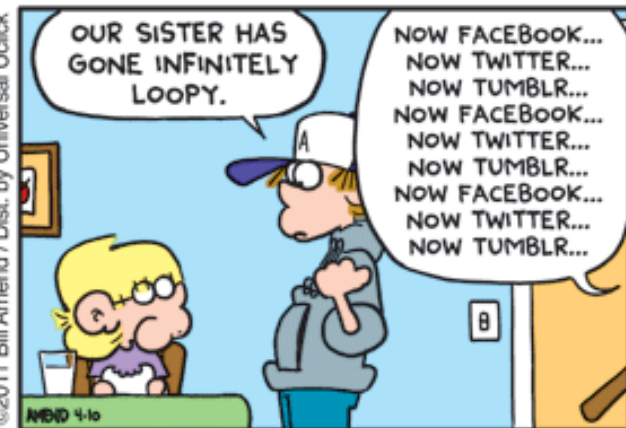
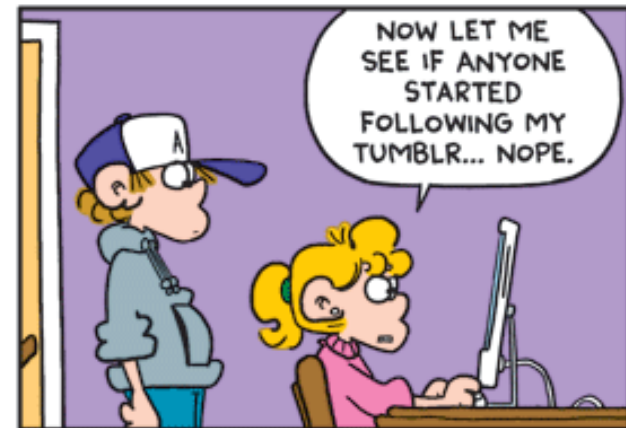
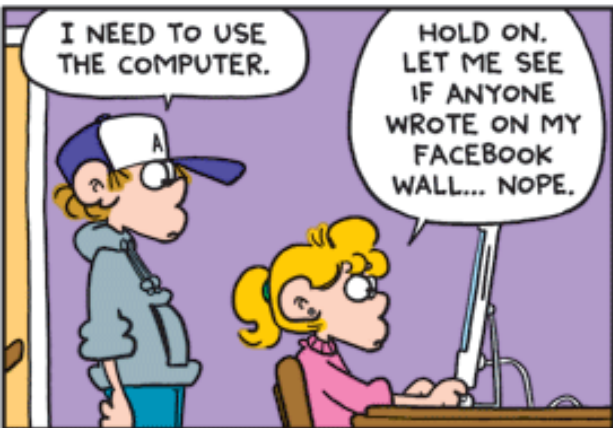


# Building Java Programs

Chapter 2

Lecture 2-2: The `for` Loop

**reading: 2.3**



# Repetition with `for` loops

- So far, repeating an action results in redundant code:

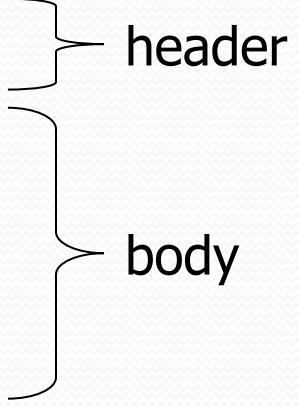
```
makeBatter();  
bakeCookies();  
bakeCookies();  
bakeCookies();  
bakeCookies();  
bakeCookies();  
bakeCookies();  
frostCookies();
```

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

```
mixBatter();  
  
for (int i = 1; i <= 5; i++) { // repeat 5 times  
    bakeCookies();  
}  
  
frostCookies();
```

# 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 **statements**.
  - 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 <= 6; 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 <= 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

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

## Shorthand

**variable**++;  
**variable**--;

```
int x = 2;  
x++;
```

```
double gpa = 2.5;  
gpa--;
```

## Equivalent longer version

**variable** = **variable** + 1;  
**variable** = **variable** - 1;

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

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



# Modify-and-assign operators

*shortcuts to modify a variable's value*

## Shorthand

**variable** += **value**;

**variable** -= **value**;

**variable** \*= **value**;

**variable** /= **value**;

**variable** %= **value**;

x += 3;

gpa -= 0.5;

number \*= 2;

## Equivalent longer version

**variable** = **variable** + **value**;

**variable** = **variable** - **value**;

**variable** = **variable** \* **value**;

**variable** = **variable** / **value**;

**variable** = **variable** % **value**;

// x = x + 3;

// gpa = gpa - 0.5;

// number = number \* 2;

