Object-oriented Programming - II

Reference:

A Programmer's Guide to Java Certification: A Comprehensive Primer

Chapter 4 & Chapter 6

Overview

- Single implementation inheritance, multiple interface inheritance and supertypes
- Assigning, casting and passing references
- The `instanceof` operator
- Polymorphism and dynamic method lookup
- Choosing between inheritance and aggregation
- Encapsulation
- Packages: usage and definition
- Accessibility modifiers for classes and interfaces: default and `private`
- Member accessibility modifiers: `public`, `protected`, default and `private`
- Abstract classes and methods
- Final classes, members and parameters

Interfaces

Interfaces: Programming by Contract

- Java provides *interfaces* which allow new type names to be introduced and used polymorphically, and also permit *multiple interface inheritance*.
- Interfaces support *programming by contract*.

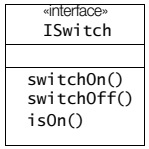
Defining Interfaces

- An interface defines a *contract* by specifying prototypes of methods, and not their implementation.

  <interface header> {
  <interface body>
  }

- An interface is abstract by definition and therefore cannot be instantiated. It should also not be declared `abstract`.
- Reference variables of the interface type can be declared.
- *Pure Design*: Java allows *contracts* to be defined by using *interfaces*.

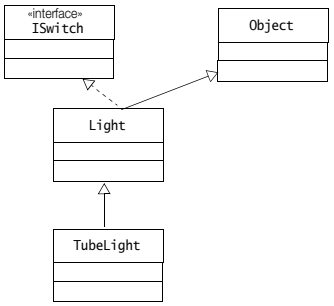
```
interface ISwitch { // method prototypes
    void switchOn();
    void switchOff();
    boolean isOn();
}
```



Design Inheritance: Implementing Interfaces

- A class specifies the interfaces it implements as a comma-separated list using the `implements` clause in the class header.

```
interface ISwitch { // method prototypes
    void switchOn();
    void switchOff();
    boolean isOn();
}
class Light implements ISwitch {
    // Method implemenations
    public void switchOn()  {...}
    public void switchOff() {...}
    public boolean isOn()   {...}
    //...
}
class TubeLight extends Light {...}
```



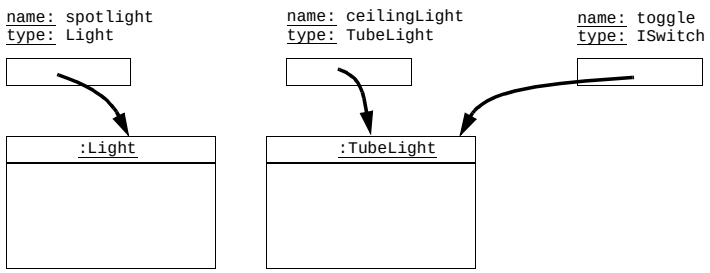
Note that subclasses `LightBulb` *and* `TubeLight` *also implement the* `ISwitch` *interface.*

A Word on Typing

Type rules determine which type of values (objects) can be manipulated by which type of variables (names).

- A variable of type `T` can denote any object of type `T` or a subtype of `T`.

```
Light spotlight = new Light();
TubeLight ceilingLight = new TubeLight();
ISwitch toggle = ceilingLight;
```



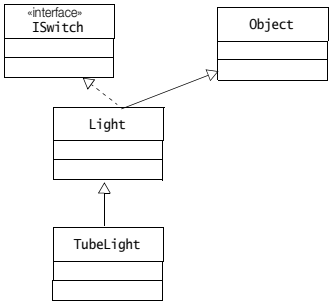
Supertypes and Subtypes

- Interfaces define new types.
- Although interfaces cannot be instantiated, variables of an interface type can be declared.
- If a class implements an interface, then references to objects of this class and its subclasses can be assigned to a variable of this interface type.
- The interfaces that a class implements and the classes it extends, directly or indirectly, are called its *supertypes*.
  - The class is then a *subtype* of its supertypes.
  - A supertype is thus a *reference type*.
- Interfaces with empty bodies are often used as markers to "tag" classes as having a certain property or behavior (`java.io.Serializable`).
- Note that a class inherits *only one* implementation of a method, regardless of how many supertypes it has.
- All interfaces are also subtypes of `Object` class.

A supertype reference can denote objects of its type and of its subtypes.

Example: Interface Types

```
interface ISwitch { // method prototypes
    public void switchOn();
    public void switchOff();
    public boolean isOn();
}
class Light implements ISwitch {
    // Method implementations
    public void switchOn()  {...}
    public void switchOff() {...}
    public boolean isOn()   {...}
    //...
}
class TubeLight extends Light {...}

// Some client
ISwitch starLight = new TubeLight();
starLight.getTubeLight();  // Compile error
starLight.switchOn();
starLight.equals(someOtherLight);
```



- Type `TubeLight` is a *subtype* of `Light`, `ISwitch` and `Object`.
  - `Light`, `ISwitch` and `Object` are *supertypes* of type `TubeLight`.
- *Objects of a type can be denoted by reference variables of its supertypes.*

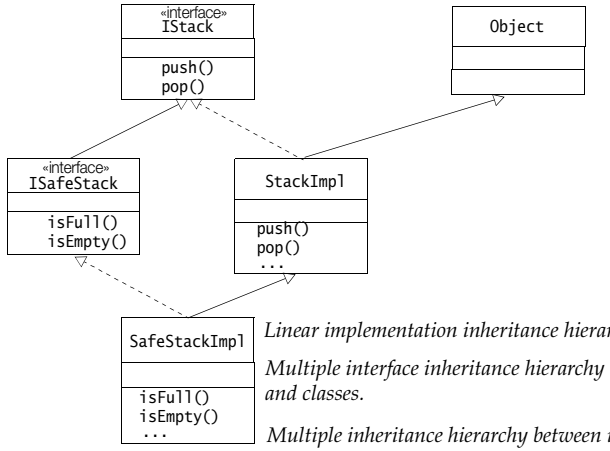
Remarks on Interfaces

- Classes which *implement* interfaces, guarantee that they will honor the contract.
- A class can choose to implement only some of the methods of its interfaces, i.e. give a partial implementation of its interfaces.
  - The class must then be declared as `abstract`.
- Note that interface methods cannot be declared `static`, because they comprise the contract fulfilled by the *objects* of the class implementing the interface and are therefore instance methods.
- The interface methods will all have `public` accessibility when implemented in the class (or its subclasses).

Extending Interfaces

- An interface can extend other interfaces, using the `extends` clause.
- Unlike extending classes, an interface can *extend* several interfaces.
- Multiple inheritance of interfaces can result in an inheritance hierarchy which has multiple roots designated by different interfaces.
- Note that there are three different inheritance relations at work when defining inheritance between classes and interfaces:
  - *Linear implementation inheritance hierarchy between classes*: a class extends another class.
  - *Multiple inheritance hierarchy between interfaces*: an interface extends other interfaces.
  - *Multiple interface inheritance hierarchy between interfaces and classes*: a class implements interfaces.
- There is only one single *implementation* inheritance into a class, which avoids many problems associated with general multiple inheritance.

Kinds of Inheritance



Linear implementation inheritance hierarchy between classes.

Multiple interface inheritance hierarchy between interfaces and classes.

Multiple inheritance hierarchy between interfaces.

