Topic 10
return values, Math methods

"Thinking like a computer scientist means more than being able to program a computer. It requires thinking at multiple levels of abstraction."

— Jeannette M. Wing

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

static methods in other Classes

- Java includes 8 primitive data types
  - byte, short, **int**, long, float, **double**, char, boolean
- The Java Standard Library includes thousands of other data types, classes
  - System, String, Graphics, Color, …
- The Math class contains static methods for common mathematical operations (for which an operator does not exist in Java)
- Call those methods: Math.<MethodName>

  Math.pow(2, 5);

Java's `Math` class

Method name	Description
`Math.abs(`*value*`)`	absolute value
`Math.ceil(`*value*`)`	moves up to ceiling
`Math.floor(`*value*`)`	moves down to floor
`Math.log10(`*value*`)`	logarithm, base 10
`Math.max(`*value1*`, `*value2*`)`	larger of two values
`Math.min(`*value1*`, `*value2*`)`	smaller of two values
`Math.pow(`*base*`, `*exp*`)`	*base* to the *exp* power
`Math.random()`	random `double` between 0 and 1
`Math.rint(`*value*`)`	Round int, nearest whole number
`Math.sqrt(`*value*`)`	square root

`Math.sin(`*value*`)`
`Math.cos(`*value*`)`
`Math.tan(`*value*`)`
	sine/cosine/tangent of an angle in radians

`Math.toDegrees(`*value*`)` `Math.toRadians(`*value*`)`	convert degrees to radians and back

Constant	Description
`Math.E`	2.7182818...
`Math.PI`	3.1415926...

No output?

- Simply calling these methods produces no visible result.

```
Math.pow(3, 4);    // no output
```

- Math method calls use a Java feature called *return values* that cause them to be treated as expressions.
- The program runs the method, computes the answer, and then "replaces" the call with its computed result value.

```
Math.pow(3, 4);    // no output
81.0;              // no output
```

- To see the result, we must print it or store it in a variable.

```
double result = Math.pow(3, 4);
System.out.println(result);      // 81.0
```

Calling `Math` methods

`Math.`**`methodName`**`(`**`parameters`**`)`

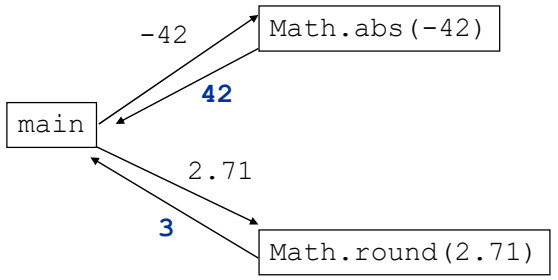
- Examples:

```
double squareRoot = Math.sqrt(121.0);
System.out.println(squareRoot);            // 11.0

int absoluteValue = Math.abs(-50);
System.out.println(absoluteValue);         // 50

System.out.println(Math.min(3, 7) + 2);    // 5
```

- The `Math` methods do not print to the console.
  - Each method produces ("returns") a numeric result.
  - The results are used as expressions (printed, stored, etc.).

Return

- **return**: To send out a value as the result of a method.
  - The opposite of a parameter:
    - Parameters send information *in* from the caller to the method.
    - Return values send information *out* from a method to its caller.
      - A call to the method can be used as part of an expression.



Why return and not print?

- It might seem more useful for the `Math` methods to print their results rather than returning them. Why don't they?
- Answer: Returning is more flexible than printing.
  - We can compute several things before printing:

```
double pow1 = Math.pow(3, 4);
double pow2 = Math.pow(10, 6);
System.out.println("Powers are " + pow1 + " and " + pow2);
```

  - We can combine the results of many computations:

```
double k = 13 * Math.pow(3, 4) + 5 - Math.sqrt(17.8);
```


Clicker 1

- What is output by the following code?

```
double a = -1.9;
double b = 2.25;
System.out.print( Math.floor(a) +
    " " + Math.ceil(b) + " " + a);
```

A. 3.0

B. -2.0 3.0 -2.0

C. -1.0 3.0 -1.0

D. -1 3 -1.9

E. -2.0 3.0 -1.9

Math questions

- Evaluate the following expressions:

```
Math.abs(-1.23)
Math.pow(3, 2)
Math.pow(10, -2)
Math.sqrt(121.0) - Math.sqrt(256.0)
Math.round(Math.PI) + Math.round(Math.E)
Math.ceil(6.022) + Math.floor(15.9994)
Math.abs(Math.min(-3, -5))
```

- `Math.max` and `Math.min` can be used to bound numbers.

  Consider an `int` variable named `age`.

  What statement would replace negative ages with 0?

  What statement would cap the maximum age to 40?

Quirks of real numbers

- Some `Math` methods return `double` or other non-`int` types.

```
int x = Math.pow(10, 3); // ERROR: incompat. types
```

- Some `double` values print poorly (too many digits).

```
double result = 1.0 / 3.0;
System.out.println(result);    // 0.3333333333333
```

- The computer represents `double`s in an imprecise way.

