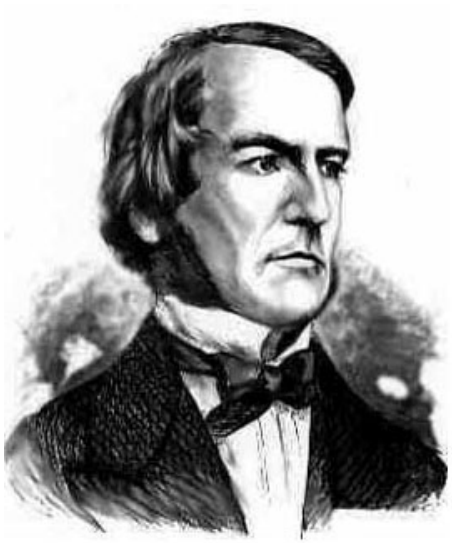
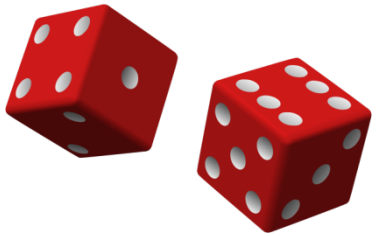
Built-in data types



logical AND	logical OR	logical NOT
&&	||	!



```
public static void main(String [] args)
```

Overview

- Variables
  - Allows us to store and compute on data
  - For now we'll be using basic Java data types
    - `String, int, double, boolean, char`
  - Variables in Java must be declared including type!
  - Converting between different basic types
- Types of errors
  - Runtime, compile
- Random numbers
  - Allow us to simulate random events
  - Needed for loops assignment

Variables and data types

- Variables
  - Stores information your program needs
  - Each has a unique name
  - Each has a specific type

Java built-in type	what it stores	example values	operations
`String`	sequence of characters	`"Hello world!"` `"I love this!"`	concatenate
`char`	characters	`'a', 'b', '!'`	compare
`int`	integer values	`42` `1234`	add, subtract, multiply, divide, remainder
`double`	floating-point values	`9.95` `3.0e8`	add, subtract, multiply, divide
`boolean`	truth values	`true` `false`	and, or, not

Some definitions

```
int a;
```

Declaration statement

"I'm going to need an integer and let's call it a"

NOTE: in Java you are *required* to declare a variable before using it!

```
a = 10;
```

Variable name

"Whenever I say a, I mean the value stored in a"

Literal

"I want the value 10"

= in CS is not the same as = in math!

```
int b;
b = 7;
```

Assignment statement

"Variable b gets the literal value 7"

```
int c = a + b;
```

Combined declaration and assignment

"Make me an integer variable called c and assign it the value obtained by adding together a and b"

Text

- `String` data type
  - A sequence of characters
  - Double quote around the characters
  - Concatenation using the + operator

```
String firstName = "Keith";
String lastName  = "Vertanen";
String fullName  = firstName + " " + lastName;
String favNumber = "42";

System.out.println(fullName +
                   "'s favorite number is " +
                   favNumber);
```

```
Keith Vertanen's favorite number is 42
```

Characters

- char data type
  - Holds a single character
  - Single apostrophe, e.g. 'a', 'z'

```
public class CharExample
{
   public static void main(String [] args)
   {
      char ch1 = 'y';
      char ch2 = 'o';
      String result = "" + ch1;

      result = result + ch2;
      result = result + ch2;
      result = result + ch2;

      System.out.println(result);
   }
}
```

Double quotes with nothing in between, an empty String

```
% java CharExample
yooo
```

Integers

- `int` data type
  - An integer value between -2^{31} and $+2^{31}-1$
    - Between -2,147,483,648 and 2,147,483,647
  - Operations:

add	subtract	multiply	divide	remainder
+	-	*	/	%

example	result	comment
`10 + 7`	17	
`10 - 7`	3	
`10 * 7`	70	
`10 / 7`	1	integer division, no fractional part
`10 % 7`	3	remainder after dividing by 7
`10 / 0`		runtime error, you can't divide an integer by 0!

Watch out for this!
/ is integer division if
both sides are integers!

