

DSA SUPREME

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- → more important note
- → Heading
- → Subheading or important point
- → Data Structure
- → Complexities

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



can't 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 placed

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
- Resume is made company specific
- Make sure others don't take your credits
- Higher position $\propto \frac{\text{Development}}{\text{DSA Complexity}}$
- Interview experience before interview
- Flex se kuch nhi hota
- Comparision se kuch nhi hota
- Don't forcefully try to increase the speed of DSA learning,
Try to increase the number of hours spent everyday in DSA learning
- if ques seems tough in another datatype but easy in another datatype, then first do that in later datatype and after solving the sol. change datatypes

→ In interview, you must have clarity and strong concepts and strong argument behind the things you say.

whether the ans comes right or wrong is another thing

→ Start writing code for smallest problem / test case and then eventually find solution pattern

→ Dont rush to make an optimised code, start from brute force

IMPORTANT C++ NOTES

→ -1 in binary 1.....1

- 2^{31} in binary 10...0

→ In left shift, vacant bit will be filled by 0

In right shift, vacant bit will be filled by MSB

1 → in -ve no.

0 → in +ve no.

$(-1) \gg n \longrightarrow$ (-1) no change
any no. of times

→ int a = 5;

cout << (++a) * (++a);

a * (++a), a = 6

a * a, a = 7

7 * 7 = 49

cout << (a++) * (a++);

5 * (a++), a = 6

5 * a, a = 7

5 * 7 = 35

cout << (++a) * (a++);

cout << (a++) * (a++);

a * (a++), a = 6

5 * (a++), a = 6

a * 6, a = 7

5 * 6, a =

7 * 6 = 42

30

→ Continue cannot be used in switch case
can only used in loops

→ int main () {

return 0; —————> returns to OS

} 0 is used to represent successful execution

→ A cpp file can't have more than 1 main function

→ main () cant have return type other than int
in offline compiler

→ % is heavy operator, so try to use it less

→ array name returns address of first index

Integer Array -

`cout << arr ;` → `A1` → address of first index of array
address of integer

→ To find max., initialize ans with INT-MIN

To find min., initialize ans with INT-MAX

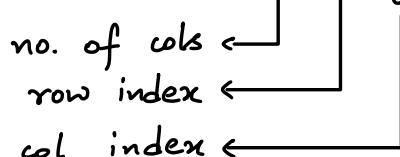
→ xor → cancels out same element

$$\rightarrow 0 \wedge \text{ans} = \text{ans}$$
$$0 \wedge 1 = 1$$
$$0 \wedge 0 = 0$$

→ Mapping of 2D array with memory 1D array

$$\text{Linear-index} = c * i + j$$

$i = \text{linear-index} / c$
 $j = \text{linear-index \% } c$



→ Arrays and 2D arrays of any datatype

↳ pass by reference

→ Search space

↳ range of ans (start and end) in binary search questions

→ store mid in ans if needed in binary search ques

→ In binary search questions

```
while (s <= e){  
    ans = mid;  
    s = mid + 1;  
}  
  
left  
search ← e = mid - 1;  
}  
  
right  
search
```

convert
ans = mid
s = mid + 1

```
while (s < e){  
    s = mid; → right search  
    left  
    search ← e = mid - 1;  
}  
  
OR  
s = mid + 1 → right  
search  
left  
search ← e = mid;  
}
```

convert
ans = mid, e = mid - 1

→ cout << (int)(-3.74);

→ - [int(3.74)]

→ - (3) → -3

cout << (-22)/7; → -3

cout << 22/(-7); → -3

→ In ASCII → '0' → 48
 'A' → 65
 'a' → 97

→ 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 $\text{isPossibleAns}(\text{mid}) \rightarrow$ go to left / right acc.
to the ques.

You can use above approach also in other
ques like find the duplicate number in an array
having elements range 1 to n

→ Week 6 Lecture 2

→ Magical line for recursion

- ↳ Ek case solve krdo baaki recursion smblial lega
- ↳ Just believe on it, dont doubt on recursion

→ Week 7 Lecture 2

→ Week 7 Lecture 3

→ If the recursion ques seems tough,
use void function and pass ans by reference
in function

- If in ques. array elements are in range $[1, n]$ or $[0, n]$, try to treat elements as indices of an array
(Week 3 Assignment)
- Try to make cnts [max element present in array] instead of making cnts [max limit given in question]
Array more than 10^6 ints cant be formed

→

```
int digit = 7;
string s;
s.push_back ( digit + '0' );
cout << s; —→ 7
```

`s.push_back(digit);
cout << s; —→ contains
char with
ascii value = digit`

'7' to 7 —→ '7' - '0'

7 to '7' —→ 7 + '0'

- Generally in linked list question, you were asked to play with links / pointers without changing data

→ In linked list , when you have to go from right to left , you have 2 options

1) reverse the linked list

2) use head recursion

→ If we pop a data set after pushing in stack, we get the answer in reverse order

So to reverse anything , you can use stack

→ Sets can be used to store only unique / distinct elements

ERROR / BAD PRACTICE

If let's go page

→ 13

31, 33, 43, 70, 71, 72, 73, 75, 76, 79, 86, 87, 89, 90, 93, 95

→ 14

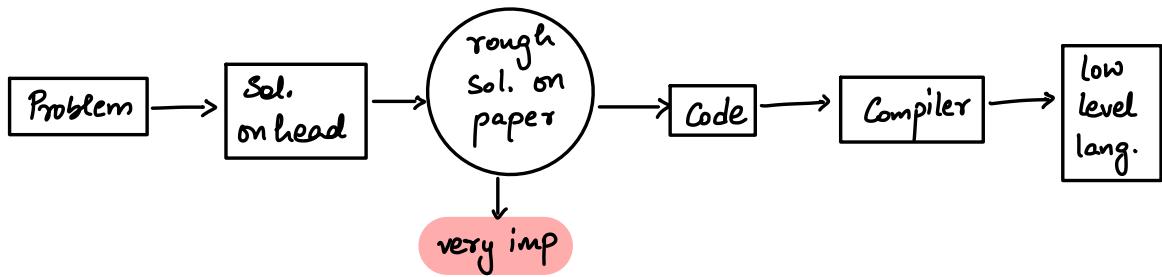
104

LET'S GO

Thought process to solve a problem-

W1-L1

- Understand a problem
- input values
- find approach



Algorithm - Sequence of steps

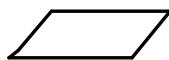
Flowchart - Graphical representation of algo

Components -



terminator

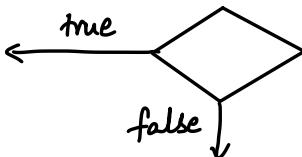
for start / end



for input /output read /write



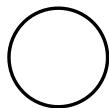
computation / process / declaration



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 keyword
using namespace std;
int main () {
    cout << "Namaste Bharat";
}
```

region where scope of keyword is defined

used to point on console/standard display

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

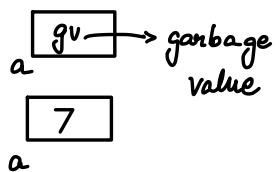
→ to end any statement

→ string

cout << endl; → for next line

cout << '\n';

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



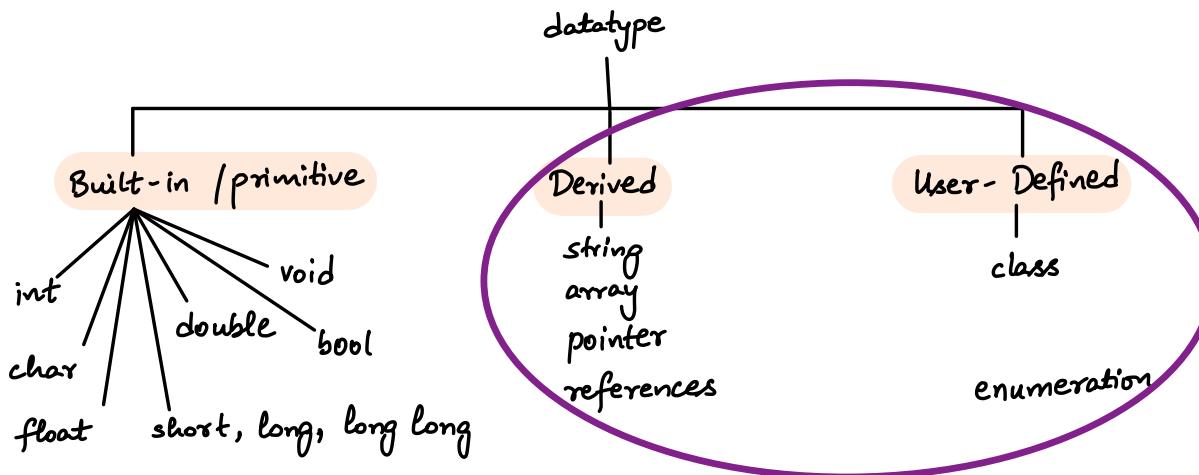
Variables

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

\longrightarrow 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

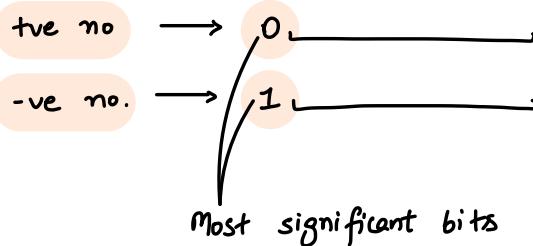
short \rightarrow 2 byte \rightarrow 16 bits

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

(1) 0...0

011...1

0.....0

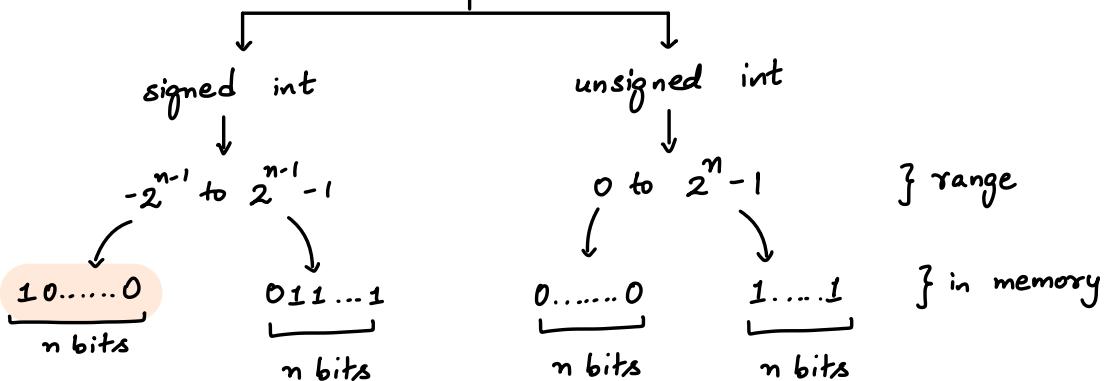
1....1

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

} in memory

General Formula

n bits in memory
↳ total no. of combinations - 2^n



$$-1 \rightarrow \underbrace{1\dots1}_{n \text{ bits}}$$

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 → 10011100001111
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 → int

float op int } float
int op float

float op float]

double	op	int	double
int	op	double	
double	op	double	
float	op	double	
double	op	float	

bool op bool → int

bool act as 0 or 1

Relational Operator

(a op b)

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

Output - 0 or 1

false \leftarrow 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

$(\text{cond}1 \&\& \text{cond}2 \&\& \text{cond}3)$

if cond1 is false

compiler will not check further
as ans will already false

$(\text{cond}1 || \text{cond}2 || \text{cond}3)$

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

```

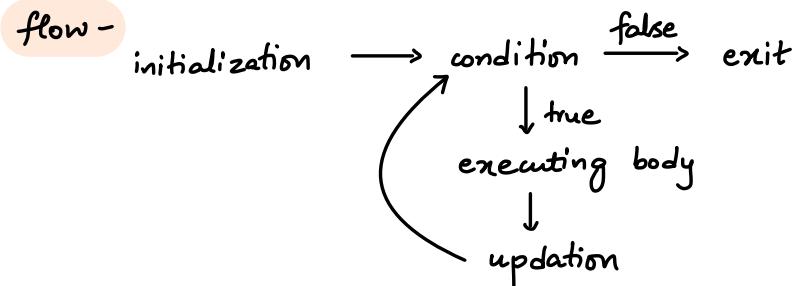
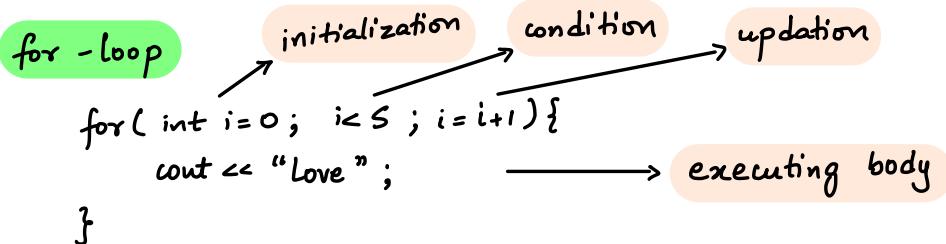
if (cond 1)
    execute 1
else {
    if () { }
    else () { }
}

```

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 input 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

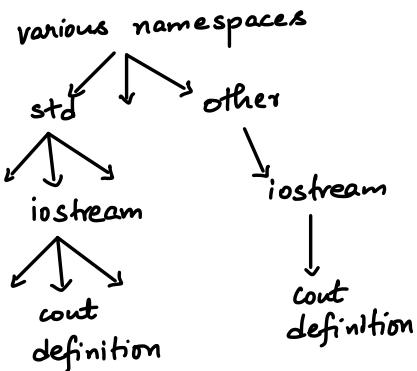
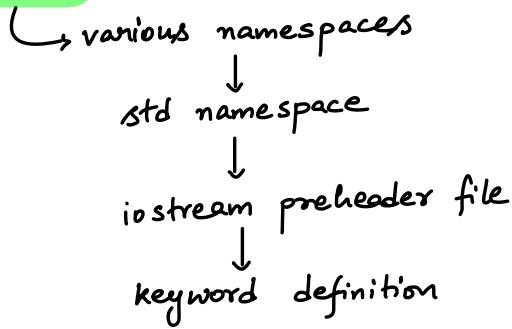
W1-L4

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

2 and 3 cant be statements, they must be exp.

ex- return (a > b) ? a : b ; → CORRECT

(a > b) ? return a : return b ; → WRONG
ERROR

these are statements, not expression

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

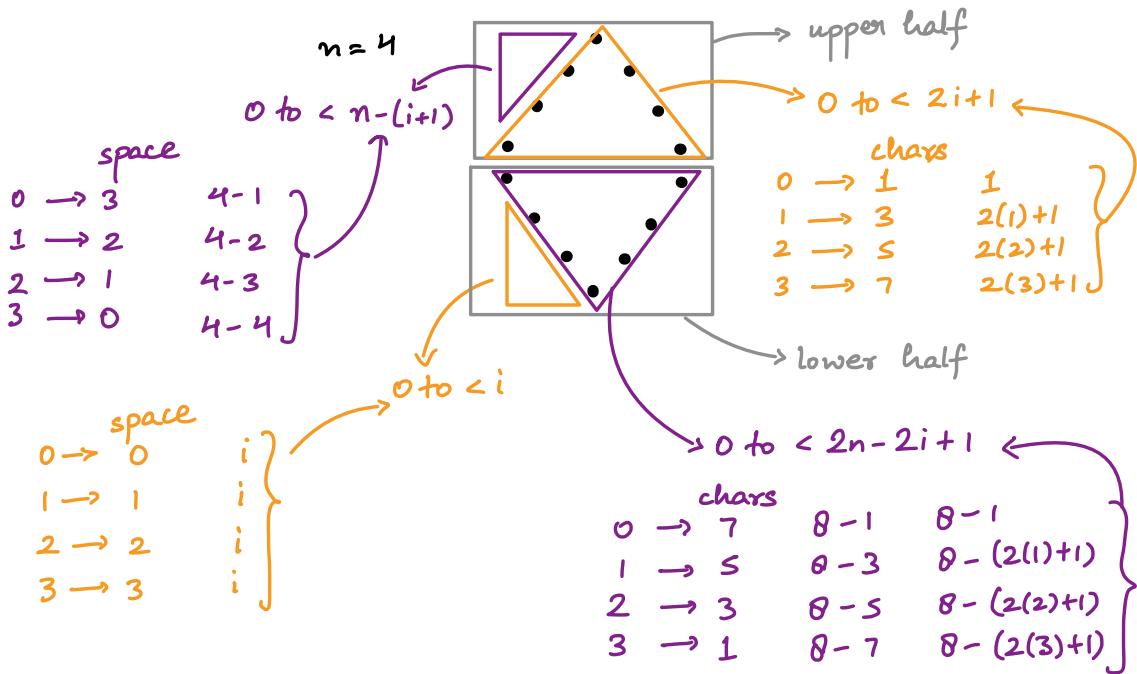
no. of times loop runs

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

$\sim 5 \rightarrow 0 \dots 0101$

$\sim 5 \rightarrow 1 \dots 1010$

↳ 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 8^v

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

$a = 5;$

in left shift \rightarrow filled with 0

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

in right shift \rightarrow filled with

in +ve no. 0 or 1
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 $\hookrightarrow 0 \dots$

\hookrightarrow +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

```
}
```

can also have
nested switch
case

not
mandatory

without break

→ all below executing body will also execute

→ continue cannot be used in switch case

→ can only use in loops

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 ) {
    executing body
}
```

void → empty / no value void x; → ERROR

cout << sizeof(int) → 4

cout << sizeof(void) → ERROR

```
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 are active
- \hookrightarrow which function calls which
- \hookrightarrow local variables of function
- \hookrightarrow return type of function

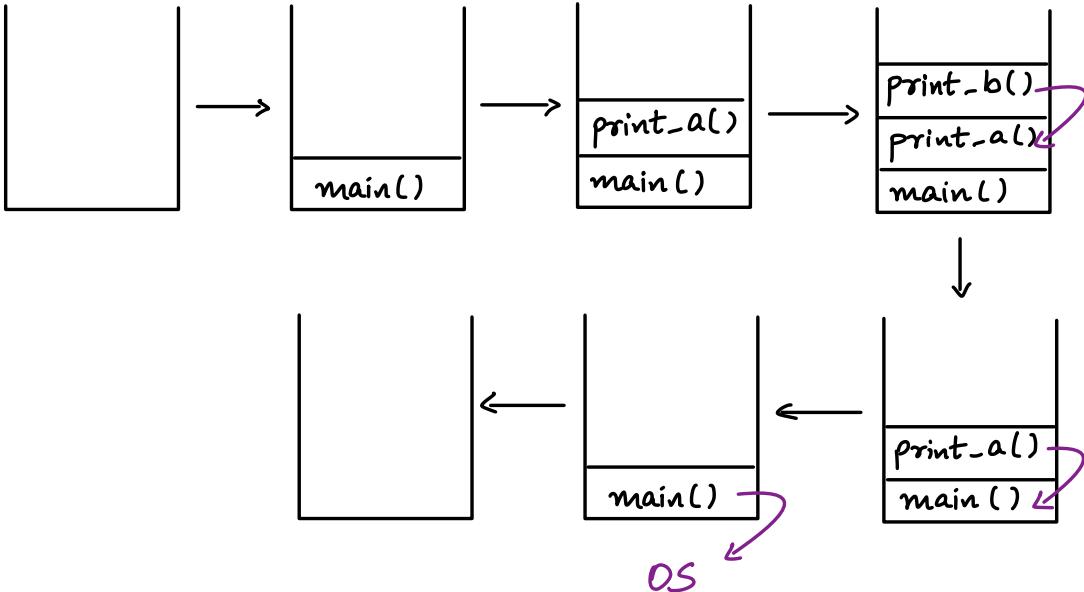
ex -

