

→ more important note and Week Lecture / homework

→ Data Structure

→ links

→ Heading

Every week from new page

→ Subheading or important point

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Bhaiya Bday
20 June 1998
7:15 AM

IMPORTANT POINTS

- Focus on work on skill and build networks those work in companies and can talk to HR for you
- Internship- do if you want to learn or convert it as PPO
- Rough sols. and dry run are very important
- Do documentation to promote and mail everything you discuss with HR or team
- Think twice, Code once
- To clarify any code you are confused, use cout statements every where to know what is going on in the code
- Code all approaches you can think of and can find & understand from google
- Revise all incorrect & skipped questions in quizes regularly
- Watch sol. only after attempting the question
- Interviewer will ask Time & Space complexity after every sol. you give

→ 2 websites

 └→ cppreference
 └→ cplusplus.com

→ Think on paper

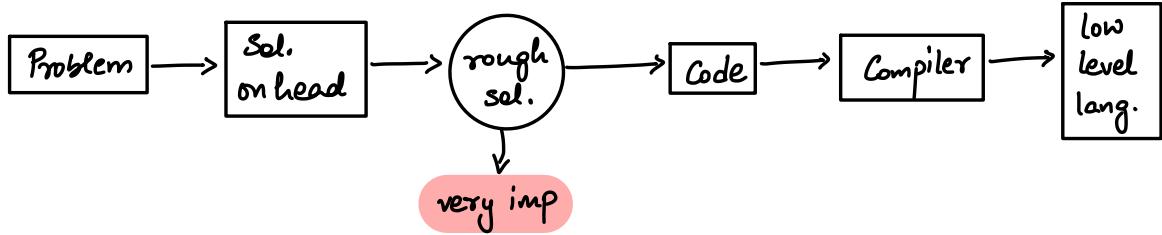
IMPORTANT C++ NOTES

- Making global variable is BAD PRACTICE
- To increase range of int / long long ,
you can use unsigned int / long long
- % → heavy operator
 - ↳ so try to use it less
Use bitwise operators instead of this if possible
- arr[n] → BAD PRACTICE
arr[100000] is better than arr[n]
- to find min., start ans from INT_MAX
- to find max, start ans from INT_MIN
- n & 1 gives rightmost bit of n
- xor → cancels out same elements
 - $0 \wedge 0 = 0$ $0 \wedge 1 = 1$
 - $0 \wedge 1 = 0$

Thought process to solve a problem-

W1-L1

- Understand a problem
- input values
- find approach



Algorithm - Sequence of steps

Flowchart - Graphical representation of algo

Components -

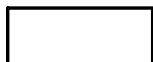


terminator

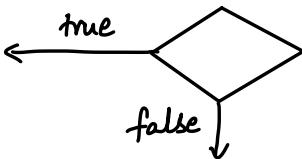
for start / end



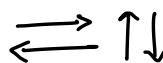
for input /output read /write



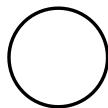
computation / process / declaration



decision making block
takes condition



flow



Connector
takes function

Pseudo Code - Generic way of writing algo

Dry Run → Very Important to understand any topic

W1-L2

IDE - Replit, VS-Code

```
# include <iostream>           → preheader file contains implementation of identifiers
using namespace std;
int main () {
    cout << "Namaste Bharat";
}
```

region where scope of identifier is defined

used to point on console/standard display

→ using standard namespace implementation of cout choosing from multiple types of namespace

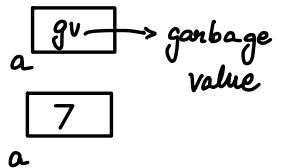
→ to end any statement

→ string

cout << endl; → for next line

cout << '\n';

int a; \longrightarrow a is an integer
 cin >> a; \longrightarrow input a from user
 ex - 7



Variables

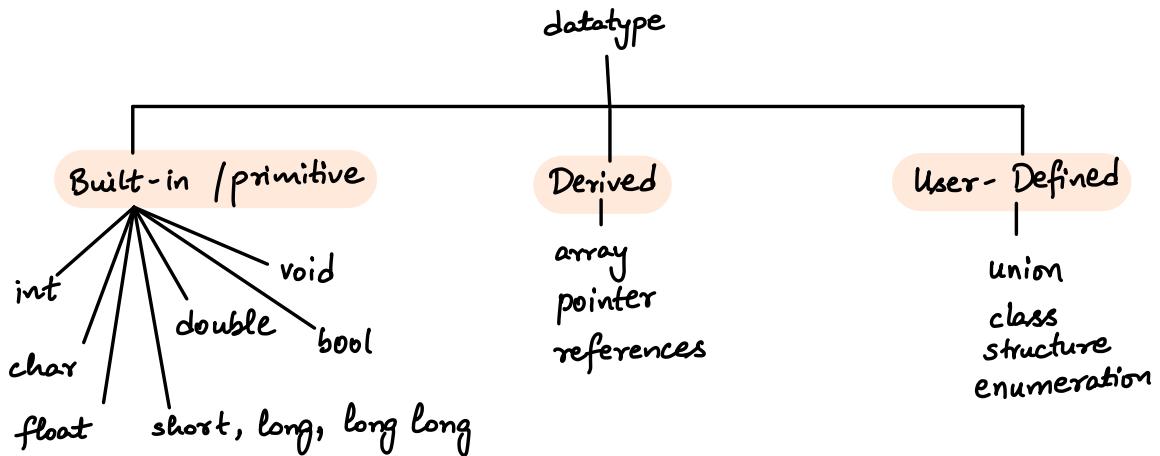
named memory location

int \downarrow
 datatype
 a = 5;
 ↓
 variable
 name

value

Datatypes

type of data



int - 4 byte - 32 bits in memory

\longrightarrow -2^{31} to $2^{31}-1$ in signed int
 \longrightarrow 0 to $2^{32}-1$ in unsigned int

char - 1 byte - 8 bits in memory

$\longleftarrow 2^8$ different chars.

