Java Container Classes

A motivating example

- Android and iOS use an event driven model for programming apps
- Apps *register* for a service by sending an object of type T to the provider of a service (this is one of three ways I know of for apps to get services)
  - T is usually an interface or abstract class
- Service responds at some later time by calling some method m(. . .) on the sent object and passing information through that method
  - Because the registered object is of type T the service knows it implements an m with the right signature

A GPS service - app side

```
class appGPSHandler
    implements GPSUser {
    ...
    void moveAlert(...) {...}
}

class myApp {
   GPSUser handler = ...
       new appGPSHandler( )
   ...
   GPS.registerAlarm(handler);
   ...
}
```

- Phones have GPS devices
- Some Apps would like to be notified by the GPS if the phone moves more than X feet
  - Can set off an alarm
  - Useful to see if people are stealing your phone
  - Useful if you are on an anchored boat
- Registration at a high level looks like code to the left

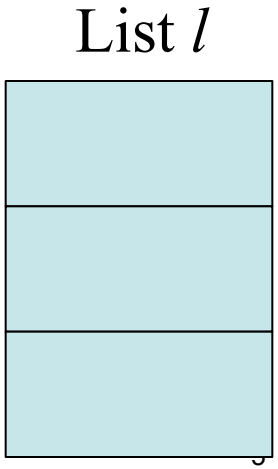
A GPS service -- Android side

```
class GPS {
   static List<GPSUser> l = new ...
   static void register(GPSUser u) {
      l.insert(u);
   }

   static void moved( ) {
      for each element e in l {
         if movement is enough {
            e.moveAlert(...);
         }
      }
   }
}
```

- When a GPS request for service is registered it is put into a list l that can hold GPSUser objects
- When the service is to be provided, the element e is pulled out of the list l and the app method *moveAlert(...)* is called on the element

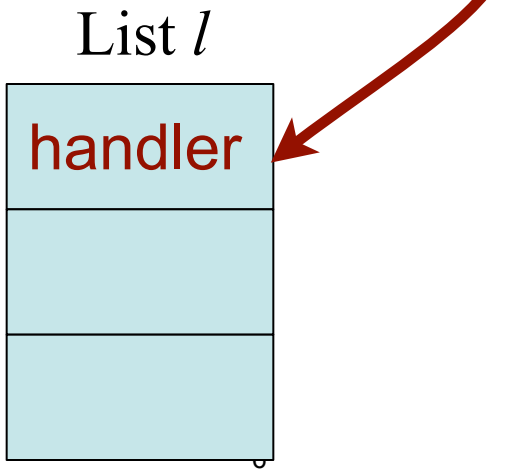
```
class appGPSHandler . . . {
   . . .
   void moveAlert(. . .) {. . .};
   . . .
}

class myApp {
   . . .
   GPS.register(handler);
   . . .
}
```

```
class GPS
   . . .
   static void register . . .
   . . .
   static void moved . . .
   . . .
}
```



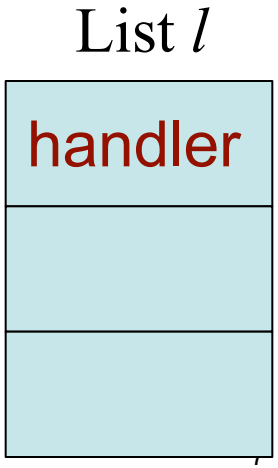
```
class appGPSHandler . . . {
   . . .
   void moveAlert(. . .) {. . .};
   . . .
}

class myApp {
   . . .
   GPS.register(handler);
   . . .
}
```

```
class GPS
   . . .
   static void register . . .
   . . .
   static void moved . . .
   . . .
}
```



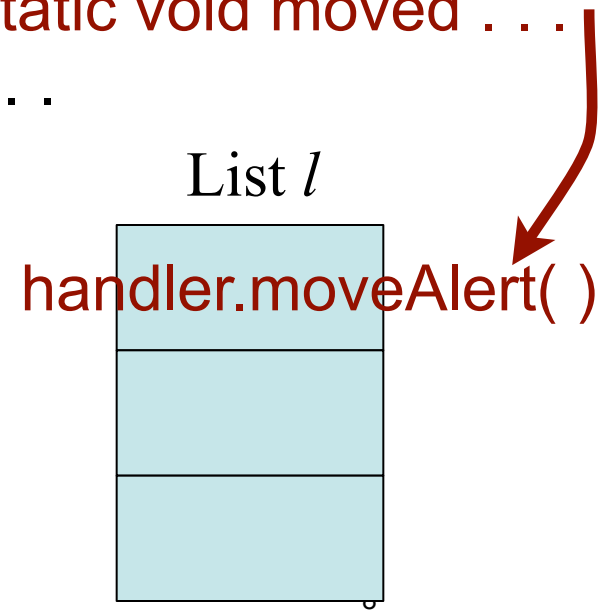
```
class appGPSHandler . . . {
   . . .
   void moveAlert(. . .) {. . .};
   . . .
}

class myApp {
   . . .
   GPS.register(handler);
   . . .
}
```

```
class GPS
   . . .
   static void register . . .
   . . .
   static void moved . . .
   . . .
}
```



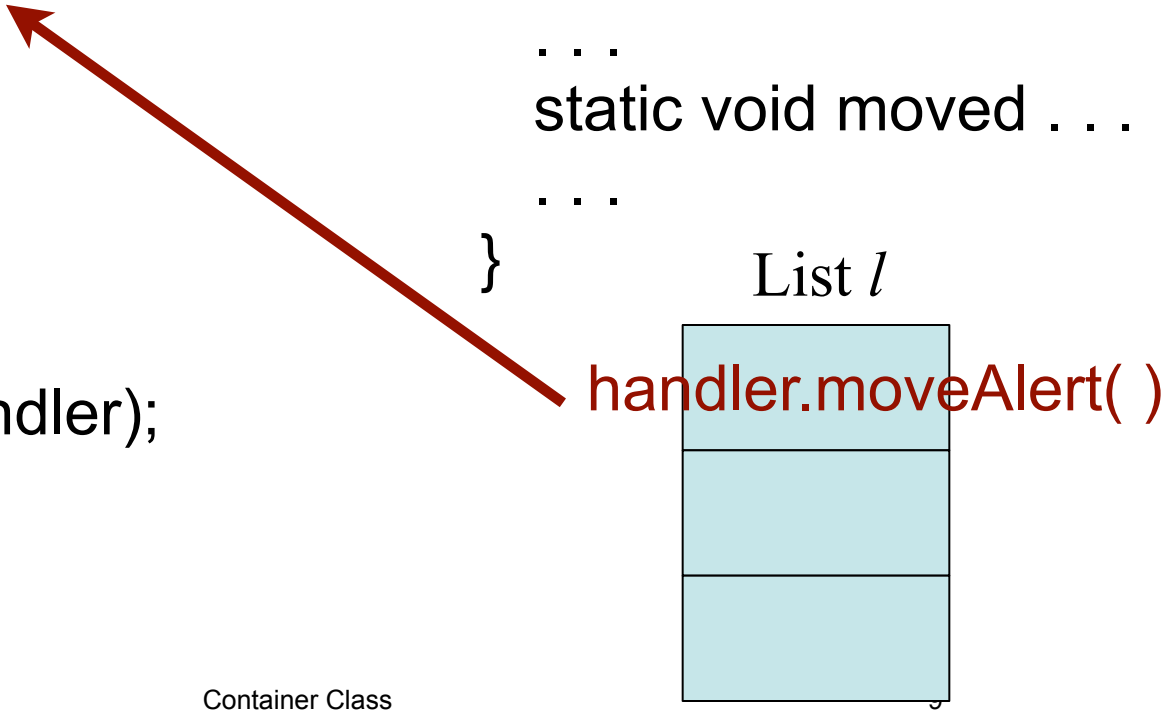
```
class appGPSHandler . . . {
   . . .
   void moveAlert(. . .) {. . .};
   . . .
}

class myApp {
   . . .
   GPS.register(handler);
   . . .
}
```

```
class GPS
   . . .
   static void register . . .
   . . .
   static void moved . . .
   . . .
}
```



