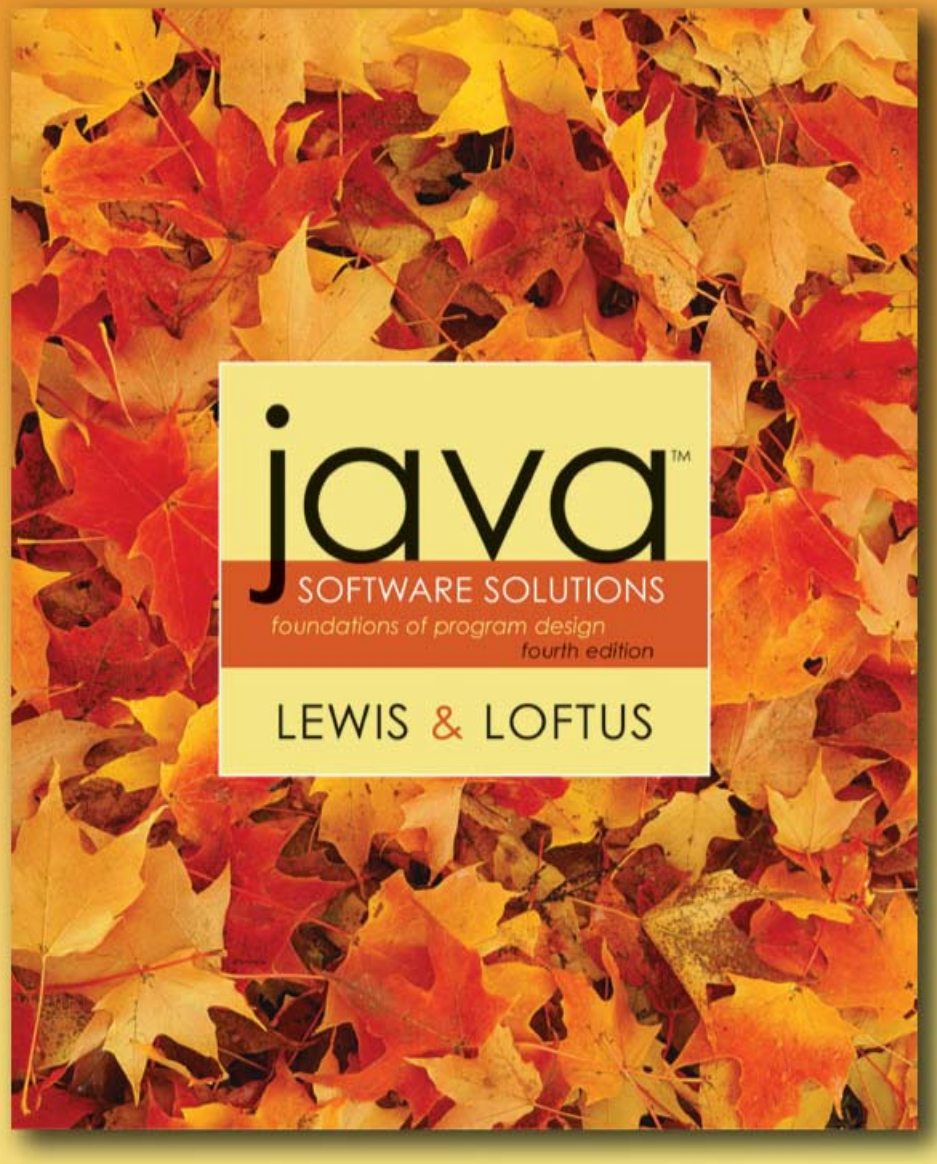
Lecture 12

Collections



PEARSON Addison Wesley

Collections

- A collection is an object that helps us organize and manage other objects
- Lecture 12 focuses on:
  - the concept of a collection
  - separating the interface from the implementation
  - dynamic data structures
  - linked lists
  - queues and stacks
  - trees and graphs
  - the Java Collection API

Outline

- Collections and Data Structures
- Dynamic Representations
- Queues and Stacks
- Trees and Graphs
- The Java Collections API

Collections

- A *collection* is an object that serves as a repository for other objects
- A collection usually provides services such as adding, removing, and otherwise managing the elements it contains
- Sometimes the elements in a collection are ordered, sometimes they are not
- Sometimes collections are *homogeneous*, containing all the same type of objects, and sometimes they are *heterogeneous*

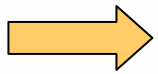
Abstraction

- Collections can be implemented in many different ways
- Our data structures should be *abstractions*
- That is, they should hide unneeded details
- We want to separate the interface of the structure from its underlying implementation
- This helps manage complexity and makes it possible to change the implementation without changing the interface

Abstract Data Types

- An *abstract data type* (ADT) is an organized collection of information and a set of operations used to manage that information
- The set of operations defines the *interface* to the ADT
- In one sense, as long as the ADT fulfills the promises of the interface, it doesn't matter how the ADT is implemented
- Objects are a perfect programming mechanism to create ADTs because their internal details are *encapsulated*

