CMPS 251

Read Chapters 3 & 6

Basic Object-Oriented Programming in Java

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Outline

- Classes and Objects
- Attributes with Getters and Setters
- Methods
- Static Methods / Attributes
- Constructors
- Value Types vs. Reference Types
- JavaDoc Comments

Classes and Objects

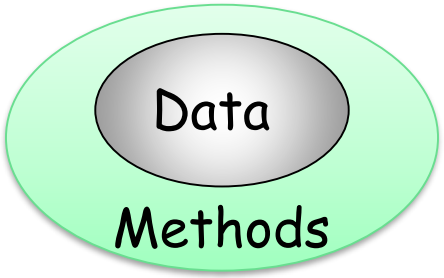
Classes

- A class is a **programmer-defined data type** and **objects are variables of that type**
  - Classes allow us to create new data types that are well suited to an application
  - A class contains private **attributes** and **methods**
- An object is an **instance** of a class

  e.g., `Student quStudent = new Student;`

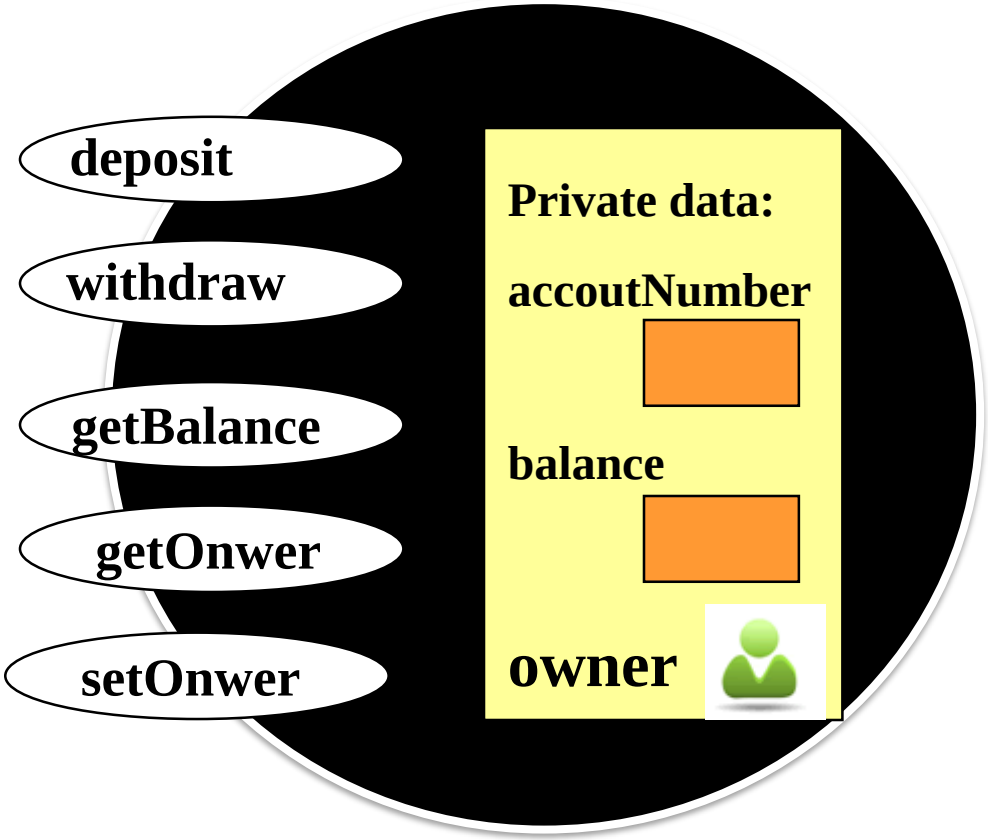
  This declares quStudent object of type Student. The object is then created using the **new** keyword

Encapsulation



- **Encapsulation** = an object **combines attributes and methods into a single unit**
  - Hiding implementation from clients
    - Clients access the object via its **public methods (public methods = *interface*)**
  - The data is *hidden*, so it is safe from any accidental alteration
  - Get and Set methods are used to read/write the object's attributes

BankAccount Example



BankAccount contains **attributes** and **methods**

An Object has:

- **Attributes** – information about the object
- **Methods** – functions the object can perform
- **Relationships** with other objects
  - e.g., A BankAccount has an Owner
  - A relationship is defined also an attribute

