Queues

- FIFO queue ADT
- Examples using queues
  - reading character string in order
  - recognize palindromes
- Queue implementations
  - LL pointer based
  - List ADT based
  - array based
  - tradeoffs

The Abstract Data Type Queue

- Another common linear data structure similar to the *stack*
- Queue is an ADT with following properties
  - elements are kept in their order of arrival
  - new items enter at the back, or rear, of the queue
  - items leave from the front of the queue
- Thus queue has first-in, first-out (FIFO) property
  - nicely models several real-world processes
    - line to buy movie tickets, or queue jobs and print requests

The Abstract Data Type Queue

- ADT queue operations
  - Create an empty queue
  - Destroy a queue
  - Determine whether a queue is empty
  - Add a new item to the queue
  - Remove the item that was added earliest
  - Retrieve the item that was added earliest

The Abstract Data Type Queue

- Operation Contract for the ADT Queue
  - isEmpty():boolean {query}
  - enqueue(in newItem:QueueItemType)
    throw QueueException
  - dequeue() throw QueueException
  - dequeue(out queueFront:QueueItemType)
    throw QueueException
  - getFront(out queueFront:QueueItemType) {query}
    throw QueueException

The Abstract Data Type Queue

Operation	Queue after operation
	front
`aQueue.createQueue()`	
`aQueue.enqueue(5)`	5
`aQueue.enqueue(2)`	5 2
`aQueue.enqueue(7)`	5 2 7
`aQueue.getFront(queueFront)`	5 2 7 (queueFront is 5)
`aQueue.dequeue(queueFront)`	2 7 (queueFront is 5)
`aQueue.dequeue(queueFront)`	7 (queueFront is 2)

Figure 7-2 Some queue operations

Example 1: Ordering Character String

- A queue can retain characters in the order in which they are typed

```
aQueue.createQueue()
while (not end of line)
{  Read a new character ch
   aQueue.enqueue(ch)
} // end while
```

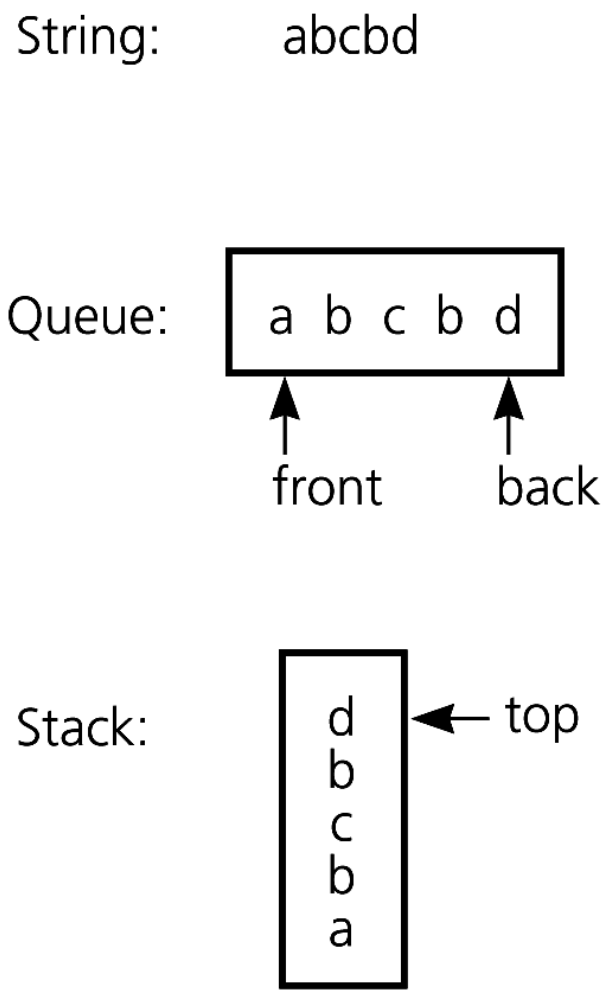
- Once the characters are in a queue, the system can process them as necessary

