CSE 2017 Data Structures and Lab

Lecture #6: List Plus

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ADT Sorted List Operations

Transformers

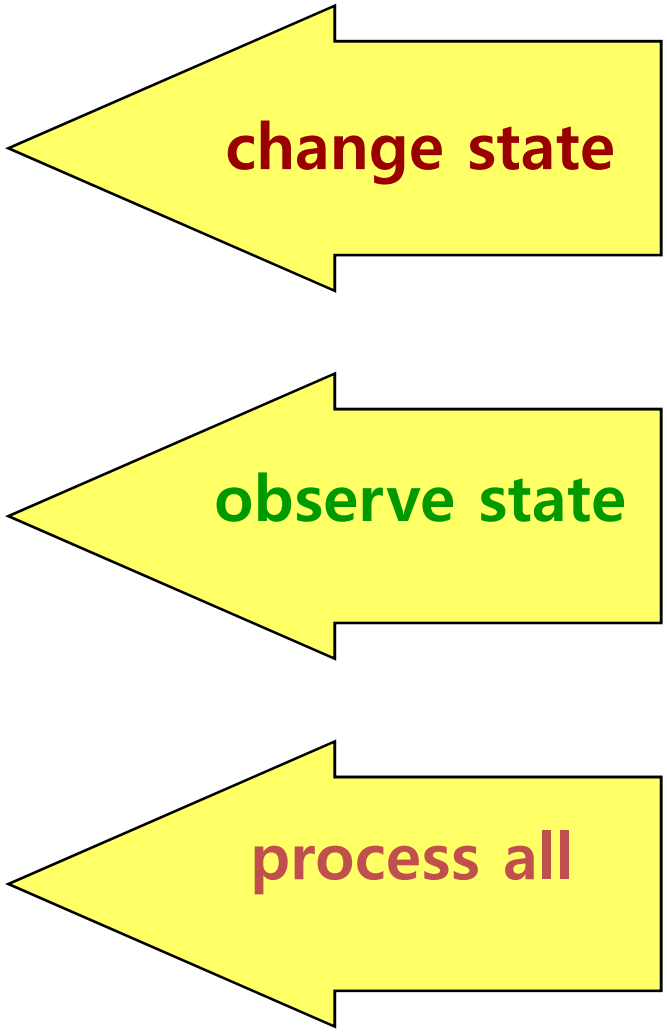
- MakeEmpty
- InsertItem
- DeleteItem

Observers

- IsFull
- LengthIs
- RetrieveItem

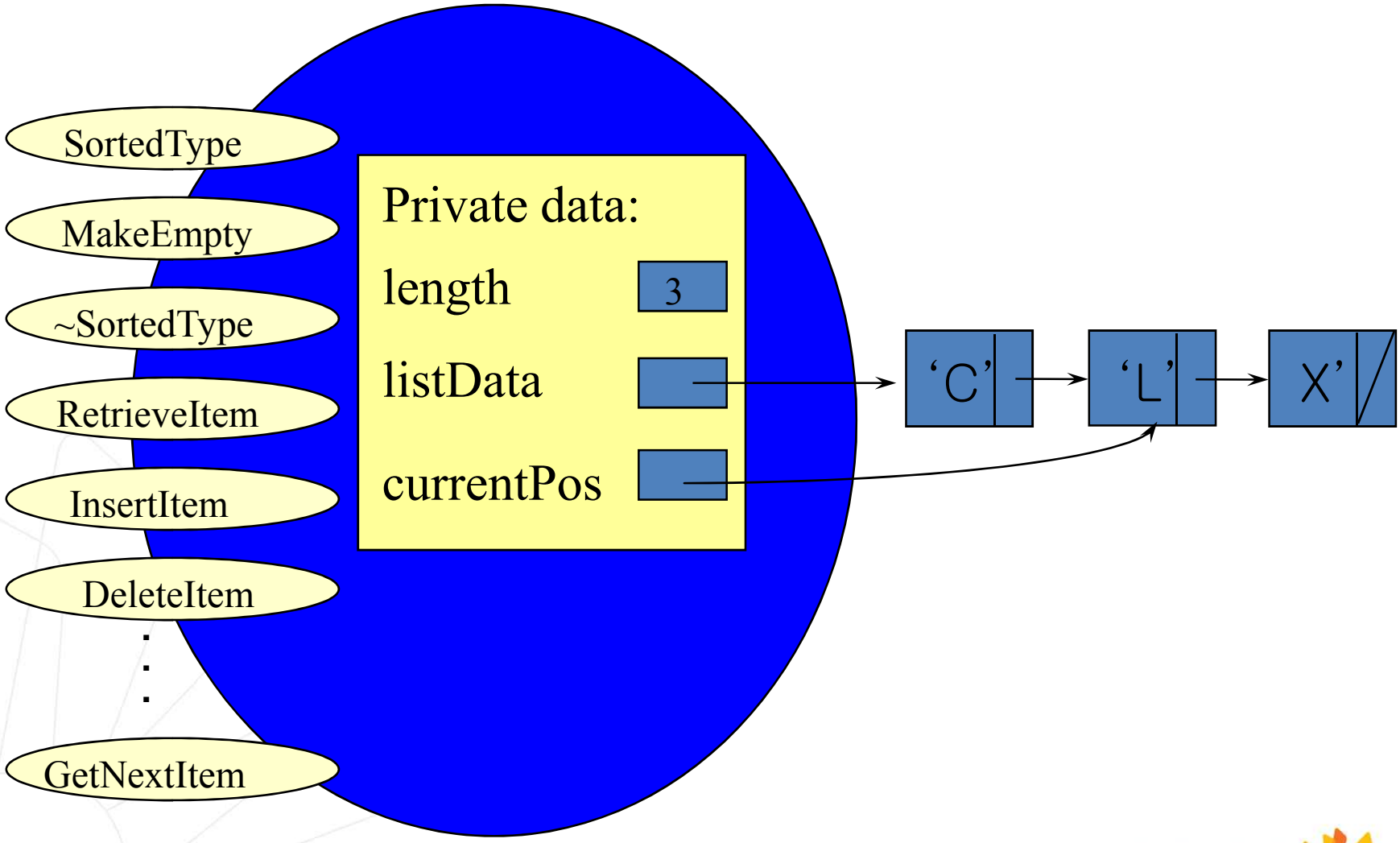
Iterators

- ResetList
- GetNextItem



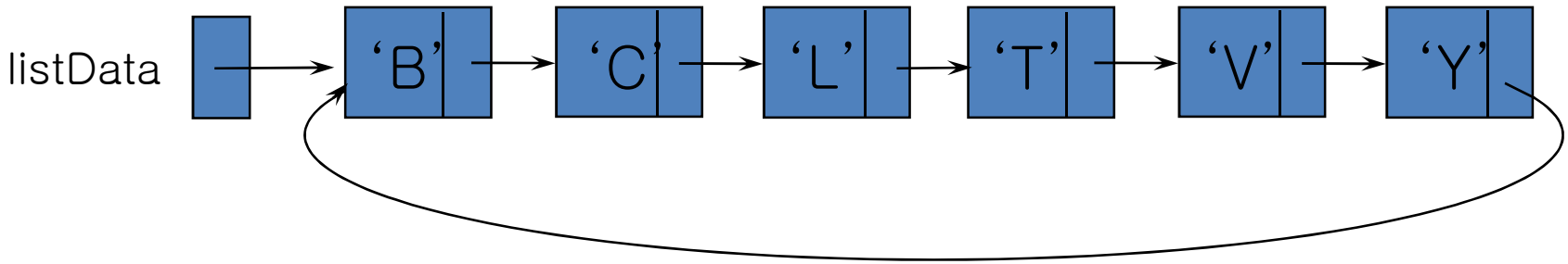
ADT Sorted List Operations

- `class SortedType<char>`



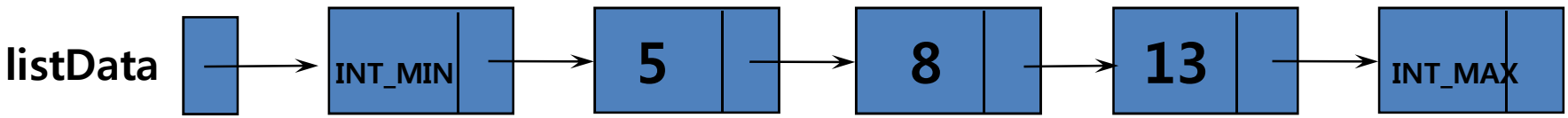
What is a Circular Linked List?

- A circular linked list is a list in which every node has a successor; the "last" element is succeeded by the "first" element.



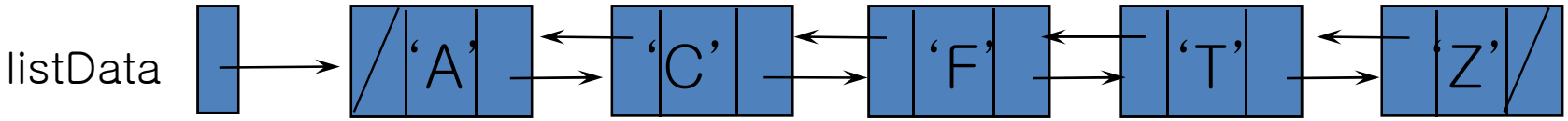
What are Header and Trailer Nodes?

- A Header Node is a node at the beginning of a list that contains a key value smaller than any possible key.
- A Trailer Node is a node at the end of a list that contains a key larger than any possible key.
