Compsci 201, L3: Object-Oriented Programming (OOP)

Logistics, Coming up

- This Wednesday, 1/25
  - Interfaces, Implementations, ArrayList data structure
  - First APT set (short programming exercises) due
  - Need to do at least 4 for full credit
- This Friday, 1/27
  - Discussion 2: APTs, Sets, Strings, Git
- Next Monday 1/30
  - Prjoect 0: Person201 due (warmup project)
  - Maps and Sets in class

Course Website Reminder

Schedule page has slides, recordings, and more

Week	Day	Reference	In Class	Due
1	M 1/9		No meeting	
	W 1/11	Z8	L1: What is Computer Science [slides] [code]	
	F 1/13		No meeting - Setup tech and review	
2	M 1/16		No meeting - M.L.K. Jr. Day	
	W 1/18	Z1-Z7 (intro Java review) as needed	L2: Intro to Java [slides] [recording]	
	F 1/20		D1: Algorithmic Problem Solving [discussion document]	
3	M 1/23	Z9	L3: Object-Oriented Programming	
	W 1/25	Z10	L4: Interfaces, Implementations, ArrayList	APT 1
	F 1/27		D2: Java, Git	
4	M 1/30	Z11	L5: Maps and Sets	P0: Person201

Course Policy Reminders

- Collaboration reminder: Can discuss projects and APTs conceptually, **code must be your own**.
  - If you can't write the code yourself, you're not going to be ready for whatever you want to do next.
- Getting Help reminder: We want to help!
  - Course website getting help page
  - Su-Th *every evening,* Use OhHai to queue
  - Some daytime hours, plus Ed discussion
  - Expect help about your process and how to make progress – not "solutions" or for TAs to debug your code for you.

Person in CS: Grace Hopper

- PhD in math from Yale in 1930s
- Joined Navy Reserve during WW2
- 1940s, began working on developing early computers:
  - Mark 1
  - UNIVAC 1
- 1950s, began work on the earliest "high level" programming languages
  - FLOW-MATIC
  - COBOL – Still in use!
- Annual Grace Hopper Celebration of Women in Computing, usually in the Fall. Consider attending!

USS Hopper

Intro Java Wrap-up

WOTO

Go to duke.is/v3y2y

Not graded for correctness, just participation.

Try to answer *without* looking back at slides and notes.

But do talk to your neighbors!

L02-WOTO2-MoreJava

* Required

* This form will record your name, please fill your name.

1

NetID *

2

What kind of method is **not** called on an object? *

- ◯ static methods
- ◯ dynamic methods
- ◯ public methods
- ◯ private methods

3

What will be printed by the following program?
*

```
public static void main(String[] args) {
    String message = "to be or not to be";
    String[] words = message.split(regex: " ");
    ArrayList<String> list = new ArrayList<>();
    int count = 0;
    for (String w : words) {
        if (list.contains(w)) {
            count++;
        }
        else {
            list.add(w);
        }
    }
    System.out.println(count);
}
```

- 0
- 1
- 2
- 3
- 4

- 5
- 6

4

The contains method on line 10 is... *

```
7       ArrayList<String> list = new ArrayList<>();
8       int count = 0;
9       for (String w : words) {
10          if (list.contains(w)) {
11              count++;
12          }
13          else {
14              list.add(w);
15          }
```

- A static method of the ArrayList class
- A dynamic method of the ArrayList class
- A static method of the String class
- A dynamic method of the String class

5

We say that the contains method on line 10... *

```
7       ArrayList<String> list = new ArrayList<>();
8       int count = 0;
9       for (String w : words) {
10          if (list.contains(w)) {
11              count++;
12          }
13          else {
14              list.add(w);
15          }
```

- ◯ Is called on w and takes list as an argument
- ◯ Is called on list and takes w as an argument
- ◯ Is called on both list and w

Comments on Java style

Code blocks:

- Opening `{` ends first line of `if`, `for`, `while`, or method
- Indent every line inside the block
- Closing `}` on a separate line, last of block, not indented

```
16          int i=0;
17          while (i < numbers.length) {
18              System.out.println(numbers[i]);
19              i++;
20          }
```

Variable & method names:

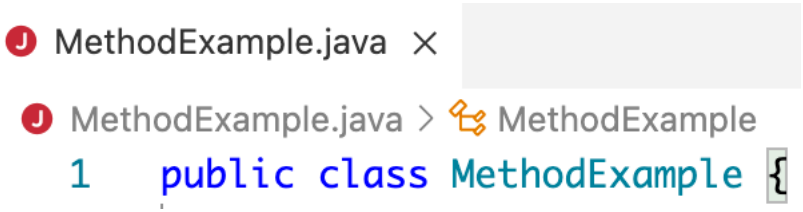
- One-word names: `lowercase`
- Multi-word names: camelCase
- Should be informative

```
23          int index = 0;
24          int maxSize = 10;
```

More comments on Java style

Class names:

- Capitalized & CamelCase
- MUST match name of .java file!

