Queues

College of Computer Science, CQU

Outline

- Queue ADT
- Circular Queue
- Linked Queue
- Comparison of Array-Based and Linked Queues

Queues

- Like the stack, the queue is a list-like structure that provides restricted access to its elements.
- Queue elements may only be inserted at the back (called an enqueue operation) and removed from the front (called a dequeue operation).

Queues

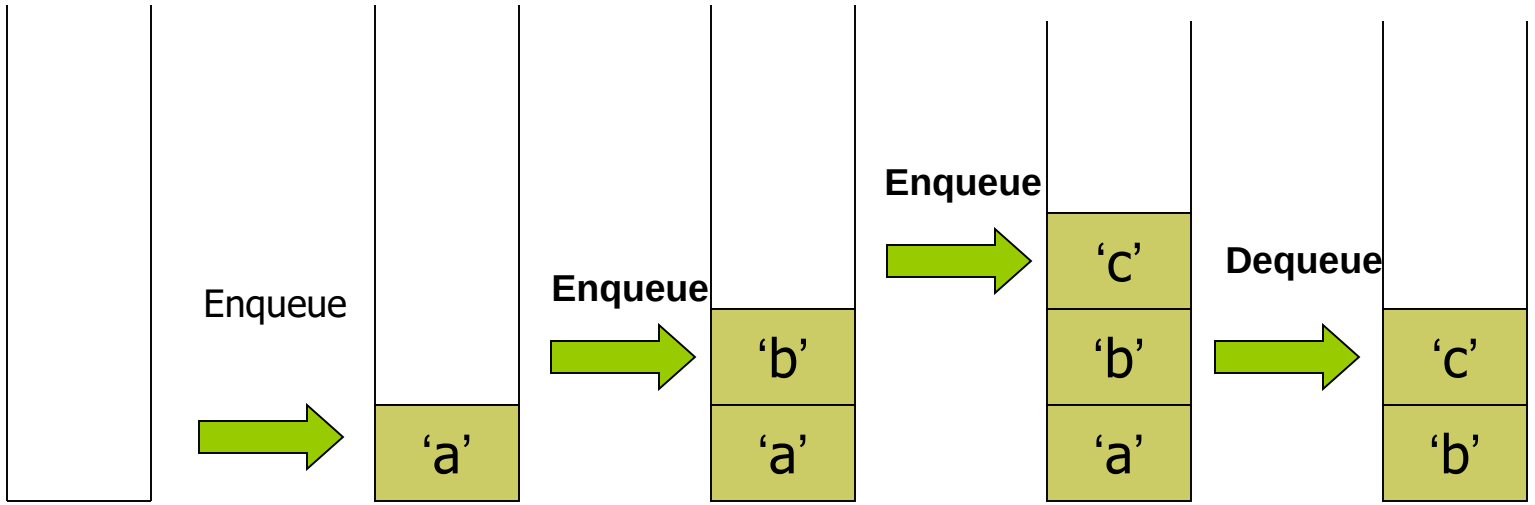
FIFO: First in, First Out

Restricted form of list: Insert at one end, remove from the other.

Notation:

- Insert: Enqueue
- Remove: Dequeue
- First element: Front
- Last element: Rear

Example: Queue of Char



Queue ADT

```
// Abstract queue class
template <typename E> class Queue {
private:
  void operator =(const Queue&) {} // Protect assignment
  Queue(const Queue&) {} // Protect copy constructor
public:
  Queue() {} // Default
  virtual ~Queue() {} // Base destructor
```

