Indian Institute of Information Technology Allahabad

Data Structures and Algorithms

Queues and Lists

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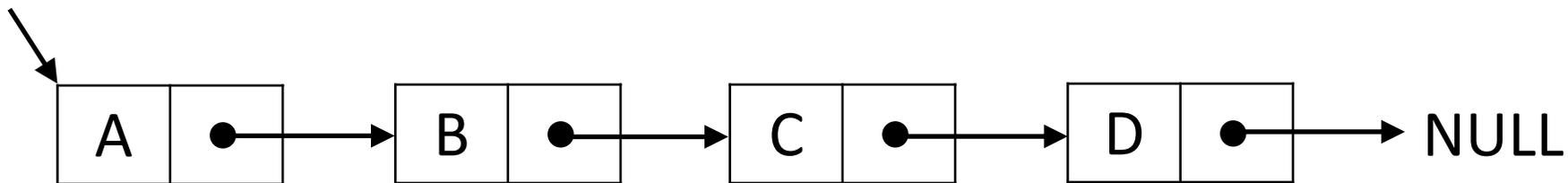# Queues and Linked Lists

Queues
Linked Lists
Doubly Linked List
Double-Ended Queues
Circular List

head

| A | ● | → | B | ● | → | C | ● | → | D | ● | → NULL |

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)

Rear

ONE WAY

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*

Queue Abstract Data Type (ADT)

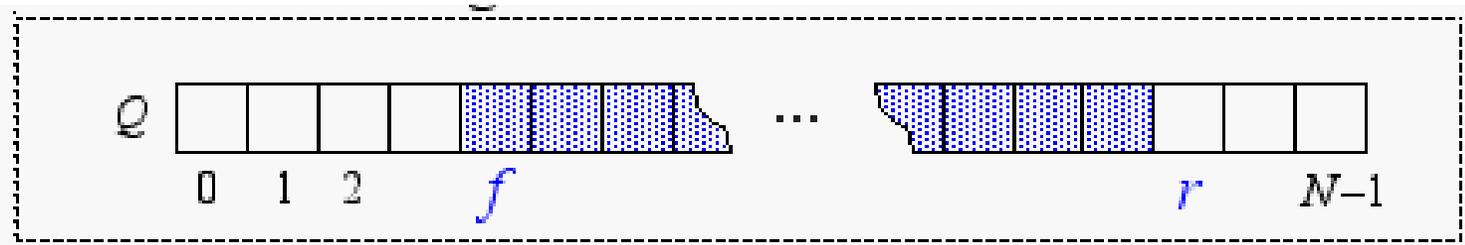These support methods should also be defined:

- **Size(S**:*ADT***):***integer*

- **IsEmpty(S**:*ADT***):***Boolean*

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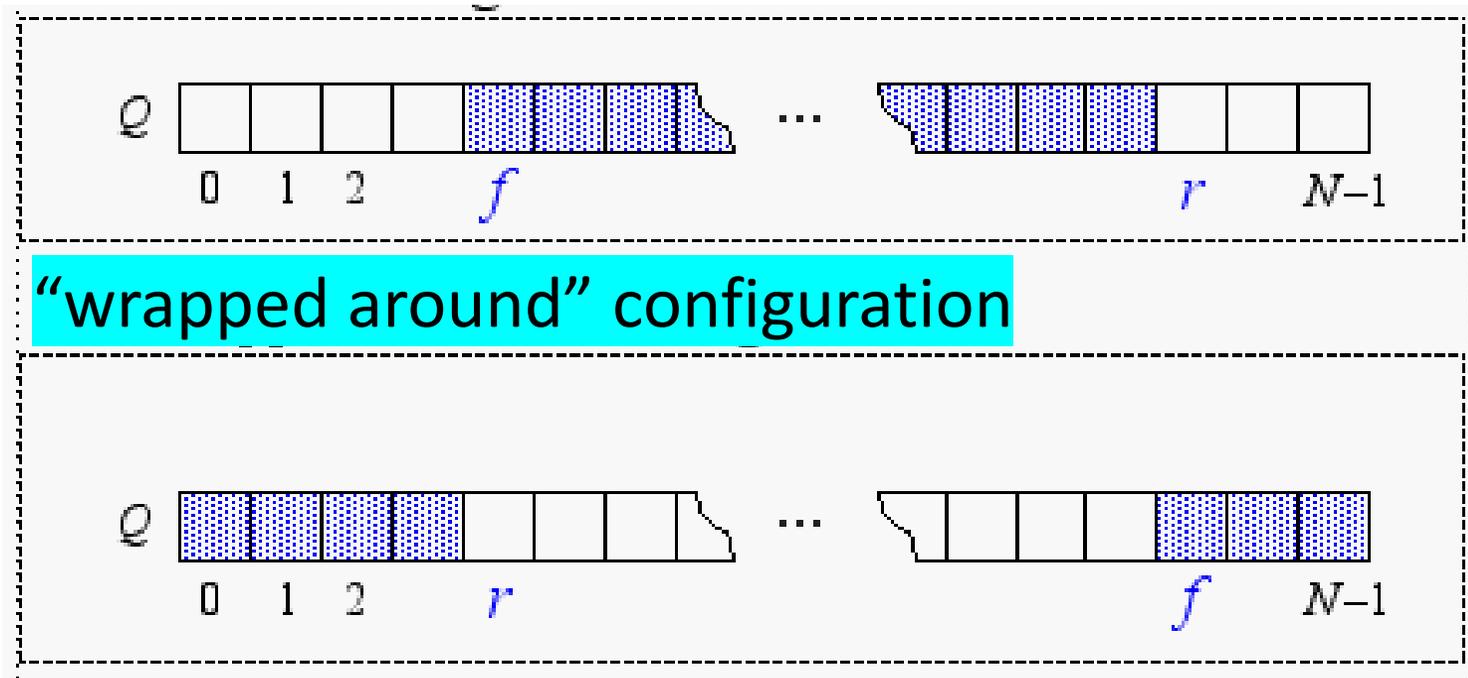
- Create a queue using an array in a circular fashion
- A maximum size N is specified, e.g. N = 1,000.
- The queue consists of an N-element array Q and two integer variables:
  - *f,* index of the front element (head – for dequeue)
  - *r*, index of the element after the rear one (tail – for enqueue)