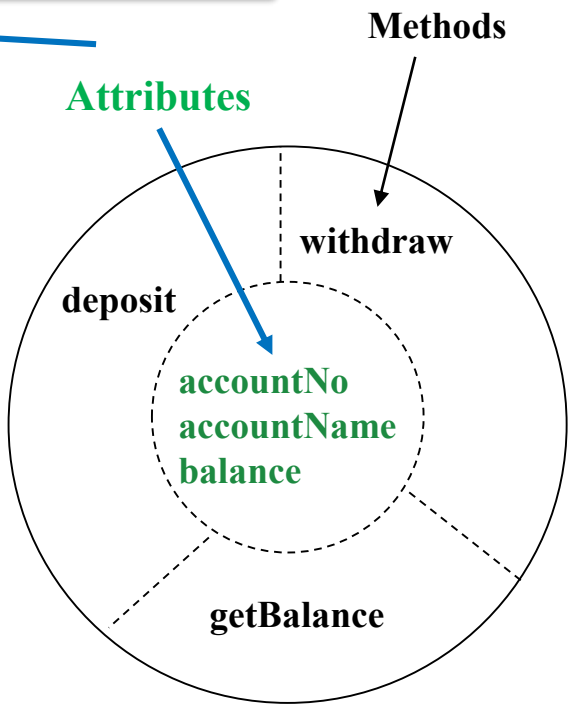
Encapsulation - Example

```
public class Account {
    private int accountNo;
    private String accountName;
    private double balance;

    public void deposit(double amount) {
        balance += amount;
    }
    public void withdraw(double amount) {
        balance -= amount;
    }
    public double getBalance() {
        return balance;
    }
    .....
}
```

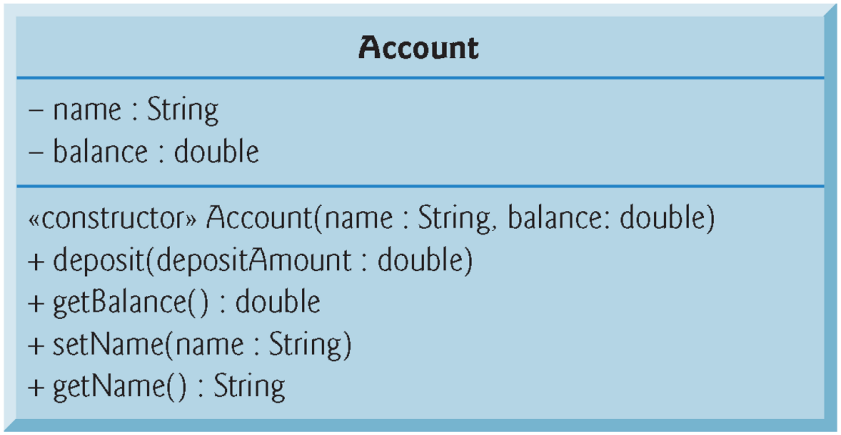
private data

public methods



Bank Account Object

UML class diagram for class Account



- Unified Modeling Language (UML) class diagram
  - A rectangle with three compartments
    - Top compartment contains the **name of the class**
    - Middle compartment contains the **class's attributes**

      (-) in front of an attribute indicates it is private
    - Bottom compartment contains the **class's functions**

      (+) in front of a method indicates it is public

Using a class

- A class is a programmer-defined type
  - Can be used to create objects i.e., variables of the class type
  - A class can be viewed as a *factory* for objects
  - To use a class you must create an object from a class (this is called **instantiation**)
    - To drive a car you must manufacture the car based on its design!
- A class can be used as the type of an attribute or local variable or as the return type of a method
- **Dot operator (.)**
  - Used to **access an object's attributes and call its methods**
  - **Call causes the method to perform its task.**
  - e.g. : `myGradeBook.displayMessage("Welcome to CMPS251 Computer Programming")`

    Calls the method `displayMessage`

Instantiation

- Instantiation = Object creation with ***new*** keyword
- **Memory is allocated for the object**'s attributes as defined in the class
- Initialization of the object attributes as specified through a ***constructor***
  - ***constructor*** a special method invoked when objects are created
  - Constructors are discuss further in these slides

Java Naming Conventions

- Start classes with uppercase letters

```
/** Short description of the class */
public class MyClass {
    ...
}
```

Use JavaDoc-style comments

- **Start other things with lowercase letters:** attributes, local variables, methods, method parameters

```
public class MyClass {
  private String firstName, lastName;
  public String getFullName() {
     String name = firstName + " " + lastName;
     return name;
  }
}
```

Attributes

Attributes

- **Attributes** = data that is stored inside an object. Also called 'Instance variables', 'data members' or object state
- Syntax

```
public class MyClass {
    private SomeType attribute1;
    private SomeType attribute2;
    //ToDo: provide getters and setters
}
```

It is conventional to make all attributes private

- Motivation
  - Lets an object have data values (i.e., a state)
    - In OOP, objects have 2 characteristics: **state** and **behavior**. The attributes provide the state.

