CSCI 136
Data Structures & Advanced Programming

Lecture 13

Fall 2018

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Announcements

- Lab today!
  - After mid-term we'll have some "non-partner" labs
  - It's Lab5 not Lab 4
- Mid-term exam is Wednesday, October 17
  - During your normal lab session
  - You'll have approximately 1 hour & 45 minutes (if you come on time!)
  - Closed-book: Covers Chapters 1-7 & 9, handouts, and all topics up through Linked Lists
  - A "sample" mid-term and study sheet will be available online
  - Review session: Monday, Oct. 15, 7:00-8:00pm TCL 203

Last Time

- Class extension
  - Abstract base classes
  - Concrete extension classes
- List: A general-purpose structure
- Implementing Lists with linked structures
  - Singly and Doubly Linked Lists

Today

- Linked List Wrap-Up
- The structure5 hierarchy so far
- Linear Structures
  - The Linear Interface (LIFO & FIFO)
  - The AbstractLinear and AbstractStack classes
- Stack Implementations
  - StackArray, StackVector, StackList,
- Stack applications
  - Expression Evaluation
  - PostScript: Page Description & Programming
  - Mazerunning (Depth-First-Search)

DoublyLinkedLists

- Keep reference/links in **both** directions
  - previous and next
- DoublyLinkedListNode instance variables
  - DLLN next, DLLN prev, E value
- Space overhead is proportional to number of elements
- ALL operations on tail (including removeLast) are fast!
- Additional work in each list operation
  - Example: add(E d, int index)
  - Four cases to consider now: empty list, add to front, add to tail, add in middle

```
public class DoublyLinkedNode<E>
{
        protected E data;
        protected DoublyLinkedNode<E> nextElement;
        protected DoublyLinkedNode<E> previousElement;

// Constructor inserts new node between existing nodes
public DoublyLinkedNode(E v,
                DoublyLinkedNode<E> next,
                DoublyLinkedNode<E> previous)
{
        data = v;
        nextElement = next;
        if (nextElement != null)  // point next back to me
                nextElement.previousElement = this;
        previousElement = previous;
        if (previousElement != null) // point previous to me
                previousElement.nextElement = this;
}
```

DoublyLinkedList Add Method

```
public void add(int i, E o) {
        Assert.pre((0 <= i) && (i <= size()),
                "Index in range.");
        if (i == 0) addFirst(o);
        else if (i == size()) addLast(o);
        else {
                // Find items before and after insert point
                DoublyLinkedNode<E> before = null;
                DoublyLinkedNode<E> after = head;
                // search for ith position
                while (i > 0) {
                   before = after;
                   after = after.next();
                   i--;
                }
        // before, after refer to items in slots i-1 and i
        // continued on next slide
```

DoublyLinkedList Add Method

```
            // Note: Still in "else" block!
            // before, after refer to items in slots i-1 and i

            // create new value to insert in correct position
            // Use DLN constructor that takes parameters
            // to set its next and previous instance variables
            DoublyLinkedNode<E> current =
                  new DoublyLinkedNode<E>(o,after,before);

            count++; // adjust size
      }
}
```

```
public E remove(E value) {
        DoublyLinkedNode<E> finger = head;
        while ( finger != null &&
                !finger.value().equals(value) )
                finger = finger.next();
        if (finger == null) return null;

        // fix next field of previous element
        if (finger.previous() != null)
                finger.previous().setNext(finger.next());
        else head = finger.next();

        // fix previous field of next element
        if (finger.next() != null)
                finger.next().setPrevious(finger.previous());
        else tail = finger.previous();
        count--;
        return finger.value();
}
```

CircularlyLinkedLists

- Use *next* reference of last element to reference head of list
- Replace ***head*** reference with ***tail*** reference
- Access head of list via *tail.next*
- ALL operations on head are still fast : O(1) time
- addLast() is now fast – O(1) time
- Only modest additional complexity in implementation
- Can "cyclically reorder" list by changing *tail* node
- Question: What's a circularly linked list of size 1?