- Both header and trailer are placeholding nodes used to simplify list processing.



What is a Doubly Linked List?

- A doubly linked list is a list in which each node is linked to both its successor and its predecessor.



Each node contains two pointers

```
template< class  ItemType >
struct   NodeType  {
    ItemType       info;                    // Data member
    NodeType<ItemType>*  back;   // Pointer to predecessor
    NodeType<ItemType>*  next;   // Pointer to successor
};
```

3000	'A'	NULL
.back	.info	.next

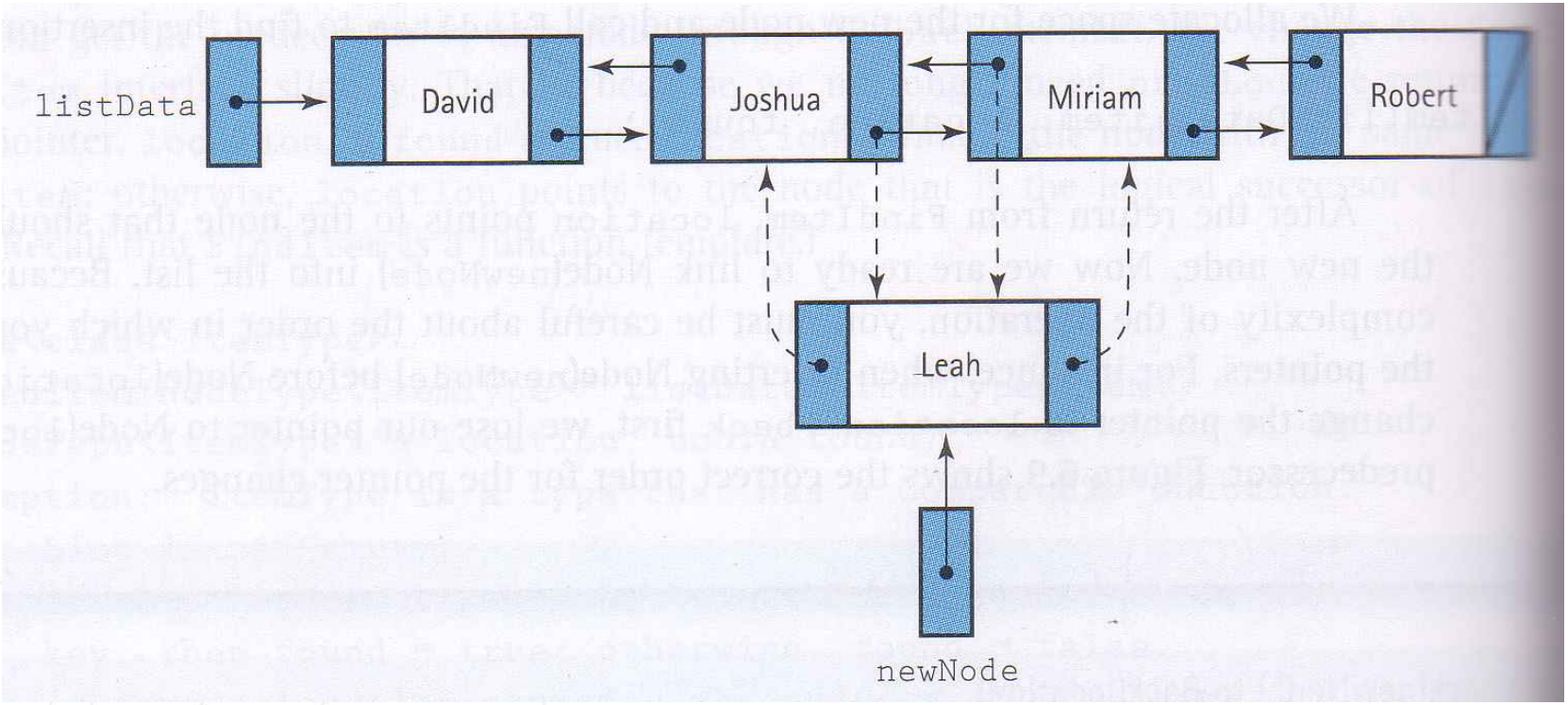
Doubly Linked List

```
template<class ItemType>
struct NodeType;
class DoublyLinkedType {
 public:
    DoublyLinkedType(int);
     ~DoublyLinkedType();
    void MakeEmpty();
    void FindItem(ItemType item, bool& found)
    void Replace(ItemType Newitem)
    bool IsEmpty() const;
    bool IsFull() const;
    void Insert(ItemType);
    void Delete(ItemType&);
    void Reverse();
 private:
    NodeType<ItemType> * listData, cursor;
    int length;
};
```

