

- more important note and Week Lecture / homework / recording
- Data Structure
- Heading
- Subheading or important point

Every week from new page

github.com/
Ujjwal2327/
DSA-SUPREME
CODES

Ujjwal
Maheshwari

linkedin.com.in/
ujjwal-maheshwari-
164886202

CONNECT

<https://www.linkedin.com/in/ujjwal-maheshwari-164886202/>

<https://github.com/Ujjwal2327/DSA-SUPREME>

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

- └→ cplusplus.com
- └→ cppreference

→ Think on paper → with 5 testcases atleast

→ Write readable codes

→ In interviews, tell approaches of questions using example

→ Signs of beginner → no logic build

- ↓
 - cant solve new ques
 - forget the approach
 - memorizing the ans

Improve → with more no. of questions

with time

with dry run on mind logic, not on code

with your new approach

(even brute force)

with a lot of practice on syntax

with consistency

→ Focus on placement, not on feeling

You are not studing to get fun

You are studing to get placement

First placement, then fun and interest.

Also focus on health of you and your parents

Bhaad me gya interest yaar, placement ke baad
karna

Jo duniya sunna chahati hai, use sunado
Growth is important

Week 4 [Connect] Class 1:45 - 2:01

→ 20-30 interview experience

↳ to break Google pattern

→ Web Dev and DSA → both are important

CP → do if you enjoy it.

→ At least learn one more approach if you
are doing questions with map

Many times if you tell map approach,
interviewer asks another approach

- Tag all khatarnak questions
 - ↳ Otherwise you will forget them after some time
- Revise and code all, every after 2 weeks
- For 6th sem student (like me),
 - ↳ At least do potd on leetcode everyday along with course
- Make notes
- In dev, you should have at least 2 major projects → 1 → in dot batch
2 → group project if you want
- Focus on Networking,
After 5 months, you should have atleast 2 friends in every company
- All questions doing in batch, should be on your tips

→ Focus on accuracy more than speed

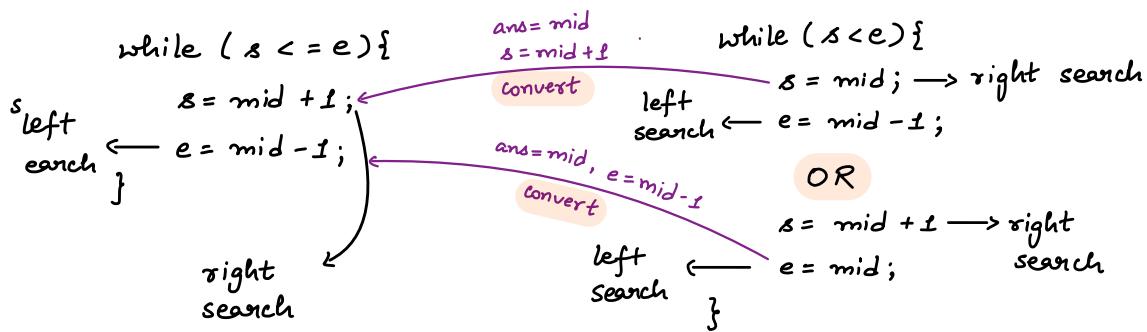
IMPORTANT C++ NOTES

- 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
 - $0 \wedge 1 = 1$
 - $0 \wedge 0 = 0$
- In ASCII → 'O' → 48
 'A' → 65
 'a' → 97

→ Search Space

- find range of search space (start & end) in ques of. Binary Search Questions
- store mid in ans if needed

→ In binary search questions



→ Types of ques in binary search

→ 1st type → classic questions

→ 2nd type → find in search space (range)

→ predicate function

→ 3rd type → observation in index

logic to decide
either left or
right

→ In sorted array, try to apply binary search or
2 pointer / 3pointer approach

→ To maximize or minimize
try to use binary search using concept of search space

→ find search space of answer

→ find mid

→ if `isPossibleAns(mid)` → go to left / right acc.
to the ques.

STL ALGORITHMS

binary search in array

```
bool ans = binary_search( arr, arr + size, target);
```

lower bound in array

```
auto ans = lower_bound( arr, arr + size, target);
```

→ iterator

upper bound in array

```
auto ans = upper_bound( arr, arr + size, target);
```

binary search in vector

```
bool ans = binary_search( arr.begin(), arr.end(), target);
```

lower bound in vector

```
auto ans = lower_bound( arr.begin(), arr.end(), target);
```

upper bound in vector

```
auto ans = upper_bound( arr.begin(), arr.end(), target);
```

INBUILT FUNCTIONS OF STRINGS

length

`str.length();`

empty or not

`str.empty();` → 1 if empty, otherwise 0

pushback

`str.push-back('char');`

pop-back

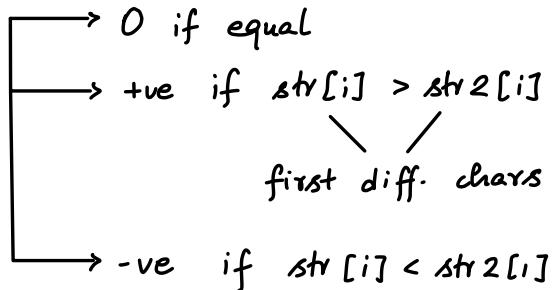
`str.pop-back();`

substring

`ans = str.substr(starting index, no. of chars);`

compare

`str.compare(str2);`



find

str. find (str 2);

→ starting index if found
→ string::npos if not found

string::npos

highest possible value

replace

str. replace (starting index, no. of chars, str 2);

erase

str. erase (starting index, no. of chars);

insert

str. insert (starting index, str 2);

string to int

int ans = stoi (str);

Sort function in strings -

→ works on randomised quick sort

```
string str = "babbar";
```

```
sort(str.begin(), str.end()); → aabbby
```

```
sort(str.begin(), str.end(), greater<char>());
```

→ rbbbbaa

Custom Comparator -

```
bool cmp(char a, char b){
```

return a < b; → can be any function
according to need

```
}
```

```
bool cmp2(char a, char b){
```

return a > b;

```
}
```

```
int main(){
```

```
    string str = "babbar";
```

```
    sort(str.begin(), str.end(), cmp);
```

cout << str; → aabbby

```
    string str2 = "babbar";
```

```
    sort(str.begin(), str.end(), cmp2);
```

cout << str2; → rbbbbaa

```
    return 0;
```

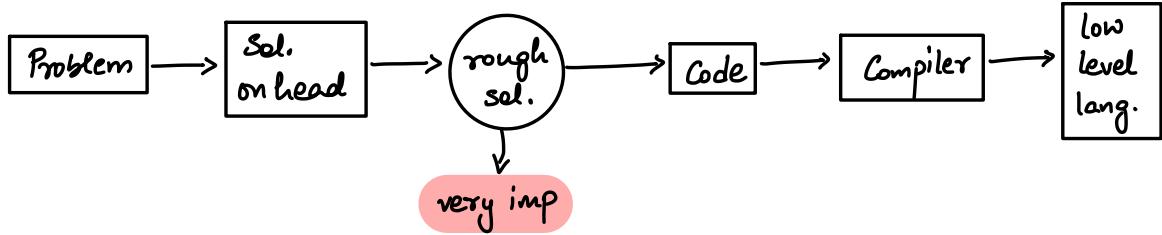
```
}
```

LET'S GO

Thought process to solve a problem-

W1-L1

- Understand a problem
- input values
- find approach



Algorithm - Sequence of steps

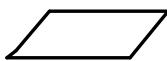
Flowchart - Graphical representation of algo

Components -



terminator

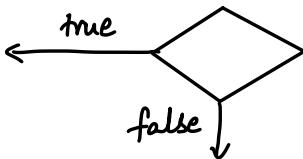
for start / end



for input /output read /write



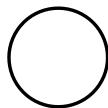
computation / process / declaration



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

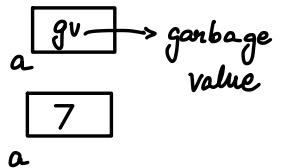
→ to end any statement

→ string

cout << endl; → for next line

cout << '\n';

