

CS350: Data Structures

Stacks

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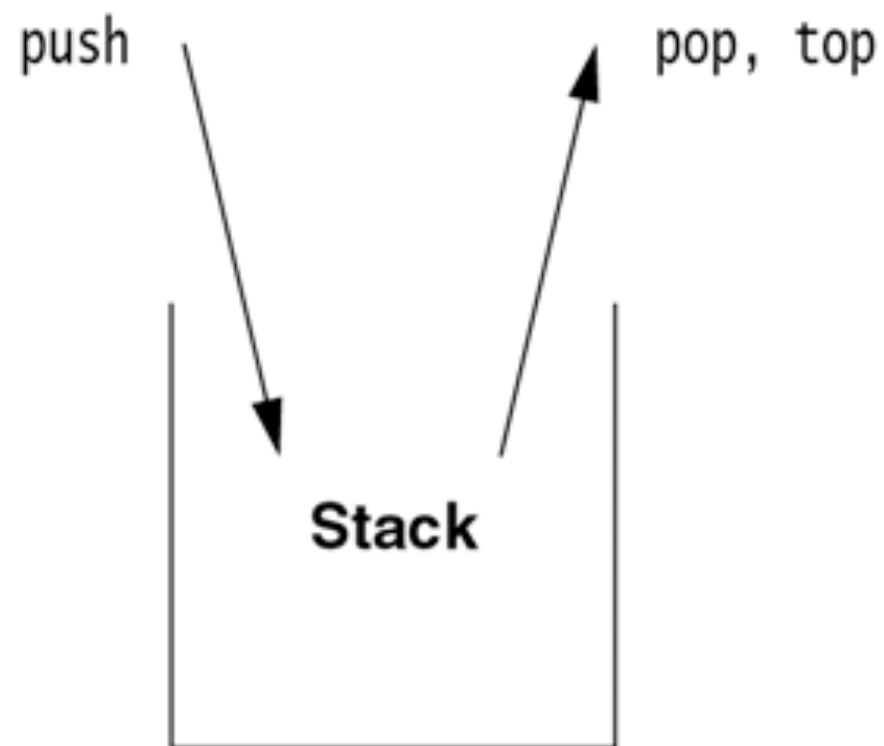
Stacks

- **Stacks are a very common data structure that can be used for a variety of data storage purposes**
- **Similar to a stack of papers sitting on a table ...**
 - Items can be placed on the stack of papers
 - You can take a look at whats on the top of your stack of papers
 - Items can be removed from the top of your stack of papers
 - If you want a paper in the middle of the stack, you must remove the papers on top to get to the paper in the middle
- **May also be referred to as a LIFO (Last-In-First-Out)**

Stack Operations

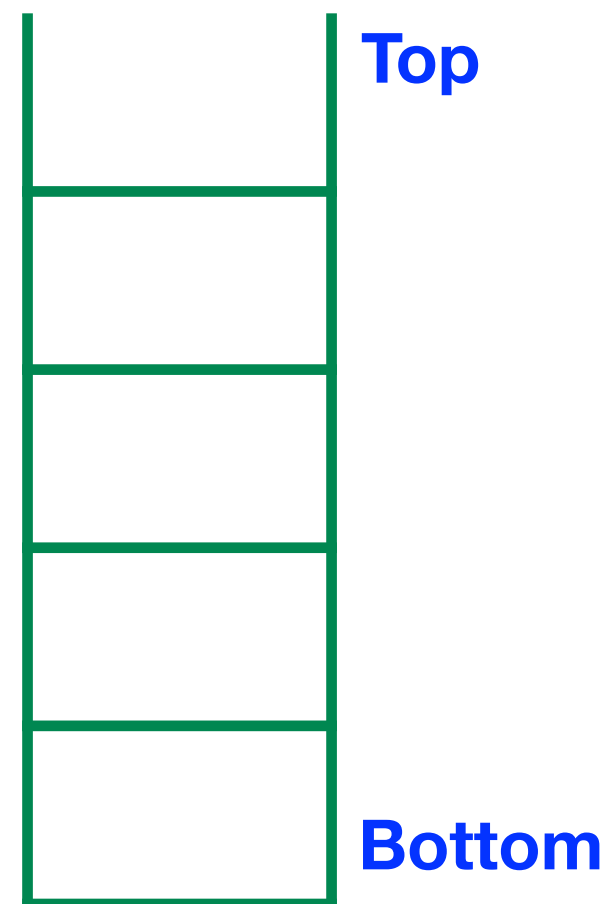
- **Stacks have three main operations**

- **Push** - puts an element on the top of the stack
- **Pop** - removes a single element from the top of the stack
- **Top** or **Peek** - returns the value of the element on the top of the stack (without removing it)



