OBJECT-ORIENTED LANGUAGE AND THEORY

8. POLYMORPHISM

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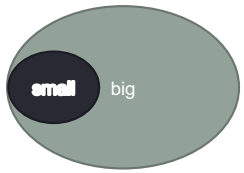
Outline

1. Upcasting and Downcasting
2. Static and dynamic bindings
3. Polymophism
4. Generic programming

2

Primitive data

- Upcasting:
  - small to big range
  - implicitly cast
  - e.g. byte => short => int => double
  - byte b = 2;
  - short s = b;
- Downcasting
  - big to small
  - explicitly cast
  - e.g. int => short
  - (short)



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1.1. Upcasting

- Moving up the inheritance hierarchy
- Up casting is the capacity to view an object of a derived class as an object of its base class.
- Automatic type conversion (implicitly)

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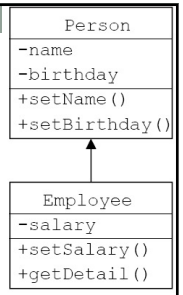
Example




```
public class Test1 {
 public static void main(String arg[]){
      Person p;
      Employee e = new Employee();
      p = e; //upcasting
      p.setName("Hoa");
      p.setSalary(350000); // compile error

      Employee e1 = (Employee) p; //downcasting
      e1.setSalary(350000); //ok
 }
```

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Example (2)

```
class Manager extends Employee {
 Employee assistant;
 // ...
 public void setAssistant(Employee e) {
      assistant = e;
 }
 // ...
}
public class Test2 {
 public static void main(String arg[]){
      Manager junior, senior;
      // ...
      senior.setAssistant(junior);
 }
}
```

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Example (3)

```
public class Test3 {
 String static teamInfo(Person p1, Person p2){
      return "Leader: " + p1.getName() +
             ", member: " + p2.getName();
 }

 public static void main(String arg[]){
      Employee e1, e2;
      Manager m1, m2;
      // ...
      System.out.println(teamInfo(e1, e2));
      System.out.println(teamInfo(m1, m2));
      System.out.println(teamInfo(m1, e2));
 }
}
```

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1.2. Downcasting

- Move back down the inheritance hierarchy
- Down casting is the capacity to view an object of a base class as an object of its derived class.
- Does not convert types automatically

  → Must cast types explicitly.

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Example

```
public class Test2 {
   public static void main(String arg[]) {
      Employee e = new Employee();
      Person p = e; // upcasting
      Employee ee = (Employee) p; // downcasting
      Manager m = (Manager) ee; // run-time error

      Person p2 = new Manager();
      Employee e2 = (Employee) p2;

      Person p3 = new Employee();
      Manager e3 = (Manager) p3;
   }
}
```


Outline

1. Upcasting and Downcasting
2. Static and dynamic bindings
3. Polymophism
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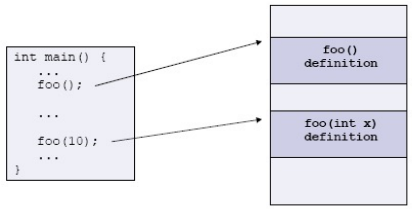
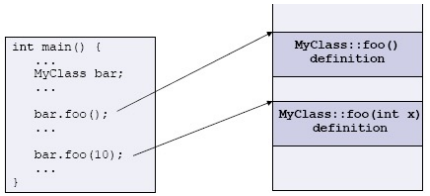
Function call binding

- Function call binding is a procedure to **specify the piece of code that need to be executed** when calling a function
- E.g. C language: a function has a unique name



OOP languages (method call binding)

- For independent classes (are not in any inheritance tree), the procedure is almost the same as function call binding
  - Compare function name, argument list to find the corresponding definition

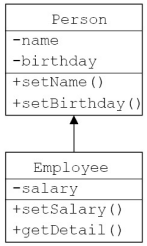


2.1. Static Binding

- Binding at the compiling time
  - Early Binding/Compile-time Binding
  - Function call is done when compiling, hence there is only one instance of the function
  - Any error will cause a compiling error
  - Advantage of speed
- C/C++ function call binding, and C++ method binding are basically examples of static function call binding