Find an Item in a Doubly Linked List

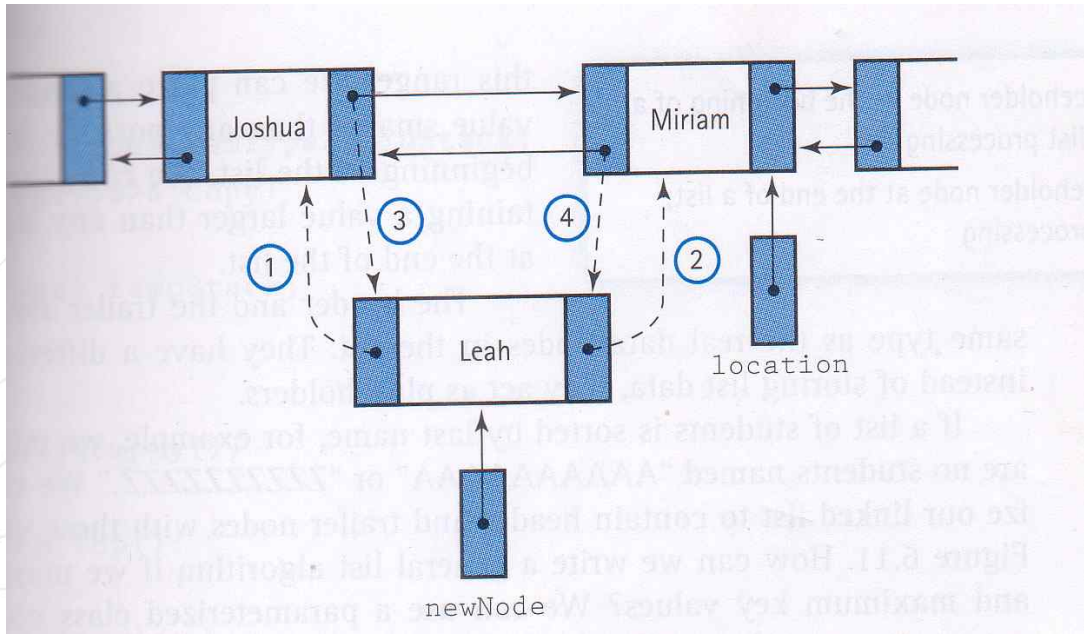
```
template<class ItemType>
void DoublyLinkedType::FindItem(ItemType item, bool& found)
  {
    NodeType<ItemType> * location;
    location = listData;
    bool moreToSearch = true;
    found = false;
    while (moreToSearch && !found) {
        if (item.CompareTo(location->info) == LESS)
            moreToSearch = false;
        else if (item.CompareTo(location->info) == EQUAL)
            found = true;
        else {
            location = location->next;
            moreToSearch = (location != NULL);
        }
    }
}
```

Insert a New Node



Insert a New Node

```
template<class ItemType>
void DoublyLinkedType::Insert(ItemType New) {
     NodeType<ItemType> newNode = NodeType();
     newNode->back = cursor;    // step 1
     newNode->next = cursor->next; // step 2
     cursor->next = newNode; // step 3
     cursor->next->back = newNode; // step 4
     cursor = newNode;
}
```



Delete from Doubly Linked List

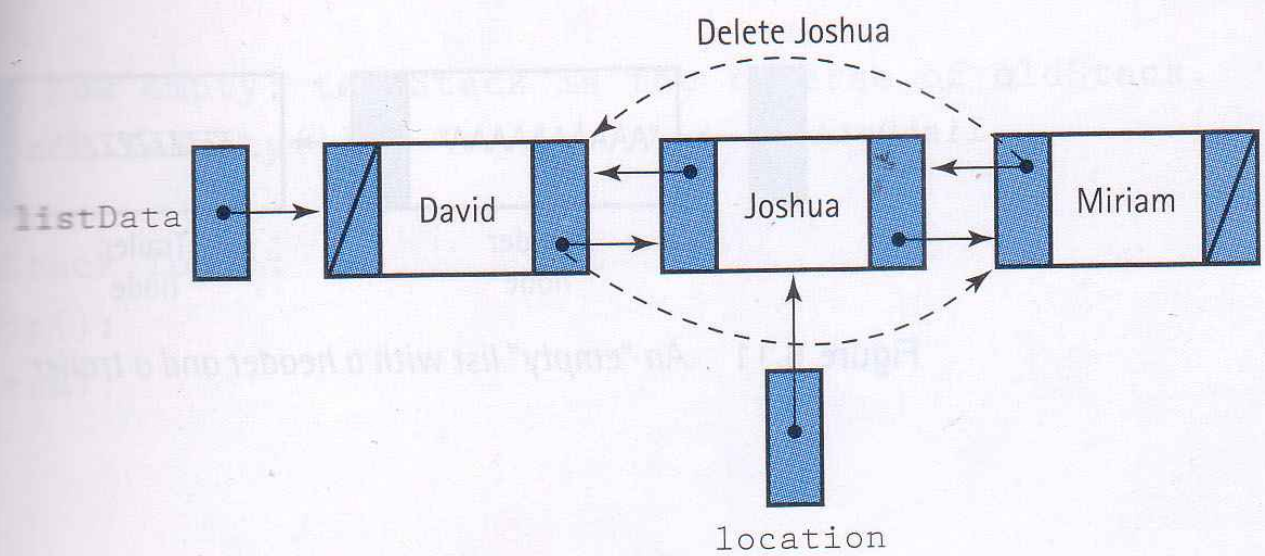


Figure 6.10 *Deleting from a doubly linked list*

Delete from Doubly Linked List

```
template<class ItemType>
void DoublyLinkedType::Delete(ItemType &Item) {
     Item = cursor->info;
     cursor->back->next = cursor->next; // step 1
     cursor->next->back = cursor->back; // step 2
     cursor = cursor->next;
}
```

