Indian Institute of Information Technology Allahabad

Data Structures and Algorithms

Queues and Lists

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Queues and Linked Lists

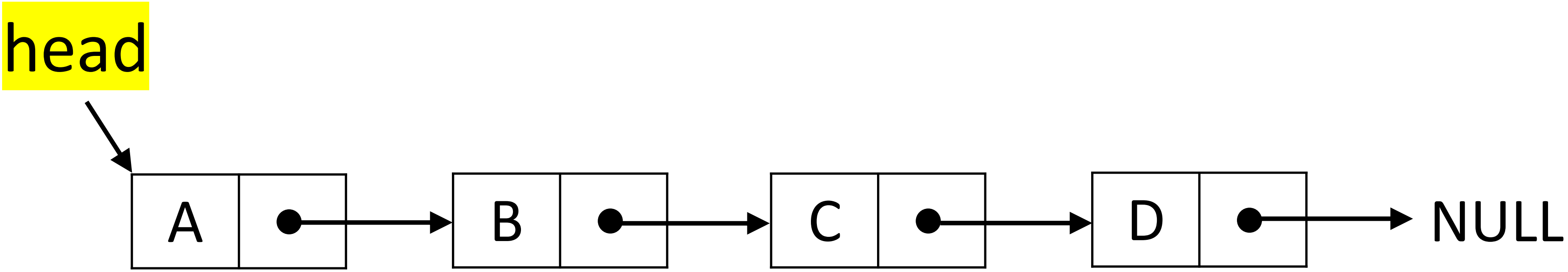
Queues

Linked Lists

Doubly Linked List

Double-Ended Queues

Circular List



Queues

- A queue differs from a stack in that its insertion and removal routines follows the **first-in-first-out (FIFO)** principle.
- Elements may be inserted at any time, but only the element which has been in the queue the longest may be removed.
- Elements are inserted at the rear (enqueued) and removed from the front (dequeued)

ONE WAY
Rear
Front

Queue Abstract Data Type (ADT)

The queue supports following fundamental methods:

- **New():***ADT* – Creates an empty queue
- **Enqueue(S**:*ADT*, **o**:element**)**:*ADT* – Inserts o at the rear of the queue
- **Dequeue(S**:*ADT***)**:*ADT* – Removes the element from the front of the queue, an error occurs when queue is empty, so need to take care.
- **Front(S**:*ADT***)**:*element* – Returns front element without removing it, an error occurs when queue is empty, so need to take care.

Queue Abstract Data Type (ADT)

These support methods should also be defined:

- **Size(S:**_ADT_**):**_integer_
- **IsEmpty(S**:_ADT_**)**:_Boolean_

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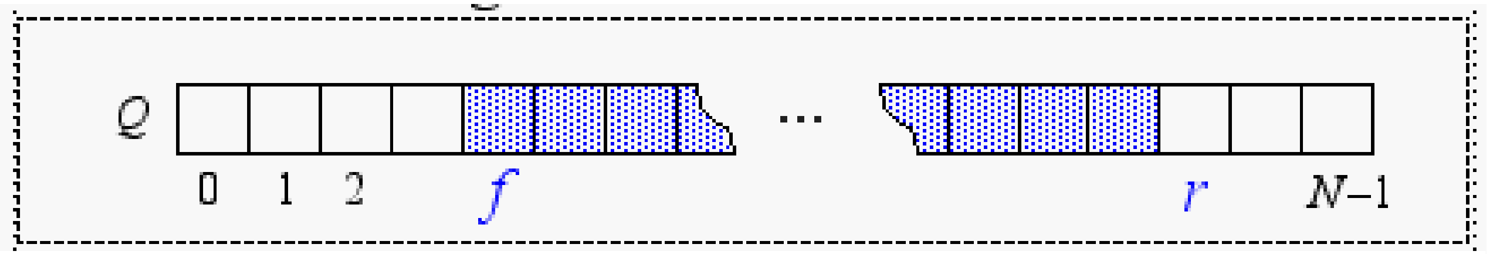
Axioms:

- **Front(Enqueue(New(), v)) = v**
- **Dequeue(Enqueue(New(), v)) = New()**
- **Front(Enqueue(Q, w)) = Front(Enqueue(Enqueue(Q, w),v))**
- **Dequeue(Enqueue(Enqueue(Q, w),v)) = Enqueue(Dequeue(Enqueue(Q, w)),v)**

An Array-Based Queue

- Create a queue using an array in a circular fashion
- A maximum size N is specified, e.g. N = 1,000.
- The queue consists of an N-element array Q and two integer variables:
    - *f*, index of the front element (head – for dequeue)
    - *r*, index of the element after the rear one (tail – for enqueue)