Outline



Collections and Data Structures

Dynamic Representations

Queues and Stacks

Trees and Graphs

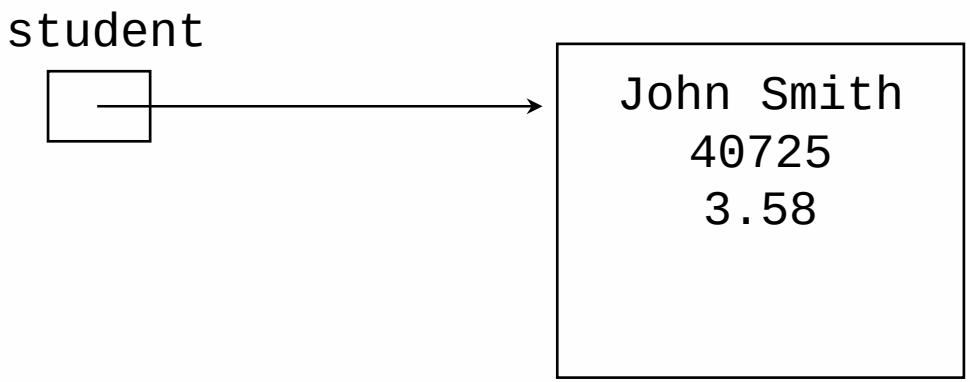
The Java Collections API

Dynamic Structures

- A *static* data structure has a fixed size
- This meaning is different from the meaning of the `static` modifier
- Arrays are static; once you define the number of elements it can hold, the size doesn't change
- A *dynamic data structure* grows and shrinks at execution time as required by its contents
- A dynamic data structure is implemented using *links*

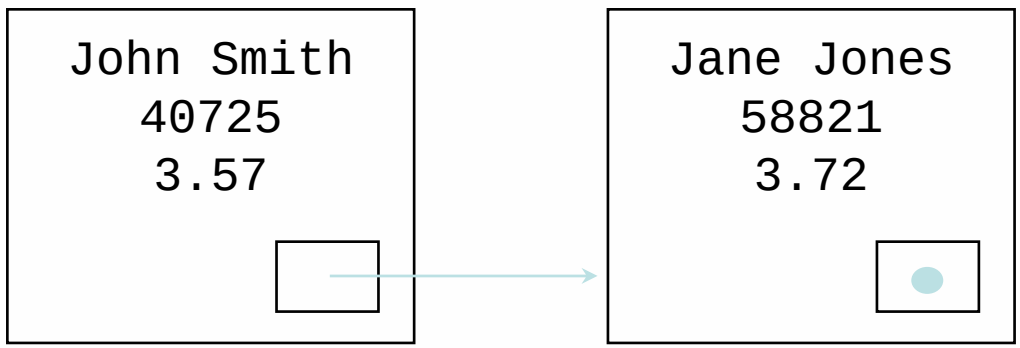
Object References

- **Recall that an *object reference* is a variable that stores the address of an object**
- **A reference also can be called a *pointer***
- **References often are depicted graphically:**



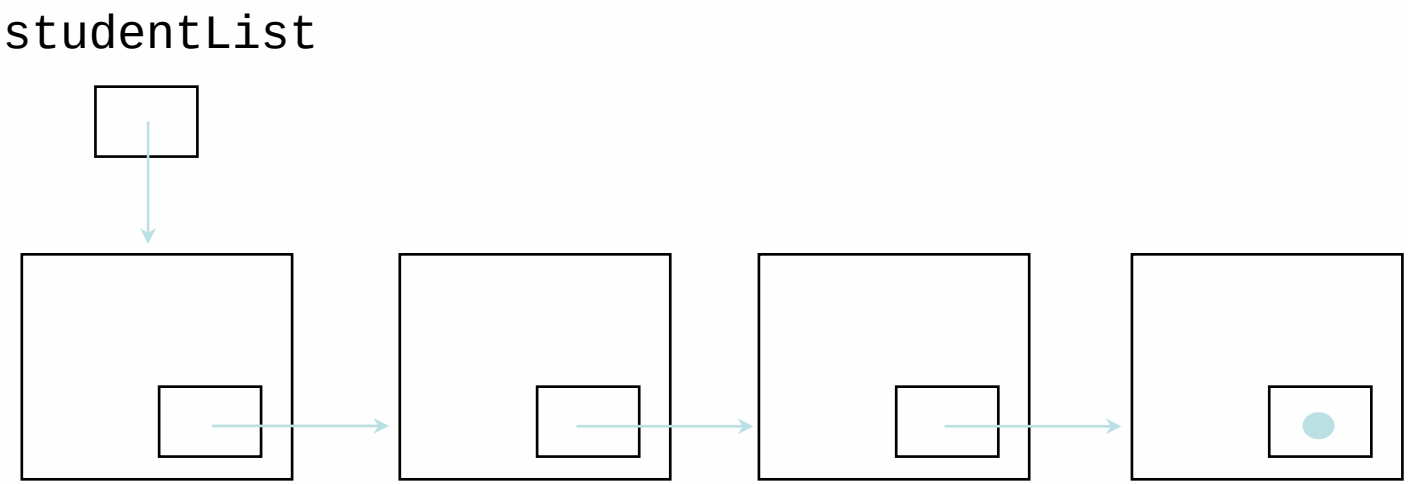
References as Links

- **Object references can be used to create *links* between objects**
- **Suppose a `Student` class contains a reference to another `Student` object**



References as Links

- **References can be used to create a variety of linked structures, such as a *linked list*:**