ASCII

↳ char maps with numerical ASCII value

char \leftrightarrow ASCII value \rightarrow store in memory

bool \rightarrow 1 byte \rightarrow 8 bits

true - 1

false - 0

↳ because minimum addressable memory is
1 byte

We cannot address 1 bit in memory

float \rightarrow 4 byte \rightarrow 32 bits

double \rightarrow 8 byte \rightarrow 64 bits

long long \rightarrow 8 byte \rightarrow 64 bits

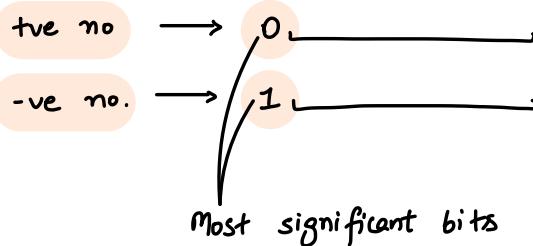
short \rightarrow 2 byte \rightarrow 16 bits

long \rightarrow 4 byte \rightarrow 32 bits

How data is stored

int a=5;

↳ 32 bits 0...00101
 29 bits



How -ve number is stored in memory

In 2's complement form

→ 1's complement + 1

→ reverse all bits

int a = -7;

7 → 0.....00111 } 32 bits

ignore -ve sign
find binary equivalent

1's (7) → 1.....11000

find 2's complement

2's (7) → 1.....11001

→ this is how -7 will be stored in memory

How to read -ve no. present in memory

→ take 2's complement

1....11001

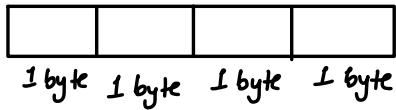
→ 1's complement → 0...00110

2's complement → 0...00111

→ + 7

-7

Interesting problem



how computer know these are 4 chars or a single integer

↳ Using datatype

↳ tell 2 things

- ↳ type of data used
- ↳ space used in memory

Signed vs Unsigned

↓
↳ 0, +ve
+ve, -ve, 0

↳ by default

int - 4 byte - 32 bits in memory

↳ total no. of combinations - 2^{32}

signed int

-2^{31} to $2^{31}-1$

unsigned int

0 to $2^{32}-1$

} range

(10...0)

011...1

0.....0

1....1

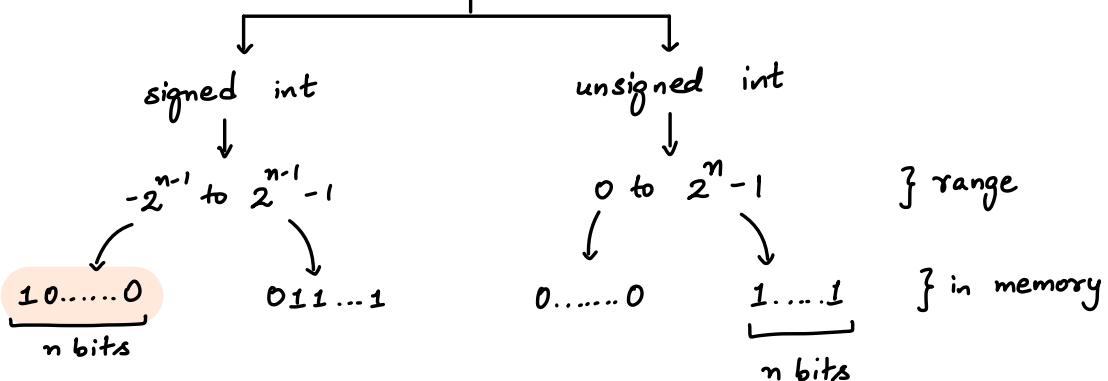
$2^{15} \rightarrow \underline{10...0} \rightarrow -2^{31}$

} in memory

General Formula

n bits in memory

↳ total no. of combinations - 2^n



Typecasting

↳ convert one type of data to another

implicit typecasting

ex- `char ch = 97;`
`cout << ch;` → (a)

explicit typecasting

ex- `char ch = (char) 97;`
`cout << ch;` → (a)

overflow ex- `char ch = 9999;`
`cout << ch;`

$9999 \xrightarrow{\text{binary conversion}} 100\ 111\ \underbrace{0000\ 1111}_{\text{stores only last 8 bits}}$

so ch stores 00001111 in memory
↓
7
↓
acc. to ASCII table

Operators -

Arithmatic Operator

$\hookrightarrow +, -, *, /, \%$

int op int \longrightarrow int

float op int }

int op float } func

float op float J

double op int]

int op double
double

double op double
float op double

double op float]

