Building Java Programs

A Back to Basics Approach

CS 210

CHAPTER 2

PRIMITIVE DATA AND DEFINITE LOOPS

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07/08/2021

Topics will be covered

- Data and Expressions
- Variables
- The for loop
- Nested for loops
- Class constants and scope

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Data and Expression

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DATA TYPES
EXPRESSIONS
PRECEDENCE
STRING CONCATENATION

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Data types

- **type**: A category or set of data values.
  - Constrains the operations that can be performed on data
  - Many languages ask the programmer to specify types
  - Examples: integer, real number, string

- Internally, computers store everything as 1s and 0s

```
104    ☾ 01101000
h   ☾ 011010
"hi"   ☾ 01101000110101
```

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Java's primitive types

- **primitive types**: 8 simple types for numbers, text, etc.
  - Java also has **object types**, which we'll talk about later

Name	Description	Examples
`int`	integers (up to 2^{31} - 1)	`42, -3, 0, 926394`
`double`	real numbers (up to 10^{308})	`3.1, -0.25, 9.4e3`
`char`	single text characters	`'a', 'X', '?', '\n'`
`boolean`	logical values	`true, false`

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Integer or Real number?

- Which category is more appropriate?

integer (`int`)	real number (`double`)
2, 4, 8, 9, 11	1, 3, 5, 6, 7, 10, 12

1. Temperature in degrees Celsius
2. The population of lemmings
3. Your grade point average
4. A person's age in years
5. A person's weight in pounds
6. A person's height in meters
7. Number of miles traveled
8. Number of dry days in the past month
9. Your locker number
10. Number of seconds left in a game
11. The sum of a group of integers
12. The average of a group of integers

- credit: Kate Deibel, http://www.cs.washington.edu/homes/deibel/CATs/

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Expressions

- **expression**: A value or operation that computes a value.

  - Examples: `1 + 4 * 5`

    ```
    (7 + 2) * 6 / 3
    42
    ```

  - The simplest expression is a *literal value*.
  - A complex expression can use operators and parentheses.

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Arithmetic operators

- **operator**: Combines multiple values or expressions.

`+`	addition
`-`	subtraction (or negation)
`*`	multiplication
`/`	division
`%`	modulus (a.k.a. remainder)

- As a program runs, its expressions are *evaluated*.
  - `1 + 1` evaluates to `2`
  - `System.out.println(3 * 4);` prints `12`
    - How would we print the text `3 * 4` ?

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Integer division with `/`

- When we divide integers, the quotient is also an integer.
  - `14 / 4` is `3`, not `3.5`

```
        3                 4                  52
  4 )  14         10 )   45         27 )   1425
       12                40                135
        2                 5                  75
                                             54
                                             21
```

- More examples:
  - `32 / 5` is `6`
  - `84 / 10` is `8`
  - `156 / 100` is `1`
  - Dividing by `0` causes an error when your program runs.

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Integer remainder with %

- The % operator computes the remainder from integer division.
  - 14 % 4 is 2
  - 218 % 5 is 3

```
      ___3            ___43
  4 ) 14          5 ) 218
      12              20
       2               18
                       15
                        3
```

What is the result?

```
45 % 6
2 % 2
8 % 20
11 % 0
```

- Applications of % operator:
  - Obtain last digit of a number: 230857 % 10 is 7
  - Obtain last 4 digits: 658236489 % 10000 is 6489
  - See whether a number is odd: 7 % 2 is 1, 42 % 2 is 0

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Precedence

- **precedence**: Order in which operators are evaluated.
  - Generally operators evaluate left-to-right.

