

Advanced Programming Methods Lecture 6

Content

Generics and Collections Part 1

- Java
- C#

JAVA GENERICS

Generics

- Parameterized types
- Started with Java 1.5
- Different than C++ templates
 - It does not generate a new class for each parameterized type
 - The constraints can be imposed on the type variables of the parameterized types.

■ Motivation:

```
Stiva s=new Stiva();      //stack of Object
s.pune("Ana");
s.pune(new Persoana("Ana", 23));
Persoana p=(Persoana)s.scoate();
Persoana p2=(Persoana)s.scoate();
//correct at compile-time, error at execution time
```

Generic Class declaration

```
[acces_mod] class NumeClasa <TipVar1[, TipVar2[, ...]] >{  
    private TipVar1 atribut1;  
    [declaratii attribute]  
    [declaratii si definitii metode]  
}
```

Obs:

Type variables must be upper letters(for example E for element, K for key, V for value, T, U, S ...).

```
public class Stiva<E>{  
    private class Nod<T>{  
        T info;  
        Nod<T> urm;  
        Nod(){info=null; urm=null;}  
        Nod(T info, Nod urm){  
            this.info=info;  
            this.urm=urm;  
        }  
    }  
} //clasa Nod  
Nod<E> varf;  
//...  
}
```

Object creation

```
public class Test{  
    public static void main(String[] args){  
        Stiva<String> ss=new Stiva<String>();  
        ss.pune("Ana");  
        ss.pune("Maria");  
        ss.pune(new Persoana("Ana", 23));    //error at compile-time  
        String elem=ss.scoate();            //NO CAST  
  
        Stiva<Persoana> sp=new Stiva<Persoana>();  
        sp.pune(new Persoana("Ana", 23));  
        sp.pune(new Persoana("Maria", 10));  
  
        Dictionar<String, String> dic=new Dictionar<String, String>();  
        dic.adauga("abc", "ABC");  
        dic.adauga(23, "acc"); //error at compile-time  
        dic.adauga("acc", 23); //error la compile-time  
    }  
}
```

Object creation

Type variables can be instantiated only with reference types. Primitive types: int, byte, char, float, double,... are not allowed. Therefore the corresponding reference types are used.

```
Stiva<int> si=new Stiva<int>();    //error at compile-time
```

```
Stiva<Integer> si=new Stiva<Integer>();
```

primitive types	Corresponding reference types
boolean	Boolean
byte	Byte
short	Short
int	Integer
long	Long
float	Float
double	Double
char	Character
void	Void

Autoboxing

- Java 1.5
- Autoboxing: automatic conversion of a value of a primitive type to an object instance of a corresponding reference type when an object is expected, and vice-versa when a primitive value is expected.

```
Stiva<Integer> si=new Stiva<Integer>();
```

```
si.pune(23);           //autoboxing
```

```
si.pune(new Integer(23));
```

```
int val=si.scoate();
```

```
Character ch = 'x';
```

```
char c = ch;
```


Generic methods

■ Methods with type variables

```
class NumClassa[<TypeVar ...>]{  
  [access_mod] <TypeVar1[, TypeVar2[,...]]> TypeR nameMethod([list_param]){  
    }  
    //...  
}
```

Obs:

- Static methods cannot use the type variables of the class.
- A generic method can contain type variables different than those used by the generic class.
- A generic method can be defined in a non-generic class.

Generic methods

```
public class MetodeGenerice {  
    public <T> void f(T x) {  
        System.out.println(x.toString());  
    }  
  
    public static <T> void copiaza(T[] elems, Stiva<T> st) {  
        for(T e:elems)  
            st.pune(e);  
    }  
}
```

Calling a generic method

- The compiler automatically infers the types which instantiate the type variables when a generic method is called.

```
public class A {  
    public <T> void print(T x) {  
        System.out.println(x);  
    }  
  
    public static void main(String[] args) {  
        A a=new A();  
        a.print(23);  
        a.print("ana");  
        a.print(new Persoana("ana",23));  
    }  
}
```

Calling a generic method

- The instantiations of the type vars are explicit given:

- Instance method:

```
a.<Integer>print(3);  
a.<Persoana>print(new Persoana("Ana",23));
```

- Static method :

```
NameClass.<Typ>nameMethod([parameters]);  
//...  
Integer[] ielem={2,3,4};  
Stiva<Integer> st=new Stiva<Integer>();  
MetodeGenerice.<Integer>copiază(ielem, st);  
//
```

- Non-static method in a class:

```
this.<Typ>nameMethod([parameters]);  
class A{  
    public <T> void print(T x){...}  
    public void g(Complex x){  
        this.<Complex>print(x);  
    }  
}
```

Generic arrays

- Cannot be created using new:

```
T[] elem=new T[dim]; //error at compile time
```

but we can use:

```
T[] elem=(T[])new Object[dim]; //warning at compile-time
```

- Alternatives:

- Using `Array.newInstance`

```
import java.lang.reflect.Array;
public class Stiva <E>{
    private E[] elems;
    private int varf;
    @SuppressWarnings("unchecked")
    public Stiva(Class<E> tip) {
        elems= (E[])Array.newInstance(tip, 10);
        varf=0;
    }
    //...
}
Stiva<Integer> si=new Stiva<Integer>(Integer.class);
```

- Using `ArrayList` instead of array.

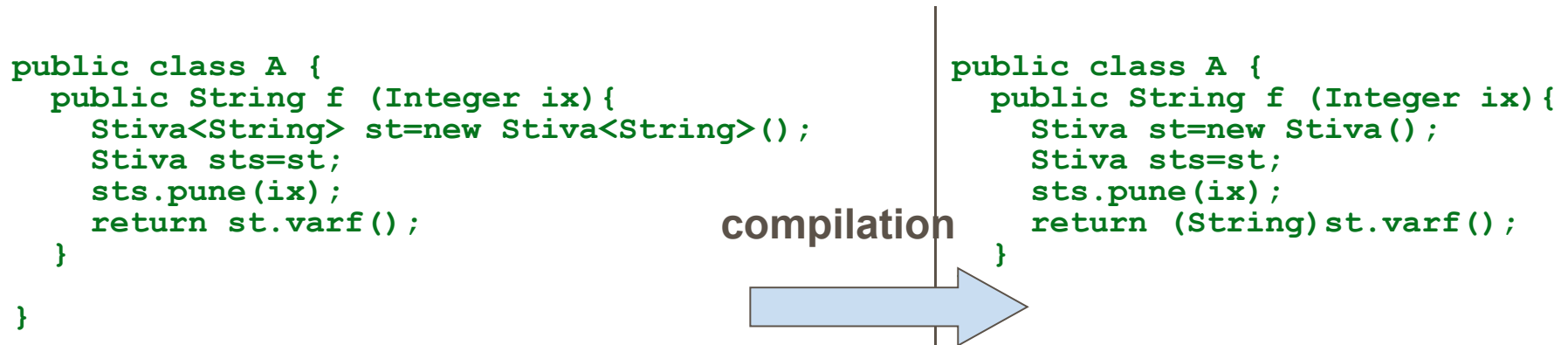
Generic arrays

- Use an array of Object, but read operation requires an explicit cast:

```
public class Stiva <E>{
    private Object[] elems;
    private int varf;
    public Stiva() {
        elems=new Object[10];
        varf=0;
    }
    public void pune(E elem){
        elems[varf++]=elem;
    }
    @SuppressWarnings("unchecked")
    public E scoate(){
        if (varf>0)
            return (E)elems[--varf];
        return null;
    }
    //...
}
```

Erasure

- Java does not create a new class for each new instantiation of the type variables in case of the generic classes.
- The compiler erases all type variables and replaces them with their upper bounds (usually Object) and explicit casts are inserted when it is necessary



- Reason: backward compatibility with the non-generic Java versions
- The generic class is not recompiled for each new instantiation of the type variables like in C++.