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



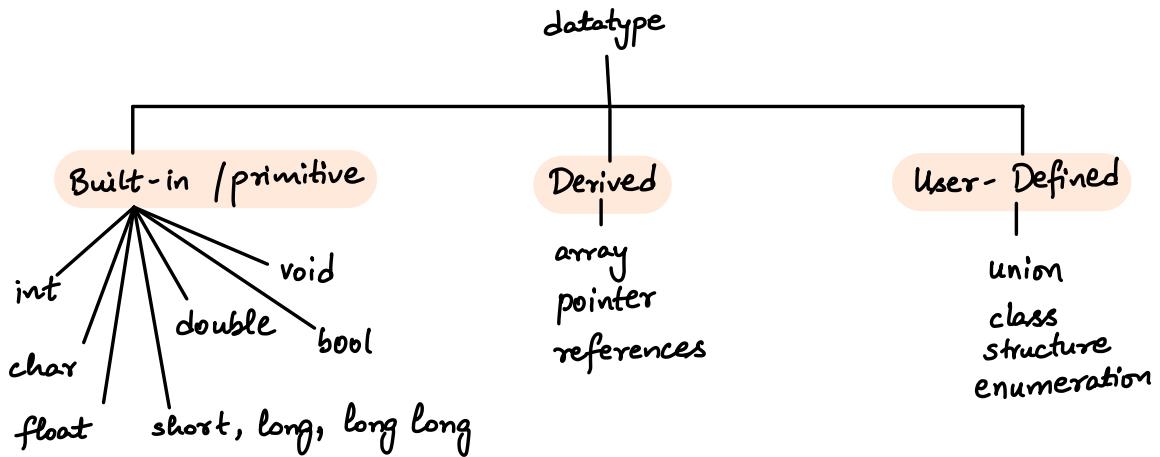
Variables

named memory location

int a = 5;
 ↓
 datatype 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

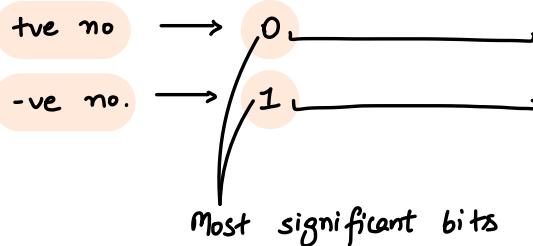
short \rightarrow 2 byte \rightarrow 16 bits

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;`

$7 \rightarrow 0\ldots00111$ } 32 bits

ignore -ve sign
find binary equivalent

1's (7) $\rightarrow 1\ldots11000$

find 2's complement

2's (7) $\rightarrow 1\ldots11001$

→ this is how -7 will be stored in memory

How to read -ve no. present in memory

→ take 2's complement

$1\ldots11001$

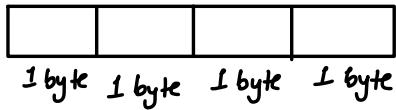
→ 1's complement $\rightarrow 0\ldots00110$

2's complement $\rightarrow 0\ldots00111$

→ $+7$

-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

(1) 0...0

011...1

0.....0

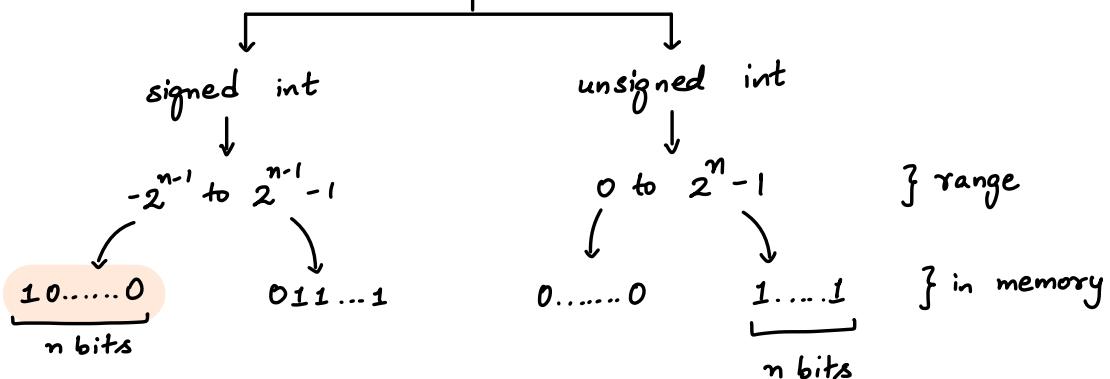
1....1

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

} 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 → 100 111 0000 1111
binary conversion 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]

Relational Operator

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

```

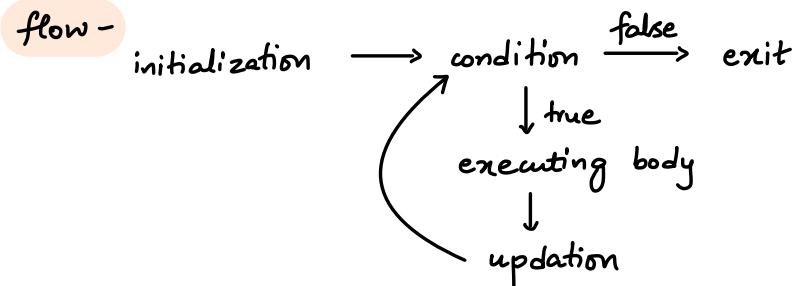
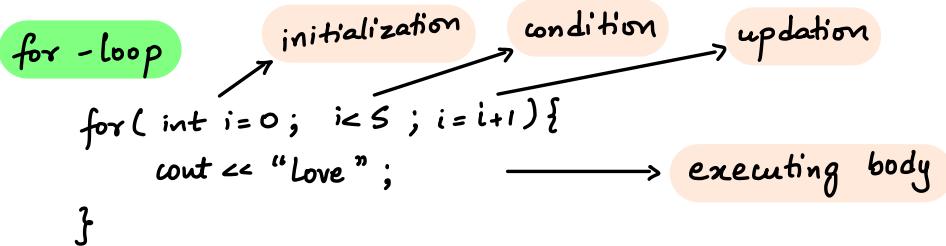
if (cond 1)
    execute 1
else {
    if () { }
    else () { }
}

```

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

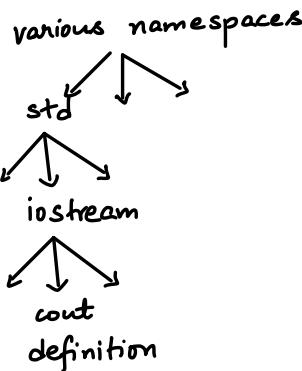
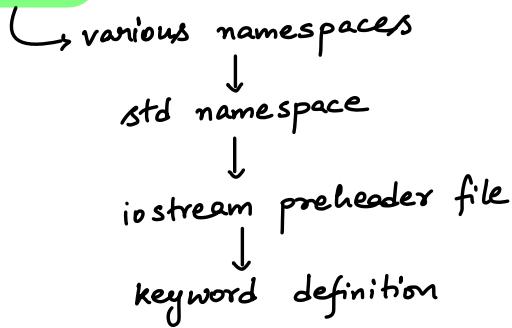
C++, C - Middle Level language

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

patterns

W2-L1

↳ 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

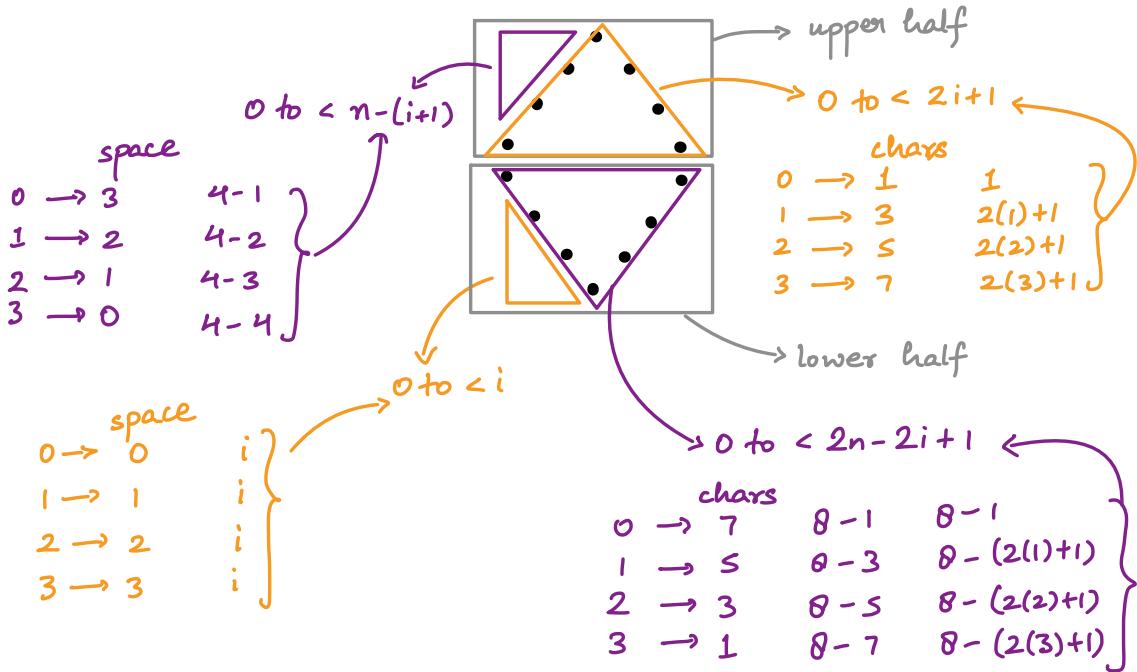
no. of times loop runs

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

$\sim 5 \rightarrow 1 \dots 1010$

$\sim 5 \rightarrow 1 \dots 1010$

↳ 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

→ links.txt in repo

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
- main cant have return type other than int in offline compiler

