

Lecture 5

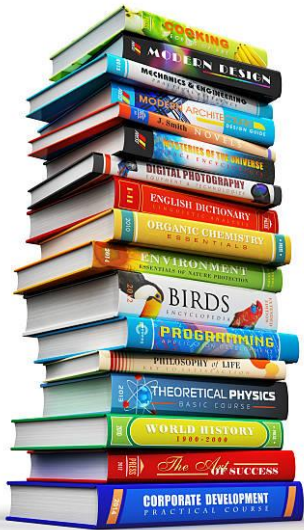
Stack and Queue

Our Roadmap

- ◆ Stack
- ◆ Queue
- ◆ Stack vs. Queue

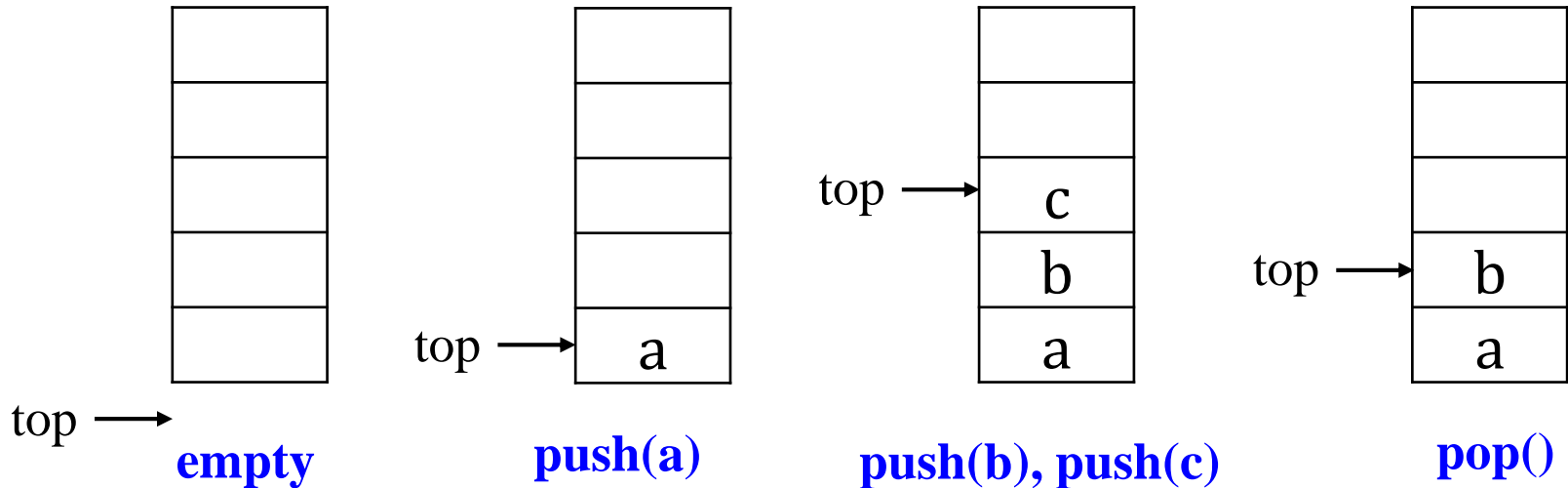
Stack

- ◆ A stack is a sequence in which:
 - ◆ Items can be added and removed only at one end (the top)
 - ◆ You can only access the item that is currently at the top
- ◆ Stack Analogy



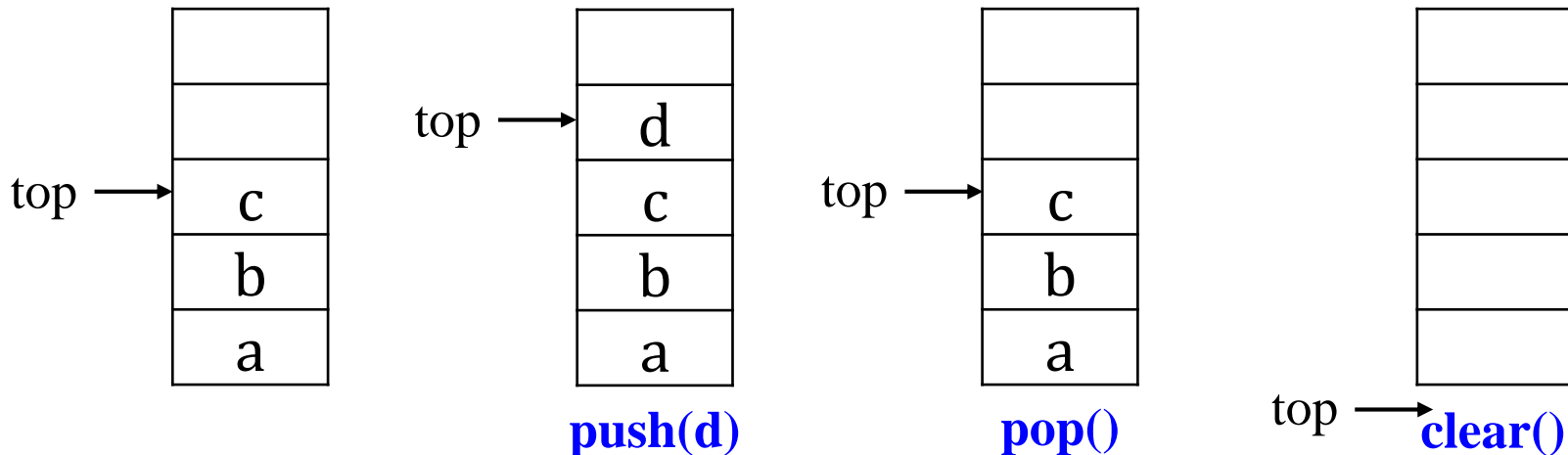
Stack

- ◆ First In Last Out (FILO)
 - ◆ Constrained item access
- ◆ Major Operations
 - ◆ **push**: add an item to the top of the stack
 - ◆ **pop**: remove the item at the top of the stack
- ◆ Illustration