Integers

- `int` data type
  - Normal rules of mathematical precedence
    - e.g. multiplication/division before addition/subtraction
  - Use ()'s to force a different order of calculation

example	result	comment
`10 + 7 * 2`	24	multiplication comes before addition
`(10 + 7) * 2`	34	()'s force addition to occur first
`10 / 7 + 2`	3	integer division result is 1 which is added to 2
`10 - 7 - 2`	1	
`(10 - 7) - 2`	1	
`10 - (7 - 2)`	5	

Floating-point numbers

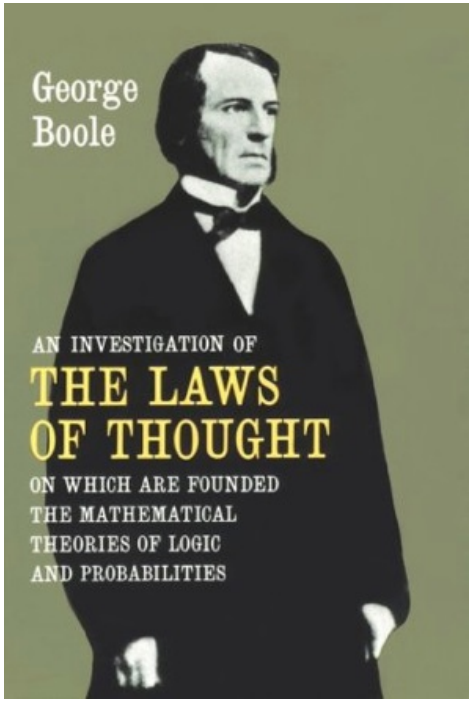
- `double` data type
  - Floating-point number (as specified by IEEE 754)
  - Operations:

add	subtract	multiply	divide
+	-	*	/

example	result
9.95 + 2.99	12.94
1.0 - 2.0	-1.0
1.0 / 2.0	0.5
1.0 / 3.0	0.3333333333333333
1.0 / 0.0	Infinity
0.0 / 123.45	0.0
0.0 / 0.0	NaN

Booleans

- `boolean` data type
  - Either `true` or `false`
  - Controls logic and flow of control in programs
  - Operations:



logical AND	logical OR	logical NOT
&&	||	!

Note: two symbols for logical AND and OR, not one!

Booleans

- `boolean` data type

logical AND	logical OR	logical NOT
&&	||	!

`!a` → "Is a set to `false`?"
`a && b` → "Are both a *and* b set to `true`?"
`a || b` → "Is either a *or* b (or both) set to `true`?"

a	!a
true	**false**
false	**true**

a	b	a && b	a || b
false	false	**false**	**false**
false	true	**false**	**true**
true	false	**false**	**true**
true	true	**true**	**true**

Comparisons

- Given two numbers → return a `boolean`

operator	meaning	true example	false example
`==`	equal	`7 == 7`	`7 == 8`
`!=`	not equal	`7 != 8`	`7 != 7`
`<`	less than	`7 < 8`	`8 < 7`
`<=`	less than or equal	`7 <= 7`	`8 <= 7`
`>`	greater than	`8 > 7`	`7 > 8`
`>=`	greater than or equal	`8 >= 2`	`8 >= 10`

Is the sum of `a`, `b` and `c` equal to `0`? `(a + b + c) == 0`

Is `grade` in the B range? `(grade >= 80.0) && (grade < 90.0)`

Is `sumItems` an even number? `(sumItems % 2) == 0`

Leap year example

- Years divisible by 4 but not by 100 → leap year
- Years divisible by 400 → leap year

```
public class LeapYear
{
   public static void main(String [] args)
   {
      int year = Integer.parseInt(args[0]);
      boolean isLeapYear;

      // Leap year if divisible by 4 but not by 100
      isLeapYear = (year % 4 == 0) && (year % 100 != 0);

      // But also leap year if divisible by 400
      isLeapYear = isLeapYear || (year % 400 == 0);
      System.out.println(isLeapYear);
   }
}
```

```
% java LeapYear 2000
true
```

Type conversion

- Java is strongly typed
  - Helps protect you from mistakes (aka "bugs")

```java
public class TypeExample0
{
   public static void main(String [] args)
   {
      int orderTotal = 0;
      double costItem = 29.95;

      orderTotal = costItem * 1.06;
      System.out.println("total=" + orderTotal);
   }
}
```

```
% javac TypeExample0.java
TypeExample0.java:7: possible loss of precision
found   : double
required: int
      orderTotal = costItem * 1.06;
                            ^
```

Type conversion

- Converting from one type to another:
  - Manually → using a cast
    - A cast is accomplished by putting a type inside ()'s
  - Casting to `int` drops fractional part
    - Does not round!

```
public class TypeExample1
{
   public static void main(String [] args)
   {
      int orderTotal = 0;
      double costItem = 29.95;

      orderTotal = (int) (costItem * 1.06);

      System.out.println("total=" + orderTotal);
   }
}
```

```
% java TypeExample1
total=31
```

