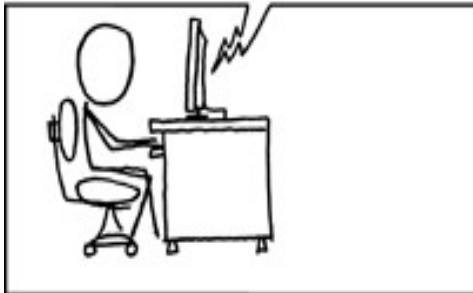


C++ Pointers (Part II), Arrays & References

```
prev->next = toDelete->next;  
delete toDelete;
```

```
// if only forgetting were  
// this easy for me.
```



```
assert "It's going to be okay.";
```



(<https://xkcd.com/379/>)

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Pointers (recap)

- Pointer values are memory addresses
- A pointer **does not** know the **number of elements** that it's pointing to.
- A pointer **does** know the **type of the object** that it's pointing to
- **Stack:** Stores local data, return addresses, used for parameter passing
 - Local variables
 - Cleared when out of scope
- **Heap:** You would use the heap if you don't know exactly how much data you will need at runtime or if you need to allocate a lot of data
 - Accessed using *new* and *delete*
 - *Memory leaks – manual delete of used memory*

Void*

- **void*** means “pointer to some memory that the compiler doesn't know the type of”
- We use **void*** when we want to transmit an address between pieces of code that really don't know each other's types – so the programmer has to know
- The primary use for void* is for passing pointers to functions that are not allowed to make assumptions about the type of the object and for returning untyped objects from functions
- There are no objects of type **void**
 - **void v;** *// error*
 - **void f();** *// f() returns nothing – f() does **not** return an object of type **void***
- Any pointer to object can be assigned to a **void***
 - **int* pi = new int;**
 - **double* pd = new double[10];**
 - **void* pv1 = pi;**
 - **void* pv2 = pd;**

void* (cont...)

- To use a **void*** we must tell the compiler what it points to

```
void f(void* pv) {  
    void* pv2 = pv;    // copying is ok (copying is what void*s are for)  
    double* pd = pv;   // error: can't implicitly convert void* to double*  
    *pv = 7;           // error: you can't dereference a void*  
    ++pv;              // error: can't increment void*  
                        // (the size of the object pointed to is unknown)  
    pv[2] = 9;         // error: you can't subscript a void*  
    int* pi = static_cast<int*>(pv);    // ok: explicit conversion  
                                         // Unsafe!!  
    // ...  
}
```

- A **static_cast** can be used to explicitly convert to a pointer to object type
 - "static_cast" is a deliberately ugly name for an ugly (and dangerous) operation
 - use it only when absolutely necessary

Warnings

- There are some serious *gotchas* when using casts on pointers, so try to avoid them
 - There is precisely **one** safe use, to get back to the type you started with – and a compiler can't check you got it right

```
myclass object();
```

```
myclass* myptr = object.addr();
```

```
void* rawptr = myptr;
```

```
...
```

```
myclass* newptr = static_cast<myclass*>(rawptr);
```

- You will often see C-style casts in C++ code derived from C – or by C programmers writing “C++”
 - They look like **(newtype)expression**
- But ***don't*** write them
 - They are extremely hard to spot in non-trivial code
 - They are even ***less*** safe than **reinterpret_cast**

void*

- **void*** is the closest C++ has to a plain machine address
- Functions using void* pointers typically exist at the very lowest level of the system, where real hardware resources are manipulated.

```
void* my_alloc(size_t n); // allocate n bytes  
                           //from my special heap
```

- **Avoid using it if you possibly can**
 - It bypasses essentially all type checks
 - Occurrences of void*s at higher levels of the system should be viewed with great suspicion because they are likely indicators of design errors.
- Pointers to functions and pointers to members cannot be assigned to void*s.