# 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));  
}
```

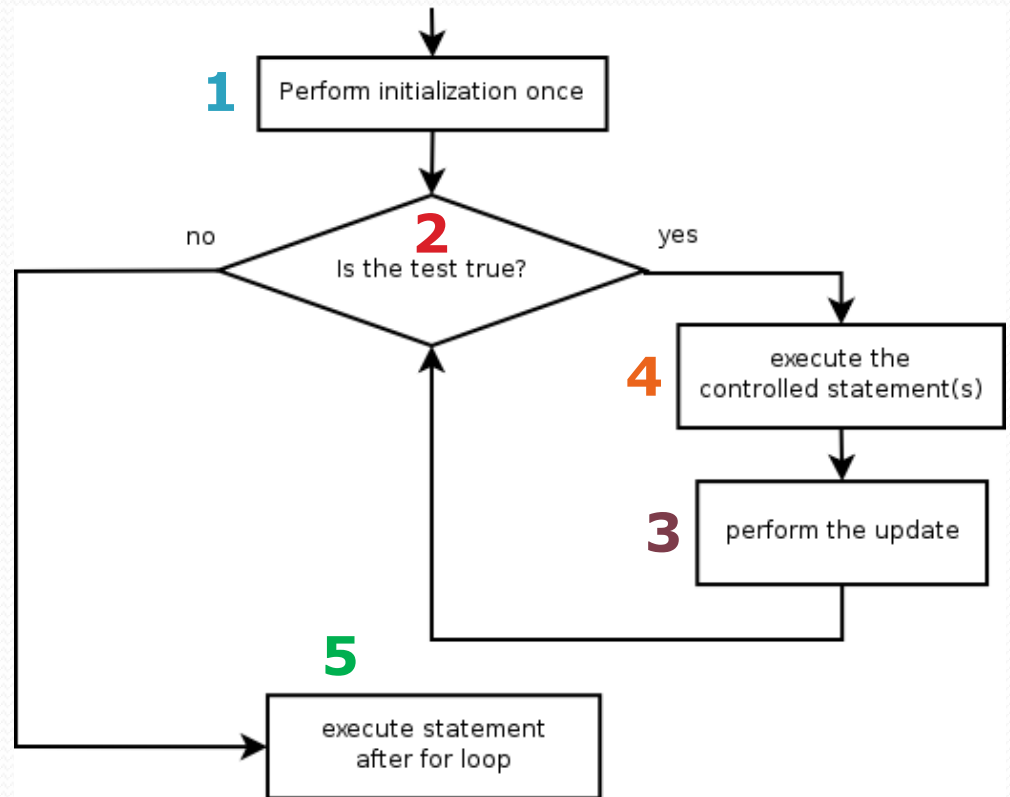
- "For each integer `i` from 1 through 6, print ..."

# Loop walkthrough

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

- 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*:

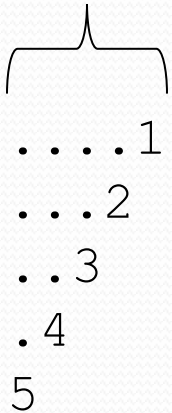
```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; i <= 10; j++) {  
        System.out.print("*");  
    }  
    System.out.println();  
}
```

```
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?

*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

# 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.

<code>count</code>	number to print	<code>5 * count</code>	<code>5 * count - 3</code>
1	2	5	2
2	7	10	7
3	12	15	12
4	17	20	17
5	22	25	22



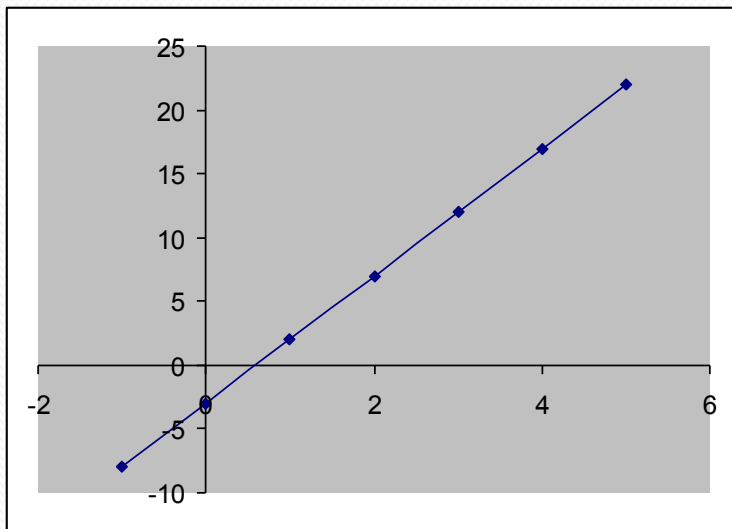
# Loop tables question

- 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	$-4 * \text{count}$	$-4 * \text{count} + 21$
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,  $y = 2$ .

$$y = m * x + b$$

$$2 = 5 * 1 + b$$

$$\text{Then } b = -3$$

- So the equation is

$$y = m * x + b$$

$$y = 5 * x - 3$$

$$y = 5 * \text{count} - 3$$

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

$$y = m * x + b$$

$$y = 5 * x - 3$$

$$y = 5 * \text{count} - 3$$

(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	$-1 * \text{line}$	$-1 * \text{line} + 5$
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();
}
```