Function Call Stack

function call \leftrightarrow function invoke

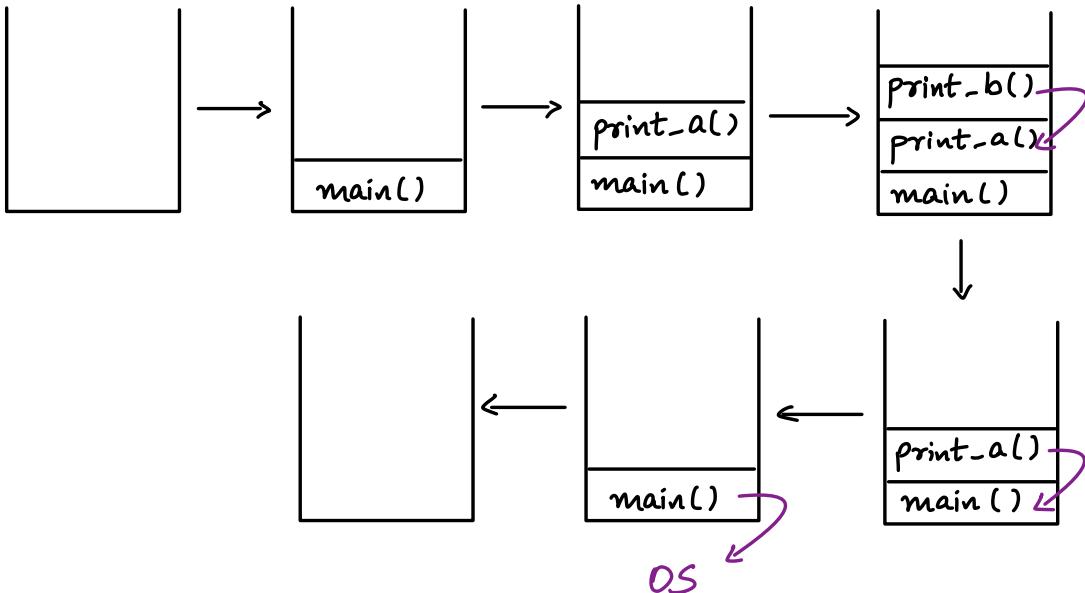
Stack

\hookrightarrow Last In First Out

- \hookrightarrow tells what functions
 - \hookrightarrow which function calls which
 - \hookrightarrow local variables of function
 - \hookrightarrow 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;  
}
```



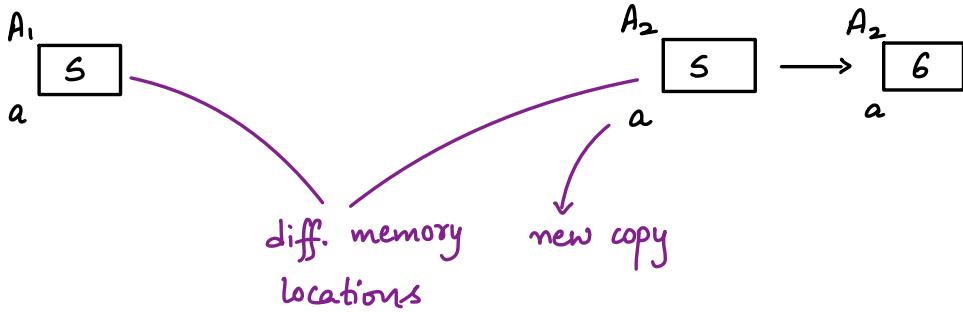
Pass by value

↳ a copy will be created of variables

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

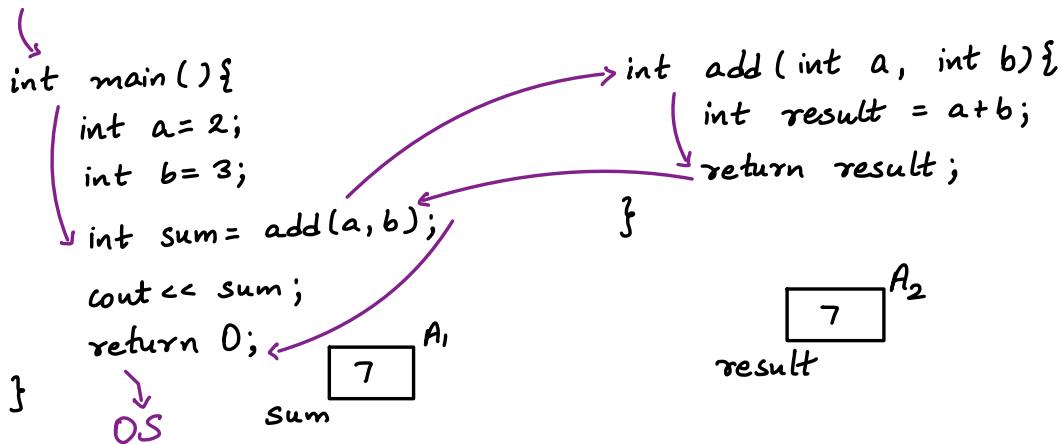
```
parameter  
void printNumber(int a){  
    cout << a;  
    a++;  
    cout << a;  
}
```

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;  
}
```

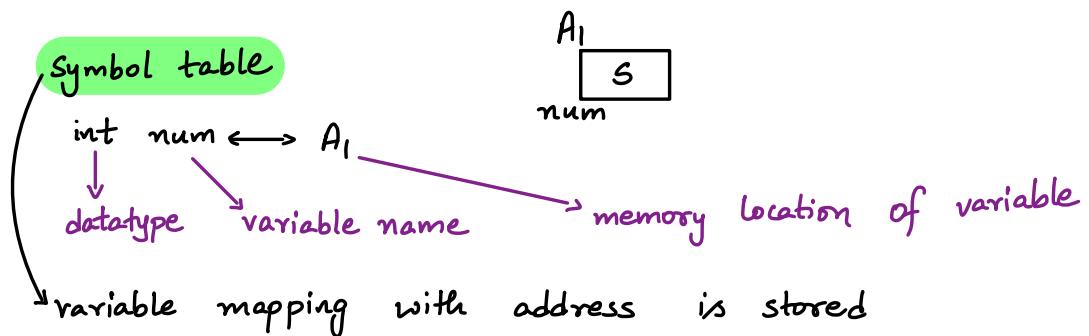
% operator → heavy operator

↳ so try to use it less

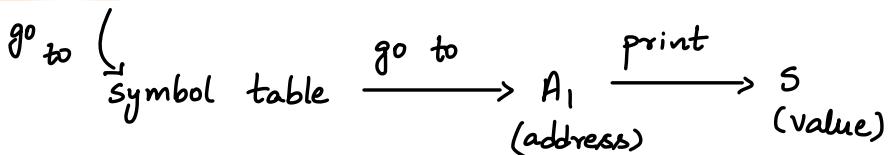
BTS

→ Behind The Scenes

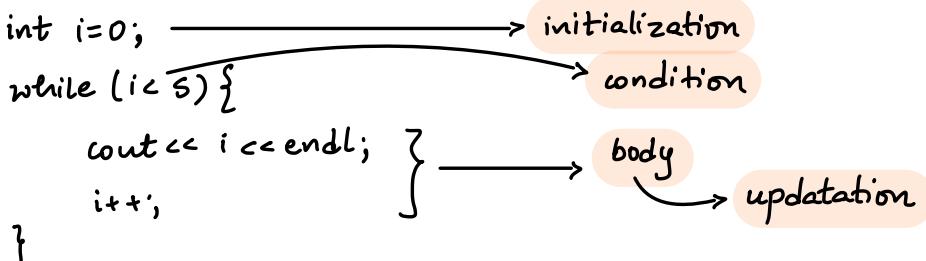
int num=5;



