BASIC DATA STRUCTURES

CS062

DATA STRUCTURES AND ADVANCED PROGRAMMING

9: Stacks, Queues, and Iterators

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Lecture 9: Stacks, Queues, and Iterators

- Stacks
- Queues
- Applications
- Java Collections
- Iterators

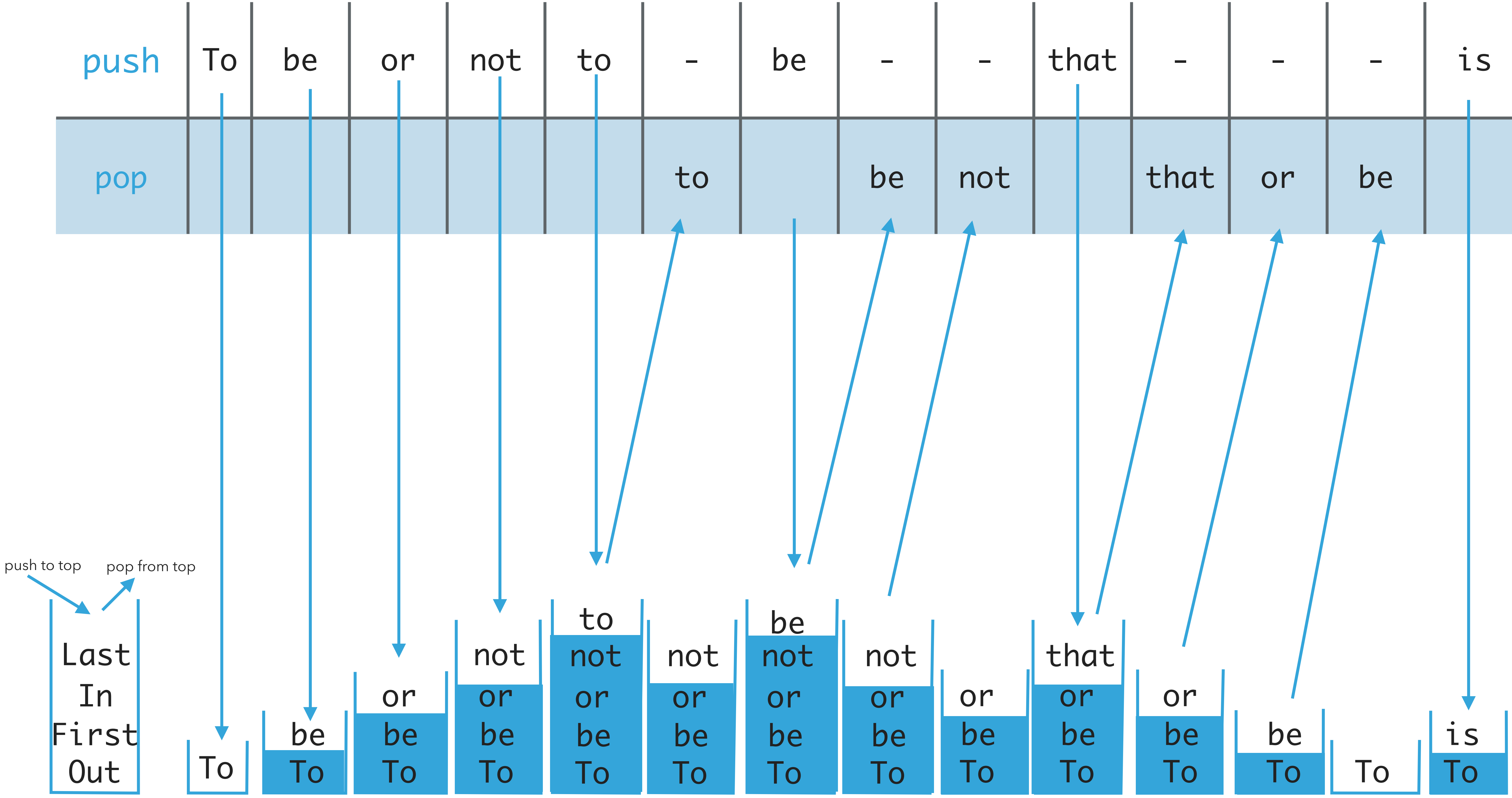
Some slides adopted from Algorithms 4th Edition and Oracle tutorials

Stacks

- Dynamic linear data structures.
- Items are inserted and removed following the LIFO paradigm.
- LIFO: Last In, First Out.
- Similar to lists, there is a sequential nature to the data.
- Remove the *most* recent item.

