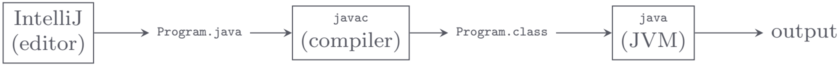
Programming Model

Outline

Programming in Java

Programming in Java

The Java workflow



Programming in Java

The Java workflow

IntelliJ (editor) → `Program.java` → `javac` (compiler) → `Program.class` → `java` (JVM) → output

Program.java

```
[package dsa;]

// Import statements.
...

// Class definition.
public class Program [implements <name>] {
    // Field declarations.
    ...

    // Constructor definitions.
    ...

    // Method definitions.
    ...

    // Function definitions.
    ...

    // Inner class definitions.
    ...
}
```

Programming in Java

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>_ ~/workspace/dsa/programs
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import stdlib.StdOut;

public class HelloWorld {
    // Entry point.
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        StdOut.println("Hello, World");
    }
}
```

Programming in Java

The application programming interface (API) for a library provides a summary of the functions in the library

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Example

stdlib.StdOut	
`static void print(Object x)`	prints an object to standard output
`static void println(Object x)`	prints an object and a newline to standard output

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Syntax errors are identified and reported by `javac` when it compiles a program

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~/workspace/dsa/programs

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~/workspace/dsa/programs

```
$ javac -d out src/HelloWorld.java
HelloWorld.java:8: error: ';' expected
        StdOut.println("Hello, World")
                                      ^
1 error
$ _
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~/workspace/dsa/programs

```
$ javac -d out src/HelloWorld.java
HelloWorld.java:6: error: cannot find symbol
        StdOut.println("Hello, World");
        ^
  symbol:   variable StdOut
  location: class HelloWorld
1 error
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```

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$ java HelloWorld
Hello, World$ _
```

Input and Output

Input and Output

input $\longrightarrow$ `Program.java` $\longrightarrow$ output

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Input types:

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Command-line inputs are strings listed right next to the program name during execution

```
>_ ~/workspace/ipp/programs

$ java Program input1 input2 input3 ...
```

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The inputs are accessed within the entry point function in the program as `args[0]`, `args[1]`, `args[2]`, and so on

Input and Output · Command-line Input

Command-line inputs are strings listed right next to the program name during execution

```
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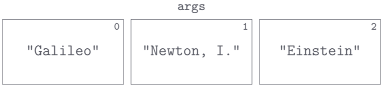
$ java Program input1 input2 input3 ...
```

The inputs are accessed within the entry point function in the program as `args[0]`, `args[1]`, `args[2]`, and so on

Example

```
>_ ~/workspace/ipp/programs
$ java Program Galileo "Newton, I." Einstein
```



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>_ ~/workspace/dsa/programs

$ java UseArgument Alice
```

Program: `UseArgument.java`

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```
>_ ~/workspace/dsa/programs

$ java UseArgument Alice
Hi, Alice. How are you?
$ _
```

Program: `UseArgument.java`

- ⇝ Command-line input: a name
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$ java UseArgument Alice
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$ java UseArgument Alice
Hi, Alice. How are you?
$ java UseArgument Bob
Hi, Bob. How are you?
$ java UseArgument Carol
Hi, Carol. How are you?
$ _
```

UseArgument.java

```java
// Accepts a name as command-line argument; and writes a message containing that name to standard
// output.

import stdlib.StdOut;

