Modern C++
An effective short way

By

Mustapha Ossama Abdelhalim

2024

Contents

Chapter 1 Starter and Installation

　　Modern C++ starts with C11, this book introduce C11 and later on, the moving to C17 section

1.1. For windows

1- Go to winlibs.com
2- Determine which list you will choose from UCRT runtime if you are using windows 10 or 11, or choose MSVCRT runtime if you are using older versions of windows.
3- If you will use the gcc for application that runs only on windows choose MCF threads, if you are using application that runs on windows and later maybe used on Linux distribution; choose POSIX threads

I will choose Win64 in UCRT runtime in POSIX thread section as I have windows 10 x64 and have 7zip installed see Figure 1 gcc releases

Release versions

UCRT runtime

- GCC 14.1.0 (with **POSIX** threads) + LLVM/Clang/LLD/LLDB 18.1.5 + MinGW-w64 11.0.1 (UCRT) - release 1　**(LATEST)**
    - Win32: 7-Zip archive* | Zip archive　-　without LLVM/Clang/LLD/LLDB: 7-Zip archive* | Zip archive
    - Win64: 7-Zip archive* | Zip archive　-　without LLVM/Clang/LLD/LLDB: 7-Zip archive* | Zip archive
- GCC 14.1.0 (with **MCF** threads) + MinGW-w64 11.0.1 (UCRT) - release 1
    - Win32 (without LLVM/Clang/LLD/LLDB): 7-Zip archive* | Zip archive
    - Win64 (without LLVM/Clang/LLD/LLDB): 7-Zip archive* | Zip archive

Figure 1 gcc releases

See this video for more details LINK

1.2. For Linux

Gcc is installed by default in ubuntu distribution

After downloading and extracting, move the mingw to c directory and get the bin path in environment variable and make sure to delete the old gcc form environment variables if exists. See Figure 2 adding bin folder path to environment variables
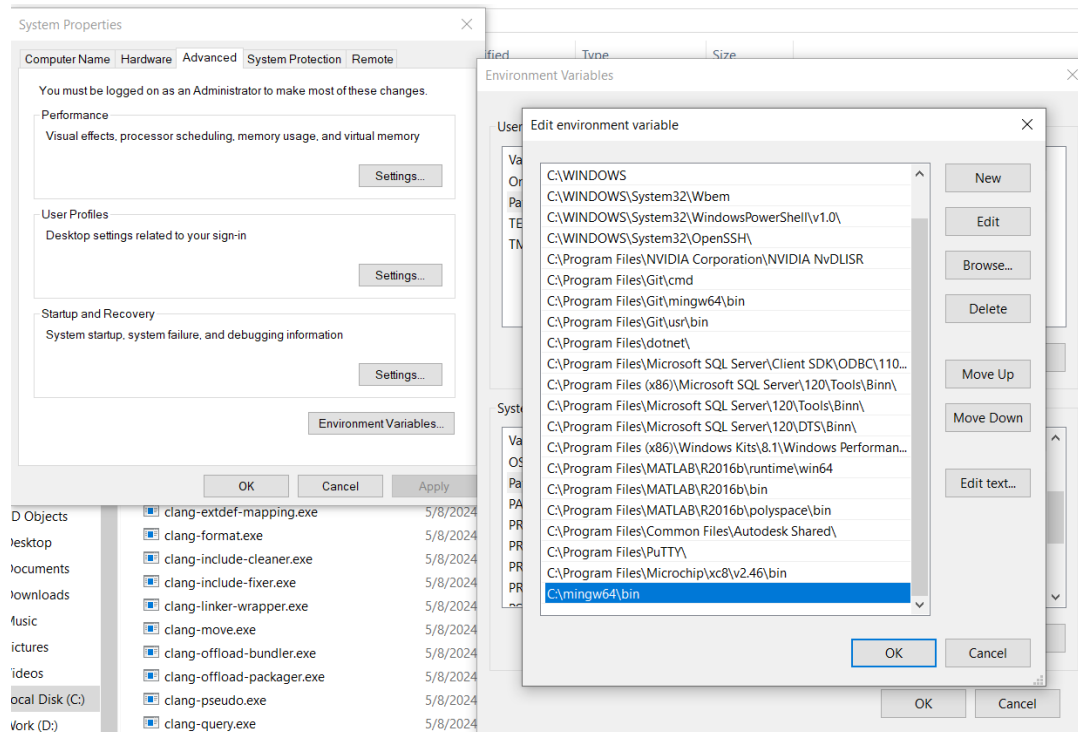
Figure 2 adding bin folder path to environment variables

Type in cmd gcc –version and you should see that gcc installed see Figure 3 verifying gcc installation

Figure 3 verifying gcc installation

Chapter 2 Basics

In this chapter, the Basics of C++ will be introduced as a refresher, the following topics will be introduced:

- **First program**
  - o Compilation Hello World
- **Variables and Data Types**
  - o Primitive types: int, char, float, double, bool
  - o Derived types: arrays, pointers, references
  - o User-defined types: structs, enums, classes
- **Operators and Expressions**
  - o Arithmetic operators: +, -, *, /, %
  - o Relational operators: ==, !=, >, <, >=, <=
  - o Logical operators: &&, ||, !
  - o Bitwise operators: &, |, ^, ~, <<, >>
  - o Assignment operators: =, +=, -=, *=, /=, %=, &=, |=, ^=, <<=, >>=
  - o Increment and decrement operators: ++, --
  - o Conditional operator: ?:
- **Control Structures**
  - o Conditional statements: if, if-else, nested if, switch-case
  - o Looping statements: for, while, do-while
  - o Jump statements: break, continue, goto, return

Introduction

A **programming language** is set of instruction to perform a task, that's it

In this book we will use notepad++ (even the simple preinstalled notepad will work fine) and compile our program in command prompt CMD, also its completely fine to use any integrated development environment (IDE), but make sure that you are using C11 gcc version.

C++ language has two types of files headers files(.h files) and source files (.cpp files), to compile the program and make it executable for windows (aka converted to .exe files to run on windows). you will use the following command in cmd

g++ -std=c++11 name.cpp -o name.exe

let's break it down

- **g++** is the gcc command to perform compilation
- **-std-c++11** is flag to specify the version of c11
- **name.cpp** is our source file
- **-o** is the flag for output the .exe file
- **name.exe** is the name of output

2.1. Hello World

1. Lets compile our first program !

```cpp
#include<iostream>
int main(){
    std::cout<<"Hello World";
    return 0;
}
```

- #include<iostream>

  is library that permit us to output data and take input from user

- int main(){
  return 0;}

  Is the entry point for our program, all programs and applications should have that function (later functions will be expressed)

- std::cout<<"hello world";

  is the command to output hello world on the screen

1- make a file named Hello.cpp for example
2- type the code above
3- open cmd in the same directory as the file Hello.cpp
4- type: g++ -std=c++11 Hello.cpp -o Hello.exe
5- to run the program type: Hello.exe

the output should be as follows in Figure 4 first program
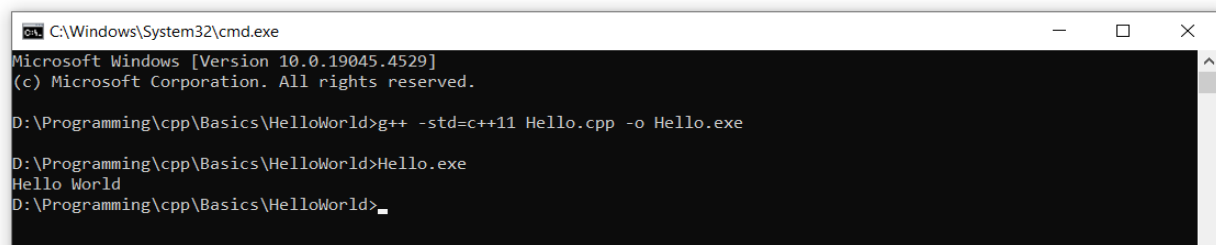
Figure 4 first program

Chapter 1 Variables and data types

C++ has types to declare each variable, each variable should have a keyword to define if it integer (like 10, 99, and120) or decimal aka float like (10.2, 0.2, and 22.8) or character (like 'a' , 'b' and 'c') , this declaration specify:

- How the variable stored in memory and takes how much of program memory
- How operation change that variable

The types in C++ is as follows in Figure 5 Types in C++ :
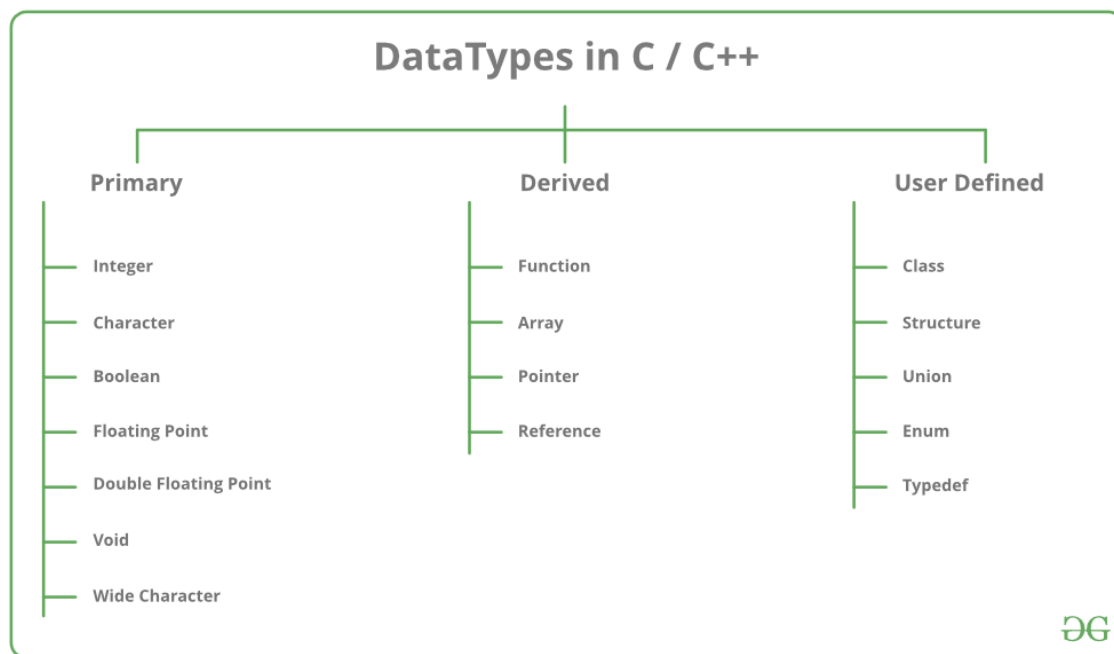
Figure 5 Types in C++

2.2. Primitive datatypes
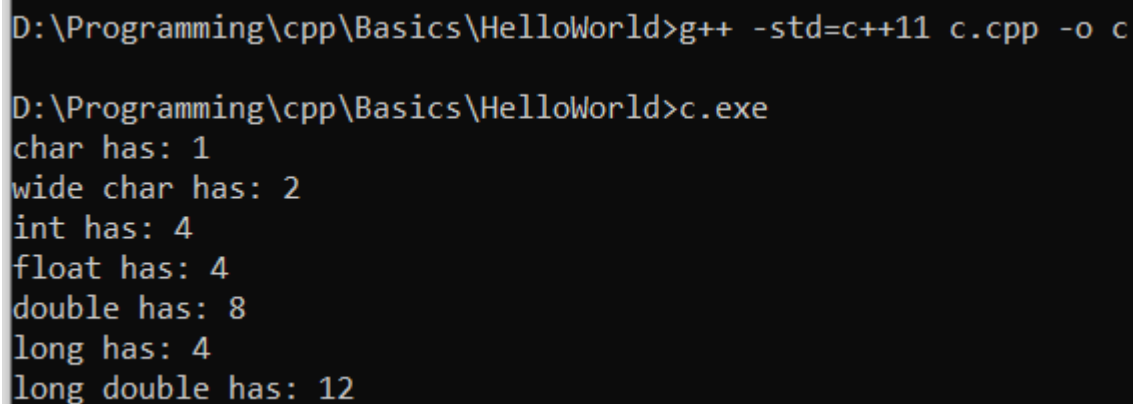
Primary (primitive) data types are compiler dependent that means that the data types could be stored in different sizes for different compilers, in gcc compiler:

Type the following to examine the sizes of different datatypes, for example int (integer saved in 4 bytes in gcc).

```cpp
#include<iostream>
using namespace std;

int main(){
    cout<<"char has: "<<sizeof(char)<<endl;
    cout<<"wide char has: "<<sizeof(wchar_t)<<endl;
    cout<<"int has: "<<sizeof(int)<<endl;
    cout<<"float has: "<<sizeof(float)<<endl;
    cout<<"double has: "<<sizeof(double)<<endl;
    cout<<"long has: "<<sizeof(long)<<endl;
    cout<<"long double has: "<<sizeof(long double)<<endl;
    return 0;
}
```

The output should be in gcc compiler (maybe different for other compilers) see Figure 6:

```
D:\Programming\cpp\Basics\HelloWorld>g++ -std=c++11 c.cpp -o c

D:\Programming\cpp\Basics\HelloWorld>c.exe
char has: 1
wide char has: 2
int has: 4
float has: 4
double has: 8
long has: 4
long double has: 12
```

Figure 6 datatypes sizes in gcc compiler

WHY we use different types of primitive (primary) variables?

To answer this question lets examine the following table

	details	Memory allocation (in GCC)	Syntax
Char	Store characters ('a','b',etc) and integers from -128 to 127	1	char x = 'a';
wchar_t	Store much more characters than char	2	wchar_t x = L'あ'
Int	Store integer numbers till 2^31 positive integers and 2^31 negative integers	4	int x = 15;
float	Store decimal numbers	4	float x = 15.12;

Also you have some modifiers like long/short and signed and unsigned

- Short: shorten integer to be usually stored in 2 bytes instead of 4 bytes which means that the value of short int will from 2^15 positives and 2^15 negatives not 2^31 positive integers and 2^31 negative integers.
- Long: will long the integers to be usually 12 bytes instead of 4 bytes which enlarge the range of that variable
- unsigned: signed (char or int or even short int) will store all bytes in positive for example, unsigned char has range of 0-255 while signed char (or char) has -128 to 127 (2^7 positives and 2^7 negatives)

back to our question, why we have different primitive data types? simply if I have variable that store integer variable of human age, I want only a variable that store positive integers of range 0 yrs old -150 yrs old, so char will be chosen or even short int (aka short) no need to take 4 bytes of integer as no human ever lived 2billion years !! so it waste of memory to choose int.

remember ! char variable store integers like 15 and characters like 'a' not only characters

what happen if:

1. what happen if: signed short int (aka short) which have range of -32768 to 32767, store number like 32770?
   ans: the variable will overflow (aka return to zero and start to count gain the reminder) which mean that 32770is higher than the capability of unsigned short (32767) by 3 so the value will be 3 like in Figure 7 Variables overflow, note: same thing to unsigned short variable the start 0 and max is 65635 so if the number exceeds; it will start counting the reminder from 0.
   Remember: when you exceed the variable range; overflow will happen
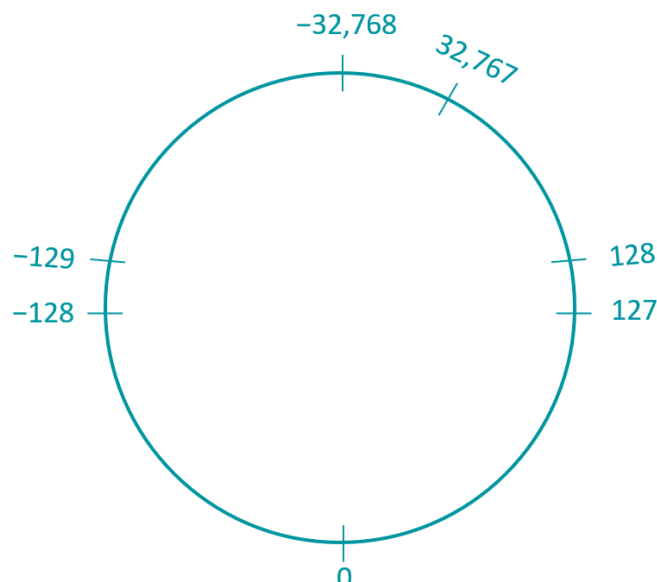
Figure 7 Variables overflow

2. what happen if: storing float number like 15.02 in integer variable like
   int x = 15.02 ?

Ans: the float point (.02) will be truncated i.e. s is 15 only

SO always remember which primitive data types to choose !!;

Exercises on primitive (primary) Data types:

Exercises : introduction

Write C++ code to introduce someone, the introduction must include:

- o Name (string): like "Ahmed" , to declare string datatype called string like:
  string name;
  cin>>name;
- o Age (unsigned short) like 28
- o Salary (unsigned short) like 15000
- o GPA (float) like 3.5
- o NOTE: the data should be as input from user: to get input from user use cin>>var;

Answer:

```cpp
#include <iostream>
using namespace std;

int main() {
    string name;
    unsigned short age,salary;
    float gpa;
    cout<<"enter your name"<<endl;
    cin>>name;
    cout<<"enter your age and salary "<<endl;
    cin>>age>>salary;
    cout<<"enter your gpa"<<endl;
    cin>>gpa;

    cout<<"Introduction\nMy name is:"<<name<<endl;
    cout<<"I am "<<age<<"years old "<<"my salary is: "<<salary<<endl;
    cout<<"my GPA is: "<<gpa;
    return 0;
}
```

NOTE: \n between " " is as same as endl after cout which means start from new line (i.e start printing at the beginning of the new following line)

NOTE: using namesapace std; is used to write cout and cin without typing std::cout and std::cin

Exercise : bankClient

Write C++ program to show:

- Client name: string
- ID: int
- Deposit money: float

Answer in the GitHub repository: LINK

All the previous was all about primitive datatypes, but how about derived and user defined datatypes? Recall Figure 5 Types in C++

derived datatypes are datatypes made from primitive

- Arrays
- Functions
- Pointers

User defined datatypes are datatypes that user build

- Struct
- Enum
- Union
- Class

Lets take them one by one:

2.3. Derived datatypes

2.3.1. Arrays

are list of some variables but must be same data type variable Like int list[3] clientAges; which means that we collect clientAges in one list instead of doing this: int client1Age; int client2Age; int client3Age;

So, to make the life easier we collect similar datatypes in one place called array

- o **Declaration**: datatype nameOfArray[number of item];
  For example: int salaries[5];
- o **Accessing each element**: salaries[i] (i must be number from 0 to 4 as salaries have 5 items

The previous array called C-Array, C++ has much powerful arrays, these arrays have built-in method like size() and other to shorten your code

- o **Declaration**: array<datatype, itemNumbers> name;
  For example: array<int, 5> salaries;
  NOTE: don't forget to include array (i.e #include <array>)
- o **Accessing each element**: salaries[i] (i must be number from 0 to 4 as salaries have 5 items

Exercise : arrays

Write C++ array of 5 integer contains some user salaries, don't use c arrays, use C++ std array

```cpp
#include<iostream>
#include<array>
using namespace std;

int main(){
    array<int, 5>salaries;
    //filling the array
    for(int i=0;i<salaries.size();i++){
        cout<<"enter the "<<i<<" element:";
        cin>>salaries[i];
        cout<<"\n";
    }
    //printing the array
    for(int i=0;i<salaries.size();i++){
        cout<<"the element "<<i<<" is: "<<salaries[i]<<"\n";
    }
}
```

2.3.2. Functions

Imagine you want to intoduce 10 peaple (like in **Exercises 1**: introduction) the program was about 10 line for one person, do write same code for the 10 person (100 lines !!) OR you can write the code for general person once in a place called function and whenever you want to use that function, call that general function and specify your details

```cpp
void introduction(string name, short age, short salary, float gpa ){
    cout<<"enter your name"<<endl;
    cout<<"enter your age and salary "<<endl;
    cout<<"enter your gpa"<<endl;
    cout<<"Introduction\nMy name is:"<<name<<endl;
    cout<<"I am "<<age<<"years old "<<"my salary is: "<<sala-ry<<endl;
    cout<<"my GPA is: "<<gpa;
}
```

You build the general function, you can now call it as many times as you want !!

```cpp
introduction("Ahmed",26,15000,3.6);
introduction(Gamal,30,2500,3.8);
introduction(Mahmoud,22,1200,3.2);
```

we will know more about functions and pointers later.

2.4. User-defined datatypes

2.4.1. Structs

Struct is used when you want to declare and object that have many attributes (i.e. variable) but different data types, e.g you want to describe a student how have name (String), id (int), gpa (float), struct came to hold these attributes (variables) in one place called struct

Example: studentStruct

In this example, struct is made for student who have 3 atributes for example name (String), id (int), gpa (float).

```cpp
//declaration
struct student{
    string name;
    int id;
    float gpa;
};

int main(){
    //create instance of a struct
    student Ahmed={"Ahmed",202410,3.45};
    /*Accessing
      Accessing is done by dot operator .
    */
    cout<<"Name:"<<Ahmed.name<<" ID:"<<Ahmed.id<<"
GPA:"<<Ahmed.gpa<<endl;
    //Assigning an instance of struct
    Ahmed.gpa = 3.58;
    cout<<"Name:"<<Ahmed.name<<" ID:"<<Ahmed.id<<"
GPA:"<<Ahmed.gpa;
}
```

NOTE: you can use comment to improve code readability:

- One line comment: using // comment
- Multiline comment: using /* comment */

1- Declaration of struct

struct name{

variable1;

variable2;

.

.

