JAVA
ONE STEP AHEAD

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Preface

The development of computer systems and programming languages now span more than half a century. During this period technology has developed tremendously both in hardware as well as software. Now even school children can afford individual laptops or desktops and use it for studies and for browsing the Internet. Computer languages have developed from unstructured languages to structured procedural languages such as C and from procedural languages to object-oriented computer languages such as C++ and Java, and from single threaded languages to the ones that support multi-threaded programming so that different parts of a large program can run concurrently on multiple processors. The language Java supports multi-thread programming and its compiled programs are independent of native operating system. Java is in tune with hardware development in which multiple processor CPUs are the order of the day.

Java is an important programming language in software development space right now. It has undergone many changes since its inception and that has led to its use in wide range of areas. From a simple web page to big scientific applications, from cell phones to supercomputers, Java is everywhere!

In view of the developments described above, it is not surprising that undergraduate courses at many universities include Java along with C and C++, and some are switching from C++ to Java. The need has long been felt for a book which makes the learning of Java easy and self-reliant.

About the Book

The present book is primarily written for beginners and intermediate level readers, at the same time the topics are dealt with appropriate complexity often needed by professionals. The book is ideal for self-learning of Java and also useful for postgraduate students.

The language of the book is simple so that core ideas are easily understood and almost every topic is followed by illustrative programs so that a reader can easily grasp the programming technique. Besides, the topics on GUIs for which Java is so popular are dealt in depth so that the reader after learning from the book can easily take up professional assignments.

The book has following salient features:

- Covers Java SE8, which is the latest version of Java language.
- Provides line-by-line explanation of programs in every chapter to enable the students understand the logic used for writing an efficient program.
- Key notes and call outs are provided at appropriate places to highlight the important points. In addition to these, common programming errors are also provided at the end of each chapter.
- Covers cartoon figures to help the readers understand the concepts in a better way.
- Numerous programming examples and application programs are provided to help readers understand the implementation of concepts learnt.
- Covers several advanced topics such as Java Beans, Java Servlet, and JDBC, which are usually not found in other books.
- Provides enhanced coverage of Swing components such as JMenu, JScrollbar, JSlider, JScrollpane, Lambda expression for ActionListner, JCheckbox, JTooltip, etc.
- Includes a variety of end-chapter exercises for practice which have subjective as well as objective questions.
- Appendices cover interview questions, history on Java versions, and making webpages.

Content and Organization of the Book

The book comprises 27 chapters and two appendices. Their details are presented below.

Chapter 1 introduces the concept of classes and objects and object oriented programming (OOP). It also gives an overview of structure of Java language, and ends with description of the points of similarities and differences between Java and C++.

Chapter 2 explains the essential structure of an application Java program with the help of simple programs. It explains in detail how to write, compile, and run the program using 'Free Java' compiler. The arithmetic operators are also introduced and illustrative computational programs are presented and explained.

Chapter 3 describes in detail the primitive data types in Java and the range of values for each *type* of variable. It explains declaration of variables, the *type* casting and scope of variables. It also elaborates on the various methods encapsulated in Math class and illustrates use of these methods through several simple programs. It also describes in detail all the operators in Java language as well as their attributes.

Chapter 4 deals with the different control statements which provide the choice to branch off such as `if` (expression), `if-else` expressions, and `switch` statement. It also takes up the looping expressions such as `while`, `do-while`, and `for` loops. The other jump conditions such as `break`, `break` with `label`, `continue`, and `continue` with `label` are also dealt in detail with examples.

Chapter 5 introduces the formal definitions of class and objects and the attributes of various classes are discussed in great detail.

Chapter 6 starts with the definition of methods in a class and their applications. The chapter also covers the topics such as Lambda functions and their applications, assigning method references, predicates, and method chains.

Chapter 7 deals with topics on single-dimensional and multi-dimensional arrays. It discusses in detail the operations involving two-dimensional arrays and three-dimensional arrays. The solution of linear algebraic equations is explained using illustrative programs.

Chapter 8 covers in detail the process of inheritance of classes and implementation of interfaces. The different types of inheritances are discussed. The problem of access control, use of keyword `super`, method overriding, and dynamic method dispatch are also explained. For all these topics, illustrative programs are provided.

Chapter 9 presents the definition and characteristics of interfaces. Various types and methods of interfaces are explained with the help of illustrative programs.

Chapter 10 discusses the packages in Java and important classes in `java.lang` package. It also includes auto-boxing and auto-unboxing, important classes of `java.util`, details of scanner class, and newly created `java.time` package for date and time.

Chapter 11 deals with how exceptions arise and how to handle them. It explains how a programmer can create own exception class and also deals with nested `try` and `catch` blocks.

Chapter 12 describes the string class and its methods and objects. The class `StringBuffer` is discussed along with its constructors and methods. The methods of `StringBuilder` class are also explained and illustrated by programs.

Chapter 13 introduces the concept of threads and their benefits, and class and methods of creating threads. The deadlock situations are analyzed and different states of threads are discussed with examples.

Chapter 14 deals with generics and types. Generic class with one type and multi-type parameters along with generic method overloading and generic interface are discussed in the chapter.

Chapter 15 discusses the basic concepts about an image in Java and the various mechanisms of manipulations of images supported in Java. It explains the various image file formats and the process of loading and displaying an image in Java.

Chapter 16 deals with the concept of collections and its types and properties along with numerous programming examples.

Chapter 17 deals with input and output streams. The file class and various other classes and their subclasses related to file handling are explained using programs.

Chapter 18 deals with applet programming including its classes and methods. The life cycle of an applet and HTML tags and how to create a web page are explained. The process of animation is explained with supporting programming examples.

Chapter 19 explains the generation of events and how they are handled by using delegation event model. It also discusses the hierarchy of event handling classes, event types, sources of events and event listener interfaces and classes. The important event classes are covered in detail.

Chapter 20 discusses the creation of AWT windows and adding graphical components to it. Different classes, methods, and layouts are explained with suitable examples.

Chapter 21 deals with drawing different shapes in an AWT window. The methods of drawing of strings, straight lines, rectangles, polygons, ellipses, and arcs are explained with the help of illustrative programs.

Chapter 22 discusses the swing packages and hierarchy of swing classes are presented. The different window panes in swing windows in applet as well as in `JFrame` objects are explained. The description of swing components, methods of adding components, and different border classes are also discussed and illustrative programs are given.

Chapter 23 explains why a single thread is used in swing GUI and various classes and components are discussed and several application programs are given. Programming with multiple panels is illustrated for generating complex window patterns.

Chapter 24 describes the internet address systems IPv4 and IPv6. The commonly used classes such as URL, URLConnection, HttpURLConnection, Sockets, ServerSocket, and classes in UDP are aptly discussed. A number of programs are given to demonstrate the implementation of the topics discussed in the chapter.

Chapter 25 covers the fundamentals of *Java beans*. The basic processes involved in bean building are also explained through live projects. The process of building various types of beans has been explained using program illustrations.

Chapter 26 explains the basic concepts related to server-side programming. The basics of servlet architecture, servlet API, and the step-by-step procedure for writing servlet programs are also covered.

Chapter 27 introduces the concepts relating to *Java database connectivity*. It includes the basics of JDBC API and procedure for making connections of Java application with database system. JDBC transaction management and batch processing are also explained using illustrative programs.

Appendix A lists important additions in different versions of Java and also includes the latest enhancements in Java SE8. *Appendix B* introduces the concept and some techniques in HTML for preparing webpages. Interview questions are also provided at the end of the book.

Online Resources

The companion website of the book offers the following online resources for instructors and students:

For Faculty

- PowerPoint Slides
- Lab exercises
- A chapter on remote method invocation (RMI)

For Students

- Additional projects
- Quizzes
- List of packages in Java
- Debugging exercises with answers
- Model question papers with answers
- Unicode system

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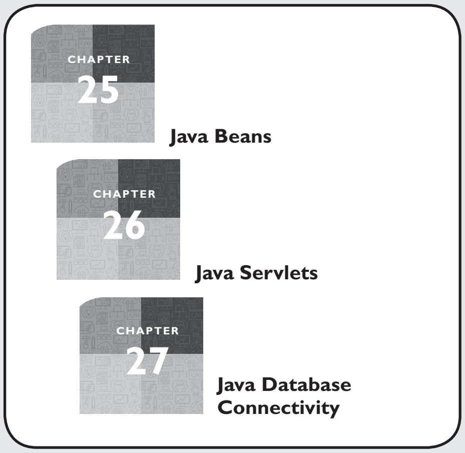


CHAPTER 25 Java Beans

CHAPTER 26 Java Servlets

CHAPTER 27 Java Database Connectivity

Advanced Topics

Dedicated chapters on advanced topics such as JDBC, Servlets, and Java Beans, delve into the networking and distributed applications of Java.

Cartoons, Notes, and Callouts

Cartoons, notes, and callouts are given along with relevant concepts and programs throughout the text. *Cartoons* help in grasping a complex concept easily through simplified figures. *Notes* and *callouts* provide additional and important information and help in avoiding mistakes.

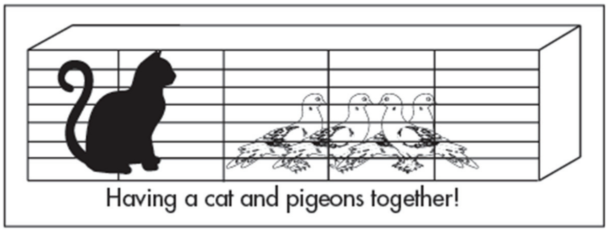
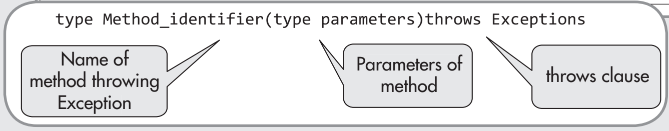


Fig. 11.5 Analogy to array store exception

Important

The default order in priority queue is the ascending order, that is, the smallest value is at the head of the queue and the largest value at the tail end.

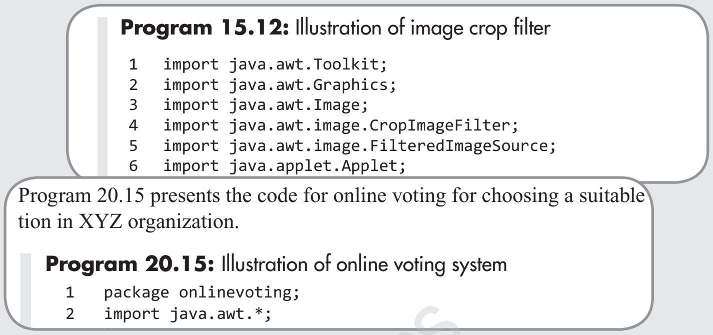


```
type Method_identifier(type parameters)throws Exceptions
```

the Book

Programming Examples

Numerous examples along with separate section on application programs (in relevant chapters) are provided to understand the working of the concepts discussed in the book and to get an idea on the practical applications of the subject.



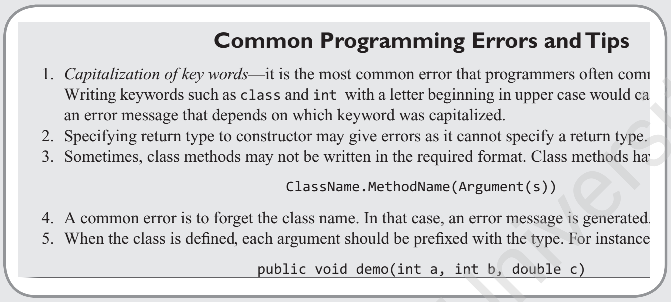
Program 15.12: Illustration of image crop filter

```
import java.awt.Toolkit;
import java.awt.Graphics;
import java.awt.Image;
import java.awt.image.CropImageFilter;
import java.awt.image.FilteredImageSource;
import java.applet.Applet;
```

Program 20.15 presents the code for online voting for choosing a suitable tion in XYZ organization.

