Collections and the Stack ADT

Objectives

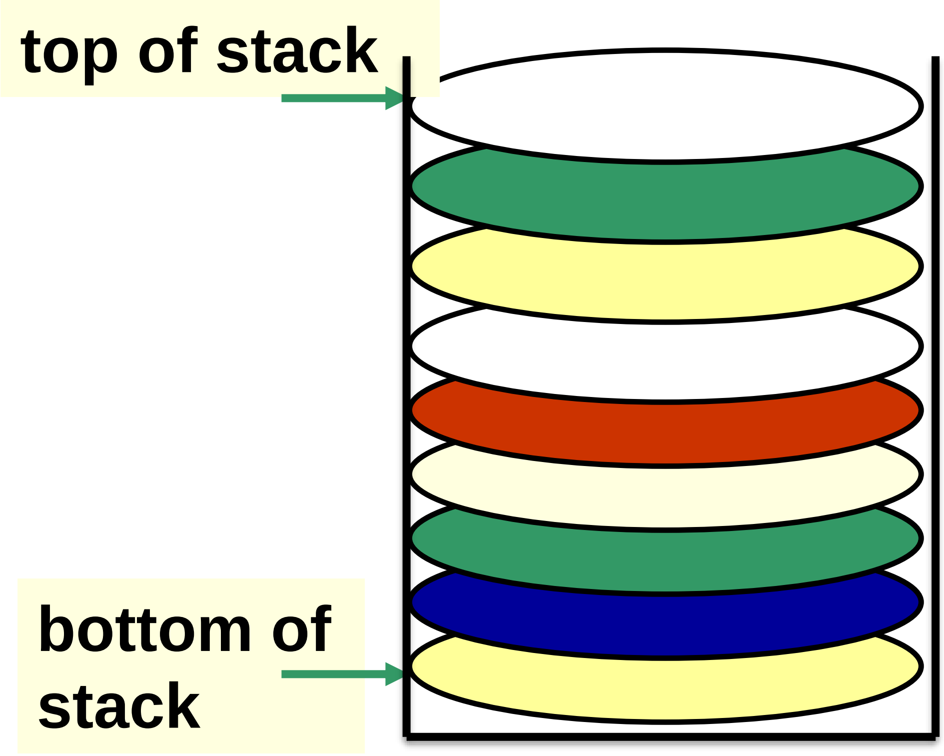
- Define the notion of collection
- Define the notion of stack
- Study an array implementation of stacks
- Uses and importance of stacks

Collections

Collection: a group of items that we wish to treat as a conceptual unit

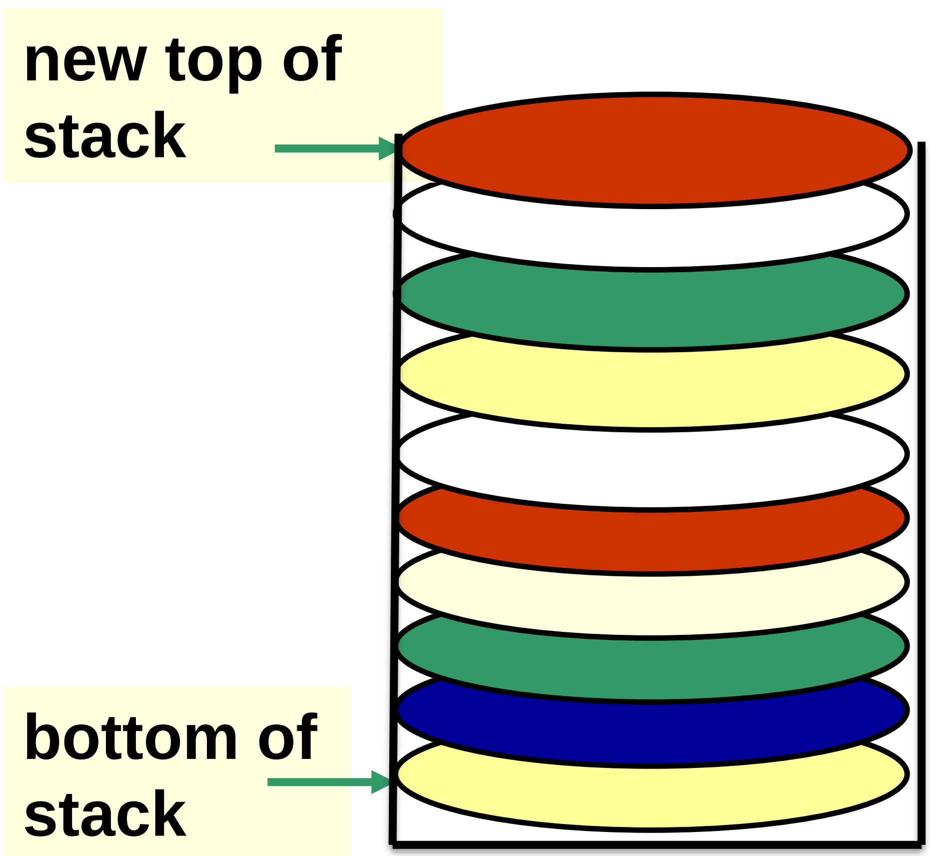
- The proper choice of a collection for a given problem can improve the efficiency and simplicity of a solution.

Conceptual View of a Stack



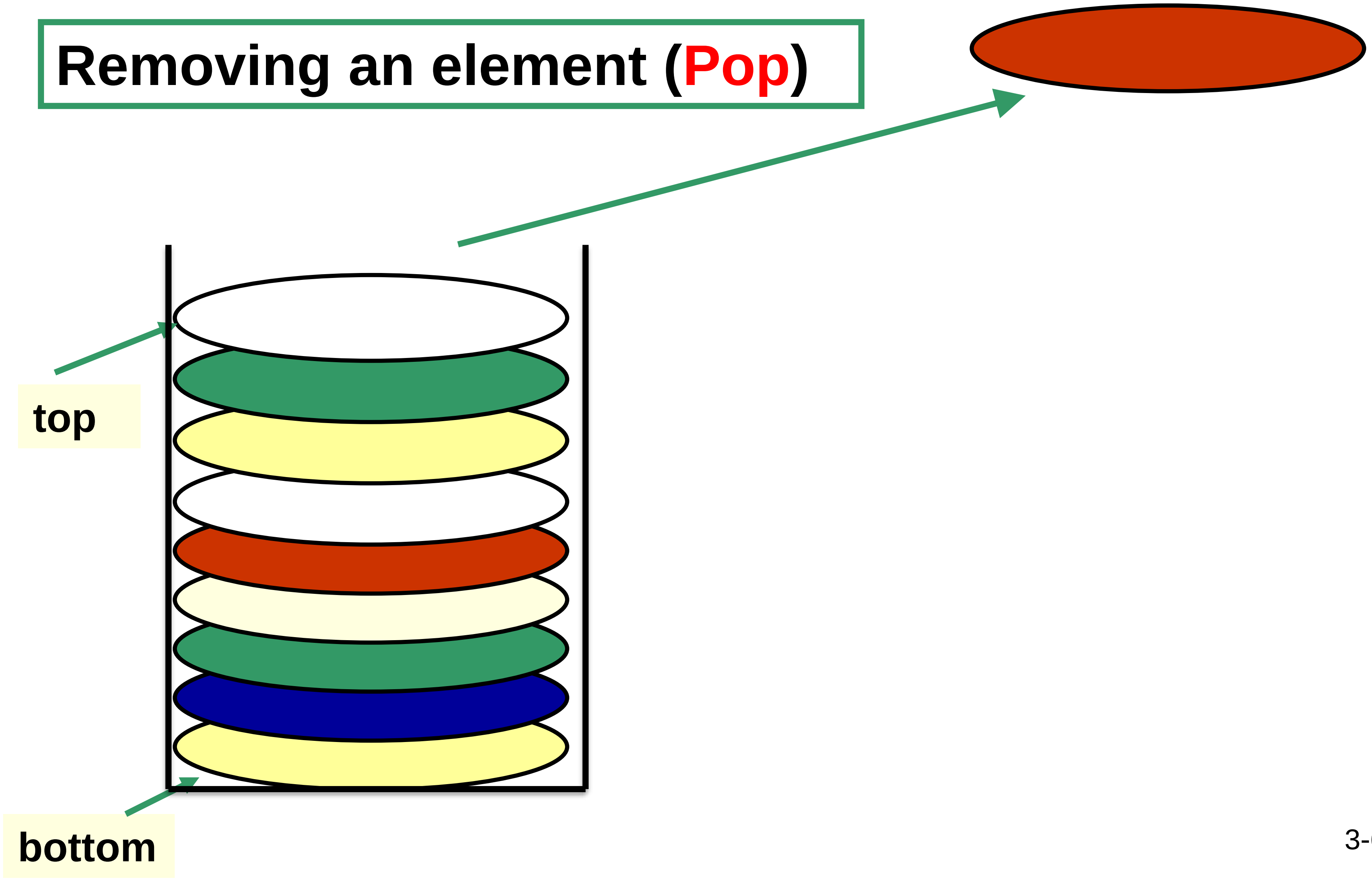
Conceptual View of a Stack

Adding an element (Push)



Conceptual View of a Stack

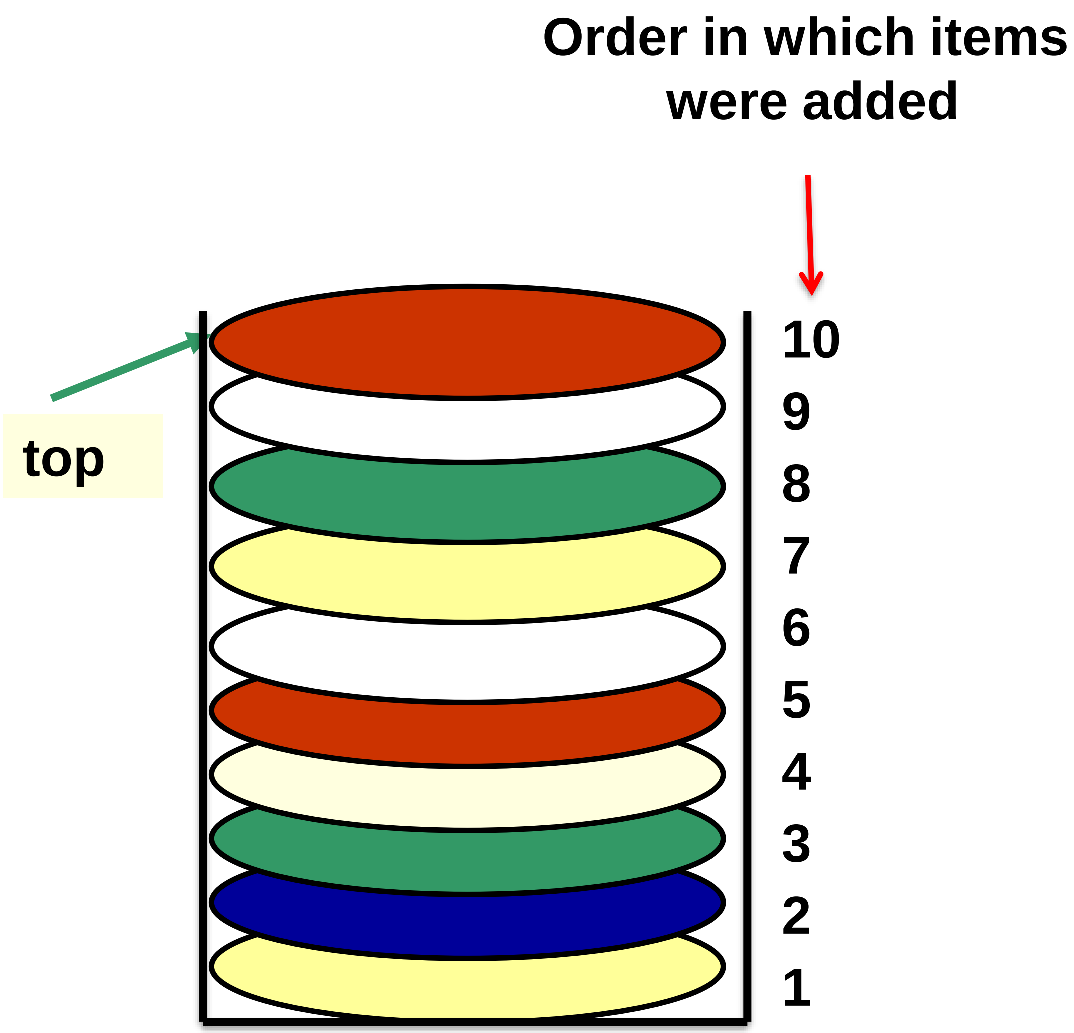
Removing an element (Pop)