};

2- Creating instance

    o 1st way: after the deceleration

```cpp
//declaration
struct student{
    string name;
    int id;
    float gpa;
};
```

    o 2nd way: by using.. struct_type struct_name;

```cpp
student Ahmed={"Ahmed",202410,3.45};
```

NOTE: struct objects (instances) could be initialized of left to be assigned later

```cpp
student Ahmed;
```

NOTE: in C++ you don't have to use struct keyword in contrast in C

In C:

```cpp
struct student Ahmed={"Ahmed",202410,3.45};
```

in C++ struct is not necessary :

```cpp
student Ahmed={"Ahmed",202410,3.45};
```

3- Accessing and Assigning

Accessing done by dot operator

```cpp
e.g cout<<"Name:"<<Ahmed.name<<" ID:"<<Ahmed.id<<"
GPA:"<<Ahmed.gpa<<endl;
```
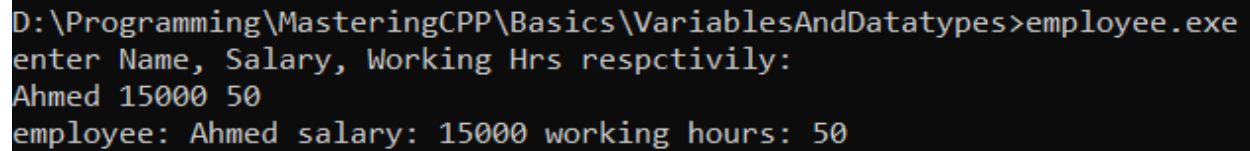
Assigning:

```
Ahmed.name="Ahmed";
```

Exercise 3: employee

Write a struct that refer to an employee that have name , salary, working hours

The answer in basics folder in the repository, see Figure 8 Exercise 3

```
D:\Programming\MasteringCPP\Basics\VariablesAndDatatypes>employee.exe
enter Name, Salary, Working Hrs respctivily:
Ahmed 15000 50
employee: Ahmed salary: 15000 working hours: 50
```

Figure 8 Exercise 3

4- **Methods**

Unlike C, in C++ we have methods in struct, methods are function inside structs or classes, Lets see how methods work

Example: structMethod

write employee struct that has name, salary, working hours, that get user data and print this data and apply bonus, so we must have 3 method(functions), see the output in Figure 9 Example

```cpp
#include<iostream>
using namespace std;
struct employee{
    string Name;
    int salary;
    short workingHrs;

    //Method to enter employ data
    void setData(){
    cout<<"enter Name, Salary, Working Hrs respctivily:\n";
    //entering the employee data from user
    cin>>Name>>salary>>workingHrs;
    //printing the employee data
    }
    //Method to print employee data
    void print(){
    cout<<"employee: "<<Name<<" salary: "<<salary<<" working
hours: "<<workingHrs<<endl;
    }
    //Method to apply bonus
    char applyBonus(int bonus){
        salary = salary + bonus;
        return 's';
    }
};

int main(){
    //create object of struct employee
    employee emp1;
    emp1.setData();
    emp1.applyBonus(500);
    emp1.print();
}
```

```
D:\Programming\MasteringCPP\Basics\VariablesAndDatatypes>g++ -std=c++11 structMethod.cpp -o structMethod.exe

D:\Programming\MasteringCPP\Basics\VariablesAndDatatypes>structMethod.exe
enter Name, Salary, Working Hrs respctivily:
Ahmed 12000 40
employee: Ahmed salary: 12500 working hours: 40
```

Figure 9 Example

5- **Constructors**

Constructor is type of method that is called by default when an instance is made, the purpose of a constructor is to initialize the object, setting up initial values for its members and performing any setup required.

Example: structConstructor

```cpp
#include <iostream>
using namespace std;

struct Person {
    string name;
    int age;

    // Constructor
    Person(string n, int a) : name(n), age(a) {
       cout << "Constructor called for " << name << endl;
    }

    // Member function to display person details
    void display() const {
        cout << "Name: " << name << ", Age: " << age << endl;
    }
};

int main() {
    // Creating an object of the Person struct
    Person person1("John Doe", 30);

    // Displaying the details of person1
    person1.display();

    return 0;
}
```

6- Inheritance

Inheritance used to create a child class of parent class or struct , e.g. if we created a class for employee that has name and age and member function named (method) role that is either writing() or reviewing() , we could create child of struct that inherit name and age but in writers employee child struct, writing() method will be created and in reviewer child struct, reviewing() method will be created.

Example: inheritance

```cpp
#include <iostream>
#include <string>
// Base struct
struct Employee {
    std::string name;
    int age;

    // Constructor for Employee
    Employee(const std::string& n, int a) : name(n), age(a) {}
};
// Derived struct for Writer
struct Writer : public Employee {
    // Constructor for Writer
    Writer(const std::string& name, int age) : Employee(name,
age) {}

    // Specific method for Writer
    void writing() const {
        std::cout << name << " is writing a document." <<
std::endl;
    }
};
// Derived struct for Reviewer
struct Reviewer : public Employee {
    // Constructor for Reviewer
    Reviewer(const std::string& name, int age) : Employee(name,
age) {}

    // Specific method for Reviewer
    void reviewing() const {
        std::cout << name << " is reviewing a document." <<
std::endl;
    }
};
```

```cpp
int main() {
    // Create instances of Writer and Reviewer
    Writer writer("Alice", 30);
    Reviewer reviewer("Bob", 45);

    // Use specific methods
    writer.writing();      // Output: Alice is writing a document.
    reviewer.reviewing();// Output: Bob is reviewing a document.

    return 0;
}
```

7- Access Modifiers : Public, Private, Protected

In the previous example, we could access display() method and any attribute (e.g name, age) anywhere, there are 3 places could a method or attribute called:

1- In the struct or class itself such enterData() call of age attribute check in the following example

```cpp
struct Person {
    string name;
    int age;
    // Member function to enter member data
    void enterData() const {
        cin >> name >> age;
        if(age<0) cout << "invalid age\n";

    }
    // Member function to display person details
    void display() const {
        enterData();
        cout << "Name: " << name << ", Age: " << age << endl;
    }
};
```
All access modifiers are accessible within a class or struct

2- In function like main() function after creating an instance of class of struct like   person1.name = "void", and   person1.display();the following example:

```cpp
int main() {
    // Creating an object of the Person struct
    Person person1("John Doe", 30);

    // Displaying the details of person1
    person1.name = "void";
    person1.display();


    return 0;
}
```

If age and name are private or protected, they wont be called outside the class or struct

3- Last call or access of attributes and method (member function) is used in inheritance like public in line 12 the inheritance example:

```cpp
4- // Base struct
5- struct Employee {
6- std::string name;
7- int age;

8- // Constructor for Employee
9- Employee(const std::string& n, int a) : name(n), age(a) {}
10-     };
11-     // Derived struct for Writer
12-     struct Writer : public Employee {
13-     // Constructor for Writer
14-     Writer(const std::string& name, int age) : Employ-
   ee(name, age) {}

15-     // Specific method for Writer
16-     void writing() const {
17-     std::cout << name << " is writing a document." <<
   std::endl;
18-     }
   };
```

Note: the line struct Writer **:** <mark>public</mark> Employee is public inheritance see Figure 10
public, protected, private inheritance, members are attributes and methods

Member Type	Public Inheritance	Protected Inheritance	Private Inheritance
Public Members	Remain public	Become protected	Become private
Protected Members	Remain protected	Remain protected	Become private
Private Members	Inaccessible	Inaccessible	Inaccessible

Figure 10 public, protected, private inheritance

The following table in Figure 11 Access Modifiers introduce how access modifiers work

Modifiers	Own Class	Derived Class inherited	Main()
Public	Yes	Yes	Yes
Private	Yes	No	No
Protected	Yes	Yes	No

Figure 11 Access Modifiers

For now we introduced only structs in user-defined data types, also we have union and enums

2.4.2. Enum

Enum is abbreviation of enumeration, which used to give some related integers names as humans don't remember and work with number well, e.g. if a worker get 500$ on Sunday and 600$ on Monday and 700$ on Tuesday ….. . an enum could hold these number and when we want give the worker 500$ on Monday, we could use Monday instead of using 500 number

Example: enum

Write C++ enum that define workday wage for a worker,

Sunday = 500, Monday = 600, Tuesday = 700, Wednesday = 800,

Thursday = 900, Friday = 1000, Saturday = 1100

```cpp
#include<iostream>
using namespace std;

enum days{
    Sunday = 500,
    Monday = 600,
    Tuesday = 700,
    Wednesday = 800,
    Thursday = 900,
    Friday = 1000,
    Saturday = 1100
    };
int main(){
    days workDay;
    cout<<"Worker earned: "<<Sunday<<"$ wage"<<endl;
    cout<<"Worker earned: "<<Monday<<"$ wage"<<endl;
    cout<<"Worker earned: "<<Tuesday<<"$ wage"<<endl;
    cout<<"Worker earned: "<<Wednesday<<"$ wage"<<endl;
    cout<<"Worker earned: "<<Thursday<<"$ wage"<<endl;
    cout<<"Worker earned: "<<Friday<<"$ wage"<<endl;
    cout<<"Worker earned: "<<Saturday<<"$ wage"<<endl;

}
```

2.4.3. Union

Union is user-defined data type that all attributes of that union share the same memory see Figure 12 Union vs struct, if I changed n in union; m will be changed too
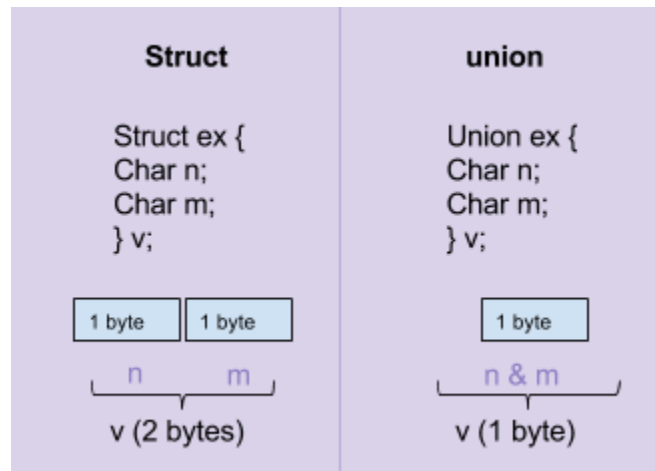
Figure 12 Union vs struct

Example: union

Write C++ union that holds char x=1 and short y=65535 , show the size of the that union and change value of x to 2 and print y and values

```cpp
#include<iostream>
using namespace std;

union storage{
    unsigned char x;
    unsigned short y;
};

int main(){
    storage var;
    var.x = 1;
    var.y = 65535;
    cout<<"size of var is: "<<sizeof(var)<<endl;
    cout<<"x y resp: "<<(unsigned short)var.x<<" "<<var.y<<endl;
    var.x = 2;
    cout<<"x y resp: "<<(unsigned short)var.x<<" "<<var.y<<endl;
}
```

You can see the output in Figure 13 union example, x is unsigned char that holds 1 byte, while y is unsigned short that holds 2 bytes, the first byte is shared by x and y

Like in Figure 14 union example explanation

```
D:\Programming\MasteringCPP\Basics\VariablesAndDatatypes>union.exe
size of var is: 2
x y resp: 255 65535
x y resp: 2 65282
```

Figure 13 union example

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
								X = 255							
Y = 65535															

when x changed to 2, y is affected as they have 1 byte shared

2nd byte								1st byte							
1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0
								X = 2							
Y = 65282															

Figure 14 union example explanation

Bitfield

Bitfield is used in struct and union to specify bit values, e.g. if we have an 8bit register that we want to change every bit, we could do that.

Example: bitfield

Write a bitfield to mimic an 8bit register by union

```cpp
#include<stdio.h>
using namespace std;

union Reg{
    struct{
        unsigned char B0:1;
        unsigned char B1:1;
        unsigned char B2:1;
        unsigned char B3:1;
        unsigned char B4:1;
        unsigned char B5:1;
        unsigned char B6:1;
        unsigned char B7:1;
    }Bits;
    unsigned char byte;
};

int main(){
    Reg DDRA;
    DDRA.Bits.B0=1;
    DDRA.Bits.B1=1;
    DDRA.Bits.B2=1;
    DDRA.Bits.B3=0;
    DDRA.Bits.B4=0;
    DDRA.Bits.B5=0;
    DDRA.Bits.B6=0;
    DDRA.Bits.B7=0;
    printf("%d",DDRA.byte);
}
```

NOTE: in this example, printf must be used instead of cout, so we have to include stdio.h library

2.5. Operators and Expressions

- Arithmetic operators: +, -, *, /, %
- Relational operators: ==, !=, >, <, >=, <=
- Logical operators: &&, ||, !
- Bitwise operators: &, |, ^, ~, <<, >>
- Assignment operators: =, +=, -=, *=, /=, %=, &=, |=, ^=, <<=, >>=
- unary operators (Increment and decrement): ++, --
- ternary operator: ?:

#Let var1 = 4 and var2 = 3

2.5.1. Arithmetic operators: +, -, *, /, %

Addition (+) e.g. var1 + var 2 = 4 + 3 =7

Subtraction (-) e.g. var1 - var 2 = 4-3=1

Multiplication (*) var1 * var 2 = 4*3=12

Division (/) e.g. var1 / var 2 =4/3 = 1

Modulo or reminder (%) e.g. var1 % var 2 4%3 = 1

see Figure 15 Division and modulo
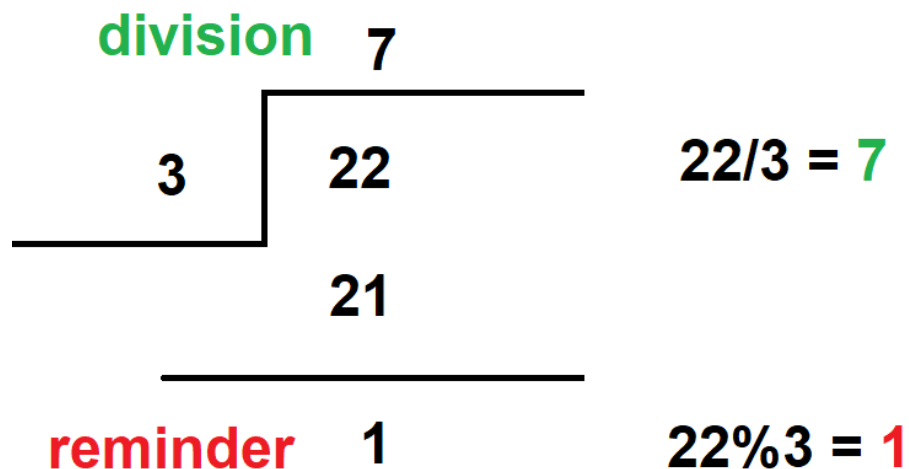
Figure 15 Division and modulo

2.5.2. Relational operators: ==, !=, >, <, >=

These operators used to determine relational between variables i.e. make comparisons as follows:

Is var1 equal var2   : var1 == var2 (return false as 4 not equal 3)

Is var1 not equal var2   : var1 != var2 (return true as 4 not equal 3)

Is var1 bigger than var2   : var1 > var2 (return true as 4 bigger than 3)

Is var1 less than var2   : var1 < var2 (return false as 4 bigger than 3)

Is var1 bigger than or equal var2   : var1 >= var2 (return true as 4 bigger than 3)

2.5.3. Logical operators: &&, ||, !

- ➤ && means **AND**
- ➤ || means **OR**
- ➤ !means **NOT**

Example: logicalOp

What if we want to combine 2 conditions?

The var1 is bigger than var2 **AND** var1 is odd:

The var1 is bigger than var2 **OR** var1 is odd:

The var1 is bigger than var2 **AND** var1 is not odd:

```cpp
#include<iostream>
using namespace std;

int main(){
    int var1 = 5, var2 = 6;
    cout<<"The var1 is bigger than  var2 AND var1 is odd: "<<((var2>var1)&&(var1%2 == 0))<<endl;
    cout<<"The var1 is bigger than  var2 OR var1 is odd: "<<((var2>var1)||(var1%2 == 0))<<endl;
    cout<<"The var1 is bigger than  var2 AND var1 is not odd: "<<((var2>var1) && (var1%2 != 0))<<endl;
    return 0;
}
```

NOTE: false means 0 and true is anything except 0, the previous code should outputs: 0 1 1 (i.e. false true true)

2.5.4. Bitwise operators: &, |, ^, ~, <<, >>

bitwise operators, used to change variable in bit level, if you have a 1-byte unsigned char of example, you can do operation on all these 8-bits freely like the following in the Figure 16 Bitwise operations :

```
Operation    A            B            Result     Symbol
----------------------------------------------------------
AND          11001100     10101010     10001000   (a & b)
OR           11001100     10101010     11101110   (a | b)
XOR          11001100     10101010     01100110   (a ^ b)
NOT          11001100                  00110011   (~a)
Left Shift   11001100                  00110000   (a << 2)
Right Shift  11001100                  00110011   (a >> 2)
```

Figure 16 Bitwise operations

2.5.5. Assignment operators: =, +=, -=, *=, /=, %=, &=, |=, ^=, <<=, >>=

These operators used to assign variables, e.g.

var1 = 2 (set var1 to 2)

var1+=2 (means var1 =var1+2 which increment var1 by 2)

var1&=1 (means var1 = var1 & 1)

The following figure contains table of what are set, clr, tog, get bit

Operation	Original	Index	Result	Explanation
Set Bit	11001100	2	11001100	Bit at index 2 is already 1, no change.
Set Bit	11001100	1	11001110	Bit at index 1 is set to 1.
Clear Bit	11001100	2	11001000	Bit at index 2 is cleared to 0.
Clear Bit	11001100	3	11000100	Bit at index 3 is already 0, no change.
Toggle Bit	11001100	2	11001000	Bit at index 2 is toggled to 0.
Toggle Bit	11001100	3	11000100	Bit at index 3 is toggled to 0.
Get Bit (original)	11001100	2	1	Bit at index 2 is 1.
Get Bit (original)	11001100	1	0	Bit at index 1 is 0.

Set bit: byte |= (1<<index) (Oring)

Clear bit: byte &=~ (1<<index) (Anding the complement)

Toggle bit: byte ^= (1<<index) (Xoring)

Get Bit: (byte>>index) & 1

Example: bitManipulation

In this example we want to make a struct named bit math that has 1 variable and 4 methods setBit(var, bit) clrBit(var, bit) togBit(var, bit) and getBit(var, bit)

NOTE: recall bitfield example and add the method mentioned: setBit() clrBit()) togBit(var, bit) and getBit(var, bit)

```cpp
#include<stdio.h>
using namespace std;

struct Register{
    union Reg{
        struct{
            unsigned char B0:1;
            unsigned char B1:1;
            unsigned char B2:1;
            unsigned char B3:1;
            unsigned char B4:1;
            unsigned char B5:1;
            unsigned char B6:1;
            unsigned char B7:1;
        }Bits;
        unsigned char byte;
    }reg;


    void setBit(int index){
        reg.byte |= (1<<index);
    }
    void clrBit(int index){
        reg.byte &=~ (1<<index);
    }
    void togBit(int index){
        reg.byte ^= (1<<index);
    }
    int getBit(int index){
        return (reg.byte>>index) & 1;
    }
};
```

```cpp
int main(){
    Register DDRA;
    DDRA.reg.byte = 0;
    DDRA.setBit(0); //setting bit number 0
    DDRA.setBit(1); //setting bit number 0

    printf("bit number 0 is %d\n",DDRA.getBit(0));
    printf("bit number 1 is %d\n",DDRA.getBit(1));
    printf("bit number 2 is %d\n",DDRA.getBit(2));

}
```
NOTE: this is pretty hard solution, but fell easier way.

2.5.6. unary operators (Increment and decrement): ++, --

increment and decrement is used on one operand (unary)

➢ post decrement/ increment

   var1 = 5; cout<< var1++; //outputs 6

➢ pre decrement/increment

   var1 = 5; cout<< ++var1; //outputs 5 but var1 after cout becomes 6

2.5.7. ternary operator: ?:

Ternary operator is type of conditionals in C++

Syntax: (condition) what to do if true: what to do if false

e.g.

var1=5;

(var1%2==0) cout<<"even" :cout<<"odd"; // the output is "even"

2.6. Control Structures

- ➢ Conditional statements: if, if-else, nested if, switch-case
- ➢ Looping statements: for, for range, while, do-while
- ➢ Jump statements: break, continue, goto, return

2.6.1. Conditional statements: if, if-else, switch-cases

Program is set of instructions to perform a task, some instructions require certain conditions to be performed, e.g. if(day == Friday) give all workers weekend wage weekend Wage()

There are 2 types of conditionals: if, else if, else AND switch

Switch case:

Switch is used to check a variable

Syntax:

switch(variable){

case 1: instructions; break;

case 2: instructions; break;

case 3: instructions; break;

.