- Metaphor of cafeteria plate dispenser.
- Want a plate? Pop the top plate.
- Add a plate? Push it to make it the new top.
- Want to see the top plate? Peek.
- We want to make push and pop as time efficient as possible

Example of stack operations



push	To	be	or	not	to	-	be	-	-	that	-	-	-	is
pop						to		be	not		that	or	be	

Implementing stacks with ArrayLists

- Where should the top go to make push and pop as efficient as possible?
- The *end/rear* represents the top of the stack.
- To push an item `add(Item item)`.
    - Adds at the end. Average $O(1)$.
- To pop an item `remove()`.
    - Removes and returns the item from the end. Average $O(1)$.
- To peek `get(size()-1).`
    - Retrieves the last item. $O(1)$.
- If the front/beginning were to represent the top of the stack, then:
    - Push, pop would be $O(n)$ and peek $O(1)$.

Implementing stacks with singly linked lists

- Where should the top go to make push and pop as efficient as possible?
- The *front* represents the top of the stack.
- To push an item `add(Item item)`.
  - Adds at the head. $O(1)$.
- To pop an item `remove()`.
  - Removes and retrieves from the head. $O(1)$.
- To peek `get(0).`
  - Retrieves the head. $O(1)$.
- If the *end* were to represent the top of the stack, then:
  - Push, pop, peek would all be $O(n)$.

Implementing stacks with doubly linked lists

- Where should the top go to make push and pop as efficient as possible?
- The *front* represents the top of the stack.
- To push an item `addFirst(Item item)`.
  - Adds at the head. $O(1)$.
- To pop an item `removeFirst()`.
  - Removes and retrieves from the head. $O(1)$.
- To peek `head.item.`
  - Retrieves the head. $O(1)$.
- Unnecessary memory overhead with extra pointers.
- If the *end* were to re[resent the top of the stack, we'd need to use `addLast(Item item)`, `removeLast()`, and `tail.item` to have $O(1)$ complexity.

Textbook implementation of stacks

- ResizingArrayStack.java: for implementation of stacks with ArrayLists.
- LinkedStack.java: for implementation of stacks with singly linked lists.