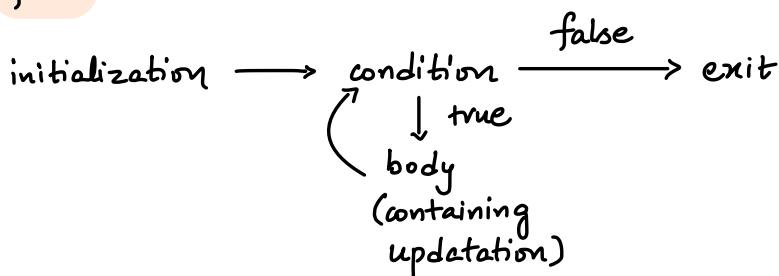
cout << num;



while loop



flow



left and right shift operators

int a = 2;

$a \ll 1;$ → no change

$\text{cout} \ll a;$ → 2

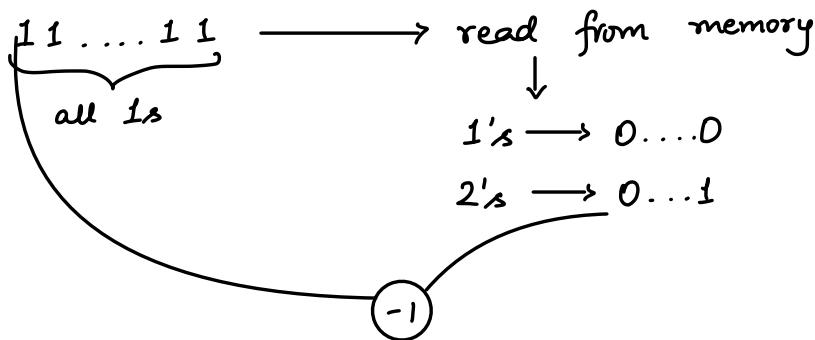
$a = a \ll 1;$ → change → left shift by 1

$\text{cout} \ll a;$ → 4

right shift in -ve no.

↳ link in links.txt in repo

How -1 is stored in memory -



$$\sim a = -(a+1) \quad \text{and} \quad \sim(\sim a) = a$$

ex - $a = 5; \rightarrow 0\dots0101$

$a = \sim a; \rightarrow 1\dots1010 \rightarrow -6 \rightarrow -(5+1)$

$a = -6;$

↳ 1...1010

read

-6

$a = \sim a; \rightarrow 0\dots0101$

↳ 5 → $-(-6+1)$

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

W3-R

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

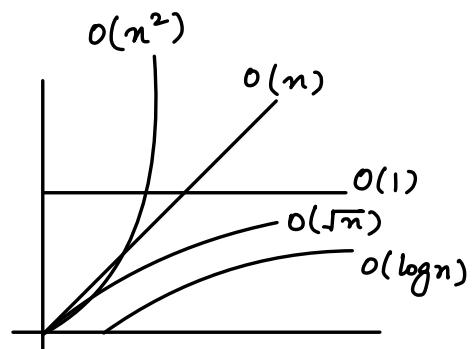
$O(n)$ → Linear time

$O(\log_2 n)$ → Logarithmic time

$O(n^2)$ → Quadratic time

$O(n^3)$ → Cubic time

nesting → multiply → { }
in sequence → add → { }
| → { }
| → { }



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

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;`

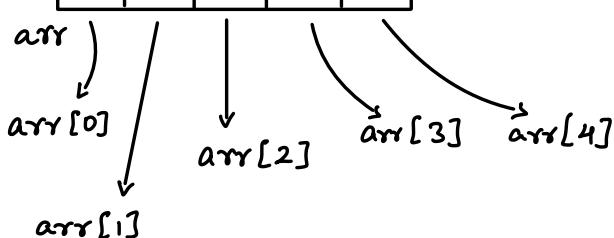
`int arr[n];` \longrightarrow BAD PRACTICE

Index and Access in memory

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

A ₁	0	1	2	3	4
	10	20	30	0	0

\hookrightarrow 0 to n-1



$\text{arr}[i] \longrightarrow$ value at address $[\text{arr} + (i * 4)]$
 thats why 0 based indexing

A_1 index
 due to int (datatype size)

taking input in array

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

due to internal working

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];`

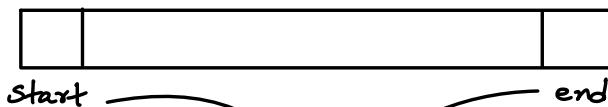
`sizeof(arr);` → 20 → in bytes

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

To find size of array

`int arr [] = { 1, 2, 3, 4 };`

`int size = sizeof(arr) / sizeof(int);`

→ datatype

Vector

W3-L2

- Data structure
 - Same as array but dynamic
 - ↳ size not fixed
 - default size → 0
 - if gets full and new items are inserted
size gets doubled
- pass by value in functions

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; size → 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);
```

Remove

```
arr.pop_back();
```

Size -

```
arr.size();
```

→ no. of elements it stores

declaration

```
vector <int> arr;
→ arr.size() → 0
→ arr.capacity() → 0
```

Empty or Not

arr.empty(); \longrightarrow true if 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

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

for each loop

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

2D Arrays

W3-L3

→ use case

→ to work on multiple rows and columns

Declaration -

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

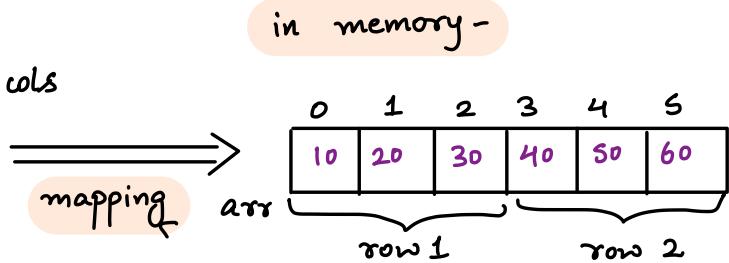
cols → 0 to $n-1$
rows → 0 to $m-1$

`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 -

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

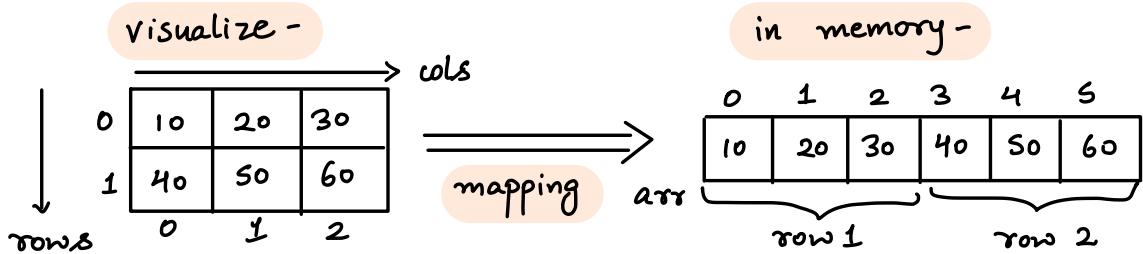
no. of cols
row index
col index

$$i = \text{linear_index} / c$$

j

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 -

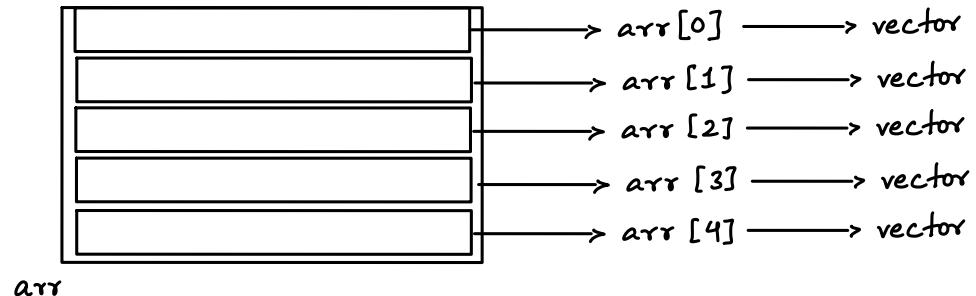
→ to make dynamically

→ 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 *i*th row
→ size of *i*th row

Initialization

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

size
↑

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

rows → no. of rows in arr

cols → no. of cols in arr

size of 1D arrays

initialization of 1D
vectors in arr

value → initial value in all elements

of all 1D vectors

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

101	101	101	101
101	101	101	101

arr

Searching and Sorting

W4-L1

Searching

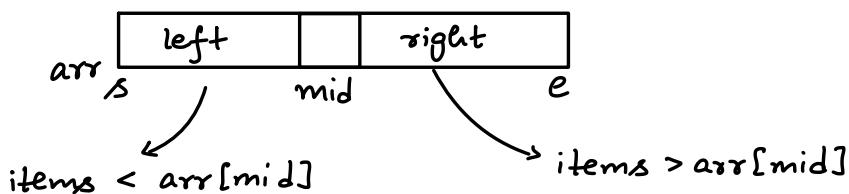
Linear Search