.

default: instructions;break

}

NOTE: case 1: means if variable == 1

    case 'a': means if variable == 'a'

NOTE: default is used when variable has value not include in cases

NOTE: don't forgot to put break after any condition

NOTE: don't make a variable case e.g. case var

if, else if, else case:

if else used when you want to check for conditions

Syntax:

      if(condition){ instructions}

      else if(condition){ instructions}

      else { instructions}

NOTE: else if is not consider unless if conditional is not fulfilled

NOTE: else is not consider unless if conditional and else if conditionals are not fulfilled

NOTE: don't make instructions between if- else if – else

        e.g. if(x==5){ cout<<"5"'}

          cin>>x; //wrong !!

          else {cout<<" x is not 5;}

Example: switch

Write C++ code to determine whether the letter is vowel or not by using switch case, Vowels are: a, e, i, o, u . Consonants are the rest of the letters .

```cpp
#include<iostream>
using namespace std;

int main(){
    char x = ' ';
    cout<<"enter a letter: ";
    cin>>x;

    switch(x){
        case 'a': cout<<"\n the letter "<<x<<" is Vowel\n";break;
        case 'e': cout<<"\n the letter "<<x<<" is Vowel\n";break;
        case 'i': cout<<"\n the letter "<<x<<" is Vowel\n";break;
        case 'u': cout<<"\n the letter "<<x<<" is Vowel\n";break;
        case 'o': cout<<"\n the letter "<<x<<" is Vowel\n";break;
        default: cout<<"\n the letter "<<x<<" is Consonant\n"; //break
at last condition doesn't matter
    }
}
```

Example: ifElse

In switch example, if 5 is entered, the output is: the letter 5 is Consonants, as its in default case, but 5 is not letter, complete the previous code to check first if the input is letter

Hint: isalpha() use this to determine if the input is letter or not

```cpp
#include<iostream>
using namespace std;

int main(){
    char x = ' ';
    cout<<"enter a letter: ";
    cin>>x;
    if(isalpha(x)){
        switch(x){
            case 'a': cout<<"\n the letter "<<x<<" is Vowel\n";break;
            case 'e': cout<<"\n the letter "<<x<<" is Vowel\n";break;
            case 'i': cout<<"\n the letter "<<x<<" is Vowel\n";break;
            case 'u': cout<<"\n the letter "<<x<<" is Vowel\n";break;
            case 'o': cout<<"\n the letter "<<x<<" is Vowel\n";break;
            default: cout<<"\n the letter "<<x<<" is Consonant\n";
//break at last condition doesn't matter
        }
    }
    else{
        cout<<'\n'<<x<<" is not letter"<<endl;
    }
}
```

2.6.2. Loops

What if we need to execute certain code many times? e.g. printing "hello" 100 time or until user enters quit

- ➢ We could type cout<<"hello" 100 times
- ➢ OR we could use loops

Loop is C++ are:

- ➢ for(start; end ;update){instructions}
- ➢ for (range){instructions}
- ➢ while(condition){instructions}
- ➢ do{instructions} while(condition)

for loop

syntax: for(start; end ;update){instructions}

e.g.

for(int itr=0;itr<10;itr++){

cout<<"hello "<<itr<<" times<<endl;

}

Used when number of iterations is known, the previous example demonstrates printing hello itr times when such that itr starts with 0 and ends when itr = 9 (itr<10), and the update is how does the variable itr changers, in this case the update is itr is increased by 1 (i.e. itr++ means itr=itr+1)

Example: forLoop

Write C++ code to print even numbers from 10 to 20

```cpp
#include <iostream>
using namespace std;

int main(){
    for(int k=10; k<=20; k=k+2 ){
        cout<<"the number "<<k<<" is even\n";
    }
    return 0;
}
```

for range loop

syntax: for(datatype item: list){instructions}

this is used to get the item of list (array or vector) without subscript Operator (i.e []), like python for loop

Example: forRangeLoop

print array of vowels without using subscriptor operator

```cpp
#include <iostream>
#include<array>
using namespace std;

int main(){
    array<char,5> vowels = {'a','e','u','i','o'};
//remember array<,> differs from c arrays (vowels[])
    for(char x: vowels)
    {cout<<x<<" is vowel"<<endl;}

}
```

While loop

syntax: while(condition){instructions}

while loop is used when number of iteration is unknown but the condition is clear

Example: whileLoop

Write C++ code to calculate the sum of user single integer input, e.g. if user entered 1251 the sum is 1+2+5+1 which is 9

NOTE: the algorithm is take the reminder and divide the number by 10

```cpp
#include <iostream>
using namespace std;

int main(){
    int x =0,sum=0, cont=0;
    cout<<"enter a number ";
    cin>>x;
    cont = x;

    while(x/10 > 0){
        sum += x%10;
        x= x/10;
    }
    sum += x; //adding the most left number
    cout<<"the sum of "<<cont<<" is: "<< sum;
}
```

Do While loop

syntax: do{instructions} while(condition);

same as while loop but the instructions are done first, then check on condition, re-member the whileLoop (previous example), we had to write the following line
`sum += x; //adding the most left number`
as the condition is reaching before getting the most left number

I.e.

Sum=0 and x=123

Reminder and divide first time Sum=3 and x=12 (`(x/10 > 0)` check is valid)

Reminder and divide second time Sum=6 and x=1 (`(x/10 > 0)` check isn't valid)

As 1/10 not bigger that 0 so number 1 (most left number of 123) is not added,

Example: doWhileLoop

Rewrite the whileLoop by by dowhile loop instead of while loop

```cpp
#include <iostream>
using namespace std;

int main(){
    int x =0,sum=0, cont=0;
    cout<<"enter a number ";
    cin>>x;
    cont = x;

    do{
        sum += x%10;
        x= x/10;
     }
    while(x > 0);

    cout<<"the sum of "<<cont<<" is: "<< sum;
}
```

2.6.3. Jump statements: break, continue, goto, return

break is used in loops to get out of the loop

continue is used to skip an iteration in the loop
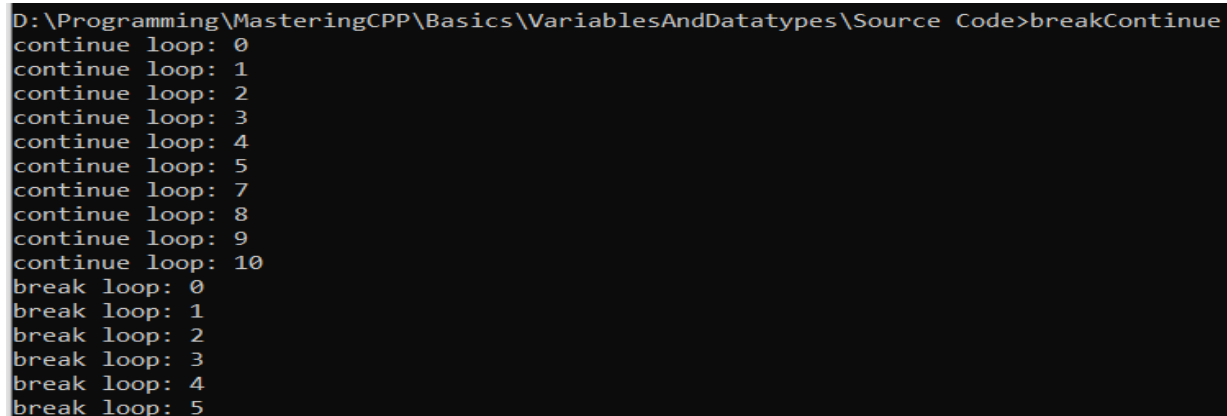
goto is used to jump to any line in the code

return is used in functions to get out the function

Example: breakContinue

In this example, break and continue are used to illustrate the difference, two for loops will be written, break will be used in one loop and continue in the other when the itr is equal 6, the break gets out when itr gets 6 but the continue, skips the 6 and continue the loop, see Figure 17 break and continue

```cpp
#include <iostream>
using namespace std;
int main(){
    for(int itr=0; itr<=10; itr++){
        if(itr==6) {continue;}
        else{cout<<"continue loop: "<<itr<<endl;}
    }
    for(int itr=0; itr<=10; itr++){
        if(itr==6){break;}
        else{cout<<"break loop: "<<itr<<endl;}
    }
}
```

```
D:\Programming\MasteringCPP\Basics\VariablesAndDatatypes\Source Code>breakContinue
continue loop: 0
continue loop: 1
continue loop: 2
continue loop: 3
continue loop: 4
continue loop: 5
continue loop: 7
continue loop: 8
continue loop: 9
continue loop: 10
break loop: 0
break loop: 1
break loop: 2
break loop: 3
break loop: 4
break loop: 5
```

Figure 17 break and continue

Example: goto

Print even number from 30 to 40 without using loops and use only one cout

```cpp
#include <iostream>
using namespace std;

int main(){
    int itr = 30;

    a:
    if(itr%2 ==0){
        cout<<"the number "<<itr<<" is even\n";
    }

    itr++;
    if(itr<=40)
    goto a;
}
```

2.7. Final project

Project Requirements: Sign-Up Application

We are developing a user registration application to store user names and ages.

We will use a struct to represent each user, stored in an array (limited to 100 records).

Users can add records and retrieve them by ID.

Steps to Complete:

1-Include necessary headers.

2-Define a struct for user records (Person), and declare an array of this type (Person records[100]).

3-Implement functions:

 A-void AddRecord(const std::string& name, int age): Adds a new record.

 B-FetchRecord(int id): Retrieves a record by ID.

 C-Quit().

4-In main(), use a loop to present options (Add Record, Fetch Record, Quit).

Handle user input using a switch statement:

Case 1: Prompt for name and age, then call AddRecord().

Case 2: Prompt for ID, then call FetchRecord() and display the result.

Case 3: Exit the loop.

You can fine code in the github repository LINK

An example: see Figure 18 Final project snapshoot

D:\Programming\MasteringCPP\Basics\FinalProject\finalProject.exe

```
Please select an option:
1- Add Record
2- Fetch Record
3- Quit

1
Add user, Please enter name and age
Ahmed 15
Please select an option:
1- Add Record
2- Fetch Record
3- Quit

2
Fetch user, Please enter id from 0 to 99
0
Name: Ahmed
Id: 15
Please select an option:
1- Add Record
2- Fetch Record
3- Quit

3_
```

Figure 18 Final project snapshoot

Chapter 3 Pointers and Memory management

One of strengths of C++ is access hardware directly specially memory, pointers is derived data type that can modify a variable (e.g. single variable or list (array or vector or even structs), you can for sure modify a variable like what we did in last chapters, but in functions it isn't applicable (next chapter).

Pointers carry the memory address of variable (e.g. single variable or list (array or vector or even structs), so that you can modify this variable, pointer like a key for accessing a flat , to enter the flat you must have a key, the pointer carry the address of the variable in memory so it can gets in and change the variable

Another benefit from using pointers is to use it to allocate a place in memory for a variable (e.g. single variable or list (array or vector)), and the pointer is the key to access the element(s) of that variable

So in this chapter and the following one, the main two benefits of pointers will be introduced which are pointer to allocate variables and pointer in functions (call by reference) (in the next chapter)

- **Introduction to Pointers**
    - o Pointer declaration, initialization, and dereferencing
    - o Operations on Pointers
    - o References and reference variables
- **Dynamic Memory Allocation**
    - o new and delete operators
    - o Allocating memory for single variables and arrays
    - o Linked List
    - o Memory leaks and how to avoid them
- **Smart Pointers**
    - o `std::unique_ptr`
    - o `std::shared_ptr`
    - o `std::weak_ptr`

3.1. Introduction to Pointers

Memory store variables in memory in bytes, its compiler dependent but in our gcc compiler char has 1 byte, short has 2 bytes, int and floats have 4 bytes, double has 8 bytes, Figure 19 how memory store variables, x is store in one byte in memory address 2000 and y also but stored in 2001 memory address, and short store 2 bytes which are 2002 and 2003 as short requires 2 bytes

```cpp
#include<iostream>
using namespace std;

int main(){
 char x;
 char y;
 short z;
}
```
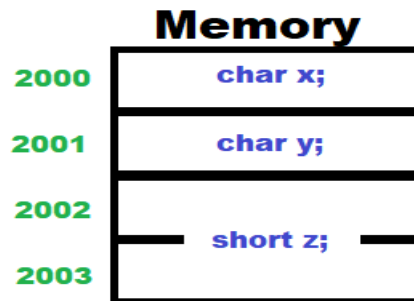

Figure 19 how memory store variables

Pointers must be as same type of what it points to (so it will be same size also) !!

NOTE: in C++ pointers forces not to change a const variable, but you can change the const variable in C

Example: ptrVar

Write C++ code to pointer to char and other to int, print the values and addresses of variables and size of the two pointers to these variables

```cpp
#include<iostream>
using namespace std;
int main(){
 char x = 'a';
 short y = 15;
 char* ptr_x = &x;
 short* ptr_y = &y;
  //derefrence operator * to access or modifiy variables
 cout<<"x has: "<<*ptr_x<<" while y has: "<<*ptr_y<<endl;

 cout<<"x is stored in : "<<(void*)ptr_x<<" whil
e y is stored in: "<<ptr_y<<" Addresses"<<endl;

 *ptr_x = 'b';
 *ptr_y = 66;;

  cout<<"After Modifiynig\nx has: "<<*ptr_x<<" while y has:
"<<*ptr_y<<endl;

  cout<<"x is stored in : "<<(void*)ptr_x<<" while y is stored in:
"<<ptr_y<<" Addresses"<<endl;
  }
```

3.1.1. Pointer definition

the array is simply a block of memory that holds some consecutive data of same type, when an array is created, *e.g. array *named x*), x is a pointer to first element of the array (x is the memory address of first element), so to access any element you have to use x pointer to access any element by x[i] or *(x+i), remember that x pointer to first address (carry address of 1st element) let the address of first element is 2000 so x is 2000 and to access the 2nd element you have to use *(x+1) which is *(2001) and 3rd element is *(x+2) which is *(2002) so the general to access any element use *(x+i) which is also x[i] see Figure 20 how memory store arrays

Figure 20 how memory store arrays

Example: ptrArray

Write array with 5 elements and get them from user and print them, don't use subscriptor operator (i.e. arr[]) use *(ptr+i) which means *(pointer_to_i^{th}element)

```cpp
#include<iostream>
#include<array>
using namespace std;
int main(){
  array<int,5> x;
  int* ptr_x = x.data(); //x.data() is used to get the pointer of ar-
ray x
  //filling array
  for(int i=0;i<x.size();i++){
    int x=0;
    cout<<"\nenter element: "<<i<<" ";
    cin>>*(ptr_x + i); //*(ptr_x + i) == ptr[i]
  }
  //printing array
    for(int i=0;i<x.size();i++){
    cout<<"\nelement "<<i<<" is"<<*(ptr_x + i); //*(ptr_x + i) ==
ptr[i]
  }
}
```

If you used C array (i.e. char x[5]) instead of stl array (array<char,5>x;)

```cpp
#include<iostream>
#include<array>
using namespace std;

int main(){
  int x[5];
  int* ptr_x = x; //&x is not used as x is address itself

  //filling array
  for(int i=0;i<5;i++){
    int x=0;
    cout<<"\nenter element: "<<i<<" ";
    cin>>x;
    *(ptr_x + i) = x; //*(ptr_x + i) == ptr[i]
  }

  //printing array
    for(int i=0;i<5;i++){
    cout<<"\nelement "<<i<<" is "<<(*(ptr_x + i)); //*(ptr_x + i) ==
ptr[i]
  }
}
```

3.1.2. Operations on Pointers

Arithmetic operators

+ and – but not /, *, %

You can add and subtract values from pointers like what we did in array *(arr+i) pointer arr (first element of the array) could be added or subtracted to iterate over an array

Question: what happens when pointer to array of 3 int is incremented ?? see Figure 21 pointer increment (remember : int has 4 bytes in gcc compiler
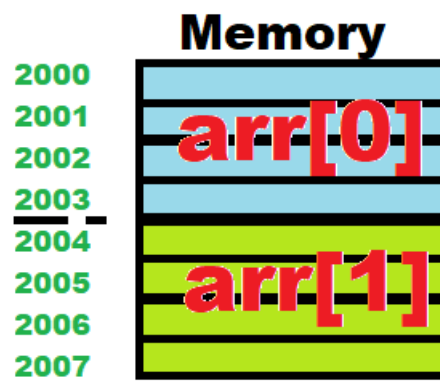
Figure 21 pointer increment

The pointer incremented by four as size of int is 4 so every increment is 4 memory addresses, if short is used; the increment will be 2-byte step as short in gcc has 2 bytes see Figure 22 pointer increment step

```cpp
#include<iostream>
#include<array>
using namespace std;
int main(){
    array<int,2> arr;
    int* ptr_arr = arr.data(); //x.arr() is used to ge
    cout<<"pointer before increment: "<<ptr_arr;
    ptr_arr++; //ptr_arr++ is ptr_arr= ptr_arr + 1
    cout<<"\npointer after increment: "<<ptr_arr;
}
```

```
D:\Programming\MasteringCPP\Pointers And Memory management\Source Code>a
pointer before increment: 0x4c481ffe50
pointer after increment: 0x4c481ffe54
D:\Programming\MasteringCPP\Pointers And Memory management\Source Code>
```

Figure 22 pointer increment step

Arrow operator

When you use dot operator (.) and dereference operator (*) like in pointer to struct you could easily use arrow operator (->) for simplicity

e.g. *(ptr_to_struct).member is equivalent to   ptr_to_struct->member

don't forgot: for simplicity also we use arr[i] instead of *(arr+i)

NOTE:

- when we use pointer to int, the datatype of the pointer should be int
- when we use pointer to char, the datatype of the pointer should be char
- SO, when we use pointer to struct, the datatype of the pointer should be as same as the struct

Example: ptrStruct

Use arrow operator to modify age of student struct that have name and age

```cpp
#include<iostream>
using namespace std;

struct Student{
    int age;
    string name;
    //constructor
    Student(int a, string n): age(a), name(n){}
};
int main(){
   Student Ahmed(25,"Ahmed");
   //assume age is 26 so we have to modifiy
   //we could modifi directly by Ahmed.age = 26
   //but in function, it is not applicable
   Student* ptr_struct = &Ahmed;

   ptr_struct->age = 26; //same as  *(ptr_struct).age = 26
   cout<<"The age of "<<ptr_struct->name<<" and have "<<ptr_struct->age<<" yrs old";
  }
```

3.2. Dynamic Memory allocation

Pointers are used to allocate memory for array or single variable, the memory allocation is like in C but mostly we use new and delete instead off malloc and calloc and realloc and free

3.2.1. new and delete operators

new is used to allocate memory for single variable and array or even structs

3.2.2. Allocating memory for single variables and arrays

Allocation:

- datatype* ptr = new datatype //for single variable
- datatype* ptr = new datatype[num] //for array

e.g. int* ptr = **new** int;

int* ptr = **new** int[];

deallocation (deletion):

- delete ptr //for single variable
- delete[num]   ptr//for array

e.g. delete ptr;

delete[] ptr;

Example: arrayAlloc

Write C++ to allocate 5-element (integers) array using new (don't use malloc())

```cpp
#include<iostream>
using namespace std;

int main(){
  int size = 5;
  int* ptr_arr = new int[size];
  //filling array
  for(int i=0;i<size;i++){
      cout<<"\nenter element :"<<i<<" ";
      cin>>*(ptr_arr+i);
  }
 //printing array
  for(int i=0;i<size;i++){
      cout<<"\nenter element "<<i<<" is "<< *(ptr_arr+i);
  }

}
```

3.2.3. Linked List

Array and vector allocate element consecutively in memory, but what happens if we want to allocate 100 element (char) in array and we have these 100 bytes in memory to store these 100 char elements, but we don't have these free 100 bytes consecutively?? Linked list came to help, in linked list you can store elements of array in different locations in memory (not consecutively primarily)

In linked list, make a struct to store data and address (pointer) of the next node, linked list primarily is struct carry node data and pointer carry address of the next node see Figure 23 Linked List basics
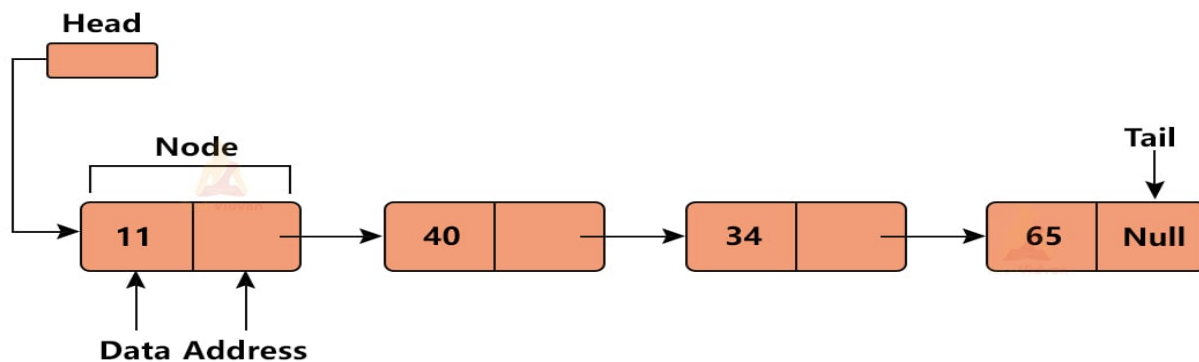
Figure 23 Linked List basics

Before getting into linked lists, I am not big fan to illustrate such thing on books and leave graphical illustrations, so open the either YouTube links that illustrate the basics if you are totally newbie to linked list and C++ , the two links one of them in Arabic and the other in English.