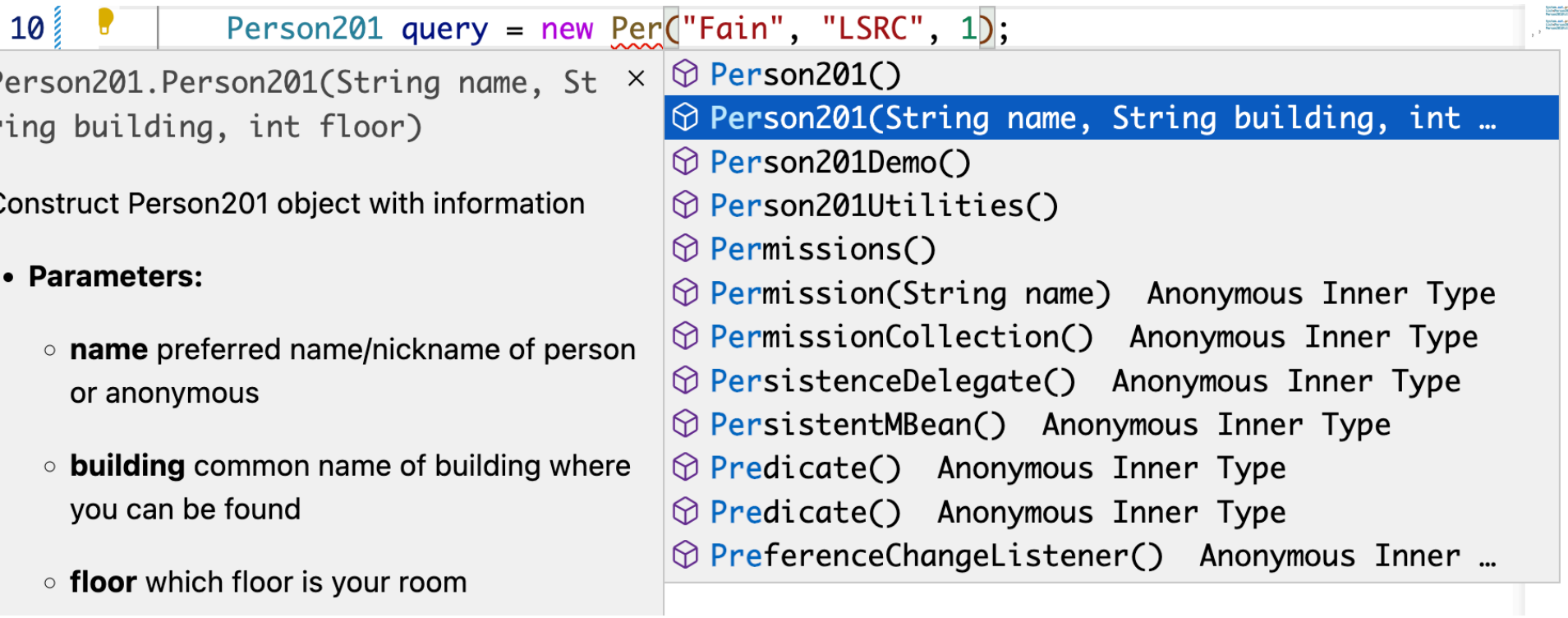


Comments:

- // for one line
- /* … */ for multiple lines

```
2    // one line comment
3    /* a
4    block
5    comment
6    */
```

Javadoc: Advanced comments



Writing Javadoc

```
24      /**
25       * Construct Person201 object with information
26       * @param name preferred name/nickname of person or anonymous
27       * @param building common name of building where you can be found
28       * @param floor which floor is your room
29       */
30      public Person201(String name, String building, int floor) {
31          myName = name;
32          myBuilding = building;
33          myFloor = floor;
34      }
```

Common annotations for methods include: @param, @returns, @throws

Java printing

```
String month = "January";
int day = 18;
System.out.println(month);
System.out.println(day);
System.out.printf("Today is %s %d\n", month, day);
```

January
13

Today is January 18

Format string with placeholders (%s, %d)

Values for placeholders

```
int[] array = {1, 2, 3};
System.out.println(array);
System.out.println(Arrays.toString(array));
```

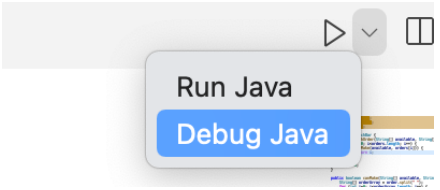
[I@7e9e5f8a

[1, 2, 3]

Debugging

- What is the **first line** of my program where something is different than I expect?

- Need to see **program state** during execution.
  - Add print statements to code, see values of variables
    - Will show up in terminal locally, or on APT server
  - Use a debugger tool, built into VS Code
    - See [the documentation here]



Java API HashSet

An import statement:

```
1    import java.util.HashSet;
```

More on `HashSet` later, but the basics:

- Generic to specify type, does not store duplicates
- Uses `add()`, `size()`, `contains()`