Intermediate Nodes

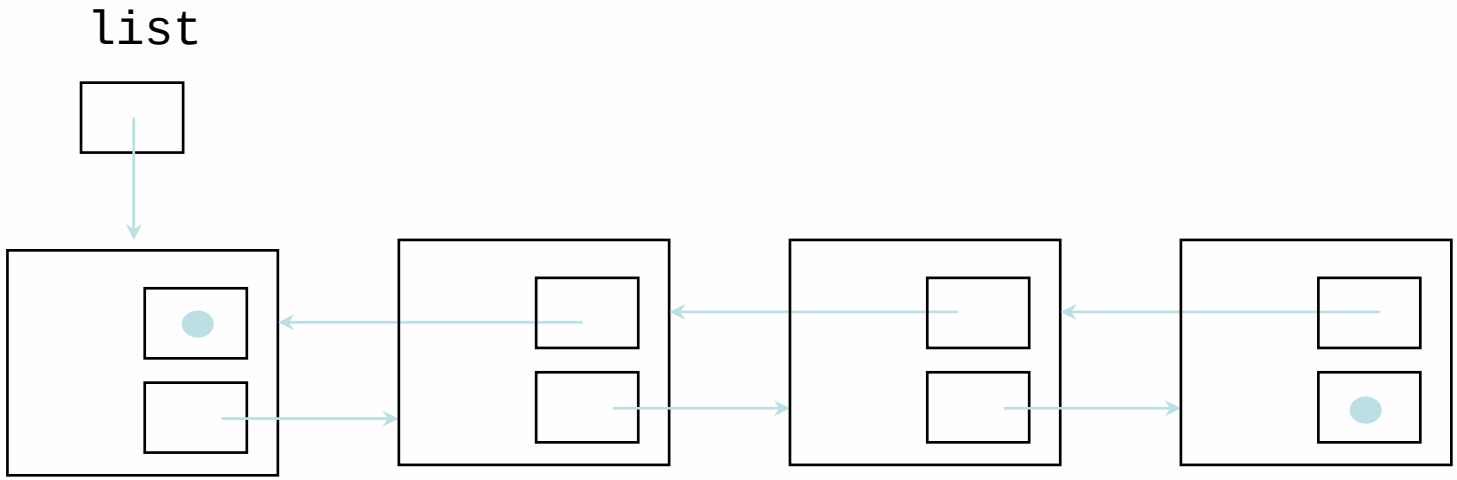
- The objects being stored should not be concerned with the details of the data structure in which they may be stored
- For example, the `Student` class should not have to store a link to the next `Student` object in the list
- Instead, we can use a separate node class with two parts: 1) a reference to an independent object and 2) a link to the next node in the list
- The internal representation becomes a linked list of nodes

Magazine Collection

- Let's explore an example of a collection of `Magazine` objects, managed by the `MagazineList` class, which has a private inner class called `MagazineNode`
- Because the `MagazineNode` is private to `MagazineList`, the `MagazineList` methods can directly access `MagazineNode` data without violating encapsulation
- See `MagazineRack.java` (page 615)
- See `MagazineList.java` (page 616)
- See `Magazine.java` (page 618)

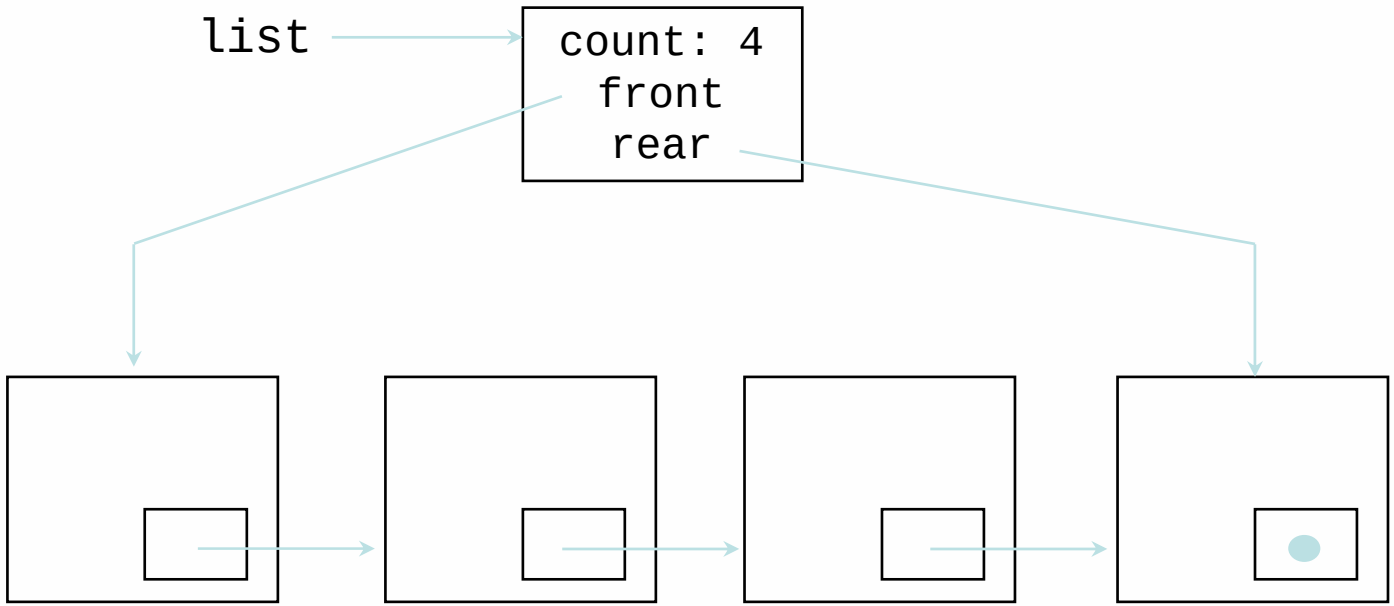
Other Dynamic Representations

- **It may be convenient to implement as list as a *doubly linked list*, with `next` and `previous` references**