351

$3.0 \rightarrow$ float / double not int

`bool op bool` → int
 { }
 \downarrow
`bool act as 0 or 1`

bool act as 0 or 1

a op b

, <, >=, <=, !=, ==

Output - 0 or 1

false  true

these are different things

Assignment Operators

=

Logical Operators

↳ when you have multiple conditions

$a \& \& b$ → and → true if both are true

$a || b$ → or → true if any one is true

$!a$ → not → negate the result

Output - 0 or 1
false ↕ true

(cond1 $\&\&$ cond2 $\&\&$ cond3)

if cond1 is false

compiler will not check further
as ans will already false

(cond1 $||$ cond2 $||$ cond3)

if cond1 is true

compiler will not check further
as ans will already true

Conditions

if (cond.){
execute
}

if

if (cond){
execute 1
}

else {
execute 2
}

if - else

W1-L3

if (cond1)
execute 1
else if (cond2)
execute 2

if - else if

```

if (cond 1)
    execute 1
else if ( cond 2)
    execute 2
else if (...)
else
    execute n

```

if - else if - else

```

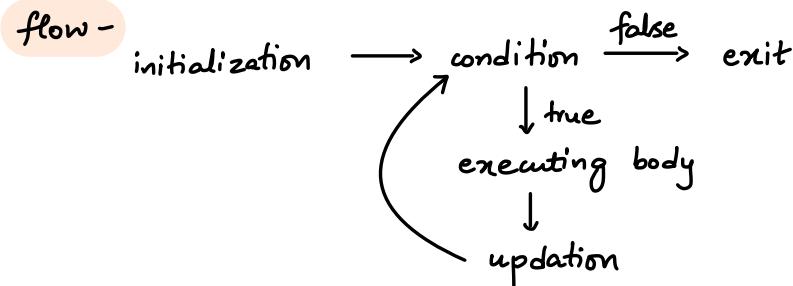
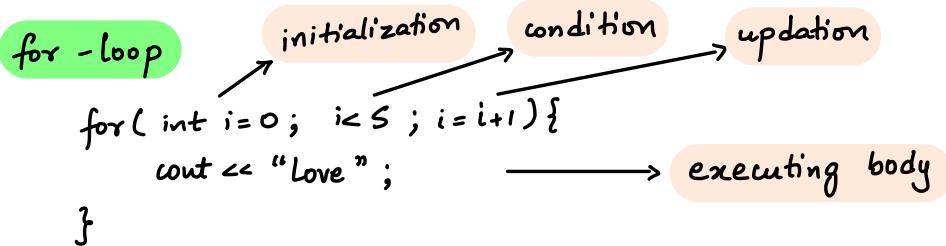
if (cond 1)
    execute 1
else {
    if () { }
    else () { }
}

```

nested if - else

Loops

↳ to do something repeatedly



initialization
condition
updation } none is mandatory
one or multiple i,c,u can be added
multiple c → i>5, i<10; → i>5 & i<10

patterns -

generally 2 loops → outer loop() {
 inner loop() {
 }
 }
cout << endl;

for rows
for cols

→ a op = b → a = a op b

op → +, -, *, /, , /

cin in if()

```
int num;  
if (cin >> num) {  
    cout << "hello";  
}  
else {  
    cout << "hi";  
}
```

it will not give error

output -
hello

for all values of num

↓
0, true, -ve

cout in if()

```
int num = 0;  
if (cout << num << endl) {  
    cout << "hello";  
}  
else {  
    cout << "hi";  
}
```

it will not give error

output -
0
hello

for all values of num

↓
0, true, -ve

HLL - High level language

↳ human readable and user friendly

W1-L4

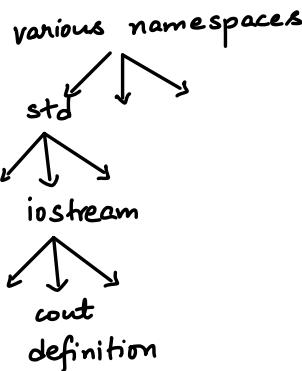
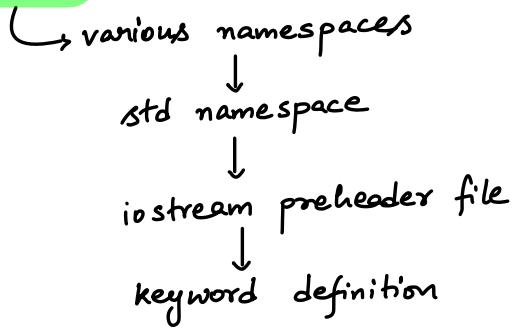
C++, C - Middle Level language

namespace → to avoid collision



multiple definitions of a single keyword

hierarchy



float f = 2.0 + 100;

cout << f ; → output -

102 or 102.0
compiler dependent

float f = 2.7;

int n = 157;

int diff = n-f;

cout << diff ;