Program 20.15: Illustration of online voting system

```
package onlinevoting;
import java.awt.*;
```



Common Programming Errors and Tips

1. *Capitalization of key words*—it is the most common error that programmers often comi Writing keywords such as `class` and `int` with a letter beginning in upper case would ca an error message that depends on which keyword was capitalized.
2. Specifying return type to constructor may give errors as it cannot specify a return type.
3. Sometimes, class methods may not be written in the required format. Class methods ha

```
ClassName.MethodName(Argument(s))
```

4. A common error is to forget the class name. In that case, an error message is generated.
5. When the class is defined, each argument should be prefixed with the type. For instance

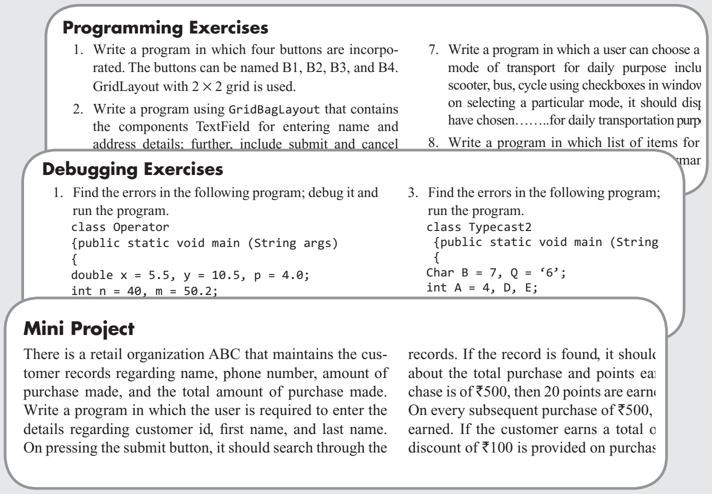
```
public void demo(int a, int b, double c)
```

Common Programming Errors and Tips

They are provided at the end of the relevant chapters and list important tips and common errors that readers tend to make while writing a program.

Chapter-end Exercises

Includes wide range of questions, such as MCQs, review exercise, programming exercises (of varying levels), debugging exercises, and mini projects to help readers self-check and apply the learnt concepts in their own programs.



Programming Exercises

1. Write a program in which four buttons are incorporated. The buttons can be named B1, B2, B3, and B4. GridLayout with 2 × 2 grid is used.
2. Write a program using `GridBagLayout` that contains the components TextField for entering name and address details; further, include submit and cancel
7. Write a program in which a user can choose a mode of transport for daily purpose inclu scooter, bus, cycle using checkboxes in windov on selecting a particular mode, it should disp have chosen……..for daily transportation purp
8. Write a program in which list of items for mar

Debugging Exercises

1. Find the errors in the following program; debug it and run the program.

```
class Operator
{public static void main (String args)
{
double x = 5.5, y = 10.5, p = 4.0;
int n = 40, m = 50.2;
```

3. Find the errors in the following program; run the program.

```
class Typecast2
 {public static void main (String
 {
Char B = 7, Q = '6';
int A = 4, D, E;
```

Mini Project

There is a retail organization ABC that maintains the customer records regarding name, phone number, amount of purchase made, and the total amount of purchase made. Write a program in which the user is required to enter the details regarding customer id, first name, and last name. On pressing the submit button, it should search through the records. If the record is found, it shoulc about the total purchase and points ear chase is of ₹500, then 20 points are earn On every subsequent purchase of ₹500, earned. If the customer earns a total o discount of ₹100 is provided on purchas

Brief Contents

Detailed Contents

CHAPTER 9

Interfaces

Learning Objectives

After reading this chapter, you will be able to

- understand what an interface is
- declare an interface
- know the types of interfaces
- familiarize yourself with the members of an interface
- learn the implementation of an interface
- comprehend nested interfaces
- be aware of inheritance of interfaces
- study the Java SE8 additions to interface, which can now have the following methods:
  – default methods
  – static method
- Java SE8 has also been added
  – functional interfaces – Java.util.function
  – predicates
- write programs involving
  – interfaces and implementation of methods declared in interfaces
  – multiple interfaces and implementation of methods declared in these interfaces
  – concept of nested interfaces
  – default and static methods in interfaces
  – concept of multiple inheritance using interfaces
  – functional interfaces

9.1 Introduction

Similar to classes, an interface also introduces a new reference type. An interface represents an encapsulation of constants, classes, interfaces, and one or more abstract methods that are implemented by a class. An interface does not contain instance variables. An interface cannot implement itself; it has to be implemented by a class. The methods in an interface have no body (except those declared default or static); only headers are declared with the parameter list that is followed by a semicolon. The class that implements the interface has to have full definitions of all the abstract methods included in the interface. An interface can be implemented by any number of unrelated classes with their own definitions of the methods of the interface.

See I have this beautiful piece of cloth! What will you like—a frock, skirt, or suit?
What about all the three?

Fig. 9.1 Interface provides means to induct polymorphism. The figure shows how various uses of constants or methods provided in an interface can be realized.

Different classes can have different definitions of the same methods but the parameter list must be identical to that in the interface. Thus, interfaces provide another way of dynamic polymorphic implementation of methods. Figure 9.1 illustrates how a variable declared in an interface may be used differently in implementing classes.

In this figure, a lady is asking her child what she wants to be stitched out of a piece of cloth—if she wants a frock, skirt, or suit. In this case, the piece of cloth is an analogy to abstract method contained in interface. As subclass provides the whole definition of this abstract method, the child would provide the dimensions and style of the outfit to be stitched.

According to modifications in Java SE8, an interface can now have default methods and static methods with full definitions and these methods are inherited by the classes that implement the interface. At the same time, the class may override the methods if necessary (see Sections 9.7 and 9.8 for the full discussion).

Any number of interfaces can be implemented by a class. This, to some extent, fulfils the need for multiple inheritance. The multiple inheritances of classes are not allowed in Java, and therefore, interfaces provide a stopgap arrangement. A class can extend (inherit) another class as well as implement a number of interfaces. For details on inheritance, see Section 8.13 in Chapter 8. With the enhancement of Java SE8, the benefits of multiple inheritances can be realized easily.

The interfaces can be extended as well as nested like classes. However, there are differences too. The similarities and dissimilarities of an interface with a class are as follows.

Figure 9.2 shows how the interfaces inherit other interfaces and the classes that implement them. A class may implement a number of interfaces besides having a super class.

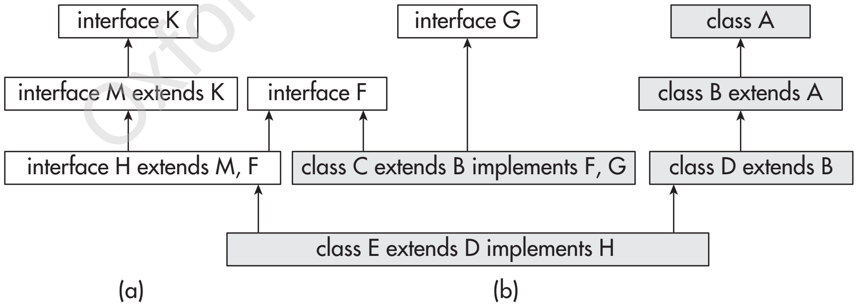


Fig. 9.2 Class can implement a number of interfaces but can extend only one class. An interface can extend any number of interfaces (a) Inheritance of interfaces (b) Inheritance of classes

There are several similarities and differences between an interface and a class, which are discussed in Sections 9.1.1 and 9.1.2.

9.1.1 Similarities between Interface and Class

1. Declaring an interface is similar to that of class; the keyword *class* is replaced by keyword *interface*.
2. Its accessibility can be controlled just like a class. An interface declared public is accessible to any class in any package, whereas the ones without an access specifier is accessible to classes in the same package only.

3. One can create variables as object references of interface that can use the interface.
4. It can contain inner classes (nested classes) and inner interfaces.
5. Since Java 8, an interface can have full definitions of methods with default or static modifiers.

9.1.2 Dissimilarities between Class and Interface

1. Interface cannot implement itself; it must be implemented by a class.
2. An interface can contain only method headers followed by a semicolon. It cannot have the full definition of a method. The full definition is given in the class that implements it. Java 8 modification allows the default and static method declarations in interfaces.
3. The methods declared in the interface are implicitly public.
4. An interface does not contain instance variables.
5. The variables declared in an interface are implicitly public, static, and final, that is, they are constants.
6. Interfaces cannot have a constructor like a class.
7. An interface cannot extend a class nor can it have a subclass. It can only extend other interfaces.
8. A class can extend (inherit) only one class but an interface can extend any number of interfaces. It is illustrated in Fig. 8.3 (see Chapter 8 for more details on inheritance).

9.1.3 Rules for Classes that Implement Interface

1. A non-abstract class that implements an interface must have concrete implementation of all the abstract methods of the interface; otherwise, the class will not compile.
2. The `@Override` annotation should be used on the definitions of interface methods in the class.
3. The methods declared static and default with full definitions in an interface are inherited by the implementing class since Java 8.
4. The class implementing a method of an interface must retain the exact signature of the method.
5. An abstract class need not implement all the abstract methods of the interfaces that it implements.

9.1.4 Types of Interfaces

From the aforementioned discussion, it is clear that an interface comprises a collection of abstract methods. It cannot contain full implementation of methods but only the signature (including name and parameters) of the method. The classes implementing the interface provide the full definition of these abstract methods. However, Java SE 8 has incorporated the concept of full implementation of default and static methods to Java interfaces. There are basically three types of interfaces that include the following:

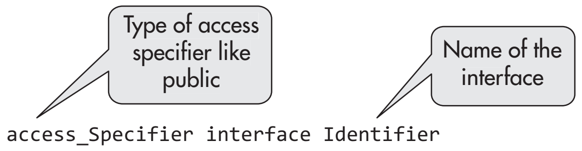
Top level interfaces It is an interface that is not nested in any class or interface. It comprises a collection of abstract methods. It can contain any number of methods that are needed to be defined in the class.

Nested interface It is an interface that is defined in the body of a class or interface. In nested interfaces, one or more interfaces are grouped, so that it becomes easy to maintain. It is referred to by the outer interface or class and cannot be accessed directly.

Generic interface Like a class, an interface is generic if it declares one or more types of variables. It comprises methods that accept or return an object. Thus, we can pass any parameter to the method that is not of the primitive type.

9.2 Declaration of Interface

Declaration of an interface starts with the access modifier followed by keyword interface which is in turn followed by its name or identifier that is followed by a block of statements; these statements contain declarations of variables and abstract methods. The variables defined in interfaces are implicitly public, static, and final. They are initialized at the time of declaration. The methods declared in an interface are public by default. An illustration of declaration of an interface is given.



```
access_Specifier interface Identifier
```

```
{ //body
type variable1_name= value1;
 -----------------------------
type Method1_name (parameter list);

// Since Java SE8 an interface may have default methods.
default void display1 ()
{System.out.println("It is default method.");

//Since Java SE8 an interface may have static methods.
static void display2(){System.out.println("cosine 60 =" +
Math.cos(60*3.141/180));}
----------------------------- }
```

9.2.1 Interface Modifiers

Access modifiers for an interface are generally public or no access modifier is used. By declaring it as public, interface can be used in any package and in any class.

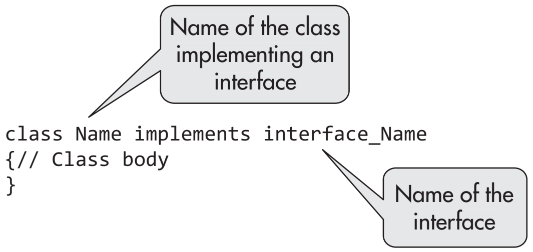
9.2.2 Members of Interface

The members of an interface comprise the following:

1. The members declared in the body of the interface.
2. The members inherited from any super interface that it extends.
3. The methods declared in the interface are implicitly public abstract member methods.
4. The field variables defined in interfaces are implicitly public, static, and final. However, the specification of these modifiers does not create a compile-type error.
5. The field variables declared in an interface must be initialized; otherwise, compile-type error occurs.
6. Since Java SE8, static and default methods with full definition can also be members of interface.

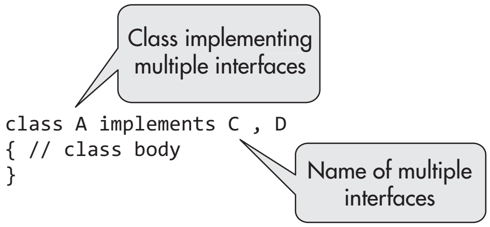
9.3 Implementation of Interface

The interfaces are implemented by classes. An illustration of declaration of class that implements an interface is as follows.



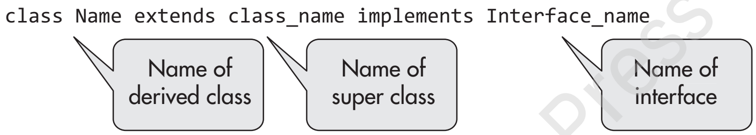
```
class Name implements interface_Name
{// Class body
}
```

A class implementing an interface must provide implementation for all its methods unless it is an abstract class.


