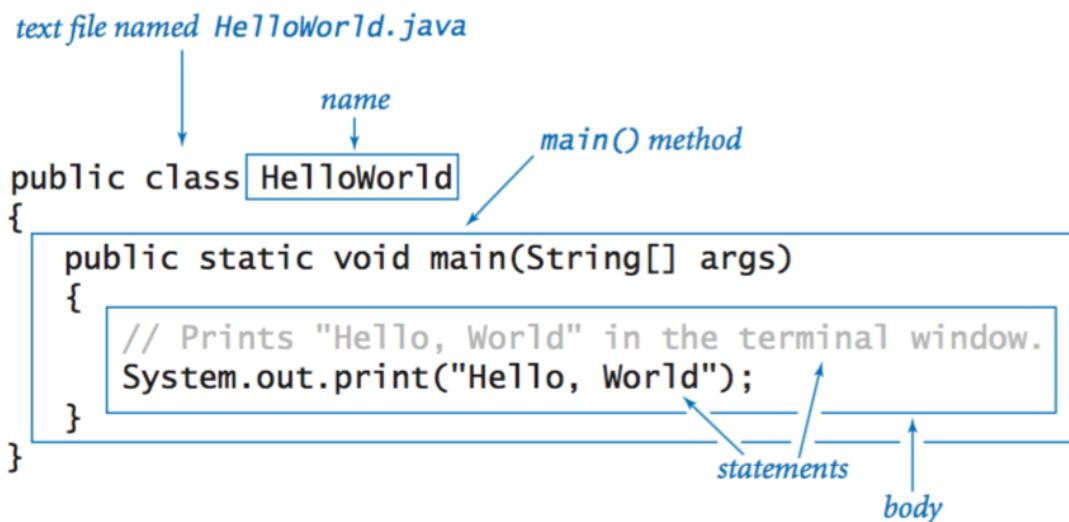
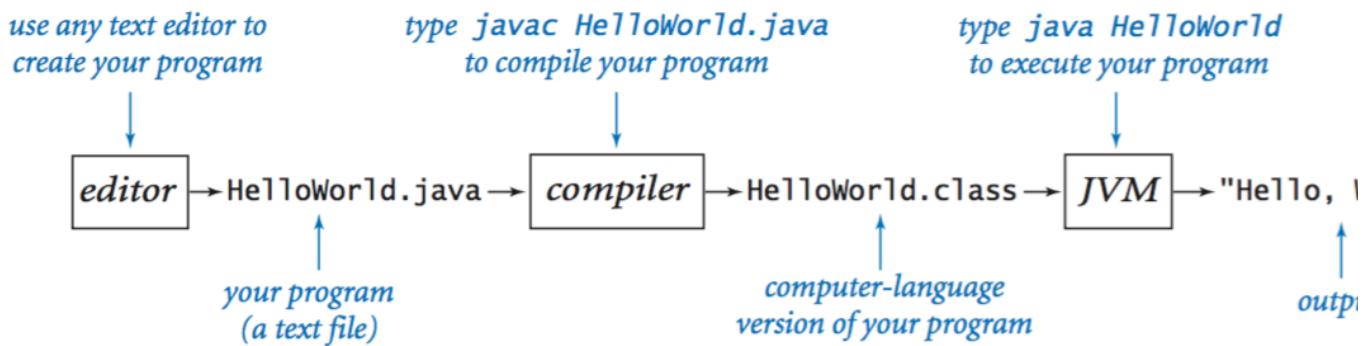


Hello, World.



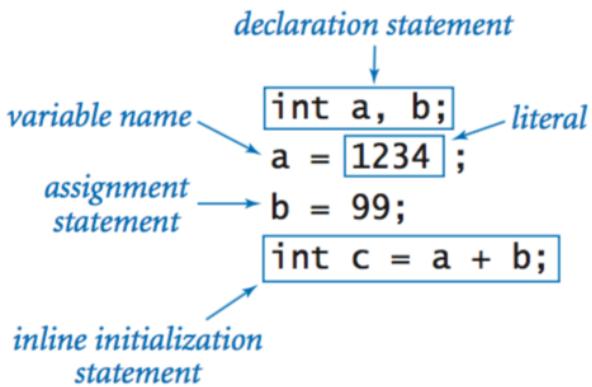
Editing, compiling, and executing.



Built-in data types.

<i>type</i>	<i>set of values</i>	<i>common operators</i>	<i>sample literal values</i>
<code>int</code>	integers	<code>+ - * / %</code>	99 12 214748364
<code>double</code>	floating-point numbers	<code>+ - * /</code>	3.14 2.5 6.022e2
<code>boolean</code>	boolean values	<code>&& !</code>	true false
<code>char</code>	characters		'A' '1' '%' '\n'
<code>String</code>	sequences of characters	<code>+</code>	"AB" "Hello" "2."

Declaration and assignment statements.



Integers.

<i>values</i>	integers between -2^{31} and $+2^{31}-1$					
<i>typical literals</i>	1234 99 0 1000000					
<i>operations</i>	<i>sign</i>	<i>add</i>	<i>subtract</i>	<i>multiply</i>	<i>divide</i>	<i>remainder</i>
<i>operators</i>	+ -	+	-	*	/	%
<hr/>						
<i>expression</i>	<i>value</i>	<i>comment</i>				
99	99	integer literal				
+99	99	positive sign				
-99	-99	negative sign				
5 + 3	8	addition				
5 - 3	2	subtraction				
5 * 3	15	multiplication				
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				

Floating-point numbers.

