

# Modern C++

## An effective short way

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## 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](http://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



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 from environment variables if exists. See Figure 2 adding bin folder path to environment variables

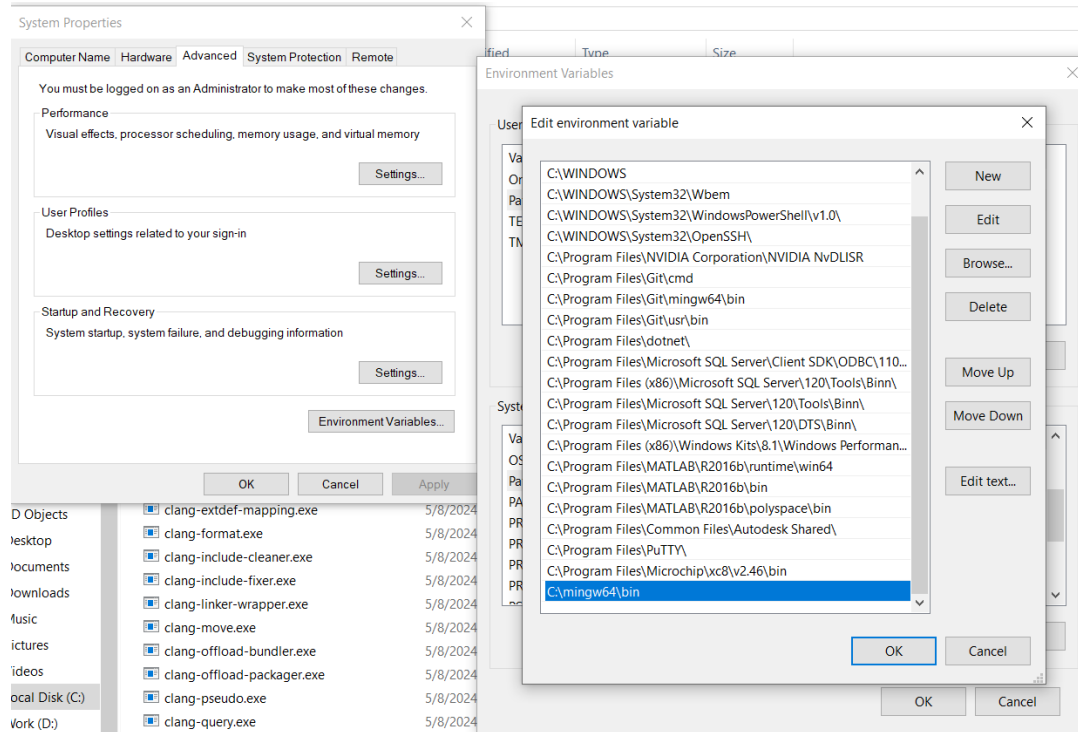


Figure 2 adding bin folder path to environment variables

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

```

C:\Users\Mustapha>gcc --version
gcc (MinGW-W64 x86_64-ucrt-posix-seh, built by Brecht Sanders, r1) 14.1.0
Copyright (C) 2024 Free Software Foundation, Inc.
This is free software; see the source for copying conditions. There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
  
