Abstract Data Types and Stacks

CSE 2320 – Algorithms and Data Structures

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Generalized Queues

- A generalized queue is an abstract data type that stores a set of objects.
  - Let's use **Item** to denote the data type of each object.
- The fundamental operations that it queue supports:
  - **void insert(Queue q, Item x):** adds object **x** to set **q**.
  - **Item delete(Queue q):** choose an object **x**, remove that object from **q**, and return it to the calling function.

  - create – creates a queue
  - destroy – destroys a queue
  - join – joins two queues

Generalized Queues

- Basic operations:
  - **void insert(Queue q, Item x)**
  - **Item delete(Queue q)**
- **delete** must choose what item to delete.
  - Last inserted -> Stack / Pushdown Stack / LIFO (Last In First Out)
  - First inserted -> FIFO Queue (First In First Out)
  - Random item.
  - Item with the smallest key (if each item contains a **key**).
    -> Priority Queue (Heap)

Pushdown Stack

- The pushdown stack supports **insert** and **delete** as follows:
  - ~~**insert**~~ **push:** the insert operation for pushdown stacks. Puts an item "on top of the stack".
  - ~~**delete**~~ **pop**: the delete operation for pushdown stacks. Removes the item from the top of the stack (the last item that was pushed in).

Push / Pop – Work sheet

push(15)
push(20)
pop()
push(30)
push(7)
push(25)
pop()
push(12)
pop()
pop()

- Conventions:
  - Value: Push value on stack
  - * : Pop from stack

Continue with the other operations.

Push / Pop – Answers

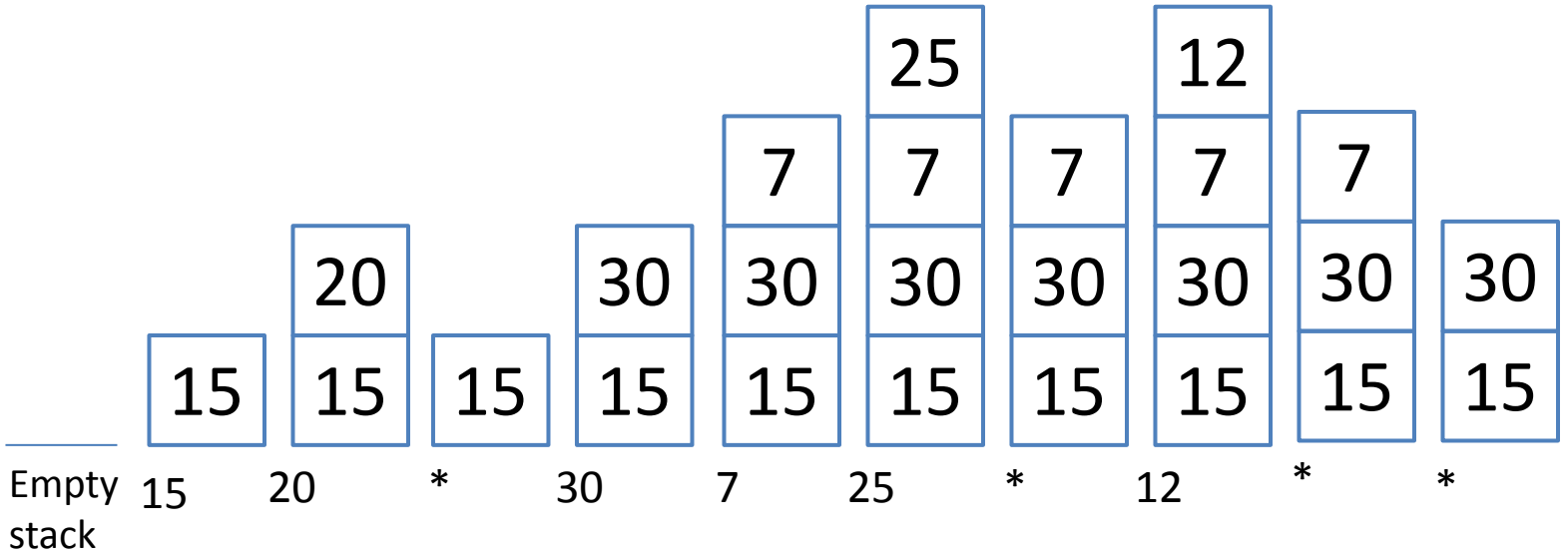
Know these ‘paper’ conventions.

push(15)
push(20)
pop()
push(30)
push(7)
push(25)
pop()
push(12)
pop()
pop()

- Conventions:
  - Push value: value
  - Pop: *

Blackboard test conventions:

