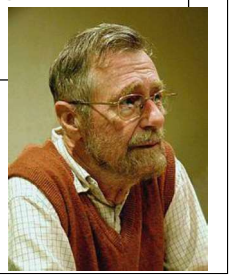
Topic 4
Expressions and Variables

"Once a person has understood the way variables are used in programming, they have understood the quintessence of programming."

-Professor Edsger W. Dijkstra



Based on slides bu Marty Stepp and Stuart Reges from http://www.buildingjavaprograms.com/

Data and expressions

reading: 2.1

The computer's view

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

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

- 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

- Binary Numbers

Java's primitive types

- **primitive types**: 8 simple types for numbers, characters, 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/

Clicker 1

- What is best choice for data type?

CHOICE	Number of days it rained in year	Sum of group of integers	Average of group of integers
A	`int`	`int`	`double`
B	`int`	`int`	`int`
C	`double`	`int`	`int`
D	`double`	`int`	`double`
E	`int`	`double`	`double`

Expressions

- **expression**: A combination of values and / or operations that results (via computation) in a value.
  - Examples: `1 + 4 * 5`
    `(7 + 2) * 6 / 3`
    `42`
    `"Hello, world!"`
  - The simplest expression is a *literal value*.
  - A complex expression uses operators and parentheses.

Arithmetic operators

- **operator**: Combines multiple values or expressions.

`+`	addition
`-`	subtraction (or negation)
`*`	multiplication
`/`	division
`%`	remainder (sometimes called modulus)

- 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.
- **Euclidean division a.k.a. division with remaineder.**

`14 / 4` is `3`, not `3.5`

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

```
  4
10 ) 45
     40
      5
```

```
  52
27 ) 1425
     135
      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 with integer division. Try floating point division by 0.

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`

Clicker 2

- What does each expression evaluate to?

CHOICE	13 % 5	5 % 13	30 % 5
A	3	3	0
B	3	5	0
C	2	5	5
D	2	13	6
E	2.4	13	6

Clicker 3

- What does the following expression evaluate to?

```
1017 % 100 + 12 % 100
```

A. 10

B. 17

C. 12

D. 22

E. 29

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
    ```

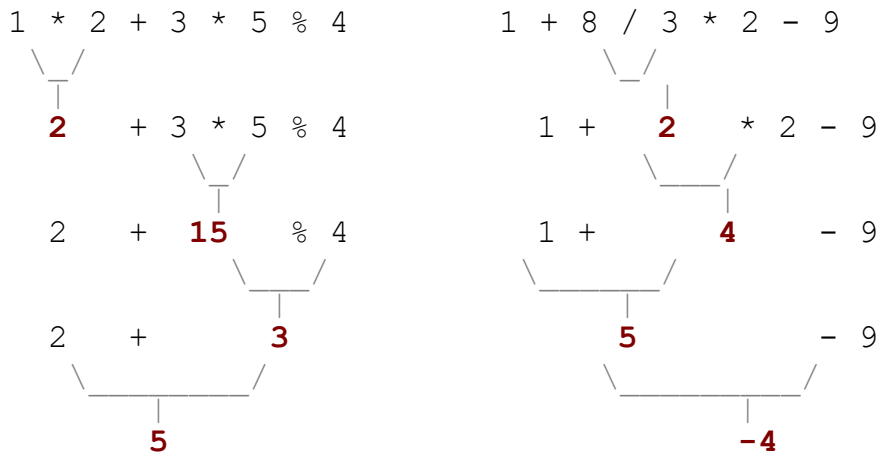
  - Parentheses can force a certain order of evaluation:

    `(1 + 3) * 4` is `16`

  - Spacing does not affect order of evaluation

    `1+3 * 4-2` is `11`

Precedence examples



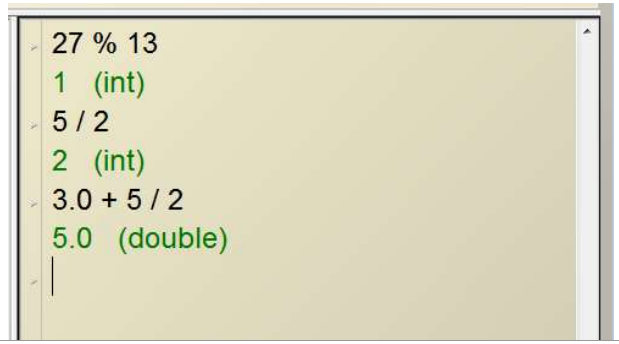
Precedence questions

- 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))
```


Practice!!