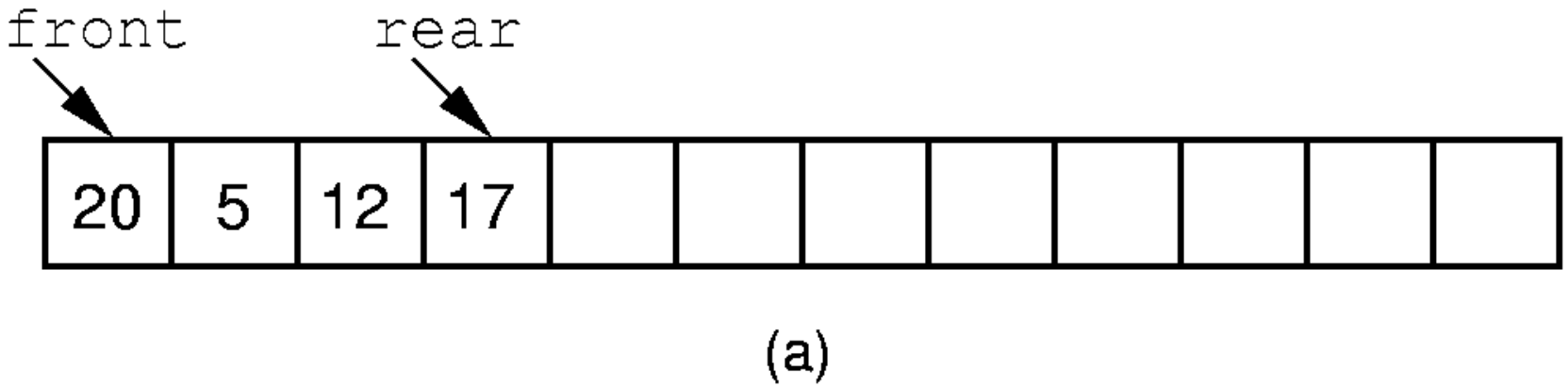
Queue ADT

```
  // Reinitialize the queue. The user is responsible for
  // reclaiming the storage used by the queue elements.
   virtual void clear() = 0;
  // Place an element at the rear of the queue.
  // it: The element being enqueued.
  virtual void enqueue(const E&) = 0;
  // Remove and return element at the front of the queue.
  // Return: The element at the front of the queue.
  virtual E dequeue() = 0;
  // Return: A copy of the front element.
  virtual const E& frontValue() const = 0;
  // Return: The number of elements in the queue.
  virtual int length() const = 0;
};
```

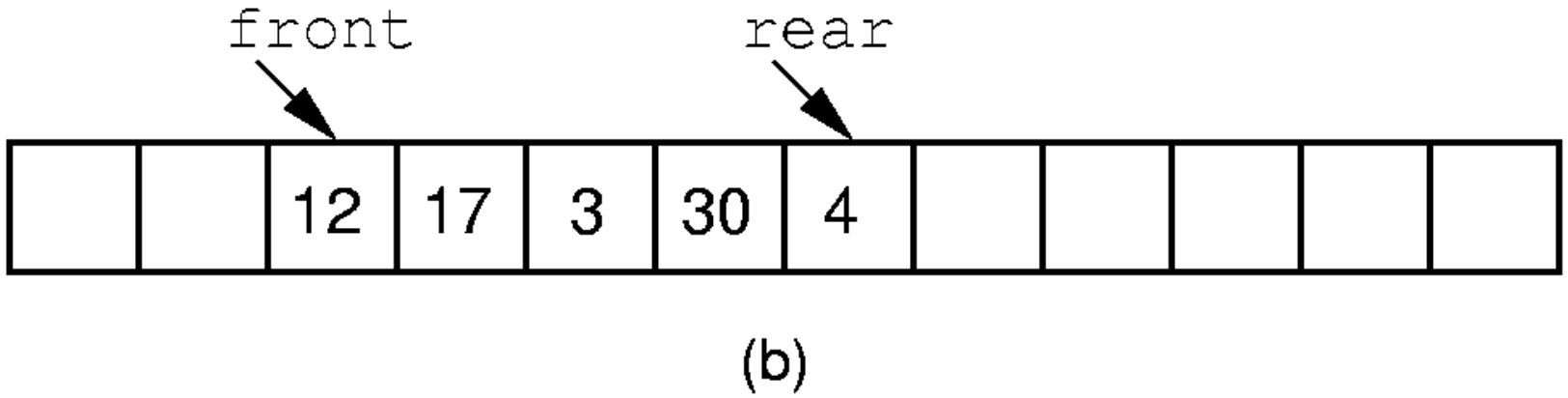
Array_based Queue

- The array-based queue is somewhat tricky to implement effectively. Assume that there are n elements in the queue.
  - If we choose the rear element of the queue to be in position 0, enqueue operations will shift the n elements currently in the queue one position in the array.
  - If instead we chose the rear element of the queue to be in position n-1, a dequeue operation must shift all of the elements down by one position to retain the property that the remaining n-1 queue elements reside in the first n-1 positions of the array.
  - A far more efficient implementation can be obtained by relaxing the requirement that all elements of the queue must be in the first n positions of the array.

