Elementary Programming

EECS1021:
Object Oriented Programming:
from Sensors to Actuators
Winter 2019

CHEN-WEI WANG

Learning Outcomes

- Learn *ingredients* of elementary programming:
  - data types [numbers, characters, strings]
  - literal values
  - constants
  - variables
  - operators [arithmetic, relational]
  - expressions
  - input and output
- Given a problem:
  - First, plan how you would solve it mathematically.
  - Then, *Implement* your solution by writing a Java program.

Entry Point of Execution: the “main” Method

For now, all your programming exercises will be defined within the body of the *main* method.

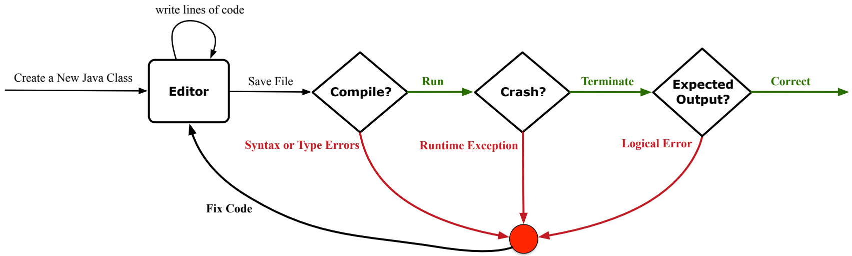
```
public class MyClass {
  public static void main(String[] args) {
    /* Your programming solution is defined here. */
  }
}
```

The *main* method is treated by Java as the *starting point* of executing your program.

Sequential Execution:

The execution starts with the first line in the *main* method, proceed line by line, from top to bottom, until there are no more lines to execute, then it *terminates*.

Development Process



Compile Time vs. Run Time

- These terms refer to two stages of developing your program.
- $\boxed{\textit{Compile time}}$: when editing programs in Eclipse.
  - There are two kinds of *compile-time errors*:
  - *Syntax errors*: your program does not conform to Java's grammar.
    - e.g., missing the semicolon, curly braces, or round parentheses
    - Java syntax is defined in the Java language specification.
  - *Type errors*: your program manipulates data in an inconsistent way
    e.g., `"York" * 23` [∵ multiplication is only for numbers]
- $\boxed{\textit{Run time}}$ is when executing/running the *main* method.
  - *Exceptions*: your program crashes and terminates *abnormally*
    - e.g., `ArithmeticException` (e.g., `10 / 0`), `ArrayIndexOutOfBoundException`, `NullPointerException`.
  - *Logical errors*: your program terminates *normally* but does not behave as expected
    e.g., calculating area of a circle with radius r using $2 \cdot \pi \cdot r$

Compile Time Errors vs. Run Time Errors

At the end of a computer lab test, if your submitted program:

- $\boxed{\text{Cannot compile}}$

  ⇒ Your program cannot even be run
  ⇒ ***Zero***!

  What you should do :
  Practice writing as many programs as possible.

- $\boxed{\text{Compiles, but run with exceptions or unexpected outputs.}}$

  ⇒ Not necessarily zero, but likely ***low marks***!

  What you should do :
  Truly understand the logic/rationale beyond programs.

Always Document Your Code

- Each important design or implementation *decision* should be carefully *documented* at the right place of your code.
- **Single-Lined** Comments: [Eclipse: `Ctrl` + `/`]

```
// This is Comment 1.
... // Some code
// This is Comment 2.
```

- **Multiple-Lined** Comments: [Eclipse: `Ctrl` + `/`]

```
/* This is Line 1 of Comment 1.
 */
... // Some code
/* This is Line 1 of Comment 2.
 * This is Line 2 of Comment 2.
 * This is Line 3 of Comment 2.
 */
```

- Comments **do not affect** the runtime behaviour of programs.
- Comments are **only interpreted by** human developers.
  ⇒ Useful for ***revision*** and ***extension***.

Literals (1)

A *literal* is a *constant value* that appears directly in a program.

1. *Character* Literals
   - A single character enclosed within a pair of single quotes
   - e.g., `'a'`, `'1'`, `'*'`, `'('`, `' '`
   - It is invalid to write an empty character: `''`
2. *String* Literals
   - A (possibly empty) sequence of characters enclosed within a pair of double quotes
   - e.g., `""`, `"a"`, `"York"`, `"*#@$"`, `" "`
3. *Integer* Literals
   - A non-empty sequence of numerical digits
   - e.g., 0, -123, 123, 23943
4. *Floating-Point* Literals
   - Specified using a combination of an integral part and a fractional part, separated by a decimal point, or using the scientific notation
   - e.g., 0.3334, 12.0, 34.298, 1.23456E+2 (for 1.23456×10^{2}), 1.23456E-2 (for 1.23456×10^{-2})

Operations

An *operation* refers to the process of applying an *operator* to its *operand*(s).

1. *Numerical* Operations [results are numbers]

   e.g., `1.1 + 0.34`

   e.g., `13 / 4` [quotient: `3`]

   e.g., `13.0 / 4` [precision: `3.25`]

   e.g., `13 % 4` [remainder: `1`]

   e.g., `-45`

   e.g., `-1 * 45`

2. *Relational* Operations [results are true or false]

   e.g., `3 <= 4` [*true*]

   e.g., `5 < 3` [*false*]

   e.g., `56 == 34` [*false*]

3. *String* Concatenations [results are strings]

   e.g., ``` ``York'' + `` '' + ``University'' ``` is equivalent to ``` ``York University'' ```

Java Data Types

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

1. *Integer* Type

`byte`	8 bits	$-128, \ldots, -1, 0, 1, \ldots, 2^7 - 1]$
`short`	16 bits	$[-2^{15},\ 2^{15} - 1]$
`int`	32 bits	$[-2^{31},\ 2^{31} - 1]$
`long`	64 bits	$[-2^{63},\ 2^{63} - 1]$

2. *Floating-Point Number* Type

`float`	32 bits
`double`	64 bits

3. *Character* Type

   `char`: the set of single characters

4. *String* Type

   `String`: the set of all possible character sequences

Declaring a variable `v` *to be of type* `T` *constrains* `v` *to store* ***only*** *those values defined in* `T`*.*

Assignments

An *assignment* designates a value for a variable, or initializes a *named constant*.

That is, an assignment replaces the *old value* stored in a placeholder with a *new value*.

An *assignment* is done using the assignment operator (=).

An *assignment operator* has two operands:

- The *left* operand is called the *assignment target*
  which must be a variable name
- The *right* operand is called the *assignment source*
  which must be an expression whose type is *compatible* with the declared type of *assignment target*

e.g., This is a *valid* assignment:

```
String name1 = ``Heeyeon'';
```

e.g., This is an *invalid* assignment:

```
String name1 = (1 + 2) * (23 % 5);
```

Named Constants vs. Variables

A *named constant* or a *variable*:

- Is an identifier that refers to a *placeholder*
- Must be declared with its *type* (of stored value) before use:

```
final double PI = 3.14159; /* a named constant */
double radius; /* an uninitialized variable */
```

- Can only store a value that is *compatible with its declared type*

However, a *named constant* and a *variable* are different in that:

- A named constant must be *initialized*, and cannot change its stored value.
- A variable may change its stored value as needed.

Expressions (1)

An *expression* is a composition of *operations*.

An expression may be:

- *Type Correct*: for each constituent operation, types of the *operands* are compatible with the corresponding *operator*.

  e.g., `(1 + 2) * (23 % 5)`

  e.g., `''Hello '' + ''world''`

- *Not Type Correct*

  e.g., `''46'' % ''4''`

  e.g., `(''YORK '' + ''University'') * (46 % 4)`

  - `''YORK''` and `''University''` are both strings
    ∴ LHS of `*` is *type correct* and is of type `String`
  - `46` and `4` are both integers
    ∴ RHS of `%` is *type correct* and is of type `int`
  - Types of LHS and RHS of `*` are not compatible
    ∴ Overall the expression (i.e., a multiplication) is *not type correct*

Multiple Executions of Same Print Statement

Executing *the same print statement* multiple times *may or may not* output different messages to the console.

e.g., Print statements involving literals or named constants only:

```
final double PI = 3.14; /* a named double constant */
System.out.println("Pi is " + PI); /* str. lit. and num. const. */
System.out.println("Pi is " + PI);
```

e.g., Print statements involving variables:

```
String msg = "Counter value is "; /* a string variable */
int counter = 1; /* an integer variable */
System.out.println(msg + counter);
System.out.println(msg + counter);
counter = 2; /* re-assignment changes variable's stored value */
System.out.println(msg + counter);
```

Case Study 1: Compute the Area of a Circle

Problem: declare two variables radius and area, initialize radius as 20, compute the value of area accordingly, and print out the value of area.

```
public class ComputeArea {
 public static void main(String[] args) {
   double radius; /* Declare radius */
   double area; /* Declare area */
   /* Assign a radius */
   radius = 20; /* assign value to radius */
   /* Compute area */
   area = radius * radius * 3.14159;
   /* Display results */
   System.out.print("The area of circle with radius ");
   System.out.println(radius + " is " + area);
 }
}
```

It would be more flexible if we can let the user specify the inputs via keyboard!

Input and Output

Reading input from the console enables *user interaction*.

```
import java.util.Scanner;
public class ComputeAreaWithConsoleInput {
 public static void main(String[] args) {
   /* Create a Scanner object */
   Scanner input = new Scanner(System.in);
   /* Prompt the user to enter a radius */
   System.out.print("Enter a number for radius: ");
   double radius = input.nextDouble();
   /* Compute area */
   final double PI = 3.14169; /* a named constant for π */
   double area = PI * radius * radius; /* area = πr² */
   /* Display result */
   System.out.println(
    "Area for circle of radius " + radius + " is " + area);
 }
}
```

Useful Methods for Scanner

- *nextInt()* which reads an integer value from the keyboard
- *nextDouble()* which reads a double value from the keyboard
- *nextLine()* which reads a string value from the keyboard

Variables: Common Mistakes (1)

Mistake: The same variable is declared more than once.

```
int counter = 1;
int counter = 2;
```

Fix 1: Assign the new value to the same variable.

```
int counter = 1;
counter = 2;
```

Fix 2: Declare a new variable (with a different name).

```
int counter = 1;
int counter2 = 2;
```

Which fix to adopt depends on what you need!

Variables: Common Mistakes (2)

Mistake: A variable is used before it is declared.

```
System.out.println("Counter value is " + counter);
int counter = 1;
counter = 2;
System.out.println("Counter value is " + counter);
```

Fix: Move a variable's declaration before its very first usage.

```
int counter = 1;
System.out.println("Counter value is " + counter);
counter = 2;
System.out.println("Counter value is " + counter);
```

Remember, Java programs are always executed, line by line, *from top to bottom*.

Case Study 2: Display Time

Problem: prompt the user for an integer value of seconds, divide that value into minutes and remaining seconds, and print the results. For example, given an input 200, output “200 seconds is 3 minutes and 20 seconds”.

```java
import java.util.Scanner;
public class DisplayTime {
 public static void main(String[] args) {
   Scanner input = new Scanner(System.in);
   /* Prompt the user for input */
   System.out.print("Enter an integer for seconds: ");
   int seconds = input.nextInt();
   int minutes = seconds / 60; /* minutes */
   int remainingSeconds = seconds % 60; /* seconds */
   System.out.print(seconds + " seconds is ");
   System.out.print(" minutes and ");
   System.out.println(remainingSeconds + " seconds");
  }
}
```

Where May Assignment Sources Come From?

In `tar = src`, the *assignment source* `src` may come from:

- A literal

```
int i = 23;
```

- A variable

```
int i = 23;
int j = i;
```

- An expression involving literals and variables

```
int i = 23;
int j = i * 2;
```

- An input from the user

```
Scanner input = new Scanner(System.in);
int i = input.nextInt();
int j = i * 2;
```

Numerical Type Conversion: Coercion

- *Implicit* and *automatic* type conversion
- Java *automatically* converts an integer value to a real number when necessary (which adds a fractional part).

```
double value1 = 3 * 4.5;   /* 3 coerced to 3.0 */
double value2 = 7 + 2;  /* result of + coerced to 9.0 */
```

- However, does the following work?

```
int value1 = 3 * 4.5;
```

  - RHS evaluates to `13.5` due to coercion.
  - LHS declares a variable for storing integers (with no fractional parts).

∴ Not compatible [***compile-time error***]
⇒ Need a way to "truncate" the fractional part!

Numerical Type Conversion: Casting

- *Explicit* and *manual* type conversion
- **Usage 1**: To assign a real number to an integer variable, you need to use explicit *casting* (which throws off the fractional part).

```
int value3 = (int) 3.1415926;
```

- **Usage 2:** You may also use explicit *casting* to force precision.

  -
    ```
    System.out.println(1 / 2);  /* 0 */
    ```
    ∵ When both operands are integers, division evaluates to quotient.

  -
    ```
    System.out.println( ((double) 1) / 2 ); /* 0.5 */
    System.out.println( 1 / ((double) 2) ); /* 0.5 */
    System.out.println( ((double) 1) / ((double) 2) ); /* 0.5 */
    ```
    ∵ Either or both of the integers operands are cast to `double` type

  -
    ```
    System.out.println((double) 1 / 2);  /* 0.5 */
    ```
    ∵ Casting has *higher precedence* than arithmetic operation.

  -
    ```
    System.out.println((double) (1 / 2));  /* 0.0 */
    ```
    ∵ Order of evaluating division is forced, via parentheses, to occur first.

Numerical Type Conversion: Exercise

Consider the following Java code:

```java
double d1 = 3.1415926;
System.out.println("d1 is " + d1);
double d2 = d1;
System.out.println("d2 is " + d2);
int i1 = (int) d1;
System.out.println("i1 is " + i1);
d2 = i1 * 5;
System.out.println("d2 is " + d2);
```

Write the **exact** output to the console.

```
d1 is 3.1415926
d2 is 3.1415926
i1 is 3
d2 is 15.0
```

Expressions (2.1)

Consider the following Java code, is each line type-correct? Why and Why Not?

```
double d1 = 23;
int i1 = 23.6;
String s1 = ' ';
char c1 = " ";
```

- **L1**: YES [coercion]
- **L2**: NO [cast assignment source, i.e., `(int) 23.6`]
- **L3**: NO [cannot assign char to string]
- **L4**: NO [cannot assign string to char]

Expressions (2.2)

Consider the following Java code, is each line type-correct? Why and Why Not?

```java
int i1 = (int) 23.6;
double d1 = i1 * 3;
String s1 = "La ";
String s2 = s1 + "La Land";
i1 = (s2 * d1) + (i1 + d1);
```

- **L1**: YES [proper cast]
- **L2**: YES [coercion]
- **L3**: YES [string literal assigned to string var.]
- **L4**: YES [type-correct string concat. assigned to string var.]
- **L5**: NO [string $\times$ number is undefined]

Augmented Assignments

- You very often want to increment or decrement the value of a variable by some amount.

```
 balance = balance + deposit;
 balance = balance - withdraw;
```

- Java supports special operators for these:

```
balance += deposit;
balance -= withdraw;
```

- Java supports operators for incrementing or decrementing by 1:

```
i ++; j --;
```

- *Confusingly*, these increment/decrement assignment operators can be used in assignments:

```
int i = 0; int j = 0; int k = 0;
k = i ++; /* k is assigned to i's old value */
k = ++ j; /* k is assigned to j's new value */
```

Literals (2)

Q. Outputs of `System.out.println('a')` versus `System.out.println("a")`? [SAME]

Q. Result of comparison `"a" == 'a'`? [TYPE ERROR]

- Literal `"a"` is a string (i.e., *character sequence*) that consists of a single character.
- Literal `'a'` is a single *character*.

∴ You cannot compare a character sequence with a character.

Escape Sequences

An *escape sequence* denotes a single character.

- Specified as a *backslash* (\) followed by a *single character*
  - e.g., `\t`, `\n`, `\'`, `\"`, `\\`
- *Does not mean literally*, but means specially to Java compiler
  - `\t` means a tab
  - `\n` means a new line
  - `\\` means a back slash
  - `\'` means a single quote
  - `\"` means a double quote
- May use an *escape sequence* in a character or string literal:
  - `'''` [INVALID; need to escape `'`]
  - `'\''` [VALID]
  - `'"'` [VALID; no need to escape `"`]
  - `"""` [INVALID; need to escape `"`]
  - `"\""` [VALID]
  - `"'"` [VALID; no need to escape `'`]
  - `"\n\t\""` [VALID]

`print` vs. `println`

Executing `System.out.println(someString)` is the same as executing `System.out.print(someString + "\n")`.