nullptr

- A pointer that does not point to an object.
- It can be assigned to any pointer type, but not to other built-in types:
 - **int* pi = nullptr;**
 - **double* pd = nullptr;**
 - **int i = nullptr;** // error: i is not a pointer
 - **int* x = 0;** // x gets the value nullptr
 - **int* p = NULL;** // error: can't assign a void* to an int*
// Macro NULL is typically (void*)0,
// which makes it illegal in C++

Arrays

- For a type T, T[size] is the type “array of size elements of type T.” indexed from 0 to size–1.

```
float v[3];    // an array of three floats: v[0], v[1], v[2]
```

```
char* a[32];   // an array of 32 pointers to char: a[0] .. a[31]
```

- Arrays don't have to be on the free store

```
char ac[7];           // global array – “lives” forever –  
                        // “in static storage” -AVOID!
```

```
int max = 100;
```

```
int ai[max];
```

```
int f(int n) {
```

```
    char lc[20]; // local array – “lives” until the end of  
                // scope – on stack
```

```
    int li[60];
```

```
    double lx[n]; // error: a local array size must be known  
                // at compile time
```

```
    std::vector<double> lx(n); would work
```

```
// ...
```

```
}
```


Initialization syntax

char ac[] = "Hello, world"; *// array of 13 **chars**, not 12 (the compiler
// counts them and then adds a null
// character at the end*

char* pc = "Howdy"; *// **pc** points to an array of 6 **chars***

char* pp = {'H', 'o', 'w', 'd', 'y', 0 }; *// another way of saying the same*

int ai[] = { 1, 2, 3, 4, 5, 6 }; *// array of 6 **ints**
// not 7 – the “add a null character at the end”
// rule is for literal character strings only*

int ai2[100] = { 0,1,2,3,4,5,6,7,8,9 }; *// the last 90 elements are initialized to 0*

double ad3[100] = { }; *// all elements initialized to 0.0*

Address of: &

- You can get a pointer to any object
 - not just to objects on the free store

```
int a;  
char ac[20];
```

```
void f(int n)  
{
```

```
    int b;
```

```
    int* p = &b;
```

```
    p = &a;
```

```
    char* pc = ac;
```

```
    pc = &ac[0];
```

```
    pc = &ac[n];
```

```
    // ...
```

```
}
```

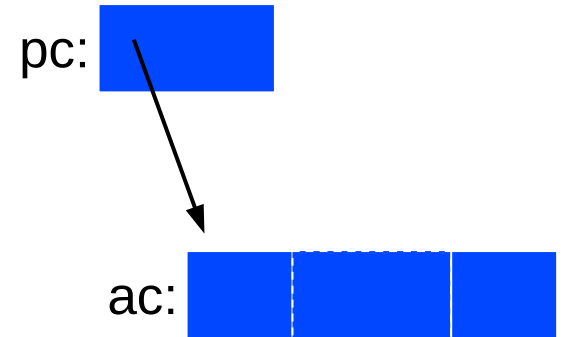
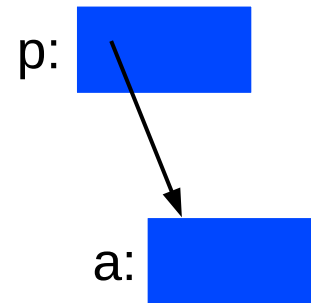
// pointer to individual variable

