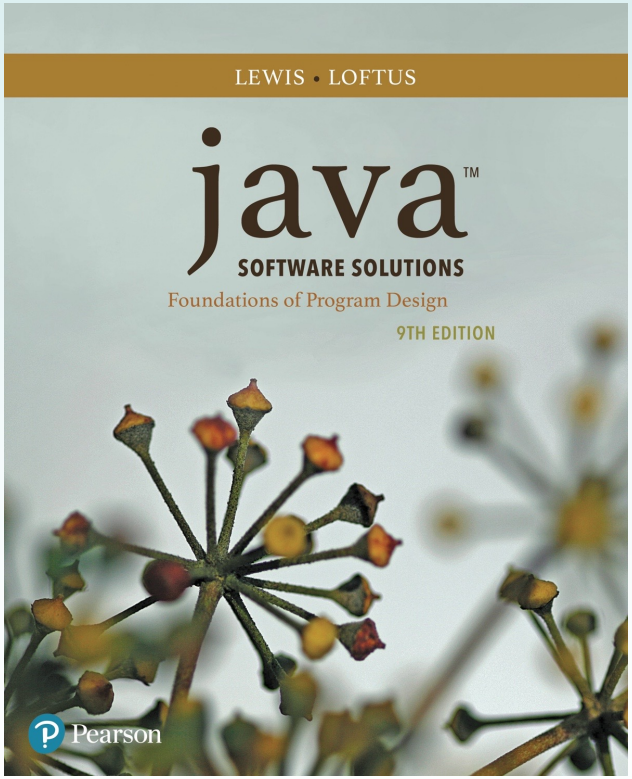
Chapter 3
Using Classes and Objects



Java Software Solutions
Foundations of Program Design
9th Edition

John Lewis
William Loftus

Using Classes and Objects

- We can create more interesting programs using predefined classes and related objects
- Chapter 3 focuses on:
  - object creation and object references
  - the `String` class and its methods
  - the Java API class library
  - the `Random` and `Math` classes
  - formatting output
  - enumerated types
  - wrapper classes
  - JavaFX graphics API
  - shape classes

Outline

- **Creating Objects**
- **The String Class**
- **Modularity**
- **The Random and Math Classes**
- **Formatting Output**
- **Enumerated Types**
- **Wrapper Classes**
- **Introduction to JavaFX**
- **Shapes and Color**

Creating Objects

- A variable holds either a primitive value or a *reference* to an object
- A class name can be used as a type to declare an *object reference variable*

```
String title;
```

- No object is created with this declaration
- An object reference variable holds the address of an object
- The object itself must be created separately

Creating Objects

- Generally, we use the `new` operator to create an object
- Creating an object is called *instantiation*
- An object is an *instance* of a particular class

```
title = new String("Java Software Solutions");
```

This calls the String *constructor*, which is a special method that sets up the object

Invoking Methods

- We've seen that once an object has been instantiated, we can use the *dot operator* to invoke its methods

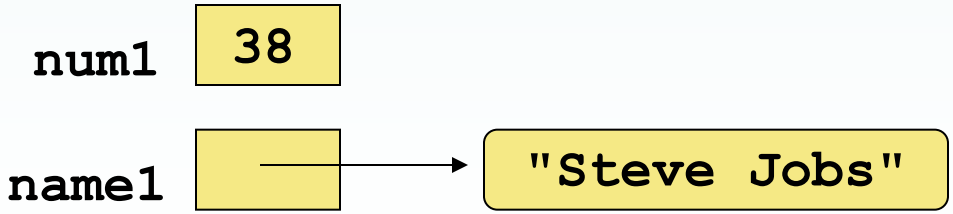
```
numChars = title.length()
```

- A method may *return a value*, which can be used in an assignment or expression

- A method invocation can be thought of as asking an object to perform a service

References

- Note that a primitive variable contains the value itself, but an object variable contains the address of the object
- An object reference can be thought of as a pointer to the location of the object
- Rather than dealing with arbitrary addresses, we often depict a reference graphically



Assignment Revisited

- The act of assignment takes a copy of a value and stores it in a variable
- For primitive types:

Before:

`num1`	38
`num2`	96

```
num2 = num1;
```

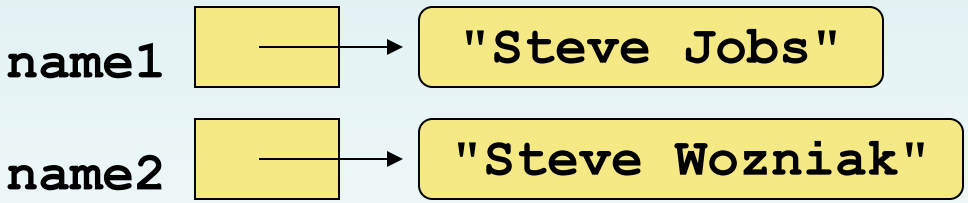
After:

`num1`	38
`num2`	38

Reference Assignment

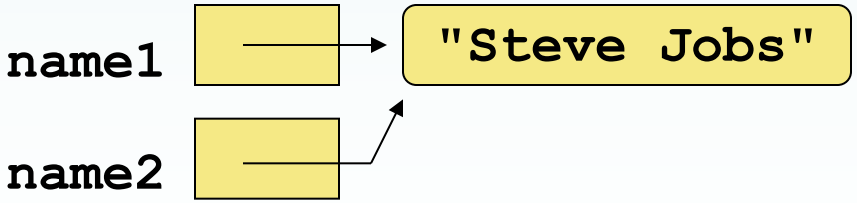
- For object references, assignment copies the address:

Before:




```
name2 = name1;
```

After:



Aliases

- Two or more references that refer to the same object are called *aliases* of each other
- That creates an interesting situation: one object can be accessed using multiple reference variables
- Aliases can be useful, but should be managed carefully
- Changing an object through one reference changes it for all of its aliases, because there is really only one object

Garbage Collection

- When an object no longer has any valid references to it, it can no longer be accessed by the program
- The object is useless, and therefore is called *garbage*
- Java performs *automatic garbage collection* periodically, returning an object's memory to the system for future use
- In other languages, the programmer is responsible for performing garbage collection

Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

The String Class

- Because strings are so common, we don't have to use the `new` operator to create a `String` object

```
title = "Java Software Solutions";
```

- This is special syntax that works <u>only</u> for strings
- Each string literal (enclosed in double quotes) represents a `String` object
- There is a special syntax for text blocks
  - Use """ before and after the text block
  - Common leading whitespace is removed

String Methods

- Once a `String` object has been created, neither its value nor its length can be changed
- Therefore we say that an object of the `String` class is *immutable*
- However, several methods of the `String` class return new `String` objects that are modified versions of the original

String Indexes

- It is occasionally helpful to refer to a particular character within a string
- This can be done by specifying the character's numeric *index*
- The indexes begin at zero in each string
- In the string `"Hello"`, the character `'H'` is at index 0 and the `'o'` is at index 4
- See `StringMutation.java`

Quick Check

What output is produced by the following?

```
String str = "Space, the final frontier.";
System.out.println(str.length());
System.out.println(str.substring(7));
System.out.println(str.toUpperCase());
System.out.println(str.length());
```

Quick Check

What output is produced by the following?

```
String str = "Space, the final frontier.";
System.out.println(str.length());
System.out.println(str.substring(7));
System.out.println(str.toUpperCase());
System.out.println(str.length());
```

```
26
the final frontier.
SPACE, THE FINAL FRONTIER.
26
```

Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

Modularity

- To deal with complexity, language design has added many structures in higher level languages
  - Statements
  - Functions/methods/subroutines/procedures
  - Classes
  - Packages
  - Modules/Components/Subsystems
- Beyond statements, each structure defines a part of the system with a well-defined interface
  - Separates usage contract from implementation details
  - To merely use something we do not need to know how it is implemented

Class Libraries

- A *class library* is a collection of classes that we can use when developing programs
- The *Java standard class library* is part of any Java development environment
- Its classes are not part of the Java language per se, but we rely on them heavily
- Various classes we've already used (`System`, `Scanner`, `String`) are part of the Java standard class library

The Java API

- The Java class library is sometimes referred to as the Java API
- API stands for Application Programming Interface
- Clusters of related classes are sometimes referred to as specific APIs:
  - JavaFX API
  - Database API
  - Network API
  - Streams API

The Java API

- Get comfortable using the online Java API at https://docs.oracle.com/en/java/javase/17/docs/api/index.html

Overview (Java SE 17 & JDK 17)

docs.oracle.com/en/java/javase/17/docs/api/index.html

OVERVIEW MODULE PACKAGE CLASS USE TREE PREVIEW NEW DEPRECATED INDEX HELP Java SE 17 & JDK 17

SEARCH:

Java® Platform, Standard Edition & Java Development Kit Version 17 API Specification

This document is divided into two sections:

Java SE

The Java Platform, Standard Edition (Java SE) APIs define the core Java platform for general-purpose computing. These APIs are in modules whose names start with `java`.