Figure 25 Arabic video

Figure 24 English video

The other thing is to recall pointer to struct:

When you use dot operator (.) and dereference operator (*) like in pointer to struct you could easily use arrow operator (->) for simplicity

e.g. *(ptr_to_struct).member is equivalent to   ptr_to_struct->member

don't forgot: for simplicity also we use arr[i] instead of *(arr+i)

NOTE:

- when we use pointer to int, the datatype of the pointer should be int
- when we use pointer to char, the datatype of the pointer should be char
- SO, when we use pointer to struct, the datatype of the pointer should be as same as the struct

So after we make the pointer to list, we could access what is in the struct by either ways   ptr_struct->member **or** *(ptr_struct).member

Steps to create linked list

➢ Create struct carry data and pointer

```cpp
struct Node{
    int data;
    Node* next;
};
```

➢ Create the head, pointer of that struct that carry is ready for storing the 1st node address

```cpp
//create the head
  Node* head = new Node;
```

➢ **To create 1st node**

    1- Create instance of that struct

```cpp
//create 1st node
  Node* newNode = new Node;
```

    2- Put the data you want and make the next points to NULL

```cpp
cout<<"enter the data of the first node ";
cin>>newNode->data;
newNode->next = NULL;
```

    3- The address (ptr_struct) is stored in head (link the new node to head)

```cpp
//link the new node to the head
head->next = newNode;
```

➢ To create further node

1- Create instance of that struct

```
//create 2nd node
Node* newNode2 = new Node;
```

2- Put the data you want and make the next points to NULL

```
cin>>newNode2->data;
newNode2->next = NULL;
```

3- The address (ptr_struct) is stored in the last node that has null_ptr (link the new node to the last node

```
(head->next)->next = newNode2;
```

> To delete node

Let the node to be deleted is n^{th} node

1- Iterate to n-1th node

```
//1- iterate to previous node of 2nd node which is 1st node
itr = head;
for(int i=0;i<1;i++){
    itr=itr->next; //we 1st node
}
```

2- In n-1th address make the address is n+1th address instead of nth address

```
//2- (unlink 2nd node) replace 1st node address by the 3rd node
instead of 2nd node
Node* temp = itr->next; //save 2nd node before unlinking
itr->next = (itr->next)->next; //pointer to pointer (address
of 3rd node)
```

3- Till here, the node is not deleted but unlinked from the list, so we have to delete the node by **delete**

```
//3-delete the 2nd node
delete temp;
```

> Print the list

```
//printing the linked list
Node* itr = head->next;
while(itr != NULL){
  cout<<itr->data<<endl;
  itr=itr->next;
 }
```

Example: linkedList

Here is to sum up:

```cpp
#include<iostream>
using namespace std;
struct Node{
    int data;
    Node* next;
};
int main(){
  //create the head
   Node* head = new Node;

   //create 1st node
   Node* newNode = new Node;
   cout<<"enter the data of the first node ";
   cin>>newNode->data;
   newNode->next = NULL;
   //link the new node to the head
   head->next = newNode;

   //create 2nd node
   Node* newNode2 = new Node;
   cout<<"enter the data of the second node ";
   cin>>newNode2->data;
   newNode2->next = NULL;
   (head->next)->next = newNode2; //Link the node

   //create 3nd node
   Node* newNode3 = new Node;
   cout<<"enter the data of the third node ";
   cin>>newNode3->data;
   newNode3->next = NULL;
   ((head->next)->next)->next = newNode3; //Link the node

   //printing the linked list
   Node* itr = head->next;
   while(itr != NULL){
   cout<<itr->data<<endl;
   itr=itr->next;
   }
```

```cpp
    //deletion of 2nd node
    //1- iterate to previous node of 2nd node which is 1st node
    itr = head;
    for(int i=0;i<1;i++){
        itr=itr->next; //we 1st node
    }
    //2- (unlink 2nd node) replace 1st node address by the 3rd node in-
stead of 2nd node
    Node* temp = itr->next; //save 2nd node before unlinking
    itr->next = (itr->next)->next; //pointer to pointer (address of 3rd
node)
    //3-delete the 2nd node
    delete temp;

    //printing the linked list again after deletion
    cout<<"after deletion of 2nd node"<<endl;
    itr = head->next;
    while(itr != NULL){
    cout<<itr->data<<endl;
    itr=itr->next;
    }
}
```

3.2.4. Memory Leaks

Memory leaks happens when manual memory allocation is performed badly such that many allocation with no deletion
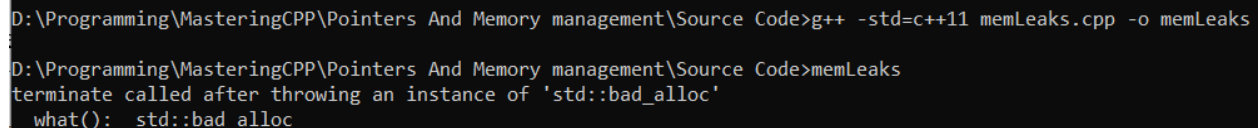
Example: memLeaks

Write C++ code that allocates array of 100 integers memory and the pointer to that array assign it to nullptr or NULL, the whole code in while(true)

```cpp
#include<iostream>
using namespace std;

int main(){
 while(true){
    int* ptr = new int[100];
    ptr = nullptr; //null pointer
    }
}
```

The previous example is like buying flats and throw away the key of each flat, the issue of throwing the key is you cannot get into the flat and the worse is takes portion of your wealth with no benefits, so the pointer (key) when forgotten (`ptr = nullptr`) the array or variable allocated remains in memory and never deleted, this causing software aging which means the program crashes and even worse the whole system. See Figure 26 Software crash (termination) due to bad memory allocation

```
D:\Programming\MasteringCPP\Pointers And Memory management\Source Code>g++ -std=c++11 memLeaks.cpp -o memLeaks

D:\Programming\MasteringCPP\Pointers And Memory management\Source Code>memLeaks
terminate called after throwing an instance of 'std::bad_alloc'
  what():  std::bad_alloc
```

Figure 26 Software crash (termination) due to bad memory allocation

Remember, one of strengths of C++ is controlling hardware (e.g. memory) freely which makes C++ fast, but if this strength used badly, it becomes weakness

NOTE: C/C++ use manual memory management while programming languages like python use garbage collection which is automatic memory management, its little bit slower bit lesser risks

Pointer types:

➢ Wild pointer

> when using pointers before assigning value to that pointer

```cpp
#include<iostream>
using namespace std;

int main(){
    int* ptr;
    cout<<*ptr;
}
NOTE: ptr points to nothing !!
```
Defending against wild pointers

> Always initialize pointer to nullptr (null pointer) like:

```cpp
int* ptr = nullptr;
```

➢ Dandling pointer

> When using a pointer that is deallocated

```cpp
#include<iostream>
using namespace std;

int main(){
    int* ptr = new int[3];
    ptr[0] = 5;
    ptr[1] = 55;
    ptr[2] = 555;
    delete ptr;
    cout<<ptr[1]; //printing deallocated pointer
}
```
Using the ptr pointer after deletion

REMEMBER:

➢ Void pointer e.g. (void *) is generic pointer that could be casted (converted) to point to any data
➢ nullptr is null pointer that points to nothing
➢ nullptr is preferred over NULL

3.3. Smart pointers

When memory leaks happens (allocate memory and not deleting them), memory is consumed with no usage as variables are still in heap memory and are not deleted, some developers don't deallocate memory well, so smart pointers came to help. Smart pointers are pointers that deallocate memory by itself (i.e. there is no need to call delete)

Smart pointers deallocate memory by keep tracking of usage of that pointer, if the pointer is not used, the deallocation done automatically.

Types of smart pointers:

- ➢ Unique pointer
- ➢ Shared pointer
- ➢ Week pointer

3.3.1. Unique pointer

This type of smart pointer keeps track of user usage of itself, if user don't use this unique pointer, it deallocates the memory allocated. See Figure 27 unique pointer
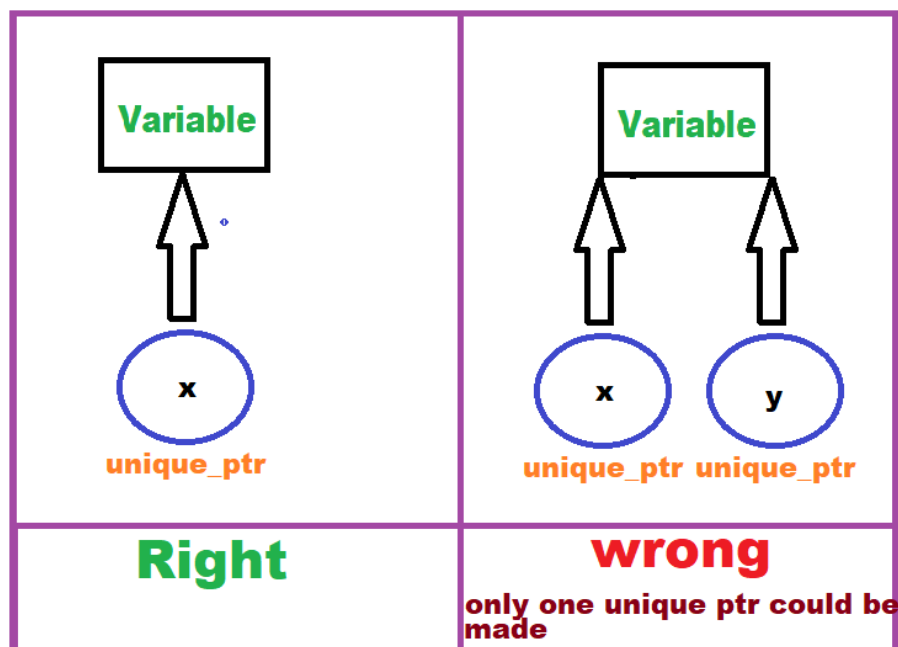
Figure 27 unique pointer

Syntax:

For allocating single variable via unique pointers

> unique_ptr<datatype> name(new datatype)
>
> or
>
> unique_ptr<datatype> name = make_unique<datatype>

For allocating array via unique pointers

> unique_ptr <datatype[]> name(new datatype[])

Example: allocate memory for single and array of int via unique_ptr

```cpp
#include<iostream>
#include<memory>
using namespace std;

int main(){
    unique_ptr<int> ptr1(new int(15));
    //make unique ptr to var init with 15
    //or use unique_ptr<int> ptr1 = make_unique<int>();

    unique_ptr<int[]> ptrArr(new int[10]);
     //allocate array via unique pointer
    //filling the array
    for(int i=0;i<10;i++){
    cout<<"enter element "<<i<<" "<<endl;
    cin>>*(ptrArr.get()+i); //or ptrArr[i]
    //note to get the address of unique pointer, use .get() method
    }

    //printing the single value
    cout<<"unique single var is :"<<*ptr1<<endl;

    //printing the array
    for(int i=0;i<10;i++){
    cout<<"unique array var is, element number : "<<i<<"
"<<ptrArr[i]<<endl;
    }

  }
```

NOTE: to get the address of unique pointer, use .get() method

3.3.1. Shared pointer

this type of smart pointer is totally like unique pointer but could have many shortcut pointers so that deallocation is done if and only if user stopped using all the shortcuts and the main pointers itself. See Figure 28 shared pointer
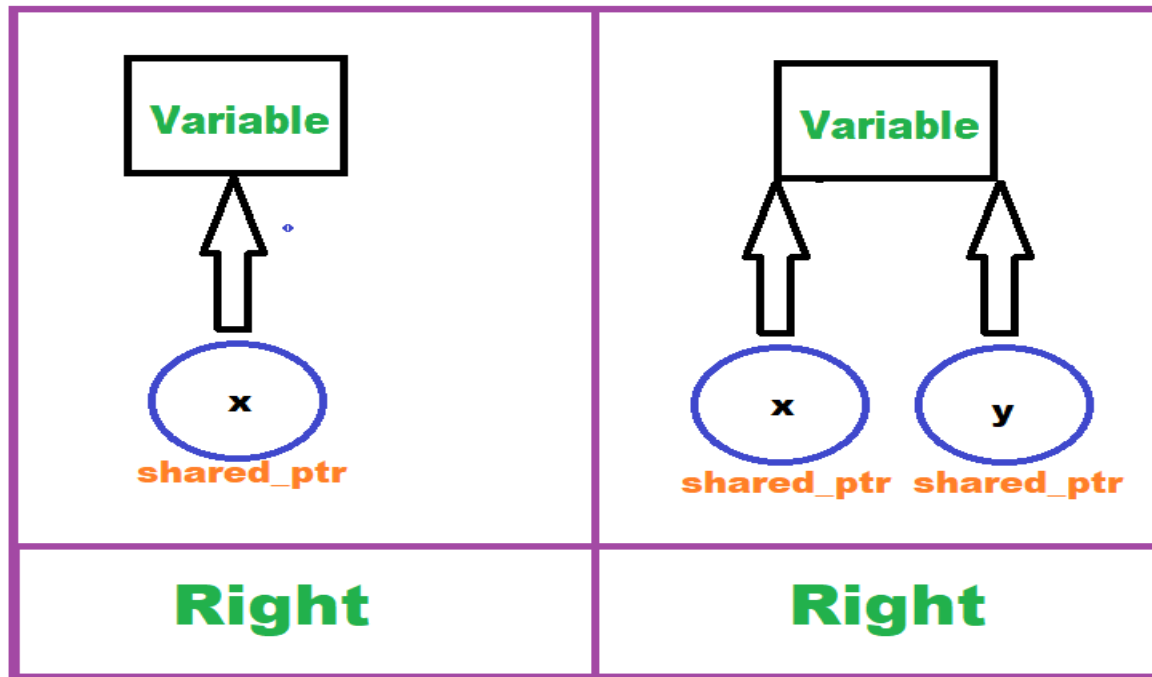
Figure 28 shared pointer

Example: allocate memory for single via 2 shared_ptr and use .use_count() method to show how many shared_ptr are used, should be 2 as we created 2 shared pointers.

```cpp
#include<iostream>
#include<memory>
using namespace std;

int main(){
    shared_ptr<int> ptr1(new int(15)); //make unique ptr to var init
with 15
    //or use unique_ptr<int> ptr1 = make_shared<int>();

    shared_ptr<int> ptr2 = ptr1;

    cout<<"first shared ptr to single var is :"<<*ptr1<<endl;
    cout<<"second shared ptr to single var is :"<<*ptr1<<endl;

    cout<<"there are "<<ptr1.use_count()<<" shared pointer";
}
```

3.3.1. Weak pointer

This type of smart pointer is like shared but the deallocation is done by only stopping usage the main pointers (shared pointers i.e. the main and its shortcuts). See Figure 29 Weak pointers, NOTE: you cannot dereference with weak pointers, you should create a var of shared_ptr type and use .lock() i.e. var = wearPointer.lock()
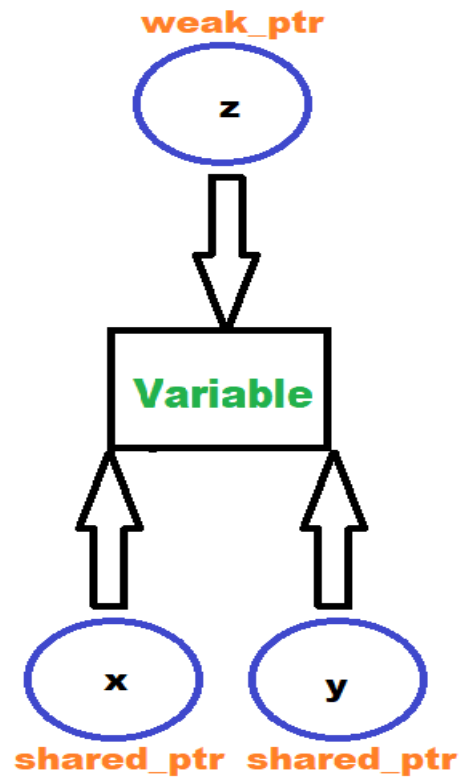
Figure 29 Weak pointers

Example: allocate memory for single via 2 shared_ptr and and 1 weak pointer then use .use_count() method to show how many pointers are used (active), should be 2 as we created 2 shared pointers as weak pointer doesn't count

```cpp
#include<iostream>
#include<memory>
using namespace std;

int main(){
    shared_ptr<int> ptr1(new int(15)); //make unique ptr to var init
with 15
    //or use unique_ptr<int> ptr1 = make_shared<int>();

    shared_ptr<int> ptr2 = ptr1;
    weak_ptr<int> ptr3 = ptr1;  //weak pointer is created

    //you cannot derefrence with weak ptr directly
    //so do this:
    //shared_ptr<int> tempPtr3 = ptr3.lock();
    cout<<"first shared ptr to single var is :"<<*ptr1<<endl;
    cout<<"second shared ptr to single var is :"<<*ptr2<<endl;
    //cout<<"third ptr (weak) to single var is :"<<*tempPtr3<<endl;

    cout<<"there are "<<ptr1.use_count()<<" pointer"; //the answer is
2
  }
```

NOTE: if we uncomment   `//shared_ptr<int> tempPtr3 = ptr3.lock();`
The answer will be 3 despite the fact of weak pointers don't count as tempPtr3 is shared_ptr type !!

Chapter 4 Functions

Function is set of instructions used to decrease program size, whenever a function called, it performs the instructions it has.

- **Function Declaration and Definition**
  - o Syntax: return_type function_name(parameters)
  - o Function prototypes
- **Parameter Passing**
  - o Pass-by-value
  - o Pass-by-reference
  - o Pass-by-pointer
  - o Default arguments
- **Overloading and Inline Functions**
  - o Function overloading
  - o Inline functions
- **Recursive Functions**
  - o Base case and recursive case
  - o Examples: factorial, Fibonacci sequence

e.g. you have 4 users to print their names, ID, age which is 12 lines of code (i.e. 3 lines to print for 4 users)

```cpp
#include<iostream>
using namespace std;
int main(){
    //print first user
    cout<<"hello "<<"Ahmed"<<endl;
    cout<<"you've "<<20<<" yrs old"<<endl;
    cout<<"your ID is "<<202014<<endl;
    //print second user
    cout<<"hello "<<"Gamal"<<endl;
    cout<<"you've "<<25<<" yrs old"<<endl;
    cout<<"your ID is "<<202015<<endl;
    //print third user
    cout<<"hello "<<"Sameh"<<endl;
    cout<<"you've "<<18<<" yrs old"<<endl;
    cout<<"your ID is "<<202016<<endl;
    //print fourth user
    cout<<"hello "<<"Emad"<<endl;
    cout<<"you've "<<23<<" yrs old"<<endl;
    cout<<"your ID is "<<202017<<endl;
    }
```

Its headache to do this for only 4 users, what if 100 users !!

Function could save the instructions and call it whenever you want with only one line !

```cpp
#include<iostream>
using namespace std;

void printUser(string name, int age, short ID); //function Declaration
int main(){
    printUser("Ahmed", 20, 202014);
    printUser("Gamal", 25, 202015);
    printUser("Sameh", 18, 202016);
    printUser("Emad", 23, 202017);
}
void printUser(string name, int age, short ID){//function Definition
    cout<<"hello "<<name<<endl;
    cout<<"you've "<<age<<" yrs old"<<endl;
    cout<<"your ID is "<<ID<<endl;
}
```

SEE the code decreased a lot

4.1. Function Declaration and Definition

4.1.1. Function declaration

Is telling the compiler what your return type and input parameters and name of your function

i.e.

return_datatype name(datatype param1, datatype param2, datatype param3 ,.);

e.g.

int add (int x, int y);

NOTE: **return_datatype** means the output of your function will be in what type, void mean the function don't return anything, int means it return in

The add function takes 2 input integers and return sum as output   which is integer too

If the function output (sum):

   float the declaration will be **float** add (int x, int y);

its critical to determine the output (return) data types

4.1.2. Function definition

Is telling the compiler what instructions the function does.

So to sum up, the declaration is:

This is user **declaration** of function takes 3 parameters and return nothing

```
void printUser(string name, int age, short ID); //function Declaration
```
and the **definition** is:

```
void printUser(string name, int age, short ID){//function Definition
    cout<<"hello "<<name<<endl;
    cout<<"you've "<<age<<" yrs old"<<endl;
    cout<<"your ID is "<<ID<<endl;
}
```

Example: addFunc

Write function to add 2 integers and return their sum as long int

Return datatype: long int

Input parameters: int x and int y

Function name: add

```cpp
#include<iostream>
using namespace std;

long int add(int x, int y); //function Declaration
int main(){
    int a,b;
    long int sum = 0;
    cout<<"enter the two addition operands :";
    cin>>a>>b;
    sum = add(a,b);
    cout<<"\n the sum is "<<sum;
}
long int add(int x, int y){ //function Definition
    return x + y;
}
```

Example: structFunc

write function to set a struct, the struct student which have name and id, the function return a struct after asking the user to enter name and id of the student

Return datatype: struct Student

Input parameters: nothing *//as the user will enter them in the function*

Function name: fillStruct

```cpp
#include<iostream>
using namespace std;

struct Student{
  string name;
   int id;
};

Student fillStruct(); //function Declaration
int main(){
    Student Ahmed = fillStruct();
    cout<<"Student: "<<Ahmed.name<<" has ID of "<<Ahmed.id;
}

Student fillStruct(){ //function Definition
    Student student;
    string name;
    int id;
    cout<<"enter your name: ";
    cin>>student.name;
    cout<<"enter your ID: ";
    cin>>student.id;
    return student;
}
```

NOTE: the return datatype of the fillStruct() was Student datatype !

4.1.3. Default arguments

Default parameters are used to set default values t function inputs, e.g. if function has input called age, if the user didn't enter his age, the programmer may set 18 by default to handle the state when user didn't enter his age ;

Example: areaFunc

Write function to calculate square and circle area, the function will have 2 parameters inputs int length to specify Radius or side, the parameter to determine length is for radius or side and determine the law of area is string shape which could be "circle" or "square" and by default it will be circle.