Class implementing multiple interfaces
Name of multiple interfaces

```
class A implements C , D
{ // class body
}
```

If a class extends another class as well as implements interfaces, it is declared as



```
class Name extends class_name implements Interface_name
```

For example, a class A that extends class B as well as implements interfaces C and D is declared as

```
class A extends B implements C , D
{// class body
}
```

For example, an interface by name `SurfaceArea` may be declared as

```
interface  SurfaceArea {
double Compute (double x);
          }
```

The implementation will determine the surface area for a figure for which definition is given in class. In Program 8.1, the aforementioned interface is implemented by two classes, one of which calculates the area of a circle, whereas another calculates the area of a square. The class Square is defined as

```
class Square implements SurfaceArea {// class body
                                    }
```

Further, class Circle is declared as

```
class Circle implements SurfaceArea {// class body
                                    }
```

The two classes include appropriate method definitions with header as given in the interface.

Program 9.1: Illustration of interface to find areas of a square and a circle

```
interface SurfaceArea {            // interface
double Compute (double x);
}                             // end of interface

class Square implements SurfaceArea   // class Square
{public double Compute (double x)
{return (x*x);}
}  // end of class Square

```

```
10   class Circle implements SurfaceArea // class Circle
11   {public double Compute(double x)
12   {return (3.141*x*x);}
13    }      // End of class Circle
14
15   class Face{
16   public static void main(String arg[]){
17   Square sqr = new Square();  // object of class square
18     Circle cirl = new Circle (); //class Circle object
19   SurfaceArea Area;  // object reference of interface
20          // Assigning Square class reference to Area
21   Area = sqr;
22   System.out.println("Area of square =" + Area.Compute(10));
23   // Assigning Circle class reference to Area
24   Area = cirl;
25   System.out.println("Area of circle =" Area.Compute(10));
26   }
27   }
```

Output

```
Area of square = 100.0
Area of circle = 314.1
```

Explanation

The interface `SurfaceArea` declared in code lines 1–3 is implemented by two classes, that is, class `Square` defined in code line 5–8 and class `Circle` declared in code line 10–13. Each class has its own definition of the method. One finds the area of a circle and the other finds the area of a square. Both need only one parameter that is declared in the method header in the interface. The class `Face` is the class with main method that executes the two classes. The objects of these classes `sqr` and `cirl` are declared in code lines 17 and 18. The object references `Area` to interface `SurfaceArea` is declared in code line 19. In line 21, the reference `sqr` is assigned to Area and area of square with side 10 is obtained. In code line 24, reference `cirl` is assigned to Area and area of circle is obtained in line 25.

9.3.1 Constants in Interfaces

In Program 9.2, an interface defines only constant values that are implemented by classes.

Program 9.2: Illustration of getting constant values from interface

```
interface Dimensions{
int x = 30;   // implicitly public and final
int y = 20;     //implicitly public and final
}// End of interface Dimensions

class Room implements Dimensions
{
public int area(){
int m = x;
int n = y;
return (m*n);}
     }     // end of class Room

class Inface
{public static void main(String arg[]){
Room rm = new Room();
     Dimensions d;
     d = rm;       // assigning Room reference to D
System.out.println("Area of room =" + rm.area());
     }
}
```

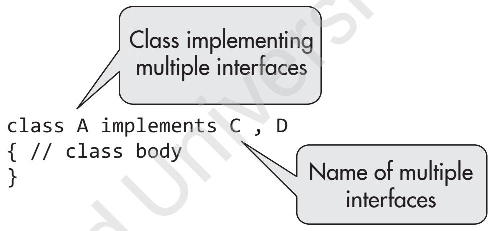
Output
```
Area of room = 600
```

Explanation
Interface `dimensions` declares two `int` values `x` and `y` that are initialized to 30 and 20 in code lines 2 and 3, respectively. These values are implicitly constant values. The values are used in class `Room` to calculate its area in code line 11. The class `Room` is executed in class `Inface` that has the main method and is declared in lines 14–21. The class defines an object `rm` of class `Room` and reference `d` to the interface `Dimensions`. The method area is invoked by the object `rm`. The output is given.

> Important: For declaring methods in an interface, method name must be chosen such that it indicates the purpose of the method in general. It may be possible that the method implemented by the class may not be related to that method name.

9.4 Multiple Interfaces

Like single interface, multiple interfaces can also be implemented in Java. For this, the class implements all the methods declared in all the interfaces. When the class is declared, names of all interfaces are listed after the keyword *implements* and separated by comma. As for example, if class A implements interfaces C and D, it is defined as.


Class implementing multiple interfaces
Name of multiple interfaces

```
class A implements C , D
{ // class body
}
```

9.4.1 Interface References

For interface references, variables can be declared as object references. In this case, the object reference would use interface as the type instead of class. The appropriate method is called on the basis of actual instance of the interface that is being referred to. In Program 9.3, two interfaces are declared. Method `show()` is called through interface reference using *t* variable that is declared to be of interface type `InfaceA` and it is assigned as an instance of `MultInterface`. Similarly, method `subtract()` is invoked through another variable `m` that is declared of the type `InfaceB` and assigned as an instance of `MultInterface`.

> Important: An interface reference can only access the methods declared in that interface. It cannot access other methods of the class implementing that interface.

In Program 9.3, the interface reference cannot access `display()` method of the class implementing the interfaces, as it is not declared in any of the interfaces.

Program 9.3: Illustration of implementing multiple interfaces
```
interface IntfaceA{                  // interface declared
public void show();                  // method declared
}
interface IntfaceB{     // another interface declared
public int method1 (int a, int b); // method declared
```

```
 6    }
 7    interface IntfaceC{
 8    public double method2 (double x);}
 9                // implements multiple interfaces
10    public class MultiInterfaceImpliment
11    implements IntfaceA, IntfaceB
12    {
13    public void show(){         // method show defined
14    System.out.println("Hello! It is java.");
15    }
16    public int method1 (int a, int b){  // method1 defined
17    return  a += b;
18    }
19    public void display()
20    {System.out.println("I cannot be called by interface references.\nOnly class object can
      call me.");}
21    public static void main(String args[])
22    {
23    /*creating interface references and assigning class object*/
24
25    IntfaceA iA = new MultiInterfaceImpliment();
26    IntfaceB iB = new MultiInterfaceImpliment();
27
28    IntfaceC iCC = (double x) -> {return x*x*x;};
29    // invoking the methods
30    iA.show();
31    System.out.println("Value after processing a and b = " +iB.method1(25, 15));
32    System.out.println("Value after processing x = " +iCC.method2(5.0));
33    //iA.display(); error
34    //iB.display(); error
35    MultiInterfaceImpliment m=new MultiInterfaceImpliment();
36    m.display();
37    }
38    }
```

Output

```
Hello! It is java.
Value after processing a and b = 40
Value after processing x = 125.0
I cannot be called by interface references.
Only class object can call me.
```

Explanation

The program illustrates the implementation of multiple interfaces by a class. Three interfaces are declared. Each has one method. The class is declared as implementing two interfaces and the third becomes the target of Lambda expression because its method is defined inside the Lambda expression. This could have been done in the normal way similar to the other two; however, the intention is to see the differences between the two ways of doing the same thing.

Interface `IntfaceA` is declared in lines 1–3. The second interface `IntfaceB` is declared in lines 4–6. The third interface `IntfaceC` is declared in lines 7–8. The implementing class with main method is declared in code lines 10–11. Method `show()`of the first interface is defined in class in code lines 13–15 and `method1()` of the second interface is defined in code lines 16–18. `method2()` of the third interface is defined, that is, body is placed inside the Lambda expression (line 28). It is not a regular definition of a method and compiler does not treat it as such. A method `display()` is declared in lines 19–20. It is a regular method of the class and regular member of class.

The methods of the first two interfaces are defined inside the class, and hence, we create references to the interfaces in lines 25 and 26 and these are assigned the class object reference. Further, methods are invoked with these references in lines 30 and 31 to get the results.

For `method2()` of the interface `IntfaceC`, the Lambda expression is defined in code line 28 that is implemented in line 32.

The regular method display() of the class cannot be called by interface references. They can call methods defined in their respective interfaces only. This method is called in line 36 by the class object defined in line 35. All the results of the three methods are given.

9.4.2 Stub Methods

As discussed earlier, if a class implements an interface, it has to define all its abstract methods; if we fail to do so, then it will make the implementing class an abstract class. In several cases, we do not need to define all the methods because we need only a few of these. In order to meet the requirement, we define *stub methods* for the methods we do not need. A stub method does not do anything; however, it fulfils the requirement. These are illustrated in Program 9.4.

In Program 9.4, an interface defines three methods, out of which, only one is needed. For the other two, stub methods are provided.

Program 9.4: Illustration of definitions of stub methods

```
interface AreaVolume {
    double surfaceAreaSphere (double radius);
    double volumeShpere (double radius);
    void setValue (double side);
}                // end of interface

public class StubMethod {
      //Definition of stub method for surfaceAreaSphere
double surfaceAreaSphere (double radius)
       { return 0; }
     //Definition of stub method for setValue
void setvalue (double side) {}
            // definition of method that is implemented
double volumeSphere (double radius)
  {return 4.0*Math.PI* Math.pow(radius, 3)/3 ;}
                      // main method
public static void main(String[] args) {
     StubMethod stm = new StubMethod();
System.out.printf("Volume of sphere of radius 10 = %.2f \n", stm.volumeSphere(10.0));

       }  }
```

Output

```
Volume of sphere of radius 10 = 4188.79
```

Explanation

The program illustrates how to provide stub methods for the methods of interfaces that are not needed; however, as per the requirement of the implementing class, all the methods must be defined. The interface of this program defines three methods out which only one, that is, `volumeShpere` is needed. The other two, that is, `surfaceAreaSphere` and `setValue` are not needed. Therefore, we provide the following two stub methods for their definition.

```
 (i)   double surfaceAreaSphere (double radius) { return 0; }
(ii)   void setvalue (double side) {}
```

These methods do not do anything but they simply fulfil the requirement. The output of the third method is given.

9.5 Nested Interfaces

An interface may be declared as a member of a class or in another interface. In the capacity of a class member, it can have the attributes that are applicable to other class members. For example, its access may be modified to public, protected, or private. In other cases, an interface can only be declared as public or with default (no-access modifier) access. Syntax of nested interface in another interface is given as

```
interface interface_ Identifier
{
……..
……….
                  interface nested_interface_ Identifier
{
…….
}
}
```

Name of outer interface

Name of inner interface

Program 9.5 illustrates an interface declared inside a class.

Program 9.5: Illustration of nested interface in a class

```
1    class A {
2    public interface Nested {
3    int max(int x, int y);}
4    }                          // End of class A
5
6    class B implements A.Nested      // implementing nested interface
7    {public int max (int x, int y )
8        {return x > y ? x: y ;}
9    }                           // End of class B
10
11   class X                     // Class with main method
12   {public static void main(String arg[])
13   { A.Nested NS = new B();  // creating object
14   System.out.println("Maximum of two numbers is = " + NS.max(30, 12));
15
16   }
17   }
```

Output

```
Maximum of two numbers is = 30
```

Explanation

A class `A` is declared in code lines 1–4 that has an interface by name `Nested` declared in the body of class `A`. The interface declares a method `max` with parameters `int x` and `int y`. You may have any other name of interface. The class B is declared to implement the interface declared in lines 6–9. The qualified name of interface is `A.Nested`. The class `X` has the main method that executes the two classes. In this class, reference of object of `B` is assigned to reference `NS` of `A.Nested` interface. `NS` calls the method `max` of class `B` with two integers and finds the greater of the two.

Program 9.6 illustrates an example of nested interface where an interface is declared within another interface.

