BASIC DATA STRUCTURES

CS062

DATA STRUCTURES AND ADVANCED PROGRAMMING

12: Stacks, Queues and Iterators

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Lecture 12: Stacks, Queues, and Iterators

- Stacks
- Queues
- Applications
- Java Collections
- Iterators

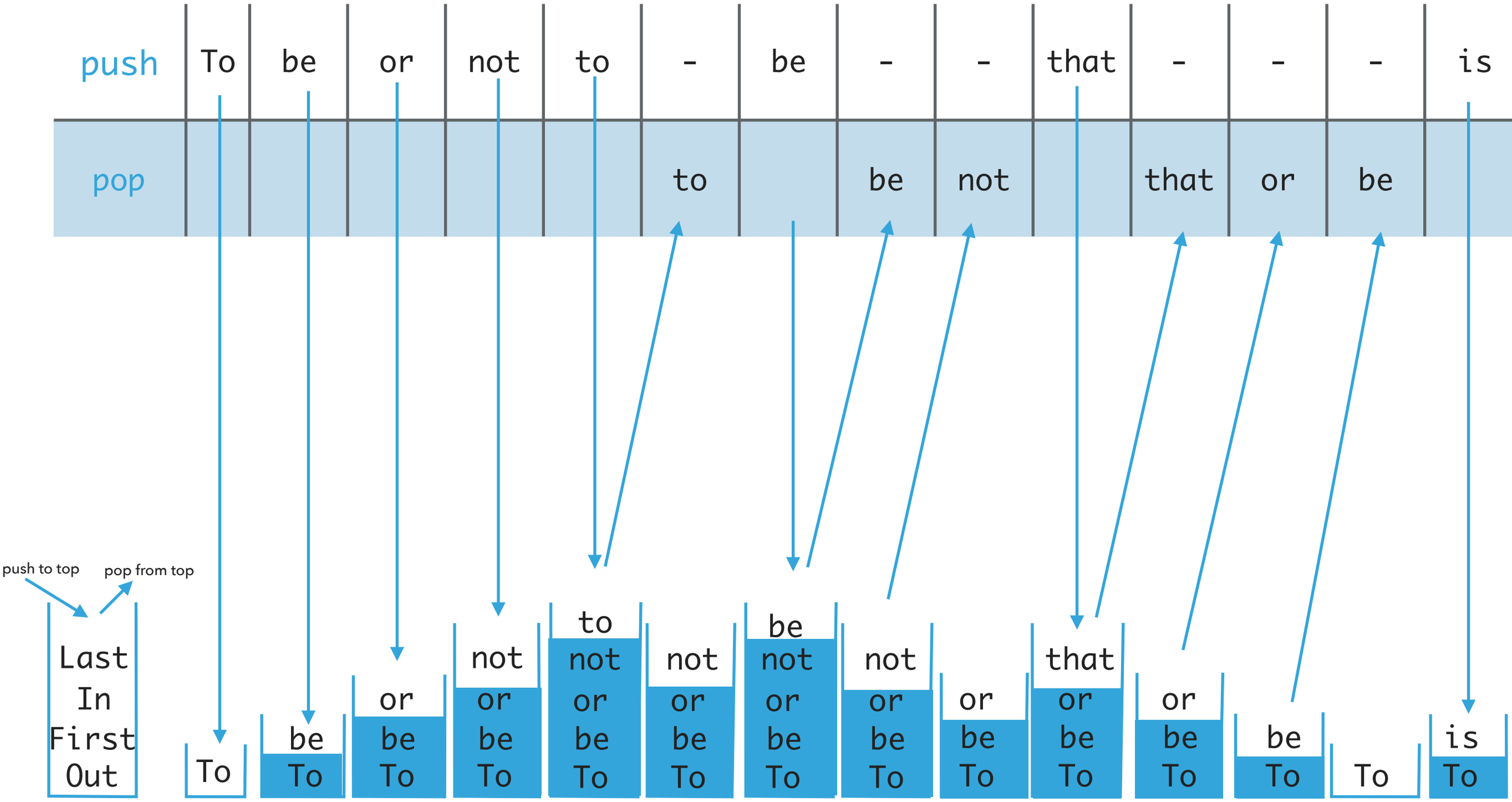
Some slides adopted from Algorithms 4th Edition and Oracle tutorials

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.
- Unlike lists, 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



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()`.
- To pop an item `remove(size()-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()`.
- To pop an item `remove()`.

