CMPSC 24: Lecture 6
Abstract Data Type: Lists

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LIST ADT

Sorted and Unsorted List ADTs

UNSORTED LIST	SORTED LIST
Elements are placed into the list in no particular order.	List elements are in a sorted order---either numerically or alphabetically by the elements themselves, or by a component of the element (called a KEY member).

Name some possible keys

ADT Unsorted List

- **Transformers**
  - **MakeEmpty**
  - **InsertItem**
  - **DeleteItem**

change state

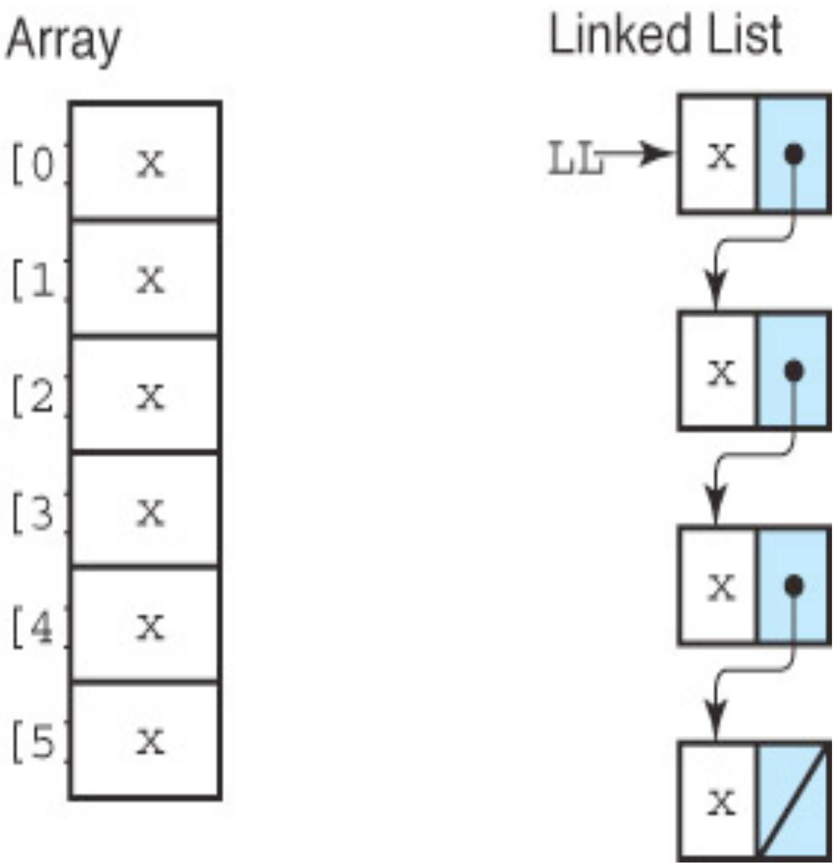
- **Observers**
  - **IsFull**
  - **GetLength**
  - **RetrieveItem**

observe state

- **Iterators**
  - **ResetList**
  - **GetNextItem**

process all

ADT Unsorted List



Two implementations

Common vocabulary

location accesses a particular element
Node(location) is all data of element
Info(location) is the user's data at location
Info(last) is the user's data at the last location
Next(location) is the node following Node(location)

Specification

```
// SPECIFICATION FILE        ( unsortedType.h )
#include "ItemType.h"

class  UnsortedType     // declares a class data type
{
public :             // 8 public member functions
  UnsortedType();
  void MakeEmpty( );
  bool IsFull( ) const;
  int  GetLength( ) const;  // returns length of list
  void RetrieveItem( ItemType&  item, bool&  found );
  void InsertItem( ItemType  item );
  void DeleteItem( ItemType  item );
  void ResetList( );
  void GetNextItem( ItemType&  item );
}
```

What is ItemType?

Public declarations are the same for both implementations; only private data changes

Generic Data Type

- A type for which the operations are defined but the types of the items being manipulated are not defined
- *How can we make the items on the list generic?*
- List items are of class `ItemType,` which has a `ComparedTo` function that returns (`LESS`, `GREATER`, `EQUAL`)