Figure 1 Inheritance Relations

Example 1 Interfaces

```
interface IStack {                                          // (1)
    void push(Object item);
    Object pop();
}

class StackImpl implements IStack {                         // (2)
    protected Object[] stackArray;
    protected int tos;

    public StackImpl(int capacity) {
        stackArray = new Object[capacity];
        tos = -1;
    }

    public void push(Object item)                           // (3)
        { stackArray[++tos] = item; }

    public Object pop() {                                   // (4)
        Object objRef = stackArray[tos];
        stackArray[tos] = null;
        tos--;
        return objRef;
    }

    public Object peek() { return stackArray[tos]; }
}
```

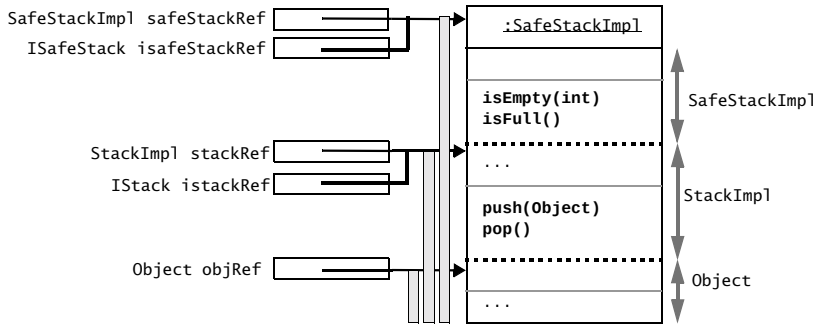


```
interface ISafeStack extends IStack {                       // (5)
    boolean isEmpty();
    boolean isFull();
}

class SafeStackImpl extends StackImpl implements ISafeStack {   // (6)

    public SafeStackImpl(int capacity) { super(capacity); }
    public boolean isEmpty() { return tos < 0; }            // (7)
    public boolean isFull() { return tos == stackArray.length-1; }  // (8)
}

public class StackUser {

    public static void main(String args[]) {                // (9)
        SafeStackImpl safeStackRef = new SafeStackImpl(10);
        StackImpl stackRef = safeStackRef;
        ISafeStack isafeStackRef = safeStackRef;
        IStack istackRef = safeStackRef;
        Object objRef = safeStackRef;

        safeStackRef.push("Dollars");                       // (10)
        stackRef.push("Kroner");
        System.out.println(isafeStackRef.pop());
        System.out.println(istackRef.pop());
        System.out.println(objRef.getClass());
    }
}
```


Output from the program:

```
Kroner
Dollars
class SafeStackImpl
```


Example: Interfaces




```
SafeStackImpl safeStackRef = new SafeStackImpl(10);
StackImpl stackRef = safeStackRef;
ISafeStack isafeStackRef = safeStackRef;
IStack istackRef = safeStackRef;
Object objRef = safeStackRef;

istackRef.isEmpty(); // Compile error
stackRef.isFull();   // Compile error
```

```
safeStackRef.push("Dollars");
stackRef.push("Kroner");
System.out.println(isafeStackRef.pop());
System.out.println(istackRef.pop());
System.out.println(objRef.getClass());
```

Constants in Interfaces

- An interface can also define constants.
- Such constants are considered to be `public`, `static` and `final`.
- An interface constant can be accessed by any client (a class or interface) using its fully qualified name, regardless of whether the client extends or implements its interface.
- A class that implements this interface or an interface that extends this interface, can also access such constants directly without using the dot (.) notation.
- Extending an interface which has constants is analogous to extending a class having static variables.
  - In particular, these constants can be shadowed by the subinterfaces.
- In the case of multiple inheritance, any name conflicts can be resolved using fully qualified names for the constants involved.
  - The compiler will flag such conflicts.

Example 2 Variables in Interfaces

```
interface Constants {
    double PI = 3.14;
    String AREA_UNITS = " sq.cm.";
    String LENGTH_UNITS = " cm.";
}
public class Client implements Constants {
    public static void main(String args[]) {
        double radius = 1.5;
        System.out.println("Area of circle is " + (PI*radius*radius) +
                           AREA_UNITS);             // (1) Direct access.
        System.out.println("Circumference of circle is " + (2*PI*radius) +
                           Constants.LENGTH_UNITS); // (2) Fully qualified name.
    }
}
```

Output from the program:

```
Area of circle is 7.0649999999999995 sq.cm.
Circumference of circle is 9.42 cm.
```


Using References

Array Types in Java.

	Corresponding Types:
Primitive data values	Primitive data types.
Reference values	Class, interface or array type (called *reference types*).
Objects	Class or array type.

- Only primitive data and reference values can be stored in variables.
- Arrays are object in Java.
- Array types (`boolean[]`, `Object[]`, `StackImpl[]`) implicitly augment the inheritance hierarchy.
- All array types implicitly extend the `Object` class.
- Note the difference between arrays of primitive data types and reference types.
  - Arrays of reference types also extend the array type `Object[]`.
- Variables of *array reference types* can be declared and arrays of reference types instantiated.
- An array reference exhibits the same polymorphic behavior as any other reference, subject to its location in the extended inheritance hierarchy.

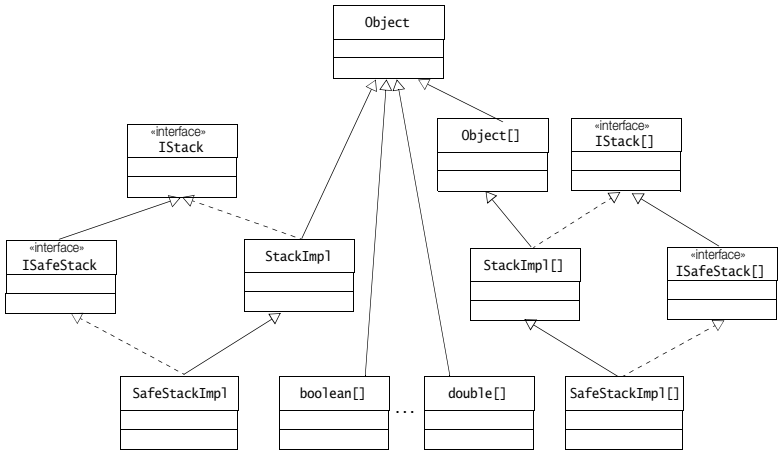


Figure 2 Array Types in Inheritance Hierarchy

Assigning, Passing and Casting References

- Reference values, like primitive values, can be assigned, cast and passed as arguments.
- For values of the primitive data types and reference types, conversions occur during:
  - Assignment
  - Parameter passing
  - Explicit casting
- The rule of thumb for the primitive data types is that *widening conversions* are permitted, but *narrowing conversions* require an explicit cast.
- The rule of thumb for reference values is that conversions up the inheritance hierarchy are permitted (called *upcasting*), but conversions down the hierarchy require explicit casting (called *downcasting*).
- *The parameter passing conversion rules are useful in creating generic data types which can handle objects of arbitrary types.*

