POINTER AND ARRAYS

Arrays

Arrays are just sequential chunks of memory:

```
char s[5] = {'H','e','l','l','o'};
```

Arrays and Pointers

Array variables are secretly pointers:

```
char s[5] = {'H','e','l','l','o'};
char *p = s;
```

```
cout << *p << endl; // prints 'H'
cout << *s << endl; // also prints 'H'
```

Arrays and Pointers

Pointers are also secretly array variables:

```
char s[5] = {'H','e','l','l','o'};
char *p = s;
```

```
for (int j = 0; j < 5; j++) {
    cout << p[j] << endl;
}
```

To the compiler:

```
p[j] == *(p + j)
```

POINTER ARITHMETIC
**Pointer Arithmetic:** char

Suppose:
char s[] = {'H', 'e', 'l', 'l', 'o'};
char* p = s;

We’ve stated that:
p[j] == *(p + j)

Another way to look at it is:
p[j] == s[j] when p == s

Thus:

**Pointer Arithmetic:** int

Now, suppose we have:
int arr[] = {42, 17, 33, 6};
int* q = arr;

It can be demonstrated that:
q[j] == *(q + j) == arr[j]

This implies that:
q[1] == *(q + 1) == arr[1] == 17

Then q + 1 is not simply 1 byte address beyond q, but must be 4 bytes beyond q.

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**Pointer Arithmetic**

- Pointer arithmetic depends on type
  - char* p → p++ advances by 1 byte
  - int* q → q++ advances by 4 bytes (size of int)

- You can add or subtract:
  - q- - → go back 4 bytes
  - q + 3 → q plus 12 bytes

- Just keep in mind the array/pointer equivalence:
  - sometime* ptr;
  - *(ptr + k) == ptr[k]  // k * sizeof(sometime)  // bytes after ptr

---

**C-style Strings**

In C, strings are simply arrays of char:
char *s = "Hello!";  // valid in C; for C++ add const

This array has size 7, not 6: the last entry stores byte value 0, or '\0':

```
H e l l o ! \0
```

Without this value, there’s no way to detect the end of a string!

With it, though, we can do:
for (char* p = s; *p != '\0'; p++) {
  ...
}

String literals in C++ are still stored this way, but convert to the string type:
string foo = "Hello";

or
string("Hello")

---

**Pointers and Reference Parameters**

Reference parameters are not pointers!
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If you have a function
void foo(int &x) {
  ...
}

Inside foo, you cannot do
*x = 10;  // incorrect!

You just do
x = 10;  // correct

---

**Miscellaneous**

**POINTER NOTES**

Sources of confusion:
- & denotes a reference parameter
- & also used as address-of operator
- References use pointers "under the covers"
Array Limitations in C++

Standard C++ does not let you do this*:

```cpp
int sz;
cout << "What size do you need?" << endl;
cin >> sz;
int arr[sz]; // compiler error
```

*Strangely, later versions of C do allow this. Confusingly, so does g++ (some versions).

Dynamic Array Allocation

So what if you know you’ll need an array, but not the size (at compile time)?

```cpp
int sz;
cout << "What size do you need?" << endl;
cin >> sz;
int *arr = new int[sz];
```

Note that `new` gives us a `pointer` to our memory.

Where Does Memory Come From?

- **Stack**: local variables, function arguments, return values. Grows "down".
- **Heap**: dynamically allocated memory (using `new`). Grows "up".
- **Data Segment**: global and static variables, constants.
- **Text Segment**: program code. Read only!

Data Segment/BSS

Global and static variables:
- Only ever one instance of them
- Get stored in their own special area
- Memory is pre-allocated, fixed in size

The Stack

- Holds “stack frames” aka “activation records”
- Each function call results in a new stack frame
- Each stack frame contains memory for:
  - Local variables declared in the function
  - Parameters passed into function
  - Return address for function
- When the function is exited, all of this memory is returned to the stack automatically.
The Heap

A big ol’ hunk of memory!

- Get pieces of it ("allocate memory") using \texttt{new}
- Pieces stay allocated until explicitly released by use of \texttt{delete}

Heap memory has a lifetime \textit{independent of scope} – it can be used after a function that created it returns. You can’t do that with local variables!

Stack vs Heap

- \textbf{Stack: local aka automatic variables and arrays:}
  
  ```
  int z;
  foo f;
  double array[100];
  ```
  
  Memory for these is allocated on the stack when they come into scope, is returned to the stack when they go out of scope (e.g., when function returns).

- \textbf{Heap: dynamically allocated objects and arrays:}
  
  ```
  int* p = new int;
  foo* fp = new foo;
  double* dptr = new double[100];
  ```

  All of these live on the heap. They will exist until explicitly deallocated by user code.

Dynamic Arrays

\textit{Allocate} dynamic arrays using \texttt{new}:

```
double *darray = new double[1024];
```

Use the array pointer just like a regular array:

```
for (int j = 0; j < 1024; j++)
    darray[j] = 0.0;
```

Always clean up (\texttt{deallocation}) when you are done:

```
delete[] darray;
```

Pointers, Objects, and Dynamic Memory

Consider this simple class:

```
class student {
    public:
        string name;
        student() { ; }
        student(string n) { name = s; }
        void eat();
        void sleep();
};
```

Creating New Objects: Stack

If we want to create a student \textit{locally}:

```
student student1;
student student2("Kirk");
```

- These are created on the \textit{stack}.
- They will vanish when exiting the current scope.

student1 is created using the default constructor:

```
student();
```

student2 is created using another constructor:

```
student(string s);
```
Creating New Objects: Heap

We can also create single objects **dynamically**:

```
student* sp1 = new student;
student* sp2 = new student("Picard");
```

These are created on the **heap**. They will live forever unless deleted:

```
delete sp1;
delete sp2;
```

Note, again, the two different constructors.

Working With Object Variables

Consider:

```
student student1;
student* p = new student;
```

We know that we can do:

```
student1.name = "Sisko";
student1.eat();
```

What can we do with `p`?

Working with Object Pointers

We have:

```
student* p = new student;
```

We could just dereference (perfectly fine!)

```
(*p).name = "Janeway";
(*p).sleep();
```

C++ gives us another operator we can use directly:

```
p->name = "Archer";
p->sleep();
```

The Destructor

The counterpart to the constructor:

- No return type
- Name is `~` followed by class name, e.g., `~student();`
- Never takes a parameter!

The destructor is called automatically when:

- A local (stack allocated) object goes out of scope
- `delete` is called on a dynamically allocated object

Arrays of Objects

We can also use `new` to create arrays of objects:

```
int n = 100;
student* arr = new student[n];
```

The **default constructor** is used to create every object in the array.

Now we can do, e.g.: 

```
for (int i = 0; i < n; i++)
arr[i].gpa = 4.0;
```

As with base types, we use `delete[]` on dynamically allocated arrays of objects:

```
delete[] arr;
The destructor is called on every object in the array.
```

WRAPPING UP
Dynamic Memory Don'ts

Never:
- Dereference a pointer which has not been set to valid memory (using new or &)
- Dereference a pointer to memory which has already been deallocated (a dangling pointer)
- Change or lose a pointer which is pointing to dynamically allocated memory (or you won’t be able to deallocate – this causes a memory leak)
- Use delete on a pointer which isn’t pointing to dynamically allocated memory (e.g., a dangling or NULL pointer)

Up Next

- Friday, Sept. 21
  - Lab 5 – Memory
  - APT 2 Due
- Monday, Sept. 24
  - Midterm Review
  - Lab 5 Due
- Wednesday, Sept. 26
  - Midterm 1 (in class)