Attributes

- Attributes = Local variables in a class definition
  - Exist throughout the life of the object
  - **Each object of a class maintains its own copy of attributes**
    - e.g., different accounts can have different balances
- Access-specifier `private` used for Data hiding
  - Makes an attribute or a method accessible only to methods of the class
- An attempt to access a `private` attribute outside a class is a compilation error

Accessor methods

- Ideas
  - Attributes should always be private
    - And made accessible to outside world with **get** and **set** methods (also know as Accessor methods)
- Syntax

```
public class MyClass {
    private String firstName;
    public String getFirstName()
      {  return(firstName); }
    public void setFirstName(String firstName)
      { this.firstName = firstName; }
}
```

- Motivation
  - Allow data validation before assigning values to the object attributes
  - Limits accidental changes

Accessor methods
get Methods and *set* Methods

- Best practice is to provide a **get** method to **read** an attribute and a **set** method to **write** to an attribute
  - Data is protected from the client. Get and set methods are used rather than directly accessing the attributes
  - Using *set* and *get* functions allows the programmer to control how clients access `private` data + **allow data validation:**
    - Can return errors indicating that attempts were made to assign invalid data
  - *set* and *get* methods should also be used even inside the class

Examples of Validation

```
class Date {
    int day, month;
    // setDay assigns its argument to the private member day.
    public void setDay(int day)
    {
      if (day >= 1 && day <= 31)
        this.day = day;
      else
        throw new Exception("The day must me between 1 and 31");
    }
    // setMonth assigns its argument to the private member month.
    public void setMonth(int month)
    {
      if (month >= 1 && month <= 12)
        this.month = month;
      else
         throw new Exception("The month must me between 1 and 12");
    }
}
```

Exception will be discussed later

An attempt to access a `private` member outside a class is a syntax error

Not all attributes need Getters and Setters

- Some attributes might not need both getters and setters. They should be provided only when appropriate
  - It is common to have fields that can be set at instantiation, but never changed again (immutable field).

```
public class Student {
    private final String studentId;
    public Student(String studentId) {
       this. studentId = studentId;
    }
    public String getStudentId() { return(studentId); }
    // No setStudentId method
}
```

final = value of the attribute cannot be changes once initialized

Generating Getters and Setters

- Eclipse will automatically generate getters/setters from instance variables
  - R-click anywhere in code
  - Choose Source → Generate Getters and Setters
  - However, if you later click on instance variable and do Refactor → Rename, Eclipse will not automatically rename the accessor methods

Methods

Overview

- Definition
  - Functions that are defined inside a class. Also called "member functions".
- Syntax

Use void if the method returns nothing.

```
public ReturnType methodName(Type1 param1, Type2 param2, ...) {
    ...
    return somethingOfReturnType;
}
```

If the method is called only by other methods in the same class, make it private.

- Motivation
  - Lets an object calculate values or do computations, usually based on its current state (i.e. attributes)
    - In OOP, objects have **state** and **behavior**. The **methods provide the behavior**

Calling Methods

- The usual way that you call a method is by doing the following:

  ```
  variableName.methodName(argumentsToMethod);
  ```

- For example, the built-in `String` class has a method called `toUpperCase` to convert to uppercase
  - This method doesn't take any parameters, so you just put empty parentheses after the method name.

```
String s1 = "Hello";

String s2 = s1.toUpperCase(); // s2 is now "HELLO"
```

Method Visibility

- public/private distinction
  - A declaration of private means that "outside" methods cannot call it – only methods within the same class can
    - Attempting to call a private method outside the class would result in an error at compile time
  - Only use public for methods that *your class will make available to users*
  - You are **free to change or eliminate private** methods without telling users of your class
- Attributes should be private by convention

Methods Overloading

- Idea
  - Classes can have more than one method (or constructor) with **the same name**
  - The methods (or constructors) have to differ from each other by **having different number or types of parameters** (or both), so that Java can always tell which one you mean
    - A method's name and number and type of parameters is called the ***signature***
- Syntax

```
public class MyClass {
    public double getRandomNum() { …};
    public double getRandomNum(double range) { … }
}
```

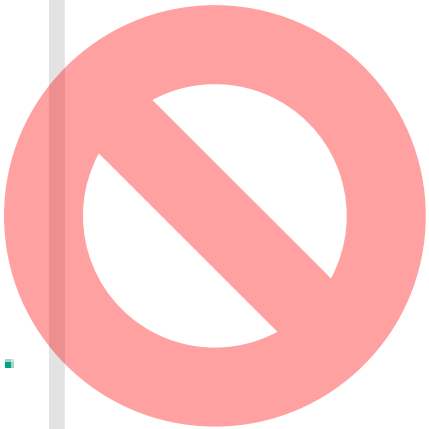
- Motivation
  - Lets you have the same name for methods doing similar operations (**ease learning and understanding your program**)
  - Overloaded constructors let you build instances in different ways

Overloading and Return Type

- You must not overload a method where the only difference is the type of value returned

```
/**
 Returns the weight of the pet.
*/
public double getWeight()

/**
 Returns '+' if overweight, '-' if
 underweight, and '*' if weight is OK.
*/
public char getWeight()
```