Program 9.6: Illustration of nested interface in an interface

```
 1    interface Shape{
 2    double getArea(double x);
 3    interface Display{
 4    public void show();
 5    }
 6    }
 7    class NestedInterface1 implements Shape, Shape.Display
 8    {
 9    double getArea(double x)
10    {
11    double area = 3.14*x*x;
12    return area;
13    }
14    public void Display.show()
15    {
16    System.out.println("Hello");
17    }
18
19    public static void main(String args[])
20    {
21    Shape.Display d=new NestedInterface1(); // reference to NestedInterface1
22    Shape s = new NestedInterface1();   // reference to class
23    d.show();
24    System.out.println("Area is = " +s.getArea(4.0)");
25    }
26
27    }
```

Output

```
Hello
Area is = 50.24
```

Explanation

In line 1, interface named `Shape` is declared. Method `getArea()` is declared in line 2. Another interface, that is, the nested interface is declared in line 3. Within this interface, method `Show()` has been declared in line 4. In line 7, class is declared that implements the interface `Shape` and nested interface `Display`. For referring to this nested interface, `Shape.Display` is used. In line 9, the method `getArea()` is defined and the keyword return is used in line 12 that returns the result of area calculated followed by closing curly brackets. Method `Show()` is defined in lines 14–17. In line 21, the variable `d` is declared of the type `Shape.Display` that refers to the nested interface and it is assigned an instance of `NestedInterface1` class. Similarly, for the `s` variable defined in line 22. `Show()` method is accessed in line 23. In line 24, the area is displayed.

Program 9.7 is another example of nested interfaces.

Program 9.7: Another example of nested interface

```
interface Demo{
interface NestedA{
public void show();
}
public  interface NestedB{
int subtract(int a, int b);
}
}
public class NestedInterface2 implements Demo.NestedA, Demo.NestedB

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

```
13    {
14    Demo.NestedA a = new NestedInterface2();
15    a.show();
16    Demo.NestedB b = new NestedInterface2();
17    System.out.println("Value after subtraction is = " +b.subtract(9,2)");
18
19    public void show()
20    {
21    System.out.println("Hello");
22    }
23    public void subtract()
24    {
25    return (a-b);
26    }
27    }
```

Output

```
Hello
Value after subtraction is = 7
```

Explanation

In line 1, interface is declared by the name `Demo`. Within this interface, another interface is declared by the name `NestedA` in line 2. In line 3, method is declared for this nested interface. In line 5, another nested interface is declared. In line 9, class implementing both the nested interfaces is declared. In line 14, variable `a` is declared of the type `Demo. NestedA` interface and assigned an instance of `NestedInterface2` class. In line 15, `Show()` method of `NestedA` interface is accessed. Similarly, another variable of type `Demo. NestedB` is declared in line 16. In line 17, method `subtract()` is accessed and the output is printed. Lines 19–22 define `Show()` method declared in interface `NestedA`. In lines 24–27, method `subtract()` is defined.

9.6 Inheritance of Interfaces

An interface can also extend an interface. The code for extension of interface is similar to the extension of classes (see Chapter 8). Here interface C extends interface B and interface A. Interface C is defined as

```
interface A {}
interface B {}
interface C extends B, A
{ // Body
}
```

Program 9.8 illustrates the inheritance of interfaces and implementation by class.

Program 9.8: Illustration of interface extending another interface

```
interface One {double Pi = 3.141;}

interface Two extends One   // extending interface
{double radius = 10.0;}
interface Three extends One, Two
      {double area ();}
class Circle implements   Three   // implementing interface
{ public double area (){ return Pi*radius*radius;}
       }

class Interface     // class with main method
```

```
12     { public static void main(String args[])
13    {
14    Circle c = new Circle ();  // creating an object
15    System.out.println( "Area of circle c =" + c.area());
16    }
17    }
```

Output

```
Area of circle C = 314.1
```

Explanation

Interface `one` defines a constant `Pi` and is inherited by interface `Two`, which defines a double value `radius`. The interfaces `one` and `two` are inherited by interface `Three`, which has an abstract method `area`. The class Circle declared in code lines 7–9 implements interface `Three`. The class `Interface` declared in lines 11–17 executes the class Circle. The output is given.

9.7 Default Methods in Interfaces

The *Java SE8* enhancement of interfaces allows the interfaces to have full definitions of default and static methods. The reason for this enhancement is given.

A class that implements an interface must define all the abstract methods of the interface. Now, if at a later stage, it is required to introduce another abstract method to the interface, then all the classes implementing the interface must be modified. To overcome this problem, the following two options are available in the existing (before Java SE8) arrangement.

1. Declare another interface that inherits the present interface and define the new method in it. Thus, only the classes that require the new method will have to be modified to implement the new interface.
2. The second option is to declare an abstract class with all the methods of the existing interface and the full definitions of new methods. In such a case, there is minimum change as all the subclasses inherit the abstract super class.

The enhancement in Java 8 spares the programmer of doing any change in the existing classes that implement the interface by allowing the interface to have full definition of default methods and static methods that are implicitly inherited by the class implementing the interface. The benefit of using the interface over having abstract superclass is that it allows the class to have another super class because in Java, there can be only one super class. Thus, by this enhancement, the existing framework is totally undisturbed, and at the same time, the new functionality can be added to the interface, which is inherited by classes implementing the interface. The inherited methods are also members of the class, and therefore, these maybe called other methods of class.

A default method is declared with keyword *default* as

```
 public interface A {
default void display () {System.out.println("It is
interface A.");}
```

Keyword default for specifying default method

However, there are restrictions to this arrangement.

1. If a class implements two or more interfaces, the interfaces cannot have default methods with the same signature because this would cause ambiguity as to which one to execute. This is illustrated in Program 9.8.
2. In the case of methods with the same name, the compiler would choose by matching parameters.

3. If the class that is extending the interfaces also defines the method with the same name, then class definition has priority over other definitions.
4. If an interface A is extended by interface B and both have a default method with the same name, the definition in interface B would be chosen. However, the programmer can specify which one to choose by using super keyword as

```
A.super.method_name();
```

   This is shown in Program 9.9
5. A default method cannot be declared final. This is illustrated in Program 9.10.
6. A default method cannot be synchronized; however, blocks of statements in the default method may be synchronized.
7. The object class is inherited by all classes. Therefore, a default method should not override any non-final method of object class.

Program 9.9: Illustration of default method in interface

```
1    interface InFace
2      {int number =10;
3            //default method
4    default void display(){System.out.println (“2 to the power 8 =” + Math.pow(2,8));}
5     }
6
7    public class DefaultMethod implements InFace{// implementing the interface
8       public static void main(String[] args) {
9    DefaultMethod df = new DefaultMethod(); // creating object
10
11   int area = number* number;
12   System.out.println(“area =” +area );
13   df.display();
14       }
15   }
```

Output

```
area = 100
2 to the power 8 = 256.0
```

Explanation

The interface `InFace` is declared in code lines 1 and 2. In the interface, an int number is defined and a default method with full definition is also defined. This is now permissible in Java SE8—an interface may have full definitions of static methods and default methods. The default method is declared with modifier default. Line 9 defines a new object of the present class. Since default methods are inherited by the class, it is simply called by the object of the class in code line 13. The integer number is used in line 11.

In Program 9.10, two interfaces are implemented by a class, and the interface has default methods with the same signature.

Program 9.10: Class implementing interfaces with default method

```
      interface InfaceA{
public void showA();
default public void display()
{
System.out.println(“Good morning to everyone”);
}
}
interface InfaceB {
```

```
9     public void showB();
10    default public void display()
11    {
12    System.out.println(“Good bye to everyone”);
13    }
14
15    class DefaultMethodA implements InfaceA, InfaceB
16    {
17    public static void main(String args[])
18    {
19    public void showA()
20    {
21    System.out.println(“It is interface A”);
22    }
23    public void showB()
24    {
25    System.out.println(“It is interface B”);
26    }
27    InfaceA a = new DefaultMethodA();
28    a.display();
29    a.showA();
30
31    InfaceB b = new DefaultMethodA();
32
33    b.display();
34    b.showB();
35    }
36    }
```

Output

```
compilation error
```

Explanation

In line 1, interface `InfaceA` is declared. In line 2, method `ShowA()` is declared. Lines 3–6 define default method `display()`. In line 8, another interface `InfaceB` is declared. Line 9 declares another method `ShowB()`. In line 10, `display()` method for this interface is defined having the same signature as that of the default method defined in interface `InfaceA`. Line 13 defines the class implementing both the interfaces. In line 19, method `ShowA()` for interface `InfaceA` is defined. Similarly, in line 23, method `ShowB()` is defined. Variable `a` of the type `InfaceA` is declared in line 27 and assigned an instance of class `DefaultMethodA`. In line 28, method `display()` is accessed. Similarly, another variable of type `DefaultMethodA` is declared in line 31. Compilation error results because the default method of the same signature is used in both the interfaces.

Program 9.11 shows the case where one of the interfaces is extended by another interface, and both having default method with the same signature.

Program 9.11: Illustration of inheritance of interfaces by using default method

```
1         interface InfaceA{
2     public void showA();
3     default public void display()
4     {
5     System.out.println(“Good morning to everyone”);
6     }
7     }
8     interface InfaceB extends InfaceA{
9     public void showB();
10    default public void display()
11    {
```

```
12    System.out.println("Good bye to everyone");
13    }
14    class DefaultMethodB implements InfaceB
15    {
16    public static void main(String args[])
17    {
18    public void showA()
19    {
20    System.out.println("It is Interface A");
21    }
22    public void showB()
23    {
24    System.out.println("It is Interface B");
25    }
26    DefaultMethodB d = new DefaultMethodB();
27    d.showA();
28    d.display();
29    d.showB();
30    }
31    }
```

Output

```
Good morning to everyone
```

Explanation

In line 1, interface `InfaceA` is declared. The method of this interface is declared in line 2. Default method `display()` is defined in lines 3–6. In line 8, interface `InfaceB` extends interface `InfaceA`. Method `ShowB()` of this interface is declared in line 9. Default method `display()` is defined in lines 10–13. Line 14 defines the class implementing both the interfaces. In lines 18–21, method `ShowA()` is defined. Similarly, in lines 22–25, method `showB()` is defined. In line 26, variable `d` of the type `DefaultMethodB` is declared. In line 27, method `ShowA()` is accessed. In line 28 `display()` method is accessed for the interface `InfaceA`. The output is shown.

Program 9.12 shows that a default method cannot be declared as final and gives compilation error.

Program 9.12: Default method declared as final

```
    interface A{
public void show();
final default public void display()        // error due to final
{
System.out.println("Good morning to everyone");
}
}
class DemoC implements A
{
public void show()
{   System.out.println("It is Interface");
}

    public static void main(String args[])
{
    DemoC d = new DemoC();
d.show();
d.display();
}
}

```

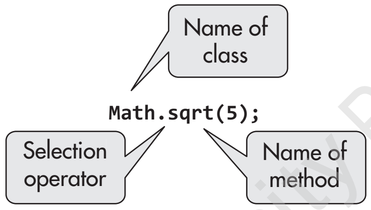
Output
```
compilation error
```

9.8 Static Methods in Interface

The Java version 8 allows full definition of static methods in interfaces. A static method is a class method. For calling a static method, one does not need an object of class. It can simply be called with class name as

```
class_name.method_name()
```

For example, we have used the method `sqrt()` of `Math` class by writing the code as in the following example, because all methods of Math class are declared static.



```
Math.sqrt(5);
```

A class that implements an interface also inherits all its static methods. The inherited method is also a class method, and therefore, the method can simply be called by using class name as illustrated.

Program 9.13: Illustration of static method in interface

```
1    interface InFace1{                // defining an interface
2    int number =1000;
3    static int compute (int num)        // static method defined
4    {int cube = num * num * num ;
5    System.out.println( "Cube of" + num + " = " + cube );
6    return  cube ;}
7         }
8    // implementing an interface
9    public class StaticMethod implements InFace1
10
11   {
12    public static void main(String[] args) {
13   StaticMethod sm = new StaticMethod();  // creating object
14   System.out.println("Cube root of 1000 = " + Math.cbrt(number));
     //Using number defined in interface
15
16   InFace1.compute(10);       // calling the static method
17   }
18   }
```

Output
```
Cube root of 1000 = 10.0
Cube of 10 = 1000
```

Explanation

The interface `InFace1` is defined in code line 1. The interface defines an integer number `1000` that is used in code line 14 for finding its cube root. The interface also contains a static method `compute ()`, which computes the cube of a number with full definition. This is allowed in Java SE 8. This method is called in the class with reference of name of interface `InFace1`. The output is shown.

9.9 Functional Interfaces

In Java SE8, a new package `java.util.function` on functional interfaces has been introduced to serve as the basis for writing Lambda functions. Functional interfaces are interfaces with one abstract method. They are also called SAM or single abstract method type. However, a functional interface can have more than one static and default methods besides the abstract method and it can override some methods of object class. The programmer may include an annotation, which is given in the following example, in order to lessen the work of complier that anyway will recognize a functional interface.