Bounds

```
public class ListaOrd<E> {
    private class Nod<E>{
        E info;
        Nod<E> urm;
        public Nod(){ info=null; urm=null; }
        private Nod(E info, Nod<E> urm) { this.info = info; this.urm = urm; }
        private Nod(E info) { this.info = info; urm=null; }
    }
    private Nod<E> cap;
    public ListaOrd(){ cap=null;}
    public void adauga(E elem){
        if (cap==null){
            cap=new Nod<E>(elem);
            return;
        }
        if (/*compare elem to cap.info*/){
            cap=new Nod<E>(elem, cap);
        }else {...}
    }
}
```


Bounds

After erasure:

```
public class ListaOrd {
    private class Nod{
        Object info;
        Nod urm;
        public Nod(){ info=null; urm=null; }
        private Nod(Object info, Nod urm){this.info = info; this.urm = urm; }
        private Nod(Object info) { this.info = info; urm=null; }
    }
    private Nod cap;
    public ListaOrd(){ cap=null;}
    public void adauga(Object elem){
        if (cap==null){
            cap=new Nod(elem);
            return;
        }
        if (/*compare elem to cap.info*/){ //which methods can be called?
            cap=new Nod(elem, cap);
        }else {...}
    }
}
```

Bounds

- Type variables can have constraints (namely bounds) using **extends**.

T extends E //T is the type E or is a subtype of E.

- General form of the constraint:

T extends [C &] I₁ [& I₂ &...& I_n]

T inherits the class C and implements the interfaces I₁, ... I_n.

- At compile-time T is replaced by the first element from the constraint expression:

T extends C //T is replaced by C

T extends C & I₁ & I₂ //T is replaced by C

T extends I₁ & I₂ //T is replaced by I₁

T extends I₁ //T is replaced by I₁

T //T is replaced by Object

- If T has constraints then through T we can call any method from the class and interfaces specified as bounds.

Bounds

```
public interface Comparable<E>{
    int compareTo(E e);
}

public class ListaOrd<E extends Comparable<E>> {
    private class Nod<E>{...}
    private Nod<E> cap;
    public ListaOrd(){ cap=null;}
    public void adauga(E elem){
        if (cap==null){
            cap=new Nod<E>(elem);
            return;
        }
        if (elem.compareTo(cap.info)<0){
            cap=new Nod<E>(elem, cap);
        }else {...}
    }
    public E retElemPoz(int poz){
        //...
    }
}
```

Wildcards

```
Lista<String> ls=new Lista<String>();  
Lista<Object> lo=ls; //ASSUME this is CORRECT  
lo.adauga(23);  
String s=ls.retElemPoz(0); //ERROR
```

Obs:

If **SB** is a subtype of **T** and **G** is a generic container class then **G<SB>** is not a subtype of **G<T>**.

```
void printLista(Lista<Object> lo){  
    for(Object o:lo)  
        System.out.println(o);  
}  
...  
Lista<String> ls=new Lista<String>();  
ls.adauga("mere");  
ls.adauga("pere");  
printLista(ls);           //error at compile-time
```

We use **?** to denote any type (or unknown type)

Wildcards

```
void printLista(Lista<?> lo){  
    for(Object o:lo)  
        System.out.println(o);  
}
```

Obs:

1. When we use `?`, the elements can be considered to be of type `Object` (upper bound).
2. When we use `?` to declare an instance, the instance elements cannot be read or write, the only allowed operation is to read `Object` and to write `null`.

```
Lista<String> ls=new Lista<String>();  
ls.adauga("mere");  
ls.adauga("pere");  
Lista<?> ll=ls;  
ll.adauga("portocale");           //error  
ll.modifica(1, "struguri");       //error  
Object el=ll.retElemPoz(0);
```

Bounded Wildcards

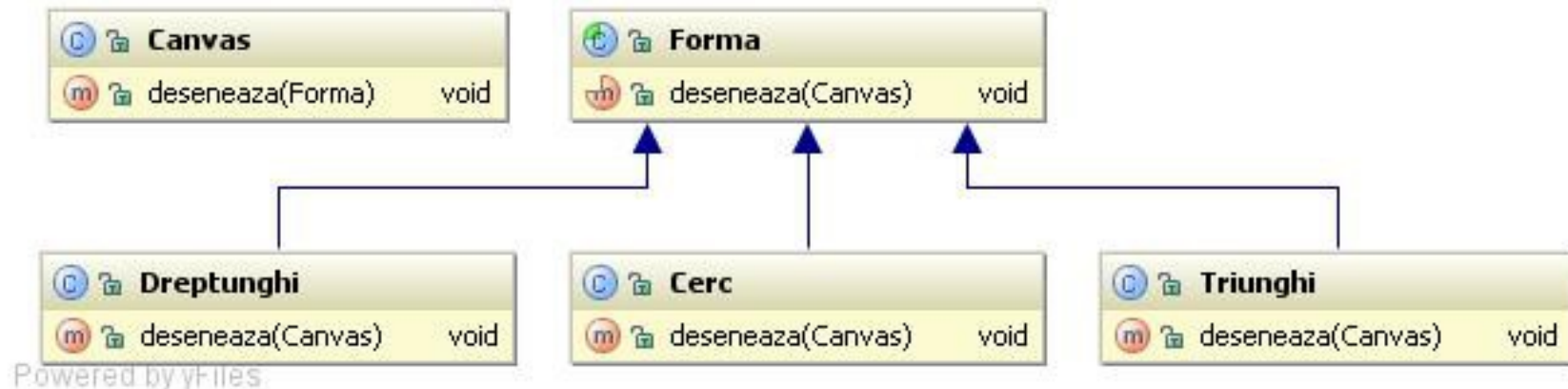
We can specify bounds for ?:

- Upper bound by `extends: ? extends C` or `? extends I`
- Lower bound by `super: ? super C` (any superclass of C)

1. Upper bound means that we can read elements of the type (or of superclass of the type) given by the upper bound.
2. Lower bound means that we can write elements of type (or of subclasses of the type) given by the lower bound.

```
Lista<Angajat> la=new Lista<Angajat>();  
la.adauga(new Angajat(...));  
Lista<? extends Persoana> lp=la;  
lp.adauga(new Angajat(...)); //error at compile time  
Persoana p=lp.retElemPoz(0);  
lp.retElemPoz(0).getNum();  
Lista<? super Angajat> linf=la;  
linf.adauga(new Angajat(...)); //correct
```

Bounded Wildcards



```
public class Canvas {  
    public void deseneaza(Forma f){ f.deseneaza(this); }  
    public void deseneaza(Lista<Forma> lf){  
        for(Forma f: lf)  
            f.deseneaza(this);  
    }  
}  
//...  
Canvas c=new Canvas();  
Lista<Cerc> lc=new Lista<Cerc>();  
c.deseneaza(lc);    //error at compile time
```


