Data Structures

Queues

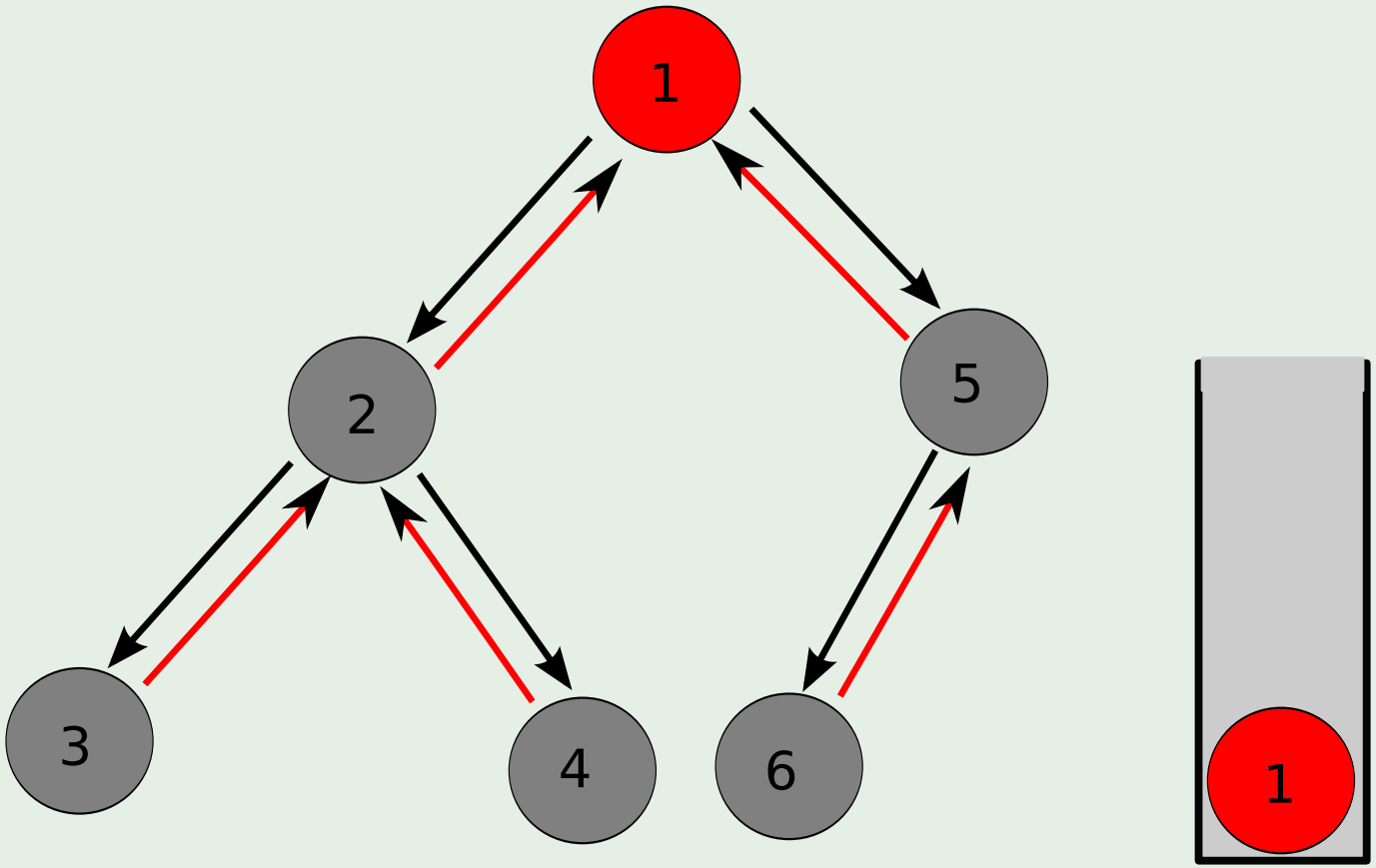
Andres Mendez-Vazquez

August 24, 2016

Outline

Imagine the following

Stack Order



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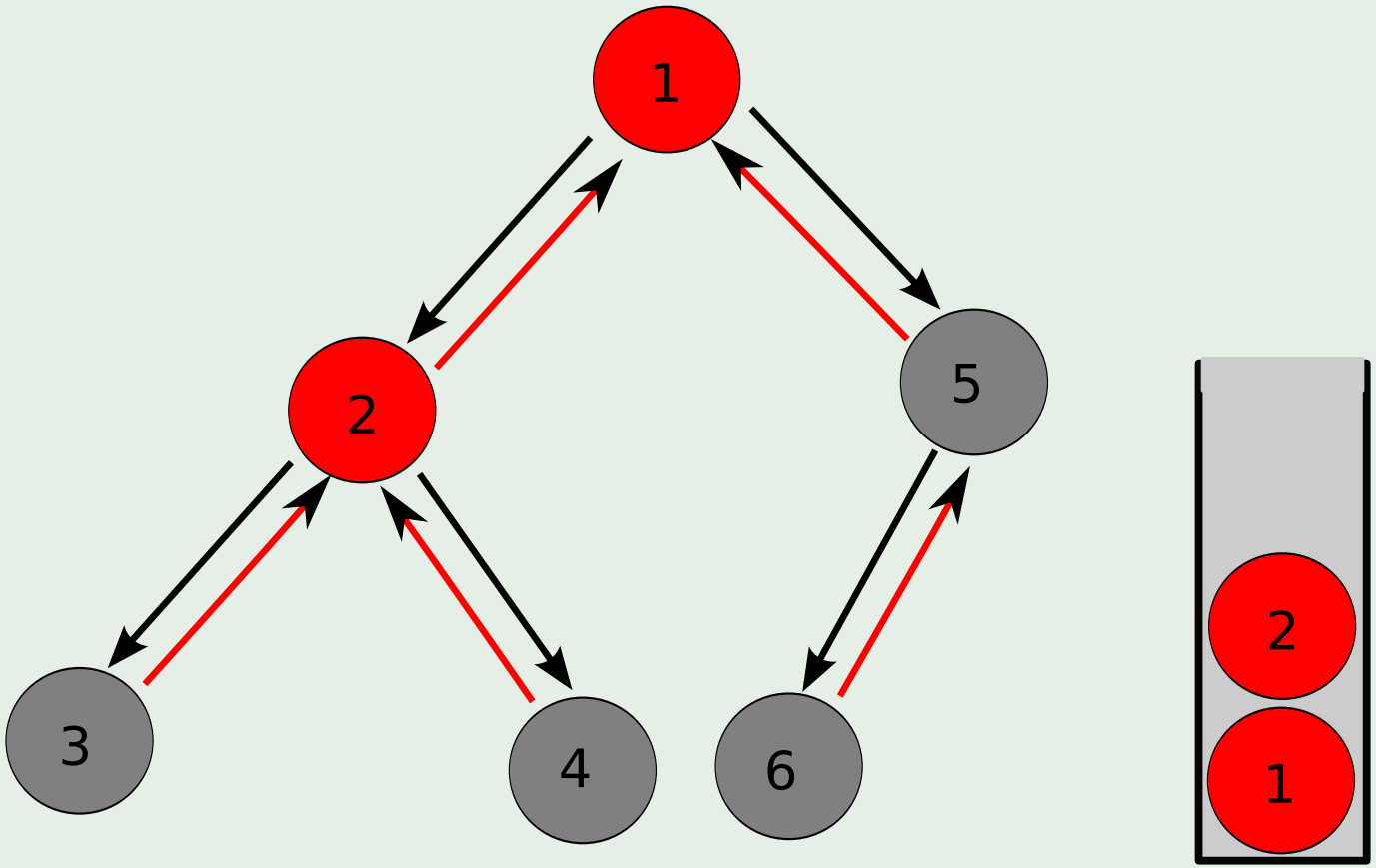

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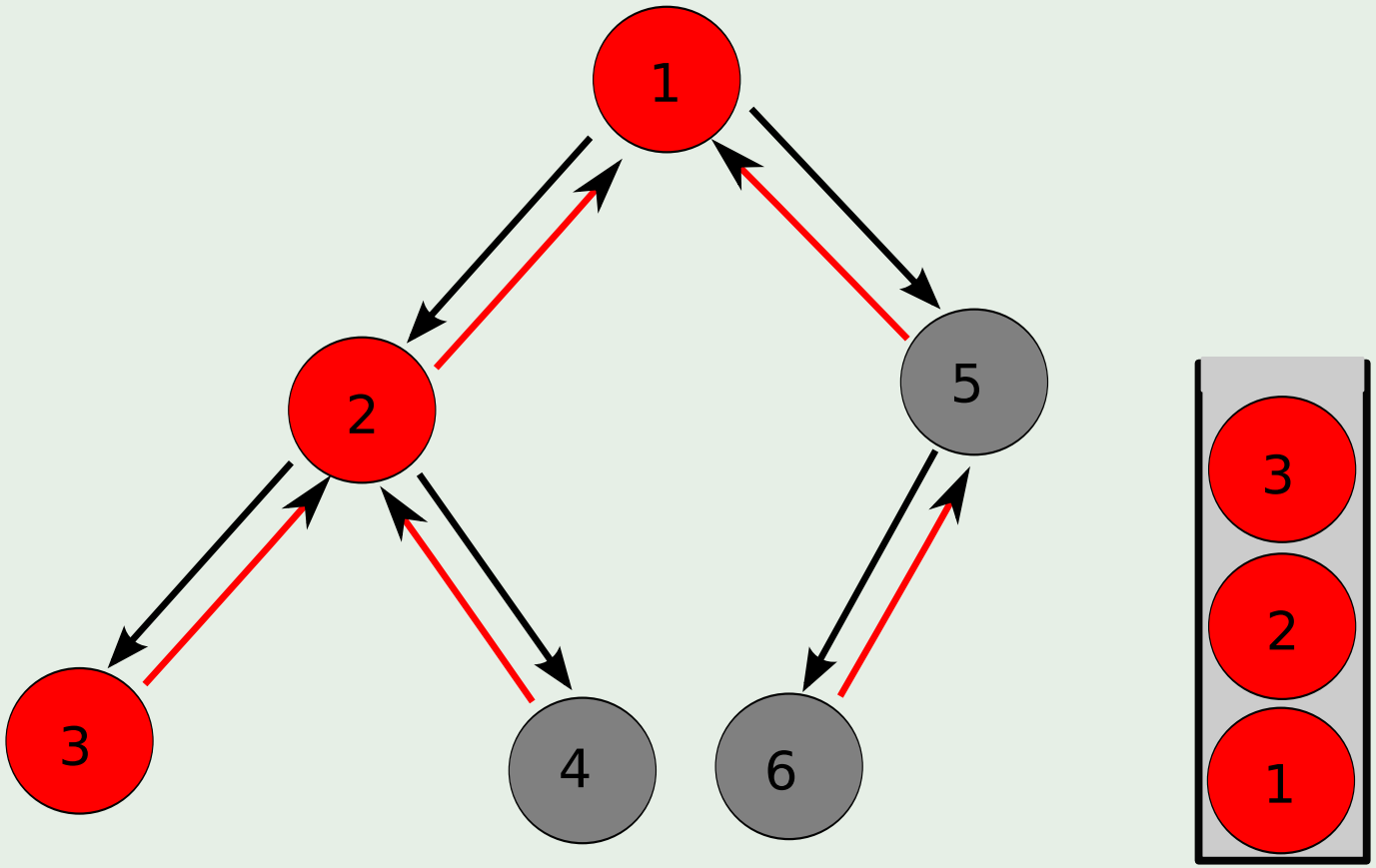

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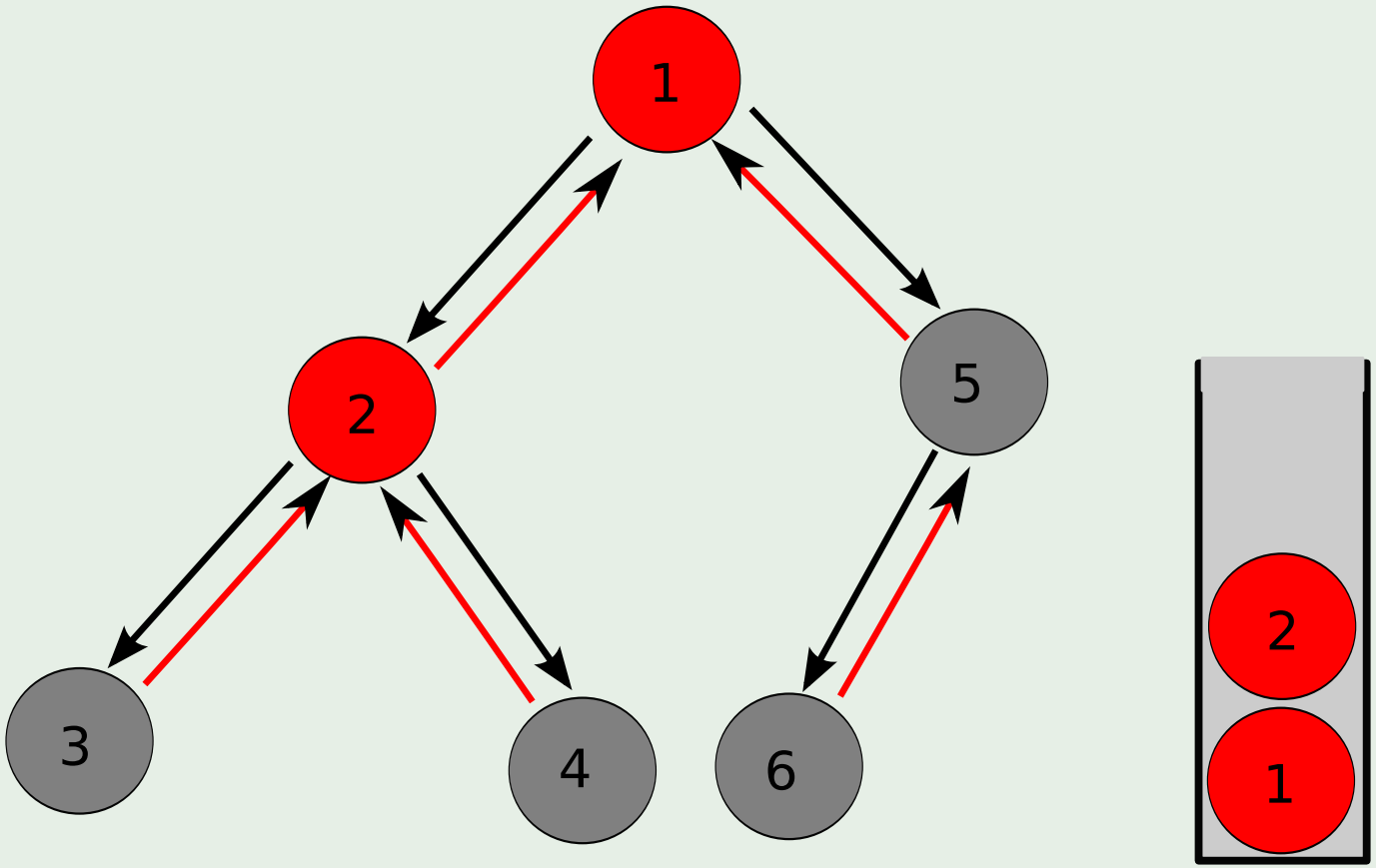