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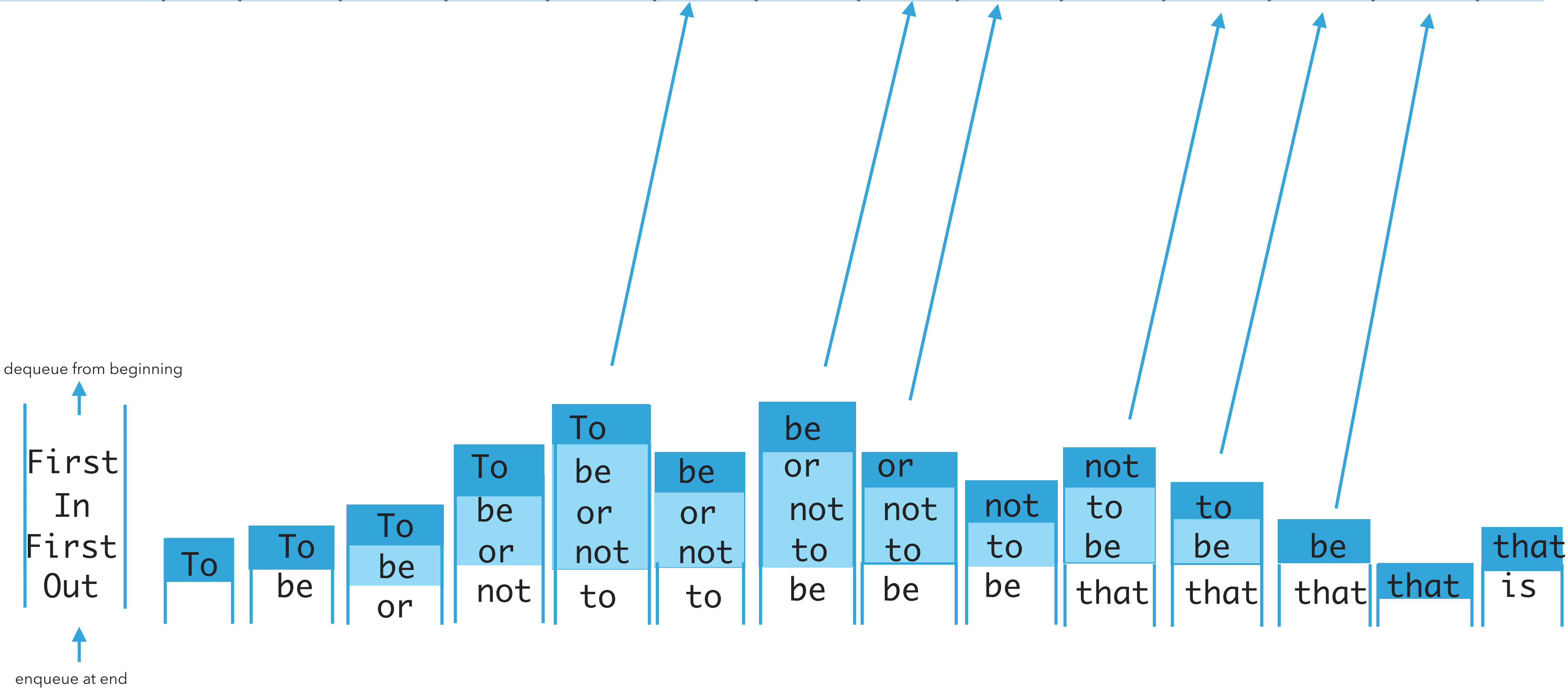
Queues

- Dynamic linear data structures.
- Items are inserted and removed following the FIFO paradigm.
- FIFO: First In, First Out.
- Similar to lists, there is a sequential nature to the data.
- Remove the *least* recent item.

- Metaphor of a line of people waiting to buy tickets.
- Just arrived? Enqueue person to the end of line.
- First to arrive? Dequeue person at the top of line.
- We want to make enqueue and dequeue as time efficient as possible.

Example of stack operations

enqueue	To	be	or	not	to	-	be	-	-	that	-	-	-	is
dequeue						To		be	or		not	to	be	



Implementing queue with ArrayLists

- Where should we enqueue and dequeue items?
- To enqueue an item `add()` at the end of arrayList. Average $O(1)$.
- To dequeue an item `remove(0).` $O(n)$`.`
- What if we add at the beginning and remove from end?
  - Now dequeue is cheap ($O(1)$) but enqueue becomes expensive ($O(n)$).

Implementing queue with singly linked list

- Where should we enqueue and dequeue items?
- To enqueue an item `add()` at the head of SLL ($O(1)$).
- To dequeue an item `remove(size()-1)` ($O(n)$).
- What if we add at the beginning and remove from end?
  - Now dequeue is cheap ($O(1)$) but enqueue becomes expensive ($O(n)$).
- $O(1)$ if we have a tail pointer.
  - Simple modification in code, big gains!
  - Version that textbook follows.

Implementing queue with doubly linked list

- Where should we enqueue and dequeue items?
- To enqueue an item `addFirst()` at the head of DLL ($O(1)$).
- To dequeue an item `removeLast()` ($O(1)$).
- What if we add at the beginning and remove from end?
  - Both are $O(1)$!

Textbook implementation of queues

- ResizingArrayQueue.java: for implementation of queues with ArrayLists.
- LinkedQueue.java: for implementation of queues with singly linked lists.