Duane's Structure Hierarchy

The structure5 package has a hierarchical structure

- A collection of *interfaces* that describe---but do not implement---the functionality of one or more data structures
- A collection of *abstract classes* provide partial implementations of one or more data structures
  - To factor out common code or instance variables
- A collection of concrete (fully implemented) classes to provide full functionality of a data structure

AbstractList Superclass

```
abstract class AbstractList<E> implements List<E> {
    public void addFirst(E element) { add(0, element); }
    public E getLast() { return get(size()-1);}
    public E removeLast() { return remove(size()-1); }
}
```

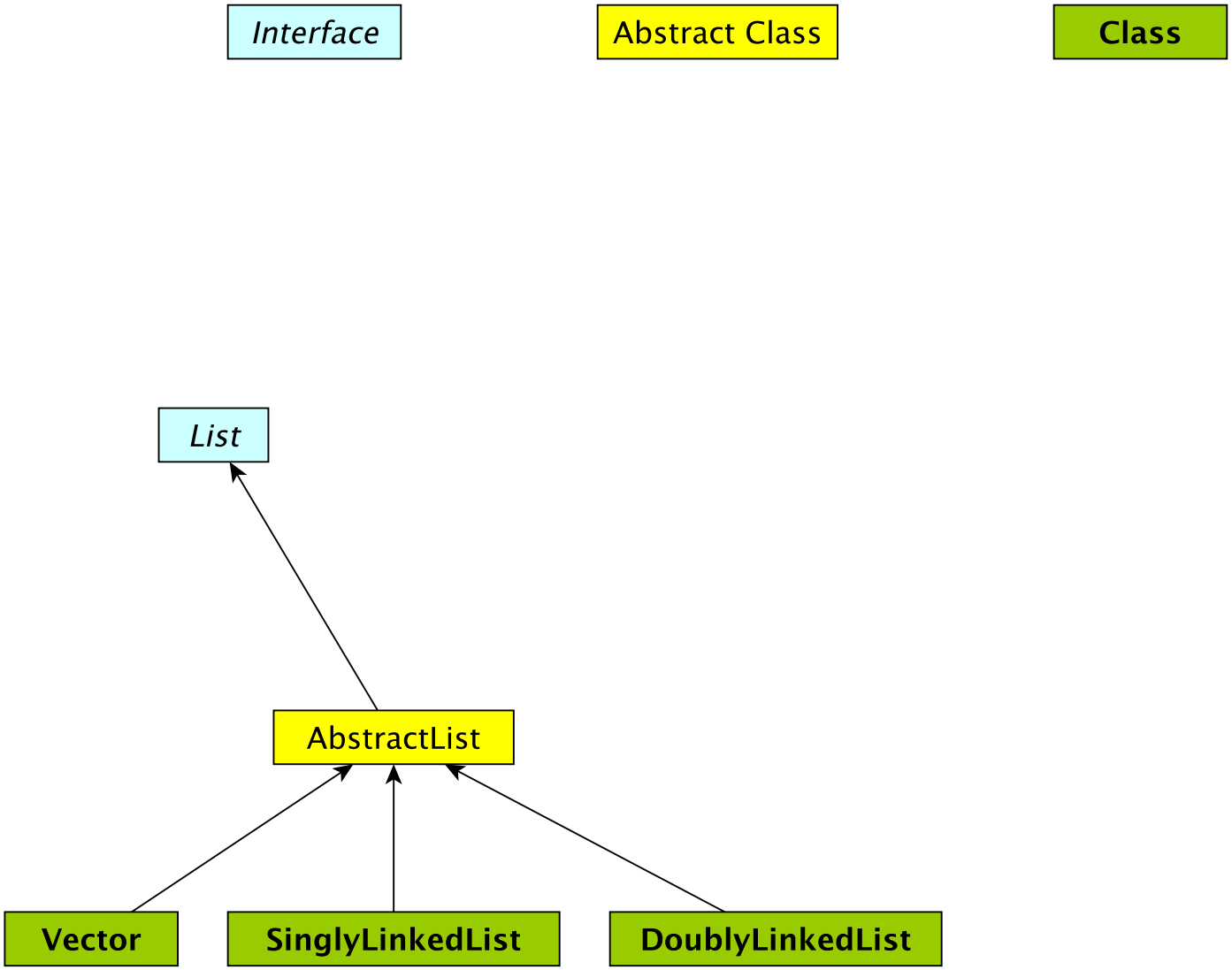
- AbstractList provides *some* of the list functionality
  - Code is shared among all sub-classes (see Ch. 7 for more info)