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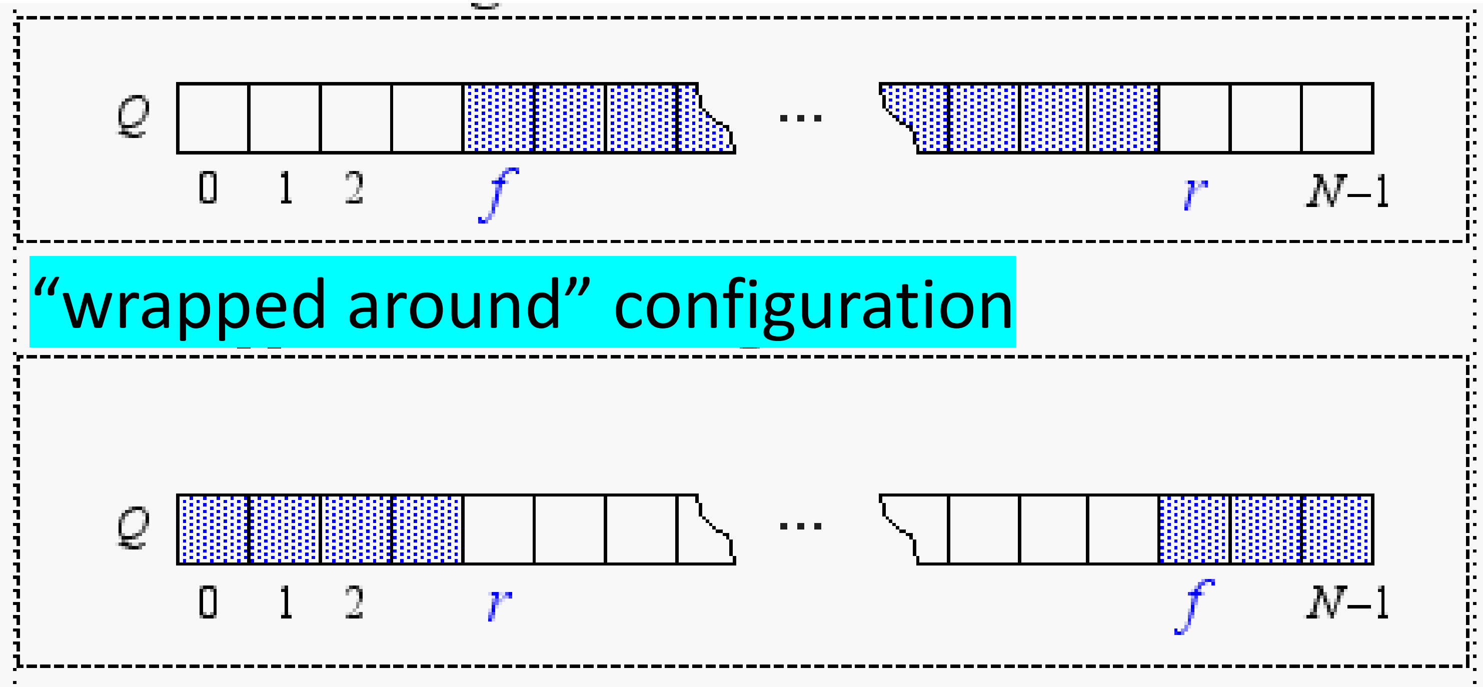
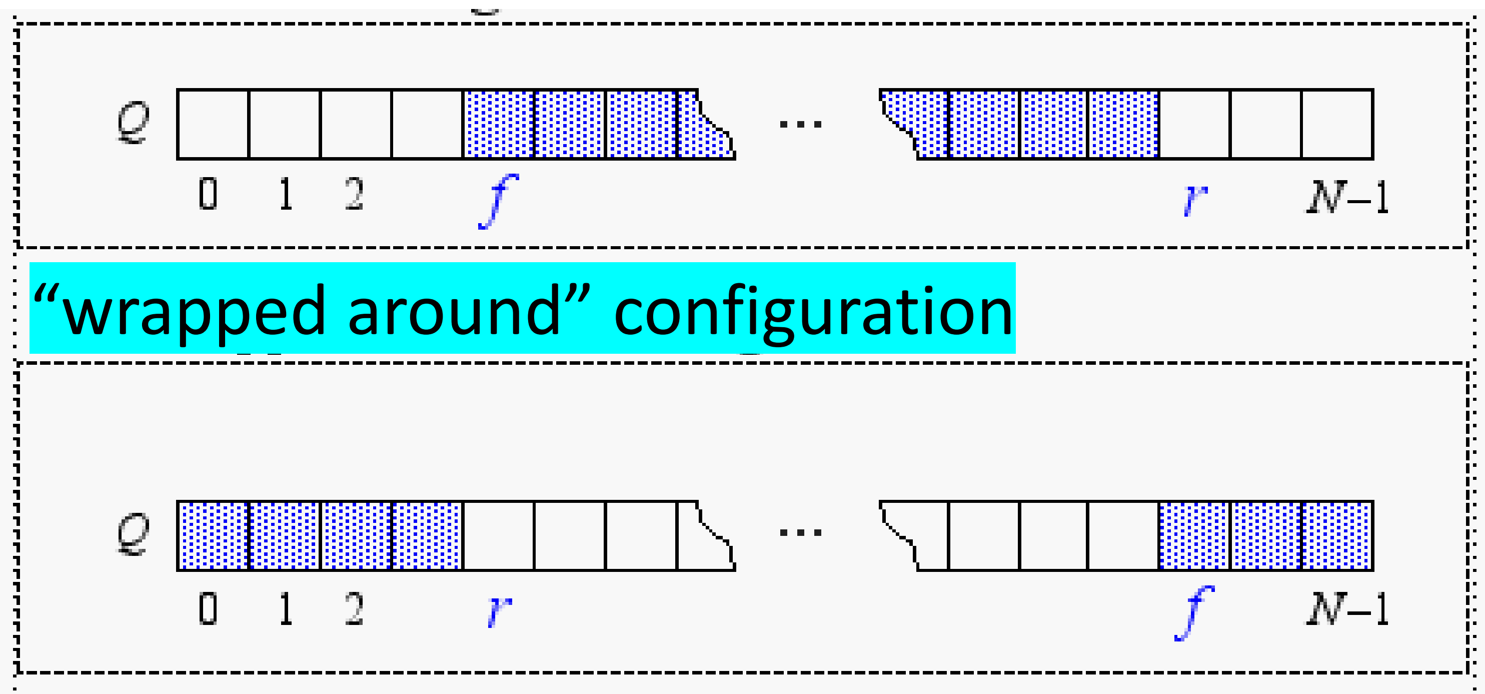


“wrapped around” configuration

An Array-Based Queue

Questions:

What does f==r mean?



“wrapped around” configuration

An Array-Based Queue

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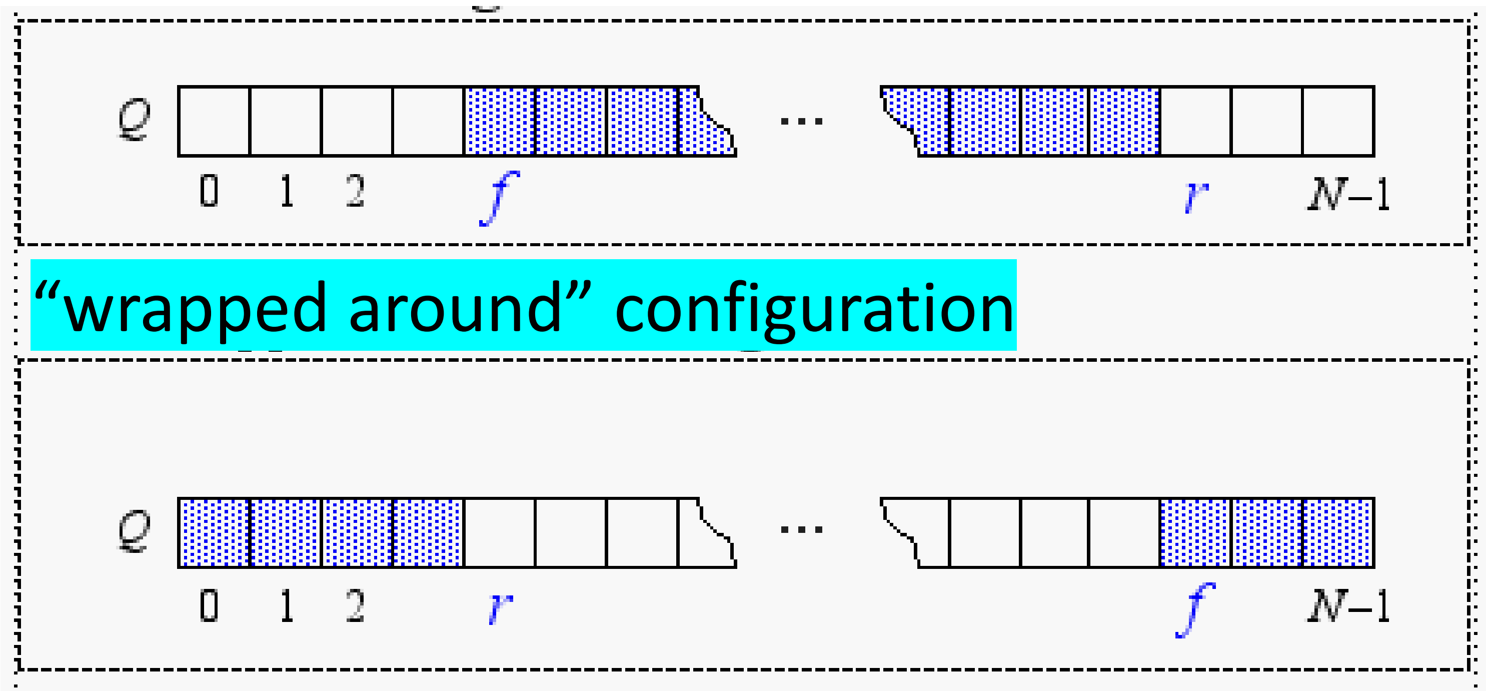
What does f==r mean?

