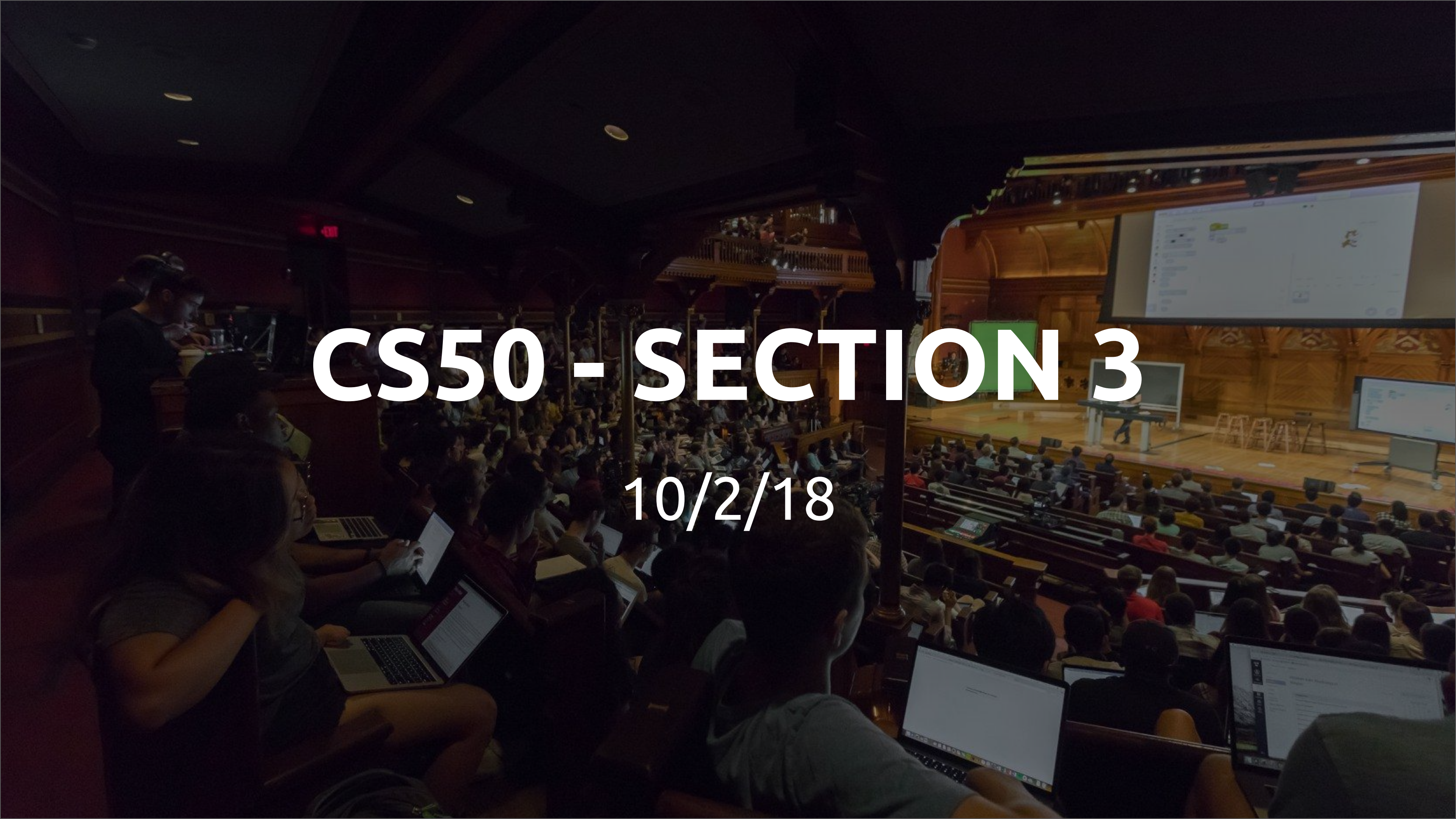


CS50 - SECTION 3

10/2/18

POST-MORTEM
ON
PSET 2

REMINDERS

1. Avoid magic numbers - Use `#define` directives, global constants, or a more expressive type instead

```
char c = (((plaintext[i] - 65) + key) % 26) + 65;
```

REMINDERS

1. Avoid <u>magic numbers</u> - Use **`#define`** directives, global constants, or a more expressive type instead

```c
char c = (((plaintext[i] - 65) + key) % 26) + 65;
```

REMINDERS

1. Avoid magic numbers - Use **`#define`** directives, global constants, or a more expressive type instead

```
char c = (((plaintext[i] - 65) + key) % 26) + 65;
```

Refactor magic numbers to something another programmer reading your code can understand:

```
char c = (((plaintext[i] - 'A') +
key) % 26) + 'A';
```

REMINDERS

2. Know the difference between explicit and implicit casting.

```c
#include <stdio.h>

int main(void) {
    int x = 7;
    printf("%i\n", x + (int) 'c');
}
```

REMINDERS

2. Know the difference between explicit and implicit casting.

```c
#include <stdio.h>


int main(void) {
    int x = 7;
    printf("%i\n", x + (int) 'c');
}
```

This is an example of explicit casting. However, C does implicit casting for you when working with arithmetic operators:

```c
#include <stdio.h>


int main(void) {
    int x = 7;
    printf("%i\n", x + 'c');
}
```

REMINDERS

3. `check50` is delicate…

REMINDERS

4. Always perform error checking at the top of your code and explicitly check for the error, *not* for valid input.

```
#include <stdio.h>
int main(void) {
   if (argc == 2)
   {
       // Rest of my code goes here...
       return 0;
   }
   else {
       printf("Incorrect input.\n")
       return 1;
   }
}
```

REMINDERS

4. Always perform error checking at the top of your code and explicitly check for the error, *not* for valid input.

```
#include <stdio.h>
int main(void) {
   if (argc == 2)
   {
       // Rest of my code goes here...
       return 0;
   }
   else {
       printf("Incorrect input.\n")
       return 1;
   }
}
```

This forces you to indent all of the code in your `main` function unnecessarily and makes it unclear what actually triggers an error in your program.

REMINDERS

4. Always perform error checking at the top of your code and explicitly check for the error, *not* for valid input.

```
#include <stdio.h>
int main(void) {
    if (argc != 2)
    {
        printf("Incorrect input.\n")
        return 1;
    }

    // Rest of my code goes here...
    return 0;
}
```

This is preferred! Notice no `else` branch is needed if the input is valid.

REMINDERS

5. Note that **`main`** will return 0 automatically if you don't specify a non-zero return.

```
#include <stdio.h>

int main(void) {
    if (argc != 2)
    {
        printf("Incorrect input.\n")
    }

    // Rest of my code goes here...
    return 0;
}
```

REMINDERS

5. Note that `main` will return 0 automatically if you don't specify a non-zero return.

```
#include <stdio.h>

int main(void) {
    if (argc != 2)
    {
        printf("Incorrect input.\n")
    }

    // Rest of my code goes here...
}
```

This will return `0`. Also note that without a `return 1` statement, it will run the rest of the code until it hits the end of the main function, at which that point it will return `0`.

REMINDERS

5. Only comment on non-obvious code.

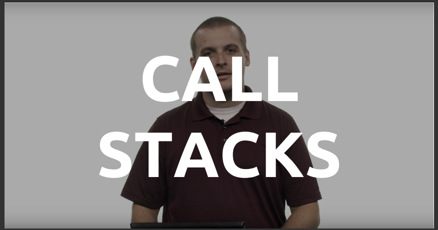
REFLECTIONS:

PSET 2

What was most difficult: correctness, design, or style? Do you think that will always be the case moving forward?