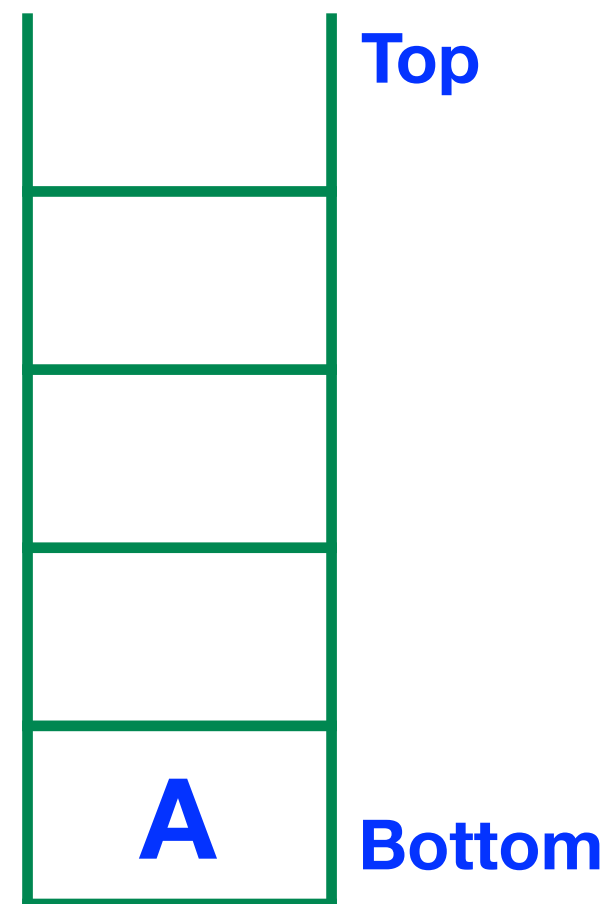
Stack Operations

Start with Empty Stack



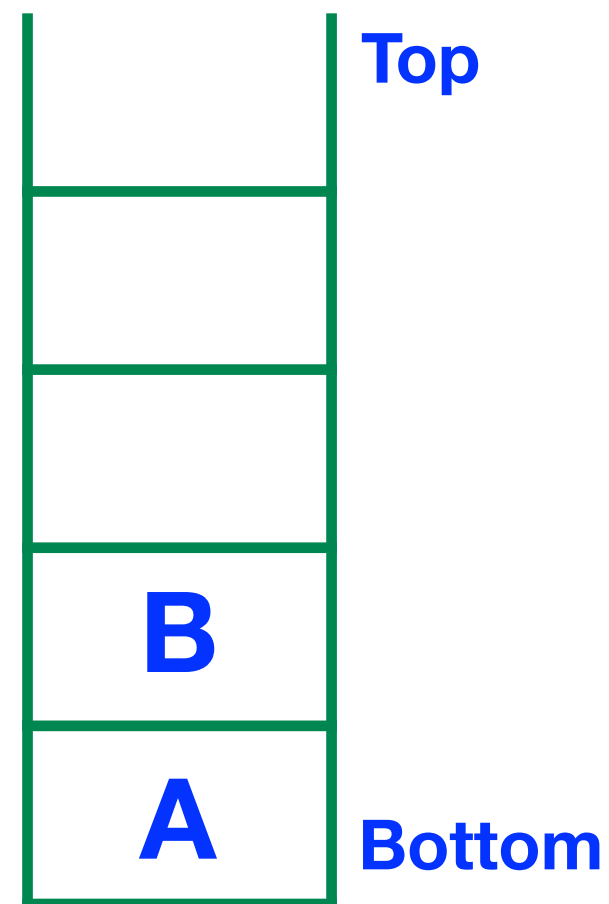
Stack Operations

Push Value: A



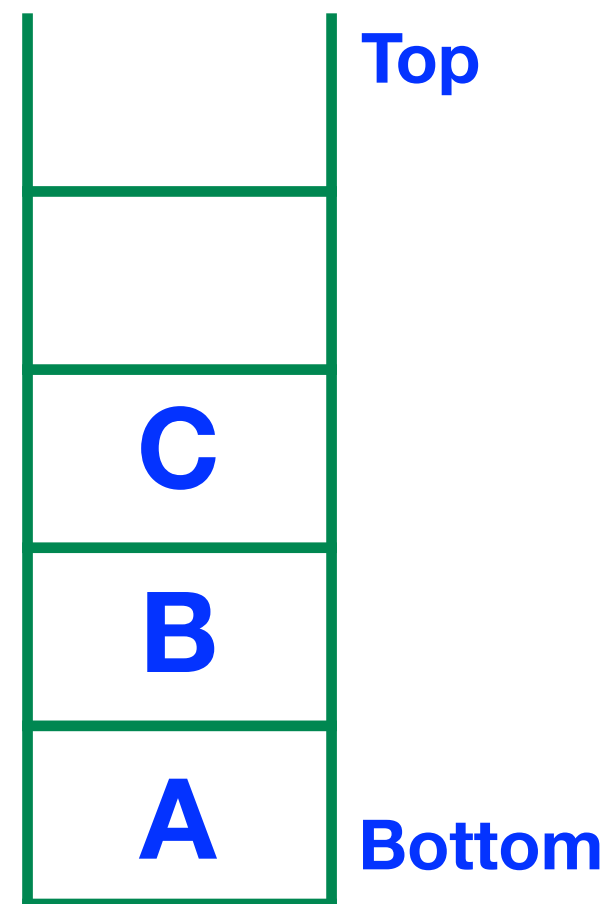
Stack Operations

Push Value: B



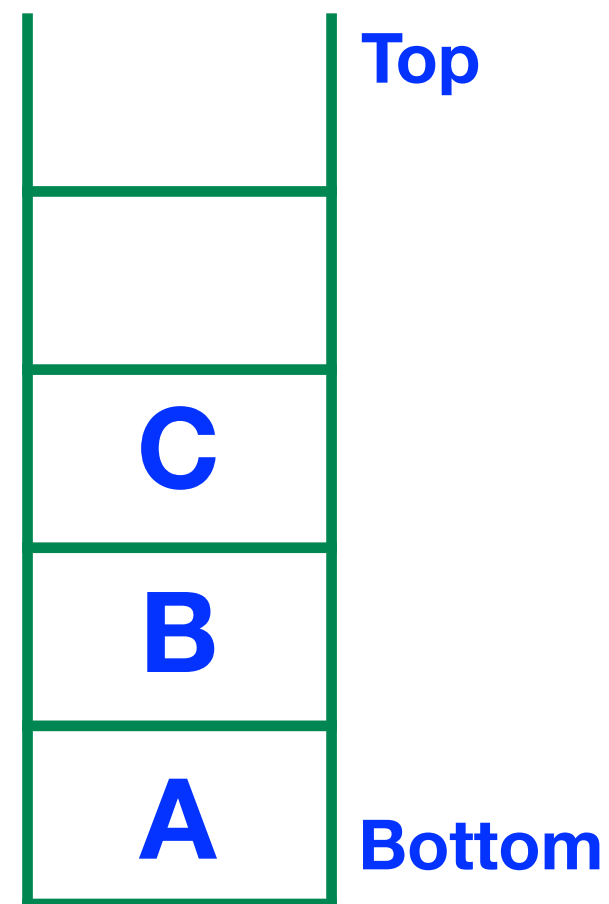
Stack Operations

Push Value: C



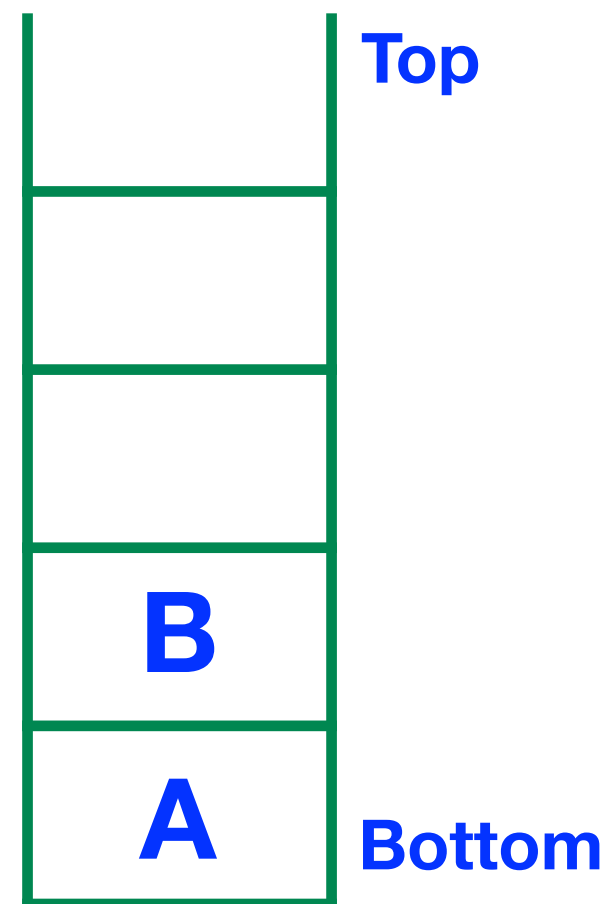
Stack Operations

