# DSA SUPREME

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

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# 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 everywhere 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

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- 2 websites
  - cppreference
  - cplusplus.com

- Think on paper → with 5 testcases atleast

- Write readable codes

- In interviews, tell approaches of questions using example

- Signs of beginner → no logic build
  - cant solve new ques
  - forget the approach
  - memorizing the ans

  ↓

  Improve → with more no. of questions
  - with time
  - with dry run on mind logic, not on code
  - with your new approach (even brute force)
  - with a lot of practice on syntax
  - with consistency

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→ 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 krna

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

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- 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 alongwith 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

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- Focus on accuracy more than speed
- Resume is made company specific
- Make sure others dont take your credits
- Higher position in career $\propto \dfrac{\text{Development}}{\text{DSA Complexity}}$
- Interview experience before interview
- Flex se kuch nhi hota
  Comparision se kuch nhi hota
- Dont 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 data type and after solving the sol. change datatypes

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→ 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

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# 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) >> n ⟶ (-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++);

a*(a++) , a = 6

a* 6 , a = 7

7* 6 = 42

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

5 * (a++) , a = 6

5 * 6 , a =

30

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

→ int main (){

return 0; ⟶ returns to OS
}
0 is used to represent successfull execution

→ A cpp file cant 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 ; ⟶ $A_1$ ⟶ address of first index of array
address of integer

cout << & arr ; ⟶ $A_1$ ⟶ base address of array arr
address of array

from symbol table

diff. things

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- To find max., initialize ans with INT_MIN

  To find min., initialize ans with INT_MAX

- xor ⟶ cancels out same element

- $0 \wedge ans = ans$ → $0 \wedge 1 = 1$, $0 \wedge 0 = 0$

- Mapping of 2D array with memory 1D array

  linear_index = c * i + j

  no. of cols ← c

  row index ← i

  col index ← j

  i = linear_index / c

  j = 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

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→ In binary search questions

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

left search ← e = mid - 1;

right search

ans = mid
s = mid + 1
convert

ans = mid, e = mid - 1
convert

```
while (s<e){
    s = mid;
    e = mid - 1;
}
```

s = mid; → right search

left search ← e = mid - 1;

OR

```
s = mid + 1
e = mid;
}
```

s = mid + 1 → right search

left search ← e = mid;

→ 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

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

- → find search space of answer
- → find mid
- → if isPossibleAns( mid) → go to left / right acc. to the ques.

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 smbhal 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

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→ 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

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→ 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

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# 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

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# LET'S GO

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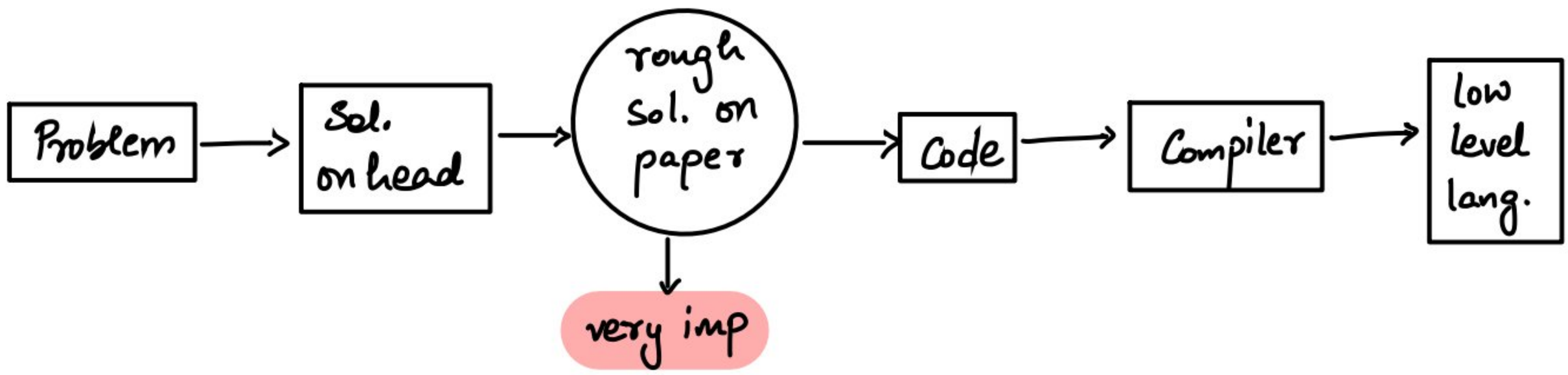
# W1-L1

## Thought process to solve a problem-

→ Understand a problem

→ input values

→ find approach

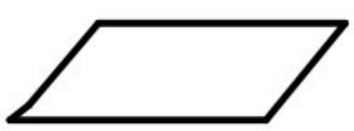



**Algorithm-** Sequence of steps

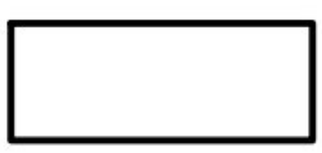
**Flowchart-** Graphical representation of algo

**Components-**

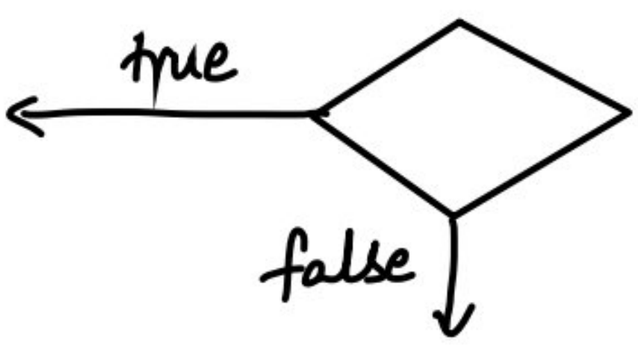
terminator for start /end



for input /output read /write

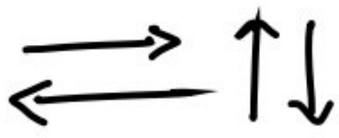


computation / process / declaration




decision making block

takes condition



flow

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

# include <iostream> → preheader file contains implementation of keyword

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

; → to end any statement

"Namaste Bharat" → string

namespace → region where scope of keyword is defined

cout << → used to print on console/ standard display

cout << endl; → for next line

cout << '\n'; → for next line

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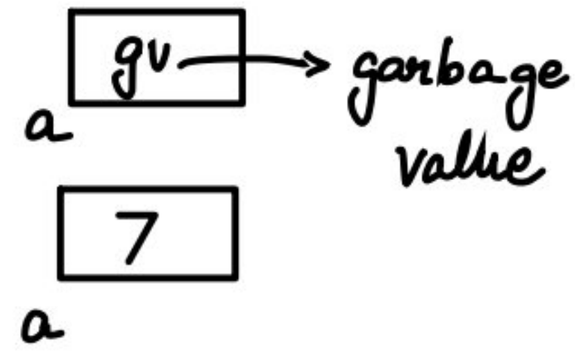
int a; ⟶ a is an integer

cin>> a; ⟶ input a from user

ex- 7




## Variables

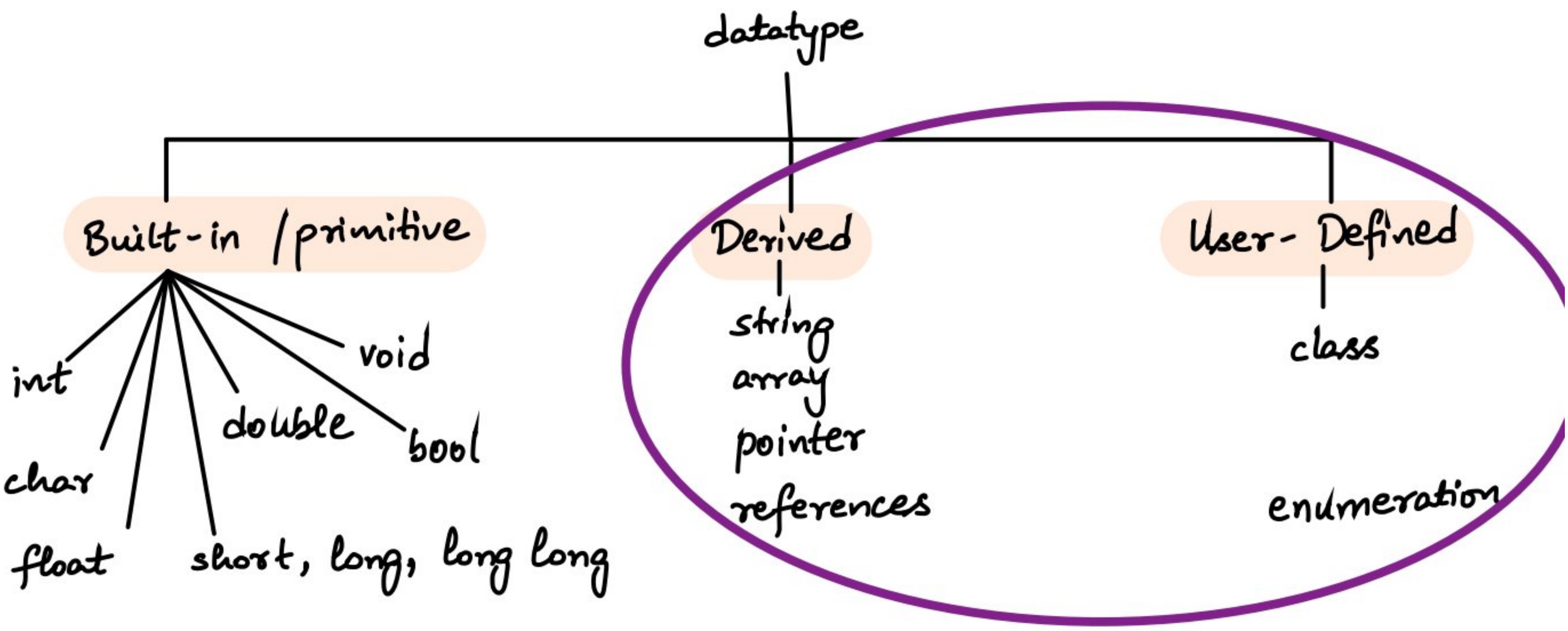
named memory location

int a = 5;

- int → datatype
- a → variable name
- 5 → value

## Datatypes

type of data




**int** - 4 byte - 32 bits in memory

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

**char** - 1 byte - 8 bits in memory

- → $2^8$ different chars.

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ASCII

↳ char maps with numerical ASCII value

char ⟷ ASCII value ⟶ store in memory

bool ⟶ 1 byte ⟶ 8 bits

true - 1
false - 0

⟶ because minimum addressable memory is 1 byte

We cannot address 1 bit in memory

float ⟶ 4 byte ⟶ 32 bits

double ⟶ 8 byte ⟶ 64 bits

long long ⟶ 8 byte ⟶ 64 bits

short ⟶ 2 byte ⟶ 16 bits

long ⟶ 4 byte ⟶ 32 bits

## How data is stored

int a = 5;

↳ 32 bits

$\underbrace{0\ldots\ 00}_{29\text{ bits}}101$

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tve no → 0

-ve no. → 1

Most significant bits

## How -ve number is stored in memory

In 2's complement form

→ 1's complement + 1

→ reverse all bits

int a= -7;

ignore -ve sign

7 → 0.....00111 } 32 bits

find binary equivalant

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

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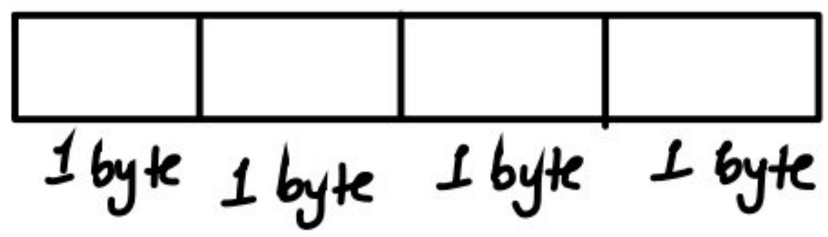
## Interesting problem




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

Signed → +ve, -ve, 0

→ by default

Unsigned → 0, +ve

**int** – 4 byte – 32 bits in memory

→ total no. of combinations – $2^{32}$

signed int → $-2^{31}$ to $2^{31}-1$

$-2^{31}$ → 1 0...0

$2^{31}-1$ → 0 1 1 ... 1

2's → 1 0 ... 0 → $-2^{31}$

unsigned int → 0 to $2^{32}-1$ } range

0 → 0.....0

$2^{32}-1$ → 1.....1 } in memory

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## General Formula

$n$ bits in memory

↳ total no. of combinations – $2^n$

signed int → $-2^{n-1}$ to $2^{n-1}-1$

unsigned int → $0$ to $2^n-1$ } range

$\underbrace{10\ldots\ldots0}_{n \text{ bits}}$ $\underbrace{011\ldots1}_{n \text{ bits}}$ $\underbrace{0\ldots\ldots0}_{n \text{ bits}}$ $\underbrace{1\ldots\ldots1}_{n \text{ bits}}$ } in memory

$-1 \longrightarrow \underbrace{1\ldots1}_{n \text{ bits}}$

## 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;

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

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

## Operators -

### Arithmatic Operator

→ +, -, *, /, %

int op int → int

float op int
int op float
float op float } float

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

bool op bool → int

bool act as 0 or 1

3 → int
3.0 → float / double → by default → not int

cout << sizeof(3.0);
↓
8

### Relational Operator

(a op b)

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

these are different things

Output - 0 or 1
0 → false
1 → true

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## 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

0 → false

1 → true

(cond 1 && cond 2 && cond 3)

if cond 1 is false

compiler will not check further as ans will already false

(cond 1 || cond 2 || cond 3)

if cond 1 is true

compiler will not check further as ans will already true

## Conditions

W1-L3

```
if (cond.){
    execute
}
```

if

```
if( cond ){
    execute 1
}
else {
    execute 2
}
```

if - else

```
if (cond 1)
    execute 1
else if( cond 2)
    execute 2
```

if - else if

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```
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

### for - loop

initialization → condition → updation

```
for( int i=0;  i<5 ; i=i+1){
    cout << "Love" ;
}
```

→ executing body

flow -

initialization → condition $\xrightarrow{\text{false}}$ exit

↓ true

executing body

↓

updation

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

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## 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, +ve, -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, +ve, -ve

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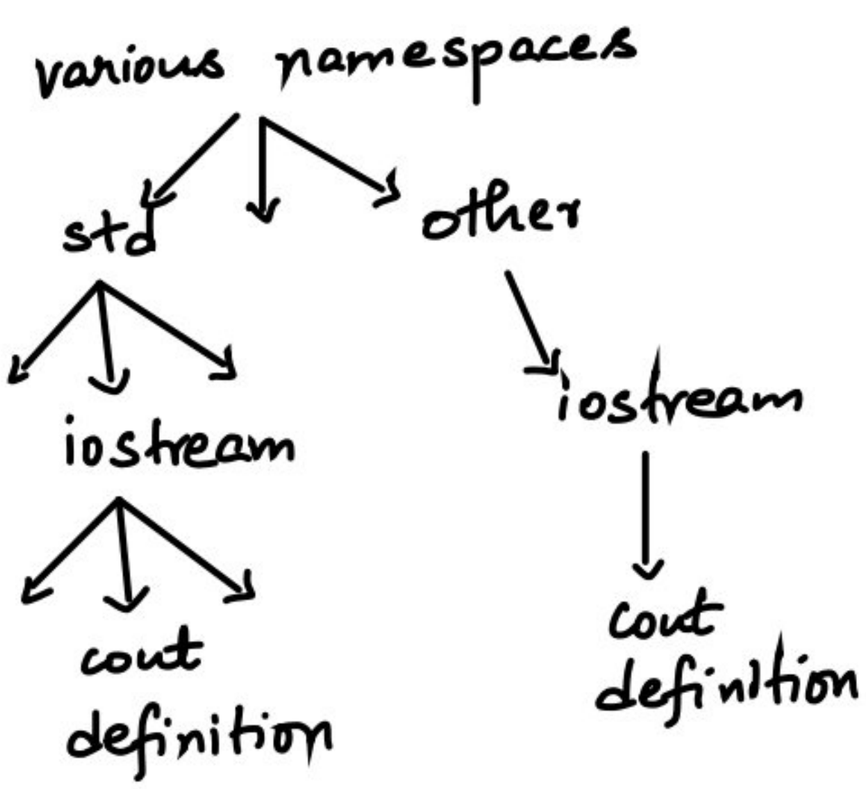
**HLL** - High level language
↳ human readable and user friendly

**W1-L4**

C++, C - Middle Level language

namespace ⟶ to avoid collision
↓
multiple definitions of a single keyword

**heirarchy**
↳ various namespaces
↓
std namespace
↓
iostream preheader file
↓
keyword definition




```
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

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# W1-HW

## ternary operator -

↳ 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

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patterns

# W2-L1

↳ how to think

→ finding formula for rows and cols

$n=5$

| row | stars | | n-1 | no. of times loop runs |
|---|---|---|---|---|
| 0 | 0 | | -1 | 0 |
| 1 | 0 | → formula - 0 to < n-1 | 0 | 0 |
| 2 | 1 | | 1 | 1 |
| 3 | 2 | | 2 | 2 |
| 4 | 3 | | 3 | 3 |

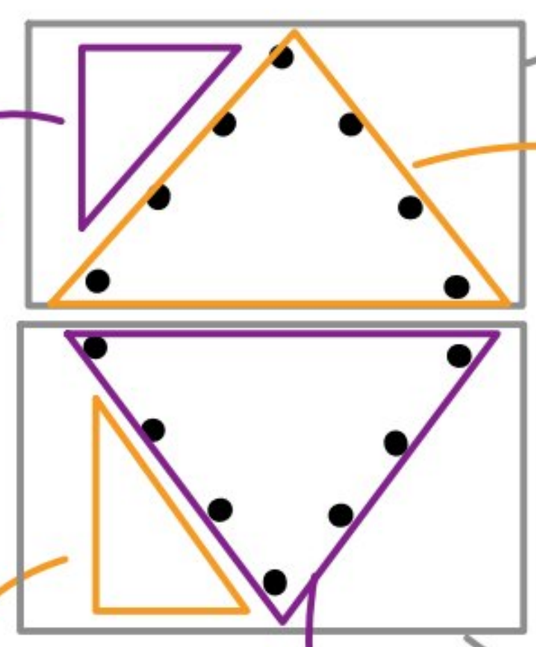
as condition fails (0 < -1)

→ to do anything n times

↳ `for( i=0 ; i<n; i++){}`

→ break the complex patterns

$n=4$



upper half

lower half

0 to < n-(i+1)

space

| | | |
|---|---|---|
| 0 → 3 | 4-1 | |
| 1 → 2 | 4-2 | |
| 2 → 1 | 4-3 | |
| 3 → 0 | 4-4 | |

0 to < 2i+1

chars

| | | |
|---|---|---|
| 0 → 1 | 1 | |
| 1 → 3 | 2(1)+1 | |
| 2 → 5 | 2(2)+1 | |
| 3 → 7 | 2(3)+1 | |

0 to < i

space

| | |
|---|---|
| 0 → 0 | i |
| 1 → 1 | i |
| 2 → 2 | i |
| 3 → 3 | i |

0 to < 2n-2i+1

chars

| | | |
|---|---|---|
| 0 → 7 | 8-1 | 8-1 |
| 1 → 5 | 8-3 | 8-(2(1)+1) |
| 2 → 3 | 8-5 | 8-(2(2)+1) |
| 3 → 1 | 8-7 | 8-(2(3)+1) |

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## 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 | (~ a) | negate the result |
| xor | (a ^ b) | same values → 0<br>diff. values → 1 |

~5

↳ 5 → 0...0101

~5 → 1...1010

↳ how compiler read this

↳ 2's complement

0....0101 → 1's complement

0...0110 → 2's complement

-6

So ~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

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$a = a << b$ a left shifts, b times → result → $a \times 2^b$

$a = a >> b$ a right shifts, b times → result → $\frac{a}{2^b}$

b cant be -ve

↳ in case of -ve

↳ gives $g^v$

```
a=5;
a=a<<1;      a=10

a=5;
a=a<<2;      a=20
```

in left shift → filled with 0

in right shift → filled with 0 or 1

0 → in +ve no.

1 → in -ve no.

right shift in -ve number

-ve no. in memory → 1 .....

↓ right shift

11....

↳ signed bit is used to fill the vacant bit

ex-

5 → 0...0 101

-5 → 1...1 011

-5>>1 → 1 ...101 → -3

-1 >> 1 → -1

left shift in number where MSB is 1 and 2nd MSB is 0

no. → 1 0 . . → -ve no.

left shift → 0 . . . .

→ +ve no.

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## Pre- Post → Increament / Decreament Operator

### pre- increament

↳ ++a

↳ first increament by 1, then use

### post - increament

↳ a++

↳ first use then increament by 1

### pre- decreament

↳ --a

↳ first decreament by 1, then use

### post - decreament

↳ a--

↳ first use then decreament by 1

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

output -
49

↳ due to operator precendence

→ links.txt in repo

## break and continue

### break

↳ exit from that loop

### continue

↳ skip that iteration

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## 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

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## 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

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# W2-L3

## Function -

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

### syntax -

```
return type functionname (input parameters){
    executing body
}
```

void → empty / no value

```
void x;
```
→ ERROR

```
cout << sizeof(int)
```
→ 4

```
cout << sizeof(void)
```
→ ERROR

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

- return 0 → returns 0 to Operating System
- return 0 → 0 is used as means of successfull execution

→ a cpp file cant have more than 1 main functions

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

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# Function Call Stack

function call ⟷ function invoke

Stack
↳ Last In First Out

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

ex-

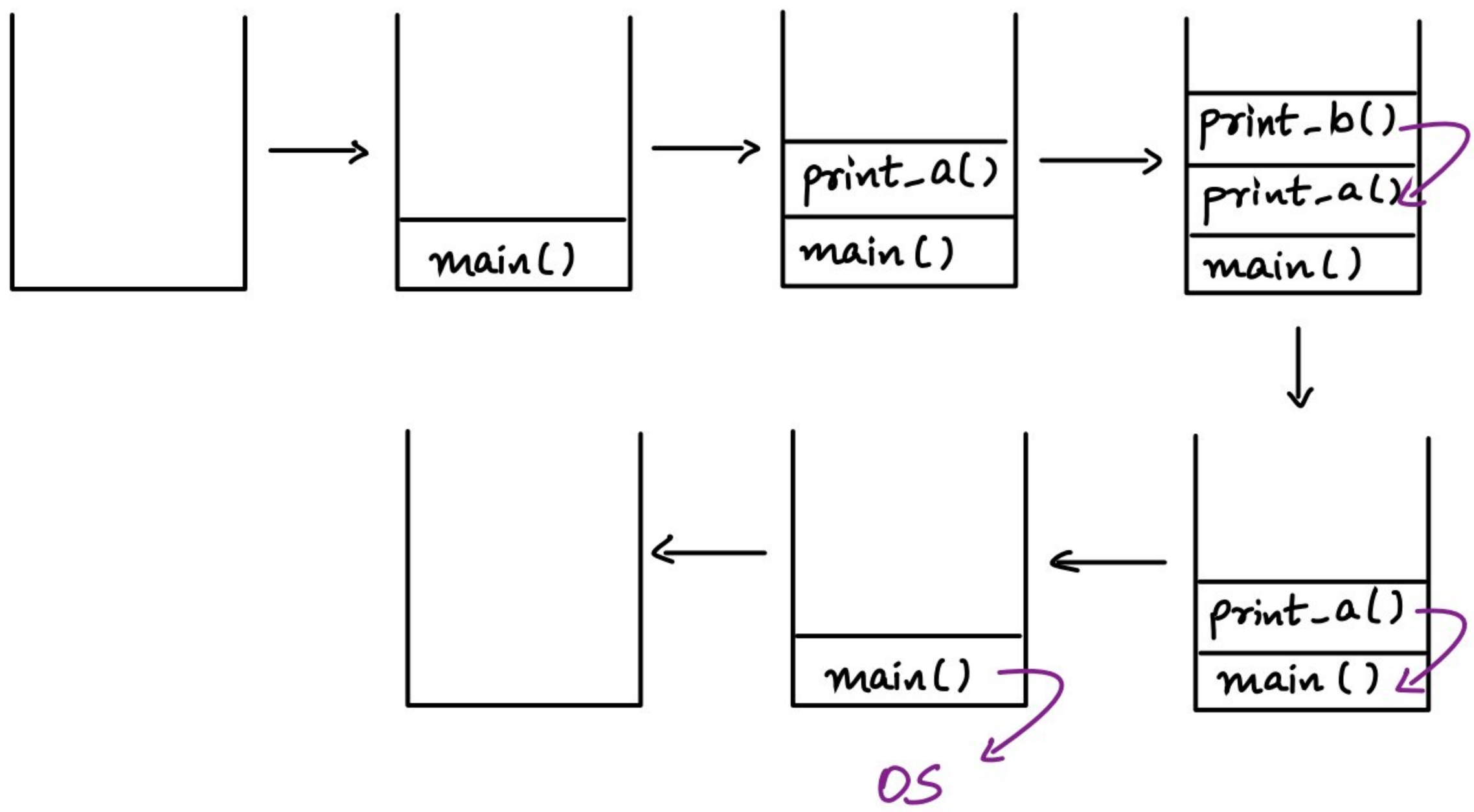
```
int main(){
    int a=5;
    print_a(a)
    return 0;
}
```

return to OS

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

```
void print_b(int b)
{
    cout<< b;
}
```

Output - 5 3

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## Pass by value → value is passed to another variable

↳ a copy will be created of variables

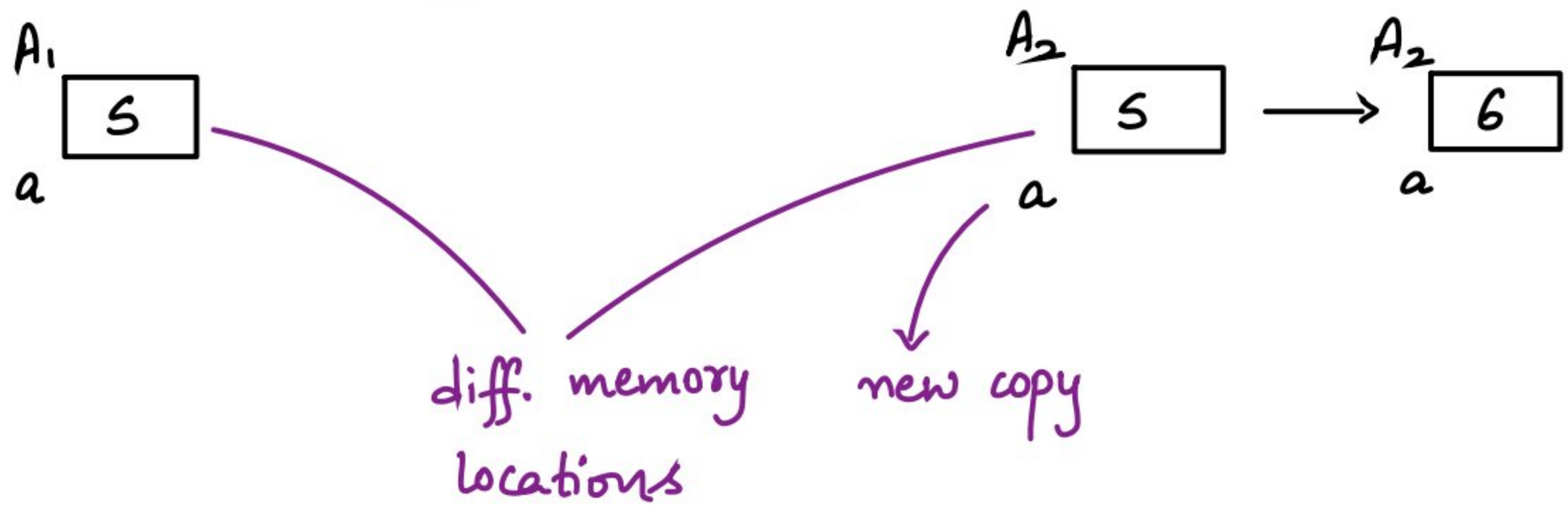
```
int main() {
    int a=5;
    printNumber(a);
    cout << a;
}
```

argument

5

```
void printNumber(int a){
    cout << a; → 5
    a++;
    cout << a; → 6
}
```

parameter




## Address Of Operator &

```
int n=5;
cout << &n;
```

→ output - address of n

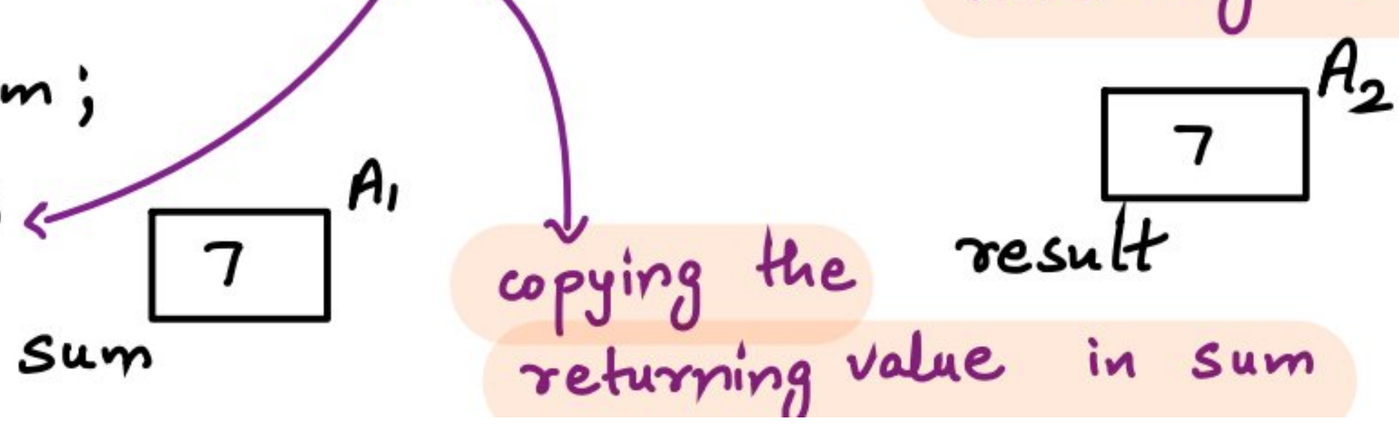
```
int main(){
    int a= 3;
    int b= 4;
    int sum= add(a,b);
    cout << sum;
    return 0;
}
```

OS

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

returning a value

copying the returning value in sum

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# 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;
}
```

function definition

% operator ⟶ heavy operator

↳ so try to use it less

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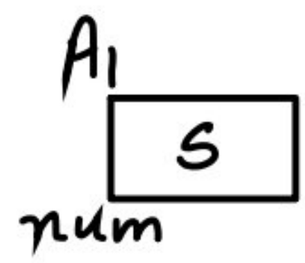
BTS → Behind The Scenes