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

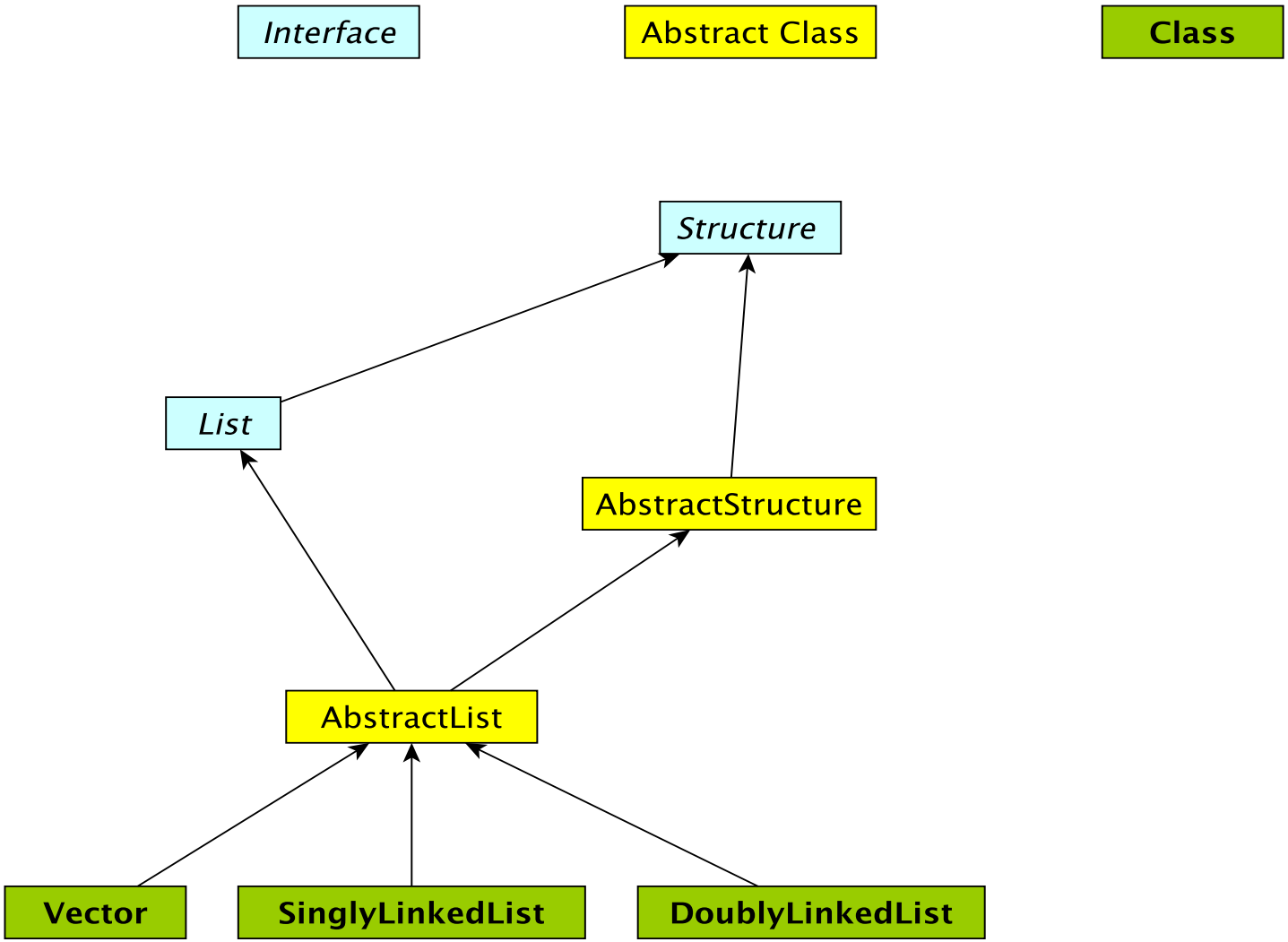
  - Concrete classes (SLL, DLL) can override the code implemented in AbstractList
- Abstract classes in general do not implement every method
  - For example, size() is not defined although it is in the List interface
- Can't create an "AbstractList" directly
- Concrete list classes extend AbstractList, implementing missing functionality

```
class Vector extends AbstractList {
    public int size() { return elementCount; }
}
```