:	empty stack
15:15	push 15 & stack
20:15,20	push 20 & stack
*:15	pop & stack

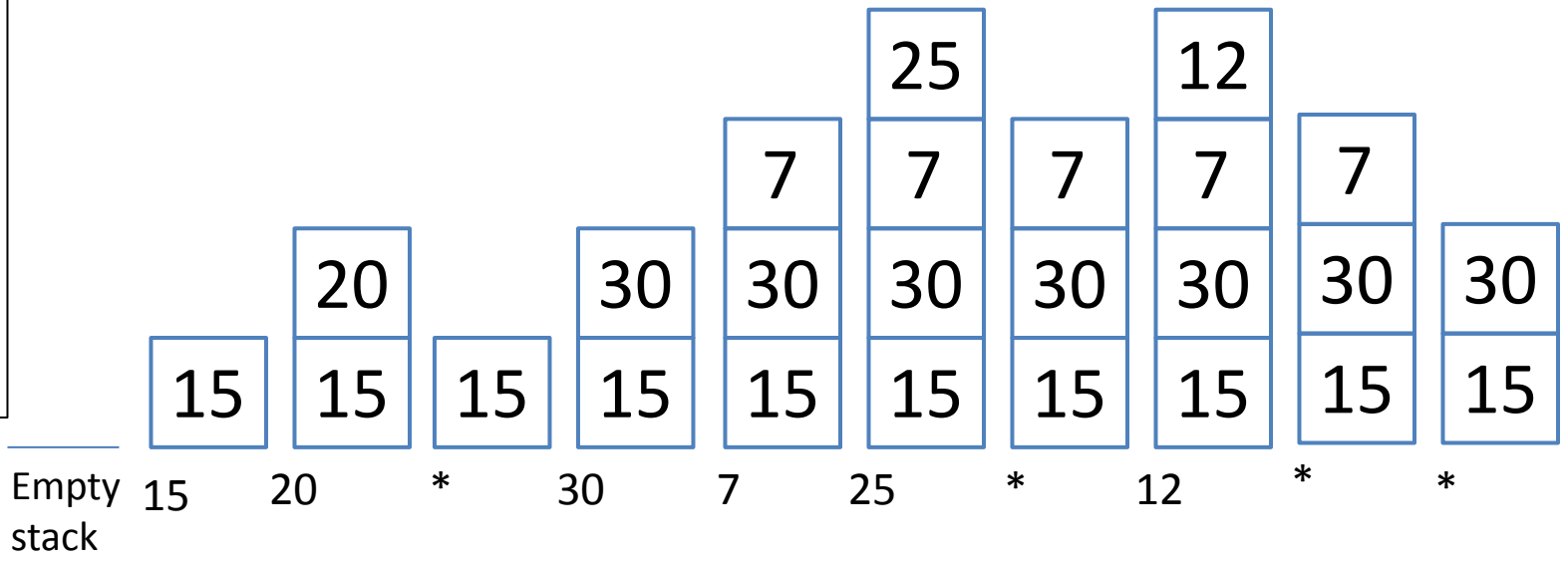


Stack – Output Sequence

- Conventions:
  - Push value: value
  - Pop: *

Operations:
15
20
*
30
7
25
*
12
*
*

The **output sequence** produced by these operations on a stack is:
20, 25, 12, 7



Exercises

Conventions:
letter – push(letter)
* - pop()

1. Given sequence of operations, show the stack & output:
   1. ROS**T*E*X*
   2. ROS**T*E***X* (error)
   3. SOM**E*T**H*I*NGTO*D**O*** (a longer example)
2. Given input and output sequence, show the push & pop operations

Example: given input: CAT and output ACT, the answer is: CA**T* .
(Insert * in the input sequence s.t. that these operations give the desired output.)

1. Input: INSATE,
   1. Output: SANETI, Operations Sequence:
   2. Output: ANSITE, Operations Sequence: (error)

Stack Applications

- Function execution in computer programs:
  - when a function is called, it enters the **calling stack**. The function that leaves the calling stack is always the last one that entered (among functions still in the stack).
- Interpretation and evaluation of symbolic expressions:
  - evaluate expressions like (5+2)*(12-3), or
  - parse C code (as a first step in the compilation process).
- Search methods.
  - traverse or search a graph

Implementing Stacks

- A stack can be implemented using:
  - lists or
  - arrays

- Both implementations are fairly straightforward.

List-Based Stacks

- **List-based** implementation:
  - What is a stack?
    - A stack is essentially a list.
  - **push(stack, item)**
    - How? :
    - O(1) – wanted (frequent operation for this data structure)
  - **pop(stack)**
    - How? :
    - O(1) – wanted (frequent operation for this data structure)
- What type of insert and remove are fast for lists?
  - How many ‘ways’ can we insert in a list?

List-Based Stacks

- List-based implementation:
  - What is a stack?
    - A stack is essentially a list.
  - **push(stack, item)**
    - How? : inserts that item at the beginning of the list.
    - O(1)
  - **pop(stack)**
    - How? : removes (and returns) the item at the **beginning** of the list.
    - O(1)

Implementation Code

- See files posted on course website:
  - **stack.h:** defines the public interface.
  - **stack_list.c:** defines stacks using lists.
  - **stack_array.c:** defines stacks using arrays.

The Stack Interface

- See file **stack.h** posted on the course website.

```
stack newStack(int mx_sz);
void destroyStack(stack s);
void push(stack s, Item data);
Item pop(stack s);      //NOTE: type Item, not link
int isEmptyStack(stack s);
```

Defining Stacks

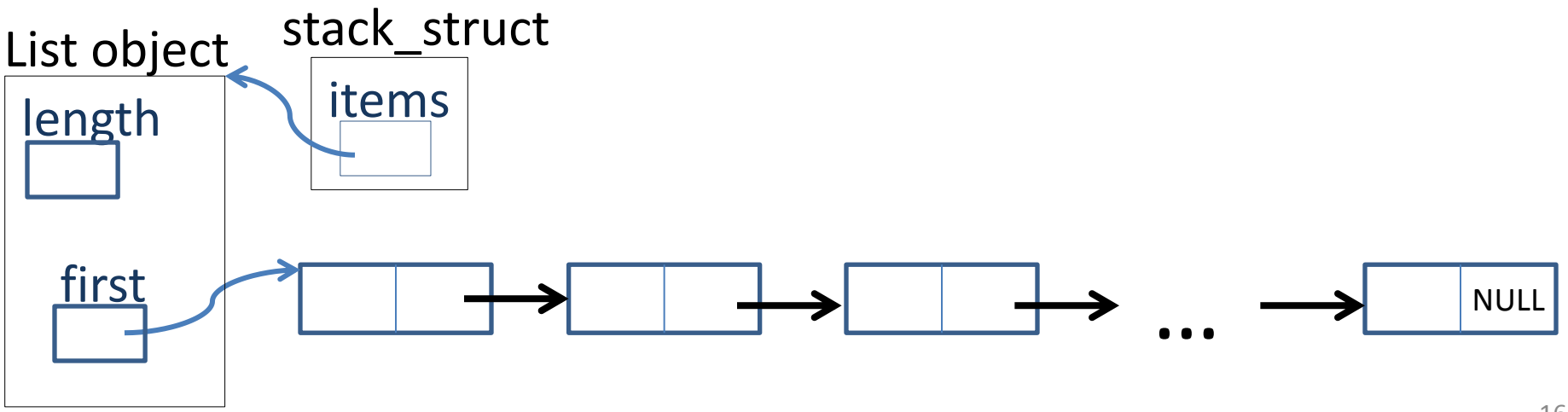
```
typedef struct stack_struct * stack;

struct stack_struct
{
    ???;
};
```

