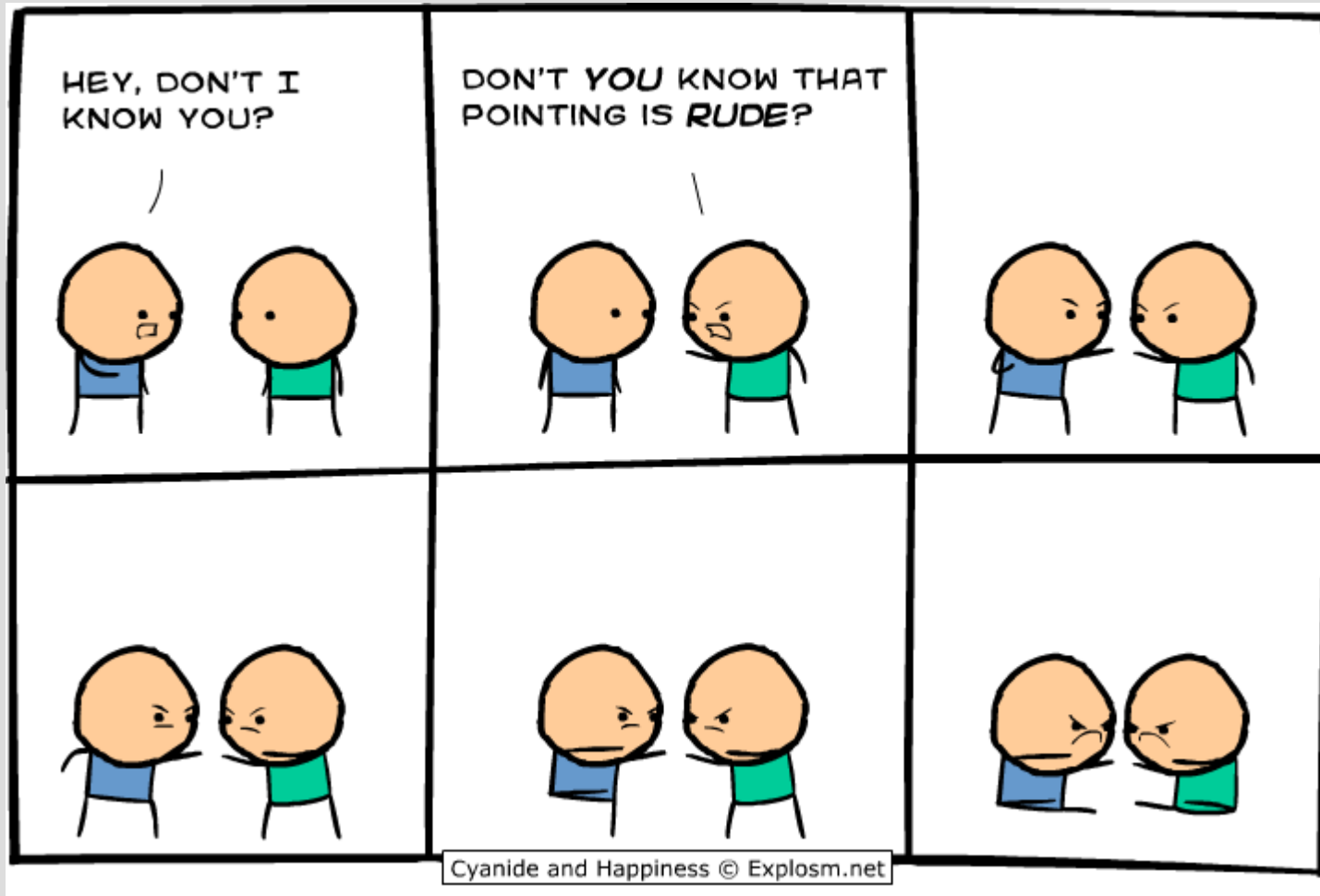


Pointers

Ch 9 & 13.1



Highlights

- pointers

```
int x = 6;  
int* xp;  
xp = &x;
```

- dynamic arrays

```
int* x = new int[5];  
x[0] = 2;  
x[1] = 7;  
// ...  
delete [] x;
```

- new & delete

```
int *xp;  
xp = new int;  
*xp = 5;  
delete xp;
```

object vs memory address

An object is simply a box in memory and if you pass this into a function it makes a copy

