Lecture 7

Pointers to Objects

Outline

- Pointers to Objects
- Linked List of Objects
- Pointers and Inheritance

Pointers to Objects

- Pointers can point to objects just as they can point to variables of basic types.

The new Operator:

- Dynamically (at run-time) allocates memory of a specific byte size and returns a pointer to its memory address.
- If it is unable to find memory space, it returns a NULL pointer.
- When you use the **new** operator with objects, it also invokes the object's **constructor**.

Example :

```
// Pointer to a String class object
String *  sp;
sp  =  new  String;
```


The delete Operator:

- To ensure safe and efficient use of memory, every new operator should have a corresponding delete operator that releases the memory.
- To delete an array entirely, the brackets [] should be written.

Example :

```
// Allocate an array of strings.
// Pointer is pointing to array.
String *  sp;
sp  =  new  String [10];
……
delete [ ]   sp;
```

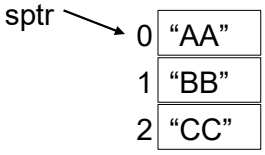
Example : String class

```
class  String
{
   int     size;
   char  *contents;

 public:
   String ();                    // Default constructor
   String (const  char *);       // Parametered constructor
   String (const  String &);     // Copy constructor

   // Overloaded assignment operator
   const  String&   operator=  (const  String  &);

   void print() ;

   ~String();      // Destructor
};
```


Example : Using a Pointer as an Array of String objects

```
int main () {
   // Define String objects
   String  s1 ("AA");
   String  s2 ("BB");
   String  s3 ("CC");

   // Dynamically allocate array of String objects
   String  * sptr  =  new  String [3];

   // Copy objects to array elements
   sptr [0]  =  s1;
   sptr [1]  =  s2;
   sptr [2]  =  s3;

   // Call print function of each element
   for (int  i=0;  i<3;  i++)
       sptr [i] . print();

   // Delete objects pointed by sptr
   delete []  sptr;
}
```

sptr is name of pointer, and also name of array.

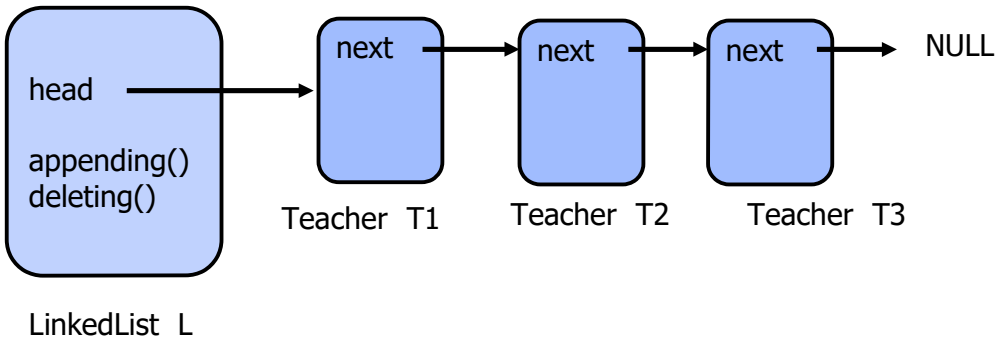


Alternative assignment method : Use constructors

```
sptr [0]  = String ("AA");
sptr [1]  = String ("BB");
sptr [2]  = String ("CC");
```

Example: Linked List of teachers

- The linked list data structure contains objects of Teacher class.
- Each element in list contains a pointer to next Teacher.
- Also a friend class (LinkedList) of Teacher is defined.
- The LinkedList class contains the **head pointer**.
- Head pointer points to the first Teacher in the linked list.
- Adding or deleting elements are done by member functions of LinkedList class.



Example : Teacher class and LinkedList class

- Teacher class contains a pointer to next Teacher.
- The next pointer is used to build a chain of objects, a linked list.

```
class   Teacher
{
   friend  class  LinkedList;

   string name;
   int numOfStudents;
   Teacher * next;
    // Pointer to next object of teacher

 public:
   Teacher (string, int); // Constructor
   void print();
  ~Teacher()    // Destructor
};
```

```
// Linked List for teachers
class   LinkedList
{
  Teacher * head;

 public:
  LinkedList ()   // Constructor
     { head = NULL; }

  bool  appending (Teacher);
  bool  deleting (Teacher);
  void  print ();
  ~LinkedList ();   // Destructor
};
```