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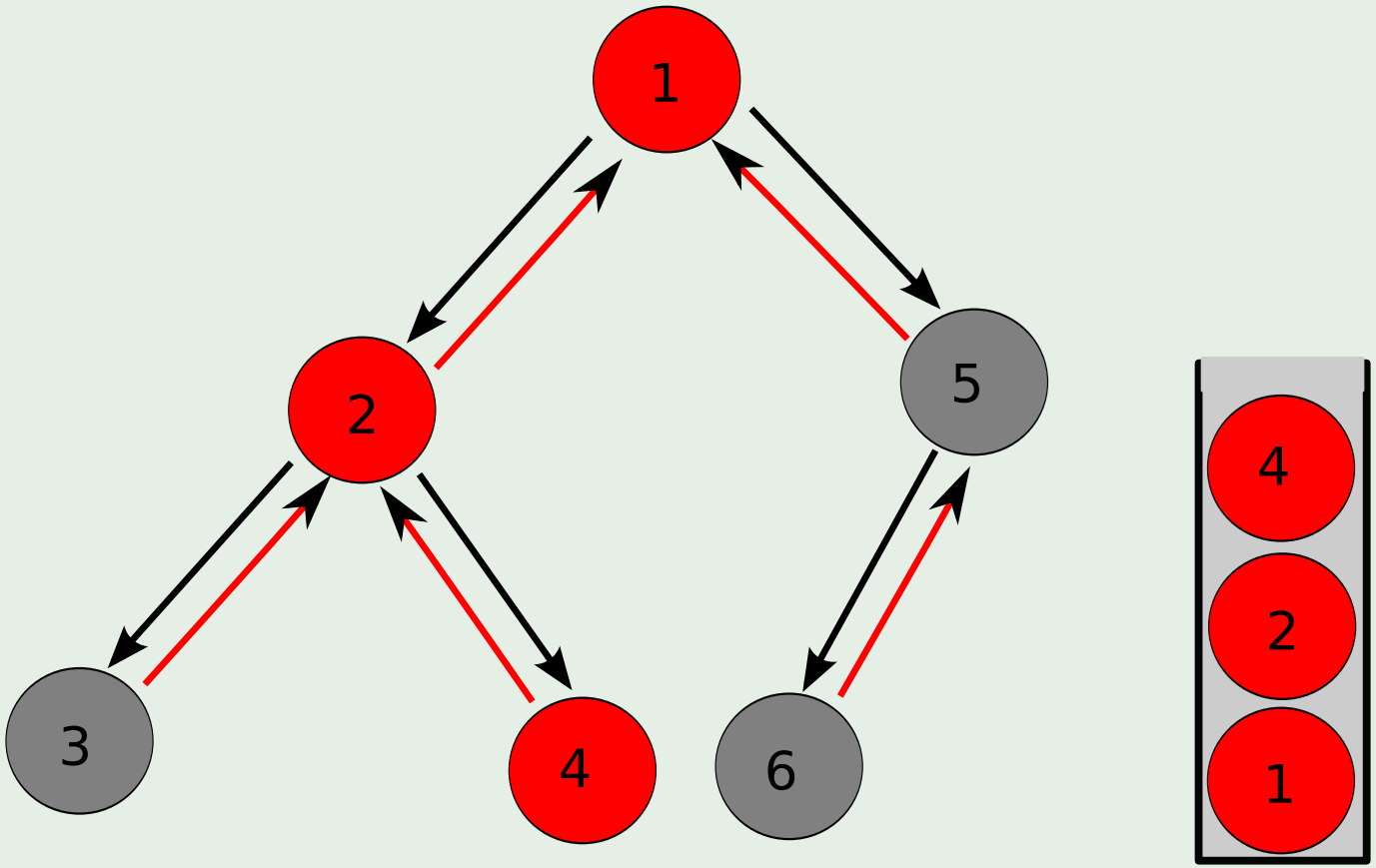

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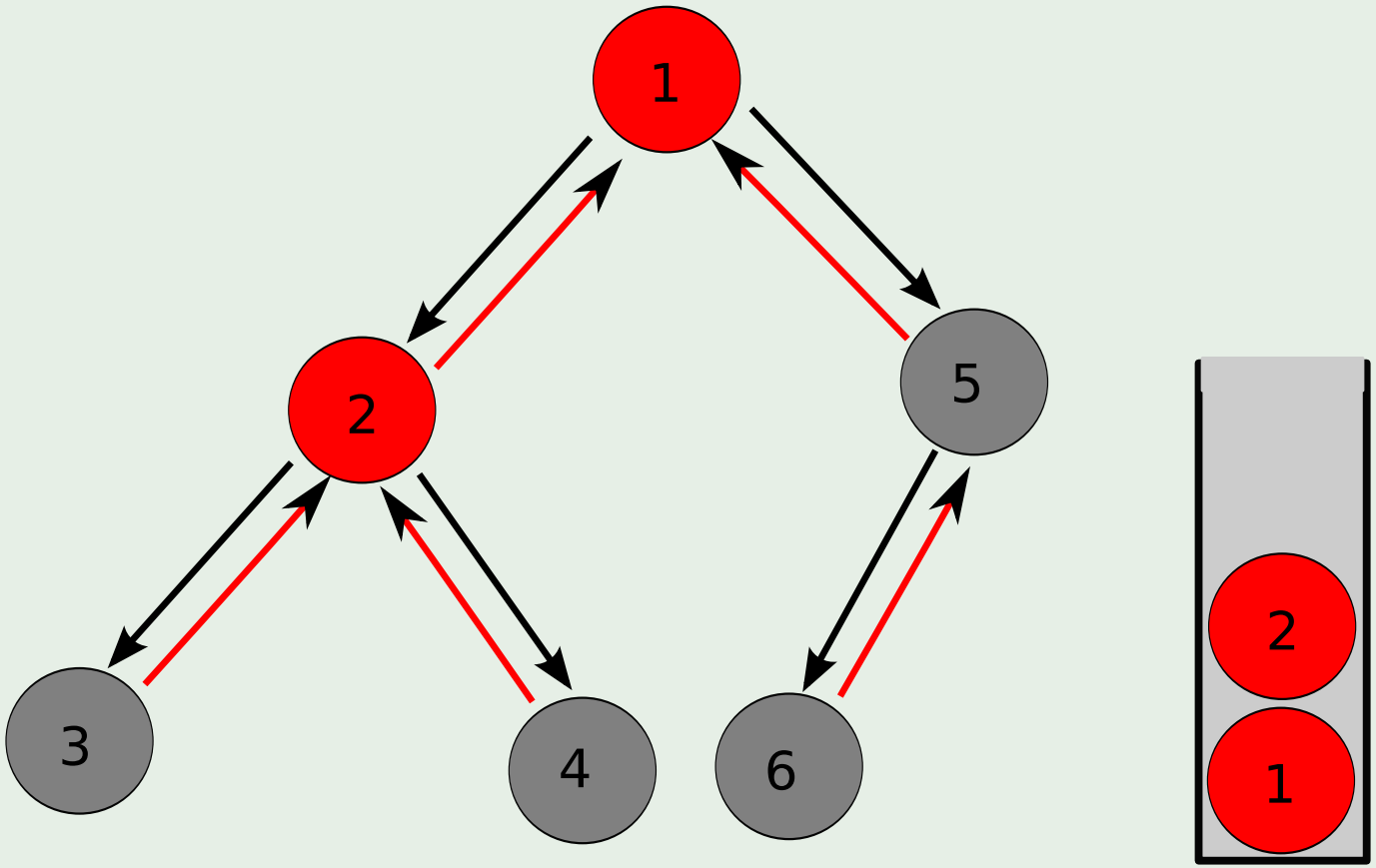

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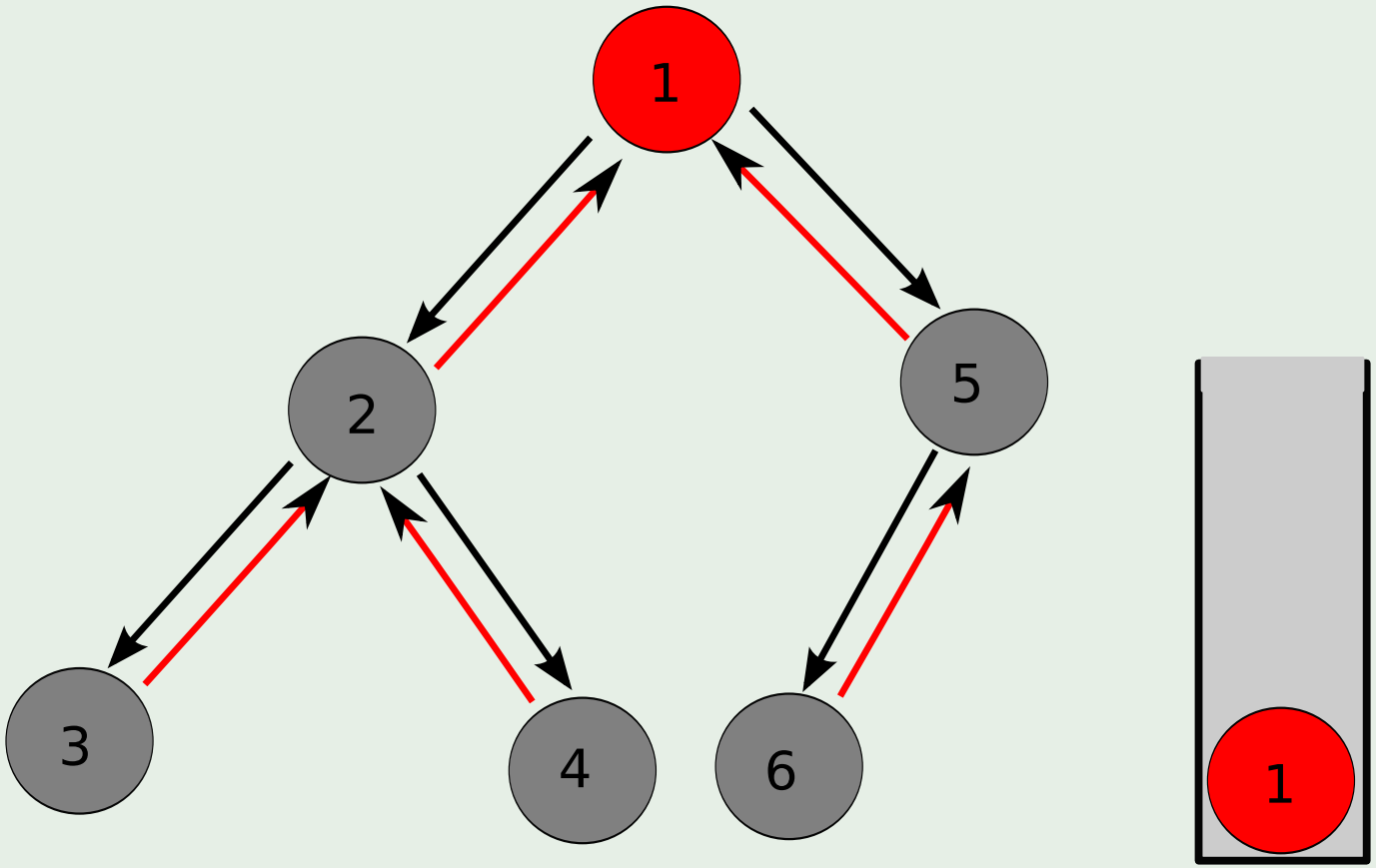

