

Chapter 2

1. Legal `int` literals: 22, -1, and -6875309

2. d. 11

3. Results of `int` expressions:

- a. 8
- b. 11
- c. 6
- d. 4
- e. 33
- f. -16
- g. 6.4
- h. 6
- i. 30
- j. 1
- k. 7
- l. 5
- m. 2
- n. 18
- o. 3
- p. 4
- q. 4
- r. 15
- s. 8
- t. 1

4. Results of `double` expressions:

- a. 9.0
- b. 9.6
- c. 2.2
- d. 6.0
- e. 6.0
- f. 8.0
- g. 1.25
- h. 3.0
- i. 3.0
- j. 3.0
- k. 5.0
- l. 6.4
- m. 37.0
- n. 8.5
- o. 9.6
- p. 4.0
- q. 4.8

5. Results of `String` expressions:

- a. 11
- b. "2 + 2 34"
- c. "2 2 + 3 4"
- d. "7 2 + 2"
- e. "2 + 2 7"
- f. "(2 + 2) 7"
- g. "hello 34 8"

6. `c.double grade = 4.0;`

```
7. int age;
   String gender;
   double height;
   int weight;
```

```
8. String year;
   int numberOfCourses;
   double gpa;
```

9. Last digit: `number % 10`

10. Mistakes in `Oops2` program:

1. line 4: There should be a `+` between `is` and `x`.
2. line 4: Variable `x` has not yet been given any value.
3. line 6: Variable `x` is being redeclared. The word `int` should be omitted.
4. line 6: Variable `x` is being given a value of the wrong type (`double`).
5. line 7: The `+ x` should be outside the quotes.
6. line 10: The word `int` should be omitted.
7. line 11: The word `and` should be surrounded by quotes.

11.

- o Second-to-last digit: `(number % 100) / 10` or `(number / 10) % 10`
- o Third-to-last digit: `(number % 1000) / 100` or `(number / 100) % 10`

12. d. 10

13. Values of `a`, `b`, and `c` after the code:

```
a: 6
b: 9
c: 16
```

14. Values of `first` and `second` after the code:

```
first: 19
second: 8
```

The code swaps the values of the variables `first` and `second`.

15. Rewritten shortened version of the code:

```
int first = 8, second = 19;
first += second;
second = first - second;
first -= second;
```

16. Values of `i`, `j`, and `k` after the code:

```
i: 4
j: 2
k: 1
```

17. Output of code:

```
46
36
23
13
```

18. Expression to compute `y` while using `*` only four times:

```
double y = x * (x * x * ((x * 12.3 - 9.1) + 19.3) - 4.6) + 34.2;
```

19. Version of ComputePay program that uses variables to avoid redundant expressions:

```
public class ComputePay {
    public static void main(String[] args) {
        // Calculate my pay at work, based on how many hours I worked each day
        int totalHours = 4 + 5 + 8 + 4;
        double salary = 8.75;
        double pay = totalHours * salary;
        double taxRate = 0.20;
        double taxesOwed = pay * taxRate;

        System.out.println("My total hours worked:");
        System.out.println(totalHours);
        System.out.println("My hourly salary:");
        System.out.println("$" + salary);
        System.out.println("My total pay:");
        System.out.println(pay);
        System.out.println("My taxes owed:");
        System.out.println(taxesOwed);
    }
}
```

20. // This program computes the total amount owed for a meal,
// assuming 8% tax and a 15% tip.

```
public class Receipt {
    public static void main(String[] args) {
        int subtotal = 38 + 40 + 30;
        System.out.println("Subtotal:");
        System.out.println(subtotal);

        double tax = subtotal * .08;
        System.out.println("Tax:");
        System.out.println(tax);

        double tip = subtotal * .15;
        System.out.println("Tip:");
        System.out.println(tip);

        double total = subtotal + tax + tip;
        System.out.println("Total:");
        System.out.println(total);
    }
}
```

21. public class Count2 {
public static void main(String[] args) {
for (int i = 1; i <= 4; i++) {
System.out.println("2 times " + i + " = " + (2 * i));
}
}
}

22.

