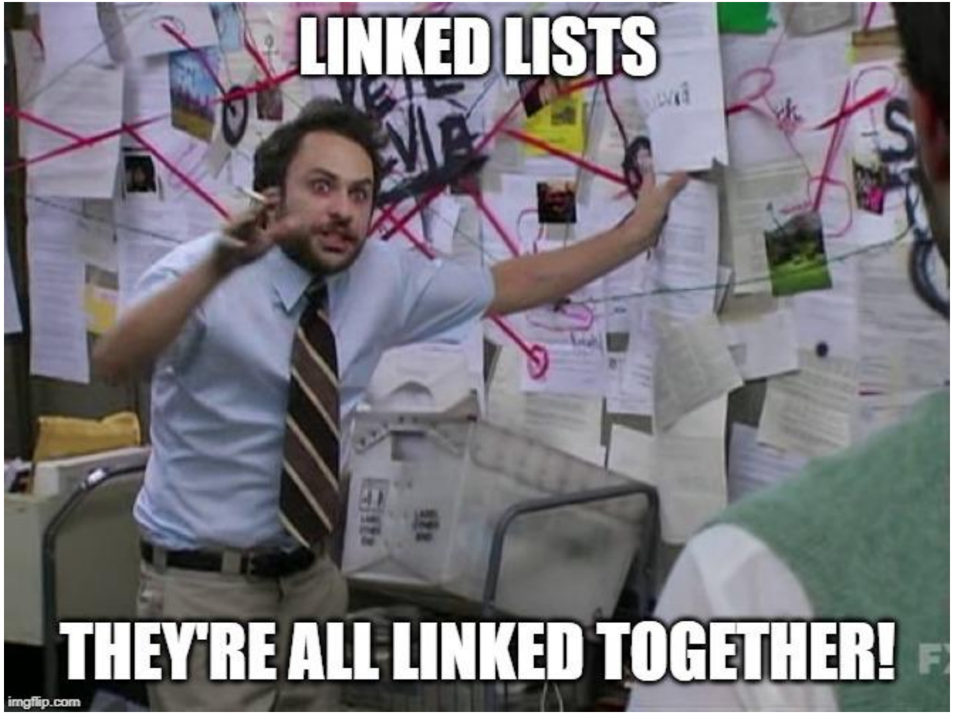
# COMP1511 - Programming Fundamentals

Week 9 - Lecture 15

# What did we learn last week?

**Linked Lists**

- A complete working implementation of Linked Lists
- Inserting nodes
- Removal of nodes
- Cleaning our memory



# What are we covering today?

**Abstract Data Types**

- A recap of Multiple File Projects
- More detail on things like typedef
- The ability to present capabilities of a type to us . . .
- . . . without exposing any of the inner workings

# Recap - Multiple File Projects

**Separating Code into Multiple files**

- Header file (`*.h`) - Function Declarations
- Implementation file (`*.c`) - Majority of the running code
- Other files - can include a Header to use its capabilities

**Separation protects data and makes functionality easier to read**

- We don't have access to internal information we don't need
- We can't accidentally change something important
- We have a simple list of functions we can call

# Using Multiple Files

## Linking the Files

- A file that **`#include`**s the Header (**`*.h`**) file will have access to its functions
- A Header's own implementation (**`*.c`**) file will always **`#include`** it
- Implementation (**`*.c`**) files are never included!

## Compilation

- All Implementation (**`*.c`**) files are compiled
- Header (**`*.h`**) files are never compiled, they're included

# An Example - CS Beats

**Assignment 2 - CS Beats is a nice example**

**`beats.h`**

- Contains only defines, typedefs and function declarations
- Is commented heavily so that it's easy to know how to use it

**`beats.c`**

- Contains actual structs
- Contains implementation of **`beats.h`**'s functions (once we've written them)

# An Example - CS Beats

**How does the main file relate to the beats files?**

**`main.c`**

- **`#include`**s **`beats.h`**
- Uses the functions in **`beats.h`**

# Abstract Data Types

**Types we can declare for a specific purpose**

- We can name them
- We can fix particular ways of interacting with them
- This can protect data from being accessed the wrong way

**We can hide the implementation**

- Whoever uses our code doesn't need to see how it was made
- They only need to know how to use it

# Typedef

## Type Definition

- We declare a new Type that we're going to use
- `typedef <original Type> <new Type Name>`
- Allows us to use a simple name for a possibly complex structure
- More importantly, hides the structure details from other parts of the code

```
typedef struct library *Library;
```

- We can use **`Library`** as a Type without knowing anything about the struct underlying it

