CS-218
DATA STRUCTURE

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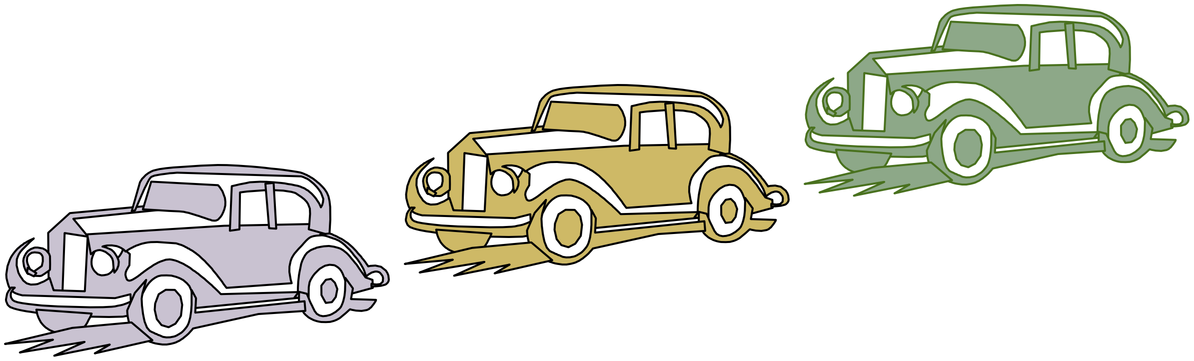


QUEUES

Queues

A ***Queue*** is a special kind of list, where items are,

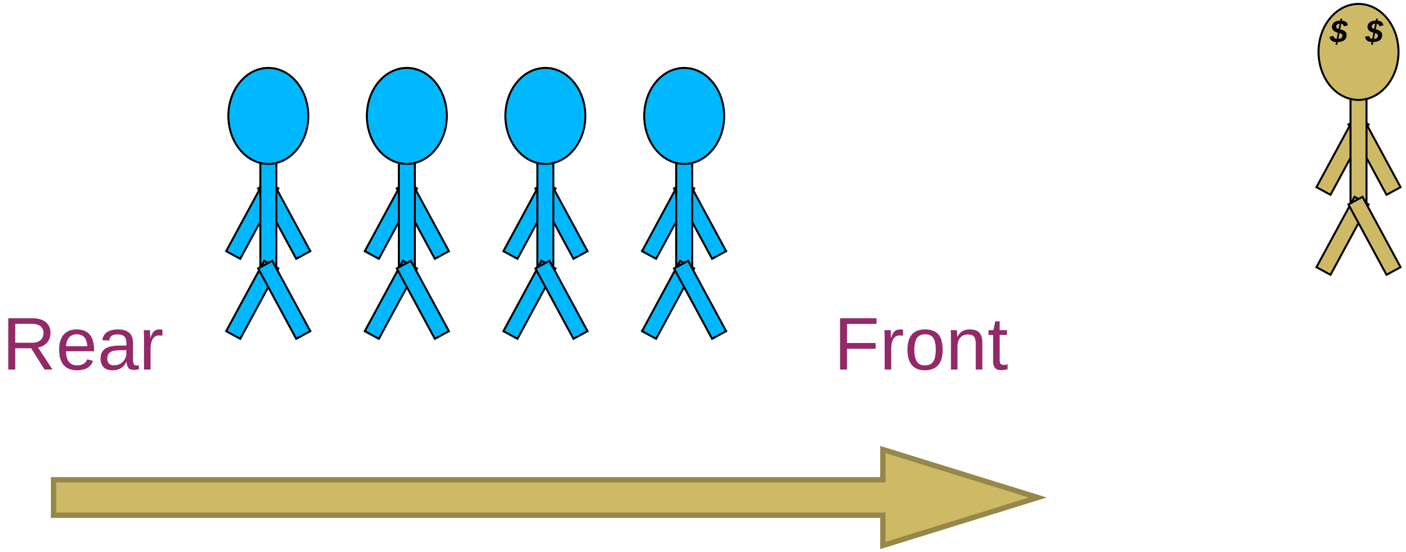
- inserted at one end (***the rear***) and
- deleted at the other end (***the front***)

Other Name:

- First In First Out (FIFO)

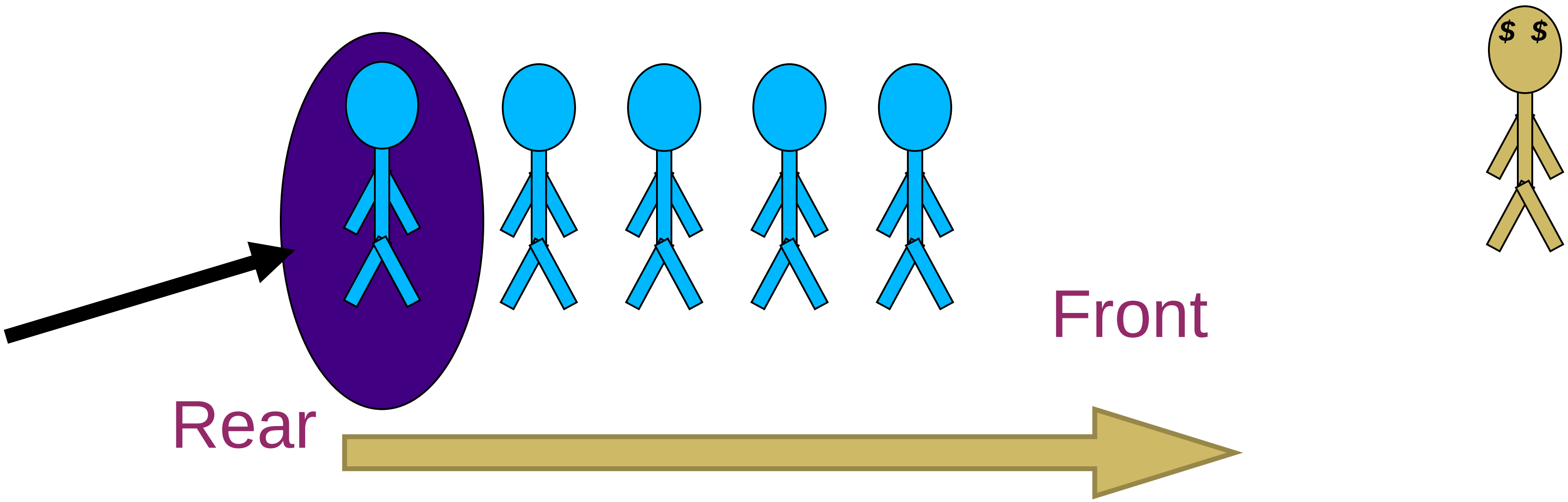
Queues

- A queue is like a line of people waiting for a bank teller.
- The queue has a **front** and a **rear**.



