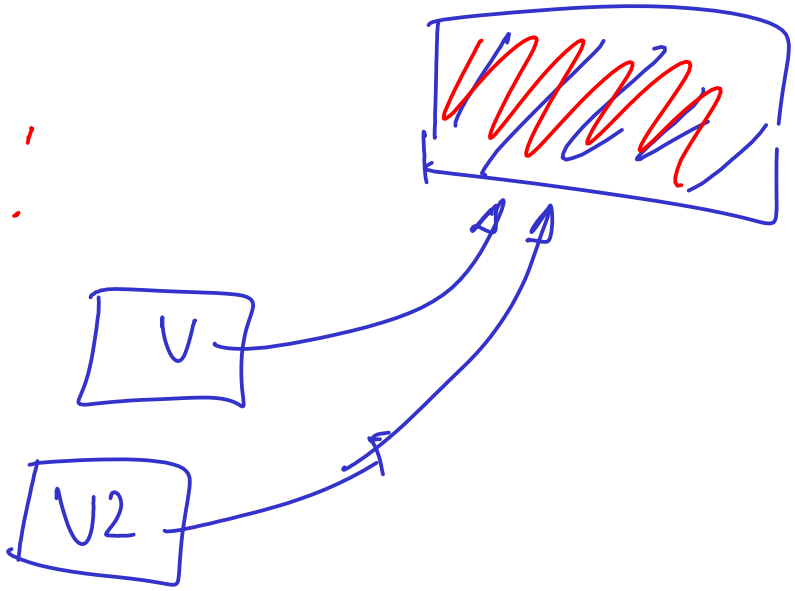
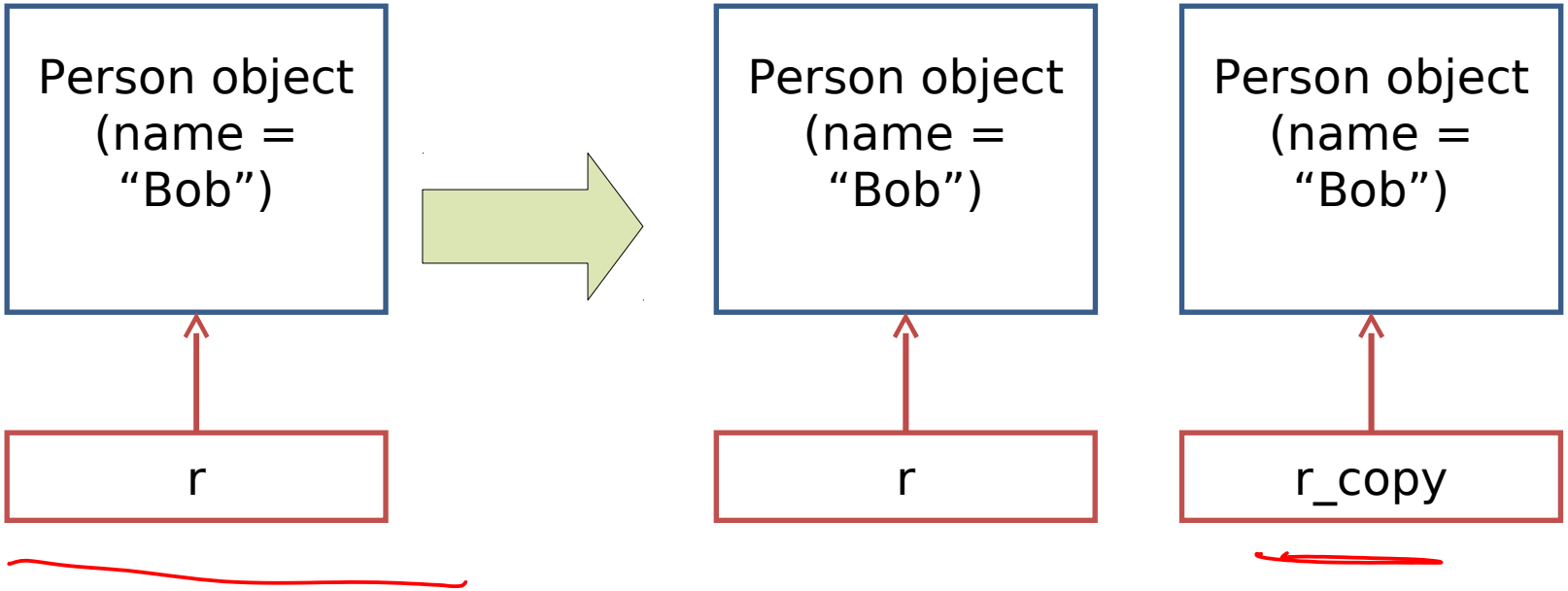
Immutable objects

```
Vector2D v = new Vector2D();
Vector2D v2 = v;
```