CONCEPTS DEEP-DIVE

“SHORTS” FOR THE WEEK



https://youtu.be/j_oJoK0LoJY

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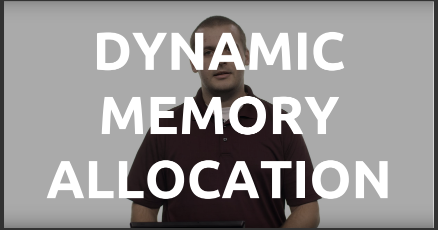

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PROBLEM SOLVING HANDOUT

Based off George Polya's How to Solve It, additions by Annie Chen, updated Fall 2017 by Amanda Vosburgh

How to Solve a CS50 Pset

1. Understanding the Problem

"What is the unknown? What is the data? What is the goal? Break the problem into parts"

What is the spec asking you to do? What types of input will you be taking? What should your program be outputting?

Steps: Write down the requirements for the spec in your own words. Watch the walkthrough.

2. Devising a Plan

"Have you seen it before? Do you know a related problem? Tackle the problem one part at a time"

How can you turn the inputs into outputs as a person? How can you get the program to do the same thing? What assumptions/prior knowledge did you as a person use? How can you get your program to know the same thing?

Steps: Using the sample inputs from the spec, figure out (without code) how to get to the outputs. Write down the steps you used to do that. Write down the pseudocode/hints from the walkthrough. Outline the entire program in pseudocode in your source code file.

3. Carrying Out The Plan: Use Examples! Use Google!

Turning concepts into code is often the difficult part, especially if you don't know how to start. What problems have you seen like this before? (In section or lecture?)

Steps: Look back on the source code from the week's lecture/section. How can you change that code to use in your pset? Figure out how the code snippets from the walkthrough fit into your pseudocode. Search reference50 and Google for more information on the functions mentioned in the psets. Understand what inputs they take and what they return. Fit them into your pseudocode.

4. Looking Back: Test Your Code!

"Can you check the result? Can you derive the result differently?"

How does your program handle invalid input? Does it ever crash? Could you have implemented the solution more efficiently?

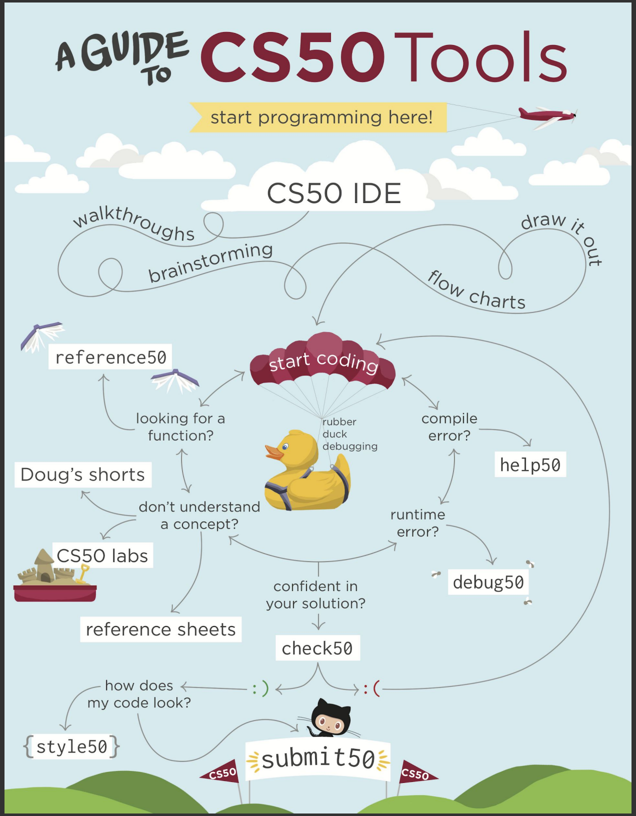
Steps: Run check50. Pinpoint what inputs (if any) your program is failing on, and figure out why they're failing. For help, use CS50 Discourse or Office Hours. Look carefully through your code for areas of improvement. Factor out common code, comment to make intent clear, fix style. When pset is graded, review feedback. Ask for clarification if needed. Watch Postmortem video. Consider how your code could be further improved, and different ways solution could have been implemented.

Checklist

- [ ] **Understand the Problem**
  - [ ] Write down the requirements for the spec in your own words.
- [ ] **Devise A Plan**
  - [ ] Watch the walkthrough.
  - [ ] Write down the pseudocode/hints from the video.
  - [ ] Using the sample inputs from the spec, figure out (without code) how to get to the outputs.
    - [ ] Write down the steps you used to do that.
  - [ ] Outline the entire program in pseudocode in your source code file.
- [ ] **Carry Out the Plan**
  - [ ] Look back on the source code from the week's lecture/section. How can you change that code to use in your pset?
  - [ ] Figure out how the code snippets from the walkthrough fit into your pseudocode.
  - [ ] Search reference50 and Google for more information on the functions mentioned in the psets.
    - [ ] Understand what inputs they take and what they return.
    - [ ] Fit them into your pseudocode.
- [ ] **Check Your Work**
  - [ ] Run check50.
    - [ ] Pinpoint what inputs (if any) your program is failing on, and figure out why they're failing.
    - [ ] For help, use CS50 Discourse or Office Hours.
  - [ ] Look carefully through your code for areas of improvement.
    - [ ] Factor out common code.
    - [ ] Add comments to make intent clear.
    - [ ] Fix style.
  - [ ] When pset is graded, review feedback.
    - [ ] Ask for clarification if needed.
    - [ ] Watch Postmortem video.
      - [ ] Consider how your code could be further improved, and different ways solution could have been implemented.

https://github.com/wadesilvestro/cs50-fall18/blob/master/handouts/solveit.pdf

USE ALL THE TOOLS & RESOURCES AVAILABLE TO YOU



PASSING DATA IN C

Remember from last week, when we wanted to know what the following code would print:

```c
#include <stdio.h>

int main(void) {
   int x = 7;
   int y = x;
   x = 2;

   printf("%i\n", y);
}
```

PASSING DATA IN C

Remember from last week, when we wanted to know what the following code would print:

This will print 2. Why?

```
#include <stdio.h>

int main(void) {
    int x = 7;
    int y = x;
    x = 2;

    printf("%i\n", y);
}
```

PASSING DATA IN C

Remember from last week, when we wanted to know what the following code would print:

```
#include <stdio.h>

int main(void) {
    int x = 7;
    int y = x;
    x = 2;

    printf("%i\n", y);
}
```

This will print 7. Why?

Because C passes the majority of variables *by value*. That means x is set equal to 7. Then y is set equal to value that x represents, which is 7. We change the value of x, but y was set equal to 7, so it prints 7.

PASSING DATA IN C

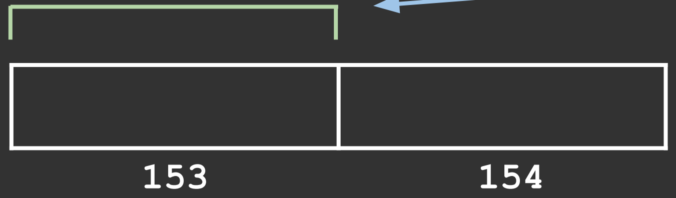
Check out this diagram which represents our computer *memory*:

The number 153 represents our location in memory. We're looking at two "slots" of contiguous memory right now.

PASSING DATA IN C

Check out this diagram which represents our computer *memory*:

We can imagine each memory slot to be 4 bytes each.