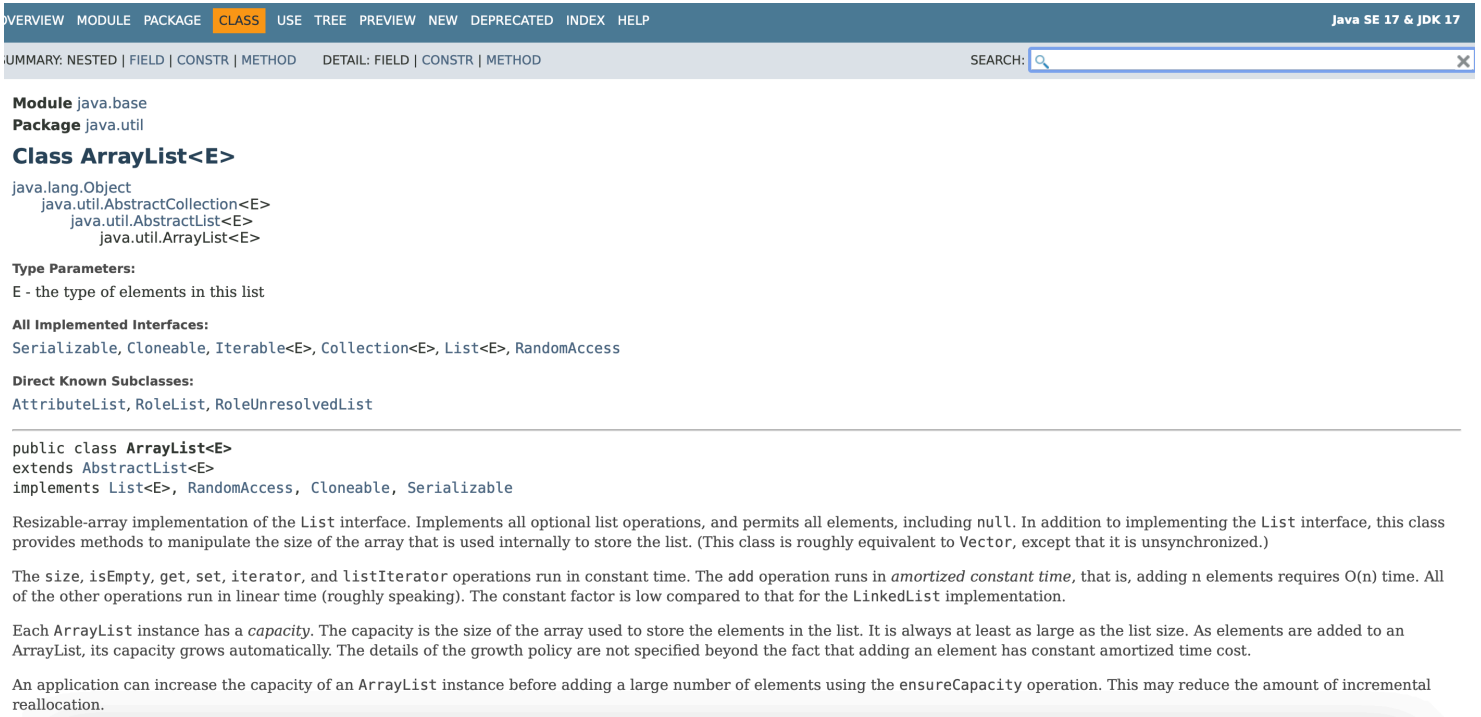
```
4       public static void main (String[] args) {
5           HashSet<String> strSet = new HashSet<>();
6           strSet.add("Hello");
7           strSet.add("World");
8           strSet.add("Hello");
9
10          if(strSet.contains("World")) {
11              System.out.println(strSet.size());
12          }
```

Prints 2, no duplicates

API Documentation

Reading documentation is an important skill:

docs.oracle.com/en/java/javase/17/docs/api



OVERVIEW MODULE PACKAGE CLASS USE TREE PREVIEW NEW DEPRECATED INDEX HELP Java SE 17 & JDK 17

UMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD SEARCH:

Module java.base
Package java.util

Class ArrayList<E>

java.lang.Object
  java.util.AbstractCollection<E>
    java.util.AbstractList<E>
      java.util.ArrayList<E>

Type Parameters:

E - the type of elements in this list

All Implemented Interfaces:

`Serializable`, `Cloneable`, `Iterable<E>`, `Collection<E>`, `List<E>`, `RandomAccess`

Direct Known Subclasses:

`AttributeList`, `RoleList`, `RoleUnresolvedList`

```
public class ArrayList<E>
extends AbstractList<E>
implements List<E>, RandomAccess, Cloneable, Serializable
```

Resizable-array implementation of the `List` interface. Implements all optional list operations, and permits all elements, including `null`. In addition to implementing the `List` interface, this class provides methods to manipulate the size of the array that is used internally to store the list. (This class is roughly equivalent to `Vector`, except that it is unsynchronized.)

The `size`, `isEmpty`, `get`, `set`, `iterator`, and `listIterator` operations run in constant time. The `add` operation runs in *amortized constant time*, that is, adding n elements requires O(n) time. All of the other operations run in linear time (roughly speaking). The constant factor is low compared to that for the `LinkedList` implementation.

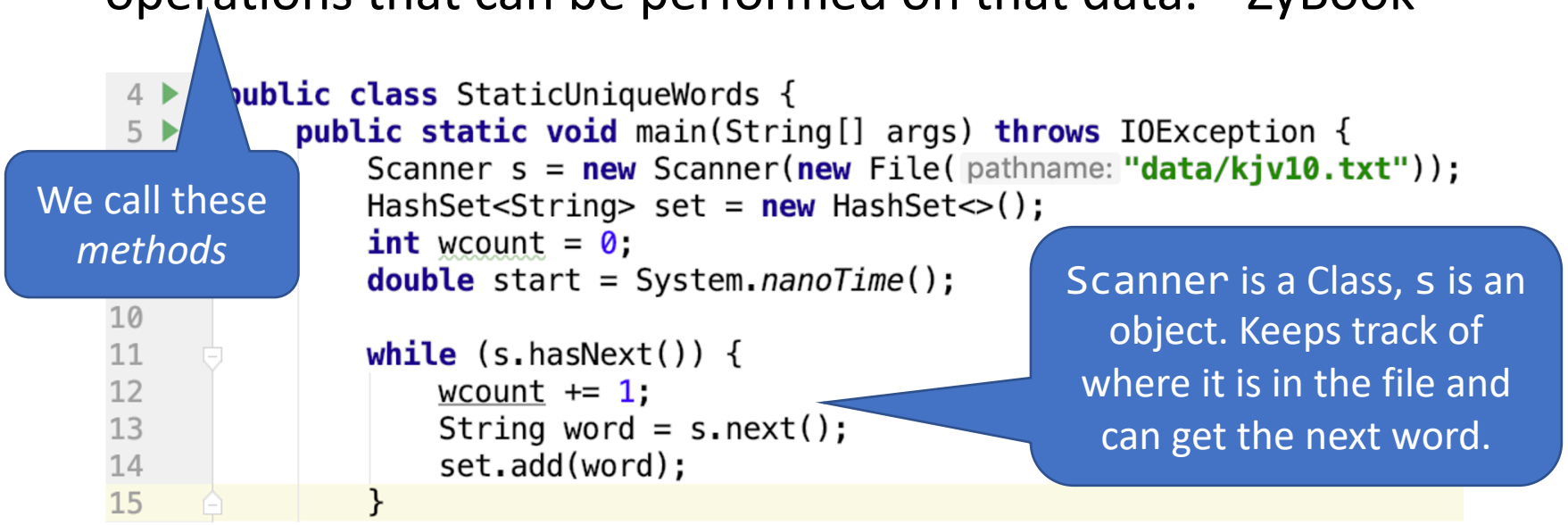
Each `ArrayList` instance has a *capacity*. The capacity is the size of the array used to store the elements in the list. It is always at least as large as the list size. As elements are added to an ArrayList, its capacity grows automatically. The details of the growth policy are not specified beyond the fact that adding an element has constant amortized time cost.