Bounded Wildcards

```
public class Canvas {  
    public void deseneaza(Forma f){ f.deseneaza(this); }  
    public void deseneaza(Lista<? extends Forma> lf){  
        for(Forma f: lf)  
            f.deseneaza(this);  
    }  
}  
//...  
Canvas c=new Canvas();  
Lista<Cerc> lc=new Lista<Cerc>();  
c.deseneaza(lc);    //correct  
Lista<? extends Forma> ll=lc;  
ll.adauga(new Cerc());    //error at compile time;
```

JAVA COLLECTIONS

Java Collections Framework (JCF)

A *collection* is an object that maintains references to other objects

JCF forms part of the `java.util` package and provides:

Interfaces

- Each defines the operations and contracts for a particular type of collection (List, Set, Queue, etc)
- Idea: when using a collection object, it's sufficient to know its interface

Implementations

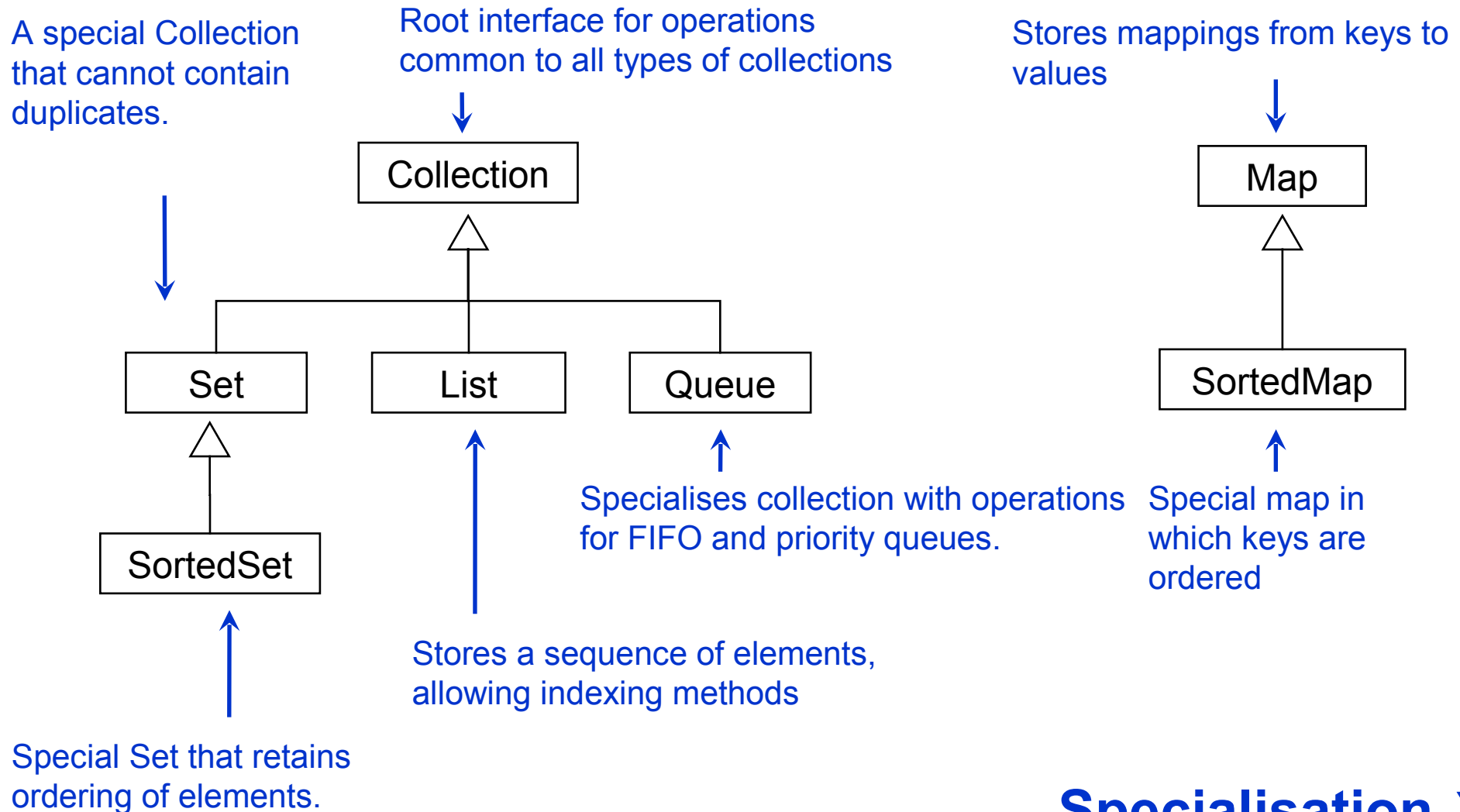
- Reusable classes that implement above interfaces (e.g. LinkedList, HashSet)

Algorithms

- Useful polymorphic methods for manipulating and creating objects whose classes implement collection interfaces
- Sorting, index searching, reversing, replacing etc.