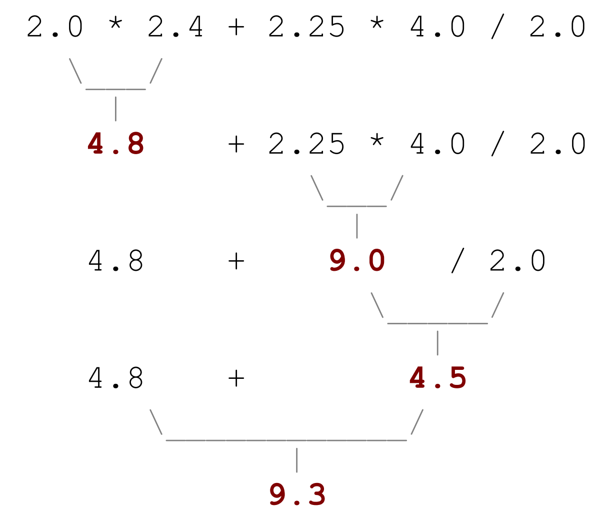
- BlueJ includes a *Code Pad*
  - *View -> Show Code Pad*
- *read - eval - print* loop
  - Alternative is JShell
- Useful to try various expressions



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 `+ -`
  - `%` works with doubles too: `1.25 % 0.75 is 0.5`

Real number example



Precision in real numbers

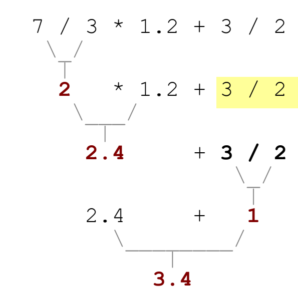
- The computer internally represents real numbers in an imprecise way.
- Example:

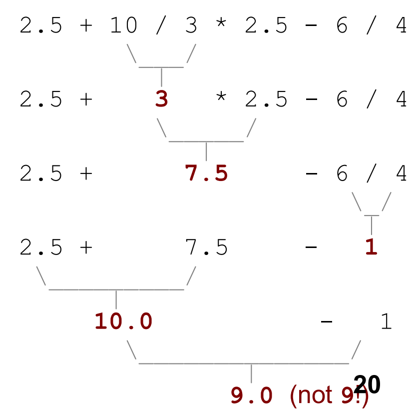
```
System.out.println(0.1 + 0.2);
```

  - 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`

Clicker 4

What does the following expression evaluate to?

1.25 + 7 / 4 + "CS" + 3 + 4

A. "3.0CS34"

B. "2.25CS7"

C. "2CS7"

D. "2.25CS34"

E. Something other than A - D

Variables

reading: 2.2

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 in a variable.
  - The value is the result of an expression;
  - the variable stores its result.
- Syntax:

<name> `=` ***<expression>;***

```
int x;
x = 3; // or int x = 3;
```

x	3

```
double myGPA;
myGPA = 1.0 + 2.25; // or double myGPA = 3.25
```

myGPA	3.25

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

Using variables

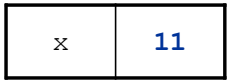
- Once given a value, a variable can be used in expressions:

```
int 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 = 3;
System.out.println(x + " here");      // 3 here

x = 4 + 7;
System.out.println("now x is " + x); // now x is 11
```



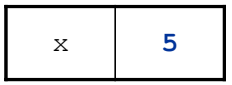
Assignment vs. algebra

- 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;    // ???
```



Clicker 5

- What is the output of the following Java code?

```
int x = 3;
int y = x; // y stores 3
x = 5; // x now stores 5
y = y + x;
System.out.println( x + " " + y);
```

A: "5 8" B: 5 10 C: 10 10

D: 5 + 10 E: 5 8

Swapping the Contents of Two Variables

- Output of this code?

```
int x = 12;
int y = 32;
x = y;
y = x;
System.out.println(x + " " + y);
```

- Output of this code?

```
int x = 12;
int y = 32;
int t = x;
x = y;
y = t;
System.out.println(x + " " + y + " " + t);
```

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 (in the same block of code. methods for now.)

```
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.
```


Example Problem - BMI

- **B**ody **M**ass **I**ndex or **BMI** is a quick calculation based on height and mass (weight) used by medical professionals to broadly categorize people .
- Formula:

$$\text{BMI} = \frac{\text{mass}_{\text{kg}}}{\text{height}_{\text{m}}^2} = \frac{\text{mass}_{\text{lb}}}{\text{height}_{\text{in}}^2} \times 703$$

- Quick tool to get a rough estimate if someone is underweight, normal weight, overweight, or obese
- Write a program to calculate BMI for a given height and mass.

Example Problem 2 - Day of Week

- For the Gregorian Calendar
- Given month, day, and year, calculate day of week
- months, 1 = January, 2 = February, … 12 = December

y = year - (14 - month) / 12

x = y + y / 4 - y / 100 + y / 400

m = month + 12 * ((14 - month) / 12) - 2

d = (day + x + (31 * m) / 12) % 7

0 = Sunday, 1 = Monday, 2 = Tuesday

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);
    }
}
```