public class UseArgument {
    // Entry point.
    public static void main(String[] args) {
        StdOut.print("Hi, ");
        StdOut.print(args[0]);
        StdOut.println(". How are you?");
    }
}
```

Primitive Types

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A data type (primitive or reference) is a set of values along with a set of operations defined on those values

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- $\rightsquigarrow$ `double` - 64-bit double-precision real numbers with arithmetic operations

Expressions · Literals

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- `'*'` is a `char` literal
- `42` is an `int` literal
- `1729L` is a `long` literal
- `3.14159D` is a `double` literal

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A variable's value is accessed as `[<target>].<name>`

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A variable's value is accessed as `[<target>].<name>`

Examples: `total`, `SPEED_OF_LIGHT`, `args`, and `Math.PI`

Expressions · Operators

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`+`, `-`, `*`, `/`, and `%` represent arithmetic operations

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The comparison operators `==`, `!=`, `<`, `<=`, `>`, and `>=` operate on numeric values and produce a boolean result

Expressions · Operators

Operator precedence (highest to lowest)

`-`	negation
`*`, `/`, `%`	multiplication, division, remainder
`+`, `-`	addition, subtraction
`<`, `<=`, `>`, `>=`	less than, less than or equal, greater than, greater than or equal
`==`, `!=`	equal, not equal
`=`	assignment
`!`, `||`, `&&`	logical not, logical or, logical and

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`=`	assignment
`!, ||, &&`	logical not, logical or, logical and

Parentheses can be used to override precedence rules

Expressions · Functions

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A function is called as `[<library>].<name>(<argument1>, <argument2>, ...)`

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A function is called as `[<library>].<name>(<argument1>, <argument2>, ...)`

Some functions (called non-void functions) return a value while others (called void functions) do not return any value

Examples:

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java.lang.Math

`static double sqrt(double x)` returns $\sqrt{\mathtt{x}}$

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java.lang.Double

`static double parseDouble(String s)` returns `double` value of `s`

java.util.Arrays

`static void sort(Comparable[] a)` sorts the array `a`

Examples (contd.):

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stdlib.StdOut

`static void println()`	prints a newline to standard output
`static void println(Object x)`	prints an object and a newline to standard output

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stdlib.StdOut

`static void println()`	prints a newline to standard output
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stdlib.StdRandom

`static double uniform(double a, double b)`	returns a double chosen uniformly at random from the interval `[a, b)`
`static boolean bernoulli(double p)`	returns `true` with probability `p` and `false` with probability `1 - p`

Examples (contd.):

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`static boolean bernoulli(double p)`	returns `true` with probability `p` and `false` with probability `1 - p`

stdlib.StdStats

`static double mean(double[] a)`	returns the average value in the array `a`
`static double stddev(double[] a)`	returns the sample standard deviation in the array `a`

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- `b * b - 4 * a * c`

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- `2, 4`
- `a, b, c`
- `b * b - 4 * a * c`
- `Math.sqrt(b * b - 4 * a * c)`

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An expression is a combination of literals, variables, operators, and non-void function calls that evaluates to a value

Examples:

- `2, 4`
- `a, b, c`
- `b * b - 4 * a * c`
- `Math.sqrt(b * b - 4 * a * c)`
- `(-b + Math.sqrt(b * b - 4 * a * c)) / (2 * a)`

Strings

Strings

The `String` data type, which is a reference type, represents strings (sequences of characters)

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Example: `"Hello, World" + "!"` evaluates to `"Hello, World!"`

The `+` operator can also be used to convert primitives to strings

Example: `"PI = " + 3.14159` evaluates to `"PI = 3.14159"`

Statements

Statements

A statement is a syntactic unit that expresses some action to be carried out

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Import statement

```
import <library>;
```

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```
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```

Examples

```
import java.util.Arrays;
import stdlib.StdOut;
```

Statements

Statements

Function call statement

```
[<library>].<name>(<argument1>, <argument2>, ...);
```

Statements

Function call statement

```
[<library>].<name>(<argument1>, <argument2>, ...);
```

Examples

```
StdOut.print("Cogito, ");
StdOut.print("ergo sum");
StdOut.println();
```

Statements

Statements

Declaration statement

```
<type> <name>;
```

Statements

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```
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```

The initial value for the variable is `false` for `boolean`, `0` for other primitive types, and `null` for any reference type

Statements

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```
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Assignment statement

```
<name> = <expression>;
```

Statements

Declaration statement

```
<type> <name>;
```

The initial value for the variable is `false` for `boolean`, `0` for other primitive types, and `null` for any reference type

Assignment statement

```
<name> = <expression>;
```

Declaration and assignment statements combined

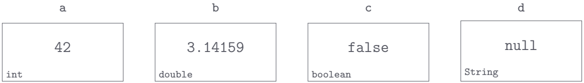
```
<type> <name> = <expression>;
```

Statements

Statements

Examples

```java
int a = 42;
double b = 3.14159D;
boolean c;
String d;
```



Statements

Statements

Equivalent assignment statement forms:

Statements

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```
<name> <operator>= <expression>;
<name> = <name> <operator> <expression>;
```

where `<operator>` is `+`, `-`, `*`, `/`, or `%`

Statements

Equivalent assignment statement forms:

```
<name> <operator>= <expression>;
<name> = <name> <operator> <expression>;
```

where <operator> is +, -, *, /, or %

```
<name>++;
++<name>;
<name> = <name> + 1;
```

Statements

Equivalent assignment statement forms:

```
<name> <operator>= <expression>;
<name> = <name> <operator> <expression>;
```

where <operator> is +, -, *, /, or %

```
<name>++;
++<name>;
<name> = <name> + 1;
```

```
<name>--;
--<name>;
<name> = <name> - 1;
```

Statements

Equivalent assignment statement forms:

```
<name> <operator>= <expression>;
<name> = <name> <operator> <expression>;
```

where `<operator>` is `+`, `-`, `*`, `/`, or `%`

```
<name>++;
++<name>;
<name> = <name> + 1;
```

```
<name>--;
--<name>;
<name> = <name> - 1;
```

Example

```
x += 1;
x = x + 1;
++x;
x++;
```

Statements

Statements

Program: `Quadratic.java`

Statements

Program: `Quadratic.java`

$\rightsquigarrow$ Command-line input: a (double), b (double), and c (double)

Statements

Program: `Quadratic.java`

- ⇝ Command-line input: a (double), b (double), and c (double)
- ⇝ Standard output: roots of the quadratic equation $ax^2 + bx + c = 0$

Statements

Program: `Quadratic.java`

- Command-line input: a (double), b (double), and c (double)
- Standard output: roots of the quadratic equation $ax^2 + bx + c = 0$

```
>_ ~/workspace/dsa/programs

$ _
```

Statements

Program: `Quadratic.java`

- Command-line input: a (double), b (double), and c (double)
- Standard output: roots of the quadratic equation $ax^2 + bx + c = 0$

```
>_ ~/workspace/dsa/programs

$ java Quadratic 1 -5 6
```