- e.g.,

```
System.out.print("Hello");
System.out.print("World");
```

```
HelloWorld
```

- e.g.,

```
System.out.println("Hello");
System.out.println("World");
```

```
Hello
World
```

Identifiers & Naming Conventions

- Identifiers are *names* for identifying Java elements: *classes*, *methods*, *constants*, and *variables*.
- An identifier:
  - Is an arbitrarily long sequence of characters: letters, digits, underscores (_), and dollar signs (`$`).
  - Must start with a letter, an underscore, or a dollar sign.
  - Must not start with a digit.
  - Cannot clash with reserved words (e.g., `class`, `if`, `for`, `int`).
- *Valid* ids: `$2`, `Welcome`, `name`, `_name`, `YORK_University`
- *Invalid* ids: `2name`, `+YORK`, `Toronto@Canada`
- More conventions:
  - Class names are compound words, all capitalized: e.g., `Tester`, `HelloWorld`, `TicTacToe`, `MagicCardGame`
  - Variable and method names are like class names, except 1st word is all lower cases: e.g, `main`, `firstName`, `averageOfClass`
  - Constant names are underscore-separated upper cases: e.g., `PI`, `USD_IN_WON`

Beyond this lecture. . .

- Create a *tester* in Eclipse.
- Try out the examples give in the slides.
- See `https://docs.oracle.com/javase/tutorial/java/nutsandbolts/datatypes.html` for more information about data types in Java.

Index (1)

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Selections

EECS1021:
Object Oriented Programming:
from Sensors to Actuators
Winter 2019

CHEN-WEI WANG

Learning Outcomes

- The Boolean Data Type
- `if` Statement
- Compound vs. Primitive Statement
- Common Errors and Pitfalls
- Logical Operations

Motivating Examples (1.1)

```
1  import java.util.Scanner;
2  public class ComputeArea {
3    public static void main(String[] args) {
4      Scanner input = new Scanner(System.in);
5      final double PI = 3.14;
6      System.out.println("Enter the radius of a circle:");
7      double radiusFromUser = input.nextDouble();
8      double area = radiusFromUser * radiusFromUser * PI;
9      System.out.print("Circle with radius " + radiusFromUser);
10     System.out.println(" has an area of " + area);
11   }
12 }
```

- When the above Java class is run as a Java Application, **Line 4** is executed first, followed by executing **Line 5**, . . . , and ended with executing **Line 10**.
- In **Line 7**, the radius value comes from the user. Any problems?

Motivating Examples (1.2)

- If the user enters a positive radius value as expected:

```
Enter the radius of a circle:
3
Circle with radius 3.0 has an area of 28.26
```

- However, if the user enters a negative radius value:

```
Enter the radius of a circle:
-3
Circle with radius -3.0 has an area of 28.26
```

  In this case, the area should *not* have been calculated!

- We need a mechanism to take *selective actions*:

  Act differently in response to *valid* and *invalid* input values.

Motivating Examples (2.1)

Problem: Take an integer value from the user, then output a message indicating if the number is negative, zero, or positive.

- Here is an example run of the program:

```
Enter a number:
5
You just entered a positive number.
```

- Here is another example run of the program:

```
Enter a number:
-5
You just entered a negative number.
```

- Your solution program must accommodate *all* possibilities!

Motivating Examples (2.2)

- So far, you only learned about writing programs that are executed line by line, top to bottom.
- In general, we need a mechanism to allow the program to:
  - Check a list of *conditions*; and
  - *Branch* its execution accordingly.
- e.g., To solve the above problem, we have 3 possible branches:

1. *If* the user input is negative, then we execute the first branch that prints `You just entered a negative number`.
2. *If* the user input is zero, then we execute the second branch that prints `You just entered zero`.
3. *If* the user input is positive, then we execute the third branch that prints `You just entered a positive number`.

The `boolean` Data Type

- A (data) type denotes a set of related *runtime values*.
- We need a *data type* whose values suggest either a condition *holds*, or it *does not hold*, so that we can take selective actions.
- The Java *boolean* type consists of 2 **literal values**: *true*, *false*
- All *relational expressions* have the boolean type.

Math Symbol	Java Operator	Example (*r* is 5)	Result
$\leq$	`<=`	`r <= 5`	*true*
$\geq$	`>=`	`r >= 5`	*true*
$=$	`==`	`r == 5`	*true*
$<$	`<`	`r < 5`	*false*
$>$	`>`	`r > 5`	*false*
$\neq$	`!=`	`r != 5`	*false*

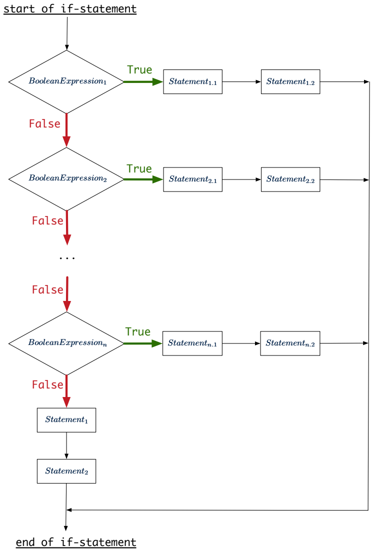
Note. You may do the following rewritings:

```
◦ x <= y        x > y        x != y       x == y
◦ !(x > y)      !(x <= y)    !(x == y)    !(x != y)
```

Syntax of `if` Statement

```
if ( BooleanExpression_1 ) { /* Mandatory */
  Statement_1.1; Statement_2.1;
}
else if ( BooleanExpression_2 ) { /* Optional */
  Statement_2.1; Statement_2.2;
}
... /* as many else-if branches as you like */
else if ( BooleanExpression_n ) { /* Optional */
  Statement_n.1; Statement_n.2;
}
else { /* Optional */
  /* when all previous branching conditions are false */
  Statement_1; Statement_2;
}
```

Semantics of `if` Statement (1.1)



Semantics of `if` Statement (1.2)

Consider a *single `if` statement* as consisting of:

- An `if` branch
- A (possibly empty) list of `else if` branches
- An optional `else` branch

At *runtime*:

- Branches of the `if` statement are *executed* from top to bottom.
- We only evaluate the **condition** of a branch if those conditions of its **preceding branches** evaluate to *false*.
- The **first** branch whose **condition** evaluates to *true* gets its body (i.e., code wrapped within { and }) *executed*.
    - After this execution, all *later* branches are *ignored*.

Semantics of `if` Statement (2.1.1)

Only **first** satisfying branch *executed*; later branches *ignored*.

```
int i = -4;
if(i < 0) {
  System.out.println("i is negative");
}
else if(i < 10) {
  System.out.println("i is less than than 10");
}
else if(i == 10) {
  System.out.println("i is equal to 10");
}
else {
  System.out.println("i is greater than 10");
}
```

```
i is negative
```

Semantics of `if` Statement (2.1.2)

Only **first** satisfying branch *executed*; later branches *ignored*.

```
int i = 5;
if(i < 0) {
  System.out.println("i is negative");
}
else if(i < 10) {
  System.out.println("i is less than than 10");
}
else if(i == 10) {
  System.out.println("i is equal to 10");
}
else {
  System.out.println("i is greater than 10");
}
```

```
i is less than 10
```

Semantics of `if` Statement (2.2)

No satisfying branches, and no `else` part, then *nothing* is executed.

```
int i = 12;
if(i < 0) {
  System.out.println("i is negative");
}
else if(i < 10) {
  System.out.println("i is less than than 10");
}
else if(i == 10) {
  System.out.println("i is equal to 10");
}
```

Semantics of `if` Statement (2.3)

No satisfying branches, then `else` part, if there, is *executed*.

```
int i = 12;
if(i < 0) {
  System.out.println("i is negative");
}
else if(i < 10) {
  System.out.println("i is less than than 10");
}
else if(i == 10) {
  System.out.println("i is equal to 10");
}
else {
  System.out.println("i is greater than 10");
}
```

```
i is greater than 10
```

Two-Way `if` Statement without `else` Part

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("Area for the circle of is " + area);
}
```

An `if` statement with the missing `else` part is equivalent to an `if` statement with an `else` part that does nothing.

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("Area for the circle of is " + area);
}
else {
  /* Do nothing. */
}
```

Multi-Way `if` Statement with `else` Part

```java
if (score >= 80.0) {
  System.out.println("A");
}
else if (score >= 70.0) {
  System.out.println("B");
}
else if (score >= 60.0) {
  System.out.println("C");
}
else {
  System.out.println("F");
}
```

```java
if (score >= 80.0) {
  System.out.println("A"); }
else { /* score < 80.0 */
  if (score >= 70.0) {
    System.out.println("B"); }
  else { /* score < 70.0 */
    if (score >= 60.0) {
      System.out.println("C"); }
    else { /* score < 60.0 */
      System.out.println("F");
    }
  }
}
```

Exercise: Draw the corresponding flow charts for both programs. Convince yourself that they are equivalent.

Multi-Way `if` Statement without `else` Part

```
String lettGrade = "F";
if (score >= 80.0) {
  letterGrade = "A";
}
else if (score >= 70.0) {
  letterGrade = "B";
}
else if (score >= 60.0) {
  letterGrade = "C";
}
```

In this case, since we already assign an initial, default value `"F"` to variable `letterGrade`, so when all the branch conditions evaluate to *false*, then the default value is kept.

Compare the above example with the example in slide 53.

Case Study: Error Handling of Input Radius (1)

Problem: Prompt the user for the radius value of a circle. Print an error message if input number is negative; otherwise, print the calculated area.

```
public class ComputeArea {
 public static void main(String[] args) {
   System.out.println("Enter a radius value:");
   Scanner input = new Scanner(System.in);
   double radius = input.nextDouble();
   final double PI = 3.14159;
   if (radius < 0) { /* condition of invalid inputs */
     System.out.println("Error: Negative radius value!");
   }
   else { /* implicit:  !(radius < 0), or radius >= 0 */
     double area = radius * radius * PI;
     System.out.println("Area is " + area);
   }
 }
}
```

Case Study: Error Handling of Input Radius (2)

The same problem can be solved by checking the *condition* of valid inputs first.

```
public class ComputeArea2 {
 public static void main(String[] args) {
  System.out.println("Enter a radius value:");
  Scanner input = new Scanner(System.in);
  double radius = input.nextDouble();
  final double PI = 3.14159;
  if (radius >= 0) { /* condition of valid inputs */
   double area = radius * radius * PI;
   System.out.println("Area is " + area);
  }
  else { /* implicit:  !(radius >= 0), or radius < 0 */
   System.out.println("Error: Negative radius value!");
  }
 }
}
```

One `if` Stmt vs. Multiple `if` Stmts (1)

Question: Do these two programs behave same at runtime?

```
if(i >= 3) {System.out.println("i is >= 3");}
else if(i <= 8) {System.out.println("i is <= 8");}
```

```
if(i >= 3) {System.out.println("i is >= 3");}
if(i <= 8) {System.out.println("i is <= 8");}
```

Question: Do these two programs behave same at runtime?

```
if(i <= 3) {System.out.println("i is <= 3");}
else if(i >= 8) {System.out.println("i is >= 8");}
```

```
if(i <= 3) {System.out.println("i is <= 3");}
if(i >= 8) {System.out.println("i is >= 8");}
```

One `if` Stmt vs. Multiple `if` Stmts (2)

```
int i = 5;
if(i >= 3) {System.out.println("i is >= 3");}
else if(i <= 8) {System.out.println("i is <= 8");}
```

```
i is >= 3
```

```
int i = 5;
if(i >= 3) {System.out.println("i is >= 3");}
if(i <= 8) {System.out.println("i is <= 8");}
```

```
i is >= 3
i is <= 8
```

Two versions behave *differently* because the two conditions $i >= 3$ and $i <= 8$ *may* be satisfied simultaneously.

One `if` Stmt vs. Multiple `if` Stmts (3)

```
int i = 2;
if(i <= 3) {System.out.println("i is <= 3");}
else if(i >= 8) {System.out.println("i is >= 8");}
```

```
i is <= 3
```

```
int i = 2;
if(i <= 3) {System.out.println("i is <= 3");}
if(i >= 8) {System.out.println("i is >= 8");}
```

```
i is <= 3
```

Two versions behave *the same* because the two conditions $i <= 3$ and $i >= 8$ *cannot* be satisfied simultaneously.

Scope of Variables (1)

When you declare a variable, there is a limited *scope* where the variable can be used.

- If the variable is declared directly under the `main` method, then all lines of code (including branches of `if` statements) may either *re-assign* a new value to it or *use* its value.

```
public static void main(String[] args) {
  int i = input.nextInt();
  System.out.println("i is " + i);
  if (i > 0) {
    i = i * 3; /* both use and re-assignment, why? */
  }
  else {
    i = i * -3; /* both use and re-assignment, why? */
  }
  System.out.println("3 * |i| is " + i);
}
```

Scope of Variables (2.1)

- If the variable is declared under an `if` branch, an `else if` branch, or an `else` branch, then only lines of code appearing within that branch (i.e., its body) may either *re-assign* a new value to it or *use* its value.

```
public static void main(String[] args) {
  int i = input.nextInt();
  if (i > 0) {
    int j = i * 3; /* a new variable j */
    if (j > 10) { ... }
  }
  else {
    int j = i * -3; /* a new variable also called j */
    if (j < 10) { ... }
  }
}
```

Scope of Variables (2.2)

- A variable declared under an `if` branch, an `else if` branch, or an `else` branch, cannot be *re-assigned* or *used* outside its scope.

```
public static void main(String[] args) {
  int i = input.nextInt();
  if (i > 0) {
    int j = i * 3; /* a new variable j */
    if (j > 10) { ... }
  }
  else {
    int k = i * -3; /* a new variable also called j */
    if ( j  < k) { ... }     ×
  }
}
```

Scope of Variables (2.3)

- A variable declared under an `if` branch, `else if` branch, or `else` branch, cannot be *re-assigned* or *used* outside its scope.

```
 1 public static void main(String[] args) {
 2   int i = input.nextInt();
 3   if (i > 0) {
 4     int j = i * 3; /* a new variable j */
 5     if (j > 10) { ... }
 6   }
 7   else {
 8     int j = i * -3; /* a new variable also called j */
 9     if (j < 10) { ... }
10   }
11   System.out.println("i * j is " + (i * j));     ×
12 }
```

  - A variable ***cannot*** be referred to outside its declared scope. [e.g., illegal use of `j` at **L11**]
  - A variable ***can*** be used:
    - within its declared scope [e.g., use of `i` at **L11**]
    - within sub-scopes of its declared scope [e.g., use of `i` at **L4**, **L8**]

Primitive Statement vs. Compound Statement

- A *statement* is a block of Java code that modifies value(s) of some variable(s).
- An assignment (=) statement is a *primitive statement*:

  It only modifies its left-hand-side (LHS) variable.
- An `if` statement is a *compound statement*:

  Each of its branches may modify more than one variables via other statements (e.g., assignments, `if` statements).

Compound `if` Statement: Example

```
int x = input.nextInt();
int y = 0;
if (x >= 0) {
  System.out.println("x is positive");
  if (x > 10) { y = x * 2; }
  else if (x < 10) { y = x % 2; }
  else { y = x * x; }
}
else { /* x < 0 */
  System.out.println("x is negative");
  if(x < -5) { y = -x; }
}
```

Exercise: Draw a flow chart for the above compound statement.

Logical Operators

- *Logical* operators are used to create *compound* Boolean expressions.
  - Similar to *arithmetic* operators for creating compound number expressions.
  - *Logical* operators can combine Boolean expressions that are built using the *relational* operators.

    e.g., `1 <= x && x <= 10`

    e.g., `x < 1 || x > 10`
- We consider three logical operators:

Java Operator	Description	Meaning
`!`	logical negation	not
`&&`	logical conjunction	and
`||`	logical disjunction	or

Logical Negation

- Logical *negation* is a *unary* operator (i.e., one operand being a Boolean expression).
- The result is the "negated" value of its operand.