A memory address is where a box is located and if you pass this into a function, you can change the variable everywhere

Memory address	Object (box)
arrays (pointers)	int, double, char, ...
using &	classes

Review: address vs value

Consider the following:

```
int x=6;  
cout << x << "\n";  
cout << &x << endl;
```

`x` is a variable (a box containing value 6)

`&x` is a memory address (sign pointing to box)

- Rather than giving the value inside the box, this gives the whole box

(see: memAddress.cpp)

Review: address vs value

Similar to a URL and a webpage

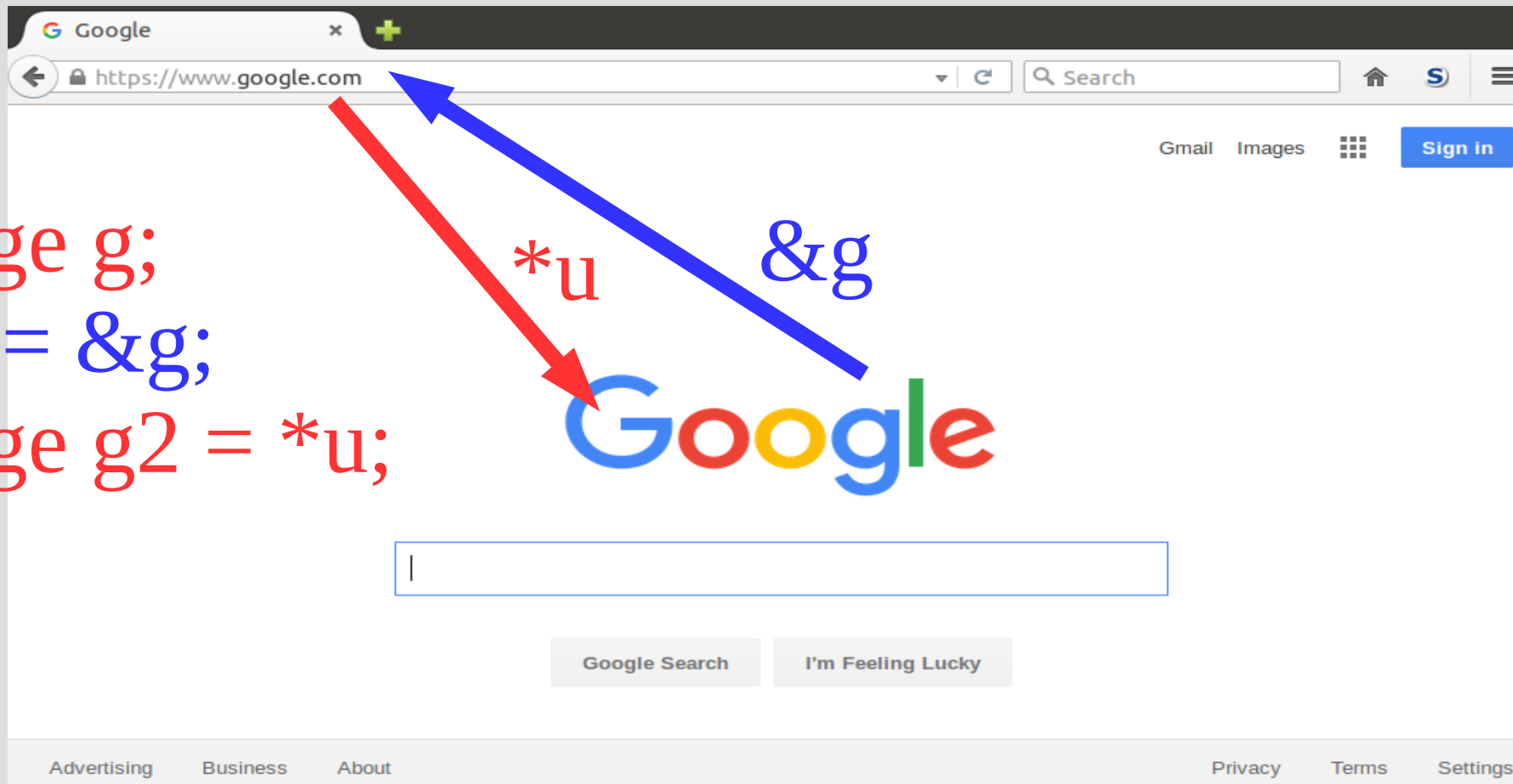
-A URL is not a webpage, but a link to one

