YEAH A1

Welcome to C++!

-Professor Oak, CS106B alum and C++ pro

Trip Master
Zheng Lian

Welcome to YEAH

- **Y**our **E**arly **A**ssignment **H**elp was conceived many moons ago to help students start early on assignments
- We'll go over each part of the assignment, and I'll give helpful tips / hints, as well as conceptual overviews for trickier topics
  - Zheng and I will do our best to answer your questions :)
- These slides are **NOT** a supplement to reading the assignment handouts!
  - Keith's explanations are far more comprehensive and insightful!
- If possible, please come to the live YEAH sessions. Zheng and I get lonely :(

About us

Trip Master

- Senior studying CS Systems (hoping to study Systems as a coterm soon)

- A Cappella nerd and teaching fanatic

Zheng Lian (right)

- Coterm studying AI (studied CS Theory as an undergrad)

- Loves to sing and photograph with farm animals

Assignment 1 Logistics

- The assignment is due on **Friday 1/22 at the <u>start</u> of class**
- This assignment must be completed **individually** (but hopefully you know that!)

Assignment Overview

- Stack Overflow
  - When recursion can go terribly wrong!

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  - Recursive text modification!

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  - Recursion is beautiful!

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- Stack Overflow
  - When recursion can go terribly wrong!
- Only Connect
  - Recursive text modification!
- Playing Fair
  - Fairness to a higher order
- Sandpiles
  - Recursion is beautiful!
- Plotter
  - Iteration can be beautiful, too :)

Before We Begin

- Please let us know if there is any technical difficulty
- And please ask clarifying questions! They are extremely helpful to both you and your peers

Part 1: stackoverflow

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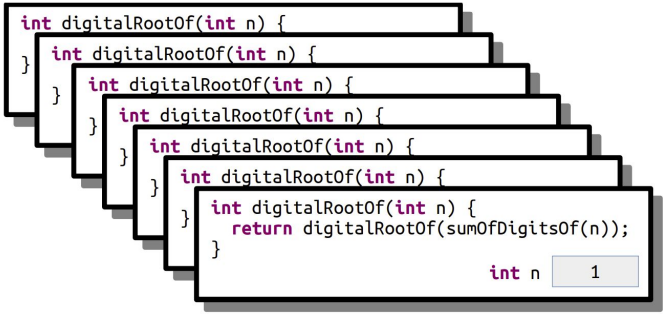
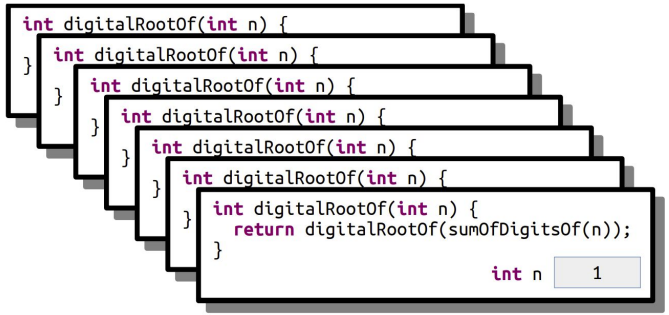
- Every time you call a function, a portion of your computer's memory (DRAM) is allocated called a **stack frame**.
- In a **recursive** function, every time we recurse, the computer needs to generate a new stack frame!



As you can see, each time digitalRootOf() calls itself, a new frame is created!

What happens if we don't include a proper terminating (base) case in our code?



Is there a limit to how many stack frames we can create?

Part 1: stackoverflow

- A program that has **infinite recursion** will run into something called **Stack Overflow**
  - **Stack Overflow** happens when your computer runs out of RAM to allocate to your programs!
  - Attempting to create infinite stack frames will do this!