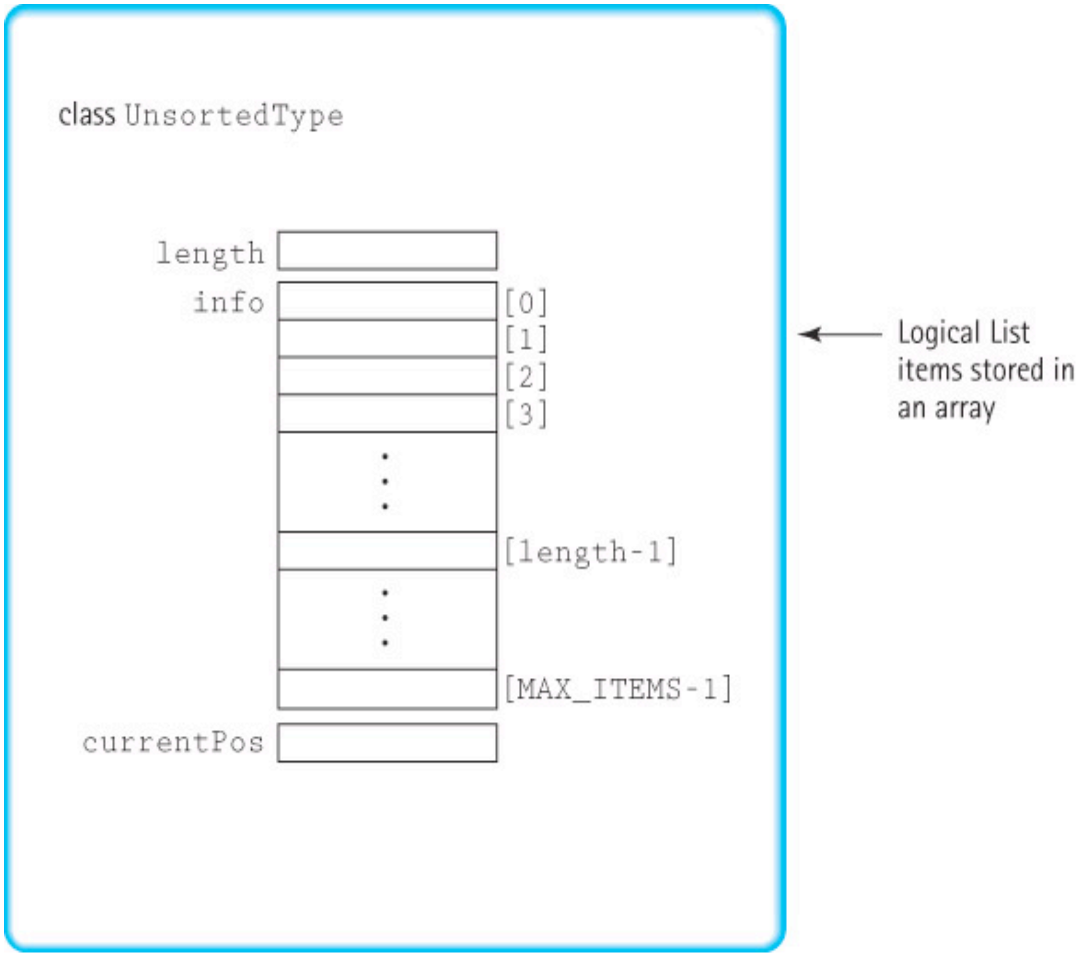
Array-Based Implementation

Private data members for array-based implementation

```
private
  int length;
  ItemType info[MAX_ITEMS];
  int currentPos;
};
```

Where does MAX_ITEMS come from?

Array-Based Implementation



Array-based implementation

Notice the difference between the array and the list stored in the array

Constructor

A special member function of a class that is implicitly invoked when a class object is defined

What should the constructor do?

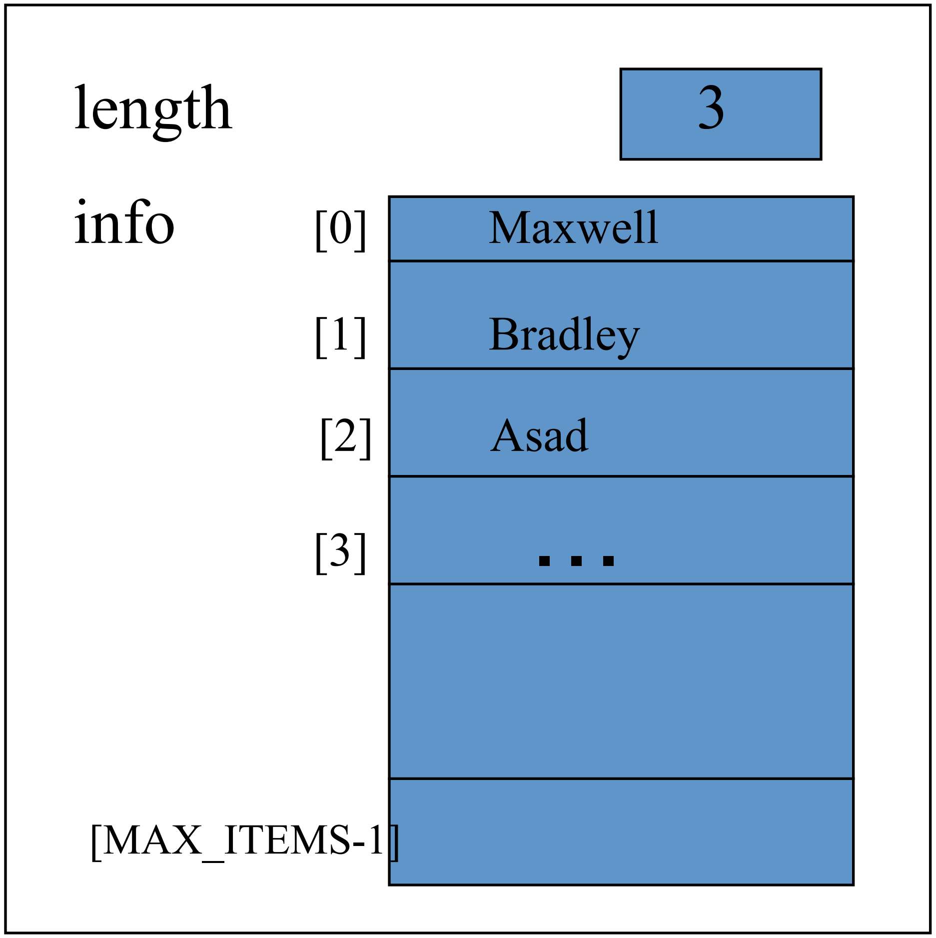
```
UnsortedType::UnsortedType()
{
 length = 0;
}
```

Checking for full and empty lists

- *What is a full list? An empty list?*

```
bool UnsortedType::IsFull()
  {
   return (length == MAX_ITEMS);
  }
bool UnsortedType::IsEmpty()
  {
   return (length == 0);
  }
```