Operand `op`	`!op`
true	*false*
false	*true*

```
double radius = input.nextDouble();
boolean isPositive = radius > 0;
if (!isPositive) {/* not the case that isPositive is true */
  System.out.println("Error: radius value must be positive.");
}
else {
  System.out.println("Area is " + radius * radius * PI);
}
```

Logical Conjunction

- Logical *conjunction* is a *binary* operator (i.e., two operands, each being a Boolean expression).
- The conjunction is *true* only when both operands are *true*.
- If one of the operands is *false*, their conjunction is *false*.

Left Operand `op1`	Right Operand `op2`	`op1 && op2`
true	*true*	*true*
true	*false*	*false*
false	*true*	*false*
false	*false*	*false*

```
int age = input.nextInt();
boolean isOldEnough = age >= 45;
boolean isNotTooOld = age < 65
if (!isOldENough) { /* young */ }
else if (isOldEnough && isNotTooOld) { /* middle-aged */ }
else { /* senior */ }
```

Logical Disjunction

- Logical *disjunction* is a *binary* operator (i.e., two operands, each being a Boolean expression).
- The disjunction is *false* only when both operands are *false*.
- If one of the operands is *true*, their disjunction is *true*.

Left Operand `op1`	Right Operand `op2`	`op1 || op2`
false	*false*	*false*
true	*false*	*true*
false	*true*	*true*
true	*true*	*true*

```
int age = input.nextInt();
boolean isSenior = age >= 65;
boolean isChild = age < 18
if (isSenior || isChild) { /* discount */ }
else { /* no discount */ }
```

Logical Laws (1)

- The *negation* of a strict inequality is a non-strict inequality.

Relation	Negation	Equivalence
`i > j`	`!(i > j)`	`i <= j`
`i >= j`	`!(i >= j)`	`i < j`
`i < j`	`!(i < j)`	`i >= j`
`i <= j`	`!(i <= j)`	`i > j`

- e.g.,

```
if( i > j ) {
  /* Action 1 */
}
else { /* !(i > j) */
  /* Action 2 */
}
```

equivalent to

```
if( i <= j ) {
  /* Action 2 */
}
else { /* !(i <= j) */
  /* Action 1 */
}
```

  - Action 1 is executed when $i > j$
  - Action 2 is executed when $i <= j$.

Logical Laws (2.1)

Say we have two Boolean expressions B_1 and B_2:

- What does `!(B1 && B2)` mean?

  It is **not** the case that both B_1 and B_2 are *true*.
- What does `!B1 || !B2` mean?

  It is either B_1 is *false*, B_2 is *false*, or both are *false*.
- Both expressions are equivalent! [proved by the truth table]

B_1	B_2	`!(B1 && B2)`	`!B1 || !B2`
true	*true*	*false*	*false*
true	*false*	*true*	*true*
false	*true*	*true*	*true*
false	*false*	*true*	*true*

Logical Laws (2.2)

```
if(0 <= i && i <= 10) { /* Action 1 */ }
else { /* Action 2 */ }
```

- **When** is *Action 2* executed? `i < 0 || i > 10`

```
if(i < 0 && false) { /* Action 1 */ }
else { /* Action 2 */ }
```

- **When** is *Action 1* executed? *false*
- **When** is *Action 2* executed? *true* (i.e., `i >= 0 || true`)

```
if(i < 0 && i > 10) { /* Action 1 */ }
else { /* Action 2 */ }
```

- **When** is *Action 1* executed? *false*
- **When** is *Action 2* executed? *true* (i.e., `i >= 0 || i <= 10`)

Lesson: Be careful not to write branching conditions that use `&&` but always evaluate to *false*.

Logical Laws (3.1)

Say we have two Boolean expressions B_1 and B_2:

- What does `!(B1 || B2)` ($!(B_1 \; || \; B_2)$) mean?

  It is **not** the case that either B_1 is *true*, B_2 is *true*, or both are *true*.

- What does $!B_1 \; \&\& \; !B_2$ mean?

  Both B_1 and B_2 are *false*.

- Both expressions are equivalent! [proved by the truth table]

B_1	B_2	$!(B_1 \; \|\| \; B_2)$	$!B_1 \; \&\& \; !B_2$
true	*true*	*false*	*false*
true	*false*	*false*	*false*
false	*true*	*false*	*false*
false	*false*	*true*	*true*

Logical Laws (3.2)

```
if(i < 0 || i > 10) { /* Action 1 */ }
else { /* Action 2 */ }
```

- **When** is *Action 2* executed? `0 <= i && i <= 10`

```
if(i < 0 || true) { /* Action 1 */ }
else { /* Action 2 */ }
```

- **When** is *Action 1* executed? *true*
- **When** is *Action 2* executed? *false* (i.e., `i >= 0 && false`)

```
if(i < 10 || i >= 10) { /* Action 1 */ }
else { /* Action 2 */ }
```

- **When** is *Action 1* executed? *true*
- **When** is *Action 2* executed? *false* (i.e., `i >= 10 && i < 10`)

Lesson: Be careful not to write branching conditions that use `||` but always evaluate to *true*.

Operator Precedence

- Operators with *higher* precedence are evaluated before those with *lower* precedence.

  e.g., `2 + 3 * 5`

- For the three *logical operators*, negation (`!`) has the highest precedence, then conjunction (`&&`), then disjunction (`||`).

  e.g., `true || true && false` means

  - `true || (true && false)`, rather than
  - `(true || true) && false`

- When unsure, use *parentheses* to force the precedence.

Operator Associativity

- When operators with the *same precedence* are grouped together, we evaluate them from left to right.

  e.g., `1 + 2 - 3` means

  `((1 + 2) - 3)`

  e.g., `false || true || false` means

  `((false || true) || false)`

Short-Circuit Evaluation (1)

- Both *Logical operators* && and || evaluate from left to right.
- Operator && continues to evaluate only when operands so far evaluate to *true*.

```
if (x != 0 && y / x > 2) {
  /* do something */
}
else {
  /* print error */ }
```

- Operator || continues to evaluate only when operands so far evaluate to *false*.

```
if (x == 0 || y / x <= 2) {
  /* print error */
}
else {
  /* do something */ }
```

Short-Circuit Evaluation (2)

- Both *Logical operators* && and || evaluate from left to right.
- Short-Circuit Evaluation is not exploited: crash when `x == 0`

```
if (y / x > 2 && x != 0) {
  /* do something */
}
else {
  /* print error */ }
```

- Short-Circuit Evaluation is not exploited: crash when `x == 0`

```
if (y / x <= 2 || x == 0) {
  /* print error */
}
else {
  /* do something */ }
```

Common Error 1: Independent `if` Statements with Overlapping Conditions

```
if (marks >= 80) {
  System.out.println("A");
}
if (marks >= 70) {
  System.out.println("B");
}
if (marks >= 60) {
  System.out.println("C");
}
else {
  System.out.println("F");
}
/* Consider marks = 84 */
```

```
if (marks >= 80) {
  System.out.println("A");
}
else if (marks >= 70) {
  System.out.println("B");
}
else if (marks >= 60) {
  System.out.println("C");
}
else {
  System.out.println("F");
}
/* Consider marks = 84 */
```

- *Conditions* in a list of `if` statements are checked *independently*.
- In a single `if` statement, *only* the *first satisfying branch* is executed.

Overlapping Conditions: Exercise (1)

- Does this program always print exactly one line?

```
if(x < 0) { println("x < 0"); }
if(0 <= x && x < 10) { println("0 <= x < 10"); }
if(10 <= x && x < 20) { println("10 <= x < 20"); }
if(x >= 20) { println("x >= 20"); }
```

- ***Yes***, because the branching conditions for the **four** if-statements are all ***non-overlapping***.
- That is, any two of these conditions ***cannot be satisfied simultaneously***:
  - `x < 0`
  - `0 <= x && x < 10`
  - `10 <= x && x < 20`
  - `x >= 20`

Overlapping Conditions: Exercise (2)

- Does this program always print exactly one line?

```
if(x < 0) { println("x < 0"); }
else if(0 <= x && x < 10) { println("0 <= x < 10"); }
else if(10 <= x && x < 20) { println("10 <= x < 20"); }
else if(x >= 20) { println("x >= 20"); }
```

- ***Yes***, because it's a **single** if-statement:

  Only ***the first satisfying branch*** is executed.
- But, can it be simplified?

  Hint: In a single if-statement, a branch is executed only if **all earlier branching conditions** fail.

Overlapping Conditions: Exercise (3)

- This simplified version is equivalent:

```
1 if(x < 0) { println("x < 0"); }
2 else if(x < 10) { println("0 <= x < 10"); }
3 else if(x < 20) { println("10 <= x < 20"); }
4 else { println("x >= 20"); }
```

- At runtime, the 2nd condition `x < 10` at **L2** is checked only when the 1st condition at **L1** ***fails***

  (i.e., `!(x < 0)`, or equivalently, `x >= 0`).
- At runtime, the 3rd condition `x < 20` at **L3** is checked only when the 2nd condition at **L2** ***fails***

  (i.e., `!(x < 10)`, or equivalently, `x >= 10`).
- At runtime, the else (default) branch at **L4** is reached only when the 3rd condition at **L3** ***fails***

  (i.e., `!(x < 20)`, or equivalently, `x >= 20`).

General vs. Specific Boolean Conditions (1)

Two or more conditions *overlap* if they can evaluate to *true* simultaneously.

e.g., Say `marks` is declared as an integer variable:

- `marks >= 80` and `marks >= 70` overlap. [why?]
  - Values 80, 81, 82, . . . make both conditions *true*
  - `marks >= 80` has **fewer** satisfying values than `marks >= 70`
  - We say `marks >= 80` is more *specific* than `marks >= 70`
  - Or, we say `marks >= 70` is more *general* than `marks >= 80`
- `marks <= 65` and `marks <= 75` overlap. [why?]
  - Values 65, 64, 63, . . . make both conditions *true*
  - `marks <= 65` has **fewer** satisfying values than `marks <= 75`
  - We say `marks <= 65` is more *specific* than `marks <= 75`
  - Or, we say `marks <= 75` is more *general* than `marks <= 65`

General vs. Specific Boolean Conditions (2)

Say we have two overlapping conditions `x >= 5` and `x >= 0`:

- What values make both conditions *true*? [5, 6, 7, . . .]
- Which condition is more *general*? [`x >= 0`]
- If we have a single if statement, then having this order

```
if(x >= 5) { System.out.println("x >= 5"); }
else if(x >= 0) { System.out.println("x >= 0"); }
```

  is different from having this order

```
if(x >= 0) { System.out.println("x >= 0"); }
else if(x >= 5) { System.out.println("x >= 5"); }
```

- Say *x* is 5, then we have
  - What output from the first program? [`x >= 5`]
  - What output from the second program? [`x >= 0`, not *specific* enough!]
- The cause of the " *not-specific-enough* " problem of the second program is that we did not check the more *specific* condition (`x >= 5`) before checking the more *general* condition (`x >= 0`).

Common Error 2: `if-elseif` Statement with Most General Condition First (1)

```
if (gpa >= 2.5) {
  graduateWith = "Pass";
}
else if (gpa >= 3.5) {
  graduateWith = "Credit";
}
else if (gpa >= 4) {
  graduateWith = "Distinction";
}
else if (gpa >= 4.5) {
  graduateWith = "High Distinction" ;
}
```

The above program will:

- Not award a "High Distinction" to *gpa* == 4.8.
- Why?

Common Error 2: `if-elseif` Statement with Most General Condition First (2)

- Always *"sort"* the branching conditions s.t. the more *specific* conditions are checked before the more *general* conditions.

```
if (gpa >= 4.5) {
  graduateWith = "High Distinction" ;
}
else if (gpa >= 4) {
  graduateWith = "Distinction";
}
else if (gpa >= 3.5) {
  graduateWith = "Credit";
}
else if (gpa >= 2.5) {
  graduateWith = "Pass";
}
else { graduateWith = "Fail"; }
```

Common Error 3: Missing Braces (1)

Confusingly, braces can be omitted if the block contains a *single* statement.

```
final double PI = 3.1415926;
Scanner input = new Scanner(System.in);
double radius = input.nextDouble();
if (radius >= 0)
  System.out.println("Area is " + radius * radius * PI);
```

In the above code, it is as if we wrote:

```
final double PI = 3.1415926;
Scanner input = new Scanner(System.in);
double radius = input.nextDouble();
if (radius >= 0) {
  System.out.println("Area is " + radius * radius * PI);
}
```

Common Error 3: Missing Braces (2)

Your program will *misbehave* when a block is supposed to execute *multiple statements*, but you forget to enclose them within braces.

```
final double PI = 3.1415926;
Scanner input = new Scanner(System.in);
double radius = input.nextDouble();
double area = 0;
if (radius >= 0)
  area = radius * radius * PI;
  System.out.println("Area is " + area);
```

This program will *mistakenly* print “Area is 0.0” when a *negative* number is input by the user, why? Fix?

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("Area is " + area);
}
```

Common Error 4: Misplaced Semicolon

Semicolon (`;`) in Java marks *the end of a statement* (e.g., assignment, `if` statement).

```
if (radius >= 0); {
  area = radius * radius * PI;
  System.out.println("Area is " + area);
}
```

This program will calculate and output the area even when the input radius is *negative*, why? Fix?

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("Area is " + area);
}
```

Common Error 5: Variable Not Properly Re-Assigned

```
1  String graduateWith = "";
2  if (gpa >= 4.5) {
3    graduateWith = "High Distinction" ; }
4  else if (gpa >= 4) {
5    graduateWith = "Distinction"; }
6  else if (gpa >= 3.5) {
7    graduateWith = "Credit"; }
8  else if (gpa >= 2.5) {
9    graduateWith = "Pass"; }
```

The above program will award “” to *gpa* == 1.5. Why?

Possible Fix 1: Change the *initial value* in Line 1 to “Fail”.

Possible Fix 2: Add an *else* branch after Line 9:

```
else { graduateWith = "fail" }
```

Compare this example with the example in slide 17.

Common Errors 6: Ambiguous `else` (1)

```
if (x >= 0)
   if (x > 100) {
      System.out.println("x is larger than 100");
   }
else {
  System.out.println("x is negative");
}
```

- When *x* is 20, this program considers it as negative. Why?

  ∵ `else` clause matches the *most recent* unmatched `if` clause.

  ∴ The above is as if we wrote:

```
if (x >= 0) {
   if (x > 100) {
      System.out.println("x is larger than 100");
   }
   else {
     System.out.println("x is negative");
   }
}
```

Common Errors 6: Ambiguous `else` (2)

- Fix?

  Use pairs of curly braces ({}) to force what you really mean to specify!

```
if (x >= 0) {
   if (x > 100) {
      System.out.println("x is larger than 100");
   }
}
else {
  System.out.println("x is negative");
}
```

Common Pitfall 1: Updating Boolean Variable

```
boolean isEven;
if (number % 2 == 0) {
  isEven = true;
}
else {
  isEven = false;
}
```

Correct, but *simplifiable* : `boolean isEven = (number%2 == 0);`

Similarly, how would you simply the following?

```
if (isEven == false) {
  System.out.println("Odd Number");
}
else {
  System.out.println("Even Number");
}
```

Simplify `isEven == false` to `!isEven`

Index (1)

Index (2)

Index (3)

Index (4)

Index (5)

Loops

EECS1021:
Object Oriented Programming:
from Sensors to Actuators
Winter 2019

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Learning Outcomes

Understand about *Loops*:

- Motivation: *Repetition* of *similar actions*
- Two common loops: `for` and `while`
- Primitive vs. Compound Statements
- *Nesting* loops within `if` statements
- *Nesting* `if` statements within loops
- Common Errors and Pitfalls

Motivation of Loops

- We may want to *repeat* the *similar action(s)* for a (bounded) number of times.