The number 153 represents our location in memory. We're looking at two "slots" of contiguous memory right now.

PASSING DATA IN C

```c
int x = 7;
```

The program looks for a memory slot big enough to hold an integer, finds slot #154 is free, and then assigns `x` to it.

PASSING DATA IN C

```c
int x = 7;
```

The program looks for a memory slot big enough to hold an integer, finds slot #154 is free, and then assigns `x` to it.

PASSING DATA IN C

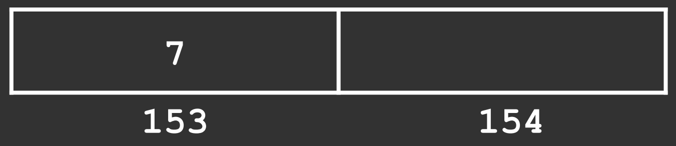
```
int y = x;
```

The program looks for another memory slot big enough to hold an integer. It finds slot #154 and reserves it for `y`.

PASSING DATA IN C

```
int y = x;
```

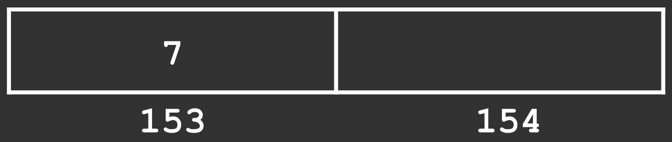
It then goes to the slot in x and finds what that value is.



PASSING DATA IN C

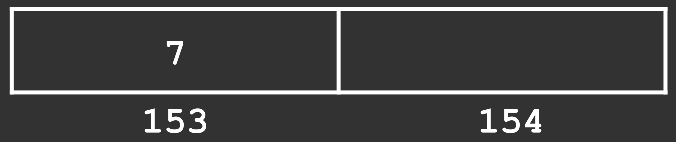
```
int y = x;
```

It then goes to the slot in x and finds what that value is.



PASSING DATA IN C

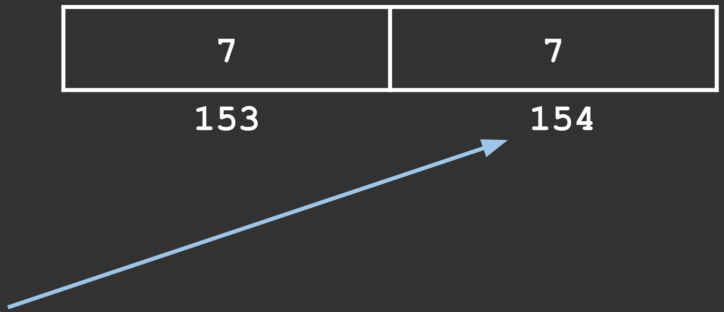
```c
int y = x;
```



Well, `x` is a variable that holds an integer equal to 7, so it passes that value back to the assignment operator.

PASSING DATA IN C

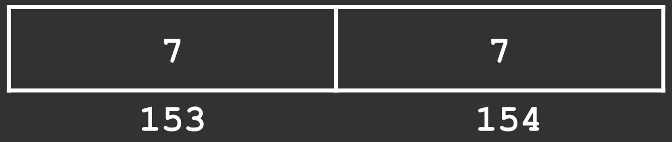
```c
int y = x;
```



Memory location #154 gets set equal to the value of `x`.

PASSING DATA IN C

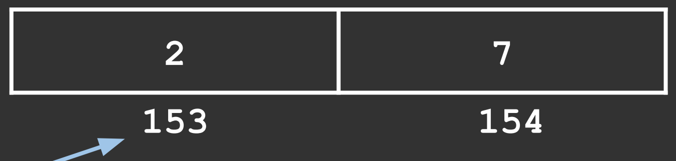
```
x = 2;
```



The assignment operator has been passed the value of 2 to update what is stored in `x`'s memory location.

PASSING DATA IN C

```
x = 2;
```



The memory location for `x` is found and updated.

PASSING DATA IN C

```
printf("%i\n", y);
```

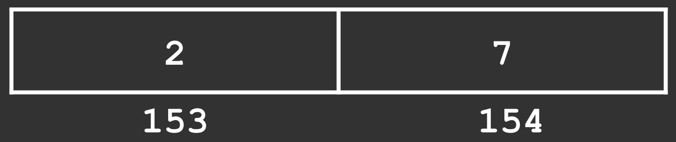
2	7

153 154

The `printf()` function is passed `y` by value.

PASSING DATA IN C

```
printf("%i\n", y);
```



The program looks for the address of `y` in memory and retrieves the value.

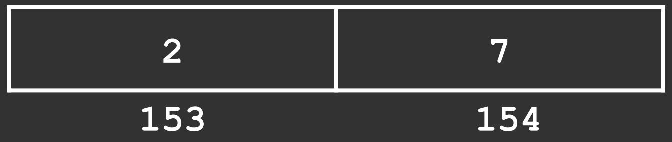
PASSING DATA IN C

```
printf("%i\n", y);
```

The `printf()` statement prints 7, the value stored at the address for `y`.

PASSING DATA IN C

```
printf("%i\n", y);
```



The `printf()` statement prints 7, the value stored at the address for `y`.

SO WHAT ABOUT THIS MATTERS?

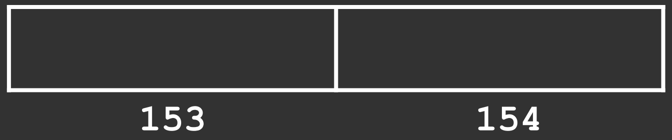
Everything you've seen thus far has been passing by value.

But we can also pass by reference. This means you pass the actual address of a memory location rather than the value store there.

How can we accomplish that?

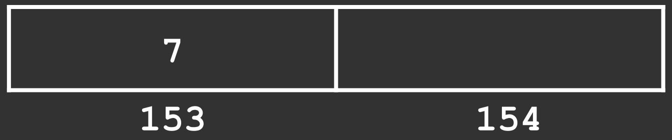
WHAT IS A POINTER?

To learn to pass by reference, we must first learn about **pointers**. Recall our memory diagram from before:



WHAT IS A POINTER?

```c
int x = 7;
```



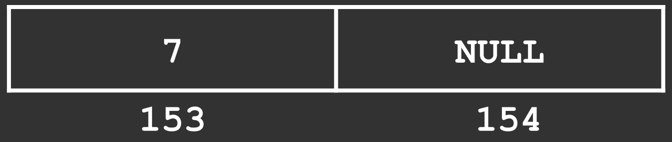
This statement assigned the value of 7 to memory location #153.

WHAT IS A POINTER?

```
int x = 7;

int *p = NULL;
```

Now we've declared a pointer and set it equal to NULL.

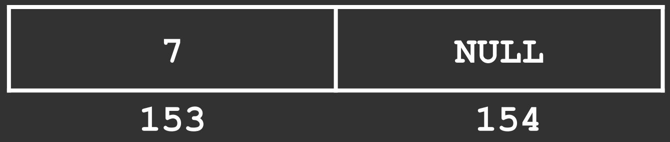


WHAT IS A POINTER?

```c
int x = 7;

int *p = NULL;
```

Now we’ve declared a pointer and set it equal to NULL.



Pointer p also takes up a memory location: slot #154. Pointers are variables too! They’re just variables that store memory locations.

WHAT IS A POINTER?

```c
int x = 7;

int *p = NULL;

p = &x;
```

7	0x99
153	154

We now pass `x` by reference and assign it to `p`. This means we get the memory location for `x` and set `p` equal to it.