Queue Implementation (1)



(a)



(b)

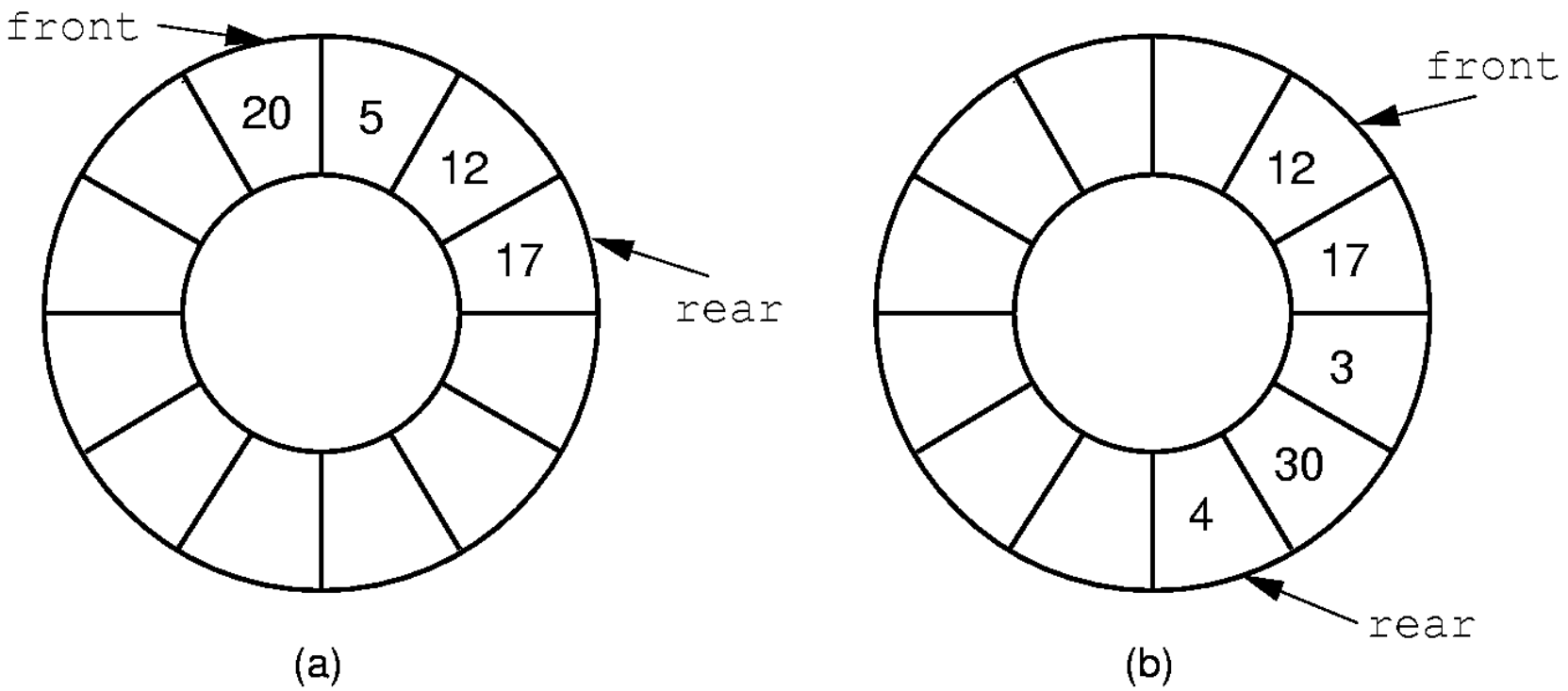
Queue Implementation (1)

- This implementation raises a new problem.
  - When elements are removed from the queue, the front index increases. Over time, the entire queue will drift toward the higher-numbered positions in the array. Once an element is inserted into the highest-numbered position in the array, the queue has run out of space. This happens despite the fact that there might be free positions at the low end of the array where elements have previously been removed from the queue.

Queue Implementation (2)

- The “drifting queue” problem can be solved by pretending that the array is circular and so allow the queue to continue directly from the highest-numbered position in the array to the lowest-numbered position.