An Array-Based Queue

- Create a queue using an array in a circular fashion
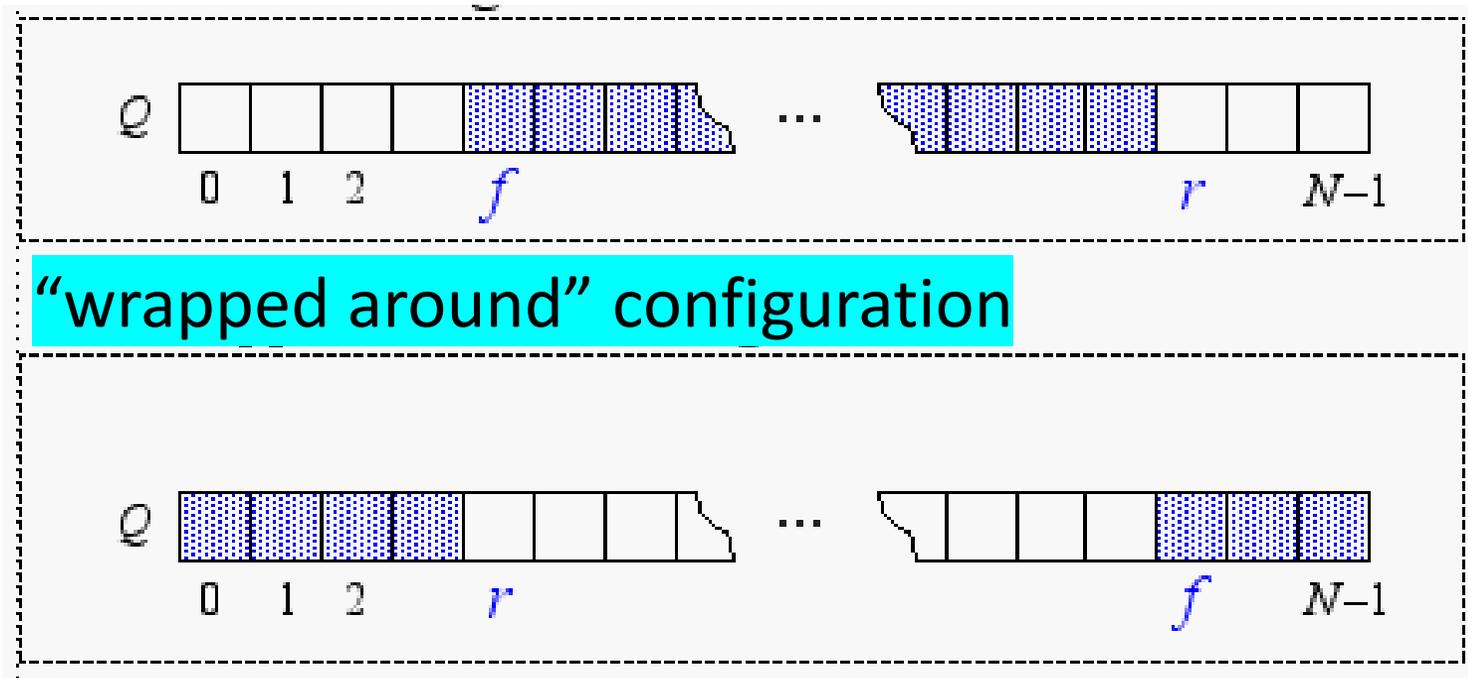- A maximum size N is specified, e.g. N = 1,000.
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  - *f,* index of the front element (head – for dequeue)
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"wrapped around" configuration

An Array-Based Queue

Questions:

What does f==r mean?