Cloning I

- Sometimes we really do want to copy an object



- Java calls this ***cloning***
- We need special support for it

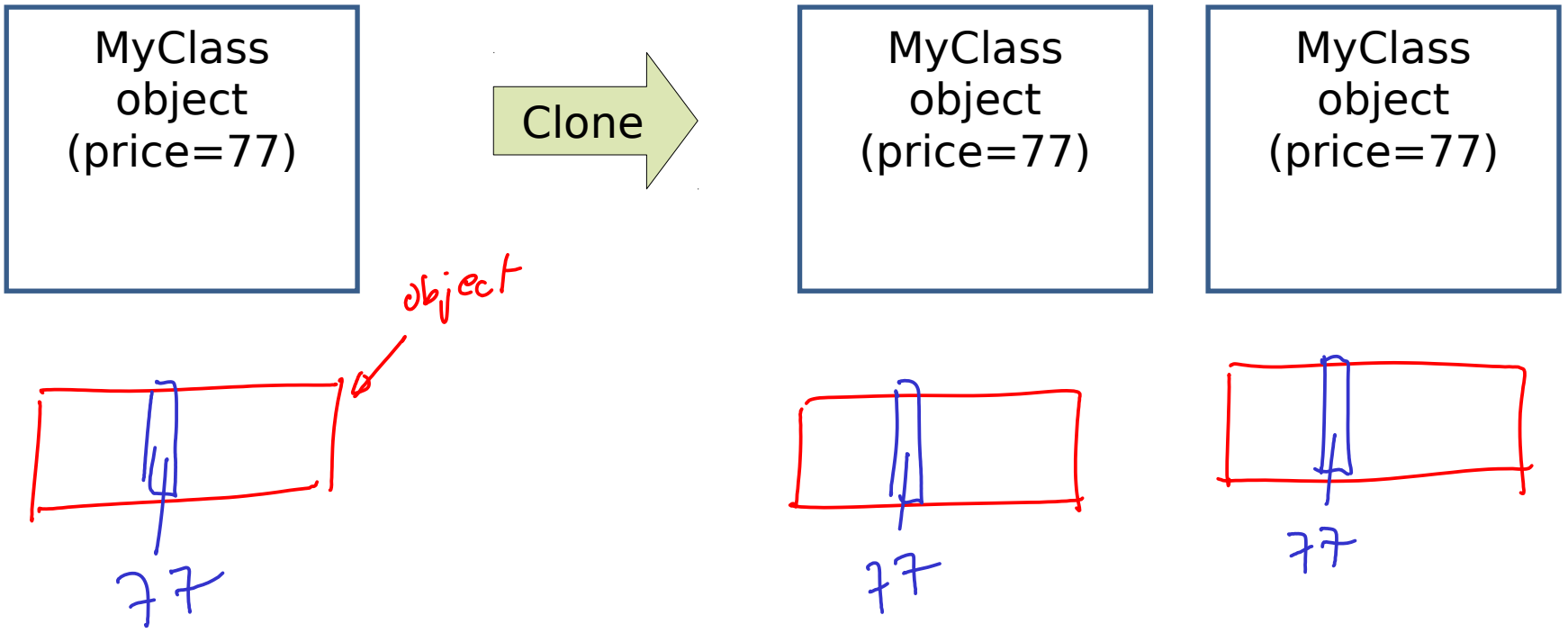
Cloning II

- Every class in Java ultimately inherits from the **Object** class
  - The **Object** class contains a clone() method
  - So just call this to clone an object, right?
  - Wrong!