Defining Stacks

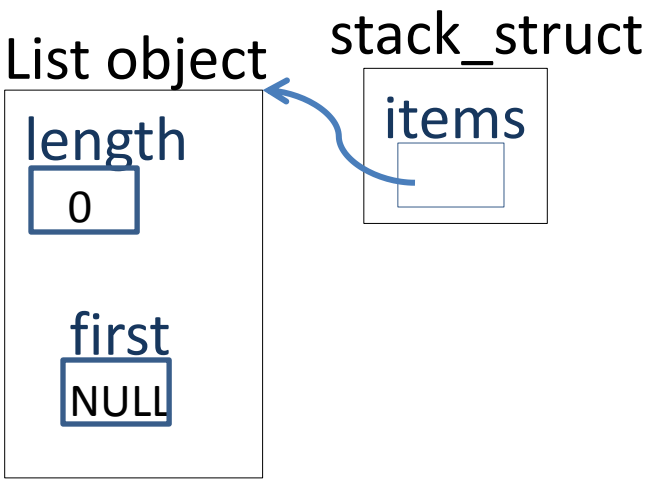
```
typedef struct stack_struct * stack;

struct stack_struct
{
    list items;
};
```



Example

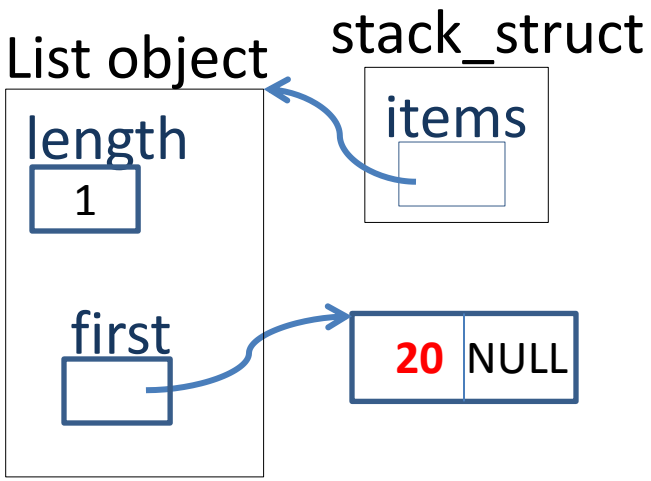
```
typedef struct stack_struct * stack;
struct stack_struct
{
    list items;
};
```



Empty stack.
We will insert values in order:
20
7
15
pop()

Example cont.

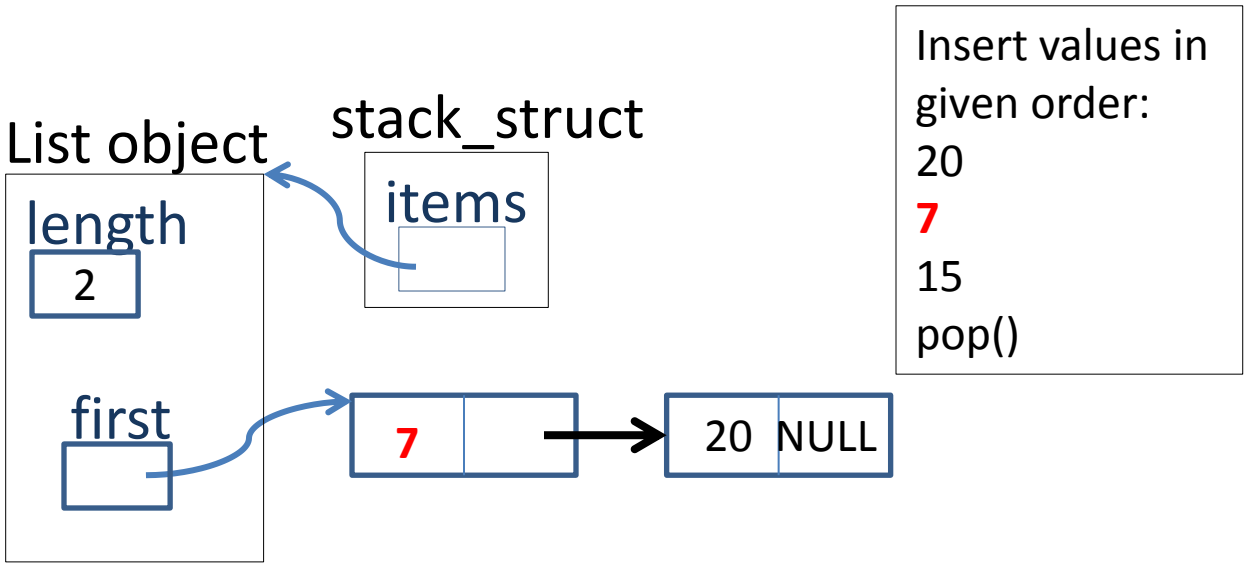
```
typedef struct stack_struct * stack;
struct stack_struct
{
    list items;
};
```



Insert values in given order:
20
7
15
pop()