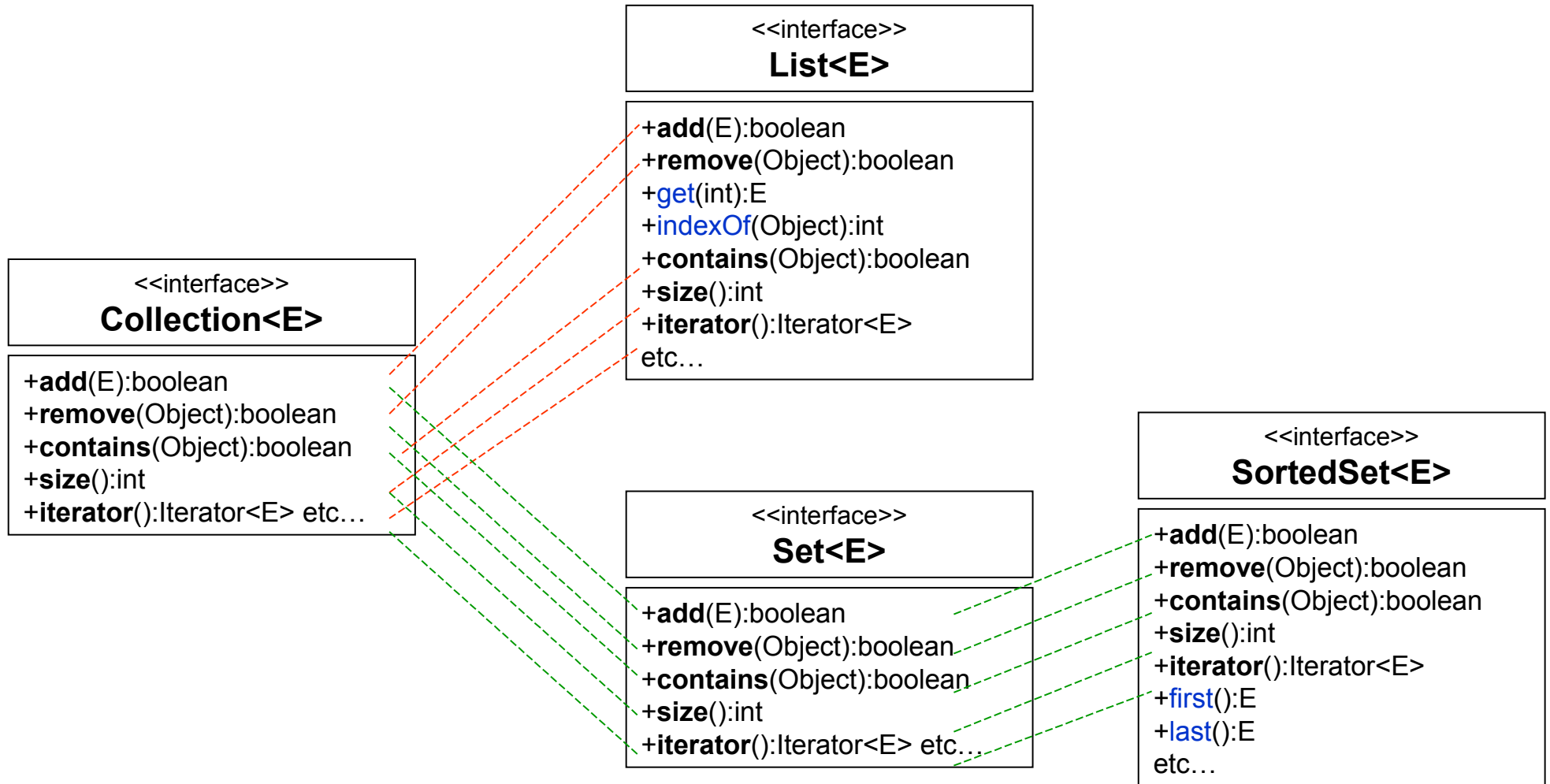
Interfaces

Generalisation



Specialisation

Expansion of contracts



The Collection Interface

- The Collection interface provides the basis for List-like collections in Java. The interface includes:

```
boolean add(Object)
boolean addAll(Collection)
void clear()
boolean contains(Object)
boolean containsAll(Collection)
boolean equals(Object)
boolean isEmpty()
Iterator iterator()
boolean remove(Object)
boolean removeAll(Collection)
boolean retainAll(Collection)
int size()
Object[] toArray()
Object[] toArray(Object[])
```

List Interface

- Lists allow duplicate entries within the collection
- Lists are an ordered collection much like an array
 - Lists grow automatically when needed
 - The list interface provides accessor methods based on index
- The List interface extends the Collections interface and add the following method definitions:
 - `void add(int index, Object)`
 - `boolean addAll(int index, Collection)`
 - `Object get(int index)`
 - `int indexOf(Object)`
 - `int lastIndexOf(Object)`
 - `ListIterator listIterator()`
 - `ListIterator listIterator(int index)`
 - `Object remove(int index)`
 - `Object set(int index, Object)`
 - `List subList(int fromIndex, int toIndex)`

Set Interface

- The Set interface also extends the Collection interface but does not add any methods to it.
- Collection classes which implement the Set interface have the add stipulation that Sets CANNOT contain duplicate elements
- Elements are compared using the equals method
- NOTE: exercise caution when placing mutable objects within a set. Objects are tested for equality upon addition to the set. If the object is changed after being added to the set, the rules of duplication may be violated.

SortedSet Interface

- SortedSet provides the same mechanisms as the Set interface, except that SortedSets maintain the elements in ascending order.
- Ordering is based on natural ordering (Comparable) or by using a Comparator.

java.util.Iterator<E>

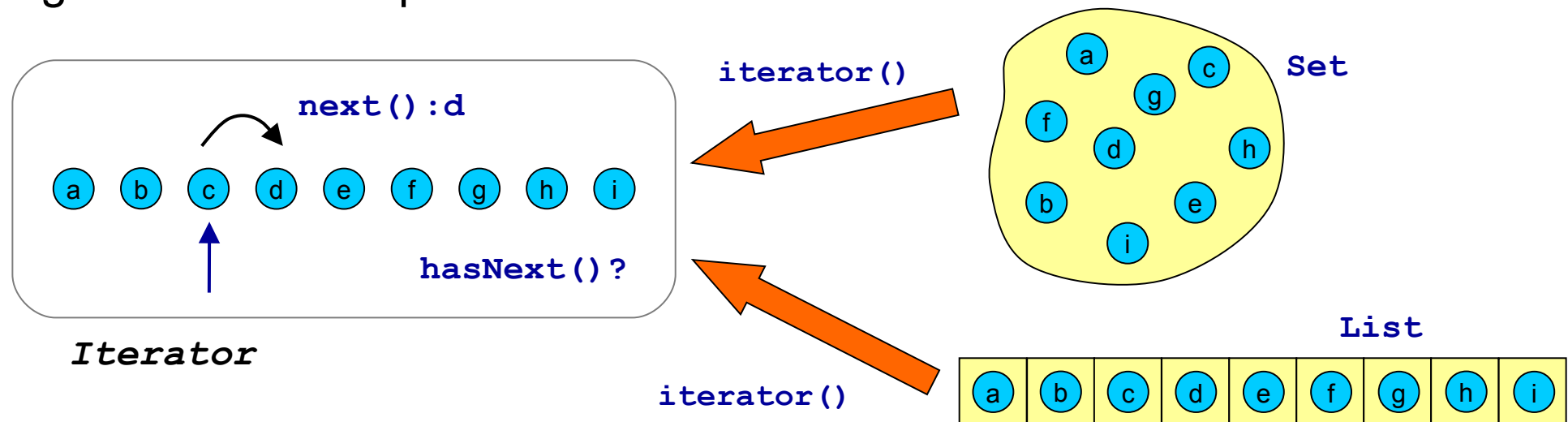
Think about typical usage scenarios for Collections

Retrieve the list of all patients

Search for the lowest priced item

More often than not you would have to traverse every element in the collection – be it a List, Set, or your own datastructure

Iterators provide a generic way to traverse through a collection regardless of its implementation



Using an Iterator

Quintessential code snippet for collection iteration:

```
public void list(Collection<Item> items) {  
    Iterator<Item> it = items.iterator();  
    while(it.hasNext()) {  
        Item item = it.next();  
        System.out.println(item.getTitle());  
    }  
}
```

<<interface>>

Iterator<E>

+hasNext():boolean

+next():E

+remove():void

Design notes:

- ✓ Above method takes in an object whose class implements Collection
 - ✓ List, ArrayList, LinkedList, Set, HashSet, TreeSet, Queue, MyOwnCollection, etc
- ✓ We know any such object can return an Iterator through method iterator()
- ✓ We don't know the exact implementation of Iterator we are getting, but **we don't care**, as long as it provides the methods next() and hasNext()
- ✓ Good practice: **Program to an interface!**

java.lang.Iterable<T>

```
for (Item item : items) {  
    System.out.println(item);  
}
```

=

```
Iterator<Item> it = items.iterator();  
while(it.hasNext()) {  
    Item item = it.next();  
    System.out.println(item);  
}
```

This is called a “**for-each**” statement

For each `item` in `items`

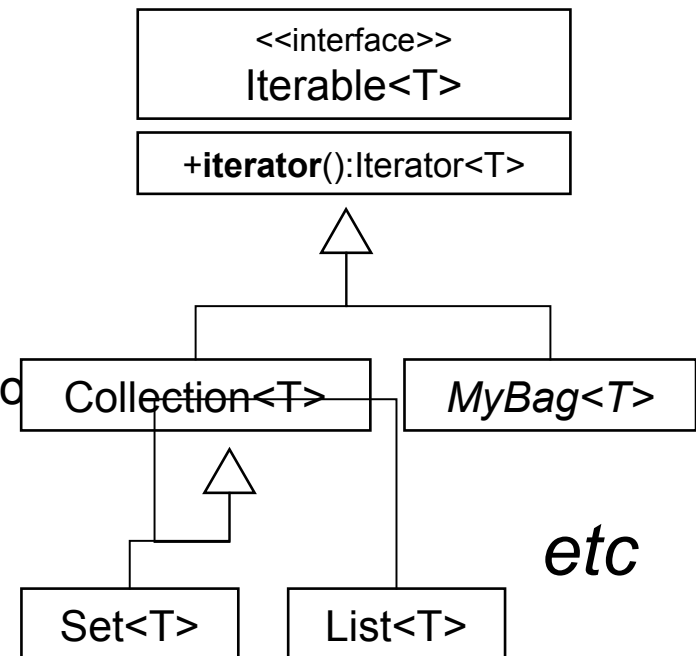
This is possible as long as `items` is of type **Iterable**

