CSE 143
Lecture 21

Advanced List Implementation

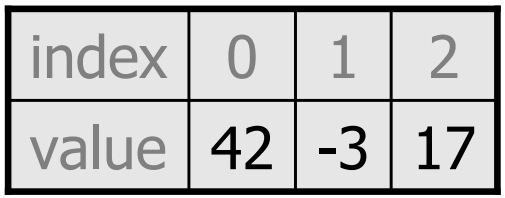
(ADTs; interfaces; abstract classes; inner classes; generics; iterators)

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

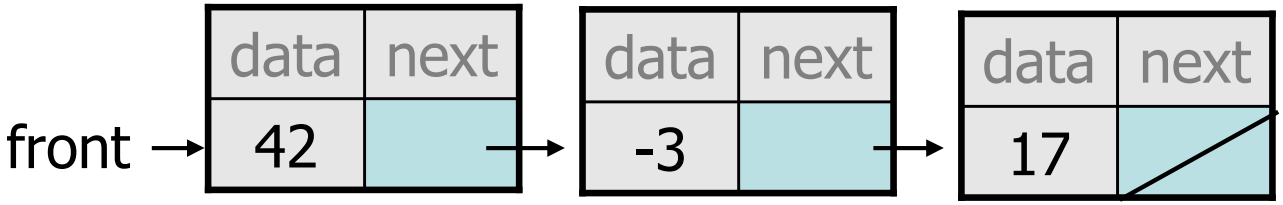
slides created by Marty Stepp
http://www.cs.washington.edu/143/

Our list classes

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



  - `LinkedIntList`



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

Common code

- Notice that some of the methods are 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 IntList {}  // error
```

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

```
public abstract class Empty implements IntList {} // ok

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

An abstract list class

```
// Superclass with common code for a list of integers.
public abstract class AbstractIntList implements IntList {
    public void add(int value) {
        add(size(), value);
    }

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

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


public class ArrayIntList extends AbstractIntList { ...
public class LinkedIntList extends AbstractIntList { ...
```

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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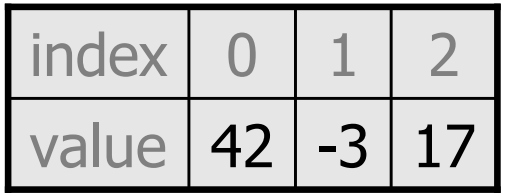

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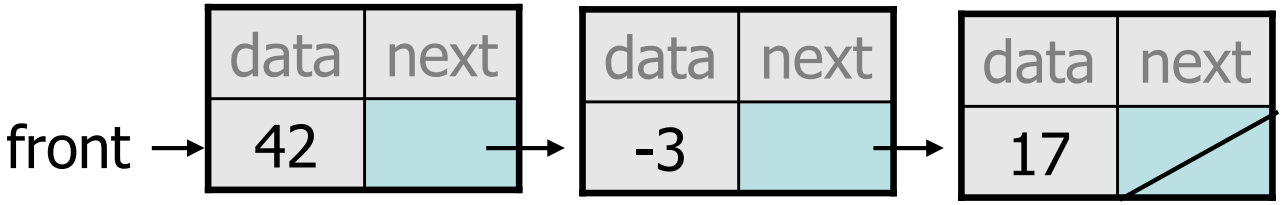

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Recall: Inner classes

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

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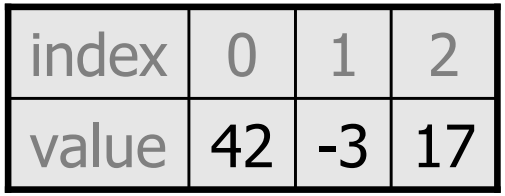

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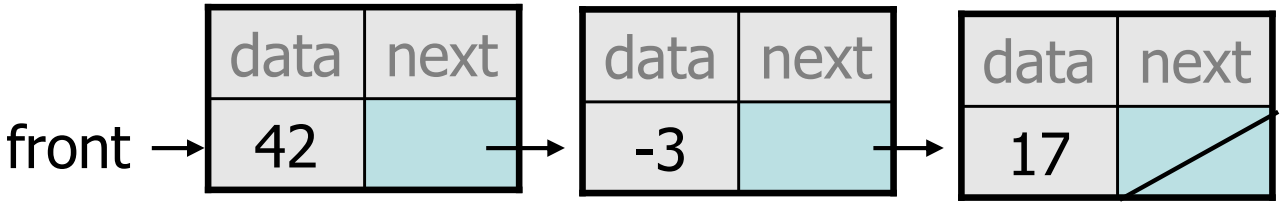

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Implementing generics

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

- Forces any client that constructs your object to supply a type.
  - Don't write an actual type such as String; the client does that.
  - Instead, write a type variable name such as `E` or `T`.
  - 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

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

- You cannot create objects or arrays of a parameterized type.
- You can create variables of that type, accept them as parameters, return them, or create arrays by casting from `Object[]`.