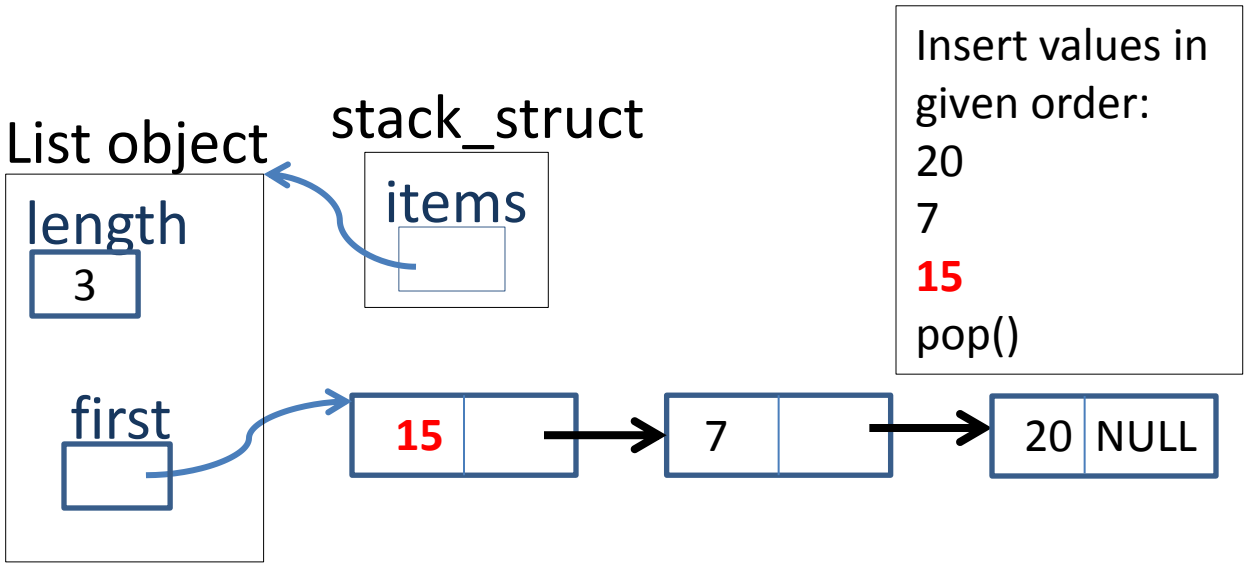
Example cont.

```
typedef struct stack_struct * stack;
struct stack_struct
{
    list items;
};
```



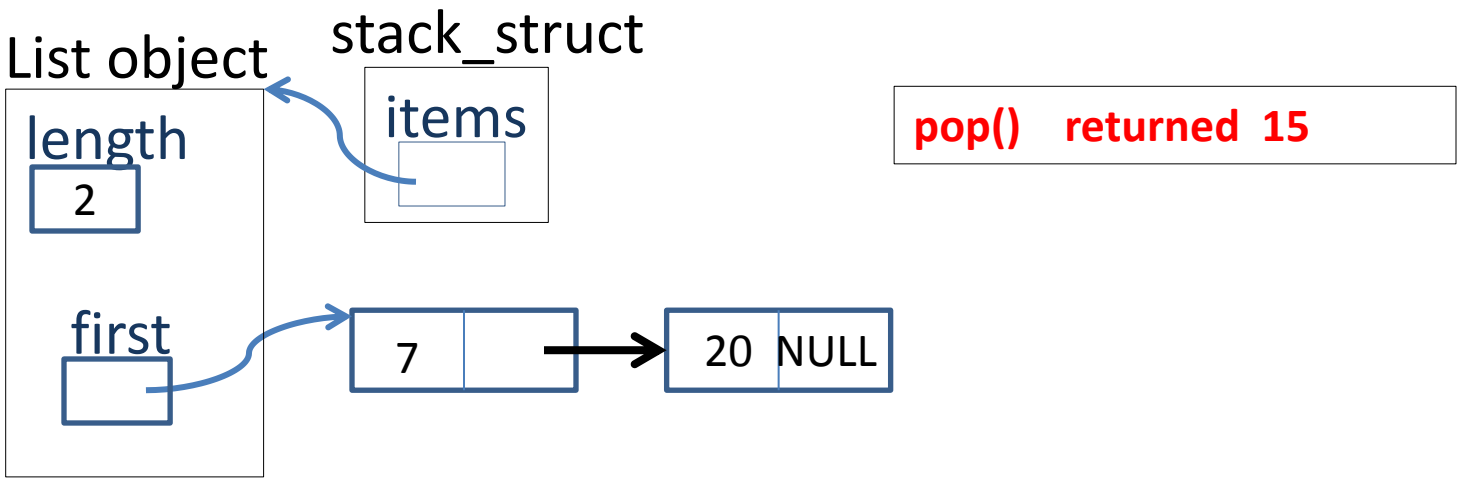
Example cont.

```
typedef struct stack_struct * stack;
struct stack_struct
{
    list items;
};
```



Example cont.

```
typedef struct stack_struct * stack;
struct stack_struct
{
    list items;
};
```



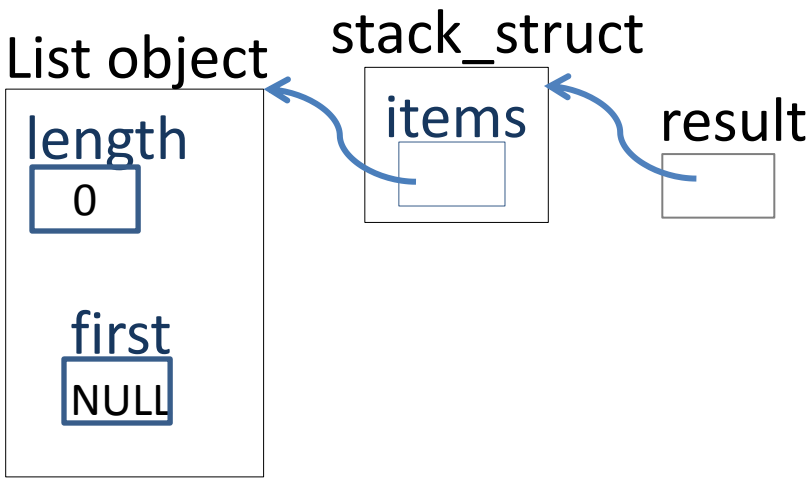
Creating a New Stack

```
typedef struct stack_struct * stack;
struct stack_struct
{
    list items;
};

stack newStack(int mx_sz)
{
    ???
}
```