An application can increase the capacity of an `ArrayList` instance before adding a large number of elements using the `ensureCapacity` operation. This may reduce the amount of incremental reallocation.

Object-Oriented Programming

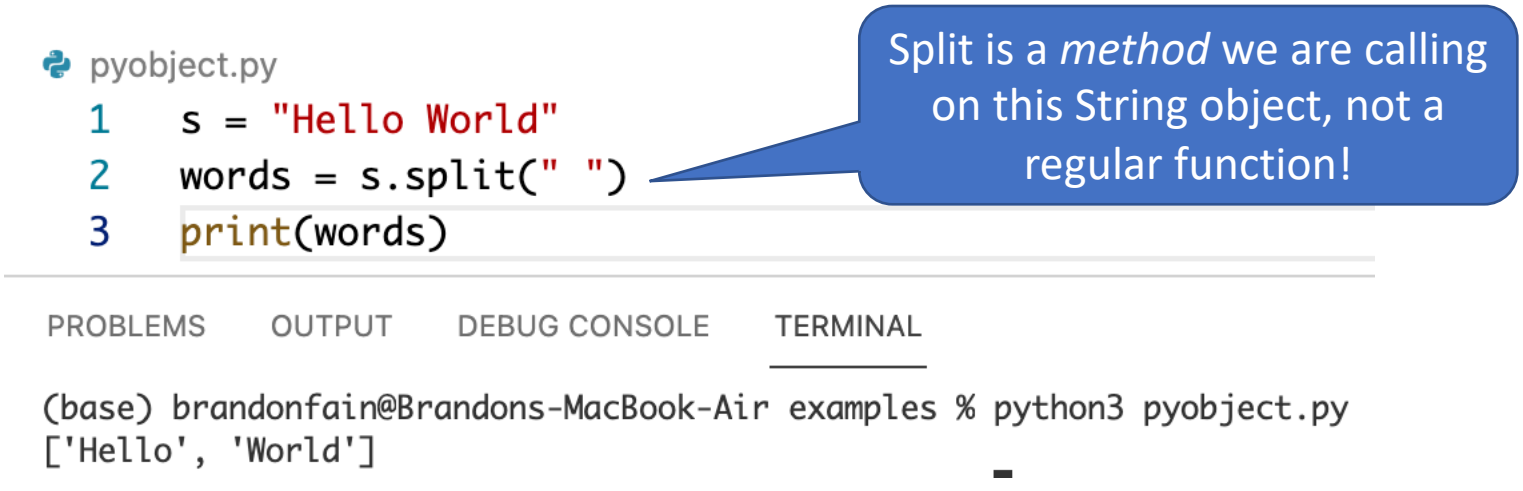
Java is object-oriented

- A language is **object-oriented** if programs in that language are organized by the specification and use of objects.
- "An **object** consists of some internal data items plus operations that can be performed on that data."–ZyBook




```
4   public class StaticUniqueWords {
5       public static void main(String[] args) throws IOException {
            Scanner s = new Scanner(new File( pathname: "data/kjv10.txt"));
            HashSet<String> set = new HashSet<>();
            int wcount = 0;
            double start = System.nanoTime();
10
11          while (s.hasNext()) {
12              wcount += 1;
13              String word = s.next();
14              set.add(word);
15          }
```

Aside: Python uses objects too



Same syntax in Python and Java for method calls:
`<object>.<method>(<method_arguments>)`

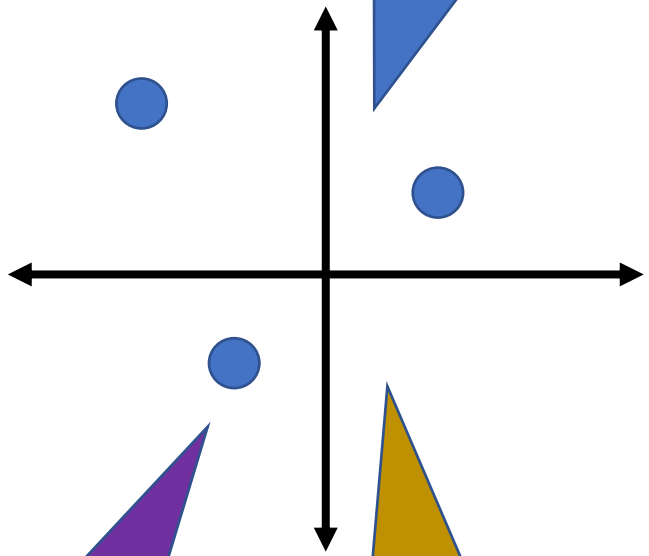
Object Concept

Consider points in two-dimensions.

