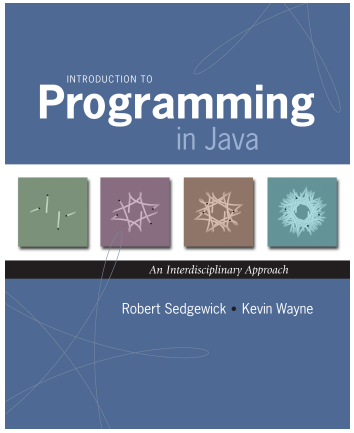
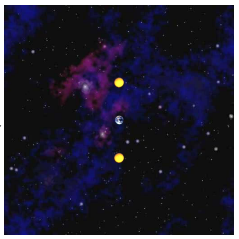
1.1 Your First Program



Why Programming?

Why programming? Need to tell computer what to do.

"Please simulate the motion of N heavenly bodies, subject to Newton's laws of motion and gravity."

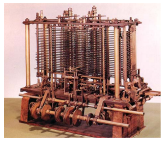


Prepackaged software solutions. Great, they do exactly what you want.

Programming. Enables you to make a computer do anything you want.

well, almost anything [stay tuned]

Ada Lovelace



Analytic Engine

Languages

Machine languages. Tedious and error-prone.

Natural languages. Ambiguous and hard for computer to parse.

Kids Make Nutritious Snacks.
Red Tape Holds Up New Bridge.
Police Squad Helps Dog Bite Victim.
Local High School Dropouts Cut in Half.

[real newspaper headlines, compiled by Rich Pattis]

High-level programming languages. Acceptable tradeoff.

"Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do." – *Donald Knuth*

Why Program?

Why program?

- A natural, satisfying and creative experience.
- Enables accomplishments not otherwise possible.
- Opens new world of intellectual endeavor.

First challenge. Learn a programming language.

Next question. Which one?

Naive ideal. A single programming language.

Our Choice: Java

Java features.

- Widely used.
- Widely available.
- Embraces full set of modern abstractions.
- Variety of automatic checks for mistakes in programs.

Java economy.

- Mars rover.
- Cell phones.
- Blu-ray Disc.
- Web servers.
- Medical devices.
- Supercomputing.
- ...

$100 billion, 5 million developers

James Gosling
http://java.net/jag

Why Java?

Java features.

- Widely used.
- Widely available.
- Embraces full set of modern abstractions.
- Variety of automatic checks for mistakes in programs.

Facts of life.

- No perfect language.
- We need to choose some language.

> *" There are only two kinds of programming languages: those people always [gripe] about and those nobody uses."*
> *– Bjarne Stroustrup*

Our approach.

- Minimal subset of Java.
- Develop general programming skills that are applicable to many languages.

It's not about the language!

A Rich Subset of the Java Language

Built-In Types	
int	double
long	String
char	boolean

System
System.out.println()
System.out.print()
System.out.printf()

Math Library	
Math.sin()	Math.cos()
Math.log()	Math.exp()
Math.sqrt()	Math.pow()
Math.min()	Math.max()
Math.abs()	Math.PI

Flow Control	
if	else
for	while

Parsing
Integer.parseInt()
Double.parseDouble()

Primitive Numeric Types		
+	-	*
/	%	++
--	>	<
<=	>=	==
!=		

Boolean	
true	false
||	&&
!	

Punctuation	
{	}
(	)
,	;

Assignment
=

String	
+	""
length()	compareTo()
charAt()	matches()

Arrays
a[i]
new
a.length

Objects	
class	static
public	private
final	toString()
new	main()

Hello, World

Programming in Java.

- Create the program by typing it into a text editor, and save it as `HelloWorld.java`.

```
/*************************************
 * Prints "Hello, World"
 * Everyone's first Java program.
 *************************************/

public class HelloWorld {
   public static void main(String[] args) {
      System.out.println("Hello, World");
   }
}
```

HelloWorld.java

Programming in Java.

- Create the program by typing it into a text editor, and save it as `HelloWorld.java`.
- Compile it by typing at the command-line:
  `javac HelloWorld.java`.

command-line →

```
% javac HelloWorld.java
```

(or click the Compile button in DrJava)

- This creates a Java bytecode file named: `HelloWorld.class`.

