Introduction

Let’s begin

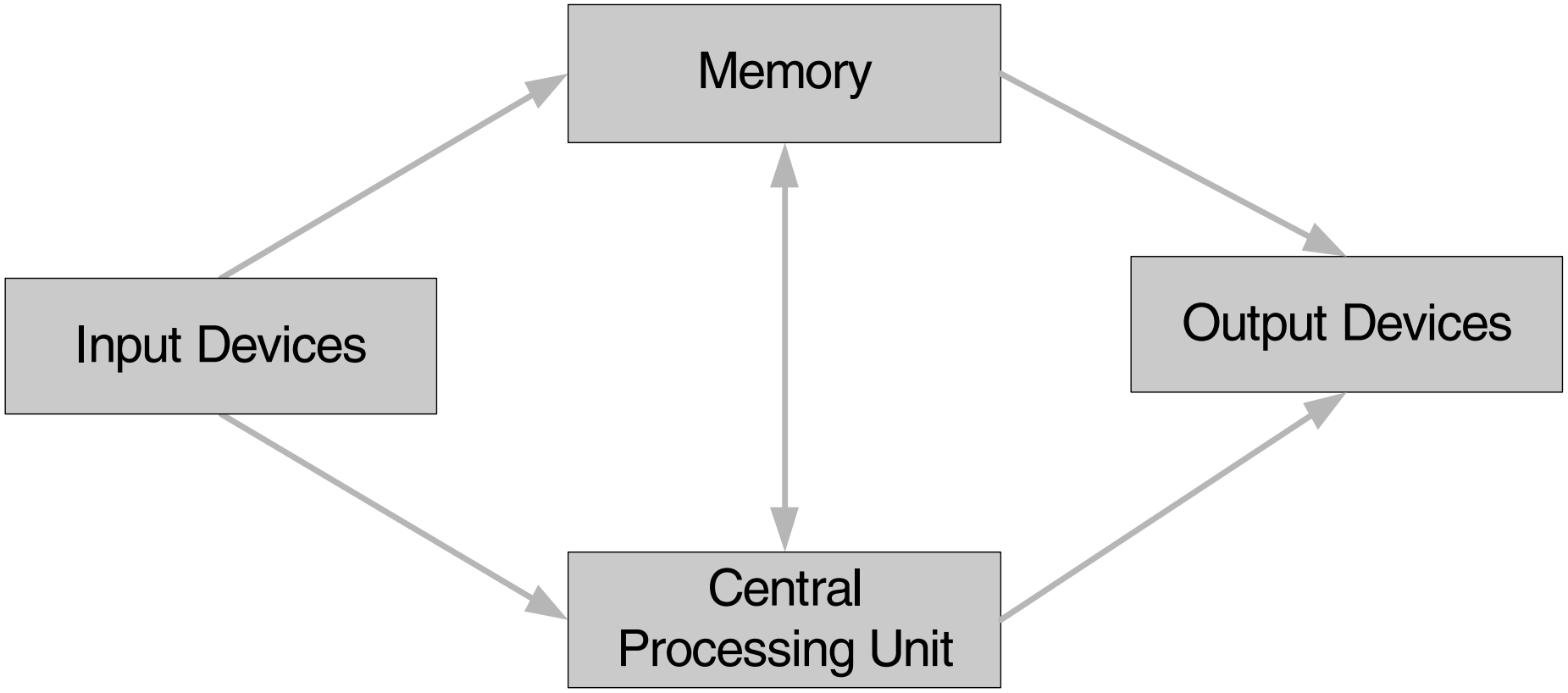
- Goal
  - Teach you how to program effectively

- Skills and information to be acquired
  - Mental model of computer and network behavior
  - Problem solving
  - Object-oriented design
  - Java

Computer Organization

- Computer advertisement specification
  - Intel® Pentium 4 Processor at 3.06GHz with 512K cache
  - 512MB DDR SDRAM
  - 200GB ATA-100 Hard Drive (7200 RPM, 9.0 ms seek time)
  - 17” LCD Monitor
  - 64MB NVIDIA GeForce4 MX Graphics Card®
  - 16x Max DVD-ROM Drive
  - 48x/24x/48x CD-RW Drive
  - 56K PCI Telephony Modem
  - Windows XP Home Edition SP2 ®
  - 10/100 Fast Ethernet Network Card

Computer Organization



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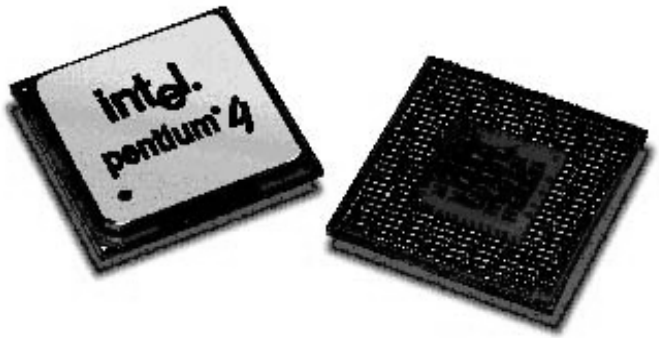

3.06 billion operations per second

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512 million bytes of memory that can be transferred at double the normal rate

A byte is 8 bits

A bit is a 0 or a 1

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Stores 200 billion bytes of data. You want high RPM and low seek time. 0.009 seconds is average

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17” on the diagonal. Resolution up to 1,280 by 1,024 pixels

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Microprocessor for displaying images with 64 million bytes of memory. More memory supports more colors and higher resolution

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Reads DVDs 16 times faster than a basic DVD drive. Can hold up to 8 billion bytes of data

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Can read and write CDs. Can hold 650 million bytes of data Reads at 48 times faster and writes 24 times faster than a basic drive

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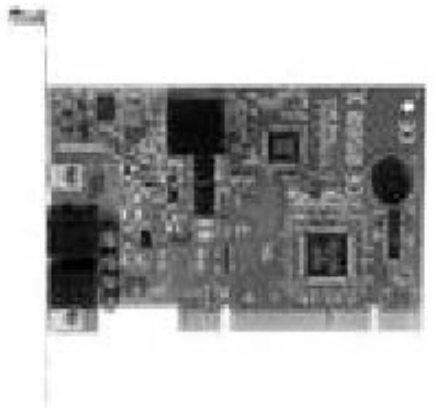

Can send or receive up to 56 thousand bits per second

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Computer operating system using a graphical interface

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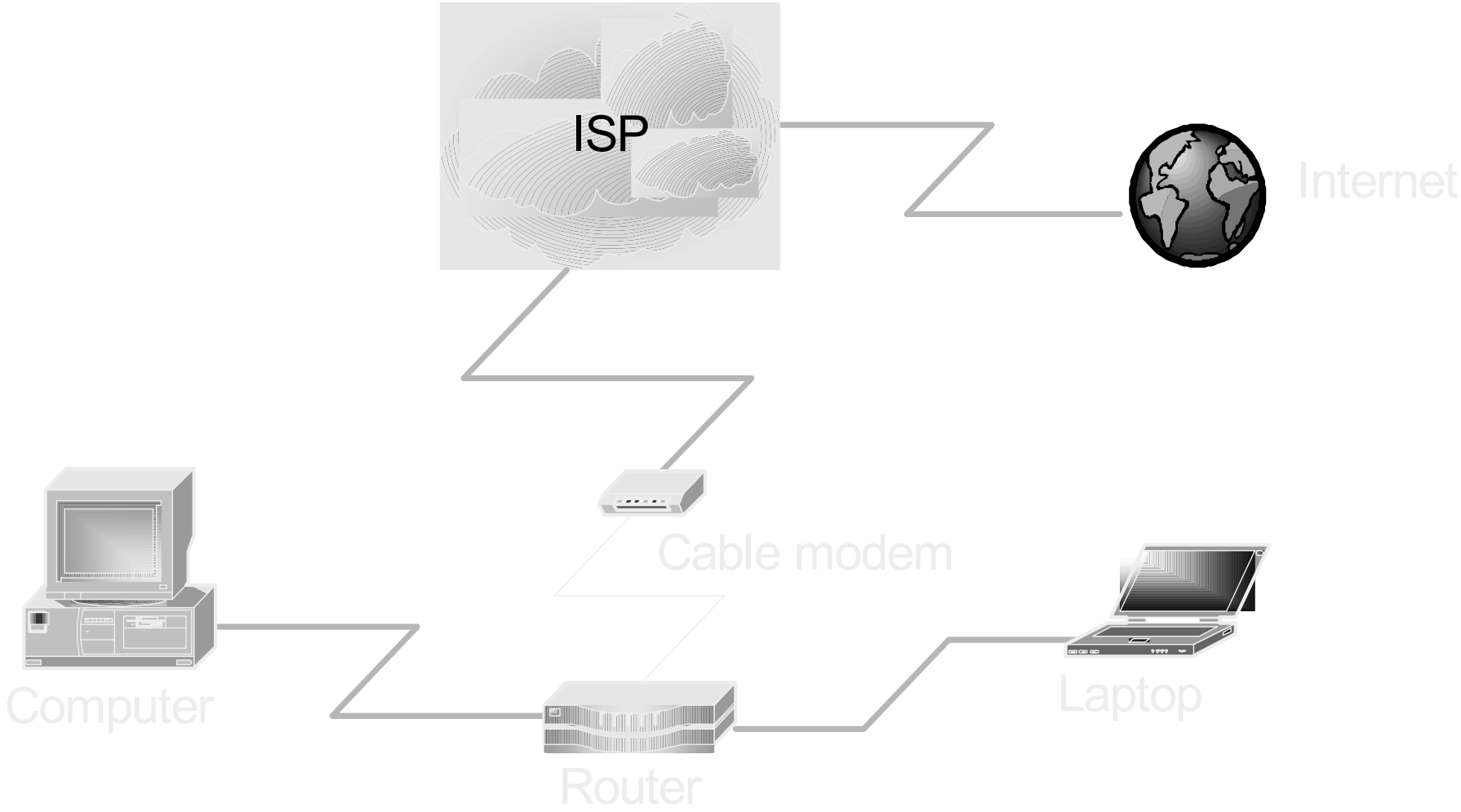
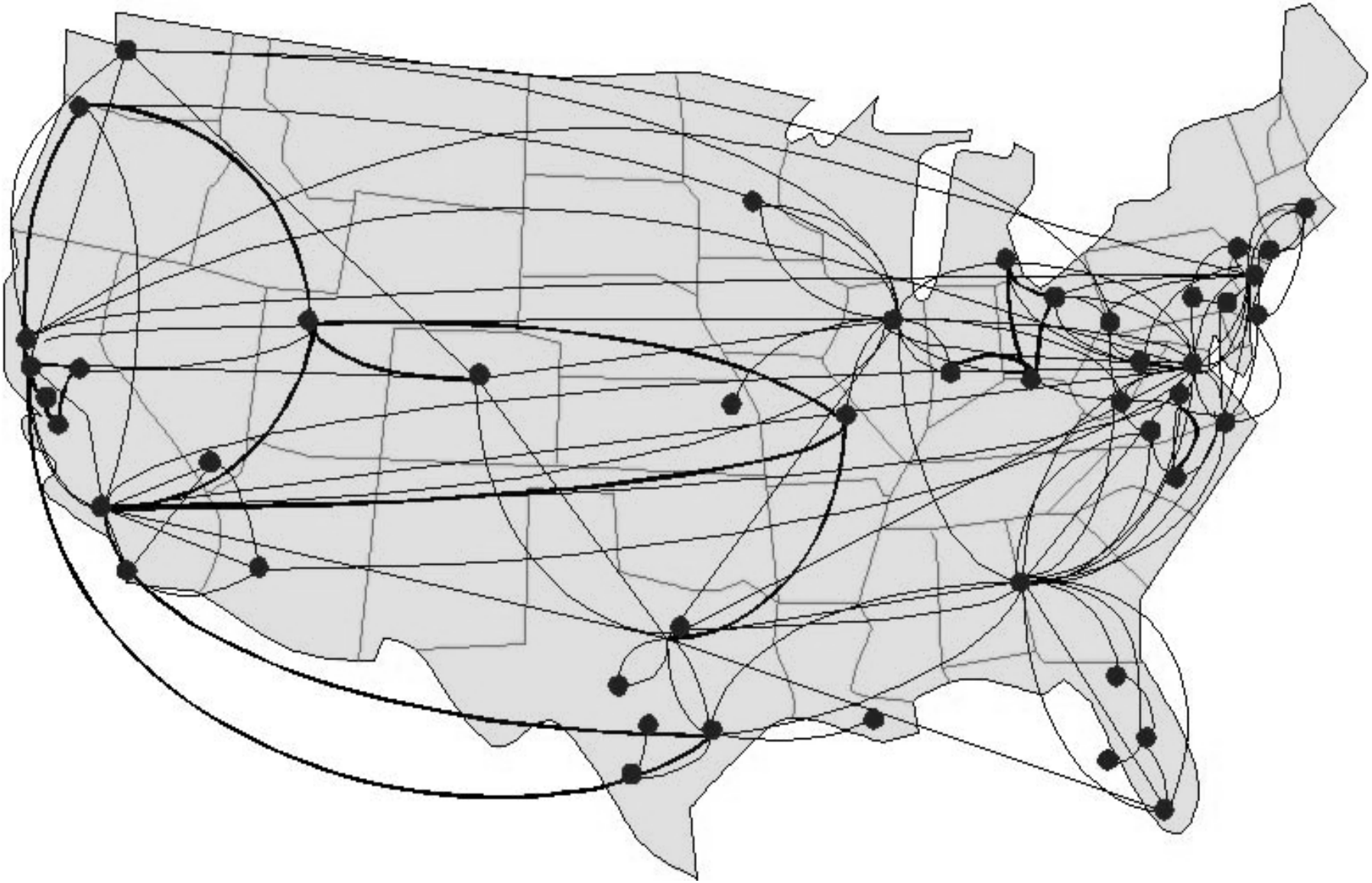
Can send or receive data at two rates – 10 or 100 million bytes per second

Home network



Backbones



Network communication

- Communication protocol
  - Set of rules that govern how data is sent and received

- TCP/IP
  - Exchanging packets of information over the Internet
- FTP
  - Exchanging files between computes
- SMTP
  - Exchanging email over the Internet
- POP
  - Exchanging email between mail reader and the ISP
- HTTP
  - Exchanging files over the WWW
- SSL
  - How information is to be encrypted

Software

- Program
  - Sequence of instruction that tells a computer what to do
- Execution
  - Performing the instruction sequence
- Programming language
  - Language for writing instructions to a computer
- Major flavors
  - Machine language or object code
  - Assembly language
  - High-level

Software

- Program
  - Sequence of instruction that tells a computer what to do
- Execution
  - Performing the instruction sequence
- Programming language
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Program to which computer can respond directly. Each instruction is a binary code that corresponds to a native instruction

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Symbolic language for coding machine language instructions

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Detailed knowledge of the machine is not required. Uses a vocabulary and structure closer to the problem being solved

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Java is a high-level programming language

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For program to be executed it must be translated

Translation

- Translator
  - Accepts a program written in a source language and translates it to a program in a target language
- Compiler
  - Standard name for a translator whose source language is a high-level language
- Interpreter
  - A translator that both translates and executes a source program

Java translation

- Two-step process

- First step
  - Translation from Java to bytecodes
    - Bytecodes are architecturally neutral object code
    - Bytecodes are stored in a file with extension .class

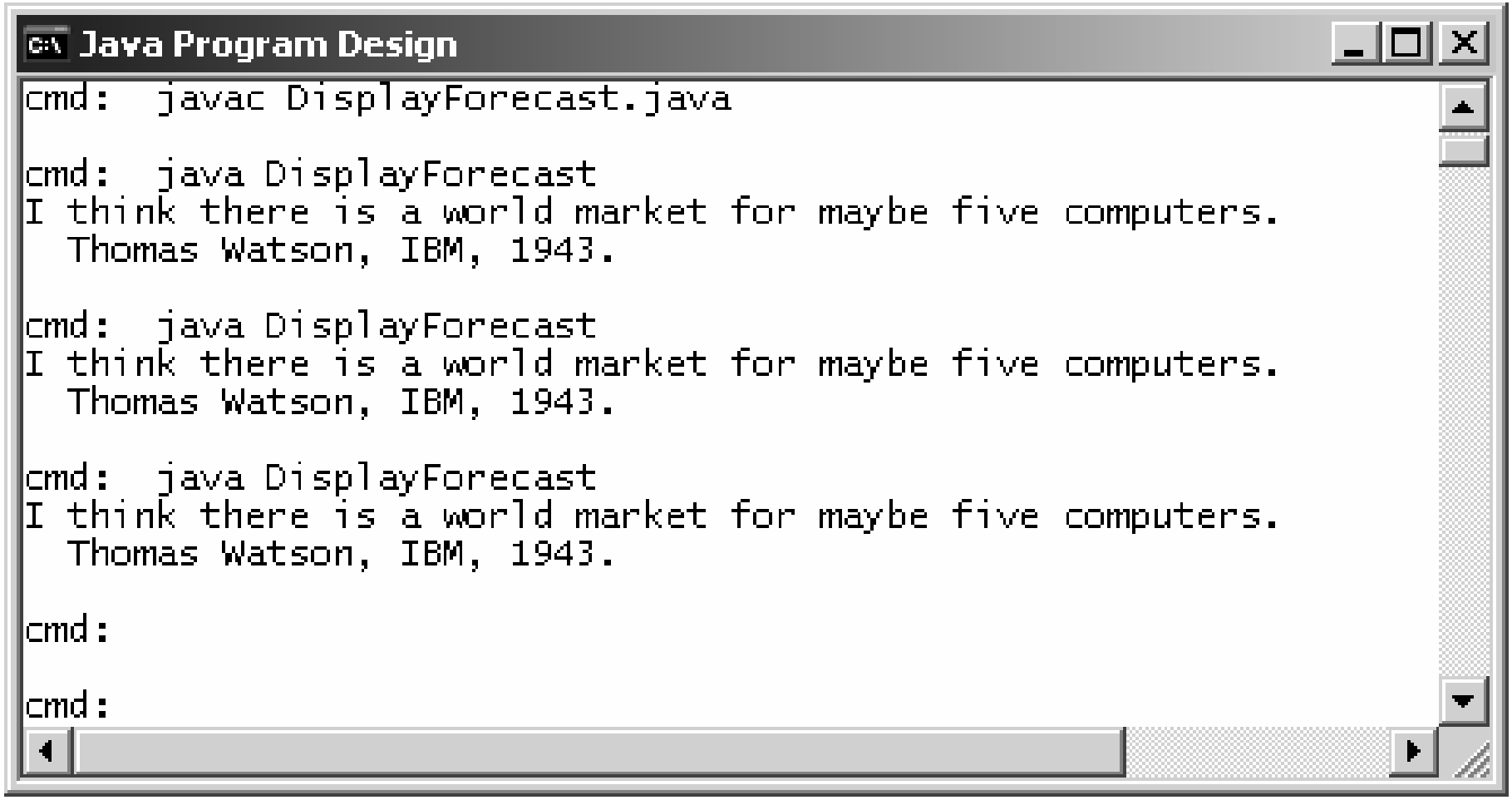
- Second step
  - An interpreter translates the bytecodes into machine instructions and executes them
    - Interpreter is known a Java Virtual Machine or JVM

Task

- Display the forecast

I think there is a world market for maybe five computers.
Thomas Watson, IBM, 1943.

Sample output



DisplayForecast.java

```
// Authors: J. P. Cohoon and J. W. Davidson
// Purpose: display a quotation in a console window

public class DisplayForecast {

  // method main(): application entry point
  public static void main(String[] args) {
     System.out.print("I think there is a world market for");
     System.out.println(" maybe five computers.");
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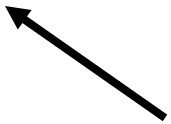

Three statements make up the action of method main()

Method main() is part of class DisplayForecast

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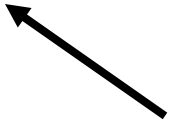

A method is a named piece of code that performs some action or implements a behavior

DisplayForecast.java

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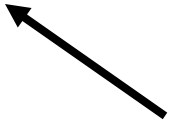
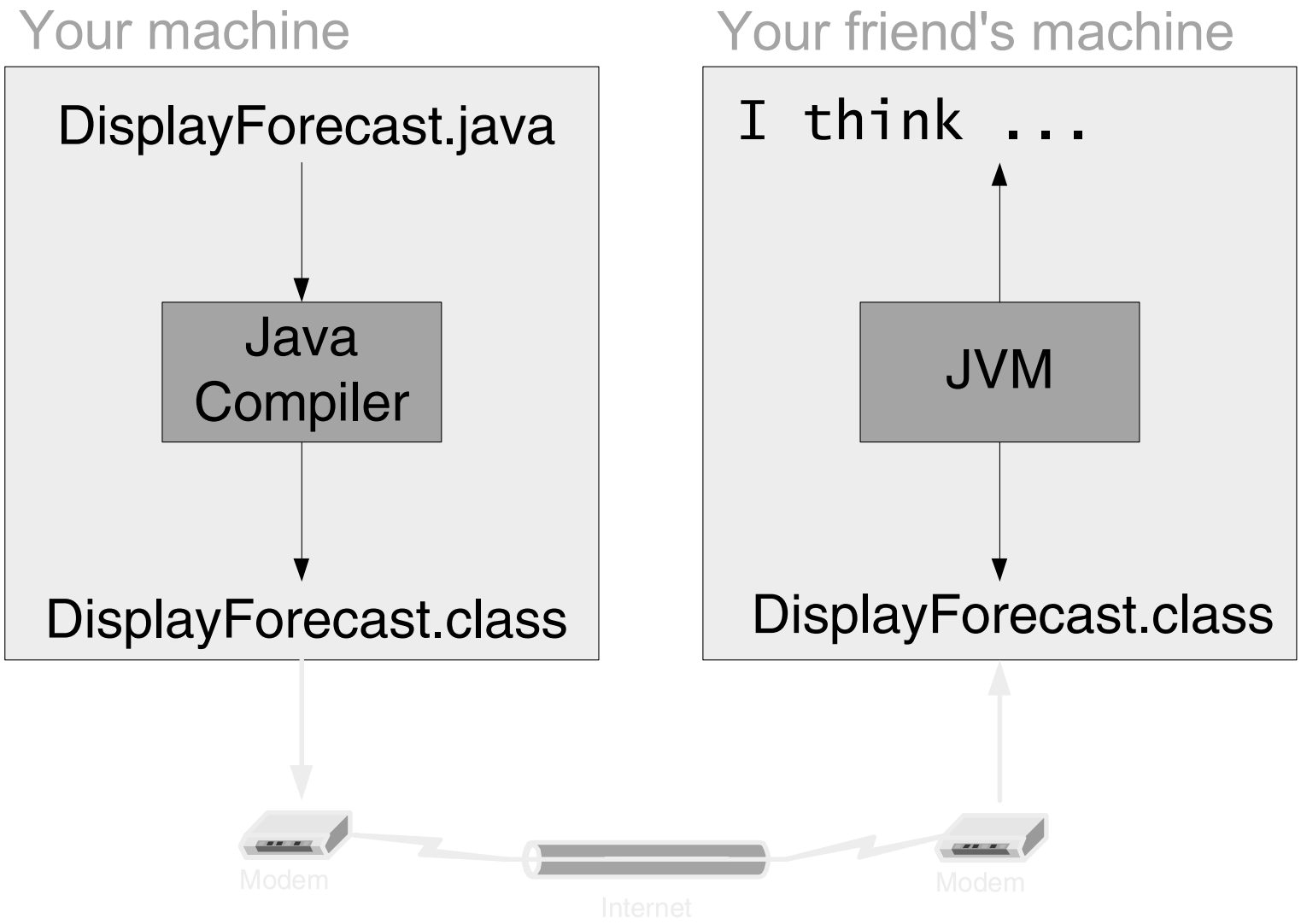


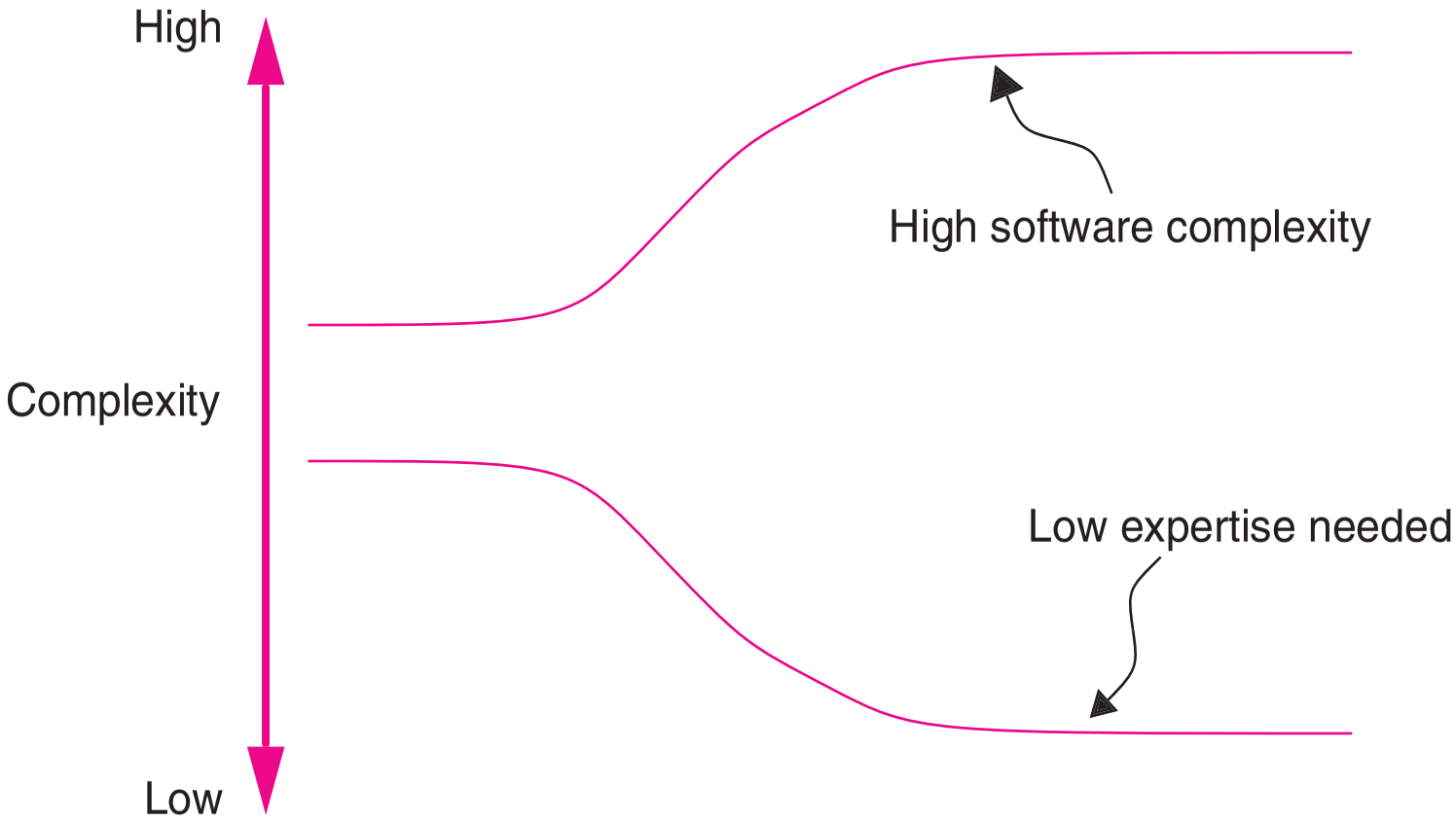
An application program is required to have a public static void method named main().

Java and the Internet



Engineering software

- Complexity of software grows as attempts are made to make it easier to use
  - Rise of wizards



Software engineering

- Goal
  - Production of software that is effective and reliable, understandable, cost effective, adaptable, and reusable

Software engineering

- Goal
  - Production of software that is effective and reliable, understandable, cost effective, adaptable, and reusable
    - Work correctly and not fail

Software engineering

- Goal
  - Production of software that is effective and reliable, understandable, cost effective, adaptable, and reusable

    - Because of the long lifetime many people will be involved
      - Creation
      - Debugging
      - Maintenance
      - Enhancement
    - Two-thirds of the cost is typically beyond creation

Software engineering

- Goal
  - Production of software that is effective and reliable, understandable, cost effective, adaptable, and reusable

    - Cost to develop and maintain should not exceed expected benefit

Software engineering

- Goal
  - Production of software that is effective and reliable, understandable, cost effective, adaptable, and reusable

    - Design software so that new features and capabilities can be added

Software engineering

- Goal
  - Production of software that is effective and reliable, understandable, cost effective, adaptable, and reusable

    - Makes sense due to the great costs involved to have flexible components that can be used in other software

Principles

- Abstraction
- Encapsulation
- Modularity
- Hierarchy

Principles

- Abstraction
- Encapsulation
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- Hierarchy

Determine the relevant properties and features while ignoring nonessential details

Principles

- Abstraction
- Encapsulation
- Modularity
- Hierarchy

Separate components into external and internal aspects

Principles

- Abstraction
- Encapsulation
- Modularity
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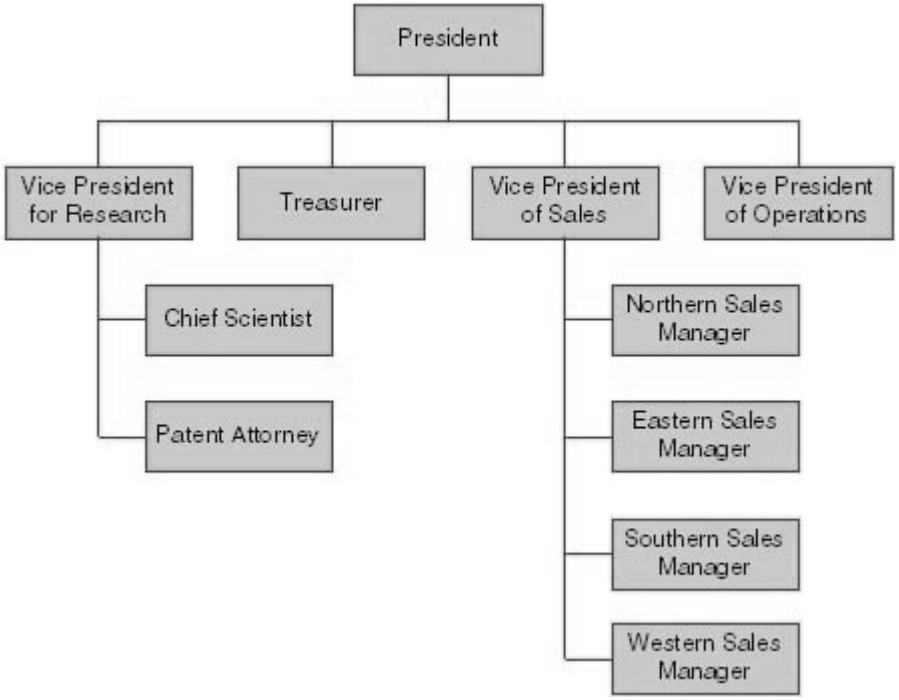
Construct a system from components and packages

Principles

- Abstraction
- Encapsulation
- Modularity
- Hierarchy

Ranking or ordering of objects



Object-oriented design

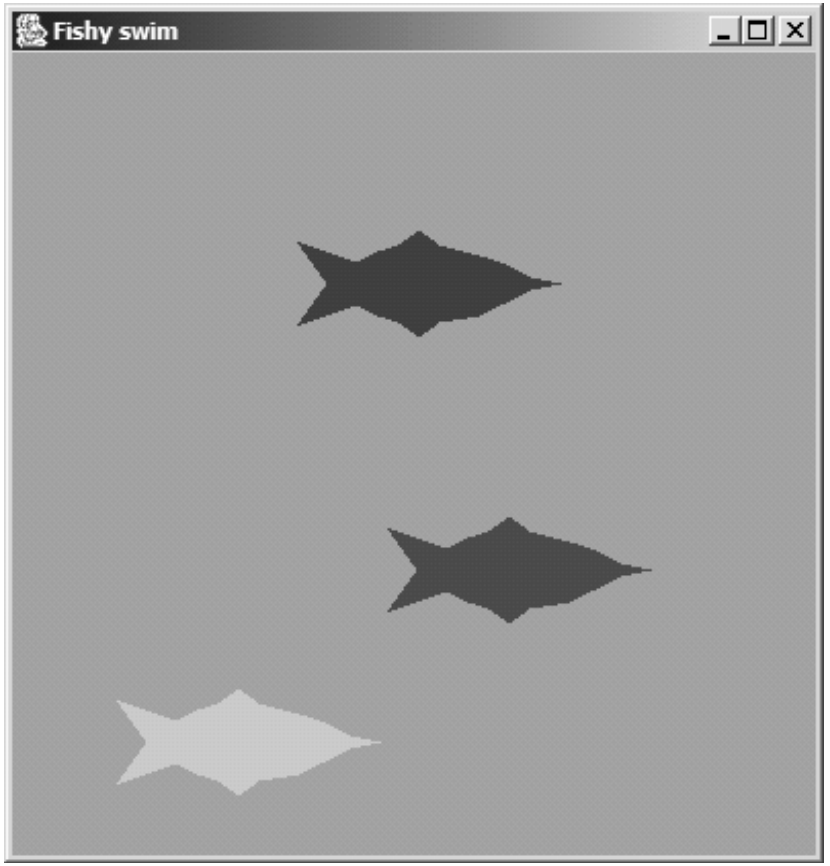
- Purpose
  - Promote thinking about software in a way that models the way we think and interact with the physical word
    - Including specialization

- Object
  - Properties or attributes
  - Behaviors

Programming

- Class
  - Term for a type of software object

- Object
  - An instance of a class with
  - specific properties and attributes



Programming

- Problem solving through the use of a computer system

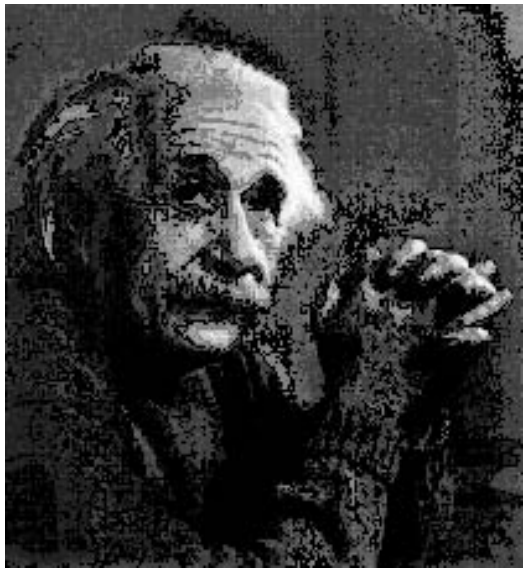
- Maxim
  - You cannot make a computer do something if you do not know how to do it yourself

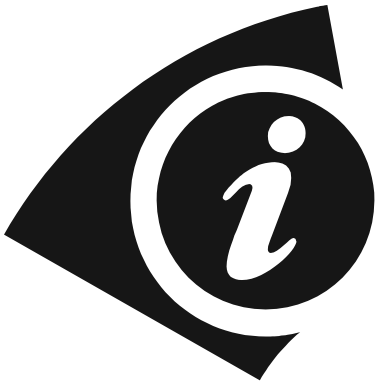
Problem Solving

- Why do you care?
  - We are all assigned tasks to do
    - At work
    - At home
    - At school
    - Why not do them
      - Right
      - Efficiently

Problem Solving

- Why care about computer-based problem solving (i.e., programming)?
  - Neat
  - Frontier of science
  - Profitable
  - Necessary
  - Quality of life





Problem Solving

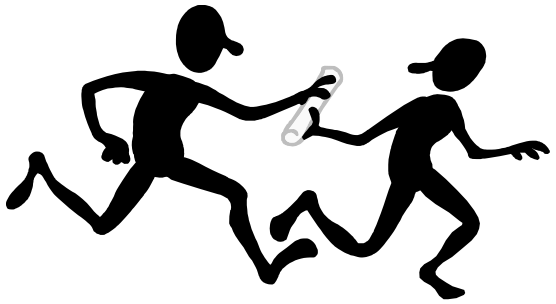
- Remember
  - The goal is not a clever solution but a correct solution

Problem Solving

- Accept
  - The process is iterative
    - In solving the problem increased understanding might require restarting

Problem Solving

- Solutions
  - Often require both concrete and abstract thinking
    - Teamwork



Problem Solving Process

- What is it?

Problem Solving Process

- What is it?
  - Analysis
  - Design
  - Implementation
  - Testing

Problem Solving Process

- What is it?
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  - Design
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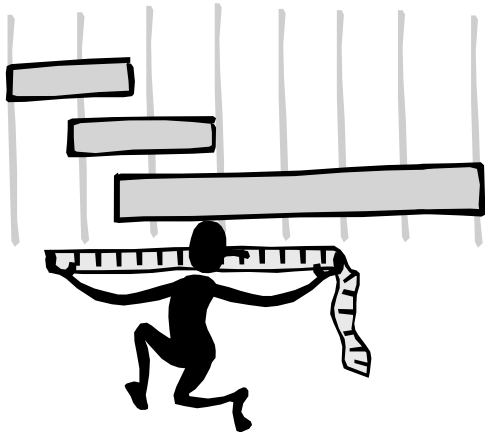
Determine the inputs, outputs, and other components of the problem

Description should be sufficiently specific to allow you to solve the problem

Problem Solving Process

- What is it?
  - Analysis
  - Design
  - Implementation
  - Testing



Describe the components and associated processes for solving the problem

Straightforward and flexible

Method – process

Object – component and associated methods

Problem Solving Process

- What is it?
  - Analysis
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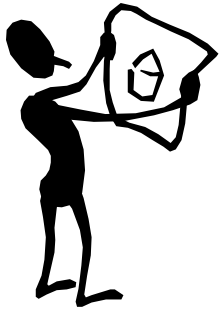

Develop solutions for the components and use those components to produce an overall solution

Straightforward and flexible

Problem Solving Process

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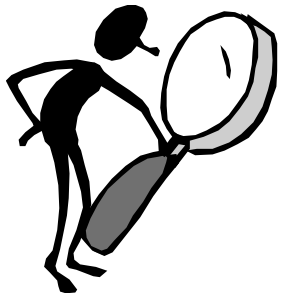
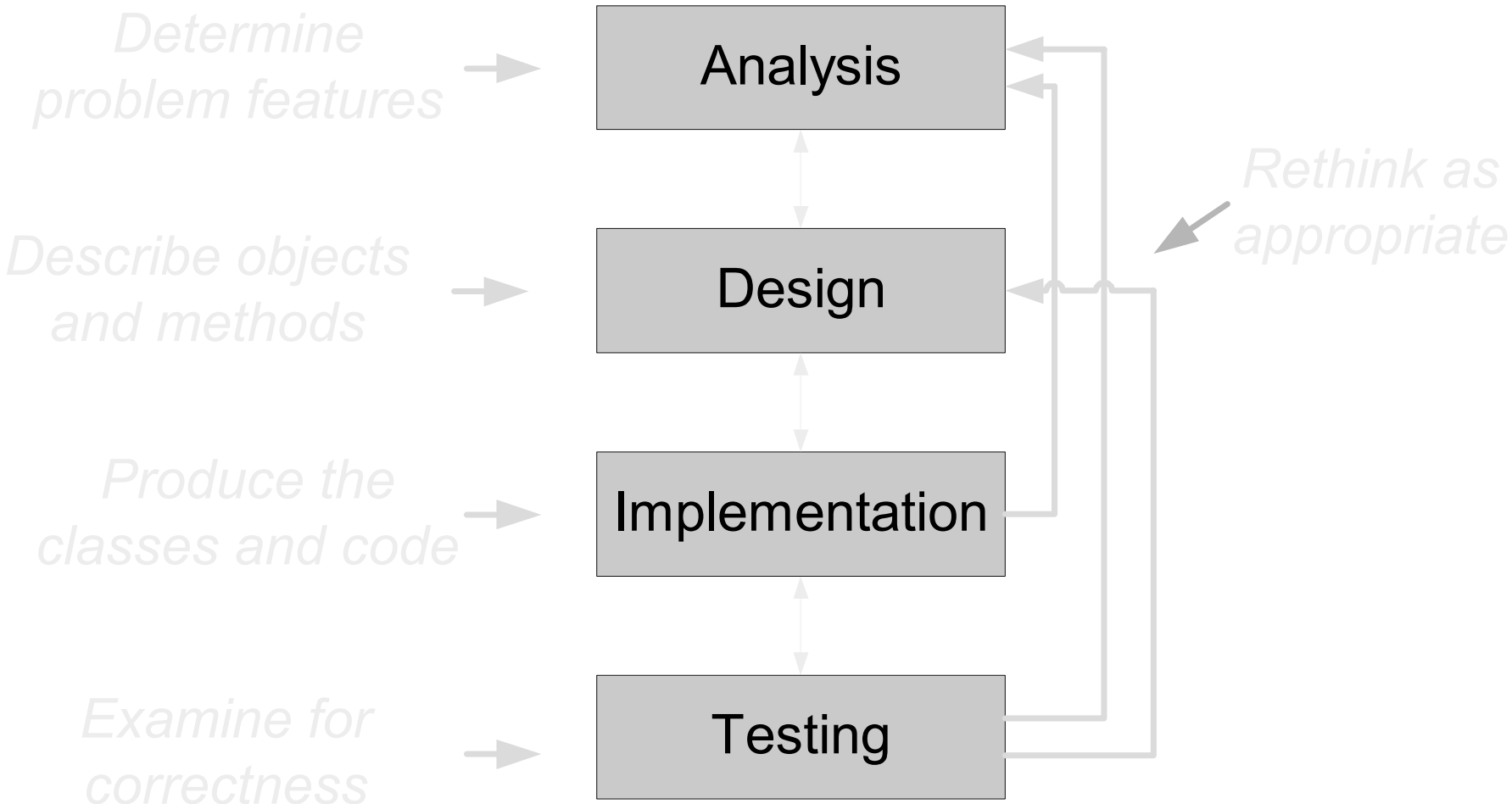
  - Analysis
  - Design
  - Implementation
  - Testing



Test the components individually and collectively

Problem Solving Process



Problem Solving Methodologies

- How to do it?
  - Depends upon your mode of thinking
- Bricolage approach
- Planned approach

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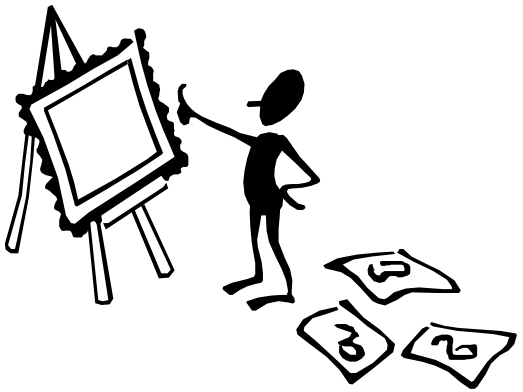

Problem features and aspects are repeatedly tried and manipulated according to your *personal* way of organizing information

A mistake is not an error, but a correction waiting to be made in the natural course of solving the problem

Problem Solving Methodologies

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  - Depends upon your mode of thinking
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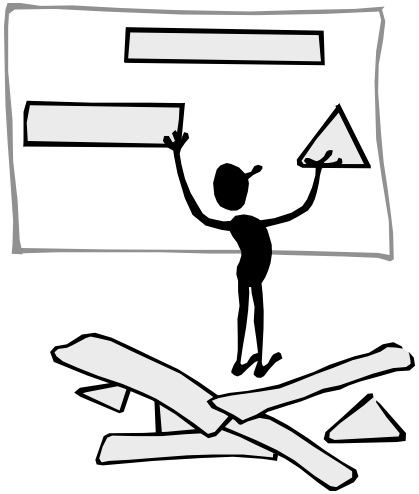
- Planned approach



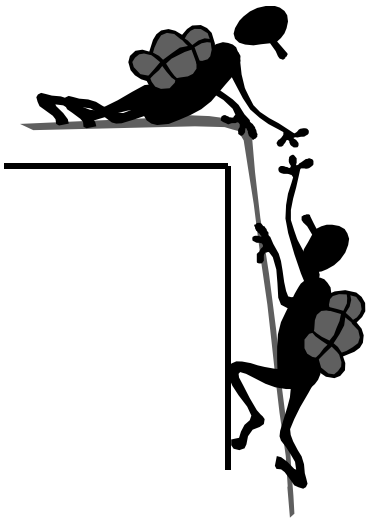
Uses logic, formalism, and engineering coupled with a structured methodology

Inherent structure of the planned approach offers makes it easier to show correctness of solution

Dominant method in terms of teaching

Tips

- Find out as much as you can
- Reuse what has been done before
- Expect future reuse
- Break complex problems into subproblems



Tips

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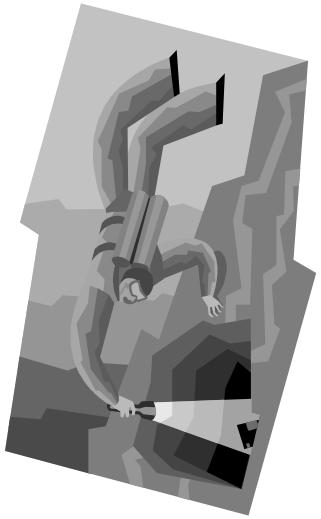


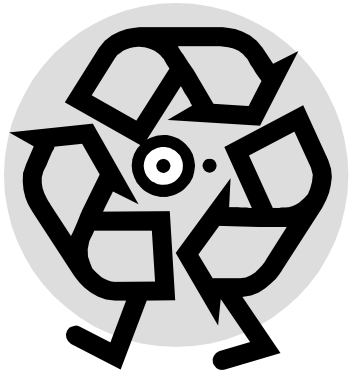
Find out what is known about the problem

Talk to the presenter

Determine what attempts have succeeded and what attempts have failed

Tips

- Find out as much as you can
- Reuse what has been done before
- Expect future reuse
- Break complex problems into subproblems



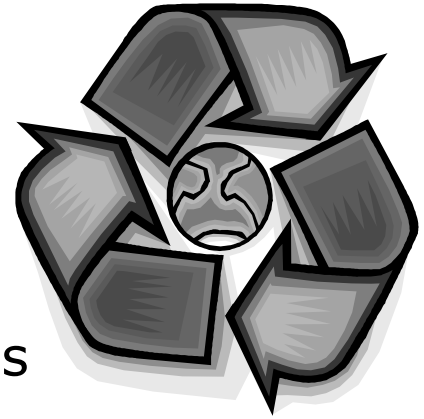
Research can require significant time and generate questions

The effort is worthwhile because the result is a better understanding

True understanding of the problem makes it easier to solve

Tips

- Find out as much as you can
- Reuse what has been done before
- Expect future reuse
- Break complex problems into subproblems

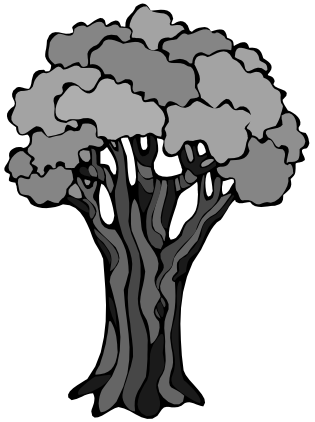


Consider

Sketching a solution and then repeatedly refine its components until the entire process is specified

Tips

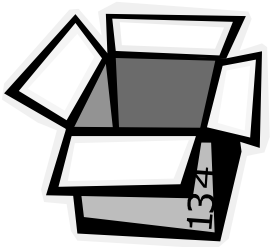
- Find out as much as you can
- Reuse what has been done before
- Expect future reuse
- Break complex problems into subproblems



Your time is valuable

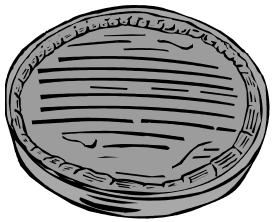
Correctness is probably even more valuable

Use existing infrastructure that is known to work

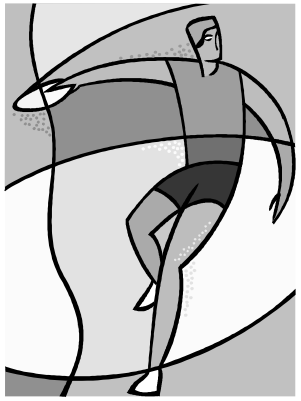


Tips

- Find out as much as you can
- Reuse what has been done before
- Expect future reuse
- Break complex problems into subproblems



Be open to *indirect* use of existing materials



Tips

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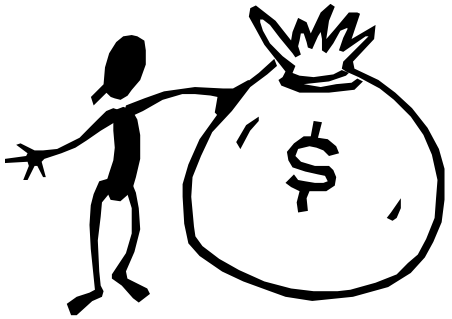
- Break complex problems into subproblems



Make as few assumptions as necessary

Maximizes the likelihood that your effort can be used in future situations

Tips

- Find out as much as you can
- Reuse what has been done before
- Expect future reuse
- Break complex problems into subproblems

Divide-and-conquer

Solve subproblems and combine into an overall solution

Java basics

Programming

- Problem solving through the use of a computer system

- Maxim
  - You cannot make a computer do something if you do not know how to do it yourself

Software

- Program
  - Sequence of instruction that tells a computer what to do
- Execution
  - Performing the instruction sequence
- Programming language
  - Language for writing instructions to a computer
- Major flavors
  - Machine language or object code
  - Assembly language
  - High-level

Program to which computer can respond directly. Each instruction is a binary code that corresponds to a native instruction

Software

- Program
  - Sequence of instruction that tells a computer what to do
- Execution
  - Performing the instruction sequence
- Programming language
  - Language for writing instructions to a computer
- Major flavors
  - Machine language or object code
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  - High-level

Symbolic language for coding machine language instructions

Software

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- Execution
  - Performing the instruction sequence
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Detailed knowledge of the machine is not required. Uses a vocabulary and structure closer to the problem being solved

Software

- Program
  - Sequence of instruction that tells a computer what to do
- Execution
  - Performing the instruction sequence
- Programming language
  - Language for writing instructions to a computer
- Major flavors
  - Machine language or object code
  - Assembly language
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Java is a high-level programming language

Software

- Program
  - Sequence of instruction that tells a computer what to do
- Execution
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- Programming language
  - Language for writing instructions to a computer
- Major flavors
  - Machine language or object code
  - Assembly language
  - High-level

For program to be executed it must be translated

Translation

- Translator
  - Accepts a program written in a source language and translates it to a program in a target language
- Compiler
  - Standard name for a translator whose source language is a high-level language
- Interpreter
  - A translator that both translates and executes a source program

Java translation

- Two-step process

- First step
  - Translation from Java to bytecodes
    - Bytecodes are architecturally neutral object code
    - Bytecodes are stored in a file with extension .class

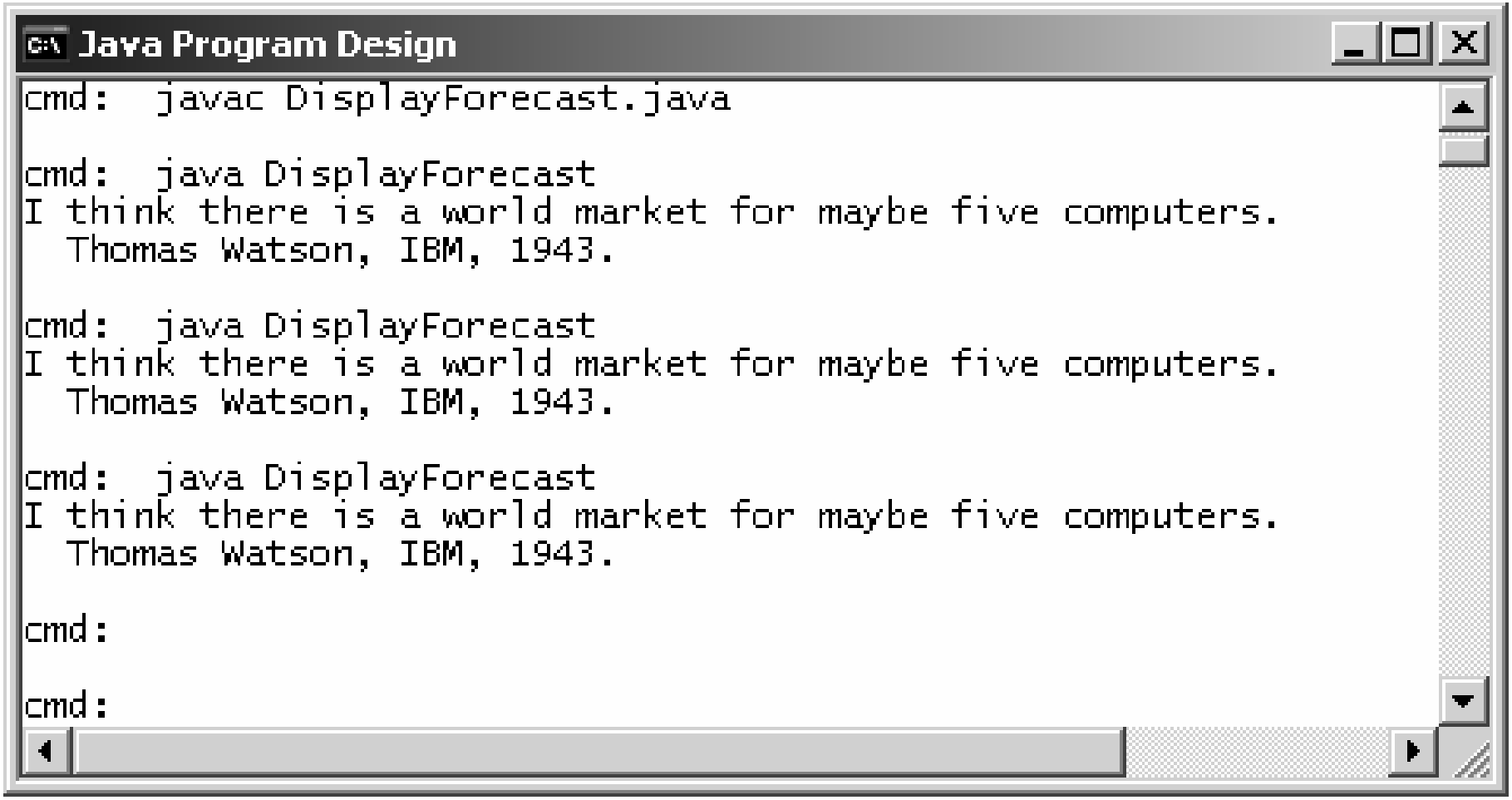
- Second step
  - An interpreter translates the bytecodes into machine instructions and executes them
    - Interpreter is known a Java Virtual Machine or JVM

Task

- Display the supposed forecast

  I think there is a world market for maybe five computers.
  Thomas Watson, IBM, 1943.

Sample output



DisplayForecast.java

```
// Authors: J. P. Cohoon and J. W. Davidson
// Purpose: display a quotation in a console window

public class DisplayForecast {

  // method main(): application entry point
  public static void main(String[] args) {
     System.out.print("I think there is a world market for");
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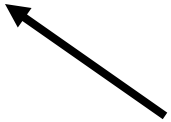

Three *statements* make up the action of method main()

Method main() is part of class DisplayForecast

DisplayForecast.java

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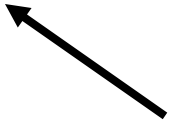

A *method* is a named piece of code that performs some action or implements a behavior

DisplayForecast.java

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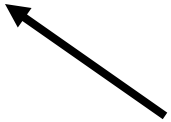

An *application program* is required to have a public static void method named main().

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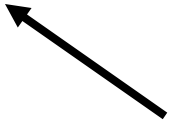

public, static, and void are *keywords*. They cannot be used as names

public means the method is shareable

DisplayForecast.java

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     System.out.print("I think there is a world market for");
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   }
}
```

Consider static and void later

DisplayForecast.java

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     System.out.println("   Thomas Watson, IBM, 1943.");
   }
}
```

Java allows a statement to be made up of multiple lines of text

Semicolons *delimit* one statement from the next

DisplayForecast.java

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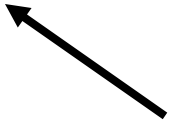

A *class* defines an *object* form. An object can have *methods* and *attributes*

Keyword class indicates a class definition follows

DisplayForecast.java

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   }
}
```

The class has a name

DisplayForecast.java

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     System.out.println("   Thomas Watson, IBM, 1943.");
   }
}
```

Programs are read by people – make sure they are readable.

Use whitespace, comments, and indentation to aid understanding

DisplayForecast.java

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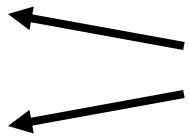

Whitespace

Whitespace separates program elements

Whitespace between program elements is ignored by Java

DisplayForecast.java

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     System.out.println(" maybe five computers.");
     System.out.println("   Thomas Watson, IBM, 1943.");
   }
}
```

Three comments

// indicates rest of the line is a comment

Comments are used to document authors, purpose, and program elements

Indentation

```
// Authors: J. P. Cohoon and J. W. Davidson
// Purpose: display a quotation in a console window

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  // method main(): application entry point
  public static void main(String[] args) {
     System.out.print("I think there is a world market for");
     System.out.println(" maybe five computers.");
     System.out.println("   Thomas Watson, IBM, 1943.");
   }
}
```

Method main() is part of DisplayForecast

Statements are part of method main()

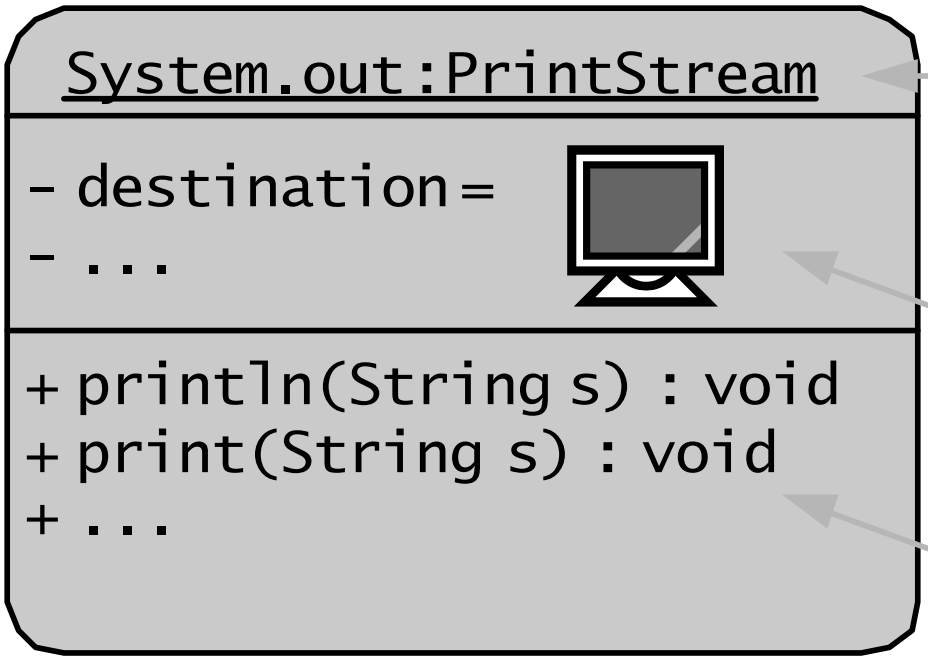
Indentation indicates subcomponents

Method main()

```
public static void main(String[] args) {
   System.out.print("I think there is a world market for");
   System.out.println(" maybe five computers.");
   System.out.println("   Thomas Watson, IBM, 1943.");
}
```

- Class System supplies objects that can print and read values
- System variable out references the standard printing object
  - Known as the standard output stream
- Variable out provides access to printing methods
  - print(): displays a value
  - println(): displays a value and moves cursor to the next line

System.out



Variable System.out gives access to an output stream of type PrintStream

The printing destination attribute for this PrintStream object is the console window

The behaviors of a PrintStream object support a high-level view of printing

Selection

The period indicates that we want to select an individual class member of System

The per
want to
clas

Method main()

```
public static void main(String[] args) {
   System.out.print("I think there is a world market for");
   System.out.println(" maybe five computers.");
   System.out.println("   Thomas Watson, IBM, 1943.");
}
```

- Method print() and println() both take a string parameter
  - The parameter specifies the value that is to be used in the invocation

Method main()

```
public static void main(String[] args) {
   System.out.print("I think there is a world market for");
   System.out.println(" maybe five computers.");
   System.out.println("   Thomas Watson, IBM, 1943.");
}
```

- The print() statement starts the program output

I think there is a world market for

Method main()

```
public static void main(String[] args) {
   System.out.print("I think there is a world market for");
   System.out.println(" maybe five computers.");
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}
```

- The first println() statement completes the first line of output

I think there is a world market for maybe five computers

Method main()

```
public static void main(String[] args) {
   System.out.print("I think there is a world market for");
   System.out.println(" maybe five computers.");
   System.out.println("   Thomas Watson, IBM, 1943.");
}
```

- The second println() statement starts and completes the second line of output

I think there is a world market for maybe five computers
  Thomas Watson, IBM, 1943

Experiment

```
public static void main(String[] args) {
   System.out.print("The real problem is not whether ");
    System.out.print("machines think but whether people ");
   System.out.println("do");
   System.out.println(“-- B.F. Skinner (paraphrased)");
}
```

- What does this method main() output?

Computation

- Programmers frequently write small programs for computing useful things

- Example – body mass index (BMI)
  - Measure of fitness
    - Ratio of person's weight to the square of the person's height
      - Weight in is kilograms, height is in meters
    - Person of interest is 4.5 feet and weighs 75.5 pounds

- Metric conversions
  - Kilograms per pound 0.454
  - Meters per foot 0.3046

Common program elements

- Type
  - Set of values along with operators that can manipulate and create values from the set
- Primitive types support numeric, character, logical values
  - double and float
    - Values with decimals
  - byte, short, int, long
    - Integers
  - char
    - Characters (considered numeric)
  - boolean
    - Logical values
- Basic operators
  - + addition - subtraction
  - * multiplication / division

Common program elements

- Constant
  - Symbolic name for memory location whose value does not change
    - KILOGRAMS_PER_POUND

- Variable
  - Symbolic name for memory location whose value can change
    - weightInPounds

Program outline for BMI.java

```
// Purpose: Compute BMI for given weight and height

public class BMI {

   // main(): application entry point
   public static void main(String[] args) {
      // define constants

      // set up person's characteristics

      // convert to metric equivalents

      // perform bmi calculation

      // display result
   }
}
```

```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;

   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
       KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

```
public static void main(String[] args) {
   // define constants
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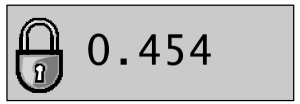

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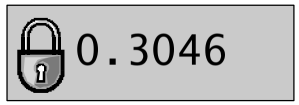


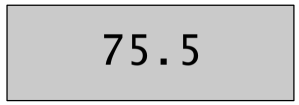
```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;

   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
       KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```



```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;

   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
       KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

heightInFeet | 4.5

```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;

   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
       KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

metricWeight | 34.2770

```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;

   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
       KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

metricHeight | 1.3706

```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;

   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
                         KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

bmi | 18.2439

```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;
                    Operator evaluation depend upon its operands
   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
                         KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

```
public static void main(String[] args) {
   // define constants
   final double KILOGRAMS_PER_POUND = 0.454;
   final double METERS_PER_FOOT = 0.3046;
                                                  Math.round(bmi) is 18
   // set up person's characteristics
   double weightInPounds = 75.5;  // our person's weight
   double heightInFeet = 4.5;     // our person's height

   // convert to metric equivalents
   double metricWeight = weightInPounds *
                         KILOGRAMS_PER_POUND;
   double metricHeight = heightInFeet * METERS_PER_FOOT;

   // perform bmi calculation
   double bmi = metricWeight / (metricHeight * metricHeight);

   // display result
   System.out.println("A person with");
   System.out.println("  weight " + weightInPounds + " lbs");
   System.out.println("  height " + heightInFeet + " feet");
   System.out.println("has a BMI of " + Math.round(bmi));
}
```

```
// Purpose: Convert a Celsius temperature to Fahrenheit

public class CelsiusToFahrenheit {

    // main(): application entry point
    public static void main(String[] args) {
        // set Celsius temperature of interest
        int celsius = 28;

       // convert to Fahrenheit equivalent
       int fahrenheit = 32 + ((9 * celsius) / 5);

       // display result
       System.out.println("Celsius temperature");
       System.out.println("   " + celsius);
       System.out.println("equals Fahrenheit temperature");
       System.out.println("   " + fahrenheit);
    }
}
```

```
// Purpose: Demonstrate char arithmetic

public class LowerToUpper {

    // main(): application entry point
    public static void main(String[] args) {
        // set lower case character of interest
        char lowerCaseLetter = 'c';

        // convert to uppercase equivalent
        char upperCaseLetter = 'A' + (lowerCaseLetter - 'a');

        // display result
        System.out.println("Uppercase equivalent of");
        System.out.println("   " + lowerCaseLetter);
        System.out.println("is");
        System.out.println("   " + upperCaseLetter);
    }
}
```

Expressions

- What is the value used to initialize expression

```
int expression = 4 + 2 * 5;
```

- What value is displayed

```
System.out.println(5 / 2.0);
```

- Java rules in a nutshell
  - Each operator has a precedence level and an associativity
    - Operators with higher precedence are done first
      - * and / have higher precedence than + and -
    - Associativity indicates how to handle ties
  - When floating-point is used the result is floating point

Question

- Does the following statement compute the average of double variables a, b, and c? Why

```
double average = a + b + c / 3.0;
```

Interactive programs

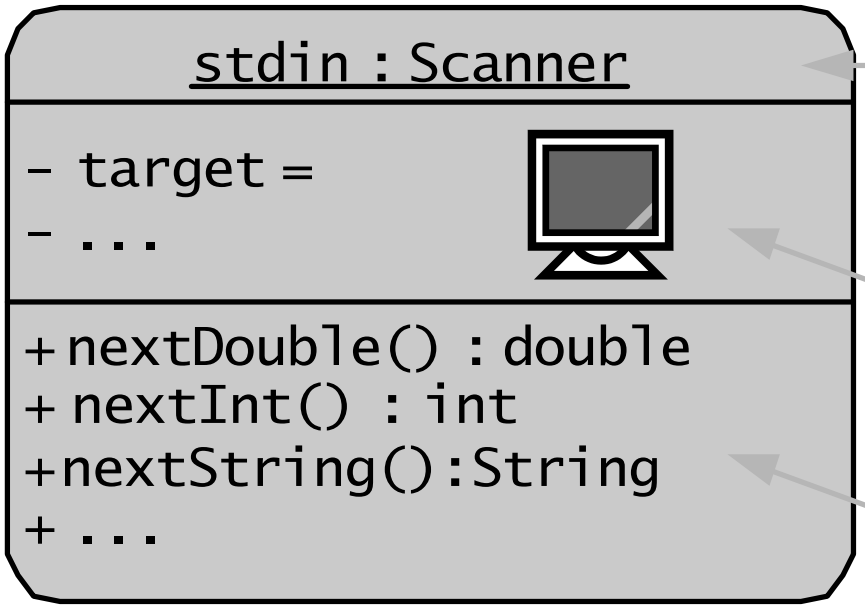
- Programs that interact with their users through statements performing input and output

- BMI.java
  - Not interactive – weight and height are fixed

Support for interactive console programs

- Variable System.in
  - Associated with the standard input stream – the keyboard
- Class Scanner
  - Supports extraction of an input as a numbers, characters, and strings

```
Scanner stdin = new Scanner(System.in);
```



Variable stdin gives access to an input stream that supports the extraction (reading) of input as values

The input destination attribute for this Scanner object is stream associated with standard input — System.in

The behaviors of a Scanner object support a high-level view of extracting values

Accessing the standard input stream

- Set up

```
Scanner stdin = new Scanner(System.in);
```

A new operation constructs a new object. The value of the operation is a reference to the new object. This new operation constructs a Scanner object out of a object representing the standard input stream

Interactive program for bmi

- Program outline

```
// Purpose: Compute BMI for user-specified
// weight and height

import java.util.*;

public class BMICalculator {

   // main(): application entry point
   public static void main(String[] args) {
       // defining constants
       // displaying legend
       // set up input stream
       // get person's characteristics
       // convert to metric equivalents
       // perform bmi calculation
       // display result
   }
}
```

```
public static void main(String[] args) throws IOException {
    final double KILOGRAMS_PER_POUND = 0.454;
    final double METERS_PER_FOOT = 0.3046;

    System.out.println("BMI Calculator\n");

    Scanner stdin = new Scanner(System.in);

    System.out.print("Enter weight (lbs): ");
    double weight = stdin.nextDouble();

    System.out.print("Enter height (feet): ");
    double height = stdin.nextDouble());

    double metricWeight = weight * KILOGRAMS_PER_POUND;
    double metricHeight = height * METERS_PER_FOOT;

    double bmi = metricWeight / (metricHeight * metricHeight);

    System.out.println("A person with");
    System.out.println("    weight " + weight + " (lbs)");
    System.out.println("    height " + height + " (feet)");
    System.out.println("has a BMI of " + bmi);
}
```

Accessing the standard input stream

- Extraction

```
System.out.print("Enter weight (lbs): ");
double weight = stdin.nextDouble();

System.out.print("Enter height (feet): ");
double height = stdin.nextDouble();
```

Primitive variable assignment

- Assignment operator =
  - Allows the memory location for a variable to be updated

```
target = expression;
```

Name of previously defined object

Expression to be evaluated

- Consider

```
int j = 11;
j = 1985;
```

Primitive variable assignment

- Assignment operator =
  - Allows the memory location for a variable to be updated

```
target = expression;
```

Name of previously defined object

Expression to be evaluated

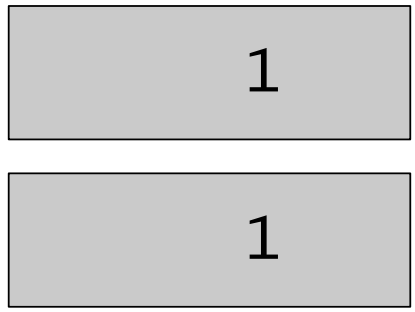
- Consider

```
int j = 11;
j = 1985;
```

Primitive variable assignment

- Consider

```
int a = 1;
int aSquared = a * a;
a = 5;
aSquared = a * a;
```



- Consider

```
int i = 0;
i = i + 1;
```

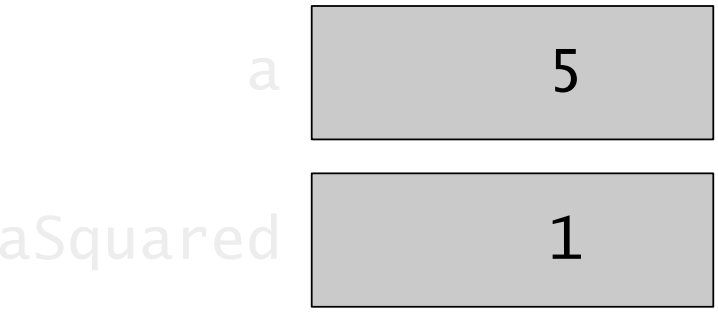
- Consider

```
int asaRating;
asaRating = 400;
```

Primitive variable assignment

- Consider

```
int a = 1;
int aSquared = a * a;
a = 5;
aSquared = a * a;
```



- Consider

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```
int asaRating;
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Primitive variable assignment

- Consider

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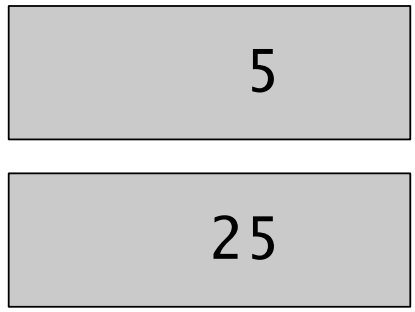

- Consider

```
int i = 0;
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- Consider

```
int asaRating;
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```

Primitive variable assignment

- Consider

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int a = 1;
int aSquared = a * a;
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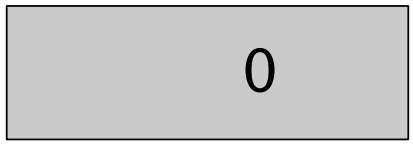
- Consider

```
int i = 0;
i = i + 1;
```

- Consider

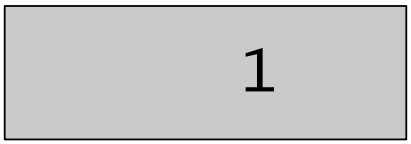
```
int asaRating;
asaRating = 400;
```



Primitive variable assignment

- Consider

```
int a = 1;
int aSquared = a * a;
a = 5;
aSquared = a * a;
```



- Consider

```
int i = 0;
i = i + 1;
```

- Consider

```
int asaRating;
asaRating = 400;
```

Primitive variable assignment

- Consider

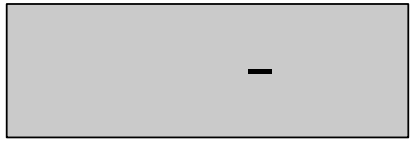
```
int a = 1;
int aSquared = a * a;
a = 5;
aSquared = a * a;
```

- Consider

```
int i = 0;
i = i + 1;
```

- Consider

```
int asaRating;
asaRating = 400;
```

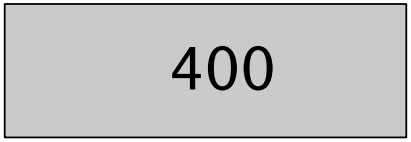


Primitive variable assignment

- Consider

```
int a = 1;
int aSquared = a * a;
a = 5;
aSquared = a * a;
```

asaRating



- Consider

```
int i = 0;
i = i + 1;
```

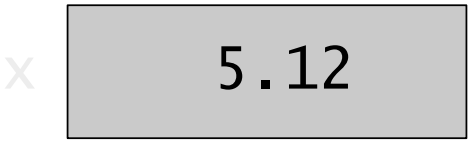
- Consider

```
int asaRating;
asaRating = 400;
```

Primitive variable assignment

- Consider

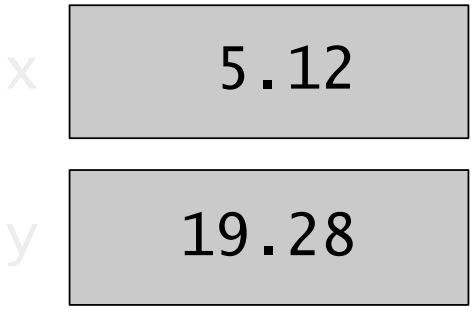
```
double x = 5.12;
double y = 19.28;
double rememberX = x;
x = y;
y = rememberX;
```



Primitive variable assignment

- Consider

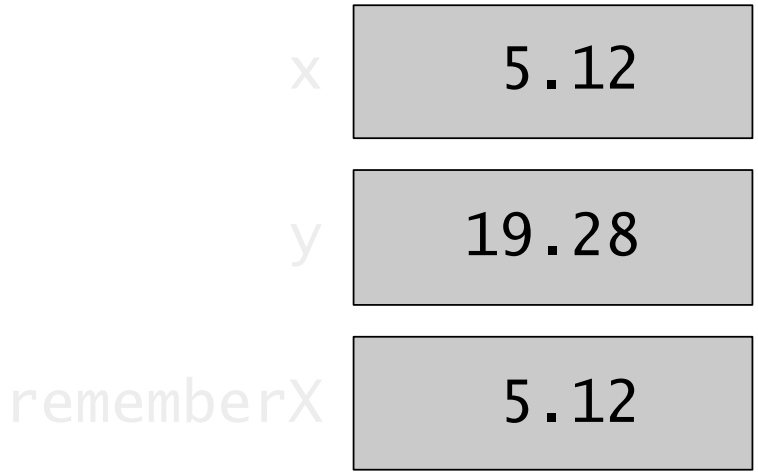
```
double x = 5.12;
double y = 19.28;
double rememberX = x;
x = y;
y = rememberX;
```



Primitive variable assignment

- Consider

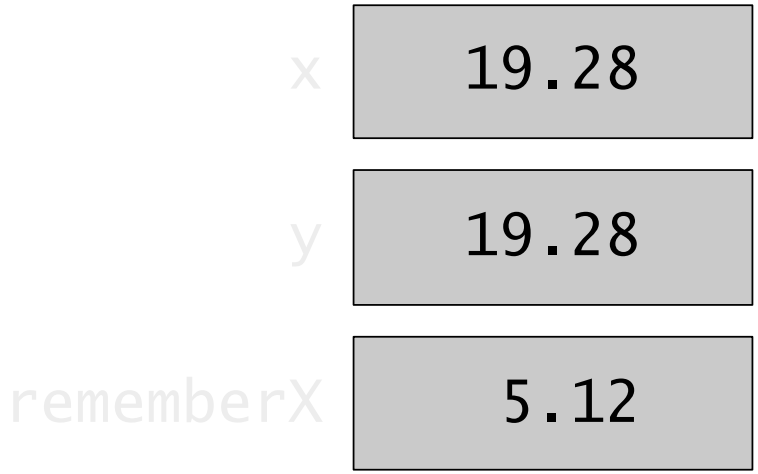
```
double x = 5.12;
double y = 19.28;
double rememberX = x;
x = y;
y = rememberX;
```



Primitive variable assignment

- Consider

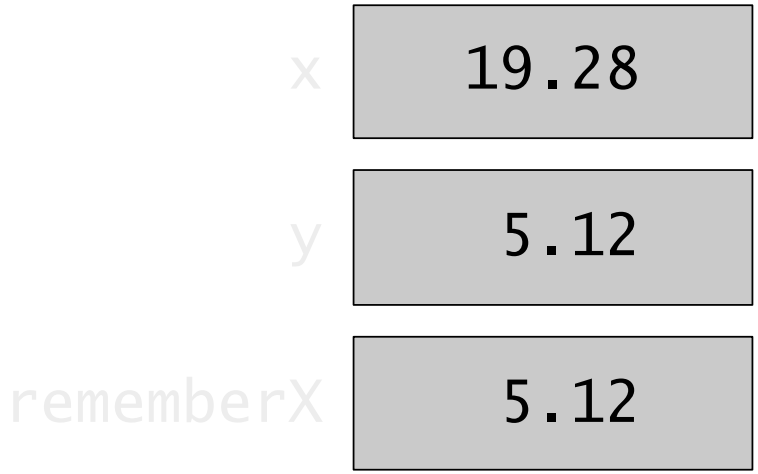
```
double x = 5.12;
double y = 19.28;
double rememberX = x;
x = y;
y = rememberX;
```



Primitive variable assignment

- Consider

```
double x = 5.12;
double y = 19.28;
double rememberX = x;
x = y;
y = rememberX;
```



Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;
++i;
System.out.println(i);
System.out.print(++i);
System.out.println(i++);
System.out.println(i);
```

Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;                    // define
++i;
System.out.println(i);
System.out.print(++i);
System.out.println(i++);
System.out.println(i);
```

Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;
++i;                          // increment
System.out.println(i);
System.out.print(++i);
System.out.println(i++);
System.out.println(i);
```

Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;
++i;
System.out.println(i);   // display
System.out.print(++i);
System.out.println(i++);
System.out.println(i);
```

Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;
++i;
System.out.println(i);
System.out.print(++i);   // update then display
System.out.println(i++);
System.out.println(i);
```

Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;
++i;
System.out.println(i);
System.out.print(++i);
System.out.println(i++); // display then update
System.out.println(i);
```

Increment and decrement operators

- ++
  - Increments a number variable by 1
- --
  - Decrements a numeric variable by 1

- Consider

```
int i = 4;
++i;
System.out.println(i);
System.out.print(++i);
System.out.println(i++);
System.out.println(i);   // display
```

Escape sequences

- Java provides escape sequences for printing special characters
  - \b backspace
  - \n newline
  - \t tab
  - \r carriage return
  - \\ backslash
  - \" double quote
  - \' single quote

Escape sequences

- What do these statements output?