Class is a blueprint for these objects

Data (instance variables)
- x-coordinate (x)
- y-coordinate (y)

Operations (methods)
- Create a point
- Print a point
- Change coordinates
- Get distance to another point

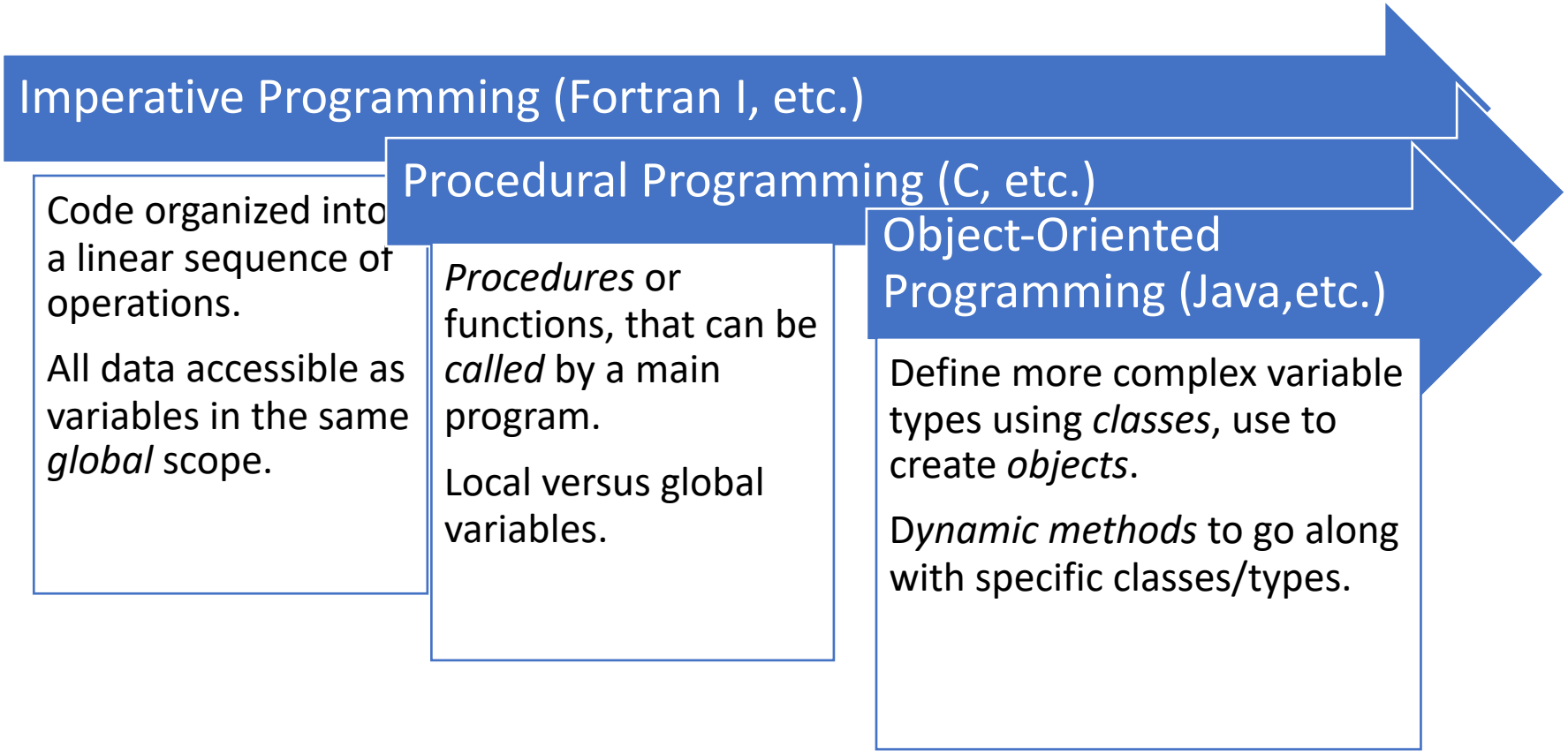


All different objects, but each of the same class

Each point object has its own x and y value.

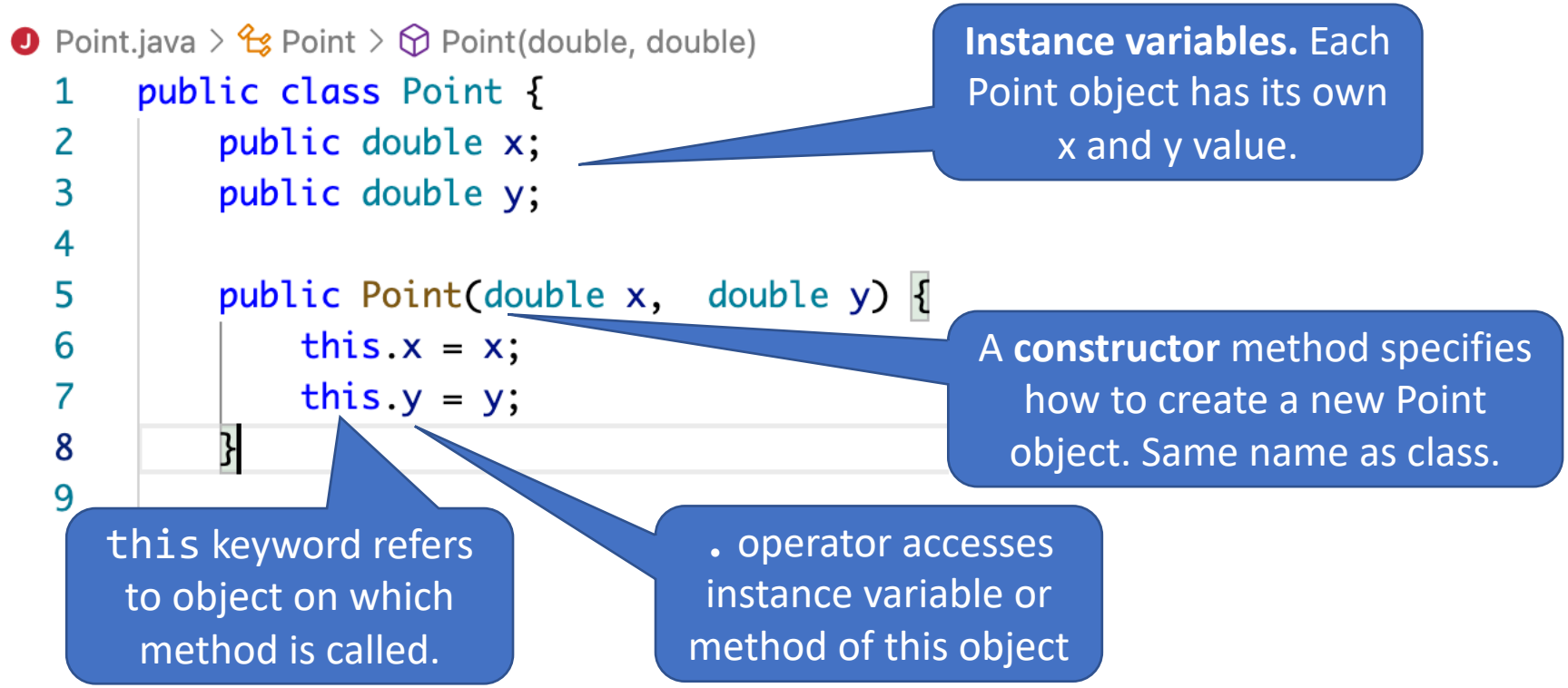
Methods should be able to operate on a particular point