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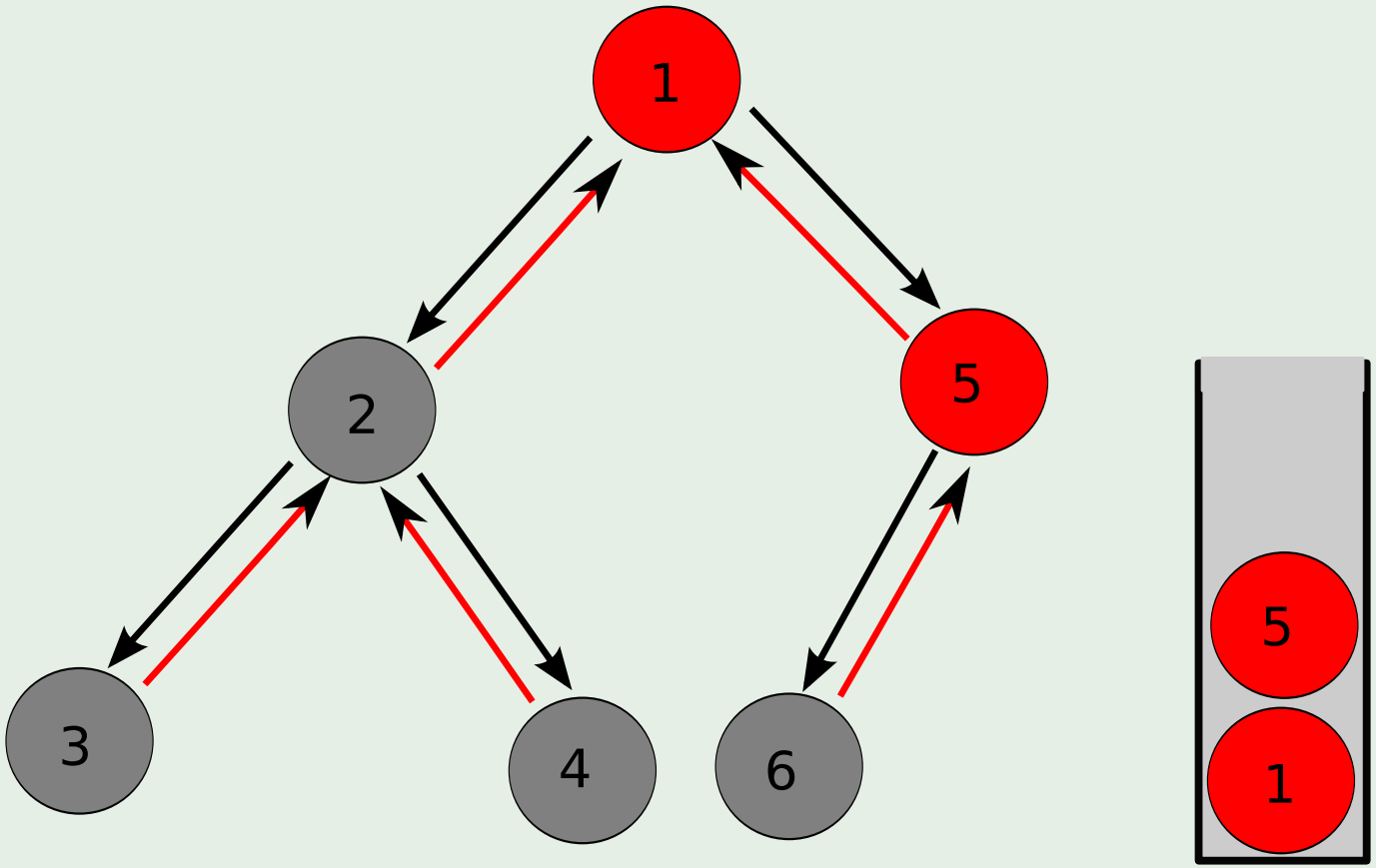

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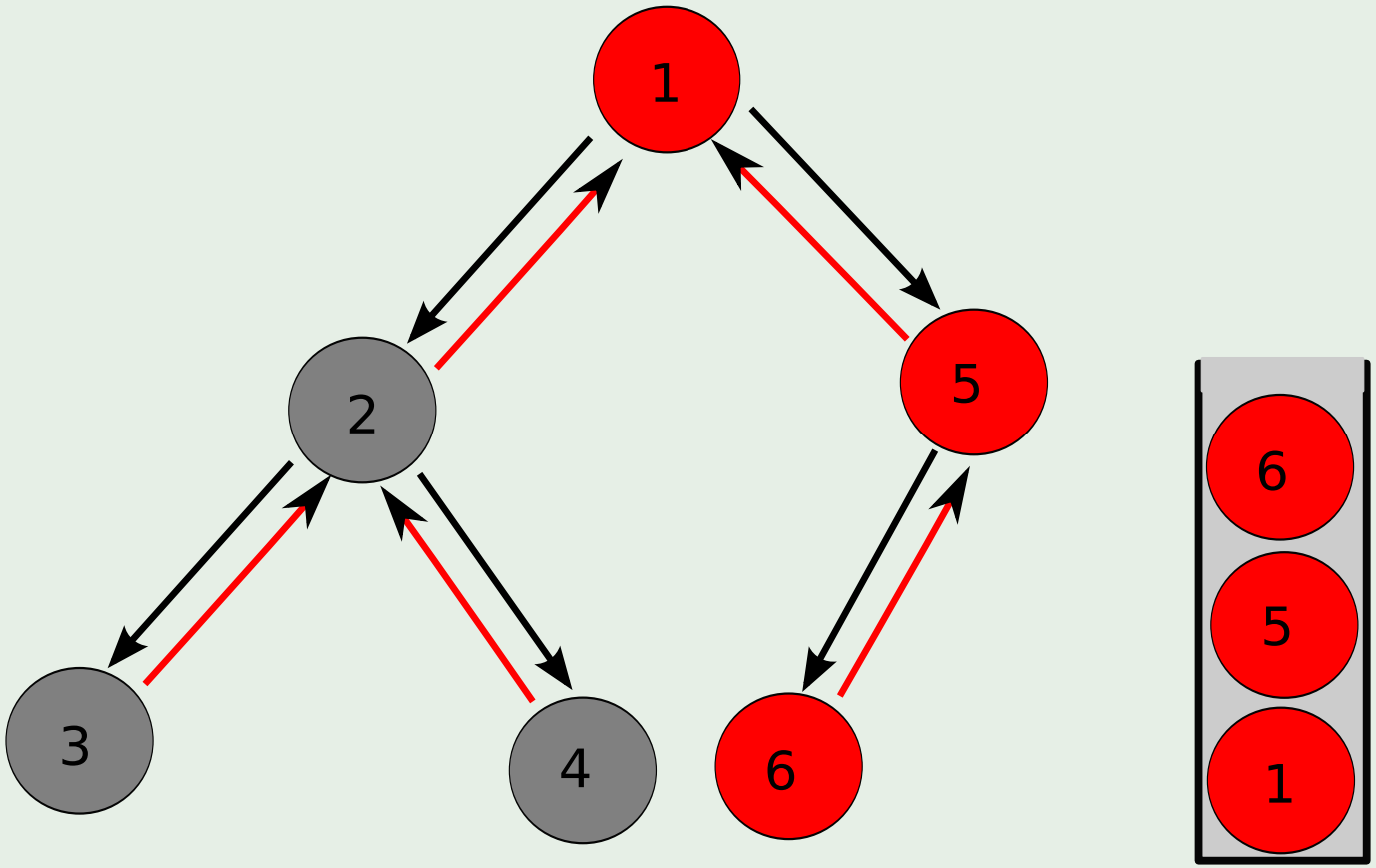

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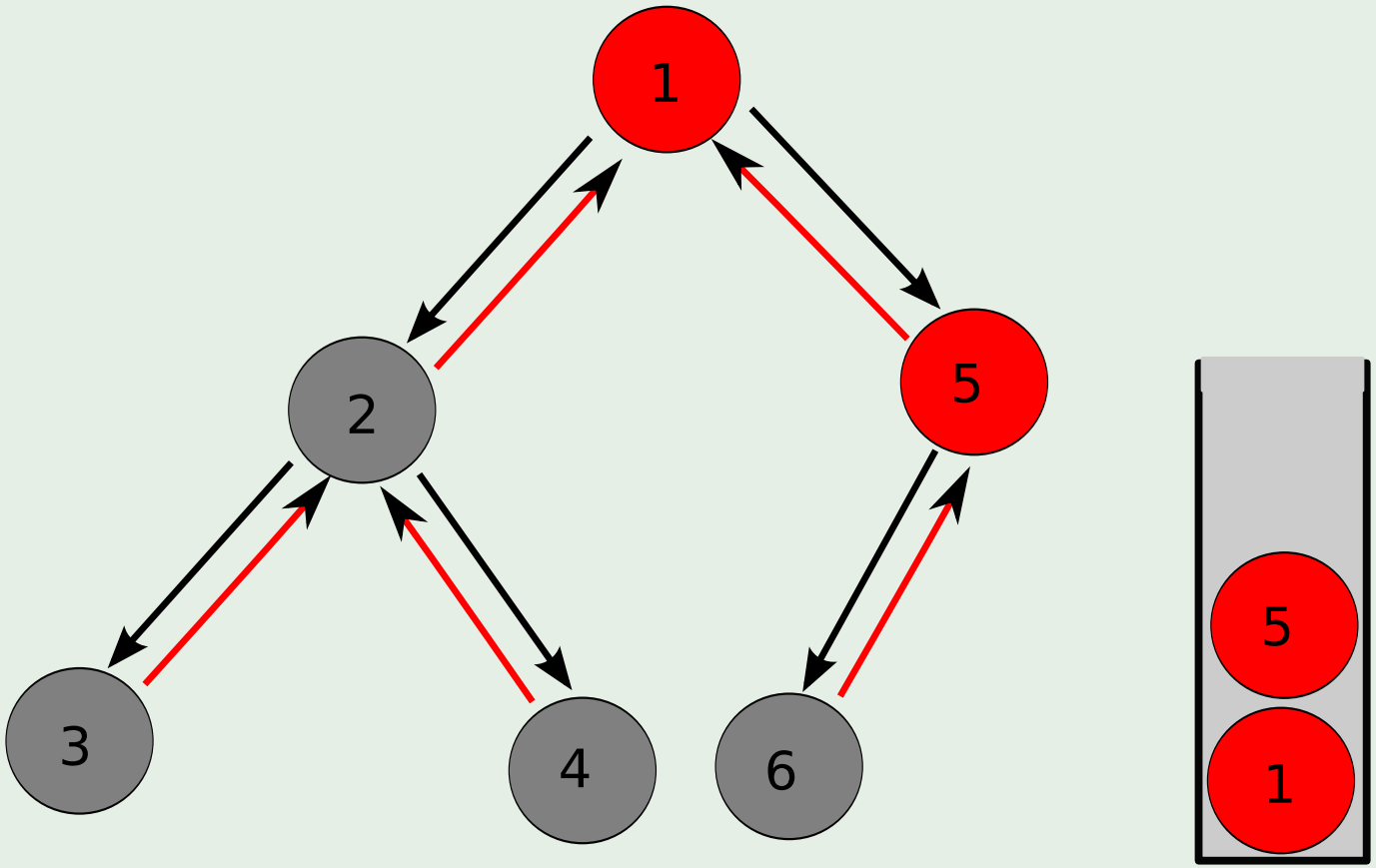

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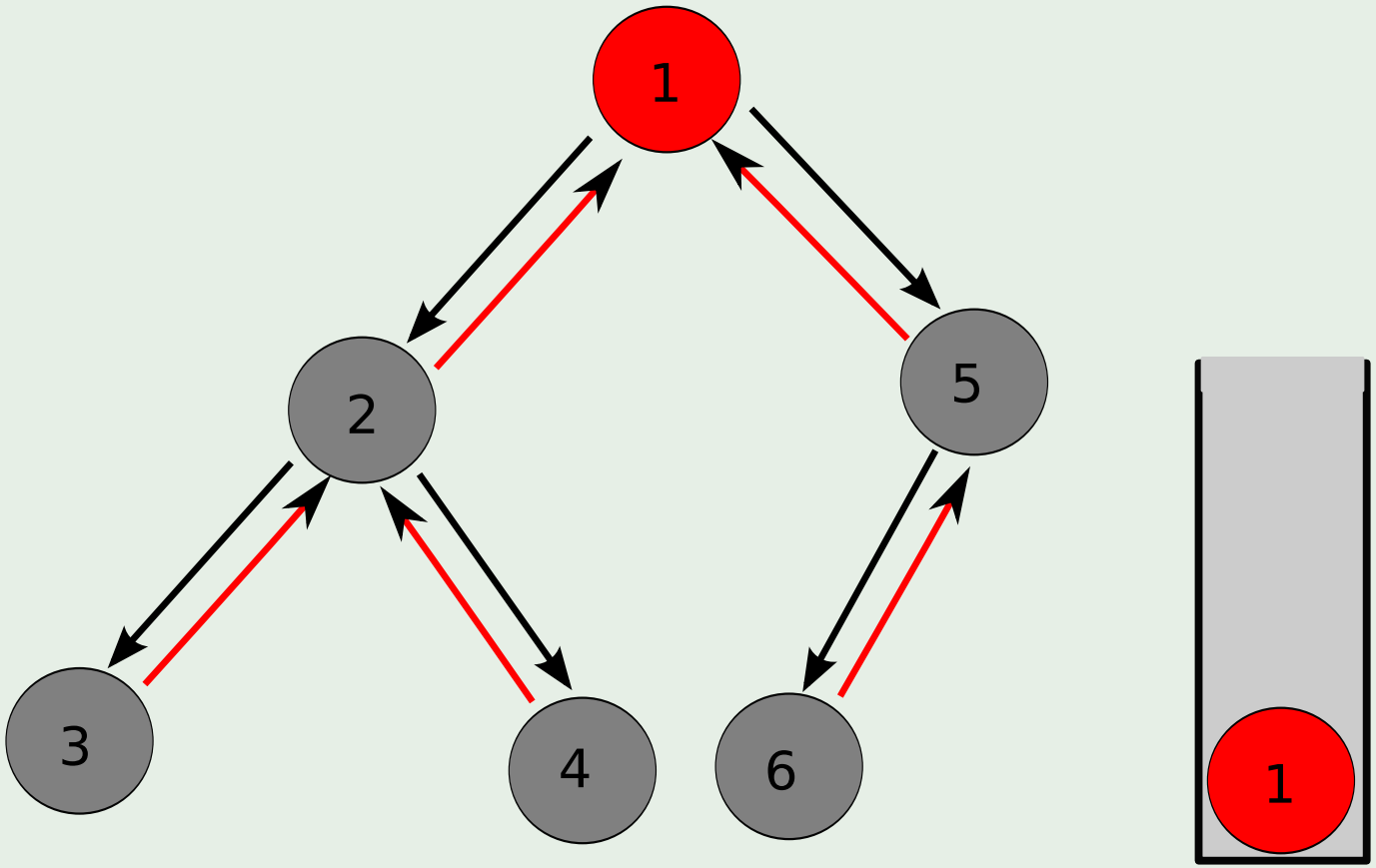

Recursion ≈ Depth First Search

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This is the classic order when recursion is done!!!