Empty

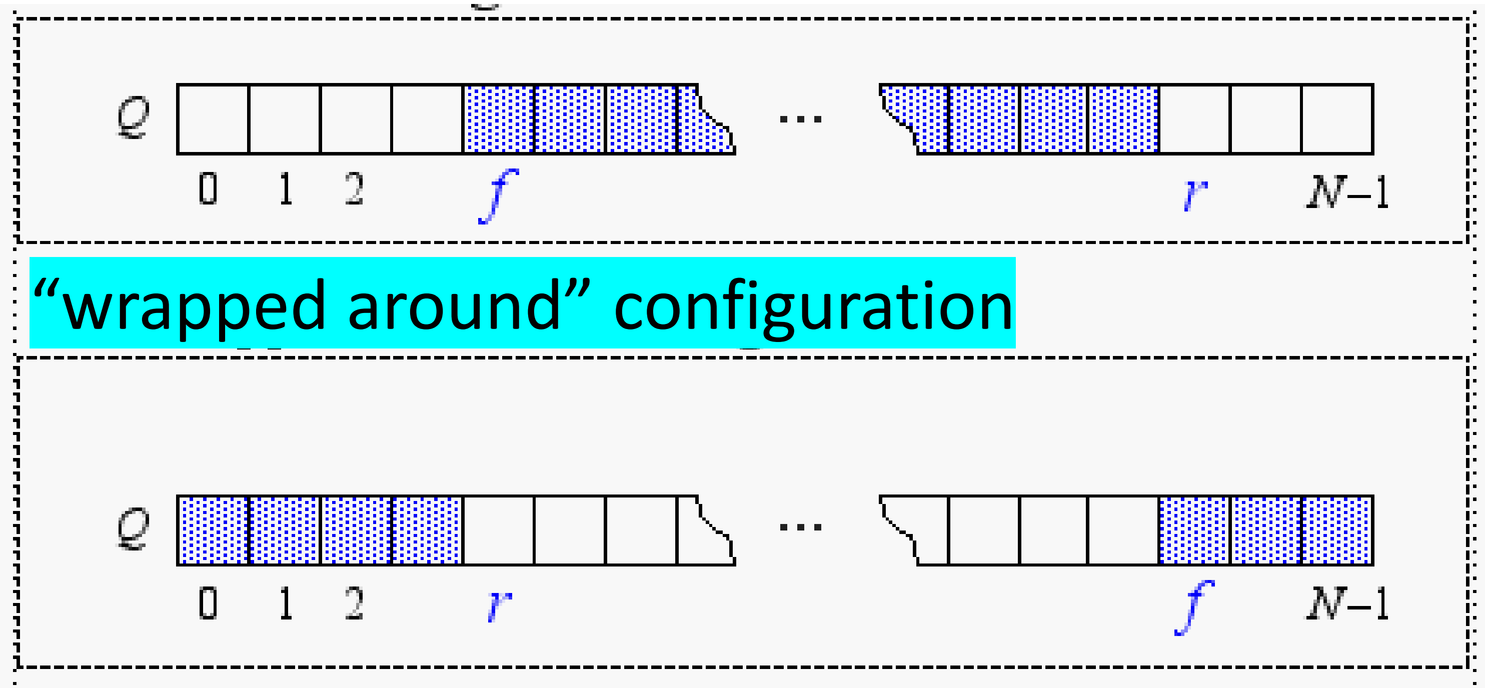


“wrapped around” configuration

An Array-Based Queue

Questions:

How do we compute the number of elements in the queue from f and r?



“wrapped around” configuration

An Array-Based Queue

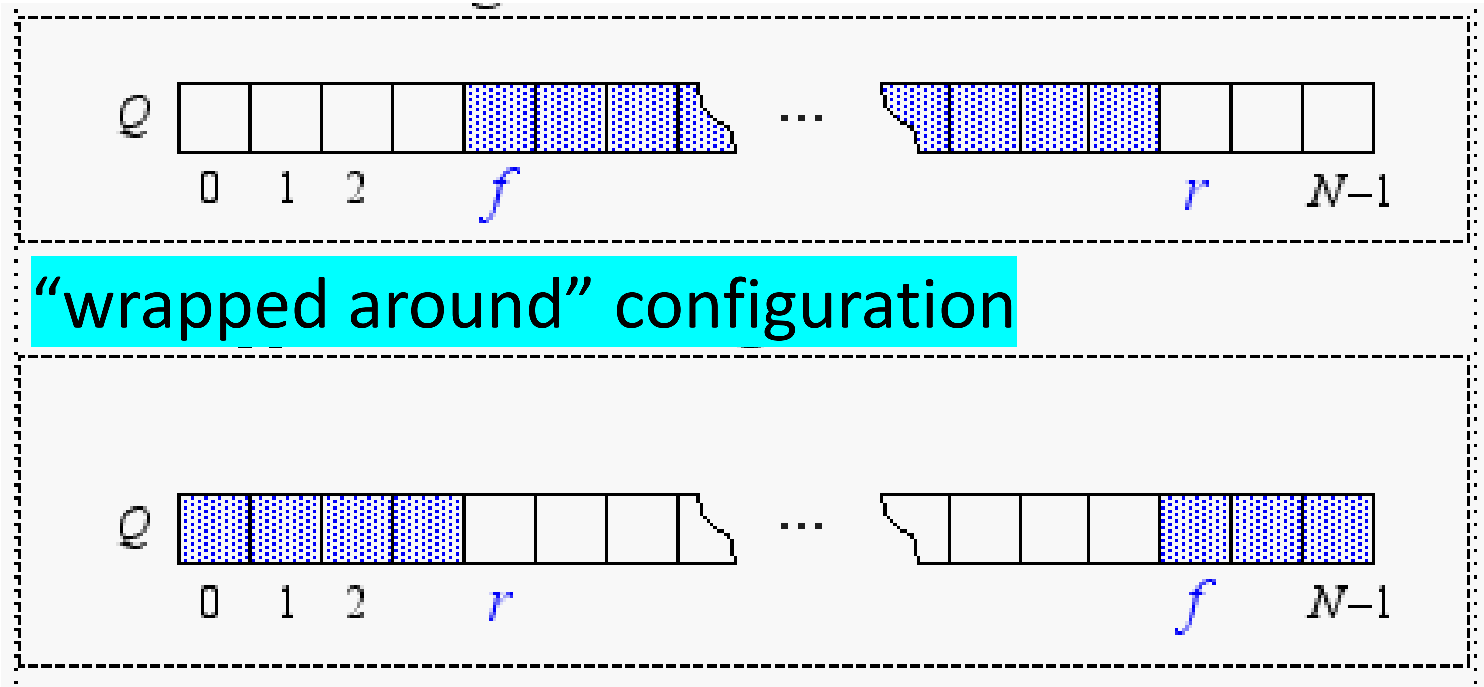
Questions:

How do we compute the number of elements in the queue from f and r?