```
System.out.println("Person\tHeight\tShoe size");
System.out.println("=========================");
System.out.println("Hannah\t5‘1\"\t7");
System.out.println("Jenna\t5'10\"\t9");
System.out.println("JJ\t6'1\"\t14");
```

- Output

```
Person  Height  Shoe size
=========================
Hannah  5‘1"    7
Jenna   5'10"   9
JJ      6'1"    14
```

Objects

Getting classy

- Your current job
  - Gain experience creating and manipulating objects from the standard Java types

- Why
  - Prepares you for defining your own classes and creating and manipulating the objects of those classes

Values versus objects

- Numbers
  - Have values but they do *not* have behaviors
- Objects
  - Have attributes and behaviors
- System.in
    - References an InputStream
      - Attribute: keyboard
      - Behaviors: reading
- System.out
  - References an OutputStream
    - Attribute: monitor
    - Behaviors: printing

Some other Java object types

- Scanner
- String
- Rectangle
- Color
- JFrame

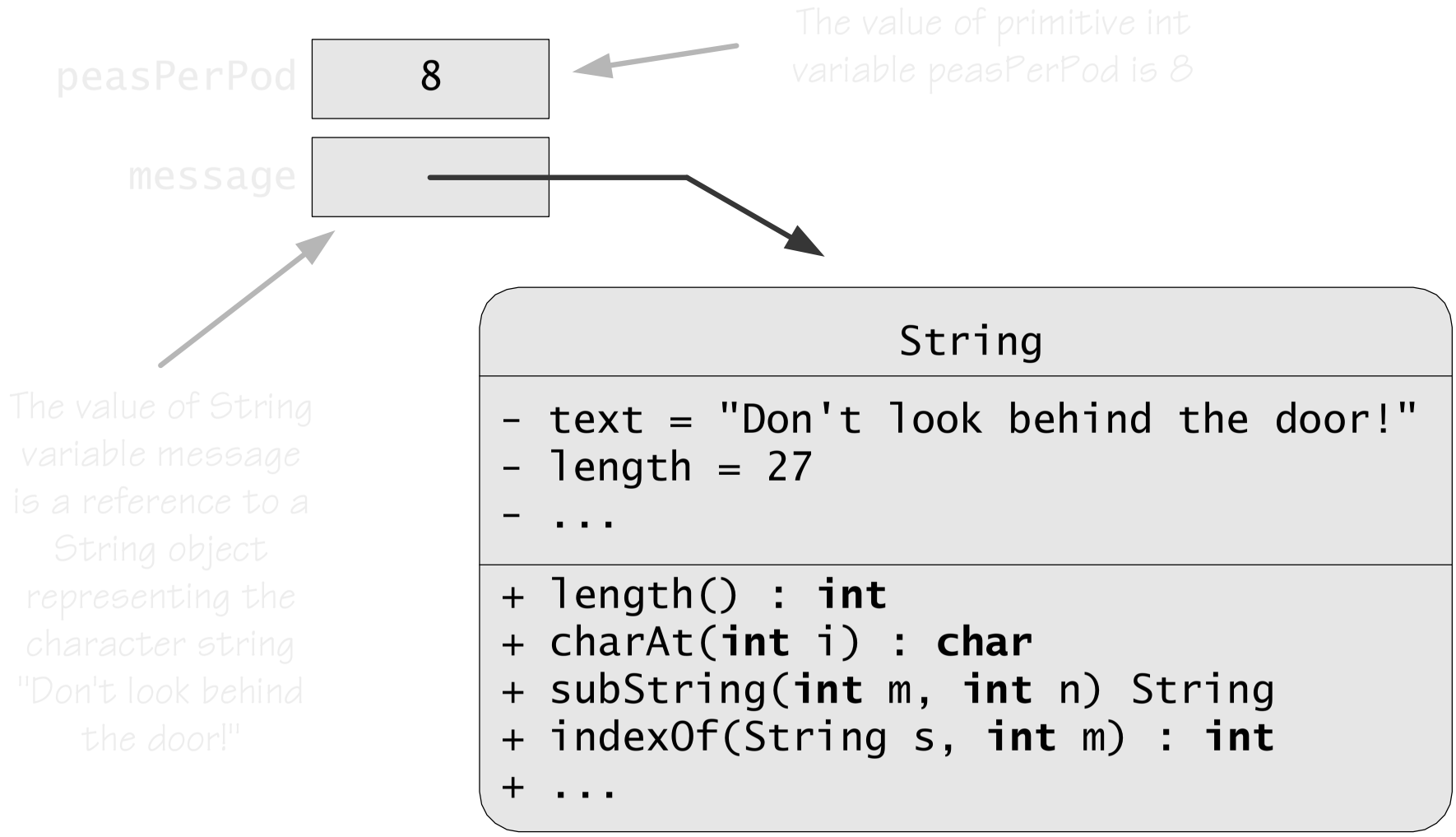
Consider

- Statements

```
int peasPerPod = 8;
String message = "Don't look behind the door!“
```

- How show we represent these definitions according to the notions of Java?

Representation



Shorthand representation

Examples

- Consider

```
String a = "excellence“;
String b = a;
```

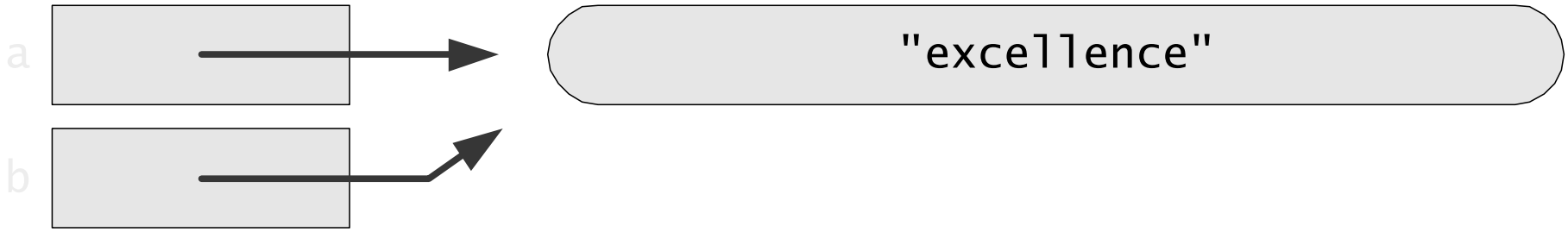
- What is the representation?

Examples

- Consider

```
String a = "excellence“;
String b = a;
```

- What is the representation?



Uninitialized versus null

- Consider

```
String dayOfWeek;
Scanner inStream;
```

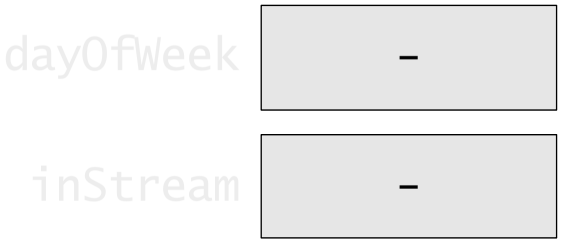
- What is the representation?

Uninitialized versus null

- Consider

```
String dayOfWeek;
Scanner inStream;
```

- What is the representation?



Uninitialized versus null

- Consider

```
String fontName = null;
Scanner fileStream = null;
```

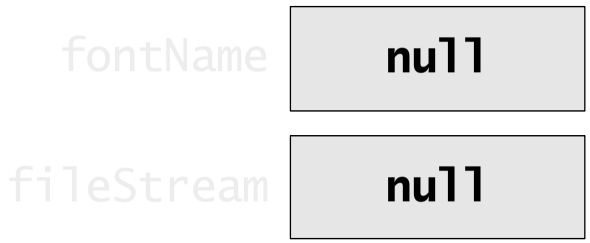
- What is the representation?

Uninitialized versus null

- Consider

```
String fontName = null;
Scanner fileStream = null;
```

- What is the representation?

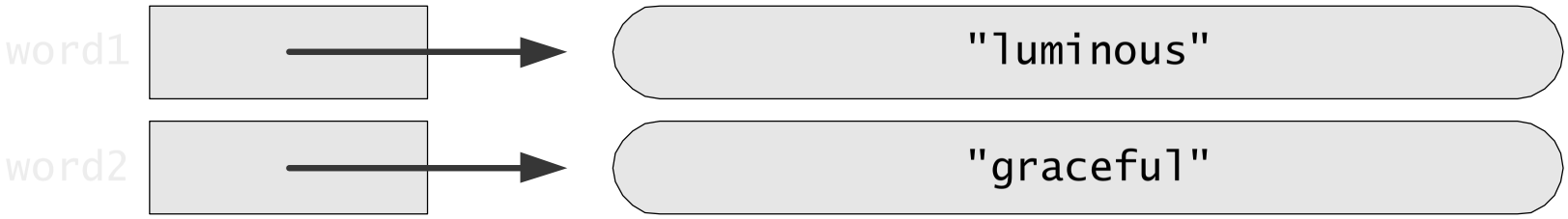


Assignment

- Consider

```
String word1 = "luminous";
String word2 = "graceful";
Word1 = word2;
```

- Initial representation

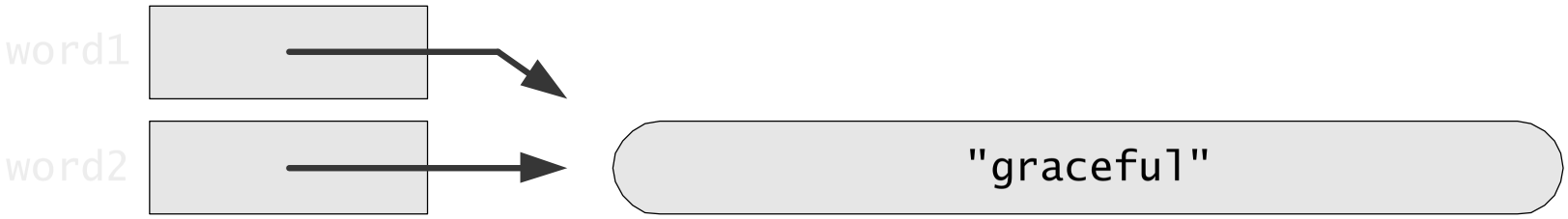


Assignment

- Consider

```
String word1 = "luminous";
String word2 = "graceful";
Word1 = word2;
```

- After assignment



Using objects

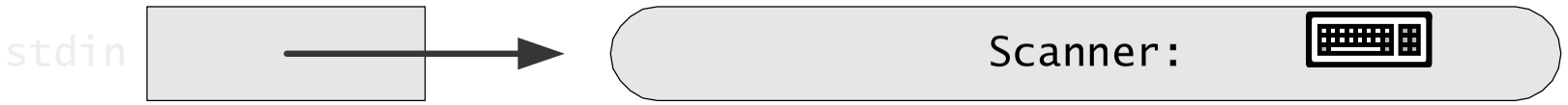
- Consider

```
Scanner stdin = new Scanner(System.in);

System.out.print("Enter your account name: ");
String response = stdin.nextLine();
```

Using objects

- Consider

```
Scanner stdin = new Scanner(System.in);

System.out.print("Enter your account name: ");
String response = stdin.nextLine();
```



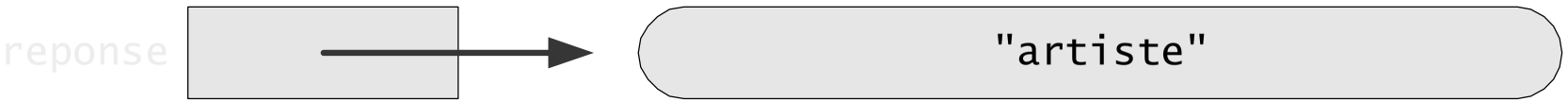
Using objects

- Consider

```
Scanner stdin = new Scanner(System.in);

System.out.print("Enter your account name: ");
String response = stdin.nextLine();
```

- Suppose the user interaction is

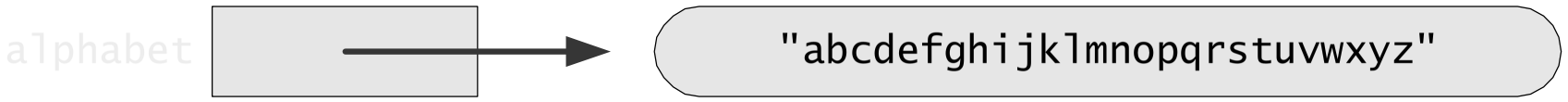
```
Enter your account name: artiste
```



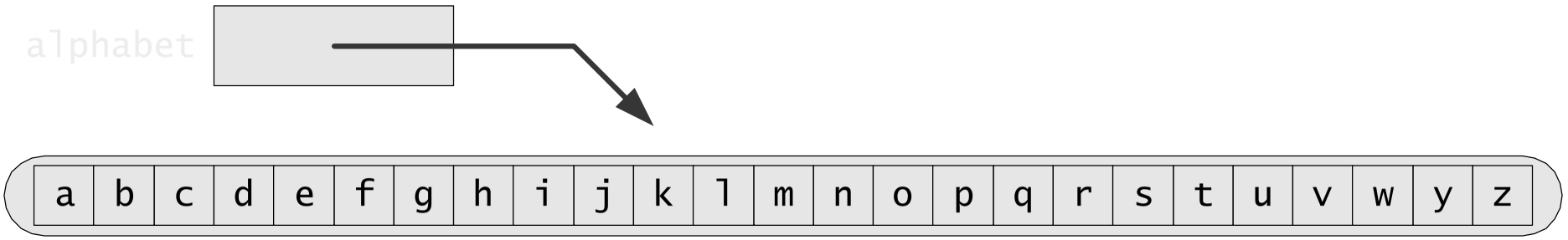
String representation

- Consider
  - String alphabet = "abcdefghijklmnopqrstuvwxyz";

- Standard shorthand representation



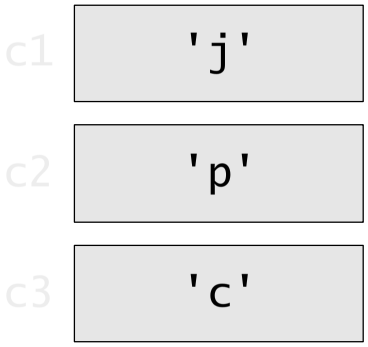
- Truer representation



String representation

- Consider
  - String alphabet = "abcdefghijklmnopqrstuvwxyz";
  - char c1 = alphabet.charAt(9);
  - char c2 = alphabet.charAt(15);
  - char c3 = alphabet.charAt(2);

- What are the values of c1, c2, and c3? Why?



Program WordLength.java

```
public class WordLength {

   public static void main(String[] args) {

       Scanner stdin = new Scanner(System.in);


       System.out.print("Enter a word: ");
       String word = stdin.readLine();

       int wordLength = word.length();

       System.out.println("Word " + word + " has length "
             + wordLength + ".");
   }
}
```

More String methods

- Consider

```
String weddingDate = "August 21, 1976";
String month = weddingDate.substring(0, 6);
System.out.println("Month is " + month + ".");
```

- What is the output?

More String methods

- Consider

```
String weddingDate = "August 21, 1976";
String month = weddingDate.substring(0, 6);
System.out.println("Month is " + month + ".");
```

- What is the output?

```
Month is August.
```

More String methods

- Consider

```
String fruit = "banana";
String searchString = "an";
int n1 = fruit.indexOf(searchString, 0);
int n2 = fruit.indexOf(searchString, n1 + 1);
int n3 = fruit.indexOf(searchString, n2 + 1);

System.out.println("First search: " + n1);
System.out.println("Second search: " + n2);
System.out.println("Third search: " + n3);
```

- What is the output?

More String methods

- Consider

```
String fruit = "banana";
String searchString = "an";
int n1 = fruit.indexOf(searchString, 0);
int n2 = fruit.indexOf(searchString, n1 + 1);
int n3 = fruit.indexOf(searchString, n2 + 1);

System.out.println("First search: " + n1);
System.out.println("Second search: " + n2);
System.out.println("Third search: " + n3);
```

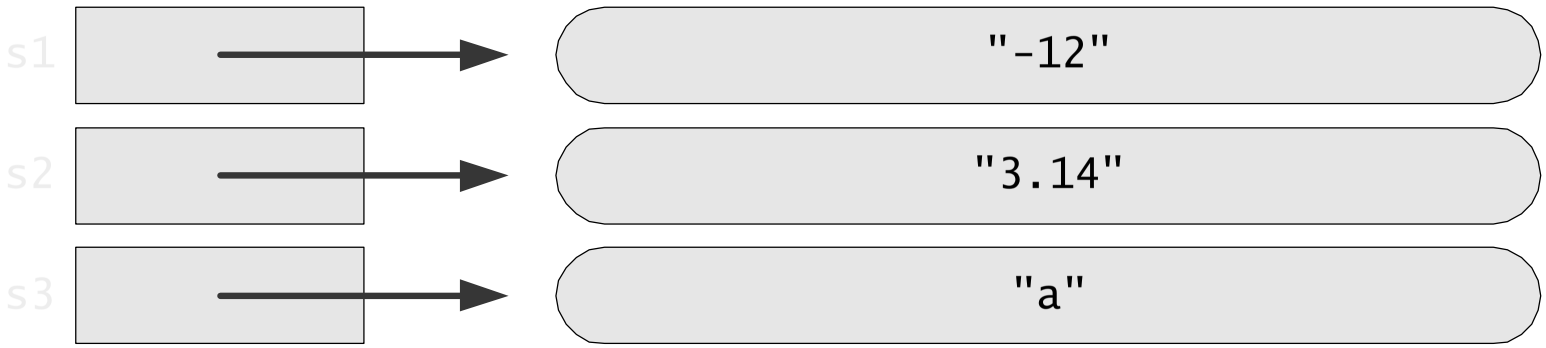
- What is the output?

```
First search: 1
Second search: 3
Third search: -1
```

More String methods

- Consider

```
int v1 = -12;
double v2 = 3.14;
char v3 = 'a';
String s1 = String.valueOf(v1);
String s2 = String.valueOf(v2);
String s3 = String.valueOf(v3);
```

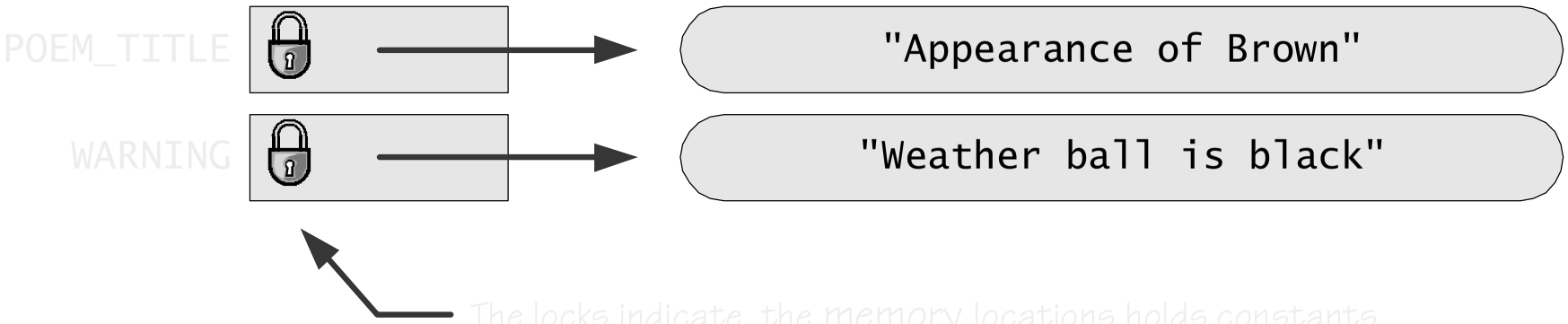


Final variables

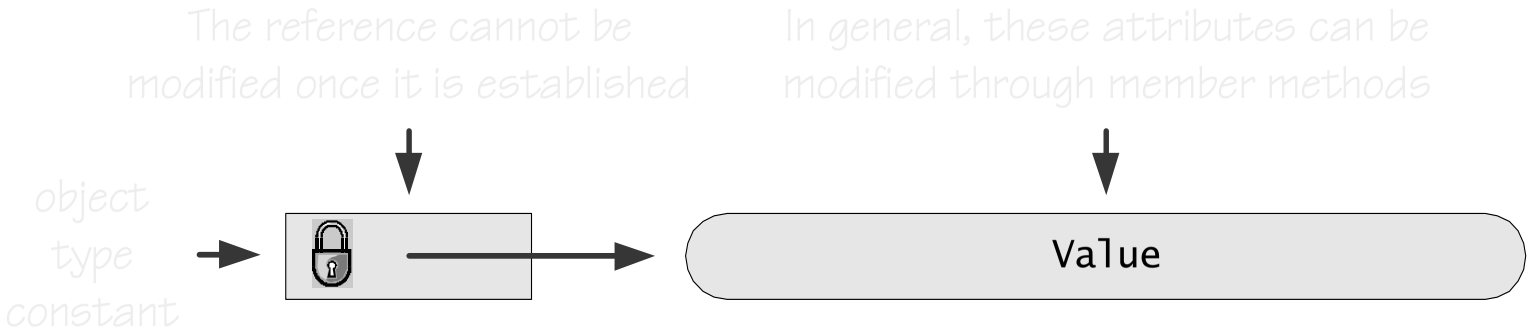
- Consider

```
final String POEM_TITLE = “Appearance of Brown";
final String WARNING = “Weather ball is black";
```

- What is the representation?



Final variables



Rectangle

The first two parameters of the Rectangle constructor specify the position of the upper-left-hand corner of the new Rectangle

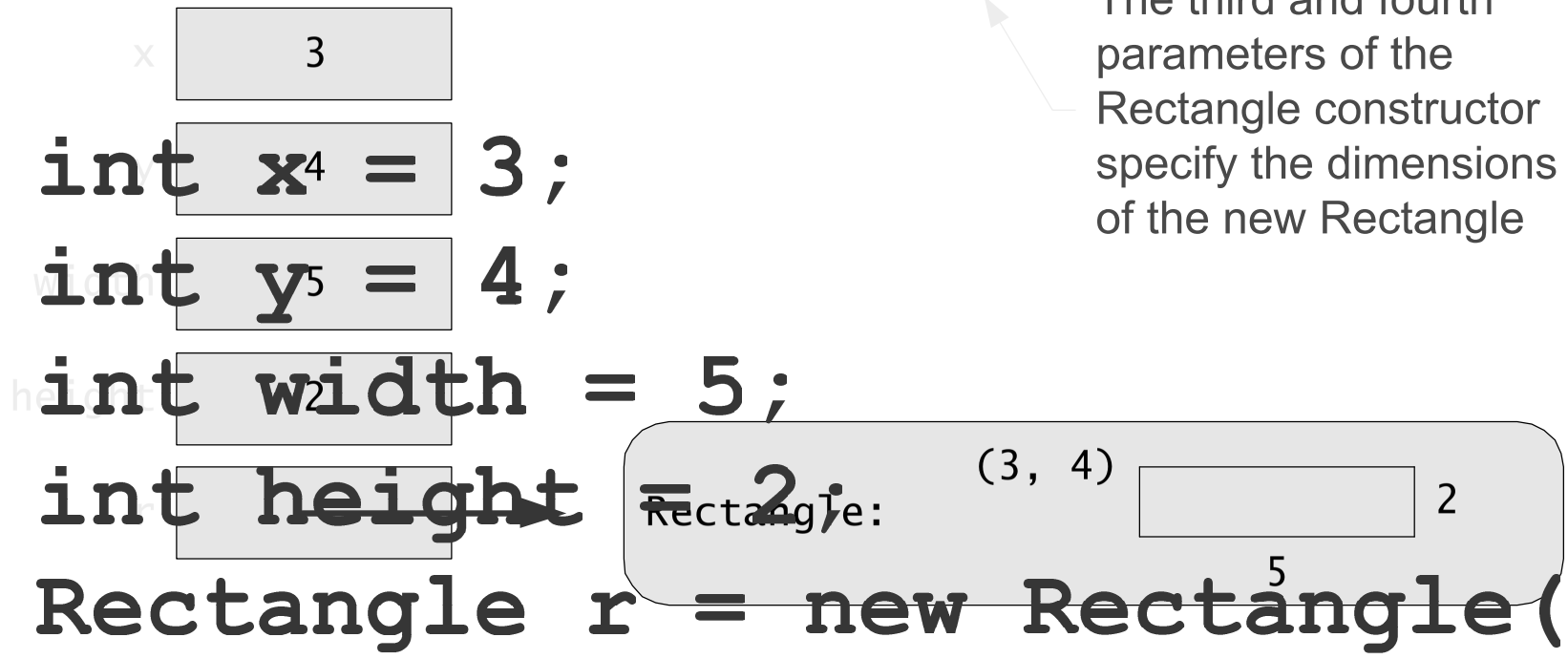
The third and fourth parameters of the Rectangle constructor specify the dimensions of the new Rectangle

```
int x = 3;
int y = 4;
int width = 5;
int height = 2;
Rectangle r = new Rectangle(x
```

Rectangle

The first two parameters of the Rectangle constructor specify the position of the upper-left-hand corner of the new Rectangle

The third and fourth parameters of the Rectangle constructor specify the dimensions of the new Rectangle



Rectangle

- Consider

```
final Rectangle BLOCK = new Rectangle(6, 9, 4, 2);
BLOCK.setLocation(1, 4);
BLOCK.resize(8, 3);
```

Rectangle

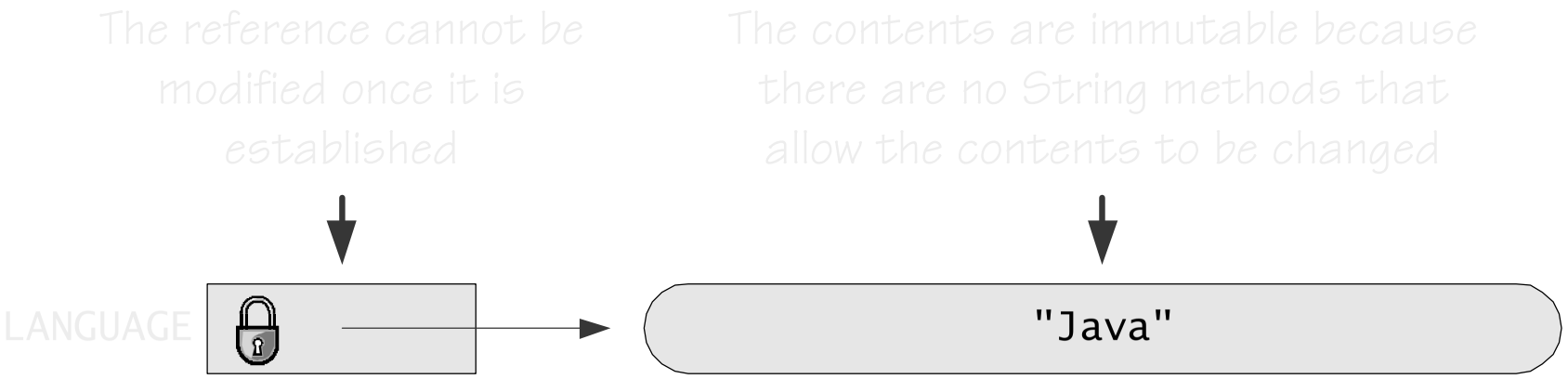
- Consider

```
final Rectangle BLOCK = new Rectangle(6, 9, 4, 2);
BLOCK.setLocation(1, 4);
BLOCK.resize(8, 3);
```

Final variables

- Consider

```
final String LANGUAGE = "Java";
```



Classes

Preparation

- Scene so far has been background material and experience
  - Computing systems and problem solving
  - Variables
  - Types
  - Input and output
  - Expressions
  - Assignments
  - Objects
  - Standard classes and methods

Ready

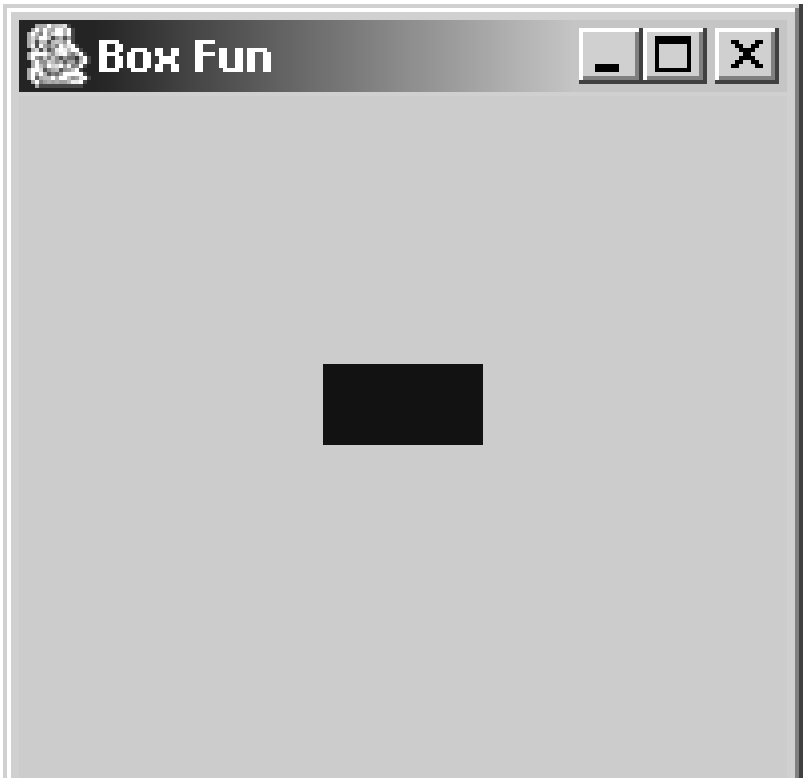
- Experience what Java is really about
  - Design and implement objects representing information and physical world objects

Object-oriented programming

- Basis
  - Create and manipulate objects with attributes and behaviors that the programmer can specify
- Mechanism
  - Classes
- Benefits
  - An information type is design and implemented once
    - Reused as needed
      - No need reanalysis and re-justification of the representation

First class – ColoredRectangle

- Purpose
  - Represent a colored rectangle in a window
  - Introduce the basics of object design and implementation



Background

- JFrame
  - Principal Java class for representing a titled, bordered graphical window.
  - Standard class
    - Part of the swing library

```
import javax.swing.* ;
```

Example

- Consider

```
JFrame w1 = new JFrame("Bigger");
JFrame w2 = new JFrame("Smaller");
w1.setSize(200, 125);
w2.setSize(150, 100);
w1.setVisible(true);
w2.setVisible(true);
```

Example

- Consider

```
JFrame w1 = new JFrame("Bigger");
JFrame w2 = new JFrame("Smaller");
w1.setSize(200, 125);
w2.setSize(150, 100);
w1.setVisible(true);
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```

Example

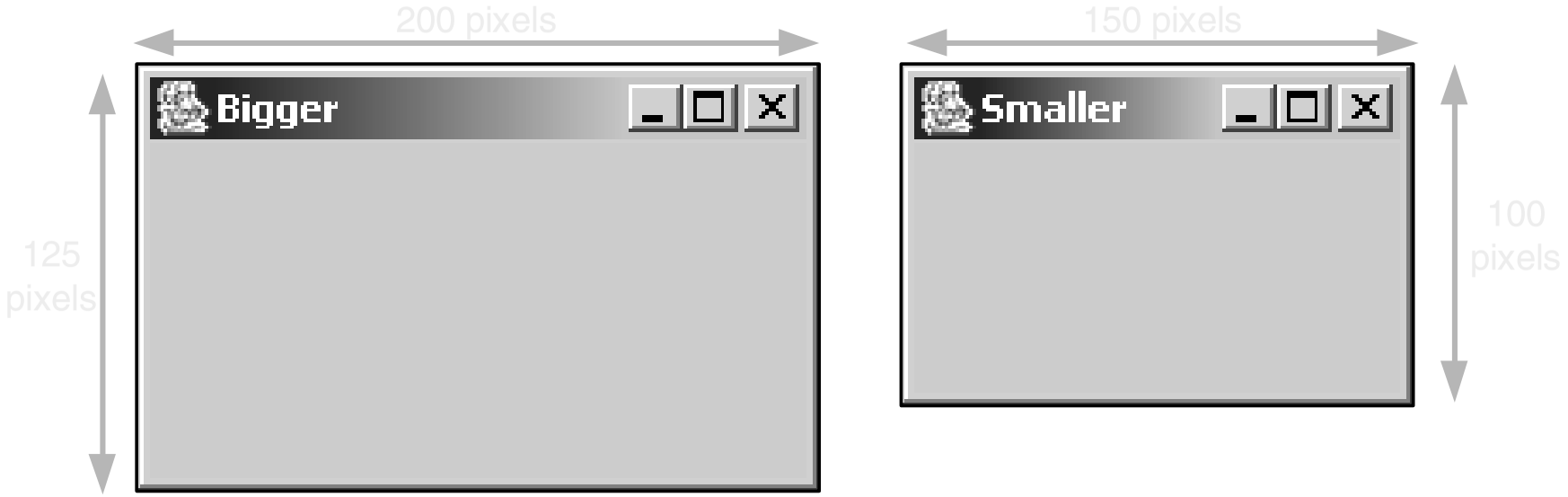
- Consider

```
JFrame w1 = new JFrame("Bigger");
JFrame w2 = new JFrame("Smaller");
w1.setSize(200, 125);
w2.setSize(150, 100);
w1.setVisible(true);
w2.setVisible(true);
```

Example

- Consider

```
JFrame w1 = new JFrame("Bigger");
JFrame w2 = new JFrame("Smaller");
w1.setSize(200, 125);
w2.setSize(150, 100);
w1.setVisible(true);
w2.setVisible(true);
```



Class ColoredRectangle – initial version

- Purpose
  - Support the display of square window containing a blue filled-in rectangle
    - Window has side length of 200 pixels
    - Rectangle is 40 pixels wide and 20 pixels high
    - Upper left hand corner of rectangle is at (80, 90)
  - Limitations are temporary
    - Remember BMI.java preceded BMICalculator.java
    - Lots of concepts to introduce

ColoredRectangle in action

- Consider

```
ColoredRectangle r1 = new ColoredRectangle();
ColoredRectangle r2 = new ColoredRectangle();

System.out.println("Enter when ready");
System.in.read();

r1.paint();  // draw the window associated with r1
r2.paint();  // draw the window associated with r2
```

ColoredRectangle in action

- Consider

```
ColoredRectangle r1 = new ColoredRectangle();
ColoredRectangle r2 = new ColoredRectangle();

System.out.println("Enter when ready");
System.in.read();

r1.paint();  // draw the window associated with r1
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```

ColoredRectangle in action

- Consider

```
ColoredRectangle r1 = new ColoredRectangle();
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System.out.println("Enter when ready");
System.in.read();

r1.paint();  // draw the window associated with r1
r2.paint();  // draw the window associated with r2
```

ColoredRectangle in action

- Consider

```
ColoredRectangle r1 = new ColoredRectangle();
ColoredRectangle r2 = new ColoredRectangle();

System.out.println("Enter when ready");
System.in.read();

r1.paint();  // draw the window associated with r1
r2.paint();  // draw the window associated with r2
```

ColoredRectangle.java outline

```
import javax.swing.*;
import java.awt.*;

public class ColoredRectangle {
    // instance variables for holding object attributes
    private int width;
    private int height;
    private int x;
    private int y;
    private JFrame window;
    private Color color;

    // ColoredRectangle(): default constructor
    public ColoredRectangle() {  // ...
    }
    // paint(): display the rectangle in its window
    public void paint() {  // ...
    }
}
```

Instance variables and attributes

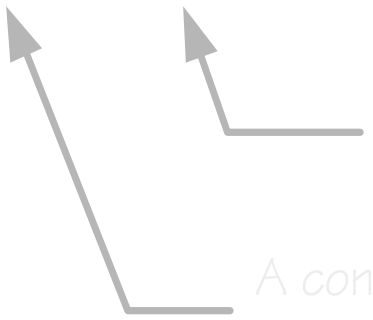
- Data field
  - Java term for an object attribute
- Instance variable
  - Symbolic name for a data field
  - Usually has private access
    - Assists in information hiding by encapsulating the object's attributes
  - Default initialization
    - Numeric instance variables initialized to 0
    - Logical instance variables initialized to false
    - Object instance variables initialized to null

```
public class ColoredRectangle {

   // instance variables for holding object attributes
   private int width;              private int x;
   private int height;             private int y;
   private JFrame window;          private Color color;

   // ColoredRectangle(): default constructor
   public ColoredRectangle() {
      window = new JFrame("Box Fun");
      window.setSize(200, 200);
      width = 40;                  x = 80;
      height = 20;                 y = 90;
      color = Color.BLUE;
      window.setVisible(true);
   }

   // paint(): display the rectangle in its window
   public void paint() {
      Graphics g = window.getGraphics();
      g.setColor(color);
      g.fillRect(x, y, width, height);
   }
}
```

```
public class ColoredRectangle {

   // instance variables for holding object attributes
   private int width;              private int x;
   private int height;             private int y;
   private JFrame window;          private Color color;

   // ColoredRectangle(): default constructor
   public ColoredRectangle() {
      window = new JFrame("Box Fun");
      window.setSize(200, 200);
      width = 40;                  x = 80;
      height = 20;                 y = 90;
      color = Color.BLUE;
      window.setVisible(true);
   }

   // paint(): display the rectangle in its window
   public void paint() {
      Graphics g = window.getGraphics();
      g.setColor(color);
      g.fillRect(x, y, width, height);
   }
}
```

ColoredRectangle default constructor

```
public class ColoredRectangle {
  // instance variables to describe object attributes
  ...

  // ColoredRectangle(): default constructor
  public ColoredRectangle() {

    ...

  }
  ...
}
```



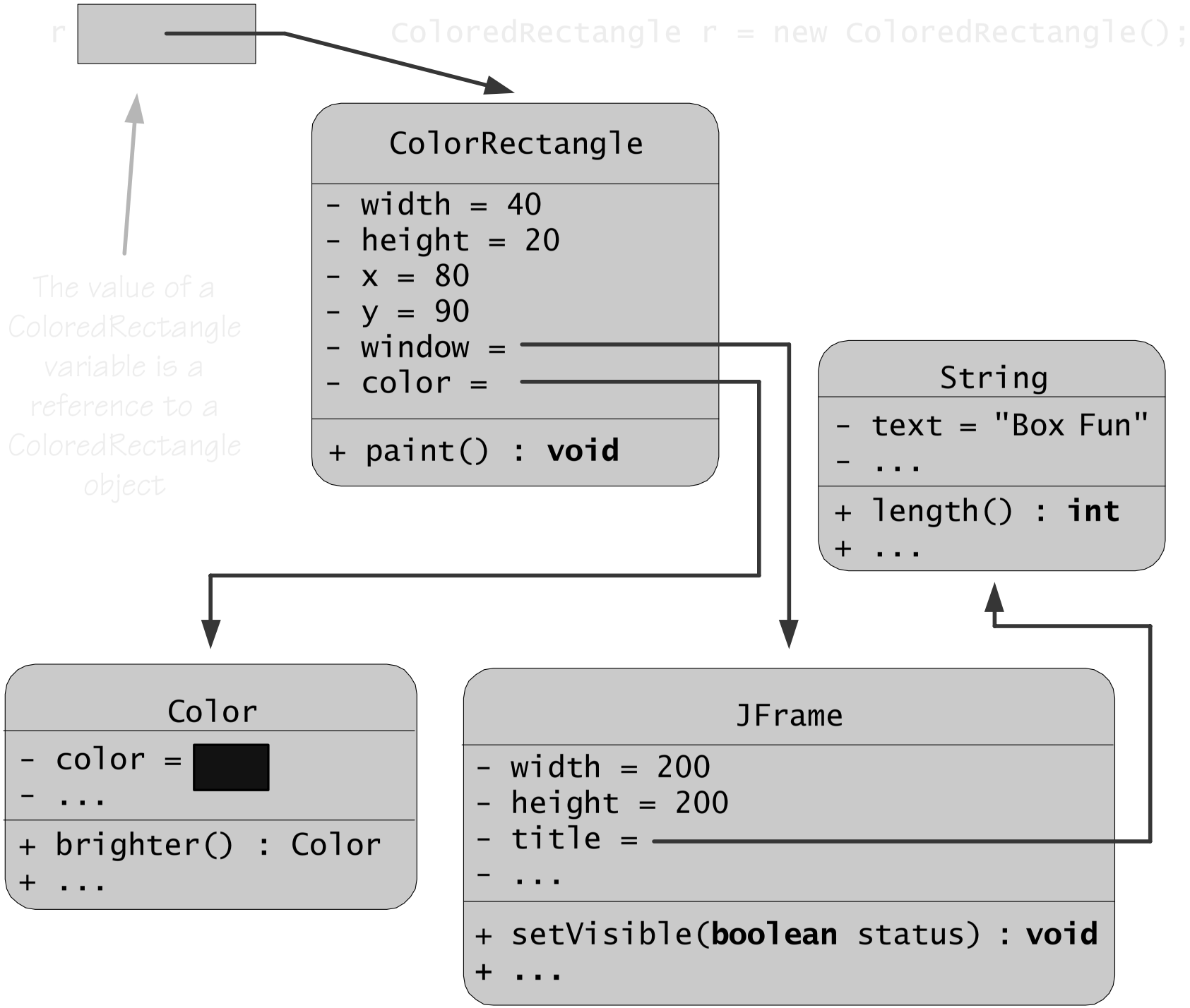
The name of a constructor always matches the name of its class

A constructor *does* not list its return type. A constructor always returns a reference to a new object of its class

```
public class ColoredRectangle {

   // instance variables for holding object attributes
   private int width;              private int x;
   private int height;             private int y;
   private JFrame window;          private Color color;

   // ColoredRectangle(): default constructor
   public ColoredRectangle() {
      window = new JFrame("Box Fun");
      window.setSize(200, 200);
      width = 40;                  x = 80;
      height = 20;                 y = 90;
      color = Color.BLUE;
      window.setVisible(true);
   }

   // paint(): display the rectangle in its window
   public void paint() {
      Graphics g = window.getGraphics();
      g.setColor(color);
      g.fillRect(x, y, width, height);
   }
}
```

Color constants

- Color.BLACK
- Color.BLUE
- Color.CYAN
- Color.DARK_GRAY
- Color.GRAY
- Color.GREEN
- Color.LIGHT_GRAY
- Color.MAGENTA
- Color.ORANGE
- Color.PINK
- Color.RED
- Color.WHITE
- Color.YELLOW

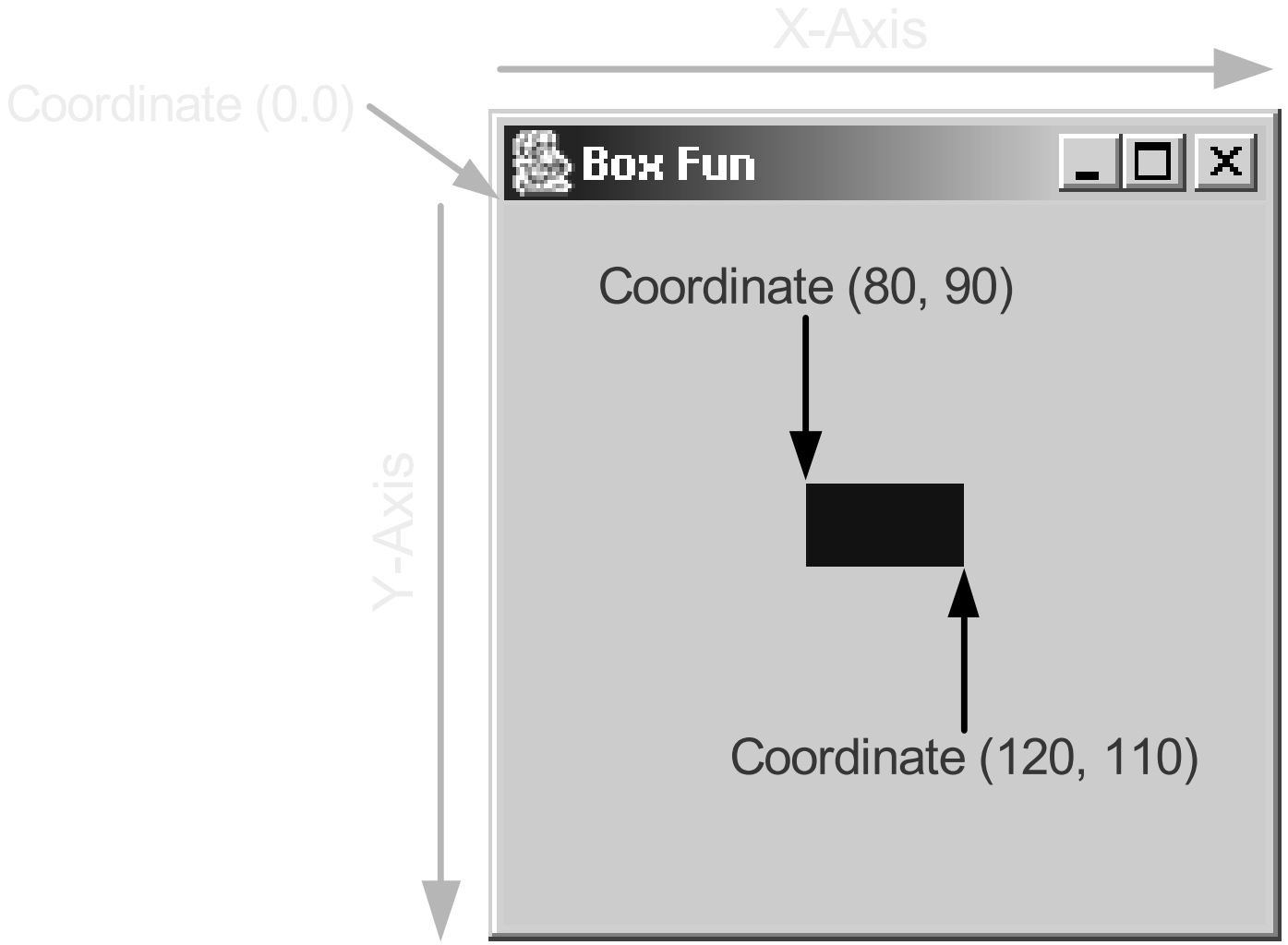

r
ColoredRectangle r = new ColoredRectangle();
The value of a ColoredRectangle variable is a reference to a ColoredRectangle object
ColorRectangle
- width = 40
- height = 20
- x = 80
- y = 90
- window =
- color =
+ paint() : void
String
- text = "Box Fun"
- ...
+ length() : int
+ ...
Color
- color =
- ...
+ brighter() : Color
+ ...
JFrame
- width = 200
- height = 200
- title =
- ...
+ setVisible(boolean status) : void
+ ...

```
public class ColoredRectangle {

   // instance variables for holding object attributes
   private int width;              private int x;
   private int height;             private int y;
   private JFrame window;          private Color color;

   // ColoredRectangle(): default constructor
   public ColoredRectangle() {
      window = new JFrame("Box Fun");
      window.setSize(200, 200);
      width = 40;                  x = 80;
      height = 20;                 y = 90;
      color = Color.BLUE;
      window.setVisible(true);
   }

   // paint(): display the rectangle in its window
   public void paint() {
      Graphics g = window.getGraphics();
      g.setColor(color);
      g.fillRect(x, y, width, height);
   }
}
```

Graphical context

- Graphics
  - Defined in java.awt.Graphics
  - Represents the information for a rendering request
    - Color
    - Component
    - Font
    - …
  - Provides methods
  - Text drawing
    - Line drawing
    - Shape drawing
      - Rectangles
      - Ovals
      - Polygons

Java coordinate system



```
public class ColoredRectangle {

   // instance variables for holding object attributes
   private int width;              private int x;
   private int height;             private int y;
   private JFrame window;          private Color color;

   // ColoredRectangle(): default constructor
   public ColoredRectangle() {
      window = new JFrame("Box Fun");
      window.setSize(200, 200);
      width = 40;                  x = 80;
      height = 20;                 y = 90;
      color = Color.BLUE;
      window.setVisible(true);
   }

   // paint(): display the rectangle in its window
   public void paint() {
      Graphics g = window.getGraphics();
      g.setColor(color);
      g.fillRect(x, y, width, height);
   }
}
```

Method invocation

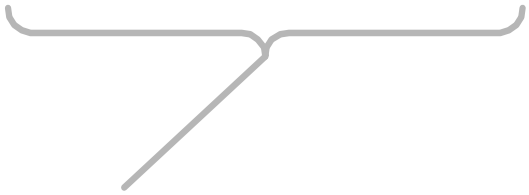
- Consider

```
r1.paint();  // display window associated with r1

r2.paint();  // display window associated with r2
```

- Observe
  - When an instance method is being executed, the attributes of the object associated with the invocation are accessed and manipulated
  - Important that you understand what object is being manipulated

Method invocation

```
public class ColoredRectangle {
  // instance variables to describe object attributes
  ...

  // paint(): display the rectangle in its window
  public void paint() {
     window.setVisible(true);
     Graphics g = window.getGraphics();
     g.setColor(color);
     g.fillRect(x, y, width, height);
  }
  ...

}
```



The values of these instance variables are also from the ColoredRectangle object that invoked method paint().

Instance variable window references the JFrame attribute of the object that caused the invocation. That is, the invocation r1.paint() causes the window attribute of the Colored-Rectangle referenced by r1 to be accessed. Similarly, the invocation r2.paint() causes the window attribute of the ColoredRectangle referenced by r2 to be accessed.

Improving ColoredRectangle

- Analysis
  - A ColoredRectangle object should
    - Be able to have any color
    - Be positionable anywhere within its window
    - Have no restrictions on its width and height
    - Accessible attributes
    - Updateable attributes

Improving ColoredRectangle

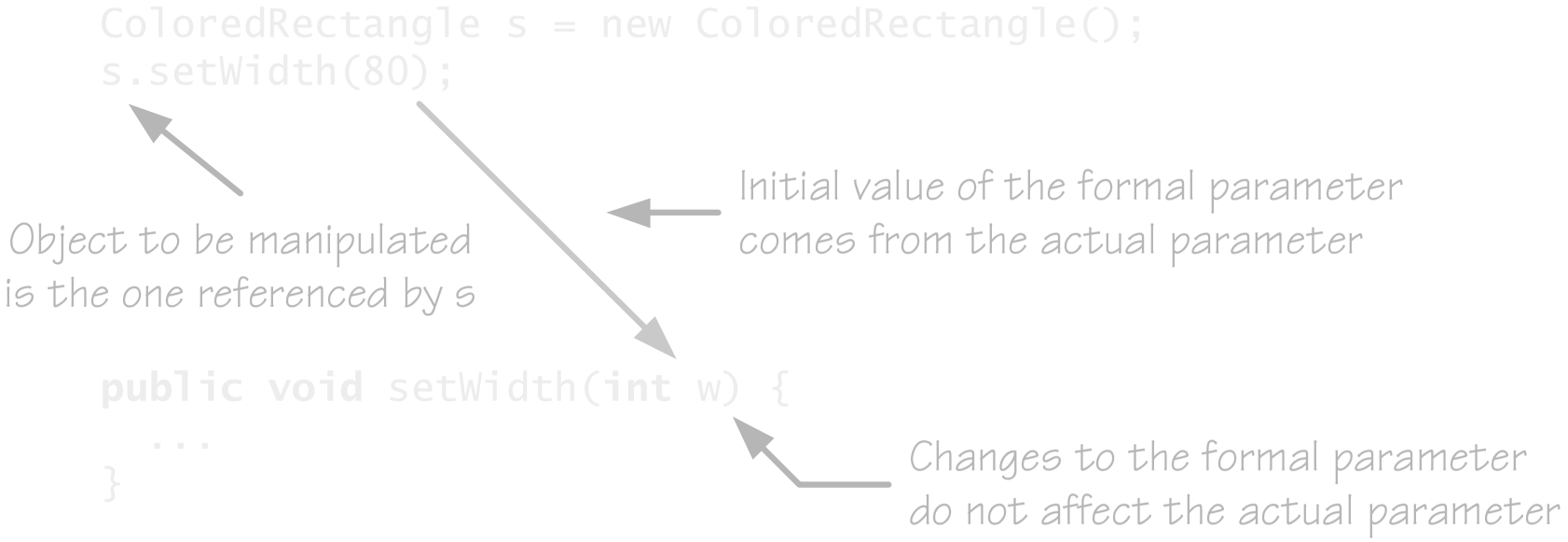
- Additional constructions and behaviors
  - Specific construction
    - Construct a rectangle representation using supplied values for its attributes
  - Accessors
    - Supply the values of the attributes
    - Individual methods for providing the width, height, x-coordinate position, y-coordinate position, color, or window of the associated rectangle
  - Mutators
    - Manage requests for changing attributes
    - Ensure objects always have sensible values
    - Individual methods for setting the width, height, x-coordinate position, y-coordinate position, color, or window of the associated rectangle to a given value

A mutator method

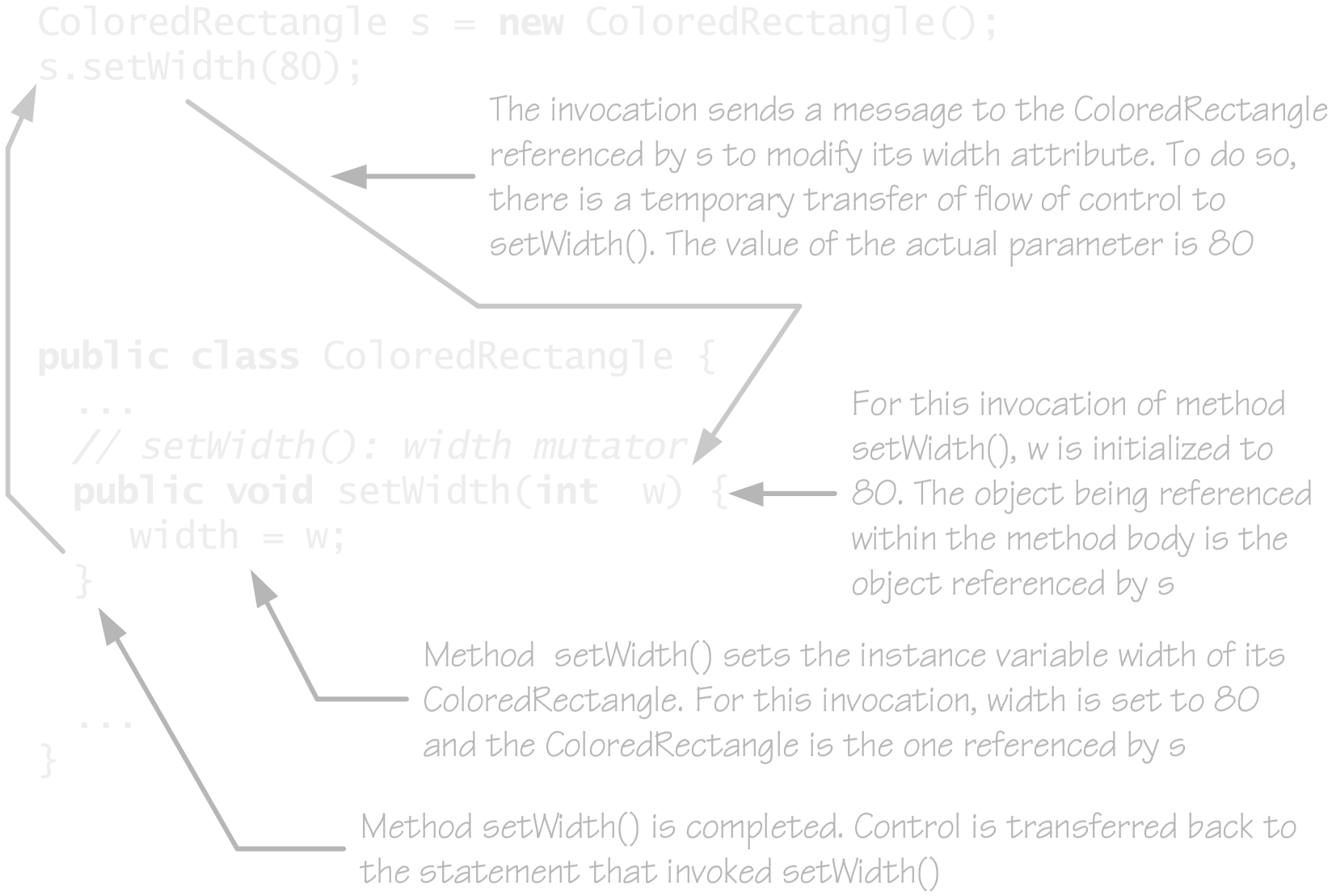
- Definition

```
// setWidth(): width mutator
public void setWidth(int w) {
    width = w;
}
```

- Usage



Mutator setWidth() evaluation



Subtleties

- Consider

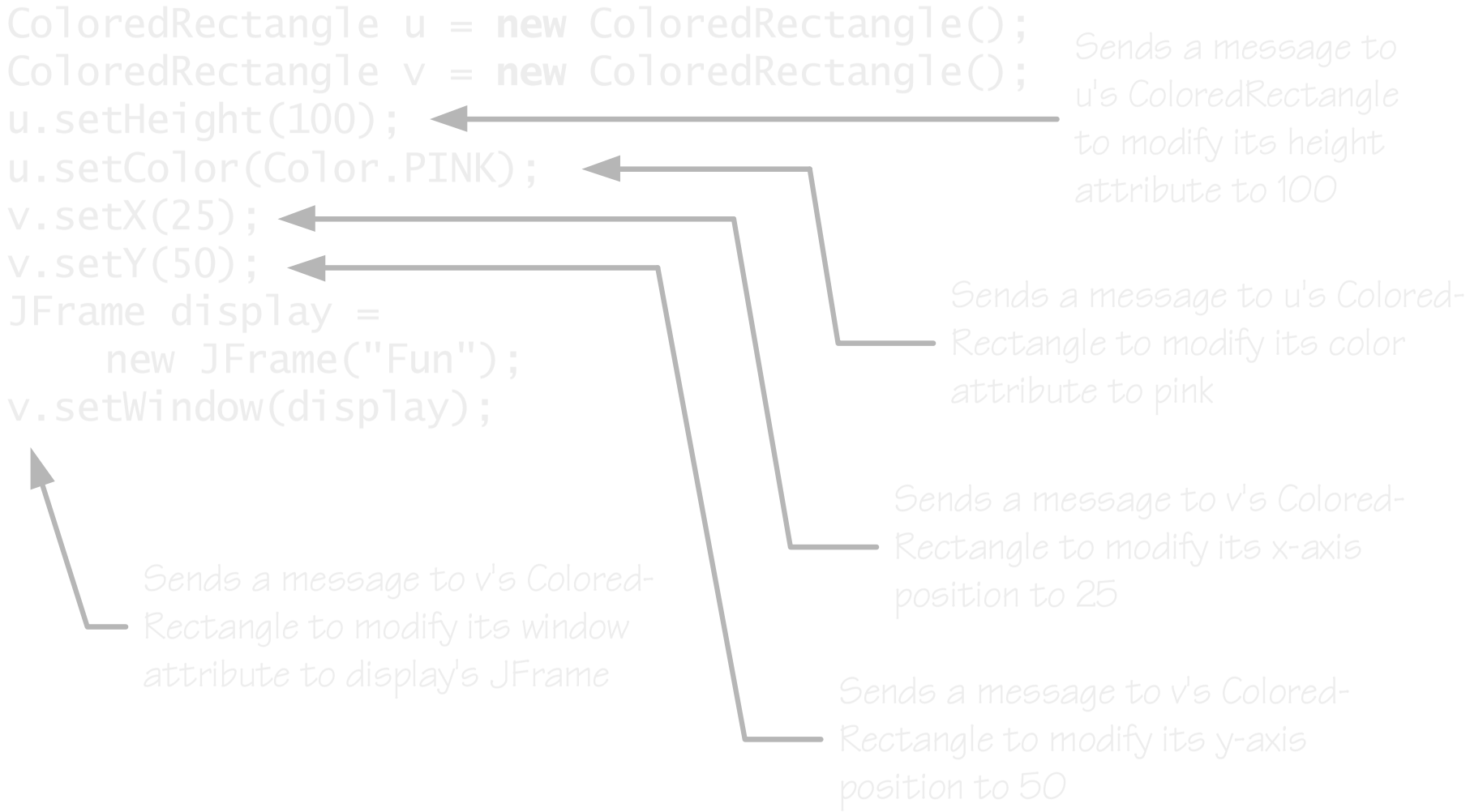
```
ColoredRectangle r = new ColoredRectangle();
r.paint();
r.setWidth(80);
r.paint();
```

- What is the width is the rectangle on the screen after the mutator executes?

Other mutators

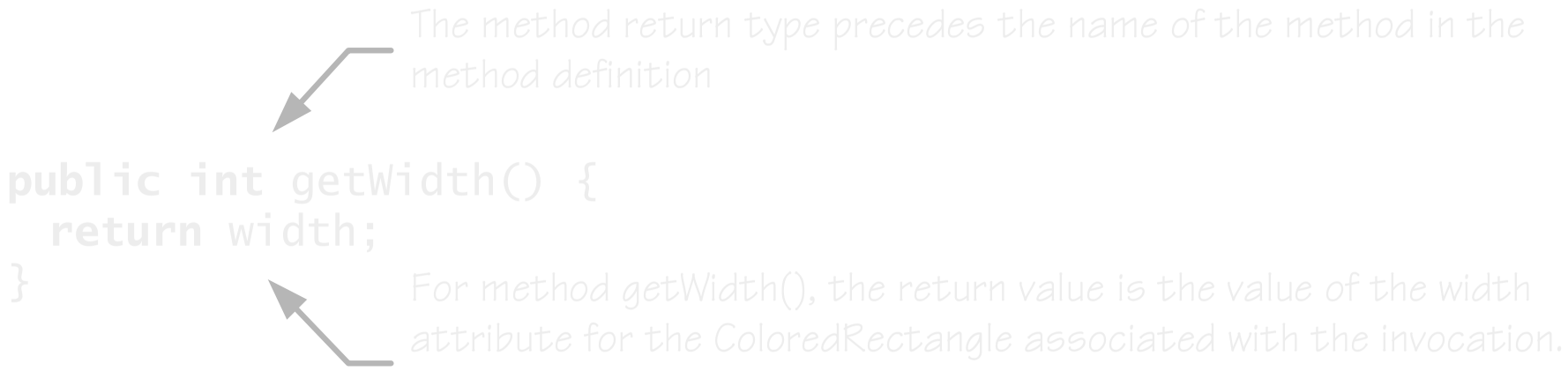
```
public void setHeight(int h) {
   height = h;
}

public void setX(int ulx) {
   x = ulx;
}

public void setY(int uly) {
   y = uly;
}

public void setWindow(JFrame f) {
   window = f;
}

public void setColor(Color c) {
   color = c;
}
```

Mutator usage

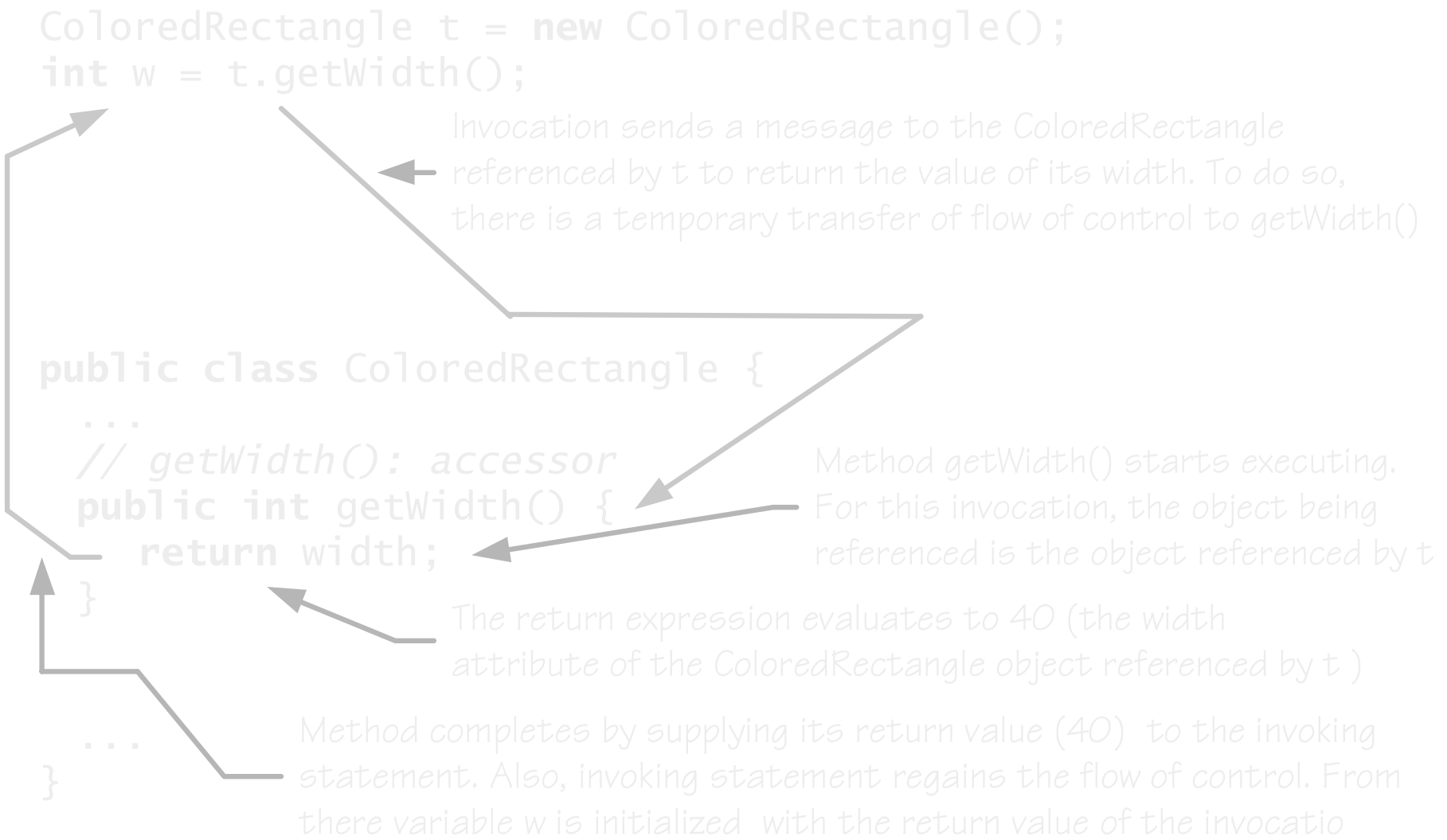


Accessors

- Properties
  - Do not require parameters
  - Each accessor execution produces a return value
    - Return value is the value of the invocation



Accessor usage



Specific construction

```
public ColoredRectangle(int w, int h, int ulx, int uly,
                                    JFrame f, Color c) {
   setWidth(w);
   setHeight(h);
   setX(ulx);
   setY(uly);
   setWindow(f);
   setColor(c);
}
```

- Requires values for each of the attributes

```
JFrame display = new JFrame("Even more fun");
display.setSize(400, 400);
ColoredRectangle w = new ColoredRectangle(60, 80,
                  20, 20, display, Color.YELLOW);
```

Specific construction

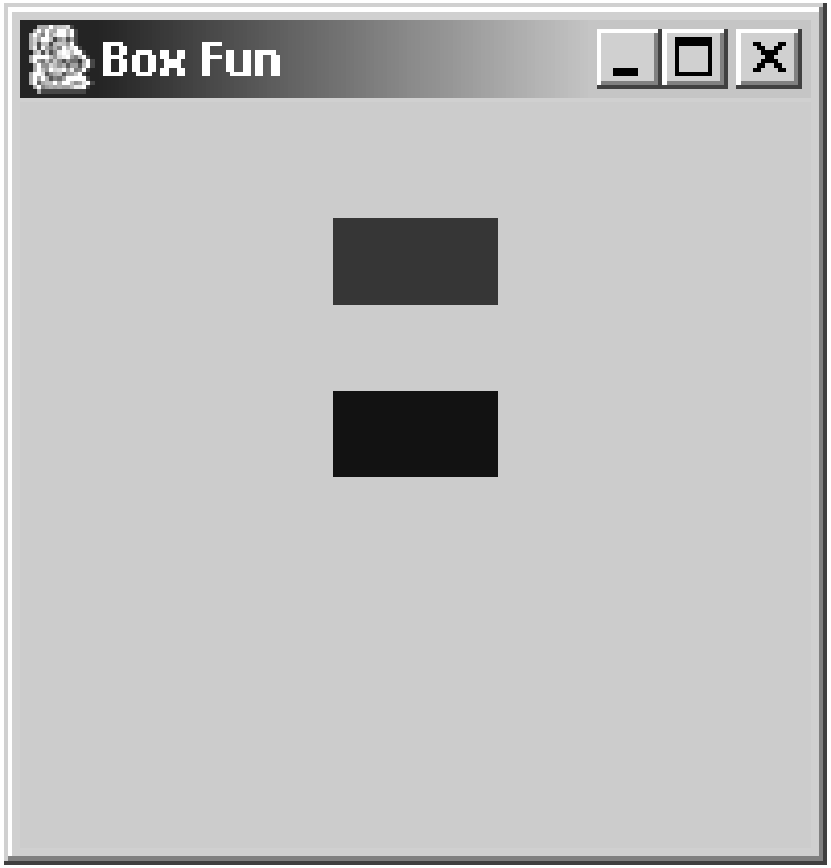
```
public ColoredRectangle(int w, int h, int ulx, int uly,
                                    JFrame f, Color c) {
   setWidth(w);
   setHeight(h);
   setX(ulx);
   setY(uly);
   setWindow(f);
   setColor(c);
}
```

- Advantages to using mutators
  - Readability
  - Less error prone
  - Facilitates enhancements through localization

Seeing double

```
import java.io.*;
import java.awt.*;

public class SeeingDouble {

   public static void main(String[] args)
                          throws IOException {

      ColoredRectangle r = new ColoredRectangle();

      System.out.println("Enter when ready");
      System.in.read();

      r.paint();

      r.setY(50);
      r.setColor(Color.RED);
      r.paint();
   }
}
```

Seeing double



Decisions

Background

- Our problem-solving solutions so far have the straight-line property
  - They execute the same statements for every run of the program

```
public class DisplayForecast
   // main(): application entry point
   public static void main(String[] args) {
      System.out.print("I think there is a world");
      System.out.print(" market for maybe five ");
      System.out.println("computers. “);
      System.out.print(" Thomas Watson, IBM, “);
      System.out.println("1943.“);
   }
}
```

Background

- For general problem solving we need more capabilities
  - The ability to control which statements are executed
  - The ability to control how often a statement is executed

- We will concentrate first on controlling which statements are executed

- Java provides the if and switch conditional constructs to control whether a statement list is executed
  - The if constructs use logical expressions to determine their course of action

- Examination begins with logical expressions

Logical expressions

- The branch of mathematics dealing with logical expressions is Boolean algebra
  - Developed by the British mathematician George Boole

Logical expressions

- A logical expression has either the value logical true or logical false
  - Some expressions whose values are logical true
    - The year 2004 is a leap year
    - A meter equals 100 centimeters
  - Some expressions whose values are logical false
    - A triangle has four sides
    - The area of square is always equal to twice its perimeter

Logical expressions

- There are three primary logical operators for manipulating logical values
  - Logical and
  - Logical or
  - Logical not

- The operators work as most of us would expect

Truth tables

- We use truth tables to give formal specifications of the operators
  - "It works as most of us would expect" allows for ambiguity of interpretation
    - Jim is smiling or Patty is smiling
      - Can both Jim and Patty be smiling?
- Truth tables
  - Lists all combinations of operand values and the result of the operation for each combination

p	q	p and q
False	False	False
False	True	False
True	False	False
True	True	True

Or and not truth tables

p	q	p or q
False	False	False
False	True	True
True	False	True
True	True	True

p	not p
False	True
True	False

Boolean algebra

- Can create complex logical expressions by combining simple logical expressions
  - not (p and q)

p	q	p and q	not (p and q)
False	False	False	True
False	True	False	True
True	False	False	True
True	True	True	False

DeMorgan's laws

- not (p and q) equals (not p) or (not q)

p	q	p and q	not (p and q)	(not p)	(not q)	(not p) or (not q)
False	False	False	True	True	True	True
False	True	False	True	True	False	True
True	False	False	True	False	True	True
True	True	True	False	False	False	False

DeMorgan's laws

- not (p or q) equals (not p) and (not q)

p	q	p or q	not (p or q)	(not p)	(not q)	(not p) and (not q)
False	False	False	True	True	True	True
False	True	True	False	True	False	False
True	False	True	False	False	True	False
True	True	True	False	False	False	False

A boolean type

- Java has the logical type **`boolean`**
- Type `boolean` has two literal constants
  - **`true`**
  - **`false`**
- Operators
  - The and operator is **`&&`**
  - The or operator is `||`
  - The not operator is `!`

Defining boolean variables

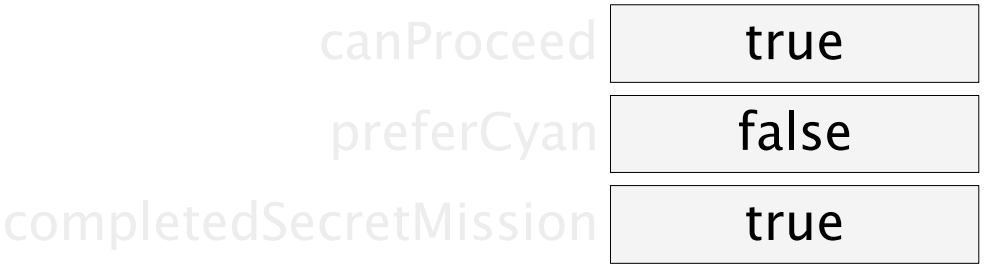
- Local boolean variables are uninitialized by default

```
boolean isWhitespace;
boolean receivedAcknowledgement;
boolean haveFoundMissingLink;
```

Defining boolean variables

- Local boolean variables with initialization

```
boolean canProceed = true;
boolean preferCyan = false;
boolean completedSecretMission = true;
```



Other operators

- Equality operators == and !=
  - Operator ==
    - Evaluates to true if the operands have the same value; otherwise, evaluates to false
  - Operator !=
    - Evaluates to true if the operands have different values; otherwise, evaluates to false
  - The operators work with all types of values

Evaluating boolean expressions

- Suppose

```
boolean p = true;
boolean q = false;
boolean r = true;
boolean s = false;
```

- What is the value of

```
p                    p && s
!s                   p == q
q                    q != r
p && r               r == s
q || s               q != s
```

Evaluating boolean expressions

- Suppose

```
int i = 1;
int j = 2;
int k = 2;
char c = '#';
char d = '%';
char e = '#';
```

- What is the value of

```
j == k
i == j
c == e
c == d
```

```
i != k
j != k
d != e
c != e
```

Take care with floating-point values

- Consider

```
double a = 1;
double b = 0.1 + 0.1 + 0.1 + 0.1 + 0.1 + 0.1
                + 0.1 + 0.1 + 0.1 + 0.1;
double c = .9999999999999999;
```

- Two false Java expressions!