- a. $2 * \text{count}$
- b. $15 * \text{count} - 11$
- c. $-10 * \text{count} + 40$
- d. $4 * \text{count} - 11$
- e. $-3 * \text{count} + 100$

23. for (int i = 1; i <= 6; i++) {
// your code here
System.out.println(18 * i - 22);
}

24. Output of oddStuff method:

```
4
2
```

25. Output of loop:

```
24 1
22 2
19 3
15 4
10 5
```

26. Output of loop:

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

27. Output of loop:

```
How many lines
How many lines
How many lines
are printed?
```

28. Output of loop:

```
T-minus 5, 4, 3, 2, 1, Blastoff!
```

29. Output of loops:

```
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
```

30. Output of loops:

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

31. Output of loops:

```
****!****!****!
****!****!****!
```

32. Output of loops:

```
*****!
*****!
```

33. Output of loops:

```
*!*!*!*!
*!*!*!*!
*!*!*!*!
*!*!*!*!
*!*!*!*!
*!*!*!*!
```

34. Mistakes in `BadNews` program:

1. The loop prints every third number, not every odd number. The statement `count = count + 2` on line 8 should be moved into the loop header instead of `count++`.
2. line 12: The variable `count` is no longer defined (its scope is limited to the `for` loop). It should be declared before the loop begins rather than inside the loop's header.
3. line 12: Too large a value is printed for the final odd number; `count` should be printed, not `count + 2`.
4. line 20: It is illegal to try to assign a new value to a constant such as `MAX_ODD`. One way to fix this would be to write two methods: one to print the odds up to 21 and a second to print the odds up to 11. (Admittedly, this solution is redundant. A better solution to this kind of problem involves parameter passing, which will be demonstrated in later chapters.)

35. Output of `Strange` program:

The result is: 55

36.

- a. $2 * \text{line} + 2 * \text{SIZE}$
- b. $4 * \text{line} + (3 * \text{SIZE})$
- c. $-\text{line} + (2 * \text{SIZE} + 3)$

37. Table for output:

line	\	!	/
1	0	22	0
2	2	18	2
3	4	14	4
4	6	10	6
5	8	6	8
6	10	2	10

- expression for \ and /: $2 * \text{line} - 2$
- expression for !: $-4 * \text{line} + 26$

38. Table for output:

line	\	!	/
1	0	14	0
2	2	10	2
3	4	6	4
4	6	2	6

- expression for \ and /: $2 * \text{line} - 2$
 - expression for !: $-4 * \text{line} + 18$
 - generalized for constant: $-4 * \text{line} + (4 * \text{SIZE} + 2)$
-

Chapter 2

1.

```
double s0 = 12.0;
double v0 = 3.5;
double a = 9.8;
int t = 10;
double s = s0 + v0 * t + a * t * t / 2.0;
System.out.println(s);
```

2.

```
int number = 1;
int increment = 3;
for (int i = 1; i <= 10; i++) {
    System.out.print(number + " ");
    number = number + increment;
    increment = increment + 2;
}
System.out.println(); // to end the line
```

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

3.

```
int n1 = 1;
int n2 = 1;
System.out.print(n1 + " " + n2 + " ");
for (int i = 3; i <= 12; i++) {
    int n3 = n1 + n2;
    n1 = n2;
    n2 = n3;
    System.out.print(n2 + " ");
}
System.out.println();
```

4.

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

5.

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

6.

```
for (int i = 1; i <= 7; i++) {
    for (int j = 1; j <= i; j++) {
        System.out.print(i);
    }
    System.out.println();
}
```

7.

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

8.

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

9.

```
int count = 20;
for (int i = 1; i <= count; i++) {
    System.out.print("--");
}
System.out.println();
for (int i = 0; i < count / 2; i++) {
    System.out.print("_^-");
}
System.out.println();
for (int i = 1; i <= count; i++) {
    System.out.print(i % 10);
    System.out.print(i % 10);
}
System.out.println();
for (int i = 1; i <= count; i++) {
    System.out.print("--");
}
System.out.println();
```

10.