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

<i>expression</i>	<i>value</i>
3.141 + 2.0	5.141
3.141 - 2.0	1.111
3.141 / 2.0	1.5705
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

Booleans.

<i>values</i>	<i>true or false</i>	
<i>literals</i>	<code>true</code> <code>false</code>	
<i>operations</i>	<code>and</code>	<code>or</code>
<i>operators</i>	<code>&&</code>	<code> </code>

<i>a</i>	<i>!a</i>	<i>a</i>	<i>b</i>	<i>a && b</i>	<i>a b</i>
<code>true</code>	<code>false</code>	<code>false</code>	<code>false</code>	<code>false</code>	<code>false</code>
<code>false</code>	<code>true</code>	<code>false</code>	<code>true</code>	<code>false</code>	<code>true</code>
		<code>true</code>	<code>false</code>	<code>false</code>	<code>true</code>
		<code>true</code>	<code>true</code>	<code>true</code>	<code>true</code>

Comparison operators.

<i>op</i>	<i>meaning</i>	<i>true</i>	<i>false</i>
<code>==</code>	<i>equal</i>	<code>2 == 2</code>	<code>2 == 3</code>
<code>!=</code>	<i>not equal</i>	<code>3 != 2</code>	<code>2 != 2</code>
<code><</code>	<i>less than</i>	<code>2 < 13</code>	<code>2 < 2</code>
<code><=</code>	<i>less than or equal</i>	<code>2 <= 2</code>	<code>3 <= 2</code>
<code>></code>	<i>greater than</i>	<code>13 > 2</code>	<code>2 > 13</code>
<code>>=</code>	<i>greater than or equal</i>	<code>3 >= 2</code>	<code>2 >= 3</code>
<i>non-negative discriminant?</i>		<code>(b*b - 4.0*a*c) >= 0.0</code>	
<i>beginning of a century?</i>		<code>(year % 100) == 0</code>	
<i>legal month?</i>		<code>(month >= 1) && (month <= 12)</code>	

Printing.

```
void System.out.print(String s)      print s
void System.out.println(String s)    print s, followed by a newline
void System.out.println()           print a newline
```

Parsing command-line arguments.

<code>int Integer.parseInt(String s)</code>	<i>convert s to an int value</i>
<code>double Double.parseDouble(String s)</code>	<i>convert s to a double value</i>
<code>long Long.parseLong(String s)</code>	<i>convert s to a long value</i>

Math library.

public class Math

double abs(double a)	<i>absolute value of a</i>
double max(double a, double b)	<i>maximum of a and b</i>
double min(double a, double b)	<i>minimum of a and b</i>
double sin(double theta)	<i>sine of theta</i>
double cos(double theta)	<i>cosine of theta</i>
double tan(double theta)	<i>tangent of theta</i>
double toRadians(double degrees)	<i>convert angle from degrees to radians</i>
double toDegrees(double radians)	<i>convert angle from radians to degrees</i>
double exp(double a)	<i>exponential (e^a)</i>
double log(double a)	<i>natural log ($\log_e a$, or $\ln a$)</i>
double pow(double a, double b)	<i>raise a to the bth power (a^b)</i>
long round(double a)	<i>round a to the nearest integer</i>
double random()	<i>random number in [0, 1)</i>
double sqrt(double a)	<i>square root of a</i>
double E	<i>value of e (constant)</i>
double PI	<i>value of π (constant)</i>

The full [java.lang.Math API](#).

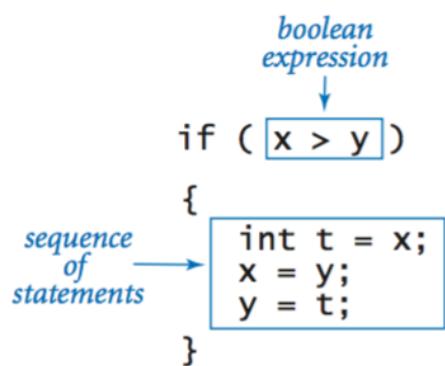
Java library calls.

method call	library	return type	value
Integer.parseInt("123")	Integer	int	123
Double.parseDouble("1.5")	Double	double	1.5
Math.sqrt(5.0*5.0 - 4.0*4.0)	Math	double	3.0
Math.log(Math.E)	Math	double	1.0
Math.random()	Math	double	<i>random in [0, 1)</i>
Math.round(3.14159)	Math	long	3
Math.max(1.0, 9.0)	Math	double	9.0

Type conversion.

<i>expression</i>	<i>expression type</i>	<i>expression value</i>
(1 + 2 + 3 + 4) / 4.0	double	2.5
Math.sqrt(4)	double	2.0
"1234" + 99	String	"123499"
11 * 0.25	double	2.75
(int) 11 * 0.25	double	2.75
11 * (int) 0.25	int	0
(int) (11 * 0.25)	int	2
(int) 2.71828	int	2
Math.round(2.71828)	long	3
(int) Math.round(2.71828)	int	3
Integer.parseInt("1234")	int	1234

Anatomy of an if statement.



If and if-else statements.

