Nested loops

reading: 2.3

self-check: 22-26
exercises: 10-14

videos: Ch. 2 #4

Redundancy between loops

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

for (int j = 1; j <= 5; j++) {
    System.out.print(2 * j + "\t");
}
System.out.println();

for (int j = 1; j <= 5; j++) {
    System.out.print(3 * j + "\t");
}
System.out.println();

for (int j = 1; j <= 5; j++) {
    System.out.print(4 * j + "\t"){
}
System.out.println();
```

Output:

```
1    2    3    4    5
2    4    6    8    10
3    6    9    12   15
4    8    12   16   20
```

Nested loops

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

```
for (int i = 1; i <= 4; i++) {
    for (int j = 1; j <= 5; j++) {
        System.out.print((i * j) + "\t");
    }
    System.out.println();  // to end the line
}
```

- Output:

```
1    2    3    4    5
2    4    6    8    10
3    6    9    12   15
4    8    12   16   20
```

- Statements in the outer loop's body are executed 4 times.
  - The inner loop prints 5 numbers each time it is run.

Nested `for` loop exercise

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

```
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?

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

- Output:

```
1
22
333
4444
55555
666666
```

Common errors

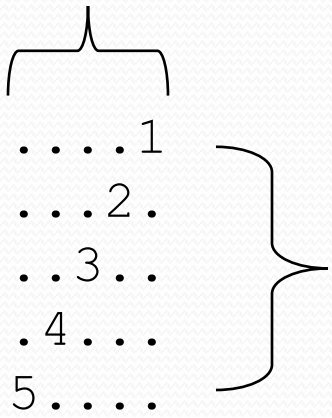
- Both of the following sets of code produce *infinite loops*:

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

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

Complex lines

- 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)

- Can 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)
  - a number
  - more dots (0 dots on the first line)

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

Nested `for` loop exercise

- A table for the dots we start with
  - Could do a second table for the other dots

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

- Output:

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

Building Java Programs

Chapter 2

Lecture 2-3: Loop Figures and Constants

reading: 2.4 - 2.5

self-checks: 27

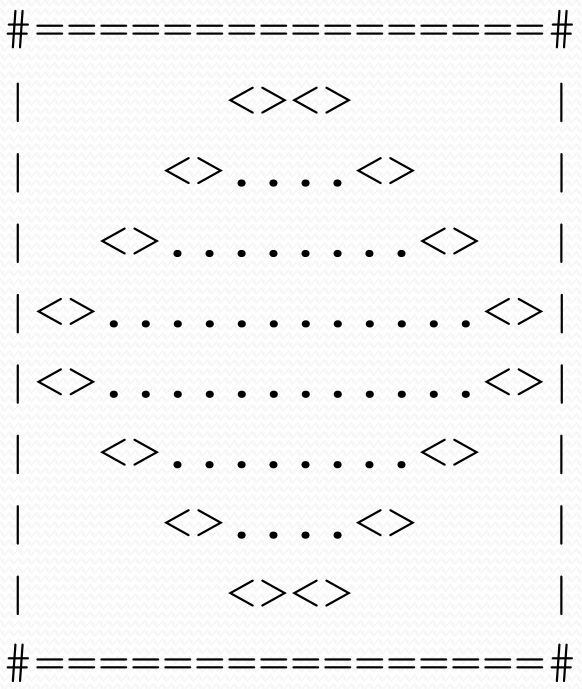
exercises: 16-17

videos: Ch. 2 #5

Drawing complex figures

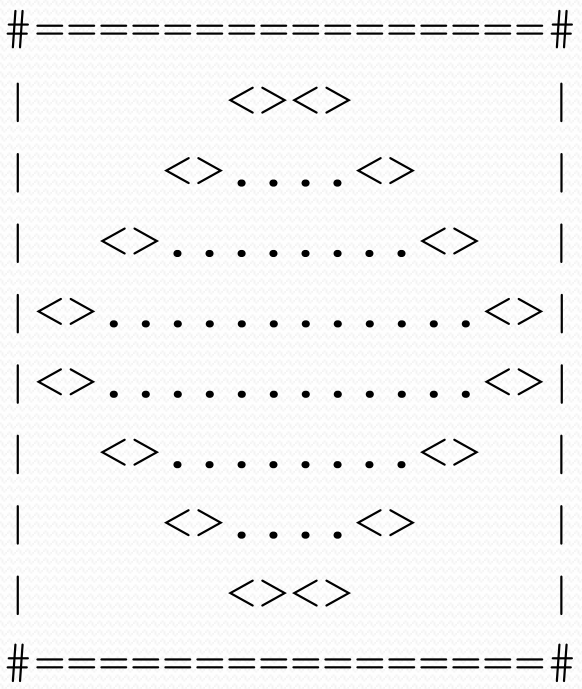
- Use nested `for` loops to produce the following output.

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



Development strategy

- Recommendations for managing complexity:
  1. Write an English description of steps required (*pseudo-code*)
     - use pseudo-code to decide methods
  2. Create a table of patterns of characters
     - use table to write loops in each method



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.
```

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

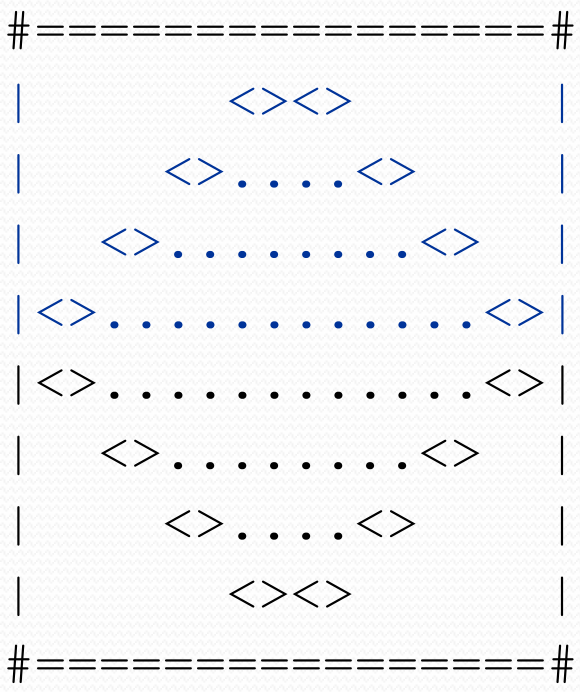
Pseudo-code algorithm

1. Line
   - # , 16 =, #

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

3. Bottom half (top half upside-down)

4. Line
   - # , 16 =, #



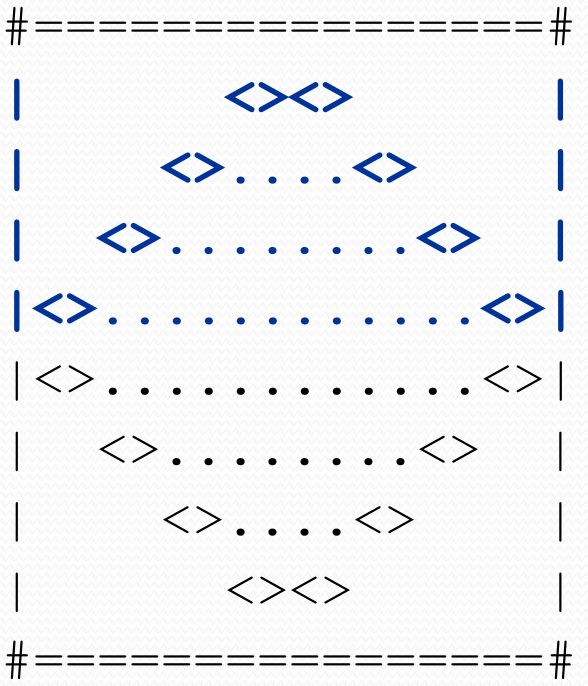
Methods from pseudocode