Stacks

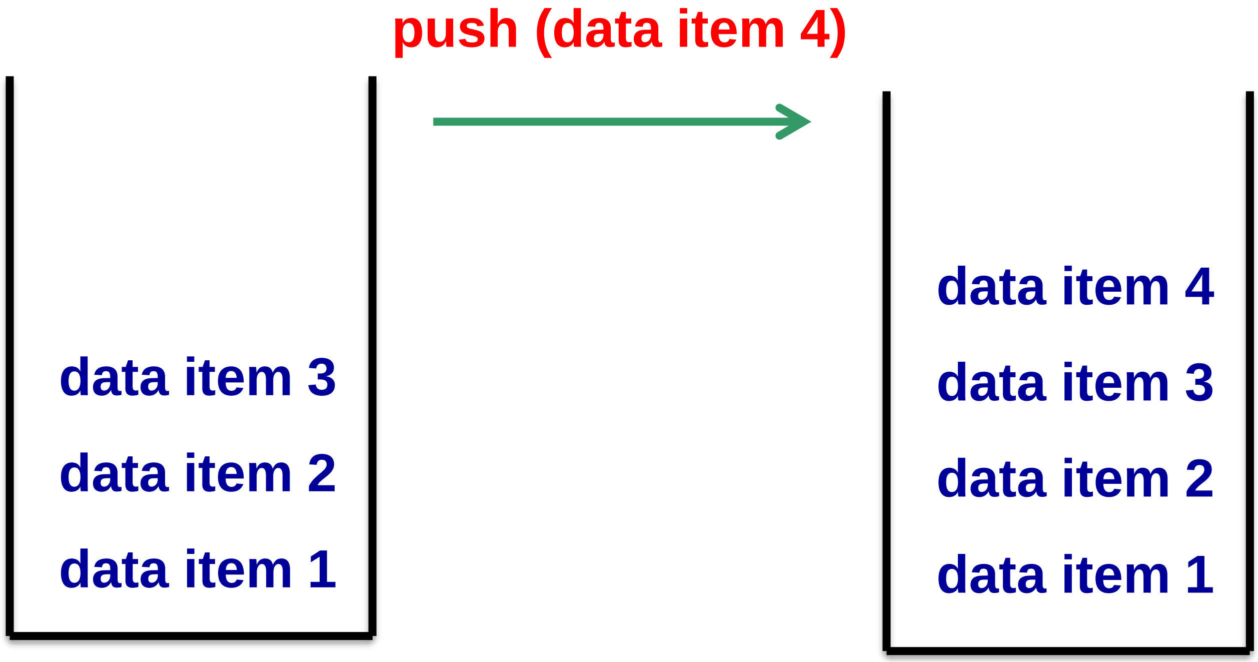
- ***Stack*: ** a collection whose elements are added and removed from one end, called the ***top*** of the stack
- Stack is a ***LIFO*** (Last In, First Out) data structure

A stack is a LIFO structure



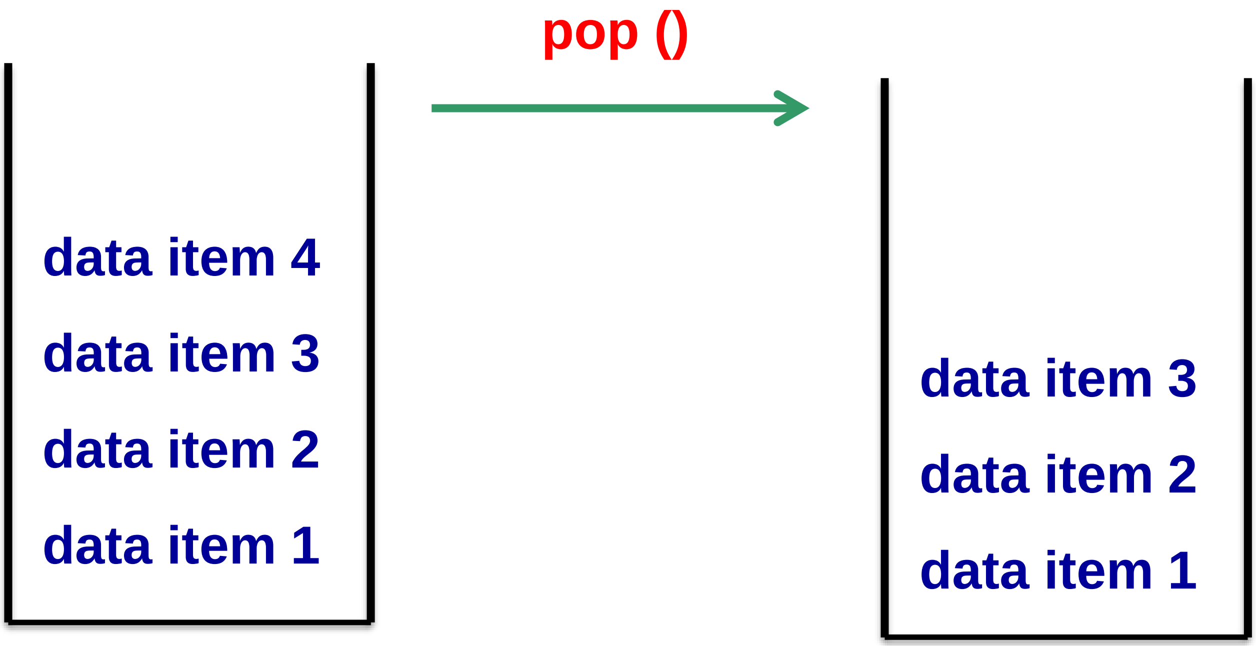
Stack Operations

- ***push***: add an element at the top of the stack



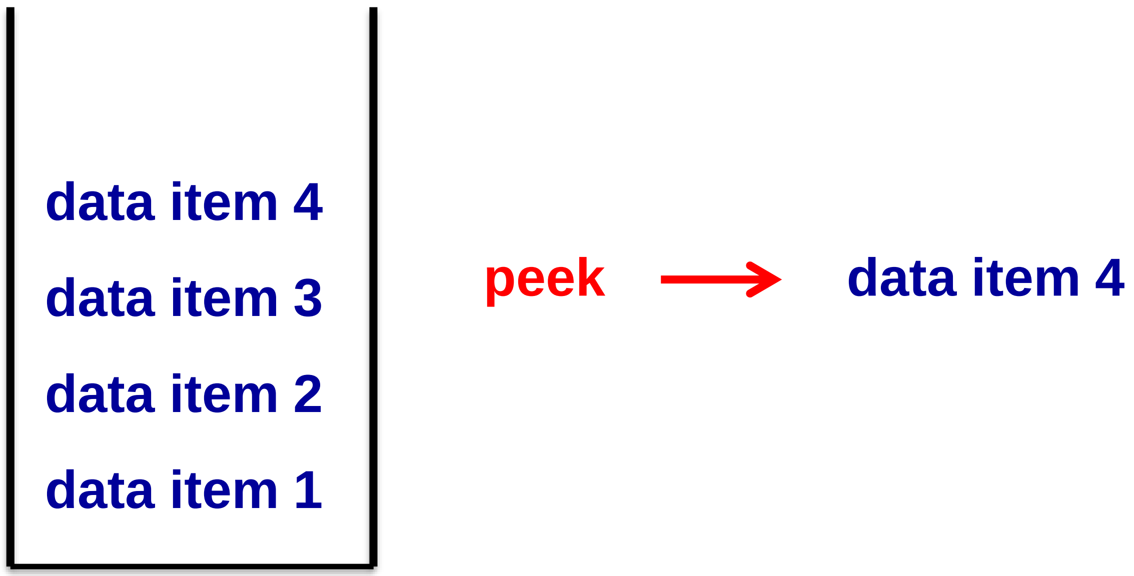
Stack Operations

- ***pop***: remove the element at the top of the stack



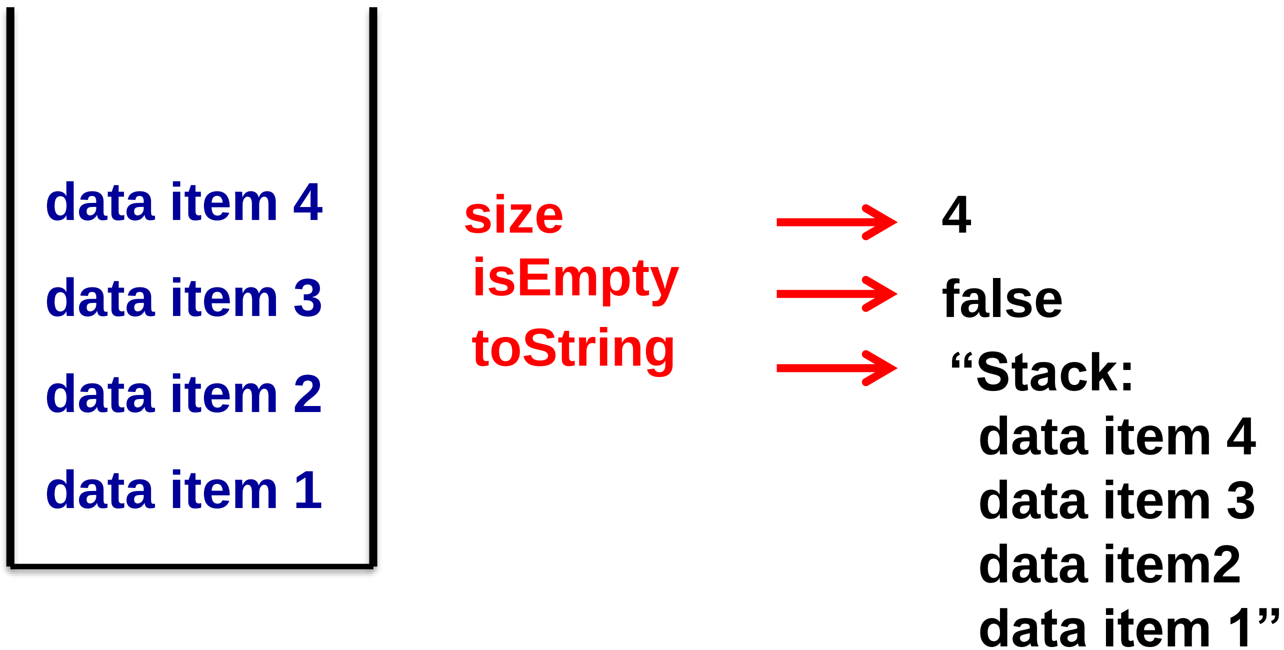
Stack Operations

- ***peek***: examine the element at the top of the stack without removing it



Stack Operations

- **size**: number of elements in the stack
- **isEmpty**: true if the stack is empty
- **toString**: string representation of stack



Abstract Data Type (ADT)

It is a ***collection*** of data together with the ***operations*** on that data.

The ADT specifies WHAT the operations do, not HOW they do it.

Stack ADT

- ***Stack Abstract Data Type (Stack ADT)***

  It is a ***collection*** of data together with the ***operations*** on that data:

  - push
  - pop
  - peek
  - Size
  - isEmpty
  - toString

Abstraction

- Abstraction separates the ***purpose*** of an entity from its ***implementation*** or how it works
  - ***Example in real life***: a car (we do not have to know how an engine works in order to drive a car)
  - ***Example in computer systems***: a computer (we do not need to know how information is stored and manipulated by the CPU to be able to execute programs)

Abstraction in Programming

Data type: a set of values and the operations defined on those values

Ex. integer data type (**int**):

- Values: … -2, -1, 0, 1, 2, …
- Operations: +, -, x, /, …

A data type is defined by a programming language.

Stack ADT

It is a ***collection*** of data together with the ***operations*** on that data:

- push
- pop
- peek
- Size
- isEmpty
- toString

An ADT is defined by the programmer.

Java Interfaces

Java has a ***programming construct*** called an ***interface*** that we can use to define what the operations on an ADT are.

```
public interface StackADT<T> {
  //  Adds one element to the top of this stack
  public void push (T dataItem);
  //  Removes and returns the top element of this stack
  public T pop( );
  //  Returns the top element of this stack
  public T peek( );
  //  Returns true if this stack is empty
  public boolean isEmpty( );
  //  Returns the number of elements in this stack
  public int size( );
  //  Returns a string representation of this stack
  public String toString( );
}
```

Java Interfaces

- *A Java interface is* a list of ***abstract methods*** (the signatures of the methods) and constants
  - Must be **public**
  - Constants must be declared as **static final**

```java
public interface StackADT<T> {
  //  Adds one element to the top of this stack
  public void push (T dataItem);
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  public int size( );
  //  Returns a string representation of this stack
  public String toString( );
}
```

Generic Types

What is this <T> in the interface definition?

- It is called a ***generic type***
  - The above interface defines a Stack for objects of type T
- The ***actual type*** is known only when an application program creates an object of that class
  - Example:
    - StackADT<String> s = new …
    - StackADT<Person> p = new …
    - StackADT<Rectangle> r = new …

      …

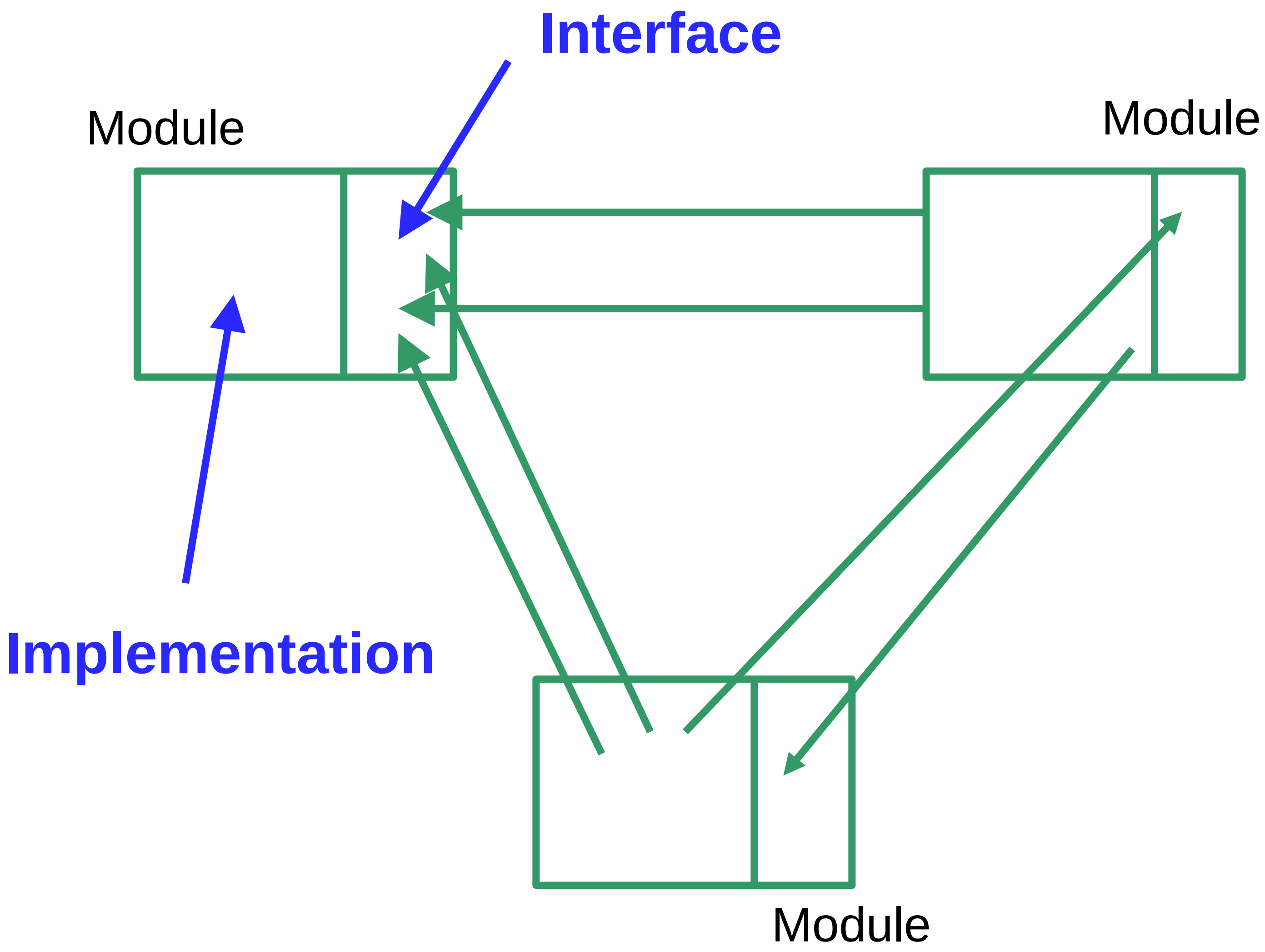
Generic Types

- Note: it is merely a convention to use the letter **T** to represent the generic type; any other letter or word can be used to represent the generic type
- In a class definition, we enclose the generic type in angle brackets: **< T >**

```
public interface StackADT<GenericType> {
  //  Adds one element to the top of this stack
  public void push (GenericType dataItem);
  //  Removes and returns the top element of this stack
  public GenericType pop( );
  //  Returns the top element of this stack
  public GenericType peek( );
  //  Returns true if this stack is empty
  public boolean isEmpty( );
  //  Returns the number of elements in this stack
  public int size( );
  //  Returns a string representation of this stack
  public String toString( );
}
```

Equivalent declaration of interface StackADT; name of generic type is not T.

Modular Design



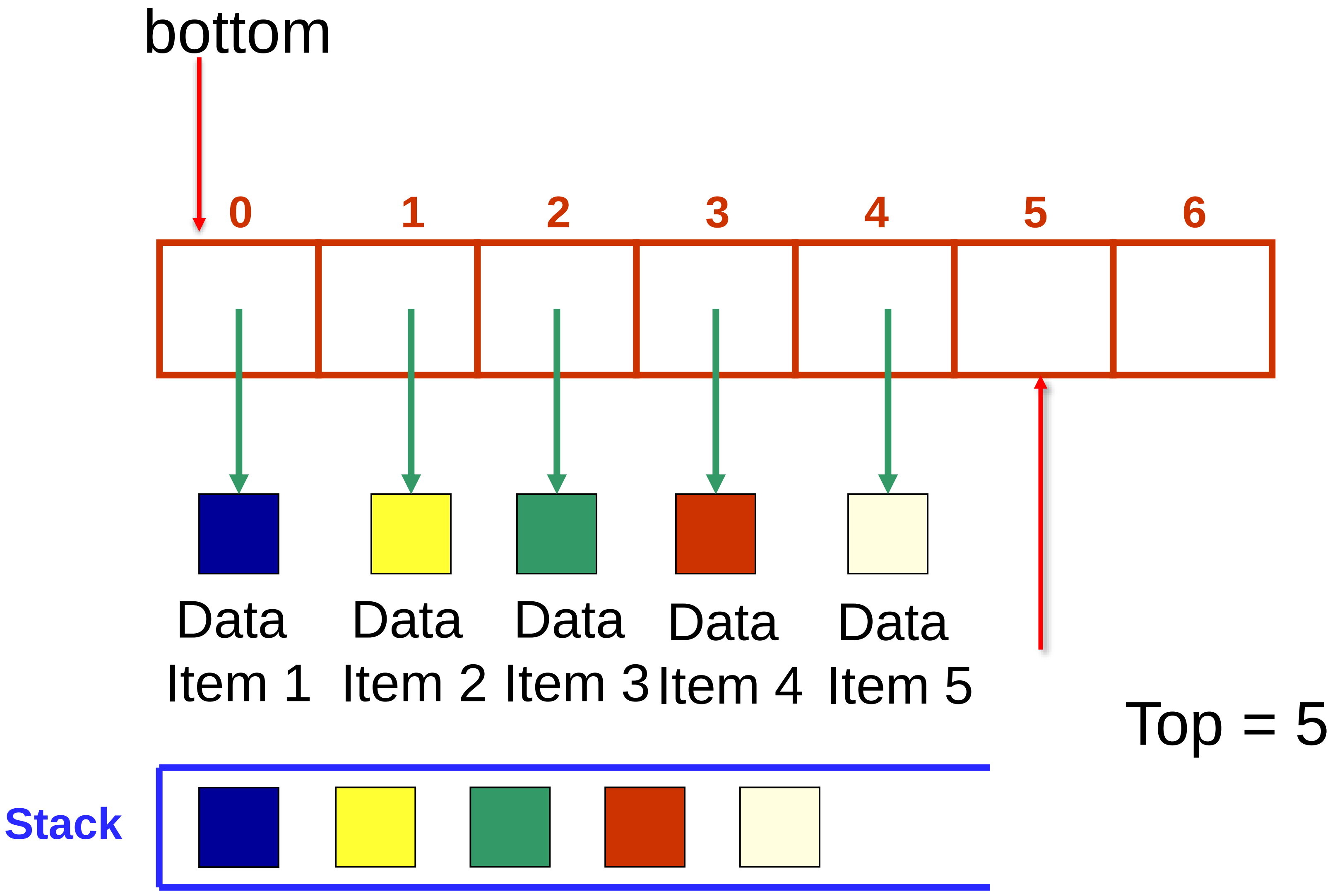
Implementing an Interface

- We cannot create an object of the class StackADT.
- To be able to create Stack objects, we first need to create a class that ***implements the interface*** by providing the implementations (code) for each of the abstract methods

Stack Implementation Issues

- What do we need to implement a stack?
  - A data structure (***container***) to hold the data elements
  - Something to indicate the ***top*** and *bottom* of the stack

