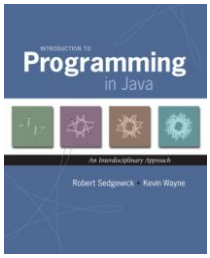
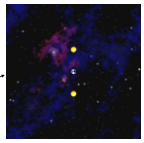
1.1 Your First Program



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


Ada Lovelace


Analytic Engine

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()

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`

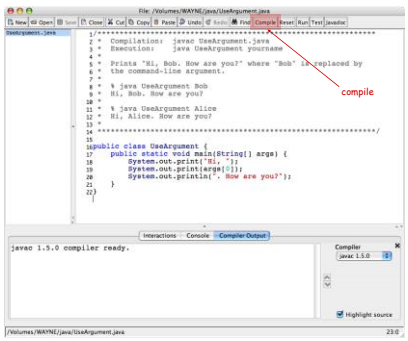
command-line

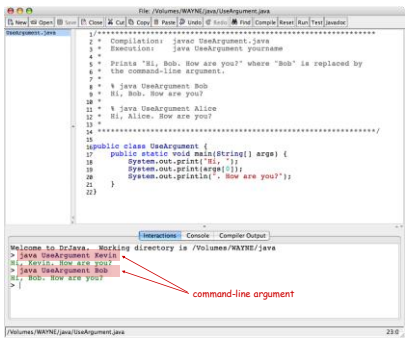
```
% javac HelloWorld.java

% java HelloWorld
Hello, World
```

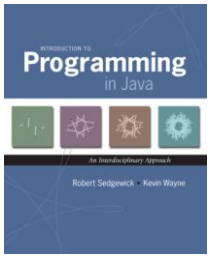

Dr. Java

http://drjava.org





1.2 Built-in Types of Data



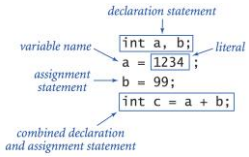
Built-in Data Types

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"` `"110 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 of declared type
Literal Programming language representation of 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

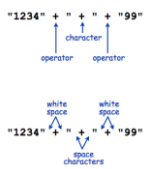
Text

`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
```

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Integers

…, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, …

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

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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

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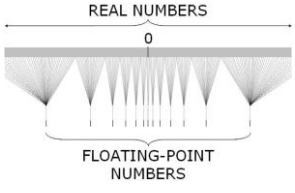
Floating-Point Numbers



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

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Excerpts from Java's 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)
```

http://download.oracle.com/javase/6/docs/api/java/lang/Math.html

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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);
   }
}
```

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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
```

$x^2 - 3x + 2$

$x^2 - x - 1$

$x^2 + x + 1$

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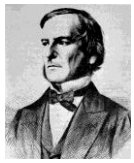
Booleans



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

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Comparisons

Comparisons Take two operands of one type (e.g., `int`) and produce a result 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)

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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
```

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Type Conversion

Type Conversion

Type conversion Convert value from one data type 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

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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
```

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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
- Ex 1: in 1996, Ariane 5 rocket exploded after takeoff because of bad type conversion
- Ex 2: `i = 0` in Matlab redefines $\sqrt{-1}$

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