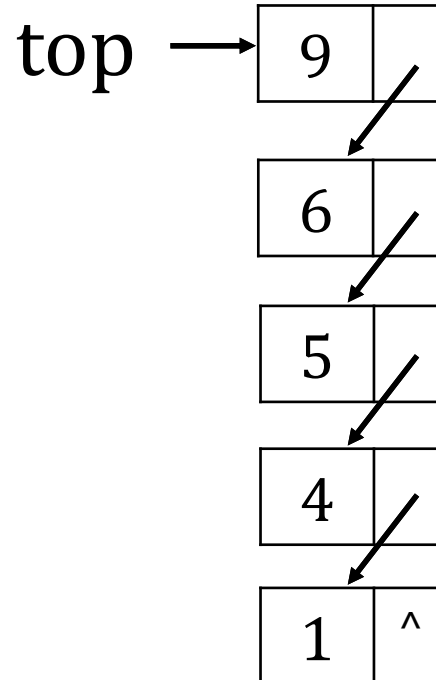
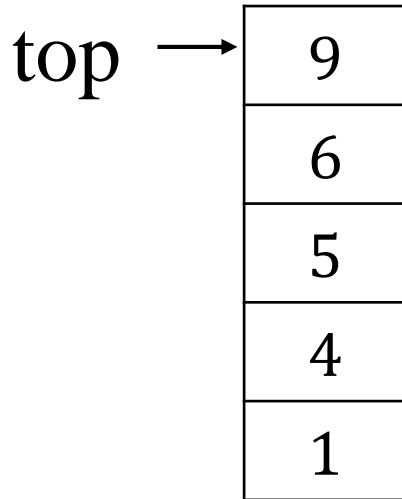
Stack Operation

- ◆ push: add an item to the top of the stack
- ◆ pop: remove the item at the top of the stack
- ◆ top/peek: get the item at the top of the stack, but do not remove it
- ◆ isEmpty: test if the stack is empty
- ◆ isFull: test if the stack is full
- ◆ clear: clear the stack, set it as empty stack
- ◆ size: return the current size of the stack



Implementation of Stack

- ◆ Array-based Stack
- ◆ Linked Stack



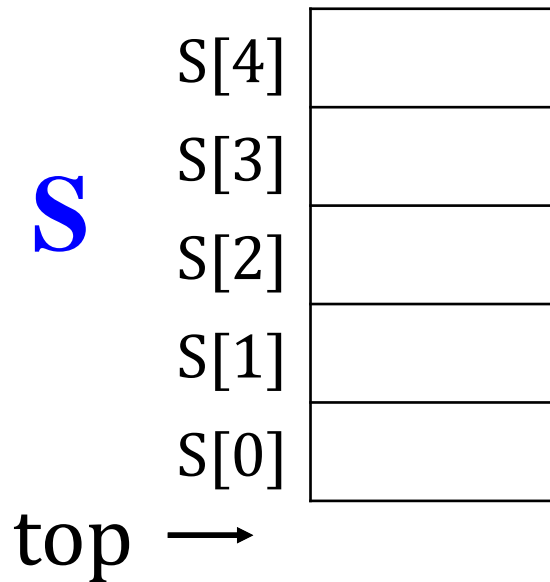
Implementation of Stack

- ◆ Array based Stack

- ◆ $\text{MAX_SIZE} = n$ // the max size of stack
- ◆ $\text{top} = -1$ // the current top position
- ◆ Array S with n elements