Static Methods / Attributes

Compare these two alternatives …

```
// This makes little sense
Math math = new Math();
float answer = math.sin(45);

// This would make more sense
float answer = Math.sin(45);
```

Static Methods are often used for Helper Class such as Math Class

Static Methods

- A static method belongs to the class rather than the object of the class.
  - Also known as “class methods” (vs. “instance methods”)
- A static method can only access the static attributes.
- A static method can be called without the need for creating an instance of the class.
  - You call a static method through the class name

```
ClassName.functionName(arguments);
```

  - For example, the **`Math`** class has a static method called **`cos`**
    - You can call **`Math.cos(3.5)`** without creating an object of the **`Math`** class
- E.g., the `main` method is a static method so the system can call it without first creating an object

Static Methods vs. Instance Methods

- In a class **Car** you might have a method

  static double convertMpgToKpl(double mpg)

  - which would be static, because one might want to call it even without creating a car object

  (mpg : miles per gallon. Kpl : Km per litre)

  - Better design is to even moved it to a utility class

- But

```
void setMileage(double mpg)
```

can't be static since it's inconceivable to call the method before any Car has been constructed.

When to use Static Methods

- Define static methods in the following scenarios only:
  - If you are writing **utility or helper classes** e.g., Math class
    - e.g., int answer = Math.sin(45);
  - Classes for which only **one instance** is needed for the whole application

  e.g. System.**out** is a static attribute as only 1 display output object is needed for the whole application to output to the screen
  - If the method is not using any instance variable and doesn't need any object to be initialized for it to be called
  - Methods such as **sorts or comparisons** that operate on multiple objects of a class and are not tied to any particular instance. E.g.,

```
Car getMoreEfficient( Car car1, Car car2 )
```

  - Wrapper classes –see next slide-

Wrapper Classes

- Java provides *wrapper classes* for each primitive type
- Allow programmer to have an object that corresponds to value of primitive type
- Contain useful predefined constants and methods
- Wrapper classes have no default constructor and no `set` methods
  - Programmer must specify an initializing value when creating new object

Wrapper Class Example: Static methods in `Character` class

Name	Description	Argument Type	Return Type	Examples	Return Value
`toUpperCase`	Convert to uppercase	`char`	`char`	`Character.toUpperCase('a')` `Character.toUpperCase('A')`	`'A'` `'A'`
`toLowerCase`	Convert to lowercase	`char`	`char`	`Character.toLowerCase('a')` `Character.toLowerCase('A')`	`'a'` `'a'`
`isUpperCase`	Test for uppercase	`char`	`boolean`	`Character.isUpperCase('A')` `Character.isUpperCase('a')`	`true` `false`
`isLowerCase`	Test for lowercase	`char`	`boolean`	`Character.isLowerCase('A')` `Character.isLowerCase('a')`	`false` `true`
`isLetter`	Test for a letter	`char`	`boolean`	`Character.isLetter('A')` `Character.isLetter('%')`	`true` `false`
`isDigit`	Test for a digit	`char`	`boolean`	`Character.isDigit('5')` `Character.isDigit('A')`	`true` `false`
`isWhitespace`	Test for whitespace	`char`	`boolean`	`Character.isWhitespace(' ')` `Character.isWhitespace('A')`	`true` `false`

Whitespace characters are those that print as white space, such as the blank, the tab character (`'\t'`), and the line-break character (`'\n'`).

Static Attributes

- Static attributes also called ***class attributes*** = NOT associated with any instance of the class.
  - Contrast with *instance attributes*
- Static attributes are **shared** by all objects
  - Only one instance of the attribute exists
  - It can be accessed by all instances of the class
- Attributes declared using **static final** are considered constants and their value **cannot** be changed (e.g., Math.PI)

Constructors

Overview

- Definition
  - Constructor is a special initialization method called when an object is created with `new`.
- Syntax
  - Constructor has the same name as the class and has no return type (not even void).

```
public class MyClass {
    public MyClass(Type paramName, … ) { … }
}
```

- Motivation
  - Lets you create an instance of the class and at the same time **initialize** the object attributes
  - Lets you **enforce the initialization of some object attributes** at the time of the object creation
  - Lets you run some custom initialization logic when the class is instantiated (e.g., open a file)

Initializing Objects with Constructors

- **Constructors = 'Methods' used to initialize an object's attributes when it is created**
  - **Call made implicitly** when the object is instantiated
    - There is no explicit way to call the constructor
  - A constructor has the same name as the class and has no return type - Not even `void`
  - A class can have zero, one or more different constructors
    - We distinguish between constructors using different number and types of parameters
  - Default constructor has no parameters
    - Java will define this automatically if the class does not have any constructors
    - If you do define a constructor, Java will not automatically define a default constructor