WHAT IS A POINTER?

```
int x = 7;

int *p = NULL;

p = &x;
```

7	0x99
153	154

We now pass `x` by reference and assign it to `p`. This means we get the memory location for `x` and set `p` equal to it.

Note that `0x99` is stored at memory location #154. Memory locations are actually represented as hexadecimal numbers: `153 = 0x99`.

WHAT IS A POINTER?

```
int x = 7;
int *p = NULL;
p = &x;
int y = *p;
```

7	0x99	7
153	154	155

Now we *dereference* our pointer and assign the value of the memory address it points to in y.

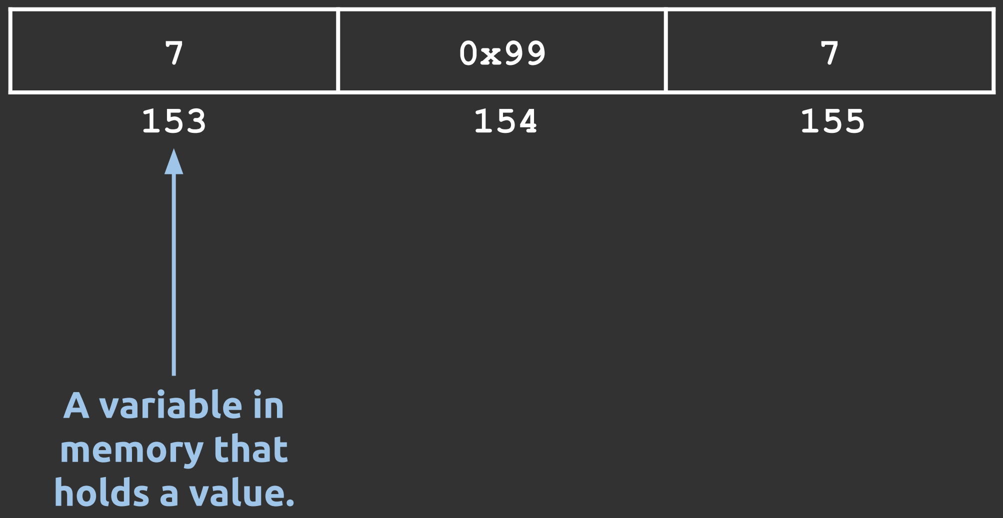
WHAT IS A POINTER?

So what do we have?

`7`	`0x99`	`7`
`153`	`154`	`155`

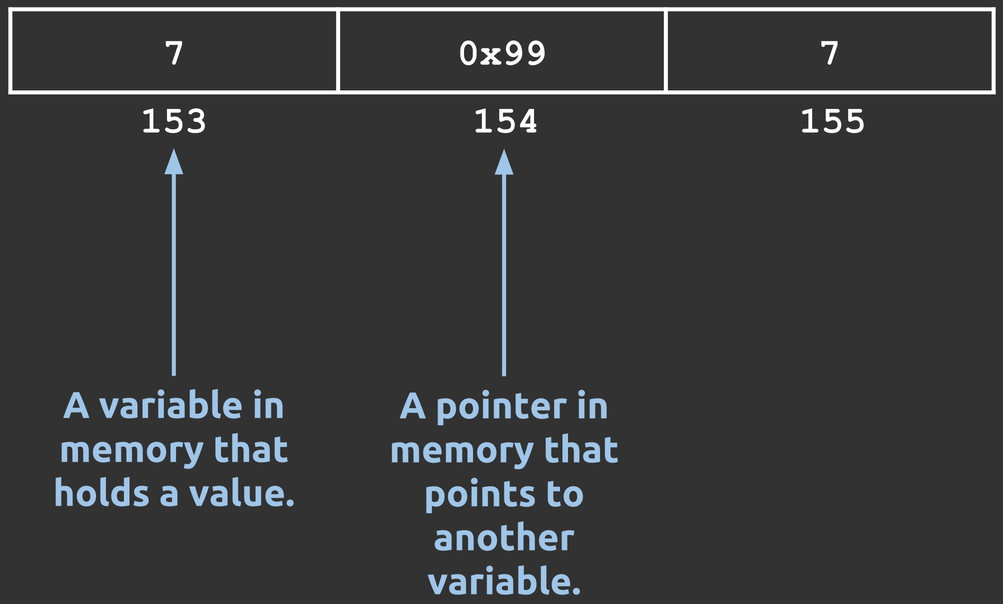
WHAT IS A POINTER?

So what do we have?



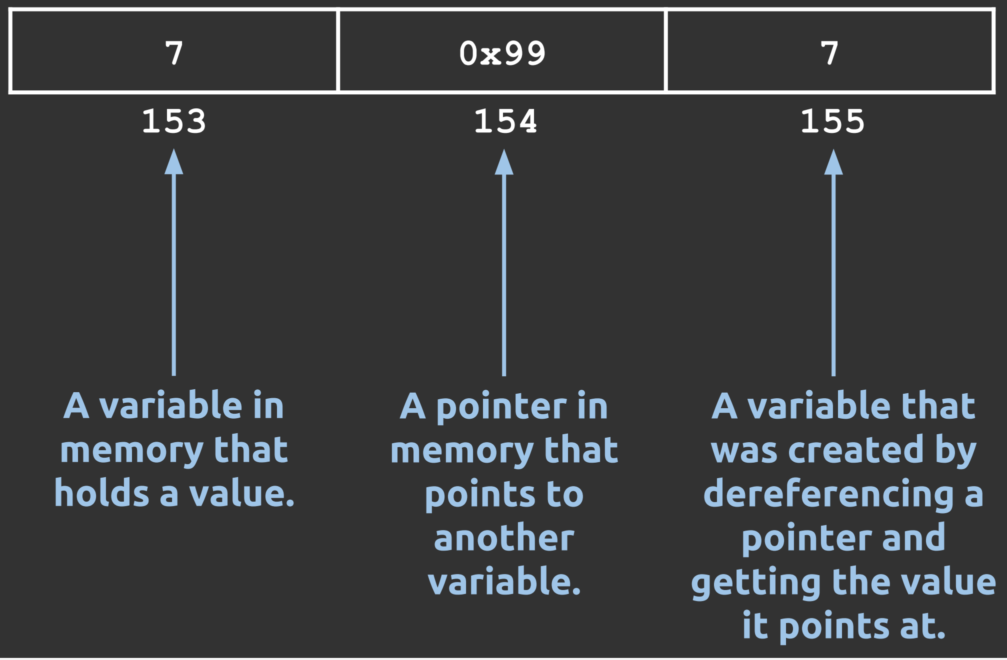
WHAT IS A POINTER?

So what do we have?



WHAT IS A POINTER?

So what do we have?



THE NULL POINTER

The simplest type of pointer in C is the null pointer:

```
int *pointer = NULL;
```

THE NULL POINTER

The simplest type of pointer in C is the null pointer:

```
int *pointer = NULL;
```

If you declare a pointer and don't use it immediately, best practices call for immediately setting it to null.

WORKING WITH POINTERS

So we've established that we can create a pointer the following way:

```
int *pointer;
```

WORKING WITH POINTERS

We can get the address of another variable using the `&` operator:

```c
int x = 3;
int *pointer = &x;
```

WORKING WITH POINTERS

We can get the address of another variable using the `&` operator:

```
int x = 3;
int *pointer = &x;
```

This tells C to get the address of `x` in memory.

If we just wanted the value of `x`, what would we do?

WORKING WITH POINTERS

We can get the address of another variable using the `&` operator:

```
int x = 3;
int *pointer = &x;
```

This tells C to get the address of `x` in memory.

