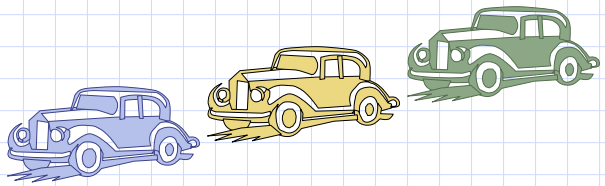
# Queues





# The Queue ADT (§4.3)

- The Queue ADT stores arbitrary objects
- Insertions and deletions follow the first-in first-out scheme
- Insertions are at the rear of the queue and removals are at the front of the queue
- Main queue operations:
  - enqueue(object): inserts an element at the end of the queue
  - object dequeue(): removes and returns the element at the front of the queue
- Auxiliary queue operations:
  - object front(): returns the element at the front without removing it
  - integer size(): returns the number of elements stored
  - boolean isEmpty(): indicates whether no elements are stored
- Exceptions
  - Attempting the execution of dequeue or front on an empty queue throws an EmptyQueueException



# Queue Example

| *Operation* | | *Output* | *Q* |
|---|---|---|---|
| enqueue(5) | – | (5) | |
| enqueue(3) | – | (5, 3) | |
| dequeue() | *5* | (3) | |
| enqueue(7) | – | (3, 7) | |
| dequeue() | *3* | (7) | |
| front() | *7* | (7) | |
| dequeue() | *7* | () | |
| dequeue() | *"error"* | () | |
| isEmpty() | *true* | () | |
| enqueue(9) | – | (9) | |
| enqueue(7) | – | (9, 7) | |
| size() | *2* | (9, 7) | |
| enqueue(3) | – | (9, 7, 3) | |
| enqueue(5) | – | (9, 7, 3, 5) | |
| dequeue() | *9* | (7, 3, 5) | |



# Applications of Queues

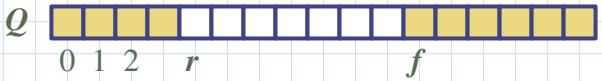
- Direct applications
  - Waiting lists, bureaucracy
  - Access to shared resources (e.g., printer)
  - Multiprogramming
- Indirect applications
  - Auxiliary data structure for algorithms
  - Component of other data structures

# Array-based Queue

- Use an array of size $N$ in a circular fashion
- Two variables keep track of the front and rear
  - $f$ index of the front element
  - $r$ index immediately past the rear element
- Array location $r$ is kept empty

normal configuration

wrapped-around configuration



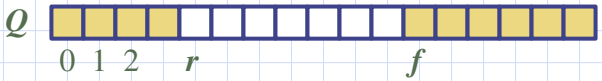



# Queue Operations

- We use the modulo operator (remainder of division)

```
Algorithm size()
  return (N − f + r) mod N

Algorithm isEmpty()
  return (f = r)
```






# Queue Operations (cont.)

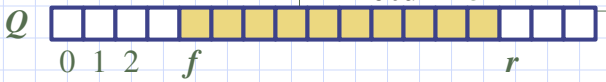
- Operation enqueue throws an exception if the array is full
- This exception is implementation-dependent

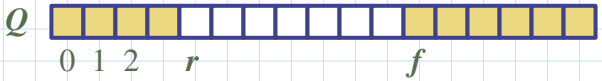
```
Algorithm enqueue(o)
  if size() = N − 1 then
    throw FullQueueException
  else
    Q[r] ← o
    r ← (r + 1) mod N
```

# Queue Operations (cont.)

- Operation dequeue throws an exception if the queue is empty
- This exception is specified in the queue ADT

```
Algorithm dequeue()
  if isEmpty() then
    throw EmptyQueueException
  else
    o ← Q[f]
    f ← (f + 1) mod N
    return o
```



# Queue Interface in Java

- Java interface corresponding to our Queue ADT
- Requires the definition of class EmptyQueueException
- No corresponding built-in Java class

```
public interface Queue {
  public int size();
  public boolean isEmpty();
  public Object front()
      throws
EmptyQueueException;
  public void enqueue(Object
o);
  public Object dequeue()
      throws
EmptyQueueException;
}
```