<i>absolute value</i>	<pre>if (x < 0) x = -x;</pre>
<i>put the smaller value in x and the larger value in y</i>	<pre>if (x > y) { int t = x; x = y; y = t; }</pre>
<i>maximum of x and y</i>	<pre>if (x > y) max = x; else max = y;</pre>
<i>error check for division operation</i>	<pre>if (den == 0) System.out.println("Division by zero"); else System.out.println("Quotient = " + num/den)</pre>
<i>error check for quadratic formula</i>	<pre>double discriminant = b*b - 4.0*c; if (discriminant < 0.0) { System.out.println("No real roots"); } else { System.out.println((-b + Math.sqrt(discriminant))/2.0); System.out.println((-b - Math.sqrt(discriminant))/2.0) }</pre>

Nested if-else statement.

```
if      (income <     0) rate = 0.00;
else if (income <  8925) rate = 0.10;
else if (income < 36250) rate = 0.15;
else if (income < 87850) rate = 0.23;
else if (income < 183250) rate = 0.28;
else if (income < 398350) rate = 0.33;
else if (income < 400000) rate = 0.35;
else                           rate = 0.396;
```

Anatomy of a while loop.

```

initialization is a
separate statement
int power = 1;
while ( power <= n/2 )
{
    power = 2*power;
}
braces are
optional
when body
is a single
statement
loop-
continuation
condition
body

```

Anatomy of a for loop.

```

initialize another
variable in a
separate
statement
int power = 1;
declare and initialize
a loop control variable
for (int i = 0; i <= n; i++)
{
    System.out.println(i + " " + power);
    power = 2*power;
}
loop-
continuation
condition
increment
body

```

Loops.

<i>compute the largest power of 2 less than or equal to n</i>	<pre>int power = 1; while (power <= n/2) power = 2*power; System.out.println(power);</pre>
<i>compute a finite sum ($1 + 2 + \dots + n$)</i>	<pre>int sum = 0; for (int i = 1; i <= n; i++) sum += i; System.out.println(sum);</pre>
<i>compute a finite product ($n! = 1 \times 2 \times \dots \times n$)</i>	<pre>int product = 1; for (int i = 1; i <= n; i++) product *= i; System.out.println(product);</pre>
<i>print a table of function values</i>	<pre>for (int i = 0; i <= n; i++) System.out.println(i + " " + 2*Math.PI*i/n);</pre>
<i>compute the ruler function (see PROGRAM 1.2.1)</i>	<pre>String ruler = "1"; for (int i = 2; i <= n; i++) ruler = ruler + " " + i + " " + ruler; System.out.println(ruler);</pre>

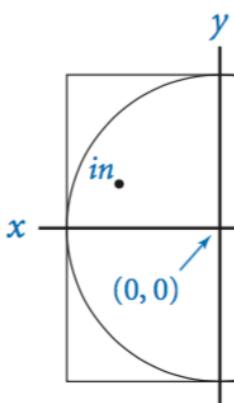
Break statement.

```
int factor;
for (factor = 2; factor <= n/factor; factor++)
    if (n % factor == 0) break;

if (factor > n/factor)
    System.out.println(n + " is prime");
```

Do-while loop.

```
do
{ // Scale x and y to be random in (-1, 1).
    x = 2.0*Math.random() - 1.0;
    y = 2.0*Math.random() - 1.0;
} while (Math.sqrt(x*x + y*y) > 1.0);
```



Switch statement.

```
switch (day) {  
    case 0: System.out.println("Sun"); break;  
    case 1: System.out.println("Mon"); break;  
    case 2: System.out.println("Tue"); break;  
    case 3: System.out.println("Wed"); break;  
    case 4: System.out.println("Thu"); break;  
    case 5: System.out.println("Fri"); break;  
    case 6: System.out.println("Sat"); break;  
}
```

Arrays.

a	a[0]
	a[1]
	a[2]
	a[3]
	a[4]
	a[5]
	a[6]
	a[7]

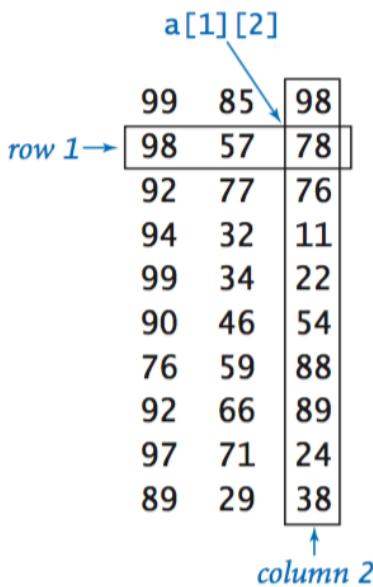
Inline array initialization.

```
String[] SUITS = { "Clubs", "Diamonds", "Hearts", "Spades" };  
  
String[] RANKS = {  
    "2", "3", "4", "5", "6", "7", "8", "9", "10",  
    "Jack", "Queen", "King", "Ace"  
};
```

Typical array-processing code.

<i>create an array with random values</i>	<pre>double[] a = new double[n]; for (int i = 0; i < n; i++) a[i] = Math.random();</pre>
<i>print the array values, one per line</i>	<pre>for (int i = 0; i < n; i++) System.out.println(a[i]);</pre>
<i>find the maximum of the array values</i>	<pre>double max = Double.NEGATIVE_INFINITY; for (int i = 0; i < n; i++) if (a[i] > max) max = a[i];</pre>
<i>compute the average of the array values</i>	<pre>double sum = 0.0; for (int i = 0; i < n; i++) sum += a[i]; double average = sum / n;</pre>
<i>reverse the values within an array</i>	<pre>for (int i = 0; i < n/2; i++) { double temp = a[i]; a[i] = a[n-1-i]; a[n-i-1] = temp; }</pre>
<i>copy sequence of values to another array</i>	<pre>double[] b = new double[n]; for (int i = 0; i < n; i++) b[i] = a[i];</pre>

Two-dimensional arrays.