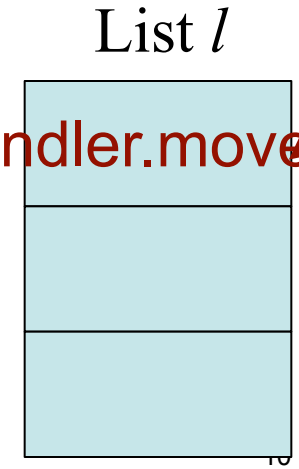
```
class appGPSHandler . . . {
   . . .
   void moveAlert(. . .) {. . .};
   . . .
}

class myApp {
   . . .
   GPS.register(handler);
   . . .
}
```

```
class GPS
   . . .
   static void register . . .
   . . .
   static void moved . . .
   . . .
}
```



```
class appGPSHandler . . . {
   . . .
   void moveAlert(. . .) {. . .};
   . . .
}

class myApp {
   . . .
   GPS.register(handler);
   . . .
}
```

```
class GPS
   . . .
   static void register . . .
   . . .
   static void moved . . .
   . . .
}
```



Abstract classes/interfaces and containers work together

- Interfaces/abstract classes force a derived class to implement functionality
  - This in turn lets users of the object know that the functionality exists in the object
  - It also allows different implementations of that functionality (e.g., list as linked list or array of elements)
- Containers supply efficient support for holding and accessing lots of objects
- Polymorphism allows
  - objects of many types to be held in a container with some base type (either an interface, base abstract class or non-abstract base class)
  - Implementations of methods in the final class to be called

In our example

- The moveAlert class can do different things based on the app.
- If a mapping app, move a marker on a map every 100 feet
- If a boat anchoring app, sound an alert
- If a tracking app, add an entry to the track log
- All of these can be done from objects in the container as long as the actual derived class contains the proper implementation
- The call to moveAlert( ) doesn't care which, only that the signature is correct

Why Container Classes?

- Many programs use arrays, vectors, lists, queues, stacks, sets to store information.
- Both C++ and Java provide container classes that automatically manage memory, i.e. they allocate additional memory when more elements are added.
- The supported container classes greatly reduce the amount of code and programming needed and improve productivity.
- Container classes and OOP are closely related:
  - Containers hold objects of different derived classes
  - Polymorphism properly invokes the correct methods

Container Class (For Code Reuse)

- A container needs to be able to hold items of different types (i.e. classes). Examples
  - list of strings, integers, floating points, student objects
  - queues of undergraduates, graduate students, staff and faculty
  - maps: name → address, student ID → name, course title → classroom
- C++ *standard template library* (STL) and Java container classes provide such functionality.

Selecting a container class

- random or sequential accesses?
- allow unique or duplicate items?
- O(1) or O(N) for array-like access (using [index])
- efficient insert / delete?
  - front
  - end
  - middle
- Java containers ***cannot*** store primitive types (int, char, float ...), they can store objects only. Primitive types, however, have corresponding object types (e.g. Integer, Boolean) that can be held in containers.
- C++ containers can store primitives.

Efficiency

operation	vector	deque	list
array-like access	O(1)	O(1)	O(N)
insert/delete at front	O(N)	O(1)+	O(1)
insert/delete at end	O(1)+	O(1)+	O(1)
insert/delete in middle	O(N)	O(N)	O(1)

N: current number of items

Two suggestions when using containers

- If code you are writing can ever exist in a multithreaded environment
  - Make sure the container is thread safe or add your own synchronization
  - Make sure actions on objects stored in the container are thread safe
- If you have the choice of using a Java or C++ container or writing your own, use the supplied one
  - Even if yours and their's are both O(N), their constant will almost certainly be smaller than yours
  - If thread safe, smart people will have spent lots of time tuning this to avoid unnecessary synchronization

Java Containers

Java List


List (Java Platform SE 6) - Mozilla Firefox
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http://java.sun.com/javase/6/docs/api/java/util/List.html
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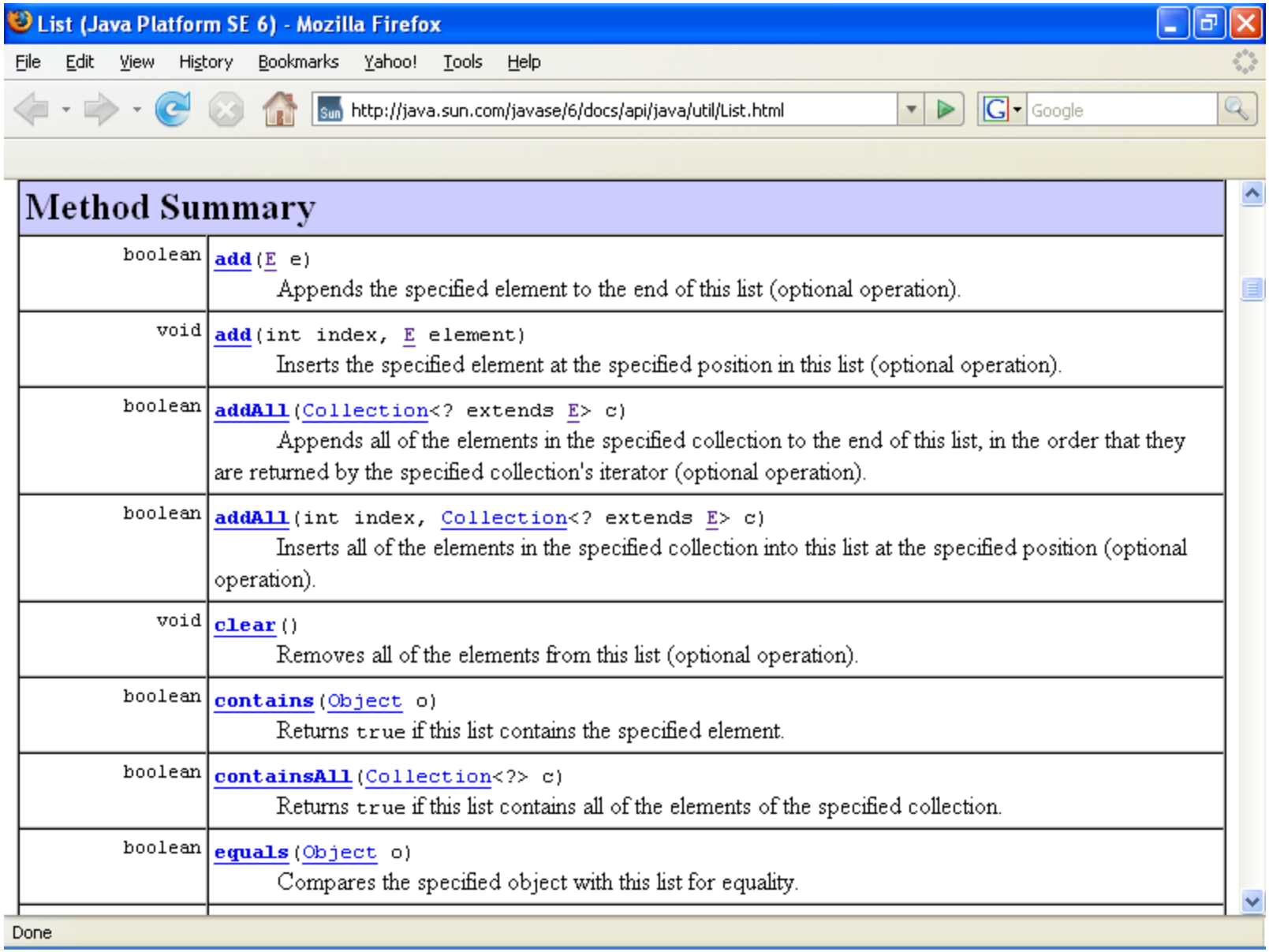
Overview Package Class Use Tree Deprecated Index Help
Java™ Platform Standard Ed. 6
PREV CLASS NEXT CLASS
FRAMES NO FRAMES All Classes
SUMMARY: NESTED | FIELD | CONSTR | METHOD
DETAIL: FIELD | CONSTR | METHOD
java.util
Interface List<E>
All Superinterfaces:
Collection<E>, Iterable<E>
All Known Implementing Classes:
AbstractList, AbstractSequentialList, ArrayList, AttributeList, CopyOnWriteArrayList, LinkedList, RoleList, RoleUnresolvedList, Stack, Vector
public interface List<E>
extends Collection<E>
An ordered collection (also known as a sequence). The user of this interface has precise control over where in the list each element is inserted. The user can access elements by their integer index (position in the list), and search for elements in the list.
Unlike sets, lists typically allow duplicate elements. More formally, lists typically allow pairs of elements e1 and e2 such that
Done