Defines single method `iterator()`

Collection (and hence all its subinterfaces) implements **Iterable**

You can do this to your own implementation of **Iterable** to

To do this you may need to return your own implementation of **Iterator**



java.util.Collections

Offers many very useful utilities and algorithms for manipulating and creating collections

Sorting lists

Index searching

Finding min/max

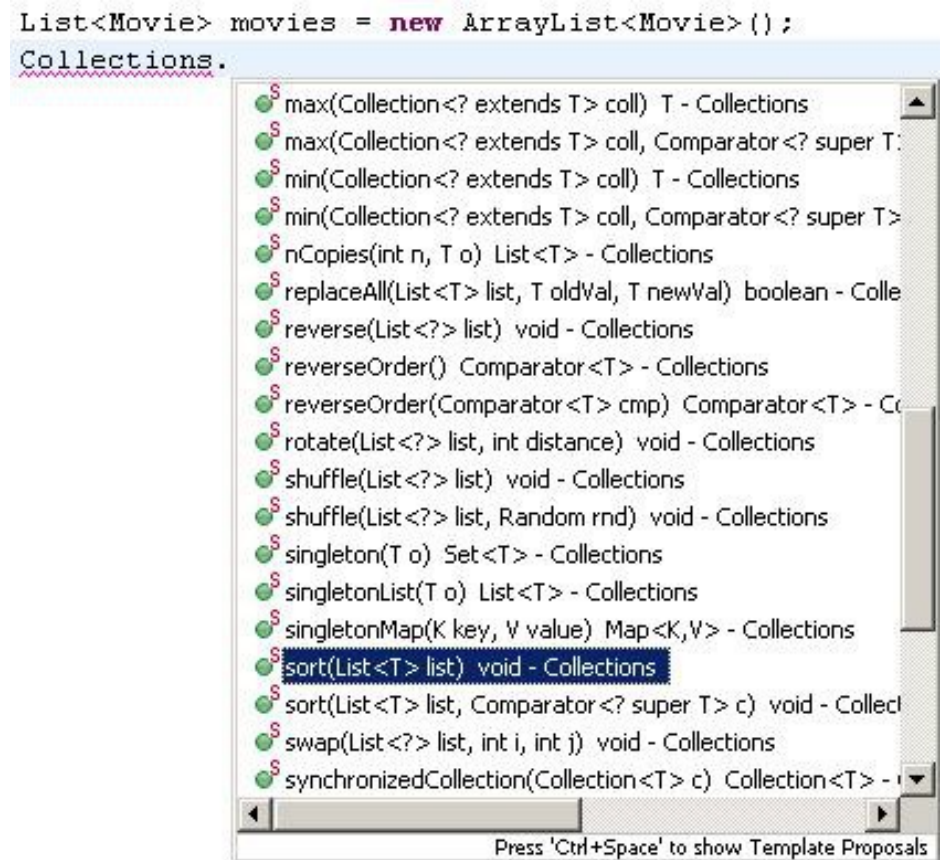
Reversing elements of a list

Swapping elements of a list

Replacing elements in a list

Other nifty tricks

Saves you having to implement them yourself → **reuse**

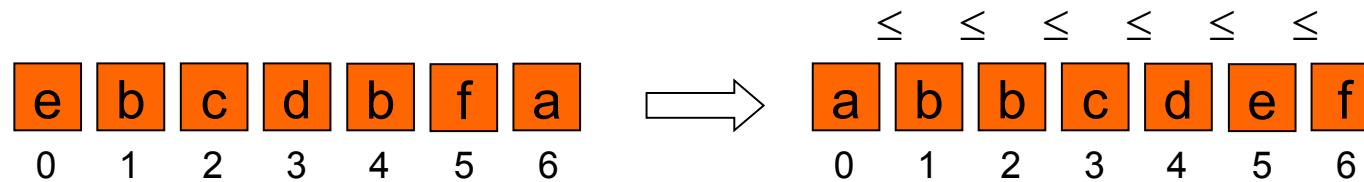


Comparable and Comparators

- You will have noted that some classes provide the ability to sort elements.
 - How is this possible when the collection is supposed to be de-coupled from the data?
- Java defines two ways of comparing objects:
 - The objects implement the Comparable interface
 - A Comparator object is used to compare the two objects
- If the objects in question are Comparable, they are said to be sorted by their "natural" order.
- Comparable object can only offer one form of sorting. To provide multiple forms of sorting, Comparators must be used.

Collections.sort()

Java's implementation of merge sort – ascending order



- ✓ What types of objects can you sort? Anything that has an **ordering**
- ✓ Two sort() methods: sort a given List according to either 1) *natural ordering* of elements or an 2) externally defined ordering.

1) `public static <T extends Comparable<? super T>> void sort(List<T> list)`

2) `public static <T> void sort(List<T> list, Comparator<? super T> c)`

✓ Translation:

1. Only accepts a List parameterised with type implementing **Comparable**
2. Accepts a List parameterised with any type as long as you also give it a **Comparator** implementation that defines the ordering for that type

java.lang.Comparable<T>

A **generic interface** with a single method: `int compareTo(T)`

Return 0 if this = other

Return **any +ve integer** if this > other

Return **any -ve integer** if this < other

Implement this interface to define **natural ordering** on objects of type T

```
public class Money implements Comparable<Money> {  
    ...  
    public int compareTo( Money other ) {  
        if( this.cents == other.cents ) {  
            return 0;  
        }  
        else if( this.cents < other.cents ) {  
            return -1;  
        }  
        else {  
            return 1;  
        }  
    }  
}
```

```
m1 = new Money(100,0);  
m2 = new Money(50,0);  
m1.compareTo(m2) returns 1;
```

A more concise way of doing this? (hint: 1 line)

```
return this.cents - other.cents;
```


Natural-order sorting

```
List<Money> funds = new ArrayList<Money>();  
funds.add(new Money(100,0));  
funds.add(new Money(5,50));  
funds.add(new Money(-40,0));  
funds.add(new Money(5,50));  
funds.add(new Money(30,0));
```

```
Collections.sort(funds);  
System.out.println(funds);
```

```
List<CD> albums = new ArrayList<CD>();  
albums.add(new CD("Street Signs", "Ozomatli", 2.80));  
//etc...  
Collections.sort(albums);
```

What's the output?
[-40.0,
5.50,
5.50,
30.0,
100.0]

CD does not implement a
Comparable interface

```
public static <T extends Comparable<? super T>> void sort(List<T> list)
```

Wildcard (later)

java.util.Comparator<T>

Useful if the type of elements to be sorted is not Comparable, or you want to define an alternative ordering