What if...

We need a different order?

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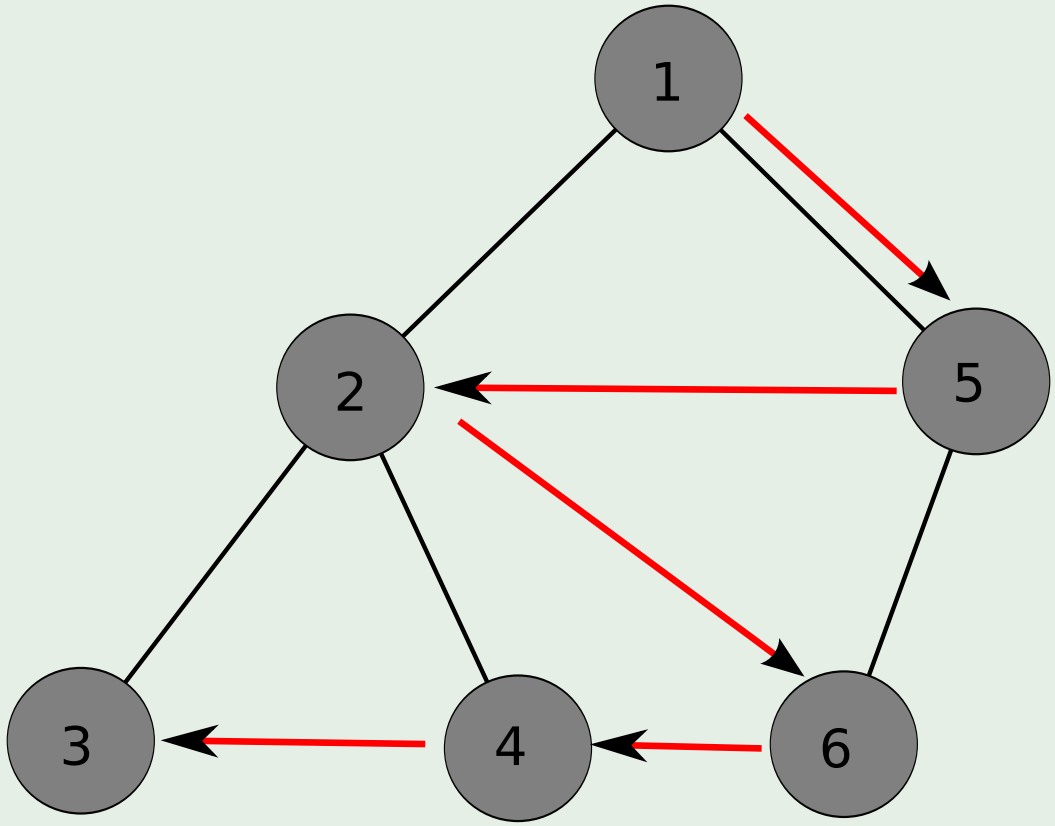
Level Order

How?



Queues

Definition of Queues

- A queue is a abstract data structure that models/enforces the **first-come first-serve order**, or equivalently the First-In First-Out (FIFO) order.

Thus

Using ADT Which is the first thing that comes to your mind to implement a queue?

IMPORTANT

- IN A QUEUE, THE FIRST ITEM INSERTED WILL BE THE FIRST ITEM DELETED: FIFO (FIRST-IN, FIRST-OUT)

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We have then

- A linear list.

Entry Points

- One end is called front.
- Other end is called rear.

Insertion and Deletions

- Additions are done at the rear only.
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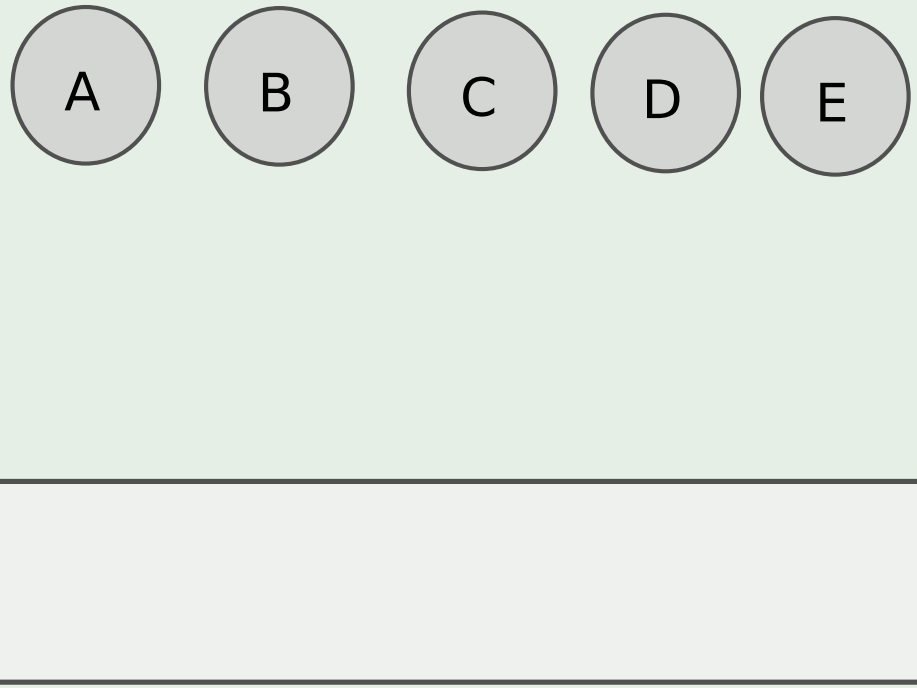

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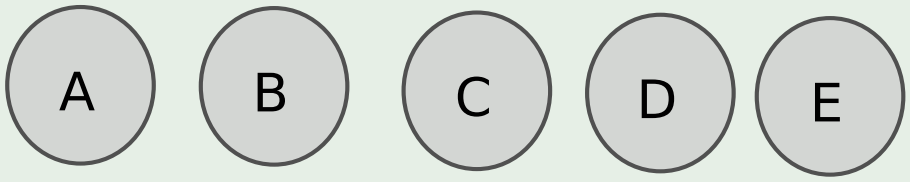

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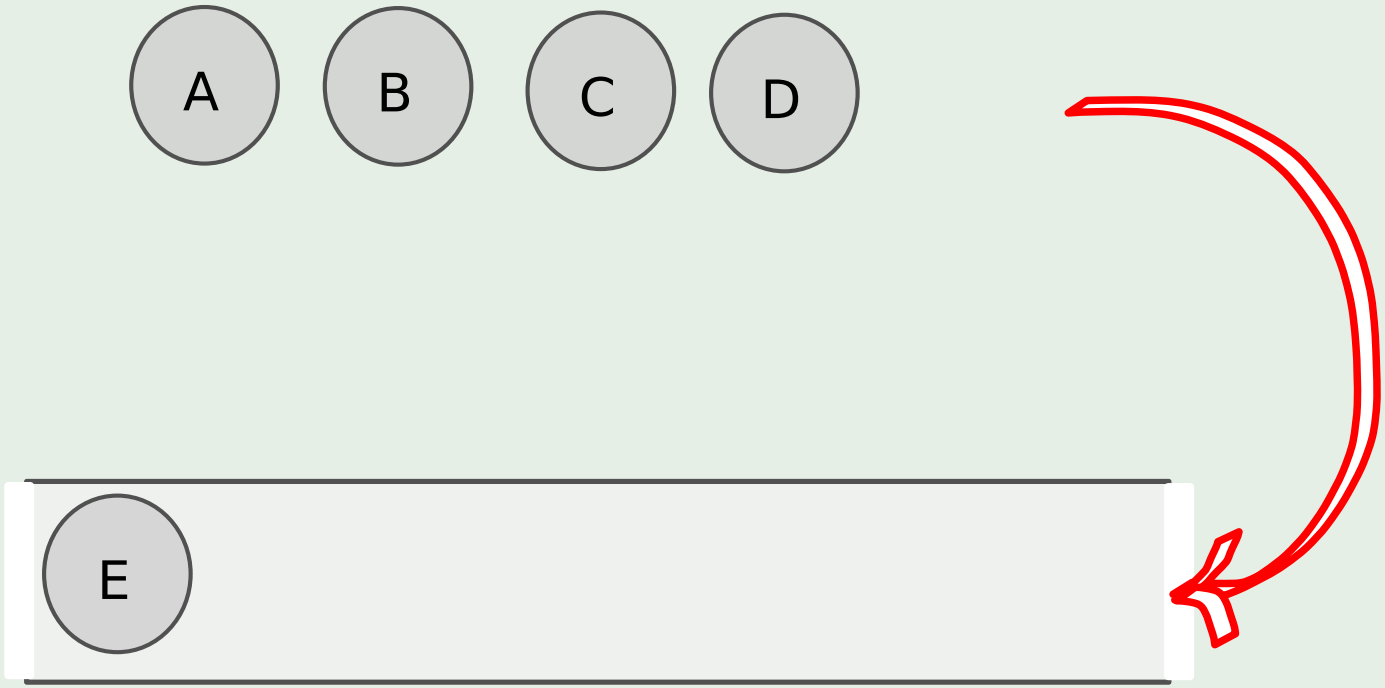

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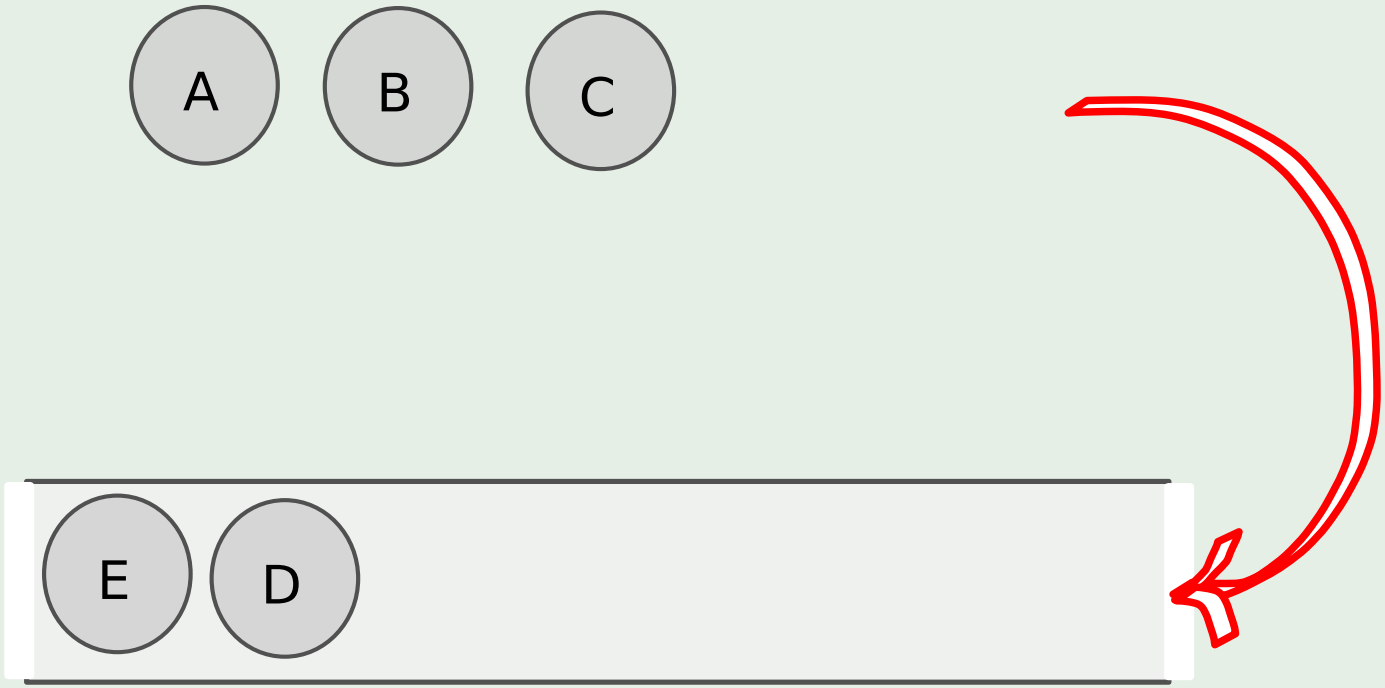

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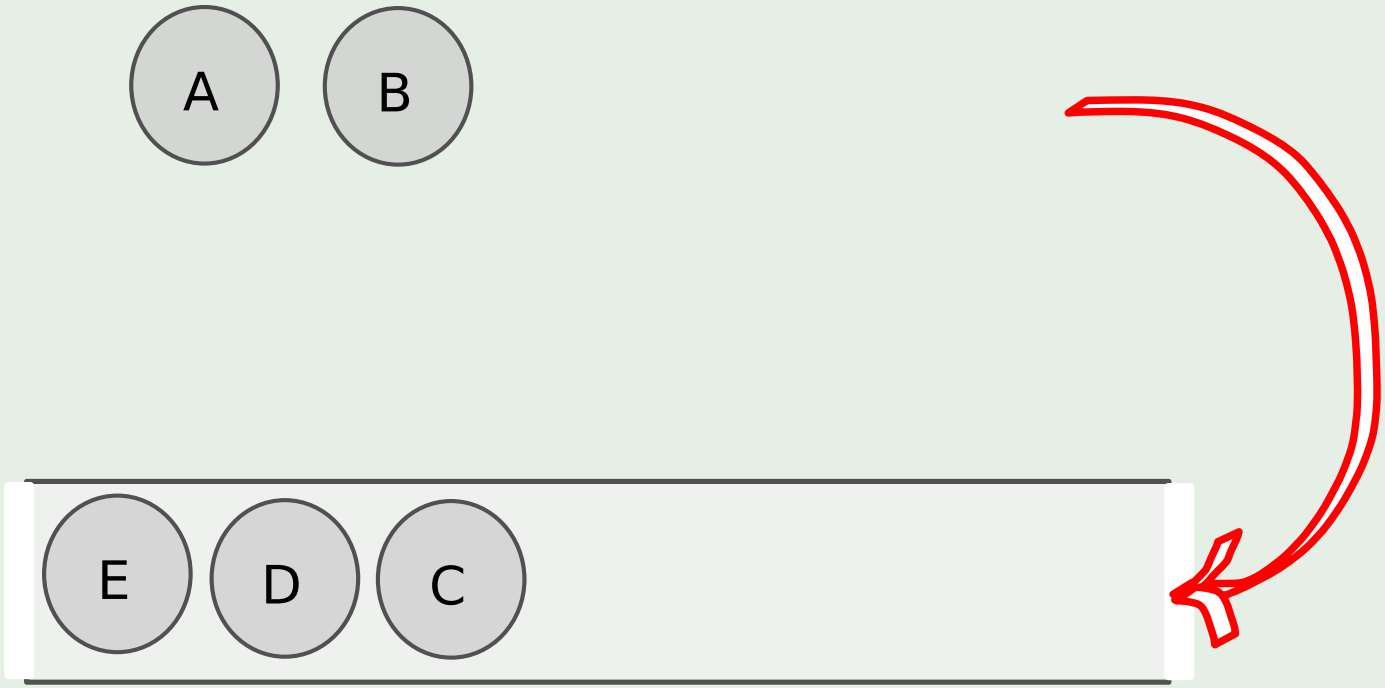