```
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;
}
```

Output - 5 3



Pass by value → value is passed to another variable

↳ a copy will be created of variables

```
int main() {
```

```
    int a=5;
```

```
    printNumber(a);
```

```
    cout << a;
```

```
}
```

A₁

5

a

argument

s

parameter ↗

```
void printNumber(int a){
```

```
    cout << a; → 5
```

```
    a++;
```

```
    cout << a; → 6
```

```
}
```

A₂

5

a

A₂

6

a

diff. memory
locations

new copy

Address Of Operator &

```
int n=5;
```

```
cout << &n;
```

→ output -
address of n

```
int main() {  
    int a=3;  
    int b=4;  
    int sum = add(a,b);
```

```
    cout << sum;  
    return 0;
```

```
}
```

sum

7

A₁

```
int add(int a, int b){  
    int result = a+b;  
    return result;
```

returning a value

7

A₂

copying the
returning value in sum

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

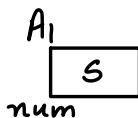
```
function declaration  
{  
int add (int a, int b);  
  
int main () {  
    int a= 3;  
    int b = 5;  
    int sum= add (a,b);  
    cout << sum;  
    return 0;  
}  
  
int add (int a, int b) {  
    return a+b;  
}
```

% operator → heavy operator

↳ so try to use it less

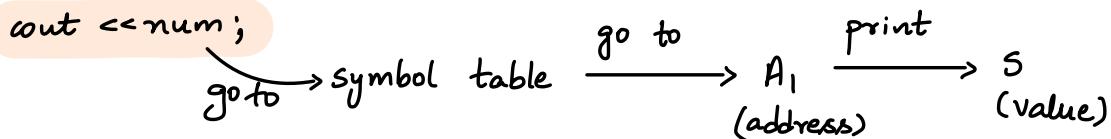
```
int num=5;
```

Symbol table

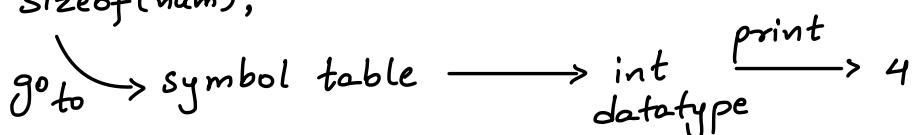


memory location of variable

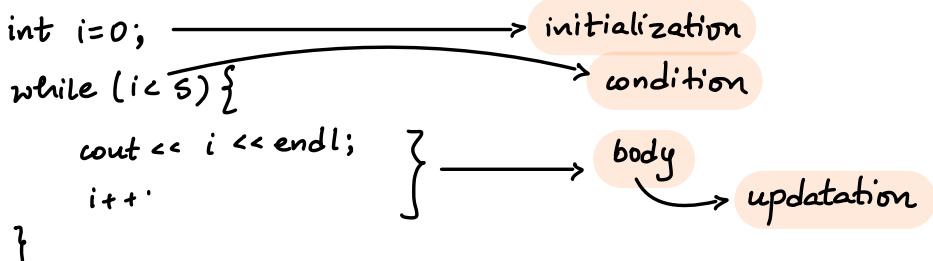
variable address mapping is stored



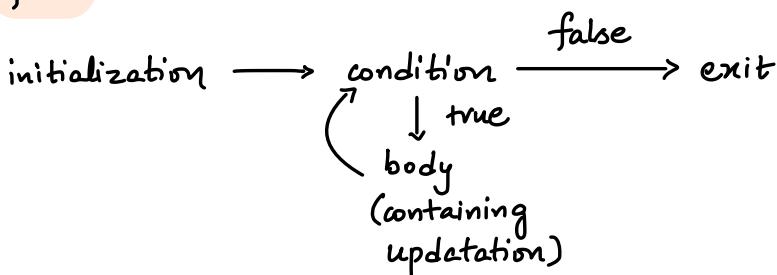
```
cout << sizeof(num);
```



while loop



flow



left and right shift operators

int a = 2;

$a \ll 1;$ → no change

$\text{cout} \ll a;$ → 2

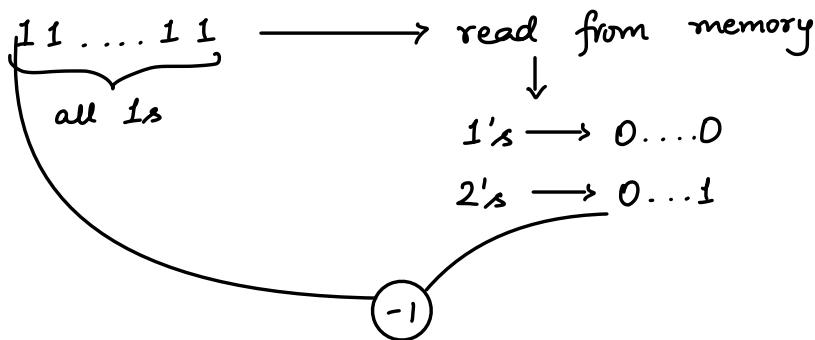
$a = a \ll 1;$ → change → left shift by 1

$\text{cout} \ll a;$ → 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 - $a = 5; \rightarrow 0...0101$

$a = \sim a; \rightarrow 1...1010 \rightarrow -6 \rightarrow -(5+1)$

$a = -6;$

↳ $1...1010$

read

-6

$a = \sim a; \rightarrow 0...0101$

↳ 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 \longrightarrow upper bound \longrightarrow worst case

Theta $\Theta \longrightarrow$ average case

Omega $\Omega \longrightarrow$ lower bound \longrightarrow best case

Big O Complexities

$O(1)$ \longrightarrow Constant time

$O(n)$ \longrightarrow Linear time

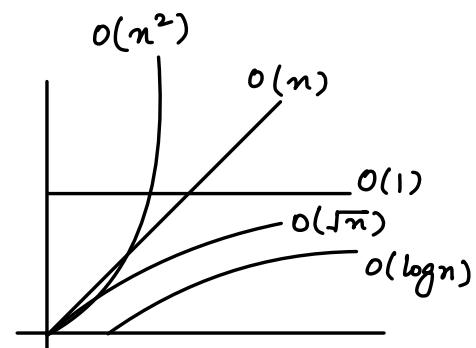
$O(\log_2 n)$ \longrightarrow Logarithmic time

$O(n^2)$ \longrightarrow Quadratic time

$O(n^3)$ \longrightarrow Cubic time

nesting \longrightarrow multiply \longrightarrow { } { }

in sequence \longrightarrow add \longrightarrow { }



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

Complexity Order

$$O(1) < O(\log_2 n) < O(\sqrt{n}) < O(n) < O(n \log_2 n) < O(n^2)$$

$$< O(n^3) < O(2^n) < O(n!) < O(n^n)$$

ARRAY

W3-L1

- Data Structure to store similar items
 - ↳ same datatype
- Continuous memory location
- use case
 - ↳ for multiple same kind of data

int a[30000]; → 30000 variables are ready

continuous memory allocation

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

int a = 5;

A



a

symbol table

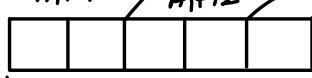
int a ↔ A

int arr ↔ A₁

Declaration

int arr[5];

A₁ A₁+4 A₁+8 A₁+12 A₁+16



arr

20 bytes

base address

continuous space

`cout << arr ;` $\longrightarrow A_1 \longrightarrow$ address of first index of array
address of integer

`cout << &arr ;` $\longrightarrow A_1 \longrightarrow$ base address of array arr
address of array

Initialization

diff. things

`int arr [] = { 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;`

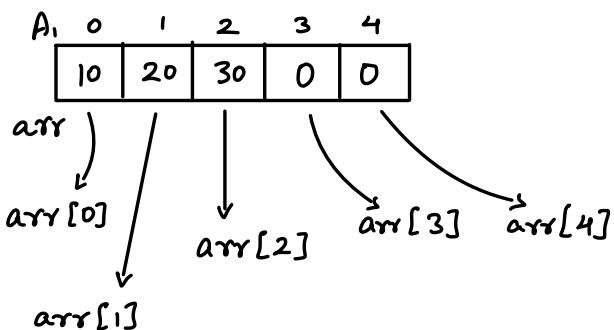
`cin >> n;`

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

Index and Access in memory

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

\hookrightarrow 0 to n-1



$\text{arr}[i] \longrightarrow \text{value at address } [A_1 + (i * 4)]$

BA
index
due to int (datatype size)

that's why 0 based indexing

taking input in array

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

due to internal working

Arrays and Function

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

array is passed by reference because pointer is passed by value

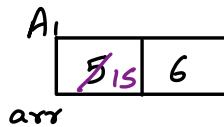
updation in actual array

always pass size alongwith arr

arr here is not an array, it is pointer pointing to first index of array (will learn ahead)

```
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;
}
```



will learn ahead

`sizeof(int);` → 4 → in bytes

`int arr [5];`

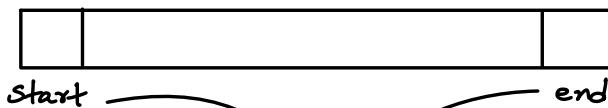
`sizeof(arr);` → 20 → in bytes
→ not 8 (size of pointer)

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};	→	<table border="1"><tr><td>10</td><td>20</td><td>30</td></tr></table>	10	20	30		
10	20	30					
vector <int> arr (5);	→	<table border="1"><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>	0	0	0	0	0
0	0	0	0	0			
vector <int> arr (5, -2);	→	<table border="1"><tr><td>-2</td><td>-2</td><td>-2</td><td>-2</td><td>-2</td></tr></table>	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2			
int n;	size value						
cin >> n;	→ let n = 5						
vector <int> arr(n);	→	<table border="1"><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>	0	0	0	0	0
0	0	0	0	0			
vector <int> arr (n, 10);	→	<table border="1"><tr><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td></tr></table>	10	10	10	10	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 of initialization

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

→ array of arrays
→ use case

→ to work on multiple rows and columns

Declaration -

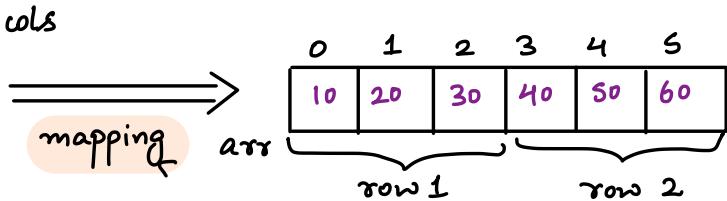
int arr [m][n]; → m*n elements
 | → cols → 0 to n-1
 | → rows → 0 to m-1

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 -

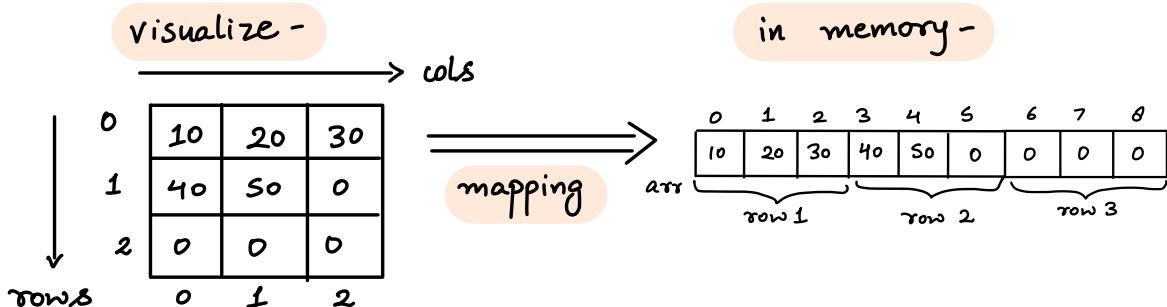
$$\text{linear_index} = c * i + j$$

no. of cols col index
row index

$$i = \text{linear_index} / c$$
$$j = \text{Linear_index \% c}$$

Initialization -

int arr[3][3] = {{10, 20, 30}, {40, 50}}; same
int arr[3][3] = {10, 20, 30, 40, 50};



2D Arrays and function -

→ pass by reference

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

actually arr
here is
int (*)[500]
(array of pointers),
not a 2D array

→ cannot leave blank

why → if dont know, put large value

500 tells size of array of pointers

→ this value and no. of cols
in array passed in function

call should be same

2D Array -

→ not an array of pointers

→ array of arrays

```

func( int a [ ] [ 3 ], int rows , int cols ) {
    cout << & a ; ----- add. of a -----> A4
    cout << a ;
    cout << a [ 0 ];
    cout << & a [ 0 ];
    cout << & a [ 0 ] [ 0 ];
    cout << a [ 0 ] [ 0 ]; -----> 10
    cout << sizeof( a ); -----> 4
    cout << sizeof( a [ 0 ]); -----> 12
}

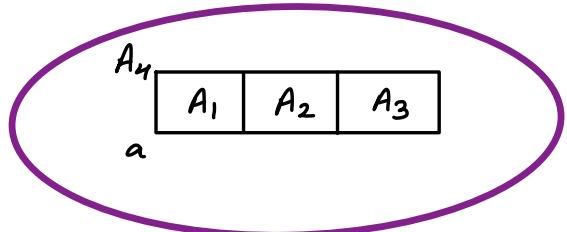
```

```

int main () {
    int arr [ 2 ] [ 3 ] = { 10, 20, 30, 40, 50 };
    func( arr, 2, 3 );
    return 0;
}

```

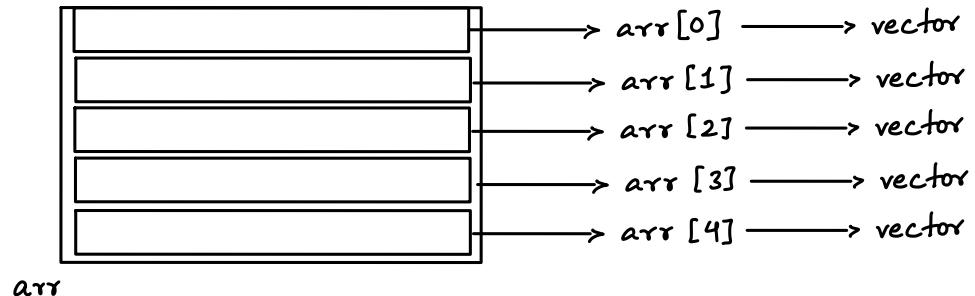
	A ₁	A ₂	A ₃
A ₁	10	20	30
A ₂	40	50	0
A ₃	0	0	0



2D Vector

Declaration -

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



Declaration -

```
vector<vector<int>> arr;           → no. of rows
```

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

Number of rows

```
arr.size()
```

Number of cols

```
arr[i].size()
```

→ in ith row
→ size of ith row

Initialization

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

rows → no. of rows in arr

cols → no. of cols in arr

→ size of 1D vector

size initial value in 2D
↑ ↑ vector

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

auto keyword -

→ automatically replace with required data type

```
int arr [4]
```

```
for( auto i = 0; i < 4; i++)
    cout << arr [i];
```

: Operator

→ belongs to operator

→ generally used for sequential access

→ map, set, array, vector

```
ex - vector<int> arr {1, 2, 3};
```

```
for( int i : arr)
    cout << i;           → 1 2 3
```

```
for( auto i : mapping)
    cout << i;
```

```
for( auto i : sett)
    cout << i;
```

Searching and Sorting

W4-L1

Searching

Linear Search

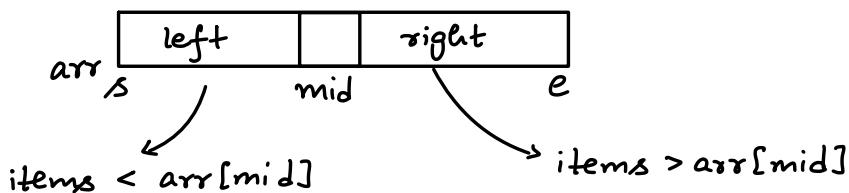
```
int linearSearch ( vector <int> arr, int target ) {  
    int n = arr.size();  
    for( int i=0; i<n ; i++ ) {  
        if ( target == arr[i] )  
            return i;  
    }  
    return -1;  
}
```

T.C - $O(n)$

S.C. - $O(1)$

Binary Search -

- condition → sorted order → monotonic function
- binary → 2 → left and right search



```

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;
}

```

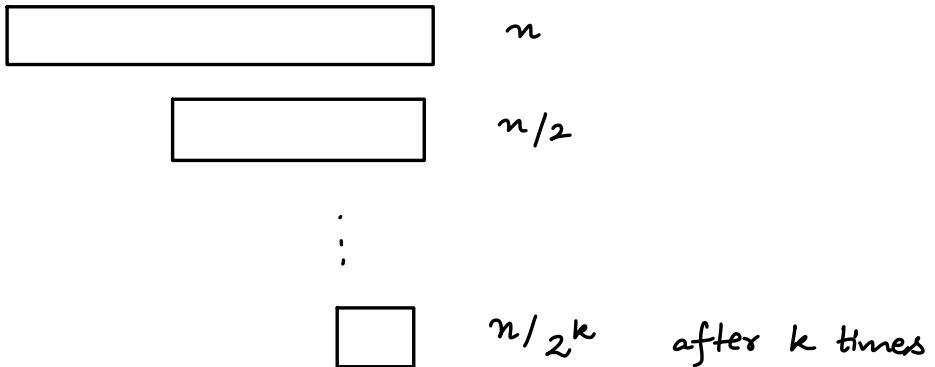
issue in $mid = \frac{s+e}{2}$; —→ int overflow
 if $s+e > INT_MAX$

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

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

S.C . - $O(1)$

T.C. of binary Search



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

→ store mid in ans if needed

→ In binary search questions

```
while (s <= e) {  
    ans = mid;  
    s = mid + 1;  
}  
left  
search ← e = mid - 1;  
}  
right  
search
```

convert