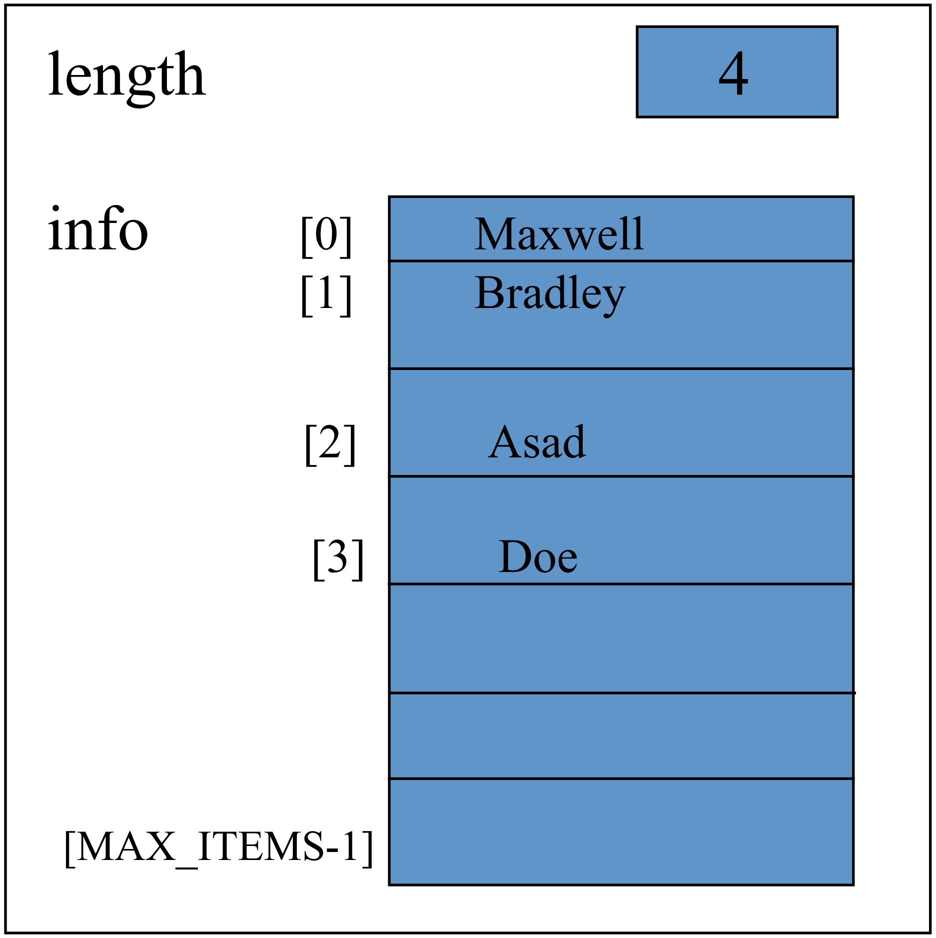
Insert



insert("Doe");

If the list is unsorted, where should the next element go ?

Insert



insert(“Doe");

That was easy! Can you code it ?

Insert

```
void UnsortedType::InsertItem(ItemType
item)
// Post: item is in the list.
{
  info[length] = item;
  length++;
}
```

RetrieveItem

How would you go about finding an item in the list?

Cycle through the list looking for the item

What are the two ending cases?

The item is found

The item is not in the list

How do we compare items?

We use function ComparedTo in class ItemType

Pseudocode for RetrieveItem

```
Initialize location to position of first item
Set found to false
Set moreToSearch to (have not examined Info(last))
while moreToSearch AND NOT found
    if (item.ComparedTo(Info(location))) == EQUAL)
      { Set found to true
        Set item to Info(location)
      }
      else
      {  Set location to Next(location)
        Set moreToSearch to (have not examined Info(last))
      }
```

Replace bold general statements with array-based code

C++ code for RetrieveItem

```
void UnsortedType::RetrieveItem(ItemType& item, bool& found)
// Pre:  Key member(s) of item is initialized.
// Post: If found, item's key matches an element's key in the
//       list and a copy of that element has been stored in item;
//       otherwise, item is unchanged.
{ bool moreToSearch;
  int location = 0;
  found = false;
  moreToSearch = (location < length);
  while (moreToSearch && !found){
    if (item.ComparedTo(info[location]) == EQUAL){
      found = true;
      item = info[location];}
     else {
       location++;
       moreToSearch = (location < length);
     }
   }
}
```

C++ code for RetrieveItem

```
void UnsortedType::RetrieveItem(ItemType& item, bool& found)
// Pre:  Key member(s) of item is initialized.
// Post: If found, item's key matches an element's key in the
//       list and a copy of that element has been stored in item;
//       otherwise, item is unchanged.
{
  bool moreToSearch;
  int location = 0;
  found = false;
  moreToSearch = (location < length);
  while (moreToSearch && !found)
  {
    if (item.ComparedTo(info[location]) == EQUAL)
    {found = true;
     item = info[location];
    }
    else
    { location++;
      moreToSearch = (location < length);
    }
   }
}
```

Loop invariant:
(location <= length) **and**
moreToSearch == (location < length) **and**
(!found → (ItemType.key **not in** Info [0..location-1])) **and**
found → ItemType.key == Info[location].key

Delete

How do you delete an item?

First you find the item

Yes, but how do you delete it?

Move those below it up one slot, or

Replace it with another item

What other item?

How about the item at info[length-1]?

C++ code for delete

```
void UnsortedType::DeleteItem ( ItemType  item )
// Pre: item’s key has been inititalized.
//   An element in the list has a key that matches item’s.
// Post: No element in the list has a key that matches item’s.
{
  int  location  =  0 ;
  while (item.ComparedTo (info[location])  !=  EQUAL)
    location++;
  // move last element into position where item was located
  info [location] = info [length - 1 ] ;
  length-- ;
}
```

Why don't we have to check for end of list?

C++ code for delete

```
void UnsortedType::DeleteItem ( ItemType  item )
// Pre: item's key has been inititalized.
//   An element in the list has a key that matches item's.
// Post: No element in the list has a key that matches item's.
{
  int  location  =  0 ;
  while (item.ComparedTo (info[location])  !=  EQUAL)
    location++;
  // move last element into position where item was located
  info [location] = info [length - 1 ] ;
  length-- ;
}
```

Loop invariant:
(location < length) **and**
(item.key **in** Info[location..length-1])

Why don't we have to check for end of list?

PrintList

```
void PrintList(ofstream& dataFile, UnsortedType list)
// Pre:  list has been initialized.
//       dataFile is open for writing.
// Post: Each component in list has been written.
//       dataFile is still open.
{
  int length;
  ItemType item;

  list.ResetList();
  length = list.GetLength();
  for (int counter = 1; counter <= length; counter++)
  {
    list.GetNextItem(item);
    item.Print(dataFile);
  }
}
```

How do ResetList and GetNextItem work?