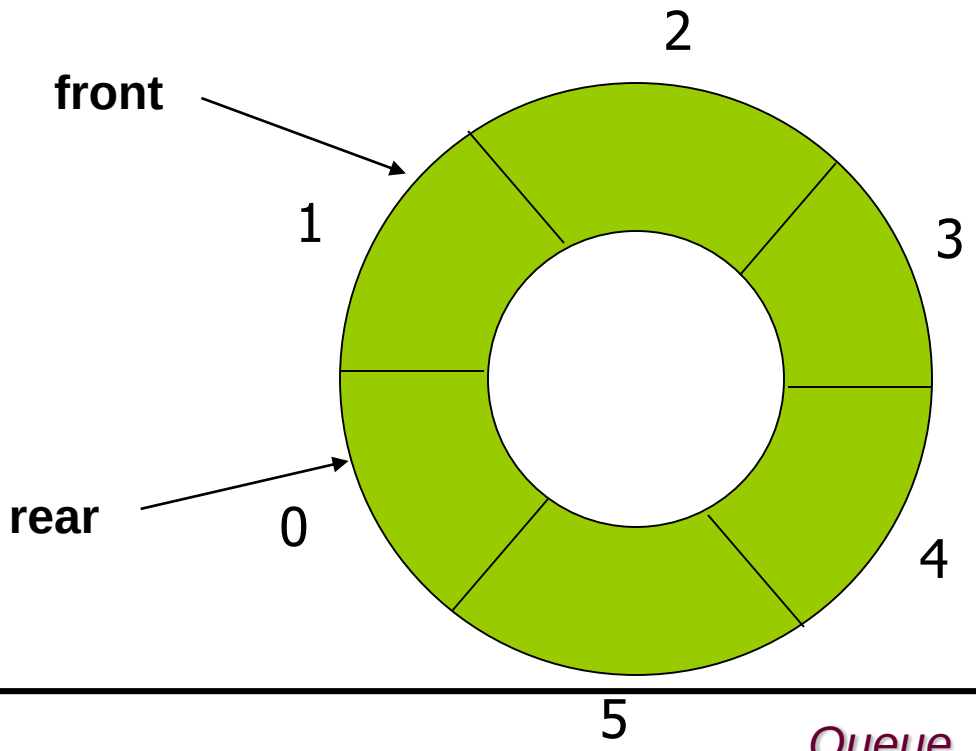
Queue Implementation (2)



Circular Queue Demo

- A refinement of the lazy approach is the circular queue

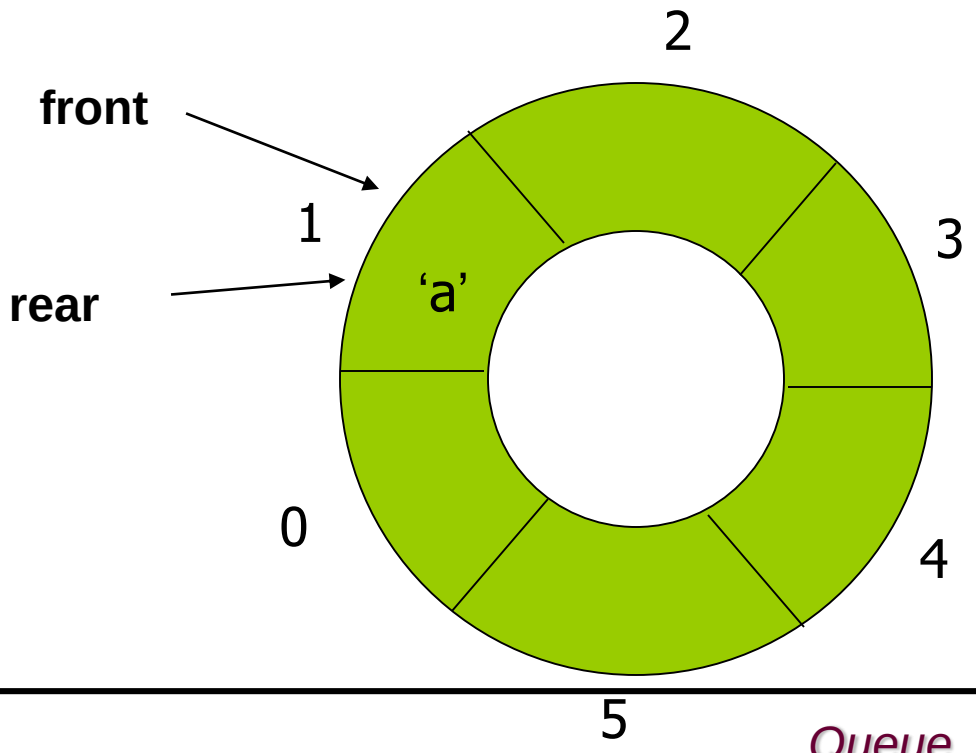
```
front = 1; rear = 0;
enQueue ('a');
```