    ```
    1 - 2 - 3 is (1 - 2) - 3 which is -4
    ```

  - But `* / %` have a higher level of precedence than `+ -`

    ```
    1 + 3 * 4                  is  13

    6 + 8 / 2 * 3
    6 +   4   * 3
    6 +     12  is  18
    ```

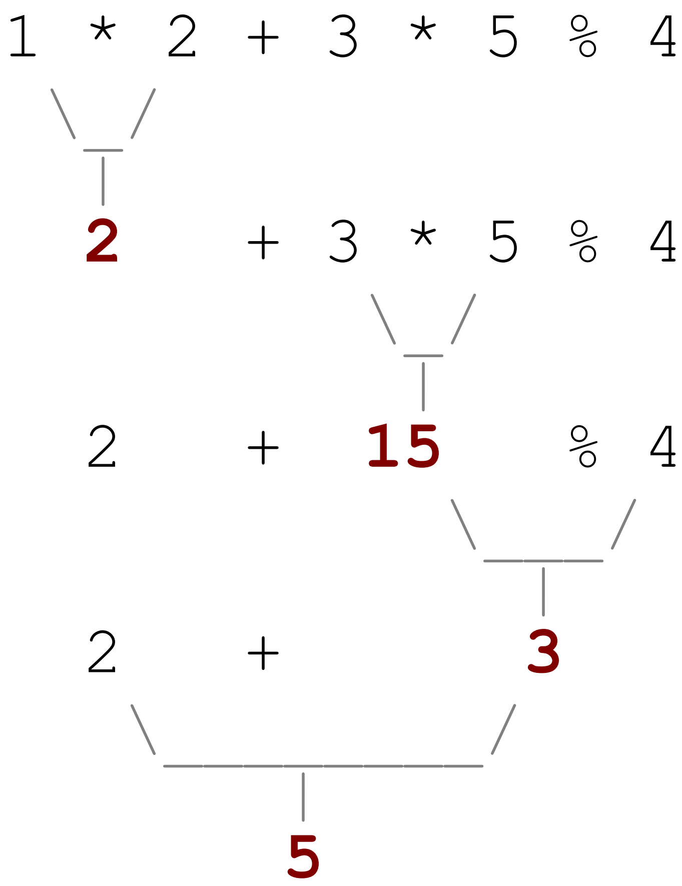
  - Parentheses can force a certain order of evaluation:

    ```
    (1 + 3) * 4                is  16
    ```

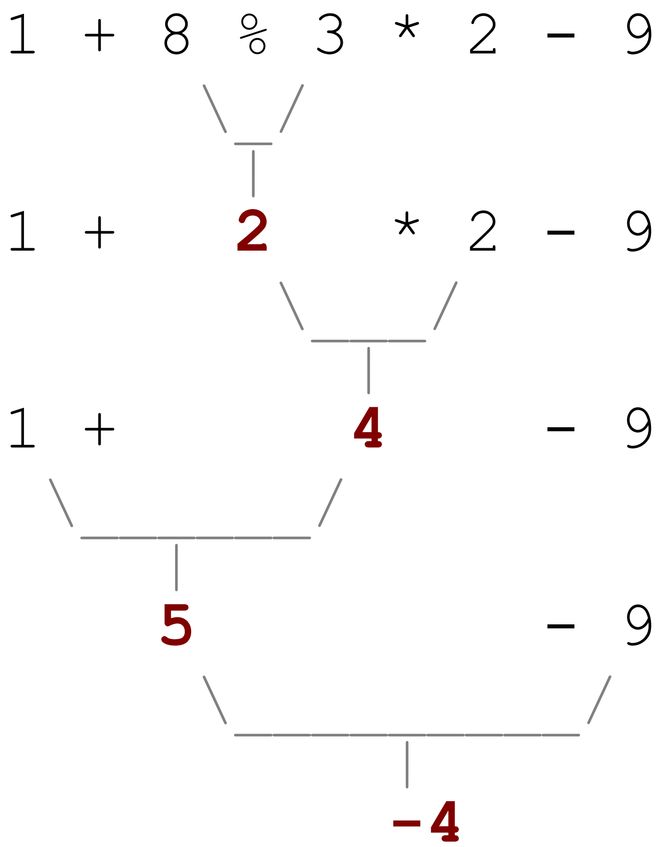
  - Spacing does not affect order of evaluation

    ```
    1+3 * 4-2                  is  11
    ```

Precedence examples



```
1 * 2 + 3 * 5 % 4
2     + 3 * 5 % 4
2     +  15   % 4
2     +       3
      5
```



```
1 + 8 % 3 * 2 - 9
1 +   2   * 2 - 9
1 +     4     - 9
    5         - 9
         -4
```

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Real numbers (type `double`)

- Examples: `6.022 , -42.0 , 2.143e17`
  - Placing `.0` or `.` after an integer makes it a `double`.
- The operators `+ - * / % ()` all still work with `double`.
  - `/` produces an exact answer: `15.0 / 2.0` is `7.5`
  - Precedence is the same: `()` before `* / %` before `+ -`

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Real number example

```
2.0 * 2.4 + 2.25 * 4.0 / 2.0
  \___/
    |
   4.8    + 2.25 * 4.0 / 2.0
              \___/
                |
   4.8    +    9.0   / 2.0
                 \_____/
                    |
   4.8    +        4.5
      \____________/
             |
            9.3
```

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Mixing types

- When `int` and `double` are mixed, the result is a `double`.
  - `4.2 * 3` is `12.6`

- The conversion is per-operator, affecting only its operands.

```
7 / 3 * 1.2 + 3 / 2
\_/
 |
 2    * 1.2 + 3 / 2
 \_____/
    |
   2.4     + 3 / 2
             \_/
              |
   2.4     +  1
   \__________/
        |
       3.4
```

```
2.5 + 10 / 3 * 2.5 - 6 / 4
      \____/
        |
2.5 +   3    * 2.5 - 6 / 4
        \_______/
            |
2.5 +      7.5     - 6 / 4
                     \_/
                      |
2.5 +      7.5     -  1
\_____________/
       |
      10.0          -  1
      \_______________/
              |
             9.0
```

`10.0 - 1` is `9.0`, NOT `9`!