- *if r > f,*

  #elements = r – f

- *if r < f,*
  - ***#elements = N – f + r***
- *if r == f,*
  - ***#elements = 0***



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An Array-Based Queue

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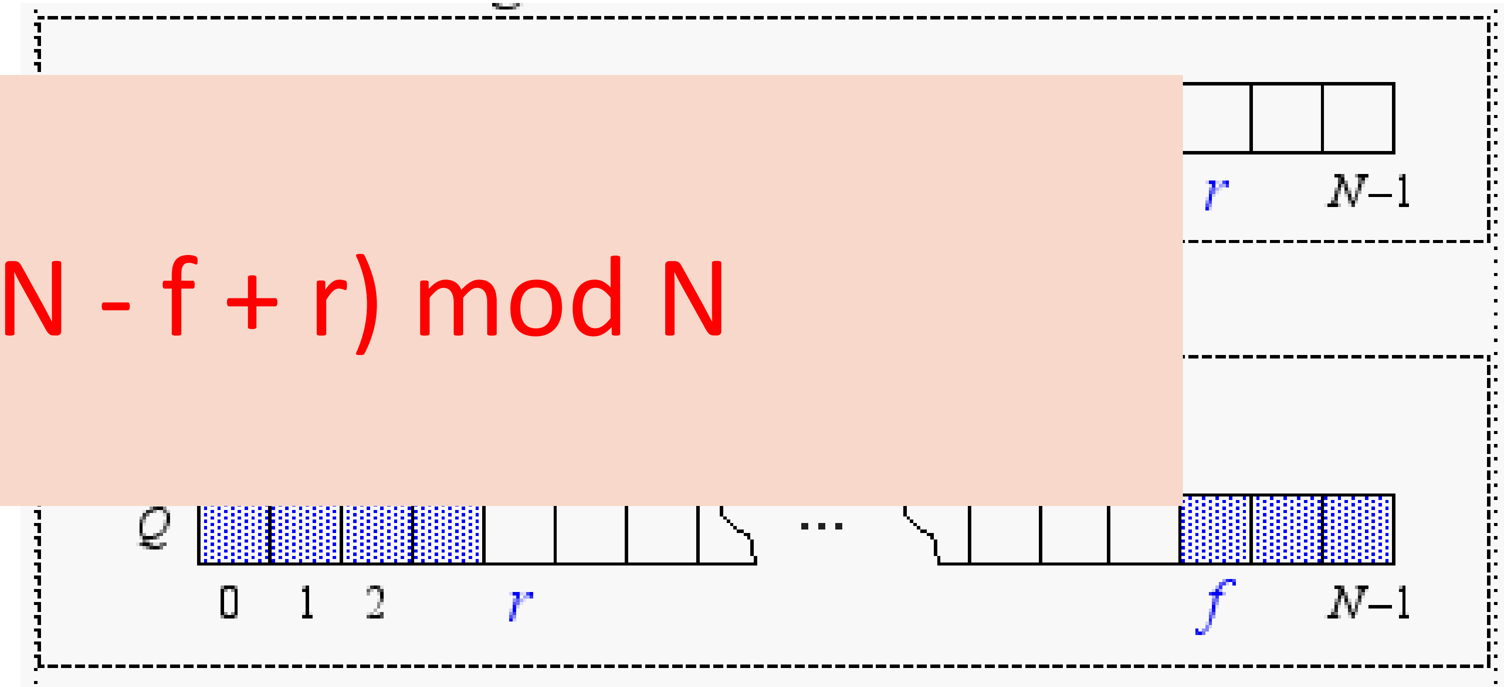


i.e., (N - f + r) mod N

An Array-Based Queue: Pseudo Code

```
Algorithm Size():
    return (N - f + r) mod N
```

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

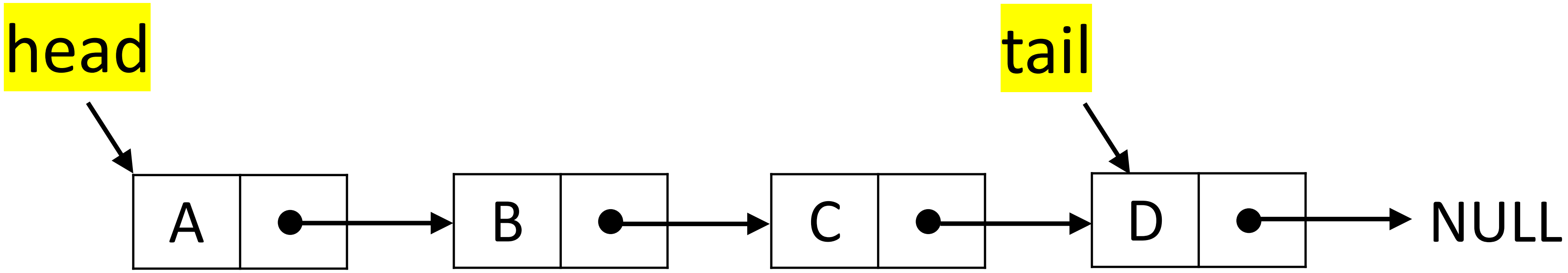
```
Algorithm Front():
    if isEmpty() then
        print “Queue is Empty”
        return NULL
    return Q[f]
```

```
Algorithm Dequeue():
    if isEmpty() then
        print “Queue is Empty”; return NULL
    temp = Q[f]
    Q[f] = null
    f = (f + 1) mod N
    return temp
```

```
Algorithm Enqueue(o):
    if Size() == N - 1 then
        print “Queue is Full”; return
    Q[r] = o
    r = (r + 1) mod N
```

