C++ Plus Data Structures

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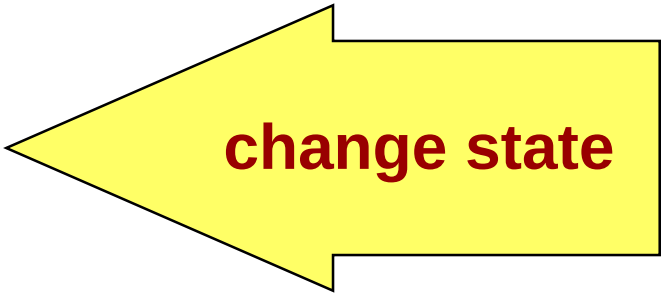
Chapter 6

Lists Plus

ADT Sorted List Operations

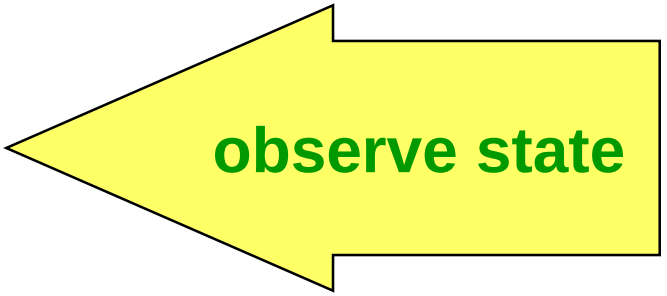
Transformers

- MakeEmpty
- InsertItem
- DeleteItem



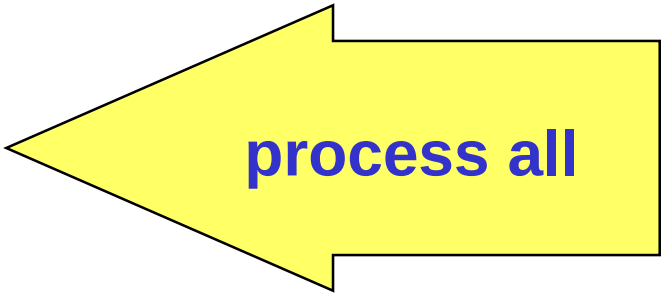
Observers

- IsFull
- LengthIs
- RetrieveItem

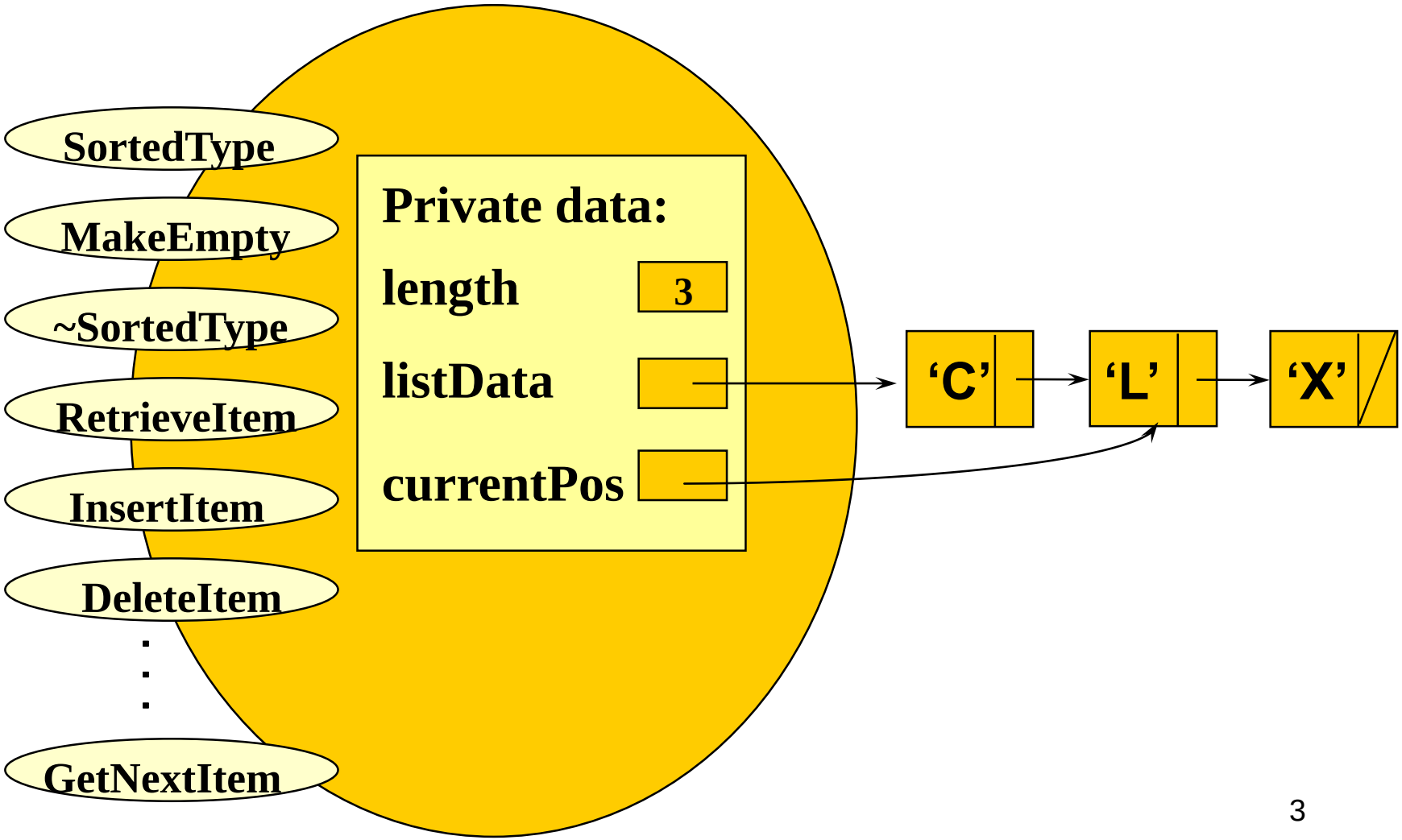


Iterators

- ResetList
- GetNextItem

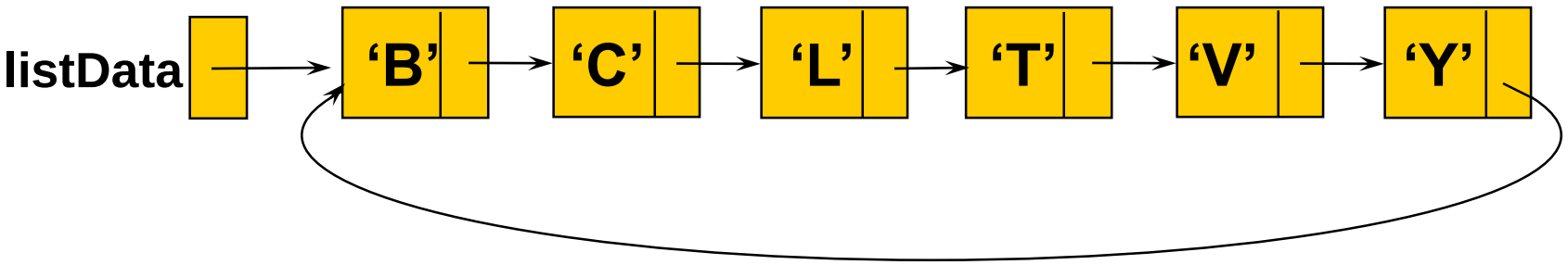


class SortedType<char>



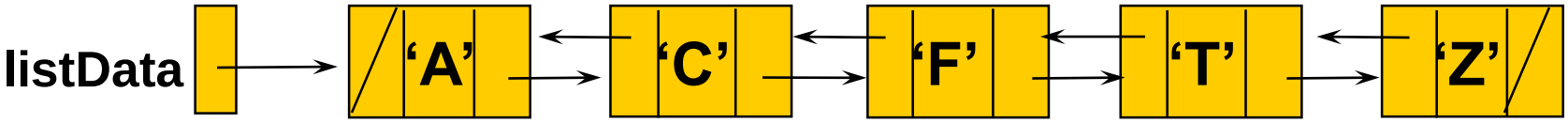
What is a Circular Linked List?

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



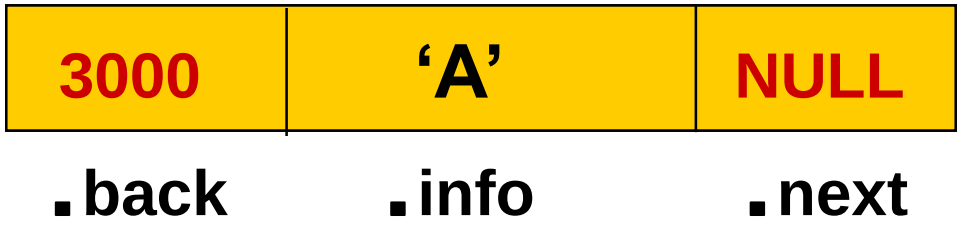
What is a Doubly Linked List?

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



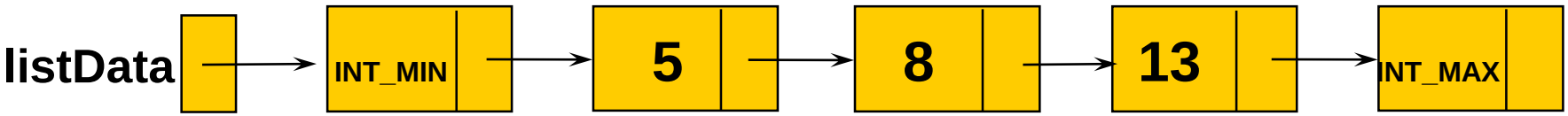
Each node contains two pointers

```
template< class  ItemType >
struct   NodeType  {

   ItemType     info;                    // Data member
   NodeType<ItemType>*  back;   // Pointer to predecessor
   NodeType<ItemType>*  next;   // Pointer to successor

};
```



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.



Recall Definition of Stack

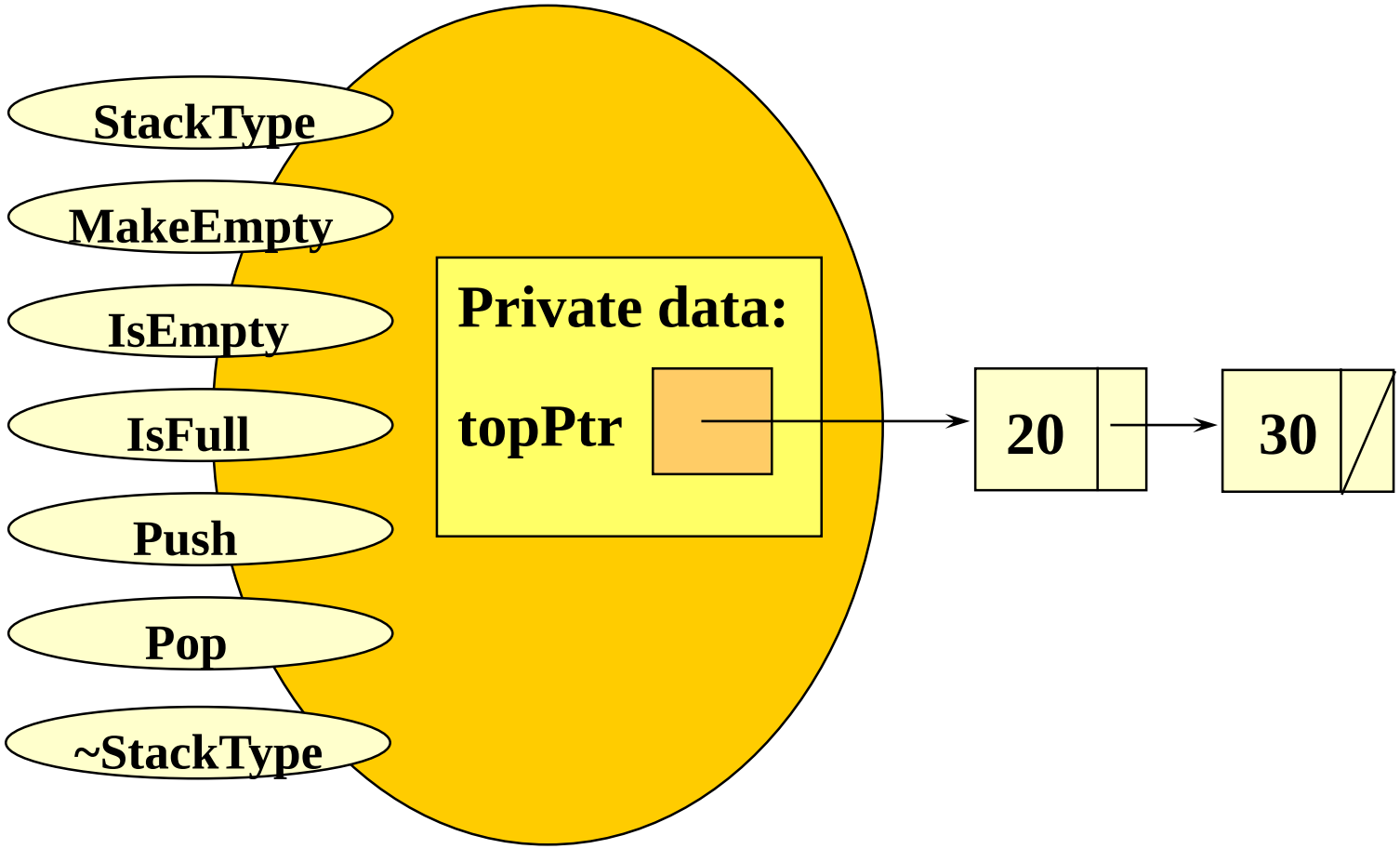
- ***Logical (or ADT) level:*** A stack is an ordered group of homogeneous items (elements), in which the removal and addition of stack items can take place only at the top of the stack.

- A stack is a LIFO "last in, first out" structure.

Stack ADT Operations

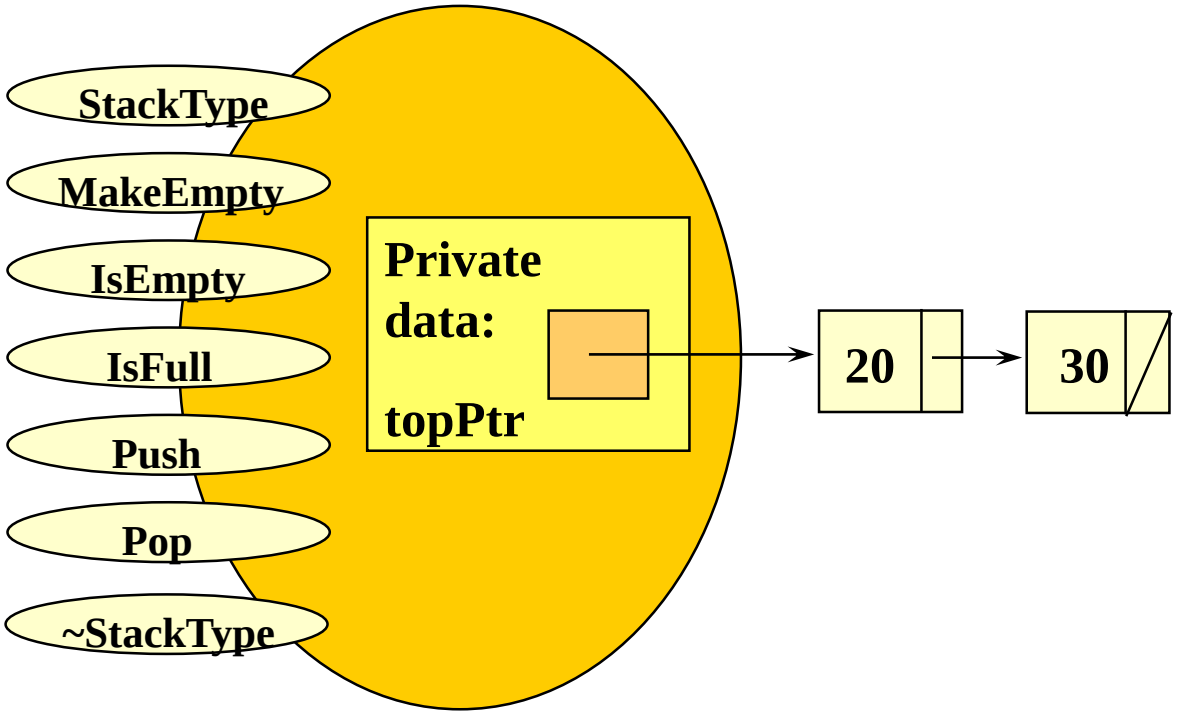
- **MakeEmpty -- Sets stack to an empty state.**
- **IsEmpty -- Determines whether the stack is currently empty.**
- **IsFull -- Determines whether the stack is currently full.**
- **Push (ItemType newItem) -- Adds newItem to the top of the stack.**
- **Pop (ItemType& item) -- Removes the item at the top of the stack and returns it in item.**

class StackType<int>



What happens . . .

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

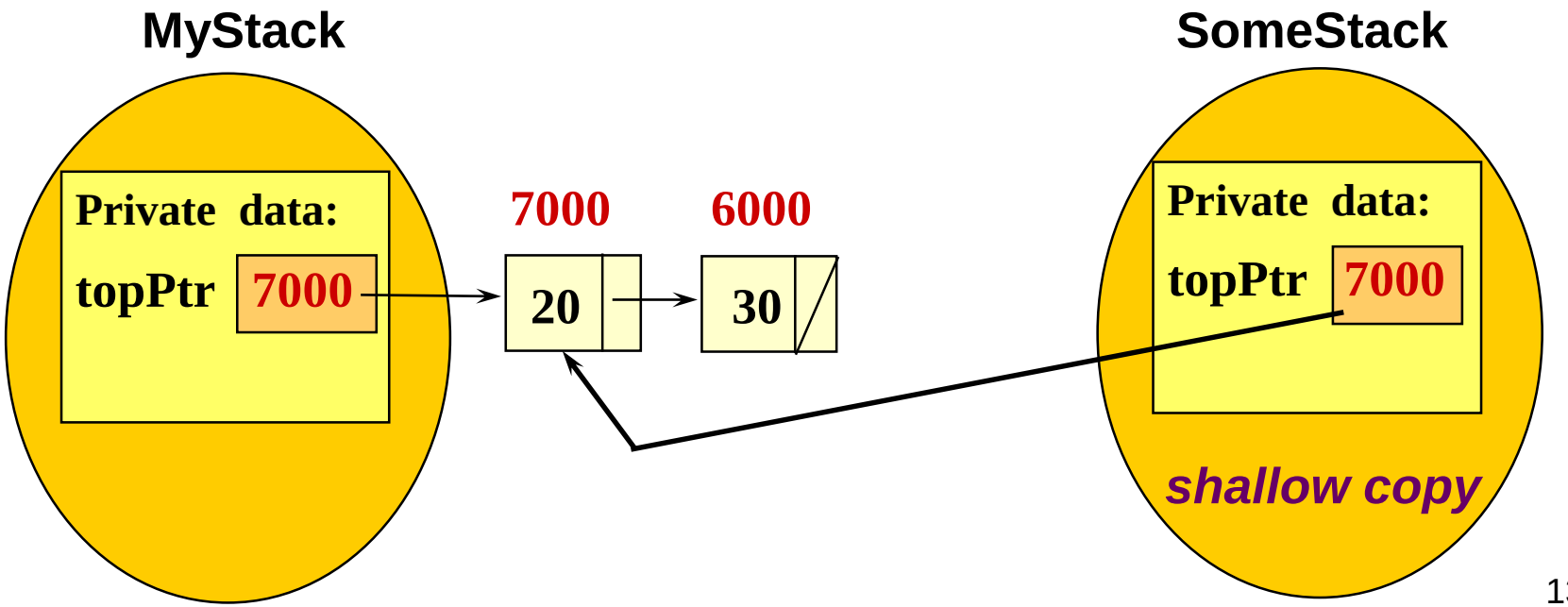


Passing a class object by value

```
                                        // 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
```



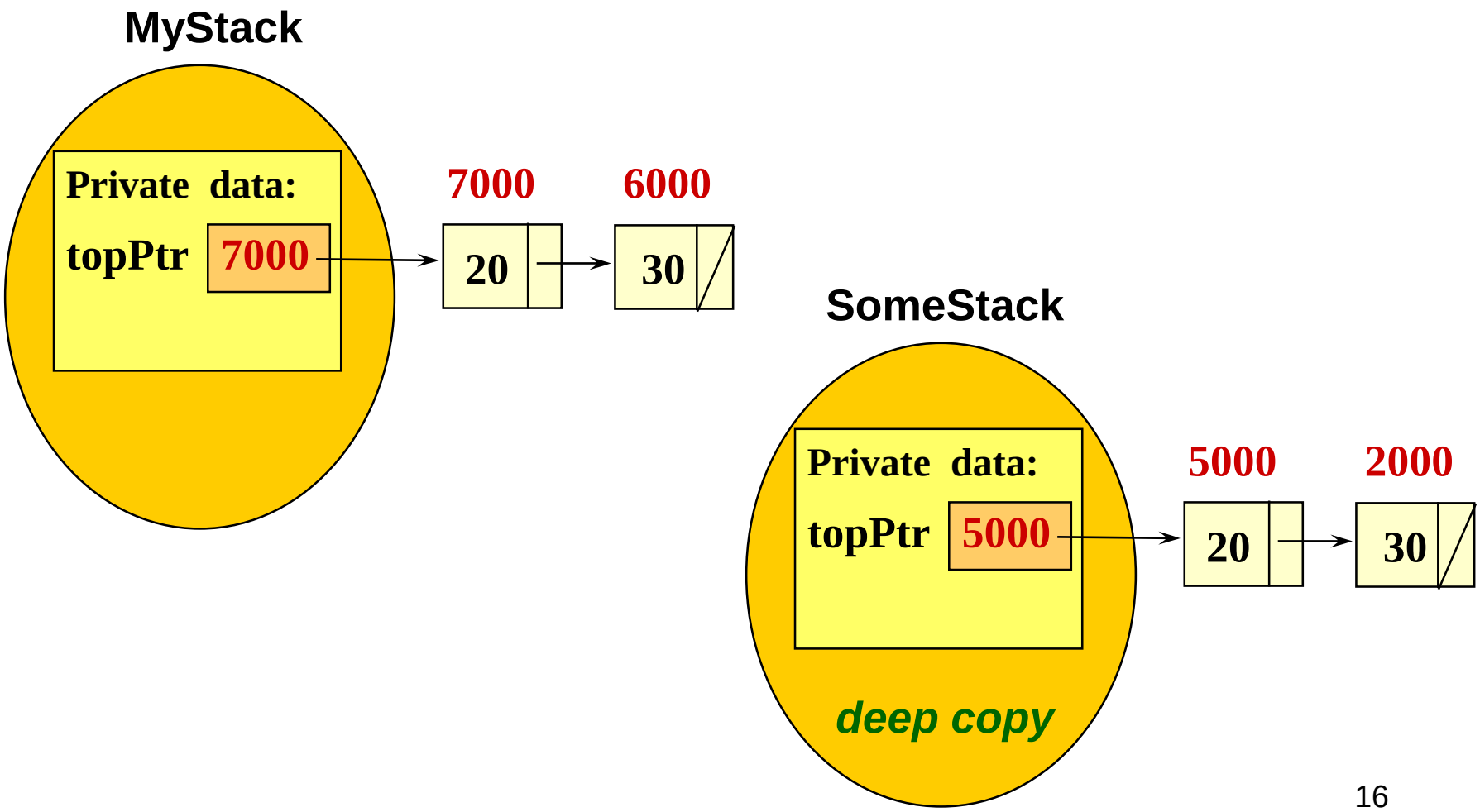
Shallow Copy vs. Deep Copy

- ***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



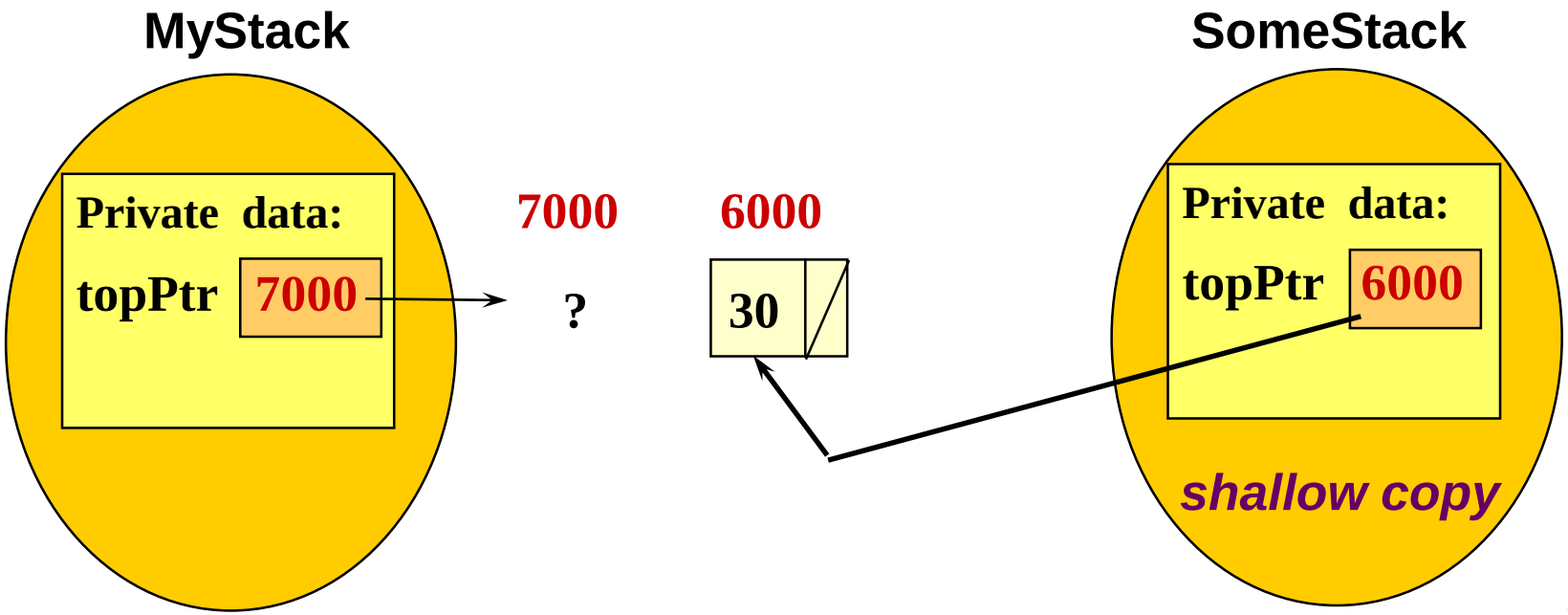
Suppose `MyFunction` Uses Pop

```
                                        // 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?

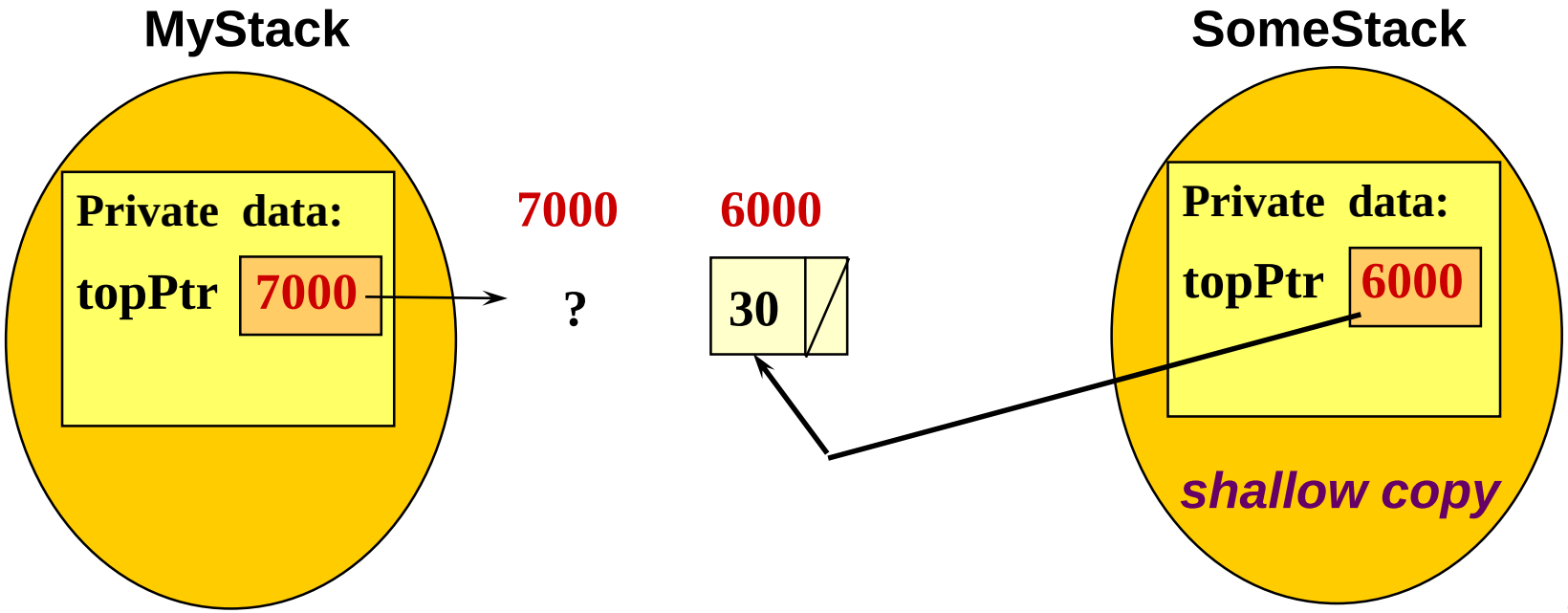
`MyStack.topPtr` is left dangling

```
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

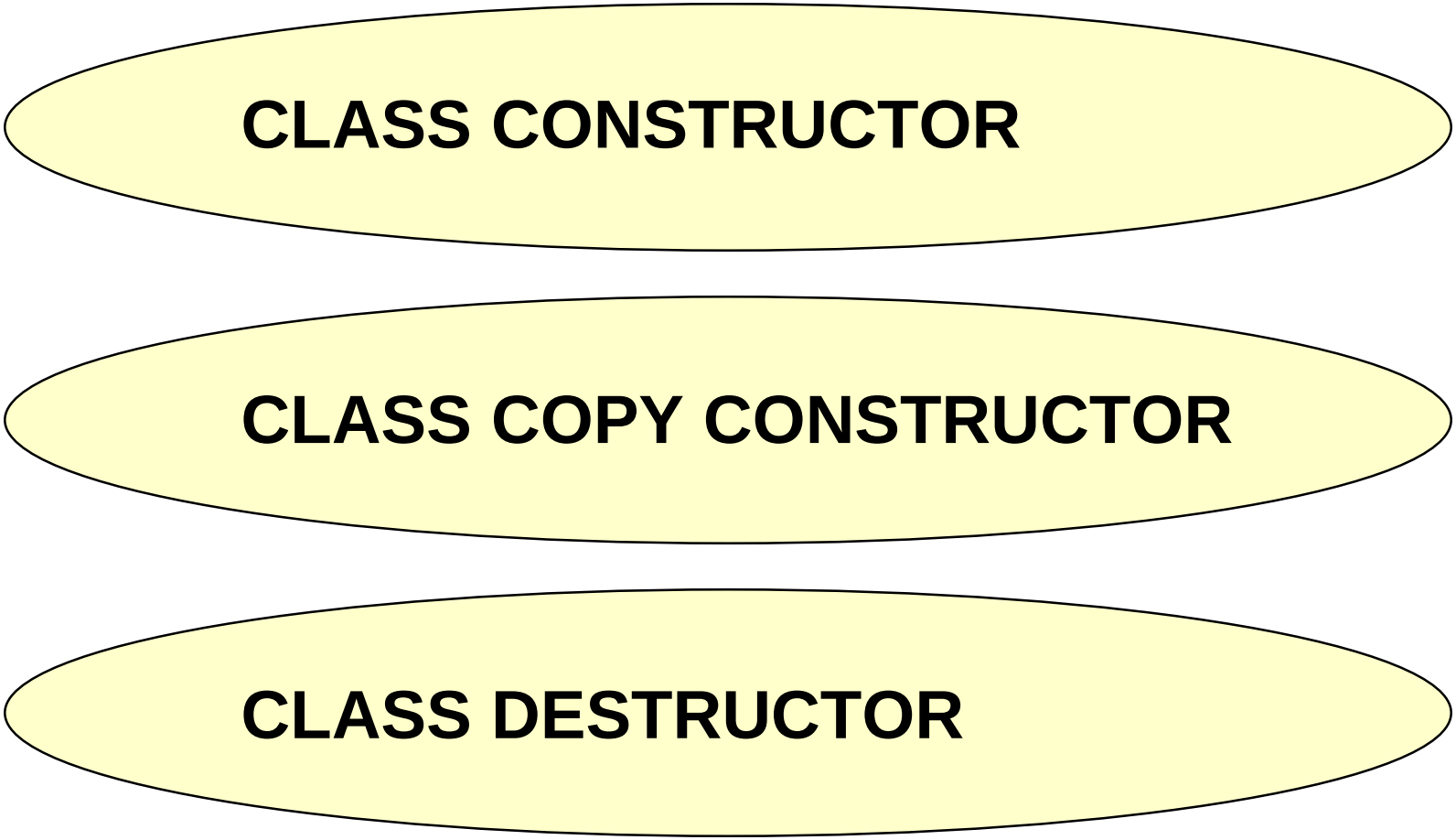
- **When there is a copy constructor provided for a class, the copy constructor is used to make copies for pass by value.**
- **You do not call the copy constructor.**
- **Like other constructors, it has no return type.**
- **Because the copy constructor properly defines pass by value for your class, 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, (ex: int a=b;)**
  - **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



```
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
   {    ptr2 = new NodeType<ItemType> ;
        topPtr = ptr2;
        ptr1 = anotherStack.topPtr;
        ptr2->info = ptr1->info ;
        while ( ptr1 != NULL )      // deep copy other nodes
        {       ptr2->next = new NodeType<ItemType> ;
                ptr2->info = ptr1->info ;
                ptr2 = ptr2->next ;
                ptr1 = ptr1->next ;
        }
        ptr2->next = NULL ;
   }
}
```

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)

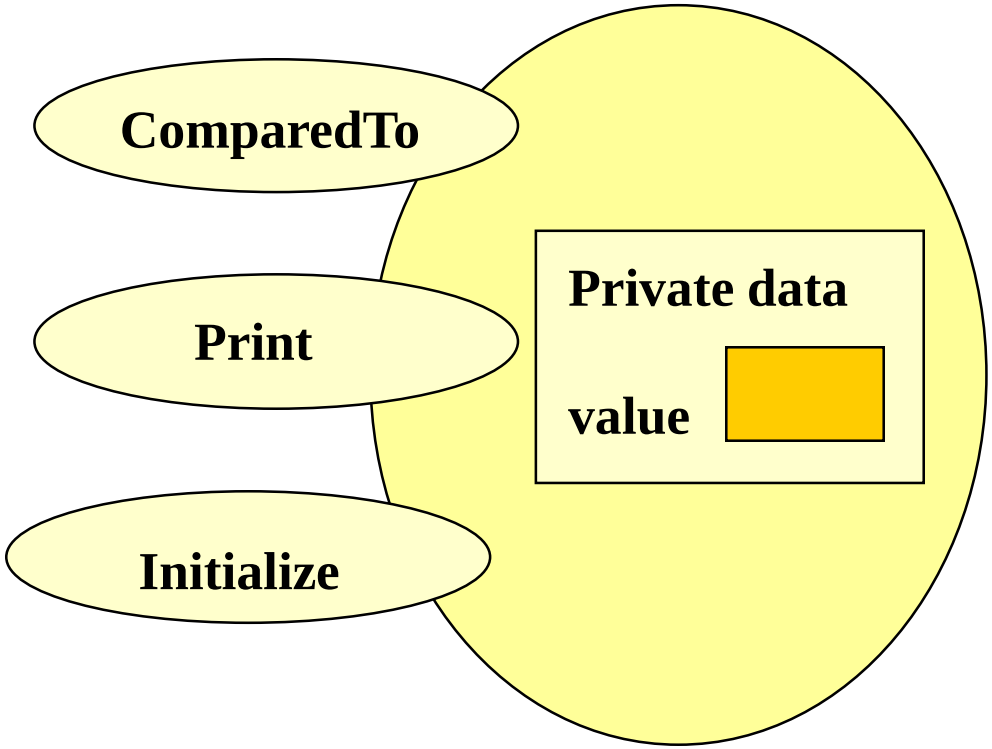
Composition (containment)

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

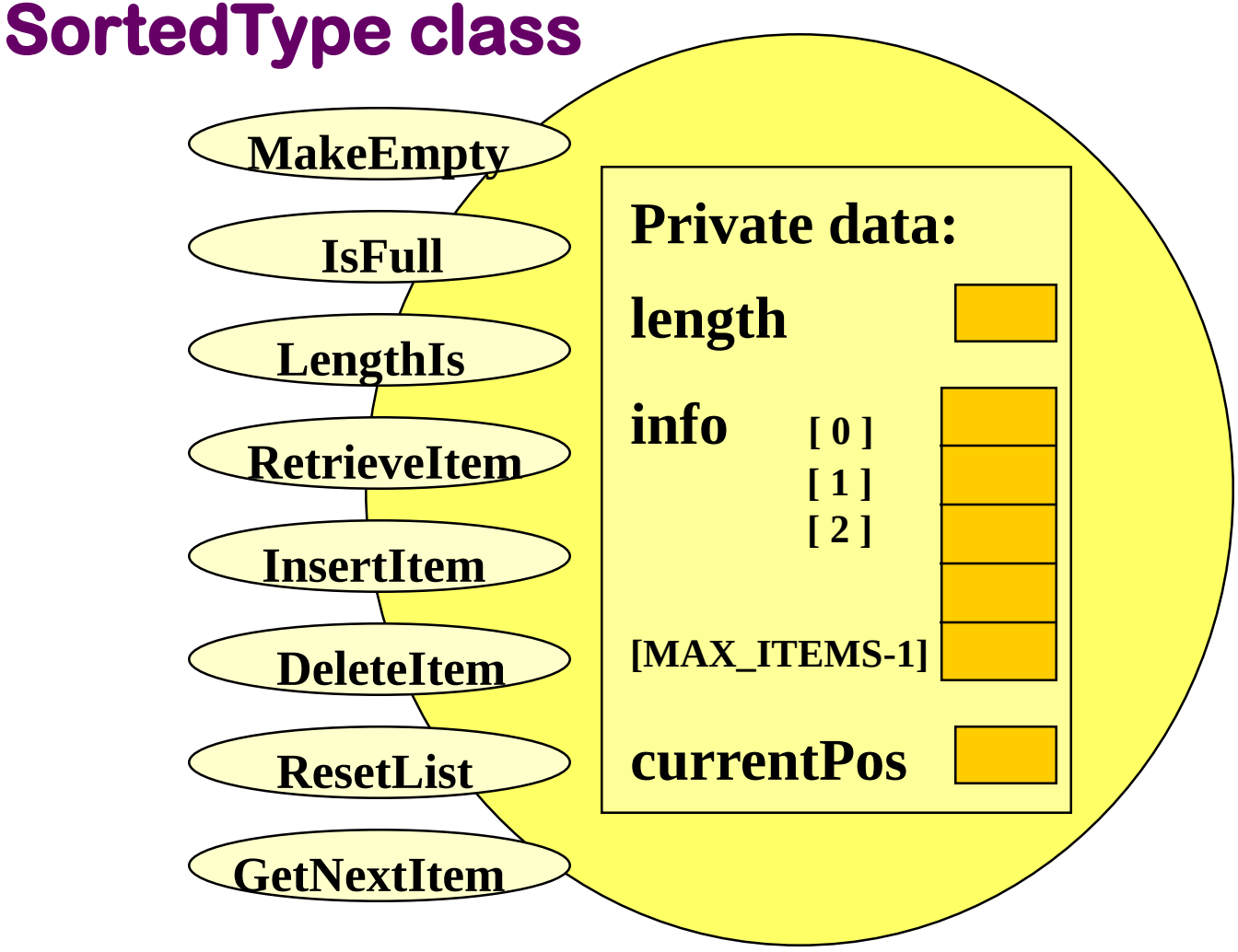
A FAMILIAR EXAMPLE . . .

ItemType
Class Interface Diagram

class ItemType



Sorted list contains an array of ItemType



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 . . .

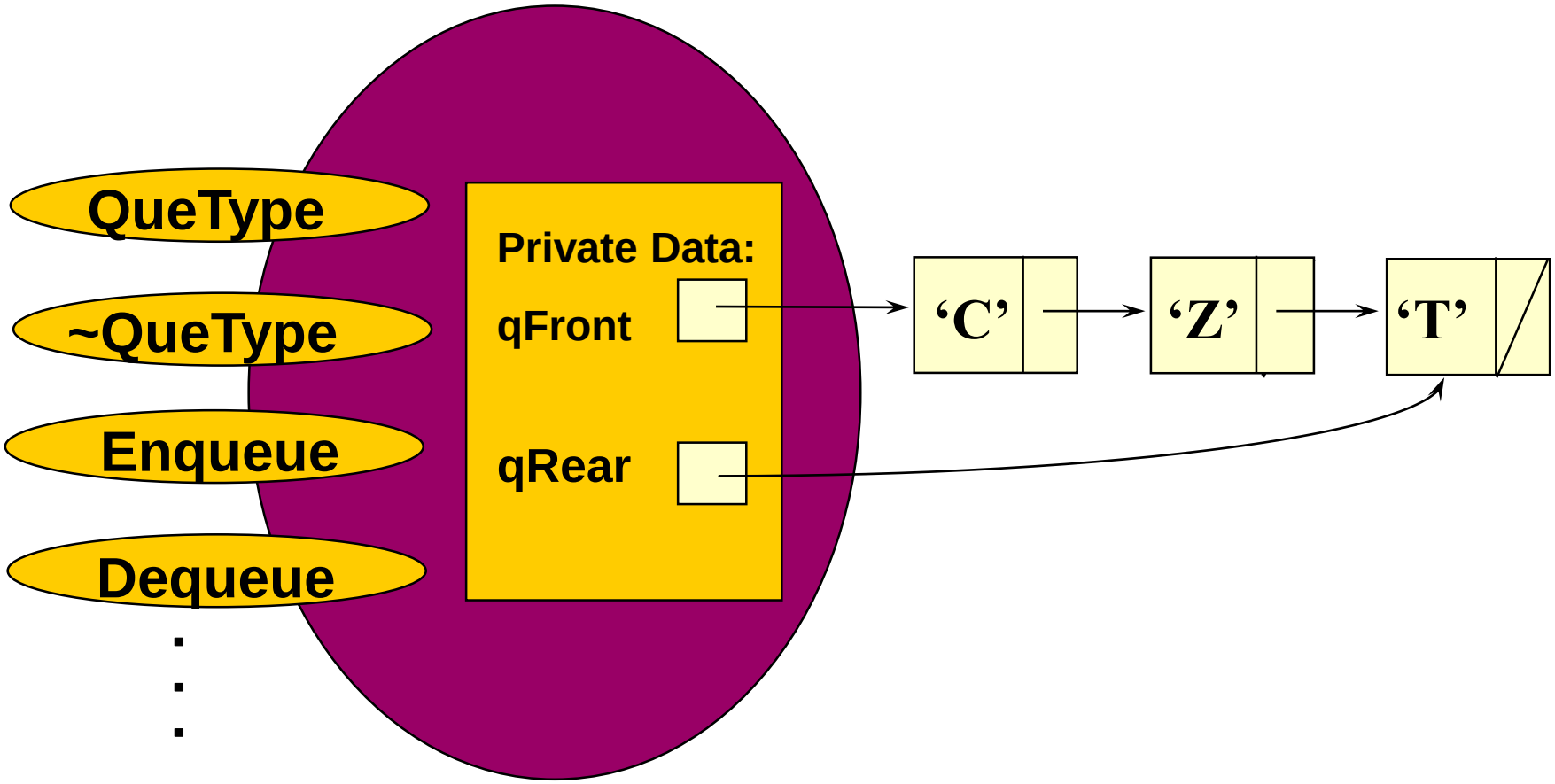
Recall Definition of Queue

- ***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>

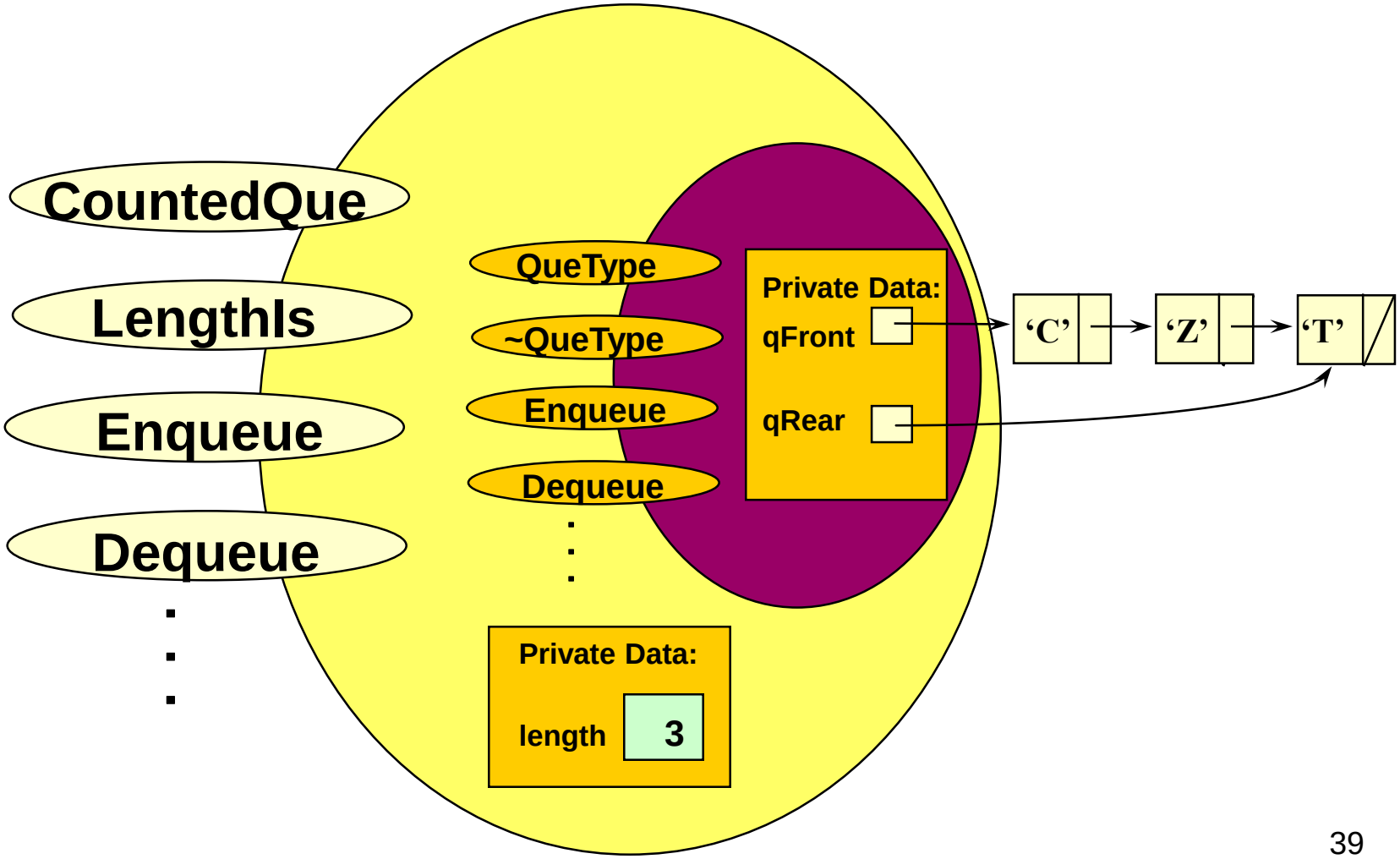


```
// DYNAMICALLY LINKED IMPLEMENTATION OF QUEUE

#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> q



```
// 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 );
}
```

Iterator Class

- It is designed to scan the list sequentially.
- Up to now, we used the member functions (ResetList(), GetNextItem()) and the member variable(currentPos) of List class.
  - Since there is only one pointer to the node, we can not access several nodes simultaneously.
- Iterator Class separates the iteration from the List Class.
  - Can access more than one node simultaneously.

Iteration Class Design

⑴ Declare IteratorType<Type> as a friend class of ListType<Type> and NodeType<Type> to enable IteratorType<Type> access the members of these two classes.

⑵ IteratorType<Type> includes a reference variable, listData, pointing to the list to be scanned. Variable listData is initialized when the iterator class object is created.

⑶IteratorType<Type> includes a private data member currentPos pointing to a node in the list.

⑷ IteratorType<Type> has public member functions including NotNull(), NextNotNull(), First(), and Next(), to access members of the list.

Iterator Class ADT

```
template <class Type> class IteratorType {
public:
    IteratorType(const ListType<Type> &iList): itrlist(iList),
     current(iList.listData) {};
    Boolean NotNull(); // Check that the current pointer is not Null
    Boolean NextNotNull(); // Check that next pointer is not null
    void ResetList(); // set the current pointer to the first node
    // Get the current node and update the current pointer
    int GetCurrentItem(Type item);
private:
    const ListType<Type> &itrList; //connect itrList to the list
    NodeType<Type> *current; // pointer to current node
};
```

List Class와 Interator class

```
template <class Type> class NodeType {
friend class IteratorType<Type>;
private:
      Type data;
      NodeType *link;
};
template <class Type> class ListType {
friend class IteratorType<Type>;
public:
      List() {listData = 0;};
     ... 기타 연산자들
private:
      NodeType<Type> *listData;
                                          };
```

Definition of Member functions

```
// Check that current pointer is not null
template <class Type>
Boolean IteratorType<Type>::NotNull() {
      if(current) return TRUE;
      else return FALSE;
}
 // check that the next node is not null.
template <class Type>
Boolean IteratorType<Type>::NextNotNull() {
      if(current && current->next) return TRUE;
      else return FALSE;
}
```

Defintion of Member Functions

```
// let current point to the first node of the list
template <class Type>
void IteratorType<Type>::ResetList() {
    current = itrList.listData;
}
// return the record pointed by current pointer. If the current
   nod is not null, return 1. Otherwise, return 0
template <class Type>
int IteratorType<Type>::GetCurrentItem(Type& item) {
     if(NotNull()) {
          item = current->data;
          current = current->next;
          return 1;
     }
     else return 0;
}
```

Iterator Class Example

```
// sum up all the values in the list
int sum(const List<int>& list)
{
    Iterator iter(list);
    int sum=0;

    iter.ResetList();
    while (iter.GetCurrentItem(item))
        sum + = item;
}
```