Pop the Top of the Stack:



Stack Operations

Pop the Top of the Stack:



A Stack Interface in Java

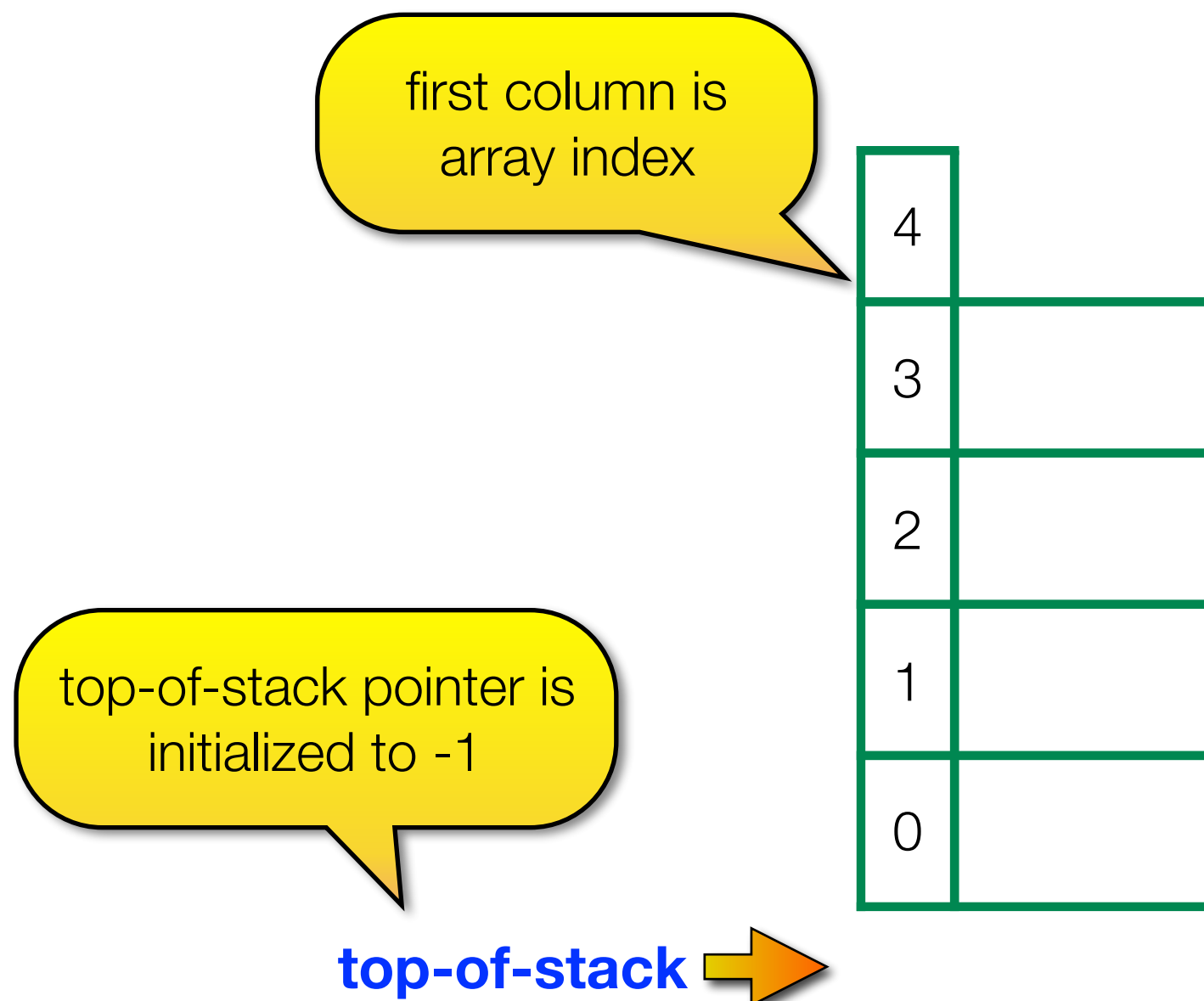
```
public interface Stack<AnyType> {  
    public void      push( AnyType x );  
  
    public AnyType pop( );  
  
    public AnyType peek( );  
  
    public boolean isEmpty( );  
  
    public void      makeEmpty( );  
}
```

