

Classes and Objects



EECS2030 E&F: Advanced
Object Oriented Programming
Fall 2024

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Required: Review Tutorials on OOP in Java



Current slides are cross-referenced throughout this review tutorials on Java OOP:

https://www.eecs.yorku.ca/~jackie/teaching/tutorials/index.html#refurbished_store

Optional: Tutorial Videos to Help You Review



- **Link to Tutorial Series:**

https://www.eecs.yorku.ca/~jackie/teaching/tutorials/index.html#java_from_scratch_w21

- **Week 1: Eclipse** work environment
- **Week 2c, 2d, 2e: Debugger** in Eclipse
- **Weeks 2, 3: Programming/Debugging Conditionals**
- **Weeks 4, 5: Programming/Debugging Arrays and Loops**
- **Weeks 6, 7, 8: Classes and Objects**

- **iPad Notes:** <https://www.eecs.yorku.ca/~jackie/teaching/tutorials/notes/EECS1022%20Tutorial%20on%20Java.pdf>

Required: Written Notes to Review



- **Inferring Classes/Methods from JUnit Tests:**

https://www.eecs.yorku.ca/~jackie/teaching/lectures/2024/F/EECS2030/notes/EECS2030_F24_Inferring_Classes_from_JUnit.pdf

- **Declaring and Manipulating Reference-Typed, Multi-Valued Attributes:** https://www.eecs.yorku.ca/~jackie/teaching/lectures/2024/F/EECS2030/notes/EECS2030_F24_Tracing_PointCollectorTester.pdf

Learning Outcomes

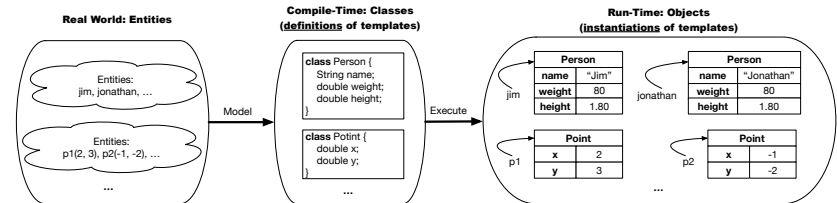


Understand:

- Object Orientation
- Classes as Templates:
 - attributes, constructors, (accessor and mutator) methods
 - use of `this`
- Objects as Instances:
 - use of `new`
 - the dot notation, method invocations
 - reference aliasing
- Reference-Typed Attributes: Single-Valued vs. Multi-Valued
- Non-Static vs. Static Variables
- Helper Methods

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Object Orientation: Observe, Model, and Execute



- Study [this tutorial video](#) that walks you through the idea of **object orientation**.
- We **observe** how real-world **entities** behave.
- We **model** the common **attributes** and **behaviour** of a set of entities in a single **class**.
- We **execute** the program by creating **instances** of classes, which interact in a way analogous to that of real-world **entities**.

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Separation of Concerns: App/Tester vs. Model



- In EECS1022/EECS1021:
 - **Model Component**: One or More Java Classes
e.g., `Person` vs. `SMS`, `Student`, `CourseRecord`
 - Another Java class that “manipulates” the model class(es)
 - **Controller** (e.g., `BMIActivity`, `LEDController`). Effects?
Visualized at a connected physical device (e.g., tablet, LED lightbulbs)
 - **Tester** (e.g., `PersonTester`, `BankTester`). Effects?
Seen (as textual outputs) at console
Asserting **expected** vs. **actual** Values in JUnit tests
 - In Java:
 - We may define more than one **classes**.
 - Each class may contain more than one **methods**.
- Object-Oriented Programming (OOP)** in Java:
- Use **classes** to define templates
 - Use **objects** to instantiate classes
 - At **runtime**, **create** objects and **call** methods on objects, to **simulate interactions** between real-life entities.

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Object-Oriented Programming (OOP)



- In real life, lots of **entities** exist and interact with each other.
e.g., **People** gain/lose weight, marry/divorce, or get older.
e.g., **Cars** move from one point to another.
e.g., **Clients** initiate transactions with banks.
- Entities:
 - Possess **attributes**;
 - Exhibit **behaviour**; and
 - Interact with each other.
- Goals: Solve problems **programmatically** by
 - **Classifying** entities of interest
Entities in the same class share **common** attributes and behaviour.
 - **Manipulating** data that represent these entities
Each entity is represented by **specific** values.

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OO Thinking: Templates vs. Instances (1.1)



Points on a two-dimensional plane are identified by their signed distances from the X- and Y-axes. A point may move arbitrarily towards any direction on the plane. Given two points, we are often interested in knowing the distance between them.

- A template called `Point` defines the common
 - **attributes** (e.g., x, y) [≈ nouns]
 - **behaviour** (e.g., move up, get distance from) [≈ verbs]

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OO Thinking: Templates vs. Instances (2.1)



A person is a being, such as a human, that has certain attributes and behaviour constituting personhood: a person ages and grows on their heights and weights.

- A template called `Person` defines the common
 - **attributes** (e.g., age, weight, height) [≈ nouns]
 - **behaviour** (e.g., get older, gain weight) [≈ verbs]

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OO Thinking: Templates vs. Instances (1.2)



- A **template** (e.g., class `Point`) defines what's **shared** by a set of related entities (i.e., 2-D points).
 - Common **attributes** (x, y)
 - Common **behaviour** (move left, move up)
- Each template may be **instantiated** as multiple instances, each with **instance-specific** values for attributes x and y:
 - `Point` instance `p1` is located at (3,4)
 - `Point` instance `p2` is located at (-4,-2)
- Instances of the same template may exhibit **distinct behaviour**.
 - When `p1` moves up for 1 unit, it will end up being at (3,5)
 - When `p2` moves up for 1 unit, it will end up being at (-4,-2)
 - Then, `p1`'s distance from origin: $[\sqrt{3^2 + 5^2}]$
 - Then, `p2`'s distance from origin: $[\sqrt{(-4)^2 + (-2)^2}]$

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OO Thinking: Templates vs. Instances (2.2)