Array Implementation of a Stack



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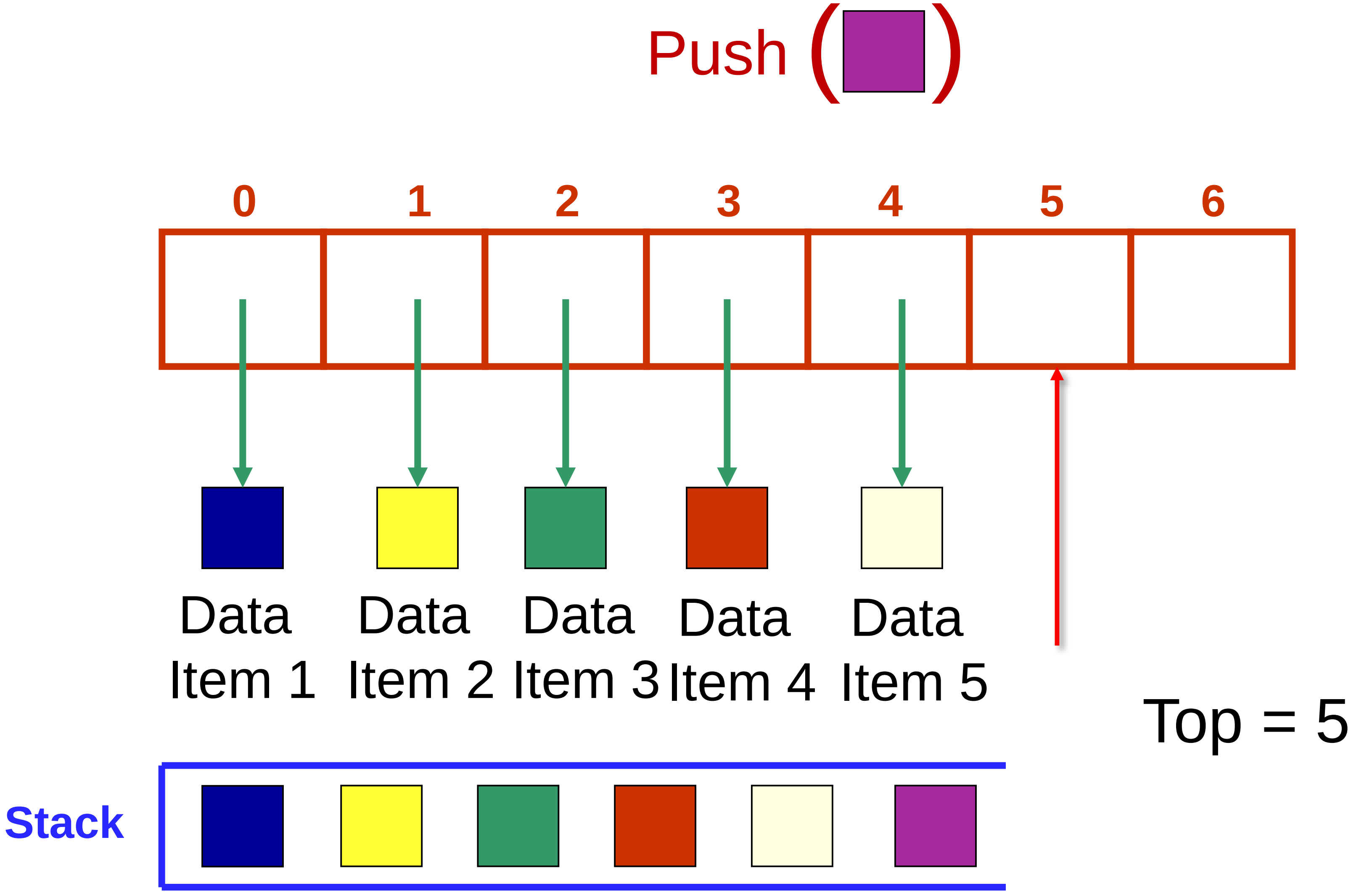

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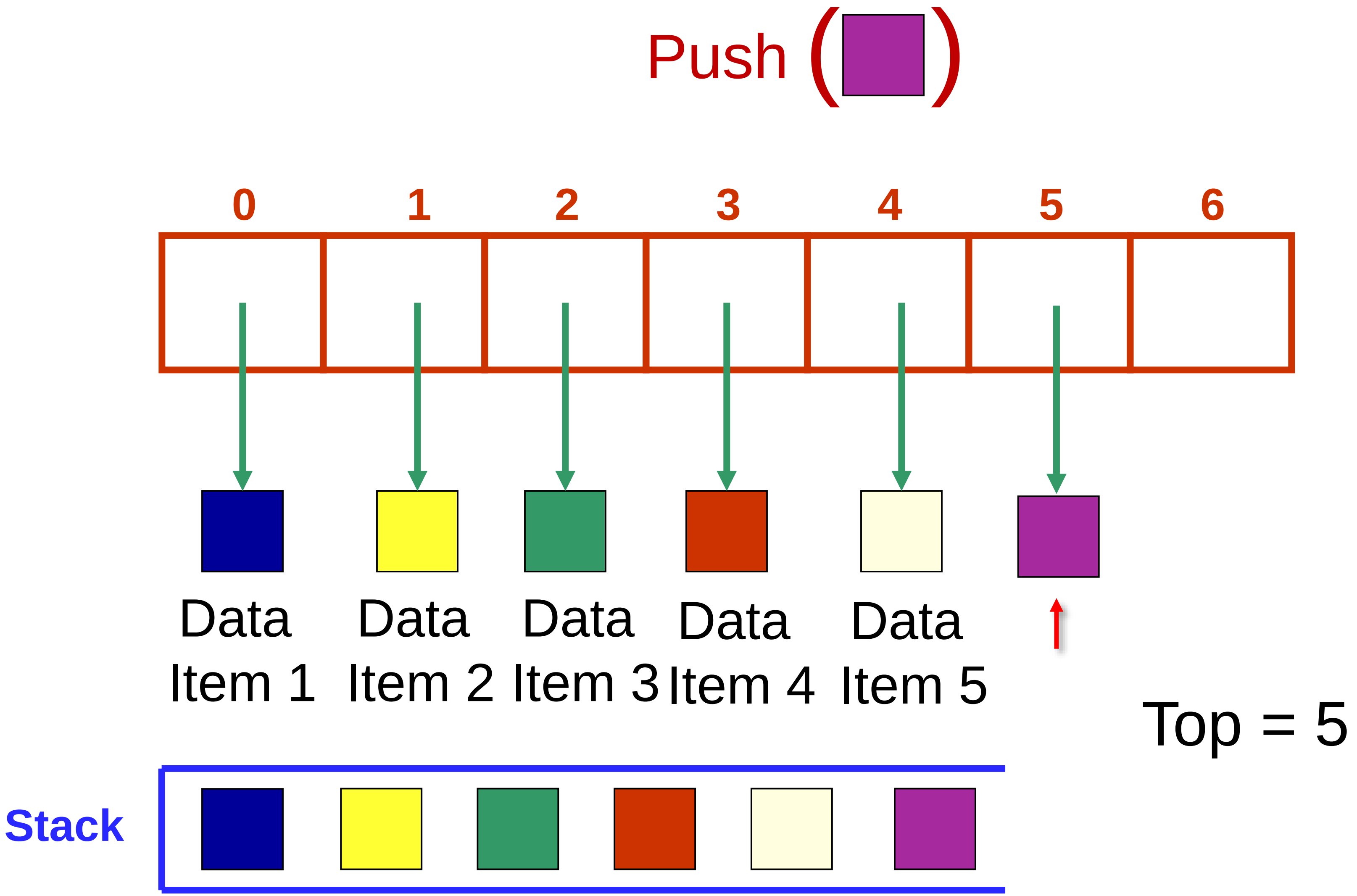

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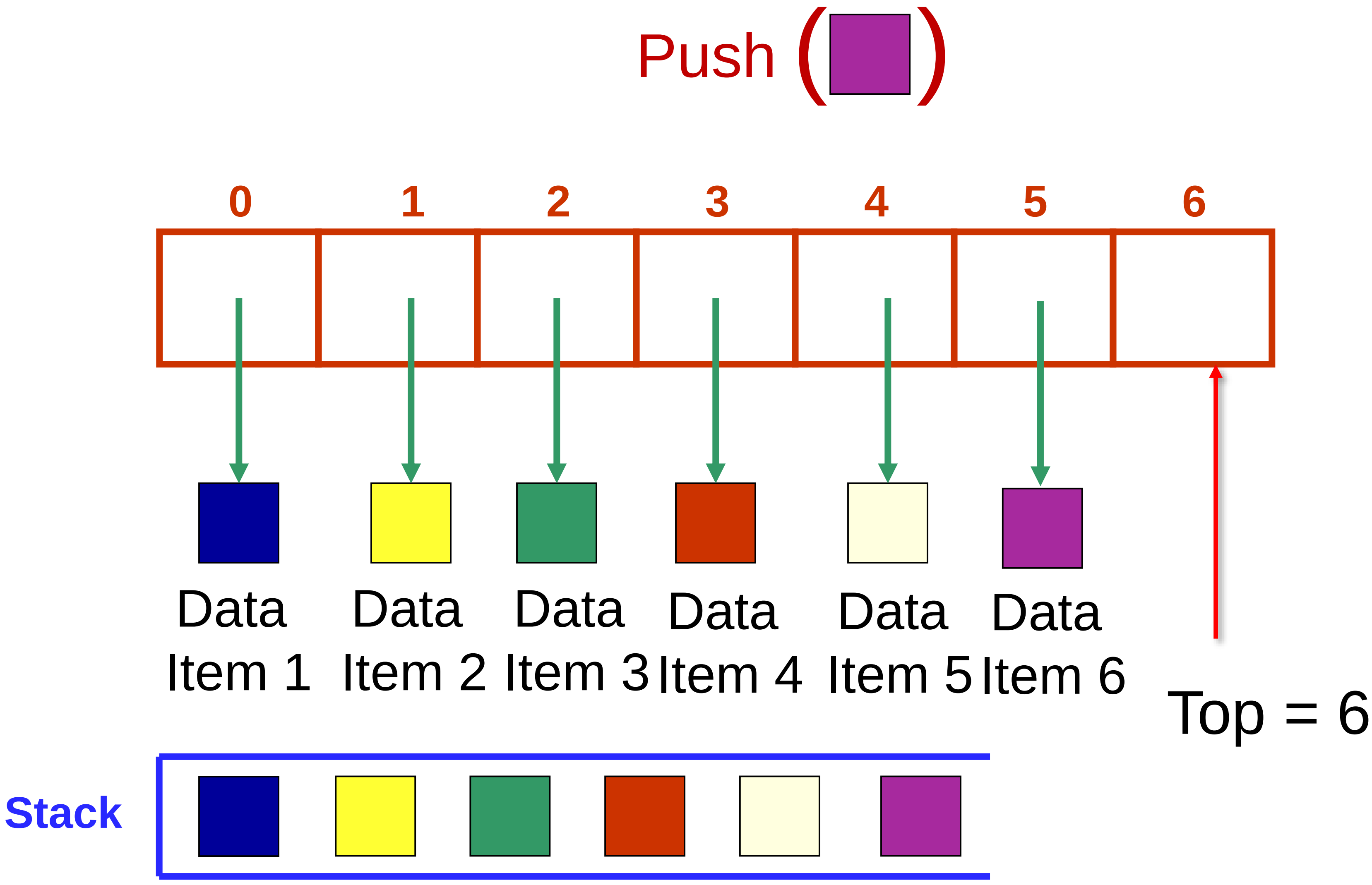