```

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

```
#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

Hello.cpp	6/17/2024 9:49 PM	C++ Source File	1 KB
Hello.exe	6/17/2024 10:16 PM	Application	44 KB

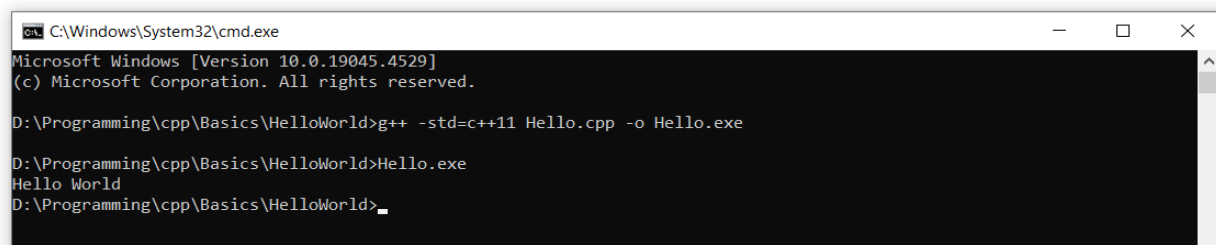


Figure 4 first program



## 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, and 120) or decimal aka float like (10.2, 0.2, and 22.8) or character (like 'a', 'b' and 'c'), this declaration specifies:

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

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

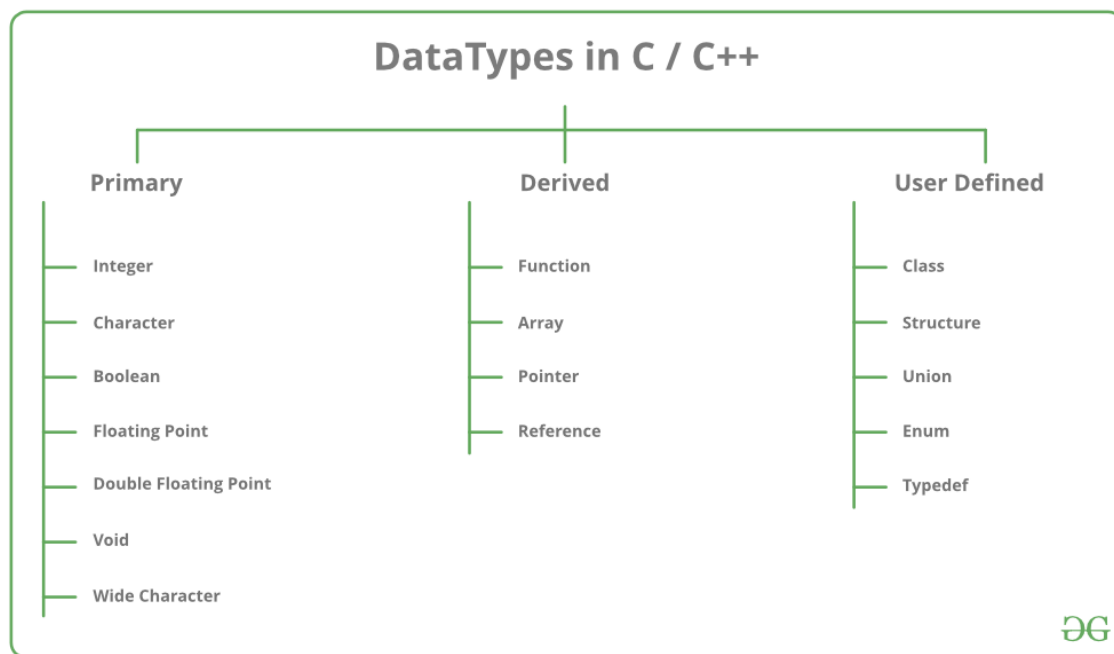


Figure 5 Types in C++

## 2.2. Primitive datatypes

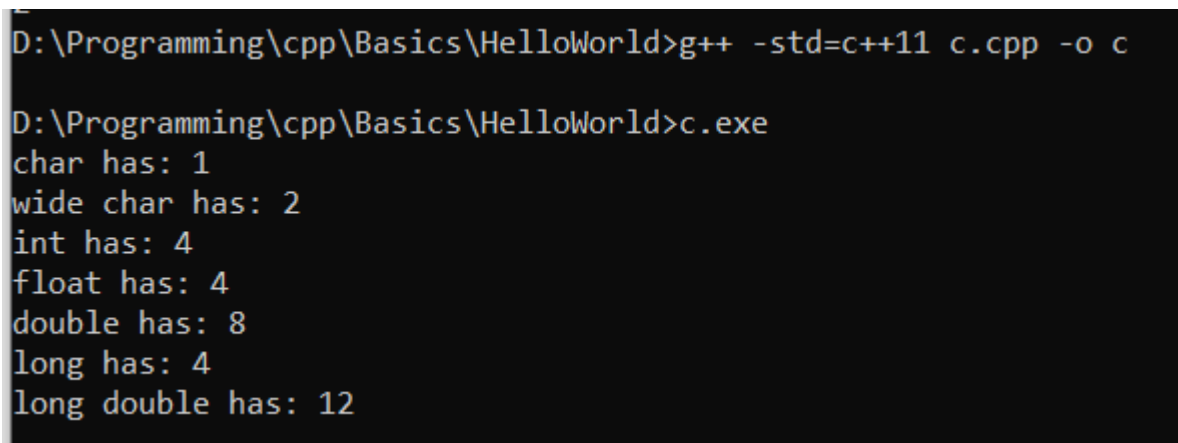
Primary (primitive) data types are compiler dependent that means that the data types could be stored in different sizes for different compilers, in gcc compiler:

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

```
#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.