"wrapped around" configuration

An Array-Based Queue

Questions:

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
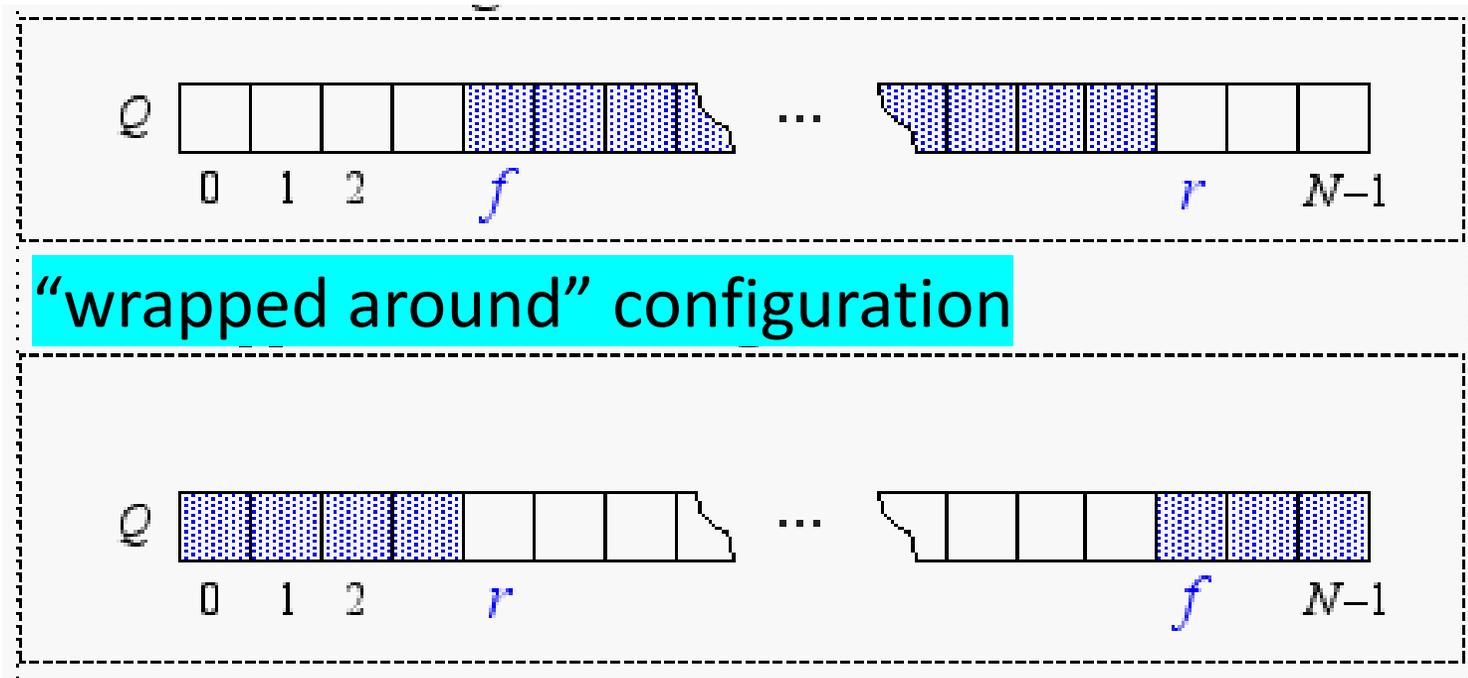
An Array-Based Queue

Questions:

How do we compute the number of elements in the queue from f and r?
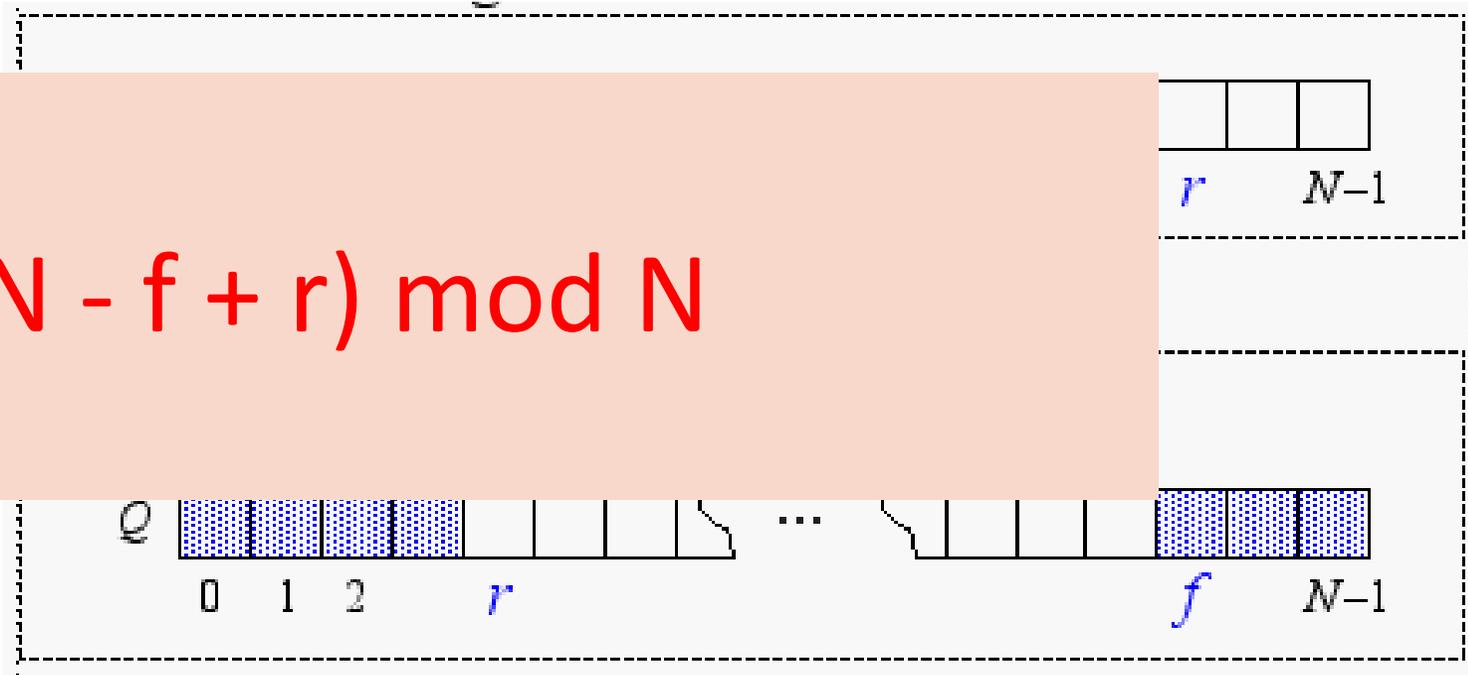
- *if r > f,*
  - *#elements = r − f*
- *if r < f,*
  - *#elements = N − f + r*
- *if r == f,*
  - *#elements = 0*