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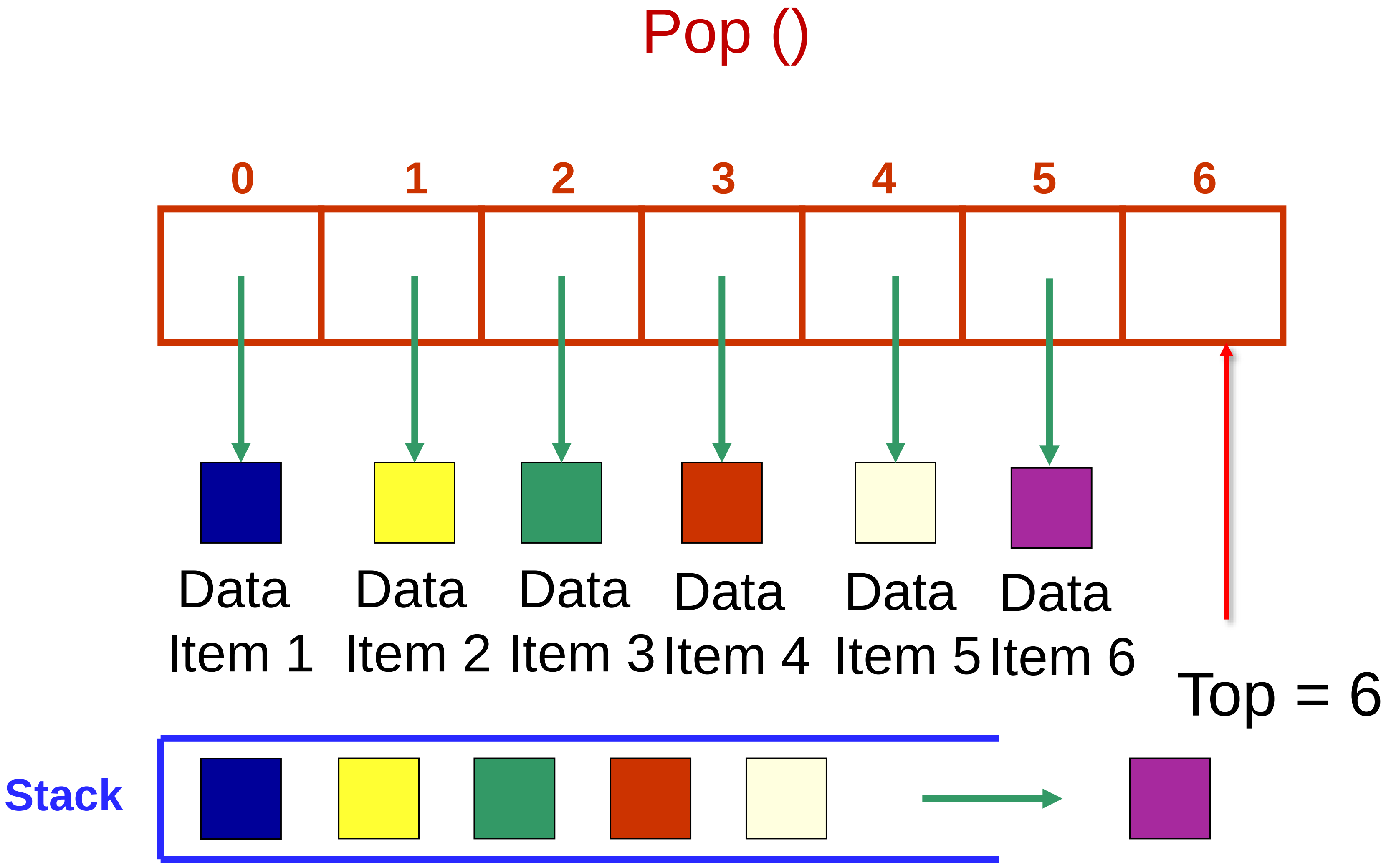

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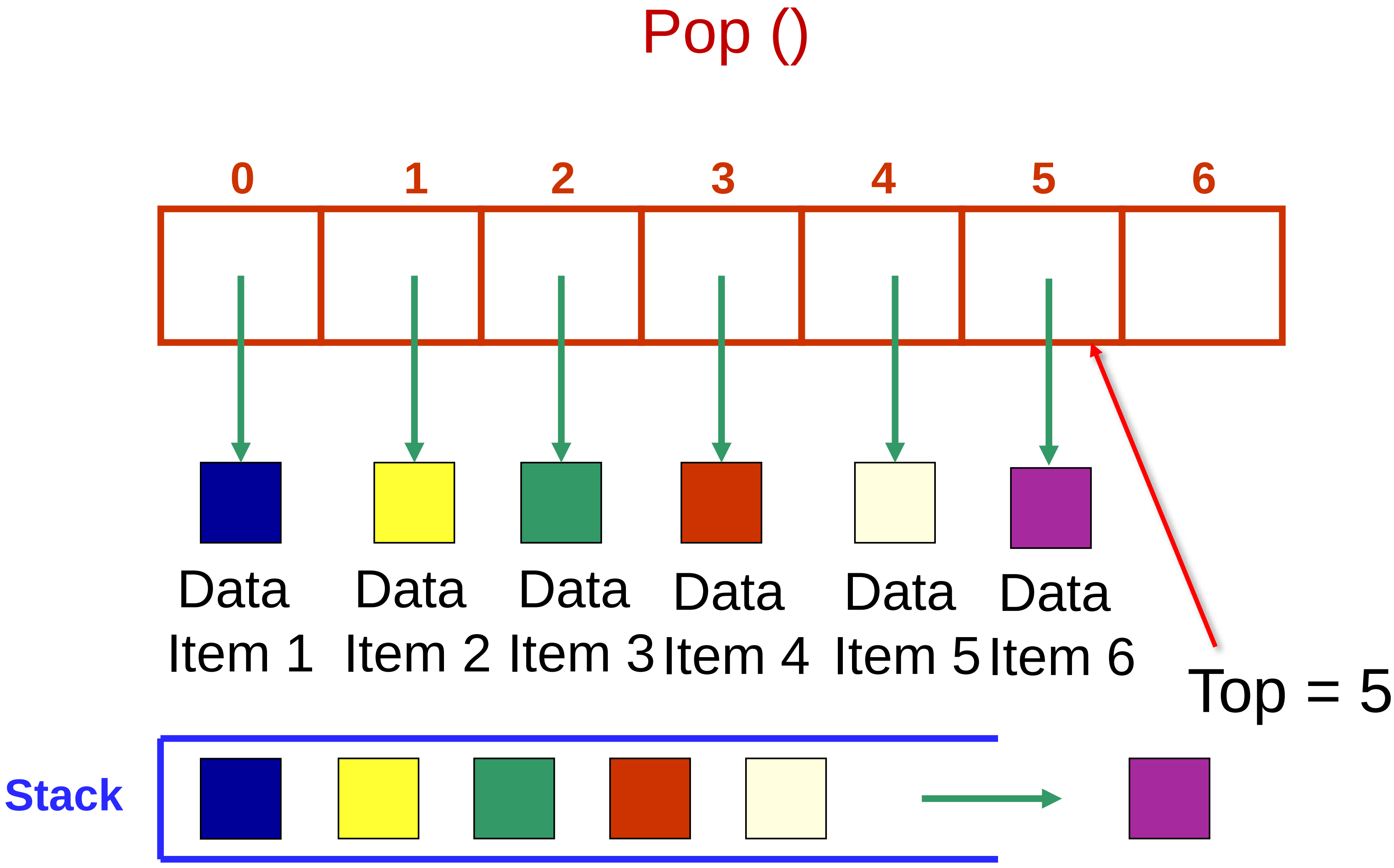

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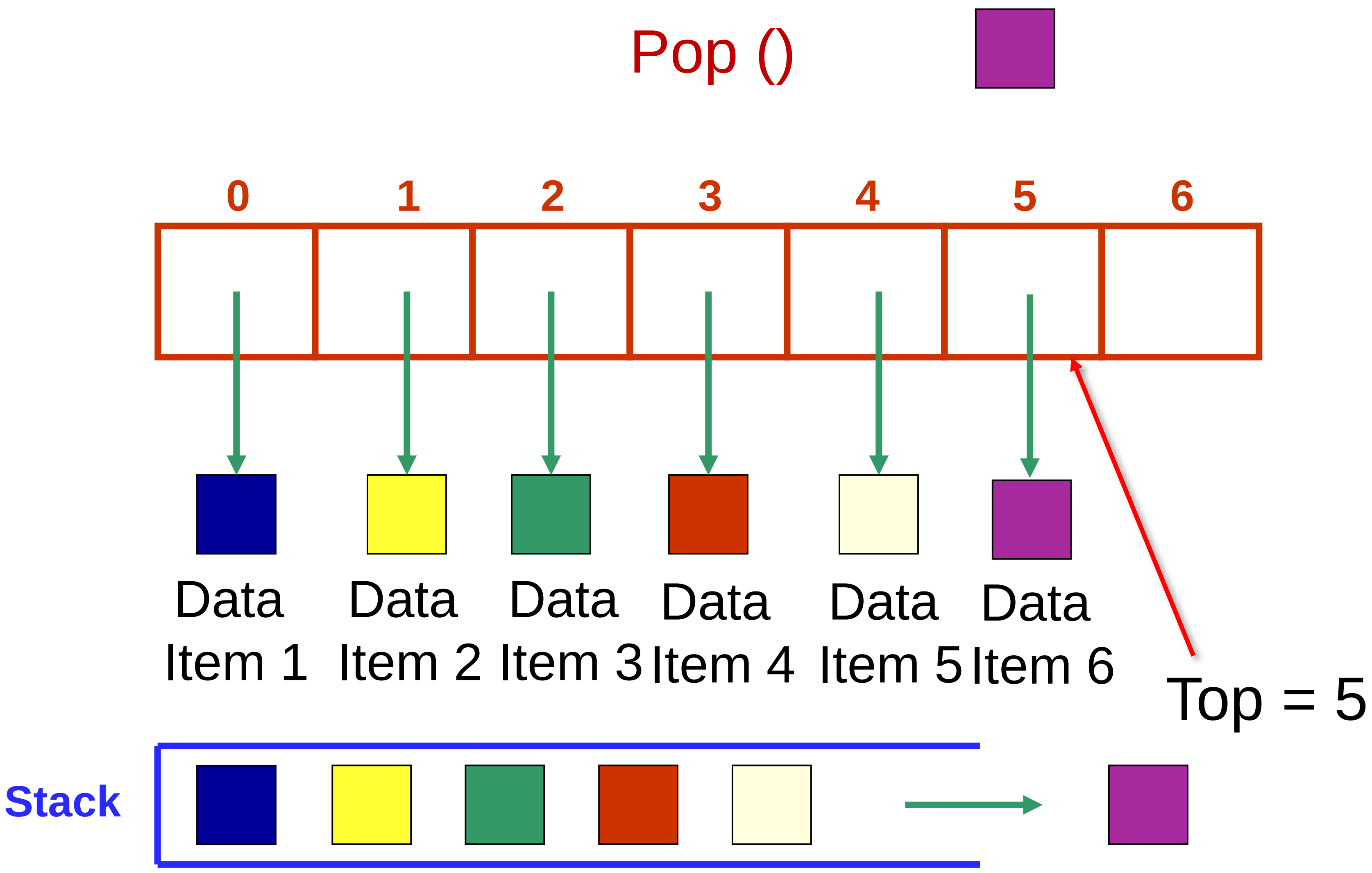