- ◆ Example

- ◆ $\text{MAX_SIZE} = 5$
- ◆ $\text{top} = -1$
- ◆ Array S

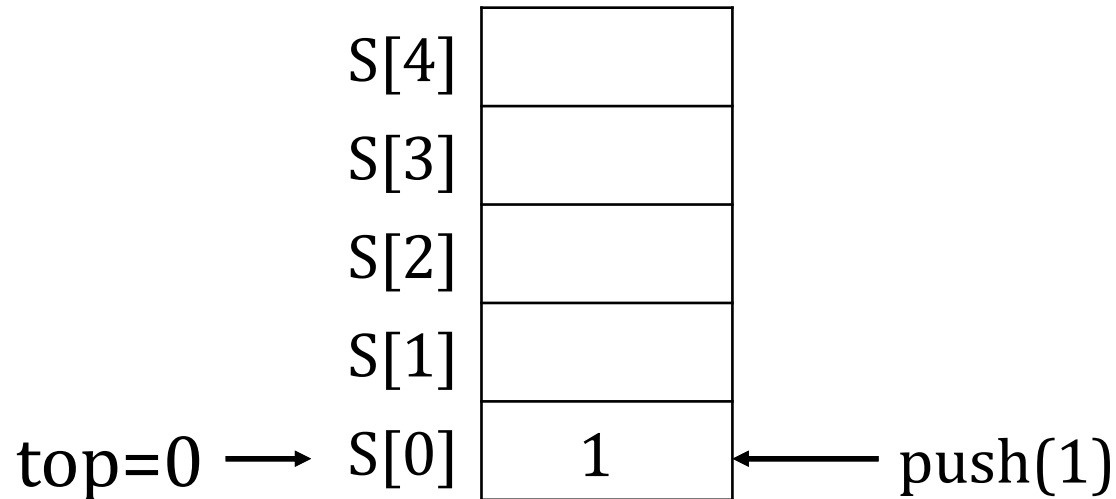


Push Operator

◆ `push(item):`

1. `top++;`
2. `S[top] = item`

◆ `push(1)`



Push Operator

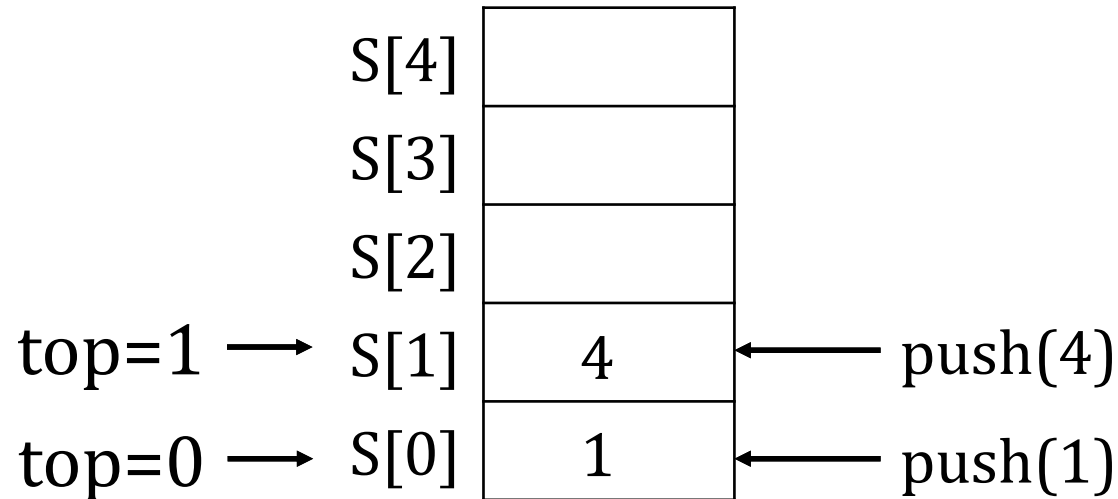
◆ `push(item):`

1. `top++;`

2. `S[top] = item`

◆ `push(1)`

◆ `push(4)`



Push Operator

◆ `push(item):`

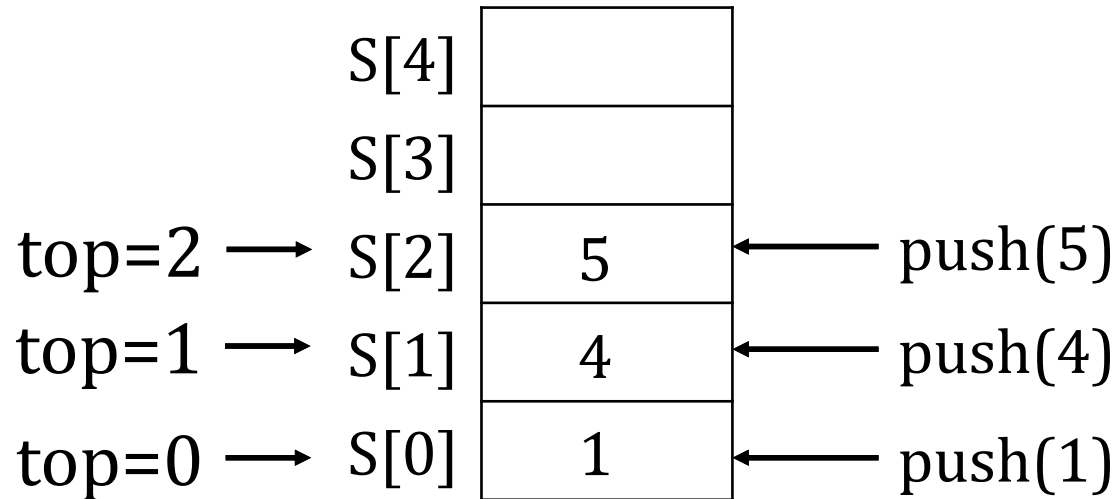
1. `top++;`

2. `S[top] = item`

◆ `push(1)`

◆ `push(4)`

◆ `push(5)`



Push Operator

◆ `push(item):`

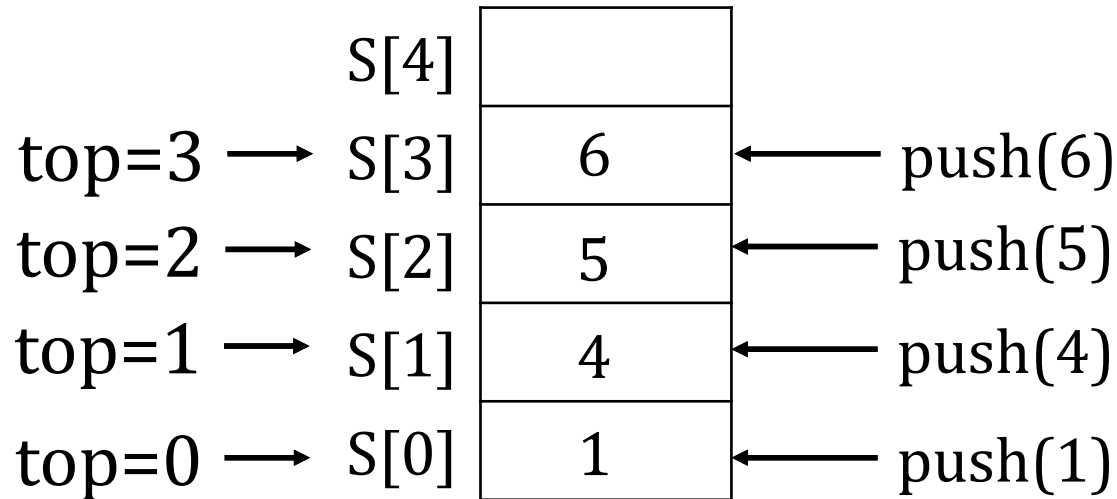
1. `top++;`
2. `S[top] = item`

◆ `push(1)`

◆ `push(4)`

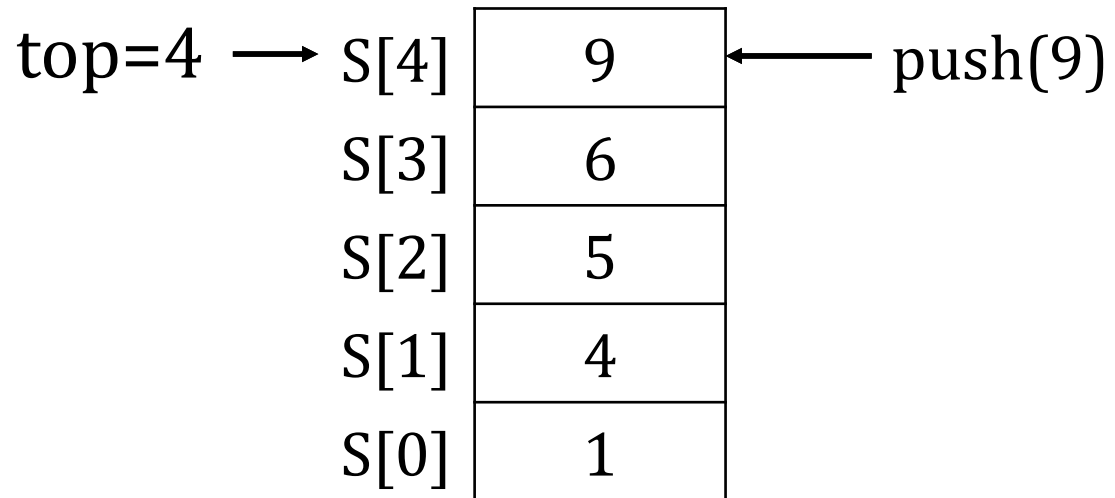
◆ `push(5)`

◆ `push(6)`



Push Operator

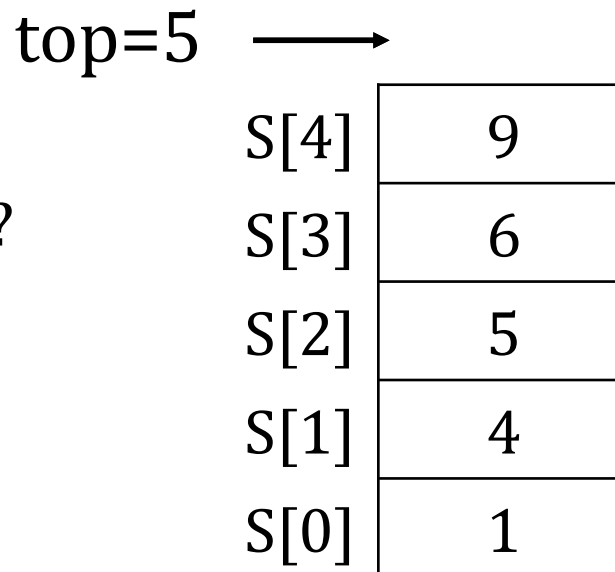
◆ push(9)



◆ push(10)

◆ OVERFLOW

◆ How to avoid that?