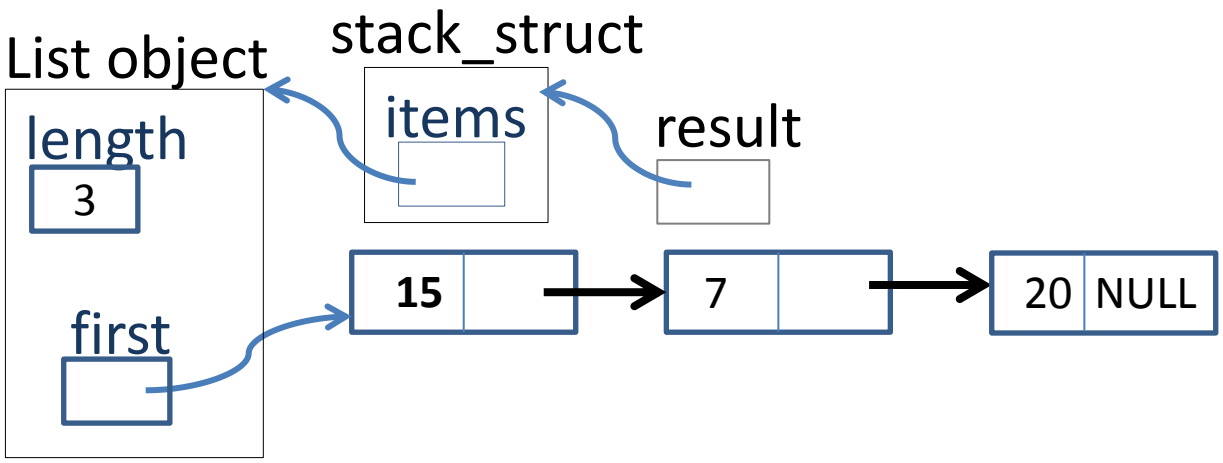
Creating a New Stack

```
typedef struct stack_struct * stack;
struct stack_struct {
    list items;
};
// mx_sz-needed for compatibility with array implementation
stack newStack(int mx_sz) {
    stack result = (stack)malloc(sizeof(*result));
    result->items = newList();  //mem allocation
    return result;
}
```



Destroying a Stack

```
typedef struct stack_struct * stack;
struct stack_struct {
    list items;
};
void destroyStack(stack s) {
    destroyList(s->items);  // free memory
    free(s);
}
```



Pushing an Item

```
typedef struct stack_struct * stack;
struct stack_struct {
    list items;
};

void push(stack s, Item data) {
    link L = newLink(data, NULL);
    insertAtBeginning(s->items, L);
}
```

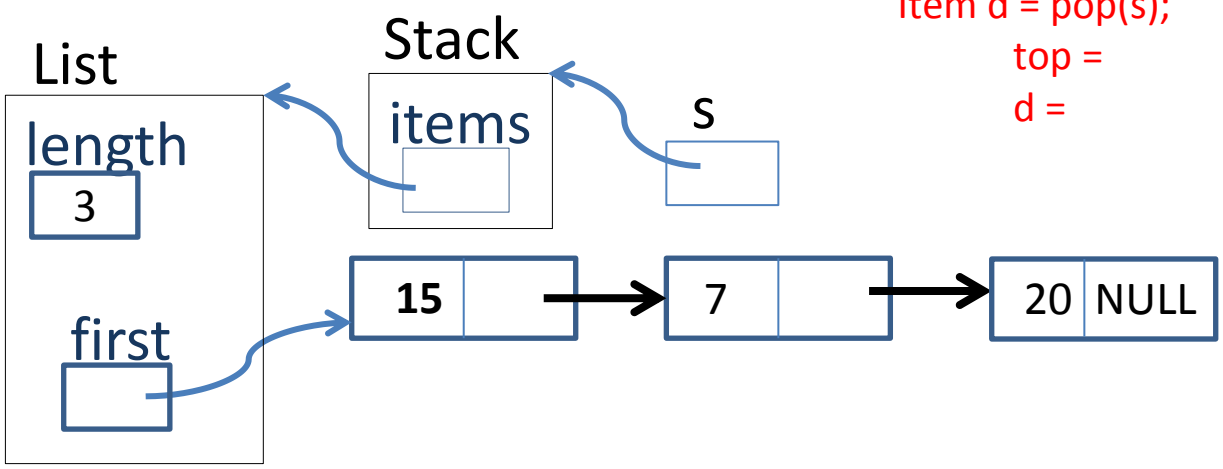
Popping an Item

```
typedef struct stack_struct * stack;
struct stack_struct {
   list items;
};
```

```
Item pop(stack s) {
   link top = removeFirst(s->items);
   return linkItem(top);
}
```

linkItem(`top`) returns the item in the node `top`

What is wrong with this definition of pop?
Item d = pop(s);
top =
d =



Popping an Item

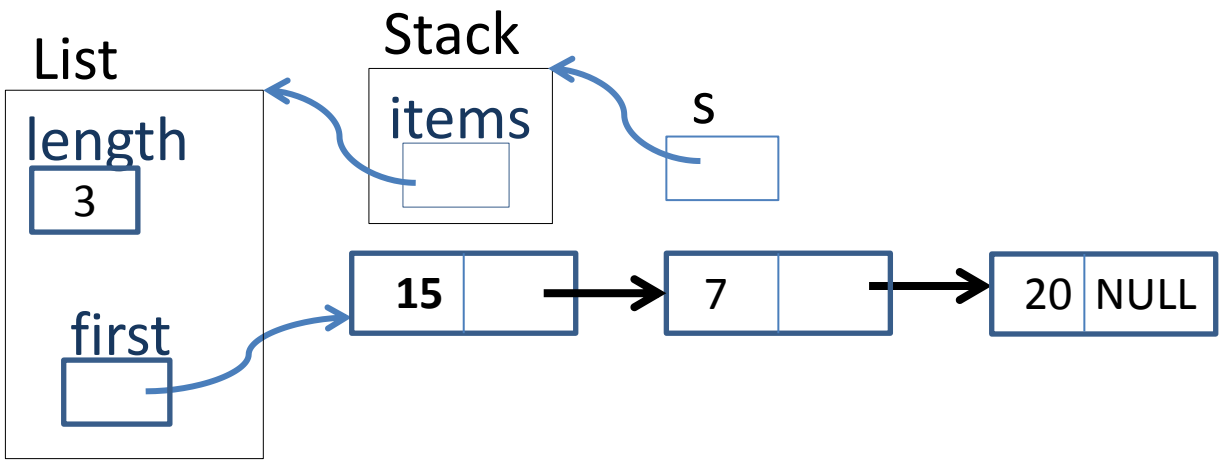
```
typedef struct stack_struct * stack;
struct stack_struct {
   list items;
};

Item pop(stack s) {
   link top = removeFirst(s->items);
   return linkItem(top);
}
```

What is wrong with this definition of **pop**? Memory leak!!!