Statements

Program: `Quadratic.java`

- Command-line input: a (double), b (double), and c (double)
- Standard output: roots of the quadratic equation $ax^2 + bx + c = 0$

```
>_ ~/workspace/dsa/programs

$ java Quadratic 1 -5 6
Root # 1 = 3.0
Root # 2 = 2.0
$ _
```

Statements

Program: `Quadratic.java`

- ⇝ Command-line input: a (double), b (double), and c (double)
- ⇝ Standard output: roots of the quadratic equation $ax^2 + bx + c = 0$

```
>_ ~/workspace/dsa/programs

$ java Quadratic 1 -5 6
Root # 1 = 3.0
Root # 2 = 2.0
$ java Quadratic 1 -1 -1
```

Statements

Program: `Quadratic.java`

- ⇝ Command-line input: a (double), b (double), and c (double)
- ⇝ Standard output: roots of the quadratic equation $ax^2 + bx + c = 0$

```
>_ ~/workspace/dsa/programs

$ java Quadratic 1 -5 6
Root # 1 = 3.0
Root # 2 = 2.0
$ java Quadratic 1 -1 -1
Root # 1 = 1.618033988749895
Root # 2 = -0.6180339887498949
$ _
```

Statements

Statements

Quadratic.java

```java
import stdlib.StdOut;

public class Quadratic {
    public static void main(String[] args) {
        double a = Double.parseDouble(args[0]);
        double b = Double.parseDouble(args[1]);
        double c = Double.parseDouble(args[2]);
        double discriminant = b * b - 4 * a * c;
        double root1 = (-b + Math.sqrt(discriminant)) / (2 * a);
        double root2 = (-b - Math.sqrt(discriminant)) / (2 * a);
        StdOut.println("Root # 1 = " + root1);
        StdOut.println("Root # 2 = " + root2);
    }
}
```

Statements

Conditional (if) statement

```
if (<expression>) {
    <statement>
    ...
} else if (<expression>) {
    <statement>
    ...
} else if (<expression>) {
    <statement>
    ...
} else {
    <statement>
    ...
}
<statement>
...
```

Statements

Statements

Program: `Grade.java`

Statements

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- ⇝ Command-line input: a percentage *score* (double)

Statements

Program: `Grade.java`

- ⇝ Command-line input: a percentage *score* (double)
- ⇝ Standard output: the corresponding letter grade

Statements

Program: `Grade.java`

- ⇝ Command-line input: a percentage *score* (double)
- ⇝ Standard output: the corresponding letter grade

```
>_ ~/workspace/dsa/programs

$ _
```

Statements

Program: `Grade.java`

- ⇝ Command-line input: a percentage *score* (double)
- ⇝ Standard output: the corresponding letter grade

```
>_ ~/workspace/dsa/programs

$ java Grade 97
```

Statements

Program: `Grade.java`

- ⇝ Command-line input: a percentage *score* (double)
- ⇝ Standard output: the corresponding letter grade

```
>_ ~/workspace/dsa/programs

$ java Grade 97
A
$ _
```

Statements

Program: `Grade.java`

- ⇝ Command-line input: a percentage *score* (double)
- ⇝ Standard output: the corresponding letter grade

```
>_ ~/workspace/dsa/programs

$ java Grade 97
A
$ java Grade 56
```

Statements

Program: `Grade.java`

- ⇝ Command-line input: a percentage *score* (double)
- ⇝ Standard output: the corresponding letter grade

```
>_ ~/workspace/dsa/programs

$ java Grade 97
A
$ java Grade 56
F
$ _
```

Statements

Statements

Grade.java

```java
import stdlib.StdOut;

public class Grade {
    public static void main(String[] args) {
        double score = Double.parseDouble(args[0]);
        if (score >= 93) {
            StdOut.println("A");
        } else if (score >= 90) {
            StdOut.println("A-");
        } else if (score >= 87) {
            StdOut.println("B+");
        } else if (score >= 83) {
            StdOut.println("B");
        } else if (score >= 80) {
            StdOut.println("B-");
        } else if (score >= 77) {
            StdOut.println("C+");
        } else if (score >= 73) {
            StdOut.println("C");
        } else if (score >= 70) {
            StdOut.println("C-");
        } else if (score >= 67) {
            StdOut.println("D+");
        } else if (score >= 63) {
            StdOut.println("D");
        } else if (score >= 60) {
            StdOut.println("D-");
        } else {
            StdOut.println("F");
        }
    }
}
```

Statements

Conditional expression

```
... <expression> ? <expression1> : <expression2> ...
```

Statements

Statements

Program: `Flip.java`

Statements

Program: `Flip.java`

$\rightsquigarrow$ Standard output: “Heads” or “Tails”

Statements

Program: `Flip.java`

⇝ Standard output: “Heads” or “Tails”

```
>_ ~/workspace/dsa/programs

$ _
```

Statements

Program: `Flip.java`

⇝ Standard output: “Heads” or “Tails”

```
>_ ~/workspace/dsa/programs

$ java Flip
```

Statements

Program: `Flip.java`

⇝ Standard output: "Heads" or "Tails"

```
>_ ~/workspace/dsa/programs

$ java Flip
Heads
$ _
```

