CS50 - SECTION 2

9/25/18

WELCOME IF YOU'RE NEW TO THE SECTION!

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POST-MORTEM ON PSET 1

REFLECTIONS:

PSET 1

How did it go? What did you like? Frustrations? Things to think about moving forward?

SOME REMINDERS

- There is no “right” way to program
  - There is only the *best* way given our context, constraints, etc.
- What are some tradeoffs we might have to make when coding?

SOME REMINDERS

- There is no “right” way to design a program
  - There is only the *best* way given our context, constraints, etc.
- What are some tradeoffs we might have to make when coding?
  - **Technical** - Memory, processing power, computational time available
  - **Knowledge** - What do we know? What solutions are available?
  - **Resources** - Developer quantity/time available, money, etc.
  - **Any many more…**
- In CS50, you’re graded on design, which tries to encapsulate a small cross-section of all the above tradeoffs

DESIGN TIP #1

Repetitive Code: What’s the number one principle in programming?

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Don't Repeat Yourself

AKA:

DRY

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DESIGN TIP #2

Unnecessarily and computationally difficult code

How can we improve the following snippet from **`cash`**?

```
// dollars is  our input from the user
int cents = round(dollars * 100);
int coins = 0;
while (cents >= 25)
{
    coins++;
    cents -= 25;
}
```

DESIGN TIP #2

This is clearer and likely even faster because we've excluded a loop

```
// dollars is  our input from the user
int cents = round(dollars * 100);
int coins = 0;

coins += cents / 25;
cents = cents % 25;
```

DESIGN TIP #3

Don’t waste memory when you don’t need to

What’s wrong with the following code?

```
int x = 132 % 7;


printf("%i", x);
```

DESIGN TIP #3

Don’t waste memory when you don’t need to

What’s wrong with the following code?

```
int x = 132 % 7;


printf("%i", x);
```

If we never intend to use `x` again, then we’re wasting memory and add unnecessary code by declaring/initializing a variable! Do this instead:

```
printf("%i", 132 % 7);
```

STYLE TIPS

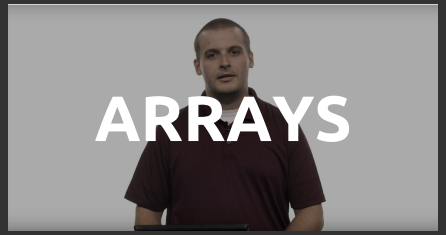
1. Use descriptive variable names (no `x`, `y`, `z`, unless it is used in a for loop and/or as a counter value)
2. Format your code cleanly—Keep your indentation, tabs, spaces, etc. clear
    a. CS50 Style guide: https://cs50.readthedocs.io/style/c/
3. Use comments to explain non-obvious parts of your code
    a. What do good commenting practices look like?
    b. We care about quantity *AND* quality

CONCEPTS DEEP-DIVE

“SHORTS” FOR THE WEEK

https://www.youtube.com/watch?v=b7-0sb-DV84

https://www.youtube.com/watch?v=thL7ILwRNMM



https://www.youtube.com/watch?v=mISkNAfWl8k

https://www.youtube.com/watch?v=w4TAY2HPLEg

EXTRA “SHORTS” IF YOU HAVE TIME

https://www.youtube.com/watch?v=3hH8kTHFw2A

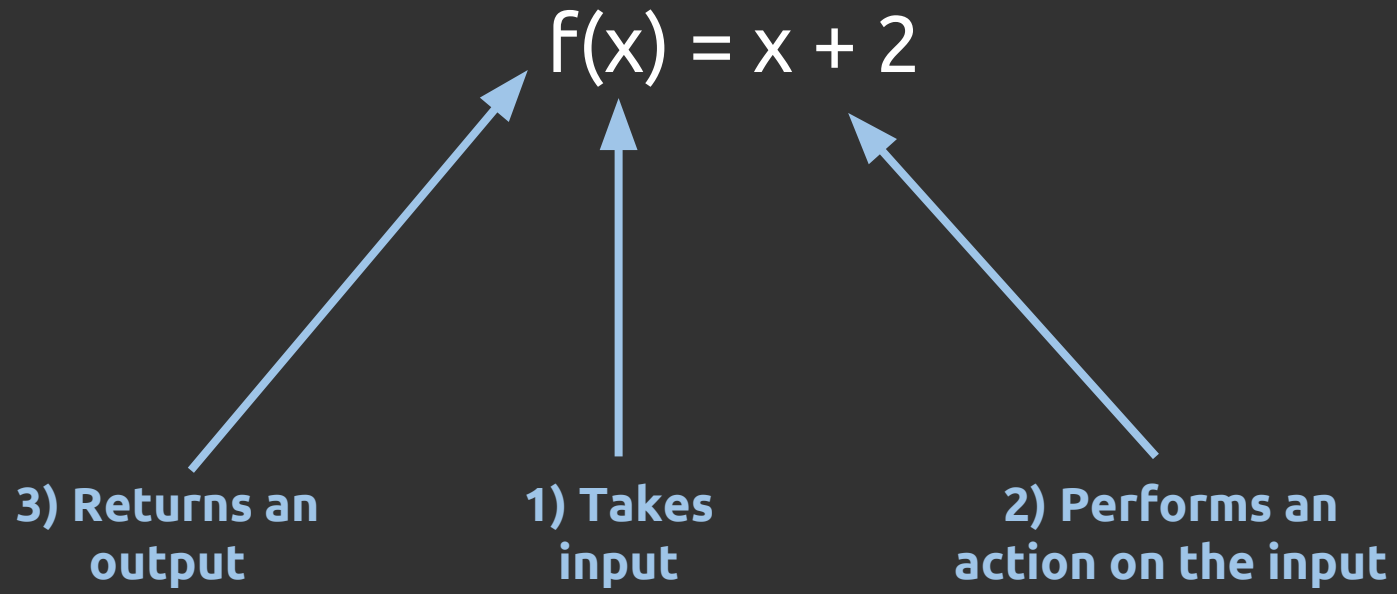
https://www.youtube.com/watch?v=RT-hUXUWQ2I

https://www.youtube.com/watch?v=O0VbBkUvriI

https://www.youtube.com/watch?v=Ns7tGNbtvV4

FUNCTIONS

What is a function?