- A **template** (e.g., class `Person`) defines what's **shared** by a set of related entities (i.e., persons).
 - Common **attributes** (age, weight, height)
 - Common **behaviour** (get older, lose weight, grow taller)
- Each template may be **instantiated** as multiple instances, each with **instance-specific** values for attributes age, weight, and height.
 - `Person` instance `jim` is
50-years old, 1.8-meters tall and 80-kg heavy
 - `Person` instance `jonathan` is
65-years old, 1.73-meters tall and 90-kg heavy
- Instances of the same template may exhibit **distinct behaviour**.
 - When `jim` gets older, he becomes 51
 - When `jonathan` gets older, he becomes 66.
 - `jim`'s BMI is based on his own height and weight $[\frac{80}{1.8^2}]$
 - `jonathan`'s BMI is based on his own height and weight $[\frac{90}{1.73^2}]$

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OOP: Classes \approx Templates



In Java, you use a **class** to define a **template** that enumerates **attributes** that are common to a set of **entities** of interest.

```
public class Person {  
    private int age;  
    private String nationality;  
    private double weight;  
    private double height;  
}
```

```
public class Point {  
    private double x;  
    private double y;  
}
```

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Java Data Types (1)



A (data) type denotes a set of related **runtime values**.

1. **Primitive Types**

- Integer Type
 - int [set of 32-bit integers]
 - long [set of 64-bit integers]
- Floating-Point Number Type
 - double [set of 64-bit FP numbers]
- Character Type
 - char [set of single characters]
- Boolean Type
 - boolean [set of true and false]

2. **Reference Type**: **Complex Type with Attributes and Methods**

- String [set of references to character sequences]
- Person [set of references to Person objects]
- Point [set of references to Point objects]
- Scanner [set of references to Scanner objects]

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Java Data Types (2)



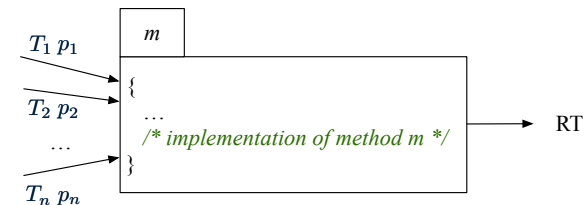
- A variable that is declared with a **type** but **uninitialized** is implicitly assigned with its **default value**.
 - Primitive Type**
 - int i; [0 is implicitly assigned to i]
 - double d; [0.0 is implicitly assigned to d]
 - boolean b; [false is implicitly assigned to b]
 - Reference Type**
 - String s; [null is implicitly assigned to s]
 - Person jim; [null is implicitly assigned to jim]
 - Point p1; [null is implicitly assigned to p1]
 - Scanner input; [null is implicitly assigned to input]
- You **can** use a **primitive** variable that is **uninitialized**. Make sure the **default value** is what you want!
- Calling a method on a **uninitialized** **reference** variable crashes your program. [NullPointerException]
Always initialize **reference** variables!

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OOP: Methods (1.1)



- A **method** is a named block of code, **reusable** via its name.



- The **Header** of a method consists of:
 - Return type [RT (which can be void)]
 - Name of method [m]
 - Zero or more **parameter names** [p₁, p₂, ..., p_n]
 - The corresponding **parameter types** [T₁, T₂, ..., T_n]
- A call to method **m** has the form: **m**(a₁, a₂, ..., a_n)
Types of **argument values** a₁, a₂, ..., a_n must match the the corresponding parameter types T₁, T₂, ..., T_n.

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OOP: Methods (1.2)

- In the body of the method, you may
 - Declare new *local variables* (whose **scope** is within that method).
 - Use or change values of *attributes*.
 - Use values of *parameters*, if any.

```
public class Person {
    private String nationality;
    public void changeNationality(String newNationality) {
        nationality = newNationality; } }
```

- Call a *method*, with a **context object**, by passing *arguments*.

```
public class PersonTester {
    public static void main(String[] args) {
        Person jim = new Person(50, "British");
        Person jonathan = new Person(60, "Canadian");
        jim.changeNationality("Korean");
        jonathan.changeNationality("Korean"); } }
```

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OOP: Methods (2)

- Each **class** *C* defines a list of methods.
 - A **method** *m* is a named block of code.
- We *reuse* the code of method *m* by calling it on an **object** *obj* of class *C*.
 - For each **method call** *obj.m(...)*:
 - obj* is the **context object** of type *C*
 - m* is a method defined in class *C*
 - We intend to apply the *code effect of method* *m* to object *obj*.
e.g., *jim.getOlder()* vs. *jonathan.getOlder()*
e.g., *p1.moveUp(3)* vs. *p2.moveUp(3)*
- All objects of class *C* share *the same definition* of method *m*.
- However:
 - ∴ Each object may have *distinct attribute values*.
 - ∴ Applying *the same definition* of method *m* has *distinct effects*.

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OOP: Methods (3)

- Constructor**
 - Same name as the class. No return type. *Initializes* attributes.
 - Called with the **new** keyword.
 - e.g., *Person jim = new Person(50, "British");*
- Mutator**
 - Changes* (re-assigns) attributes
 - void return type
 - Cannot be used when a value is expected
 - e.g., *double h = jim.setHeight(78.5)* is illegal!
- Accessor**
 - Uses* attributes for computations (without changing their values)
 - Any return type other than void
 - An explicit *return statement* (typically at the end of the method) returns the computation result to where the method is being used.
e.g., *double bmi = jim.getBMI();*
e.g., *println(p1.getDistanceFromOrigin());*

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OOP: Class Constructors (1.1)

- The purpose of defining a *class* is to be able to create *instances* out of it.
- To *instantiate* a class, we use one of its **constructors**.
- A constructor
 - declares input *parameters*
 - uses input parameters to *initialize* **some or all** of its *attributes*

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OOP: Class Constructors (1.2)



For each *class*, you may define *one or more* **constructors**:

- Names of all constructors must match the class name.
- No return types need to be specified for constructors.
- Overloaded constructors have *distinct* lists of *parameter types*.
 - Person(String n), Person(String n, int age) ✓
 - Person(String n, int age), Person(int age, String n) ✓
 - Person(String fN, int age), Person(String lN, int id) ✗
- Each *parameter* that is used to initialize an attribute must have a *matching type*.
- The *body* of each constructor specifies how *some or all* *attributes* may be *initialized*.