```
a == b      b != c
```

- Two true Java expressions!

```
a != b      b == c
```

- Problem lies with the finite precision of the floating-point types
  - Instead test for closeness with floating-point values

```
Math.abs(a – b) < Small number
```

Ordering operators

- Java provides ordering operators for the primitive types
  - Four ordering operators, <, >, <=, and >=
  - They correspond to mathematical operators of <, >, ≤, and ≥
- Together the equality and ordering operators are known as the relational operators
- False is less than true

Evaluation boolean expressions

- Suppose

```
int i = 1;
int j = 2;
int k = 2;
```

- What is the value of

```
i < j
j < k
i <= k
j >= k
i >= k
```

Unicode values

- Character comparisons are based on their Unicode values

- Characters ‘0’, ‘1’, … ‘9’ have expected order
  - Character ‘0’ has the encoding 48
  - Character ‘1’ has the encoding 49, and so on.

- Upper case Latin letters ‘A’, ‘B’, … ‘Z’ have expected order
  - Character ‘A’ has the encoding 65, character ‘B’ has the encoding 66, and so on.

- Lower case Latin letters ‘a’, ‘b’, … ‘z’ have expected order
    - Character ‘a’ has the encoding 97
    - Character ‘b’ has the encoding 98, and so on.

Evaluation boolean expressions

- Suppose

```
char c = '2';
char d = '3';
char e = '2';
```

- What is the value of

```
c < d
c < e
c <= e
d >= e
c >= e
```

Operator precedence revisited

- Highest to lowest
  - Parentheses
  - Unary operators
  - Multiplicative operators
  - Additive operators
  - Relational ordering
  - Relational equality
  - Logical and
  - Logical or
  - Assignment

Conditional constructs

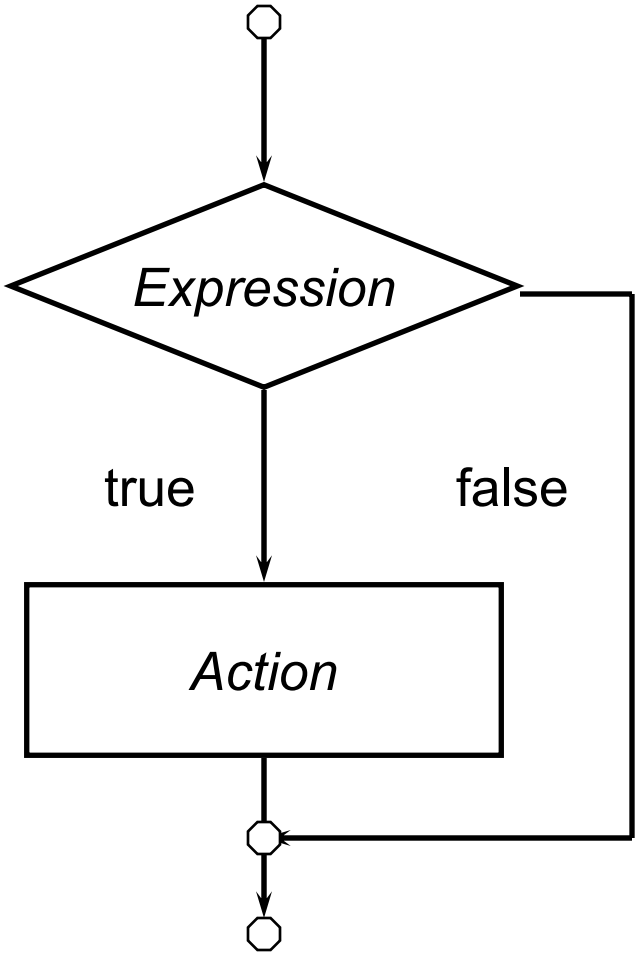
- Provide
  - Ability to control whether a statement list is executed
- Two constructs
  - If statement
    - if
    - if-else
    - if-else-if
  - Switch statement

Basic if statement

- Syntax

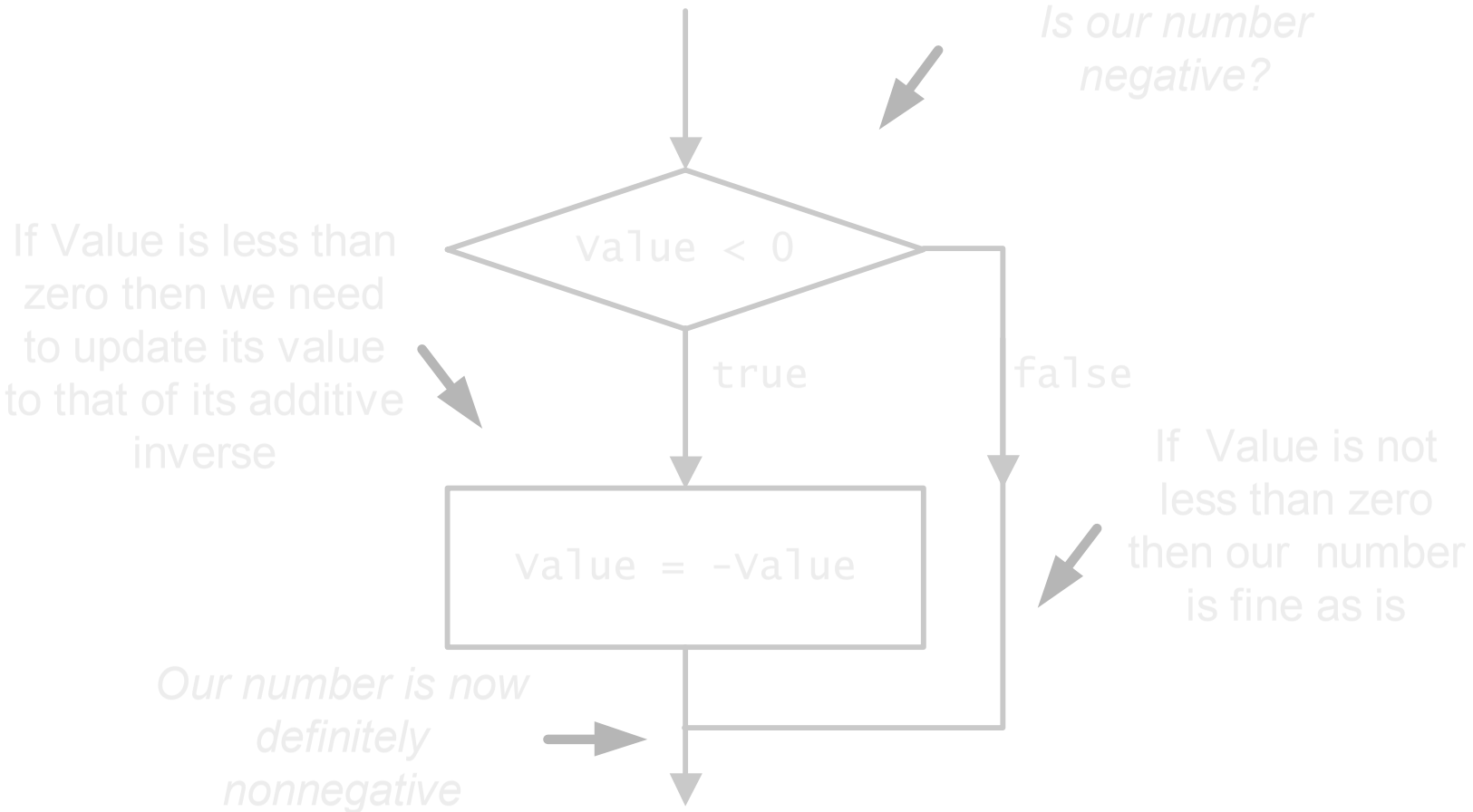
```
if (Expression)
    Action
```

- If the *Expression* is true then execute *Action*
- *Action* is either a single statement or a group of statements within braces
- For us, it will always be a group of statements within braces



Example

```
if (value < 0) {
   value = -value;
}
```



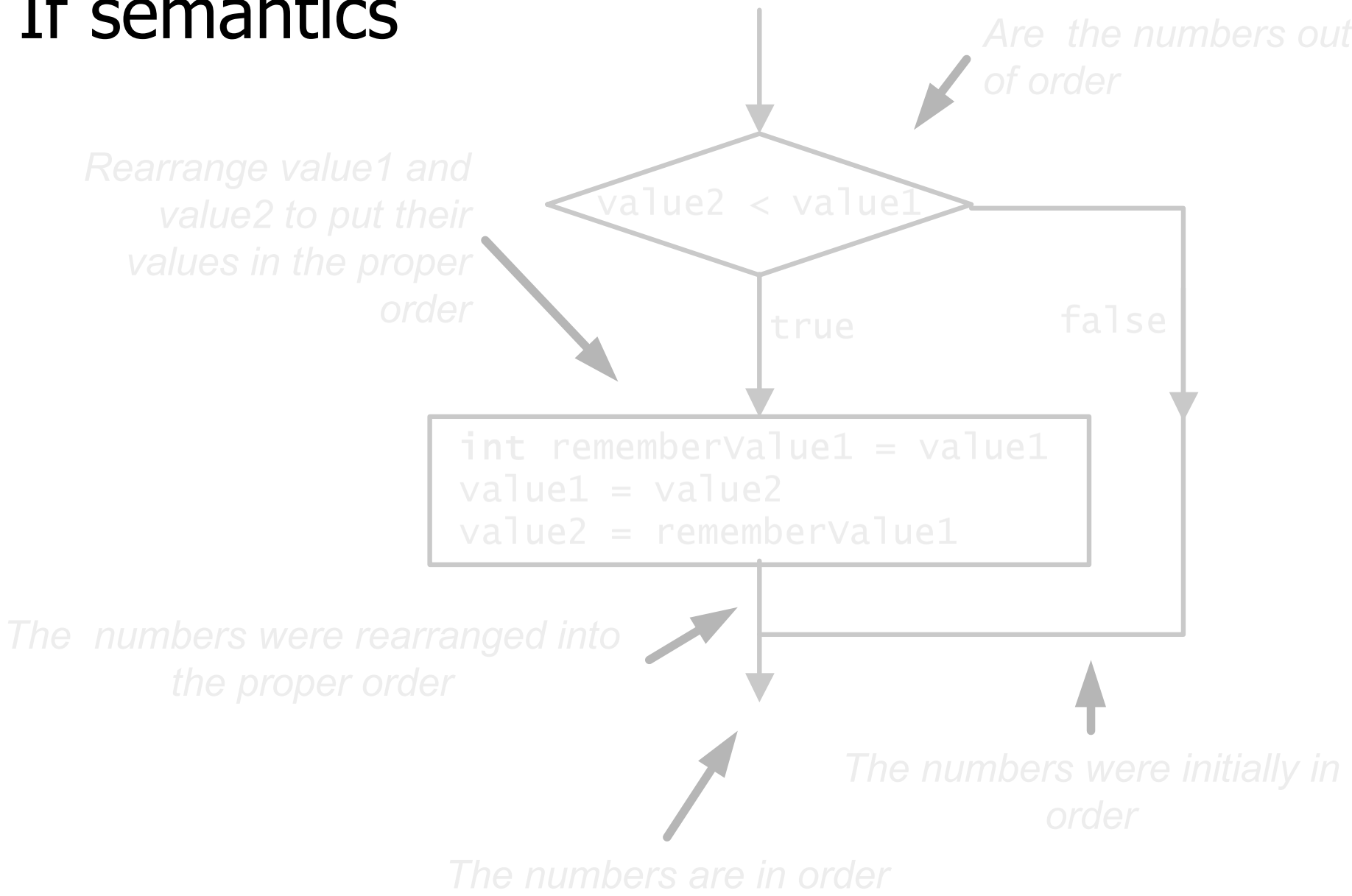
Sorting two values

```
System.out.print("Enter an integer number: ");
int value1 = stdin.nextInt());
System.out.print("Enter another integer number: ");
int value2 = stdin.nextInt());

// rearrange numbers if necessary
if (value2 < value1) {
    // values are not in sorted order
    int rememberValue1 = value1;
    value1 = value2;
    value2 = rememberValue1;
}

// display values
System.out.println("The numbers in sorted order are "
    + value1 + " and then " + value2);
```

What happens if the user enters 11 and 28?

What happens if the user enters 11 and 4?

If semantics



Why we always use braces

- What is the output?

```
int m = 5;
int n = 10;

if (m < n)
  ++m;
  ++n;

System.out.println(" m = " + m + " n = " + n);
```

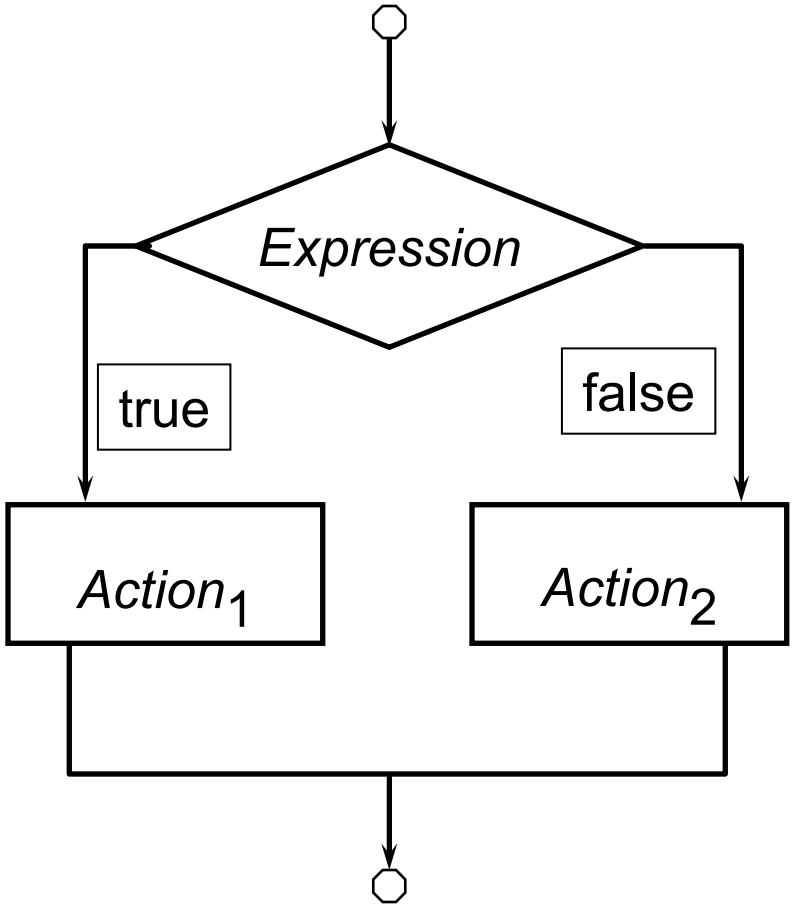
The if-else statement

- Syntax

  `if` (*Expression*)
  Action$_1$
  `else`
  Action$_2$

- If *Expression* is true then execute *Action*$_1$ otherwise execute *Action*$_2$

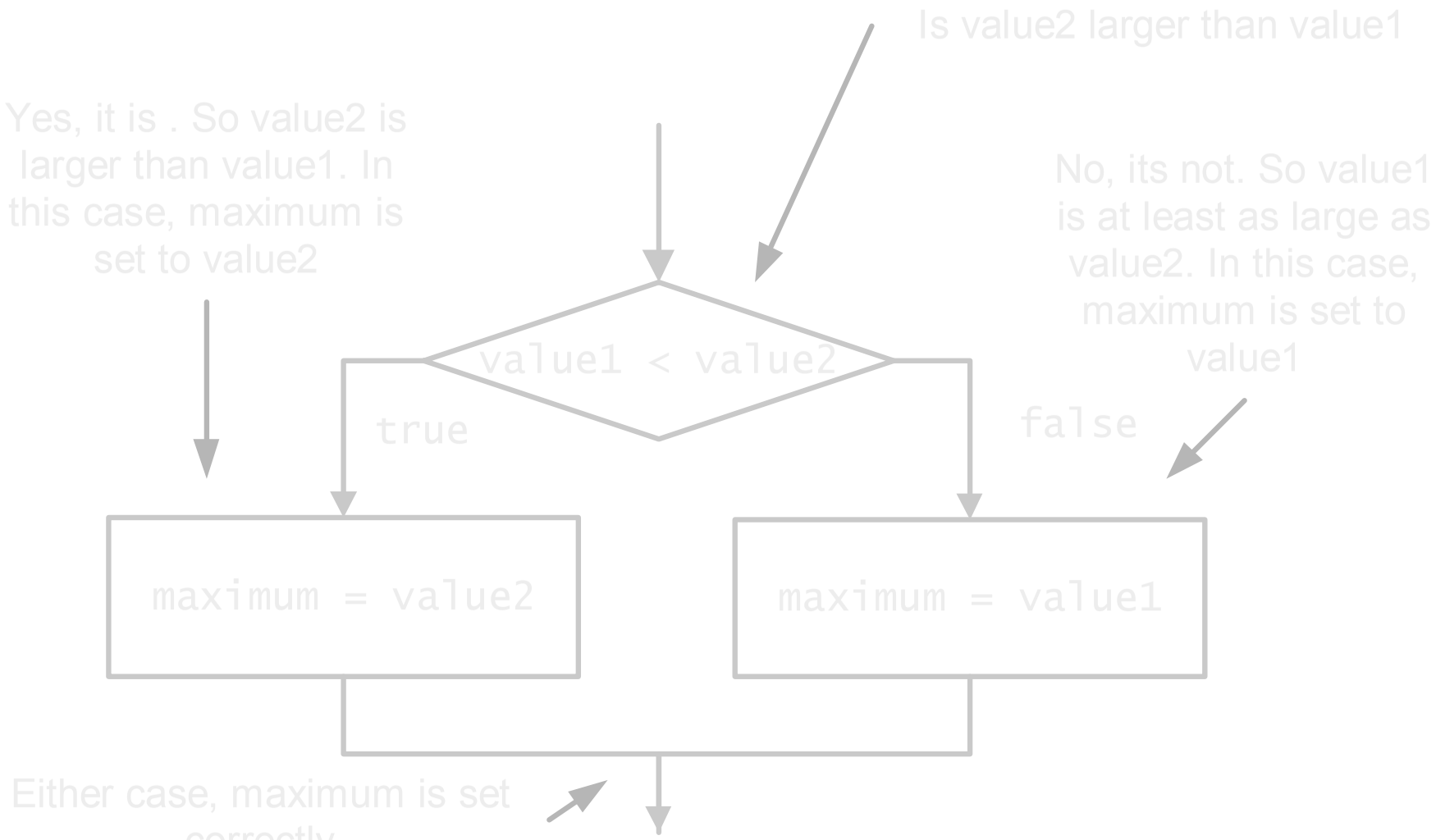
- The actions are either a single statement or a list of statements within braces



Finding the maximum of two values

```
System.out.print("Enter an integer number: ");
int value1 = stdin.nextInt();
System.out.print("Enter another integer number: ");
int value2 = stdin.nextInt();

int maximum;
if (value1 < value2) {   // is value2 larger?
   maximum = value2;     // yes: value2 is larger
}
else { // (value1 >= value2)
   maximum = value1;     // no: value2 is not larger
}
System.out.println("The maximum of " + value1
       + " and " + value2 + " is " + maximum);
```

Finding the maximum of two values



Why we use whitespace

- What does the following do?

```
System.out.print("Enter an integer number: ");
int value1 = stdin.nextInt();
System.out.print("Enter another integer number: ");
int value2 = stdin.nextInt());
if (value2 < value1) {
int rememberValue1 = value1;
value1 = value2;
value2 = rememberValue1;
}
System.out.println("The numbers in sorted order are "
+ value1 + " and then " + value2);
```

Testing objects for equality

- Consider

```
System.out.print("Enter an integer number: ");
int n1 = stdin.nextInt();
System.out.print("Enter another integer number: ");
int n2 = stdin.nextInt();

if (n1 == n2) {
   System.out.println("Same");
}
else {
   System.out.println(“Different");
}
```

What is the output if the user enters 88 both times?

What is the output if the user enters 88 and 3?

Testing objects for equality

- Consider

```
System.out.print("Enter a string: ");
String s1 = stdin.next();
System.out.print("Enter another string: ");
String s2 = stdin.next();

if (s1 == s2) {
   System.out.println("Same");
}
else {
   System.out.println("Different");
}
```

What is the output if the user enters "pastel" both times?

Testing objects for equality

- When it is executed

```
System.out.print("Enter a string: ");
String s1 = stdin.next();
System.out.print("Enter another string: ");
String s2 = stdin.next();
```

- Memory looks like

- As a result no matter what is entered s1 and s2 are not the same
  - They refer to different objects

Testing operators for equality

- Consider

```
System.out.print("Enter a string: ");
String s1 = stdin.next();
System.out.print("Enter another string: ");
String s2 = stdin.next();

if (s1.equals(s2)) {
   System.out.println("Same");
}
else {
   System.out.println("Different");
}
```

Tests whether s1 and s2 represent the same object

All objects have a method equals(). Their implementation is class-specific. The String equals() method – like many others – tests for equivalence in representation

Some handy String class methods

- isDigit()
  - Tests whether character is numeric
- isLetter()
  - Tests whether character is alphabetic
- isLowerCase()
  - Tests whether character is lowercase alphabetic
- isWhiteSpace()
  - Tests whether character is one of the space, tab, formfeed, or newline characters

Some handy String class methods

- isUpperCase()
  - Tests whether character is uppercase alphabetic
- toLowerCase()
  - If the character is alphabetic then the lowercase equivalent of the character is returned; otherwise, the character is returned
- toUpperCase()
  - If the character is alphabetic then the uppercase equivalent of the character is returned; otherwise, the character is returned

If-else-if

- Consider

```
if (number == 0) {
   System.out.println("zero");
}
else {
   if (number > 0) {
      System.out.println("positive");
   }
   else {
      System.out.println("negative");
   }
}
```

If-else-if

- Better

```
if (number == 0) {
   System.out.println("zero");
}
else if (number > 0) {
   System.out.println("positive");
}
else {
   System.out.println("negative");
}
```

Same results as previous segment – but this segment better expresses the meaning of what is going on

Sorting three values

- For sorting values n1, n2, and n3 there are six possible orderings
  - $n1 \leq n2 \leq n3$
  - $n1 \leq n3 \leq n2$
  - $n2 \leq n1 \leq n3$
  - $n2 \leq n3 \leq n1$
  - $n3 \leq n1 \leq n2$
  - $n3 \leq n2 \leq n1$

- Suppose s1, s2, s3 are to made a sorted version of n1, n2, and n3

Sorting three values

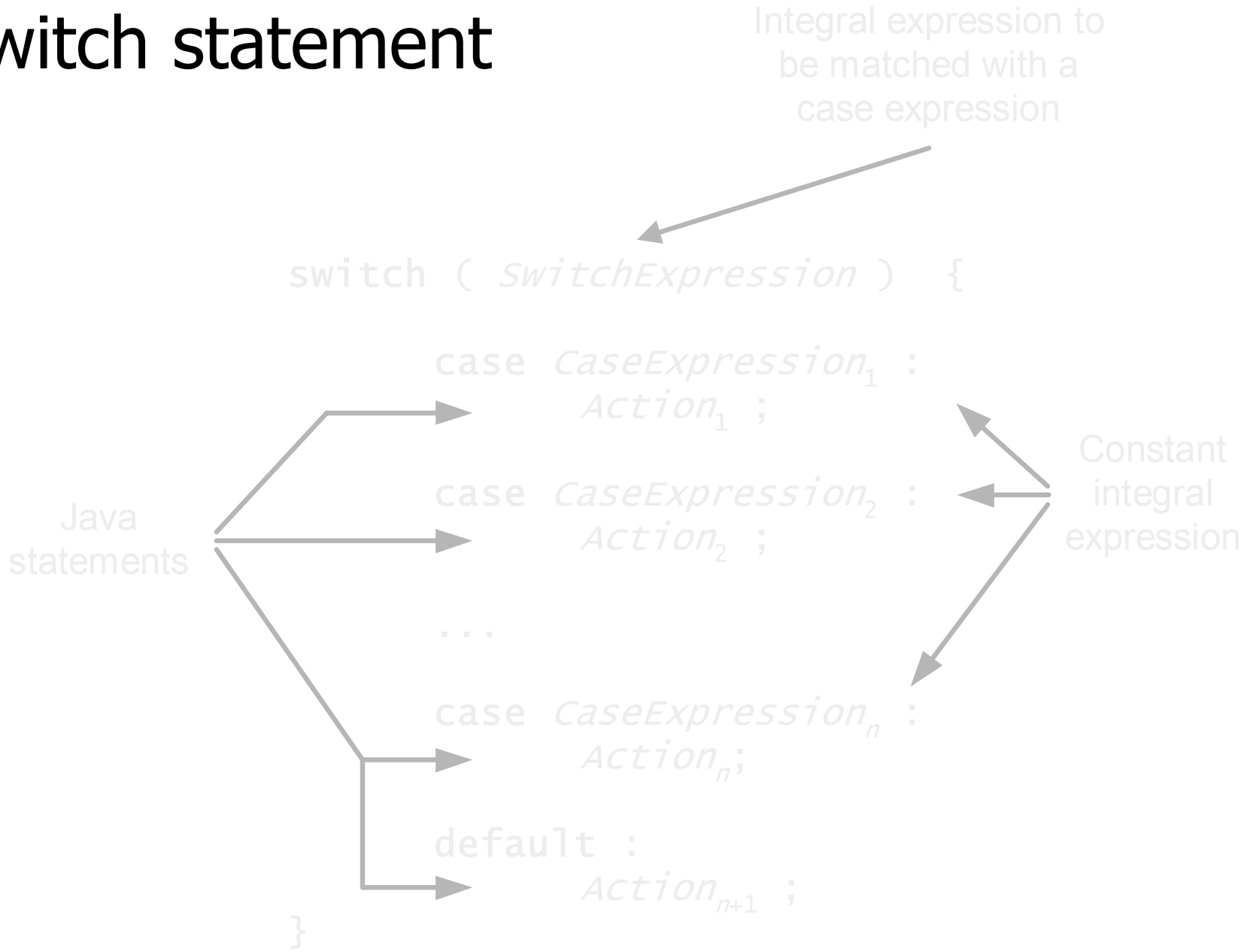
```
if ((n1 <= n2) && (n2 <= n3)) {       // n1 <= n2 <= n2
    s1 = n1;   s2 = n2;   s3 = n3;
}
else if ((n1 <= n3) && (n3 <= n2)) { // n1 <= n3 <= n2
    s1 = n1;   s2 = n3;   s3 = n2;
}
else if ((n2 <= n1) && (n1 <= n3)) { // n2 <= n1 <= n3
    s1 = n2;   s2 = n1;   s3 = n3;
}
else if ((n2 <= n3) && (n3 <= n1)) { // n2 <= n3 <= n1
    s1 = n2;   s2 = n3;   s3 = n1;
}
else if ((n3 <= n1) && (n1 <= n2)) { // n3 <= n1 <= n2
    s1 = n3;   s2 = n1;   s3 = n2;
}
else { // n3 <= n2 <= n1
    s1 = n3;   s2 = n2;   s3 = n1;
}
```

Switch statement

- Software engineers often confronted with programming tasks where required action depends on the values of integer expressions
  - The if-else-if construct can be used
    - Separately compare the desired expression to a particular value
      - If the expression and value are equal, then perform the appropriate action

- Because such programming tasks occur frequently
  - Java includes a switch statement
    - The task is often more readable with the switch then with the if-else-if

Switch statement



Testing for vowel-ness

```
switch (ch) {
  case 'a': case 'A':
  case 'e': case 'E':
  case 'i': case 'I':
  case 'o': case 'O':
  case 'u': case 'U':
      System.out.println("vowel“);
      break;
  default:
      System.out.println("not a vowel“);
}
```

The break causes an exiting of the switch

Handles all of the other cases

Processing a request

```
System.out.print("Enter a number: ");
int n1 = stdin.nextInt();

System.out.print("Enter another number: ");
int n2 = stdin.nextInt();

System.out.print("Enter desired operator: ");
char operator = stdin.next().charAt(0);

switch (operator) {
   case '+' : System.out.println(n1 + n2); break;
   case '-' : System.out.println(n1 - n2); break;
   case '*' : System.out.println(n1 * n2); break;
   case '/' : System.out.println(n1 / n2); break;
   default: System.out.println(“Illegal request“);
}
```

Short-circuit evaluation

- The value of a logical expression can be known before all the operands have been considered
  - If left operand of && is false, then the value must be false
  - If right operand of || is true, then the value must be true

- Java uses these properties to make logical operations efficient
  - Evaluates left operand before it evaluates right operand
  - If the operator value is determined from the left operand, then the right operand is not evaluated
    - The operation is short-circuited

Short-circuit evaluation

- Short-circuit evaluation is useful when some property must be true for some other expression to be evaluated

- Suppose you are interested in knowing whether scoreSum divided by nbrScores is greater than value
  - The condition can be evaluated only if nbrScores is nonzero

- The following expression correctly represents the condition

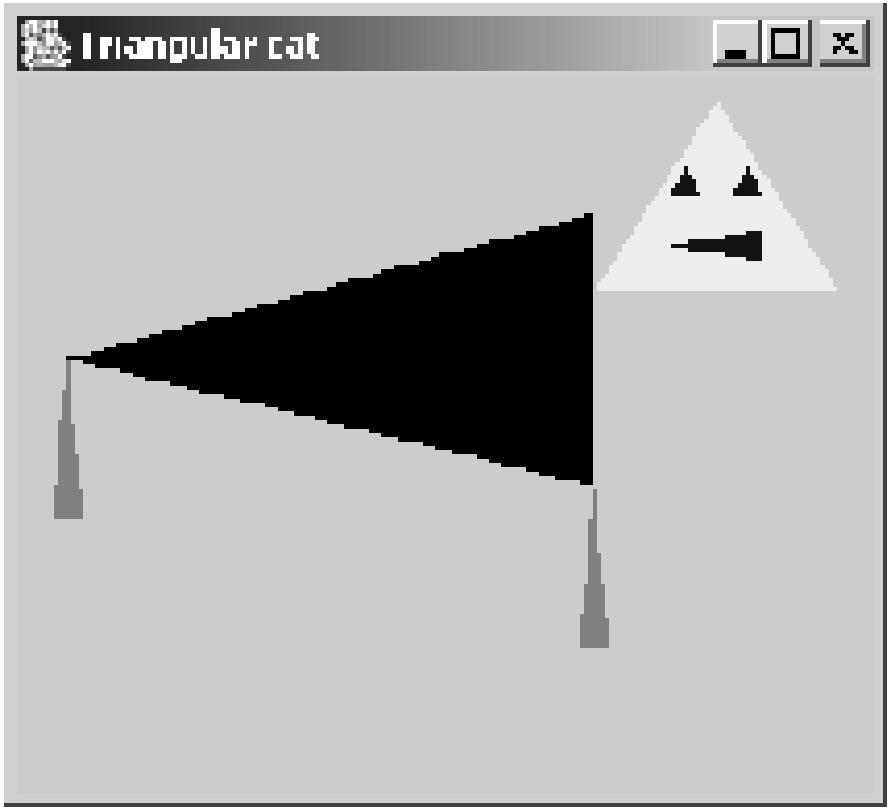
  (nbrScores != 0) && ((scoreSum / nbrScores) > value)

ColoredTriangle

- Background
  - Triangles are an important shape in the world of computer graphics
  - When computer animations are created, scenes are typically decomposed into a collection of colored triangles

- Informal specification
  - Represent a colored triangle in two-dimensional space
  - Provide the constructors and methods a reasonable user would expect

ColoredTriangle – see the cat



ColoredTriangle – expected constructors

- Default construction
  - Construct a reasonable triangle representation even though no explicit attributes values are given

    public ColoredTriangle()

- Specific construction
  - Construct a triangle representation from explicit attributes values

    public ColoredTriangle(Point v1, Point v2, Point v3,
    Color c)

ColoredTriangle – expected behaviors

- Provide the area
  - Return the area of the associated triangle

    public double getArea()

- Provide the perimeter
  - Return the perimeter of the associated triangle

    public double getPerimeter()

- Access an endpoint
  - Provide a requested endpoint of the associated triangle

    public Point getPoint(int i)

ColoredTriangle – expected behaviors

- Access the color
  - Provide the color of the associated triangle

    public Point getColor()

- Set an endpoint
  - Set a particular endpoint point of the associated triangle to a given value

    public void setPoint(int i, Point p)

- Set color of the triangle
  - Set the color of the associated triangle to a given value

    public void setColor(Color c)

ColoredTriangle – expected behaviors

- Render
  - Draw the associated triangle in a given graphical context

    public void paint(Graphics g)

- Test equality
  - Report whether the associated triangle is equivalent to a given triangle

    public boolean equals(Object v)

- String representation
  - Provide a textual representation of the attributes of the associated triangle

    public String toString()

ColoredTriangle – attributes

- To implement the behaviors
  - Knowledge of the triangle color and three endpoints suffices
  - Endpoint can be represented using two int values per location or as a Point
    - Point seem more natural

  private Color color
    - Color of the associated triangle

  private Point p1
    - References the first point of the associated triangle

  private Point p2
    - References the second point of the associated triangle

  private Point p3
    - References the third point of the associated triangle

Default constructor – implementation

```
// ColoredTriangle(): default constructor
public ColoredTriangle() {
  Point a = new Point(1, 1);
  Point b = new Point(2, 2);
  Point c = new Point(3, 3);
  setPoint(1, a);
  setPoint(2, b);
  setPoint(3, c);
  setColor(Color.BLACK);
}
```

Create endpoint values

Copy desired endpoint values to data fields

Copy desired color to data fields

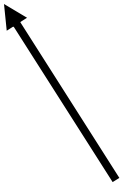
Implementation – accessor getPoint()

```
// getPoint(): endpoint accessor
public Point getPoint(int i) {
    if (i == 1) {
        return p1;
    }
    else if (i == 2) {
        return p2;
    }
    else if (i == 3) {
        return p3;
    }
    else {
        System.output.println("Unexpected endpoint access: “
                                        + i);
        System.exit(i);
        return null;
    }
}
```

Won’t be executed but compiler wants every execution path to end with a return

Implementation – facilitator toString()

```
// toString(): string facilitator
public String toString() {
    Point v1 = getPoint(1);
    Point v2 = getPoint(2);
    Point v3 = getPoint(3);
    Color c = getColor();

    return "ColoredRectangle[" + v1 + ", " + v2 + ", " + v3
                              + ", " + c + "]";
}
```



Standard to include class name
when expected use is for debugging

Implementation – facilitator toString()

```
Point a = new Point(2,1),
Point b = new Point(1,2)
Point c = new Point(3,2);
ColoredTriangle u = new ColoredTriangle(a, b, c, Color.RED);
System.out.println(u);  // displays string version of u

ColoredTriangle[java.awt.Point[x=2,y=1],
    java.awt.Point[x=1,y=2], java.awt.Point[x=3,y=2],
    java.awt.Color[r=255,g=0,b=0]]
```

Implementation – facilitator equals()

```
// equals(): equals facilitator
public boolean equals(Object p) {
    if (p instanceof ColoredTriangle) {
        Point v1 = getPoint(1);
        Point v2 = getPoint(2);
        Point v3 = getPoint(3);
        Color c = getColor();
        ColoredTriangle t = (ColoredTriangle) p;

        return v1.equals(t.getPoint(1))
               && v2.equals(t.getPoint(2))
               && v3.equals(t.getPoint(3))
               && c.equals(t.getColor());
        }
    else {
        return false;
    }
}
```

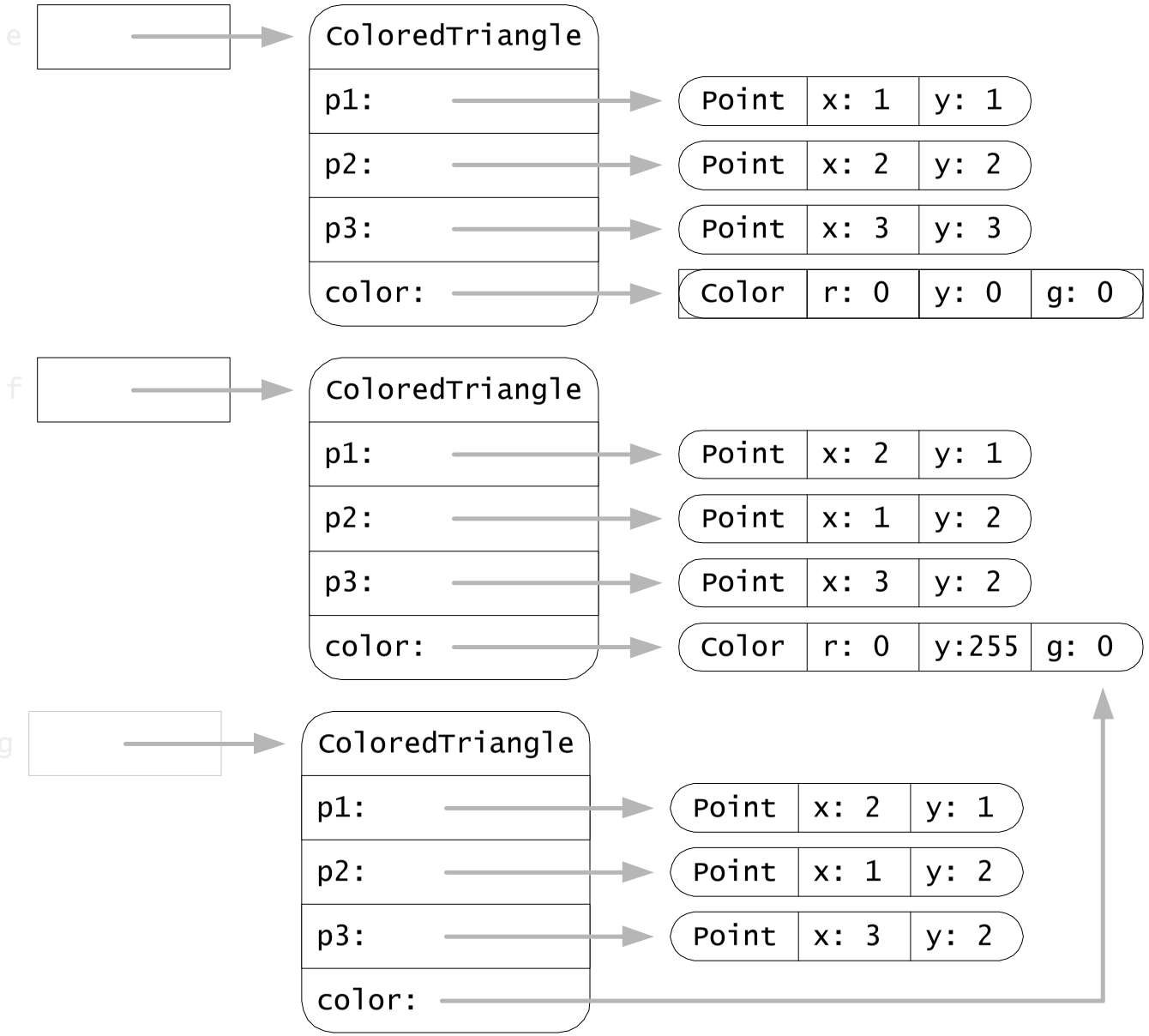
Because its an override the parameter type is Object

instanceof tests whether left operand is an instance of right operand

Implementation – facilitator equals()

```
ColoredTriangle e = new ColoredTriangle();
ColoredTriangle f = new ColoredTriangle(new Point(2,1),
       new Point(1,2), new Point(3,2), Color.YELLOW);
ColoredTriangle g = new ColoredTriangle(new Point(2,1),
       new Point(1,2), new Point(3,2), Color.YELLOW);

boolean flag1 = e.equals(f);
boolean flag2 = e.equals(g);
boolean flag2 = e.equals(g);

System.out.println(flag1 + " " + flag2 + " "  + flag3);
```

Implementation – facilitator equals()



Implementation – facilitator paint()

```
// paint(): render facilitator
public void paint(Graphics g) {
    Point v1 = getPoint(1);
    Point v2 = getPoint(2);
    Point v3 = getPoint(3);
    Color c = getColor();

    g.setColor(c);

    Polygon t = new Polygon();
    t.addPoint(v1.x, v1.y);
    t.addPoint(v2.x, v2.y);
    t.addPoint(v3.x, v3.y);

    g.fillPolygon(t);
}
```

Part of awt

Renders a polygon using the list of points in the polygon referenced by t

Iteration

Java looping

- Options
  - while
  - do-while
  - for

- Allow programs to control how many times a statement list is executed

Averaging

- Problem
  - Extract a list of positive numbers from standard input and produce their average
    - Numbers are one per line
    - A negative number acts as a *sentinel* to indicate that there are no more numbers to process
- Observations
  - Cannot supply sufficient code using just assignments and conditional constructs to solve the problem
    - Don’t how big of a list to process
  - Need ability to repeat code as needed

Averaging

- Problem
  - Extract a list of positive numbers from standard input and produce their average
    - Numbers are one per line
    - A negative number acts as a *sentinel* to indicate that there are no more numbers to process
- Algorithm
  - Prepare for processing
  - Get first input
  - While there is an input to process do {
    - Process current input
    - Get the next input
  - }
  - Perform final processing

Averaging

- Problem
  - Extract a list of positive numbers from standard input and produce their average
    - Numbers are one per line
    - A negative number acts as a *sentinel* to indicate that there are no more numbers to process
- Sample run

```
Enter positive numbers one per line.
Indicate end of list with a negative number.
4.5
0.5
1.3
-1
Average 2.1
```

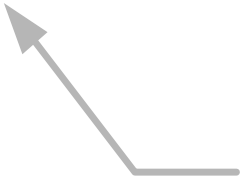
```
public class NumberAverage {
   // main(): application entry point
   public static void main(String[] args)
               throws IOException {
      // set up the list processing

      // prompt user for values

      // get first value

      // process values one-by-one
      while (value >= 0) {
            // add value to running total
            // processed another value
            // prepare next iteration - get next value
      }

      // display result
      if (valuesProcessed > 0)
            // compute and display average
      else
            // indicate no average to display
   }
}
```

```
System.out.println("Enter positive numbers 1 per line.\n"
  + "Indicate end of the list with a negative number.");

Scanner stdin = new Scanner(System.in);

int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

While syntax and semantics

```
while ( Expression ) Action
```

Logical expression that determines whether Action is to be executed — if Expression evaluates to true, then Action is executed; otherwise, the loop is terminated

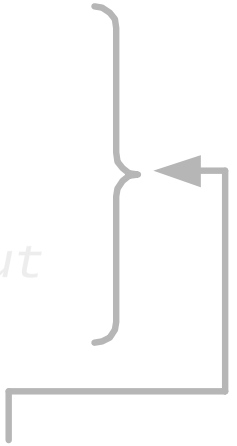


Action is either a single statement or a statement list within braces. The action is also known as the body of the loop. After the body is executed, the test expression is reevaluated. If the expression evaluates to true, the body is executed again. The process repeats until the test expression evaluates to false

While semantics for averaging problem

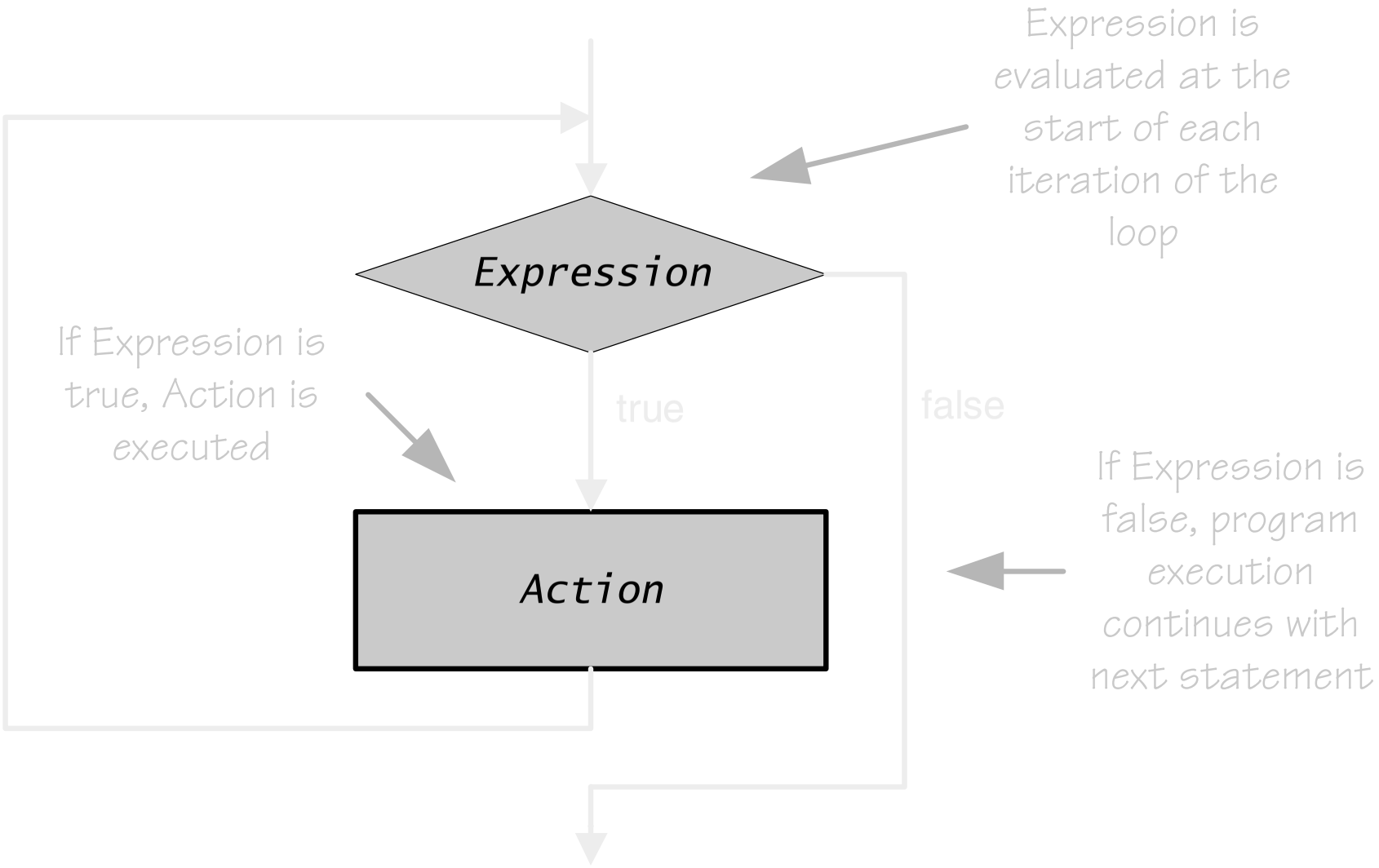
```
// process values one-by-one
while (value >= 0) {
    // add value to running total
    valueSum += value;
    // processed another value
    ++valuesProcessed;
    // prepare to iterate -- get the next input
    value = stdin.nextDouble());
}
```

Test expression is evaluated at the start of each iteration of the loop. Its value indicates whether there is a number to process



If test expression is true, these statements are executed. Afterward, the test expression is reevaluated and the process repeats

While Semantics



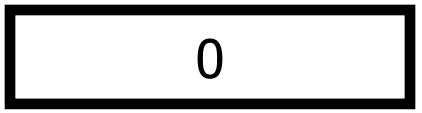
Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

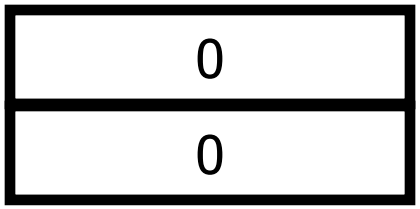
Suppose input contains: 4.5 0.5 1.3 -1




```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1




```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1


```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1


```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	0
valueSum	4.5
value	4.5

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1


```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1


```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	1
valueSum	4.5
value	0.5

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1


```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	2
valueSum	5.0
value	0.5

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	2
valueSum	5.0
value	1.3

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	2
valueSum	5.0
value	1.3

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	2
valueSum	6.3
value	1.3

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	3
valueSum	6.3
value	1.3

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	3
valueSum	6.3
value	-1

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

valuesProcessed	3
valueSum	6.3
value	-1

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

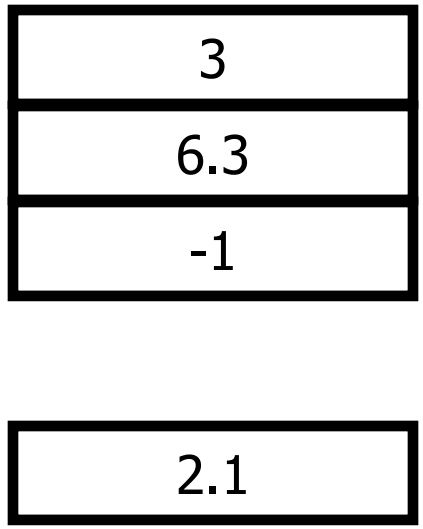
valuesProcessed	3
valueSum	6.3
value	-1

```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```

Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

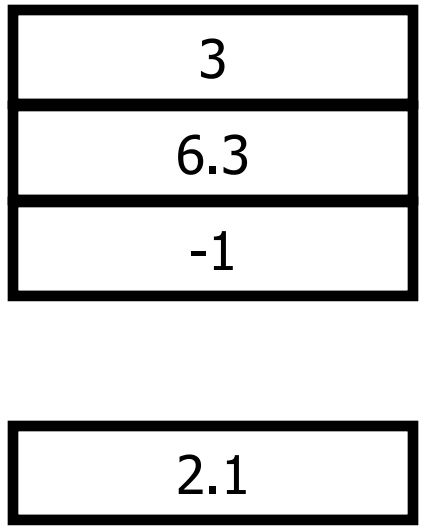
```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```



Execution Trace

Suppose input contains: 4.5 0.5 1.3 -1

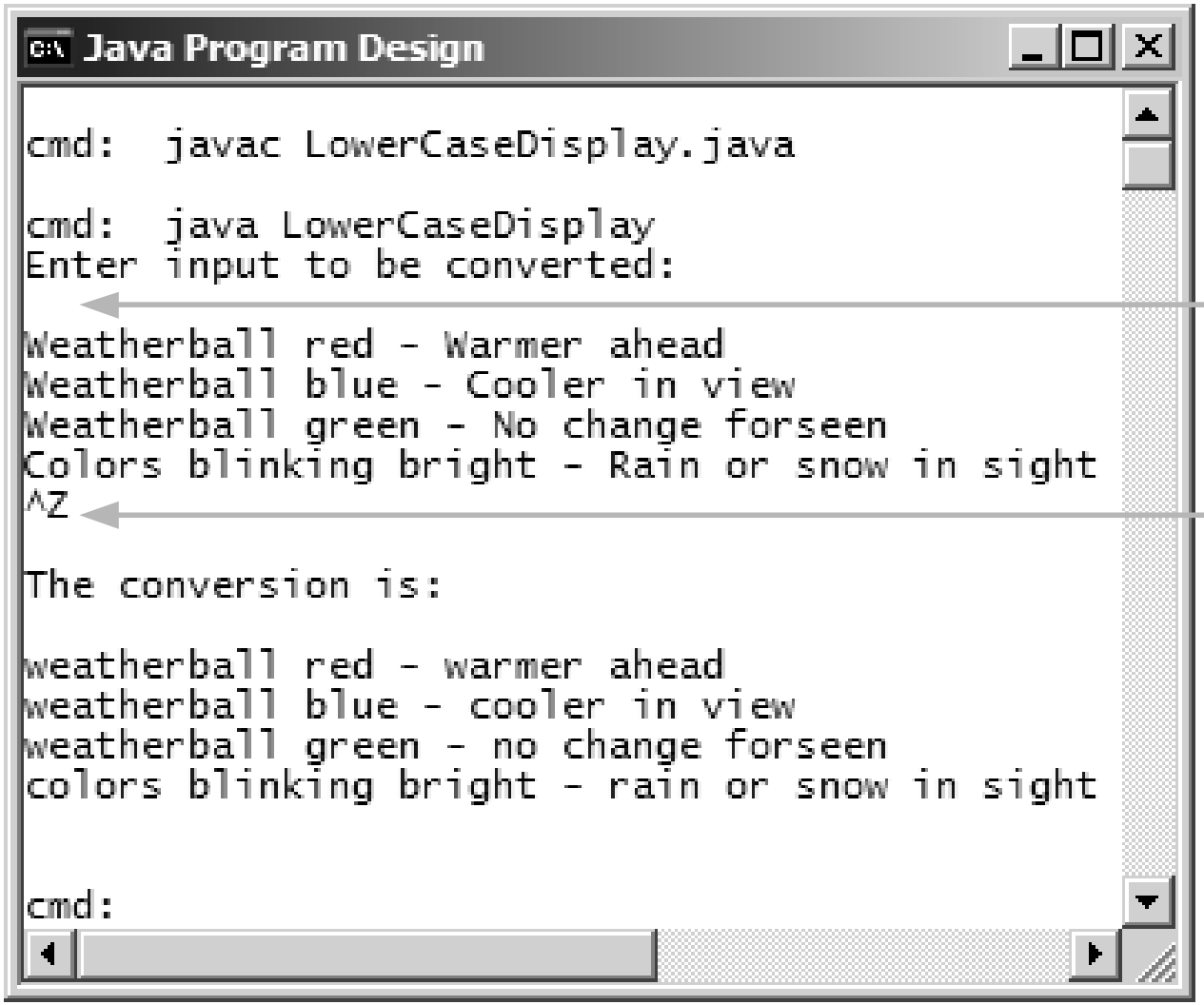
```
int valuesProcessed = 0;
double valueSum = 0;

double value = stdin.nextDouble());

while (value >= 0) {
   valueSum += value;
   ++valuesProcessed;
   value = stdin.nextDouble());
}

if (valuesProcessed > 0) {
   double average = valueSum / valuesProcessed;
   System.out.println("Average: " + average);
}
else {
   System.out.println("No list to average");
}
```



Converting text to strictly lowercase

```
public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);

   System.out.println("Enter input to be converted:");

   String converted = "";

   while (stdin.hasNext()) {
       String currentLine = stdin.nextLine();
       String currentConversion =
             currentLine.toLowerCase();
       converted += (currentConversion + "\n");
   }

   System.out.println("\nConversion is:\n" + converted);
}
```

Sample run



An empty line was entered

A Ctrl+z was entered. It is the Windows escape sequence for indicating end-of-file

Program trace

```
public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);

   System.out.println("Enter input to be converted:");

   String converted = "";

   while (stdin.hasNext()) {
       String currentLine = stdin.nextLine();
       String currentConversion =
             currentLine.toLowerCase();
       converted += (currentConversion + "\n");
   }

   System.out.println("\nConversion is:\n" + converted);
}
```

Program trace

```
public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);

   System.out.println("Enter input to be converted:");

   String converted = "";

   while (stdin.hasNext()) {
       String currentLine = stdin.nextLine();
       String currentConversion =
             currentLine.toLowerCase();
       converted += (currentConversion + "\n");
   }

   System.out.println("\nConversion is:\n" + converted);
}
```

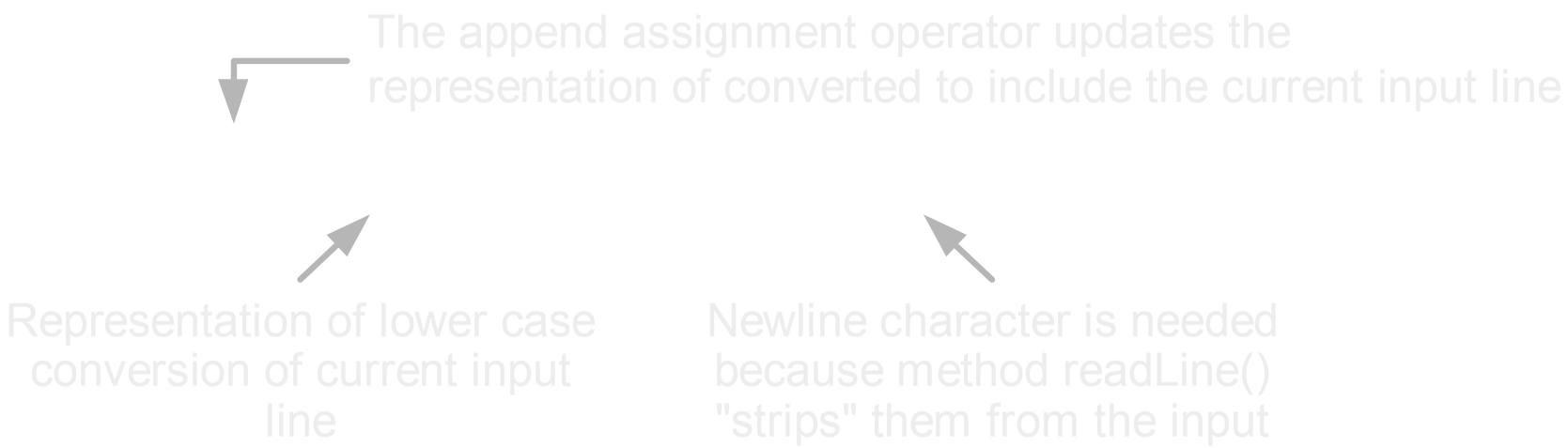
Program trace

```
public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);

   System.out.println("Enter input to be converted:");

   String converted = "";

   while (stdin.hasNext()) {
       String currentLine = stdin.nextLine();
       String currentConversion =
             currentLine.toLowerCase();
       converted += (currentConversion + "\n");
   }

   System.out.println("\nConversion is:\n" + converted);
}
```

Program trace

```
public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);

   System.out.println("Enter input to be converted:");

   String converted = "";

   while (stdin.hasNext()) {
       String currentLine = stdin.nextLine();
       String currentConversion =
             currentLine.toLowerCase();
       converted += (currentConversion + "\n");
   }

   System.out.println("\nConversion is:\n" + converted);
}
```

Program trace



Converting text to strictly lowercase

```
public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);

   System.out.println("Enter input to be converted:");

   String converted = "";

   while (stdin.hasNext()) {
       String currentLine = stdin.nextLine();
       String currentConversion =
             currentLine.toLowerCase();
       converted += (currentConversion + "\n");
   }

   System.out.println("\nConversion is:\n" + converted);
}
```

Loop design

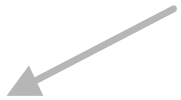
- Questions to consider in loop design and analysis
  - What initialization is necessary for the loop's test expression?
  - What initialization is necessary for the loop's processing?
  - What causes the loop to terminate?
  - What actions should the loop perform?
  - What actions are necessary to prepare for the next iteration of the loop?
  - What conditions are true and what conditions are false when the loop is terminated?
  - When the loop completes what actions are need to prepare for subsequent program processing?

Reading a file

- Background

Scanner provids a way to process text input

System.in is an InputStream variable. The stream contains text



```
Scanner stdin  = new Scaner(System.in));
```

Reading a file

- Class File
  - Provides a system-independent way of representing a file name

- Constructor File(String s)
  - Creates a File with name s
  - Name can be either an absolute pathname or a pathname relative to the current working folder

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Set up standard input stream

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Determine file name

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Determine the associated file

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Set up file stream

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Process lines one by one

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Is there any text

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Get the next line of text

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Display current line

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Make sure there is another to process
If not, loop is done

Reading a file

```
Scanner stdin = new Scanner(System.in);

System.out.print("Filename: ");
String filename = stdin.next();

File file = new File(filename);

Scanner fileIn = new Scanner(file);


while (fileIn.hasNext()) {
   String currentLine = fileIn.nextLine();
   System.out.println(currentLine);
}

fileIn.close();
```

Close the stream

The For Statement

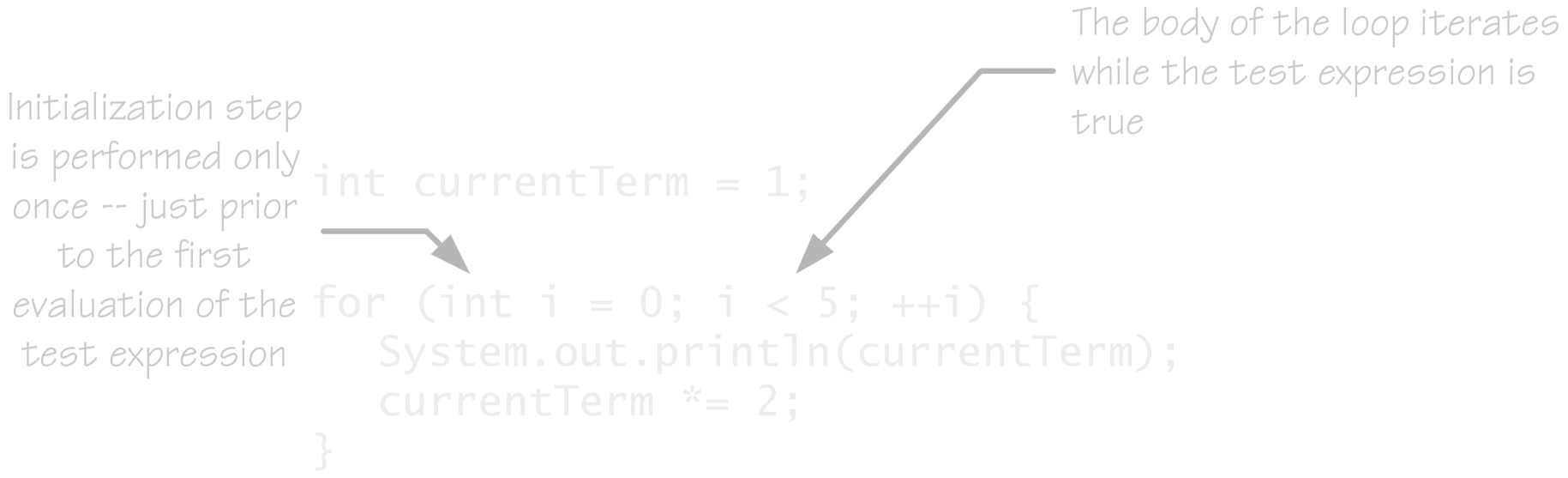
```
int currentTerm = 1;


for (int i = 0; i < 5; ++i) {
   System.out.println(currentTerm);
   currentTerm *= 2;
}
```

The For Statement

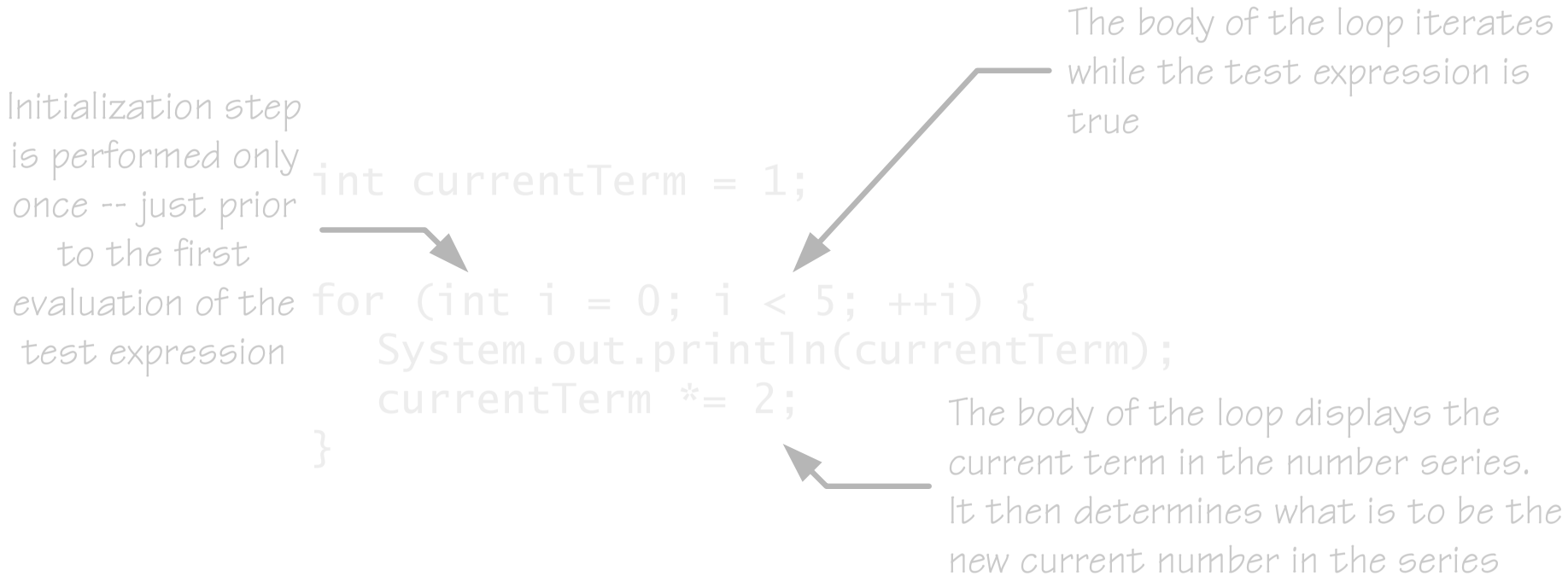
Initialization step is performed only once -- just prior to the first evaluation of the test expression