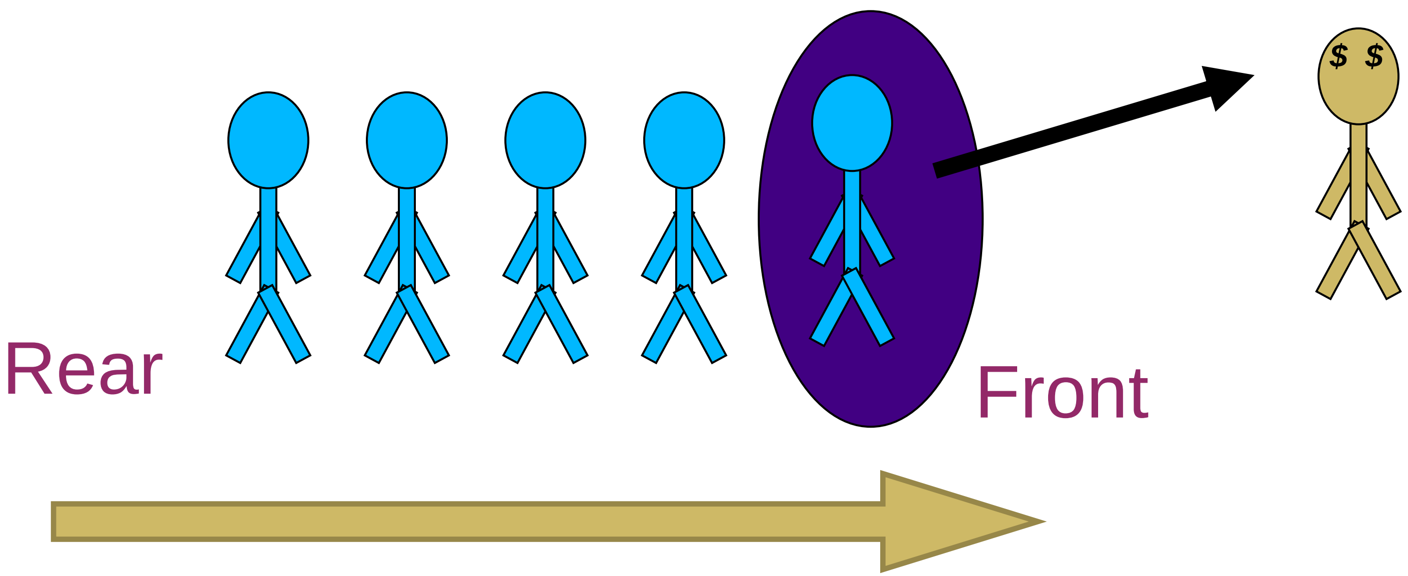
Queues

- New people must enter the queue at the **rear.**



Queues

- When an item is taken from the queue, it always comes from the front.



Examples

- Billing counter
  - Booking movie tickets
  - Queue for paying bills

- A print queue
- Vehicles on toll-tax bridge
- Luggage checking machine

Applications

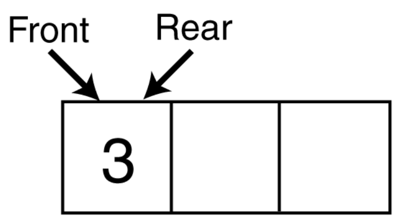
- **Operating system**
  - multi-user/multitasking environments, where several users or tasks may be requesting the same resource simultaneously.
- **Communication Software**
  - queues to hold *information* received over networks and dial up connections.
  - Information can be transmitted faster than it can be processed, so is placed in a queue waiting to be processed.

Common Operations

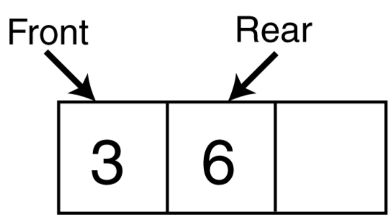
1. **MAKENULL(Q):** Makes Queue Q be an empty list.
2. **FRONT(Q):** Returns the first element on Queue Q.
3. **ENQUEUE(x, Q):** Inserts element x at the end of Queue Q.
4. **DEQUEUE(Q):** Deletes the first element of Q.
5. **EMPTY(Q):** Returns true if and only if Q is an empty queue.

Enqueue & Dequeue

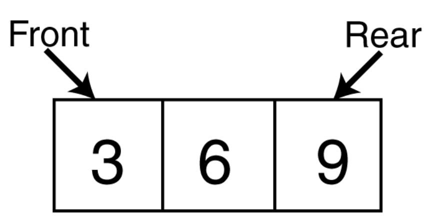
Enqueue(3);



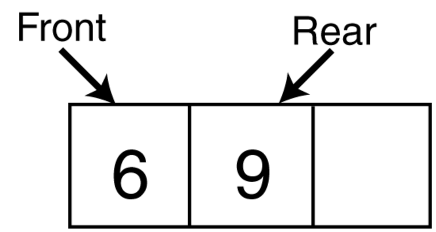
Enqueue(6);



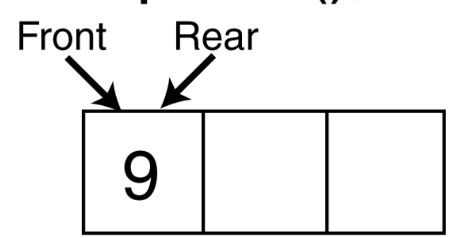
Enqueue(9);



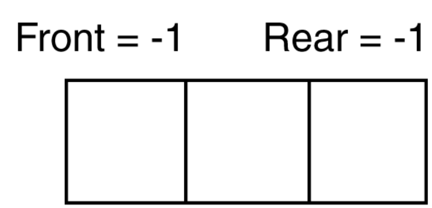
Dequeue();



Dequeue();



Dequeue();



Enqueue Operation

- **Step 1** – Check if the queue is full.
- **Step 2** – If the queue is full, produce overflow error and exit.
- **Step 3** – If the queue is not full, increment rear pointer to point the next empty space.
- **Step 4** – Add data element to the queue location, where the rear is pointing.
- **Step 5** – Return success.