If we just wanted the value of `x`, what would we do?

You just pass by value: `int *pointer = x;`

WORKING WITH POINTERS

We can get the value at the memory address the pointer is referencing using *, the **dereference operator**:

```
int x = 3;
int *pointer = &x;
int y = *pointer;
```

This goes the memory address that `pointer` points to, retrieves the value, and then returns it.

Note the notation is the same thing we use to declare pointers.

WORKING WITH POINTERS

Take caution: The * you use to declare pointers is part of both the type and variable name:

```c
int *px, py, pz;
```

WORKING WITH POINTERS

Take caution: The * you use to declare pointers is part of both the type and variable name:

```
~~int *px, py, pz;~~
int *px, *py, *pz;
```

QUICK QUESTION

If a pointer just holds a memory address, and all memory addresses are just hexadecimal numbers so they take up roughly space in memory, why do we have to specify a pointer's type?

QUICK QUESTION

If a pointer just holds a memory address, and all memory addresses are just hexadecimal numbers so they take up roughly space in memory, why do we have to specify a pointer's type?

Because pointers point to different data types which all vary in size. C wouldn't know where to stop "reading" memory if it couldn't distinguish between the size of memory blocks that its pointing to.

CHALKBOARD PROBLEM

Write a function on the chalkboard that uses pointers to swap two integers:

```
#include <cs50.h>
#include <stdio.h>
void swap(int* a, int* b);
int main(void)
{
   printf("please enter value of x: ");
   int x = get_int();
   printf("please enter value of y: ");
   int y = get_int();
   printf("x is %i\n", x);
   printf("y is %i\n", y);
   printf("Swapping...\n");
   swap(&x, &y);
   printf("Swapped!\n");
   printf("x is %i\n", x);
   printf("y is %i\n", y);

}
```

CHALKBOARD PROBLEM - SOLUTION

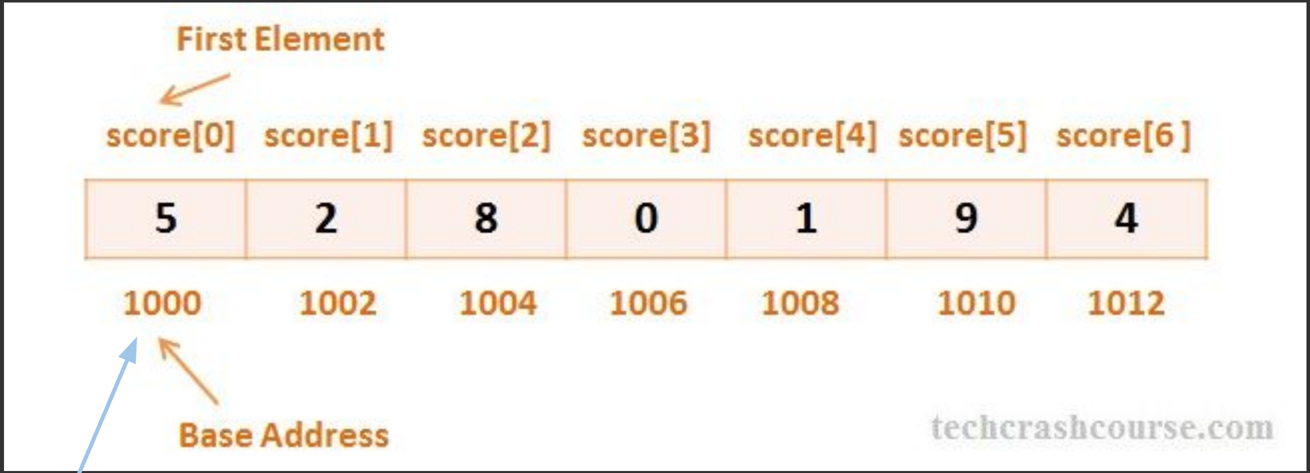
```
void swap(int* a, int* b)
{
    int temp = *a;
    *a = *b;
    *b = temp;
}
```

THE RELATIONSHIP BETWEEN ARRAYS & POINTERS

We discussed last section the idea of passing by value vs. reference and went into more detail about it today.

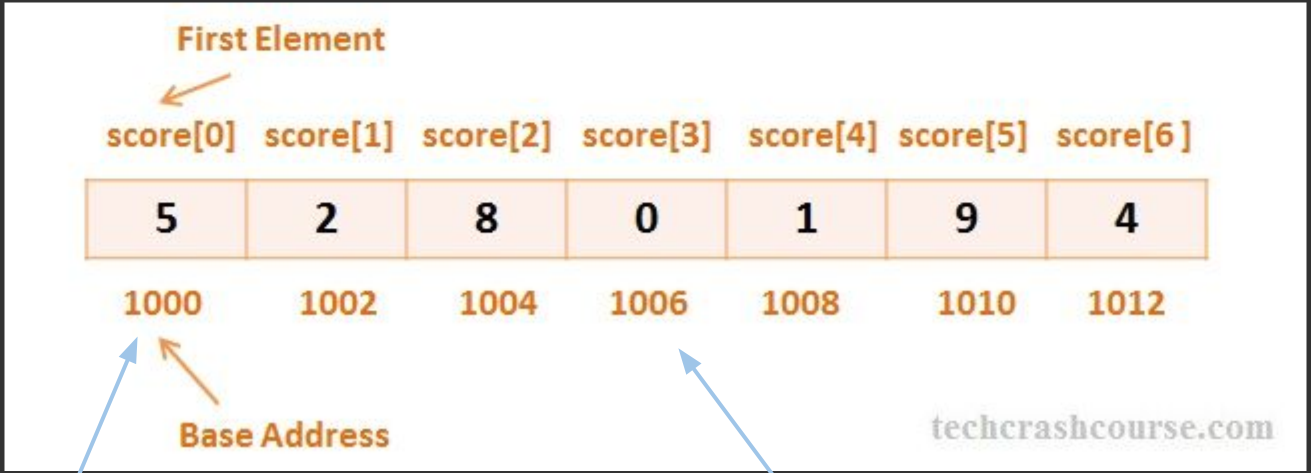
Recall that arrays are passed by *reference*.