The image shows a screenshot of the Google homepage in a web browser. The browser's address bar contains the URL `https://www.google.com`. A blue arrow points from the address bar to the Google logo, and a red arrow points from the text 'Webpage g;' to the letter 'g' in the logo. Another blue arrow points from the text 'cout << &g;' to the letter 'g' in the logo. The text 'Webpage g;' is in red, and 'cout << &g;' is in blue. The Google logo is in its characteristic multi-colored font. Below the logo is a search input field and two buttons: 'Google Search' and 'I'm Feeling Lucky'. The footer of the page includes links for 'Advertising', 'Business', 'About', 'Privacy', 'Terms', and 'Settings'.

Webpage g;
cout << &g;

Pointers

Just as `&` goes from value (webpage) to address (url), `*` goes the opposite:



Webpage `g`;
URL `u = &g`;
Webpage `g2 = *u`;

Pointers

You can also think of pointers as “phone numbers” and what they point to as “people”



1-800-presdnt
(pointer)



Trump
(object)



Pointers

If multiple people have the same “phone number”, they call the same person (object)



Trump
(object)



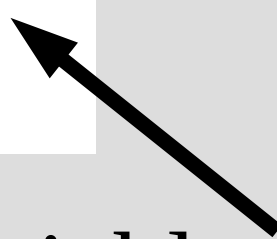
1-800-presdnt
(pointer/
memory address)

1-800-presdnt

Pointers

A pointer is used to store a memory address and denoted by a * (star!)

```
int x = 6;  
int* xp;  
xp = &x;
```



Here variable “xp” has type “integer pointer”

```
cout << *(&x); // *(&x) same as x
```

The * goes from address to variable (e.g. like hitting ENTER on a url, or “call” on a phone contact) (See: pointerBasics.cpp)

Pointers (phone analogy)

```
int* jacky;
```

Make a contact name called "jacky"

Make a phone-number for an person (int)

```
int Jacqueline_Wu = 9;
```

Make a person (int) "Jacqueline Wu" exist

```
jacky = & Jacqueline_Wu;
```

(& = address of)

Save Jacqueline Wu's phone number into the "jacky" contact

```
*jacky = 9001;
```

Call the "jacky" contact (and connect with Jacqueline Wu)

* = call up

Pointers

It is useful to think of pointers as types:

```
int* xp;
```

Here I declared a variable “xp” of type “int*”

Just like arrays and [], the use of the * is different for the declaration than elsewhere:

Declaration: the * is part of the type (**int*** xp;)

Everywhere else: * follows the pointer/address
(i.e. ***xp = 2;** puts 2 where xp is pointing to)

Pointers

Pointers and references allow you to change anything into a memory address that you want

This can make it easier to share variables across functions

You can also return a pointer from a function
(return links to variables)
(see: `returnPointer.cpp`)

Pointers

Why do we need pointers? (memory addresses are stupid!!!)

Suppose we had the following class:

```
class Person{  
    string name;  
    Person mother;  
    Person father;  
};
```

Will this work?

Pointers

As is, it will not... it is impossible to make a box enclose two other equal sized boxes

The only way it can enclose something like itself is that thing is smaller

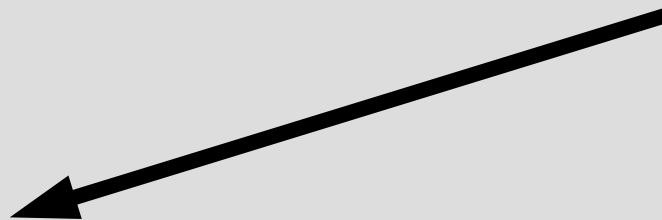


Pointers

To do this we can use pointers instead!

A pointer does not store the whole class data, it only remembers where it is (like a URL)

```
class person{  
    string name;  
    person* mother;  
    person* father;  
};
```



(See: person.cpp) (more on this shortly)

->

When dealing with classes, often you need to dereference (*) and access a member (.)

