12. Dynamic Data Structures & Generics

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Objectives

- Define and use an instance of `ArrayList`
- Describe general idea of linked list data structures and implementation
- Manipulate linked lists
- Use inner classes in defining linked data structures
- Describe, create, use iterators
- Define, us classes with generic types

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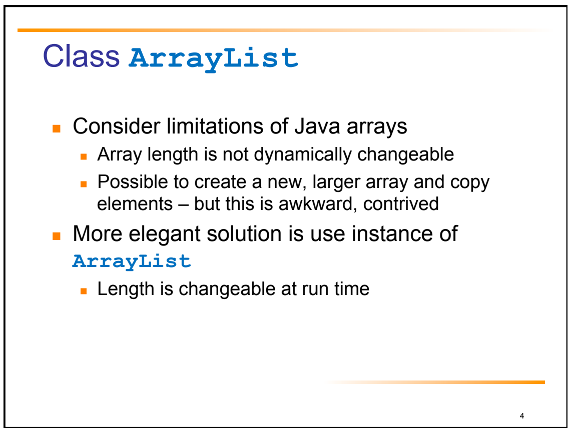
Array-Based Data Structures: Outline

The Class `ArrayList`
Creating an Instance of `ArrayList`
Using Methods of `ArrayList`
Programming Example: A To-Do List
Parameterized Classes and Generic Data Types



Class `ArrayList`

- Consider limitations of Java arrays
  - Array length is not dynamically changeable
  - Possible to create a new, larger array and copy elements – but this is awkward, contrived
- More elegant solution is use instance of `ArrayList`
  - Length is changeable at run time

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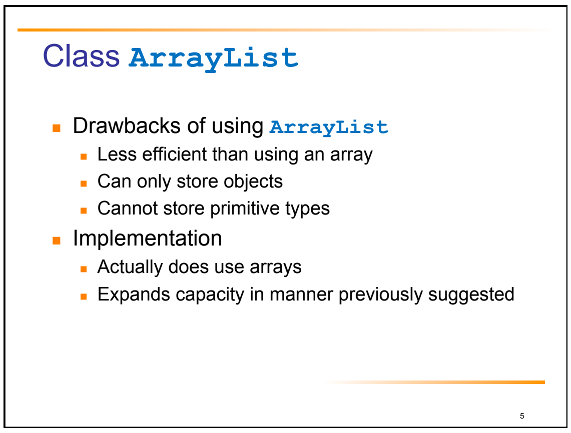

Class `ArrayList`

- Drawbacks of using `ArrayList`
  - Less efficient than using an array
  - Can only store objects
  - Cannot store primitive types
- Implementation
  - Actually does use arrays
  - Expands capacity in manner previously suggested

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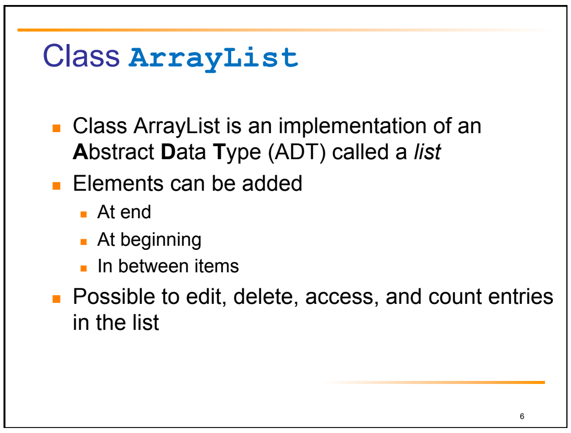

Class `ArrayList`

- Class ArrayList is an implementation of an **A**bstract **D**ata **T**ype (ADT) called a *list*
- Elements can be added
  - At end
  - At beginning
  - In between items
- Possible to edit, delete, access, and count entries in the list

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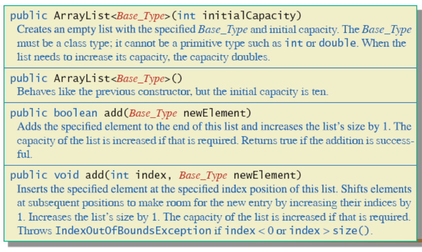
Class `ArrayList`

- Methods of class `ArrayList`



`public ArrayList<`*Base_Type*`>(int initialCapacity)`
Creates an empty list with the specified *Base_Type* and initial capacity. The *Base_Type* must be a class type; it cannot be a primitive type such as `int` or `double`. When the list needs to increase its capacity, the capacity doubles.