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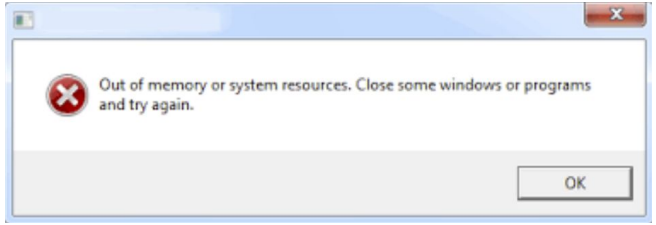
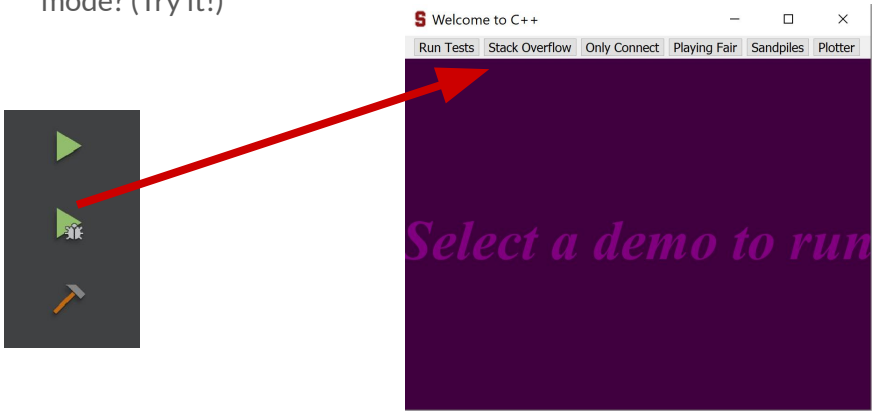


Stack Overflow problems happen all the time in the real world!

Part 1: stackoverflow

- In this first part, your task is to examine the file `Stackoverflow.cpp`and step through it in the **debugger**
- All you have to do is run the Stack Overflow program in the debugger.
  - Question for the reader: what's the difference between running this program in normal mode vs debug mode? (Try it!)



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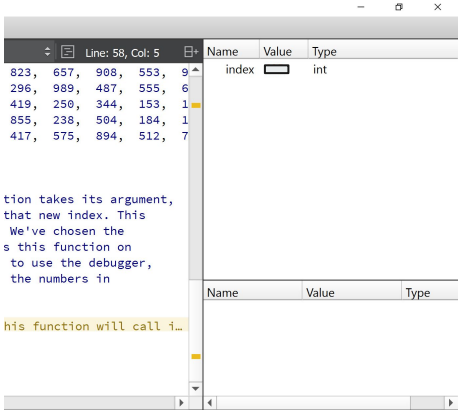

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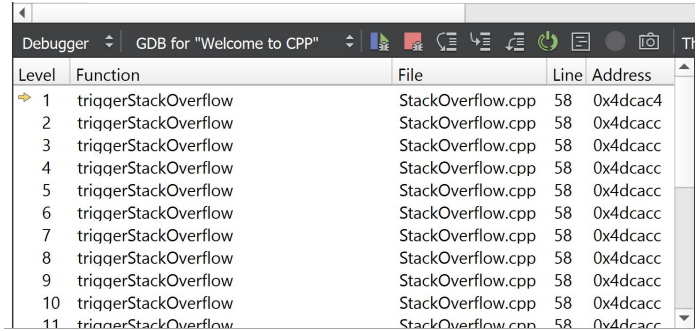
- As you click on other instances in the **call stack**, you'll notice that the value of *index* will change!



Level	Function	File	Line	Address
1	triggerStackOverflow	StackOverflow.cpp	58	0x4dcac4
2	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc
3	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc
4	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc
5	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc
6	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc
7	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc
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11	triggerStackOverflow	StackOverflow.cpp	58	0x4dcacc