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OOP: Class Constructors (2.2)



```
public class Person {
    private int age;
    private String nationality;
    private double weight;
    private double height;
    public Person(int initAge, String initNat) {
        age = initAge;
        nationality = initNat;
    }
    public Person(double initW, double initH) {
        weight = initW;
        height = initH;
    }
    public Person(int initAge, String initNat,
        double initW, double initH) {
        ... /* initialize all attributes using the parameters */
    }
}
```

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OOP: Class Constructors (2.1)



```
public class Point {
    private double x;
    private double y;

    public Point(double initX, double initY) {
        x = initX;
        y = initY;
    }

    public Point(char axis, double distance) {
        if (axis == 'x') { x = distance; }
        else if (axis == 'y') { y = distance; }
        else { /* Error: invalid axis */ }
    }
}
```

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Visualizing Objects at Runtime (1)



- To trace a program with sophisticated manipulations of objects, it's critical for you to visualize how objects are:
 - Created using *constructors*
Person jim = new Person(50, "British", 80, 1.8);
 - Inquired using *accessor methods*
double bmi = jim.getBMI();
 - Modified using *mutator methods*
jim.gainWeightBy(10);
- To visualize an object:
 - Draw a **rectangle box** to represent **contents** of that object:
 - Title** indicates the *name of class* from which the object is instantiated.
 - Left column** enumerates *names of attributes* of the instantiated class.
 - Right column** fills in *values* of the corresponding attributes.
 - Draw **arrow(s)** for *variable(s)* that store the object's **address**.

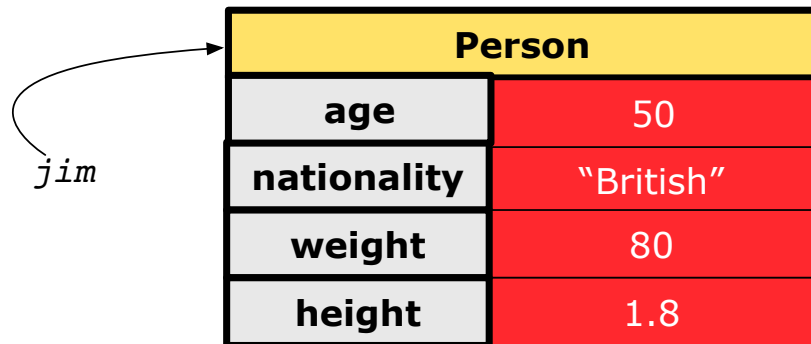
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Visualizing Objects at Runtime (2.1)



After calling a *constructor* to create an object:

```
Person jim = new Person(50, "British", 80, 1.8);
```



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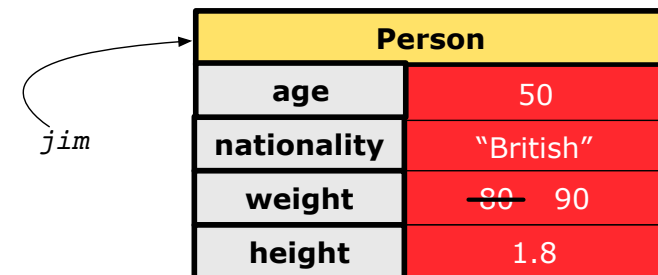
Visualizing Objects at Runtime (2.3)



After calling a *mutator* to modify the state of context object jim:

```
jim.gainWeightBy(10);
```

- *Contents* of the object pointed to by jim change.
- *Address* of the object remains unchanged.
⇒ jim points to the same object!



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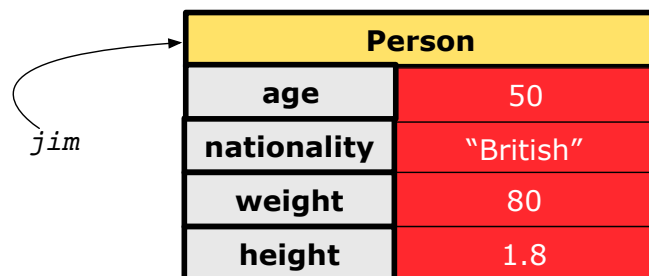
Visualizing Objects at Runtime (2.2)



After calling an *accessor* to inquire about context object jim:

```
double bmi = jim.getBMI();
```

- Contents of the object pointed to by jim remain intact.
- Returned value $\frac{80}{(1.8)^2}$ of jim.getBMI() stored in variable bmi.



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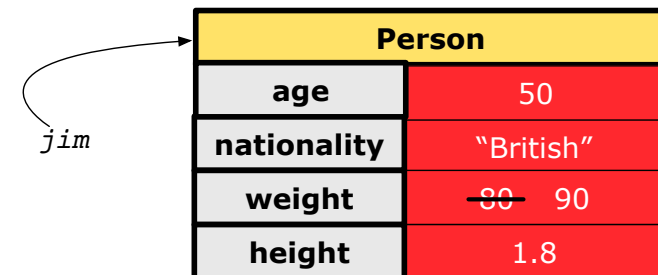
Visualizing Objects at Runtime (2.4)



After calling the same *accessor* to inquire the *modified* state of context object jim:

```
bmi = jim.getBMI();
```

- Contents of the object pointed to by jim remain intact.
- Returned value $\frac{90}{(1.8)^2}$ of jim.getBMI() stored in variable bmi.



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Object Creation (1.1)

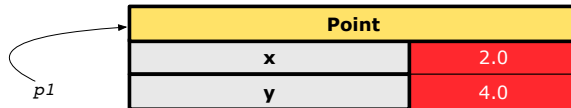
```
Point p1 = new Point(2, 4);
```

1. **RHS (Source) of Assignment:** `new Point(2, 4)` creates a new *Point object* in memory.

Point	
x	2.0
y	4.0

2. **LHS (Target) of Assignment:** `Point p1` declares a *variable* that is meant to store the *address of some Point object*.

3. **Assignment:** Executing `=` stores new object's address in `p1`.



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Object Creation (2)

```
Point p1 = new Point(2, 4);
System.out.println(p1);
```

```
Point@677327b6
```

By default, the address stored in `p1` gets printed.

Instead, print out attributes separately:

```
System.out.println("(" + p1.getX() + ", " + p1.getY() + ")");
```

```
(2.0, 4.0)
```

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Object Creation (1.2)

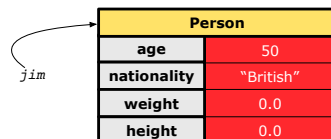
```
Person jim = new Person(50, "British");
```

1. **RHS (Source) of Assignment:** `new Person(50, "British")` creates a new *Person object* in memory.