Language History: A story of increasing abstraction and organization



Classes and objects

Class specifies the data and operations for a type of object. They are a template or a blueprint for objects. Alternately, objects are ***instances*** of a class.



Creating objects, calling methods

```
10      public void printPoint() {
11          System.out.printf("(%.1f, %.1f)%n", x, y);
12      }

14      public static void main(String[] args) {
15          Point p = new Point(-2.0, 2.0);
16          Point q = new Point (1.0, 1.0);
17
18          p.printPoint();
19          q.printPoint();
20      }
```

Method defined inside the point class

new Point allocates memory and calls the constructor to set the instance variables

(-2.0, 2.0)

(1.0, 1.0)

Note how the `printPoint()` method "knows" the correct value for x and y – they are stored with the objects on which we call the method as *instance variables*.

Two reasons to call a method

For the **side effect**, what it did to the object

```
4       public static void main(String[] args) {
5           HashSet<String> strSet = new HashSet<>();
6           strSet.add("Hello");
7           strSet.add("World");
8           strSet.add("Hello");
9
10          if(strSet.contains("World")) {
11              System.out.println(strSet.size());
12          }
```

For the **return value**, no change to object

== or .equals()?

Point.java

Point.java > Point > main(String[])

```
1   public class Point {
2       public double x;
3       public double y;
4
5       public Point(double x,  double y) {
6           this.x = x;
7           this.y = y;
8       }
9
        Run | Debug
10      public static void main(String[] args) {
11          Point p = new Point(0.0, 0.0);
12          Point q = p;
13          Point r = new Point(0.0, 0.0);
14
15          System.out.println(p == q);
16          System.out.println(p == r);
17      }
18
19  }
```

true

false

- For primitive types: == checks for equal values.
- For objects, == generally does ***not***.
- Need to use `.equals()` method for objects.
  - Correct way to compare `String` objects.
  - Must be implemented for the given Class!

Default Object `.equals`

```
14      /*
15      @Override
16      public boolean equals(Object o) {
17          Point other = (Point) o;
18          if ((this.x == other.x) && (this.y == other.y)) {
19              return true;
20          }
21          return false;
22      }
23      */
24
        Run | Debug
25      public static void main(String[] args) {
26          Point p = new Point(0.0, 0.0);
27          Point r = new Point(0.0, 0.0);
28          System.out.println(p.equals(r));
29      }
```

Prints `false`, is just checking memory locations

Overriding default Object `.equals`

```
14
15      @Override
16      public boolean equals(Object o) {
17          Point other = (Point) o;
18          if ((this.x == other.x) && (this.y == other.y)) {
19              return true;
20          }
21          return false;
22      }
23
24
        Run | Debug
25      public static void main(String[] args) {
26          Point p = new Point(0.0, 0.0);
27          Point r = new Point(0.0, 0.0);
28          System.out.println(p.equals(r));
29      }
```

Prints `true`, is using the method we wrote to check values

Object vs. object, Inheritance?

- Object: ancestor of all classes
  - Default behavior that's not too useful, …
  - @Override for `.equals`
- object – synonym for instance of a class
  - What you get when you call new
- Inheritance is a major topic in object-oriented programming

How do I know what `.equals` does for Java API classes?

Read at the Java API documentation!!!

docs.oracle.com/en/java/javase/17/docs/api

```
public class ArrayList<E>
extends AbstractList<E>
implements List<E>, RandomAccess, Cloneable, Serializable
```

Resizable-array implementation of the `List` interface. Implements all optional list operations, and permits all elements, including `null`. In addition to implementing the `List` interface, this class provides methods to manipulate the size of the array that is used internally to store the list. (This class is roughly equivalent to `Vector`, except that it is unsynchronized.)

equals

```
public boolean equals(Object o)
```

Compares the specified object with this list for equality. Returns `true` if and only if the specified object is also a list, both lists have the same size, and all corresponding pairs of elements in the two lists are *equal*. (Two elements `e1` and `e2` are *equal* if `(e1==null ? e2==null : e1.equals(e2))`.) In other words, two lists are defined to be equal if they contain the same elements in the same order.