"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,*
  - *#el...*
- *if r <*
  - *#e...*
- *if r =– j,*
  - *#elements = 0*

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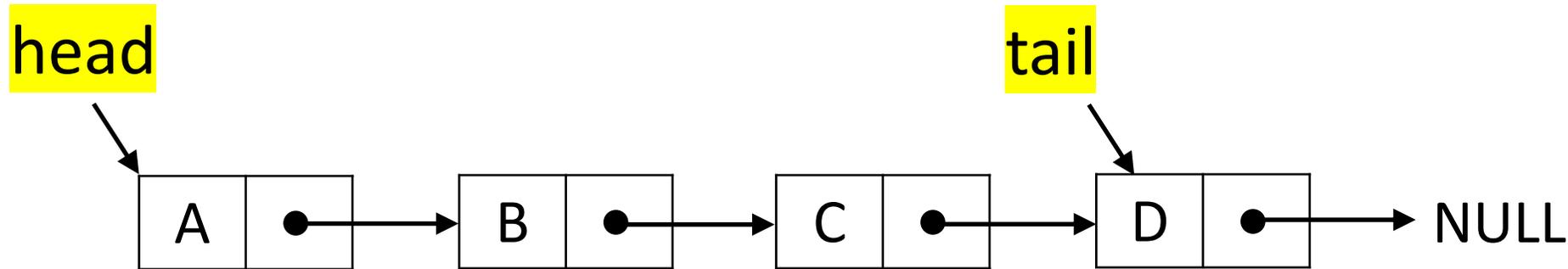
Algorithm **Dequeue**():
    if **isEmpty()** then
        print "Queue is Empty"; return NULL
    temp = Q[f]
    Q[f] = null
    f = (f + 1) mod N
    return temp

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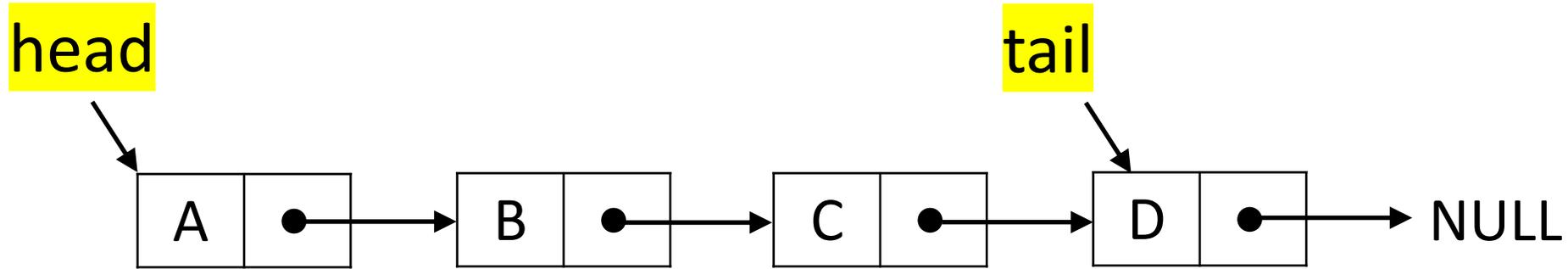   Q[r] = o
    r = (r + 1) mod N