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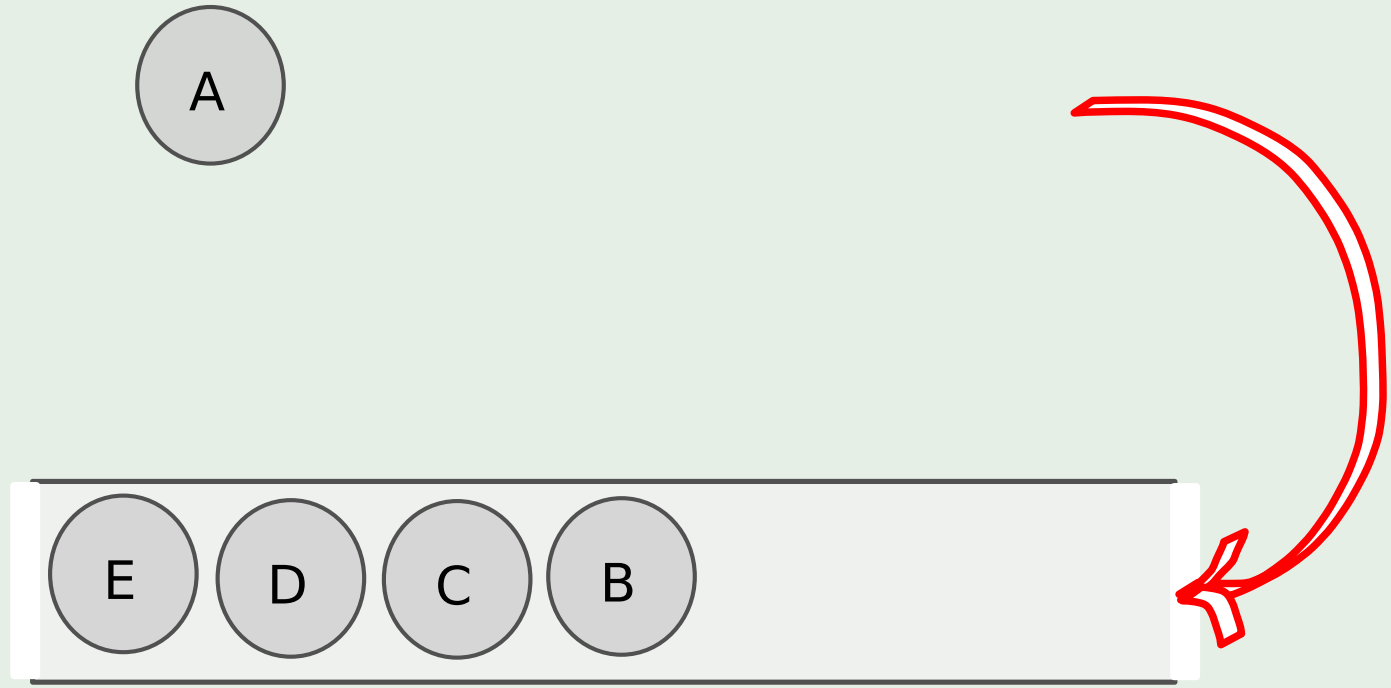

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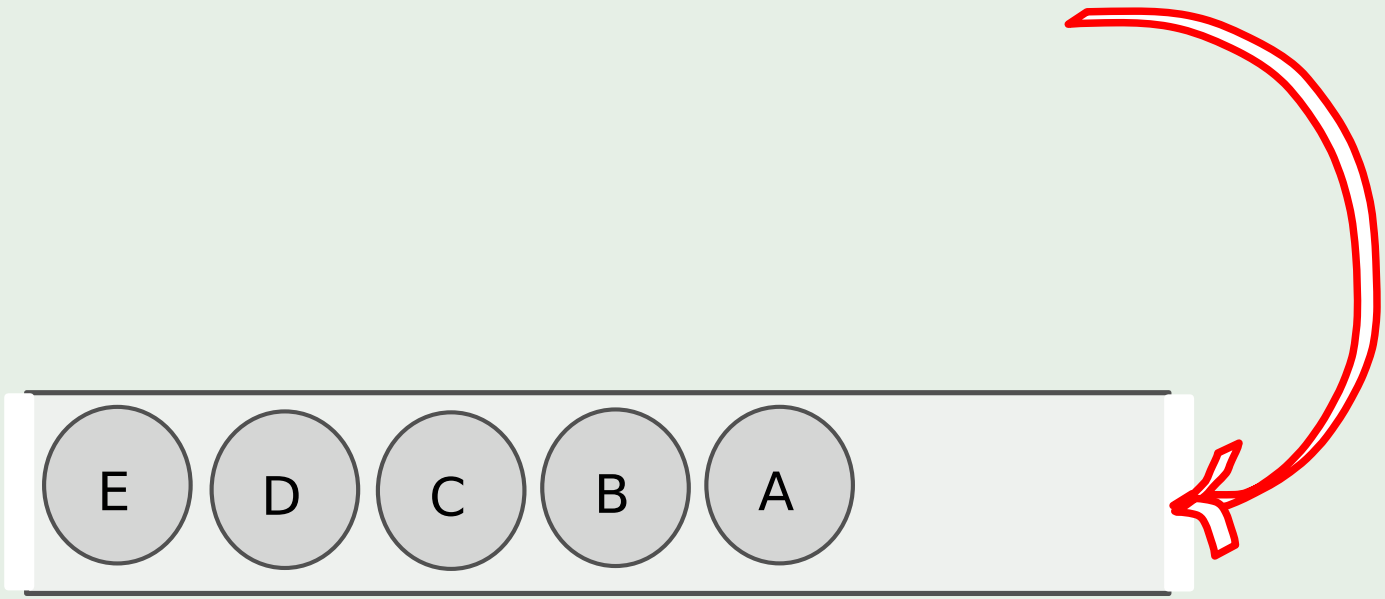

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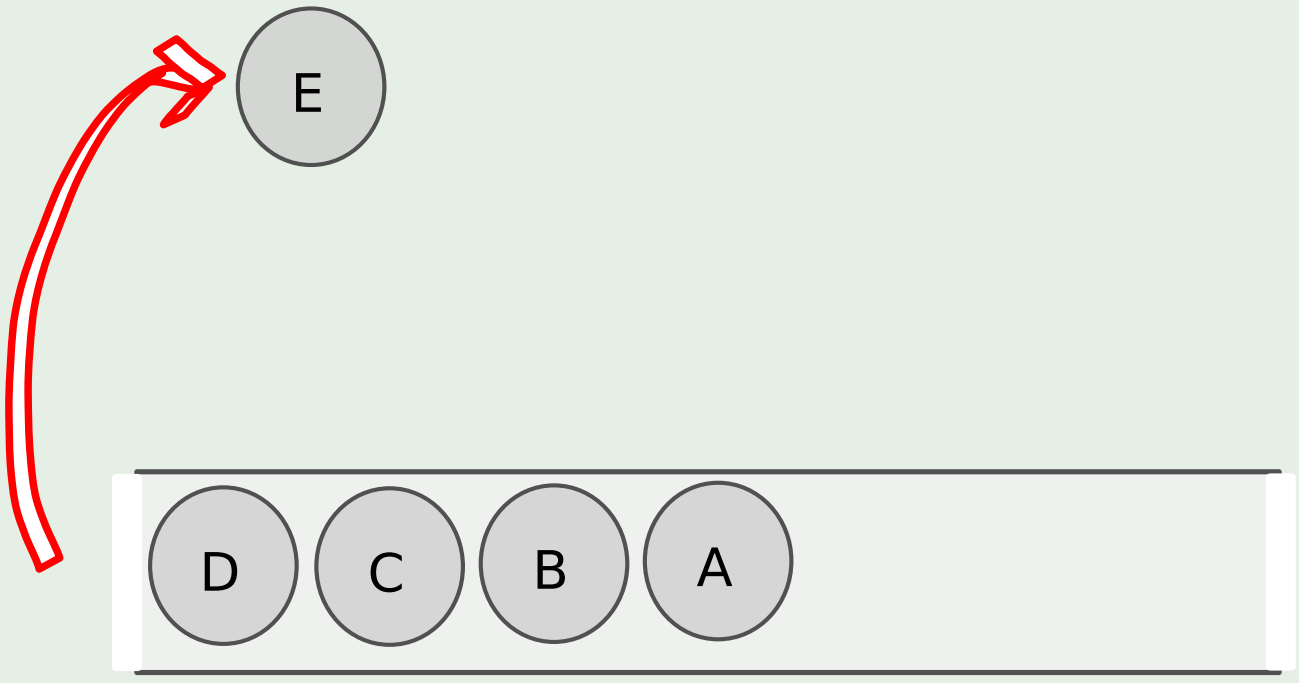

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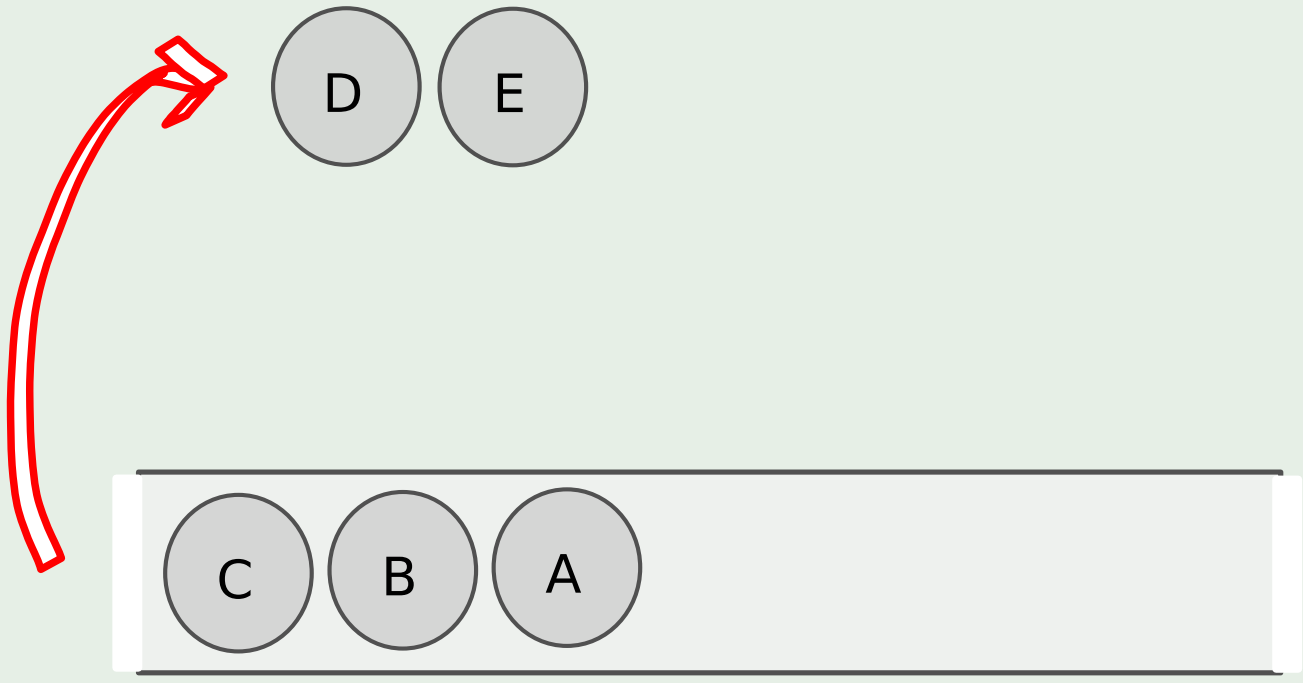