Inline initialization.

```

double [][] a =
{
    { 99.0, 85.0, 98.0, 0.0 },
    { 98.0, 57.0, 79.0, 0.0 },
    { 92.0, 77.0, 74.0, 0.0 },
    { 94.0, 62.0, 81.0, 0.0 },
    { 99.0, 94.0, 92.0, 0.0 },
    { 80.0, 76.5, 67.0, 0.0 },
    { 76.0, 58.5, 90.5, 0.0 },
    { 92.0, 66.0, 91.0, 0.0 },
    { 97.0, 70.5, 66.5, 0.0 },
    { 89.0, 89.5, 81.0, 0.0 },
    { 0.0, 0.0, 0.0, 0.0 }
};

```

Our standard output library.

```

public class StdOut

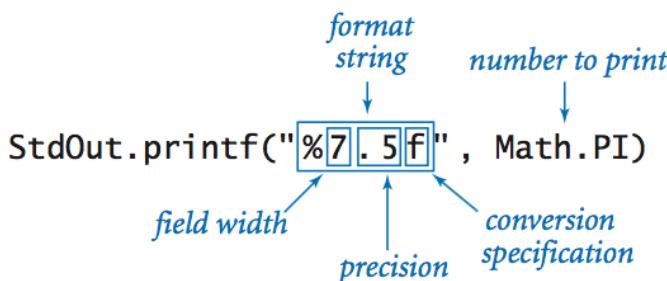
    void print(String s)
    void println(String s)
    void println()
    void printf(String format, ... )

```

print s to standard output
print s and a newline to standard output
print a newline to standard output
print the arguments to standard output, as specified by the format string format

The full [StdOut API](#).

Formatted printing.



<i>type</i>	<i>code</i>	<i>typical literal</i>	<i>sample format strings</i>	<i>converted string values for output</i>	
int	d	512	"%14d" "%-14d"	"512"	512"
double	f	1595.1680010754388	"%14.2f"	"	1595.17"
	e		"%.7f" "%14.4e"	"1595.1680011" "1.5952e+03"	
String	s	"Hello, World"	"%14s" "%-14s" "%-14.5s"	"Hello, World" "Hello, World " "Hello "	Hello, World"
boolean	b	true	"%b"	"true"	

Our standard input library.

public class StdIn

methods for reading individual tokens from standard input

boolean isEmpty()	<i>is standard input empty (or only whitespace)?</i>
int readInt()	<i>read a token, convert it to an int, and return it</i>
double readDouble()	<i>read a token, convert it to a double, and return it</i>
boolean readBoolean()	<i>read a token, convert it to a boolean, and return it</i>
String readString()	<i>read a token and return it as a String</i>

methods for reading characters from standard input

boolean hasNextChar()	<i>does standard input have any remaining characters</i>
char readChar()	<i>read a character from standard input and return it</i>

methods for reading lines from standard input

boolean hasNextLine()	<i>does standard input have a next line?</i>
String readLine()	<i>read the rest of the line and return it as a String</i>

methods for reading the rest of standard input

int[] readAllInts()	<i>read all remaining tokens and return them as an int[]</i>
double[] readAllDoubles()	<i>read all remaining tokens and return them as a double[]</i>
boolean[] readAllBooleans()	<i>read all remaining tokens and return them as a boolean[]</i>
String[] readAllStrings()	<i>read all remaining tokens and return them as a String[]</i>
String[] readAllLines()	<i>read all remaining lines and return them as a String[]</i>
String readAll()	<i>read the rest of the input and return it as a String</i>

The full [StdIn API](#).

Our standard drawing library.

```
public class StdDraw
```

drawing commands

```
void line(double x0, double y0, double x1, double y1)
void point(double x, double y)
void circle(double x, double y, double radius)
void filledCircle(double x, double y, double radius)
void square(double x, double y, double radius)
void filledSquare(double x, double y, double radius)
void rectangle(double x, double y, double r1, double r2)
void filledRectangle(double x, double y, double r1, double r2)
void polygon(double[] x, double[] y)
void filledPolygon(double[] x, double[] y)
void text(double x, double y, String s)
```

control commands

void setXscale(double x0, double x1)	<i>reset x-scale to (x0, x1)</i>
void setYscale(double y0, double y1)	<i>reset y-scale to (y0, y1)</i>
void setPenRadius(double radius)	<i>set pen radius to radius</i>
void setPenColor(Color color)	<i>set pen color to color</i>
void setFont(Font font)	<i>set text font to font</i>
void setCanvasSize(int w, int h)	<i>set canvas size to w-by-h</i>
void enableDoubleBuffering()	<i>enable double buffering</i>
void disableDoubleBuffering()	<i>disable double buffering</i>
void show()	<i>copy the offscreen canvas to the onscreen canvas</i>
void clear(Color color)	<i>clear the canvas to color color</i>
void pause(int dt)	<i>pause dt milliseconds</i>
void save(String filename)	<i>save to a .jpg or .png file</i>

The full [StdDraw API](#).

Our standard audio library.

```
public class StdAudio
```

void play(String filename)	play the given .wav file
void play(double[] a)	play the given sound wave
void play(double x)	play sample for 1/44100 sec
void save(String filename, double[] a)	save to a .wav file
double[] read(String filename)	read from a .wav file

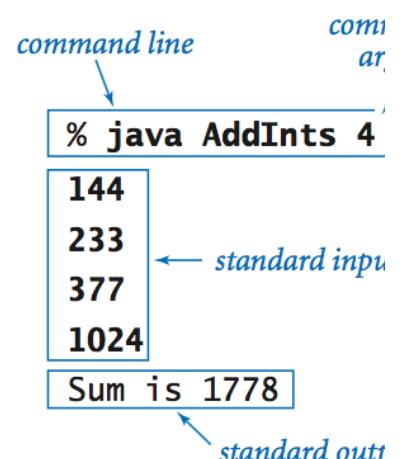
The full [StdAudio API](#).