Example

```
public class Test {
 public static void main(String arg[]){
      Person p = new Person();
      p.setName("Hoa");
      p.setSalary(350000); //compile-time error
 }
}
```



Static binding in Java

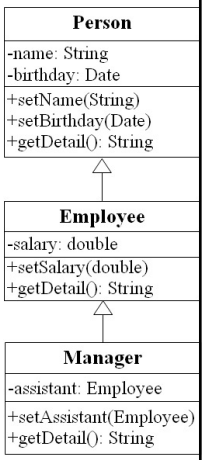
```
class Human {
    public static void walk() {
        System.out.println("Human walks");
    }
}
public class Boy extends Human {
    public static void walk() {
        System.out.println("Boy walks");
    }
    public static void main(String args[]) {
        // Reference is of Human type and object is Boy type
        Human obj1 = new Boy();

        // Reference is of Human type and object is Human type.
        Human obj2 = new Human();

        // Reference is of Human type and object is Human type.
        Boy obj3 = new Boy();

        obj1.walk();
        obj2.walk();
        obj3.walk();

        obj1 = obj3;
        obj1.walk();
    }
}
```


2.2. Dynamic binding

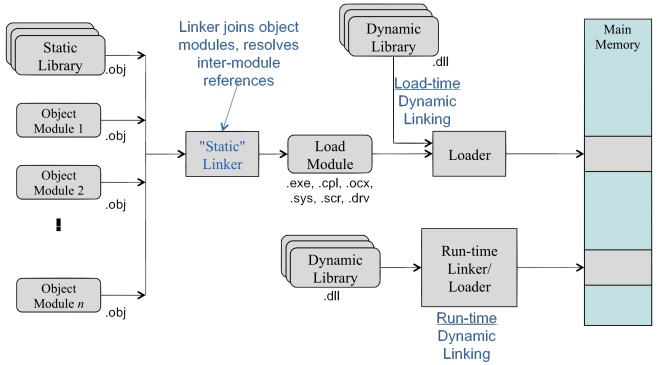
- The method call is done at run-time
  - Late binding/Run-time binding
  - Instance of method is suitable for called object.
  - Java uses dynamic binding by default

Example

```
public class Test {
  public static void main(String arg[]){
    Person p = new Person();
     // ...
    Employee e = new Employee();
    // ...
    Manager m = new Manager();
     // ...
    Person pArr[] = {p, e, m};//upcasting
    for (int i=0; i< pArr.length; i++){
      System.out.println(
            pArr[i].getDetail());
    }
  }
}
```



Linker and Loader



Outline

1. Upcasting and Downcasting
2. Static and dynamic bindings
3. Polymorphism
4. Generic programming

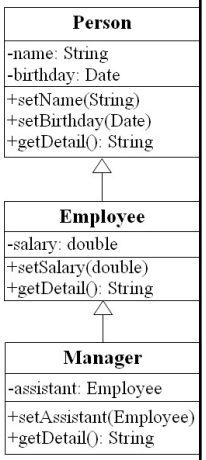
3. Polymorphism

- Polymorphism: multiple ways of performance, of existance
- Polymorphism in OOP
  - Method polymorphism:
    - Methods with the same name, only difference in argument lists => method overloading
  - Object polymorphism
    - **Multiple types:** A single object to represent multiple different types (upcasting and downcasting)
    - **Multiple implementations/behaviors:** A single interface to objects of different types (upcasting+overriding – dynamic binding)

3. Polymophism (2)

- A single symbol to represent multiple different types
  → Upcasting and Downcasting

```
public class Test3 {
  public static void main(String args[]){
    Person p1 = new Employee();
    Person p2 = new Manager();

    Employee e = (Employee) p1;
    Manager m = (Manager) p2;
  }
}
```



3. Polymophism (5)

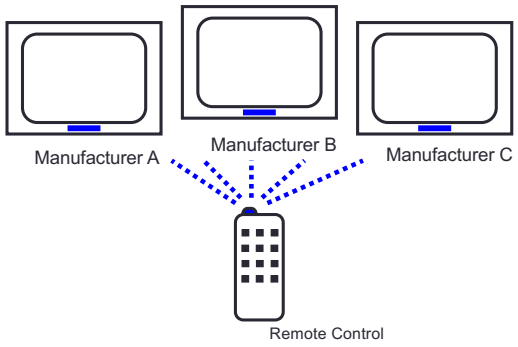
- A single interface to entities of different types
  →Dynamic binding (Java)

- Example:

```
Person p1 = new Person();
Person p2 = new Employee();
Person p3 = new Manager();
// ...
System.out.println(p1.getDetail());
System.out.println(p2.getDetail());
System.out.println(p3.getDetail());
```


Why Polymorphism?