```
int linearSearch ( vector <int> arr, int target ) {  
    int n = arr.size();  
    for( int i=0; i<n ; i++ ) {  
        if ( target == arr[i] )  
            return i;  
    }  
    return -1;  
}
```

T, C - $O(n)$

Binary Search -

- condition → sorted order → monotonic function
- binary → 2 → start and end pointers



```

int binarySearch ( int arr[], int n , int target ) {

    int s= 0, e=n-1;

    int mid = s+(e-s)/2;

    while( s<=e) {

        int element = arr[mid];

        if (target == element)
            return mid;

        else if ( target < element)
            e=mid - 1; —→ search in left subarray

        else
            s= mid + 1; —→ search in right
                           subarray

        mid = s + (e-s)/2;
    }

    return -1;
}

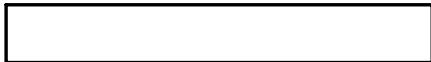
```

issue in $mid = \frac{s+e}{2}$; —→ int overflow
 if $s+e < INT_MAX$

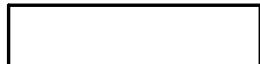
└—————> so use $mid = s + \frac{e-s}{2}$;

T.C - $O(\log_2 n)$

T.C. of binary Search



n



$n/2$

:



$n/2^k$ after k times

at last $\frac{n}{2^k} = 1$

$$k = \log_2 n$$

So loop runs $\log_2 n$ times

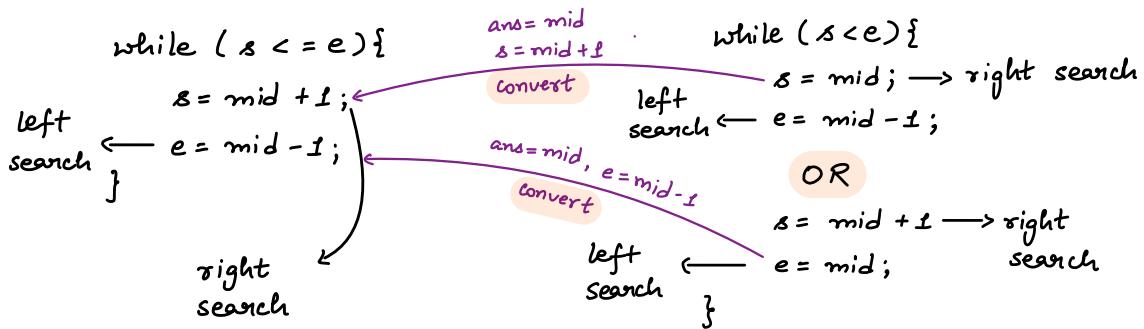
$$\text{T.C.} = O(\log_2 n)$$

W4-L2

→ Search Space

- find range of search space (start & end) in ques of. Binary Search Questions
- store mid in ans if needed

→ In binary search questions



cout << (int)(-3.74);

W4-L3

→ - [int(3.74)]

→ - (3) → - 3

cout << (-22)/7; → - 3

cout << 22/(-7); → - 3

Types of ques in binary search

→ 1st type → classic questions

→ lower bound

upper bound

peak in mountain array

can also find array is sorted or not

pivot in sorted rotated array

search in sorted rotated array

↓ pivot index = n-1

→ 2nd type → find in search space (range)

- predicate function
- logic to decide either left or right
- sqrt of a no.
- divide 2 numbers

Advance Binary Search Problems

→ Book allocation

Painters Partition

Aggressive Cows

Roti / Paratha Spoj

Eko Spoj

→ 3rd type → observation in index

- missing element in sorted array
- add appearing element in array

Sorting

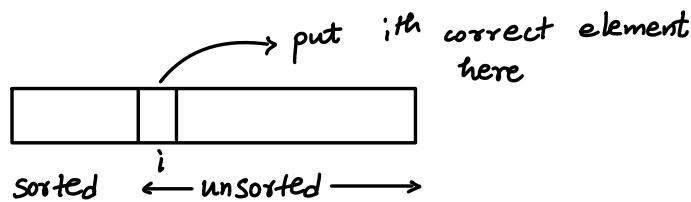
W4-L5

- putting all elements either in increasing order or decreasing order

Selection Sort -

- select minimum element and put it in its right position
- select correct element for i^{th} index
 - minimum

```
void selectionSort ( int arr[], int n){  
    for( int i=0; i<n-1; i++) {  
        mini = i;  
        for( int j=i+1 ; j<n ; j++) {  
            if ( arr[mini] > arr[j] )  
                mini = j;  
        }  
        swap (arr[i], arr[mini]);  
    }  
}
```



T.C. $O(n^2)$

S.C. $O(1)$

Use Case - for small size array

Bubble Sort -

→ in i^{th} round put i^{th} largest element to its correct position using adjacent comparisions

```
void bubbleSort ( int arr[], int n){  
    for( int i=0 ; i<n-1 ; i++) {  
        bool swapping = false;  
        for( int j= 0 ; j<n-i-1 ; j++) {  
            if (arr[j] > arr[j+1]) {  
                swap ( arr [j], arr [j+1]);  
                swapping = true;  
            }  
        }  
        if (swapping == false)  
            break;  
    }  
}
```

T.C. - $O(n^2)$ → reverse sorted
Worst and average case

$O(n)$ → best case → already sorted

S.C. - $O(1)$

Use Case - To put i^{th} largest element to its correct position

Insertion Sort -

→ take an element and insert it on its correct position by shifting

```
void insertionSort( int arr[], int n){
```

```
    for( int i = 1; i < n; i++ ) {
```

```
        int curr = arr[i];
```

```
        int j = i - 1;
```

```
        for( ; j >= 0; j-- ) {
```

```
            if( arr[j] > curr )
```

```
                arr[j+1] = arr[j]; // shifting
```

```
            else
```

```
                break;
```

```
}
```

```
        arr[j+1] = curr; // inserting
```

```
}
```

```
}
```

T.C. - $O(n^2)$ → worst & average case

$O(n)$ → best case

S.C. - $O(1)$

Use Case - When array is small or when array is partially sorted

CHAR ARRAYS & STRING

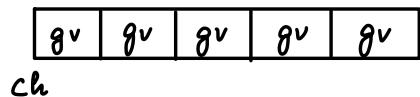
W5-L1

Char Arrays -

→ Data structure → used to store data

Not Datatype → tells type of data

char ch[5];



Taking input in char array

char ch[7];

`cin >> ch[i];`

`cin >> ch;` → by default NULL char will
insert at end
↓
NULL char shows string termination

→ `cin` reads until it gets any white space

→ space ''
tab '\t'
endl '\n'

`cout << ch;` → print until it gets delimiter

```
char ch [10];
```

cin >> ch ; → Ujjwal

store in buffer memory

'U'	'j'	'j'	'w'	'a'	'l'	'\0'
-----	-----	-----	-----	-----	-----	------

buffer

copy in memory of ch

'U'	'j'	'j'	'w'	'a'	'l'	'\0'	gv	gv	gv
-----	-----	-----	-----	-----	-----	------	----	----	----

ch 0 1 2 3 4 5 6 7 8 9

cout << ch ; → Ujjwal → stops after 'l'

because of '\0' char

Overflow -

```
char ch [4];
```

cin >> ch ; → Ujjwal

cout << ch ; → Compiler Dependent

sizeof (char array)

