Lecture 2: Queues

EECG142- Data Structures

Textbook:
Data Structures via C++: Objects by Evolution
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First year - EECE Department

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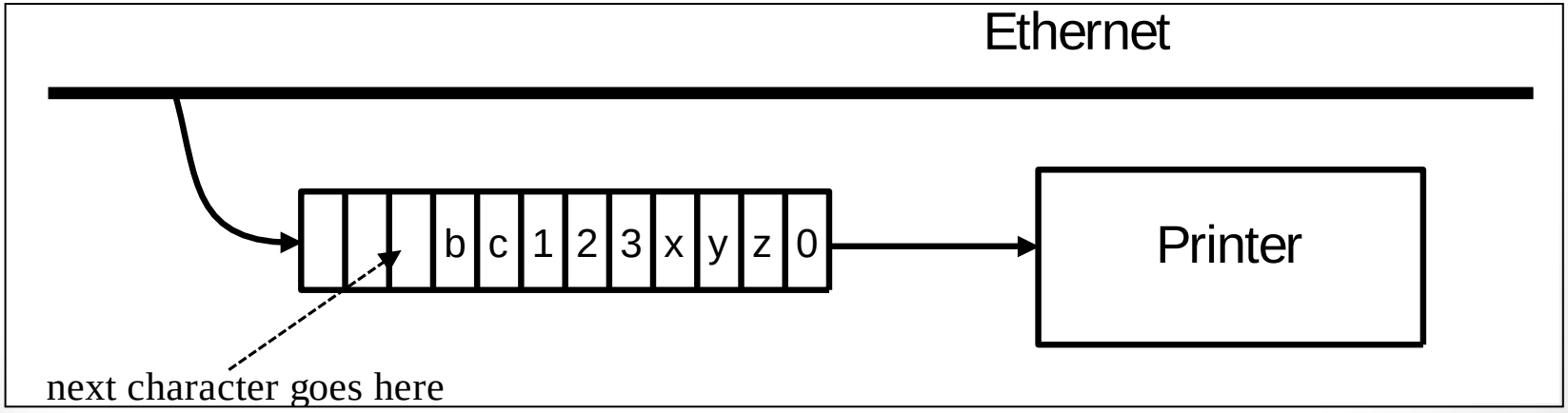
This lecture covers

1. Queue definition and examples
2. Queue implementation using linear arrays
3. Queue implementation using circular arrays
4. Queue implementation using linked-lists

Queue Example

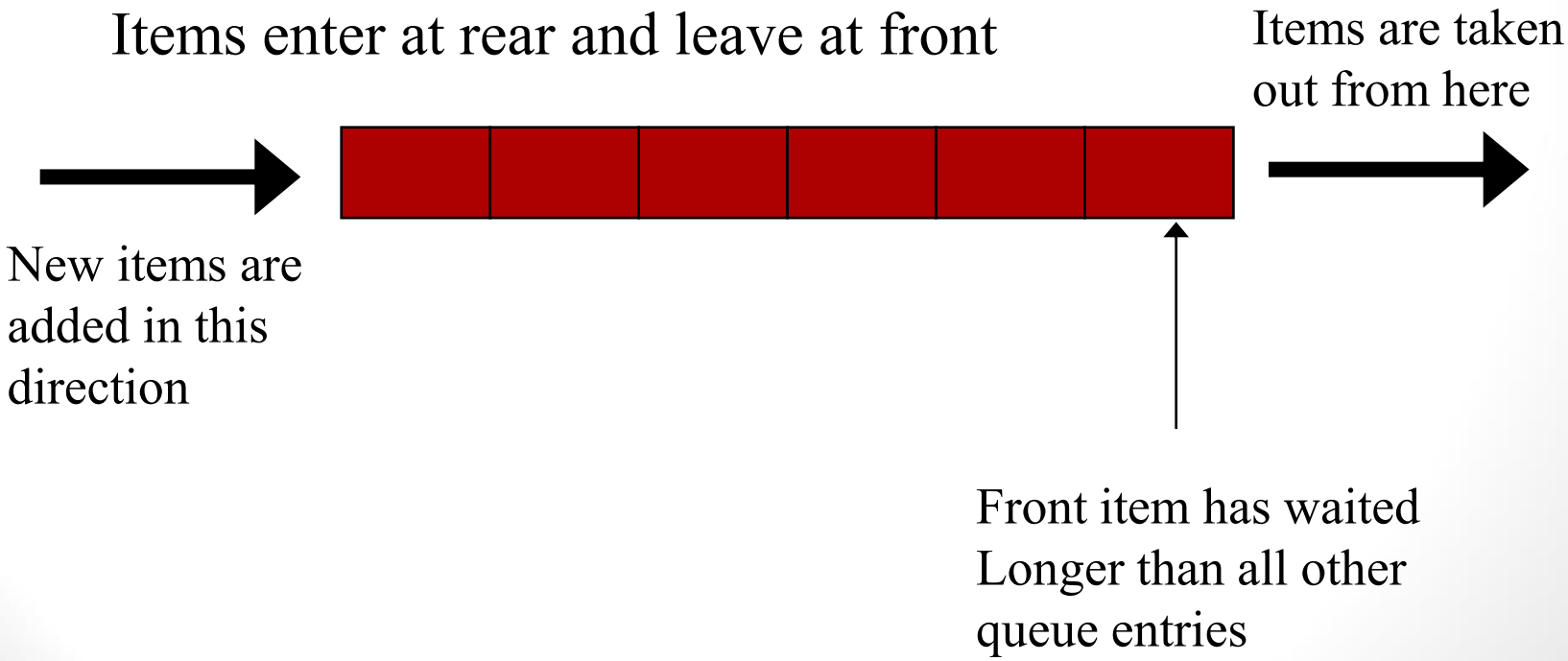
Examples of queues include:

- people waiting in line for a movie or a shop.
- jobs waiting to be executed by a processors
- documents needed to be printed by a printer
- data in a buffer waiting to be transmitted



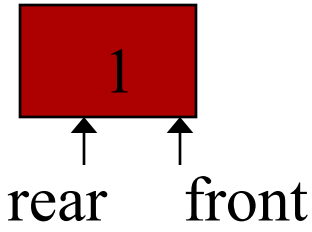
Queues

Unlike stacks, queues have a First in, first out (FIFO) property. Items are added to the rear and removed from the front

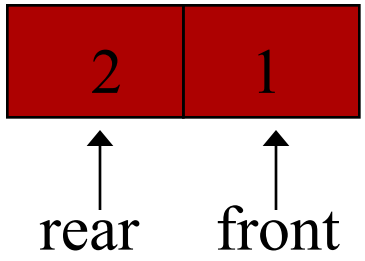


Simple Queue Operations

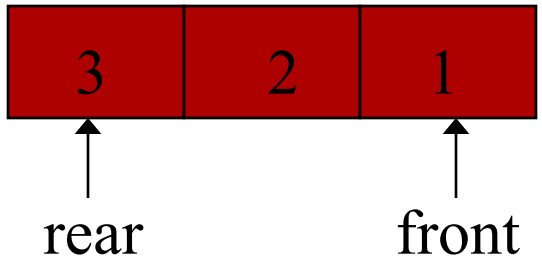
q.enqueue(1)



q.enqueue(2)