Type conversion

- Automatic conversion
  - Numeric types:
    - If no loss of precision → automatic promotion

```
public class TypeExample2
{
   public static void main(String [] args)
   {
      double orderTotal = 0.0;
      int costItem = 30;

      orderTotal = costItem * 1.06;

      System.out.println("total=" + orderTotal);
   }
}
```

```
% java TypeExample2
total=31.8
```

Type conversion

- Automatic conversion
  - `String` concatenation using the + operator converts numeric types to also be a `String`

```
public class TypeExample3
{
   public static void main(String [] args)
   {
      double costItem = 29.95;

      String message = "The widget costs ";
      message = message + costItem;
      message = message + "!";

      System.out.println(message);
   }
}
```

```
% java TypeExample3
The widget costs 29.95!
```

args array

Program input comes in as Strings from command line (for now)

```
public static void main(String [] args)
```

```
% java CostCalc bananas 12 0.21
To buy 12 bananas you will need $2.52
```

identifier	meaning	value	type
`args[0]`	1st thing on command line after Java class name	`"bananas"`	`String`
`args[1]`	2nd thing on command line	`"12"`	`String`
`args[2]`	3rd thing on command line after Java class	`"0.21"`	`String`
`args.length`	# of things on command line	3	`int`

Static methods

- Java has lots of helper methods
  - Things that take value(s) and return a result
    - e.g. Math functions
    - e.g. Type conversion: `String` → `int`
      `String` → `double`
    - e.g. Random number generation
- For now, we'll stick to `static` methods
  - Live in some particular Java class
    - e.g. `Math`, `Integer` or `Double`
  - Call using class name followed by dot

Converting text to a numeric type

method	description
`Integer.parseInt(String a)`	converts text a into an int
`Double.parseDouble(String a)`	convert text a into a double

```
public class CostCalc
{
   public static void main(String [] args)
   {
      String product = args[0];
      int    qty     = Integer.parseInt(args[1]);
      double cost    = Double.parseDouble(args[2]);

      double total = qty * cost;

      System.out.print("To buy " + qty);
      System.out.print(" " + product);
      System.out.println(" you will need $" + total);
   }
}
```

```
% java CostCalc elections 2 1e6
To buy 2 elections you will need $2000000.0
```

Different types of errors: runtime

runtime error

```
% java CostCalc apples 6 -10
To buy 6 apples you will need $-60.0

% java CostCalc apples 6 foo
Exception in thread "main" java.lang.NumberFormatException: For input string: "foo"
        at sun.misc.FloatingDecimal.readJavaFormatString
        (FloatingDecimal.java:1222)
        at java.lang.Double.parseDouble(Double.java:510)
        at CostCalc.main(ArgsExample.java:7)

% java CostCalc apples 6.1 0.25
Exception in thread "main" java.lang.NumberFormatException: For input string: "6.1"
        at java.lang.NumberFormatException.forInputString
        (NumberFormatException.java:48)
        at java.lang.Integer.parseInt(Integer.java:458)
        at java.lang.Integer.parseInt(Integer.java:499)
        at CostCalc.main(ArgsExample.java:6)

% java CostCalc apples 6.0 0.25
Exception in thread "main" java.lang.NumberFormatException: For input string: "6.0"
        at java.lang.NumberFormatException.forInputString
        (NumberFormatException.java:48)
        at java.lang.Integer.parseInt(Integer.java:458)
        at java.lang.Integer.parseInt(Integer.java:499)
        at CostCalc.main(ArgsExample.java:6)
```

Different types of errors: compile time

```
public class CostCalc
{
    public static void main(String [] args)
    {
        String  product = args[0];
        int     qty     = args[1];
        double  cost    = args[2];
        double  total   = qty * cost;

        System.out.print("To buy " + qty);
        System.out.print(" " + product);
        System.out.println(" you will need $" + total);
    }
}
```

compile time error

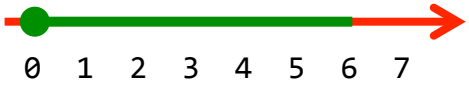
```
% javac CostCalc.java
CostCalc.java:6: incompatible types
found   : java.lang.String
required: int
        int     qty     = args[1];
                                ^
CostCalc.java:7: incompatible types
found   : java.lang.String
required: double
        double  cost    = args[2];
                                ^
2 errors
```

Randomness

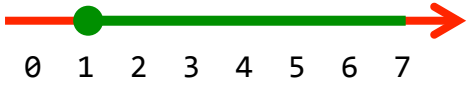
- Simulate roll of two 6-sided dice
- Generate two random #'s between 1 and 6