```
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() {
        // ...
    }
}
```

2. Tables

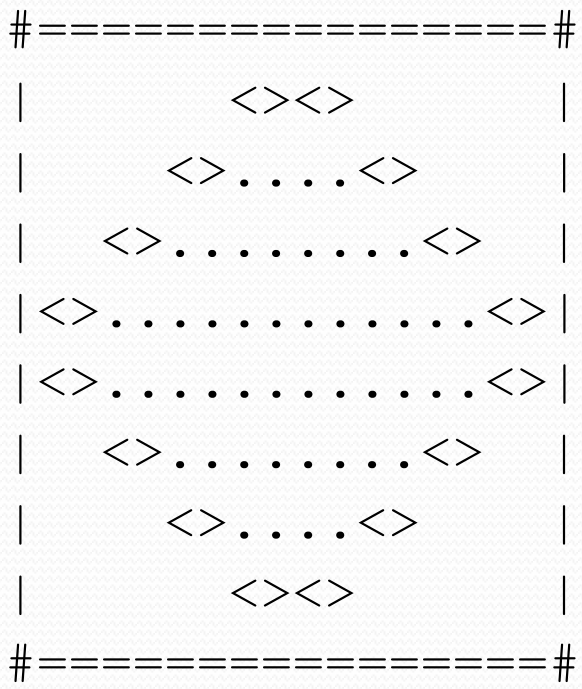
- A table for the top half:
  - Compute spaces and dots expressions from line number

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



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

reading: 2.4

self-check: 28

exercises: 11

videos: Ch. 2 #5

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

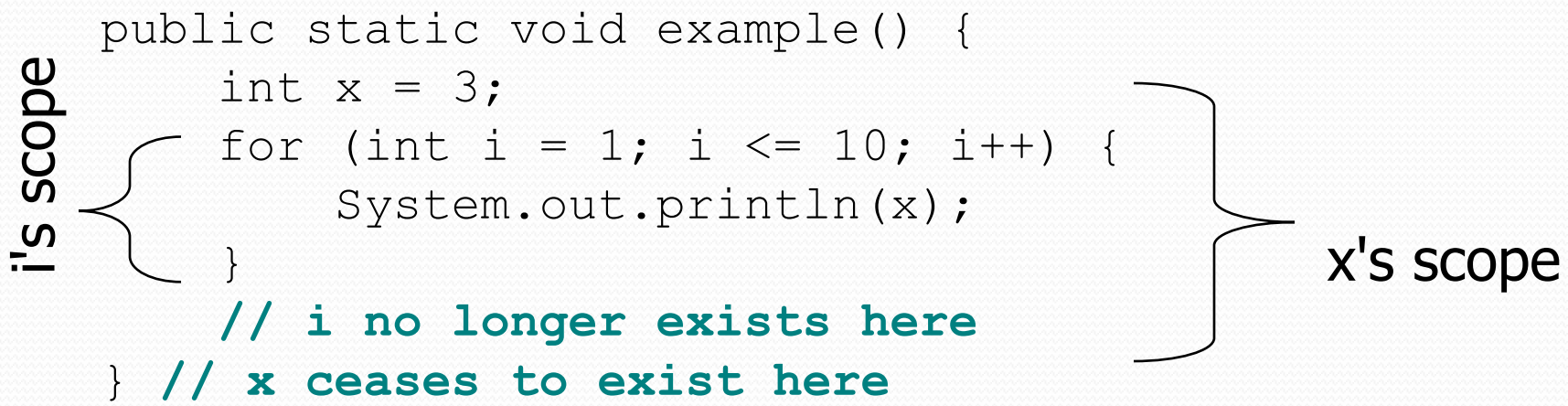
- Idea: Make a variable to represent the size.
  - Use the variable's value in the methods.

- 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
        ...
    }
}
```

Variable 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.