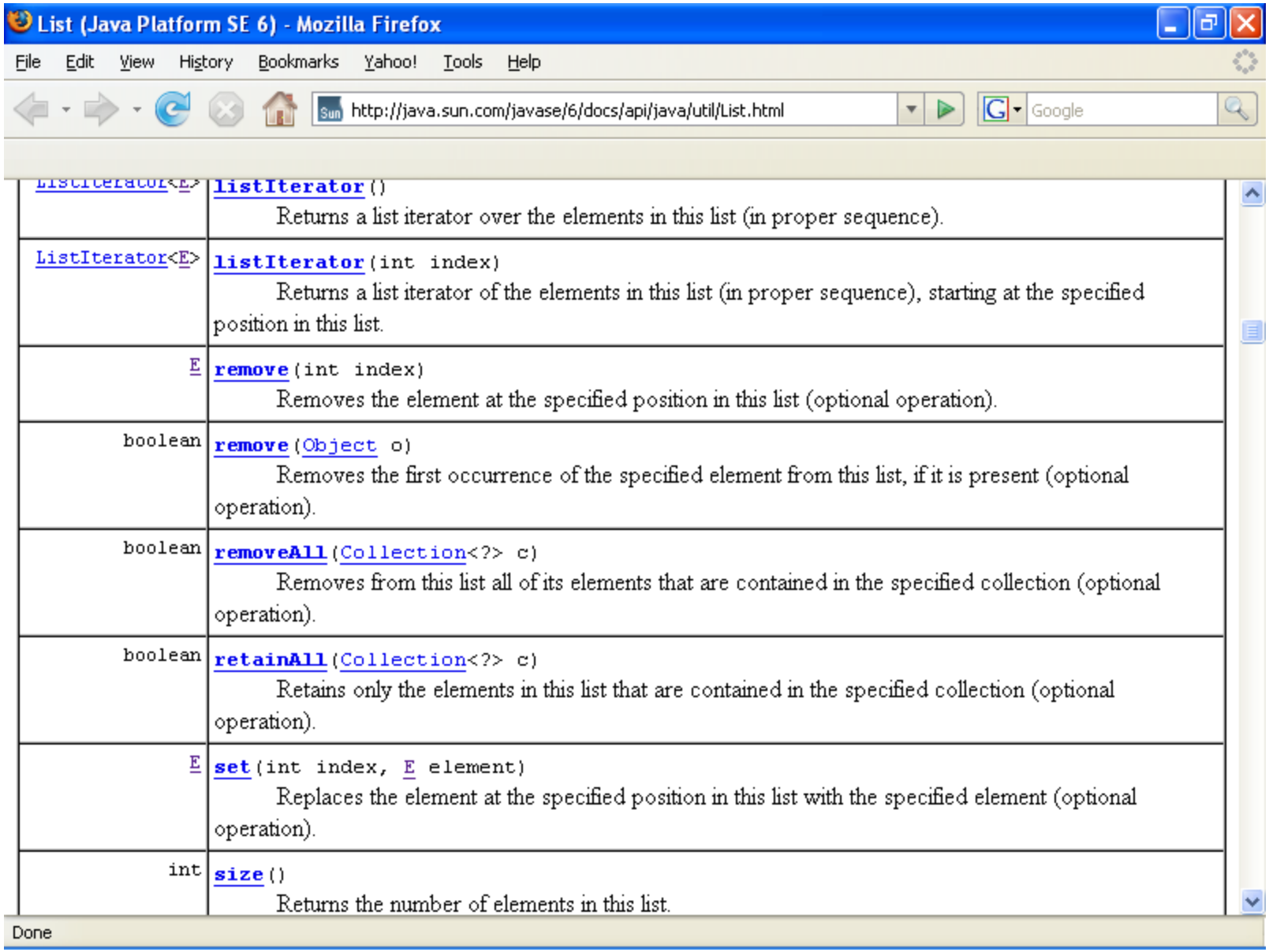
Interface and Class

- A Java interface serves as an *abstract class* and cannot be instantiated.
- An interface can be implemented by classes.
- Typically, an interface is a common base for several related classes, for example, interface *List* as the base of *ArrayList*, *LinkedList*, *Stack*, and *Vector*.



Method Summary

boolean	**add**(E e) Appends the specified element to the end of this list (optional operation).
void	**add**(int index, E element) Inserts the specified element at the specified position in this list (optional operation).
boolean	**addAll**(Collection<? extends E> c) Appends all of the elements in the specified collection to the end of this list, in the order that they are returned by the specified collection's iterator (optional operation).
boolean	**addAll**(int index, Collection<? extends E> c) Inserts all of the elements in the specified collection into this list at the specified position (optional operation).
void	**clear**() Removes all of the elements from this list (optional operation).
boolean	**contains**(Object o) Returns true if this list contains the specified element.
boolean	**containsAll**(Collection<?> c) Returns true if this list contains all of the elements of the specified collection.
boolean	**equals**(Object o) Compares the specified object with this list for equality.