Popping an Item

```
Item pop(stack s) {
    if (isStackEmpty(s))
        ERROR. No item to remove!!!
    link top = removeFirst(s->items);
    Item item = linkItem(top);
    free(top);
    return item;
}
```



Abstract Datatypes (ADT)

- *ADT* (Abstract Data Type)
  - is a *data type* (a set of values and a collection of operations on those values) that can only be accessed through an *interface*.

- *Client* is a program that uses an ADT.
  - E.g.: walmart.c
  - Will have: #include “list.h”
- *Implementation* is a program that specifies the data type and the operations for it.
  - E.g.: list.c
  - Function definitions and struct definitions (or class definitions)
- *Interface* a list of operations available for that datatype.
  - E.g.: list.h (notice, a header file, not a c file)
  - It will contain headers of functions and typedef for data types,
  - It is *opaque*: the client can not see the implementation through the interface.

WHY use a Stack ADT?

- Why should we have a Stack interface, when all we do is use list operations? Why not use a list directly?
  - **Protection**: from performing unwanted operations (e.g. an insert at a random position in the list)
  - **Flexibility**:
    - To modify the current implementation
    - To use another stack implementation
  - **Isolates the dependency** of the Stack implementation on the List interface: if the list INTERFACE (.h file) is modified we will only need to go and change the STACK implementation (.c file), not all the lines of code where a stack operation is done in all the client programs.
  - It makes the **stack behavior explicit**: what we can do and we can not do with a stack.

“Explicitly, why is this better than just using a list where I only insert and delete from the beginning?”

- Keep in mind that your goal here is to implement a stack datatype, for others to use, not for your own one-time usage.
- Directly providing a list, gives access to operations not allowed for a stack like reversing it, or removing an item other than the ‘top’ one.
- Any client code that includes the stack.h file, can only use the functions provided in that file so they can only call: pop, push, isEmpty, newStack, destroyStack. They can not reverse the list because they do not have access to the stack_struct definition so they can not get the list object.
- A function in the stack_list.cpp file can call any list function but that is the point where you focus on implementing a stack and so you should not do operations that are not allowed. Notice that even in this file, you cannot access fields of the list_struct directly. It has to go through function calls (e.g. you cannot write *my_list->length*, but you can write *getLength(my_list)*). The file stack_list.cpp is a client for list.cpp and so it does not have access to the underlying list representation.

Array-Based Implementation of Stacks

Array-based Stacks

- **Array-based** implementation:
  - What is a stack? What will hold the data of the stack?
  - **push(stack, item)**
    - How? :
    - O(1) - can we get this?
  - **pop(stack)**
    - How? :
    - O(1) - can we get this?

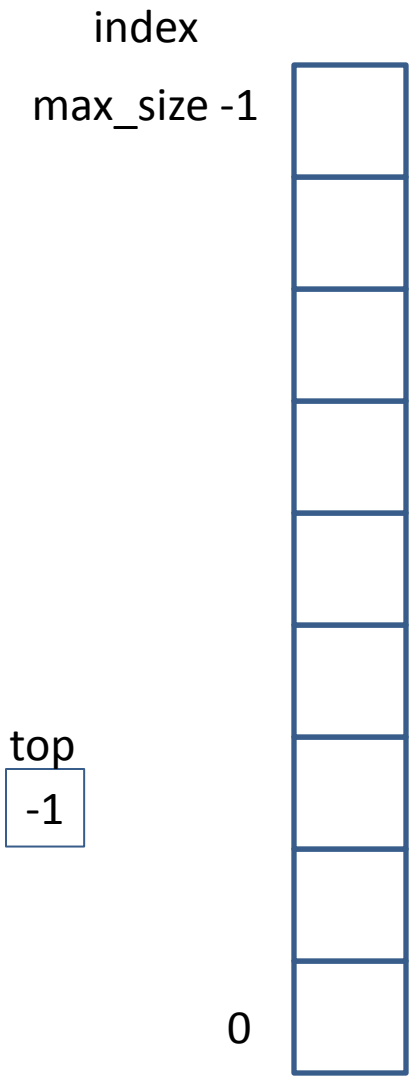
Array-based Stacks

- **Array-based** implementation:
  - What is a stack? What will hold the data of the stack?
    - **An array.**
  - **push(stack, item)**
    - How? : **'insert' at the end of the array.**
    - O(1) - **Yes**
  - **pop(stack)**
    - How? : **'remove' from the end of the array.**
    - O(1) - **Yes**

- See stack_array.c

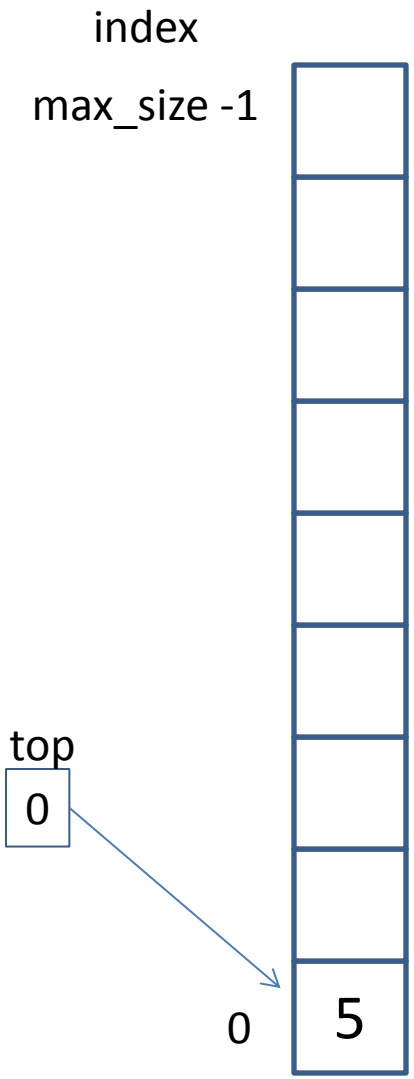
Array-based Stacks

push(5)
push(8)
push(20)
pop()



