

# COMP 6481: Programming and Problem Solving

Tutorial 6:

Array List, Linked List, Stack, and Queue

# Quick Background

- Array List
- Linked List
- Stack
- Queue

# Array List

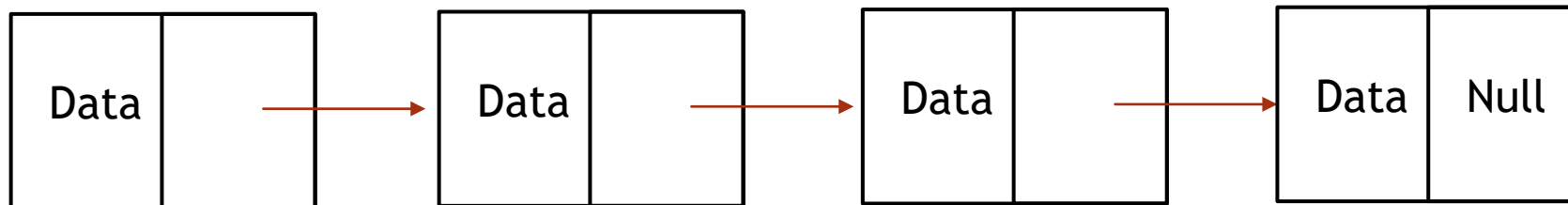
- ▶ An *Array List* stores its elements in a linear sequential way and supports access to these elements by their indices.
- ▶ An *Array List* extends an array and is far more superior than it.
- ▶ An *Array List* grows as items are added to it, it is searchable, sortable, etc.

# The Array List ADT - Methods

- ▶ *get(i)*: Return the element of  $S$  with index  $i$ ; an error condition occurs if  $i < 0$  or  $i > \text{size}() - 1$ .
- ▶ *set(i,e)*: Replace with  $e$  and return the element at index  $i$ ; an error condition occurs if  $i < 0$  or  $i > \text{size}() - 1$ .
- ▶ *add(i,e)*: Insert a new element  $e$  into  $S$  to have index  $i$ ; an error condition occurs if  $i < 0$  or  $i > \text{size}()$ .
- ▶ *remove(i)*: Remove from  $S$  the element at index  $i$ ; an error condition occurs if  $i < 0$  or  $i > \text{size}() - 1$ .
- ▶ *size()*: Return the number of elements in the Array List.
- ▶ *isEmpty()*: Return a Boolean indicating if the Array List is empty.

# Linked list

A linked list is a linked data structure consisting of a single chain of nodes, each connected to the next by a link.



# Linked list

Each node in the linked list consists of two parts:

1. data, which is consistent across all the nodes of the linked list
2. reference, which is a pointer to the next node.

```
Node {  
    private int content;  
    private Node nextNode;  
    ...  
}
```

# Linked list

The Node constructor creates a new node and points the one passed via its parameter.

```
Node {  
    private int content;  
    private Node nextNode;  
  
    Node(int value, Node extern)  
    {  
        content = value;  
        nextNode = extern;  
    }  
}
```

# The Stack ADT - Definition

A stack is a collection of objects that are inserted and removed according to the last-in first-out (LIFO) principle. The name “Stack” is derived from the metaphor of stack of plates.



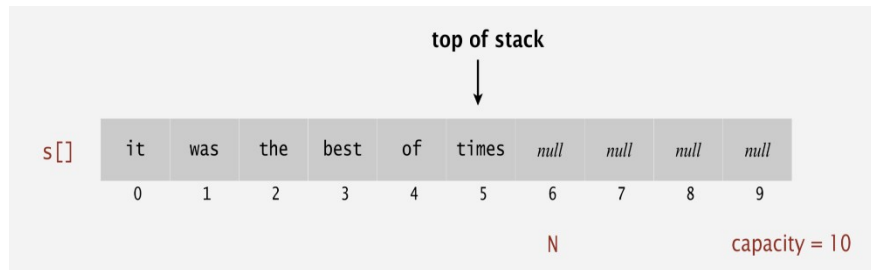


# The Stack ADT - Methods

- ▶ `push(e)`: Insert element  $e$ , to be the top of the stack.
- ▶ `pop()`: Remove from the stack and return the top element on the stack; an error occurs if the stack is empty.
- ▶ `size()`: Return the number of elements in the stack.
- ▶ `isEmpty()`: Return a Boolean indicating if the stack is empty.
- ▶ `top()`: Return the top element in the stack, without removing it; an error occurs if the stack is empty.

