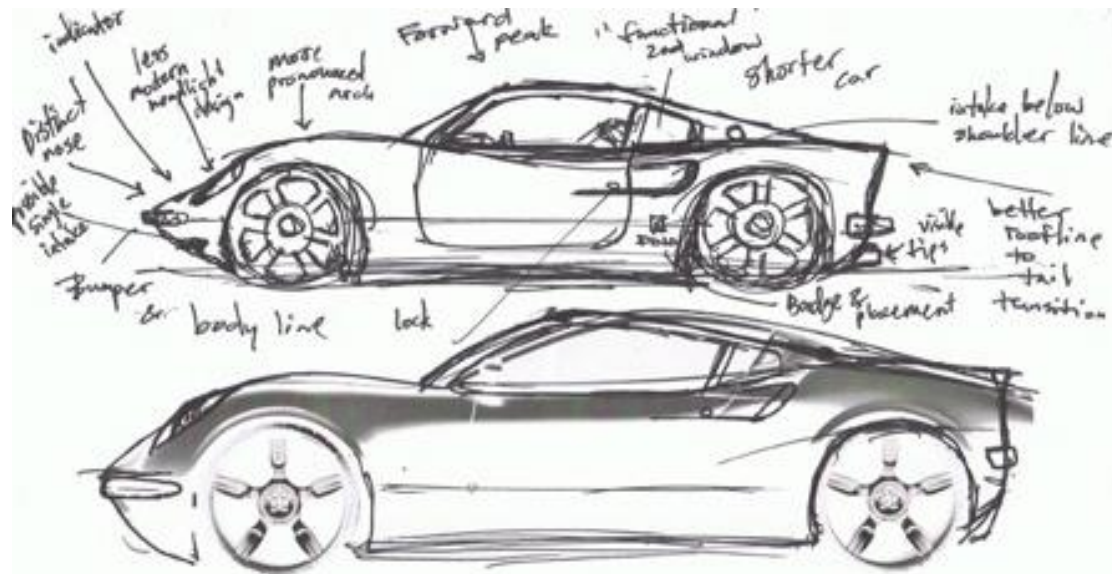
- ▶ Suppose that our computational task is to drive a car and accelerate it by pressing down on its accelerator pedal (油门)



How to make it happen?

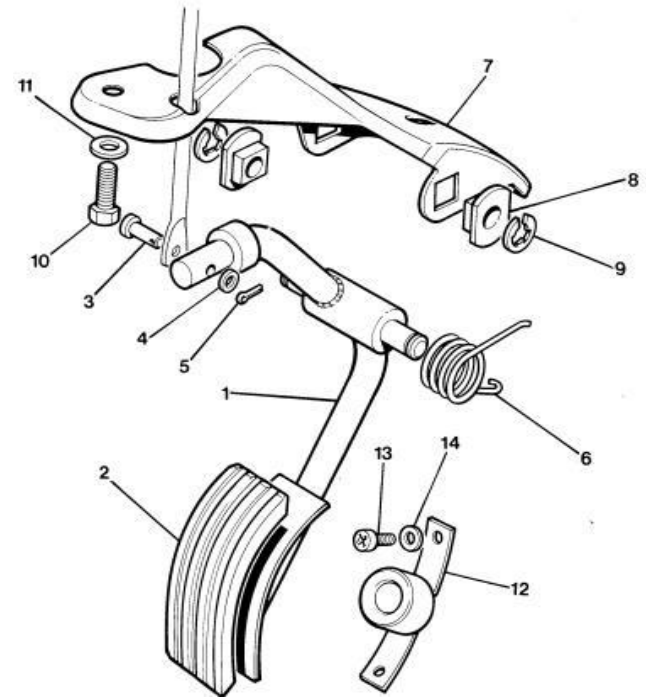
# The Car Driving Analogy

- ▶ **The very first step:** Before you can drive a car, someone has to design it (**engineering drawings / blueprints**).