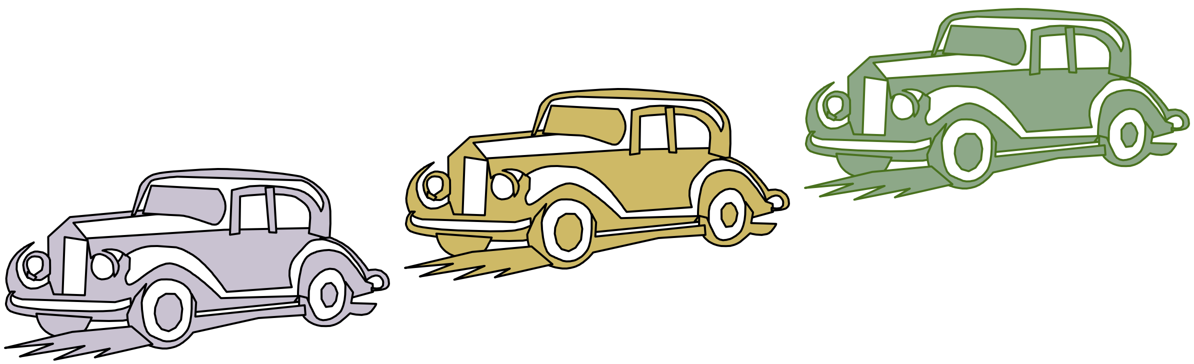
Dequeue Operation

- **Step 1** – Check if the queue is empty.
- **Step 2** – If the queue is empty, produce underflow error and exit.
- **Step 3** – If the queue is not empty, access the data where front is pointing.
- **Step 4** – Increment front pointer to point to the next available data element.
- **Step 5** – Return success.

Implementation

- Static
  - Queue is implemented by **an array**, and size of queue remains fix

- Dynamic
  - A queue can be implemented as a **linked list** and *expand* or *shrink* with each *enqueue* or *dequeue* operation.



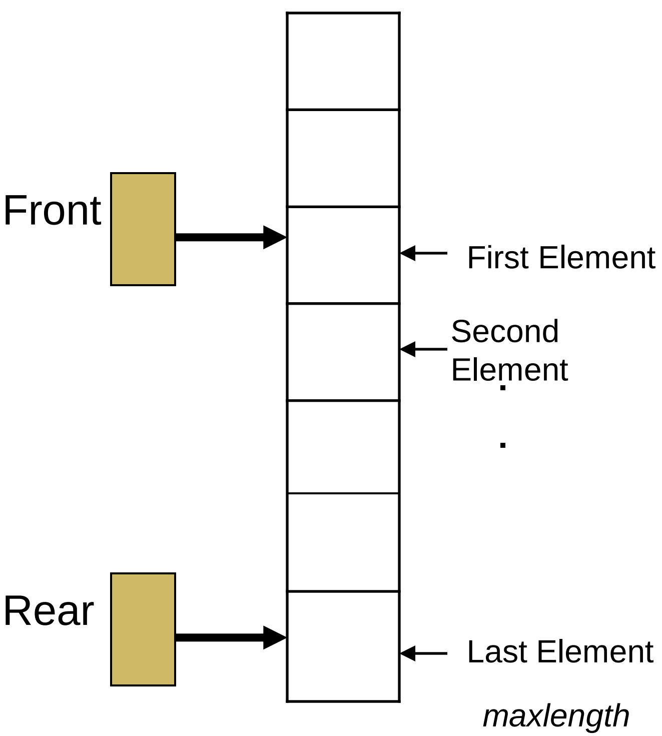
ARRAY IMPLEMENTATION

Array Implementation

- As with Stacks, signify *zero* index as rear.
- **Enqueue**
  - Shift elements to the right
  - As expensive as with stacks
- **Dequeue**
  - Need to save index of first item inserted
- On Dequeue, decrement index
- On Enqueue, increment index

Array Implementation

- Use two counters that signify **rear** and **front**



- When **queue is empty,** both front and rear are set to -1
- While **enqueueing** increment rear by 1, and while **dequeuing** increment front by 1
- When there is **only one value in the Queue**, both rear and front have same index

Array Implementation

5	4	6	7	8	7	6		
0	1	2	3	4	5	6	7	8

Front=0
Rear=6

				8	7	6		
0	1	2	3	4	5	6	7	8

Front=4
Rear=6

					7	6	12	67
0	1	2	3	4	5	6	7	8

Front=5
Rear=8

Array Implementation

5	4	6	7	8	7	6		
0	1	2	3	4	5	6	7	8

Front=0
Rear=6

				8	7	6		
0	1	2	3	4	5	6	7	8

Front=4
Rear=6

					7	6	12	67
0	1	2	3	4	5	6	7	8

Front=5
Rear=8

How can we insert more elements? Rear index can not move beyond the last element….

Array Implementation

How can we insert more elements? Rear index can not move beyond the last element….

Solution:

Using Circular Queue

Circular Queue

- Allow rear to wrap around the array.

```
if(rear == queueSize-1)
        rear = 0;
else
        rear++;
```

- Or use **modular arithmetic**

```
rear = (rear + 1) % queueSize;
```

Circular Queue

					7	6	12	67
0	1	2	3	4	5	6	7	8

Front=5
Rear=8

Enqueue 39, Rear = (Rear+1) mod Queue Size = (8+1) mod 9 = 0

39					7	6	12	67
0	1	2	3	4	5	6	7	8

Front=5
Rear=0

IMPLEMENTATION

Implementation … Queue Class


```
class IntQueue {
private:
        int *queueArray;
        int queueSize;
        int front;
        int rear;
        int numItems;
public:
        IntQueue(int);
        ~IntQueue(void);
        void enqueue(int);
        int dequeue(void);
        bool isEmpty(void);
        bool isFull(void);
        void clear(void);
};
```

Note, the member function clear, which clears the queue by resetting the front and rear indices and setting the numItems to 0.