```
ans = mid  
s = mid + 1  
left  
search ← e = mid - 1;
```

OR

```
ans = mid, e = mid - 1  
left  
search ← e = mid;  
s = mid + 1 → right  
search
```

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

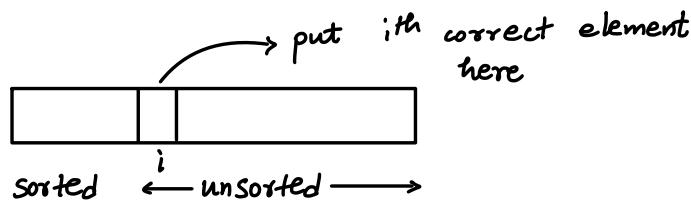
W4-L5

- 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
 - ↳ i^{th} minimum element

```
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

- ↳ put i^{th} lowest element to its correct position

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

Inbuilt sort function

- sort (arr.begin(), arr.end());
- algo used is Intro sort
 - hybrid of quick sort, heap sort, insertion sort
- min. time than any of other sort

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

S. C. - Not Defined

Stable and Unstable Algorithm

Stable → order preserve after sorting
 ↓
 of same values

Stable Sorting Algo

2 1 2 2 3
 ↓
 after sorting

if $A[i] = A[j]$, $i < j$
then $A[i]$ comes first before
 $A[j]$ after sorting too

1 2 2 3

Stable - Bubble Sort, Insertion Sort, Merge Sort,
Count Sort

Other (unstable) sorting algorithms can be made stable
by some changes

T.C. and S.C Sorting Algorithm Table

Algo	S. C.	Worst T.C.	Avg. T.C.	Best T.C.
Selection	$O(1)$	$O(n^2)$	$O(n^2)$	$O(n^2)$
Bubble	$O(1)$	$O(n^2)$	$O(n^2)$	$O(n)$
Insertion	$O(1)$	$O(n^2)$	$O(n^2)$	$O(n)$
sort func. (intro sort)	not defined	$O(n \log n)$	$O(n \log n)$	$O(n \log n)$
merge	$O(n)$	$O(n \log n)$	$O(n \log n)$	$O(n \log n)$
quick	$O(n)$	$O(n \log n)$	$O(n \log n)$	$O(n^2)$

CHAR ARRAYS & STRING

W5-L1

Char Arrays -

→ Data structure → used to store data

Not Datatype → tells type of data

char ch[5];

gv	gv	gv	gv	gv
ch				

char ch[] = {'U', 'j', 'j', 'w', 'a', 'l'};

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

char ch[] = "Ujjwal";

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

Taking input in char array

char ch[7];

cin >> ch[i];

cin >> ch; → by default NULL char will

insert at end

→ '\0'

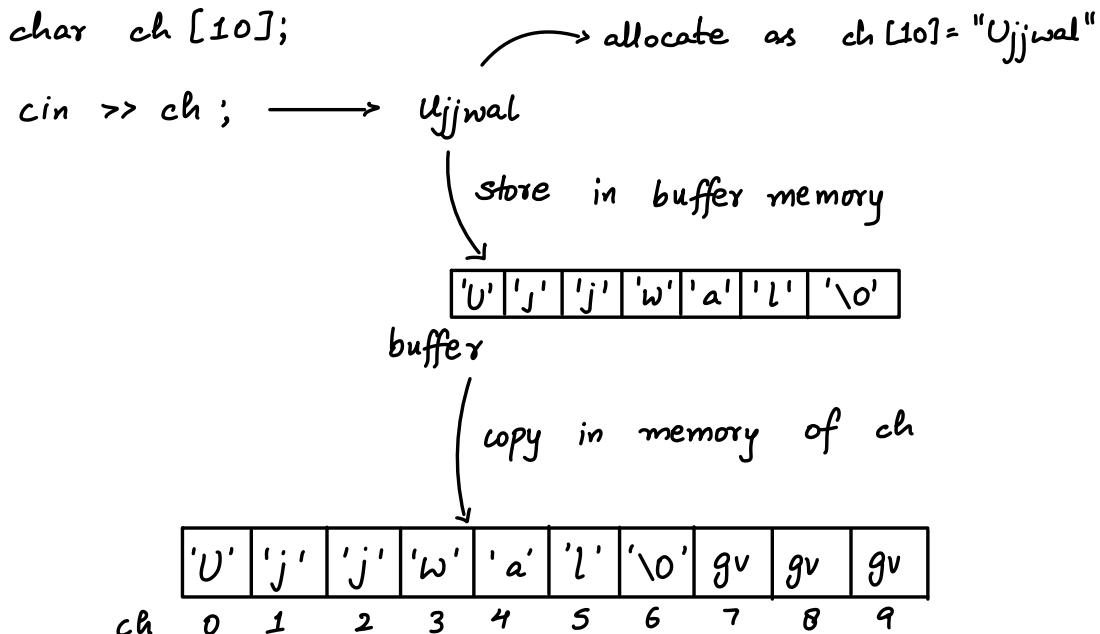


NULL char refers string termination

→ cin reads until it gets any white space

→ space ''
tab '\t'
endl '\n'

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



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
↓

length + 1
→ NULL char

char ch [] = {'U', 'j', 'j', 'w', 'a', 'l'}

cout << sizeof(ch);

→ 6
↓
length

as there is no NULL char at last

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[]){
}`

actually pass by value but ch is address, so any change acts as pass by reference

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);`

String 8

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

string str; → empty string created

cin >> str; → Ujjwal

['U' | 'j' | 'j' | 'w' | 'a' | 'l' | '\0']

cout << str; → Ujjwal str

cout << str.length(); → 6, not 7

getline -

string str;

getline (cin, str);

char array

char ch [] = "B_abba-\r";

cout << ch; → B_abba-\r

cout << arr.size () → 9

ch[1] = '\0';

ch[6] = '\0';

cout ch; → B

stops just as it gets NULL char

string

string str = "B_abba-\r";

cout << str; → B_abba-\r

cout << str.length () → 8

cout << str.size () → 8

str[1] = '\0';

str[6] = '\0';

cout << str; → Babbar

Runs till the length of string

Sort function in strings -

W5-L3

```
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;

-----> ascending order

```
}
```

```
int main () {
```

string str = "babbar";

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

cout << str; -----> aabbby

string str2 = "babbar";

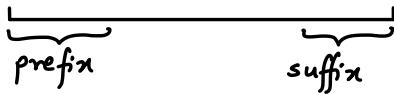
```
sort (str.begin(), str.end(), cmp2);
```

cout << str2; -----> rbbbbaa

return 0;

```
}
```

Prefix and Suffix



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

SYMBOL TABLE

W6-L1

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

Symbol Table	
name	→ address
a	A ₁
b	A ₂

int a = 5;

A ₁	5
a	

int b = 5;

A ₂	5
b	

→ entry of a in symbol table
is made

cout << a; → s

& Address Of Operator

cout << &a; → A₁ → address of

hexadecimal



variable a in
memory

cout << &b; → A₂

Not 100%
Sure

{ A₂ = A₁ ± 4 → because of consecutive
variables in memory
↓
int datatype
of a and b

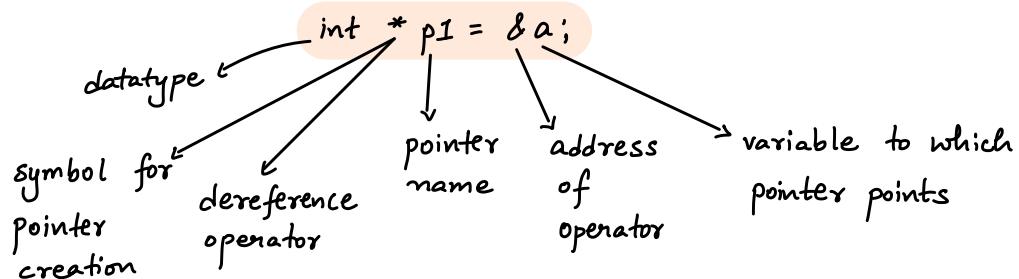
POINTERS

→ 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
```

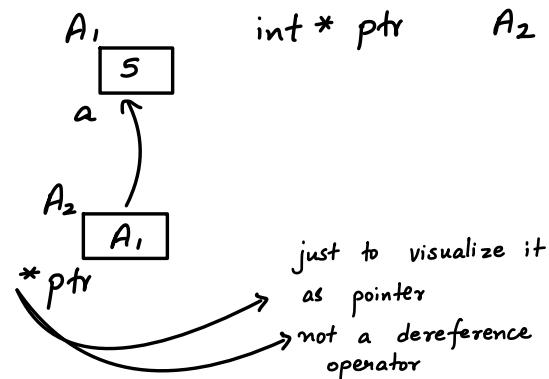
```
cout << * ptr; → 5
```

```
cout << &ptr; → A2
```

symbol table

int a A₁

int * ptr A₂



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

$\& \text{ptr}$ → address of ptr

size of pointer

$\text{sizeof}(\text{ptr})$; → 8
64 bit architecture

depends on
architecture
compiler implementation
memory organization

Always
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;
cout << ptr; → gv

VERY BAD PRACTICE

Segmentation fault

A1
 $* \text{ptr}$ gv

ptr points to a memory location that may not be of its program

Segmentation fault -

→ using other's memory

NULL Pointer

```
int * ptr = 0;
```

```
int * ptr2 = NULL;
```

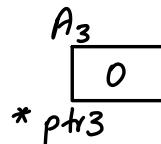
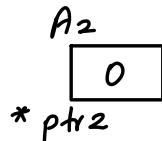
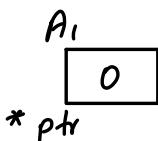
```
int * ptr3 = nullptr;
```

```
cout << ptr ; → 0
```

```
cout << *ptr ; → ERROR
```

```
cout << &ptr ; → A1
```

same



Segmentation fault

Arithmetic Operations In Pointers

```
int a=5;
```

```
a++;
```

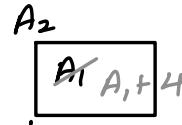
```
int * ptr = &a;
```

```
*ptr++;
```

```
ptr++;
```



a



*ptr

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

int a = 10;

int *ptr = &a;

a 10

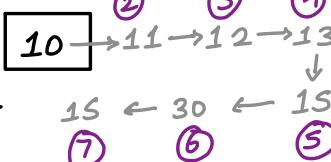
&a A₁

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

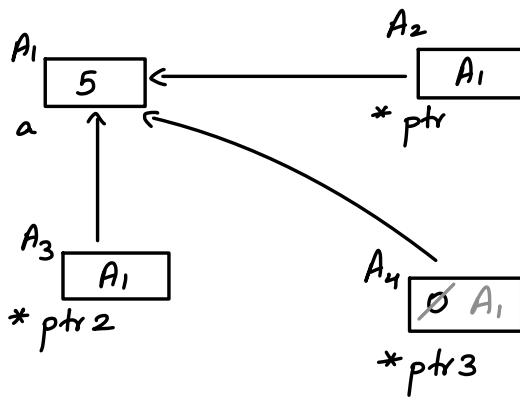
int a = 5;

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

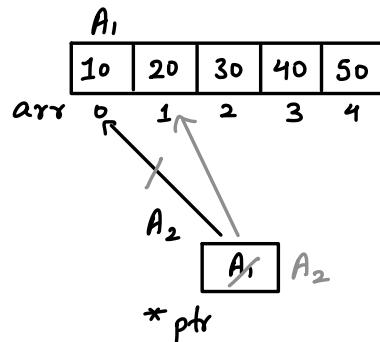
also does not have separate memory

$\text{arr}[i]$ → element at index i

$\&\text{arr}[i]$ → address of $\text{arr}[i]$

$\text{cout} \ll \text{arr}[0];$ → 10

$\text{cout} \ll \&\text{arr}[0];$ → A_1



{ $\text{cout} \ll \text{arr};$ → A_1

$\text{cout} \ll \&\text{arr};$ → A_1

same address unlike pointers

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

$\text{cout} \ll *ptr;$ → 10

$\text{cout} \ll ptr;$ → A_1

$\text{cout} \ll \&ptr;$ → A_2

$\text{cout} \ll *arr;$ → 10

$\text{cout} \ll *(\&\text{arr});$ → 10

$\text{cout} \ll *(*\&\text{arr}[0]);$ → 10

Symbol table

type	name	address
------	------	---------

$\text{int}(*)[5]$	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 $A_1 + 4$ cant be change

→ You can access subpart of an array using pointers

`int *ptr = arr;`

`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;` $\longrightarrow A_1 \} \text{Same}$
`cout << &arr;` $\longrightarrow A_1 \}$

- ② `arr ++;` \longrightarrow ERROR

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

Pointers / Normal pointers

`int *ptr = arr;`

- ① `cout << ptr;` $\longrightarrow A_1 \} \text{diff.}$
`cout << &ptr` $\longrightarrow A_4 \}$

- ② `ptr ++;` \longrightarrow VALID

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

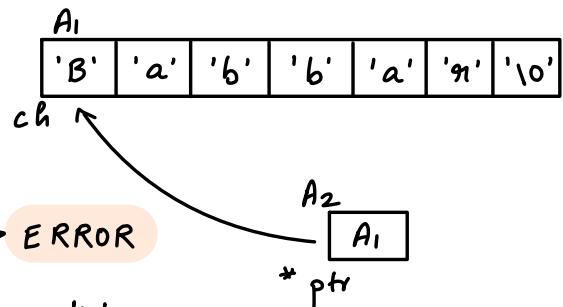
```
int * p1 = arr;
```

```
int * p2 = &arr; -----> ERROR
```

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

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'|

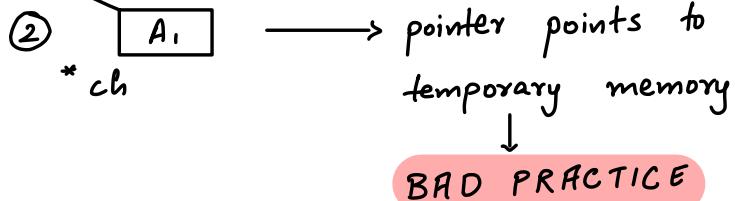
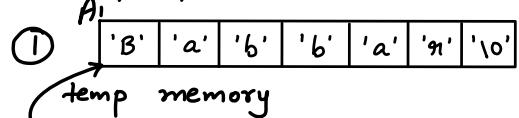
temp memory } copy

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

ch

```
char * ch = "Babbar"
```

→ 2 step process



POINTERS WITH FUNCTIONS

→ pass by value

a copy of pointer is made

→ but simulates pass by reference

→ as in case of arrays & functions

→ pointer is passed

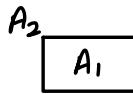
```
int func ( int arr[]){
```

cout << arr; → A1

cout << *arr; → 10

cout << &arr; → A2

cout << sizeof(arr); → 8



copy of pointer
is created

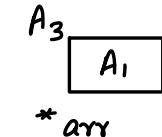
```
int func2 ( int * arr ) {
```

cout << arr; → A₁

cout << * arr; → 10

cout << &arr; → A₃

cout << sizeof(arr); → 8

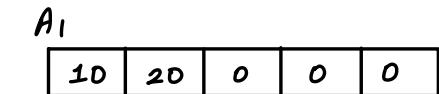


copy of pointer
is created

}

```
int main() {
```

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



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

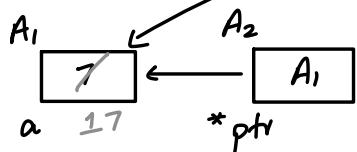
→ pass by reference for array

→ copy of pointer pointing to base address will be created

```

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

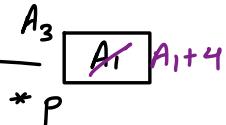
```



```

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

```



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

Function to Pointers in HW

Basic Mathematics for DSA

Sieve of Eratosthenes Theorem

W6-L3 R

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

Steps-

- make an array of size n and mark them all as primes from 2 to n
- 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

```

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

    vector <int> isPrime (n, true);
    isPrime [0] = isPrime [1] = 0; // making both 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;
}

```

i ≠ i < n
↳ to optimize T.C.
as 2i to (i-1)*i are
already marked when
i = 2 to (i-1)

$$TC - O(n * \log(\log n)) \quad SC - O(n)$$

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

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

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

Same with **segmented sieve** → having high & low

GCD/HCF and LCM

→ Greatest Common Divisor

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

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

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

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

takes more time bcz
of \% op.