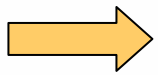


Other Dynamic Representations

- **It may be convenient to use a separate *header node*, with a count and references to both the front and rear of the list**



Outline



- Collections and Data Structures
- Dynamic Representations
- Queues and Stacks
- Trees and Graphs
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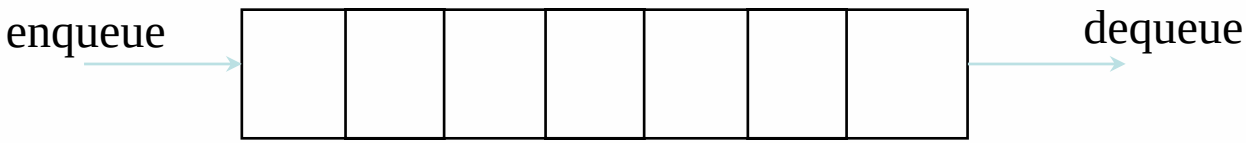
Classic Data Structures

- **Now we'll examine some classic data structures**
- **Classic *linear data structures* include *queues* and *stacks***
- **Classic *nonlinear data structures* include *trees* and *graphs***

Queues

- A *queue* is similar to a list but adds items only to the rear of the list and removes them only from the front
- It is called a FIFO data structure: First-In, First-Out
- Analogy: a line of people at a bank teller's window



Queues

- We can define the operations for a queue
  - enqueue - add an item to the rear of the queue
  - dequeue (or serve) - remove an item from the front of the queue
  - empty - returns true if the queue is empty
- As with our linked list example, by storing generic `Object` references, any object can be stored in the queue
- Queues often are helpful in simulations or any situation in which items get “backed up” while awaiting processing

Queues

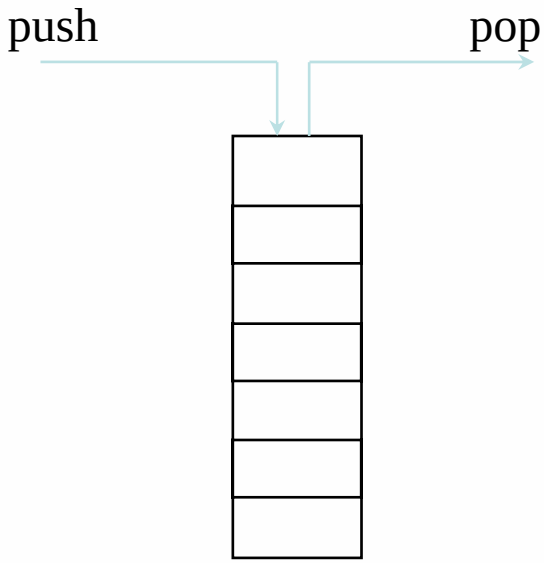
- A queue can be represented by a singly-linked list; it is most efficient if the references point from the front toward the rear of the queue
- A queue can be represented by an array, using the remainder operator (%) to “wrap around” when the end of the array is reached and space is available at the front of the array

Stacks

- A *stack* ADT is also linear, like a list or a queue
- Items are added and removed from only one end of a stack
- It is therefore LIFO: Last-In, First-Out
- Analogies: a stack of plates in a cupboard, a stack of bills to be paid, or a stack of hay bales in a barn

Stacks

- **Stacks often are drawn vertically:**



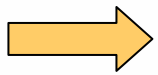
Stacks

- **Some stack operations:**
  - **push - add an item to the top of the stack**
  - **pop - remove an item from the top of the stack**
  - **peek (or top) - retrieves the top item without removing it**
  - **empty - returns true if the stack is empty**
- **A stack can be represented by a singly-linked list; it doesn't matter whether the references point from the top toward the bottom or vice versa**
- **A stack can be represented by an array, but the new item should be placed in the next available place in the array rather than at the end**

Stacks

- The `java.util` package contains a `Stack` class
- Like `ArrayList` operations, the `Stack` operations operate on `Object` references
- See `Decode.java` (page 623)

Outline



Collections and Data Structures

Dynamic Representations

Queues and Stacks

Trees and Graphs

The Java Collections API

Trees

- A *tree* is a non-linear data structure that consists of a *root node* and potentially many levels of additional nodes that form a hierarchy
- Nodes that have no children are called *leaf nodes*
- Nodes except for the root and leaf nodes are called *internal nodes*
- In a general tree, each node can have many child nodes

Binary Trees

- In a *binary tree*, each node can have no more than two child nodes
- A binary tree can be defined recursively. Either it is empty (the base case) or it consists of a *root* and two *subtrees*, each of which is a binary tree
- Trees are typically are represented using references as dynamic links, though it is possible to use fixed representations like arrays
- For binary trees, this requires storing only two links per node to the left and right child