# Typedef in a Header file

**The Header file provides an interface to the functionality**

- We can put this in a header (`*.h`) file along with functions that use it
- This allows someone to see a Type without knowing exactly what it is
- The details go in the `*.c` file which is not included directly
- We can also see the functions without knowing how they work

- We are able to see the **header** and use the information
- We hide the **implementation** that we don't need to know about

# An Example of an Abstract Data Type - A Stack

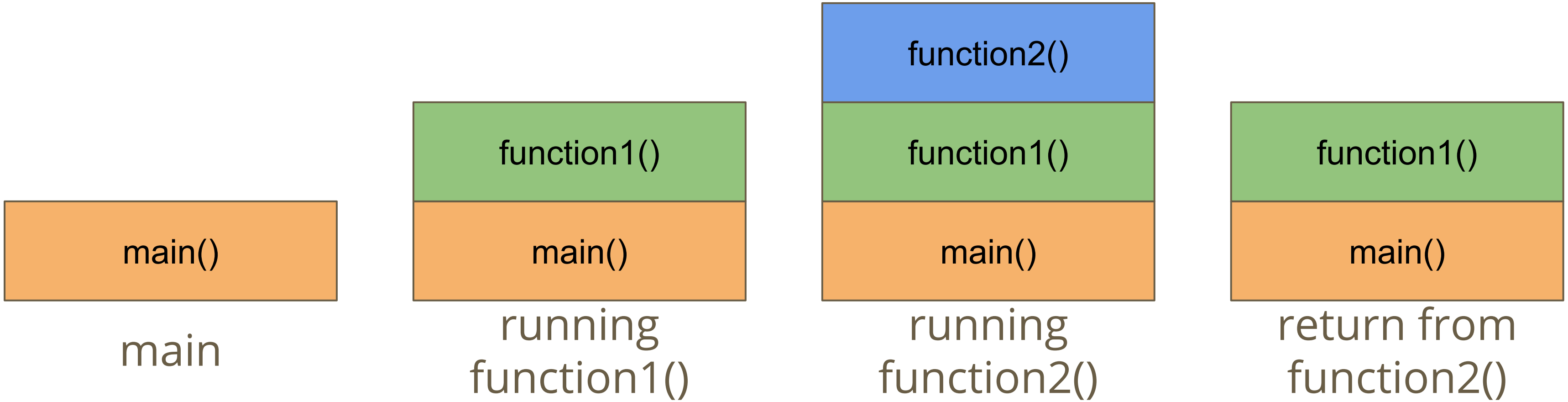
**A stack is a very common data structure in programming**

- It is a "Last in first out" structure
- You can put something on top of a stack
- You can take something off the top of a stack
- You can't access anything underneath

# This is actually how functions work!

**The currently running code is on the top of the stack**

- **`main()`** calls **`function1()`** - only **`function1()`** is accessible
- **`function1()`** calls **`function2()`** - only **`function2()`** is accessible
- control returns to **`function1()`** when **`function2()`** returns



# What makes it Abstract?

**A Stack is an idea**

- An Array or a Linked List is a very specific implementation
- A Stack is just an idea of how things should be organised
- There's a set of rules, but there's no implementation!

**Abstract Data Type for a Stack**

- We can have a header saying how the Stack is used
- The Implementation could use an Array or a Linked List to store the objects in the Stack, but we wouldn't know!

# Break Time

**Programming Languages**

- C++, Java, C# and many others are based on C
- There are too many programming languages to count or learn!

- Remember the fundamentals!
- C syntax is not as important as your plans and thinking
- You will encounter many programming languages, some will feel very different from C in their approach
- But if you learn how you want to communicate with computers, the actual language you use will never be a barrier for you

# Let's build a Stack ADT

**We're only concerned with how we'll use it, not what it's made of**

- Our user will see a "Stack" rather than an Array or Linked List
- We will start with a Stack of integers
- We will provide access to certain functions:
  - Create a Stack
  - Destroy a Stack
  - Add to the Stack (known as "push")
  - Remove from the Stack (known as "pop")
  - Count how many things are in the Stack

# A Header File for a Stack

```c
// stack type hides the struct that it is implemented as
typedef struct stack_internals *Stack;

// functions to create and destroy stacks
Stack stack_create(void);
void stack_free(Stack s);

// Push and Pop items from stacks
// Removing the item returns the item for use
void stack_push(Stack s, int item);
int stack_pop(Stack s);

// Check on the size of the stack
int stack_size(Stack s);
```

# What does our Header (not) Provide?

**Standard Stack functions are available**

- We can push or pop an element onto or off the Stack
- We are not given access to anything else inside the Stack!
- We cannot pop more than one element at a time
- We aren't able to loop through the Stack

**The power of Abstract Data Types**

- They stop us from accessing the data incorrectly!

