This exception method is the default method used by new, and is the one used in a declarationlike:

```
bobby = new int [5];  // if it fails an exception is thrown
```

The other method is known as `nothrow`, and what happens when it is used is that when a memory allocation fails, instead of throwing a `bad_alloc` exception or terminating the program, the pointer returned by `new` is a null pointer, and the program continues its execution.

This method can be specified by using a special object called `nothrow`, declared in header `<new>`, as argument for `new`:

```
bobby = new (nothrow) int [5];
```

In this case, if the allocation of this block of memory failed, the failure could be detected by checking if `bobby` took a null pointer value:

```
int * bobby;
bobby = new (nothrow) int [5];
if (bobby == 0) {
  // error assigning memory. Take measures.
  };
```

This `nothrow` method requires more work than the exception method, since the value returned has to be checked after each and every memory allocation, but I will use it in our examples due to its simplicity. Anyway this method can become tedious for larger projects, where the exception method is generally preferred. The exception method will be explained in detail later in this tutorial.

Operators delete and delete[]

Since the necessity of dynamic memory is usually limited to specific moments within a program, once it is no longer needed it should be freed so that the memory becomes available again for other requests of dynamic memory. This is the purpose of the operator `delete`, whose format is:

```
delete pointer;
delete [] pointer;
```

The first expression should be used to delete memory allocated for a single element, and the second one for memory allocated for arrays of elements.

The value passed as argument to delete must be either a pointer to a memory block previously allocated with `new`, or a null pointer (in the case of a null pointer, `delete` produces no effect).

```
// rememb-o-matic
#include <iostream>
#include <new>
using namespace std;

int main ()
{
  int i,n;
  int * p;
  cout << "How many numbers would you like to type? ";
  cin >> i;
  p= new (nothrow) int[i];
  if (p == 0)
    cout << "Error: memory could not be allocated";
  else
  {
    for (n=0; n<i; n++)
    {
      cout << "Enter number: ";
      cin >> p[n];
    }
    cout << "You have entered: ";
    for (n=0; n<i; n++)
      cout << p[n] << ", ";
    delete[] p;
  }
  return 0;
}
```

```
How many numbers would you like to type? 5
Enter number : 75
Enter number : 436
Enter number : 1067
Enter number : 8
Enter number : 32
You have entered: 75, 436, 1067, 8, 32,
```

Notice how the value within brackets in the `new` statement is a variable value entered by the user (`i`), not a constant value:

```
p= new (nothrow) int[i];
```

But the user could have entered a value for i so big that our system could not handle it. For example, when I tried to give a value of 1 billion to the "How many numbers" question, my system could not allocate that much memory for the program and I got the text message we prepared for this case (`Error: memory could not be allocated`). Remember that in the case that we tried to allocate the memory without specifying the nothrow parameter in the new expression, an exception would be thrown, which if it's not handled terminates the program.

It is a good practice to always check if a dynamic memory block was successfully allocated. Therefore, if you use the `nothrow` method, you should always check the value of the pointer returned. Otherwise, use the exception method, even if you do not handle the exception. This way, the program will terminate at that point without causing the unexpected results of continuing executing a code that assumes a block of memory to have been allocated when in fact it has not.

Dynamic memory in ANSI-C

Operators `new` and `delete` are exclusive of C++. They are not available in the C language. But using pure C language and its library, dynamic memory can also be used through the functions malloc, calloc, realloc and free, which are also available in C++ including the `<cstdlib>` header file (see cstdlib for more info).

The memory blocks allocated by these functions are not necessarily compatible with those returned by new, so each one should be manipulated with its own set of functions or operators.

Data structures

We have already learned how groups of sequential data can be used in C++. But this is somewhat restrictive, since in many occasions what we want to store are not mere sequences of elements all of the same data type, but sets of different elements with different data types.

Data structures

A data structure is a group of data elements grouped together under one name. These data elements, known as *members*, can have different types and different lengths. Data structures are declared in C++ using the following syntax:

```
struct structure_name {
member_type1 member_name1;
member_type2 member_name2;
member_type3 member_name3;

.
} object_names;
```

where `structure_name` is a name for the structure type, `object_name` can be a set of valid identifiers for objects that have the type of this structure. Within braces `{ }` there is a list with the data members, each one is specified with a type and a valid identifier as its name.

The first thing we have to know is that a data structure creates a new type: Once a data structure is declared, a new type with the identifier specified as `structure_name` is created and can be used in the rest of the program as if it was any other type. For example:

```
struct product {
  int weight;
  float price;
} ;

product apple;
product banana, melon;
```

We have first declared a structure type called `product` with two members: `weight` and `price`, each of a different fundamental type. We have then used this name of the structure type (`product`) to declare three objects of that type: `apple`, `banana` and `melon` as we would have done with any fundamental data type.

Once declared, `product` has become a new valid type name like the fundamental ones `int`, `char` or `short` and from that point on we are able to declare objects (variables) of this compound new type, like we have done with `apple`, `banana` and `melon`.