Programming in Java.

- Create the program by typing it into a text editor, and save it as `HelloWorld.java`.
- Compile it by typing at the command-line:
  `javac HelloWorld.java`.
- Execute it by typing at the command-line:
  `java HelloWorld`.

command-line →

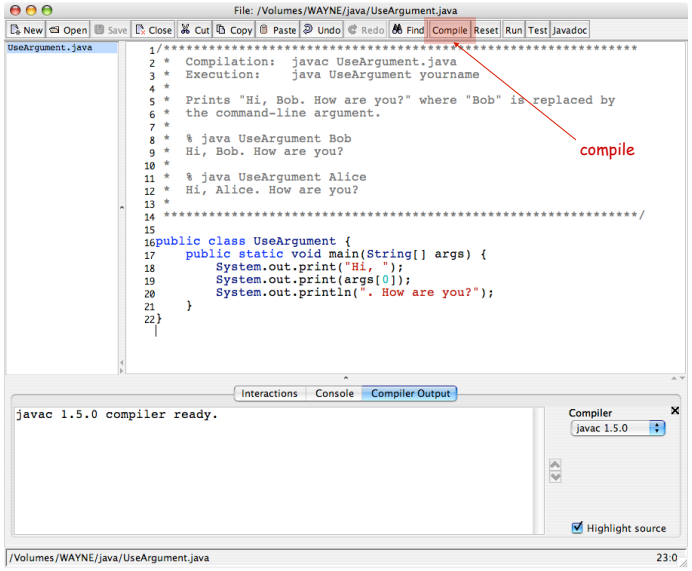
```
% javac HelloWorld.java

% java HelloWorld
Hello, World
```


Dr. Java

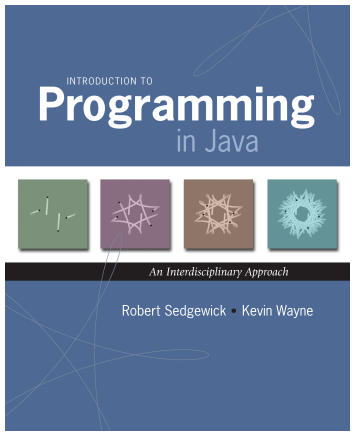
http://drjava.org

Dr. Java



Dr. Java

1.2 Built-in Types of Data



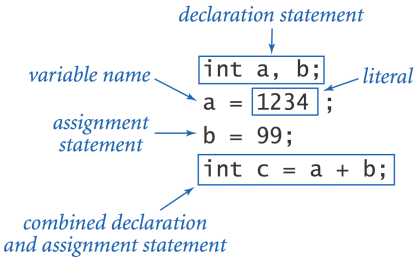
Built-in Data Types

Data type. A set of values and operations defined on those values.

type	set of values	literal values	operations
`char`	characters	`'A'` `'@'`	compare
`String`	sequences of characters	`"Hello World"` `"126 is fun"`	concatenate
`int`	integers	`17` `12345`	add, subtract, multiply, divide
`double`	floating-point numbers	`3.1415` `6.022e23`	add, subtract, multiply, divide
`boolean`	truth values	`true` `false`	and, or, not

Basic Definitions

Variable. A name that refers to a value.
Assignment statement. Associates a value with a variable.



Trace

Trace. Table of variable values after each statement.

	a	b	t
`int a, b;`	*undefined*	*undefined*	
`a = 1234;`	1234	*undefined*	
`b = 99;`	1234	99	
`int t = a;`	1234	99	1234
`a = b;`	99	99	1234
`b = t;`	99	1234	1234

Text

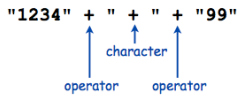
Text

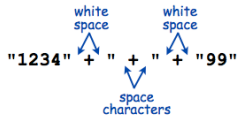
`String` data type. Useful for program input and output.

values	sequences of characters
typical literals	`"Hello," "1 " " * "`
operation	concatenate
operator	+

expression	*value*
`"Hi, " + "Bob"`	`"Hi, Bob"`
`"1" + " 2 " + "1"`	`"1 2 1"`
`"1234" + " + " + "99"`	`"1234 + 99"`
`"1234" + "99"`	`"123499"`

Caveat. Meaning of characters depends on context.





