# CSE 143
# Lecture 26

Advanced collection classes

(ADTs; abstract classes; inner classes; generics; iterators)

read 11.1, 9.6, 15.3-15.4, 16.4-16.5

slides created by Marty Stepp, adapted by Alyssa Harding

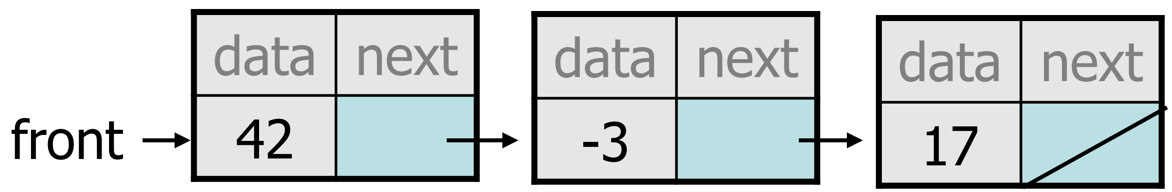
http://www.cs.washington.edu/143/

# Our list classes

- We implemented the following two list classes:
  - `ArrayIntList`

| index | 0 | 1 | 2 |
|---|---|---|---|
| value | 42 | -3 | 17 |

  - `LinkedIntList`




  - Problems:
    - **We should be able to treat them the same way in client code.**
    - They can store only `int` elements, not any type of value.
    - Some of their methods are implemented the same way (redundancy).
    - Linked list carries around a clunky extra node class.
    - It is inefficient to get or remove each element of a linked list.

# Recall: ADT interfaces (11.1)

- **abstract data type (ADT)**: A specification of a collection of data and the operations that can be performed on it.
  - Describes *what* a collection does, not *how* it does it.

- Java's collection framework describes ADTs with interfaces:
  - `Collection`, `Deque`, `List`, `Map`, `Queue`, `Set`, `SortedMap`

- An ADT can be implemented in multiple ways by classes:
  - `ArrayList` and `LinkedList` implement `List`
  - `HashSet` and `TreeSet` implement `Set`
  - `LinkedList` , `ArrayDeque`, etc. implement `Queue`

- Exercise: Create an ADT interface for the two list classes.

# An `IntList` interface (16.4)

```
// Represents a list of integers.
public interface IntList {
    public void add(int value);
    public void add(int index, int value);
    public boolean contains(int value);
    public int get(int index);
    public int indexOf(int value);
    public boolean isEmpty();
    public void remove(int index);
    public void set(int index, int value);
    public int size();
}

public class ArrayIntList implements IntList { ...

public class LinkedIntList implements IntList { ...
```

# Our list classes

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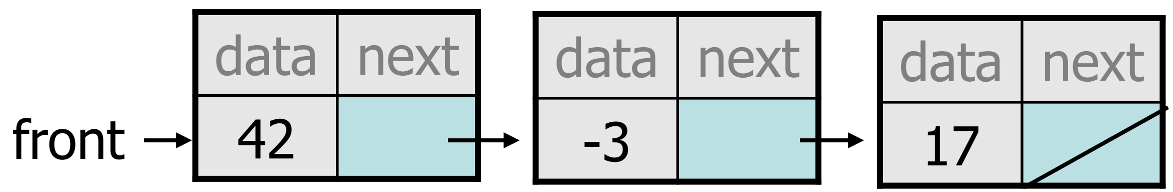


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# Type Parameters (Generics)

```
ArrayList<Type> name = new ArrayList<Type>();
```

- Recall: When constructing a `java.util.ArrayList`, you specify the type of elements it will contain between < and >.
  - We say that the `ArrayList` class accepts a **type parameter**, or that it is a **generic** class.

```
ArrayList<String> names = new ArrayList<String>();
names.add("Marty Stepp");
names.add("Stuart Reges");
```

# Implementing generics

```
// a parameterized (generic) class
public class name<Type> {
    ...
}
```

- By putting the **Type** in < >, you are demanding that any client that constructs your object must supply a type parameter.
  - You can require multiple type parameters separated by commas.
- The rest of your class's code can refer to that type by name.

- Exercise: Convert our list classes to use generics.

# Generics and arrays (15.4)

```
public class Foo<T> {
    private T myField;                    // ok

    public void method1(T param) {
        myField = new T();               // error
        T[] a = new T[10];               // error
    }
}
```

– You cannot create objects or arrays of a parameterized type.