```
@FunctionalInterface
```

By adding the aforementioned annotation, it can be helpful in detecting compile time errors. If the functional interface contains more than one abstract method, the compiler will throw an error. As we all know, Java programming language is purely an object-oriented language and an object can call only the methods encapsulated in the class for the object. There is no independent existence of methods in Java. Methods are like bonded labourers. However, there are several occasions when a method is required to be passed as argument to another method. In order to overcome this limitation of Java language, functional interfaces have been defined in package `java.util.function` with only one method to serve as target for Lambda functions or expressions. A partial list of these is given in Table 9.1. The letters T, U, R, etc., represent type parameters.

Program 9.14: Illustration of uses of functional interfaces

```
 1    import java.util.function.Function;      //importing classes
 2    import java.util.function.BinaryOperator;
 3    public class BiOperator {
 4    public static void main(String args[]){
 5    Function <Double, Double>logrithm = Math::log;
 6    // method reference assigned to Function
 7    System.out.println( "log of 10 to the base e = " + logrithm.apply(10.0));
 8    // method reference assigned to BinaryOperator
 9    BinaryOperator<Integer> minimum = Math::min;
10
11    System.out.println ("Minimum of 20 and 46 is " + minimum.apply(20, 46));
12    }
13    }
```

Output

```
log of 10 to the base e = 2.302585092994046
Minimum of 20 and 46 is 20
```

Explanation

Out of the list of functional interfaces given in Table 9.1, the program uses two of them, that is,

```
(a) function (Double, Double)
(b) binaryOperator (Integer)
```

The first has been assigned the reference of `Math::log` and the second is assigned the reference of method `Math::min`. The first is used in line 7 to find the logarithm of 10 to the base e. Further, the second is used to find the minimum of two specified numbers in line 11. The output is shown.

Single argument functional interfaces that return Boolean output are used for filtering with a specified test condition. These are discussed in detail in Section 6.13 in Chapter 6.

Table 9.1 Some standard functional interfaces of package java.util.function

Interface	*Description*
BiConsumer<T,U>	Stands for methods that accept two arguments and return no value
BiFunction<T,U,R>	Stands for methods that accept two arguments and return a result
BinaryOperator<T>	Stands for methods/operation that accept two operands of the same type and produces a result of the same type
BiPredicate<T, U>	Stands for predicate method that accepts two arguments and produces a Boolean type result
BooleanSupplier	Stands for supplier of Boolean type values
Consumer <T>	Stands for methods that accept single argument and produce no result
DoubleBinaryOperator	Stands for operation on two double valued operands resulting in a double valued result
DoubleConsumer	Stands for operation that accepts single double-type argument and produces no result
DoubleFuntion<R>	Stands for methods that accept double-type argument and produce a result
DoublePredicate	Stands for predicate methods that accept one `double` argument and give Boolean output
DoubleSupplier	Stands for methods that supply double values
DoubleToIntFunction	Stands for functions that accept `double` type input and result in `int` type value output
DoubleToLongFunction	Stands for functions that accept `double` type input and result in `long` type value output
DoubleUnaryOperator	Stands for operation on a single `double` type operand that yields a `double` type result
Function <T, R>	Stands for function that accepts one input object and yields appropriate object as output
IntBinaryOperator	Stands for operation on two `int` operands that gives `int` type result
IntConsumer	Stands for operations that accepts a single `int` type argument and produce no result
IntFunction <R>	Stands for function that accepts an int type argument and produces a result
IntPredicate	Stands for predicates with one `int` type argument
IntSupplier	Stands for method that supplies `int` type values
IntToDoubleFunction	Presents a function that accepts `int` input and results in `double` type value output
IntToLongFunction	Stands for function that accepts `int` type input and results in `long` type value output
IntUnaryOperator	Stands for operation on a single `int` type operand, which yields an `int` type result
LongBinaryOperator	Stands for operation on two `long` type operands, which give a `long` type result
LongConsumer	Stands for operations that accepts a single `long` type argument but results in no output
LongFunction <R>	Stands for function that accepts long type argument and produces a result
LongPredicate	Stands for predicates with one `long` type argument

(*Contd*)

Table 9.1 (*Contd*)

Interface	*Description*
LongSupplier	Stands for supplier of `long` type values
LongToDoubleFunction	Stands for functions that accept a `long` type argument and produces a `double` type result
LongToIntFunction	Stands for functions that accept `long` type input and results in `int` type output
LongUnaryOperator	Stands for operations on a single `long` type operand that yields a `long` type result
ObjDoubleConsumer <T>	Stands for operations that accept an object value and a `double` type argument but return no output
ObjLongConsumer <T>	Stands for operations that accepts an object value and a `long` type argument and returns no result
Predicate <T>	Stands for predicate that accepts one input and determines if the input object satisfies some criteria
Supplier <T>	A supplier of objects of type T
ToDoubleBiFunction <T, U>	Targets the functions that accept two arguments and produce a `double` output
ToDoubleFunction <T>	Stands for function that results in `double` type result
ToIntBiFunction <T, R>	Stands for the functions that accept two arguments and produce an `int` type output
ToIntFunction <T>	Stands for functions that produce an `int` type result
ToLongBiFunction <T, U>	Targets the functions that accept two arguments and produce a `long` type output
ToLongFunction <T>	Stands for function that gives long type result
UnaryOperator <T>	Stands for operations/methods on single operand and gives results of the same type

The described functional interfaces have one abstract method and provide the target type for Lambda functions and method references that are discussed in Chapter 8. We take a few examples of use of some of these functionals in Program 9.15.

Program 9.15: Illustration of application of predicates in filtering arrays

```
import java.util.function.Predicate; // importing the class
public class Predicate2 {
public static void main(String[] args) { // main class

Predicate<String>str = Predicate.isEqual("Delhi");
// using Predicate to test for "Delhi"

System.out.println(str.test("Katty"));
System.out.println(str.test("Mahma"));


String [] names={"Indore", "Aligarh", "Patiala" ,"Delhi"};

for(inti =0; i<names.length; i++) // for loop
   if (str.test (names[i]))
System.out.println(names[i]);
17
18    for(String s: names)            // filtering the array
19        if (!str.test(s))
20    System.out.print(s +“   ”);
21    System.out.println();
22      }
      }
```

Output

```
false
false
Delhi
Indore   Aligarh   Patiala
```

Explanation

The program illustrates the method `isEqual` applied with a predicate. It is used to compare strings with string `“Delhi”` to test if they are equal. The first code line imports the standard library interface predicate, which is of the following form.

```
Predicate<T>
```

It is defined with method `isEqual(“Delhi”)` in line 5 and applied in code lines 8 and 9 to see if `“Katty”` or `“Mahma”` is equal to Delhi . Obviously, it is false and this result is displayed in the first two lines of the output.

The method is also used to select `“Delhi”` from an array of strings through code lines 14–16. The same predicate may be used to filter the array as done in code lines 18–21. The output comprises strings of the array `names` without `“Delhi”`.

Program 9.16 illustrates the application of `IntBinaryOperator`, `DoubleBinaryOperator`, and `BiFunction <T, U, R>`. The Lambda expression is used to define the methods.

Program 9.16: Illustration of application of some functional interfaces

```
1     import java.util.function.Function;
2     import java.util.function.IntBinaryOperator;
3     import java.util.function.DoubleBinaryOperator;
4     import java.util.function.BiFunction;
5
6     public class Functional1 {
7     public static void main(String args[]){
8
9     IntBinaryOperator ibo = (int m, int n) -> { return (m*m + n*n);};
10
11    System.out.println(“The resultant value = ” + ibo.applyAsInt(20, 4));
12    DoubleBinaryOperator dbo = (double a, double b) -> { return Math.pow(a, b);};
13    System.out.println(“Three to the power four = ” + dbo.applyAsDouble(3.0, 4.0));
14    BiFunction<Integer, Integer, Boolean> bif = (x, y) -> {return x.equals( y);};
15    System.out.println(“Is 45 equal to 30 ?  ” + bif.apply(45, 30));
16    }
17    }
```

Output

```
The resultant value = 416
Three to the power four = 81.0
Is 45 equal to 30 ?  false
```

Explanation

Lambda expressions are used to define the methods for the three functionals. For the first functional, a reference is created in code line 9 as `ibo` and is assigned the method reference. `ibo` is used in code line 11 and gets the value returned by the method. The body of the method for the first one is defined as `{return (m*m + n*n);}`. It returns the sum of squares of two integers. For the arguments 20 and 4, the output is obviously 416.

For the second, it is defined in code line 12 as `a` raised to the power `b`. For the arguments 3.0 and 4.0, the result is $3.0^{4.0}$ that is 81. For the `Bifunction(Integer, Integer, Boolean)`, the two integers 45 and 30 are compared for equality. The output is a Boolean that is obviously false. The results are given.

9.9.1 Functional `Consumer<T>`

The interface declaration is

```
@FunctionalInterface
public interface Consumer {void accept(T t);}
```

It declares one abstract method `void accept(T t)`. The method only consumes its argument. It does not give any return value. Hence, it is of `void` type. The methods that may be defined are printing methods or setting methods that set the values but do not return any value. Program 9.17 illustrates its application.

Program 9.17: Illustration of application of functional interface `Consumer<T>`

```
 1    import java.util.function.Consumer;
 2    public class Functional2 {
 3
 4    public static void main(String[] args) {
 5    Consumer <Double> consumer=(Double d) -> { display(d);};
 6    consumer.accept(3.14159);
 7
 8    Consumer<String> consumer1=(String s) -> {display(s);};
 9    String [] sray ={“Akriti”, “Kirin”, “Lata”, “Sunita”};
10
11    System.out.println(“\nDisplay of Consumer1.”);
12         for ( String str :sray )
13         consumer1.accept(str);
14
15    System.out.println(“\nDisplay of Consumer2”);
16    Consumer<Integer> consumer2=(Integer n) -> {display(n);};
17    Integer [] xray = {5,6,8,9,2};
18
19          for (Integer x :xray)
20          consumer2.accept(x);
21          System.out.println();
22    }
23        // Generic definition of display method
24    public static<T> void display(T t) {
25    System.out.print( t + “   ”);
26    }
27        }
```

Output

```
3.14159
Display of Consumer1.
Akriti   Kirin   Lata   Sunita
Display of Consumer2
5   6   8   9   2
```

Explanation

The program defines a generic method `display()` in code lines 24–26, which is used to display any type of object. The `Consumer` interface has only one method `accept()`, which takes only a single argument. Code line 5 defines a reference of the interface with name `consumer` in which method `display()` consumes the object, which is a double value. This forms the first output.

Code line 8 defines another reference `consumer1` that displays String values. It can consume String objects. At a time, it takes only one string, and therefore, for consuming an array, a *for–each* loop is used in lines 12 and 13.

Code line 16 defines a consumer reference `consumer2` for consuming `Integer` values. It takes one integer value at a time. For display of an array of integers, a *for–each* loop is used in lines 19 and 20. All outputs are shown.

9.9.2 Functional Supplier

The functional **`Supplier`** is the opposite of `consumer`. It simply supplies an object through its method `get()`, which does not take an argument. The method can be used in such a situation where there is no input but there is output. The declaration of functional is as follows.

```
@FunctionalInterface
public interface Supplier {
  T get();
}
```

Program 9.18 illustrates the application of the functional.

Program 9.18: Illustration of application of functional `Supplier`

```
 1    import java.util.Random;
 2    import java.util.function.Supplier;
 3    class MyNumber {
 4    public int getNumber(){
 5    return (int)(Math.random()*100);
 6    }}
 7    public class Functional3 {
 8     public static void main(String[] args) {
 9    Supplier<MyNumber> supplier = MyNumber::new;
10    MyNumber number = supplier.get();
11    System.out.println(number.getNumber());
12    }
13    }
```

Output

```
23
```

Explanation

The program illustrates the application of functional `Supplier<T>`. A class `MyNumber` is declared in code lines 3–6. A member of the class generates random numbers. Another class with method main is declared in lines 7–13. The reference `supplier` of interface `Supplier` is defined in code line 9 and is assigned reference of class object. The reference is used to invoke the get method of `Supplier` as used in code line 10, which is displayed in line 11. The output is given.

9.10 Annotations

Annotation framework in Java language was first introduced in Java 5 through a provisional interface `Apt`; however, it was formally introduced in Javac compiler in Java SE 6. It is a type of metadata that can be integrated with the source code without affecting the running of the program. Comments are also a way of adding information in a source code without affecting the implementation; however, comments are simply neglected at compile time and do not go further. The comments are introduced only for the user/programmer for understanding the program. However, annotations may be retained up to runtime and may be used to instruct the compiler and runtime system to do or not to do certain things.

Since Java SE 8, the annotations may be applied to classes, fields, interfaces, methods, and type declarations like throw clauses. The annotations are no longer simply for metadata inclusion in the program but have become a method for user's communication with compiler or runtime system.

For example, consider the case of a super class method that is overridden in a subclass. In such a case, both the method definitions should have the same signature. If, by mistake, a type or a parameter in subclass definition is changed, the method is no longer overridden, instead it becomes an overloaded method. The program will still compile without any error but the result will not be as expected. Besides, it is difficult to catch such an error. The remedy is to add the following annotation before the method definition in subclass.