# Stack.c

**Our *.c file is the implementation of the functionality**

- The C file is like the detail under the "headings" in the header
- Each declaration in the header is like a title of what is implemented

- Let's start with a Linked List as the underlying data structure
- A Linked List makes sense because we can grow it and shrink it easily
- We can also look at how to implement this with arrays . . .

# The implementation behind a type definition

## We can create a pair of structs

- `stack_internals` represents the whole Stack
- `stack_node` is a single element of the list

```
// Stack internals holds a pointer to the start of a linked list
struct stack_internals {
    struct stack_node *head;
};

struct stack_node {
    struct stack_node *next;
    int data;
};
```

# Creation of a Stack

**If we want our struct to be persistent, we'll allocate memory for it**

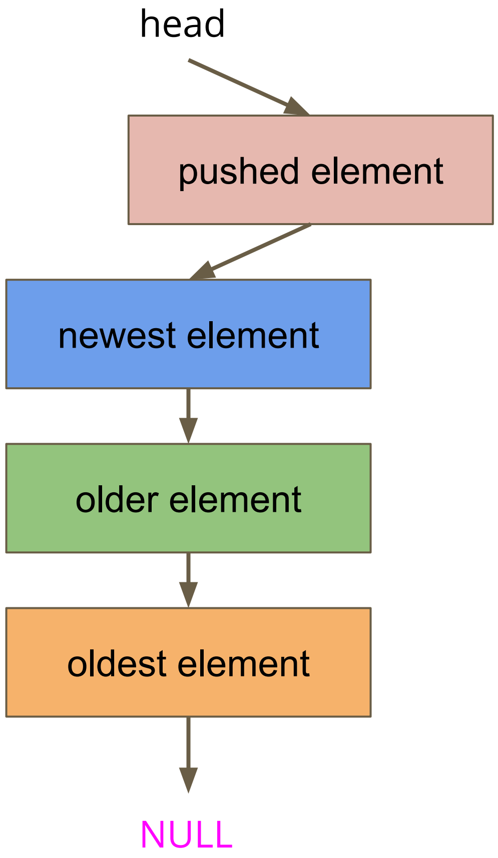
We create our Stack empty, so the pointer to the head is NULL

```
// Create an empty Stack
Stack stack_create(void) {
    Stack new_stack = malloc(sizeof(struct stack_internals));
    new_stack->head = NULL;
    return new_stack;
}
```

# Pushing items onto the Stack

**We push items onto the head of the Stack**

- We can insert the new element at the head
- All the other elements will stay in the same order they were in



# Code for Pushing

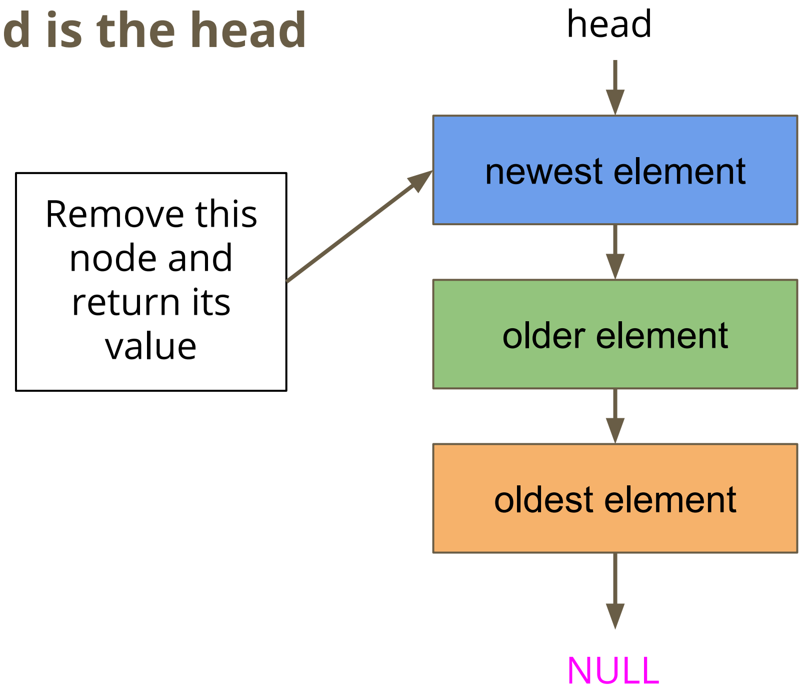
## Adding to the head of a linked list is something we've done before

```
void stack_push(Stack s, int item) {
    struct stack_node *new_node = malloc(sizeof(struct stack_node));
    new_node->data = item;

    // Attach new_node to the old head and make it the new head
    new_node->next = s->head;
    s->head = new_node;
}
```