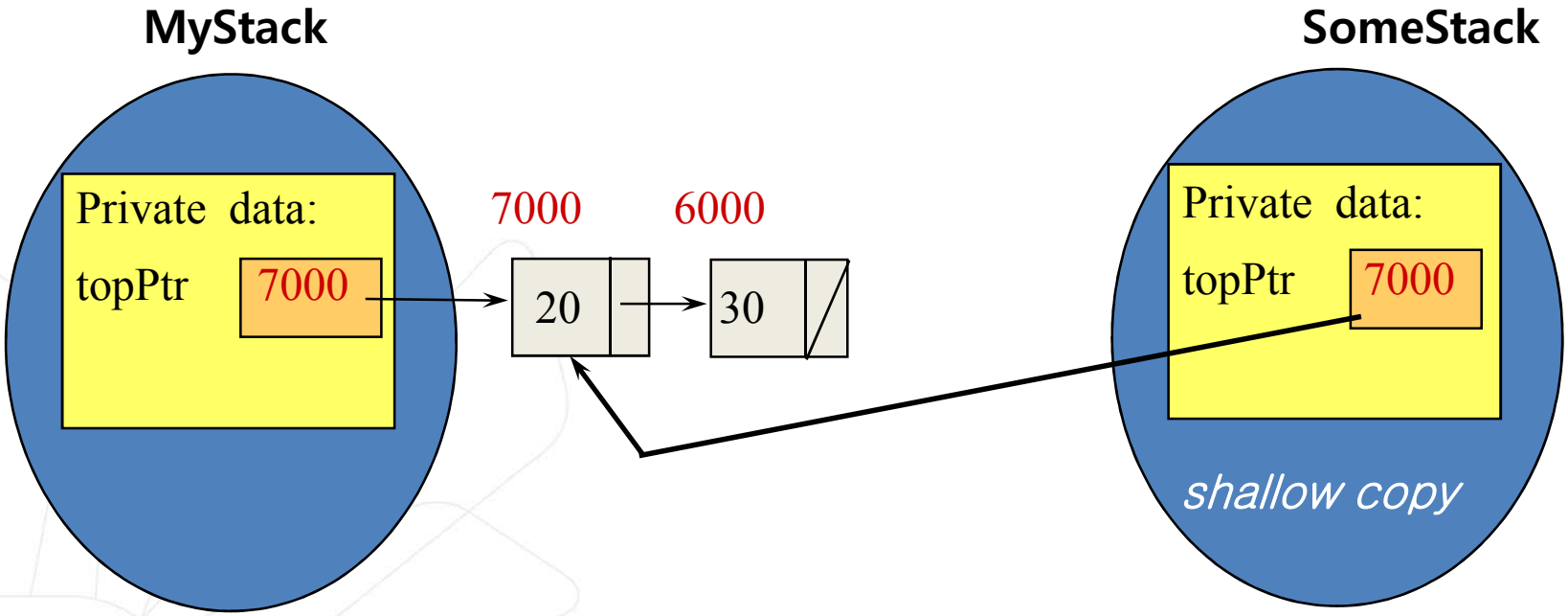
Passing a class object by value

- When a function is called that uses **pass by value** for a class object like our dynamically linked stack?

```
  // FUNCTION CODE
template<class ItemType>
void  MyFunction( StackType<ItemType> SomeStack )
  // Uses pass by value
{
        .
                .
        .
        .
}
```

Pass by value makes a shallow copy

```
StackType<int>   MyStack;          //  CLIENT CODE
      .
      .
      .
MyFunction( MyStack );             //  function call
```



Shallow Copy vs. Deep Copy

- ***A shallow copy*** **copies only the class data members, and does not copy any pointed-to data.**

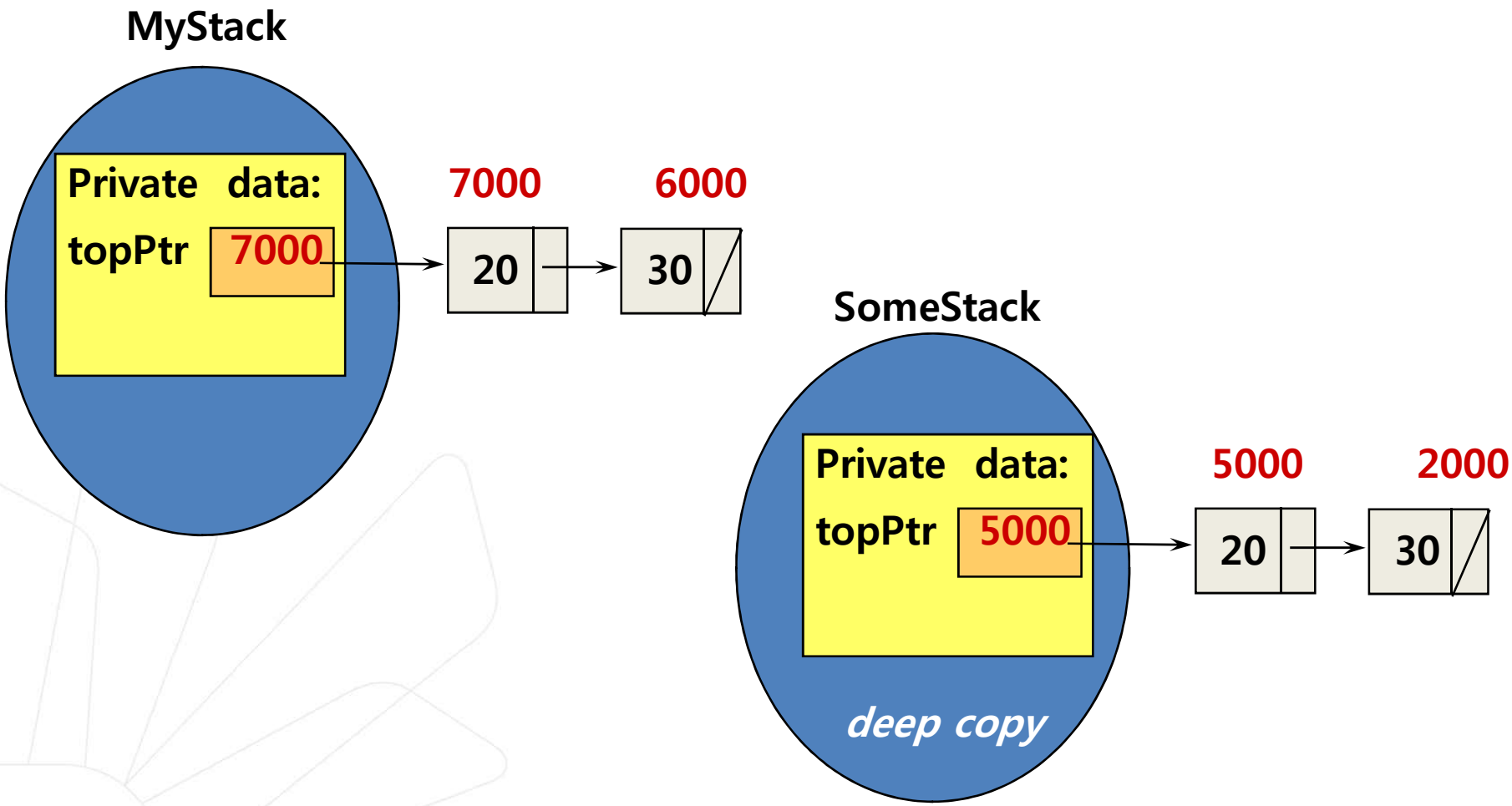
- ***A deep copy*** **copies not only the class data members, but also makes separately stored copies of any pointed-to data.**

What's the difference?