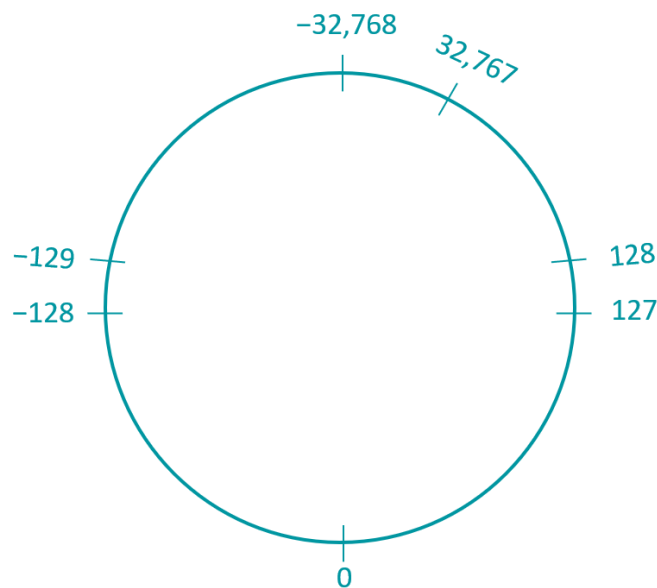
remember ! char variable store integers like 15 and characters like 'a' not only characters

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 32770 is 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 65535 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. x 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:

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

Answer:

```
#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 namespace 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

- **Declaration:** datatype nameOfArray[number of item];  
For example: int salaries[5];
- **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

- **Declaration:** array<datatype, itemNumbers> name;  
For example: array<int, 5> salaries;  
NOTE: don't forget to include array (i.e #include <array>)
- **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

```
#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 introduce 10 people (like in **Exercises 1**: introduction) the program was about 10 lines 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

```
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: "<<salary<<endl;
    cout<<"my GPA is: "<<gpa;
}
```

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

```
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 an object that has many attributes (i.e. variable) but different data types, e.g. you want to describe a student who has 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 a student who has 3 attributes for example name (String), id (int), gpa (float).

```
//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

- 1<sup>st</sup> way: after the deceleration

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

- 2<sup>nd</sup> way: by using.. struct\_type struct\_name;

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

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

```
student Ahmed;
```

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

In C:

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

in C++ struct is not necessary :

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

## 3- Accessing and Assigning

Accessing done by dot operator

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 respctively:
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

```
#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 respctively:\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: "<<work-
ingHrs<<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 respctively:
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

```
#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

```
#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;
    }
};

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

```
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:

```
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:

```

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) : Employee(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 : public 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

```
#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

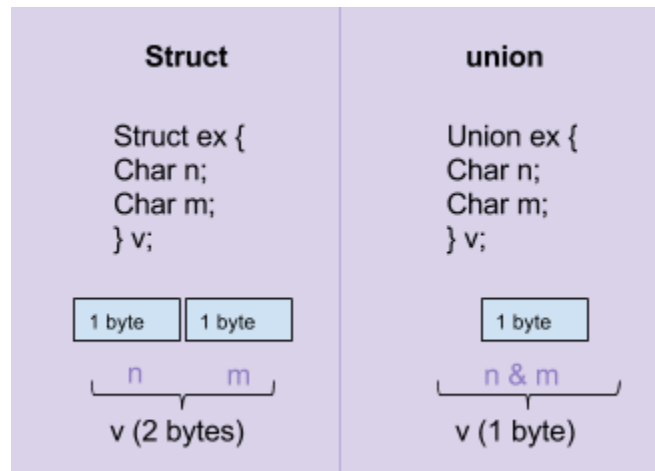


Figure 12 Union vs struct

#### 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

```
#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

```
#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 remainder (%) e.g. `var1 % var 2 4%3 = 1`

see Figure 15 Division and modulo

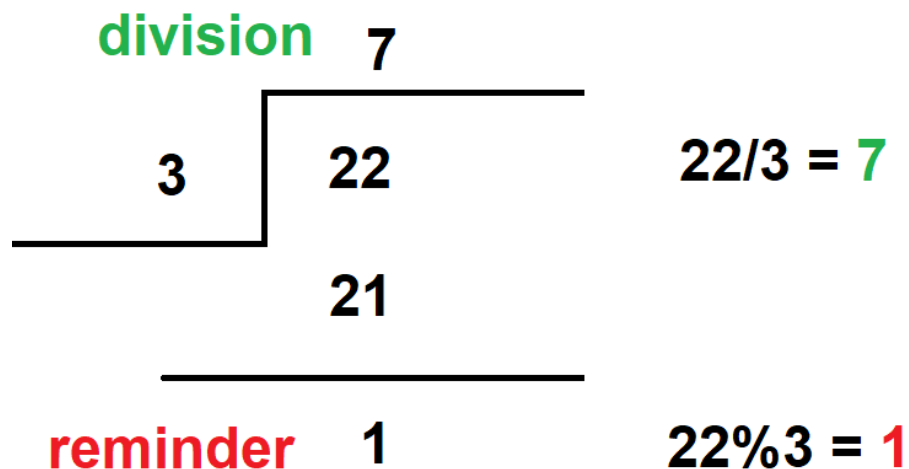


Figure 15 Division and modulo

### 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:

```
#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)

```
#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;
    }
};

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 .

```
#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

```
#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 times or until user enters quit

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

Loop in 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 changes, 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

```
#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

```
#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

```
#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, remember 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 than 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

```
#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

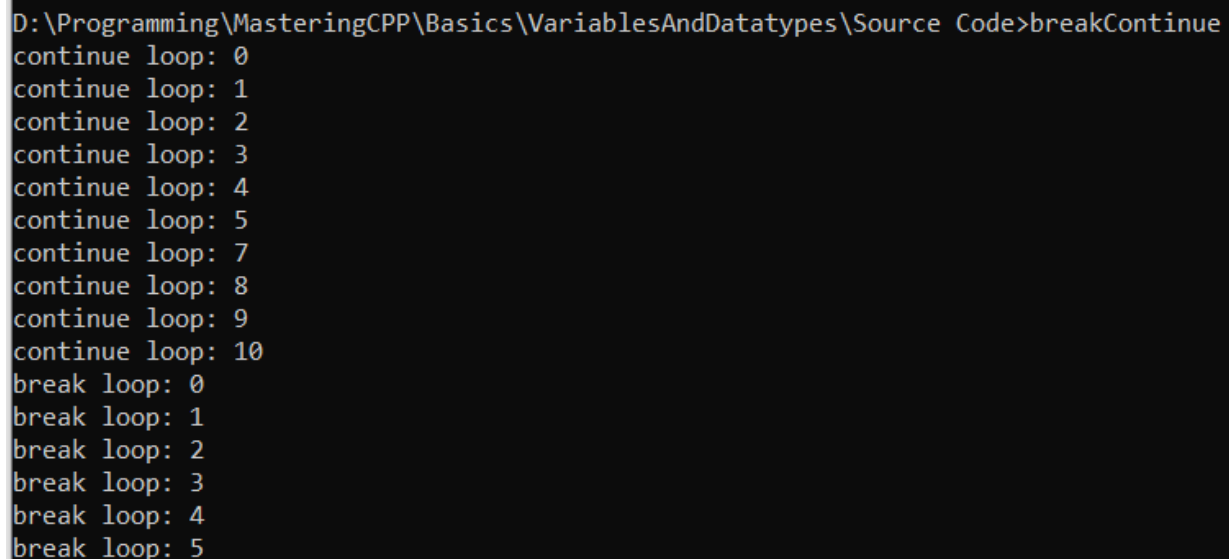
**goto** is used to jump to any line in the code

**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