# Generics/arrays, fixed

```
public class Foo<T> {
    private T myField;                        // ok

    public void method1(T param) {
        myField = param;                      // ok
        T[] a2 = (T[]) (new Object[10]);      // ok
    }
}
```

- But you can create variables of that type, accept them as parameters, return them, or create arrays by casting `Object[]`.

# Generic interface (15.3, 16.5)

```
// Represents a list of values.
public interface List<E> {
    public void add(E value);
    public void add(int index, E value);
    public E get(int index);
    public int indexOf(E value);
    public boolean isEmpty();
    public void remove(int index);
    public void set(int index, E value);
    public int size();
}

public class ArrayIntList<E> implements IntList<E> { ...
public class LinkedIntList<E> implements IntList<E> { ...
```

# Our list classes

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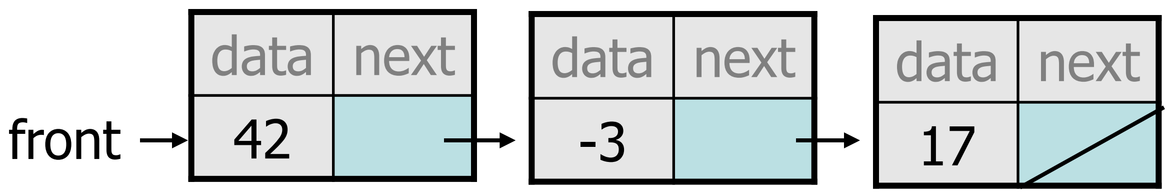


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# Common code

- Notice that some of the methods can be implemented the same way in both the array and linked list classes.
  - `add(`**value**`)`
  - `contains`
  - `isEmpty`

- Should we change our interface to a class? Why / why not?
  - How can we capture this common behavior?

# Abstract classes (9.6)

- **abstract class**: A hybrid between an interface and a class.
  - defines a superclass type that can contain method declarations (like an interface) and/or method bodies (like a class)
  - like interfaces, abstract classes that cannot be instantiated (cannot use `new` to create any objects of their type)

- What goes in an abstract class?
  - implementation of common state and behavior that will be inherited by subclasses (parent class role)
  - declare generic behaviors that subclasses must implement (interface role)

# Abstract class syntax

```
// declaring an abstract class
public abstract class name {
    ...

    // declaring an abstract method
    // (any subclass must implement it)
    public abstract type name(parameters);

}
```

- A class can be `abstract` even if it has no abstract methods
- You can create variables (but not objects) of the abstract type

- Exercise: Introduce an abstract class into the list hierarchy.

# Abstract and interfaces

- Normal classes that claim to implement an interface must implement all methods of that interface:

```
public class Empty implements List<E> {}  // error
```

- Abstract classes can claim to implement an interface without writing its methods; subclasses must implement the methods.

```
public abstract class Empty implements List<E> {} // ok

public class Child extends Empty {}          // error
```

# An abstract list class

```
// Superclass with common code for a list of E.
public abstract class AbstractList<E> implements List<E> {
    public void add(E value) {
        add(size(), value);
    }

    public boolean contains(E value) {
        return indexOf(value) >= 0;
    }

    public boolean isEmpty() {
        return size() == 0;
    }
}


public class ArrayList<E> extends AbstractList<E> { ...

public class LinkedList<E> extends AbstractList<E> { ...
```

# Abstract class vs. interface

- Why do both interfaces and abstract classes exist in Java?
  - An abstract class can do everything an interface can do and more.
  - So why would someone ever use an interface?

- Answer: Java has single inheritance.
  - can extend only one superclass
  - can implement many interfaces
  - Having interfaces allows a class to be part of a hierarchy (polymorphism) without using up its inheritance relationship.

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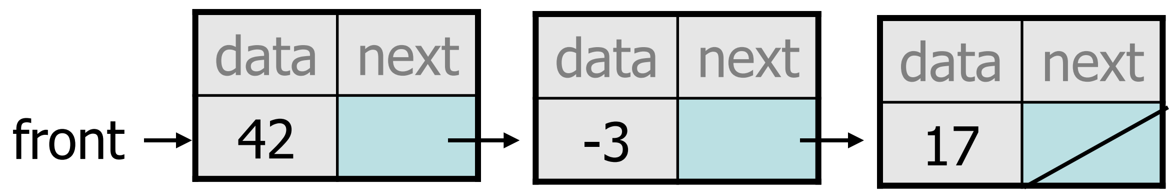