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

11.

```
public class NumberOutput2 {
    public static final int COUNT = 6;
    public static final int INNER_COUNT = 10;
    public static void main(String[] args) {
        for (int i = 1; i <= COUNT; i++) {
            for (int j = 1; j <= INNER_COUNT - 1; j++) {
                System.out.print(" ");
            }
            System.out.print("|");
        }
        System.out.println();
        for (int i = 1; i <= COUNT; i++) {
            for (int j = 1; j <= INNER_COUNT; j++) {
                System.out.print(j % INNER_COUNT);
            }
        }
        System.out.println();
    }
}
```

12.

```
for (int i = 1; i <= 3; i++) {
    for (int j = 0; j <= 9; j++) {
        for (int k = 1; k <= 3; k++) {
            System.out.print(j);
        }
    }
    System.out.println();
}
```

13.

```
for (int i = 1; i <= 5; i++) {
    for (int j = 9; j >= 0; j--) {
        for (int k = 1; k <= 5; k++) {
            System.out.print(j);
        }
    }
    System.out.println();
}
```

14.

```
for (int i = 1; i <= 4; i++) {
    for (int j = 9; j >= 0; j--) {
        for (int k = 1; k <= j; k++) {
            System.out.print(j);
        }
    }
    System.out.println();
}
```

15.

```
public static void printDesign() {
    for (int line = 1; line <= 5; line++) {
        for (int dash = 1; dash <= -1 * line + 6; dash++) {
            System.out.print("-");
        }
        for (int number = 1; number <= 2 * line - 1; number++) {
            System.out.print(2 * line - 1);
        }
        for (int dash = 1; dash <= -1 * line + 6; dash++) {
            System.out.print("-");
        }
        System.out.println();
    }
}
```

16.

```
public class SlashFigure {
    public static void main(String[] args) {
        for (int line = 1; line <= 6; line++) {
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("\\");
            }
            for (int i = 1; i <= -4 * line + 26; i++) {
                System.out.print("!");
            }
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("/");
            }
            System.out.println();
        }
    }
}
```


17.

```
public class SlashFigure2 {
    public static final int SIZE = 4;
    public static void main(String[] args) {
        for (int line = 1; line <= SIZE; line++) {
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("\\");
            }
            for (int i = 1; i <= -4 * line + (4 * SIZE + 2); i++) {
                System.out.print("!");
            }
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("/");
            }
            System.out.println();
        }
    }
}
```

18.

```
overall algorithm:
    draw a horizontal line
    draw 3 lines of bars
    draw a line
    draw 3 lines of bars
    draw a line
how to draw a horizontal line:
    print a +
    print 3 = signs
    System.out.print("+");
    print a +
    print 3 = signs
    print a +
how to draw a line of bars:
    print a |
    print 3 spaces
    print a |
    print 3 spaces
    print a |
```

19.

```
// Draws a resizable window figure with nested for loops
// and a class constant.
public class Window {
    public static final int COUNT = 3;
    public static void main(String[] args) {
        drawLine();
        for (int i = 1; i <= 2; i++) {
            for (int j = 1; j <= COUNT; j++) {
                drawBars();
            }
            drawLine();
        }
    }
    // Draws a horizontal line: +==+==+
    public static void drawLine() {
        System.out.print("+");
        for (int i = 1; i <= COUNT; i++) {
            System.out.print("=");
        }
        System.out.print("+");
        for (int i = 1; i <= COUNT; i++) {
            System.out.print("=");
        }
        System.out.println("+");
    }
    // Draws a single line of bars: | | |
    public static void drawBars() {
        System.out.print("|");
        for (int i = 1; i <= COUNT; i++) {
            System.out.print(" ");
        }
        System.out.print("|");
        for (int i = 1; i <= COUNT; i++) {
            System.out.print(" ");
        }
        System.out.println("|");
    }
}
```

20.

```
public class StarFigure {
    public static void main(String[] args) {
        for (int line = 1; line <= 5; line++) {
            for (int i = 1; i <= -4 * line + 20; i++) {
                System.out.print("/");
            }
            for (int i = 1; i <= 8 * line - 8; i++) {
                System.out.print("*");
            }
            for (int i = 1; i <= -4 * line + 20; i++) {
                System.out.print("\\");
            }
            System.out.println();
        }
    }
}
```