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-L4

int a = 5;

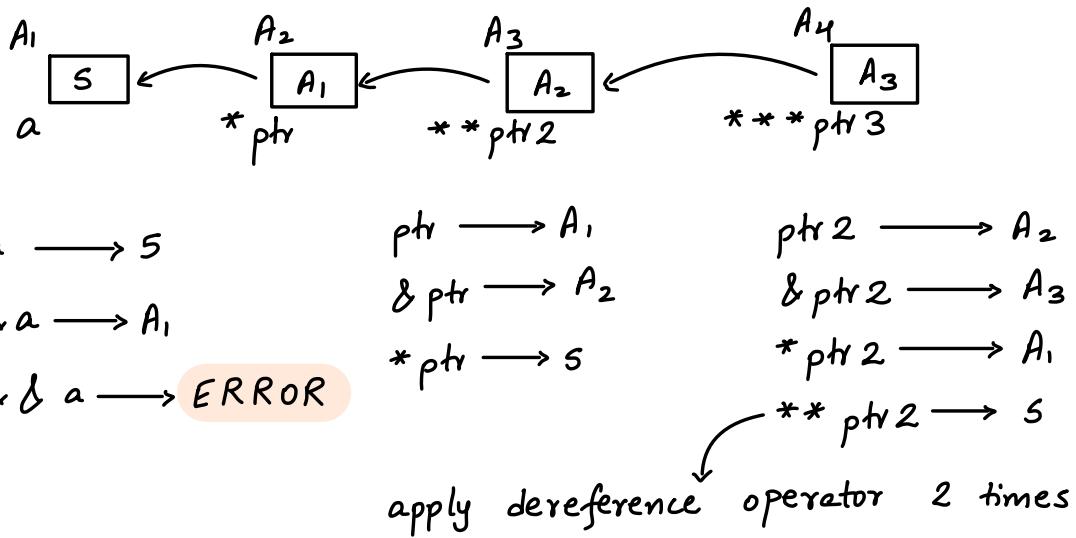
int *ptr = &a;

int **ptr2 = &ptr → double pointer

→ ptr2 is a pointer to int * data

int ***ptr3 = &ptr2;

→ ptr3 is a pointer to int ** data



$ptr3 \rightarrow A_3$

$**ptr3 \rightarrow A_1$

$\&ptr3 \rightarrow A_4$

$***ptr3 \rightarrow 5$

$*ptr3 \rightarrow A_2$

```

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

```

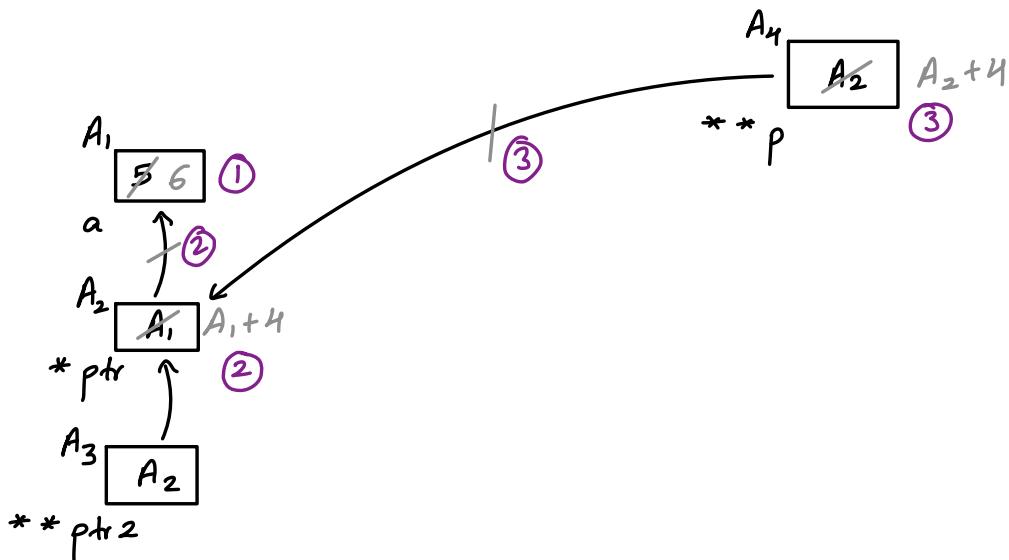
```

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
 - $a, *ptr, **ptr \longrightarrow a$
diff. names of same memory location
 - 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;

A₁

Symbol Table

a	A ₁
b	A ₁

int &b = a;

5
a, b

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;  
}
```

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

① $x++;$

}

PASS BY
REFERENCE

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

② $(*p)++;$

}

PASS BY
VALUE

A₂

A₁

*p

A₁

5

a, x

6

① → 6 → 7
②
③ ↓
8

A₃

A₁

*ptr

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

③ $(*pt)++;$

}

A₄

A₁

*pt

```

vector<int> func( vector<int> &arr) {
    for (int i=0; i < arr.size(); i++)
        arr[i]++;
    return arr;
}

```

int solve (int & arr) { this is reference variable
of type int

```

} cout << arr;
}

```

int solve (int & arr[]) ERROR

```
int main () {
```

```
vector<int> arr { 1, 2, 3, 4 };
```

```
vector<int> ans = func(arr);
```

```
for ( auto i: ans)
```

```
cout << i ; 2 3 4 5
```

solve(arr); ERROR vector != int

```
int arr2 [ ] = { 1, 2, 3 };
```

solve(arr2); ERROR int [3] != int

```
return 0;
```

```
}
```

RETURN BY REFERENCE

→ return a variable , not a value

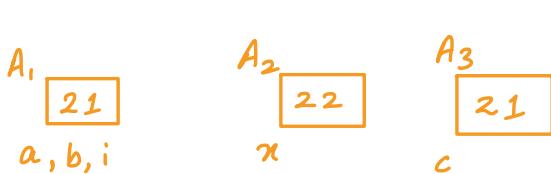
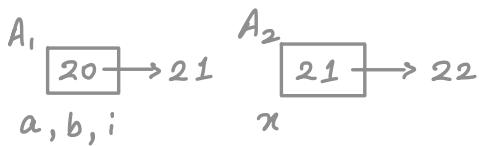
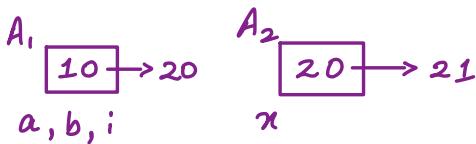
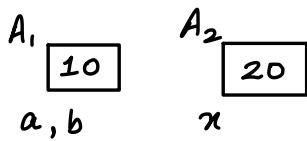
→ To implement atleast 1 of 2 conditions
must be true.

1. passing a reference variable
2. passing a global variable

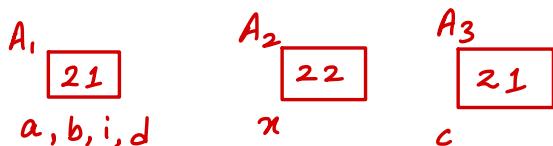
passing a reference variable

```
int main (){  
    int a = 10;  
    int & b = a;  
    int x = 20;  
    ref(a) = x;  
    x++;  
    ref(b) = x;  
    x++;  
    int c = ref(a);  
    int &d = ref(a);  
  
    return 0;  
}
```

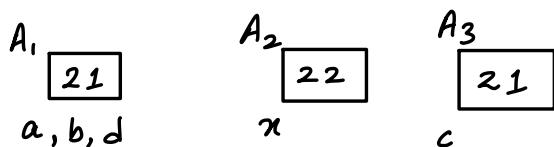
```
int & ref( int &i){  
    return i;  
}
```



```
int c = ref(a) = i;
int c = 21;
```



```
int &d = ref(a) = i;
int &d = i;
```



passing a global variable

```
int x = 5;
```

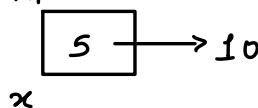
```
int main () {
```

```
    ref () = 10;
```

```
    x = 10;  
    ref2 () = 20; → ERROR  
    return 0;
```

```
}
```

A,



x

```
int & ref () {
```

```
    return x;
```

```
}
```

```
int ref2 () {
```

```
    return x;
```

```
}
```

returning a value, not variable

10 = 20;

↳ that's why ERROR

pass by value but return by reference

```
int main () {
```

```
    int a = 10;
```

```
    int & b = a;
```

```
    int x = 20;
```

```
    ref(a) = x;
```

```
    x++;
```

```
    ref(b) = x;
```

```
    x++;
```

BAD PRACTICE

ERROR

```
int & ref ( int temp ) {
```

```
    return temp;
```

```
}
```

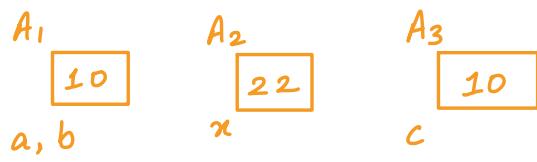
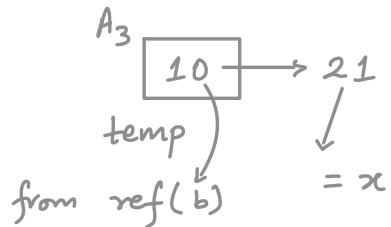
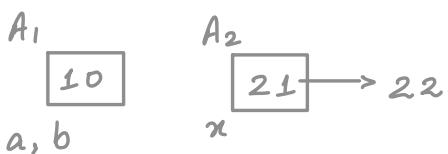
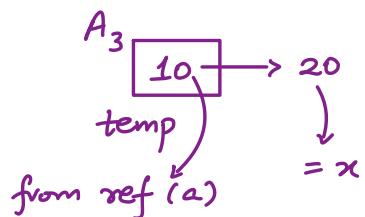
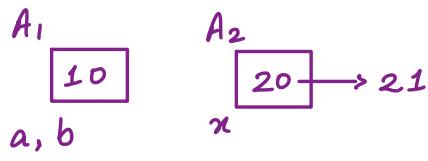
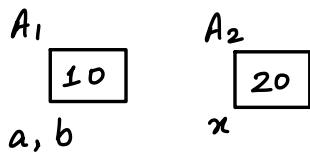
returning a variable stored
in temporary memory

```

int c = ref(a);
int &d = ref(a);
return 0;
}

```

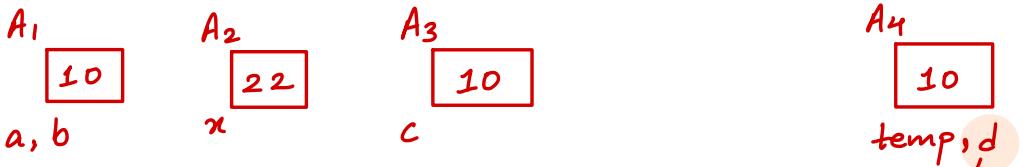
lets assume it will run , then this would happen



```

int c = ref(a) = temp;
int c = temp;
int c = 10

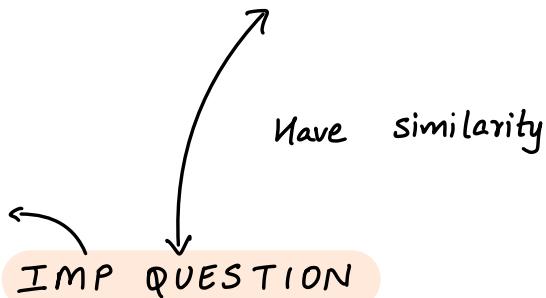
```



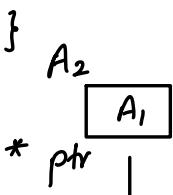
d (variable of main function refers to
a temporary memory

→ BAD PRACTICE

DON'T DO THIS
AT HOME

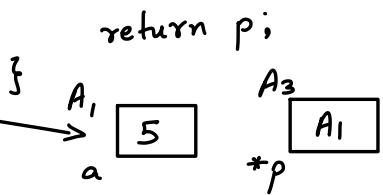


```
int main () {
    int * ptr = solve ();
    return 0;
}
```



pointing to a temp
memory, 'a' variable → BAD PRACTICE
will finished outside
solve function so value
of 'a' can be change with time

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



BAD PRACTICE

Some Important Questions

W6-A

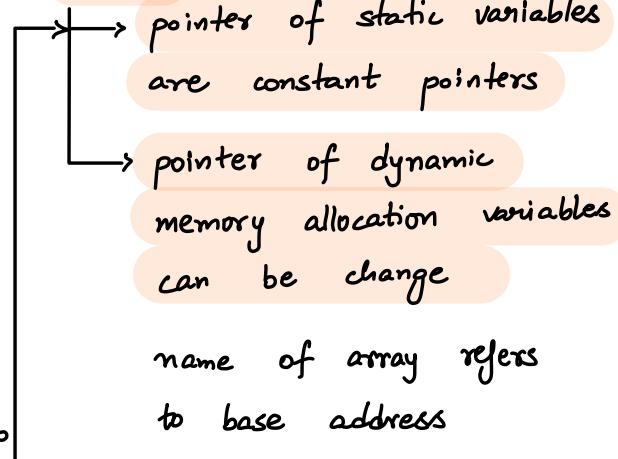
→ `int *ptr = 0;`
`int a = 10;`
`*ptr = a; -----> runtime ERROR`
`cout << *ptr;`

→ `char *ch = 'a';`
`char *ptr = &a;`
`ch++;`
`cout << *ptr; -----> 'b'`

→ `int a[] = {1, 2, 3, 4, 5};`

`int *p = a++; -----> ERROR`

`cout << *p;`



→ `char ch = "hello";`
`cout << ch; -----> hello`
`ch++; -----> ERROR`
`cout << ch;`

name of array refers
to base address

→ double arr [] = { 2.5, 7.9, 50.25 } ;

double * ptr = arr ;

ptr = ptr + 0.25 ; → ERROR

cout << ptr ;

pointer arithmetic op-
can only be done
using integers

→ int arr [] = { 1, 2, 3, 4, 5 } ;

int * ptr1 = arr ;

int * ptr2 = arr + 3 ;

cout << ptr2 - ptr1 ; → 3, NOT 12

→ int a = 5 ;

int * ptr = &a ;

int ** ptr2 = &ptr ;

ptr2 = &a ; → ERROR → int ** cant convert

cout << *ptr2 ; to int *

→ int a = 5 ;

int * p = &a ;

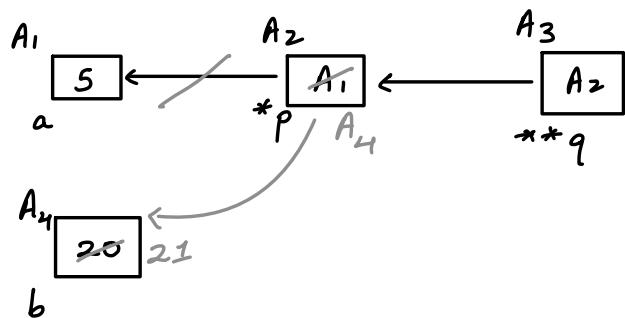
int ** q = &p ;

int b = 20 ;

* q = &b ;

(*p)++ ;

cout << a << ' ' << b ; → 5 21



→ int a = 5;

int * ptr = &a;

int ** ptr2 = &ptr;

int ** ptr3 = &(&a); —————> ERROR

cout << *** ptr3;

address of (address in
memory location)

(doesn't make any sense)

W6-L5

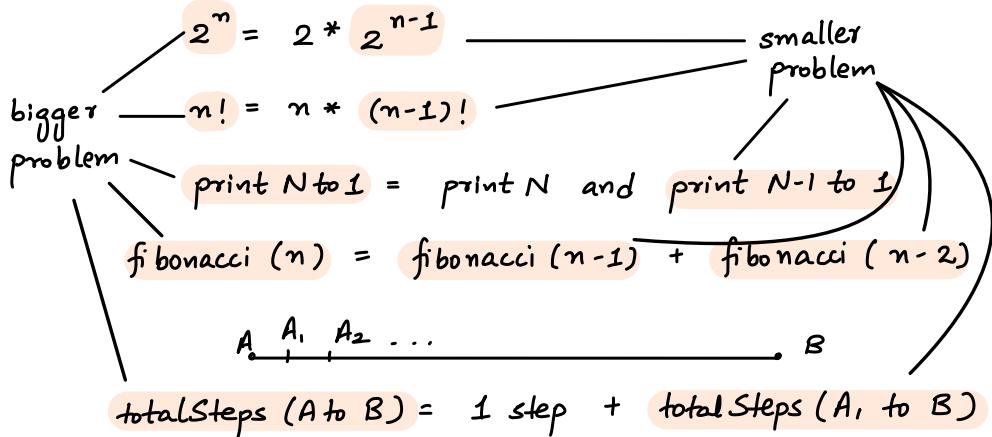
POITER IMP DOUBT

(IN DASH BOARD)

RECURSION

W7-L1

- When a function calls itself
- When sol. of bigger problem depends on similar smaller problem (s)



Components of Recursion

- Base Case / Stopping cond. → return statement
- Recurrence Relation (recursive call)
- Processing → optional

Head Recursion

- recurrence relation before processing

Tail Recursion

- recurrence relation after processing

```

int main () {
    int n = 4;
    print (n);
    return 0;
}

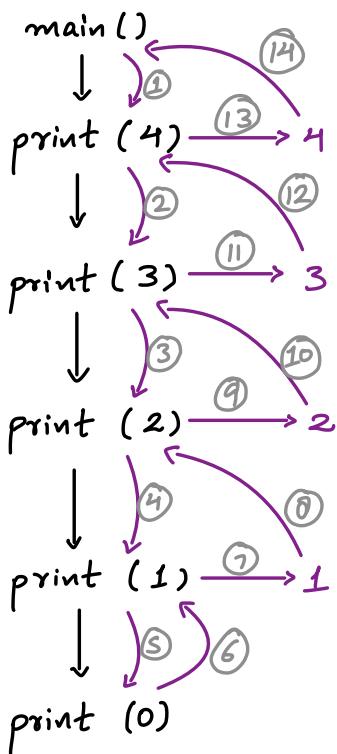
```

```

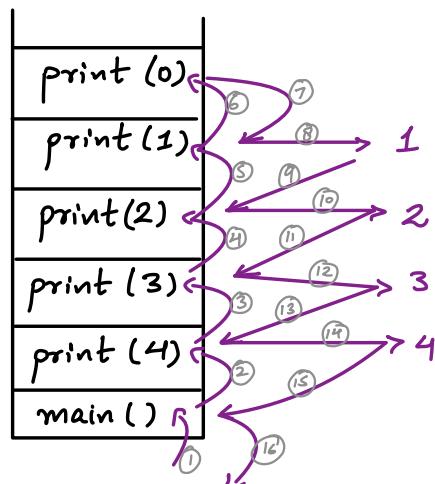
void print ( int n) {
    // base condition
    if ( n==0)
        return;
    // recurrence relation
    print (n-1);
    // processing
    cout << n;
}

```

Recursion Tree



Call Stack



Output - 1 2 3 4

```

int main(){
    int n = 4,
        ans = fib(n);
    cout << ans;
    return 0;
}

```

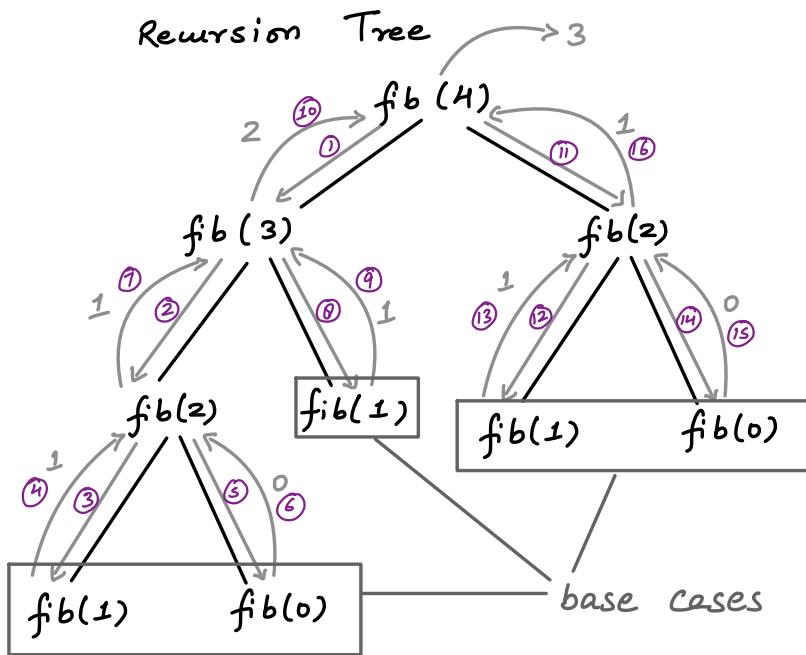
```

int fib( int n){
    if( n == 0 || n == 1)
        return n;
    return fib(n-1) + fib(n-2);
}

```

$n \rightarrow 0 \ 1 \ 2 \ 3 \ 4$

$\text{fib}(n) \rightarrow 0 \ 1 \ 1 \ 2 \ 3$



Magical line for Recursion

Ek case solve krdo, baaki recursion sambhal lega

Just believe on it, dont doubt on recursion

W7-L2

→ func(vector<int> arr, int i, int &ans)

pass by reference

if we want to retain value of ans after function call

→ Try to pass everything by reference IF POSSIBLE

└ SC Yes

TC Yes (no copying of variables again & again)