ResetList and GetNextItem

```
void UnsortedType::ResetList ( )
// Pre:  List has been initialized.
// Post: Current position is prior to first element.
{
  currentPos  =  -1 ;
}
void UnsortedType::GetNextItem ( ItemType&  item )
// Pre:  List has been initialized. Current position is
   defined.
//       Element at current position is not last in list.
// Post: Current position is updated to next position.
//       item is a copy of element at current position.
{
  currentPos++  ;
  item = info [currentPos] ;
}
```

Class **ItemType**

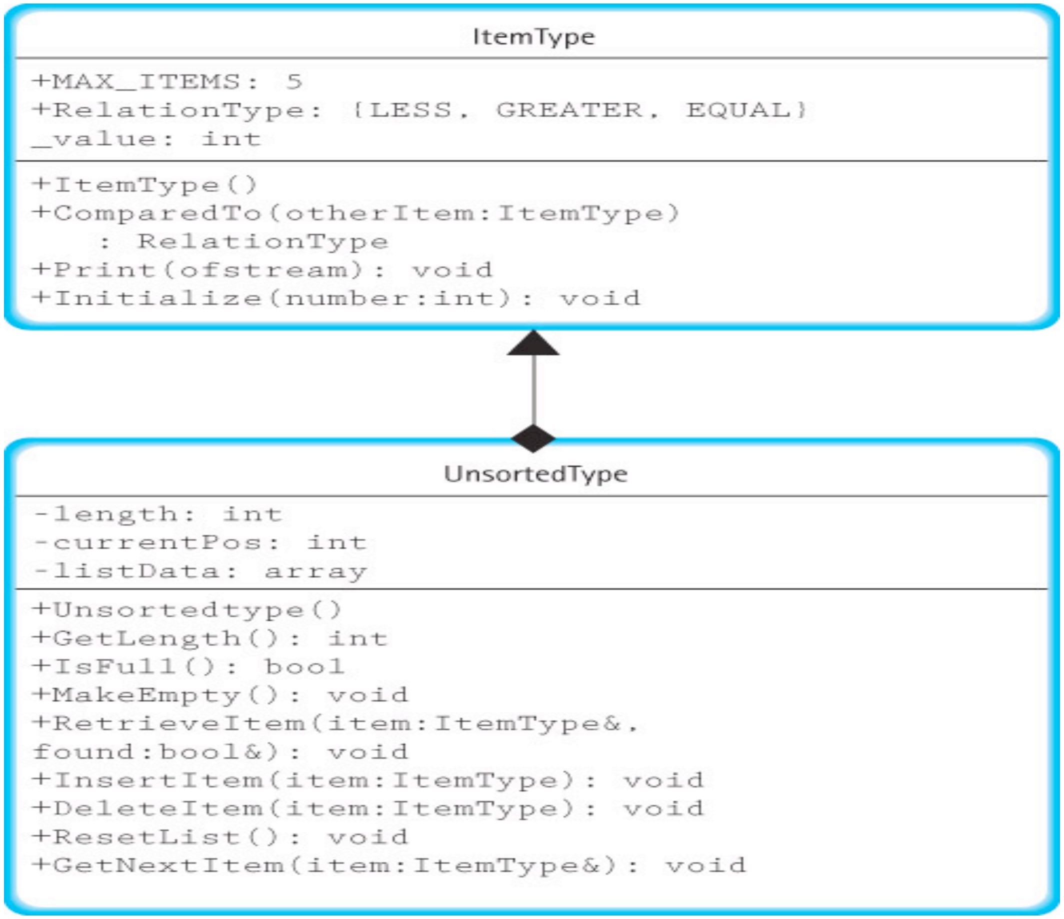
```
//  SPECIFICATION FILE itemtype.h

const int  MAX_ITEM = 5;
enum  RelationType { LESS, EQUAL, GREATER };

class  ItemType       // declares class data type
{
  public :          // 3 public member functions
  RelationType ComparedTo( ItemType )  const;
  void Print( )  const;
  void Initialize( int  number );

  private :         // one private data member
    int value;         // could be any type
} ;
```

Class ItemType

```
//  IMPLEMENTATION FILE ( itemtype.cpp )
//  Implementation depends on the  data type of value.

#include “itemtype.h”
#include <iostream>

RelationType ComparedTo( ItemType  otherItem ) const
{
  if ( value  <  otherItem.value )
    return  LESS;
  else if ( value  > otherItem.value )
    return  GREATER;
  else  return  EQUAL;
}
void Print( ) const
{
  using namespace std;
  cout  <<  value  <<  endl;
}
void Initialize( int number )
{
  value  =  number;
}
```

How would this class change if the items on the list were strings rather than integers?

UML Diagram


ItemType
+MAX_ITEMS: 5
+RelationType: {LESS, GREATER, EQUAL}
_value: int
+ItemType()
+ComparedTo(otherItem:ItemType)
: RelationType
+Print(ofstream): void
+Initialize(number:int): void
UnsortedType
-length: int
-currentPos: int
-listData: array
+Unsortedtype()
+GetLength(): int
+IsFull(): bool
+MakeEmpty(): void
+RetrieveItem(item:ItemType&,
found:bool&): void
+InsertItem(item:ItemType): void
+DeleteItem(item:ItemType): void
+ResetList(): void
+GetNextItem(item:ItemType&): void

Class **ItemType**

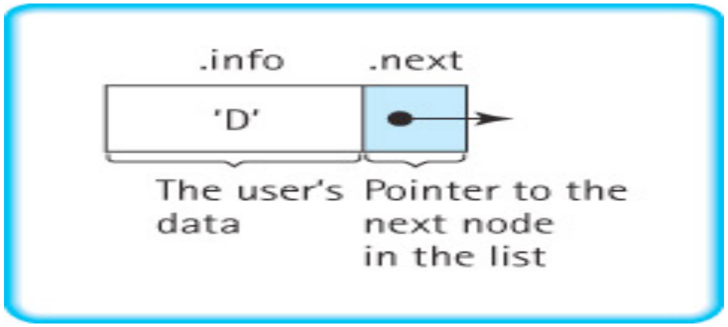
```
//  SPECIFICATION FILE itemtype.h

const int  MAX_ITEM = 5;
enum  RelationType { LESS, EQUAL, GREATER };

class  ItemType        // declares class data type
{
  public :          // 3 public member functions
  RelationType ComparedTo( ItemType )  const;
  void Print( )  const;
  void Initialize( int  number );

  private :         // one private data member
    int value;         // could be any type
} ;
```