Circular Queue Demo

- A refinement of the lazy approach is the circular queue

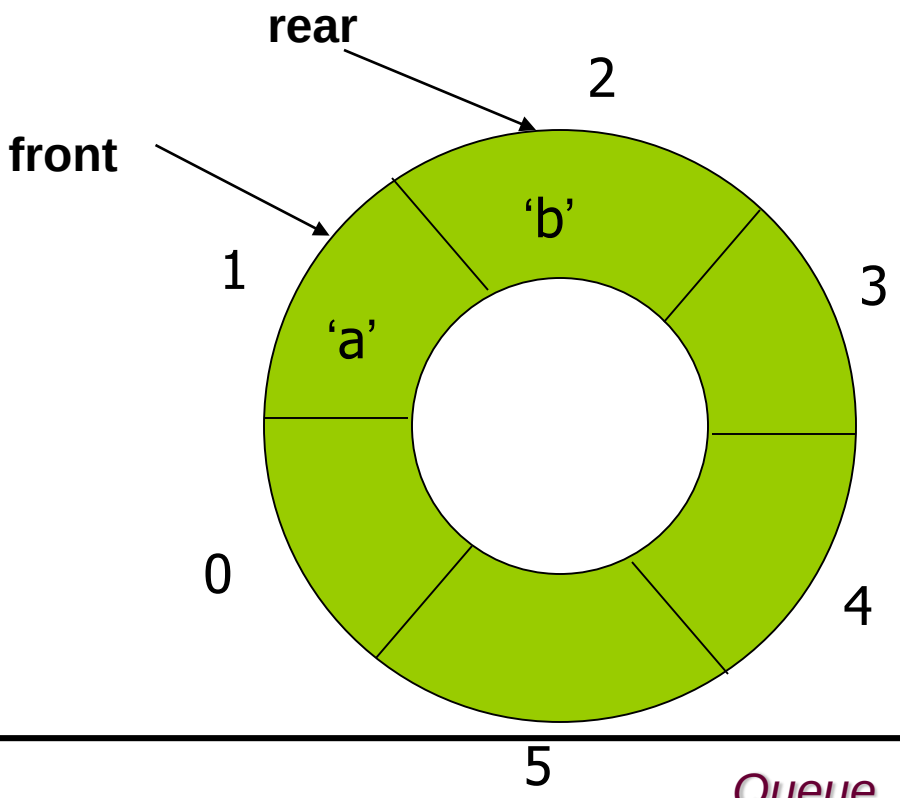
```
enQueue ('a');
enQueue ('b');
```



Circular Queue Demo

- A refinement of the lazy approach is the circular queue

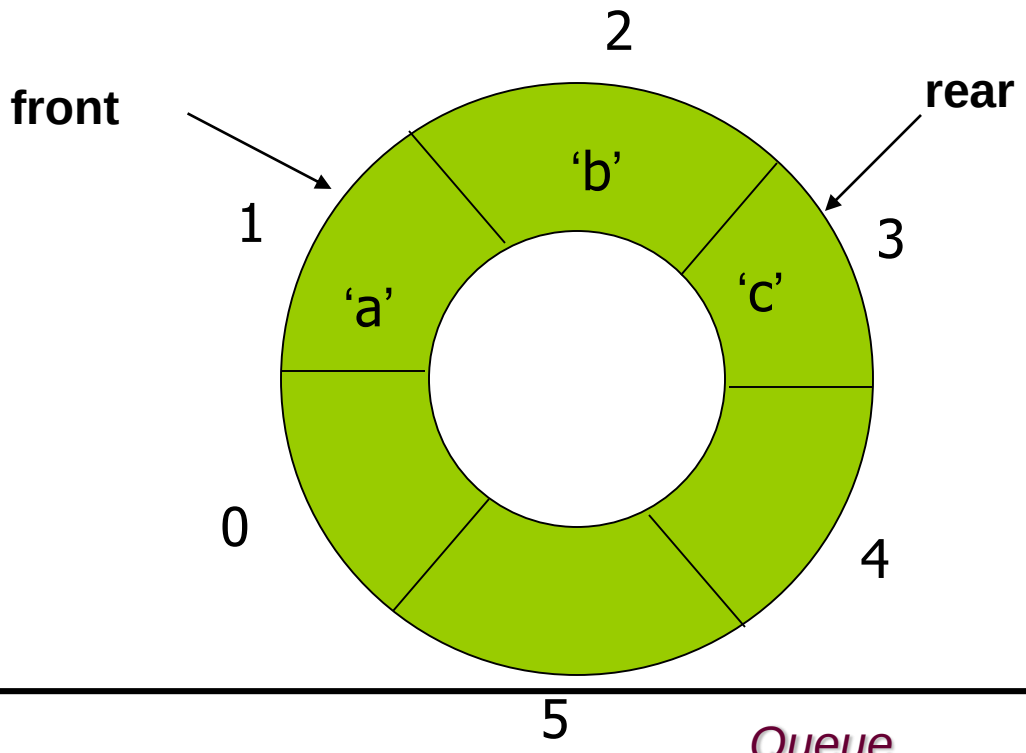
```
enQueue ('a');
enQueue ('b');
enQueue ('c');
```