Statements

Program: `Flip.java`

⇝ Standard output: “Heads” or “Tails”

```
>_ ~/workspace/dsa/programs

$ java Flip
Heads
$ java Flip
```

Statements

Program: `Flip.java`

⇝ Standard output: "Heads" or "Tails"

```
>_ ~/workspace/dsa/programs

$ java Flip
Heads
$ java Flip
Heads
$ _
```

Statements

Program: `Flip.java`

⇝ Standard output: "Heads" or "Tails"

```
>_ ~/workspace/dsa/programs

$ java Flip
Heads
$ java Flip
Heads
$ java Flip
```

Statements

Program: `Flip.java`

⇝ Standard output: “Heads” or “Tails”

```
>_ ~/workspace/dsa/programs

$ java Flip
Heads
$ java Flip
Heads
$ java Flip
Tails
$ _
```

Statements

Statements

Flip.java

```java
import stdlib.StdOut;
import stdlib.StdRandom;

public class Flip {
    public static void main(String[] args) {
        String result = StdRandom.bernoulli(0.5) ? "Heads" : "Tails";
        StdOut.println(result);
    }
}
```

Statements

Loop (while) statement

```
while (<expression>) {
    <statement>
    ...
}
<statement>
...
```

Statements

Statements

Program: `NHellos.java`

Statements

Program: `NHellos.java`

$\rightsquigarrow$ Command-line input: n (int)

Statements

Program: `NHellos.java`

- $\rightsquigarrow$ Command-line input: n (int)
- $\rightsquigarrow$ Standard output: n Hellos

Statements

Program: `NHellos.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: n Hellos

```
>_ ~/workspace/dsa/programs

$ _
```

Statements

Program: `NHellos.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: n Hellos

```
>_ ~/workspace/dsa/programs

$ java NHellos 10
```

Statements

Program: `NHellos.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: n Hellos

```
>_ ~/workspace/dsa/programs

$ java NHellos 10
Hello # 1
Hello # 2
Hello # 3
Hello # 4
Hello # 5
Hello # 6
Hello # 7
Hello # 8
Hello # 9
Hello # 10
$ _
```

Statements

Statements

NHellos.java

```java
import stdlib.StdOut;

public class NHellos {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        int i = 1;
        while (i <= n) {
            StdOut.println("Hello # " + i);
            i++;
        }
    }
}
```

Statements

Statements

Loop (for) statement

```
for (<initialization>; <expression>; <update>) {
    <statement>
    ...
}
<statement>
...
```

Statements

Statements

Program: `Harmonic.java`

Statements

Program: `Harmonic.java`

$\rightsquigarrow$ Command-line input: n (int)

Statements

Program: `Harmonic.java`

- $\rightsquigarrow$ Command-line input: n (int)
- $\rightsquigarrow$ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs
$ _
```

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java Harmonic 10
```

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java Harmonic 10
2.9289682539682538
$ _
```

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java Harmonic 10
2.9289682539682538
$ java Harmonic 1000
```

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java Harmonic 10
2.9289682539682538
$ java Harmonic 1000
7.485470860550343
$ _
```

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java Harmonic 10
2.9289682539682538
$ java Harmonic 1000
7.485470860550343
$ java Harmonic 10000
```

Statements

Program: `Harmonic.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java Harmonic 10
2.9289682539682538
$ java Harmonic 1000
7.485470860550343
$ java Harmonic 10000
9.787606036044348
$ _
```

Statements

Statements

Harmonic.java

```java
import stdlib.StdOut;

public class Harmonic {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        double total = 0.0;
        for (int i = 1; i <= n; i++) {
            total += 1.0 / i;
        }
        StdOut.println(total);
    }
}
```

Statements

Statements

The if, while, and for statements can be nested within one another

Statements

Statements

Program: `DivisorPattern.java`

Statements

Program: `DivisorPattern.java`

$\rightsquigarrow$ Command-line input: n (int)

Statements

Program: `DivisorPattern.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: a table where entry (i, j) is a star ("*") if j divides i or i divides j and a space (" ") otherwise

Statements

Program: `DivisorPattern.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: a table where entry (i, j) is a star ("*") if j divides i or i divides j and a space (" ") otherwise

```
>_ ~/workspace/dsa/programs

$ _
```

Statements

Program: `DivisorPattern.java`

- Command-line input: n (int)
- Standard output: a table where entry (i, j) is a star ("*") if j divides i or i divides j and a space (" ") otherwise

```
>_ ~/workspace/dsa/programs

$ java DivisorPattern 10
```

Program: `DivisorPattern.java`

⇝ Command-line input: n (int)

⇝ Standard output: a table where entry (i, j) is a star ("*") if j divides i or i divides j and a space (" ") otherwise

```
>_ ~/workspace/dsa/programs

$ java DivisorPattern 10
* * * * * * * * * * 1
* *   *   *   *   * 2
*   *     *     *   3
* *   *       *     4
*       *         * 5
* * *     *         6
*           *       7
* *   *       *     8
*   *           *   9
* *     *         * 10
$ _
```

Statements

Statements

DivisorPattern.java