THE RELATIONSHIP BETWEEN ARRAYS & POINTERS



The array variable, `score`, is a pointer to the first element in the array

THE RELATIONSHIP BETWEEN ARRAYS & POINTERS

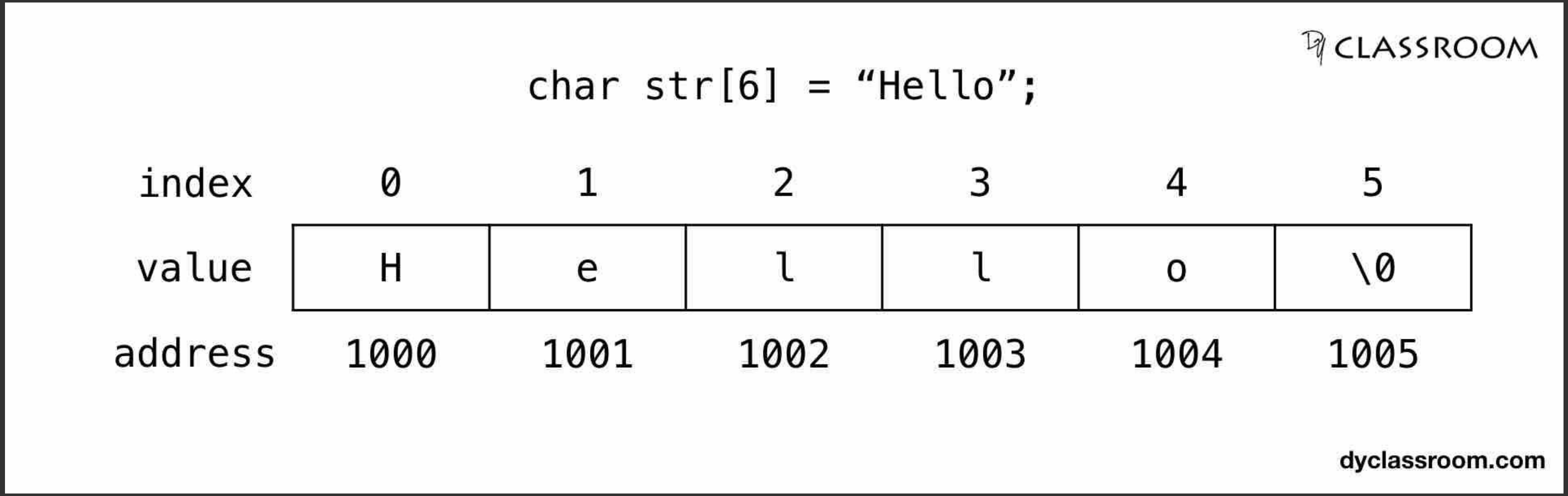


The array variable, `score`, is a pointer to the first element in the array

Requesting a specific index, like `score[3]`, specifies that you want to go to another part of the array in memory

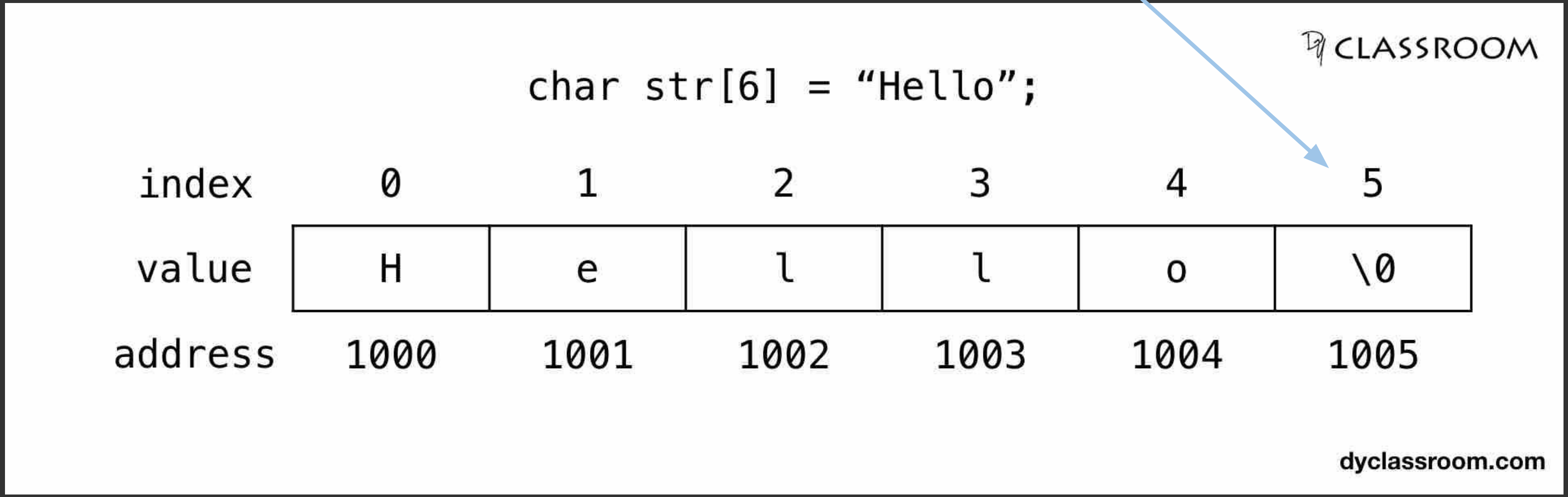
STRINGS ARE ARRAYS AND THUS POINTERS

If a string is really just an array of characters, then it's actually a pointer to where the string starts in memory:



STRINGS ARE ARRAYS AND THUS POINTERS

Why do we null terminate strings in C?



STRINGS ARE ARRAYS AND THUS POINTERS

Why do we null terminate strings in C?

Because when we pass a string in C, other parts of our code might not know the length of the string and where to stop "reading" it from memory

CLASSROOM

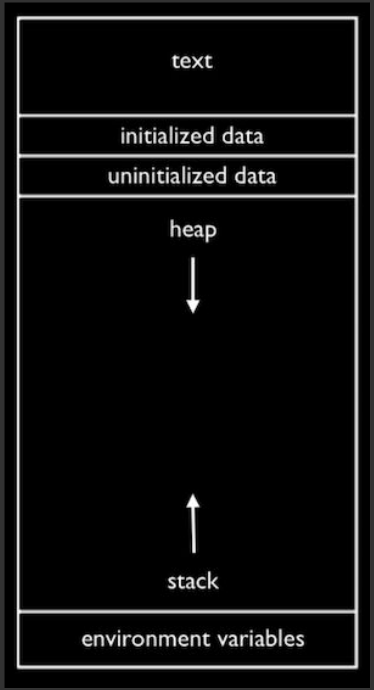
```
char str[6] = "Hello";
```

index	0	1	2	3	4	5
value	H	e	l	l	o	\0
address	1000	1001	1002	1003	1004	1005

dyclassroom.com

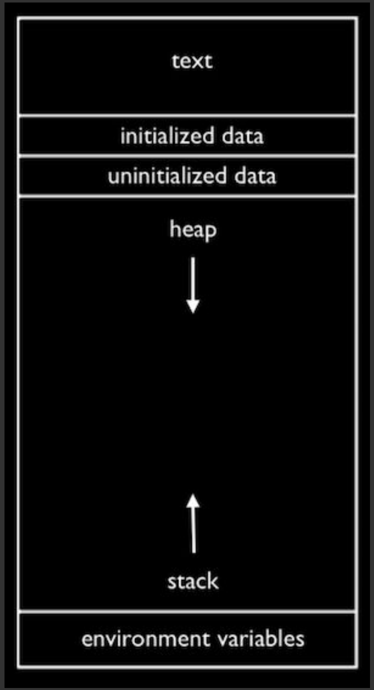
A CRASH COURSE ON MEMORY MANAGEMENT

What purpose do each of these different regions of memory serve?



A CRASH COURSE ON MEMORY MANAGEMENT

What purpose do each of these different regions of memory serve?

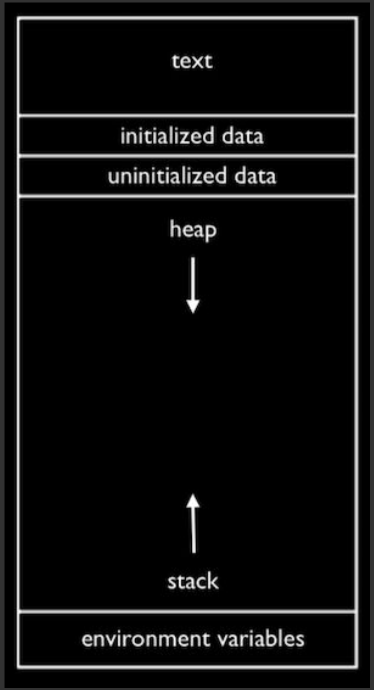


Raw binary code of program

A CRASH COURSE ON MEMORY MANAGEMENT

What purpose do each of these different regions of memory serve?