Also a generic interface that defines methods **compare(T, T)** and **equals(Object)**

Usually only need to define **compare(T, T)**

Define ordering by CD's getPrice() → **Money**

Note: PriceComparator implements a Comparator parameterised with CD → T “becomes” CD

<<interface>> Comparator<T>
+compare(T o1, T o2):int +equals(Object other):boolean

CD
+getTitle():String +getArtist():String +getPrice():Money

```
public class PriceComparator
implements Comparator<CD> {
    public int compare(CD c1, CD c2) {
        return c1.getPrice().compareTo(c2.getPrice());
    }
}
```

Comparator and Comparable
going hand in hand 😊

Comparator sorting

```
List<CD> albums = new ArrayList<CD>();  
albums.add(new CD("Street Signs", "Ozomatli", new Money(3, 50)));  
albums.add(new CD("Jazzinho", "Jazzinho", new Money(2, 80)));  
albums.add(new CD("Space Cowboy", "Jamiroquai", new Money(5, 00)));  
albums.add(new CD("Maiden Voyage", "Herbie Hancock", new Money(4, 00)));  
albums.add(new CD("Here's the Deal", "Liquid Soul", new Money(1, 00)));  
  
Collections.sort(albums, new PriceComparator());  
System.out.println(albums);
```

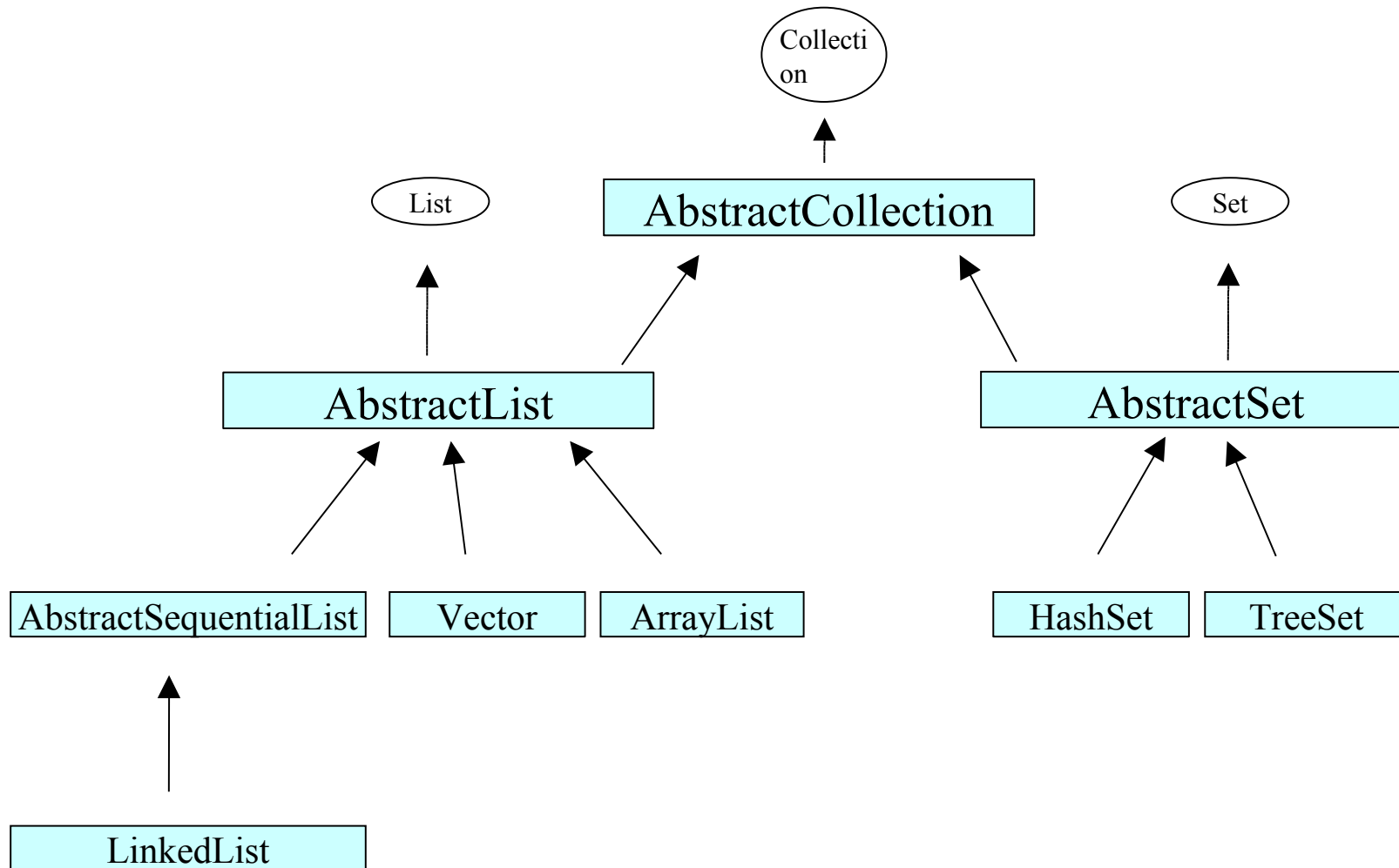
implements `Comparator<CD>`

Note, in `sort()`, `Comparator` overrides natural ordering
i.e. Even if we define natural ordering for `CD`, the given
comparator is still going to be used instead
(On the other hand, if you give `null` as `Comparator`, then
natural ordering is used)

```
public static <T> void sort(List<T> list, Comparator<? super T> c)
```

The Class Structure

- The Collection interface is implemented by a class called AbstractCollection. Most collections inherit from this class.



Lists

- Java provides 3 concrete classes which implement the list interface
 - Vector
 - ArrayList
 - LinkedList
- Vectors try to optimize storage requirements by growing and shrinking as required
 - Methods are synchronized (used for Multi threading)
- ArrayList is roughly equivalent to Vector except that its methods are not synchronized
- LinkedList implements a doubly linked list of elements
 - Methods are not synchronized

Sets

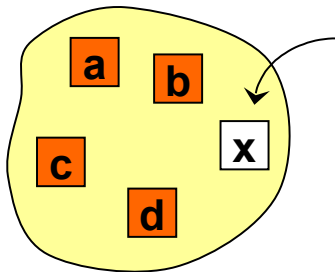
- Java provides 2 concrete classes which implement the Set interface
 - HashSet
 - TreeSet
- HashSet behaves like a HashMap except that the elements cannot be duplicated.
- TreeSet behaves like TreeMap except that the elements cannot be duplicated.
- Note: Sets are not as commonly used as Lists

Set<E>

Mathematical Set abstraction – contains **no duplicate** elements
i.e. no two elements e_1 and e_2 such that $e_1.equals(e_2)$

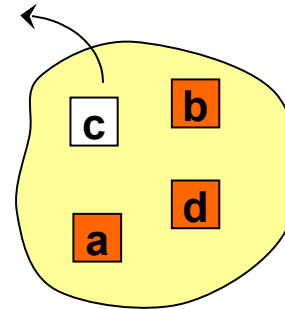
add(x)
→ *true*

add(b)
→ *false*



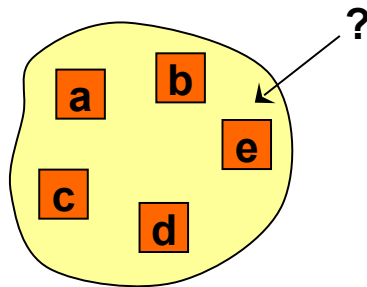
remove(c)
→ *true*

remove(x)
→ *false*



contains(e)
→ *true*

contains(x)
→ *false*



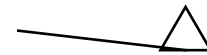
isEmpty()
→ *false*

size()
→ 5

<<interface>>

Set<E>

+**add**(E):boolean
+**remove**(Object):boolean
+**contains**(Object):boolean
+**isEmpty**():boolean
+**size**():int
+**iterator**():Iterator<E> etc...