List (Java Platform SE 6) - Mozilla Firefox
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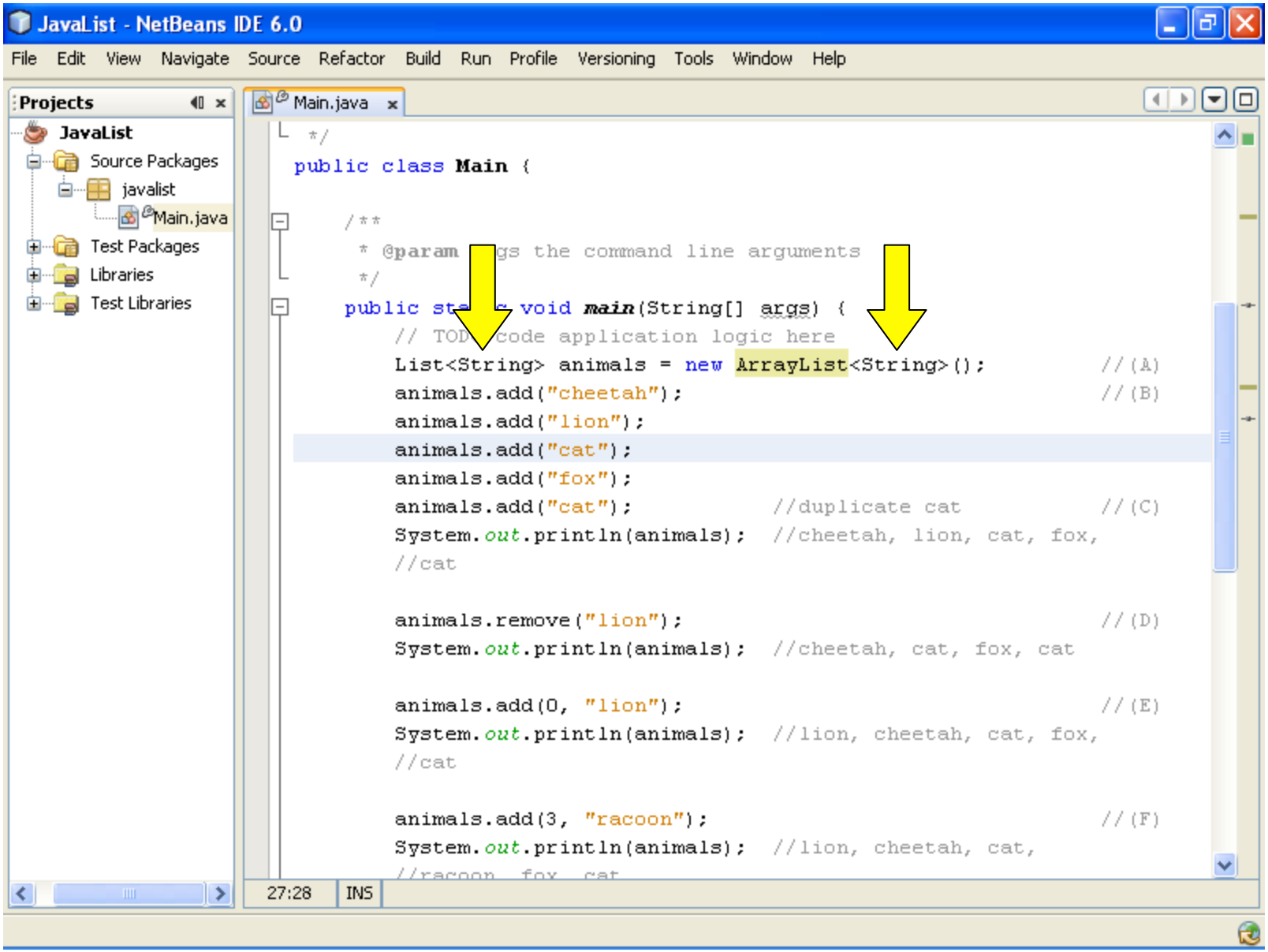
http://java.sun.com/javase/6/docs/api/java/util/List.html
Google
ListIterator<E> listIterator()
Returns a list iterator over the elements in this list (in proper sequence).
ListIterator<E> listIterator(int index)
Returns a list iterator of the elements in this list (in proper sequence), starting at the specified position in this list.
E remove(int index)
Removes the element at the specified position in this list (optional operation).
boolean remove(Object o)
Removes the first occurrence of the specified element from this list, if it is present (optional operation).
boolean removeAll(Collection<?> c)
Removes from this list all of its elements that are contained in the specified collection (optional operation).
boolean retainAll(Collection<?> c)
Retains only the elements in this list that are contained in the specified collection (optional operation).
E set(int index, E element)
Replaces the element at the specified position in this list with the specified element (optional operation).
int size()
Returns the number of elements in this list.
Done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Projects
JavaList
Source Packages
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Main.java
Test Packages
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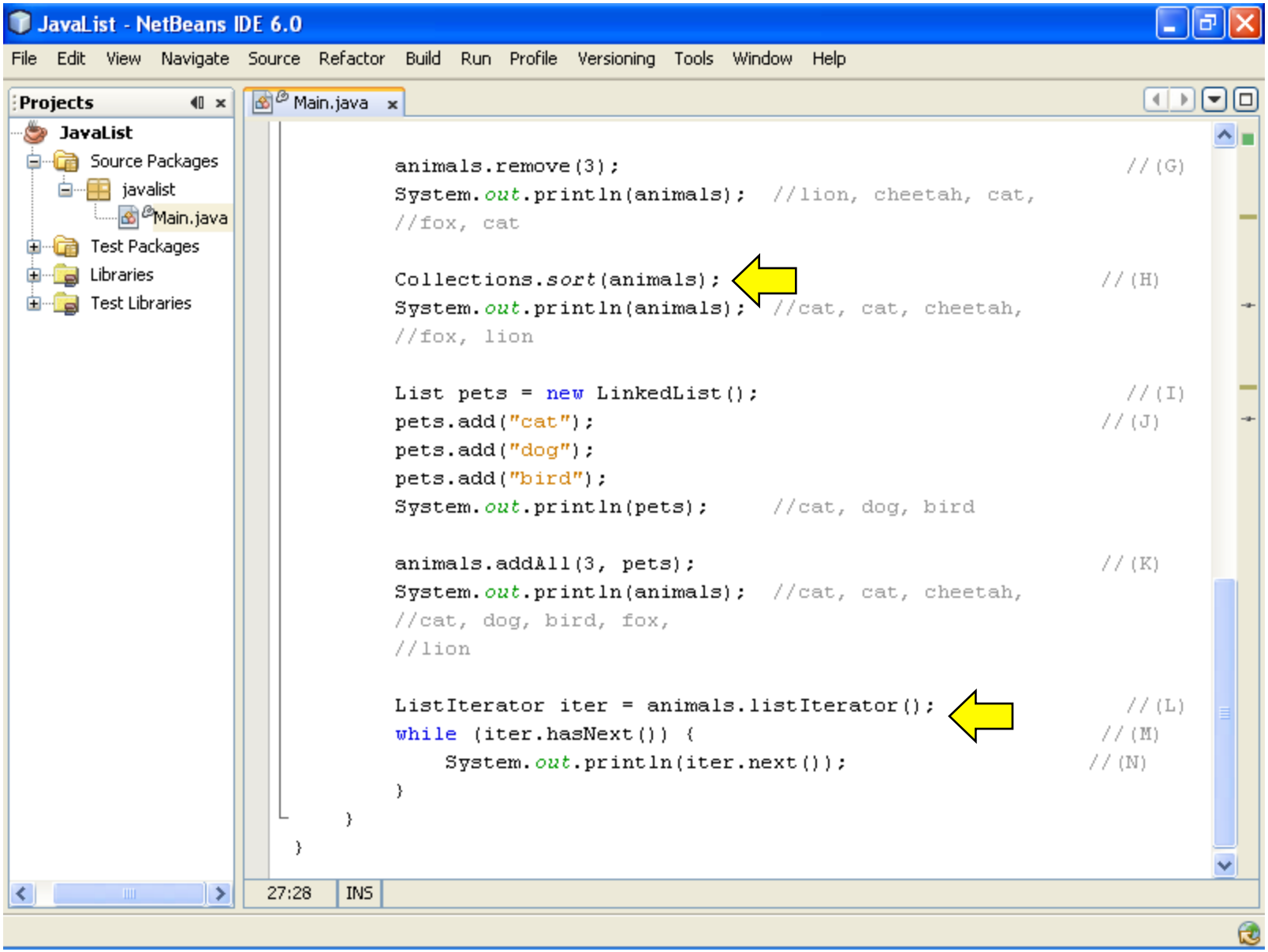
Test Libraries
Main.java
*/
public class Main {
/**
* @param args the command line arguments
*/
public static void main(String[] args) {
// TODO code application logic here
List<String> animals = new ArrayList<String>(); //(A)
animals.add("cheetah"); //(B)
animals.add("lion");
animals.add("cat");
animals.add("fox");
animals.add("cat"); //duplicate cat //(C)
System.out.println(animals); //cheetah, lion, cat, fox,
//cat
animals.remove("lion"); //(D)
System.out.println(animals); //cheetah, cat, fox, cat
animals.add(0, "lion"); //(E)
System.out.println(animals); //lion, cheetah, cat, fox,
//cat
animals.add(3, "racoon"); //(F)
System.out.println(animals); //lion, cheetah, cat,
27:28
INS

What is an array list?