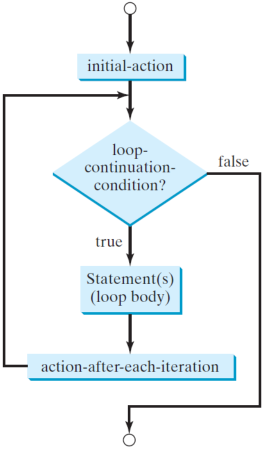
  e.g., Print the "Hello World" message for 100 times

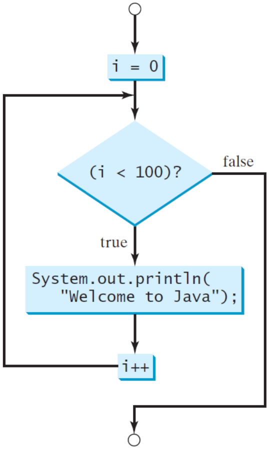
  e.g., To find out the maximum value in a list of numbers
- We may want to *repeat* the *similar action(s)* under certain circumstances.

  e.g., Keep letting users enter new input values for calculating the BMI until they enter "quit"
- *Loops* allow us to repeat similar actions either
  - *for* a specified number of times; or
  - *while* a specified condition holds *true*.

The `for` Loop (1)

```
for (int i = 0; i < 100; i ++) {
  System.out.println("Welcome to Java!");
}
```





The `for` Loop (2)

```
for (int i = 0; i < 100; i ++) {
  System.out.println("Welcome to Java!");
}
```

i	$i < 100$	Enter/Stay Loop?	Iteration	Actions
0	$0 < 100$	*True*	1	print, `i ++`
1	$1 < 100$	*True*	2	print, `i ++`
2	$2 < 100$	*True*	3	print, `i ++`
...				
99	$99 < 100$	*True*	100	print, `i ++`
100	$100 < 100$	*False*	–	–

- The number of *iterations* (i.e., 100) corresponds to the number of times the loop body is executed.
- # of times that we check the *stay condition (SC)* (i.e., 101) is # of iterations (i.e., 100) plus 1. [*True* $\times$ 100; *False* $\times$ 1]

The `for` Loop (3)

```
for ( int i = 0; i < 100; i ++) {
  System.out.println("Welcome to Java!");
}
```

- The *"initial-action"* is executed *only once*, so it may be moved right before the `for loop`.
- The *"action-after-each-iteration"* is executed repetitively to *make progress*, so it may be moved to the end of the `for loop` body.

```
int i = 0;
for (; i < 100; ) {
  System.out.println("Welcome to Java!");
  i ++;
}
```

The `for` Loop: Exercise (1)

Compare the behaviour of this program

```
for (int count = 0; count < 100; count ++) {
  System.out.println("Welcome to Java!");
}
```

and this program

```
for (int count = 1; count < 201; count += 2) {
  System.out.println("Welcome to Java!");
}
```

- Are the outputs same or different?
- It is similar to asking if the two intervals

$$[0, 1, 2, \dots, 100) \texttt{ and } [1, 3, 5, \dots, 201)$$

  contain the same number of integers.
- *Same*, both loop bodies run exactly 100 times and do not depend on the value of *count*.

The `for` Loop: Exercise (2)

Compare the behaviour of this program

```
int count = 0;
for (; count < 100; ) {
  System.out.println("Welcome to Java " + count + "!");
  count ++; /* count = count + 1; */
}
```

and this program

```
int count = 1;
for (; count <= 100; ) {
  System.out.println("Welcome to Java " + count + "!");
  count ++; /* count = count + 1; */
}
```

Are the outputs same or different? *Different*, both loop body run exactly 100 times and depend on the value of *count*.

The `for` Loop: Exercise (3)

Compare the behaviour of the following three programs:

```
for (int i = 1; i <= 5 ; i ++) {
  System.out.print(i); }
```

Output: `12345`

```
int i = 1;
for ( ; i <= 5 ; ) {
  System.out.print(i);
  i ++; }
```

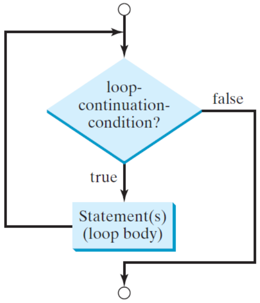
Output: `12345`

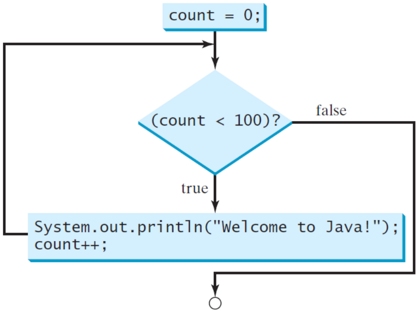
```
int i = 1;
for ( ; i <= 5 ; ) {
  i ++;
  System.out.print(i); }
```

Output: `23456`

The `while` Loop (1)

```
int count = 0;
while (count < 100) {
  System.out.println("Welcome to Java!");
  count ++; /* count = count + 1; */
}
```





The `while` Loop (2)

```
int j = 3;
while (j < 103) {
  System.out.println("Welcome to Java!");
  j ++; /* j = j + 1; */ }
```

j	$j < 103$	Enter/Stay Loop?	Iteration	Actions
3	$3 < 103$	*True*	1	print, `j ++`
4	$4 < 103$	*True*	2	print, `j ++`
5	$5 < 103$	*True*	3	print, `j ++`
...				
102	$102 < 103$	*True*	100	print, `j ++`
103	$103 < 103$	*False*	–	–

- The number of *iterations* (i.e., 100) corresponds to the number of times the loop body is executed.
- # of times that we check the *stay condition (SC)* (i.e., 101) is # of iterations (i.e., 100) plus 1. [*True* × 100; *False* × 1]

The `while` Loop: Exercise (1)

Compare the behaviour of this program

```
int count = 0;
while (count < 100) {
  System.out.println("Welcome to Java!");
  count ++; /* count = count + 1; */
}
```

and this program

```
int count = 1;
while (count <= 100) {
  System.out.println("Welcome to Java!");
  count ++; /* count = count + 1; */
}
```

Are the outputs same or different? *Same*, both loop bodies run exactly 100 times and do not depend on the value of *count*.

The while Loop: Exercise (2)

Compare the behaviour of this program

```
int count = 0;
while (count < 100) {
  System.out.println("Welcome to Java " + count + "!");
  count ++; /* count = count + 1; */
}
```

and this program

```
int count = 1;
while (count <= 100) {
  System.out.println("Welcome to Java " + count + "!");
  count ++; /* count = count + 1; */
}
```

Are the outputs same or different? *Different*, both loop body run exactly 100 times and depend on the value of *count*.

Primitive Statement vs. Compound Statement

- A *statement* is a block of Java code that modifies value(s) of some variable(s).
- An assignment (=) statement is a *primitive statement*: it only modifies its left-hand-side (LHS) variable.
- An `for` or `while` loop statement is a *compound statement*: the loop body may modify more than one variables via other statements (e.g., assignments, `if` statements, and `for` or `while` statements).
  - e.g., a loop statement may contain as its body `if` statements
  - e.g., a loop statement may contain as its body loop statements
  - e.g., an `if` statement may contain as its body `loop` statements

Compound Loop: Exercise (1.1)

How do you *extend* the following program

```
System.out.println("Enter a radius value:");
double radius = input.nextDouble();
double area = radius * radius * 3.14;
System.out.println("Area is " + area);
```

with the ability to *repeatedly* prompt the user for a radius value, until they explicitly enter a negative radius value to terminate the program (in which case an error message is also printed)?

```
System.out.println("Enter a radius value:");
double radius = input.nextDouble();
while (radius >= 0) {
  double area = radius * radius * 3.14;
  System.out.println("Area is " + area);
  System.out.println("Enter a radius value:");
  radius = input.nextDouble(); }
System.out.println("Error: negative radius value.");
```

Compound Loop: Exercise (1.2)

Another alternative: Use a boolean variable `isPositive`

```
1  System.out.println("Enter a radius value:");
2  double radius = input.nextDouble();
3  boolean isPositive = radius >= 0;
4  while (isPositive) {
5    double area = radius * radius * 3.14;
6    System.out.println("Area is " + area);
7    System.out.println("Enter a radius value:");
8    radius = input.nextDouble();
9    isPositive = radius >= 0; }
10 System.out.println("Error: negative radius value.");
```

- In **L2**: What if user enters `2`? What if user enters `-2`?
- Say in **L2** user entered `2`, then in **L8**:

  What if user enters `3`? What if user enters `-3`?
- What if `isPositive = radius >= 0` in **L9** is missing?

Compound Loop: Exercise (1.3)

Another alternative: Use a boolean variable `isNegative`

```
 1  System.out.println("Enter a radius value:");
 2  double radius = input.nextDouble();
 3  boolean isNegative = radius < 0;
 4  while (!isNegative) {
 5    double area = radius * radius * 3.14;
 6    System.out.println("Area is " + area);
 7    System.out.println("Enter a radius value:");
 8    radius = input.nextDouble();
 9    isNegative = radius < 0; }
10  System.out.println("Error: negative radius value.");
```

- In **L2**: What if user enters `2`? What if user enters `-2`?
- Say in **L2** user entered `2`, then in **L8**:

  What if user enters `3`? What if user enters `-3`?
- What if `isNegative = radius < 0` in **L9** is missing?

Converting between `for` and `while` Loops (1)

- To convert a `while` loop to a `for` loop, leave the initialization and update parts of the `for` loop empty.

```
while(B) {
  /* Actions */
}
```

  is equivalent to:

```
for( ; B ; ) {
  /* Actions */
}
```

  where *B* is any valid Boolean expression.
- However, when there is not a loop counter (i.e., *i*, *count*, *etc.*) that you intend to explicitly maintain, stick to a `while` loop.

Converting between `for` and `while` Loops (2)

- To convert a `for` loop to a `while` loop, move the initialization part immediately before the `while` loop and place the update part at the end of the `while` loop body.

```
for(int i = 0 ; B ; i ++ ) {
  /* Actions */
}
```

  is equivalent to:

```
int i = 0;
while(B) {
  /* Actions */
  i ++;
}
```

  where *B* is any valid Boolean expression.
- However, when there is a loop counter (i.e., *i*, *count*, *etc.*) that you intend to explicitly maintain, stick to a `for` loop.

Stay Condition (SC) vs. Exit Condition (1)

- A `for(...; SC ; ...)` loop or a `while(SC)` loop
  - *stays* to repeat its body **as long as** SC evaluates to *true*.
  - *exits* **as soon as** its SC evaluates to *false*.
- Say we have two Boolean variables:

```
boolean p, q;
```

- When does the loop exit (i.e., stop repeating Action 1)?

```
while(p && q) { /* Action 1 */ }
```

  `!(p && q)`
  this is equivalent to `!p || !q`
- When does the loop exit (i.e., stop repeating Action 2)?

```
while(p || q) { /* Action 2 */ }
```

  `!(p || q)`
  this is equivalent to `!p && !q`

Stay Condition (SC) vs. Exit Condition (2)

Consider the following loop:

```
int x = input.nextInt();
while(10 <= x || x <= 20) {
  /* body of while loop */
}
```

- It compiles, but has a logical error. Why?
- Think about the *exit condition* :
  - `!(10 <= x || x <= 20)` [∵ *negation* of stay condition]
  - `!(10 <= x) && !(x <= 20)` [∵ law of disjunction]
  - `10 > x && x > 20` [∵ law of negation]
- `10 > x && x > 20` is equivalent to *false*, since there is no number smaller than 10 and larger than 20 at the same time.
- An exit condition being *false* means that there is no way to exit from the loop! [infinite loops are *BAD*!]

Problems, Data Structures, and Algorithms

- A *well-specified* *computational problem* precisely describes the desired *input/output relationship*.
  - **Input:** A sequence of n numbers $\langle a_1, a_2, \ldots, a_n \rangle$
  - **Output:** The maximum number *max* in the input array, such that $max \geq a_i$, where $1 \leq i \leq n$
  - An *instance* of the problem: $\langle 3, 1, 2, 5, 4 \rangle$
- A *data structure* is a systematic way to store and organize data in order to facilitate *access* and *modifications*.
- An *algorithm* is:
  - A solution to a well-specified *computational problem*
  - A *sequence of computational steps* that takes value(s) as *input* and produces value(s) as *output*
- Steps in an *algorithm* manipulate well-chosen *data structure(s)*.

Arrays: A Simple Data Structure

- An array is a *linear* sequence of elements.

940	880	830	790	750	660	650	590	510	440
0	1	2	3	4	5	6	7	8	9

- *Types* of elements in an array are the *same*.
  - an array of integers [`int[]`]
  - an array of doubles [`double[]`]
  - an array of characters [`char[]`]
  - an array of strings [`String[]`]
  - an array of booleans [`boolean[]`]
- Each element in an array is associated with an integer index.
- *Range of valid indices* of an array is constrained by its *size*.
  - The 1st element of an array has the index *0*.
  - The 2nd has index 1.
  - The i^{th} element has index $i - 1$.
  - The last element of an array has the index value that is equal to the *size of the array minus one*.

Arrays: Initialization and Indexing

- Initialize a new array object with a *fixed* size:

```
String[] names = new String[10];
```

- Alternatively, initialize a new array explicitly with its contents:

```
String[] names = {"Alan", "Mark", "Tom"};
```

- Access elements in an array through indexing:

```
String first = names[0];
String last = names[names.length - 1];
```

An illegal index triggers an *ArrayInexOutOfBoundsException*.

Arrays: Iterations

- Iterate through an array using a *for-loop*:

```
for (int i = 0; i < names.length; i ++) {
  System.out.println (names[i]);
}
```

- Iterate through an array using a *while-loop*:

```
int i = 0;
while (i < names.length) {
  System.out.println (names[i]);
  i ++;
}
```

The `for` Loop: Exercise (3)

Problem: Given an array `numbers` of integers, how do you print its average?

e.g., Given array $\{1, 2, 6, 8\}$, print `4.25`.

```
int sum = 0;
for(int i = 0; i < numbers.length; i ++) {
  sum += numbers[i];
}
double average = (double) sum / numbers.length;
System.out.println("Average is " + average);
```

Q: What's the printout when the array is empty

(e.g., `int[] numbers = {};`)?

A: Division by zero (i.e., `numbers.length` is 0). Fix?

The `for` Loop: Exercise (4)

Problem: Given an array `numbers` of integers, how do you print its contents backwards?

e.g., Given array $\{1, 2, 3, 4\}$, print `4 3 2 1`.

Solution 1: Change bounds and updates of loop counter.

```
for(int i = numbers.length - 1; i >= 0; i --) {
  System.out.println(numbers[i]);
}
```

Solution 2: Change indexing.

```
for(int i = 0; i < names.length; i ++) {
  System.out.println(numbers[ names.length - i - 1 ]);
}
```

The `for` Loop: Exercise (5)

Problem: Given an array `names` of strings, how do you print its contents separated by commas and ended with a period?

e.g., Given array $\{''Alan'', ''Mark'', ''Tom''\}$,
print ”Names: Alan, Mark, Tom.”

```
System.out.print("Names:")
for(int i = 0; i < names.length; i ++) {
  System.out.print(names[i]);
  if (i < names.length - 1) {
    System.out.print(", ");
  }
}
System.out.println(".");
```

Array Iterations: Translating `for` to `while` (1)

- Use either when you intend to iterate through the entire array.
-
```
int[] a = new int[100];
for(int i = 0; i < a.length; i ++) {
  /* Actions to repeat. */
}
```
  In a `for` loop, the *initialization* and *update* of the *loop counter* *i* are specified as part of the loop header.
-
```
int[] a = new int[100];
int i = 0;
while(i < a.length) {
   /* Actions to repeat. */
   i ++;
}
```
  In a `while` loop, the *loop counter* *i*
  - Is *initialized* outside and before the loop header
  - Is *updated* at the end of the loop body

Array Iterations: Translating `for` to `while` (2)

- In both the `for` and `while` loops:
  - The stay/continuation conditions are *identical*.
  - The loop counter *i* is initialized only *once* before first entrance.
  - In each iteration, the loop counter *i* is executed *at the end* of the loop body.

Compound Loop: Exercise (2)

Given an integer array:

```
int[] a = {2, 1, 3, 4, -4, 10}
```

How do you print out positive numbers only?
Hint: Use a `for` loop to *iterate* over the array. In the loop body, *conditionally* print out positive numbers only.

```
for(int i = 0; i < a.length; i ++) {
  if (a[i] > 0) {
    System.out.println(a[i]);
  }
}
```

Exercise: Write the equivalent using a `while` loop.

Compound Loop: Exercise (3)

Given a *non-empty* integer array, e.g., `int[] a = {2, 1, 3, 4, -4, 10}`, find out its maximum element.

Hint: *Iterate* over the array. In the loop body, maintain the *maximum found so far* and update it when necessary.

```
1  int max = a[0];
2  for(int i = 0; i < a.length; i ++) {
3    if (a[i] > max) {  max = a[i]; }
4  }
5  System.out.println("Maximum is " + max);
```

Q: What if we change the initialization in **L1** to `int max = 0`?

A: NO ∵ Contents of `a` may be all smaller than this initial value (e.g., all negatives).

Q: What if we change the initialization in **L2** to `int i = 1`?

A: YES ∵ `a[0] > a[0]` is always *false* anyway.

Compound Loop: Exercise (3) Demo

```
int[] a = {2, 1, 3, 4, -4, 10}
int max = a[0];
for(int i = 0; i < a.length; i ++) {
  if (a[i] > max) {
    max = a[i]; } }
System.out.println("Maximum is " + max);
```

i	$a[i]$	$a[i] > max$	update max?	max
0	–	–	–	2
0	2	*false*	N	2
1	1	*false*	N	2
2	3	*true*	**Y**	3
3	4	*true*	**Y**	4
4	-4	*false*	N	4
5	10	*true*	**Y**	10

Compound Loop: Exercise (4.1)

- **Problem:** Given an array of numbers, determine if it contains *all* positive number.

```
1  int[] numbers = {2, 3, -1, 4, 5};
2  boolean soFarOnlyPosNums = true;
3  int i = 0;
4  while (i < numbers.length) {
5    soFarOnlyPosNums = soFarOnlyPosNums && (numbers[i] > 0);
6    i = i + 1;
7  }
8  if (soFarOnlyPosNums) { /* print a msg. */ }
9  else { /* print another msg. */ }
```

- Change **Line 5** to `soFarOnlyPosNums = numbers[i] > 0;`?
- **Hints:** Run both versions on the following three arrays:
  1. `{2, 3, 1, 4, 5, 6, 8, 9, 100}` [all positive]
  2. `{2, 3, 100, 4, 5, 6, 8, 9, -1}` [negative at the end]
  3. `{2, 3, -1, 4, 5, 6, 8, 9, 100}` [negative in the middle]

Compound Loop: Exercise (4.1) Demo (1)

```
int[] ns = {2, 3, -1, 4, 5};
boolean soFarOnlyPosNums = true;
int i = 0;
while (i < ns.length) {
  soFarOnlyPosNums = soFarOnlyPosNums && (ns[i] > 0);
  i = i + 1;
}
```

i	*soFarOnlyPosNums*	*i* < *ns.length*	stay?	*ns*[*i*]	*ns*[*i*] > *0*
0	*true*	*true*	YES	2	*true*
1	*true*	*true*	YES	3	*true*
2	*true*	*true*	YES	-1	*false*
3	*false*	*true*	YES	4	*true*
4	*false*	*true*	YES	5	*true*
5	*false*	*false*	NO	–	–

Compound Loop: Exercise (4.1) Demo (2)

```
int[] ns = {2, 3, -1, 4, 5};
boolean soFarOnlyPosNums = true;
int i = 0;
while (i < ns.length) {
  soFarOnlyPosNums = ns[i] > 0; /* wrong */
  i = i + 1;
}
```

i	*soFarOnlyPosNums*	*i* < *ns.length*	stay?	*ns*[*i*]	*ns*[*i*] > *0*
0	*true*	*true*	YES	2	*true*
1	*true*	*true*	YES	3	*true*
2	*true*	*true*	YES	-1	*false*
3	*false*	*true*	YES	4	*true*
4	*true*	*true*	YES	5	*true*
5	*true*	*false*	NO	–	–

Compound Loop: Exercise (4.2)

Problem: Given an array of numbers, determine if it contains *all* positive number. Also, *for efficiency, exit from the loop as soon as you find a negative number*.

```
int[] numbers = {2, 3, -1, 4, 5};
boolean soFarOnlyPosNums = true;
int i = 0;
while (soFarOnlyPosNums && i < numbers.length) {
  soFarOnlyPosNums = numbers[i] > 0;
  i = i + 1;
}
if (soFarOnlyPosNums) { /* print a msg. */ }
else { /* print another msg. */ }
```

Compound Loop: Exercise (4.2) Demo (1)

```
int[] ns = {2, 3, -1, 4, 5};
boolean soFarOnlyPosNums = true;
int i = 0;
while (soFarOnlyPosNums && i < ns.length) {
  soFarOnlyPosNums = soFarOnlyPosNums && ns[i] > 0;
  i = i + 1;
}
```

i	*soFarOnlyPosNums*	$i < ns.length$	stay?	$ns[i]$	$ns[i] > 0$
0	*true*	*true*	YES	2	*true*
1	*true*	*true*	YES	3	*true*
2	*true*	*true*	YES	-1	*false*
3	*false*	*true*	NO	–	–

Compound Loop: Exercise (4.2) Demo (2)

```
int[] ns = {2, 3, -1, 4, 5};
boolean soFarOnlyPosNums = true;
int i = 0;
while (soFarOnlyPosNums && i < ns.length) {
  soFarOnlyPosNums = ns[i] > 0;
  i = i + 1;
}
```

i	*soFarOnlyPosNums*	*i < ns.length*	stay?	*ns*[*i*]	*ns*[*i*] > *0*
0	*true*	*true*	YES	2	*true*
1	*true*	*true*	YES	3	*true*
2	*true*	*true*	YES	-1	*false*
3	*false*	*true*	NO	–	–

Compound Loop: Exercise (4.3) Summary

Four possible solutions (`posNumsSoFar` is initialized as *true*):

1. Scan the entire array and accumulate the result.

```
for (int i = 0; i < ns.length; i ++) {
  posNumsSoFar = posNumsSoFar && ns[i] > 0; }
```

2. Scan the entire array but the result is **not** accumulative.

```
for (int i = 0; i < ns.length; i ++) {
  posNumsSoFar = ns[i] > 0; } /* Not working.  Why?  */
```

3. The result is accumulative until the early exit point.

```
for (int i = 0; posNumsSoFar && i < ns.length; i ++) {
  posNumsSoFar = posNumsSoFar && ns[i] > 0; }
```

4. The result is **not** accumulative until the early exit point.

```
for (int i = 0; posNumsSoFar && i < ns.length; i ++) {
  posNumsSoFar = ns[i] > 0; }
```

Compound Loop: Exercise (5)

Problem: Given an array a of integers, how do determine if it is sorted in a *non-decreasing* order?

e.g., Given $\{1, 2, 2, 4\}$, print *true*; given $\{2, 4, 3, 3\}$ print *false*.

```
boolean isSorted = true;
for(int i = 0; i < a.length - 1; i ++) {
  isSorted = isSorted && (a[i] <= a[i + 1]);
}
```

Alternatively (with early exit):

```
boolean isSorted = true;
for(int i = 0; isSorted && i < a.length - 1; i ++) {
  isSorted = a[i] <= a[i + 1];
}
```

Compound Loop: Exercise (5) Demo [A]

```
int[] a = {1, 2, 2, 4}
boolean isSorted = true;
for(int i = 0; i < a.length - 1; i ++) {
  isSorted = isSorted && (a[i] <= a[i + 1]);
}
```

i	$a[i]$	$a[i+1]$	$a[i] <= a[i+1]$	*isSorted*	exit?
0	–	–	–	*true*	N
0	1	2	*true*	*true*	N
1	2	2	*true*	*true*	N
2	2	4	*true*	*true*	**Y**

Compound Loop: Exercise (5) Demo [B]

```
int[] a = {2, 4, 3, 3}
boolean isSorted = true;
for(int i = 0; i < a.length - 1; i ++) {
  isSorted = isSorted && (a[i] <= a[i + 1]);
}
```

i	*a*[*i*]	*a*[*i* + *1*]	*a*[*i*] <= *a*[*i* + *1*]	*isSorted*	exit?
0	–	–	–	*true*	N
0	2	4	*true*	*true*	N
1	4	3	*false*	*false*	N
2	3	3	*true*	*false*	**Y**

Compound Loop: Exercise (5) Demo [C]

```java
int[] a = {2, 4, 3, 3}
boolean isSorted = true;
for(int i = 0; isSorted && i < a.length - 1; i ++) {
  isSorted = a[i] <= a[i + 1];
}
```

i	$a[i]$	$a[i+1]$	$a[i] <= a[i+1]$	*isSorted*	exit?
0	–	–	–	*true*	N
0	2	4	*true*	*true*	N
1	4	3	*false*	*false*	**Y**

Checking Properties of Arrays (1)

- Determine if *all* elements satisfy a property.
- We need to repeatedly apply the logical *conjunction*.
- *As soon as* we find an element that *does not satisfy* a property, then we exit from the loop.

  e.g., Determine if all elements in array `a` are positive.

```java
boolean allPos = true;
for(int i = 0; i < a.length; i ++) {
  allPos = allPos && (a[i] > 0);
}
```

  Alternatively (with early exit):

```java
boolean allPos = true;
for(int i = 0; allPos && i < a.length; i ++) {
  allPos = a[i] > 0;
}
```

Checking Properties of Arrays (1): Demo

```
1  int[] a = {2, 3, -1, 4, 5, 6, 8, 9, 100};
2  boolean allPos = true;
3  for(int i = 0; allPos && i < a.length; i ++) {
4    allPos = a[i] > 0;
5  }
```

i	*a*[*i*]	*a*[*i*] > *0*	*allPos*	exit?
0	–	–	*true*	N
0	2	*true*	*true*	N
1	3	*true*	*true*	N
2	-1	*false*	*false*	**Y**

- **Question:** Why do we initialize `allPos` as *true* in Line 2?
- **Question:** What if we change the stay condition in Line 3 to only `i < a.length`?

  Intermediate values of `allPos` will be overwritten!

Checking Properties of Arrays (2)

- Determine if *at least one* element satisfies a property.
- *As soon as* we find an element that *satisfies* a property, then we exit from the loop.

  e.g., Is there at lease one negative element in array `a`?

  Version 1: Scanner the Entire Array

```
boolean foundNegative = false;
for(int i = 0; i < a.length; i ++) {
  foundNegative = foundNegative || a[i] < 0;
}
```

  Version 2: Possible Early Exit

```
boolean foundNegative = false;
for(int i = 0; ! foundNegative && i < a.length; i ++) {
  foundNegative = a[i] < 0;
}
```

Checking Properties of Arrays (2) Demo

```
int[] a = {2, 3, -1, 4, 5, 6, 8, 9, 100};
boolean foundNegative = false;
for(int i = 0; !foundNegative && i < a.length; i ++) {
  foundNegative = a[i] < 0;
}
```

i	*a*[*i*]	*a*[*i*] < *0*	*foundNegative*	!*foundNegative*	exit?
0	–	–	*false*	*true*	N
0	2	*false*	*false*	*true*	N
1	3	*false*	*false*	*true*	N
2	-1	*true*	*true*	*false*	**Y**

- **Question:** Why do we initialize `foundNegative` as *false* in Line 2?

Observations

- In some cases, you *must* iterate through the *entire* array in order to obtain the result.

  e.g., max, min, total, *etc.*

- In other cases, you *exit* from the loop *as soon as* you obtain the result.

  e.g., to know if all numbers positive, it is certainly *false* *as soon as* you find the first negative number

  e.g., to know if there is at least one negative number, it is certainly *true* *as soon as* you find the first negative number

Arrays: Indexing and Short-Circuit Logic (1)

Problem: Ask the user how many integers they would like to input, prompt them accordingly, then ask them for an integer index, and check if the number stored at that index is even (i.e., error if it is odd).

```
How many integers?
2
Enter an integer:
23
Enter an integer:
24
Enter an index:
1
24 at index 1 is even.
```

Arrays: Indexing and Short-Circuit Logic (2)

```
 1  Scanner input = new Scanner(System.in);
 2  System.out.println("How many integers?");
 3  int howMany = input.nextInt();
 4  int[] ns = new int[howMany];
 5  for(int i = 0; i < howMany; i ++) {
 6    System.out.println("Enter an integer");
 7    ns[i] = input.nextInt(); }
 8  System.out.println("Enter an index:");
 9  int i = input.nextInt();
10  if(ns[ i ] % 2 == 0) {
11    System.out.println("Element at index " + i + " is even."); }
12  else { /* Error ∵ ns[i] is odd */ }
```

- Does the above code work? [*not* always!]
  - It *works* if `0 <= i && i < ns.length`
  - It *fails* on **L10** if `i < 0 || i >= ns.length` [*ArrayIndexOutOfBoundException*]

Arrays: Indexing and Short-Circuit Logic (3.1)

```
Scanner input = new Scanner(System.in);
System.out.println("How many integers?");
int howMany = input.nextInt();
int[] ns = new int[howMany];
for(int i = 0; i < howMany; i ++) {
  System.out.println("Enter an integer");
  ns[i] = input.nextInt(); }
System.out.println("Enter an index:");
int i = input.nextInt();
if( 0 <= i && i < ns.length && ns[i] % 2 == 0) {
  println(ns[i] + " at index " + i + " is even."); }
else { /* Error: invalid index or odd ns[i] */ }
```

- Does the above code work? [*always*!]
- Short-circuit effect of *conjunction* has L-to-R evaluations:

  `ns[i] % 2 == 0` is evaluated only when the *guard*
  (i.e., `0 <= i && i < ns.length`) evaluates to *true*.

Arrays: Indexing and Short-Circuit Logic (3.2)

```
Scanner input = new Scanner(System.in);
System.out.println("How many integers?");
int howMany = input.nextInt();
int[] ns = new int[howMany];
for(int i = 0; i < howMany; i ++) {
  System.out.println("Enter an integer");
  ns[i] = input.nextInt(); }
System.out.println("Enter an index:");
int i = input.nextInt();
if( i < 0 || i >= ns.length || ns[i] % 2 == 1) {
  /* Error: invalid index or odd ns[i] */ }
else { println(ns[i] + " at index " + i + " is even."); }
```

- Does the above code work? [*always*!]
- Short-circuit effect of *disjunction* has L-to-R evaluations:

  `ns[i] % 2 == 1` is evaluated only when the *guard* (i.e., `i < 0 || i >= ns.length`) evaluates to *false*.