Example 3 Assigning and Passing Reference Values

```
interface IStack { /* See Example 1 for definition */ }
class StackImpl implements IStack { /* See Example 1 for definition */ }
interface ISafeStack extends IStack { /* See Example 1 for definition */ }
class SafeStackImpl extends StackImpl implements ISafeStack {
    /* See Example 1 for definition */
}

public class ReferenceConversion {

    public static void main(String args[]) {

        Object objRef;
        StackImpl stackRef;
        SafeStackImpl safeStackRef = new SafeStackImpl(10);
        IStack iStackRef;
        ISafeStack iSafeStackRef;

        // SourceType is a class type
        objRef = safeStackRef;       // (1) Always possible
        stackRef = safeStackRef;     // (2) Subclass to superclass assignment
        iStackRef = stackRef;        // (3) StackImpl implements IStack
        iSafeStackRef = safeStackRef;// (4) SafeStackImpl implements ISafeStack

        // SourceType is an interface type
        objRef = iStackRef;          // (5) Always possible
        iStackRef = iSafeStackRef;   // (6) Sub- to super-interface assignment
```



```
        // SourceType is an array type.
        Object[] objArray = new Object[3];
        StackImpl[] stackArray = new StackImpl[3];
        SafeStackImpl[] safeStackArray = new SafeStackImpl[5];
        ISafeStack[] iSafeStackArray = new SafeStackImpl[5];
        int[] intArray = new int[10];

        objRef = objArray;           // (7) Always possible
        objRef = stackArray;         // (8) Always possible
        objArray = stackArray;       // (9) Always possible
        objArray = iSafeStackArray;  // (10) Always possible
        objRef = intArray;           // (11) Always possible
//      objArray = intArray;         // (12) Compile time error
        stackArray = safeStackArray; // (13) Subclass array to superclass array
        iSafeStackArray =
              safeStackArray;        // (14) SafeStackImpl implements ISafeStack
        // Parameter Conversion
        System.out.println("First call:");
        sendParams(stackRef, safeStackRef, iStackRef,
                   safeStackArray,iSafeStackArray);                    // (15)
//      Call Signature: sendParams(StackImpl, SafeStackImpl, IStack,
//                                 SafeStackImpl[], ISafeStack[]);
        System.out.println("Second call:");
        sendParams(iSafeStackArray, stackRef, iSafeStackRef,
                   stackArray, safeStackArray);                        // (16)
//      Call Signature: sendParams(ISafeStack[], StackImpl, ISafeStack,
//                                 StackImpl[], SafeStackImpl[]);
    }
```

```
    public static void sendParams(Object objRefParam, StackImpl stackRefParam,
            IStack iStackRefParam, StackImpl[] stackArrayParam,
            IStack[] iStackArrayParam) {                              // (17)
    //  Signature: sendParams(Object, StackImpl, IStack, StackImpl[], IStack[])
    //  Print class name of object denoted by the reference at runtime.
        System.out.println(objRefParam.getClass());
        System.out.println(stackRefParam.getClass());
        System.out.println(iStackRefParam.getClass());
        System.out.println(stackArrayParam.getClass());
        System.out.println(iStackArrayParam.getClass());
    }
}
```

Output from the program:

```
First call:
class SafeStackImpl
class SafeStackImpl
class SafeStackImpl
class [LSafeStackImpl;
class [LSafeStackImpl;
Second call:
class [LSafeStackImpl;
class SafeStackImpl
class SafeStackImpl
class [LSafeStackImpl;
class [LSafeStackImpl;
```


Reference Casting and `instanceof` Operator

- The expression to cast *<reference>* of *<source type>* to *<destination type>* has the following syntax:

  (*<destination type>*) *<reference>*
- The binary `instanceof` operator has the following syntax:

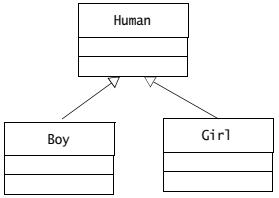
  <reference> `instanceof` *<destination type>*
- The `instanceof` operator (note that the keyword is composed of only lowercase letters) returns the value `true` if the left-hand operand (any reference) can be *cast* to the right-hand operand (a class, interface or array type).
- A compile time check determines whether a reference of *<source type>* and a reference of *<destination type>* can denote objects of a class (or its subclasses) where this class is a common subtype of both *<source type>* and *<destination type>* in the inheritance hierarchy.
- At runtime, it is the *actual object denoted by the reference* that is compared with the type specified on the right-hand side.
- Typical usage of the `instanceof` operator is to determine what object a reference is denoting.

Example: Boys and Girls are Human

- We use names to denote humans.
- We can have boy names.
  `Boy tom, dick, harry;`
- We can have girl names:
  `Girl pandora, venus, medusa;`
- Some human names can be for a boy or a girl.
  `Human pat, sandy, alex;`

  A `Boy` *is a* `Human`.

  A `Girl` *is a* `Human`.



- We can create people and give them names:

```
tom = new Boy();
pandora = new Girl();
sandy = new Girl(); // A Girl is a Human
alex = tom; // Alias of the same boy. A Boy is a Human.
pandora = sandy; // Danger!
                 // It is not always the case that a Human is a Girl.
                 // What if sandy was a Boy?
pandora = (Girl) sandy; // Compiler requires a cast.
```


- Names can be used to manipulate people.
- We cannot write
  `sandy.giveBirth();`

  as we do not know if `sandy` is a `Girl`, and only a `Girl` can give birth.
- We might try:

```
((Girl) sandy).givebirth(); // Compiler is happy.
```

  or

```
pandora = (Girl) sandy; // Compiler is happy.
pandora.giveBirth();
```

- What if at runtime `sandy` was really a `Boy`?

  In that case we get an execution error, `ClassCastException`.

  Obviously we cannot have a `Girl` name denote a `Boy`.
- We should only cast if we are sure that `sandy` is a `Girl`.

```
if(sandy instanceof Girl) { // Full proof
    pandora = (Girl) sandy; // Compiler is happy.
    pandora.giveBirth();
    // Alternative
    ((Girl) sandy).giveBirth();
}
```

- A cast does *not* change the type of the object, and only the *reference value* is cast.
- Note that both variables and objects have a *type*.
- The type of a variable or an object *cannot* be changed.

  Objects are people, i.e. either boys and girls.

  Variables are names of people.

  i.e. use names to denote people.

  In Java, you use variables to denote objects.
- `Human` can be an `abstract` class.
  - It provides *partial* implementation for a human.
  - For example, a `getGender()` method must be defined for all humans.
- `Boy` and `Girl` can be `final` classes.
  - We do not want boys and girls to be further specialized.

Upcasting and Downcasting

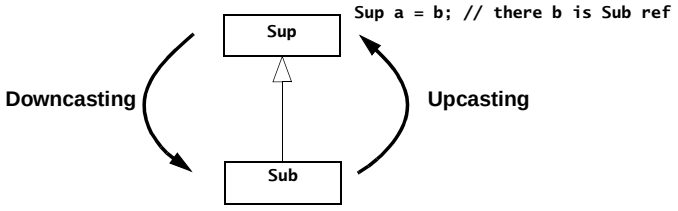
- *Upcasting*: References of supertypes can be declared, and these can denote objects of its type or its subtypes.
- *Downcasting*: Converting a supertype reference to a subtype reference requires explicit casting.
  - use the `instanceof` operator to make sure the cast is legal.