Stack Implementations

- **Stacks can be implemented in multiple ways**
- **Two popular methods for implementing stacks include**
 - (1) Arrays
 - (2) Linked Lists
- **Both of these implementation approaches allow for constant time operations - $O(1)$**

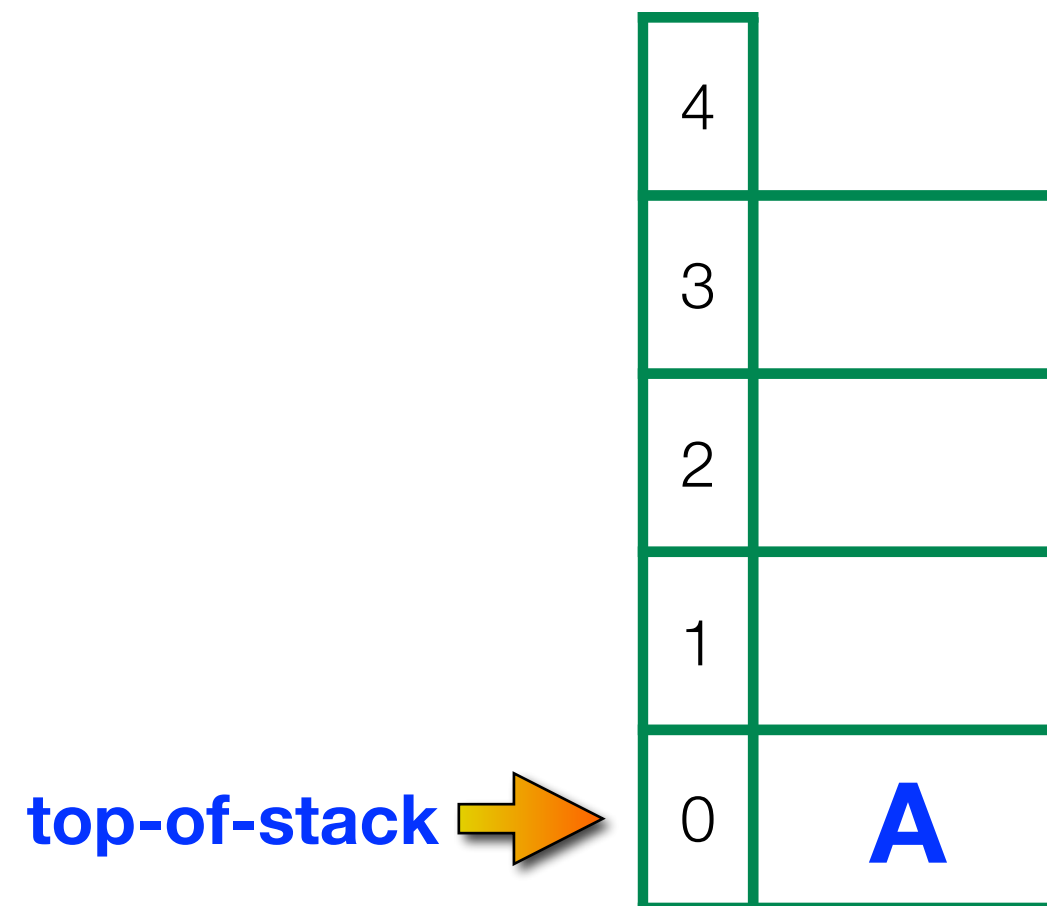
Stack Implementation Using an Array

Start with Empty Stack (i.e. an array)



