Iterators

- An iterator is an object that is used with a collection to provide sequential access to the collection elements
  - This access allows examination and possible modification of the elements
- An iterator imposes an ordering on the elements of a collection even if the collection itself does not impose any order on the elements it contains
  - If the collection does impose an ordering on its elements, then the iterator will use the same ordering

The `Iterator<T>` Interface

- Java provides an `Iterator<T>` interface
  - Any object of any class that satisfies the `Iterator<T>` interface is an `Iterator<T>`
- An `Iterator<T>` does not stand on its own
  - It must be associated with some collection object using the method `iterator`
  - If `c` is an instance of a collection class (e.g., `HashSet<String>`), the following obtains an iterator for `c`:

```
Iterator iteratorForC = c.iterator();
```

Methods in the `Iterator<T>` Interface (Part 1 of 2)

Methods in the `Iterator<T>` Interface

The `Iterator<T>` interface is in the `java.util` package.
All the exception classes mentioned are the kind that are not required to be caught in a `catch` block or declared in a `throws` clause.
`NoSuchElementException` is in the `java.util` package, which requires an import statement if your code mentions the `NoSuchElementException` class. All the other exception classes mentioned are in the package `java.lang` and so do not require any import statement.

```
public T next()
```

Returns the next element of the collection that produced the iterator.
Throws a `NoSuchElementException` if there is no next element.

(continued)

Methods in the `Iterator<T>` Interface (Part 2 of 2)

Methods in the `Iterator<T>` Interface

```
public boolean hasNext()
```

Returns `true` if `next()` has not yet returned all the elements in the collection; returns `false` otherwise.

```
public void remove() (Optional)
```

Removes from the collection the last element returned by `next`.
This method can be called only once per call to `next`. If the collection is changed in any way, other than by using `remove`, the behavior of the iterator is not specified (and thus should be considered unpredictable).
Throws `IllegalStateException` if the `next` method has not yet been called, or the `remove` method has already been called after the last call to the `next` method.
Throws an `UnsupportedOperationException` if the `remove` operation is not supported by this `Iterator<T>`.

Adapted from material by Walter Savitch

Using an Iterator with a HashSet<T> Object

- A **`HashSet<T>`** object imposes no order on the elements it contains
- However, an iterator will impose an order on the elements in the hash set
  - That is, the order in which they are produced by **`next()`**
  - Although the order of the elements so produced may be duplicated for each program run, there is no requirement that this must be the case

An Iterator (Part 1 of 3)

An Iterator

```
1   import java.util.HashSet;
2   import java.util.Iterator;

3   public class HashSetIteratorDemo
4   {
5       public static void main(String[] args)
6       {
7           HashSet<String> s = new HashSet<String>();

8           s.add("health");
9           s.add("love");
10          s.add("money");

11          System.out.println("The set contains:");
```

(continued)

An Iterator (Part 2 of 3)

An Iterator

```
12          Iterator<String> i = s.iterator();
13          while (i.hasNext())
14              System.out.println(i.next());

15          i.remove();

16          System.out.println();
17          System.out.println("The set now contains:");

18          i = s.iterator();
19          while (i.hasNext())
20              System.out.println(i.next());

21          System.out.println("End of program.");
22      }
23  }
```

You cannot "reset" an iterator "to the beginning." To do a second iteration, you create another iterator.

(continued)

An Iterator (Part 3 of 3)

An Iterator

SAMPLE DIALOGUE

```
The set contains:
money
love
health

The set now contains:
money
love
End of program.
```

The `HashSet<T>` *object does not order the elements it contains, but the iterator imposes an order on the elements.*

Tip: For-Each Loops as Iterators

- Although it is not an iterator, a for-each loop can serve the same purpose as an iterator
  - A for-each loop can be used to cycle through each element in a collection
- For-each loops can be used with any of the collections discussed here

For-Each Loops as Iterators (Part 1 of 2)

For-Each Loops as Iterators

```
1   import java.util.HashSet;
2   import java.util.Iterator;

3   public class ForEachDemo
4   {
5       public static void main(String[] args)
6       {
7           HashSet<String> s = new HashSet<String>();

8           s.add("health");
9           s.add("love");
10          s.add("money");

11          System.out.println("The set contains:");
```

(continued)

For-Each Loops as Iterators (Part 2 of 2)

For-Each Loops as Iterators

```
12          String last = null;
13          for (String e : s)
14          {
15              last = e;
16              System.out.println(e);
17          }

18          s.remove(last);

19          System.out.println();
20          System.out.println("The set now contains:");

21          for (String e : s)
22              System.out.println(e);

23          System.out.println("End of program.");
24      }
25  }
```