# Popping (removing) a Node

**The only node that can be popped is the head (the top of the stack)**



# Code for Popping

```
// Remove the head from the list and free the memory used
int stack_pop(Stack s) {
    if (s->head == NULL) {
        printf("Attempt to pop an element from an empty stack.\n");
        exit(1);
    }
    // Read the value from the head
    int return_data = s->head->data;
    struct stack_node *remNode = q->head;

    // move the stack head to the new head and free the old
    s->head = s->head->next;
    free(remNode);

    return return_data;
}
```

# Testing Code in our Main.c

```
int main(void) {
    printf("Creating a deck of cards.\n");
    Stack deck = stack_create();

    int card = 7;
    printf("Putting %d on top of the deck!\n", card);
    stack_push(deck, card);
    card = 10;
    printf("Putting %d on top of the deck!\n", card);
    stack_push(deck, card);

    printf("Card %d just got removed from the deck!\n", stack_pop(deck));

    card = 3;
    printf("Putting %d on top of the deck!\n", card);
    stack_push(deck, card);
}
```

# Other Functionality

**There are some functions in the header we haven't implemented**

- **Destroying and freeing the Stack**
- We're still at risk of leaking memory because we're only freeing on removal
- **Checking the Number of Elements**
- This would be very handy because it would allow us to tell how many elements we can pop before we risk errors
- You could even store an int in the Stack struct that increments every time you push and decrements every time you pop . . .

# Different Implementations

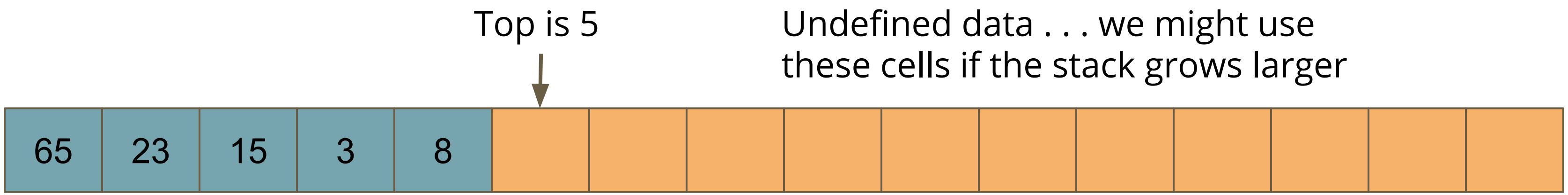
**Stack.c doesn't have to be a linked list . . . so long as it implements the functions in Stack.h**

- We could use an array instead
- Our data can be stored in an array with a large maximum size
- We'll keep track of where the top is with an int

# Array Implementation of a stack

**A large array where only some of it is used**

- Top is a particular index
- Top signifies where our data ends
- It also happens to be exactly the number of elements in the stack!



# stack.c

```
// Struct representing the stack using an array
struct stack_internals {
    int stack_data[MAX_STACK_SIZE];
    int top;
};

// create a new stack
stack stack_create() {
    stack s = malloc(sizeof(struct stack_internals));
    s->top = 0;
    return s;
}
```

# Push and Pop

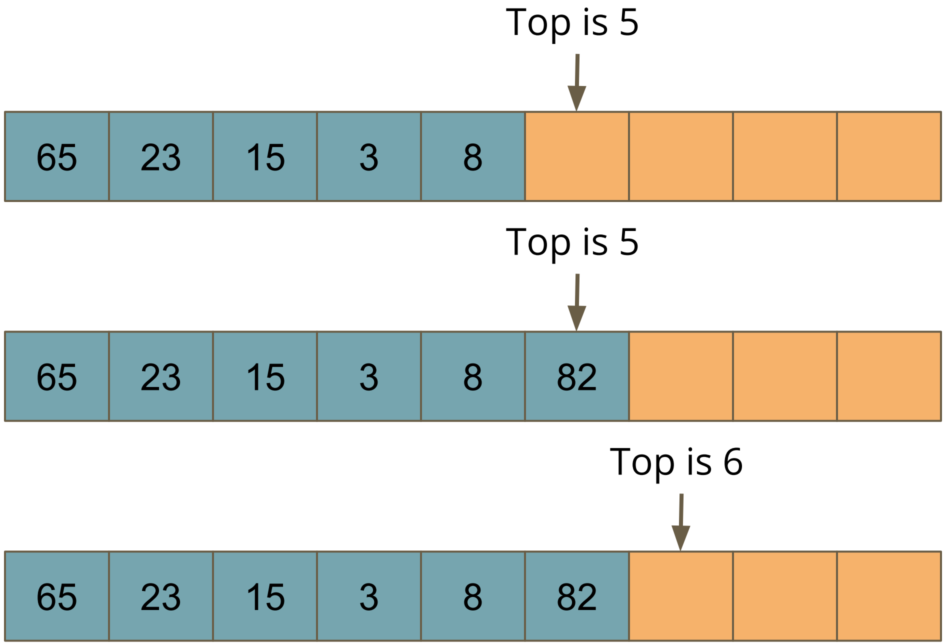
**These should only interact with the top of the stack**