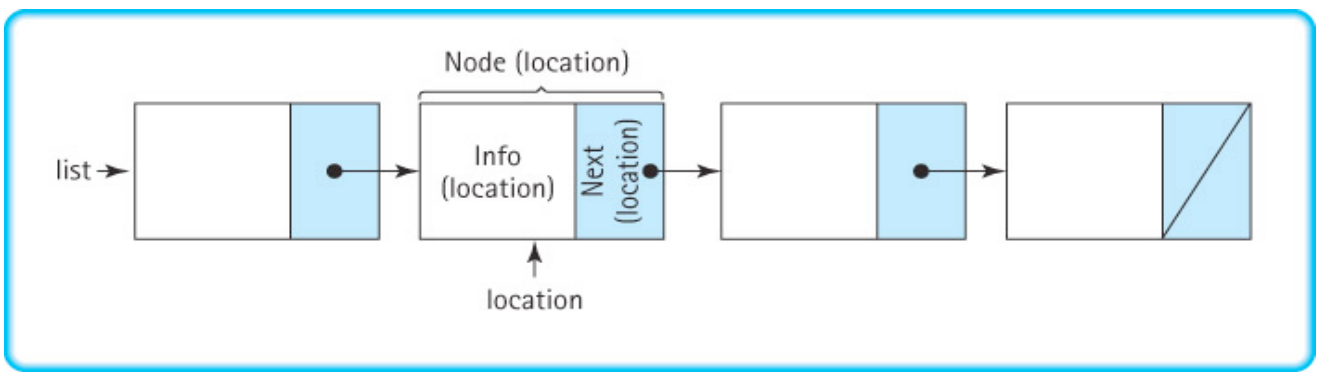
Class ItemType

```
//  IMPLEMENTATION FILE ( itemtype.cpp )
//  Implementation depends on the  data type of value.

#include “itemtype.h”
#include <iostream>

RelationType ComparedTo( ItemType  otherItem ) const
{
  if ( value  <  otherItem.value )
    return  LESS;
  else if ( value  > otherItem.value )
    return  GREATER;
  else  return  EQUAL;
}
void Print( ) const
{
  using namespace std;
  cout  <<  value  <<  endl;
}
void Initialize( int number )
{
  value  =  number;
}
```

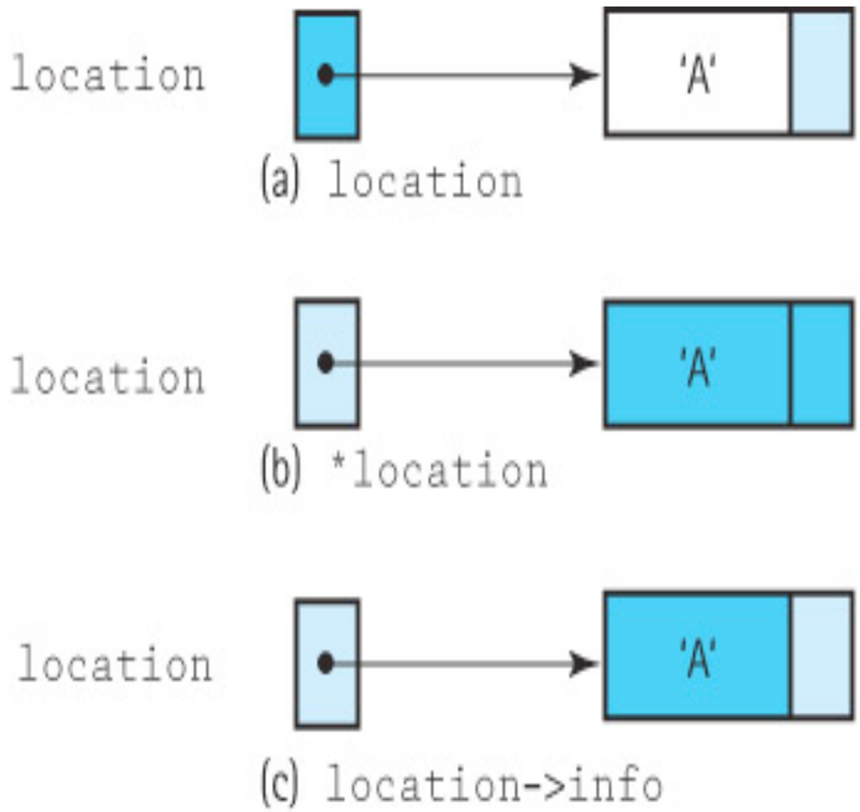
How would this class change if the items on the list were strings rather than integers?

Linked List Implementation of Unsorted List





Linked List Implementation



Be sure you understand the differences among `location`*,* `*location`*, and* `location->info`

Specification

```
// SPECIFICATION FILE      ( unsortedType.h )
#include "ItemType.h"
struct NodeType;

class  UnsortedType     // declares a class data type
{
public :             // 8 public member functions
  UnsortedType();
  void MakeEmpty( );
  bool IsFull( ) const;
  int  GetLength( ) const;  // returns length of list
  void RetrieveItem( ItemType&  item, bool&  found );
  void InsertItem( ItemType  item );
  void DeleteItem( ItemType  item );
  void ResetList( );
  void GetNextItem( ItemType&  item );
```

Linked List Implementation

Remember the design notation?