<<interface>>

SortedSet<E>

+**first**():E
+**last**():E
etc...

HashSet<E>

Typically used implementation of Set.

Hash? Implemented using HashMap (later)

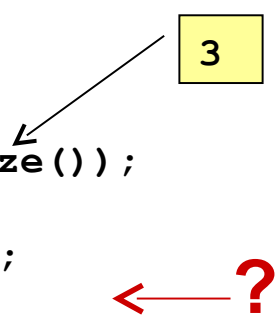
Parameterise Sets just as you parameterise Lists

Efficient (constant time) insert, removal and contains check – all done through hashing

x and y are duplicates if x.equals(y)

How are elements ordered? Quiz:

```
Set<String> words = new HashSet<String>();  
words.add("Bats");  
words.add("Ants");  
words.add("Crabs");  
words.add("Ants");  
System.out.println(words.size());  
for (String word : words) {  
    System.out.println(word);  
}
```



<<interface>>
Set<E>

+**add**(E):boolean
+**remove**(Object):boolean
+**contains**(Object):boolean
+**size**():int
+**iterator**():Iterator<E> etc...



HashSet<E>

- a) Bats, Ants, Crabs
- b) Ants, Bats, Crabs
- c) Crabs, Bats, Ants
- d) Nondeterministic

TreeSet<E> (SortedSet<E>)

If you want an ordered set, use an implementation of a SortedSet: TreeSet

What's up with "Tree"? Red-black tree

Guarantees that all elements are ordered (sorted) at all times

add() and **remove()** preserve this condition

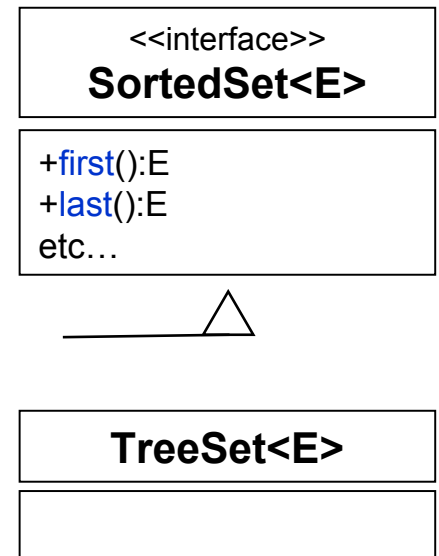
iterator() always returns the elements in a specified order

Two ways of specifying ordering

Ensuring elements have natural ordering (**Comparable**)

Giving a **Comparator<E>** to the constructor

Caution: TreeSet considers x and y are duplicates if `x.compareTo(y) == 0` (or `compare(x,y) == 0`)



TreeSet construction

```
Set<String> words = new TreeSet<String>();  
words.add("Bats");  
words.add("Ants");  
words.add("Crabs");  
for (String word : words) {  
    System.out.println(word);  
}
```

String has a **natural ordering**, so empty constructor

What's the output?

Ants; Bats; Crabs

✓ But CD doesn't, so you must pass in a Comparator to the constructor

```
Set<CD> albums = new TreeSet<CD>(new PriceComparator());  
albums.add(new CD("Street Signs", "O", new Money(3, 50)));  
albums.add(new CD("Jazzinho", "J", new Money(2, 80)));  
albums.add(new CD("Space Cowboy", "J", new Money(5, 00)));  
albums.add(new CD("Maiden Voyage", "HH", new Money(4, 00)));  
albums.add(new CD("Here's the Deal", "LS", new Money(2, 80)));  
System.out.println(albums.size());  
for (CD album : albums) {  
    System.out.println(album);  
}
```

What's the output?

4

Jazzinho; Street; Maiden; Space

The Map Interface

- The Map interface provides the basis for dictionary or key-based collections in Java. The interface includes:

```
void clear()
boolean containsKey(Object)
boolean containsValue(Object)
Set entrySet()
boolean equals(Object)
Object get(Object)
boolean isEmpty()
Set keySet()
Object put(Object key, Object value)
void putAll(Map)
boolean remove(Object key)
int size()
Collection values()
```

Maps

- Java provides 3 concrete classes which implement the Map interface
 - HashMap
 - WeakHashMap
 - TreeMap
- HashMap is the most commonly used Map.
 - Provides access to elements through a key.
 - The keys can be iterated if they are not known.
- WeakHashMap provides the same functionality as Map except that if the key object is no longer used, the key and its value will be removed from the Map.
- A Red-Black implementation of the Map interface

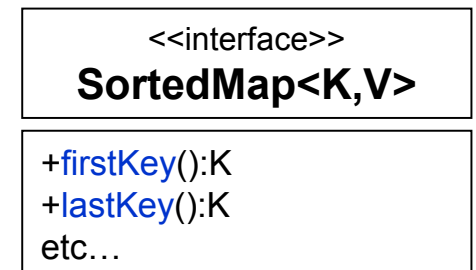
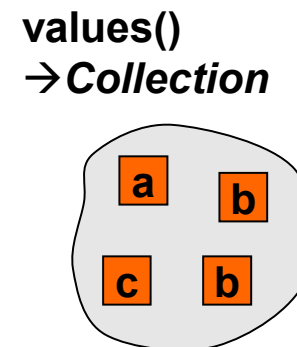
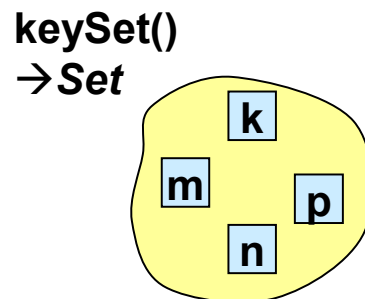
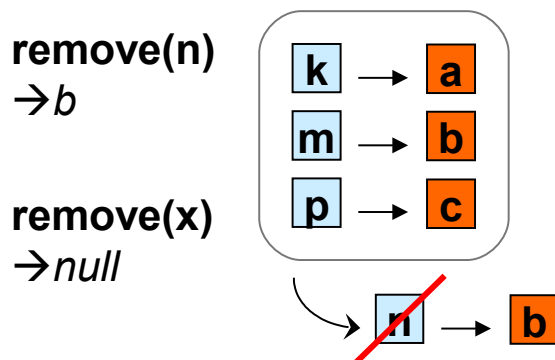
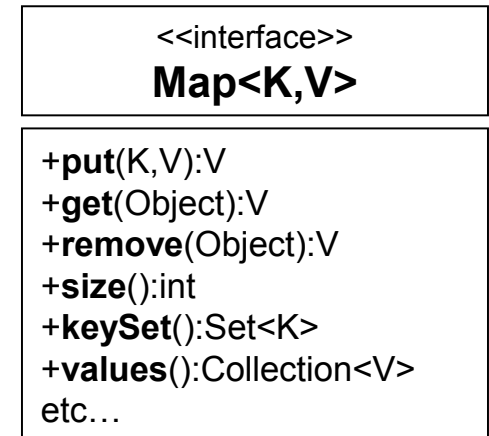
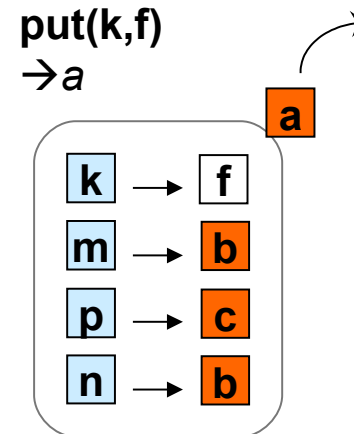
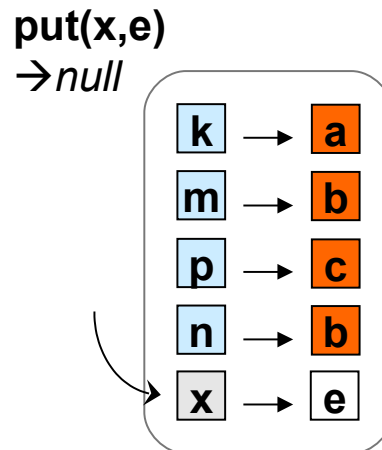
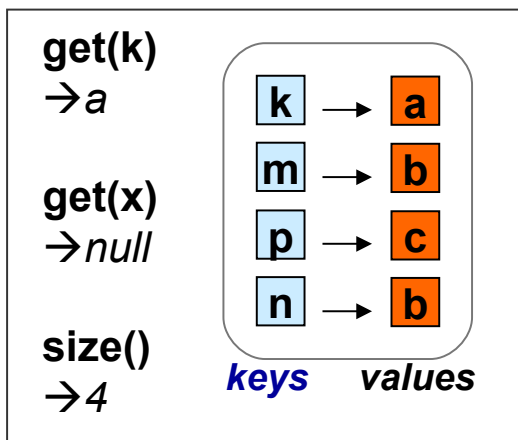
Map<K, V>