# W2-L4

```
int num=5;
```

## Symbol table




int num ⟷ $A_1$

- int → datatype
- num → variable name
- $A_1$ → memory location of variable

variable address mapping is stored

```
cout <<num;
```

go to → symbol table —go to→ $A_1$ (address) —print→ 5 (value)

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

go to → symbol table → int datatype —print→ 4

## while loop

```
int i=0;
while (i<5){
    cout << i <<endl;
    i++
}
```

- int i=0; → initialization
- while (i<5) → condition
- { cout << i <<endl; i++ } → body → updatation

### flow

initialization → condition —false→ exit

condition ↓ true → body (containing updatation) → condition

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## left and right shift operators

int a= 2;

a<<1; ⟶ no change

cout<< a; ⟶ 2

a= a<<1; ⟶ change ⟶ left shift by 1

cout <<a; ⟶ 4

## right shift in -ve no.

↳ link in links.txt in repo

## How -1 is stored in memory -

$\underbrace{1\,1\,\ldots\,1\,1}_{\text{all 1s}}$ ⟶ read from memory

↓

1's ⟶ 0....0

2's ⟶ 0...1

-1

## ~a = -(a+1) and ~(~a) = a

ex - a=5; ⟶ 0...0101

a= ~a; ⟶ 1...1010 ⟶ -6 ⟶ -(5+1)

↳ read ⟶ 2's ⟶ 0...0110

-6

a= -6;

↳ 1...1010

a=~a; ⟶ 0...0101

↳ 5 ⟶ -(-6+1)

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# W2-R

## 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

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## Binary to Decimal

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

## 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

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## Units to represent Complexity

Big O ⟶ upper bound ⟶ worst case

Theta $\Theta$ ⟶ average case

Omega $\Omega$ ⟶ lower bound ⟶ best case

## Big O Complexities

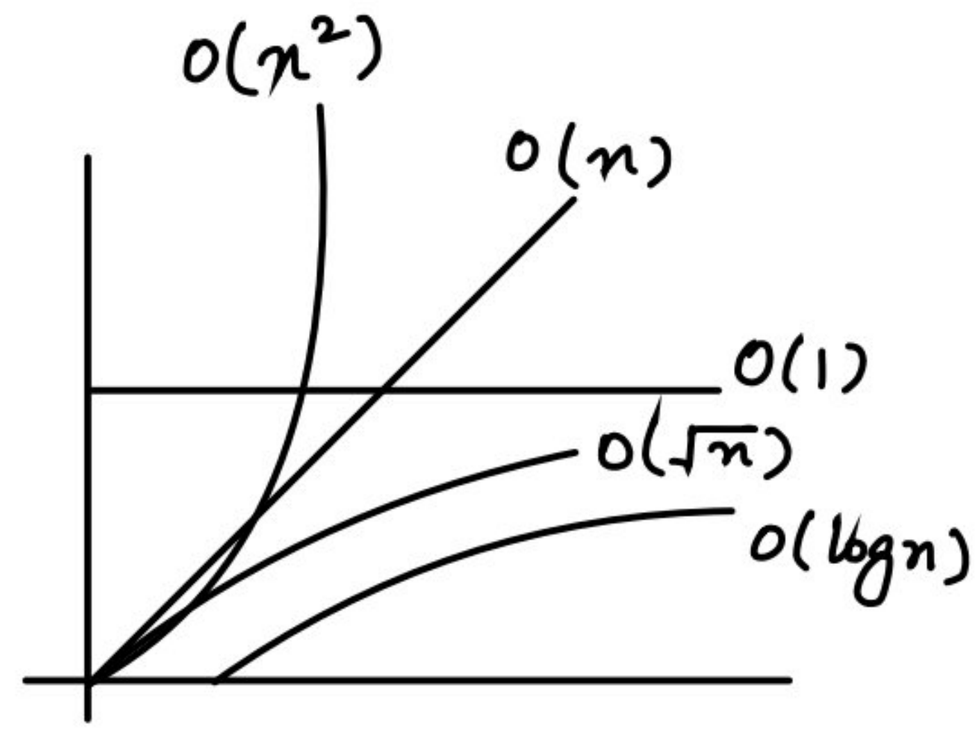
$O(1)$ ⟶ Constant time

$O(n)$ ⟶ Linear time

$O(\log_2 n)$ ⟶ Logarithmic time

$O(n^2)$ ⟶ Quadratic time

$O(n^3)$ ⟶ Cubic time




nesting ⟶ multiply ⟶ { { } }

in sequence ⟶ add ⟶ { } { }

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

## Complexity Order

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

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

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# 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

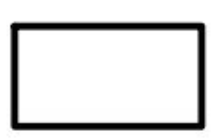
## continuous memory allocation

- memory wastage

  if needable memory is present but not in continuous way

int a = 5;

A



a

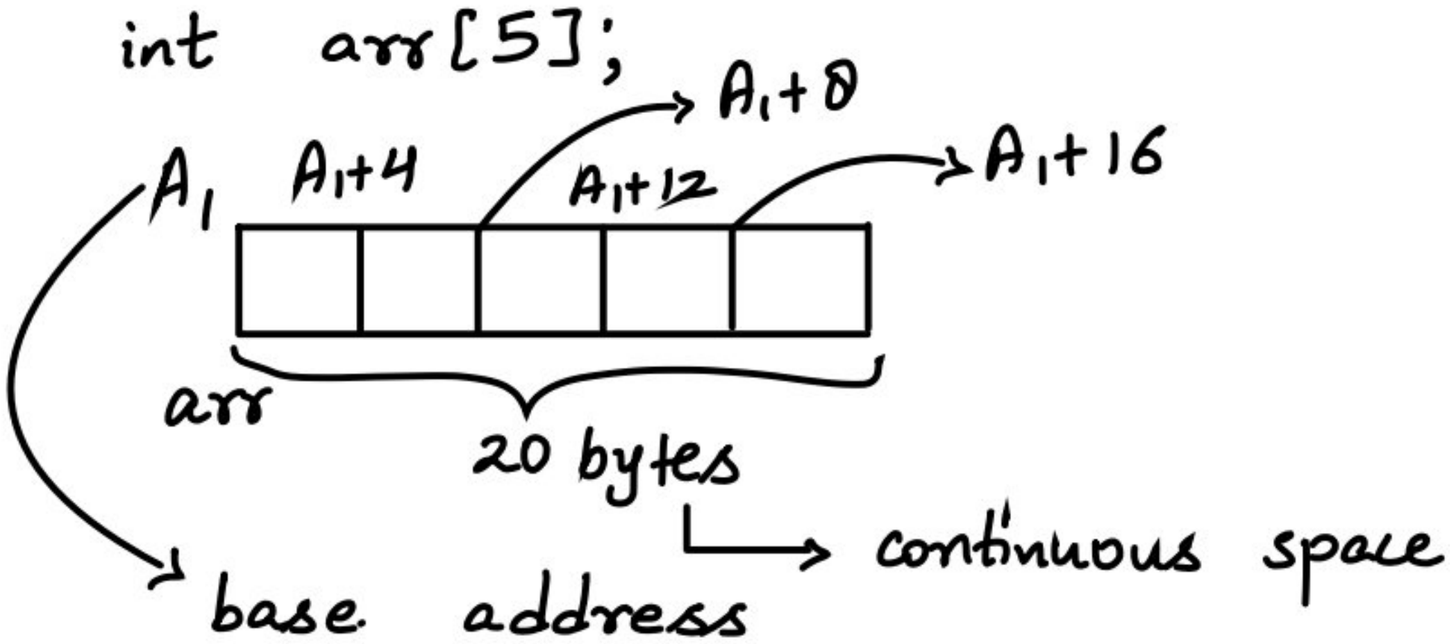
symbol table

int a ⟷ A

int arr ⟷ $A_1$

## Declaration

int arr[5];

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cout << arr ; ⟶ $A_1$ ⟶ address of first index of array
address of integer

cout << & arr ; ⟶ $A_1$ ⟶ base address of array arr
address of array

diff. things

## Initialization

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

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

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

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

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

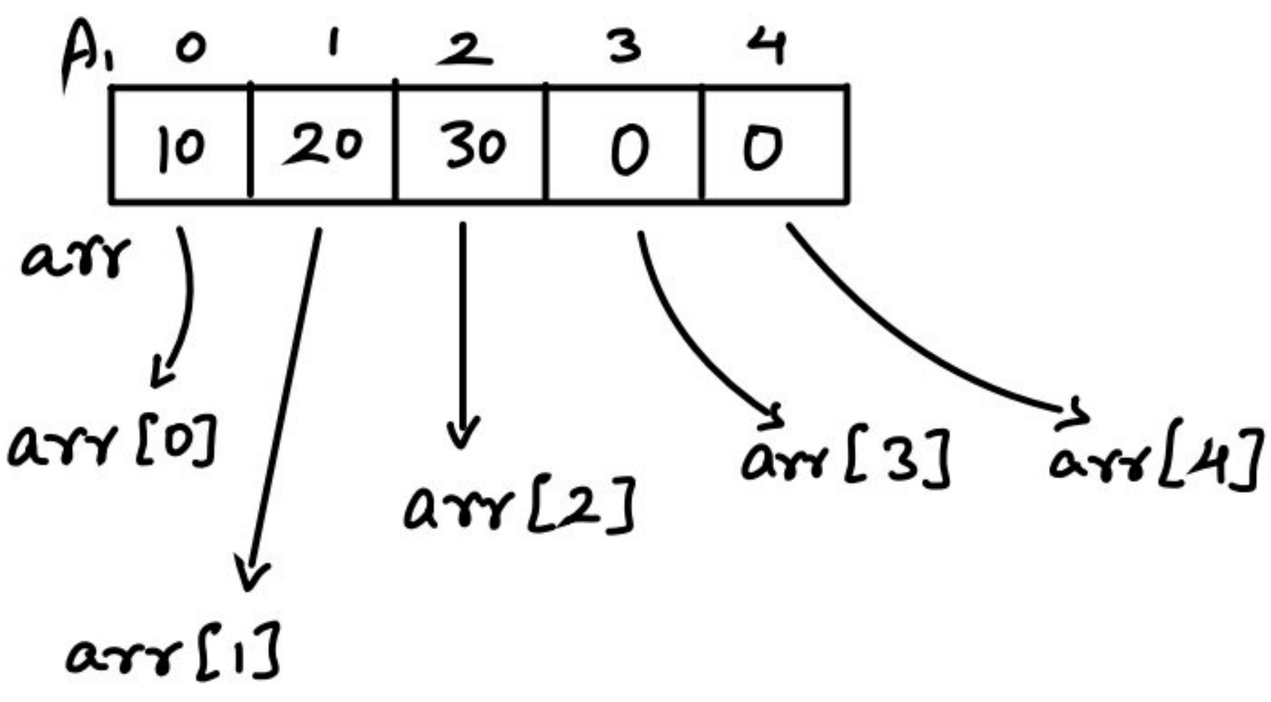
## Making array at runtime

```
int n;
cin >> n;
int arr[n];
```
⟶ BAD PRACTICE

## Index and Acess in memory

```
int arr[5] = {10, 20, 30};
```

⟶ $0^{th}$ based indexing
↳ 0 to n-1

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arr[i] ⟶ value at address [ $A_1$ + (i * 4) ]

BA

index

due to int (datatype size)

thats why 0 based indexing

due to internal working

## taking input in array

```
cin >> arr[i];
```

## Arrays and Function

```
func ( int arr[], int size) {
}
```

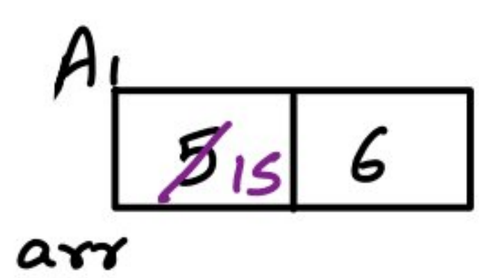
array is passed by reference because pointer is passed by value

updation in actual array

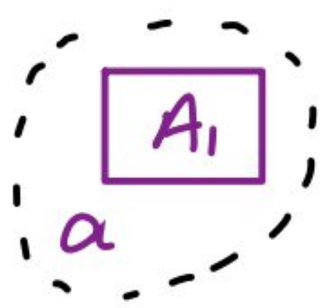
always pass size alongwith arr

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

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sizeof( int); ⟶ 4 ⟶ in bytes

int arr [5];

size of( arr); ⟶ 20 ⟶ in bytes

⟶ not 8 ( size of pointer)

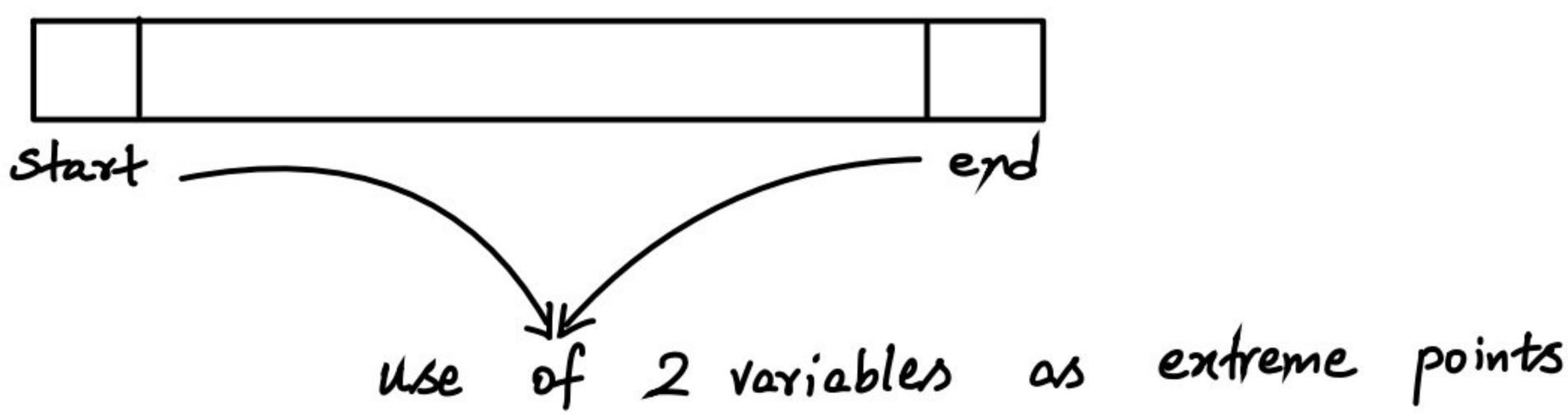
## linear search in array

## INT_MIN and INT_MAX

→ to find max., start ans with INT_MIN

→ to find min., start ans with INT_MAX

## 2 pointer approach




## To find size of array

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

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

⟶ datatype

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# Vector

# W3-L2

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

## Initialization

```
vector <int> arr {10, 20, 30};
```

→

| | | |
|---|---|---|
| 10 | 20 | 30 |

```
vector <int> arr (5);
```

→

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

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

size value

→

| | | | | |
|---|---|---|---|---|
| -2 | -2 | -2 | -2 | -2 |

```
int n;
cin >> n;
```

→ let n = 5

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

→

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

```
vector <int> arr (n, 10);
```

→

| | | | | |
|---|---|---|---|---|
| 10 | 10 | 10 | 10 | 10 |

## Insertion -

```
arr. push_back (5);
```

## Remove

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

## Size -

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

→ no. of elements it stores

## declaration

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

- → arr. size() → 0
- → arr. capacity() → 0

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## Empty or Not

arr.empty();  ⟶ true if empty

## Capacity -

arr.capacity(); ⟶ * 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); ⟶ compiler dependent initially

cout << arr ; ⟶ give ERROR

→ Xor ⟶ Cancels out same element

0 ^ ans = ans ⟶ 0 ^ 1 = 1, 0 ^ 0 = 0

## for each loop

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

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# 2D Arrays

# W3-L3

- array of arrays
- use case
  - to work on multiple rows and columns

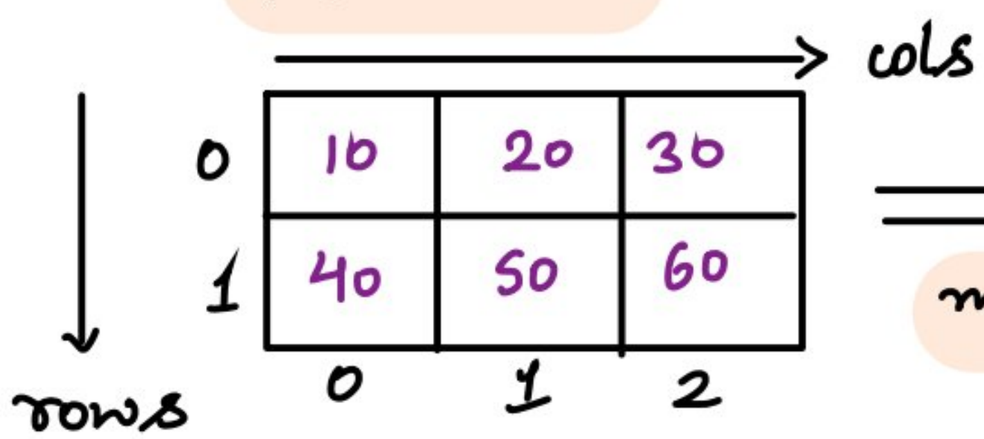
## Declaration -

```
int arr[m][n];
```

- m*n elements
- n → cols → 0 to n-1
- m → rows → 0 to m-1

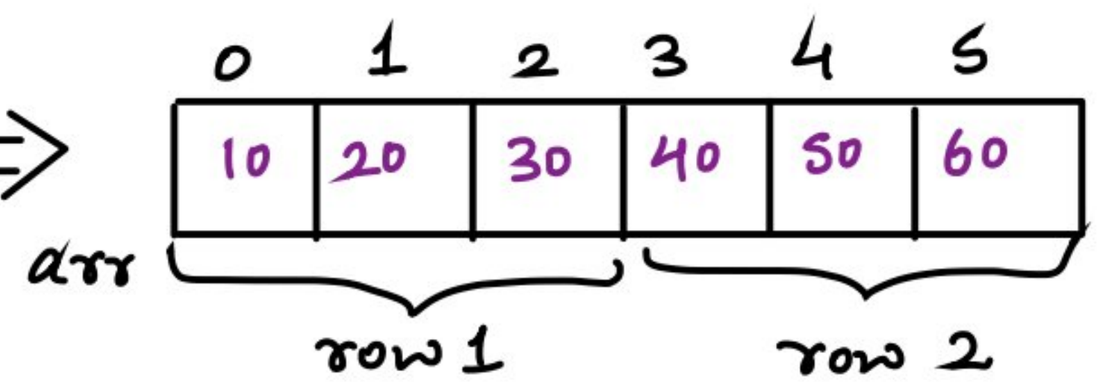
```
int arr[2][3];
```

visualize -




mapping

in memory -




## Access -

```
arr[i][j];
```

- j → col index  $0 \le j < n$
- i → row index  $0 \le i < m$

## Mapping -

linear_index = c * i + j

- c → no. of cols
- i → row index
- j → col index

i = linear_index / c

j = linear_index % c

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## Initialization -

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

same

visualize -

→ cols

↓ rows

| | 0 | 1 | 2 |
|---|---|---|---|
| 0 | 10 | 20 | 30 |
| 1 | 40 | 50 | 0 |
| 2 | 0 | 0 | 0 |

mapping ⟹

in memory -

arr

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 10 | 20 | 30 | 40 | 50 | 0 | 0 | 0 | 0 |

row 1 row 2 row 3

## 2D Arrays and function -

→ pass by reference

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

→ 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

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

2D Array -

→ not an array of pointers

→ array of arrays

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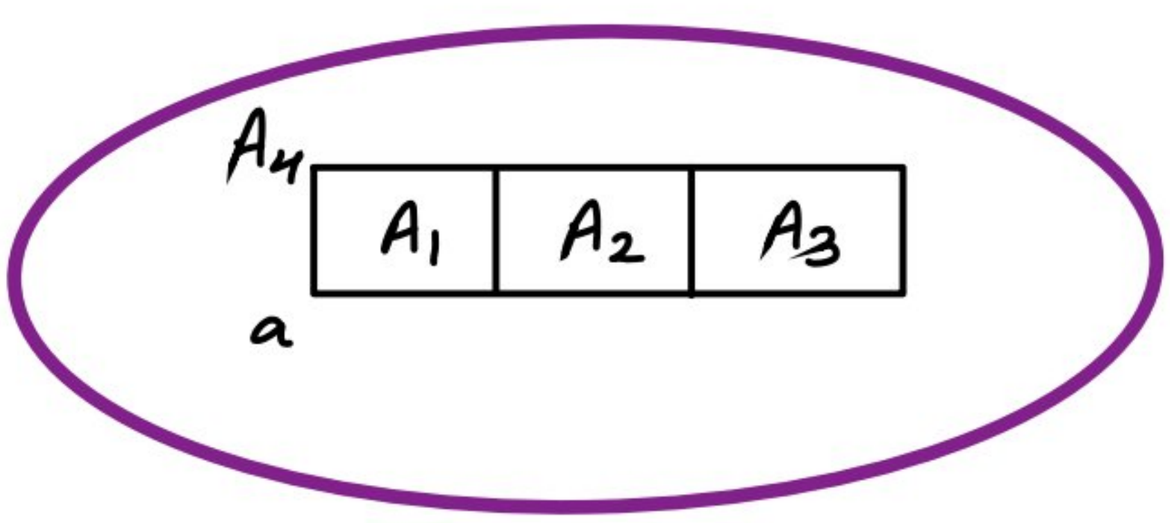
```
func( int a[][3], int rows, int cols) {
    cout << &a;  ---> add. of a ---> A4
    cout << a;   ---------------------> A1
    cout << a[0];
    cout << &a[0];
    cout << &a[0][0];
    cout << a[0][0];  ---------------> 10
    cout << sizeof( a);  ------------> 4
    cout << sizeof ( a[0]); ---------> 12

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

    return 0;

}
```

arr $A_1$

| | | | |
|---|---|---|---|
| $A_2$ | 10 | 20 | 30 |
| $A_3$ | 40 | 50 | 0 |
| | 0 | 0 | 0 |

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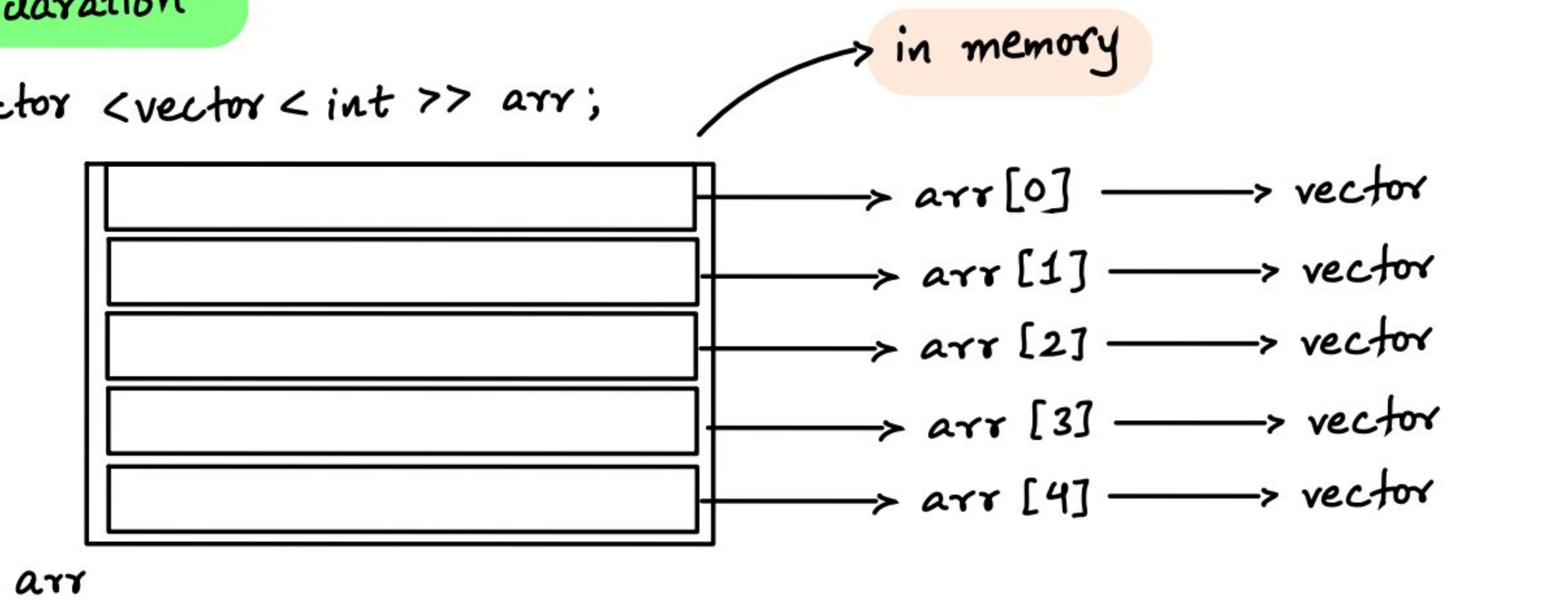
# 2D Vector

## Declaration -

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




## Declaration -

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

→ no. of rows

## Number of rows

```
arr. size ()
```

## Number of cols

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

→ in ith row
→ size of ith row

## Initialization

size — initial value in 2D vector

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

initialization of 1D vectors in arr

rows → no. of rows in arr

cols → no. of cols in arr
→ size of 1D vector

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

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```
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;
```

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# Searching and Sorting

**W4-L1**

## Searching

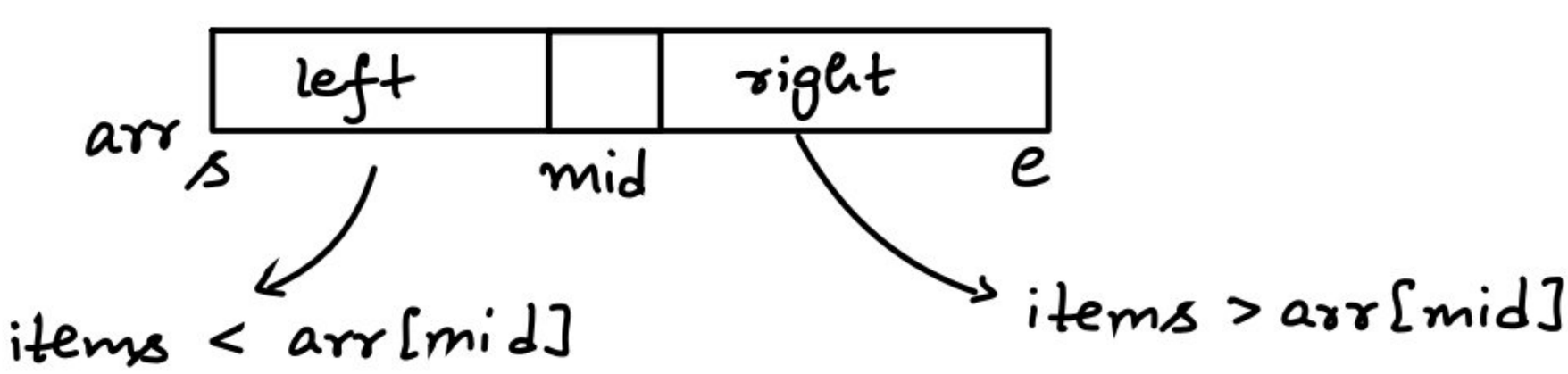
### Linear Search

```
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

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```
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. - $O(1)$

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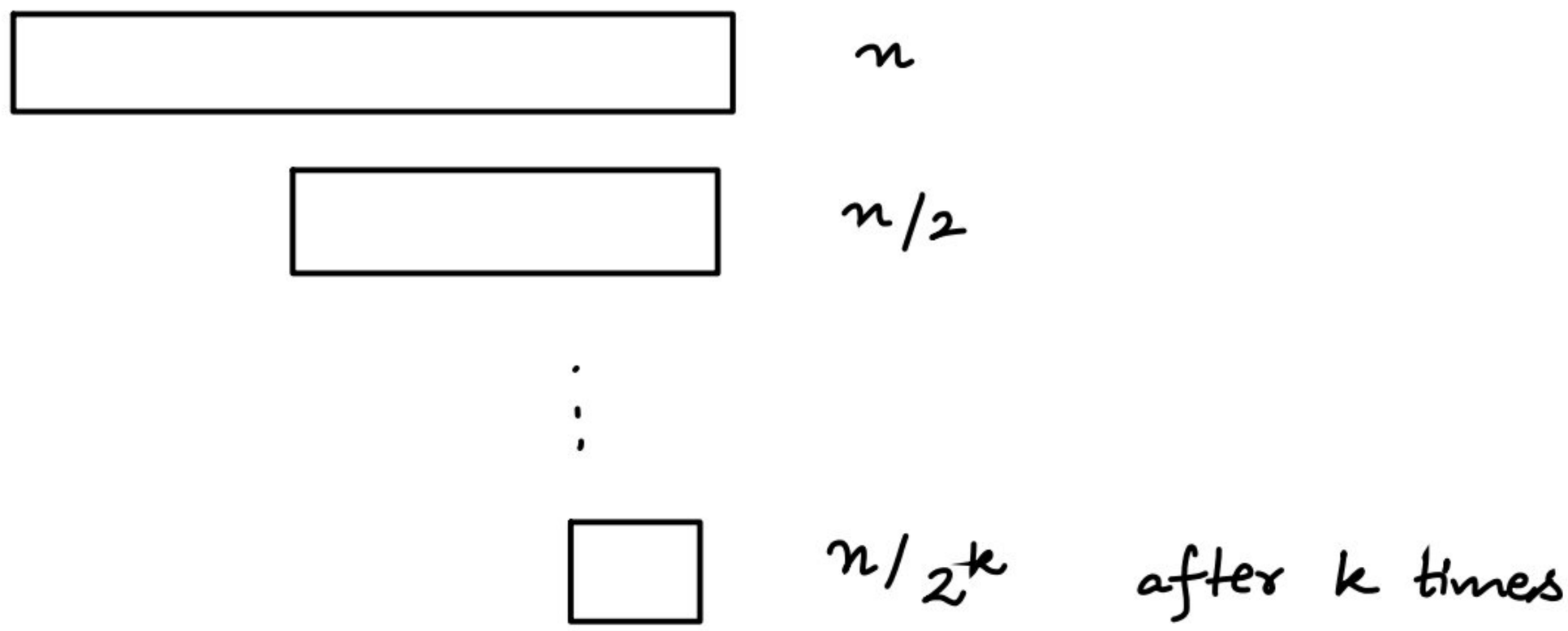
## T.C. of binary Search




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

$k = \log_2 n$

So loop runs $\log_2 n$ times

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

**W4-L2**

→ Search Space

↳ find range of search space (start & end) in ques of. Binary Search

→ store mid in ans if needed

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→ In binary search questions

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

left search ← e = mid - 1;

right search ← s = mid + 1;

ans = mid
s = mid + 1
convert

```
while (s<e){
    s = mid;
    e = mid - 1;
}
```

s = mid; → right search

left search ← e = mid - 1;