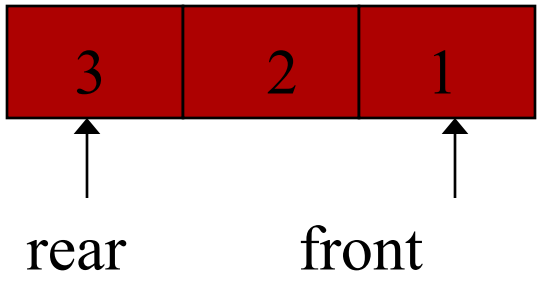
q.enqueue(3)



Simple Queue Operations

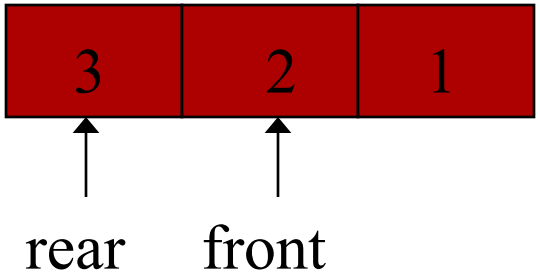
cout << q.front();

1



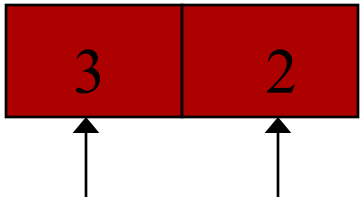
cout << q.dequeue();

1



cout << q.front();

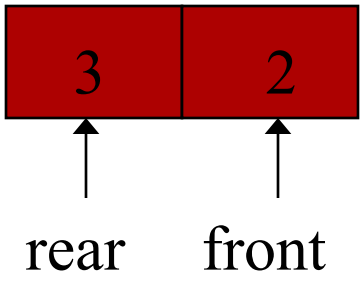
2



Simple Queue Operations

```
if (q.isEmpty())
  cout << "empty" << endl;
else
  cout << "not empty" << endl;
```

not empty

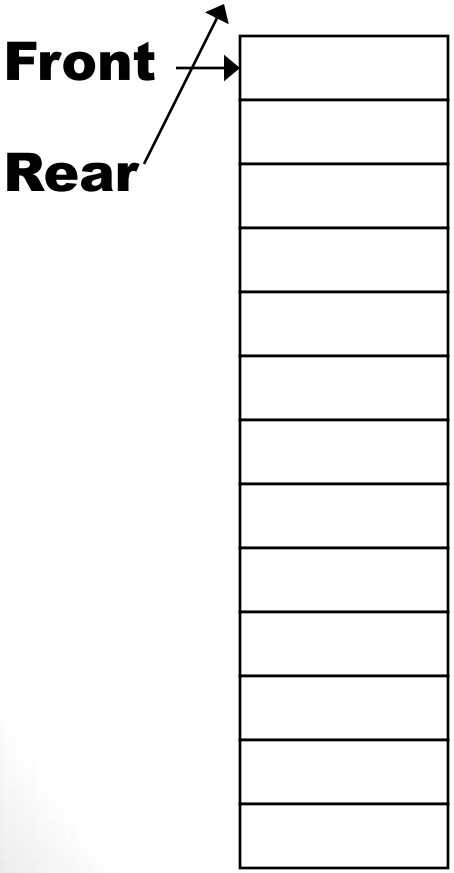


Array-based Implementation

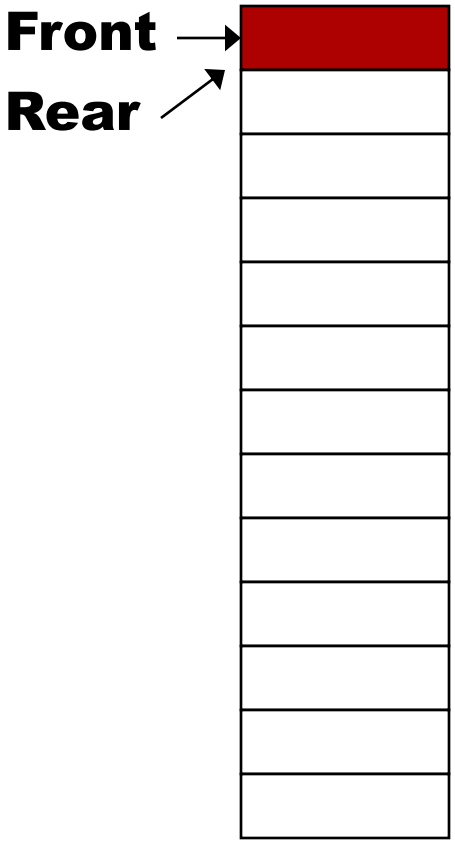
- You need to keep track of the queue's front and rear.
- The rear index of the queue will normally be higher than its front index with the exceptions
  - Empty queue (rear < front)
  - One-item queue (rear = front)
- A full queue has its rear index = array size-1