Adapted from material by Walter Savitch

The `ListIterator<T>` Interface

- The **`ListIterator<T>`** interface extends the **`Iterator<T>`** interface, and is designed to work with collections that satisfy the **`List<T>`** interface
  - A **`ListIterator<T>`** has all the methods that an **`Iterator<T>`** has, plus additional methods
  - A **`ListIterator<T>`** can move in either direction along a list of elements
  - A **`ListIterator<T>`** has methods, such as **`set`** and **`add`**, that can be used to modify elements

Methods in the `ListIterator<T>` Interface (Part 1 of 4)

Methods in the `ListIterator<T>` Interface

The `ListIterator <T>` interface is in the `java.util` package.
The *cursor position* is explained in the text and in Display 16.11.
All the exception classes mentioned are the kind that are not required to be caught in a `catch` block or declared in a `throws` clause.
`NoSuchElementException` is in the `java.util` package, which requires an import statement if your code mentions the `NoSuchElementException` class. All the other exception classes mentioned are in the package `java.lang` and so do not require any import statement.

```
public T next()
```

Returns the next element of the list that produced the iterator. More specifically, returns the element immediately after the cursor position.
Throws a `NoSuchElementException` if there is no next element.

(continued)

Methods in the `ListIterator<T>` Interface (Part 2 of 4)

Methods in the `ListIterator<T>` Interface

```
public T previous()
```

Returns the previous element of the list that produced the iterator. More specifically, returns the element immediately before the cursor position.
Throws a `NoSuchElementException` if there is no previous element.

```
public boolean hasNext()
```

Returns `true` if there is a suitable element for `next()` to return; returns `false` otherwise.

```
public boolean hasPrevious()
```

Returns `true` if there is a suitable element for `previous()` to return; returns `false` otherwise.

```
public int nextIndex()
```

Returns the index of the element that would be returned by a call to `next()`. Returns the list size if the cursor position is at the end of the list.

(continued)

Methods in the `ListIterator<T>` Interface (Part 3 of 4)

Methods in the `ListIterator<T>` Interface

```
public int previousIndex()
```

Returns the index that would be returned by a call to `previous()`. Returns `-1` if the cursor position is at the beginning of the list.

```
public void add(T newElement) (Optional)
```

Inserts `newElement` at the location of the iterator cursor (that is, before the value, if any, that would be returned by `next()` and after the value, if any, that would be returned by `previous()`).
Cannot be used if there has been a call to `add` or `remove` since the last call to `next()` or `previous()`.
Throws `IllegalStateException` if neither `next()` nor `previous()` has been called, or the `add` or `remove` method has already been called after the last call to `next()` or `previous()`.
Throws an `UnsupportedOperationException` if the `remove` operation is not supported by this `Iterator<T>`.
Throws a `ClassCastException` if the class of `newElement` prevents it from being added.
Throws an `IllegalArgumentException` if some property other than the class of `newElement` prevents it from being added.

(continued)

Methods in the `ListIterator<T>` Interface (Part 4 of 4)

Methods in the `ListIterator<T>` Interface

`public void remove()` *(Optional)*

Removes from the collection the last element returned by `next()` or `previous()`.
This method can be called only once per call to `next()` or `previous()`.
Cannot be used if there has been a call to `add` or `remove` since the last call to `next()` or `previous()`.
Throws `IllegalStateException` if neither `next()` nor `previous()` has been called, or the `add` or `remove` method has already been called after the last call to `next()` or `previous()`.
Throws an `UnsupportedOperationException` if the `remove` operation is not supported by this `Iterator<T>`.

`public void set(T newElement)` *(Optional)*

Replaces the last element returned by `next()` or `previous()` with `newElement`.
Cannot be used if there has been a call to `add` or `remove` since the last call to `next()` or `previous()`.
Throws an `UnsupportedOperationException` if the `set` operation is not supported by this `Iterator<T>`.
Throws `IllegalStateException` if neither `next()` nor `previous()` has been called, or the `add` or `remove` method has been called since the last call to `next()` or `previous()`.
Throws an `ClassCastException` if the class of `newElement` prevents it from being added.
Throws an `IllegalArgumentException` if some property other than the class of `newElement` prevents it from being added.