- *A shallow copy* shares the pointed to data with the original class object.

- *A deep copy* stores its own copy of the pointed to data at different locations than the data in the original class object.

Making a deep copy



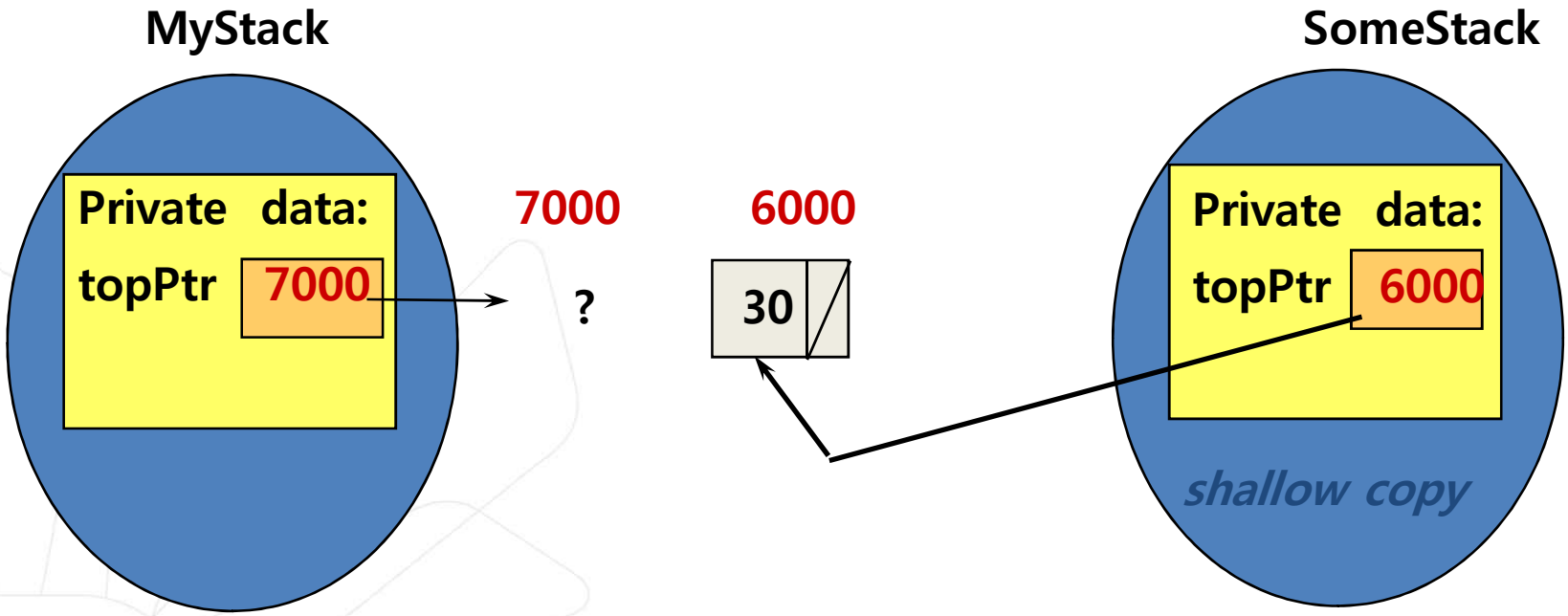
Suppose MyFunction Uses Pop

```
 // FUNCTION CODE
template<class ItemType>
void  MyFunction( StackType<ItemType> SomeStack )
 // Uses pass by value
{
      ItemType  item;
      SomeStack.Pop(item);
            .
      .
      .
}
```

WHAT HAPPENS IN THE SHALLOW COPY SCENARIO?

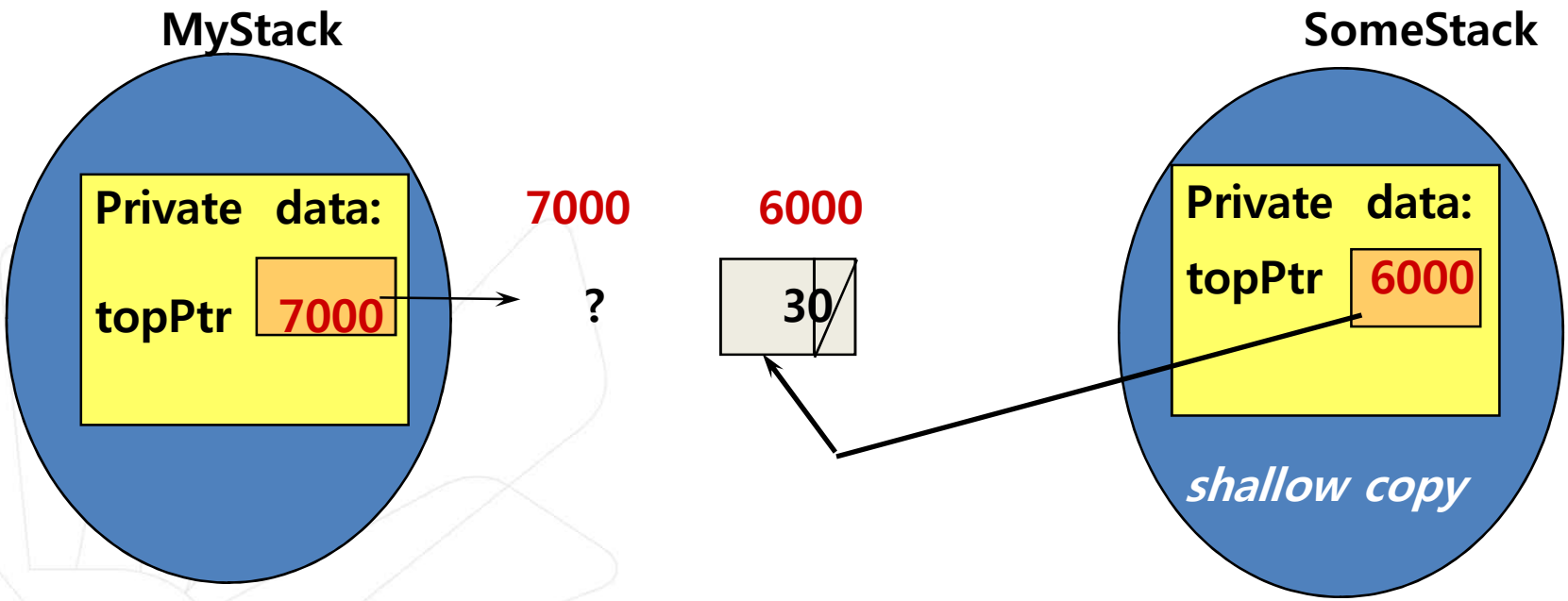
MyStack.topPtr is left dangling

```
StackType<int>   MyStack;        // CLIENT CODE
      .
      .
      .
MyFunction( MyStack );
```



MyStack.topPtr is left dangling

NOTICE THAT NOT JUST FOR THE SHALLOW COPY, BUT ALSO FOR ACTUAL PARAMETER MyStack, THE DYNAMIC DATA HAS CHANGED!