FUNCTIONS IN C

Here is a function that calculates the balance in a bank account after 1 year of simple interest has accumulated

```
double accumulate_interest(double balance, double rate)
{
    double updated_balance = balance + rate * balance;
    return updated_balance;
}
```

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1) Takes input

2) Performs an action on the input

3) Returns an output

FUNCTIONS IN C

A program that uses it might look like this:

```
#include <cs50.h>
#include <stdio.h>
double accumulate_interest(double balance, double rate);
int main(void)
{
    printf("Starting balance: ");
    double start = get_double();
    printf("Annual interest rate: ");
    double interest = get_double();
    double updated = accumulate_interest(start, interest);
    printf("Updated balance: %.2f\n", updated);
}
double accumulate_interest(double balance, double rate)
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```

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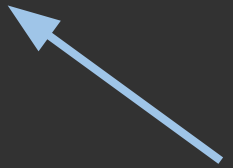
```



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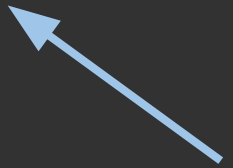

What is this?
A function prototype

FUNCTIONS IN C

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}
double accumulate_interest(double balance, double rate)
{
    double updated_balance = balance + rate * balance;
    return updated_balance;
}
```
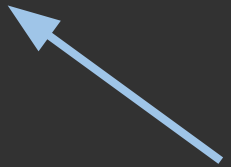



What is this? A function prototype

C reads top to bottom like we do, so if you "call" a function before you define it, an error will be thrown

FUNCTIONS IN C

Alternatively, define your function first to exclude the prototype:

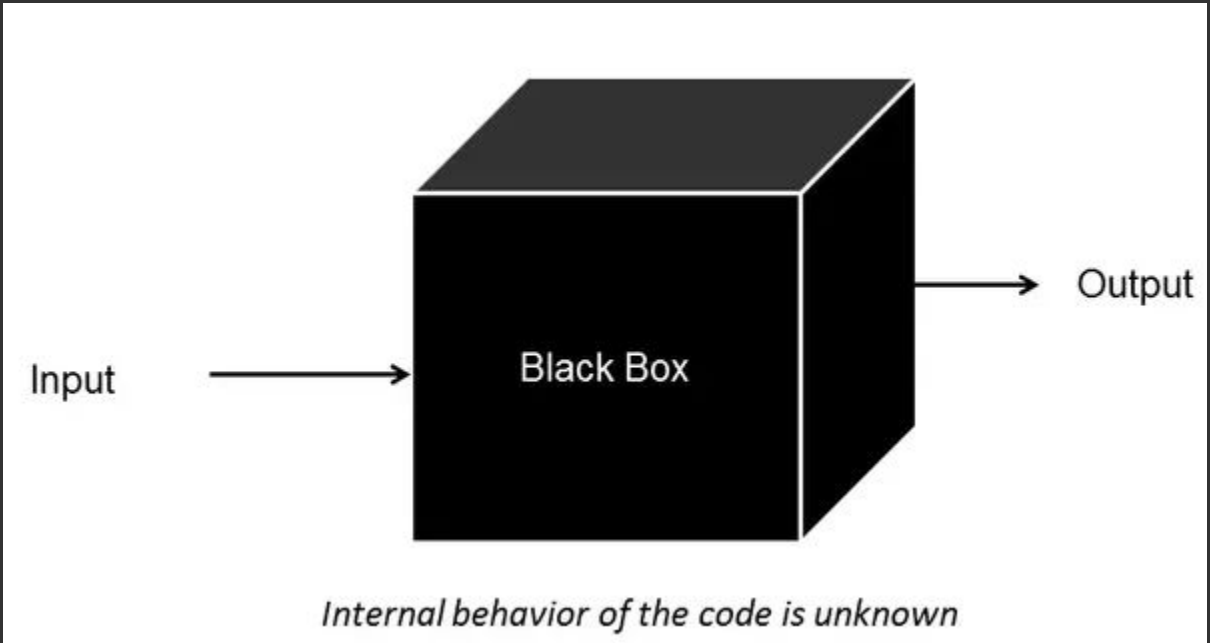
```
#include <cs50.h>
#include <stdio.h>
double accumulate_interest(double balance, double rate)
{
    double updated_balance = balance + rate * balance;
    return updated_balance;
}