Person	
age	50
nationality	"British"
weight	0.0
height	0.0

2. **LHS (Target) of Assignment:** `Person jim` declares a *variable* that is meant to store the *address of some Person object*.

3. **Assignment:** Executing `=` stores new object's address in `jim`.



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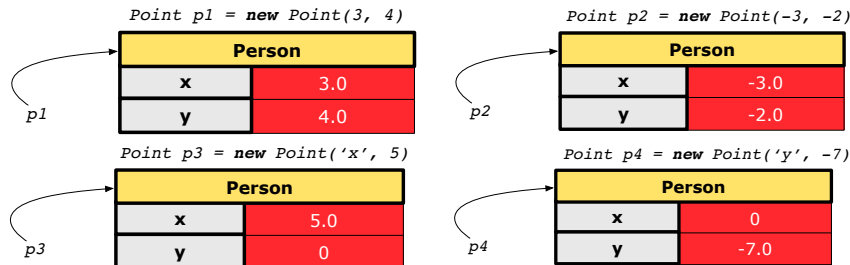
OOP: Object Creation (3.1.1)

A constructor may only *initialize* some attributes and leave others *uninitialized*.

```
public class PointTester {
    public static void main(String[] args) {
        Point p1 = new Point(3, 4);
        Point p2 = new Point(-3 -2);
        Point p3 = new Point('x', 5);
        Point p4 = new Point('y', -7);
    }
}
```

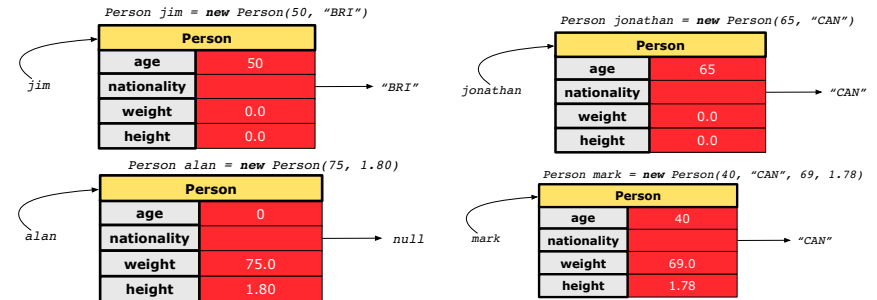
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OOP: Object Creation (3.1.2)



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OOP: Object Creation (3.2.2)



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OOP: Object Creation (3.2.1)



A constructor may only *initialize* some attributes and leave others *uninitialized*.

```
public class PersonTester {
    public static void main(String[] args) {
        /* initialize age and nationality only */
        Person jim = new Person(50, "BRI");
        /* initialize age and nationality only */
        Person jonathan = new Person(65, "CAN");
        /* initialize weight and height only */
        Person alan = new Person(75, 1.80);
        /* initialize all attributes of a person */
        Person mark = new Person(40, "CAN", 69, 1.78);
    }
}
```

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OOP: Object Creation (4)



- When using the constructor, pass **valid argument values**:
 - The type of each argument value must match the corresponding parameter type.
 - e.g., `Person(50, "BRI")` matches `Person(int initAge, String initNationality)`
 - e.g., `Point(3, 4)` matches `Point(double initX, double initY)`
- When creating an instance, *uninitialized* attributes implicitly get assigned the **default values**.
 - Set *uninitialized* attributes properly later using **mutator** methods

```
Person jim = new Person(50, "British");
jim.setWeight(85);
jim.setHeight(1.81);
```

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OOP: The Dot Notation (1)

- A binary operator:
 - **LHS** an object
 - **RHS** an attribute or a method
- Given a **variable** of some **reference type** that is **not null**:
 - We use a dot to retrieve any of its **attributes**.
Analogous to 's in English
e.g., jim.nationality means jim's nationality
 - We use a dot to invoke any of its **mutator methods**, in order to **change** values of its attributes.
e.g., jim.changeNationality("CAN") changes the nationality attribute of jim
 - We use a dot to invoke any of its **accessor methods**, in order to **use** the result of some computation on its attribute values.
e.g., jim.getBMI() computes and returns the BMI calculated based on jim's weight and height
 - Return value of an **accessor method** must be stored in a variable.
e.g., double jimBMI = jim.getBMI()

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The this Reference (2)

- In the **method** definition, each **attribute** has an **implicit this** which refers to the **context object** in a call to that method.

```
public class Point {
    private double x;
    private double y;
    public Point(double newX, double newY) {
        this.x = newX;
        this.y = newY;
    }
    public void moveUp(double units) {
        this.y = this.y + units;
    }
}
```

- Each time when the **class** definition is used to create a new **Point object**, the **this** reference is substituted by the name of the new object.

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The this Reference (1)

- Each **class** may be instantiated to multiple **objects** at runtime.

```
public class Point {
    private double x; private double y;
    public void moveUp(double units) { y += units; }
}
```

- Each time when we call a method of some class, using the dot notation, there is a specific **target/context** object.

```
1 Point p1 = new Point(2, 3);
2 Point p2 = new Point(4, 6);
3 p1.moveUp(3.5);
4 p2.moveUp(4.7);
```

- p1 and p2 are called the **call targets** or **context objects**.
- **Lines 3 and 4** apply the same definition of the **moveUp** method.
- But how does Java distinguish the change to **p1.y** versus the change to **p2.y**?

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The this Reference (3)

- After we create p1 as an instance of Point

```
Point p1 = new Point(2, 3);
```

- When invoking **p1.moveUp(3.5)**, a version of **moveUp** that is specific to **p1** will be used:

```
public class Point {
    private double x;
    private double y;
    public Point(double newX, double newY) {
        p1.x = newX;
        p1.y = newY;
    }
    public void moveUp(double units) {
        p1.y = p1.y + units;
    }
}
```

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The this Reference (4)

- After we create p2 as an instance of Point

```
Point p2 = new Point(4, 6);
```

- When invoking p2.moveUp(4.7), a version of moveUp that is specific to p2 will be used:

```
public class Point {
    private double x;
    private double y;
    public Point(double newX, double newY) {
        p2.x = newX;
        p2.y = newY;
    }
    public void moveUp(double units) {
        p2.y = p2.y + units;
    }
}
```

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The this Reference (6.1): Common Error

The following code fragment compiles but is problematic:

```
1 public class Person {
2     private String name;
3     private int age;
4     public Person(String name, int age) {
5         name = name;
6         age = age;
7     }
8     public void setAge(int age) {
9         age = age;
10    }
11 }
```

- Why? [variable **shadowing**]
Target (LHS) of the assignment (L5) refers to parameter name (L4).
- Fix?