Return datatype: float

Input parameters: int length, string shape

Function name: calc_area

```cpp
#include<iostream>
using namespace std;

float calc_area(int length, string shape = "circle");
int main(){
    double len, area=0;
    string choice;
    cout<<"do you want to calculate area of circle or square?" ;
    cin>>choice;
    cout<<"\nplease enter the length (side or radius) :";
    cin>>len;

    area = calc_area(len, choice);

}

float calc_area(int length, string shape){
    if(shape == "circle"){
        double pi = 3.14159265359;
        cout<<"\nthe area of circle is: "<<pi*length*length;
        return pi*length;
    }
    else if(shape == "square"){
        cout<<"\nthe area of square is: "<<length*length;
        return length*length;
    }
    else{
        cout<<"\nshape must be 'circle' or 'square'"<<endl;
        return 0;
    }}
```

NOTE: All default parameters should be at last (most right) in declaration

```cpp
float calc_area(int length, string shape = "circle");
NOT float calc_area(string shape = "circle",  int length); //error
```

4.2. Overloading and Inline Functions

4.2.1. Inline functions

Inline functions are optimization technique done by compiler to replace the call function by function code (i.e. instructions), this makes the code faster as it decrease function call overhead (e.g. passing parameters and return the output) see Figure 31 inline function vs normal function
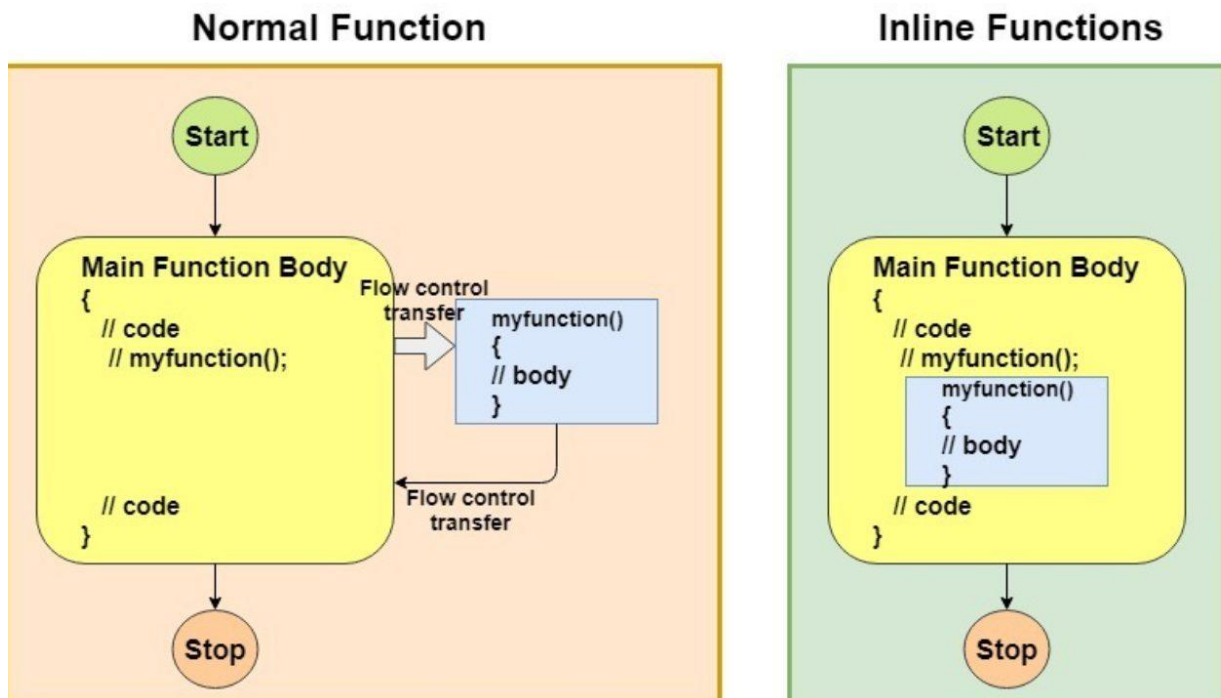
Figure 31 inline function vs normal function

NOTE: inline function done for small functions

NOTE: compiler determine whether let inline function act as inline or normal fuction unless you pass __attribute__((always_inline)) before inline

Example: inlineFunc

Make inline function to add 2 floats and return a float

> **Return datatype**: float

> **Input parameters**: float x , float y

> **Function name**: add

```cpp
#include<iostream>
using namespace std;
inline float add(float x, float y);
int main(){
    float product;
    float x,y;
    cout<<"enter the 2 operands :";
    cin>>x>>y;
    product = add(x,y);
    cout<<"the addition is: "<<product;

}

inline float add(float x, float y){
    return x + y;
}
```

NOTE: the compiler may decline the inline based on optimization level so add __attribute__((always_inline)) before inline

```cpp
#include<iostream>
using namespace std;
__attribute__((always_inline))inline float add(float x, float y);
int main(){
    float product;
    float x,y;
    cout<<"enter the 2 operands :";
    cin>>x>>y;
    product = add(x,y);
    cout<<"the addition is: "<<product;

}
__attribute__((always_inline))inline float add(float x, float y)
{

    return x + y;
}
```

4.2.2. Overloading
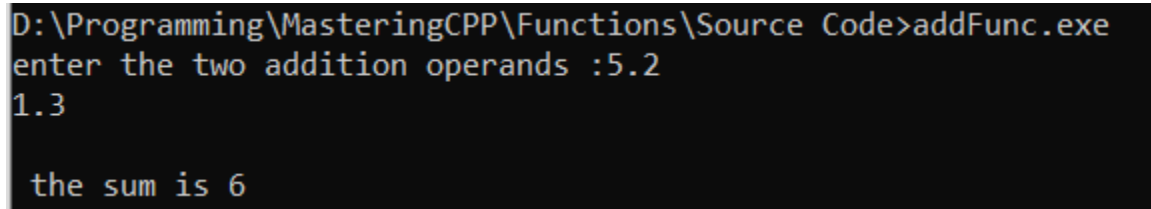
Overloading is done when 2 or more function having same name but different parameter list (i.e. different parameter: datatypes, order, or number)

Recall **Example** addFunc

```cpp
#include<iostream>
using namespace std;

long int add(int x, int y); //function Declaration
int main(){
    float a,b;
    long int sum = 0;
    cout<<"enter the two addition operands :";
    cin>>a>>b;
    sum = add(a,b);
    cout<<"\n the sum is "<<sum;
}
long int add(int x, int y){ //function Definition
    return x + y;
}
```

What happens if we entered a and b 5.2 and 1.3 (i.e. entering floats) but the function takes integer as in declaration ?! truncation will be happen as the compile waits for integer and user provide float, the compiler may truncate the decimal point and treat 5.2 as 5 and 1.3 as 1 so output is 6 !! see Figure 32 truncation input parameters

```
D:\Programming\MasteringCPP\Functions\Source Code>addFunc.exe
enter the two addition operands :5.2
1.3

the sum is 6
```

Figure 32 truncation input parameters

how to SOLVE?? Overloading came to help

Example: overloading
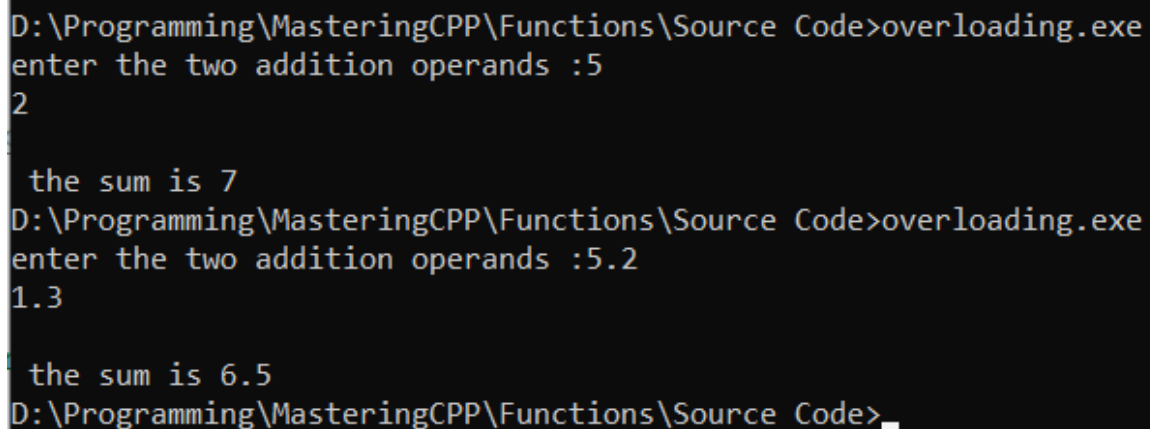
Use overloading to make add() in addFunc example handles both integers and floats

```cpp
#include<iostream>
using namespace std;

double add(int x, int y); //function Declaration
double add(float x, float y); //function Declaration

int main(){
    float a,b;
    double sum = 0;
    cout<<"enter the two addition operands :";
    cin>>a>>b;
    sum = add(a,b);
    cout<<"\n the sum is "<<sum;
}
double add(int x, int y){ //function Definition
    return x + y;
}
double add(float x, float y){ //function Declaration
    return x + y;
}
```

See! The function behave based upon the input, the function call function with float inputs when the input parameters are floats and call int function when inputs are int, overloading solved the problem

```
D:\Programming\MasteringCPP\Functions\Source Code>overloading.exe
enter the two addition operands :5
2

 the sum is 7
D:\Programming\MasteringCPP\Functions\Source Code>overloading.exe
enter the two addition operands :5.2
1.3

 the sum is 6.5
D:\Programming\MasteringCPP\Functions\Source Code>_
```

Figure 33 output of overloading example

VI NOTE: templates solve the problem better, later we will discuss it

4.3. Recursive Functions

Recursive functions are functions that call itself, this must contain what in the Figure 34 recursion composition
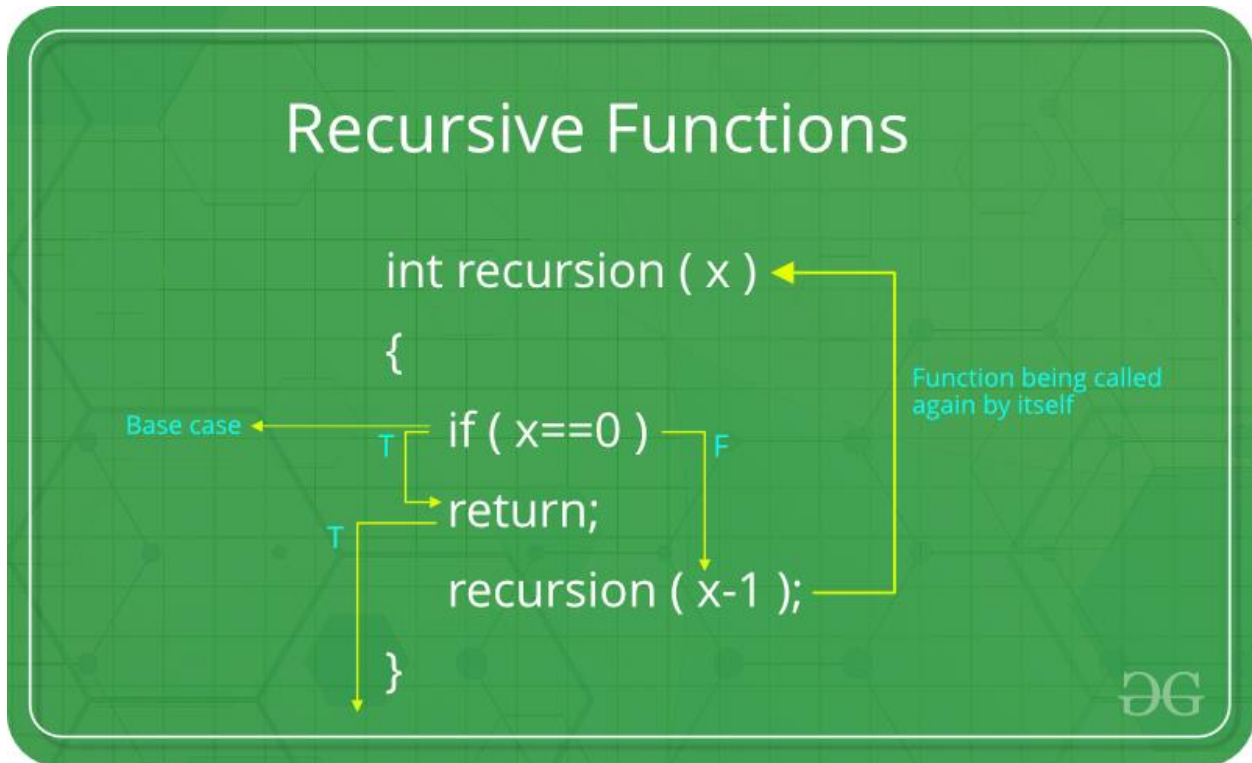
Figure 34 recursion composition

NOTE: The recursion must contains base case to stop the recursion

Example: factRecursion

Write recursive function to calculate factorial of a number

```cpp
#include<iostream>
using namespace std;

int fact(int num);

int main(){
    int n;
    cin>>n;
    cout<<"the answer is: "<<fact(n);
}

int fact(int num){
    //base case
    if(num==1)
     return 1;
    else{
        return num*fact(num-1);
    }
}
```

Example: powerRecursion

Write recursive function to calculate power of a base and power expression

```cpp
#include<iostream>
using namespace std;

int pwr(int base, int pow_num);

int main(){
    int base, power;
    cout<<"enter base and power resp. ";
    cin>>base>>power;
    cout<<"the answer is: "<<pwr(base,power);
}

int pwr(int base, int pow_num){
    //base case
    if(pow_num==0)
     return 1;
    else{
        return base*pwr(base,pow_num-1);
    }
}
```

4.4. Pass by value, reference and pointer

In functions, the input parameters could be passed by value or by reference or by pointer, let's see the differences.

4.4.1. Pass by value

Till now, all parameters passed in this book is passed by value which is a copy of the variable not the variable itself, so you can't modify the variable by passing by value, pass by value is useful when a variable is wanted but not to modify it,

Example: passByVal

Write function to add 2 integers and save the result in another value

Return datatype: int

Input parameters: int a , int b, int sum
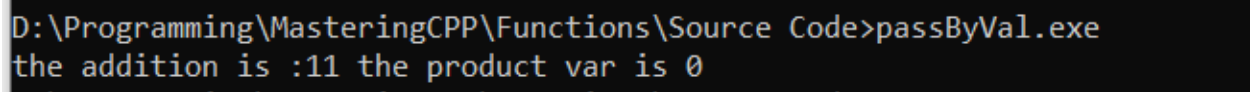
Function name: add

```cpp
#include<iostream>
using namespace std;

int add(int a, int b, int sum){
    sum = a+b;
    return sum;
}

int main(){
    int x=5 ,y=6, product=0;
    //pass by value       add(x,y, product);
    cout<<"the addition is :" <<add(x,y, product)<<" the product var
is "<<product;
}
```

See the output in Figure 35 pass by value output the product variable has not changes despite the fact we passed it and modify it, because we did not pass the product variable itself we passed an image (copy)


```
D:\Programming\MasteringCPP\Functions\Source Code>passByVal.exe
the addition is :11 the product var is 0
```

Figure 35 pass by value output

4.4.2. Pass by reference

If we want to modify the variable itself, we could do it by passing by reference, to do so, just add reference operator & before parameter name in function declaration **e.g.** int add(int a , int b, int &sum); and pass it by add(x, y, product) the product passed by reference and could be modified but x and y passed by value and could not be modified.

Example: passByRef

Modify example passByVal to make the product modified correctly.

```cpp
#include<iostream>
using namespace std;

int add(int a, int b, int &sum){
    sum = a+b;
    return sum;
}

int main(){
    int x=5 ,y=6, product=0;
    //pass by reference
    cout<<"the addition is :" <<add(x,y, product)<<" the product
var is "<<product;
}
```

NOTE: the only change was the reference operator & before sum in function declaration

NOTE: this function is declared and defined at one block not separated, you can separate the declaration and definition or combine them (same meaning), but some times we declare function in file and the definition in other file (will be discussed later in compilation process chapter)

4.4.1. Pass by pointer

passing by pointer is as same as pass by reference but in pass by reference we pass the variable itself but in pass by pointer we pass the address of that variable that also could modified after dereferencing it (i.e. using *)

the key feature of pass by value is that we could move the variable to different memory location as we pass the address, but remember, passing by pointer is ticky sometimes as pointers could be NULL (i.e. pointing to noting) this fault is programmer's fault when he forgot to assign the pointer to point to the variable before calling the function

Example: passByPointer

Write function to perform swap of two variable without using the third variable temp like in   Figure 36 swap by using third variable temp instead use the method in Figure 37 swap without using third variable temp
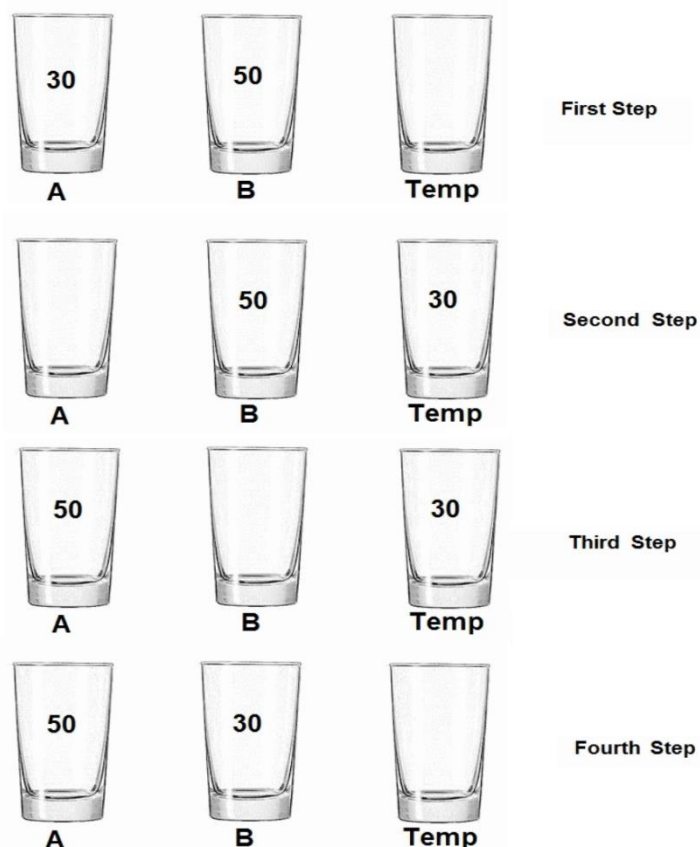
Figure 36 swap by using third variable temp
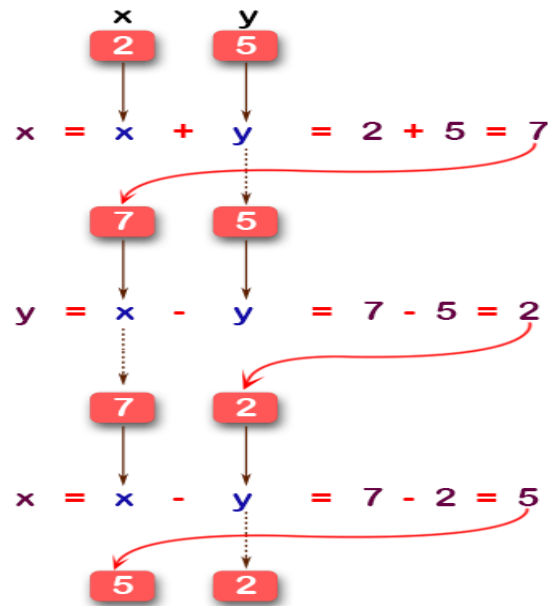
Figure 37 swap without using third variable temp

Return datatype: void //as we don't output we only want to swap

Input parameters: int a, int b

Function name: swapping

```cpp
#include<iostream>
using namespace std;

void swapping(int *a, int *b){
    *a = *a + *b;
    *b = *a - *b;
    *a = *a - *b;
}

int main(){
    int x=5 ,y=6;
    //pass by pointer
    cout<<"Before swapping:\nx is:" <<x<<"\ny is:"<<y<<endl;
    //swap
    swapping(&x,&y);
    /*dont forget in pass by pointer
    to add in reference operator in call*/
    cout<<"After swapping:\nx is:" <<x<<"\ny is:"<<y<<endl;
}
```
NOTE: don't forget in pass by pointer to add in reference operator in call

```cpp
swapping(&x,&y);
```

See Figure 38 pass by pointer example output

```
D:\Programming\MasteringCPP\Functions\Source Code>passByPointer.exe
Before swapping:
x is:5
y is:6
After swapping:
x is:6
y is:5
```

Figure 38 pass by pointer example output

4.5. Final Project

Write Linked List program as functions

The program has the following functions:

- ➢ Append element at last
- ➢ Insert element
- ➢ Delete element
- ➢ Print element

Code: linkedList

```cpp
#include <iostream>
using namespace std;

//creating linked list structure
struct Node{
    int DATA;
    Node *NEXT;
};
//function declarations
void Append(Node* &head,int data);
void Insert(Node* &head,int data, int index);
void Delete(Node* &head, int index);
void Print(Node* head);


int main() {
    //creating head
    Node* head=nullptr;
    Append(head, 15);
    Append(head, 42);
    Append(head, 70);
    Insert(head, 61, 2);
    Print(head);
    Delete(head, 2);
    Print(head);

    return 0;
}
```

```cpp
//function Definitions
void Append(Node* &head,int data){
    cout<<"Appending Node "<<data<<" \n";
    //create the node
    Node* newNode = new Node;
    newNode->DATA = data;
    newNode->NEXT = nullptr;
    //detect if there no node (only head)
    if(head == nullptr){
        head = newNode;
    }
    else{
        //get the last node
        Node* temp = head;
        while(temp->NEXT != nullptr){
            temp = temp->NEXT;
        }
        temp->NEXT = newNode;
    }
}


void Insert(Node* &head,int data, int index){
    cout<<"Inserting Node "<< data<<" at "<<index<<" \n";
    //move to node before index node
    Node* temp = head;
    for(int i=0;i<index-1;i++){
        temp = temp->NEXT;
    }
    //crete new node
    Node* newNode = new Node;
    newNode->DATA = data;
    newNode->NEXT = temp->NEXT; //make the new node to point to node
index+1

    temp->NEXT = newNode ;//name the node at index-1 points to new
node


}
```

```cpp
void Delete(Node* &head, int index){
    cout<<"Deleting Node at: "<<index<<endl;
    //move to node before index node
    Node* temp = head;
    for(int i=0;i<index-1;i++){
        temp = temp->NEXT;
    }
    //unlinking:
    //put the address saved in node(index-1) to be address of
node(index+1)
    Node* toDelete = temp->NEXT;
    temp->NEXT = (temp->NEXT)->NEXT;
    //to delete the node ar index
    delete toDelete;
}




void Print(Node* head){
    cout<<"Printing Nodes..\n";
    while(head != nullptr){
        cout<<"item: "<<head->DATA<<endl;
        head = head-> NEXT;
    }
}
```

NOTES:

In decelerations:

```cpp
//function declarations
void Append(Node* &head,int data);
void Insert(Node* &head,int data, int index);
void Delete(Node* &head, int index);
void Print(Node* head);
```

Node* &head: means pass by reference (for modifying the linked list) and the data type is pointer (Node*)

SO: Node* is the data type

   &head is passing by reference to be able to modify (add and delete nodes)

Entry point function main()

```cpp
int main() {
    // Creating head node
    Node* head = nullptr;

    // Append nodes to the list
    Append(head, 15);
    Append(head, 42);
    Append(head, 70);

    // Insert a node at position 2
    Insert(head, 61, 2);

    // Print the list
    Print(head);

    // Delete the node at position 2
    Delete(head, 2);

    // Print the list again
    Print(head);

    return 0;
}
```
NOTE: the head node init with nullptr so next have nothing

In Append() function:

```cpp
//function Definitions
void Append(Node* &head,int data){
    cout<<"Appending Node "<<data<<" \n";
    //create the node
    Node* newNode = new Node;
    newNode->DATA = data;
    newNode->NEXT = nullptr;
    //detect if there no node (only head)
    if(head == nullptr){
        head = newNode;
    }
    else{
        //get the last node
        Node* temp = head;
        while(temp->NEXT != nullptr){
            temp = temp->NEXT;
        }
        temp->NEXT = newNode;
    }
}
```

NOTE: head = newNode;

NOT head->next = newNode;

As head is the pointer to access the first node not a node itself

Get the code from the repository LINK or scan Qr code in Figure 39 linked List Qr code

Figure 39 linked List Qr code

Chapter 5 Preprocessor Directives

Preprocessor directive are keywords followed by hashtag #. Each keyword has functionality.

