Chapter 2: Primitive Data and Definite Loops
Lecture outline

- repetition
  - the for loop
  - nested loops
The for loop

reading: 2.3
Repetition with for loops

- So far, when we wanted to perform a task multiple times, we have written redundant code:

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

- Java has a statement called a for loop statement that instructs the computer to perform a task many times.

  ```java
  for (int i = 1; i <= 5; i++) { // repeat 5 times
      System.out.println("I am so smart");
  }
  System.out.println("S-M-R-T");
  System.out.println("I mean S-M-A-R-T");
  ```
for loop syntax

- **for loop**: A Java statement that executes a group of statements repeatedly until a given test fails.

  - General syntax:
    
    ```java
    for (<initialization> ; <test> ; <update>) {
      <statement>;
      <statement>;
      ...
      <statement>;
    }
    ```

  - Example:
    ```java
    for (int i = 1; i <= 10; i++) {
      System.out.println("His name is Robert Paulson");
    }
    ```
for loop over range of ints

- We'll write for loops over integers in a given range.
  - The loop declares a loop counter variable that is used in the test, update, and body of the loop.

    ```java
    for (int <name> = 1; <name> <= <value>; <name>++)
    ```

- Example:

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

- Interpretation: "For each integer i from 1 through 6, ..."

- Output:

    1 squared is 1
    2 squared is 4
    3 squared is 9
    4 squared is 16
    5 squared is 25
    6 squared is 36
Behavior of the `for` loop:

- Start out by performing the `<initialization>` once.
- Repeatedly execute the `<statement(s)>` followed by the `<update>` as long as the `<test>` is still a true statement.
Let's walk through the following `for` loop:

```java
for (int i = 1; i <= 3; i++) {
    System.out.println(i + " squared is " + (i * i));
}
```

Output:
1 squared is 1
2 squared is 4
3 squared is 9
Another example for loop

The body of a for loop can contain multiple lines.

Example:

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

Output:
```
+-----+
\ \ / \\
/ \ \\
/ \ \\
/ \ \\
+-----+
```
The initial and final values for the loop counter variable can be arbitrary numbers or expressions:

- **Example:**
  ```java
  for (int i = -3; i <= 2; i++) {
    System.out.println(i);
  }
  ```
  **Output:**
  
  ```
  -3
  -2
  -1
  0
  1
  2
  ```

- **Example:**
  ```java
  for (int i = 1 + 3 * 4; i <= 5248 % 100; i++) {
    System.out.println(i + " squared is " + (i * i));
  }
  ```
The update can also be a `--` or other operator, to make the loop count down instead of up.

- This also requires changing the test to say `>=` instead of `<=`.

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

**Output:**

T-minus 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, blastoff!
When a `for` loop only has one statement in its body, the `{ }` braces may be omitted.

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

However, this can lead to mistakes where a line appears to be inside a loop, but is not:

```java
for (int i = 1; i <= 3; i++)
    System.out.println("This is printed 3 times");
    System.out.println("So is this... or is it?");
```

**Output:**

This is printed 3 times
This is printed 3 times
This is printed 3 times
So is this... or is it?
for loop questions

Write a loop that produces the following output.

On day #1 of Christmas, my true love sent to me
On day #2 of Christmas, my true love sent to me
On day #3 of Christmas, my true love sent to me
On day #4 of Christmas, my true love sent to me
On day #5 of Christmas, my true love sent to me
...
On day #12 of Christmas, my true love sent to me

Write a loop that produces the following output.

2 4 6 8
Who do we appreciate
Mapping loops to numbers

Suppose that we have the following loop:

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

What statement could we write in the body of the loop that would make the loop print the following output?

3 6 9 12 15

Answer:

```java
for (int count = 1; count <= 5; count++) {
    System.out.print(3 * count + " ");
}
```
Now consider another loop of the same style:

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

What statement could we write in the body of the loop that would make the loop print the following output?

4 7 10 13 16

**Answer:**

```
for (int count = 1; count <= 5; count++) {
    System.out.print(3 * count + 1 + " ");
}
```
What statement could we write in the body of the loop that would make the loop print the following output?

2 7 12 17 22

To find the pattern, it can help to make a table of the count and the number to print.

- Each time count goes up by 1, the number should go up by 5.
- But count * 5 is too great by 3, so we must subtract 3.

<table>
<thead>
<tr>
<th>count</th>
<th>number to print</th>
<th>count * 5</th>
<th>count * 5 - 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
<td>25</td>
<td>22</td>
</tr>
</tbody>
</table>
Loop table question

What statement could we write in the body of the loop that would make the loop print the following output?

17 13 9 5 1

Let's create the loop table together.