Constructor Example

- Constructor = special method that handles the object initialization
- A constructor **is used to initialize the objects during object construction.**
- Example:

```
Account saraAcct = new
Account(123, "Sara",
             "Saving");
```

```
public class Account {
private int id;
private String name;
private String type;
private double balance;


Account (int id, String name, String type) {
     this.id = id;
     this.name = name;
     this.type = type;
     balance = 0;
}

...

}
```

Constructor

The `this` Variable

- The `this` object reference can be used inside any non-static method to **refer to the current object**
  - `this` is used to **refer to the object** from inside its class definition
  - The keyword `this` stands for the receiving object
- `this` is commonly used to **resolve name conflicts**
  - Using **`this`** permits the use of attributes in methods that have local variables / parameters with the same name

```
public void setName(String name) {
        this.name = name;
}
```

This is an attribute. To avoid confusion we add **this.** in-front of it

This is a parameter

Value Types vs. Reference Types

Back

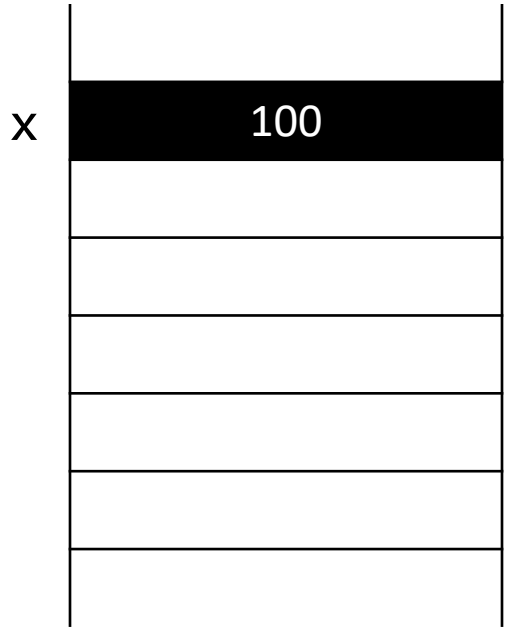
There are two types of variables

1. **Value:**
   Stores the actual value

2. **Reference:**
   Stores a reference to the actual value

Value types store values

```
int x = 100;
```



The value (also called primitive) types in Java are `boolean`, `byte`, `char`, `short`, `int`, `long`, `float` and `double`.

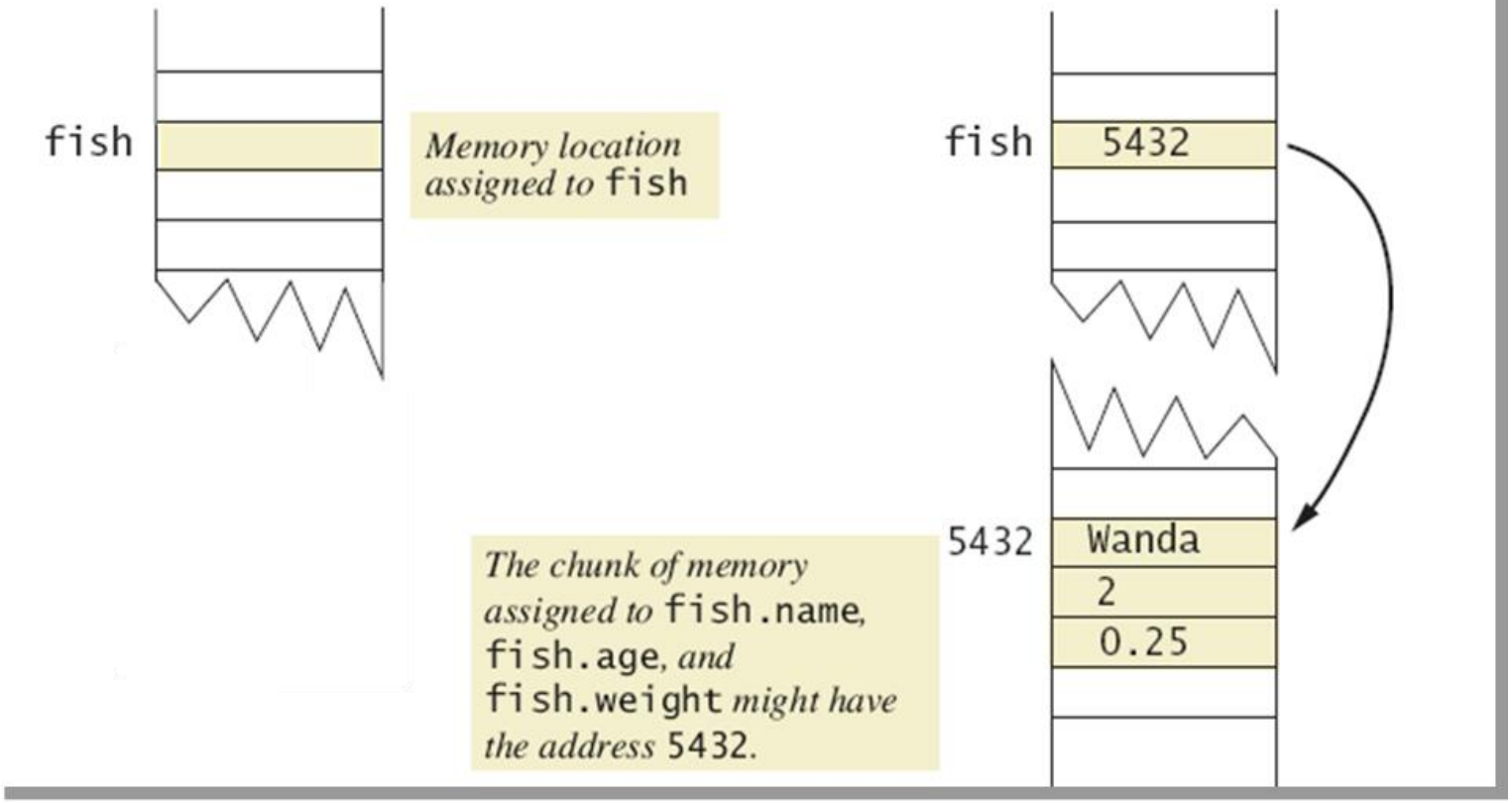
Using new ClassName constructs the object and returns a reference

```
Pet fish;
```