Implementing Queue with a Singly Linked List

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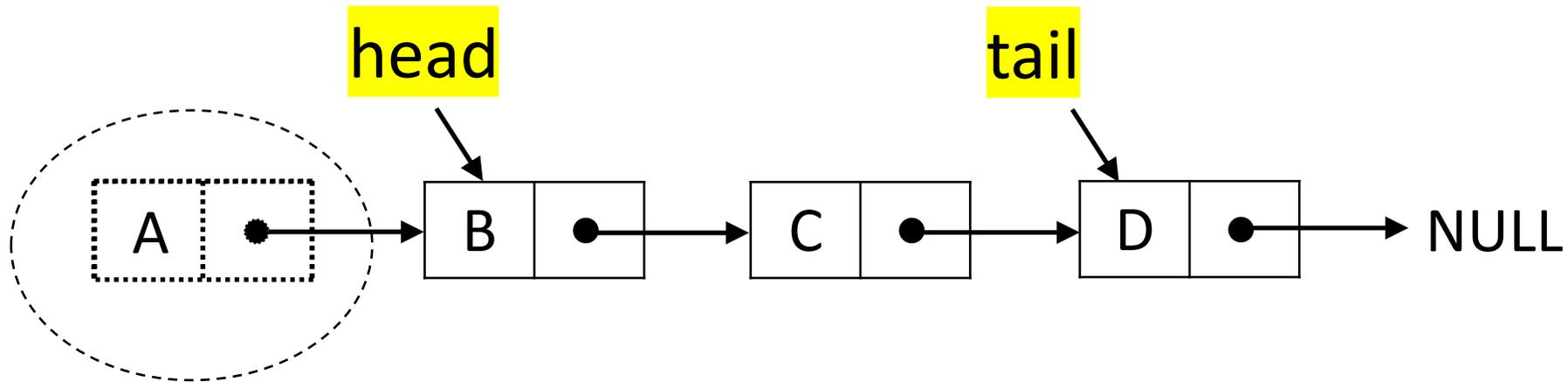

- The head of the list is the front of the queue, the tail of the list is the rear of the queue. **Why not the opposite?**
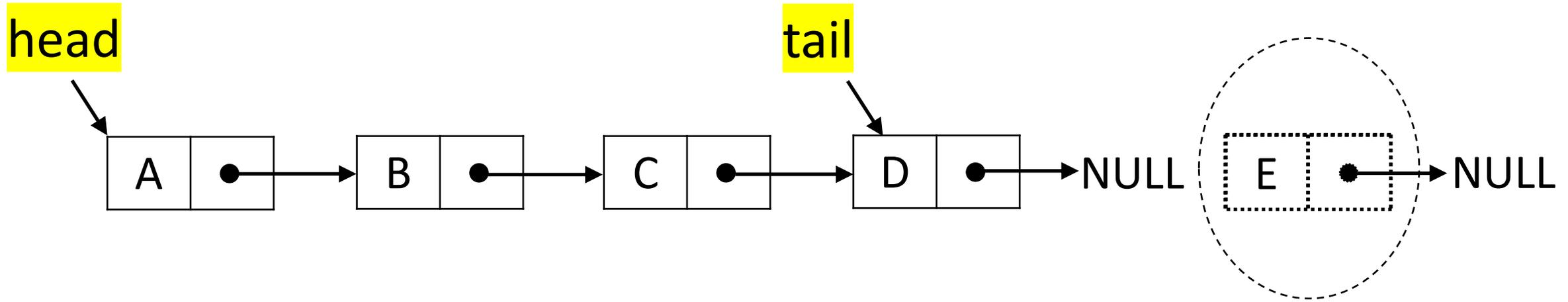
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Queue: Removing at the Head (Dequeue)