```
int currentTerm = 1;

for (int i = 0; i < 5; ++i) {
    System.out.println(currentTerm);
    currentTerm *= 2;
}
```

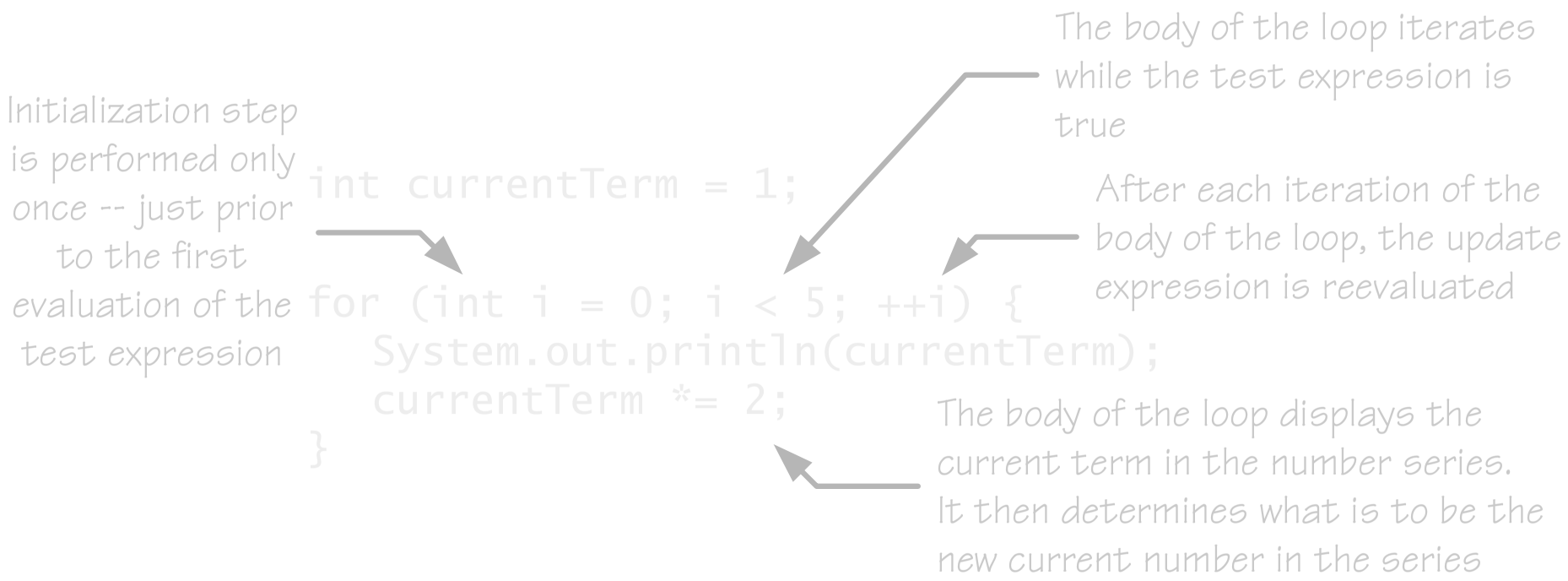
The For Statement

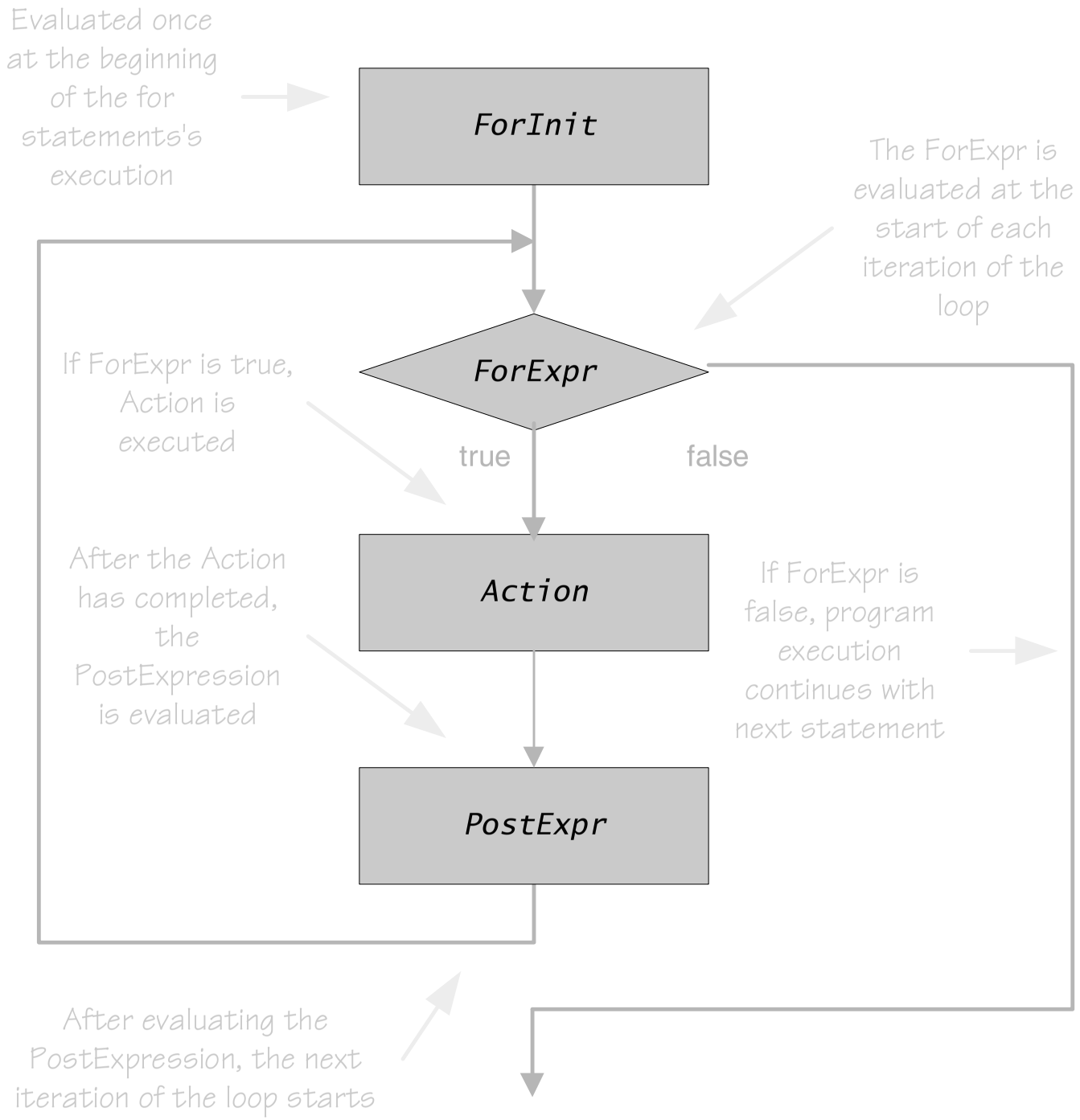


The For Statement

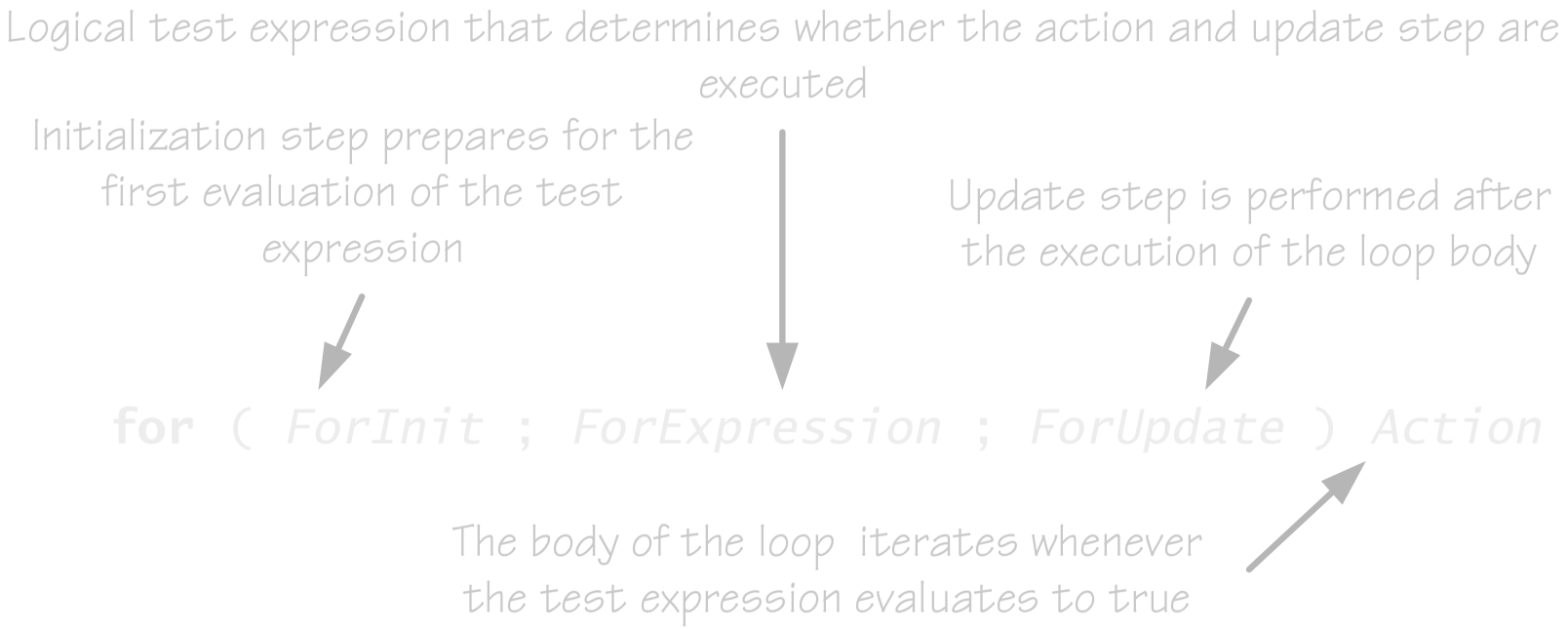


The For Statement



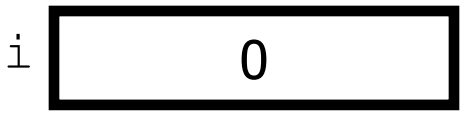

Evaluated once at the beginning of the for statements's execution
ForInit
The ForExpr is evaluated at the start of each iteration of the loop
If ForExpr is true, Action is executed
ForExpr
true
false
After the Action has completed, the PostExpression is evaluated
Action
If ForExpr is false, program execution continues with next statement
PostExpr
After evaluating the PostExpression, the next iteration of the loop starts

For statement syntax



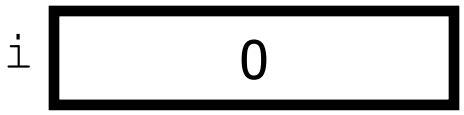
Execution Trace

```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```



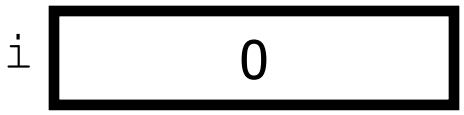
Execution Trace

```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```



Execution Trace

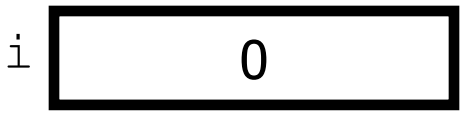
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
```

Execution Trace

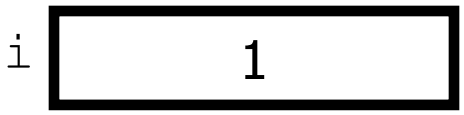
```
for (int i = 0; i < 3; ++i) {
   System.out.println(“i is " + i);
}

System.out.println(“all done");
```




```
i is 0
```

Execution Trace

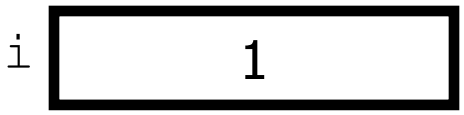
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
```

Execution Trace

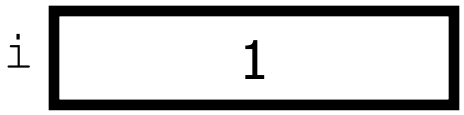
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
```

Execution Trace

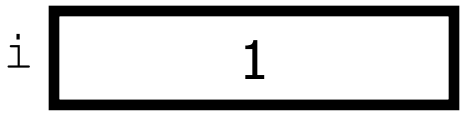
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
```

Execution Trace

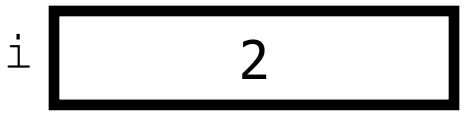
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
```

Execution Trace

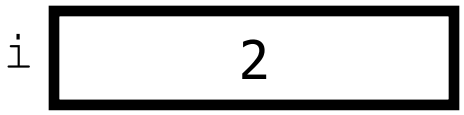
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
```

Execution Trace

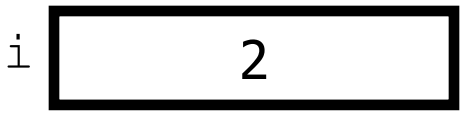
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
```

Execution Trace

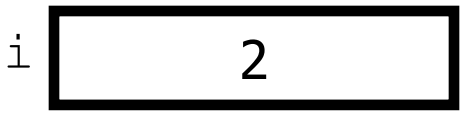
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
i is 2
```

Execution Trace

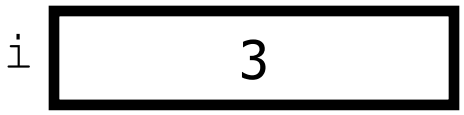
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
i is 2
```

Execution Trace

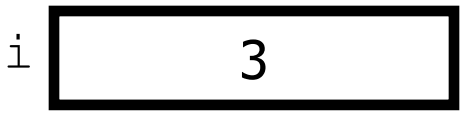
```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
i is 2
```

Execution Trace

```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```




```
i is 0
i is 1
i is 2
```

Execution Trace

```
for (int i = 0; i < 3; ++i) {
   System.out.println("i is " + i);
}

System.out.println("all done");
```

3

```
i is 0
i is 1
i is 2
all done
```

Variable i has gone out of scope – it is *local* to the loop

Nested loops

```
int m = 2;
int n = 3;
for (int i = 0; i < n; ++i) {
   System.out.println("i is " + i);
   for (int j = 0; j < m; ++j) {
       System.out.println("   j is " + j);
   }
}
```

Nested loops

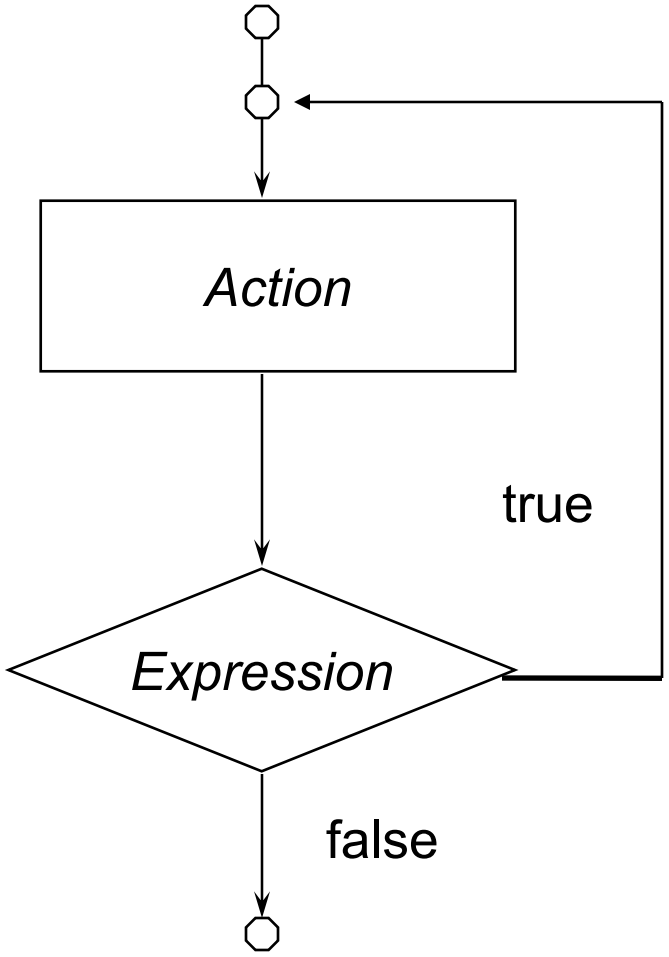
```
int m = 2;
int n = 3;
for (int i = 0; i < n; ++i) {
   System.out.println("i is " + i);
   for (int j = 0; j < m; ++j) {
       System.out.println("   j is " + j);
   }
}
```

```
i is 0
   j is 0
   j is 1
i is 1
   j is 0
   j is 1
i is 2
   j is 0
   j is 1
```

The do-while statement

- Syntax

  do *Action*
  `while` (*Expression*)
- Semantics
  - Execute *Action*
  - If *Expression* is true then execute *Action* again
  - Repeat this process until *Expression* evaluates to false
- *Action* is either a single statement or a group of statements within braces



Picking off digits

- Consider

```
System.out.print("Enter a positive number: ");
int number = stdin.nextInt());
do {
   int digit = number % 10;
   System.out.println(digit);
   number = number / 10;
} while (number != 0);
```

- Sample behavior

```
Enter a positive number: 1129
9
2
1
1
```

Problem solving

Internet per 100 people for 189 entities

0.09	0.16	8.97	0.23	6.52	6.75	1.42	13.65	34.45
0.16	4.32	5.84	0.08	3.74	1.78	22.89	6.24	0.25
1.44	1.01	1.54	2.94	9.14	5.28	0.08	0.07	0.05
41.3	1.84	0.04	0.04	16.58	1.74	38.64	13.7	2.07
5.67	0.27	5.59	0.54	17.88	9.71	0.01	36.59	0.22
1.86	1.42	0.71	0.8	0.15	0.13	27.21	73.4	1.47
14.43	6.43	1.22	0.92	0.42	29.18	0.15	9.47	4.36
0.7	0.1	0.25	6.04	0.25	0.62	7.15	59.79	0.54
0.39	20.7	20.26	23.04	3.11	29.31	2.53	0.62	0.65
40.25	7.84	1.06	0.11	6.19	8.58	0.19	0.02	0.18
22.66	0.19	0.15	15.9	2.23	0.17	13.08	1.17	0.19
2.74	39.71	1.26	0.71	0.06	0.01	1.71	0.22	24.39
21.67	0.99	0.04	0.18	49.05	25.05	3.55	0.09	1.1
2.81	0.73	9.74	2.01	7.25	24.94	10.22	5.01	1.2
3.57	0.06	4.79	3.09	0.56	48.7	4.36	0.93	0.42
0.1	29.87	12.03	15.08	0.46	0.01	5.49	13.43	0.64
2.7	0.99	45.58	29.62	0.19	28.1	0.05	3.79	2.47
7.73	2.61	3.06	0.13	0.18	0.69	28.2	30.12	0.33
11.09	0.49	2.03	3.93	0.25	0.08	3.76	0.19	0.37
25.86	0.22	0.27	7.78	37.23	1.75	0.94	1.8	6.09
3.17	18.6	7.4	0.1	0.86	45.07	11.15	7.29	

Data set manipulation

- Often five values of particular interest
  - Minimum
  - Maximum
  - Mean
  - Standard deviation
  - Size of data set

- Let’s design a data set representation

What facilitators are needed?

Implication on facilitators

- public double getMinimum()
  - Returns the minimum value in the data set. If the data set is empty, then Double.NaN is returned, where Double.NaN is the Java double value representing the status not-a-number

- public double getMaximum()
  - Returns the maximum value in the data set. If the data set is empty, then Double.NaN is returned

Implication on facilitators

- public double getAverage()
  - Returns the average value in the data set. If the data set is empty, then Double.NaN is returned

- public double getStandardDeviation()
  - Returns the standard deviation value of the data set. If the data set is empty, then Double.NaN is returned

    - Left to the interested student

- public int getSize()
  - Returns the number of values in the data set being represented

What constructors are needed?

Constructors

- public DataSet()
  - Initializes a representation of an empty data set

- public DataSet(String s)
  - Initializes the data set using the values from the file with name s

- public DataSet(File file)
  - Initializes the data set using the values from the file
    - Left to interested student

Other methods

- public void addValue(double x)
  - Adds the value x to the data set being represented
- public void clear()
  - Sets the representation to that of an empty data set
- public void load(String s)
  - Adds the vales from the file with name s to the data set being represented
- public void load(File file)
  - Adds the vales from the file to the data set being represented
    - Left to interested student

What instance variables are needed?

Instance variables

- private int n
  - Number of values in the data set being represented
- private double minimumValue
  - Minimum value in the data set being represented
- private double maximumValue
  - Maximum value in the data set being represented
- private double xSum
  - The sum of values in the data set being represented

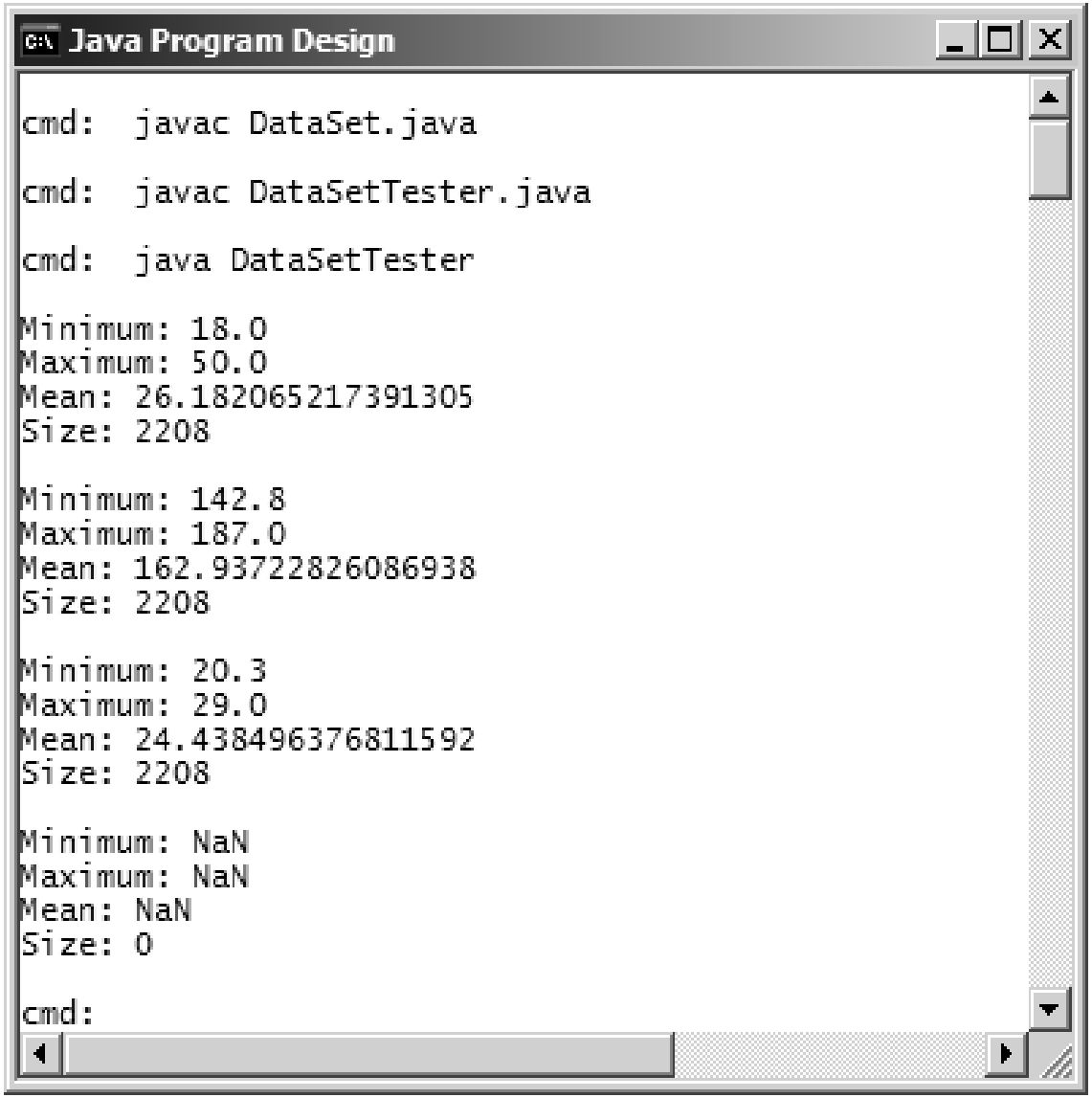
Example usage

```
DataSet dataset = new DataSet("age.txt");
System.out.println();
System.out.println("Minimum: " + dataset.getMinimum());
System.out.println("Maximum: " + dataset.getMaximum());
System.out.println("Mean: " + dataset.getAverage());
System.out.println("Size: " + dataset.getSize());
System.out.println();
dataset.clear();

dataset.load("stature.txt");
System.out.println("Minimum: " + dataset.getMinimum());
System.out.println("Maximum: " + dataset.getMaximum());
System.out.println("Mean: " + dataset.getAverage());
System.out.println("Size: " + dataset.getSize());
System.out.println();
dataset.clear();
```

Example usage

```
dataset.load("foot-length.txt");
System.out.println("Minimum: " + dataset.getMinimum());
System.out.println("Maximum: " + dataset.getMaximum());
System.out.println("Mean: " + dataset.getAverage());
System.out.println("Size: " + dataset.getSize());
System.out.println();
dataset.clear();

System.out.println("Minimum: " + dataset.getMinimum());
System.out.println("Maximum: " + dataset.getMaximum());
System.out.println("Mean: " + dataset.getAverage());
System.out.println("Size: " + dataset.getSize());
System.out.println();
```

Example usage



Methods getMinimum() and getMaximum()

- Straightforward implementations given correct setting of instance variables

```
public double getMinimum() {
        return minimumValue;
}

public double getMaximum() {
        return maximumValue;
}
```

Method getSize()

- Straightforward implementations given correct setting of instance variables

```
public int getSize() {
        return n;
}
```

Method getAverage()

- Need to take into account that data set might be empty

```
public double getAverage() {
        if (n == 0) {
                return Double.NaN;
        }
        else {
                return xSum / n;
        }
}
```

DataSet constructors

- Straightforward using clear() and load()

```
public DataSet() {
        clear();
}

public DataSet(String s) throws IOException {
        clear();
        load(s);
}
```

Facilitator clear()

```
public void clear() {
        n = 0;
        xSum = 0;
        minimumValue = Double.NaN;
        maximumValue = Double.NaN;
}
```

Facilitator add()

```
public void addValue(double x) {
      xSum += x;
      ++n;
      if (n == 1) {
            minimumValue = maximumValue = x;
      }
      else if (x < minimumValue) {
            minimumValue = x;
      }
      else if (x > maximumValue) {
            maximumValue = x;
      }
}
```

Facilitator load()

```
public void load(String s) throws IOException {
	// get a reader for the file
	Scanner fileIn = new Scanner( new File(s) );

	// add values one by one
	while (fileIn.hasNext()) {
		double x = fileIn.nextDouble);
		addValue(x);
	}

	// close up file
	fileIn.close();
}
```

Programming with methods and classes

Methods

- Instance method
  - Operates on a object (i.e., and *instance* of the class)

```
String s = new String("Help every cow reach its "
  + "potential!");
int n = s.length();
```

 Instance method

- Class method
  - Service provided by a class and it is not associated with a particular object

```
String t = String.valueOf(n);
```

 Class method

Data fields

- Instance variable and instance constants
  - Attribute of a particular object
  - Usually a variable

```
Point p = new Point(5, 5);
int px = p.x;
```

Instance variable

- Class variable and constants
  - Collective information that is not specific to individual objects of the class
  - Usually a constant

```
Color favoriteColor = Color.MAGENTA;
double favoriteNumber = MATH.PI - MATH.E;
```

Class constants

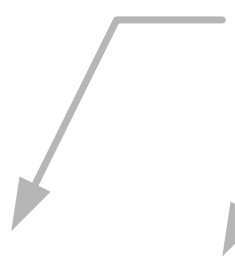
Task – Conversion.java

- Support conversion between English and metric values
  - 1 gallon = 3.785411784 liters
  - 1 mile = 1.609344 kilometers
  - d degrees Fahrenheit = (d – 32)/1.8 degrees Celsius
  - 1 ounce (avdp) = 28.349523125 grams
  - 1 acre = 0.0015625 square miles = 0.40468564 hectares

Conversion Implementation

```
public class Conversion {

  // conversion equivalencies
  private static final double
      LITERS_PER_GALLON = 3.785411784;


  private static final double
      KILOMETERS_PER_MILE = 1.609344;
  private static final double
      GRAMS_PER_OUNCE = 28.349523125;
  private static final double
      HECTARES_PER_ACRE = 0.40468564;
```

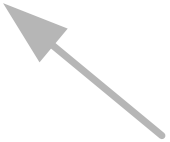
Conversion implementation



Modifier public indicates other classes can use the method

Modifier static indicates the method is a class method

```
public static double gallonsToLiters(double g) {
   return gallons * LITERS_PER_GALLON;
}
```



Observe there is no reference in the method to an attribute of an implicit Conversion object (i.e., a "this" object). This absence is a class method requirement. Class methods are invoked without respect to any particular object

Conversion Implementation

```
// temperature conversions methods
public static double fahrenheitToCelsius(double f) {
    return (f - 32) / 1.8;
}

public static double celsiusToFahrenheit(double c) {
    return 1.8 * c + 32;
}

// length conversions methods
public static double kilometersToMiles(double km) {
    return km / KILOMETERS_PER_MILE;
}
```

Conversion Implementation

```
// mass conversions methods
public static double litersToGallons(double liters) {
    return liters / LITERS_PER_GALLON;
}

public static double gallonsToLiters(double gallons) {
    return gallons * LITERS_PER_GALLON;
}

public static double gramsToOunces(double grams) {
    return grams / GRAMS_PER_OUNCE;
}

public static double ouncesToGrams(double ounces) {
    return ounces * GRAMS_PER_OUNCE;
}
```

Conversion Implementation

```
    // area conversions methods
    public static double hectaresToAcres(double hectares) {
        return hectares / HECTARES_PER_ACRE;
    }

    public static double acresToHectares(double acres) {
        return acres * HECTARES_PER_ACRE;
    }
}
```

Conversion use

Consider

```
Scanner stdin = new Scanner(System.in);

System.out.print("Enter number of gallons: ");

double liters = stdin.nextDouble();

double gallons = Conversion.litersToGallons(liters);

System.out.println(gallons + " gallons = "  + liters
  + " liters");
```

Produces

```
Number of gallons: 3.0
3.00 gallons  = 11.356235351999999 liters
```

A preferred Conversion use

Part of java.text

```
NumberFormat style = NumberFormat.getNumberInstance();

style.setMaximumFractionDigits(2);
style.setMinimumFractionDigits(2);

System.out.println(gallons + " gallons = "
   + style.format(liters) + " liters");
```

Rounds

```
3.0 gallons = 11.36 gallons
```

Method invocations

- Actual parameters provide information that is otherwise unavailable

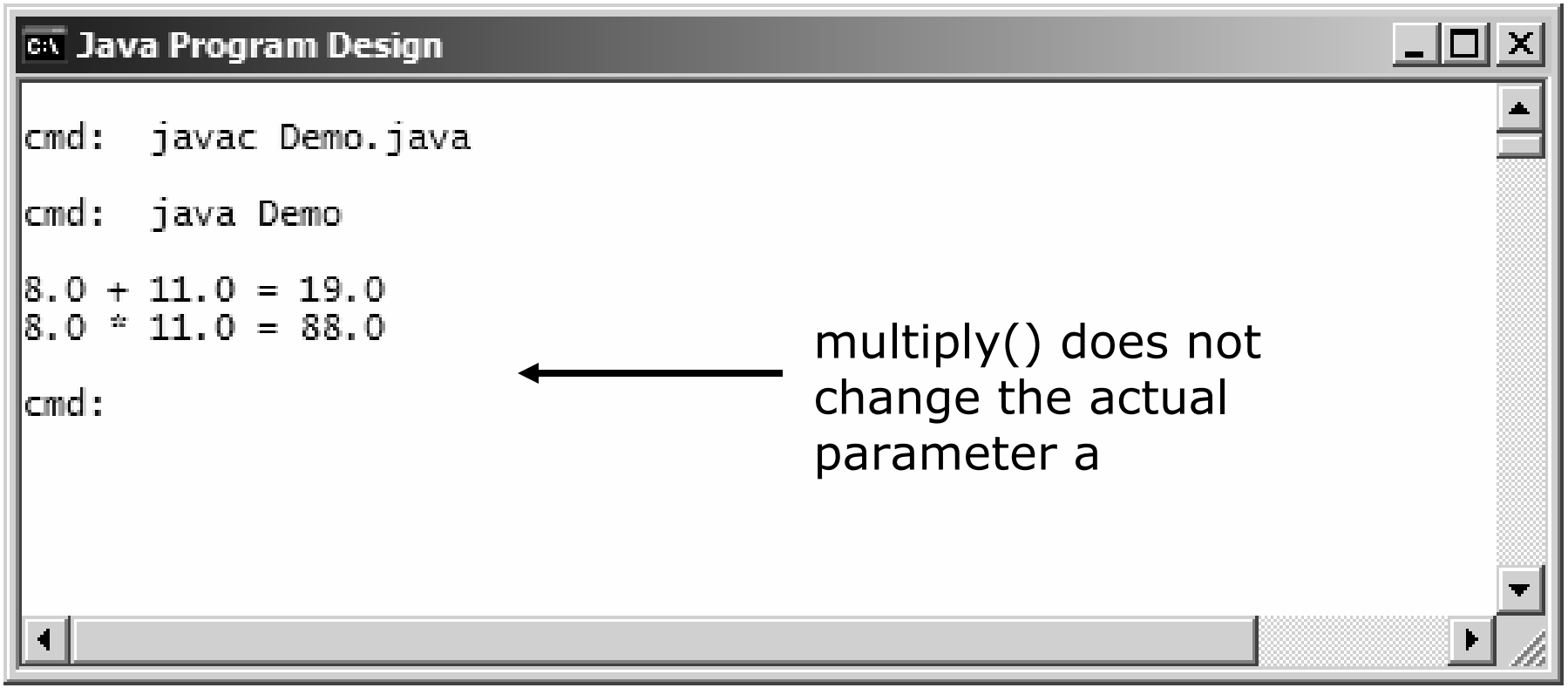
```
double gallons = Conversion.litersToGallons(liters);
```

- When a method is invoked
  - Java sets aside *activation record* memory for that particular invocation
    - Activation record stores, among other things, the values of the formal parameters and local variables
  - Formal parameters initialized using the actual parameters
    - After initialization, the actual parameters and formal parameters are independent of each other
  - Flow of control is transferred temporarily to that method

Value parameter passing demonstration

```
public class Demo {
   public static double add(double x, double y) {
        double result = x + y;
        return result;
   }

   public static double multiply(double x, double y) {
        x = x * y;
        return x;
   }

   public static void main(String[] args) {
        double a = 8;
        double b = 11;

        double sum = add(a, b);
        System.out.println(a + " + " + b + " = " + sum);

        double product = multiply(a, b);
        System.out.println(a + " * " + b + " = " + product);
   }
}
```

Value parameter passing demonstration

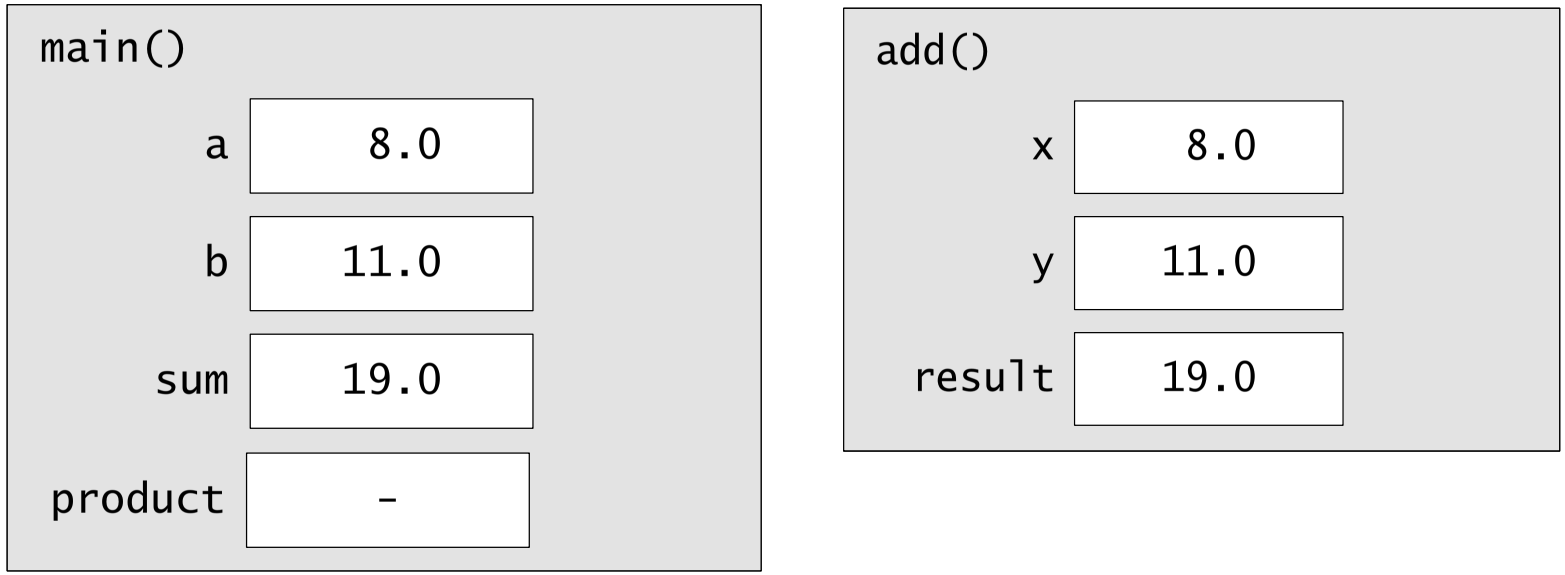


Demo.java walkthrough

```
double sum = add(a, b);
```

Initial values of formal parameters come from the actual parameters

```
public static double add(double x, double y) {
    double result = x + y
    return result;
}
```

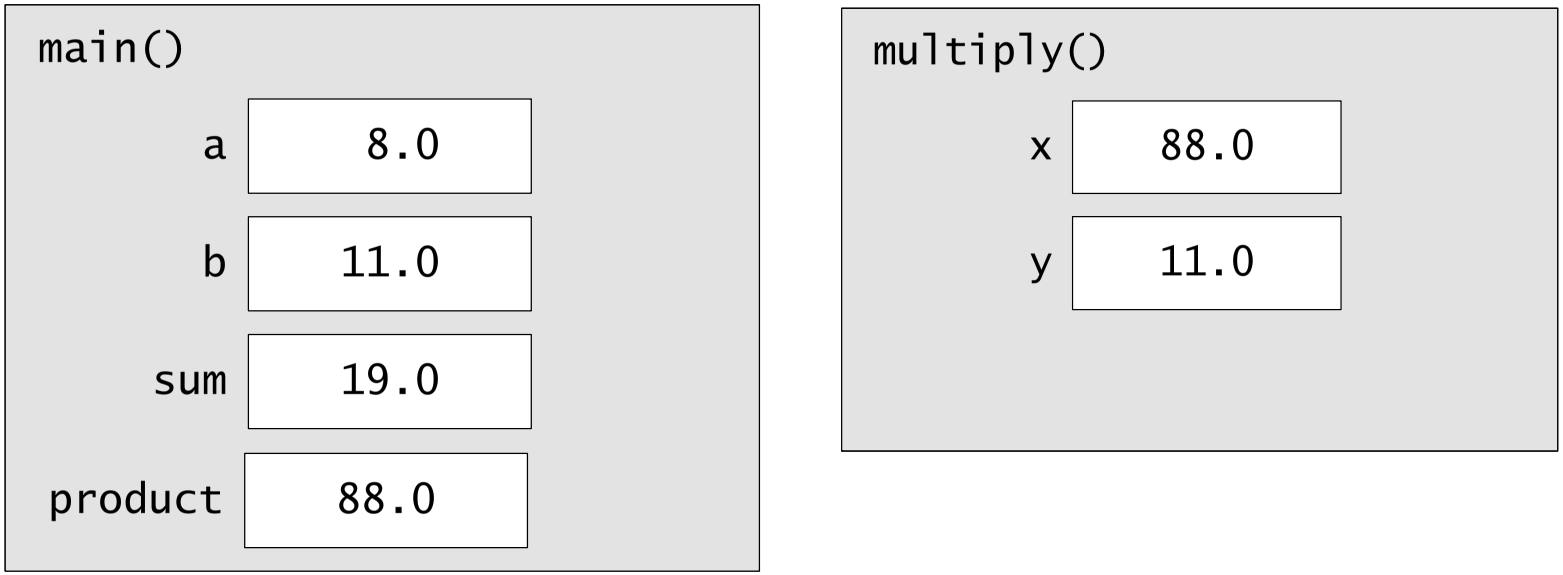


Demo.java walkthrough

```
double multiply = multiply(a, b);
```

Initial values of formal parameters come from the actual parameters

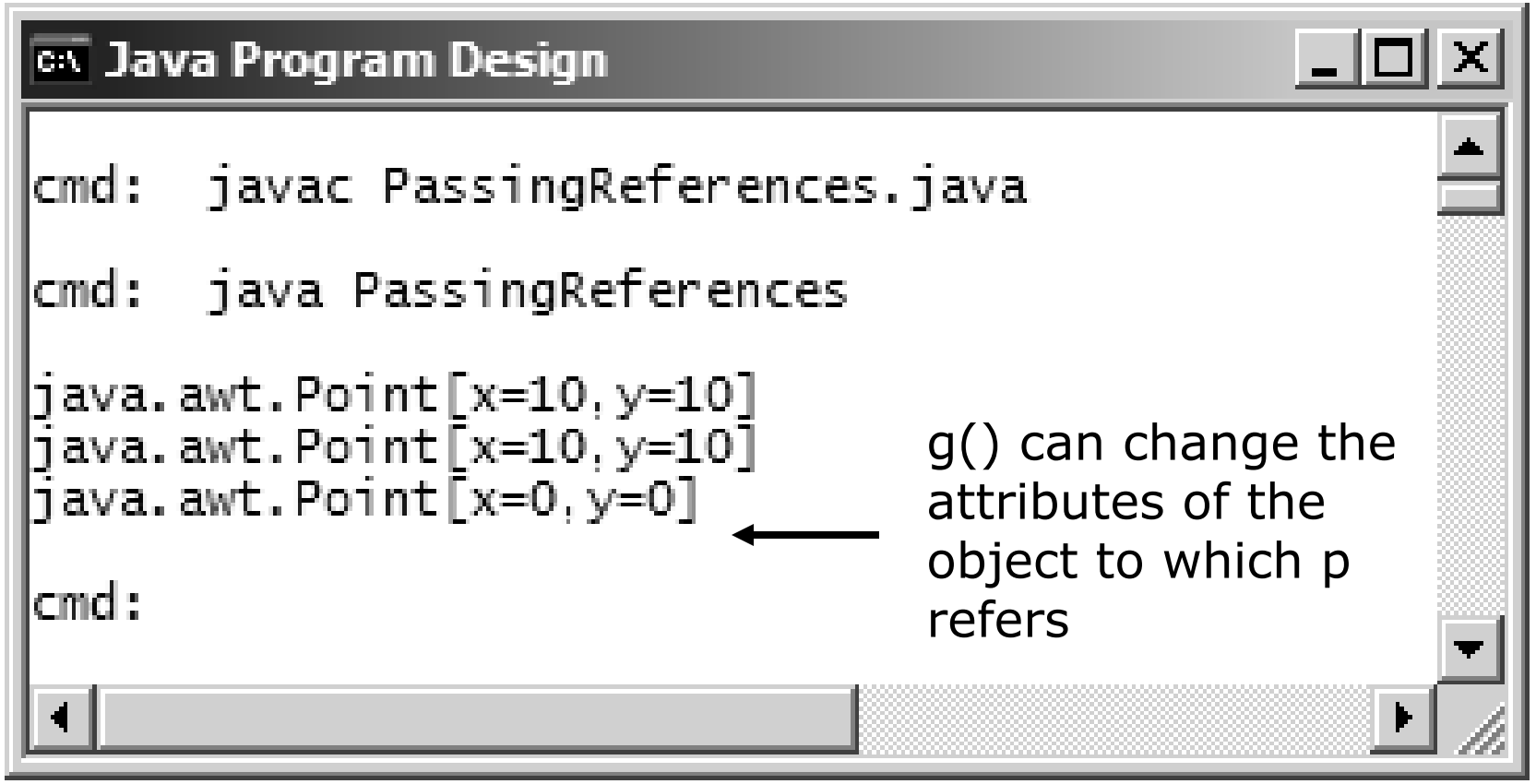
```
public static double multiply(double x, double y)
{
    x = x + y
    return x;
}
```



PassingReferences.java

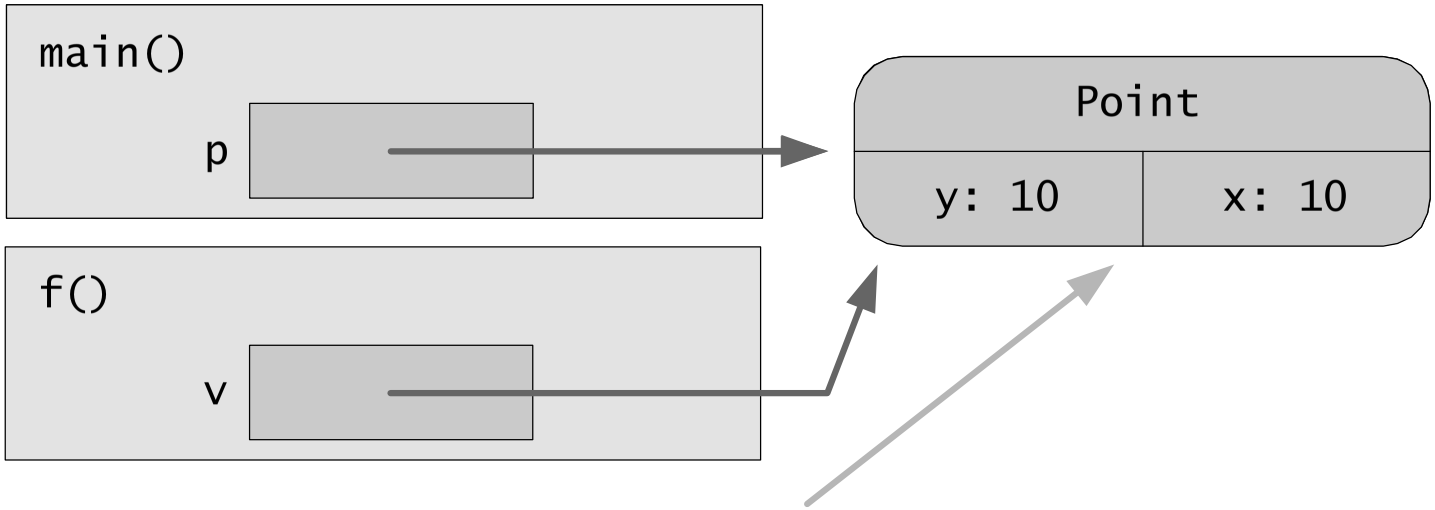
```
public class PassingReferences {
   public static void f(Point v) {
       v = new Point(0, 0);
   }

   public static void g(Point v) {
       v.setLocation(0, 0);
   }

   public static void main(String[] args) {
       Point p = new Point(10, 10);
       System.out.println(p);

       f(p);
       System.out.println(p);

       g(p);
       System.out.println(p);
   }
}
```

PassingReferences.java run



PassingReferences.java

```
public static void main(String[] args) {
    Point p = new Point(10, 10);
    System.out.println(p);

    f(p);
```

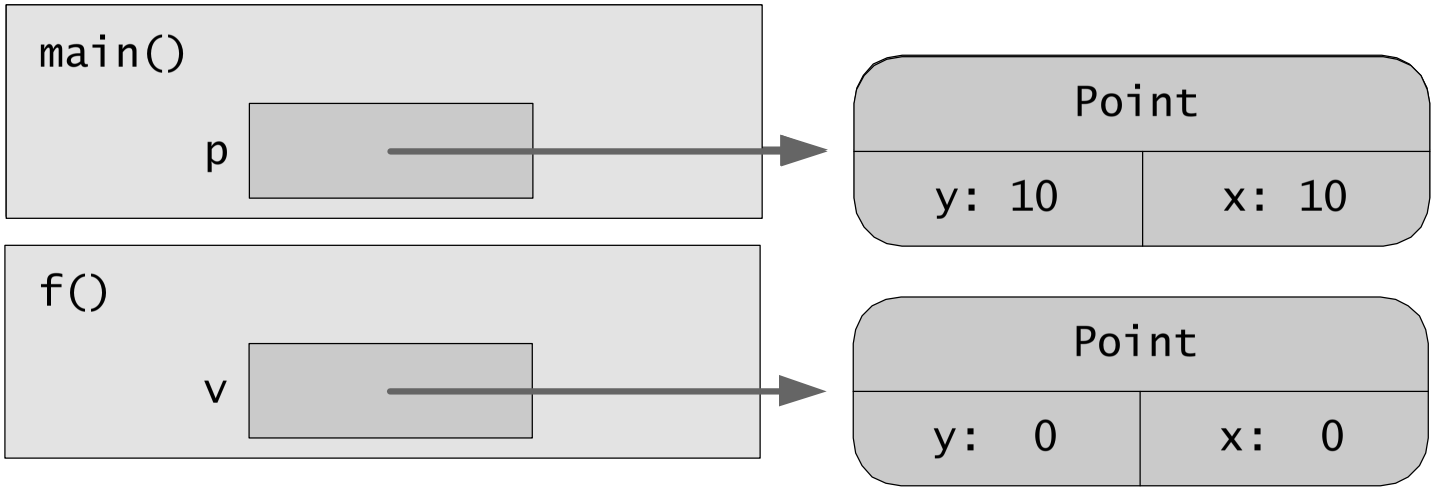


Method main()'s variable p and method f()'s formal parameter v have the same value, which is a reference to an object representing location (10, 10)

```
java.awt.Point[x=10,y=10]
```

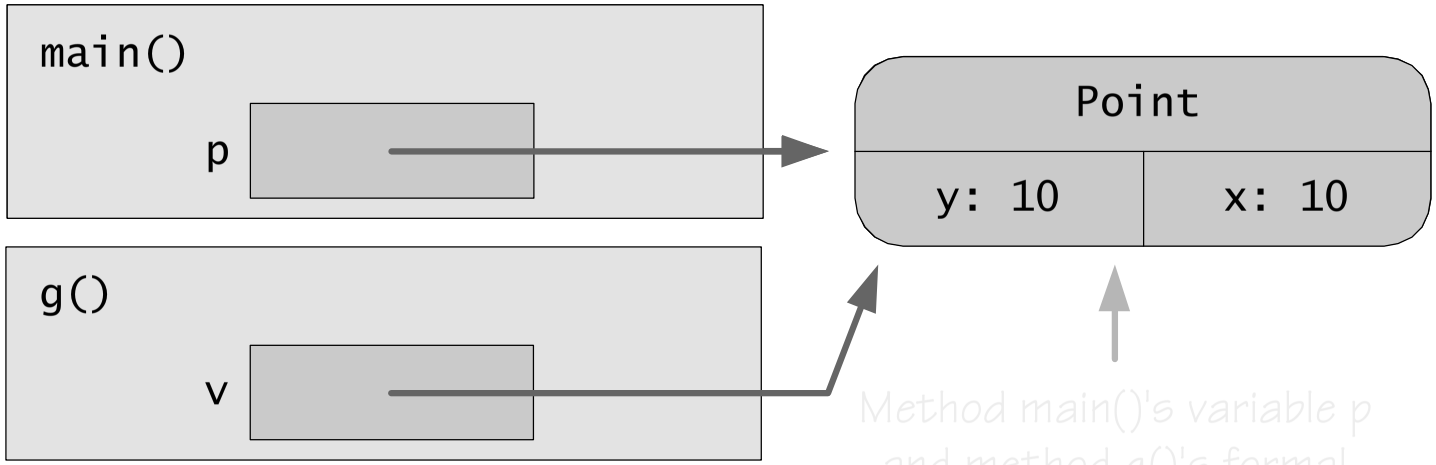
PassingReferences.java

```
public static void f(Point v) {
    v = new Point(0, 0);
}
```



PassingReferences.java

```
public static void main(String[] args) {
    Point p = new Point(10, 10);
    System.out.println(p);

    f(p);

    System.out.println(p);

    g(p);
```

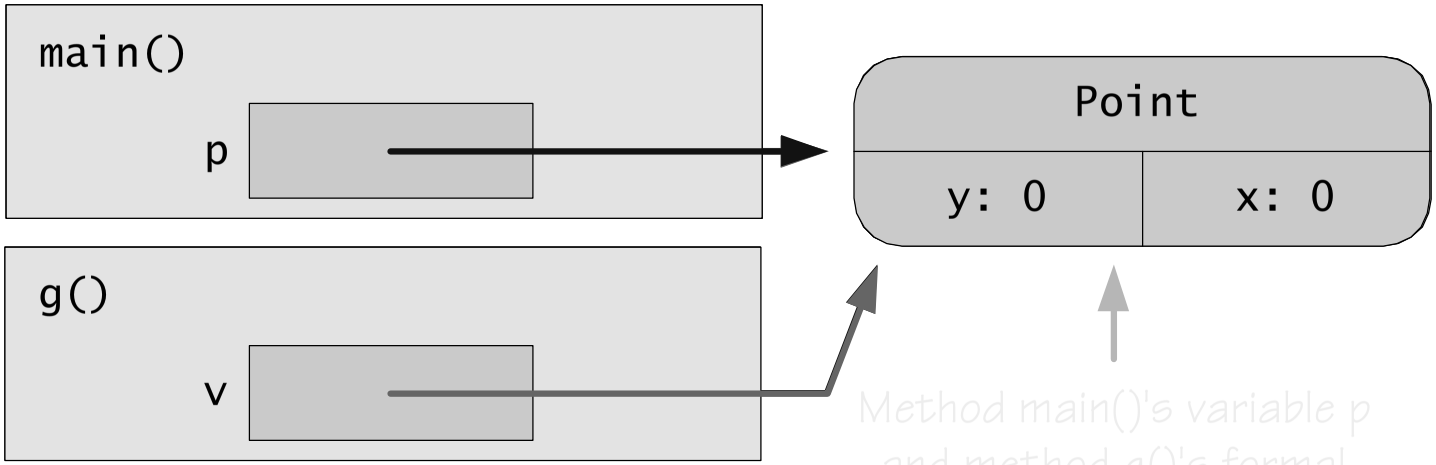


Method main()'s variable p and method g()'s formal parameter v have the same value, which is a reference to an object representing location (10, 10)

```
 java.awt.Point[x=10,y=10]
 java.awt.Point[x=10,y=10]
```

PassingReferences.java

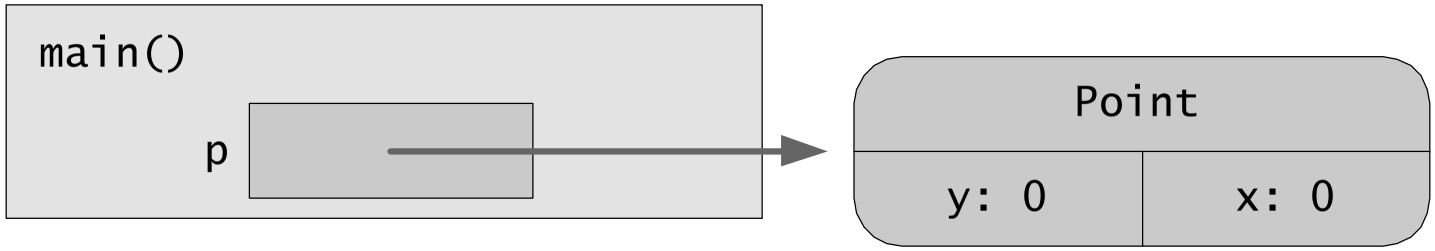
```
public static void g(Point v) {
    v.setLocation(0, 0);
}
```



Method main()'s variable p and method g()'s formal parameter v have the same value, which is a reference to an object representing location (10, 10)

PassingReferences.java

```
public static void main(String[] args) {
    Point p = new Point(10, 10);
    System.out.println(p);

    f(p);

    System.out.println(p);

    g(p);
    System.out.println(p);
```




```
 java.awt.Point[x=10,y=10]
 java.awt.Point[x=10,y=10]
 java.awt.Point[x=0,y=0]
```

What's wrong?

```
class Scope {
   public static void f(int a) {
        int b = 1;                  // local definition
        System.out.println(a); // print 10
        a = b;                      // update a
        System.out.println(a); // print 1
   }

   public static void main(String[] args) {
        int i = 10;          // local definition
        f(i);                // invoking f() with i as parameter
        System.out.println(a);
        System.out.println(b);
   }
}
```

Variables a and b do not exist in the *scope* of method main()

Blocks and scope rules

- A block is a list of statements nested within braces
  - A method body is a block
  - A block can be placed anywhere a statement would be legal
    - A block contained within another block is a nested block
- A formal parameter is considered to be defined at the beginning of the method body
- A local variable can be used only in a statement or nested blocks that occurs after its definition
- An identifier name can be reused as long as the blocks containing the duplicate declarations are not nested one within the other
- Name reuse within a method is permitted as long as the reuse occurs in distinct blocks

Legal

```
class Scope2 {
   public static void main(String[] args) {
        int a = 10;
        f(a);
        System.out.println(a);
   }

   public static void f(int a) {
        System.out.println(a);
        a = 1;
        System.out.println(a);
   }
}
```

Legal but not recommended

```
public void g() {
   {
       int j = 1;                    // define j
       System.out.println(j);        // print 1
   }
   {
       int j = 10;                   // define a different j
       System.out.println(j);        // print 10
   }
   {
       char j = '@';                 // define a different j
       System.out.println(j);        // print '@'
   }
}
```

What's the output?

```
for (int i = 0; i < 3; ++i) {
   int j = 0;
   ++j;
   System.out.println(j);
}
```

- The scope of variable j is the body of the for loop
  - j is not in scope when ++i
  - j is not in scope when i < 3 are evaluated
  - j is redefined and re-initialized with each loop iteration

Task – Triple.java

- Represent objects with three integer attributes

- What constructors should we have?
- What accessors and mutators should we have?
- What facilitators should we have?

Task – Triple.java

- `public Triple()`
  - Constructs a default Triple value representing three zeros
- public Triple(int a, int b, int c)
  - Constructs a representation of the values a, b, and c

Task – Triple.java

- public int getValue(int i)
  - Returns the i-th element of the associated Triple
- public void setValue(int i, int value)
  - Sets the i-th element of the associated Triple to value

Task – Triple.java

- public String toString()
  - Returns a textual representation of the associated Triple

- public Object clone()
  - Returns a new Triple whose representation is the same as the associated Triple

- public boolean equals(Object v)
  - Returns whether v is equivalent to the associated Triple

These three methods are overrides of inherited methods

Triple.java implementation

```
// Triple(): specific constructor
public Triple(int a, int b, int c) {
   setValue(1, a);
   setValue(2, b);
   setValue(3, c);
}
```

Triple.java implementation

```
// Triple(): specific constructor - alternative definition
public Triple(int a, int b, int c) {
   this.setValue(1, a);
   this.setValue(2, b);
   this.setValue(3, c);
}
```

Triple.java implementation

```
// Triple(): default constructor
public Triple() {
   this(0, 0, 0);
}
```

The new Triple object (the this object) is constructed by invoking the Triple constructor expecting three int values as actual parameters

```
public Triple() {
   int a = 0;
   int b = 0;
   int c = 0;
   this(a, b, c);
}
```

Illegal this() invocation. A this() invocation must begin its statement body

Triple.java implementation

- Class Triple like every other Java class
  - Automatically an extension of the standard class Object
  - Class Object specifies some basic behaviors common to all objects
    - These behaviors are said to be inherited
  - Three of the inherited Object methods
    - toString()
    - clone()
    - equals()

Recommendation

- Classes should override (i.e., provide a class-specific implementation)
    - toString()
    - clone()
    - equals()

- By doing so, the programmer-expected behavior can be provided

```
System.out.println(p); // displays string version of
                       // object referenced by p
System.out.println(q); // displays string version of
                       // object referenced by q
```

Triple.java toString() implementation

```
public String toString() {
   int a = getValue(1);
   int b = getValue(2);
   int c = getValue(3);

   return "Triple[" + a + ", " + b + ", " + c + "]");
}
```

- Consider

```
Triple t1 = new Triple(10, 20, 30);
System.out.println(t1);

Triple t2 = new Triple(8, 88, 888);
System.out.println(t2);
```

- Produces

```
Triple[10, 20, 30]
Triple[8, 88, 888]
```

Triple.java clone() implementation

```
public Object clone() {
   int a = getValue(1);
   int b = getValue(2);
   int c = getValue(3);

   return new Triple(a, b, c);
}
```

← Return type is Object
(Every class is a specialized Object)

- Consider

```
Triple t1 = new Triple(9, 28, 29);
Triple t2 = (Triple) t1.clone();

System.out.println("t1 = " + t1);
System.out.println("t2 = " + t2);
```

← Must cast!

- Produces

```
Triple[9, 28, 29]
Triple[9, 28, 29]
```

Triple.java equals() implementation

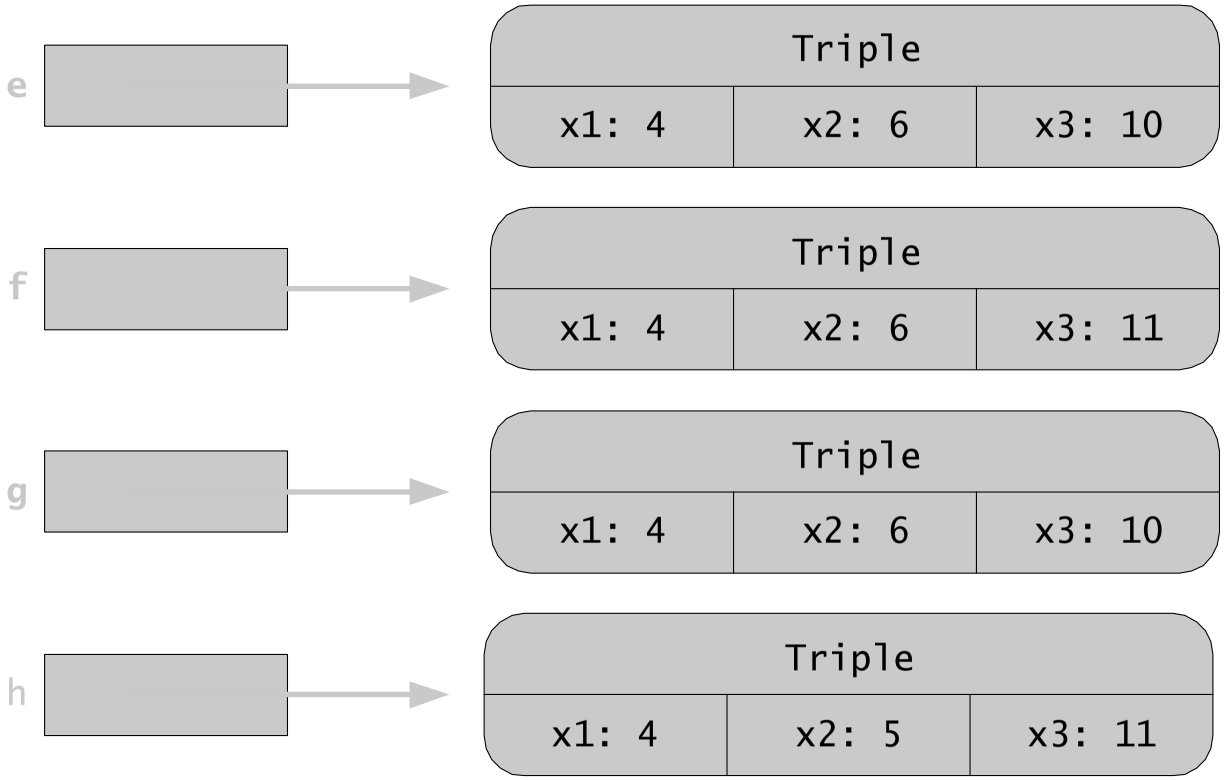
```
public boolean equals(Object v) {
   if (v instanceof Triple) {
        int a1 = getValue(1);
        int b1 = getValue(2);
        int c1 = getValue(3);

        Triple t = (Triple) v;
        int a2 = t.getValue(1);
        int b2 = t.getValue(2);
        int c2 = t.getValue(3);

        return (a1 == a2) && (b1 == b2) && (c1 == c2);
   }
   else {
        return false;
   }
}
```

Can't be equal unless it's a Triple

Compare corresponding attributes

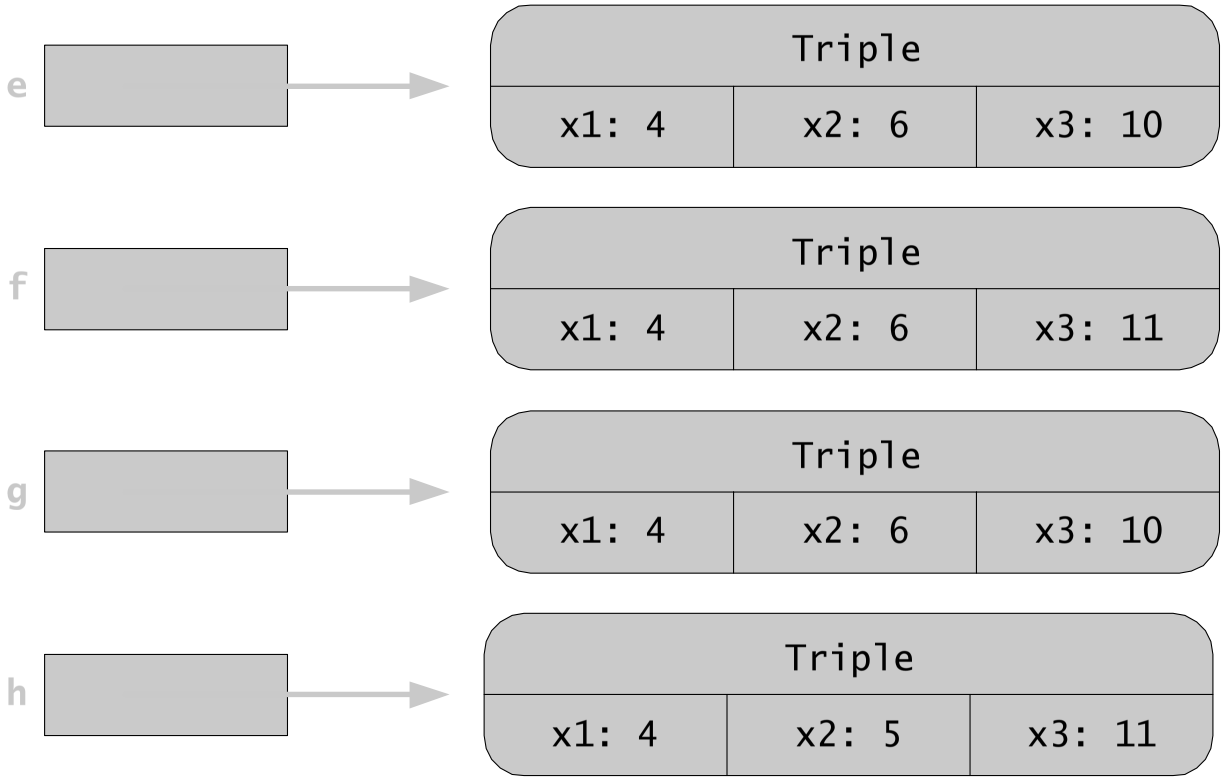
Triple.java equals()

```
Triple e = new Triple(4, 6, 10);
Triple f = new Triple(4, 6, 11);,
Triple g = new Triple(4, 6, 10);
Triple h = new Triple(4, 5, 11);
boolean flag1 = e.equals(f);
```



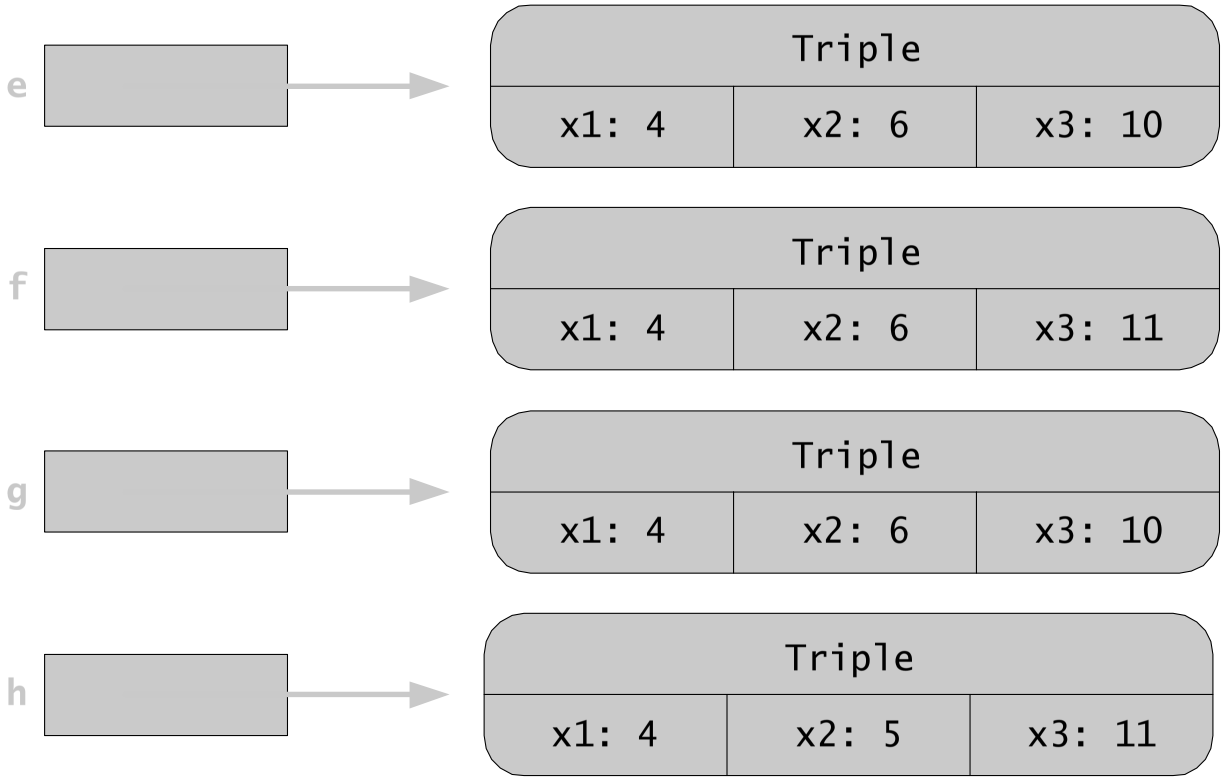
Triple.java equals()

```
Triple e = new Triple(4, 6, 10);
Triple f = new Triple(4, 6, 11);,
Triple g = new Triple(4, 6, 10);
Triple h = new Triple(4, 5, 11);
boolean flag2 = e.equals(g);
```



Triple.java equals()

```
Triple e = new Triple(4, 6, 10);
Triple f = new Triple(4, 6, 11);,
Triple g = new Triple(4, 6, 10);
Triple h = new Triple(4, 5, 11);
boolean flag3 = g.equals(h);
```



Overloading

- Have seen it often before with operators

```
int i = 11 + 28;
 double x = 6.9 + 11.29;
 String s = "April " + "June";
```

- Java also supports method overloading
  - Several methods can have the same name
  - Useful when we need to write methods that perform similar tasks but different parameter lists
  - Method name can be overloaded as long as its signature is different from the other methods of its class
    - Difference in the names, types, number, or order of the parameters

Legal

```
public static int min(int a, int b, int c) {
   return Math.min(a, Math.min(b, c));
}

public static int min(int a, int b, int c, int d) {
   return Math.min(a, min(b, c, d));
}
```

Legal

```
public static int power(int x, int n) {
   int result = 1;
   for (int i = 1; i <= n; ++i) {
       result *= x;
   }
   return result;
}

public static double power(double x, int n) {
   double result = 1;
   for (int i = 1; i <= n; ++i) {
       result *= x;
   }
   return result;
}
```

What's the output?