```
#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

```
#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:

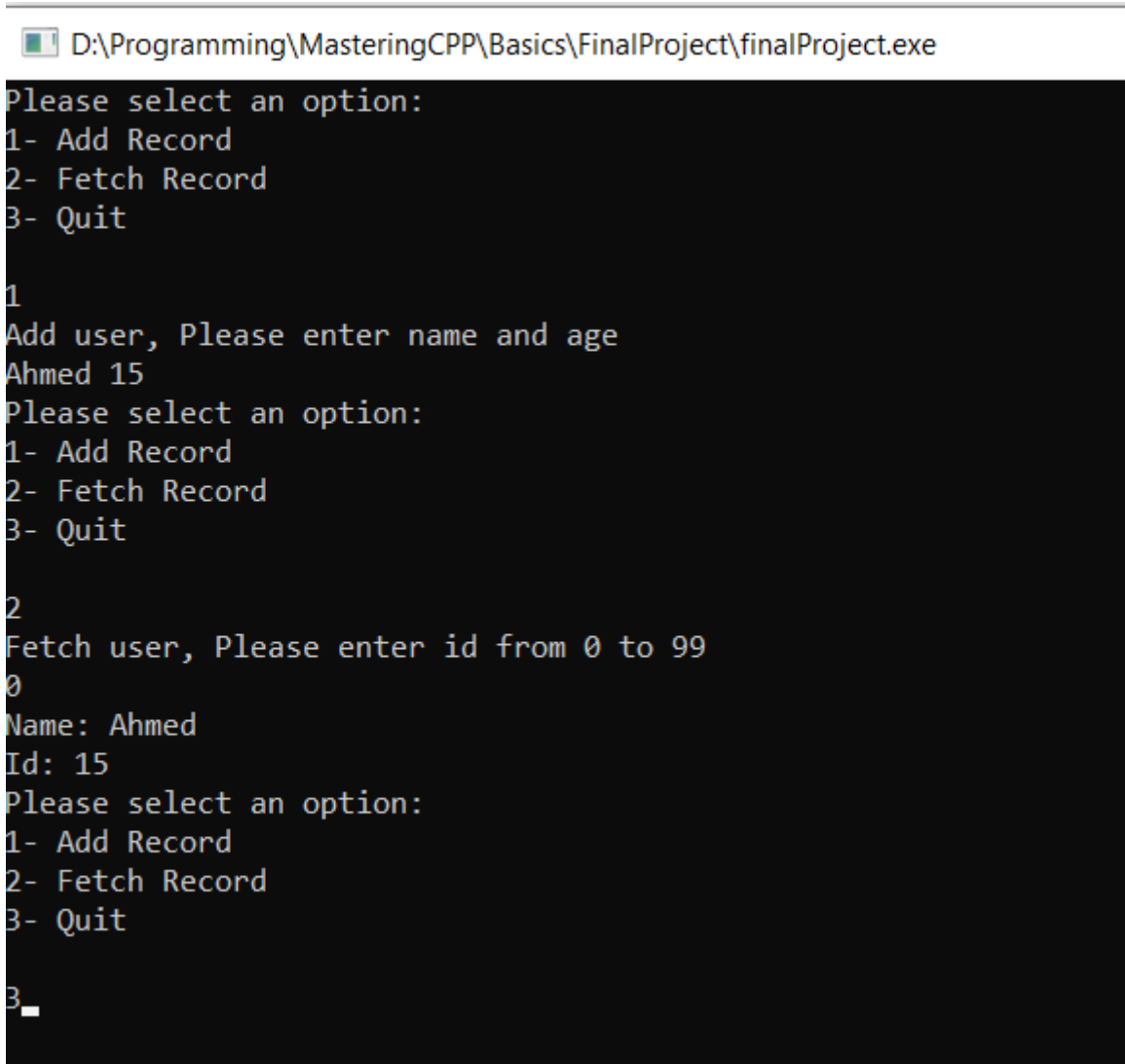
Case 1: Prompt for name and age, then call AddRecord().

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

Case 3: Exit the loop.

You can find code in the github repository [LINK](#)

An example: see Figure 18 Final project snapshot



```
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 snapshot*

## 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)

### 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

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

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

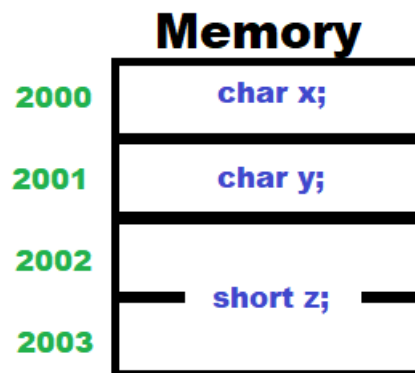


Figure 19 how memory store variables

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

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

int main() {
    char x = 'a';
    short y = 15;
    char* ptr_x = &x;
    short* ptr_y = &y;
    //dereference operator * to access or modify variables
    cout<<"x 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;

    *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 1<sup>st</sup> element) let the address of first element is 2000 so x is 2000 and to access the 2<sup>nd</sup> element you have to use \*(x+1) which is \*(2001) and 3<sup>rd</sup> 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

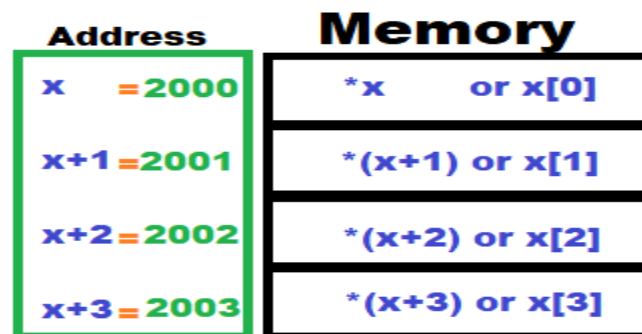


Figure 20 how memory store arrays

#### 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<sup>th</sup> element)

```
#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 array 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;)