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The this Reference (5)

The this reference can be used to **disambiguate** when the names of **input parameters** clash with the names of **class attributes**.

```
public class Point {
    private double x;
    private double y;
    public Point(double x, double y) {
        this.x = x;
        this.y = y;
    }
    public void setX(double x) {
        this.x = x;
    }
    public void setY(double y) {
        this.y = y;
    }
}
```

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The this Reference (6.2): Common Error

Always remember to use this when **input parameter** names clash with **class attribute** names.

```
public class Person {
    private String name;
    private int age;
    public Person(String name, int age) {
        this.name = name;
        this.age = age;
    }
    public void setAge(int age) {
        this.age = age;
    }
}
```

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OOP: Mutator Methods

- These methods *change* values of attributes.
- We call such methods **mutators** (with void return type).

```
public class Person {
    ...
    public void gainWeight(double units) {
        this.weight = this.weight + units;
    }
}
```

```
public class Point {
    ...
    public void moveUp() {
        this.y = this.y + 1;
    }
}
```

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OOP: Method Calls

```
1 Point p1 = new Point (3, 4);
2 Point p2 = new Point (-4, -3);
3 System.out.println(p1. getDistanceFromOrigin() );
4 System.out.println(p2. getDistanceFromOrigin() );
5 p1. moveUp (1) ;
6 p2. moveUp (1) ;
7 System.out.println(p1. getDistanceFromOrigin() );
8 System.out.println(p2. getDistanceFromOrigin() );
```

- Lines 1 and 2** create two different instances of Point
- Lines 3 and 4:** invoking the same accessor method on two different instances returns *distinct* values
- Lines 5 and 6:** invoking the same mutator method on two different instances results in *independent* changes
- Lines 3 and 7:** invoking the same accessor method on the same instance *may* return *distinct* values, why?

Line 5

See the lecture recording on tracing the above program [here](#)

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OOP: Accessor Methods

- These methods *return* the result of computation based on attribute values.
- We call such methods **accessors** (with non-void return type).

```
public class Person {
    ...
    public double getBMI() {
        double bmi = this.height / (this.weight * this.weight);
        return bmi;
    }
}
```

```
public class Point {
    ...
    public double getDistanceFromOrigin() {
        double dist =
            Math.sqrt(this.x * this.x + this.y * this.y);
        return dist;
    }
}
```

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OOP: Use of Mutator vs. Accessor Methods

- Calls to **mutator methods** *cannot* be used as values.
 - e.g., System.out.println(jim.setWeight (78.5)); ✗
 - e.g., double w = jim.setWeight (78.5); ✗
 - e.g., jim.setWeight (78.5); ✓
- Calls to **accessor methods** *should* be used as values.
 - e.g., jim.getBMI (); ✗
 - e.g., System.out.println(jim.getBMI()); ✓
 - e.g., double w = jim.getBMI (); ✓

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OOP: Method Parameters

- **Principle 1:** A **constructor** needs an *input parameter* for every attribute that you wish to initialize.
e.g., `Person(double w, double h)` vs.
`Person(String fName, String lName)`
- **Principle 2:** A **mutator** method needs an *input parameter* for every attribute that you wish to modify.
e.g., `In Point, void moveToXAxis()` vs.
`void moveUp(double unit)`
- **Principle 3:** An **accessor method** needs *input parameters* if the attributes alone are not sufficient for the intended computation to complete.
e.g., `In Point, double getDistFromOrigin()` vs.
`double getDistFrom(Point other)`

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OOP: Reference Aliasing (2.1)

Problem: Consider assignments to *primitive* variables:

```
1 int i1 = 1;
2 int i2 = 2;
3 int i3 = 3;
4 int[] numbers1 = {i1, i2, i3};
5 int[] numbers2 = new int[numbers1.length];
6 for(int i = 0; i < numbers1.length; i++) {
7     numbers2[i] = numbers1[i];
8 }
9 numbers1[0] = 4;
10 System.out.println(numbers1[0]);
11 System.out.println(numbers2[0]);
```

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OOP: Reference Aliasing (1)

```
1 int i = 3;
2 int j = i; System.out.println(i == j); /*true*/
3 int k = 3; System.out.println(k == i && k == j); /*true*/
```

- **Line 2** copies the number stored in `i` to `j`.
- After **Line 4**, `i`, `j`, `k` refer to three separate integer placeholder, which happen to store the same value 3.

```
1 Point p1 = new Point(2, 3);
2 Point p2 = p1; System.out.println(p1 == p2); /*true*/
3 Point p3 = new Point(2, 3);
4 System.out.println(p3 == p1 || p3 == p2); /*false*/
5 System.out.println(p3.x == p1.x && p3.y == p1.y); /*true*/
6 System.out.println(p3.x == p2.x && p3.y == p2.y); /*true*/
```

- **Line 2** copies the *address* stored in `p1` to `p2`.
- Both `p1` and `p2` refer to the same object in memory!
- `p3`, whose *contents* are same as `p1` and `p2`, refer to a different object in memory.

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OOP: Reference Aliasing (2.2)

Exercise: Consider assignments to *reference* variables:

```
1 Person alan = new Person("Alan");
2 Person mark = new Person("Mark");
3 Person tom = new Person("Tom");
4 Person jim = new Person("Jim");
5 Person[] persons1 = {alan, mark, tom};
6 Person[] persons2 = new Person[persons1.length];
7 for(int i = 0; i < persons1.length; i++) {
8     persons2[i] = persons1[i]; }
9 persons1[0].setAge(70);
10 System.out.println(jim.getAge());
11 System.out.println(alan.getAge());
12 System.out.println(persons2[0].getAge());
13 persons1[0] = jim;
14 persons1[0].setAge(75);
15 System.out.println(jim.getAge());
16 System.out.println(alan.getAge());
17 System.out.println(persons2[0].getAge());
```

See the lecture recording on tracing the above program [here](#)

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Java Data Types (3.1)

- An **attribute** may store the reference to another object.

```
public class Person { private Person spouse; }
```