Example2: Recognizing Palindromes

- A palindrome is a string of characters that reads the same backwards and forwards
  - RADAR, MADAM, EYE, etc.
- Observations
  - stack reverses the order of occurrences
  - queue preserves the order of occurrences
- A palindrome stored in both stack and queue will display a match when retrieved

Example2: Recognizing Palindromes

- A nonrecursive recognition algorithm for palindromes
  - traverse character string from left to right
  - insert each character into both a queue and a stack
  - compare the characters at the front of the queue and the top of the stack



see C7-palin.cpp

Implementations of the ADT Queue

- Linked list based queue implementation
  - can maintain pointers to *front* and *back* of Queue
  - circular linked list with one external reference also possible
- Using ADT List class to implement queue
  - possible less efficient, but simple
- An array-based queue implementation
  - problem of *rightward-drift*

Linked List Implementations

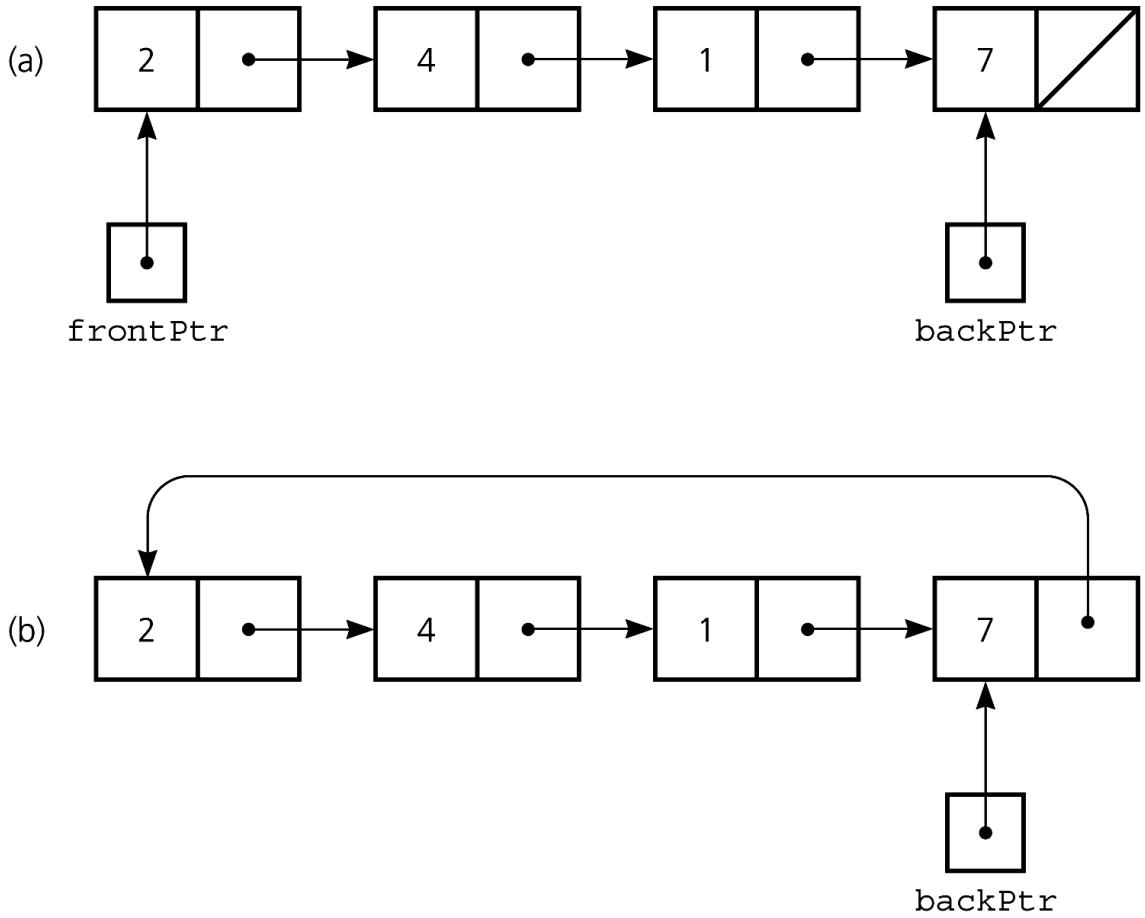


Figure 7-4 A pointer-based implementation of a queue: (a) a linear linked list with two external pointers; (b) a circular linear linked list with one external pointer

Operations in LL Implementation

Figure 7-5 Inserting an item into a nonempty queue

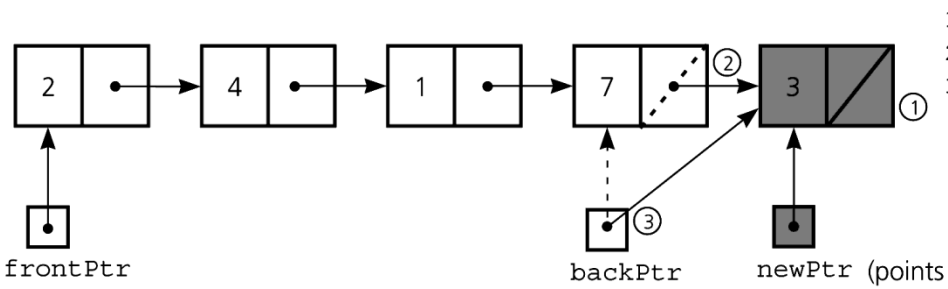


Figure 7-6 Inserting an item into an empty queue:
(a) before insertion;
(b) after insertion

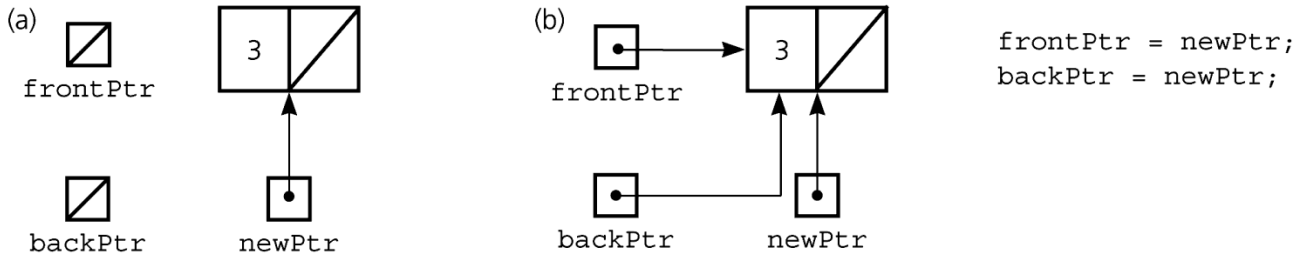
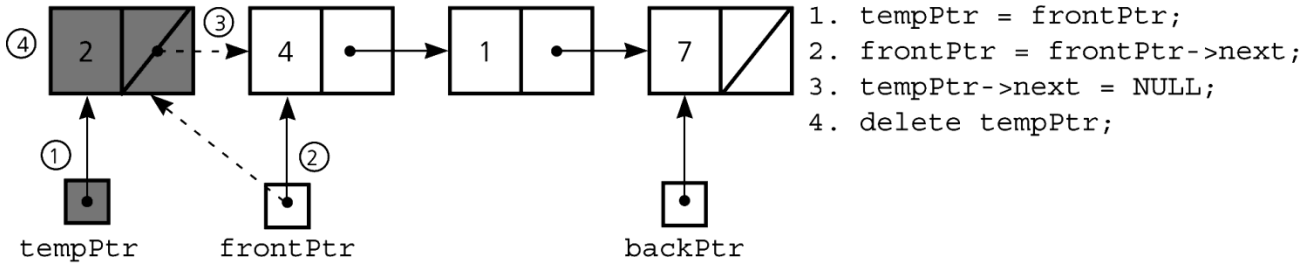