The **print function** of LinkedList class iteratively travels from a node to next node (by looping), and calls the print function of Teacher class.

```
// Prints all elements of list on screen
void  LinkedList  ::  print ()
{
   Teacher  * tempPtr;

   if (head == NULL)
   {
      cout << "The list is empty \n";
      return;
   }

   tempPtr = head;
   while ( tempPtr != NULL)
   {
       tempPtr -> print();
       tempPtr  =  tempPtr -> next;
    }

}
```

```
int main()
{
  Teacher   T1  ("AA", 100);
  Teacher   T2  ("BB", 150);
  Teacher   T3  ("CC", 80);

  LinkedList   L;

  L . appending (T1);
  L . appending (T2);
  L . appending (T3);

  L . print();
}
```



```
// Destructor
// Deletes all elements of the linked list one-by-one

LinkedList  ::  ~LinkedList ()
{
   Teacher  * tempPtr;

   while ( head != NULL )   // Check if the list is not empty
   {
      tempPtr = head;
      head = head -> next;
      delete  tempPtr;
   }

}
```

Extending the existing classes

- In the previous example the Teacher class must have a pointer to the "next" object, and the LinkedList class must be declared as a friend.
- Usually programmers use **ready-made classes**, written by other programmers, for example classes from libraries. And these classes may not have a **next** pointer.
- To build linked lists of such ready-made classes (without a next pointer), there are two techniques.
  - Inheritance (is-a)
  - Composition (has-a)
- The following is an example class that has no next pointer as a member variable.

```
class   Teacher  {
    string  name;
    int       numOfStudents;
 public:
    Teacher (string, int);
    void  print();
   ~Teacher()
};
```


Example1: Inheritance from Teacher

- Programmer can derive a new class (**TeacherForList**) from Teacher class.
- TeacherForList class contains a **next pointer**, to build the linked list.

```
// TeacherForList  is-a  Teacher
class  TeacherForList  :  public  Teacher
{
   friend  class  LinkedList;

   // Pointer to next TeacherForList
   TeacherForList  *  next;

   TeacherForList (string, int); // Constructor
};
```

```
int main() {
  TeacherForList   T1 ("AA", 100);
  TeacherForList   T2 ("BB", 150);
  TeacherForList   T3 ("CC", 80);
  LinkedList   L;
  L . appending (T1);
  L . appending (T2);
  L . appending (T3);
  L . print();
}
```

```
// Constructor
TeacherForList  ::  TeacherForList (string  n,  int  nos)
                                    : Teacher (n, nos)
{
    next = NULL;
}
```

Example2: Composition from Teacher

- Another way to a build linked list of ready classes is to define a **node class.**
- Each object of the node class **has-a** pointer to a Teacher object (element).
- Node also contains a **next pointer**, to build the linked list.

```
// TeacherNode has-a Teacher
class TeacherNode
{
   friend class LinkedList;

   Teacher * element;   // The element of the linked list (Composition)

   TeacherNode * next;  // Pointer to next node

   TeacherNode (string, int);   // Constructor
   ~TeacherNode ();             // Destructor
};
```



```
// TeacherNode Constructor
TeacherNode :: TeacherNode (string n, int nos)
{
   element = new Teacher (n, nos);   // Teacher constructor
   next = NULL;
}
```

```
// TeacherNode Destructor
TeacherNode :: ~TeacherNode ()
{
  delete element;
}
```

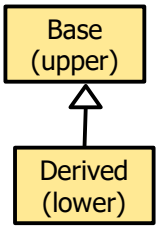
```
int main()
{
  TeacherNode T1 ("AA", 100);
  TeacherNode T2 ("BB", 150);
  TeacherNode T3 ("CC", 80);

  LinkedList L;
  L . appending (T1);
  L . appending (T2);
  L . appending (T3);
  L . print();
}
```

Pointers and Inheritance

- If a Derived class has a public Base class, then a pointer to Derived can be assigned to a pointer to Base, without use of explicit type conversion (up-casting).
- In other words, a **pointer to Base** can carry the address of a **Derived object**.
- For example, a pointer to Teacher can point to objects of Teacher and also to objects of Principal.
- A principal **is-a** teacher, but a teacher is not always a principal.
- The opposite conversion, from (pointer-to-Base) to (pointer-to-Derived), must be explicit (down-casting).

