

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
<code>int</code>	integers (up to $2^{31} - 1$)	42, -3, 0, 926394
<code>double</code>	real numbers (up to 10^{308})	3.1, -0.25, 9.4e3
<code>char</code>	single text characters	'a', 'X', '?', '\n'
<code>boolean</code>	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 $3 * 4$?

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Integer division with /

- When we divide integers, the quotient is also an integer.
 - $14 / 4$ is 3, not 3.5
- | | | |
|---|--|---|
| $\begin{array}{r} \underline{3} \\ 4 \) \ 14 \\ \underline{12} \\ 2 \end{array}$ | $\begin{array}{r} \underline{4} \\ 10 \) \ 45 \\ \underline{40} \\ 5 \end{array}$ | $\begin{array}{r} \underline{52} \\ 27 \) \ 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.

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Integer remainder with %

- The % operator computes the remainder from integer division.

- $14 \% 4$ is 2
- $218 \% 5$ is 3

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

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

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

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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 + -

$$1 + 3 * 4 \quad \text{is } 13$$

$$\begin{array}{l} 6 + 8 / 2 * 3 \\ 6 + 4 * 3 \\ 6 + 12 \end{array} \quad \text{is } 18$$

- Parentheses can force a certain order of evaluation:

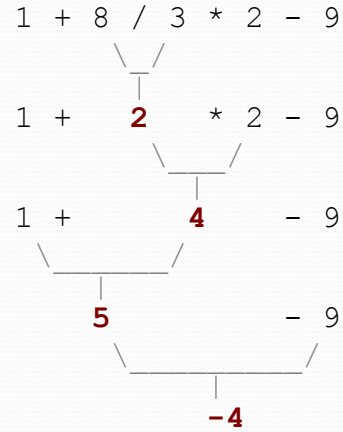
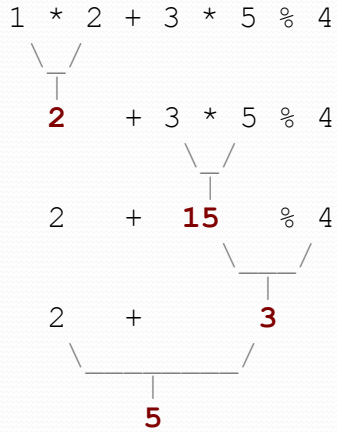
$$(1 + 3) * 4 \quad \text{is } 16$$

- Spacing does not affect order of evaluation

$$1+3 * 4-2 \quad \text{is } 11$$

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Precedence examples



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Precedence questions

- What values result from the following expressions?

- $9 / 5$
- $695 \% 20$
- $7 + 6 * 5$
- $7 * 6 + 5$
- $248 \% 100 / 5$
- $6 * 3 - 9 / 4$
- $(5 - 7) * 4$
- $6 + (18 \% (17 - 12))$

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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

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

$$\begin{array}{r} \underbrace{2.0 * 2.4}_{4.8} + 2.25 * 4.0 / 2.0 \\ 4.8 + \underbrace{2.25 * 4.0}_{9.0} / 2.0 \\ 4.8 + \underbrace{9.0 / 2.0}_{4.5} \\ \underbrace{4.8 + 4.5}_{9.3} \end{array}$$

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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);
```

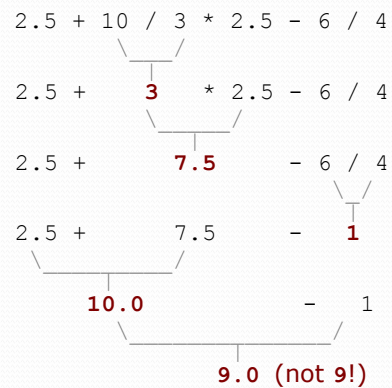
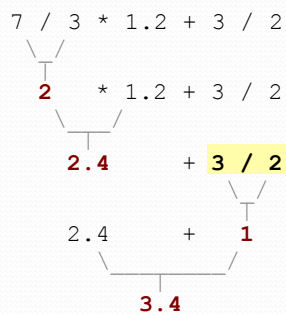
- The output is 0.30000000000000004!

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

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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

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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

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Declaration

- **variable declaration:** Sets aside memory for storing a value.
 - Variables must be declared before they can be used.

- Syntax:

<type> <name>;

- `int zipcode;`

zipcode	
---------	--

- `double myGPA;`

myGPA	
-------	--

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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;`

zipcode	90210
---------	-------

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

myGPA	3.25
-------	------

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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
---	----

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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
-------	------

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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; // ???
```

x	5
---	---

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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);
```

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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 ?

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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);
    }
}
```