As a result . . .

- This default method used for pass by value is not the best way when a data member pointer points to dynamic data.

- Instead, you should write what is called a copy constructor, which makes a deep copy of the dynamic data in a different memory location.

More about copy constructors

- When there is a copy constructor provided for a class, the copy constructor is used to make copies for pass by value.
- You do not call the copy constructor.
- Like other constructors, it has no return type.
- Because the copy constructor properly defines pass by value for your class, it must use pass by reference in its definition.

Copy Constructor

- Copy constructor is a special member function of a class that is implicitly called in these three situations:
  - passing object parameters by value,
  - initializing an object variable in a declaration,
  - returning an object as the return value of a function.

```
// DYNAMICALLY LINKED IMPLEMENTATION OF STACK

template<class ItemType>
class StackType  {
public:
  StackType( );
        // Default constructor.
        // POST:  Stack is created and empty.
  StackType( const StackType<ItemType>& anotherStack );
        // Copy constructor.
        // Implicitly called for pass by value.

  .
  .
  .
  ~StackType( );
        // Destructor.
        // POST: Memory for nodes has been deallocated.
private:
  NodeType<ItemType>*  topPtr ;
};
```

Classes with Data Member Pointers Need

CLASS CONSTRUCTOR

CLASS COPY CONSTRUCTOR

CLASS DESTRUCTOR

```
template<class ItemType>          // COPY CONSTRUCTOR
StackType<ItemType>::
StackType( const StackType<ItemType>& anotherStack )
{ NodeType<ItemType>* ptr1 ;
  NodeType<ItemType>* ptr2 ;
  if ( anotherStack.topPtr == NULL )
        topPtr = NULL ;
  else                        // allocate memory for first node
  {     topPtr = new NodeType<ItemType> ;
        topPtr->info = anotherStack.topPtr->info ;
        ptr1 = anotherStack.topPtr->next ;
        ptr2 = topPtr ;
        while ( ptr1 != NULL )      // deep copy other nodes
        {       ptr2->next = new NodeType<ItemType> ;
                ptr2 = ptr2->next ;
                ptr2->info = ptr1->info ;
                ptr1 = ptr1->next ;
        }
        ptr2->next = NULL ;
27 }
}
```

What about the assignment operator?

- The **default method** used for assignment of class objects makes a **shallow copy**.

- If your class has a data member pointer to dynamic data, you should write a member function to **overload the assignment operator to make a deep copy** of the dynamic data.

```
// DYNAMICALLY LINKED IMPLEMENTATION OF STACK

template<class ItemType>
class StackType  {
public:
  StackType( );
        // Default constructor.
  StackType( const StackType<ItemType>& anotherStack );
        // Copy constructor.
  void  operator= ( StackType<ItemType> );
        // Overloads assignment operator.

  .
  .
  .

  ~StackType( );
        // Destructor.
private:
  NodeType<ItemType>*  topPtr ;
};
```

C++ Operator Overloading Guides

1. All operators except these :: . sizeof ?: may be overloaded.
2. At least one operand must be a class instance.
3. You cannot change precedence, operator symbols, or number of operands.
4. Overloading ++ and -- requires prefix form use by default, unless special mechanism is used.
5. To overload these operators = ( ) [ ] member functions (not friend functions) must be used.
6. An operator can be given multiple meanings if the data types of operands differ.

Using Overloaded Binary operator+

When a Member Function was defined

```
myStack + yourStack

myStack.operator+(yourStack)
```

When a Friend Function was defined

```
myStack + yourStack

operator+(myStack, yourStack)
```

Object-Oriented Design:

- Composition
- Inheritance
- …

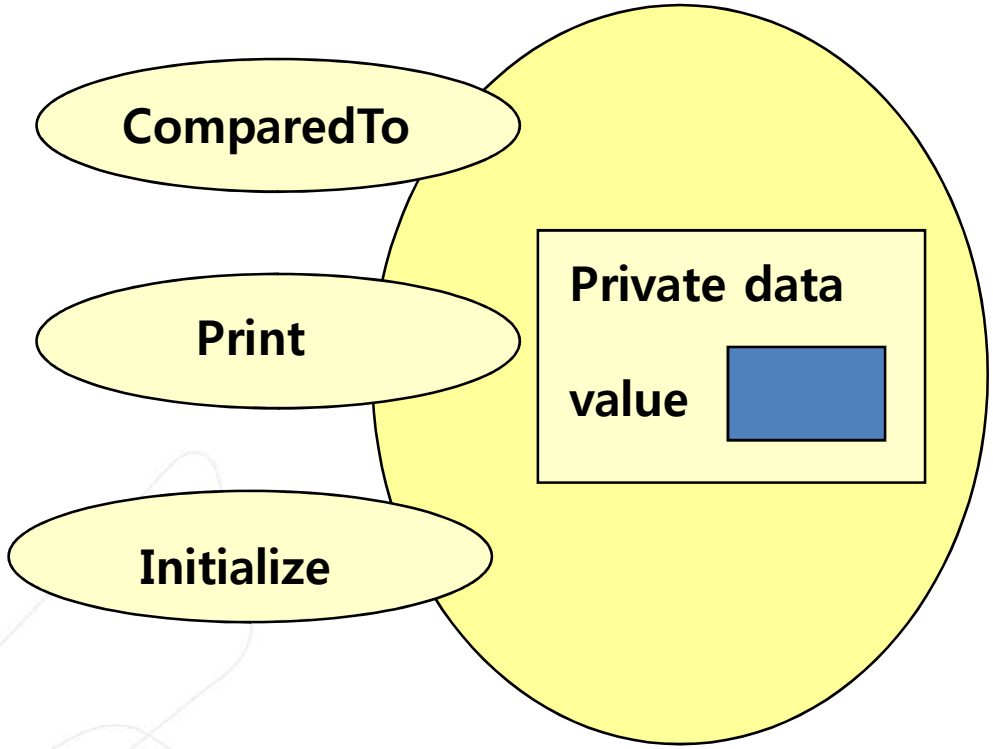
Composition (containment)

- **Composition (or containment) means that an internal data member of one class is defined to be an object of another class type.**

A FAMILIAR EXAMPLE . . .