Stores mappings from (unique) keys (type K) to values (type V)

See, you can have more than one type parameters!

Think of them as “arrays” but with objects (keys) as indexes

Or as “directories”: e.g. "Bob" \rightarrow 021999887



HashMap<K, V>

aka Hashtable (SE250)

keys are hashed using `Object.hashCode()`

i.e. no guaranteed ordering of keys

`keySet()` returns a `HashSet`

`values()` returns an unknown Collection

<<interface>>

Map<K,V>

+**put**(K,V):V
+**get**(Object):V
+**remove**(Object):V
+**size**():int
+**keySet**():Set<K>
+**values**():Collection<V>
etc...



HashMap<K,V>

```
Map<String, Integer> directory
    = new HashMap<String, Integer>();
directory.put("Mum", new Integer(9998888));
directory.put("Dad", 9998888);
directory.put("Bob", 12345678);
directory.put("Edward", 5553535);
directory.put("Bob", 1000000);
System.out.println(directory.size());
for (String key : directory.keySet()) {
    System.out.print(key+"'s number: ");
    System.out.println(directory.get(key));
}
System.out.println(directory.values());
```

"autoboxing"

4 or 5?

Set<String>

What's Bob's number?

TreeMap<K, V>

Guaranteed ordering of keys (like TreeSet)

In fact, TreeSet is implemented using TreeMap ☺

Hence `keySet()` returns a `TreeSet`

`values()` returns an unknown Collection – ordering depends on ordering of **keys**

<<interface>>
SortedMap<K,V>

+`firstKey():K`
+`lastKey():K`
etc...



TreeMap<K,V>

Empty constructor
→ natural ordering

```
Map<String, Integer> directory
    = new TreeMap<String, Integer>();
directory.put("Mum", new Integer(9998888));
directory.put("Dad", 9998888);
directory.put("Bob", 12345678);
directory.put("Edward", 5553535);
directory.put("Bob", 1000000);
System.out.println(directory.size());
for (String key : directory.keySet()) {
    System.out.print(key+"'s #: ");
    System.out.println(directory.get(key));
}
System.out.println(directory.values());
```

4

Loop output?

Bob's #: 1000000
Dad's #: 9998888
Edward's #: 5553535
Mum's #: 9998888

?

TreeMap with Comparator

As with TreeSet, another way of constructing TreeMap is to give a Comparator → necessary for non-Comparable keys

```
Map<CD, Double> ratings
    = new TreeMap<CD, Double>(new PriceComparator());
ratings.put(new CD("Street Signs", "O", new Money(3, 50)), 8.5);
ratings.put(new CD("Jazzinho", "J", new Money(2, 80)), 8.0);
ratings.put(new CD("Space Cowboy", "J", new Money(5, 00)), 9.0);
ratings.put(new CD("Maiden Voyage", "H", new Money(4, 00)), 9.5);
ratings.put(new CD("Here's the Deal", "LS", new Money(2, 80)), 9.0);

System.out.println(ratings.size());
for (CD key : ratings.keySet()) {
    System.out.print("Rating for "+key+": ");
    System.out.println(ratings.get(key));
}
System.out.println("Ratings: "+ratings.values());
```

4

Ordered by key's price

Depends on key ordering

Most Commonly Use Methods

- While it is a good idea to learn and understand all of the methods defined within this infrastructure, here are some of the most commonly used methods.
- For Lists:
 - `add(Object)`, `add(index, Object)`
 - `get(index)`
 - `set(index, Object)`
 - `remove(Object)`
- For Maps:
 - `put(Object key, Object value)`
 - `get(Object key)`
 - `remove(Object key)`
 - `keySet()`

Which class should I use?

- You'll notice that collection classes all provide the same or similar functionality. The difference between the different classes is how the structure is implemented.
 - This generally has an impact on performance.
- Use Vector
 - Fast access to elements using index
 - Optimized for storage space
 - Not optimized for inserts and deletes
- Use ArrayList
 - Same as Vector except the methods are not synchronized. Better performance
- Use linked list
 - Fast inserts and deletes
 - Stacks and Queues (accessing elements near the beginning or end)
 - Not optimized for random access

Which class should I use?

- Use Sets
 - When you need a collection which does not allow duplicate entries
- Use Maps
 - Very Fast access to elements using keys
 - Fast addition and removal of elements
 - No duplicate keys allowed
- When choosing a class, it is worthwhile to read the class's documentation in the Java API specification. There you will find notes about the implementation of the Collection class and within which contexts it is best to use.

Collections and Fundamental Data Types

- Note that collections can only hold Objects.
 - One cannot put a fundamental data type into a Collection
- Java has defined "wrapper" classes which hold fundamental data type values within an Object
 - These classes are defined in java.lang
 - Each fundamental data type is represented by a wrapper class
- The wrapper classes are:
 - Boolean
 - Byte
 - Character
 - Double
 - Float
 - Short
 - Integer
 - Long

Wrapper Classes

- The wrapper classes are usually used so that fundamental data values can be placed within a collection
- The wrapper classes have useful class variables.
 - `Integer.MAX_VALUE`, `Integer.MIN_VALUE`
 - `Double.MAX_VALUE`, `Double.MIN_VALUE`, `Double.NaN`, `Double.NEGATIVE_INFINITY`, `Double.POSITIVE_INFINITY`
- They also have useful class methods
 - `Double.parseDouble(String)` - converts a `String` to a `double`
 - `Integer.parseInt(String)` - converts a `String` to an `integer`