Command line.

```
public class AddInts
{
    public static void main(String[] args)
    {
        int n = Integer.parseInt(args[0]);
        int sum = 0;
        for (int i = 0; i < n; i++)
        {
            int value = StdIn.readInt();
            sum += value;
        }
        StdOut.println("Sum is " + sum);
    }
}
```

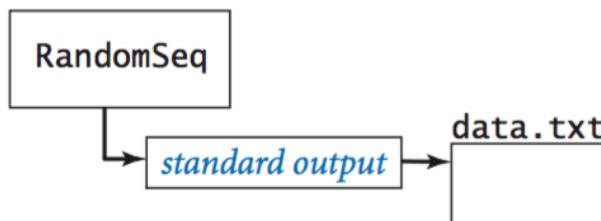
Annotations:

- `Integer.parseInt(args[0])`: parse command-line argument
- `StdIn.readInt()`: read from standard input stream
- `StdOut.println("Sum is " + sum)`: print to standard output stream

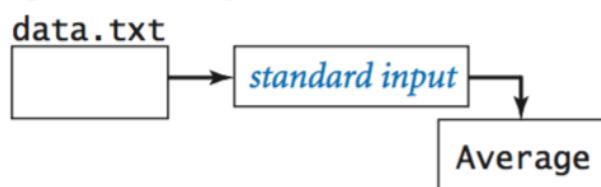


Redirection and piping.

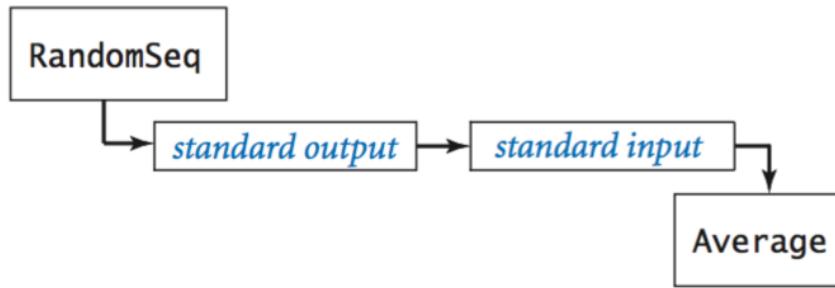
```
% java RandomSeq 1000 > data.txt
```



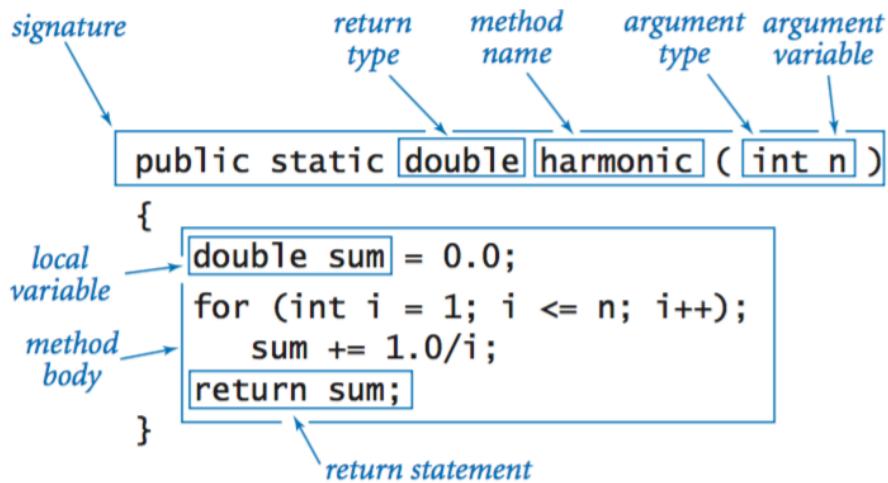
```
% java Average < data.txt
```



```
% java RandomSeq 1000 | java Average
```



Functions.



<i>absolute value of an int value</i>	<pre>public static int abs(int x) { if (x < 0) return -x; else return x; }</pre>
<i>absolute value of a double value</i>	<pre>public static double abs(double x) { if (x < 0.0) return -x; else return x; }</pre>
<i>primality test</i>	<pre>public static boolean isPrime(int n) { if (n < 2) return false; for (int i = 2; i <= n/i; i++) if (n % i == 0) return false; return true; }</pre>
<i>hypotenuse of a right triangle</i>	<pre>public static double hypotenuse(double a, double b) { return Math.sqrt(a*a + b*b); }</pre>
<i>harmonic number</i>	<pre>public static double harmonic(int n) { double sum = 0.0; for (int i = 1; i <= n; i++) sum += 1.0 / i; return sum; }</pre>
<i>uniform random integer in [0, n)</i>	<pre>public static int uniform(int n) { return (int) (Math.random() * n); }</pre>
<i>draw a triangle</i>	<pre>public static void drawTriangle(double x0, double y0, double x1, double y1, double x2, double y2) { StdDraw.line(x0, y0, x1, y1); StdDraw.line(x1, y1, x2, y2); StdDraw.line(x2, y2, x0, y0); }</pre>

client

```
Gaussian.pdf(x)
```

```
Gaussian.cdf(z)
```

calls library methods

API

```
public class Gaussian
```

```
    double pdf(double x)   φ(x)  
    double cdf(double z)  Φ(z)
```