→ to reverse answer, you can use recursion

Integer literal with a leading 0

n = 0100 ; → interpreted as an octal number

cout << n; → 64 → convert 0100 octal to decimal

cin >> n; → (0100)

cout << n; → 100 → no conversion as
cin reads 0100 as 100

Entry in function call stack

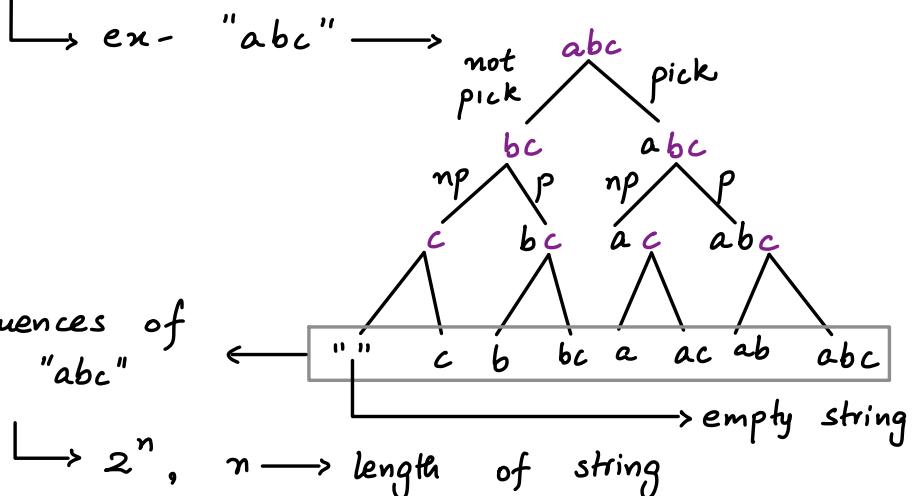
W7-L3

└ Computer has track of variables of that function about their memory location and all in symbol table

→ Expression can't be pass by reference

Subsequences

→ Made by either including or excluding every element, but order remains same



Arithmetic Operations on Strings

s1 = "Ujjwal";

s2 = "2327";

cout << "Ujjwal" + "2327"; → ERROR

s1 = s1 + s2;

cout << s1; → "Ujjwal2327" → Concatenate

- , * , / , % → NOT VALID in strings

Coin change problem

W7-L4

→ find min. coins equivalent to given amount

```
int coinChange( vector<int> arr, int amount) {  
    if (amount == 0)  
        return 0;  
    if (amount < 0)  
        return INT_MAX; // means INVALID or  
                           can't be changed  
    int mini = INT_MAX;  
    for (int i=0; i<arr.size(); i++) {  
        mini = min (mini, coinChange (arr, target - arr[i]));  
    }  
    // now min. coins req. has been found  
    if (mini == INT_MAX)  
        return INT_MAX; // means INVALID or  
                           can't be changed  
    else  
        return mini + 1;  
}
```

Type 1 - inclusion exclusion pattern → for using
either this or that subsequence questions

Type 2 - for loop in recursion

→ If the recursion ques seems tough,
use void function and pass ans by reference
in function

TC & SC of Recursive Solutions

W7-R

T.C. → Can be found by recursive relation
or recursive tree

S.C. → found using max depth of function call stack
└→ max space used in any particular time
instant in function call stack

Linear Search

$$f(n) = k + f(n-1) \quad \text{Base case} \rightarrow \text{for } n=0$$

Recursive Relation Method -

$$T(n) = k + T(n-1)$$

$$T(n-1) = k + T(n-2)$$

.

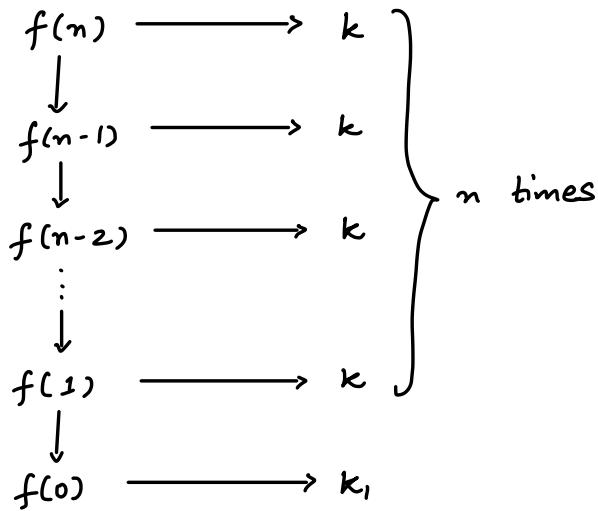
$$T(0) = k,$$

$$T(n) = nk + k_1$$

$$T(n) = O(n)$$

T.C - $O(n)$

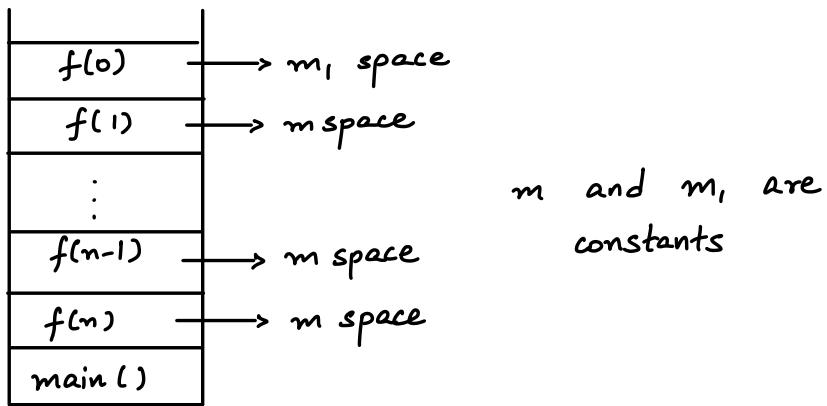
Recursive Tree Method - Best method



$$T(n) = nk + k_1$$

$$T(n) = O(n)$$

Space Complexity -



$$SC = mn + m_1$$

$$SC = O(n)$$

$\xrightarrow{\quad}$ max depth

Binary Search

$$f(n) = k + f(n/2); \quad \text{base case} \rightarrow \text{for } n=0$$

Recursive Relation Method

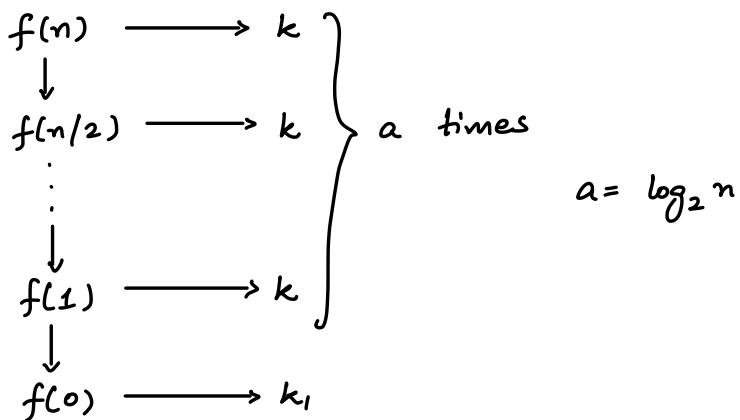
$$\begin{aligned} T(n) &= k + T(n/2) \\ T(n/2) &= k + T(n/4) \\ &\vdots \\ T(1) &= k + T(0) \\ T(0) &= k_1 \end{aligned} \quad \left. \begin{array}{l} \\ \\ \\ \end{array} \right\} a \text{ times} \quad a = \log_2 n$$

$$T(n) = ak + k_1$$

$$T(n) = k \log_2 n + k_1$$

$$T(n) = O(\log_2 n)$$

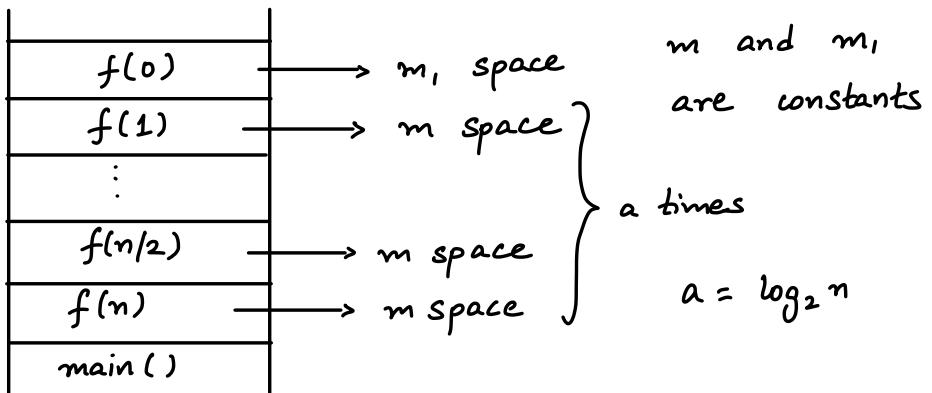
Recursive Tree Method



$$TC = k \log_2 n + k_1$$

$$TC = O(\log_2 n)$$

Space Complexity -



$$SC = m \log_2 n + m_1$$

$$SC = O(\log_2 n)$$

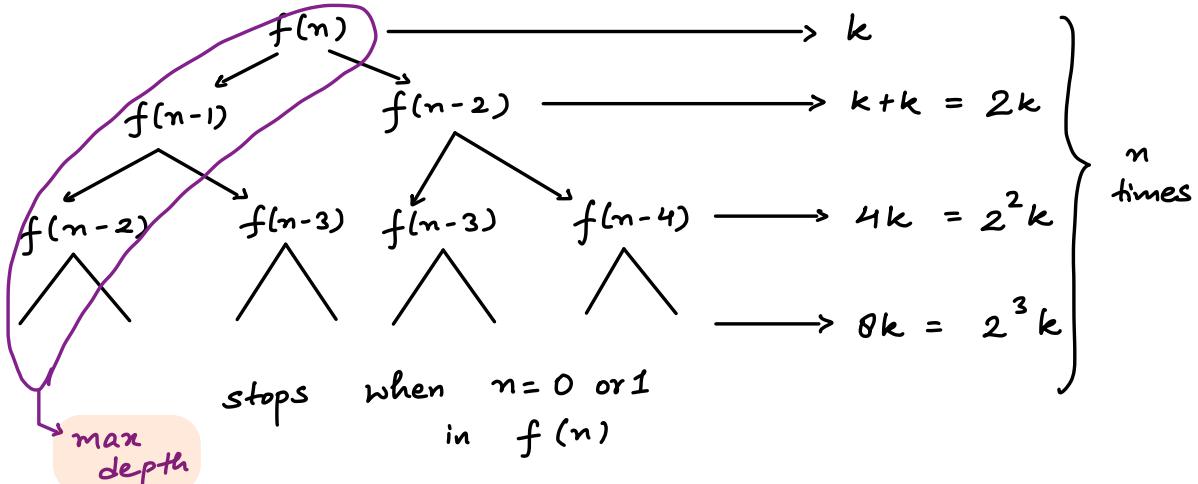
max depth

Fibonacci Series

$$f(n) = k + f(n-1) + f(n-2)$$

base case \rightarrow for $n=0$ or 1

Recursive Tree Method



$$T.C \leq [k + 2k + 2^2k + \dots + 2^{n-1}k]$$

$$T.C. \leq k * [1 + 2 + 2^2 + \dots + 2^{n-1}]$$

$$T.C \leq k * (2^n - 1)$$

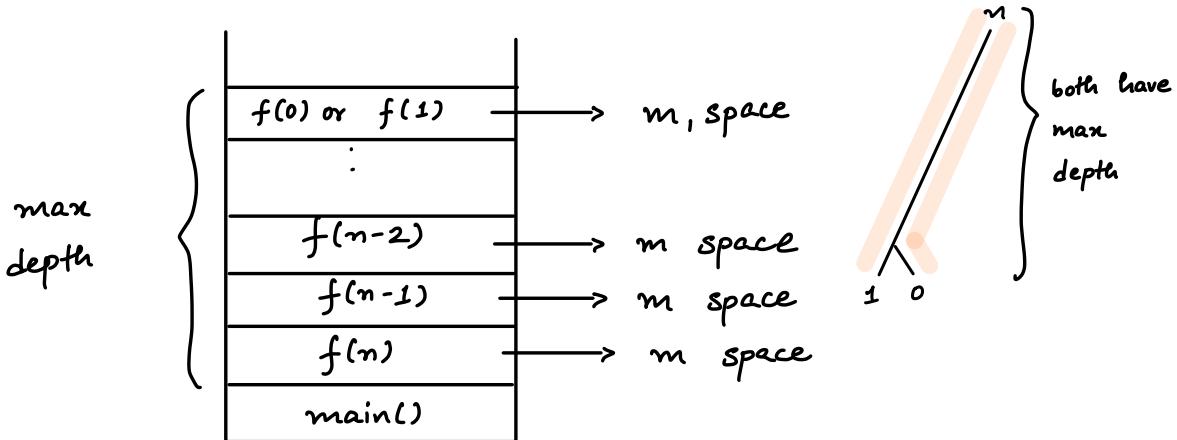
$$T.C = O(2^n)$$

assume
for simplicity
and for large
numbers

→ exponential TC

→ very bad

Space Complexity



$$SC = m(n-1) + m,$$

$$SC = O(n)$$

→ max depth

if this is such a case

fun(0)	→ n^3 space / time
fun(1)	→ n^2 space / time
:	
fun(n-1)	→ n space / time
fun(n)	→ k space / time
main()	

$$S.C. - n * n^3$$

↳ max SC in any call

$$T.C. - n * n^3$$

↳ max T.C. in any call

Divide & Conquer

→ using recursion

W8-L1

Merge Sort

- Divide the array in 2 halves
- Sort them
- Merge those 2 sorted subarrays

Standard Merge Sort

```
void merge( vector <int> &arr, int s, int e) {  
    int mid = e - (s + e)/2;  
    int len1 = s - mid + 1;  
    int len2 = e - mid;  
    vector <int> left (len1);  
    vector <int> right (len2);  
    int i=0, j=0, k=s;  
  
    while (i < len1)  
        left [i++] = arr [k++];  
  
    while (j < len2)  
        right [j++] = arr [k++];  
  
    i=0, j=0, k=s;
```

```

while ( i < len1 && j < len2 ) {
    if ( left [ i ] <= right [ j ] )
        arr [ k ++ ] = left [ i ++ ];
    else
        arr [ k ++ ] = right [ j ++ ];
}
while ( i < len1 )
    arr [ k ++ ] = left [ i ++ ];
while ( j < len2 )
    arr [ k ++ ] = right [ j ++ ];
}

void mergeSort ( vector < int > & arr, int s, int e ) {
    if ( s >= e )
        return ;
    int mid = s + ( e - s ) / 2;
    mergeSort ( arr, s, mid );
    mergeSort ( arr, mid + 1, e );
    merge ( arr, s, e );
}

```

}

T.C. - $O(n \log n)$ → number of levels
S.C. - $O(n)$ → $(n + \frac{n}{2} + \frac{n}{4} + \frac{n}{8} + \dots \text{ till } 1)$

IMPLACE MERGE SORT - GFG

due to copy in every level

→ in best case too →

Quick Sort

→ Partition

Choose one element named pivot and put it on its correct position

Put elements less than pivot in left subarray and otherwise in right subarray

→ Sort left & right subarrays recursively

```
int partition( vector<int> &arr, int s, int e){
    int pivotIndex = s; —————> This is one way
    int pivot = arr[s];
Other ways - choose last  
- choose random
↓  
randomised  
quick sort
    int cnt = 0;
    for( int i=s+1; i<=e ; i++ ){
        if( arr[i] > pivot )
            cnt++;
    }
    int correctPosition = s + cnt;
    swap( arr[pivotIndex], arr[correctPosition] );
    pivotIndex = correctPosition
}
```

```

int i=s, j=e;
while( i < correctPosition && j > correctPosition) {
    while( arr[i] < pivot)
        i++;
    while( arr[j] >= pivot)
        j--;
    if( i < correctIndex && j > correctIndex)
        swap( arr[i++], arr[j--]);
}
return correctPosition;
}

void quickSort( vector<int> &arr, int s, int e){
if( s >= e)
    return;
int p = partition( arr, s, e);
quickSort( arr, s, p-1);
quickSort( arr, p+1, e);
}

```

T.C. - $O(n \log n)$ → log_n number of function calls

$O(n^2)$ → for both ascending & descending sort

S.C. - $O(n)$ → n number of function calls

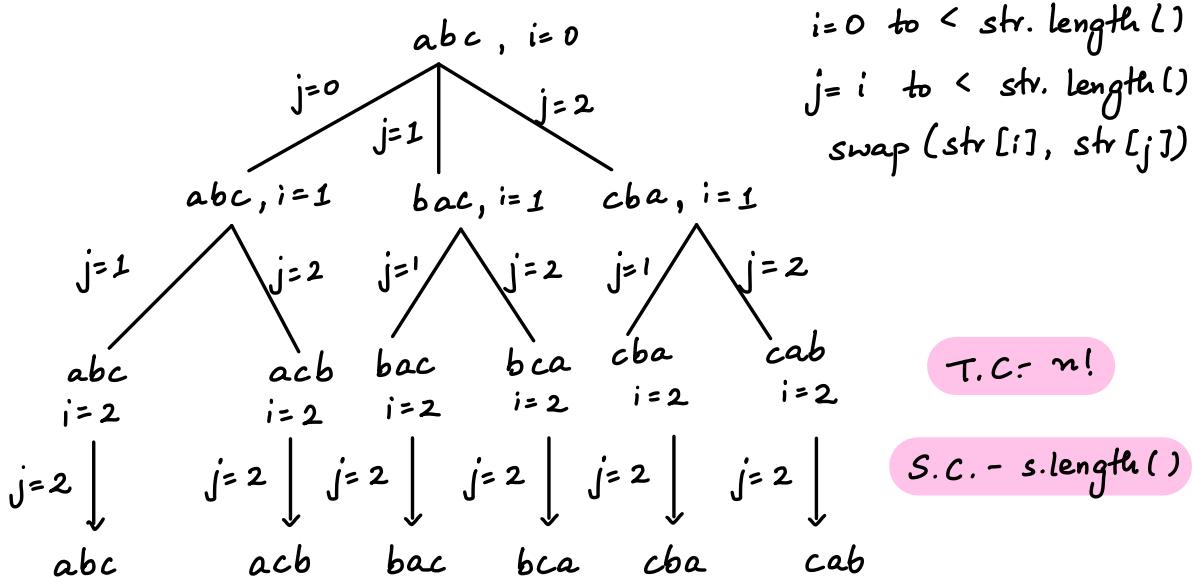
Backtracking

- specific form of recursion
 - explore all possible solutions and
 - don't check the solution you have already discarded
 - brute force
 - used for reference variables passed in functions

Permutation in a string

permutations - abc, acb,
| gab, cba

$\rightarrow \text{total} - n!$



Time Complexity

- max time required by an algorithm as a function of input
 - for worst case
- number of calls * T.C. - time in 1 call
- T.C. - total time in 1 level * number of levels