- Is it an an Array or is it a list?
- From http://docs.oracle.com/javase/6/docs/api/java/util/ArrayList.html
  - Resizable-array implementation of the `List` interface. Implements all optional list operations, and permits all elements, including `null`.
  - In addition to implementing the `List` interface, this class provides methods to manipulate the size of the array that is used internally to store the list.
  - (This class is roughly equivalent to `Vector`, except that it is unsynchronized.)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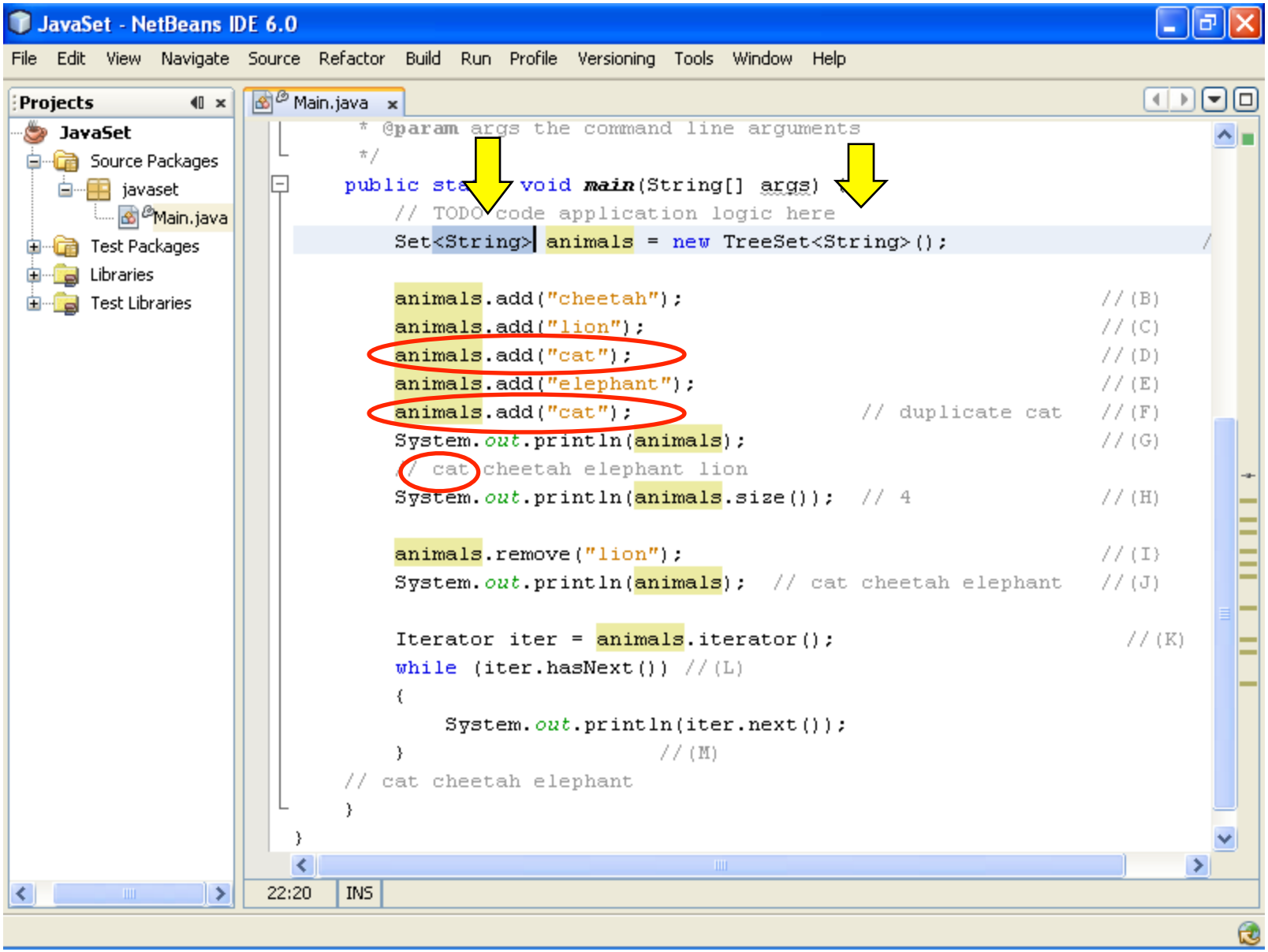
Main.java
animals.remove(3); //(G)
System.out.println(animals); //lion, cheetah, cat,
//fox, cat
Collections.sort(animals); //(H)
System.out.println(animals); //cat, cat, cheetah,
//fox, lion
List pets = new LinkedList(); //(I)
pets.add("cat"); //(J)
pets.add("dog");
pets.add("bird");
System.out.println(pets); //cat, dog, bird
animals.addAll(3, pets); //(K)
System.out.println(animals); //cat, cat, cheetah,
//cat, dog, bird, fox,
//lion
ListIterator iter = animals.listIterator(); //(L)
while (iter.hasNext()) { //(M)
System.out.println(iter.next()); //(N)
}
}
}
27:28
INS

Iterators

- Iterators are easy ways to traverse a collection of objects
- To be safe, unless allowed or specified by the documentation:
  - Don’t assume an order for how objects are visited
  - Don't change what is being iterated on - be especially careful of adds and deletes
  - Don't assume iterators are thread safe
    - *CopyOnWriteArrayList* is
    - *Vector* iterator is not

Java Set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Main.java
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Libraries
Test Libraries
Main.java
* @param args the command line arguments
*/
public static void main(String[] args)
// TODO code application logic here
Set<String> animals = new TreeSet<String>();
animals.add("cheetah"); //(B)
animals.add("lion"); //(C)
animals.add("cat"); //(D)
animals.add("elephant"); //(E)
animals.add("cat"); // duplicate cat //(F)
System.out.println(animals); //(G)
// cat cheetah elephant lion
System.out.println(animals.size()); // 4 //(H)
animals.remove("lion"); //(I)
System.out.println(animals); // cat cheetah elephant //(J)
Iterator iter = animals.iterator(); //(K)
while (iter.hasNext()) //(L)
{
System.out.println(iter.next());
} //(M)
// cat cheetah elephant
}
}
22:20
INS

java.util

Class TreeSet<E>

java.lang.Object
  java.util.AbstractCollection<E>
    java.util.AbstractSet<E>
      java.util.TreeSet<E>

Type Parameters:

`E` - the type of elements maintained by this set

All Implemented Interfaces:

Serializable, Cloneable, Iterable<E>, Collection<E>, NavigableSet<E>, Set<E>, SortedSet<E>

```
public class TreeSet<E>
extends AbstractSet<E>
implements NavigableSet<E>, Cloneable, Serializable
```

A `NavigableSet` implementation based on a `TreeMap`. The elements are ordered using their natural ordering, or by a `Comparator` provided at set creation time, depending on which constructor is used.

This implementation provides guaranteed log(n) time cost for the basic operations (`add`, `remove` and `contains`).

Note that the ordering maintained by a set (whether or not an explicit comparator is provided) must be *consistent with equals* if it is to correctly implement the `Set` interface. (See `Comparable` or `Comparator` for a precise definition of *consistent with equals*.) This is so because the `Set` interface is defined in terms of the `equals` operation, but a `TreeSet` instance performs all element comparisons using its `compareTo` (or `compare`) method, so two elements that are deemed equal by this method are, from the standpoint of the set, equal. The behavior of a set *is* well-defined even if its ordering is inconsistent with equals; it just fails to obey the general contract of the `Set` interface.