Implementation … Queue Class


```
IntQueue::IntQueue(int s) //constructor
{
    queueArray = new int[s];
    queueSize = s;
    front = -1;
    rear = -1;
    numItems = 0;
}


IntQueue::~IntQueue(void) //destructor

{
     delete [] queueArray;

}
```

Implementation … Enqueue Function


```
//*************************************************
// Function enqueue inserts the value in num *
// at the rear of the queue.                 *
//*************************************************
void IntQueue::enqueue(int num){
      if (isFull())
            cout << "The queue is full.\n";
      else{
            // Calculate the new rear position
            rear = (rear + 1) % queueSize;
            // Insert new item
            queueArray[rear] = num;
            // Update item count
            numItems++;
      }
}
```

Implementation … Dequeue Function


```
//*****************************************
// Function dequeue removes the value at the   *
// front of the queue, and copies it into num. *
//*****************************************
int IntQueue::dequeue(void){
      if (isEmpty())
            cout << "The queue is empty.\n";
      else{
            // Move front
            front = (front + 1) % queueSize;
            // Retrieve the front item
            int num = queueArray[front];
            // Update item count
            numItems--;
      }
      return num;
}
```

Implementation … isEmpty Function


```
//****************************************************
// Function isEmpty returns true if the queue  *
// is empty, and false otherwise.              *
//****************************************************

bool IntQueue::isEmpty(void){
      if (numItems)
            return false;
      else
            return true;
}
```

Implementation … isFull Function


```
//*****************************************************
// Function isFull returns true if the queue *
// is full, and false otherwise.               *
//*****************************************************

bool IntQueue::isFull(void){
      if (numItems < queueSize)
            return false;
      else
            return true;
}
```

Implementation … Clear Function


```
//**************************************************
// Function clear resets the front and rear *
// indices and sets numItems to 0.          *
//**************************************************

void IntQueue::clear(void){
      front = - 1;
      rear = - 1;
      numItems = 0;
}
```

Implementation … Demonstration


```
//Program demonstrating the IntQueue class
void main(void){
	IntQueue iQueue(5);
	cout << "Enqueuing 5 items...\n";
	// Enqueue 5 items.
	for (int x = 0; x < 5; x++)
		iQueue.enqueue(x);
	// Attempt to enqueue a 6th item.
	cout << "Now attempting to enqueue again...\n";
	iQueue.enqueue(5);

	// Deqeue and retrieve all items in the queue
	cout << "The values in the queue were:\n";
	while (!iQueue.isEmpty()){
		int value;
		value = iQueue.dequeue();
		cout << value << endl;
	}
}
```

Implementation ... Output

Program Output:

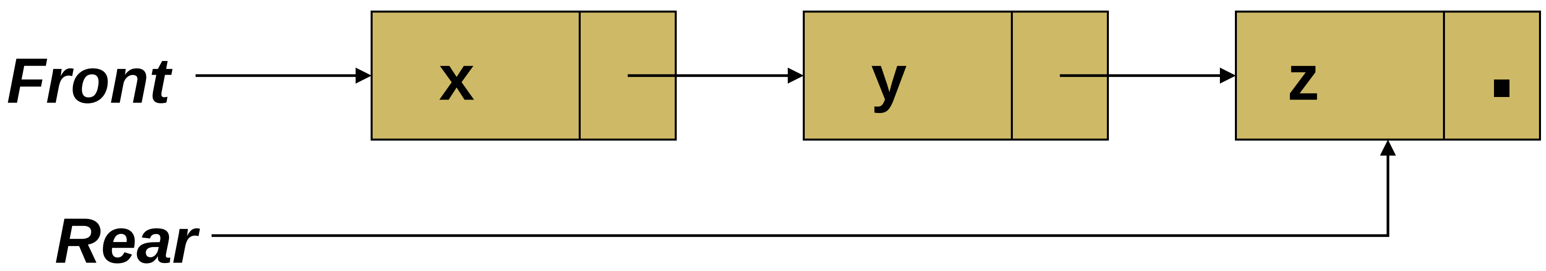
```
Enqueuing 5 items...
Now attempting to enqueue again...
The queue is full.
The values in the queue were:
0

1

2

3

4
```

A POINTER-BASED IMPLEMENTATION

A Pointer based Implementation

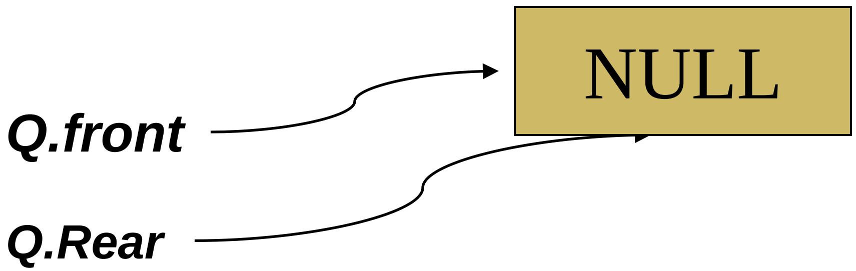
Keep two pointers:

- **FRONT:** A pointer to the first element of the queue.
- **REAR:** A pointer to the last element of the queue.

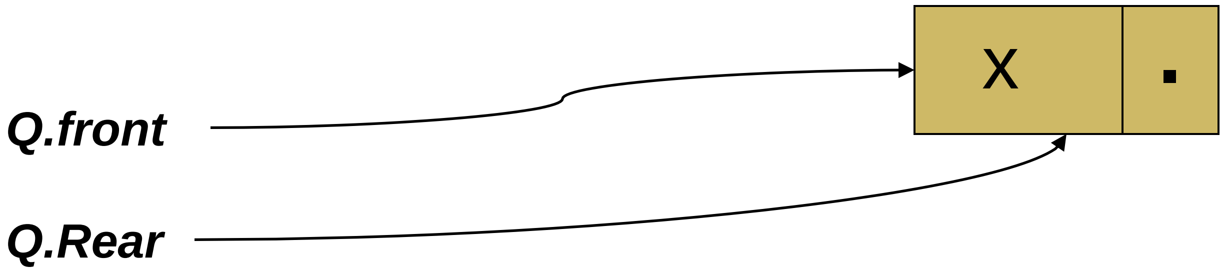


A Pointer based Implementation

MAKENULL(Q)