Arrays: Indexing and Short-Circuit Logic (4)

- ∵ Short-circuit evaluations go from **left** to **right**.
  ∴ **Order** in which the operands are placed matters!
- Consider the following changes to **L10**:
  - `ns[i] % 2 == 0 && 0 <= i && i < ns.length`
    What if input `i` is s.t. `i < 0`? [*crash*]
    What if input `i` is s.t. `i >= ns.length`? [*crash*]
  - `0 <= i && ns[i] % 2 == 0 && i < ns.length`
    What if input `i` is s.t. `i < 0`? [*works*]
    What if input `i` is s.t. `i >= ns.length`? [*crash*]
  - `i < ns.length && ns[i] % 2 == 0 && 0 <= i`
    What if input `i` is s.t. `i < 0`? [*crash*]
    What if input `i` is s.t. `i >= ns.length`? [*works*]
- When does each change to **L10** *work* and *crash*?
  - `ns[i] % 2 == 1 || i < 0 || i >= ns.length`
  - `i < 0 || ns[i] % 2 == 1 || i >= ns.length`
  - `i >= ns.length || ns[i] % 2 == 1 || i < 0`

Parallel Loops vs. Nested Loops

- *Parallel Loops* :
  Each loop completes an *independent* phase of work.
  e.g., Print an array from left to right, then right to left.

```
System.out.println("Left to right:");
for(int i = 0; i < a.length; i ++) {
  System.out.println(a[i]); }
System.out.println("Right to left:");
for(int i = 0; i < a.length; i ++) {
  System.out.println(a[a.length - i - 1]); }
```

- *Nested Loops* :
  Loop counters form *all combinations* of indices.

```
for(int i = 0; i < a.length; i ++) {
  for(int j = 0; j < a.length; j ++) {
    System.out.println("(" + i + ", " + j + ")");
  } }
```

Nested Loops: Finding Duplicates (1)

- Given an integer array `a`, determine if it contains any duplicates. e.g., Print *false* for $\{1, 2, 3, 4\}$. Print *true* for $\{1, 4, 2, 4\}$.
- **Hint:** When can you conclude that there are duplicates? *As soon as* we find that two elements at difference indices happen to be the same

```
1  boolean hasDup = false;
2  for(int i = 0; i < a.length; i ++) {
3    for(int j = 0; j < a.length; j ++) {
4      hasDup = hasDup || (i != j && a[i] == a[j]);
5    } /* end inner for */ } /* end outer for */
6  System.out.println(hasDup);
```

- **Question:** How do you modify the code, so that we exit from the loops *as soon as* the array is found containing duplicates?
  - **L2**: `for(...; !hasDup && i < a.length; ...)`
  - **L3**: `for(...; !hasDup && j < a.length; ...)`
  - **L4**: `hasDup = (i != j && a[i] == a[j]);`

Nested Loops: Finding Duplicates (2)

```
/* Version 1 with redundant scan */
int[] a = {1, 2, 3}; /* no duplicates */
boolean hasDup = false;
for(int i = 0; i < a.length; i ++) {
  for(int j = 0; j < a.length; j ++) {
    hasDup = hasDup || (i != j && a[i] == a[j]);
  } /* end inner for */ } /* end outer for */
System.out.println(hasDup);
```

i	j	i != j	a[i]	a[j]	a[i] == a[j]	hasDup
0	0	*false*	1	1	*true*	*false*
0	1	*true*	1	2	*false*	*false*
0	2	*true*	1	3	*false*	*false*
1	0	*true*	2	1	*false*	*false*
1	1	*false*	2	2	*true*	*false*
1	2	*true*	2	3	*false*	*false*
2	0	*true*	3	1	*false*	*false*
2	1	*true*	3	2	*false*	*false*
2	2	*false*	3	3	*true*	*false*

Nested Loops: Finding Duplicates (3)

```
/* Version 1 with redundant scan and no early exit */
int[] a = {4, 2, 4}; /* duplicates: a[0] and a[2] */
boolean hasDup = false;
for(int i = 0; i < a.length; i ++) {
  for(int j = 0; j < a.length; j ++) {
    hasDup = hasDup || (i != j && a[i] == a[j]);
  } /* end inner for */ } /* end outer for */
System.out.println(hasDup);
```

i	j	i != j	a[i]	a[j]	a[i] == a[j]	hasDup
0	0	*false*	4	4	*true*	*false*
0	1	*true*	4	2	*false*	*false*
0	2	*true*	4	4	*true*	*true*
1	0	*true*	2	4	*false*	*true*
1	1	*false*	2	2	*true*	*true*
1	2	*true*	2	4	*false*	*true*
2	0	*true*	4	4	*true*	*true*
2	1	*true*	4	2	*false*	*true*
2	2	*false*	4	4	*true*	*true*

Nested Loops: Finding Duplicates (4)

```
/* Version 2 with redundant scan */
int[] a = {1, 2, 3}; /* no duplicates */
boolean hasDup = false;
for(int i = 0; i < a.length && !hasDup; i ++) {
  for(int j = 0; j < a.length && !hasDup; j ++) {
    hasDup = i != j && a[i] == a[j];
  } /* end inner for */ } /* end outer for */
System.out.println(hasDup);
```

i	j	i != j	a[i]	a[j]	a[i] == a[j]	hasDup
0	0	*false*	1	1	*true*	*false*
0	1	*true*	1	2	*false*	*false*
0	2	*true*	1	3	*false*	*false*
1	0	*true*	2	1	*false*	*false*
1	1	*false*	2	2	*true*	*false*
1	2	*true*	2	3	*false*	*false*
2	0	*true*	3	1	*false*	*false*
2	1	*true*	3	2	*false*	*false*
2	2	*false*	3	3	*true*	*false*

Nested Loops: Finding Duplicates (5)

```
/* Version 2 with redundant scan and early exit */
int[] a = {4, 2, 4}; /* duplicates: a[0] and a[2] */
boolean hasDup = false;
for(int i = 0; i < a.length && !hasDup ; i ++) {
  for(int j = 0; j < a.length && !hasDup ; j ++) {
    hasDup = i != j && a[i] == a[j] ;
  } /* end inner for */ } /* end outer for */
System.out.println(hasDup);
```

i	j	i != j	a[i]	a[j]	a[i] == a[j]	hasDup
0	0	*false*	4	4	*true*	*false*
0	1	*true*	4	2	*false*	*false*
0	2	*true*	4	4	*true*	*true*

Nested Loops: Finding Duplicates (6)

The previous two versions scan all pairs of array slots, but with redundancy: e.g., `a[0] == a[2]` and `a[2] == a[0]`.

```
/* Version 3 with no redundant scan */
int[] a = {1, 2, 3, 4}; /* no duplicates */
boolean hasDup = false;
for(int i = 0; i < a.length && !hasDup ; i ++) {
  for(int j = i + 1 ; j < a.length && !hasDup ; j ++) {
    hasDup = a[i] == a[j] ;
  } /* end inner for */ } /* end outer for */
System.out.println(hasDup);
```

i	j	a[i]	a[j]	a[i] == a[j]	hasDup
0	1	1	2	*false*	*false*
0	2	1	3	*false*	*false*
0	3	1	4	*false*	*false*
1	2	2	3	*false*	*false*
1	3	2	4	*false*	*false*
2	3	3	4	*false*	*false*

Nested Loops: Finding Duplicates (7)

```
/* Version 3 with no redundant scan:
 * array with duplicates causes early exit
 */
int[] a = {1, 2, 3, 2}; /* duplicates: a[1] and a[3] */
boolean hasDup = false;
for(int i = 0; i < a.length && !hasDup; i ++) {
  for(int j = i + 1; j < a.length && !hasDup; j ++) {
    hasDup = a[i] == a[j];
  } /* end inner for */ } /* end outer for */
System.out.println(hasDup);
```

i	j	a[i]	a[j]	a[i] == a[j]	hasDup
0	1	1	2	*false*	*false*
0	2	1	3	*false*	*false*
0	3	1	2	*false*	*false*
1	2	2	3	*false*	*false*
1	3	2	2	*true*	*true*

Common Error (1): Improper Initialization of Loop Counter

```
boolean userWantsToContinue;
while (userWantsToContinue) {
  /* some computations here */
  String answer = input.nextLine();
  userWantsToContinue = answer.equals("Y");
}
```

The default value for an initialized boolean variable is *false*.

Fix?

```
boolean userWantsToContinue = true;
while (userWantsToContinue) {
  /* some computations here */
  String answer = input.nextLine();
  userWantsToContinue = answer.equals("Y");
}
```

Common Error (2): Improper Stay Condition

```
for (int i = 0; i <= a.length; i ++) {
  System.out.println(a[i]);
}
```

The maximum index for array `a` is `a.length - 1`

Fix?

```
for (int i = 0; i < a.length; i ++) {
  System.out.println(a[i]);
}
```

Common Error (3): Improper Update to Loop Counter

Does the following loop print all slots of array `a`?

```
int i = 0;
while (i < a.length) {
  i ++;
  System.out.println(a[i]);
}
```

The indices used to print will be: `1`, `2`, `3`, `...`, `a.length`

Fix?

```
int i = 0;
while (i < a.length) {
  System.out.println(a[i]);
  i ++;
}
```

```
int i = 0;
while (i < a.length) {
  i ++;
  System.out.println(a[i - 1]);
}
```

Common Error (4): Improper Update of Stay Condition

```
1 String answer = input.nextLine();
2 boolean userWantsToContinue = answer.equals("Y");
3 while (userWantsToContinue) { /* stay condition (SC) */
4   /* some computations here */
5   answer = input.nextLine();
6 }
```

What if the user's answer in **L1** is simply `Y`? An *infinite loop*!!

∵ **SC** never gets updated when a new answer is read. Fix?

```
String answer = input.nextLine();
boolean userWantsToContinue = answer.equals("Y");
while (userWantsToContinue) {
  /* some computations here */
  answer = input.nextLine();
  userWantsToContinue = answer.equals("Y");
}
```

Common Error (5): Improper Start Value of Loop Counter

```
int i = a.length - 1;
while (i >= 0) {
  System.out.println(a[i]); i --; }
while (i < a.length) {
  System.out.println(a[i]); i ++; }
```

The value of loop counter *i* after the first `while` loop is -1!

Fix?

```
int i = a.length - 1;
while (i >= 0) {
  System.out.println(a[i]); i --; }
i = 0;
while (i < a.length) {
  System.out.println(a[i]); i ++; }
```

Common Error (6): Wrong Syntax

How about this?

```
while(int i = 0; i < 10; i ++) { ... }
```

You meant:

```
for(int i = 0; i < 10; i ++) { ... }
```

How about this?

```
for(i < 10) { ... }
```

You meant:

```
while(i < 10) { ... }
```

or

```
for( ; i < 10 ; ) { ... }
```

Common Error (7): Misplaced Semicolon

Semicolon (`;`) in Java marks *the end of a statement* (e.g., assignment, `if` statement, `for`, `while`).

```
int[] ia = {1, 2, 3, 4};
for (int i = 0; i < 10; i ++); {
  System.out.println("Hello!");
}
```

Output?

```
Hello!
```

Fix?

```
for (int i = 0; i < 10; i ++) {
 System.out.println("Hello!");
}
```

Index (1)

Index (2)

Index (3)

Index (4)

Index (5)

Index (6)

Classes and Objects

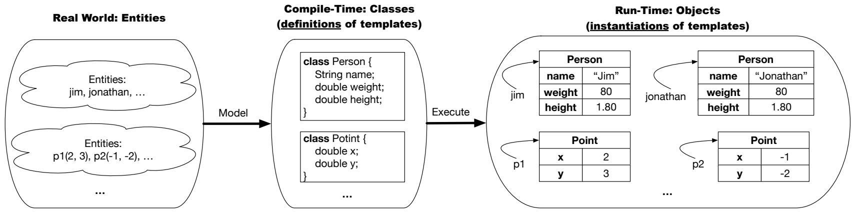
EECS1021:
Object Oriented Programming:
from Sensors to Actuators
Winter 2019

CHEN-WEI WANG

Where are we? Where will we go?

- We have developed the Java code *solely* within `main` method.
- In Java:
  - We may define more than one *classes*
  - Each class may contain more than one *methods*
- *object-oriented programming* 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.

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*.

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 *bebaviour*; and
  - Interact with each other.
- Goals: Solve problems *programmatically* by
  - *Classifying* entities of interest
    Entities in the same class share *common* attributes and bebaviour.
  - *Manipulating* data that represent these entities
    Each entity is represented by *specific* values.

OO Thinking: Templates vs. Instances (1.1)

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]

OO Thinking: Templates vs. Instances (1.2)

- Persons share these common *attributes* and *behaviour*.
  - Each person possesses an age, a weight, and a height.
  - Each person's age, weight, and height might be *distinct*
    e.g., `jim` is 50-years old, 1.8-meters tall and 80-kg heavy
    e.g., `jonathan` is 65-years old, 1.73-meters tall and 90-kg heavy
- Each person, depending on the *specific values* of their attributes, might 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 $[\frac{90}{1.73^2}]$

OO Thinking: Templates vs. Instances (1.3)

- 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* into multiple instances.
  - `Person` instance `jim`
  - `Person` instance `jonathan`
- Each *instance* may have *specific values* for the attributes.
  - Each `Person` instance has an age:
    - `jim` is 50-years old
    - `jonathan` is 65-years old
- Therefore, instances of the same template may exhibit *distinct behaviour*.
  - Each `Person` instance can get older:
    - `jim` getting older from 50 to 51
    - `jonathan` getting older from 65 to 66

OO Thinking: Templates vs. Instances (2.1)

Points on a two-dimensional plane are identified by their signed distances from the X- and Y-axises. 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]

OO Thinking: Templates vs. Instances (2.2)

- Points share these common *attributes* and *behaviour*.
  - Each point possesses an x-coordinate and a y-coordinate.
  - Each point's location might be *distinct*
    e.g., `p1` is located at $(3, 4)$
    e.g., `p2` is located at $(-4, -3)$
- Each point, depending on the *specific values* of their attributes (i.e., locations), might 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: $[\sqrt{(-4)^2 + (-2)^2}]$

OO Thinking: Templates vs. Instances (2.3)

- 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* into multiple instances.
  - `Point` instance `p1`
  - `Point` instance `p2`
- Each *instance* may have *specific values* for the attributes.
  - Each `Point` instance has an age:
    - `p1` is at `(3, 4)`
    - `p2` is at `(-3, -4)`
- Therefore, instances of the same template may exhibit *distinct behaviour*.
  - Each `Point` instance can move up:
    - `p1` moving up from `(3, 3)` results in `(3, 4)`
    - `p2` moving up from `(-3, -4)` results in `(-3, -3)`

OOP: Classes ≈ 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 {
  int age;
  String nationality;
  double weight;
  double height;
}
```

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

OOP: Define Constructors for Creating Objects (1.1)

- Within class `Point`, you define *constructors*, specifying how instances of the `Point` template may be created.

```
public class Point {
  ... /* attributes: x, y */
  Point(double newX, double newY) {
    x = newX;
    y = newY; } }
```

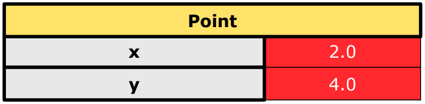
- In the corresponding tester class, each *call* to the `Point` constructor creates an instance of the `Point` template.

```
public class PointTester {
  public static void main(String[] args) {
    Point p1 = new Point(2, 4);
    println(p1.x + " " + p1.y);
    Point p2 = new Point(-4, -3);
    println(p2.x + " " + p2.y); } }
```

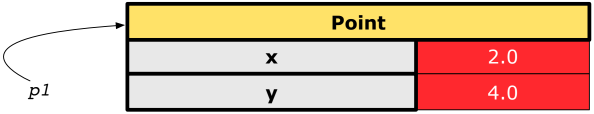
OOP: Define Constructors for Creating Objects (1.2)

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

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



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`.



OOP: Define Constructors for Creating Objects (2.1)

- Within class `Person`, you define *constructors*, specifying how instances of the `Person` template may be created.

```
public class Person {
  ... /* attributes: age, nationality, weight, height */
  Person(int newAge, String newNationality) {
    age = newAge;
    nationality = newNationality; } }
```

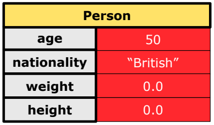
- In the corresponding tester class, each *call* to the `Person` constructor creates an instance of the `Person` template.

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

OOP: Define Constructors for Creating Objects (2.2)

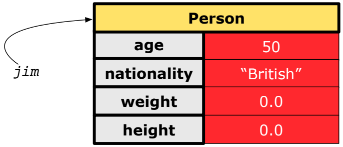
```
Person jim = new Person(50, "British");
```

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**: `Point 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`.



Person	
age	50
nationality	"British"
weight	0.0
height	0.0

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*

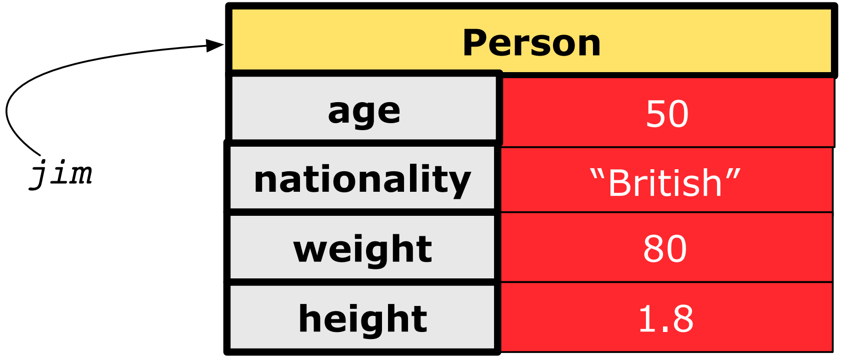
    ```
    double bmi = jim.getBMI();
    ```
  - Modified using *mutator methods*

    ```
    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*.

Visualizing Objects at Runtime (2.1)

After calling a *constructor* to create an object:

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

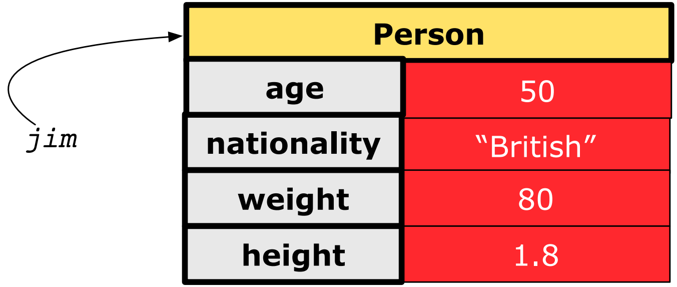


Visualizing Objects at Runtime (2.2)

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

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

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



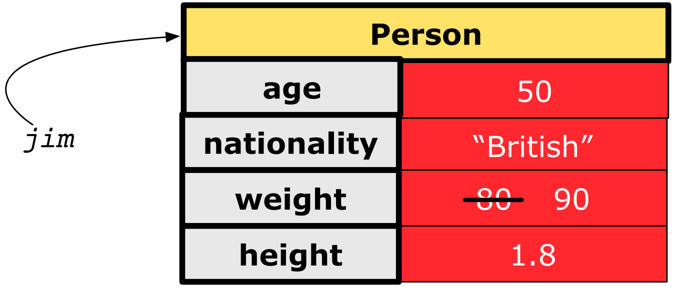
Visualizing Objects at Runtime (2.3)

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!

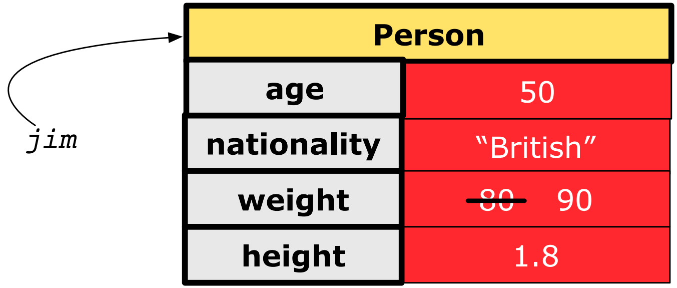


Visualizing Objects at Runtime (2.4)

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

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

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



The `this` Reference (1)

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

```
class Point {
  double x; double y;
  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`?