JDK

The Java Development Kit (JDK) APIs are specific to the JDK and will not necessarily be available in all implementations of the Java SE Platform. These APIs are in modules whose names start with `jdk`.

All Modules | Java SE | JDK | Other Modules

Module	Description
java.base	Defines the foundational APIs of the Java SE Platform.
java.compiler	Defines the Language Model, Annotation Processing, and Java Compiler APIs.
java.datatransfer	Defines the API for transferring data between and within applications.
java.desktop	Defines the AWT and Swing user interface toolkits, plus APIs for accessibility, audio, imaging, printing, and JavaBeans.
java.instrument	Defines services that allow agents to instrument programs running on the JVM.
java.logging	Defines the Java Logging API.
java.management	Defines the Java Management Extensions (JMX) API.
java.management.rmi	Defines the RMI connector for the Java Management Extensions (JMX) Remote API.
java.naming	Defines the Java Naming and Directory Interface (JNDI) API.

Packages

- For purposes of accessing them, classes in the Java API are organized into *packages*
- These often overlap with specific APIs
- Examples:

Package	Purpose
java.lang	General support
java.util	Utilities
java.net	Network communication
javafx.scene.shape	Graphical shapes
javafx.scene.control	GUI controls

The import Declaration

- When you want to use a class from a package, you could use its *fully qualified name*

```
java.util.Scanner
```

- Or you can *import* the class, and then use just the class name

```
import java.util.Scanner;
```

- To import all classes in a particular package, you can (but don't) use the * wildcard character

```
import java.util.*;
```

- All classes of the `java.lang` package are imported automatically into all programs

Defining Packages

- We have discussed classes from the standard java packages
- It is easy to define your own packages!
  - The first line in the source code file is a package statement
    - package mypackagename;
    - package q1;
    - package ca.bcit.infosys.servletutils;
  - The source code file must be in a directory (directories) corresponding to the package name
    - Replace period with directory separator

Assignment 1

- For assignments, each programming problem will have a separate package:
  - q1 for problem 1
  - q2 for problem 2
  - similarly q3, q4, q5 for problem 3, 4, 5
- We will also be giving you a template and ant script
  - to build and package your code for assignment submission
  - the lab instructor will walk you through the process

Java Platform Module System

- Partitions Java libraries into commonly used subsystems
- Allows large systems to be designed with reusable components
  - increases scalability
- Module contains
  - Collection of packages
  - Optional resource files and native libraries
  - List of accessible packages in the module
  - List of modules on which this module depends
- Defined by `module-info.java` in base directory

Basic Modules

- Module name: letters, digits, underscores, periods
  - No hierarchy is implied by the name
  - Name should be globally unique
  - Typically name after its highest level package
- Format of simple `module-info.java`:

```
module module.name {
    requires javafx.controls;
    …
    exports my.package;
    …
}
```

- No `module-info.java` → Non modular project

Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

The Random Class

- The `Random` class is part of the `java.util` package
- Provides methods that generate pseudorandom numbers
- See `java.util.random` package API discussion
- A `Random` object performs complicated calculations based on a *seed value* to produce a stream of seemingly random values
- See `RandomNumbers.java`

Quick Check

Given a `Random` object named `gen`, what range of values are produced by the following expressions?

```
gen.nextInt(25)
gen.nextInt(6) + 1
gen.nextInt(100) + 10
gen.nextInt(50) + 100
gen.nextInt(10) - 5
gen.nextInt(22) + 12
```

Quick Check

Given a `Random` object named `gen`, what range of values are produced by the following expressions?