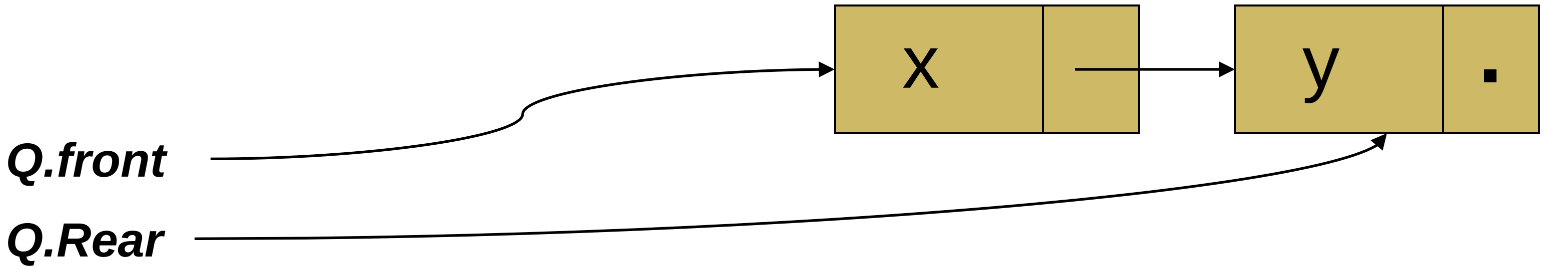


ENQUEUE(x,Q)

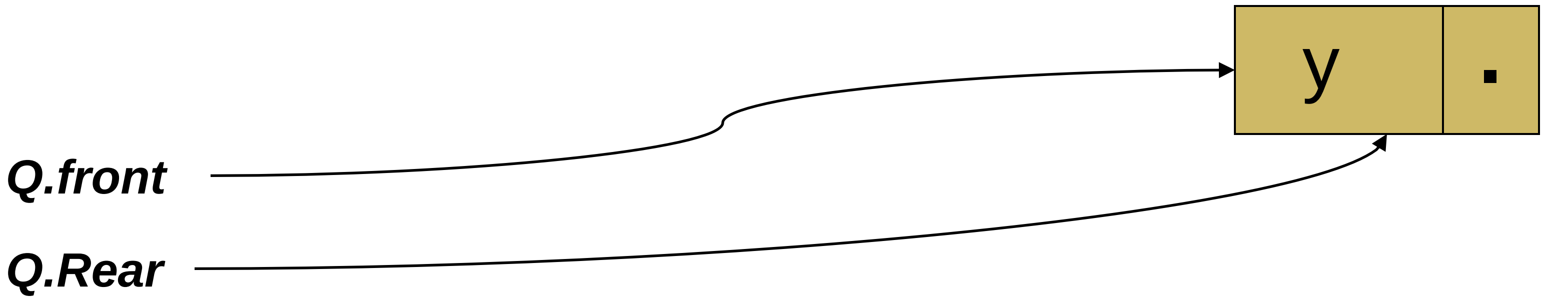


A Pointer based Implementation

ENQUEUE(y,Q)

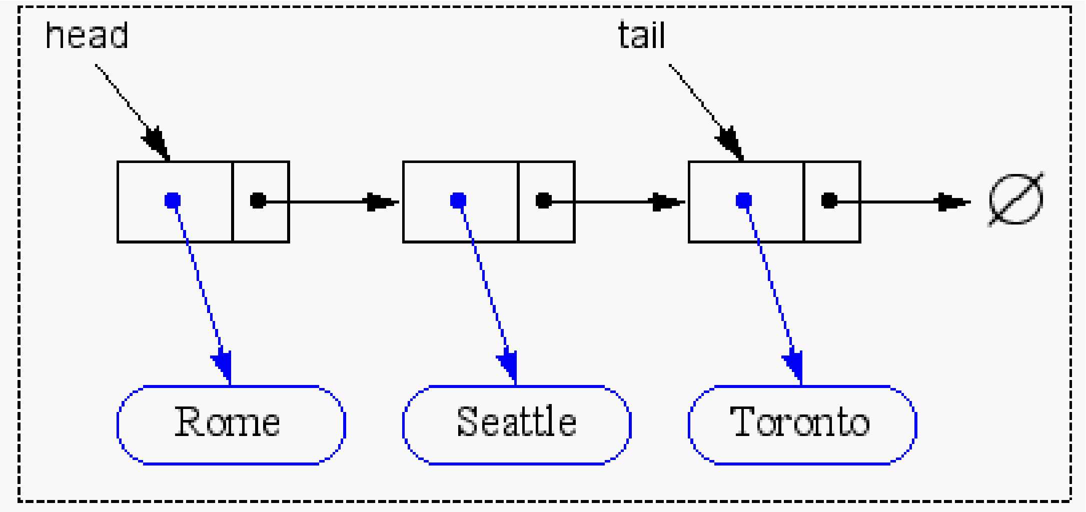


DEQUEUE(Q)