Special case: Converting References of Class and Interface Types

- *Upcasting*: References of interface type can be declared, and these can denote objects of classes that implement this interface.
- *Downcasting*: Converting a reference of interface type to the type of the class implementing the interface requires explicit casting.

```
IStack istackOne = new StackImpl(5);               // Upcasting
StackImpl stackTwo = (StackImpl) istackOne;        // Downcasting

Object obj1 = istackOne.pop();       // OK. Method in IStack interface.
Object obj2 = istackOne.peek();      // Not OK. Method not in IStack interface.
```

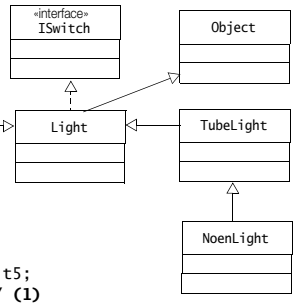

Sub *is* Sup




```
if (a instanceof Sub) // there a is Sup ref
    Sub b = (Sub) a;
```

Example: Upcasting and Downcasting

```
interface ISwitch { // method prototypes
    public void switchOn();
    public void switchOff();
    public boolean isOn();
}

class Light implements ISwitch {...}
class LightBulb extends Light {...}
class TubeLight extends Light {...}
class NoenLight extends TubeLight {...}

// Some client
boolean result1, result2, result3, result4, result5;
ISwitch light1 = new LightBulb();              // (1)
//  String str = (String) light1;              // (2) Compile error.
//  result1 = light1 instanceof String;        // (3) Compile error.
    result2 = light1 instanceof TubeLight;     // (4) false. Peer class.
//  TubeLight tubeLight1 = (TubeLight) light1; // (5) ClassCastException.
light1 = new NeonLight();                      // (8)
if (light1 instanceof TubeLight) {             // (9) true
   TubeLight tubeLight2 = (TubeLight) light1;  // (10) OK
   // Can now use tubeLight2 to access object of class NeonLight.
}
```



Using Inheritance

Polymorphism and Dynamic Method Lookup

- Which object a reference will actually denote during runtime cannot always be determined at compile time.
- Polymorphism allows a reference to denote different objects in the inheritance hierarchy at different times during execution.
  - Such a reference is a supertype reference.
- When a method is invoked using a reference, the method definition which actually gets executed is determined both by *the class of the object* denoted by the reference at runtime and *the method signature*.
- Dynamic method lookup is the process of determining which method definition a method signature denotes during runtime, based on the class of the object.
- Polymorphism and dynamic method lookup form a powerful programming paradigm which simplifies client definitions, encourages object decoupling and supports dynamically changing relationships between objects at runtime.

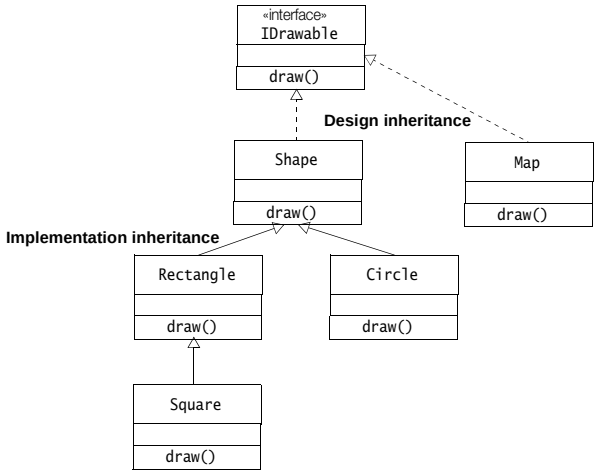


Figure 3 Polymorphic Methods

Example 4 Polymorphism and Dynamic Method Lookup

```
interface IDrawable {
    void draw();
}
class Shape implements IDrawable {
    public void draw() { System.out.println("Drawing a Shape."); }
}
class Circle extends Shape {
    public void draw() { System.out.println("Drawing a Circle."); }
}
class Rectangle extends Shape {
    public void draw() { System.out.println("Drawing a Rectangle."); }
}
class Square extends Rectangle {
    public void draw() { System.out.println("Drawing a Square."); }
}
class Map implements IDrawable {
    public void draw() { System.out.println("Drawing a Map."); }
}
```



```
public class PolymorphRefs {
    public static void main(String args[]) {
        Shape[] shapes = {new Circle(), new Rectangle(), new Square()};   // (1)
        IDrawable[] drawables = {new Shape(), new Rectangle(), new Map()};// (2)

        System.out.println("Draw shapes:");
        for (int i = 0; i < shapes.length; i++)                           // (3)
            shapes[i].draw();

        System.out.println("Draw drawables:");
        for (int i = 0; i < drawables.length; i++)                        // (4)
            drawables[i].draw();
    }
}
```

Output from the program:

```
Draw shapes:
Drawing a Circle.
Drawing a Rectangle.
Drawing a Square.
Draw drawables:
Drawing a Shape.
Drawing a Rectangle.
Drawing a Map.
```


Static and Dynamic Binding

- Compile time: Static binding
  - the compiler verifies that the type of the element `drawables[i]` has a method called `draw()`.
- Runtime: Dynamic Binding
  - the runtime system invokes the `draw()` method of the *actual object* that is denoted by `drawables[i]`.
  - method `draw()` represents different methods depending on the type of the object denoted by `drawables[i]`.

Programming by Contract

- Program design uses interfaces and relies on polymorphism:

```
public void drawAll(IDrawable[] figures) {
    for (int i = 0; i < figures.length; i++)
        figures[i].draw();
}
```

Note that elements of array `IDrawable` *can be objects of* `Shape`, `Circle`, `Square`, `Rectangle` *or* `Map`.

Choosing between Inheritance and Aggregation

- Choosing between inheritance and aggregation to model relationships can be a crucial design decision.
- A good design strategy advocates that inheritance should be used only if the relationship *is-a* is unequivocally maintained throughout the lifetime of the objects involved, otherwise aggregation is the best choice.
- A *role* is often confused with an *is-a* relationship.
  - Changing roles would involve a new object to represent the new role every time this happened.
- Code reuse is also best achieved by aggregation when there is no *is-a* relationship.
- Aggregation with *method delegating* can result in robust abstractions.
- Both inheritance and aggregation promote encapsulation of *implementation*, as changes to the implementation are localized to the class.
- Changing the *contract* of a superclass can have consequences for the subclasses (called the *ripple effect*) and also for clients who are dependent on a particular behavior of the subclasses.

Achieving Polymorphism

- Polymorphism is achieved through *inheritance and interface implementation*.
- Code relying on polymorphic behavior will still work without any change if new subclasses or new classes implementing the interface are added.
- If no obvious *is-a* relationship is present, then polymorphism is best achieved by using *aggregation with interface implementation*.