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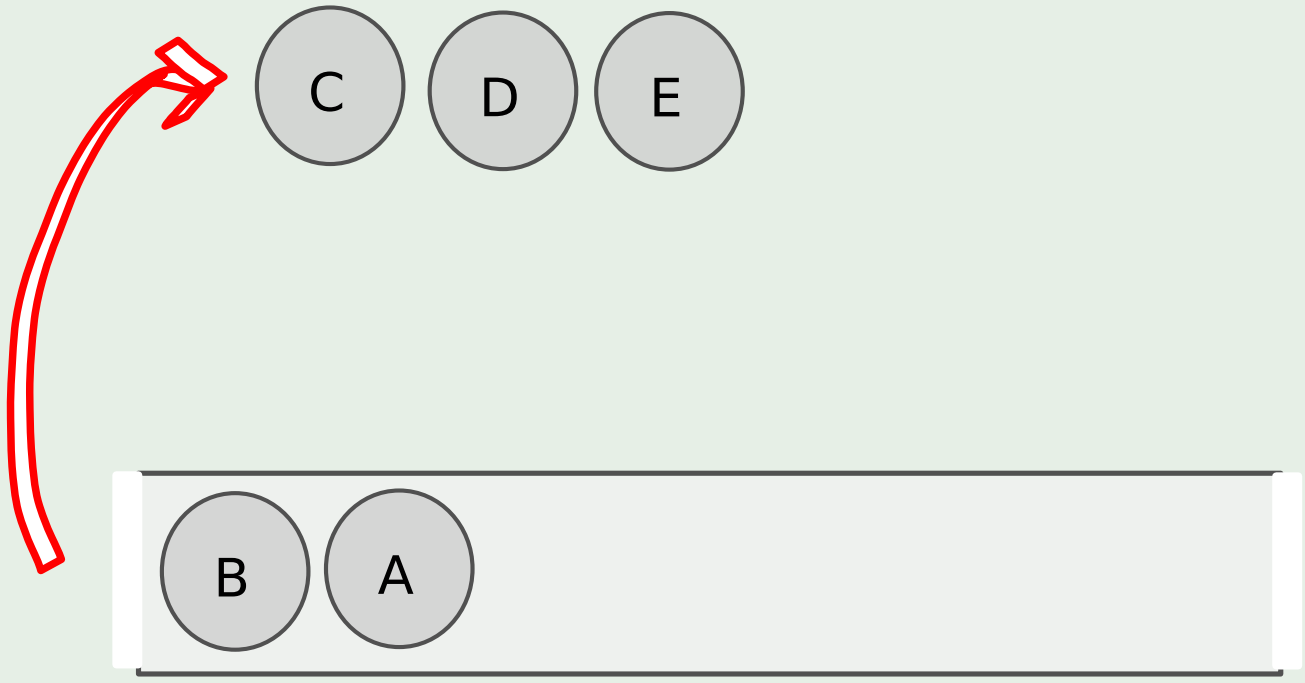

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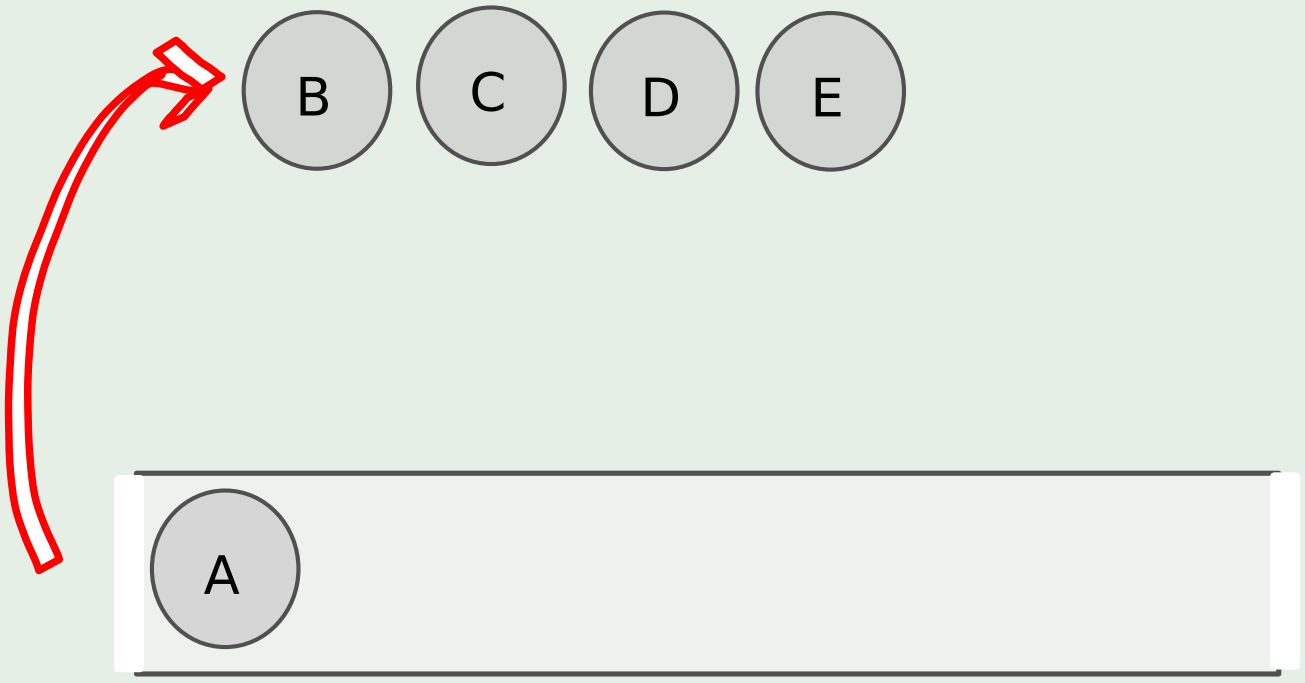

Outline

Queue Interface

Code

```
public interface Queue<Item>{
      public boolean empty();
      public Item front();
      public Item rear();
      public Item Dequeue();
      public void Enqueue(Item theObject);
      public int size();
}
```

Explanation

public boolean empty()

- Check whether the queue is empty.
- Return TRUE if it is empty and FALSE otherwise.

Example

public Item front()

- Return the value of the item at the font of the queue without removing it.

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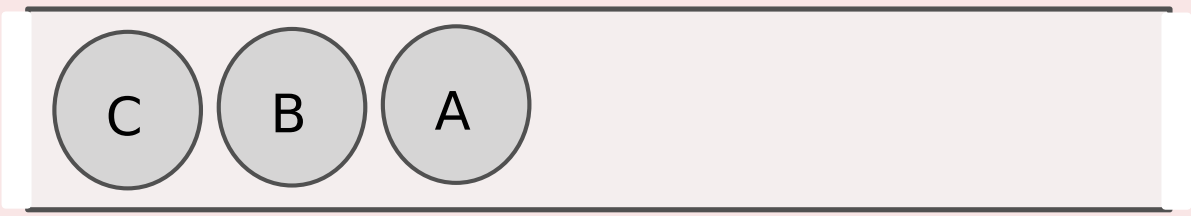

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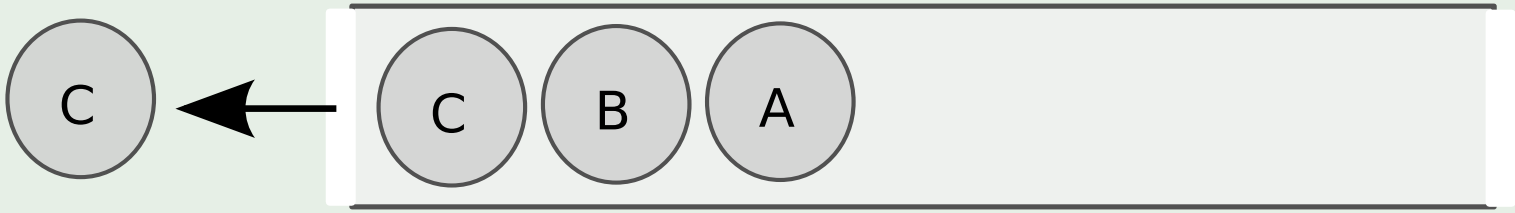

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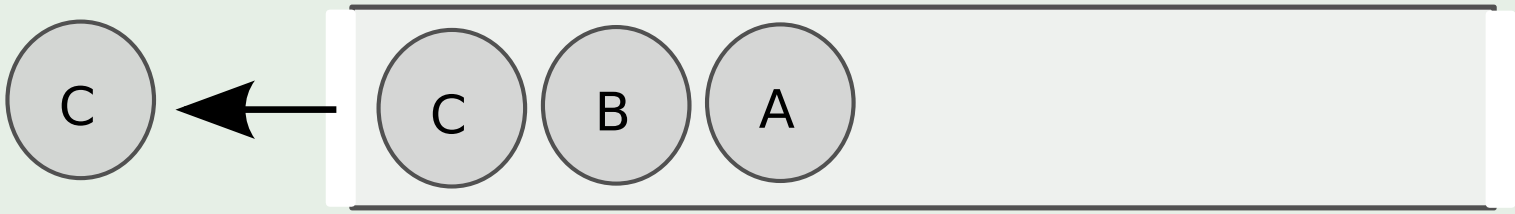

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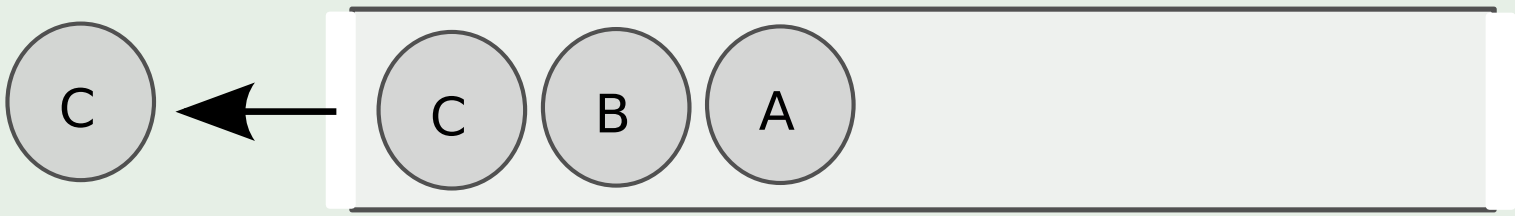

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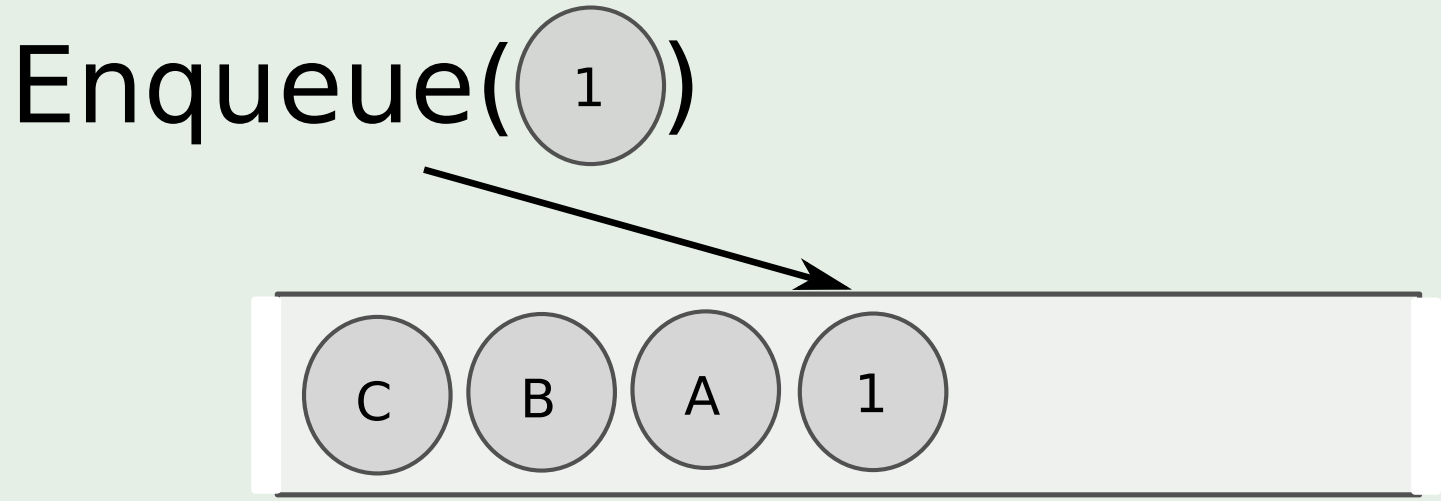

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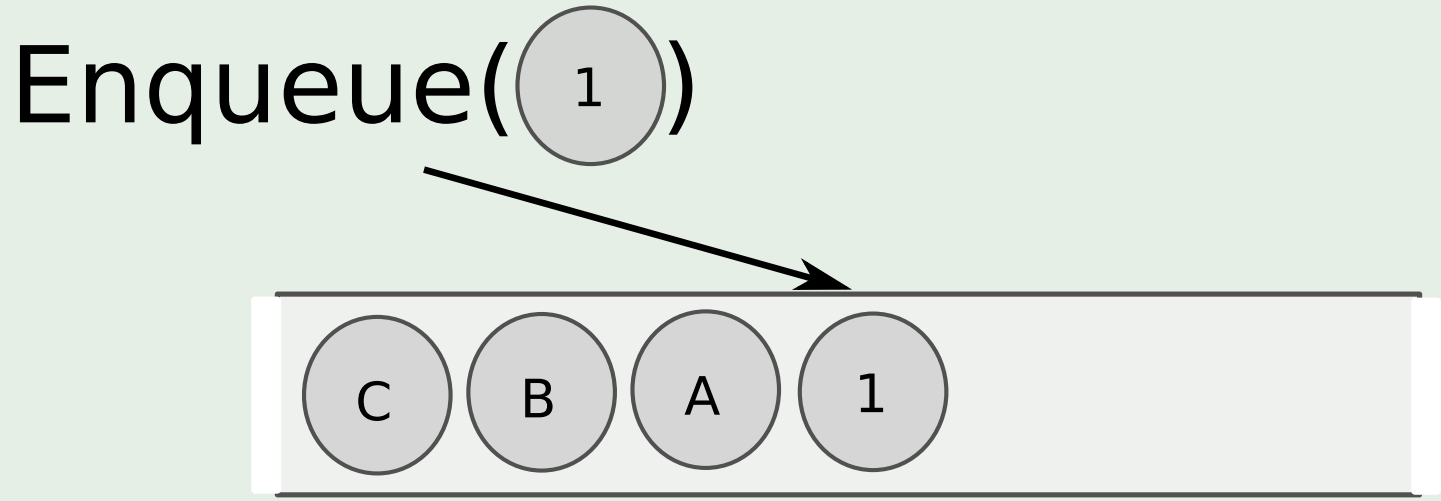