```
@Override
```

This will cause the compiler to check and report if the method is really overridden or it is simply overloaded. Thus, it helps the programmer to catch and correct the error at compile time.

An annotation like `@Override` consists of two distinct words `@` and `Override`. It does not matter if there is a white space between the two. It may as well be written as `@ Override`; however, the general convention is not to have a gap. The name `Override` is the name of the interface that defines the annotation. There are a number of annotations that are predefined and are part of the package `java.lang.annotation`. However, a programmer may also define an annotation appropriate for his/her program. Annotations are defined by interfaces that are preceded by the tag character `@`. Thus, annotations can be easily recognized by symbol `@` in the code. Java language library has several predefined annotations in its library like the one illustrated. These annotations are suitable for a majority of programming requirements. However, Java language has provisions for user-defined annotations as well as plug-in third party developments.

Program 9.19 illustrates the application of `@override` annotation.

Program 9.19: Illustration of application of annotation `@override`

```
class XX {
public void display(){System.out.println("This is class XX.");
  }}      // end of class XX

class YY extends XX
{@Override public void display(){System.out.println("This is class YY.");
  }}             // end of class YY

class ZZ extends XX

{ @Override
public void display(){System.out.println("This is class ZZ.");
   }}     // end of class ZZ
                // below is class with main method
public class OverrideSuper {
public static void main (String Str[])
 {
     XX objX = new XX();
     YY objY = new YY();
     ZZ objZ = new ZZ();

objX.display();
 objY.display();
 objZ.display();
 }
}
```

Output
```
This is class XX.
This is class YY.
This is class ZZ.
```

Explanation

The super class `XX` defines a method `Display` and the two sub classes `YY` and `ZZ` override this method. It is the information for the compiler to check whether type signature of the three methods is the same as given in `XX`. In the program, the three definitions have the same signature, and therefore, there is no compile error by the compiler and the program runs successfully. The output is given.

9.10.1 Benefits of Using Annotations

1. It provides useful information to the compiler for detecting errors.
2. The information may also be used for suppressing warnings.
3. Annotations may be used for generating code in xml.
4. Annotation may be retained by another annotation for processing at runtime.
5. It can carry metadata up to runtime and the information may be obtained at runtime.

9.10.2 Annotation Basics

An annotation is an interface that declares only methods and is preceded by symbol `@`. An annotation may be defined with no methods or with one or more methods.

1. An annotation with no methods is declared as

```
@interface MyAnnotation{}
```

2. An annotation with one method may be declared as

```
@interface MyAnn{
int value();
}
```

   The method is treated as a field and may be assigned a default value as

```
@interface MyAnn{
int value() default 0; }
```

3. An annotation with more than one member method and with default values may be declared as

```
@ interface MyAnno {
int value1() default 10;
double value2() default 0.0;
String value3() default " ";
}
```

The methods included in an annotation do not have a body. They are more like fields and values are assigned either in an interface or class. An annotation with two methods is.

```
@ interface TwoAnno {
int value1() default 0;
double value2() default 0.0 ;}
```

The values may be assigned as

```
class AnnoValue {
@TwoAnno { value1 = 100, value2 = 20.45}
public static void Method1() { /* statements*/}
```

Note that the values are assigned to the names of methods, and no parentheses are used. In the aforementioned case, annotation `TwoAnno` is connected with `method1`.

9.10.3 Retention Policy

It specifies how long the annotation can be retained in the program. The property is imparted by another annotation called `@Retention`. Three retention options (constants) are defined in the language.

Source With this retention policy, the annotation is retained in the source file and is discarded at compile time. It is just like a comment.

Class With this policy specification, the annotation goes up to the .class file. It is a part of the compiled program but it does not go further. It is not available at runtime.

Runtime With this retention policy, the annotation is accessible throughout the running of the program. One can get the method values of the annotation if it has any.

The retention policy is declared through an argument of predefined annotation `@Retention`. The following example illustrates the specification.

```
@Retention(RetentionPolicy.RUNTIME)
@interface MyAnn{
int value() default 0;
}
```

The policy applies to the following annotation.

9.10.4 Predefined Annotations

A number of annotations were introduced in Java 1.6. New annotations have been added in Java 8 as well. There are two types of annotations.

1. The annotations that directly apply to the code.
2. The annotations that specify some property of other annotations, that is, they apply to the annotations.

Some of the predefined annotations that are generally used are described as follows:

1. `@Deprecated`: It tells the compiler that the targeted code may be class, field, methods, or if any other feature has been superseded by a newer code.
2. `@Documented`: If an element is marked by this annotation, the Javadoc utility outputs it to the documentation file that it creates.
3. `@Encrypted`: It is annotation of security annotation framework (SAF) for encryption of write and decryption of read operation.
4. `@FunctionalInterfaces`: The annotation tells the compiler that it is a functional interface–an interface with one abstract method. This annotation has been added since Java 8.
5. `@Not_Null`: Added since Java 8. It informs the compiler that annotated element must not be null.
6. `@Override`: It tells the compiler that the targeted method overrides a super class method.
7. `@Repeatable`: It specifies that the annotation may be applied more than once.
8. `@SuppressWarnings`: This annotation instructs the compiler not to issue a warning, if otherwise it would.
9. `@SafeVarargs`: The annotation conveys to the compiler that the code is safe, and therefore, some of the tests may be skipped for increasing the speed.
10. `@Retention`: It is the annotation that specifies the length of retention of the targeted annotation. There are three options that are described in Section 9.10.3.
11. `@Target`: When a user constructs own annotation, it is better to tell the compiler about its target elements. The targets are described in Table 9.2. Its application is illustrated which specifies the targets as METHOD and FIELD.

```
@Target(ElementType.METHOD, ElementType.FIELD)
```

Table 9.2 Target elements

Target	*Description*
`ElementType.ANNOTATION_TYPE`	It is applicable to an annotation.
`ElementType.CONSTRUCTOR`	It is applicable to a constructor.
`ElementType.FIELD`	It is applicable to field or property
`ElementType.LOCAL_VARIABLE`	It is applicable to a local variable.
`ElementType.METHOD`	It is applicable to a method.
`ElementType.PACKAGE`	It applies to a declaration of package.
`ElementType.PARAMETER`	It applies to a parameter of a method.
`ElementType.TYPE`	It applies to a type declaration.
`@Inherited`	It specifies that the target annotation is inherited.

9.10.5 `Class Method`

The Java language has provided a facility so that its code can enquire about itself. This is provided by classes and interfaces in the package **`java.lang.reflect`** that contains interface **`Member`** and several classes. The `class` **`Method`** is one of the classes of this package.

The methods of `class Method` are useful in dealing with annotations. It has several methods that can access annotations at runtime and get information that they carry. The declaration of `class Method` is as follows.

```
public final class Method extends AccessibleObject
implements GenericDeclaration, Member
```

9.10.5.1 *Methods of `class Method`*

Some methods useful for the present section are given in Table 9.3.

Table 9.3 Methods of class Method

Method	*Description*
`boolean equals(Object obj)`	Compares the `Method` object with specified object
`<T extends Annotation> T getAnnota-tion(Class <T> annotationClass)`	Returns this element's annotation if present; otherwise, null
`Annotation[] getDeclaredAnnotations()`	Returns all the annotations in an array
`Class<?> getDeclaringClass()`	Returns the class or interface reference that declares `this Method` object
`object getDefaultValue()`	Returns the default value of annotation member
`int hashCode()`	Returns hash code
`int getModifiers()`	Returns modifiers used with this `Method` object

(*Contd*)

Table 9.3 (*Contd*)

Method	*Description*
`String getName()`	Returns name of method represented by `this Method` object
`Class<?> getReturnType()`	Returns a class object that represents the formal return type of the method
`String toString()`	Returns a string that describes the `Method` object

The methods inherited by `class Method` are as follows:

1. The class inherits all the methods of Object class.
2. The class inherits the methods of `java.lang.reflect.AccessibleObject`, which it extends. These methods are as follows:

```
getAnnotations(),     isAccessible(),      isAnnotationPresent(),
setAccessible(),     setAccessible()
```

9.10.6 User Defined Annotation

We have already discussed the basics of annotations and some predefined annotations. A programmer may construct own annotation and use it. In the following discussion, we shall take a few examples of constructing annotations and using them.

9.10.6.1 *Marker Annotation*

A marker annotation does not contain any member method. It simply marks a declaration. Its presence may be obtained by the method `isAnnotationPresent()`.

Program 9.20 illustrates the declaration of Marker annotation and also the application of some of the methods of `class Method`.

Program 9.20: Illustration of working of Marker annotation and methods of `class Method`

```
import java.lang.reflect.Method;
    import java.lang.annotation.*;

    @Retention(RetentionPolicy.RUNTIME)
    @Target(ElementType.METHOD)
    @interface MarkerAnnotation1 {} // Marker annotation

    class MAnno {
@MarkerAnnotation1   // Application of annotation
public void display(){System.out.println("The Marker Annotation has no methods.");}
    }
  public class  MarkerAnno  {
  public static void main(String args[])throws Exception{
    MAnno manno = new MAnno();
    MarkerAnno markeranno = new MarkerAnno();
    Method m = manno.getClass().getMethod("display");
System.out.println("The Name of method is " + m.getName());
    System.out.println(m.toString());
if(m.isAnnotationPresent(MarkerAnnotation1.class))
    System.out.println("The MarkerAnnotation is present.");
else
22    System.out.println("The MarkerAnnotation is not present.");
23
24    manno.display();
25        }}
```

Output

```
The Name of method is display
public void javaapplication1.MAnno.display()
The MarkerAnnotation is present.
The MarkerAnnotation has no methods.
```

Explanation

The program illustrates Marker Annotation as well as the use of some methods of `class Method` in enquiry of the annotation. The Marker annotation is defined in code line 6. Its retention is up to runtime. It is used in line 9 in `class Manno`. The class with main method is declared in line 12. Code lines 14–16 define the objects of the classes. The method `getName()` is used in line 17 and its output is the name of method `display` (see the first line of output). The second line of output is the result of code line 18, that is, output of method `toString()`. Code lines 19 and 20 test the presence of annotation and give the output displayed in the third line of output. The last line of output is the result of invoking method `display()` by the object manno of class Manno.

9.10.6.2 *Single Method Annotation*

The annotations declare only methods; however, these do not have bodies and the methods behave like fields. Program 9.21 illustrates the case when an annotation has a single method.

Program 9.21: Illustration of single method (value) user's annotation

```
 1   import java.lang.reflect.Method;
 2       import java.lang.annotation.*;
 3
 4       @Retention(RetentionPolicy.RUNTIME) //defines retention
 5       @Target(ElementType.METHOD)   // defines target
 6       @interface Single {           // declares annotation
 7       double value () ;
 8       }
 9      class SingleData{
10       @Single(3.14159 )       // defines annotation value
11   public void display(){System.out.println("It is a user
12   annotation with single method.");}
13       }
14   public class SingleValue {     // class with main method
15   public static void main(String args[])throws Exception{
16
17   SingleData data =new SingleData();  // declares object
18   Method m = data.getClass().getMethod("display");
19   Single single = m.getAnnotation(Single.class);
20   System.out.println("The value = "+ single.value());
21   data.display(); //the object data invokes method display
22       }
23   }
```

Output

```
The value = 3.14159
It is a user annotation with single method.
```

Explanation

The program declares an annotation with single method, that is, `double value ();`. The name of the annotation is `Single`. The value assigned to method is 3.34159 in code line 10. Note that there is no semicolon at the end of the annotation (see line 10). The class `SingleData` also declares a method `display` linked to the annotation and this is used for declaring object `m` of class Method. For enquiring into the annotation, we have to have objects of classes SingleData and Method and reference of annotation Single. Code line 20 returns the value of the method of the annotation, which is displayed.

9.10.6.3 *Metadata in Annotation*

Program 9.22 illustrates the annotation that simply carries metadata that is retrieved at runtime. Three methods are declared in the annotation. All the three are of type String. The values carried by the annotation is the title of a book and names of its two authors.

Program 9.22: Illustration of metadata in annotation