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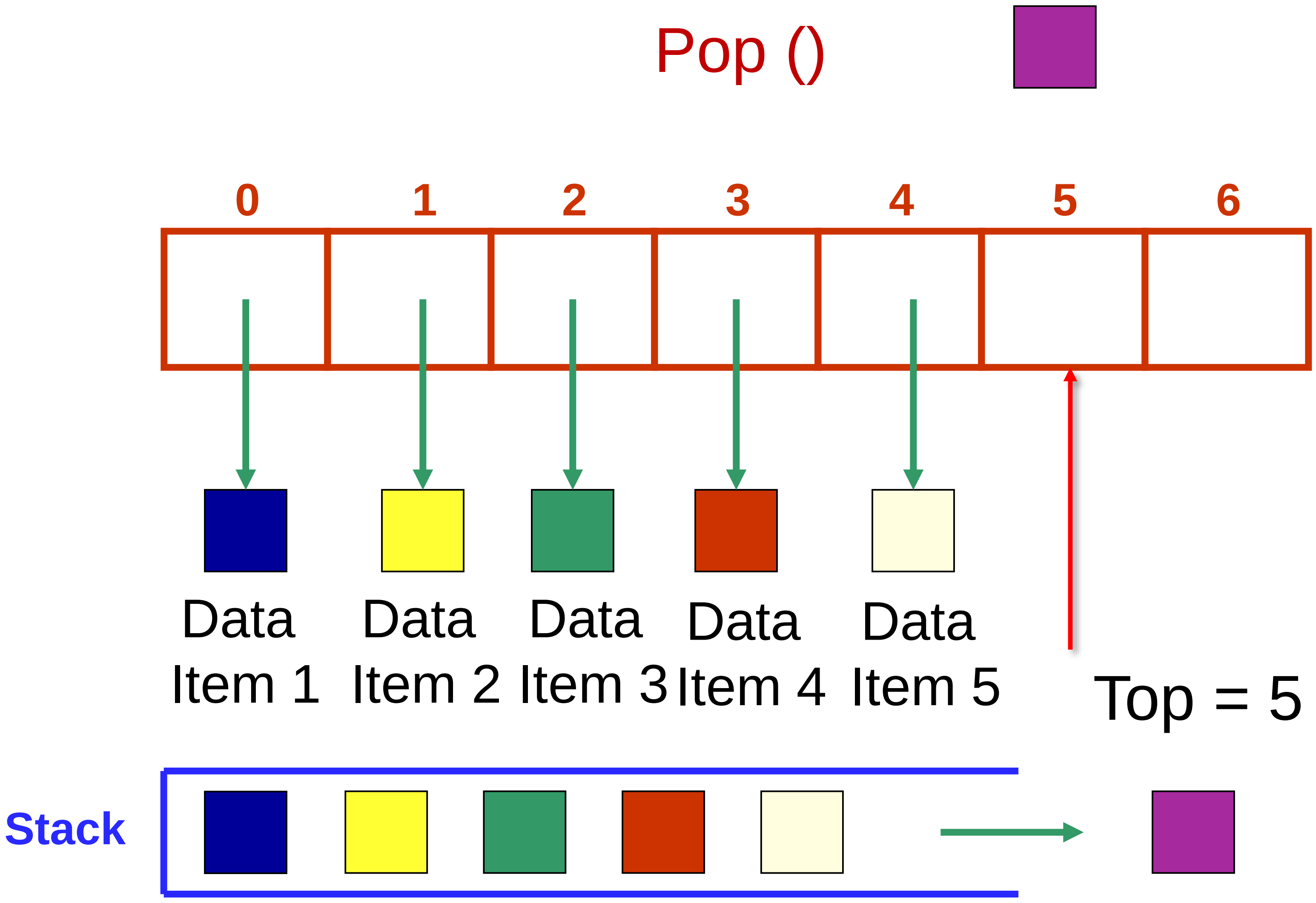

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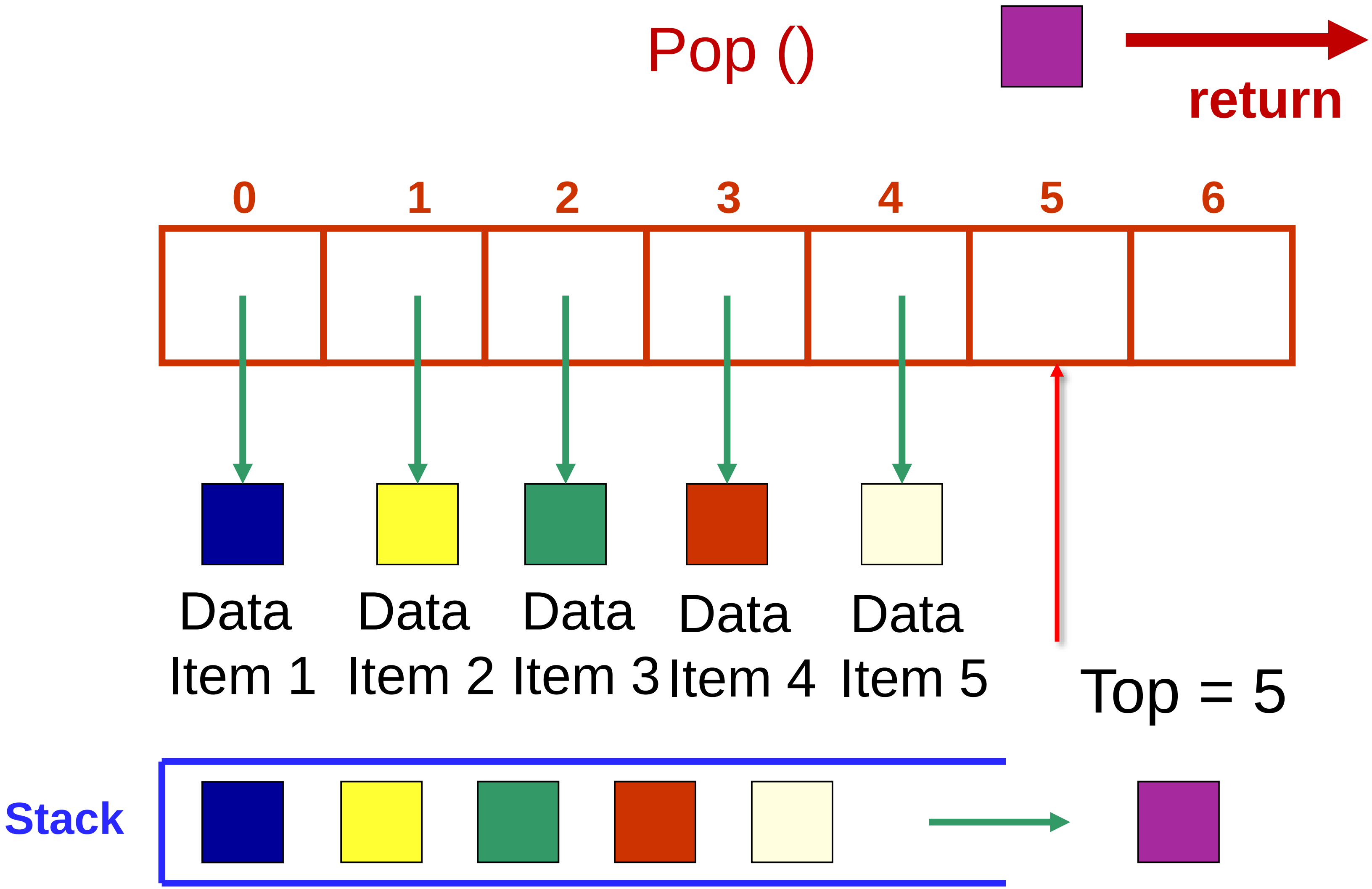

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  //  Adds one element to the top of this stack
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  public T peek( );
  //  Returns true if this stack is empty
  public boolean isEmpty( );
  //  Returns the number of elements in this stack
   public int size( );
  //  Returns a string representation of this stack
   public String toString( );
}
```

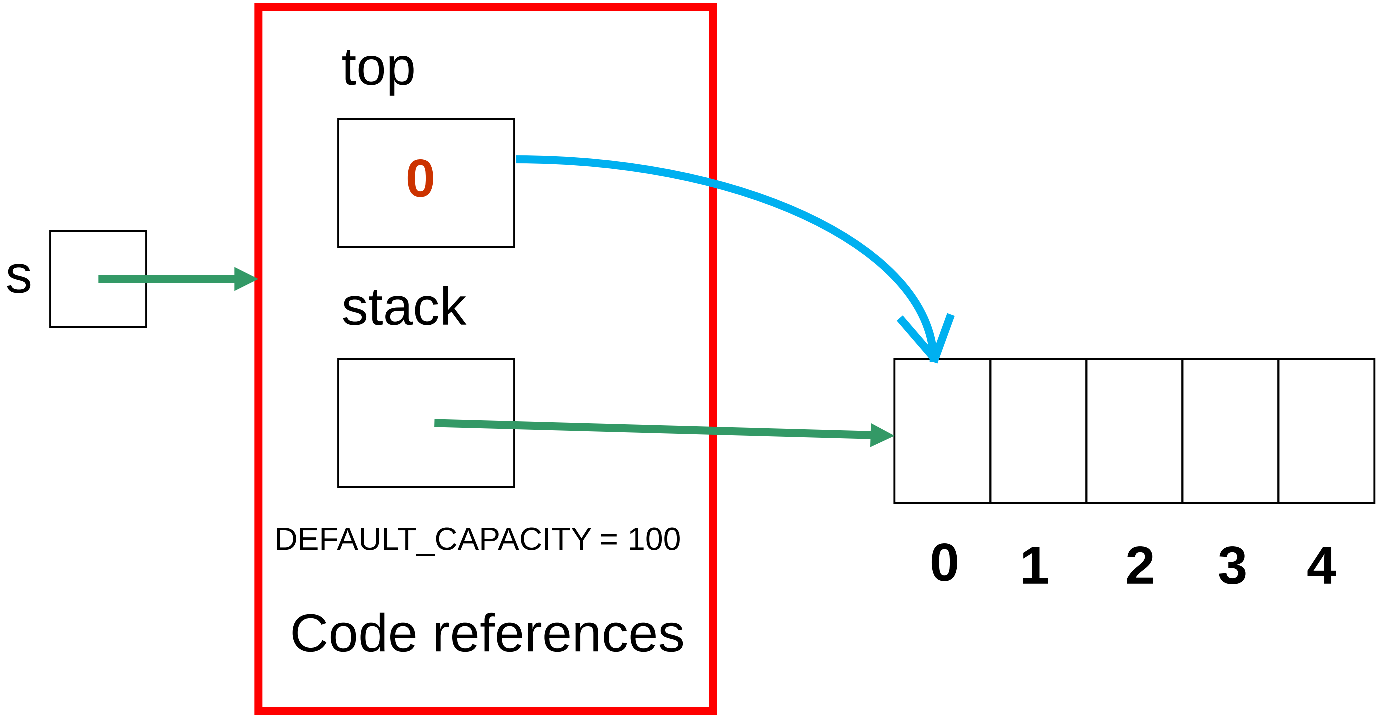
```
public class ArrayStack<T> implements StackADT<T> {
  private T[ ] stack;   // Array for the data
  private int top;        // Top of stack
  private final int DEFAULT_CAPACITY=100;

  public ArrayStack( ) {
    top = 0;
    stack = (T[ ]) (new Object[DEFAULT_CAPACITY]);
  }

