C++ Definitions:
based on "C Programming" K.N. King, Norton, 1995.

## Class Definition

Defining a CLASS in C++ is much like defining a structure, for example:

```
class Fraction {
   int numerator
   int denominator
};
```

numerator and denominator are said to be **data members**. Note use of Initial case for ClassName (just a convention, not a requirement of C++). Now we are free to use the new class (type) called Fraction:

```
Fraction f1, f2;
```

f1 and f2 are **instances** of the Fraction class. An instance of any class is also known as an **object**.

Unlike structures we **cannot** access these elements with

```
f1.numerator       // this is illegal, private member
bottom = f2.denominator       // again illegal
```

To be accessible the private data members need "public" operators. By default data members are private.

Ignoring for the moment the possibility of public data members, let us consider how public access functions are declared.

## Member Functions

If data members are private within a class how then can they be updated or even inspected? The answer: via access functions (operators) which are associated with the class. These are called **member functions**.

let us expand our example:

```
class Fraction {
public:
   void create (int, int);
   void print();
private:
   int numerator;
   int denominator;
};
```

`create` and `print` are two functions that access the private members. One possible set of operator declarations is:

```
void Fraction :: create (int num, int denom)
{
   numerator = num;
   denominator = denom;
}
void Fraction :: print ()
{
   cout << ((float) numerator) / ((float) denominator);
}
```

Then the two commands:

```
    f1.create(1, 2);
    f1.print();
```

would set f1.numerator == 1 and f2.denominator == 2, and print 0.5

It is possible and useful to initialize the parameters to the member functions, as with all functions, for example:

```
class Fraction {
public:
    void create (int num = 0, int denom = 1);
    void print();
private:
    int numerator;
    int denominator;
};
```

then we could write

```
f1.create (5,3);     // set numerator == 5 and denominator == 3
f1.create (5);       // sets numerator == 5 and denominator == 1
f1.create ();        // set numerator == 0 and denominator == 1
f1.create (,3);      // how about this one?
```

A second example using **constructors** and **destructors**

Dynamic storage allocation and deallocation is a place where constructors and destructors are useful. Consider the case where we want to create a genuine String datatype (class), which retains the string length data member for ease of access.

A String object could contain strings of arbitrary length, instead of being held in some fixed size array.
The String length could be kept, thus reducing use of the `strlen()` function, which searches the entire string for the terminating NULL character.
We can add special string manipulation operators, instead of being restricted to what `<string.h>` supplies.

Let us assume that string objects can be declared as follows:

```
String s1("abc"), s2("pqrs");     // C++
               // The C++ case is more general
String s1 = "abc", s2 = "pqrs";  // C
```

Anyway, we want s1 and s2 to have these values initially, but to be changed later. Clearly our String class is going to need a member function (constructor operator) which allocates space to our strings and initializes them appropriately:

```
class String {
    String (const char* s); // our constructor
    ......
private:
    char* text;          // pointer to a string
    int len;             // length of string
};
```

and our constructor function could be defined as:

```
String :: String (const char* s)
{
    len = strlen(s);
    text = new char[len+1];
    strcpy(text, s);
}
```

after computing the length of the string that s points to, the constructor uses it to allocate enough space for a copy of a string, before finally moving it into place.

To give back the space we need a **destructor**. If we don't have one, then consider the problems of using the String class within a procedure

```
void procedure ()
{
    String s1("abc");
    ........
}
```

when `procedure` is called the object s1 is created by the constructor, but when the procedure returns the fields `text` and `len` of s1 are removed, but the string "abc" itself (that `text` points to) remains. This failure to return all the memory acquired during procedure execution is called a **memory leak**.

A destructor, a function that is called automatically when an object ceases to exist, saves the day. Constructors and destructors are matched pairs. Thus a destructor is a member function just like a constructor and has the same name, but with a tilde (~) pre-pended. For example:

```
class String {
public:
    String (const char* s);
    ~String () { delete [] text; }    // destructor
    ........
private:
    char* text;
    int len;
};
```

The ~String member function, specified completely above, releases the space pointed to by text.

## Overloading

In C++, two functions in the same scope may have the same name. When functions are overloaded this way, the C++ compiler determines which one is needed by examining the function's arguments. For example, suppose that two versions of the function `foo` exist in the same scope

```
void foo (int);
void foo (double);      // now we are overloading
```

Now

```
foo (1);       // generates a call to foo (int)
foo (1.0);     // generates a call to foo (double)
```

By this means functions which do the same operation, but with parameters of different type may use the same name. This cuts down on the number of names we need to create. An obvious example might be

```
int power (int x, int y);
double power (double x, double y);
```

or

```
sort (int N, char* s);
sort (int N, int* i);
sort (int N, double* r);    // well, perhaps not!
```

Because of this overloading of the identifier `sort` we will need three constructors and three destructors.

Overloading is also useful for initialization purposes in classes. Consider

```
class String {
public:
    String (const char* s);        // constructor
    String () { text = ""; len = 0; }   // overloading
    ~String () { delete [] text; }
    .......
private:
    char* text;
    int len;
};
```

with the general constructor declared as:

```
String :: String (const char* s)
{
    len = strlen(s);
    text = new char[len+1];
    strcpy(text, s);
}
```

A couple of points. Why not `text = NULL;` or `text = 0;` since we clearly want the null string in the overloaded function? No good reason, just a common practice.