There is a shortcut to de-reference and call a member (follow arrow and go inside a box)

You can replace (*var).x with var->x, so...

```
(* (me.mother)).name;
```

... same as ...

```
me.mother->name;
```


Person class

How would you make your grandmother?
How could you get your grandmother using only yourself as a named object?

```
class person{  
    string name;  
    person* mother;  
    person* father;  
};
```

(See: personV2.cpp)

Pointers and memory

Ch 9 & 13.1

```
#INCLUDE <STDIO.H>
STATIC CHAR *PTR="OKAY";
INT MAIN(INT
```

THE SEGFALT
IN OUR

CHAR STARS

```
ARGV) {
C.CH (PTR) {
AR**A WHILE PRINTF("%c", *PTR++) }
RGV) { (PTR) { \n", *PTR++), } }
```

Boxes

What is comes next in this pattern?

Basic programming: `int x;`
Ask for one box with a name

Intermediate programming: `int x[20];`
Ask for multiple boxes with one name

Advanced programming: ???
???

Boxes

What is comes next in this pattern?

Basic programming: `int x;`
Ask for one box with a name

Intermediate programming: `int x[20];`
Ask for multiple boxes with one name

Advanced programming: `new int;`
Ask for a box without giving it a name

new

Pointers are also especially useful to use with the new command

The new command will create a variable (box) of the type you want

```
int x;  
x = 2;
```

← ask for box

```
int *xp;  
xp = new int;  
*xp = 4;
```

The new integer has no separate name, just part of xp (as array boxes part of array name)
(See: newMemory.cpp)

new

What does this do?

```
int main()  
{  
    while(true)  
    {  
        int *x = new int;  
    }  
    return 0; //totally going to get here!  
}
```

new

What does this do?

```
int main()
{
    while(true)
    {
        int *x = new int;
    }
    return 0; //totally going to get here!
}
```

Asking for a lot of boxes there...
(See: memoryLeak.cpp)

delete

When your program exits, the operating system will clean up your memory

If you want to clean up your memory while the program is running, use delete command

```
int *imaPointer; // pointer box (holds address)
imaPointer = new int; // point here!
// do some stuff...
delete imaPointer; // goodbye pointer
```

(See: deleteMemory.cpp)

delete

This is also a memory leak:

```
int *ptr; // make a pointer
ptr = new int; // point here
ptr = new int; // more the merrier
delete ptr; // ERASE
```

By the 3rd line, there is no link back to the box on the 2nd line (dangling pointer)

There should be a “delete” for every “new”

delete

As you can manage how you want to create new variables/boxes, using new/delete is called dynamic memory

Before, the computer took care of memory by creating variables/boxes when you use a type then deleting when the function ends



← Before

Now →



delete

Memory management is a hard part of C++

You need to ensure you delete all your boxes after you are done with them, but before the pointer falls out of scope
(see: `lostPointer.cpp`)



Some other languages manage memory for you

Person class

The ability to have non-named boxes allows you to more easily initialize pointers

```
class person{  
    string name;  
    person* mother;  
    person* father;  
};
```

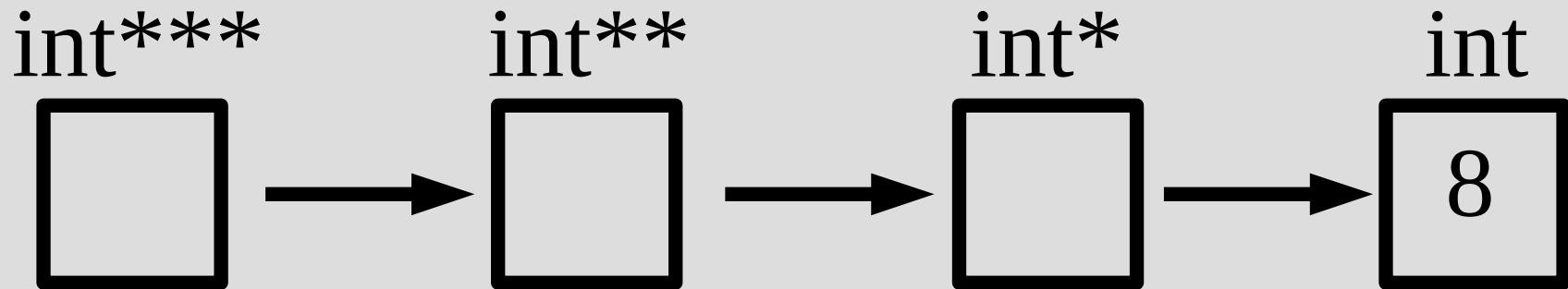
(See: personV3.cpp)

Pointer to pointer

You can have multiple stars next to types:

```
int*** x;
```

Each star indicates **how many arrows** you need to follow before you find the variable