int main(void)
{
    printf("Starting balance: ");
    double start = get_double();
    printf("Annual interest rate: ");
    double interest = get_double();
    double updated = accumulate_interest(start, interest);
    printf("Updated balance: %.2f\n", updated);
}
```

WHY DO WE USE FUNCTIONS?

1) They help us better organize our code.

WHY DO WE USE FUNCTIONS?

2) They offer us a powerful tool of abstraction.



WHY DO WE USE FUNCTIONS?

2) They offer us a powerful tool of abstraction.

You have called a variety of functions from the CS50 library already:

- get_int()
- get_float()
- get_string()

You have no clue how these functions are actually *implemented*, but it doesn't matter. *You know what inputs to provide and what outputs to expect, so you can use them reliably!*

WHY DO WE USE FUNCTIONS?

2) They offer us a powerful tool of abstraction.

Imagine you needed to change our interest function from before to use compound interest. How might you do that?

WHY DO WE USE FUNCTIONS?

2) They offer us a powerful tool of abstraction.

Imagine you needed to change our interest function from before to use compound interest. How might you do that?

Simply change the formula in the function! This means anywhere you call that function, it's using the new formula. You change your code in one place and not a dozen...

WHY DO WE USE FUNCTIONS?

3) They simplify development of our program.

You can worry about testing/debugging a single function rather than everything at once.

They also help us think about breaking our problem into smaller parts. This is a fundamental CS principle.

WHY DO WE USE FUNCTIONS?

4) They offer reusability.

You can call a function over and over again instead of rewriting that code.

Look for ways to **refactor** your code to extract out “common parts” and put them in a function.

WAIT, WHAT'S ANOTHER FUNCTION WE'VE ALREADY SEEN?

What is one function you've already used in every C program you've written?

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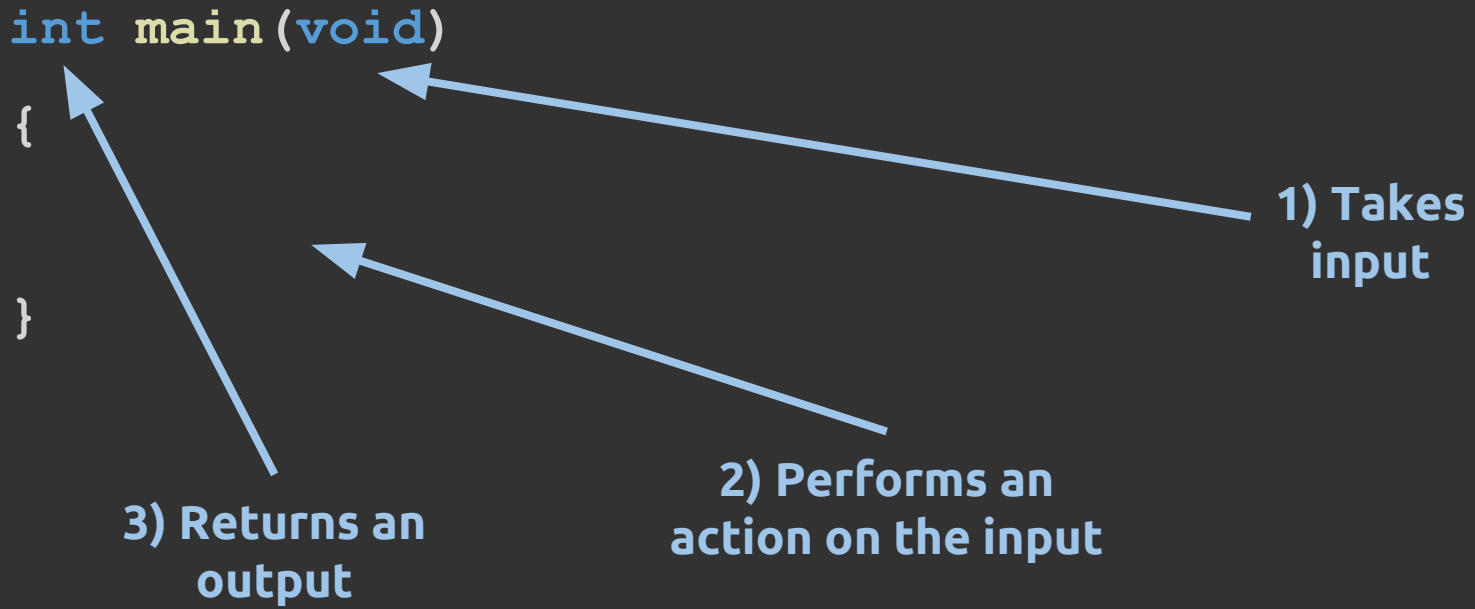
The main function!

WAIT, WHAT'S ANOTHER FUNCTION WE'VE ALREADY SEEN?



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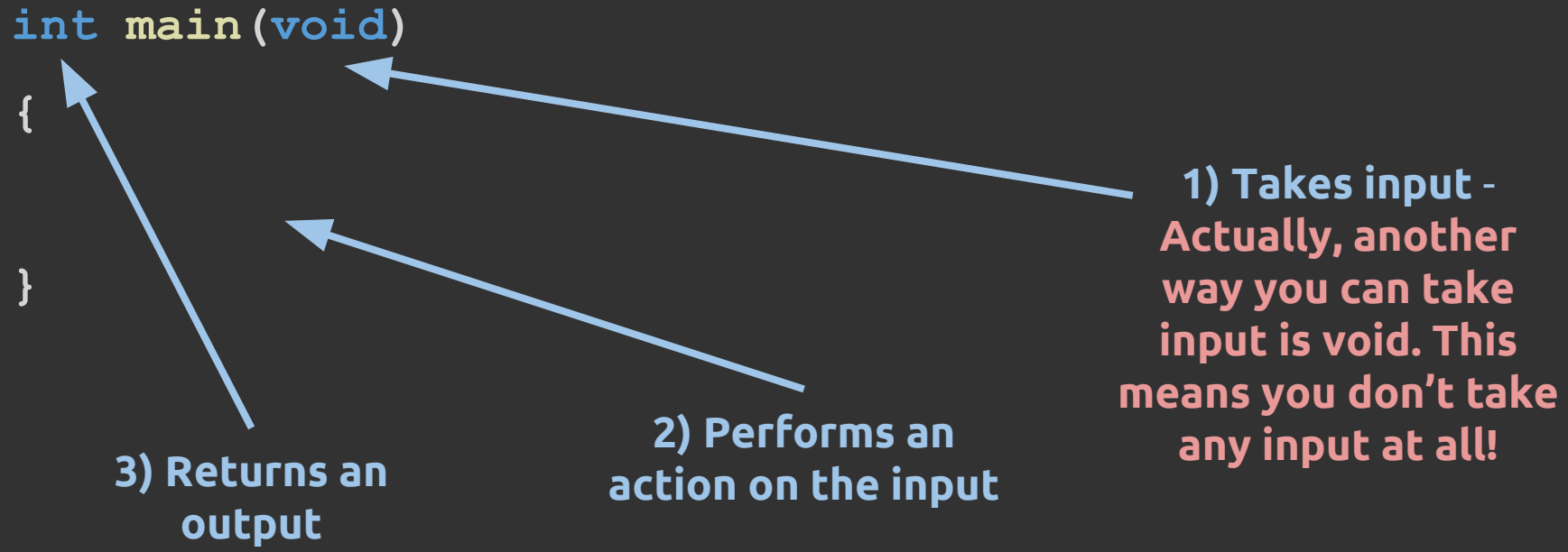
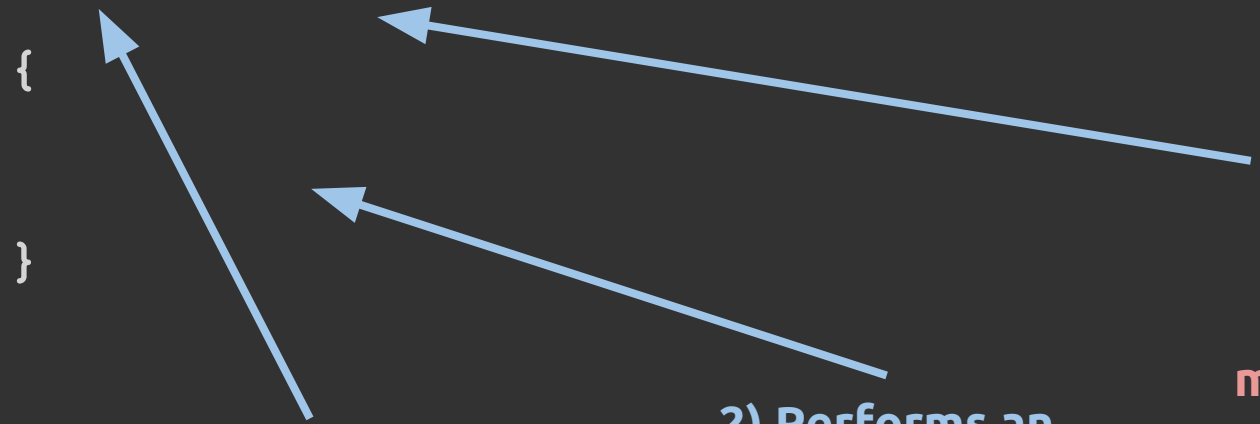


WAIT, WHAT'S ANOTHER FUNCTION WE'VE ALREADY SEEN?