```
public static void f(int a, int b) {
   System.out.println(a + b);
}

public static void f(double a, double b) {
   System.out.println(a - b);
}

public static void main(String[] args) {
   int i = 19;
   double x = 54;

   f(i, x);
}
```

Arrays

Background

- Programmer often need the ability to represent a group of values as a list
  - List may be one-dimensional or multidimensional
- Java provides arrays and the collection classes
- Consider arrays first

Basic terminology

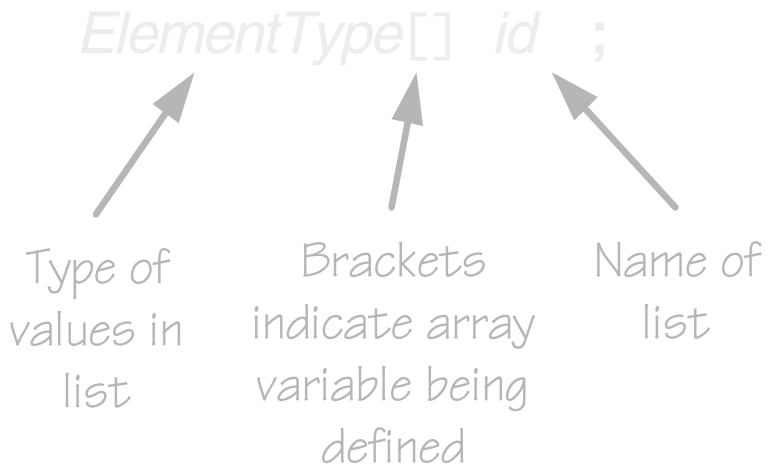
- List is composed of *elements*
- Elements in a list have a *common name*
- The list as a whole is referenced through the common name
- List elements are of the same type — the base type
- Elements of a list are referenced by *subscripting* (indexing) the common name

Java array features

- Subscripts are denoted as expressions within brackets: [ ]
- Base (element) type can be any type
- Size of array can be specified at run time
- Index type is integer and the index range must be 0 ... n-1
  - Where n is the number of elements
- Automatic bounds checking
  - Ensures any reference to an array element is valid
- Data field length specifies the number of elements in the list
- Array is an object
  - Has features common to all other objects

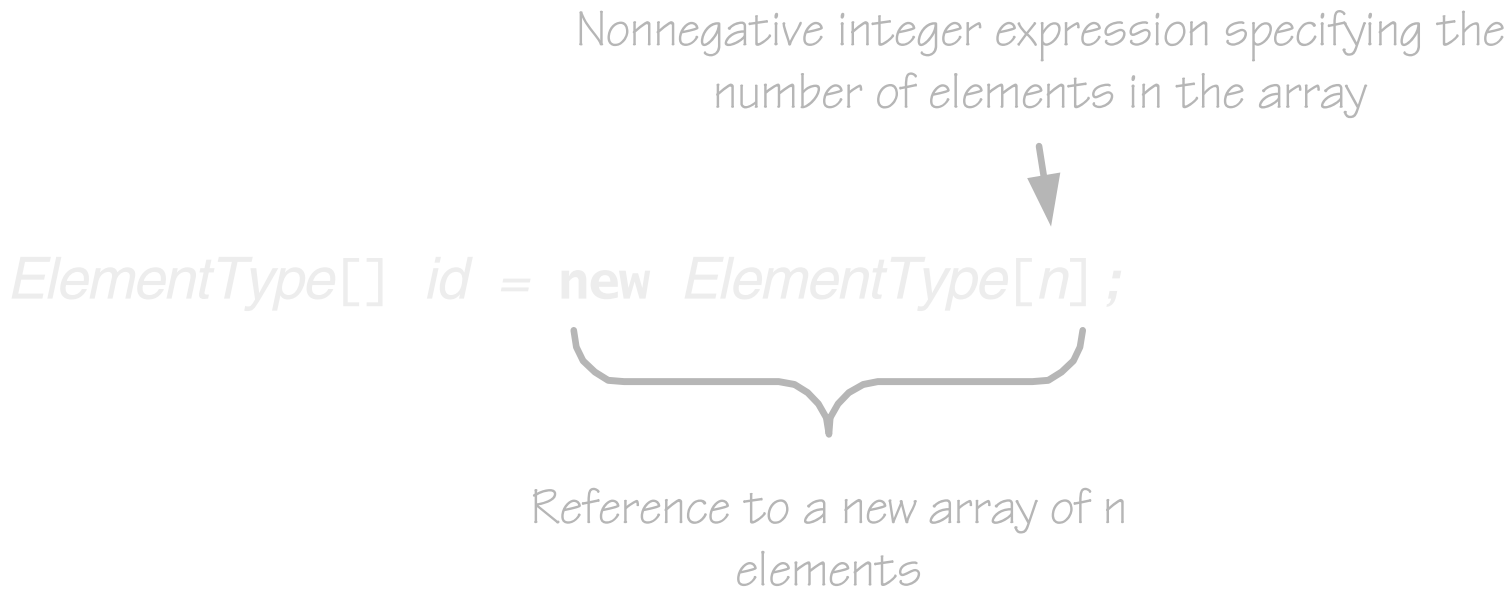
Array variable definition styles

- Without initialization



Array variable definition styles

- With initialization

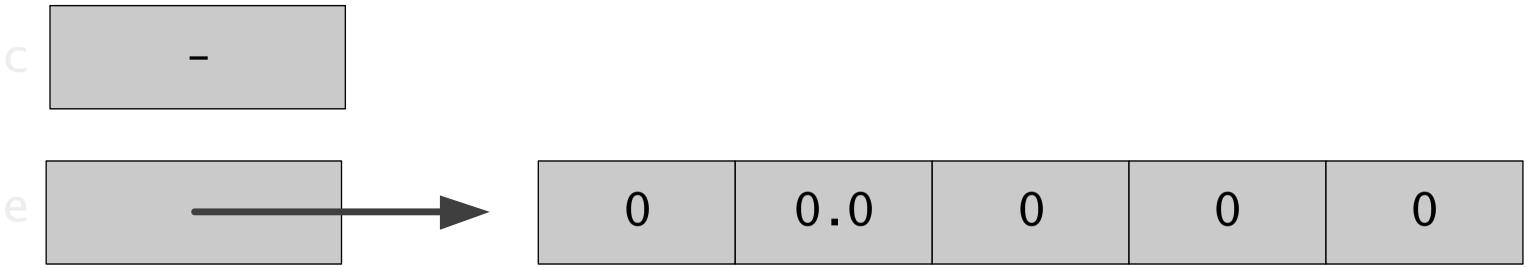


Example

- Definitions

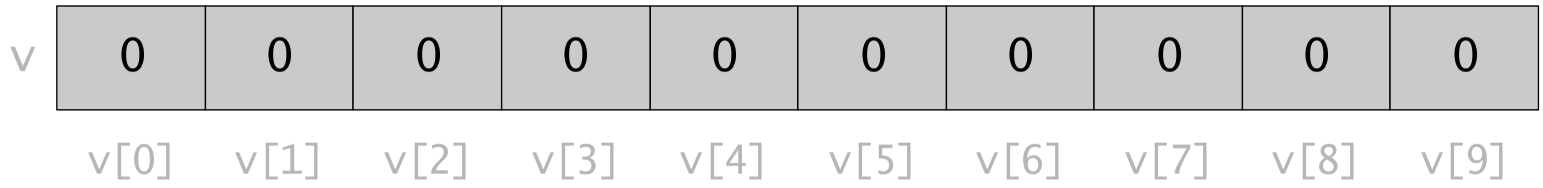
```
char[] c;
int[] value = new int[10];
```

- Causes
  - Array object variable c is un-initialized
  - Array object variable v references a new ten element list of integers
    - Each of the integers is default initialized to 0



Consider

```
int[] v = new int[10];
int i = 7;
int j = 2;
int k = 4;
v[0] = 1;
v[i] = 5;
v[j] = v[i] + 3;
v[j+1] = v[i] + v[0];
v[v[j]] = 12;
System.out.println(v[2]);
v[k] = stdin.nextInt();
```



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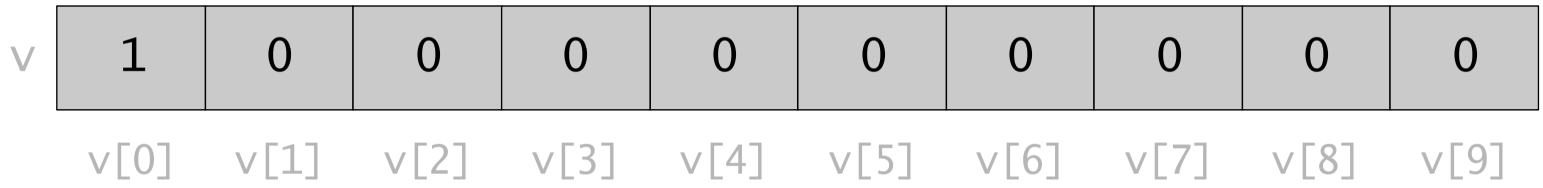

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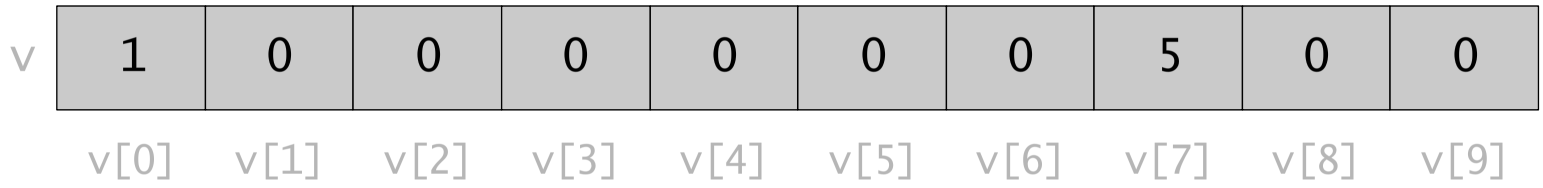

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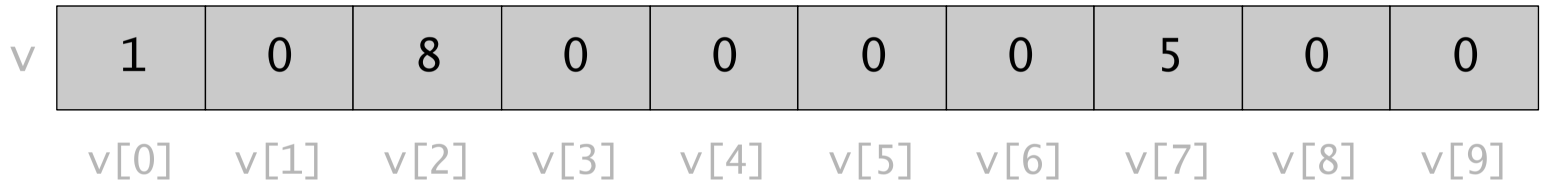

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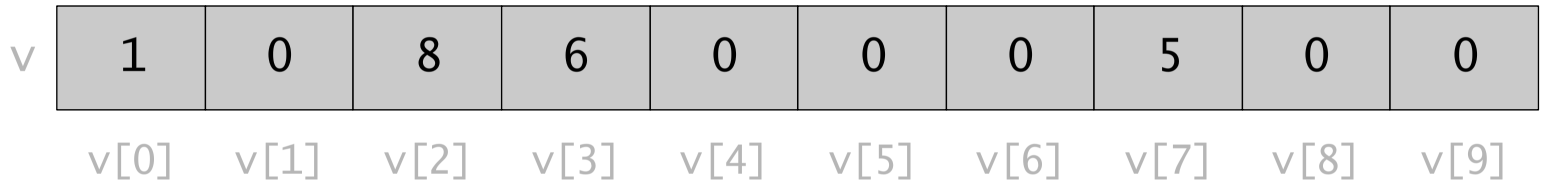

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int k = 4;
v[0] = 1;
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v[j] = v[i] + 3;
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v[v[j]] = 12;
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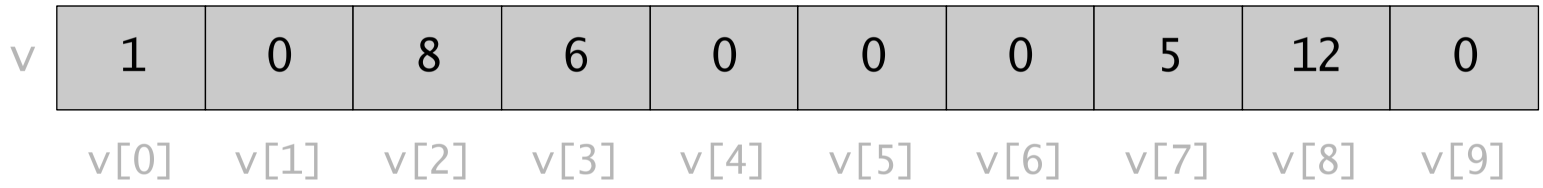

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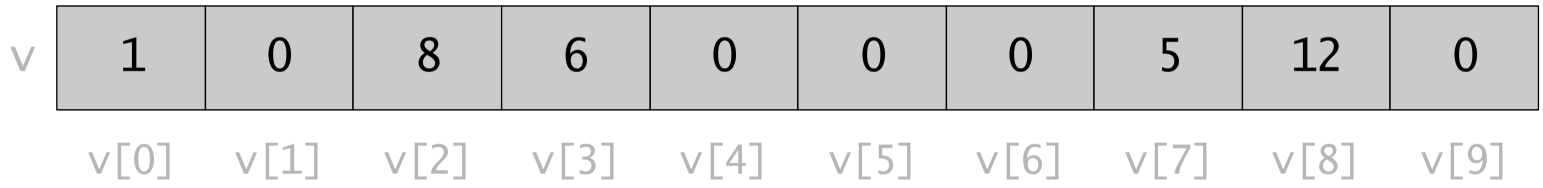
8 is displayed



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v[v[j]] = 12;
System.out.println(v[2]);
v[k] = stdin.nextInt();
```

Suppose 3 is extracted

Consider

- Segment

```
int[] b = new int[100];
b[-1] = 0;
b[100] = 0;
```

- Causes
  - Array variable to reference a new list of 100 integers
    - Each element is initialized to 0
  - Two exceptions to be thrown
    - -1 is not a valid index – too small
    - 100 is not a valid index – too large

      – IndexOutOfBoundsException

Consider

```
Point[] p = new Point[3];
p[0] = new Point(0, 0);
p[1] = new Point(1, 1);
p[2] = new Point(2, 2);
p[0].setX(1);
p[1].setY(p[2].getY());
Point vertex = new Point(4,4);
p[1] = p[0];
p[2] = vertex;
```

Consider

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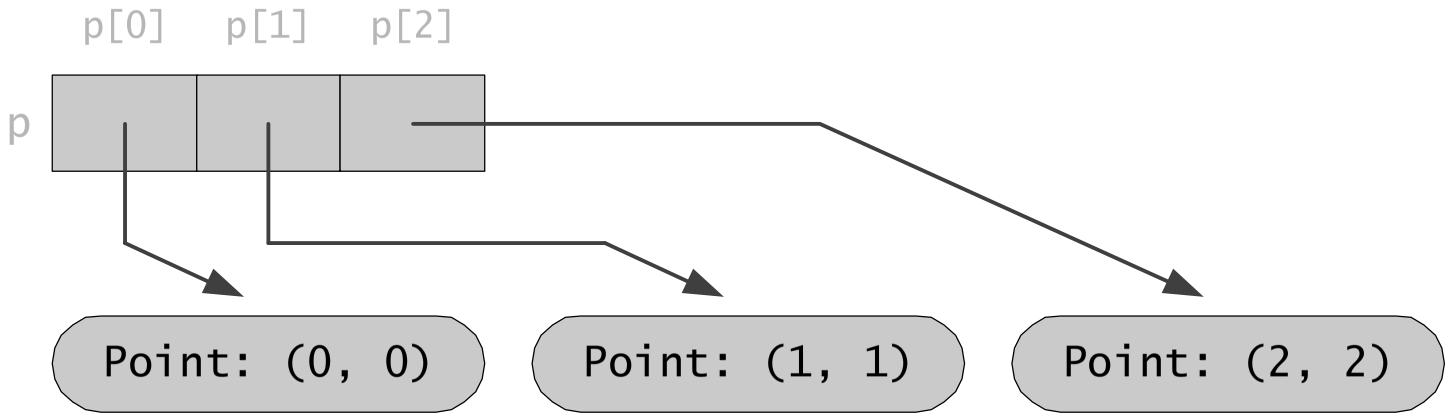

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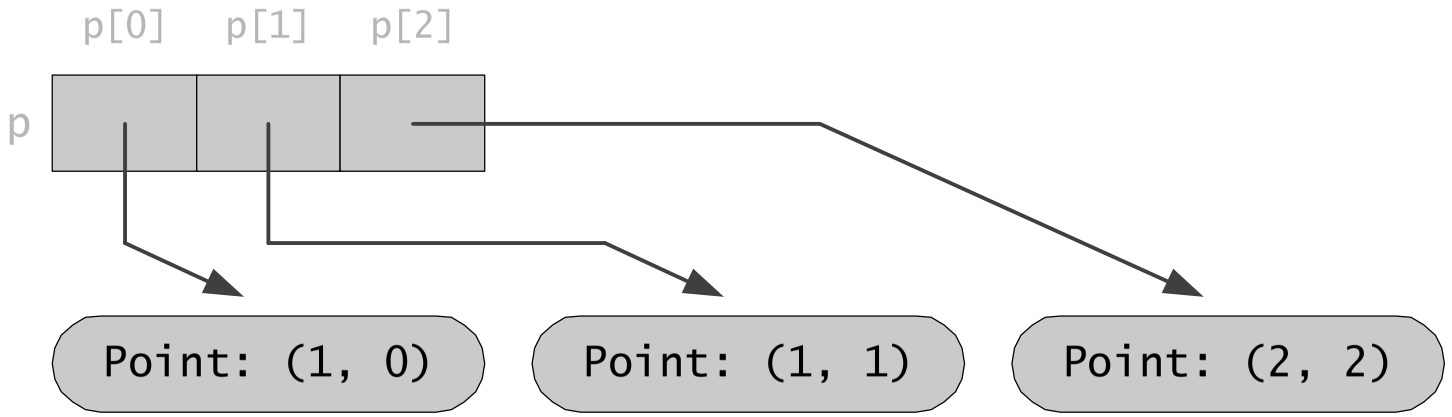

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p[1] = p[0];
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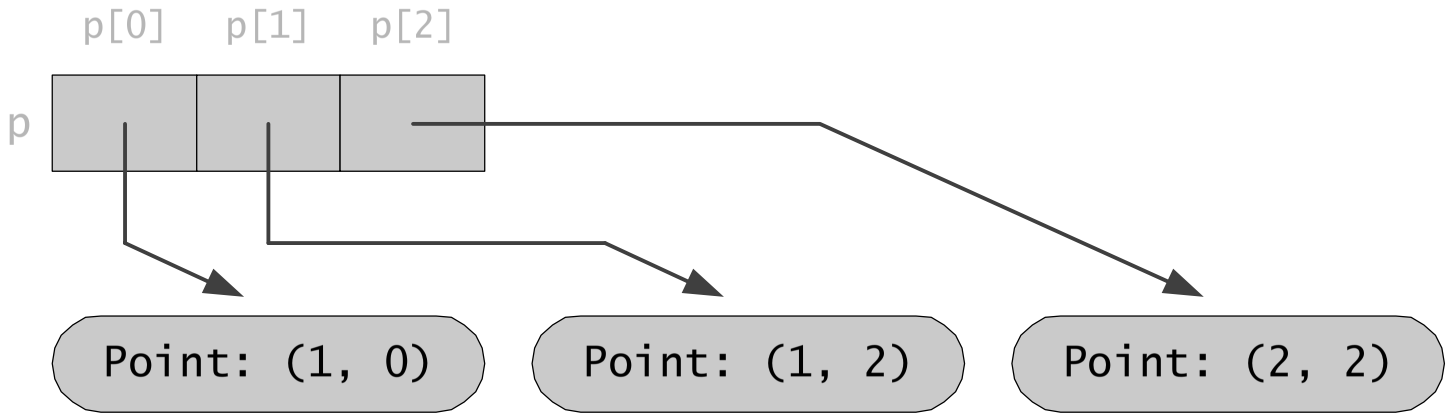

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p[1] = p[0];
p[2] = vertex;
```

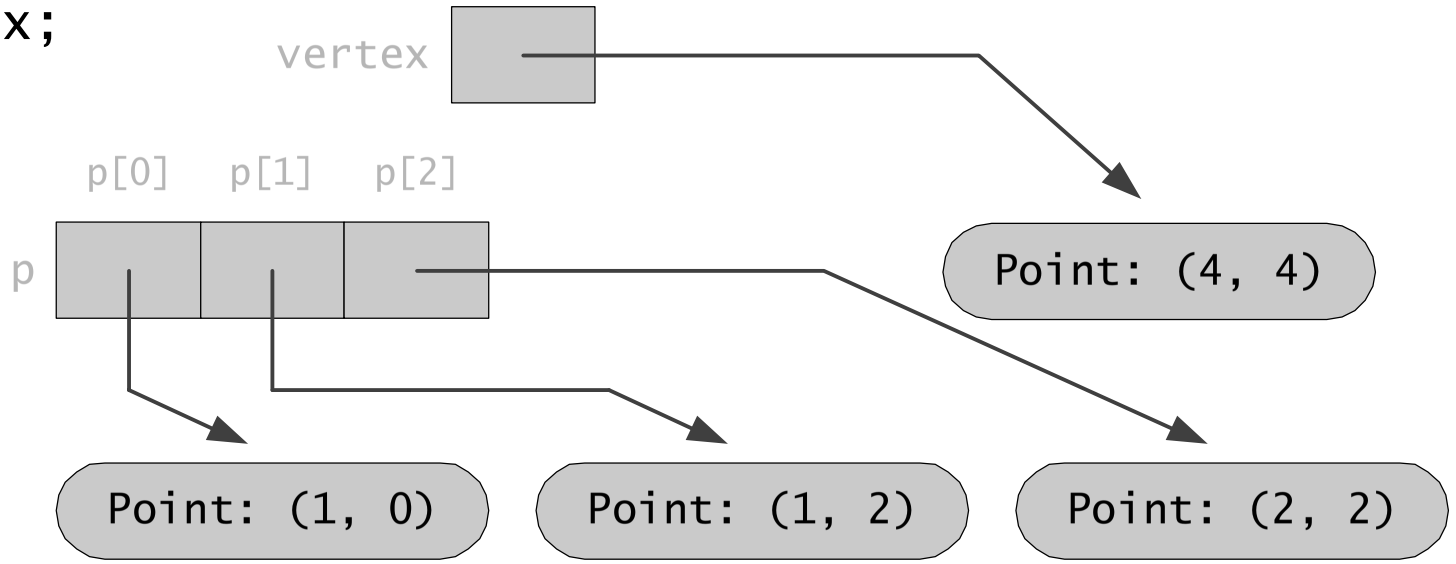

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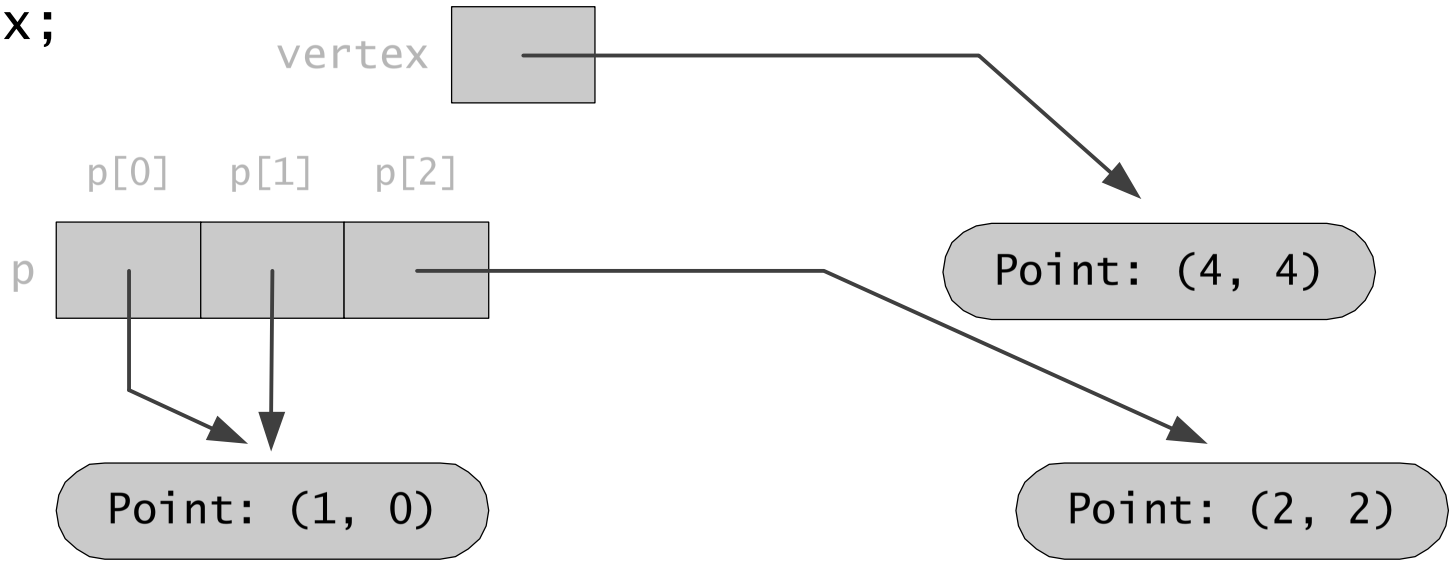

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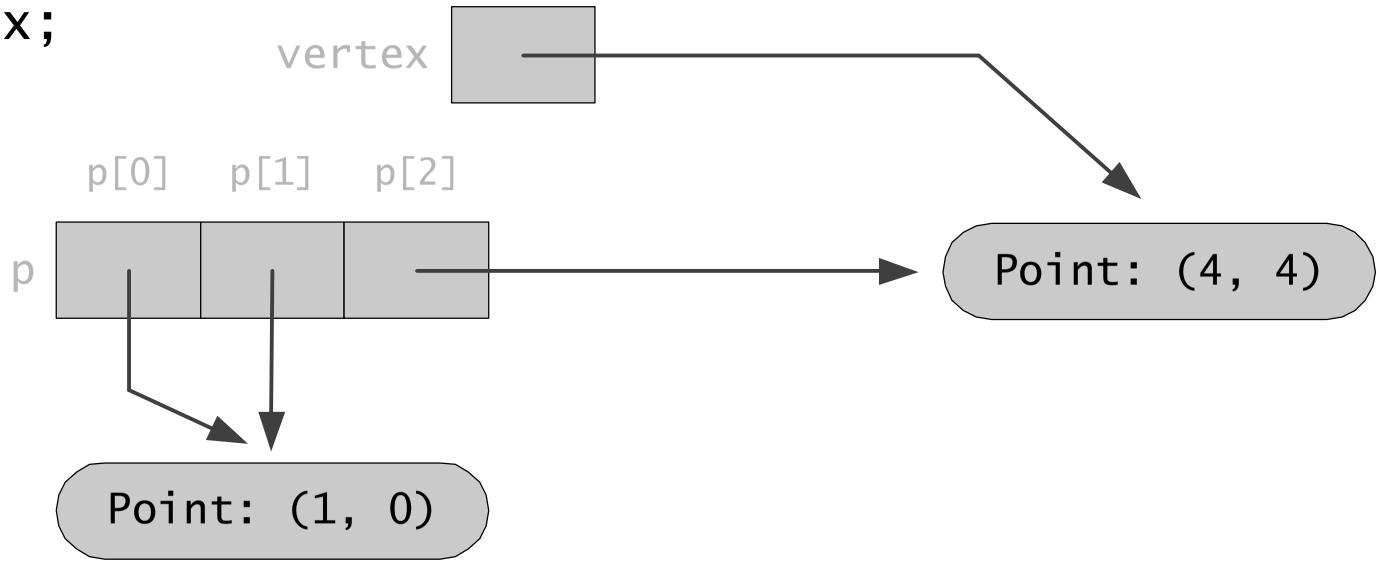
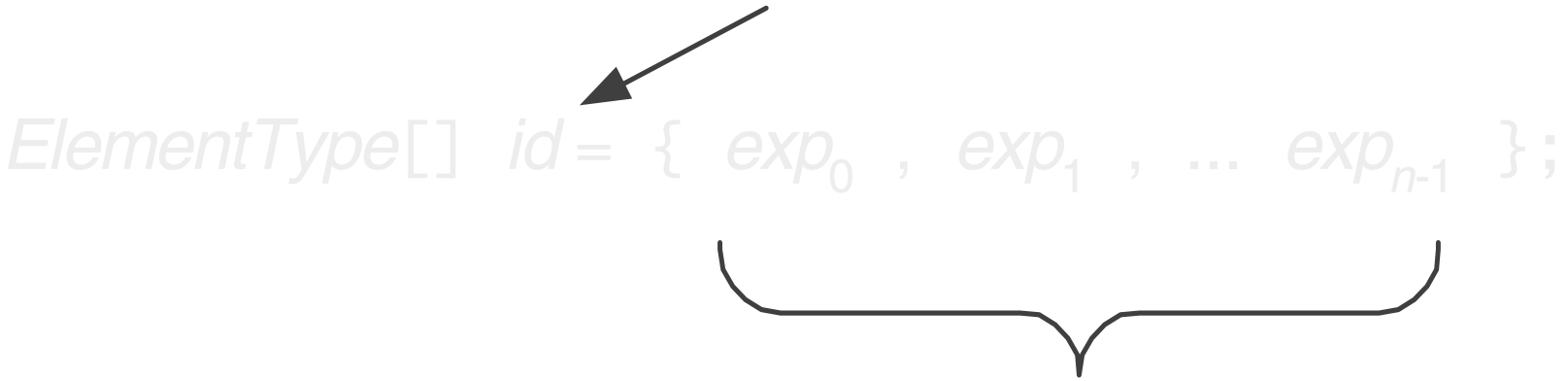


Explicit initialization

- Syntax

id references an array of n elements. id[0] has value exp_0, id[1] has value exp_1, and so on.



Each exp_i is an expression that evaluates to type ElementType

Explicit initialization

- Example

```
String[] puppy = { "nilla“, “darby“, "galen",
  "panther" };
int[] unit = { 1 };
```

- Equivalent to

```
String[] puppy = new String[4];
puppy[0] = "nilla";   puppy[1] = “darby";
puppy[2] = "galen";   puppy[4] = "panther";

int[] unit = new int[1];
unit[0] = 1;
```

Array members

- Member length
  - Size of the array

```
for (int i = 0; i < puppy.length; ++i) {
  System.out.println(puppy[i]);
}
```

Array members

- Member clone()
  - Produces a shallow copy

```
Point[] u = { new Point(0, 0), new Point(1, 1)};
Point[] v = u.clone();
                    v[1] = new Point(4, 30);
```

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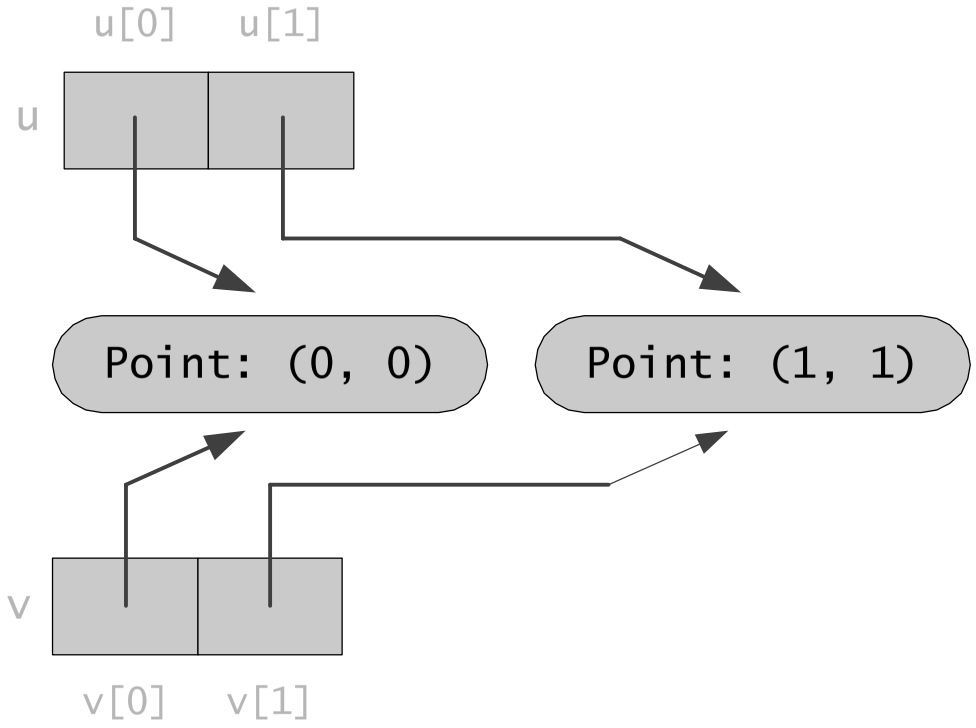

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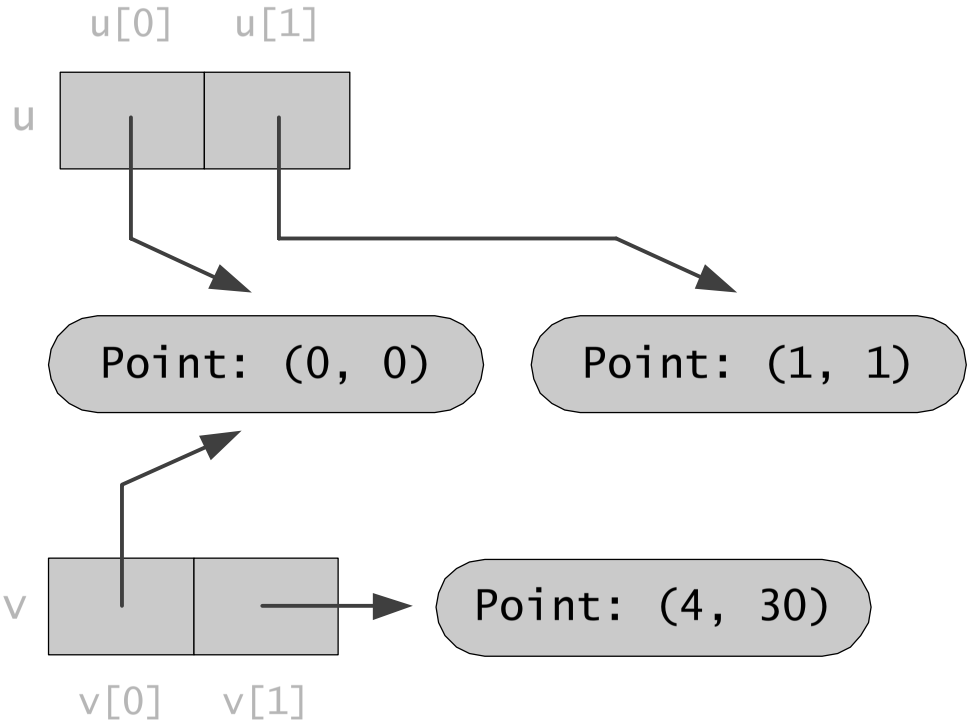
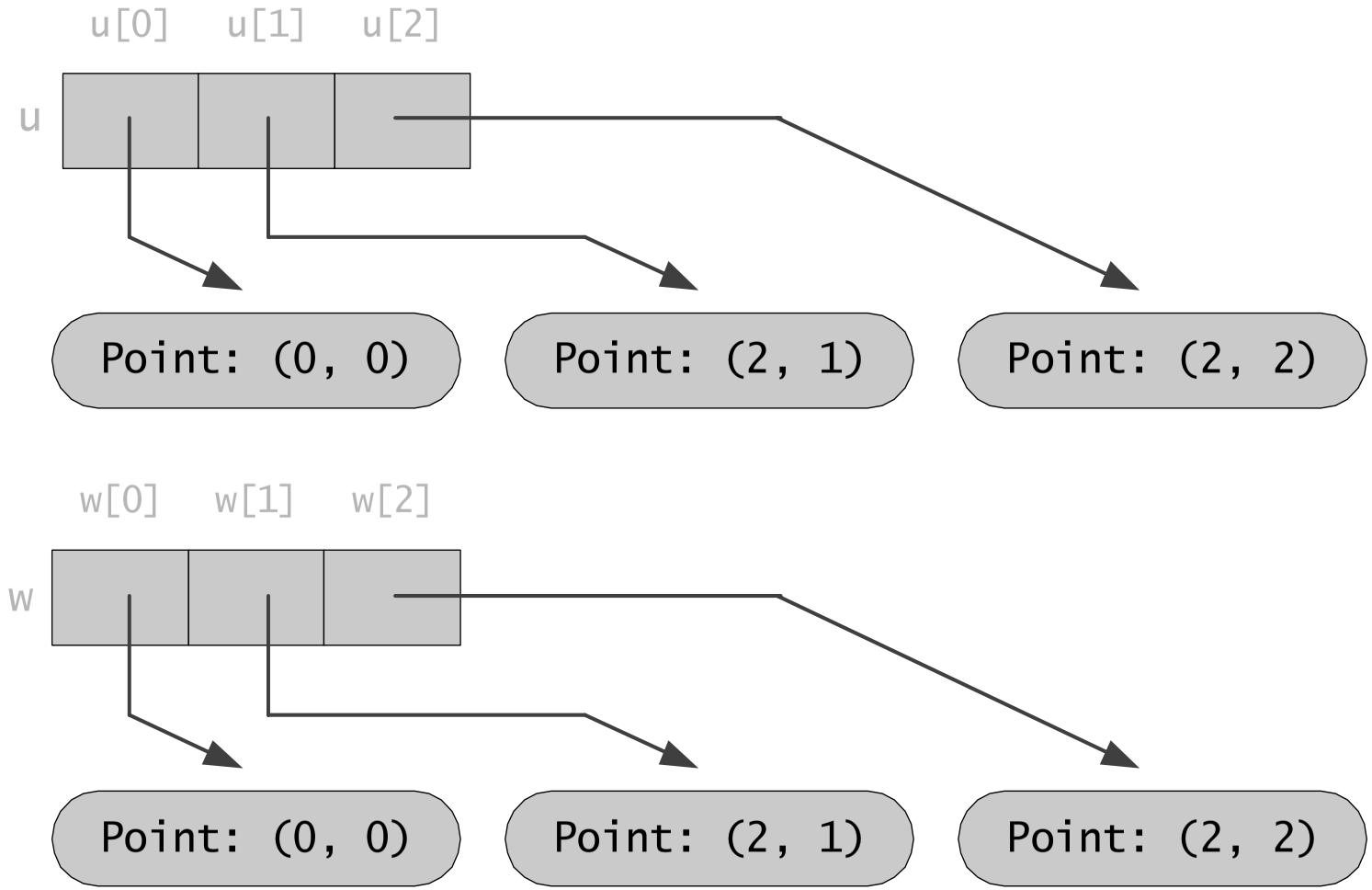


Making a deep copy

- Example

```
Point[] w = new Point[u.length];
for (int i = 0; i < u.length; ++i) {
  w[i] = u[i].clone();
}
```

Making a deep copy



Searching for a value

```
System.out.println("Enter search value (number): ");
int key = stdin.nextInt();

int i;
for (i = 0; i < data.length; ++i) {
   if (key == data[i]) {
       break;
   }
}

if (i != data.length) {
   System.out.println(key + " is the " + I
       + "-th element");
}
else {
   System.out.println(key + " is not in the list");
}
```

Searching for a value

```
System.out.println("Enter search value (number): ");
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int i;
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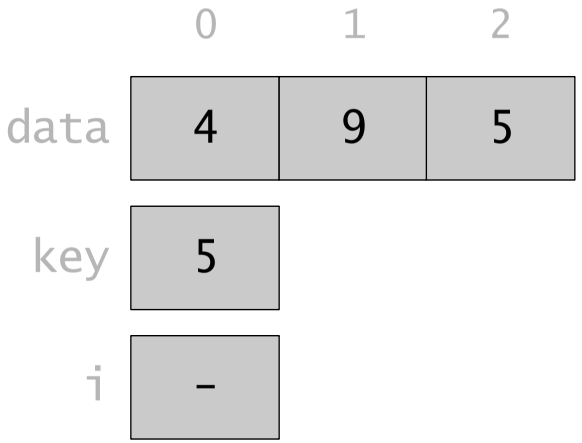

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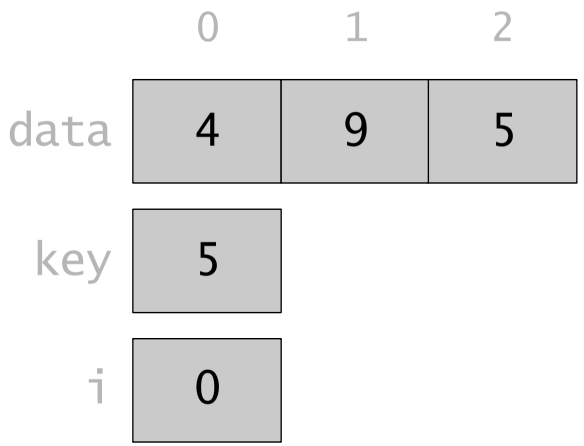

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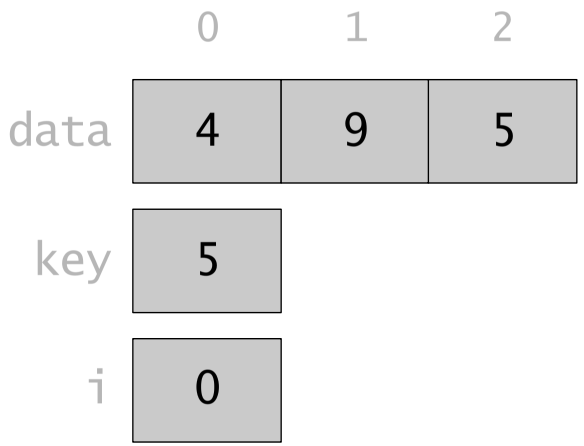

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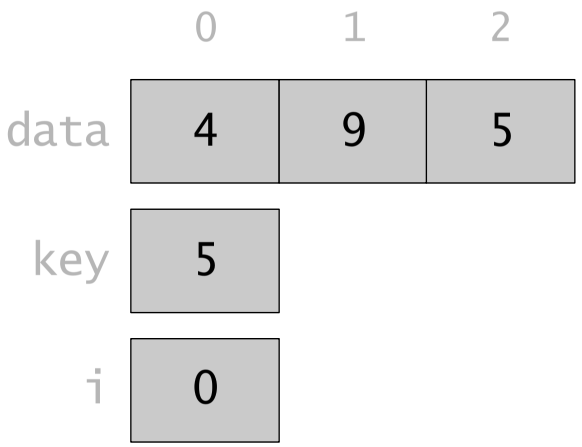

Searching for a value

```
System.out.println("Enter search value (number): ");
int key = stdin.nextInt();

int i;
for (i = 0; i < data.length; ++i) {
   if (key == data[i]) {
       break;
   }
}

if (i != data.length) {
   System.out.println(key + " is the " + I
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}
else {
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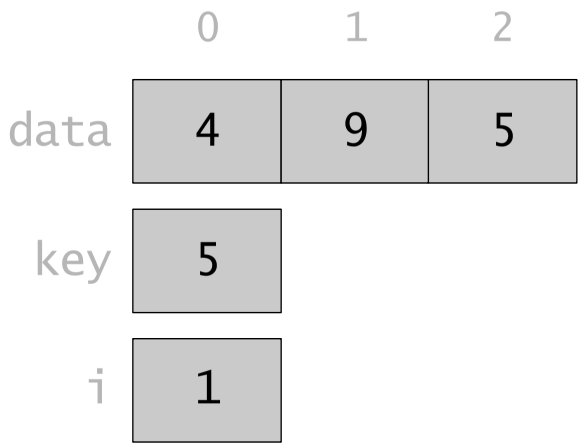
}
```



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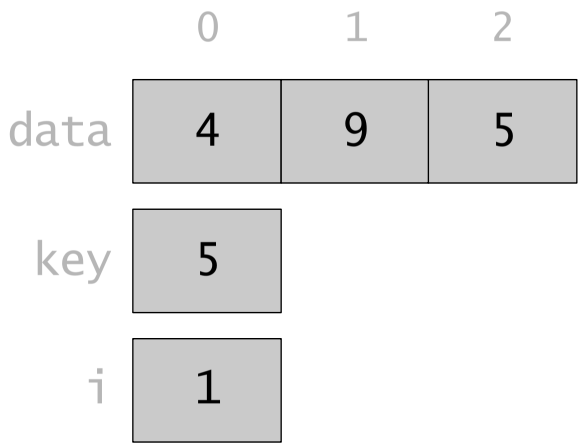

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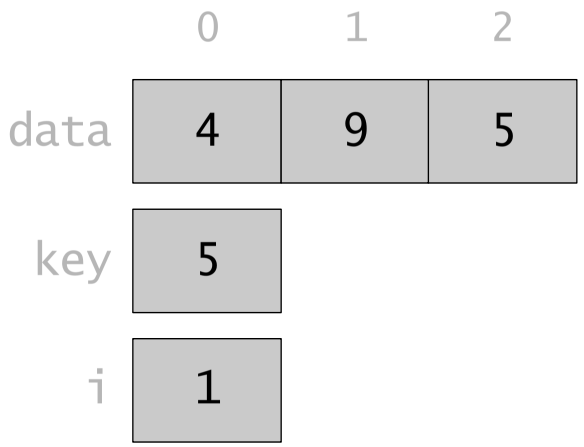

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   }
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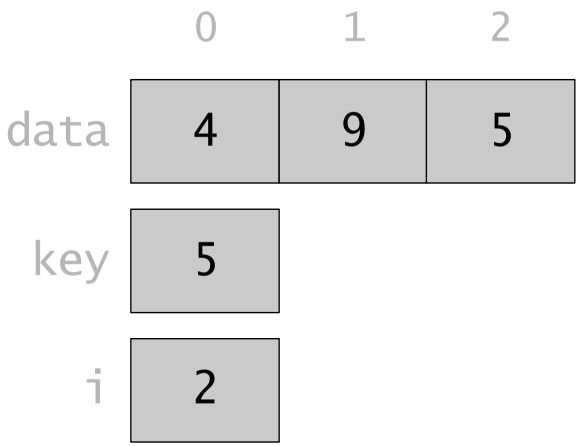

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int i;
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   if (key == data[i]) {
       break;
   }
}

if (i != data.length) {
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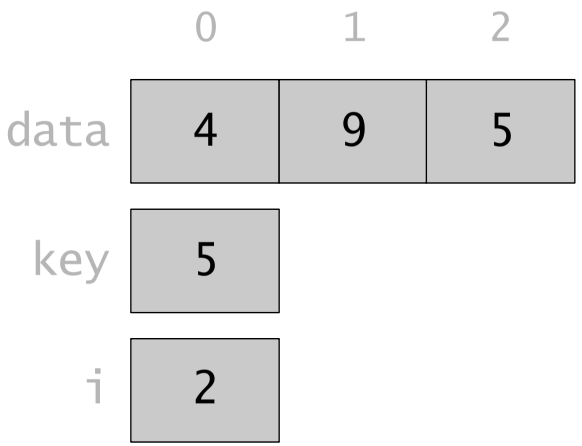

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int i;
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       break;
   }
}

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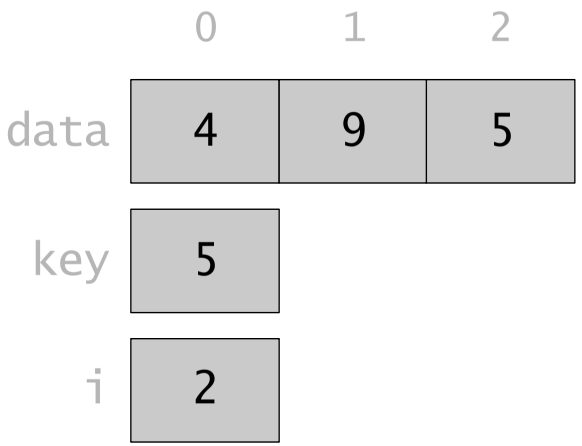

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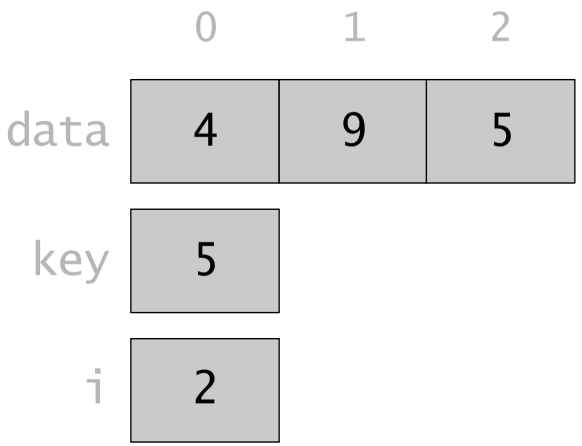

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}
```

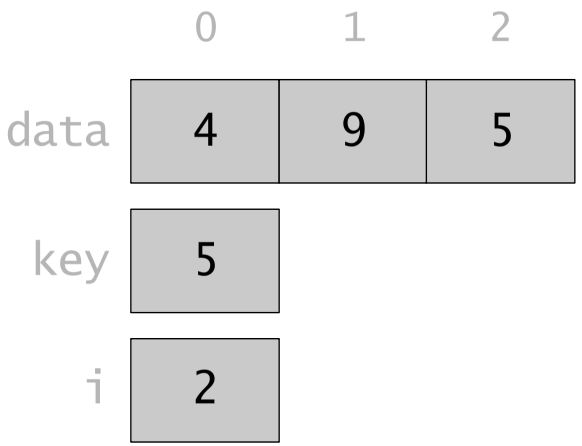

Searching for the minimum value

- Segment

```
int minimumSoFar = sample[0];
for (int i = 1; i < sample.length; ++i) {
  if (sample[i] < minimumSoFar) {
       minimumSoFar = sample[i];
  }
}
```

ArrayTools.java method sequentialSearch()

```
public static int sequentialSearch(int[] data, int key) {
   for (int i = 0; i < data.length; ++i) {
       if (data[i] == key) {
             return i;
             }
   }

   return -1;
}
```

- Consider

```
int[] score = { 6, 9, 82, 11, 29, 85, 11, 28, 91 };
int i1 = sequentialSearch(score, 11);
int i2 = sequentialSearch(score, 30);
```

ArrayTools.java method sequentialSearch()

```
public static int sequentialSearch(int[] data, int key) {
   for (int i = 0; i < data.length; ++i) {
       if (data[i] == key) {
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             }
   }

   return -1;
}
```
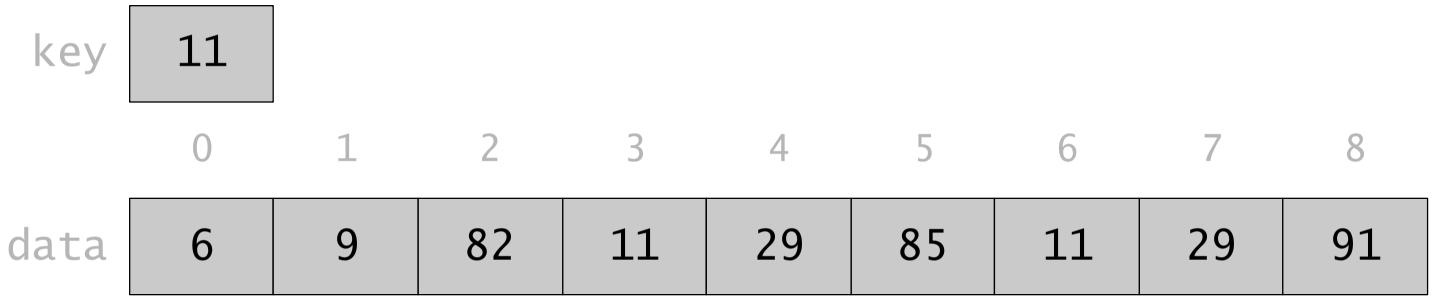



- Consider

```
int[] score = { 6, 9, 82, 11, 29, 85, 11, 28, 91 };
int i1 = sequentialSearch(score, 11);
int i2 = sequentialSearch(score, 30);
```

ArrayTools.java method putList()

```
public static void putList(int[] data) {
   for (int i = 0; i < data.length; ++i) {
       System.out.println(data[i]);
   }
}
```

- Consider

```
int[] score = { 6, 9, 82, 11, 29, 85, 11, 28, 91 };
putList(score);
```

```
public static int[] getList() {
   Scanner stdin = new Scanner(System.in);
   int[] buffer = new int[MAX_LIST_SIZE];
   int listSize = 0;
   for (int i = 0; (stdin.hasNextInt()) && i < MAX_LIST_SIZE;
               ++i) {
               buffer[i] = stdin.nextInt();
               ++listSize;
   }
   int[] data = new int[listSize];
   for (int i = 0; i < listSize; ++i) {
       data[i] = buffer[i];
   }
   return data;
}
```

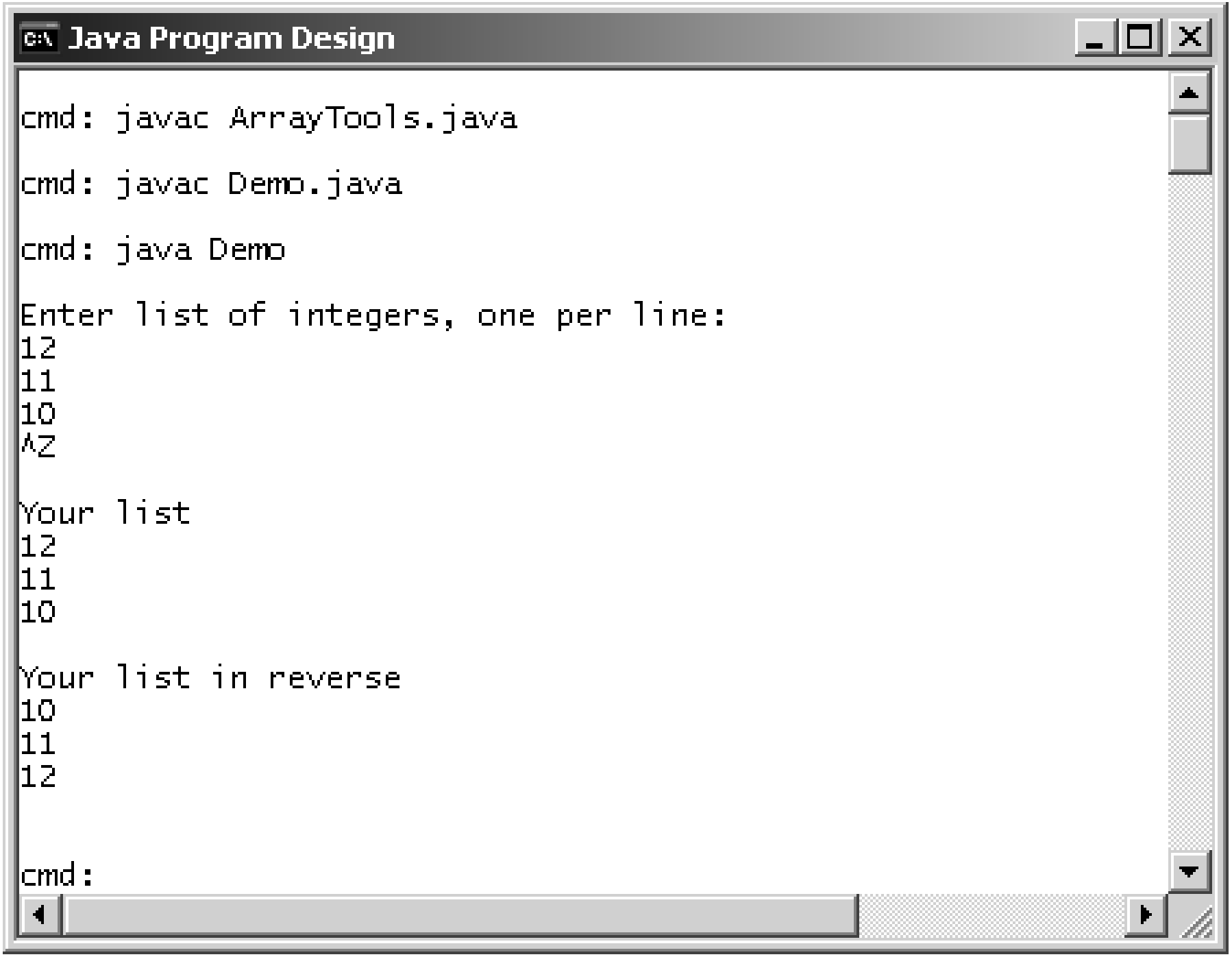
ArrayTools.java
method getList()

ArrayTools.java – outline

```
public class ArrayTools {

  // class constant
  private static final int MAX_LIST_SIZE = 1000;

  // sequentialSearch(): examine unsorted list for key
  public static int binarySearch(int[] data, int key) { ...

  // valueOf(): produces a string representation
  public static void putList(int[] data) { ...

  // getList(): extract and return up to MAX_LIST_SIZE values
  public static int[] getList() throws IOException { ...

  // reverse(): reverses the order of the element values
  public static void reverse(int[] list) { ...

  // binarySearch(): examine sorted list for a key
  public static int binarySearch(char[] data, char key) { ...
}
```

Demo.java

```
import java.util.*;

public class Demo {
   // main(): application entry point
   public static void main(String[] args) {
        System.out.println("");
        System.out.println("Enter list of integers:");
        int[] number = ArrayTools.getList();

        System.out.println("");
        System.out.println("Your list");
        ArrayTools.putList(number);

        ArrayTools.reverse(number);
        System.out.println("");
        System.out.println("Your list in reverse");
        ArrayTools.putList(number);
        System.out.println();
   }
}
```


Java Program Design
cmd: javac ArrayTools.java
cmd: javac Demo.java
cmd: java Demo
Enter list of integers, one per line:
12
11
10
^Z
Your list
12
11
10
Your list in reverse
10
11
12
cmd:

Sorting

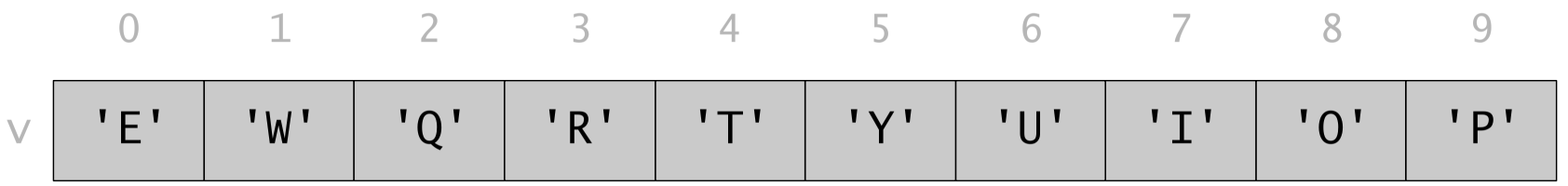
- Problem
  - Arranging elements so that they are ordered according to some desired scheme
    - Standard is non-decreasing order
      - Why don't we say increasing order?

- Major tasks
  - Comparisons of elements
  - Updates or element movement

Selection sorting

- Algorithm basis
  - On iteration i, a selection sorting method
    - Finds the element containing the ith smallest value of its list v and exchanges that element with v[i]

- Example – iteration 0
  - Swaps smallest element with v[0]
  - This results in smallest element being in the correct place for a sorted result



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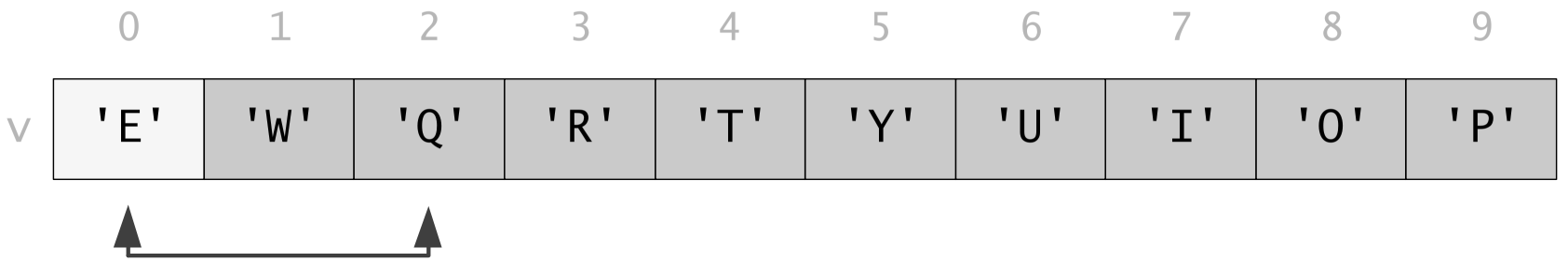
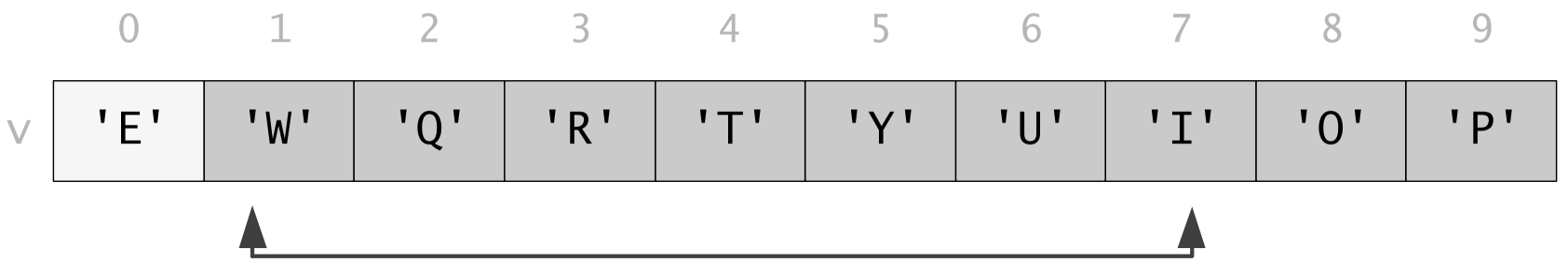


Selection sorting

- Algorithm basis
  - On iteration i, a selection sorting method
    - Finds the element containing the ith smallest value of its list v and exchanges that element with v[i]

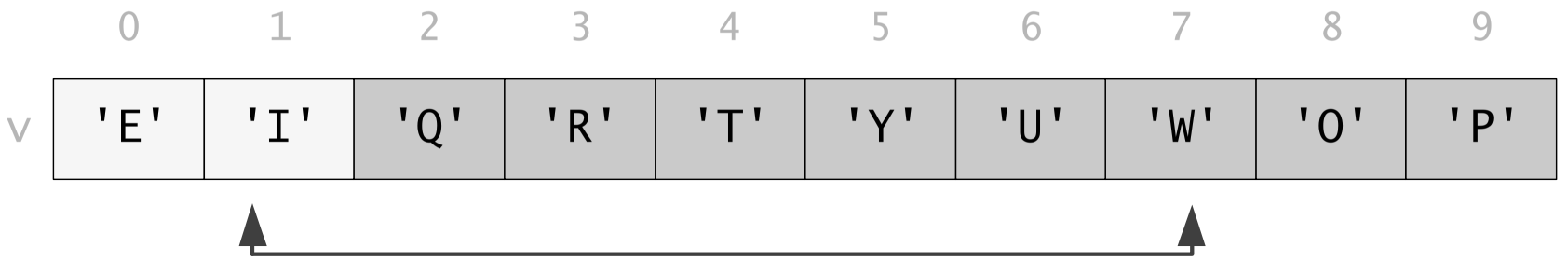
- Example – iteration 1
  - Swaps second smallest element with v[1]
  - This results in second smallest element being in the correct place for a sorted result



Selection sorting

- Algorithm basis
  - On iteration i, a selection sorting method
    - Finds the element containing the ith smallest value of its list v and exchanges that element with v[i]

- Example – iteration 1
  - Swaps second smallest element with v[1]
  - This results in second smallest element being in the correct place for a sorted result



ArrayTools.java selection sorting

```
public static void selectionSort(char[] v) {
   for (int i = 0; i < v.length-1; ++i) {
      // guess the location of the ith smallest element
       int guess = i;
       for (int j = i+1; j < v.length; ++j) {
          if (v[j] < v[guess]) { // is guess ok?
             // update guess to index of smaller element
             guess = j;
          }
       }

       // guess is now correct, so swap elements
       char rmbr = v[i];
       v[i] = v[guess];
       v[guess] = rmbr;
   }
}
```

Iteration i

```
// guess the location of the ith smallest element
int guess = i;
for (int j = i+1; j < v.length; ++j) {
  if (v[j] < v[guess]) // is guess ok?
      // update guess with index of smaller element
      guess = j;
}

// guess is now correct, swap elements v[guess] and v[0]
```

Multidimensional arrays

- Many problems require information be organized as a two-dimensional or multidimensional list

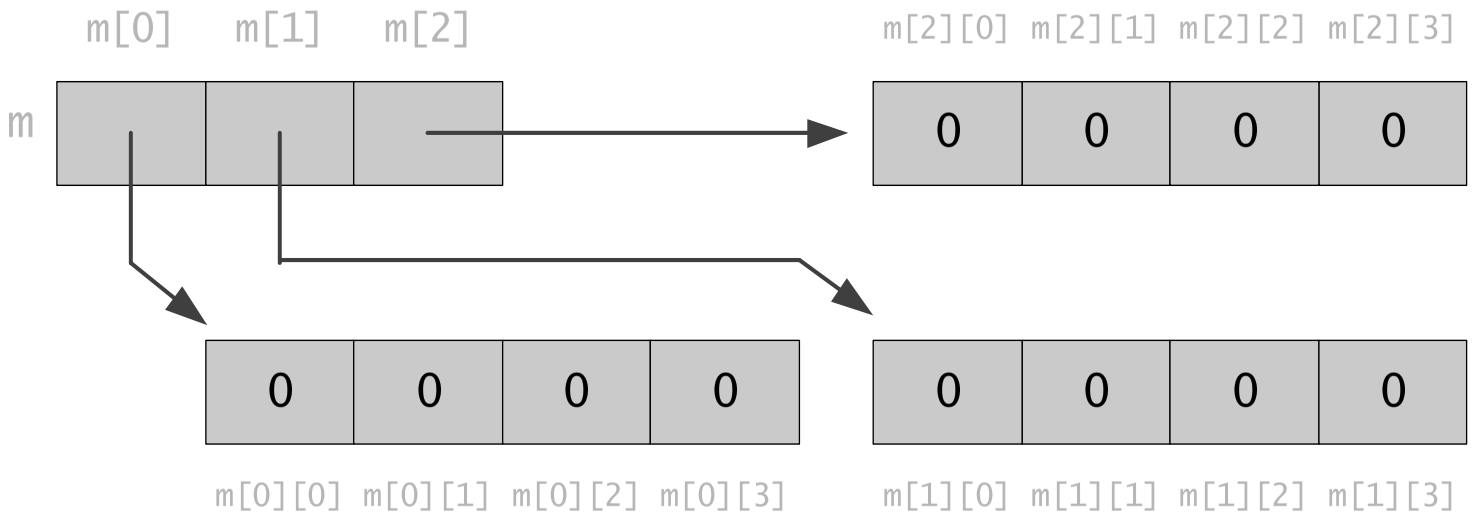
- Examples
  - Matrices
  - Graphical animation
  - Economic forecast models
  - Map representation
  - Time studies of population change
  - Microprocessor design

Example

- Segment

```
int[][] m = new int[3][];
m[0] = new int[4];
m[1] = new int[4];
m[2] = new int[4];
```

- Produces



Example

- Segment

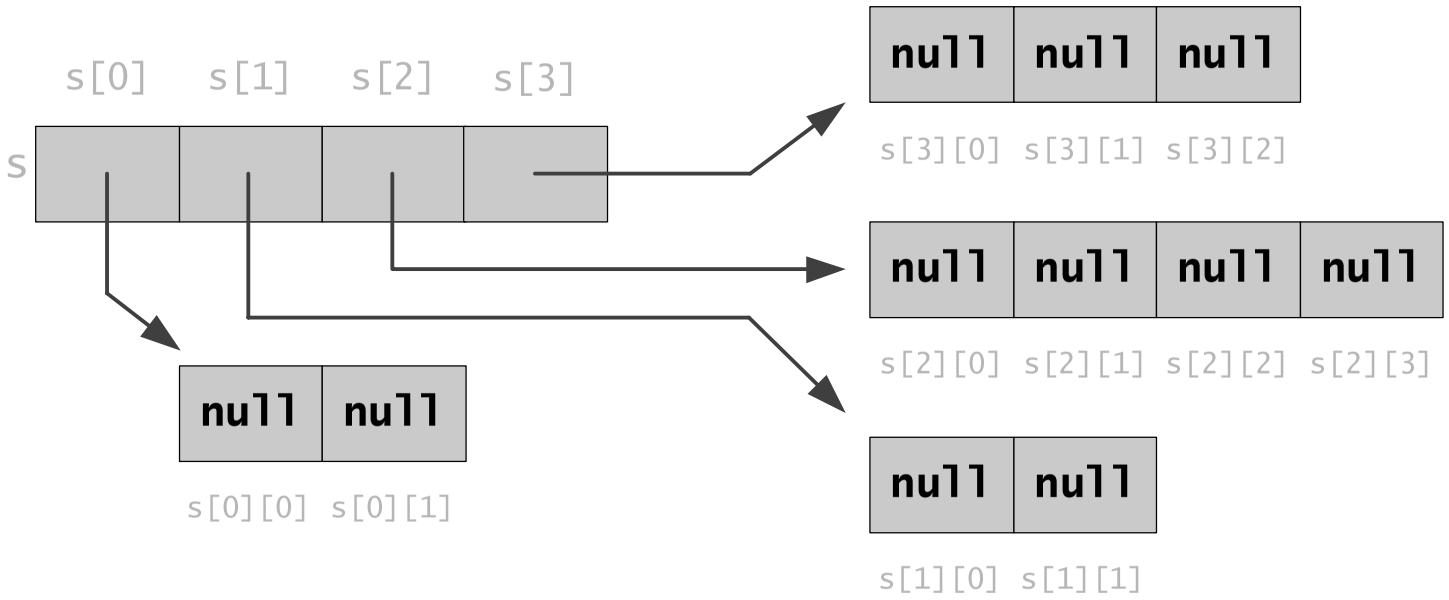
```
for (int r = 0; r < m.length; ++r) {
  for (int c = 0; c < m[r].length; ++c) {
   System.out.print("Enter a value: ");
   m[r][c] = stdin.nextInt();
  }
}
```

Example

- Segment

```
String[][] s = new String[4][];
s[0] = new String[2];
s[1] = new String[2];
s[2] = new String[4];
s[3] = new String[3];
```

- Produces

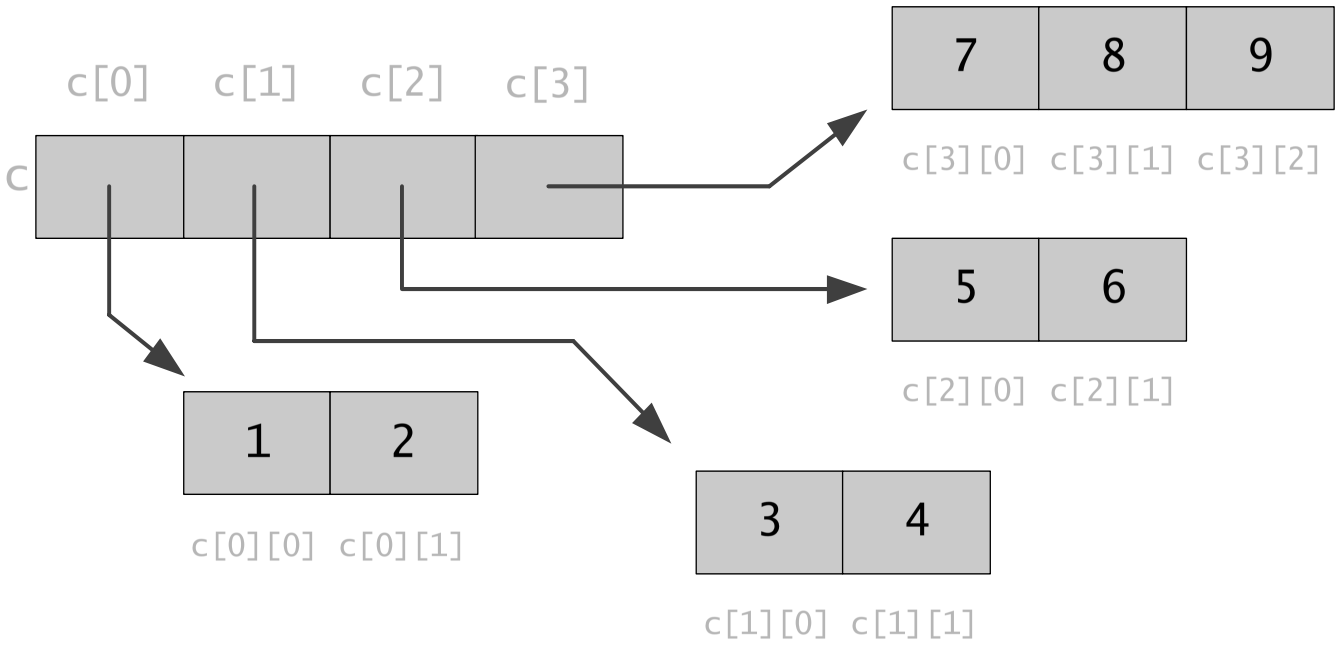


Example

- Segment

```
int c[][] = {{1, 2}, {3, 4}, {5, 6}, {7, 8, 9}};
```

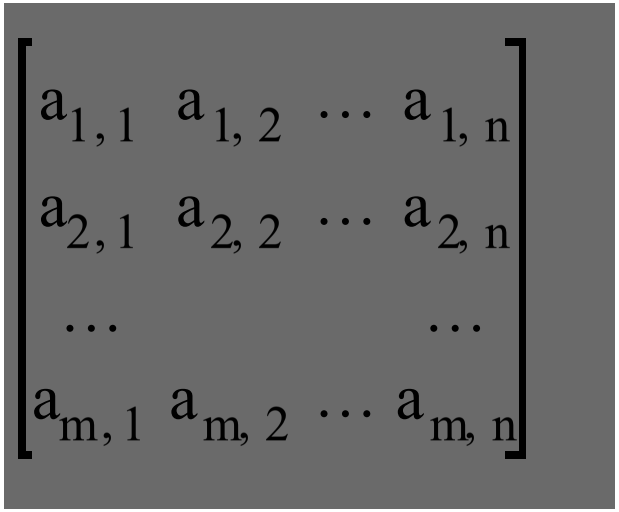
- Produces



Matrices

- A two-dimensional array is sometimes known as a matrix because it resembles that mathematical concept

- A matrix a with m rows and n columns is represented mathematically in the following manner



Matrix addition

- Definition C = A + B
  - $c_{ij} = a_{1i}b_{1j} + a_{i2}b_{2j} + \ldots + a_{in}b_{nj}$
  - c_{ij} is sum of terms produced by multipling the elements of a's row i with b's column c

Matrix addition

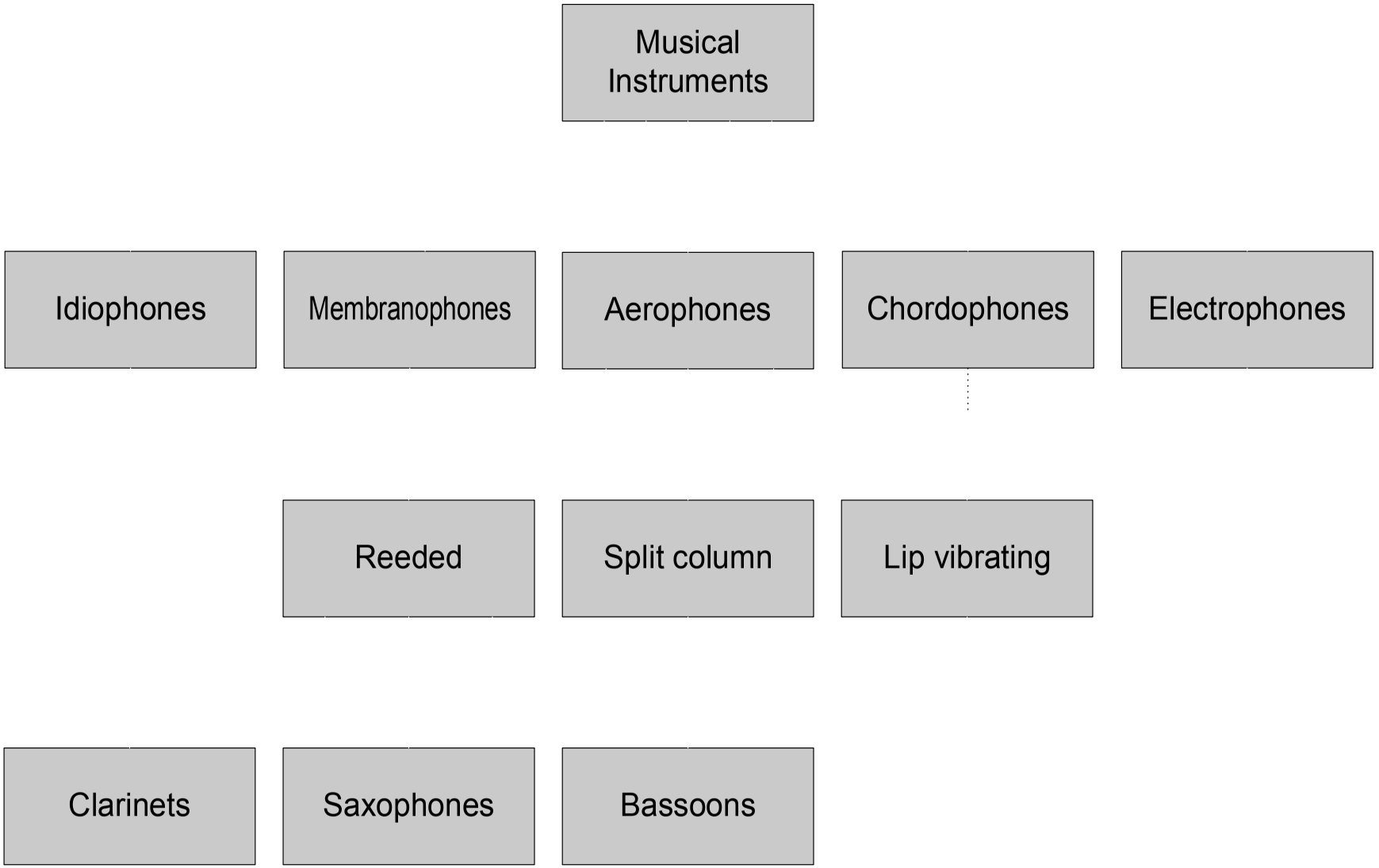
```
public static double[][] add(double[][] a, double[][]
                b) {

   // determine number of rows in solution
   int m = a.length;

   // determine number of columns in solution
   int n = a[0].length;