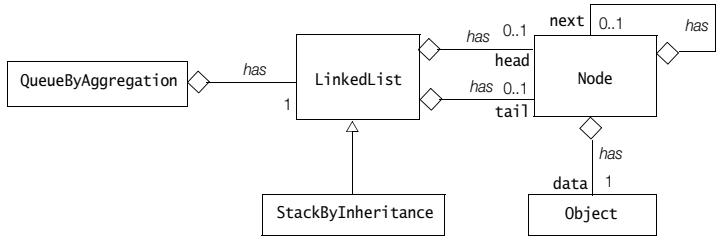


Figure 4 Inheritance and Aggregation

Example 5 Inheritance and Aggregation

```
class Node {                                                    // (1)
    private Object data;    // Data
    private Node next;      // Next node

    // Constructor for initializing data and reference to the next node.
    public Node(Object obj, Node link) {
        data = obj;
        next = link;
    }

    // Accessor methods
    public void setData(Object obj) { data = obj; }
    public Object getData() { return data; }
    public void setNext(Node node) { next = node; }
    public Node getNext() { return next; }
}

class LinkedList {                                              // (2)

    protected Node head = null;
    protected Node tail = null;
    // Modifier methods
    public void insertInFront(Object dataObj) {
        if (isEmpty()) head = tail = new Node(dataObj, null);
        else head = new Node(dataObj, head);
    }
```



```
    public void insertAtBack(Object dataObj) {
        if (isEmpty())
            head = tail = new Node(dataObj, null);
        else {
            tail.setNext(new Node(dataObj, null));
            tail = tail.getNext();
        }
    }
    public Object deleteFromFront() {
        if (isEmpty()) return null;
        Node removed = head;
        if (head == tail) head = tail = null;
        else head = head.getNext();
        return removed.getData();
    }
    // Selector method
    public boolean isEmpty() { return head == null; }
}
class QueueByAggregation {                                      // (3)
    private LinkedList qList;
    // Constructor
    public QueueByAggregation() {
        qList = new LinkedList();
    }
    // Methods
    public void enqueue(Object item) { qList.insertAtBack(item); }
```

```
    public Object dequeue() {
        if (empty()) return null;
        else return qList.deleteFromFront();
    }
    public Object peek() {
        Object obj = dequeue();
        if (obj != null) qList.insertInFront(obj);
        return obj;
    }
    public boolean empty() { return qList.isEmpty(); }
}

class StackByInheritance extends LinkedList {                  // (4)
    public void push(Object item) { insertInFront(item); }
    public Object pop() {
        if (empty()) return null;
        else return deleteFromFront();
    }
    public Object peek() {
        return (isEmpty() ? null : head.getData());
    }
    public boolean empty() { return isEmpty(); }
}
```



```
public class Client {                                           // (5)
    public static void main(String args[]) {
        String string1 = "Queues are boring to stand in!";
        int length1 = string1.length();
        QueueByAggregation queue = new QueueByAggregation();
        for (int i = 0; i<length1; i++)
            queue.enqueue(new Character(string1.charAt(i)));
        while (!queue.empty())
            System.out.print((Character) queue.dequeue());
        System.out.println();

        String string2 = "!no tis ot nuf era skcatS";
        int length2 = string2.length();
        StackByInheritance stack = new StackByInheritance();
        for (int i = 0; i<length2; i++)
            stack.push(new Character(string2.charAt(i)));
        stack.insertAtBack(new Character('!'));                 // (6)
        while (!stack.empty())
            System.out.print((Character) stack.pop());
        System.out.println();

    }
}
```

Output from the program:

```
Queues are boring to stand in!
Stacks are fun to sit on!!
```


Encapsulation

Abstraction and Encapsulation

- In OOSD, *abstraction* for an object comes before its *implementation*.
- *Abstraction* focuses on visible behavior of an object (called the *contract* or *interface*), whereas *encapsulation* focuses on *implementation* which give this behavior.
- Encapsulation helps to make clear the distinction between an object's contract and implementation.
  - Objects are regarded as "black boxes" whose internals are hidden.

A class has 2 *views*:

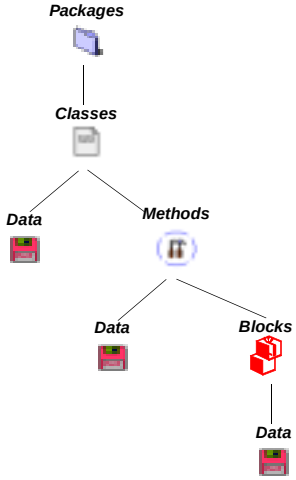
- *Contract* which corresponds to our abstraction of behaviors common to all instances of the class.
  - specification/documentation on how *clients* (i.e. other objects) can use instances of the class, in particular, how each method should be called.
  - WHAT the class offers.
- *Implementation* which corresponds to *representation* of the abstraction and the *mechanisms* which give provide the desired behaviors.
  - comprises of the instance variables and Java instructions which, when executed, give the desired behavior.
  - HOW the class implements its behaviors - *not a concern of the clients*.

This separation of concerns has major implications in system design.

Encapsulation: Consequences for Program Development

- Results in programs that are "black boxes".
- Implementation of an object can change without implications for the clients.
- Reduces dependency between program modules (hence complexity), as the internals of an object are hidden from the clients, who cannot influence its implementation.
- Encourages code-reuse.

Encapsulation Levels



Packages in Java

What is a Package?

- A package in Java is an *encapsulation mechanism* that can be used to group related classes, interfaces and subpackages.
- The *fully qualified name* of a package member is the "containment path" from the root package to the package member, specified using the dot (.) operator.

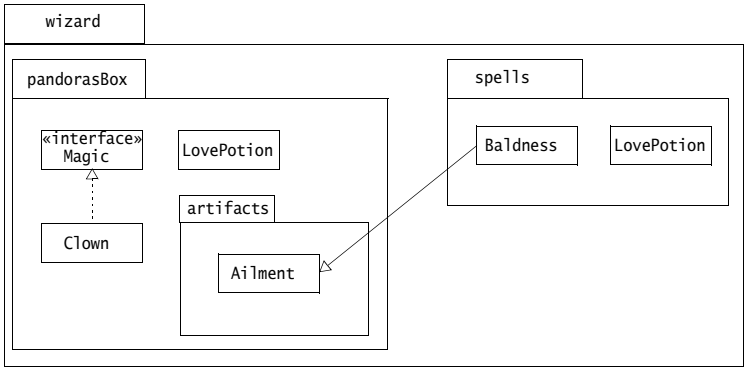


Figure 5 Package Hierarchy

`wizard.pandorasBox.artifacts.Ailment`

`wizard.spells.LovePotion`

`wizard.pandorasBox.LovePotion`

Defining Packages

- A package hierarchy represents the organization of the *Java byte code* of classes and interfaces.
- Each Java source file (also called *compilation unit*) can contain zero or more definitions of classes and interfaces, but the compiler produces a separate *class* file containing the Java byte code for each of them.
- A class or interface can indicate that its Java byte code be placed in a particular package, using a `package` declaration.

  `package` *<fully qualified package name>*;
- At most one `package` declaration can appear in a source file, and it must be the first statement in the compilation unit.

```
// File: Clown.java
package wizard.pandorasBox;              // Package declaration

public class Clown implements Magic {
     LovePotion tlc;
     public static void main(String[] args) { System.out.println("Mamma mia!"); }
}

class LovePotion {/*...*/}

interface Magic {/*...*/}
```


Compiling Packages

- In file `Clown.java`, the statement

  `package wizard.pandorasBox;  // Package declaration`

  instructs the compiler to place the Java byte code for all the classes (and interface) specified in the source file in the package `wizard.pandorasBox`.
- Think of a package name as a *path* in the file system.

  In this case the package name `wizard.pandorasBox` corresponds to the path name `wizard/pandorasBox`.

  So the Java byte code for all the classes (and interface) specified in the source file `Clown.java` will be placed under the catalog `wizard/pandorasBox`.

Question: where is `wizard/pandorasBox`?

