Similar, yet Different, Concepts

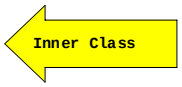
- Inner classes
- Inheritance
- Both are based on hierarchical ("tree-like") structures

Inner Classes

- In Java (and C++), classes can be nested within one another.
- Objects in the inner class has available instance variables and methods of the outer class.

Ways to Construct ClosedList

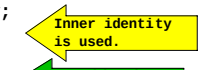
- ```
  class Cell {…}
  class ClosedList {…}
  ```
- ```
  class ClosedList
  {
    class Cell {…}
    ...
  }
  ```

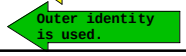


Interpretation of Identifiers

- In an inner class, the innermost meaning of an identifier applies.

```
class ClosedList
{
  String identity;
  class Cell
   {
   String identity;
   ...
   }
  ...
}
```





Usage

- Normally one or more objects of the inner class are created for a given object of the outer class.
- Objects of the inner class only make sense in the context of a supporting object of the outer class.

Exporting Inner Objects

- Inner objects *can* be used outside, understanding that they are always *relative* to the object in which they are contained.

Example: List Iterator

- We want to define an Iterator for a ClosedList.
- For read-only Iteration, the Iterator class can be defined outside the ClosedList class.
- For modification, such as **`remove()`**, it is sometimes necessary for the Iterator to *change* part of the list itself.

Example: List Iterator (2)

- By making the **`ListIterator`** an inner class, we can:
  - Use data elements defined in the **`ClosedList`**.
  - Avoid exposing those data elements to the world at large.
  - Use Iterators outside **`ClosedList`**.

ClosedList.Iterator

```
class ClosedList
{
private Cell head;
private Cell tail;
…
public Iterator getIterator()
  {
  return new Iterator(head);
  }

public class Iterator // inner class to ClosedList
  {
  private Cell current;
  private Cell previous;      // keep track of previous

  public Iterator(Cell head)
    {
    current = head;
    previous = null;
    }
    ...
```

Can export Iterator to outside!

ClosedList.Iterator: remove()

Defined to remove the value just produced by next().

```
public void remove()
   {
   if( previous == null )
     {
     head = head.getNext();
     }
   else
     {
     previous.setData(current.getData());  // reuse
     previous.setNext(current.getNext());  // previous
     current = previous;                   // lose current
     }
   }
```

head is defined in outer class!

Aside: Converting a list to a String (e.g. for printing entire list at once)

```
public String toString()
  {
  StringBuffer buffer = new StringBuffer();
  Iterator it = new Iterator(head);
  if( it.hasNext() )
    {
    buffer.append(it.next()); // first element
    }

  while( it.hasNext() )
    {
    buffer.append(" " + it.next()); // leave space
    }
  return buffer.toString();
  }
```

Test Program

```
class ClosedListTest
{
public static void main(String arg[])
  {
  int numItems = 10;
  ClosedList L = new ClosedList();

  for( int i = 0; i < numItems; i++ )
    {
    L.enqueue(new Integer(i));
    }

  ClosedList.Iterator it = L.getIterator();

  System.out.println("removing " + it.next());
  it.remove();  // remove first item
}
```

Test Program

```
class ClosedListTest
{
public static void main(String arg[])
  {
  int numItems = 10;
  ClosedList L = new ClosedList();

  // add 10 items to L

  for( int i = 0; i < numItems; i++ )
    {
    L.enqueue(new Integer(i));
    }

  System.out.println("Initial list contents: " + L);

  // starting from the beginning, skip 3 items

  ClosedList.Iterator it = L.getIterator();

  for( int i = 0; i < 3; i++ )
    {
    System.out.println("skipping " + it.next());
    }

  // remove 2 items

  System.out.println("removing " + it.next());
  it.remove();

  System.out.println("removing " + it.next());
  it.remove();

  System.out.println("List contents after removing two: " + L);

  for( int i = 0; i < 3; i++ )
    {
    System.out.println("skipping " +it.next());      // ignore value
    }

  // insert 3 items

  for( int i = 0; i < 3; i++ )
    {
    int value = 10*(i+1);
    System.out.println("inserting " + value);
    it.insert(new Integer(value));
    }

  System.out.println("List contents after inserting three: " + L);
  }
}
```

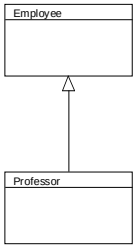
Test Program Output

```
Initial list contents: 0 1 2 3 4 5 6 7 8 9
skipping 0
skipping 1
skipping 2
removing 3
removing 4
List contents after removing two: 0 1 2 5 6 7 8 9
skipping 5
skipping 6
skipping 7
inserting 10
inserting 20
inserting 30
List contents after inserting three: 0 1 2 5 6 7 10 20 30 8 9
```

Inheritance

- "Inheritance" is a way of building one class on top of another
  - The original class is called the **base class,** or **parent class**.
  - The new class is called the **derived class**, or **child class.**

Diagrammatic Notation (UML)



class Professor
extends
class Employee

UML = Unified Modeling Language

Inherited Capabilities

- **Extension**:
  The derived class can potentially use all data components and methods from the base class, and add more of its own.
- **Over-Riding:**
  It can also selectively re-define or "over-ride" methods of the same name.

Purposes of Inheritence

- Use the same concepts and code for many classes (base-class concepts and code shared by derived classes):
  - Work economy
  - Intellectual economy
- Tie together similar classes:
  - Increases the utility of methods that **use** such classes.