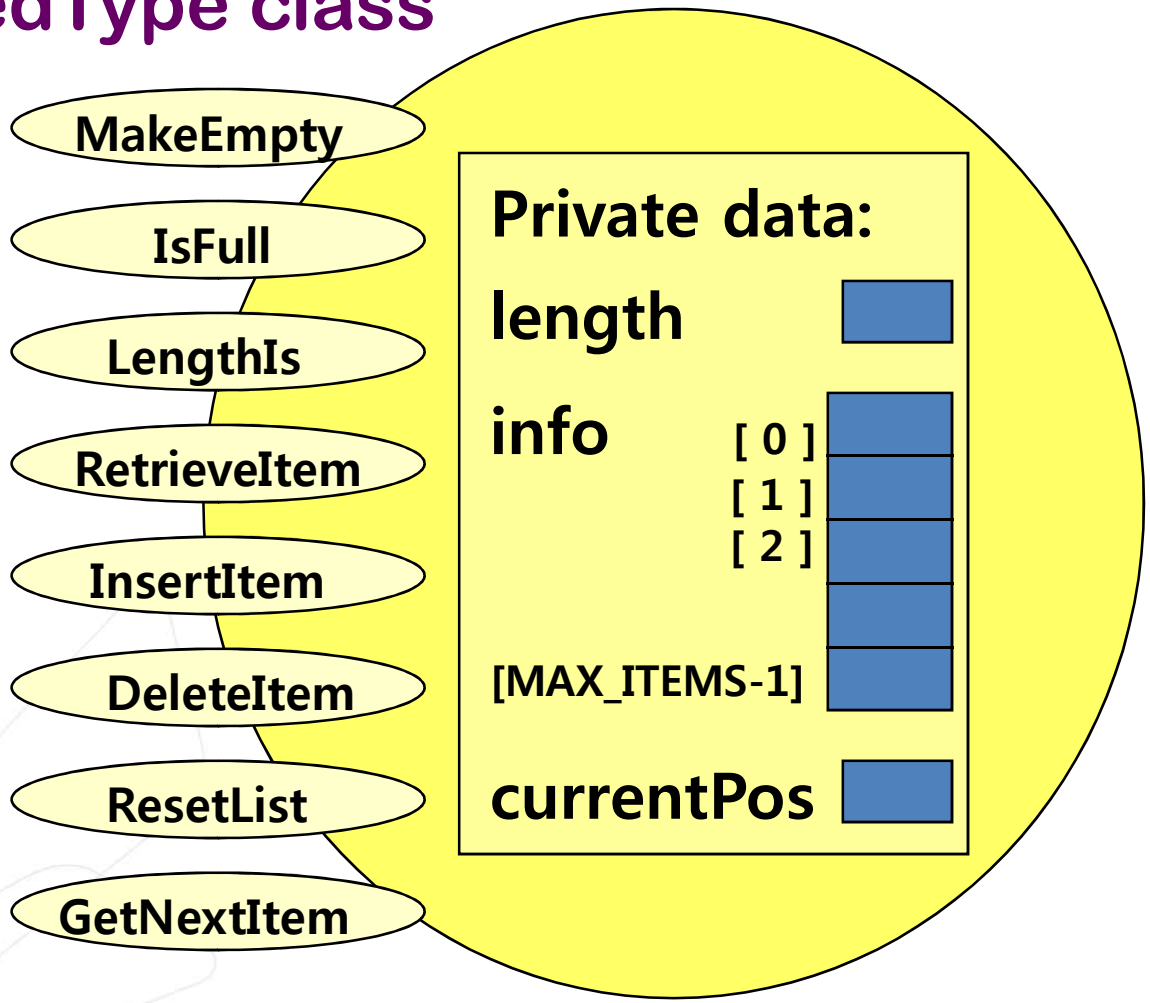
ItemType Class Interface Diagram

class ItemType



Sorted list contains an array of ItemType

SortedType class



Inheritance

- Inheritance is a means by which one class acquires the properties--both data and operations--of another class.
- When this occurs, the class being inherited from is called the Base Class.
- The class that inherits is called the Derived Class.

AN EXAMPLE . . .

Recall Definition of Queue

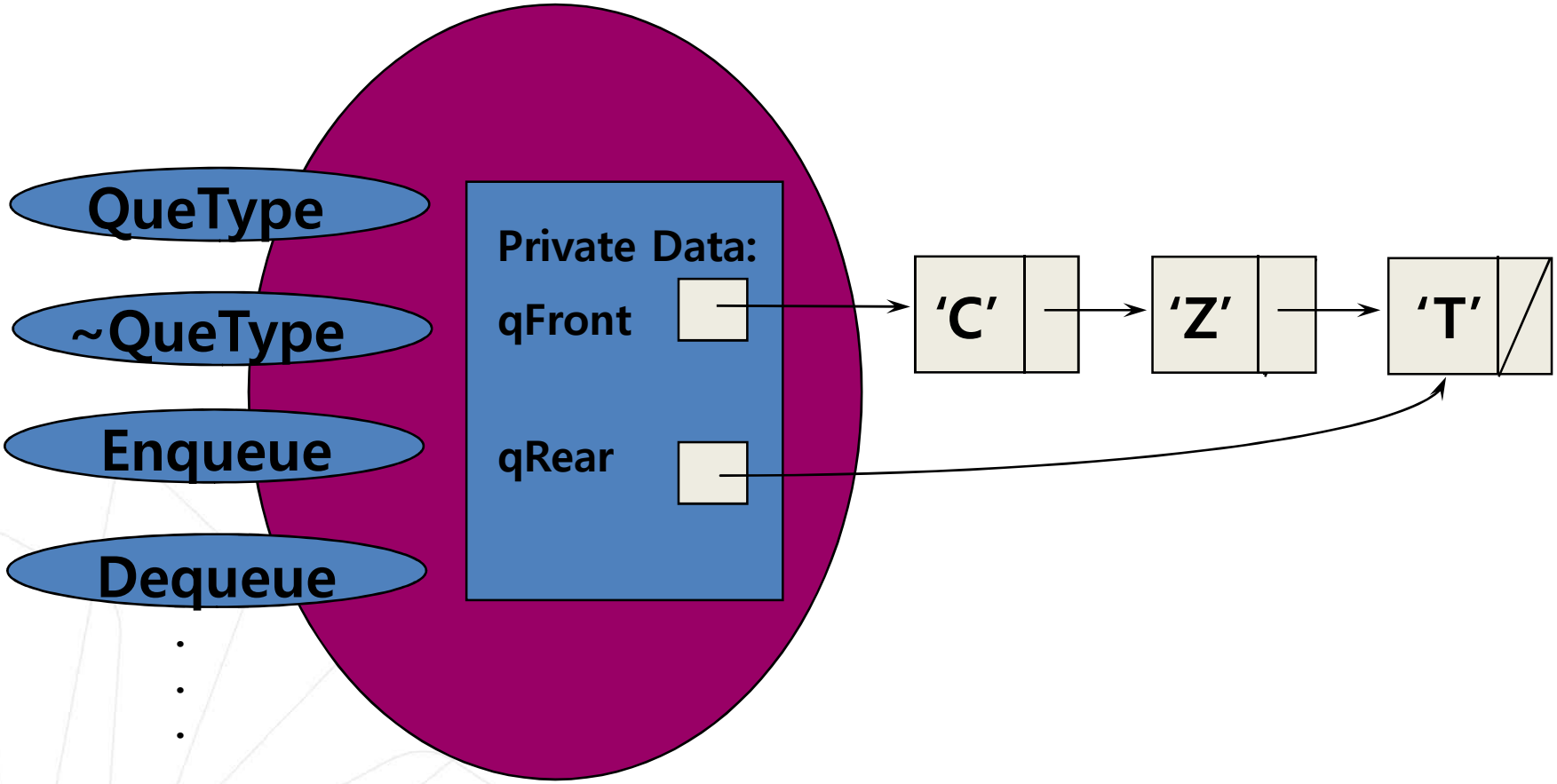
- *Logical (or ADT) level:* A queue is an ordered group of homogeneous items (elements), in which new elements are added at one end (the rear), and elements are removed from the other end (the front).