Initialized global/static variables



Raw binary code of program

A CRASH COURSE ON MEMORY MANAGEMENT

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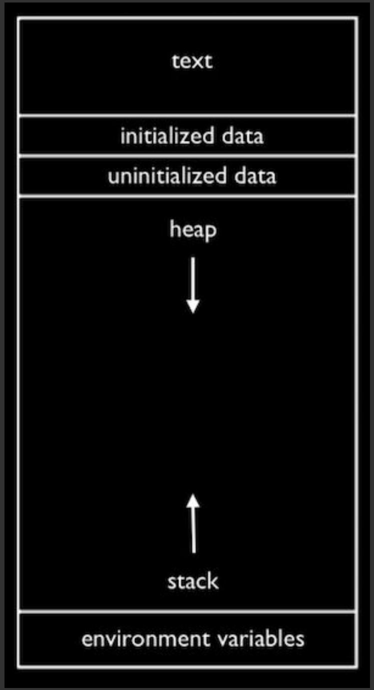

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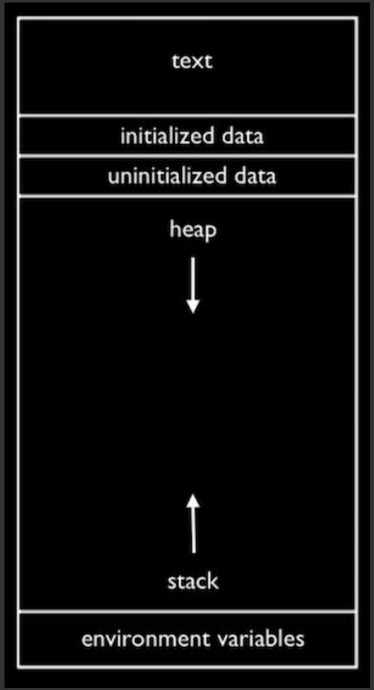

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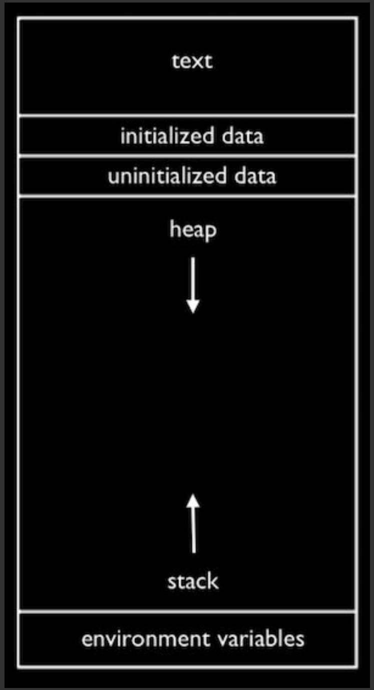

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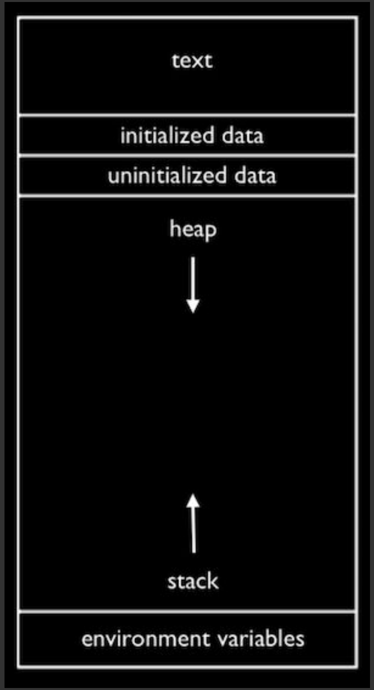

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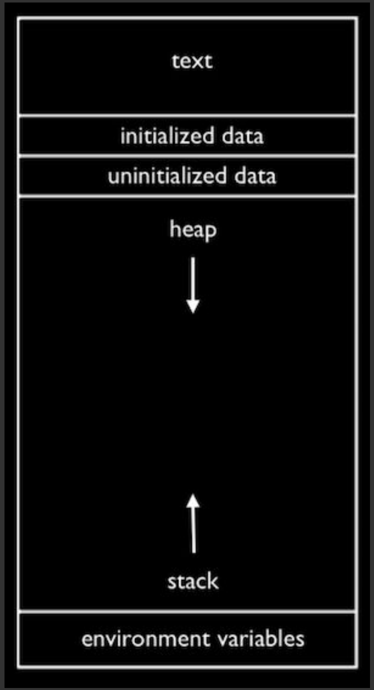
Which of this memory is read only?



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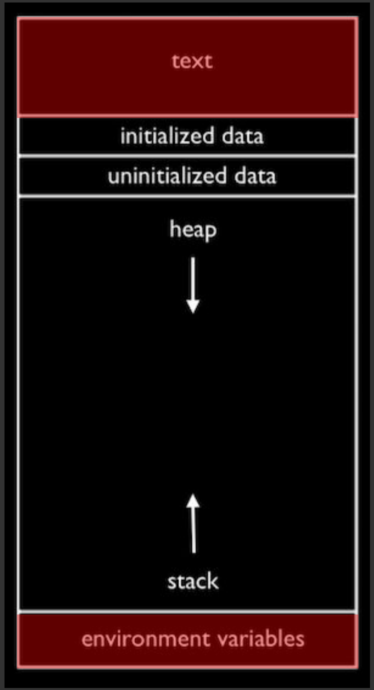

Memory used by functions in the program

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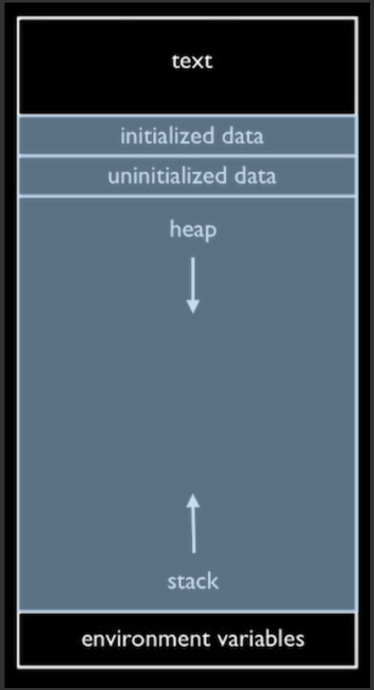
A CRASH COURSE ON MEMORY MANAGEMENT

That means the following memory we can both read AND write from:



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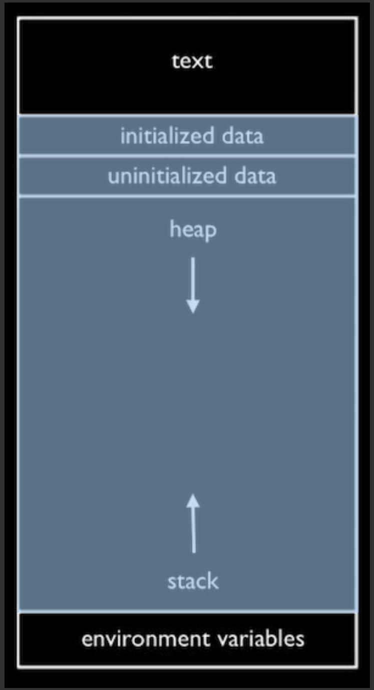
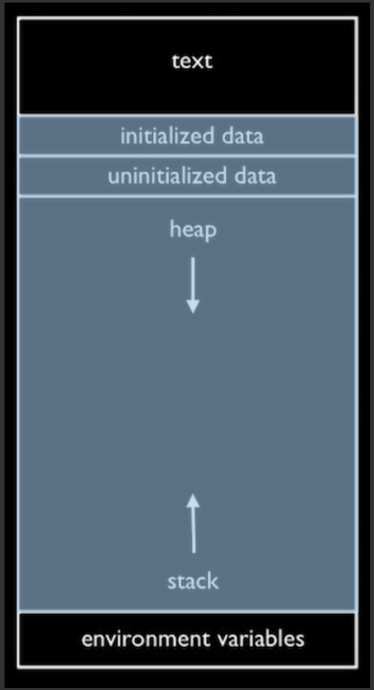


Most of these areas of memory are "compile-time constant." Once your program is compiled, C knows exactly how much memory to allocate throughout the lifetime of the program.