- Surprisingly, the problem is defining what copy actually means

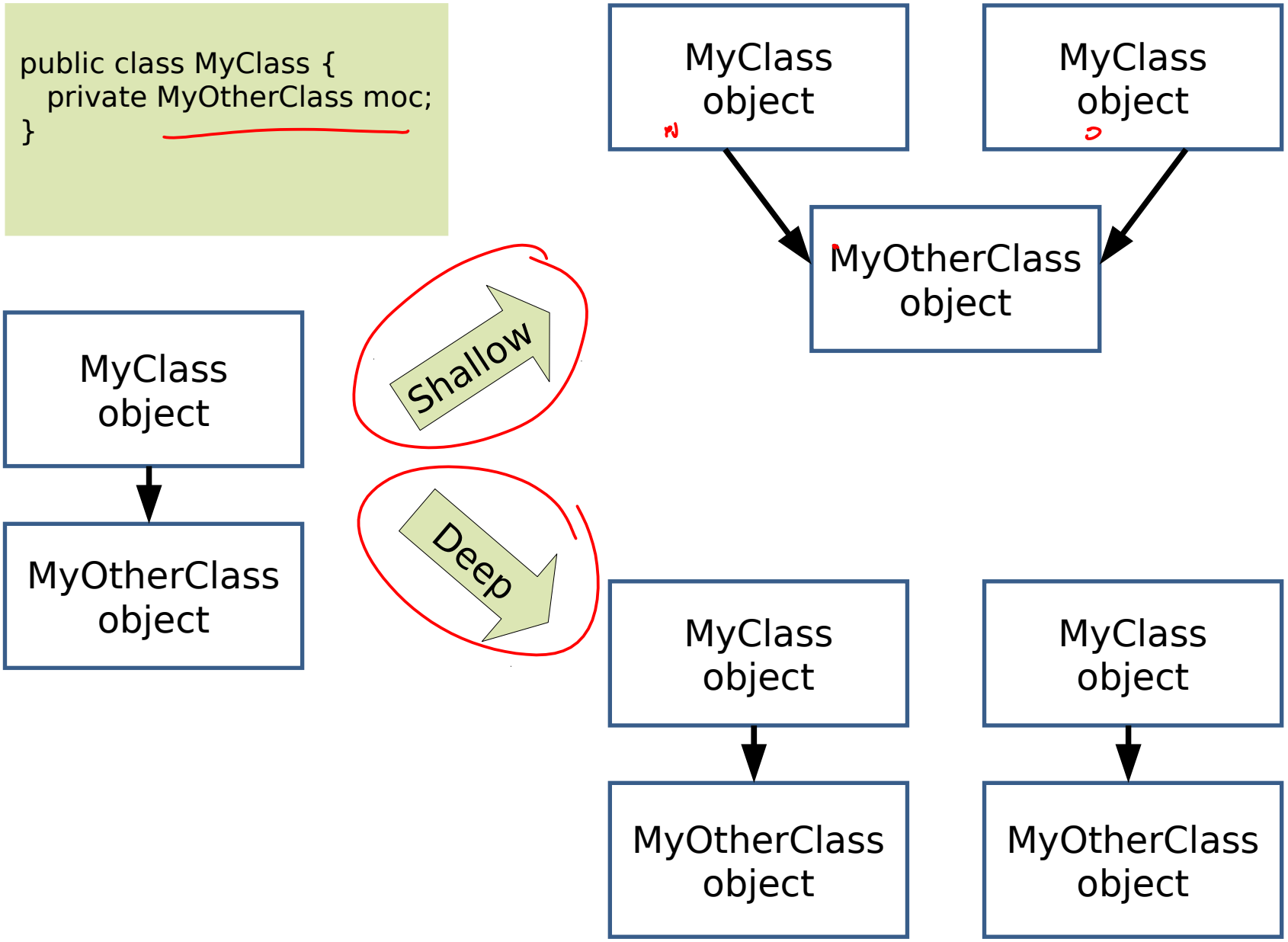
Cloning III

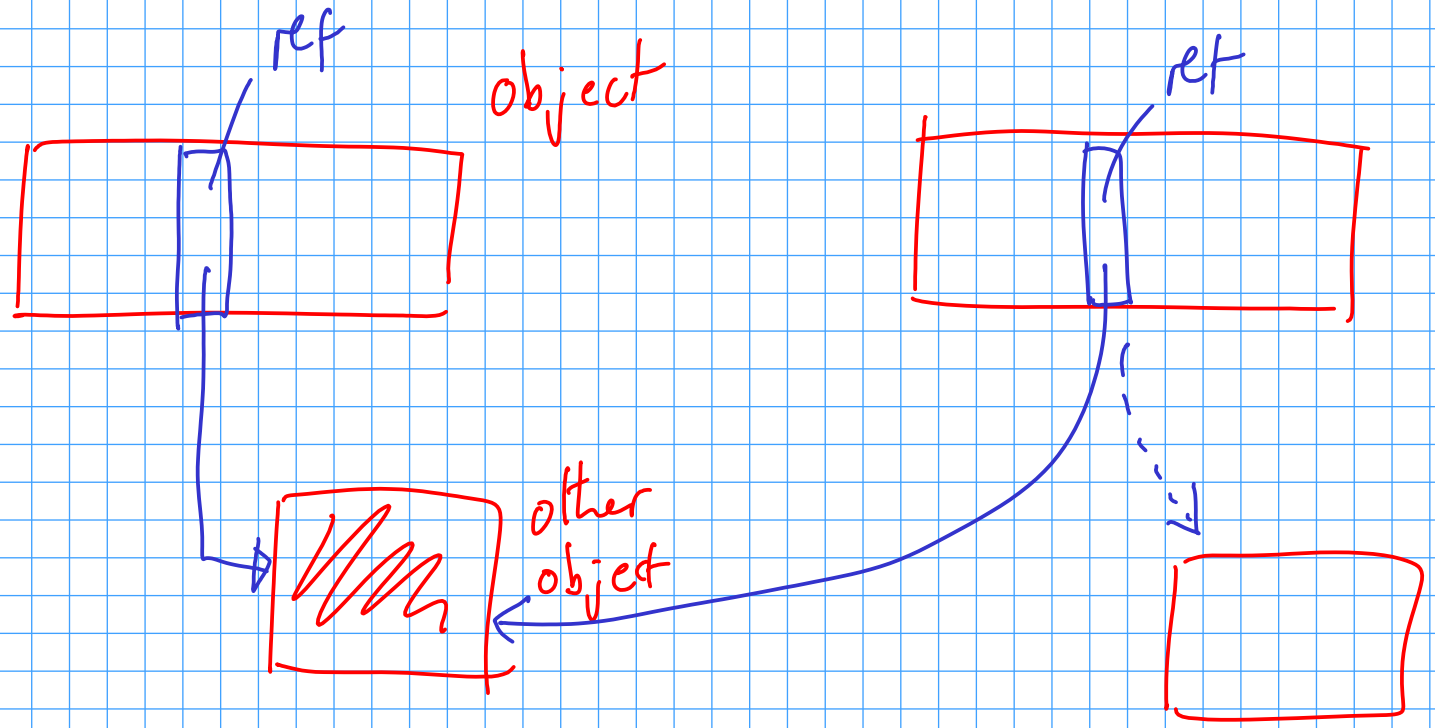
```
public class MyClass {
   private float price = 77;
}
```



Shallow and Deep Copies

```
public class MyClass {
   private MyOtherClass moc;
}
```




ref
object
ref
other
object

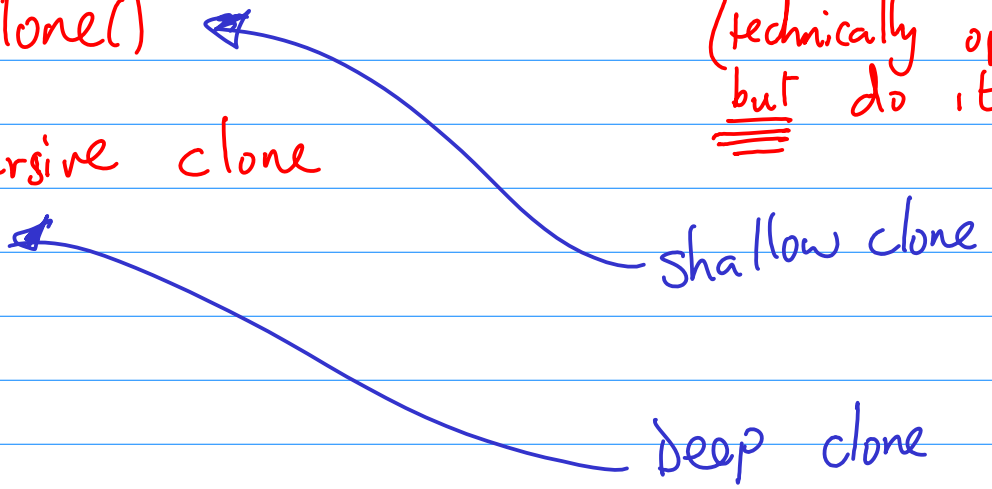
Java Cloning

- So do you want shallow or deep?
  - The default implementation of clone() performs a shallow copy
  - But Java developers were worried that this might not be appropriate: they decided they wanted to know for sure that we'd thought about whether this was appropriate

- Java has a **Cloneable** interface
  - If you call clone on anything that doesn't extend this interface, it fails

Cloning

1. implement interface Cloneable
2. make clone() public (optional)
3. super.clone() (technically optional but do it)
4. Add recursive clone calls