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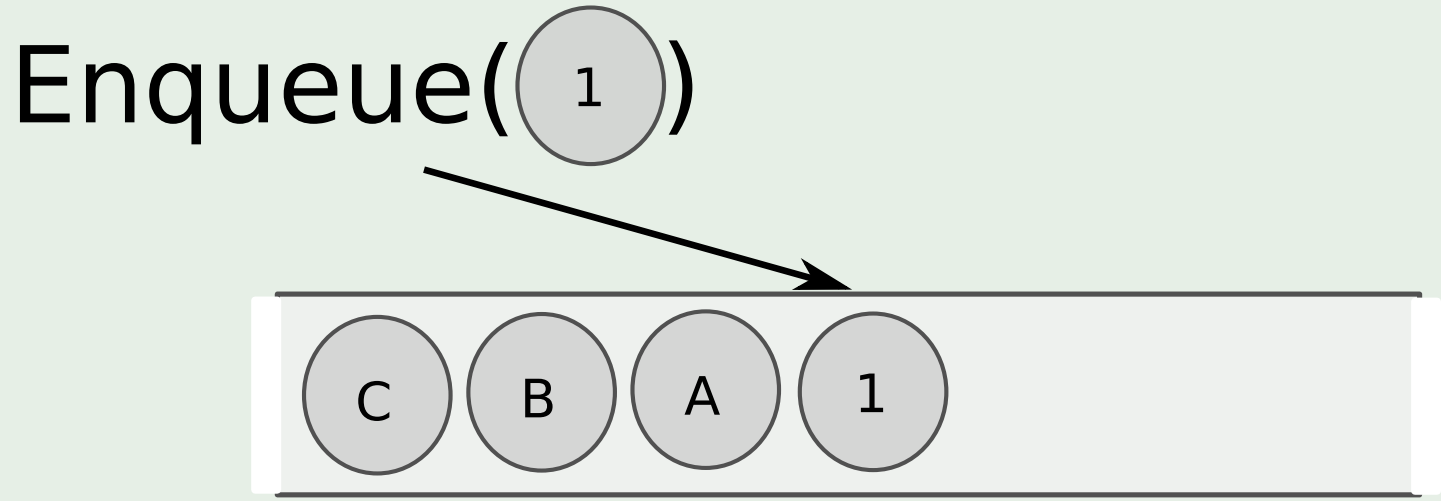

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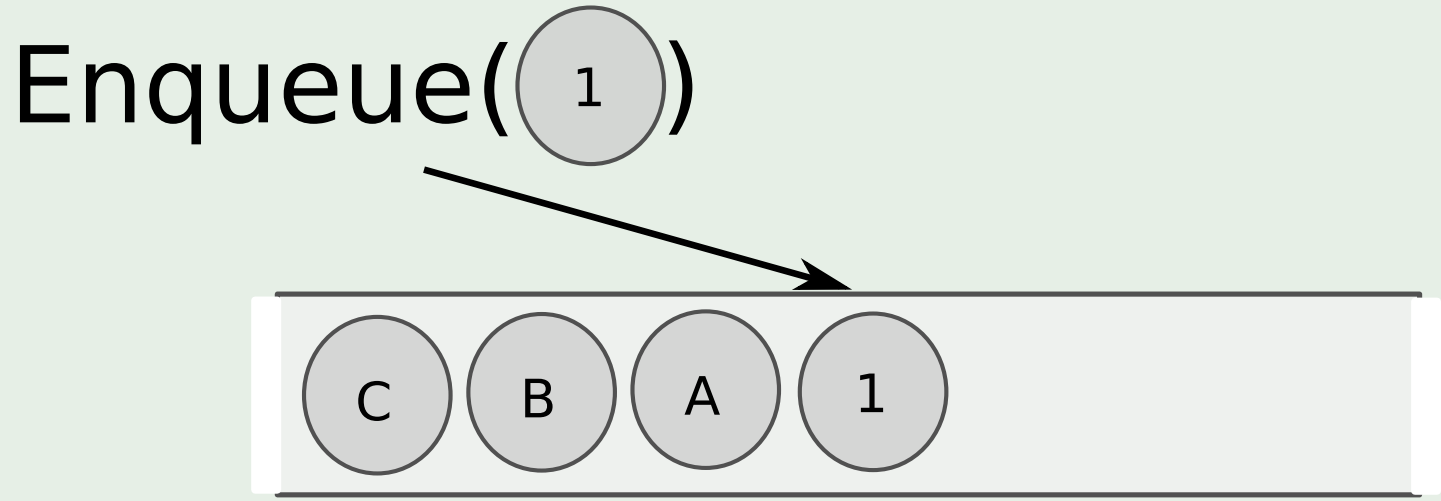

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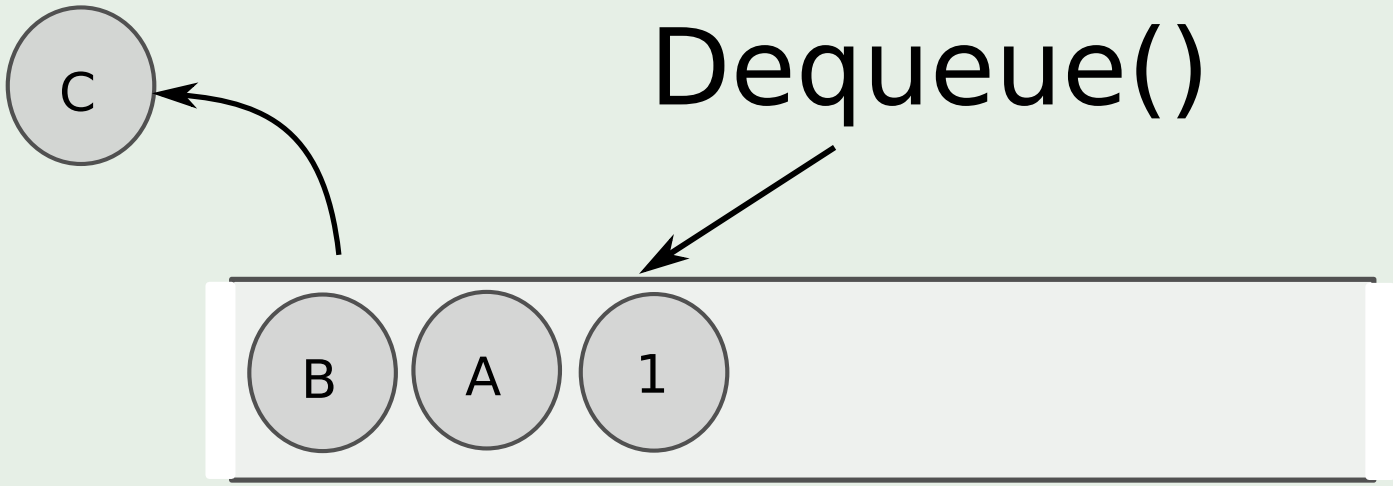

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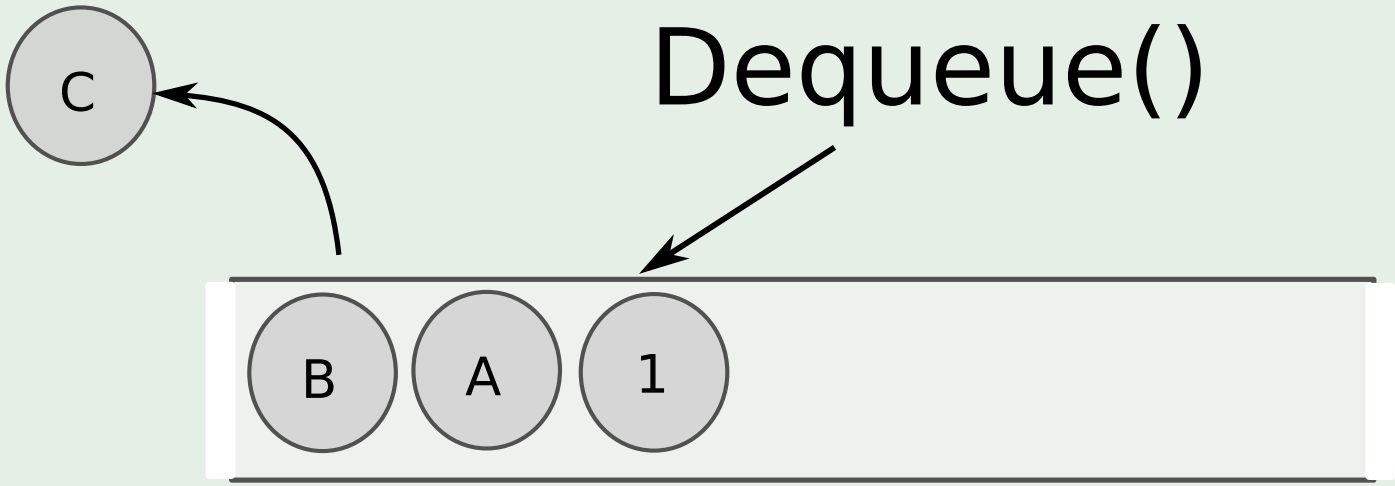

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- Waiting lists
  - Queue Theory for Networking
- Bureaucracy Access to shared resources (e.g., printer)
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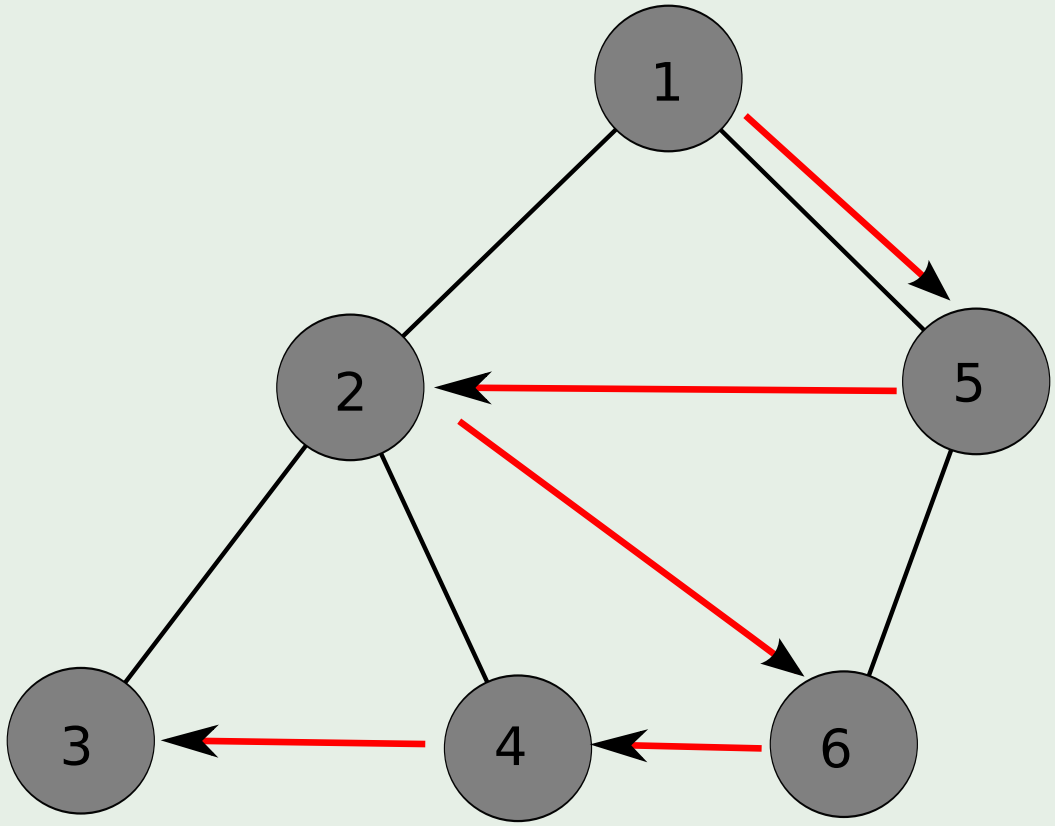
Change the Order of Recursion

Remember



Thus, Using a Trick

and Queue

- We can change the direction of the recursion!!!
- Look at the board

Outline

Radix Sort Using Bins

Example

Order ten 2 digit numbers in 10 bins (0-9) from least significative number to most significative number.

Digits

91,06,85,15,92,35,30,22,39

Let us do it

In the board!!!

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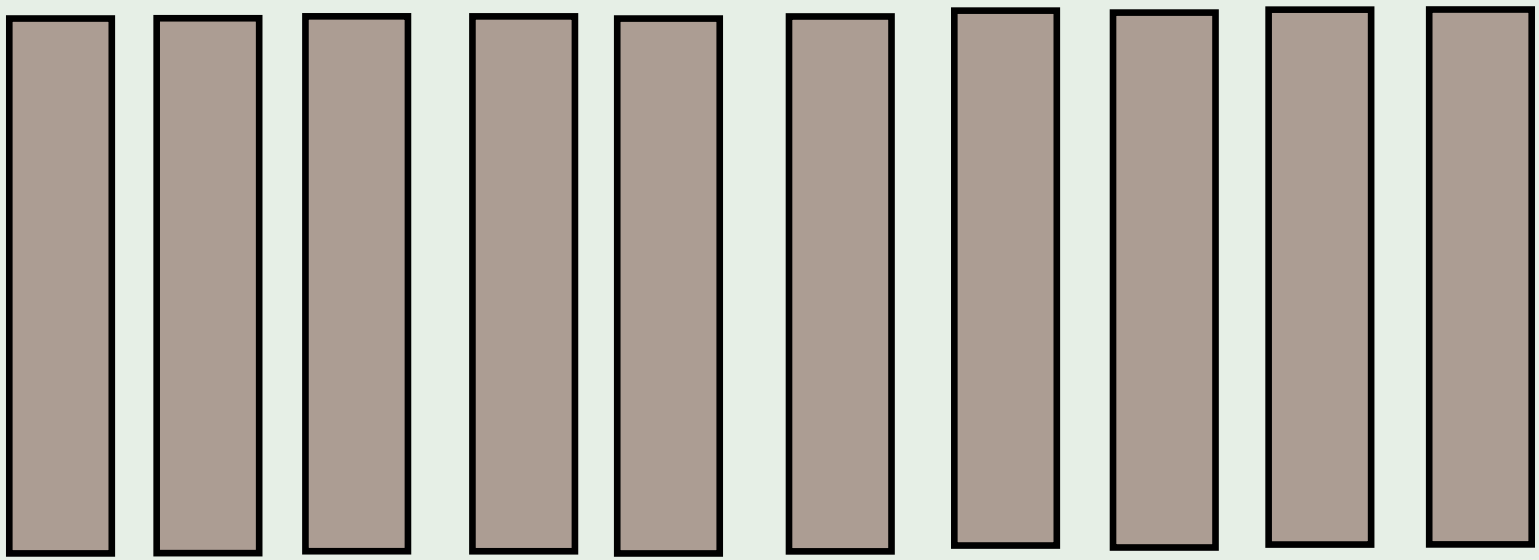
Pass 0: Distribute the digits into bins according to the 1's digit (10^0).