Graphs

- A *graph* is a non-linear structure
- Unlike a tree or binary tree, a graph does not have a root
- Any node in a graph can be connected to any other node by an *edge*
- Analogy: the highway system connecting cities on a map

Digraphs

- **In a *directed graph* or *digraph*, each edge has a specific direction.**
- **Edges with direction sometimes are called *arcs***
- **Analogy: airline flights between airports**

Representing Graphs

- **Both graphs and digraphs can be represented using dynamic links or using arrays.**
- **As always, the representation should facilitate the intended operations and make them convenient to implement**

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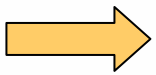


Collection Classes

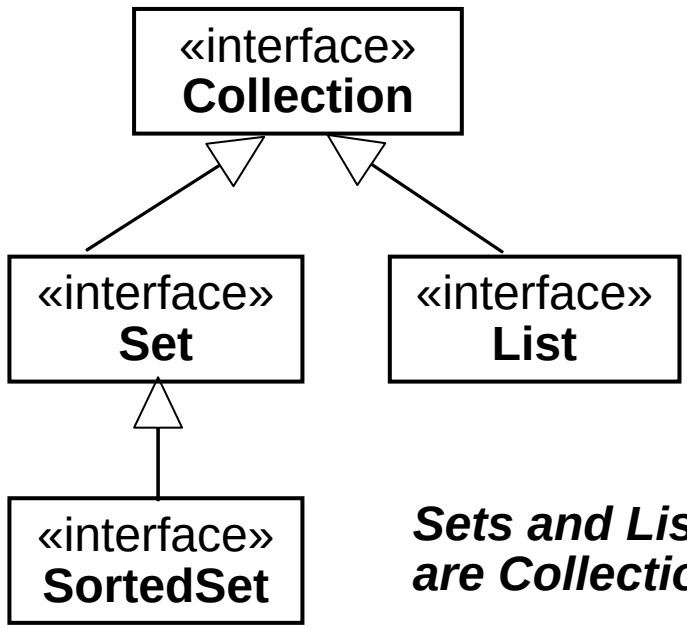
- **The Java standard library contains several classes that represent collections, often referred to as the *Java Collections API***
- **Their underlying implementation is implied in the class names such as `ArrayList` and `LinkedList`**
- **Several interfaces are used to define operations on the collections, such as `List`, `Set`, `SortedSet`, `Map`, and `SortedMap`**

The Java Collections Framework

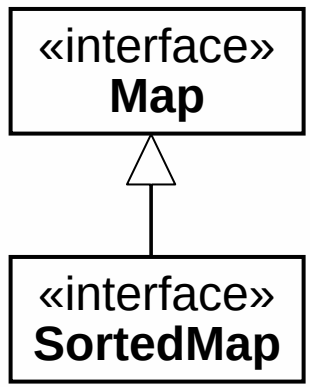
- In this lecture you will get a short introduction to the Collections framework
- In the exercises you will use the framework to implement a solution to the Jumble Puzzle (following an idea of *Prof. O. Nierstrasz*)
- To simplify matters, we will describe the collections API without generics first
- Later, we will see examples which use classes of the Collections framework in a generic manner

The Collections Framework

The Java Collections framework (in java.util) consists of *interfaces*, *implementations* and *algorithms* for manipulating collections of elements.