OR

ans = mid, e = mid - 1
convert

```
s = mid + 1
e = mid;
}
```

s = mid + 1 → right search

e = mid; ← left search

W4-L3

cout << (int)(-3.74);

→ -[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
- pivot in sorted rotated array ← can also find array is sorted or not
  - ↳ pivot index = n-1
- search in sorted rotated array

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→ $2^{nd}$ 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

→ $3^{rd}$ type → observation in index

- → missing element in sorted array
- odd appearing element in array

W4-L5

Sorting

→ putting all elements either in increasing order or decreasing order

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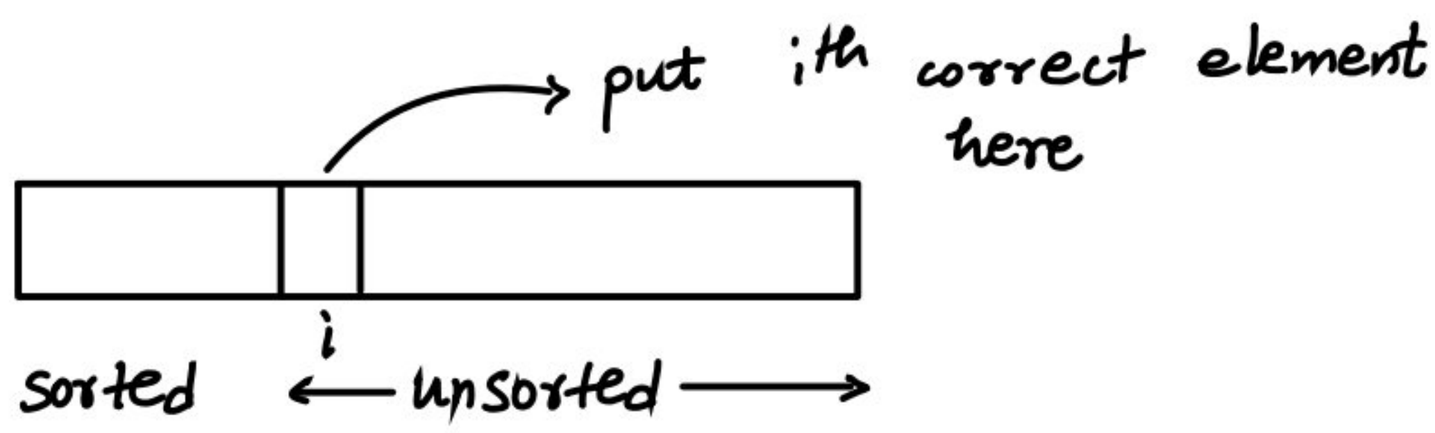
## Selection Sort -

- 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 ith lowest element to its correct position

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## 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. - $O(n^2)$ → Worst (→ reverse sorted) 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

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## 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

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## Inbuilt sort function

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

T. C. - O(nlogn)

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

1 2 2 2 3

if A[i] = A[j] , i < j

then A[i] comes first before A[j] after sorting too

Stable - Bubbe Sort, Insertion Sort, Merge Sort, Count Sort

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

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# 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 | $O(n)$ | $O(n\log n)$ | $O(n\log n)$ | $O(n^2)$ |

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# CHAR ARRAYS & STRING

W5-L1

## Char Arrays -

→ Data structure → used to store data

Not Data type → tells type of data

```
char ch[5];
```

| | | | | |
|---|---|---|---|---|
| gv | gv | gv | gv | gv |

ch

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

ch

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

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

ch

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

## Taking input in char array

```
char ch[7];
cin >> ch[i];
```

`cin >> ch;` → by defaut NULL char will → '\0'

insert at end

↓

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 delimeter

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

→ allocate as ch[10] = "Ujjwal"

```
cin >> ch;
```

→ Ujjwal

store in buffer memory

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

buffer

copy in memory of ch

| 'U' | 'j' | 'j' | 'w' | 'a' | 'l' | '\0' | gv | gv | gv |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

ch

```
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

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## get line

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

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

```
func( char ch[]){

}
```

## Size of char array ⟶ $\frac{\text{sizeof (ch)}}{\text{sizeof (char)}}$ − 1

sizeof (char) ⟶ 1

## Some inbuilt functions of char array

strlen(ch);

strcmp(ch1, ch2);

strcpy(ch1, ch2);

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## Strings

- → Datatype
  Not DataStructure
- → 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

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## Sort function in strings -

**W5-L3**

```
string str = "babbar";
sort(str.begin(), str.end()); ---> aabbbr
sort(str.begin(), str.end(), greater<char>());
                                  ---> rbbbaa
```

## Custom Comparator -

```
bool cmp(char a, char b){
    return a<b;
}
bool cmp2(char a, char b){
    return a>b;
}
int main(){
    string str = "babbar";

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

    cout << str; ---------------> aabbbr

    string str2 = "babbar";
    sort(str.begin(), str.end(), cmp2);
    cout << str2; ---------------> rbbbaa

    return 0;
}
```

can be any function according to need

ascending order

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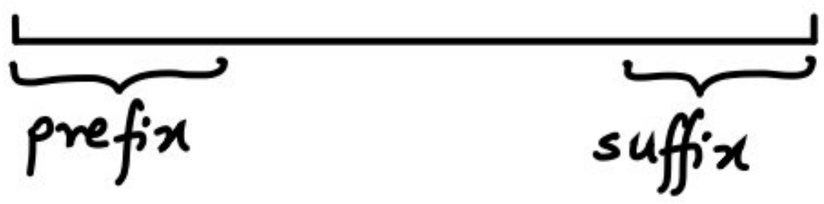
## Prefix and Suffix




## 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
```

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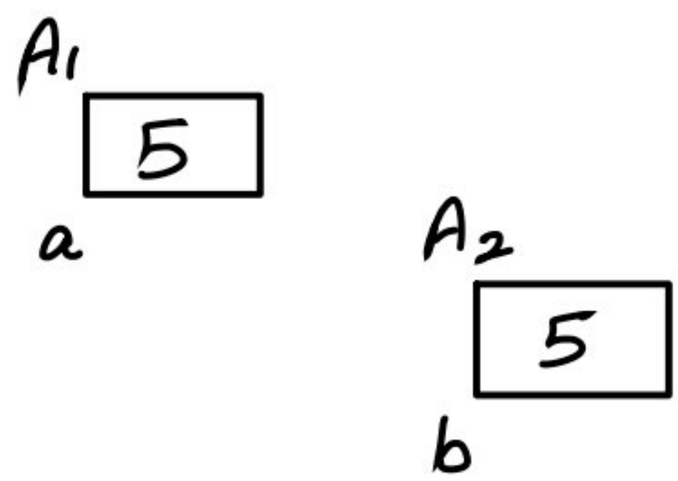
# SYMBOL TABLE

W6-L1

- → Data Structure
- → Stores mapping of variable name, datatype & memory location address → Done by OS
- → entries in symbol table cant be change

int a = 5;

int b = 5;




Symbol Table

| name | → address |
|---|---|
| a | $A_1$ |
| b | $A_2$ |

→ entry of a in symbol table is made

cout << a; → 5

## & Address Of Operator

cout << &a; → $A_1$ → address of variable a in memory (↑ hexadecimal)

cout << &b; → $A_2$

Not 100% Sure

$A_2 = A_1 \pm 4$ → because of consecutive variables in memory

↓ int datatype of a and b

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# 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

```
int * p1 = &a;
```

- int → datatype
- * → symbol for pointer creation
- * → dereference operator
- p1 → pointer name
- & → address of operator
- a → variable to which pointer points

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

```
string * ptr = &s
```

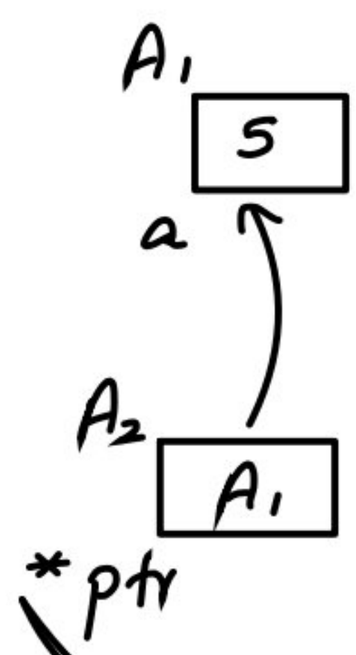
→ ptr is a pointer to string datatype

```
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 | $A_1$ |
| int * | ptr | $A_2$ |




just to visualize it as pointer

not a dereference operator

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*ptr → value at (address stored in ptr)

→ dereference operator

& ptr → address of ptr

## size of pointer

sizeof(ptr); → 8 → Always

→ depends on
architecture
compiler implementation
memory organization

↓

it stores address,
datatype does not matters

8 → 64 bit architecture

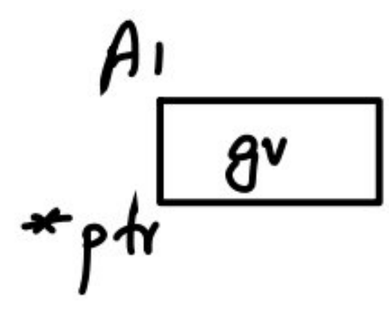
## Use case of pointer

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

int * ptr; → VERY BAD PRACTICE

→ Segmentation fault

cout << ptr; → gv

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

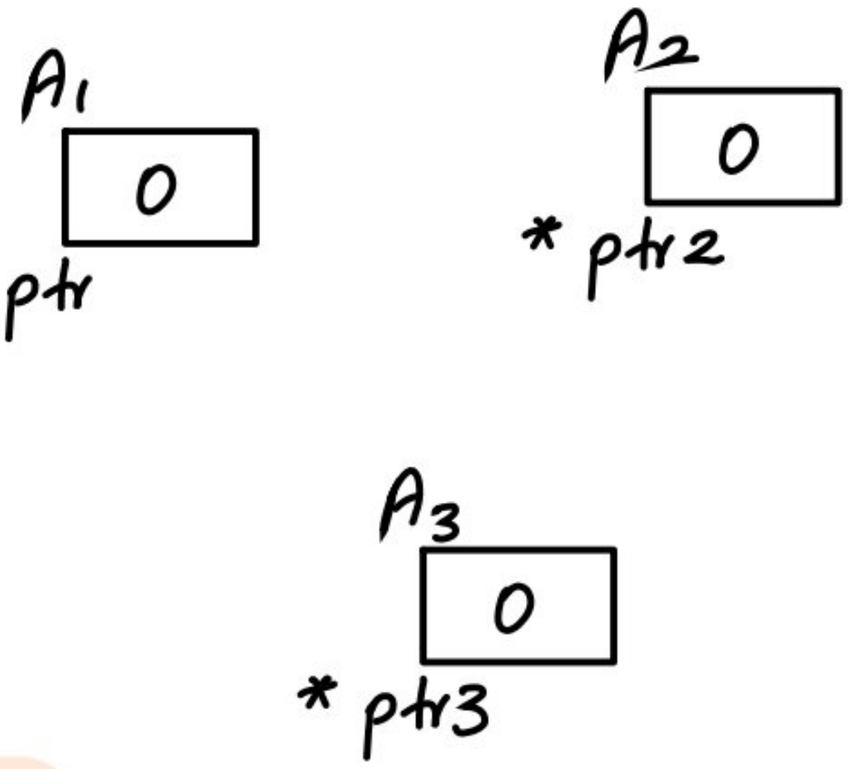
## Segmentation fault -

→ using other's memory

## NULL Pointer

```
int * ptr = 0;
int * ptr2 = NULL;
int * ptr3 = nullptr;
```

} same

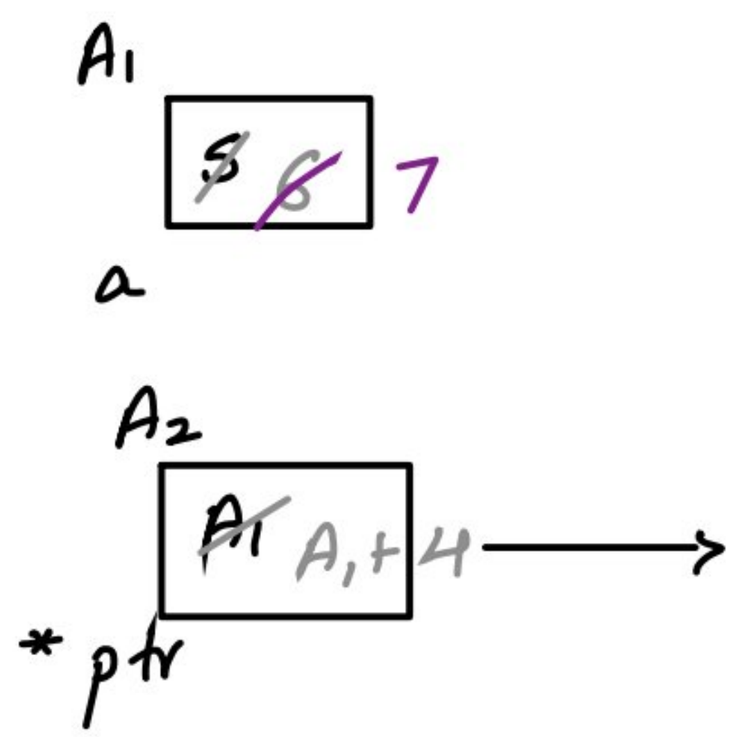



```
cout << ptr ;   ──→ 0
cout << *ptr ;  ──→ ERROR
cout << &ptr ;  ──→ A1
```

ERROR → Segmentation fault

## Arithmetic Operations In Pointers

```
int a = 5;
a++;
int * ptr = &a;
*ptr++;
ptr++;
```




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

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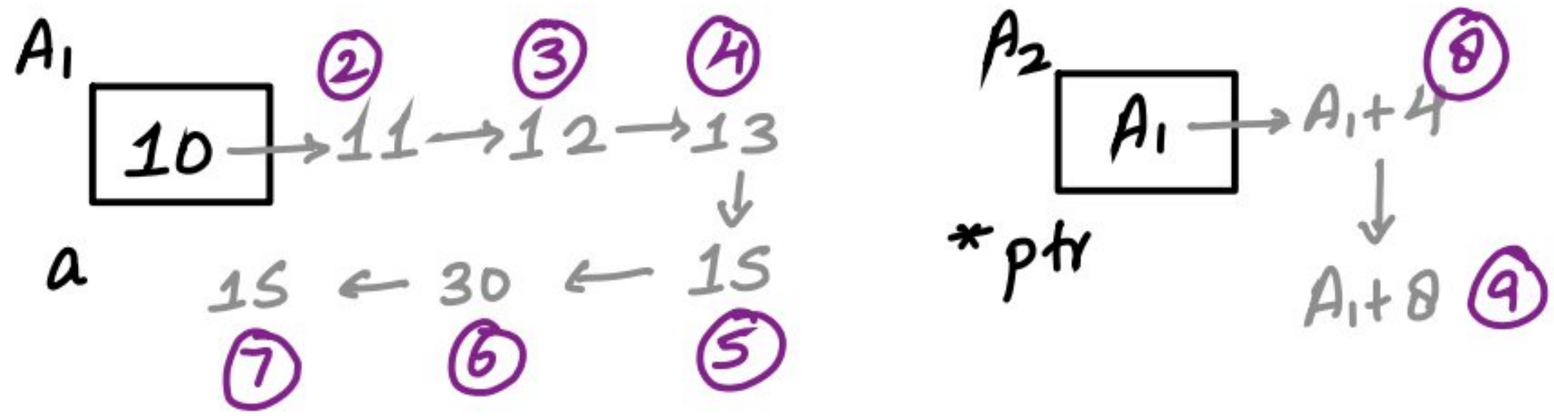
```
int  a = 10;

int  *ptr = &a;
```




| | |
|---|---|
| a | 10 |
| &a | $A_1$ |
| ptr | $A_1$ |
| *ptr | 10 |
| &ptr | $A_2$ |

| | | |
|---|---|---|
| 1 | *ptr * 2 | 20 |
| 2 | (*ptr)++ | 10 |
| 3 | ++(*ptr) | 12 |
| 4 | a = a+1 | 13 |
| 5 | *ptr = *ptr + 2 | 15 |
| 6 | *ptr = *ptr *2 | 30 |
| 7 | *ptr = $\frac{*ptr}{2}$ | 15 |
| 8 | *(ptr++) | 15 |
| 9 | *(++ptr) | gv |

```
int  a = 5;

int *ptr = a;  ———————→ ERROR
```

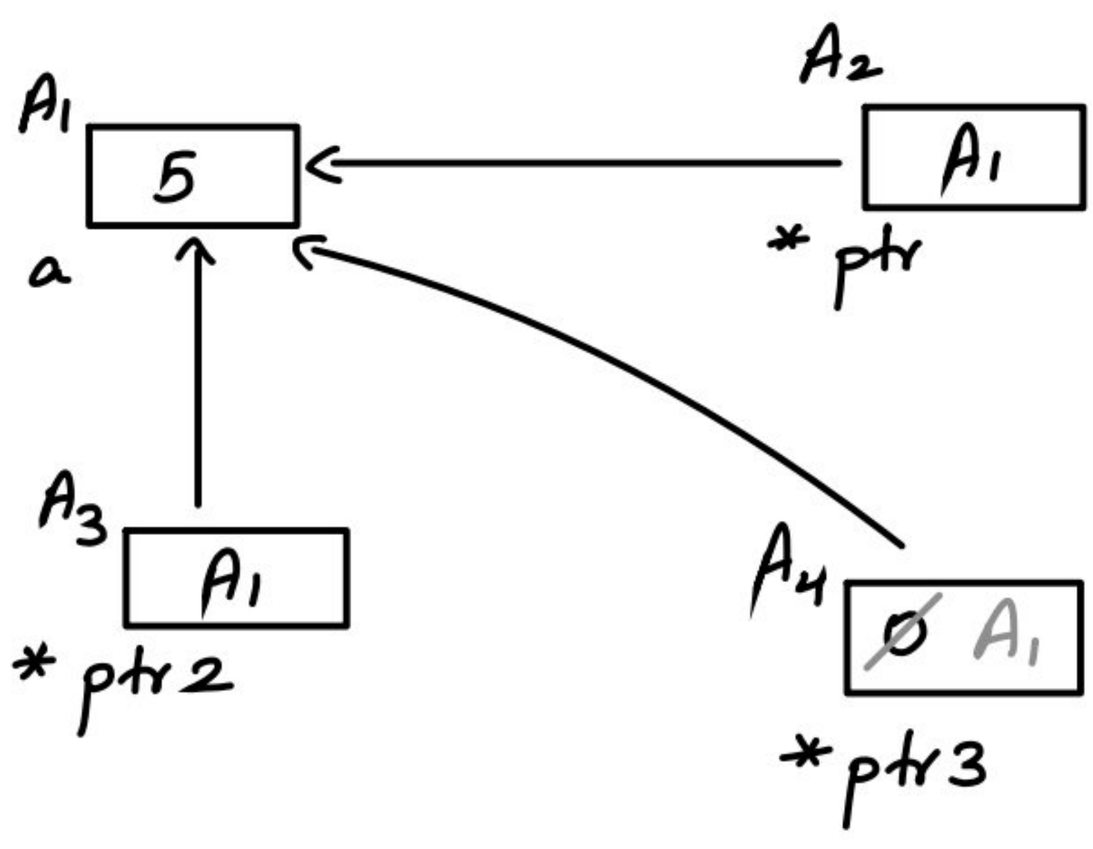
## Copying a pointer

```
int  a = 5;

int  * ptr = & a;

{ int  *  ptr2 = ptr;

{ int  *  ptr 3 = 0;
  ptr 3 =  ptr ;
```

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# ARRAYS & POINTERS

**W6-L2**

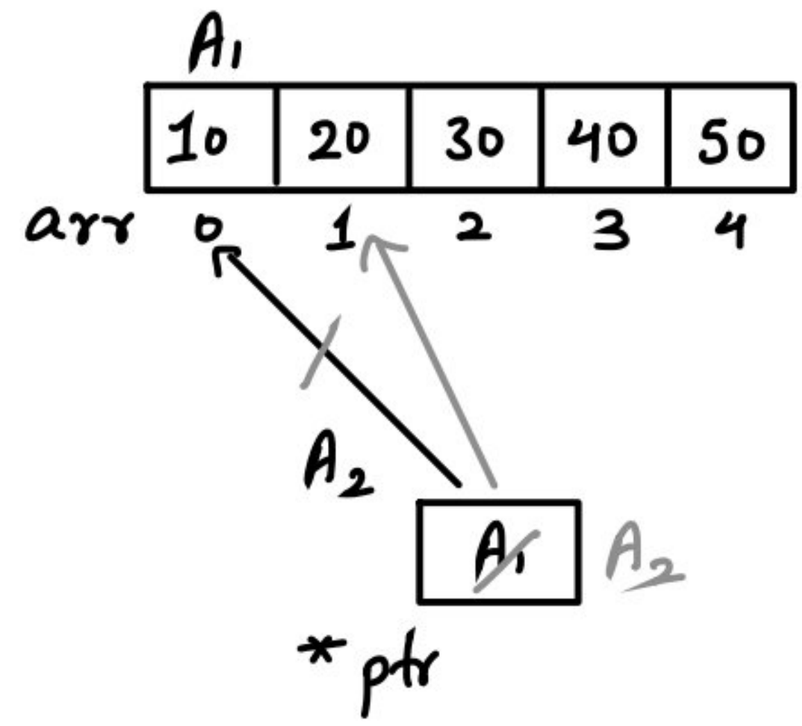
```
int arr[] = {10, 20, 30, 40, 50};
```

→ CONSTANT pointer to the first element of array

- cannot change
- also does not have seperate memory

arr[i] ⟶ element at index i

& arr[i] ⟶ address of arr[i]




```
cout << arr[0];      ⟶ 10
cout << & arr[0];    ⟶ A1
```

```
cout << arr;         ⟶ A1
```
→ array name returns add. of 1st index of array

```
cout << & arr;       ⟶ A1
```
→ from symbol table (add. of array)

same address unlike pointers

| Symbol table | | |
|---|---|---|
| type | name | address |
| int(*)[5] | arr | $A_1$ |
| int * | ptr | $A_2$ |

```
int * ptr = arr;
cout << * ptr;       ⟶ 10
cout << ptr;         ⟶ A1
cout << & ptr;       ⟶ A2

cout << * arr;       ⟶ 10
cout << *(& arr);    ⟶ 10
cout << *(& arr[0]); ⟶ 10
```

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cout << *arr +1; ⟶ 11

cout << *(arr + 1); ⟶ 20

cout << *(arr + 2); ⟶ 30

cout << arr [2]; ⟶ 30

cout << 2[arr]; ⟶ 30

arr[i] ⟷ *(arr + i) ⟷ i[arr]

arr++; ⟶ ERROR ⟶ Entry in symbol table cant be change

ptr++; ⟶ $A_1+4$

→ You can access subpart of an array using pointers

int* ptr = arr;

cout << *(ptr + 2); ⟶ 40

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

| Arrays / Array pointers | Pointers / Normal pointers |
| --- | --- |
| int arr[] = {10, 20, 30}; | int * ptr = arr; |
| ① cout << arr; ⟶ $A_1$ } same<br>cout << &arr; ⟶ $A_1$ | ① cout << ptr; ⟶ $A_1$ } diff.<br>cout << &ptr ⟶ $A_4$ |
| ② arr++; ⟶ ERROR | ② ptr++; ⟶ VALID |
| ③ sizeof(arr); ⟶ 3*4=12 | ③ sizeof(ptr) ⟶ 8 ↓ size of address |

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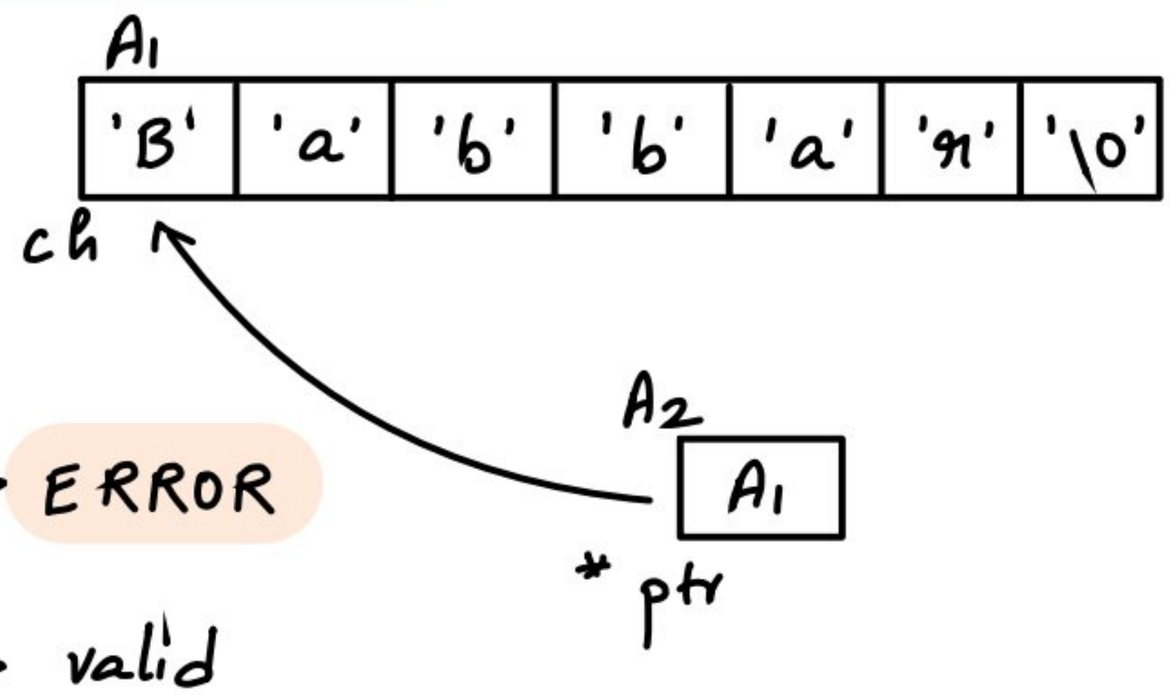
```
int * p1 = arr;
int * p2 = & arr;   ---> ERROR
int * p3 = & arr[0];
```

## 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
```

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ch[i] ⟷ *(ch + i) ⟷ 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; ⟶ $A_1$

cout << *(ch + 3); ⟶ n

cout << ptr; ⟶ Sherbano

cout << &ptr; ⟶ $A_2$

cout << *(ptr + 3); ⟶ n

cout << ptr + 2; ⟶ erbano

cout << *ptr; ⟶ S

cout << ptr + 8; ⟶ " ⟶ NULL char

cout << ptr + 9; ⟶ gv

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```
cout << ch[0];  ──────────→ S
cout << &ch[0]; ──────────→ Sherbano
cout << &(*ch); ──────────→ Sherbano
```

## CHAR AND POINTER

```
char ch = 'k';
char * ptr = &ch;

cout << ch;  ──────────→ k
cout << &ch; ──────────→ k.....
                          ├──→ gv
                          └──→ print until it gets '\0'
cout << ptr; ──────────→ k.....
                          ├──→ gv
                          └──→ print until it gets '\0'
cout << &ptr; ─────────→ A2
cout << *ptr; ─────────→ k
```

## Behind The Scenes

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

└──→ 2 step process

① temp memory

| 'B' | 'a' | 'b' | 'b' | 'a' | 'r' | '\0' |
|---|---|---|---|---|---|---|

copy ↓

② ch

| 'B' | 'a' | 'b' | 'b' | 'a' | 'r' | '\0' | gv | gv | gv |
|---|---|---|---|---|---|---|---|---|---|

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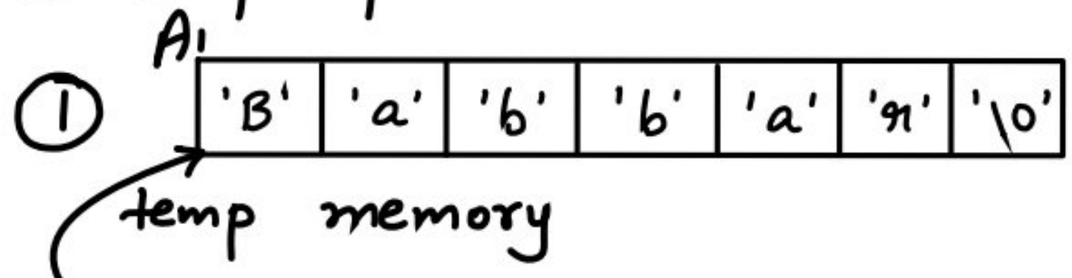
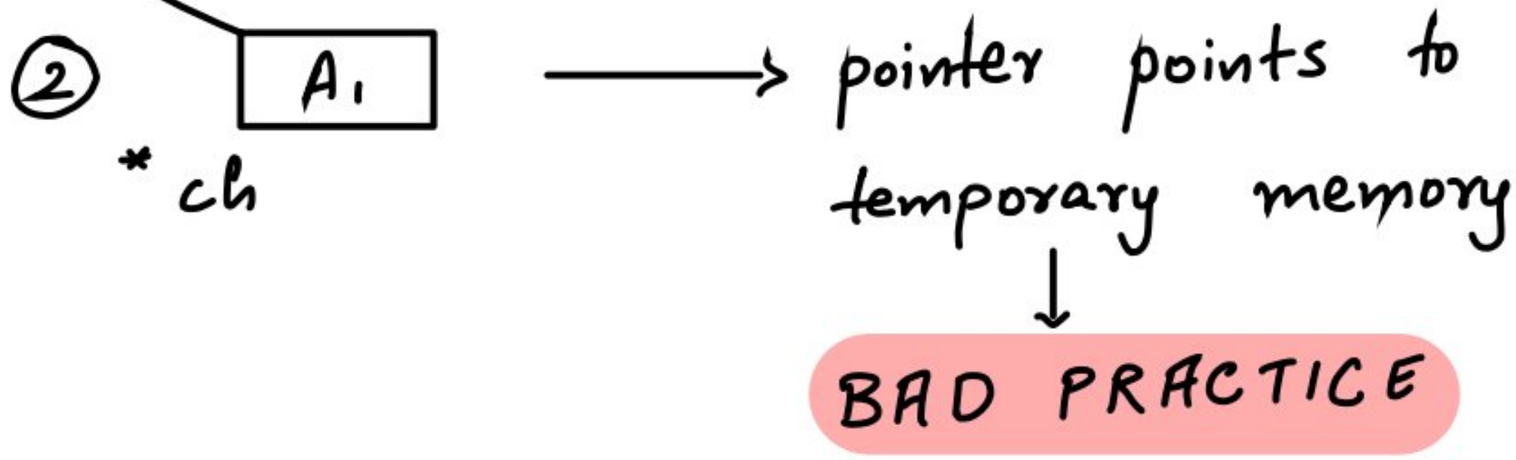
```
char * ch = "Babbar"
```

→ 2 step process



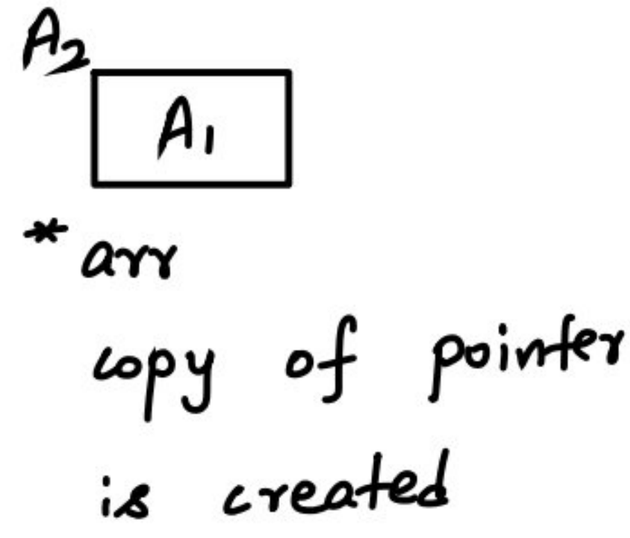




## POINTERS WITH FUNCTIONS

- → pass by value
  - a copy of pointer is made
- → but simulates pass by reference
  - → as in case of arrays & functions

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

→ pointer is passed

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```
int func2 ( int * arr ){
    cout << arr ;        ---> A1
    cout << * arr ;      ---> 10
    cout << & arr ;      ---> A3
    cout << sizeof(arr) ;---> 8
}
```

pointer is passed

A3

| A1 |
|---|

*arr

copy of pointer is created

A1

| 10 | 20 | 0 | 0 | 0 |
|---|---|---|---|---|

arr

```
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 (arr2);
    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

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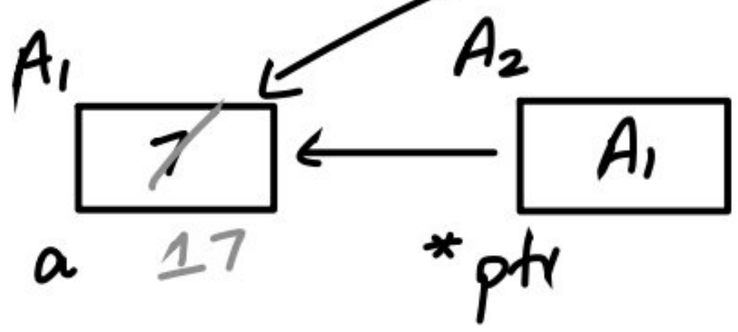
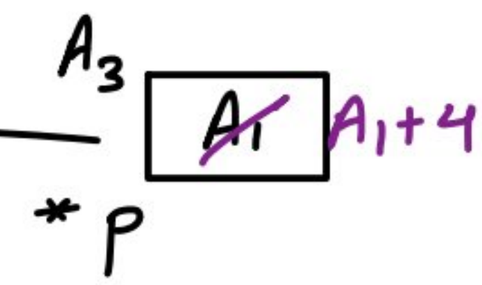
```
int main(){
    int a = 7;
    int * ptr = &a;
    update (ptr);
    return 0;
}
```

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




$*(A_1) = *(A_1) + 10$

$*(A_1) = 7 + 10 = 17$

$a = 17$

## 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 $n$ → seive
- → 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 remaing marked prime numbers

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```
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 - $O(n * \log(\log n))$

SC - $O(n)$

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

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

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

Same with $\boxed{\text{segmented sieve}}$ ⟶ having high & low

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# GCD/HCF and LCM

→ Greatest Common Divisor

→ $gcd(a,b) = gcd(a-b, b)$ $\quad a > b$

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

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

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

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;
    }
```

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

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

## LCM

$$lcm * gcd = a * b$$

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

## Modulo Arithmetic

- $a \% n \longrightarrow [0, n)$
- $(a + b) \% n = (a \% n) + (b \% n)$

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

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

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

## Fast Exponentiation

- $a^b = a^{b/2} * a^{b/2}$ , b is even

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

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```
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

Scanned with OKEN Scanner

# MULTI LEVEL POINTER

**W6-L4**

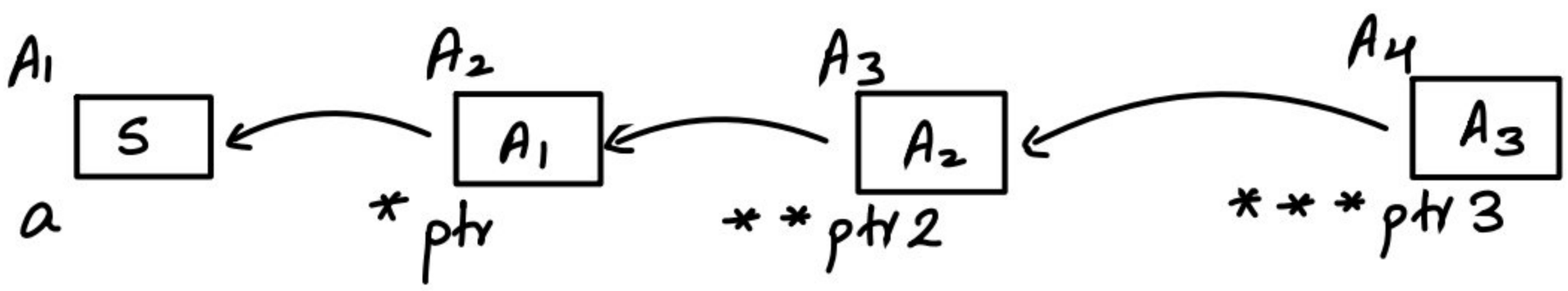
```
int  a = 5;

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




a → 5

&a → A1

&&a → ERROR

ptr → A1

&ptr → A2

*ptr → 5

ptr2 → A2

&ptr2 → A3

*ptr2 → A1

**ptr2 → 5

apply dereference operator 2 times

ptr3 → A3

&ptr3 → A4

*ptr3 → A2

**ptr3 → A1

***ptr3 → 5

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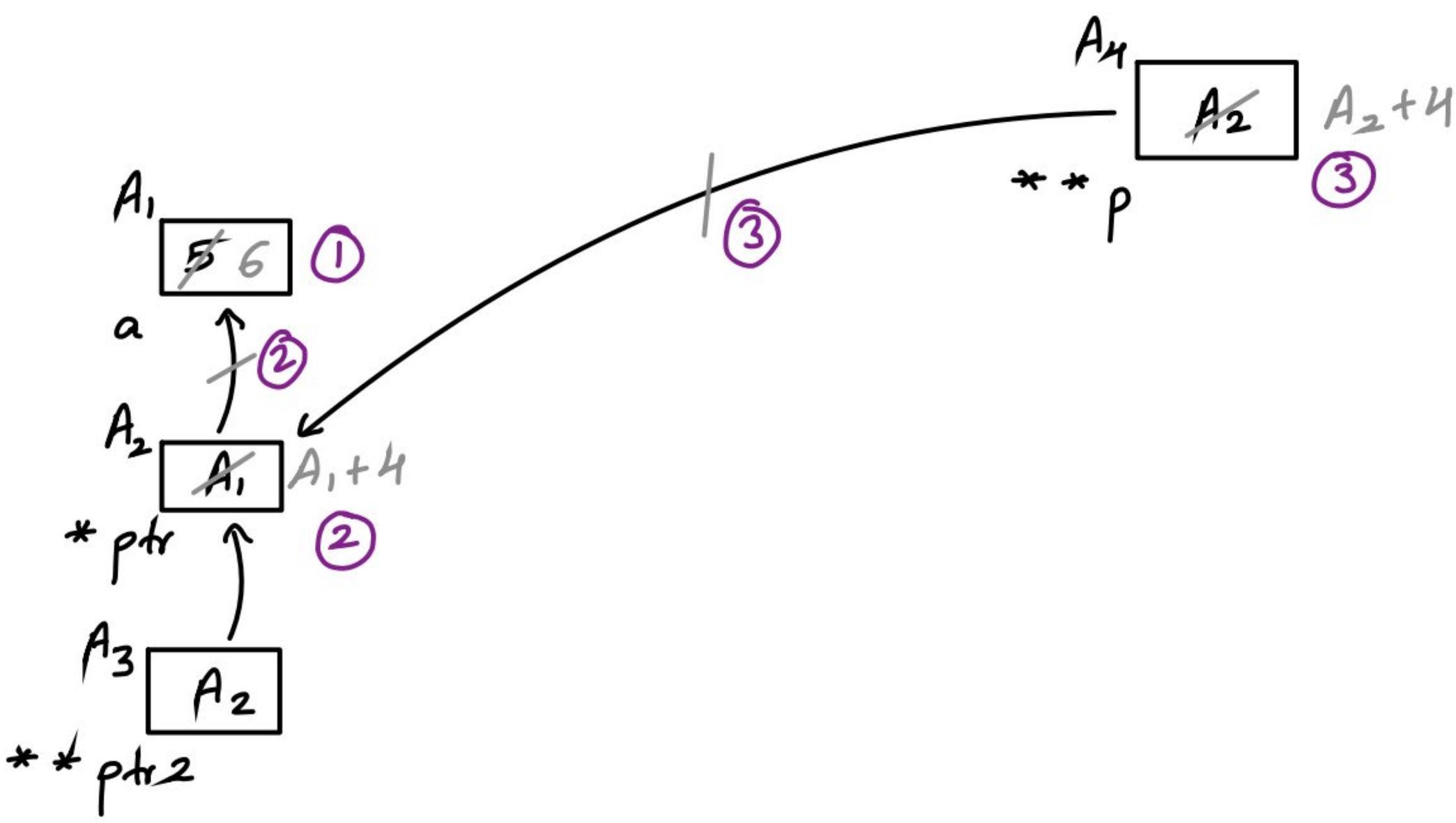
```
int main(){
    int a = 5;
    int *ptr = &a;
    int **ptr2 = &ptr;
    func(ptr2);
    return 0;
}
```

both are same

```
func(&ptr);
```

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




```
int a = 5;
int *p = &a;
int **q = p;
```

→ ERROR

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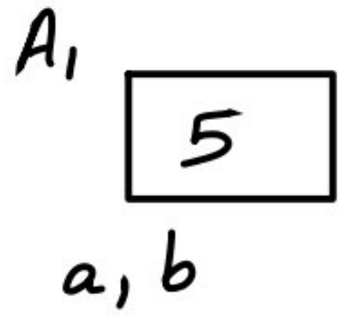
# REFERENCE VARIABLE

- alternate of pointers → $\underbrace{a, *ptr, **ptr}_{\text{diff. names of same memory location}} \longrightarrow a$
  - → very confusing
- diff. names of same variable
  - → same memory location
- only new entry in symbol table, no other memory will allocate
- can access a variable by diff. names

```
int a = 5;
int &b = a;
```




Symbol Table

| | |
|---|---|
| a | $A_1$ |
| b | $A_1$ |

## Use Case

- reference variable cant 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

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# 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);
    update3 ( ptr);
    return 0;
}
```

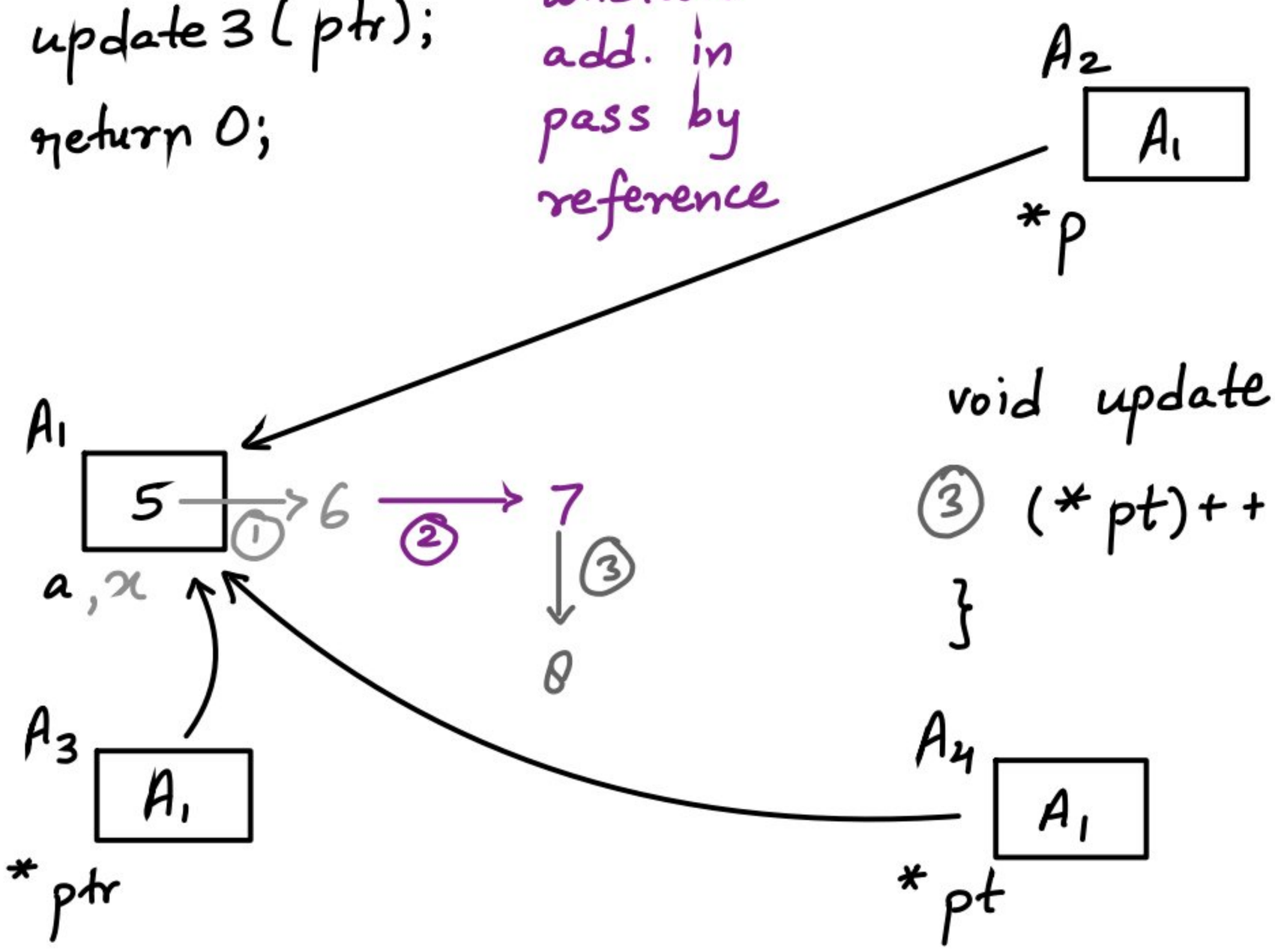
→ ERROR constant add. in pass by reference

```
void update( int & x){
  ① x++;
}
```

PASS BY REFERENCE

```
void update2 ( int * p) {
  ② (* p) ++;
}
```

PASS BY VALUE




```
void update3 (int * & pt){
  ③ (* pt)++;
}
```

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

int solve ( int & arr ){
    cout << arr;
}
```

this is reference variable of type int

```
int solve (int & arr[])
```

ERROR

array of reference is not allowed

```
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;
}
```

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# 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;
}
```

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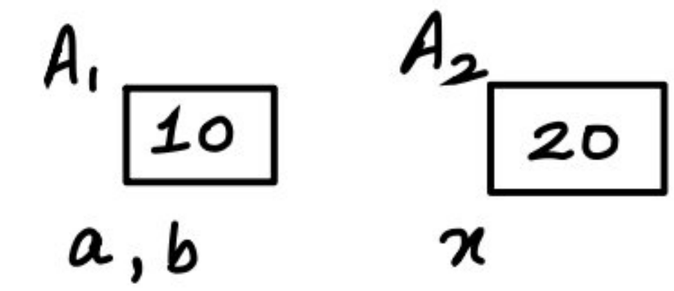
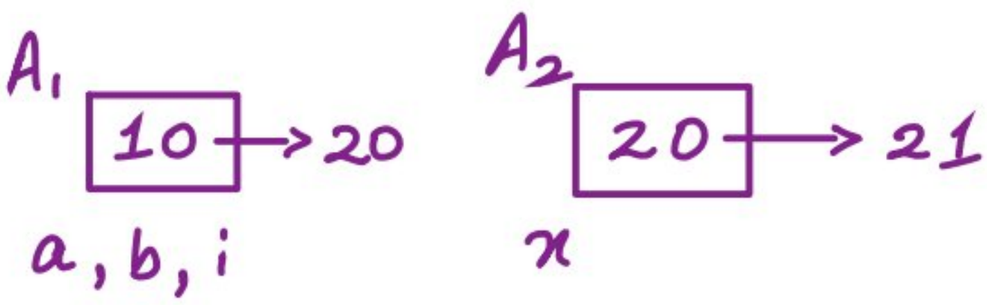
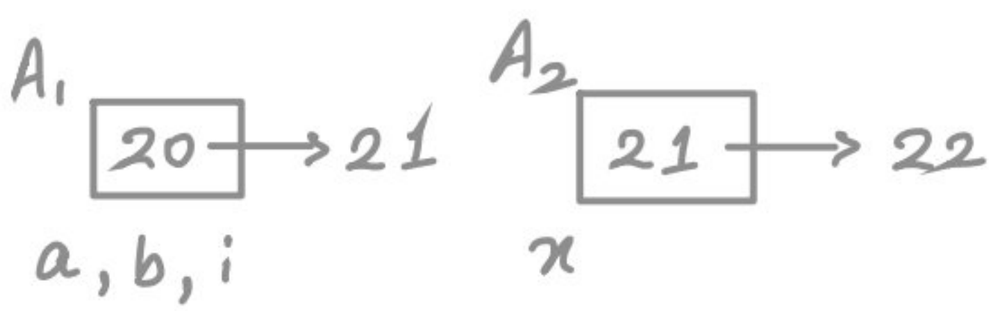
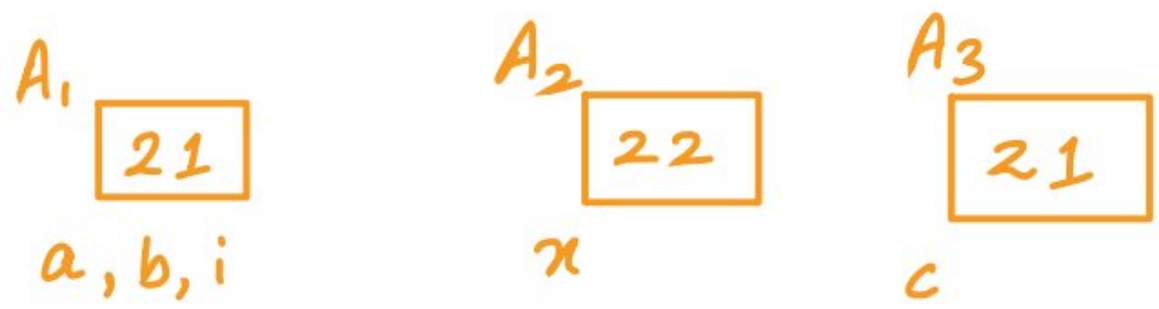
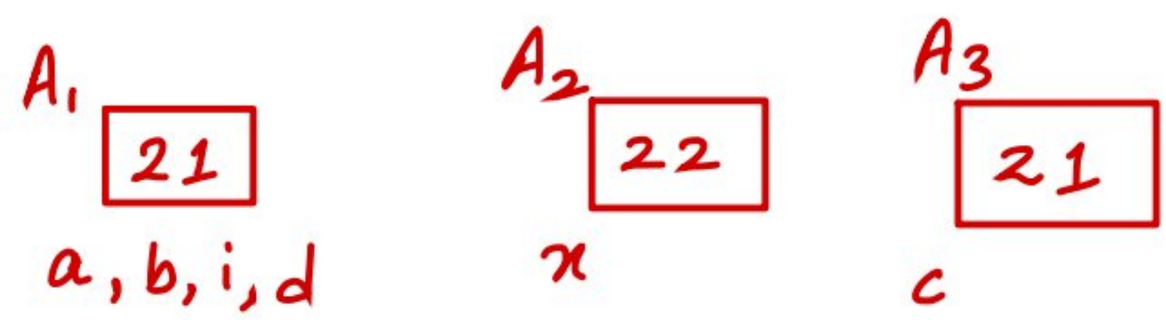


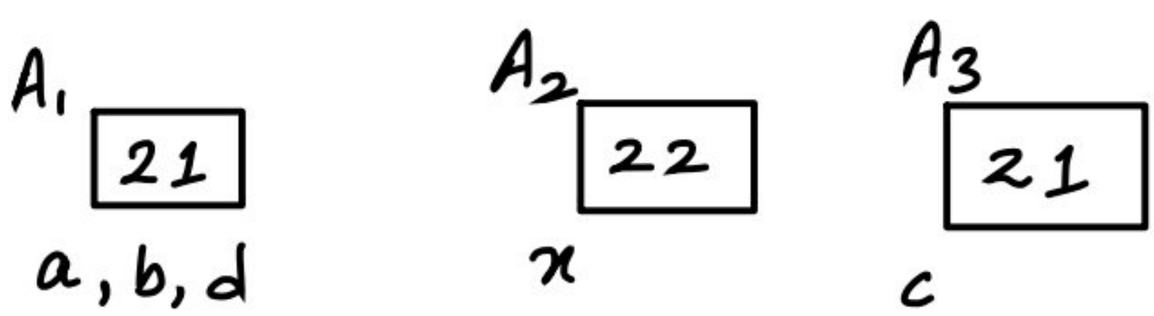




```
int c= ref(a) =i;
int c = 21;
```




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

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## passing a global variable

```
int x = 5;

int main () {
    ref () = 10;

    ref 2() = 20;
    return 0;
}
```

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

int ref2(){
    return x;
}
```

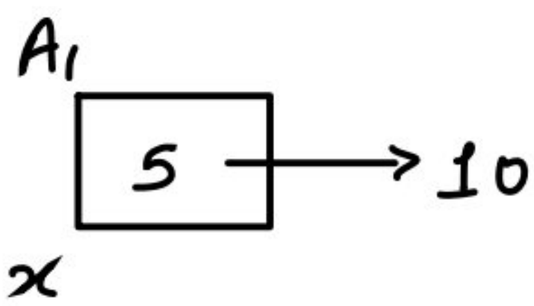
$x = 10;$

ERROR

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

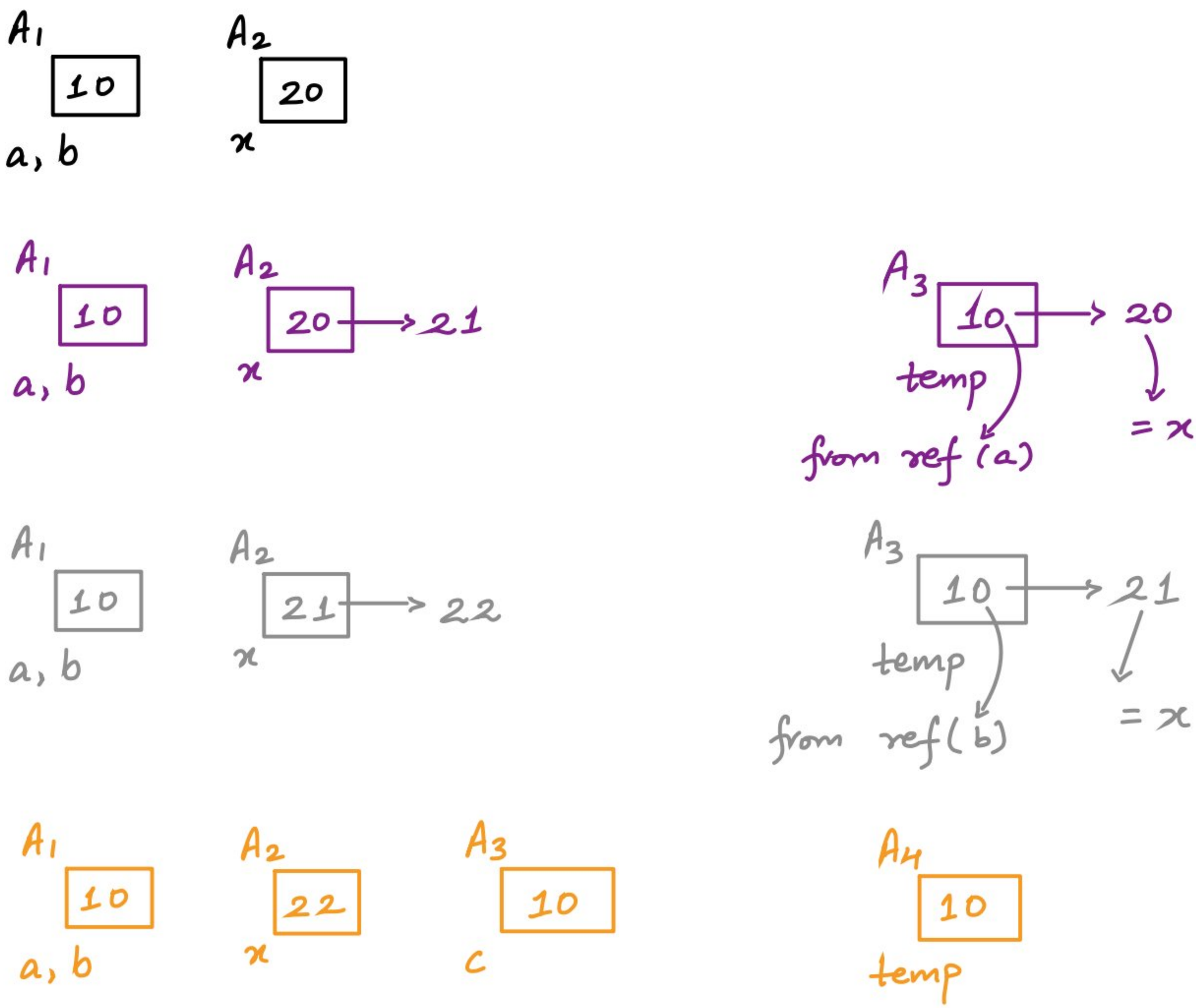
```
int & ref ( int temp){
    return temp ;
}
```

returning a variable stored in temporary memory

Scanned with OKEN Scanner

```
    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

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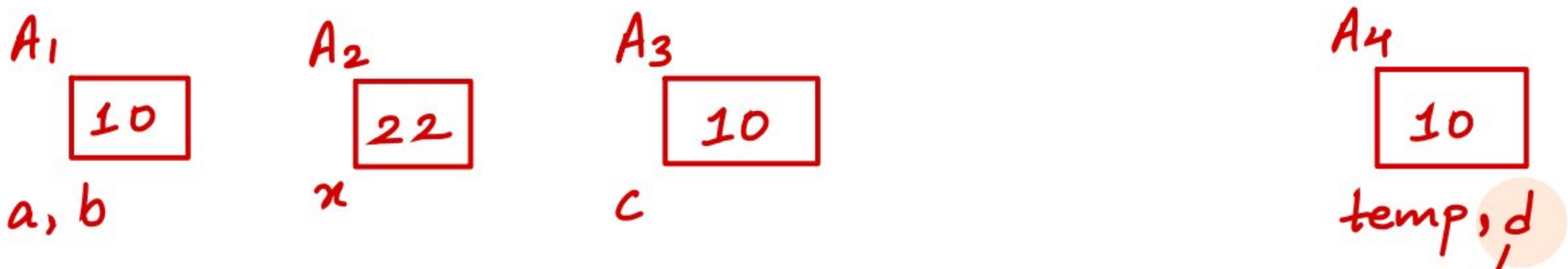



d (variable of main function refers to a temporary memory

BAD PRACTICE

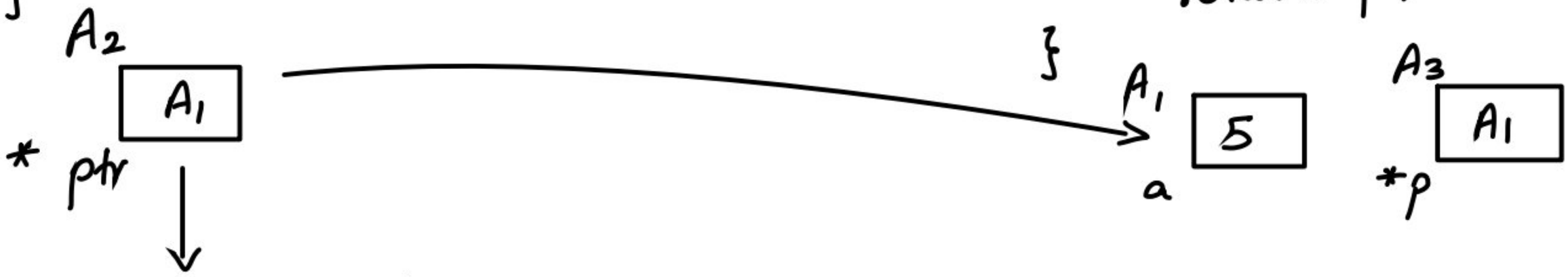
Have similarity

DON'T DO THIS AT HOME

IMP QUESTION

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

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




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

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# 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;

→ pointer of static variables are constant pointers

→ pointer of dynamic memory allocation variables can be change

name of array refers to base address

→ char ch = "hello";
cout << ch; → hello
ch++; → ERROR
cout << ch;

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→ double arr [] = {2.5, 7.9, 50.25} ;

double * ptr = arr ;

ptr = ptr + 0.25 ; ⟶ ERROR

↳ pointer arithmetic op can only be done using integers

cout << ptr ;

→ 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 to int *

cout << *ptr2;

→ int a = 5;

int * p = &a;

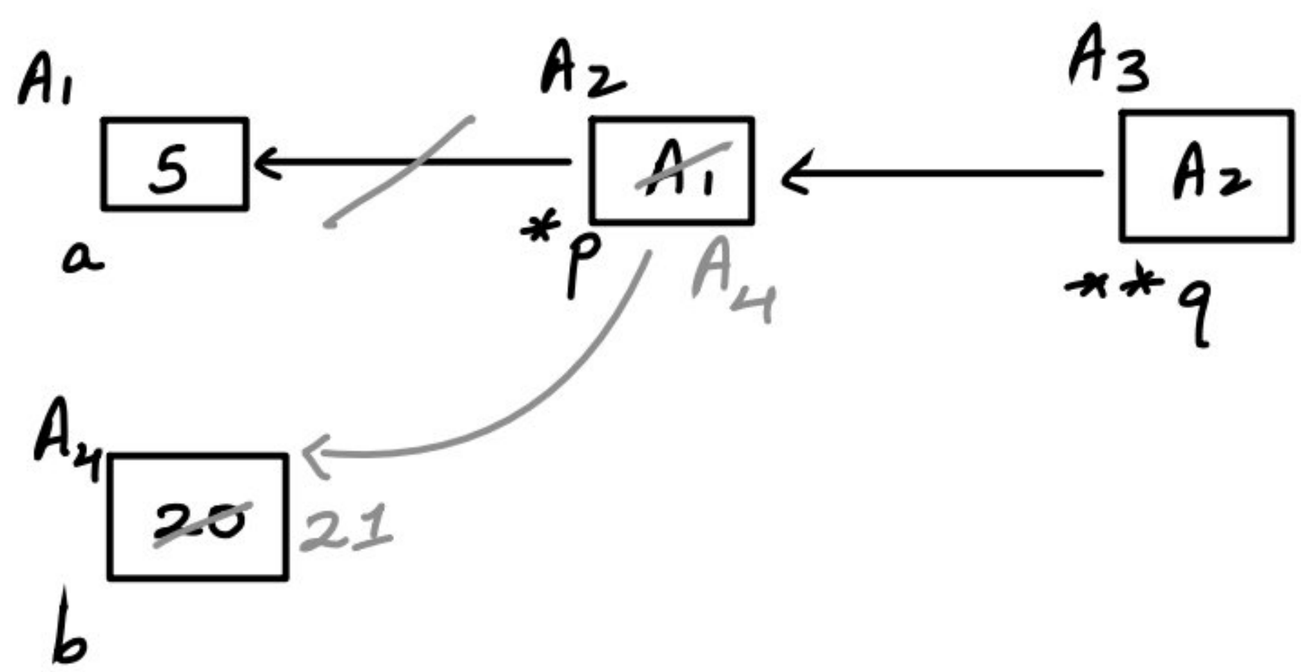
int ** q = &p ;

int b = 20;

* q = &b;

(* p) ++;

cout << a << " " << b; ⟶ 5 21

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```
int a = 5;
int * ptr = &a;
int ** ptr2 = &ptr;
int ** ptr3 = &(&a);
cout << ** ptr3;
```

→ ERROR

↓

address of (address in memory location)

(doesn't make any sense)

POITER IMP DOUBT

(IN DASH BOARD)

W6-L5

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# RECURSION

# W7-L1

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

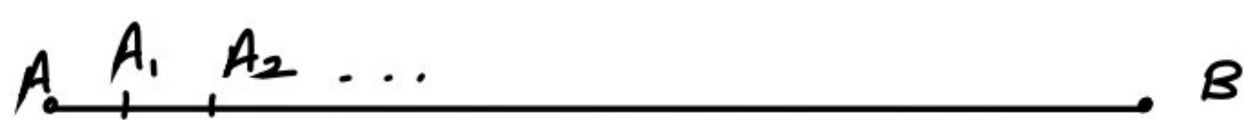
bigger problem

$2^n = 2 * 2^{n-1}$

$n! = n * (n-1)!$

print N to 1 = print N and print N-1 to 1

fibonacci (n) = fibonacci (n-1) + fibonacci (n-2)




totalSteps (A to B) = 1 step + totalSteps (A1 to B)

smaller problem

## 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

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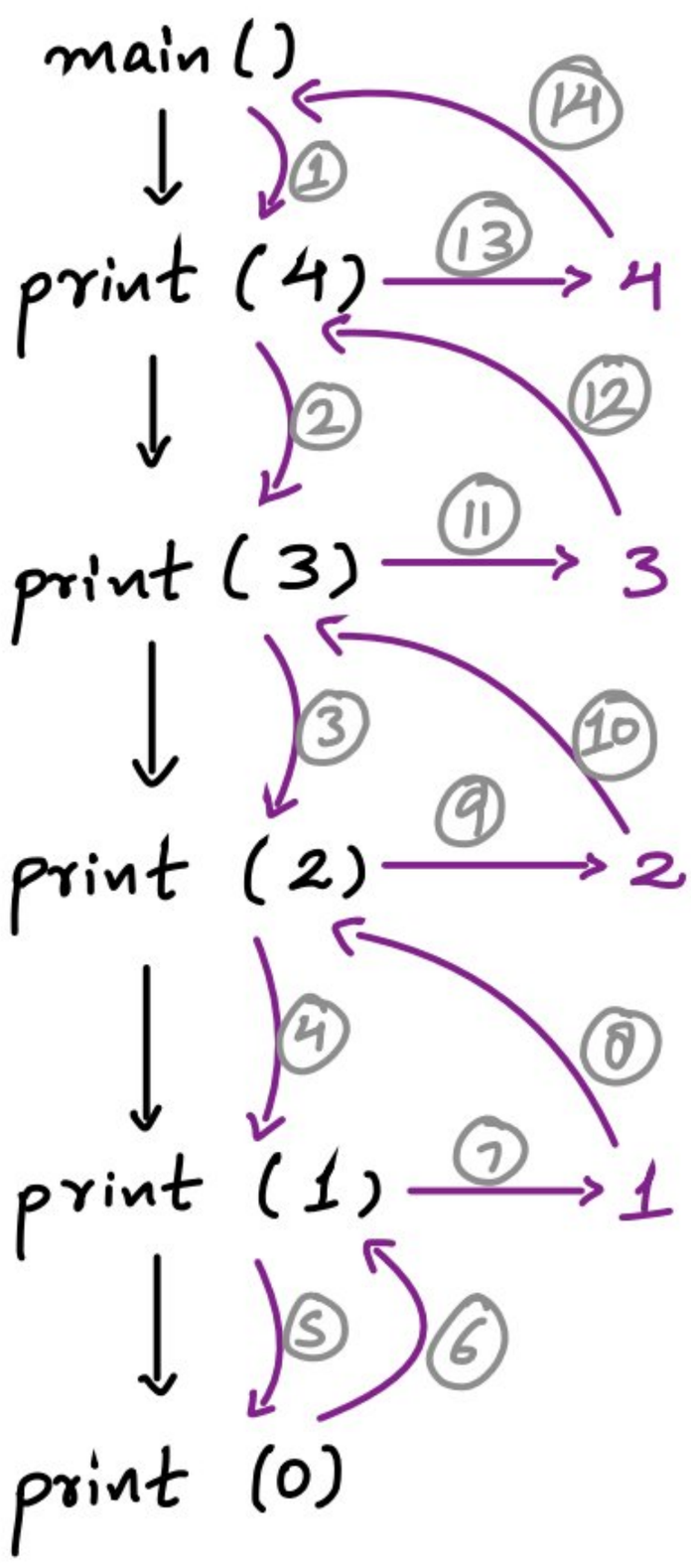
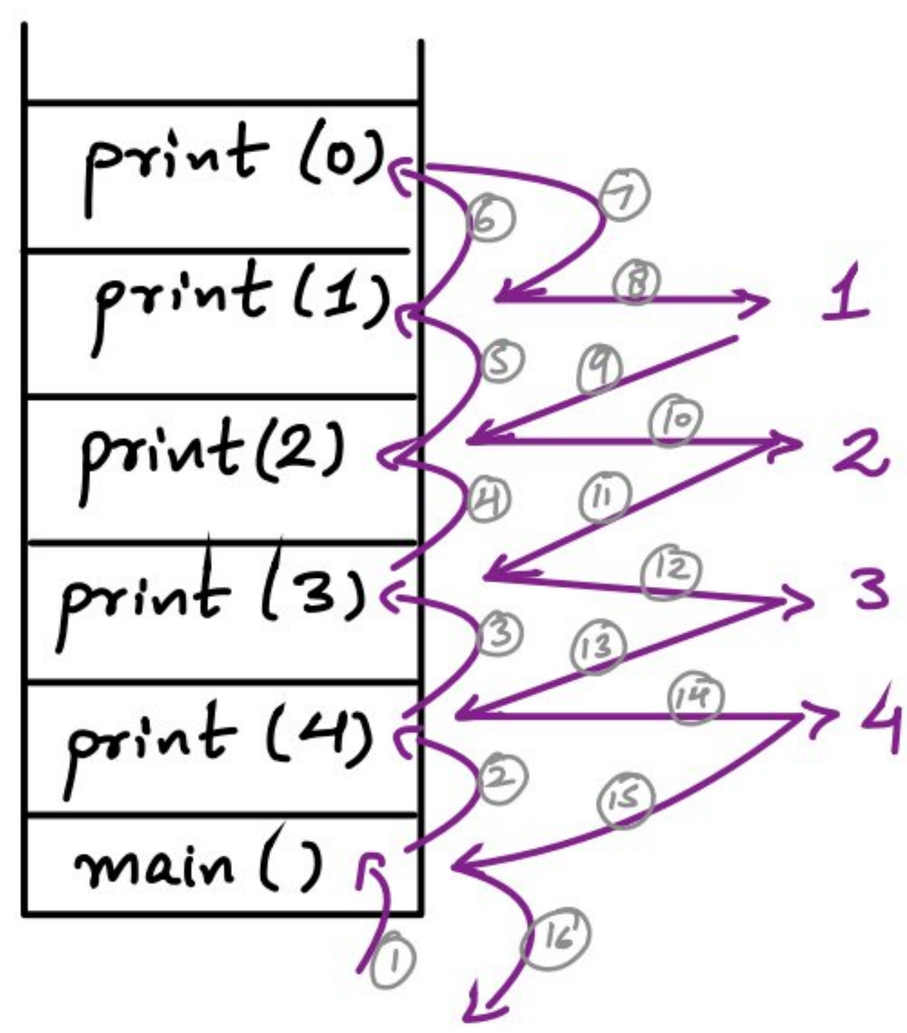
```
int main () {
    int n = 4;
    print (n);
    return 0;
}
```

```
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

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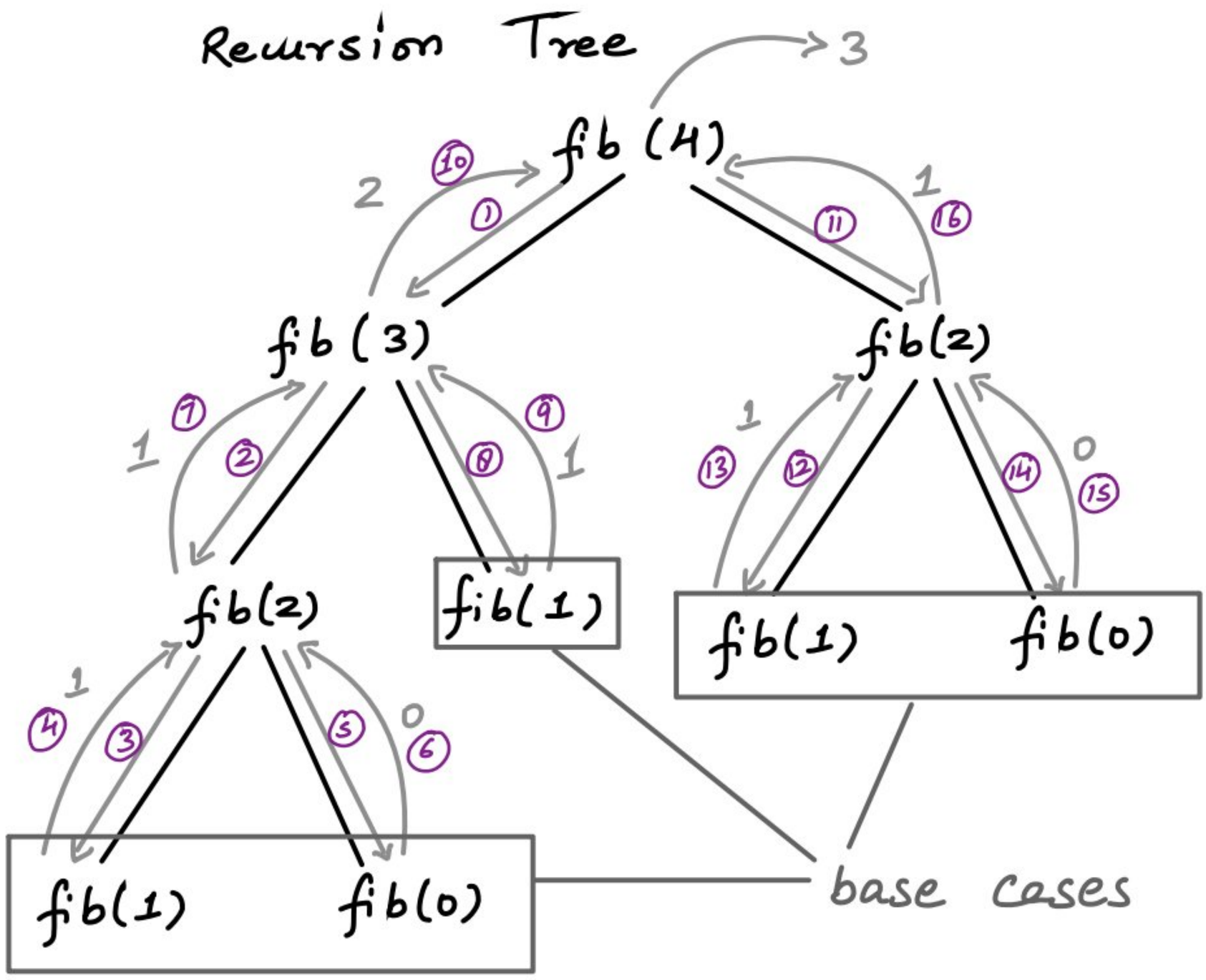
```
int main(){
    int n = 4,
    int ans = fib(n);
    cout << ans;
    return 0;
}
```

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

| | | | | | |
|---|---|---|---|---|---|
| $n \longrightarrow$ | 0 | 1 | 2 | 3 | 4 |
| $fib(n) \longrightarrow$ | 0 | 1 | 1 | 2 | 3 |

Recursion Tree




## Magical line for Recursion

Ek case solve krdo, baaki recursion sambhal lega

→ Just believe on it, dont doubt on recursion

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

**W7-L2**

pass by reference

if we want to retain value of ans after function call

→ Try to pass everything by reference IF POSSIBE

↳ SC ↓es

TC ↓es (no copying of variables again & again)

→ to reverse answer, you can use recursion

## Integer literal with a leading 0

n= 0100 ; ⟶ interpretted as an octal number

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

cin >> n ; ⟶ ( 0 1 00)

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

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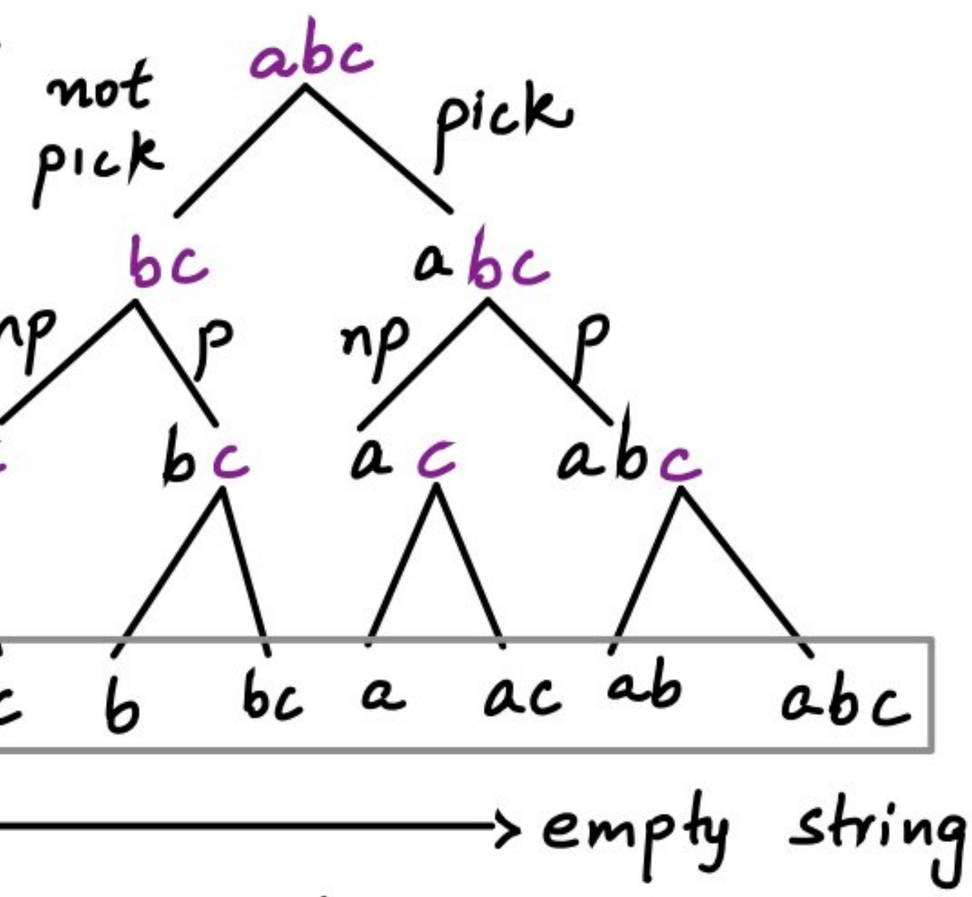
→ Expression can't be pass by reference

## Subsequences

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

→ ex- "abc" →




subsequences of string "abc" ←

→ $2^n$, $n$ → length of string

## Arithmetic Operations on Strings

```
s1 = "Ujjwal";
s2 = "2327";
cout << "Ujjwal" + "2327";
```
→ ERROR

```
s1 = s1 + s2;
cout << s1;
```
→ "Ujjwal2327" → Concatinate

-, *, /, % → NOT VALID in strings

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## Coin change problem

W7-L4

→ find min. coins equivalant to given amount

```
int coinChange( vector<int> arr, int amount) {
    if (amount == 0)
        return 0;
    if (amount < 0)
        return INT_MAX;     // means INVALID or
                                cant 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
                                cant be changed
    else
        return mini +1;
}
```

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

**Type 2** - for loop in recursion

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→ 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

$f(n) = k + f(n-1)$ Base case → for $n = 0$

Recursive Relation Method -

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

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

$\vdots$

$T(0) = k_1$

$T(n) = nk + k_1$

$T(n) = O(n)$

T.C - $O(n)$

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## Recursive Tree Method - Best method

$$\left.\begin{array}{l} f(n) \longrightarrow k \\ \downarrow \\ f(n-1) \longrightarrow k \\ \downarrow \\ f(n-2) \longrightarrow k \\ \vdots \\ \downarrow \\ f(1) \longrightarrow k \end{array}\right\} n \text{ times}$$

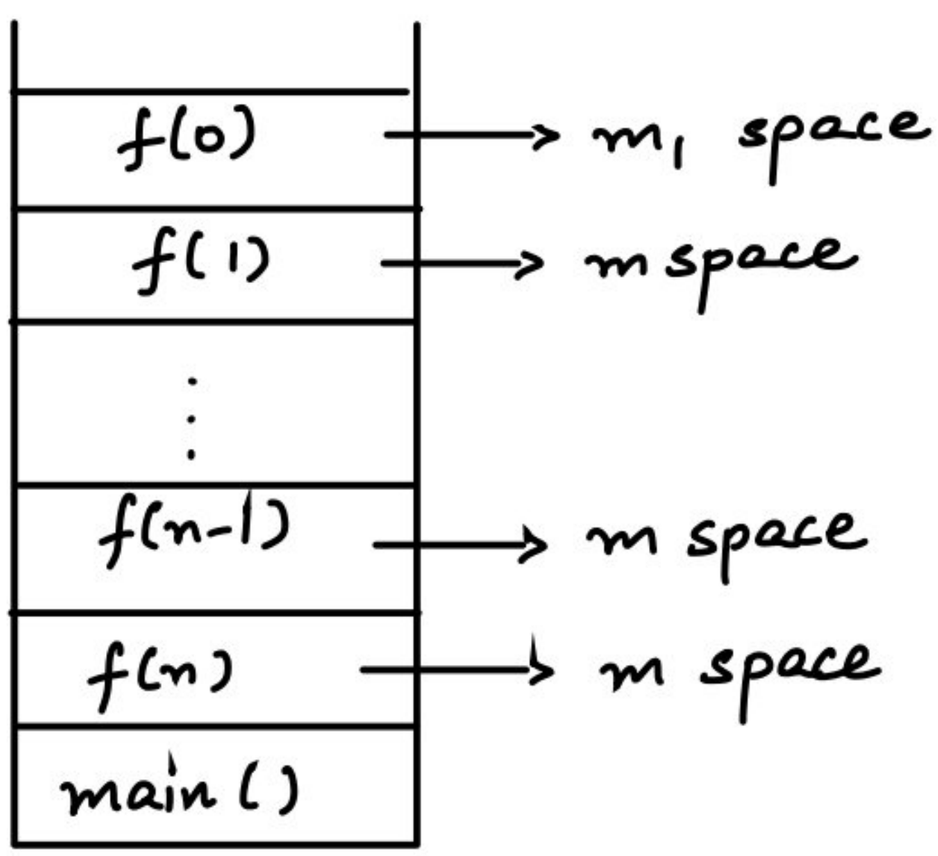
$$\downarrow$$

$$f(0) \longrightarrow k_1$$

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

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

## Space Complexity -




$m$ and $m_1$ are constants

$$SC - mn + m_1$$

$$SC - O(n)$$

$\longrightarrow$ max depth

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## Binary Search

$f(n) = k + f(n/2)$ ; base case $\longrightarrow$ for $n = 0$

### Recursive Relation Method

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

$$T(0) = k_1$$

$a = \log_2 n$

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

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

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

### Recursive Tree Method

$$\left.\begin{aligned} f(n) &\longrightarrow k \\ &\downarrow \\ f(n/2) &\longrightarrow k \\ &\vdots \\ &\downarrow \\ f(1) &\longrightarrow k \\ &\downarrow \\ f(0) &\longrightarrow k_1 \end{aligned}\right\} a \text{ times}$$

$a = \log_2 n$

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

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

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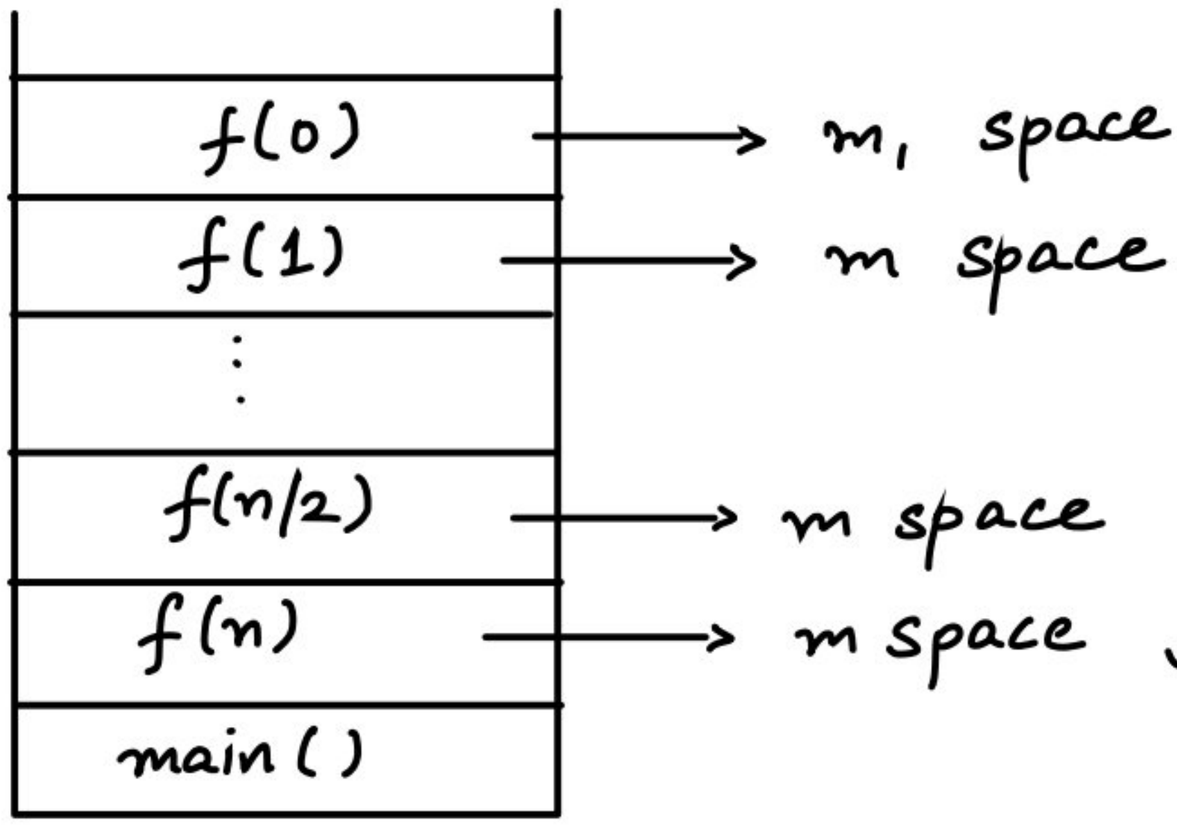
## Space Complexity -




a times

m and $m_1$ are constants

$a = \log_2 n$

$SC - m \log_2 n + m_1$

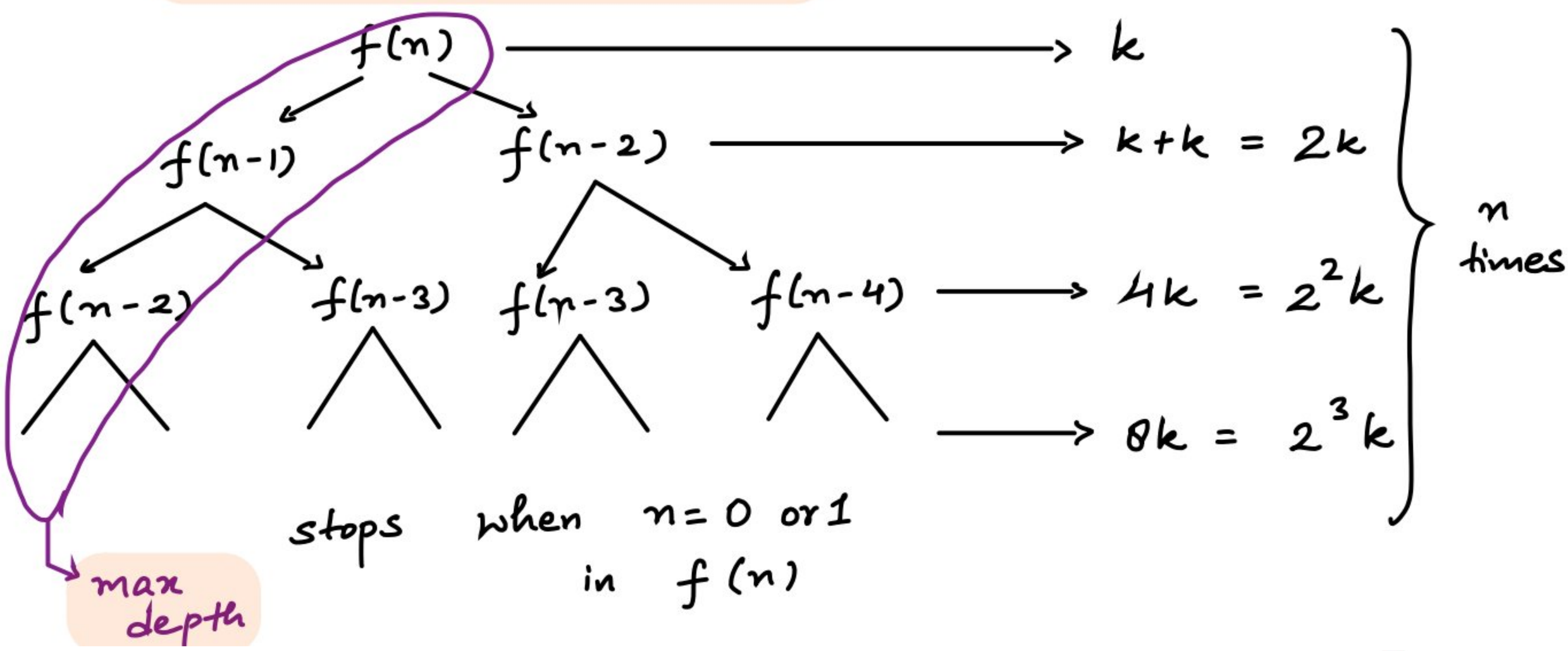
$SC - O(\log_2 n)$ → max depth

## Fibonacci Series

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

base case → for $n = 0$ or $1$

## Recursive Tree Method




stops when $n = 0$ or $1$ in $f(n)$

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

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

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

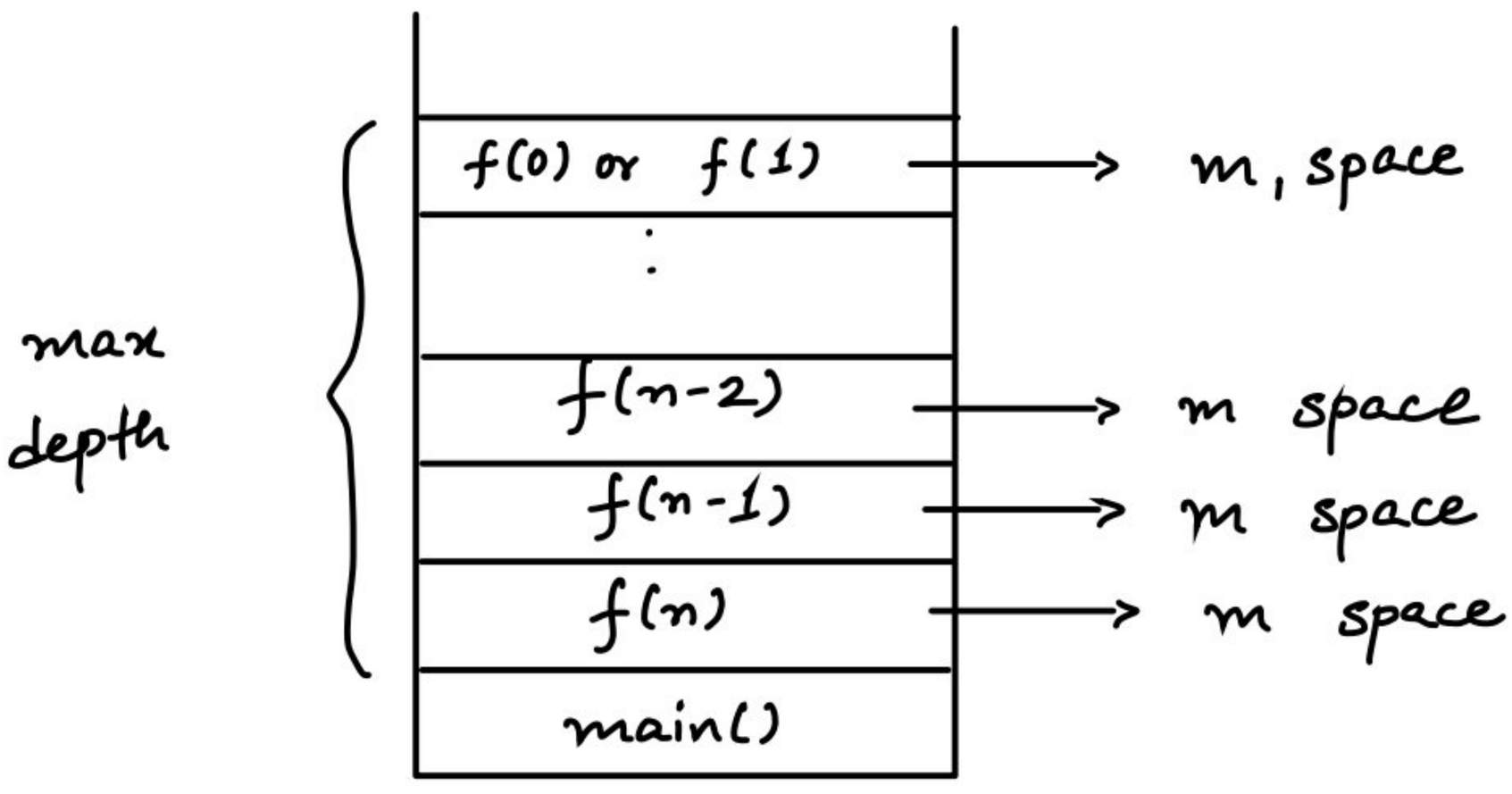
assume for simplicity and for large numbers

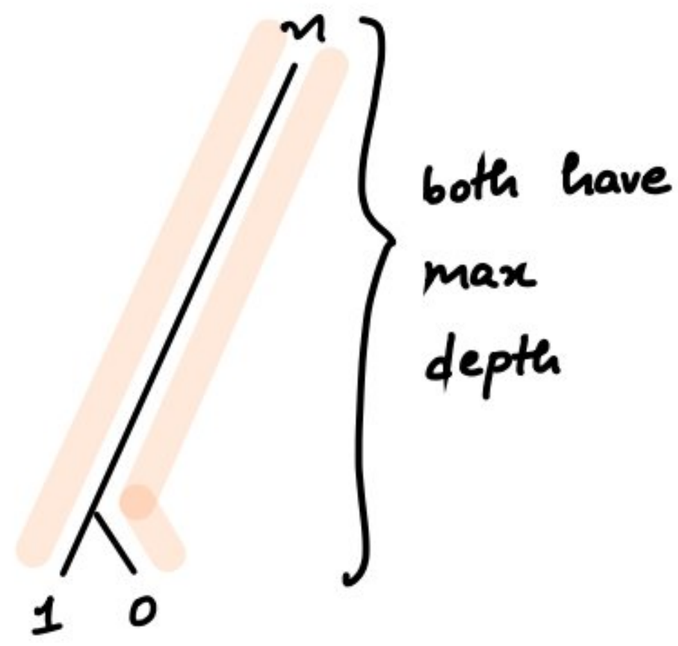
$T.C - O(2^n)$

→ exponential TC

→ very bad

## Space Complexity




$$SC - m(n-1) + m_1$$

$SC - O(n)$

→ max depth

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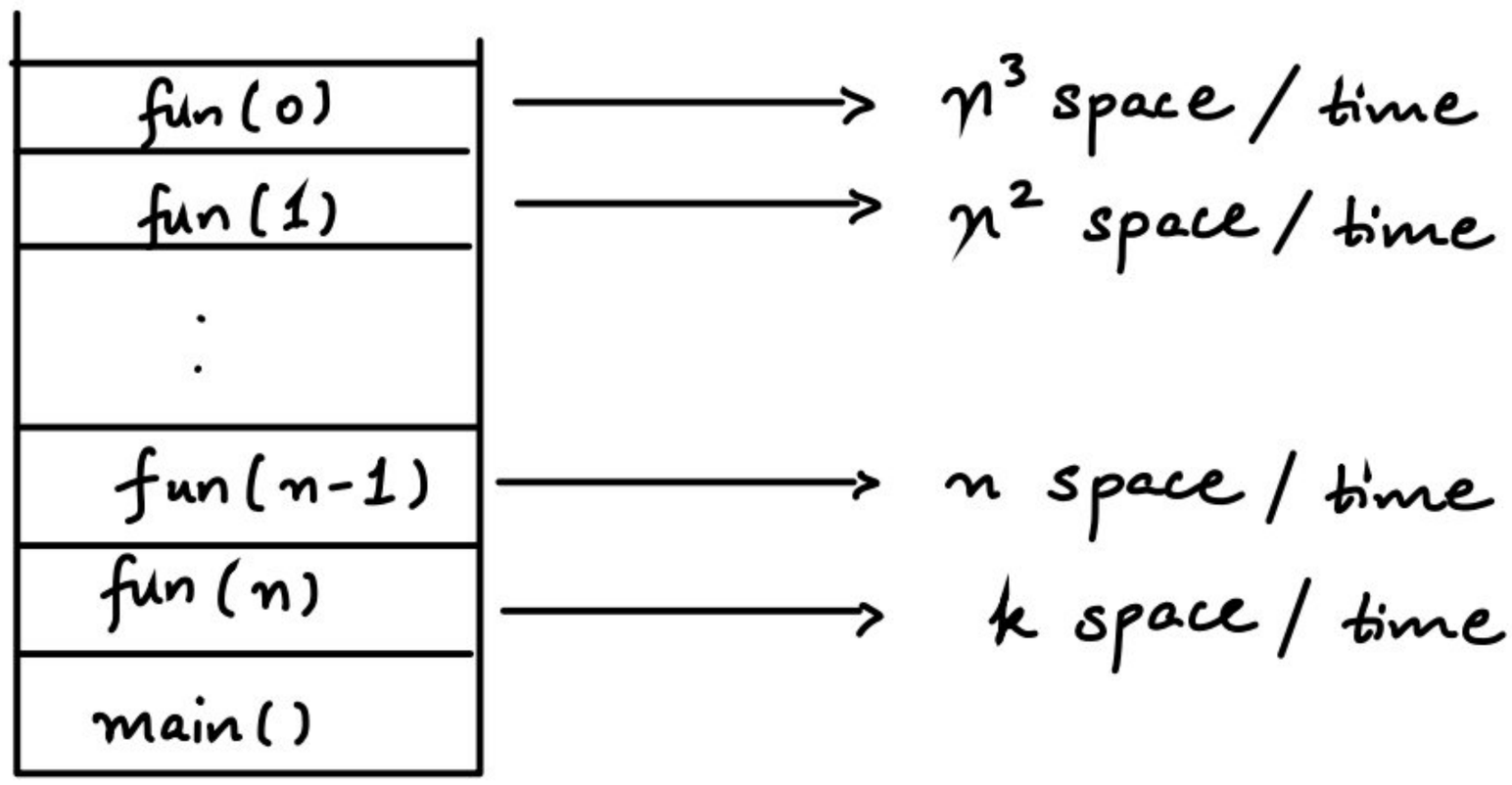
if this is such a case




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

$\longrightarrow$ max SC in any call

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

$\longrightarrow$ max T.C. in any call

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# W8-L1

## Divide & Conquer

→ using recursion

## 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 len 1 = s - mid + 1;
    int len 2 = e - mid;
    vector <int> left (len 1);
    vector <int> right ( len 2);

    int i=0, j=0, k=s;

    while ( i< len1)
        left [i++] = arr[k++];

    while ( j< len 2)
        right [j++] = arr[k++];

    i=0, j=0, k=s;
```

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```
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);
}
```

due to copy in every level

in best case too

T.C. - $O(n\log n)$ → number of levels

S.C. - $O(n)$ → $(n + \frac{n}{2} + \frac{n}{4} + \frac{n}{8} + \cdots$ till $1)$

## IMPLACE MERGE SORT - GFG

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# Quick Sort

W8-L2

→ 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;
    int pivot = arr[s];

    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
```

This is one way

Other ways - choose last
- choose random
↓
randomised quick sort

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```
    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

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## Backtracking

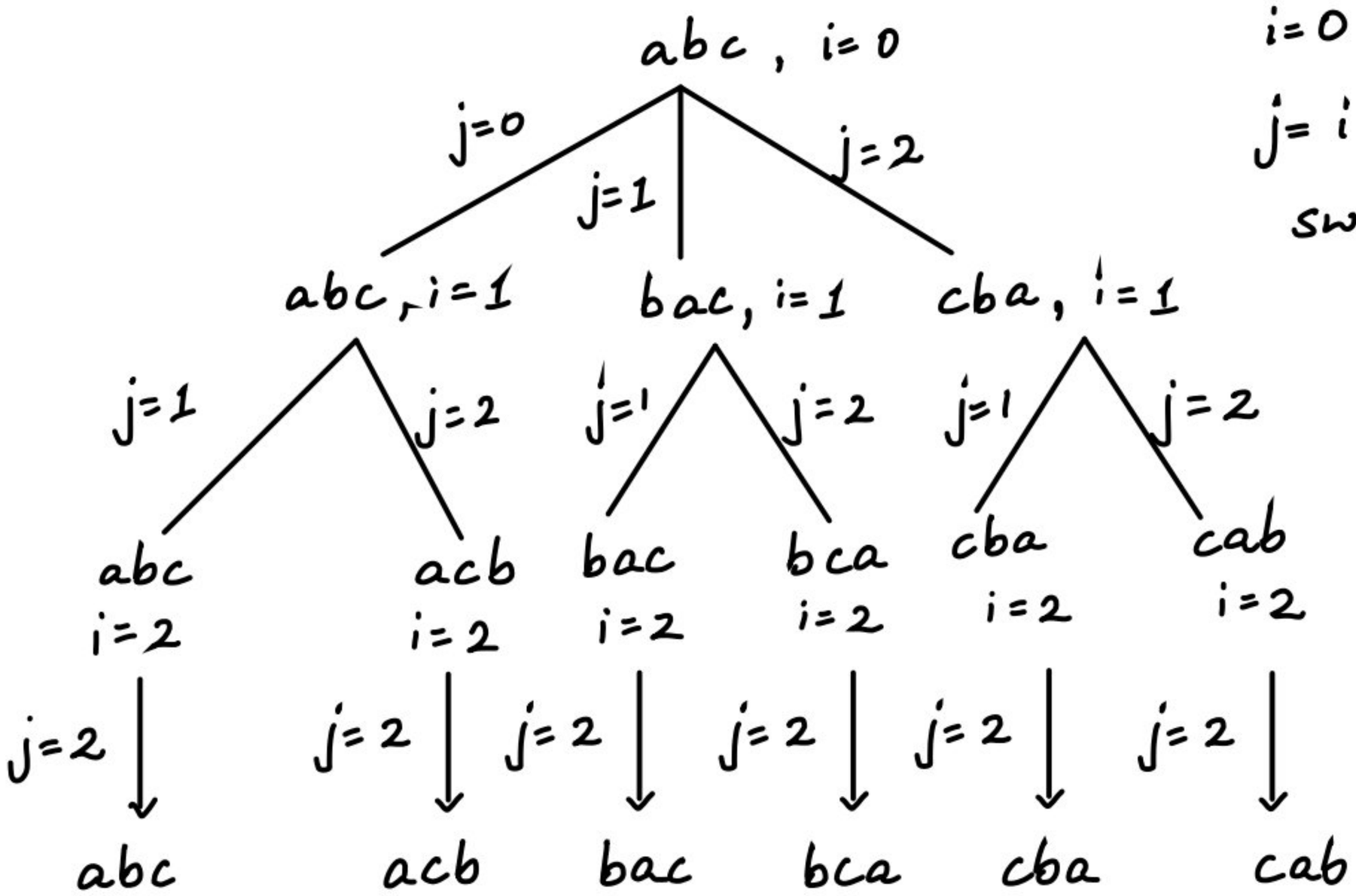
- specific form of recursion
- explore all possible solutions and
- dont check the solution you have already discard
- brute force
- used for reference variables passed in functions

## Permutation in a string

s = "abc"

permutations - abc, acb, bac, bca, cab, cba

→ total - n!




i=0 to < str.length()

j= i to < str.length()

swap (str[i], str[j])

T.C:- n!

S.C. - s.length()

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# W8-L7

## 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)
}
```

$k_1$, $k_2$ } $k$

} $k$ → pass by value: 1 variable $n$ is created

→ pass by reference: min space is constant

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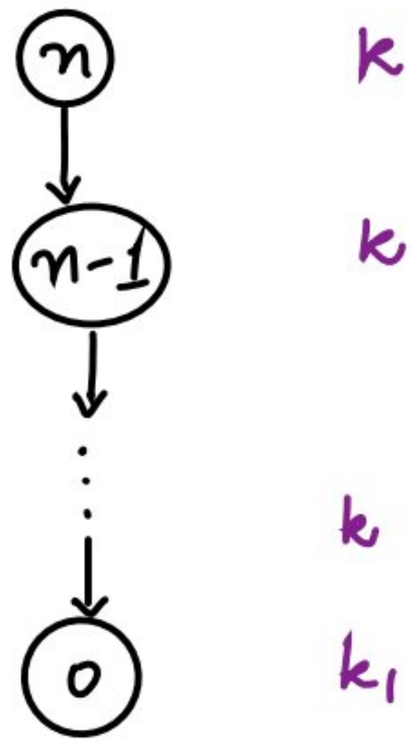
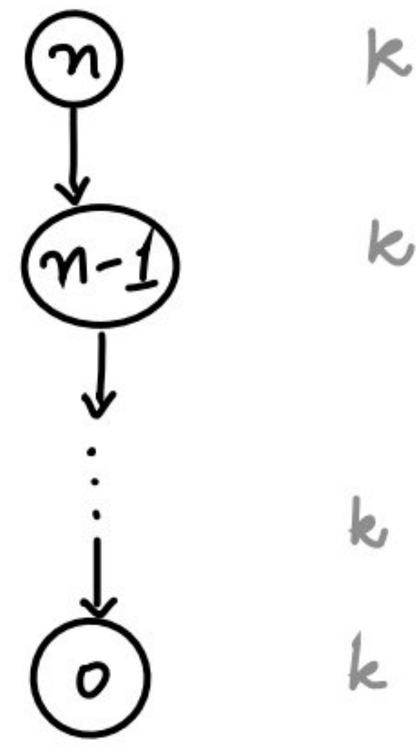



T.C. - $nk + k_1$

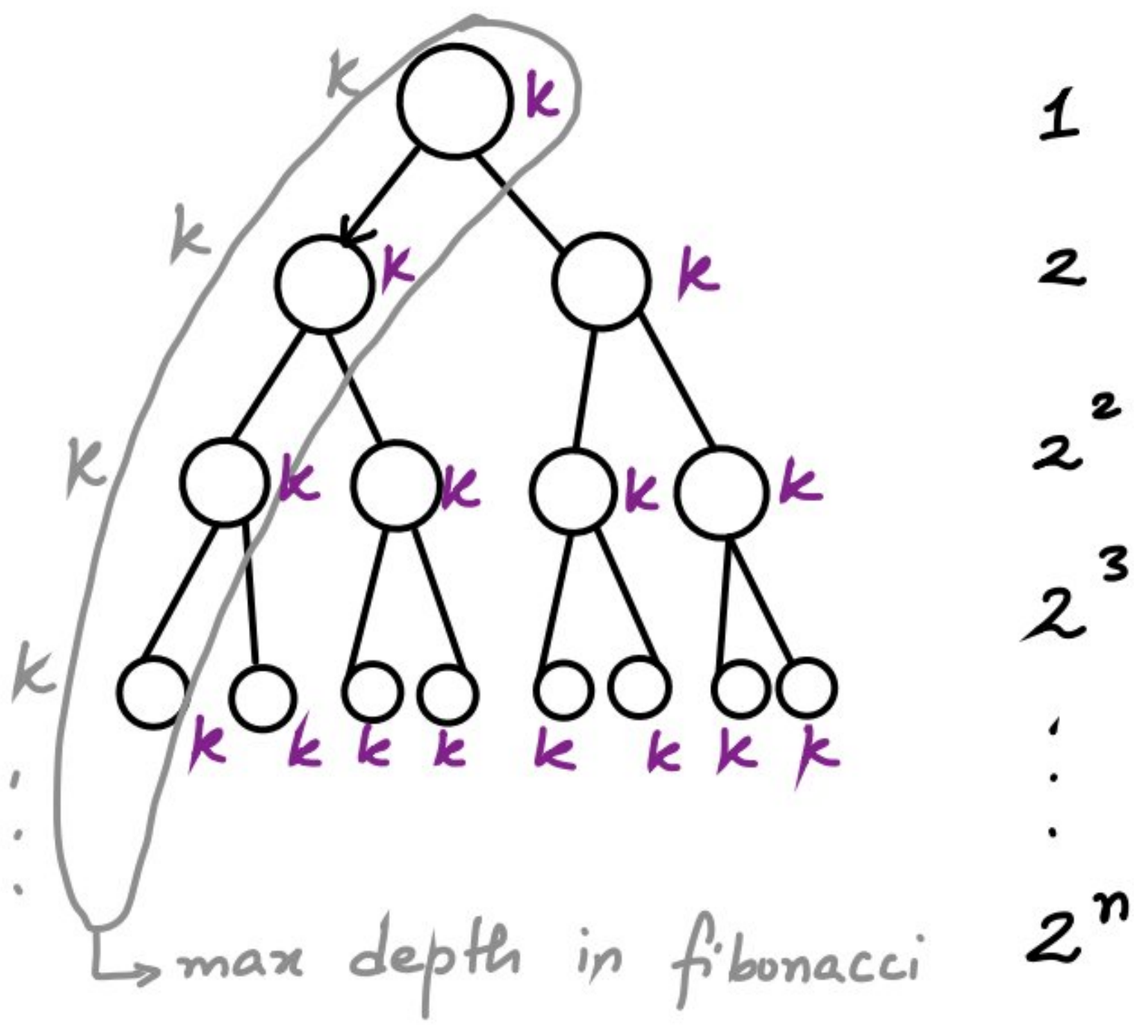
**T.C. - $O(n)$**

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

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

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

S.C. - $nk$

S.C. - $O(n)$

fibonacci

jump stairs

subsequences

## Type 3 Logarithmic

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

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

binary search

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

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

array / vector pass by reference

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

S.C. - $n \log n$

vector pass by value

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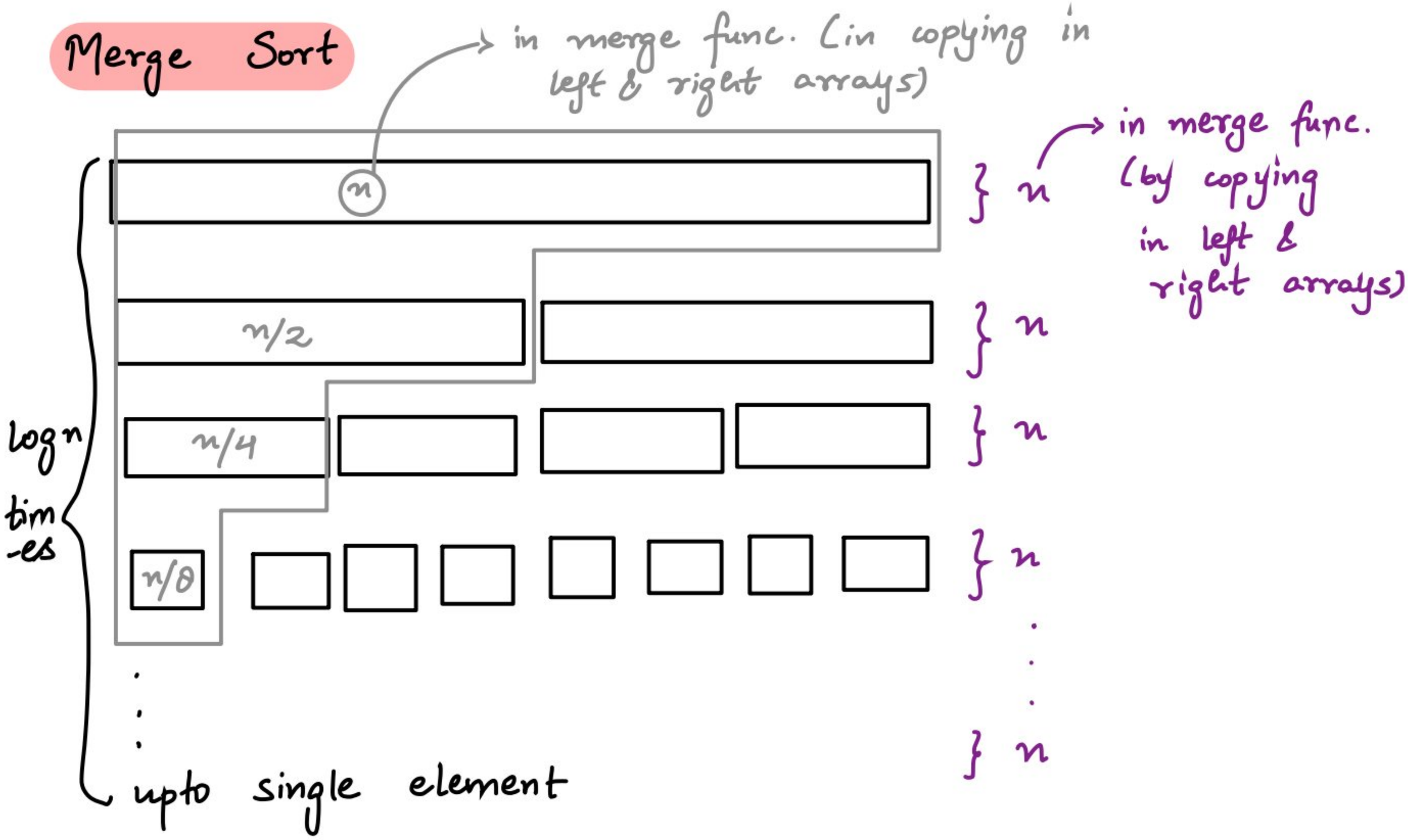
# Merge Sort




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

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

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

S.C. - $n + \frac{n}{2} + \frac{n}{4} + \cdots + 2$

S.C. - $O(n)$

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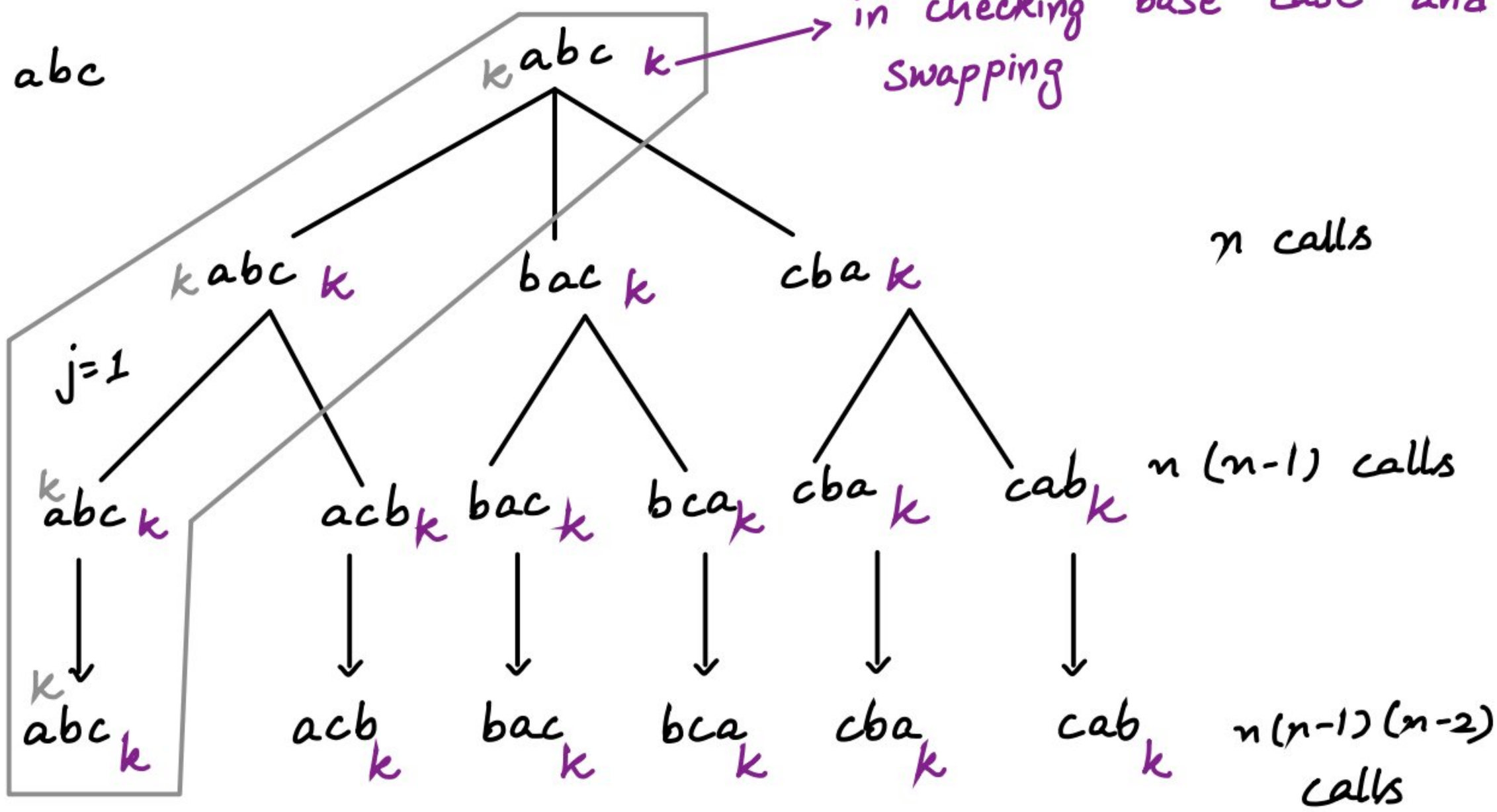
# Backtracking Questions

## Permutations of a string

$s = abc$




T.C. – $k + nk + n(n-1)k + n(n-1)(n-2)k + \cdots + n!\,k$

**T.C. – $O(n!)$**

S.C. – $n * k$

**S.C. – $O(n)$**

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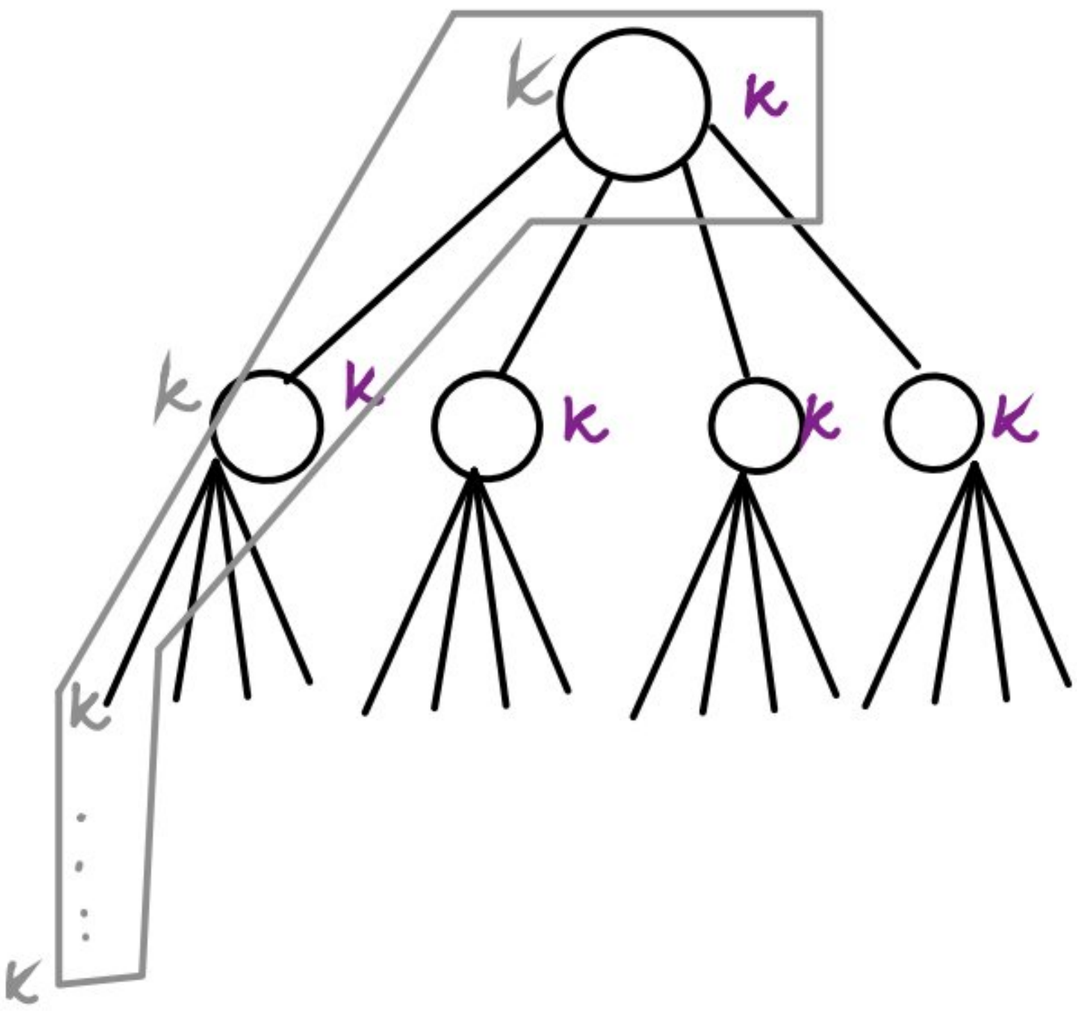
# Rat in a maze

m rows

n cols

```
func( )
    base case

    4 recursive calls
        ↳ down , left, right, up
}
```




1

4

16

⋮

m * n levels

T.C. - $k + 4k + 4^2k + \cdots + 4^nk$

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

S.C. - $k * mn + mn$

depth

of visited 2D array & pass by reference

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

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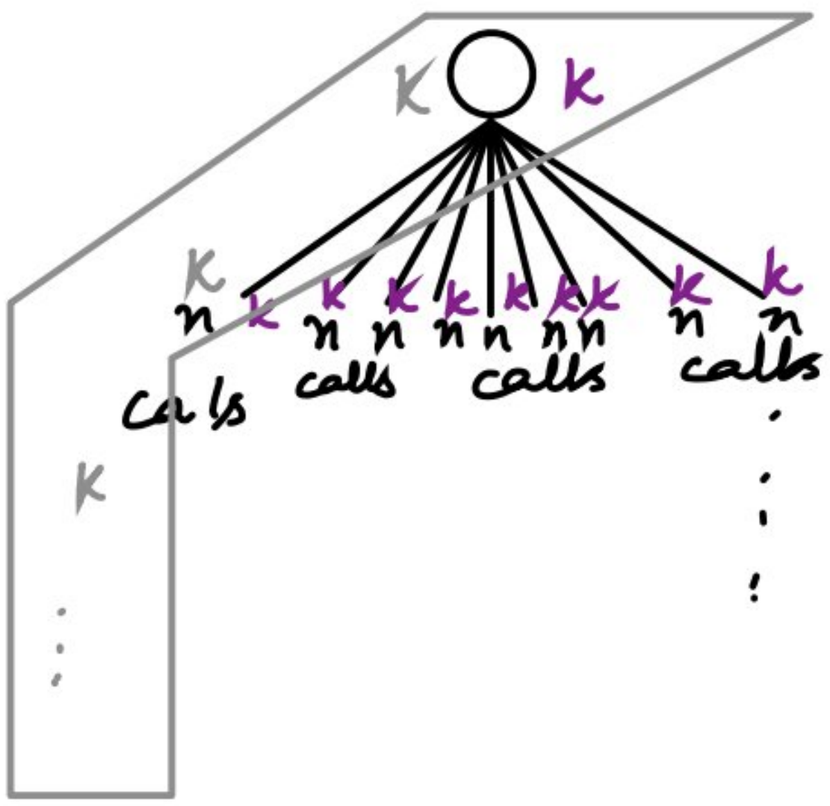
# Sudoku Solve

$n * n$ matrix

standard
↳ $n = 9$

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




$n * n$ levels
↳ number of elements in a matrix

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

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

$$S.C. - k * (n * n)$$ → depth

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

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

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# N Queens

func( )

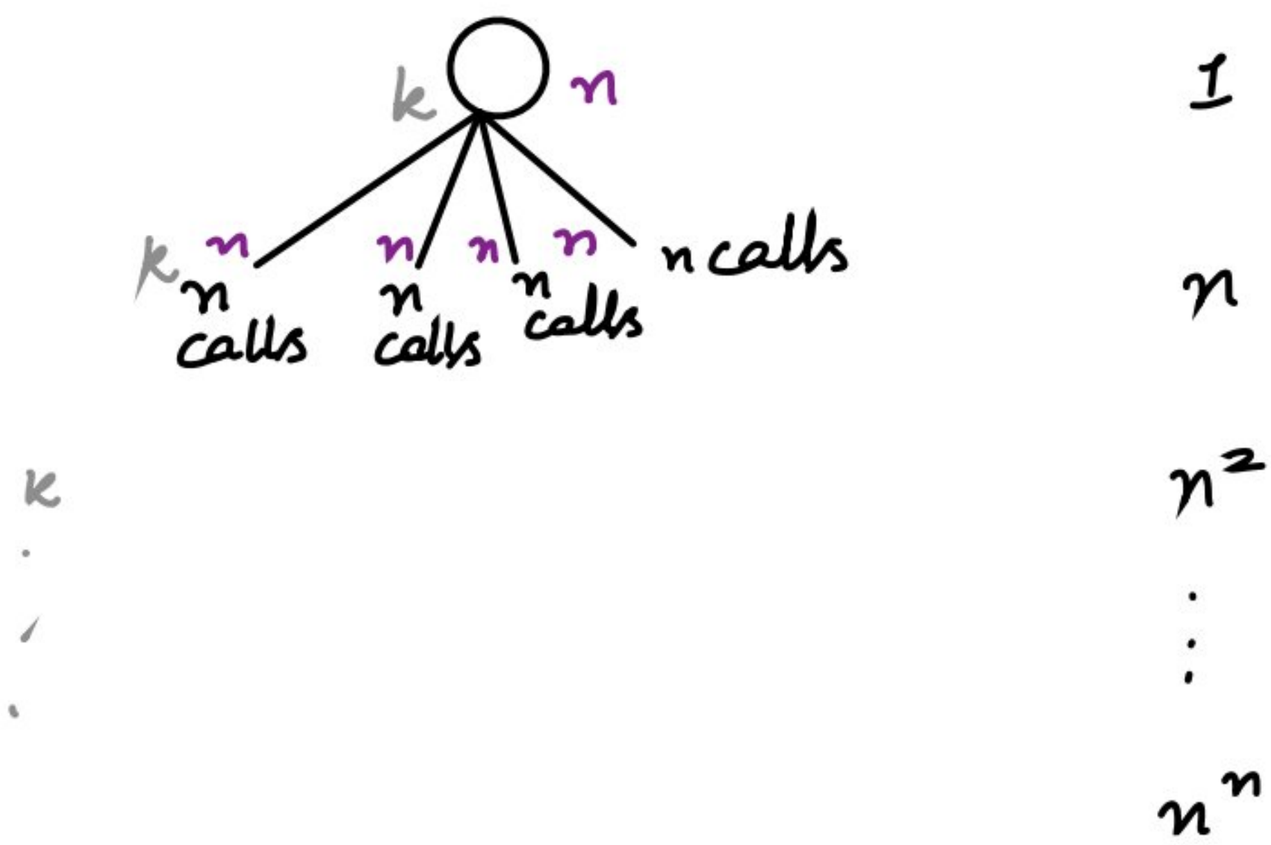
$k \begin{cases} k_1 \\ k_2 \end{cases}$

base case $\longrightarrow$ $k$

n isSafe function $\longrightarrow$ $O(n)$ $\Big\}$ $O(n)$

n recursive calls

}




T.C. - $n(1) + n(n) + n(n^2) + \cdots + n(n^n)$

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. - $k * n + n$ $\longrightarrow$ in optimized sol for creating 3 maps

S.C. - $O(n)$

- $\rightarrow$ $n * n!$ can be written as $n!$
- $\rightarrow$ $n * 2^n$ can be written as $2^n$

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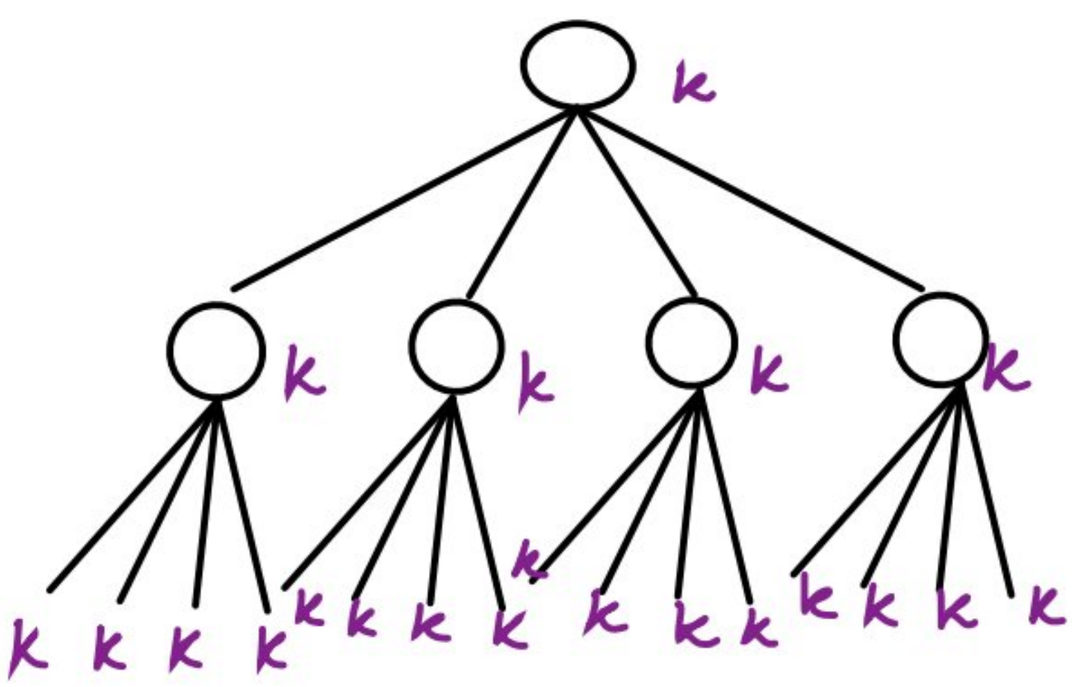
# Phone Keypad Problem

| | | |
|---|---|---|
| 1 | 2<br>abc | 3<br>def |
| 4<br>ghi | 5<<br>jkl | 6<br>mno |
| 7<br>pqrs | 8<br>tuv | 9<br>wxyz |

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




$1$

$4$

$4^2$

$\vdots$

$4^n$

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

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

S.C. - $(k + 2k + \dots + nk) + (4^n * n)$

in max depth

length of 1 output string

store output in base case

no. of strings stored in ans array

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

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# W9-L1

## OPP

- 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 mantain
  - 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

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→ 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, so min. possible memory is allocated

```
class  animal {
    int age ;
};
cout << sizeof (animal) ;
```

→ 4

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```
class    animal {
    string  name;
};
cout << sizeof (animal) ;  ---->  24
```

Why?

```
class    animal {
    int  age ;
    char  ch;
};
cout << sizeof (animal) ;  ---->  8
```

↳ 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

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## Static Object Creation

```
animal ramesh ;
```

## Accessing state and method of object

not class

```
objectName. state ;
objectName. 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 class child

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```
class animal {
    public :
    string name;
    string age;
    void sleep () {
        cout << name;
    }
    private :
    void eat () {
    }
};
```

→ after marking, all below state / behaviour will be of that type

To access private member outside class

↳ use public methods getter and setter

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

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

int main(){
    animal ramesh;
    cout << ramesh.name; ———> ERROR
    cout << ramesh.getName(); ———> gv
    ramesh.setName("Lion");
    cout << ramesh.getName(); ———> Lion
```

## Dynamic Memory Allocation

2 types of memory

- stack
  - small
  - static memory allocation
- heap
  - large
  - dynamic memory allocation
  - new keyword
    - allocate memory in heap and returns it memory location address

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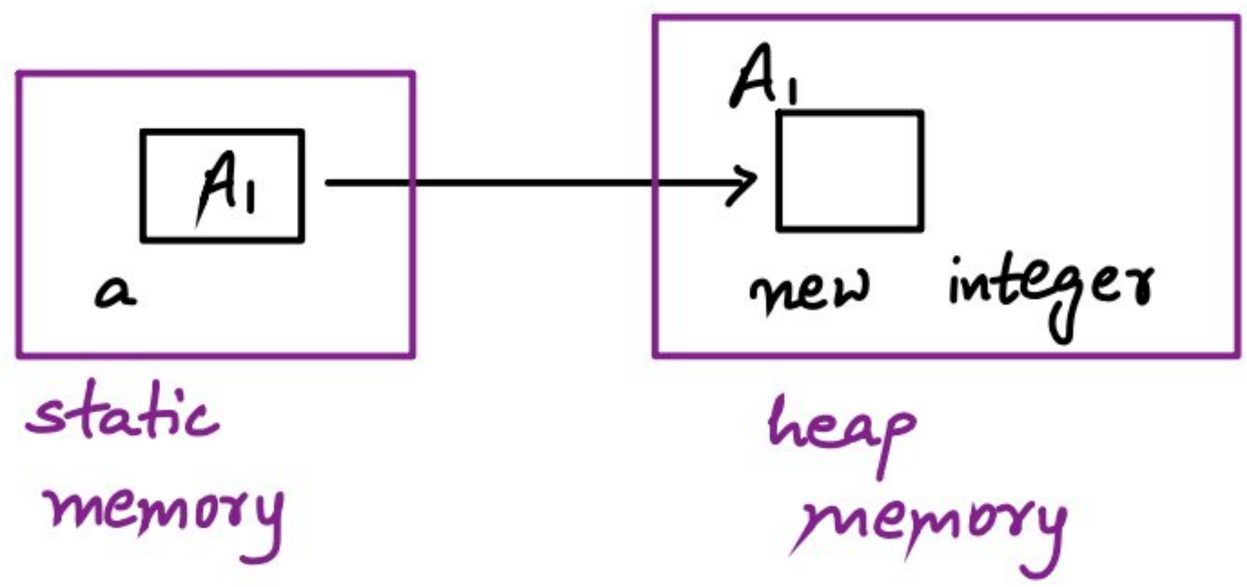
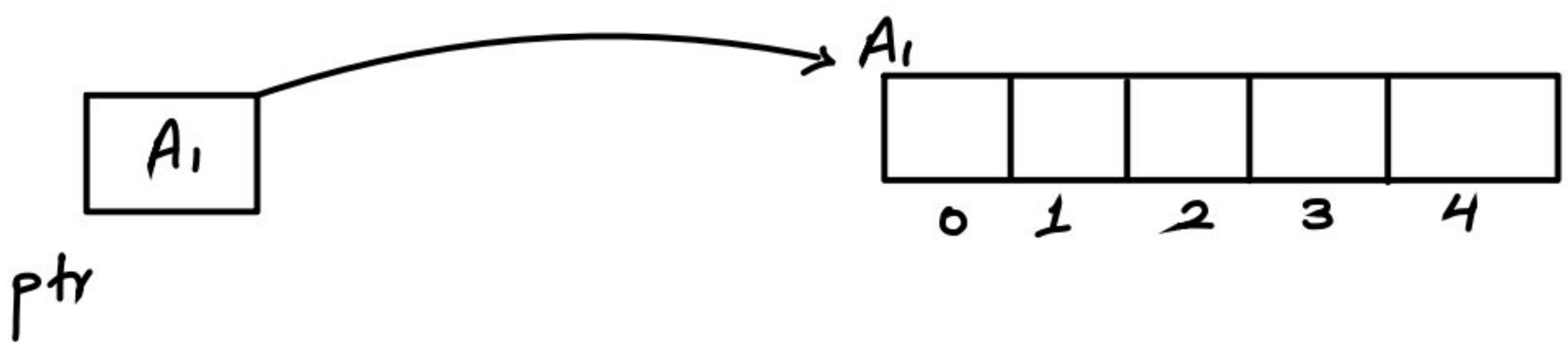
```
int a = 5;
```

```
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];
```

Deallocation

```
delete a;

delete arr [];
```

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## Object Creation using dynamic memory allocation

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

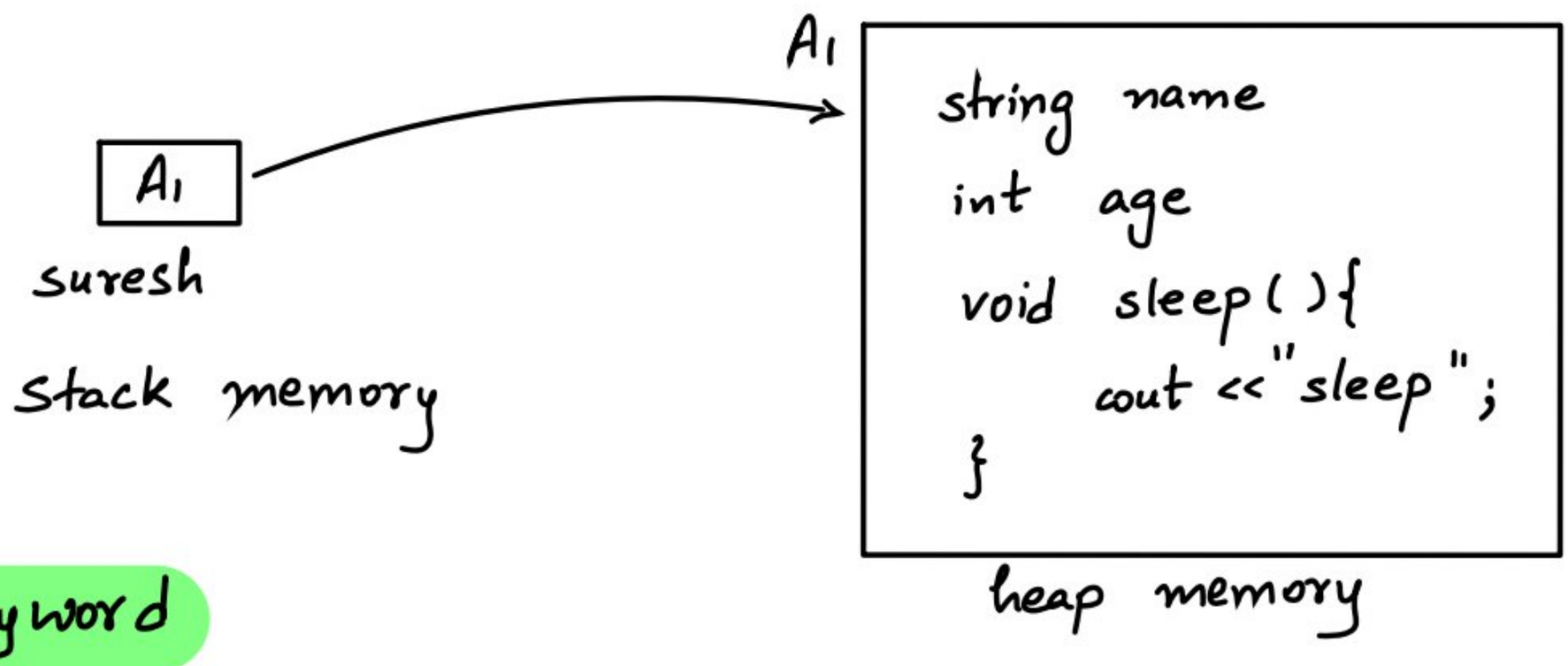
suresh. name; ⟶ ERROR as suresh is a pointer, * suresh is object

```
(*suresh). name;
(*suresh). sleep();
```

} 1st way of access

```
suresh → name;
suresh → sleep();
```

} 2nd way of access




## this keyword

↳ pointer to current object

```
class animal {
    int age;
    public:
    void setAge (int age){
        this → age = age;
        // (*this). age = age;
    }
};
```

} both are correct

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# 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";
    }
```

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```
// 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";
}

// copy constructor (right 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

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## 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 ";
    }
}
```

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# W9-L2

## 4 Pillers of OOPs

- Encapsulation
- Inheritence
- Polymorphism
- Abstraction (Pitaji of all OOPs pillers)

## 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

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# Inheritence

- inherit some properties ( data members and data functions) from parent / super / base class to sub / child / derived class
- Objective → Reusability
- is a relationship
- syntax

  childName is a parentName

```
class childName : mode1 parentName1,
        ..., mode N parentName N {
    //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 {

}
```

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| Access Modifier of Base class | Mode of inheritence | | |
|---|---|---|---|
| | Public | Protected | Private |
| Public | Public | Protected | Private |
| Protected | Protected | Protected | Private |
| Private | NA | NA | NA |

NA → Not Accessible
↳ cant 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

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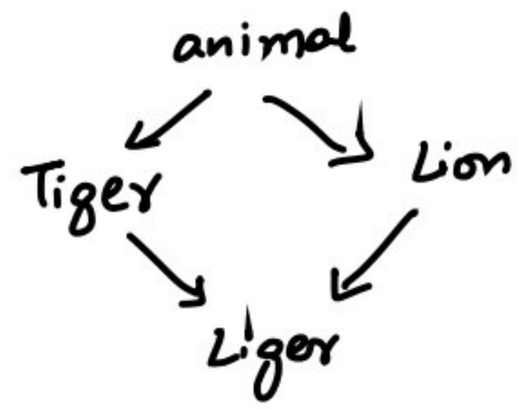
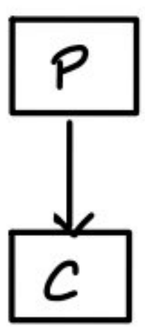
P- Parent C- Child

## Type of Inheritence

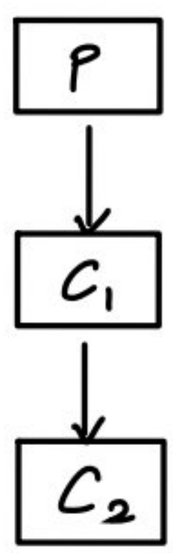
- Single
- Multilevel
- Multiple
- Heirarchical
- Hybrid → mixture of all above 4



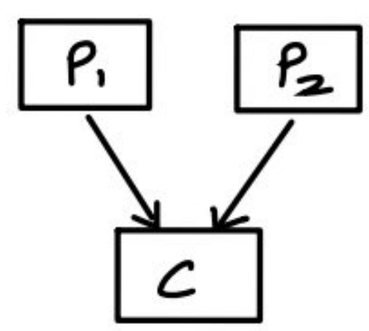

Single



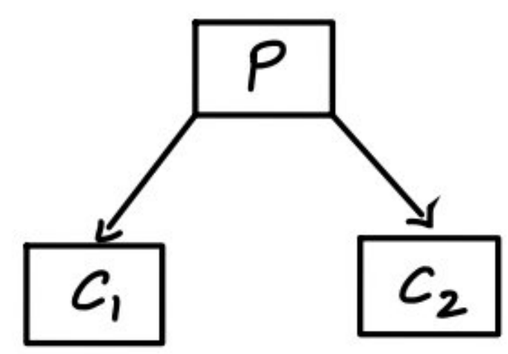

Multilevel




Multiple




Heirarchical

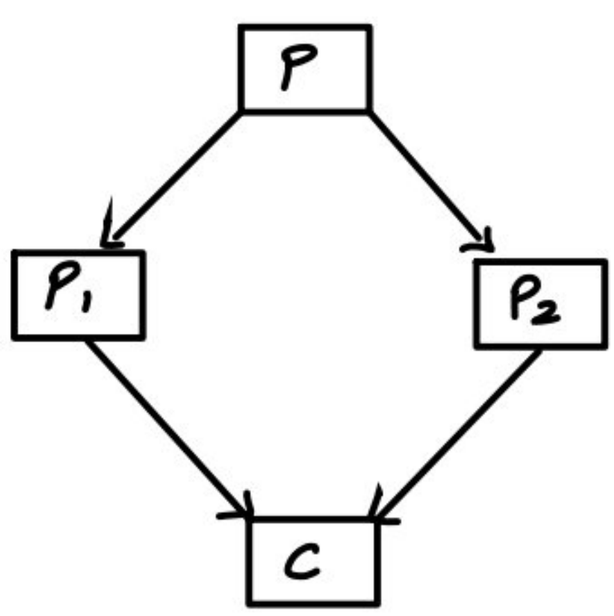



## Diamond Problem / Inheritence Ambiguity Problem

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

→ objectName . ParentClassName :: property ;

scope resolution operator

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→ If parent and child have same property, then parent property inside child class will get overwrite by child property

→ Multiple inheritence is possible in C++, not in Java

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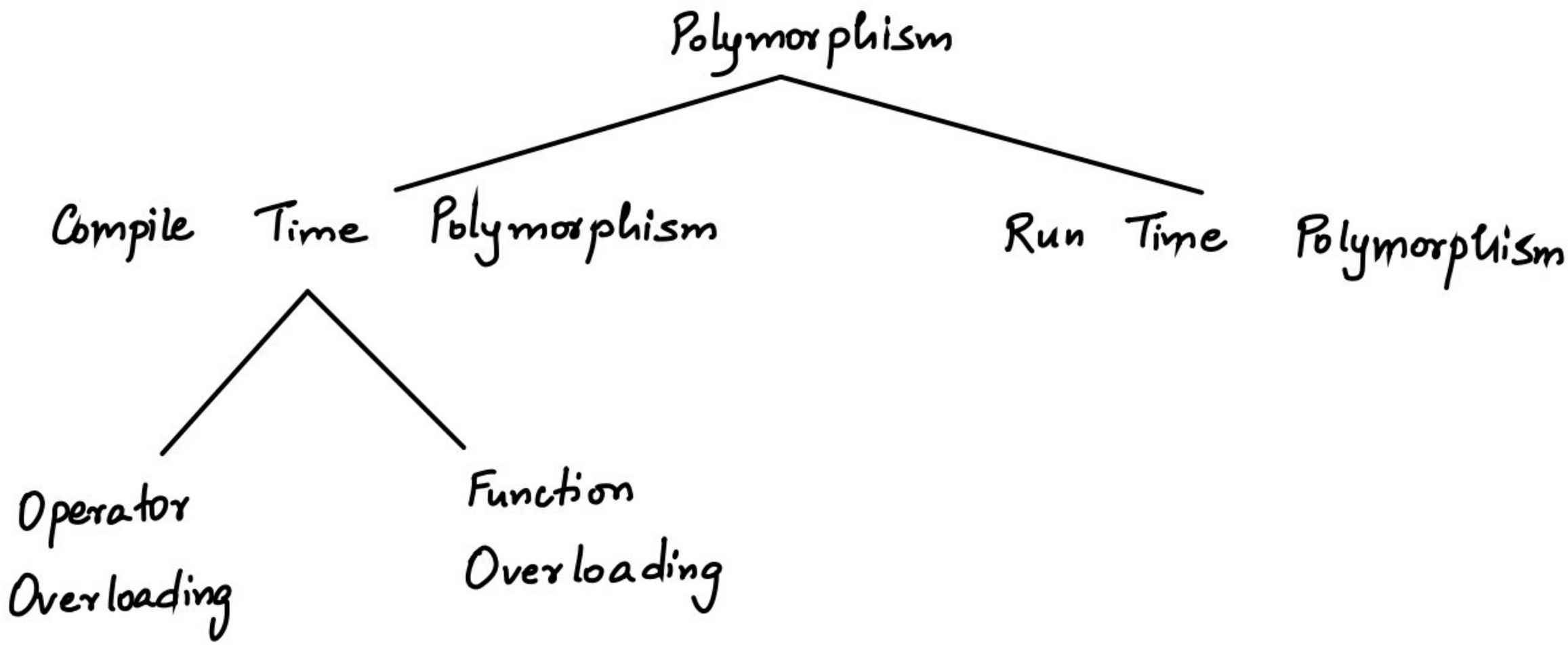
## Polymorphism

- form
- existed in many forms




## Function Overloading

- one function existing in multiple forms / signatures

→ Multiple Signatures

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

→ 5.12 ⟶ double

5.12f ⟶ float

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```
class Maths {
    public:
    int sum (int a, int b){
        return a+b;
    }
    float sum ( int a, double ){
        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;
}
```

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## Operator Overloading -

→ to make new implementation of an operator

object 1 op variable 2

- → same as
  object 1. op ( variable2 );
- → object 1 → current object
- → op → method
- → variable 2 → input parameter

```
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;
    }
};
```

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```
int main (){
    Para a(5);
    Para b(2);
    cout << a + b;
    a+ 'c';
    a+ '7';
    return 0;
}
```

cout << a + b; → same as a.+(b) → 3

a+ 'c'; → 15

a+ '7'; → 15

→ "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 -

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## Function / Method Over-riding

- when function of parent class is defined seperately 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:
```

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// 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

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Abstraction

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

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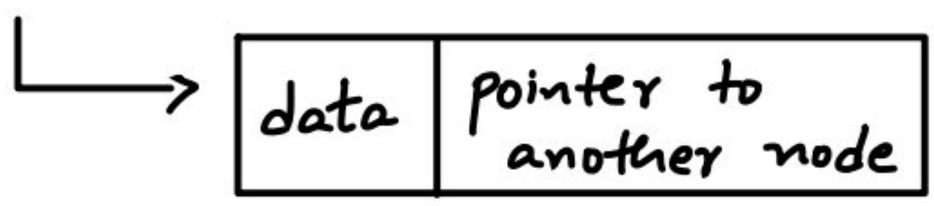
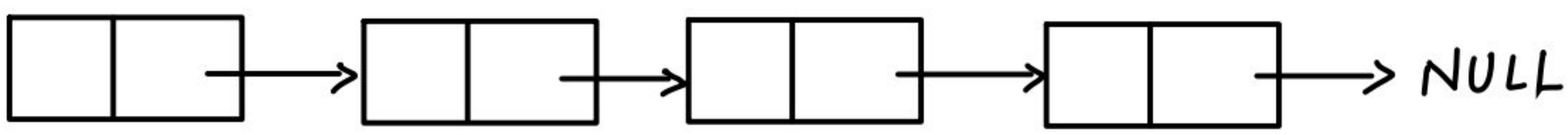
# LINKED LIST

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;
}
```

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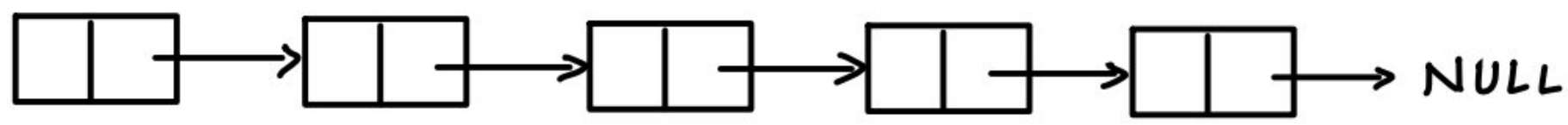
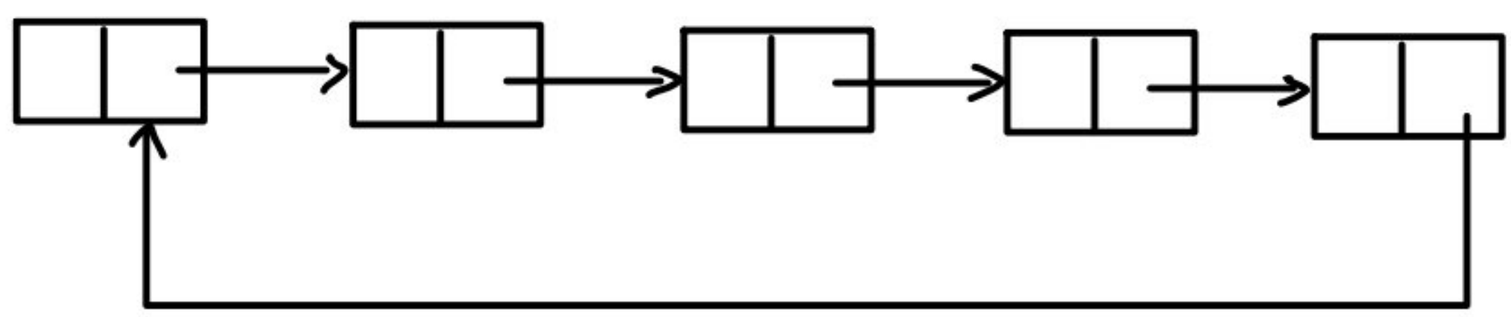
# Types of linked list

