# Building Java Programs

Chapter 2
Lecture 2-1: Expressions and Variables

reading: 2.1 - 2.2
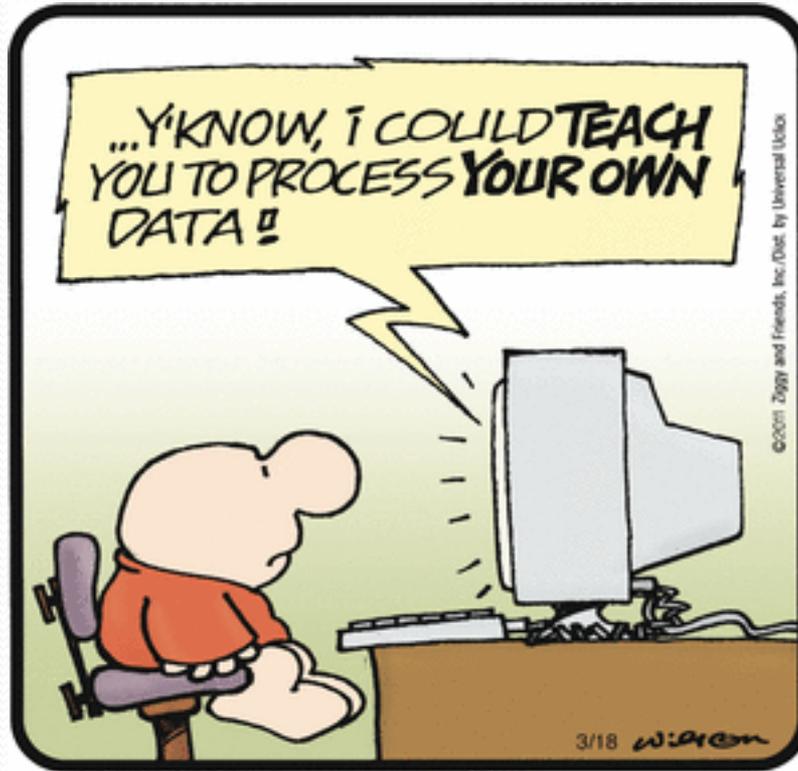
Data and expressions

reading: 2.1

Data types

- Internally, computers store everything as 1s and 0s

  ```
  104     → 01101000
  "hi"    → 0110100001101001
  h       → 01101000
  ```

- How are `h` and `104` differentiated?

- **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

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

  - Why does Java distinguish integers vs. real numbers?

Integer or real number?

- Which category is more appropriate?

integer (`int`)	real number (`double`)

1. Temperature in degrees Celsius
2. The population of lemmings
3. Your grade point average
4. A person's age in years
5. A person's weight in pounds
6. A person's height in meters
7. Number of miles traveled
8. Number of dry days in the past month
9. Your locker number
10. Number of seconds left in a game
11. The sum of a group of integers
12. The average of a group of integers

- credit: Kate Deibel, http://www.cs.washington.edu/homes/deibel/CATs/

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`

```
        3                      4                        52
  4 ) 14              10 ) 45                  27 )  1425
      12                   40                        135
       2                    5                         75
                                                      54
                                                      21
```

- 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`

```
      3
  4 ) 14
      12
       2
```

```
       43
   5 ) 218
       20
       18
       15
        3
```

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
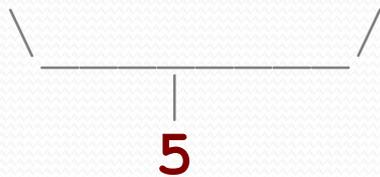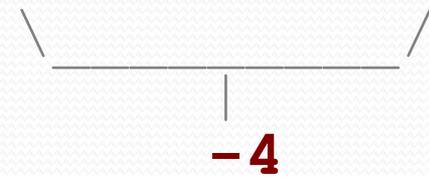
```
1  *  2  +  3  *  5  %  4              1  +  8  %  3  *  2  -  9
   \__/                                      \__/
    |                                         |
    2     +  3  *  5  %  4              1  +  2     *  2  -  9
             \__/                                _____/
              |                                      |
    2     +  15      %  4              1  +       4      -  9
              _____/                    _____/
                 |                            |
    2     +       3                   5              -  9
       _____/                     _____/
            |                                 |
           5                                 -4
```