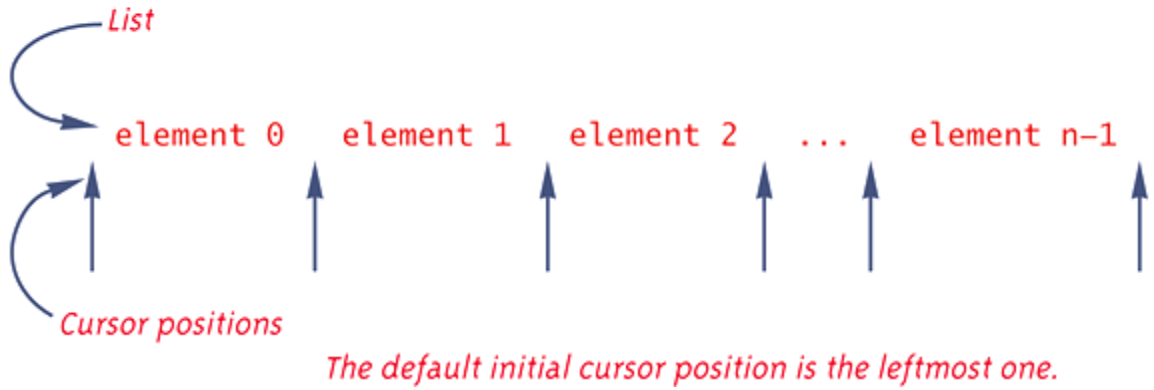
Adapted from material by Walter Savitch

The `ListIterator<T>` Cursor

- Every **`ListIterator<T>`** has a position marker known as the *cursor*
  - If the list has *n* elements, they are numbered by indices 0 through *n*-1, but there are *n*+1 cursor positions
  - When **`next()`** is invoked, the element immediately following the cursor position is returned and the cursor is moved forward one cursor position
  - When **`previous()`** is invoked, the element immediately before the cursor position is returned and the cursor is moved back one cursor position

`ListIterator<T>` Cursor Positions

`ListIterator<T>` Cursor Positions



The default initial cursor position is the leftmost one.

Adapted from material by Walter Savitch

Pitfall: `next` and `previous` Can Return a Reference

- Theoretically, when an iterator operation returns an element of the collection, it might return a copy or clone of the element, or it might return a reference to the element
- Iterators for the standard predefined collection classes, such as **`ArrayList<T>`** and **`HashSet<T>`**, actually return references
  - Therefore, modifying the returned value will modify the element in the collection

An Iterator Returns a Reference (Part 1 of 4)

An Iterator Returns a Reference

The class `Date` *is defined in Display 4.13, but you can easily guess all you need to know about* `Date` *for this example.*

```
1  import java.util.ArrayList;
2  import java.util.Iterator;

3  public class IteratorReferenceDemo
4  {
5      public static void main(String[] args)
6      {
7          ArrayList<Date> birthdays = new ArrayList<Date>();


8          birthdays.add(new Date(1, 1, 1990));
9          birthdays.add(new Date(2, 2, 1990));
10         birthdays.add(new Date(3, 3, 1990));


11         System.out.println("The list contains:");
```

(continued)

An Iterator Returns a Reference (Part 2 of 4)

An Iterator Returns a Reference

```
12          Iterator<Date> i = birthdays.iterator();
13          while (i.hasNext())
14              System.out.println(i.next());

15          i = birthdays.iterator();
16          Date d = null; //To keep the compiler happy.
17          System.out.println("Changing the references.");
18          while (i.hasNext())
19          {
20              d = i.next();
21              d.setDate(4, 1, 1990);
22          }
```

(continued)

An Iterator Returns a Reference (Part 3 of 4)

An Iterator Returns a Reference

```
23          System.out.println("The list now contains:");


24          i = birthdays.iterator();
25          while (i.hasNext())
26              System.out.println(i.next());


27          System.out.println("April fool!");
28      }
29  }
```

(continued)

An Iterator Returns a Reference (Part 4 of 4)

An Iterator Returns a Reference

SAMPLE DIALOGUE

```
The list contains:
January 1, 1990
February 2, 1990
March 3, 1990
Changing the references.
The list now contains:
April 1, 1990
April 1, 1990
April 1, 1990
April fool!
```

Tip: Defining Your Own Iterator Classes

- There is usually little need for a programmer defined `Iterator<T>` or `ListIterator<T>` class
- The easiest and most common way to define a collection class is to make it a derived class of one of the library collection classes
  - By doing this, the `iterator()` and `listIterator()` methods automatically become available to the program
- If a collection class must be defined in some other way, then an iterator class should be defined as an inner class of the collection class