- A queue is a FIFO "first in, first out" structure.

Queue ADT Operations

- **MakeEmpty** -- Sets queue to an empty state.
- **IsEmpty** -- Determines whether the queue is currently empty.
- **IsFull** -- Determines whether the queue is currently full.
- **Enqueue (ItemType newItem)** -- Adds newItem to the rear of the queue.
- **Dequeue (ItemType& item)** -- Removes the item at the front of the queue and returns it in item.

class QueType<char>



```
// DYNAMICALLY LINKED IMPLEMENTATION OF QUEUE

#include "ItemType.h"        // for ItemType

template<class ItemType>
class QueType  {
public:
  QueType( );                // CONSTRUCTOR
  ~QueType( ) ;              // DESTRUCTOR
  bool IsEmpty( ) const;
  bool IsFull( ) const;
  void Enqueue( ItemType item );
  void Dequeue( ItemType&  item );
  void MakeEmpty( );
private:
  NodeType<ItemType>*  qFront;
  NodeType<ItemType>*  qRear;
};
```

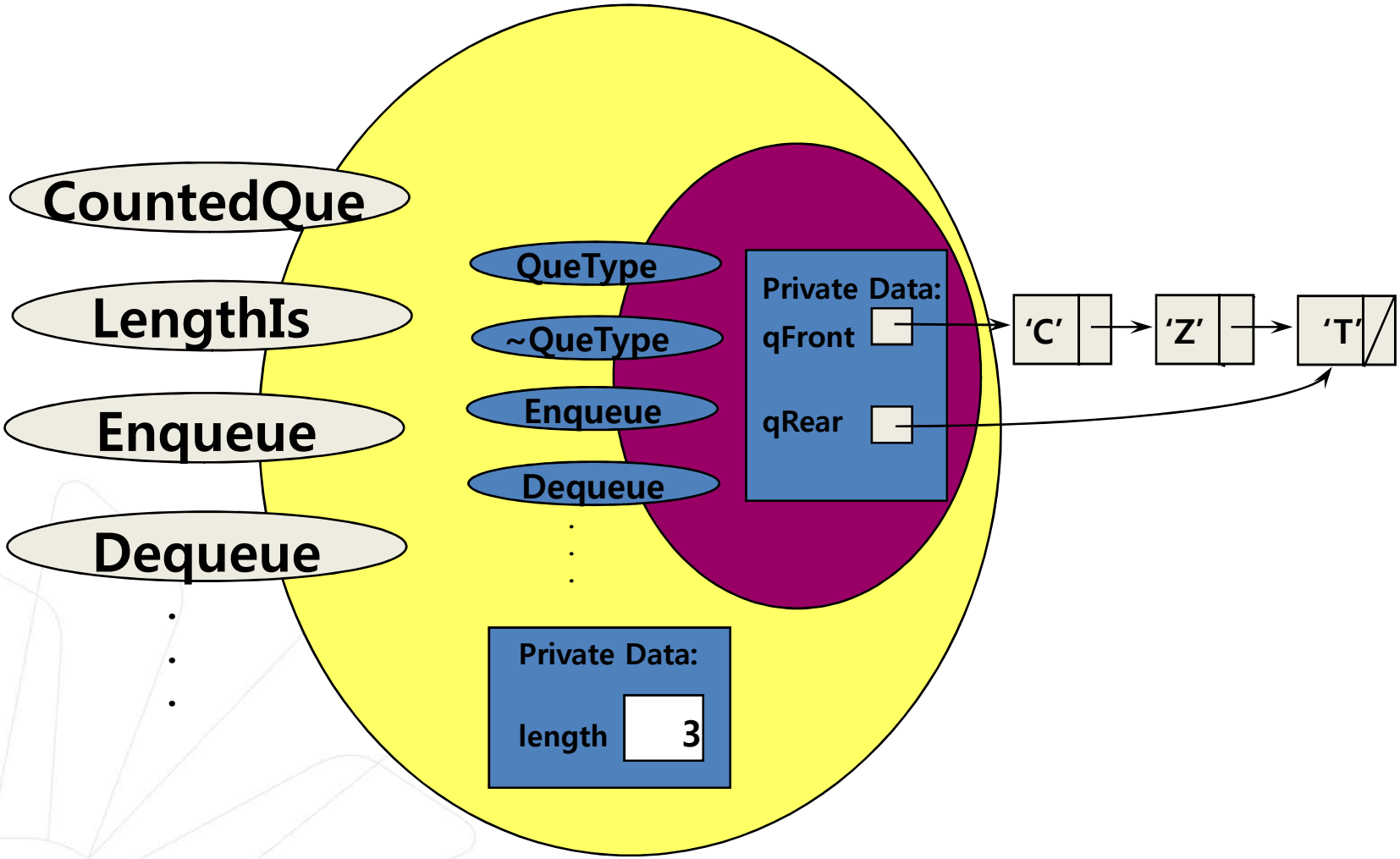
SAYS ALL PUBLIC MEMBERS OF QueType CAN BE INVOKED FOR OBJECTS OF TYPE CountedQue

```
// DERIVED CLASS CountedQue FROM BASE CLASS QueType

template<class ItemType>
class CountedQue : public QueType<ItemType>
{
public:
  CountedQue( );
  void Enqueue( ItemType newItem );
  void Dequeue( ItemType&  item );
  int LengthIs( ) const;
  // Returns number of items on the counted queue.

private:
  int length;
};
```

class CountedQue<char>



```
// Member function definitions for class CountedQue

template<class ItemType>
CountedQue<ItemType>::CountedQue( ) : QueType<ItemType>( )
{
  length = 0 ;
}


template<class ItemType>
int CountedQue<ItemType>::LengthIs( ) const
{
  return  length ;
}
```

```
template<class ItemType>
void CountedQue<ItemType>::Enqueue( ItemType newItem )
        // Adds newItem to the rear of the queue.
        // Increments length.
{
  length++;

  QueType<ItemType>::Enqueue( newItem );
}

template<class ItemType>
void CountedQue<ItemType>::Dequeue(ItemType& item )
        // Removes item from the rear of the queue.
        // Decrements length.
{
  length--;

  QueType<ItemType>::Dequeue( item );
}
```