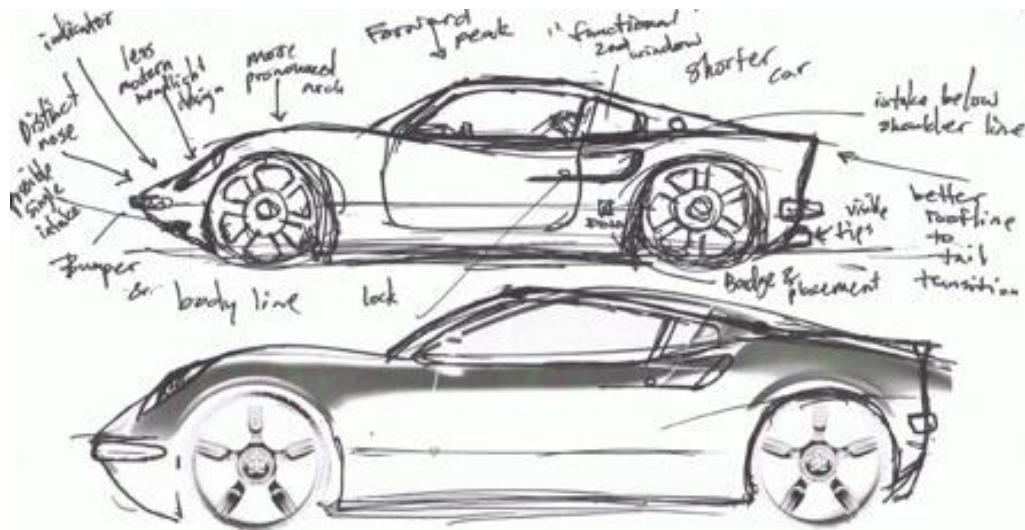
# The Car Driving Analogy

- ▶ The car's blueprints should also include the design for an accelerator pedal.
- ▶ A lot of other components should also be designed, e.g., the brake pedal (刹车), the steering wheel (方向盘)



# The Car Driving Analogy

- ▶ We cannot drive a car's engineering drawings





# The Car Driving Analogy

- ▶ We cannot drive a car's engineering drawings
- ▶ Before we drive a car, it must be **built from the engineering drawings**
- ▶ Even building a car is not enough, the driver must **press the accelerator pedal** to perform the task of driving the car



# The Car Driving Analogy

- ▶ We cannot drive a car's engineering drawings **Designing classes**
- ▶ Before we drive a car, it must be **built from the engineering drawings** **Creating concrete instances of a class**
- ▶ Even building a car is not enough, the driver must **press the accelerator pedal** to perform the task of driving the car **Invoking methods for computation**

# Detailed Analysis

- ▶ When programming in Java, we begin by creating a program unit called **class**, just like we begin with engineering draws in the driving example.
- ▶ In a class, we provide one or more **methods** that are designed to perform the class's tasks
  - speedup()
  - slowdown()
  - turn()
  - ...

# Detailed Analysis

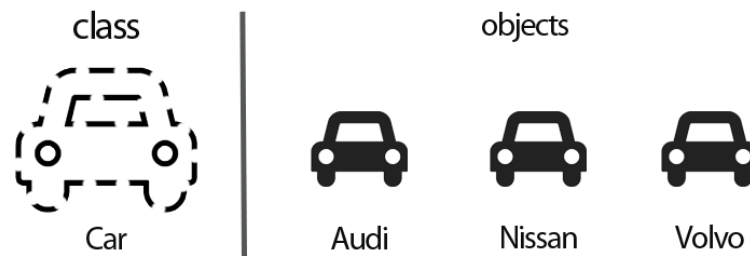
- ▶ Methods hide from users the complex tasks that they perform, just like the accelerator pedal of a car hides from the driver the complex mechanisms that make the car move faster.

## Design vs implementation

- **Drivers don't need to know the complex mechanisms behind the design to drive the car.**
- Have you ever wondered how characters are printed on screen by `System.out.println()` method?

# Detailed Analysis

- ▶ We cannot drive a car's engineering drawings. Similarly, we cannot “drive” a class to perform a task
- ▶ Just as we have to build a car from its engineering drawings before driving it, we must build an **object** of a class before getting the program to perform tasks.



# Detailed Analysis

- ▶ When driving a car, pressing the accelerator pedal sends a message to the car to perform a task – make the car go faster.
- ▶ Similarly, we send a message to an object by a method call to tell the method of the object to perform its task.

# Instance Variables

- ▶ A car can have many **attributes**: its color, the amount of gas in its tank, its current speed, and the total miles driven
- ▶ These attributes are represented as part of a car's design
- ▶ As you drive a car, **these attributes are always associated with the car**
- ▶ These attributes are specified as the class's **instance variables**.