# STACK Array/Array List Implementation

- ▶ Simple way to implement stack
- ▶ Add element from left to right
- ▶ Keep track of the index of the top element



- ▶ Requires client to provide the capacity
- ▶ Array List (Solution with Resizing array):
  - ▶ Create a new array of twice the size when array is full and copy items.
  - ▶ Halve size of array when array is one-quarter full

# STACK SINGLY LINKED LIST IMPLEMENTATION (1)

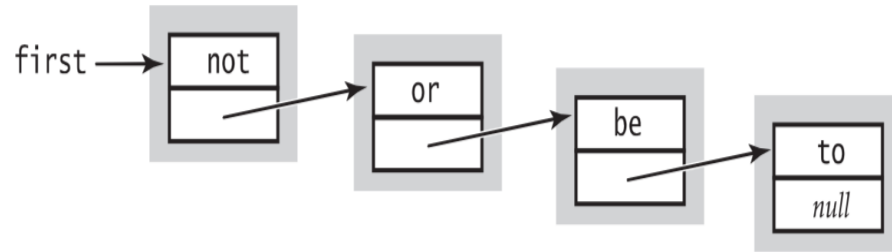
- ▶ Need a class to represent a node in the list

```
Class Node {  
    Type data;  
    Node next;  
}
```

- ▶ The list keeps track of the head

# STACK SINGLY LINKED LIST IMPLEMENTATION (2)

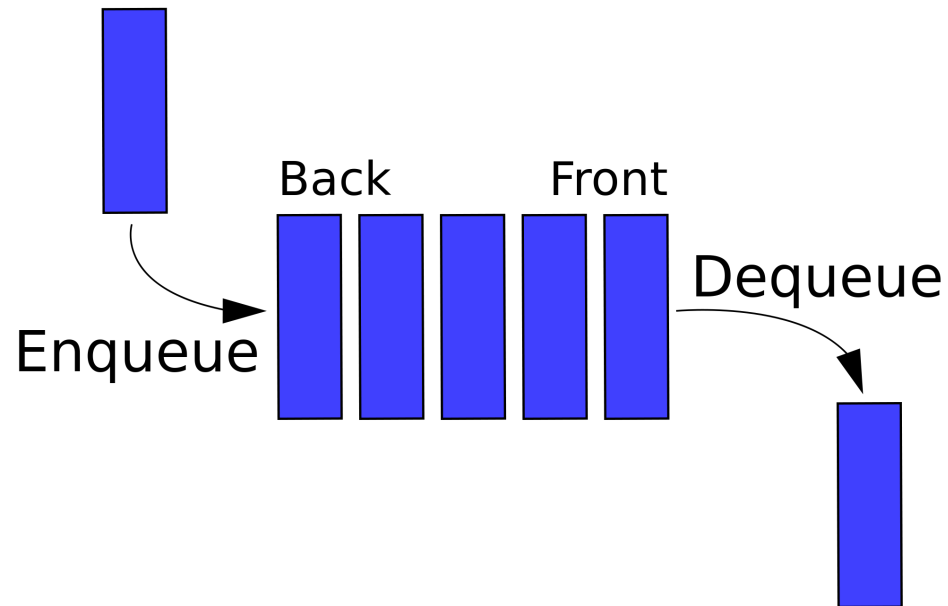
```
Class List{  
Node first;  
// all operations  
}
```



- ▶ Add element from right to left.
- ▶ Nb: can use doubly linked list to implement stack

# The Queue ADT - Definition

Another fundamental data structure is the queue. Objects are inserted and removed according to the first-in first-out (FIFO) principal.

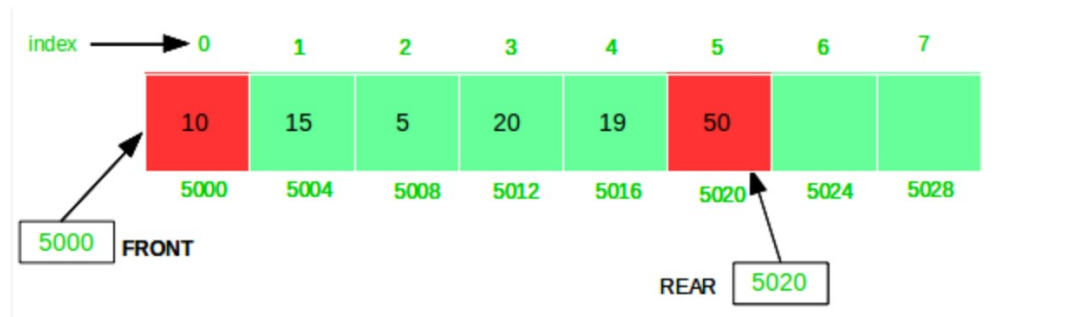


# The Queue ADT - Methods

- ▶ `enqueue(e)`: Insert element *e* at the rear of the queue.
- ▶ `dequeue()`: Remove and return from the queue the object at the front; an error occurs if the queue is empty.
- ▶ `size()`: Return the number of objects in the queue.
- ▶ `isEmpty()`: Return a Boolean value that indicates whether the queue is empty.
- ▶ `front()`: Return, but do not remove, the front object in the queue; an error occurs if the queue is empty.