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
```

Class constants

- **class constant**: A value visible to the whole class.
  - value can only be set at declaration
  - value can't be changed while the program is running

- Syntax:

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

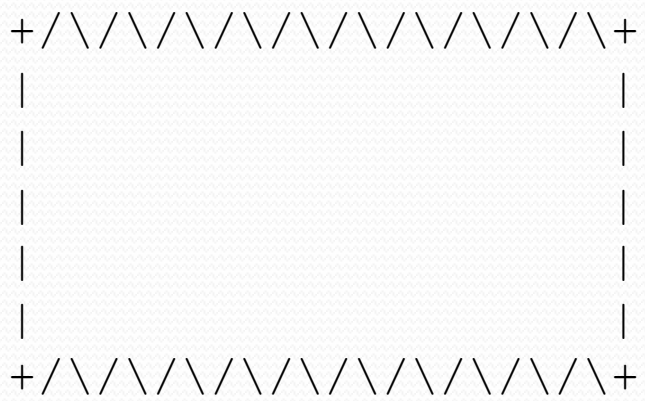
  - name is usually in ALL_UPPER_CASE

  - Examples:

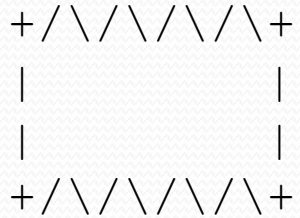
```
public static final int DAYS_IN_WEEK = 7;
public static final double INTEREST_RATE = 3.5;
public static final int SSN = 658234569;
```

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("|");
        }
    }
}
```

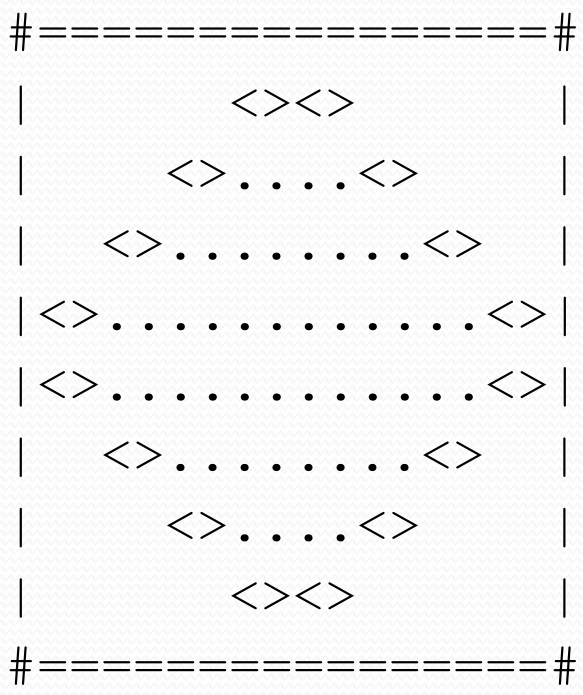
Adding a constant

```
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("|");
        }
    }
}
```

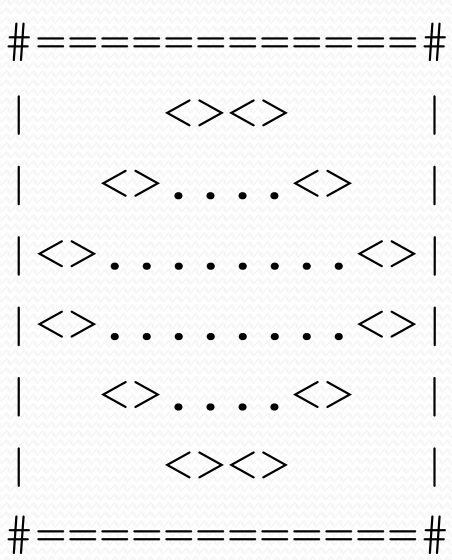
Complex figure w/ constant

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

A mirror of size 4:



A mirror of size 3:



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
        ...
    }
}
```

Loop tables and constant

- Let's modify our loop table to use `SIZE`

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
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("|");
    }
}
```

Observation about constant

- It doesn't replace *every* occurrence of the original value.
  - "Different fours" for different reasons
  - A good reason to use variables to keep things straight

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