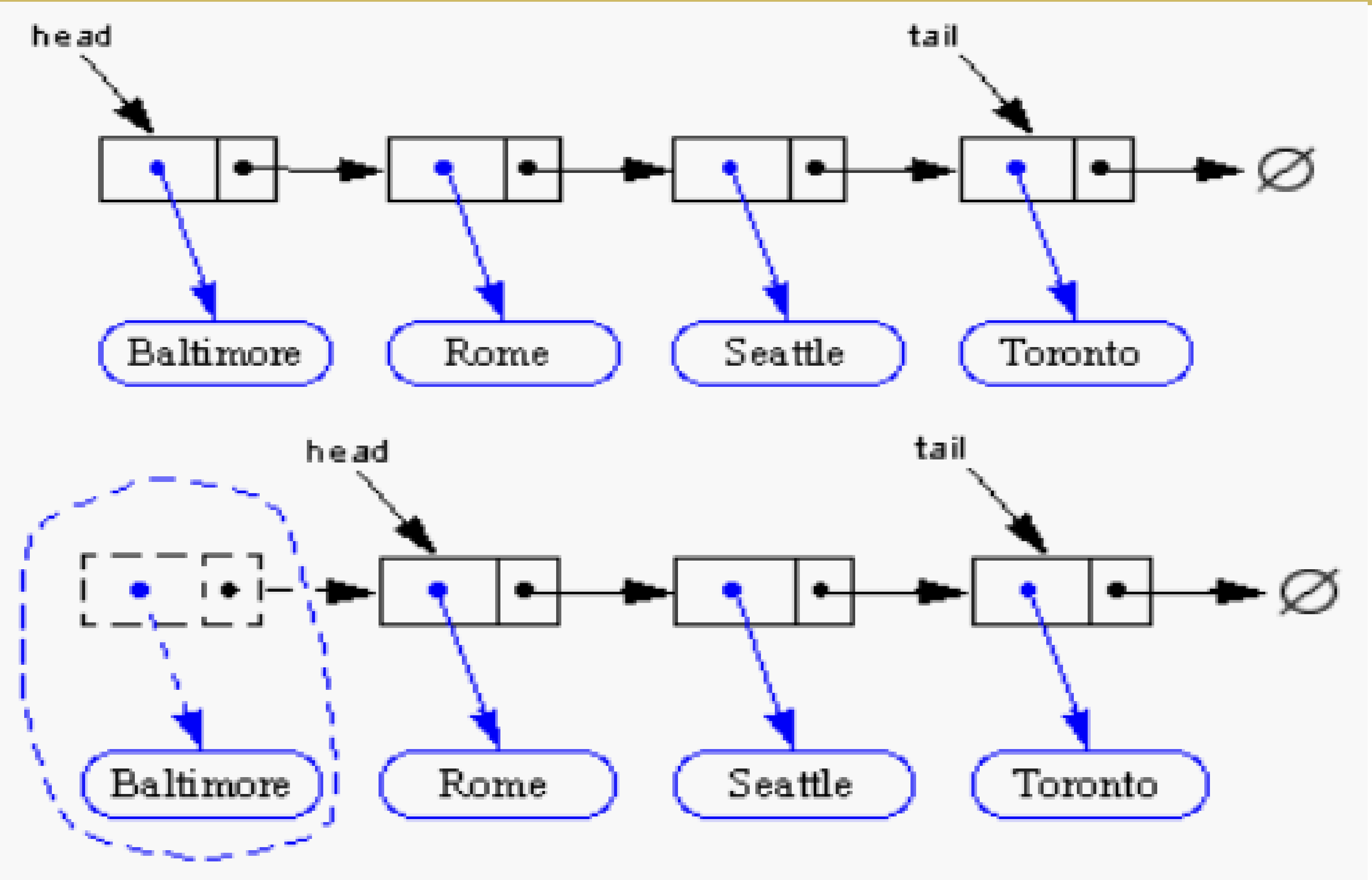
Singly Linked List based Implementation

Nodes connected in a chain by links

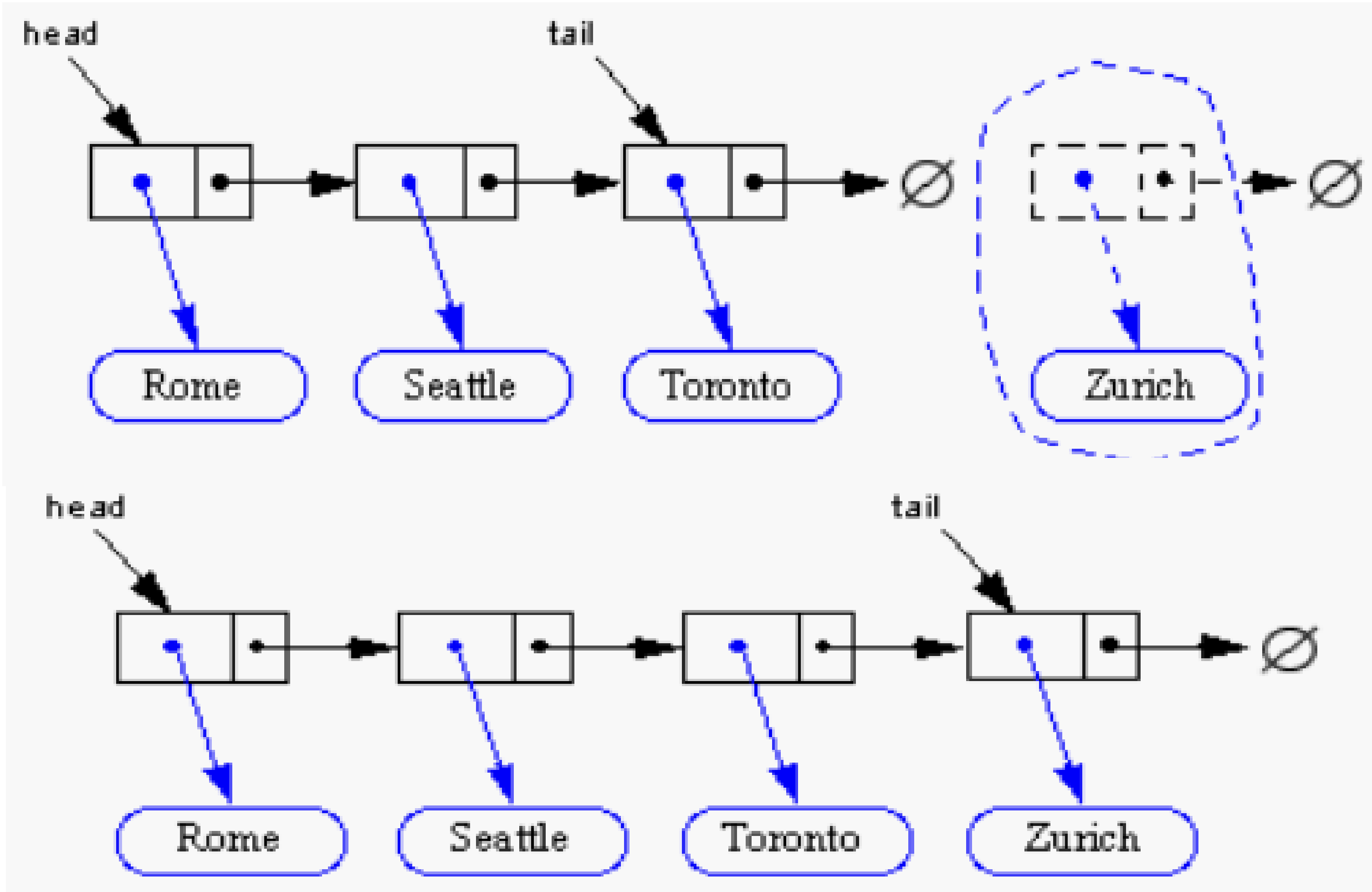


The *head of the list is the front of the queue*, the *tail of the list is the rear of the queue*.