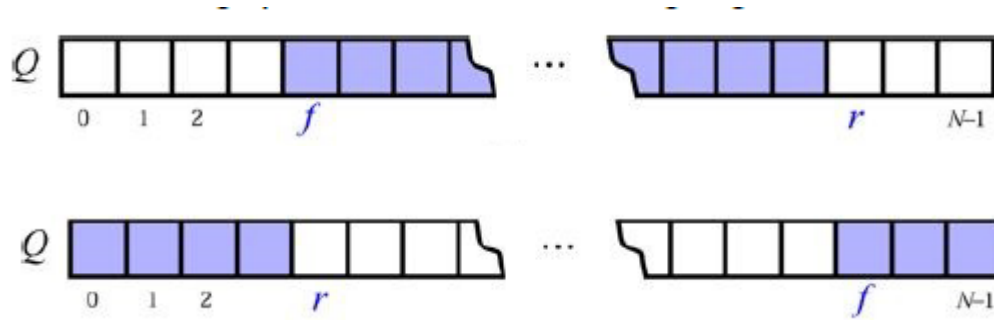
# QUEUE: ARRAY IMPLEMENTATION

- ▶ Simple implementation
- ▶ Need to keep track of the index of the front and the rear



- ▶ With a simple array when we dequeue we need to shift all the elements in the front
- ▶ Solution: Make the array circular or use an ArrayList

# Highlights on a Queue Implementation Using a Circular Array



- ▶ The following variables are defined:
  - ▶  $f$ : index to the cell storing the first element in the queue (candidate to be removed)
  - ▶  $r$ : index to the next available cell
- ▶ Operations:
  - ▶  $\text{size}() \sqcap (N - f + r) \bmod N$
  - ▶  $\text{isEmpty}() \sqcap f = r$
  - ▶  $\text{enqueue}(x) \sqcap r = (r + 1) \bmod N$
  - ▶  $\text{dequeue}() \sqcap f = (f + 1) \bmod N$



# QUEUE: LIST IMPLEMENTATION

- ▶ Use doubly linked list.

```
Class Node {  
    Type data;  
    Node next;  
    Node previous;  
}
```

- ▶ Need to keep track of the front and rear of the list:

```
Class List {  
    Node first;  
    Node rear;  
    // all operations  
}
```

# WORST CASE TIME COMPLEXITY LINEAR DATA STRUCTURE

Data Structure	Worst Case Time Complexity			
	Access	Search	Insertions	Delete
Array	$O(1)$	$O(n)$	$O(n)$	$O(n)$
Stack	$O(n)$	$O(n)$	$O(1)$	$O(1)$
Queue	$O(n)$	$O(n)$	$O(1)$	$O(1)$
Singly Linked List	$O(n)$	$O(n)$	Begin: $O(1)$ , End: $O(n)$	Begin: $O(1)$ , End: $O(n)$

# Question 1

- ▶ Describe the output of the following series of stack operations:
- ▶ push(5), push(3), pop(), push(2), push(8), pop(), pop(), push(9), push(1), pop(), push(7), push(6), pop(), pop(), push(4), pop(), pop().

## Question 2

- ▶ Suppose an initially empty stack  $S$  has performed a total of 25 push operations, 12 top operations, and 10 pop operations, 3 of which generated `StackEmptyExceptions`, which were caught and ignored.
- ▶ What is the current size of  $S$ ?

## Question 3

- ▶ Suppose you have a stack in which the values 1 through 5 must be pushed on the stack in that order, but that an item on the stack can be popped at any time. Give a sequence of push and pop operations such that the values are popped in the following order:
  - a) 2,4,5,3,1
  - b) 1,5,4,2,3
  - c) 1,3,5,4,2
- ▶ It might not be possible in each case.

## Question 4

- ▶ write a program that reads in a positive integer and prints the binary representation of that integer.
- ▶ Hint: divide the integer by 2.

## Question 5

- ▶ Write a program that checks whether an input string is a palindrome or not using a stack.

## Question 6

- ▶ Describe the output for the following sequence of queue operations:
- ▶ enqueue(5), enqueue(3), dequeue(), enqueue(2), enqueue(8), dequeue(), dequeue(), enqueue(9), enqueue(1), dequeue(), enqueue(7), enqueue(6), dequeue(), dequeue(), enqueue(4), dequeue(), dequeue().



## Question 7

- ▶ Suppose an initially-empty queue  $Q$  has performed a total of 32 enqueue operations, 10 front operations, and 15 dequeue operations, 5 of which generated `QueueEmptyExceptions`, which were caught and ignored.
- ▶ What is the current size of  $Q$ ?

## Question 8

- ▶ Give an algorithm for reversing a queue Q. Only the following standard operations are allowed on queue.
- ▶ enqueue(x) : Add an item x to rear of queue.
- ▶ dequeue() : Remove an item from front of queue.
- ▶ empty() : Checks if a queue is empty or not.

## Question 9

- ▶ Describe how to implement the stack ADT using two queues.
- ▶ What is the running time of the `push()` and `pop()` methods in this case?