X

(See: `pointerPointers.cpp`)

What pointers can/cannot do

Pointers CAN do

```
int *ptr;  
int x = 2;  
ptr = &x;
```

```
// pointer to...  
int **ptr2;  
// .. a pointer!  
int *ptr;  
int x = 10;  
ptr2 = &ptr;  
ptr = &x;
```

Pointers CANNOT do

```
int *ptr;  
ptr = new int;  
*ptr=3;  
int x;  
&x = ptr;  
//cannot relabel/move box
```

```
int *ptr;  
double x = 2.5;  
ptr = &x;  
// may seem weird...
```

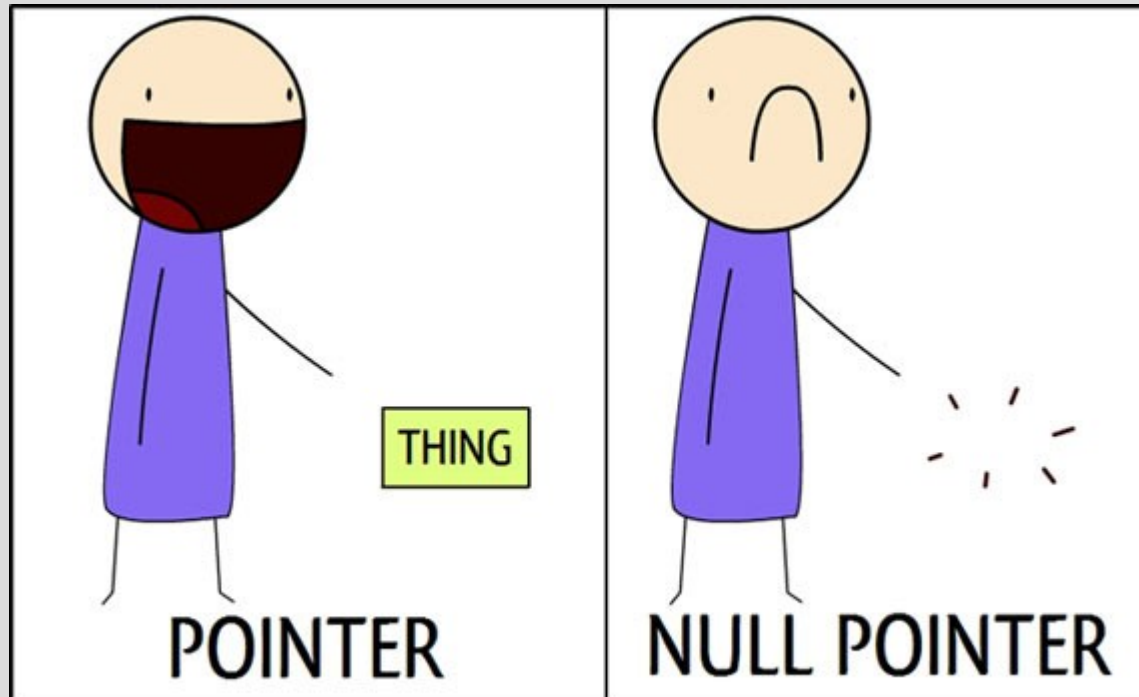
nullptr

When you type this, what is ptr pointing at?

```
int *ptr;
```

Answer: nullptr (or NULL)

```
int *ptr = nullptr;
```



nullptr

The null pointer is useful to indicate that you are not yet pointing at anything

However, if you try to de-reference it (use *), you will seg fault

```
int *ptr = nullptr;  
cout << *ptr << endl;
```

```
Terminal  
Segmentation fault (core dumped)  
  
-----  
(program exited with code: 139)  
Press return to continue
```

Do not try to ask
the computer
to go here

(see: nullptr.cpp)

Multiple deletes

Every new should have one corresponding delete command (one for one always)

The delete command gives the memory where a variable is pointing back to the computer

However, the computer will get angry if you try to give it places you do not own (i.e. twice)

```
int* x = new int;  
delete x;  
delete x;
```

Dynamic arrays

One of the downsides of arrays, is that we needed to have a fixed size

To get around this we have been making them huge and only using a part of it:

```
const int SIZE = 400;  
int list[SIZE]; // SIZE must be const
```

Then we need to keep track of how much of the array we are currently using

Dynamic arrays

Arrays are memory addresses (if you pass them into function you can modify original)