21.

```
public class StarFigure2 {
    public static final int SIZE = 5;

    public static void main(String[] args) {
        for (int line = 1; line <= SIZE; line++) {
            for (int i = 1; i <= -4 * line + 4 * SIZE; i++) {
                System.out.print("/");
            }
            for (int i = 1; i <= 8 * line - 8; i++) {
                System.out.print("*");
            }
            for (int i = 1; i <= -4 * line + 4 * SIZE; i++) {
                System.out.print("\\");
            }
            System.out.println();
        }
    }
}
```

22.

```
public class DollarFigure {
    public static void main(String[] args) {
        for (int line = 1; line <= 7; line++) {
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("*");
            }
            for (int i = 1; i <= -1 * line + 8; i++) {
                System.out.print("$");
            }
            for (int i = 1; i <= -2 * line + 16; i++) {
                System.out.print("*");
            }
            for (int i = 1; i <= -1 * line + 8; i++) {
                System.out.print("$");
            }
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("*");
            }
            System.out.println();
        }
    }
}
```

23.

```
public class DollarFigure2 {
    public static final int SIZE = 7;

    public static void main(String[] args) {
        for (int line = 1; line <= SIZE; line++) {
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("*");
            }
            for (int i = 1; i <= -1 * line + (SIZE + 1); i++) {
                System.out.print("$");
            }
            for (int i = 1; i <= -2 * line + (2 * SIZE + 2); i++) {
                System.out.print("*");
            }
            for (int i = 1; i <= -1 * line + (SIZE + 1); i++) {
                System.out.print("$");
            }
            for (int i = 1; i <= 2 * line - 2; i++) {
                System.out.print("*");
            }
            System.out.println();
        }
    }
}
```



Building Java Programs

Chapter 2

Primitive Data and Definite Loops

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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
 - "hi" → 01101000110101

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

- Why does Java distinguish integers vs. real numbers?

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.

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` ?

Integer division with /

- When we divide integers, the quotient is also an integer.

– $14 / 4$ is 3, not 3.5

$$\begin{array}{r} 3 \\ 4 \overline{) 14} \\ \underline{12} \\ 2 \end{array}$$

$$\begin{array}{r} 4 \\ 10 \overline{) 45} \\ \underline{40} \\ 5 \end{array}$$

$$\begin{array}{r} 52 \\ 27 \overline{) 1425} \\ \underline{135} \\ 75 \\ \underline{54} \\ 21 \end{array}$$

- More examples:

– $32 / 5$ is 6

– $84 / 10$ is 8

– $156 / 100$ is 1

– Dividing by 0 causes an error when your program runs.

Integer remainder with %

- The % operator computes the remainder from integer division.

– 14 % 4 is 2

– 218 % 5 is 3

$$\begin{array}{r} 3 \\ \hline 4 \) \ 14 \\ \underline{12} \\ 2 \end{array}$$

$$\begin{array}{r} 43 \\ \hline 5 \) \ 218 \\ \underline{20} \\ 18 \\ \underline{15} \\ 3 \end{array}$$