output -

154

explanation -

$$n-f = 157 - 2.7 = 154.3$$

int diff = n-f

diff = 154

ternary operator -

W1-HW

↳ syntax

variable = (condition) ? expression2 : expression3

(condition)? variable = expression2 : variable = expression3

by default -

cout << sizeof(2.3); → 8
 |
 → float

cout << sizeof(a); → 4 → int
 |
 → -(2^{31} -1) to 2^{31} -1

cout << sizeof(- 2^{31}); → 8
 |
 → long long

↳ how to think

→ finding formula for rows and cols

$n=5$

row	stars
0	0
1	0
2	1
3	2
4	3

→ formula -

0 to $< n-1$

$n-1$

-1

0

1

2

3

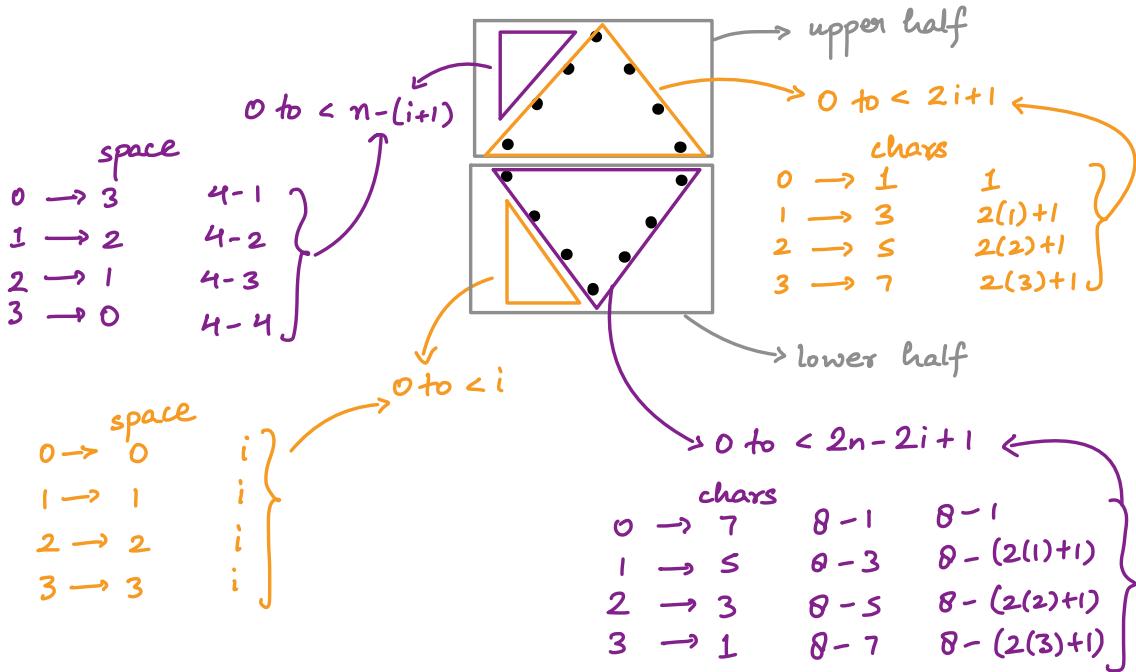
no. of times loop runs

as condition fails ($0 < -1$)

→ to do anything n times

↳ `for(i=0 ; i<n ; i++) {}`

→ break the complex patterns



Bitwise Operators

W2-L2

→ use on bit level

And $(a \& b)$ 1 if both bits are 1

Or $(a | b)$ 1 if any or both bits are 1

not $(\sim a)$ negate the result

nor $(a ^ b)$ same values $\rightarrow 0$
diff. values $\rightarrow 1$

~ 5

$\sim 5 \rightarrow 0 \dots 0101$

$\sim 5 \rightarrow 1 \dots 1010$

↳ how compiler read this

↳ 2's complement

$0 \dots 0101 \rightarrow 1$'s complement

$0 \dots 0110 \rightarrow 2$'s complement

-6

So $\sim 5 = -6$

Left and right shift operators

<<

shift all bits to left

* by 2 (not in every case)

↳ if MSB is 1 and

2nd MSB is 0

>>

shift all bits to right

/ by 2 (not in every case)

↳ in -1

$a = a \ll b$ a left shifts, b times \rightarrow result $\rightarrow a \times 2^b$

$a = a \gg b$ a right shifts, b times \rightarrow result $\rightarrow \frac{a}{2^b}$
b cant be -ve

↳ in case of -ve

$a = 5;$

↳ gives 8v

$a = a \ll 1;$ $a = 10$

$a = 5;$

$a = a \ll 2;$ $a = 20$

in left shift \rightarrow filled with 0

in right shift \rightarrow filled with

0 and 1
in +ve no.
in -ve no.

right shift in -ve number

-ve no. in memory $\rightarrow 1 \dots$

↓ right shift

1 1 ...

signed bit is used to fill
the vacant bit

ex-

$s \rightarrow 0 \dots 0 101$

$-s \rightarrow 1 \dots 1 011$

$-s \gg 1 \rightarrow 1 \dots 1 01 \rightarrow -3$

$-1 \gg 1 \rightarrow -1$

left shift in number where MSB is 1

and 2nd MSB is 0

no. $\rightarrow 1 0 \dots \rightarrow$ -ve no.

left shift $\rightarrow 0 \dots$

\rightarrow +ve no.

Pre- Post → Increment / Decrement Operator

pre- increment

↳ $++a$

↳ first increment by 1, then use

post - increment

↳ $a++$

↳ first use then increment by 1

pre- decrement

↳ $--a$

↳ first decrement by 1, then use

post - decrement

↳ $a--$

↳ first use then decrement by 1

```
int a = 5;  
cout << (++a) * (++a);
```

output -
49

↳ due to operator
precedence

break and continue

break

↳ exit from that loop

continue

↳ skip that iteration

Variable Scoping -

```
int g= 25;           -----> global variable
int main(){
    int a;           -----> declaration
    int b= 5;         -----> initialization
    b = 10;          -----> updation
    //int b= 15;      -----> redefinition is not allowed
    int c= 7;
    g= 30;
    cout << g;       -----> 30
    if (true){
        int b= 15;
        cout << b;     -----> 15
        cout << c;     -----> 7
        g= 50;
        cout << g;     -----> 50
    }
    cout << a;       -----> gv
    cout << b;       -----> 10
    cout << c;       -----> 7
    cout << g;       -----> 50
}
```