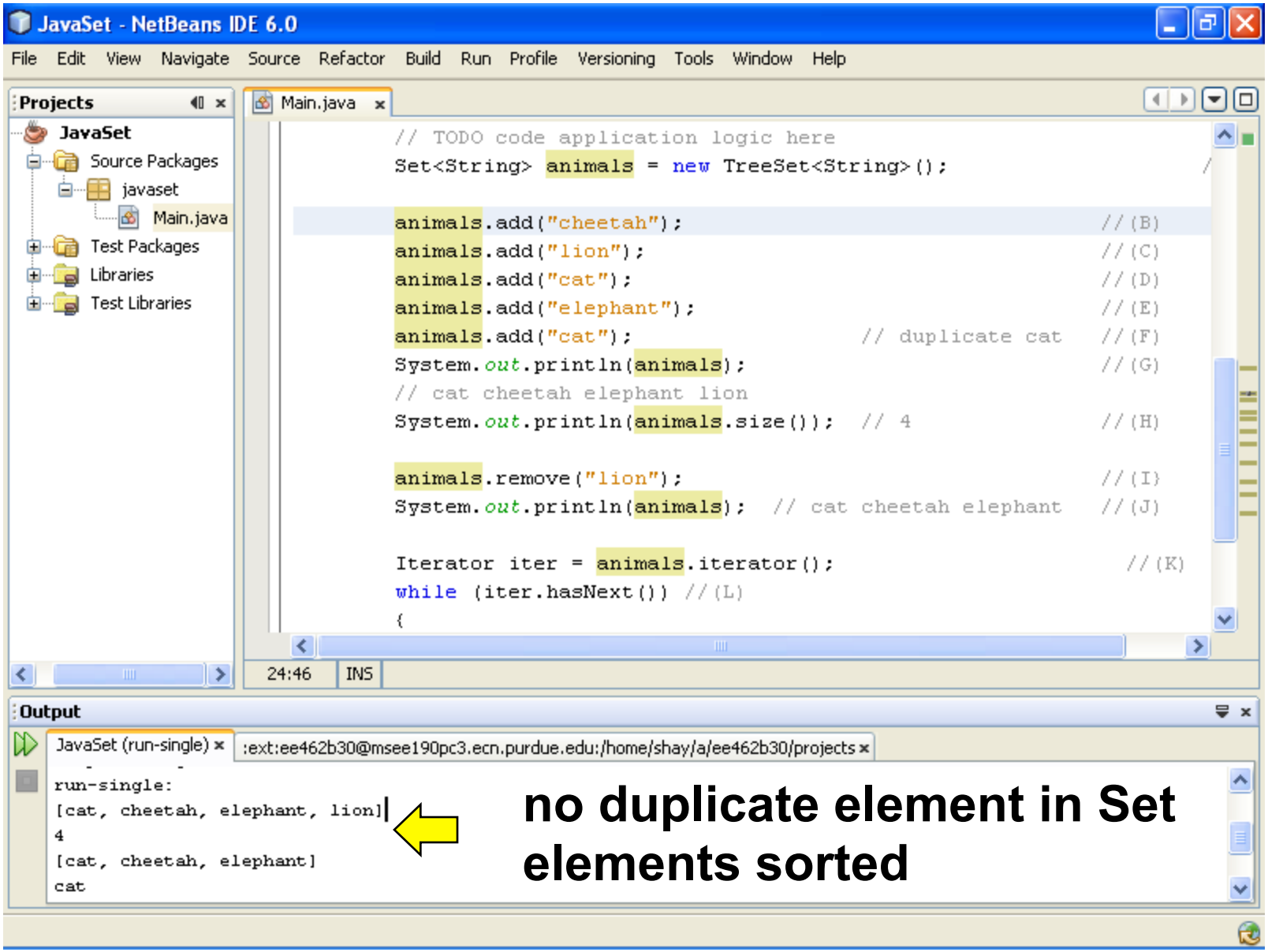
Note that this implementation is not synchronized. If multiple threads access a tree set concurrently, and at least one of the threads modifies the set, it *must* be synchronized externally. This is typically accomplished by synchronizing on some object that naturally encapsulates the set. If no such object exists, the set should be "wrapped" using the `Collections.synchronizedSortedSet` method. This is best done at creation time, to prevent accidental unsynchronized access to the set:

```
SortedSet s = Collections.synchronizedSortedSet(new TreeSet(...));
```

The iterators returned by this class's `iterator` method are *fail-fast*: if the set is modified at any time after the iterator is created, in any way except through the iterator's own `remove` method, the iterator will throw a `ConcurrentModificationException`. Thus, in the face of concurrent modification, the iterator fails quickly and cleanly, rather than risking arbitrary, non-deterministic behavior at an undetermined time in the future.

Note that the fail-fast behavior of an iterator cannot be guaranteed as it is, generally speaking, impossible to make any hard guarantees in the presence of unsynchronized concurrent modification. Fail-fast iterators throw `ConcurrentModificationException` on a best-effort basis. Therefore, it would be wrong to write a program that depended on this exception for its correctness: *the fail-fast behavior of iterators should be used only to detect bugs.*

This class is a member of the Java Collections Framework.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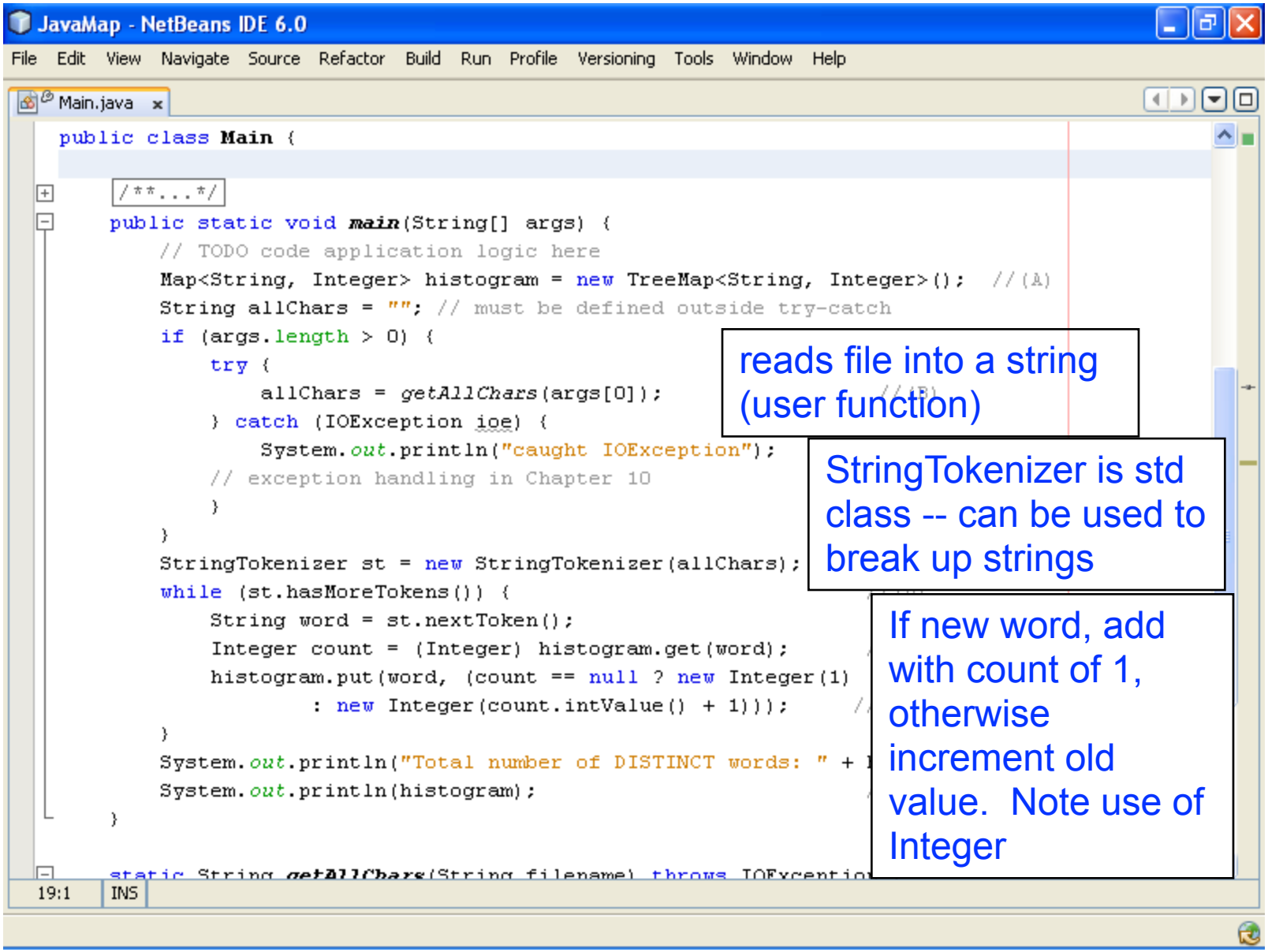
Main.java
// TODO code application logic here
Set<String> animals = new TreeSet<String>();
animals.add("cheetah"); //(B)
animals.add("lion"); //(C)
animals.add("cat"); //(D)
animals.add("elephant"); //(E)
animals.add("cat"); // duplicate cat //(F)
System.out.println(animals); //(G)
// cat cheetah elephant lion
System.out.println(animals.size()); // 4 //(H)
animals.remove("lion"); //(I)
System.out.println(animals); // cat cheetah elephant //(J)
Iterator iter = animals.iterator(); //(K)
while (iter.hasNext()) //(L)
{
24:46
INS
Output
JavaSet (run-single)
:ext:ee462b30@msee190pc3.ecn.purdue.edu:/home/shay/a/ee462b30/projects
run-single:
[cat, cheetah, elephant, lion]
4
[cat, cheetah, elephant]
cat
no duplicate element in Set
elements sorted