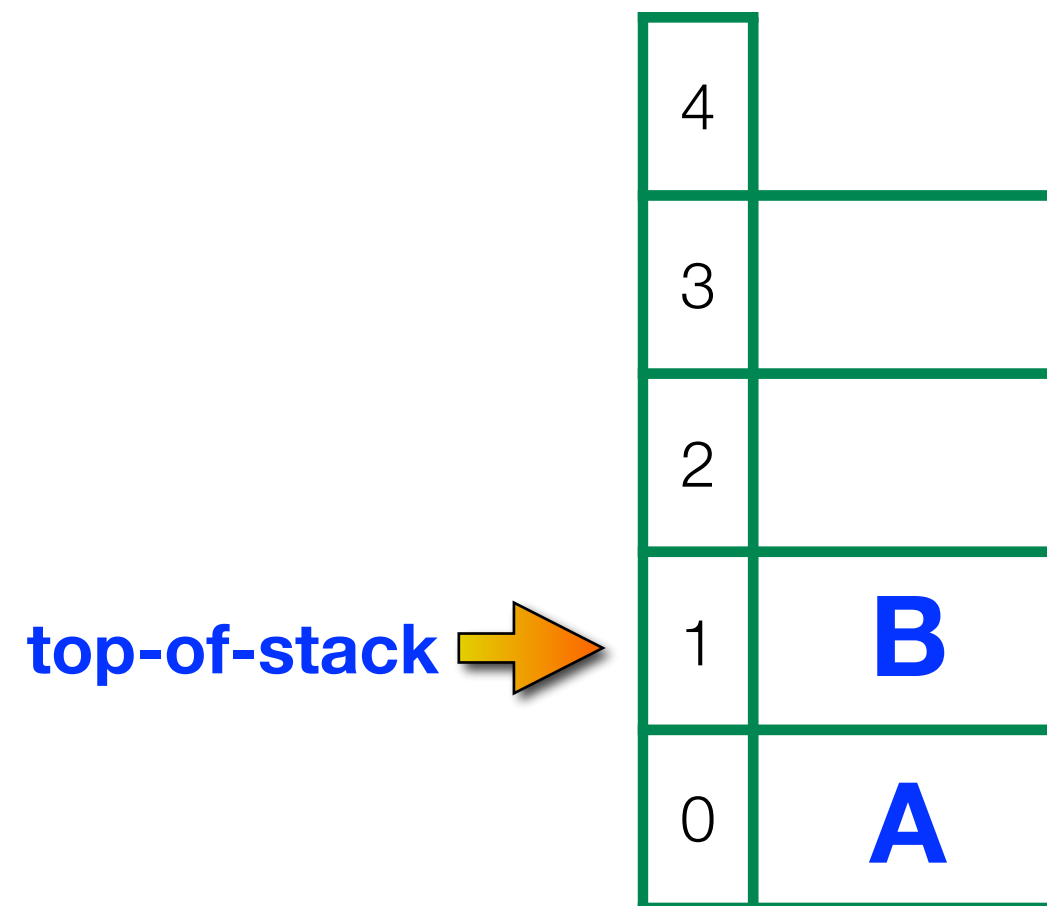
Stack Implementation Using an Array

Insert Value: A



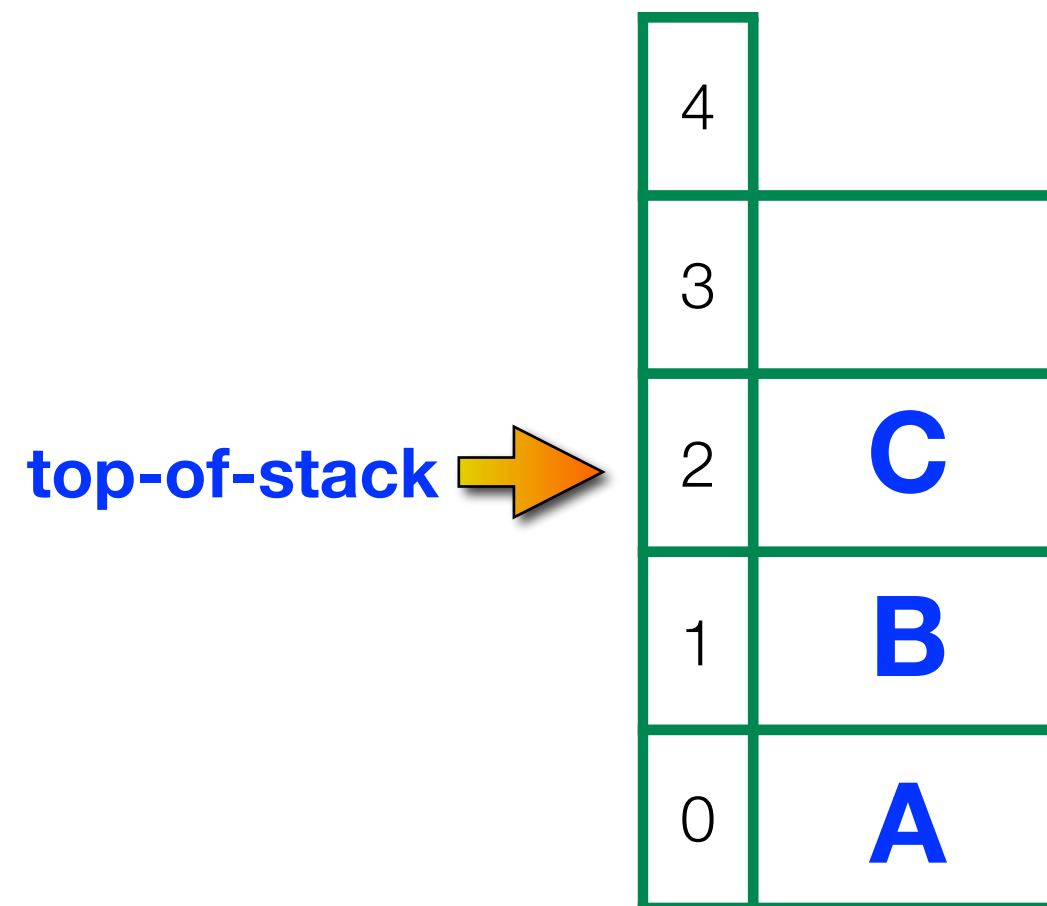
Stack Implementation Using an Array

Insert Value: B



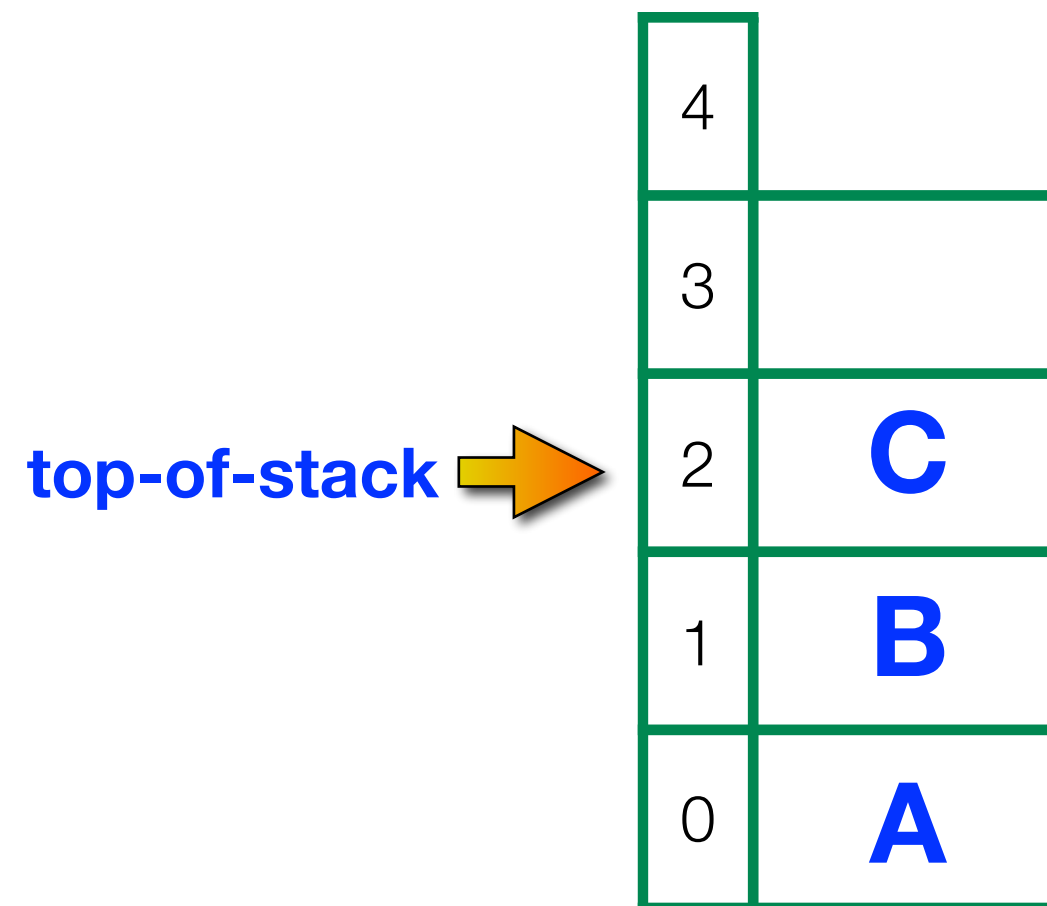
Stack Implementation Using an Array

Insert Value: C



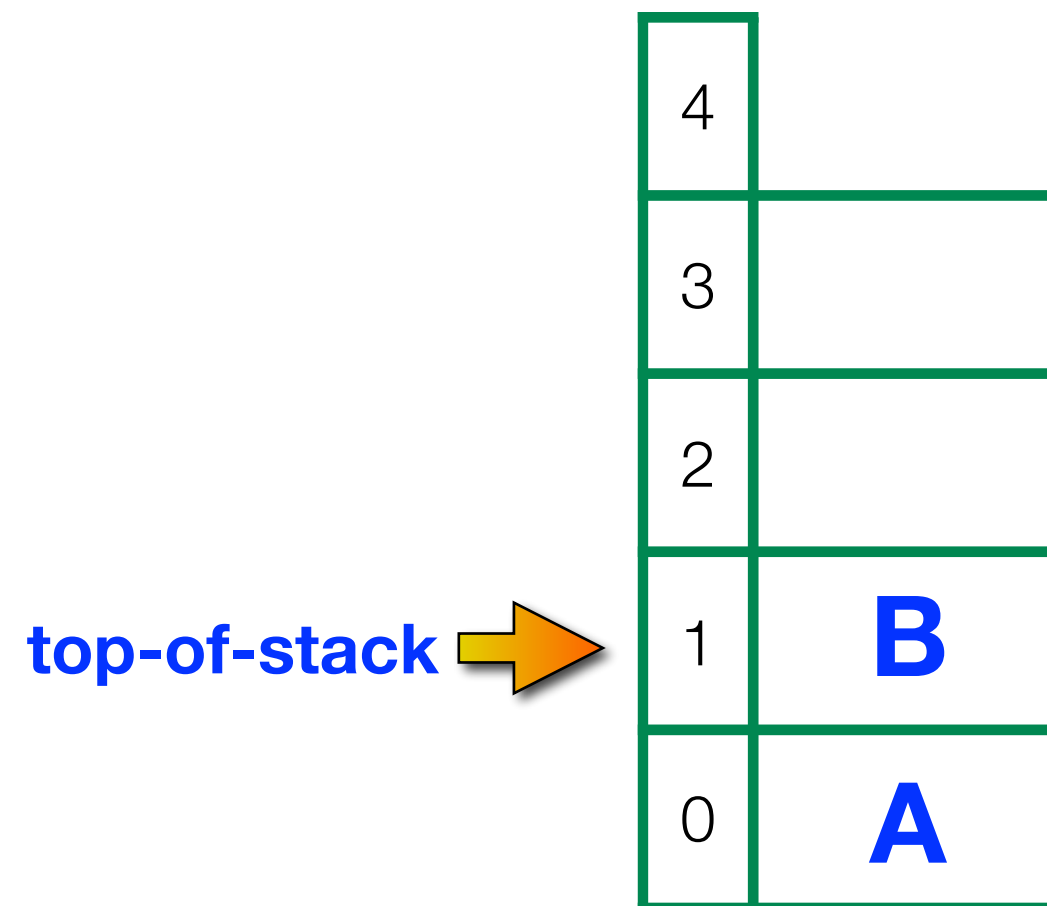
Stack Implementation Using an Array

Pop the Top of the Stack:



Stack Implementation Using an Array

Pop the Top of the Stack:



Stack Implementation Using an Array

- **Considerations when using an array implementation**

- **Push**, **Pop**, and **Peek** operations all run in constant time ... in most cases
- What happens when your array is full and you want to **Push** another element?
 - Array must be increased in size which takes time and more memory
 - Time to copy and create new array is $O(N)$
 - Time to copy array is amortized over the lifetime of the array
 - May not be suitable for all types of systems (e.g. RTOS)

Stack Implementation Using an Array (Java)

```
/**
 * Stack constructor
 */
public ArrayStack( )
{
    theArray = (AnyType [ ]) new Object[ DEFAULT_CAPACITY ];
    topOfStack = -1;
}
```

Stack Implementation Using an Array (Java)

```
/**
 * Test if the stack is logically empty.
 * @return true if empty, false otherwise.
 */
public boolean isEmpty( )
{
    return topOfStack == -1;
}
```

Stack Implementation Using an Array (Java)

```
/**
 * Make the stack logically empty.
 */
public void makeEmpty( )
{
    topOfStack = -1;
}
```

Stack Implementation Using an Array (Java)

```
/**
 * Insert a new item into the stack.
 * @param x the item to insert.
 */
public void push( AnyType x )
{
    if( topOfStack + 1 == theArray.length )
        doubleArray( );
    theArray[ ++topOfStack ] = x;
}
```