# Instance Variables

- ▶ Recall instance methods vs static methods

	Methods	Variables
instance		
static		

- Every car maintains its own attributes (e.g., knowing how much gas is left in its tank, but do not know about other cars)
- For example, a bank account object has a balance attribute that represents the amount of money in that account.



# The Whole Picture

- ▶ **Class** – a car's engineering drawings (a blueprint/template)
  - **Instance variable** – to specify the attributes (e.g., color)
  - **Method** – designed to perform tasks (e.g., making a car move)
- ▶ **Object** – the real car that we drive
- ▶ **Method call** – perform the task (pressing the accelerator pedal)

# Objectives

- ▶ Understand classes, objects, instance variables
- ▶ Learn to **declare** a class and use it to create an object
- ▶ Learn to declare **instance methods** to implement **class behavior**
- ▶ Learn to declare **instance variables** to implement **class attributes**
- ▶ Learn to use a **constructor** to initialize an object when it is created

# Declaring a Class

Every class declaration contains the keyword `class` + the class' name

```
public class GradeBook {  
    // every class' body is enclosed in a pair of  
    // left and right curly braces  
}
```

The **access modifier** `public` indicates that the declared class is visible to all classes everywhere.

# Declaring a Method

A class usually consists of one or more methods.


Method = **Method header** + **Method body** (enclosed by { })

```
public class GradeBook {  
    // display welcome message to the user  
    public void displayMessage() {  
        System.out.println("Welcome to the Grade Book!");  
    }  
}
```

# Declaring a Method

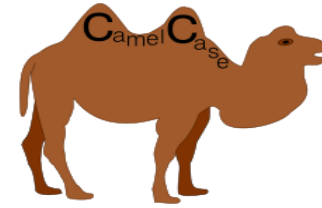
The **return type** specifies the type of data the method returns after performing its task, **void** means returning nothing to its calling method.

```
public class GradeBook {  
    // display welcome message to the user  
    public void displayMessage() {  
        System.out.println("Welcome to the Grade Book!");  
    }  
}
```



The **access modifier public** indicates that the method is “available to public”, that is, **can be directly called** from the methods of other classes.

# Declaring a Method



By convention, **method names** are in **Lower Camel Case**: the initial letter is in lower case, subsequent words begin with a capital letter.

```
public class GradeBook {  
    // display welcome message to the user  
    public void displayMessage() {  
        System.out.println("Welcome to the Grade Book!");  
    }  
}
```

The parentheses enclose the information that the method requires to perform its task. Empty parentheses indicate no information needs.

# Declaring a Method

Like class, the method body is also enclosed in { }. The method body contains **statements** that perform the method's task.

```
public class GradeBook {  
    // display welcome message to the user  
    public void displayMessage() {  
        System.out.println("Welcome to the Grade Book!");  
    }  
}
```

**Tips:** (1) Don't forget the ; after a statement; (2) try to use meaningful names when declaring a method to make your programs understandable.




# Can We Run the Program?

```
public class GradeBook {  
    // display welcome message to the user  
    public void displayMessage() {  
        System.out.println("Welcome to the Grade Book!");  
    }  
}
```

# Object Creation and Method Calling

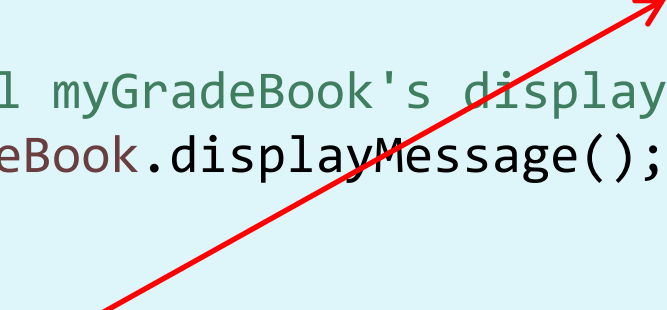
```
public class GradeBookTest {  
    public static void main(String[] args) {  
        // create a GradeBook object  
        // assign it to myGradeBook  
        GradeBook myGradeBook = new GradeBook();  
  
        // call myGradeBook's displayMessage method  
        myGradeBook.displayMessage();  
    }  
}
```



Define a variable of the type `GradeBook`. Note that each new class you create becomes a new data type. Java is an **extensible language**.