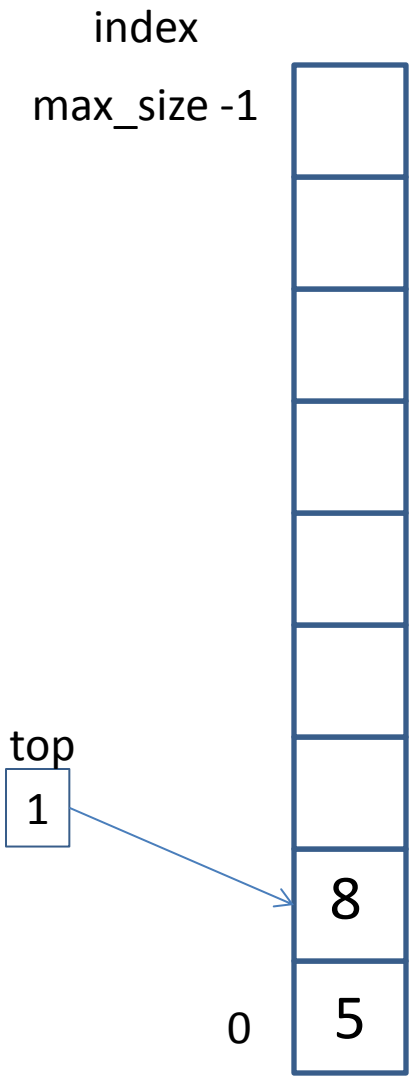
Array-based Stacks

push(5)
push(8)
push(20)
pop()



Array-based Stacks

push(5)
push(8)
push(20)
pop()



Array-based Stacks

push(5)
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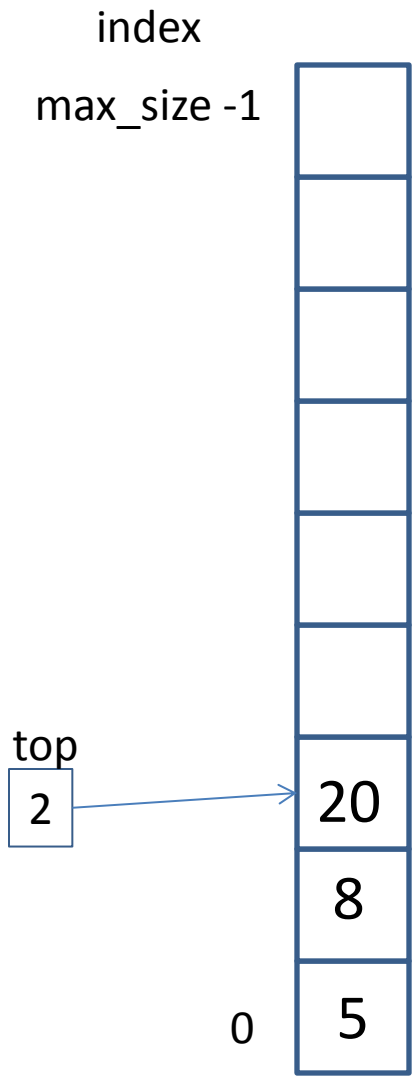
pop()