Example : Pointer up-casting and down-casting

```
class  Base  { };

class  Derived  :  public  Base  { };
```




```
int main() {
Derived   d;

Base   * bp;
bp  =  &d;   // Implicit conversion from derived to base  (up-casting)

Derived  * dp;
dp  =   bp;    // ERROR!  Base is not Derived

dp   =   static_cast < Derived * >   ( bp );
// Explicit conversion from base to derived  (down-casting)
}
```

Accessing members of Derived class, via a pointer to Base class

- When a pointer to Base class points to objects of Derived class, only the members inherited from Base can be accessed.
- In other words, the extra members just defined in Derived class, can not be accessed via a pointer to Base class.
- **For example**, a pointer to Teacher can hold the address of a Principal object.
- Using that pointer (Teacher type) it is possible to access only teacher properties of principal, i.e. only the members that the Principal inherits from Teacher class.
- Using a pointer to derived type (Principal) it is possible to access all (public) members of Principal (both inherited from Teacher and defined in Principal).

Example : Using pointer to base class

```
// Base class
class Teacher
{
  protected:
    string  name;
    int  numOfStudents;
  public:
    void  teachClass ();    // Teacher's  function
};
```

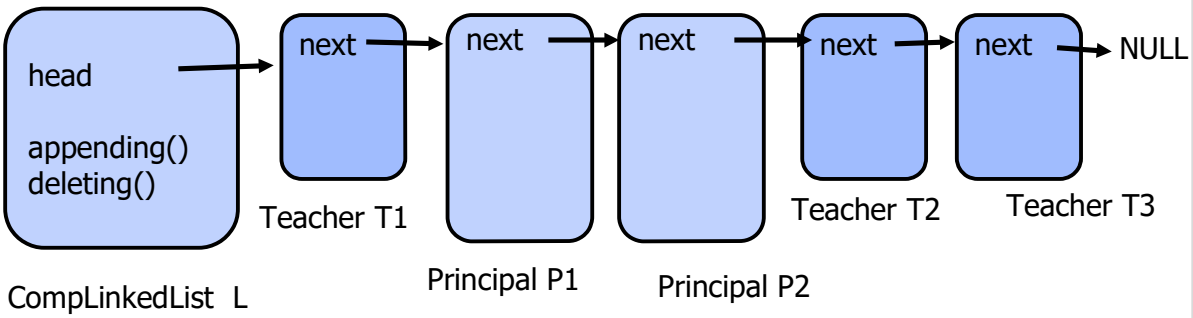
```
// Derived class
class Principal : public Teacher
{
     string  school_name;
   public:
      void  directSchool ();    // Principal's function
};
```

```
int main()
{
  Principal  objPrincipal;       // Object of Principal type

  Teacher   * ptrTeacher;      // Pointer to base class

  ptrTeacher  =  & objPrincipal; // Pointer to Teacher(base) points to Principal (derived)

  ptrTeacher -> teachClass ();     // OK. Teaching is a teacher-function

  ptrTeacher -> directSchool ();  // ERROR! Directing a school is not a teacher-function.

  //-------------------------------------------------------------------------------
  Principal   * ptrPrincipal;

  ptrPrincipal  =  & objPrincipal;       // Pointer to Principal

  ptrPrincipal -> teachClass ();        // OK. Principal is a Teacher also

  ptrPrincipal -> directSchool ();      // OK. Principal's function
}
```


Compound Linked List

- A linked list specified in terms of pointers to a base class can hold objects of any class derived from this base class.
- Using inheritance and pointers, a compound linked list can be build.
- The nodes in a compound linked list can be Teacher and Principal objects.
- Compound linked lists can be used in **polymorphism**.

Example: A linked list of teachers and principals



```
//  Compound Linked List
// for teachers and principals

class   CompLinkedList
{
  TeacherNode * head; // Base pointer

  public:
   LinkedList ()   // Constructor
     { head = NULL; }

   bool  appending (TeacherNode *);
   bool  deleting (TeacherNode *);
   void  print ();
   ~LinkedList ();
};
```

```
int main()
{
  TeacherNode   T1  ("AA", 100);
  TeacherNode   T2  ("BB", 150);
  TeacherNode   T3  ("CC", 80);
  PrincipalNode   P1  ("DD", 300, "QQQ");
  PrincipalNode   P2  ("EE",  200, "UUU");

  CompLinkedList   CL;  // Compound Linked List

  //  Pass addresses to the append function
  CL . appending ( & T1 );  // Teacher1
  CL . appending ( & P1 );  // Principal1
  CL . appending ( & P2 );  // Principal2
  CL . appending ( & T2 );  // Teacher2
  CL . appending ( & T3 );  // Teacher3

  CL . print();
}
```