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.

```
class Point {
  double x;
  double y;
  Point(double newX, double newY) {
    this.x = newX;
    this.y = newY;
  }
  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.

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:

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

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:

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

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*.

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

The `this` Reference (6.1): Common Error

The following code fragment compiles but is problematic:

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

Why? Fix?

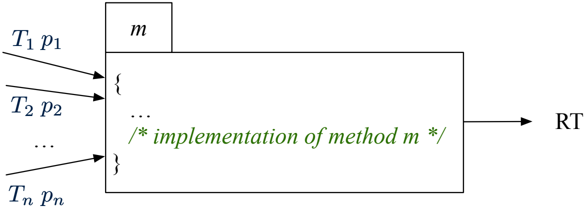
The `this` Reference (6.2): Common Error

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

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

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* [$p_1, p_2, \ldots, p_n$]
  - The corresponding *parameter types* [$T_1, T_2, \ldots, T_n$]
- A call to method m has the form: $m(a_1, a_2, \ldots, a_n)$
  Types of *argument values* $a_1, a_2, \ldots, a_n$ must match the the corresponding parameter types $T_1, T_2, \ldots, T_n$.

OOP: Methods (1.2)

- In the body of the method, you may
  - Declare and use new *local variables*
    Scope of local variables is only within that method.
  - Use or change values of *attributes*.
  - Use values of *parameters*, if any.

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

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

```
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"); } }
```

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*.

OOP: Methods (3)

1. *Constructor*
   - Same name as the class. No return type. *Initializes* attributes.
   - Called with the **new** keyword.
   - e.g., `Person jim = new Person(50, "British");`
2. *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!
3. *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());`

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()`

OOP: Method Calls

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

OOP: Class Constructors (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*

OOP: Class Constructors (2)

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

OOP: Class Constructors (3)

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

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

  Point(char axis, double distance) {
    if (axis == 'x') { x = distance; }
    else if (axis == 'y') { y = distance; }
    else { System.out.println("Error: invalid axis.") }
  }
}
```

OOP: Class Constructors (4)

- 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.
  - Each constructor must have a *distinct* list of *input parameter types*.
  - 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*.

OOP: Object Creation (1)

```
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.x + ", " + p1.y + ")");
```

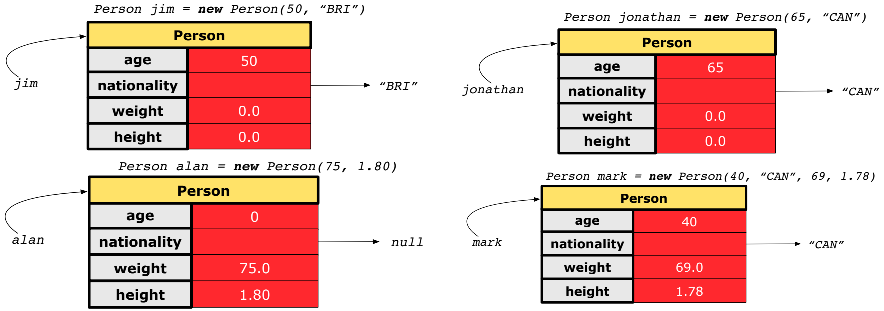
```
(2.0, 4.0)
```

OOP: Object Creation (2)

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);
 }
}
```

OOP: Object Creation (3)



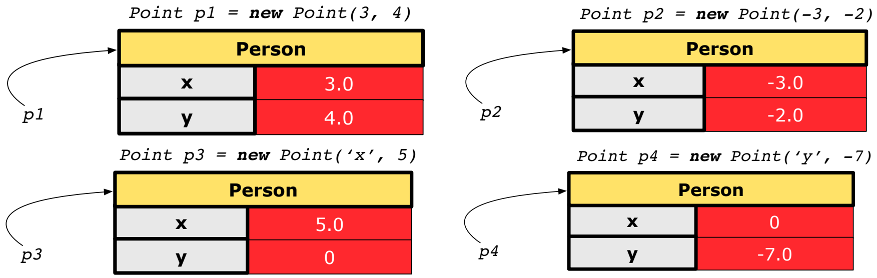
```
Person jim = new Person(50, "BRI")
Person jonathan = new Person(65, "CAN")
Person alan = new Person(75, 1.80)
Person mark = new Person(40, "CAN", 69, 1.78)
```

OOP: Object Creation (4)

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);
  }
}
```

OOP: Object Creation (5)



Point p1 = new Point(3, 4)
Person
x
3.0
y
4.0
p1
Point p2 = new Point(-3, -2)
Person
x
-3.0
y
-2.0
p2
Point p3 = new Point('x', 5)
Person
x
5.0
y
0
p3
Point p4 = new Point('y', -7)
Person
x
0
y
-7.0
p4

OOP: Object Creation (6)

- 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);
```

OOP: Mutator Methods

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

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

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

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

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

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();` ✓

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 moveUpBy(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)`

OOP: Object Alias (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  Systme.out.println(p3 == p1 || p3 == p2);  /* false */
5  Systme.out.println(p3.x == p1.x && p3.y == p1.y);  /* true */
6  Systme.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.

OO Program Programming: Object Alias (2.1)

Problem: Consider assignments to *primitive* variables:

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

OO Program Programming: Object Alias (2.2)

Problem: Consider assignments to *reference* variables:

```
Person alan = new Person("Alan");
Person mark = new Person("Mark");
Person tom = new Person("Tom");
Person jim = new Person("Jim");
Person[] persons1 = {alan, mark, tom};
Person[] persons2 = new Person[persons1.length];
for(int i = 0; i < persons1.length; i ++) {
 persons2[i] = persons1[i]; }
persons1[0].setAge(70);
System.out.println(jim.age);
System.out.println(alan.age);
System.out.println(persons2[0].age);
persons1[0] = jim;
persons1[0].setAge(75);
System.out.println(jim.age);
System.out.println(alan.age);
System.out.println(persons2[0].age);
```

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]

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!

Java Data Types (3.1)

- An attribute may store the reference to some object.

```
class Person { Person spouse; }
```

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

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

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

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

Java Data Types (3.2.1)

An attribute may be of type `Point[]`, storing references to `Point` objects.

```
class PointCollector {
  Point[] points; int nop; /* number of points */
  PointCollector() { points = new Point[100]; }
  void addPoint(double x, double y) {
    points[nop] = new Point(x, y); nop++; }
  Point[] getPointsInQuadrantI() {
    Point[] ps = new Point[nop];
    int count = 0; /* number of points in Quadrant I */
    for(int i = 0; i < nop; i ++) {
      Point p = points[i];
      if(p.x > 0 && p.y > 0) { ps[count] = p; count ++; } }
    Point[] q1Points = new Point[count];
    /* ps contains null if count < nop */
    for(int i = 0; i < count; i ++) { q1Points[i] = ps[i] }
    return q1Points;
  } }
```

Required Reading: Point and PointCollector

Java Data Types (3.2.2)

```
class PointCollectorTester {
 public static void main(String[] args) {
  PointCollector pc = new PointCollector();
  System.out.println(pc.nop);  /* 0 */
  pc.addPoint(3, 4);
  System.out.println(pc.nop);  /* 1 */
  pc.addPoint(-3, 4);
  System.out.println(pc.nop);  /* 2 */
  pc.addPoint(-3, -4);
  System.out.println(pc.nop);  /* 3 */
  pc.addPoint(3, -4);
  System.out.println(pc.nop);  /* 4 */
  Point[] ps = pc.getPointsInQuadrantI();
  System.out.println(ps.length);  /* 1 */
  System.out.println("(" + ps[0].x + ", " + ps[0].y + ")");
  /* (3, 4) */
 }
}
```

Java Data Types (3.3.1)

An attribute may be of type `ArrayList<Point>`, storing references to `Point` objects.

```
 1  class PointCollector {
 2   ArrayList<Point> points;
 3   PointCollector() { points = new ArrayList<>(); }
 4   void addPoint(Point p) {
 5    points.add (p); }
 6   void addPoint(double x, double y) {
 7    points.add (new Point(x, y)); }
 8   ArrayList<Point> getPointsInQuadrantI() {
 9    ArrayList<Point> q1Points = new ArrayList<>();
10    for(int i = 0; i < points.size(); i ++) {
11     Point p = points.get(i);
12     if(p.x > 0 && p.y > 0) { q1Points.add (p); } }
13    return q1Points;
14  } }
```

L8 & L9 may be replaced by:

```
for(Point p : points) { q1Points.add(p); }
```

Java Data Types (3.3.2)

```
class PointCollectorTester {
 public static void main(String[] args) {
   PointCollector pc = new PointCollector();
   System.out.println(pc.points.size());  /* 0 */
   pc.addPoint(3, 4);
   System.out.println(pc.points.size());  /* 1 */
   pc.addPoint(-3, 4);
   System.out.println(pc.points.size());  /* 2 */
   pc.addPoint(-3, -4);
   System.out.println(pc.points.size());  /* 3 */
   pc.addPoint(3, -4);
   System.out.println(pc.points.size());  /* 4 */
   ArrayList<Point> ps = pc.getPointsInQuadrantI();
   System.out.println(ps.length);  /* 1 */
   System.out.println("(" + ps[0].x + ", " + ps[0].y + ")");
   /* (3, 4) */
 }
}
```

The `this` Reference (7.1): Exercise

Consider the `Person` class

```
class Person {
  String name;
  Person spouse;
  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?

The `this` Reference (7.2): Exercise

```
void marry(Person other) {
  if(this.spouse != null || other.spouse != null) {
    System.out.println("Error: both must be single.");
  }
  else { this.spouse = other; other.spouse = this; }
}
```

When we call `jim.marry(elsa)`: `this` is substituted by the call target `jim`, and `other` is substituted by the argument `elsa`.

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

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

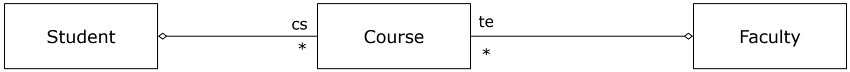
```
class Person {
  String name;
  Person spouse;
}
```

  - 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 trigger *NullPointerException*!!
  - Assuming that:
    - `jim` is not single. [`jim.spouse != null`]
    - The marriage is mutual. [`jim.spouse.spouse != null`]

    What does `jim.spouse.spouse.name` mean? [`jim.name`]

OOP: The Dot Notation (3.1)

In real life, the relationships among classes are sophisticated.



```
class Student {
  String id;
  Course[] cs;
}
```

```
class Course {
  String title;
  Faculty prof;
}
```

```
class Faculty {
  String name;
  Course[] te;
}
```

Aggregation links between classes constrain how you can *navigate* among these classes.

e.g., In the context of class `Student`:

- Writing ***`cs`*** denotes the array of registered courses.
- Writing ***`cs[i]`*** (where `i` is a valid index) navigates to the class `Course`, which changes the context to class `Course`.

OOP: The Dot Notation (3.2)

```
class Student {
  String id;
  Course[] cs;
}
```

```
class Course {
  String title;
  Faculty prof;
}
```

```
class Faculty {
  String name;
  Course[] te;
}
```

```
class Student {
  ... /* attributes */
  /* Get the student's id */
  String getID() { return this.id; }
  /* Get the title of the ith course */
  String getCourseTitle(int i) {
    return this.cs[i].title;
  }
  /* Get the instructor's name of the ith course */
  String getInstructorName(int i) {
    return this.cs[i].prof.name;
  }
}
```

OOP: The Dot Notation (3.3)

```
class Student {
  String id;
  Course[] cs;
}
```

```
class Course {
  String title;
  Faculty prof;
}
```

```
class Faculty {
  String name;
  Course[] te;
}
```

```
class Course {
  ... /* attributes */
  /* Get the course's title */
  String getTitle() { return this.title; }
  /* Get the instructor's name */
  String getInstructorName() {
    return this.prof.name;
  }
  /* Get title of ith teaching course of the instructor */
  String getCourseTitleOfInstructor(int i) {
    return this.prof.te.[i].title;
  }
}
```

OOP: The Dot Notation (3.4)

```
class Student {
  String id;
  Course[] cs;
}
```

```
class Course {
  String title;
  Faculty prof;
}
```

```
class Faculty {
  String name;
  Course[] te;
}
```

```
class Faculty {
  ... /* attributes */
  /* Get the instructor's name */
  String getName() {
    return this.name;
  }
  /* Get the title of ith teaching course */
  String getCourseTitle(int i) {
    return this.te[i].title;
  }
}
```

OOP: Equality (1)

```
Point p1 = new Point(2, 3);
Point p2 = new Point(2, 3);
boolean sameLoc = (p1 == p2);
System.out.println("p1 and p2 same location?" + sameLoc);
```

```
p1 and p2 same location?  false
```

OOP: Equality (2)

- Recall that
  - A *primitive* variable stores a primitive *value*
    e.g., `double d1 = 7.5; double d2 = 7.5;`
  - A *reference* variable stores the *address* to some object (rather than storing the object itself)
    e.g., `Point p1 = new Point(2, 3)` assigns to `p1` the address of the new `Point` object
    e.g., `Point p2 = new Point(2, 3)` assigns to `p2` the address of *another* new `Point` object
- The binary operator == may be applied to compare:
  - *Primitive* variables: their *contents* are compared
    e.g., `d1 == d2` evaluates to *true*
  - *Reference* variables: the *addresses* they store are compared (**rather than** comparing contents of the objects they refer to)
    e.g., `p1 == p2` evaluates to *false* because `p1` and `p2` are addresses of *different* objects, even if their contents are *identical*.

Static Variables (1)

```
class Account {
  int id;
  String owner;
  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.id != acc2.id);
}
```

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

Static Variables (2)

```
class Account {
  static int globalCounter = 1;
  int id; String owner;
  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.id != acc2.id); }
```

- 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 `c1` is also visible to `c2`.