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

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

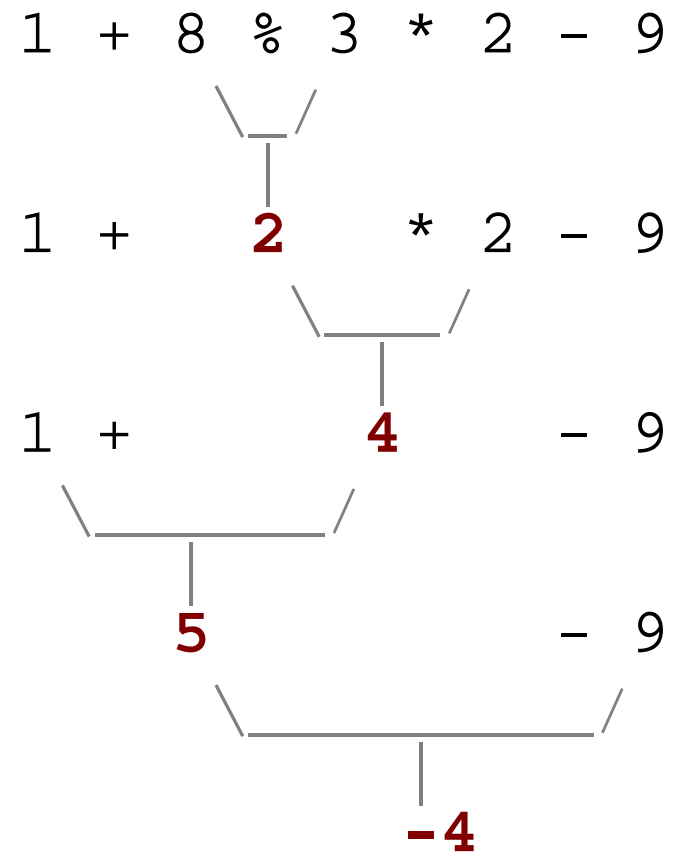
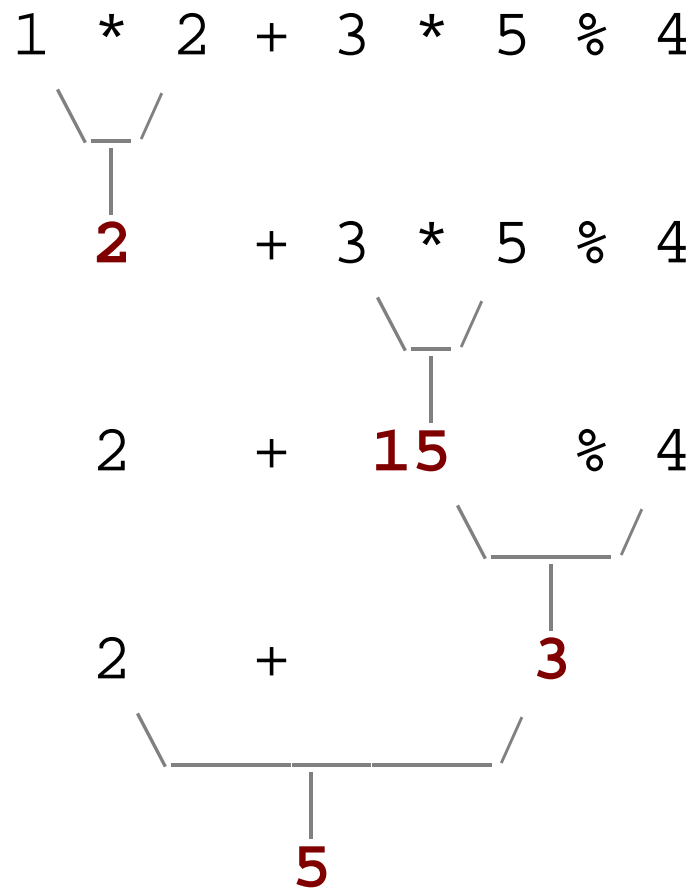
– Parentheses can force a certain order of evaluation:

(1 + 3) * 4 is 16

– Spacing does not affect order of evaluation

1+3 * 4-2 is 11

Precedence examples



Precedence questions

- What values result from the following expressions?