```
int main(void)
{


}
```



1) Takes input - Actually, another way you can take input is void. This means you don't take any input at all!

2) Performs an action on the input

3) Returns an output - We return an "exit code" which is an integer.

READING DOCUMENTATION/REFERENCE

CS50 provides reference/documentation at:
https://reference.cs50.net/

SYNOPSIS

```
#include <cs50.h>
float get_float(string format, ...);
```

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SYNOPSIS

```
#include <cs50.h>
float get_float(string format, ...);
```

Parameters (input)

Return type

READING DOCUMENTATION/REFERENCE

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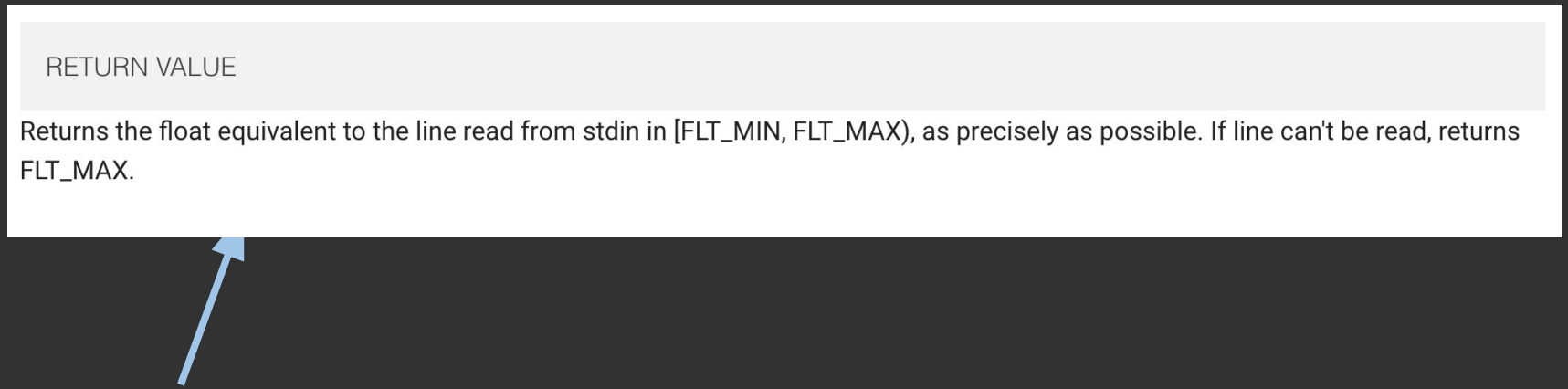

Return value to expect - Notice that implementation details are excluded

VARIABLE SCOPES

In C, we have two types of scope:

- **Global -** Defined outside of a function (including main) and available to the entire program
  - That is, unless you override them with precedence…
- **Local -** Defined inside of a function and available only within that “block”

VARIABLE SCOPES

Where are the local and global variables in this code?

```c
#include <stdio.h>

int g;

int main () {
    int a, b;
    a = 10;
    b = 20;
    g = a + b;

    printf ("value of a = %d, b = %d and g = %d\n", a, b, g);
}
```

VARIABLE SCOPES

Where are the local and global variables in this code?

```c
#include <stdio.h>

int g;

int main () {

    int a, b;

    a = 10;

    b = 20;

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    printf ("value of a = %d, b = %d and g = %d\n", a, b, g);

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```
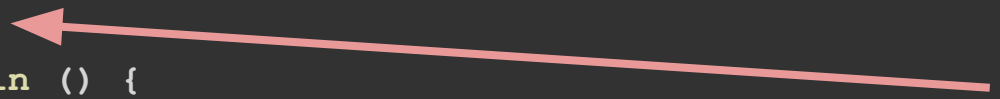
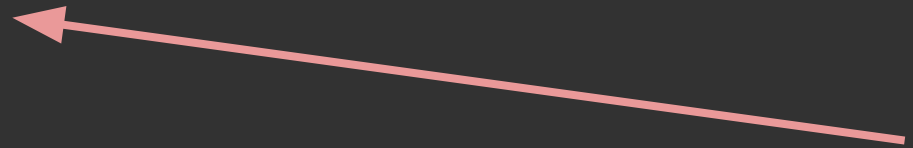



Global Variable



Local Variables

VARIABLE SCOPES

You can use `{}` to create a new block and specify a local scope:

```
#include <stdio.h>
int main () {
    int a = 7;

    {
        int a = 4;
        printf("%i\n", a);
    }

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

VARIABLE SCOPES

You can use `{}` to create a new block and specify a local scope:

```c
#include <stdio.h>
int main () {
    int a = 7;

    {
        int a = 4;
        printf("%i\n", a);
    }

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

This will print 4 and then 7.

Note: If you compile this with `make`, it will throw an error because of how it's configured, but `clang` will let it through. Technically, this points out that it's bad practice to name variables the same thing, even if their scope is different.

HANDS ON PRACTICE - TASK #1 (`temp1.c`)

http://bit.ly/2DvR5nb

You'll use this sandbox for all the practice in this section.

HANDS ON PRACTICE - SOLUTION #1 (`temp1.c`)

```c
#include <stdio.h>
#include <cs50.h>

float ctof(float temp);
float ftoc(float temp);

int main(void) {
   double temp1 = 45.3;
   double temp2 = 23.8;

   printf("%f\n", ftoc(temp1));
   printf("%f\n", ctof(temp2));
}

float ctof(float temp) {
   return (temp * (9.0 / 5.0)) + 32.0;
}

float ftoc(float temp) {
   return (temp - 32.0) * (5.0 / 9.0);
}
```

ARRAYS

What is an array?

ARRAYS

What is an array?

A data type that allows us to store multiple values of the same type in memory

ARRAYS - HOW DO WE DECLARE THEM?

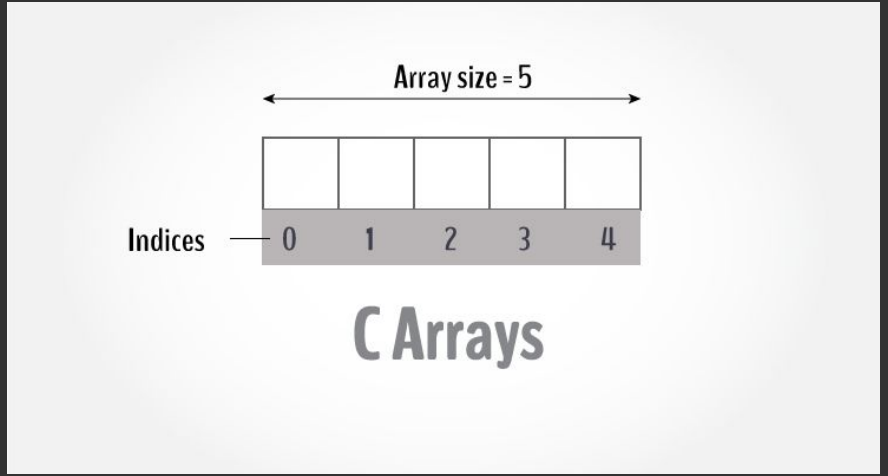
```
type name[size];
```

- A note on types: Arrays must contain values of the same type—Why do we think that might be?

ARRAYS - HOW DO WE DECLARE THEM?

```
type name[size];
```

- A note on types: Arrays must contain values of the same type—Why do we think that might be?
  - **C has only partitioned enough memory for that particular type and size of array!**



ARRAYS - HOW DO WE INITIALIZE THEM?

- You can either initialize with declaration (instantiation):

```
type name[size] = {<values>};
```

- Or you can initialize separately:

```
name[i] = {<value>};
```

ARRAYS - HOW DO WE INITIALIZE THEM?

- Not providing a size for the declaration will set the array equal to whatever you initialize with:

```
int arr[] = {1, 2, 3};
```

This causes C to create an array of size 3 implicitly

ARRAYS - HOW DO WE ACCESS VALUES?

```
name[i];
```

- `i` is our counter value
- Note that arrays are indexed from zero—If want to access the nth element, we use `name[n-1]`

ARRAYS - OUT OF BOUNDS

```
int a[10];


printf("%i", a[143]);
```

This code will generate an error due to the configuration of **`make`** and **`clang`** in CS50 Labs/Sandbox, but being notified of this error is not always the case!

ARRAYS - OUT OF BOUNDS

```c
int a[3] = {1, 2, 3};


printf("%i", a[143]);
```

Without error reporting, C will often try to access that memory location and give you back a random value. Where do we think that value is coming from?

ARRAYS - OUT OF BOUNDS

```c
int a[3] = {1, 2, 3};


printf("%i", a[143]);
```

C will often give you back a random value. Where do we think that value is coming from? - **It's coming from whatever is located at that memory location adjacent to the array**

ARRAYS - OUT OF BOUNDS

```c
int a[3] = {1, 2, 3};

printf("%i", a[143]);
```

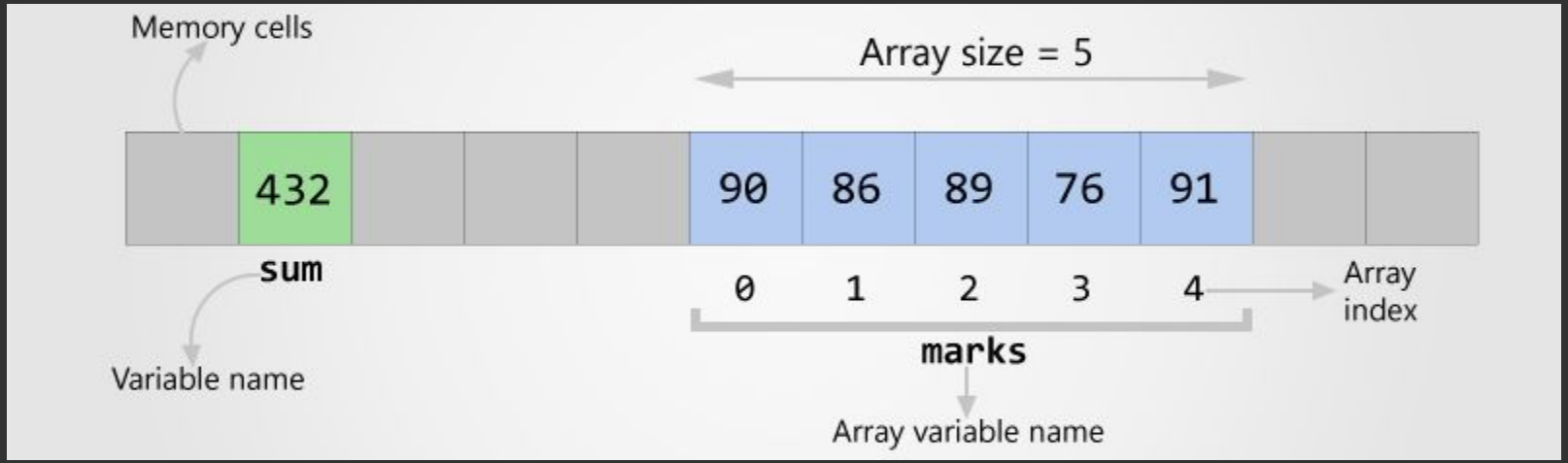
Other times you'll get a scary error:

```
Segmentation fault
```

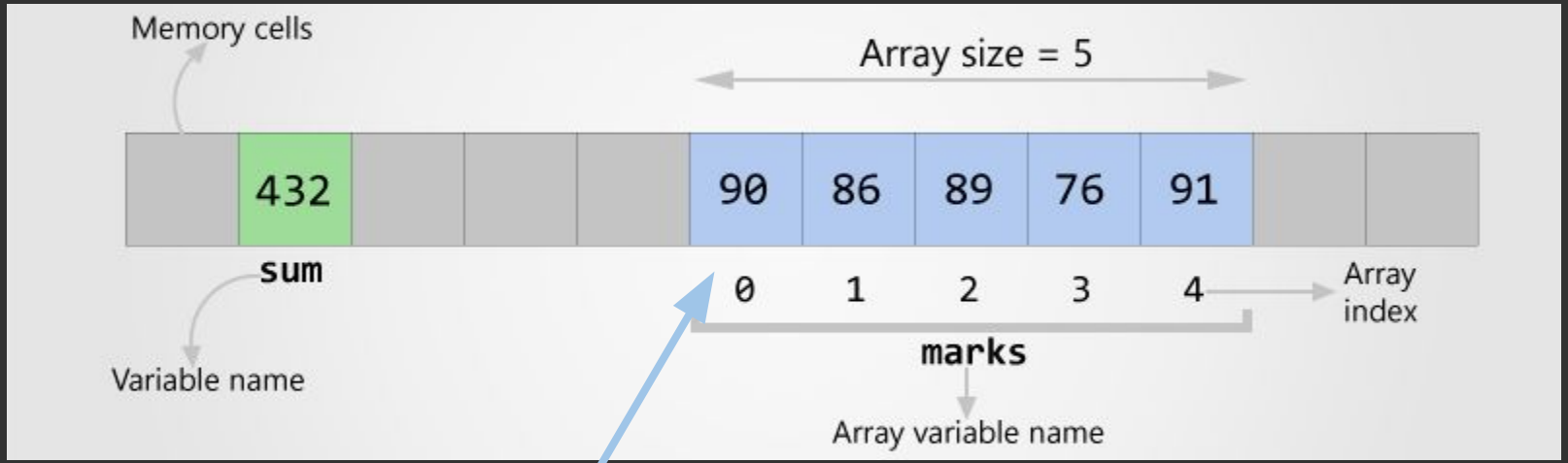
This means you're trying to read/write to an illegal memory location