So we can actually make a dynamic array in a very similar fashion

```
int x;  
cin >> x;  
int *list; // pointer to array  
list = new int[x];  
// arrays are just memory addresses
```

(this memory spot better to store large stuff)

Dynamic arrays

One important difference to normal pointers

When you delete an array you must do:

```
int *list; // pointer to array  
list = new int[x];  
delete [] list;
```

need empty
square brackets



If you do the normal one, you will only delete a single index (list[0]) and not the whole thing

```
int *list; // pointer to array  
list = new int[x];  
delete list; // BAD BAD BAD BAD BAD
```

(See: dynamicArrays.cpp)

Functions & pointers

Another issues with arrays is that we could not return them from functions

Since arrays are memory addresses, we would only return a pointer to a local array

However, before this local array would just fall out of scope, but no more as dynamic memory stays until you manually delete it (See: `returnArrays.cpp`)

Dynamic 2D arrays

Since pointers can act like arrays...
(i.e. `int*` acts like `int []`)

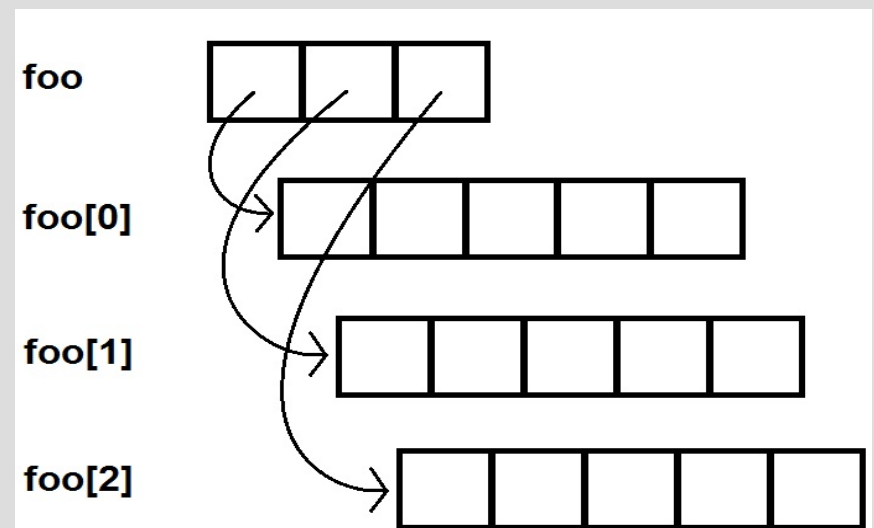
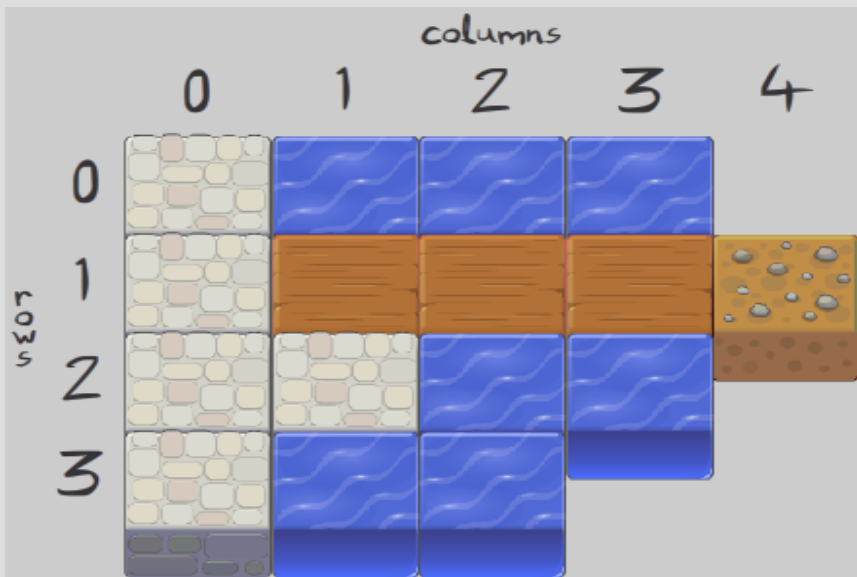
... `int**` can act like a two dimensional array

But need to use `new` to create each column individually (but can change the size of them)

When deleting, same structure but backwards (delete each column, then rows)