Assigns a memory location to `fish`

```
fish = new Pet();
```

Assigns a chunk of memory for an object of the class `Pet`*—that is, memory for a name, an age, and a weight—and places the address of this memory chunk in the memory location assigned to* `fish`



Objects and References

- Once a class is defined, you can declare variables (object reference) of that type

```
Ship ship1, ship2;
Point startPoint;
Color blue;
```

- Object references are initially **`null`**
  - The **`null`** is a special value in Java indicating that the object is NOT created yet

- The ***`new`*** operator is required to create the object

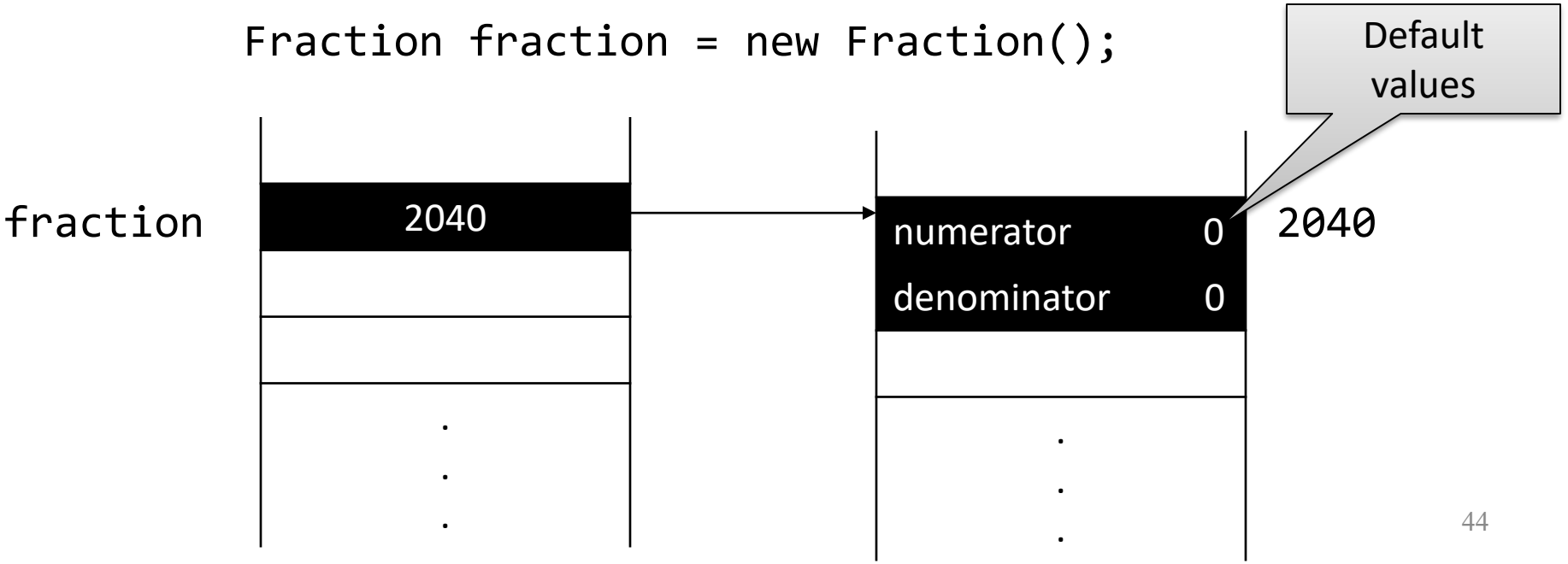
```
ClassName variableName = new ClassName();
```