Removing at the Head



Inserting at the Tail



Homework

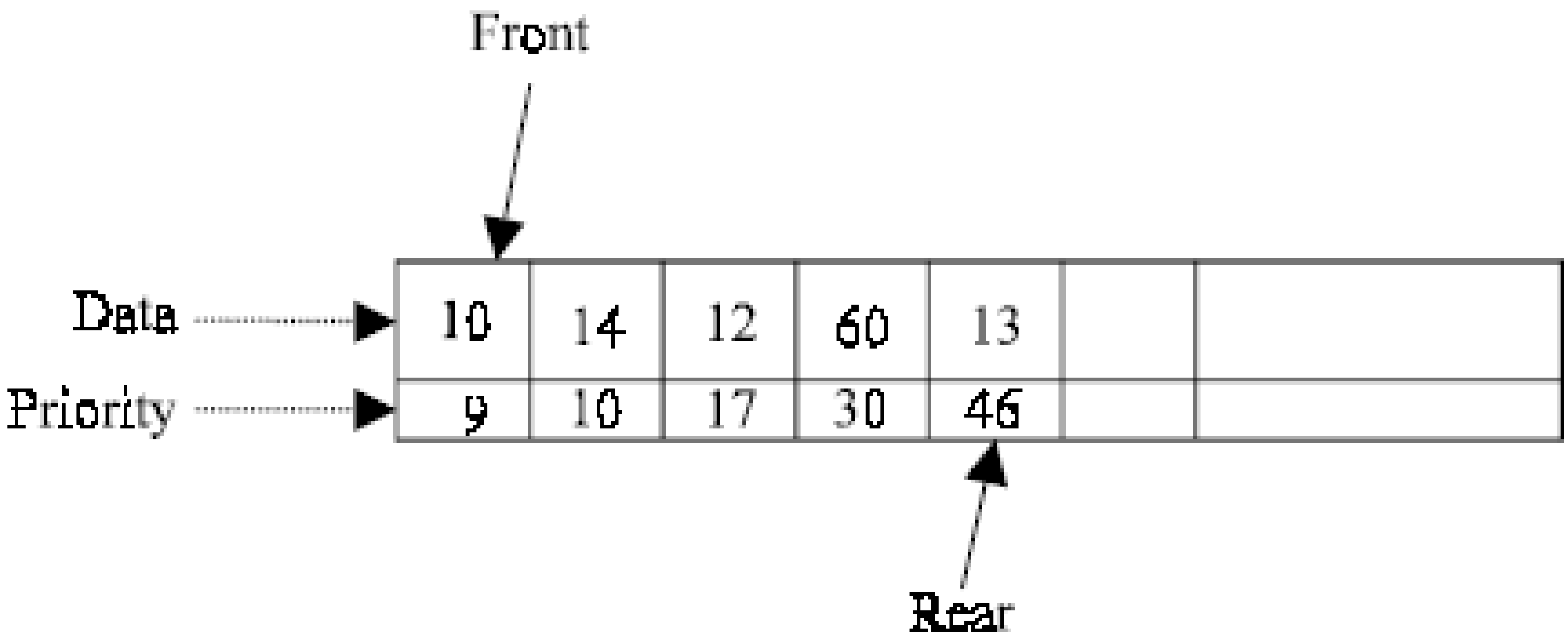
- Implement the same program given in previous slides with the help of,
  - Singly Linked List
  - Doubly Linked List