```

#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)

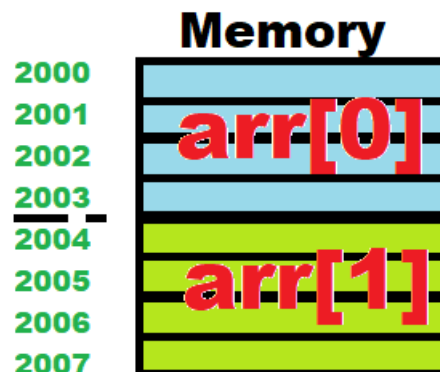
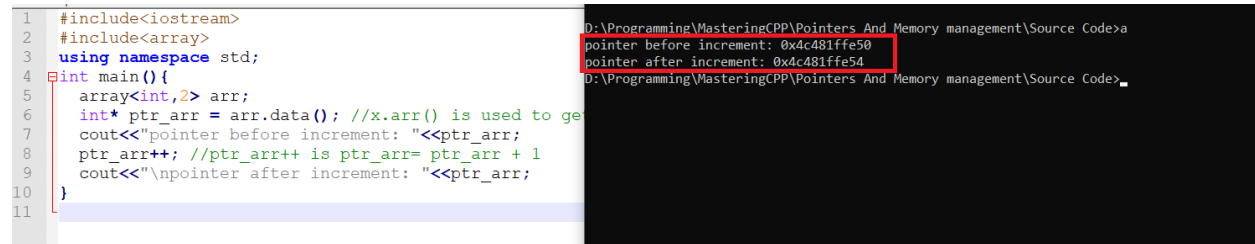


Figure 21 pointer increment



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



```
1 #include<iostream>
2 #include<array>
3 using namespace std;
4 int main() {
5     array<int,2> arr;
6     int* ptr_arr = arr.data(); //x.arr() is used to get
7     cout<<"pointer before increment: "<<ptr_arr;
8     ptr_arr++; //ptr_arr++ is ptr_arr= ptr_arr + 1
9     cout<<"\npointer after increment: "<<ptr_arr;
10 }
11
```

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 forget: 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

```
#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 modify
    //we could modify 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 of 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() )

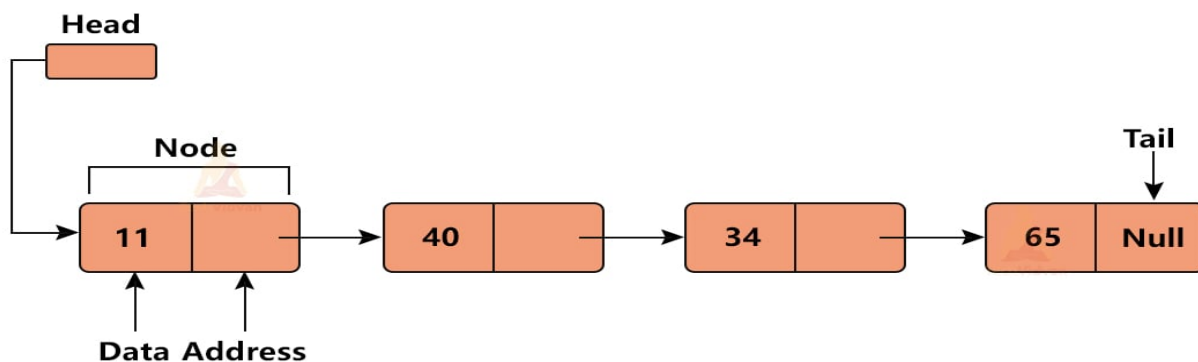
```
#include<iostream>
using namespace std;

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

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

- Create the head, pointer of that struct that carry is ready for storing the 1<sup>st</sup> node address

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

- **To create 1<sup>st</sup> node**

- 1- Create instance of that struct

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

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

```
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)

```
//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  $n^{\text{th}}$  node

1- Iterate to  $n-1^{\text{th}}$  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  $n-1^{\text{th}}$  address make the address is  $n+1^{\text{th}}$  address instead of  $n^{\text{th}}$  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:

```
#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 3rd 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;
    }

    //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 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-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)

```

#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 but lesser risks

### Pointer types:

#### ➤ Wild pointer

when using pointers before assigning value to that pointer

```
#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:

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

#### ➤ Dangling pointer

When using a pointer that is deallocated

```
#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