```
 1      import java.lang.reflect.Method;
 2        import java.lang.annotation.*;
 3
 4        @Retention(RetentionPolicy.RUNTIME)
 5        @Target(ElementType.METHOD)
 6        @interface MetaData {    // declaration of annotation
 7        String title()  ;
 8        String author1() default “”;
 9       String author2()  default “”;
10        }
11       class AnnoData{
12        @MetaData(title = “Programming with Java”, author1 = “B. L. Juneja”, author2 =
    “Anita Seth”)
13        public void display(){System.out.println(“It is a user annotation.”); }
14        }
15     public class AUserAnnotation {
16     public static void main(String args[])throws Exception{
17
18      AnnoData data =new AnnoData();
19      Method m = data.getClass().getMethod(“display”);
20      MetaData md = m.getAnnotation(MetaData.class);
21
22      System.out.println(“The Title is:” + md.title());
23      System.out.println(“The author1 is:” + md.author1());
24      System.out.println(“The author2 is:” + md.author2());
25       data.display();
26      }
27    }
```

Output

```
The Title is: Programming with Java
The author1 is: B. L. Juneja
The author2 is: Anita Seth
It is a user annotation.
```

Explanation

This program is similar to Program 9.21. Both have multi-method annotations. In the present program, the data supplied is of type String and concerns a book and its authors. It is like metadata. Code line 6 declares the annotation that has three methods, that is, title, author1, and author2. The default values of the last two methods are given as empty strings (“ ”). The class Annodata defines the annotation with book and its authors. The class Annodata defines the annotation with actual data. The class also has a method. Another class with name AUserAnnotation is declared with main method. This class defines three objects and references, one each of classes AnnoData, Method, and annotation MetaData in lines 18, 19, and 20, respectively. The reference md of MetaData is used to inquire into the annotation in code lines 22–24. The output of this enquiry is shown.

Program 9.23 provides an example where multi-method annotation is being used.

Program 9.23: Illustration of a multi-method annotation

```
 1    import java.lang.reflect.Method;
 2    import java.lang.annotation.*;
 3
 4        @Retention(RetentionPolicy.RUNTIME)
 5        @Target(ElementType.METHOD)
 6                    // annotation is declared below.
 7        @interface MultiAnnotation {
 8        int value1()  default 0;
 9        double value2() default 0.0;
10        char value3()  default ‘A’;
11        String value4() default “ ”;
12        }
13
14      class Data{
15    @MultiAnnotation(value1 = 5, value2 = 10.45 , value3 = ‘D’, value4= “Delhi”)
      // note there is no semi-column.
16     public void display(){System.out.println(“It is a user annotation.”); }
17        }
18
19     public class MultiMethods {
20     public static void main(String args[])throws Exception{
21        Data data = new Data();
22        Method m = data.getClass().getMethod(“display”);
23       System.out.println(m.getDeclaringClass());
24                        // below we use for-each loop
25    for(Annotation an : m.getDeclaredAnnotations())
26       System.out.println(an);
27       System.out.println(m.getDeclaredAnnotations());
28       System.out.println(m.getDeclaredAnnotations().length);
29    MultiAnnotation  mA = m.getAnnotation (MultiAnnotation.class);
      // reference of MultiAnnotation
30
31        System.out.println(“The value1 = ”+ mA.value1());
32        System.out.println(“The value2 = ” + mA.value2());
33        System.out.println(“The value3 = ” + mA.value3());
34        System.out.println(“The value4 = ” + mA.value4());
35       data.display();
36        }
37         }
```

Output

```
class Data
@MultiAnnotation(value2=10.45, value1=5,
value4=Delhi, value3=D)
[Ljava.lang.annotation.Annotation;@1540e19d
1
The value1 = 5
The value2 = 10.45
The value3 = D
The value4 = Delhi
It is a user annotation.
```

Explanation

The program illustrates four-member annotation and the code for accessing the data of the annotation. Besides, it also determines other information about the annotation. Code lines 7–12 declare a four-method annotation. The return types of methods are `int`, `double`, `char`, and `String`. Each default value is also declared with each method. The values of methods are set in code line 15 in `class Data`. Line 16 declares a linking method. Note that values are assigned with names of the methods.

Code line 19 declares a class with main method. The objects of `class Data` and `class Method` are declared in code lines 21 and 22. The reference to the annotation is defined in line 29.

Code line 23 gets information about the declaring class. The first line of output is the result–`class Data`. Code lines 25 and 26 make use of *for–each* loop to find the annotations. The second line of output is the result. It gives the name of annotation and its values.

9.10.7 Restrictions on Annotations

1. The annotations can have only methods as their members.
2. The methods have no parameters and no body. They have type, name, and a pair of parentheses followed by semicolon. (e.g., `String value ();`)
3. The methods can return values that are of primitive type, anum type, Class, String, another annotation, or an array of these.
4. The methods cannot have any throw classes.
5. An annotation cannot extend another annotation.
6. Default value to the methods may be declared.

9.11 Application Programs

As we know in an interface, normally abstract methods are declared. Several different concrete methods may be derived from the same abstract method. This is also a kind of polymorphism. Figure 9.3 and Program 9.24 illustrate the same. A `cutAndStitch()` method is declared in an interface `Dress`. The method may be used for stitching a shirt, a frock, or a suit. This is illustrated in Program 9.24. Lambda expressions are used for executing concrete method declaration in the expression.

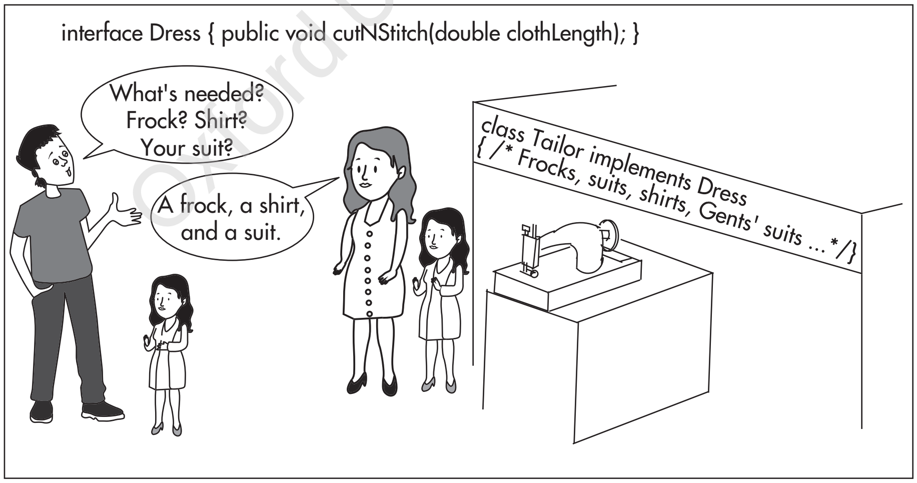

interface Dress { public void cutNStitch(double clothLength); }
What's needed? Frock? Shirt? Your suit?
A frock, a shirt, and a suit.
class Tailor implements Dress { /* Frocks, suits, shirts, Gents' suits ... */}

Fig. 9.3 Abstract method of interface leading to several concrete methods (see Program 9.24, which is written based on these figures)

Program 9.24: Illustration of use of data and method declared in an interface

```
interface Dress {
int frockTime =6; //Labour time (hours) for stitching frock
int suitTime =100;   //time (hours) needed for suit
4      int shirtTime =8 ;   //time(hours) needed for shirt
5
6      public double cutNStitch(double clothLength, double CC, double lC, int time);
7      //cc= cost of cloth, lC = labour cos/hour,
8      // Time = time of stitching
9      }                  // end of interface
10                  // class that implements interface
11     public class Tailor {
12     public static void main(String[] args) {
13                 // Declares costs of respective dresses
14       double frockCost, shirtCost, SuitCost;
15                // Method definitions in Lambda expression
16     Dress frock  = (clothLength,CC, lC, time) -> {return(clothLength *CC +lC*
       (1 + .5)*Dress.frockTime);};
17     Dress shirt = (clothLength,CC, lC, time) -> {return(clothLength *CC +lC*
       (1 + .5)*Dress.shirtTime);};
18     Dress suit = (clothLength,CC, lC, time) ->  {return(clothLength *CC +lC*
       (1 + .5)*Dress.suitTime);};
19          // Implementation of methods
20
21     double costFrock = frock.cutNStitch(1.5, 120.0, 25.0, 1);
22     double costShirt = shirt.cutNStitch(2.2, 150.0, 30.0, 8);
23     double costSuit = suit.cutNStitch(3.0, 750.0, 40.0, 100);
24
25     // output of costs for bill
26     System.out.println("Cost of stitching frock = " + costFrock);
27     System.out.println("Cost of Stitching shirt = " + costShirt);
28     System.out.println("Cost of Stitching suit = " + costSuit);
29          // Making total bill
30     System.out.println("Total Bill = " + (costFrock + costShirt + costSuit));
31         }
       }
```

Output

```
Cost of stitching frock = 405.0
Cost of Stitching shirt = 690.0
Cost of Stitching suit = 8250.0
Total Bill = 9345.0
```

Explanation

The program computes the cost of stitching a dress. The different data given in the exercise is arbitrary. The interface declares time durations in hours required for stitching a frock, a suit, and a shirt. It also declares an abstract method for computing the cost of dresses. The variables of method are `double clothLength`–length of cloth needed for the job, `double CC`–cost of cloth per metre for dress, `double lC`–cost of labour per hour, and time in hours needed by labour to complete the job. Fifty percent of the labour cost is taken as overhead cost for all cases and is included in labour cost.

Code line 14 declares variables for cost of three dresses. Lines 16–18 define the cost method for each dress. Although the method is same, separate definitions are given so that different formulations may be possible in the future. Lines 21–23 supply the data and calculate costs for the three dresses. The costs are displayed by lines 26–28. Line 30 prepares and displays the total bill for the three dresses. The outputs are given.

Program 9.25 illustrates an application program in which the area and volume of a given cylindrical shape is calculated.

Program 9.25: Illustration of another application program

```
     interface Shape{
public double area(double r, double h);
```

```
 3    public double volume(double r, double h);
 4    interface Nested{
 5    public void display();
 6    }
 7    }
 8
 9    public class ShapeCylinder implements Shape
10    {
11    double r, h;
12    public ShapeCylinder(){
13    double radius = r;
14    double height = h;
15    }
16    public double area()
17    {
18            double radius = r;
19    double height = h;
20
21    return 2*3.14*radius*(radius + height);
22    }
23    public double volume()
24    {
25    double radius = r;
26    double height = h;
27    return (3.14*radius*radius * height);
28    }
29    public void display(){
30    System.out.println("Volume and Area of cylinder is computed here");
31
32    }
33    }
34    public class ShapeImplement {
35    public static void main(String args[])
36    {
37     Shape.Nested a;
38       ShapeCylinder   sc  =new ShapeCylinder();
39     a = sc;
40     a.display();
41     Shape b;
42     ShapeCylinder   st  =new ShapeCylinder();
43         b = st;
44    System.out.println("Area of Cylinder is = " +b.area(7,15));
45
46    System.out.println("Volume of Cylinder is = " +b.volume(7,15));
47
48    }
49    }
```

Output

```
Volume and Area of cylinder is computed here
Area of Cylinder is =  967.12
Volume of Cylinder is = 2307.9
```

Explanation

The program declares two interfaces, one with name `Shape` and the other with name `Nested`. Two methods are declared in `Shape` and one in `Nested`. A class with name `ShapeCylinder` implements the interface `Shape`. This class does not have main method. Therefore, another class `ShapeImplement` with main method executes the class `ShapeCylinder`. The important point is how to access nested interface. See line 37 in which reference to `Nested` is declared. The `a` calls method `display`. A reference to `Shape` is created in line 41 which is assigned object reference of class `ShapeCylinder`. This is used to call methods of Shape. The output is given.

Common Programming Errors and Tips

Some common programming errors are described here.

1. The field variables declared in the interface must be initialized; otherwise, it will not compile.
2. A class implementing an interface must implement all its abstract methods.
3. The type signature of the implementing method should be exactly same as the type signature specified in the interface definition; otherwise, it may result in error.
4. Interfaces cannot implement themselves and they have no constructor methods, and hence, they cannot have objects. Use of operator new for their reference is wrong.

```
interface Book{}
Book book = new Book();     // wrong
```

   The reference to Book may be created as in the following code, which is similar to declaration of primitive types of declaration.

```
Book book;
```

5. An interface with single abstract method can be the target of Lambda expression, which is explained in Chapter 6.
6. The field variables defined in top-level interfaces are implicitly public, static, and final. However, the specification of these modifiers with variables does not create a compile-type error.
7. All the annotations declare only methods; however, they have no bodies and parameters. Their values are like field variables.
8. Only the name of member is used while assigning a value to an annotation member. The parentheses are not used. Thus, if `String name();` is one member, the value is assigned as `name = "Geeta"` in the case of multi-method annotation. For single method, an annotation uses `value` as name.
9. Do not create instances of interface directly. For this, create an instance of some class that implements the interface and reference that instance as an instance of interface.
10. All the variables in interface are public, and therefore, public keyword in the variable declaration can be avoided.
11. All default, abstract, and static methods in interface are implicitly public, and therefore, public keyword in the method declaration can be omitted.
12. Nested interfaces cannot be accessed directly; it must be referred by the outer interface or class.
13. Nested interface can have any access modifier if it is declared within the class. However, it must be public if it is declared inside the interface.

SUMMARY

- Declaration of an interface starts with the access modifier followed by the keyword interface. This is followed by its name or identifier, and then, by the block of statements containing declarations of variables and abstract methods.
- The variables defined in interfaces can be implicitly public, static, and final. They are initialized at the time of declaration.
- The modifiers that can be used with declaration of interfaces include public, private, and protected. However, for top-level interfaces, it is only public.
- The interfaces are implemented by classes. An interface can be declared as a member of a class or in another interface. In the capacity of a class member, it can have the attributes, which are applicable to other class members. Its access may be modified to public, protected, or private. In other cases, an interface can only be declared as public or with default (no-access modifier) access.
- An interface can also extend an interface.
- The Java version 8 allows full definition of default and static methods in interfaces. A static method is a class method. For calling a static method, one does not need an object of class. It can simply be called with class name.
- The functional interfaces are added in Java SE8. These are interfaces with one abstract method only and may be used as target for Lambda expressions and method references.

- A functional interface can have more than one static and default methods besides the abstract methods and it can override some methods of object class.
- In the program, an annotation, which is given, can be included in order to lessen the work of complier that will recognize a functional interface.

```
@FunctionalInterface
```

Adding the aforementioned annotation would be helpful in detecting compile time errors.
- A new package `java.util.function` has been introduced in Java 8 that contains the predefined functional interfaces and that may be used as target for Lambda expressions for most of the applications.

GLOSSARY

`@Functional Interface` A connotation for compiler to indicate that it is functional interface.
Abstract method It is a method that is only declared in a class but not defined. An abstract class is any class that includes an abstract method.
Default methods in interfaces Java 8 has allowed full definition of default methods in interfaces. The method definition has to be qualified by keyword default.
Functional interfaces An interface that has one abstract method; also called SAM (single abstract method type).
Generic interface Like a class, an interface is generic if it declares one or more type of variables.
Java.util.function A new package is created in Java 8 that contains predefined functional interfaces having one abstract method to be used as target for Lambda expressions.
Nested interface It is an interface that is defined in the body of a class or interface.
Static method A static method is a class method and we do not need an object of class for calling a static method.
Static methods in interfaces Java 8 has allowed full definition of static methods in interfaces. The method definition has to be qualified by keyword static.
Top-level interfaces It is an interface that is not nested in any class or interface.

EXERCISES

Multiple-choice Questions

1. Which of the following statements are correct?
   (a) An interface can extend only one class.
   (b) An interface can extend any number of classes.
   (c) An interface can extend only one interface.
   (d) An interface can extend any number of interfaces.
2. Which of the following access specifiers can be used for an interface?
   (a) Public (c) Protected
   (b) Private (d) All of these
3. Which of the following statements are correct?
   (a) Class can extend an interface.
   (b) Interface can extend a class.
   (c) Class implements interfaces.
   (d) None of these.
4. Which of the following statements are correct?
   (a) A concrete class implementing an interface must implement all the abstract methods of the interface.
   (b) A class may partially implement an interface.
   (c) A class that implements an interface must implement at least one abstract method of interface.
   (d) A class implementing fully a number of interfaces must be declared an abstract class.
5. Which of the following is the correct way of implementing an interface Acceleration by class Vehicle?
   (a) class Vehicle implements Acceleration {}
   (b) class Vehicle extends Acceleration {}
   (c) class Vehicle imports Acceleration {}
   (d) None of these
6. Which of the following statements are correct for classes implementing one interface?
   (a) All the classes that implement an interface must have the same definitions of methods declared in an interface.
   (b) Different classes can have different definitions of the methods of the interface.
   (c) Classes can assign different values to variables defined in an interface.
   (d) Variables defined in an interface are static and final.
7. Which of the following represents the correct definition of interface?
   (a) interface Shape {void draw() {}}
   (b) interface Shape {void draw()}
   (c) interface shape {void draw};
   (d) interface Shape {void draw();}
8. Which of the following statements are correct regarding interfaces?

(a) An interface cannot implement itself.
(b) An interface can have object references.
(c) A class can extend an interface.
(d) An interface can implement another interface.

9. How many abstract methods should a functional interface have?
(a) One (c) Three
(b) Two (d) Any number

10. In Java, default methods can be declared in which of the following cases?
(a) In classes only
(b) In interfaces only
(c) In classes as well as in interfaces
(d) Outside classes or interfaces

11. Which of the following is correct for calling a static method?
(a) `Object_name.class_name.method_name`
(b) `Class_name.object_name`
(c) `class_name.method_name`
(d) None of these

12. Which of the following statements is correct?
(a) A functional interface may have default and static methods besides abstract method and/or other variables.
(b) A functional interface can have only one default method besides one abstract method.
(c) A functional interface can have only one static method besides one abstract method.
(d) A functional interface cannot have default or static methods.

13. Which of the following lines would give compilation error?
```
interface Score {
        int p = 15;
// line 1
         public   static   int   x   =   23;
         // line 2
         public int y = 34;
            // line 3
         public  static  final  int  z  =  56;
         // line 4
}
```
(a) 1 (c) 3
(b) 2 (d) 4
(e) None of these

14. Which of the following statements are correct regarding default methods in interfaces?
(a) A default method may be declared final.
(b) A default method can be synchronized.
(c) A default method cannot override the non-final methods of Object class.
(d) None of these.

15. What would be the output of the following codes?
```
interface Show{
public void method();
}
class X {
public void method(){
System.out.println (" Class X method");
}
}
class Y extends X implements Show{
public void method() {
System.out.println (" Class Y method");
}
}
public class Demo extends Y {
    public static void main (String[] args)
{
Show s = new Y();
s.method();}
}
```
(a) Class Y method
(b) Class X method
(c) Compiles but does not print anything
(d) Gives compilation error

Review Exercises

1. Differentiate between a class and an interface.
2. What is the purpose of having an interface in a program?
3. What are functional interfaces?
4. What is the difference between an interface and an abstract class?
5. What are the attributes of a variable declared in an interface?
6. How do you declare an interface?
7. How do you implement an interface?
8. How are methods declared in an interface?
9. Does an interface extend another interface?
10. Does an interface implement another interface?
11. Can you declare an interface inside a class?
12. Can you declare a class in an interface?
13. How do you access an interface declared in a class?
14. Can an interface extend more than one interface?
15. What is a predicate?

Programming Exercises

1. Declare an interface with a method to calculate the volume with one double parameter. Implement the same for finding the volume of a sphere and cube by two different classes.
2. Write a program that illustrates accessing a nested interface in another interface that is nested in a class.
3. Write a program to illustrate the implementation of nested interfaces.
4. Write a program to illustrate use of interface with a nested class.
5. Write a program in which a class implements more than two interfaces.
6. Write a program to illustrate an interface extending two interfaces and implemented by a class.
7. Write a program that uses a predicate to test if an array of integers contains a particular number.
8. Design an interface named `InfaceX` with a method `reverse()` that reverses the digits of the number (i.e., if 45,678 is the number, then it should return 87,654).
9. Design an interface with the following details:

   Interface named InfaceA having method

   getVelocity(r) that calculates and returns velocity of satellite as given

   Velocity = sqrt. of (μ/r)

   where r is the altitude of satellite measured from the centre of the earth, μ is the Kepler's constant with value $3.986004418 \times 10^{5.}$

   There is nested interface, InfaceB with method, and getAcceleration(r) that calculates and returns the acceleration of the satellite as

   Acceleration = (μ/r^2)
10. Write a program in which interface is given by name MeanInterface. Method mean() is defined in this interface that calculates the mean of the given numbers arranged in an array. This interface is then extended and method is defined in this interface that calculates deviation from the mean value evaluated for each of the numbers.
11. Write a program that illustrates the functional Binary Operator.
12. Write a program that illustrates the functional Function.

Debugging Exercises

1. Debug the following program and run it to find the area of a circle and a square.

```
interface Volume;
{double Compute (double x);
}


class Cube implements Volume
{public double Compute (double x)
{return (x*x*x);}
}
class Sphere implements Volume
{public double Compute(double x)
{return ( 4*3.141*x*x*x/3);}
}
classCubSpher;
{public static void main(String arg[])
{ Cube Cub = new Cube()
Sphere Sphr = new Sphere();
Volume Vol;
Vol = Cub;
System.out.println("Volume of cube = " +
Vol.Compute(10));
Vol =Sphr;
System.out.println("Volume of sphere = " +
Vol.Compute());
}}
```

2. Debug the following program and run it to find the area of a circle and a square.

```
public interface A{
int area(int x, int y);
{
int i = x;
int j = y;
return (i*j);
}
}
class SingleRoom implements A
{
public int area(int x, int y);
}
class Room
{
public static void main(String args[])
{
Room r=new Room();
System.out.println("Area of room is = " +
r.area(4.0, 7.0)");
}
```

3. Debug the following program and run it to find the area of a circle and a square.

```
class demo {
public interface Inface {
```

```
int sum( int x, int y);}
}

class B implements Inface
{
public int sum (int x, int y )
    {return x + y  ; }
}

class ABC
{public static void main(String arg[])
{
inface s = new B();
System.out.println("Addition of two numbers
is = " + s.sum (30, 12));
}
```

4. Debug the following program and run it to find the area of a circle and a square.

```
interface InfaceD
{
double getVolume(double x);
interface Display{
public void show();
}
}
1. class Calculate implements InfaceD, Dis-
play
{
double getVolume(double x)
{
double volume = 4/3*PI*x*x*x;
return volume;
}
public void Display.show()
{
System.out.println("Volume of given
shapes");
}

public static void main(String args[])
{
2. Display d=new Calculate();
  InfaceD s = new Calculate();
d.show();
System.out.println("Volume is = " +d.get-
Volume(4.0)");
}
```

5. Debug the following program and run it to find the area of a circle and a square.

```
import java.lang.reflect.Method;
    import java.lang.annotation.*;

    @Retention(RetentionPolicy.RUNTIME)
    @Target(ElementType.METHOD)
        // annotation is declared below.
    @interface MultiAnnotation {
    int value1() default 0;
    double value2() default 0.0;
    char value3() default 'A';
    String value4() default " ";
    }

 class Data{
 @MultiAnnotation(value1 = 5, value2 = 10.45
, value3 = 'D', value4= "Delhi")
public void display(){System.out.println("It
is a user annotation."); }
    }

 public class MultiMethods {       // class
with main method
  public  static  void  main(String  args[])
throws Exception{

    Data data = new Data();
    Method m = data.getClass().get-
Method("display");
  System.out.println(m.getDeclared
Class());
    System.out.println(m.getDeclaringAnnota-
tions());

System.out.println(m.getDeclaredAnnota-
tions().length);
MultiAnnotation  mA=m.getAnnotation(MultiAn-
notation.class);

      System.out.println("The  value1  =  "  +
mA.value1());
      System.out.println("The  value2  =  "  +
mA.value2());

      System.out.println("The  value3  =  "  +
mA.value3());
System.out.println("The value4 = " + mA.val-
ue4());
   data.display();
    }
         }
```

Answers to Multiple-choice Questions

1. (d)	2. (a)	3. (c)	4. (a)	5. (a)
6. (b) and (d)	7. (d)	8. (a) and (b)	9. (d)	10. (b)
11. (c)	12. (a)	13. (e)	14. (c)	15. (a)