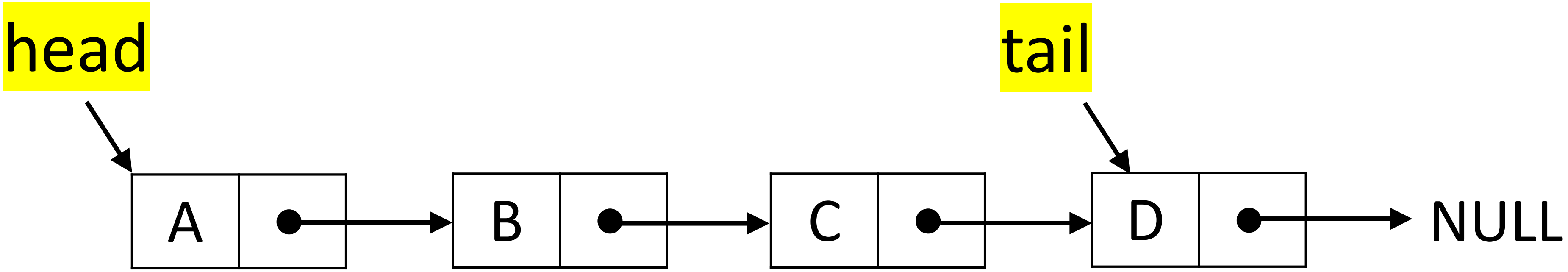
Implementing Queue with a Singly Linked List

- Nodes (*data, pointers*) connected in a chain by links

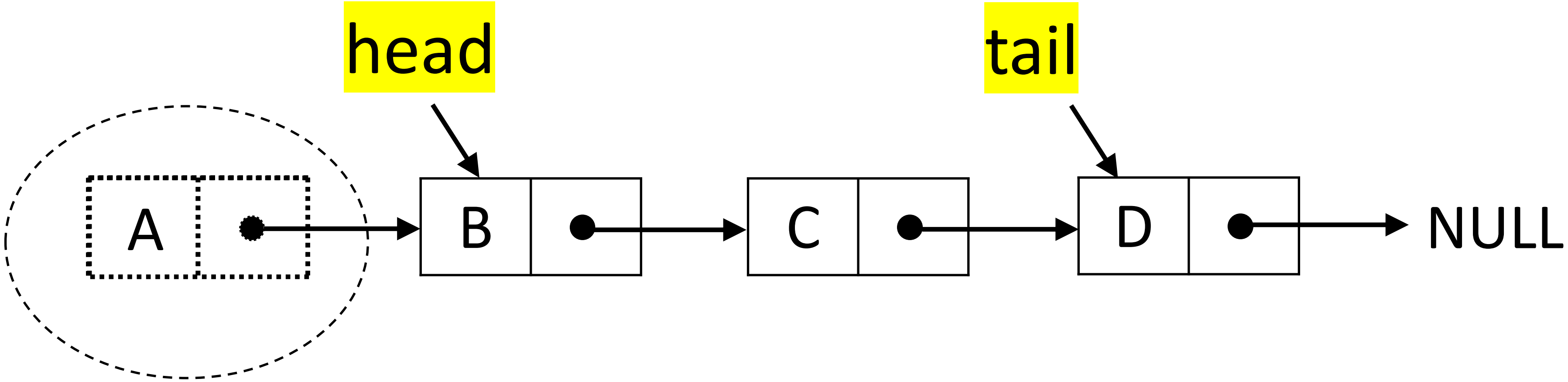


- The head of the list is the front of the queue, the tail of the list is the rear of the queue. ***Why not the opposite?***

Queue: Removing at the Head (Dequeue)



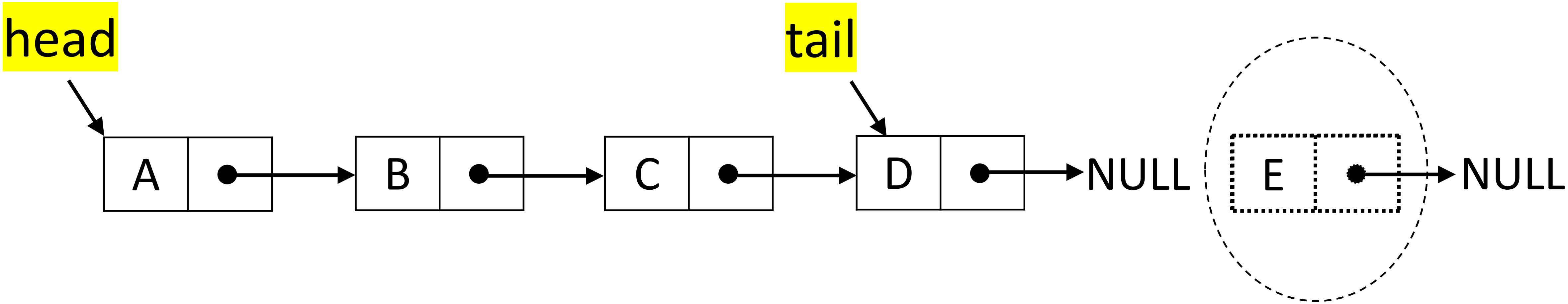
Advance head reference



Inserting at the head is just as easy

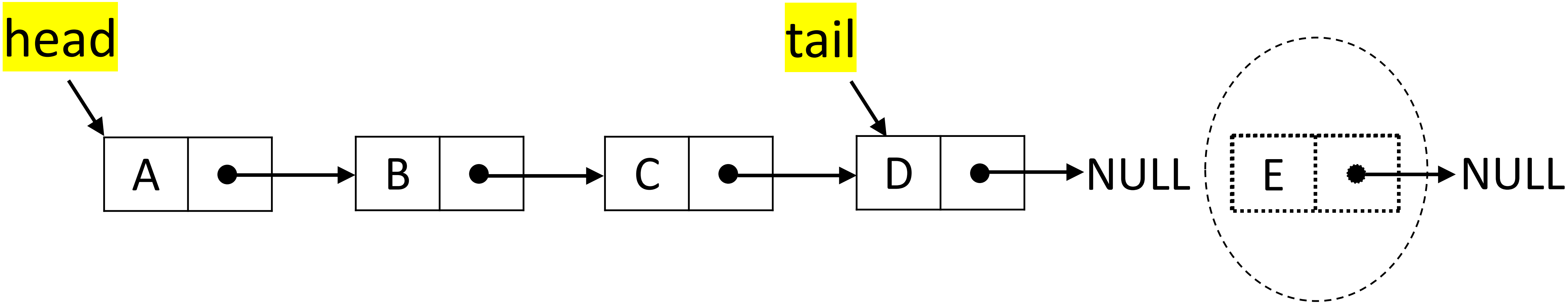
Queue: Inserting at the Tail (Enqueue)

Create a new node

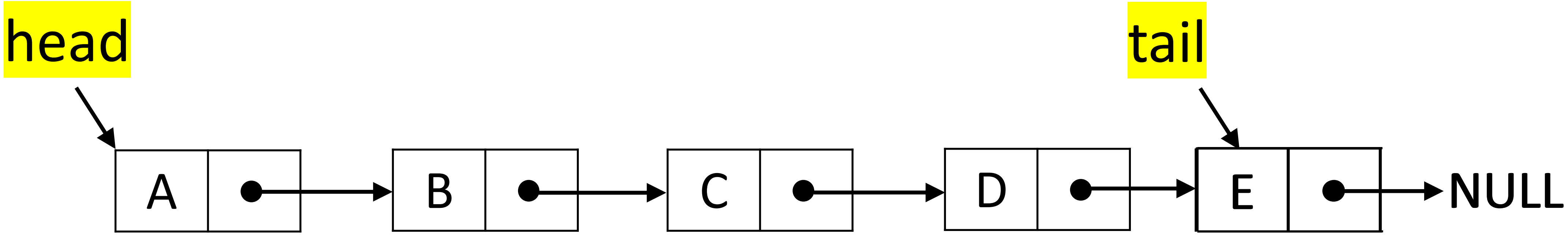


Queue: Inserting at the Tail (Enqueue)

Create a new node



Chain it and move the tail reference



How about removing at the tail?