$$- 9 / 5$$

$$- 695 \% 20$$

$$- 7 + 6 * 5$$

$$- 7 * 6 + 5$$

$$- 248 \% 100 / 5$$

$$- 6 * 3 - 9 / 4$$

$$- (5 - 7) * 4$$

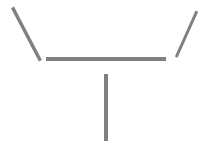
$$- 6 + (18 \% (17 - 12))$$

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 `+` `-`

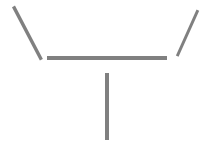
Real number example

$$2.0 * 2.4 + 2.25 * 4.0 / 2.0$$



4.8

$$+ 2.25 * 4.0 / 2.0$$



9.0

4.8

$$+ \quad \quad \quad / 2.0$$



4.5

4.8

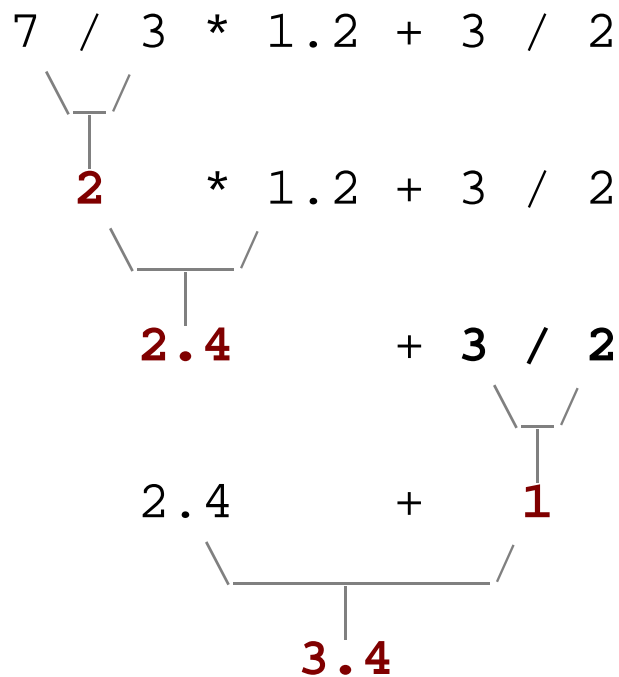
+



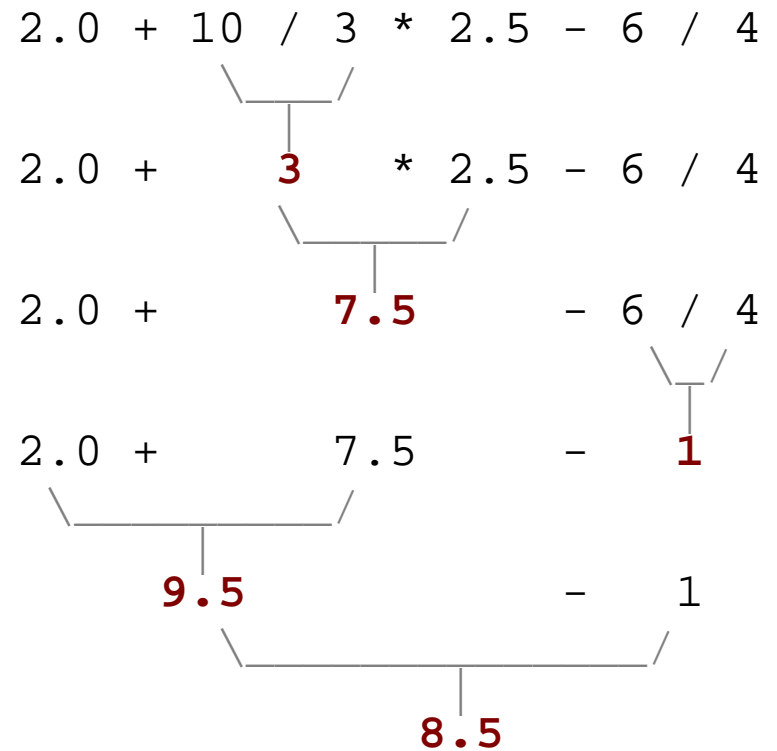
9.3

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.



– `3 / 2` is 1 above, not 1.5.



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



Variables

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

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

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 x;`



– `double myGPA;`



Assignment

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

name = expression ;

```
- int x;  
  x = 3;
```



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



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:

```
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
```



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
---	----

Assignment and algebra

- Assignment uses = , but it is not an algebraic equation.
 - = means, *"store the value at right in variable at left"*
 - 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
---	---

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?