Making global variable is very BAD PRACTICE

Operator Precedence

- order of priority of operator
- no need to remember
- use brackets properly

Switch Case

```
switch (expression) {
```

```
    case value1 :
```

executing body 1

```
    break ;
```

```
    case value2 :
```

executing body 2

```
    break ;
```

:

```
    case value n :
```

executing body n

```
    break ;
```

```
default :
```

executing body

```
}
```

without break

→ all below executing body will also execute

→ continue cannot be used in switch case

→ can only use in loops

can also have
nested switch
case

not
mandatory

Function -

- program linked with well defined task
- why
 - reusable
 - readable
- without
 - bulky
 - lengthy
 - buggy if mistake in any place

syntax -

```
return type function name ( input parameters ) {
    function executing body
}
```

void → empty / no value

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

→ returns 0 to Operating System
 → 0 is used as means of successful execution

→ a cpp file cant have more than 1 main functions

Function Call Stack

function call \leftrightarrow function invoke

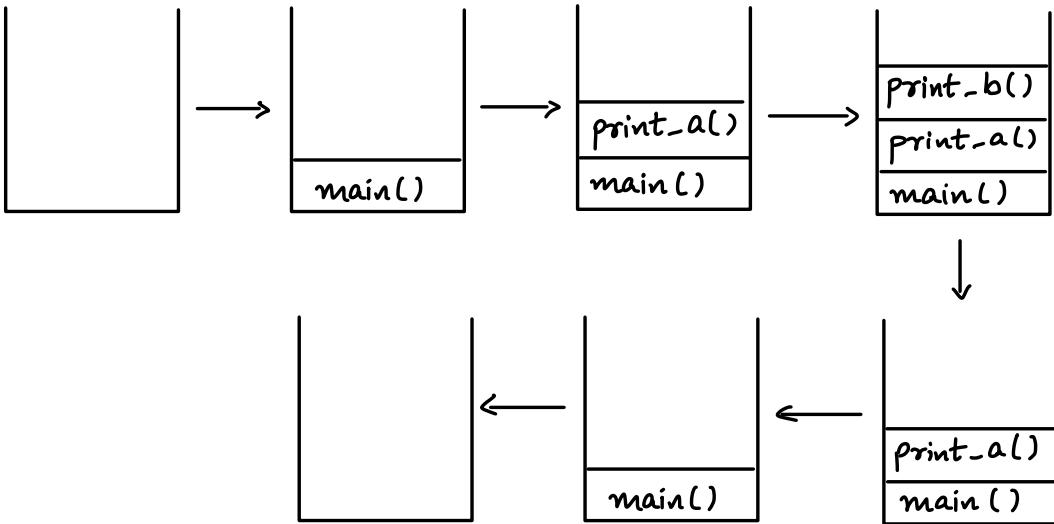
Stack

\hookrightarrow Last In First Out

- tells → what functions
 - which function calls which
 - local variables of function
 - return type of function

ex -

```
int main() {  
    int a=5;  
    print_a(a);  
    return 0;  
}  
  
void print_a(int a){  
    cout << a;  
    int b=3;  
    print_b(b);  
}  
  
void print_b(int b){  
    cout << b;  
}
```



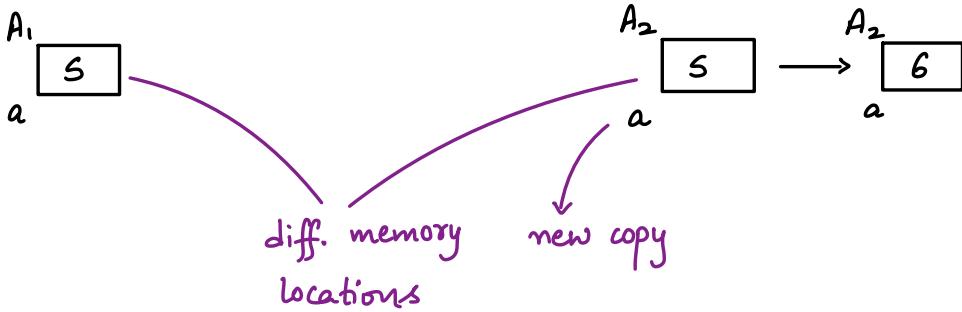
Pass by value

↳ a copy will be created of variables

```
int main() {  
    int a=5;  
    printNumber(a);  
    cout << a;  
}
```

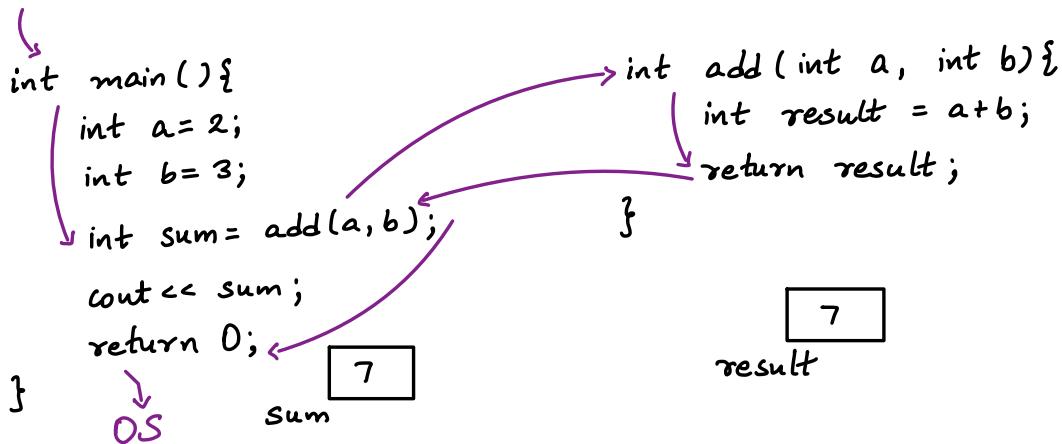
```
parameter  
void printNumber(int a){  
    cout << a;  
    a++;  
    cout << a;  
}
```

argument



Address Of Operator &

```
int n=5;  
cout << &n;           → output -  
address of n
```