`public ArrayList<`*Base_Type*`>()`
Behaves like the previous constructor, but the initial capacity is ten.

`public boolean add(`*Base_Type* `newElement)`
Adds the specified element to the end of this list and increases the list's size by 1. The capacity of the list is increased if that is required. Returns true if the addition is successful.

`public void add(int index, `*Base_Type* `newElement)`
Inserts the specified element at the specified index position of this list. Shifts elements at subsequent positions to make room for the new entry by increasing their indices by 1. Increases the list's size by 1. The capacity of the list is increased if that is required. Throws `IndexOutOfBoundsException` if `index` < 0 or `index` > `size()`.

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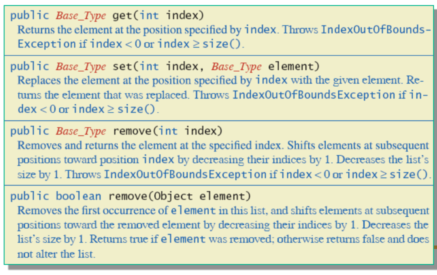
Class `ArrayList`

- Methods of class `ArrayList`



`public `*Base_Type*` get(int index)`
Returns the element at the position specified by `index`. Throws `IndexOutOfBoundsException` if `index` < 0 or `index` ≥ `size()`.

`public `*Base_Type*` set(int index, `*Base_Type* `element)`
Replaces the element at the position specified by `index` with the given element. Returns the element that was replaced. Throws `IndexOutOfBoundsException` if `index` < 0 or `index` ≥ `size()`.

`public `*Base_Type*` remove(int index)`
Removes and returns the element at the specified index. Shifts elements at subsequent positions toward position `index` by decreasing their indices by 1. Decreases the list's size by 1. Throws `IndexOutOfBoundsException` if `index` < 0 or `index` ≥ `size()`.

`public boolean remove(Object element)`
Removes the first occurrence of `element` in this list, and shifts elements at subsequent positions toward the removed element by decreasing their indices by 1. Decreases the list's size by 1. Returns true if `element` was removed; otherwise returns false and does not alter the list.

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Creating Instance of `ArrayList`

- Necessary to
  `import java.util.ArrayList;`
- Create and name instance

```
ArrayList<String> list =
   new ArrayList<String>(20);
```

- This list will
  - Hold `String` objects
  - Initially hold up to 20 elements

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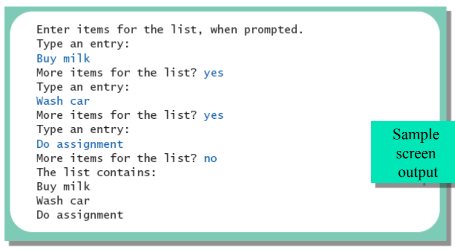
Using Methods of `ArrayList`

- Object of an ArrayList used like an array
  - But methods must be used
  - Not square bracket notation
- Given
  ```
  ArrayList<String> aList =
      new ArrayList<String> (20);
  ```
  - Assign a value with
    ```
    aList.add(index, "Hi Mom");
    aList.set(index, "Yo Dad");
    ```

Programming Example

- A To-Do List
  - Maintains a list of everyday tasks
  - User enters as many as desired
  - Program displays the list
- View source code
  `class ArrayListDemo`

Programming Example



```
Enter items for the list, when prompted.
Type an entry:
Buy milk
More items for the list? yes
Type an entry:
Wash car
More items for the list? yes
Type an entry:
Do assignment
More items for the list? no
The list contains:
Buy milk
Wash car
Do assignment
```

Sample screen output

Programming Example

- When accessing all elements of an `ArrayList` object
  - Use a For-Each loop
- Use the `trimToSize` method to save memory
- To copy an `ArrayList`
  - Do not use just an assignment statement
  - Use the `clone` method, e.g. `aList.clone()`

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Parameterized Classes, Generic Data Types

- Class `ArrayList` is a *parameterized class*
  - It has a parameter which is a type
- Possible to declare our own classes which use types as parameters
- Note earlier versions of Java had a type of `ArrayList` that was not parameterized

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Linked Data Structures:Outline

The Class `LinkedList`
Linked Lists
Implementing Operations of a Linked List
A Privacy Leak
Inner Classes