Right at the end of the `struct` declaration, and before the ending semicolon, we can use the optional field `object_name` to directly declare objects of the structure type. For example, we can also declare the structure objects `apple`, `banana` and `melon` at the moment we define the data structure type this way:

```
struct product {
  int weight;
  float price;
} apple, banana, melon;
```

It is important to clearly differentiate between what is the structure type name, and what is an object (variable) that has this structure type. We can instantiate many objects (i.e. variables, like `apple`, `banana` and `melon`) from a single structure type (`product`).

Once we have declared our three objects of a determined structure type (`apple`, `banana` and `melon`) we can operate directly with their members. To do that we use a dot (`.`) inserted between the object name and the member name. For example, we could operate with any of these elements as if they were standard variables of their respective types:

```
apple.weight
apple.price
banana.weight
banana.price
melon.weight
melon.price
```

Each one of these has the data type corresponding to the member they refer to: `apple.weight`, `banana.weight` and `melon.weight` are of type `int`, while `apple.price`, `banana.price` and `melon.price` are of type `float`.

Let's see a real example where you can see how a structure type can be used in the same way as fundamental types:

```
// example about structures
#include <iostream>
#include <string>
#include <sstream>
using namespace std;

struct movies_t {
  string title;
  int year;
} mine, yours;

void printmovie (movies_t movie);

int main ()
{
  string mystr;

  mine.title = "2001 A Space Odyssey";
  mine.year = 1968;

  cout << "Enter title: ";
  getline (cin,yours.title);
  cout << "Enter year: ";
  getline (cin,mystr);
  stringstream(mystr) >> yours.year;

  cout << "My favorite movie is:\n ";
  printmovie (mine);
  cout << "And yours is:\n ";
  printmovie (yours);
  return 0;
}

void printmovie (movies_t movie)
{
  cout << movie.title;
  cout << " (" << movie.year << ")\n";
}
```

```
Enter title: Alien
Enter year: 1979

My favorite movie is:
 2001 A Space Odyssey (1968)
And yours is:
 Alien (1979)
```

The example shows how we can use the members of an object as regular variables. For example, the member `yours.year` is a valid variable of type `int`, and `mine.title` is a valid variable of type `string`.

The objects `mine` and `yours` can also be treated as valid variables of type `movies_t`, for example we have passed them to the function `printmovie` as we would have done with regular variables. Therefore, one of the most important advantages of data structures is that we can either refer to their members individually or to the entire structure as a block with only one identifier.

Data structures are a feature that can be used to represent databases, especially if we consider the possibility of building arrays of them:

```
// array of structures
#include <iostream>
#include <string>
#include <sstream>
using namespace std;

#define N_MOVIES 3

struct movies_t {
  string title;
  int year;
} films [N_MOVIES];

void printmovie (movies_t movie);

int main ()
{
  string mystr;
  int n;

  for (n=0; n<N_MOVIES; n++)
  {
    cout << "Enter title: ";
    getline (cin,films[n].title);
    cout << "Enter year: ";
    getline (cin,mystr);
    stringstream(mystr) >> films[n].year;
  }

  cout << "\nYou have entered these movies:\n";
  for (n=0; n<N_MOVIES; n++)
    printmovie (films[n]);
  return 0;
}

void printmovie (movies_t movie)
{
  cout << movie.title;
  cout << " (" << movie.year << ")\n";
}
```

```
Enter title: Blade Runner
Enter year: 1982
Enter title: Matrix
Enter year: 1999
Enter title: Taxi Driver
Enter year: 1976

You have entered these movies:
Blade Runner (1982)
Matrix (1999)
Taxi Driver (1976)
```

Pointers to structures

Like any other type, structures can be pointed by its own type of pointers:

```
struct movies_t {
  string title;
  int year;
};

movies_t amovie;
movies_t * pmovie;
```

Here `amovie` is an object of structure type `movies_t`, and `pmovie` is a pointer to point to objects of structure type `movies_t`. So, the following code would also be valid:

```
pmovie = &amovie;
```

The value of the pointer `pmovie` would be assigned to a reference to the object `amovie` (its memory address).