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.
```

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

Repetition with `for` loops

- So far, repeating a statement is redundant:

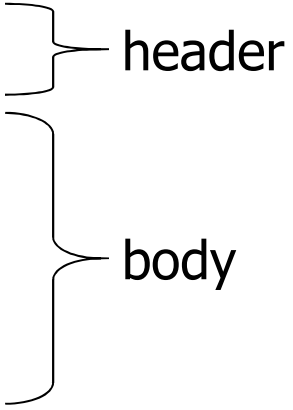
```
System.out.println("Homer says:");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("I am so smart");
System.out.println("S-M-R-T... I mean S-M-A-R-T");
```

- 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 **statements**.
 - Perform the **update**.

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

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

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));  
}
```

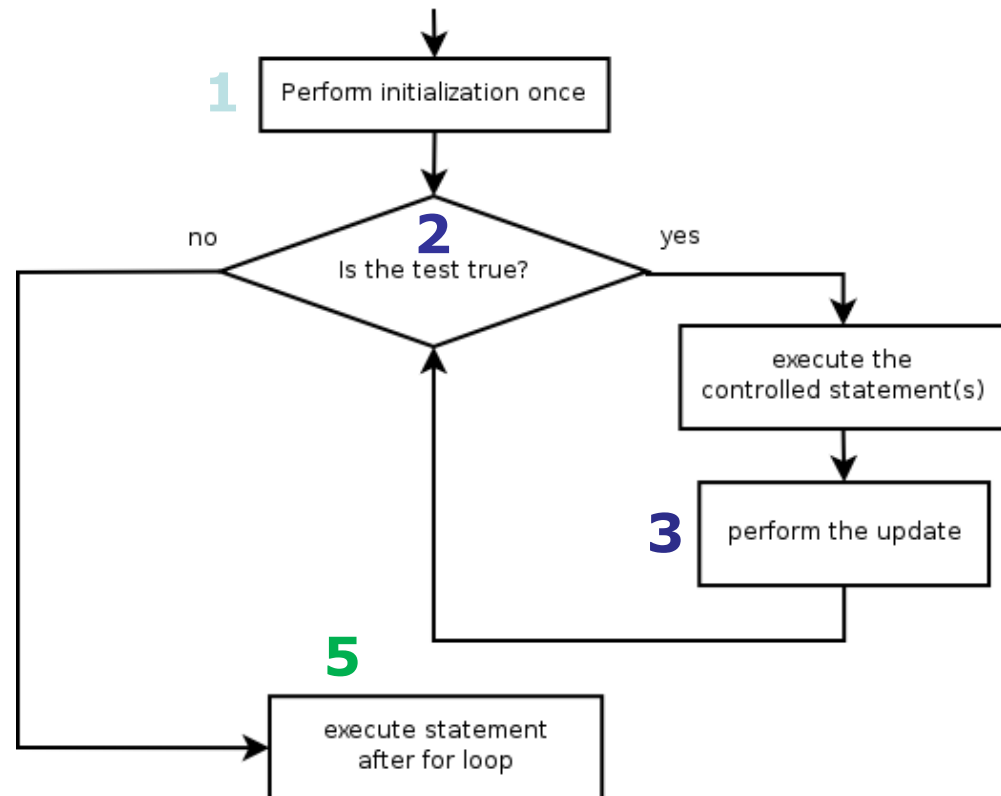
– "For each integer `i` from 1 through 6, print ..."

Loop walkthrough

```
for (int i 1 = 1; i 2 <= 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);
}
```

– 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 for loops

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*:

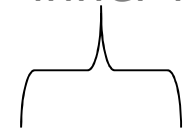
```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; i <= 10; j++) {  
        System.out.print("*");  
    }  
    System.out.println();  
}
```

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

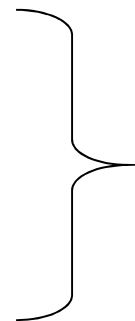

Complex lines

- 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 ...