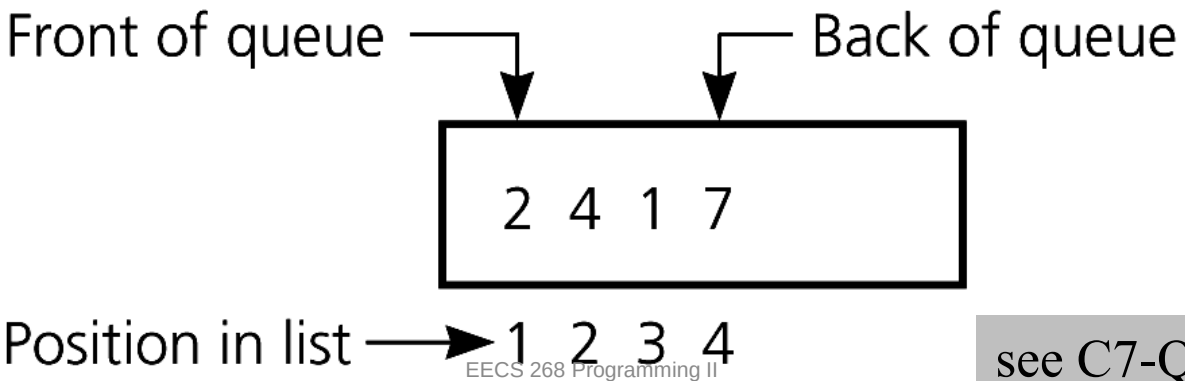
Figure 7-7 Deleting an item from a queue of more than one item



see C7-QueueP.cpp

List Based Queue Implementation

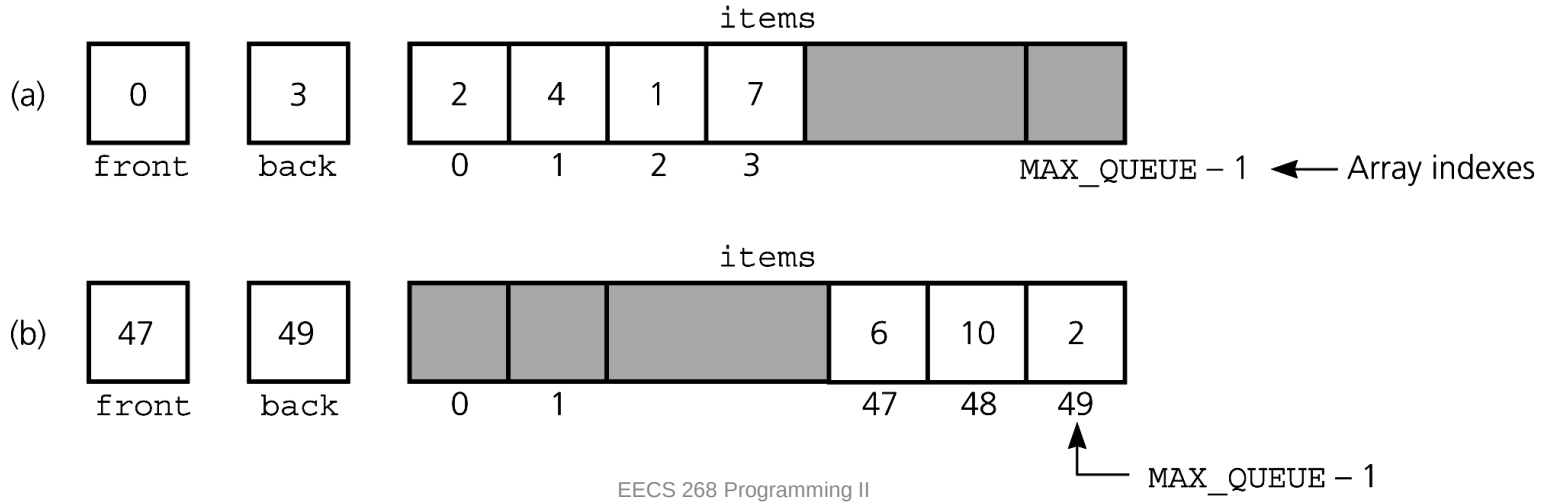
- Queue operations map well to ADT List operations
  - enqueue(item) → insert(getLength()+1, item)
  - dequeue() → remove(1)
  - getFront(qfront) → retrieve(1, qfront)
- We can built the queue ADT as a wrapper over the List ADT