- `3 / 2` is `1` above, NOT `1.5`!

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String concatenation

- **string concatenation**: Using + between a string and another value to make a longer string.

```
"hello" + 42  is "hello42"
1 + "abc" + 2 is "1abc2"
"abc" + 1 + 2 is "abc12"
1 + 2 + "abc" is "3abc"
"abc" + 9 * 3 is "abc27"
"1" + 1 is "11"
4 - 1 + "abc" is "3abc"
```

- Use + to print a string and an expression's value together.
  - `System.out.println("Grade: " + (95.1 + 71.9) / 2);`
  - **Output:** `Grade: 83.5`

Expression Exercise

- #1 - #10: What values result from the following expressions?

```
1:   9 / 5
2:   (5 – 7) * 4
3:   248 % 100 / 5
4:   6 + 18 % (17 - 12)
5:   89 % 10 / 4 * 2.0 / 5
6:   23 / 5 * 2.5 + 3
7:   23 / 5 * (int) 2.5 + 3
8:   “welcome ” + 6 / 3 + “ CS 210”
9:   “1” + 8 / 3 + 3
10: 37 % 4 + “2” + 3 + 4
```

Variables

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DECLARATION
INITIALIZATION
ASSIGNMENT
RECEIPT EXAMPLE

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Receipt example

What's bad about the following code?

```
public class Receipt {
    public static void main(String[] args) {
        // Calculate total owed, assuming 8% tax / 15% tip
        System.out.println("Subtotal:");
        System.out.println(38 + 40 + 30);
        System.out.println("Tax:");
        System.out.println((38 + 40 + 30) * .08);
        System.out.println("Tip:");
        System.out.println((38 + 40 + 30) * .15);
        System.out.println("Total:");
        System.out.println(38 + 40 + 30 +
                           (38 + 40 + 30) * .08 +
                           (38 + 40 + 30) * .15);
    }
}
```

- The subtotal expression `(38 + 40 + 30)` is repeated
- So many `println` statements

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Variables

- **variable**: A piece of the computer's memory that is given a name and type, and can store a value.
  - Like preset stations on a car stereo, or cell phone speed dial:

  - Steps for using a variable:
    - *Declare* it - state its name and type
    - *Initialize* it - store a value into it
    - *Use* it - print it or use it as part of an expression

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Declaration

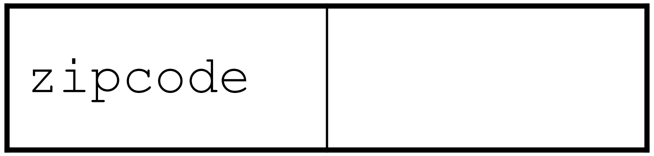
- **variable declaration**: Sets aside memory for storing a value.
  - Variables must be declared before they can be used.

- Syntax:

  type name;

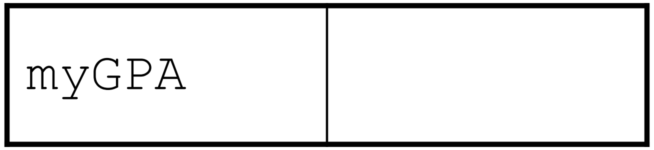
  - The name is an *identifier*.

  - `int zipcode;`



zipcode

  - `double myGPA;`



myGPA

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Assignment

- **assignment**: Stores a value into a variable.
  - The value can be an expression; the variable stores its result.

- Syntax:

```
name = expression;
```

  -
    ```
    int zipcode;
    zipcode = 98007;
    ```

zipcode	98007

  -
    ```
    double myGPA;
    myGPA = 1.0 + 2.25;
    ```

myGPA	3.25

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Using variables

- Once given a value, a variable can be used in expressions:

```
int x;
x = 3;
System.out.println("x is " + x);        // x is 3

System.out.println(5 * x - 1);          // 5 * 3 - 1
```

- You can assign a value more than once:

x	11

```
int x;
x = 3;
System.out.println(x + " here");        // 3 here

x = 4 + 7;
System.out.println("now x is " + x); // now x is 11
```

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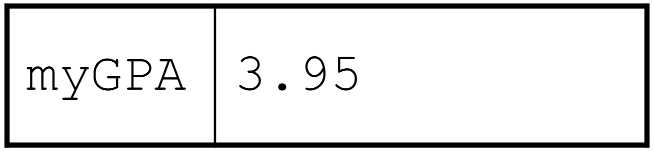
Declaration/initialization

- A variable can be declared/initialized in one statement.