Reference types store references

Consider the Fraction class:

Fraction
- numerator: int - denominator: int
+ getNumerator(): int + setNumerator(int n): void + getDenominator(): int + setDenominator(int d): void + Fraction(int n, int d);

```
Fraction fraction = new Fraction();
```



Lets compare value types

```
int x = 100;
```

x 100

```
int y = 200;
```

y 200

```
x == y ?
```

false

```
x = y;
```

x 200

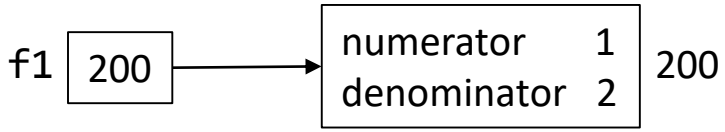
y 200

```
x == y ?
```

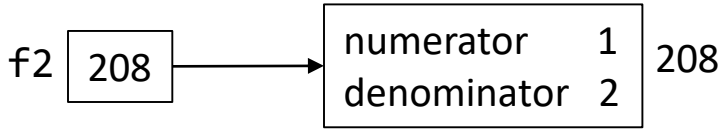
true

Now lets compare reference types

```
Fraction f1 = new Fraction(1, 2);
```



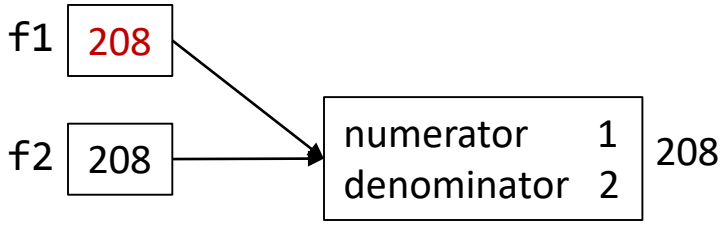

```
Fraction f2 = new Fraction(1, 2);
```




```
f1 == f2 ?
```

false

```
f1 = f2;
```




```
f1 == f2 ?
```

true

The solution to the == problem?

Define an `equals` method

```
public class Fraction {
…..
    public boolean equals(Fraction f) {

        return this.numerator == f.numerator &&
               this.denominator == f.denominator;

    }
}
```

Two fractions are equal if both their numerator and denominator values are the same.

Code Deconstructed
<equals method>

```
Fraction f1 = new Fraction(1, 2);

Fraction f2 = new Fraction(1, 2);


if (f1 == f2)
   System.out.println("Both variables refer to the same object");
else
   System.out.println("Each variable refers to a different object");


if ( f1.equals(f2) )
   System.out.println("Both objects have the same value");
else
   System.out.println("Each object has a different value");
```

JavaDoc

Comments and JavaDoc

- Java supports 3 types of comments
  - // Comment to end of line.
  - /* Block comment containing multiple lines. */
  - /** A JavaDoc comment placed before class definition and methods. Text may contain HTML tags, hyperlinks, and JavaDoc tags. */
- JavaDoc is used to generate on-line documentation

```
javadoc Foo.java Bar.java -d outputdir
javadoc *.java -d docs
```

- More information about JavaDoc available @

https://docs.oracle.com/en/java/javase/12/tools/javadoc.html

Useful JavaDoc Tags

- **@author**
  - Specifies the author of the document
  - Must use `javadoc -author ...` to generate in output

```
/** Description of some class ...
 *
  *    @author <a href="author@coding.com">
  *          Java Programmer</a>
 */
```