Push / Pop Operator

◆ push(item):

1. if(top == MAXSIZE-1)
2. Stack is FULL! No push!
3. else
4. top++;
5. S[top] = item

◆ pop(): // should avoid underflow

1. if(top == -1)
2. Stack is EMPTY! No pop!
3. else
4. top--;

Application of Stacks

- ◆ Making sure the delimiters (parens, brackets, etc.) are balanced:
 - ◆ Push open (i.e., left) delimiters onto a stack
 - ◆ When you encounter a close (i.e., right) delimiter, pop an item off the stack and see if it matches
- ◆ Evaluating arithmetic expressions
 - ◆ Parsing arithmetic expressions written using infix notation
- ◆ The runtime stack in memory
 - ◆ Converting a recursive algorithm to an iterative one by using a stack to emulate the runtime stack

Brackets Balance Problem

- ◆ $a + \{2 - [b + c]^* (8^* [8 + g] / [m - e] - 7) - p\}$
- ◆ $\{ [] ([] []) \}$
- ◆ Skip operators and notations
- ◆ Is the bracket expression balanced or not?
 - ◆ $()$ Yes
 - ◆ $[]$ No
 - ◆ $\{ [()] \}$ No
 - ◆ $\{ [] ([] []) \}$ Yes
 - ◆ $\{ \{ \{ \{ \{ [[[[[(((((()))))]]]]] \} \} \} \} \}$ Yes

Brackets Balance Problem

- ◆ Given a bracket expression, determine whether it is balanced or not?
- ◆ `{[]([] [])}`
 - ◆ How to solve it by using stack?
 - ◆ Bracket pairs: `()`, `[]`, `{ }`
 - ◆ Any ideas?
- ◆ Methodology
 - ◆ Employ stack store checked left bracket
 - ◆ Pop out left bracket if it is matched

Arithmetic Expression Evaluation

- ◆ Arithmetic expression
 - ◆ operands (a, b, c), operator (+, *)
 - ◆ $a + b * c$
- ◆ Prefix expression
 - ◆ $+ a * b c$
- ◆ Infix expression
 - ◆ $a + b * c$
- ◆ Postfix expression
 - ◆ $a b c * +$

Postfix Expression

- ◆ Infix expression
 - ◆ $5 * ((9 + 3) * (4 * 2) + 7)$
- ◆ Postfix expression
 - ◆ $5\ 9\ 3\ +\ 4\ 2\ *\ * 7\ +\ *$
- ◆ Parse postfix expression is somewhat easier problem than directly parsing infix (why)
- ◆ Postfix has a nice property that parentheses are unnecessary
- ◆ Postfix Expression Evaluation
 - ◆ Convert from infix to postfix
 - ◆ Evaluate a postfix expression

Postfix Expression

- ◆ Postfix expression

- ◆ 5 9 3 + 4 2 * * 7 + *

- ◆ Methodology

- ◆ Read the tokens in one at a time
 - ◆ If it is an operand, push it on the stack
 - ◆ If it is a binary operator:
 - ◆ pop top two elements from the stack,
 - ◆ apply the operator,
 - ◆ and push the result back on the stack

Postfix Expression Evaluation

◇ 5 9 3 + 4 2 * * 7 + *

◇ Postfix Expression Evaluation

Stack operations

Stack elements

◇ push(5)

5

◇ push(9)

5 9

◇ push(3)

5 9 3

◇ push(pop() + pop())

5 12

◇ push(4)

5 12 4

◇ push(2)

5 12 4 2

◇ push(pop() * pop())

5 12 8

◇ push(pop() * pop())

5 96

◇ push(7)

5 96 7

◇ push(pop() + pop())

5 103

◇ push(pop() * pop())

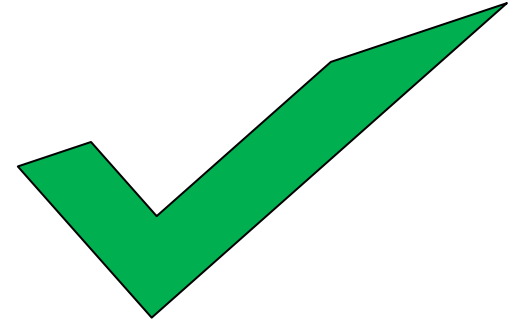
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Our Roadmap