- Syntax:

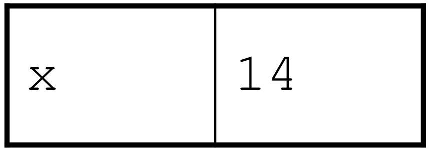
  type name = **value**;

  - `double myGPA = 3.95;`



myGPA 3.95

  - `int x = (11 % 3) + 12;`



x 14

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Assignment vs. algebra

- Assignment uses = , but it is not an algebraic equation.
  - `=` means, *"store the value at right in variable at left"*
  - `x = 3` means, *"x becomes 3"* or *"x should now store 3"*
  - The right side expression is evaluated first, and then its result is stored in the variable at left.

- What happens here?

```
int x = 3;
x = x + 2;    // ???
```

x	5

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Assignment Exercise

- What is the output of the following Java code?

```
int x;
x = 3;
int y = x;
x = 5;
y = y + x;
System.out.println(x);
System.out.println(y);
```

x	5
y	8

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Assignment and types

- A variable can only store a value of its own type.
  - `int x = 2.5;      // ERROR: incompatible types`

- An `int` value can be stored in a `double` variable.
  - The value is converted into the equivalent real number.
  - `double myGPA = 4;`

myGPA	4.0

  - `double avg = 11 / 2;`

avg	**5.0**

    - Why does `avg` store `5.0` and not `5.5` ?

Compiler errors

- A variable can't be used until it is assigned a value.

  -
    ```
    int x;
    System.out.println(x);    // ERROR: x has no value
    ```
- You may not declare the same variable twice.

  -
    ```
    int x;
    int x;                    // ERROR: x already exists
    ```

  -
    ```
    int x = 3;
    int x = 5;                // ERROR: x already exists
    ```
    - How can this code be fixed?

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Printing a variable's value

- Use + to print a string and a variable's value on one line.

```
double grade = (95.1 + 71.9 + 82.6) / 3.0;
System.out.println("Your grade was " + grade);

int students = 11 + 17 + 4 + 19 + 14;
System.out.println("There are " + students +
                   " students in the course.");
```

Output:

```
Your grade was 83.2
There are 65 students in the course.
```

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Receipt question

Improve the receipt program using variables.

```
public class Receipt {
    public static void main(String[] args) {
        // Calculate total owed, assuming 8% tax / 15% tip
        System.out.println("Subtotal:");
        System.out.println(38 + 40 + 30);

        System.out.println("Tax:");
        System.out.println((38 + 40 + 30) * .08);

        System.out.println("Tip:");
        System.out.println((38 + 40 + 30) * .15);

        System.out.println("Total:");
        System.out.println(38 + 40 + 30 +
                           (38 + 40 + 30) * .15 +
                           (38 + 40 + 30) * .08);
    }
}
```

Receipt answer

```
public class Receipt {
    public static void main(String[] args) {
        // Calculate total owed, assuming 8% tax / 15% tip
        int subtotal = 38 + 40 + 30;
        double tax = subtotal * .08;
        double tip = subtotal * .15;
        double total = subtotal + tax + tip;

        System.out.println("Subtotal: " + subtotal);
        System.out.println("Tax: " + tax);
        System.out.println("Tip: " + tip);
        System.out.println("Total: " + total);
    }
}
```

The `for` loop

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Repetition with for loops

- So far, repeating a statement is redundant:

```
System.out.println("Homer says:");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("S-M-R-T... I mean S-M-A-R-T");
```

- Java's **for loop** statement performs a task many times.

```
System.out.println("Homer says:");
for (int i = 1; i <= 4; i++) {    // repeat 4 times
    System.out.println("I am so smart");
}
System.out.println("S-M-R-T... I mean S-M-A-R-T");
```

for loop syntax

```
for (initialization; test; update) {
        statement;
        statement;
        ...
        statement;
}
```

header

body

- Perform **initialization** once.
- Repeat the following:
  - Check if the **test** is true. If not, stop.
  - Execute the **statement**s.
  - Perform the **update**.

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Initialization

```
for (int i = 1; i <= 6; i++) {
      System.out.println("I am so smart");
  }
```

- Tells Java what variable to use in the loop
  - Performed once as the loop begins
  - The variable is called a *loop counter*
    - can use any name, not just `i`
    - can start at any value, not just `1`

Test

```
for (int i = 1; i <= 6; i++) {
        System.out.println("I am so smart");
  }
```

- Tests the loop counter variable against a limit
  - Uses comparison operators:

<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to

Increment and decrement

```
for (int i = 1; i <= 6; i++)  {
        System.out.println("I am so smart");
  }
```

shortcuts to increase or decrease a variable's value by 1

Shorthand	Equivalent longer version
variable++;	**variable** = **variable** + 1;
variable--;	**variable** = **variable** - 1;

