Another thing that may call your attention is the line:

```
int * p1, * p2;
```

This declares the two pointers used in the previous example. But notice that there is an asterisk (*) for each pointer, in order for both to have type `int*` (pointer to `int`).

Otherwise, the type for the second variable declared in that line would have been `int` (and not `int*`) because of precedence relationships. If we had written:

```
int * p1, p2;
```

`p1` would indeed have `int*` type, but `p2` would have type `int` (spaces do not matter at all for this purpose). This is due to operator precedence rules. But anyway, simply remembering that you have to put one asterisk per pointer is enough for most pointer users.

Pointers and arrays

The concept of array is very much bound to the one of pointer. In fact, the identifier of an array is equivalent to the address of its first element, as a pointer is equivalent to the address of the first element that it points to, so in fact they are the same concept. For example, supposing these two declarations:

```
int numbers [20];
int * p;
```

The following assignment operation would be valid:

```
p = numbers;
```

After that, `p` and `numbers` would be equivalent and would have the same properties. The only difference is that we could change the value of pointer `p` by another one, whereas `numbers` will always point to the first of the 20 elements of type `int` with which it was defined. Therefore, unlike `p`, which is an ordinary pointer, `numbers` is an array, and an array can be considered a *constant pointer*. Therefore, the following allocation would not be valid:

```
numbers = p;
```

Because `numbers` is an array, so it operates as a constant pointer, and we cannot assign values to constants.

Due to the characteristics of variables, all expressions that include pointers in the following example are perfectly valid:

```
// more pointers
#include <iostream>
using namespace std;

int main ()
{
  int numbers[5];
  int * p;
  p = numbers;  *p = 10;
  p++;  *p = 20;
  p = &numbers[2];  *p = 30;
  p = numbers + 3;  *p = 40;
  p = numbers;  *(p+4) = 50;
  for (int n=0; n<5; n++)
    cout << numbers[n] << ", ";
  return 0;
}
```

```
10, 20, 30, 40, 50,
```

In the chapter about arrays we used brackets (`[]`) several times in order to specify the index of an element of the array to which we wanted to refer. Well, these bracket sign operators `[]` are also a dereference operator known as *offset operator*. They dereference the variable they follow just as `*` does, but they also add the number between brackets to the address being dereferenced. For example:

```
a[5] = 0;       // a [offset of 5] = 0
*(a+5) = 0;     // pointed by (a+5) = 0
```

These two expressions are equivalent and valid both if `a` is a pointer or if `a` is an array.

Pointer initialization

When declaring pointers we may want to explicitly specify which variable we want them to point to:

```
int number;
int *tommy = &number;
```

The behavior of this code is equivalent to:

```
int number;
int *tommy;
tommy = &number;
```

When a pointer initialization takes place we are always assigning the reference value to where the pointer points (`tommy`), never the value being pointed (`*tommy`). You must consider that at the moment of declaring a pointer, the asterisk (`*`) indicates only that it is a pointer, it is not the dereference operator (although both use the same sign: *). Remember, they are two different functions of one sign. Thus, we must take care not to confuse the previous code with:

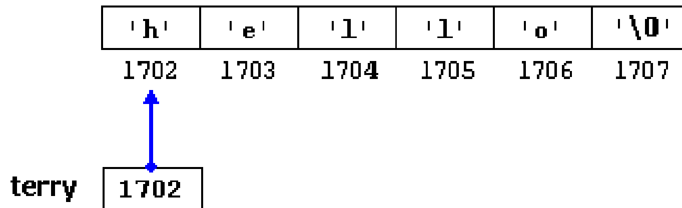
```
int number;
int *tommy;
*tommy = &number;
```

that is incorrect, and anyway would not have much sense in this case if you think about it.

As in the case of arrays, the compiler allows the special case that we want to initialize the content at which the pointer points with constants at the same moment the pointer is declared:

```
char * terry = "hello";
```

In this case, memory space is reserved to contain "hello" and then a pointer to the first character of this memory block is assigned to terry. If we imagine that "hello" is stored at the memory locations that start at addresses 1702, we can represent the previous declaration as:



It is important to indicate that terry contains the value 1702, and not 'h' nor "hello", although 1702 indeed is the address of both of these.