- Each time count goes up 1, the number should ...
- But this multiple is off by a margin of ...

<table>
<thead>
<tr>
<th>count</th>
<th>number to print</th>
<th>count * -4</th>
<th>count * -4 + 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>-4</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>-8</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>-12</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>-16</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>-20</td>
<td>1</td>
</tr>
</tbody>
</table>
Degenerate loops

- Some loops execute 0 times, because of the nature of their test and update.

```java
// a degenerate loop
for (int i = 10; i < 5; i++) {
    System.out.println("How many times do I print?");
}
```

- Some loops execute endlessly (or far too many times), because the loop test never fails.

- A loop that never terminates is called an infinite loop.

```java
for (int i = 10; i >= 1; i++) {
    System.out.println("Runaway Java program!!!");
}
```
**Nested loops**

- **nested loop**: Loops placed inside one another.
  - The inner loop's counter variable must have a different name.

```java
for (int i = 1; i <= 3; i++) {
    System.out.println("i = " + i);
    for (int j = 1; j <= 2; j++) {
        System.out.println("  j = " + j);
    }
}
```

Output:
```
i = 1
  j = 1
  j = 2
i = 2
  j = 1
  j = 2
i = 3
  j = 1
  j = 2
```
More nested loops

- In this example, all of the statements in the outer loop's body are executed 5 times.
  - The inner loop prints 10 numbers each of those 5 times, for a total of 50 numbers printed.

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

Output:

1 2 3 4 5 6 7 8 9 10
2 4 6 8 10 12 14 16 18 20
3 6 9 12 15 18 21 24 27 30
4 8 12 16 20 24 28 32 36 40
5 10 15 20 25 30 35 40 45 50
What is the output of the following nested `for` loops?

```java
for (int i = 1; i <= 6; i++) {
    for (int j = 1; j <= 10; j++) {
        System.out.print("*");
    }
    System.out.println();
}
```

Output:

```
**********
**********
**********
**********
**********
**********
```
Nested for loop exercise

What is the output of the following nested for loops?

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

Output:

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

Copyright 2006 by Pearson Education
What is the output of the following nested `for` loops?

```java
for (int i = 1; i <= 6; i++) {
    for (int j = 1; j <= i; j++) {
        System.out.print(i);
    }
    System.out.println();
}
```

**Output:**

1
22
333
4444
55555
666666
Nested for loop exercise

What nested for loops produce the following output?

1, 1
2, 1
3, 1
1, 2
2, 2
3, 2

Answer:

```java
for (int y = 1; y <= 2; y++) {
    for (int x = 1; x <= 3; x++) {
        System.out.println(x + "", " + y);
    }
}
```
Nested for loop exercise

- What nested for loops produce the following output?

  inner loop (repeated characters on each line)

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

- This is an example of a nested loop problem where we build multiple complex lines of output:
  - outer "vertical" loop for each of the lines
  - inner "horizontal" loop(s) for the patterns within each line
First we write the outer loop, which always goes from 1 to the number of lines desired:

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

We notice that each line has the following pattern:
- some number of dots (0 dots on the last line)
- a number

```
....1  
...2  
..3    
..4    
5
```
Next we make a table to represent any necessary patterns on that line:

<table>
<thead>
<tr>
<th>line</th>
<th># of dots</th>
<th>value displayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Answer:

```java
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    System.out.println(line);
}
```
A for loop can have more than one loop nested in it.

What is the output of the following nested for loops?

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

<table>
<thead>
<tr>
<th>line</th>
<th># of dots</th>
<th>value displayed</th>
<th># of dots</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

Answer:

```java
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();
}
```
- It is easy to accidentally type the wrong loop variable.
  - What is the output of the following nested loops?
    ```java
    for (int i = 1; i <= 10; i++) {
        for (int j = 1; i <= 5; j++) {
            System.out.print(j);
        }
        System.out.println();
    }
    ```

- What is the output of the following nested loops?
  ```java
  for (int i = 1; i <= 10; i++) {
      for (int j = 1; j <= 5; i++) {
          System.out.print(j);
      }
      System.out.println();
  }
  ```
How to comment: for loops

Place a comment on complex loops explaining what they do conceptually, not the mechanics of the syntax.

- Bad:

  // This loop repeats 10 times, with i from 1 to 10.
  for (int i = 1; i <= 10; i++) {
      for (int j = 1; j <= 5; j++) {
          // loop goes 5 times
          System.out.print(j);
          // print the j
      }
  }
  System.out.println();

- Better:

  // Prints 12345 ten times on ten separate lines.
  for (int i = 1; i <= 10; i++) {
      for (int j = 1; j <= 5; j++) {
          System.out.print(j);
      }
  }
  System.out.println(); // end the line of output