ARRAYS - UNDER THE HOOD

We can understand why we get the segmentation fault error better if we look at how arrays are stored by C under the hood:

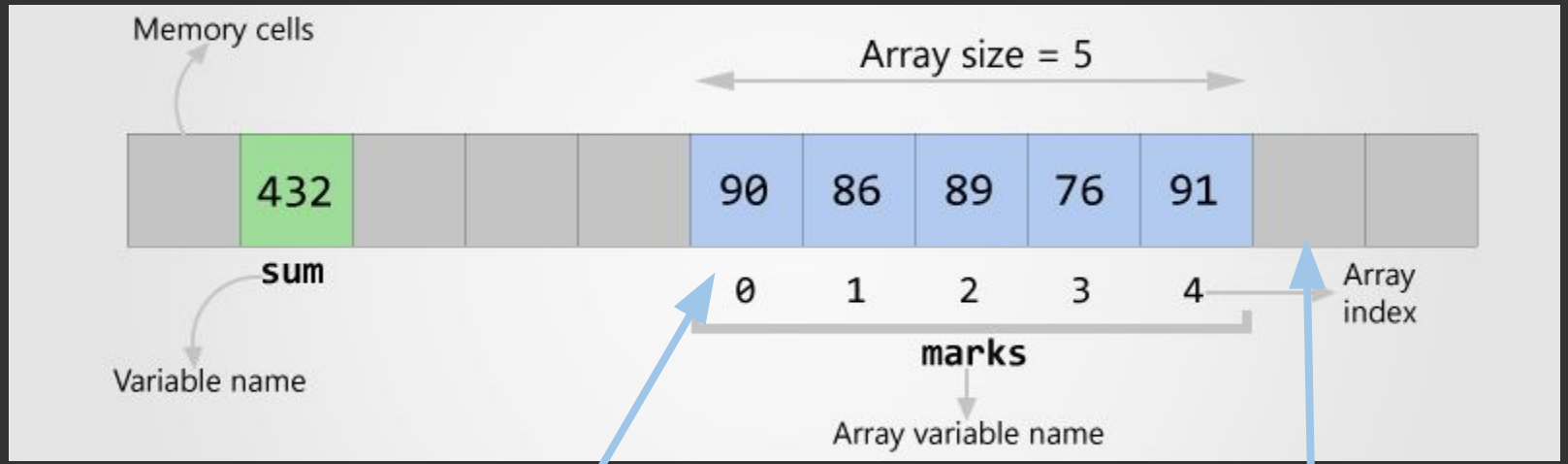


ARRAYS - UNDER THE HOOD



Notice that arrays are stored in *contiguous memory*

ARRAYS - UNDER THE HOOD



Notice that arrays are stored in *contiguous memory*

If we try to access a value outside of the array bounds, we hit other values in memory

ARRAYS - IMPORTANT NOTES

1. Because C reserves a set amount of memory upon the declaration of an array, **you cannot change the size of your array after creating it**.

How might we accomplish changing the size of our array given this constraint?

ARRAYS - IMPORTANT NOTES

1. Because C reserves a set amount of memory upon the declaration of an array, **you cannot change the size of your array after creating it**.

How might we accomplish changing the size of our array given this constraint?

You would have to create an entirely new array of a larger size and then copy the values from the old array into the new one.

ARRAYS - IMPORTANT NOTES

2. C does not treat arrays as a single entity. Meaning you can't copy the values of one array to another by just setting them equal to one another.

```
int arr1[3] = {1, 2, 3};
int arr2[3];
arr2 = arr1;
```

The above is not permitted by C!

ARRAYS - IMPORTANT NOTES

2. C does not treat arrays as a single entity. Meaning you can't copy the values of one array to another by just setting them equal to one another.

If you want to copy values, you have to do it one-by-one:

```
int arr1[3] = {1, 2, 3};
int arr2[3];

for(int i=0; i<3; i++) {
   arr2[i] = arr1[i];
}
```

ARRAYS - IMPORTANT NOTES

2. C does not treat arrays as a single entity. Meaning you can’t copy the values of one array to another by just setting them equal to one another.

“But why does C subject us to this insanity???” you may be asking.

A SHORT DIVERSION

What does the following program print?

```
int x = 4;
int y = x;
x = 7;

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

A SHORT DIVERSION

What does the following program print?

```
int x = 4;
int y = x;
x = 7;

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

It prints 4! This is because most variables in C are passed by value.

For example, this program sets `x` equal to 4 and then `y` equal to `x`. `y` is referencing 4 because C literally assigns 4 to y, not the memory location of x to y.

Had we been passing by reference, then anytime x changes, y would also change since it references what x is.

ARRAYS - IMPORTANT NOTES

2. C does not treat arrays as a single entity. Meaning you can't copy the values of one array to another by just setting them equal to one another.

"But why does C subject us to this insanity???" you may be asking.

So, C subjects us to this "insanity" because arrays are passed by reference! Setting two arrays equal to one another simply assigns one to the other's memory location.

ARRAYS - IMPORTANT NOTES

3. We can declare an array, initialize some/all of its values to a specific list we provide, or we can initialize them all to zero.