Space Complexity -

- max space taken by an algorithm at any particular instant
- S.C. - space in 1 call * max depth

→ Remember min space and time can be $O(1)$
not $O(0)$

Type 1 Linear Tree

```
fun (n){
```

Base Case

Processing

fun (n-1)

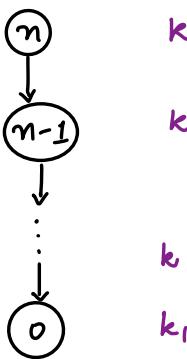
}

k_1
 k_2

$\} k$

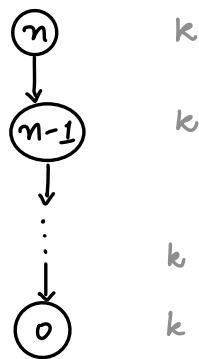
pass by value
1 variable n is created

→ pass by reference
min space is constant



T.C. - $nk + k_1$

T.C. - $O(n)$

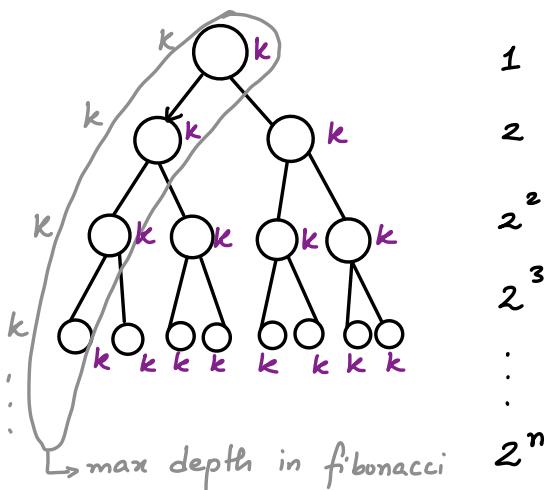


S.C. - $(n+1)k$

S.C. - $O(n)$

Counting
factorial
power of 2
check sorted
max in array
min in array

Type 2 Non Linear Tree



$$T.C. = k + 2k + 4k + \dots + 2^n k$$

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

S.C. - $n k$

S.C. - $O(n)$

fibonacci

jump stairs

subsequences

Type 3 Logarithmic



T.C. - $\log n * k$

S.C. - $\log n * k$

S.C. - $\log n * n$

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

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

S.C. - $n \log n$

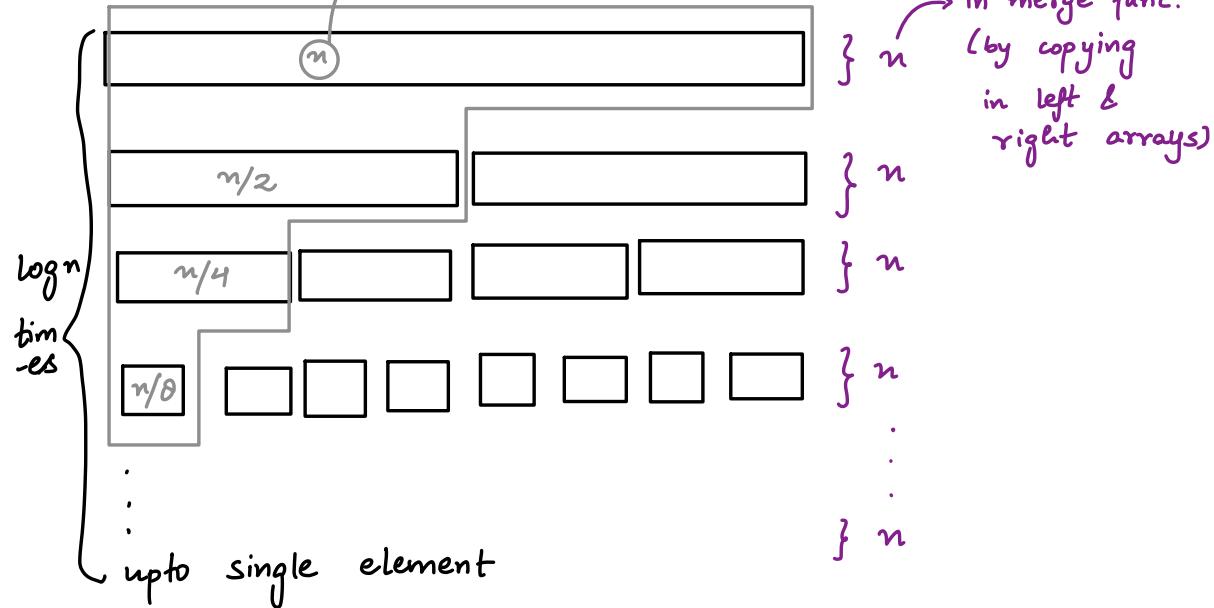
binary search

array / vector
pass by reference

vector pass
by value

Merge Sort

in merge func. (in copying in left & right arrays)



T.C - time in 1 level * number of levels

$$T.C. = n * \log n$$

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

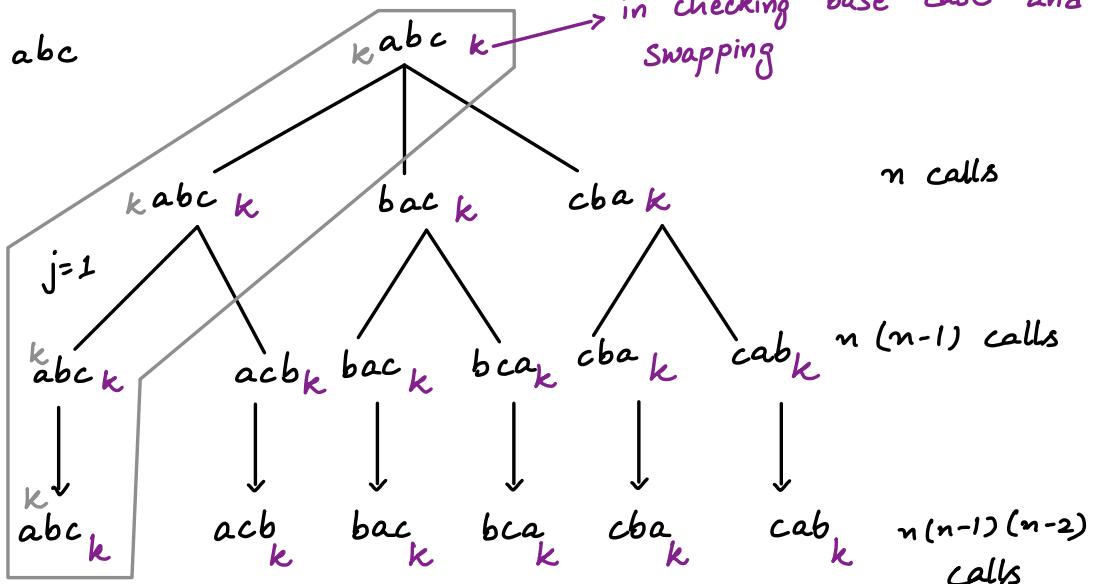
$$S.C. = n + \frac{n}{2} + \frac{n}{4} + \dots + 2$$

$$S.C. = O(n)$$

Backtracking Questions

Permutations of a string

$s = abc$



$$T.C. - k + nk + n(n-1)k + n(n-1)(n-2)k + \dots + n!k$$

$$T.C. - O(n!)$$

$$S.C. - n^* k$$

$$S.C. - O(n)$$

Rat in a maze

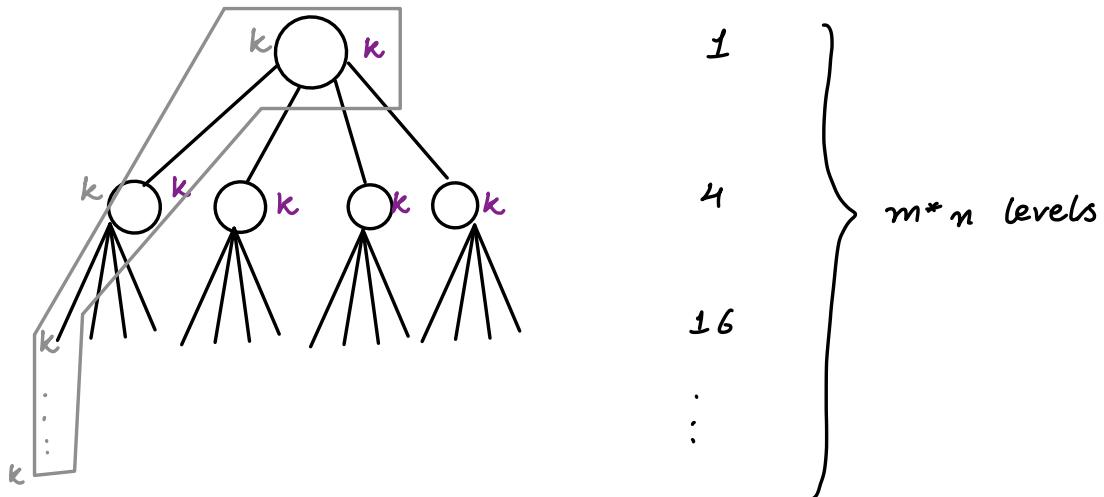
m rows
 n cols

func()
base case

4 recursive calls

↳ down, left, right, up

}



$$T.C. - k + 4k + 4^2k + \dots + 4^n k$$

$$T.C. - O(4^{mn})$$

S.C. - $k * mn$ $\xrightarrow{\text{depth}}$ of visited 2D array & pass by reference

$$S.C. - O(m * n)$$

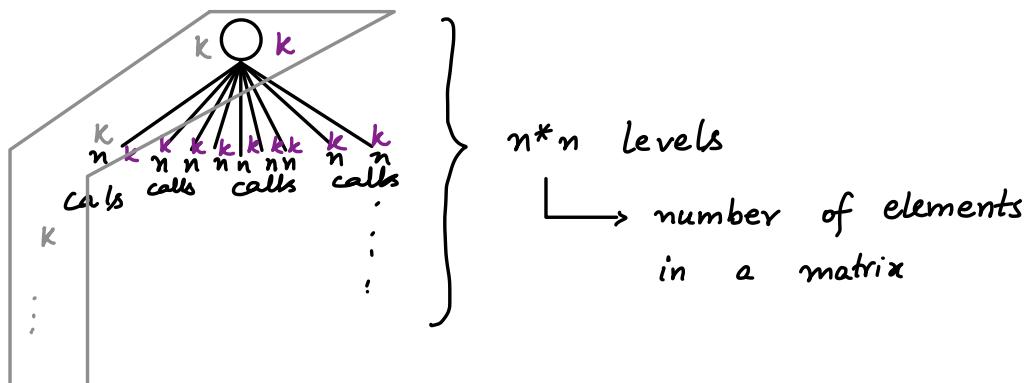
Sudoku Solve

$n \times n$ matrix

standard

$$\hookrightarrow n = 9$$

```
func() {
    base case
    n recursive calls + isSafe func.
}
```



$$T.C. - k + kn + kn^2 + \dots kn^{n \times n}$$

$$T.C. - O(n^{n^2})$$

$$S.C. - k * (\overbrace{n \times n}^{\text{depth}})$$

$$S.C. - O(n^2)$$

if n is already given 9, $T.C. - O(1)$ & $S.C. - O(1)$

N Queens

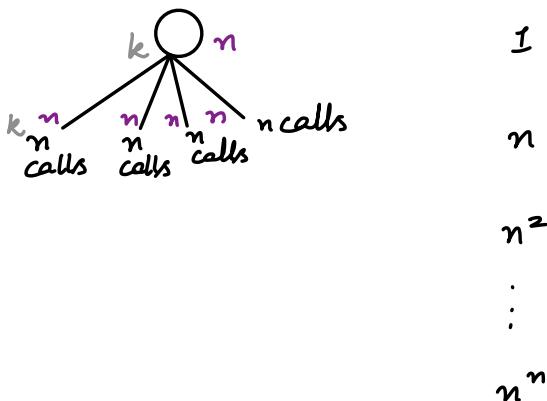
func()

$k \left\{ \begin{array}{l} k_1 \\ k_2 \end{array} \right.$ base case $\longrightarrow k$

n is safe function $\longrightarrow O(n)$

n recursive calls

}



$$T.C. = n(1) + n(n) + n(n^2) + \dots + n(n^n)$$

T.C. - $O(n^n) \longrightarrow$ worst case

T.C. - $O(n!)$ \longrightarrow average case

$$S.C. - k * n$$

$$S.C. - O(n)$$

S.C. - $k * n + n \xrightarrow{\text{in optimized sol for creating 3 maps}}$

$$S.C. - O(n)$$

→ $n * n!$ can be written as $n!$

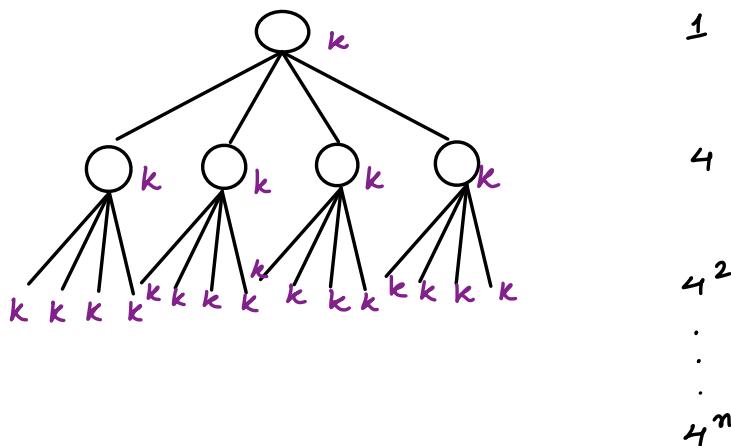
→ $n * 2^n$ can be written as 2^n

Phone Keypad Problem

1	2	3
abc		def
4	5	6
ghi	jkl	mno
7	8	9
pqrs	tuv	wxyz

```

    fun( ) {
        base case k
        ↳ store output in ans array
        at max 4 recursive calls
    }
  
```



$$T.C. = k + 4k + 4^2k + \dots + 4^n k$$

T.C. - $O(4^n)$

in max depth length of 1 output string
 ↑ ↑
 $S.C. = (k + 2k + \dots + nk) + (4^n * n)$
 ↓ ↓
 store output in base case no. of strings stored in ans array

S.C. - $O(4^n)$

OPP

W9-L1

- Object Oriented Programming
- programming technique in which everything revolves around objects
 - creation
 - interaction
 - access
 - changes
- 2 things
 - property / state → variables
 - behaviour / method → functions
- why ?
 - readable
 - reusable
 - easily maintain
 - easily to understand

Class

- to make user defined / custom datatype
- has structure definition
 - class - design / blueprint / idea
 - object - actual entity
 - instance of class
 - has existence

→ Class and Object both take memory

Creating a class

```
class className {  
    // states  
    string name;  
  
    // method  
    void sleep(){  
    }  
};
```

sizeof (class) -

```
class animal {
```

```
} ;
```

```
cout << sizeof (animal); → 1 to give existence  
for identifying this
```

```
class animal {
```

```
    int age;
```

```
} ;
```

```
class, so min.  
possible memory is  
allocated
```

```
cout << sizeof (animal); → 4
```

```
class animal {  
    string name;  
};
```

```
cout << sizeof(animal);
```

24

Why?

```
class animal {  
    int age;  
    char ch;  
};
```

```
cout << sizeof(animal);
```

↳ due to padding
and greedy alignment

```
class animal {
```

```
    string name;  
    string age;
```

```
    void sleep() {
```

```
        cout << name << " is sleeping";
```

```
}
```

```
};
```

} states / properties / data members

} method /
behaviour /
member
function

Static Object Creation

animal ramesh ;

Accessing state and method of object
object Name state : not class

object Name. method(parameters);

ex- ramesh. age ;

ramesh . sleep();

Access Modifiers

→ defines access scope of state / method

3 types

public

can access that

state / behaviour

inside as well as
outside the class

private (by default)

can access that

state / behaviour

only inside the
class, not outside
the class

protected

same as

private but

can be

access

inside
child

```
class animal {  
    public : —————> after marking,  
            all below state /  
            behaviour will be of  
            that type  
        string name ;  
        string age ;  
        void sleep () {  
            cout << name ;  
        }  
        private :  
        void eat () {  
        }  
};
```

To access private member outside class

↳ use public methods getter and setter

```
class animal {  
    string name ;  
    public :  
        string getName () { getter  
            return name ;  
        }  
};
```

```

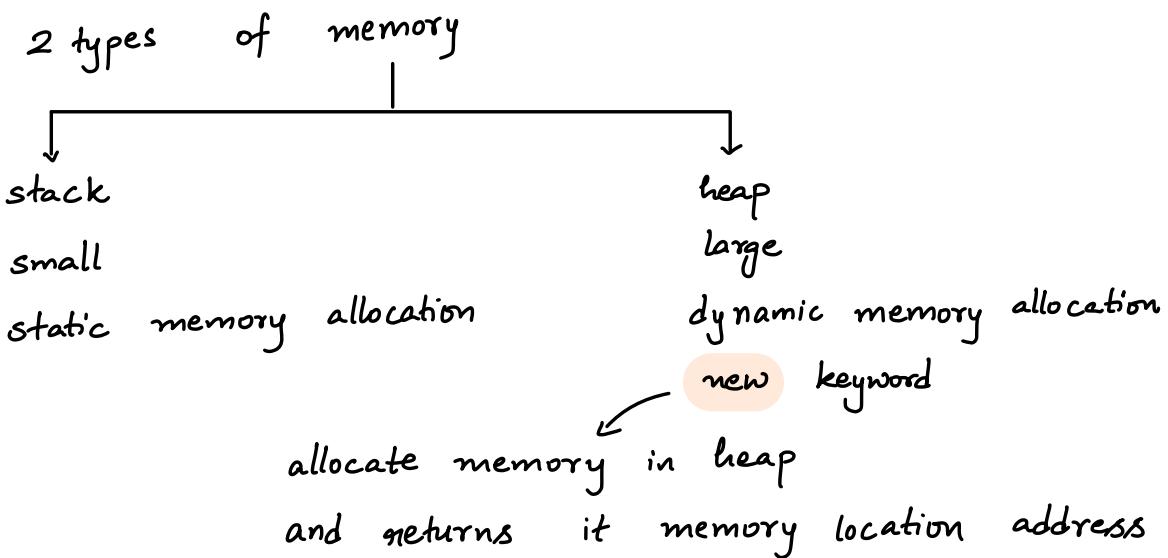
void setName ( string newName) {    setter
    name = newName;
}

};

int main( ) {
    animal ramesh;
    cout << ramesh. name; -----> ERROR
    cout << ramesh. getName(); -----> gu
    ramesh. setName ("Lion ");
    cout << ramesh. getName(); -----> Lion