Stack Implementation Using an Array (Java)

```
/**
 * Remove the most recently inserted item from the stack.
 * @throws UnderflowException if the stack is empty.
 */
public void pop( )
{
    if( isEmpty( ) )
        throw new UnderflowException( "ArrayStack pop" );
    topOfStack--;
}
```

Stack Implementation Using an Array (Java)

```
/**
 * Get the most recently inserted item in the stack.
 * Does not alter the stack.
 * @return the most recently inserted item in the stack.
 * @throws UnderflowException if the stack is empty.
 */
public AnyType peek( )
{
    if( isEmpty( ) )
        throw new UnderflowException( "ArrayStack top" );
    return theArray[ topOfStack ];
}
```


Stack Implementation Using an Array (Java)

```
/**
 * Internal method to extend theArray.
 */
private void doubleArray( )
{
    AnyType [ ] newArray;

    newArray = (AnyType [ ]) new Object[ theArray.length * 2 ];
    for( int i = 0; i < theArray.length; i++ )
        newArray[ i ] = theArray[ i ];
    theArray = newArray;
}
```

Stack Implementation Using a LinkedList

Start with Empty Stack (i.e. a null LinkedList)

top-of-stack points to the
head of the linked list

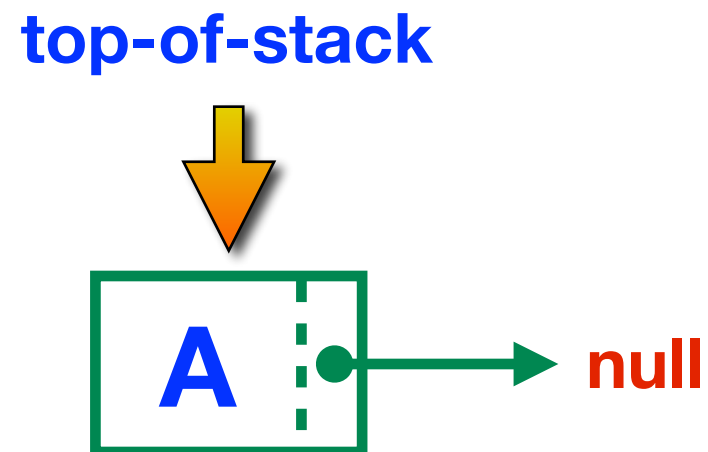
top-of-stack



null

Stack Implementation Using a LinkedList

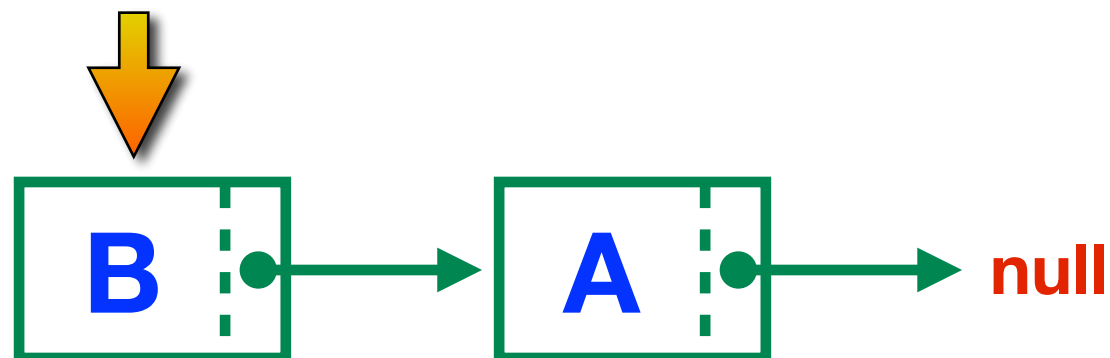
Push Value: A



Stack Implementation Using a LinkedList

Push Value: B

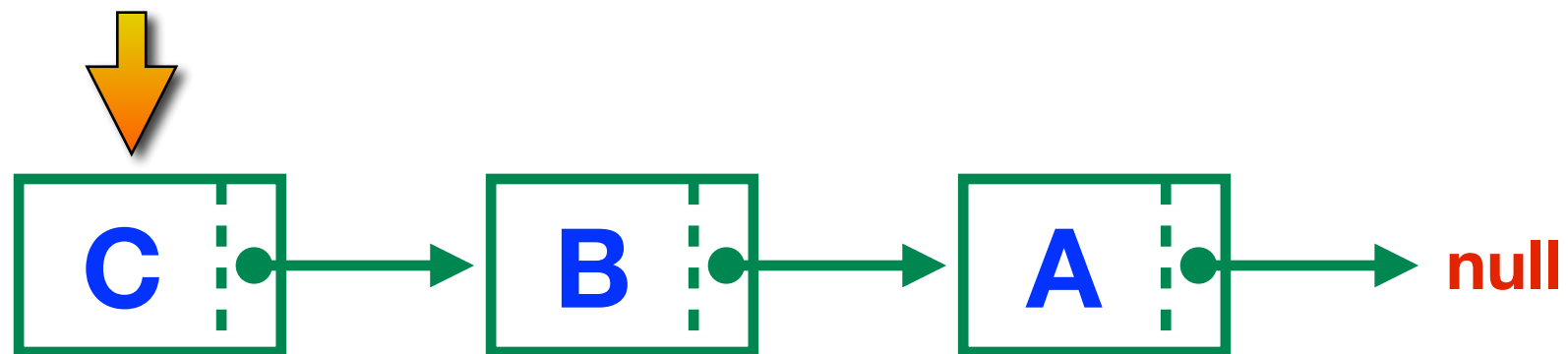
top-of-stack



Stack Implementation Using a LinkedList

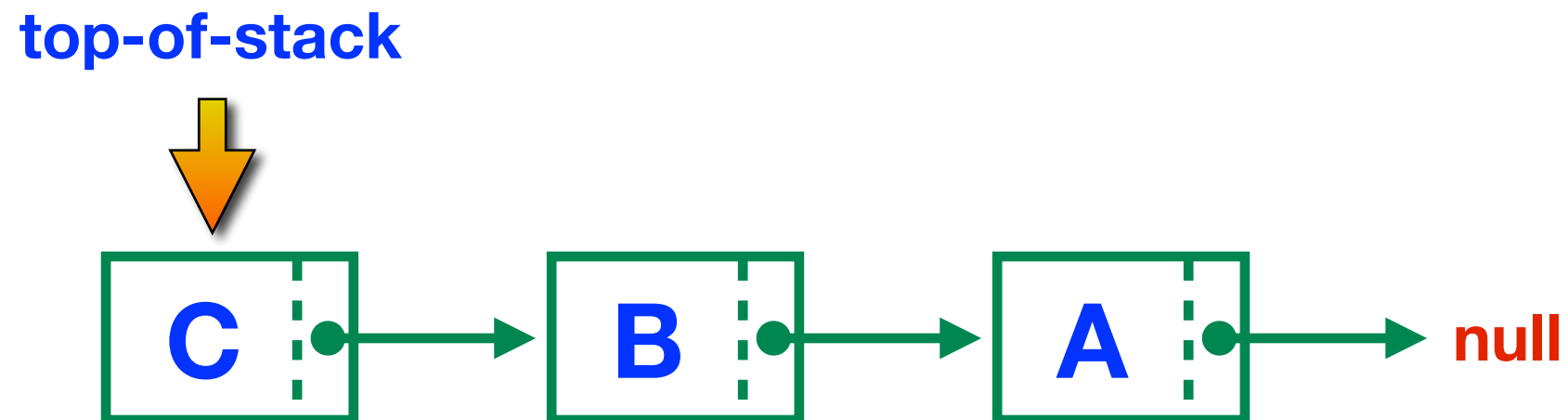
Push Value: C

top-of-stack



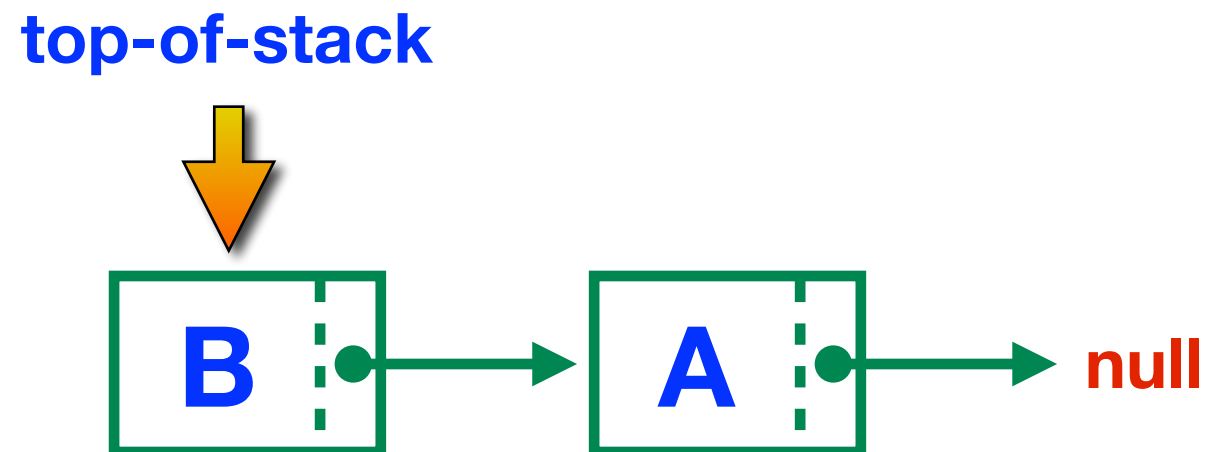
Stack Implementation Using a LinkedList

Pop the Top of the Stack:



Stack Implementation Using a LinkedList

Pop the Top of the Stack:



Stack Implementation Using a LinkedList

- **Considerations when using a LinkedList implementation**