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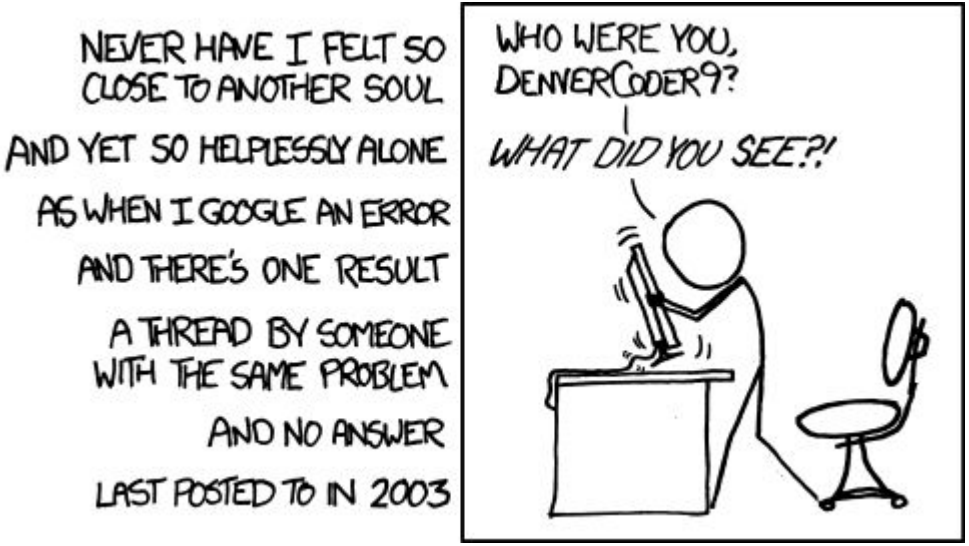
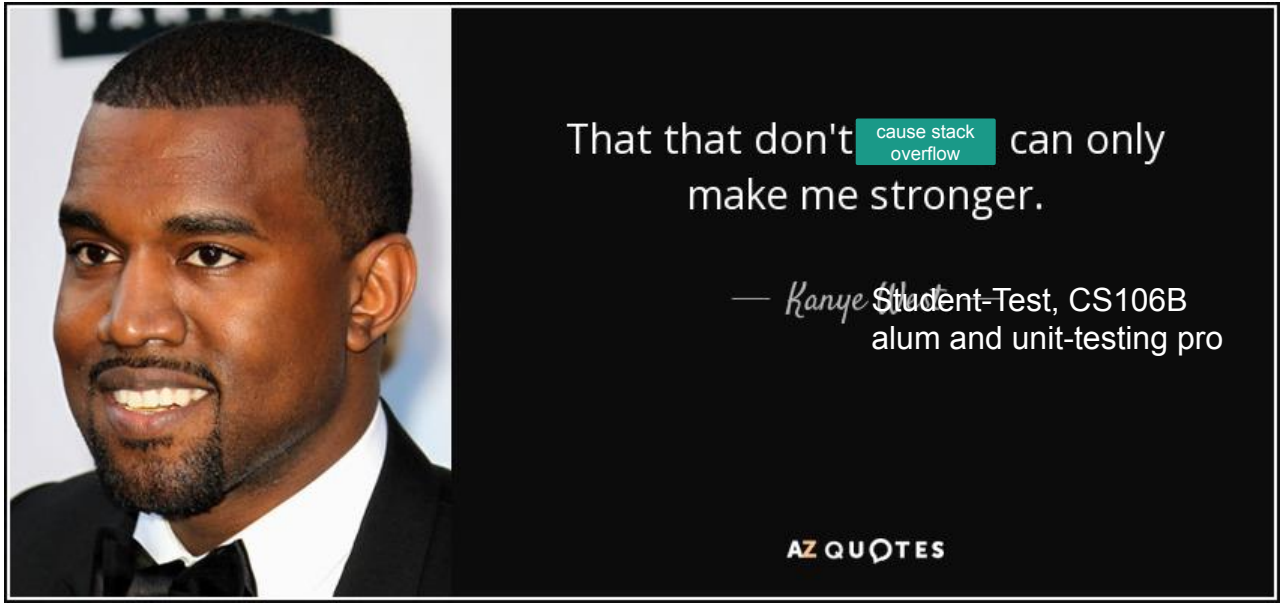
- Once your program has crashed due to Stack Overflow, you'll need to examine the **call stack**, the sequence of function calls that the program executed.
- You should notice a variable *index* appear in your debug window on the right side of your screen. (I've hidden its value)
- As you click on other instances in the **call stack**, you'll notice that the value of *index* will change!
- **Your task is to identify the <u>cycle</u> in the values of *index*, which is causing the infinite recursion!**
  - Report these numbers in the comments of the `Stackoverflow.cpp` file

Questions about stackoverflow?



Before we continue, let’s talk about…

Kanye StudentTest's Testing Overview!