PRIORITY QUEUE

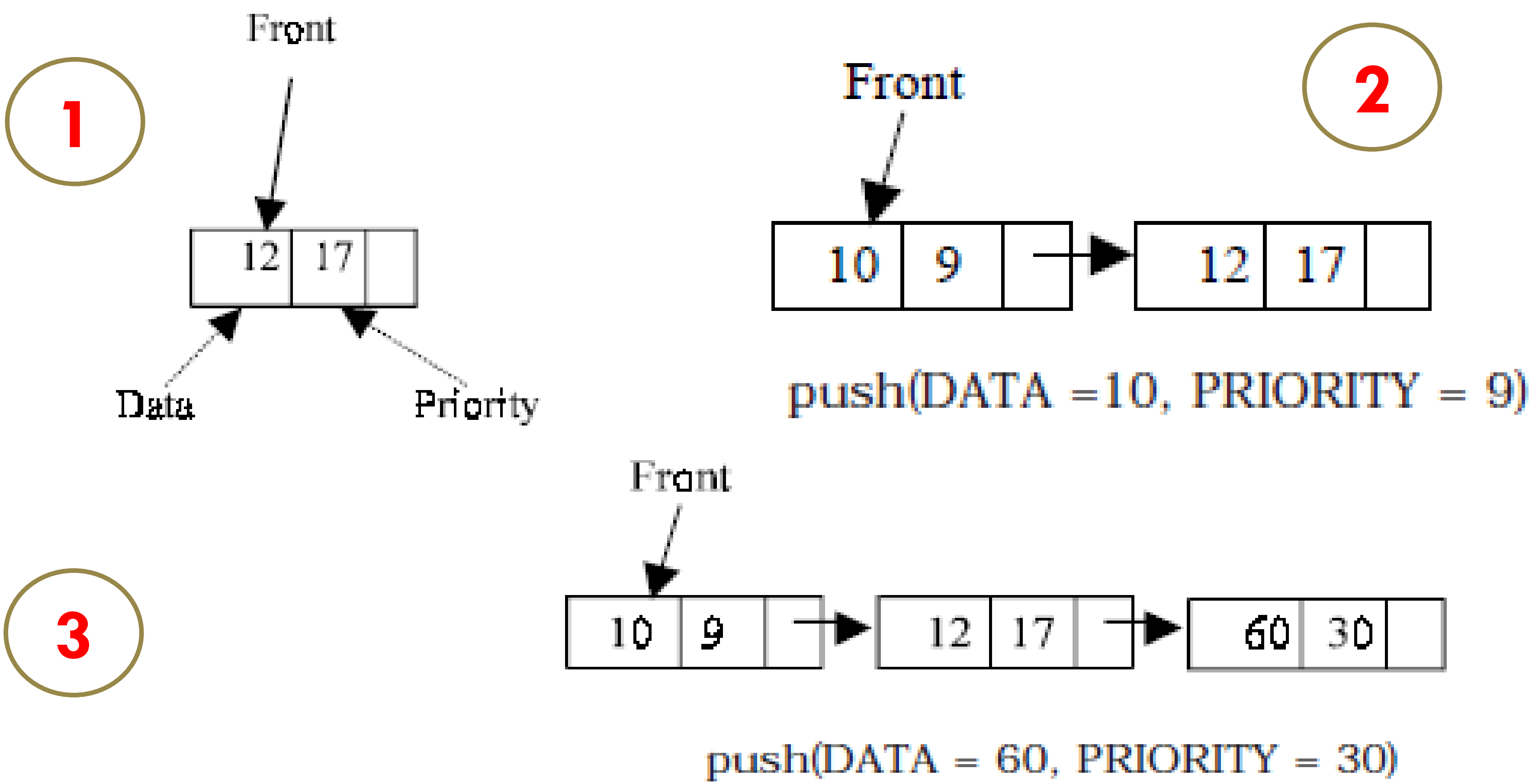
Priority Queue

- ✓ Priority Queue is a queue where *each element is assigned a priority*.
- ✓ In priority queue, the elements are deleted and processed by following rules.
  - An element of higher priority is processed before any element of lower priority.
  - Two elements with the same priority are processed according to the order in which they were inserted to the queue.

Priority Queue

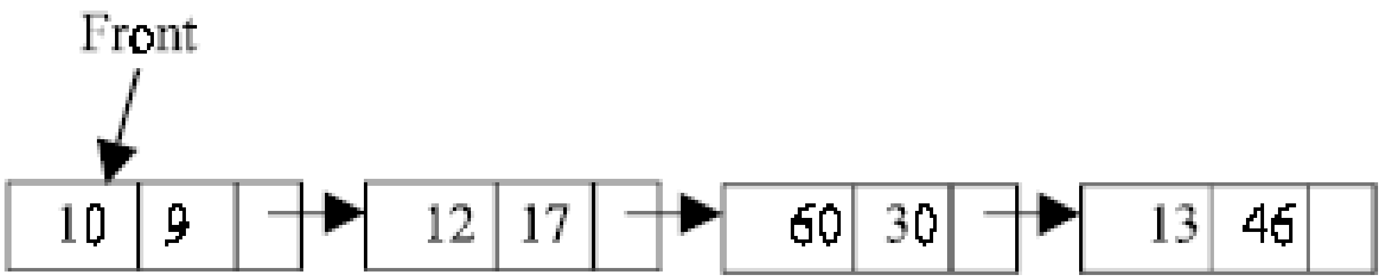


Priority Queue



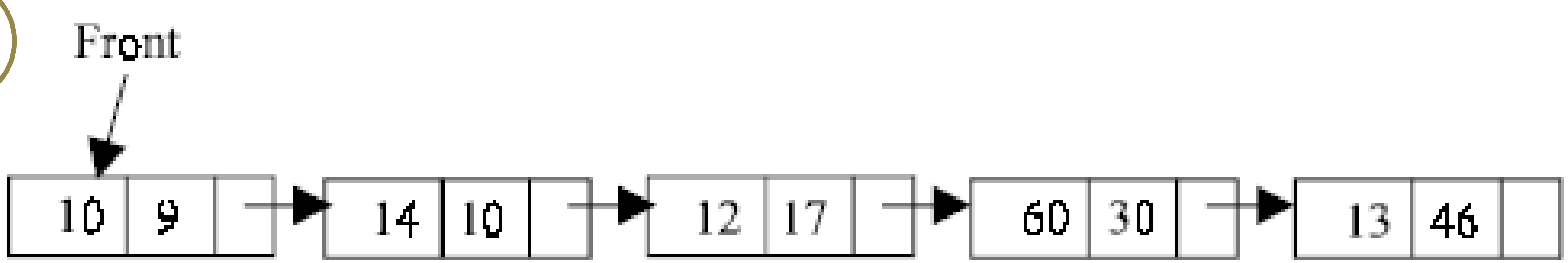
Priority Queue

4



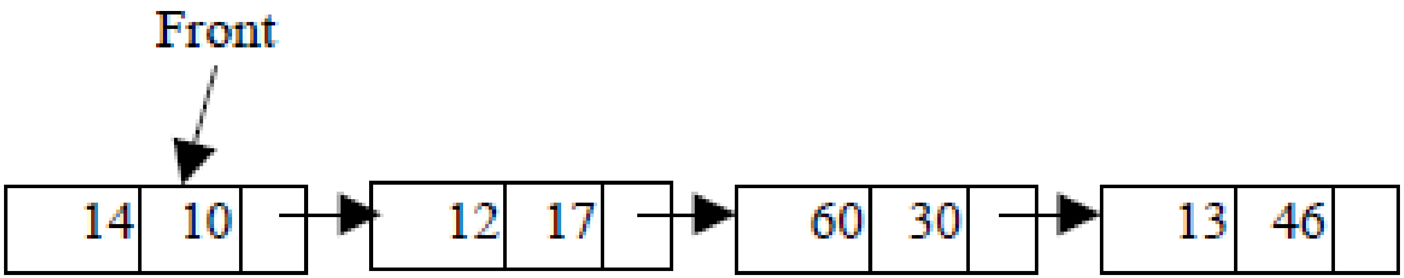
push(DATA = 13, PRIORITY = 46)

5

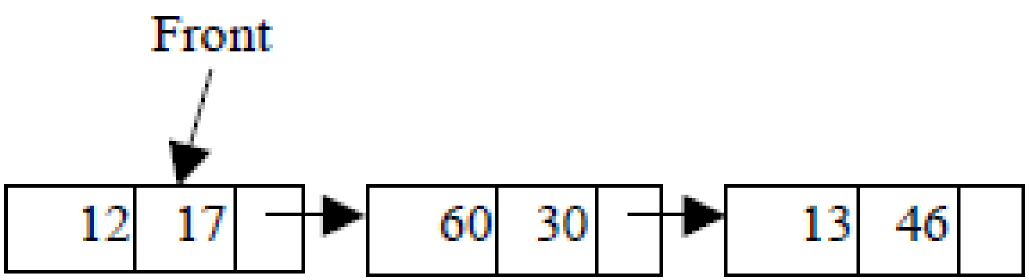


push(DATA = 14, PRIORITY = 10)

Priority Queue



$x = \text{pop}()$ (*i.e.*, 10)



$x = \text{pop}()$ (*i.e.*, 14)

Reading Materials

- Chapter 8, Data Structures by Larry Nyhoff