Comparing generic objects

```
public class ArrayList<E> {
    ...
    public int indexOf(E value) {
        for (int i = 0; i < size; i++) {
        // if (elementData[i] == value) {
            if (elementData[i].equals(value)) {
                return i;
            }
        }
        return -1;
    }
}
```

– When testing objects of type E for equality, must use `equals`

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 ArrayList<E> implements List<E> { ...
public class LinkedList<E> implements List<E> { ...
```

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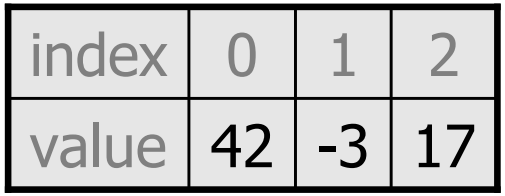

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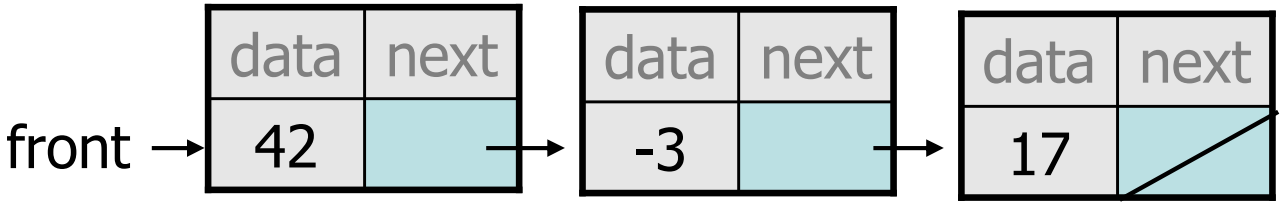

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Linked list iterator

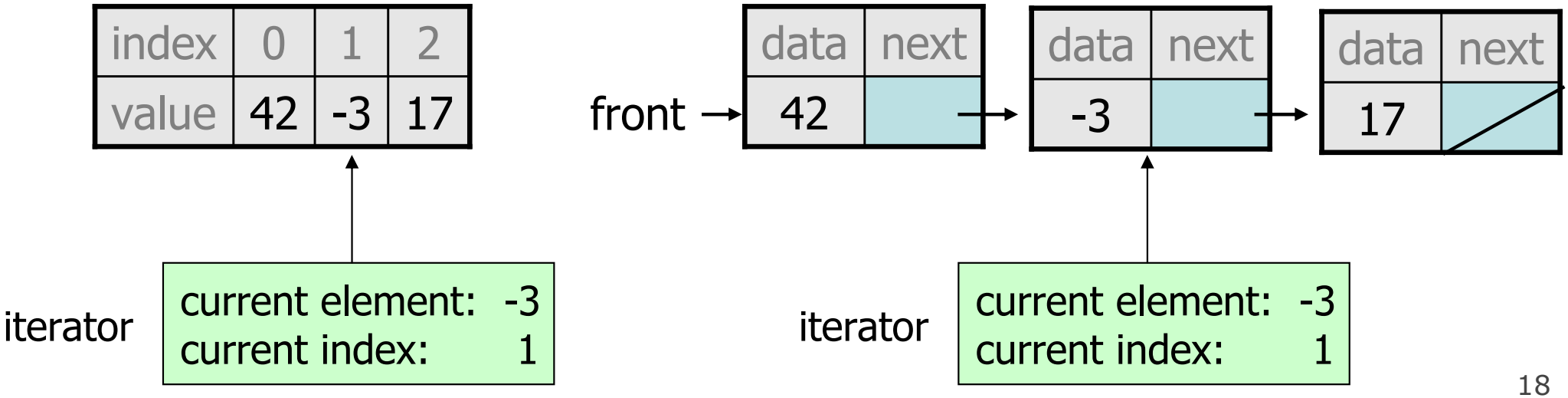
- The following code is particularly slow on linked lists:

```
List<Integer> list = new LinkedList<Integer>();
...
for (int i = 0; i < list.size(); i++) {
    int value = list.get(i);
    if (value % 2 == 1) {
        list.remove(i);
    }
}
```

  - Why?
  - What can we do to improve the runtime?

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
  - 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 linked list and array 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();
}
```