- The ability to hide many different implementations behind a single interface

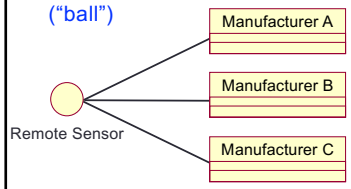


- interface TVInterface {
  public void turnOn();
  public void volumnUp(int steps);
  …
- }
- class TVA implements TVInterface {
  public void turnOn() { … }
  …
- }
- class TVB implements TVInterface {…}
- class TVC implements TVInterface {…}
- class RemoteControl {
  TVInterface tva = new TVA(); tva.turnOn(); tva.volumnUp(2);
  TVInterface tvb = new TVB(); tvb.turnOn(); tvb.volumnUp(2);
  TVInterface tvc = new TVC(); tvc.turnOn(); tvc.volumnUp(2);
- }

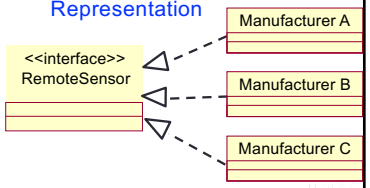
What Is an Interface?

- A declaration of a coherent set of public features and obligations
  - A contract between providers and consumers of services

Elided/Iconic Representation ("ball")



Canonical (Class/Stereotype) Representation



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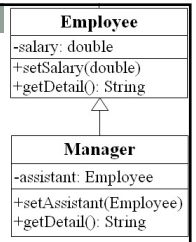
Other examples




```
class EmployeeList {
  Employee list[];
  ...
  public void add(Employee e) {...}
  public void print() {
     for (int i=0; i<list.length; i++) {
           System.out.println(list[i].getDetail());
     }
}
 ...
  EmployeeList list = new EmployeeList();
  Employee e1; Manager m1;
  ...
  list.add(e1); list.add(m1);
  list.print();
```

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Operator instanceof

```
public class Employee extends Person {}
public class Student extends Person {}

public class Test{
  public doSomething(Person e) {
   if (e instanceof Employee) {...
   } else if (e instanceof Student) {... ){
   } else {...}
  }
}
```

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Static methods

- Static methods in Java are inherited, but can not be overridden.
- If you declare the same method in a subclass, you hide the superclass method instead of overriding it.
- Static methods are not polymorphic. At the compile time, the static method will be statically linked

```
Writing
Writing
Writing
Writing book
```

```
public class Writer {
   public static void write() {
      System.out.println("Writing");
   }
}

public class Author extends Writer {
   public static void write() {
      System.out.println("Writing book");
   }
}

public class Programmer extends Writer {
   public static void write() {
      System.out.println("Writing code");
   }
   public static void main(String[] args) {
      Writer w = new Programmer();
      w.write();

      Writer secondWriter = new Author();
      secondWriter.write();

      Writer thirdWriter = null;
      thirdWriter.write();

      Author firstAuthor = new Author();
      firstAuthor.write();
   }
}
```

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Static method

```
package a;

class Writer {
   public static void write() {
      System.out.println("Writing");
   }
}

public class Author extends Writer {
   public static void main(String[] args) {
      Author a = new Author();
      a.write();
   }
}
```

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Outline

1. Upcasting and Downcasting
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4. Generic programming

- Generalizing program so that it can work with different data types, including some future data types
  - Algorithm is already defined
- Example:
  - C: using pointer void
  - C++: using template
  - Java: take advantage of upcasting
  - Java 1.5: Template

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Example: C using void pointer

- Memcpy function:

```
void* memcpy(void* region1,
             const void* region2, size_t n){
  const char* first = (const char*)region2;
  const char* last = ((const char*)region2) + n;
  char* result = (char*)region1;
  while (first != last)
     *result++ = *first++;
  return result;
}
```