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

  - Instead of 0.3, the output is `0.30000000000000004`

Type casting

- **type cast**: A conversion from one type to another.
  - To promote an `int` into a `double` for floating point division
  - To truncate a `double` from a real number to an integer
- Syntax:

  (type) expression

Examples:

```
double result = (double) 19 / 5;     // 3.8
int result2 = (int) result;          // 3
int x = (int) Math.pow(10, 3);       // 1000
```


More about type casting

- Type casting has high precedence and only casts the item immediately next to it.

```
double x = (double) 1 + 1 / 2;       // 1.0
double y = 1 + (double) 1 / 2;       // 1.5
```

- You can use parentheses to force evaluation order.

```
double average = (double) (a + b + c) / 3;
```

- A conversion to `double` can be achieved in other ways.

```
double average = 1.0 * (a + b + c) / 3;
```

Returning a value from a method

```
public static type name(parameters) {
    statements;
    ...
    return expression;
}
```

- Example:

```
// Returns the slope of the line between the given points.
public static double slope(int x1, int y1, int x2, int y2) {
    double dy = y2 - y1;
    double dx = x2 - x1;
    return dy / dx;
}
```

`slope(5, 11, 1, 3)` returns `2.0`

Clicker 2

- Have we (in CS312, before today) used a method that returns a value in lecture?

A. No
B. Yes, a few times
C. Yes, hundreds of time
D. Lecture?? What lecture?
E. Maybe?

Return examples

```
// Converts degrees Fahrenheit to Celsius.
public static double fToC(double degreesF) {
    double degreesC = 5.0 / 9.0 * (degreesF - 32);
    return degreesC;
}

// Computes triangle hypotenuse length given its side lengths.
public static double hypotenuse(int a, int b) {
    double c = Math.sqrt(a * a + b * b);
    return c;
}
```

- You can shorten the examples by returning an expression:

```
public static double fToC(double degreesF) {
    return 5.0 / 9.0 * (degreesF - 32);
}
```


Common error: Not storing

- a `return` statement DOES NOT send a variable's name back to the calling method.

```
public static void main(String[] args) {
    slope(0, 0, 6, 3);
    System.out.println("The slope is " + result);
  // ERROR: result not defined

}
public static double slope(int x1, int x2, int y1, int y2) {
    double dy = y2 - y1;
    double dx = x2 - x1;
    double result = dy / dx;
    return result;
}
```

Fixing the common error

- Instead, returning sends the variable's *value* back.
  - The returned value must be stored into a variable or used in an expression to be useful to the caller.

```
public static void main(String[] args) {
    double s = slope(0, 0, 6, 3);
    System.out.println("The slope is " + s);
}

public static double slope(int x1, int x2, int y1, int y2) {
    double dy = y2 - y1;
    double dx = x2 - x1;
    double result = dy / dx;
    return result;
}
```


Clicker 3

- What is the output of the following code?

```
int x = 5;
int y = 7;
System.out.print(m(x, y) + " " + x + " " + m(y, x));

public static int m(int x, int y) {
      x += 2;
      System.out.print(x + " ");
      y -= 2;
      return x * y;
}
```

A. 7 9 35 5 27
B. 7 7 35 7 27
C. 7 5 9 27 35
D. 35 7 5 9 27
E. None of A - D are correct

Exercise

- In physics, the *displacement* of a moving body represents its change in position over time while accelerating.
  - Given initial velocity v_0 in m/s, acceleration a in m/s^2, and elapsed time t in s, the displacement of the body is:
  - Displacement = $v_0 t + \frac{1}{2} a t^2$
- Write a method `displacement` that accepts v_0, a, and t and computes and returns the change in position.
  - example: `displacement(3.0, 4.0, 5.0)` returns `65.0`

Exercise solution

```
public static double displacement(
        double v0, double a,
        double t) {

    double d = v0 * t + 0.5
            * a * Math.pow(t, 2);
    return d;
}
```

Exercises

- write a method to
  - return the int average of 3 ints
  - return the double average of 3 ints
  - return the average of a given number of rolls of 2 six sided dice
  - calculate and return N factorial (N!).
  - return the number of seconds in a given number of years.
  - return the Nth digit of a given integer.
  - return the distance between two points.

Exercise

- If you drop two balls, which will hit the ground first?
  - Ball 1: height of 600m, initial velocity = 25 m/sec downward
  - Ball 2: height of 500m, initial velocity = 15 m/sec downward
- Write a program that determines how long each ball takes to hit the ground (and draws each ball falling).
- Total time is based on the force of gravity on each ball.
  - Acceleration due to gravity $\cong$ 9.81 m/s^2, downward
  - Displacement = $v_0 t + \frac{1}{2} a t^2$

Ball solution

```
// Simulates the dropping of two balls from various heights.
import java.awt.*;

public class Balls {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(600, 600);
        Graphics g = panel.getGraphics();

        int ball1x = 100,  ball1y =   0,  v01 = 25;
        int ball2x = 200,  ball2y = 100,  v02 = 15;

        // draw the balls at each time increment
        for (double t = 0; t <= 10.0; t = t + 0.1) {
            g.setColor(Color.GRAY);
            panel.fillRect(0, 0, 600, 600);
            g.setColor(Color.RED);
            double disp1 = displacement(v01, t, 9.81);
            g.fillOval(ball1x, ball1y + (int) disp1, 10, 10);
            double disp2 = displacement(v02, t, 9.81);
            g.fillOval(ball2x, ball2y + (int) disp2, 10, 10);

            panel.sleep(50);   // pause for 50 ms
}
    }
    ...
```