Special Cases of a Queue

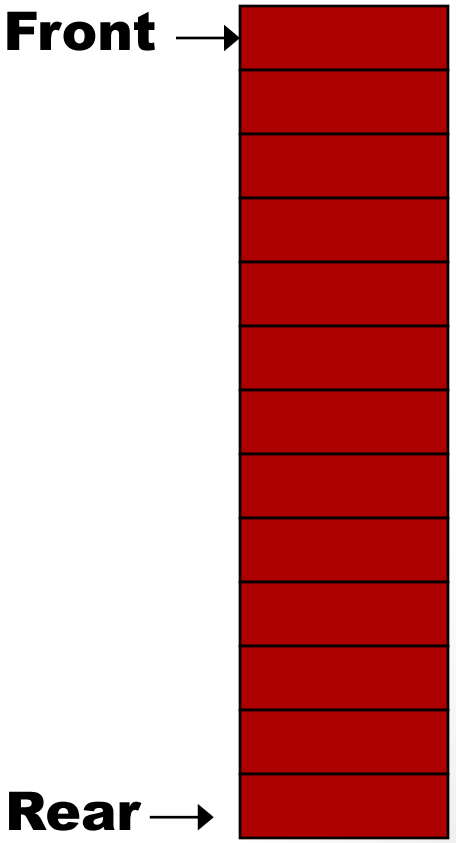
Empty queue



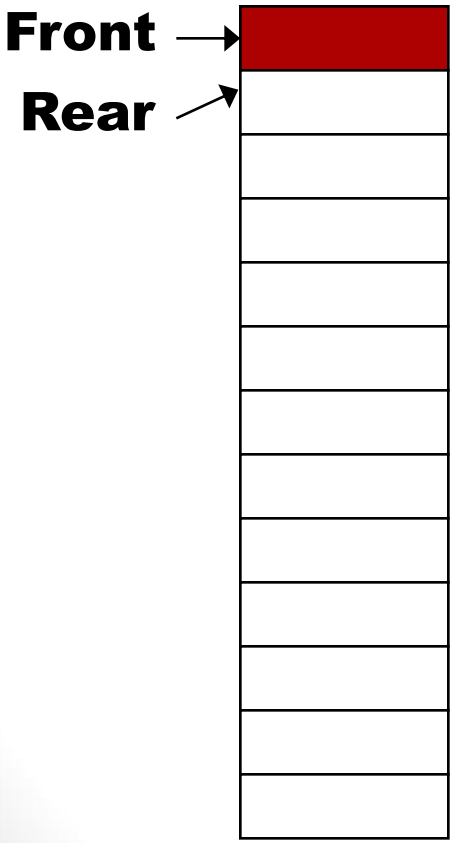
Single element queue

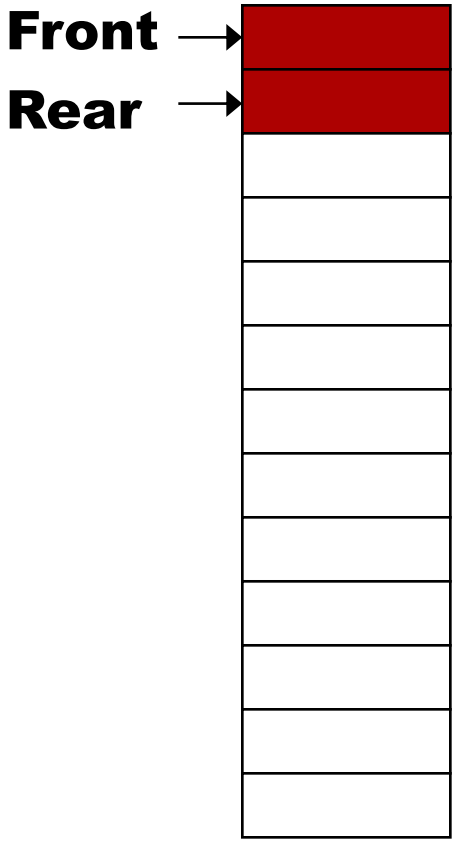


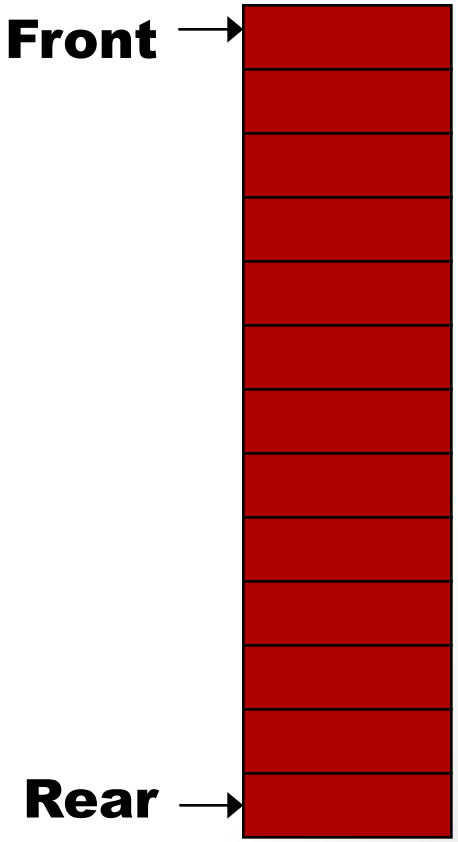
Full queue



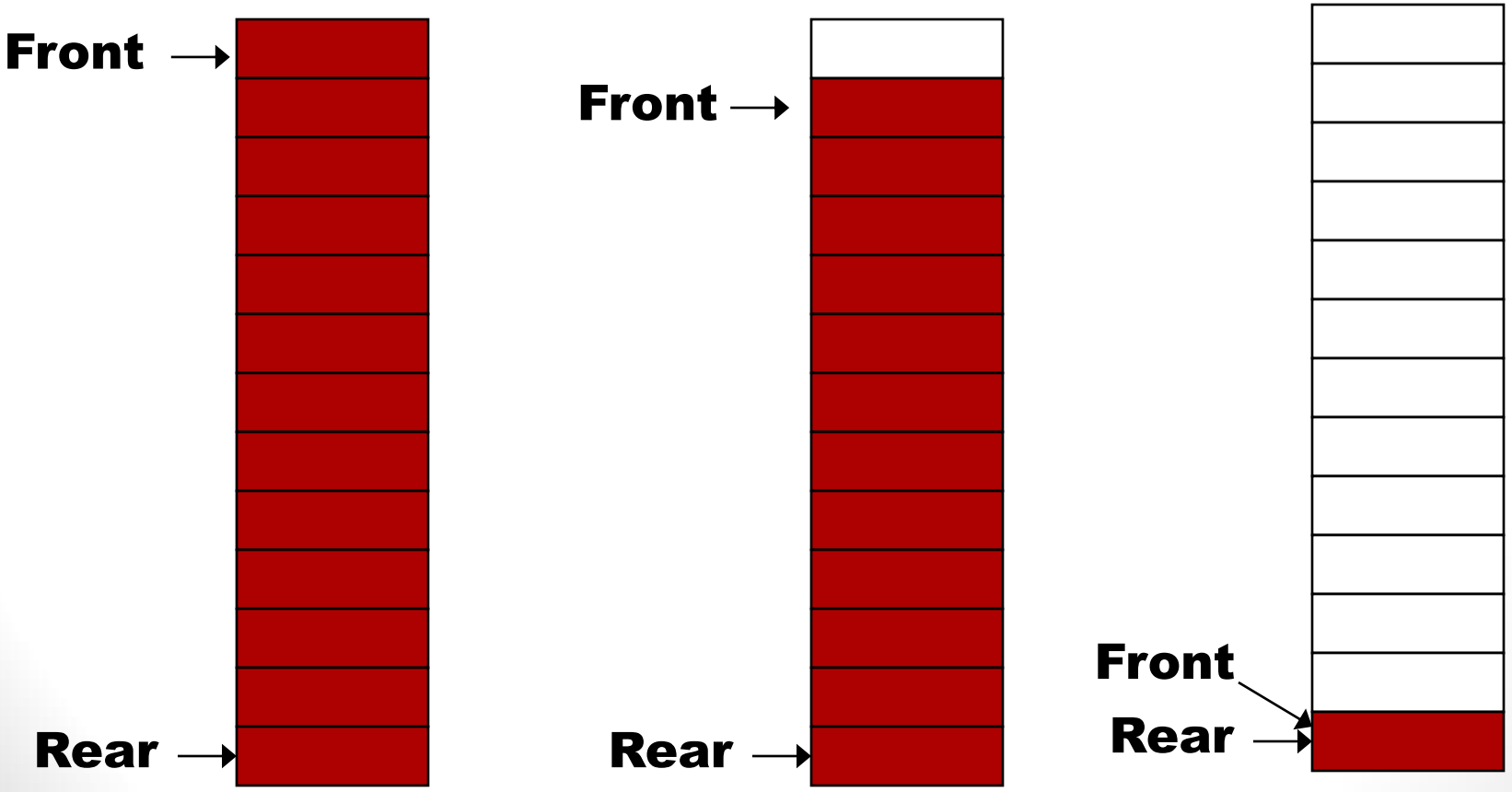