   // create the array to hold the sum
   double[][] c = new double[m][n];

   // compute the matrix sum row by row
   for (int i = 0; i < m; ++i) {
       // produce the current row
       for (int j = 0; j < n; ++j) {
              c[i][j] = a[i][j] + b[i][j];
       }
   }

   return c;
}
```

Inheritance and Polymorphism

Inheritance

- Organizes objects in a top-down fashion from most general to least general
- Inheritance defines a “is-a” relationship
  - A mountain bike “is a” kind of bicycle
  - A SUV “is a” kind of automobile
  - A border collie “is a” kind of dog
  - A laptop “is a” kind of computer

Musical instrument hierarchy

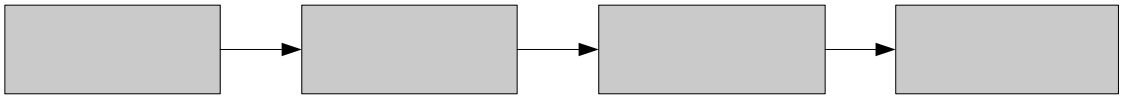


Musical instrument hierarchy

- The hierarchy helps us understand the relationships and similarities of musical instruments
  - A clarinet “is a” kind of reeded instrument
  - Reeded instruments “are a” kind of aerophone
- The “is-a” relationship is transitive
  - A clarinet “is a” kind of reeded instrument
  - A reeded instrument “is a” kind of aerophone
  - A clarinet “is a” kind of aerophone

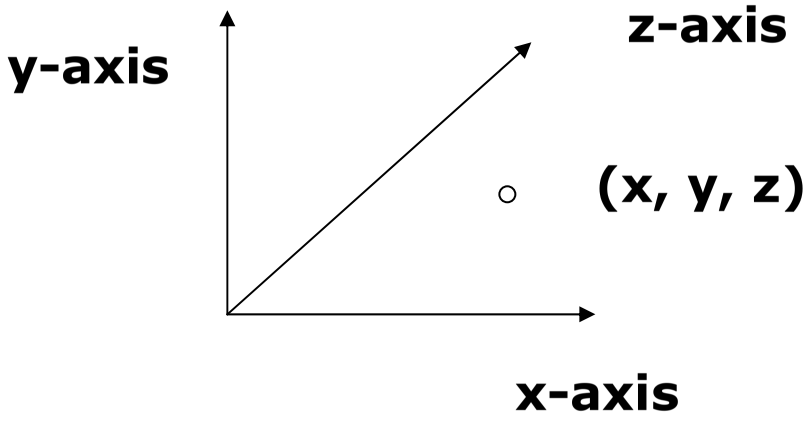
Object-oriented terminology

- In object-oriented programming languages, a class created by extending another class is called a *subclass*
- The class used for the basis is called the *superclass*
- Alternative terminology
  - The superclass is also referred to as the *base* class
  - The subclass is also referred to as the *derived* class



ThreeDimensionalPoint

- Build a new class `ThreeDimensionalPoint` using inheritance
  - `ThreeDimensionalPoint` extends the `awt` class `Point`
    - `Point` is the superclass (base class)
    - `ThreeDimensionalPoint` is the subclass (derived class)
  - `ThreedimensionalPoint` extends `Point` by adding a new property to `Point`—a z-coordinate



Class ThreeDimensionalPoint

```
package geometry;

import java.awt.*;


public class ThreeDimensionalPoint extends Point {
   // private class constant
   private final static int DEFAULT_Z = 0;

   // private instance variable
   public int z = DEFAULT_Z;
```

See next slide

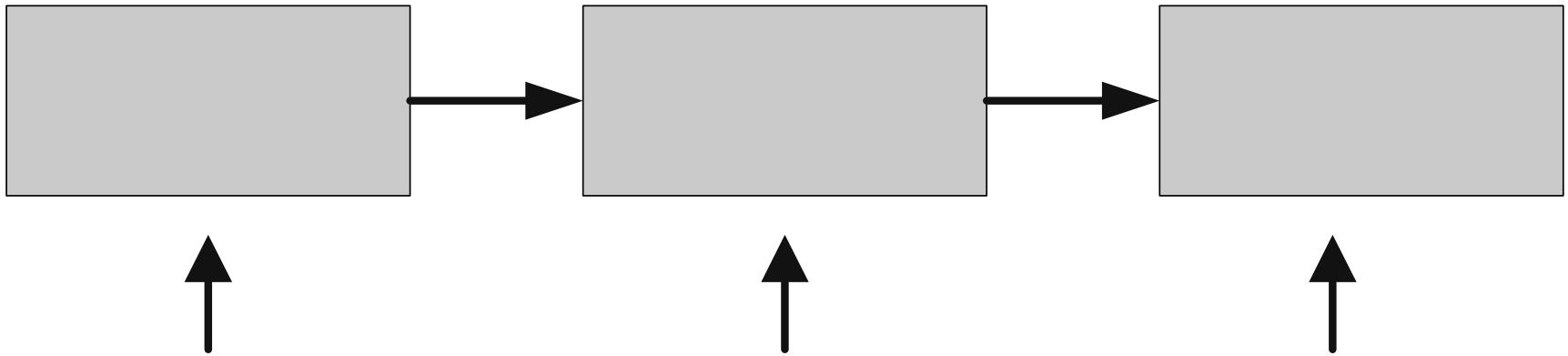
Keyword extends indicates that `ThreeDimensionalPoint` is a subclass of `Point`

New instance variable

Packages

- Allow definitions to be collected together into a single entity—a package
- `ThreeDimensionalPoint` will be added to the `geometry` package
  - Classes and names in the same package are stored in the same folder
  - Classes in a package go into their own namespace and therefore the names in a particular package do not conflict with other names in other packages
  - For example, a package called `Graph` might have a different definition of `ThreeDimensionalPoint`
  - When defining members of a class or interface, Java does not require an explicit access specification. The implicit specification is known as *default access*. Members of a class with default access can be accessed only by members of the package.

Java's Mother-of-all-objects—Class Object



Three
Dimensional
Point

P

ThreeDimensionalPoint

```
ThreeDimensionalPoint a =
   new ThreeDimensionalPoint(6, 21, 54);
a.translate(1, 1);    // invocation of superclass translate()
a.translate(2, 2, 2); // invocation of subclass translate()
```

- Java determines which method to use based on the number of parameters in the invocation
- After the first call to `translate`, what is the value of `a`?
- After the second call to `translate`, what is the value of `a`?

ThreeDimensionalPoint

- Methods `toString()`, `equals()` , and `clone()` should not have different signatures from the `Point` versions

```
ThreeDimensionalPoint c = new ThreeDImensionalPoint(1, 4, 9);

ThreeDimensionalPoint d = (ThreeDimensionalPoint) c.clone();
```

Cast is necessary as return type of subclass method `clone()` is Object

```
String s = c.toString();
```

Invocation of subclass `toString()` method

```
boolean b = c.equals(d);
```

Invocation of subclass `equals()` method

ThreeDimensionalPoint

- Constructors

```
// ThreeDimensionalPoint(): default constructor
public ThreeDimensionalPoint() {
    super();
}

// ThreeDimensionalPoint(): specific constructor
public ThreeDimensionalPoint(int a, int b, int c) {
    super(a, b);
    setZ(c);
}
```

ThreeDimensionalPoint

- Accessors and mutators

```
// getZ(): z-coordinate accessor
public double getZ() {
    return z;
}

// setZ(): y-coordinate mutator
public void setZ(int value) {
    z = value;
}
```

ThreeDimensionalPoint

- Facilitators

```
// translate(): shifting facilitator
public void translate(int dx, int dy, int dz) {
    translate(dx, dy);

    int zValue = (int) getZ();

    setZ(zValue + dz);
}
```

ThreeDimensionalPoint

- Facilitators

```
// toString(): conversion facilitator
public String toString() {
    int a = (int) getX();
    int b = (int) getY();
    int c = (int) getZ();
    return getClass() +
     "[" + a + ", " + b + ", " + c + "]";
}
```

ThreeDimensionalPoint

- Facilitators

```
// equals(): equality facilitator
public boolean equals(Object v) {
    if (v instanceof ThreeDimensionalPoint) {
        ThreeDimensionalPoint p =
         (ThreeDimensionalPoint) v;
        int z1 = (int) getZ();
        int z2 = (int) p.getZ();

        return super.equals(p) && (z1 == z2);
    }
    else {
        return false;
    }
}
```

ThreeDimensionalPoint

- Facilitators

```
// clone(): clone facilitator
public Object clone() {
    int a = (int) getX();
    int b = (int) getY();
    int c = (int) getZ();

    return new ThreeDimensionalPoint(a, b, c);
}
```

ColoredPoint

- Suppose an application calls for the use of colored points.
- We can naturally extend class `Point` to create `ColoredPoint`
- Class `ColoredPoint` will be added to **package** `geometry`

```
package geometry;

import java.awt.*;

public class ColoredPoint extends Point {
   // instance variable
   Color color;
   …
```

ColoredPoint

- Constructors

```
// ColoredPoint(): default constructor
public ColoredPoint() {
    super();
    setColor(Color.blue);
}

// ColoredPoint(): specific constructor
public ColoredPoint(int x, int y, Color c) {
    super(x, y);
    setColor(c);
}
```

ColoredPoint

- Accessors and mutators

```
// getColor(): color property accessor
public Color getColor() {
    return color;
}

// setColor(): color property mutator
public void setColor(Color c) {
    color = c;
}
```

ColoredPoint

- Facilitators

```
// clone(): clone facilitator
public Object clone() {
    int a = (int) getX();
    int b = (int) getY();
    Color c = getColor();
    return new ColoredPoint(a, b, c);
}
```

ColoredPoint

- Facilitators

```
// toString(): string representation facilitator
public String toString() {
    int a = (int) getX();
    int b = (int) getY();
    Color c = getColor();
    return getClass() +
     "[" + a + ", " + b + ", " + c + "]";
}
```

ColoredPoint

- Facilitators

```
// toString(): string representation facilitator
public String toString() {
    int a = (int) getX();
    int b = (int) getY();
    Color c = getColor();
    return getClass() +
     "[" + a + ", " + b + ", " + c + "]";
}
```

ColoredPoint

- Facilitators

```
// equals(): equal facilitator
public boolean equals(Object v) {
    if (v instanceof ColoredPoint) {
        Color c1 = getColor();
        Color c2 = ((ColoredPoint) v).getColor();
        return super.equals(v) && c1.equals(c2);
    }
    else {
        return false;
    }
```

Colored3DPoint

- Suppose an application needs a colored, three-dimensional point.
- Can we create such a class by extending both ThreeDimensionalPoint and ColoredPoint?
  - No. Java does not support multiple inheritance
  - Java only supports single inheritance

```
package Geometry;
import java.awt.*;

public class Colored3DPoint extends ThreeDimensionalPoint {
   // instance variable
   Color color;
```

Colored3DPoint

- Constructors

```
// Colored3DPoint(): default constructor
public Colored3DPoint() {
    setColor(Color.blue);
}

// Colored3DPoint(): specific constructor
public Colored3DPoint(int a, int b, int c, Color d) {
    super(a, b, c);
    setColor(d);
}
```

Colored3DPoint

- Accessors and mutators

```
// getColor(): color property accessor
public Color getColor() {
    return color;
}

// setColor(): color property mutator
public void setColor(Color c) {
    color = c;
}
```

Colored3DPoint

- Facilitators

```
// clone(): clone facilitator
public Object clone() {
    int a = (int) getX();
    int b = (int) getY();
    int c = (int) getZ();
    Color d = getColor();
    return new Colored3DPoint(a, b, c, d);
}
```

Colored3DPoint

- Facilitators

```
// toString(): string representation facilitator
public String toString() {
    int a = (int) getX();
    int b = (int) getY();
    int c = (int) getZ();
    Color d = getColor();
    return getClass() +
     "[" + a + ", " + b + ", " + c + ", " + d + "]";
}
```

Colored3DPoint

- Facilitators

```
// equals(): equal facilitator
public boolean equals(Object v) {
    if (v instanceof Colored3DPoint) {
        Color c1 = getColor();
        Color c2 = ((Colored3DPoint) v).getColor();
        return super.equals(v) && c1.equals(c2);
    }
    else {
        return false;
    }
```

Polymorphism

- A code expression can invoke different methods depending on the types of objects being manipulated
- Example: function overloading like method `min()` from `java.lang.Math`
  - The method invoked depends on the types of the actual arguments

Example

```
int a, b, c;
double x, y, z;
…
c = min(a, b);    // invokes integer min()
z = min(x, y);    // invokes double min
```

Polymorphism

- Two types of polymorphism
  - Syntactic polymorphism—Java can determine which method to invoke at compile time
    - Efficient
    - Easy to understand and analyze
    - Also known as primitive polymorphism
  - Pure polymorphism—the method to invoke can only be determined at execution time

Polymorphism

- Pure polymorphism example

```
public class PolymorphismDemo {
   // main(): application entry point
   public static void main(String[] args) {
        Point[] p = new Point[4];

        p[0] = new Colored3DPoint(4, 4, 4, Color.BLACK);
        p[1] = new ThreeDimensionalPoint(2, 2, 2);
        p[2] = new ColoredPoint(3, 3, Color.RED);
        p[3] = new Point(4, 4);

        for (int i = 0; i < p.length; ++i) {
                String s = p[i].toString();
                System.out.println("p[" + i + "]: " + s);
        }

        return;
   }
}
```

Inheritance nuances

- When a new object that is a subclass is constructed, the constructor for the superclass is always called.
  - Constructor invocation may be implicit or explicit

Example

```
public class B {
   // B(): default constructor
   public B() {
       System.out.println("Using B's default constructor");
   }

   // B(): specific constructor
   public B(int i) {
       System.out.println("Using B's int constructor");
   }
}
```

Inheritance nuances

```
public class C extends B {
   // C(): default constructor
   public C() {
        System.out.println("Using C's default constructor");
        System.out.println();
   }

   // C(int a): specific constructor
   public C(int a) {
        System.out.println("Using C's int constructor");
        System.out.println();
   }
```

Inheritance nuances

```
// C(int a, int b): specific constructor
public C(int a, int b) {
    super(a + b);
    System.out.println("Using C's int-int constructor");
    System.out.println();
}

// main(): application entry point
public static void main(String[] args) {
    C c1 = new C();
    C c2 = new C(2);
    C c3 = new C(2,4);
    return;
}
```

Inheritance nuances

Output

```
Using B's default constructor
Using C's default constructor

Using B's default constructor
Using C's int constructor

Using B's int constructor
Using C's int-int constructor
```

Controlling access

- Class access rights

Member Restriction	this	Subclass	Package	General
`public`	✓	✓	✓	✓
`protected`	✓	✓	✓	—
`default`	✓	—	✓	—
`private`	✓	—	—	—

Controlling access

Example

```
package demo;

public class P {
   // instance variable
   private int data;

   // P(): default constructor
   public P() {
       setData(0);
   }

   // getData(): accessor
   public int getData() {
       return data;
   }
```

Controlling access

Example (continued)

```
    // setData(): mutator
    protected void setData(int v) {
        data = v;
    }

    // print(): facilitator
    void print() {
        System.out.println();
    }
}
```

Controlling access

Example

```
import demo.P;

public class Q extends P {
   // Q(): default constructor
   public Q() {
        super();
   }

   // Q(): specific constructor
   public Q(int v) {
        setData(v);
        }
```

Q can access superclass's public default constructor

Q can access superclass's protected mutator

Controlling access

Example

```
  // toString(): string facilitator
  public String toString() {
      int v = getData();
      return String.valueOf(v);
  }
  // invalid1(): illegal method
  public void invalid1() {
      data = 12;
  }
  // invalid2(): illegal method
  public void invalid2() {
      print();
  }
}
```

Q can access superclass's public accessor

Q cannot access superclass's private data field

Q cannot directly access superclass's default access method print()

Controlling access

Example

```
package demo;

public class R {
  // instance variable
  private P p;

  // R(): default constructor
  public R() {
      p = new P();
  }
  // set(): mutator
  public void set(int v) {
      p.setData(v);
  }
```

R can access P's public default constructor

R can access P's protected mutator

Controlling access

Example

```
// get(): accessor
public int get() {
    return p.getData();
}
// use(): facilitator
public void use() {
    p.print();
}
// invalid(): illegal method
public void invalid() {
    p.data = 12;
}
```

R can access P's public accessor

R can access P's default access method

R cannot directly access P's private data

Controlling access

Example

```
import demo.P;

public class S {
  // instance variable
  private P p;

  // S(): default constructor
  public S() {
      p = new P();
  }
  // get(): inspector
  public int get() {
      return p.getData();
  }
```

S can access P's public default constructor

S can access P's public accessor

Controlling access

Example

```
   // illegal1(): illegal method
   public void illegal1(int v) {
        p.setData(v);
   }
   // illegal2(): illegal method
   public void illegal2() {
        p.data = 12;
   }
   // illegal3(): illegal method
   public void illegal3() {
        p.print();
   }
}
```

S cannot access P's protected mutator

S cannot access directly P's private data field

S cannot access directly P's default access method print()

Data fields

- A superclass's instance variable can be hidden by a subclass's definition of an instance variable with the same name

Example

```
public class D {
  // D instance variable
  protected int d;

  // D(): default constructor
  public D() {
      d = 0;
  }
  // D(): specific constructor
  public D(int v) {
      d = v;
  }
```

Data fields

Class D (continued)

```
    // printD(): facilitator
    public void printD() {
        System.out.println("D's d: " + d);
        System.out.println();
    }
}
```

Data fields

- Class F extends D and introduces a new instance variable named d. F's definition of d hides D's definition.

```
public class F extends D {
   // F instance variable
   int d;

   // F(): specific constructor
   public F(int v) {
        d = v;
        super.d = v*100;
   }
```

Modification of this's d

Modification of superclass's d

Data fields

Class F (continued)

```
 // printF(): facilitator
public void printF() {
    System.out.println("D's d: " + super.d);
    System.out.println("F's d: " + this.d);
    System.out.println();
}
```

Inheritance and types

Example

```
public class X {
   // default constructor
   public X() {
       // no body needed
   }
   // isX(): class method
   public static boolean isX(Object v) {
       return (v instanceof X);
   }
   // isObject(): class method
   public static boolean isObject(X v) {
       return (v instanceof Object);
   }
}
```

Inheritance and types

Example

```
public class Y extends X {
   // Y(): default constructor
   public Y() {
       // no body needed
   }

   // isY(): class method
   public static boolean isY(Object v) {
       return (v instanceof Y);
   }
```

Inheritance and types

Example (continued)

```
public static void main(String[] args) {
    X x = new X();
    Y y = new Y();
    X z = y;

    System.out.println("x is an Object: " +
     X.isObject(x));
    System.out.println("x is an X: " + X.isX(x));
    System.out.println("x is a Y: " + Y.isY(x));
    System.out.println();
```

Inheritance and types

Example (continued)

```
        System.out.println("y is an Object: " +
         X.isObject(y));
        System.out.println("y is an X: " + X.isX(y));
        System.out.println("y is a Y: " + Y.isY(y));
        System.out.println();

        System.out.println("z is an Object: " +
         X.isObject(z));
        System.out.println("z is an X: " + X.isX(z));
        System.out.println("z is a Y: " + Y.isY(z));
        return;
    }
}
```

Inheritance and types

- The program outputs the following:

```
x is an Object: true
x is an X: true
x is a Y: false

y is an Object: true
y is an X: true
y is a Y: true

z is an Object: true
z is an X: true
z is a Y: true
```

Polymorphism and late binding

Example

```
public class L {
   // L(): default constructor
   public L() {
   }
   // f(): facilitator
   public void f() {
       System.out.println("Using L's f()");
       g();
   }
   // g(): facilitator
   public void g() {
       System.out.println("using L's g()");
   }
}
```

Polymorphism and late binding

Example

```
public class M extends L {
   // M(): default constructor
   public M() {
       // no body needed
   }
   // g(): facilitator
   public void g() {
       System.out.println("Using M's g()");
   }
```

Polymorphism and late binding

Example

```
   // main(): application entry point
   public static void main(String[] args) {
        L l = new L();
        M m = new M();
        l.f();
        m.f();
        return;
   }
}
```

Outputs

```
    Using L's f()
    using L's g()
    Using L's f()
    Using M's g()
```

Finality

- A final class is a class that cannot be extended.
  - Developers may not want users extending certain classes
  - Makes tampering via overriding more difficult

Example

```
final public class U {
   // U(): default constructor
   public U() {
   }

   // f(): facilitator
   public void f() {
       System.out.println("f() can't be overridden:“
    + "U is final");
   }
}
```

Finality

- A final method is a method that cannot be overridden.

Example

```
public class V {
   // V(): default constructor
   public V() {
   }

   // f(): facilitator
   final public void f() {
        System.out.println("Final method f() can't be " +
         " overridden");
   }
}
```

Abstract base classes

- Allows creation of classes with methods that correspond to an abstract concept (i.e., there is not an implementation)
- Suppose we wanted to create a class `GeometricObject`
  - Reasonable concrete methods include
    - `getPosition()`
    - `setPosition()`
    - `getColor()`
    - `setColor()`
    - `paint()`
  - For all but `paint()`, we can create implementations.
  - For `paint()`, we must know what kind of object is to be painted. Is it a square, a triangle, etc.
  - Method `paint()` should be an abstract method

Abstract base classes

Example

Makes `GeometricObject` an abstract class

```
import java.awt.*;

abstract public class GeometricObject {
   // instance variables
   Point position;
   Color color;

   // getPosition(): return object position
   public Point getPosition() {
       return position;
   }
   // setPosition(): update object position
   public void setPosition(Point p) {
       position = p;
   }
```

Abstract base classes

Example (continued)

```
    // getColor(): return object color
    public Color getColor() {
        return color;
    }
    // setColor(): update object color
    public void setColor(Color c) {
        color = c;
    }
    // paint(): render the shape to graphics context g
    abstract public void paint(Graphics g);
}
```

Indicates that an implementation of method paint() will not be supplied

Interfaces

- An interface is a template that specifies what must be in a class that imlements the interface
  - An interface cannot specify any method implementations
  - All the methods of an interface are public
  - All the variables defined in an interface are `public`, `final`, and `static`

Interfaces

- An interface for a colorable object

```
public interface Colorable {
   // getColor(): return the color of the object
   public Color getColor();
   // setColor(): set the color of the object
   public void setColor(Color c);
}
```

- Now the interface can be used to create classes that implement the interface

Interfaces

- ColorablePoint

```
import java.awt.*;

public class ColorablePoint extends Point implements Colorable
   {
   // instance variable
   Color color;

   // ColorablePoint(): default constructor
   public ColorablePoint() {
        super();
        setColor(Color.blue);
   }
```

…

Class ColorablePoint must provide implementations of getColor() and setColor()

Exceptions

Exception

- Abnormal event occurring during program execution

- Examples
  - Manipulate nonexistent files

```
FileReader in = new FileReader("mumbers.txt“);
```

  - Improper array subscripting

```
int[] a = new int[3];
a[4] = 1000;
```

  - Improper arithmetic operations

```
a[2] = 1000 / 0;
```

Java treatment of an exception

- If exception occurs and a *handler* is in effect
  - Flow of control is transferred to the handler
  - After handler completes flow of control continues with the statement following the handler

- If exception occurs and there is no handler for it
  - The program terminates

Task

- Prompt and extract the name of a file
- From that file, two integer values are to be extracted
- Compute and display the quotient of the values

Implementation

```
public static void main(String[] args) throws IOException {

   Scanner stdin = new Scanner(System.in);
   System.out.print("Filename: ");
   String s = stdin.nextLine();

   File file = new File(s);
   Scanner fileIn = new Scanner(file);

   int a = fileIn.nextInt();
   int b = fileIn.nextInt();

   System.out.println( a / b );
}
```

What can go wrong?

```
public static void main(String[] args) throws
    IOException {

    Scanner stdin = new Scanner(System.in);
    System.out.print("Filename: ");
    String s = stdin.nextLine();

    File file = new File(s);
    Scanner fileIn = new Scanner(file);

    int a = fileIn.nextInt();
    int b = fileIn.nextInt();

    System.out.println( a / b );
}
```

How can we deal with the problems?

```
public static void main(String[] args) throws IOException {

    Scanner stdin = new Scanner(System.in);
    System.out.print("Filename: ");
    String s = stdin.nextLine();

    File File = new File(s);
    Scanner fileIn = new Scanner(file);(

    int a = fileIn.nextInt());
    int b = fileIn.nextInt());

    System.out.println( a / b );
}
```

Exception handlers

- Code that might generate an exception is put in a try block
  - If there is no exception, then the handlers are ignored
- For each potential exception type there is a catch handler
  - When handler finishes the program continues with statement after the handlers

```
try {
  Code that might throw exceptions of types E or F
}
catch (E e) {
  Handle exception e
}
catch (F f) {
  Handle exception f
}
More code
```

Introduce try-catch blocks

```
public static void main(String[] args) throws IOException {

   Scanner stdin = new Scanner(System.in);
   System.out.print("Filename: ");
   String s = stdin.nextLine();

   File file = new File(s);
   Scanner fileIn = new Scanner(file);

   int a = fileIn.nextInt();
   int b = fileIn.nextInt());

   System.out.println( a / b );
}
```

Setting up the file stream processing

```
Scanner stdin = new Scanner(System.in);
System.out.print("Filename: ");
String s = stdin.nextLine();
// set up file stream for processing
Scanner fileIn = null;

try {
   File file = new File(s);
   fileIn = new Scanner(file);
}
catch (FileNotFoundException e) {
   System.err.println(s + ": Cannot be opened for reading");
   System.exit(0);
}
```

How come the main() throws expression did not indicate it could throw a FileNotFoundException?

Getting the inputs

```
try {
   int a = fileIn.nextInt();
   int b = fileIn.nextInt();
   System.out.println( a / b );
}
catch (InputMismatchException e) {
   System.err.println(s + ": contains nonnumeric inputs");
   System.exit(0);
}
```

Converting the inputs

```
try {
   int a = fileIn.nextInt();
   int b = fileIn.nextInt();
   System.out.println( a / b );
}
catch (InputMismatchException e) {
   System.err.println(s + ": contains nonnumeric inputs");
   System.exit(0);
}
catch (NoSuchElementException e) {
   System.err.println(s + ": does not contain two inputs");
   System.exit(0);
   }
catch (ArithmeticException e) {
   System.err.println(s + ": unexpected 0 input value");
   System.exit(0);

   }
}
```

Run time exceptions

- Java designers realized
  - Runtime exceptions can occur throughout a program
  - Cost of implementing handlers for runtime exceptions typically exceeds the expected benefit

- Java makes it optional for a method to catch them or to specify that it throws them

- However, if a program does not handle its runtime exceptions it is terminated when one occurs

Commands type and cat

- Most operating systems supply a command for listing the contents of files
  - Windows: type
  - Unix, Linux, and OS X: cat

type $filename_1$ $filename_2$ … $filename_n$

- Displays the contents of $filename_1$ $filename_2$ … and $filename_n$ to the console window

Possible method main() for Type.java

```
public static void main(String[] args) {
   for (int i = 0; i < args.length; ++i) {
       File file = new File(args[i]);
       Scanner fileIn = new Scanner(file);

       while (fileIn.hasNext()) {
          String s = fileIn.nextLine();
          System.out.println(s);
       }
       fileIn.close();
   }
}
```

What can go wrong?

Use a finally block

```
public static void main(String[] args) {
   for (int i = 0; i < args.length; ++i) {
       File fileIn = new File(args[i]);
       Scanner fileIn = new Scanner(file);
       while (fileIn.hasNext()) {
          String s = fileIn.nextLine();
          System.out.println(s);
       }
       fileIn.close();
   }
}
```

File should be closed once its processing stops, regardless why it stopped

Use a finally block

```
try {
   fileIn = null;
   File file = new File(args[i]);
   fileIn = new Scanner(file);
   while (fileIn.hasNext()) {
        String s = fileIn.nextLine();
        System.out.println(s);
   }
}
catch (FileNotFoundException e) {
   System.err.println(args[i] + ": cannot be opened");
}
catch (IOException e) {
   System.err.println(args[i] + ": processing error");
}
finally {
   if (fileIn != null) {
      filein.close();
   }
}
```

← Always executed after its try-catch blocks complete

Exceptions

- Can create your exception types
- Can throw exceptions as warranted

Task

- Represent the depositing and withdrawing of money from a bank account

- What behaviors are needed
  - Construct a new empty bank account

    ```
    BankAccount()
    ```
  - Construct a new bank account with initial funds

    ```
    BankAccount(int n)
    ```
  - Deposit funds

    ```
    addFunds(int n)
    ```
  - Withdraw funds

    ```
    removeFunds(int n)
    ```
  - Get balance

    ```
    Int getBalance()
    ```

Sample usage

```
public static void main(String[] args)
   Scanner stdin = new Scanner(System.in);

   BankAccount savings = new BankAccount();

   System.out.print("Enter deposit: ");
   int deposit = stdin.nextInt());
   savings.addFunds(deposit);

   System.out.print("Enter widthdrawal: ");
   int withdrawal = stdin.nextInt();
   savings.removeFunds(withdrawl);

   System.out.println("Closing balance: "
       + savings.getBalance());
}
```

Task

- Represent the depositing and withdrawing of money from a bank account

- What behaviors are needed
  - Construct a new empty bank account

    ```
    BankAccount()
    ```
  - Construct a new bank account with initial funds

    ```
    BankAccount(int n)
    ```
  - Deposit funds

    ```
    addFunds(int n)
    ```
  - Withdraw funds

    ```
    removeFunds(int n)
    ```
  - Get balance

    ```
    int getBalance()
    ```

What can go wrong?

Create a NegativeAmountException

```
// Represents an abnormal bank account event

public class NegativeAmountException extends Exception {
   // NegativeAmountException(): creates exception with
   // message s
   public NegativeAmountException(String s) {
       super(s);
   }
}
```

- Class Exception provides the exceptions behavior that might be needed
- Class NegativeAmountException gives the specialization of exception type that is needed

Sample usage

```
public static void main(String[] args)
       throws IOException, NegativeAmountException {

   Scanner stdin = new Scanner(System.in);

   BankAccount savings = new BankAccount();

   System.out.print("Enter deposit: ");
   int deposit = stdin.nextInt());
   savings.addFunds(deposit);

   System.out.print("Enter withdrawal: ");
   int withdrawal = stdin.nextInt());
   savings.removeFunds(withdrawl);

   System.out.println("Closing balance: "
       + savings.getBalance());
}
```

Class BankAccount

- Instance variable
  `balance`
- Construct a new empty bank account
  `BankAccount()`
- Construct a new bank account with initial funds
  `BankAccount(int n) throws NegativeAmountException`
- Deposit funds
  `addFunds(int n) throws NegativeAmountException`
- Withdraw funds
  `removeFunds(int n) throws NegativeAmountException`
- Get balance
  `Int getBalance()`

Class BankAccount

```
// BankAccount(): default constructor for empty balance
public BankAccount() {
   balance = 0;
}

// BankAccount(): specific constructor for a new balance n
public BankAccount(int n) throws NegativeAmountException {
   if (n >= 0) {
        balance = n;
   }
   else {
        throw new NegativeAmountException("Bad balance");
   }
}
```

Class BankAccount

```
// getBalance(): return the current balance
public int getBalance() {
   return balance;
}

// addFunds(): deposit amount n
public void addFunds(int n) throws NegativeAmountException {
   if (n >= 0) {
        balance += n;
   }
   else {
        throw new NegativeAmountException("Bad deposit");
   }
}
```

Class BankAccount

```
// removeFunds(): withdraw amount n
public void removeFunds(int n) throws NegativeAmountException
   {
   if (n < 0) {
        throw new NegativeAmountException("Bad withdrawal");
   }
   else if (balance < n) {
        throw new NegativeAmountException("Bad balance");
   }
   else {
        balance -= n;
   }
}
```

Using NegativeAmountException

```
System.out.print("Enter deposit: ");
try {
   int deposit = stdin.nextInt();
   savings.addFunds(deposit);
}
catch (NegativeAmountException e) {
   System.err.println(“Cannot deposit negative funds“);
   System.exit(0);
}
```

Using NegativeAmountException

```
System.out.print("Enter withdrawal: ");
try {
   int withdrawal = stdin.nextInt();
   savings.removeFunds(withdrawl);
}
catch (NegativeAmountException e) {
   if (e.message().equals("Bad withdrawal"))
       System.err.println(“Cannot withdraw negative funds“);
   else {
       System.err.println("Withdrawal cannot leave "
          "negative balance");
   }
   System.exit(0);
}
```

Recursion

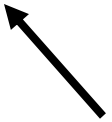
Recursive definitions

- A definition that defines something in terms of itself is called a recursive definition.
  - The *descendants* of a person are the person's children and all of the *descendants* of the person's children.
  - A *list of numbers* is a number or a number followed by a comma and a *list of numbers*.
- A recursive algorithm is an algorithm that invokes itself to solve smaller or simpler instances of a problem instances.
  - The factorial of a number *n* is *n* times the factorial of *n*-1.

Factorial

- An imprecise definition

$$n! = \begin{cases} 1 & n = 0 \\ n \cdot (n-1) \cdot \ldots \cdot 1 & n \geq 1 \end{cases}$$



Ellipsis tells the reader to use intuition to recognize the pattern

- A precise definition

$$n! = \begin{cases} 1 & n = 0 \\ n \cdot (n\text{-}1)! & n \geq 1 \end{cases}$$

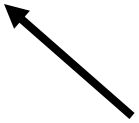
Recursive methods

- A recursive method generally has two parts.
  - A termination part that stops the recursion.
    - This is called the base case.
    - The base case should have a simple or trivial solution.
  - One or more recursive calls.
    - This is called the recursive case.
    - The recursive case calls the same method but with simpler or smaller arguments.

Method factorial()

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

Base case



Recursive case deals with a simpler (smaller) version of the task

Method factorial()

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

public static void main(String[] args) {
   Scanner stdin = new Scanner(System.in);
   int n = stdin.nextInt();
   int nfactorial = factorial(n);
   System.out.println(n + "! = " + nfactorial;
}
```

Recursive invocation

- A new activation record is created for *every* method invocation
  - Including recursive invocations

Recursive invocation

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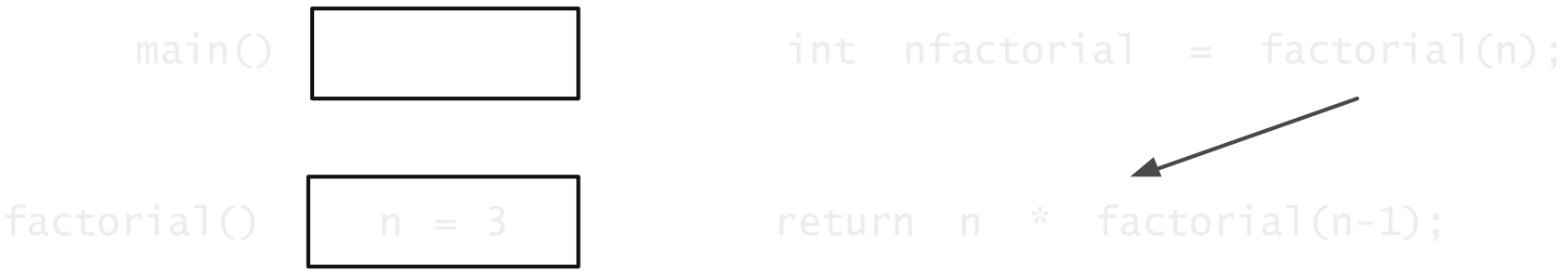

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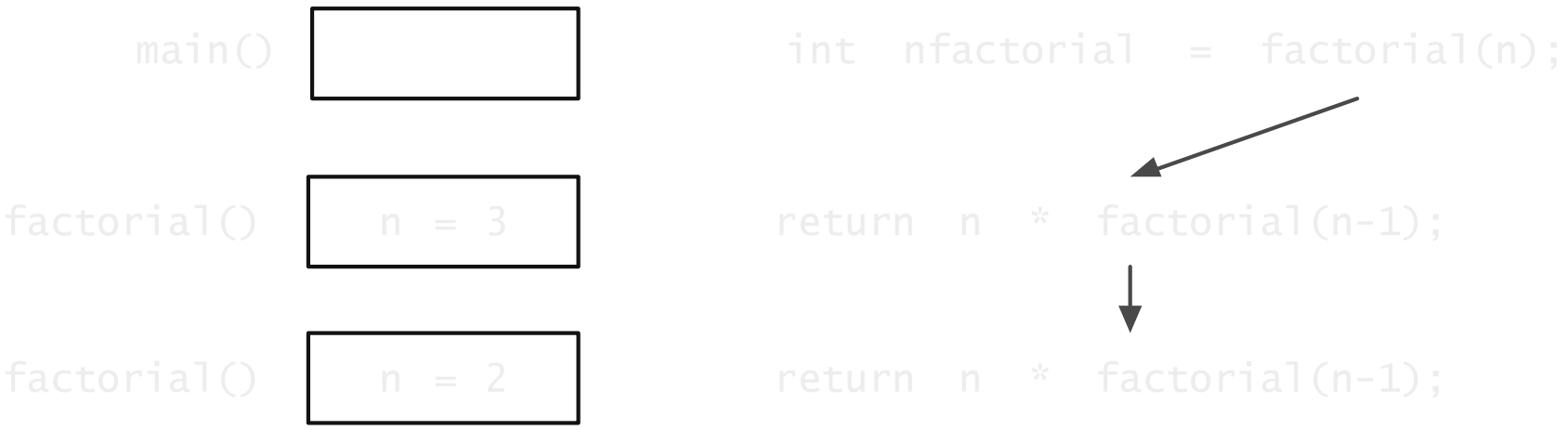

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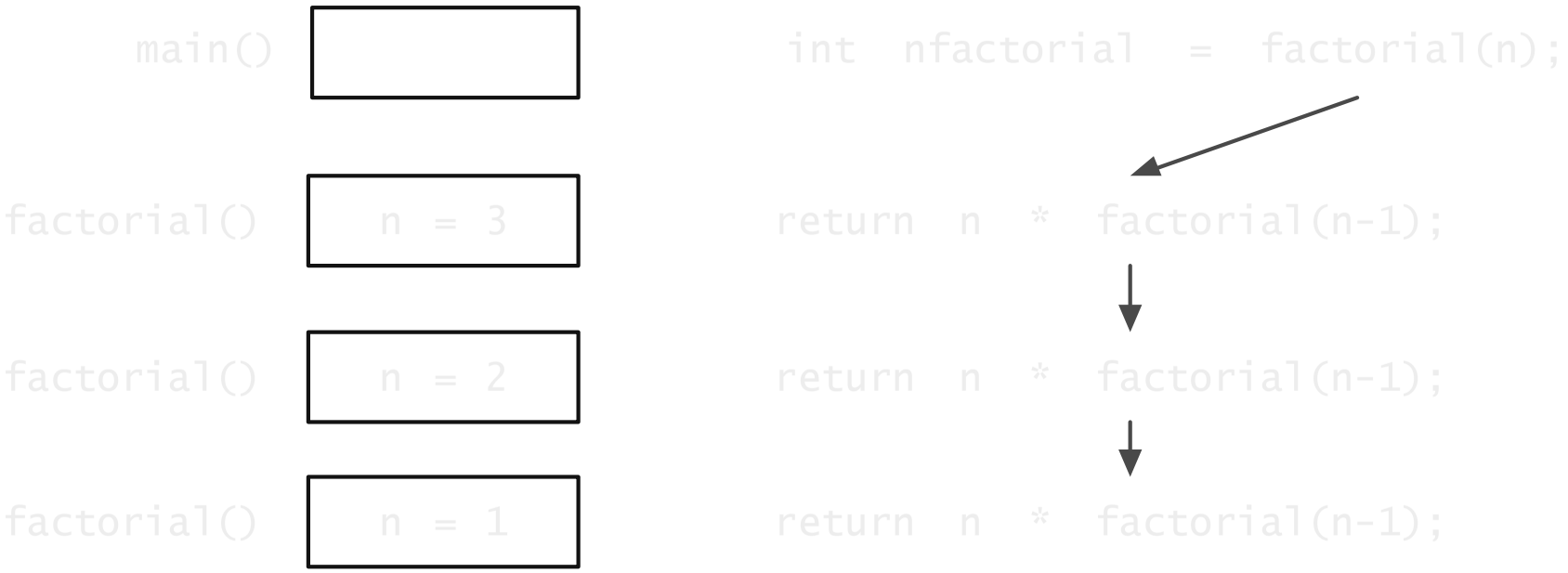

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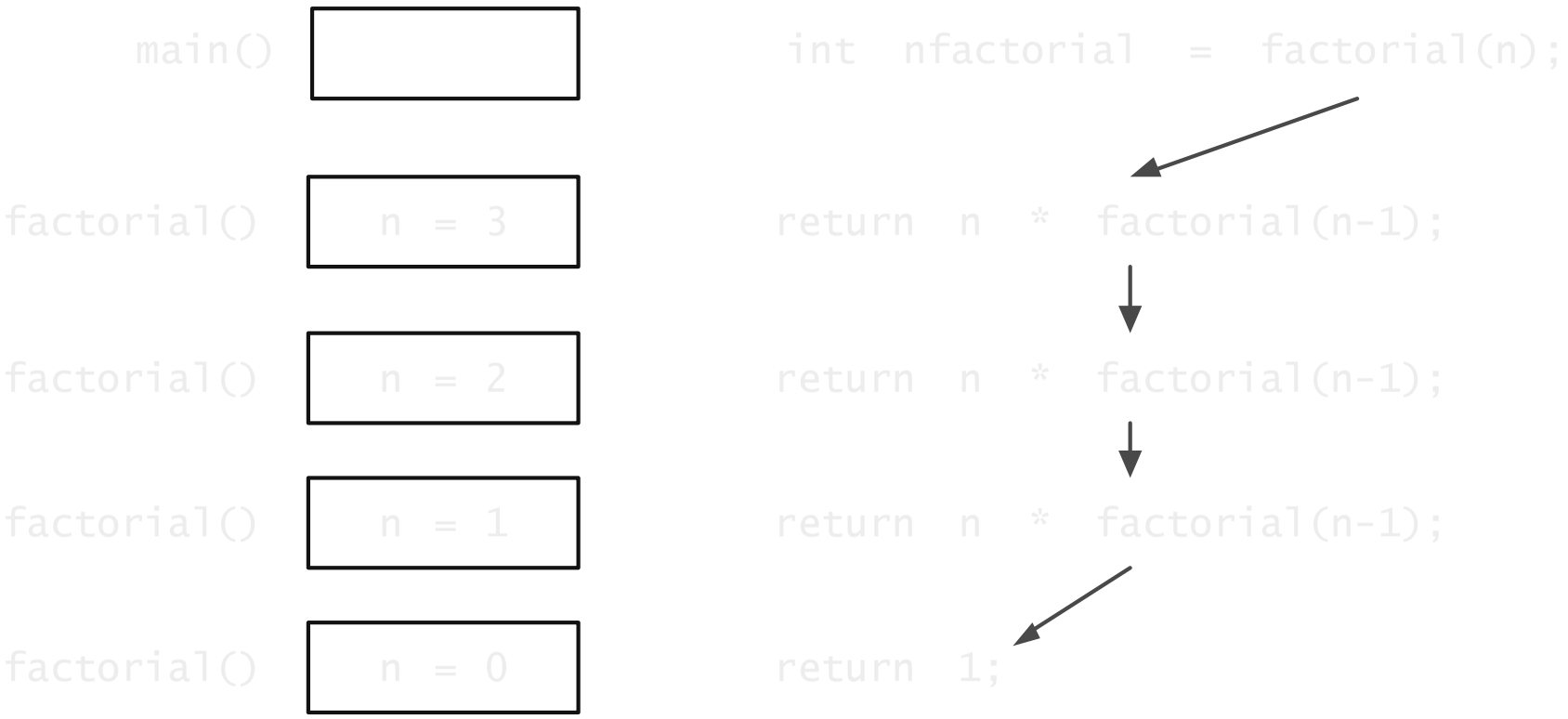

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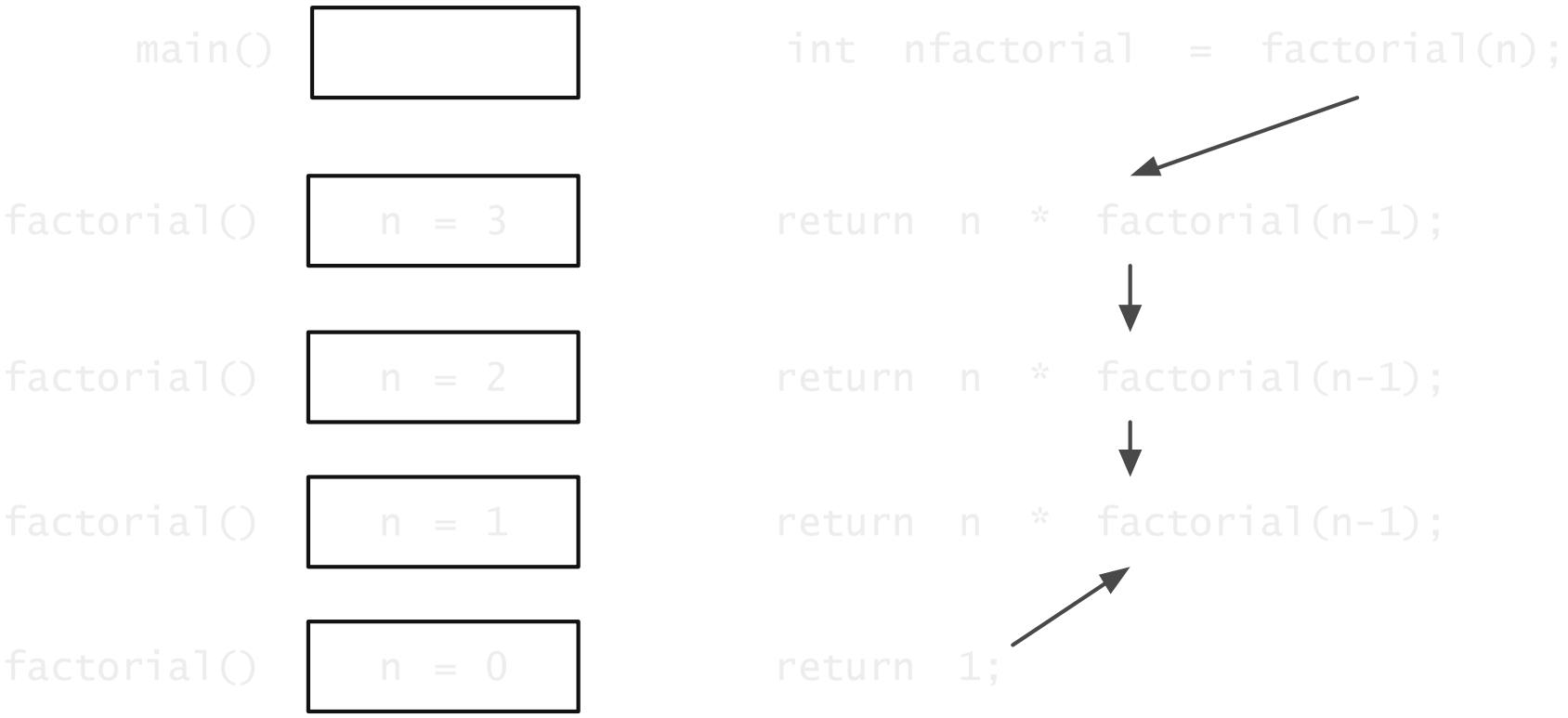

Recursive invocation

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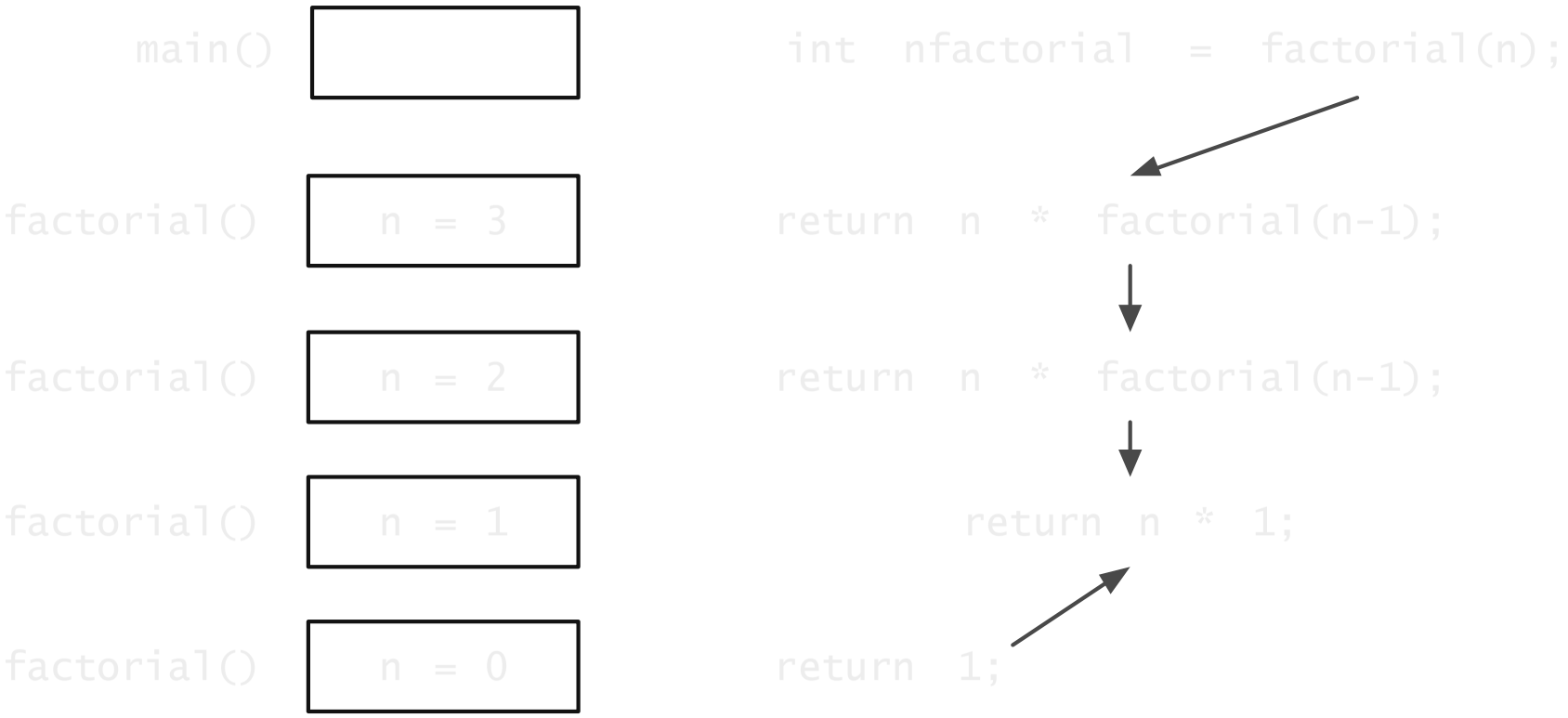

Recursive invocation

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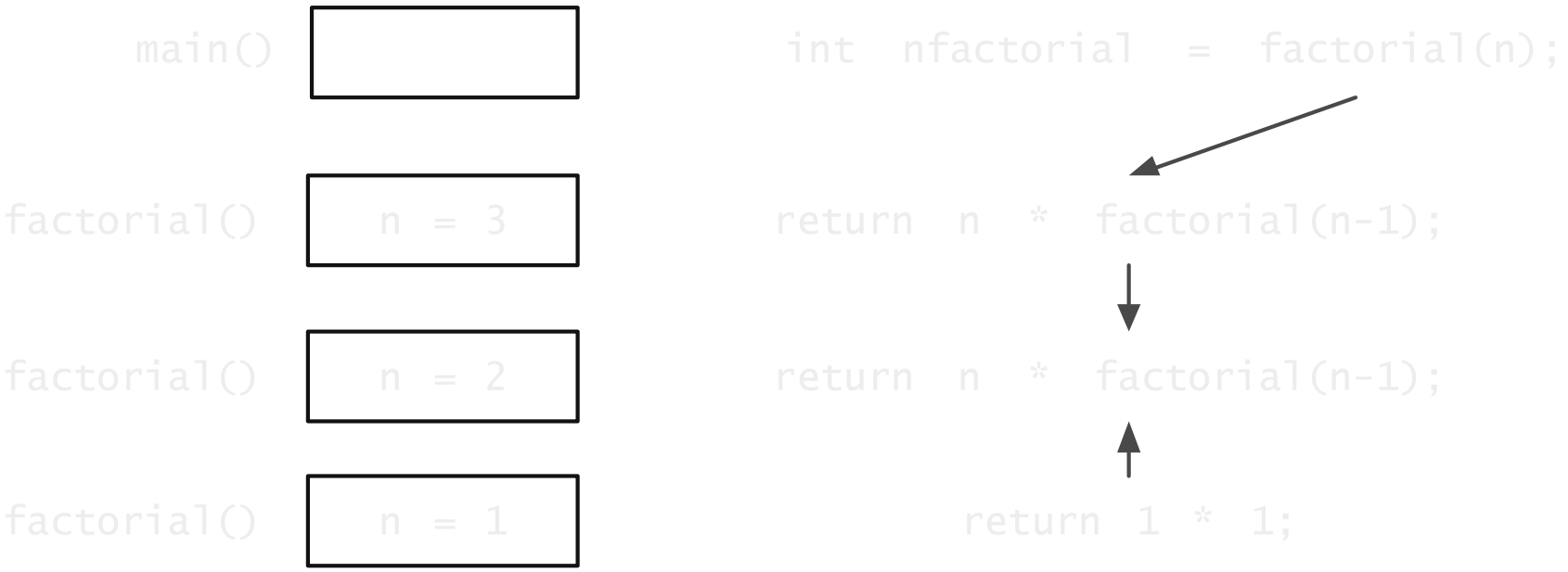

Recursive invocation

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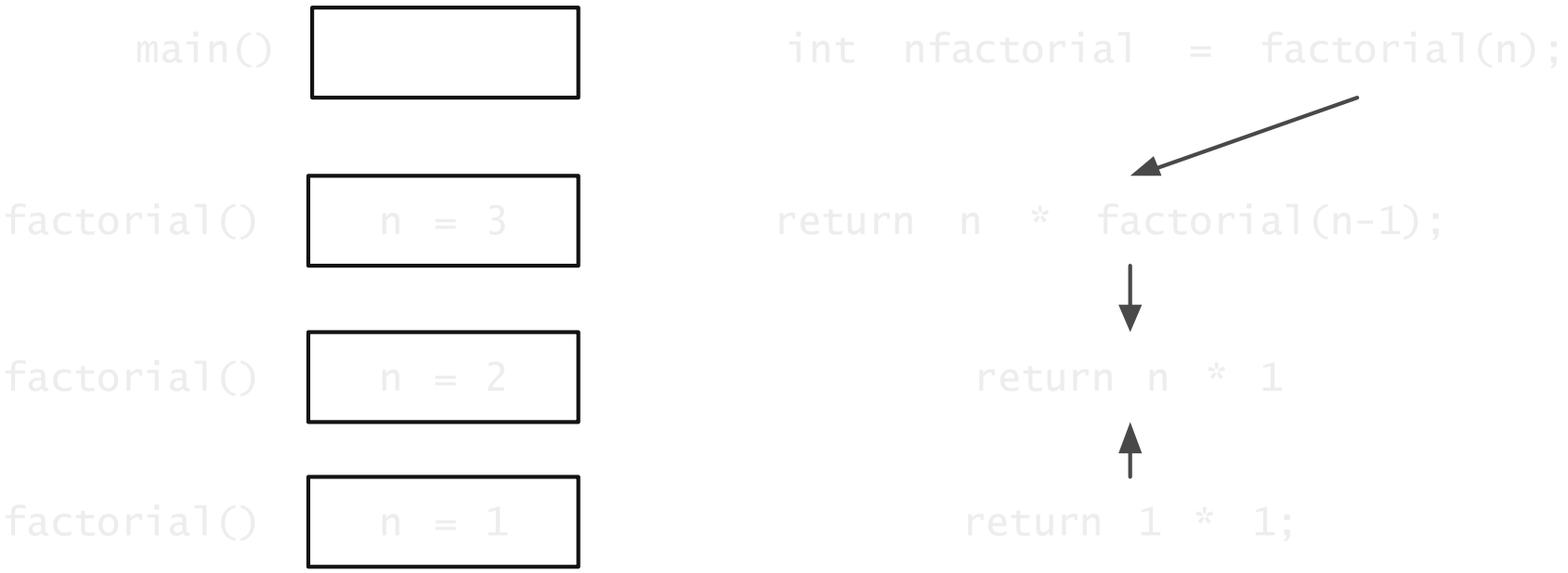

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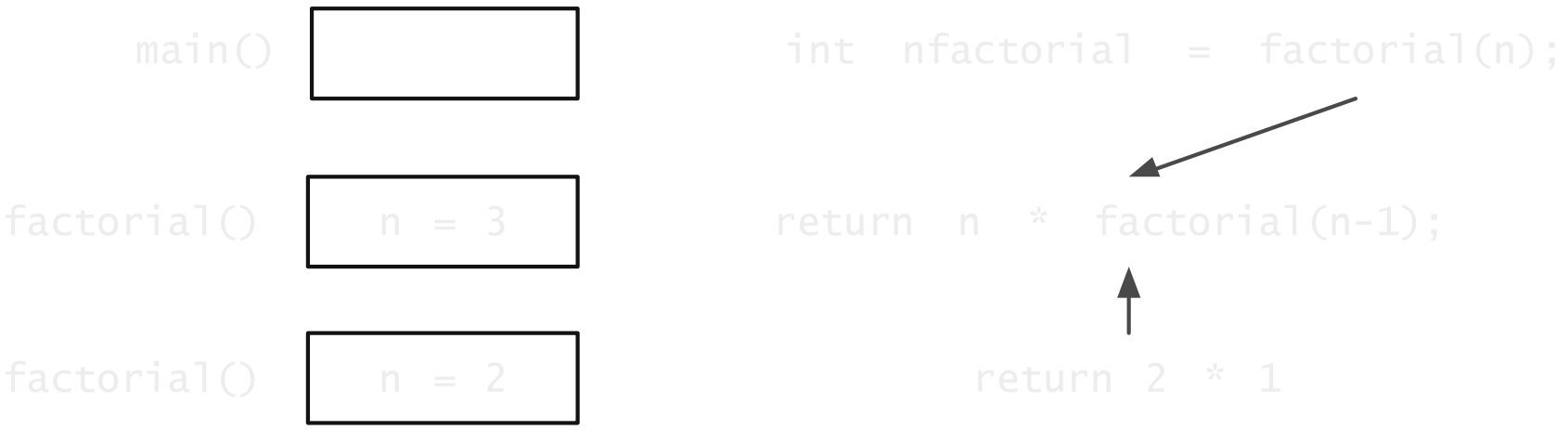

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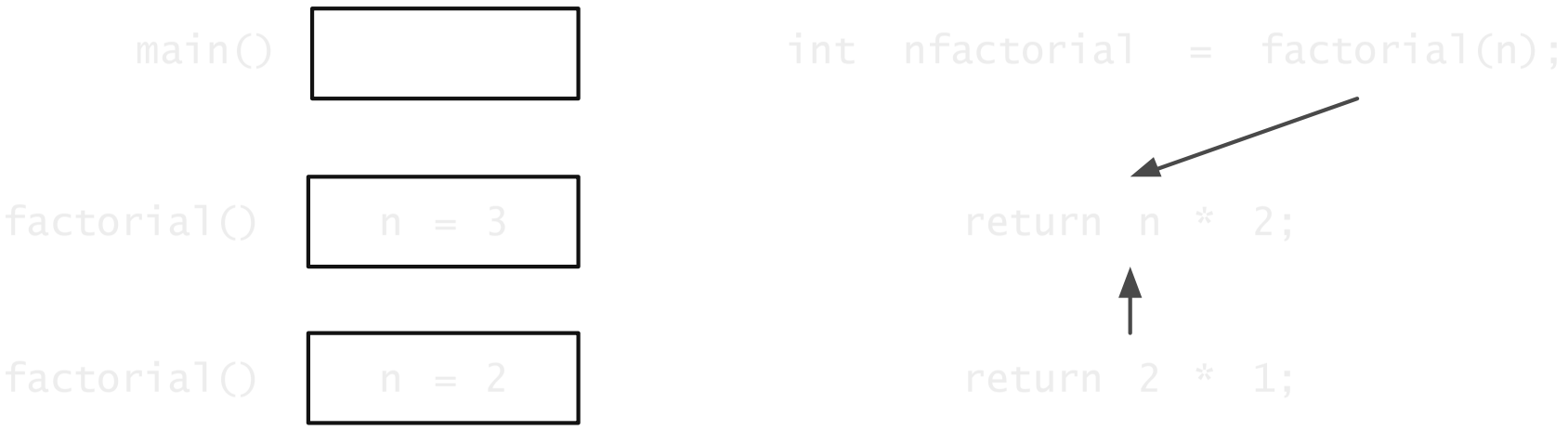

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Fibonacci numbers

- Developed by Leonardo Pisano in 1202.
  - Investigating how fast rabbits could breed under idealized circumstances.
  - Assumptions
    - A pair of male and female rabbits always breed and produce another pair of male and female rabbits.
    - A rabbit becomes sexually mature after one month, and that the gestation period is also one month.
  - Pisano wanted to know the answer to the question how many rabbits would there be after one year?

Fibonacci numbers

- The sequence generated is: 1, 1, 2, 3, 5, 8, 13, 21, 34, …
- The number of pairs for a month is the sum of the number of pairs in the two previous months.
- Insert Fibonacci equation

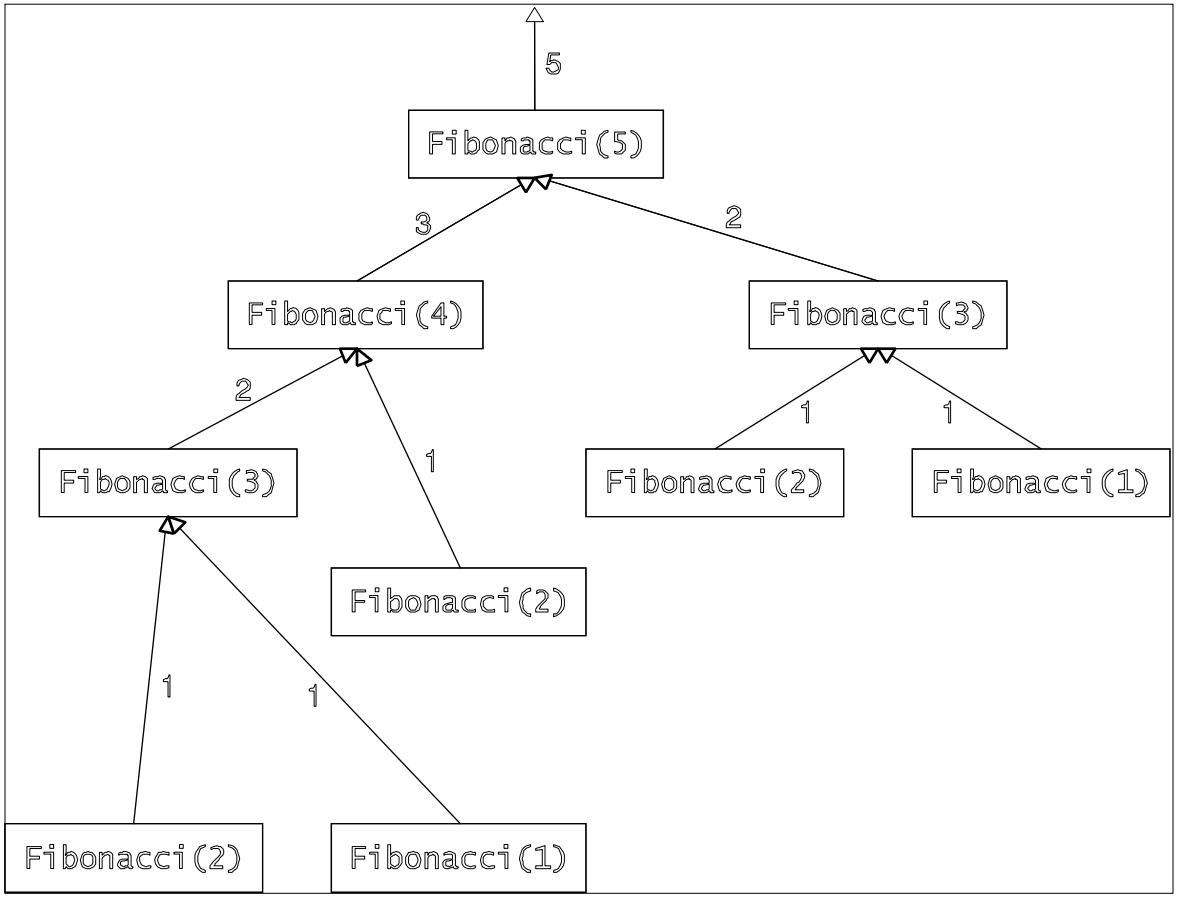
Fibonacci numbers

- Recursive method pattern

```
if ( termination code satisfied ) {
   return value;
}
else {
   make simpler recursive call;
}
```

```
public static int fibonacci(int n) {
   if (n <= 2) {
       return 1;
   }
   else {
       return fibonacci(n-1) + fibonacci(n-2);
   }
}
```

Fibonacci numbers

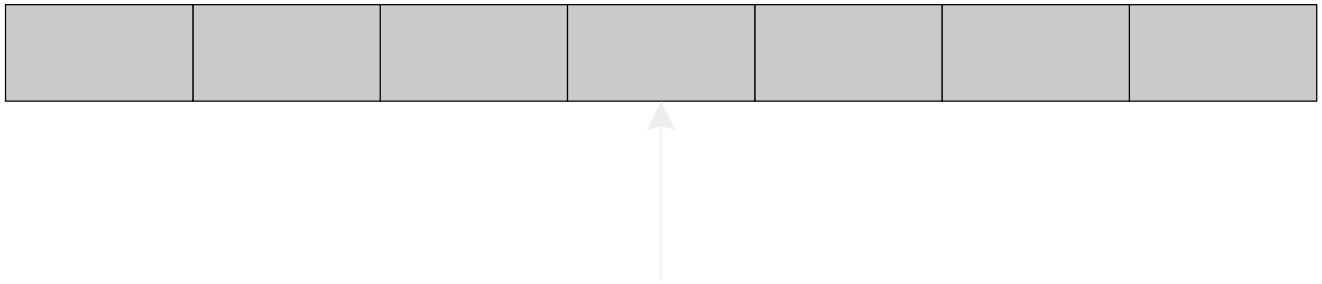


Infinite recursion

- A common programming error when using recursion is to not stop making recursive calls.
  - The program will continue to recurse until it runs out of memory.
  - Be sure that your recursive calls are made with simpler or smaller subproblems, and that your algorithm has a base case that terminates the recursion.

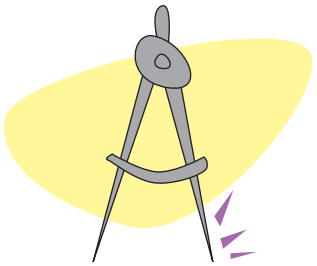
Binary search

- Compare the entry to the middle element of the list. If the entry matches the middle element, the desired entry has been located and the search is over.
- If the entry doesn’t match, then if the entry is in the list it must be either to the left or right of the middle element.
- The correct sublist can be searched using the same strategy.



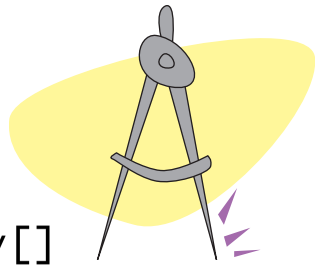
Develop search for an address book

```
public class AddressEntry {
   private String personName;
   private String telephoneNumber;

   public AddressEntry(String name, String number) {
      personName = name;
      telephoneNumber = number;
   }
   public String getName() {
      return personName;
   }
   public String getNumber() {
      return telephoneNumber;
   }
   public void setName(String Name) {
       personName = Name;
   }
   public void setTelephoneNumber(String number) {
      telephoneNumber = number;
   }
}
```



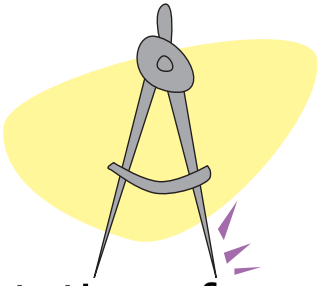
Binary search

- Public interface
  - Should be as simple as possible
  - No extraneous parameters



```
public static AddressEntry recSearch(AddressEntry[]
 addressBook, String name)
```

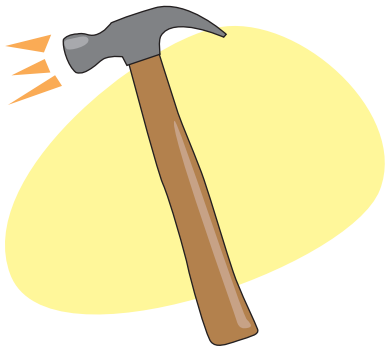
- Private interface
  - Invoked by implementation of public interface
  - Should support recursive invocation by implementation of private interface



```
private static AddressEntry recSearch(AddressEntry[]
 addressBook, String name, int first, int last)
```

Binary search

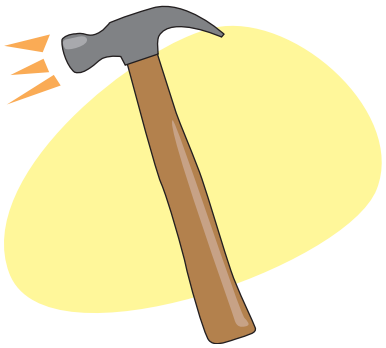
- Public interface implementation



```
public static AddressEntry recSearch(AddressEntry[]
   addressBook, String name) {
    return recSearch(addressBook, name, 0,
   addressBook.length-1);
}
```

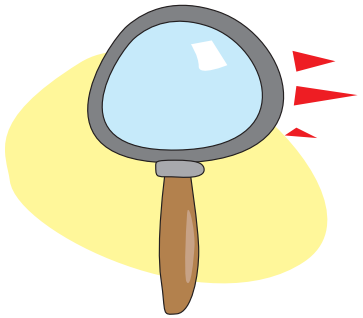
Private interface implementation

```
static AddressEntry recSearch(AddressEntry[] addressBook,
 String name, int first, int last) {
   // base case: if the array section is empty, not found
   if (first > last)
      return null;
   else {
      int mid = (first + last) / 2;
      // if we found the value, we're done
      if (name.equalsIgnoreCase(addressBook[mid].getName()))
         return addressBook[mid];
      else if (name.compareToIgnoreCase(
       addressBook[mid].getName()) < 0) {
          // if value is there at all, it's in the left half
          return recSearch(addressBook, name, first, mid-1);
      }
       else { // array[mid] < value
          // if value is there at all, it's in the right half
          return recSearch(addressBook, name, mid+1, last);
      }
   }
}
```



Testing

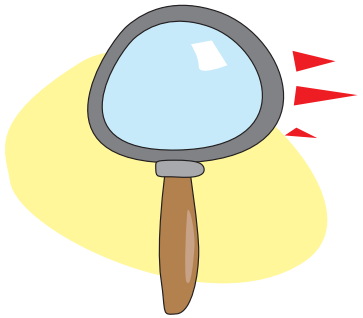
- Develop tests cases to exercise every possible unique situation



```
public static void main(String[] args) {
   // list must be in sorted order
   AddressEntry addressBook[] = {
      new AddressEntry("Audrey", "434-555-1215"),
      new AddressEntry("Emily" , "434-555-1216"),
      new AddressEntry("Jack"  , "434-555-1217"),
      new AddressEntry("Jim"   , "434-555-2566"),
      new AddressEntry("John"  , "434-555-2222"),
      new AddressEntry("Lisa"  , "434-555-3415"),
      new AddressEntry("Tom"   , "630-555-2121"),
      new AddressEntry("Zach"  , "434-555-1218")
   };
```

Testing

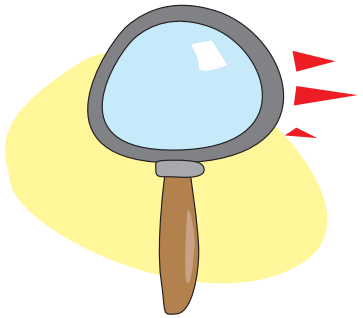
- Search for first element



```
AddressEntry p;
// first element
p = recSearch(addressBook, "Audrey");
if (p != null) {
   System.out.println("Audrey's telephone number is " +
    p.getNumber());
}
else {
   System.out.println("No entry for Audrey");
}
```

Testing

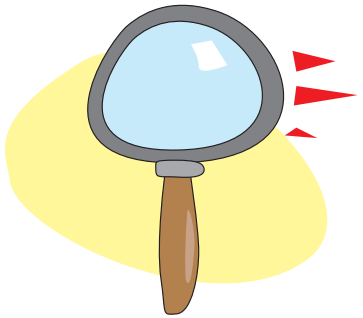
- Search for middle element



```
p = recSearch(addressBook, "Jim");
if (p != null) {
   System.out.println("Jim's telephone number is " +
    p.getNumber());
}
else {
   System.out.println("No entry for Jim");
}
```

Testing

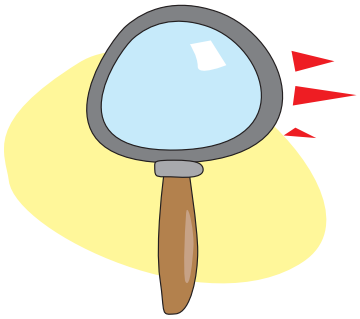
- Search for last element



```
p = recSearch(addressBook, "Zach");
if (p != null) {
   System.out.println("Zach's telephone number is " +
    p.getNumber());
}
else {
   System.out.println("No entry for Zach");
}
```

Testing

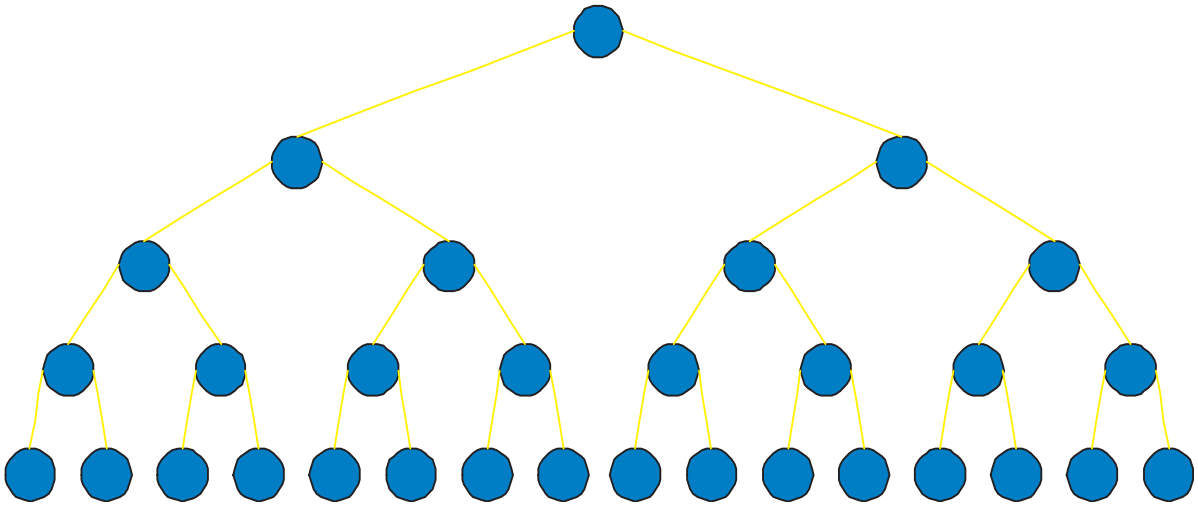
- Search for non-existent element



```
p = recSearch(addressBook, "Frank");
if (p != null) {
   System.out.println("Frank's telephone number is " +
    p.getNumber());
}
else {
   System.out.println("No entry for Frank");
}
```

Efficiency of binary search

- Height of a binary tree is the worst case number of comparisons needed to search a list
- Tree containing 31 nodes has a height of 5
- In general, a tree with n nodes has a height of $\log_2(n+1)$
- Searching a list with a billion nodes only requires 31 comparisons
- Binary search is efficient!