But this poses a problem...

A CRASH COURSE ON MEMORY MANAGEMENT

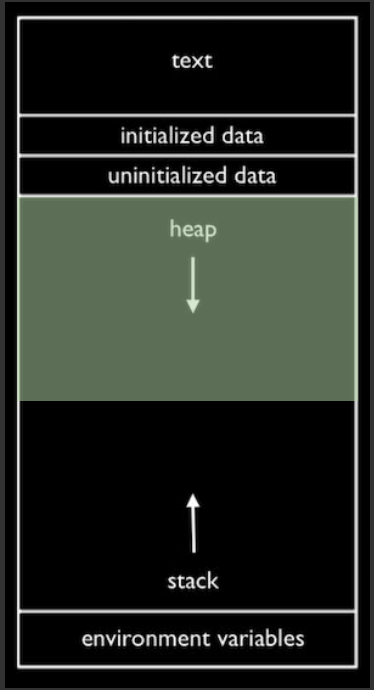
What do you do about the fact that we don't always know how much memory we'll need?



Suppose we have use the `get_string()` function. What if the user enters a paragraph instead of just a word? That's variable in size and not "constant."

A CRASH COURSE ON MEMORY MANAGEMENT

The solution is to use *dynamically allocated* memory, which occurs in the **heap**.



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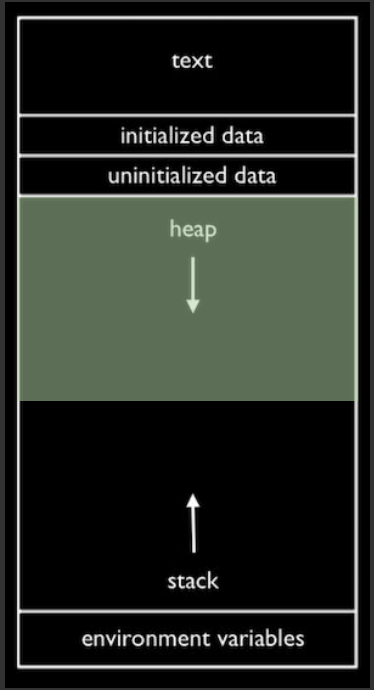

We allocate memory from the heap as needed and can load things into memory and then free them from memory as we need. It doesn't have to be "compile-time" constant.

A CRASH COURSE ON MEMORY MANAGEMENT

You can utilize **`malloc()`** to allocate memory from the heap:

```c
#include <stdlib.h>

int main(void) {
    int *ptr = malloc(sizeof(int));
}
```

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You can utilize `malloc()` to allocate memory from the heap:

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int main(void) {
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`malloc()` takes in the number of bytes you want to allocate and returns a memory address. We can use `sizeof()` to determine the size of a data type in C.

A CRASH COURSE ON MEMORY MANAGEMENT

When you’re done with that memory, you need to free it:

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#include <stdlib.h>

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int main(void) {
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```

`free()` takes a pointer to a memory location in the heap and frees it for you.

SOME ERRORS TO WATCH OUT FOR

- **Segmentation Fault** - You’ve tried to access an “illegal” area of memory or write to a read-only part of memory

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- **Segmentation Fault** - You've tried to access an "illegal" area of memory or write to a read-only part of memory
- **Stack Overflow** - Your functions have used up all the space available in the stack so they "overflow" out of it
- **Memory Leak** - You forget to free dynamically allocated memory, so you have less of it available as your program runs causing performance/memory issues

GRINDING OUT THOSE MEMORY LEAKS

Interactive Demonstration:

http://bit.ly/2Rg48fj

GRINDING OUT THOSE MEMORY LEAKS

Some reminders with valgrind:

- Check for read-write errors with memory -> Your program will often still compile, but valgrind will reveal these
- Check for memory leaks and ensure you prevent them by freeing the memory before the program exits
- Don't forget you can run **`valgrind`**'s output through **`help50`**!

FILE I/O

What type of input/output (I/O) have we seen thus far?

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We've only seen terminal I/O (a subset of `<stdio.h>`), meaning you can only read/write from the terminal.

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FILE I/O

```
#include <stdio.h>
int main(void)
{
    FILE* in = fopen("input.txt", "r");
    if(in == NULL)
        return 1;
    else
    {
        FILE* out = fopen("output.txt", "w");

        if(out == NULL)
            return 2;

        int c = fgetc(in);
        while(c != EOF)
        {
            fputc(c, out);
            c = fgetc(in);
        }

        fclose(in);
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```

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Closes the input and output files from read/write access

FILE I/O - Notes

- When you open a file, you're really loading that file into memory and creating a pointer to the first location of it in memory
- You must always close files to free them from memory, just like with pointers
- **`EOF`** is a "sentinel value" that tells us the file is ended
  - You should use this as the cue to "break" whatever loop you're using to read from a file

FILE I/O - Quick Reference

- `fopen()` - creates a file reference
- `fread()` - reads some amount of data from a file
- `fwrite()` - writes some amount of data to a file
- `fgets()` - reads a single string from a file (typically, a line)
- `fputs()` - writes a single string to a file (typically, a line)
- `fgetc()` - reads a single character from a file
- `fputc()` - writes a single character from a file
- `fseek()` - like rewind and fast forward on YouTube, to navigate around a file
- `ftell()` - like the timer on YouTube, tells you where you are in a file (how many bytes in)
- `fclose()` - closes a file reference, used once done working with the file

HANDS ON PRACTICE

http://bit.ly/2RkhAOZ

This contains practice problems for:

- **Pointers**
- **Dynamic memory allocation**
- **File I/O**

HANDS ON PRACTICE - SOLUTIONS

http://bit.ly/2NivL3R

PROBLEM SET 3 PREVIEW

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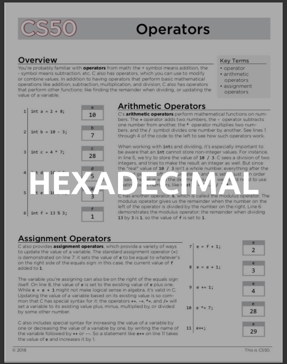
Submit:

- `whodunit.c` **(using CS50 Lab)**
- `resize.c` **([less] or [more] using CS50 IDE)**
- `recover.c` **(using CS50 IDE)**

If you submit both versions of `resize.c`, the higher of your two scores will be taken.

REFERENCE SHEETS



https://www.dropbox.com/sh/5y662ey1hc4sde4/AACjgHN3NtSKk4ShsRDFd_Sja?dl=0&m=&preview=Hexadecimal.pdf

FINAL NOTES

★ Look out for the section survey I'll be sending out over email—I want your feedback on how to make this section as useful as possible for you

★ Go to office hours because the course will start quickly *ramping up*

★ Check out CS50 Tutoring if you need some one-on-one help with the concepts—it's free!