Linked Data Structures:Outline

Node Inner Classes
Iterators
The Java `Iterator` Interface
Exception Handling with Linked Lists
Variations on a Linked List
Other Linked Data Structures

Class `LinkedList`

- Linked data structure
  - Collection of objects
  - Each object contains data and a reference to another object in the collection
- Java provides a class to do this, `LinkedList`
  - More efficient memory use than `ArrayList`
- We will write our own version to learn the concepts of a linked list

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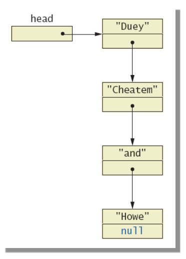
Linked Lists

- A dynamic data structure
- Links items in a list to one another



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Linked Lists

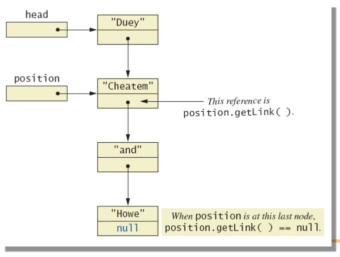
- Node of a linked list object requires two instance variables
  - Data
  - Link
- View sample class
  `class ListNode`
  - This example has `String` data
  - Note the link, a reference to the type which is the class

Implementing Operations of Linked Lists

- Now we create a linked list class which uses the node class
- View class
  class **`StringLinkedList`**
- Note the single instance variable of type **`ListNode`**
- Note method to traverse and print the contents of the list

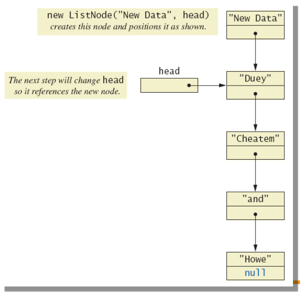
Implementing Operations of Linked Lists

- Moving down a linked list


head
"Duey"
position
"Cheatem"
This reference is position.getLink( ).
"and"
"Howe"
null
When position is at this last node, position.getLink( ) == null.

Implementing Operations of Linked Lists

- Adding a node at the start of a linked list


new ListNode("New Data", head)
creates this node and positions it as shown.
The next step will change head so it references the new node.
head
"New Data"
"Duey"
"Cheatem"
"and"
"Howe"
null

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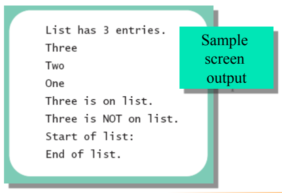
Implementing Operations of Linked Lists

- View linked-list demonstration
  class StringLinkedListDemo



```
List has 3 entries.
Three
Two
One
Three is on list.
Three is NOT on list.
Start of list:
End of list.
```

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Implementing Operations of Linked Lists

- Java automatically returns memory used by deleted node to the operating system.
  - Called automatic *garbage collection*
- In this context, note the significance of `NullPointerException` messages
- Consider the fact that our program has a reference (name) to only the head node

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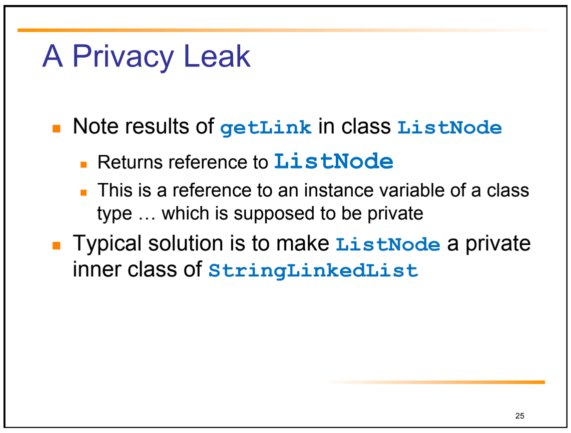

A Privacy Leak

- Note results of `getLink` in class `ListNode`
  - Returns reference to `ListNode`
  - This is a reference to an instance variable of a class type … which is supposed to be private
- Typical solution is to make `ListNode` a private inner class of `StringLinkedList`