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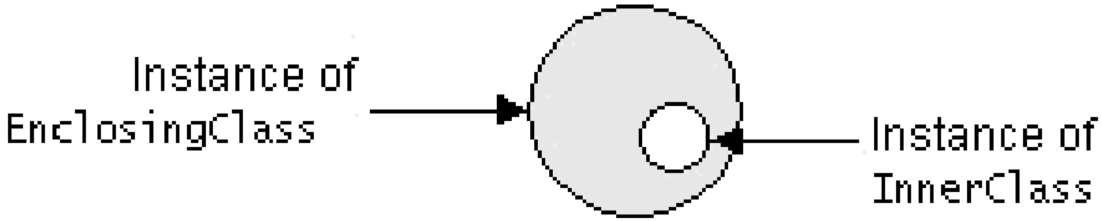
# Inner classes

- **inner class**: A class defined inside of another class.
  - can be created as `static` or non-static
  - we will focus on standard non-static ("nested") inner classes

- usefulness:
  - inner classes are hidden from other classes (encapsulated)
  - inner objects can access/modify the fields of the outer object



# Inner class syntax

```
// outer (enclosing) class
public class name {
    ...

    // inner (nested) class
    private class name {
        ...
    }
}
```

- Only this file can see the inner class or make objects of it.
- Each inner object is associated with the outer object that created it, so it can access/modify that outer object's methods/fields.
  - If necessary, can refer to outer object as **OuterClassName**`.this`

- Exercise: Convert the linked node into an inner class.

# Generics and inner classes

```
public class Foo<T> {
    private class Inner<T> {}    // incorrect

    private class Inner {}       // correct
}
```

- If an outer class declares a type parameter, inner classes can also use that type parameter.
- Inner class should NOT redeclare the type parameter. (If you do, it will create a second type parameter with the same name.)

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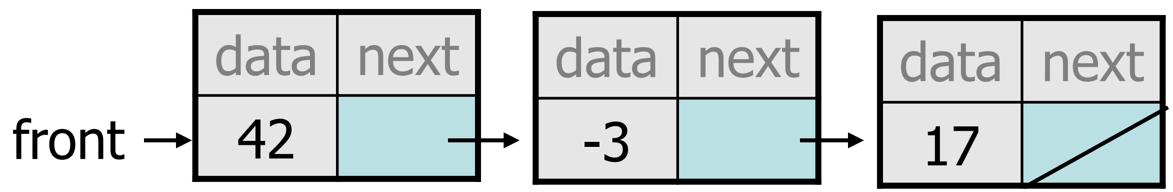


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# Linked list iterator

- The following code is particularly slow on linked lists:

```
List<Integer> list = new LinkedList<Integer>();
...
 public String toString() {
     if (size() == 0) {
         return "[]";
     } else {
         String result = "[" + get(0);
         for (int i = 1; i < size(); i++) {
             result += ", " + get(i);
         }
         return result + "]";
     }
}
```