Circular Queue Demo

- A refinement of the lazy approach is the circular queue

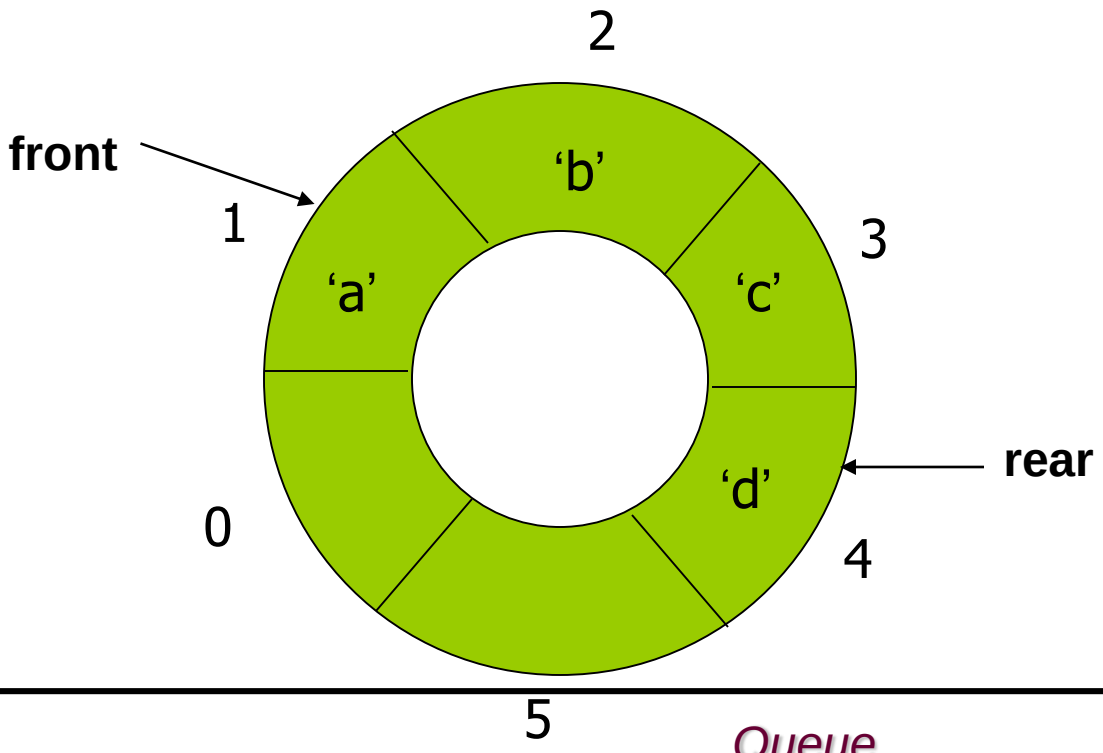
```
enQueue ('a');
enQueue ('b');
enQueue ('c');
enQueue ('d');
```



Circular Queue Demo

- A refinement of the lazy approach is the circular queue

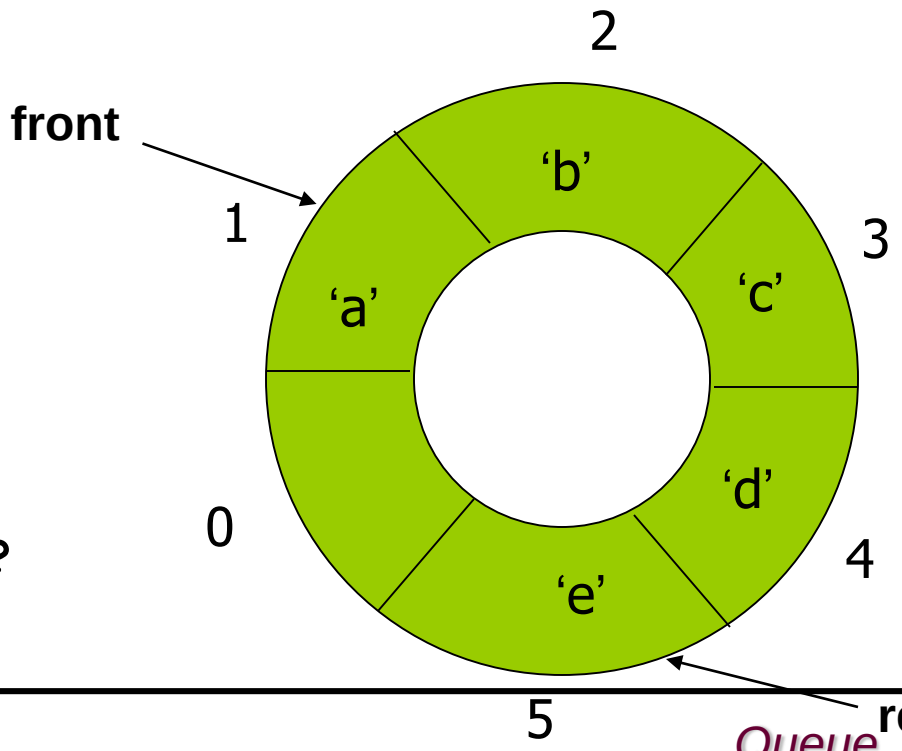
```
enQueue ('a');
enQueue ('b');
enQueue ('c');
enQueue ('d');
enQueue ('e');
```