<code>count</code>	number to print	<code>-4 * count</code>	<code>-4 * count + 21</code>
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
.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();
}
```


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

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

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.
```

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


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


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

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
        ...
    }
}
```

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
```

i's scope

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
```

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:**

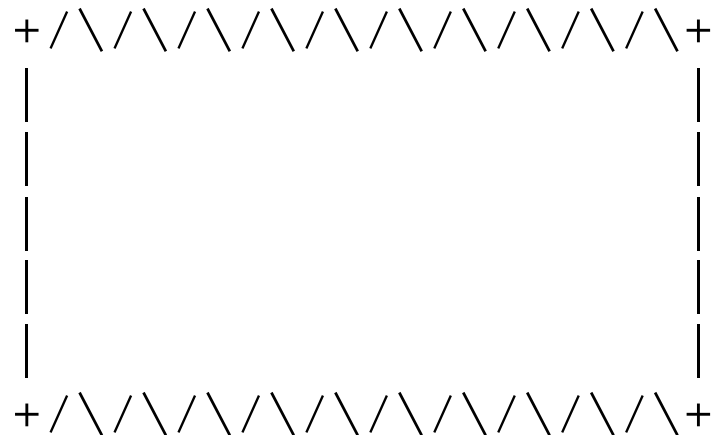
```
public static final int DAYS_IN_WEEK = 7;
```

```
public static final double INTEREST_RATE = 3.5;
```

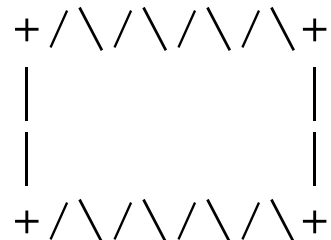
```
public static final int SSN = 658234569;
```

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

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();
}

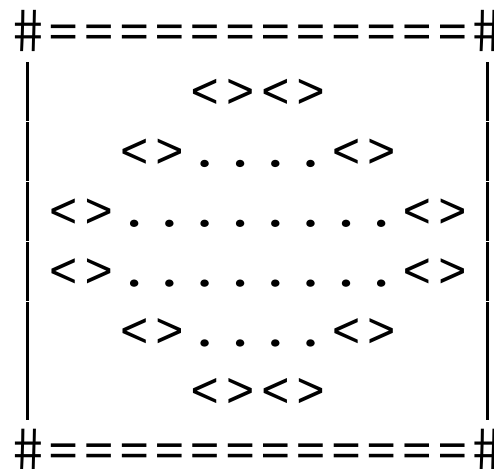
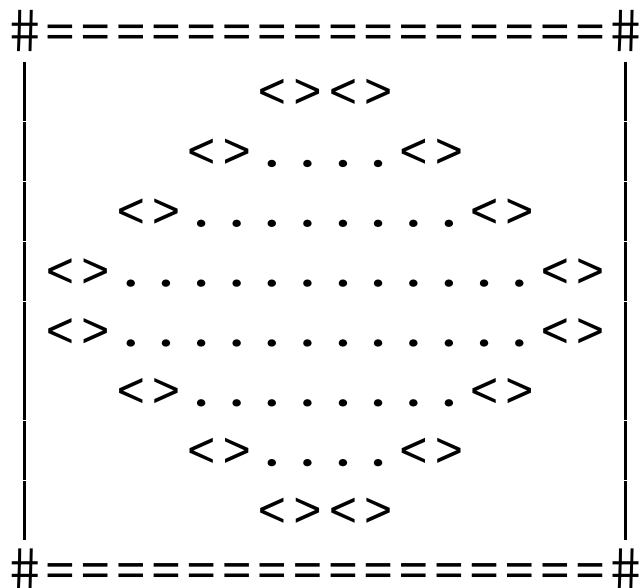
public static void topHalf() {
    for (int i = 1; i <= SIZE; i++) {           // OK
        ...
    }
}

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`
 - This can change the amount added in the loop expression

SIZE	line	spaces	$-2*\text{line} + (2*\text{SIZE})$	dots	$4*\text{line} - 4$
4	1,2,3,4	6,4,2,0	$-2*\text{line} + \mathbf{8}$	0,4,8,12	$4*\text{line} - 4$
3	1,2,3	4,2,0	$-2*\text{line} + \mathbf{6}$	0,4,8	$4*\text{line} - 4$



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(".");
}
```