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()`.
- To pop an item `removeFirst()`.
- Unnecessary memory overhead with extra pointers.

Textbook implementation of stacks

- `ResizingArrayStack.java`: for implementation of stacks with ArrayLists.
- `LinkedStack.java`: for implementation of stacks with singly linked lists.
- Make sure to check the code!

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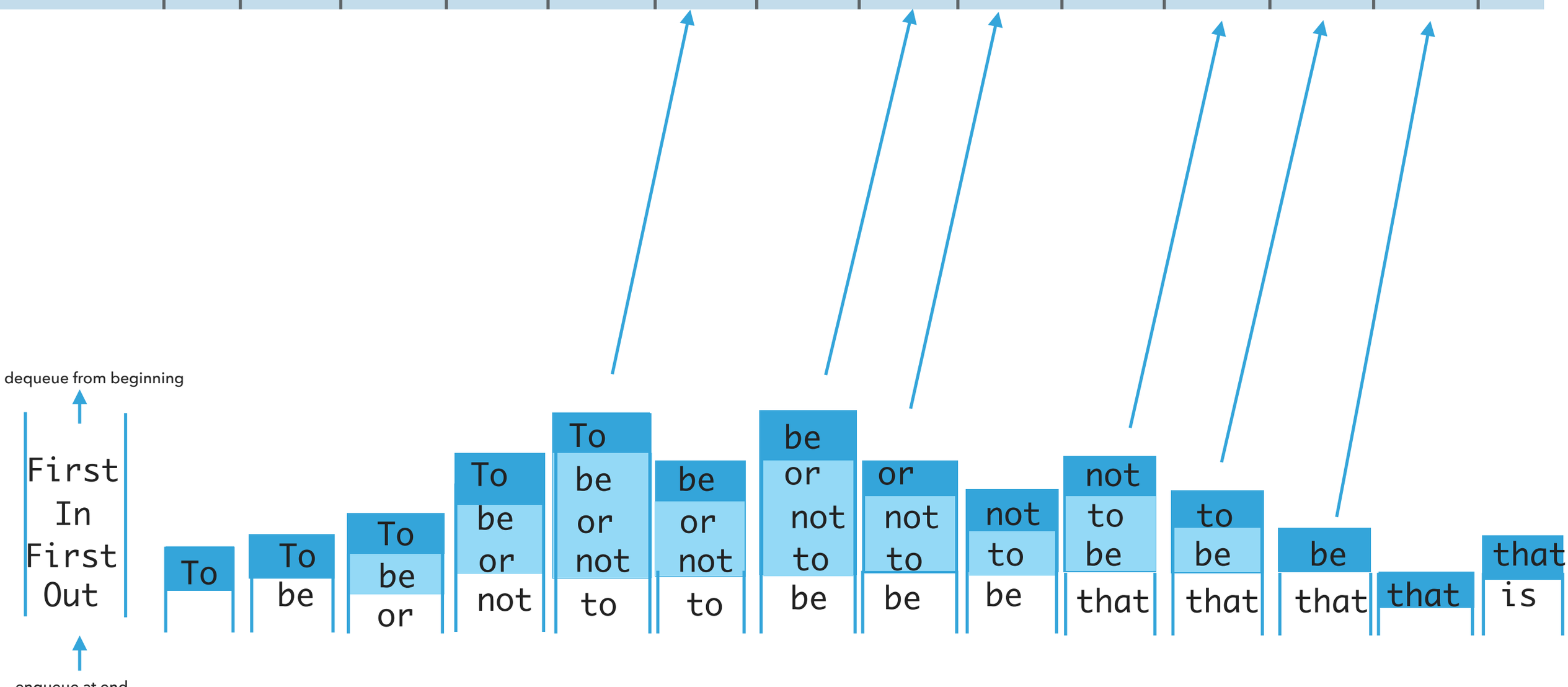
Queues

- 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.
- Unlike lists, 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 (cheap).
- To dequeue an item `remove(0)` (expensive).
- What if we add at the beginning and remove from end?
- Now remove is cheap but add becomes expensive.

Implementing queue with singly linked list

- Where should we enqueue and dequeue items?
- To enqueue an item `add()` at the head of SLL (cheap).
- To dequeue an item `remove(size()-1)` (expensive).
- What if we add at the beginning and remove from end?
- Now remove is cheap but add becomes expensive.