- ◆ Stack

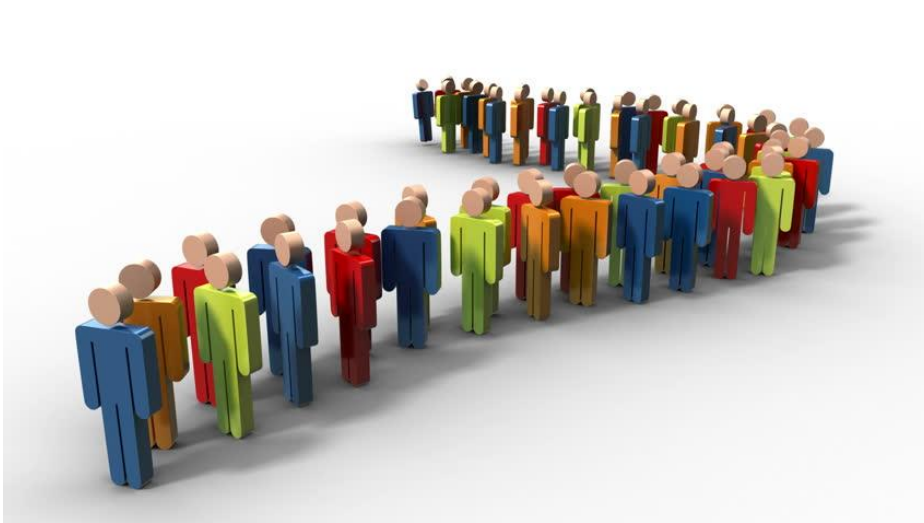
- ◆ Queue

- ◆ Stack vs. Queue



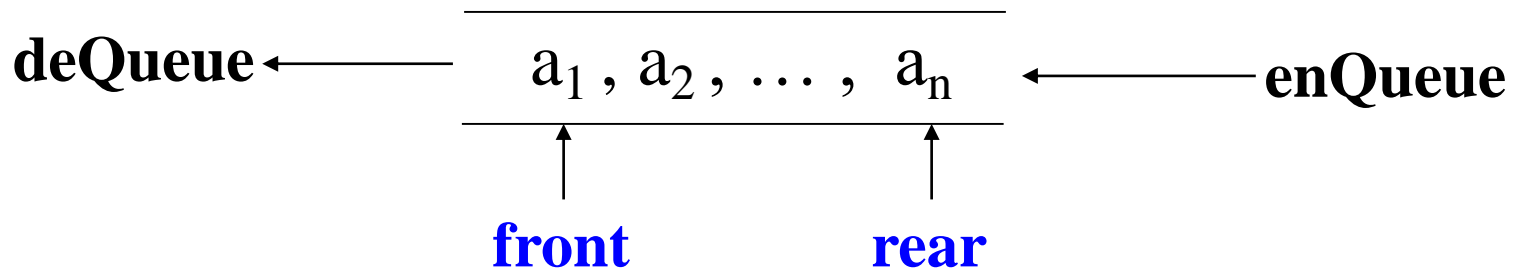
Queue

- ❖ A queue is a sequence in which:
 - ❖ items are added at the rear and removed from the front
 - ❖ You can only access the item that is currently at the front
- ❖ Queue Analogy



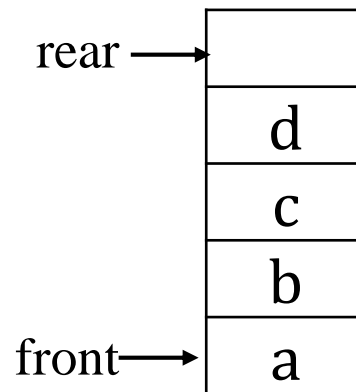
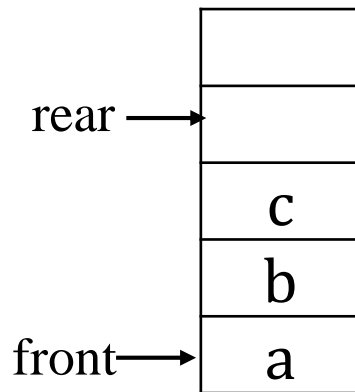
Queue

- ◆ First In First Out (FIFO)
 - ◆ Items access constrained
- ◆ Major elements
 - ◆ **front**: the first element in the queue (remove)
 - ◆ **rear**: the last element in the queue (add)
- ◆ Illustration

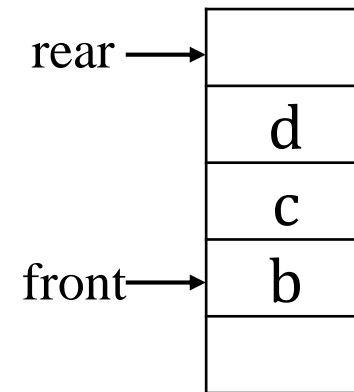


Queue Operations

- ◆ enQueue: add an item at the rear of the queue
- ◆ deQueue: remove the item at the front of the queue
- ◆ front: get the item at the front of the queue, but do not remove it
- ◆ isEmpty: test if the queue is empty
- ◆ isFull: test the queue is full
- ◆ clear: clear the queue, set it as empty queue
- ◆ size: return the current size of the queue



enQueue(d)



deQueue()

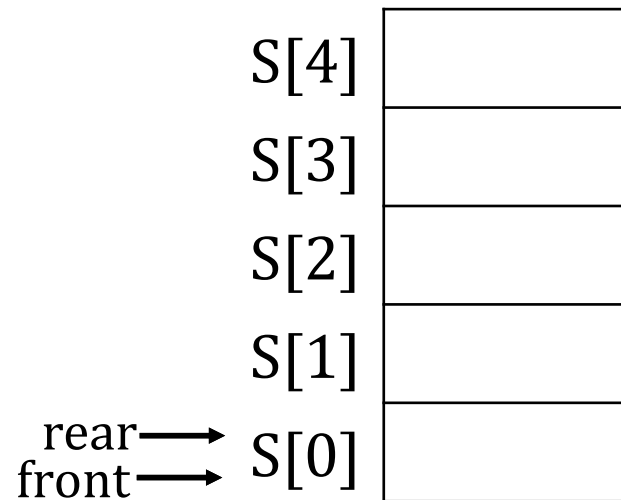
Implementation of Queue

◆ Array based Queue

- ◆ $\text{MAX_SIZE} = n$ // the max size of stack
- ◆ $\text{front} = 0$ // the current front
- ◆ $\text{rear} = 0$ // the current rear
- ◆ Array S with n elements

◆ Example

- ◆ $\text{MAX_SIZE} = 5$
- ◆ $\text{front} = 0$
- ◆ $\text{rear} = 0$
- ◆ Array S



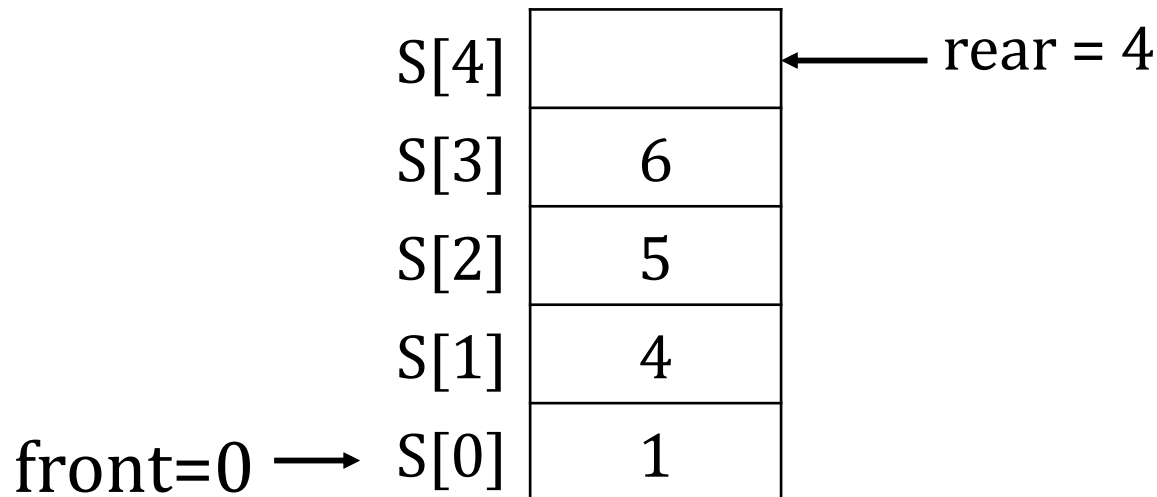
S

enQueue Operator

◆ enQueue(item):