- **Macros**
    - #define, #undef
    - Function-like Macro
- **Conditional Compilation**
    - #ifdef, #ifndef, #if, #else, #elif, #endif
    - Conditional compilation directives
- **File Guards**

5.1. Macros

Macros is text replacement, that replace the name by it value e.g. #define num 5, whenever num is typed, it will be replaced by 5 while #undef delete the effect of #define (undo the #define)

5.1.1. #define and #undef

Example: define

Write code to print age and name without declaring any variables

```cpp
#include<iostream>

#define name "Ahmed"
#define age 19

int main(){
    std::cout<<"My name is "<<name<<" and I've "<<age<<"yrs old";
    return 0;
}
```

NOTE: preprocessor directives aren't compiled its only replacement, think about it like after you wrote the code:

```cpp
std::cout<<"My name is "<<name<<" and I've "<<age<<"yrs old";
```

and then name and age you came and replace them by their values

```cpp
std::cout<<"My name is "<<"Ahmed"<<" and I've "<<19<<"yrs old";
then the compiler change C++ code to binary
```

> ➤ **The first issue** of not being compiled is that if you are not careful enough, some unintended behavior may occur and you will never knew like:

```cpp
#include<iostream>
#define square(x) x*x
int main(){
    std::cout<<square(1+2);
    //the answers is 5  as it replaces square(1+2)
    //with x*x (but x = 1+2)
    //so after replacement
    // 1+2*1+2 which is 5
    //but the intended value is 3*3 which is 9
    return 0;
}
```

the answers is 5 as it replaces square(1+2) with x*x (but x = 1+2)
so after replacement 1+2*1+2 which is 5

but the intended value is 3*3 which is 9

Blind text replacement !!

> ➤ **The second issue** is that there is no type check

if you define a macro that performs an operation on a variable, the preprocessor won't check if the variable type is appropriate for the operation.

5.1.2. Function-like macro

Object-like macro Is like what we did #define name "Ahmed", function-like macro is a pseudo function e.g. #define square(x) x*x, i.e.

multi-line marco is by its name function macro but with multiple lines, to do so, put \ at end of each line except the last macro line

Example: macroFunction

Write function-like macro with multi-lines macro, that print data of student who has name, age and id.

```cpp
#include<iostream>
using namespace std;
#define print(name, age, id) cout<<"my name is "<< name<<endl; \
                             cout<<"I've "<< age<<" yrs old "<<endl; \
                             cout<<"my ID is "<< id;
int main(){
    print("Ahmed", 19, 202014)
    return 0;
}
```

NOTE: the semicolon ; is not written in   `print("Ahmed", 19, 202014)`
As the last macro line have semicolon `cout<<"my ID is "<< id;`
You could put semicolon in print call but remove last line semicolon like:

```cpp
#include<iostream>
using namespace std;
#define print(name, age, id) cout<<"my name is "<< name<<endl; \
                             cout<<"I've "<< age<<" yrs old "<<endl; \
                             cout<<"my ID is "<< id
int main(){
    print("Ahmed", 19, 202014);
    return 0;
}
```

Some developers what to write real multi line function like macro like simple macro, as

```
print(name, age, id) cout<<"my name is "<< name<<endl; \
                           cout<<"I've "<< age<<" yrs old "<<endl; \
                           cout<<"my ID is "<< id;
```

lacks the {} to hold function body (in this case the 3 cout lines).

the modification:

```
print(name, age, id) {cout<<"my name is "<< name<<endl; \
                           cout<<"I've "<< age<<" yrs old "<<endl; \
                           cout<<"my ID is "<< id;}
```

Example: multiLineMacro

```
#include<iostream>
using namespace std;
#define valid true
#define print(name, age, id) {cout<<"my name is "<< name<<endl; \
                           cout<<"I've "<< age<<" yrs old "<<endl; \
                           cout<<"my ID is "<< id;\
                          }
int main(){
    if(valid)
            print("Ahmed", 19, 202014);
    else
        cout<<"not valid";

    return 0;
}
```

*This will throw and **error** as expansion will be:*

```
int main(){
    if(valid)
       {cout<<"my name is "<< "Ahmed"<<endl; \
       cout<<"I've "<< 19<<" yrs old "<<endl; \
       cout<<"my ID is "<< 202014;\
                        };

    else
        cout<<"not valid";

    return 0;
}
```

So in this case you are forced to remove semicolon from the call

```
            print("Ahmed", 19, 202014)
but it not what C++ developer used to do, so another approach is do-while
multi lines
```

remember: do while statement is as follows:

do{statements}

while(condition);

so after while a semicolon should be add, we could use this fact to put semicolon at calls

```cpp
#include<iostream>
using namespace std;
#define valid true
#define print(name, age, id) do{cout<<"my name is "<< name<<endl; \
                                 cout<<"I've "<< age<<" yrs old "<<endl; \
                                 cout<<"my ID is "<< id;\
                                 }while(0)
int main(){
    if(valid)
            print("Ahmed", 19, 202014);
    else
        cout<<"not valid";

    return 0;
}
```

The expansion will be:

```cpp
int main(){
    if(valid)
            do{cout<<"my name is "<< name<<endl; \
                                 cout<<"I've "<< age<<" yrs old "<<endl; \
                                 cout<<"my ID is "<< id;\
                                 }while(0);
    else
        cout<<"not valid";

    return 0;
}
```
Works well !!

5.2. Conditional Compilation

#if, #else, #elif, #endif

These macros used to do conditionals (i.e if and elif and else) before runtime, as preprocessor directives are text replacement and is done in compilation not run time, this will speed the code as many code lines are determined before the run time

NOTE: you must add #endif at end of contidions

Example: conditionalCompilation

Write C++ code that determines the area of shape , don't use if and else if and else, instead use #if #elif #else

```cpp
#include<iostream>
using namespace std;

// you have to options:
// 0 for circle
// 1 for square
#define circle 0
#define square 1

#define shape square

int main(){
    #if shape == circle
        float pi = 3.14,raduis=0;
        cout<<"enter the radius ";
        cin>>raduis;
        cout<<"\nArea of cricle is "<<pi*raduis*raduis;
    #elif shape == square
        float len=0;
        cout<<"enter the length ";
        cin>>len;
        cout<<"\nArea of square is "<<len*len;
    #endif
    return 0;
}
```

NOTE: compilation conditionals don't perform string comparison like:

```cpp
#include<iostream>
using namespace std;

// you have to options: circle square
#define shape "circle"

int main(){
    #if shape == "circle"
        float pi = 3.14,r=0;
        cout<<"enter the radius ";
        cin>>raduis;
        cout<<"\nArea of "<<shape<<" is "<<pi*r*r;
    #elif shape == "square"
        float len=0;
        cout<<"enter the length ";
        cin>>len;
        cout<<"\nArea of "<<shape<<" is "<<len*len;
    #endif
    return 0;
}
```

This is an <u>error</u> !

```cpp
    #if shape == "circle"
    #elif shape == "square"
```

Are wrong !

5.3. File guards

In C/C++ .cpp files are source files that contains code implementation while another type of file has suffix of .h files which are header file that contains variable and functions declarations, the header file is included in the .cpp file by #include"filename.h", remember #include<> is used for bultin function like iostream and stdio.h while user header files are included by " " not <> see

Example: headers

Write application that has .cpp file contains the implementation of printing student data (name, age, id) and 2 headers, first header contains the student struct and other contains the student data to be filled in the struct

- The first file headers.cpp is the source file

```cpp
#include <iostream>
#include "headers1.h"
#include "headers2.h"
using namespace std;

void fillStruct(Student &stud){
    stud.name = studentName;
    stud.age = studentAge;
    stud.id = studentId;
}
int main(){
    Student Ahmed;
    fillStruct(Ahmed);
    cout<<"Student "<<Ahmed.name<<" has "<<Ahmed.age<<" yrs old.\nID: "<<Ahmed.id;
}
```

- The first header headers1.h

```cpp
#include<string>

struct Student{
    std::string name;
    int age;
    int id;
};

void fillStruct(Student &stud);
```

- The second header headers2.h

```
#define  studentName "Ahmed"
#define studentAge 15
#define studentId 202015
```

The source file headers.cpp will replace each file by its contents, like this:

➢ Headers.cpp before replacing headers1.h and headers2.h

```
#include <iostream>
#include "headers1.h"
#include "headers2.h"
using namespace std;

void fillStruct(Student &stud){
    stud.name = studentName;
    stud.age = studentAge;
    stud.id = studentId;
}
int main(){
    Student Ahmed;
    fillStruct(Ahmed);
    cout<<"Student "<<Ahmed.name<<" has "<<Ahmed.age<<" yrs old.\nID:
"<<Ahmed.id;
}
```

➢ Headers.cpp After replacing headers1.h and headers2.h

```
#include <iostream>
#include<string>

struct Student{
    std::string name;
    int age;
    int id;
};

void fillStruct(Student &stud);

#define  studentName "Ahmed"
#define studentAge 15
#define studentId 202015

void fillStruct(Student &stud){
    stud.name = studentName;
    stud.age = studentAge;
    stud.id = studentId;
}
```

```cpp
int main(){
    Student Ahmed;
    fillStruct(Ahmed);
    cout<<"Student "<<Ahmed.name<<" has "<<Ahmed.age<<" yrs
old.\nID: "<<Ahmed.id;
}
```

See the output Figure 40 headers example output

```
D:\Programming\MasteringCPP\Preprocessor Directives\Source Code>g++ -std=c++11 headers.cpp -o headers.exe

D:\Programming\MasteringCPP\Preprocessor Directives\Source Code> headers.exe
Student Ahmed has 15 yrs old.
ID: 202015
```

Figure 40 headers example output

But there is one problem, what if we include a header.h multiple times?? the .cpp files include the same header

The compiler will throw redefinition error see Figure 41 redefinition error

```
D:\Programming\MasteringCPP\Preprocessor Directives\Source Code>g++ -std=c++11 headers.cpp -o headers.exe
In file included from headers.cpp:3:
headers2.h:5:8: error: redefinition of 'struct Student'
    5 | struct Student{
      |        ^~~~~~~
In file included from headers.cpp:2:
headers1.h:3:8: note: previous definition of 'struct Student'
    3 | struct Student{
      |        ^~~~~~~
```

Figure 41 redefinition error

Because struct is defined twice so we could use file guard to protect against redefinition error, the file guard method is done by typing:

 at start the header file:

```cpp
#ifndef anyHeaderName
#define anyHeaderName
```

At and the header file:

```cpp
#endif
```

So Coding the headers example again:

➢ The headers.cpp remain as its

➢ The headers1.h will be:

```cpp
#ifndef HEADERS1
#define HEADERS1

#include<string>

struct Student{
    std::string name;
    int age;
    int id;
};

void fillStruct(Student &stud);

#endif
```

➢ The headers2.h will be:

```cpp
#ifndef HEADERS2
#define HEADERS2

#define  studentName "Ahmed"
#define studentAge 15
#define studentId 202015

#endif
```

Even in headers.cpp if one header .h included multiple times, no redefinition error

Chapter 6 Compilation Process

Programing languages have ways to make sure that code is valid and convert the programming lines of code into format that computer machines understand, the two ways are compilation and interpretation

- **Compilation** is changing C/C++ files (.c files ot .cpp files) into executable format that computers or microcontrollers understand (e.g. .exe for computers run windows or .hex for microcontroller), after conversion into binaries (i.e. .exe or .hex) the target machine can run the code
- **Interpretation** converting lines of code like python lines into something targes understand on runtime, the interpreter interprets line by line on runtime

- ➢ Preprocessing
- ➢ Compilation
- ➢ Assembly
- ➢ Linking
- ➢ Compiling many source files

C and C++ are compiled languages, the compilation process is as follows in Figure 42 Compilation process,

 ➢ the source code is the .cpp file that contains C++ code, it then gets in the process of removing preprocessor directives (e.g. #define #if etc.)
 ➢ then the compiler converts the output into assembly code.
 ➢ then the assembler converts the assembly code into machine code.
 ➢ typically, there will be many source files each will be converted into machine code (object code), the linker will combine all object files into only one executable .

6.1. Compilation process

```
┌─────────────────────────┐
│      Source File        │
└─────────────────────────┘
              ↓
┌─────────────────────────┐
│     Preprocessor        │
└─────────────────────────┘
              ↓  Preprocessed File (.i file)
┌─────────────────────────┐
│       Compiler          │
└─────────────────────────┘
              ↓  Assembly code (.s file)
┌─────────────────────────┐
│      Assembler          │
└─────────────────────────┘
              ↓  Object code (.o file)
┌─────────────────────────┐
│        Linker           │
└─────────────────────────┘
              ↓  Executable
```
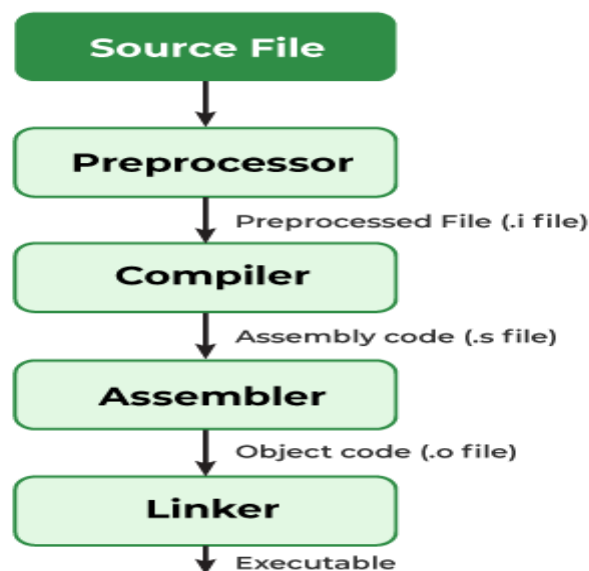
Figure 42 Compilation process

In the following, examples we will demonstrate the process:

Example: main

Write C++ code that have preprocessor directives and print name of user named Ahmed

```cpp
#include<iostream>
#define username "Ahmed"

int main(){
    std::cout<<"username is "<<username;
    return 0;
}
```

Here is the source code main.cpp

6.1.1. Preprocessor directive

Example: preprocessor

Convert main.cpp into preprocessor directive free using command

 g++ -std=c++11 -E main.cpp -o preprocessor.i

The output which is preprocessor directives free in this small example is 30088 lines, and what last few lines will be:

```
# 4 "main.cpp"
int main(){
    std::cout<<"My name is "<<"Ahmed"<<" and I've "<<19<<"yrs old";
    return 0;
}
```

Lets explain:

```
#include<iostream>
#define username "Ahmed"

int main(){
    std::cout<<"username is "<<username;
    return 0;
}
```

The source file, have preprocessor directive #include, so this line will be replaced by built in file of iostream which is around 30080 lines

Then the next line there is another preprocessor directive #define so every line has username keword, will be replacement with the value of username which is "Ahemd", thas why the line:

```
    std::cout<<"username is "<<username;
```
changed into:
```
    std::cout<<"My name is "<<"Ahmed"<<" and I've "<<19<<"yrs old";
```
in preprocceor deirecives free output after command: g++ -std=c++11 -E main.cpp -o preprocessor.i

6.1.2. Compiler

The compiler will receive the preprocessor directive free output (preprocessor.i)a nd convert it into assembly code named assembly.S

Example: compiler

Convert preprocessor.i into assembly code using command

g++ -std=c++11 -S preprocessor.i -o assembly.s

```
    .file   "main.cpp"
    .text
    .section .rdata,"dr"
_ZStL19piecewise_construct:
    .space 1
.LC0:
    .ascii "My name is \0"
.LC1:
    .ascii "Ahmed\0"
.LC2:
    .ascii " and I've \0"
.LC3:
    .ascii "yrs old\0"
    .text
    .globl  main
    .def    main;   .scl    2;  .type   32; .endef
    .seh_proc   main
main:
.LFB1808:
    pushq   %rbp
    .seh_pushreg    %rbp
    movq    %rsp, %rbp
    .seh_setframe   %rbp, 0
    subq    $32, %rsp
    .seh_stackalloc 32
    .seh_endprologue
    call    __main
    leaq    .LC0(%rip), %rax
    movq    %rax, %rdx
    movq    .refptr._ZSt4cout(%rip), %rax
    movq    %rax, %rcx
    call    _ZStlsISt11char_traitsIcEERSt13basic_ostreamIcT_ES5_PKc
    movq    %rax, %rcx
    leaq    .LC1(%rip), %rax
    movq    %rax, %rdx
    call    _ZStlsISt11char_traitsIcEERSt13basic_ostreamIcT_ES5_PKc
    movq    %rax, %rcx
    leaq    .LC2(%rip), %rax
    movq    %rax, %rdx
    call    _ZStlsISt11char_traitsIcEERSt13basic_ostreamIcT_ES5_PKc
```

```
    movl     $19, %edx
    movq     %rax, %rcx
    call     _ZNSolsEi
    movq     %rax, %rcx
    leaq     .LC3(%rip), %rax
    movq     %rax, %rdx
    call     _ZStlsISt11char_traitsIcEERSt13basic_ostreamIcT_ES5_PKc
    movl     $0, %eax
    addq     $32, %rsp
    popq     %rbp
    ret
    .seh_endproc
    .def     __main; .scl    2;  .type    32; .endef
    .ident   "GCC: (MinGW-W64 x86_64-ucrt-posix-seh, built by Brecht
Sanders, r1) 14.1.0"
    .def     _ZStlsISt11char_traitsIcEERSt13basic_ostreamIcT_ES5_PKc;
.scl    2; .type    32; .endef
    .def     _ZNSolsEi; .scl    2;  .type    32; .endef
    .section     .rdata$.refptr._ZSt4cout, "dr"
    .globl   .refptr._ZSt4cout
    .linkonce    discard
.refptr._ZSt4cout:
    .quad    _ZSt4cout
```

the output will be this, the mov and add and call are the assembly code related to my machine that output this which is intel x86 architecture.

NOTE: the compilation oupout (assembly code) will be different with every target, if you run this on ARM or MIPS for example, the output will be different as the instruction set architecture is different from target to another

NOTE: instruction set architecture(ISA) is the interface between hardware (the real register of the target) and the software that user writes, so the commands like in intel x86 mov add call will be changed into machine code and the ISA inside the processor will interpret this software command and perform it by using the hardware like the registers inside the target.

6.1.3. Assembler

The Assembler will receive the assembly code (assembly.s)a and convert it into object file (hex decimal code)

Example: objectFile

Convert main.cpp into assembly code using command

 g++ -std=c++11 -S assembly.s -o object.o

to open the output object file, you require a hex viewer, you can download free hex viewer neo from this LINK
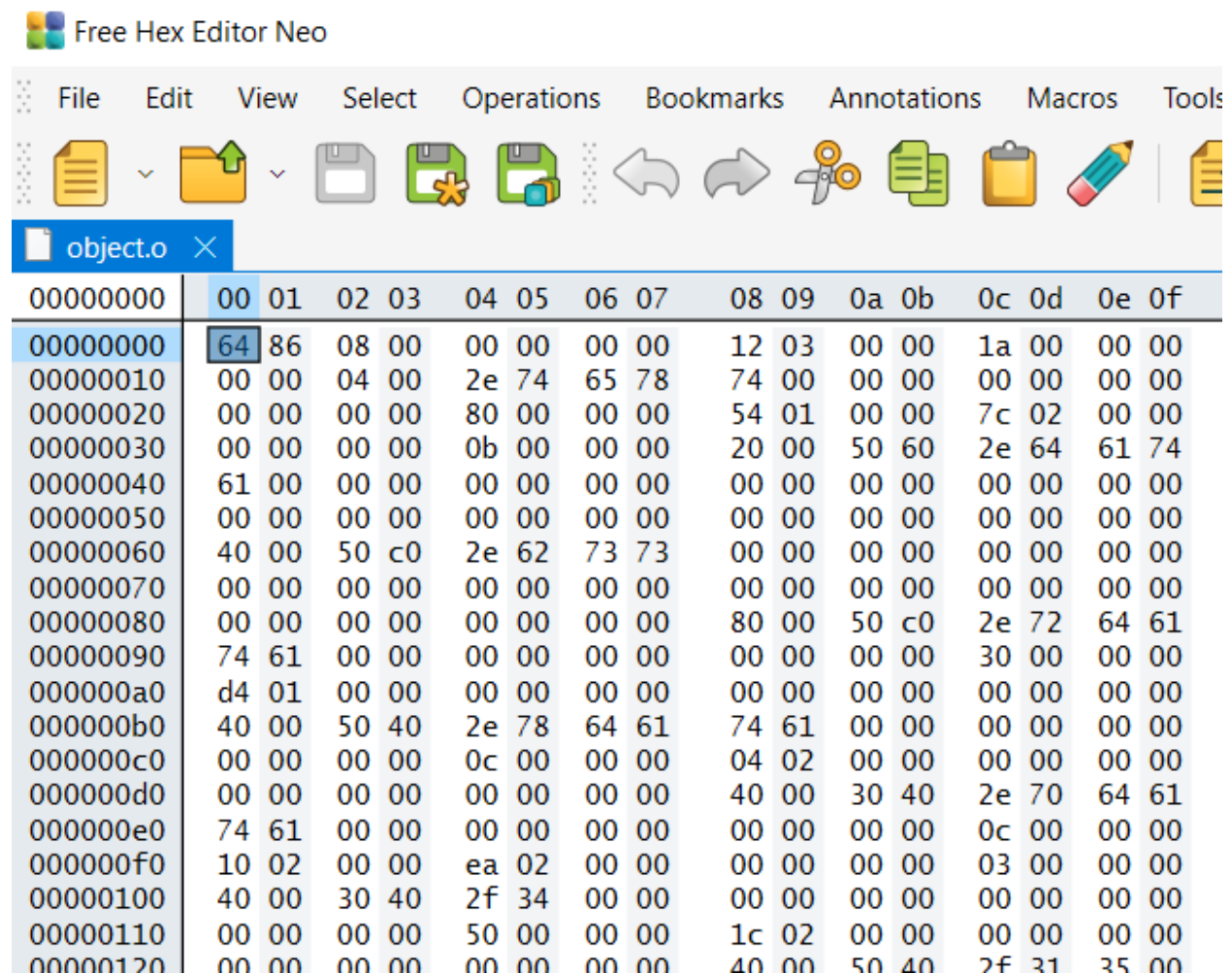
In the following: Figure 43 Object file

Figure 43 Object file

The output is the hex decimal (bineries that the target (intel x86 computer) understands)

6.1.4. Linker

The linker links all the object files into one executable, this is used by this command: g++ -std=c++11 object.o -o main.exe