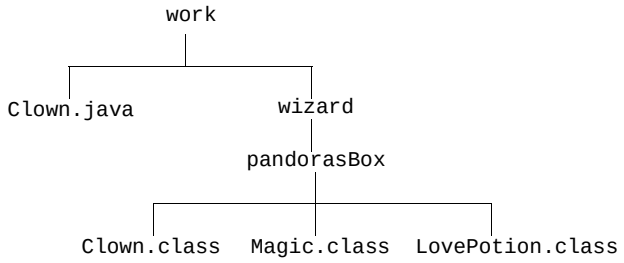
- You can choose the location of `wizard/pandorasBox` by using the `-d` option (`d` for destination) when compiling with `javac`.
- Assume that the current directory is called `work`, and the source code file `Clown.java` is to be found here.
- The command

  `javac -d . Clown.java`

  (Note the dot after the `-d` option to indicate the current directory)

  will create `wizard/pandorasBox` under the current directory, and place the Java byte code for all the classes (and interface) in it.
  - Without the `-d` option, the file `Clown.class` will be placed in the current directory.

Package Location



Question: How do we run the program?

- Since the current directory is `work` and we want to run `Clown.class`, the *full name* of the `Clown` class must be specified in the `java` command:

  ```
  java wizard.pandorasBox.Clown
  ```

- This will now result in the `main()` method from the `wizard.pandorasBox.Clown` class being executed.

Using Packages

- Types in a package must have the right accessibility in order to be referenced from outside the package.
- Given that a type is accessible from outside a package, a type can be accessed in two ways.
  - The first method is to use the fully qualified name of the type.
  - The second method is a short-hand for specifying the fully qualified name of the type, and involves using the `import` declaration.
- The `import` declarations must be the first statement after any `package` declaration in a source file.
- An `import` declaration does not recursively import subpackages.
- The `import` declaration does not result in inclusion of the *source code* of the types.
- The `import` declaration only imports type names.
- Name conflicts can be resolved using variations of the `import` declaration together with fully qualified names.

Individual Type Import:

`import` *<fully qualified type name>*`;`

- The *simple* name of the type (i.e. its identifier) can be used to access this particular type.

Import on Demand:

`import` *<fully qualified package name>*`.*;`

- This allows any types from the specified package to be accessed by its simple name.

```
package wizard.spells;                          // Package declaration
import wizard.pandorasBox.*;                    // Import on demand
import wizard.pandorasBox.artifacts.Ailement;   // Individual type import

class Baldness extends Ailment {                //
      Magic hairyTrick;
      wizard.pandorasBox.LovePotion tlcOne;     // From wizard.pandorasBox package
      LovePotion tlcTwo;                        // From wizard.spells package
}

class LovePotion { /*...*/ }
```

- The `classpath` or `sourcepath` options of the `javac` compiler can be used to indicate the location of the imported classes and interfaces.

Modifiers for Classes and Interfaces

Accessibility Modifiers for Classes and Interfaces

- Top-level classes and interfaces within a package can be specified as `public`.
  - This means that they are accessible from everywhere, both inside and outside of this package.
- The access modifier can be omitted (called *package* or *default accessibility*).
  - In this case they are only accessible in the package, but not in any subpackages.
- If a class is accessible, it does not automatically mean that members of the class are also accessible.
  - Member accessibility is governed separately from class accessibility.
  - However, if the class is not accessible, its members will not be accessible, regardless of member accessibility.

Table 1 Summary of Accessibility Modifiers for Classes and Interfaces

Modifiers	Classes and Interfaces
default (No modifier)	Accessible in its package (package accessibility)
`public`	Accessible anywhere

Example 6 Accessibility Modifiers for Classes and Interfaces

```
// File: Clown.java
package wizard.pandorasBox;               // Package declaration

public class Clown implements Magic {
     LovePotion tlc;
     /*...*/
}

class LovePotion {/*...*/}

interface Magic {/*...*/}


// File: Ailment.java
package wizard.pandorasBox.artifacts;     // Package declaration

public class Ailment {/*...*/}


// File: Client.java
import wizard.pandorasBox.*;               // Import of classes.

public class Client {
    Clown performerOne;                    // OK. Abbreviated class name
    wizard.pandorasBox.Clown performerTwo; // OK. Fully qualified class name

//  LovePotion moreTLC;                    // Error. Not accessible
//  Magic magician;                        // Error. Not accessible
}
```


Other Modifiers for Classes

`abstract` **Classes**

- Any class can be specified with the keyword `abstract` to indicate that it cannot be instantiated.
- A class might choose to do this if the abstraction it represents is so general that it has to be specialized in order to be of practical use.

```
abstract class Vehicle { /* ... */ }    // too general
class Car extends Vehicle { /* ... */ } // more specific
class Bus extends Vehicle { /* ... */ }
```

- A class that has an `abstract` method must be declared `abstract`.
  - Such classes cannot be instantiated, as their implementation is only partial.
  - A class might choose this strategy to dictate certain behavior, but allow its subclasses the freedom to provide the relevant implementation.
  - A subclass which does not provide an implementation of its inherited methods is also abstract.
- *Reference variables of an abstract class can be declared, but an abstract class cannot be instantiated.*

Example 7 Abstract Classes

```
abstract class Light {
    // Instance variables
    int noOfWatts;           // wattage
    boolean indicator;       // on or off
    String location;         // placement

    // Instance methods
    public void switchOn()  { indicator = true; }
    public void switchOff() { indicator = false; }
    public boolean isOn()   { return indicator; }

    // Abstract Instance Method
    abstract public double KWHprice();              // (1) No method-body
}
class TubeLight extends Light {
    // Instance variables
    int tubeLength;
    int color;

    // Implementation of inherited abstract method.
    public double KWHprice() { return 2.75; }       // (2)
}
class Factory {
    TubeLight cellarLight = new TubeLight();        // (3) OK.
    Light spotlight;                                // (4) OK.
//  Light tableLight = new Light();                 // (5) Compile time error.
}
```

Interfaces are abstract.

- Interfaces just specify the method prototypes and not the implementation; they are, by their nature, implicitly abstract, i.e. they cannot be instantiated.
  - Thus specifying an interface with the keyword `abstract` is not appropriate, and should be omitted.

`final` Classes

- A `final` class cannot be extended.
  - Its behavior cannot be changed by subclassing.
  - It marks the lower boundary of its *implementation inheritance hierarchy.*
  - Only a class whose definition is complete (i.e. has implementations of all the methods) can be specified to be `final`.
- A final class must be *complete*, whereas an abstract class is considered *incomplete*.
  - Classes therefore cannot be both abstract and final at the same time.

```
final class TubeLight extends Light {
    // Instance variables
    int tubeLength;
    int color;

    // Implementation of inherited abstract method.
    public double KWHprice() { return 2.75; }
}
```

- The Java API includes many `final` classes, for example `java.lang.String` which cannot be specialized any further by subclassing.

Table 2 Summary of Other Modifiers for Classes and Interfaces

Modifiers	Classes	Interfaces
`abstract`	Class may contain abstract methods, and thus cannot be instantiated.	Implied.
`final`	The class cannot be extended, i.e. it cannot be subclassed.	Not possible.