Running Tests in CS106B

- An important part of CS106B is **testing**, the ability to write small pieces of functionality that you can test.
- There are 4 functions you'll be frequently using this quarter, TIME_OPERATION, EXPECT, EXPECT_EQUAL, and EXPECT_ERROR.
  - You will create STUDENT_TESTs and use TIME_OPERATION, EXPECT, EXPECT_EQUAL, and EXPET_ERROR to verify the correctness of your functions!
- TIME_OPERATION (inputsize, operation) function call times how long it takes to perform function OPERATION on INPUTSIZE elements, and reports these numbers to the console.
- Check out the use of the EXPECT functions use on the next slide!

Running Tests in CS106B

```
int returnFive (int num) {
    if (num == -1) error ("Error, cannot process -1!");
    return 5;
}
// EXPECT tests the provided predicate.
STUDENT_TEST ("Verifies that returnFive returns five with EXPECT") {
    EXPECT (returnFive (0) == 5);
}
// EXPECT_EQUAL compares two values.
STUDENT_TEST ("Verifies that returnFive returns five with EXPECT_EQUAL") {
    EXPECT_EQUAL (returnFive (0), 5);
}
// EXPECT_ERROR passes if and only if the code it runs throws an error.
STUDENT_TEST ("Verifies that returnFive throws an error on bad input with EXPECT_ERROR") {
    EXPECT_ERROR (returnFive (-1));
}
```

Questions about testing?

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Let’s start coding!

Part 2: Only Connect

- In this part of the assignment, you'll be asked to implement the following **recursive** function:

```
string onlyConnectize(string phrase);
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  which, given a string of text, removes all characters **except** the consonants, and converts the remainder to uppercase.

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`onlyConnectize("Elena Kagan")` returns `"LNKGN"`,
`onlyConnectize("Antonin Scalia")` returns `"NTNNSCL"`,
`onlyConnectize("EE 364A")` returns `""`,
`onlyConnectize("For sale: baby shoes, never worn.")` returns `"FRSLBBSHSNVRWRN"`,
`onlyConnectize("Thank you, next (next)")` returns `"THNKNXTNXT"`, and
`onlyConnectize("Annie Mae, My Sea Anemone Enemy!")` returns `"NNMMSNMNNM"`.

Part 2: Only Connect

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yeet

What should you return if the first character is a vowel / non letter?
Do we even care about remembering this character?

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  - Take a look at the Stanford library "strlib.h" for some ~helpful~ string functions.
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  - Here are a few helpful char functions to help you get started!

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Returns a nonzero value (equivalent to true) if the provided character is in the alphabet

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But wait… why do these functions take in **ints** and not **chars**?

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It’s time for...

Charole Baskin's brief foray into char representation via the ASCII set!

-**Char**ole Baskin, 106B alum and mariticide suspect

How do we represent characters?

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- The computing world decided to get together to create a **standard number representation for popular chars** (128 of them!). **Each char would correspond to an integer in a table called the ASCII set.**
- For example, 'A' -> 65, and 'a' -> 97.

What does this code print?

```
string s = "apple";
cout << toupper(s[0]) << endl;
```

How do we represent characters?

- You need to be careful that you're not working directly with integers when you work with characters!
  - If a function returns an int, be sure **you're storing the data as a character** so that it can be read properly!

```
string s = "apple";
char firstLetter = toupper(s[0]);
cout << firstLetter << endl;
```

Back to the program...

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  - Feel free to add helper functions like **isVowel**! We love decomposition :)
  - Remember that we're treating 'y' like a vowel :)
  - **Be sure to add robust tests to your program to verify its correctness on tricky cases!**

Questions about Only Connect?

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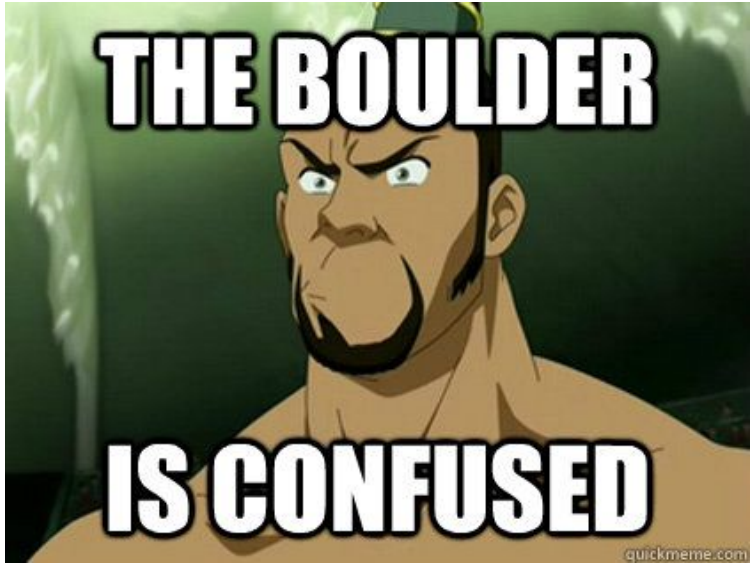

Confusion is nothing to be ashamed of -- just ask The Boulder!

Part 3: Playing Fair

- Next up, you'll be writing **two recursive** functions that, given some integer **n**, produce either an **A sequence** or a **B sequence** of order **n**.