```java
import stdlib.StdOut;

public class DivisorPattern {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 1; i <= n; i++) {
            for (int j = 1; j <= n; j++) {
                if (i % j == 0 || j % i == 0) {
                    StdOut.print("* ");
                } else {
                    StdOut.print("  ");
                }
            }
            StdOut.println(i);
        }
    }
}
```

Statements

Break statement

```
break;
```

Break statement

```
break;
```

Example

```
for (int n = 10, i = 0; true; i += 2) {
    if (i == n) {
        break;
    }
    StdOut.println(i + " ");
}
StdOut.println();
```

Break statement

```
break;
```

Example

```
for (int n = 10, i = 0; true; i += 2) {
    if (i == n) {
        break;
    }
    StdOut.println(i + " ");
}
StdOut.println();
```

```
0 2 4 6 8
```

Statements

Continue statement

```
continue;
```

Continue statement

```
continue;
```

Example

```
for (int n = 10, i = 0; i <= n; i++) {
    if (i % 2 == 0) {
        continue;
    }
    StdOut.print(i + " ");
}
StdOut.println();
```

Continue statement

```
continue;
```

Example

```
for (int n = 10, i = 0; i <= n; i++) {
    if (i % 2 == 0) {
        continue;
    }
    StdOut.print(i + " ");
}
StdOut.println();
```

```
1 3 5 7 9
```

Declaration

```
<type>[] <name>;
```

Declaration

```
<type>[] <name>;
```

Creation

```
<name> = new <type>[<capacity>];
```

Declaration

```
<type>[] <name>;
```

Creation

```
<name> = new <type>[<capacity>];
```

Explicit initialization

```
int n = <name>.length;
for (int i = 0; i < n; i++) {
    <name>[i] = <expression>;
}
```

Arrays · One-dimensional (1D) Arrays

Declaration

```
<type>[] <name>;
```

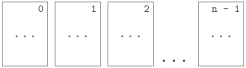
Creation

```
<name> = new <type>[<capacity>];
```

Explicit initialization

```
int n = <name>.length;
for (int i = 0; i < n; i++) {
    <name>[i] = <expression>;
}
```

Memory model for `<name>[]`



Arrays · One-dimensional (1D) Arrays

Program: `Sample.java`

Program: `Sample.java`

$\rightsquigarrow$ Command-line input: m (int) and n (int)

Program: `Sample.java`

- ⇝ Command-line input: m (int) and n (int)
- ⇝ Standard output: a random sample (without replacement) of m integers from the interval $[0, n)$

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- ⇝ Command-line input: m (int) and n (int)
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```
>_ ~/workspace/dsa/programs

$ _
```

Program: `Sample.java`

- ⇝ Command-line input: m (int) and n (int)
- ⇝ Standard output: a random sample (without replacement) of m integers from the interval $[0, n)$

```
>_ ~/workspace/dsa/programs

$ java Sample 6 16
```

Program: `Sample.java`

- Command-line input: m (int) and n (int)
- Standard output: a random sample (without replacement) of m integers from the interval $[0, n)$

```
>_ ~/workspace/dsa/programs

$ java Sample 6 16
10 7 11 1 8 5
$ _
```

Program: `Sample.java`

- ⇝ Command-line input: m (int) and n (int)
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```
>_ ~/workspace/dsa/programs

$ java Sample 6 16
10 7 11 1 8 5
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```

Program: `Sample.java`

- ⇝ Command-line input: m (int) and n (int)
- ⇝ Standard output: a random sample (without replacement) of m integers from the interval $[0, n)$

```
>_ ~/workspace/dsa/programs

$ java Sample 6 16
10 7 11 1 8 5
$ java Sample 10 1000
258 802 440 28 244 256 564 11 515 24
$ _
```

Program: `Sample.java`

- ⇝ Command-line input: m (int) and n (int)
- ⇝ Standard output: a random sample (without replacement) of m integers from the interval $[0, n)$

```
>_ ~/workspace/dsa/programs

$ java Sample 6 16
10 7 11 1 8 5
$ java Sample 10 1000
258 802 440 28 244 256 564 11 515 24
$ java Sample 20 20
```

Program: `Sample.java`

⇝ Command-line input: m (int) and n (int)

⇝ Standard output: a random sample (without replacement) of m integers from the interval $[0, n)$

```
>_ ~/workspace/dsa/programs

$ java Sample 6 16
10 7 11 1 8 5
$ java Sample 10 1000
258 802 440 28 244 256 564 11 515 24
$ java Sample 20 20
15 11 13 1 5 8 16 7 0 4 10 18 19 14 3 12 2 6 9 17
$ _
```

Sample.java

```java
import stdlib.StdOut;
import stdlib.StdRandom;

public class Sample {
    public static void main(String[] args) {
        int m = Integer.parseInt(args[0]);
        int n = Integer.parseInt(args[1]);
        int[] perm = new int[n];
        for (int i = 0; i < n; i++) {
            perm[i] = i;
        }
        for (int i = 0; i < m; i++) {
            int r = StdRandom.uniform(i, n);
            int temp = perm[r];
            perm[r] = perm[i];
            perm[i] = temp;
        }
        for (int i = 0; i < m; i++) {
            StdOut.print(perm[i] + " ");
        }
        StdOut.println();
    }
}
```