Circular Queue Demo

- A refinement of the lazy approach is the circular queue

```
enQueue (q, 'a');
enQueue (q, 'b');
enQueue (q, 'c');
enQueue (q, 'd');
enQueue (q, 'e');
enQueue (q, 'f'); ???
```



Queue Implementation (2)

- How can we recognize when the circular queue is empty or full?
  - For both empty queue and full queues， the value for **rear** is one less than the **value** for front。
  - One obvious solution is to keep an explicit count of the number of elements in the queue, or a Boolean variable that indicates whether the queue is empty or not.
  - Another solution is to make the array be of size n+ 1, and only allow n elements to be stored.

Circular Queue Demo

- A refinement of the lazy approach is the circular queue

Empty:

length() == 0;

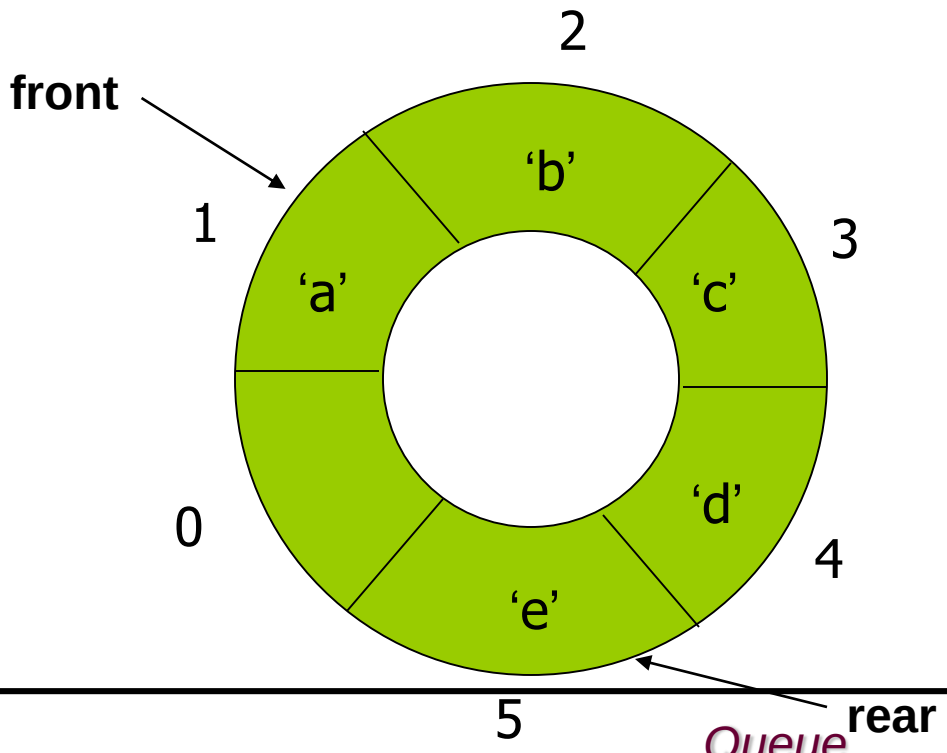
Full:

（rear +2)%N == front

General Equations:

front = (front +1)%N;

rear = (rear+1)%N;



Array-based Queue Implementation

```
template <typename E> class AQueue: public Queue<E> {
private:
  int maxSize; // Maximum size of queue
  int front; // Index of front element
  int rear; // Index of rear element
  E *listArray; // Array holding queue elements
public:
  AQueue(int size =defaultSize) { // Constructor
  // Make list array one position larger for empty slot
    maxSize = size+1;
    rear = 0; front = 1;
    listArray = new E[maxSize];
  }
  ~AQueue() { delete [] listArray; } // Destructor
```