*defines signatures
and describes
library methods*

implementation

```
public class Gaussian  
{ ...
```

```
    public static double pdf(double x)  
    { ... }
```

```
    public static double cdf(double z)  
    { ... }
```

```
}
```

*Java code that
implements
library methods*

Our standard random library.

```
public class StdRandom
```

void setSeed(long seed)	<i>set the seed for re</i>
int uniformInt(int n)	<i>integer between 0 and n - 1</i>
double uniformDouble(double lo, double hi)	<i>real between lo and hi</i>
boolean bernoulli(double p)	<i>true with probability p</i>
double gaussian()	<i>normal, mean 0, standard deviation 1</i>
double gaussian(double mu, double sigma)	<i>normal, mean mu, standard deviation sigma</i>
int discrete(double[] probabilities)	<i>i with probability probabilities[i]</i>
void shuffle(double[] a)	<i>randomly shuffle array a</i>

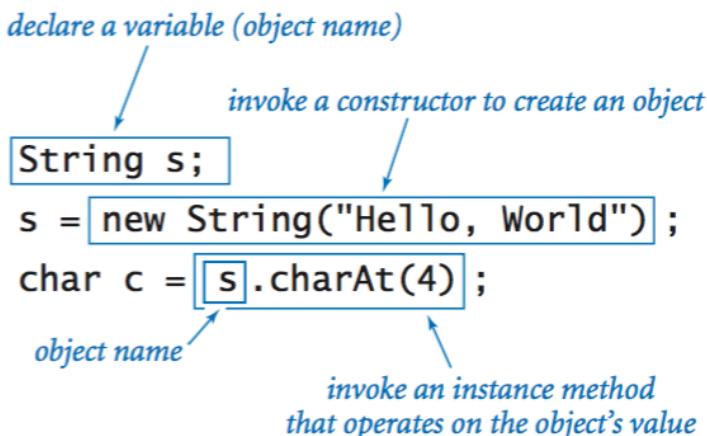
Our standard statistics library.

```
public class StdStats
```

double max(double[] a)	<i>largest value</i>
double min(double[] a)	<i>smallest value</i>
double mean(double[] a)	<i>average</i>
double var(double[] a)	<i>sample variance</i>
double stddev(double[] a)	<i>sample standard deviation</i>
double median(double[] a)	<i>median</i>
void plotPoints(double[] a)	<i>plot points at (i, a[i])</i>
void plotLines(double[] a)	<i>plot lines connecting (i, a[i])</i>
void plotBars(double[] a)	<i>plot bars to points at (i, a[i])</i>

The full [StdStats API](#).

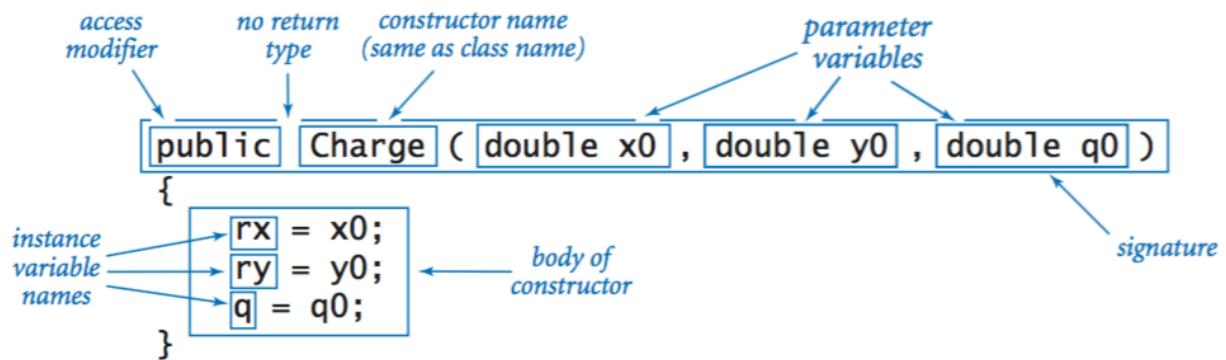
Using an object.



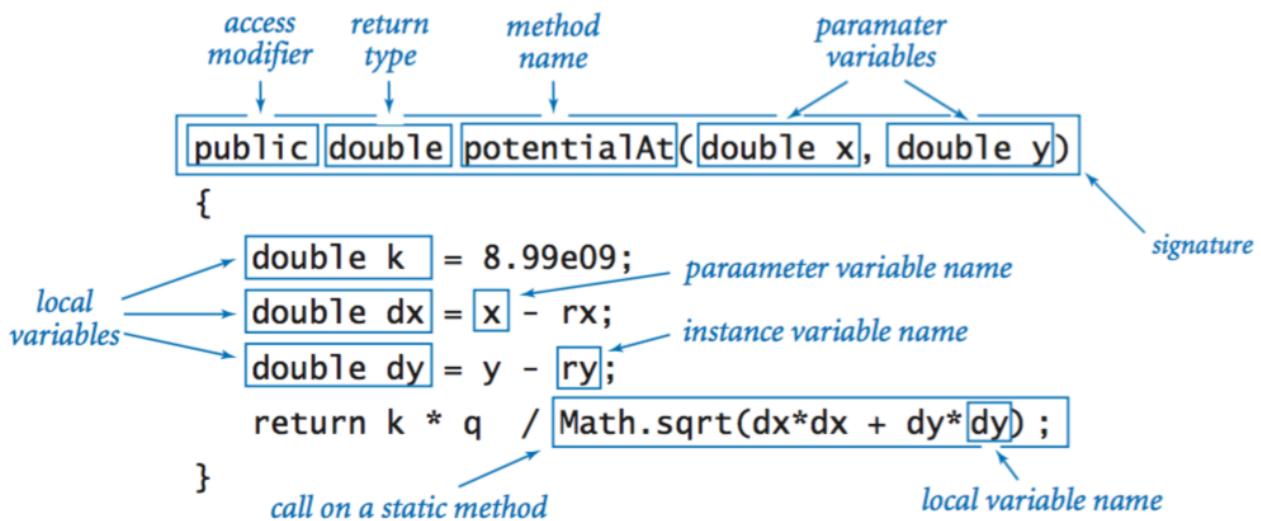
Instance variables.

```
public class Charge
{
    private final double rx, ry;
    private final double q;
}
```

Constructors.



