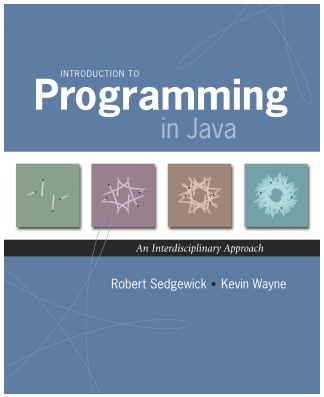
1.1 Your First Program



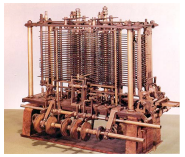
Why Programming?

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

Prepackaged software solutions. Great, if it does exactly what you need.

Computer programming. Art of making a computer do what you want.


Ada Lovelace


Analytic Engine

Languages

> *"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*

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.

Why 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.

Caveat.

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

Why Java?

Java features.

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

Caveat. No perfect language.

Our approach.

- Minimal subset of Java.
- Develop general programming skills that are applicable to: C, C++, C#, Perl, Python, Ruby, Matlab, Fortran, Fortress, …

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
toString()	equals()
new	main()

Create, Compile, Execute

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`

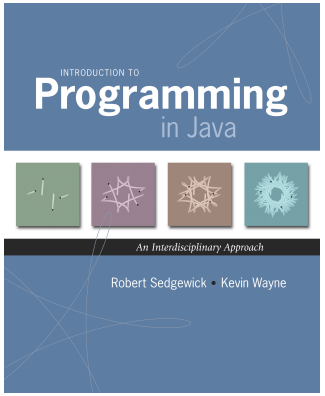
command-line

```
% javac HelloWorld.java

% java HelloWorld
Hello, World
```

(or click the Run button in DrJava)

1.2 Built-in Types of Data



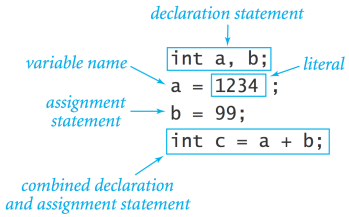
Built-in Data Types

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"` `"CS 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"`

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

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

Floating-Point Numbers

`double` data type. Useful in scientific applications.

values	approximations to real numbers			
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	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

Math Library

`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)*

See booksite for other available functions.

Excerpts from Java's mathematics library

Quadratic Equation

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                          x² - 3x + 2
2.0                          ↖ command-line arguments
1.0

% java Quadratic -1.0 -1.0                         x² - x - 1
1.618033988749895  ← golden ratio
-0.6180339887498949

% java Quadratic 1.0 1.0                           x² + x + 1
NaN
NaN  ← not a number

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

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


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)`

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)

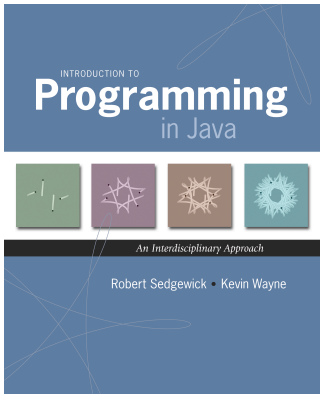
double between 0.0 and 1.0

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
```

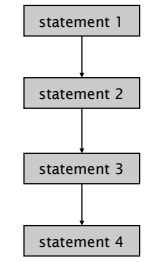

1.3 Conditionals and Loops



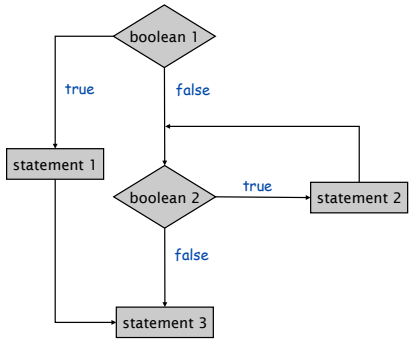
Control Flow

Control flow.

- Sequence of statements that are actually executed in a program.
- Conditionals and loops: enable us to choreograph control flow.



straight-line control flow



control flow with conditionals and loops

Conditionals

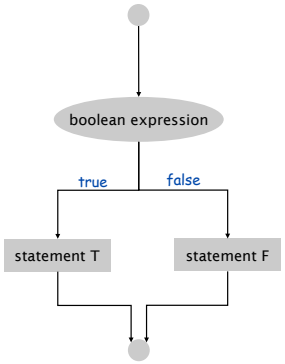
If Statement

The `if` statement. A common branching structure.

- Check `boolean` condition.
- If `true`, execute some statements.
- If `false`, execute other statements.

```
if (boolean expression) {
   statement T;
}
else {
   statement F;
}
```

can be any sequence of statements



If Statement

Ex. Take different action depending on value of variable.

```
public class Flip {
   public static void main(String[] args) {
      if (Math.random() < 0.5) System.out.println("Heads");
      else                     System.out.println("Tails");
   }
}
```

If-Else: Leap Year

If-else. Take different action depending on value of variable.

- If `isLeapYear` is `true`, then print `"is a"`.
- Otherwise, print `"isn't a "`.

```
System.out.print(year + " ");

if (isLeapYear) {
   System.out.print("is a");
}
else {
   System.out.print("isn't a");
}

System.out.println(" leap year");
```


Oblivious Sorting

Sort. Read in 3 integers and rearrange them in ascending order.

```
public class Sort3 {
   public static void main(String[] args) {

      int a = Integer.parseInt(args[0]);
      int b = Integer.parseInt(args[1]);
      int c = Integer.parseInt(args[2]);

      if (b > c) { int t = b; b = c; c = t; }
      if (a > b) { int t = a; a = b; b = t; }
      if (b > c) { int t = b; b = c; c = t; }

      System.out.println(a + " " + b + " " + c);
   }
}
```

read in 3 integers from command-line

swap b and c

swap a and b

swap b and c

```
% java Sort3 9 8 7
7 8 9

% java Sort3 2 1 7
1 2 7
```

Puzzle 1. Sort 4 integers with 5 compare-exchanges.

Puzzle 2. Sort 6 integers with 12.