// the name of an array names a pointer to its first element

// equivalent to pc = ac

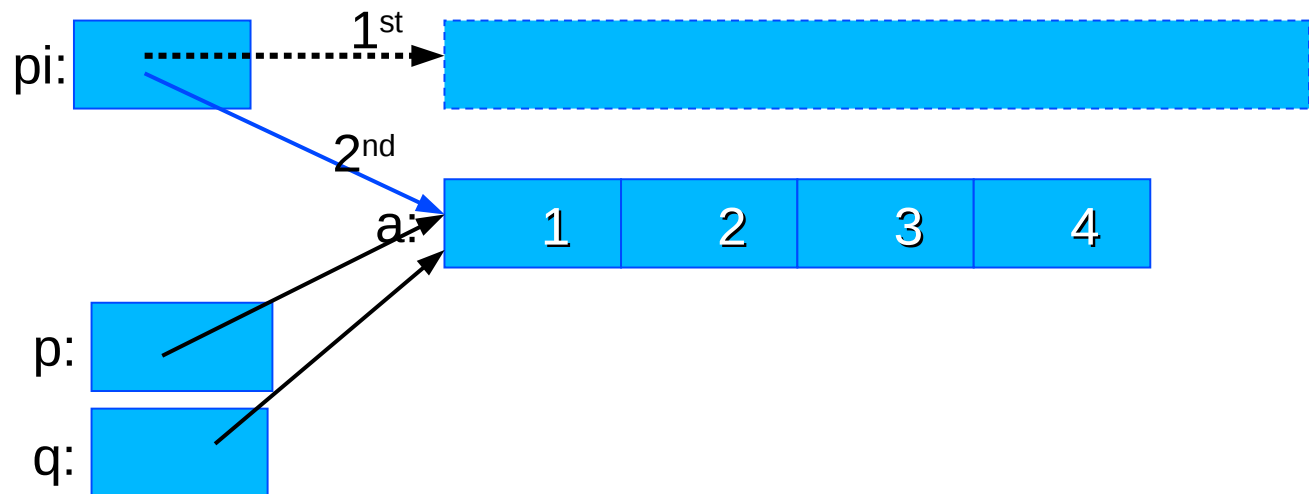
// pointer to ac's nth element (starting at 0th)

// warning: range is not checked



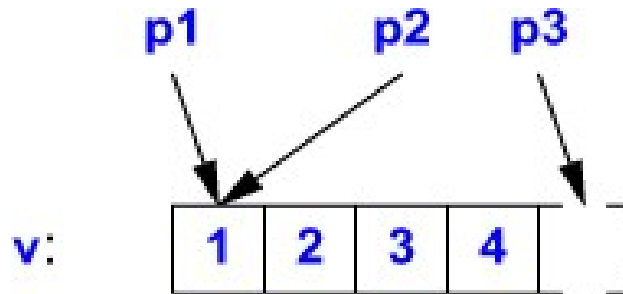
Arrays (often) convert to pointers

```
void f(int pi[ ]) // equivalent to void f(int* pi)
{
    int a[ ] = { 1, 2, 3, 4 };
    int b[ ] = a; // error: copy isn't defined for arrays
    b = pi; // error: copy isn't defined for arrays. Think of a
    // (non-argument) array name as an immutable pointer
    pi = a; // ok: but it doesn't copy: pi now points to a's first element
    // Is this a memory leak? (maybe)
    int* p = a; // p points to the first element of a
    int* q = pi; // q points to the first element of a
}
```



Arrays into pointers

```
int v[] = { 1, 2, 3, 4 };  
int* p1 = v;           // pointer to initial element (implicit  
                        // conversion)  
int* p2 = &v[0];       // pointer to initial element  
int* p3 = v+4;          // pointer to one-beyond-last element
```



```
int* p4 = v-1; // before the beginning, undefined: don't do it  
int* p5 = v+7; // beyond the end, undefined: don't do it
```