Initialize All Values:

```
int arr[3] = {1,2,3};
```

This initializes all three "slots" of the array

Initialize Some Values:

```
int arr[3] = {1};
```

This initializes `arr[0]` to 1 and sets the remaining "slots" equal to zero

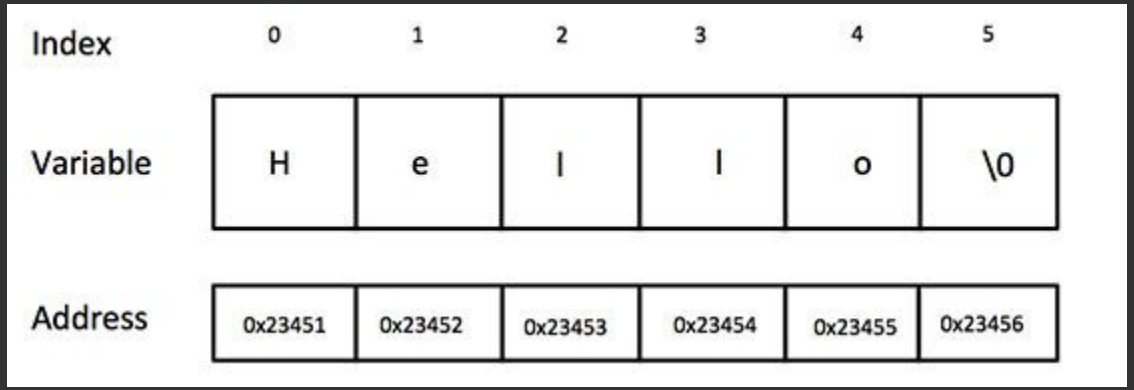
Initialize All to Zero:

```
int arr[3] = {0};
```

This sets all slots of the array equal to zero

ARRAYS - WAIT...WHAT IS A STRING AGAIN?

Strings as we've dealt with so far were implemented by the CS50 library. But in reality, they are actually an array of characters



ARRAYS - WAIT...WHAT IS A STRING AGAIN?

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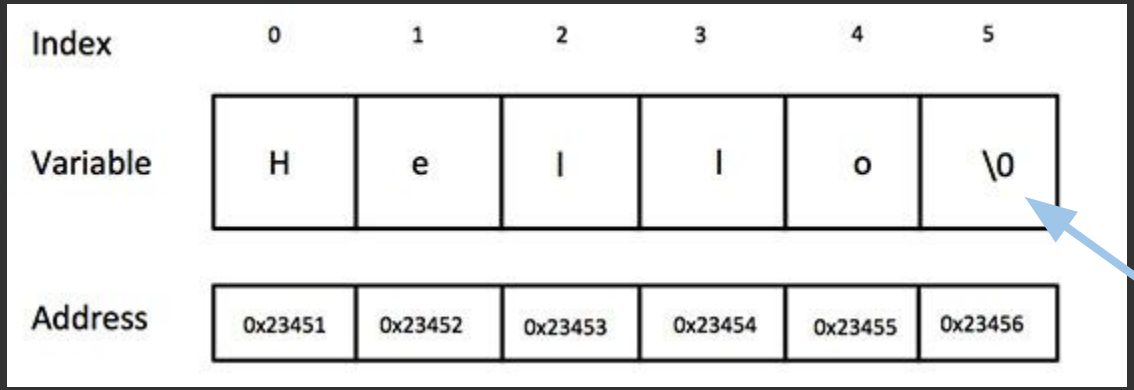

This is called a "null terminator." It tells C that our char array has ended. More on the specifics later...

ARRAYS - MULTIDIMENSIONAL

We can even create multidimensional arrays in C:

```
bool arr[10][10];
```

The above gives us a 10x10 array to work with. How might multidimensional arrays be useful?

ARRAYS - MULTIDIMENSIONAL

We can even create multidimensional arrays in C:

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bool arr[10][10];
```

The above gives us a 10x10 array to work with. How might multidimensional arrays be useful?

Representing complex physical things digitally (e.g. board games), working with multivariable functions, etc...

HANDS ON PRACTICE - TASK #2 (`temp2.c`)

http://bit.ly/2DvR5nb

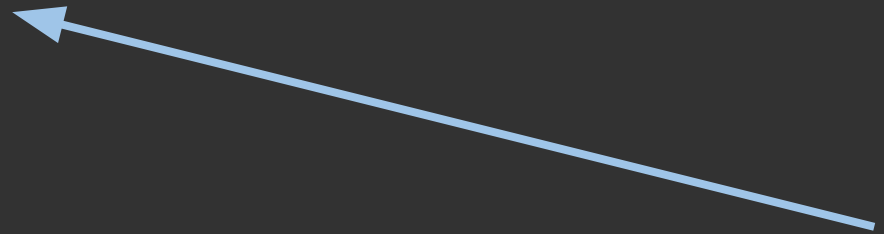
Now continue to `temp2.c` and complete the second task.

HANDS ON PRACTICE - SOLUTION #2 (`temp2.c`)

```c
#include <stdio.h>
#include <cs50.h>

float ctof(float temp);
float ftoc(float temp);

int main(void) {
   // Temperatures in Fahrenheit
   float temp[5] = {73.2, 24.1, 98.5, 101.9, 45.2};

   float temp_c[5];
   for(int i = 0; i < 5; i++) {
       temp_c[i] = ftoc(temp[i]);
       printf("%f\n", temp_c[i]);
   }
}

float ctof(float temp) {
   return (temp * (9.0 / 5.0)) + 32.0;
}

float ftoc(float temp) {
   return (temp - 32.0) * (5.0 / 9.0);
}
```

REVISITING THE MAIN FUNCTION

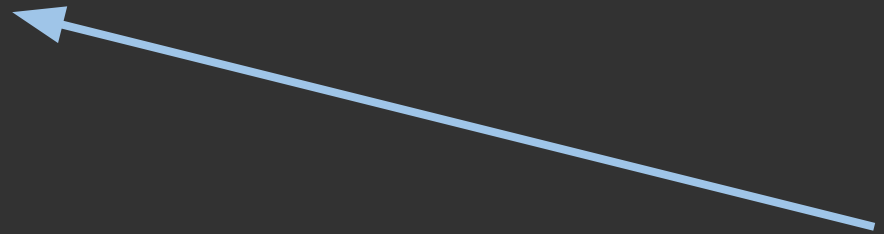
```
int main(void)
{


}
```



Does the input always have to be void?

REVISITING THE MAIN FUNCTION

```
int main(void)
{


}
```



Does the input always have to be void?

NO!

COMMAND LINE ARGUMENTS

We can use command line arguments to pass arguments into our program:

```
int main(int argc, string argv[]) {


}
```

`argc` represents the number of arguments we've passed via the command line

`argv` is an array of strings with the different command line arguments

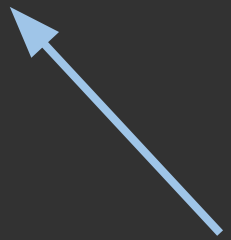
COMMAND LINE ARGUMENTS