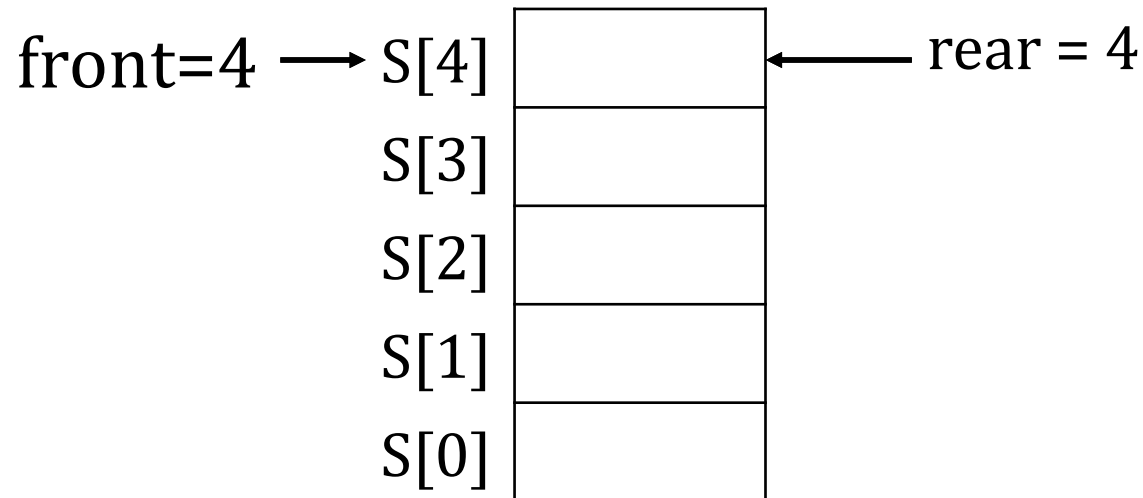
1. if(rear < MAXSIZE)
2. S[rear] = item
3. rear++
3. else
4. Queue is FULL, no enQueue

◆ enQueue (1), enQueue(4), enQueue(5), enQueue(6)



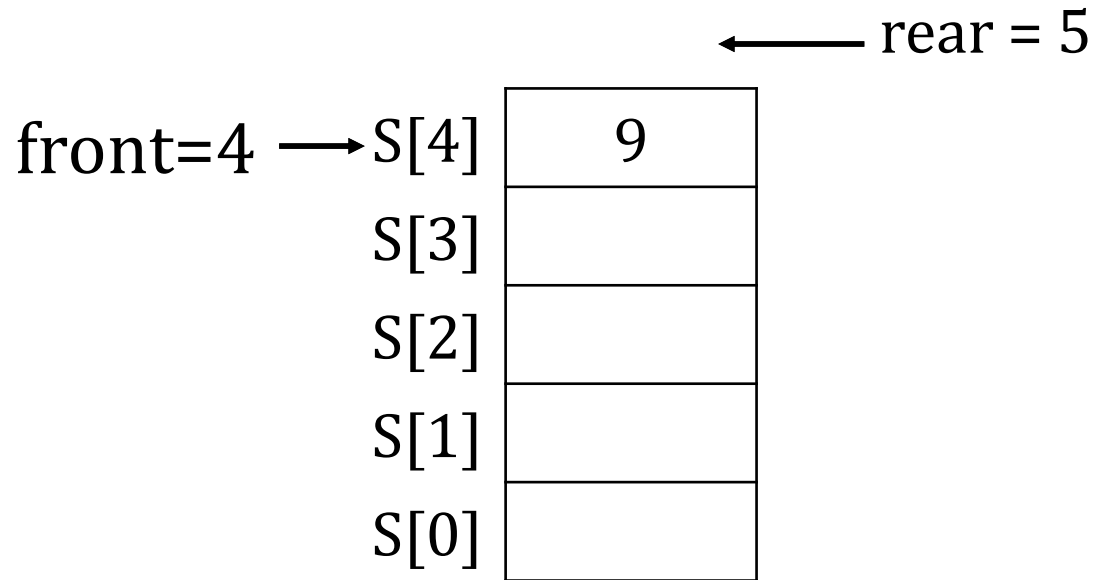
deQueue Operator

- ◆ deQueue():
 1. if(front < rear)
 2. front++
 3. else
 4. Queue is empty, no deQueue
- ◆ deQueue (), deQueue(), deQueue(), deQueue()



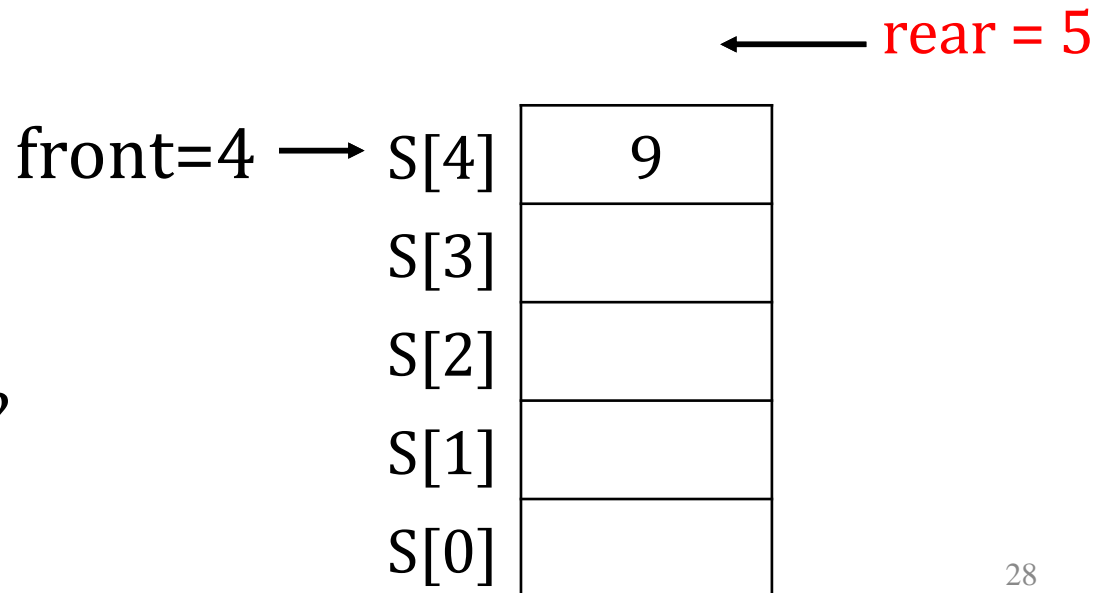
enQueue and deQueue

◆ enQueue(9)

