**POINTERS**

When you add for example 3 to (int) pointer, 3 (int) sizes are added to your pointer.

You can also use minus operator for pointers. You subtract an int from a pointer and the meaning is subtract this much memory locations.

int \* iptry; int \*p1, v1;

int \*\*p = &iptr; p1 = &v1;

You can do: “cout << &i;” (i is integer).

*!!!In call-by-reference, address of actual argument was passed.*

int \*p1, \*p2, v1, v2;

p1, p2 hold pointers to int variables; v1, v2 are ordinary int variables.

**Allocating Memory**

In C 🡪 int \* ap = (int\*)malloc(100\*sizeof(int));

In C++, we don’t like this bc we should know the return type.

In C++ 🡪 int \* ap = new int[100];

ap is now pointing to the beginning of 100 integers.

new is C++ keyword. It returns the proper pointer type.

You can do: Money \* ap = new Money[100];

new operator will call 100 constructors for money. You can’t do this kind of stuff with malloc.

You can put int variable instead of 100.

In C, we have free ; in C++, we have delete (delete ap) to return space to the system.

Don’t use malloc and free in C++.



\*p1 returns non-const int reference.

After this code, address in p1 and address in p2 are same. So they are pointing to same location.

This would be bad if you delete p1.

If you have for example (after allocate memory with new) 0xAB07 in p1 integer pointer and if you delete p1, then 0xAB07 will stay in p1 but the place that p1 is pointing will be gone, it is garbage (or it is memory management system dependent).

You can invoke different constructor with initializer arguments.

MyClass \*mcPtr;

mcPty = new MyClass(32.0, 17);

int \*n;

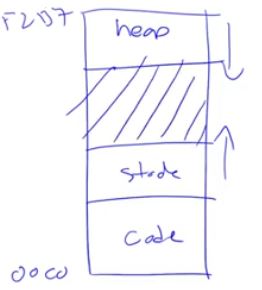
Initializes \*n to 17

n = new int(17);

Pointers can be function parameters and can be returned from functions.

**Memory Management**

* Heap (freestore)
  + Reserved for dynamically allocated variables
  + All new dynamic variables consume memory in freestore
    - If too many 🡪 could use all freestore memory
* new operations will fail if freestore is full



Stack is used for keeping your local variables inside your functions also for keeping the return addresses when you do function calls.

Globals are stored at the top of the heap.

Whatever you store in the stack, it is automatically created and deleted for you; whatever you store in the heap, it is created and deleted manually.

**C++11 nullptr**

* NULL is actually the number 0 (it is actually 🡪 “#define NULL 0”) and can lead to ambiguity.
  1. void func(int \*p);
  2. void func (int i);
* Which func is invoked given “func(NULL)”? Both are equally valid since NULL is 0.
* C++11 resolves this problem by introducing a new constant, nullptr
* nullptr is not 0
* Can use anywhere you could use NULL
* func(nullptr) will definitely call first function.

*!!! new operator will return nullptr if there isn’t enough space.*

int \*p;

p = new int;

if (p == nullptr){

cout << “Error: insufficient memory.\n”;

exit(1); }

cout or endl or NULL are not part of the language but nullptr is part of the language.

nullptr is pointer of each type but its value is fixed (constant, zero).

For newer compilers, if new operation fails program terminates automatically and produces error message but you should use nullptr check.

NULL represents the empty pointer or a pointer to nothing and will be used later to mark the end of a list.

OS keeps some parts of the program in the memory, not all of the program. Rest of the program stays on the disk. OS swap back and forth.

At the beginning the area for your program in the memory is very small maybe half a MB.

**delete operator**

free is a function, delete is an operator.

int \*p;

p = new int(5);

It is safe to assign p to nullptr so that nobody can access to garbage address that stays in p.

…

delete p;

p = nullptr;

With this, you get dangling reference. This is dangerous too.

Also if you are returning a reference to a local variable, after the function runs that local variable will go away then you have a dangling reference.

int &i = \*p;

delete p;

After you deleted p, if you do “p = nullptr”, i is still a reference to the original p location.

*!!!Memory management system only manages the heap, not stack. You can’t delete anything from stack.*

You can do stuffs like:

typedef int\* IntPtr;

Defines a new type alias. These two are equivalent:

IntPtr p;

int \*p;

Money ma[100]; 🡪 100 Money objects are created in stack

Remember name ma doesn’t have a place in the memory.

ma is const Money pointer: Money \* const ma;

You can do: Money \*mp = ma;

You can’t do: ma = nullptr; (bc ma is constant)

Array ma is deleted when its block is ended.

**Deleting a Dynamic Array**

int k = …;

You have to tell to compiler that da is pointing to an array. So compiler deletes all of them. If we just say “delete da;” compiler only deletes first one.

Money \*da = new Money[k];

…

delete [] da;

da = nullptr;

delete knows the size, it is detail of the memory management system.



int \* p1

const int \* p2 (whatever p2 is pointing is const)

int \* const p3 (p3 is const)

const int \* const p4

int a[10]; 🡪 here a is number 3 (p3). You cannot change a.

const int b[10]; 🡪 here b is number 4 (p4). You cannot change b and you cannot change any elements.

You have to initialize this.