`Math.random()` → number in [0, 1.0)
e.g. 0.0, 0.312, 0.9999999

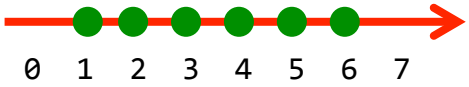
`Math.random()*6` → number in [0, 6.0)
e.g. 0.0, 1.872, 5.9999999



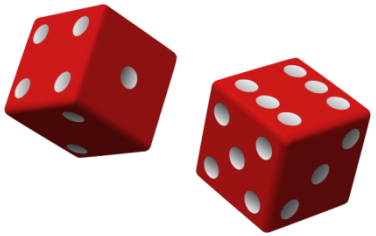
`(Math.random()*6)+1` → number in [1, 7.0)
e.g. 1.0, 2.872, 6.9999999



`(int)(Math.random()*6)+1` → number in set {1, 2, 3, 4, 5, 6}
e.g. 1, 2, 6



Randomness



- Simulate roll of two 6-sided dice
- Generate two random #'s between 1 and 6

```
public class TwoDice
{
   public static void main(String [] args)
   {
      int dice1 = (int) (Math.random() * 6) + 1;
      int dice2 = (int) (Math.random() * 6) + 1;
      int sum   = dice1 + dice2;

      System.out.println(dice1 + " + " +
                         dice2 + " = " +
                         sum);
   }
}
```

```
% java TwoDice
3 + 4 = 7
% java TwoDice
1 + 6 = 7
% java TwoDice
1 + 1 = 2
```

Type conversion quiz

- Automatic: no loss of precision
  - `int` will convert to a `double` if need be
  - `double` cannot automatically convert to `int`
- Manual: cast or using a method

expression	resulting type	resulting value
`(int) 3.14159`		
`Math.round(3.6)`		
`2 * 3.0`		
`2 * (int) 3.0`		
`(int) 2 * 3.0`		

Type conversion quiz

- Automatic: no loss of precision
  - `int` will convert to a `double` if need be
  - `double` cannot automatically convert to `int`
- Manual: cast or using a method

expression	resulting type	resulting value
`(int) 3.14159`	`int`	`3`
`Math.round(3.6)`	`long`	`4`
`2 * 3.0`	`double`	`6.0`
`2 * (int) 3.0`	`int`	`6`
`(int) 2 * 3.0`	`double`	`6.0`

String conversion quiz

- `String` conversion, using:
  - `Integer.parseInt()`
  - `Double.parseDouble()`

expression	resulting type	resulting value
`Integer.parseInt("30")`		
`Double.parseDouble("30")`		
`Integer.parseInt("30.1")`		
`Double.parseDouble("30.1")`		
`Integer.parseInt("$30")`		
`Double.parseDouble(3.14)`		

String conversion quiz

- `String` conversion, using:
  - `Integer.parseInt()`
  - `Double.parseDouble()`

expression	resulting type	resulting value
`Integer.parseInt("30")`	`int`	`30`
`Double.parseDouble("30")`	`double`	`30.0`
`Integer.parseInt("30.1")`	(runtime error, can't parse as int)	
`Double.parseDouble("30.1")`	`double`	`30.1`
`Integer.parseInt("$30")`	(runtime error, can't parse as int)	
`Double.parseDouble(3.14)`	(compile error, 3.14 not a String)	

String concatenation quiz

- + is addition for numeric types
- + is concatenation for `String` type
- numeric types convert to `String` if needed
  - Strings never (automatically) go back to number

expression	resulting type	resulting value
`"testing " + 1 + 2 + 3`		
`"3.1" + 4159`		
`"2" + " + " + "3"`		
`1 + 2 + 3 + "66"`		

String concatenation quiz

- + is addition for numeric types
- + is concatenation for `String` type
- numeric types convert to `String` if needed
  - Strings never (automatically) go back to number

expression	resulting type	resulting value
`"testing " + 1 + 2 + 3`	`String`	`"testing 123"`
`"3.1" + 4159`	`String`	`"3.14159"`
`"2" + " + " + "3"`	`String`	`"2 + 3"`
`1 + 2 + 3 + "66"`	`String`	`"666"`

Summary

- Variables
  - Allows us to store and compute on data
  - `String, int, double, boolean, char`
  - Boolean operators for logic and program flow control (more on this next time!)
- Type conversion
  - Automatic

    e.g. `int` converting itself to a `double`
  - Explicit via cast or method call
  - Important!
    - Cause of many, many, many software bugs