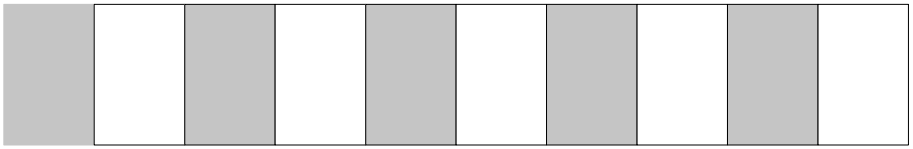


Mergesort

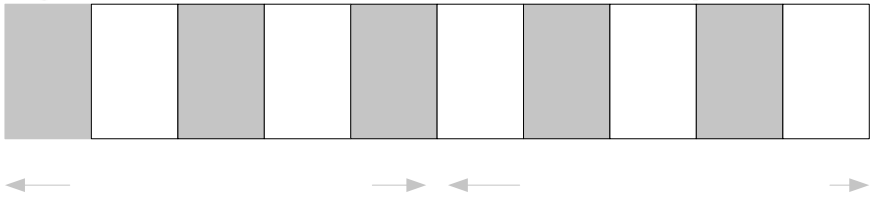
- Mergesort is a recursive sort that conceptually divides its list of *n* elements to be sorted into two sublists of size *n*/2.
  - If a sublist contains more than one element, the sublist is sorted by a recursive call to mergeSort().
  - After the two sublists of size *n*/2 are sorted, they are merged together to produce a single sorted list of size *n*.
- This type of strategy is known as a divide-and-conquer strategy—the problem is divided into subproblems of lesser complexity and the solutions of the subproblems are used to produced the overall solution.
- The running time of method mergeSort() is proportional to *n* log *n*.
- This performance is sometimes known as *linearithmic* performance.

Mergesort

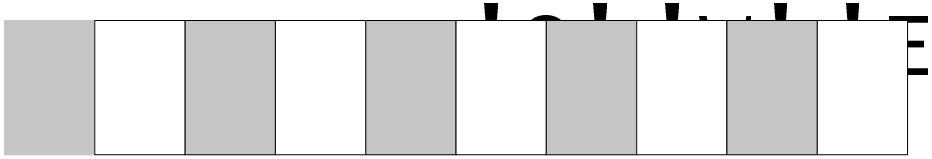
- Suppose we are sorting the array shown below.



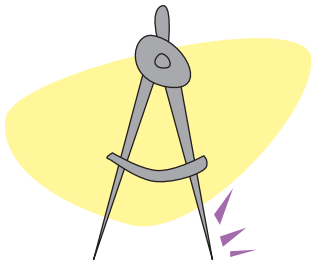
- After sorting the two sublists, the array would look like



- Now we can do the simple task of merging the two arrays to get

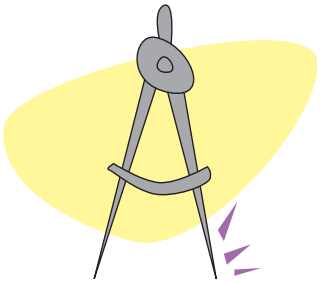


Mergesort



- Public interface
  - Should be as simple as possible
  - No extraneous parameters

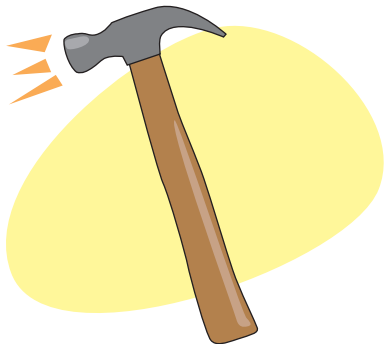
```
public static void mergeSort(char[] a)
```



- Private interface
  - Invoked by implementation of public interface
  - Should support recursive invocation by implementation of private interface

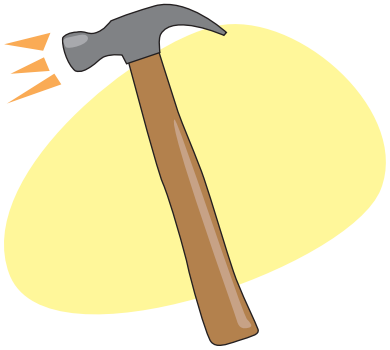
```
private static void mergeSort(char[] a, int left, int right)
```

Mergesort



```
private static void
   mergeSort(char[] a, int left, int right) {
   if (left < right) {
        // there are multiple elements to sort.

        // first, recursively sort the left and right sublists
        int mid = (left + right) / 2;
        mergeSort(a, left, mid);
        mergeSort(a, mid+1, right);
```

Mergesort



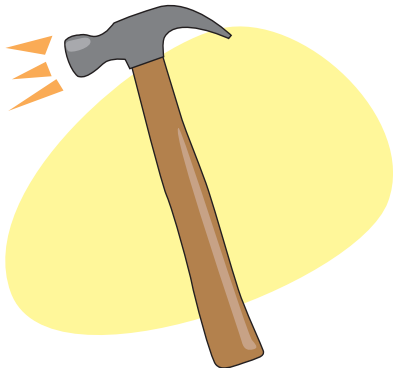
```
// next, merge the sorted sublists into
// array temp
char[] temp = new char[right - left + 1];

int j = left; // index of left sublist smallest ele.
int k = mid + 1; // index of right sublist smallest ele.
```

Mergesort

```
for (int i = 0; i < temp.length; ++i) {
   // store the next smallest element into temp
   if ((j <= mid) && (k <= right)) {
      // need to grab the smaller of a[j]
      // and a[k]
      if (a[j] <= a[k]) { // left has the smaller element
         temp[i] = a[j];
         ++j;
      }
      else { // right has the smaller element
         temp[i] = a[k];
         ++k;
      }
   }
```

Mergesort

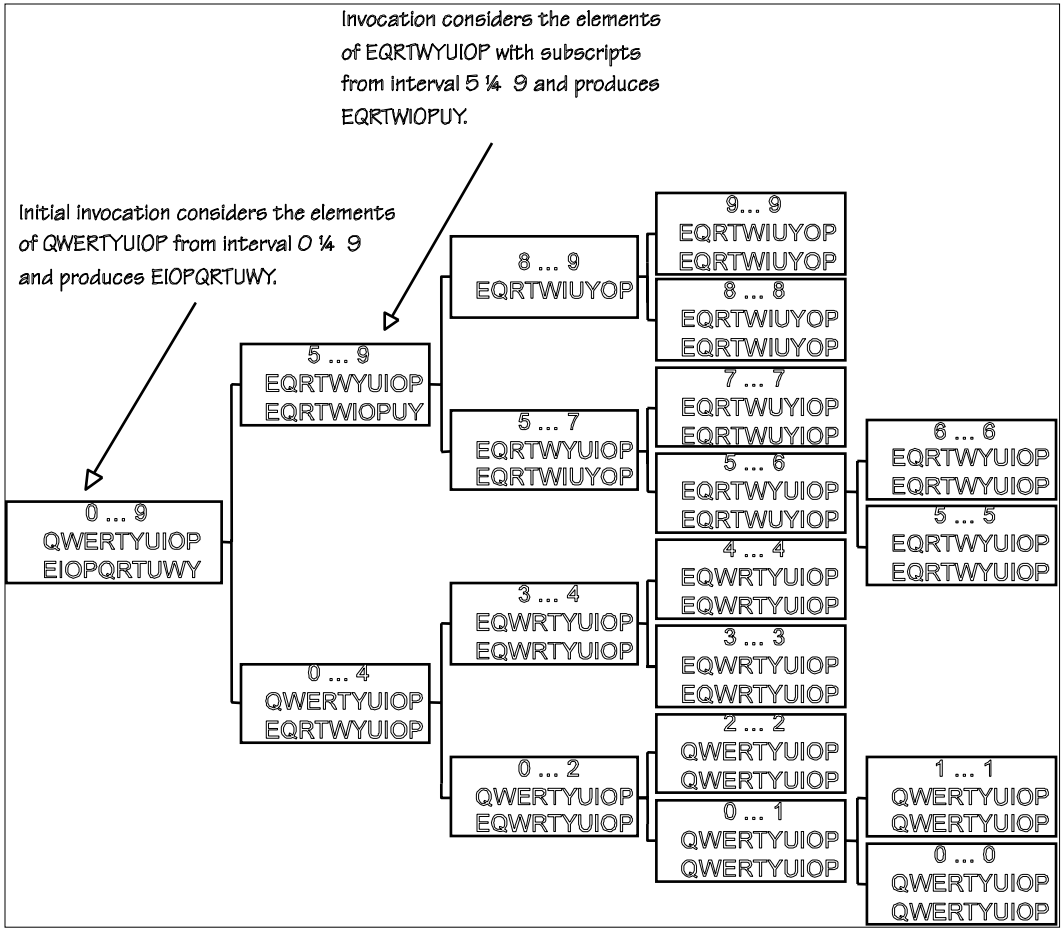
```
 else if (j <= mid) { // can only grab from left half
       temp[i] = a[j];
       ++j;
    }
    else { // can only grab from right half
       temp[i] = a[k];
       ++k;
    }
}
```



Mergesort

```
    // lastly, copy temp into a
    for (int i = 0; i < temp.length; ++i) {
        a[left + i] = temp[i];
        }
    }
}
```

Mergesort


Invocation considers the elements of EQRTWYUIOP with subscripts from interval 5 ¼ 9 and produces EQRTWIOPUY.
Initial invocation considers the elements of QWERTYUIOP from interval 0 ¼ 9 and produces EIOPQRTUWY.
0 ... 9
QWERTYUIOP
EIOPQRTUWY
5 ... 9
EQRTWYUIOP
EQRTWIOPUY
0 ... 4
QWERTYUIOP
EQRTWYUIOP
8 ... 9
EQRTWIUYOP
5 ... 7
EQRTWYUIOP
EQRTWIUYOP
3 ... 4
EQWRTYUIOP
EQWRTYUIOP
0 ... 2
QWERTYUIOP
EQWRTYUIOP
9... 9
EQRTWIUYOP
EQRTWIUYOP
8 ... 8
EQRTWIUYOP
EQRTWIUYOP
7 ... 7
EQRTWUYIOP
EQRTWUYIOP
5 ... 6
EQRTWYUIOP
EQRTWUYIOP
4 ... 4
EQWRTYUIOP
EQWRTYUIOP
3 ... 3
EQWRTYUIOP
EQWRTYUIOP
2 ... 2
QWERTYUIOP
QWERTYUIOP
0 ... 1
QWERTYUIOP
QWERTYUIOP
6 ... 6
EQRTWYUIOP
EQRTWYUIOP
5 ... 5
EQRTWYUIOP
EQRTWYUIOP
1 ... 1
QWERTYUIOP
QWERTYUIOP
0 ... 0
QWERTYUIOP
QWERTYUIOP

Recursion versus iteration

- Iteration can be more efficient
  - Replaces method calls with looping
  - Less memory is used (no activation record for each call)
- Many problems are more naturally solved with recursion
  - Towers of Hanoi
  - Mergesort
- Choice depends on problem and the solution context

Daily Jumble

JUMBLE®

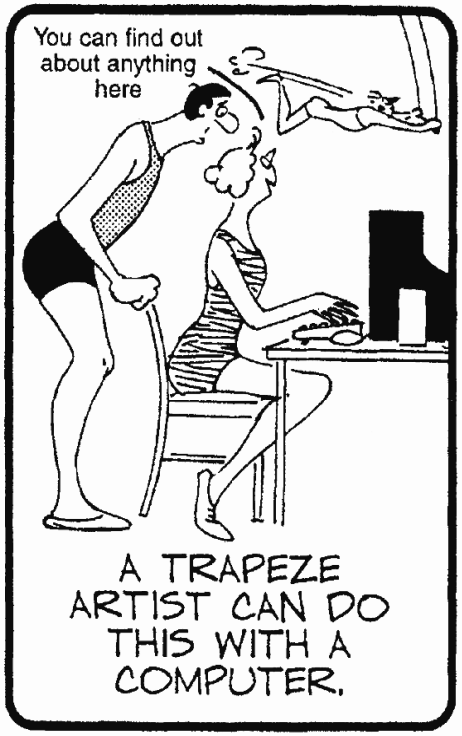
Unscramble these four Jumbles, one letter to each square, to form four ordinary words.

MEZIA

CIDDE

HUCNAH

BOUSTE



Now arrange the circled letters to form the surprise answer, as suggested by the above cartoon.

Print answer here: ◯◯◯ THE " ◯◯◯ "

Daily Jumble

- Task
  - Generate all possible permutation of letters
    - For n letters there are n! possibilities
      - n choices for first letter
      - n-1 choices for second letter
      - n-2 choices for third letter
      - …
- Iterator
  - Object that produces successive values in a sequence
- Design
  - Iterator class PermuteString that supports the enumeration of permutations

Class PermuteString

- Constructor

  `public PermuteString(String s)`

  - Constructs a permutation generator for string s

- Methods

  `public String nextPermutation()`

  - Returns the next permutation of the associated string

  public boolean morePermutations()

  - Returns whether there is unenumerated permutation of the associated string

Class PermuteString

- Instance variables

  `private String word`

  - Represents the word to be permuted

  `private int index`

  - Position within the word being operated on

  `public PermuteString substringGenerator`

  - Generator of substrings

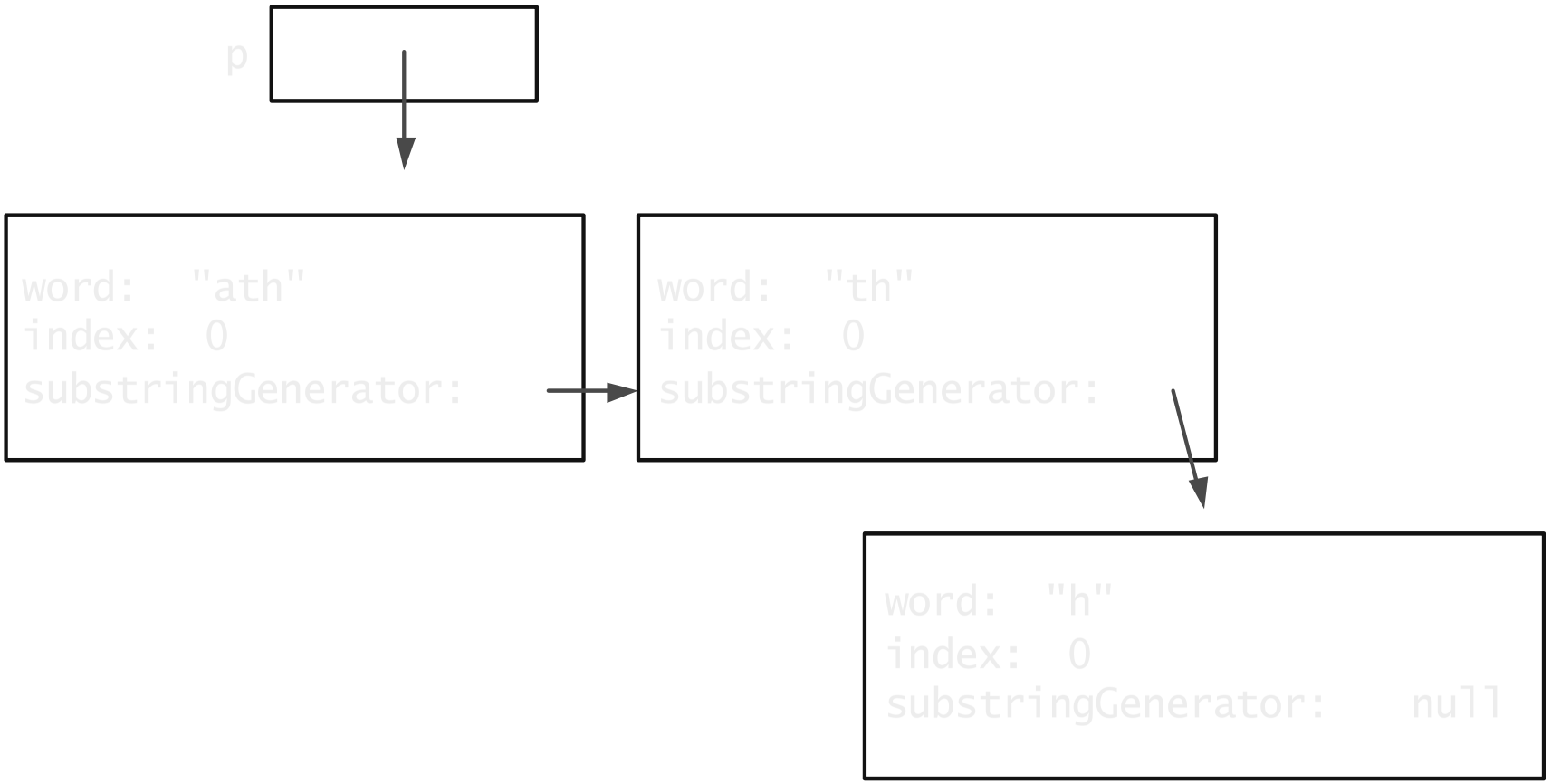
Constructor

```
public PermuteString(String s) {
   word = s;
   index = 0;
   if (s.length() > 1) {
        String substring = s.substring(1);
        substringGenerator = new PermuteString(substring);
   }
   else {
        substringGenerator = null;
   }
}
```

Consider

- What happens?

```
PermuteString p = new PermuteString(“ath“);
```



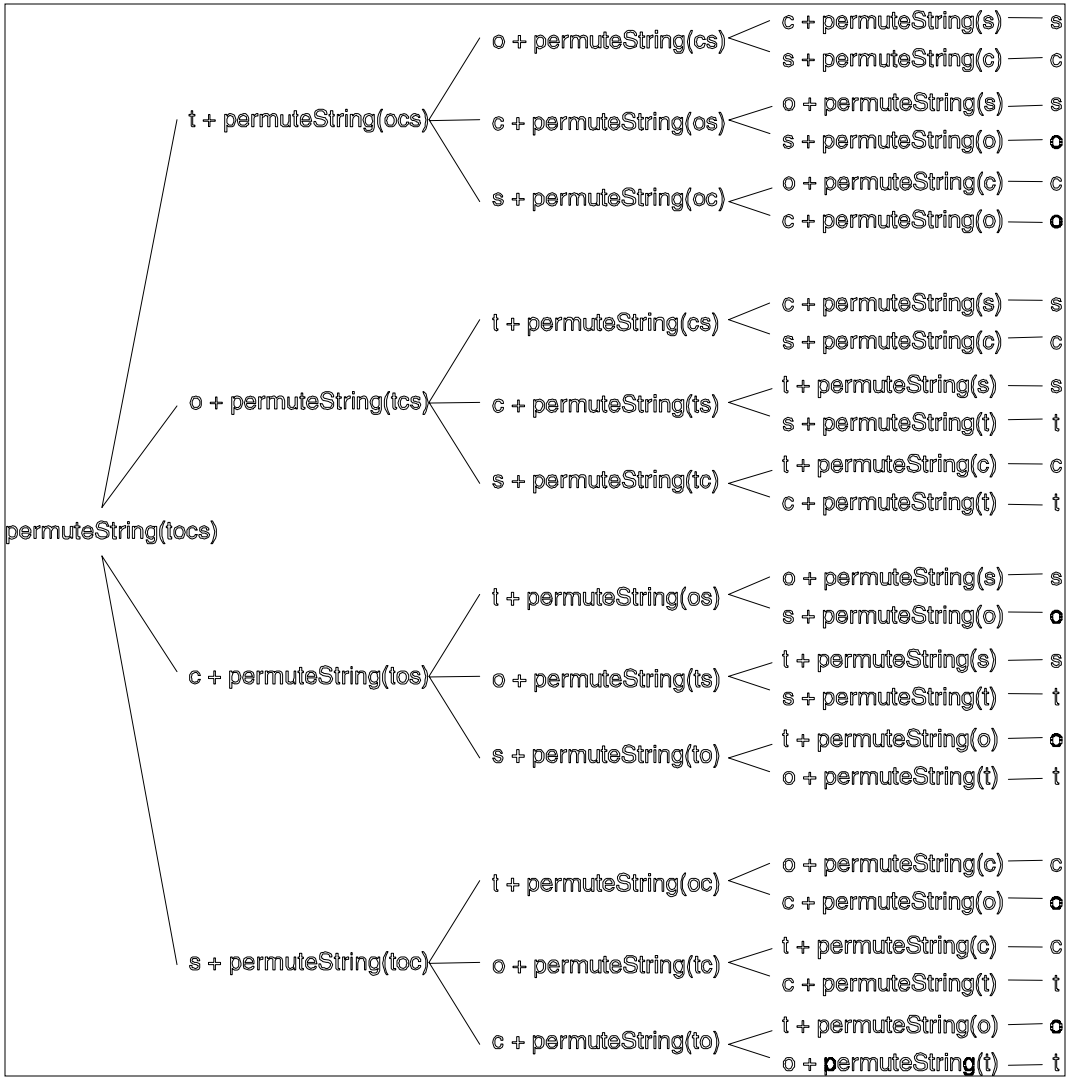
Method

```
public boolean morePermuations() {
   return index < word.length;
}
```

Method

```
public boolean nextPermutation() {
   if (word.length() == 1) {
        ++index;
        return word;
   }
   else {
        String r = word.charAt(index)
                  + substringGenerator.nextPermutation();
        if (!substringGenerator.morePermutations()) {
           ++index;
           if (index < word.length()) {
               String tail = word.substring(0, index)
                    + word.substring(index + 1);
               substringGenerator = new permuteString(tail);
           }
        }
        return r;
   }
}
```

Daily Jumble



Threads

Story so far

- Our programs have consisted of single flows of control
  - Flow of control started in the first statement of method main() and worked its way statement by statement to the last statement of method main()
  - Flow of control could be passed temporarily to other methods through invocations, but the control returned to main() after their completion

- Programs with single flows of control are known as sequential processes

```
Single-threaded Program {
   Statement 1;
   Statement 2;
   ...
   Statement k;
}
```

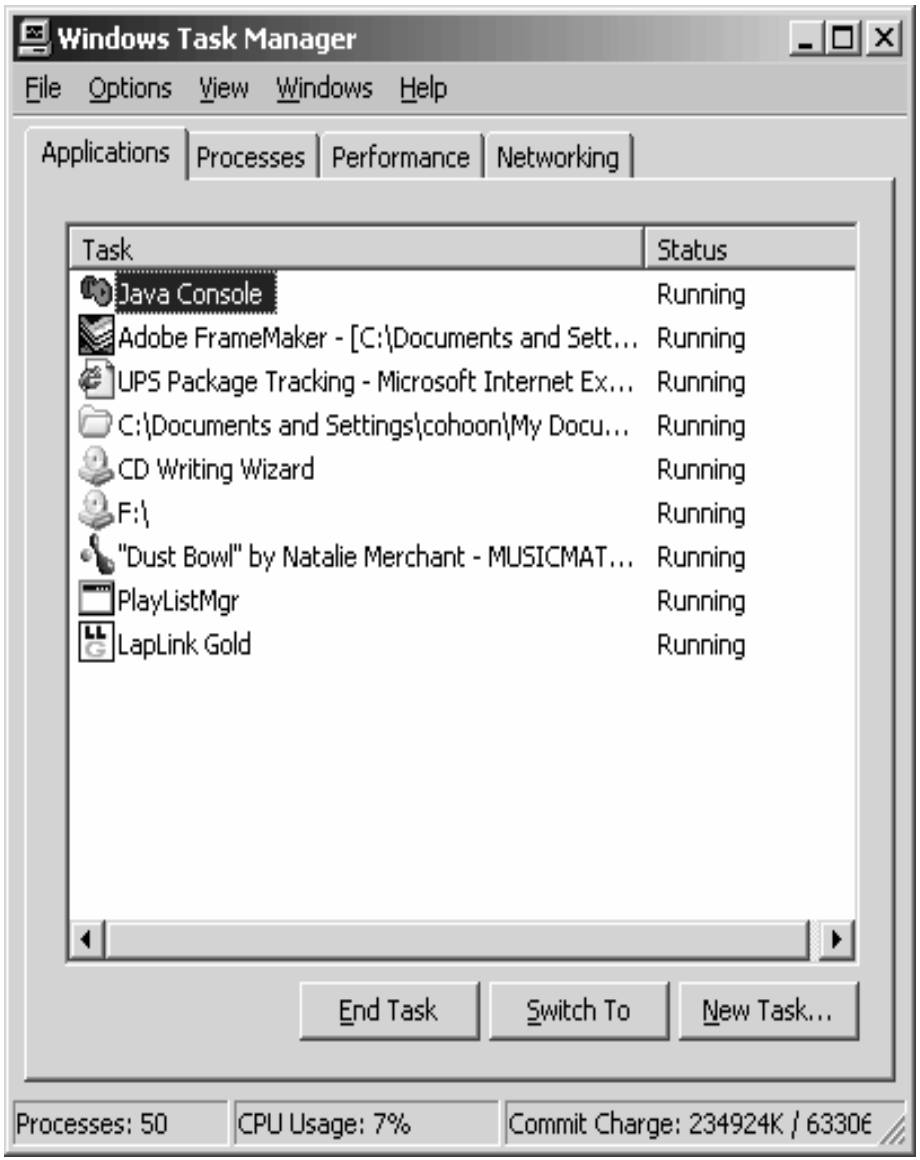
Although the statements within a single flow of control may invoke other methods, the next statement is not executed until the current statement completes

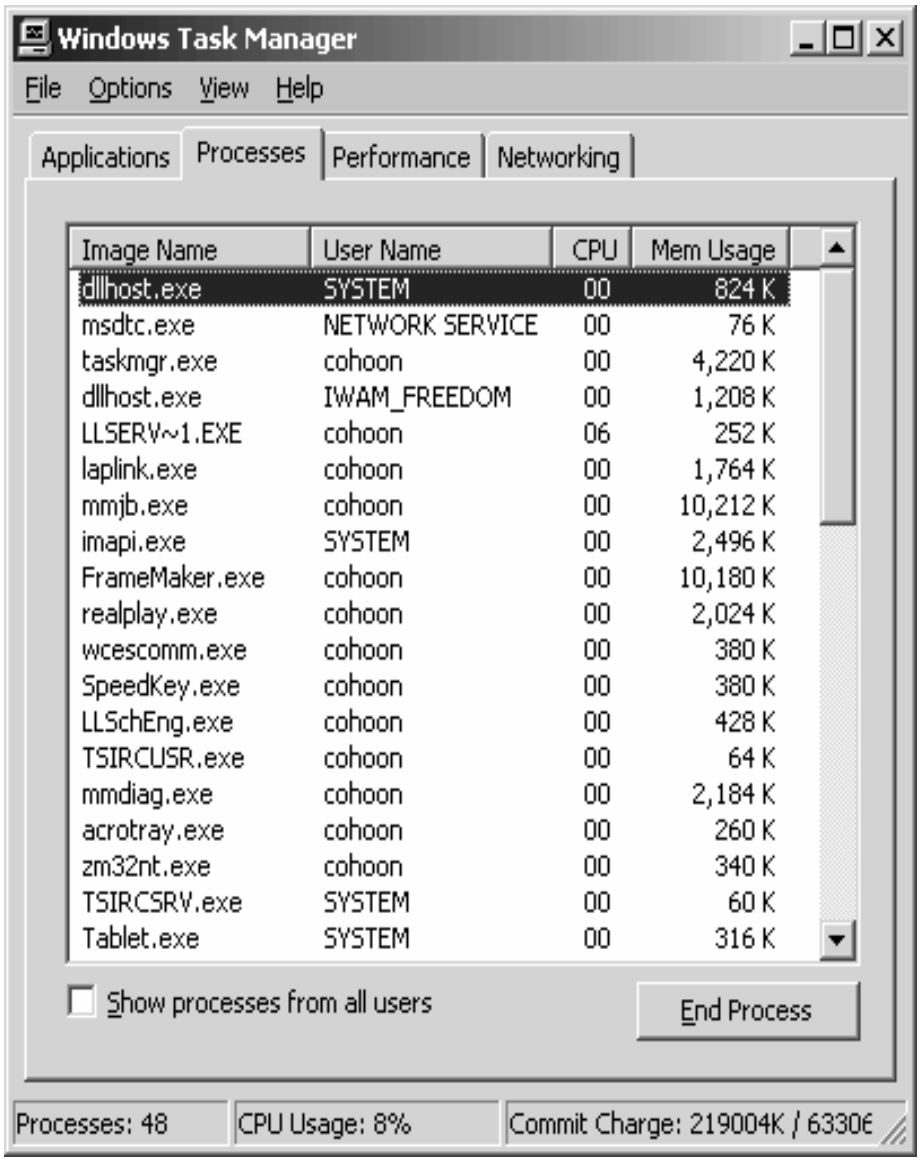
Processes

- The ability to run more than one process at the same time is an important characteristic of modern operating systems
  - A user desktop may be running a browser, programming IDE, music player, and document preparation system

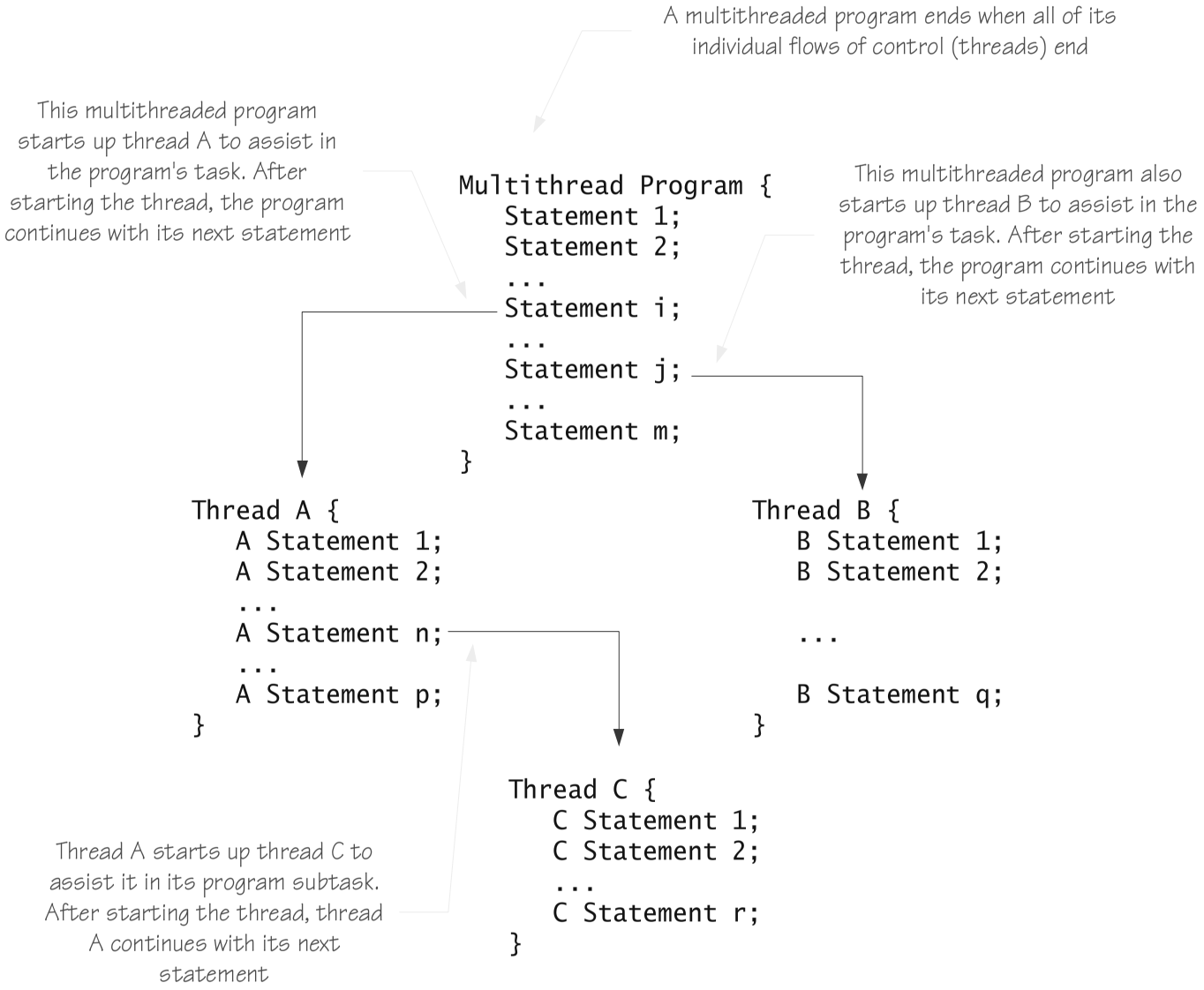
- Java supports the creation of programs with concurrent flows of control – threads
  - Threads run within a program and make use of its resources in their execution
    - Lightweight processes

Processes


Windows Task Manager
File Options View Windows Help
Applications Processes Performance Networking
Task Status
Java Console Running
Adobe FrameMaker - [C:\Documents and Sett... Running
UPS Package Tracking - Microsoft Internet Ex... Running
C:\Documents and Settings\cohoon\My Docu... Running
CD Writing Wizard Running
F:\ Running
"Dust Bowl" by Natalie Merchant - MUSICMAT... Running
PlayListMgr Running
LapLink Gold Running
End Task Switch To New Task...
Processes: 50 CPU Usage: 7% Commit Charge: 234924K / 6330€


Windows Task Manager
File Options View Help
Applications Processes Performance Networking
Image Name User Name CPU Mem Usage
dllhost.exe SYSTEM 00 824 K
msdtc.exe NETWORK SERVICE 00 76 K
taskmgr.exe cohoon 00 4,220 K
dllhost.exe IWAM_FREEDOM 00 1,208 K
LLSERV~1.EXE cohoon 06 252 K
laplink.exe cohoon 00 1,764 K
mmjb.exe cohoon 00 10,212 K
imapi.exe SYSTEM 00 2,496 K
FrameMaker.exe cohoon 00 10,180 K
realplay.exe cohoon 00 2,024 K
wcescomm.exe cohoon 00 380 K
SpeedKey.exe cohoon 00 380 K
LLSchEng.exe cohoon 00 428 K
TSIRCUSR.exe cohoon 00 64 K
mmdiag.exe cohoon 00 2,184 K
acrotray.exe cohoon 00 260 K
zm32nt.exe cohoon 00 340 K
TSIRCSRV.exe SYSTEM 00 60 K
Tablet.exe SYSTEM 00 316 K
Show processes from all users
End Process
Processes: 48 CPU Usage: 8% Commit Charge: 219004K / 6330€

Multithread processing



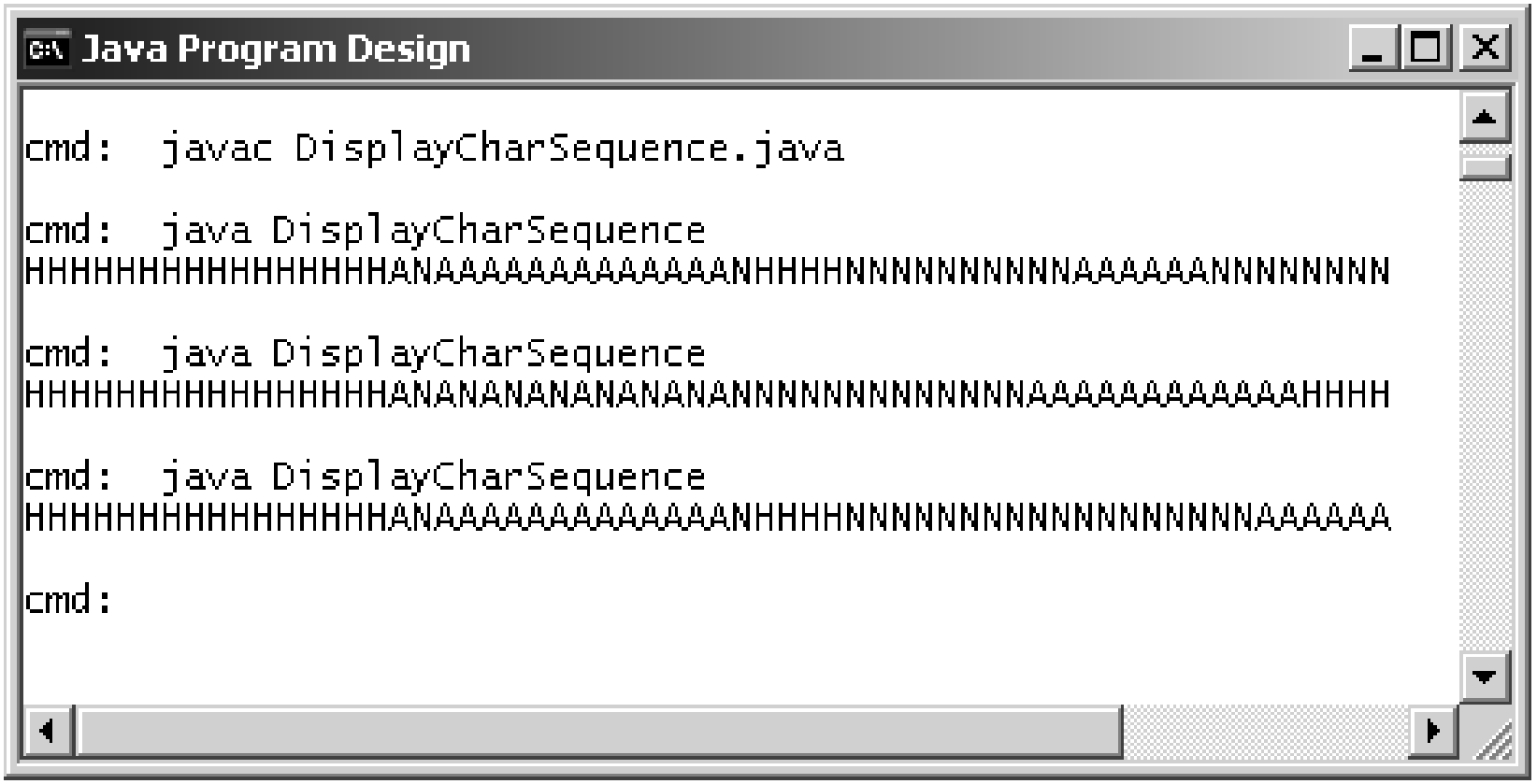
Timer and TimerTask

- Among others, Java classes java.util.Timer and java.util.TimerTask support the creation and scheduling of threads

- Abstract class Timer has methods for creating threads after either some specified delay or at some specific time
  - public void schedule(TimerTask task, long m)
    - Runs task.run() after waiting m milliseconds.
  - public void schedule(TimerTask task, long m, long n)
    - Runs task.run() after waiting m milliseconds. It then repeatedly reruns task.run() every n milliseconds.
  - public void schedule(TimerTask task, Date y)
    - Runs task.run() at time t.
- A thread can be created By extending TimerTask and specifying a definition for abstract method run()

Running after a delay

- Class DisplayCharSequence extends TimerTask to support the creation of a thread that displays 20 copies of some desired character (e.g., “H”, “A”, or “N”)



Using DisplayCharSequence

```
public static void main(String[] args) {
   DisplayCharSequence s1 =
       new DisplayCharSequence('H');

   DisplayCharSequence s2 =
       new DisplayCharSequence('A');

   DisplayCharSequence s3 =
       new DisplayCharSequence('N');
}
```

Defining DisplayCharSequence

```
import java.util.*;
public class DisplayCharSequence extends TimerTask {
   private char displayChar;
   Timer timer;
   public DisplayCharSequence(char c) {
       displayChar = c;
       timer = new Timer();
       timer.schedule(this, 0);
   }
   public void run() {
       for (int i = 0; i < 20; ++i) {
          System.out.print(displayChar);
       }
       timer.cancel();
   }
}
```

Implementing a run() method

- A subclass implementation of TimerTask's abstract method run() has typically two parts
  - First part defines the application-specific action the thread is to perform
  - Second part ends the thread
    - The thread is ended when the application-specific action has completed

```
// run(): display the occurences of the character of interest
public void run() {
    for (int i = 0; i < 20; ++i) {
       System.out.print(displayChar);
    }

    timer.cancel();
}
```

Desired action to be performed by thread

Desired action is completed so thread is canceled

Running repeatedly

- Example
  - Having a clock face update every second


```
public static void main(String[] args) {
      SimpleClock clock = new SimpleClock();
}
```

```
public class SimpleClock extends TimerTask {
   final static long MILLISECONDS_PER_SECOND = 1000;
   private JFrame window = new JFrame("Clock");
   private Timer timer = new Timer();
   private String clockFace = "";

   public SimpleClock() {
       window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
       window.setSize(200, 60);
       Container c = window.getContentPane();
       c.setBackground(Color.white);
       window.setVisible(true);

       timer.schedule(this, 0, 1*MILLISECONDS_PER_SECOND);
   }

   public void run() {
       Date time = new Date();
       Graphics g = window.getContentPane().getGraphics();
       g.setColor(Color.WHITE);
       g.drawString(clockFace, 10, 20);

       clockFace = time.toString();
       g.setColor(Color.BLUE);
       g.drawString(clockFace, 10, 20);
   }
}
```

SimpleClock scheduling

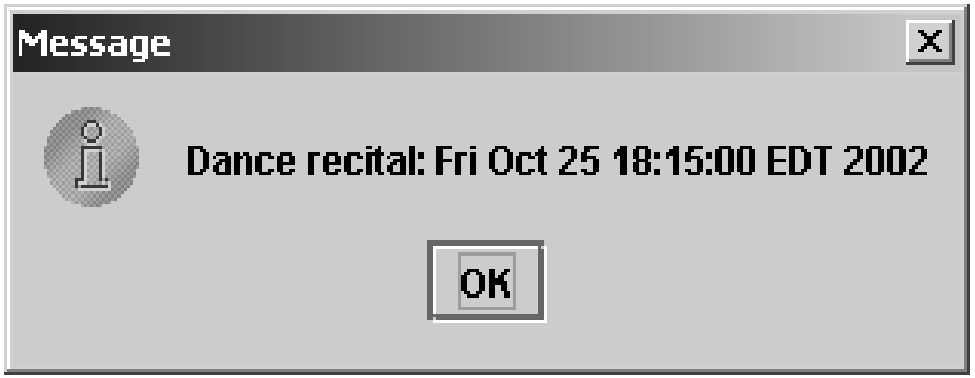
```
timer.schedule(this, 0, 1*MILLISECONDS_PER_SECOND);
```

The millisecond delay before the thread is first scheduled

The number of milliseconds between runs of the thread

Running at a chosen time

- Example
  - Scheduling calendar pop-ups using class DisplayAlert



Using DisplayAlert

```
public static void main(String[] args) {
   Calendar c = Calendar.getInstance();

   c.set(Calendar.HOUR_OF_DAY, 9);
   c.set(Calendar.MINUTE, 30);
   c.set(Calendar.SECOND, 0);

   Date studentTime = c.getTime();

   c.set(Calendar.HOUR_OF_DAY, 18);
   c.set(Calendar.MINUTE, 15);
   c.set(Calendar.SECOND, 0);

   Date danceTime = c.getTime();

   DisplayAlert alert1 = new DisplayAlert(
       "Prospective student meeting", studentTime);

   DisplayAlert alert2 = new DisplayAlert(
       "Dance recital", danceTime);
}
```

Defining DisplayAlert

```
import javax.swing.JOptionPane;
import java.awt.*;
import java.util.*;

public class DisplayAlert extends TimerTask {
   private String message;
   private Timer timer;

   public DisplayAlert(String s, Date t) {
       message = s + ": " + t;
       timer = new Timer();
       timer.schedule(this, t);
   }

   public void run() {
       JOptionPane.showMessageDialog(null, message);
       timer.cancel();
   }
}
```

Sleeping

- Threads can be used to pause a program for a time
- Standard class java.lang.Thread has a class method sleep() for pausing a flow of control

  public static void sleep(long n) throws InterruptedException
  - Pauses the current thread for n milliseconds. It then throws an InterruptedException.

Sleeping example

- Code

```
Date t1 = new Date();
System.out.println(t1);
try {
  Thread.sleep(10000);
}
catch (InterruptedException e) {
}
Date t2 = new Date();
System.out.println(t2);
```

- Output

```
Fri Jan 31 19:29:45 EST 2003
Fri Jan 31 19:29:55 EST 2003
```

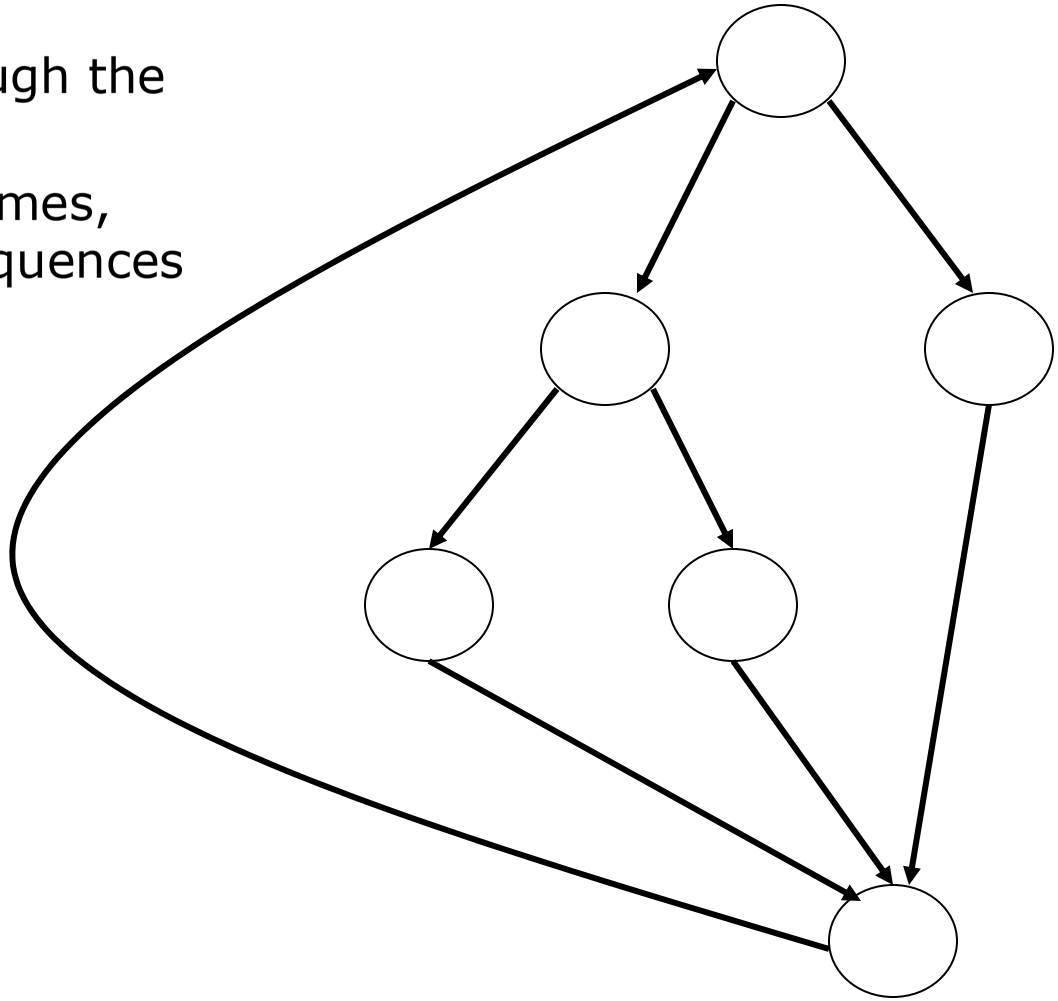
Testing and Debugging

Testing Fundamentals

- Test as you develop
  - Easier to find bugs early rather than later
  - Prototyping helps identify problems early
- Categories of bugs
  - software crashes or data corruption
  - failure to meet or satisfy the specification
  - poor or unacceptable performance
  - hard or difficult to use

Testing fundamentals

- Impossible to test a program completely
- Three distinct paths through the program
- If the loop executes 20 times, there are 3^{20} different sequences of executions



Reviews and inspections

- Inspections
  - Formal process of reviewing code
  - First employed by IBM in 1976
  - Early work showed that design and review inspections remove 60 percent of the bugs in a product

Reviews and inspections

- Roles of participants
  - Moderator
    - Runs the inspection
    - Ensure that the process moves along
    - Referees the discussion
    - Ensures action items done
  - Inspector
    - Someone other than author
    - Some interest in the code
    - Carefully review code before inspection meeting
  - Author
    - Minor role
    - May answer questions about code

Reviews and inspections

- Roles of participants
  - Scribe
    - Record all errors detected
    - Keep list of action items

Reviews and inspections

- Inspection process
  - Planning
    - Code to review chosen
    - Moderator assigns task
    - Checklists created
    - Moderator assigns a presenter (usually one of the inspectors)
  - Overview
    - Author describes high-level aspects of project that affected the design or code
    - Sometimes skipped (if all participants are knowledgeable)

Reviews and inspections

- Inspection process
  - Preparation
    - Working alone, each inspector reviews code noting problems or questions
    - Shouldn’t take more than a couple of hours
  - Inspection meeting
    - Presenter walks through the code
    - Problems are discussed
    - Scribe records all errors and action items
    - Errors are not fixed at this time
  - Inspection report
    - Moderator prepares a written report

Black-box and white-box testing

- White-box testing indicates that we can “see” or examine the code as we develop test cases
- Block-box testing indicates that we cannot examine the code as we devise test cases
  - Seeing the code can bias the test cases we create
  - Forces testers to use specification rather than the code
- Complementary techniques

Black-box and white-box testing

Test boundary conditions

```
public static int binarySearch(char[] data, char key) {
   int left = 0;
   int right = data.length - 1;
   while (left <= right) {
        int mid = (left + right)/2;
        if (data[mid] == key) {
               return mid;
        }
        else if (data[mid] < key) {
               left = mid + 1;
        }
        else {
               right = mid - 1;
        }
   }
   return data.length;
}
```

Black-box and white-box testing

Boundary conditions

```
// validate input
if ((year < CALENDAR_START) || (month < 1) || (month > 12)) {
   System.output.println("Bad request: " + year + " "
       + month);
   return;
}
```

Black-box and white-box testing

- Suggests the following boundary tests

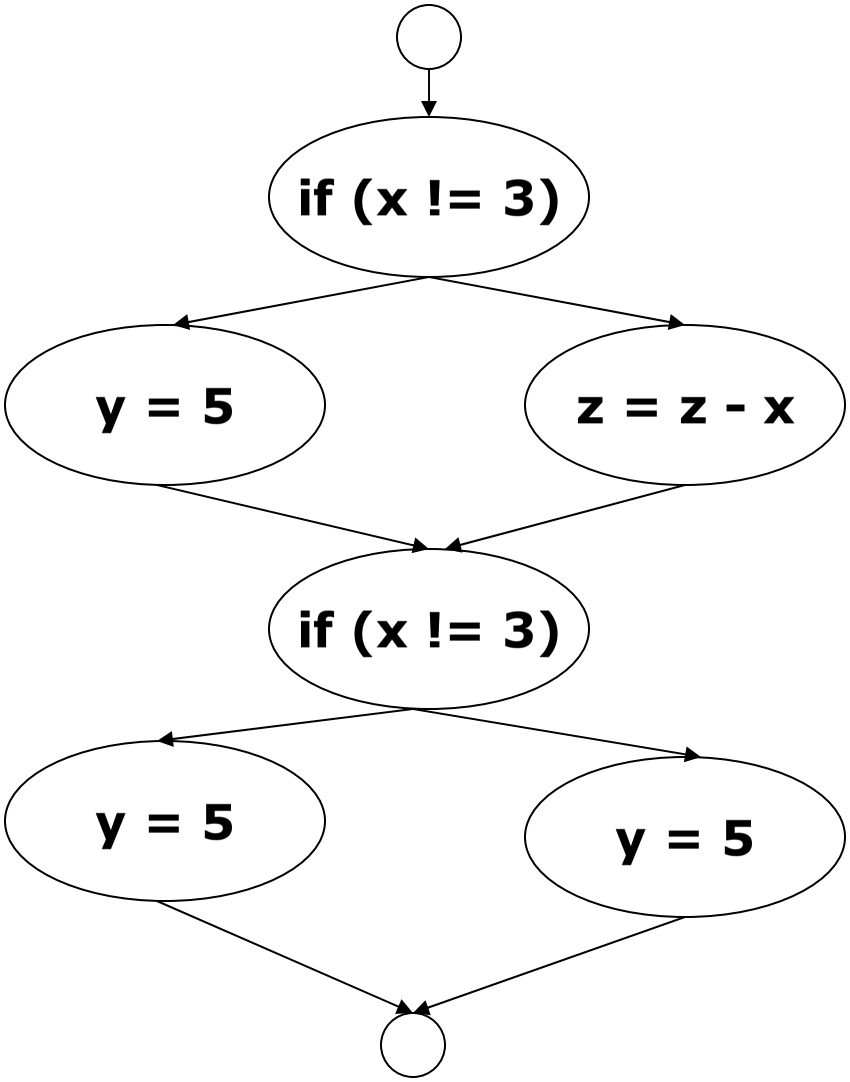
Input Year	Input Month
1582	2
1583	0
1583	13
1583	1
1583	12

Black-box and white-box testing

- Path coverage or path testing—create test cases that causes each edge of the program's controlflow graph to be executed

Example

```
if (x != y) {
   y = 5;
}
else {
   z = z - z;
}
if (x > 1) {
   z = z / x;
}
else {
   z = 0;
}
```



Black-box and white-box testing

- Testing tips
  - Test early
  - Use inspections
  - Test boundaries
  - Test exceptional conditions
  - Make testing easily repeatable

Integration and system testing

- Integration testing is done as modules or components are assembled.
  - Attempts to ensure that pieces work together correctly
  - Test interfaces between modules
- System testing occurs when the whole system is put together

Debugging

- Use the scientific method
  - Gather data
  - Develop a hypothesis
  - Perform experiments
  - Predict new facts
  - Perform experiments
  - Prove or disprove hypothesis

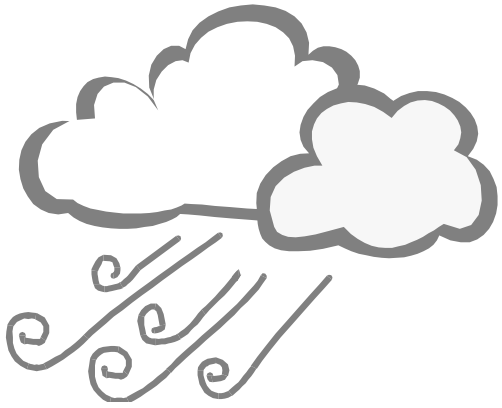
Debugging

- Tips and techniques
  - Simplify the problem
  - Stabilize the error
  - Locate the error
  - Explain the bug to someone else
  - Recognize common bugs
    - Oversubscripting
    - Dereferencing null
  - Recompile everything
  - Gather more information
  - Pay attention to compiler warnings
  - Fix bugs as you find them
  - Take a break

GUI programming

Graphical user interface-based programming

Windchill

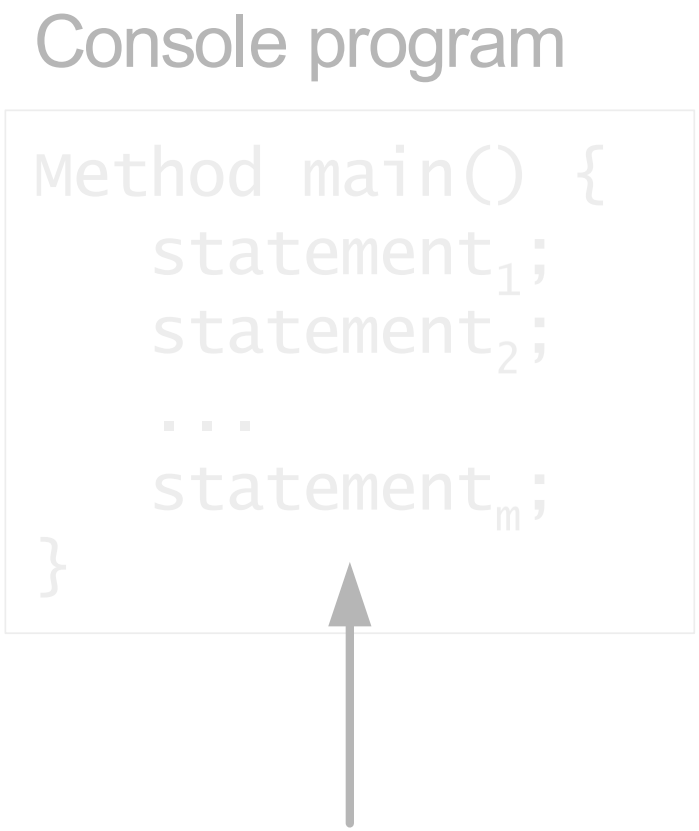


- Windchill
  - There are several formulas for calculating the windchill temperature t_{wc}
  - The one provided by U.S. National Weather Service and is applicable for a windspeed greater than four miles per hour

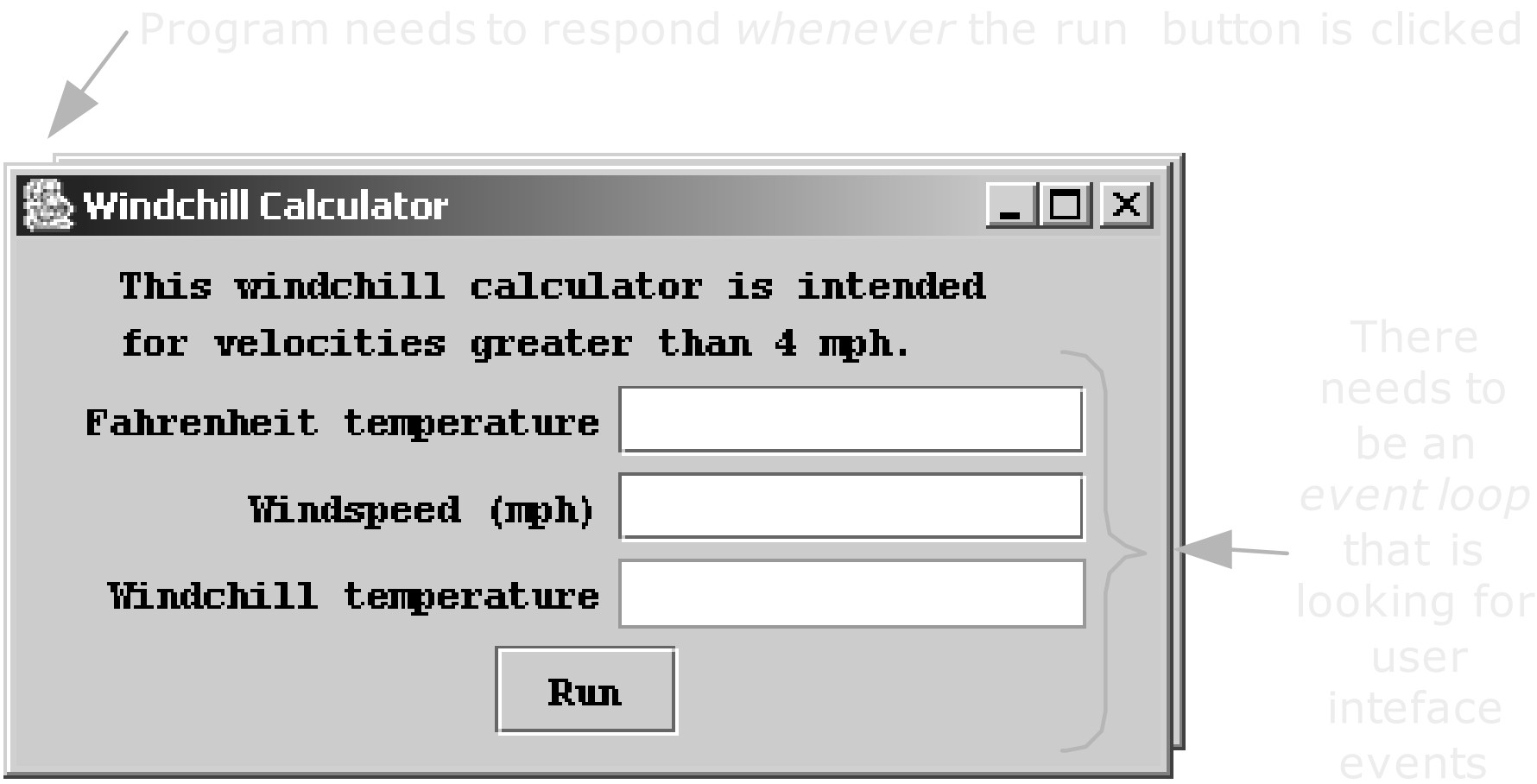
$$t_{wc} = 0.081(t - 91.4)(3.71\sqrt{v} + 5.81 - 0.25v) + 91.4$$

  - Where
    - Variable t is the Fahrenheit temperature
    - Variable v is the windspeed in miles per hour

Console-based programming



In use


Program needs to respond *whenever* the run button is clicked
Windchill Calculator
This windchill calculator is intended
for velocities greater than 4 mph.
Fahrenheit temperature
Windspeed (mph)
Windchill temperature
Run
There needs to be an *event loop* that is looking for user inteface events

GUI-based programming

GUI program begins in method main(). The method creates a new instance of the GUI by invoking the GUI constructor. On completion, the event dispatching loop is begun

GUI Program

```
main() {
   GUI gui = new GUI();
}

GUI Constructor() {
   constructor1;
   constructor2;
   ...
   constructorn;
}

Action Performer() {
   action1;
   action2;
   ...
   actionk;
}
```

Constructor configures the components of the GUI. It also registers the listener-performer for user interactions

Event-dispatching loop

```
do
   if an event occurs
      then signal its
      action listeners
until program ends
```

The event-dispatching loop watches for user interactions with the GUI. When an event occurs, its listener-performers are notified

The action performer implements the task of the GUI. After it completes, the event-dispatching loop is restarted

Java support

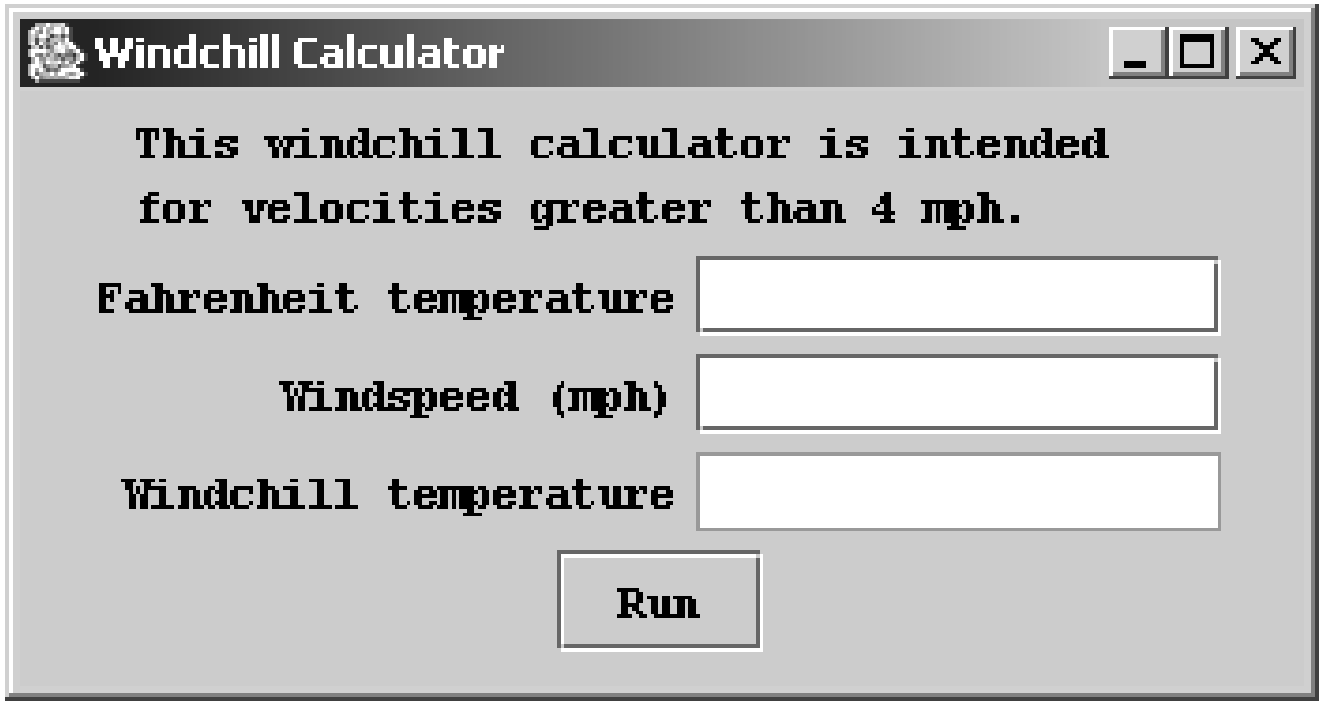
- JFrame
  - Represents a titled, bordered window

- JLabel
  - Represents a display area suitable for one or both of a single-line text or image.
- JTextField
  - Represents an editable single-line text entry component
- JButton
  - Represents a push button

- JTextArea
  - Represents an editable multiline text entry component

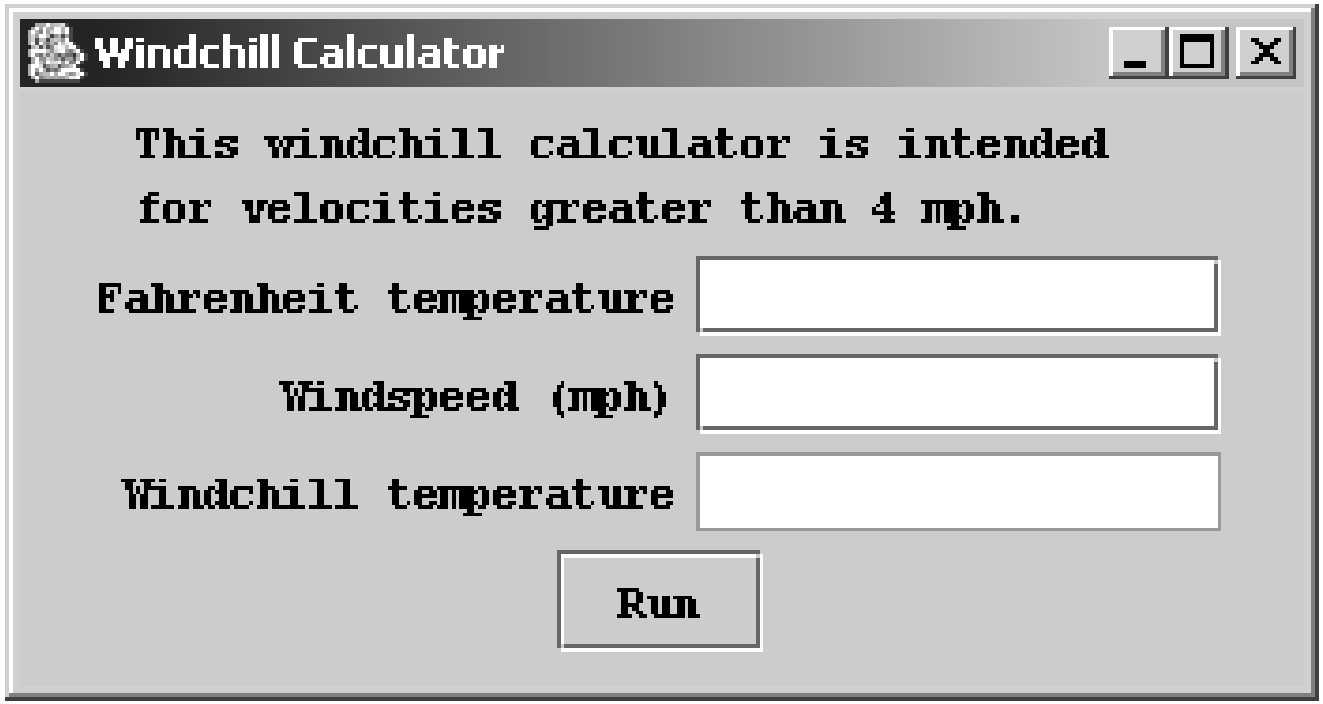
Instance variables

- private JFrame window
  - References the window containing the other components of the GUI



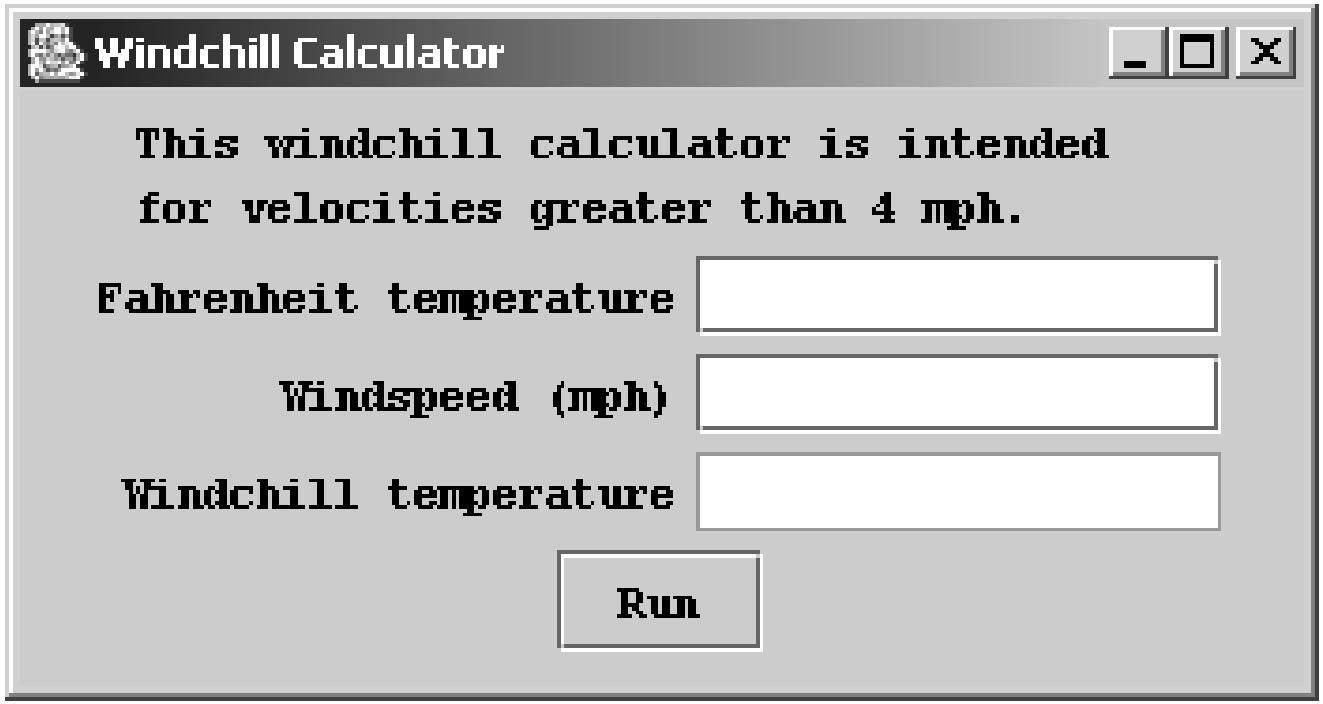
Instance variables

- private JTextArea legendArea
  - References the text display for the multiline program legend