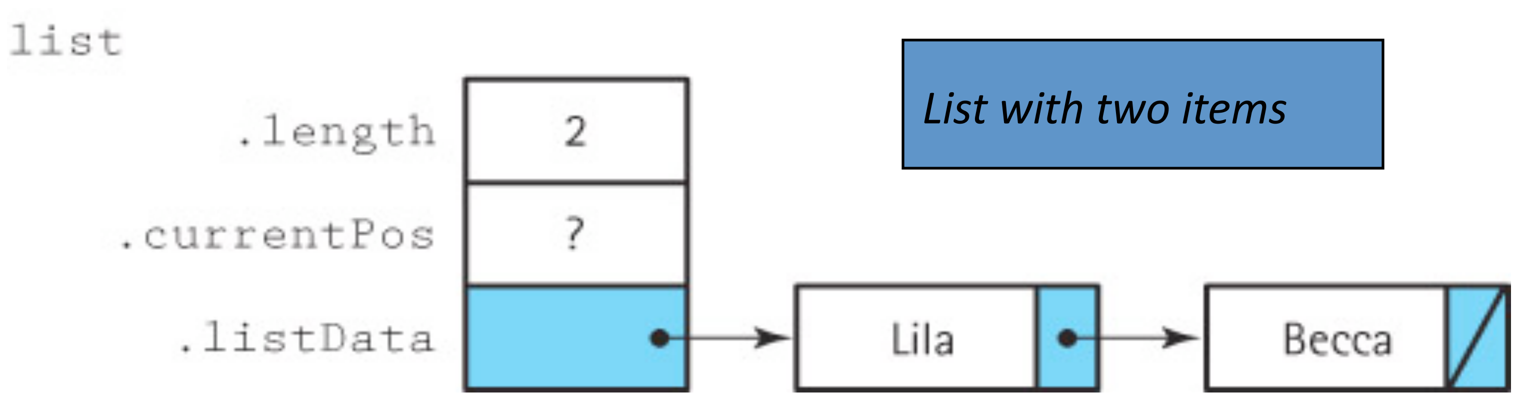
Node(location)	*location
Info(location)	location->info
Next(location)	location->next

How do you set location to Next (location)?

How do you set Info(location) to value?

Linked List Implementation (private part)

```
private:
  NodeType* listData;
  int length;
  NodeType* currentPos;

 struct  NodeType
  {
    ItemType Info;
    NodeType *next;
  }
```



Linked List Implementation

How do you know that a linked list is empty?

`listData` is `NULL`

What should the constructor do?

Set `length` to 0

Set `listData` to `NULL`

What about *`currentPos?`*

We let `ResetList` take care of initializing `currentPos`

Linked List Implementation

What about the observers `IsFull` and `GetLength`?

GetLength just returns length

Can a linked list ever be full?

Yes, if you run out of memory

Ask for a new node within a try/catch

Linked List Implementation of IsFull

```
bool Unsortedtype::IsFull() const
{
  NodeType* location;
  try
  {
    location = new NodeType;
    delete location;
    return false;
  }
  catch (std::bad_alloc exception)
  {
    return true;
  }
}
```

What about `MakeEmpty`?

Exceptions

An unusual, generally unpredictable event, detectable by software or hardware, that requires special processing; the event may or may note be erroneous

Three parts to an exception mechanism:

- **Define** the exception
- **Generate** (raising) the exception
- **Handling** the exception

Try, throw, and catch statements in C++

Exceptions

- An exception is an unusual situation that occurs when the program is running.
- Exception Management
  - Define the error condition
  - Enclose code containing possible error (try).
  - Alert the system if error occurs (throw).
  - Handle error if it is thrown (catch).

try, catch, and throw

```
Try
{
   // code that contains a possible error
   … throw string("An error has occurred in
   function …");


}
Catch (string message)
{
   std::cout << message << std::endl;
   return 1;
}
```

Linked List Implementation of MakeEmpty

```
void Unsortedtype::MakeEmpty()
{
  NodeType* tempPtr;
  while (listData != NULL)
  {
    tempPtr = listData;
    listData = listData->next;
    delete tempPtr;
  }
  length = 0;
}
```

Why can't we just set `listData` to NULL?

Linked List Implementation of RetrieveItem

```
Initialize location to position of first item
Set found to false
Set moreToSearch to (have not examined Info(last))
while moreToSearch AND NOT found
     if item.ComparedTo(Info(location)) == EQUAL
  { Set found to true;
    Set item to Info(location)
  }
  else
  {
    Set location to Next(location)
        Set moreToSearch to (have not examined Info(last))
  }
```

Replace bold general statements with linked list code

RetrieveItem

```
void  UnsortedType::RetrieveItem( ItemType&  item, bool&  found )
// Pre: Key member of item is initialized.
// Post: If found, item's key matches an element's key in the list
// and a copy of that element has been stored in item; otherwise,
//      item is unchanged.
{  bool  moreToSearch;
   NodeType*  location;
      location = listData;
   found = false ;
   moreToSearch = ( location  !=  NULL )
   while ( moreToSearch  &&  !found )
   {
        if  (item.ComparedTo(location->info) == EQUAL)
        { found = true;
      item  = location->info;
     }
     else
     { location = location->next;
       moreToSearch = ( location  !=  NULL );
        }
      }
}
```

Loop invariant:

(location == NULL or points to a node on the list) **and**
moreToSearch == (location != NULL) **and**
(!found → (ItemType.key **not in** list prior to location) **and**
found → ItemType.key == Info[location].key

InsertItem

How do we add a node to our list?