Subdivisions of a Ruler

```
public class Ruler {
   public static void main(String[] args) {
      String ruler1 = "1";
      String ruler2 = ruler1 + " 2 " + ruler1;
      String ruler3 = ruler2 + " 3 " + ruler2;
      String ruler4 = ruler3 + " 4 " + ruler3;
      System.out.println(ruler4);
   }
}
```

```
"1"
"1 2 1"
"1 2 1 3 1 2 1"
```

string concatenation

```
% java Ruler
1 2 1 3 1 2 1 4 1 2 1 3 1 2 1
```

Integers

Integers

`int` data type. Useful for expressing algorithms.

values	integers between -2^{31} and $+2^{31}-1$				
typical literals	1234	99	-99	0	1000000
operations	add	subtract	multiply	divide	remainder
operators	+	-	*	/	%

expression	*value*	*comment*
5 + 3	8	
5 - 3	2	
5 * 3	15	
5 / 3	1	no fractional part
5 % 3	2	remainder
1 / 0		run-time error
3 * 5 - 2	13	* has precedence
3 + 5 / 2	5	/ has precedence
3 - 5 - 2	-4	left associative
(3 - 5) - 2	-4	better style
3 - (5 - 2)	0	unambiguous

Integer Operations

```
public class IntOps {
   public static void main(String[] args) {
      int a = Integer.parseInt(args[0]);
      int b = Integer.parseInt(args[1]);
      int sum  = a + b;
      int prod = a * b;
      int quot = a / b;
      int rem  = a % b;
      System.out.println(a + " + " + b + " = " + sum);
      System.out.println(a + " * " + b + " = " + prod);
      System.out.println(a + " / " + b + " = " + quot);
      System.out.println(a + " % " + b + " = " + rem);
   }
}
```

command-line arguments

```
% javac IntOps.java
% java IntOps 1234 99
1234 + 99 = 1333
1234 * 99 = 122166
1234 / 99 = 12
1234 % 99 = 46
```

Java automatically converts `a`, `b` , and `rem` to type `String`

```
1234 = 12*99 + 46
```

Floating-Point Numbers

`double` data type. Useful in scientific applications.

values	real numbers (specified by IEEE 754 standard)			
typical literals	`3.14159`	`6.022e23`	`-3.0`	`2.0`	`1.4142135623730951`
operations	add	subtract	multiply	divide
operators	`+`	`-`	`*`	`/`

expression	*value*
`3.141 + .03`	`3.171`
`3.141 - .03`	`3.111`
`6.02e23 / 2.0`	`3.01e23`
`5.0 / 3.0`	`1.6666666666666667`
`10.0 % 3.141`	`0.577`
`1.0 / 0.0`	`Infinity`
`Math.sqrt(2.0)`	`1.4142135623730951`
`Math.sqrt(-1.0)`	`NaN`

`public class Math`

`double abs(double a)`	*absolute value of a*
`double max(double a, double b)`	*maximum of a and b*
`double min(double a, double b)`	*minimum of a and b*

Note 1: `abs()`, `max()`, *and* `min()` *are defined also for* `int`, `long`, *and* `float`.

`double sin(double theta)`	*sine function*
`double cos(double theta)`	*cosine function*
`double tan(double theta)`	*tangent function*

Note 2: Angles are expressed in radians. Use `toDegrees()` *and* `toRadians()` *to convert.*
Note 3: Use `asin()`, `acos()`, *and* `atan()` *for inverse functions.*

`double exp(double a)`	*exponential* (e^a)
`double log(double a)`	*natural log* ($\log_e a$, *or* $\ln a$)
`double pow(double a, double b)`	*raise a to the bth power* (a^b)
`long round(double a)`	*round to the nearest integer*
`double random()`	*random number in* [0, 1)
`double sqrt(double a)`	*square root of a*
`double E`	*value of e (constant)*
`double PI`	*value of π (constant)*

`http://java.sun.com/javase/6/docs/api/java/lang/Math.html`

Ex. Solve quadratic equation $x^2 + bx + c = 0$.