# Object Creation and Method Calling

```
public class GradeBookTest {  
    public static void main(String[] args) {  
        // create a GradeBook object  
        // assign it to myGradeBook  
        GradeBook myGradeBook = new GradeBook();  
  
        // call myGradeBook's displayMessage method  
        myGradeBook.displayMessage();  
    }  
}
```



**Class instance creation expression.** The keyword **new** is used to create a new object of the specified class. Class name + () represent a call to a **constructor** (a special method used to initialize the object's data).

# Object Creation and Method Calling

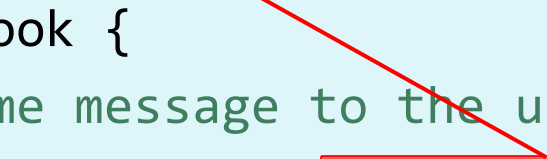
```
public class GradeBookTest {  
    public static void main(String[] args) {  
        // create a GradeBook object  
        // assign it to myGradeBook  
        GradeBook myGradeBook = new GradeBook();  
  
        // call myGradeBook's displayMessage method  
        myGradeBook.displayMessage();  
    }  
}
```

We can use the variable `myGradeBook` to refer to the created object and call the method `displayMessage()` using the **member operator** “.”.

Empty parentheses indicate that we provide no data to the called method.

# Method Parameters

- ▶ Sometimes a method needs **additional information** to perform its task. **Parameters** are for this purpose.



```
public class GradeBook {  
    // display welcome message to the user  
    public void displayMessage( String courseName ) {  
        System.out.printf("Welcome to the Grade Book for  
        the course%s!\n", courseName);  
    }  
}
```

# Method Call with Arguments

```
public class GradeBookTest {  
    public static void main(String[] args) {  
        GradeBook myGradeBook = new GradeBook();  
        myGradeBook.displayMessage("Java Programming");  
    }  
}
```

- Here when calling the method `displayMessage`, we supply a value for the parameter `courseName`. We call such values **arguments**.
- **(Parameter vs. Argument, 形式参数与实际参数)** A parameter is the variable that is part of the method's declaration. An argument is an expression used when calling the method.

# Objectives

- ▶ Understand classes, objects, instance variables
- ▶ Learn to declare a class and use it to create an object
- ▶ Learn to declare instance methods to implement class behavior
- ▶ Learn to declare **instance variables** to implement **class attributes**
- ▶ Learn to use a **constructor** to initialize an object when it is created

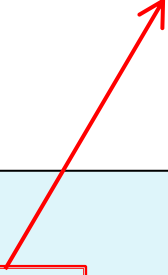


# More on Instance Variables

- ▶ An object has **attributes** (e.g., the amount of gas of a car) that are carried with the object as it is used in a program.
- ▶ Such attributes exist before a method is called on an object and after the method completes execution.
- ▶ A class typically consists of one or more **methods** that **manipulate the attributes** of a particular object of the class.

# More on Instance Variables


Object attributes are represented as variables (called **fields**) in a class declaration.



```
public class GradeBook {  
    private String courseName;  
    public void displayMessage( String courseName ) {  
        System.out.printf("Welcome to the Grade Book for  
        the course%s!\n", courseName);  
    }  
}
```

# More on Instance Variables


Each object (instance) of the class has its own copy of an attribute in memory, the **field** that represents the attribute is also known as an **instance variable**.



```
public class GradeBook {  
    private String courseName;  
    public void displayMessage( String courseName ) {  
        System.out.printf("Welcome to the Grade Book for  
        the course%s!\n", courseName);  
    }  
}
```

# Don't Confuse with Local Variables

```
public class GradeBookTest {  
  
    public static void main(String[] args) {  
        GradeBook myGradeBook = new GradeBook();  
        myGradeBook.displayMessage("Java Programming");  
    }  
}
```



Variables declared in the body of a particular method are known as **local variables** and can be only used in that method.

**Instance variables** are declared inside a class declaration, but **outside** the bodies of the class' method declarations.

# Manipulating Instance Variables with Methods

```
public class GradeBook {  
    private String courseName;  
  
    // method to set the course name  
    public void setCourseName(String name) {  
        courseName = name;  
    }  
  
    // method to retrieve the course name  
    public String getCourseName() {  
        return courseName;  
    }  
}
```

# Access Modifiers

Most instance variables are declared to be **private for data hiding**.