Enqueueing Items



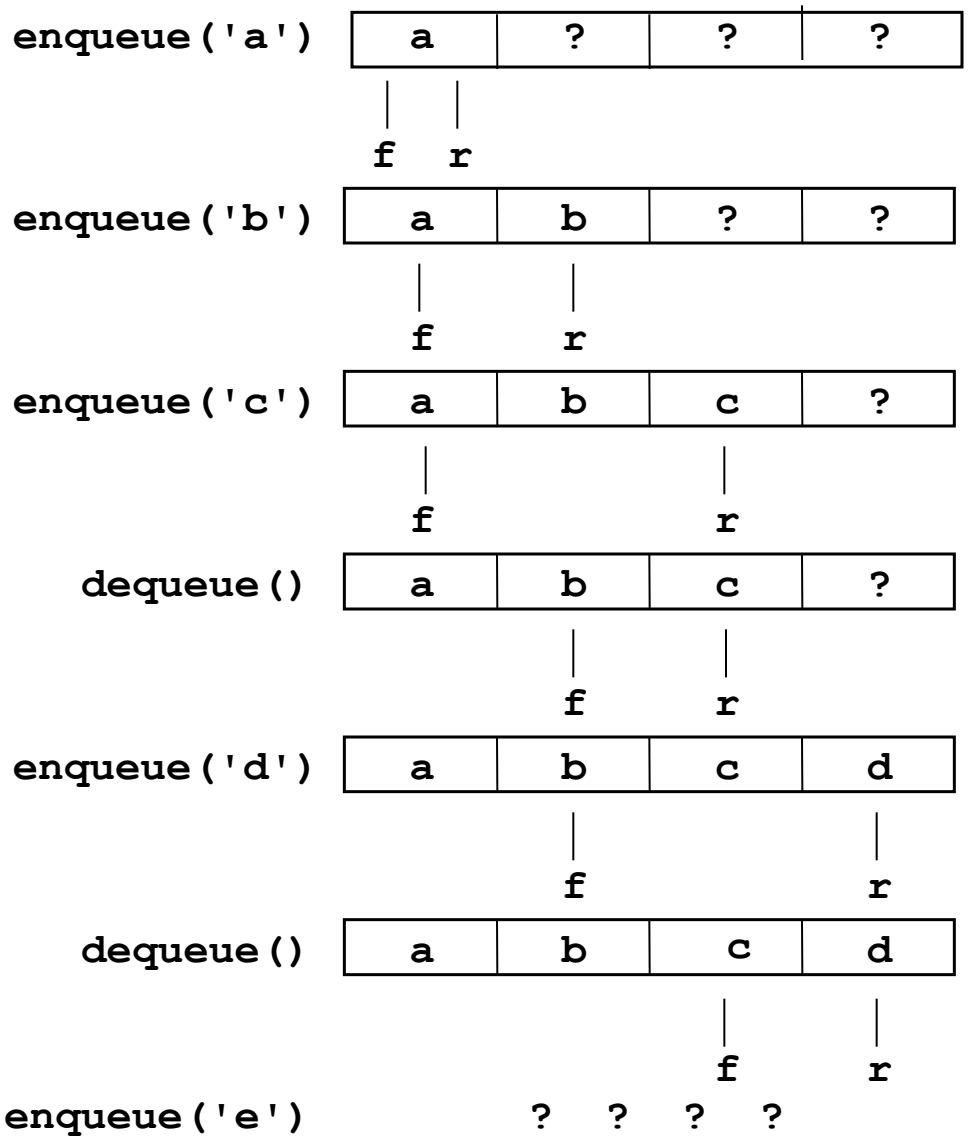




Dequeuing Items

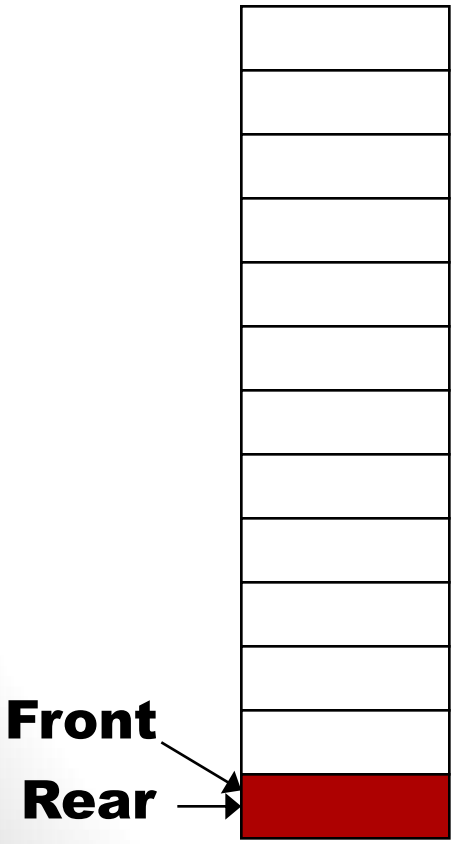


Implementation Problems



Implementation Problems

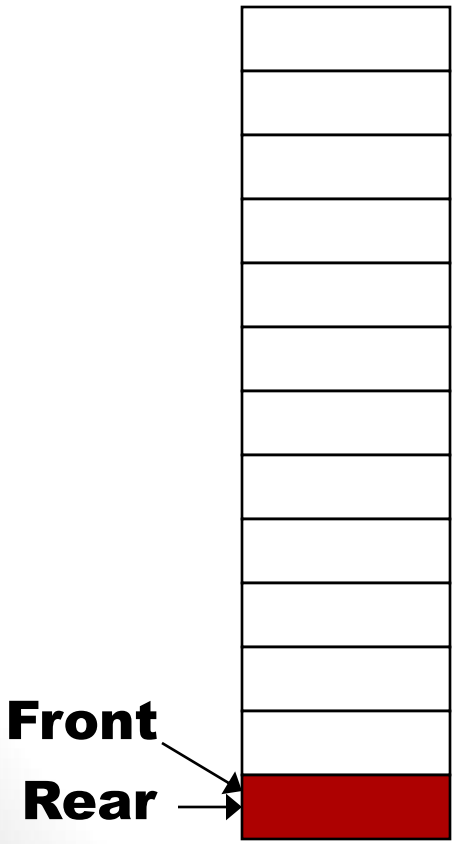
This single element queue is still considered full