Double-Ended Queue

- A double-ended queue, or deque, supports insertion and deletion from the front and back.
- The Deque supports following fundamental methods:
    - **insertFirst(S**:*ADT*, **o**:element**)**:*ADT* - Inserts e at the beginning of deque.
    - **insertLast(S**:*ADT*, **o**:element**)**:*ADT* - Inserts e at the end of deque.
    - **removeFirst(S**:*ADT***)**:*ADT* - Removes the first element.
    - **removeLast(S**:*ADT***)**:*ADT* - Removes the last element.
    - **first(S**:*ADT***)**:*element* - Return the first element.
    - **last(S**:*ADT***)**:*element* - Return the last element.

Implementing Deques

With Singly Linked Lists

- Not a good idea
  - As deletion at tail is costly

Implementing Deques

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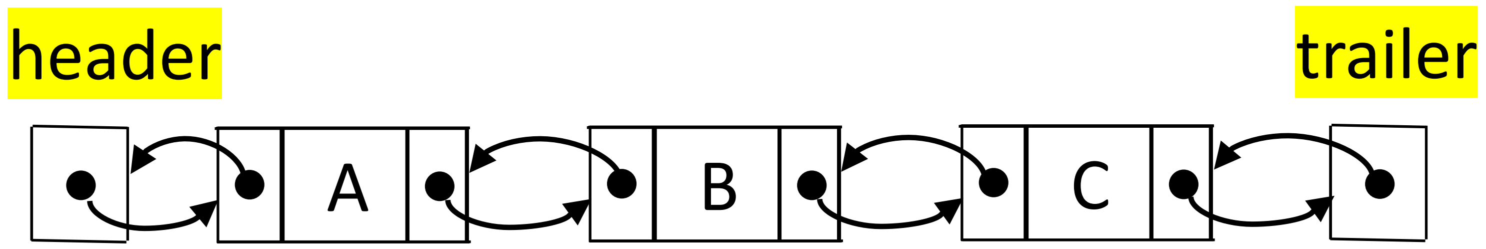
Solution: Use Doubly Linked List

Implementing Deques with Doubly Linked Lists

- Deletions at the tail of a singly linked list cannot be done in constant time.
- To implement a deque, we use a doubly linked list with special header and trailer nodes

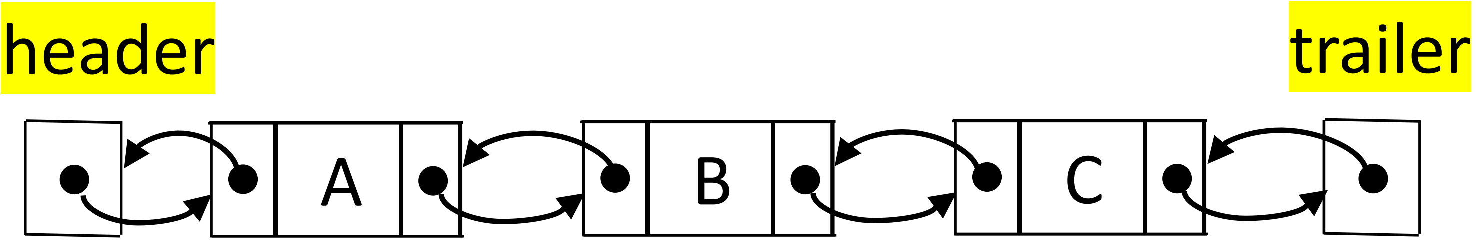


- A node of a doubly linked list has a next and a prev link.
- By using a doubly linked list, all the methods of a deque run in O(1) time.

Implementing Deques with Doubly Linked Lists

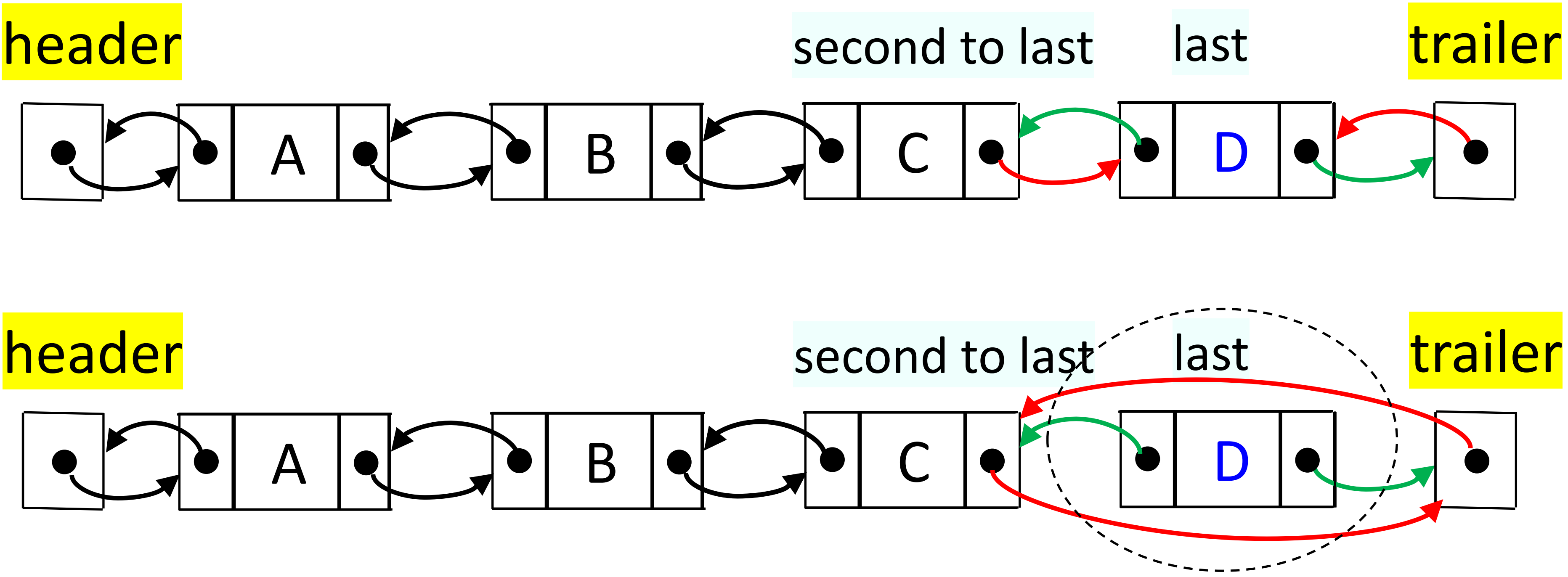
- When implementing a doubly linked lists, we add two special nodes to the ends of the lists: the header and trailer nodes.
    - The ***header*** node goes before the first list element. It has a valid next link but a null prev link.
    - The ***trailer*** node goes after the last element. It has a valid prev reference but a null next reference.