Implementing queue with doubly linked list

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

Textbook implementation of queues

- `ResizingArrayQueue.java`: for implementation of queues with ArrayLists.
- `LinkedQueue.java`: for implementation of queues with singly linked lists.
- Make sure to check the code!

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Stack applications

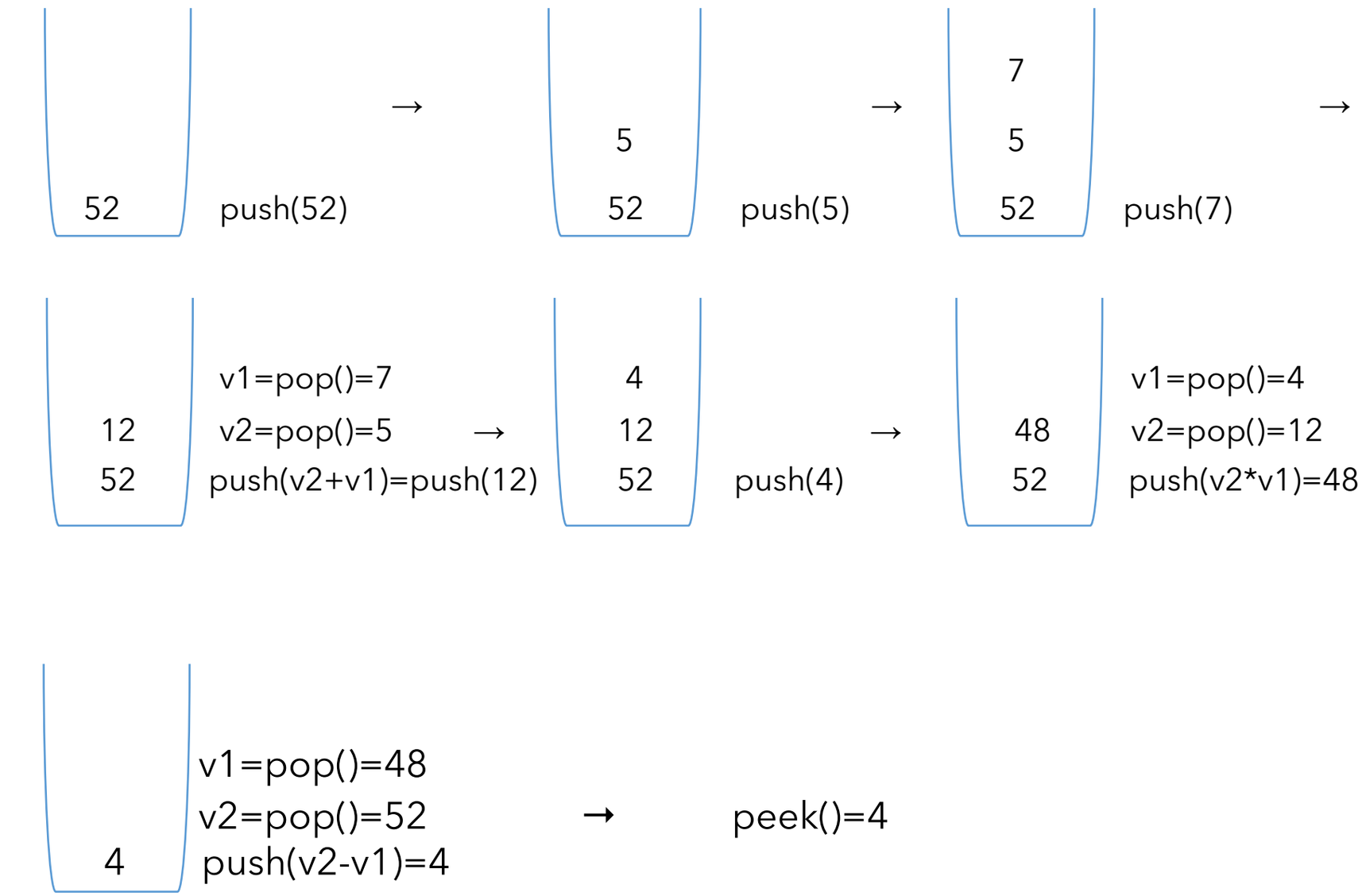
- Java Virtual Machine.
- Basic mechanisms in compilers, interpreters (see CS101).
- Back button in browser.
- Undo in word processor.
- Infix expression evaluation (Dijskstra's algorithm with two stacks).
- Postfix expression evaluation.