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Example: C++ using template

When using, we can replace ItemType by int, string,… or any object of any class

```
template<class ItemType>
void sort(ItemType A[], int count ) {
  // Sort count items in the array, A, into increasing order
  // The algorithm that is used here is selection sort
  for (int i = count-1; i > 0; i--) {
    int index_of_max = 0;
     for (int j = 1; j <= i ; j++)
        if (A[j] > A[index_of_max]) index_of_max = j;
     if (index_of_max !=  i) {
       ItemType temp = A[i];
       A[i] = A[index_of_max];
       A[index_of_max ] = temp;
     }
  }
}
```

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Example: Java using upcasting and Object

```
class MyStack {
 ...
 public void push(Object obj) {...}
 public Object pop() {...}
}
public class TestStack{
 MyStack s = new MyStack();
 Point p = new Point();
 Circle c = new Circle();
 s.push(p); s.push(c); //upcasting
 Circle c1 = (Circle) s.pop(); //downcasting
 Point p1 = (Point) s.pop(); //downcasting
}
```

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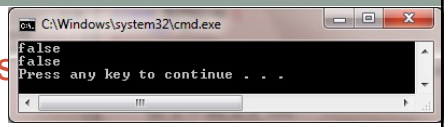
Recall – equals




```
class MyValue {
 private int number;
 public MyValue(int number){this.number = number;}
 public boolean equals(Object obj){

 }
 public int getNumber(){return number;}
}
public class EqualsMethod2 {
 public static void main(String[] args) {
   MyValue v1 = new MyValue(100);
   MyValue v2 = new MyValue(100);
   System.out.println(v1.equals(v2));
   System.out.println(v1==v2);
 }
```

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Exercise

- Re-write method **equals** for the class **MyValue** (this method is inherited from the class Object)

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```
class MyValue {
 int i;
 public boolean equals(Object obj) {
      return (this.i == ((MyValue) obj).i);
 }
}
public class EqualsMethod2 {
 public static void main(String[] args) {
   MyValue v1 = new MyValue();
   MyValue v2 = new MyValue();
   v1.i = v2.i = 100;
   System.out.println(v1.equals(v2));
   System.out.println(v1==v2);
 }
}
```

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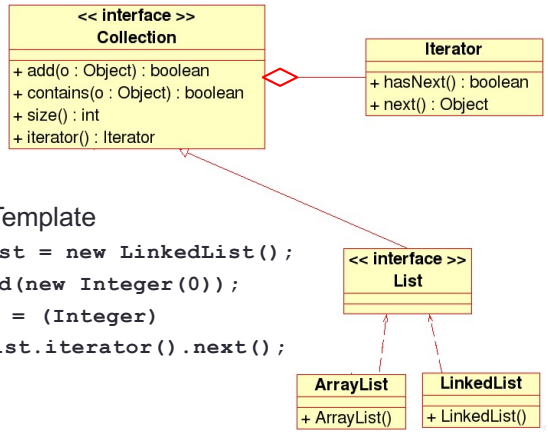
Example: Java 1.5: Template



- Without Template

```
List myList = new LinkedList();
myList.add(new Integer(0));
Integer x = (Integer)
      myList.iterator().next();
```

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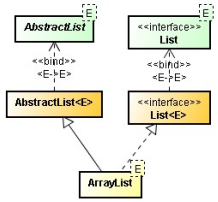
Example: Java 1.5: Template (2)

- Using Template:

```
List<Integer> myList = new LinkedList<Integer>();
myList.add(new Integer(0));
Integer x = myList.iterator().next();