Instance methods.



Classes.

```

public class Charge {
    private final double rx, ry;
    private final double q;

    public Charge(double x0, double y0, double q0)
    { rx = x0; ry = y0; q = q0; }

    public double potentialAt(double x, double y)
    {
        double k = 8.99e09;
        double dx = x - rx;
        double dy = y - ry;
        return k * q / Math.sqrt(dx*dx + dy*dy);
    }

    public String toString()
    { return q + " at (" + rx + ", " + ry + ")"; }

    public static void main(String[] args)
    {
        double x = Double.parseDouble(args[0]);
        double y = Double.parseDouble(args[1]);
        Charge c1 = new Charge(0.51, 0.63, 21.3);
        Charge c2 = new Charge(0.13, 0.94, 81.9);
        double v1 = c1.potentialAt(x, y);
        double v2 = c2.potentialAt(x, y);
        StdOut.printf("%.2e\n", (v1 + v2));
    }
}

```

Annotations:

- instance variables*: points to the declaration of `rx`, `ry`, and `q`.
- constructor*: points to the constructor `Charge(double x0, double y0, double q0)`.
- instance methods*: points to the method `potentialAt(double x, double y)` and the `toString()` method.
- test client*: points to the `main` method.
- create and initialize object*: points to the two lines of code that create and initialize objects `c1` and `c2`.
- object name*: points to the identifier `c1` and `c2`.
- invoke constructor*: points to the constructor call `new Charge(0.51, 0.63, 21.3)` and `new Charge(0.13, 0.94, 81.9)`.
- invoke method*: points to the method calls `c1.potentialAt(x, y)` and `c2.potentialAt(x, y)`.
- class name*: points to the identifier `Charge`.
- instance variable names*: points to the identifiers `rx`, `ry`, and `q` within the `potentialAt` method.

Object-oriented libraries.

client

```
Charge c1 = new Charge(0.51, 0.63, 21.3);  
  
c1.potentialAt(x, y)
```

*creates objects
and invokes methods*

API

```
public class Charge  
  
    Charge(double x0, double y0, double q0)  
  
    double potentialAt(double x, double y) potential at (x, y)  
due to charge  
  
    String toString() string  
representation
```

*defines signatures
and describes methods*

implementation

```
public class Charge  
{  
    private final double rx, ry;  
    private final double q;  
  
    public Charge(double x0, double y0, double q0)  
    { ... }  
  
    public double potentialAt(double x, double y)  
    { ... }  
  
    public String toString()  
    { ... }  
}
```

*defines instance variables
and implements methods*

Java's String data type.

public class String

String(String s)	<i>create a string with the same value</i>
String(char[] a)	<i>create a string that represents the sequence of characters as in a[]</i>
int length()	<i>number of characters</i>
char charAt(int i)	<i>the character at index i</i>
String substring(int i, int j)	<i>characters at indices i through (j - 1)</i>
boolean contains(String substring)	<i>does this string contain substring?</i>
boolean startsWith(String prefix)	<i>does this string start with prefix?</i>
boolean endsWith(String postfix)	<i>does this string end with postfix?</i>
int indexOf(String pattern)	<i>index of first occurrence of pattern</i>
int indexOf(String pattern, int i)	<i>index of first occurrence of pattern, starting at index i</i>
String concat(String t)	<i>this string, with t appended</i>
int compareTo(String t)	<i>string comparison</i>
String toLowerCase()	<i>this string, with lowercase letters</i>
String toUpperCase()	<i>this string, with uppercase letters</i>
String replace(String a, String b)	<i>this string, with as replaced by bs</i>
String trim()	<i>this string, with leading and trailing whitespace removed</i>
boolean matches(String regexp)	<i>is this string matched by the regular expression?</i>
String[] split(String delimiter)	<i>strings between occurrences of delimiter</i>
boolean equals(Object t)	<i>is this string's value the same as t?</i>
int hashCode()	<i>an integer hash code</i>

The full [java.lang.String API](#).

```

String a = new String("now is");
String b = new String("the time");
String c = new String(" the");

```

<i>instance method call</i>	<i>return type</i>	<i>return value</i>
a.length()	int	6
a.charAt(4)	char	'i'
a.substring(2, 5)	String	"w i"
b.startsWith("the")	boolean	true
a.indexOf("is")	int	4
a.concat(c)	String	"now is the"
b.replace("t", "T")	String	"The Time"
a.split(" ")	String[]	{ "now", "is" }
b.equals(c)	boolean	false

Java's Color data type.

```
public class java.awt.Color
```

Color(int r, int g, int b)	
int getRed()	<i>red intensity</i>
int getGreen()	<i>green intensity</i>
int getBlue()	<i>blue intensity</i>
Color brighter()	<i>brighter version of this color</i>
Color darker()	<i>darker version of this color</i>
String toString()	<i>string representation of this color</i>
boolean equals(Object c)	<i>is this color's value the same as c ?</i>

The full [java.awt.Color API](#).