```
int x = 2;
x++; // x = x + 1;
     // x now stores 3

double gpa = 2.5;
gpa--; // gpa = gpa - 1;
       // gpa now stores 1.5
```

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Modify-and-assign

shortcuts to modify a variable's value

Shorthand	Equivalent longer version
variable `+=` **value**;	**variable** `=` **variable** `+` **value**;
variable `-=` **value**;	**variable** `=` **variable** `-` **value**;
variable `*=` **value**;	**variable** `=` **variable** `*` **value**;
variable `/=` **value**;	**variable** `=` **variable** `/` **value**;
variable `%=` **value**;	**variable** `=` **variable** `%` **value**;

```
x += 3;// x = x + 3;

gpa -= 0.5;  // gpa = gpa - 0.5;

number *= 2; // number = number * 2;
```

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`for` loop is NOT a method

- The `for` loop is a ***control structure*** – a syntactic structure that *controls* the execution of other statements.

- Example:
  - “Shampoo hair. Rinse. **Repeat**.”

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Repetition over a range

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```
System.out.println("1 squared = " + 1 * 1);
System.out.println("2 squared = " + 2 * 2);
System.out.println("3 squared = " + 3 * 3);
System.out.println("4 squared = " + 4 * 4);
System.out.println("5 squared = " + 5 * 5);
System.out.println("6 squared = " + 6 * 6);
```

- Intuition: "I want to print a line for each number from 1 to 6"

- The `for` loop does exactly that!

```
for (int i = 1; i <= 6; i++) {
      System.out.println(i + " squared = " + (i *
i));
}
```

- "For each integer **i** from 1 through 6, print ..."

Loop walkthrough

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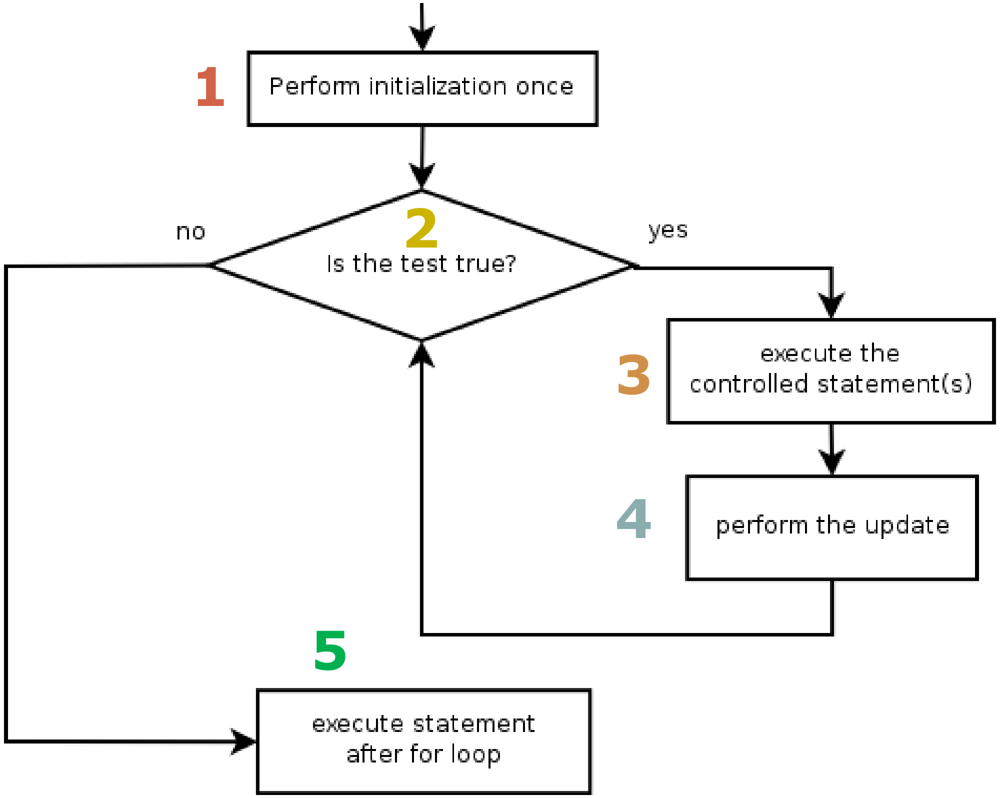
```
   for (int i 1= 1; i 2<= 4; 4i++) {
     3 System.out.println(i + " squared = " + (i * i));
   }
5  System.out.println("Whoo!");
```

Output:

```
1 squared = 1
2 squared = 4
3 squared = 9
4 squared = 16
Whoo!
```


1
Perform initialization once
2
Is the test true?
no
yes
3
execute the controlled statement(s)
4
perform the update
5
execute statement after for loop

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Multi-line loop body

```
System.out.println("+----+");
for (int i = 1; i <= 3; i++) {
    System.out.println("\\    /");
    System.out.println("/    \\");
}
System.out.println("+----+");
```

- Output:

```
+----+
\    /
/    \
\    /
/    \
\    /
/    \
+----+
```

Expressions for counter

```
int highTemp = 5;
for (int i = -3; i <= highTemp / 2; i++) {
    System.out.println(i * 1.8 + 32);
}
```

- Output:

```
26.6
28.4
30.2
32.0
33.8
35.6
```

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System.out.print

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- Prints without moving to a new line
  - allows you to print partial messages on the same line

```
int highestTemp = 5;
for (int i = -3; i <= highestTemp / 2; i++) {
    System.out.print((i * 1.8 + 32) + "  ");
}
```

  - Output:

```
26.6  28.4  30.2  32.0  33.8  35.6
```

    - Concatenate " " to separate the numbers

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Counting down

- The **update** can use -- to make the loop count down.
  - The **test** must say > instead of <

```
System.out.print("T-minus ");
for (int i = 10; i >= 1; i--) {
     System.out.print(i + ", ");
}
System.out.println("blastoff!");
System.out.println("The end.");
```

  - **Output:**

```
T-minus 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, blastoff!
The end.
```

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Nested `for` loops

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Nested loops

- **nested loop**: A loop placed inside another loop.

```
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= 10; j++) {
        System.out.print("*");
    }
    System.out.println();    // to end the line
}
```

- Output:

```
**********
**********
**********
**********
**********
```

- The outer loop repeats 5 times; the inner one 10 times.
  - "sets and reps" exercise analogy

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Nested `for` loop exercise 1

- What is the output of the following nested `for` loops?

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

- Output:

```
*
**
***
****
*****
```

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Nested `for` loop exercise 2

- What is the output of the following nested `for` loops?

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

- Output:

Common errors

- Both of the following sets of code produce *infinite loops*:

```
for (int i = 1; i <= 5; i++) {
    for (int j = 1; i <= 10; j++) {
        System.out.print("*");
    }
    System.out.println();
}

for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= 10; i++) {
        System.out.print("*");
    }
    System.out.println();
}
```

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Complex lines

- What nested `for` loops produce the following output?

inner loop (repeated characters on each line)

```
....1
...2
..3
.4
5
```

outer loop (loops 5 times because there are 5 lines)

- We must build multiple complex lines of output using:
  - an *outer "vertical" loop* for each of the lines
  - *inner "horizontal" loop(s)* for the patterns within each line

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Outer and inner loop

- First write the outer loop, from 1 to the number of lines.

```
for (int line = 1; line <= 5; line++) {
    ...
}
```

- Now look at the line contents. Each line has a pattern:
  - some dots (0 dots on the last line), then a number

```
....1
...2
..3
.4
5
```

  - Observation: the number of dots is related to the line number.

Mapping loops to numbers

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

- What statement in the body would cause the loop to print:

```
4 7 10 13 16
```

```
for (int count = 1; count <= 5; count++) {
    System.out.print(3 * count + 1 + " ");
}
```

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Loop tables exercise 1

- What statement in the body would cause the loop to print:

```
2 7 12 17 22
```

- To see patterns, make a table of `count` and the numbers.
  - Each time count goes up by 1, the number should go up by 5.
  - But `count * 5` is too great by 3, so we subtract 3.

`count`	number to print	`5 * count`	`5 * count - 3`
1	2	5	2
2	7	10	7
3	12	15	12
4	17	20	17
5	22	25	22

Loop tables exercise 2

- What statement in the body would cause the loop to print:
  `17 13 9 5 1`
- Let's create the loop table together.
  - Each time `count` goes up 1, the number printed should ...
  - But this multiple is off by a margin of ...

`count`	number to print	`-4 * count`	`-4 * count + 21`
1	17	-4	17
2	13	-8	13
3	9	-12	9
4	5	-16	5
5	1	-20	1

Nested `for` loop exercise

- Make a table to represent any patterns on each line.

```
....1
...2
..3
.4
5
```

line	# of dots	-1 * line	-1 * line + 5
1	4	-1	4
2	3	-2	3
3	2	-3	2
4	1	-4	1
5	0	-5	0

- To print a character multiple times, use a `for` loop.

```
for (int j = 1; j <= 4; j++) {
    System.out.print(".");          // 4 dots
}
```

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Nested `for` loop solution

- Answer:

```
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    System.out.println(line);
}
```

- Output:

```
....1
...2
..3
.4
5
```

Nested `for` loop exercise 1

- What is the output of the following nested `for` loops?

```
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    for (int k = 1; k <= line; k++) {
        System.out.print(line);
    }
    System.out.println();
}
```

- Output:

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Nested `for` loop exercise 2

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- Modify the previous code to produce this output:

```
....1
...2.
..3..
.4...
5....
```

- Answer:

```
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    System.out.print(line);
    for (int j = 1; j <= (line - 1); j++) {
        System.out.print(".");
    }
    System.out.println();
}
```

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Drawing complex figures

- Use nested `for` loops to produce the following output.

- Why draw ASCII art?
  - Real graphics require a lot of finesse
  - ASCII art has complex patterns
  - Can focus on the algorithms

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

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Development strategy

- Recommendations for managing complexity:

  1. Design the program (think about steps or methods needed).
     - write an English description of steps required
     - use this description to decide the methods

  2. Create a table of patterns of characters
     - use table to write your `for` loops

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

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Step 1. Pseudo-code

- **pseudo-code**: An English description of an algorithm.

- Example: Drawing a 12 wide by 7 tall box of stars

```
print 12 stars.
for (each of 5 lines) {
    print a star.
    print 10 spaces.
    print a star.
}
print 12 stars.
```

```
************
*          *
*          *
*          *
*          *
*          *
************
```

Pseudo-code algorithm

1. Line
   - # , 16 =, #

2. Top half
   - |
   - spaces (decreasing)
   - <>
   - dots (increasing)
   - <>
   - spaces (same as above)
   - |

3. Bottom half (top half upside-down)

4. Line
   - # , 16 =, #

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

Methods from pseudocode

```
public class Mirror {
    public static void main(String[] args) {
        line();
        topHalf();
        bottomHalf();
        line();
    }

    public static void topHalf() {
        for (int line = 1; line <= 4; line++) {
            // contents of each line
        }
    }

    public static void bottomHalf() {
        for (int line = 1; line <= 4; line++) {
            // contents of each line
        }
    }

    public static void line() {
        // ...
    }
}
```

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Step 2. Tables

- A table for the top half:
  - Compute spaces and dots expressions from line number

line	spaces	line * -2 + 8	dots	4 * line - 4
1	6	6	0	0
2	4	4	4	4
3	2	2	8	8
4	0	0	12	12

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

Step 3. Writing the code

- Useful questions about the top half:
    - What methods? (think structure and redundancy)
    - Number of (nested) loops per line?

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

Partial solution

```
// Prints the expanding pattern of <> for the top half of the figure.
public static void topHalf() {
    for (int line = 1; line <= 4; line++) {
        System.out.print("|");

        for (int space = 1; space <= (line * -2 + 8); space++) {
            System.out.print(" ");
        }

        System.out.print("<>");

        for (int dot = 1; dot <= (line * 4 - 4); dot++) {
            System.out.print(".");
        }

        System.out.print("<>");

        for (int space = 1; space <= (line * -2 + 8); space++) {
            System.out.print(" ");
        }

        System.out.println("|");
    }
}
```

Class constants and scope

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Scaling the mirror

- Let's modify our Mirror program so that it can scale.
  - The current mirror (left) is at size 4; the right is at size 3.

- We'd like to structure the code so we can scale the figure by changing the code in just one place.

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

```
#============#
|    <><>    |
|  <>....<>  |
|<>........<>|
|<>........<>|
|  <>....<>  |
|    <><>    |
#============#
```

Limitations of variables

- Idea: Make a variable to represent the size.
  - Use the variable's value in the methods.

- Problem: A variable in one method can't be seen in others.

```
public static void main(String[] args) {
    int size = 4;
    topHalf();
    printBottom();
}

public static void topHalf() {
    for (int i = 1; i <= size; i++) {     // ERROR: size not found
        ...
    }
}

public static void bottomHalf() {
    for (int i = size; i >= 1; i--) {     // ERROR: size not found
        ...
    }
}
```

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Scope

- **scope**: The part of a program where a variable exists.
  - From its declaration to the end of the `{ }` braces
    - A variable declared in a `for` loop exists only in that loop.
    - A variable declared in a method exists only in that method.

```
public static void example() {
    int x = 3;
    for (int i = 1; i <= 10; i++) {
        System.out.println(x);
    }
    // i no longer exists here
} // x ceases to exist here
```

x's scope

Scope implications

- Variables without overlapping scope can have same name.

```
for (int i = 1; i <= 100; i++) {
    System.out.print("/");
}
for (int i = 1; i <= 100; i++) {   // OK
    System.out.print("\\");
}
int i = 5;                  // OK: outside of loop's scope
```

- A variable can't be declared twice or used out of its scope.

```
for (int i = 1; i <= 100 * line; i++) {
    int i = 2;              // ERROR: overlapping scope
    System.out.print("/");
}
i = 4;                      // ERROR: outside scope
```