```

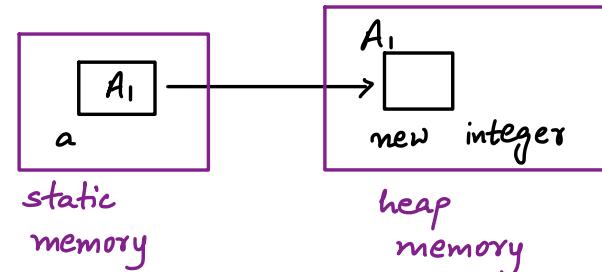
Dynamic Memory Allocation



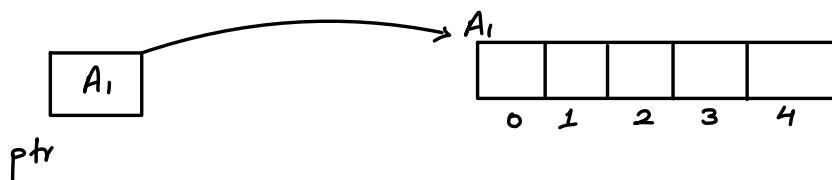
```
int a = 5;
```



```
int * a = new int
```



```
int * ptr = new int [5];
```



- space allocated in heap memory, cannot be cleaned automatically even after finishing of func.
- there is no garbage collector in C++

Allocation

```
int * a = new int;
```

```
int * arr = new int [5];
```

De allocation

```
delete a;
```

```
delete arr [];
```

Object Creation using dynamic memory allocation

```
animal * suresh = new animal;
```

suresh.name; \longrightarrow ERROR as suresh is a pointer, *suresh is object

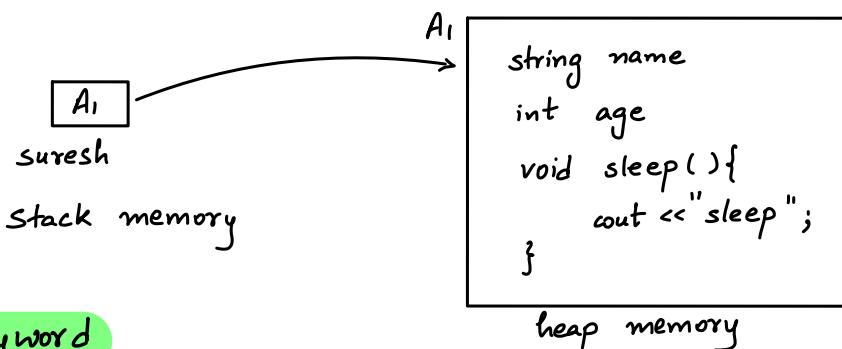
(*suresh).name; } 1st way of access

(*suresh).sleep();

suresh \rightarrow name;

suresh \rightarrow sleep();

} 2nd way of access



this keyword

\hookrightarrow pointer to current object

```
class animal {
```

```
    int age;
```

```
public:
```

```
    void setAge( int age) {
```

```
        this  $\rightarrow$  age = age;
```

```
        // (*this).age = age;
```

```
}
```

```
};
```

} both are correct

Object Creation

→ Constructor Call (in both static and dynamic allocation)

- initialize the object
- function with no return type
- its name is same as class
- created by default

```
class animal {
```

```
    int age;  
    int weight;
```

// default constructor

```
animal () {  
    cout << "Constructor Called";  
    this->age = 10;  
    this->weight = 20;
```

```
}
```

} now built-in
constructor does not
called, it will be
called

→ accessing members and methods

using this keyword is **GOOD PRACTICE**

// parameterised constructor

```
animal (int age) {  
    this->age = age;  
    cout << "Parameterised constructor called";  
}
```

// parameterised constructor 2

```
animal ( int age, int weight){  
    this->age = age;  
    this->weight = weight;  
    cout << "Parameterised constructor 2 called";  
}
```

// copy constructor (wrong way)

```
animal (animal obj) {  
    this->age = obj.age;  
    this->weight = obj.weight;  
    cout << "Copy Constructor Called";  
}
```

```
animal a;  
animal b = new animal;
```

```
animal c = a;  
animal d(a);  
animal e = *b;  
animal f (*b);
```

)

↳ copy constructor call
↳ pass by value

↓
infinite loop

// copy constructor (right way)

```
animal (animal & obj) {  
    this->age = obj.age;  
    this->weight = obj.weight;  
    cout << "Copy Constructor Called";  
}
```

}

Destructor

- free memory
- for static object creation,
destructor gets called automatically
where object's scope ends
- for dynamic object creation,
you have to do it manually using
`delete objName;`
- no return type
- no input parameter

```
class animal {  
    int age;  
    int weight;
```

// destructor

```
~animal () {  
    cout << "destructor called";  
}
```

}

4 Pillars of OOPs

W9-L2

- Encapsulation
- Inheritance
- Polymorphism
- Abstraction (Pitaji of all OOPs pillars)

Encapsulation

- Wrap data members and member functions in one parent entity (class)
- Objective → Data Hiding
 - security
 - privacy
 - can make readonly
 - can decide what to hide and what to show
 - work with parent entity is simple

Objective of class → Encapsulation

Perfect / Full / 100% Encapsulation

- When all data members are marked private and access them using getter and setter

Inheritance

- inherit some properties (data members and data functions) from parent / super / base class to sub / child / derived class
- Objective → Reusability
- is a relationship
 - childName is a parentName
- Syntax
 - ↳ class childName : mode1 parentName1,
..., modeN parentNameN {
// additional states and methods
}

```
class Animal {  
    int age;  
public:  
    int weight;  
protected:  
void eat () {  
    cout << "eating";  
}  
};
```

```
class Dog : public Animal {  
};  
Dog is a Animal  
class cat : public Animal,  
protected Dog {  
};
```

Access Modifier of Base class	Mode of inheritance		
	Public	Protected	Private
Public	Public	Protected	Private
Protected	Protected	Protected	Private
Private	NA	NA	NA

NA → Not Accessible

↳ can't be inherited

Protected

↳ Same as private access modifier

but can be inherited



can be accessed inside child class

Private

↳ can access inside class but not outside

cannot be inherited

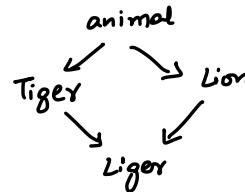


cannot be accessed inside child class

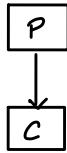
Type of Inheritance

P - Parent C - Child

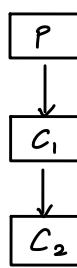
- Single
- Multilevel
- Multiple
- Heirarchical
- Hybrid → mixture of all above 4



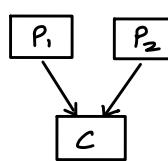
Single



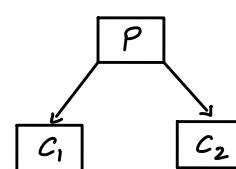
Multilevel



Multiple



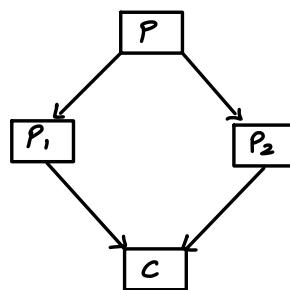
Heirarchical



Diamond Problem / Inheritance Ambiguity Problem

→ If multiple parents have same property
then how to access them

→ `objectName. Parent Class Name :: property ;`



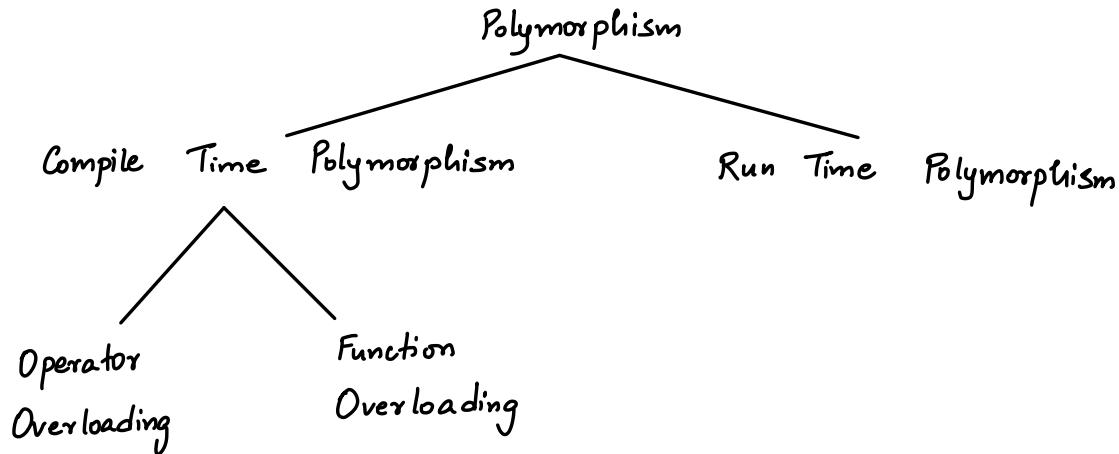
scope resolution operator

- If parent and child have same property, then parent property inside child class will get overwrite by child property
- Multiple inheritance is possible in C++, not in Java

Polymorphism

↳ form

→ existed in many forms



Function Overloading

↳ one function existing in multiple forms / signatures

→ Multiple Signatures

↳ diff. in either no. of parameters or type of parameters,
not diff. in return type

→ 5.12 → double

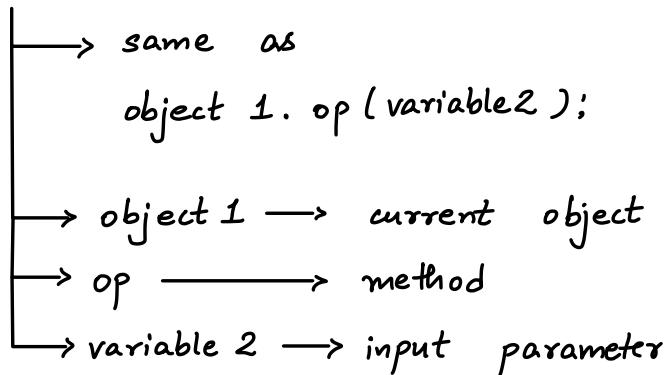
5.12f → float

```
class Maths {  
public:  
    int sum (int a, int b){  
        return a+b;  
    }  
    float sum ( int a, double b){  
        return a+b;  
    }  
    int sum( int a, int b, int c){  
        return a+b+c;  
    }  
};  
int main () {  
    Maths m;  
    cout << m.sum(5, 2); -----> 7  
    cout << m.sum(5, 2.5); -----> 7.5  
    cout << m.sum(5, 2, 7); -----> 14  
    return 0;  
}
```

Operator Overloading -

→ to make new implementation of an operator

object1 op variable2



```
class Para {
```

```
public:
```

```
int val;
```

```
Para ( int val ) {
```

```
    this → val = val;
```

```
}
```

```
int operator + ( Para obj2 ) {
```

```
    return this → val - obj2. val;
```

```
}
```

```
int operator + ( char ch ) {
```

```
    cout << this → val + 10;
```

```
}
```

```
} ;
```

```

int main (){
    Para a(5);
    Para b(2);
    cout << a + b; -----> same as a.+ (b)
                                         ↳ 3
    a + 'c'; -----> 15
    a + '7' ; -----> 15
    return 0;
}

```

→ "operator +" function must have exactly
 1 parameter as + is binary operator

↓
 2 operands
 current object input parameter

Run Time Polymorphism -

↳ polymorphism after execution

Function Overriding -

Function / Method Over-riding

- when function of parent class is defined separately inside child class
- reusable + custom behaviour wherever you want

```
class Animal {
```

```
public:
```

```
void speak (){
```

```
    cout << "speak";
```

```
}
```

```
};
```

```
class Dog : public Animal {
```

```
public:
```

```
void speak (){
```

```
    cout << "bark";
```

```
}
```

```
};
```

```
int main () {
```

```
    Animal a;
```

```
    cout << a.speak();
```

```
    Dog d;
```

```
    cout << d.speak();
```

```
class Animal {
```

```
public:
```

// upcasting

Animal * b = new Dog ;

cout << b. speak(); —————> speak → function of parent class called

Animal * b = new Dog;

cout << b. speak(); —————> bark

// down casting

Dog * c = new Animal ; —————> Compiler dependent (ERROR or not)

cout << c. speak(); —————> bark

Dog * c = new Animal ;

OOPS Week is not completed

from my side

will complete in future

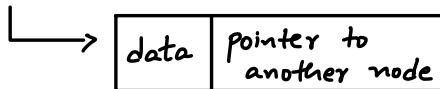
Abstraction

- Objective → Implementation Hiding
- Talk about in a larger scale
not focus on detail

LINKED LIST

W10-L1

- Dynamic linear data structure to store similar data
- non-continuous memory allocation
- insertion and deletion is easy
 $O(1)$ if you are standing on that node / pointer
- no concept of indexing,
it has concept of addresses
- collection of nodes

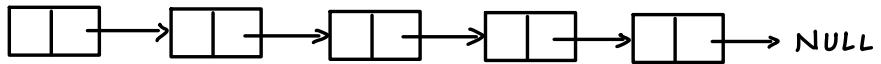


node creation (simplest)

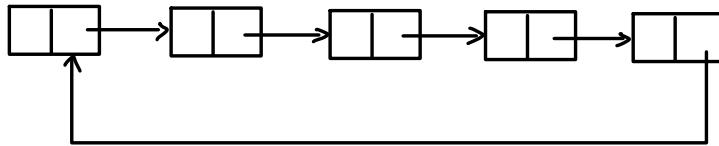
```
class node {  
public:  
    int data;  
    node * next;  
}
```

Types of linked list

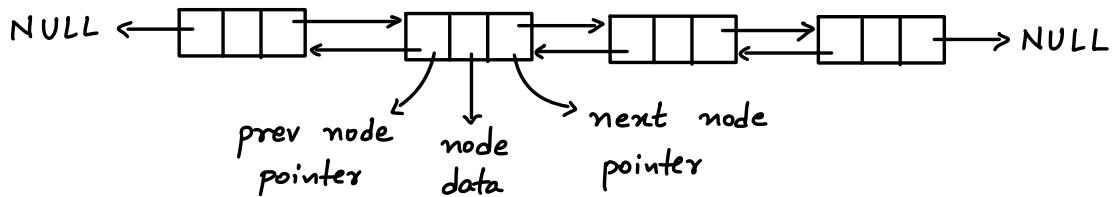
→ Singly LL



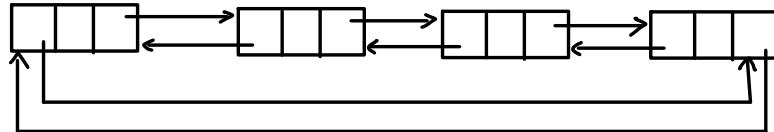
→ Circular LL



→ Doubly LL



→ Circular Doubly LL



→ LL is nothing but Hindi (any other language)

→ Linear Data Structure

└ single descendent

→ In LL ques, there are high chances of error, so check edge cases (head, tail, size=1, not found, and more) before submit.

W10-L2

Doubly Linked list

→ node creation

```
class node {  
public:  
    int data;  
    node * next;  
    node * prev;  
}
```

Circular Linked List

→ no Head and Tail

→ insertion & deletion is only on the basis of value

→ Converting loop code to recursion code

→ Add parameters that are changing in loop

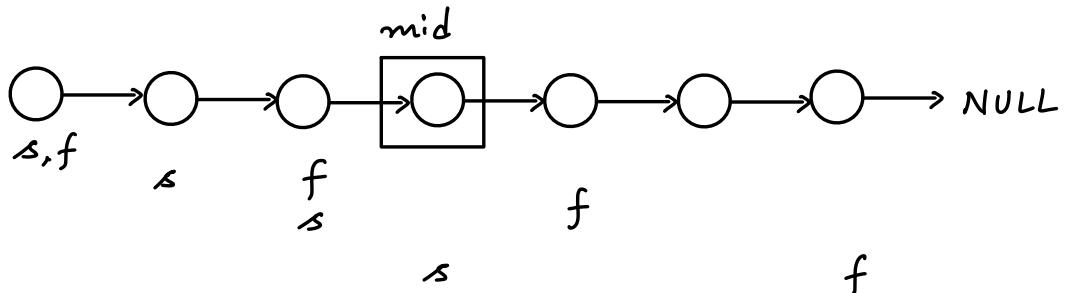
→ Stopping condition in loop acts as base case

Tortoise Algorithm

W10-L3

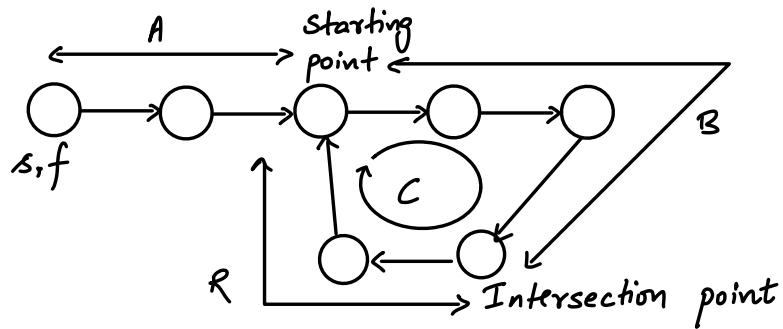
- fast and slow pointer approach
- get middle

```
int getMiddle ( node * head) {  
    if (head == NULL)  
        return -1;  
  
    node * fast = head;  
    node * slow = head;  
  
    while (fast != NULL){  
        fast = fast -> next;  
        if (fast != NULL){  
            fast = fast -> next;  
            slow = slow -> next;  
        }  
    }  
    return slow -> data;  
}
```



Floyd's Cyclic Detection Algorithm

- to detect and delete loop in linked list
- detect the loop in linked list
find starting point of loop in linked list
delete the loop from linked list



$$\text{distance } (f) = 2 * \text{distance (slow)}$$

$$A + B + xC = 2(A + B + yC)$$

$$A + B = (x - y)C$$

$A + B$ made some cycles

$$B = (x - y)C - A$$

so after B steps from intersection point,
some no. of cycles starting from starting
point get completed

So intersection point + A \Rightarrow reach starting point

Also head + A \Rightarrow reach starting point

$$R + zC = A$$

```
162 // also works if loop starts from head
163 void removeLoop(node* &head){
164     if(head==NULL)
165         return;    node *&head
166
167     node* fast = also.works if loop starts from head;
168     node* slow = head;
169     bool loopFound = false;
170
171     while(fast!=NULL){
172         fast = fast->next;
173         if(fast != NULL){
174             fast = fast->next;
175             slow = slow->next;
176         }
177
178         if(fast==slow){
179             loopFound = true;
180             break;
181         }
182     }
183
184     if(loopFound){
185         slow = head;
186         while(fast!=slow){
187             fast = fast->next;
188             slow = slow->next;
189         }
190
191         cout << "loop started from " << slow->data << '\n';
192         node*prev = slow;
193         while(prev->next!=slow){
194             prev = prev->next;
195         }
196         prev->next = NULL;
197
198     }
199     else{
200         cout << "no loop was present\n";
201     }
202 }
```