Accessing Array Elements

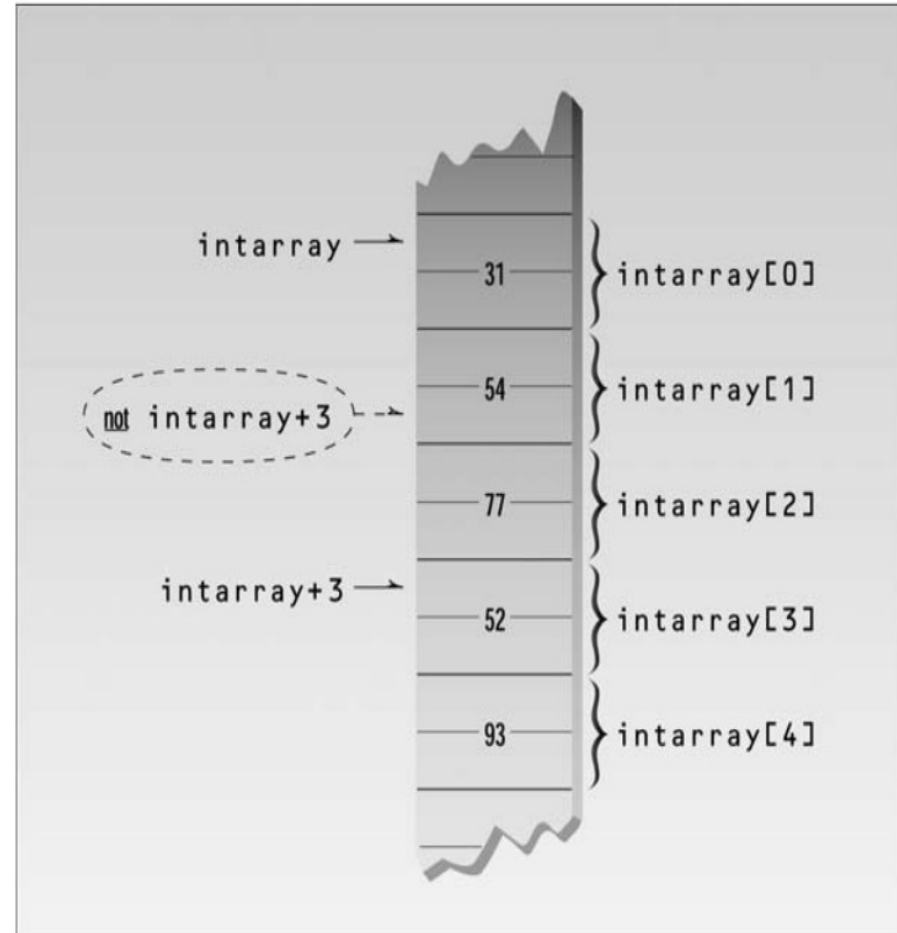
```
void fi(char v[]) {  
    for (int i = 0; v[i] != 0; ++i)  
        use(v[i]);  
}
```

```
void fp(char v[]) { //Using Pointers  
    for (char* p = v; *p != 0; ++p)  
        use(*p);  
}
```

Subscripting a built-in array `a[j]`:

`a[j] == &a[0][j] == *(a+j) == *(j+a) == j[a]`

`3["Texas"] == "Texas"[3] == 'a' (But, don't do it!)`



Multidimensional Arrays

- are represented as arrays of arrays.
- a 3-by-5 array is declared like this:
`int ma[3][5]; // 3 arrays with 5 ints each`
- We can initialize ma like this:

```
void init_ma() {  
    for (int i = 0; i!=3; i++)  
        for (int j = 0; j!=5; j++)  
            ma[i][j] = 10*i+j;  
}
```

ma:

00	01	02	03	04	10	11	12	13	14	20	21	22	23	24
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

The array ma is simply 15 ints that we access as if it were 3 arrays of 5 ints. In particular, there is no single object in memory that is the matrix ma – only the elements are stored. The dimensions 3 and 5 exist in the compiler source only.

Be careful with arrays and pointers

```
char* f() {  
    char ch[20];  
    char* p = &ch[90];  
    // ...  
    *p = 'a';           // we don't know what this'll overwrite  
    char* q;           // forgot to initialize  
    *q = 'b';           // we don't know what this'll overwrite  
    return &ch[10];      // oops: ch disappear upon return from f()  
                        // (an infamous "dangling pointer")  
}
```



```
void g() {  
    char* pp = f();  
    *pp = 'c';           // we don't know what this'll overwrite  
    // (f's ch are gone for good after the return from f)  
}
```

Passing Arrays

- Arrays **cannot** directly be passed by value

```
void comp(double arg[10]) {      // arg is a double*  
    for (int i=0; i!=10; ++i)  
        arg[i]+=99;  
}
```