Modifiers for Members

Scope and Accessibility of Members

- Member scope rules govern where in the program a variable or a method is accessible.
- In most cases, Java provides *explicit modifiers* to control the accessibility of members, but in two areas this is governed by specific *scope rules*:
  - *Class scope for members*
  - *Block scope for local variables*

Class Scope for Members

- Class scope concerns accessing members (including inherited ones) by their simple names from code within a class.
- Accessibility of members from outside the class is primarily governed by the accessibility modifiers.
- Static methods can only access static members.
- *Within a class definition, reference variables of the class's type can access all members regardless of their accessibility modifiers.*

  i.e. if `obj1` and `obj2` are objects of the same class, instance methods of `obj1` can access all members of `obj2`, and vice versa.

Example 8 Class Scope

```
class Light {
    // Instance variables
    private int noOfWatts;          // wattage
    private boolean indicator;      // on or off
    private String location;        // placement

    // Instance methods
    public void switchOn()  { indicator = true; }
    public void switchOff() { indicator = false; }
    public boolean isOn()   { return indicator; }

    public static Light duplicateLight(Light oldLight) {       // (1)
        Light newLight = new Light();
        newLight.noOfWatts = oldLight.noOfWatts;               // (2)
        newLight.indicator = oldLight.indicator;               // (3)
        newLight.location = new String(oldLight.location);     // (4)
        return newLight;
    }
}
```


Block Scope for Local Variables

- Declarations and statements can be grouped into a *block* using braces, {}.
- Note that the body of a method is a block.
- Blocks can be nested and certain scope rules apply to local variable declarations in such blocks.
- A local declaration can appear anywhere in a block.
- *Local variables* of a method are comprised of formal parameters of the method and variables that are declared in the method body.
  - A local variable can exist in different invocations of the same method, with each invocation having its own storage for the local variable.
- The general rule is that a variable declared in a block is *in scope* inside the block in which it is declared, but it is not accessible outside of this block.
  - Block scope of a declaration begins from where it is declared in the block and ends where this block terminates.
  - It is not possible to declare a new variable if a local variable of the same name is already declared in the current scope.

```
public static void main(String args[]) {                  // Block 1
//  String args = "";         // (1) Cannot redeclare parameters.
    char digit;
    for (int index = 0; index < 10; ++index) {             // Block 2
        switch(digit) {                                    // Block 3
            case 'a':
                int i;        // (2)
            default:
//              int i;        // (3) Already declared in the same block.
        } // switch
        if (true) {                                        // Block 4
            int i;            // (4) OK
//          int digit;        // (5) Already declared in enclosing block 1.
//          int index;        // (6) Already declared in enclosing block 2.
        } //if
    } // for
    int index;                // (7) OK
} // main
```

Figure 6 Block Scope

Member Accessibility Modifiers

- Accessibility modifiers for members help a class to define a *contract* so that clients know exactly what services are offered by the class.
- Accessibility of members can be one of the following (in the order of decreasing accessibility):
  - `public`
  - `protected`
  - default (also called *package accessibility*)
  - `private`
- In UML notation, `+` , `#` and `-` as prefix to the member name indicates `public`, `protected` and `private` member access respectively, whereas no prefix indicates default or package access.

`public` Members

- Public access is the least restrictive of all the access modifiers.
- A `public` member is accessible everywhere, both in its class's package and in other packages where its class is visible.
  - This is true for both instance and static members.
- *Subclasses can access their inherited public members directly, and all clients can access `public` members through an instance of the class.*

Example 9 Public Accessibility of Members

```
// Filename: SuperclassA.java                              (1)
package packageA;
public class SuperclassA {
    public int superclassVarA;                        // (2)
    public void superclassMethodA() {/*...*/}         // (3)
}
class SubclassA extends SuperclassA {
    void subclassMethodA() { superclassVarA = 10; }  // (4) OK.
}
class AnyClassA {
    SuperclassA obj = new SuperclassA();
    void anyClassMethodA() {
        obj.superclassMethodA();                      // (5) OK.
    }
}
```

```
// Filename: SubclassB.java                          (6)
package packageB;
import packageA.*;
public class SubclassB extends SuperclassA {
    void subclassMethodB() { superclassMethodA(); }  // (7) OK.
}
class AnyClassB {
    SuperclassA obj = new SuperclassA();
    void anyClassMethodB() {
        obj.superclassVarA = 20;                     // (8) OK.
    }
}
```

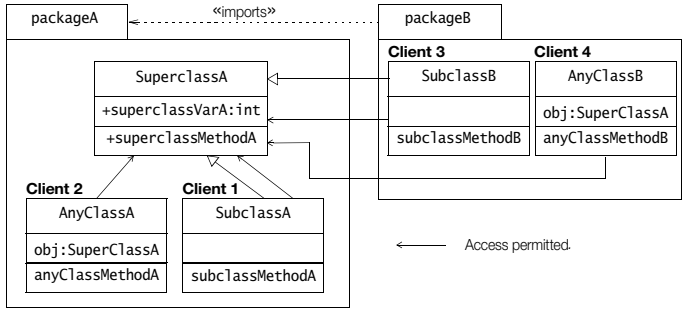



Figure 7 Public Accessibility

`protected` Members

- Protected members are accessible in the package containing this class, and by all subclasses of this class in any package where this class is visible.
  - In other words, non-subclasses in other packages cannot access protected members from other packages.
- *It is less restrictive than the default accessibility.*

```
public class SuperclassA {
    protected int superclassVarA;                    // (2)
    protected void superclassMethodA() {/*...*/}     // (3)
}
```

- Client 4 in package `packageB` cannot access these members, as shown in Figure 8.

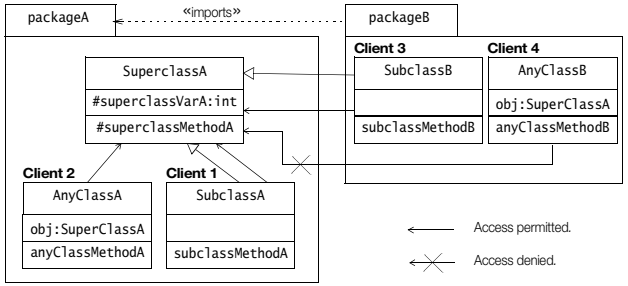


Figure 8 Protected Accessibility

- *A subclass in another package can only access protected members in the superclass via references of its own type or a subtype.*

```
//...
import packageA.*;
//...
public class SubclassB extends SuperclassA {          // In packageB.

    SuperclassA objRefA = new SubclassB();            // (1)
    SubclassB objRefB = new SubclassB();              // (2)

    void subclassMethodB() {
        objRefB.superclassMethodA();                  // (3) OK.
        objRefA.superclassVarA;                       // (4) Not OK.
    }
}
```

- The above restriction helps to ensure that subclasses in packages different from their superclass can only access protected members of the superclass in their part of the inheritance hierarchy.

Default Accessibility for Members

- When no access modifier is specified for a member, it is only accessible by another class in the package where its class is defined.
- Even if its class is visible in another (possibly nested) package, the member is not accessible there.

```
public class SuperclassA {
    int superclassVarA;                               // (2)
    void superclassMethodA() {/*...*/}                // (3)
}
```

- The clients in package `packageB` (i.e. Clients 3 and 4) cannot access these members.