Get a node using `new`

```
location = new NodeType
```

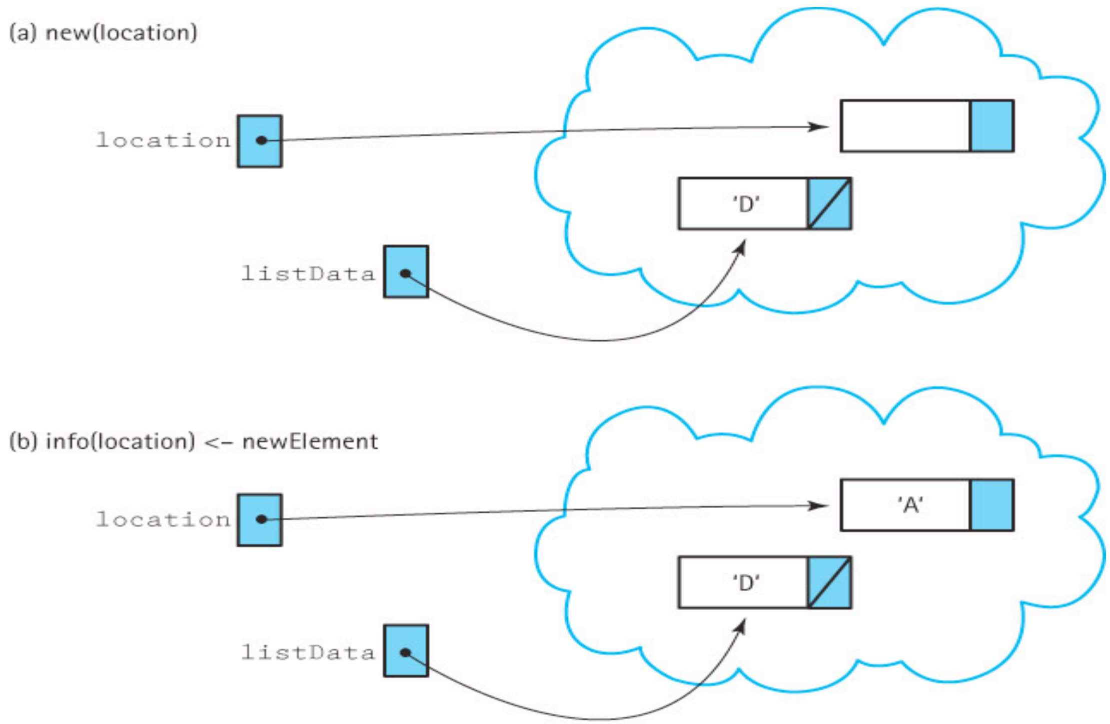
Put value into info portion

```
location->info = Item
```

Put node into list …

Where? Where should the node go?
Does it matter?

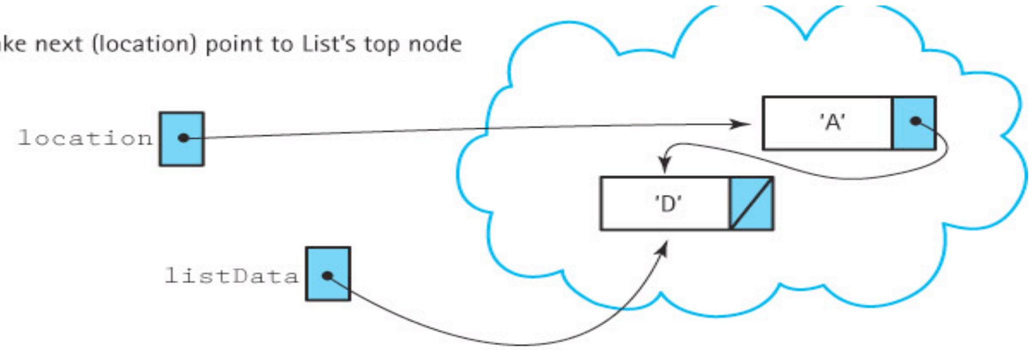
InsertItem



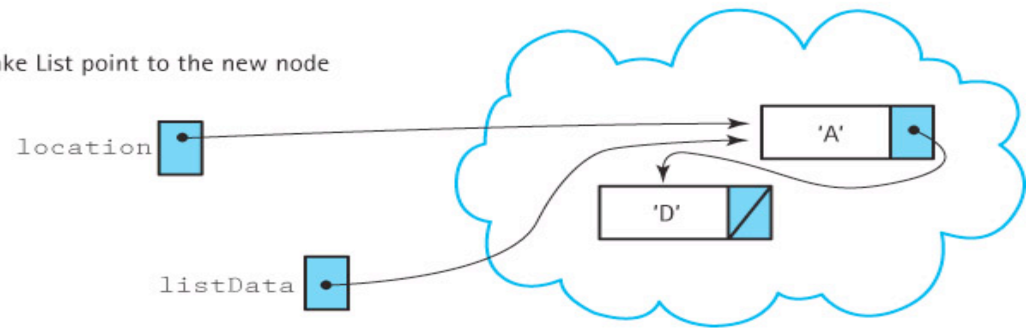
Now we must put the two parts together--carefully!

InsertItem

(c) Make next (location) point to List's top node



(d) Make List point to the new node



These steps must be done in this order! Why?

InsertItem Implementation

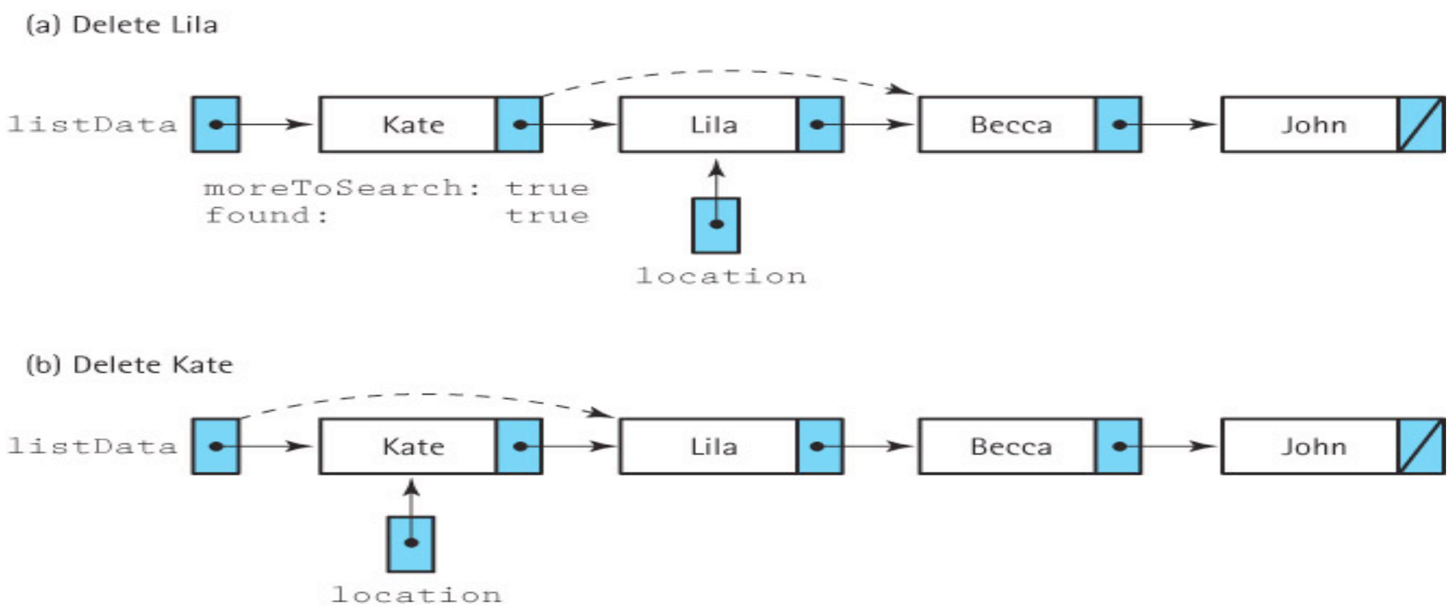
```
void UnsortedType::InsertItem ( ItemType  item )
// Pre: list is not full and item is not in list.
// Post: item is in the list; length has been incremented.
{
  NodeType* location;
   // obtain and fill a node
  location = new  NodeType<ItemType>;
  location->info = item;
  location->next = listData;
  listData = location;
  length++;
}
```