Clone Example I

```
public class Velocity {
   public float vx;
   public float vy;
   public Velocity(float x, float y) {
      vx=x;
      vy=y;
   }
 };

 public class Vehicle {
   private int age;
   private Velocity vel;
   public Vehicle(int a, float vx, float vy) {
      age=a;
      vel = new Velocity(vx,vy);
   }
 };
```

Clone Example II

```
public class Vehicle implements Cloneable {
  private int age;
  private Velocity vel;
  public Vehicle(int a, float vx, float vy) {
      age=a;
      vel = new Velocity(vx,vy);
  }

  public Object clone() {
      return super.clone();
  }

};
```

Clone Example III

```
  public class Velocity implement Cloneable {
      ....
     public Object clone() {
        return super.clone();
     }
};


public class Vehicle implements Cloneable {
  private int age;
  private Velocity v;
  public Student(int a, float vx, float vy) {
     age=a;
     vel = new Velocity(vx,vy);
  }

  public Object clone() {
     Vehicle cloned = (Vehicle) super.clone();
     cloned.vel = (Velocity)vel.clone();
     return cloned;
  }

};
```

Marker Interfaces

- If you look at what's in the Cloneable interface, you'll find it's empty!! What's going on?
- Well, the clone() method is already inherited from **Object** so it doesn't need to specify it
- This is an example of a **Marker Interface**
  - A marker interface is an empty interface that is used to label classes
  - This approach is found occasionally in the Java libraries

or tag interfaces.

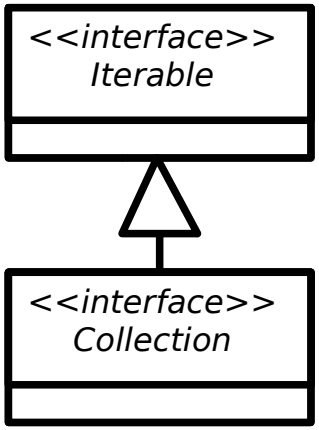
The Java Class Libraries

Java Class Library

- Java the platform contains around 4,000 classes/interfaces
  - Data Structures
  - Networking, Files
  - Graphical User Interfaces
  - Security and Encryption
  - Image Processing
  - Multimedia authoring/playback
  - And more...

- All neatly(ish) arranged into packages (see API docs)

Java's Collections Framework

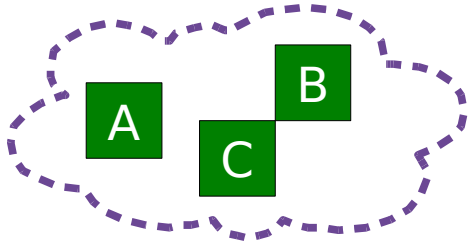


- Important chunk of the class library
- A collection is some sort of grouping of things (objects)
- Usually when we have some grouping we want to go through it ("***iterate*** over it")

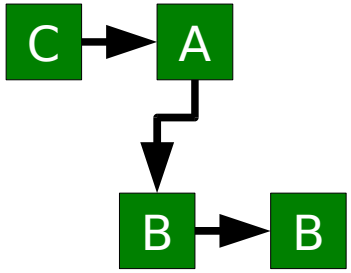
- The Collections framework has two main interfaces: Iterable and Collections. They define a set of operations that all classes in the Collections framework support
- add(Object o), clear(), isEmpty(), etc.

Major Collections Interfaces I

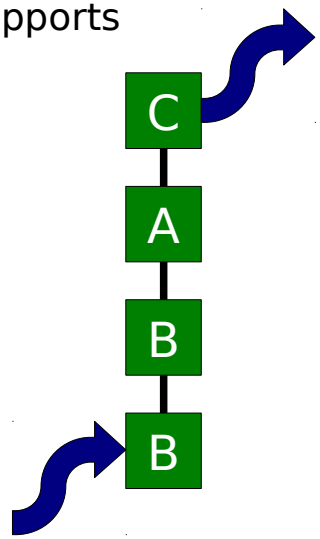
- <<interface>> Set
  - Like a mathematical set in DM 1
  - A collection of elements with no duplicates
  - Various concrete classes like TreeSet (which keeps the set elements sorted)



- <<interface>> List
  - An ordered collection of elements that may contain duplicates
  - ArrayList, Vector, LinkedList, etc.



- <<interface>> Queue
  - An ordered collection of elements that may contain duplicates and supports removal of elements from the head of the queue
  - PriorityQueue, LinkedLIst, etc.



Major Collections Interfaces II

- <<interface>> Map
  - Like relations in DM 1, or dictionaries in ML
  - Maps key objects to value objects
  - Keys must be unique
  - Values can be duplicated and (sometimes) null.