```
string aSequenceOfOrder(int n);
string bSequenceOfOrder(int n);
```

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- Next up, you'll be writing **two recursive** functions that, given some integer **n**, produce either an **A sequence** or a **B sequence** of order **n**.
- Here's what these sequences look like in various orders!

	Order 0	*Order 1*	*Order 2*	*Order 3*	*Order 4*
A-sequence:	**A**	**AB**	**ABBA**	**ABBABAAB**	**ABBABAABBAABABBA**
B-sequence:	**B**	**BA**	**BAAB**	**BAABABBA**	**BAABABBAABBABAAB**

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B-sequence:	**B**	**BA**	**BAAB**	**BAABABBA**	**BAABABBAABBABAAB**

```
cout << aSequenceOfOrder(0) << endl;        // "A"
cout << bSequenceOfOrder(3) << endl;    // "BAABABBA"
```

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- To get insight into solving this problem, it will help to think about **building a solution from the ground up**.

	Order 0	*Order 1*	*Order 2*	*Order 3*	*Order 4*
A-sequence:	A	AB	ABBA	ABBABAAB	ABBABAABBAABABBA
B-sequence:	B	BA	BAAB	BAABABBA	BAABABBAABBABAAB

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  - For example, an order-1 A sequence is simply an order-0 A sequence concatenated with an order-0 B sequence!

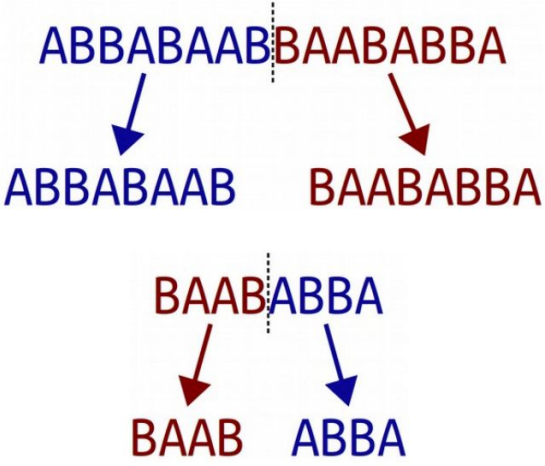
	Order 0	*Order 1*	*Order 2*	*Order 3*	*Order 4*
A-sequence:	A	AB	ABBA	ABBABAAB	ABBABAABBAABABBA
B-sequence:	B	BA	BAAB	BAABABBA	BAABABBAABBABAAB

  - Does this pattern continue for an order-n sequence?

Part 3: Playing Fair

- It totally does!

This order-4 A sequence consists of an order-3 A sequence and an order-3 B Sequence!



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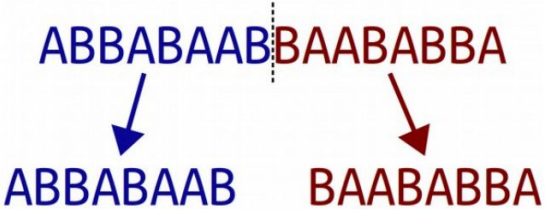
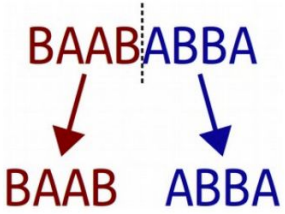


This order-3 B sequence consists of an order-2 B sequence and an order-2 A Sequence!



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    - Keep in mind that you are allowed to call the **BSequence()** function from the **ASequence()** function!

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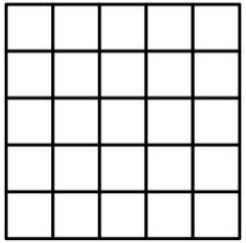
    - Keep in mind that you are allowed to call the **BSequence()** function from the **ASequence()** function!
  - Recall that this function takes an integer input *n*. If the user inputs a **negative number**, you should raise an error via the following syntax!