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Stack applications

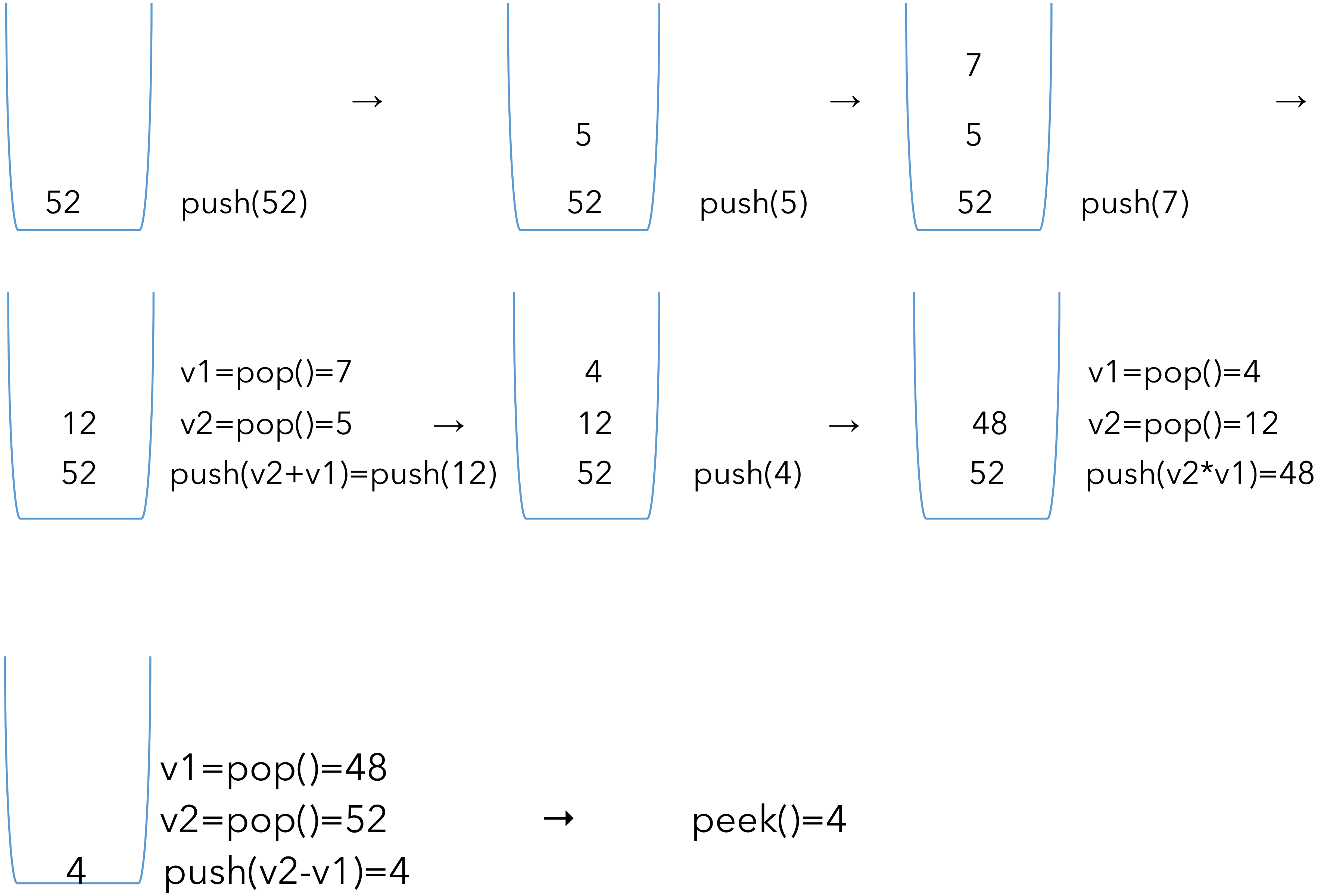
- Java Virtual Machine.
- Basic mechanisms in compilers, interpreters (see CS101).
- Back button in browser.
- Undo in word processor.
- Infix expression evaluation (Dijskstra's algorithm with two stacks).
- Postfix expression evaluation.