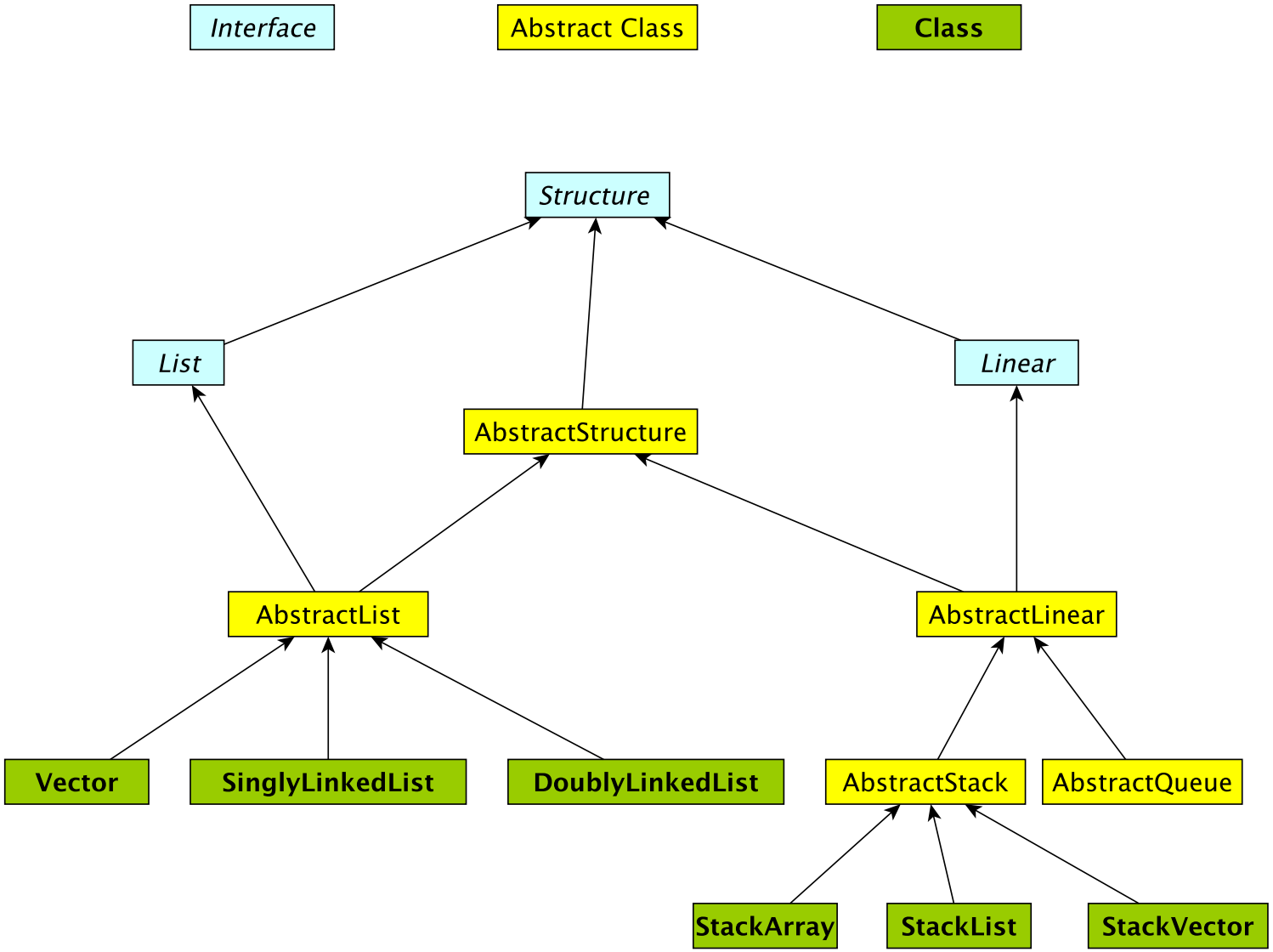
The Structure5 Universe (almost)