```
char ch [] = "Ujjwal";
```

cout << sizeof(ch) ; → 7

6 + 1

NULL char

get line

`cin.getline (char array, max char to write, delimiter);`

char where taking input stops
↓
by default '\n' → enter

ex - `cin.getline (ch, 50);`

`cin.getline (ch, 50, '');`

Char arrays and function

→ pass by reference

`func (char ch[]){`

}

Size of char array → $\frac{\text{sizeof}(ch)}{\text{sizeof}(char)}$

→ 1

Some inbuilt functions of char array

`strlen(ch);`

`strcmp(ch1, ch2);`

`strcpy(ch1, ch2);`

Strings

- Datatype
- Not Data Structure
- Dynamic char array
- NULL char at last of string

string str; → empty string created

cin >> str; → Ujjwal

cout << str; → Ujjwal str

'U'	'j'	'j'	'w'	'a'	'l'	'\0'
-----	-----	-----	-----	-----	-----	------

getline -

string str;

getline (cin, str);

char array

char ch [100] = "B_abba-\0";

cout << ch; → B_abba-\0

ch [1] = '\0';

ch [6] = '\0';

cout ch; → B

stops just as it gets
NULL char

string

string str = "B_abba-\0";

cout << str;

→ B_abba-\0

str [1] = '\0';

str [6] = '\0';

cout << str;

→ Babbar

Runs till the length of string

Sort function in strings -

W5-L3

→ works on randomised quick sort

```
string str = "babbar";
```

```
sort(str.begin(), str.end()); → aabbby
```

```
sort(str.begin(), str.end(), greater<char>());
```

→ rybbbaa

Custom Comparator -

```
bool cmp(char a, char b){
```

return a < b; → can be any function
according to need

}

```
bool cmp2(char a, char b){
```

return a > b;

}

```
int main(){
```

```
    string str = "babbar";
```

```
    sort(str.begin(), str.end(), cmp);
```

cout << str; → aabbby

```
    string str2 = "babbar";
```

```
    sort(str.begin(), str.end(), cmp2);
```

cout << str2; → rybbbaa

```
    return 0;
```

}

Hash Map → WILL LEARN LATER

→ Data structure

→ data stored in key-value pair

Initialization

`map<key datatype, value datatype> map-name;`

`map<int, char> m;` → ordered map

`m[0] = 'a';`

`m[1] = 'b';`

`m[25] = 'z';`

`cout << m[0];` → 'a'

`cout << m[25];` → 'z'

`cout << m[20];` → " " → NULL char

`cout << (int) m[20];` → 0

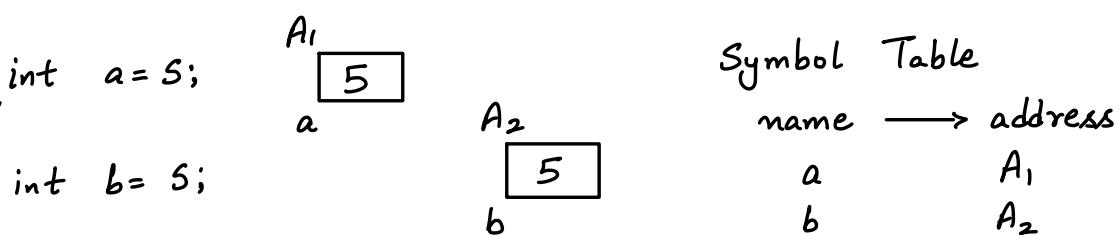
auto keyword

→ finds automatically datatype of variable

SYMBOL TABLE

W6-L1

- Data Structure
- Stores mapping of variable name and memory location address → Done by OS
- entries in symbol table can't be changed



entry of a in symbol table
is made

cout << a; → 5

& Address Of Operator

cout << &a; → A₁ → address of
variable a in
memory

A₂ = A₁ ± 4 → because of consecutive

variables in memory

int datatype
of a and b

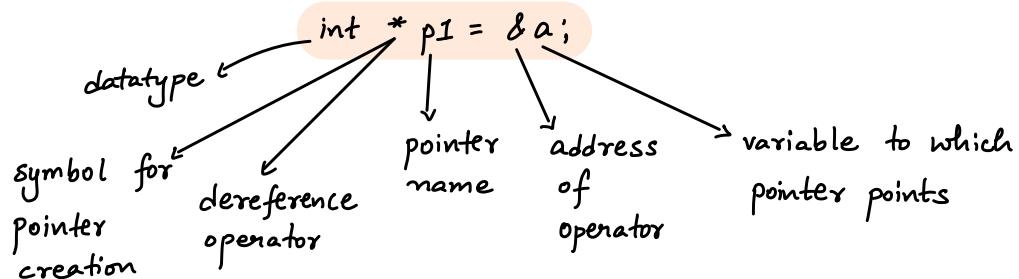
POINTERS

→ stores address

→ NOT a datatype, just a variable
storing address of another variable

```
int a = 5;
```

int * p1 = &a; p1 is a pointer to integer datatype



```
string s = "Ujjwal 2327";
```

string * ptr = &s → ptr is a pointer to string datatype

```
int a = 5;
```

```
int * ptr = &a;
```

```
cout << a; → 5
```

```
cout << * a; → ERROR
```

```
cout << &a; → A1
```

```
cout << ptr; → A1
```

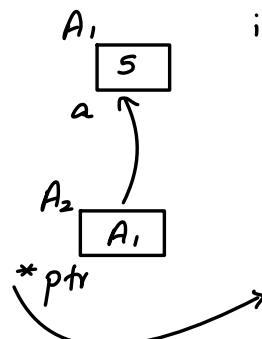
```
cout << * ptr; → 5
```

```
cout << &ptr; → A2
```

symbol table

int a A₁

int * ptr A₂



just to visualize it
as pointer
not a dereference
operator

$* \text{ptr}$ → value at (address stored in ptr)
→ dereference operator

$\& \text{ptr}$ → address of ptr

size of pointer

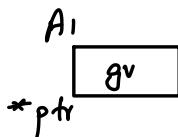
$\text{sizeof}(\text{ptr})$; → 8 → Always
64 bit architecture → it stores address,
datatype does not matter

Use case of pointer

- dynamic memory allocation
- memory management
- pointer arithmetic
 - ↳ go from one location to other
- pass by reference in array
- to create pointer to function
 - ↳ passing a function inside another function as an argument

`int * ptr;` → VERY BAD PRACTICE

`cout << ptr;` → gv → Segmentation fault

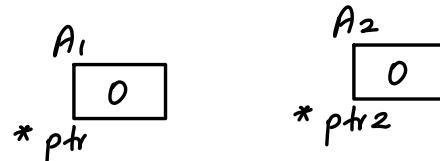


Segmentation fault -

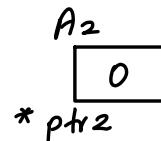
→ using other's memory

NULL Pointer

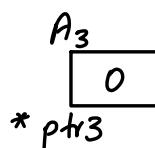
{ int * ptr = 0;



{ int * ptr2 = NULL;



{ int * ptr3 = nullptr;



cout << ptr ; → 0

Segmentation
fault

cout << *ptr ; → ERROR

cout << &ptr ; → A₁

Arithmetic In Pointers

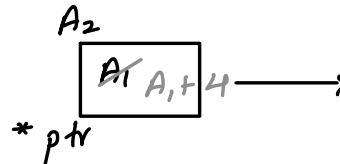
int a=5;



a++;

a

int * ptr = &a;



ptr++;

A₁ to A₁+3 has
already been taken
by integer a,
so next address
will be A₁+4

*ptr++;

int a = 10;

int *ptr = &a;

a 10

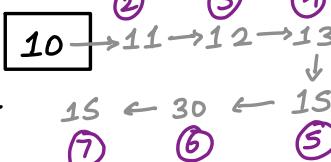
&a A₁

ptr A₁

*ptr 10

&ptr A₂

A₁



① *ptr * 2

② (*ptr) ++

③ ++ (*ptr)

④ a = a + 1

⑤ *ptr = *ptr + 2 15

⑥ *ptr = *ptr * 2 30

⑦ *ptr = *ptr
2 15

⑧ *(ptr++) 15

⑨ *(++ptr) 9v

int a = 5;

int *ptr = a; → ERROR

Copying a pointer

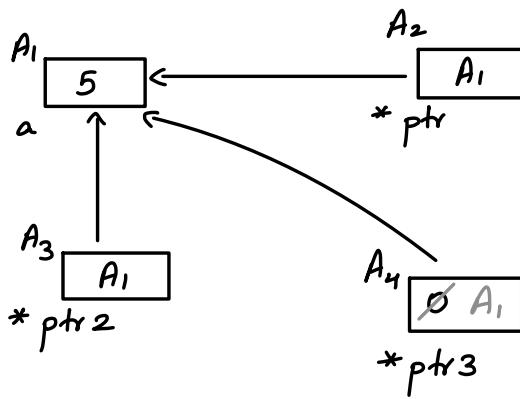
int a = 5;

int *ptr = &a;

{ int *ptr2 = ptr;

{ int *ptr3 = 0;

{ ptr3 = ptr;



ARRAYS & POINTERS

W6-L2

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

CONSTANT pointer to the first element of array

cannot change

also does not have separate memory

arr[i] → element at index i

& arr[i] → address of arr[i]

cout << arr[0]; → 10

cout << &arr[0]; → A₁

{ cout << arr; → A₁

cout << &arr; → A₁
→ from symbol table

Same address unlike pointers