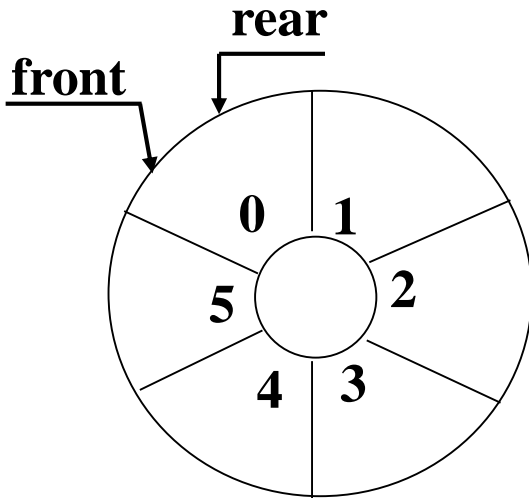


◆ enQueue(10)

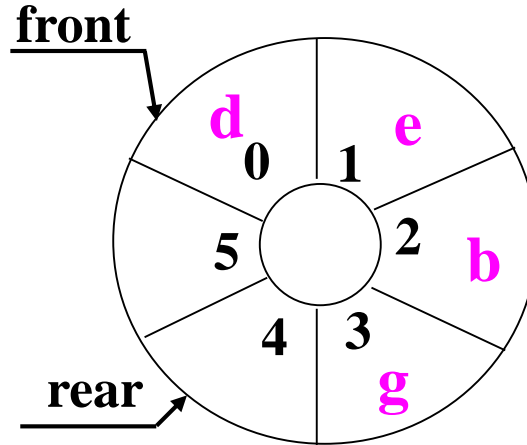
- ◆ rear \geq MAXSIZE
- ◆ Queue is FULL!!!
- ◆ Wrong OVERFLOW
- ◆ S[0] to S[3] is empty?
- ◆ How to address it?



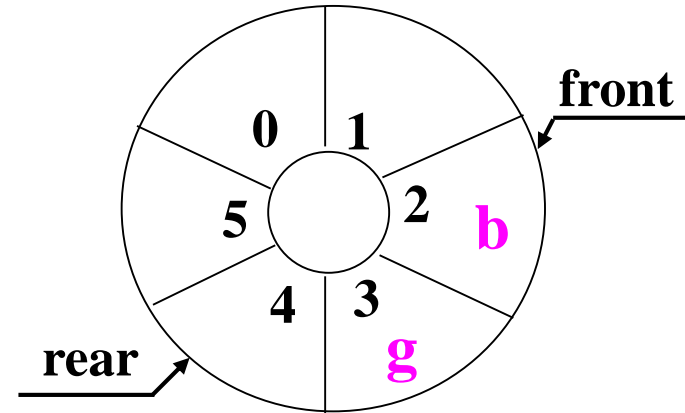
Ring Queue



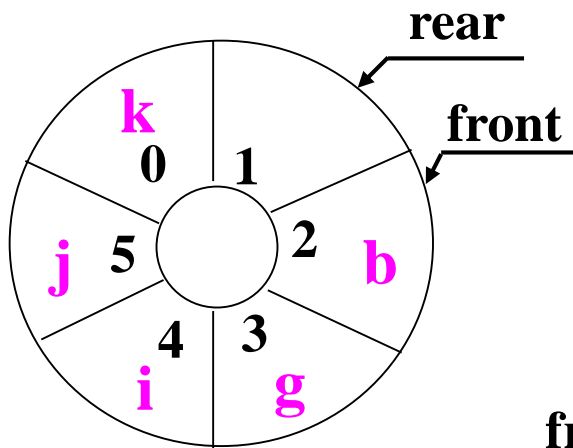
(a) empty



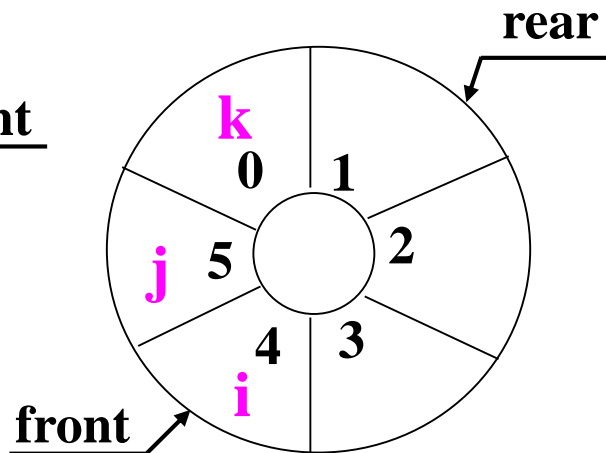
(b) d, e, b, g enQueue



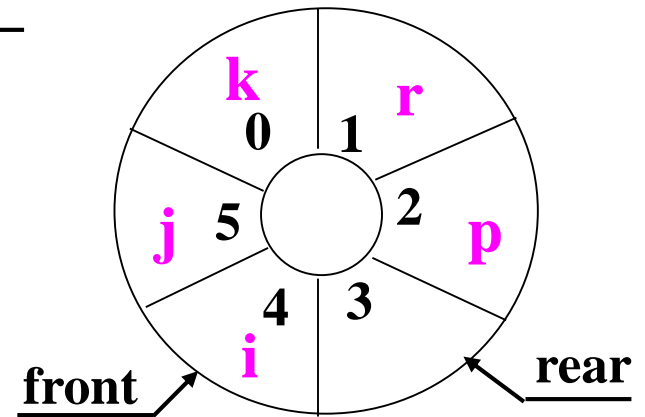
(c) d, e deQueue



(d) i, j, k enQueue



(e) b, g deQueue



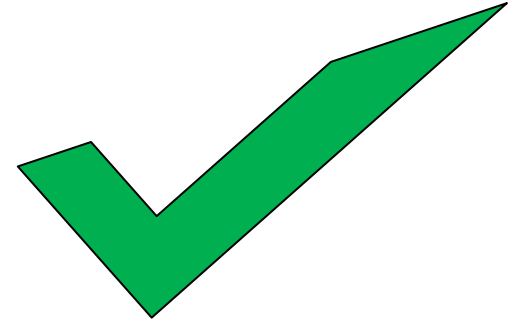
(f) r, p, s, t deQueue

Application of Queues

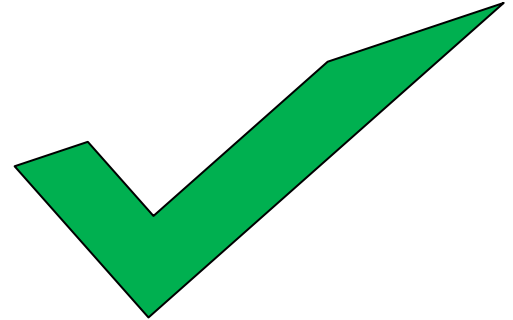
- ◆ First-in first-out (FIFO) inventory control
 - ◆ OS scheduling: processes, print jobs, packets, etc.
 - ◆ Breadth-first traversal of a graph or level-order traversal of a binary tree (more on these later)
- ◆ Real applications
 - ◆ iTunes playlist.
 - ◆ Data buffers (iPod, TiVo).
 - ◆ Asynchronous data transfer (file IO, pipes, sockets).
 - ◆ Dispensing requests on a shared resource (printer, processor)