NOTE***: the header and trailer nodes are sentinel or "dummy" nodes because they do not store elements. Here's a diagram of our doubly linked list:***



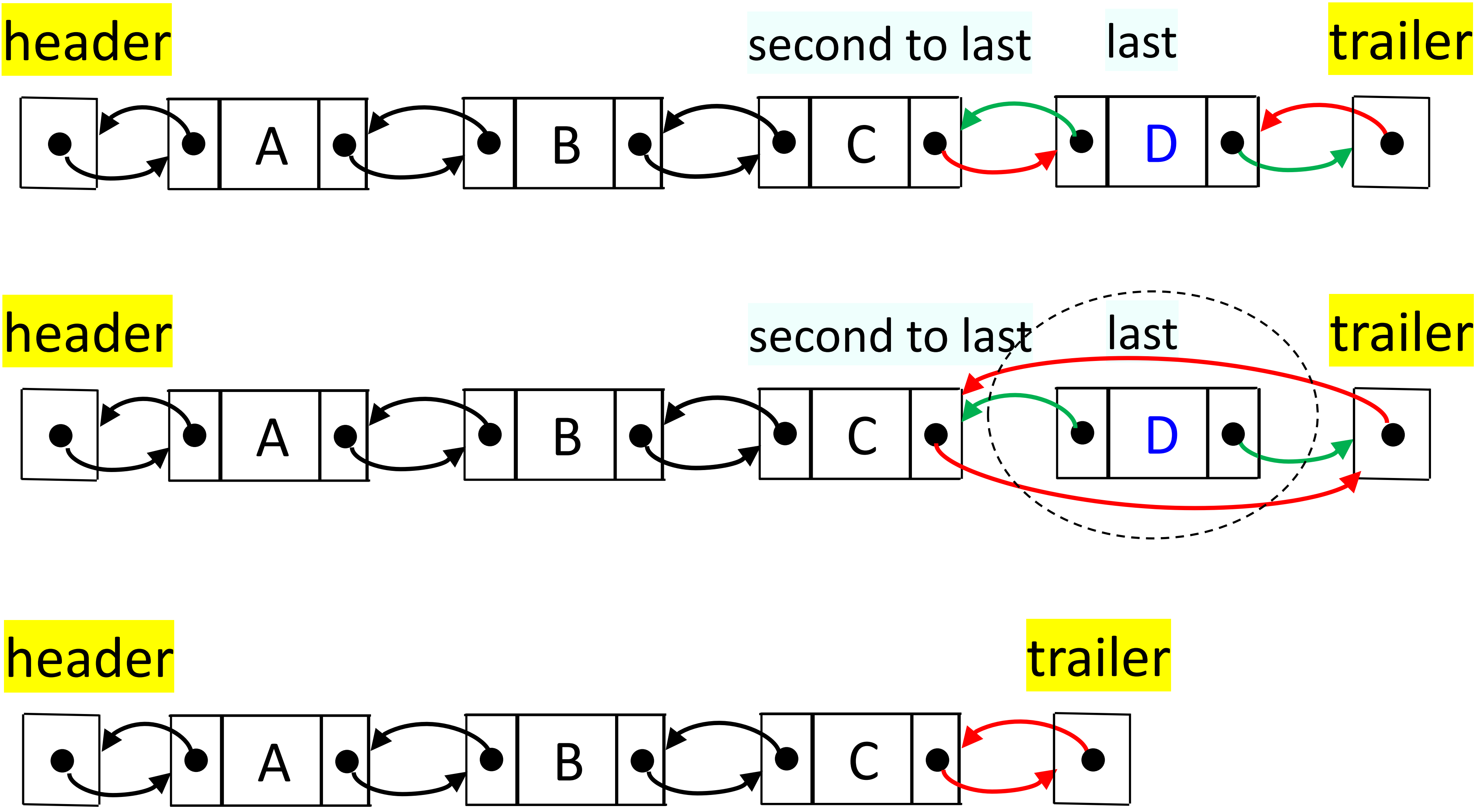
Implementing Deques with Doubly Linked Lists

Here’s a visualization of the code for removeLast().



Implementing Deques with Doubly Linked Lists

Here’s a visualization of the code for removeLast().



Implementing Stacks and Queues with Deques

Implementing ADTs using implementations of other ADTs as building blocks

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Implementing ADTs using implementations of other ADTs as building blocks

Stacks with Deques:

Stack Method	**Deque Implementation**
size()	size()
isEmpty()	isEmpty()
top()	last()
push(e)	insertLast(e)
pop()	removeLast()

Implementing Stacks and Queues with Deques

Implementing ADTs using implementations of other ADTs as building blocks

Stacks with Deques:

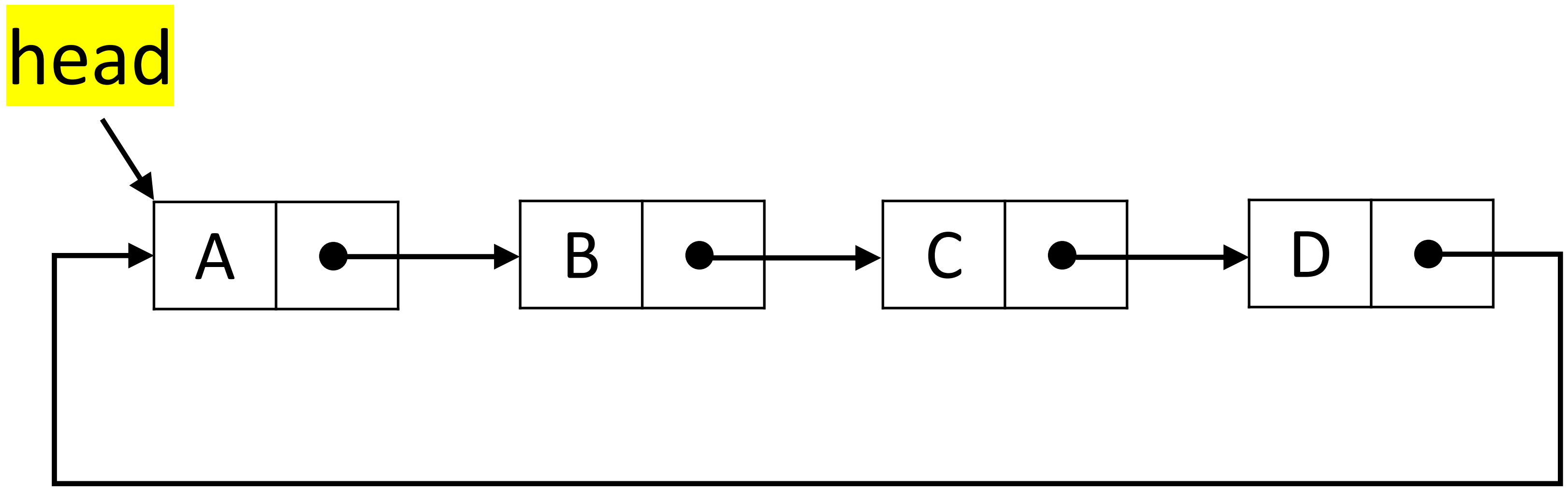
Stack Method	Deque Implementation
size()	size()
isEmpty()	isEmpty()
top()	last()
push(e)	insertLast(e)
pop()	removeLast()

