Building Java Programs

Chapter 2
Lecture 2-2: The `for` Loop

reading: 2.3


I NEED TO USE THE COMPUTER.
HOLD ON. LET ME SEE IF ANYONE WROTE ON MY FACEBOOK WALL... NOPE.
NOW LET ME SEE IF ANYONE REPLIED TO ME ON TWITTER... NOPE.
NOW LET ME SEE IF ANYONE STARTED FOLLOWING MY TUMBLR... NOPE.
DONE?
LET ME CHECK FACEBOOK AGAIN. SOMEONE COULD HAVE WRITTEN SOMETHING IN THE LAST 30 SECONDS... NOPE.
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NOW LET ME CHECK TWITTER AGAIN... NOW TUMBLR...
OUR SISTER HAS GONE INFINITELY LOOPY.
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Repetition with `for` loops

- So far, repeating a statement is redundant:

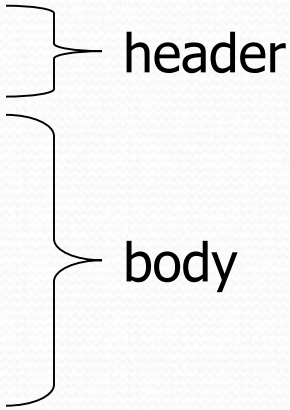
```
System.out.println("Homer says:");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("S-M-R-T... I mean S-M-A-R-T");
```

- 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;
}
```



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

Control structures

- **Control structure**: a programming construct that affects the flow of a program's execution
- Controlled code may include one or more statements
- The for loop is an example of a looping control structure

Initialization

```
for (int i = 1; i <= 4; i++) {
    System.out.println("I am so smart");
}
```

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

Test

```
for (int i = 1; i <= 4; 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

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
```

Modify-and-assign operators

shortcuts to modify a variable's value

Shorthand	Equivalent longer version
variable += **exp**;	**variable** = **variable** + (**exp**);
variable -= **exp**;	**variable** = **variable** - (**exp**);
variable *= **exp**;	**variable** = **variable** * (**exp**);
variable /= **exp**;	**variable** = **variable** / (**exp**);
variable %= **exp**;	**variable** = **variable** % (**exp**);

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

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

number *= 2 + 1;         // number = number * (2 + 1);
```

`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**."

Repetition over a range

```
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));
}
```

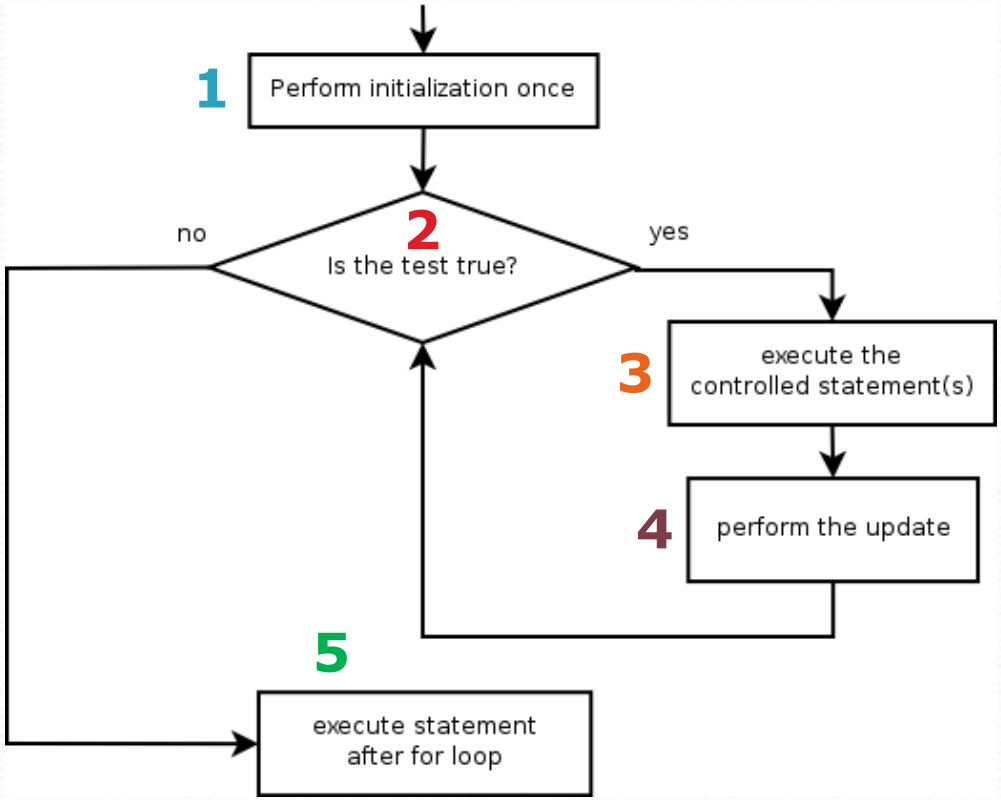
- "For each integer **i** from 1 through 6, print ..."