Array-based Queue Implementation

```
void clear() { rear = 0; front = 1; } // Reinitialize
void enqueue(const E& it) { // Put "it" in queue
  Assert((rear+2) % maxSize) != front, "Queue is full")
  rear = (rear+1) % maxSize; // Circular increment
  listArray[rear] = it;
}
E dequeue() { // Take element out
  Assert(length() != 0, "Queue is empty");
  E it = listArray[front];
  front = (front+1) % maxSize; // Circular increment
  return it;
}
```

Array-based Queue Implementation

```
  const E& frontValue() const { // Get front value
     Assert(length() != 0, "Queue is empty");
     return listArray[front];
  }
  virtual int length() const // Return length
    { return ((rear+maxSize) - front + 1) % maxSize; }
};
```

Linked Queues Implementation

- The linked queue implementation is a straightforward adaptation of the linked list.
- On initialization, the front and rear pointers will point to the header node, and front will always point to the header node while rear points to the true last link node in the queue.

Linked Queues Implementation

```
template <typename E> class LQueue: public Queue<E> {
private:
  Link<E>* front; // Pointer to front queue node
  Link<E>* rear; // Pointer to rear queue node
  int size; // Number of elements in queue
public:
  LQueue(int sz =defaultSize) // Constructor
     { front = rear = new Link<E>(); size = 0; }
  ~LQueue() { clear(); delete front; } // Destructor
```

Linked Queues Implementation

```
void clear() { // Clear queue
   while(front->next != NULL) { // Delete each link node
   rear = front;
   front=front->next;
   delete rear;
   }
   rear = front;
   size = 0;
}

void enqueue(const E& it) { // Put element on rear
   rear->next = new Link<E>(it, NULL);
   rear = rear->next;
   size++;
}
```

Linked Queues Implementation

```
E dequeue() { // Remove element from front
  Assert(size != 0, "Queue is empty");
  E it = front->next->element; // Store dequeued value
  Link<E>* ltemp = front->next; // Hold dequeued link
  front->next = ltemp->next; // Advance front
  if (rear == ltemp) rear = front; // Dequeue last element
  delete ltemp; // Delete link
  size --;
  return it; // Return element value
}
```

Linked Queues Implementation

```
  const E& frontValue() const { // Get front element
    Assert(size != 0, "Queue is empty");
    return front->next->element;
  }
  virtual int length() const { return size; }
};
```

Comparison of Array-Based and Linked Queues

- All member functions for both the array-based and linked queue implementations require constant time.
- The space comparison issues are the same as for the equivalent stack implementations.

Problem：

- Let Q be a non-empty queue, and let S be an empty stack. Using only the stack and queue ADT functions and a single element variable X, write an algorithm to reverse the order of the elements in Q.

Solution

```
void reverse(Queue& Q, Stack& S) {
  E X;
  while (!Q.length()) {
    X = Q.dequeue();
    S.push(X);
  }
  while (!S. length()) {
    X = S.pop();
    Q.enqueue(X);
  }
}
```

Homework

- 4.13
- 4.14
- 4.15

Reference

- **Data Structures and Algorithm Analysis in C++ .Third Edition.Clifford A. Shaffer**(P.129-134)

Project2

- You are to create programs that keep track of inventory and shipping at a store or business of your choosing. Suppose there are five different categories of items, and there are five linked lists correspondingly. When items are made, they are put into certain linked list inventory according to its category. When you ship something, it comes out of inventory and goes into a shipping queue. When an item is delivered, it is taken out of the shipping queue. You should keep a list of all delivered items. Users of your system should be able to do the following:

1. Input an item (some category, some name) and an amount. The item and amount should be inserted into a *linked list* of inventory items.
2. Push a button to get a list displayed of all the items and their quantities in the inventory.
3. Push a button to take the next item from inventory and put it in a shipping *queue.*
4. Push a button to get a list displayed of all the items that are currently shipping.
5. Push a button to indicate that a shipped item has been delivered and should be taken out of the shipping queue. Shipped items are put in and taken out FIFO.
6. Push a button to display all the things that have been delivered.

Project 2

- You are to create classes for the different data structures and nodes. You also need a driver program that takes user input and manipulates a node object and prints output. The driver should be written as a C++ application with buttons and text input and output.

- One way to do the application is to have two text fields for input, a text area for output, and buttons that say “add to inventory,” “display inventory,” etc. Think about your design and draw it out *before* you write the code. Also, draw your data structures before you write any code. Draw out the operations of taking things from one data structure and putting them into another. Think about what goes in your application and your class *before* you write any code.

-END-