- Methods may take as **parameters** references to other objects.

```
public class Person {
    public void marry(Person other) { ... } }
```

- Return values** from methods may be references to objects.

```
public class Point {
    public void moveUp(double i) { this.y = this.y + i; }
    Point movedUpBy(double i) {
        Point np = new Point(this.x, this.y);
        np.moveUp(i);
        return np;
    }
}
```

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See the lecture recording on tracing the above program [here](#)

Java Data Types (3.2.1)

An attribute may be **multi-valued**, **reference**-typed e.g., of type **Point[]**, storing references to Point objects.

```
1 public class PointCollector {
2     private Point[] points; private int nop; /* number of points */
3     public PointCollector() { this.points = new Point[100]; }
4     public void addPoint(double x, double y) {
5         this.points[this.nop] = new Point(x, y); this.nop++; }
6     public Point[] getPointsInQuadrantI() {
7         Point[] ps = new Point[this.nop];
8         int count = 0; /* number of points in Quadrant I */
9         for(int i = 0; i < this.nop; i++) {
10             Point p = this.points[i];
11             if(p.getX() > 0 && p.getY() > 0) { ps[count] = p; count++; } }
12         Point[] q1Points = new Point[count];
13         /* ps contains null if count < nop */
14         for(int i = 0; i < count; i++) { q1Points[i] = ps[i] }
15         return q1Points;
16     } }
```

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Required Reading: Point and PointCollector

Java Data Types (3.2.2)

```
1 public class PointCollectorTester {
2     public static void main(String[] args) {
3         PointCollector pc = new PointCollector();
4         System.out.println(pc.getNumberOfPoints()); /* 0 */
5         pc.addPoint(3, 4);
6         System.out.println(pc.getNumberOfPoints()); /* 1 */
7         pc.addPoint(-3, 4);
8         System.out.println(pc.getNumberOfPoints()); /* 2 */
9         pc.addPoint(-3, -4);
10        System.out.println(pc.getNumberOfPoints()); /* 3 */
11        pc.addPoint(3, -4);
12        System.out.println(pc.getNumberOfPoints()); /* 4 */
13        Point[] ps = pc.getPointsInQuadrantI();
14        System.out.println(ps.length); /* 1 */
15        System.out.println("(" +
16            ps[0].getX() + ", " + ps[0].getY() + ")"); /* (3, 4) */
17    }
18 }
```

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See the lecture recording on tracing the above program [here](#)

Anonymous Objects (1)

- What's the difference between these two fragments of code?

```
1 double square(double x) {
2     double sqr = x * x;
3     return sqr; }
```

```
1 double square(double x) {
2     return x * x; }
```

After L2, the result of $x * x$:

- LHS: it can be reused (without recalculating) via the name `sqr`.
- RHS: it is not stored anywhere and returned right away.

- Same principles applies to objects:

```
1 Person getP(String n) {
2     Person p = new Person(n);
3     return p; }
```

```
1 Person getP(String n) {
2     return new Person(n); }
```

new Person(n) is an object whose address is not stored in a variable.

- LHS: L2 stores the address of this anonymous object in `p`.
- RHS: L2 returns the address of this anonymous object directly.

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Anonymous Objects (2.1)

Anonymous objects can also be used as *assignment sources* or *argument values*:

```
class Member {
    private Order[] orders;
    private int noo;
    /* constructor omitted */
    public void addOrder(Order o) {
        this.orders[this.noo] = o;
        this.noo++;
    }
    public void addOrder(String n, double p, double q) {
        this.addOrder(new Order(n, p, q));
        /* Equivalent implementation:
        * this.orders[this.noo] = new Order(n, p, q); noo ++;
        */
    }
}
```

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Anonymous Objects (2.2)

One more example on using anonymous objects:

```
public class MemberTester {
    public static void main(String[] args) {
        Member m = new Member("Alan");
        Order o = new Order("Americano", 4.7, 3);
        m.addOrder(o);
        m.addOrder(new Order("Cafe Latte", 5.1, 4));
    }
}
```

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The this Reference (7.1): Exercise

Consider the Person class

```
public class Person {
    private String name;
    private Person spouse;
    public Person(String name) {
        this.name = name;
    }
}
```

How do you implement a mutator method marry which marries the current Person object to an input Person object?

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The this Reference (7.2): Exercise

```
public void marry(Person other) {
    if(this.spouse != null || other.spouse != null) {
        /* Error: both must be single */
    }
    else { this.spouse = other; other.spouse = this; }
}
```

When we call jim.marry(elsa): this is substituted by the *context object* jim, and other by the *argument* elsa.

```
public void marry(Person other elsa) {
    ...
    jim.spouse = elsa;
    elsa.spouse = jim;
    ...
}
```

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OOP: The Dot Notation (2)

- LHS of dot **can be more complicated than a variable**:

- It can be a **path** that brings you to an object

```
public class Person {
    private String name; /* public accessor: name() */
    private Person spouse; /* public accessor: spouse() */
}
```

- Say we have `Person jim = new Person("Jim Davies")`
- Inquire about jim's name? `[jim.name()]`
- Inquire about jim's spouse's name? `[jim.spouse().name()]`
- But what if jim is single (i.e., `jim.spouse() == null`)?
Calling `jim.spouse().name()` will cause **NullPointerException!!**
- **Question.** Assuming that:
 - jim is not single. `[jim.spouse() != null]`
 - The marriage is mutual. `[jim.spouse().spouse() == jim]`
 What does `jim.spouse().spouse().name()` mean?

Answer. `jim.name()`

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OOP: Helper (Accessor) Methods (2.1)

```
public class PersonCollector {
    private Person[] ps;
    private final int MAX = 100; /* max # of persons to store */
    private int nop; /* number of persons */
    public PersonCollector() {
        this.ps = new Person[MAX];
    }
    public void addPerson(Person p) {
        this.ps[this.nop] = p;
        this.nop++;
    }
    /* Tasks:
     * 1. An accessor: boolean personExists(String n)
     * 2. A mutator: void changeWeightOf(String n, double w)
     * 3. A mutator: void changeHeightOf(String n, double h)
     */
}
```

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OOP: Helper Methods (1)

- After you complete and test your program, feeling confident that it is **correct**, you may find that there are lots of **repetitions**.
- When similar fragments of code appear in your program, we say that your code "**smells**"!
- We may eliminate **repetitions** of your code by:
 - **Factoring out** recurring code fragments into a new method.
 - This new method is called a **helper method**:
 - You can replace every occurrence of the recurring code fragment by a **call** to this helper method, with appropriate argument values.
 - That is, we **reuse** the body implementation, rather than repeating it over and over again, of this helper method via calls to it.
- This process is called **refactoring** of your code:

Modify the code structure **without** compromising **correctness**.