Static Variables (3)

```
class Account {
  static int globalCounter = 1;
  int id; String owner;
  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`.

Static Variables (4.1): Common Error

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

```
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.accounts[0] */
  steve.addAccount(acc2);
    /* mistakenly added to steve.accounts[1]! */
}
```

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:

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

Static Variables (5.1): Common Error

```
1 public class Bank {
2   public string branchName;
3   public static int nextAccountNumber = 1;
4   public static void useAccountNumber() {
5     System.out.println (branchName + ...);
6     nextAccountNumber ++;
7   }
8 }
```

- *Non-static method cannot be referenced from a static context*
- **Line 4** declares that we *can* call the method `userAccountNumber` without instantiating an object of the class `Bank`.
- However, in **Lined 5**, the *static* method references a *non-static* attribute, for which we *must* instantiate a `Bank` object.

Static Variables (5.2): Common Error

```
public class Bank {
   public string branchName;
   public static int nextAccountNumber = 1;
   public static void useAccountNumber() {
      System.out.println (branchName + ...);
      nextAccountNumber ++;
   }
}
```

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

```
Bank .useAccountNumber();
```

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

```
Bank b1 = new Bank(); b1.setBranch("Songdo IBK");
System.out.println( b1 .branchName);
```

Static Variables (5.3): Common Error

There are two possible ways to fix:

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

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*.

OOP: Helper (Accessor) Methods (2.1)

```
class PersonCollector {
  Person[] ps;
  final int MAX = 100; /* max # of persons to be stored */
  int nop; /* number of persons */
  PersonCollector() {
    ps = new Person[MAX];
  }
  void addPerson(Person p) {
    ps[nop] = p;
    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)
   */
}
```

OOP: Helper (Accessor) Methods (2.2.1)

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

OOP: Helper (Accessor) Methods (2.2.2)

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

OOP: Helper (Accessor) Methods (2.3)

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

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`.

OOP: Helper (Accessor) Methods (3.2)

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

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

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

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

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(ohterX - this.x, 2)
     +
     Math.pow(otherY - this.y, 2));
}
```

OOP: Helper (Accessor) Methods (3.4)

```
class Point {
 double x; double y;
 double getDistanceFrom(double otherX, double otherY) {
  return Math.sqrt(Math.pow(ohterX - 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)
 }
}
```

OOP: Helper (Mutator) Methods (4.1)

```
class Student {
  String name;
  double balance;
  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)
   */
}
```

OOP: Helper (Mutator) Methods (4.2.1)

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

OOP: Helper (Mutator) Methods (4.2.2)

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

OOP: Helper (Mutator) Methods (4.3)

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

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Using API in Java

EECS1021:
Object Oriented Programming:
from Sensors to Actuators
Winter 2019

CHEN-WEI WANG

Learning Outcomes

Understand:

- Self-Exploration of Java API
- Method Header
- Parameters vs. Arguments
- Non-Static Methods and Collection Library
- Static Methods and Math Library

Application Programming Interface (API)

- Each time before you start solving a problem:
  - As a ***beginner***, crucial to implement **everything** by yourself.
  - As you get more ***experienced***, first check to see if it is already solved by one of the library classes or methods.

    Rule of the Thumb: DO NOT REINVENT THE WHEEL!
- An *Application Programming Interface (API)* is a collection of *programming facilities* for *reuse* and building your applications.
- Java API contains a library of *classes* (e.g., `Math`, `ArrayList`, `HashMap`) and *methods* (e.g., `sqrt`, `add`, `remove`):

  `https://docs.oracle.com/javase/8/docs/api/`
- To use a library class, put a corresponding `import` statement:

```
import java.util.ArrayList;
class MyClass {
  ArrayList myList;
  ...
}
```

Classes vs. Methods

- A *method* is a ***named*** block of code *reusable* by its name.
  e.g., As a user of the `sqrt` method (from the `Math` class):
  - Implementation code of `sqrt` is *hidden* from you.
  - You only need to know how to *call* it in order to use it.
  - A *non-static method* must be called using a context object.
    e.g., Illegal to call `ArrayList.add("Suyeon")`. Instead:

```
ArrayList<String> list = new ArrayList<String>();
list.add("Suyeon")
```

  - A *static method* can be called using the name of its class.
    e.g., By calling `Math.sqrt(1.44)`, you are essentially *reusing* a block of code, *hidden* from you, that will be executed and calculate the square root of the input value you supply (i.e., `1.44`).
- A *class* contains a collection of *related* methods.
  e.g., The `Math` *class* supports *methods* related to more advanced mathematical computations beyond the simple arithmetical operations we have seen so far (i.e., `+`, `−`, `*`, `/`, and `%`).

Parameters vs. Arguments

- *Parameters* of a *method* are its *input variables* that you read from the API page.

  e.g., `double pow(double a, double b)` has:
  - two parameters `a` and `b`, both of type `double`
  - one output/return value of type `double`
- *Arguments* of a *method* are the specific *input values* that you supply/pass in order to use it.

  e.g., To use the `pow` method to calculate 3.4^5, we call it by writing `Math.pow(3.4, 5)`.
- *Argument values* must conform to the corresponding *parameter types*.

  e.g., `Math.pow("three point four", "5")` is an invalid call!

Header of a Method

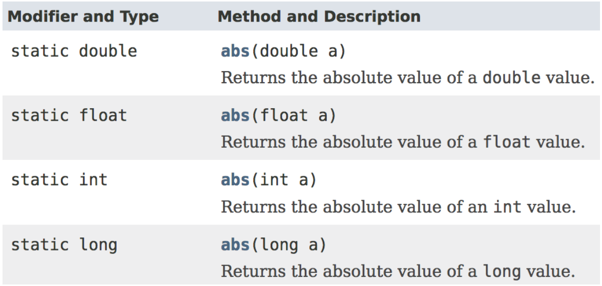
Header of a *method* informs users of the *intended usage*:

- *Name* of method
- List of *inputs* (a.k.a. *parameters*) and their types
- Type of the *output* (a.k.a. *return type*)
  - Methods with the `void` return type are mutators.
  - Methods with non-`void` return types are accessors.

e.g. In Java API, the **Method Summary** section lists *headers* and descriptions of methods.

Example Method Headers: Math Class

- The class Math contains methods for performing basic numeric operations such as the elementary exponential, logarithm, square root, and trigonometric functions.



Modifier and Type	Method and Description
`static double`	**`abs`**`(double a)` Returns the absolute value of a `double` value.
`static float`	**`abs`**`(float a)` Returns the absolute value of a `float` value.
`static int`	**`abs`**`(int a)` Returns the absolute value of an `int` value.
`static long`	**`abs`**`(long a)` Returns the absolute value of a `long` value.

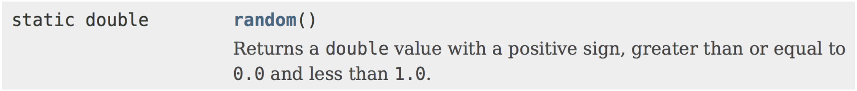
- *Method Overloading* : multiple methods sharing the *same name*, but with *distinct lists* of parameters (e.g., `abs` method).
- The `abs` method being `static` allows us to write `Math.abs(-2.5)`.

Case Study: Guessing a Number

Problem: Your program:

- *internally* and *randomly* sets a number between 0 and 100
- *repeatedly* asks the user to enter a guess, and hints if they got it, or should try something smaller or larger
- once the user got it and still wishes to continue, *repeat* the game with a different number

Hints:



static double	**random**() Returns a double value with a positive sign, greater than or equal to 0.0 and less than 1.0.

```
(int) Math.random() * 100
```

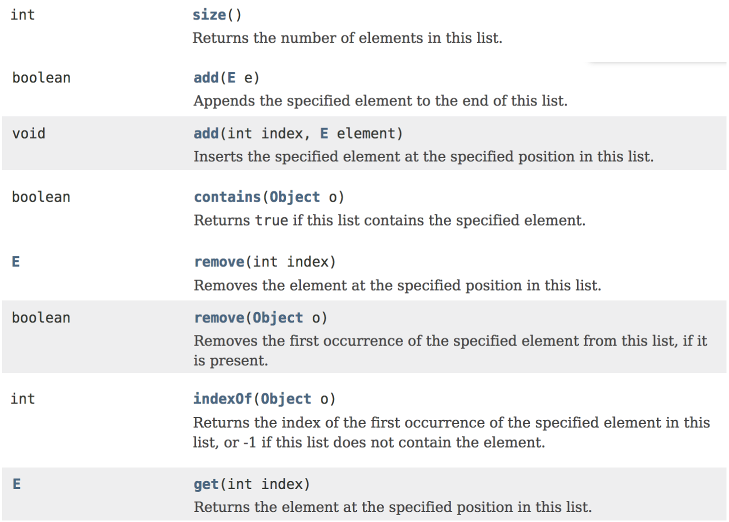
or

```
(int) (Math.random() * 100)
```

??

Example Method Headers: ArrayList Class

An ArrayList acts like a “resizable” array (indices start with 0).



`int`	`size()` Returns the number of elements in this list.
`boolean`	`add(E e)` Appends the specified element to the end of this list.
`void`	`add(int index, E element)` Inserts the specified element at the specified position in this list.
`boolean`	`contains(Object o)` Returns `true` if this list contains the specified element.
`E`	`remove(int index)` Removes the element at the specified position in this list.
`boolean`	`remove(Object o)` Removes the first occurrence of the specified element from this list, if it is present.
`int`	`indexOf(Object o)` Returns the index of the first occurrence of the specified element in this list, or -1 if this list does not contain the element.
`E`	`get(int index)` Returns the element at the specified position in this list.

Case Study: Using an ArrayList

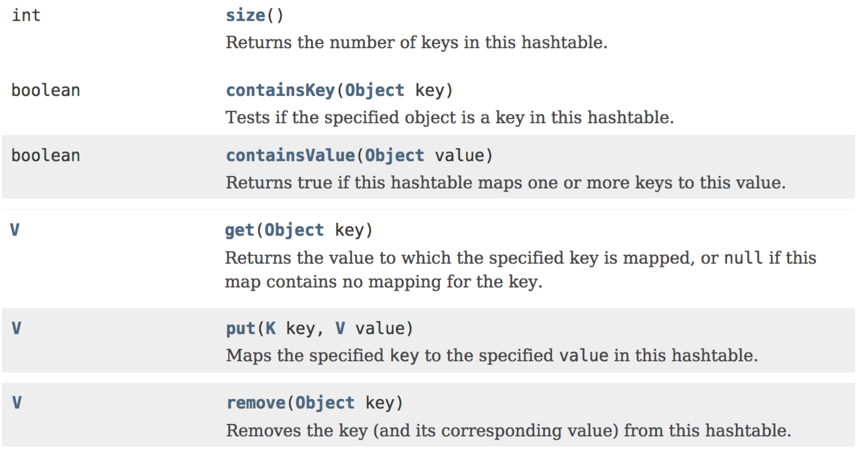
```java
import java.util.ArrayList;
public class ArrayListTester {
 public static void main(String[] args) {
  ArrayList<String> list = new ArrayList<String>();
  println(list.size());
  println(list.contains("A"));
  println(list.indexOf("A"));
  list.add("A");
  list.add("B");
  println(list.contains("A")); println(list.contains("B")); println(list.contains("C"));
  println(list.indexOf("A")); println(list.indexOf("B")); println(list.indexOf("C"));
  list.add(1, "C");
  println(list.contains("A")); println(list.contains("B")); println(list.contains("C"));
  println(list.indexOf("A")); println(list.indexOf("B")); println(list.indexOf("C"));
  list.remove("C");
  println(list.contains("A")); println(list.contains("B")); println(list.contains("C"));
  println(list.indexOf("A")); println(list.indexOf("B")); println(list.indexOf("C"));

  for(int i = 0; i < list.size(); i ++) {
   println(list.get(i));
  }
 }
}
```

See ***Java Data Types*** (3.3.1) – (3.3.2) in ***Classes and Objects*** for another example on ArrayList.

Example Method Headers: HashTable Class

A HashTable acts like a two-column table of (searchable) keys and values.



`int`	`size()` Returns the number of keys in this hashtable.
`boolean`	`containsKey(Object key)` Tests if the specified object is a key in this hashtable.
`boolean`	`containsValue(Object value)` Returns true if this hashtable maps one or more keys to this value.
`V`	`get(Object key)` Returns the value to which the specified key is mapped, or `null` if this map contains no mapping for the key.
`V`	`put(K key, V value)` Maps the specified key to the specified `value` in this hashtable.
`V`	`remove(Object key)` Removes the key (and its corresponding value) from this hashtable.

Case Study: Using a HashTable

```
import java.util.Hashtable;
public class HashTableTester {
 public static void main(String[] args) {
  Hashtable<String, String> grades = new Hashtable<String, String>();
  System.out.println("Size of table: " + grades.size());
  System.out.println("Key Alan exists: " + grades.containsKey("Alan"));
  System.out.println("Value B+ exists: " + grades.containsValue("B+"));
  grades.put("Alan", "A");
  grades.put("Mark", "B+");
  grades.put("Tom", "C");
  System.out.println("Size of table: " + grades.size());
  System.out.println("Key Alan exists: " + grades.containsKey("Alan"));
  System.out.println("Key Mark exists: " + grades.containsKey("Mark"));
  System.out.println("Key Tom exists: " + grades.containsKey("Tom"));
  System.out.println("Key Simon exists: " + grades.containsKey("Simon"));
  System.out.println("Value A exists: " + grades.containsValue("A"));
  System.out.println("Value B+ exists: " + grades.containsValue("B+"));
  System.out.println("Value C exists: " + grades.containsValue("C"));
  System.out.println("Value A+ exists: " + grades.containsValue("A+"));
  System.out.println("Value of existing key Alan: " + grades.get("Alan"));
  System.out.println("Value of existing key Mark: " + grades.get("Mark"));
  System.out.println("Value of existing key Tom: " + grades.get("Tom"));
  System.out.println("Value of non-existing key Simon: " + grades.get("Simon"));
  grades.put("Mark", "F");
  System.out.println("Value of existing key Mark: " + grades.get("Mark"));
  grades.remove("Alan");
  System.out.println("Key Alan exists: " + grades.containsKey("Alan"));
  System.out.println("Value of non-existing key Alan: " + grades.get("Alan"));
    }
}
```

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Wrap-Up

EECS1021:
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Winter 2019

CHEN-WEI WANG

Why this Course?

- *Computational thinking (CT)* is a fundamental skill for **everyone**, not just for computer scientists.
  - Reference: Wing, J.M., 2006. *Computational thinking*. Communications of the ACM, 49(3), pp.33 – 35.
  - Thinking like a computer scientist means **more than being able to program** a computer. It requires **thinking at multiple levels of abstraction**.
    - ***Level of Java Code***: How Programs Behave at Runtime
    - ***Above the Level of Code***: *Logical rationale* behind some *functioning*/*malfunctioning* code.
- Being able to think *abstractly* without seeing changes on a physical device is an important skill you are expected to acquire when graduating.
  - Think of programming interviews at Google: Given problems described in English, solve it on a whiteboard.

What You Learned (1)

- *Procedural Programming in Java*
  - primitive data types
  - assignments
  - casting vs. coercion for numbers
  - Boolean expressions, logical operators, short-circuit evaluation
  - `if`-statements
  - Solving problems *iteratively*: `for` vs. `while` loops
  - one-dimensional arrays

What You Learned (2)

- *Object-Oriented Programming in Java*
  - classes, attributes, objects, reference data types
  - methods: constructors, accessors, mutators, helper
  - dot notation, context objects, method calls
  - aliasing
  - Java API: `Math`, `Scanner`, `ArrayList`, `Hashtable`
- keywords: `final`, `this`, `static`

What You Learned (3)

- *Integrated Development Environment (IDE) for Java: Eclipse*
  - Compile Time vs. Runtime
    - Syntax Errors
    - Type Errors
    - Logical Errors
  - Creating Console App's via Classes with `main` method
  - User interactions
  - *Breakpoints and Debugger*

Beyond this course. . .

- Java Tutorials

  https://www.youtube.com/playlist?list=PL5dxAmCmjv_5NRNPG3OiWZWAqmvCjiLfG

- Two-Dimensional Arrays

  https://www.eecs.yorku.ca/~jackie/teaching/lectures/index.html#EECS1022_W18

- Advanced Object-Oriented Programming

  https://www.eecs.yorku.ca/~jackie/teaching/lectures/index.html#EECS2030_F18

Wish You the Best

- What you have learned will be **assumed** in `EECS2030`.
- Do **not** abandon Java during the break!!

Course Evaluation

`courseevaluations.yorku.ca`