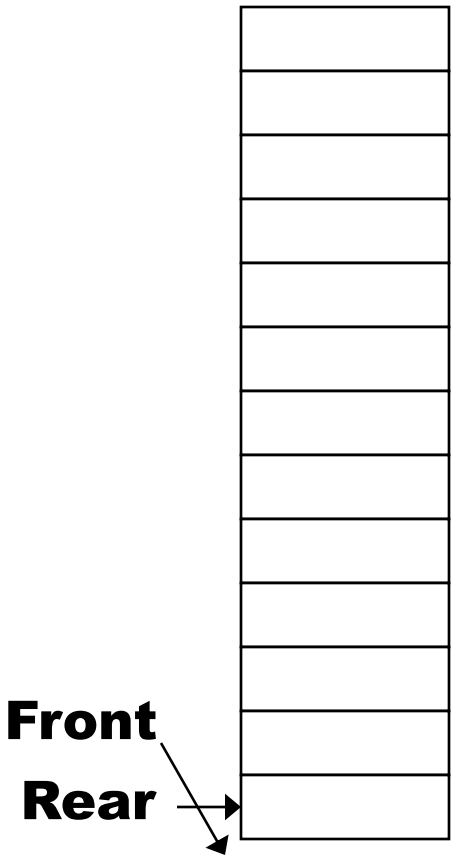
- Once the rear reaches the last index of the array, the queue is considered full and cannot accept more items even if there are empty cells after dequeuing
- We need to wait till the queue becomes empty and then reset the rear index.
- Such way is inefficient and unacceptable in many applications

Implementation Problems

Single element queue



Is the queue empty or full?



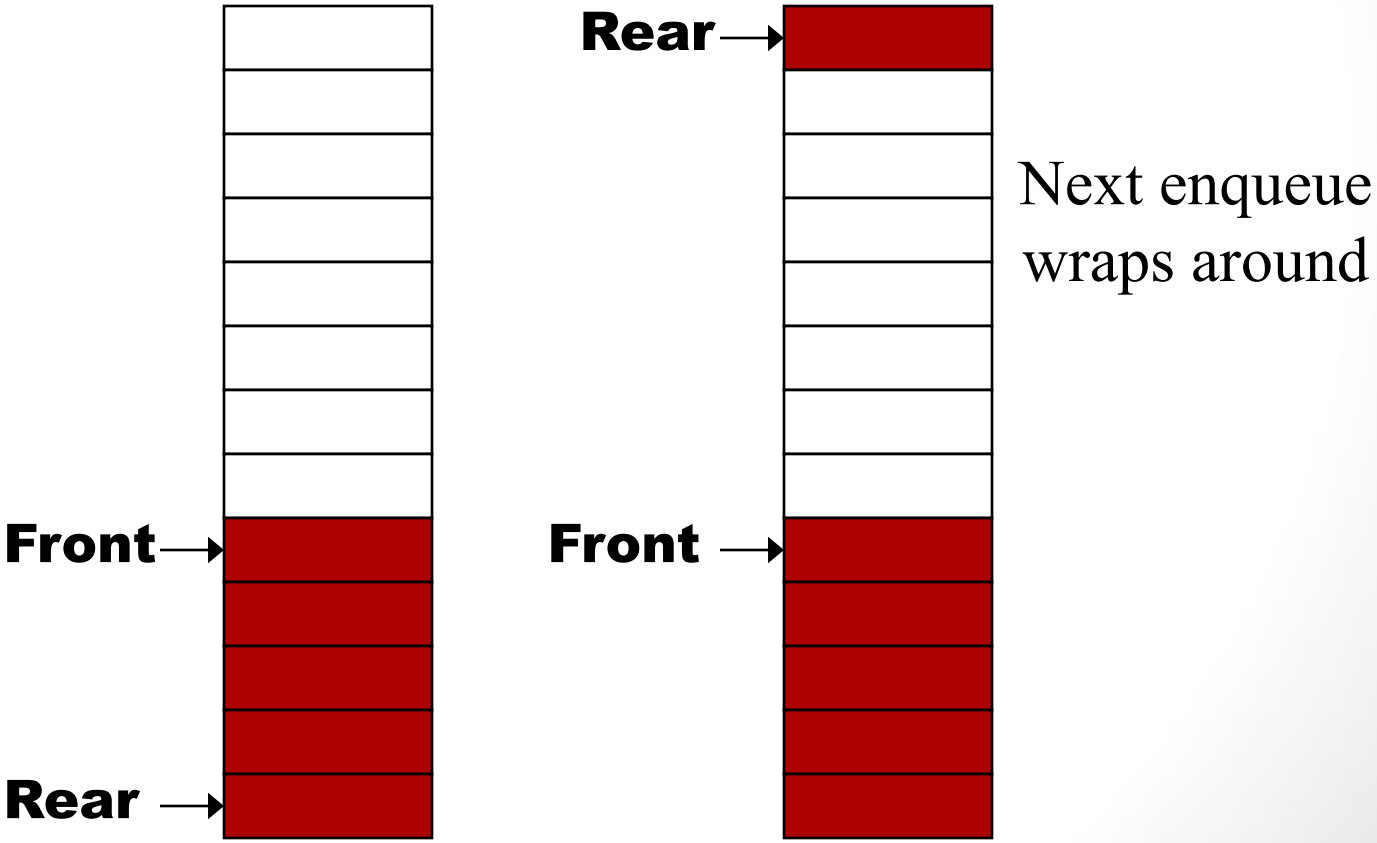
Our definition of empty is rear < front, so it is empty.

But, rear has reached its limit. It cannot go beyond the array, Therefore,
the queue is full!

Solution: Wrapping Around

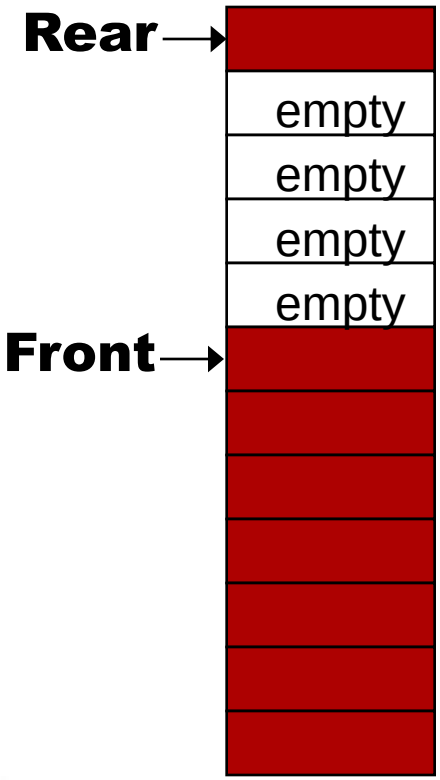
If rear + 1 > maxQueue -1, then rear = 0