When do I need new? Every time I create an object, not automatic!

```
1   public class Point {
2       public double x;
3       public double y;
4       public Point(double x,  double y) {
5           this.x = x;
6           this.y = y;
7       }

            Run | Debug
9       public static void main(String[] args) {
10          Point[] pointArray = new Point[5];
11          System.out.print(pointArray[0].x);
12      }
```

We created the array, but did not call new for the individual Point objects.

```
Exception in thread "main" java.lang.NullPointerException: Cann
ot read field "x" because "pointArray[0]" is null
        at Point.main(Point.java:11)                    Point.java:11
```

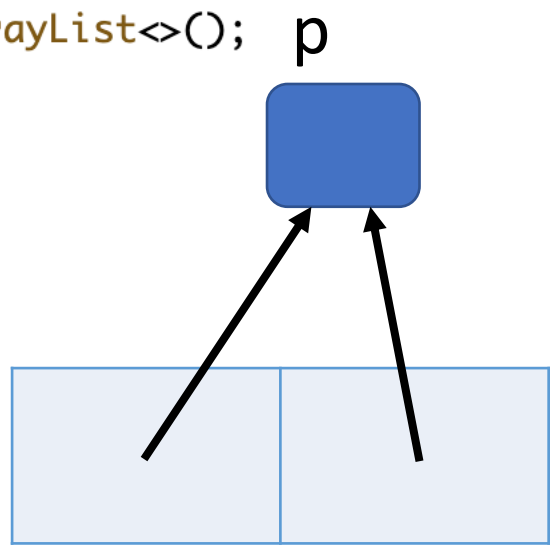
When do I need new again? For every object you want to create!

An even stranger error… creating one object but multiple references to it.

```
5       public static void main(String[] args) {
6           ArrayList<Point> myPoints = new ArrayList<>();
7           Point p = new Point(0.0, 0.0);
8           myPoints.add(p);
9           p.x = 2.0;
10          myPoints.add(p);
11
12          for (Point q : myPoints) {
13              q.printPoint();
14          }
```

Prints

```
(2.0, 0.0)
(2.0, 0.0)
```



Creating a List of points; `contains` uses `equals`

```
1   import java.util.ArrayList;
2
3   public class Point {
4       public double x;
5       public double y;
6       public Point(double x,  double y) {
7           this.x = x;
8           this.y = y;
9       }
10
        Run | Debug
11      public static void main(String[] args) {
12          ArrayList<Point> pointList = new ArrayList<>();
13          for (int i=0; i<10; i++) {
14              pointList.add(new Point(0.0, 0.0));
15          }
16          Point p = new Point(0.0, 0.0);
17          System.out.println(pointList.contains(p));
18      }
```

Good, we called new for *every Point object we want to create*.

Prints `false`. `ArrayList.contains` loops over list checking `.equals()`, but only default implementation here!

WOTO

Go to duke.is/g6hhd

Not graded for correctness, just participation.

Try to answer *without* looking back at slides and notes.

But do talk to your neighbors!

L03-WOTO2-OOP

* Required

* This form will record your name, please fill your name.

1

NetID *

Responses Received 310 responses

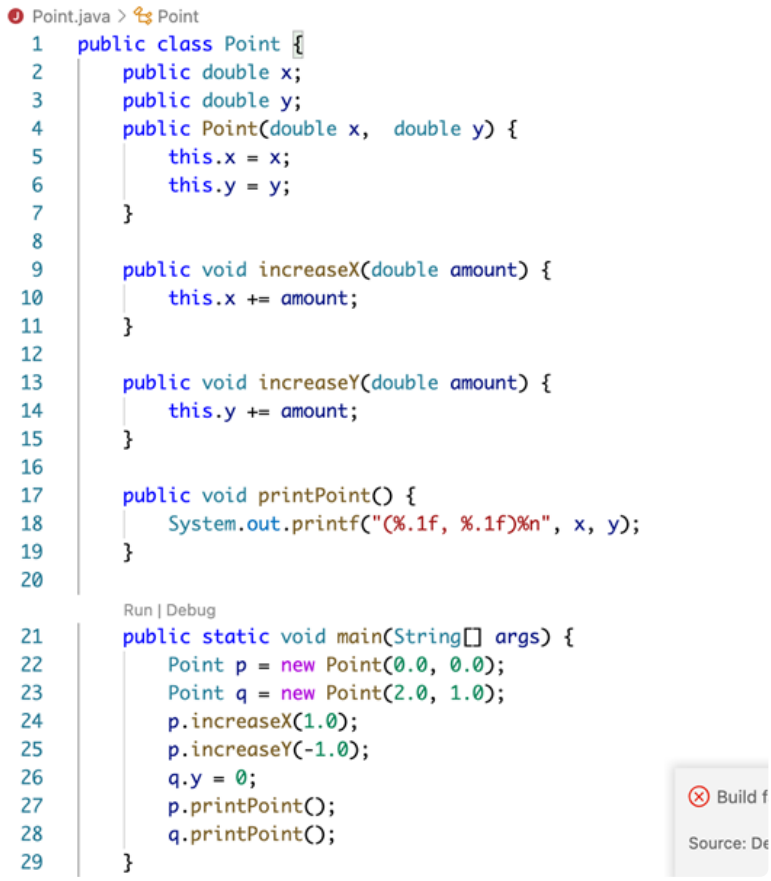
2

What is the best place to find reliable information about how a method works for a Java API class? *

- Reddit
- Stackoverflow
- Random googling
- Java API Documentation

3

Consider the following Point class. On which line is the constructor declared? *



- ◯ Line 1
- ◯ Line 4
- ◯ Line 21
- ◯ There is no constructor

4

Same code. When the increaseX method called on line 24 executes, what will **this** refer to? *