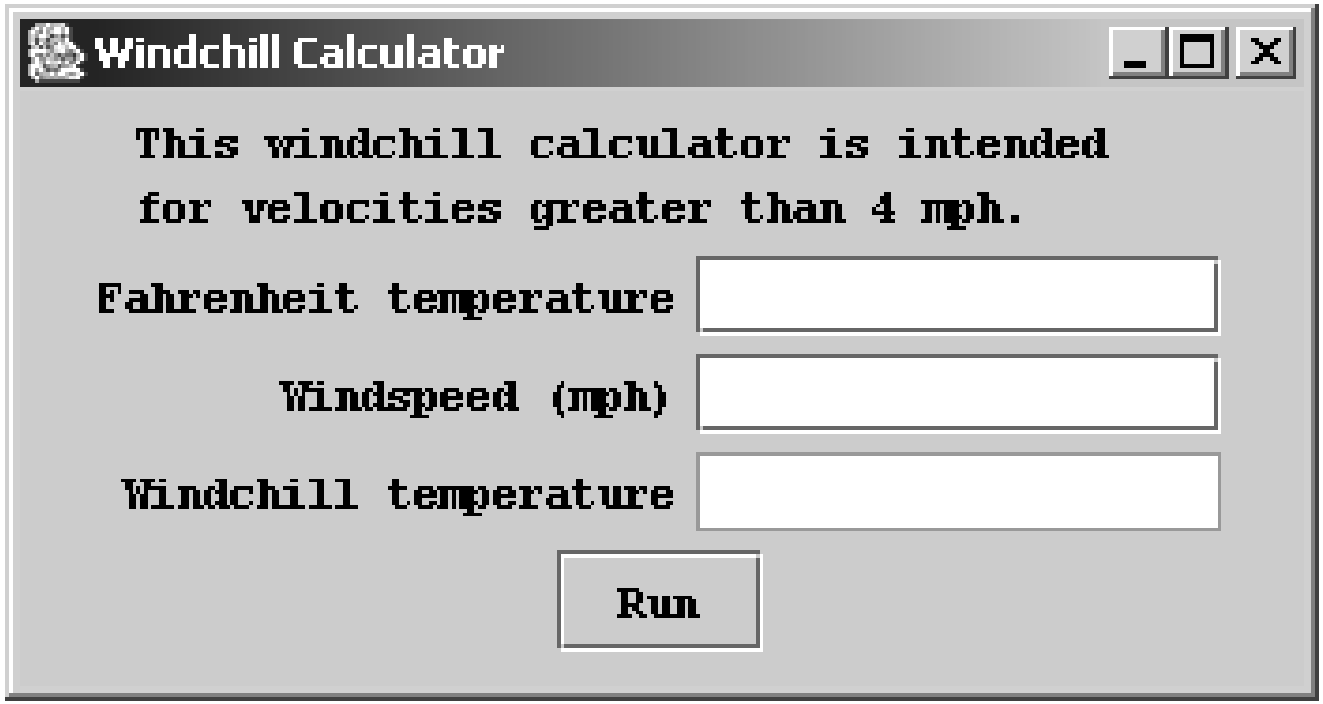
Instance variables

- private JLabel fahrTag
  - References the label for the data entry area supplying the temperature



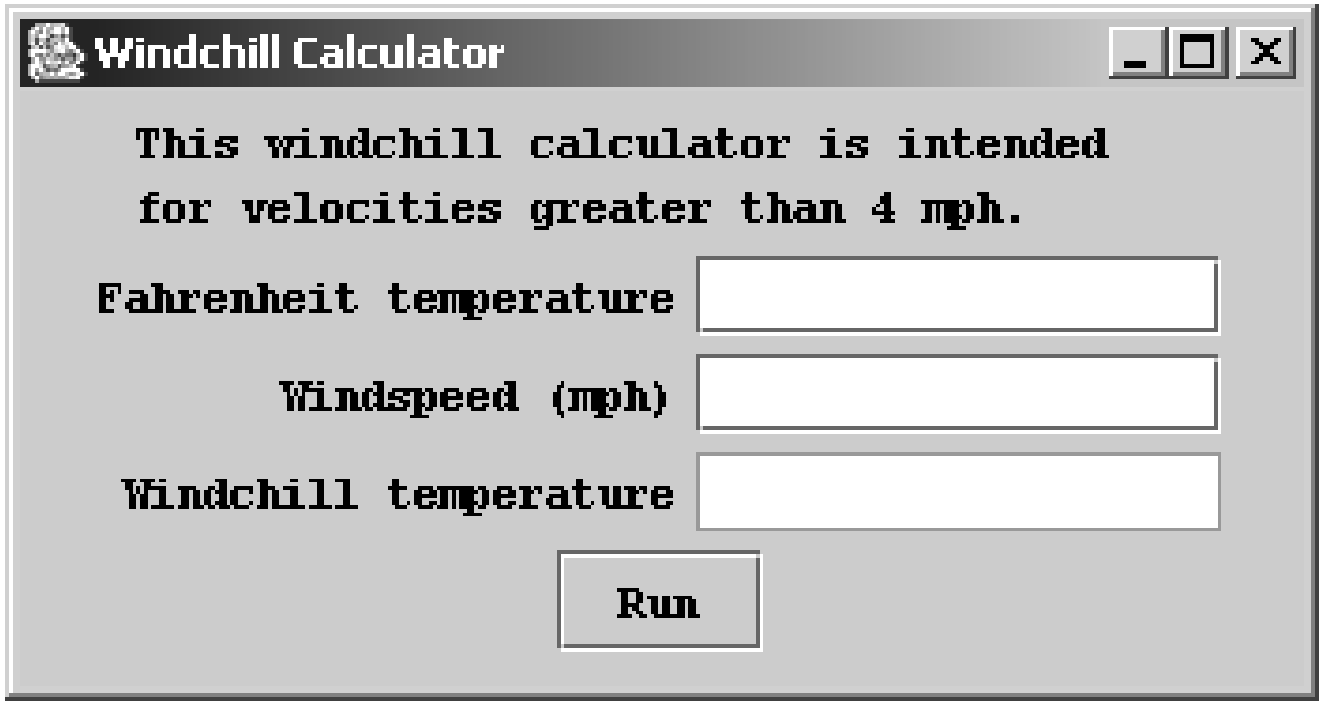
Instance variables

- private JTextField fahrText
  - References the data area supplying the temperature



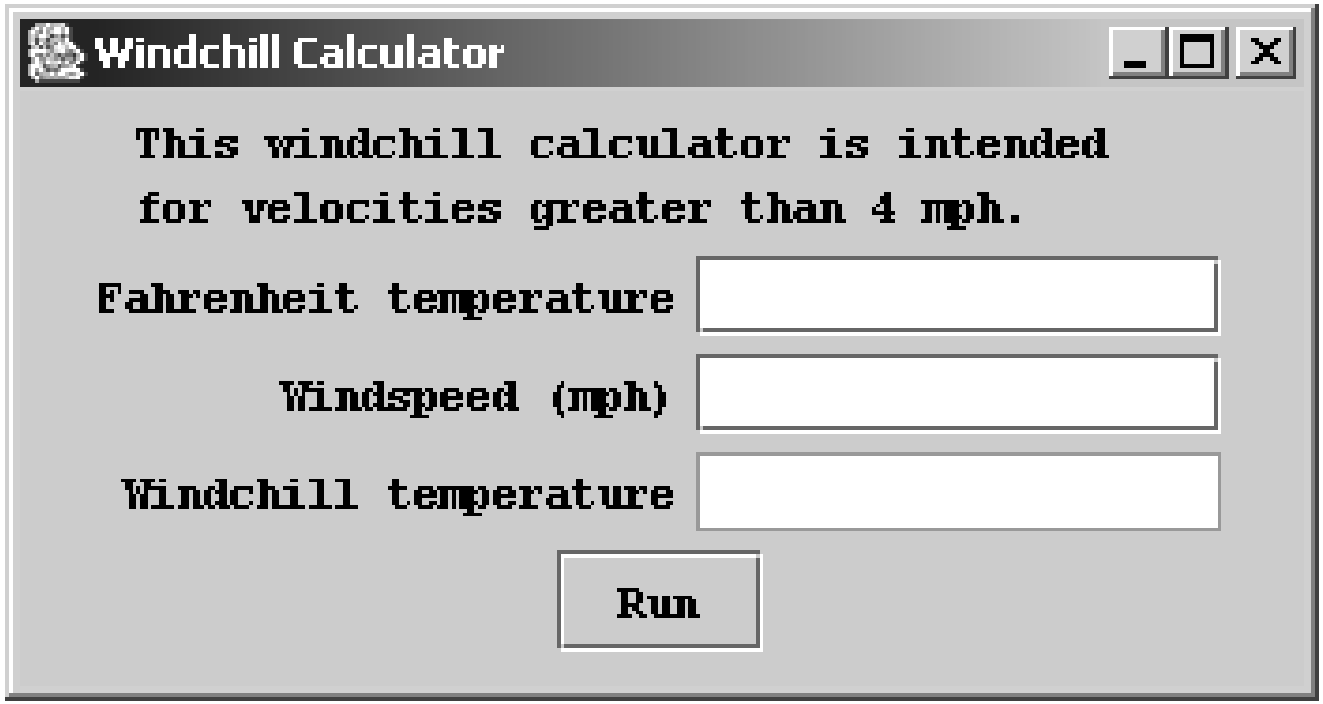
Instance variables

- private JLabel windTag
  - References the label for the data entry area supplying the windspeed



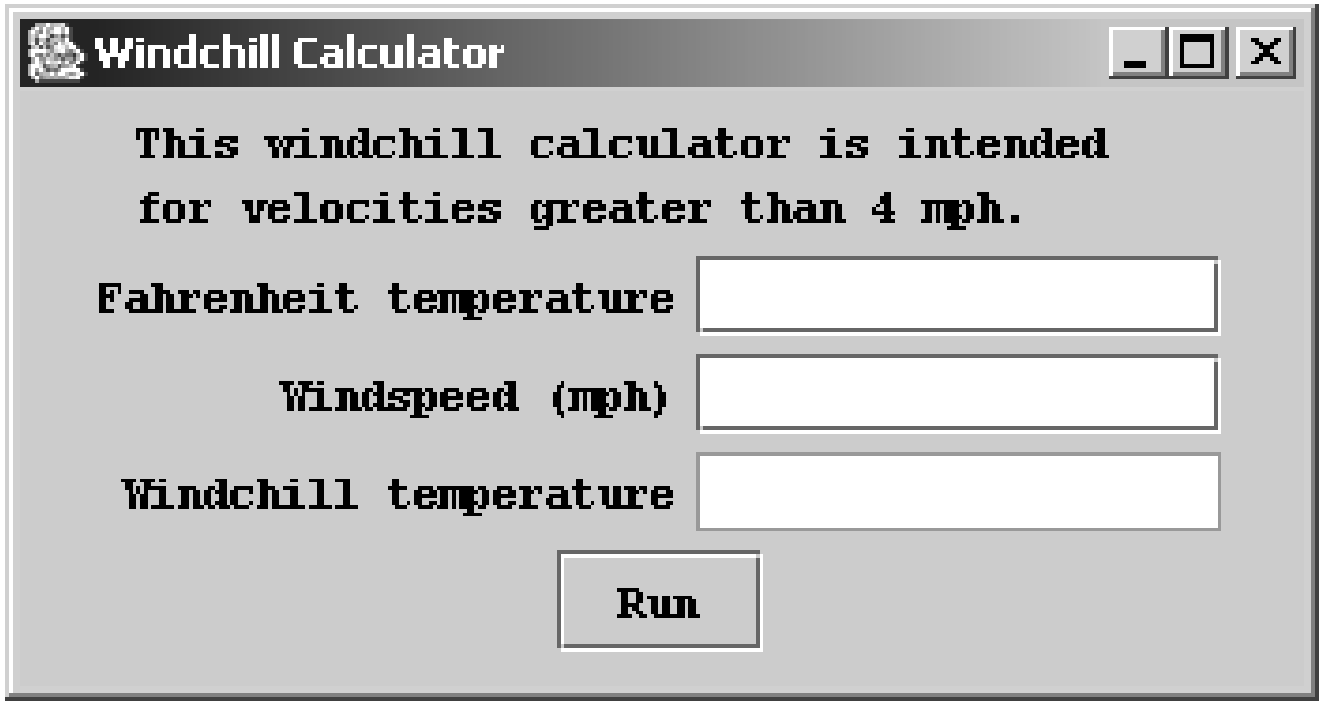
Instance variables

- private JTextField windText
  - References the data area supplying the windspeed



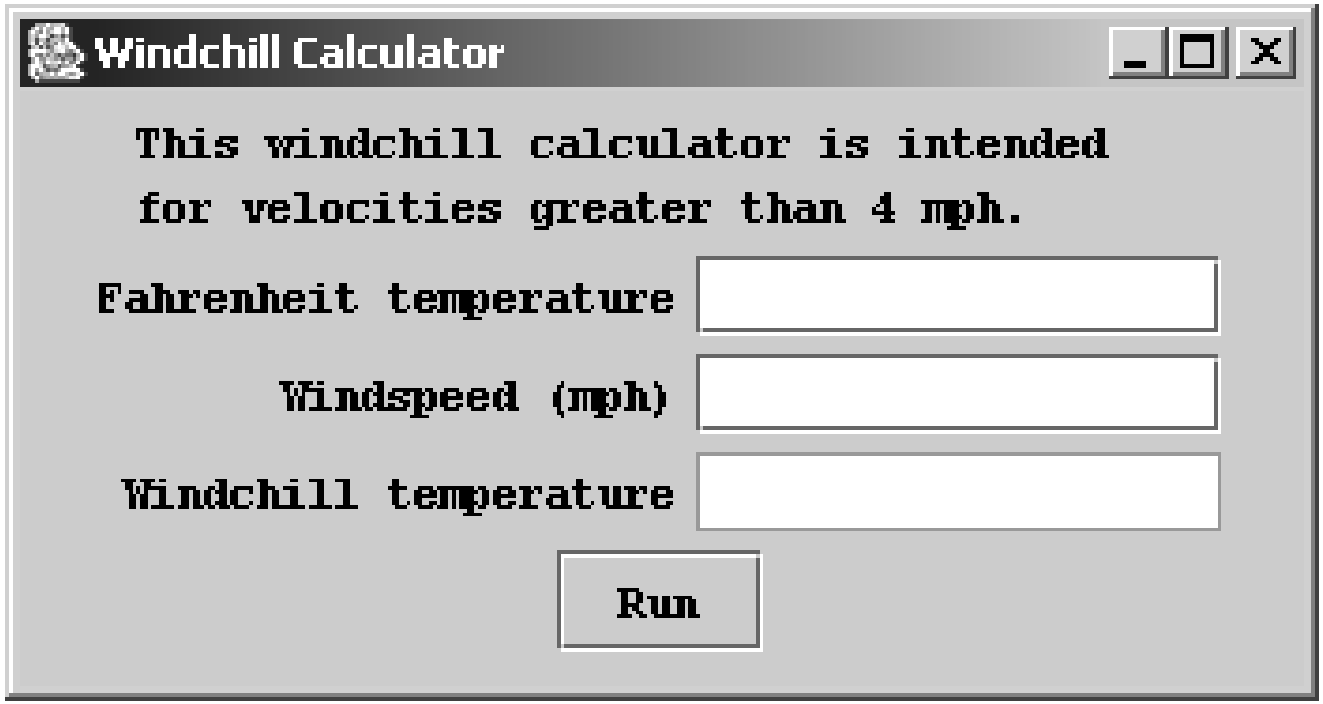
Instance variables

- private JLabel chillTag
  - References the label for the data area giving the windchill



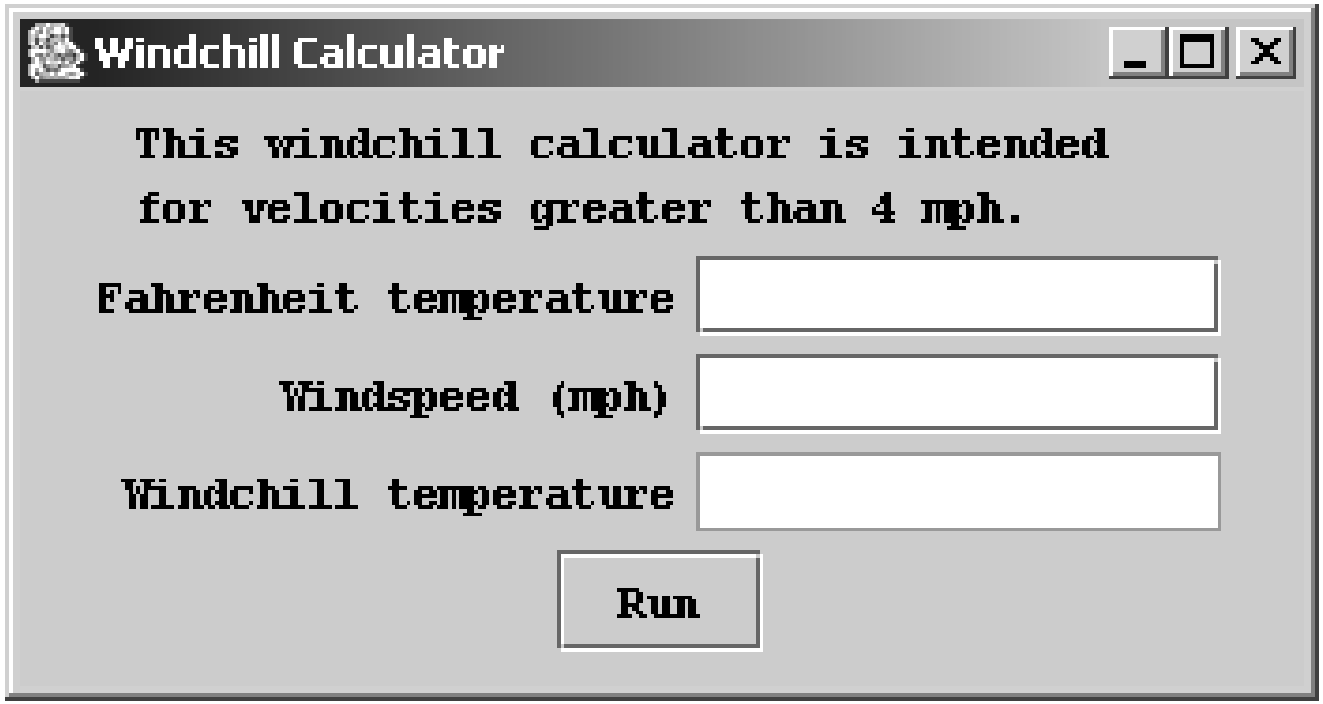
Instance variables

- private JTextField chillText
  - References the data area giving the windchill



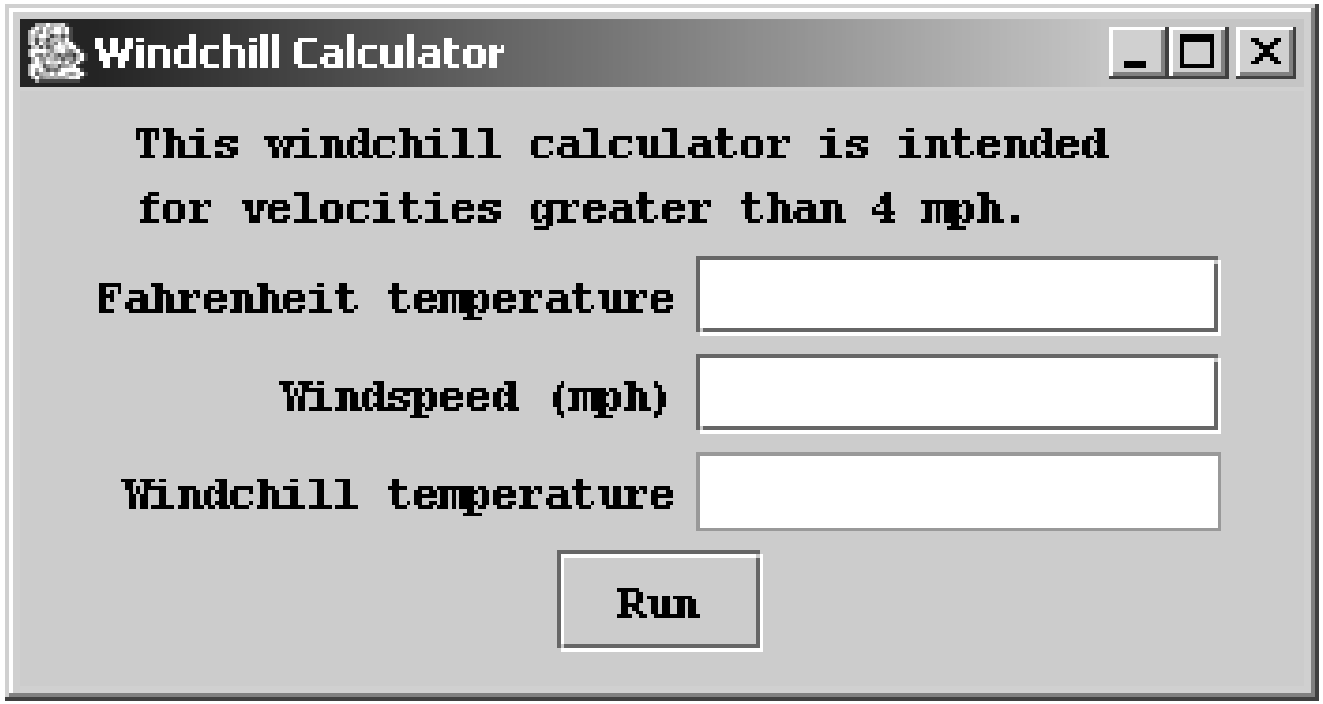
Class constants

- private static final String LEGEND = "This windchill calculator"
  + "is intended for velocities greater than 4 mph."
  - Program legend text



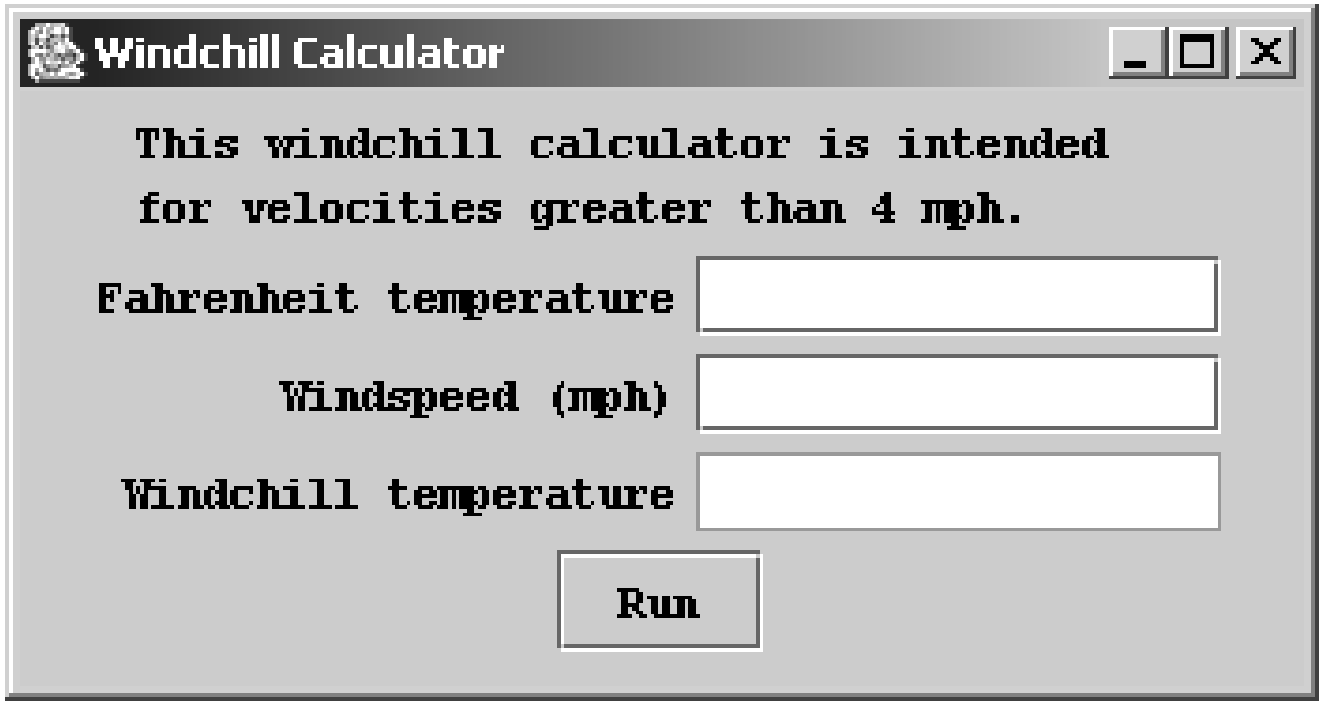
Class constants

- private static final int WINDOW_WIDTH = 350
  - Initial width of the GUI



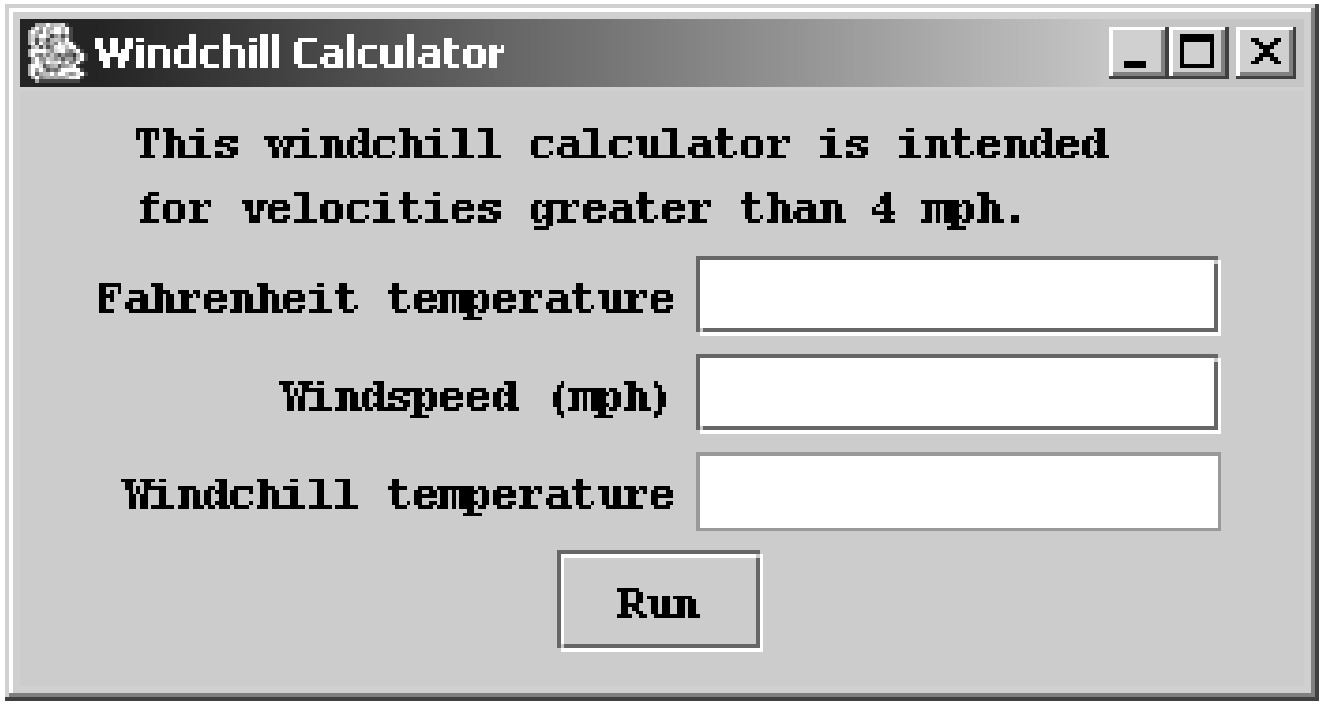
Class constants

- private static final int WINDOW_HEIGHT = 185
  - Initial height of the GUI



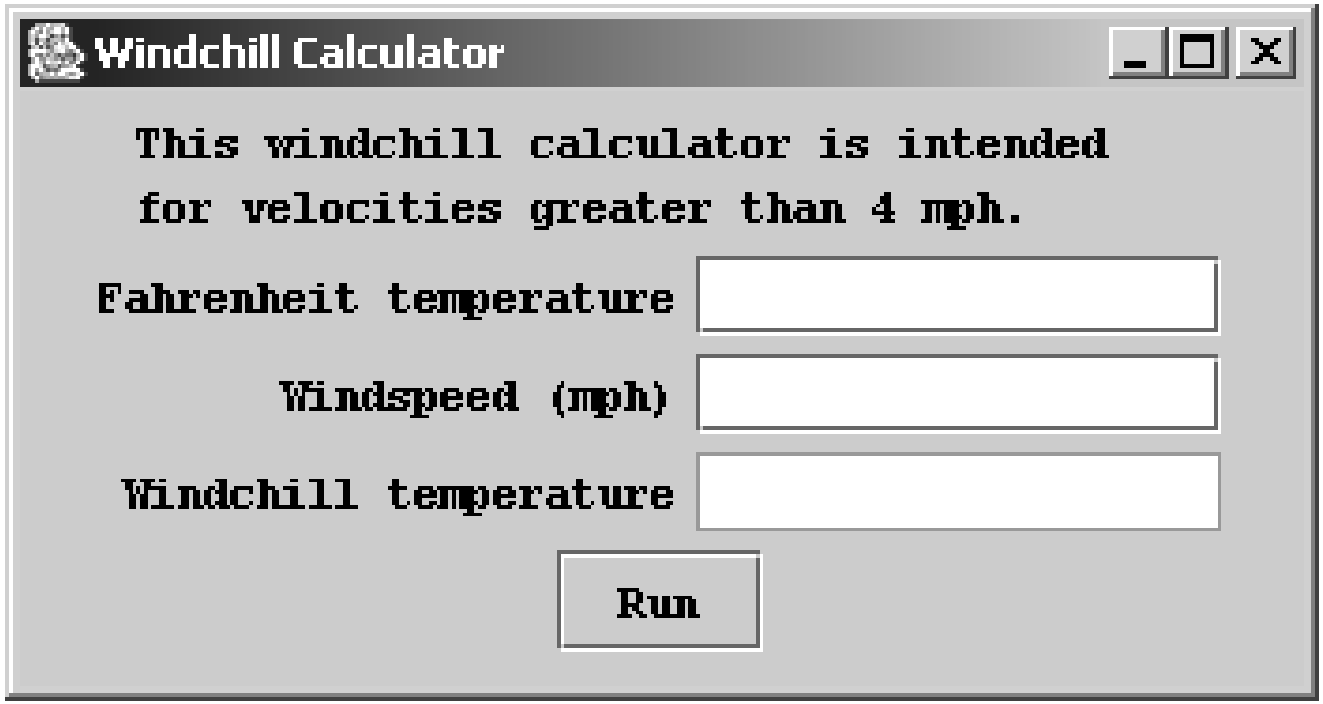
Class constants

- private static final int AREA_WIDTH = 40
  - Width of the program legend in characters



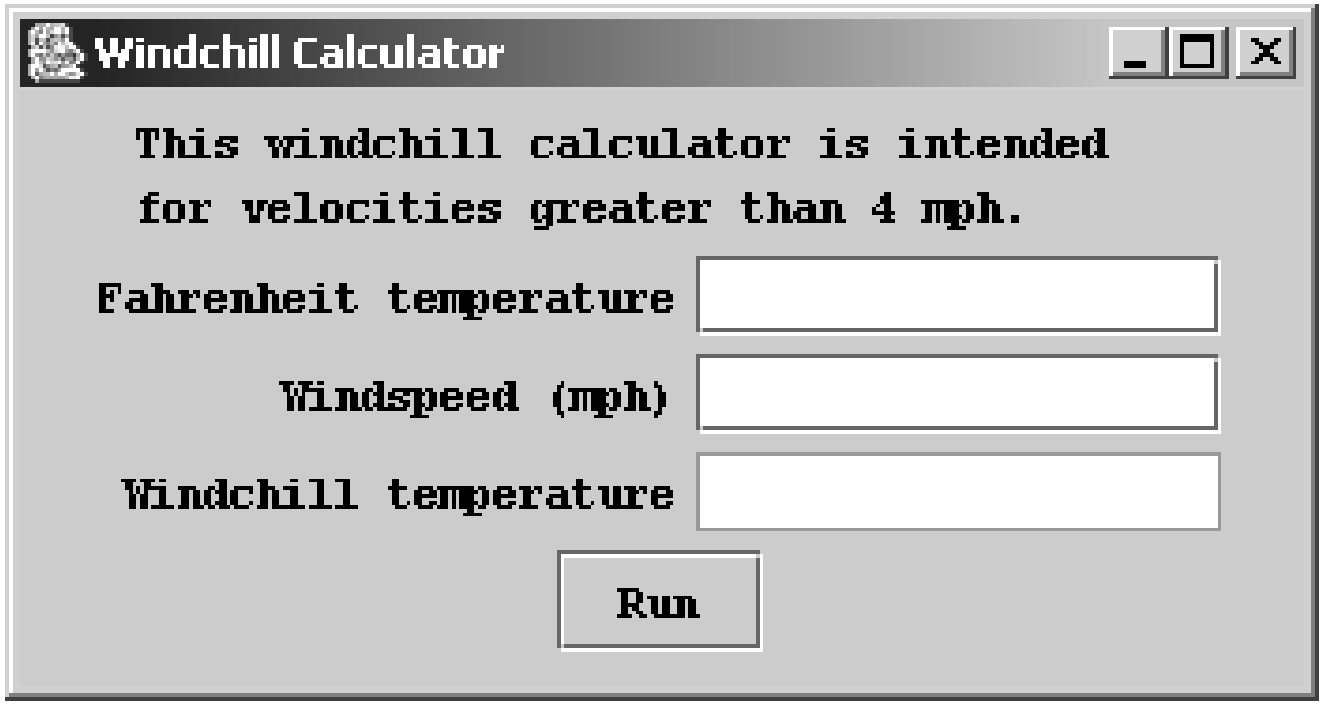
Class constants

- private static final int FIELD_WIDTH = 40
  - Number of characters per data entry area



Class constants

- private static final FlowLayout LAYOUT_STYLE =
  new FlowLaout()
  - References manager that lays out GUI components in a top-to-bottom, left-to-right manner



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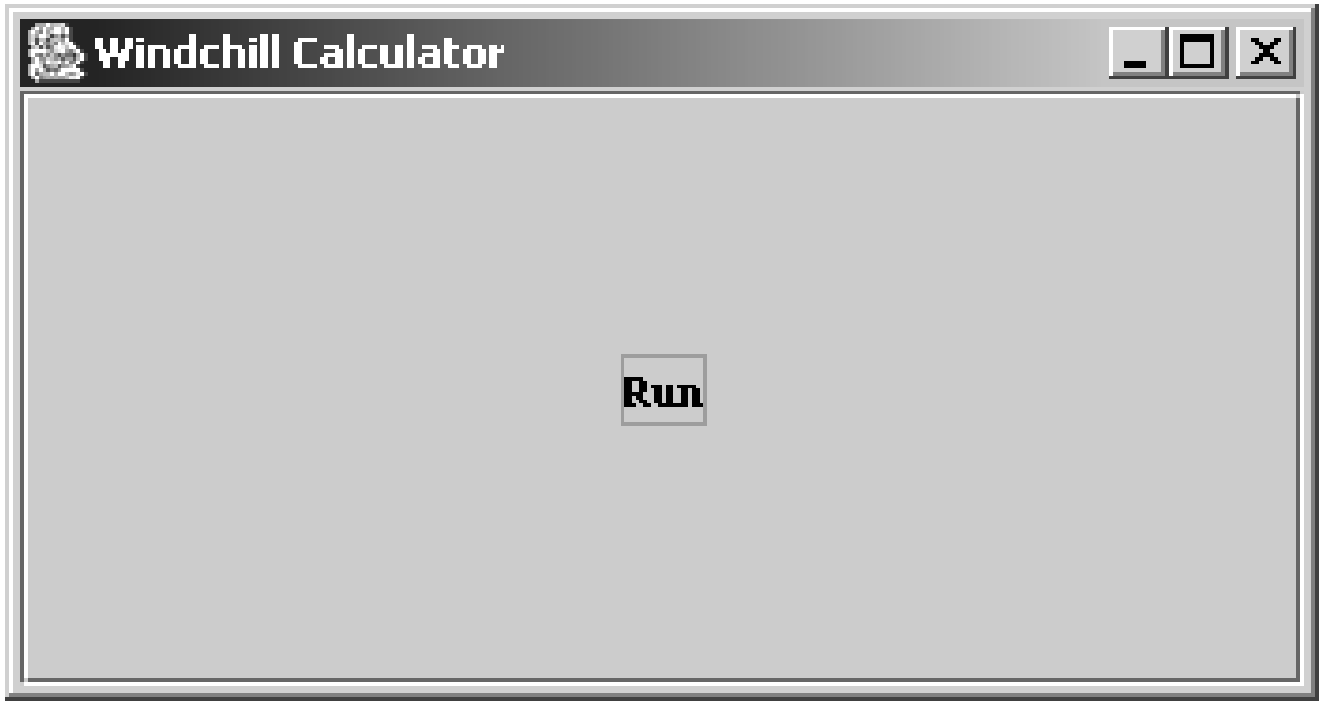
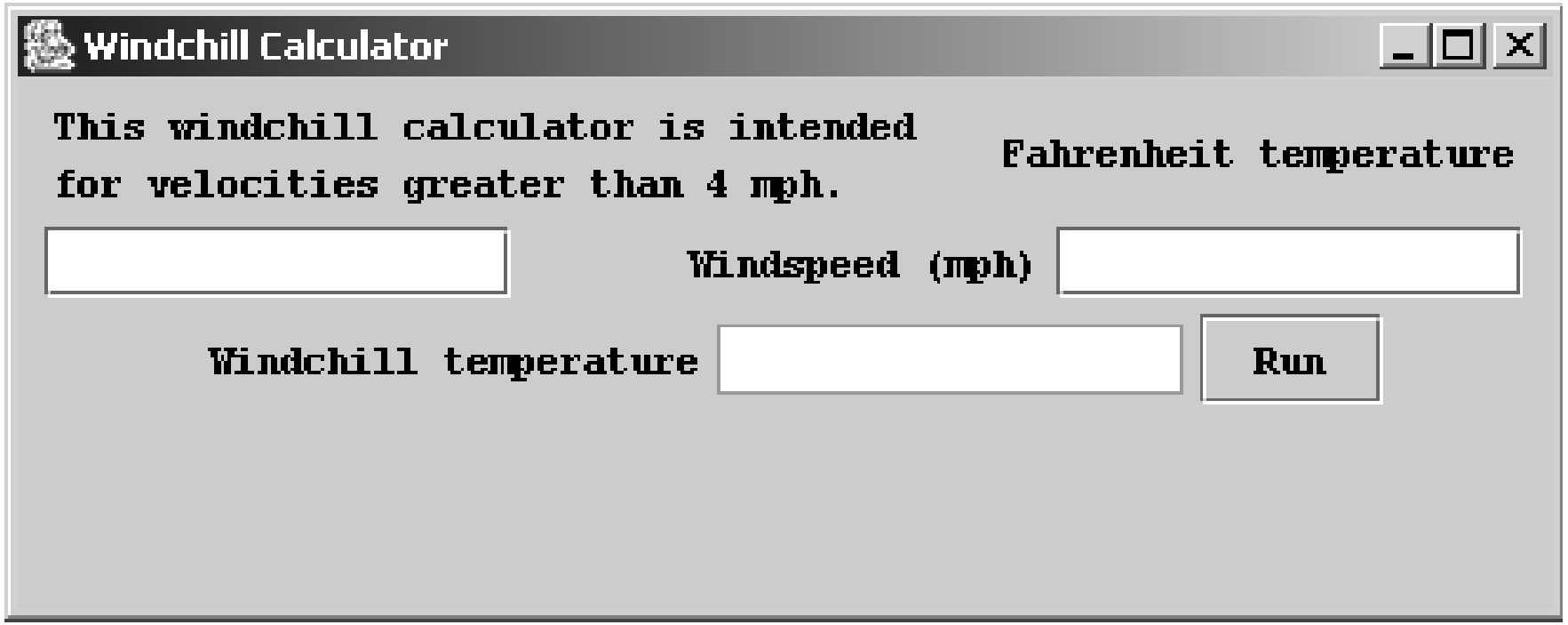


Class constants

- private static FlowLayout LAYOUT_STYLE =
  new FlowLaout()
  - References manager that lays out GUI components in a top-to-bottom, left-to-right manner



Program Windchill.java

```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class Windchill implements ActionListener {
   // class constants

   // instance variables with initialization

   // Windchill(): default constructor

   // actionPerformed(): run button action event handler

   // main(): application entry point

}
```

Program Windchill.java – class constants

```
private static final int WINDOW_WIDTH = 350;   // pixels

private static final int WINDOW_HEIGHT = 185;  // pixels

private static final int FIELD_WIDTH = 20;     // characters

private static final int AREA_WIDTH = 40;      // characters

private static final FlowLayout LAYOUT_STYLE =
        new FlowLayout();

private static final String LEGEND = "This windchill "
        + "calculator is intended for velocities greater than 4 mph.";
```

Program Windchill.java – instance variables

```
// window for GUI
private JFrame window =
   new JFrame("Windchill Calculator");

// legend
private JTextArea legendArea = new JTextArea(LEGEND, 2,
       AREA_WIDTH);

// user entry area for temperature
private JLabel fahrTag = new JLabel("Fahrenheit temperature");

private JTextField fahrText = new JTextField(FIELD_WIDTH);
```

Program Windchill.java – instance variables

```
// user entry area for windspeed
private JLabel windTag = new JLabel("       Windspeed (mph)");

private JTextField windText = new JTextField(FIELD_WIDTH);

// entry area for windchill result
private JLabel chillTag =
   new JLabel(" Windchill temperature");

private JTextField chillText = new JTextField(FIELD_WIDTH);

// run button
private JButton runButton = new JButton("Run");
```

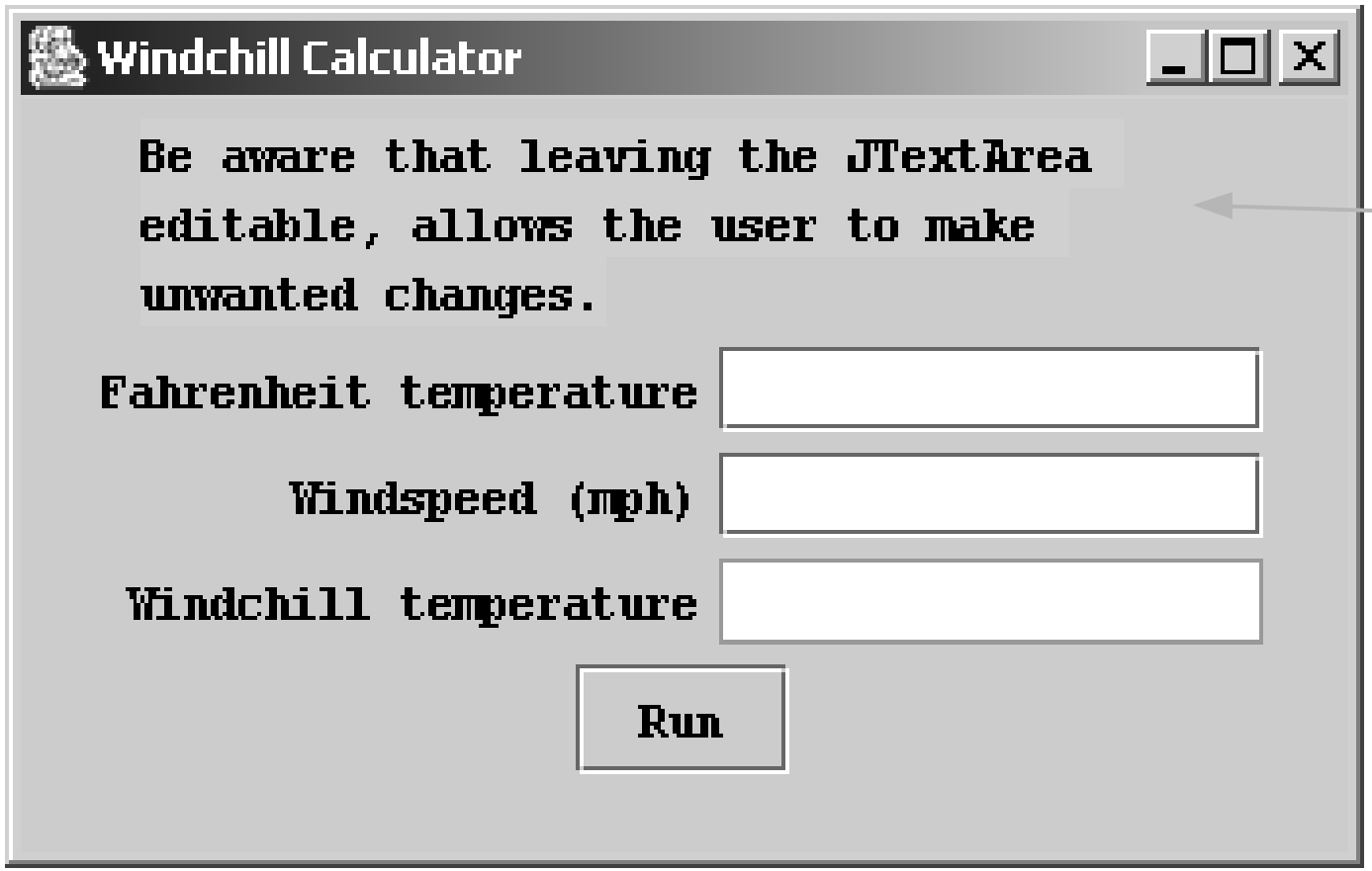
Program Windchill.java – constructor

```
public Windchill() {
   // configure GUI

   // register event listener

   // add components to container

   // display GUI

}
```

Program Windchill.java – constructor

```
public Windchill() {
   // configure GUI
   window.setSize(WINDOW_WIDTH, WINDOW_HEIGHT);
   window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

   legendArea.setEditable(false);
   legendArea.setLineWrap(true);
   legendArea.setWrapStyleWord(true);
   legendArea.setBackground(window.getBackground());

   chillText.setEditable(false);
   chillText.setBackground(Color.WHITE);
```

Bad line wrapping

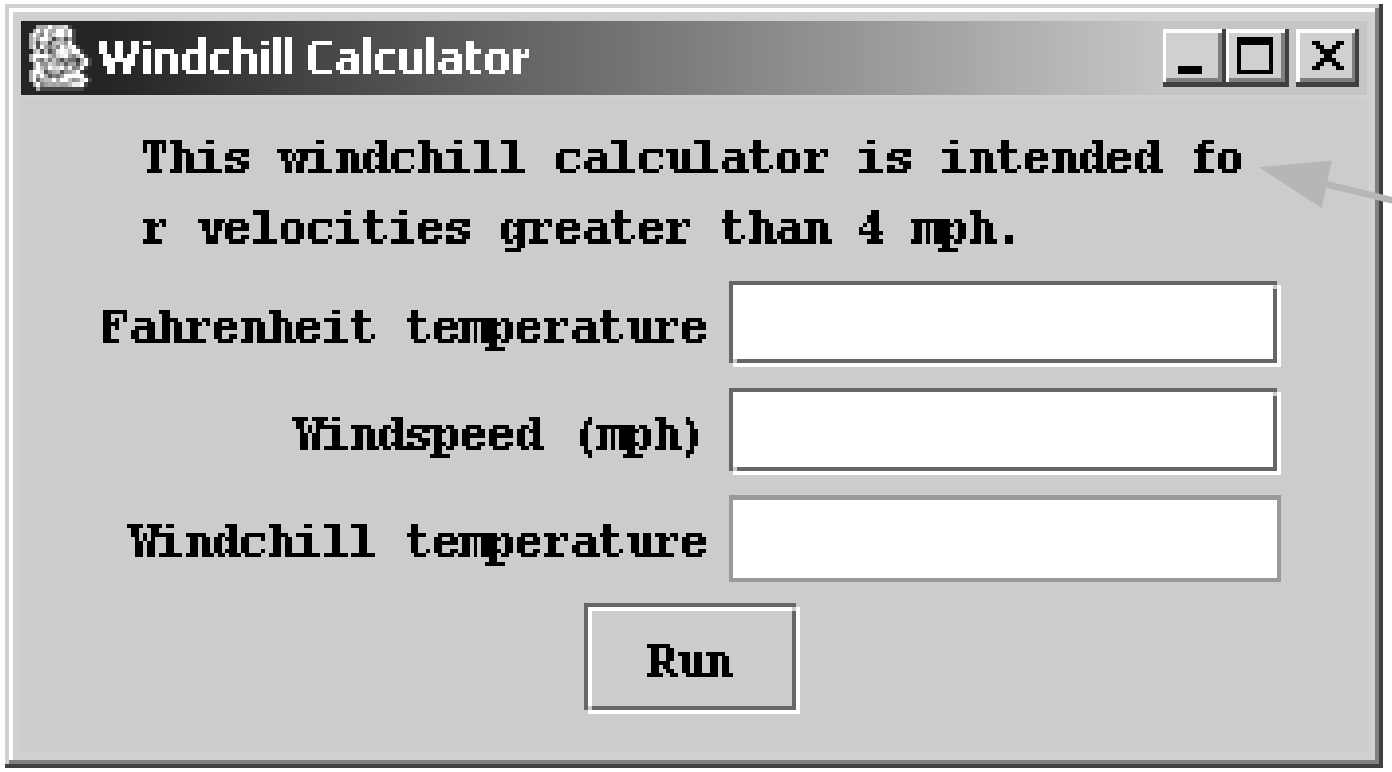


It is important to make program legends uneditable

Program Windchill.java – constructor

```
public Windchill() {
   // configure GUI
   window.setSize(WINDOW_WIDTH, WINDOW_HEIGHT);
   window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

   legendArea.setEditable(false);
   legendArea.setLineWrap(true);
   legendArea.setWrapStyleWord(true);
   legendArea.setBackground(window.getBackground());

   chillText.setEditable(false);
   chillText.setBackground(Color.WHITE);
```

Dangers of an editable legend



Line wrapping in the middle of a word

Program Windchill.java – constructor

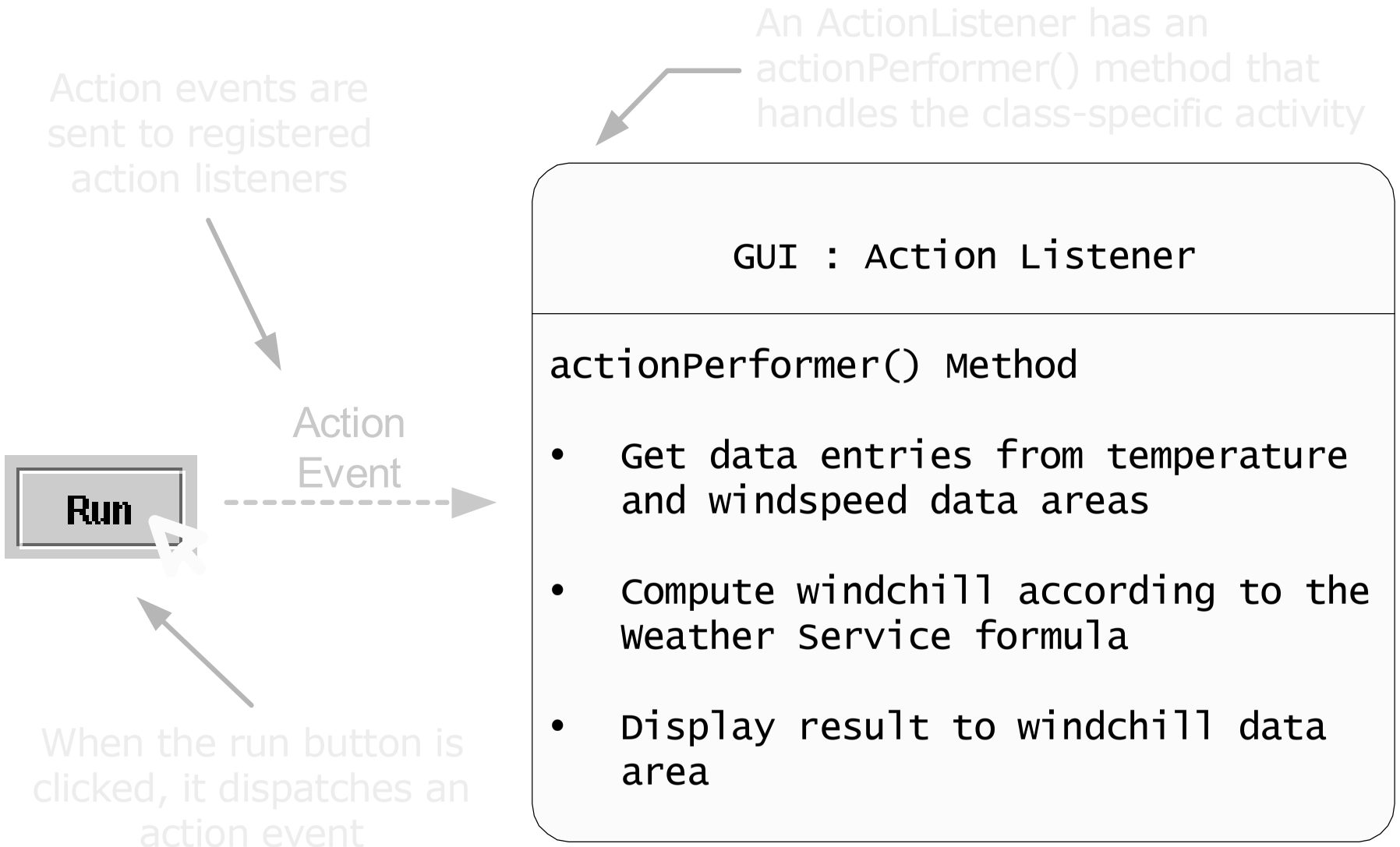
```
public Windchill() {
   // configure GUI
   window.setSize(WINDOW_WIDTH, WINDOW_HEIGHT);
   window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

   legendArea.setEditable(false);
   legendArea.setLineWrap(true);
   legendArea.setWrapStyleWord(true);
   legendArea.setBackground(window.getBackground());

   chillText.setEditable(false);
   chillText.setBackground(Color.WHITE);
```

Bad line wrapping

Program Windchill.java – constructor

```
public Windchill() {
   // configure GUI …

   // register event listener
   runButton.addActionListener(this);
```

Run button action-event handling



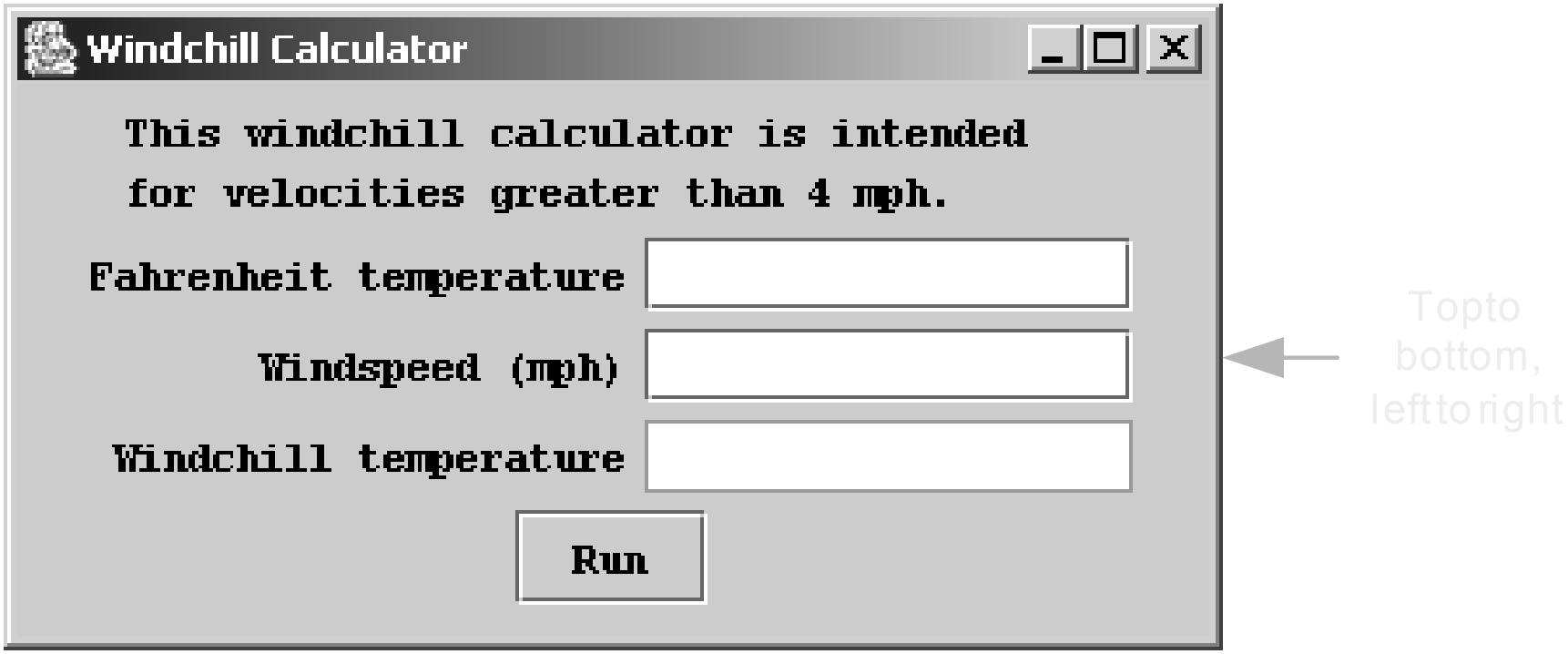
Program Windchill.java – constructor

```
public Windchill() {
    // configure GUI …

    // register event listener …

    // add components to container
    Container c = window.getContentPane();
    c.setLayout(LAYOUT_STYLE);

    c.add(legendArea);
    c.add(fahrTag);
    c.add(fahrText);
    c.add(windTag);
    c.add(windText);
    c.add(chillTag);
    c.add(chillText);
    c.add(runButton);
```

Program Windchill.java – constructor

```
public Windchill() {
    // configure GUI …

    // register event listener …

    // add components to container …

    // make GUI visible
    window.setVisible(true);
```

Laying out the GUI components



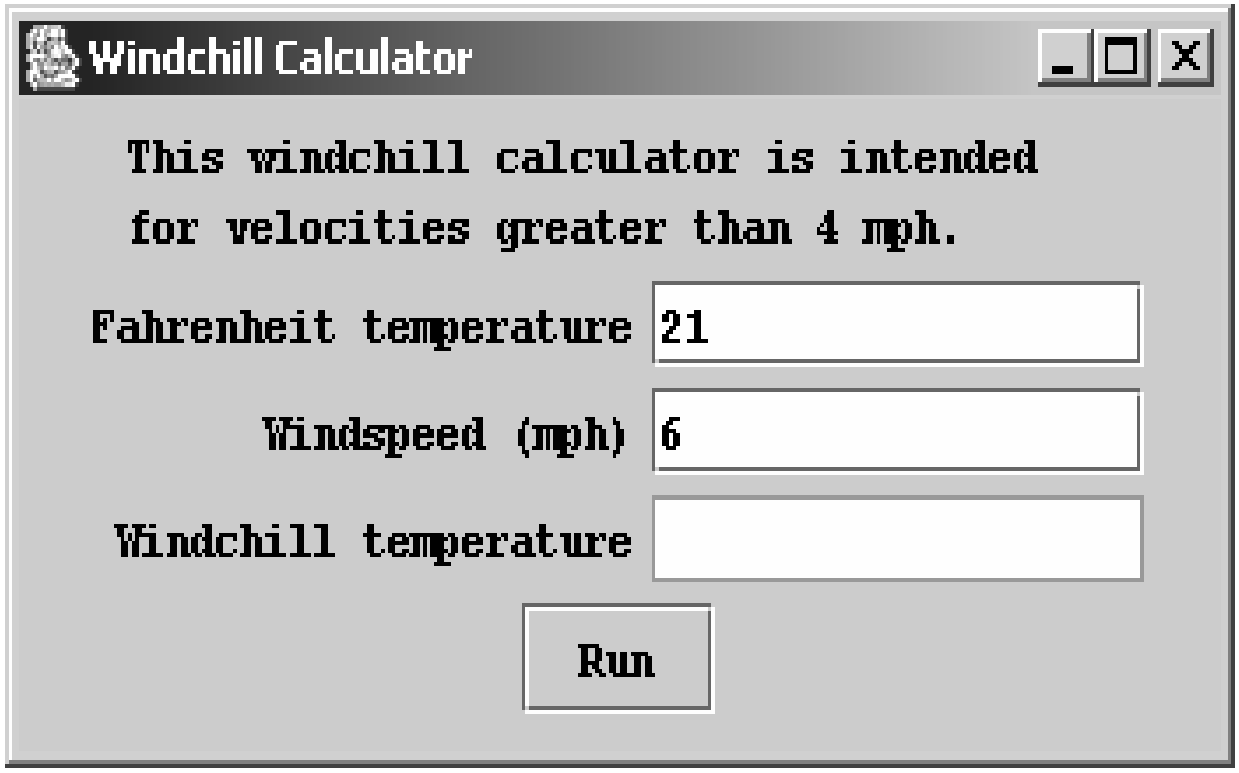
Program Windchill.java – action performer

```
public void actionPerformed(ActionEvent e) {
   // get user's responses

   // compute windchill

   // display windchill
}
```

Program Windchill.java – action performer

```
public void actionPerformed(ActionEvent e) {
   // get user's responses
    String response1 = fahrText.getText();
    double t = Double.parseDouble(response1);
    String response2 = windText.getText();
    double v = Double.parseDouble(response2);

   // compute windchill

   // display windchill
}
```

Program Windchill.java – action performer



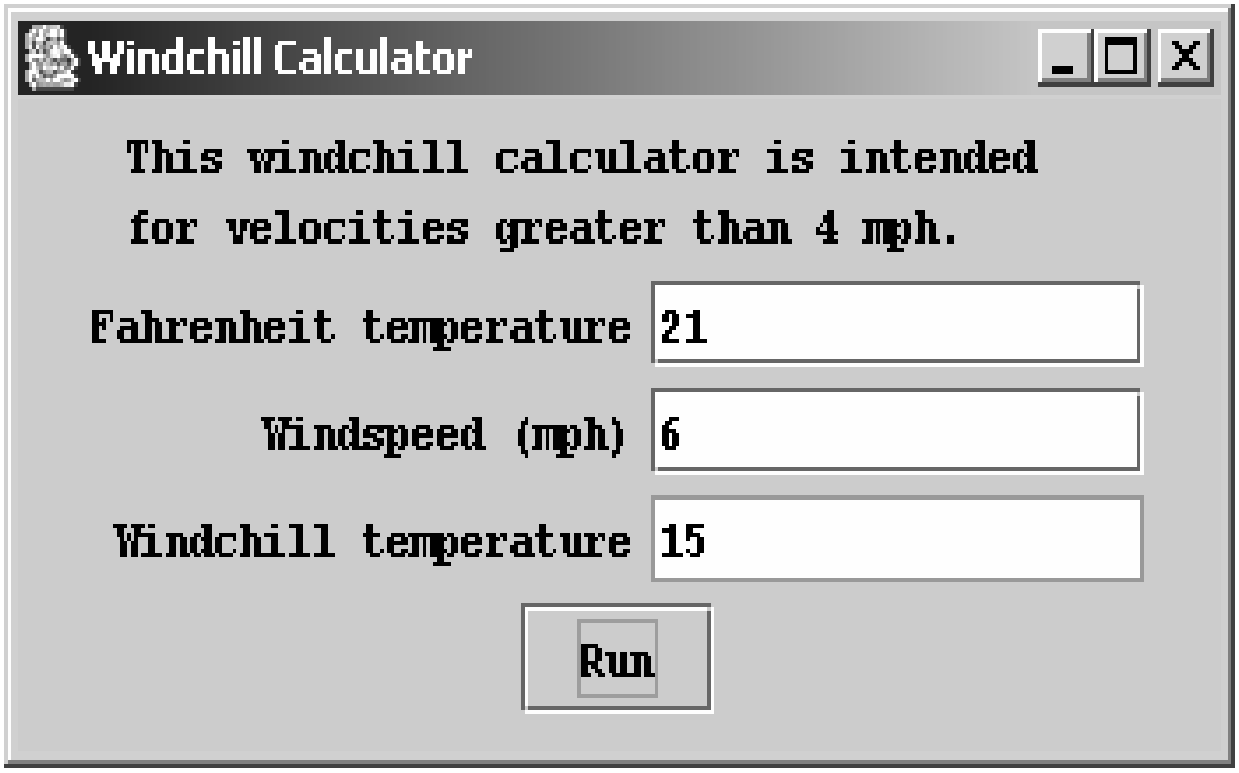
Program Windchill.java – action performer

```
public void actionPerformed(ActionEvent e) {
   // get user's responses
    String response1 = fahrText.getText();
    double t = Double.parseDouble(response1);
    String response2 = windText.getText();
    double v = Double.parseDouble(response2);

   // compute windchill
   double windchillTemperature = 0.081 * (t - 91.4)
          * (3.71*Math.sqrt(v) + 5.81 - 0.25*v) + 91.4;

   int perceivedTemperature =
       (int) Math.round(windchillTemperature);

   // display windchill
}
```

Program Windchill.java – action performer

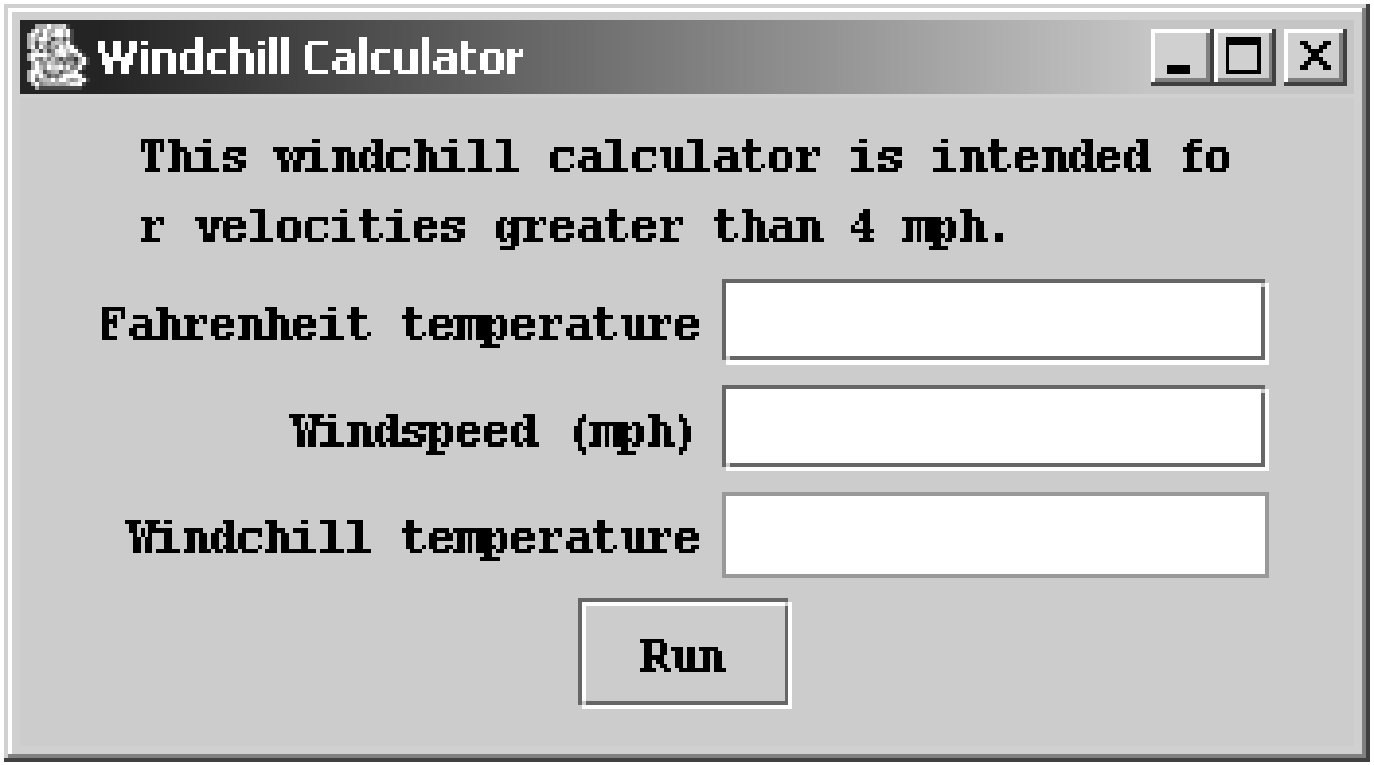
```
public void actionPerformed(ActionEvent e) {
   // get user's responses
    String response1 = fahrText.getText();
    double t = Double.parseDouble(response1);
    String response2 = windText.getText();
    double v = Double.parseDouble(response2);

   // compute windchill
   double windchillTemperature = 0.081 * (t - 91.4)
          * (3.71*Math.sqrt(v) + 5.81 - 0.25*v) + 91.4;

   int perceivedTemperature =
       (int) Math.round(windchillTemperature);

   // display windchill
   String output = String.valueOf(perceivedTemperature);
   chillText.setText(output);
}
```

Program Windchill.java – action performer



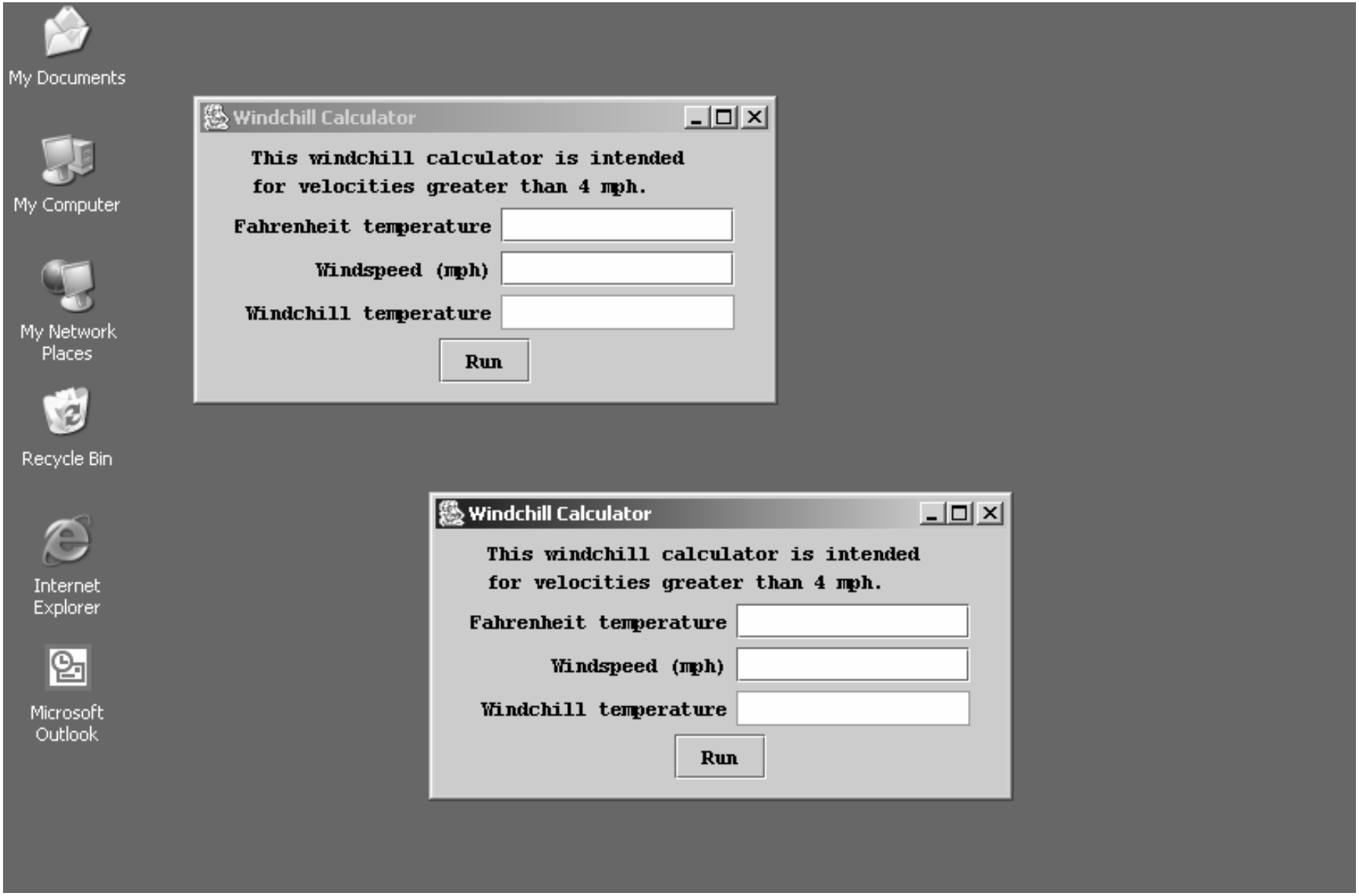
Method main()

```
public static void main(String[] args) {
   Windchill gui = new Windchill();
}
```



Another method main()

```
public static void main(String[] args) {
    Windchill gui1 = new Windchill();
    Windchill gui2 = new Windchill();
}
```


My Documents
My Computer
My Network Places
Recycle Bin
Internet Explorer
Microsoft Outlook
Windchill Calculator
This windchill calculator is intended for velocities greater than 4 mph.
Fahrenheit temperature
Windspeed (mph)
Windchill temperature
Run
Windchill Calculator
This windchill calculator is intended for velocities greater than 4 mph.
Fahrenheit temperature
Windspeed (mph)
Windchill temperature
Run

Inheritance

- Definition
  - Ability to define a new class using an existing class as a basis

- Terms
  - Subclass
    - The new class inheriting the attributes and behaviors of the class on which it is based
  - Superclass
    - The basis for a subclass

Inheritance

- Default
  - Class has Object as its superclass

- Java allows only single inheritance
  - A class can be defined in terms of one other class

Inheritance

- Subclass can define
  - Additional attributes
  - Additional behaviors

- Subclass can override
  - Superclass behaviors

Applets

- Java program run within a browser
  - Implies an applet is run from a web page
- Applets may not access or modify the file system running the applet
- A modern applet has JApplet as its superclass
  - JApplet is part of the swing package
- An applet does use JFrame
    - A JApplet has a content pane

Applets

- Important inherited methods
  - init()
    - Run when browser loads applet
  - start()
    - Run by browser to start applet execution
  - stop()
    - Run by browser to stop its execution
  - destroy()
    - Run by browser immediately before it its ended
  - paint(Graphics g)
    - Run by browser to refresh its GUI

- By default the inherited methods do nothing

A simple applet

```
import java.awt.*;
import javax.swing.*;
public class DisplayQuote extends JApplet {
   public void paint(Graphics g) {
      g.drawString("Anyone who spends their life on a "
            + " computer is pretty unusual.", 20, 30);
      g.drawString("Bill Gates, Chairman of Microsoft",
  25, 45);
   }
}
```

Web page – quote.htm

```
<html>
   <title> Windchill </title>
   <applet code="DisplayQuote.class" width=400 height=300>
   </applet>
</html>
```