The pointer terry points to a sequence of characters and can be read as if it was an array (remember that an array is just like a constant pointer). For example, we can access the fifth element of the array with any of these two expression:

```
*(terry+4)
terry[4]
```

Both expressions have a value of 'o' (the fifth element of the array).

Pointer arithmetics

To conduct arithmetical operations on pointers is a little different than to conduct them on regular integer data types. To begin with, only addition and subtraction operations are allowed to be conducted with them, the others make no sense in the world of pointers. But both addition and subtraction have a different behavior with pointers according to the size of the data type to which they point.

When we saw the different fundamental data types, we saw that some occupy more or less space than others in the memory. For example, let's assume that in a given compiler for a specific machine, char takes 1 byte, short takes 2 bytes and long takes 4.

Suppose that we define three pointers in this compiler:

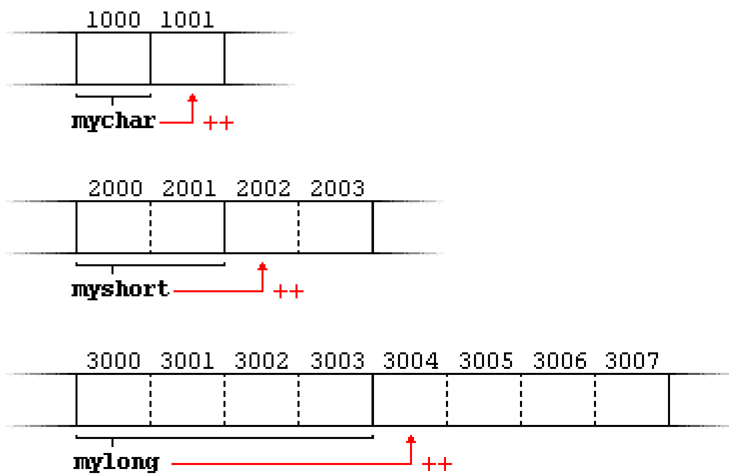
```
char *mychar;
short *myshort;
long *mylong;
```

and that we know that they point to memory locations 1000, 2000 and 3000 respectively.

So if we write:

```
mychar++;
myshort++;
mylong++;
```

mychar, as you may expect, would contain the value 1001. But not so obviously, myshort would contain the value 2002, and mylong would contain 3004, even though they have each been increased only once. The reason is that when adding one to a pointer we are making it to point to the following element of the same type with which it has been defined, and therefore the size in bytes of the type pointed is added to the pointer.



This is applicable both when adding and subtracting any number to a pointer. It would happen exactly the same if we write:

```
mychar = mychar + 1;
myshort = myshort + 1;
mylong = mylong + 1;
```

Both the increase (++) and decrease (--) operators have greater operator precedence than the dereference operator (*), but both have a special behavior when used as suffix (the expression is evaluated with the value it had before being increased). Therefore, the following expression may lead to confusion:

```
*p++
```

Because ++ has greater precedence than *, this expression is equivalent to *(p++). Therefore, what it does is to increase the value of p (so it now points to the next element), but because ++ is used as postfix the whole expression is evaluated as the value pointed by the original reference (the address the pointer pointed to before being increased).

Notice the difference with:

```
(*p)++
```

Here, the expression would have been evaluated as the value pointed by p increased by one. The value of p (the pointer itself) would not be modified (what is being modified is what it is being pointed to by this pointer).

If we write:

```
*p++ = *q++;
```

Because ++ has a higher precedence than *, both p and q are increased, but because both increase operators (++) are used as postfix and not prefix, the value assigned to *p is *q before both p and q are increased. And then both are increased. It would be roughly equivalent to:

```
*p = *q;
++p;
++q;
```

Like always, I recommend you to use parentheses () in order to avoid unexpected results and to give more legibility to the code.