See the lecture recording on helper methods [here](#)

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OOP: Helper (Accessor) Methods (2.2.1)

```
public class PersonCollector {
    /* ps, MAX, nop, PersonCollector(), addPerson */
    public boolean personExists(String n) {
        boolean found = false;
        for(int i = 0; i < nop; i++) {
            if(ps[i].getName().equals(n)) { found = true; } }
        return found;
    }
    public void changeWeightOf(String n, double w) {
        for(int i = 0; i < nop; i++) {
            if(ps[i].getName().equals(n)) { ps[i].setWeight(w); } }
    }
    public void changeHeightOf(String n, double h) {
        for(int i = 0; i < nop; i++) {
            if(ps[i].getName().equals(n)) { ps[i].setHeight(h); } }
    }
}
```

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OOP: Helper (Accessor) Methods (2.2.2)



```
public class PersonCollector { /* code smells:repetitions! */
    /* ps, MAX, nop, PersonCollector(), addPerson */
    public boolean personExists(String n) {
        boolean found = false;
        for(int i = 0; i < nop; i++) {
            if(ps[i].getName().equals(n)) { found = true; } }
        return found;
    }
    public void changeWeightOf(String n, double w) {
        for(int i = 0; i < nop; i++) {
            if(ps[i].getName().equals(n)) { ps[i].setWeight(w); } }
    }
    public void changeHeightOf(String n, double h) {
        for(int i = 0; i < nop; i++) {
            if(ps[i].getName().equals(n)) { ps[i].setHeight(h); } }
    }
}
```

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OOP: Helper (Accessor) Methods (3.1)



Problems:

- A Point class with x and y coordinate values.
- Accessor double `getDistanceFromOrigin()`.
p.getDistanceFromOrigin() returns the distance between p and (0, 0).
- Accessor double `getDistancesTo(Point p1, Point p2)`.
p.getDistancesTo(p1, p2) returns the sum of distances between p and p1, and between p and p2.
- Accessor double `getTriDistances(Point p1, Point p2)`.
p.getDistancesTo(p1, p2) returns the sum of distances between p and p1, between p and p2, and between p1 and p2.

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OOP: Helper (Accessor) Methods (2.3)



```
public class PersonCollector { /* Code Smell Eliminated */
    /* ps, MAX, nop, PersonCollector(), addPerson */
    private int indexOf(String n) { /* Helper Methods */
        int i = -1;
        for(int j = 0; j < nop; j++) {
            if(ps[j].getName().equals(n)) { i = j; }
        }
        return i; /* -1 if not found; >= 0 if found. */
    }
    public boolean personExists(String n) {
        return this.indexOf(n) >= 0;
    }
    public void changeWeightOf(String n, double w) {
        int i = indexOf(n); if(i >= 0) { ps[i].setWeight(w); }
    }
    public void changeHeightOf(String n, double h) {
        int i = indexOf(n); if(i >= 0) { ps[i].setHeight(h); }
    }
}
```

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OOP: Helper (Accessor) Methods (3.2)



```
class Point { /* code smells:repetitions! */
    double x; double y;

    double getDistanceFromOrigin() {
        return Math.sqrt(Math.pow(this.x - 0, 2) + Math.pow(this.y - 0, 2));
    }

    double getDistancesTo(Point p1, Point p2) {
        return
            Math.sqrt(Math.pow(this.x - p1.x, 2) + Math.pow(y - p1.y, 2))
            +
            Math.sqrt(Math.pow(this.x - p2.x, 2) + Math.pow(y - p2.y, 2));
    }

    double getTriDistances(Point p1, Point p2) {
        return
            Math.sqrt(Math.pow(this.x - p1.x, 2) + Math.pow(y - p1.y, 2))
            +
            Math.sqrt(Math.pow(this.x - p2.x, 2) + Math.pow(y - p2.y, 2))
            +
            Math.sqrt(Math.pow(p1.x - p2.x, 2) + Math.pow(p1.y - p2.y, 2));
    }
}
```

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OOP: Helper (Accessor) Methods (3.3)



- The code pattern

```
Math.sqrt(Math.pow(... - ..., 2) + Math.pow(... - ..., 2))
```

is written down explicitly every time we need to use it.

- Create a **helper method** out of it, with the right *parameter* and *return* types:

```
double getDistanceFrom(double otherX, double otherY) {  
    return Math.sqrt(  
        Math.pow(otherX - this.x, 2)  
        +  
        Math.pow(otherY - this.y, 2));  
}
```

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OOP: Helper (Mutator) Methods (4.1)



```
public class Student {  
    private String name;  
    private double balance;  
    public Student(String n, double b) {  
        name = n;  
        balance = b;  
    }  
  
    /* Tasks:  
    * 1. A mutator void receiveScholarship(double val)  
    * 2. A mutator void payLibraryOverdue(double val)  
    * 3. A mutator void payCafeCoupons(double val)  
    * 4. A mutator void transfer(Student other, double val)  
    */  
}
```

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OOP: Helper (Accessor) Methods (3.4)



```
public class Point { /* Code Smell Eliminated */  
    private double x; private double y;  
    double getDistanceFrom(double otherX, double otherY) {  
        return Math.sqrt(Math.pow(otherX - this.x, 2) +  
            Math.pow(otherY - this.y, 2));  
    }  
    double getDistanceFromOrigin() {  
        return this.getDistanceFrom(0, 0);  
    }  
    double getDistancesTo(Point p1, Point p2) {  
        return this.getDistanceFrom(p1.x, p1.y) +  
            this.getDistanceFrom(p2.x, p2.y);  
    }  
    double getTriDistances(Point p1, Point p2) {  
        return this.getDistanceFrom(p1.x, p1.y) +  
            this.getDistanceFrom(p2.x, p2.y) +  
            p1.getDistanceFrom(p2.x, p2.y);  
    }  
}
```

