Building Java Programs

Chapter 2
Lecture 2-1: Expressions and Variables

reading: 2.1 - 2.2

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Data and expressions

reading: 2.1

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The computer's view

- Internally, computers store everything as 1's and 0's
  - Example:

```
h      → 0110100
"hi"   → 01101000110101
104    → 0110100
```

- How can the computer tell the difference between an `h` and `104`?

- **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

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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?

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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/

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Expressions

- **expression**: A value or operation that computes a value.
  - Examples:
```
1 + 4 * 5
(7 + 2) * 6 / 3
42
"Hello, world!"
```
  - The simplest expression is a *literal value*.
  - A complex expression can use operators and parentheses.

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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
```

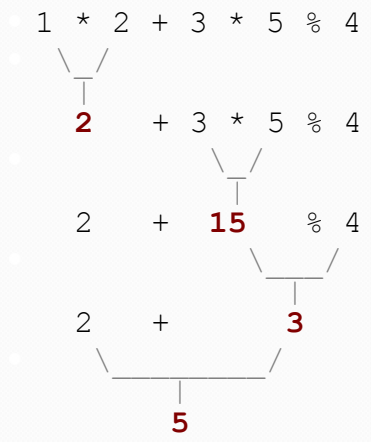
- Applications of `%` operator:
  - Obtain last digit of a number: `230857 % 10` is `7`
  - Obtain last 4 digits: `658236489 % 10000` is `6489`
  - See whether a number is odd: `7 % 2` is `1`, `42 % 2` is `0`

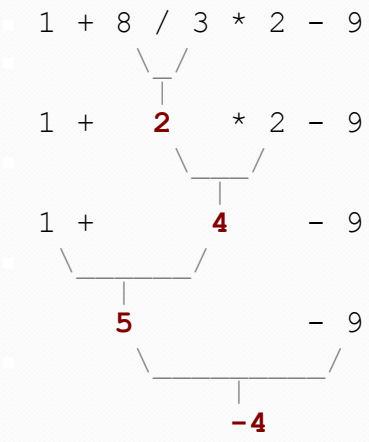
Remember PEMDAS?

- **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 `+ -`

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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
```

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Precision in real numbers

- The computer internally represents real numbers in an imprecise way.
- Example:

```
System.out.println(0.1 + 0.2);
```

  - The output is `0.30000000000000004`!

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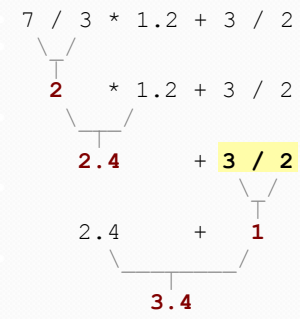
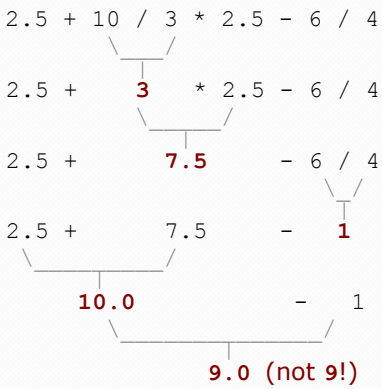
Mixing types

- 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`.

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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`

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Variables

reading: 2.2

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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>;

  - `int x;`

x	

  - `double myGPA;`

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;`

x	3

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

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);        // 14
```

- 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
```

x	11

Declaration/initialization

- A variable can be declared/initialized in one statement.
- Syntax:

  <type> <name> = ***<expression>***;

  - `int x = (11 % 3) + 12;`

x	14

  - `double myGPA = 3.95;`

myGPA	3.95

Assignment vs. algebra

- Assignment uses `=` , but it is not an algebraic equation.
  - `=` means, *"store the value at right in variable at left"*
  - `x = 3;` means, *"x becomes 3"* or *"x should now store 3"*
- **ERROR**: `3 = 1 + 2;` is an illegal statement, because `3` is not a variable.
- What happens here?

```
int x = 3;
x = x + 2;   // ???
```

Assignment exercise

- What is the output of the following Java code?

```
int x;
x = 3;
int y = x;
x = 5;
y = y + x;
System.out.println(x);
System.out.println(y);
```

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**

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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?

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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.
    ```

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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);
    }
}
```

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```

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);
    }
}
```

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