// writes to arg[i] are writes directly to the elements of comp()'s argument, rather than to a copy

```
void f() {  
    double a1[10];  
    double a2[5];  
    double a3[100];  
  
    comp(a1);  
    comp(a2);    // disaster!  
    comp(a3);    // uses only the first 10 elements  
};
```


Arrays don't know their own size

```
void f(int pi[ ], int n, char pc[ ]) {
```

*// equivalent to **void f(int* pi, int n, char* pc)***

// warning: very dangerous code, for illustration only,

// never “hope” that sizes will always be correct

```
char buf1[200];
```

```
strcpy(buf1,pc);
```

*// copy characters from **pc** into **buf1***

// strcpy terminates when a '\0' character is found

*// hope that **pc** holds less than 200 characters*

```
strncpy(buf1,pc,200);
```

*// copy 200 characters from **pc** to **buf1**
// padded if necessary, but final '\0' not guaranteed*

```
int buf2[300];
```

*// you can't say **char buf2[n]**; **n** is a variable*

```
if (300 < n) error("not enough space");
```

```
for (int i=0; i<n; ++i) buf2[i] = pi[i];
```

*// hope that **pi** really has space for*

*// **n** ints; it might have less*

```
}
```

Pointers and Consts

- `constexpr`: Evaluate at compile time
- `const`: Do not modify in this scope

```
const int model = 90;           // model is a const
```

```
const int v[] = { 1, 2, 3, 4 }; // v[i] is a const
```

```
const int x;                   // error: no initializer
```

// Declaring something const ensures that its value will not change within its scope:

```
void f() {
```

```
    model = 200;    // error
```

```
    v[2] = 3;      // error
```

```
}
```

Pointers and const

```
void f1(char* p) {  
    char s[] = "Gorm";  
  
    const char* pc = s;      // pointer to constant  
    pc[3] = 'g';             // error: pc points to constant  
    pc = p;                  // OK  
  
    char* const cp = s;      // constant pointer  
    cp[3] = 'a';             // OK  
    cp = p;                  // error: cp is constant  
  
    const char *const cpc = s; // const pointer to const  
    cpc[3] = 'a';             // error: cpc points to constant  
    cpc = p;                  // error: cpc is constant  
}
```

Pointers and references

- Think of a reference as an automatically dereferenced pointer
 - Or as “an alternative name for an object”
 - A reference must be initialized
 - The value of a reference cannot be changed after initialization

```
int x = 7;
```

```
int y = 8;
```

```
int* p = &x;
```

```
*p = 9;
```

```
p = &y; // ok
```

```
int& r = x;
```

```
x = 10;
```

```
r = &y; // error (and so is all other attempts to change what r refers to)
```

Vectors and Arrays (C++11)

Vectors are sequence containers, that are dynamic and they know their size

- `vector<int> vi; // create a zero-size vector of int`
`array<int, 5> ai;`
- `// create array object of 5 ints`
`array<double, 4> ad = {1.2, 2.1, 3.43, 4.3}`

Iterating through vectors

// Normal way of iteration

```
for(int i=0; i < vector.size(); i++){  
    std::cout << vector[i] << std::endl;  
}
```

// Safe way to iterate – will never go over the size! Exception handling

```
for(int i=0; i < vector.size(); i++){  
    std::cout << vector.at(i) << std::endl;  
}
```

Iterating through vectors

// Normal

```
for(std::vector<T>::size_type i = 0; i != v.size(); i++)  
    v[i].doSomething();
```

// Iterators

```
for(std::vector<T>::iterator it = v.begin(); it != v.end(); ++it)  
    it->doSomething();
```

// auto

```
for (auto it = v.begin(); it != v.end(); ++it)  
    it->doSomething ();
```

// elements

```
for (auto & element : v) {  
    element.doSomething ();  
}
```

// for_each

```
std::for_each(v.begin(), v.end(), doSomething());
```