Array-based Stacks

push(5)
push(8)
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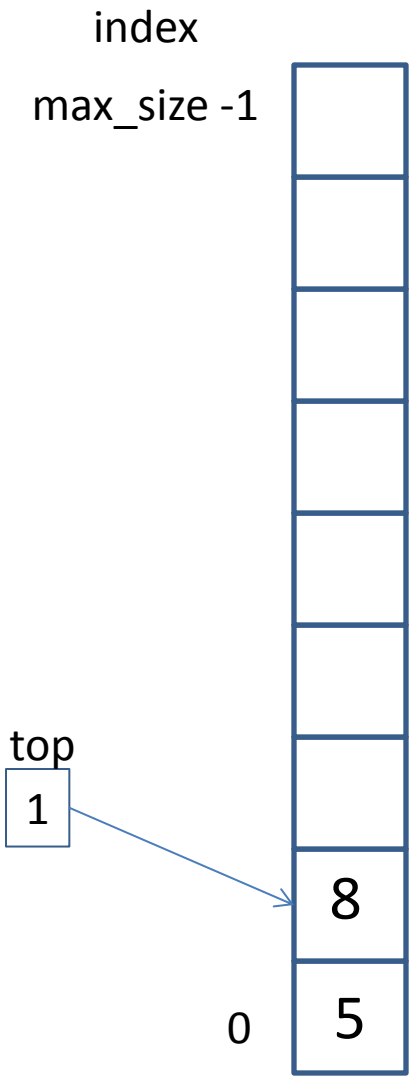
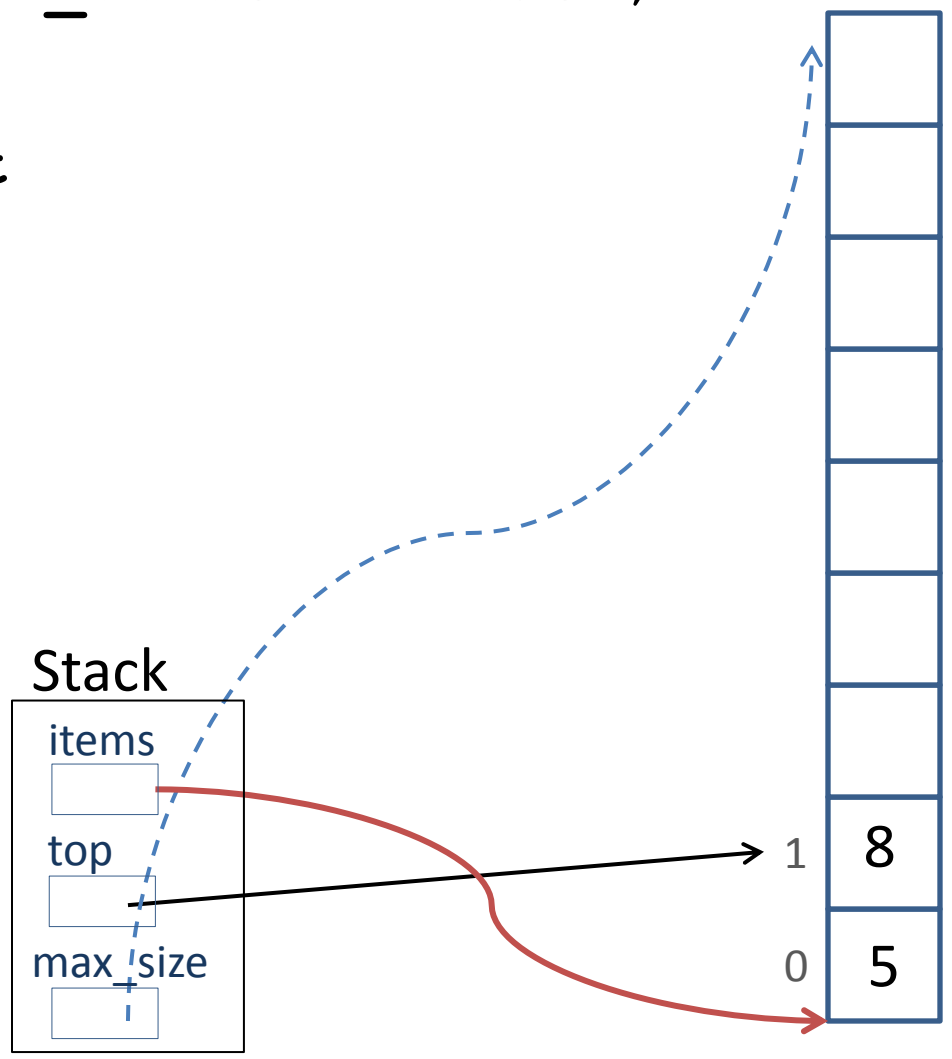
pop()



Defining Stacks Using Arrays

```
typedef struct stack_struct * stack;

struct stack_struct
{
    Item * items;
    int top;
    int max_size;
};
```

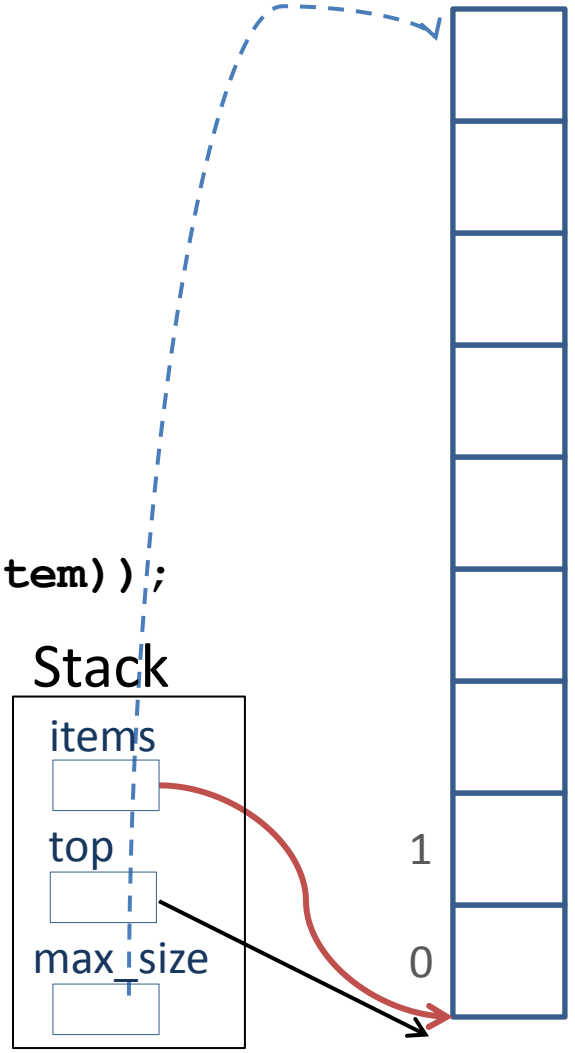


Creating a New Stack

```
struct stack_struct
{ Item * items;
  int top;
  int max_size;
};

stack newStack(int mx_sz)
{
  stack res = (stack)malloc(sizeof(*res));
  res->items = (Item*)malloc(mx_sz*sizeof(Item));
  res->max_size = mx_sz;
  res->top = -1;
  return res;
}
```

Do not use an array for items (e.g. items[100])!
See the Victim-TAB example showing the difference between Stack and Heap memory.



Destroying a Stack

```
struct stack_struct
{   Item * items;
    int top;
    int max_size;
};

void destroyStack(stack s)
{
    free(s->items); // s->items is an array
    free(s);
}
```

Pushing an Item

```
struct stack_struct
{   Item * items;
    int top;
    int max_size;
};
```

```
void push(stack s, Item data)
{
    if (s->top == s->max_size - 1)
        ERROR. No more room ( the array is full)!!!
        return;

    s->top = s->top + 1;
    s->items[s->top] = data;
}
```

Popping an Item

```
struct stack_struct
{   Item * items;
    int top;
    int max_size;
};

Item pop(stack s)
{
    if (isStackEmpty(s))
        //ERROR. No data to pop!!!
        return 0; // return zeroItem();
    Item item = s->items[s->top];
    s->top = s->top - 1;
    return item;
}
```