Here we have formed the new String constructor called the **default constructor**, because it has no arguments, which will be invoked when String objects are declared without a specified value.

```
String s;     // default constructor is invoked
```

In addition to function overloading, C++ also supports operator overloading, where the same operator serves two different purposes depending on the context.

```
cin >> N;     // in C >> is right-shift bitstring
```

In C++ the << also represents an input operation, not a left shift operation on bit strings, as it does in C. Different purposes saves on the need to create more symbols.

There are more advanced examples that are useful in ADT applications, but we will leave these for now.

## Object Oriented Programming

For a language to be object-oriented it must at least include the following three capabilities

### Encapsulation

The ability to define a new type and a set of operations on that type, without revealing the representation of the type. C++ classes support encapsulation by restricting access to private data members.

### Inheritance

The ability to create new types that inherit properties from existing types. C++ support inheritance through a mechanism known as **class derivation**.

### Polymorphism

The ability of objects that belong to related classes to respond differently to the same operation. In C++ **virtual functions** support polymorphism.

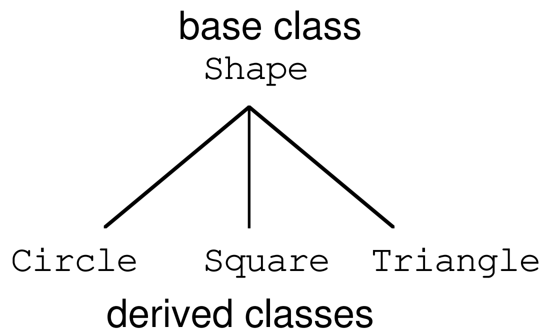
Thus we now need to look at class derivation and virtual functions.

## Derivation

In C++ we can derive a class from a previously defined one. For example we might need `Circle`, `Square` and `Triangle` objects which can be derived from some general class called `Shape`. If every shape has in common a colour and an x-y position, and if every shape can change its position and colour, then we could start with:

```
class Shape {
public:
    void change_colour (int new_colour);
    void move (int x_change, int y_change);
    ......
private:
    int  x,  y;        // coordinates of the origin
    int  colour;       //  current  colour
    .....
};
```

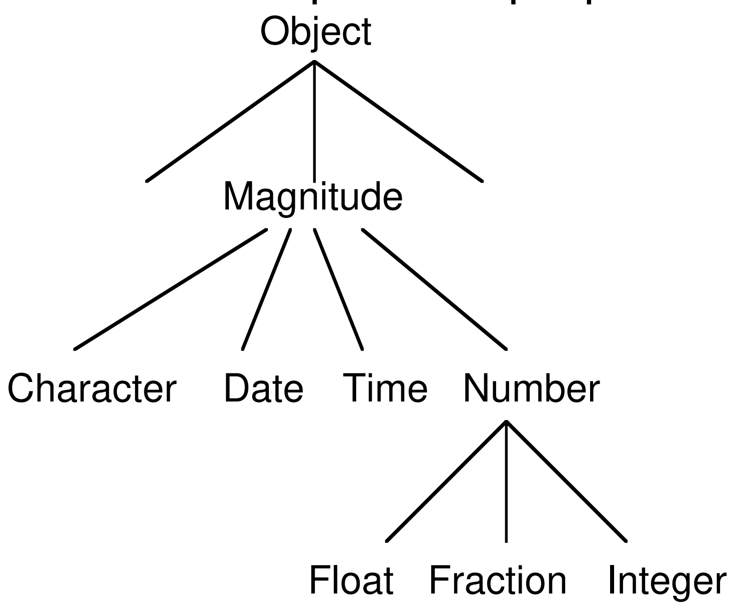
`Shape` is said to be the base class, while `Circle`, `Square` and `Triangle` are derived classes. The aim here is to make it possible to re-use code on a grand scale.




If we want to add, say, a `Pentagon` we need only code the part that is different from `Shape`.

This whole process can be generalized to libraries of objects, as illustrated in the following relationship diagram.

Each class has all the properties of its base class, plus others that are unique to the object. For example, the objects in the magnitude class share common need for a relational operator for comparison purposes.




Let us now look at some specifics to explain how `Circle` inherits the members of `Shape`, along with its constructors and destructors. The basics:

```
class Circle: public Shape {
   .......  // Circle will be based on Shape
};
```

Typically the derived class declares additional data members and member functions. For example a Circle may need its radius to compute the circumference or area, while this may not be relevant for a general shape.

```
class Circle: public Shape {
public:
   .....
private:
   int radius;    // radius of circle
};
```

Thus radius is in addition to the colour and origin members that it inherits from Shape.

When one class is derived from another, then C++ allows a base pointer to point to an instance of a derived class: For example a variable of type `Shape*` can point to a `Circle`, `Square` or `Triangle` object.

```
Circle c;             // define a circle
Shape* p = &c;        // p points to a Circle
```

Thus a parameter of type `Shape*` can match any actual argument that points to a derived member. Although it <u>appears</u> that the following function <u>requires</u> a `Shape` argument, it can in fact receive a `Circle`, `Square` or `Triangle`.

```
void add_to_list (Shape& s)
{
    ......
}
```

Thus `add_to_list` is a highly versatile function that can handle differ kinds of shape arguments.