	Range
`gen.nextInt(25)`	`0 to 24`
`gen.nextInt(6) + 1`	`1 to 6`
`gen.nextInt(100) + 10`	`10 to 109`
`gen.nextInt(50) + 100`	`100 to 149`
`gen.nextInt(10) - 5`	`-5 to 4`
`gen.nextInt(22) + 12`	`12 to 33`

Quick Check

Write an expression that produces a random integer in the following ranges:

Range
`0 to 12`
`1 to 20`
`15 to 20`
`-10 to 0`

Quick Check

Write an expression that produces a random integer in the following ranges:

Range	
`0 to 12`	`gen.nextInt(13)`
`1 to 20`	`gen.nextInt(20) + 1`
`15 to 20`	`gen.nextInt(6) + 15`
`-10 to 0`	`gen.nextInt(11) - 10`

The Math Class

- The `Math` class is part of the `java.lang` package
- The `Math` class contains methods that perform various mathematical functions
- These include:
  - absolute value
  - square root
  - exponentiation
  - trigonometric functions

The Math Class

- The methods of the `Math` class are *static methods* (also called *class methods*)

- Static methods are invoked through the class name – no object of the `Math` class is needed

```
value = Math.cos(90) + Math.sqrt(delta);
```

- We discuss static methods further in Chapter 7

- See `Quadratic.java`

Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

Formatting Output

- It is often necessary to format output values in certain ways so that they can be presented properly
- The Java standard class library contains classes that provide formatting capabilities
- The `NumberFormat` class allows you to format values as currency or percentages
- The `DecimalFormat` class allows you to format values based on a pattern
- Both are part of the `java.text` package

Formatting Output

- The `NumberFormat` class has static methods that return a formatter object

```
getCurrencyInstance()

getPercentInstance()
```

- Each formatter object has a method called `format` that returns a string with the specified information in the appropriate format
- See `Purchase.java`

Formatting Output

- The `DecimalFormat` class can be used to format a floating point value in various ways
- For example, you can specify that the number should be truncated to three decimal places
- The constructor of the `DecimalFormat` class takes a string that represents a pattern for the formatted number
- See `CircleStats.java`

Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

Enumerated Types

- Java allows you to define an *enumerated type*, which can then be used to declare variables
- An enumerated type declaration lists all possible values for a variable of that type
- The values are identifiers of your own choosing
- The following declaration creates an enumerated type called `Season`

```
enum Season {winter, spring, summer, fall};
```

- Any number of values can be listed

Enumerated Types

- Once a type is defined, a variable of that type can be declared:

```
Season time;
```

- And it can be assigned a value:

```
time = Season.fall;
```

- The values are referenced through the name of the type
- Enumerated types are *type-safe* – you cannot assign any value other than those listed

Ordinal Values

- Enumerated types are stored in variables as references, like all objects
- All references for a given value are aliases, values are immutable
- Each value has a name and an ordinal
  - The first value in an enumerated type has an ordinal value of zero, the second one, and so on
- You cannot assign a numeric value to an enumerated type variable

Enumerated Types

- The declaration of an enumerated type is a special type of class, and each variable of that type is an object
- The `ordinal` method returns the ordinal value of the object
- The `name` method returns the name of the identifier corresponding to the object's value
- See `IceCream.java`

Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

Wrapper Classes

- The `java.lang` package contains *wrapper classes* that correspond to each primitive type:

Primitive Type	Wrapper Class
`byte`	`Byte`
`short`	`Short`
`int`	`Integer`
`long`	`Long`
`float`	`Float`
`double`	`Double`
`char`	`Character`
`boolean`	`Boolean`

Wrapper Classes

- The following declaration creates an `Integer` object which represents the integer 40 as an object

```
Integer age = new Integer(40);
```

- An object of a wrapper class can be used in any situation where a primitive value will not suffice
  - For example, some objects serve as containers of other objects
  - Primitive values could not be stored in such containers, but wrapper objects could be
- Values of wrapper classes are immutable

Wrapper Classes

- Wrapper classes also contain static methods that help manage the associated type
- For example, the `Integer` class contains a method to convert an integer stored in a `String` to an `int` value:

```
num = Integer.parseInt(str);
```

- They often contain useful constants as well
- For example, the `Integer` class contains `MIN_VALUE` and `MAX_VALUE` which hold the smallest and largest `int` values

Autoboxing

- *Autoboxing* is the automatic conversion of a primitive value to/from a corresponding wrapper object:

```
Integer obj;
int num = 42;
obj = num;
```

- The assignment creates the appropriate `Integer` object
- The reverse conversion (called *unboxing*) also occurs automatically as needed

Quick Check

Are the following assignments valid? Explain.

```
Double value = 15.75;
```

```
Character ch = new Character('T');
char myChar = ch;
```

Quick Check

Are the following assignments valid? Explain.

```
Double value = 15.75;
```

Yes. The double literal is autoboxed into a `Double` object.

```
Character ch = new Character('T');
char myChar = ch;
```

Yes, the char in the object is unboxed before the assignment.

Outline

Creating Objects

The String Class

Modularity

The Random and Math Classes

Formatting Output

Enumerated Types

Wrapper Classes

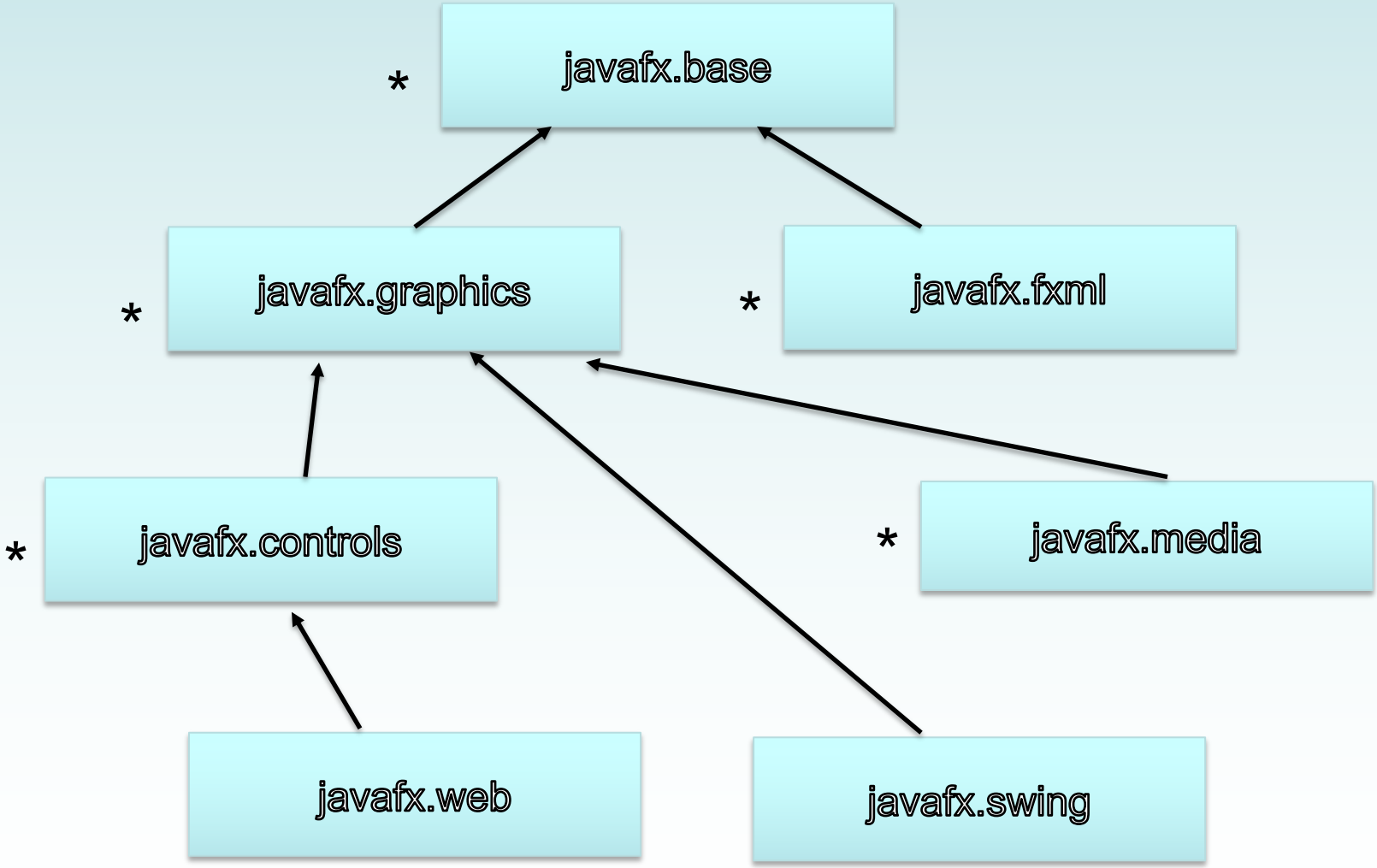
Introduction to JavaFX

Shapes and Color

Intro to JavaFX

- The programs we've explored thus far have been text-based
- They are called *command-line applications*, which interact with the user using simple text prompts
- We'll now begin to explore programs that use graphics and graphical user interfaces (GUIs)
- Support for these programs will come from the JavaFX API
- JavaFX has replaced older approaches (AWT and Swing)

JavaFX Module Structure



Intro to JavaFX

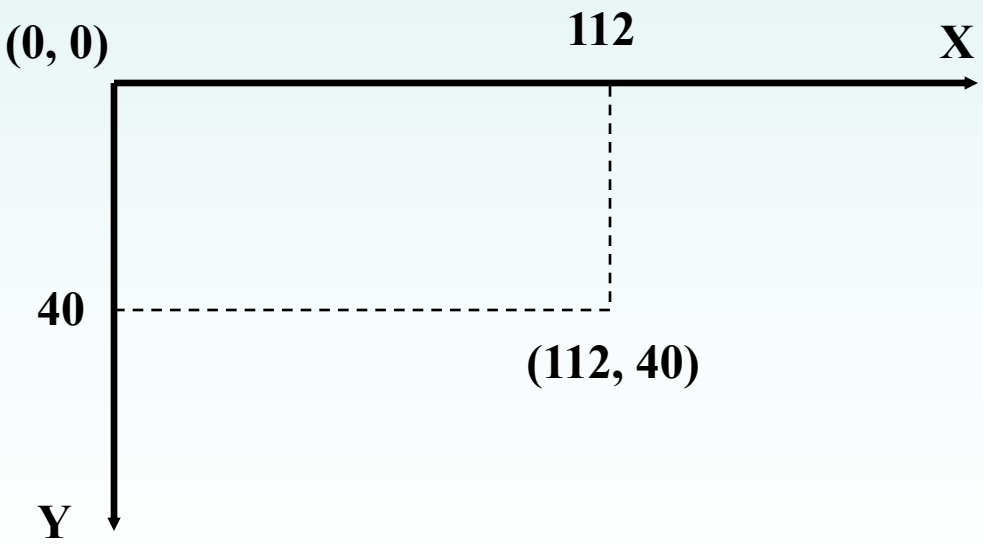
- JavaFX programs extend the `Application` class, inheriting core graphical functionality
- A JavaFX program has a `start` method
- The `main` method is only needed to launch the JavaFX application
- The `start` method accepts the primary stage (window) used by the program as a parameter
- JavaFX embraces a theatre analogy
- See `HelloJavaFX.java`

Intro to JavaFX

- In this example, two `Text` objects are added to a `Group`
- The group serves as the *root node* of a `Scene`
- The scene is displayed on the primary `Stage` (window)
- The size and background color of the scene can be set when the `Scene` object is created
- The position of each `Text` object is specified explicitly (in this case)

Intro to JavaFX

- The origin of the Java coordinate system is in the upper left corner
- All visible points have positive coordinates



Outline

- Creating Objects
- The String Class
- Modularity
- The Random and Math Classes
- Formatting Output
- Enumerated Types
- Wrapper Classes
- Introduction to JavaFX
- Shapes and Color

Basic Shapes

- JavaFX shapes are represented by classes in the javafx.scene.shape package
- A line segment is defined by the `Line` class, whose constructor accepts the coordinates of the two endpoints:

```
Line(startX, startY, endX, endY)
```

- For example:

```
Line myLine = new Line(10, 20, 300, 80);
```

Basic Shapes

- A rectangle is specified by its upper left corner and its width and height:

```
Rectangle(x, y, width, height)
```

```
Rectangle r = new Rectangle(30, 50, 200, 70);
```

- A circle is specified by its center point and radius:

```
Circle(centerX, centerY, radius)
```

```
Circle c = new Circle(100, 150, 40);
```

Basic Shapes

- An ellipse is specified by its center point and its radius along the x and y axis:

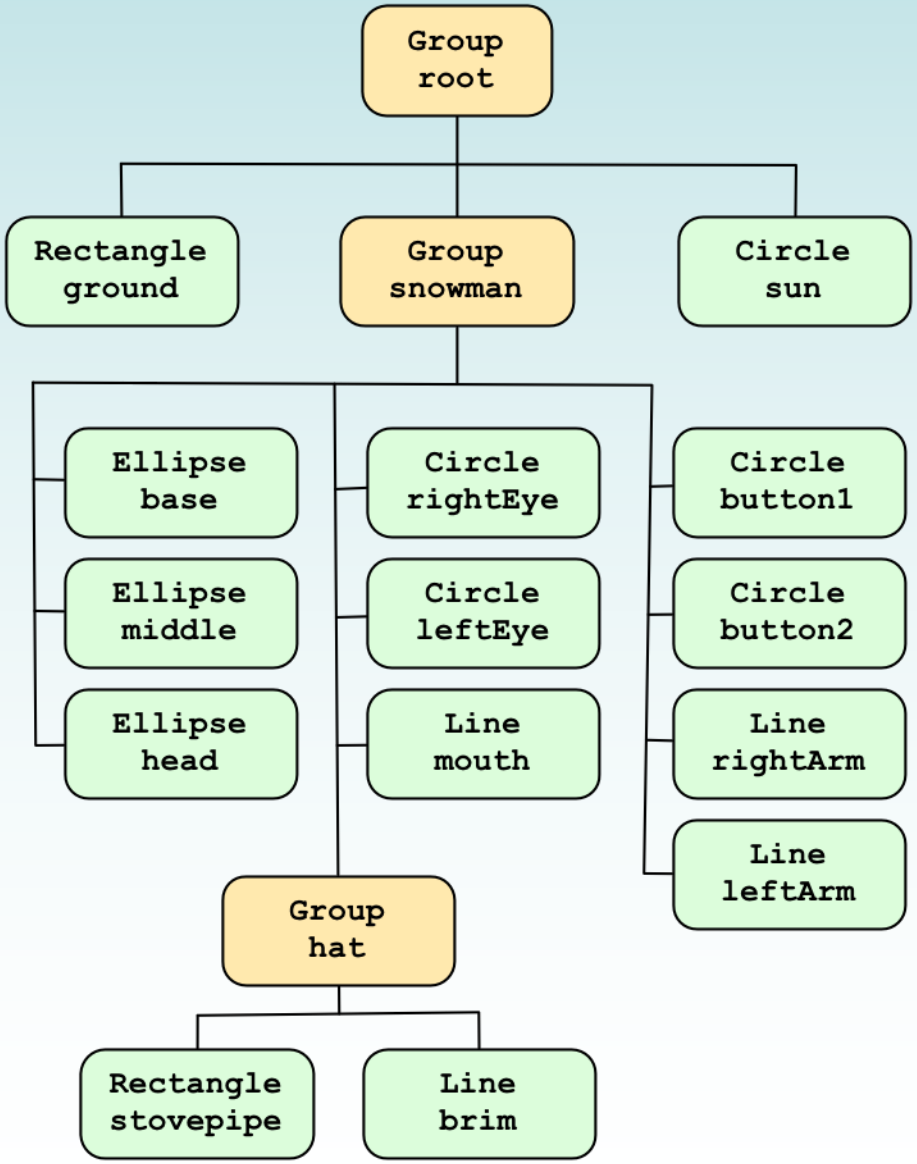
```
Ellipse(centerX, centerY, radiusX, radiusY)
```

```
Ellipse e = new Ellipse(100, 50, 80, 30);
```

- Shapes are drawn in the order in which they are added to the group
- The stroke and fill of each shape can be set
- See `Einstein.java`

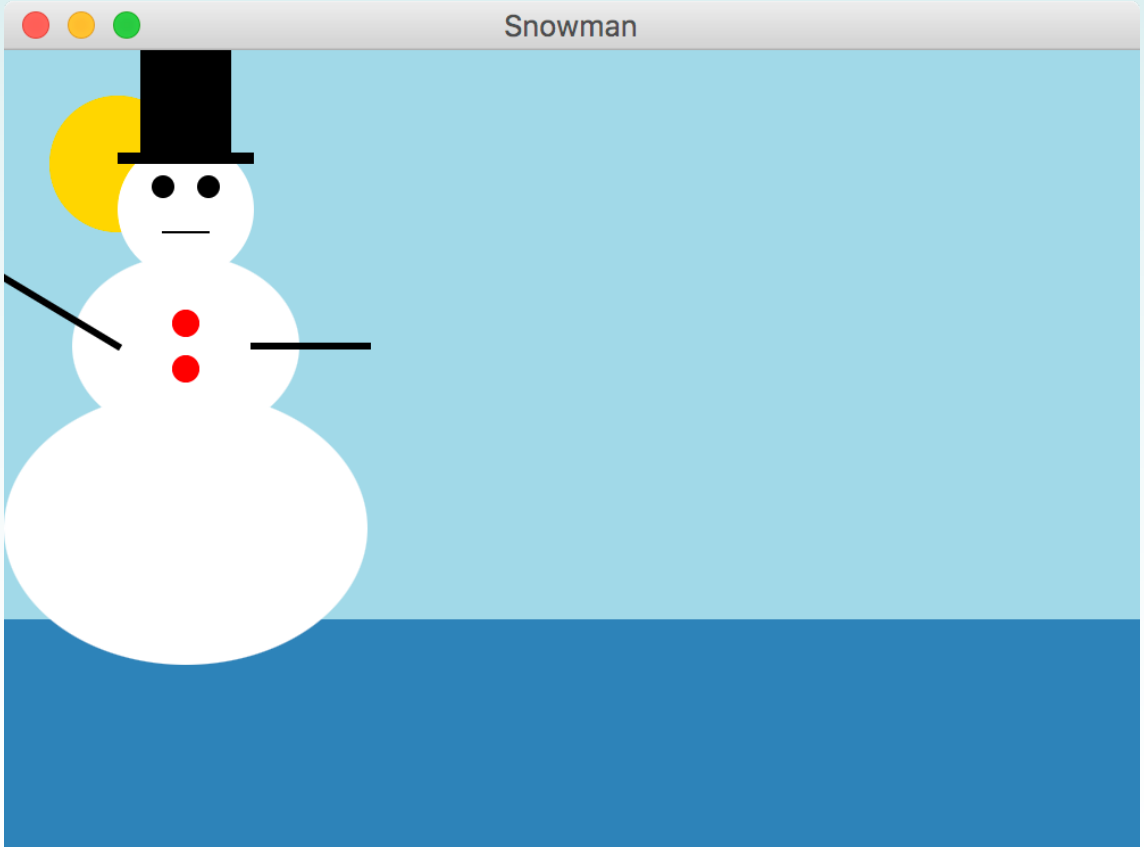
Basic Shapes

- Groups can be nested within groups
- *Translating* a shape or group shifts its position along the x or y axis
- A shape or group can be rotated using the `setRotate` method
- See `Snowman.java`



Basic Shapes

- Without translating (shifting) the snowman's position:



Representing Color

- A color in Java is represented by a `Color` object
- A color object holds three numbers called an RGB value, which stands for Red-Green-Blue
- Each number represents the contribution of that color
- This is how the human eye works
- Each number in an RGB value is in the range 0 to 255

Representing Color

- A color with an RGB value of 255, 255, 0 has a full contribution of red and green, but no blue, which is a shade of yellow

- The static `rgb` method in the `Color` class returns a `Color` object with a specific RGB value:

```
Color purple = Color.rgb(183, 44, 150);
```

- The `color` method uses percentages:

```
Color maroon = Color.color(0.6, 0.1, 0.0);
```

Representing Color

- For convenience, several `Color` objects have been predefined, such as:

`Color.BLACK`	0, 0, 0
`Color.WHITE`	255, 255, 255
`Color.CYAN`	0, 255, 255
`Color.PINK`	255, 192, 203
`Color.GRAY`	128, 128, 128

- See the online documentation of the `Color` class for a full list of predefined colors

Summary

- Chapter 3 focused on:
  - object creation and object references
  - the `String` class and its methods
  - the Java standard class library
  - the `Random` and `Math` classes
  - formatting output
  - enumerated types
  - wrapper classes
  - JavaFX graphics API
  - shape classes