```
int *ptr = arr;
```

cout << *ptr; → 10

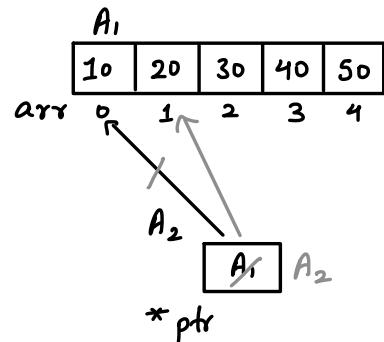
cout << ptr; → A₁

cout << &ptr; → A₂

cout << *arr; → 10

cout << *(&arr); → 10

cout << *(&arr[0]); → 10



Symbol table

type	name	address
int(*)[5]	arr	A ₁
int*	ptr	A ₂

`cout << *arr + 1;` \longrightarrow 11

`cout << *(arr + 1);` \longrightarrow 20

`cout << *(arr + 2);` \longrightarrow 30

`cout << arr[2];` \longrightarrow 30

`cout << 2[arr];` \longrightarrow 30

`arr[i] \longleftrightarrow *(arr + i) \longleftrightarrow i[arr]`

`arr ++;` \longrightarrow ERROR \longrightarrow Entry in symbol table

`ptr ++;` \longrightarrow A₁+4 cant be change

→ You can access subpart of an array using pointers

`cout << *(ptr + 2);` \longrightarrow 40

`cout << *(ptr + 100);` \longrightarrow gv / segmentation fault / out of bound error

Arrays / Array pointers

`int arr [] = {10, 20, 30};`

- ① `cout << arr;` \longrightarrow A₁ } same
`cout << &arr;` \longrightarrow A₁

- ② `arr ++;` \longrightarrow ERROR

- ③ `sizeof(arr);` \longrightarrow 3*4=12

Pointers / Normal pointers

`int *ptr = arr;`

- ① `cout << ptr;` \longrightarrow A₁ } diff.
`cout << &ptr` \longrightarrow A₄

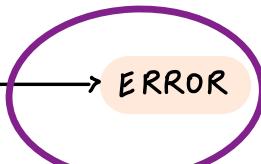
- ② `ptr ++;` \longrightarrow VALID

- ③ `sizeof(ptr)` \longrightarrow ↓
size of address

```
int * p1 = arr;
```

```
int * p2 = &arr;
```

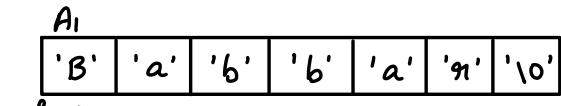
```
int * p3 = &arr[0];
```



Why?

CHAR ARRAYS & POINTERS

```
char ch [] = "Babbar";
```



```
char * ptr = ch;
```



```
char * p = &ch; -----> ERROR
```

```
char * p2 = &ch[0]; -----> valid
```

```
cout << ch; -----> Babbar
```

not an address

```
cout << ptr; -----> Babbar
```

not an address

whole string from that
location until NULL char

cout implementation
is diff. in char
pointers and char arrays

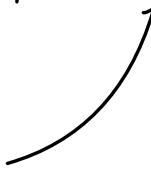
```
cout << &ch; -----> A1
```

```
cout << ch[0]; -----> B
```

```
cout << &ch[0]; -----> Babbar
```

```
cout << *ptr; -----> B
```

```
cout << &ptr; -----> A2
```



$$ch[i] \longleftrightarrow * (ch + i) \longleftrightarrow i[ch]$$

→ ch, &ch[0], and ptr values are addresses
but due to diff. cout implementation in char pointers
and char arrays,
cout << ch , cout << &ch[0] and cout << ptr
will give Babbar

char ch[] = "Sherbano";

char *ptr = ch;

cout << ch ; → Sherbano

cout << *ch ; → S

cout << &ch ; → A₁

cout << *(ch + 3); → n

cout << ptr ; → Sherbano

cout << &ptr ; → A₂

cout << *(ptr + 3); → n

cout << ptr + 2; → erbano

cout << *ptr ; → S

cout << ptr + 8; → " → NULL char

cout << ptr + 9; → gv

`cout << ch[0];` → S

`cout << &ch[0];` → Sherban

`cout << &(*ch);` → Sherban

CHAR AND POINTER

`char ch = 'k';`

`char * ptr = &ch;`

`cout << ch;` → k

`cout << &ch;` → k.....

→ gv
print until it gets '\0'

`cout << ptr;` → k.....

`cout << &ptr;` → A₂ → gv
print until it gets '\0'

`cout << *ptr;` → k

Behind The Scenes

`char ch[10] = "Babber";`

→ 2 step process

① |'B'| 'a'| 'b'| 'b'| 'a'| 'g'| '\0'|

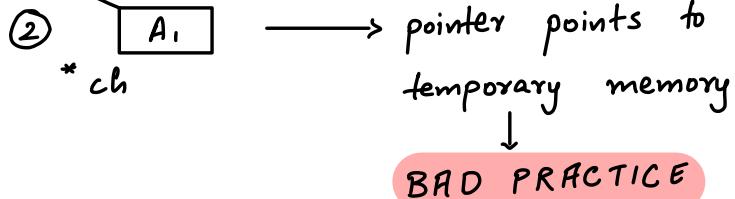
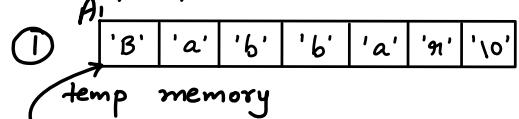
temp memory } copy

② |'B'| 'a'| 'b'| 'b'| 'a'| 'g'| '\0'| gv | gv | gv |

ch

`char * ch = "Babbar"`

→ 2 step process



POINTERS WITH FUNCTIONS

→ a copy of pointer is made

int func (int arr[]){
 cout << arr; → A1
 cout << *arr; → 10
 cout << &arr; → A2
 cout << sizeof(arr); → 8

A2
A1
*arr
copy of pointer
is created

```
int func2 ( int * arr ) {
```

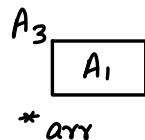
cout << arr; → A₁

cout << * arr; → 10

cout << &arr; → A₃

cout << sizeof(arr); → 8

pointer is passed



copy of pointer
is created

}

```
int main() {
```

int arr [5] = { 10, 20 }; arr

cout << arr; → A₁

cout << * arr; → 10

cout << &arr; → A₁

cout << sizeof(arr); → 5 * 4 = 20

func (arr);

func (arr 2);

return 0;

}

whole array will not pass

only array pointer / base address will pass

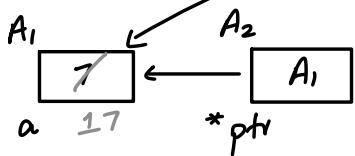
pass by reference

copy of pointer pointing to base address will be created

```

int main() {
    int a = 7;
    int * ptr = &a;
    update (ptr);
    return 0;
}

```



```

void update( int * p) {
    ① * p = * p + 10;
    ② p++;
}

```

Diagram illustrating pointer modification:

- Initial state: A_1 contains 17. The address of A_1 is stored in $*p$.
- Step 1: $*p = *p + 10$ (Line 1) - The value at $*p$ is updated to 27. The diagram shows A_1 with a purple border and $A_1 + 4$ pointing to the new value 27.
- Step 2: $p++$ (Line 2) - The pointer p is incremented to point to the next memory location, A_2 , which contains 17.

$$\begin{aligned}
 & *p \\
 & * (A_1) = * (A_1) + 10 \\
 & * (A_1) = 7 + 10 = 17 \\
 & a = 17
 \end{aligned}$$

Basic Mathematics for DSA

W6-R

Sieve of Eratosthenes Theorem

→ to find no. of prime numbers between 1 & n

Steps-

- make an array of size n and mark them all as primes
- Start from 2 till end, mark all no. > 2 comes in the table of 2 as non prime
- Do above step for numbers 2 to $<n$ if they are marked prime
- Count all remaining marked prime numbers

seive