Java Map

Map (Hash Table)

- array: integer → element (object)
- map: key (object, integer, or string ...) → value (object)
- example:
  - name → phone number
  - student ID → department
  - city name → zip code
- *Keys must be unique* and do not have to be contiguous (as is required for array indexes).
- Values do not have to be unique.

Java Map
Histogram of Words


JavaMap - NetBeans IDE 6.0
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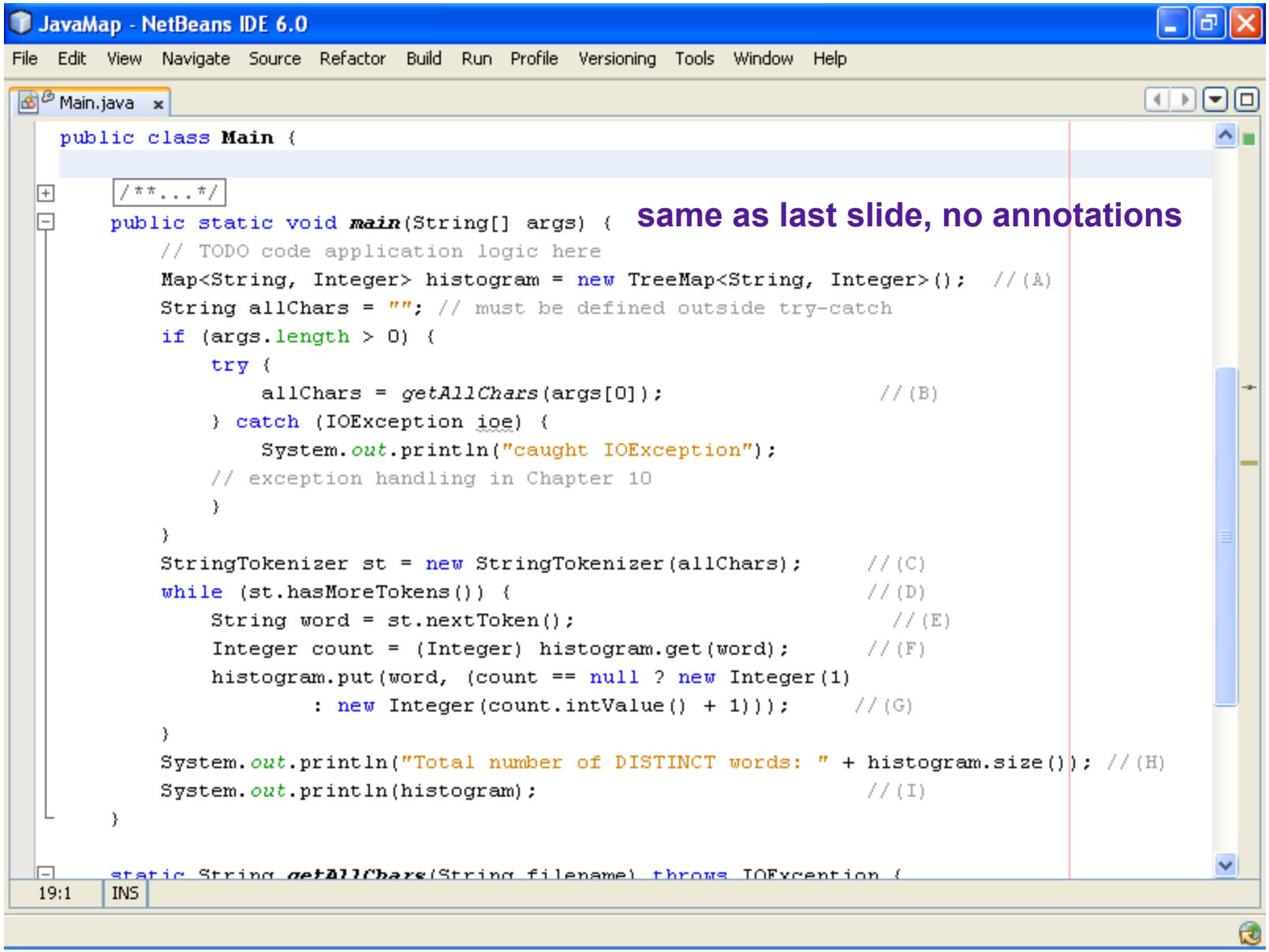
Main.java
public class Main {
/**...*/
public static void main(String[] args) {
// TODO code application logic here
Map<String, Integer> histogram = new TreeMap<String, Integer>(); //(A)
String allChars = ""; // must be defined outside try-catch
if (args.length > 0) {
try {
allChars = getAllChars(args[0]);
} catch (IOException ioe) {
System.out.println("caught IOException");
// exception handling in Chapter 10
}
}
StringTokenizer st = new StringTokenizer(allChars);
while (st.hasMoreTokens()) {
String word = st.nextToken();
Integer count = (Integer) histogram.get(word);
histogram.put(word, (count == null ? new Integer(1)
: new Integer(count.intValue() + 1)));
}
System.out.println("Total number of DISTINCT words: " +
System.out.println(histogram);
}
19:1
INS
reads file into a string (user function)
StringTokenizer is std class -- can be used to break up strings
If new word, add with count of 1, otherwise increment old value. Note use of Integer