In this book till now we used to use one command that do all what we have done in this chapter which is

g++ -std=c++11 main.cpp -o main.exe

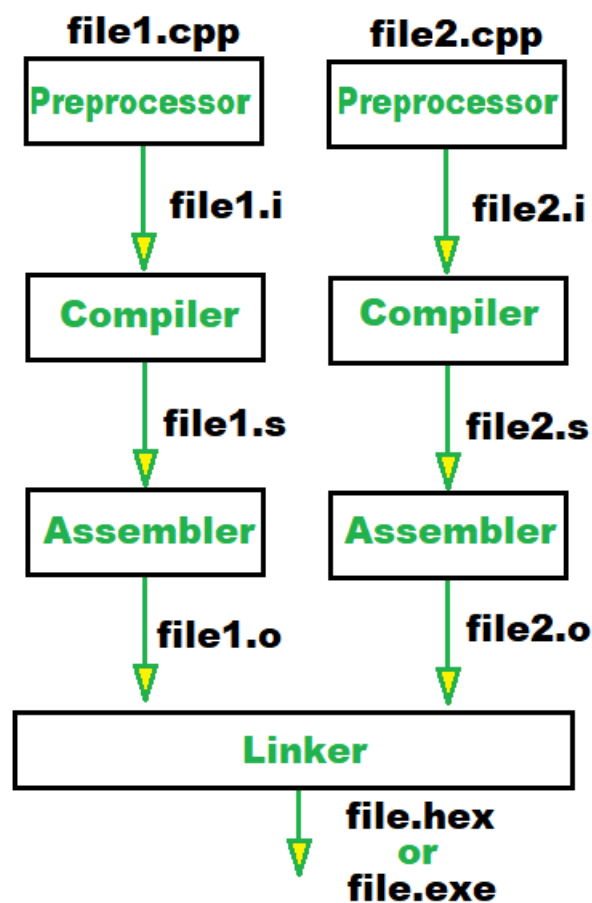see the summary in Figure 44 Compiling multiple source files

Figure 44 Compiling multiple source files

6.2. Compile multiple files

All Examples in this book so far have only one .cpp file, what if we have multiple cpp files like in Figure 44 Compiling multiple source files? We can convert each .cpp file into object file then all object files into one executable file OR convert all .cpp files into one executable file by only one command

6.2.1. Convert each file into object files then link

Compile each source file:

```
g++ -c file1.cpp -o file1.o
g++ -c file2.cpp -o file2.o
g++ -c file3.cpp -o file3.o
```

Link all source files:

```
g++ file1.o file2.o file3.o -o myExecutable
```

6.2.2. Convert all .cpp files into one executable file

This is the easy way, compile all source files into one executable

```
g++ file1.cpp file2.cpp file3.cpp -o myExecutable
```

NOTE: don't put any .h files, put only source files (i.e. .cpp files)

Example: MultpileCompilations

Write main.cpp files to setUser() and printUser, these functions is declared one in file1.h and the other in file2.h while file1.cpp and file2.cpp have the implementation of these function, the User is a struct that has name and id

NOTE: use file guards !!

file1.h:

```cpp
#ifndef FILE1
#define FILE1

#include "file2.h"
void printUser(USER &user);
#endif
```

file1.cpp:

```cpp
#include"file1.h"
void printUser(USER &user){
    std::cout<<"Username "<<user.name<<" ID "<<user.id<<std::endl;
}
```

file2.h:

```cpp
#ifndef FILE2
#define FILE2

#include<iostream>

struct USER{
    std::string name;
    int id;
};

void setUser(USER &user);

#endif
```

file2.cpp:

```cpp
#include"file2.h"
void setUser(USER &user){
    std::cout<<"enter username and id: ";
    std::cin>>user.name>>user.id;
}
```
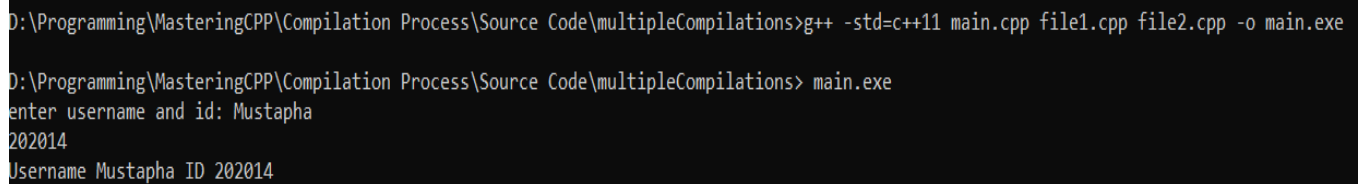
main.cpp:

```cpp
#include"file2.h"
#include"file1.h"

int main(){
    USER Ahmed;
    setUser(Ahmed);
    printUser(Ahmed);
}
```

Compilation:

g++ -std=c++11 main.cpp file1.cpp file2.cpp -o main.exe

See the output in Figure 45 multiple file compilation and output:

```
D:\Programming\MasteringCPP\Compilation Process\Source Code\multipleCompilations>g++ -std=c++11 main.cpp file1.cpp file2.cpp -o main.exe

D:\Programming\MasteringCPP\Compilation Process\Source Code\multipleCompilations> main.exe
enter username and id: Mustapha
202014
Username Mustapha ID 202014
```

Figure 45 multiple file compilation and output

Chapter 7 Object oriented programming OOP

In this chapter, object-oriented programming will be introduced, a tic tac toe game will be the final project, after starting from creating empty class then stacking and implementing OOP concepts concept by concept <u>using animal class examples</u>.

PLEASE: read the whole chapter one time fast, before starting studying thoroughly

NOTE: OOP has main four items to know despite the programming language you use

- **Inheritance** (make child class from parent class)
- **Encapsulation** (hide data for safety)
- **Polymorphism** (make multiple (poly) use for one function depending which child class use this function)
- **Abstraction** (abstract user from studying the code and let him build on your code easily)

Topics:

- **Classes and Objects**
    - o Class definition and declaration
    - o Access specifiers: public, private, protected
    - o Member variables and member functions
    - o Object instantiation
- **Constructors and Destructors**
    - o Default constructor
    - o Parameterized constructor
    - o Copy constructor
    - o Destructor
- **Inheritance**
    - o Base and derived classes
    - o Types of inheritance: single, multiple, multilevel, hierarchical, hybrid
    - o Constructor and destructor calls in inheritance
- **Polymorphism**
    - o Compile-time polymorphism: function overloading, operator overloading
    - o Runtime polymorphism: virtual functions, pure virtual functions, abstract classes

- **Encapsulation**
  - Data hiding
  - Setter and Getter (Accessor and mutator functions)
- **Abstraction**
  - Abstract classes and interfaces
  - Virtual function and pure virtual function
- **Operator Overloading**
  - Overloading unary and binary operators
  - Overloading operators using member and friend functions
- **Static Members**
  - Static member variables and functions
  - Class-level data and behavior
- **Multiple Inheritance**
  - Diamond problem and virtual inheritance
- **Rules**
  - Rule of Three

7.1. Classes and Objects

Classes are as same as structs, the only difference between them are the access modifiers defaults , when you make a class, its members are private by default and in structs are public by defaults. Like:

Example: structVsClass1

```cpp
#include<iostream>
using namespace std;

struct StudentStruct{
    int gpa;
};

class StudentClass{
    int gpa;
};
int main(){
    StudentClass Mohamed;
    StudentStruct Ahmed;
    //Ahmed is struct instance so gpa is public
    //(could be accesed and modified)
    Ahmed.gpa = 3.45;
    //Mohamed is class instance so gpa is private
    //couldn't be accesed and modified)
    // Mohamed.gpa = 3.58; //error
    return 0;
}
```

Also in inheritance the default child modifier is private for classes and public for structs

Example: structVsClass2

```cpp
#include<iostream>
using namespace std;
struct AnimalStruct{
    //parent struct
    int age;
};

struct TigerStruct: AnimalStruct{
    //child struct
    int speed;
};

class AnimalClass{
    //parent class
    int age;
};
class TigerClass:  AnimalClass{
    //child struct
    int speed;
};
int main(){
    TigerClass tiger;
    TigerStruct tigress;

    //tigress inherits age as public
    tigress.age = 15;

    //tiger error its private inheritance
    //so age becomes private for the child
    tiger.age = 15;

    return 0;
}
```

In TigerStruct child the default is public inheritance i.e.

```cpp
 struct TigerStruct: public AnimalStruct{
    //child struct
    int speed;
};
```

While in TigerClass child the default is private inheritance i.e.

```cpp
 struct TigerStruct: private AnimalStruct{
    //child struct
    int speed;
};
```

Anyway, if you specify the access modifiers like:

```
struct TigerStruct: public AnimalStruct{
    //child struct
    int speed;
};
struct TigerStruct: protected AnimalStruct{
    //child struct
    int speed;
};
struct TigerStruct: private AnimalStruct{
    //child struct
    int speed;
};
```

Recall Access modifier from Basics in Figure 46 Access modifiers in inheritance

Member Type	Public Inheritance	Protected Inheritance	Private Inheritance
Public Members	Remain public	Become protected	Become private
Protected Members	Remain protected	Remain protected	Become private
Private Members	Inaccessible	Inaccessible	Inaccessible

Figure 46 Access modifiers in inheritance

It seems there is no big difference but mostly all OOP topics either in book or courses, will use classes so we will stick to convention !

7.1.1. Class definition and declaration

As we introduced, the classes like struct in everything like definition and declaration but different in default access modifiers, just replace struct keyword by class keyword

Example: animalClass

Write class for animal that has sound and have name and age and length

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;
    //function member
    void sound(string sound){
        cout<<name<<"have "<<sound<<" sound\n";
    }
};

int main(){
    return 0;
}
```

7.1.2. Access specifiers: public, private, protected

As we mentioned earlier access modifiers determine how to access class/struct members (i.e. function (method) and attributes)

public: is to access or modify members anywhere

private: is accessed inside the class/struct only, even child class could modify or access these members

protected: like private but also child class could access or modify these members

	public members	private members	protected members
Accessed inside class ?	YES	YES	YES
Accessed inside child classes ?	YES	NO	YES

7.1.3. Member variables and member functions

Members are variables (attributes) or functions (method), objects in real life have attributes (e.g. name, length, age etc..) and have something done by them (e.g. playing, eating, make sounds etc..) or something happen to them (being eaten, dies, grow etc…) so in object oriented programming we have:

- **Variables** : to mimic object attributes
- **Functions** (methods): to mimic object function or what object can do or how the object is changes.

in animal example, name, age, length are class variable (class attributes) while sound(string sound) is class function (class method)

7.1.4. Object instantiation

To use the objects, we made we have to instantiate (i.e. make instance), like we have mentioned, classes are like structs, so same instantiation but replace struct by class keyword

Example: animalInstantiation

Instantiate tiger as instance or animal class that we made previously

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
};

int main(){
    Animal tiger;
    tiger.name = "tiger";
    tiger.sound("roar");
    return 0;
}
```

The output: tiger have roar sound

7.2. Constructors and Destructors

Constructors are function that got called when an instance is made while a destructor are called when objects go out of scope or when cleaned (i.e. deleted)

7.2.1. Default constructor

Constructor that have no parameters at all

Example: defaultConstructor

Make a default constructior to set name of the animal class we made

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;

    //default constructor
    Animal(){
        cout<<"constructor called, enter animal name: \n";
        cin>>name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
};

int main(){
    Animal tiger;
    tiger.sound("roar");
    return 0;
}
```
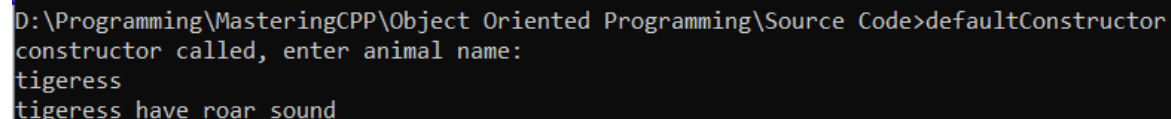
The output should be as : Figure 47 default constructor example output

```
D:\Programming\MasteringCPP\Object Oriented Programming\Source Code>defaultConstructor
constructor called, enter animal name:
tigeress
tigeress have roar sound
```

Figure 47 default constructor example output

7.2.2. Parameterized constructor

Parameterized constructor is like default constructor but have parameters

Example: parameterizedConstructor

Modify *defalutConstructor* example to make it more easier by using Parameterized constructor

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;

    //Parameterized constructor
    Animal(string s): name(s){
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
};

int main(){
    Animal tiger("tigress");
    tiger.sound("roar");
    return 0;
}
```

output: tigress have roar sound

NOTE: you can initialize all attributes not only name like:

```cpp
    //Parameterized constructor
    Animal(string s, int a, float l): name(s), age(a), length(l){
    }
```

7.2.3. Copy constructor

Copy constructor is made when an instance is set by another existing instance, this is a parameterized constructor, and the input type must be as same as its class type, copy constructors are made to prevent compiler to make the default copy, as the default copy is shallow copy.

Shallow is copying the old object data to the new made instance, the problem comes when the class have dynamically allocated data which in this case, one of the class attributes is a pointer to point to this allocated data, when shallow copy happens, the pointer of new object will be the old one so the old and new object have the same pointer !! which means no new object hasn't allocated memory for itself see Figure 48 shallow vs deep copy
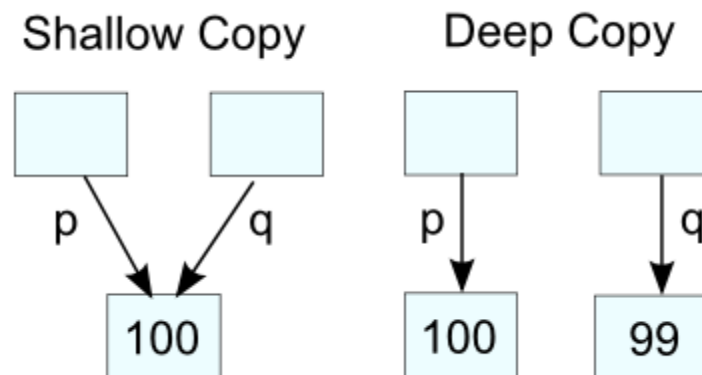

Figure 48 shallow vs deep copy

Example: copyConstructor

Make a copy constrctor to set tiger to be as same as tigress instance.

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;

    //Parameterized constructor
    Animal(string s): name(s){
    }

    //copy constructor
    Animal(const Animal& oldObject){
        name = oldObject.name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
};

int main(){
    Animal tiger("tigress");
    Animal newtiger = tiger;
    newtiger.sound("roar");
    return 0;
}
```
The output should be as same as last example

NOTE: don't forget to in constructor to use const to prevent the old object to be modified unintentionally and take the old object by reference.

```cpp
i.e.    Animal(const Animal& oldObject){}
```

7.2.4. Destructor

Destructor are called when the class gets out of the scope or deleted

Example: destructor

Make a destructor for animal class

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;

    //Parameterized constructor
    Animal(string s): name(s){
    }

    //copy constructor
    Animal(const Animal& oldObject){
        name = oldObject.name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;
    }
};

int main(){
    Animal tiger("tigress");
    tiger.sound("roar");
    return 0;
}
```

Output:

tigress have roar sound

destructor is called for instance: tigress

7.3. Inheritance

Inheritance comes when a child's class (i.e. derived class) takes attributes and methods of parent class

7.3.1. Base and derived classes

Base class is the parent class that a child class (derived class) will take its attributes and methods.

Example: inheritance

Drive tiger and lion child classes from animal class we made previously

```cpp
#include<iostream>
using namespace std;
class Animal{
    public:
    string name;
    int age;
    float length;

    //default constructor
    Animal(){
        cout<<"enter animal name ";
        cin>>name;
    }

    //copy constructor
    Animal(const Animal& oldObject){
        name = oldObject.name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;
    }
};
class Tiger: Animal{
};
class Lion: public Animal{
};
int main(){
    Tiger teg;
    Lion leo;
    leo.sound("growls");
    teg.sound("roar");
return 0;}
```

see the output in

```
D:\Programming\MasteringCPP\Object Oriented Programming\Source Code>g++ -std=c++11 inheritance.cpp -o inheritance
inheritance.cpp: In function 'int main()':
inheritance.cpp:40:14: error: 'void Animal::sound(std::string)' is inaccessible within this context
   40 |     teg.sound("roar");
      |             ~~~~~~~~~~^~~~~~~~~~
inheritance.cpp:21:10: note: declared here
   21 |     void sound(string sound){
      |          ^~~~~
inheritance.cpp:40:14: error: 'Animal' is not an accessible base of 'Tiger'
   40 |     teg.sound("roar");
      |             ~~~~~~~~~~^~~~~~~~~~
```

Figure 49 default private inheritance

The problem is that teg (i.e. Tiger instance)   is inherited private (by default), so public members are changes to private, so they are only accessed in Tiger class, so to remove the error we either comment the private member .sound() in main function   `teg.sound("roar");`
Or to make the Tiger class inherit from Animal class as public like Lion class

```cpp
class Tiger: public Animal{};
```

NOTE: Always remember, the class inheritance is private by default while the struct is public by default

7.3.2. Types of inheritance

Single inheritance: when a child class inherit from <u>one</u> base (parent) class

Multiple inheritance: when a <u>one</u> child class inherit from <u>many</u> base (parent) class

Hierarchical inheritance: when <u>many</u> child classes inherit from <u>one</u> base (parent) class

Multi-level inheritance: : when a grandchild class inherit child class which inherited from <u>one </u>base (parent) class

Hybrid inheritance: : when multiple types are involved

See Figure 50 inheritance types

Inheritance in C++

Base Class

Derived Class

ig. Single level inheritance

Base Class

Derived Class

Fig. Multiple Inheritance

Fig. Hybrid Inheritance

Base Class

Derived Class A

Derived Class B

Fig. Multi level inheritance

Base Class

Derived Classes
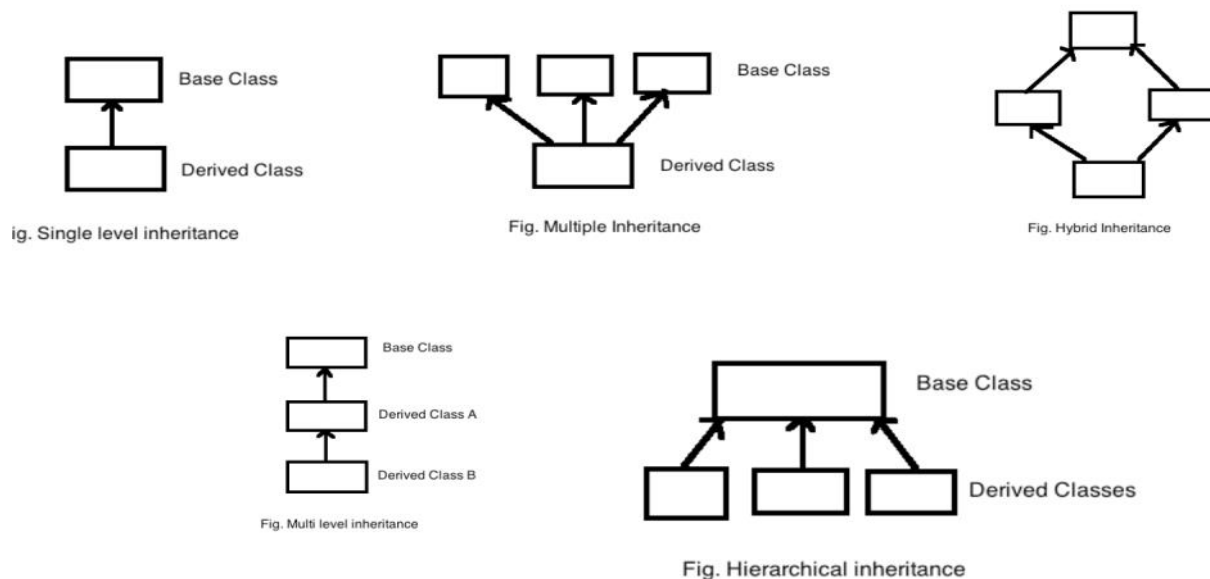
Fig. Hierarchical inheritance

Figure 50 inheritance types

7.3.3. Constructor and destructor calls in inheritance

If the parent do something when initialized in constructor (e.g. print his class name which is Animal in our examples), when the child (e.g. Tiger) is initialized, sometimes we want to specialized the constructor for that child, so we have to override the parent class constructor.

Example: childConstructor

Override parent Animal class constructor in child class Tiger

```cpp
#include<iostream>
using namespace std;

class Animal{
    public:
    string name;
    int age;
    float length;

    //default constructor
    Animal(string s, int a, float l):name(s),age(a),length(l){
        cout<<"enter animal name ";
        cin>>name;
    }

    //copy constructor
    Animal(const Animal& oldObject){
        name = oldObject.name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;
    }
};

class Tiger: public Animal{
    public:
    Tiger(string s, int a, float l):Animal(s,a,l){
        cout<<"Tiger "<<s<<" came\n";
    }
};
int main(){
    Tiger teg("teg",2,2.5);
    teg.sound("roar");
    return 0;}
```

see the example output in Figure 51 inheritance example

Figure 51 inheritance example

7.1. Encapsulation

Encapsulation is to hide the data from developers to prevent fatal mistakes, accessing and modifying members of class <u>directly</u> without any validation may ruin the code.