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Class constants

- **class constant:** A fixed value visible to the whole program.
  - value can be set only at declaration; cannot be reassigned

- Syntax:

`public static final` **type name** `=` **value**`;`

  - name is usually in ALL_UPPER_CASE

  - Examples:

```
public static final int DAYS_IN_WEEK = 7;
public static final double INTEREST_RATE = 3.5;
public static final int SSN = 658234569;
```

Constants and figures

- Consider the task of drawing the following scalable figure:

```
+/\/\/\/\/\/\/\/\/\/\/\+
|                    |
|                    |
|                    |
|                    |
|                    |
+/\/\/\/\/\/\/\/\/\/\/\+
```

Multiples of 5 occur many times

```
+/\/\/\/\+
|        |
|        |
+/\/\/\/\+
```

The same figure at size 2

Repetitive figure code

```
public class Sign {

    public static void main(String[] args) {
        drawLine();
        drawBody();
        drawLine();
    }

    public static void drawLine() {
        System.out.print("+");
        for (int i = 1; i <= 10; i++) {
            System.out.print("/\\");
        }
        System.out.println("+");
    }

    public static void drawBody() {
        for (int line = 1; line <= 5; line++) {
            System.out.print("|");
            for (int spaces = 1; spaces <= 20; spaces++) {
                System.out.print(" ");
            }
            System.out.println("|");
        }
    }
}
```

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Adding a constant

```
public class Sign {
    public static final int HEIGHT = 5;

    public static void main(String[] args) {
        drawLine();
        drawBody();
        drawLine();
    }

    public static void drawLine() {
        System.out.print("+");
        for (int i = 1; i <= HEIGHT * 2; i++) {
            System.out.print("/\\");
        }
        System.out.println("+");
    }

    public static void drawBody() {
        for (int line = 1; line <= HEIGHT; line++) {
            System.out.print("|");
            for (int spaces = 1; spaces <= HEIGHT * 4; spaces++) {
                System.out.print(" ");
            }
            System.out.println("|");
        }
    }
}
```

Complex figure w/ constant

- Modify the Mirror code to be resizable using a constant.

A mirror of size 4:

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

A mirror of size 3:

```
#============#
|    <><>    |
|  <>....<>  |
|<>........<>|
|<>........<>|
|  <>....<>  |
|    <><>    |
#============#
```

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Using a constant

- Constant allows many methods to refer to same value:

```
public static final int SIZE = 4;

public static void main(String[] args) {
    topHalf();
    printBottom();
}

public static void topHalf() {
    for (int i = 1; i <= SIZE; i++) {     // OK
        ...
    }
}

public static void bottomHalf() {
    for (int i = SIZE; i >= 1; i--) {     // OK
        ...
    }
}
```

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Loop tables and constant

- Let's modify our loop table to use `SIZE`
  - This can change the amount added in the loop expression

SIZE	line	spaces	`-2*line + (2*SIZE)`	dots	`4*line - 4`
4	1,2,3,4	6,4,2,0	-2*line + **8**	0,4,8,12	4*line - 4
4	1,2,3,4	6,4,2,0	-2*line + **8**	0,4,8,12	4*line - 4
3	1,2,3	4,2,0	-2*line + **6**	0,4,8	4*line - 4
3	1,2,3	4,2,0	-2*line + **6**	0,4,8	4*line - 4

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

```
#============#
|    <><>    |
|  <>....<>  |
|<>........<>|
|<>........<>|
|  <>....<>  |
|    <><>    |
#============#
```

Partial solution

```
public static final int SIZE = 4;

// Prints the expanding pattern of <> for the top half of the figure.
public static void topHalf() {
    for (int line = 1; line <= SIZE; line++) {
        System.out.print("|");

        for (int space = 1; space <= (line * -2 + (2*SIZE)); space++)
  {
            System.out.print(" ");
        }

        System.out.print("<>");

        for (int dot = 1; dot <= (line * 4 - 4); dot++) {
            System.out.print(".");
        }

        System.out.print("<>");

        for (int space = 1; space <= (line * -2 + (2*SIZE)); space++)
  {
            System.out.print(" ");
        }

        System.out.println("|");
    }
}
```

Observations about constant

- The constant can change the "intercept" in an expression.
  - Usually the "slope" is unchanged.

```
public static final int SIZE = 4;

for (int space = 1; space <= (line * -2 + (2 * SIZE));
  space++) {
    System.out.print(" ");
}
```

- It doesn't replace *every* occurrence of the original value.

```
for (int dot = 1; dot <= (line * 4 - 4); dot++) {
    System.out.print(".");
}
```

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The End

CS 210

CHAPTER 2

PRIMITIVE DATA AND DEFINITE LOOPS

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07/08/2021