- **Push** should add an element after the end of the stack
- It should then move the top index to that new element

- **Pop** should return the element on the top of the stack
- It should then move the top index down one

# Push

**Push a new element "82" onto the stack**




The stack starts like this

82 is added at top's index

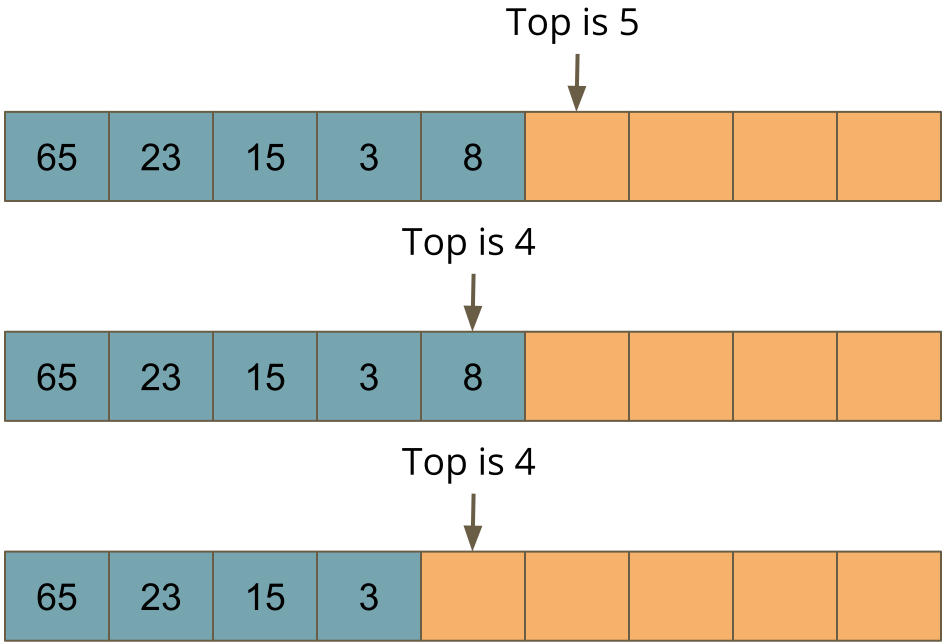
Top then moves up one

# Push code

```
// Add an element to the top of the stack
void stack_push(stack s, int item) {
    // check to see if we've used up all our memory
    if(s->top == MAX_STACK_SIZE) {
        printf("Maximum stack size reached, cannot push.\n");
        exit(1);
    }
    s->stack_data[s->top] = item;
    s->top++;
}
```

# Pop

**Pop removes the top element from the stack**




The stack starts like this

Top moves down one

Read the element at top and return it

# Pop code

```
// Remove an element from the top of the stack
int stack_pop(stack s) {
    // check to see if the stack is empty
    if(s->top <= 0) {
        printf("Stack is empty, cannot pop.\n");
        exit(1);
    }
    s->top--;
    return s->stack_data[s->top];
}
```

# Hidden Implementations

**Neither Implementation needs to change the Header**

- The main function doesn't know the difference!
- The structures and implementations are hidden from the header file and the rest of the code that uses it
- If we want or need to, we can change the underlying implementation without affecting the main code

# Other Abstract Data Types

**Stacks are obviously not the only possibility here**

- If we simply change the rules (last in, first out), we can make other structures
- A Queue is "first in, first out", and could be created using similar techniques
- There are many possibilities that we can create!

# What did we cover today?

**Abstract Data Types**

- Makes use of Multi-file projects we discussed earlier
- `typedef` to protect a struct from open access
- Using multiple files to control how a type is used
- Hiding the implementation
- Providing a fixed interface
- Showing that different implementations can work with the same ADT