Queues with Deques:

Queue Method	Deque Implementation
size()	size()
isEmpty()	isEmpty()
front()	first()
enqueue(e)	insertLast(e)
dequeue()	removeFirst()

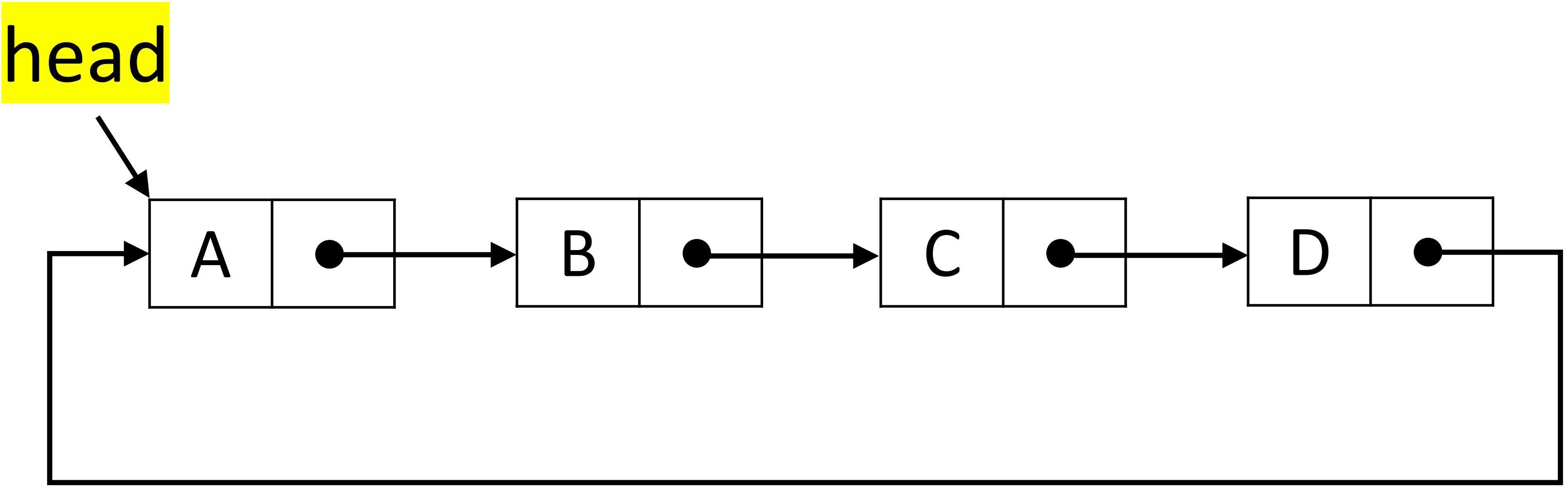
Circular Lists

- No end and no beginning of the list, only one pointer as an **entry point**
- *Circular doubly linked list with a sentinel* is an elegant implementation of a stack or a queue



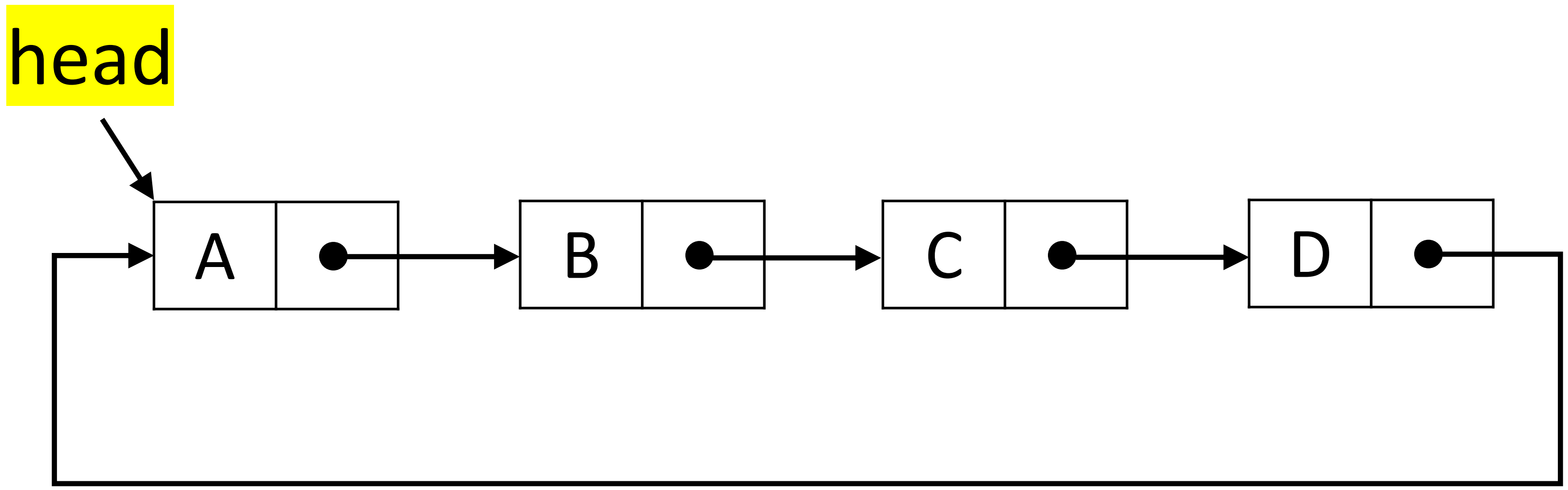
Circular Lists

- **Insertion a node F at head:** create a new node, insert between A and B, copy A to this new node and replace A of head node with F.



Circular Lists

- **Deleting the head node:** copy node B to node A and delete original node B.



Acknowledgement

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