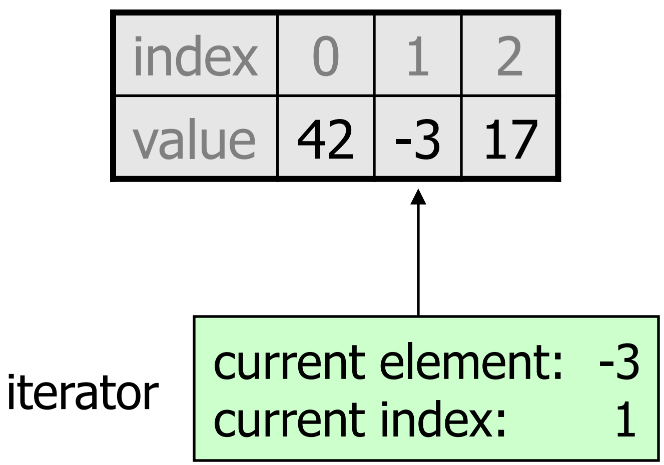
# Complexity comparison

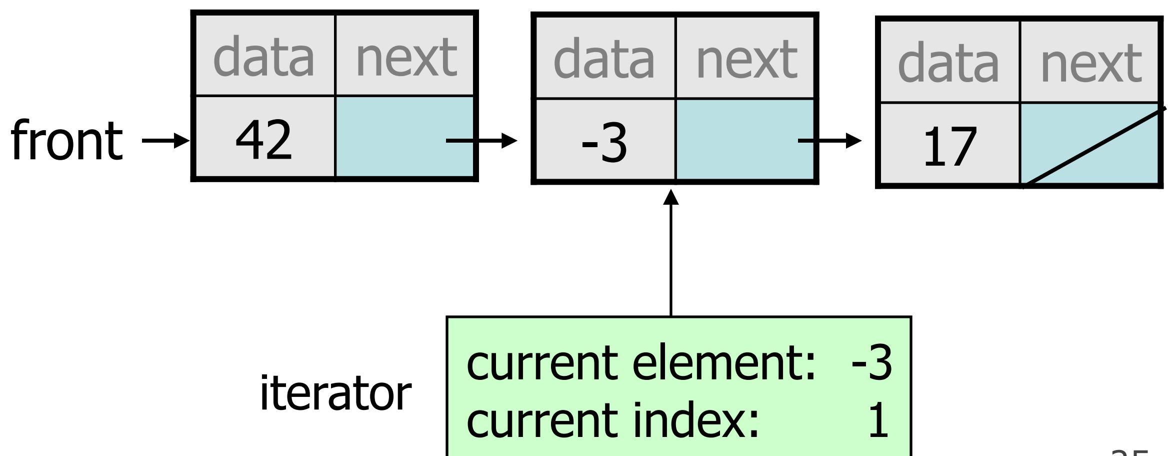
| **method** | `ArrayList` | `LinkedList` |
| --- | --- | --- |
| `isEmpty()` | **O(1)** | **O(n)** |
| `contains()` | **O(n)** | **O(n)** |
| `add(value)` | **O(n)** | **O(n)** |
| `toString()` | **O(n)** | **O($n^2$)** |

- Ouch!
- Our code worked pretty well for **`ArrayList`**, but not **`LinkedList`**
- Can we both reduce redundancy and maintain efficiency?

# Recall: Iterators (11.1)

- **iterator**: An object that allows a client to traverse the elements of a collection, regardless of its implementation.
  - Remembers a position within a collection, and allows you to:
    - get the element at that position
    - advance to the next position
    - (possibly) remove or change the element at that position
  - Benefit: A common way to examine *any* collection's elements.



# `Iterator` methods

| | |
|---|---|
| `hasNext()` | returns `true` if there are more elements to examine |
| `next()` | returns the next element from the collection (throws a `NoSuchElementException` if there are none left to examine) |
| `remove()` | removes from the collection the last value returned by `next()` (throws `IllegalStateException` if you have not called `next()` yet) |

- every provided collection has an `iterator` method

```
Set<String> set = new HashSet<String>();
...
Iterator<String> itr = set.iterator();
...
```

- Exercise: Write iterators for our array list and linked list.
  - You don't need to support the `remove` operation.

# Array list iterator

```
public class ArrayList<E> extends AbstractIntList<E> {
    ...
    // not perfect; doesn't forbid multiple removes in a row
    private class ArrayIterator implements Iterator<E> {
        private int index;   // current position in list
        public ArrayIterator() {
            index = 0;
        }
        public boolean hasNext() {
            return index < size();
        }
        public E next() {
            index++;
            return get(index - 1);
        }

        public void remove() {
            ArrayList.this.remove(index - 1);
            index--;
        }
    }
}
```

# Linked list iterator

```
public class LinkedList<E> extends AbstractIntList<E> {
    ...
    // not perfect; doesn't support remove
    private class LinkedIterator implements Iterator<E> {
        private ListNode current;   // current position in list
        public LinkedIterator() {
            current = front;
        }
        public boolean hasNext() {
            return current != null;
        }
        public E next() {
            E result = current.data;
            current = current.next;
            return result;
        }

        public void remove() {      // not implemented for now
            throw new UnsupportedOperationException();
        }
    }
}
```

# for-each loop and `Iterable`

- Java's collections can be iterated using a "for-each" loop:

```
List<String> list = new LinkedList<String>();
...
for (String s : list) {
    System.out.println(s);
}
```

  – Our collections do not work in this way.

- To fix this, your list must implement the `Iterable` interface.

```
public interface Iterable<E> {
    public Iterator<E> iterator();
}
```

# Final `List` interface (15.3, 16.5)

```
// Represents a list of values.
public interface List<E> extends Iterable<E> {
    public void add(E value);
    public void add(int index, E value);
    public E get(int index);
    public int indexOf(E value);
    public boolean isEmpty();
    public Iterator<E> iterator();
    public void remove(int index);
    public void set(int index, E value);
    public int size();
}
```