The Structure5 Universe (so far)



The Structure5 Universe (soon)



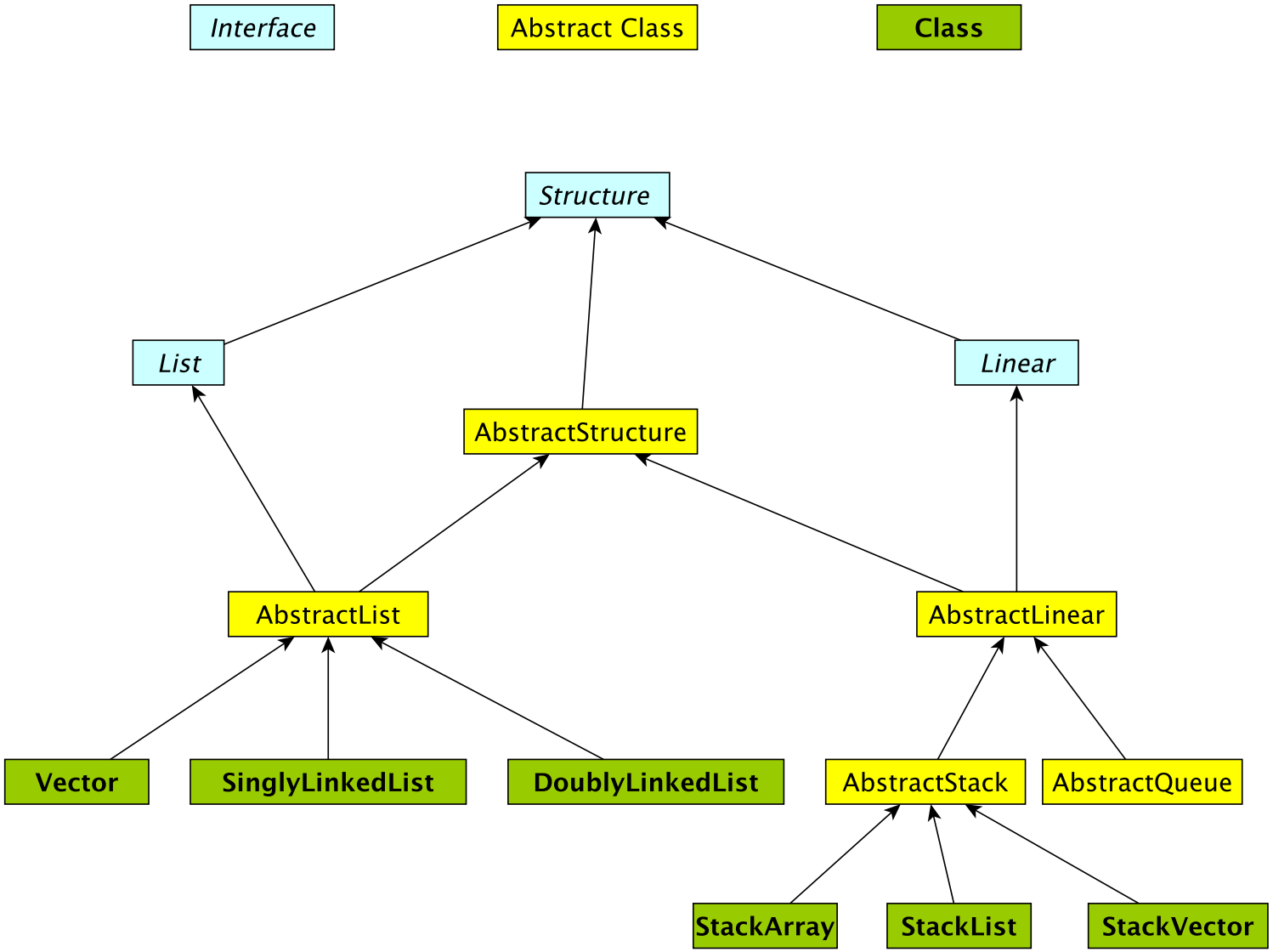
Linear Structures

- What if we want to impose *access restrictions* on our lists?
  - I.e., provide only one way to add and remove elements from list
  - No longer provide access to middle
- Key Examples: Order of removal depends on order elements were added
  - LIFO: Last In First Out
  - FIFO: First In First Out

Examples

- FIFO: First In – First Out (Queue)
  - Line at dining hall
  - Data packets arriving at a router
- LIFO: Last In – First Out (Stack)
  - Stack of trays at dining hall
  - Java Virtual Machine stack

The Structure5 Universe (next)



Linear Interface

- How should it differ from List interface?
  - Should have fewer methods than List interface since we are limiting access …
- Methods:
  - Inherits all of the Structure interface methods
    - add(E value) – Add a value to the structure.
    - E remove(E o) – Remove value o from the structure.
      - But this is awkward---why?
    - int size(), isEmpty(), clear(), contains(E value), …
  - Adds
    - E get() – Preview the next object to be removed.
    - E remove() – Remove the *next* value from the structure.
    - boolean empty() – same as isEmpty()

Linear Structures

- Why no "random access"?
  - I.e., no access to middle of list
- More restrictive than general List structures
  - Less functionality can result in
    - Simpler implementation
    - Greater efficiency
- Approaches
  - Use existing structures (Vector, LL), or
  - Use underlying organization, but simplified

Stacks

- Examples: stack of trays or cups
  - Can only take tray/cup from top of stack
- What methods do we need to define?
  - Stack interface methods
- New terms: push, pop, peek
  - Only use push, pop, peek when talking about stacks
  - Push = add to top of stack
  - Pop = remove from top of stack
  - Peek = look at top of stack (do not remove)

Notes about Terminology

- When using stacks:
  - pop = remove