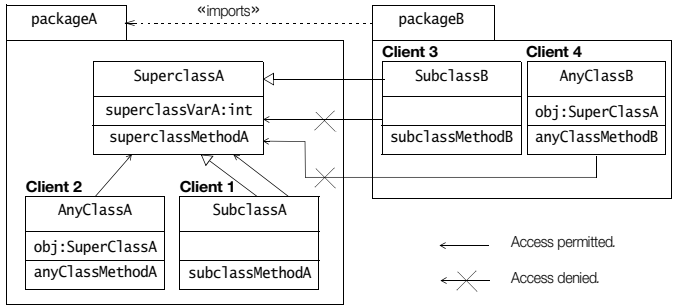


Figure 9 Default Accessibility

`private` Members

- This is the most restrictive of all the access modifiers.
- Private members are not accessible from any other class.
  - This also applies to subclasses, whether they are in the same package or not.
- It is not to be confused with inheritance of members by the subclass.
  - Members are still inherited, but they are not accessible in the subclass.
- *It is a good design strategy to make all member variables private, and provide public accessor methods for them.*
- Auxiliary methods are often declared private, as they do not concern any client.

```
public class SuperclassA {
    private int superclassVarA;                       // (2)
    private void superclassMethodA() {/*...*/}        // (3)
}
```

- None of the clients in Figure 10 can access these members.

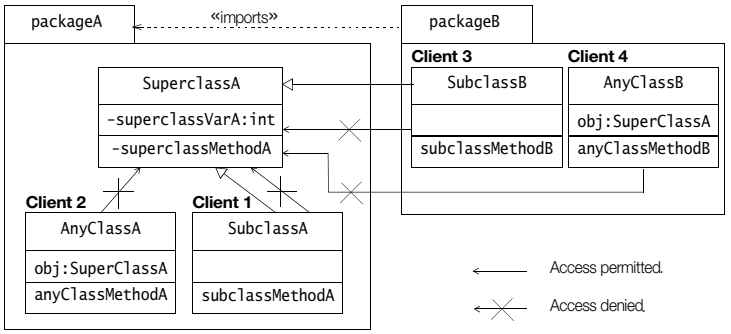


Figure 10 Private Accessibility

*Table 3 Summary of **Accessibility** Modifiers for Members*

Modifiers	Members
`public`	Accessible everywhere.
`protected`	Accessible by any class in the same package as its class, and accessible only by subclasses of its class in other packages.
default (no modifier)	Only accessible by classes, including subclasses, in the same package as its class (package accessibility).
`private`	Only accessible in its own class and not anywhere else.

Other Modifiers for Members

Table 4 Summary of Other Modifiers for Members

Modifiers	Variables	Methods
`static`	Defines a class variable.	Defines a class method.
`final`	Defines a constant.	The method cannot be overridden.
`abstract`	Not relevant.	No method body is defined. Its class is then implicitly abstract.

`static` Members

Static variables

- They only exist in the class they are defined in.
- They are not instantiated when an instance of the class is created.
- When the class is loaded, static variables are initialized to their default values if no other explicit initialization is provided.

Static methods

- A static method in a class can directly access other static members in the class.
- It cannot access instance (i.e. non-static) members of the class, as there is no object being operated on when a static method is invoked.
- Note, however, that a static method in a class can always use a reference of the class's type to access its members, regardless of whether these members are static or not.
- A typical static method might perform some task on behalf of the whole class and/or for objects of the class.

Example 10 Accessing Static Members

```
class Light {
    // Instance variables
    int noOfWatts;          // wattage
    boolean indicator;      // on or off
    String location;        // placement

    // Static variable
    static int counter;     // No. of Light objects created.        (1)

    // Explicit Default Constructor
    Light() {
        noOfWatts = 50;
        indicator = true;
        location = new String("X");
        ++counter;          // Increment counter.
    }

    // Static method
    public static void writeCount() {
         System.out.println("Number of lights: " + counter);      // (2)

         // Error. noOfWatts is not accessible
         // System.out.println("Number of Watts: " + noOfWatts);  // (3)

    }
}
```



```
public class Warehouse {
    public static void main(String args[]) {                    // (4)

        Light.writeCount();                         // Invoked using class name

        Light aLight = new Light();                 // Create an object
        System.out.println(
            "Value of counter: " + Light.counter    // Accessed via class name
        );
        Light bLight = new Light();                 // Create another object
        bLight.writeCount();                        // Invoked using reference
        Light cLight = new Light();                 // Create another object
        System.out.println(
            "Value of counter: " + cLight.counter // Accessed via reference
        );

    }
}
```

Output from the program:

```
Number of lights: 0
Value of counter: 1
Number of lights: 2
Value of counter: 3
```


`final` Members

Final Variables

- A `final` *variable* is a constant, and its value cannot be changed once it's initialized.
- Note that a `final` variable need not be initialized at its declaration, but it must be initialized once before it is used.
- These variables are also known as *blank final variables*.
- *Instance, static and local variables, including parameters* can be declared `final`.
- For `final` variables of primitive datatypes, it means that, once the variable is initialized, its value cannot be changed.
- For a `final` variable of a reference type it means that its reference value cannot be changed, but the state of the object it references may be changed.
- `Final` static variables are commonly used to define *manifest constants*, for example `Integer.MAX_VALUE`, which is the maximum `int` value.
- Variables defined in an interface are implicitly `final`.

Final Methods

- A `final` method in a class is complete (i.e. has an implementation) and cannot be overidden in any subclass.
- Subclasses are restricted in changing the behavior of the method.
- `Final` variables ensure that values cannot be changed, and `final` methods ensure that behavior cannot be changed.

- For `final` members, the compiler is able to perform certain code optimizations because certain assumptions can be made about such members.

Example 11 Accessing Final Members

```
class Light {
    // Final static variable                    (1)
    final public static double KWH_PRICE = 3.25;

    int noOfWatts;

    // Final instance methods                   (2)
    final public void setWatts(int watt) {
         noOfWatts = watt;
    }

    public void setKWH() {
      // KWH_PRICE = 4.10;                  // (3) Not OK. Cannot be changed.
    }
}
class TubeLight extends Light {
    // Final method cannot be overriden.
    // This will not compile.
    /*
    public void setWatts(int watt) {       // (4) Attempt to override.
         noOfWatts = 2*watt;
    }
    */
}
```



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

        final Light aLight = new Light();// (5) Final local variable.
        aLight.noOfWatts = 100;          // (6) OK. Changing object state.
    //  aLight = new Light();            // (7) Not OK. Changing final reference.
    }
}
```


`abstract` Methods

- An abstract method has the following syntax:

  `abstract` ... <*return type*> <*method name*> (<*parameter list*>) <*throws clause*>;
- An abstract method does not have an implementation, i.e. no method body is defined for an `abstract` method, only the method prototype is provided in the class definition.
- Its class is then `abstract` (i.e. incomplete) and must be explicitly declared as such.
  - Subclasses of its class are then forced to provide the method implementation.
- A `final` method cannot be `abstract` (i.e. cannot be incomplete), and vice versa.
- Methods specified in an interface are implicitly `abstract`, as only the method prototypes are defined in an interface.

OOP (Object-oriented Programming)

OOP is an implementation methodology,

where a program is organized as a collection of co-operating ***objects****,*

where each object is ***an instance of a class****, and*

where all classes are members in a hierarchy of classes based on ***inheritance*** *relationships.*

- If the last criteria is not fulfilled, the implementation methodology is called *OBP* (*Object-based Programming*).
- One major consequence of OOP is that it promotes *code-reuse*, i.e. that classes can be "recycled".

Data + Methods = Objects