http://algs4.cs.princeton.edu

1.3 DIJKSTRA'S 2-STACK DEMO

Postfix expression evaluation example

Example: (52 - ((5 + 7) * 4) ⇒ 52 5 7 + 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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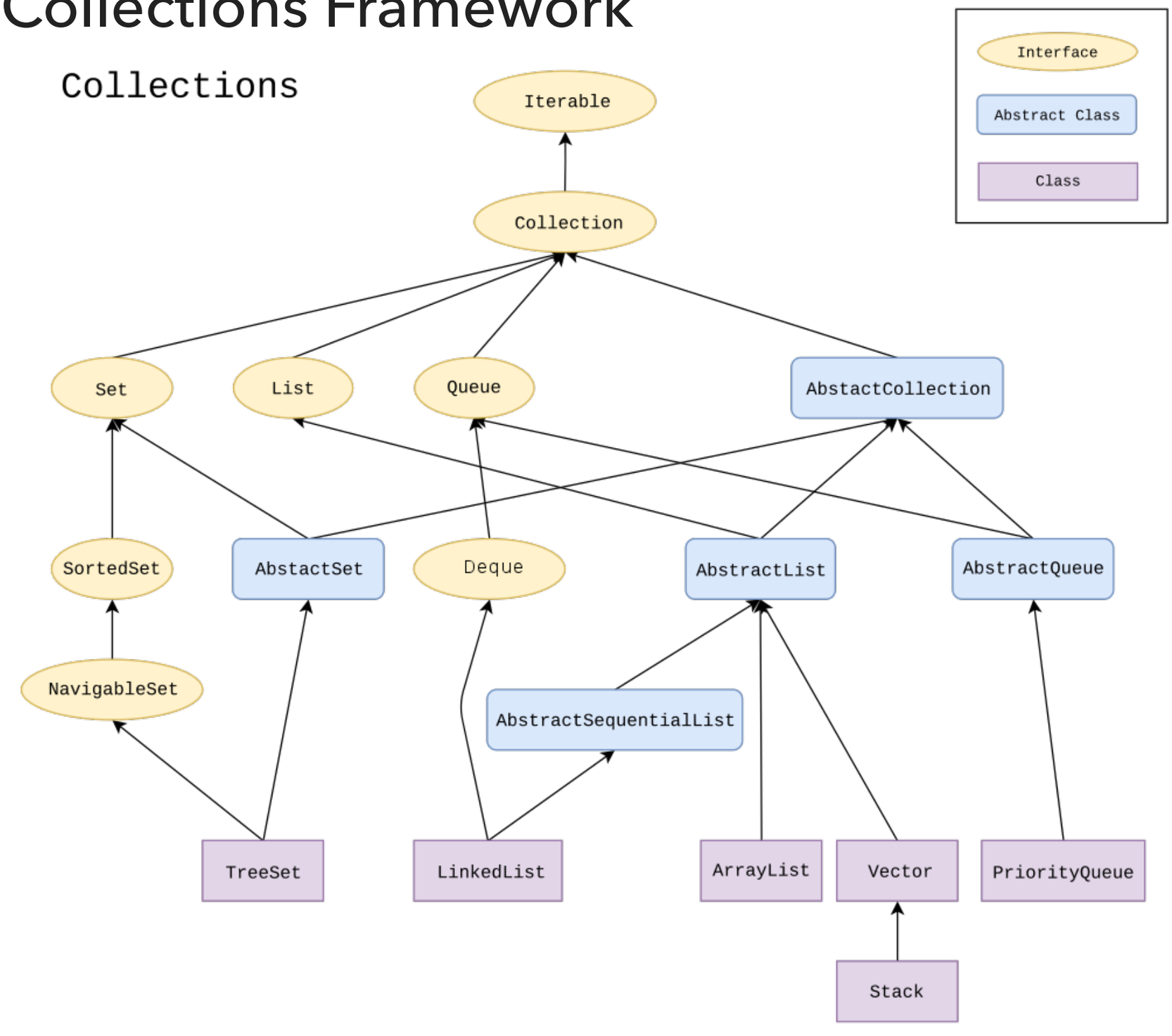
The Java Collections Framework



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