Advance head reference
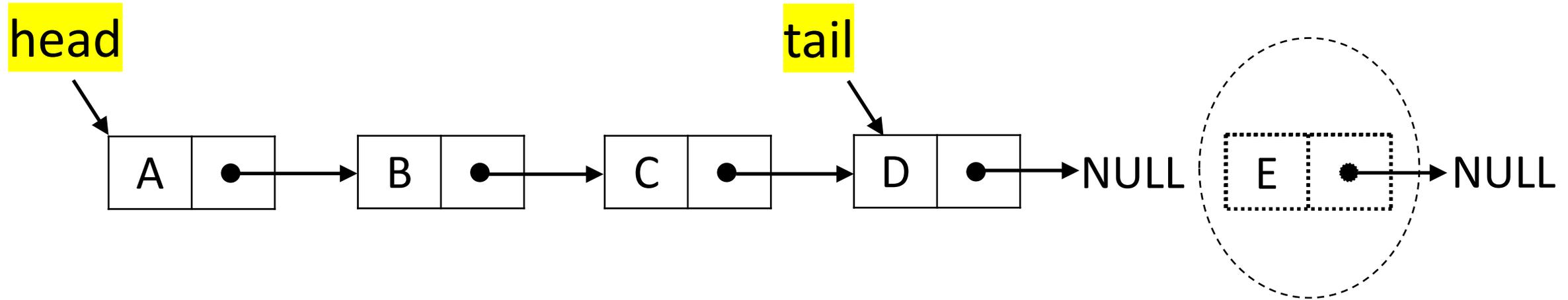

Inserting at the head is just as easy

Queue: Inserting at the Tail (Enqueue)
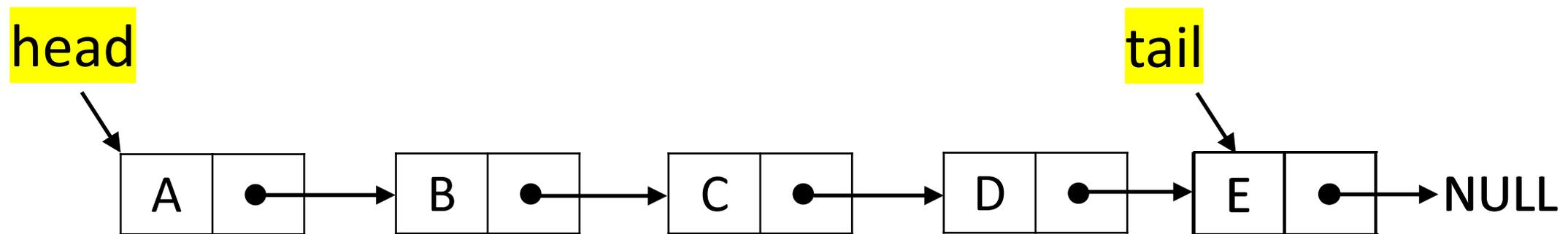
Create a new node

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

With Singly Linked Lists

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

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

header   trailer

A   B   C
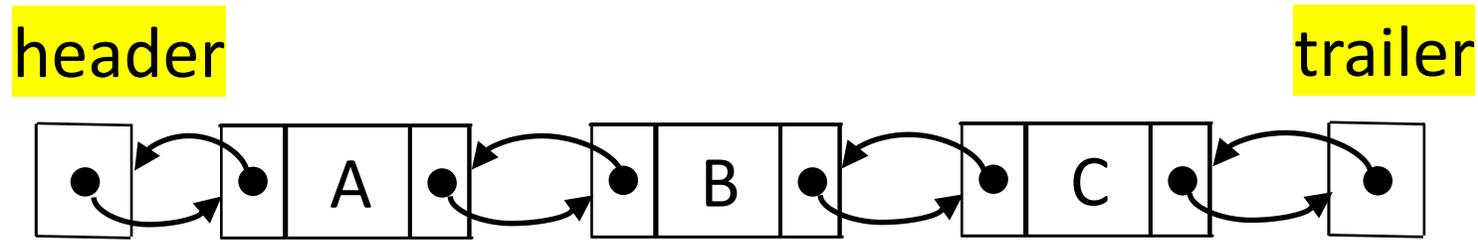
- A node of a doubly linked list has a next and a prev link.

- 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:*
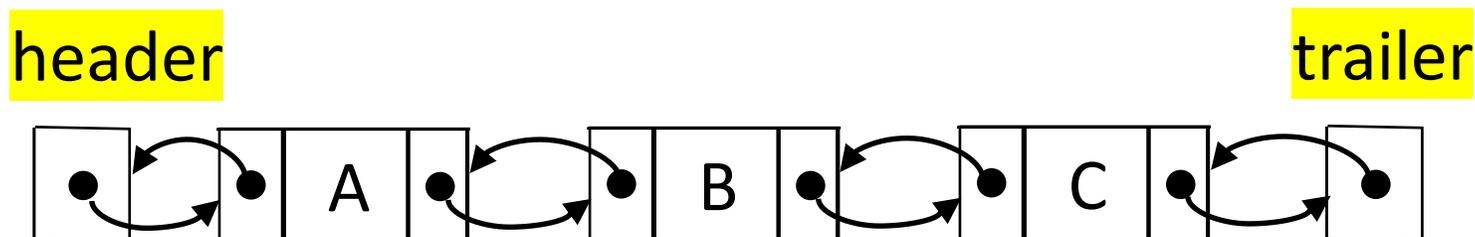
header   trailer
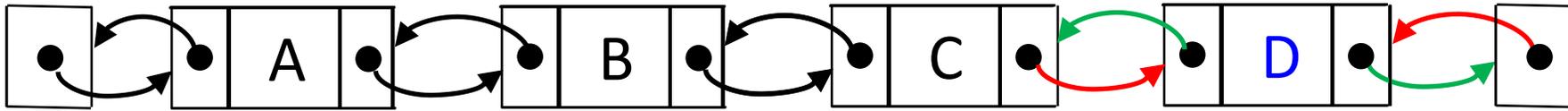