Arrays · Two-dimensional (2D) Arrays

Declaration

```
<type>[][] <name>;
```

Declaration

```
<type>[][] <name>;
```

Creation

```
<name> = new <type>[<capacity>][<capacity>];
```

Declaration

```
<type>[][] <name>;
```

Creation

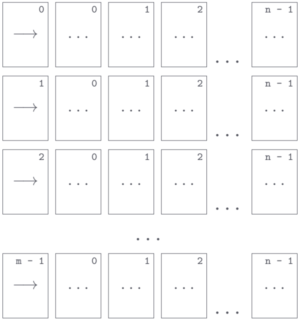
```
<name> = new <type>[<capacity>][<capacity>];
```

Explicit initialization

```
int m = <name>.length;
for (int i = 0; i < m; i++) {
    int n = <name>[i].length;
    for (int j = 0; j < n; j++) {
        <name>[i][j] = <expression>;
    }
}
```

Arrays · Two-dimensional (2D) Arrays

Memory model for <name>[][]



Program: `SelfAvoid.java`

Program: `SelfAvoid.java`

$\rightsquigarrow$ Command-line input: n (int) and $trials$ (int)

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and $trials$ (int)
- ⇝ Standard output: percentage of dead ends encountered in $trials$ self-avoiding random walks on an $n \times n$ lattice

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs
$ _
```

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs

$ java SelfAvoid 20 1000
```

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs

$ java SelfAvoid 20 1000
33% dead ends
$ _
```

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs

$ java SelfAvoid 20 1000
33% dead ends
$ java SelfAvoid 40 1000
```

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs

$ java SelfAvoid 20 1000
33% dead ends
$ java SelfAvoid 40 1000
78% dead ends
$ _
```

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs

$ java SelfAvoid 20 1000
33% dead ends
$ java SelfAvoid 40 1000
78% dead ends
$ java SelfAvoid 80 1000
```

Program: `SelfAvoid.java`

- ⇝ Command-line input: n (int) and *trials* (int)
- ⇝ Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
>_ ~/workspace/dsa/programs

$ java SelfAvoid 20 1000
33% dead ends
$ java SelfAvoid 40 1000
78% dead ends
$ java SelfAvoid 80 1000
98% dead ends
$ _
```

Arrays · Two-dimensional (2D) Arrays

SelfAvoid.java

```java
import stdlib.StdOut;
import stdlib.StdRandom;

public class SelfAvoid {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        int trials = Integer.parseInt(args[1]);
        int deadEnds = 0;
        for (int t = 0; t < trials; t++) {
            boolean[][] a = new boolean[n][n];
            int x = n / 2;
            int y = n / 2;
            while (x > 0 && x < n - 1 && y > 0 && y < n - 1) {
                a[x][y] = true;
                if (a[x - 1][y] && a[x + 1][y] && a[x][y - 1] && a[x][y + 1]) {
                    deadEnds++;
                    break;
                }
                int r = StdRandom.uniform(1, 5);
                if (r == 1 && !a[x + 1][y]) {
                    x++;
                } else if (r == 2 && !a[x - 1][y]) {
                    x--;
                } else if (r == 3 && !a[x][y + 1]) {
                    y++;
                } else if (r == 4 && !a[x][y - 1]) {
                    y--;
                }
            }
        }
        StdOut.println(100 * deadEnds / trials + "% dead ends");
    }
}
```

Defining Functions

Defining Functions

Function definition

```
public|private static void|<type> <name>(<parameter1>, <parameter2>, ...) {
    <statement>
    ...
}
```

Defining Functions

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```
public|private static void|<type> <name>(<parameter1>, <parameter2>, ...) {
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    ...
}
```

Return statement

```
return [<expression>];
```

Defining Functions

Function definition

```
public|private static void|<type> <name>(<parameter1>, <parameter2>, ...) {
    <statement>
    ...
}
```

Return statement

```
return [<expression>];
```

Example

```
private static boolean isPrime(int x) {
    if (x < 2) {
        return false;
    }
    for (int i = 2; i <= x / i; i++) {
        if (x % i == 0) {
            return false;
        }
    }
    return true;
}
```

Defining Functions

Defining Functions

Properties of functions:

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⇝ Arguments are passed by value

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Properties of functions:

- ⇝ Arguments are passed by value
- ⇝ Function names can be overloaded
- ⇝ A function has a single return value but may have multiple return statements
- ⇝ A function can have side effects

Defining Functions

Defining Functions

Program: `HarmonicRedux.java`

Defining Functions

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$\rightsquigarrow$ Command-line input: n (int)

Defining Functions

Program: `HarmonicRedux.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

Defining Functions

Program: `HarmonicRedux.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ _
```

Defining Functions

Program: `HarmonicRedux.java`

- Command-line input: n (int)
- Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java HarmonicRedux 10
```

Defining Functions

Program: `HarmonicRedux.java`

- Command-line input: n (int)
- Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java HarmonicRedux 10
2.9289682539682538
$ _
```

Defining Functions

Program: `HarmonicRedux.java`

- Command-line input: n (int)
- Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java HarmonicRedux 10
2.9289682539682538
$ java HarmonicRedux 1000
```