Variables (or methods) declared to be private are accessible only to methods of the class in which they are declared.

```
public class GradeBook {  
    private String courseName;  
  
    public void setCourseName(String name) {  
        courseName = name;  
    }  
  
    public String getCourseName() {  
        return courseName;  
    }  
}
```

# Using Getter and Setter

```
public class GradeBook {  
    private String courseName;  
  
    public void setCourseName(String name) {  
        courseName = name;  
    }  
  
    public String getCourseName() {  
        return courseName;  
    }  
  
    public void displayMessage() {  
        System.out.printf("Welcome to the grade book  
        for\n%s!\n", getCourseName());  
    }  
}
```

Manipulate the  
value of fields

Retrieve the  
value of fields



# Using Getter and Setter

```
public class GradeBook {  
    ...  
    public void displayMessage() {  
        System.out.printf("Welcome to the grade book  
        for\n%s!\n", getCourseName());  
    }  
}
```

```
import java.util.Scanner;  
public class GradeBookTest {  
    public static void main(String[] args) {  
        GradeBook myGradeBook = new GradeBook();  
        Scanner input = new Scanner(System.in);  
        System.out.printf("Enter course name: ");  
        String theName = input.nextLine();  
        myGradeBook.setCourseName(theName);  
        System.out.println();  
        myGradeBook.displayMessage();  
    }  
}
```

Enter course name: CS102

Welcome to the grade book for  
CS102

# Objectives

- ▶ Understand classes, objects, instance variables
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- ▶ Learn to declare instance variables to implement class attributes
- ▶ Learn to use a **constructor** to initialize an object when it is created

# Initializing Objects with Constructors

- ▶ Each class can provide a special method called a **constructor** to be used to **initialize an object of a class when the object is created**
- ▶ Java requires a constructor call for **every** object that is created
- ▶ Keyword **new** instantiates a class (creates an object) by allocating memory for a new object and returning a reference to that memory, then calls the corresponding class's constructor to initialize the object.
  - GradeBook myGradeBook = **new** GradeBook();

**Declaration      Instantiation & Initialization**

# Initializing Objects with Constructors

```
GradeBook myGradeBook = new GradeBook();
```

- ▶ The empty parentheses after "`new GradeBook`" indicate a call to the class's constructor without arguments
- ▶ When you declare a class, you can provide your own constructor to specify **custom initialization** for objects of your class

```
GradeBook myGradeBook = new GradeBook("Java");
```

```
GradeBook myGradeBook = new GradeBook("Alice", "Java");
```

```
GradeBook myGradeBook = new GradeBook(2022, "Spring", "Java");
```

# Example

```
public class GradeBook {  
    public String courseName; // course name for this grade book  
    // constructor initializes courseName with String argument  
    public GradeBook(String name) {  
        courseName = name; // initializes courseName  
    }  
    // method to set the course name  
    public void setCourseName(String name) {  
        courseName = name;  
    }  
    // ...  
}
```

# Initializing Objects with Constructors

```
public GradeBook(String name) {  
    courseName = name; // initialize courseName  
}
```

- ▶ Like a method, a constructor's parameter list specifies the data it requires to perform its task.
  - When creating a new object, the data is placed in the parentheses after the class name: `GradeBook book = new GradeBook("CS102A");`
- ▶ A **class instance creation expression** returns a **reference** to the new object (the address to its variables and methods in memory).

# Initializing Objects with Constructors

```
public class GradeBookTest {  
    public static void main(String[] args) {  
        // create GradeBook objects  
        GradeBook gradeBook1 = new GradeBook(  
            "CS101 Introduction to Java Programming");  
        GradeBook gradeBook2 = new GradeBook(  
            "CS102 Data Structures in Java");  
  
        // display initial value of CourseName for each GradeBook  
        System.out.printf("gradeBook1 course name is: %s\n",  
            gradeBook1.getCourseName());  
        System.out.printf("gradeBook2 course name is: %s\n",  
            gradeBook2.getCourseName());  
    }  
}
```

```
gradeBook1 course name is: CS101 Introduction to Java Programming  
gradeBook2 course name is: CS102 Data Structures in Java
```

# Initializing Objects with Constructors

- ▶ An important difference between constructors and methods is that **constructors cannot return values, so they cannot specify a return type** (not even `void`).
- ▶ Normally, constructors are declared **public**.
- ▶ The compiler provides a **default constructor** with no parameters in any class that does not explicitly include a constructor
  - When a class has only the default constructor, its instance variables are initialized with default values (e.g., an `int` variable gets the value 0)
  - If you declare any constructors for a class, the Java compiler will not create a default constructor for the class.