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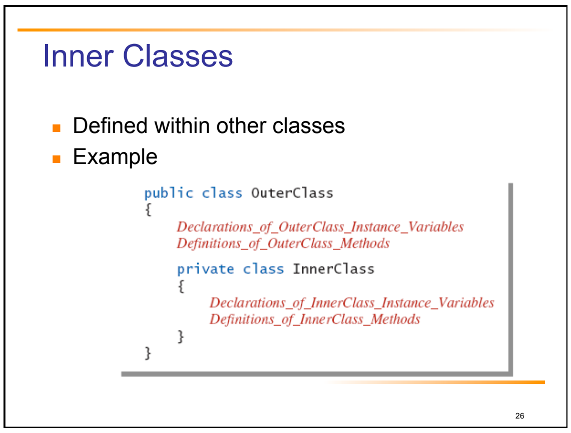

Inner Classes

- Defined within other classes
- Example

```
public class OuterClass
{
    Declarations_of_OuterClass_Instance_Variables
    Definitions_of_OuterClass_Methods
    private class InnerClass
    {
        Declarations_of_InnerClass_Instance_Variables
        Definitions_of_InnerClass_Methods
    }
}
```

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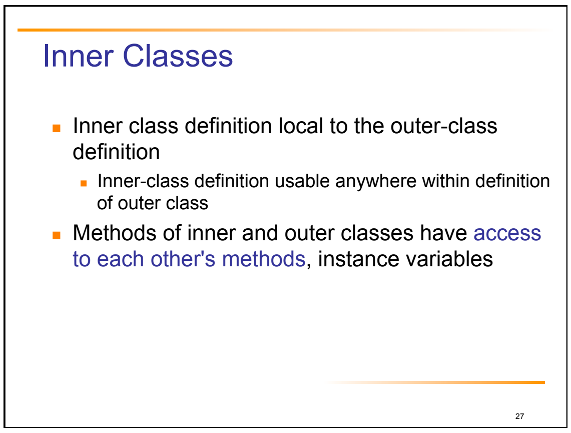

Inner Classes

- Inner class definition local to the outer-class definition
  - Inner-class definition usable anywhere within definition of outer class
- Methods of inner and outer classes have access to each other's methods, instance variables

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Node Inner Classes

- We show `ListNode` as a private inner class
  - This is safer design
  - Hides method getLink from world outside `StringLinkedList` definition
- View new version, listing 12.5
  class `StringLinkedListSelfContained`

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Iterators

- A variable that allows you to step through a collection of nodes in a linked list
  - For arrays, we use an integer
- Common to place elements of a linked list into an array
  - For display purposes, array is easily traversed
- View method to do this, listing 12.6
  `method toArray`

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Iterators

- Consider an iterator that will move through a linked list
  - Allow manipulation of the data at the nodes
  - Allow insertion, deletion of nodes
- View sample code
  `class StringLinkedListWithIterator`

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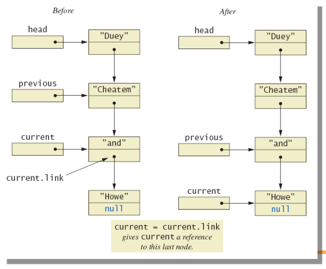
Iterators

- The effect of `goToNext` on a linked list



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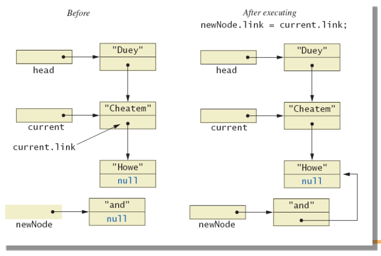
Iterators

- Adding node to linked list using `insertAfterIterator`



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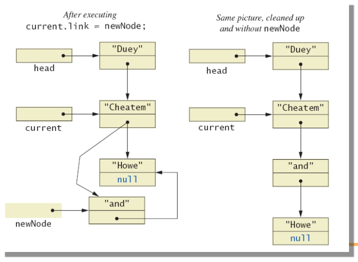
Iterators

- Adding node to linked list using `insertAfterIterator`



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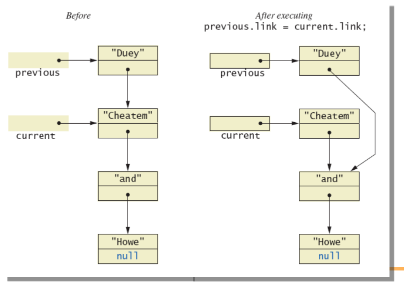
Iterators

- Deleting a node



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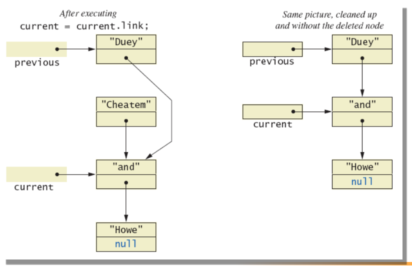
Iterators