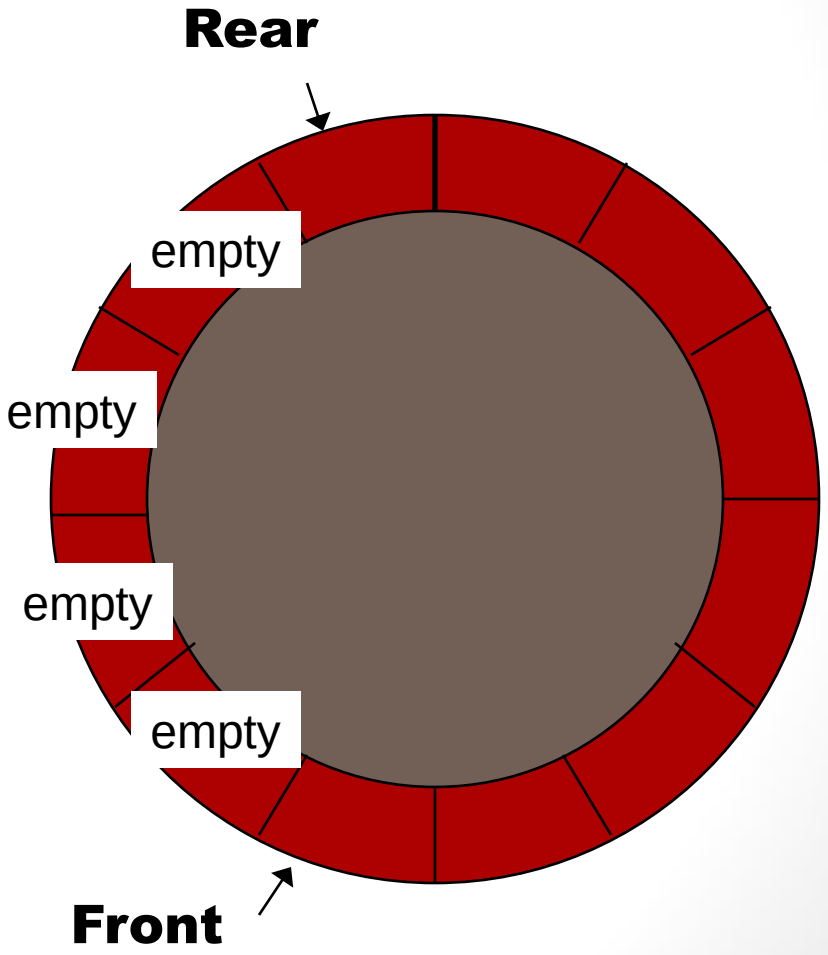
rear = (rear+1) % maxQueue



The Circular Queue

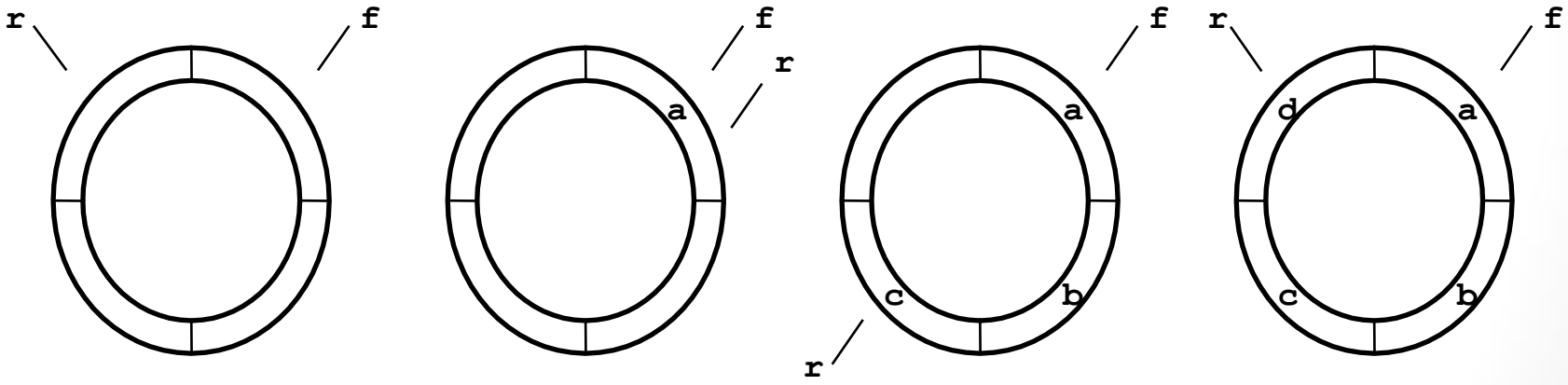
Circular queue



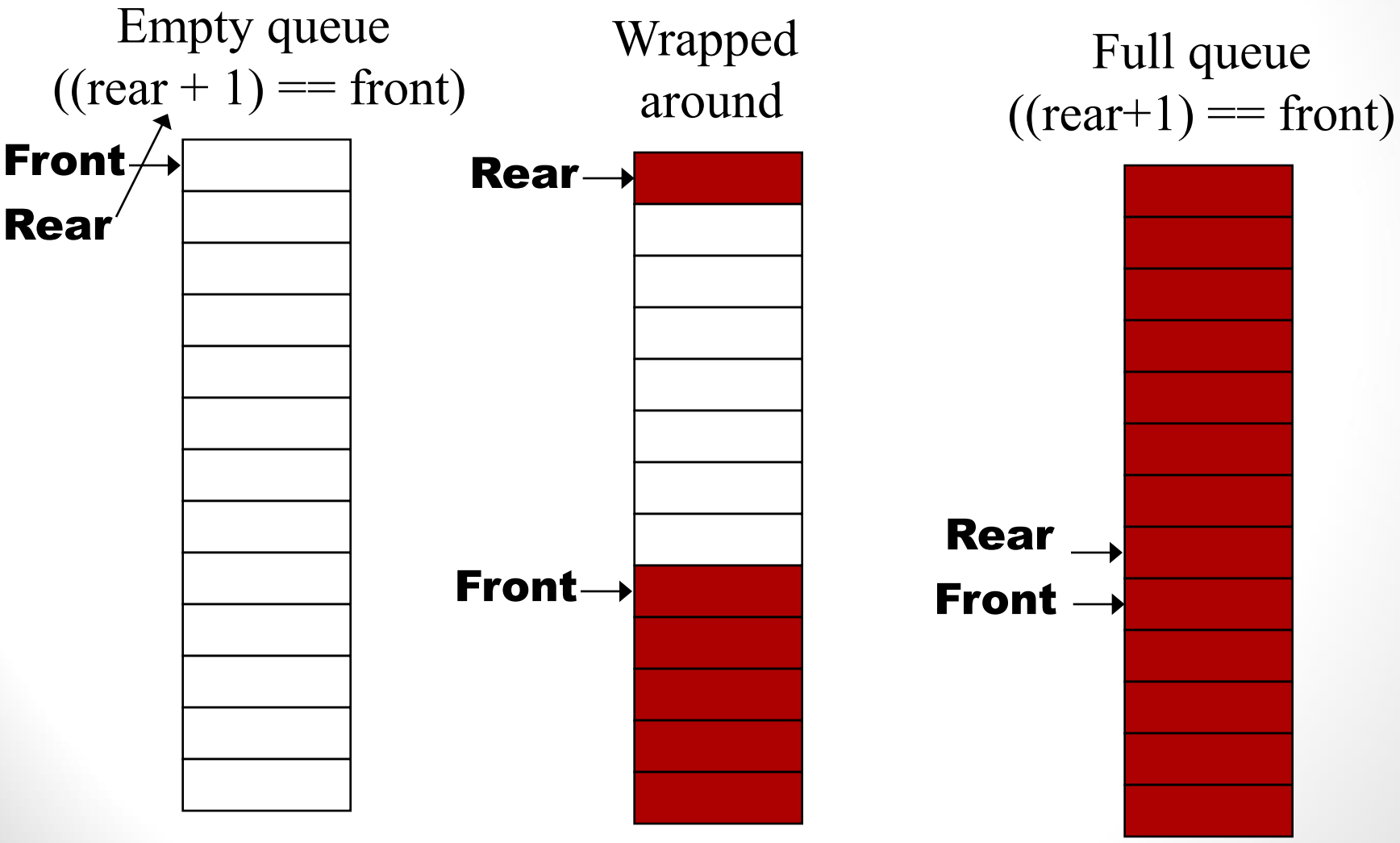


Is this queue empty or full?