  public ArrayStack (int initialCapacity) {
    top = 0;
    stack = (T[ ]) (new Object[initialCapacity]);
  }
```

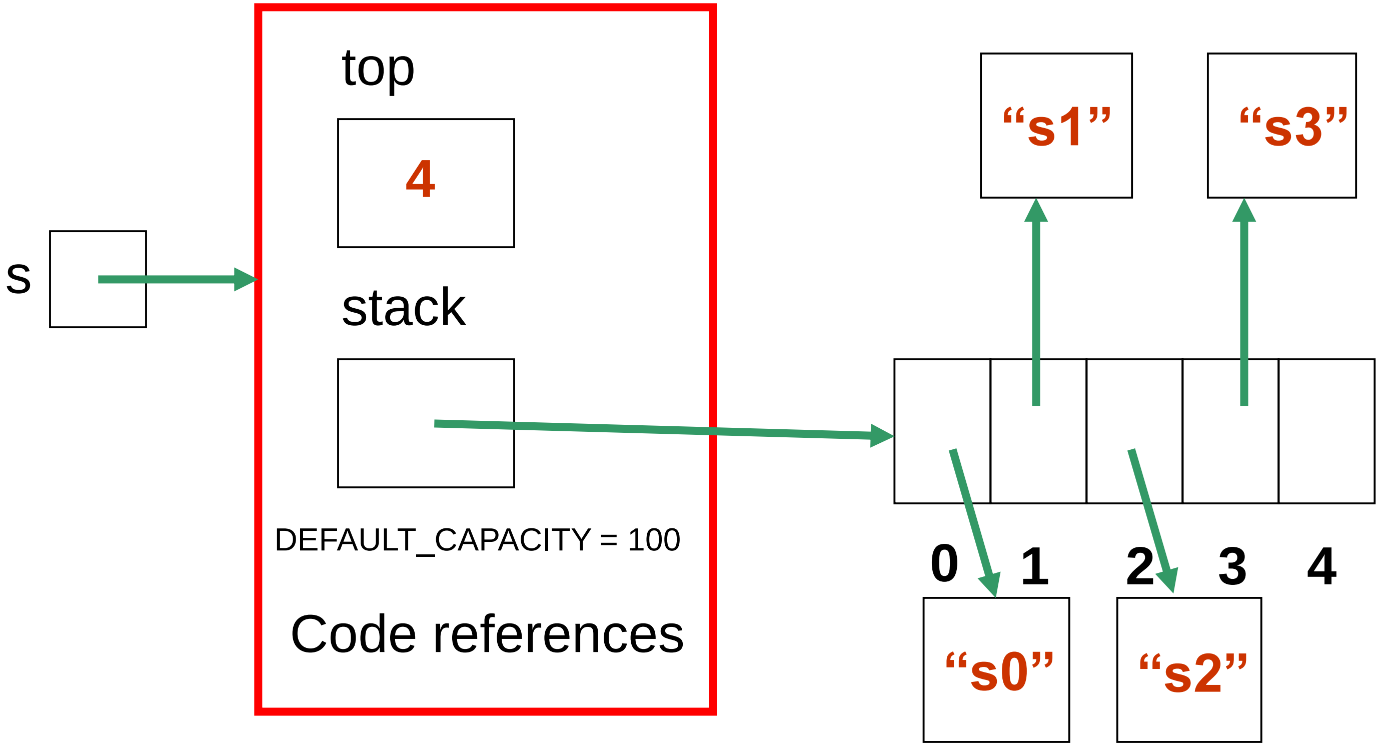
Example of using Constructor to create a Stack of Strings

```
ArrayStack<String> s =
                new ArrayStack<String>(5);
```



Example: the same **ArrayStack** object after four items have been pushed on

```
ArrayStack<String> s =
                new ArrayStack<String>(5);
```



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  public ArrayStack( ) {
    top = 0;
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  }

  public ArrayStack (int initialCapacity) {
    top = 0;
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  }
```

Why such complex declaration?

```
public class ArrayStack<T> implements StackADT<T> {
    private T[ ] stack;   // Array for the data
    private int top;          // Top of stack
    private final int DEFAULT_CAPACITY=100;

    public ArrayStack( ) {
        top = 0;
        stack = (T[ ]) (new Object[DEFAULT_CAPACITY]);
    }

    public ArrayStack (int initialCapacity) {
        top = 0;
        stack = new T[initialCapacity];
    }
```

Why is this wrong?

```
public class ArrayStack<T> implements StackADT<T> {
   private T[ ] stack;   // Array for the data
   private int top;        // Top of stack
   private final int DEFAULT_CAPACITY=100;

   public ArrayStack( ) {
      top = 0;
      stack = (T[ ]) (new Object[DEFAULT_CAPACITY]);
   }

   public ArrayStack (int initialCapacity) {
      top = 0;
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   }
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```
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  //  Returns a string representation of this stack
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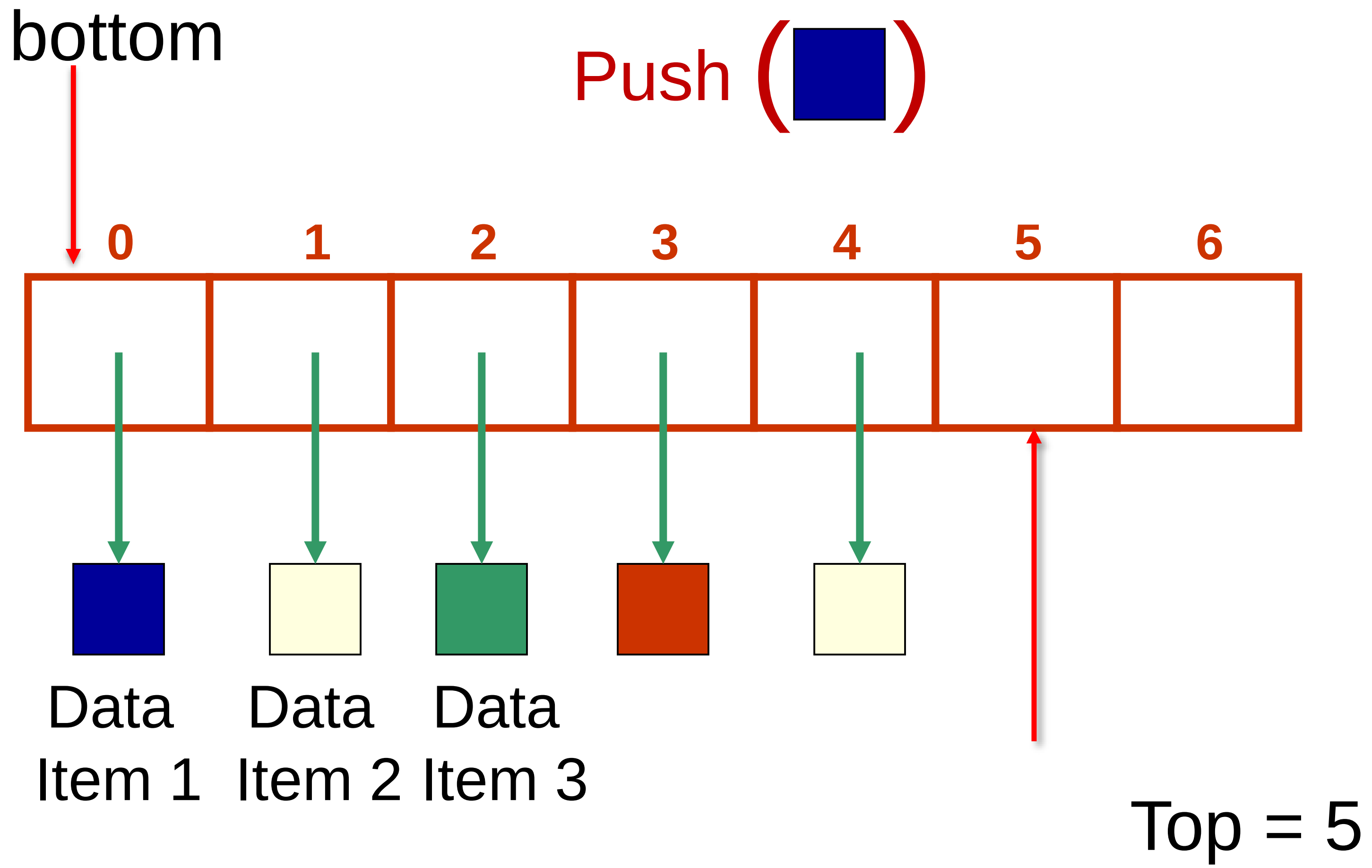
```

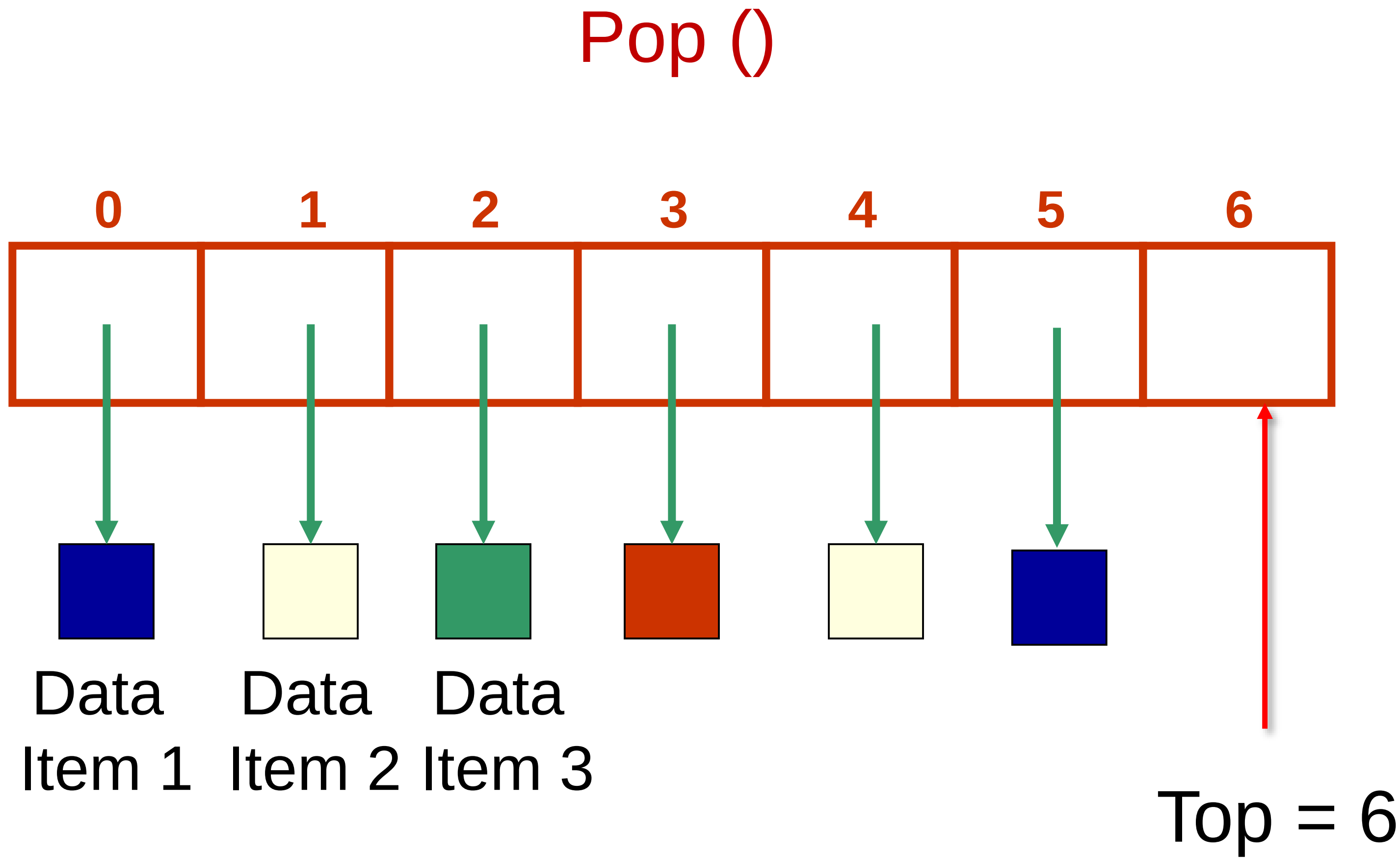
Array Implementation of a Stack



```java
//-----------------------------------------------------------------
//  Adds the specified element to the top of the stack,
//  expanding the capacity of the stack array if necessary
//-----------------------------------------------------------------
public void push (T dataItem) {
   if (top == stack.length)
       expandCapacity( );

   stack[top] = dataItem;
   top++;
}
```