- Deleting a node



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Java `Iterator` Interface

- Java formally considers an iterator to be an object
- Note interface named Iterator with methods
  - `hasNext` – returns boolean value
  - `next` – returns next element in iteration
  - `remove` – removes element most recently returned by `next` method

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Exception Handling with Linked Lists

- Recall class `StringLinkedListWithIterator`
  - Methods written so that errors caused screen message and program end
- More elegant solution is to have them throw exceptions
  - Programmer decides how to handle
- Note class which does this class `LinkedListException`

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Variations on a Linked List

- Possible to make a linked list where data element is of any type
  - Replace type String in definition of node class with desired data type
- Consider keeping a reference to last node in list
  - Called the *tail* of the list
  - Constructors, methods modified to accommodate new reference

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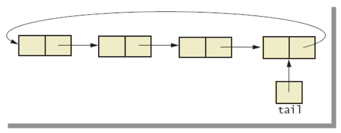
Variations on a Linked List

- Consider having last link point back to head
  - Creates a circular linked list
- Circular linked list



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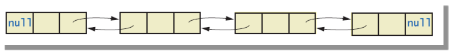
Variations on a Linked List

- Also possible to have backward as well as forward links in the list
  - Doubly linked list
  - Possible to traverse in either direction
- Doubly linked list

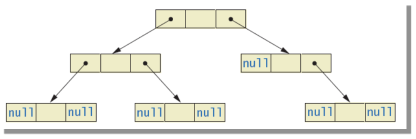


Other Linked Data Structures

- Stack
  - Elements removed from ADT in reverse order of initial insertion
  - Can be implemented with linked list
- Tree
  - Each node leads to multiple other nodes
  - Binary tree leads to at most two other nodes

Other Linked Data Structures

- Binary tree



Generics: Outline

The Basics

Programming Example: A Generic Linked List

Basics of Generics

- Beginning with Java 5.0, class definitions may include parameters for types
  - Called *generics*
- Programmer now can specify any class type for the type parameter
- View class definition
  `class Sample<T>`
- Note use of `<T>` for the type parameter

Basics of Generics

- Legal to use parameter T almost anywhere you can use class type
  - Cannot use type parameter when allocating memory such as `anArray = new T[20];`
- Example declaration

```
Sample <String> sample1 =
    new Sample<String>();
```

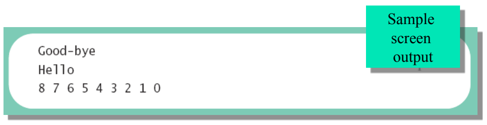
- Cannot specify a primitive type for the type parameter

Programming Example

- Generic linked list
  - Revision of listing 12.5
  - Use type parameter E instead of String
- Note similarities and differences of parameterized class with non-parameterized classes
- View generic class
  `class LinkedList <E>`

Programming Example

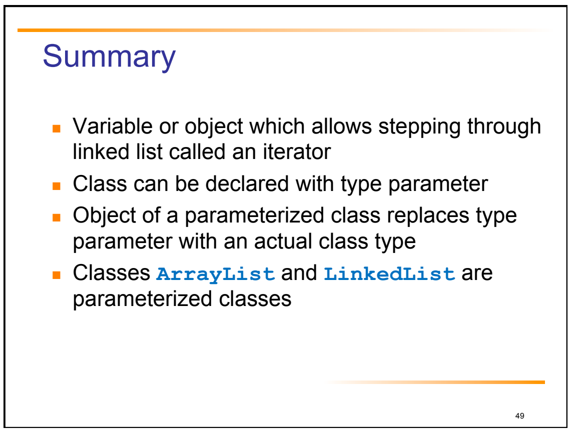
- View demo program
  `class LinkedListDemo`



```
Good-bye
Hello
8 7 6 5 4 3 2 1 0
```

Summary

- Java Class Library includes `ArrayList`
  - Like an array that can grow in length
  - Includes methods to manipulate the list
- Linked list data structure contains nodes (objects)
- Linked data structure is self-contained by making the node class an inner class



Summary

- Variable or object which allows stepping through linked list called an iterator
- Class can be declared with type parameter
- Object of a parameterized class replaces type parameter with an actual class type
- Classes `ArrayList` and `LinkedList` are parameterized classes

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