# More on Default Constructors

```
public class GradeBook { // no constructor provided by the programmer
    private String courseName;
    public void setCourseName(String name) {
        courseName = name;
    }
    public String getCourseName() {
        return courseName;
    }
    public void displayMessage() {
        System.out.printf("Welcome to the grade book for\n%s!\n", getCourseName());
    }
}
```



Can we write the following statement to create a GradeBook object?

```
GradeBook myGradeBook = new GradeBook();
```

Yes. Compiler will provide a default constructor with no parameters.

# More on Default Constructors

```
public class GradeBook { // this version has a constructor
    private String courseName;
    public GradeBook(String name) {
        courseName = name;
    }
    public void setCourseName(String name) {
        courseName = name;
    }
    public String getCourseName() {
        return courseName;
    } ...
}
```



Can we write the following statement to create a GradeBook object?

```
GradeBook myGradeBook = new GradeBook();
```

**No.** Compiler will not provide a default constructor this time. The statement will cause a **compilation error**.

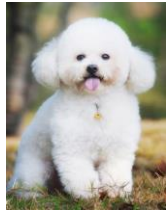
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**Case Study Time!**

# Case Study I : Pet Show

- ▶ A happy family has two pets: a poodle (贵宾犬) named “Fluffy”, a hound (猎犬) named “Alfred”.
- ▶ Suppose we want to write a Java program for a pet show: each dog makes a self introduction.



“Hello, my name is **Fluffy**. I am a **poodle**.”



“Hello, my name is **Alfred**. I am a **hound**.”

# Program Design

- ▶ **Observation 1:** The two pets are both dogs. So we can design a Dog class to represent them.

```
public class Dog {  
  
}
```

# Program Design

- ▶ **Observation 2:** The two pets have their own names and belong to different breeds (品种). We can define two instance variables to represent such information.

```
public class Dog {  
    private String name;  
    private String breed;  
}
```

# Program Design

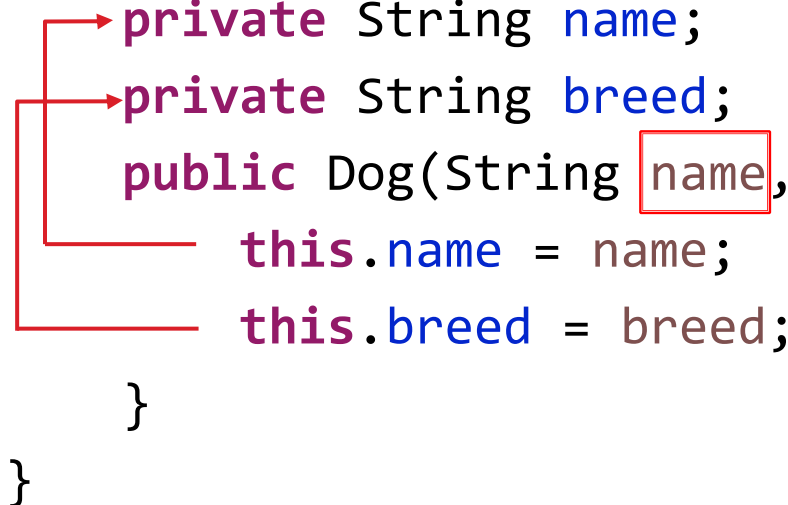
- ▶ In order to create instances of the Dog class, we need to define a constructor. Since each dog has two attributes, we can define a constructor that takes two arguments.

```
public class Dog {  
    private String name;  
    private String breed;  
    public Dog(String name, String breed) {  
        this.name = name;  
        this.breed = breed;  
    }  
}
```

# Program Design

- ▶ In order to create instances of the Dog class, we need to define a constructor. Since each dog has two attributes, we can define a constructor that takes two arguments.

```
public class Dog {  
    private String name;  
    private String breed;  
    public Dog(String name, String breed) {  
        this.name = name;  
        this.breed = breed;  
    }  
}
```



The passed arguments will be used to initialize the attributes.



# Program Design

- ▶ In order to create instances of the Dog class, we need to define a constructor. Since each dog has two attributes, we can define a constructor that takes two arguments.

```
public class Dog {  
    private String name;  
    private String breed;  
    public Dog(String name, String breed) {  
        this.name = name;  
        this.breed = breed;  
    }  
}
```

The keyword “this” points to the current object. Helps differentiate the method parameters (local variables) and the instance variables.