*ANY CONSTANTS THAT YOU DEFINE ANYWHERE, YOU HAVE TO INITIALIZE THEM.*

**Function that Returns an Array**

int [] f(); NOT OK!

int \* f(); OK.

**Array Example**

**Alternative Array Manipulation**

Use pointer arithmetic

Step thru array without indexing:

for (int i = 0; i < arraySize; ++i)

cout << \*(d+i) << “ ”;

SAME AS

for (int i = 0; i < arraySize; ++i)

cout << d[i] << “ “;

typedef double \* DoublePtr;

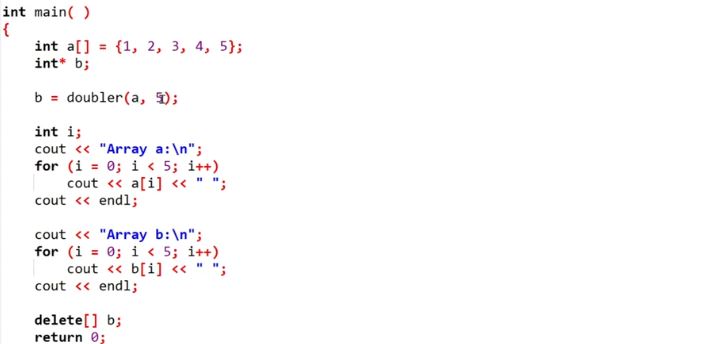
DoublePtr d;

d = new double[10];

* + d contains address of d[0]
  + d + 1 evaluates to address of d[1]
  + d + 2 evaluates to address of d[2]

You can do “\*(d+1) = 2.17;”

![Diagram

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDaRXhpZgAATU0AKgAAAAgABAE7AAIAAAAFAAAISodpAAQAAAABAAAIUJydAAEAAAAKAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAE1lcnQAAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAMwMAAAkpIAAgAAAAMwMAAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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**Multidimensional Dynamic Array**

typedef int\* IntArrayPtr;

IntArrayPtr \*m = new IntArrayPtr[3];

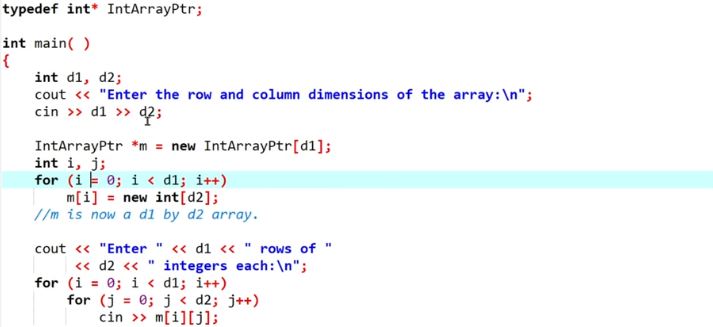
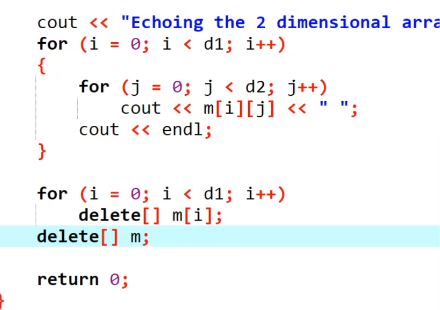
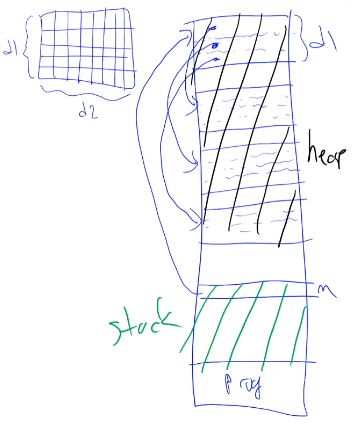
----> Creates array of 3 pointers

----> Make each allocate array of 4 ints:

for (int i = 0; i < 3; ++i)

m[i] = new int[4];

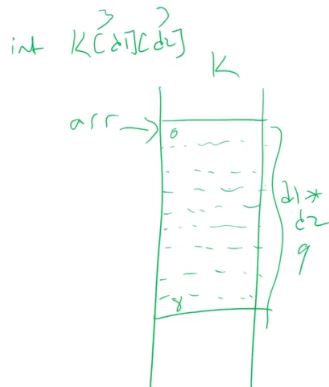
----> Results in 3-by-4 dynamic array.



same with: int\* \*m = new int\*[d1];

We need to run delete d1 + 1 times.

+ 1 is for d1 itself.

Normal 2D array.

This one is cheaper.

If you want to calculate K[2][1], you do these:

* K + 2\*3\*sizeof(int) + 1;
  + 4 operations.

You refer to the memory just once.

What about dynamically? You do these when you want to calculate m[2][1]:

* m + 2\*sizeof(int\*) + 1\*sizeof(int)
  + 4 operations again?

Instead of sizeof(int\*), you can do sizeof(decltype \*m) and instead of sizeof(int), you can do sizeof(decltype \*\*m).

This one is more expensive bc there are 2 memory lookup: 1 is inside d1, 2nd one is inside d2.

Also dynamic array stores 9 int + 3 int\* while normal one stores just 9 int in the memory.