Function Order

Order 1

```
int add (int a, int b) {  
    return a+b;  
}  
  
int main () {  
    int a= 3;  
    int b = 5;  
    int sum= add (a,b);  
    cout << sum;  
    return 0;  
}
```

function
declaration
and
definition

Order 2

```
function declaration  
{  
int add (int a, int b);  
  
int main () {  
    int a= 3;  
    int b = 5;  
    int sum= add (a,b);  
    cout << sum;  
    return 0;  
}  
  
int add (int a, int b) {  
    return a+b;  
}
```

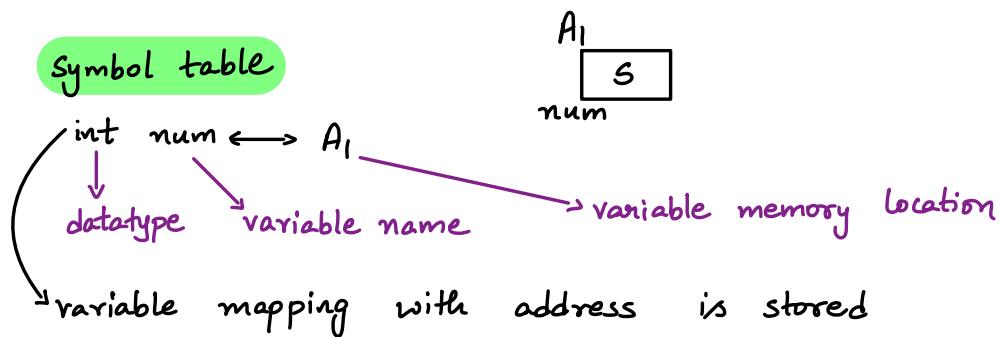
% operator → heavy operator

↳ so try to use it less

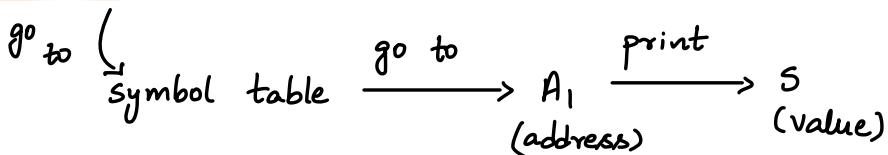
BTS

→ Behind The Scenes

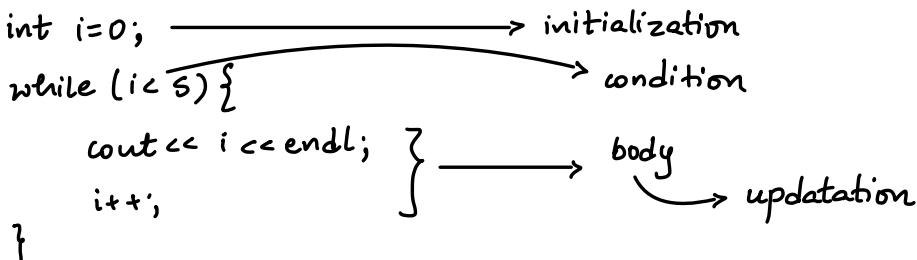
int num=5;



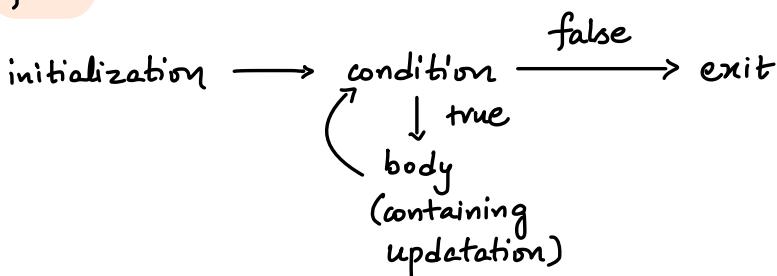
cout << num;



while loop



flow



left and right shift operators

int a = 2;

$a \ll 1;$ → no change

$\text{cout} \ll a;$ → 2

$a = a \ll 1;$ → change → left shift by 1

$\text{cout} \ll a;$ → 4

right shift in -ve no.

