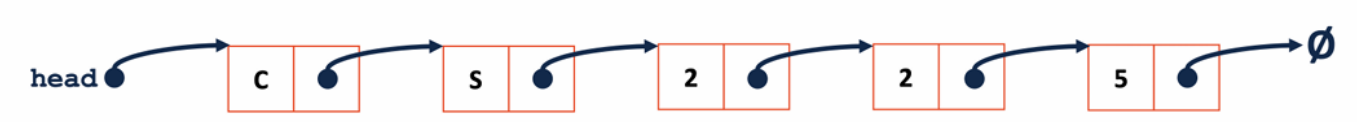
quiz3

List implementation

1. Linked list (using points)
2. Array

Array	Linked Lists
stored in contiguous location	not stored in contiguous location
fixed in size	dynamic in size
memory is allocated at compile time	memory is allocated in run time
use less memory than linked list	use more memeory(both data and address of the next node)
elements can be accessed easily	elements accessing requires the traversal of the whole list
insertation and deletion operation takes time	faster

Linked Memory




```
//list.h
class ListNode{
    T data;
    ListNode * next;
    ListNode( T & data) : data(data), next(NULL) { }
};

//struct
struct ListNode{
    T data;
    ListNode * next;
    //init list
    ListNode( T & data) : data(data), next(NULL) { }
};
```

struct vs. class

struct :

1. start from public

2. never contain member functions

class : srart from private

```
class List{
    public:
        /* functions here */
    private:
        class ListNode{
            T data;
            ListNode * next;
            ListNode( T & data) : data(data), next(NULL) { };

        ListNode *head_;
};
}
```

private class: not available outside the class **poblice class**: List::ListNode

if *ListNode * next* is not declared as pointer, it will head ListNode will contain every node's data.

insert at front:

```
#include "List.h"

template <typename T>
void List::insertAtFront(const T& d){
    ListNode * nex_node = new ListNode(d);
    new_node->next = head_;
    head_ = new_node;
}
```

runtime for insert at front:

1. if list empty? #operation = 3
2. if list contains n nodes? #operation = 3 contain time = O(1) constant time

find node:

recursion version : tail recursion

Recursion

The process in which a function call itself directly or indirectly: ex. Tree travesal, factonial of a number

Base case: simplest case for the solution is trivial

Recursion case: define the problem in terms of small problems

***ensure the recursion terminates**

all work done before recursion

```
template<typename T>
typename List<T>::ListNode *& List<T>::_index(unsigned index){
        _index_help(head_, index);
    }
//not for sure
List<T>::ListNode *&_index_help(ListNode *& n, unsigned i){
    if(n == 0){
        return n;
    }
    else{
        return _index_help(n->next, i - 1);
    }
}
```

print reverse:

```
//not for sure
void List<T>printReverse() const{
    //any intuition
}
void List::helper(
    ListNode<T>*char{
        if(cur->next != NULL){
            _helper(curr->next);
            count<<cur->next<<endl;
        }
    }
)
```

Sentinel Node:

nodes designed nodes do not hold or refer to any data of the list E.g. different conditions of insertion:

1. at the front of the linked list
2. after a given node
3. at the end of the linked lisk

modify node's data:

```
template<typename T>
T & List<T>::operator[](unsigned index){
    ListNode * node = _index(index);
    return node->data;
```

```
}

mylist[2] = 'i';
```

insert node:

1. find pointer to node at index 2
2. create new node with data
3. new node next is what at index 2
4. pointer to index 2 point to new node

```
template<typename T>
void List<T>::insert(const T & t, unsigned index){
    ListNode *& node =_index(index); // 1
    ListNode *new_node = new ListNode(t); // 2
    new_node->next = node; // 3
    node = new_node; //4
}
```

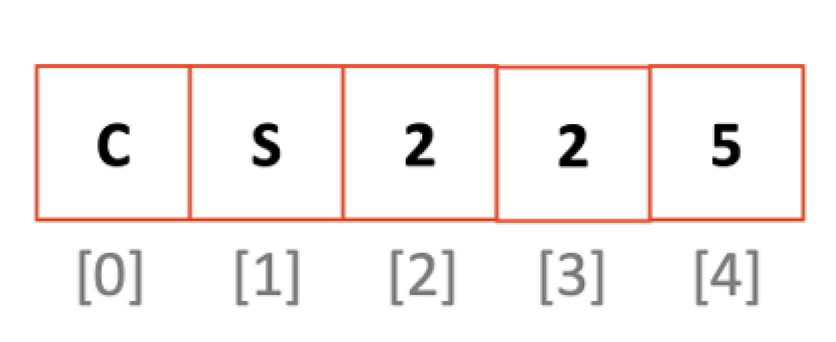
remove node:

```
template <typename T>
void List<T>::remove(unsigned index){
    ListNode *&node = _index(index);
    ListNode * tmp = node; // purpose save when node changes
    node = node->next;
    delete tem; // clean up memory;
}
```

Array

```
template <typename T>
class List{
    public:
        /* functions here */
    private:
        T * data_;
        unsigned size_;
        unsigned cap_;
};
```

Array implementation

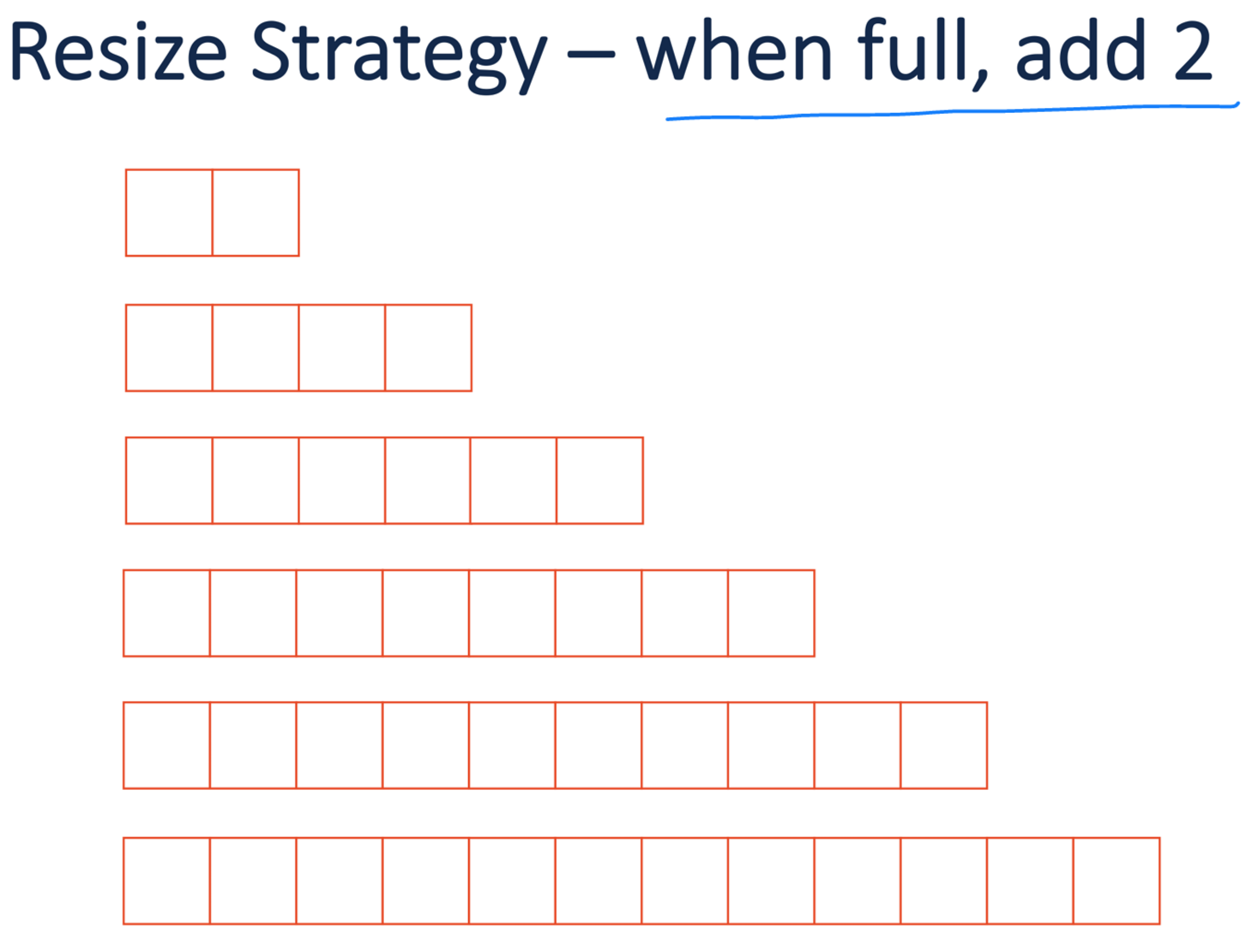



```
T getdata(unsigned index){
    return data_[index];
}

addBack(& value){
    data_[size_] = value;
    size++;
}
```

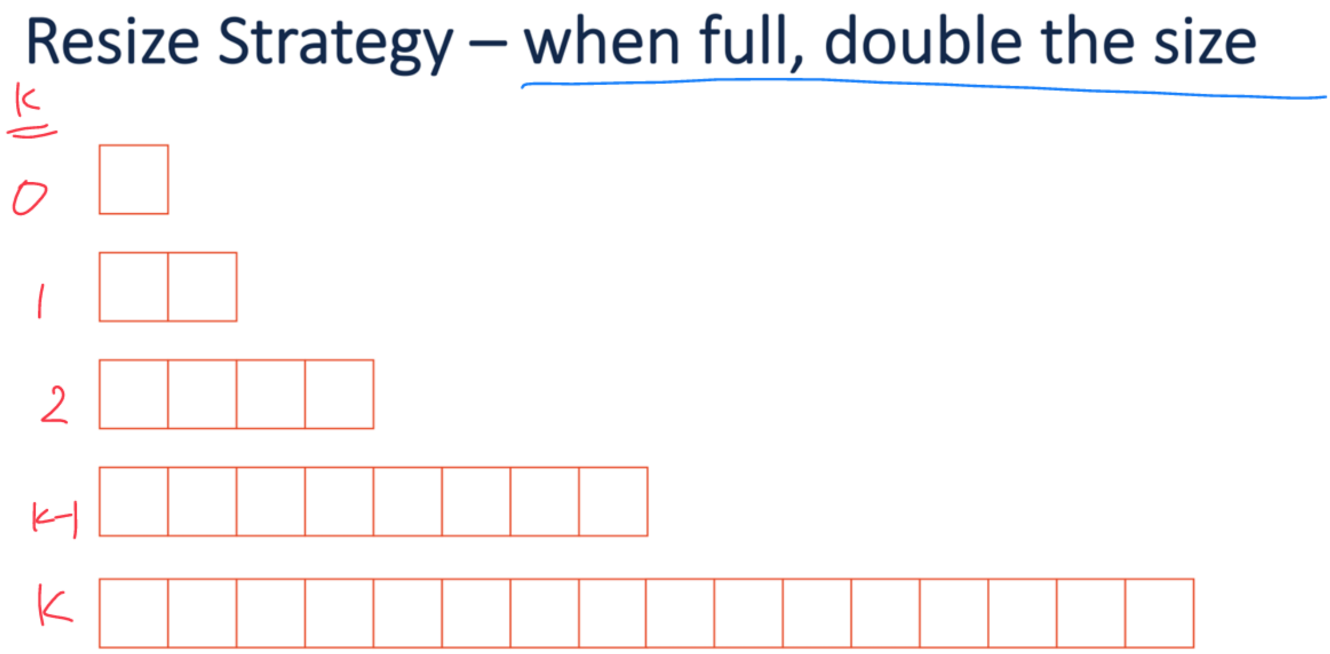
what if full? full allocate new copy free old

resize



$$ \sum_{k=0}^\infty 2k = r^2 + r $$ r: number of rounds n: number of items r = $\frac{n}{2}$ $$ (\frac{n}{2})^2 + \frac{n}{2} = \frac{n^2 + 2n}{4} $$ O(n^2) copies for n items

n insert takes O(n^2) time one insert takes $\frac{O(n^2)}{n} = O(n)$



$$ \sum_{k=0}^{r} 2^r= 2(2^r-1)+1 $$ $$ 2^r = n \ r= lg(n) $$ 2n-1 copies for n inserts:$\frac{O(n)}{n}$ Amortized O(1) runtime

2n space to store n items O(n) for n items or O(1) per item

	Singly Linked List	Array
insert/remove at front	O(1)	Amortized O(1)//we may need allocate new space
insert at given element	O(1)//given location	O(n)worest case: all element have to be moved
remove at given element	O(1)//given location	O(n)worest case: all element have to be moved
insert at arbitrary location	O(n)	O(n)worest case: all element have to be moved
remove at arbitrary location	O(n)	O(n)worest case: all element have to be moved

Array List vs. Linked List 时间复杂度对比

Array List (动态数组)

操作	无序列表	有序列表	说明
`insertAtFront`	O(n)	O(n)	需移动所有元素；扩容摊还成本 O(1)。
`insertAtIndex`	O(n)	O(n)	插入位置后的元素需移动（有序列表需先查找位置）。
`removeAtIndex`	O(n)	O(n)	删除位置后的元素需移动。
`insertAfterElement`	O(n)	O(n)	需线性搜索目标元素；有序列表可用二分查找但插入仍需移动元素。
`removeAfterElement`	O(n)	O(n)	需线性搜索目标元素并删除后续元素。

操作	无序列表	有序列表	说明
`findIndex`	O(1)	O(1)	直接通过索引随机访问。
`findData`	O(n)	O(log n)	无序列表线性搜索；有序列表二分查找（仅数组支持）。

Linked List (链表)

操作	无序列表	有序列表	说明
`insertAtFront`	O(1)	O(1)	直接修改头节点指针。
`insertAtIndex`	O(n)	O(n)	需遍历到目标索引或位置。
`removeAtIndex`	O(n)	O(n)	需遍历到目标索引。
`insertAfterElement`	O(n)	O(n)	需线性搜索目标元素，插入操作为 O(1)。
`removeAfterElement`	O(n)	O(n)	需线性搜索目标元素，删除操作为 O(1)。
`findIndex`	O(n)	O(n)	需从头遍历到目标索引。
`findData`	O(n)	O(n)	链表无法二分查找，无论是否有序均需线性遍历。

关键差异总结

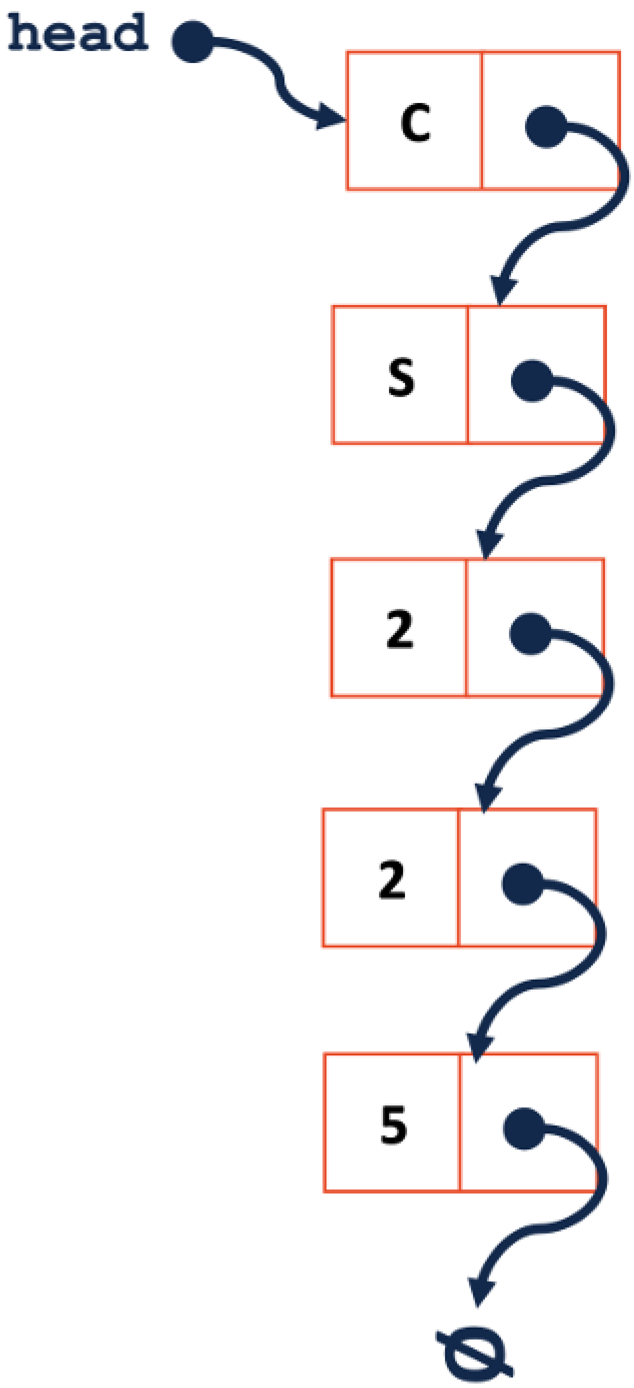
场景	更优数据结构	原因
频繁头部插入/删除	Linked List	链表 `insertAtFront` 和 `removeFront` 为 O(1)，数组需 O(n) 移动元素。
随机访问（按索引）	Array List	数组直接通过索引访问（O(1)），链表需遍历（O(n)）。
有序数据的高效查找	Array List	数组支持二分查找（O(log n)），链表只能线性搜索（O(n)）。
频繁中间插入/删除	Linked List	链表插入/删除节点只需修改指针（O(1)），数组需移动元素（O(n)）。
内存占用与缓存效率	Array List	数组连续存储，缓存友好；链表节点分散，额外存储指针占用空间。

List ADT

1. Linked Memory Implementation(Linked List)
    1. O(1) insert/remove at front/back
    2. O(1) insert/remove after a given element
    3. O(n) lookup by index

2. Array Implementation(Array List)
    1. O(1) insert/remove at front/back(amortized)
    2. O(n) insert/remove after a given element
    3. O(1) lookup by index

stack




```
//stack.h
template<class T>
class Stack {
    public:
```

```
        //stack ADT
        void push(T & t);
        T& pop(); //return the value on the top of stack
        bool isEmpty() const;

        Stack(); //creat an empty stack

        //rule of three
        Stack(const Stack &other);
        ~Stack();
        Stack& operator = (const Stack &other);
    private:
        unsigned size_;
        unsigned count_;
        T* array_;
}
```

first in first out

based on list:

```

void Stack<T>::push(T & t){
    stackNode *Node = new stackNode(t);
    node->next = head_;
    head = node;
}
T & Stack<T>::pop(){
    stackNode *Node = head_;
    head = head->next;
    T& data = node->next;
    delete node;
    return data;
}
```

based on array:

```

void Stack<T>::push(T & t){
    //if we are about to overflow, double the size of the array:
    if(count + 1 == size){
        T *newarr = new T[size_ * 2];
        size_ = size_ * 2;
        copy(array_, newarr);
        delete [] arr;
        array_ = newarray;
    }
    //insert the element into the array-backed stack:
    array_[count ++] = t;
    /*
    1 yield current value
```

```
    2 add one
    */
T & Stack<T>::pop(){
    return array_[--count];
    /*
    1 substract one
    2 yield current value
    */
}
```

queue

```
template<typename T>
class Queue{
    public:
        void enqueue(T e);
        T dequeue();
        bool isEmpty();
    private:
        T *items_;
        unsigned capacity_;
        unsigned size_;
        unsigned start_;// track where we are
};
index = (size_ + start_) % capacity_;
item_[index];
```

```
Queue<char> q;
q.enqueue(m);
q.enqueue(o);
q.enqueue(n);
q.enqueue(d);
q.enqueue(a);
q.enqueue(y);
```

m	o	n	d	a	y

```
q.enqueue();
q.enqueue(h);
```

h	o	n	d	a	y

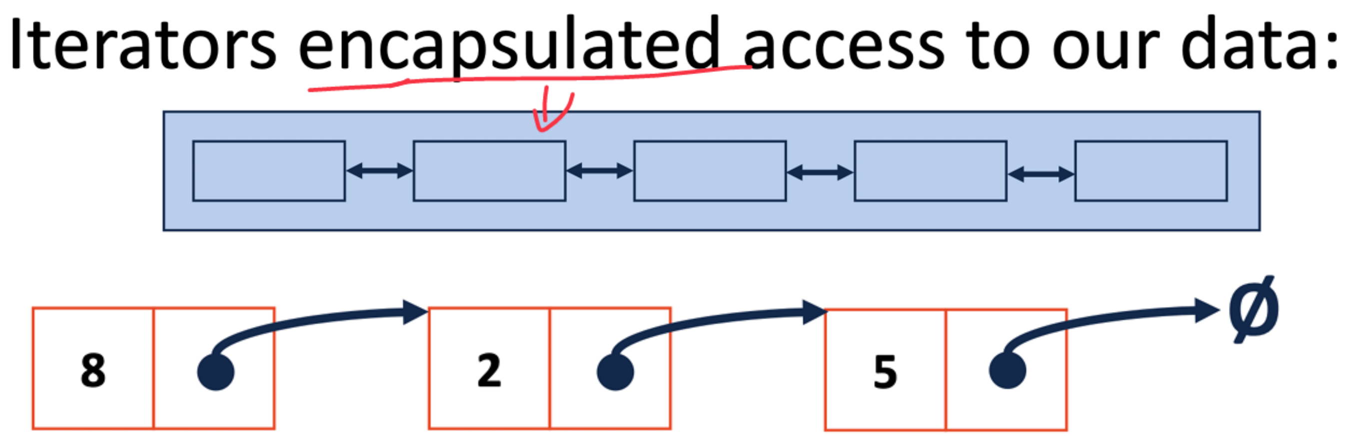
```
q.enqueue(i);
```

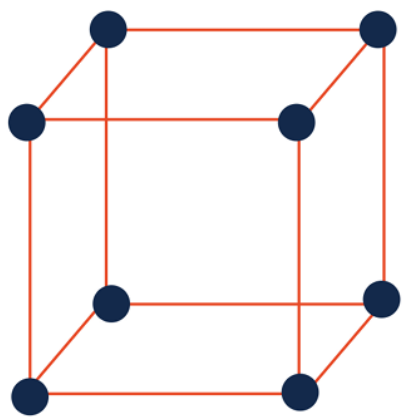
resize by double (amurtized contant) *attention to order*

o	n	d	a	y	h	i

Double Pointer

inerators





	curr location	curr data	next
list	Node *p	p->data	p = p->next
array	unsigned index	data[index]	i++
hyper cube	<x,y,z>	?(return value)	?(x,y,z if not max)

interators

every calss that implements an interator has two pieces

1. [Implementing Class]:

    1. begin():return iterator to start of data
    2. end():return interator to the end to just past end of data

2. [Implementing Class' Iterator]:

    1. Must have the base class **std::iterator**
    2. **std::iterator** requires us to minimally implement:
        1. operator *() - return data iterator reference by reference
        2. operator ++() - move iterator to next data item in class
        3. operator != - compare to iterator

	::begin	**::end**
for list:	intalize pointer; p = head_	p = NULL
for array:	i = 0	i = length_(size)

```
using namespace std;
int main()
{
    vector<int> v = { 1,2,3} ;
    vector<int>::iterator i;
    int j ;
    //accessing element
    for( j = 0; j < 3; ++j){
        v[j]
    }
    for( i = v.begin(); i != v.end(); ++i){
        *i;
    }
    for( j = 0; j < 4; ++j){
        v[j];
    }
    for( i = v.vector(); i != v.end(); ++i){
        *i;
    }
}
```

Literals: expression not stored in a variable

Implications of Design

	storage by reference	**storage by pointer**	**storage by value**
who control lifecycle	client	client	our copy
can store NULL	no	yes	no

	storage by reference	storage by pointer	storage by value
user code change the data, is change reflected in our data stucture?	yes	yes	no
can store literals	no	no	yes
speed	fast	fast	slow on large objs

Function Object(Functors)

funcors are objects that can be called like a function.

big ideas:

1. member functions and variable are only inherited in derived classes. 2. class scope determines access to private members.

Pointers	Iterators
A pointer holds an address in memory.	An iterator may hold a pointer, but it may be something more complex. For example, an iterator can iterate over data: - On a file system - Spread across multiple machines - Generated programmatically Example: A linked list iterator moves through nodes whose RAM addresses may be scattered.
Supports pointer arithmetic: `++`, `--`, `+n`, `-n`	Operations are restricted by iterator type: - Forward iterators cannot decrement (`--`) - Non-random-access iterators cannot add integers (`+n`)
A `T*` pointer can point to any `T` type object.	Bound to container types: Example: `vector<double>::iterator` can only point to `double` elements within a `vector`.
Memory management with `delete`: `delete ptr;`	No `delete` concept: Containers handle memory management automatically.