```
$ ./ main "x" "y" "z"
```

COMMAND LINE ARGUMENTS

```
$ ./ main "x" "y" "z"
```

`argc` would be 4

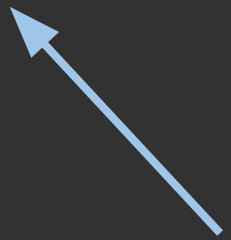


argv[0]	argv[1]	argv[2]	argv[3]
“main”	“x”	“y”	“z”

COMMAND LINE ARGUMENTS

```
$ ./ main "x" "y" "z"
```

`argc` would be 4



`argv[0]` is always the name of the program

argv[0]	argv[1]	argv[2]	argv[3]
“main”	“x”	“y”	“z”

COMMAND LINE ARGUMENTS - SOME NOTES

- `argv[]` gives us an array of strings
  - If you want command line arguments that are processed as integers, use `atoi(<string>)`
  - Likewise, you can use `atof(<string>)` for doubles and various other functions

COMMAND LINE ARGUMENTS - SOME NOTES

Because they're strings, we can treat them as a multidimensional array. How?

```
$ ./ main "bob" "gloria" "suzy"
```

COMMAND LINE ARGUMENTS - SOME NOTES

Because they're strings, we can treat them as a multidimensional array. How?

```
$ ./ main "bob" "gloria" "suzy"
```

`argv[1][1]` would give us "o".

HANDS ON PRACTICE - TASK #3 (`temp3.c`)

http://bit.ly/2DvR5nb

Now continue to `temp3.c` and complete the second task.

HANDS ON PRACTICE - SOLUTION #3 (`temp3.c`)

```c
#include <stdio.h>
#include <cs50.h>

float ctof(float temp);
float ftoc(float temp);

int main(int argc, string argv[]) {
    if(argv[1][0] == 'f') {
        for(int i = 2; i < argc; i++) {
            printf("%f\n", ftoc(atof(argv[i])));
        }
    }
    else {
        for(int i = 2; i < argc; i++) {
            printf("%f\n", ctof(atof(argv[i])));
        }
    }
}

float ctof(float temp) {
    return (temp * (9.0 / 5.0)) + 32.0;
}

float ftoc(float temp) {
    return (temp - 32.0) * (5.0 / 9.0);
}
```

HANDS ON PRACTICE - SOLUTIONS

http://bit.ly/2DsL0YD

Sample implementations for all three tasks are contained in the Sandbox above.

DEBUGGING

What types of bugs might we encounter?

DEBUGGING

What types of bugs might we encounter?

- **Syntax Error** - There is a mistake in the rules/grammar of the language with your code
  - Easiest to fix, but can be tough to find
- **Logic Error** - Something about your algorithm is wrong
  - Think through your algorithm, step-by-step (on paper!)
- **Input Error** - Your code didn't anticipate a particular type of input (e.g. a negative number) and did not include provisions to catch these errors
  - Think about edge cases to anticipate what these might be
- Any many more...

DEBUGGING

We have `help50` to assist us with debugging

- When you run into an error, simply prepend `help50` before the command that threw the error and it will interpret the problem and provide suggestions to you

DEBUGGING

Other tips to help you with debugging:

- Think through algorithm on paper before you attempt to code it
  - Writing pseudocode before real code prevents mistakes
- Use `printf()` statements to understand the flow of your program and whether certain areas are even being reached
  - Can also reveal what the inner contents of variables are at different steps to help you see where your algorithm is messing up
  - Later, we'll learn about `debug50` which helps automate this process
- Not debugging related, but use `style50` to help improve your style!

PROBLEM SET 2 PREVIEW

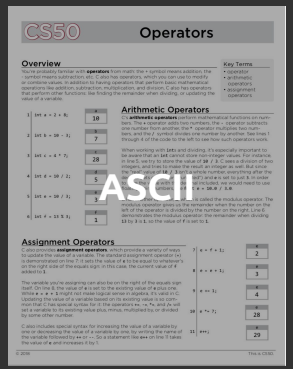
PROBLEM SET 2 PREVIEW

Submit any two (2) of:

- `caesar.c`
- `vigenere.c`
- `crack.c`

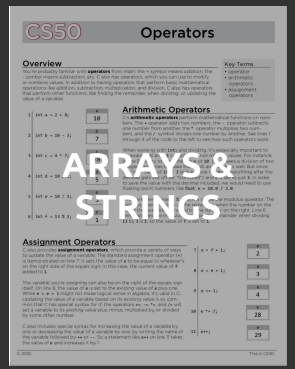
If you submit all three, your highest two scores will count.

REFERENCE SHEETS



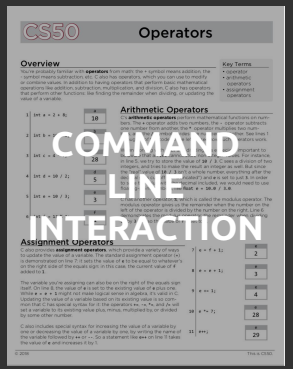
ASCII

https://www.dropbox.com/sh/5y662ey1hc4sde4/AACTZ9s1PxHcq1nQ-qLOSmKDa/ASCII.pdf?dl=0



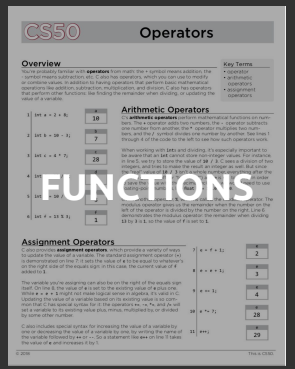
ARRAYS & STRINGS

https://www.dropbox.com/sh/5y662ey1hc4sde4/AAANVfQjHejjkx_HhI3rm4DSa/Arrays%20and%20Strings.pdf?dl=0



COMMAND LINE INTERACTION

https://www.dropbox.com/sh/5y662ey1hc4sde4/AADuQLOrUhJBC8ITuLvCp5cTa/Command-Line%20Interaction.pdf?dl=0



FUNCTIONS

https://www.dropbox.com/sh/5y662ey1hc4sde4/AABW3PttM7UdTY4ny_TS1tePa/Functions.pdf?dl=0

COME HAVE BRUNCH WITH ME!

This Sunday @ **11am** in **Winthrop Dining Hall**.

Survey Link

Finish the survey if you haven't already or are new to the section:

tinyurl.com/y7mxcdnu