 - **Push**, **Pop**, and **Peek** operations all run in constant time ... still
 - Each element inserted into the stack requires a pointer to the data and a second pointer to the next node in the LinkedList

Stack Implementation Using a LinkedList (Java)

```
/**
 * Stack constructor
 */
public ListStack( )
{
    topOfStack = null;
}

private ListNode<AnyType> topOfStack;
```

Stack Implementation Using a LinkedList (Java)

```
/**
 * Test if the stack is logically empty.
 * @return true if empty, false otherwise.
 */
public boolean isEmpty( )
{
    return topOfStack == null;
}
```

Stack Implementation Using a LinkedList (Java)

```
/**
 * Make the stack logically empty.
 */
public void makeEmpty( )
{
    topOfStack = null;
}
```

Stack Implementation Using a LinkedList (Java)

```
/**
 * Insert a new item into the stack.
 * @param x the item to insert.
 */
public void push( AnyType x )
{
    topOfStack = new ListNode<AnyType>( x, topOfStack );
}
```

Stack Implementation Using a LinkedList (Java)

```
/**
 * Remove the most recently inserted item from the stack.
 * @throws UnderflowException if the stack is empty.
 */
public void pop( )
{
    if( isEmpty( ) )
        throw new UnderflowException( "ListStack pop" );
    topOfStack = topOfStack.next;
}
```

Stack Implementation Using a LinkedList (Java)

```
/**
 * Get the most recently inserted item in the stack.
 * Does not alter the stack.
 * @return the most recently inserted item in the stack.
 * @throws UnderflowException if the stack is empty.
 */
public AnyType peek( )
{
    if( isEmpty( ) )
        throw new UnderflowException( "ListStack top" );
    return topOfStack.element;
}
```

Example Applications for Stacks

- **Postfix expression evaluation**

$2 + 3 * 4$ VS $2\ 3\ 4\ *\ +$

- **Checking for balanced delimiters**

- Balancing parenthesis/braces in a programming languages