Defining Functions

Program: `HarmonicRedux.java`

- Command-line input: n (int)
- Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java HarmonicRedux 10
2.9289682539682538
$ java HarmonicRedux 1000
7.485470860550343
$ _
```

Defining Functions

Program: `HarmonicRedux.java`

- Command-line input: n (int)
- Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java HarmonicRedux 10
2.9289682539682538
$ java HarmonicRedux 1000
7.485470860550343
$ java HarmonicRedux 10000
```

Defining Functions

Program: `HarmonicRedux.java`

- Command-line input: n (int)
- Standard output: the nth harmonic number $H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$

```
>_ ~/workspace/dsa/programs

$ java HarmonicRedux 10
2.9289682539682538
$ java HarmonicRedux 1000
7.485470860550343
$ java HarmonicRedux 10000
9.787606036044348
$ _
```

Defining Functions

Defining Functions

HarmonicRedux.java

```java
import stdlib.StdOut;

public class HarmonicRedux {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        StdOut.println(harmonic(n));
    }

    private static double harmonic(int n) {
        double total = 0.0;
        for (int i = 1; i <= n; i++) {
            total += 1.0 / i;
        }
        return total;
    }
}
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

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Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0\text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

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```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
```

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Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0, \text{ and} \\ 1 & \text{if } n = 0 \end{cases}$$

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    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
```

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Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0 \text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
```

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Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0\text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```java
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
              3 * factorial(2)
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0\text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
              3 * factorial(2)
                    2 * factorial(1)
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0, \text{ and} \\ 1 & \text{if } n = 0 \end{cases}$$

```java
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
              3 * factorial(2)
                    2 * factorial(1)
                          1 * factorial(0)
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0\text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```java
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
              3 * factorial(2)
                    2 * factorial(1)
                          1 * 1
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0 \text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
              3 * factorial(2)
                    2 * 1
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0 \text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * factorial(3)
              3 * 2
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0, \text{ and} \\ 1 & \text{if } n = 0 \end{cases}$$

```java
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * factorial(4)
        4 * 6
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0 \text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```java
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
factorial(5)
  5 * 24
```

A recursive function is one that calls itself, has a base case, addresses subproblems that are smaller in some sense, and does not address subproblems that overlap

Example (computing $n!$)

$$n! = \begin{cases} n(n-1)! & \text{if } n > 0\text{, and} \\ 1 & \text{if } n = 0 \end{cases}$$

```
private static int factorial(int n) {
    if (n == 0) {
        return 1;
    }
    return n * factorial(n - 1);
}
```

Call trace for `factorial(5)`

```
120
```

Program: `Factorial.java`

Program: `Factorial.java`

$\rightsquigarrow$ Command-line input: n (int)

Program: `Factorial.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: $n!$

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- ⇝ Command-line input: n (int)
- ⇝ Standard output: $n!$

```
>_ ~/workspace/dsa/programs

$ _
```

Program: `Factorial.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: $n!$

```
>_ ~/workspace/dsa/programs

$ java Factorial 0
```

Program: `Factorial.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: $n!$

```
>_ ~/workspace/dsa/programs

$ java Factorial 0
1
$ _
```

Program: `Factorial.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: $n!$

```
>_ ~/workspace/dsa/programs

$ java Factorial 0
1
$ java Factorial 5
```

Program: `Factorial.java`

- ⇝ Command-line input: n (int)
- ⇝ Standard output: $n!$

```
>_ ~/workspace/dsa/programs

$ java Factorial 0
1
$ java Factorial 5
120
$ _
```

Defining Functions · Recursive Functions

Factorial.java

```java
import stdlib.StdOut;

public class Factorial {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        StdOut.println(factorial(n));
    }

    private static int factorial(int n) {
        if (n == 0) {
            return 1;
        }
        return n * factorial(n - 1);
    }
}
```

Scope of Variables

Scope of Variables

The scope of a variable is the part of the program that can refer to that variable by name

Scope of Variables

The scope of a variable is the part of the program that can refer to that variable by name

Example

Harmonic.java

```java
1  import stdlib.StdOut;
2  
3  public class Harmonic {
4      public static void main(String[] args) {
5          int n = Integer.parseInt(args[0]);
6          double total = 0.0;
7          for (int i = 1; i <= n; i++) {
8              total += 1.0 / i;
9          }
10         StdOut.println(total);
11     }
12 }
```

Variable	Scope
`args`	lines 4 — 11
`n`	lines 5 — 11
`total`	lines 6 — 11
`args`	lines 7 — 9

Input and Output Revisited

Input and Output Revisited

stdlib.StdOut

`static void print(Object x)`	prints an object to standard output
`static void println(Object x)`	prints an object and a newline to standard output
`static void printf(String fmt, Object... args)`	prints `args` to standard output using the format string `fmt`

Input and Output Revisited

Input and Output Revisited

Program: `RandomSeq.java`

Input and Output Revisited

Program: `RandomSeq.java`

$\rightsquigarrow$ Command-line input: n (int), lo (double), hi (double)

Input and Output Revisited

Program: `RandomSeq.java`

- ⇝ Command-line input: n (int), lo (double), hi (double)
- ⇝ Standard output: n random doubles in the range $[lo, hi)$, each up to 2 decimal places

Input and Output Revisited

Program: `RandomSeq.java`

- ⇝ Command-line input: n (int), lo (double), hi (double)
- ⇝ Standard output: n random doubles in the range $[lo, hi)$, each up to 2 decimal places