STACKS

W11-L1

→ Data Structure

→ LIFO (Last In First Out) Order

→ no index based accessing, only can access top

initialization

```
stack <int> s;
```

insertion

```
s.push(20);
```

deletion

```
s.pop();
```

top element

```
s.top();
```

can only be used if we are
sure that stack is non empty

empty or not

```
s.empty();
```

size

```
s.size();
```

→ If we pop a data set after pushing in stack, we get the answer in reverse order

So to reverse anything or to use LIFO order you can use stack

→ Stack can be implemented either by array (static or dynamic) or linked list

{ in implementation dont use vector as it is stl class }

Copying a stack

W11-L2

```
stack <int> st 1;
```

```
stack <int> st 2 = st 1;
```

→ if we have to do something for every element of stack, generally we need to write 2 functions,

first → for removing top, storing it and use recursion

second → for doing that something on a single element (top) of stack

ex - sort a stack

↳ insert top of stack in sorted stack

reverse a stack

↳ insert top of stack at the bottom

→ General format to solve standard stack question

void func (st)

if (st. empty ()) {

base case

processing

return;

}

int top = st. top ();

save top

st. pop ();

pop

func (st);

recursion call

processing

processing

}

Pair -

pair < int , char > p ;

} initialize

p = make - pair (27 , 'x') ;

p . first = 27 ; p . second = 'x' ;

p = { 27 , 'x' } ;

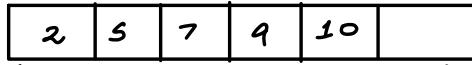
} insert

W11-L3

QUEUE

W12-L1

→ Data Structure in which data is stored in the form FIFO (first in first out) order



front
deletion

first element of queue

q.front()

q.back()

rear

insertion

place to insert next element

creation

```
queue <int> q;
```

rear always shows
empty block

insertion -

```
q.push(10);
```

deletion -

```
q.pop();
```

front element

```
q.front();
```

back element

```
q.back();
```

size

q. `size();`

empty or not

q. `empty();`

- queue can be implemented using either by dynamic array or by linked list
- if `front == rear` → queue is empty
- element access through index is not possible
- if iterative and recursive, both have same complexities, then iterative sol. takes less time generally

→ queue patterns

- queue / deque in sliding window
- traversals (trees and graph)
- use after sorting vector
- circular tour ques.

sliding window

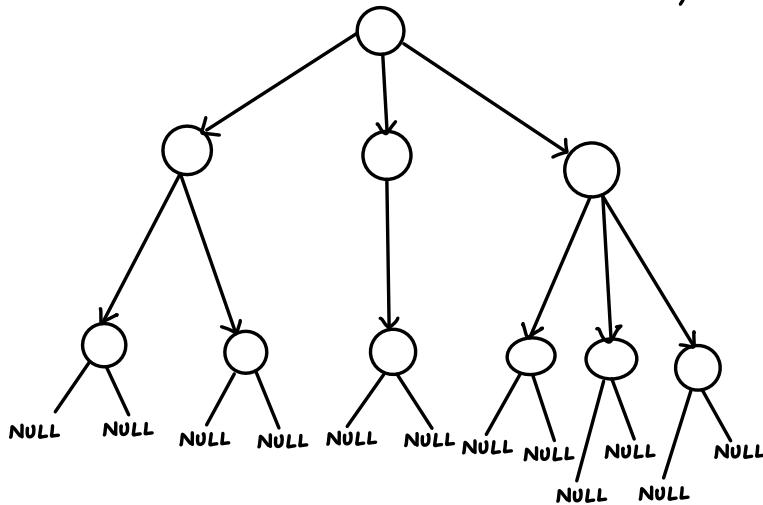
→ process first window

→ repeatedly remove first element of window &
add next element in window to process
next window

TREE

W13-L1

→ non linear data structure in which data is stored in hierarchical form



Binary Tree

→ Tree having no. of children for each node is less than or equal to 2

n-ary tree

→ Tree having no. of children for each node is less than or equal to n
→ generic tree

node

→ smallest unit of tree

for binary tree

```
class node {  
    int data;  
    node * left;  
    node * right;  
}
```

for many tree

```
class node {  
    int data;  
    vector<node*> child;  
}
```

root node

→ top most / starting node of the tree
→ only one in whole tree

leaf node

→ node with no child

non leaf node

→ node other than root and leaf nodes

parent → child

→ parent of root node is either NULL or itself or anything else according to the ques

ancestor

→ all nodes in the path from that node to root node

descendent

→ all nodes in the path from that node to any no. of leaf nodes

sibling

→ nodes that are children of same parent

level

→ start from root as 0 and increase as we go below towards leaf by 1

height of node

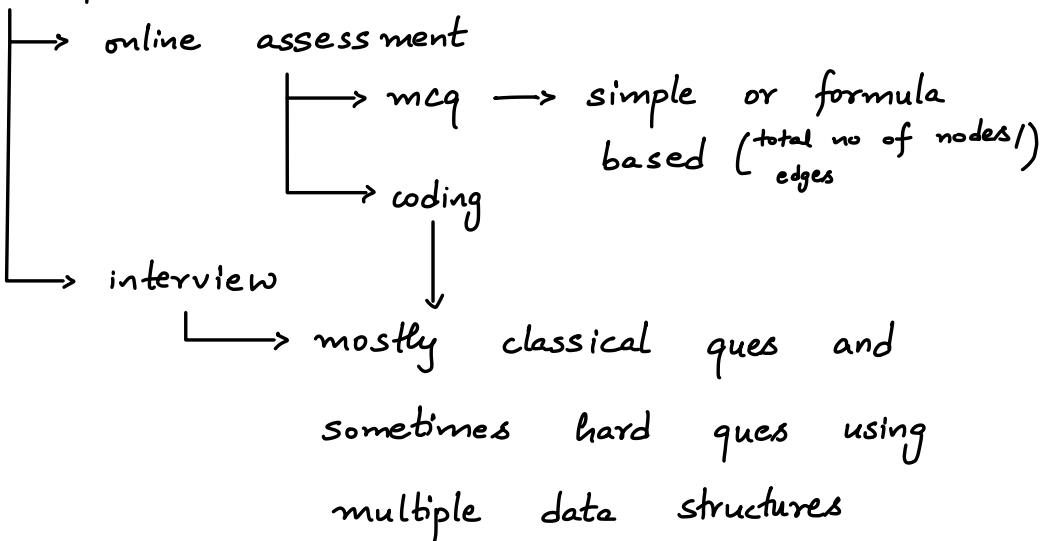
→ acc. to ques no. of nodes/edges from leaf to node in longest path

→ start from bottom most node as 1 and increase as we go upwards towards the root by 1

height of tree

→ height of root node

→ trees questions



→ tree is aasaan if you know recursion

Tree traversal algorithms

- level order traversal (BFS)
- spiral traversal (BFS)
- preorder, inorder, postorder traversal (DFS)
 - ↓
 - ↓
 - ↓
 - CLR LCR LRC

C - process curr node L - goto left R - goto right
- moris traversal

→ there is no official algo to create tree from data

skew tree

- tree in which each node has only left child
or
- tree in which each node has only right child

→ int main () {
 // wrong way
 node * root = func(); }

 // right way
 node * root = NULL; }
 root = func(); }
}

node * func () {
 return node;
}

 *root → gva → valid add.
 from func.
 *root → 0 → wrong way
 valid add.
 from func.

→ if we have to store nodes, then store their pointers (node *) as we know that node size can either be larger but node pointer will always of same size i.e. either 4 or 8 acc. to compiler
Another reason is that multiple nodes can have same data but with diff. addresses

Balanced Binary Tree

W13-L2

- at every node the absolute diff. between heights of left and right subtree must be ≤ 1

Perfect / Full Binary Tree

- every node has either 0 or 2 children and only last level has leaf nodes

Complete Binary Tree

- tree in which nodes are created levelwise and from left to right
- all levels are completely filled except last one

Sum Tree

- replace every node value with sum of values of that node, left subtree sum, and right subtree su

→ if you don't find logic to solve tree question,
just start running recursion in examples and
you will find solution eventually

W13-L4

→ There are only 2 approaches to solve any tree question

- use recursion in both left and right subtree
- OR
- find path from root to that node/leaf

- build tree from inorder and preorder (C L R)
- build tree from inorder and postorder (L R C)
- right recursion call before }
left recursion call }

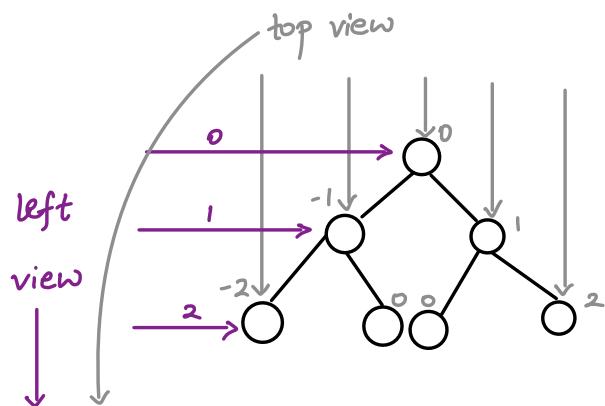
→ In ques. where we find views

(like top / left/ bottom/ right view of the tree)

we use 3 concepts

- map
- level order traversal
- horizontal distance

from root



store in map and not
update if another found
on the same level /
horizontal distance

for bottom and right view
store in map and
update if another found
on the same level /
horizontal distance

left view & right view → 4 approaches

)

in github repo code

BINARY SEARCH TREE

W14-L1

for every node, every data in left subtree should be smaller than node data and every data in right subtree should be greater than node data

→ inorder traversal of BST is always sorted
 ↳ store or use acc. to ques

→ in average case, height of tree is $\log_2 n$
 ↓
 simple & BST both

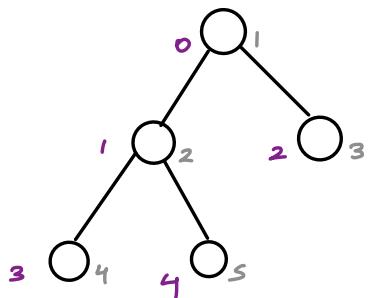
→ in interviews, there is very high chances of asking variation of deletion in BST

→ given a leaf node, find its successor and predecessor leaf node of that node

→ Data Structure that exists in the form of Complete Binary Tree and holds heap property

max heap - every parent value is greater than its children value

min heap - every parent value is less than its children value



i^{th} node → left child - $2i+1$, right child - $2i+2$
 → parent - $(i-1)/2$

i^{th} node → left child - $2i$, right child - $2i+1$
 → parent - $i/2$

→ We visualize heap as tree but create as array

insertion and deletion

insertion

- insert at bottom
- rearrange the nodes if heap property is violated
 - compare node with its parent
- T.C. - $O(n)$

deletion

- deletion is only done of top / root node
- replace last value with top node
- delete last node (reduce size by 1)
- rearrange the nodes if heap property is violated
 - compare node with both of its children
- T.C. - $O(n)$

Use Case of Heap

→ to find maximum & minimum element
in $O(1)$ time

Heapify

→ process of rearranging a node to its correct position starting from that node as tree
→ same as deletion code
 ↳ rearrange the nodes if heap property is violated
 → compare node with both of its children

→ if there are n nodes in heap (CBT), then from $(\frac{n}{2} + 1)^{th}$ to n^{th} nodes (in 1 based indexing) are leaf nodes and so are valid heap and there is no need to heapify those leaf nodes

Build heap

- convert a given array to a heap
- use heapify function
- T. C. - $O(n)$

Heap Sort

- swap first node and last node
- reduce size by 1
- run heapify algo
- repeat these steps till size becomes 1
- T. C. - $O(n \log n)$

DYNAMIC PROGRAMMING

W17-L1

→ technique used to optimize sol.

key point

↳ those who forget the past are condemned
to repeat it



don't compute the things, you have
already completed



store all the distinct answers

you are getting within the process

Phases of question solving

- Recursion
- Top Down Approach (Recursion + Memoisation)
- Bottom Up Approach (Iterative + Tabulation)
- Space Optimization

2 Conditions needed to apply DP

- overlapping subproblems
 - ↳ solving same problem again & again
- optimal substruture
 - ↳ optimal sol. of bigger problem can be calculated using optimal sol. of smaller problem

Top Down (Recursion + Memoisation)

- create and initialize the dp array or map
- store all the new answers in dp array and return that
- check whether the ans is already exists in dp array
write condition after base case
if (dp array contains ans for given input)
return ans;

Bottom Up (Iterative + Tabulation)

- create and initialize dp array / map
- store base case answers in dp array
- find ans. from bottom to up (reverse of recursion) iteratively and store them in dp array.
using loops
- add extra base case(s) if necessary

S.C. (bottom up) is better than S.C. (top down)

↓
iterative

↓
recursive

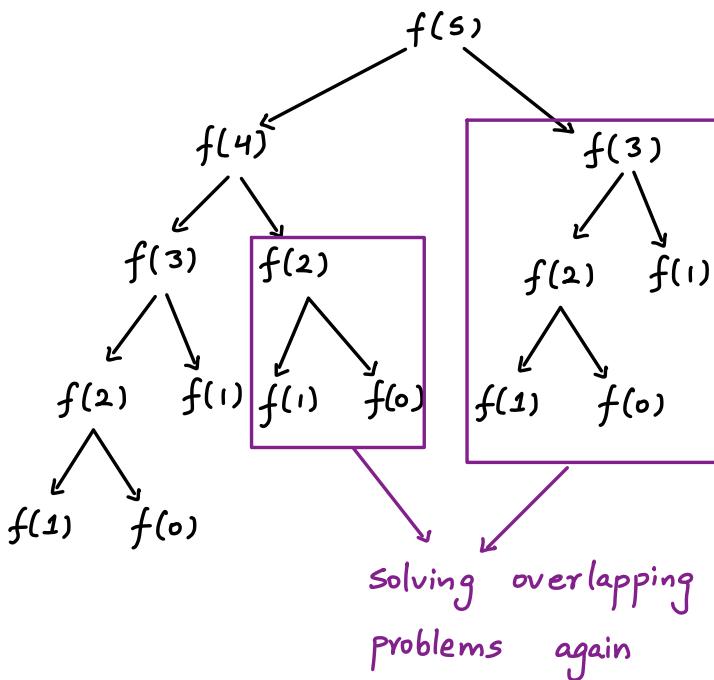
→ In majority cases size of dp array in bottom up is same as that of top down, but in some we have to change it

→ No. of dimensions of dp array (1D, 2D, etc) depends upon the no. of changing parameters in the ques

Space Optimization Sol.

- check where the useless space is used and try to reduce it.
- Analyze the dp expression and findout to what parameters curr value is dependent and find out the pattern in those parameters

ex- fibonacci



recursion

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

S.C. - $O(n)$

top down

T.C. - $O(n)$

S.C. - $O(n+n)$

bottom up

T.C. - $O(n)$

S.C. - $O(n)$

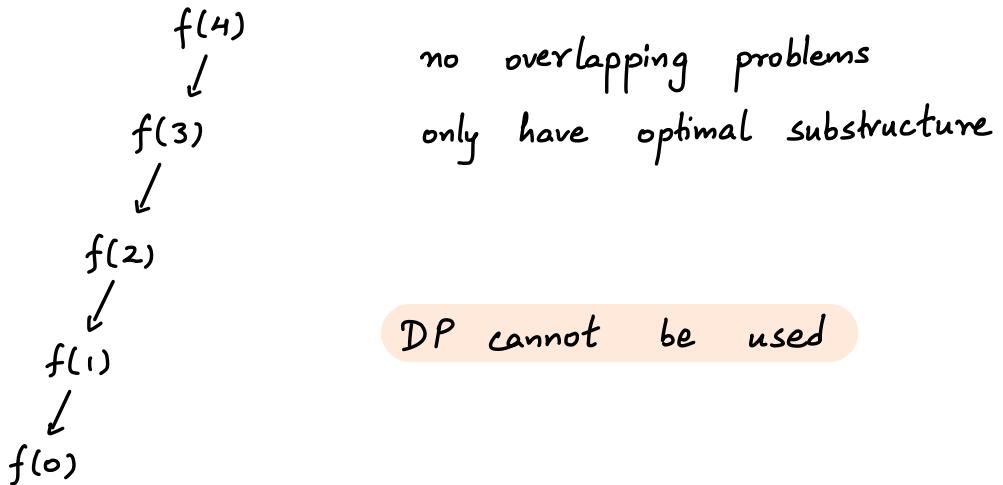
space optimization

T.C. - $O(n)$

S.C. - $O(1)$

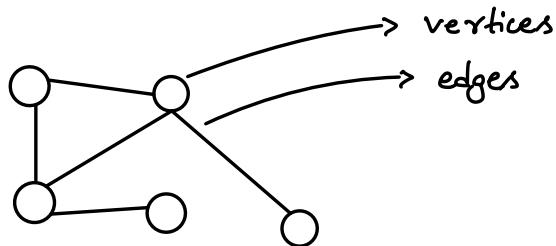
DP can be used

factorial



GRAPHS

→ Data Structure made up of nodes and edges (vertices)



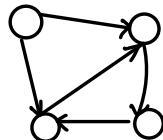
→ use case

↳ google map, facebook

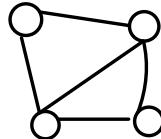
Types of graphs

→ Directed Graph

→ Undirected Graph

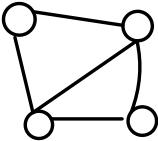
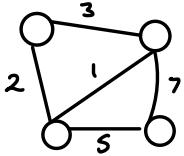


Directed



Undirected

↳ Weighted Graph



if weight is not given
and we need it,
assume it as 1

Degree

- no. of edges attach to a node in undirected graph
- types of degree
 - in degree
 - no. of incoming edges to a node
 - out degree
 - no. of outgoing edges from a node

Path

- sequence of nodes you traversed such that a node visits atmost once

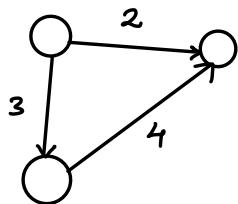
Cyclic Graph

- Graph in which at least one cycle is formed
- All undirected graphs are cyclic

Acyclic Graph

- ↳ Directed Graph that has no edges

Weighted Acyclic Directed Graph



Graph Implementation -

- Adjacency Matrix → 2D array → element - 0/1 or weight
- Adjacency List → Unordered map of vector / list of int / pair
↳ {node, weight}
- majorly used