//myList.add(new Long(0)); → Compile error
```



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4.1. Java collections framework

- Collection is a object that can contain other objects.
- Basic operations on a collection
  - Add/remove object to/from the collection
  - Check if an object is in the collection
  - Take an object out of the collection
  - Iretate on the collections
  - Remove all items from the collection

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4.1. Java Collections Framework

- Collections Framework (since Java 1.2)
  - Is the consistent architecture to represent a collection and the operations on it.
  - Make the collection interface independent with their implementation.

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4.1. Java Collections Framework

- Advantages:
  - Reduce the programming time
  - Increase the performent
  - Can develop further collections
  - Foster code reuse

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4.1. Java Collections Framework

- Collections Framework includes
  - Interfaces: the interface of different types of collection, e.g., List, Set, Map.
  - Implementations: are the available implemented collections that follow the collection interfaces.
  - Algorithms: are the operation on the collection, e.g., sort, find the maximum elements, etc.

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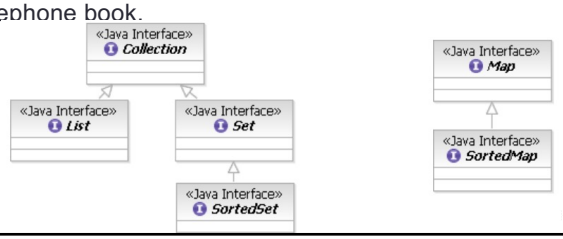
Availble collections

- Collection: a collection of objects
  - List: a collection of objects that are sequential, consecutive and repeatable
  - Set: a collection of objects that are not repeatable
- Map: Collection of key-value pairs (key is unique)
  - Linking objects in this set to other sets as a dictionary/a telephone book.



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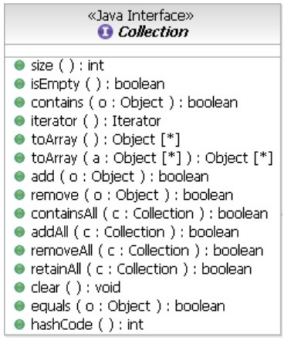
a. Interface of Collection

- Specifies basic interface for manipulating a set of objects
  - Add to collection
  - Remove from collection
  - Check if existing
- Contains methods to manipulate individual objects or a set of objects
- Provide methods to traverse objects in a repeatable collection and convert a collection to an array



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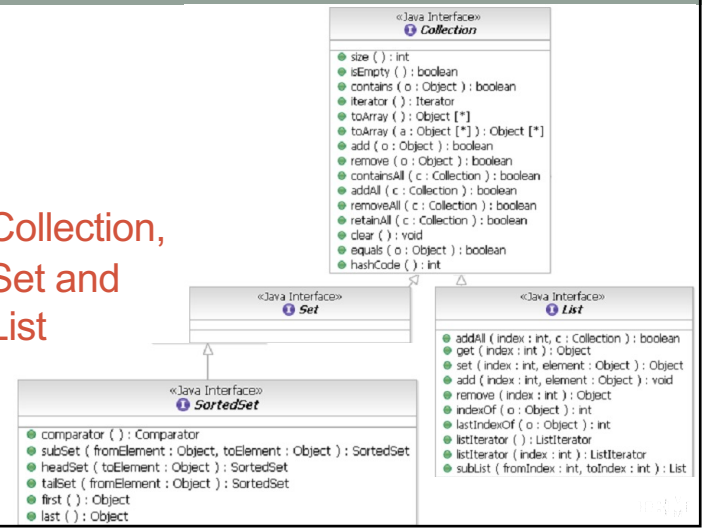
Collection, Set and List



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b. Interface of Map

- A basic interface for manipulating a set of pairs key-value
  - Add a pair key-value
  - Remove a pair key-value
  - Get a value of a given key
  - Check if existing (key or value)
- 3 views for the content of collections:
  - Key collection
  - Value collection
  - Mapping collection of key-value

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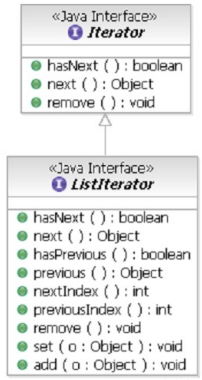
c. Iterator

- Provide a mechanism to visit (repeat) all the members of a collection
  - Similar to SQL cursor
- ListIterator has methods to show the sequential attribute of the basic list
- Iterator of a sorted collection will visit in the sorting order



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Source code for Iterator