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OOP: Helper (Mutator) Methods (4.2.1)



```
public class Student {  
    /* name, balance, Student(String n, double b) */  
    public void receiveScholarship(double val) {  
        balance = balance + val;  
    }  
    public void payLibraryOverdue(double val) {  
        balance = balance - val;  
    }  
    public void payCafeCoupons(double val) {  
        balance = balance - val;  
    }  
    public void transfer(Student other, double val) {  
        balance = balance - val;  
        other.balance = other.balance + val;  
    }  
}
```

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OOP: Helper (Mutator) Methods (4.2.2)



```
public class Student { /* code smells:repetitions! */
    /* name, balance, Student(String n, double b) */
    public void receiveScholarship(double val) {
        balance = balance + val;
    }
    public void payLibraryOverdue(double val) {
        balance = balance - val;
    }
    public void payCafeCoupons(double val) {
        balance = balance - val;
    }
    public void transfer(Student other, double val) {
        balance = balance - val;
        balance = other.balance + val;
    }
}
```

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Static Variables (1)



```
public class Account {
    private int id;
    private String owner;
    public int getID() { return this.id; }
    public Account(int id, String owner) {
        this.id = id;
        this.owner = owner;
    }
}
```

```
class AccountTester {
    Account acc1 = new Account(1, "Jim");
    Account acc2 = new Account(2, "Jeremy");
    System.out.println(acc1.getID() != acc2.getID());
}
```

But, managing the unique id's *manually* is **error-prone** !

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OOP: Helper (Mutator) Methods (4.3)



```
public class Student { /* Code Smell Eliminated */
    /* name, balance, Student(String n, double b) */
    public void deposit(double val) { /* Helper Method */
        balance = balance + val;
    }
    public void withdraw(double val) { /* Helper Method */
        balance = balance - val;
    }
    public void receiveScholarship(double val) { this.deposit(val); }
    public void payLibraryOverdue(double val) { this.withdraw(val); }
    public void payCafeCoupons(double val) { this.withdraw(val); }
    public void transfer(Student other, double val) {
        this.withdraw(val);
        other.deposit(val);
    }
}
```

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Static Variables (2)



```
class Account {
    private static int globalCounter = 1;
    private int id; String owner;
    public Account(String owner) {
        this.id = globalCounter;
        globalCounter++;
        this.owner = owner; } }
}
```

```
class AccountTester {
    Account acc1 = new Account("Jim");
    Account acc2 = new Account("Jeremy");
    System.out.println(acc1.getID() != acc2.getID());
}
```

- Each instance of a class (e.g., acc1, acc2) has a *local* copy of each attribute or instance variable (e.g., id).
 - Changing acc1.id does not affect acc2.id.
- A **static** variable (e.g., globalCounter) belongs to the class.
 - All instances of the class share a *single* copy of the **static** variable.
 - Change to globalCounter via acc1 is also visible to acc2.

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Static Variables (3)

```
public class Account {
    private static int globalCounter = 1;
    private int id; private String owner;
    public Account(String owner) {
        this.id = globalCounter;
        globalCounter++;
        this.owner = owner;
    }
}
```

- **Static** variable `globalCounter` is not instance-specific like **instance** variable (i.e., attribute) `id` is.
- To access a **static** variable:
 - **No** context object is needed.
 - Use of the class name suffices, e.g., `Account.globalCounter`.
- Each time `Account`'s constructor is called to create a new instance, the increment effect is **visible to all existing objects** of `Account`.

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Static Variables (4.2): Common Error

- Attribute `numberOfAccounts` should **not** be declared as **static** as its value should be specific to the client object.
- If it were declared as **static**, then every time the `addAccount` method is called, although on different objects, the increment effect of `numberOfAccounts` will be visible to all `Client` objects.
- Here is the correct version:

```
public class Client {
    private Account[] accounts;
    private int numberOfAccounts;
    public void addAccount(Account acc) {
        accounts[this.numberOfAccounts] = acc;
        this.numberOfAccounts++;
    }
}
```

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Static Variables (4.1): Common Error

```
public class Client {
    private Account[] accounts;
    private static int numberOfAccounts = 0;
    public void addAccount(Account acc) {
        accounts[this.numberOfAccounts] = acc;
        this.numberOfAccounts++;
    }
}
```

```
public class ClientTester {
    Client bill = new Client("Bill");
    Client steve = new Client("Steve");
    Account acc1 = new Account();
    Account acc2 = new Account();
    bill.addAccount(acc1);
    /* correctly added to bill.getAccounts()[0] */
    steve.addAccount(acc2);
    /* mistakenly added to steve.getAccounts()[1]! */
}
```

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Static Variables (5.1): Common Error

```
1 public class Bank {
2     private string branchName;
3     public String getBrachName() { return this.branchName; }
4     private static int nextAccountNumber = 0;
5     public static String getInfo() {
6         nextAccountNumber++;
7         return this.branchName + nextAccountNumber;
8     }
9 }
```

- **Non-static method cannot be referenced from a static context**
- **Line 5** declares that we **can** call the method `getInfo` without instantiating an object of the class `Bank`.
- However, in **Line 7**, the **static** method references a **non-static** attribute, for which we **must** instantiate a `Bank` object.

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Static Variables (5.2): Common Error



```
1 public class Bank {  
2     private String branchName;  
3     public String getBranchName() { return this.branchName; }  
4     private static int nextAccountNumber = 0;  
5     public static String getInfo() {  
6         nextAccountNumber++;  
7         return this.branchName + nextAccountNumber;  
8     }  
9 }
```

- To call `getInfo()`, no instances of `Bank` are required:

```
Bank.getInfo();
```

- Contradictorily*, to access `branchName`, a *context object* is required:

```
Bank b = new Bank(); b.setBranch("Songdo IBK");  
System.out.println(b.getBranchName());
```

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Static Variables (5.3): Common Error



There are two possible ways to fix:

- Remove all uses of *non-static* variables (i.e., `branchName`) in the *static* method (i.e., `getInfo`).
- Declare `branchName` as a *static* variable.
 - This does not make sense.
 \therefore `branchName` should be a value specific to each `Bank` instance.

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Index (1)



Required: Review Tutorials on OOP in Java

Optional: Tutorial Videos to Help You Review

Required: Written Notes to Review

Learning Outcomes

Separation of Concerns: App/Tester vs. Model

Object Orientation:

Observe, Model, and Execute

Object-Oriented Programming (OOP)

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