↳ link in links.txt in repo

Number System

↳ method to represent numeric values using digits

Decimal Number System

↳ base 10

↳ digits → 0 to 9

Binary Number System

→ base 2

↳ digits → 0, 1

→ used in CPU, memory, computer

→ 0 → power off

→ 1 → power on

→ number, images, all files & folder are in binary

Decimal to Binary

→ divide no. by 2

→ store remainder

→ repeat above steps until no. is 0 or 1

→ reverse the bits so obtained

Binary to Decimal

- multiply each bit with its place value
 - ↳ base i
- add all products
 - ↳ 2^i

Time & Space Complexity

Time Complexity

- amount of time taken by an algo as a function of length of input
- not actual time
- it defines CPU operations
- use case -
 - to make efficient programs
 - ask by interviewer after every sol. you give

Space Complexity

- ↳ amount of space taken by an algo as a function of length of input

Units to represent Complexity

Big O → upper bound → worst case

Theta Θ → average case

Omega Ω → lower bound → best case

Big O Complexities

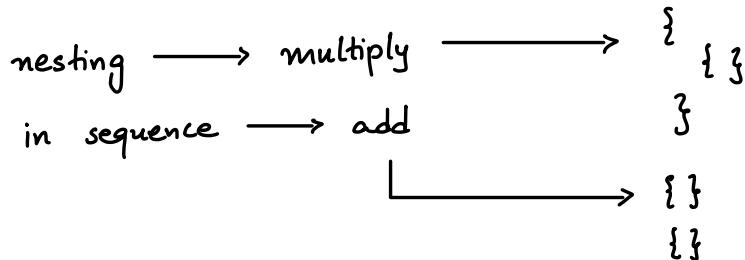
$O(1)$ → Constant time

$O(n)$ → Linear time

$O(\log_2 n)$ → Logarithmic time

$O(n^2)$ → Quadratic time

$O(n^3)$ → Cubic time



$$f(n) = 4n^4 + \frac{n^3}{5} + \log n + n \log n \rightarrow O(n^4)$$

Complexity Order

$$\begin{aligned} O(1) &< O(\log_2 n) &< O(\sqrt{n}) &< O(n) &< O(n \log_2 n) &< O(n^2) \\ &< O(n^3) &< O(2^n) &< O(n!) &< O(n^n) \end{aligned}$$

ARRAY

W3-L1

- Data Structure to store similar items
 - ↳ same datatype
- Continuous memory location space
- use case
 - ↳ for multiple huge same kind of data
`int a[30000];` → 30000 variables are ready

continuous memory location

↳ memory wastage
if needable memory is present but not in continuous way

`int a = 5;`

A



a

symbol table

`int a ↔ A`

`int arr ↔ A1`

Declaration

`int arr[5];`

$A_1 \rightarrow A_1 + 4 \rightarrow A_1 + 8 \rightarrow A_1 + 12 \rightarrow A_1 + 16$



arr

20 bytes

base address ↳ continuous space

`cout << arr ;` \longrightarrow A₁

`cout << &arr ;` \longrightarrow A₁

Initialization

`int arr [7] = { 2, 4, 6, 8, 10 };`

`int arr2 [5] = { 2, 4, 6, 8, 10 };`

`int arr3 [10] = { 2, 4, 6, 8, 10 };` \longrightarrow remaining 5 will be 0

`int arr4 [4] = { 2, 4, 6, 8, 10 };` \longrightarrow ERROR

`int arr5 [10] = { 0 };` \longrightarrow initializing all values with 0

Making array at runtime

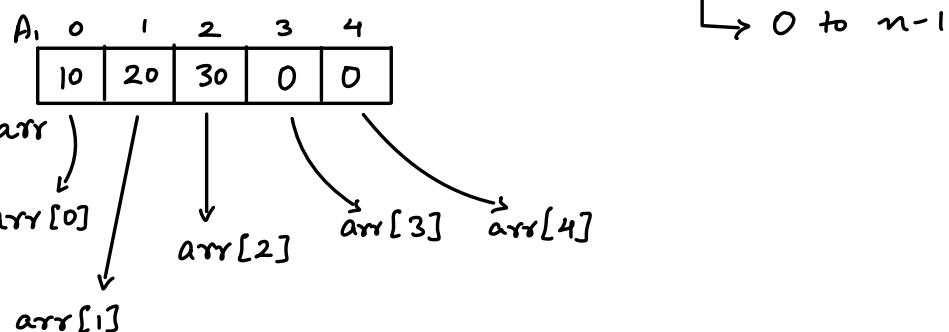
`int n;`

`cin >> n;`

`int arr[n];` \longrightarrow BAD PRACTICE

Index and Access in memory

`int arr[5] = { 10, 20, 30 };` \longrightarrow 0th based indexing



$\text{arr}[i] \longrightarrow$ value at address $[\text{arr} + (i * \text{size})]$
 that's why 0 based indexing

A_i
 index
 due to int
 (datatype size)

taking input in array

$\hookrightarrow \text{cin} \gg \text{arr}[i];$

Arrays and Function

$\hookrightarrow \text{func}(\text{int arr[], int size})\{$

}

\hookrightarrow pass by reference
 \hookrightarrow updation in actual array
 \hookrightarrow always pass size alongwith arr

```

int main() {
    int arr[] = {5, 6};
    int size = 2;
    func(arr, size);
    return 0;
}
  
```

```

void func(int a[], int size) {
    a[0] = a[0] + 10;
}
  
```

5	6
arr	

`sizeof(int);` → 4 → in bytes

`int arr [5];`

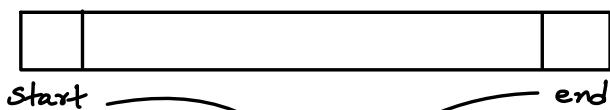
`sizeof(arr);` → 20 → in bytes

linear search in array

INT_MIN and INT_MAX

- to find max. , start ans with INT_MIN
- to find min. , start ans with INT_MAX

2 pointer approach



use of 2 variables as extreme points

Vector

- Data structure
- Same as array but dynamic
 - size not fixed
- default size → 0
- if gets full and new items are inserted
 - size gets doubled