Loop walkthrough

```
          1        2     4
for (int i = 1; i <= 4; i++) {
  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!
```



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);
}
```

- This computes the Fahrenheit equivalents for -3 degrees Celsius to 2 degrees Celsius.

- Output:

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

System.out.print

- 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

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.
```

Nested loops

reading: 2.3

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

Nested `for` loop exercise

- 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:

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

Nested `for` loop exercise

- 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:

```
1
22
333
4444
55555
```

Common errors

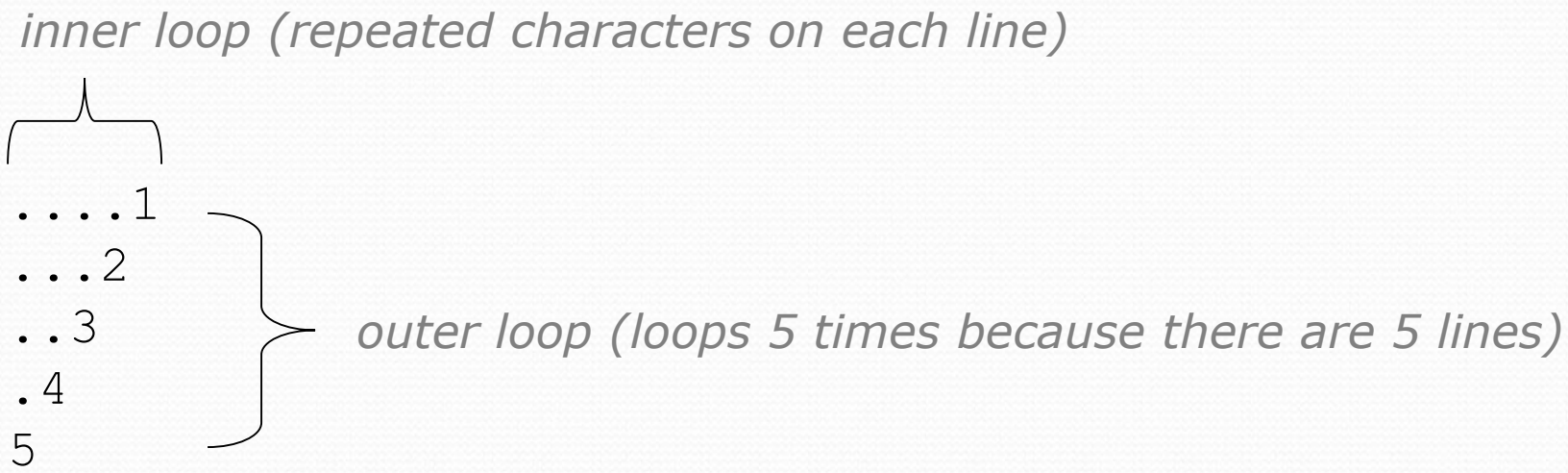
- Both of the following sets of code produce *infinite loops*:

```
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();
}
```

Complex lines

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



- 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

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 + " ");
}
```

Loop tables

- 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 question

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

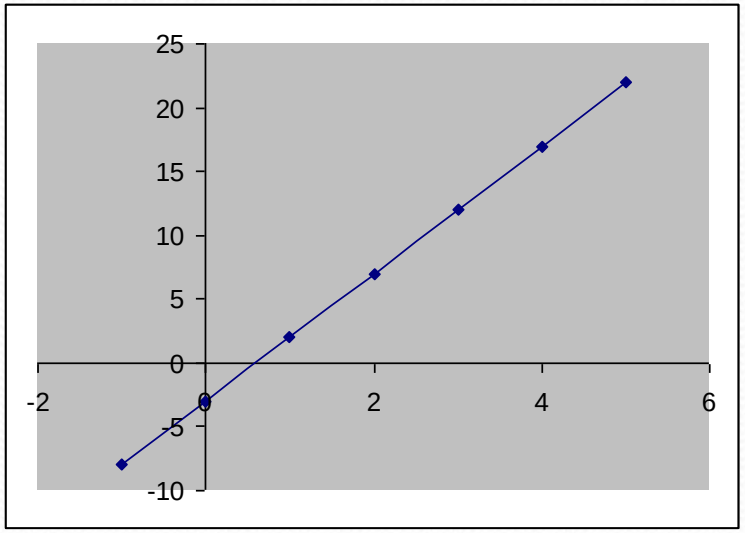
```
17 13 9 5 1
```

- 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

Another view: Slope-intercept

- The next three slides present the mathematical basis for the loop tables. Feel free to skip it.



`count (x)`	number to print (`y`)
1	2
2	7
3	12
4	17
5	22

Another view: Slope-intercept

- *Caution*: This is algebra, not assignment!
- Recall: slope-intercept form (`y = mx + b`)
- Slope is defined as "rise over run" (i.e. rise / run). Since the "run" is always `1` (we increment along `x` by 1), we just need to look at the "rise". The rise is the difference between the `y` values. Thus, the slope (`m`) is the difference between `y` values; in this case, it is `+5`.
- To compute the y-intercept (`b`), plug in the value of `y` at `x = 1` and solve for `b`. In this case, `y = 2`.

```
y = m * x + b
2 = 5 * 1 + b
```

Then `b = -3`

- So the equation is

```
y = m * x + b
y = 5 * x - 3
y = 5 * count - 3
```

`count (x)`	number to print (`y`)
1	2
2	7
3	12
4	17
5	22

Another view: Slope-intercept

- Algebraically, if we always take the value of `y` at `x = 1`, then we can solve for `b` as follows:

$$y = m * x + b$$
$$y_1 = m * 1 + b$$
$$y_1 = m + b$$
$$b = y_1 - m$$

- In other words, to get the `y`-intercept, just subtract the slope from the first `y` value (`b = 2 - 5 = -3`)
  - This gets us the equation

```
y = m * x + b
y = 5 * x - 3
y = 5 * count - 3
```

(which is exactly the equation from the previous slides)

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
}
```

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

- 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();
}
```

- Answer:

```
....1
...22
..333
.4444
55555
```

Nested `for` loop exercise

- 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();
}
```