$$\text{roots} = \frac{-b \pm \sqrt{b^2 - 4c}}{2}$$

```
public class Quadratic {
   public static void main(String[] args) {

      // parse coefficients from command-line
      double b = Double.parseDouble(args[0]);
      double c = Double.parseDouble(args[1]);

      // calculate roots
      double discriminant = b*b - 4.0*c;
      double d = Math.sqrt(discriminant);
      double root1 = (-b + d) / 2.0;
      double root2 = (-b - d) / 2.0;

      // print them out
      System.out.println(root1);
      System.out.println(root2);
   }
}
```

Testing

Testing. Some valid and invalid inputs.

```
% java Quadratic -3.0 2.0
2.0                          ← command-line arguments
1.0

% java Quadratic -1.0 -1.0
1.618033988749895            ← golden ratio
-0.6180339887498949

% java Quadratic 1.0 1.0
NaN                          ← not a number
NaN

% java Quadratic 1.0 hello
java.lang.NumberFormatException: hello

% java Quadratic 1.0
java.lang.ArrayIndexOutOfBoundsException
```

$x^2 - 3x + 2$

$x^2 - x - 1$

$x^2 + x + 1$

Booleans

Booleans

boolean data type. Useful to control logic and flow of a program.

values	true or false		
literals	`true` `false`		
operations	and	or	not
operators	&&	||	!

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

Truth-table definitions of `boolean` *operations*

Comparisons

Comparisons. Take operands of one type and produce an operand of type `boolean`.

op	*meaning*	`true`	`false`
`==`	*equal*	`2 == 2`	`2 == 3`
`!=`	*not equal*	`3 != 2`	`2 != 2`
`<`	*less than*	`2 < 13`	`2 < 2`
`<=`	*less than or equal*	`2 <= 2`	`3 <= 2`
`>`	*greater than*	`13 > 2`	`2 > 13`
`>=`	*greater than or equal*	`3 >= 2`	`2 >= 3`

non-negative discriminant?	`(b*b - 4.0*a*c) >= 0.0`
beginning of a century?	`(year % 100) == 0`
legal month?	`(month >= 1) && (month <= 12)`

Typical comparison expressions

Leap Year

Q. Is a given year a leap year?

A. Yes if either (i) divisible by 400 or (ii) divisible by 4 but not 100.

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

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

      // or divisible by 400
      isLeapYear = isLeapYear || (year % 400 == 0);

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

```
% java LeapYear 2004
true
% java LeapYear 1900
false
% java LeapYear 2000
true
```


Type Conversion

Type Conversion

Type conversion. Convert from one type of data to another.

- Automatic: no loss of precision; or with strings.
- Explicit: cast; or method.

expression	*expression type*	*expression value*
"1234" + 99	String	"123499"
Integer.parseInt("123")	int	123
(int) 2.71828	int	2
Math.round(2.71828)	long	3
(int) Math.round(2.71828)	int	3
(int) Math.round(3.14159)	int	3
11 * 0.3	double	3.3
(int) 11 * 0.3	double	3.3
11 * (int) 0.3	int	0
(int) (11 * 0.3)	int	3

Random Integer

Ex. Generate a pseudo-random number between `0` and `N-1`.

```
public class RandomInt {
   public static void main(String[] args) {
      int N = Integer.parseInt(args[0]);
      double r = Math.random();
      int n = (int) (r * N);

      System.out.println("random integer is " + n);
   }
}
```

String to int (method)

double between 0.0 and 1.0

double to int (cast)

int to double (automatic)

int to String (automatic)

```
% java RandomInt 6
random integer is 3
% java RandomInt 6
random integer is 0
% java RandomInt 10000
random integer is 3184
```

Summary

A data type is a set of values and operations on those values.

- `String` text processing.
- `double`, `int` mathematical calculation.
- `boolean` decision making.

In Java, you must:

- Declare type of values.
- Convert between types when necessary.


example of bad type conversion

Why do we need types?

- Type conversion must be done at some level.
- Compiler can help do it correctly.
- Example: in 1996, Ariane 5 rocket exploded after takeoff because of bad type conversion.