# Program Design

- ▶ In order to create instances of the Dog class, we need to define a constructor. Since each dog has two attributes, we can define a constructor that takes two arguments.

```
public class Dog {  
    private String name;  
    private String breed;  
    public Dog(String dogName, String dogBreed) {  
        name = dogName;  
        breed = dogBreed;  
    }  
}
```

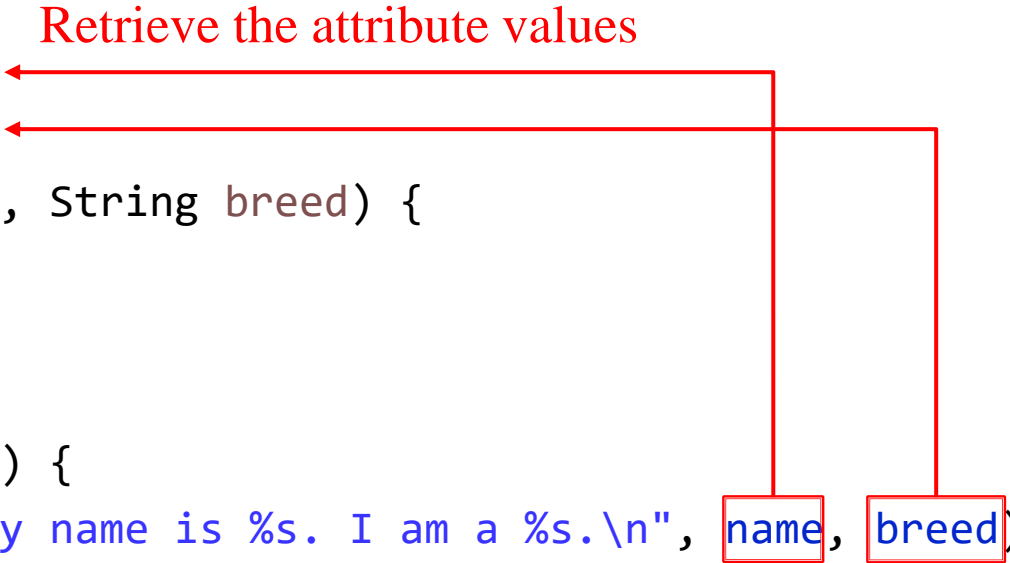
“this” is not compulsory if the parameters and instance variables have different names (no ambiguity).

# Program Design

- ▶ The dogs have the ability of making self introductions.

```
public class Dog {  
    private String name;  
    private String breed;  
    public Dog(String name, String breed) {  
        this.name = name;  
        this.breed = breed;  
    }  
    public void selfIntro() {  
        System.out.printf("My name is %s. I am a %s.\n", name, breed);  
    }  
}
```

Retrieve the attribute values



# Program Design

- ▶ Finally, we implement the PetShow program with a main method.

```
public class PetShow {  
    public static void main(String[] args) {  
        Dog dog1 = new Dog("Fluffy", "poodle");  
        Dog dog2 = new Dog("Alfred", "hound");  
        dog1.selfIntro();  
        dog2.selfIntro();  
    }  
}
```

Invoke the constructor to create two dog objects

# Program Design

- ▶ Finally, we implement the PetShow program with a main method.

```
public class PetShow {  
    public static void main(String[] args) {  
        Dog dog1 = new Dog("Fluffy", "poodle");  
        Dog dog2 = new Dog("Alfred", "hound");  
        dog1.selfIntro();  
        dog2.selfIntro();  
    }  
}
```

Invoke methods on the two objects.

Object references (or names) are needed to invoke instance methods.