```
Collection c;
// Some code to build the collection

Iterator i = c.iterator();
while (i.hasNext()) {
 Object o = i.next();
 // Process this object
}
```

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Interface and Implementation

- Set<String> mySet = new TreeSet<String>();
- Map<String,Integer> myMap = new HashMap<String,Integer>();

		IMPLEMENTATIONS				
		Hash Table	Resizable Array	Balanced Tree	Linked List	Legacy
INTERFACES	Set	HashSet		TreeSet		
	List		ArrayList		LinkedList	Vector, Stack
	Map	HashMap		TreeMap		HashTable, Properties

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```
public class MapExample {
  public static void main(String args[]) {
    Map map<String,Integer> = new HashMap<String,Integer>();
      Integer ONE = new Integer(1);
      for (int i=0, n=args.length; i<n; i++) {
        String key = args[i];
        Integer frequency = map.get(key);
        if (frequency == null) { frequency = ONE; }
        else {
          int value = frequency.intValue();
          frequency = new Integer(value + 1);
        }
        map.put(key, frequency);
      }
      System.out.println(map);
      Map sortedMap = new TreeMap(map);
      System.out.println(sortedMap);
  }
```

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4.2. Defining and using Template

```
class MyStack<T> {
    ...
    public void push(T x) {...}
    public T pop() {
        ...
    }
}
```

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Using template

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

      MyStack<Integer> s1 = new MyStack<Integer>();
      s1.push(new Integer(0));
      Integer x = s1.pop();

      //s1.push(new Long(0)); → Error

      MyStack<Long> s2 = new MyStack<Long>();
      s2.push(new Long(0));
      Long y = s2.pop();

 }
}
```

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Defining Iterator

```
public interface List<E>{
     void add(E x);
     Iterator<E> iterator();
}

public interface Iterator<E>{
     E next();
     boolean hasNext();
}
class LinkedList<E> implements List<E> {
// implementation
}
```

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4.3. Wildcard

```
public class Test {
 public static void main(String args[]) {
     List<String> lst0 = new LinkedList<String>();
     //List<Object> lst1 = lst0; → Error
     //printList(lst0); → Error
 }

 void printList(List<Object> lst) {
     Iterator it = lst.iterator();
     while (it.hasNext())
          System.out.println(it.next());
 }
}
```

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Example: Using Wildcards

```
public class Test {
 void printList(List<?> lst) {
     Iterator it = lst.iterator();
     while (it.hasNext())
        System.out.println(it.next());
 }

 public static void main(String args[]) {
     List<String> lst0 =
                new LinkedList<String>();
     List<Employee> lst1 =
                new LinkedList<Employee>();

     printList(lst0);   // String
     printList(lst1);   // Employee
 }
```

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Widcards of Java 1.5

- "? extends Type": Specifies a set of children types of Type. This is the most useful wildcard.
- "? super Type": Specifies a set of parent types of Type
- "?": Specifies all the types or any types.

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Example of wildcard (1)

```
public void printCollection(Collection c) {
  Iterator i = c.iterator();
  for(int k = 0;k<c.size();k++) {
    System.out.println(i.next());
  }
}
```

→ Using wildcard:

```
void printCollection(Collection<?> c) {
  for(Object o:c) {
    System.out.println(o);
  }
}
```

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Example of wildcard (2)

```
public void draw(List<Shape> shape) {
  for(Shape s: shape) {
    s.draw(this);
  }
 }
```

→ What is the difference compared with:

```
public void draw(List<? extends Shape> shape) {
  // rest of the code is the same
}
```

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Template Java 1.5 vs. C++

- Template in Java does not create new classes
- Check the consistancy of types when compiling
  - All the objects are basically of the type Object

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Function call vs. Message passing

- Call function
  - Indicate the exact piece of code to be executed.
  - Has only an execution of a function with some specific name.
  - There are no functions with the same name
- Message passing
  - **Request a service from an object and the object will decide what to do**
  - **Different objects will have different re-actions/behaviors for a message.**

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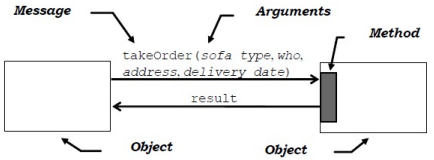
Message vs. Method

- Message
  - Is sent from an object to another object and does not contain any piece of code to be executed
- Method
  - Method/function in structure programming languages
  - Is an execution of service that is requested in the message
  - Is a piece of code to be executed in order to respond to a message sent to an object



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