We will now go with another example that includes pointers, which will serve to introduce a new operator: the arrow operator (->):

```
// pointers to structures
#include <iostream>
#include <string>
#include <sstream>
using namespace std;

struct movies_t {
  string title;
  int year;
};

int main ()
{
  string mystr;

  movies_t amovie;
  movies_t * pmovie;
  pmovie = &amovie;

  cout << "Enter title: ";
  getline (cin, pmovie->title);
  cout << "Enter year: ";
  getline (cin, mystr);
  (stringstream) mystr >> pmovie->year;

  cout << "\nYou have entered:\n";
  cout << pmovie->title;
  cout << " (" << pmovie->year << ")\n";

  return 0;
}
```

```
Enter title: Invasion of the body snatchers
Enter year: 1978

You have entered:
Invasion of the body snatchers (1978)
```

The previous code includes an important introduction: the arrow operator (->). This is a dereference operator that is used exclusively with pointers to objects with members. This operator serves to access a member of an object to which we have a reference. In the example we used:

```
pmovie->title
```

Which is for all purposes equivalent to:

```
(*pmovie).title
```

Both expressions `pmovie->title` and `(*pmovie).title` are valid and both mean that we are evaluating the member `title` of the data structure pointed by a pointer called `pmovie`. It must be clearly differentiated from:

```
*pmovie.title
```

which is equivalent to:

```
*(pmovie.title)
```

And that would access the value pointed by a hypothetical pointer member called `title` of the structure object `pmovie` (which in this case would not be a pointer). The following panel summarizes possible combinations of pointers and structure members:

Expression	What is evaluated	Equivalent
a.b	Member b of object a	
a->b	Member b of object pointed by a	(*a).b
*a.b	Value pointed by member b of object a	*(a.b)

Nesting structures

Structures can also be nested so that a valid element of a structure can also be in its turn another structure.

```
struct movies_t {
  string title;
  int year;
};

struct friends_t {
  string name;
  string email;
  movies_t favorite_movie;
  } charlie, maria;

friends_t * pfriends = &charlie;
```

After the previous declaration we could use any of the following expressions:

```
charlie.name
maria.favorite_movie.title
charlie.favorite_movie.year
pfriends->favorite_movie.year
```

(where, by the way, the last two expressions refer to the same member).

Other Data Types

Defined data types (typedef)

C++ allows the definition of our own types based on other existing data types. We can do this using the keyword `typedef`, whose format is:

```
typedef existing_type new_type_name ;
```

where `existing_type` is a C++ fundamental or compound type and `new_type_name` is the name for the new type we are defining. For example:

```
typedef char C;
typedef unsigned int WORD;
typedef char * pChar;
typedef char field [50];
```

In this case we have defined four data types: `C`, `WORD`, `pChar` and `field` as `char`, `unsigned int`, `char*` and `char[50]` respectively, that we could perfectly use in declarations later as any other valid type:

```
C mychar, anotherchar, *ptc1;
WORD myword;
pChar ptc2;
field name;
```

`typedef` does not create different types. It only creates synonyms of existing types. That means that the type of `myword` can be considered to be either `WORD` or `unsigned int`, since both are in fact the same type.

`typedef` can be useful to define an alias for a type that is frequently used within a program. It is also useful to define types when it is possible that we will need to change the type in later versions of our program, or if a type you want to use has a name that is too long or confusing.

Unions

Unions allow one same portion of memory to be accessed as different data types, since all of them are in fact the same location in memory. Its declaration and use is similar to the one of structures but its functionality is totally different:

```
union union_name {
  member_type1 member_name1;
  member_type2 member_name2;
  member_type3 member_name3;
  .
  .
} object_names;
```

All the elements of the `union` declaration occupy the same physical space in memory. Its size is the one of the greatest element of the declaration. For example:

```
union mytypes_t {
  char c;
  int i;
  float f;
  } mytypes;
```

defines three elements:

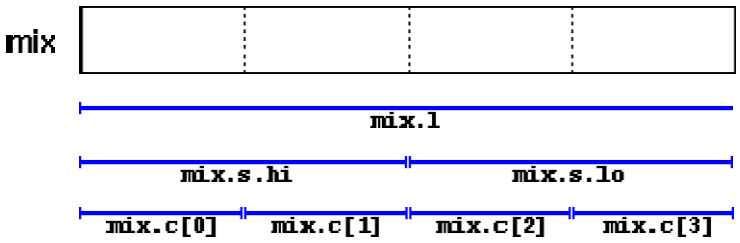
```
mytypes.c
mytypes.i
mytypes.f
```

each one with a different data type. Since all of them are referring to the same location in memory, the modification of one of the elements will affect the value of all of them. We cannot store different values in them independent of each other.

One of the uses a union may have is to unite an elementary type with an array or structures of smaller elements. For example:

```
union mix_t {
  long l;
  struct {
    short hi;
    short lo;
    } s;
  char c[4];
} mix;
```

defines three names that allow us to access the same group of 4 bytes: `mix.l`, `mix.s` and `mix.c` and which we can use according to how we want to access these bytes, as if they were a single `long`-type data, as if they were two `short` elements or as an array of `char` elements, respectively. I have mixed types, arrays and structures in the union so that you can see the different ways that we can access the data. For a *little-endian* system (most PC platforms), this union could be represented as:



The exact alignment and order of the members of a union in memory is platform dependant. Therefore be aware of possible portability issues with this type of use.

Anonymous unions

In C++ we have the option to declare anonymous unions. If we declare a union without any name, the union will be anonymous and we will be able to access its members directly by their member names. For example, look at the difference between these two structure declarations: