Object - Oriented Programming (CS2000)

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LTPC : 2 0 4 4
↓
Tue (10 am)
Thurs (11 am)

OOP → C++ (85%)
OOP → Java (15%)

1 midsem (for theory & lab)

1 endsem (for theory & lab)

Theory-cum-practical course

better to do : a course project (do it as a 4-5 member team)
↓
build an app/software using C++/Java & OOPs concepts.

refer to Deitel & Deitel for first level intro to C-programming. Then go to Dennis Ritchie.

↳ 10th edition has OOPs. "How to program in C"
↓
start reading on your own.

C++ will be covered.

syntax - rules to implement logic.
semantics - logic/solution

C → structured programming paradigm. (imperative style)
main → user-defined function.

- programmers forced to think wrt functions.
- operations are behaviours. behaviours aren't unique. identity is.
  entities irl → attributes + behaviours (data)
- assigning meaning to data → information.

DATA ——comp. sci——→ INFORMATION

C → gives priority to functions rather than data.
C++ → OOP paradigm. more importance to data over functions.

Prog. Paradigms

① structure - Imperative ; action / function oriented.
like in C, users think in terms of functions.

entities → attributes → data.
entities → behaviour → functions

IRL, attributes / data resonate more.
↓
hence, the programming paradigms shift more

towards Objects / data ⟶ object oriented.
(we still use functions)

OOPs - Overpractices

1. data encapsulation
2. data abstraction.
3. polymorphism
4. Operating overloading.
5. Inheritance.
6. Templates

{data + fn} → OOPs.

main fn. ⟶ Also called as Test / Boss Driver Routine.
↳ fns. I develop can only be tested iff they are called in main.

fn
- declaration - return type, arguments & fn. name
- definition - what does it do with the args. to return something.

fn (int a, int b) ; fn (x, y)

formal param. actual param.

OOP ⟶ steps in for data security.
↳ enforce permissions for functions to operate ONLY on certain type of data.
e.g. ⟶ only faculties can access students' data.
↳ data encapsulation is done - cover both data & functions in one place (classes?)

C++ and not ++C ⟶ can run 'C' code also

x++ → assignment, then increment.

(incremented features will work along with older version – "C")

C → building blocks of C++.

in C → we use structures for defining user-specific data types.

Can we have fns. in structures? wouldn't this encapsulate attr. & behaviours?

Not directly, but can use fn. pointers.

interface vs implementation

#include <____> ⟶ system defined header files.

#include "____" ⟶ user defined header files

interface | $ cd /usr/include → and ls to see the content.

header files only have fn. declaration (not defn.)

↳ header files help users focus only on interface. (unwanted info/ data filtered).

example → do rational no. operations.

→ create "rational.h"

→ declare functions here like ratadd, ratsubt, etc----

→ define functions like ratadd (struct rat a,

struct rat b);

in files like <function>.c

→ compile these files with:

gcc -c ratadd.c.

(or) do

gcc main.c ratadd.c ratmult.c

and so on...

Larger Idea → separate interface from implementation.
(header, fn. files, main file)

OOP ≡ group data & behaviour — into classes - whose instances are objects.

Class - named software repn. for abstraction

⇓

abstraction - named collection of data & behaviour relevant to modelling something for some purpose.

⇓

Object - distinct instance of a class - structurally identical to other instances of the class.

⇓

code to → define classes, instantiate objects & manipulate objects.

SRS → Software / System Required Specifications

↳ Spelling out requirements from a software.

↳ An english Text (like us giving to ChatGPT LOL)

↳ nouns ≡ data → CLASSES

Verbs ≡ functions.

```
class faculty
{
   char name[100];
   int fac_id;
   void coursestaught();
   void init();
}
```

→ probably an Andhra faculty - Sir, 11:35 AM, 20th Aug.

→ DATA ENCAPSULATION.

DON'T define fns. in the class → keep it secretive
↳ ಯಾವಾಗಲೂ ಕ್ಲಾಸಿನಲ್ಲಿ ಮೆಥಡ್‌ಗಳನ್ನು ಇಡಬೇಡ

once the class is defined, u needn't tell "class" again while declaring an object, unlike structs. just say: Faculty f;

size of object = size of {data + fn.}

Classes → data members
Classes → member functions. (methods in Java)

member access specifiers → Private / Public.

DATA Encapsulation

(Linux, e.g.) Free-end Open Source Software (FOSS)

Access Specifiers

* Private * Protected * Public

(open access)

Linux : built on UNIX, by Linus.
development → best in Linux as its Open source

LaTeX → used to type formal scientific / engineering documents.
↳ FOSS, again. (Donald E Guth ?)

Windows (Ctrl+C Ctrl+V)'d Task Manager from Linux's Ctrl+Alt+Del. LOL.

Access specifiers → tell which data can be accessed by which fn. and so on...

output : { cout << " iiitdm \n " << endl;
cout << data;

OO. way of outputting.

cout → object of class ostream
cin → object of class istream
in <iostream.h>

\n → positions the cursor to the home of next line.

\r → " " " " " " " current line. → in Linux, if we do \r & type more, chars will be overwritten.

cout << a << b << c;
↳ stream direction in C++.

{operational overloading ?}

(usually left shift, but here this!!)

```
class Example
{
   private: int data;
   public : void initialize (int val);
   void increment ();
};
```

can't access outside the class

int data member is private

→ assigns val to data part of object.

```
void Example :: initialize (int val);
{
   if (val >=1)
   {
     data = val;
   }
   else
   {
     cout << "Invalid " >> endl;
   }
}
```

↳ member functions public
↳ data members private.

- Scope resolution operator.
- define member fn. to class Example, OUTSIDE the class.

↳ OO way of ending line

```
void Example :: increment ()
{
   data += 1;
   cout << "Incremented Val is: " << data << endl;
}
```

```
int main ()
{
   Example O1;
   O1.initialize ();
   O1.increment ();
```

obj.fn()
↳ call fn. wrt obj.

x needs to be output, so

```
    return 0;
}
```

push from x, to cout.

```
cout << x;
cin >> a;
```

input needs to be saved to var a, so push from cin to a.

./a.out → CALLS the main fn.

CONSTRUCTORS / DESTRUCTORS

↳ major part of data - encapsulation.
↳ they are ALSO member functions.

C++ Class → members are private by default.
C++ Structure → members are public by default.

member functions defined in class: INLINE.

if not INLINE, control transfer takes place to a diff world. we pass arguments to that world & get the return value back from it. (internally, a stack works) → This is better, as the function defn. DOESN'T get pasted in main → in cases of BIG defns.

if fn. defns. are BIG ⟶ not INLINE.
" " " are SMALL ⟶ INLINE.

```
main ( )
{
   Example 01;
   01. data = 10; ⟶ WON'T WORK . . . .
}
```

(data is private, & it's not safe)

BETTER define fns.

What can be done: define member fns. that'll get obj. data & return its location or something? (Will it work?)

```
int *a;
int c = 80;
  a = &c;
```

pointers → to manipulate data directly at its location.

const → ALSO a Secure access.

int * a; → Assign many times

int * const a; → Assign only once.

const int * a; → Assign many times only to const ints.

const int * const a; Assign only once, only to const int.

(read from R → L)

(ADA used in ISRO)

MOST SECURE! EXPLOIT in STANDALONE fns.

CONSTRUCTORS / DESTRUCTORS

* Are also member functions.
* constructors → create / initialize an object of a class : assign values to data members. (Malloc will be done here, if dynamic members are present)
* destructors → free the memory used after end of program.

* name of the constructor / destructor = SAME as the className.
* default constructors & destructors are available, but it's better to define on our own.
  ↓
  - doesn't need arguments to pass!
  - WE can't specify a return Type for them.

```
Class Test()
{
  private: int a;
  private: float b;

  public: Test();
  public: test(int a, float b);
  public: display();
}
```

```
#include "test.h"
```

```
Test :: Test ()
{
    a=0;
    b=0.0;
}
```

→ * default
* no return Type

```
Test :: test(int v1, float v2)
{
    a = ((v1>=0) ? v1 : 0);
    b = ((v2>=0) ? v2 : 0);
}
```

→ * parameterised

ternary :
* $e_1 ? e_2 : e_3$
* eval e_1. if true, eval e_2 & return result & assign. else, eval e_3 & return result & assign.

Time t1; }

This AUTOMATICALLY calls the constructor & initializes t1.
[t1.Time() is done automatically - even if it has mAlloc & stuff]

Time t2.Time(5,6,7)

↳ compiler knows this is parameterized, hence user defined constructor.

function differentiated by
- parameters.
- name.

Everything told for constructors holds good for destructors → but declare destructors using:

~className();

↳ negated operation of constructor.

① Create Time Package – with constructors / destructors · check for data validity · convert into AM/PM format · do formatting properly.

② Similarly create a date package · given a date, find day.

FUNCTION POINTERS

* bubbleSort in ascending & descending are the same, EXCEPT for the comparison! So, have a generic bubbleSort fn, & write comparison logic separately.

```
void bubbleSort (int work[], int size,
                 int (*compare)(int a, int b));
int ascending (int a, int b);
int descending (int a, int b);

scanf ("%d", order);

if (order == 1)
    bubbleSort (a, size, ascending);
```

↓

this will return truth value of arr[i], arr[i+1].

if you NEED ascending, then if arr[i+1] > arr[i], swap ISNT reqd, so return 0.

else, SWAP is reqd, so return 1.

if DESCENDING, exact opp. logic.

③ run fn. ptr. logic for bubblesort.

④ write fn. ptr logic for ANY one fn. in number operation package, IN C.

```
int a = 0;
void main()
{
   printf("Hello %d\n", a);
   a++;
   if (a<3)
   {
     main();
   }
   printf("World %d\n", a);
}
```

→ run & test.

```
Hello 0
Hello 1
Hello 2
World 3
World 3
World 3
```

STORAGE CLASS / SCOPE

* auto, static, register, external
* function Scope, file Scope, global Scope, block Scope.

* Scope ≡ Where all in the source code can I access a variable is Scope. lifetime wrt code.

* Storage Class ≡ how long will a variable be accessible, from a MEMORY pt. of view.

```
int a = 1;
main() {
  int a=5;
  printf("%d\n", a);  ⟶ 5
  {
    int a=6;
    printf("%d\n",a);  ⟶ 8
  }
  printf("%d\n", a);  ⟶ 5
  fn1();  ⟶ (6,7)
  fn2();  ⟶ (40,41)
  fn3();  ⟶ (1,20)
  fn1();  ⟶ (6,7)
  fn2();  ⟶ (41,42)
  fn3();  ⟶ (20,400)
  return 0;
}
fn1() {
  int a = 6;
  printf("%d \n", a);
```

```
    printf("%d\n", a);
}
fn2(){
    static int a = 40;
    printf("%d\n", a);
    a++;
    printf("%d\n", a);
}
fn3(){
    printf("%d\n", a);
    a *= 20;
    printf("%d\n", a);
}
```

register → faster memory access, but restricted in storage
→ use loop variables : as access is quick
→ if registers run out, data converted to auto.

extern → inter file variable access.

Bhadra

CLASS - COMPOSITION

↳ can have an instance of another class as its data-member.

```
Example :: Example(void) {
    if (val >= 0) {
        i = val;
```

Example
↓

```
}
else {
    cout << "Invalid" << endl;
}
```

```
class Employee {
private:
    int Aadhar;
    char* Fname;
    char* Lname;
    Date dob;
    Time tob;
}
```

```
Example :: ~Example (void) {
    cout << "Destructor called" << endl;
}
```

functions are allowed to default their variables to some values.

Example (int=0)

↓

both default & parameterised constructors.

We can't do Example(int=0)

↓

Example()

```
Example One(1); ← 1
int main() {
    Example two(2); ← 2
    static Example three(3); ← 3
    standalonefn();
    Example four(4); ← 7
    return 0;
}
```

```
void standalonefn() {
    Example five(5); ← 4
    Static Example six(6); ← 5
    Example seven(7); ← 6
}
```

democratic INDIAN programmers can dck off.

- if you default, default values to ALL Arguments.

else, dont.

- if you default, DEFINE a parameterised constructor...

01, 02, 03, 05, 06, 07, 07, 05,
04, 04, 06, 03, 02, 01.

↓

live longer.

04, 02, 01, 06, 03 → ACTUAL ORDER.

- execute storage classes & scopes for obj creation & destruction programs.

FUNCTION OVERLOADING

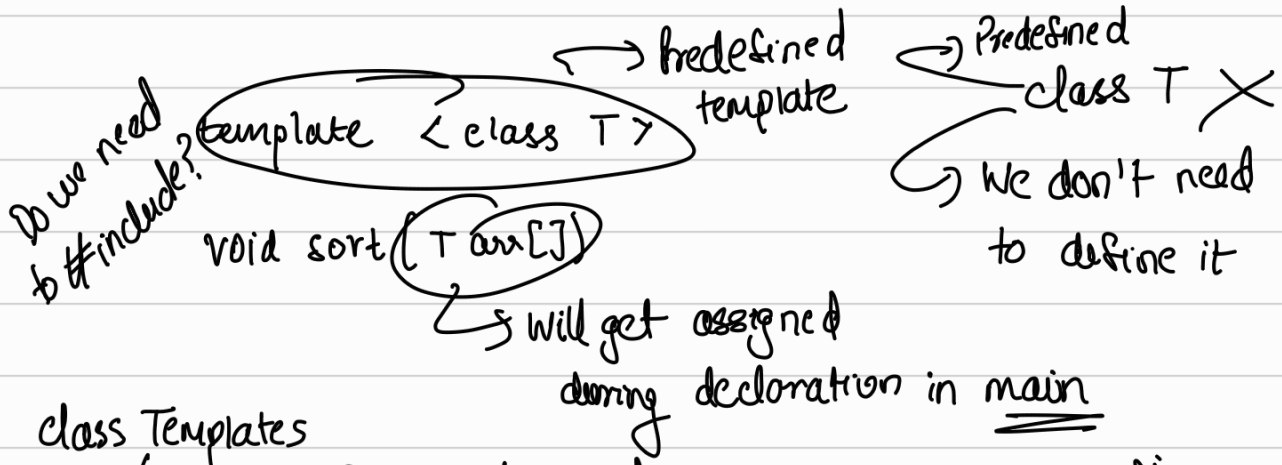
↳ MORE THAN 1 definition for the same function.
(e.g. same sort fn., but with diff. parameters)
↳ diff. signatures.

↳ execute fn. overloading to sort arr of chars, ints & floats. → once with 3 fns, & once with template.

↳ check magic square.

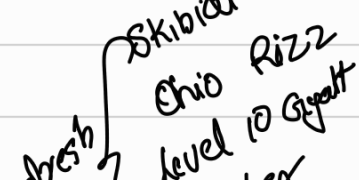
↳ Optional: generate a magic square for a given value of n (nxn)

↳ Latin Square: generate permutations



class Templates
↳ will be further discussed towards the ending of the course

fns generated out of function templates



↳ template fns.

#DEFINE SQ(X) X*X → MACRO.

→ STRING REPLACEMENT - - - -

↳ NOT FUNCTIONS, but like functions.

```
m() {
  int a=5;
  SQ(a);
}
```

↳ if I put a+1,

a+1 * a+1 = 2a+1 happens.

COMPOSITION

use this...

editors: • emacs

• VI editor (VIM)

```
Class Date {

private:
        int month;
        int day;
        int year;
        int check_day(int);
public :
        Date(int=1, int=1, int=2003);
        Void display() const;
};
```

C++ → has bool data-type (boolean)

↳ C doesn't have it.

↳ gives only READ access to data members.

```
class Employee {
```

follow:

```
private:
        char fname[25];
        char lname[25];
        const Date dob;
        const Date doj;

public:
        Employee(char*, char*,
                 int, int, int, int, int,
                 int);
        void display() const;
        ~Employee();
};
```

principle of least priviledge (PLP)

public fns.
↳ interface.
private fns.
↳ helper fns.

```
Employee::Employee(Char* fn, Char* ln, int bm,
                   int bd, int by, int jm, int jd,
                   int jy): Birth_Date(bm, bd, by),
                            Join_Date(jm, jd, jy)
{
    int length = strlen(fn);
    strncpy(fname, fn, length);
    fn[length] = '\0';
        length = strlen(ln);
    strncpy(lname, ln, length);
    ln[length] = '\0';
}

void Employee::display(){

    cout << fname << " " << lname;
    id.Print();
```

"%[^\n]s"

```
    bd.print();
    cout << endl;
}
```

COPY CONSTRUCTOR

```
Employee e1;
Employee e2(e1);
```

→ Copy e1's state into e2.

→ CALLS copy constructor.
(series of values to be assigned)

→ in single go, create & copy state of another object into this.

Class Student
- int ssn;
- int age;
- float cgpa;

Syntax of cpyconstr: `Student (const Student s)`

```
Student s1(x,y,z);
Student s2(s1)
```

→ inside fn:

```
ssn = s.ssn;
age = s.age;
cgpa = s.cgpa;
```

pass by value → operates on the copy of an

actual value
→ ensures data security.
→ wastage of memory.

pass by reference → operates directly on the actual value (usage of pointers)
→ data - vulnerable.
→ No wastage.

SAFEST → const int * const e
&
BEST

↳ passed by reference
↳ const ptr.
↳ ptng. to const int.

FOR COPY CONSTRUCTOR, we can't do PASS BY VALUE, as PASS BY VALUE creates a copy of the value of a certain datatype, but we are LITERALLY JUST creating the copy fn. for our datatype (TWIST!!!)

defn → Student (Student * const s)
call → Student (&s)

OPERATOR OVERLOADING

unary, binary & ternary.

binary operators.

ARITY → no. of operands that the operator work on.

ARITY = no of operands does the operator work on.

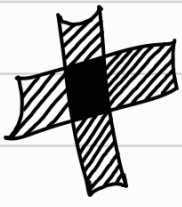
$ ./a.out >> op → push output into the file, rather than displaying on the screen. (this will append) → SAFER.

(out-direction)

Why not ./a.out > op ? → this REWRITES from the first bit.

(in-direction) (write)

./a.out << ip → input the params. from a file into the executable during runtime.



I want to do cout << e, where e is probably an instance of some class with data members.

↓ it should display all the data members.

currently, it will show SYNTAX ERROR (as the class might have ≥ 1 data-member)

↳ ASSIGN a NEW MEANING to the << operator s.t. it will display all the data members.

|| if A & B → 2 matrices, A + B SHOULD do $A_{ij} + B_{ij}$ $\forall i, j$ ||

```
class Test {
    private:
        int a;
        int b;
    public:
        Test (int=0, int=0);
        void setValue (int, int);
        int getVal();
        int &setValue (int);
};

Test :: Test (int V1, int V2) {
    a = V1;
    b = V2;
}

int &setValue (int V3) {
    a = V3;
    return a;
}

int main() {
    Test 01;
    int &aref = 01.setValue(50);
    aref = 30; // undesired modif.
    01.setValue(50) = 70;
    return 0;
}
```

returned reference

}

used as rvalue

```
Test {
    mem1, 2, 3;
    &set1();
    &set2();
    &set3();
    &setall();
}
```

```
Test & setall(){
    set1(v1);
    set2(v2);
    set3(v3);
    return *this;
}
```

```
Test & set1(){
    mem1 = v1;
    return *this;
}
```

```
Test & set2(){
    mem2 = v2;
    return *this;
}
```

```
Test & set3(){
    mem3 = v3;
    return *this;
}
```

in main,

$o1.set1(v_1).set2(v_2).set3(v_3)$

(1)

$\Downarrow\Downarrow$

$o1'.set2(v_2).set3(v_3)$

(2)

$\Downarrow$

$o_1''.set3(v_3)$

(3)

$o_1''' \equiv o_1''.set3(v_3)$

location of o1 with the latest changes

CASCADING WAY.
(Better Approach than

setall)

$m_4 = m_1 + m_2 + m_3$ { m_is → matrices }

① returns address of resultant matrix

$= m_{12} + m_3$

②

$m_4 = m_{123}$ → returns address of final matrix.

OPERATOR OVERLOADING X THIS *

FRIEND → functions
FRIEND → classes

```
class Example {
      friend void fn1 (Example &, int);
      void display(){
        cout << value;
      }
      Example() {
         data = 0;
      }
      private:
            int data;
};

void fn1(Example &e, int d) {
      e.data = d;
```

}

ALLOWED AS A RESULT of friends feature.

cout << a << b → cout << b

ALSO CASCADING EFFECT!

cout is an object of class ostream

cout available for b, AFTER a.

OPERATOR OVERLOADING is acheived by functions:
- ↳ primarily by MEMBER functions.
- ↳ if not, make the standAlone fn. a friend of the class.

HOW DO I ACHEIVE addn. of 2 matrices m_1 & m_2, and return result to m_3?

if LHS of Operand is of the same class of reference, then use member fns. else, non-member fns.

EXAMPLE:

```
friend ostream & operator << (ostream &, Emp &) ;
```

- friend → allow non-
- ostream & → for Cascading
- operator → keyword
- << → the operator
- (ostream &, Emp &) → operating object (cout) ; operand object
- input object's data members

member fns.
to operate on
private data members

definition:

```
ostream & operator << (ostream & O, Emp & e) {
    O << e.fn << endl;
    O << e.ln << endl;
    return O;
}
```

CASCADING STILL WORKS for O — as its predefined ....

COPY CONSTRUCTOR
↓
similar to obj1 = obj2
↓
but cpy happens in same line of construction

if A → array,
will ++A work? Yes, if in defn. we add a dummy int in the LHS of ++. Duh.

```
class IntArray {
friend ostream & operator << (ostream &, IntArray &);
friend istream & operator >> (istream &, IntArray &);
public:
```

LHS of operator not object of same class.

```
IntArray(int = 20);
IntArray(const IntArray &);
~IntArray();
const IntArray & operator = (const IntArray &);
bool operator == (const IntArray &) const;
bool operator != (const IntArray &) const;
int & operator [] (int);
const int & operator [] (int) const;
```

LHS of operator is obj of same class.

[] → array indexing operator.

static → on a class basis.

how many array objects has the user created during the runtime

```
private:
    int *aptr;
    int size;
    static int arrayCount;
};
```

a[-5] → out of bounds error → not checked in C

```
IntArray::IntArray(int sz) {
    size = sz;
    aptr = new int[size];
    ++arrayCount;
    for (int i=0; i<size; i++) {
        aptr[i] = 0;
    }
}
```

→ like mAlloc.

C++ → Typesafe.

```
IntArray::~IntArray() {
    delete [] aptr;
}
```

→ works only with new.

```
IntArray::IntArray(const IntArray &source) {
    size = source.size;
    aptr = new int[size];
    for (int i=0; i<size; i++) {
```

```
        aptr[i] = source.aptr[i];
    }
}
```

→ macro → pre-processor director?

```
assert (aptr != NULL)
```

correct SYNTAX?

```
const IntArray & IntArray :: operator = (const IntArray &right){
    if ( right != this){ → (or) &right != this ?
        if (size != right.size){
            delete [] aptr;
            size = right.size;
            aptr = new int [size];
        }
        for(int i=0 ; i<size ; i++){
            aptr[i] = right.aptr[i];
        }
    }
    return this *;
}

bool IntArray :: operator == (const IntArray &rt){
    if (size != rt.size){
        return FALSE;
    }
    for (int i=0 ; i<size; i++){
        if (aptr[i] != rt.aptr[i]){
            return FALSE;
        }
    }
    return TRUE;
}
bool IntArray :: Operator != (const IntArray &) const {
    return !( *this == right);
```

```
}
ostream & operator << (ostream & o, const IntArray &a){
  for (int i=0 ; i<a.size; i++){
     o << aptr[i];
  }
  return o;
}
istream & operator >> (istream & o , const IntArray &a){
   for (int i=0; i< a.size; i++){
      o >> a.aptr[i];
   }
   return o;
}
int & operator [] (int sscript){
  if (sscript >=0 && sscript < size){
   return *(aptr + sscript);
  }
  else{
    abort();
  }
}
int & operator [] (int sscript) const{
  if (sscript >=0 && sscript < size){
   return *(aptr + sscript);
  }
  else{
    abort();
  }
}
```

↳ CAN'T MAKE IT A CONST fn. as object o is being written on.

↓ could put this condn. in Assert macro too.

OVERLOADING UNARY OPERATORS

↳ member fn. overload if LHS of the operator has object of same class

↳ ambiguity occurs in ++ → if post / pre increment. (signatures conflict!!)

↳ for post increment → pass DUMMY INTEGER ?

```
class A {
    private:
        increment();
        n1, n2, n3;
    public:
        A(int=0, int=0, int=0); } → DIY. eZ.
        ~A();
        A & operator ++();
        A & operator ++(int);
};
```

HELPER FNs. (help PUBLIC fns.)

DUMMY INT?

A++ → should ideally do n1++, n2++ & n3++.

B = A++ → should ideally assign A to B first, & then increment A.

```
A & operator ++(){
    increment();
    return *this;
}
```

```
A & operator ++(int){
    A temp = *this;
    increment();
```

B = ++A.

B = A.operator ++();

↓ returns updated A.

B = A.operator ++(int);

```
    return temp;
}
```

↓ returns temp
↳ which is old A.

Compiler knows if operator is in the LHS/RHS of the object (UNARY) → in Any case it does A.operator <unary> ().

POST INC = POSTFIX.
PRE INC = PREFIX.

do this for MATRIX → m_{ij}++ (or) ++m_{ij}
m_{ij}-- (or) --m_{ij}

ARITY (or) ASSOCIATIVITY of an operator CAN'T BE CHANGED ⟶ compiler defined....

democratic indian users will try to create their own operators ⟶ NOT ALLOWED !!!

MISSED a class in b/w - intro to inheritance

Types of INHERITANCE:

1) Single - level
2) Multi - level
3) Multiple

Base - classes → Abstract ⟶ Helps with virtual fns.
→ Virtual

fn. overriding ⟶ checks wrt. what obj. the fn. has been called.

polymorphism ⟶ imp. in the context of OS.
↳ powerful inheritance.

```
class DerivedClassName : mode BaseClassName
                          ↓ public, private, protected.
{
    derived class attributes }
    derived class behaviours } ↘ DON'T HAVE TO DECLARE AGAIN.
}
```

DERIVATION of CLASS:

	TYPE of INHERITANCE		
BASE CLASS	PUBLIC	PROTECTED	PRIVATE
PUBLIC	Public in derived class (can be accessed by all non-static member & friend fns.)	Protected in derived class. (can be accessed by all non-static member & friend fns.)	Private in derived class (can be accessed by all non-static member & friend fns.)

for private inheritance → CAN ACCESS members ONLY thru public interfaces OF THE BASE CLASS

```
class Student {
    protected:
        char *fname;
        char *lname;
        friend ostream & operator << (ostream &,
                                      const Student &);
    public:
        Student ( char*, char* );
        ~Student ();
};

class Graduate : public Student {
    friend ostream & operator << (ostream &,
                                  const Graduate&);
    public:
        Graduate (char * = "", char * = "", char* = "");
    protected:
        char * degree;
};

Graduate :: Graduate (char *fna, char * lna, char *dg)
                        : Student (fna, lna)
{
    degree = char new [strlen (dg) + 1];
    strcpy (degree, dg);
}
```

CAN ALSO BE CALLED as a sep. fn. inside the graduate constructor.

```
ostream & operator << (ostream &out, const Graduate &grad)
{
```

↳ OVERRIDING fn ⟹ diff. behaviour of same operator in base & derived class.

```
    out << "Fname is \t" << static.cast<Student>(grad);
```

(?)

(?)

```
}
```

```
Student *sptr = 0,S("f", "l");
Graduate *gptr = 0,G("f1", "l1", "B.E");

cout << S << "\n";
cout << G << "\n";

sptr = &G; → derived fellow : mismatch (??)
cout << *sptr; } → will show only f & l names (?)

sptr = &S;
gptr = static.cast < Graduate *> (sptr);
cout << gptr;

return 0;
```

BASE constructed before derived.
those constructed first get destructed at last

polymorphism ⟶ powerful inheritance → virtual fns.

used

pointers → do data manipulation at its address.

Sptr = &G → SYNTACTICALLY ALLOWED
gptr = &G → SAFE
↳ But mismatch

upcasting a ptr → assigning derived fellow's address to base ptr.
(SAFE)
(Sptr = &G)
↳ SYNTACTICALLY AND SEMANTICALLY ALLOWED (derived class obj = instance of base class)

Sptr = &G
cout << *Sptr → only outputs { student members
STATIC BINDING ←
↳ see the class of Sptr → not the actual obj //

the opposite → down casting → syntactically OK, semantically wrong !!!

fn overriding → STATICALLY BOUND.

gptr = &S → dangerous, as S→ doesn't have degree field.

↳ Virtual fns. help with this //

MULTIPLE INHERITANCE

↳ do: class C : <mode> A, <mode> B

const. of C → C(int i, char j, double k)
: A(j), B(k)
↑ member registration operator (?)

in main:

```
A o1(50), *aptr = NULL;
B o2('B'), *bptr = NULL;
C o3(10, 'C', 1.1);
o1.print();
o2.print();
cout << o3; ⟶ overloaded.
aptr = &o3;
aptr→print(); ⟶ calls print of A only.
bptr = &o3;
bptr→print(); ⟶ calls print of B only.
```

STATICALLY BOUND.

Casting ≠ polymorphism
↳ more to do with fns. than with attributes.

```
class B : virtual Public A {
    :
    :
}
class C : virtual Public A {
    :
```

```
}
class D : public A, public B {
    .
    .
}
```

inheritance
↳ reusability

→ B has attributes of A, & A is present explicitly in D as well → so, which member of A to use?
↳ virtual there to help.
↳ make base class virtual

POLYMORPHISM

* using virtual fns → dynamic binding.

```
class Shape {

    public :
        virtual double area () const { return 0.0; }
        virtual double volume() const { return 0.0; }

        virtual void printShapeName() const = 0;
        virtual void print() const = 0;
};
```

→ NO DATA MEMBERS ONLY BEHAVIOURS!
↳ CALLED ABSTRACT CLASSES → usually in inheritance setup
↳ MUST have at least 1 PURE virtual fn.

↳ CAN'T create a direct obj. of an abstract class.

if virtual fns. are equated to 0 → WILL NOT have a defn. in base class. (or) CAN'T.

↳ Pure Virtual Functions.

opp. of Abstract classes ⟶ concrete classes.

```
class Point : public Shape {
    public:
        Point(int=0, int=0);
        void setPoint(int, int);
        int getX() const {return x;}
        int getY() const {return y;}
        virtual void printShapeName() const
                                {cout << "Point: ";}
        virtual void print() const;

    private:
        int x;
        int y;
};
```

sim. for circle & cylinder → override fn. declarations / definitions.

in main:

```
Shape * arrOfShapes[3];

arrOfShapes[0] = &point;
arrOfShapes[1] = &circle;
arrOfShapes[2] = &Cylinder;
```
→ point, circle, cylinder obj. instantiated before.

```
for (int i=0; i<3; i++){

    virtualViaPointer(arrofshapes[i]);
```
↳ let it be a ptr.

→ does: ptr → printShapeName();
ptr → print();
cout << ptr → Area();
cout << ptr → volume();

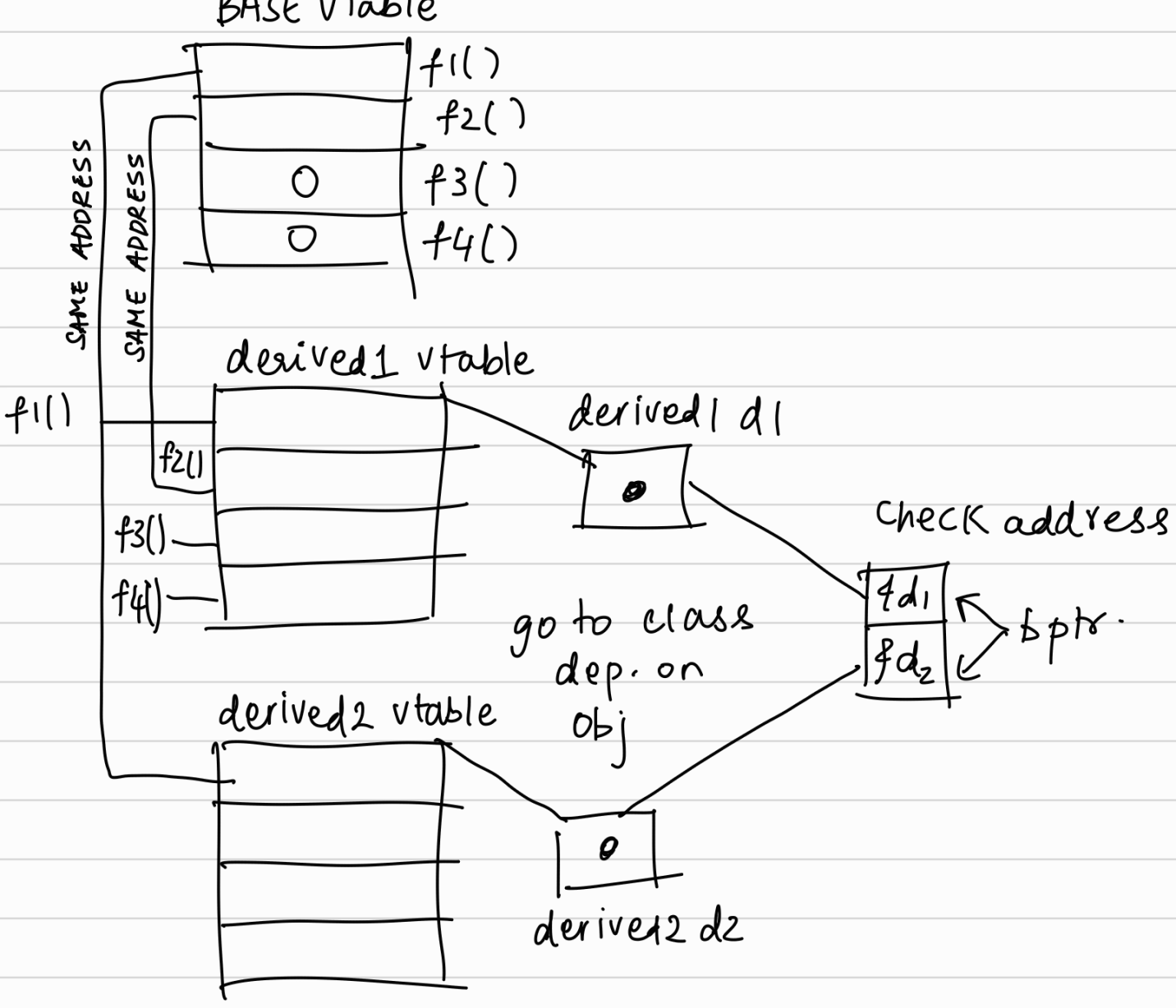
```
}
```

ptr → stores ref. of Point / circle / cylinder
→ ptr → fn(); calls fn. wrt. the class of the object at reference
→ POWER of POLYMORPHISM!!!

** Book topic
→ Internals behing Polymorphic behaviour

C++ compiler exploits function pointer to implement virtual functions.

for EVERY abstract class, ∃ a VFTable, which is an array of fn. ptrs.
↳ virtual function table



Vftable → ONLY for POLYMORPHIC BEHAVIOUR.
↳ fn. ptrs exist ONLY for virtual fns...

CLASS TEMPLATES

```
template <class T>
 Class Stack{
   public:
      Stack( int=20);
      ~Stack();
       bool push (const T &);
       bool pop(T&)
   private:
```

→ relevance wrt data structures (only datatype varies, behaviour is same)

STL → standard template

```
    int size;
    int top;
    T * stackptr;
    bool isEmpty() const {
      return (top == -1);
    }
    bool isFull() const{
      return (top==size-1);
    }
};
```

HELPER fns

libraries.

avoids duplication

no const coz you COULD potentially operate ON the popped value... (why pass anything into the fn. at all?)

ANSWERED LATER...

```
template <class T>
Stack <T> :: Stack (int sz)
{
   size = (sz > 0) ? sz : 20;
   top = -1;
   Stackptr = new T [size];
}
template <class T>
Stack <T> :: ~Stack()
{
   delete [] stackptr;
}
bool Stack <T> :: push (const T & pval)
{
   if (!isFull())
   {
      Stackptr [++top] = pval;
      return true;
   }
   return false;
```

to store the POPPED

```
}
bool Stack <T> :: pop ( T & popval)
{
    if (! isEmpty)
    {
        popval = stackptr[top--];
        return true;
    }
    return false;
}
```

value some where.