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Implementing Deques with Doubly Linked Lists
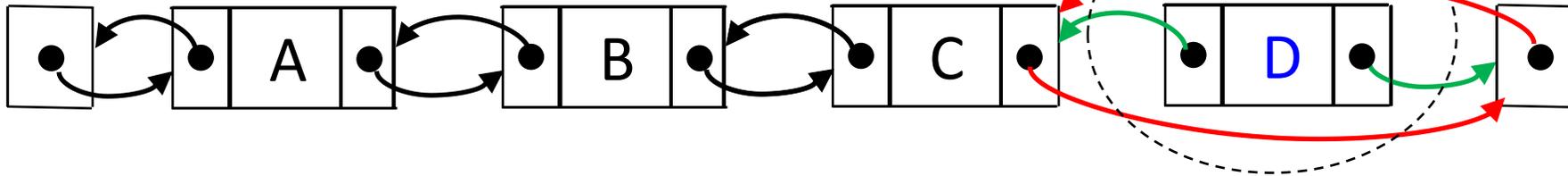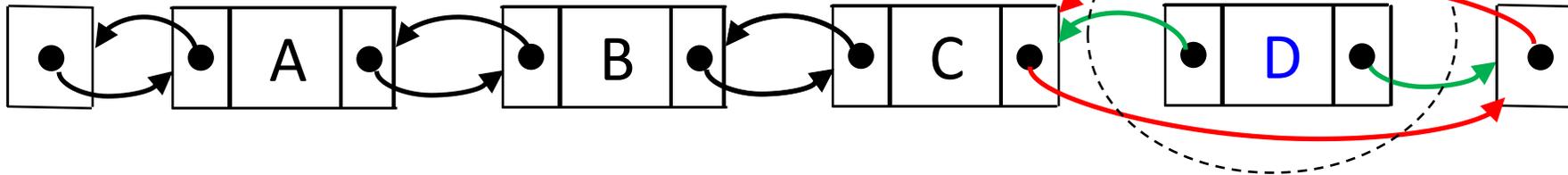
Here's a visualization of the code for removeLast().

Implementing Deques with Doubly Linked Lists

Here's a visualization of the code for removeLast().
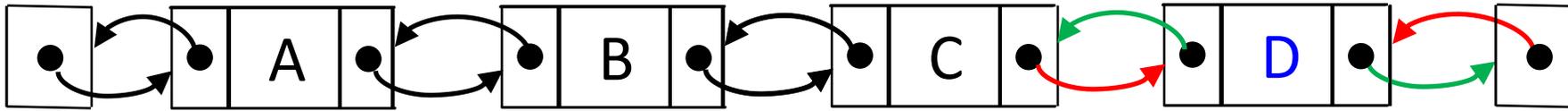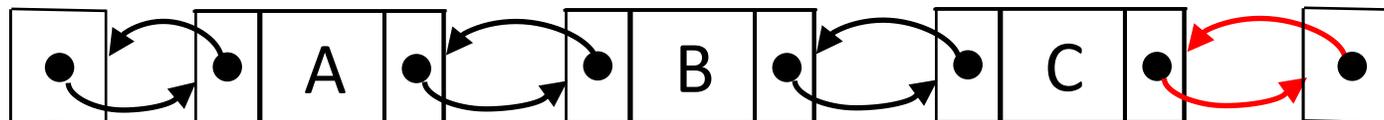
Implementing Stacks and Queues with Deques

Implementing ADTs using implementations of other ADTs as building blocks

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()

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**
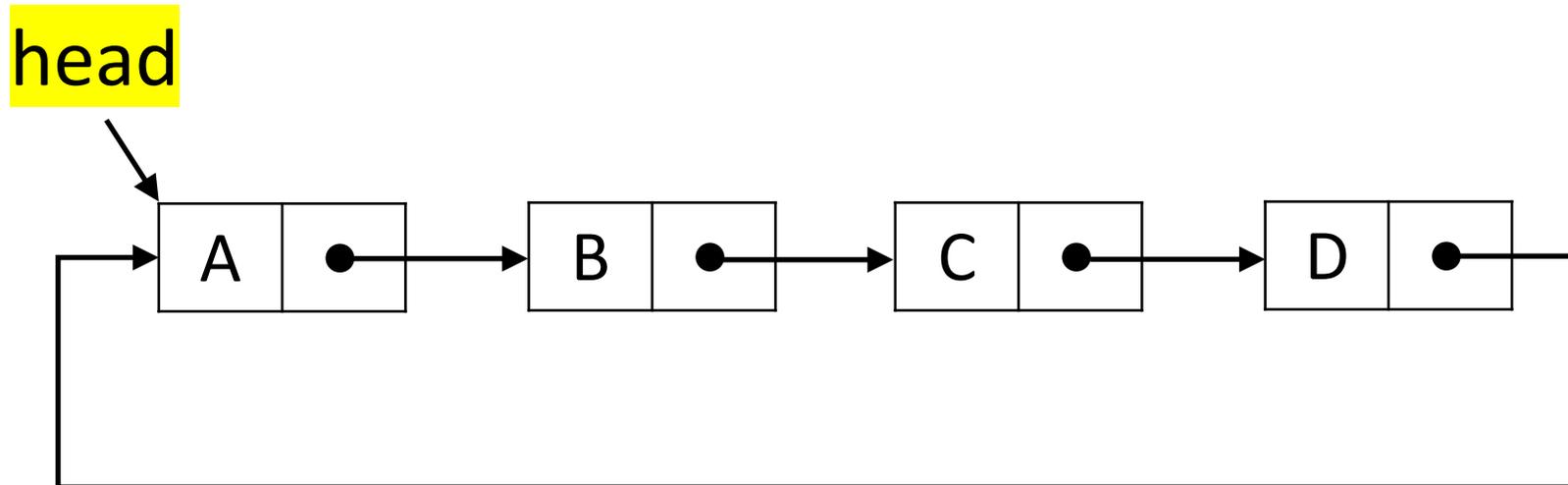- *Circular doubly linked list with a sentinel* is an elegant implementation of a stack or a queue
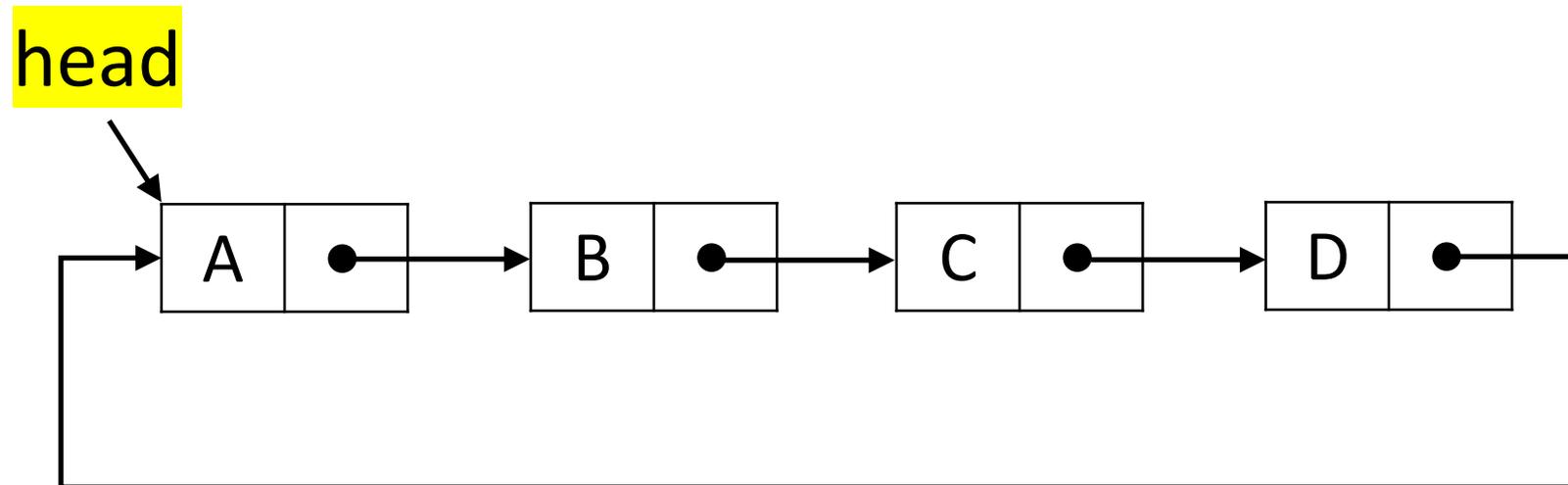
Circular Lists