DeleteItem

How do you delete an item?

Find the item

Remove the item



Linked List Implementation of DeleteItem

```
void UnsortedType::DeleteItem(ItemType item)
//Pre: item's key has been initialized and an element in the list has a key that
    matches item's
//Post: No element in the list has a key that matches item's
{ NodeType* location = listData;
 NodeType* tempLocation;
 // Find the item
 if (item.ComparedTo(listData->info) == EQUAL)
 { // item in first location
   tempLocation = location;
   listData = listData->next;
 }
 else
 {
  while (item.ComparedTo((location->next)->info) != EQUAL)
        location = location->next;
    tempLocation = location->next;
    location->next = (location ->next)->next;
 }
delete tempLocation;
length--;
}
```

Loop invariant:
(location points to a node on list) **and** (item.key **in** remainder of list)

Linked Implementation

ResetList and GetNextItem

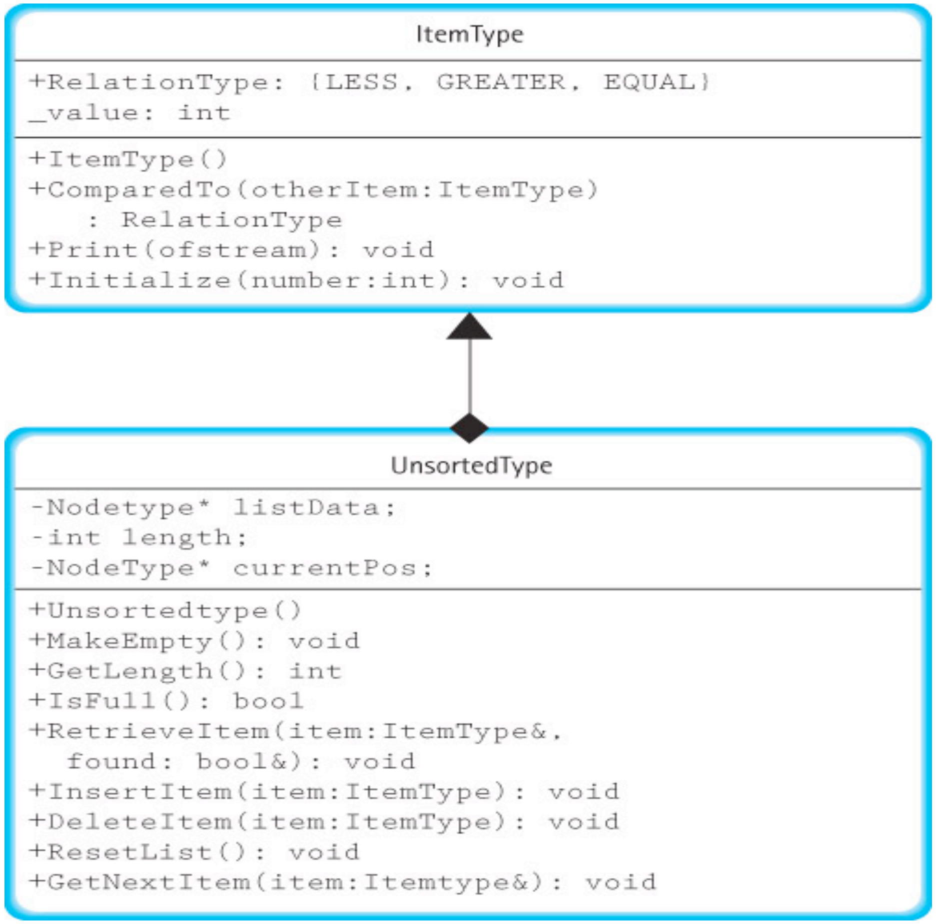
What was `currentPos` *in the array-based implementation?*

What would be the equivalent in a linked implementation?

ResetList and GetNextItem

```
void UnsortedType::ResetList()
// Pre: List has been initialized.
// Post: Current position is prior to first element.
{
  currentPos = NULL;
}
void UnsortedType::GetNextItem(ItemType& item)
// Pre:  List has been initialized. Current position is
   defined.
//       Element at current position is not last in list.
// Post: Current position is updated to next position.
//        item is a copy of element at current position.
{
  if (currentPos == NULL)
    currentPos = listData;
  else
    currentPos = currentPos->next;
  item = currentPos->info;
}
```

UML Diagram



Note the differences between the UML Diagrams for the two implementations

C++ concepts to come

Exceptions

Deep vs. shallow copying

Constructor, destructor, copy constructor