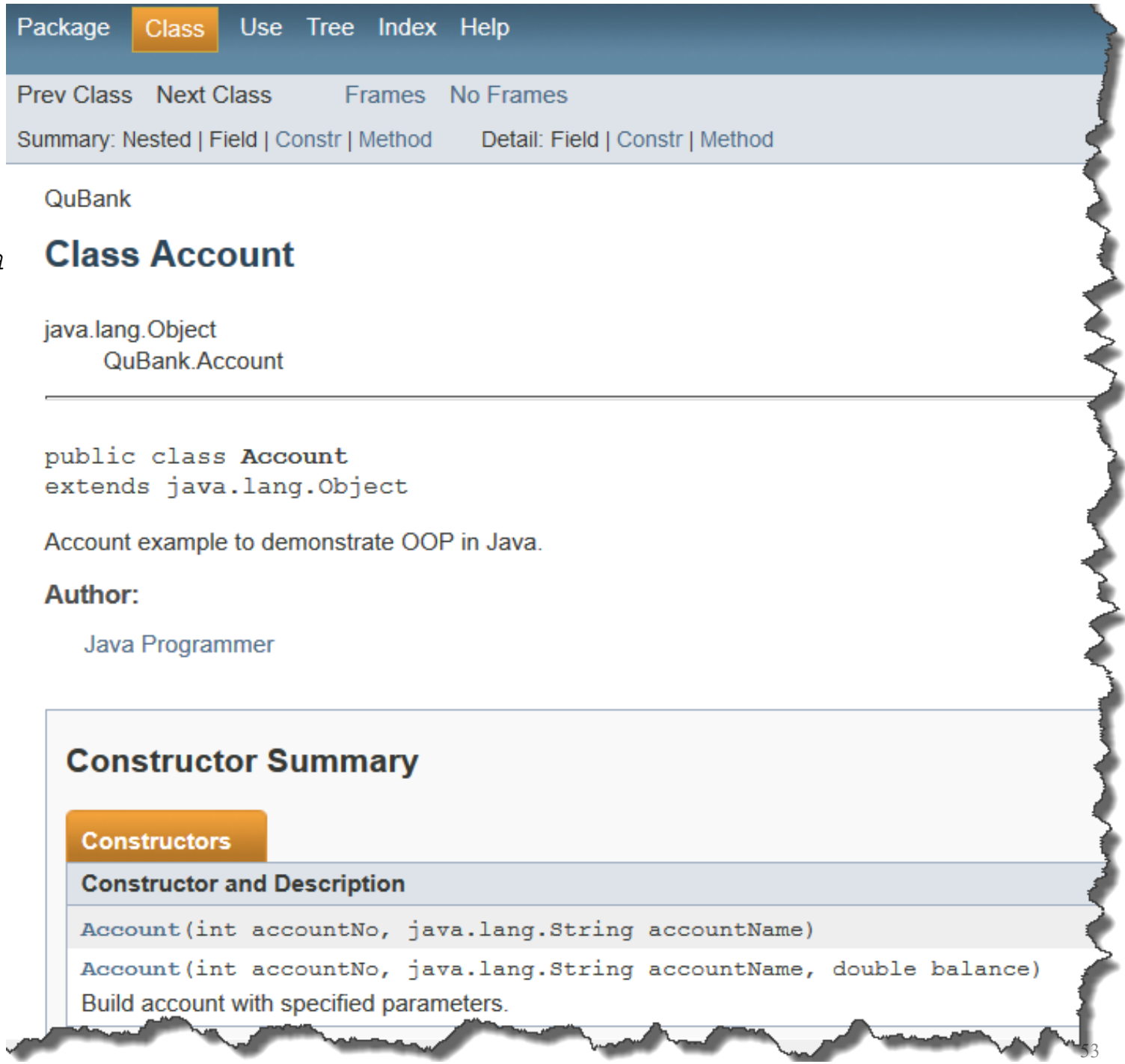
- **@version**
  - Version number of the document
  - Must use `javadoc -version ...` to generate in output
- **@param**
  - Documents a method argument
- **@return**
  - Documents the return type of a method

JavaDoc comment example

```
/** An example to demonstrate Javadoc comment
 * @author <a href="erradi@coding.com"> Erradi </a>
 * A method that determines the quotient of two integers.
 * @param x
 *     The number that is going to be divided
 * @param y
 *     The number that x is going to be divided by
 * @return
 *     The quotient that is the result of x/y.
 * @throws ArithmeticException
 *     Indicates that y is equal to zero.
 */
public static int divide(int x, int y) throws
ArithmeticException
```

JavaDoc Example

```
javadoc *.java
```



Package | Class | Use | Tree | Index | Help

Prev Class Next Class Frames No Frames

Summary: Nested | Field | Constr | Method Detail: Field | Constr | Method

QuBank

Class Account

java.lang.Object
    QuBank.Account

```
public class Account
extends java.lang.Object
```

Account example to demonstrate OOP in Java.

Author:

Java Programmer

Constructor Summary

Constructors

Constructor and Description
`Account(int accountNo, java.lang.String accountName)`
`Account(int accountNo, java.lang.String accountName, double balance)` Build account with specified parameters.

Programming Conventions and Best Practices

- Make all attributes private and provide getters and setters
- Class names start with upper case
- Method names and variable names start with lower case
- Choose **meaningful names** for classes, methods and variables
  - makes programs more readable and understandable
- Use JavaDoc-style comments to generate useful documentation
- Indent nested blocks consistently to communicate the structure of your program
  - **Proper indentation helps comprehension**

Summary

- In OOP, we decompose a program into *classes*
- A class consists of attributes to store data and methods to perform actions
- Once a class has been defined, objects of that class can be created (instantiated)
- Methods are called on an object, and may cause the data of the object to change
- A `static` method can be called without creating an object
- A `static` variable is shared by all objects of the class
- Constructor method creates and initializes object's attributes
  - Default constructor has no parameters
- Methods overloading allow us to have multiple methods or constructors with the same name.
  - They must differ in method signatures (number and/or type of parameters)