  - push = add
  - peek = get
- In Stack interface, pop/push/peek methods call add/remove/get methods that are defined in Linear interface
- But "add" is not mentioned in Stack interface (it is inherited from Linear)
- Stack interface **extends** Linear interface
  - Interfaces *extend* other interfaces
  - Classes *implement* interfaces

Stack Implementations

- Array-based stack
  - int top, Object data[ ]
  - Add/remove from index top

  \+ all operations are O(1)

  – wasted/run out of space

- Vector-based stack
  - Vector data
  - Add/remove from tail

  +/– most ops are O(1) (add is O(n) in worst case)

  – potentially wasted space

- List-based stack
  - SLL data
  - Add/remove from *head*

  \+ all operations are O(1)

  +/– O(n) space overhead (no "wasted" space)

Stack Implementations

- structure5.StackArray
  - int top, Object data[ ]
  - Add/remove from index top

  \+ all operations are O(1)

  – wasted/run out of space

- structure5.StackVector
  - Vector data
  - Add/remove from tail

  +/– most ops are O(1) (add is O(n) in worst case)

  – potentially wasted space

- structure5.StackList
  - SLL data
  - Add/remove from head

  \+ all operations are O(1)

  +/– O(n) space overhead (no "wasted" space)

Summary Notes on The Hierarchy

- Linear interface *extends* Structure
  - add(E val), empty(), get(), remove(), size()
- AbstractLinear (partially) implements Linear
- AbstractStack class (partially) *extends* AbstractLinear
  - Essentially introduces "stack-ish" names for methods
  - push(E val) is add(E val), pop() is remove(), peek() is get()
- Now we can extend AbstractStack to make "concrete" Stack types
  - StackArray<E>: holds an array of type E; add/remove at high end
  - StackVector<E>: similar, but with a vector for dynamic growth
  - StackList<E>: A singly-linked list with add/remove at head
  - We implement add, empty, get, remove, size directly
    - push, pop, peek are then indirectly implemented

The Structure5 Universe (so far)