1.3 DIJKSTRA'S 2-STACK DEMO

http://algs4.cs.princeton.edu

Postfix expression evaluation example

Example: (52 - ((5 + 7) * 4) ⇒ 52 5 7 + 4 * -



52 push(52) →

5
52 push(5) →

7
5
52 push(7) →

12
52
v1=pop()=7
v2=pop()=5
push(v2+v1)=push(12) →

4
12
52 push(4) →

48
52
v1=pop()=4
v2=pop()=12
push(v2*v1)=48

4
v1=pop()=48
v2=pop()=52
push(v2-v1)=4 →

peek()=4

Queue applications

- Spotify playlist.
- Data buffers (netflix, Hulu, etc.).
- Asynchronous data transfer (file I/O, sockets).
- Requests in shared resources (printers).
- Traffic analysis.
- Waiting times at calling center.

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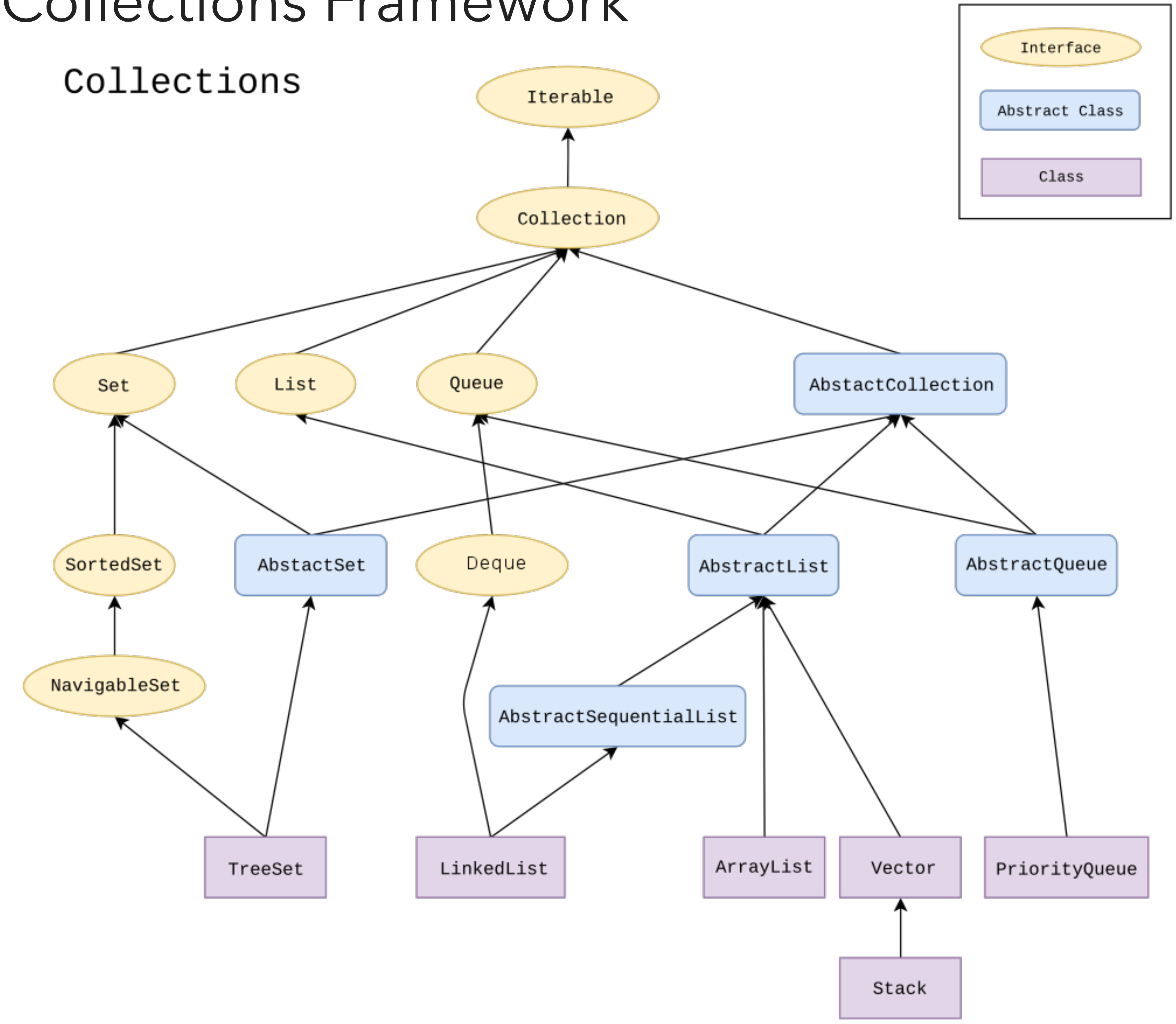
The Java Collections Framework