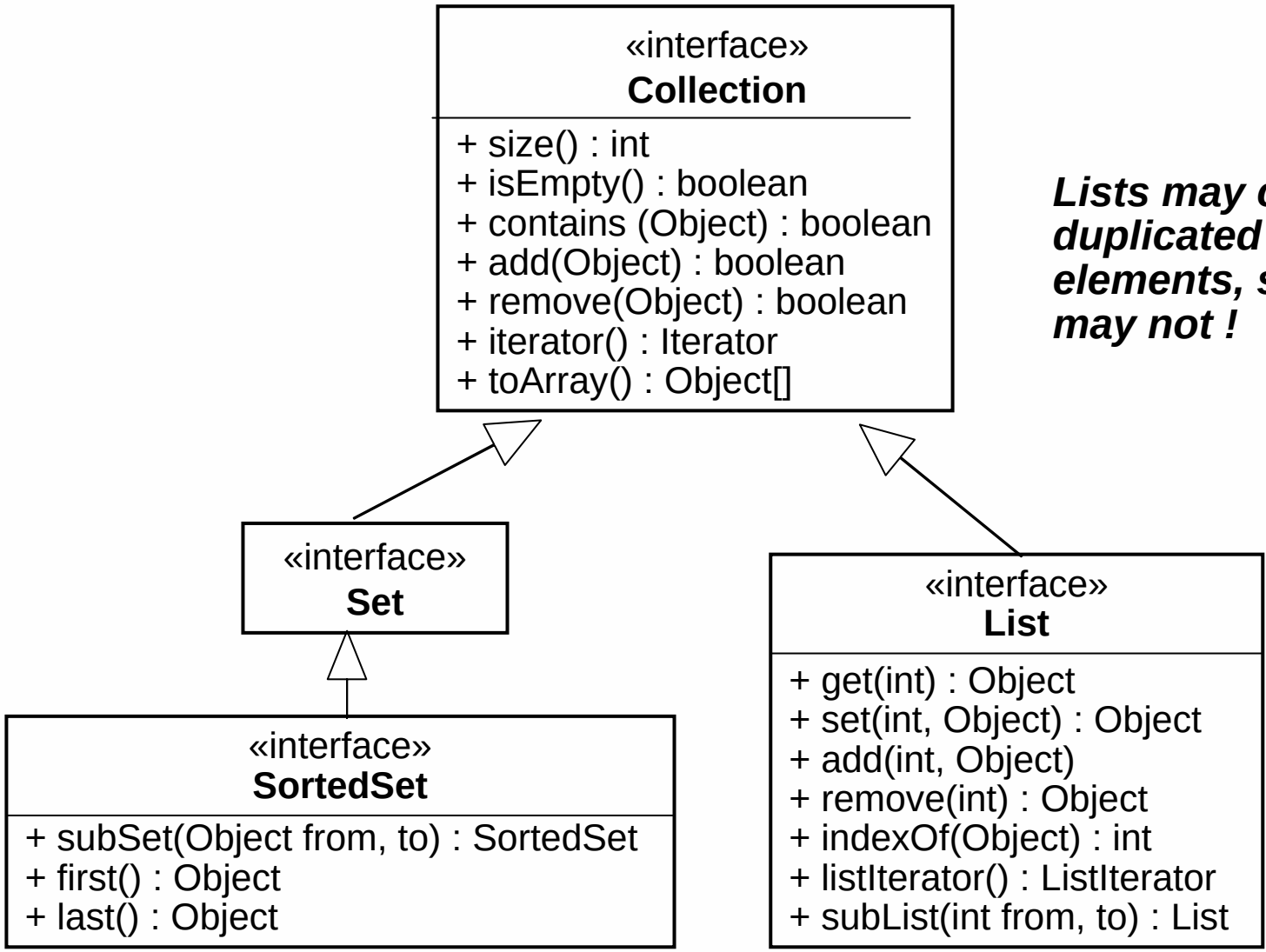


Sets and Lists are Collections



Maps provide mappings from keys to values

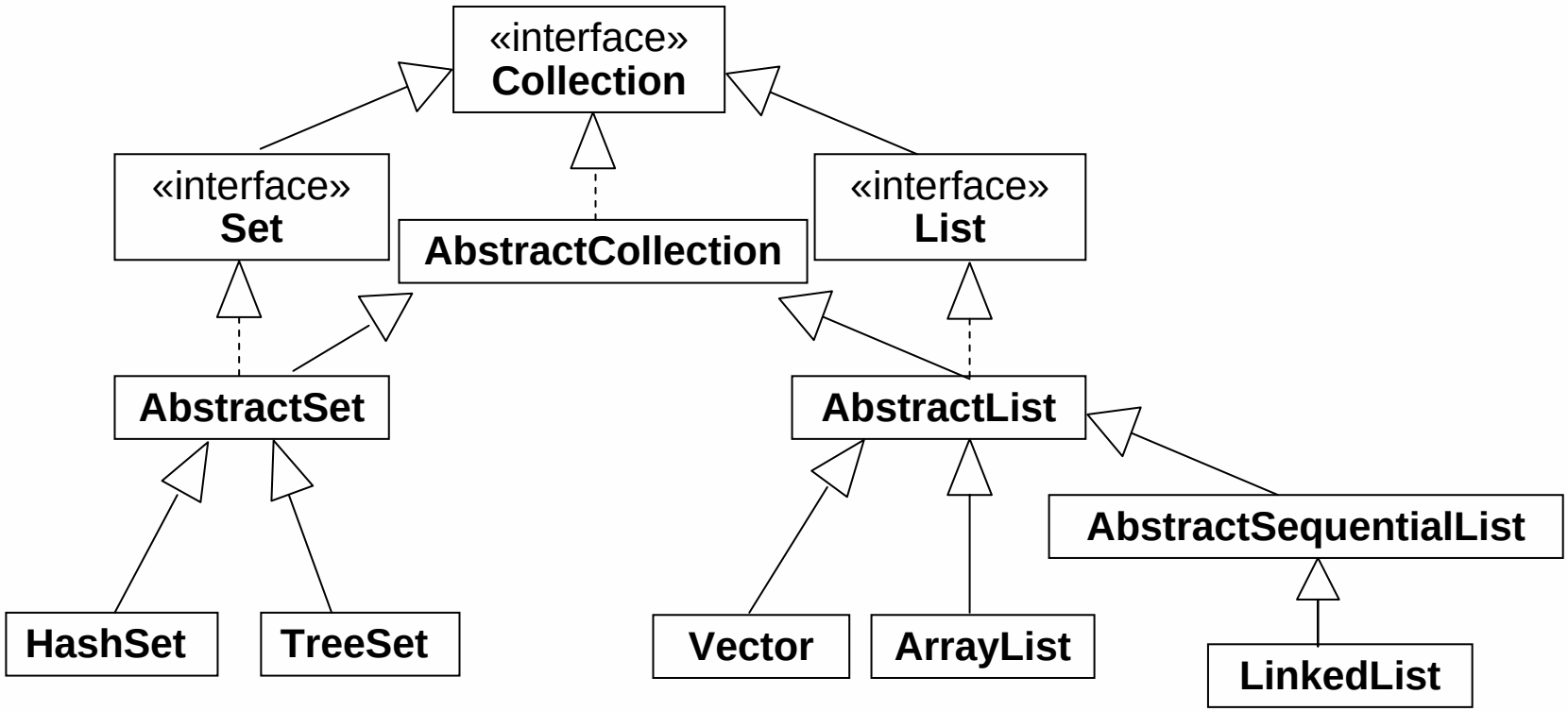
Collection Interfaces



Lists may contain duplicated elements, sets may not !