Dynamic 2D arrays

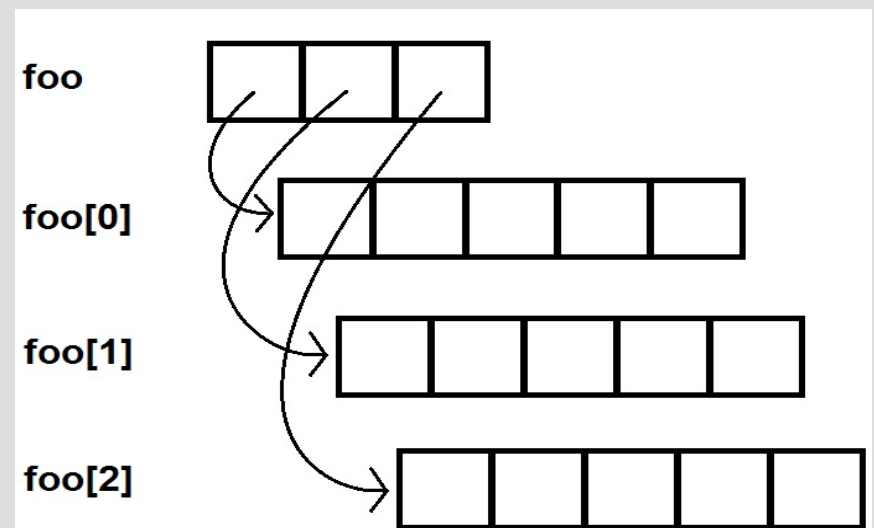
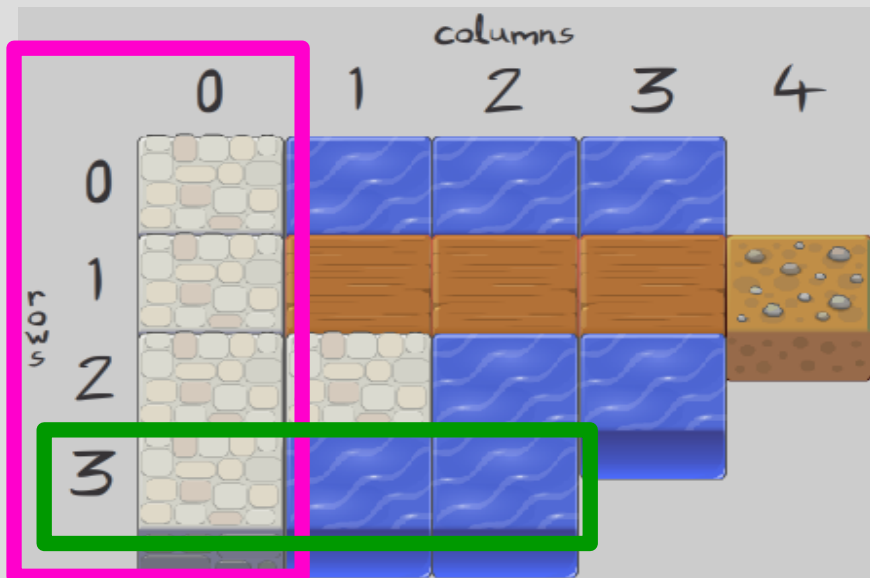
```
int** arr;  
arr = new int*[4]; // 4 rows (of pointers)  
arr[0] = new int[4]; // 1st row = 4 cols  
arr[1] = new int[5]; // 2nd row = 5 cols  
arr[2] = new int[4]; // 3rd row = 4 cols  
arr[3] = new int[3]; // 4th row = 3 cols
```



(See: raggedArray.cpp)

Dynamic 2D arrays

```
int** arr;  
arr = new int*[4]; // 4 rows (of pointers)  
arr[0] = new int[4]; // 1st row = 4 cols  
arr[1] = new int[5]; // 2nd row = 5 cols  
arr[2] = new int[4]; // 3rd row = 4 cols  
arr[3] = new int[3]; // 4th row = 3 cols
```



(See: raggedArray.cpp)

Reasons why pointer

Why use pointers?

1. Want to share variables (multiple names for the same box)
2. Dynamic sized arrays
3. Return arrays from functions (or any case of keep variable after scope ends)
(DOWN WITH GLOBAL VARIABLES)
4. Store classes within themselves
5. Automatically initialize the number 4 above