```

int countPrimes ( int n) {
    if (n <= 1)
        return 0;

    vector <int> isPrime (n, true);
    isPrime [0] = isPrime [1] = 0; // same as isPrim[0]=0;
                                // isPrim [1]=0;
    int ans = 0;

    for( int i=2 ; i<n ; i++){
        if ( isPrime [i]){
            ans++;
            for( int j= 2*i ; j<n ; j+= i)
                isPrime [j] = false;
        }
    }
    return ans;
}

```

$$TC - O(n^* \log(\log n))$$

$$SC - O(n)$$

$$n \left[\frac{n}{2} + \frac{n}{3} + \frac{n}{5} + \frac{n}{7} + \frac{n}{11} + \dots \right]$$

$$n^2 \left[\frac{1}{2} + \frac{1}{3} + \frac{1}{5} + \frac{1}{7} + \frac{1}{11} + \dots \right]$$

$$n \log(\log n)$$

Same with segmented sieve \longrightarrow having high & low

GCD/HCF and LCM

→ Greatest Common Divisor

$$\rightarrow \text{gcd}(a, b) = \text{gcd}(a - b, b) \quad a > b$$

$$\text{gcd}(a, b) = \text{gcd}(b - a, a) \quad b > a$$

$$\text{gcd}(a, b) = \text{gcd}(a \% b, b) \quad a > b$$

$$\text{gcd}(a, b) = \text{gcd}(b \% a, a) \quad b > a$$

Use first method as $\%$ is heavy operator
and computer takes more time

→ Euclid Algorithm

Apply above formula till one of the parameter becomes 0

And other one will be GCD

```
int gcd( int a, int b ) {
```

```
    if (a == 0)
```

```
        return b;
```

```
    else if (b == 0)
```

```
        return a;
```

```
    while (a > 0 && b > 0) {
```

```
        if (a > b)
```

```
            a = a - b;
```

```
        else
```

```
            b = b - a;
```

```
}
```

}

```
return (a == 0) ? b : a;
```

$$TC = O(\min(a, b))$$

LCM

$$\text{lcm} * \text{gcd} = a * b$$

$$\text{lcm} = \frac{a * b}{\text{gcd}}$$

Modulo Arithmetic

$$\rightarrow a \% n \longrightarrow [0, n)$$

$$\rightarrow (a + b) \% n = (a \% n) + (b \% n)$$

$$(a - b) \% n = (a \% n) - (b \% n)$$

$$(a * b) \% n = (a \% n) * (b \% n)$$

$$(\dots ((a \% n) \% n) \dots \% n) = a \% n$$

Fast Exponentiation

$$\rightarrow a^b = a^{b/2} * a^{b/2}, \quad b \text{ is even}$$

$$a^b = [a^{b/2} * a^{b/2}] * a, \quad b \text{ is odd}$$

```
int fastExponentiation ( int a, int b){  
    int ans = 1;  
    while (b){  
        if (b & 1)  
            ans = ans * a;  
        a = a * a ;  
        b >>= 1; // b = b >> 1 or b = b / 2  
    }  
    return ans  
}
```

dry run code on 2^5 , if confusion

T.C. - $O(\log n)$

Learn wild, void and dangling pointers from dashboard
after learning dynamic allocation

MULTI LEVEL POINTER

W6-L3

int a = 5;

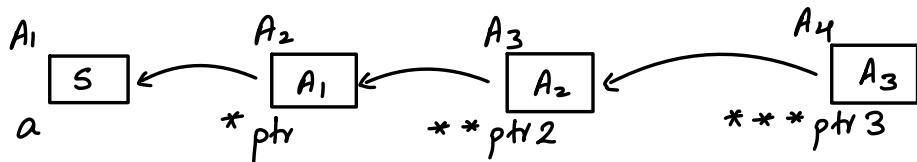
int *ptr = &a;

int **ptr2 = &ptr → double pointer

→ ptr2 is a pointer to int * data

int ***ptr3 = &ptr2;

→ ptr3 is a pointer to int ** data



a → 5

&a → A1

&&a → ERROR

ptr → A1

&ptr → A2

*ptr → 5

ptr2 → A2

&ptr2 → A3

*ptr2 → A1

**ptr2 → 5

apply dereference operator 2 times

ptr3 → A3

***ptr3 → A1

&ptr3 → A4

****ptr3 → 5

*ptr3 → A2

```

int main(){
    int a = 5;
    int * ptr = &a;
    int ** ptr2 = &ptr;
    func( ptr2 );
    return 0;
}

```

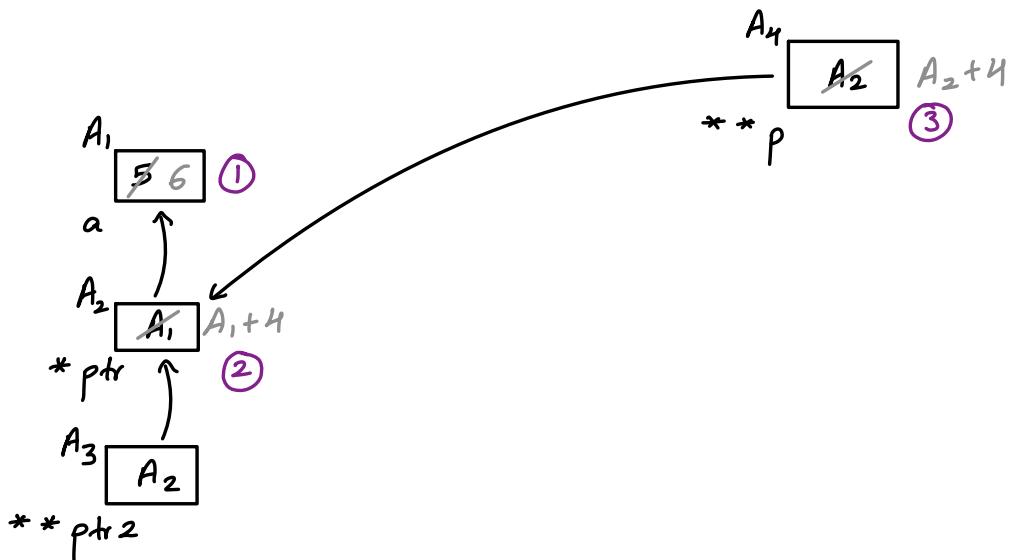
```

void func( int *** p ){
    ① (** p) ++ ;
    ② (* p) ++ ;
    ③ p ++ ;
}

```

both are same

func(&ptr);



```

int a = 5;
int * p = &a;
int ** q = p; -----> ERROR

```

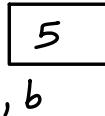
REFERENCE VARIABLE

- alternate of pointers
 - very confusing
- diff. names of same variable
 - same memory location
- only new entry in symbol table,
no other memory will allocate
- can access a variable by diff. names

int a = 5;

int &b = a;

A₁



Symbol Table

a	A ₁
b	A ₁

Use Case

- reference variable can't be set to NULL
pointers can be set to NULL
So more safety in reference variable
Always points to valid object / variable
- pointers are difficult to understand
more readability in reference variable
- generally used to implement **PASS BY REFERENCE** concept

PASS BY REFERENCE

- reference variable passes in function
- does not create copy

```
int main () {  
    int a = 5;  
    update (a);  
    update2 (&a);  
    int *ptr = &a;  
    //update3 (&a); → ERROR  
    update3 (ptr);  
    return 0;  
}
```

constant
add. in
pass by
reference

```
void update( int &x){
```

① x++;
}

PASS BY
REFERENCE

```
void update2( int * p){
```

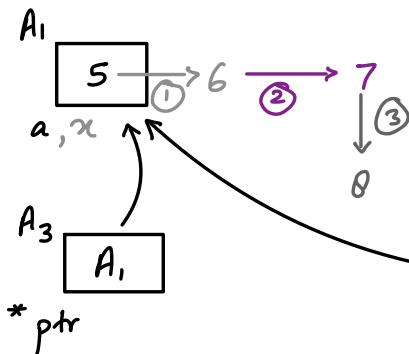
② (* p)++;
}

PASS BY
VALUE

A₂

A₁

P



```
void update3( int * &pt){
```

③ (* pt)++;
}

A₄
 A_1
 $*pt$

IMP QUESTION

```
int main () {  
    int * ptr = solve ();  
    return 0;  
}
```

A₂ A₁ → pointing to a temp
ptr memory , 'a' variable
 will finished outside
 solve function

```
int * solve () {  
    int a=5;  
    int * p = &a;  
    return p;
```

A₂ A₃
a 5 A₁
ptr