Implementations

There are at least two implementations for each interface



Object-oriented principles

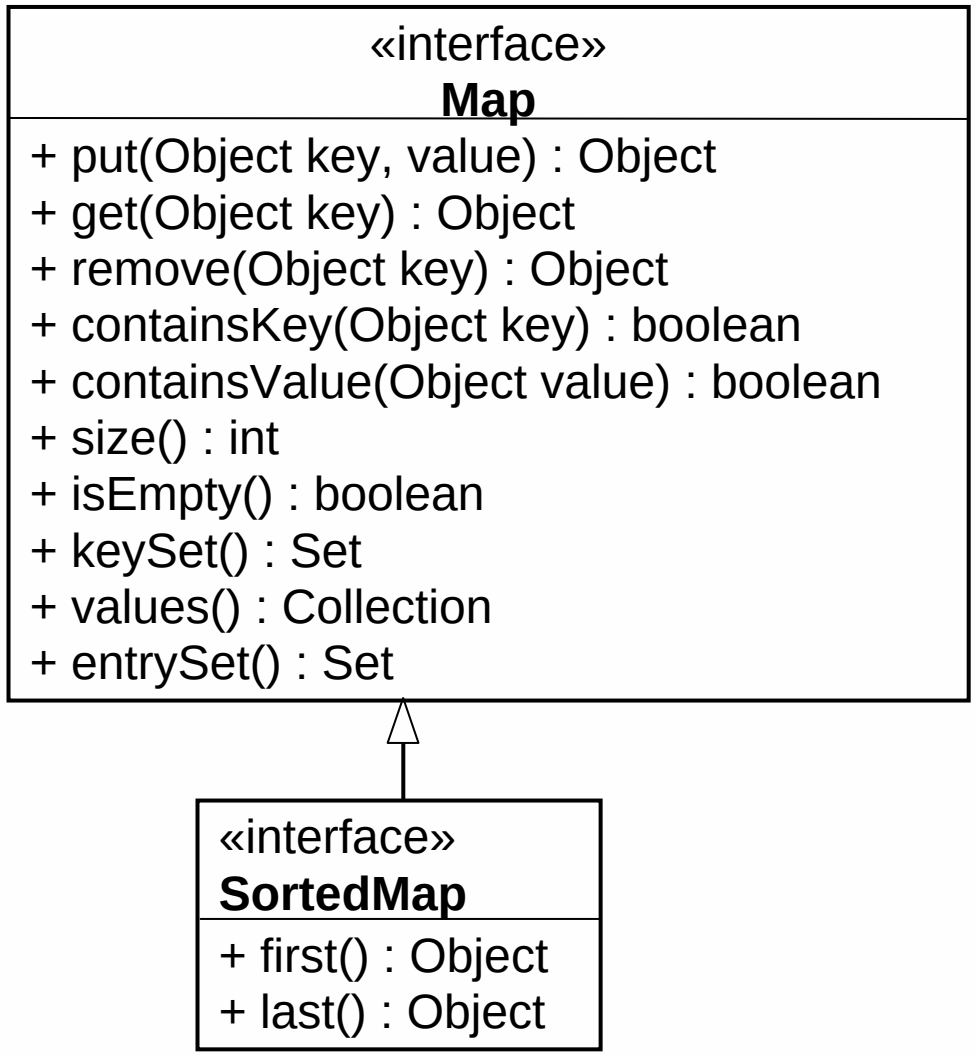
- **Programs using collections generally only depend on interfaces, not classes**
- **Classes may implement multiple interfaces**
- **Slogan: *single inheritance, multiple subtyping***
- ***Abstract classes* define common behavior shared by subclasses but cannot be instantiated, because they are incomplete**