# Case Study II: Account Balances

- ▶ Suppose we are asked to design a Java program for managing bank accounts.
- ▶ For simplicity, we assume that the bank only provides two types of services: (1) adding money to an account (存款), (2) checking the balance of an account (查询余额)

## The key task is to define an Account class

```
account1 balance: $50.00
```

```
account2 balance: $0.00
```

```
Enter deposit amount for account1: 25.53
```

```
adding 25.53 to account1 balance
```

```
account1 balance: $75.53
```

```
account2 balance: $0.00
```

```
Enter deposit amount for account2: 123.45
```

```
adding 123.45 to account2 balance
```

```
account1 balance: $75.53
```

```
account2 balance: $123.45
```

```
// Account class with a constructor to validate and  
// initialize instance variable balance of type double
```

```
public class Account {  
    // instance variable that stores the balance  
    private double balance;  
  
    // constructor  
    public Account(double initialBalance) {  
        // if initialBalance is not greater than 0.0  
        // balance is initialized to the default value 0.0  
        if(initialBalance > 0.0) balance = initialBalance;  
    }  
  
    // add an amount to the account  
    public void credit(double amount) {  
        balance += amount;  
    }  
  
    // return the account balance  
    public double getBalance() {  
        return balance;  
    }  
}
```



# Validating Constructor Arguments

- ▶ It's common for users to open an account to deposit money immediately, so the constructor receives a parameter `initialBalance` of type `double` that represents the initial balance.
  - The constructor ensures that `initialBalance` is greater than `0.0`
  - If so, `initialBalance`'s value is assigned to instance variable `balance`.
  - Otherwise, `balance` remains to be `0.0` (its default initial value).

```
// constructor
public Account(double initialBalance) {
    // if initialBalance is not greater than 0.0
    // balance is initialized to the default value 0.0
    if(initialBalance > 0.0) balance = initialBalance;
}
```

# Case Study II: Account Balances

- ▶ We further define a class `AccountTest` that creates and manipulates two `Account` objects.

```
import java.util.Scanner;
public class AccountTest {
    public static void main(String[] args) {
        Account account1 = new Account(50.00);
        Account account2 = new Account(-7.53);

        // display initial balance of each object
        System.out.printf("account1 balance: $%.2f\n",
            account1.getBalance());
        System.out.printf("account2 balance: $%.2f\n\n",
            account2.getBalance());

        Scanner input = new Scanner(System.in);
        double depositAmount; // deposit amount read from user
    }
}
```

```
System.out.print("Enter deposit amount for account1: ");  
depositAmount = input.nextDouble();  
System.out.printf("\nadding %.2f to account1 balance\n\n",  
    depositAmount);  
account1.credit(depositAmount); // add to account1 balance  
  
// display balances  
System.out.printf("account1 balance: $%.2f\n",  
    account1.getBalance());  
System.out.printf("account2 balance: $%.2f\n\n",  
    account2.getBalance());
```

```
System.out.print("Enter deposit amount for account2: ");
depositAmount = input.nextDouble();
System.out.printf("\nadding %.2f to account2 balance\n\n",
    depositAmount);
account2.credit(depositAmount); // add to account2 balance

//display balances
System.out.printf("account1 balance: $%.2f\n",
    account1.getBalance());
System.out.printf("account2 balance: $%.2f\n\n",
    account2.getBalance());
input.close();
}
}
```

account1 balance: \$50.00

account2 balance: \$0.00

Enter deposit amount for account1: 25.53

adding 25.53 to account1 balance

account1 balance: \$75.53

account2 balance: \$0.00

Enter deposit amount for account2: 123.45

adding 123.45 to account2 balance

account1 balance: \$75.53

account2 balance: \$123.45

# Primitive Types vs. Reference Types

- ▶ Java types are divided into two categories: **primitive types** and **reference types**.
- ▶ Primitive types are the basic types of data
  - byte, short, int, long, float, double, boolean, char
  - A primitive-type variable can store one value of its declared type

Type	Description	Default value	Size	Example code
boolean	Truth value	false	1 bit	<code>boolean b = false;</code>
char	Unicode character	<code>\u0000</code>	16 bits	<code>char c = 'z';</code>

# Primitive Types vs. Reference Types

- ▶ All non-primitive types are reference types, including **instantiable classes and arrays** (an array is a container object that holds a fixed number of values of a single type)
  - Scanner, String, String[], int[]
- ▶ Reference-type variables **store the memory locations of objects**
  - Dog **dog1** = new Dog("Fluffy", "Poodle");
  - Such a variable is said to refer to an object in the program. Objects that are referenced may each contain instance variables of primitive or reference types.



# Primitive Types vs. Reference Types

- ▶ Reference-type variables, if not explicitly initialized, are initialized by default to the value **null** (reference to nothing).
- ▶ To call methods of an object, you need to use the reference (**must be non-null**) to the object: `dog1.selfIntro();`
- ▶ Primitive-type variables (e.g., `int` variables) do not refer to objects, so such variables cannot be used to call methods