Extension = Java Inheritance

- In Java, the keyword for "inherits from" is **extends**
- The derived class *extends* the base class.
- Extension allows over-riding as well; there is no separate keyword for over-riding.

Extension Example

- class **Account** defines a basic bank account
- class **CheckingAccount** defines a special account for check-writing

```
class Account
{
Money balance;

Account(Money initialBalance)
  {
  balance = initialBalance;
  }

void deposit(Money amount)
  {
  balance = balance.add(amount);
  }

boolean withdraw(Money amount)
  {
  if( balance.lessThan(amount) )
    return false;
  balance = balance.subtract(amount);
  return true;
  }

void showBalance(PrintStream out)
  {
  out.println("Balance: " + balance);
  }
```

Only allow withdrawal if sufficient funds; return boolean to indicate success or failure.

```
class CheckingAccount extends Account
{
Money serviceCharge;

CheckingAccount(Money initialBalance, Money serviceCharge)
  {
  super(initialBalance);
  this.serviceCharge = serviceCharge;
  }

boolean cashCheck(Money amount)
  {
  return withdraw(amount.add(serviceCharge));
  }

(continued next page)
```

Additional variable for the derived class.

"super" means "the constructor of the base class".

Added service charge

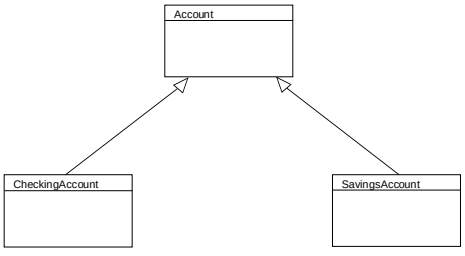
```
(program continued)

 public static void main(String arg[])
 {
 CheckingAccount myCheckingAccount =
   new CheckingAccount(new Money(10000),
                       new Money(100));

 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.deposit(new Money(5000));
 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.cashCheck(new Money(2000));
 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.cashCheck(new Money(1000));
 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.withdraw(new Money(1000));
 myCheckingAccount.showBalance(System.out);
 }
}
```

Program Output

```
Balance: $100.0
Balance: $150.0
Balance: $129.0
Balance: $118.0
Balance: $108.0
```

(Link to the complete program: **Bank**)

Multiple derived classes



Which methods can be over-ridden?

- In order to be over-ridden, a method must be declared either:
  - **`public`**
  - **`protected`**

in the base class.

Inheritance Examples from Java Libraries

class java.lang.Object

class java.util.AbstractCollection (implements java.util.Collection)

class java.util.AbstractList (implements java.util.List)

class java.util.AbstractSequentialList

extends class java.util.LinkedList (implements java.util.List)

class java.util.ArrayList (implements java.util.List)

class java.util.Vector (implements java.util.List)

class java.util.Stack

Implications of Inheritance

- The preceding diagram means, for example, that to find all methods for class java.util.Stack, you may wish to look at:
  - java.util.Vector
  - java.util.AbstractList
  - java.util.AbstractCollection
  - java.lang.Object

Methods of java.util.Stack

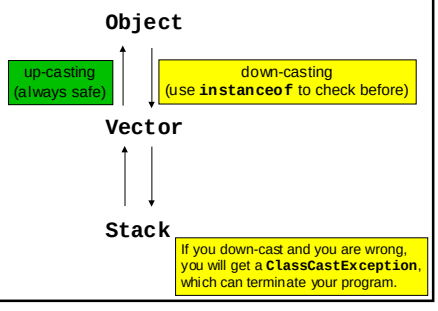
- Methods of Stack proper:
  - boolean empty()
  - Object peek()
  - Object pop()
  - Object push(Object item)
  - int search(Object o)
- Methods of Vector:
  - add, add, addAll, addAll, addElement, capacity, clear, clone, contains, containsAll, copyInto, elementAt, elements, ensureCapacity, equals, firstElement, get, hashCode, indexOf, insertElementAt, isEmpty, lastElement, lastIndexOf, remove, removeAll, removeAllElements, removeElement, removeElementAt, removeRange, retainAll, set, setElementAt, setSize, size, subList, toArray, toString, trimToSize
- Methods of AbstractList:
  - iterator, listIterator
- Methods of Object (not otherwise over-ridden)
  - finalize, getClass, notify, notifyAll, wait

Testing where Object is in Hierarchy

- *instanceof* operator

```
Object ob = …;

if( ob instanceof Vector ) …
if( ob instanceof Stack ) …
```

Casting



class *Object*

- Object is the ancestor of all classes
- Some methods of Object:
  - boolean equals(Object)
  - Class getClass(): returns a Class object
  - String toString()
- Method of class Class:
  - String getName()

Implementing an Interface is similar to Inheritance

- Interface ≈ Base Class
- Implementor ≈ Derived Class
- By declaring methods to use the Interface rather than the Implementor class as an argument, more **generality** is afforded to that method.

Example

- `java.util.Iterator` is standard
- Make `ClosedList.Iterator` implement `java.util.Iterator`
- Any other code accepting a `java.util.Iterator` can now use our:
  `ClosedList.Iterator`
- We can *still* do everything we did before.

Morals

- When possible, write your methods to use Interfaces rather than classes.
- Define Interfaces for your classes, on which others can depend.
- Ideally, define the Interfaces first.