Our Roadmap

- ◆ Stack



- ◆ Queue

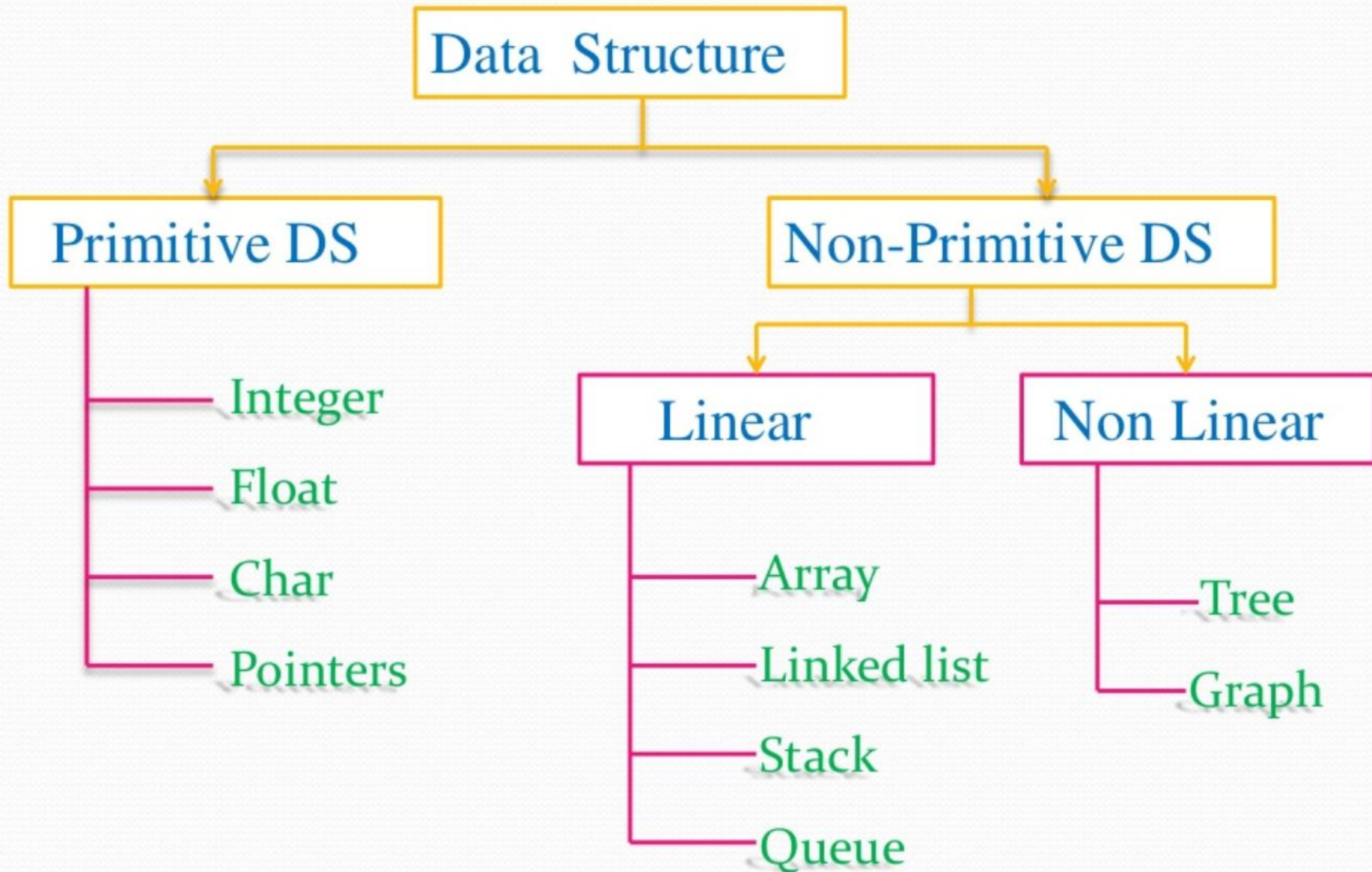


- ◆ Stack vs. Queue

Stack VS. Queue

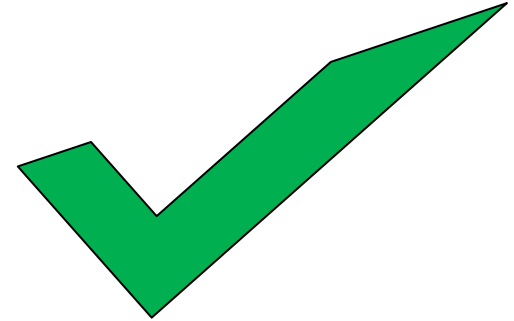
	Stack	Queue
In-Out	FILO	FIFO
Application	function runtime	OS scheduling
Operations	push pop	enQueue, deQueue
Ops Time Complexity	$O(1)$	$O(1)$
Implementation	Array-based, Linked-based	Array-based, Linked-based

Data Structure

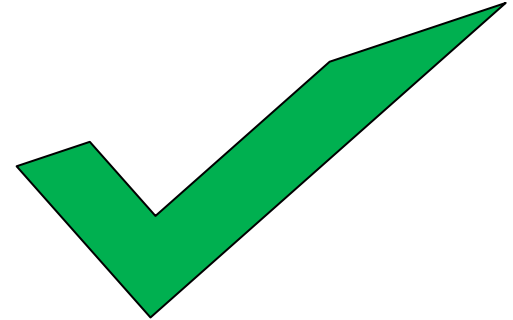


Our Roadmap

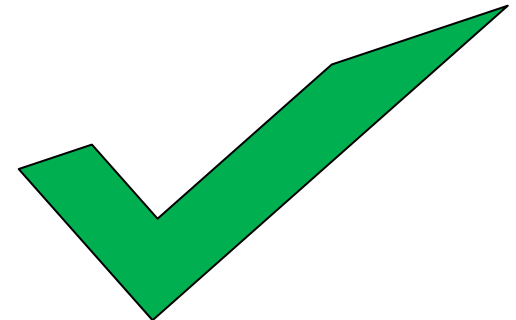
- ◆ Stack



- ◆ Queue



- ◆ Stack vs. Queue



Thank You!