see C7-QueueL.cpp

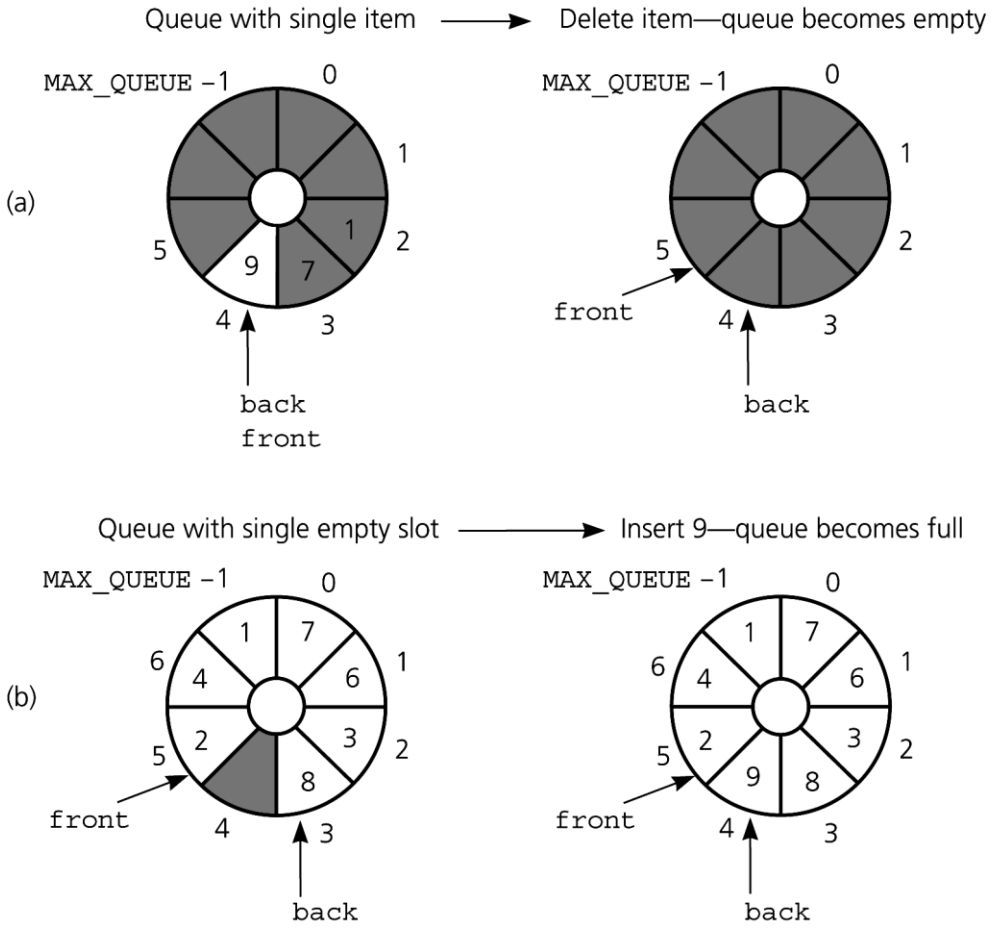
An Array-Based Implementation

- Using arrays is slightly more complex
  - naïve implementation causes *rightward drift*
  - queue appears full even when array does not hold MAX_QUEUE-1 elements
- Solutions to rightward drift
  - always copy array elements to left – expensive
  - maintain circular array – how to detect queue full/empty?