Maps

A *Map* object consists of a set of (key, value) pairs

Map is implemented by _HashMap_ and _TreeMap_

In a _SortedMap_ object, the entries are stored in ascending order



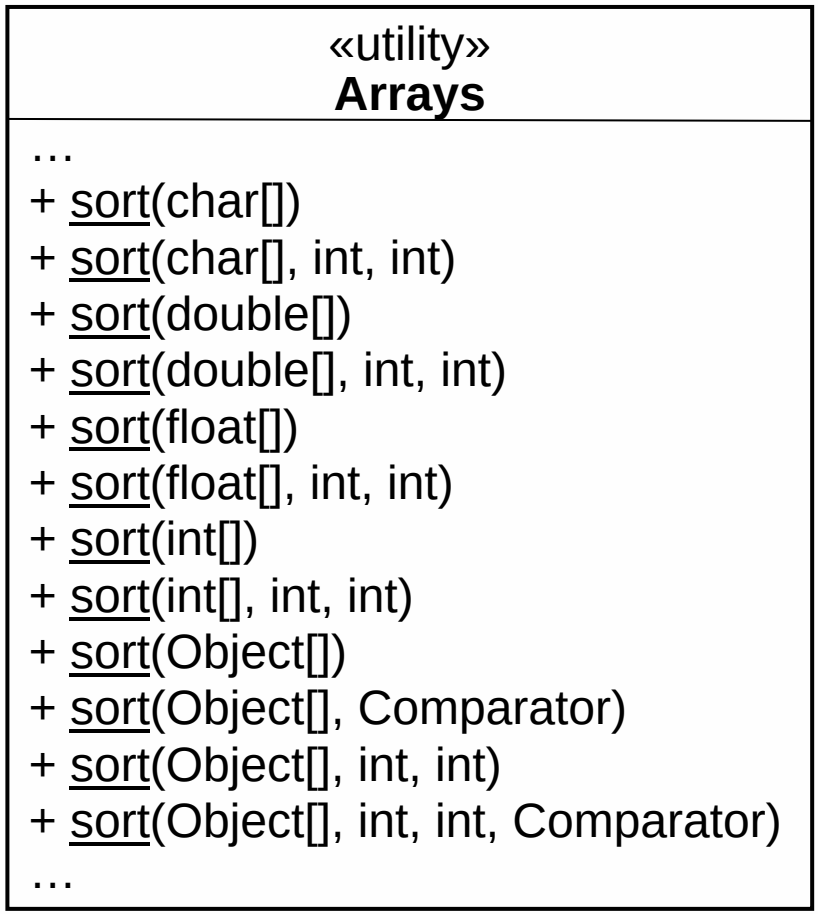
Algorithms

«utility»
Collections
+ binarySearch(List, Object) : int
+ copy(List, List)
+ max(Collection) : Object
+ min(Collection) : Object
+ reverse(List)
+ shuffle(List)
+ sort(List)
+ sort(List, Comparator)
…

The Collections Framework contains several algorithms for sorting and searching, which work *uniformly (polymorphycally)* on arbitrary Collections.

These algorithms are static methods (utilities) of the Collections class.

Array Algorithmen

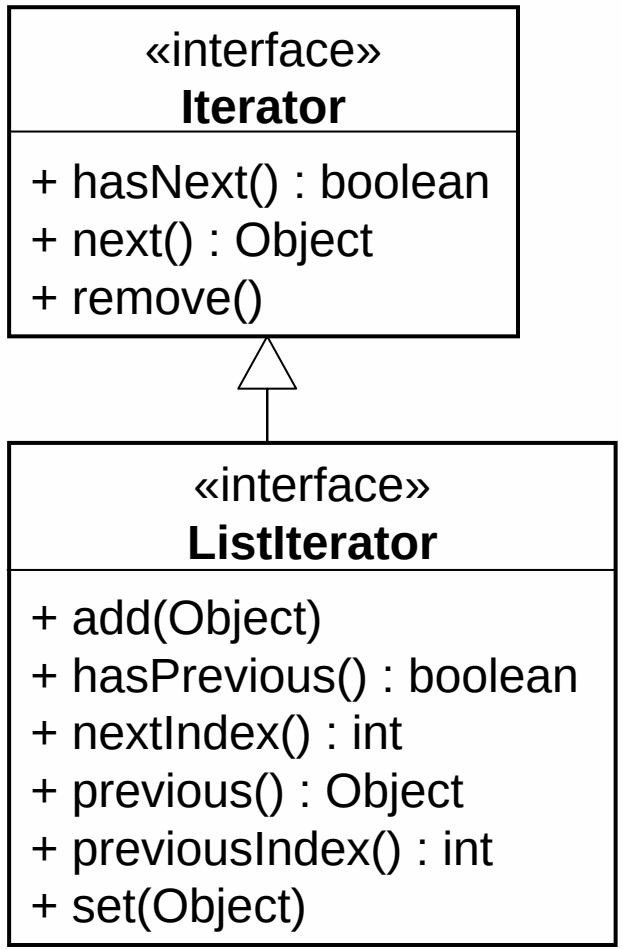


Further, there is the Arrays class, consisting of static methods for Searching and Sorting Java arrays.

Iterators

An Iterator is an object that lets you walk through an arbitrary collection.

A ListIterator, in addition, allows traversal in either direction and modify the collection during iteration



Generics

- As mentioned in Lecture 7, Java supports *generic types,* which are useful when defining collections
- A class can be defined to operate on a generic data type which is specified when the class is instantiated:

```
LinkedList<Book> myList =
  new LinkedList<Book>();
```

- By specifying the type stored in a collection, only objects of that type can be added to it
- Furthermore, when an object is removed, its type is already established

Some examples of generic collections

- A program that demonstrates the LinkedList class (see ListTester.java)
- A program that demonstrates the HashSet class (see SetTester.java)
- A program that demonstrates the HashMap class (see MapTester.java)

Tutorial on Collections

- **Visit J. Bloch's tutorial at**

  http://java.sun.com/docs/books/tutorial/collections/

Summary

- **Lecture 12 has focused on:**
  - **the concept of a collection**
  - **separating the interface from the implementation**
  - **dynamic data structures**
  - **linked lists**
  - **queues and stacks**
  - **trees and graphs**
  - **The Java collection API**
  - **generics**