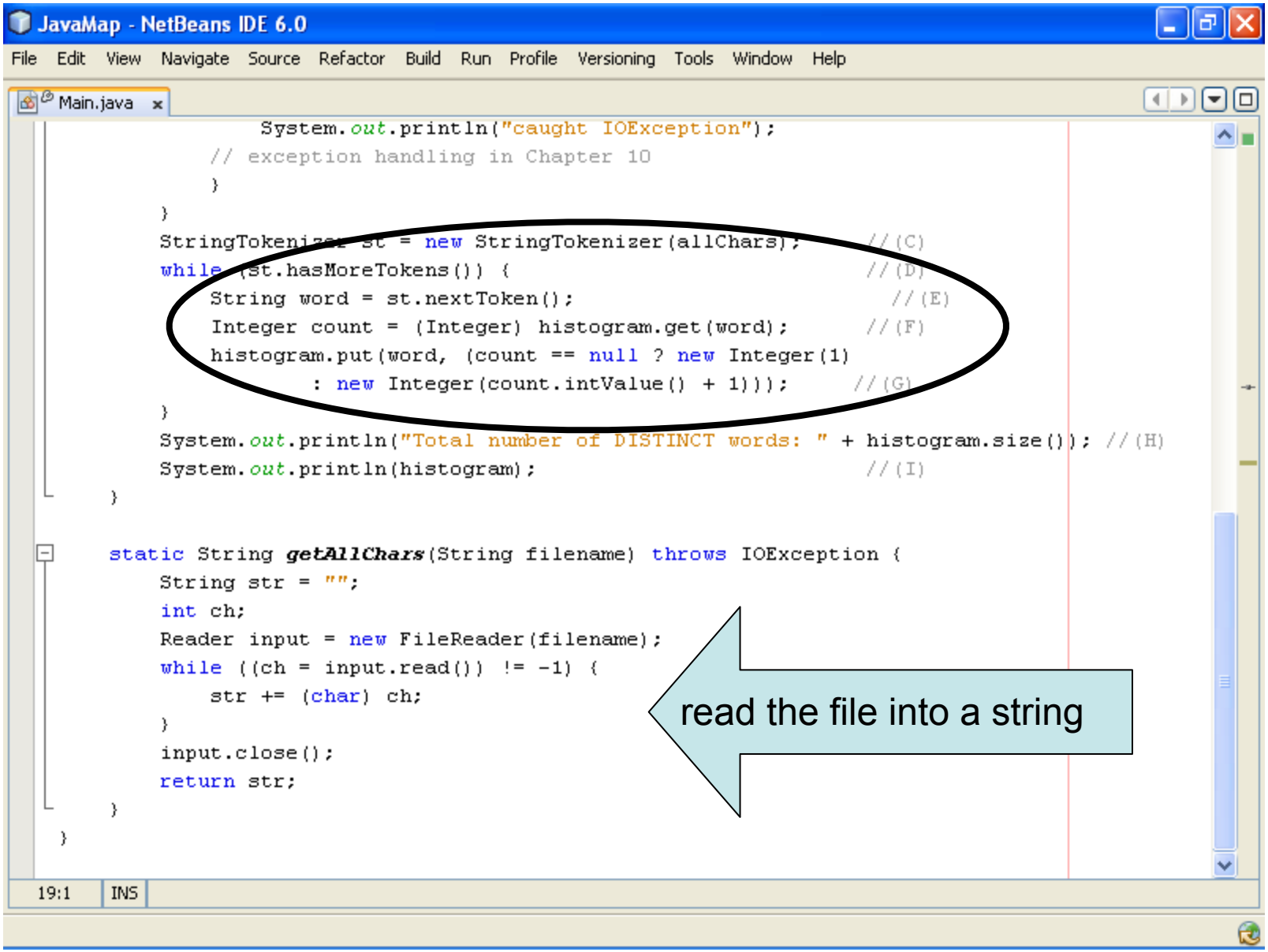
The last slide without text




```
public class Main {

    /**...*/
    public static void main(String[] args) {
        // TODO code application logic here
        Map<String, Integer> histogram = new TreeMap<String, Integer>();  //(A)
        String allChars = ""; // must be defined outside try-catch
        if (args.length > 0) {
            try {
                allChars = getAllChars(args[0]);                  //(B)
            } catch (IOException ioe) {
                System.out.println("caught IOException");
            // exception handling in Chapter 10
            }
        }
        StringTokenizer st = new StringTokenizer(allChars);      //(C)
        while (st.hasMoreTokens()) {                             //(D)
            String word = st.nextToken();                          //(E)
            Integer count = (Integer) histogram.get(word);       //(F)
            histogram.put(word, (count == null ? new Integer(1)
                    : new Integer(count.intValue() + 1)));      //(G)
        }
        System.out.println("Total number of DISTINCT words: " + histogram.size()); //(H)
        System.out.println(histogram);                           //(I)
    }

    static String getAllChars(String filename) throws IOException {
```


JavaMap - NetBeans IDE 6.0
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Main.java
System.out.println("caught IOException");
// exception handling in Chapter 10
}
}
StringTokenizer st = new StringTokenizer(allChars); //(C)
while (st.hasMoreTokens()) { //(D)
String word = st.nextToken(); //(E)
Integer count = (Integer) histogram.get(word); //(F)
histogram.put(word, (count == null ? new Integer(1)
: new Integer(count.intValue() + 1))); //(G)
}
System.out.println("Total number of DISTINCT words: " + histogram.size()); //(H)
System.out.println(histogram); //(I)
}
static String getAllChars(String filename) throws IOException {
String str = "";
int ch;
Reader input = new FileReader(filename);
while ((ch = input.read()) != -1) {
str += (char) ch;
}
input.close();
return str;
}
}
19:1 INS
read the file into a string

java.util

Class StringTokenizer

java.lang.Object
    java.util.StringTokenizer

All Implemented Interfaces:

Enumeration<Object>

```
public class StringTokenizer
extends Object
implements Enumeration<Object>
```

The string tokenizer class allows an application to break a string into tokens. The tokenization method is much simpler than the one used by the `StreamTokenizer` class. The `StringTokenizer` methods do not distinguish among identifiers, numbers, and quoted strings, nor do they recognize and skip comments.

The set of delimiters (the characters that separate tokens) may be specified either at creation time or on a per-token basis.

An instance of `StringTokenizer` behaves in one of two ways, depending on whether it was created with the `returnDelims` flag having the value `true` or `false`:

- If the flag is `false`, delimiter characters serve to separate tokens. A token is a maximal sequence of consecutive characters that are not delimiters.
- If the flag is `true`, delimiter characters are themselves considered to be tokens. A token is thus either one delimiter character, or a maximal sequence of consecutive characters that are not delimiters.

A `StringTokenizer` object internally maintains a current position within the string to be tokenized. Some operations advance this current position past the characters processed.

A token is returned by taking a substring of the string that was used to create the `StringTokenizer` object.

The following is one example of the use of the tokenizer. The code:

```
StringTokenizer st = new StringTokenizer("this is a test");
while (st.hasMoreTokens()) {
    System.out.println(st.nextToken());
}
```

Method Summary

Methods

Modifier and Type	Method and Description
`int`	**`countTokens()`** Calculates the number of times that this tokenizer's `nextToken` method can be called before it generates an exception.
`boolean`	**`hasMoreElements()`** Returns the same value as the `hasMoreTokens` method.
`boolean`	**`hasMoreTokens()`** Tests if there are more tokens available from this tokenizer's string.
`Object`	**`nextElement()`** Returns the same value as the `nextToken` method, except that its declared return value is `Object` rather than `String`.
`String`	**`nextToken()`** Returns the next token from this string tokenizer.

nextToken

```
public String nextToken()
```

Returns the next token from this string tokenizer.

Returns:

the next token from this string tokenizer.

Throws:

`NoSuchElementException` - if there are no more tokens in this tokenizer's string.

StringTokenizer

```
public StringTokenizer(String str)
```

Constructs a string tokenizer for the specified string. The tokenizer uses the default delimiter set, which is `" \t\n\r\f"`: the space character, the tab character, the newline character, the carriage-return character, and the form-feed character. Delimiter characters themselves will not be treated as tokens.

Parameters:

`str` - a string to be parsed.

Throws:

`NullPointerException` - if str is `null`