```
>_ ~/workspace/dsa/programs

$ _
```

Input and Output Revisited

Program: `RandomSeq.java`

- ⇝ Command-line input: n (int), lo (double), hi (double)
- ⇝ Standard output: n random doubles in the range $[lo, hi)$, each up to 2 decimal places

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 10 100 200
```

Input and Output Revisited

Program: `RandomSeq.java`

- ⇝ Command-line input: n (int), lo (double), hi (double)
- ⇝ Standard output: n random doubles in the range $[lo, hi)$, each up to 2 decimal places

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 10 100 200
186.69
102.34
176.05
182.78
161.95
169.34
155.65
154.96
194.41
103.91
$ _
```

Input and Output Revisited

Input and Output Revisited

RandomSeq.java

```java
import stdlib.StdOut;
import stdlib.StdRandom;

public class RandomSeq {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        double lo = Double.parseDouble(args[1]);
        double hi = Double.parseDouble(args[2]);
        for (int i = 0; i < n; i++) {
            double r = StdRandom.uniform(lo, hi);
            StdOut.printf("%.2f\n", r);
        }
    }
}
```

Input and Output Revisited

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Standard input is input entered interactively on the terminal

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stdlib.StdIn

`static boolean isEmpty()`	returns `true` if standard input is empty, and `false` otherwise
`static double readDouble()`	reads and returns the next double from standard input

Input and Output Revisited

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Program: `Average.java`

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- ⇝ Standard input: a sequence of doubles

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- ⇝ Standard input: a sequence of doubles
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```
>_ ~/workspace/dsa/programs

$ _
```

Input and Output Revisited

Program: `Average.java`

- ⇝ Standard input: a sequence of doubles
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```
>_ ~/workspace/dsa/programs

$ java Average
```

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_
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Input and Output Revisited

Program: `Average.java`

- ⇝ Standard input: a sequence of doubles
- ⇝ Standard output: their average value

```
>_ ~/workspace/dsa/programs

$ java Average
1.0 5.0 6.0
```

Input and Output Revisited

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- ⇝ Standard input: a sequence of doubles
- ⇝ Standard output: their average value

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Input and Output Revisited

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```
>_ ~/workspace/dsa/programs

$ java Average
1.0 5.0 6.0
3.0 7.0 32.0
```

Input and Output Revisited

Program: `Average.java`

- ⇝ Standard input: a sequence of doubles
- ⇝ Standard output: their average value

```
>_ ~/workspace/dsa/programs

$ java Average
1.0 5.0 6.0
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_
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Input and Output Revisited

Program: `Average.java`

- ⇝ Standard input: a sequence of doubles
- ⇝ Standard output: their average value

```
>_ ~/workspace/dsa/programs

$ java Average
1.0 5.0 6.0
3.0 7.0 32.0
<ctrl-d>
```

Input and Output Revisited

Program: `Average.java`

- ⇝ Standard input: a sequence of doubles
- ⇝ Standard output: their average value

```
>_ ~/workspace/dsa/programs

$ java Average
1.0 5.0 6.0
3.0 7.0 32.0
<ctrl-d>
Average is 10.5
$ _
```

Input and Output Revisited

Input and Output Revisited

Average.java

```java
import stdlib.StdIn;
import stdlib.StdOut;

public class Average {
    public static void main(String[] args) {
        double total = 0.0;
        int count = 0;
        while (!StdIn.isEmpty()) {
            double x = StdIn.readDouble();
            total += x;
            count++;
        }
        double average = total / count;
        StdOut.println("Average is " + average);
    }
}
```

Input and Output Revisited

Input and Output Revisited

Output redirection operator (`>`)

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs
$ _
```

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
$ _
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
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Input redirection operator (<)

```
>_ ~/workspace/dsa/programs

$ _
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
$ _
```

Input redirection operator (<)

```
>_ ~/workspace/dsa/programs

$ java Average < data.txt
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
$ _
```

Input redirection operator (<)

```
>_ ~/workspace/dsa/programs

$ java Average < data.txt
Average is 149.1812199999999
$ _
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
$ _
```

Input redirection operator (<)

```
>_ ~/workspace/dsa/programs

$ java Average < data.txt
Average is 149.1812199999999
$ _
```

Piping operator (|)

```
>_ ~/workspace/dsa/programs

$ _
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
$ _
```

Input redirection operator (<)

```
>_ ~/workspace/dsa/programs

$ java Average < data.txt
Average is 149.1812199999999
$ _
```

Piping operator (|)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 | java Average
```

Input and Output Revisited

Output redirection operator (>)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 > data.txt
$ _
```

Input redirection operator (<)

```
>_ ~/workspace/dsa/programs

$ java Average < data.txt
Average is 149.1812199999999
$ _
```

Piping operator (|)

```
>_ ~/workspace/dsa/programs

$ java RandomSeq 1000 100.0 200.0 | java Average
Average is 150.0588699999999
$ _
```