- **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.
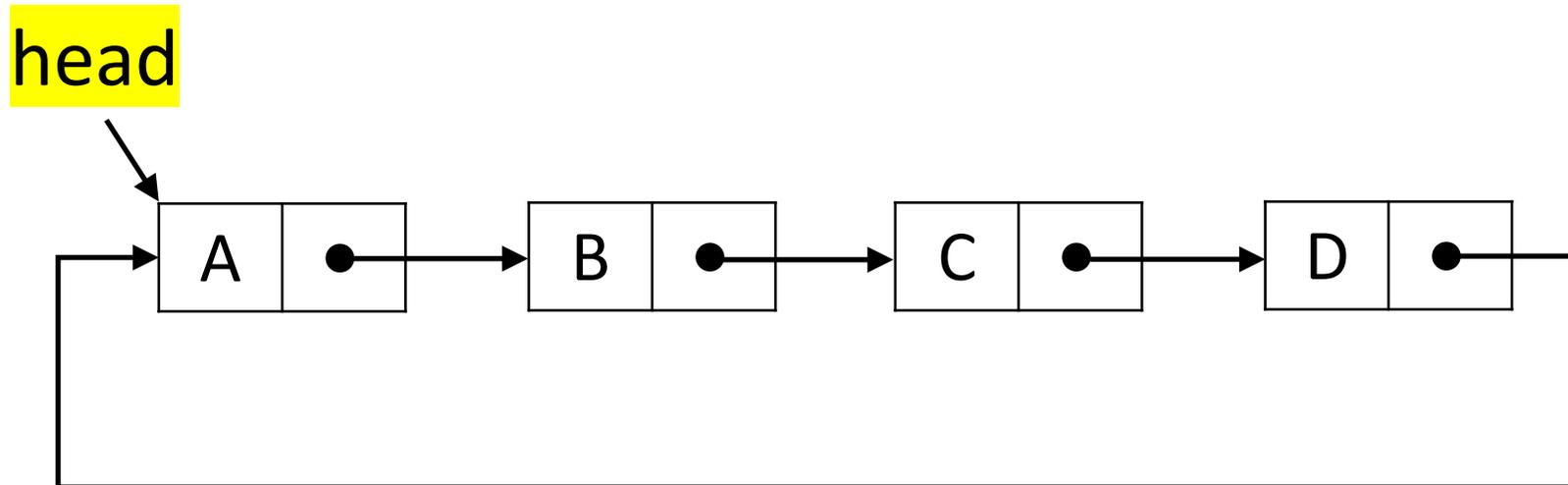
Circular Lists

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

head

Acknowledgement

- IIT Delhi

Thank You