```
error("a string containing your error message");
```

Questions about Playing Fair?

```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

Part 4: Sandpiles



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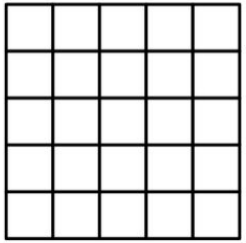
Part 4: Sandpiles



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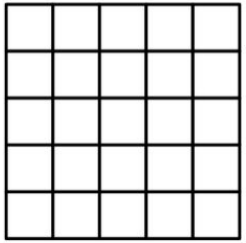


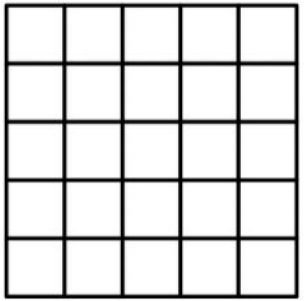
- In this penultimate part, you'll be writing code to simulate a sandbox like so:
- Each tile represents an entry in a `Grid<int>`called **world**.
- More specifically, you'll need to simulate the dropping of a grain of sand into this world via the recursive function:

```
void dropSandOn(Grid<int>& world, int row, int col);
```

  which attempts to drop a grain of sand into **world** at location **{row, col}**

Part 4: Sandpiles

Here's how dropping sand works:



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dropSandOn(world,
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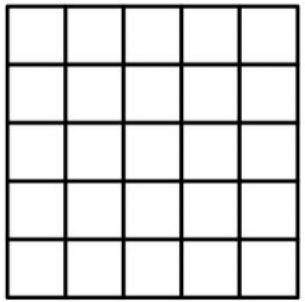

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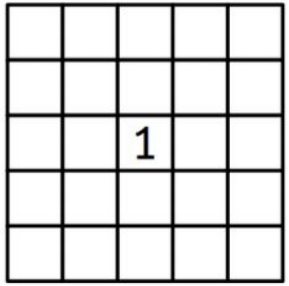
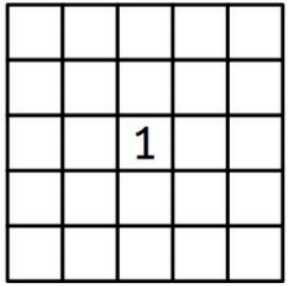


Now we have a single element at location{2,2}

Part 4: Sandpiles

Here's how dropping sand works:

```
dropSandOn(world,
2,2);
dropSandOn(world,
2,2);
```



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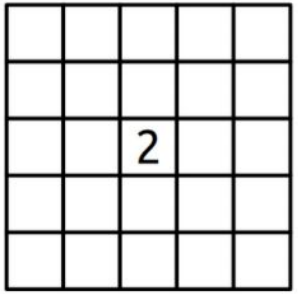

The number increases for every grain added!

Part 4: Sandpiles

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```
dropSandOn(world,
2,2);
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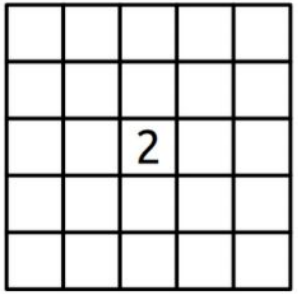

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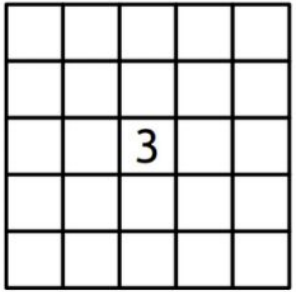

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Part 4: Sandpiles

Here's how dropping sand works:

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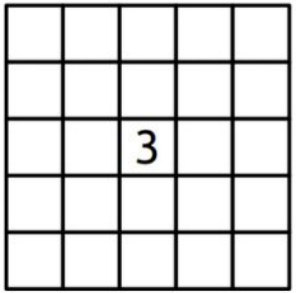
dropSandOn(world, 2,2);
dropSandOn(world, 2,2);
dropSandOn(world, 2,2);
dropSandOn(world, 2,2);
```



But something different happens any time a cell hits the number "4"...

Part 4: Sandpiles

Here's how dropping sand works:

```
dropSandOn(world, 2,2);
dropSandOn(world, 2,2);
dropSandOn(world, 2,2);
dropSandOn(world, 2,2);
```

		1		
	1		1	
		1		

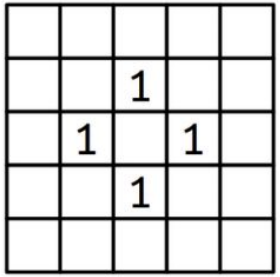
Boom!

Part 4: Sandpiles

		1		
	1		1	
		1		

- Here's what happened:
  - When a fourth piece of sand was placed on a square where 3 existed previously, the pile "**toppled,**" meaning the following:
    - It set the value in its current square to 0

Part 4: Sandpiles



- Here's what happened:
  - When a fourth piece of sand was placed on a square where 3 existed previously, the pile "**toppled,**" meaning the following:
    - It set the value in its current square to 0
    - It increased the value in squares in each of the cardinal directions by 1, effectively repeating the "dropping" process in those 4 locations!
      - Yes, this means that dropping sand in one location could cause a chain reaction if neighboring (cardinal) cells already have 3 piles of sand in them!

Part 4: Sandpiles

- A few more details about this problem:
  - This function must be done **recursively**. The sandpile routine should look quite self-similar when you need to topple piles of 4!

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  - This function must be done **recursively**. The sandpile routine should look quite self-similar when you need to topple piles of 4!
  - Beware of the bounds of the grid. Any pile that topples on the boundary of a grid should not attempt to modify out of bounds locations.
    - You can determine whether a coordinate set is in bounds with the `grid.inBounds(row,col)` function.

Part 4: Sandpiles

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  - This function must be done **recursively**. The sandpile routine should look quite self-similar when you need to topple piles of 4!
  - Beware of the bounds of the grid. Any pile that topples on the boundary of a grid should not attempt to modify out of bounds locations.
    - You can determine whether a coordinate set is in bounds with the `grid.inBounds(row,col)` function.
  - In case you need a refresher, here's how you might access / set the {0,0} element of some existing grid **world**!

```
world[0][0] = 137;

cout << world[0][0] << endl;  // 137
```

Questions about Sandpiles?

-Anakin Try(-catch)walker, 106B cynic and disgraced Jedi (in that order)

Part 5: Plotter

- It’s time for the final part of the assignment, and guess what?

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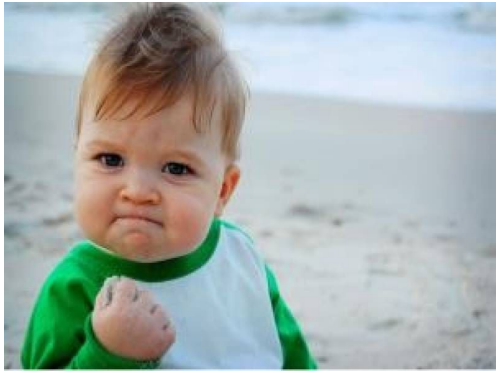

This serious!

Part 5: Plotter

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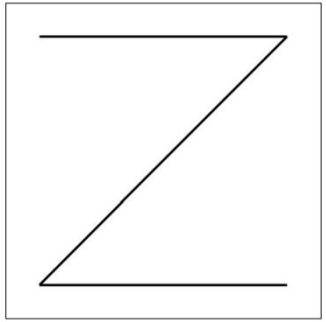
  - A **plotter** is a coordinate-based drawing system that turns a series of commands into a drawing on a simply canvas!
  - Here's an example:

```
MoveAbs -0.8 0.8
PenDown
MoveAbs 0.8 0.8
MoveAbs -0.8 -0.8
MoveAbs 0.8 -0.8
```



Notice that the pen starts at (0,0), so `MoveAbs(-0.8,0.8)` would move the pen to the **upper**-**left**

Part 5: Plotter

- Here are a few logistics about the plotter:
  - The pen initially begins at (0,0), which in the **center** of the canvas. It begins **not on the canvas**, with **width=1** and **color=black**

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void drawLine(double x0, double y0,
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I draw a line from (x0,y0) to (x1, y1), with a pen **width** and **color** determined by the **PenStyle** struct!

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struct PenStyle {
    double width;
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A **struct** is a custom-defined container. **PenStyle** is defined in "`plotter.h`"

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I draw a line from (x0,y0) to (x1, y1), with a pen **width** and **color** determined by the **PenStyle** struct!

```
PenStyle style;
style.width = 2.71828;
style.color = "orange";
cout << style.color << endl;
```

Here's how to declare and store properties inside a struct. Remember that **width** and **color** were defined by the programmer in the struct signature on the right!

```
struct PenStyle {
    double width;
    std::string color;
};
```

A **struct** is a custom-defined container. **PenStyle** is defined in "`plotter.h`"

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```
void runPlotterScript(istream& script);
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I contain a series of commands (stored as **strings**) that you will read in line by line! These commands are instructions for your plotter!

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```
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```
for (string line; getline(name-of-stream, line); ) {
    /* ... do something with line ... */
}
```

Here's how you might read individual lines from the **script** stream!

Part 5: Plotter

- Here are the kinds of commands (lines) that you'll encounter!

`PenDown`: Lowers the pen. Has no effect if the pen is already down.

`PenUp`: Raises the pen. Has no effect if the pen is already up.

`MoveAbs` *x y*: Moves the pen to position (x, y), drawing a line if the pen was down. The values of x and y can be any real numbers and might not fit within the bounds of the paper. If that's the case, just move the pen off the page. Our `drawLine` function is smart enough to only draw the part of the line that happens to be on the page.

`MoveRel` *dx dy*: Adds dx to the pen's x coordinate and dy to the pen's y coordinate, drawing a line if the pen was down. As above, dx and dy can be any real numbers and might take the pen off the page.

`PenColor` *color*: Changes the color of the pen to the string given by *color*. (The `drawLine` function supports basic color names like `red`, `orange`, `yellow`, etc., along with HTML colors like `#c41e3a`. If you haven't seen HTML colors before, check out this link for some examples.)

`PenWidth` *width*: Changes the width of the pen to the number given by *width*, which can be any positive real number. Larger widths draw thicker lines.

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I'm gonna post on this slide for a second for questions!

Part 5: Plotter

- Here's another example list of commands:

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MoveAbs 0 1
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PenUp
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PenDown
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- Notice that many of the commands include numbers as arguments.

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- Notice that many of the commands include numbers as arguments.
- These arguments will always be **delimited** (separated) by spaces in a line, so if you want to turn a single command into a **vector of tokens** (items separated by delimiters), use the following function: (in "`strlib.h`")

```
Vector<string> name-of-result = stringSplit(string-to-split, what-to-split-on);
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Part 5: Plotter

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  `Vector<string> name-of-result = stringSplit(string-to-split, what-to-split-on);`
- You can turn string representations of numbers into floating point numbers via `stringToReal(string s)`

Part 5: Plotter

- Some final thoughts:
  - You can assume that the stream provided to you is properly formatted -- even though the case might be strange, data will always be formatted correctly like it was in the examples :)

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  - Remember to **initialize** the plotter (set the initial position to (0,0), and set the **color=black** and **width=1**) <u>before</u> you begin reading from the stream!

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  - Whenever dealing with strings, take another looksie through "`strlib.h`"! You might surprise yourself with the helpful functions!

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  - Whenever dealing with strings, take another looksie through "`strlib.h`"! You might surprise yourself with the helpful functions!
  - You'll be testing your **plotter** by running pre-packaged plotter scripts, and then you will manually inspect them for correctness. Don't worry -- if your implementation is incorrect you should be able to tell by inspection :)

Questions about Plotter?

An old Hewlett-Packard Plotter machine. Kinda… ugly, no?

Congrats! You're ready to tackle A1!

Good luck! If you get stuck, remember that you have your wonderful **Section Leaders** and **LAIR** hours for help!