Point.java > Point

```
1  public class Point {
2      public double x;
3      public double y;
4      public Point(double x,  double y) {
5          this.x = x;
6          this.y = y;
7      }
8
9      public void increaseX(double amount) {
10         this.x += amount;
11     }
12
13     public void increaseY(double amount) {
14         this.y += amount;
15     }
16
17     public void printPoint() {
18         System.out.printf("(%.1f, %.1f)%n", x, y);
19     }
20
       Run | Debug
21     public static void main(String[] args) {
22         Point p = new Point(0.0, 0.0);
23         Point q = new Point(2.0, 1.0);
24         p.increaseX(1.0);
25         p.increaseY(-1.0);
26         q.y = 0;
27         p.printPoint();
28         q.printPoint();
29     }
```

Build f

Source: De

- ◯ The Point class
- ◯ The Point object that p refers to
- ◯ The Point object that q refers to
- ◯ None of the above

5

Consider the Blob class shown below as well as the BlobDriver class containing a single psvm method. What will be printed by that psvm method on line 16 of BlobDriver? *

```java
public class Blob {
    public String color;
    public String shape;
    public Blob(String color, String shape) {
        this.color = color;
        this.shape = shape;
    }

    @Override
    public boolean equals(Object obj) {
        Blob other = (Blob) obj;
        if (other.shape.equals(this.shape)) {
            return true;
        }
        return false;
    }
}
```

```java
import java.util.ArrayList;

public class BlobDriver {
    Run | Debug
    public static void main(String[] arg
        ArrayList<Blob> myBlobs = new Ar
        String[] colors = {"red", "white
        String[] shapes = {"round", "obl
        for (String color : colors) {
            for (String shape : shapes)
                Blob newBlob = new Blob(
                if (! myBlobs.contains(n
                    myBlobs.add(newBlob)
                }
            }
        }
        System.out.println(myBlobs.size(
    }
}
```

- ◯ 0
- ◯ 3
- ◯ 4
- ◯ 7
- ◯ 12

Public vs. Private

- **Public** – Can be accessed by code *outside* of the class.
- **Private** – Can *only* be accessed by code *inside* of the class.

Record.java > Record

```
1   public class Record {
2       public String displayName;
3       private int uniqueID;
4
5       public Record(String name, int id) {
6           displayName = name;
7           uniqueID = id;
8       }
9
```

PublicPrivate.java > ...

```
1   public class PublicPrivate {
        Run | Debug
2       public static void main (String[] args) {
3           Record rec = new Record("Fain", 12345);
4           System.out.println(rec.displayName);
5           System.out.println(rec.uniqueID);
6       }
7   }
```

Can access this **public** instance variable

Cannot access this **private** instance variable

The value of privacy

Suppose your entire system crashes terribly if some code is called on a negative `uniqueID`.

Record.java > Record

```
1   public class Record {
2       public String displayName;
3       private int uniqueID;
4
5       public Record(String name) {
6           displayName = name;
7       }
8
9       public void setID(int id) {
10          if (id < 0) {
11              System.out.println("Must be nonnegative");
12          }
13          else {
14              uniqueID = id;
15          }
16      }
```

`uniqueID` is private, so other code cannot directly change it

Can check for correctness in only code allowed to change `uniqueID`

(Im)mutability

- An object is **immutable** if you cannot change it after creation. Methods that change objects are called **mutators.**

- Java Strings are immutable, even though you can "append" to them. Creates a new String and assigns it every time!

```
String s = "Hello";
s += " World";
```

More like

```
String sOld = "Hello";
String sNew = "" + sOld + " World";
```

(and then get rid of `sOld`)

Static belongs to the class

- Regular instance variables and methods are called on an object.
- Static methods are called on the class, do not use any instance variables. Often utility “functions”

StaticExample.java > ...

```
1   public class StaticExample {
        Run | Debug
2       public static void main(String[] args) {
3           String s = "Hello World!";
4           System.out.println(s.split(" ")[0]);
5
6           System.out.println(Math.sqrt(4.0));
7       }
8   }
```

Note that `split` is called on a String object

Whereas `sqrt` is called on the `Math` class

PSVM: Public Static Void Main

Method that is:

- public – can call outside of class
- static – belongs to class, not an object
- void – no return value
- main – starting point for a program to run

`args` allows for command-line arguments

MainExample.java > ...

```
1   public class MainExample {
        Run | Debug
2       public static void main(String[] args) {
3           for (String s : args) {
4               System.out.println(s);
5           }
6       }
7   }
```

```
$javac MainExample.java
$java MainExample Hello World!
Hello
World!
$
```

APT and OOP, making a PSVM method

Suppose you're working on the SandwichBar APT.

```
1   public class SandwichBar {
2           public int whichOrder(String[] available, String[] orders){
3              // fill in code here
4              return 0;
5           }
6       }
```

Remember what you know about Java OOP:

- whichOrder is a regular method, need to call on an *object* of the SandwichBar class.
- whichOrder has parameters, need to supply those.
- All java programs must begin in a PSVM method.

APT and OOP, making a PSVM method

```
1   public class SandwichBar {
2           public int whichOrder(String[] available, String[] orders){
3              // fill in code here
4              return 0;
5           }
6
            Run | Debug
7           public static void main(String[] args) {
8               String[] testAvailable = { "ham", "cheese", "mustard" };
9               String[] testOrders = { "ham cheese" };
10              SandwichBar testInstance = new SandwichBar();
11              int testResult = testInstance.whichOrder(testAvailable, testOrders);
12              System.out.println(testResult);
13          }
14      }
```

PSVM method can be in the same class or in a separate “driver” class in the same directory.

Creating test parameters, using example from APT site.

Make a SandwichBar object

Call the method

Why use Classes/objects?

- Because you must in Java
- Formal specification for complex data structures
- Convenience and ease of correct programming
- Composition, Interfaces, & Implementations, Extending & Inheritance – More later!

It’s ok to not be fully “convinced” yet. But OOP has proven itself to be a powerful paradigm for designing complex scalable software.