https://en.wikipedia.org/wiki/Java_collections_framework

Deque in Java Collections

- Do not use Stack.
- Queue is an interface…
- It's recommended to use Deque instead.
- Double-ended queue (can add and remove from either end).

```
java.util.Deque;

public interface Deque<E> extends Queue<E>
```

- You can choose between LinkedList and ArrayDeque implementations.
  - `Deque deque = new ArrayDeque(); //preferable`

https://docs.oracle.com/javase/8/docs/api/java/util/Deque.html

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Iterator Interface

- Interface that allows us to traverse a collection one element at a time.

```
public interface Iterator<E> {
  //returns true if the iteration has more elements
  //that is if next() would return an element instead of throwing an exception
  boolean hasNext();

  //returns the next element in the iteration
  //post: advances the iterator to the next value
  E next();

  //removes the last element that was returned by next
  default void remove(); //optional, better avoid it altogether
}
```

https://docs.oracle.com/javase/8/docs/api/java/util/Iterator.html

Iterator Example

```
List<String> myList = new ArrayList<String>();
//… operations on myList

Iterator listIterator = myList.iterator();

while(listIterator.hasNext()){
  String elt = listIterator.next();
  System.out.println(elt);
}
```

Java8 introduced lambda expressions

- `Iterator` interface now contains a new method.
- `default void forEachRemaining(Consumer<? super E> action)`
- Performs the given action for each remaining element until all elements have been processed or the action throws an exception.

```
listIterator.forEachRemaining(System.out::println);
```

Iterable Interface

- Interface that allows an object to be the target of a for-each loop:

```
for(String elt: myList){
   System.out.println(elt);
}
```

```
interface Iterable<E>{
  //returns an iterator over elements of type E
  Iterator<E> iterator();

  //Performs the given action for each element of the Iterable until all elements 
have
  //been processed or the action throws an exception.
  default void forEach(Consumer<? super E> action);
}
myList.forEach(elt-> {System.out.println(elt)});
myList.forEach(System.out::println);
```

https://docs.oracle.com/javase/8/docs/api/java/lang/Iterable.html

How to make your data structures iterable?

1. Implement `Iterable` interface.
2. Make a private class that implements the `Iterator` interface.
3. Override `iterator()` method to return an instance of the private class.

Example: making ArrayList iterable

```
public class ArrayList<Item> implements Iterable<Item> {
    //…
    public Iterator<Item> iterator() {

        return new ArrayListIterator();
    }


    private class ArrayListIterator implements Iterator<Item> {

        private int i = 0;

        public boolean hasNext() {
            return i < n;

        }

        public Item next() {

            return a[i++];

        }

        public void remove() {
            throw new UnsupportedOperationException();

        }

    }
```

Traversing ArrayList

- All valid ways to traverse ArrayList and print its elements one by one.

```
for(String elt:a1) {
    System.out.println(elt);
}

a1.forEach(System.out::println);
a1.forEach(elt->{System.out.println(elt);});

a1.iterator().forEachRemaining(System.out::println);
a1.iterator().forEachRemaining(elt->{System.out.println(elt);});
```

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Readings:

- Oracle's guides:
  - Collections: https://docs.oracle.com/javase/tutorial/collections/intro/index.html
  - Deque: https://docs.oracle.com/javase/8/docs/api/java/util/Deque.html
  - Iterator: https://docs.oracle.com/javase/8/docs/api/java/util/Iterator.html
  - Iterable: https://docs.oracle.com/javase/8/docs/api/java/lang/Iterable.html
- Textbook:
  - Chapter 1.3 (Page 126-157)
- Website:
  - Stacks and Queues: https://algs4.cs.princeton.edu/13stacks/

Practice Problems:

- 1.3.2-1.3.8, 1.3.32-1.3.33