Circular Array Implementation

- Problem:
  - *front == (back+1)* is true for both queue full & empty
- Solution:
  - use integer counter to hold size of queue
  - update on each enqueue/dequeue



An Array-Based Implementation

- Initialize the queue,

  `front` = 0, `back` = `MAX_QUEUE - 1`,

  `count` = 0

- Inserting into a queue

```
back = (back+1) % MAX_QUEUE;
items[back] = newItem;
++count;
```

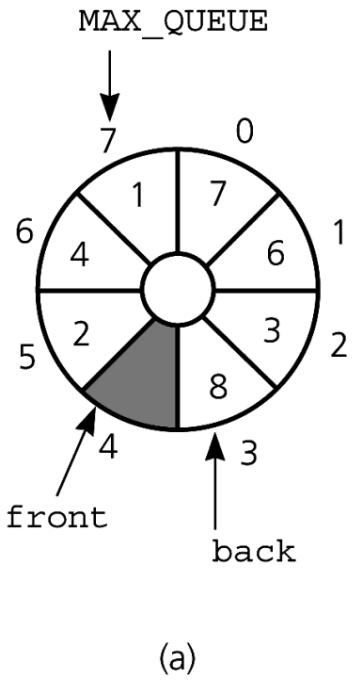
- Deleting from a queue

```
front = (front+1) % MAX_QUEUE;
--count;
```

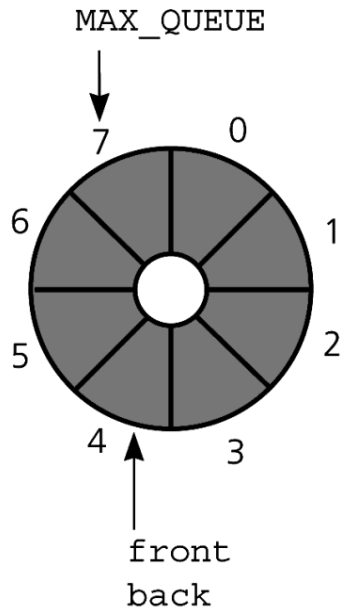
see C7-QueueA.cpp

Array Implementation Variations

- Use a flag `isFull` to distinguish between the full and empty conditions
- Declare `MAX_QUEUE + 1` locations for the array items, but use only `MAX_QUEUE` of them for queue items



(a)



(b)

Comparing Implementations

- Static arrays Vs. dynamically allocated LLs
  - enqueue operation cannot add item if array is full
  - no size restriction with LL (unless memory full)
- LL Vs List bases array implementations
  - LL-based implementation is more efficient
  - ADT list approach reuses already implemented class
    - much simpler to write
    - saves programming time

A Summary of Position-Oriented ADTs

- Position-oriented ADTs
  - List
  - Stack
  - Queue
- Stacks and queues
  - Only the end positions can be accessed
- Lists
  - All positions can be accessed

A Summary of Position-Oriented ADTs

- Stacks and queues are very similar
  - Operations of stacks and queues can be paired off
    - createStack and createQueue
    - Stack isEmpty and queue isEmpty
    - push and enqueue
    - pop and dequeue
    - Stack getTop and queue getFront

Summary

- ADT queue has first-in, first-out (FIFO) behavior
- Circular array eliminates the problem of rightward drift in array-based implementation
- To distinguish between the queue-full and queue-empty conditions in a circular array
  - count the number of items in the queue
  - use an isFull flag
  - leave one array location empty
- LL and List ADT based implementations possible