We cannot use ‘rear < front’ as a test of empty circular queue because of the wrapping around.

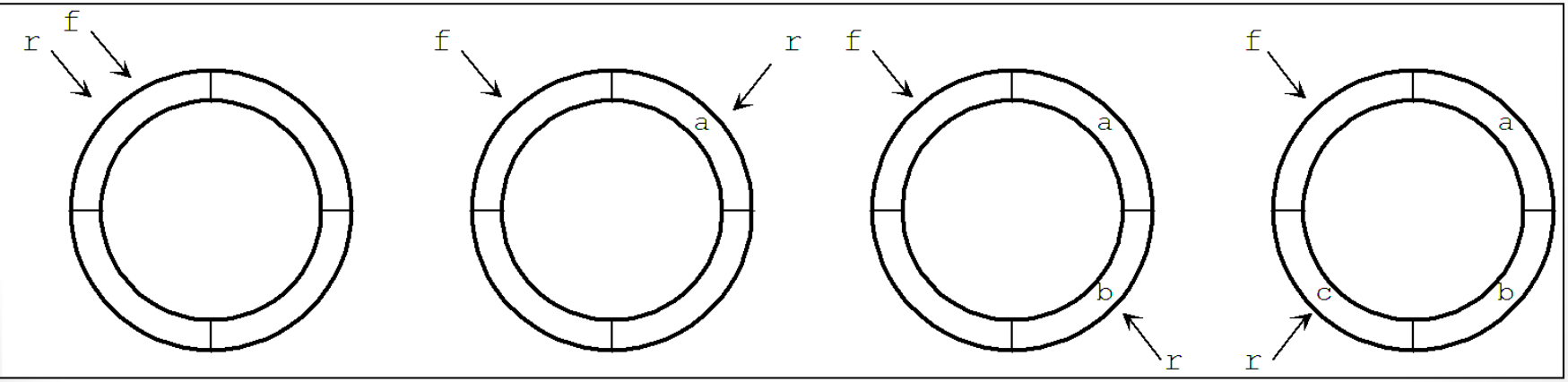


Explanation using Conventional Arrays

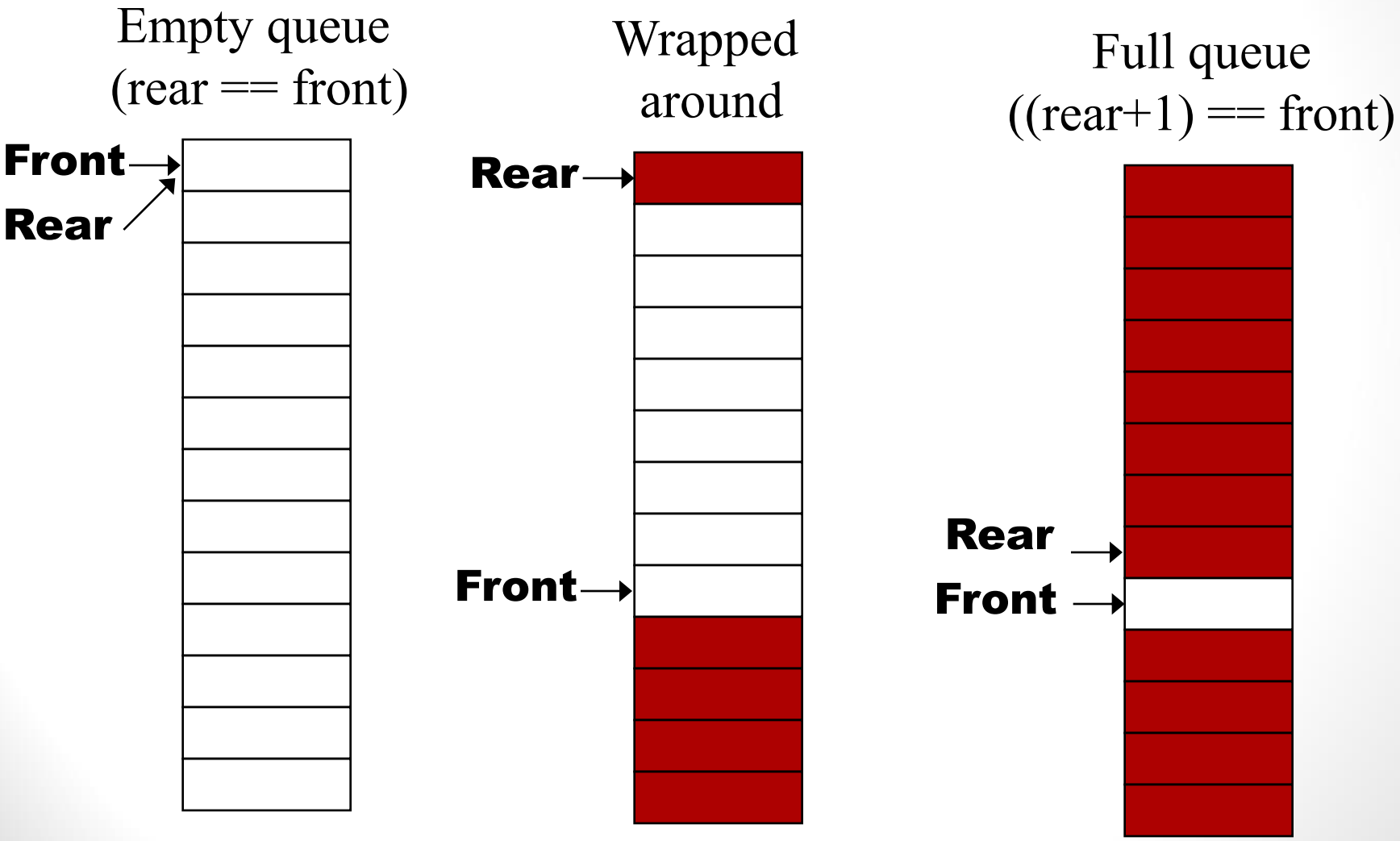


Empty or Full fix

- Let the front <u>always</u> point to an empty cell.
- Elements are added at nextPos(rear)
- An empty queue is defined by rear==front
- A full queue is defined by nextPos(rear) == front