Initialization

- vector <int> arr {10, 20, 30}; →

10	20	30
----	----	----
- vector <int> arr (5); →

0	0	0	0	0
---	---	---	---	---
- vector <int> arr (5, -2); →

-2	-2	-2	-2	-2
----	----	----	----	----
- int n;
cin >> n; → let n = 5
- vector <int> arr(n); →

0	0	0	0	0
---	---	---	---	---
- vector <int> arr (n, 10); →

10	10	10	10	10
----	----	----	----	----

Insertion -

arr.push_back (5);

declaration

vector <int> arr;

→ arr.size() → 0

→ arr.capacity() → 0

Remove

arr.pop_back();

Size -

arr.size();

→ no. of elements it stores

Empty or Not

arr.empty();

Capacity -

arr.capacity(); \longrightarrow * by 2 if arr gets fully filled
and a new element is inserted

→ no. of elements it can store

→ in initialization, capacity = size in all methods

sizeof(arr); \longrightarrow compiler dependent initially

cout << arr; \longrightarrow give ERROR

→ Xor \longrightarrow cancels out same element

$$0 \wedge \text{ans} = \text{ans} \quad \begin{cases} 0 \wedge 1 = 1 \\ 0 \wedge 0 = 0 \end{cases}$$

for each loop

```
for (auto val: arr){  
    cout << val << ' ';  
}
```

2D Arrays

→ use case

→ to work on multiple rows and columns

Declaration -

`int arr[m][n];` → $m \times n$ elements

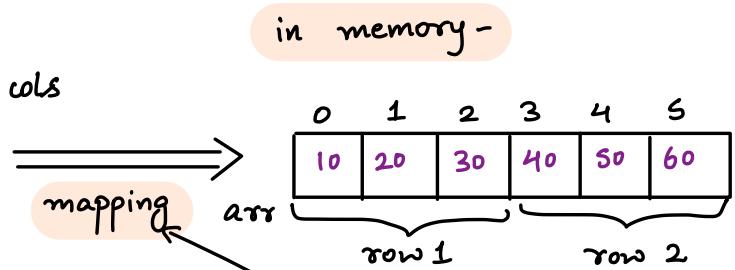
cols → 0 to $n-1$
rows → 0 to $m-1$

`int arr[2][3];`

visualize -

	cols		
0	10	20	30
1	40	50	60
rows	0	1	2

in memory -



Access -

`arr[i][j];`

col index $0 \leq j < n$
row index $0 \leq i < m$

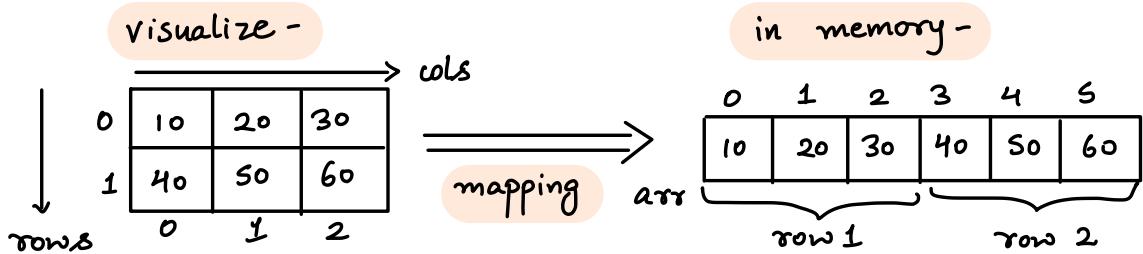
Mapping -

$$\text{linear_index} = c * i + j$$

col index
row index
no. of cols

Initialization -

```
int arr [2][3] = {{10, 20, 30}, {40, 50, 60}};
```



2D Arrays and function -

→ pass by reference

```
func ( arr [ ] [500], int rows, int cols )
```

this value and
no. of cols
in array
passed in func
should be same

cannot leave blank

why if dont know, put large value

for mapping

→ linear_index = c * i + j

→ So that compiler can know

2D Array -

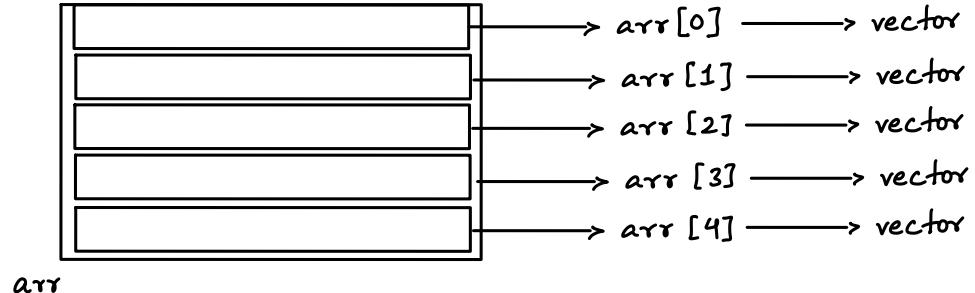
→ to make dynamically

→ vector of vectors

2D Vector

Declaration -

```
vector<vector<int>> arr;
```



Declaration -

```
vector<vector<int>> arr;
```

```
vector<vector<int>> arr(m);
```

Number of rows

arr.size()

Number of cols

arr[i].size

in ith row

Initialization

```
vector<vector<int>> arr
```

```
vector<vector<int>> arr (rows, (vector<int> (cols, value)));
```

rows → no. of rows in arr

cols → no. of cols in arr

value → initial value in all elements
of all 1D vectors

initialization of 1D
vectors in arr

```
vector<vector<int>> arr(2, vector<int>(4, 101));
```



101	101	101	101
101	101	101	101