7.1.1. Data hiding

make members private or protected and to access or modify these members use getters and setters.

e.g.

```cpp
class Animal{
    private:
    string name;
    int age;
    float length;
    …
    …
};
```

7.1.2. Setter and Getter (Accessor and mutator functions)

getters to get the member data and setter to set member data.

e.g.

```cpp
class Animal{
    private:
```

```cpp
    …
    …
    public:
    …
    …
    //getters
    string getName(){
        return name;
    }
    int getAge(){
        return age;
    }
    float getLength(){
        return length;
    }
    //setter
    void setName(string s){
        name = s;
    }
    void setAge(int a){
        age = a;
    }
    void setLength(float l){
        length = l;
    }
    …
    …
};
```

Example: encapsulation

Encapsulate the animal class and print Tiger data

```cpp
#include<iostream>
using namespace std;
class Animal{
    private:
```

```cpp
    string name;
    int age;
    float length;

    public:
    //constructor
    Animal(string s, int a, float l):name(s),age(a),length(l){

    }
    //copy constructor
    Animal(const Animal& oldObject){
        name = oldObject.name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
    //getters
    string getName(){
        return name;
    }
    int getAge(){
        return age;
    }
    float getLength(){
        return length;
    }
    //setter
    void setName(string s){
        name = s;
    }
    void setAge(int a){
        if(a>0)
        age = a;
    }
    void setLength(float l){
        if(l>0)
        length = l;
    }
    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;}
};
class Tiger: public Animal{
    public:
    Tiger(string s, int a, float l):Animal(s,a,l){
    }
};

int main(){
    Tiger teg(" ",0,0.0);//init empty
```

```cpp
    teg.setName("teg");
    teg.setAge(2);
    teg.setLength(1.5);
    cout<<"Tiger '"<<teg.getName()<<"' has "<<teg.getAge()<<" yr(s)
and "<<teg.getLength()<<" in length\n";
    return 0;
}
```

See   the   output   in

```
D:\Programming\MasteringCPP\Object Oriented Programming\Source Code>encapsulation
Tiger 'teg' has 2 yr(s) and 1.5 in length
destructor is called for instance: teg
```

Figure 52 encapsulation example:

```
D:\Programming\MasteringCPP\Object Oriented Programming\Source Code>encapsulation
Tiger 'teg' has 2 yr(s) and 1.5 in length
destructor is called for instance: teg
```

Figure 52 encapsulation example

7.2. Polymorphism

What is child class what to override a member method? e.g. the method .sound() in parent class Animal is general , what if we want to build specific sound

for each inherited child classes (i.e. lion child class growls , tiger child class, and so on), we can for each inherited child class override the base (parent) class.

NOTE: overriding is not overloading

Remember overload functions with different signatures (different return type, input parameters (number, type, order) but similar function names) within the same scope or class

While overriding is like overloading but in a different scope i.e. child class

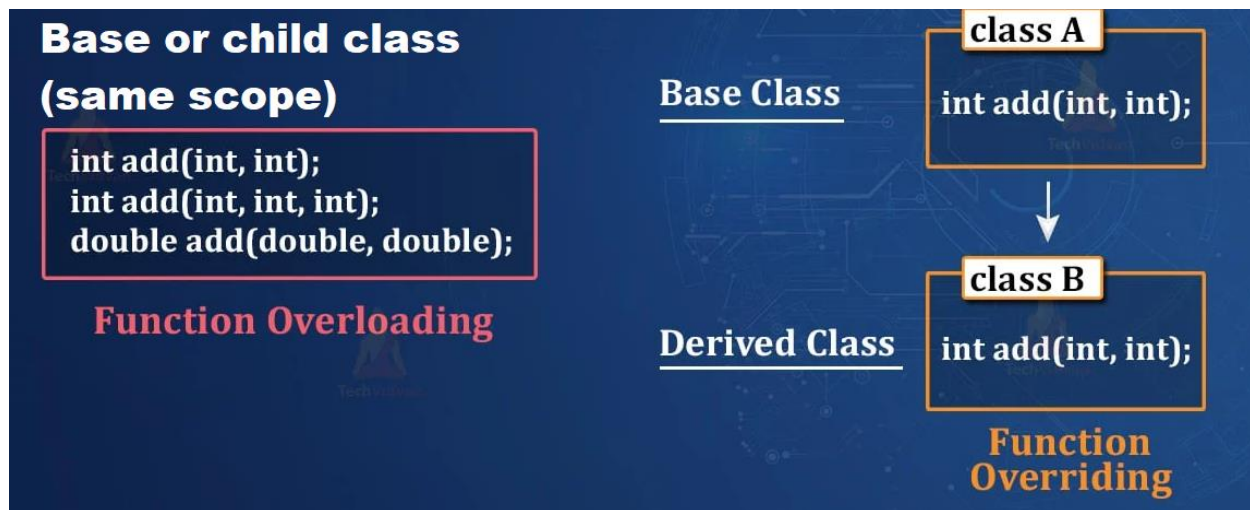See Figure 53 Overloading vs Overriding

Figure 53 Overloading vs Overriding

NOTE: return type alone is insufficient for function to be overloading

7.2.1. Compile-time polymorphism: function overloading, operator overloading

In base or derived class you can overload a method e.g.

```cpp
#include <iostream>
using namespace std;

class Printer {
public:
    // Overloaded functions
    void print(int i) {
        cout << "Printing integer: " << i << endl;
    }

    void print(double d) {
        cout << "Printing double: " << d << endl;
    }

    void print(string s) {
        cout << "Printing string: " << s << endl;
    }
};

int main() {
    Printer p;
    p.print(5);          // Calls print(int)
    p.print(3.14);       // Calls print(double)
    p.print("Hello");    // Calls print(string)

    return 0;
}
```

7.2.2. Runtime polymorphism: virtual functions, pure virtual functions, abstract classes

You can override (change) function implementation of parent class to use it in child class (make the function member appropriate for child class) by using virtural keyword

```cpp
#include <iostream>
using namespace std;

class Base {
public:
    // Virtual function for overriding
    virtual void show() {
        cout << "Base class show function" << endl;
    }
};

class Derived : public Base {
public:
    // Overriding the base class function
    void show() override {
        cout << "Derived class show function" << endl;
    }
};

int main() {
    Base baseObj;        // Create an object of Base
    Derived derivedObj; // Create an object of Derived

    // Call show() function for Base object
    baseObj.show();      // Outputs: Base class show function

    // Call show() function for Derived object
    derivedObj.show();   // Outputs: Derived class show function
    return 0;
}
```

7.3. Abstraction

7.3.1. Abstract classes and interfaces

Imagine a personal computer PC company that produces lots of PCs products like desktop PC and laptop,

the production of laptop in a section and production of desktop PC on other section, each section completed its section and pass it for branding section, the branding section doesn't need to know how the laptop battery charging or how the desktop PC boots up,

the branding section only want to know the desktop PC and laptop both boots up, charging and so on, so we have to provide some sort of abstraction to make the life easier for branding section

in this case we could make like in polymorphism but not to provide any implementation for each member function and rely on implementation of function in the derived (child) classes

this is done by:

```cpp
class Base {
public:
    // Virtual function for overriding
    virtual void show() = 0;
};
```

Instead of what we used in polymorphism:

```cpp
class Base {
public:
    // Virtual function for overriding
    virtual void show() {
        cout << "Base class show function" << endl;
    }
};
```

7.3.2. Virtual function and pure virtual function

this is pure virtual function, which used in abstraction

```cpp
class Base {
public:
    // Virtual function for overriding
    virtual void show() = 0;
};
```

While this is virtual function which used in polymorphism

```cpp
class Base {
public:
    // Virtual function for overriding
    virtual void show() {
        cout << "Base class show function" << endl;
    }
};
```

7.4. Static Members

7.4.1. Class-level data and behavior

Class level data is when a variable that all instances of classes share, e.g. if you want to keep track of number of instances made, so in class constructor, you can make static variable to increment every time an instance is made.

7.4.2. Static member variables and functions

Imagine in Animal class we want to keep track of number of animals in zoo, we could make a static counter so that every time and animal come to the zoo, the constructor increment that counter.

Example: staticvariable

Count number of animals in the zoo

```cpp
#include<iostream>
using namespace std;
class Animal{
    private:
    string name;
    int age;
    float length;
    public:
    static int animalCount;
    //constructor
    Animal(string s, int a, float l):name(s),age(a),length(l){
        animalCount++;
    }
      …
      …
    //getters
      …
      …
    //setter
      …
      …
    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;
    }
};
// static member variables need to be declared inside
// the class definition and then defined outside of it
int Animal::animalCount = 0;
int main(){
    Animal Tiger("teg", 2, 2.5);
    Animal Lion("leo",1,2);
    Animal Bird("fly", 1, 0.2);
    cout<<"The zoo has "<<Animal::animalCount<<" animals\n";
    return 0;}
```

The output should be: *The zoo has 3 animals*

destructor is called for instance: fly

destructor is called for instance: leo

destructor is called for instance: teg

static methods are class level that also don't need objects to be called, it could call without instantiating any object as its class level not instance(object) level

Example: staticMethod

Make a static method getAnimalCount() to show the animals count even if no object is made!

```cpp
#include<iostream>

using namespace std;

class Animal{
    private:
    string name;
    int age;
    float length;

    public:
    //static memver indicating for animals count
    static int animalCount;
    // Static member function to get animal count
    static int getAnimalCount() {
    cout<<"The zoo has "<<animalCount<<" animals\n";
        return animalCount;
    }
    //constructor
    Animal(string s, int a, float l):name(s),age(a),length(l){
        cout<<"Animal: "<<s<<" come\n";
        animalCount++;
    }
      …
    //getters
      …
    //setter
      …
    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;
    }
};
```
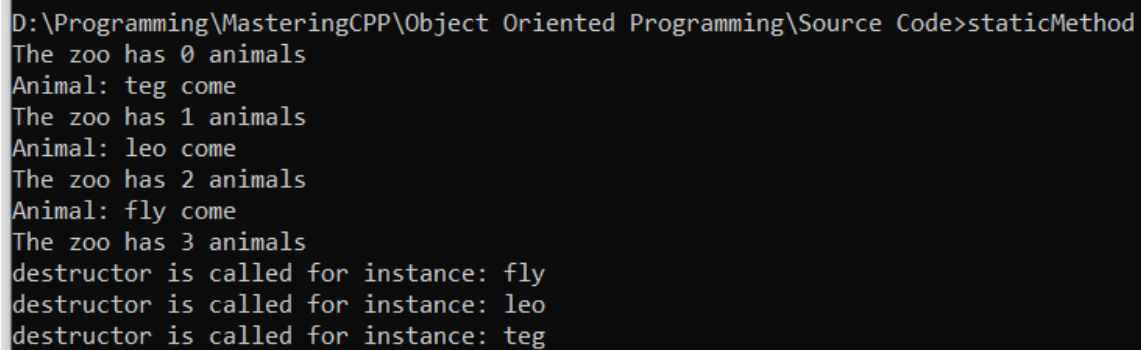
```cpp
// static member variables need to be declared inside
// the class definition and then defined outside of it
int Animal::animalCount = 0;




int main(){
    //calling static method getAnimalCount() without any object made !
    Animal::getAnimalCount();
    Animal Tiger("teg", 2, 2.5);
    Animal::getAnimalCount();
    Animal Lion("leo",1,2);
    Animal::getAnimalCount();
    Animal Bird("fly", 1, 0.2);
    Animal::getAnimalCount();
    return 0;
}
```

See the output in Figure 54 Static method

```
D:\Programming\MasteringCPP\Object Oriented Programming\Source Code>staticMethod
The zoo has 0 animals
Animal: teg come
The zoo has 1 animals
Animal: leo come
The zoo has 2 animals
Animal: fly come
The zoo has 3 animals
destructor is called for instance: fly
destructor is called for instance: leo
destructor is called for instance: teg
```

Figure 54 Static method

7.5. Multiple Inheritance

We knew previously that there are types of inheritance, a grandchild class that inherits from 2 parent class (multiple inheritance) then these 2 parent classes inherit from a parent class like Figure 55 hybrid inheritance case
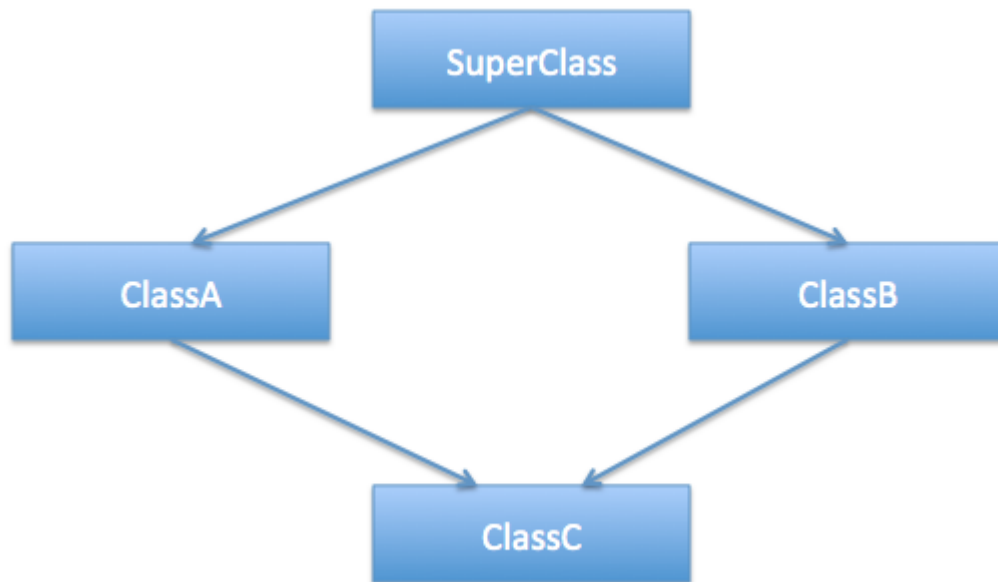

Figure 55 hybrid inheritance case

7.5.1. Diamond problem and virtual inheritance

Imagine if the class named SuperClass has int x, while ClassA has int y while ClassB has int z

The ClassA will have x and y attributes

The ClassB will have x and z

So when ClassC inherits from ClassA and ClassB

The ClassC will have y and z attributes and also inherits the same x attribute twice

So when you try to access ClassC.x will throw an error because compiler doesn't know which x attribute you want to access as ClassC have 2 of attribute x

```cpp
#include <iostream>
using namespace std;

class SuperClass {
public:
    int x;
};

class ClassA : public SuperClass {
public:
    int y;
};

class ClassB : public SuperClass {
public:
    int z;
};

class ClassC : public ClassA, public ClassB {
    // ClassC has both y and z, but x is ambiguous
};

int main() {
    ClassC obj;

    obj.x = 15; //error: x is ambiguous!

    return 0;
}
```

Example: diamondProblem

Solve the problem of diamond problem by inheriting ClassA and ClassB from SuberClass in virtual inheritance mode.

```cpp
#include <iostream>
using namespace std;

class SuperClass {
public:
    int x;
};

class ClassA :virtual public SuperClass {
public:
    int y;
};

class ClassB : virtual public SuperClass {
public:
    int z;
};

class ClassC : public ClassA, public ClassB {
    // ClassC has both y and z, but x is ambiguous
};

int main() {
    ClassC obj;

    obj.x = 15; //error: x is ambiguous!

    return 0;
}
```
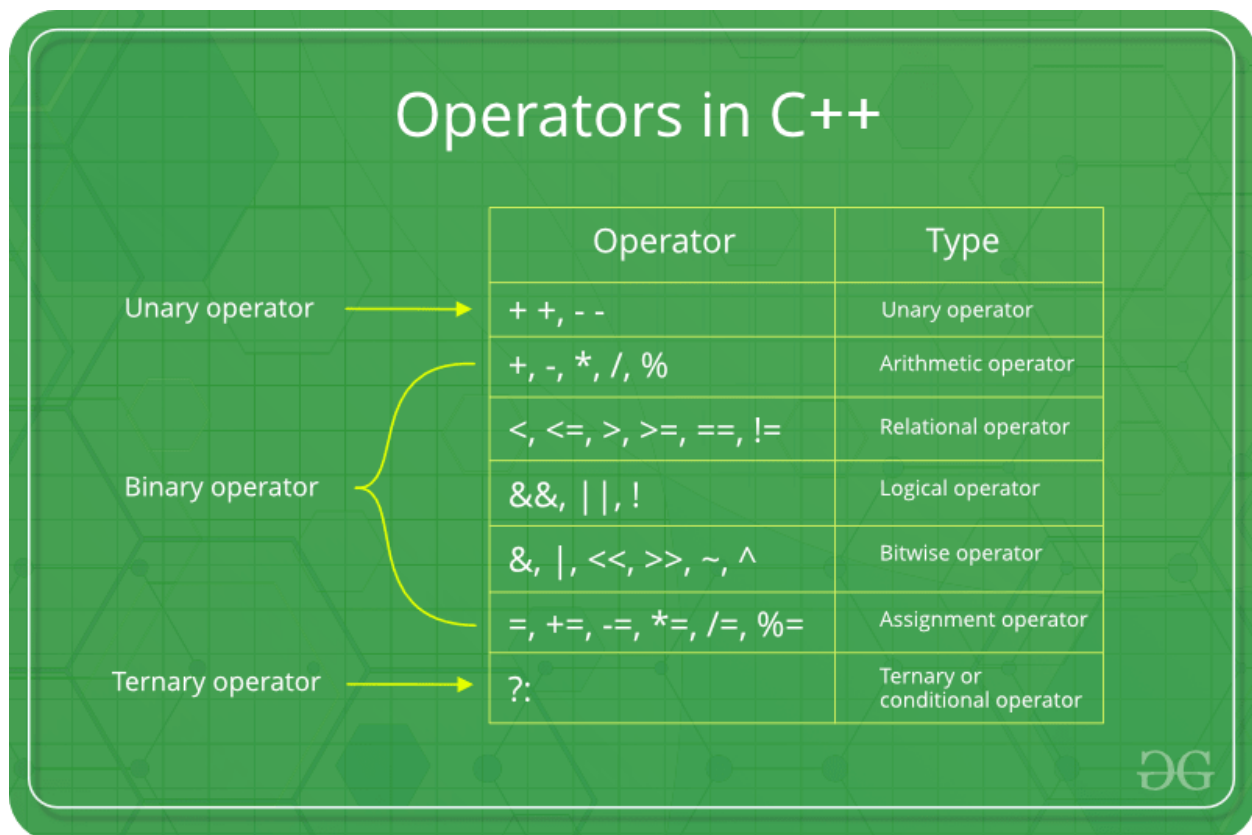
7.6. Operator overloading

Compiler know how to process operators well, e.g. it knows what how to add integer, floats, even strings, when it comes to user-defined data types, it becomes pretty hard , the complier don't know your intention if an instance of class (e.g. Person) is added together, the compiler don't know what do you mean of Person1+Person2, so you must tell the compiler what does this addition mean (e.g. the addition for the 2 person class might be adding their salaries).

Firstly, lets know what unary and binary operator are (see Figure 56 unary and binary operators (the photo from (geek for geek)), unary operators have one operand while binary operators have 2 operands .

Figure 56 unary and binary operators (the photo from (geek for geek)

7.6.1. Overloading unary operators

Example: unaryOverloading

```cpp
#include<iostream>
using namespace std;

class Animal{
    private:
    string name;
    int age;
    float length;

    public:
    //constructor
    Animal(string s, int a, float l):name(s),age(a),length(l){
    }
    //copy constructor
    Animal(const Animal& oldObject){
        name = oldObject.name;
    }
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
    //getters
      …
    //setter
      …

    //destructor
    ~Animal(){
        cout<<"destructor is called for instance: "<<name<<endl;
    }
    friend Animal& operator++(Animal& obj);
};

Animal& operator++(Animal& obj){
    obj.age++;
    return obj;
}
int main(){
    Animal Tiger("Teg",2,1.5);
    cout<<"Tiger age before increament "<<Tiger.getAge()<<endl;
    ++Tiger;
    cout<<"Tiger age after increament "<<Tiger.getAge()<<endl;

    return 0;
}
```

7.6.2. Overloading binary operators

Example: binaryOverloading

Make a binary operator overloading + to add 2 Animal length of class we made, to make sure that a two animal could be lifted on a car that has a length of 4 meter

```cpp
#include<iostream>
using namespace std;
#define cageLength 4
class Animal{
    private:
    string name;
    int age;
    float length;

    public:
    //constructors
      …
    //function member
    void sound(string sound){
        cout<<name<<" have "<<sound<<" sound\n";
    }
    //getters
    …
    //setter
    …
    //destructor
    …
friend float operator+(Animal& obj1, Animal& obj2);
};

float operator+(Animal& obj1, Animal& obj2){
    return obj1.length + obj2.length;
}
int main(){
    Animal Tiger("Teg",2,1.5);
    Animal Liger("Leg",2,2);
    if(Tiger+Liger<cageLength){
        cout<<"they could fit in the cage\n";
    }
    else{
        cout<<"they couldn't fit in the cage\n";
    }
    return 0;
}
```

REMEMBER: two classes by default couldn't have + operator by default, that's why we make + operator overloading, also you can overload any operator

7.6.3. Insertion and extraction overloading

if we tried to cout the instance of a class, an error would pop up as insertion and extraction (i.e << in cout OR >> in cin) don't have a definition for printing a user defined instance, so to print an instance, we have to define what will happen when we use cout<<instanceClass for example

Example: insertionOverload

Print the Animal instance name and age and length using cout<<Tiger;

```cpp
#include<iostream>
using namespace std;
#define cageLength 4
class Animal{
    private:
    string name;
    int age;
    float length;

    public:
    //constructors
    …
    //getters
    …
    //destructor
    …
    friend ostream& operator<<(ostream& out, Animal& obj);
};

ostream& operator<<(ostream& out, Animal& obj){
    out<<"Animal name: "<<obj.name<<" has "<<obj.age;
    out<<" yrs and "<<obj.length<<" in length\n";
    return out;
}
int main(){
    Animal Tiger("Teg",2,1.5);
    return 0;
}
```

NOTE: cout<<Tiger; has no meaning by default so we overload it to define what happens when we use cout<<Tiger or any instance

7.7. Rules

7.7.1. Rule of Three

The "Rule of Three" in C++ is a guideline that helps manage resources properly and avoid common pitfalls related to resource management, especially when dealing with classes that allocate dynamic memory or other resources.

When a class is built, make three things:

- Copy Constructor (discussed in constructor section)
  - To prevent shallow copy by using deep copy
  - Used to create a new object as a copy of an existing object.
- Destructor (discussed in destructor section)
  - Used to release resources that were acquired by the object.
- Copy Assignment operator
  - Used to copy the contents of one object to an already-existing object

7.8. Final Project

Tic-tac-toe game in console will be made with OOP flavored, the code may have:

Inheritance

- **Base Class**: `Player` is the base class.
- **Derived Classes**: `HumanPlayer` and `ComputerPlayer` are derived from `Player`

Abstraction

- **Play()**: virtual `play()= 0;`

Encapsulation

- Maybe not necessary as no data to hide so no need for getters and setters

Polymorphism

- Add polymorphism is possible

MODEL answer fount at LINK or Scan QR code