Explanation using Conventional Arrays



Queue Header file

```
const int maxQueue = 200;
template < class queueElementType >
class Queue {
public:
  Queue();
  void enqueue(queueElementType e);
  queueElementType dequeue();
  queueElementType front();
  bool isEmpty();
private:
  int f; // marks the front of the queue
  int r; // marks the rear of the queue
  queueElementType elements[maxQueue];
```

Queue Header file (cntd.)

```
int nextPos(int p)
{
  if (p == maxQueue - 1) // at end of circle
    return 0;
  else
    return p+1;
}
};
```

Queue Implementation

```
template < class queueElementType >
Queue < queueElementType >::Queue()
{ // start both front and rear at 0
   f = 0;
   r = 0;
}
template < class queueElementType > bool
Queue < queueElementType >::isEmpty()
{ // return true if the queue is empty
   return bool(f == r);
}
```

Queue Implementation

```
template < class queueElementType >
Void Queue < queueElementType > ::
   enqueue(queueElementType e)
{   // add e to the rear and advance r
   assert(nextPos(r) != f);
   r = nextPos(r);
   elements[r] = e;
}
```

Queue Implementation

```
template < class queueElementType >
queueElementType
Queue < queueElementType >::dequeue()
{// advance the front and return the value at the front
   assert(f != r);
   f = nextPos(f);
   return elements[f];
}
```

Queue Implementation

```
template < class queueElementType >
queueElementType
Queue < queueElementType >::front()
{
  // return value of element at the front
  assert(f != r);
  return elements[nextPos(f)];
}
```

Header for Queue as Linked-list

```
template < class queueElementType >
class Queue {
public:
   Queue();
   void enqueue(queueElementType e);
   queueElementType dequeue();
   queueElementType front();
   bool isEmpty();
```

Private section

```
private:
Struct Node;
typedef Node * nodePtr;
struct Node {
      queueElementType data;
      nodePtr next;
   };
nodePtr f;
   nodePtr r;
};
```

Linked-lists based implementation

```
template < class queueElementType >
Queue < queueElementType >::Queue()
{// set both front and rear to null pointers
f = NULL;
  r = NULL;
}
template < class queueElementType > bool
Queue < queueElementType >::isEmpty()
{// true if the queue is empty -- when f is a null pointer
  return bool(f == NULL);
}
```

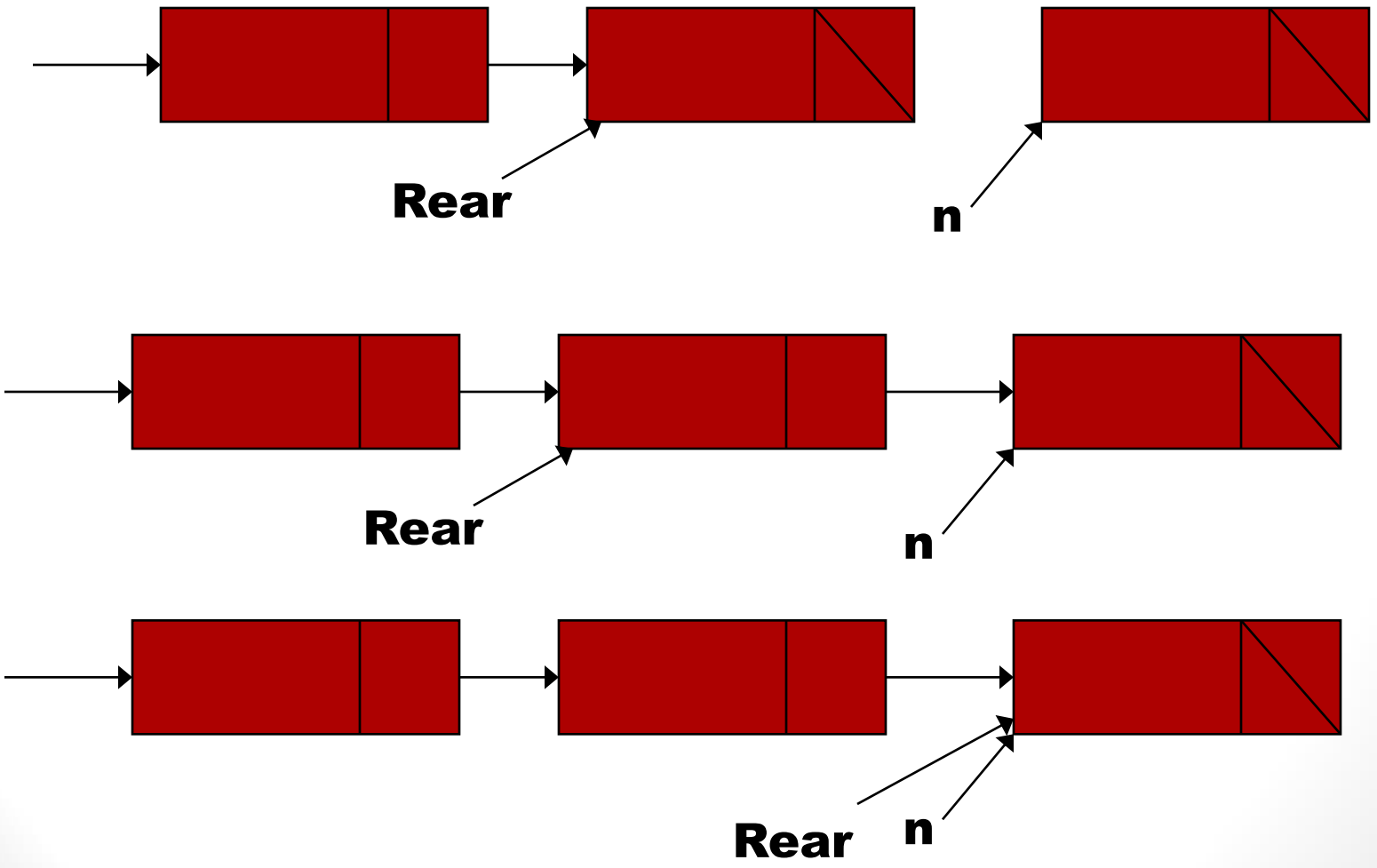
Linked-lists based implementation

```
template < class queueElementType >
queueElementType
Queue < queueElementType >::front()
{
  assert(f);
  return f->data;
}
```

Linked-lists based implementation

```
template < class queueElementType >
void Queue < queueElementType > ::enqueue(queueElementType e)
{// create a new node, insert it at the rear of the queue
   nodePtr n=new Node;
   assert(n);
   n->next = NULL;
   n->data = e;
   if (f != NULL) { // existing queue is not empty
      r->next = n; // add new element to end of list
      r = n;
   } else {// adding first item in the queue
      f = n; // so front, rear must be same node
      r = n;
   }
}
```

enqueueing



dequeue( )

```
template < class queueElementType > queueElementType
Queue < queueElementType >::dequeue()
{  assert(f); // make sure queue is not empty
queueElementType frontElement = f->data;
   nodePtr n=f;
f = f->next;
   delete n;
   if (f == NULL) // we're deleting last node
      r = NULL;
   return frontElement;
}
```

dequeueing