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
                \___/
                  |
   4.8    +     9.0   / 2.0
                  \_____/
                     |
   4.8    +         4.5
     _____/
           |
          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.

```
7 / 3 * 1.2 + 3 / 2              2.0 + 10 / 3 * 2.5 - 6 / 4

  2    * 1.2 + 3 / 2            2.0 +    3    * 2.5 - 6 / 4

    2.4      + 3 / 2            2.0 +       7.5      - 6 / 4

    2.4      +    1             2.0 +       7.5      -    1

         3.4                           9.5             -    1

                                              8.5
```
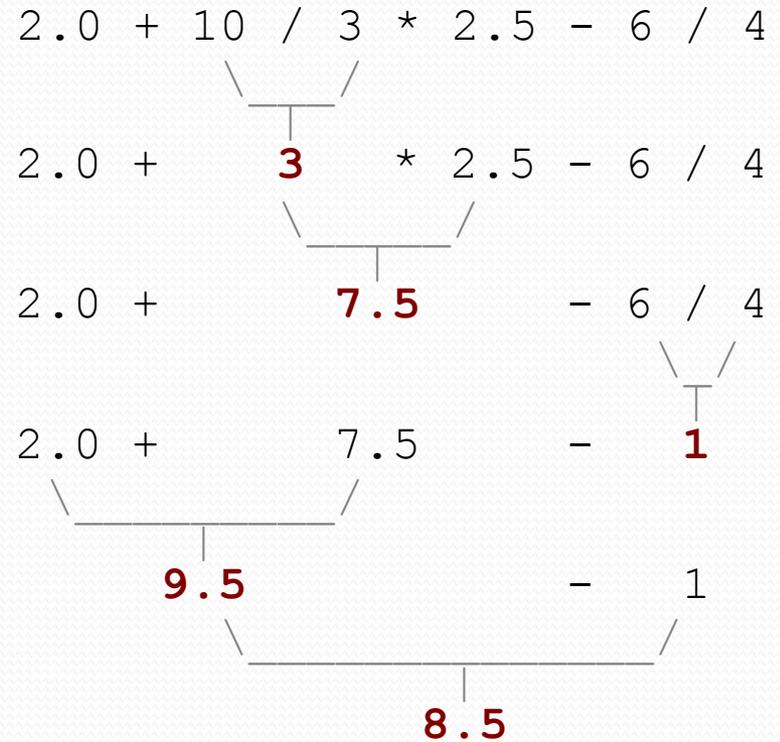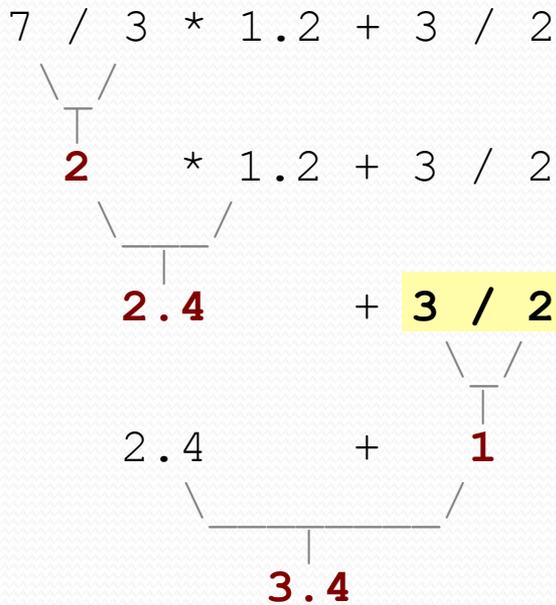
  - `3 / 2` is `1` above, not `1.5`.

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

reading: 2.2

Receipt example

What's bad about the following code?

```java
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 zipcode;`

  - `double myGPA;`

zipcode	

myGPA	

Assignment

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

- Syntax:

  name = **expression**;

  - `int zipcode;`
    zipcode = 90210;

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

zipcode	**90210**

myGPA	**3.25**

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:

x	**11**

```
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
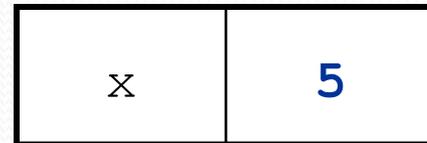
Assignment and types

- 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;`**

    - Why does `avg` store `5.0` and not `5.5` ?

avg	**5.0**

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.

```java
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

```java
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);
    }
}
```