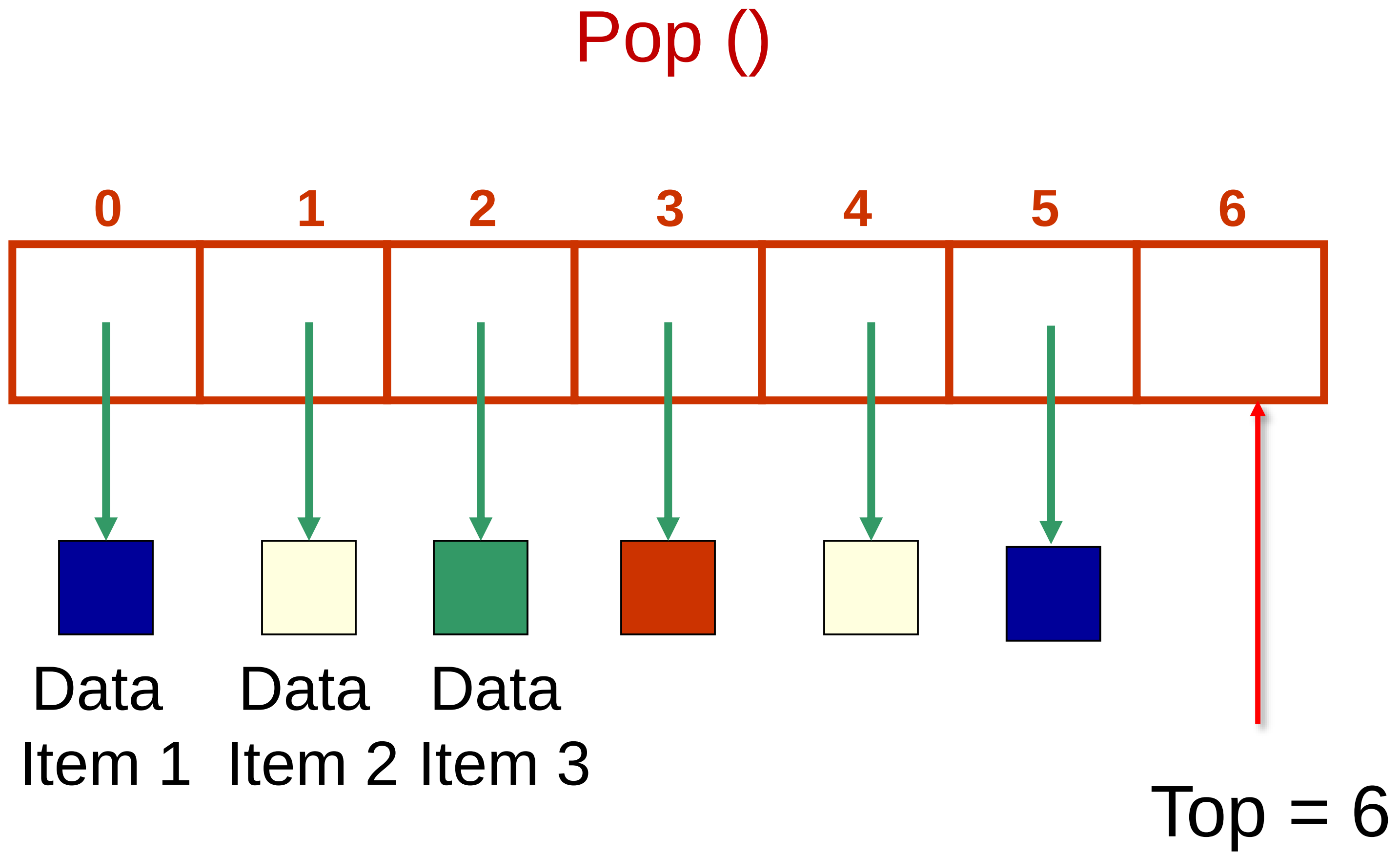
```
//  Helper method to create a new array to store the
// contents of the stack, with twice the capacity
private void expandCapacity( ) {
   T[ ] larger = (T[ ]) (new Object[stack.length*2]);

   for (int index=0; index < stack.length; index++)
      larger[index] = stack[index];

   stack = larger;
}
```

Array Implementation of a Stack



```
//  Removes the element at the top of the stack and returns a
//  reference to it. Throws an EmptyCollectionException if the
//  stack is empty.
public T pop( ) throws EmptyCollectionException {
   if (top == 0)
      throw new EmptyCollectionException(“Empty stack” );
   top--;
   T topItem = stack[top];
   stack[top] = null;
   return topItem;
}
```

Array Implementation of a Stack



```
//  Returns the element at the top of the stack. Throws an
//  EmptyCollectionException if the stack is empty.
public T peek( ) throws EmptyCollectionException {
   if (top == 0)
      throw new EmptyCollectionException(“Empty stack” );
   return stack[top-1];
}
```

```
//  Returns the number of elements in the stack
   public int size( ) {
      return top;
   }

   //  Returns true if the stack is empty and false otherwise
   public boolean isEmpty( ) {
      return (top == 0);
   }
```

```
//--------------------------------------------------------------------
//  Returns a string representation of this stack.
//--------------------------------------------------------------------
  public String toString( ) {
    String result = “Stack:\n";

    for (int index=0; index < top; index++)
      result = result + stack[index].toString( )
                  + "\n";


     return result;
   }
}
```

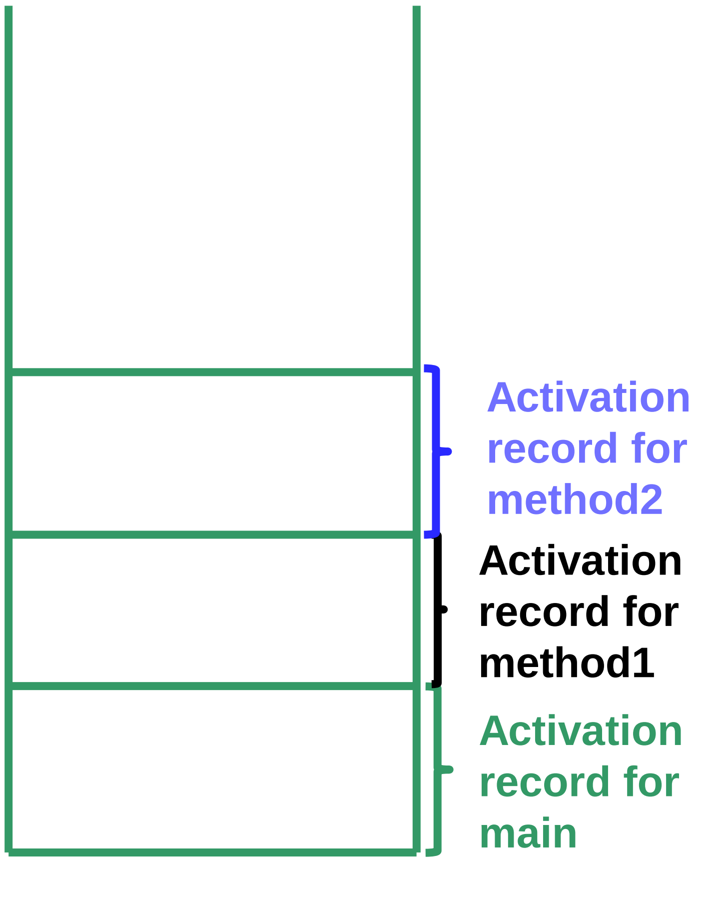
Uses of Stacks in Computing

Stacks are fundamental structures in Computer Science

- ***Execution stack (runtime or call stack)***
  - Used by runtime system when methods are invoked
  - Holds “activation records” (or “frames” or “call frames”) containing local variables, parameters, return address, etc.

Execution Stack

```
public static void main (String[] args) {
    method1();
}

private void method1() {
method2(x);
}

private void method2(int x) {
}
```



Execution stack

Uses of Stacks in Computing

Useful for any kind of problem involving ***LIFO*** data

- ***Backtracking***: in solving a maze or finding a path in a map

Uses of Stacks in Computing

- ***Word processors or editors***
  - To check expressions or strings of text for matching parentheses / brackets e.g. if (a == b) {

```
        c = ((d + e) – f) * (d + e);
    }
```

Uses of Stacks in Computing

- ***Word processors or editors***

  To implement *undo* operations

  - Keeps track of the most recent operations

    if (a == b)) c =

Using a Stack: Postfix Expressions

- Normally, we write expressions using ***infix notation***:
  - Operators are between operands: 3 + 4 * 2
  - Parentheses force precedence: (3 + 4) * 2
- In a ***postfix expression***, the operator comes ***after*** its two operands
  - Examples above would be written as:

3 4 2 * +

3 4 + 2 *

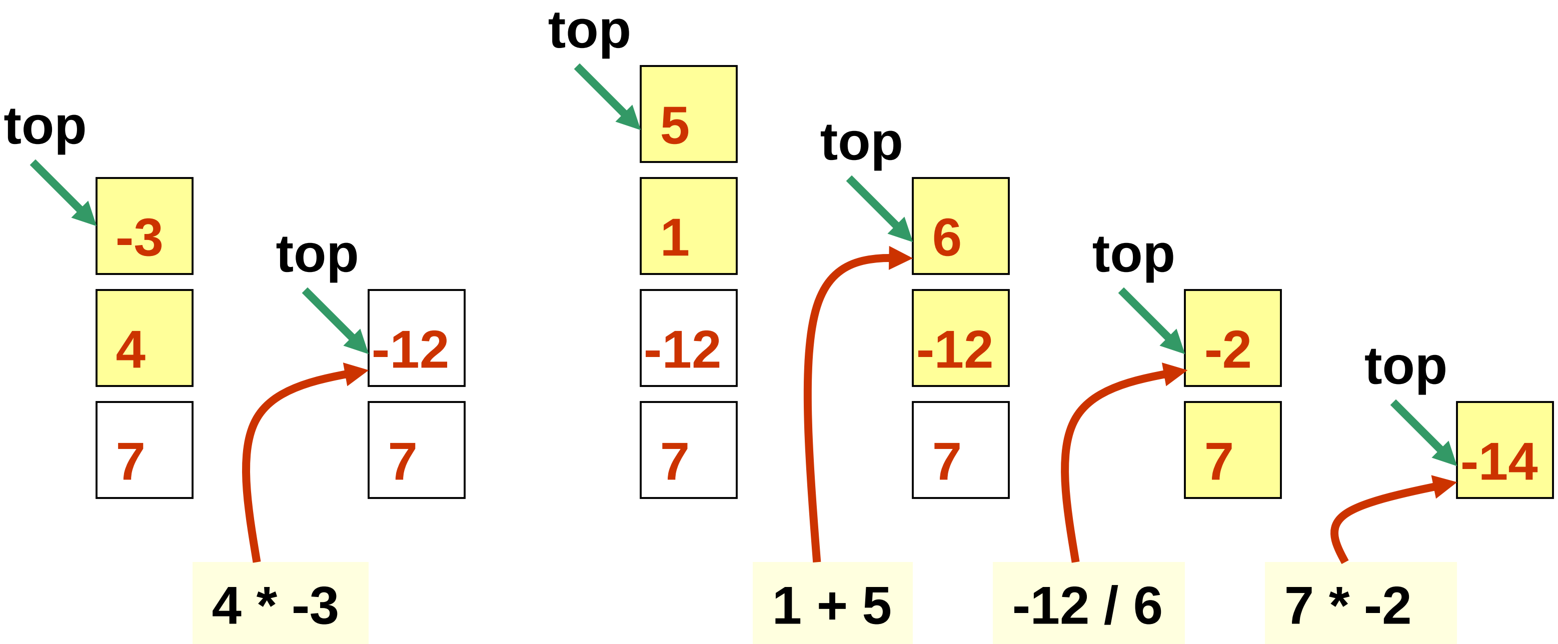
Evaluating Postfix Expressions

- *Algorithm to evaluate a postfix expression*:
  - Scan from left to right, determining if the next token is an operator or operand
  - If it is an operand, push it on the stack
  - If it is an operator, pop the stack twice to get the two operands, perform the operation, and push the result back onto the stack
- Try the algorithm on our examples …
- At the end, there will be one value in the stack – what is it?

Using a Stack to Evaluate a Postfix Expression

Evaluation of

7 4 -3 * 1 5 + / *



At end of evaluation, the result is the only item on the stack