Our input library.

```
public class In
```

In()	<i>create an input stream from standard input</i>
In(String name)	<i>create an input stream from a file or website</i>
<i>instance methods that read individual tokens from the input stream</i>	
boolean isEmpty()	<i>is standard input empty (or only whitespace)?</i>
int readInt()	<i>read a token, convert it to an int, and return it</i>
double readDouble()	<i>read a token, convert it to a double, and return it</i>
...	

instance methods that read characters from the input stream

boolean hasNextChar()	<i>does standard input have any remaining characters?</i>
char readChar()	<i>read a character from standard input and return it</i>
<i>instance methods that read lines from the input stream</i>	
boolean hasNextLine()	<i>does standard input have a next line?</i>
String readLine()	<i>read the rest of the line and return it as a String</i>

instance methods that read the rest of the input stream

int[] readAllInts()	<i>read all remaining tokens; return as array of integers</i>
double[] readAllDoubles()	<i>read all remaining tokens; return as array of doubles</i>
...	

The full [In API](#).

Our output library.

```
public class Out
```

Out()	<i>create an output stream to standard output</i>
Out(String name)	<i>create an output stream to a file</i>
void print(String s)	<i>print s to the output stream</i>
void println(String s)	<i>print s and a newline to the output stream</i>
void println()	<i>print a newline to the output stream</i>
void printf(String format, ...)	<i>print the arguments to the output stream, as specified by the format string format</i>

The full [Out API](#).

Our picture library.

public class Picture

Picture(String filename)	<i>create a picture from a file</i>
Picture(int w, int h)	<i>create a blank w-by-h picture</i>
int width()	<i>return the width of the picture</i>
int height()	<i>return the height of the picture</i>
Color get(int col, int row)	<i>return the color of pixel (col, row)</i>
void set(int col, int row, Color color)	<i>set the color of pixel (col, row) to color</i>
void show()	<i>display the picture in a window</i>
void save(String filename)	<i>save the picture to a file</i>

The full [Picture API](#).

Our stack data type.

public class Stack<Item> implements Iterable<Item>

Stack()	<i>create an empty stack</i>
boolean isEmpty()	<i>is the stack empty?</i>
void push(Item item)	<i>push an item onto the stack</i>
Item pop()	<i>return and remove the item that was inserted most recently</i>
int size()	<i>number of items on stack</i>

The full [Stack API](#).

Our queue data type.

public class Queue<Item> implements Iterable<Item>

Queue()	<i>create an empty queue</i>
boolean isEmpty()	<i>is the queue empty?</i>
void enqueue(Item item)	<i>insert an item onto queue</i>
Item dequeue()	<i>return and remove the item that was inserted least recently</i>
int size()	<i>number of items on queue</i>

The full [Queue API](#).

Iterable.

```

import java.util.Iterator; ← Iterator  

                                ← not in language

public class Queue<Item>
    implements Iterable<Item> ← promise to implement iterator()
{
    private Node first;
    private Node last;
    private class Node
    {
        Item item;
        Node next;
    }
    public void enqueue(Item item)
    ...
    public Item dequeue()
    ...

    public Iterator<Item> iterator()
    { return new ListIterator(); }

private class ListIterator
    implements Iterator<Item> ← implementation for Iterable interface
{
    Node current = first;
    public boolean hasNext() ← promise to implement hasNext(), next(), and remove()
    { return current != null; }

    public Item next()
    {
        Item item = current.item;
        current = current.next;
        return item;
    }

    public void remove()
    { }

}

public static void main(String[] args)
{
    Queue<Integer> queue = new Queue<Integer>();
    while (!StdIn.isEmpty())
        queue.enqueue(StdIn.readInt());
    for (int s : queue) ← foreach statement
        StdOut.println(s);
}
}

```

Our symbol table data type.

```
public class ST<Key extends Comparable<Key>, Value>
```

ST()	<i>create an empty symbol table</i>
void put(Key key, Value val)	<i>associate val with key</i>
Value get(Key key)	<i>value associated with key</i>
void remove(Key key)	<i>remove key (and its associated value)</i>
boolean contains(Key key)	<i>is there a value associated with key?</i>
int size()	<i>number of key-value pairs</i>
Iterable<Key> keys()	<i>all keys in the symbol table</i>

The full [ST API](#).

Our set data type.

```
public class SET<Key extends Comparable<Key>> implements Itera
```

SET()	<i>create an empty set</i>
boolean isEmpty()	<i>is the set empty?</i>
void add(Key key)	<i>add key to the set</i>
void remove(Key key)	<i>remove key from set</i>
boolean contains(Key key)	<i>is key in the set?</i>
int size()	<i>number of elements in set</i>

The full [SET API](#).

Our graph data type.

```
public class Graph
```

Graph()	<i>create an empty graph</i>
Graph(String filename, String delimiter)	<i>create graph from file</i>
void addEdge(String v, String w)	<i>add edge between vertices v and w</i>
int V()	<i>number of vertices</i>
int E()	<i>number of edges</i>
Iterable<String> vertices()	<i>vertices in graph</i>
Iterable<String> adjacentTo(String v)	<i>neighbors of vertex v</i>
int degree(String v)	<i>number of edges connected to v</i>
boolean hasVertex(String v)	<i>is v a vertex?</i>
boolean hasEdge(String v, String w)	<i>is v-w an edge?</i>

The full [Graph API](#).