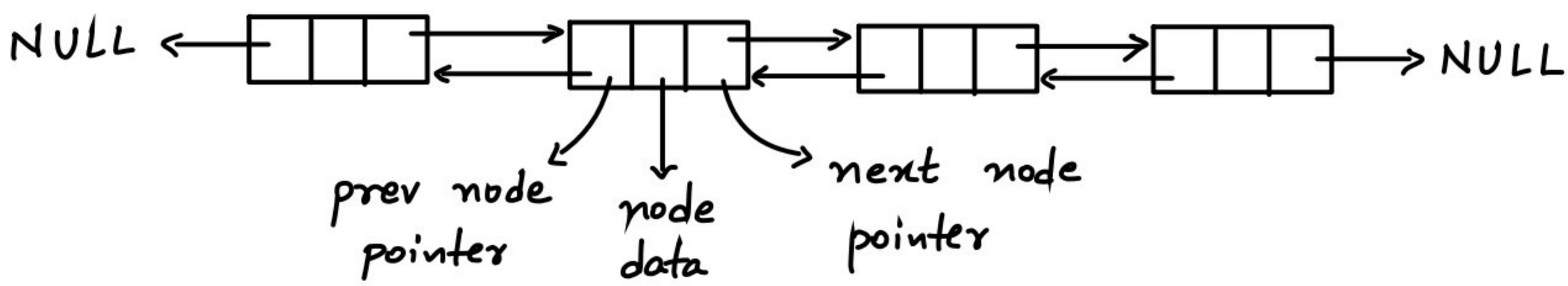
- Singly LL



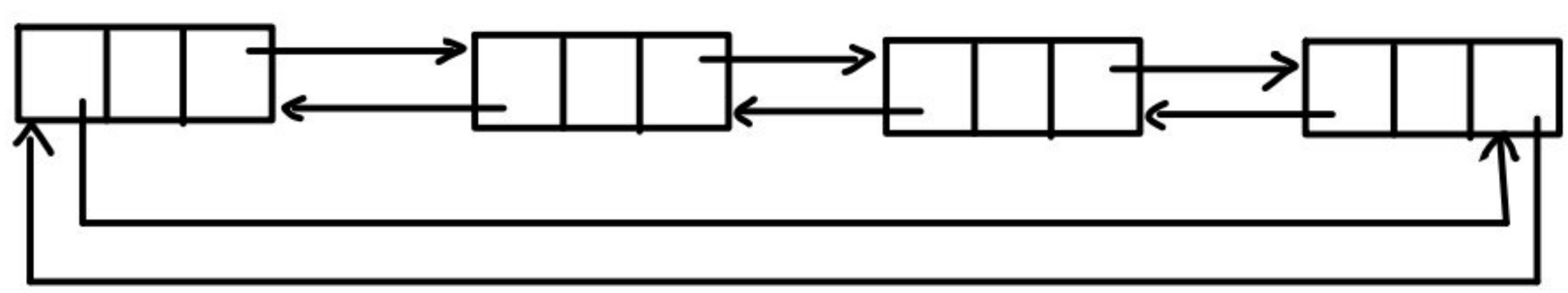

- Circular LL



- Doubly LL




- Circular Doubly LL



- LL is nothing but Hindi (any other language)
- Linear Data Structure
  - single descendent

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→ 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

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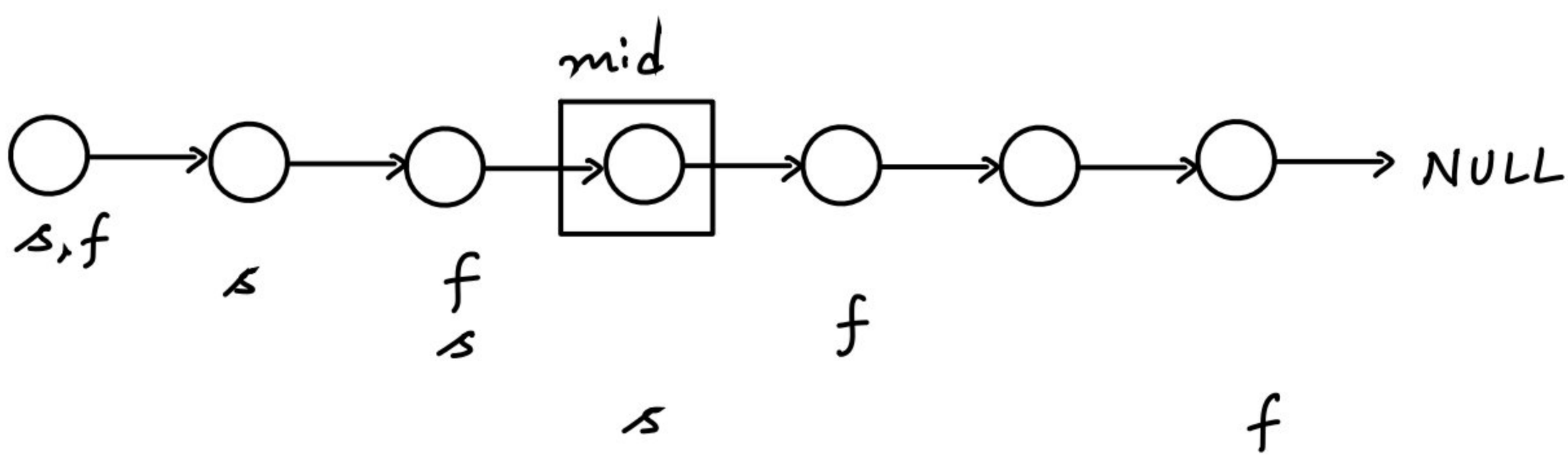
# Tortoise Algorithm

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;
}
```

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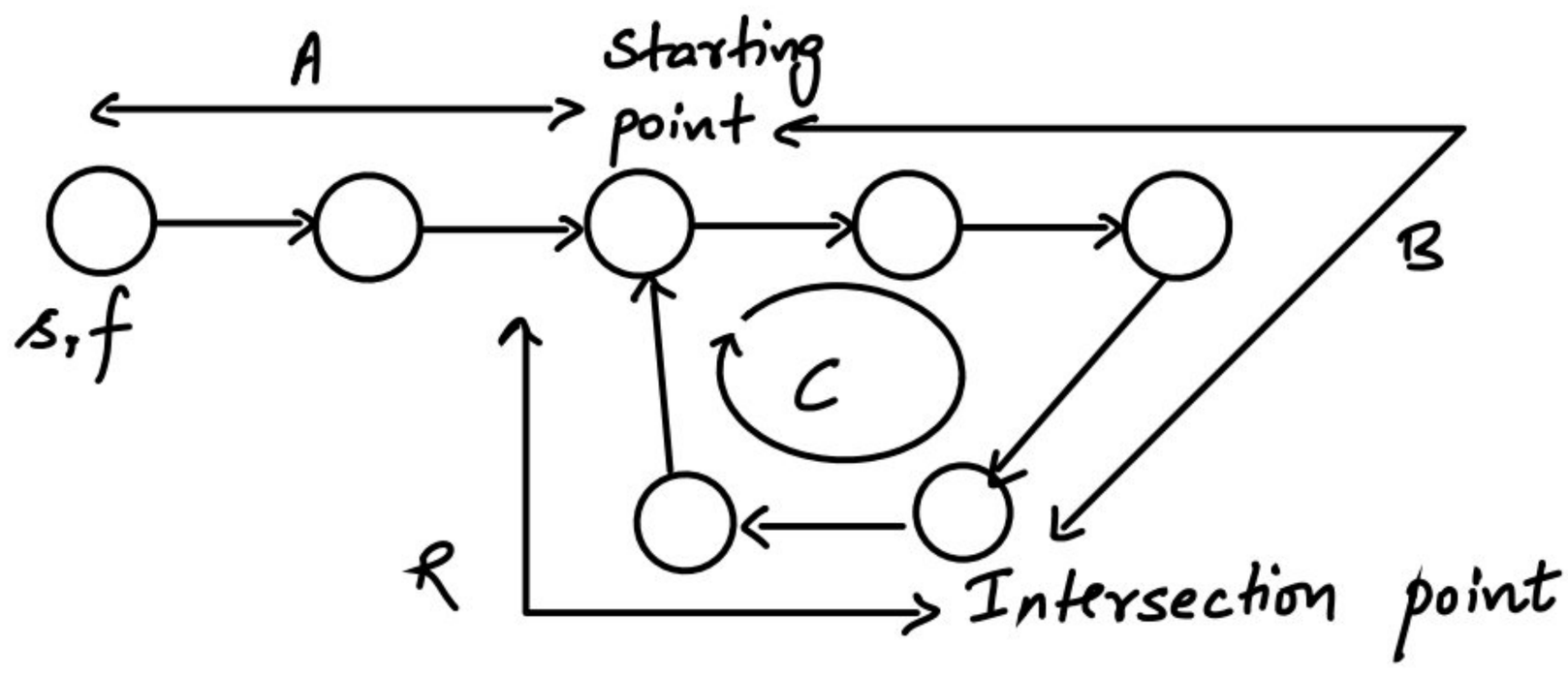
# Floyd's Cyclic Detection Algorithm

- → 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




distance (f) = 2* 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

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So intersection point + A ⇒ reach starting point

Also head + A ⇒ reach starting point

$R + z C = A$

```cpp
// also works if loop starts from head
void removeLoop(node* &head){
    if(head==NULL)
        return;

    node* fast = head;
    node* slow = head;
    bool loopFound = false;

    while(fast!=NULL){
        fast = fast->next;
        if(fast != NULL){
            fast = fast->next;
            slow = slow->next;
        }

        if(fast==slow){
            loopFound = true;
            break;
        }
    }

    if(loopFound){
        slow = head;
        while(fast!=slow){
            fast = fast->next;
            slow = slow->next;
        }

        cout << "loop started from " << slow->data << '\n';
        node*prev = slow;
        while(prev->next!=slow){
            prev = prev->next;
        }
        prev->next = NULL;

    }
    else{
        cout << "no loop was present\n";
    }
}
```

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# 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 use if we are sure that stack is non empty

## empty or not

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

## size

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

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→ 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 implement 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

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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 -

W11-L3

```
pair <int , char > p ;                 } initialize
p = make_pair( 27, 'x' );
p. first = 27;   p. second = 'x';      } insert
p = {27, 'x'};
```

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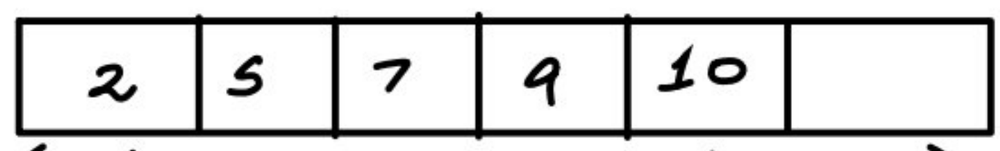
# QUEUE

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

rear always shows empty block

**creation**

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

**insertion -**

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

**deletion -**

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

**front element**

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

**back element**

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

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**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.

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## sliding window

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

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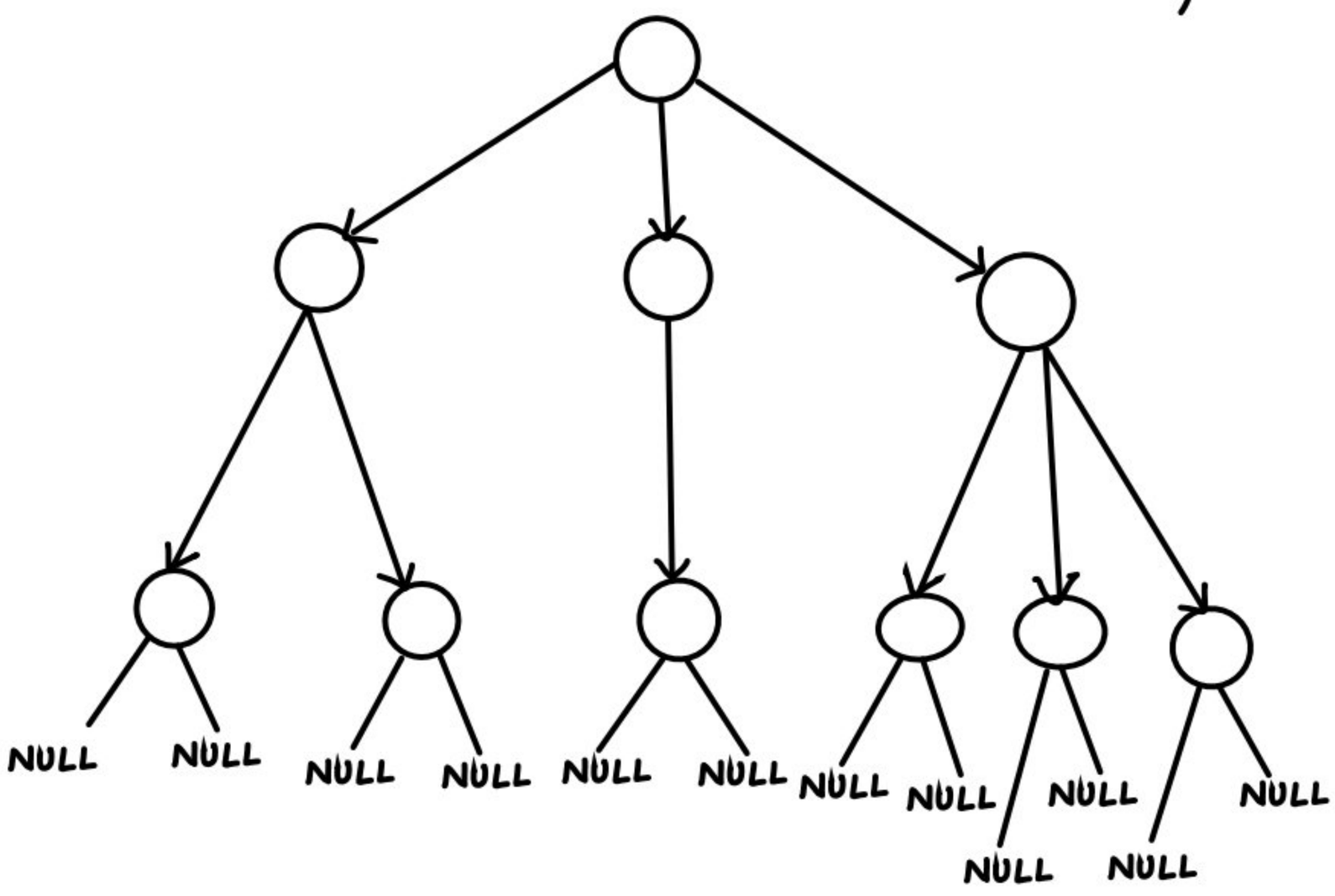
# TREE

W13-L1

→ non linear data structure in which data is stored in heirarchical 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

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## node

→ smallest unit of tree

**for binary tree**

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

**for n-ary 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

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**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** → no. of $\overbrace{\text{nodes/edges}}^{\text{acc. to ques}}$ 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

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→ trees questions

- → online assessment
  - → mcq → simple or formula based (total no of nodes/edges)
  - → coding
- → interview
  - → mostly classical ques and sometimes hard ques using multiple data structures

→ tree is aasaan if you know recursion

Tree traversal algorithms

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

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

→ there is no official algo to create tree from data

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## skew tree

→ tree in which each node has only left child

or

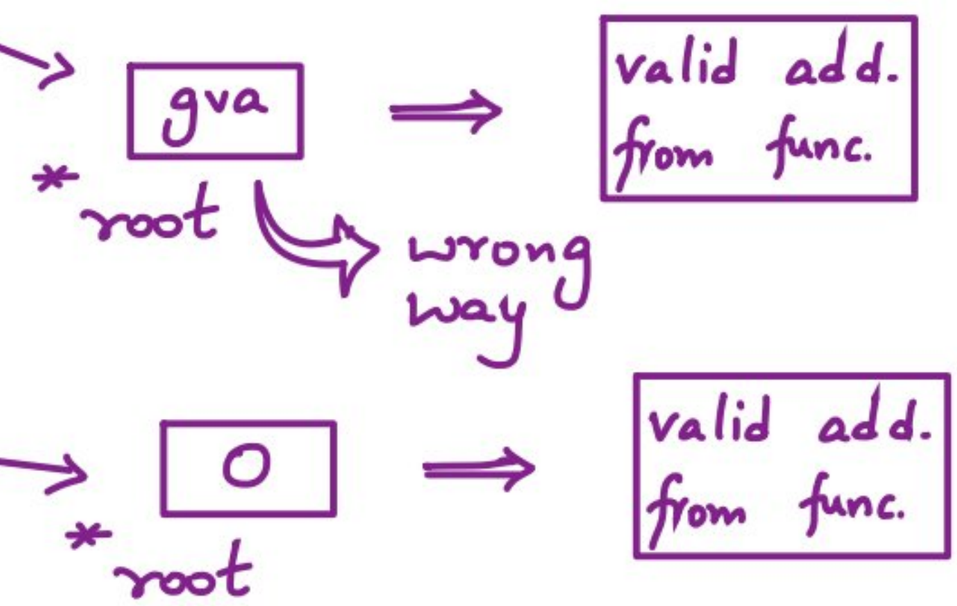
tree in which each node has only right child

→ int main ( ){

```
// wrong way
node * root = func();

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

```
node * func ( ){
    return node;
}
```




→ 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

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# W13-L2

## Balanced Binary Tree

→ at every node the absolute diff. between heights of left and right subtree must be $\leq 1$

## 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

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→ if you dont find logic to solve tree question, just start running recursion in examples and you fill 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 (CLR)

→ build tree from inorder and postorder (LRC)

→ right recursion call before
left recursion call

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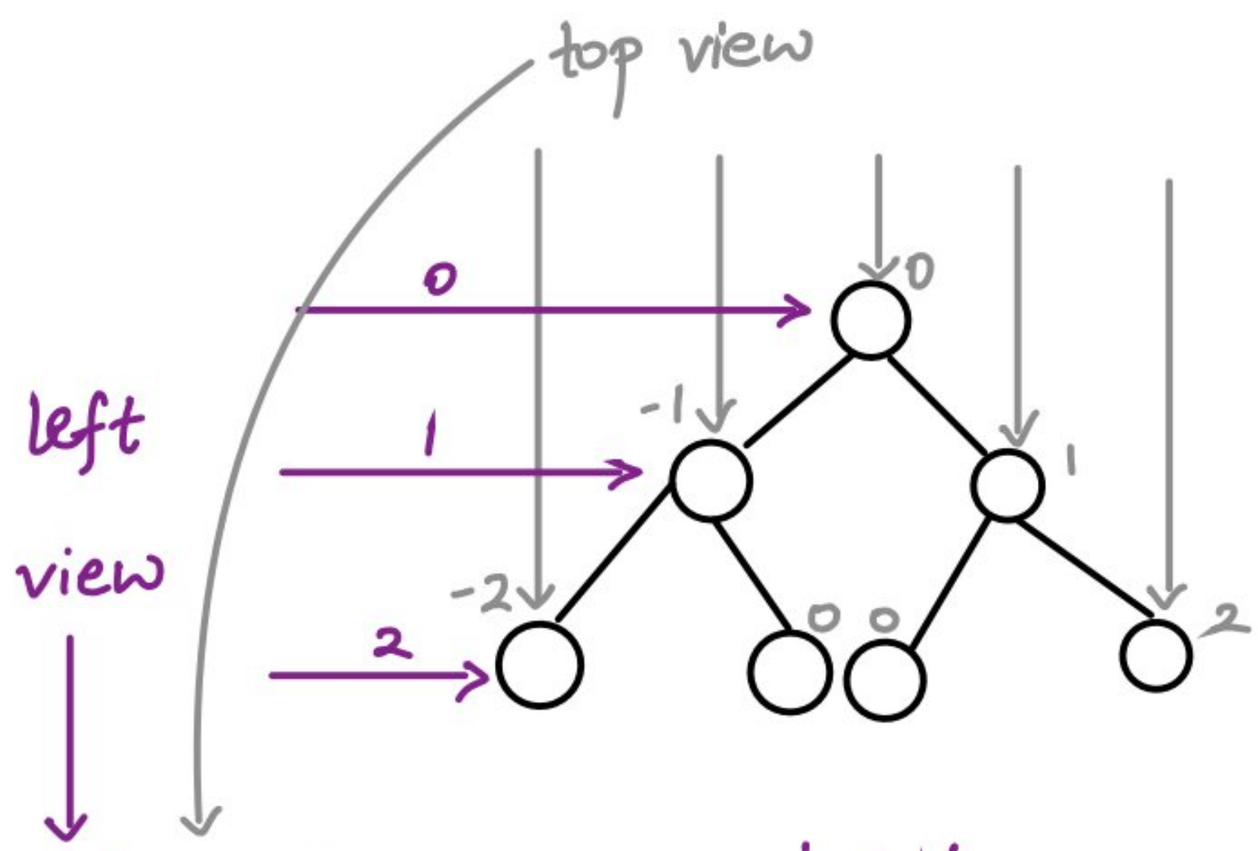
→ In ques. where we find views (like top / left / bottom / right view of the tree)

**W13-L5**

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

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# 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

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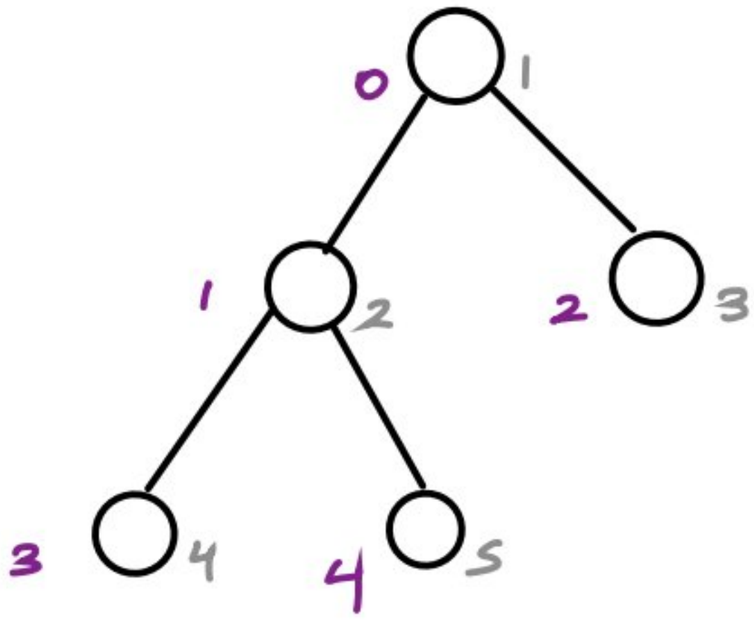
# HEAPS

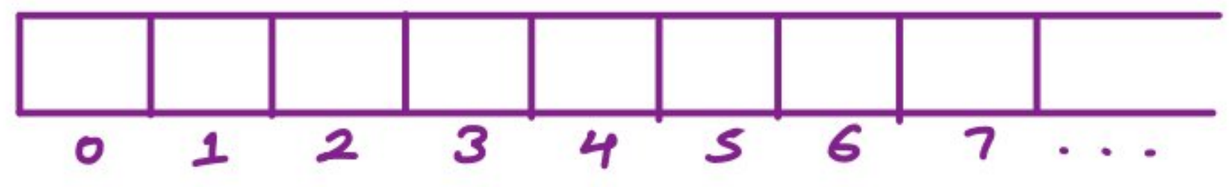
W15-L1

→ 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 - $i/2$

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→ 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)

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## 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 $\left(\frac{n}{2}+1\right)^{th}$ 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

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## 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. - $O(n \log n)$

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# DYNAMIC PROGRAMMING

W17-L1

- technique used to optimize sol.
- key point
  - those who forget the past are condemned to repeat it

    ⇓

    dont 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

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## 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;

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## 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.
  - iteratively → 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

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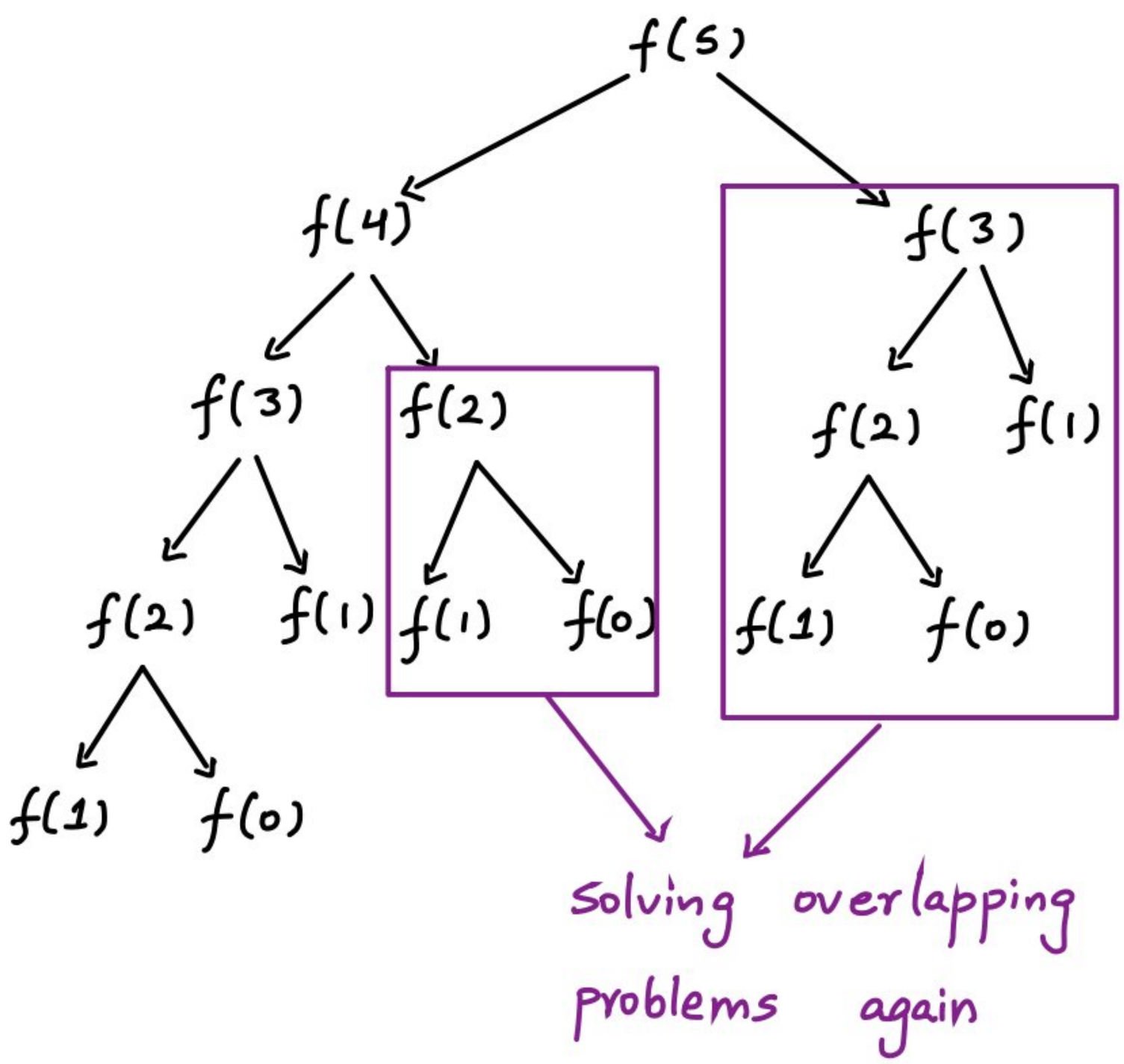
## Space Optimization Sol.

- 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




DP can be used

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. - $O(1)$

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factorial

$f(4)$
↓
$f(3)$
↓
$f(2)$
↓
$f(1)$
↓
$f(0)$

no overlapping problems

only have optimal substructure

DP cannot be used

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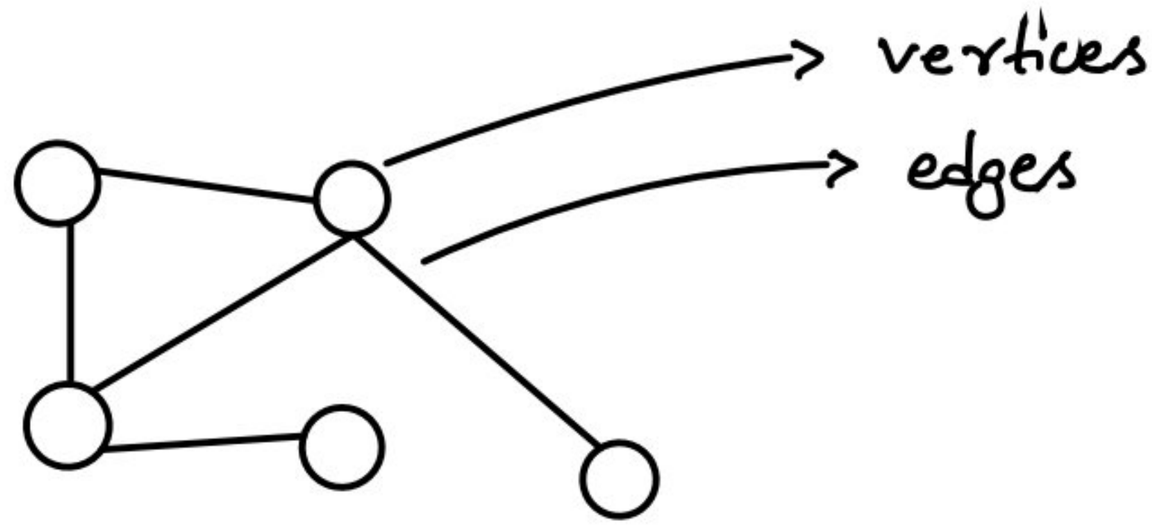
# GRAPHS

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



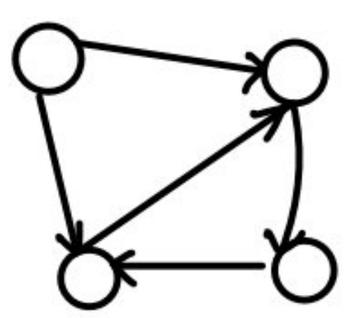

→ use case

→ google map, facebook

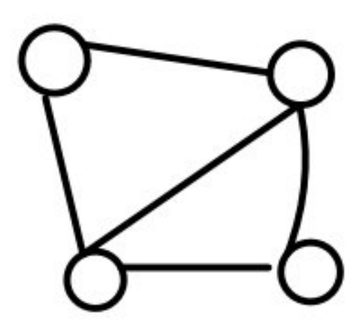
## Types of graphs

→ Directed Graph

→ Undirected Graph



Directed



Undirected

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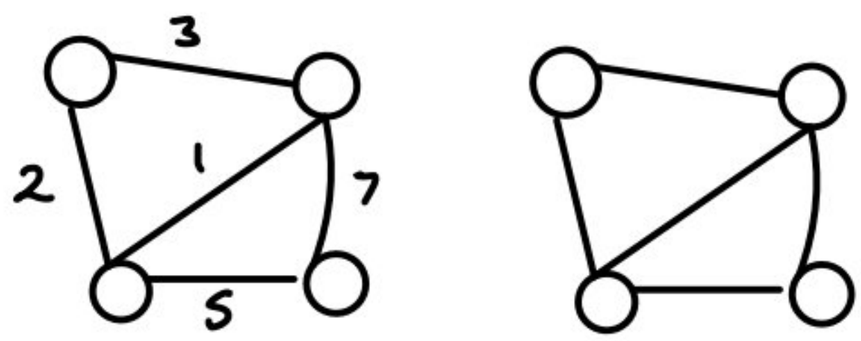
→ Weighted Graph




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
  - → indegree
    - → 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

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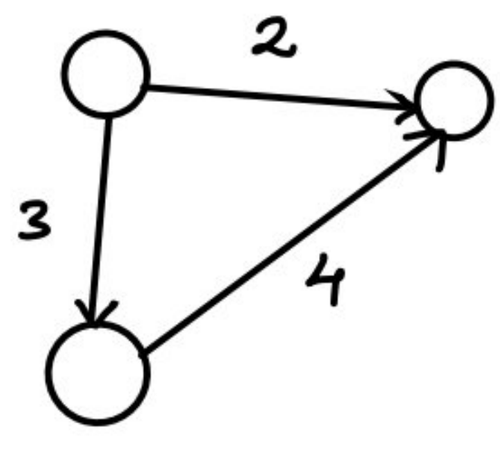
## Cyclic Graph

- → 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

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