Finally

Next

- Dequeue the values from the queue 0 to queue 9.
- Put values in a list in that order.

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Pass 1: Take the new sequence and distribute the cards into bins determined by the 10's digit (10^1)

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Code

We need something else

```
public static RadixSort(LinearList Element, int k){
    int Radix = 10
    int power = 1
    int digit;
    Queue<Integer>[] digitQueue = (Queue<Integer>[])
                                    new Queue[10];
    for (int i=0; i<k ; i++)
                {
            for (int j=0; j< Element.size(); j++){
                digit = Element.remove(0);
                digitQueue[(digit/power)%10].
                enqueue(digit);
            }
            for (int j=0;j< Radix; j++){
                    // WHAT?
                                    }
        power *= 10;
                }
}
```

Radix Sort: Complexity

Lemma 1

Given n d-digit numbers in which each digit can take on up to k possible values, RADIX-SORT correctly sorts these numbers in $O(d(n+k))$ time.

Outline

Simulating Waiting Lines

Simulation is used to study the performance

- Of a physical ("real") system.
- By using a physical, mathematical, or computer model of the system.

Simulation allows designers to estimate performance

- Before building a system

Simulation can lead to design improvements

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- Frequent flyer (FF) passenger arrives in line
- Regular (R) passenger arrives in line
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  1. Agent finishes, then serves next FF passenger
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Using some other constraints

- Max # FF served between regular passengers
- Arrival rate of FF passengers
- Arrival rate of R passengers
- Service time

Queuing Theory

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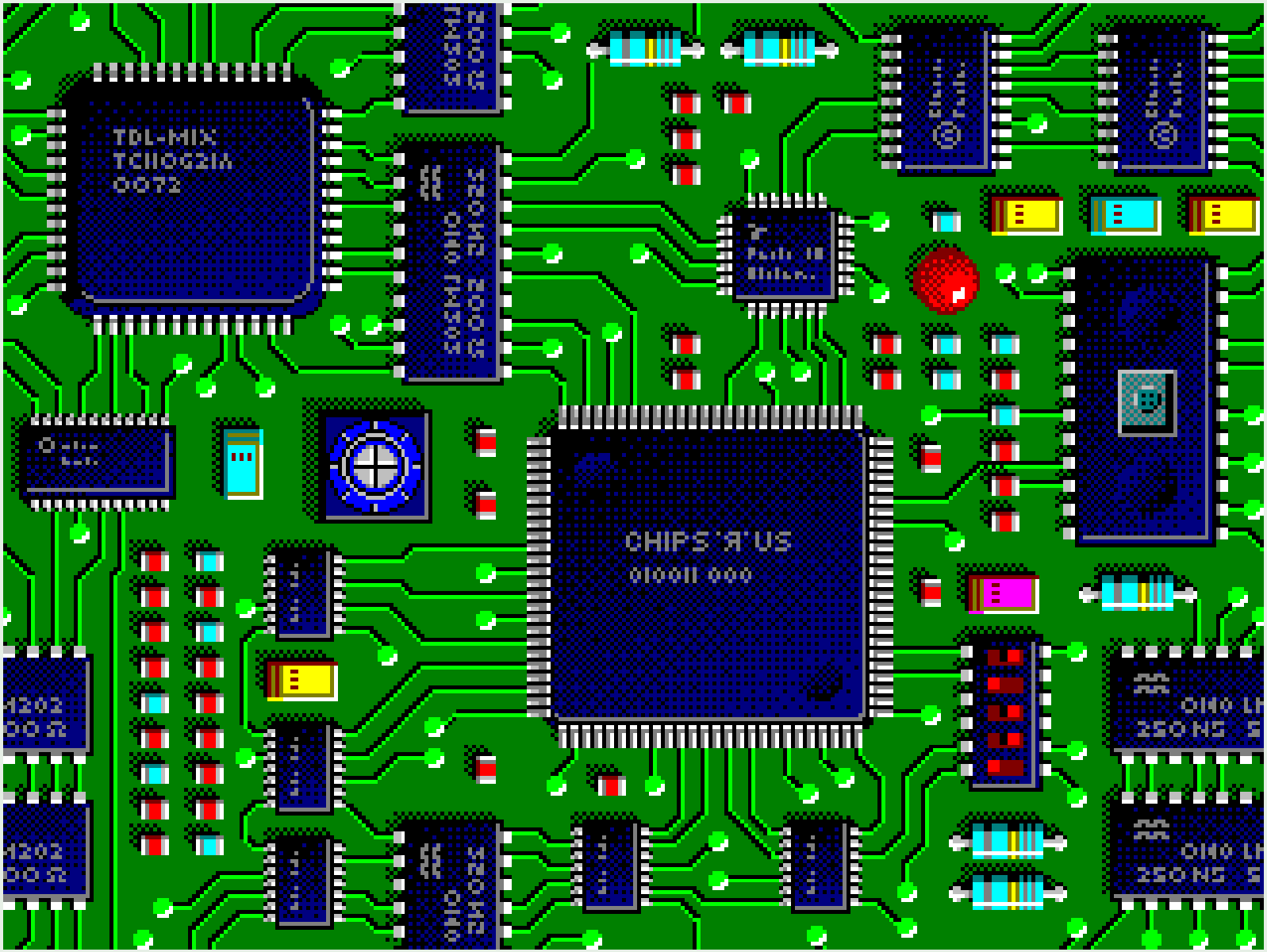
Outline

Example

Circuit Board

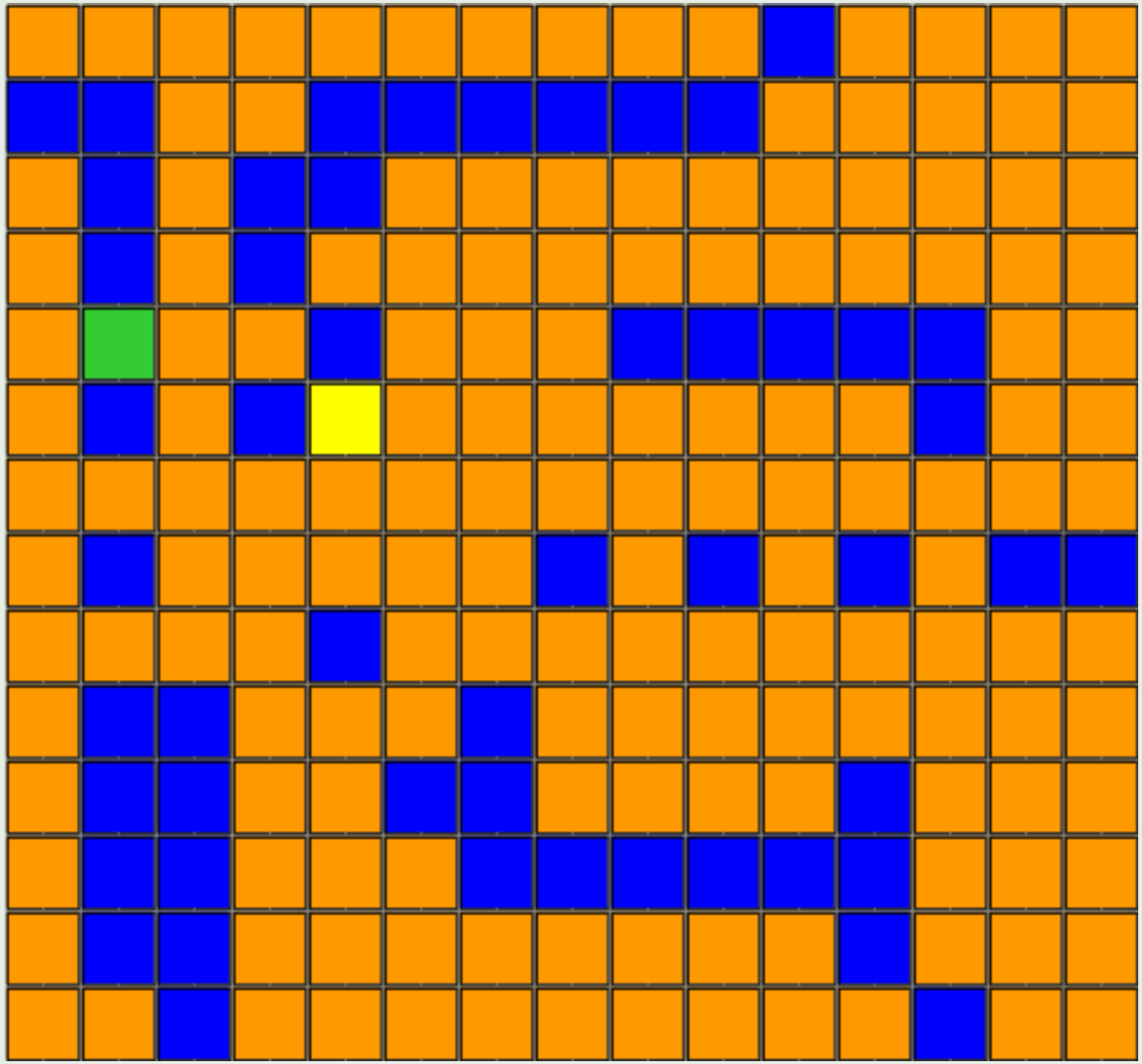


Example

Circuit Board - Label all reachable squares 1 unit from start

start pin

end pin

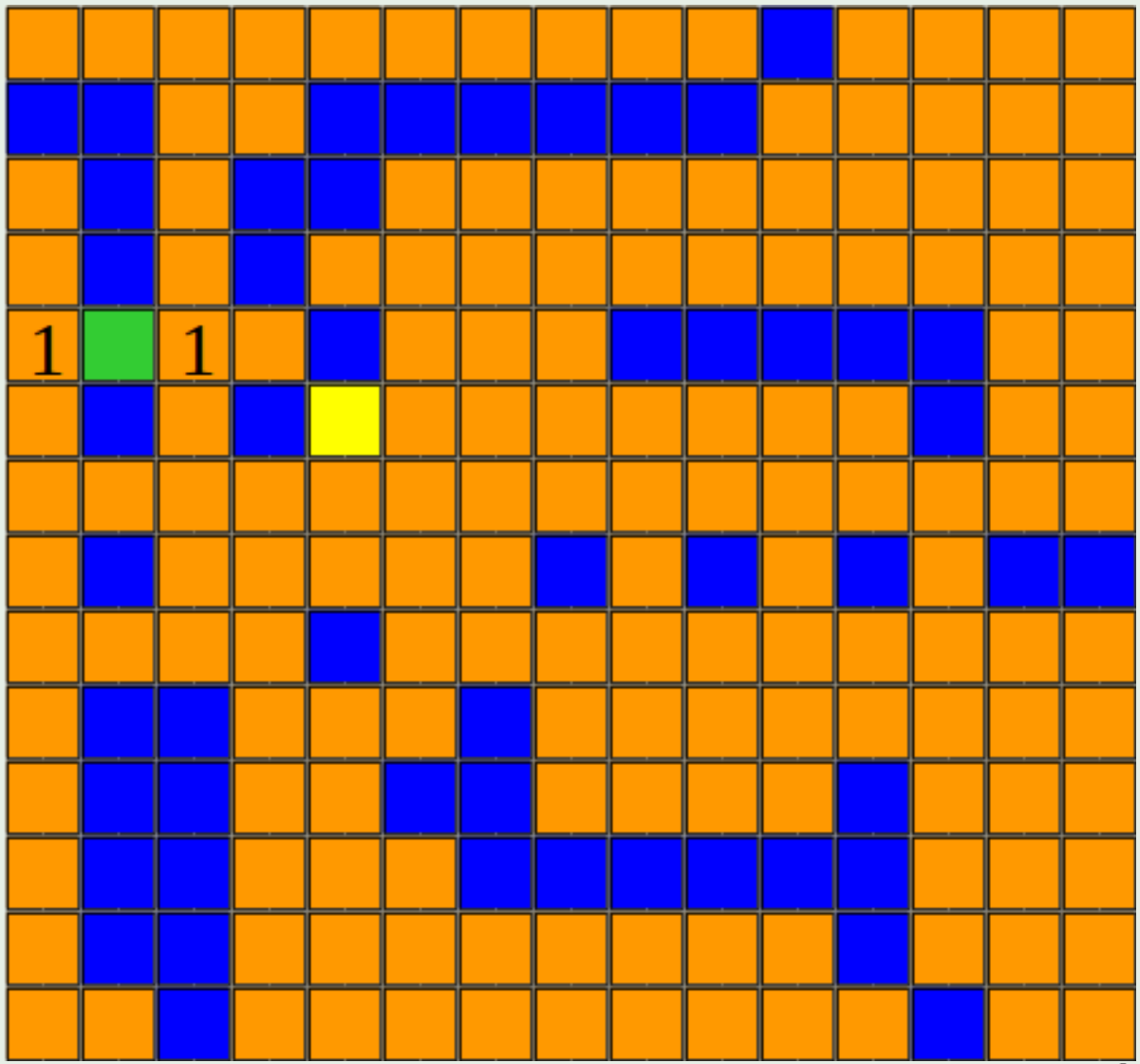


Example

Circuit Board - Label all reachable unlabeled squares 2 units from start.

start pin

end pin

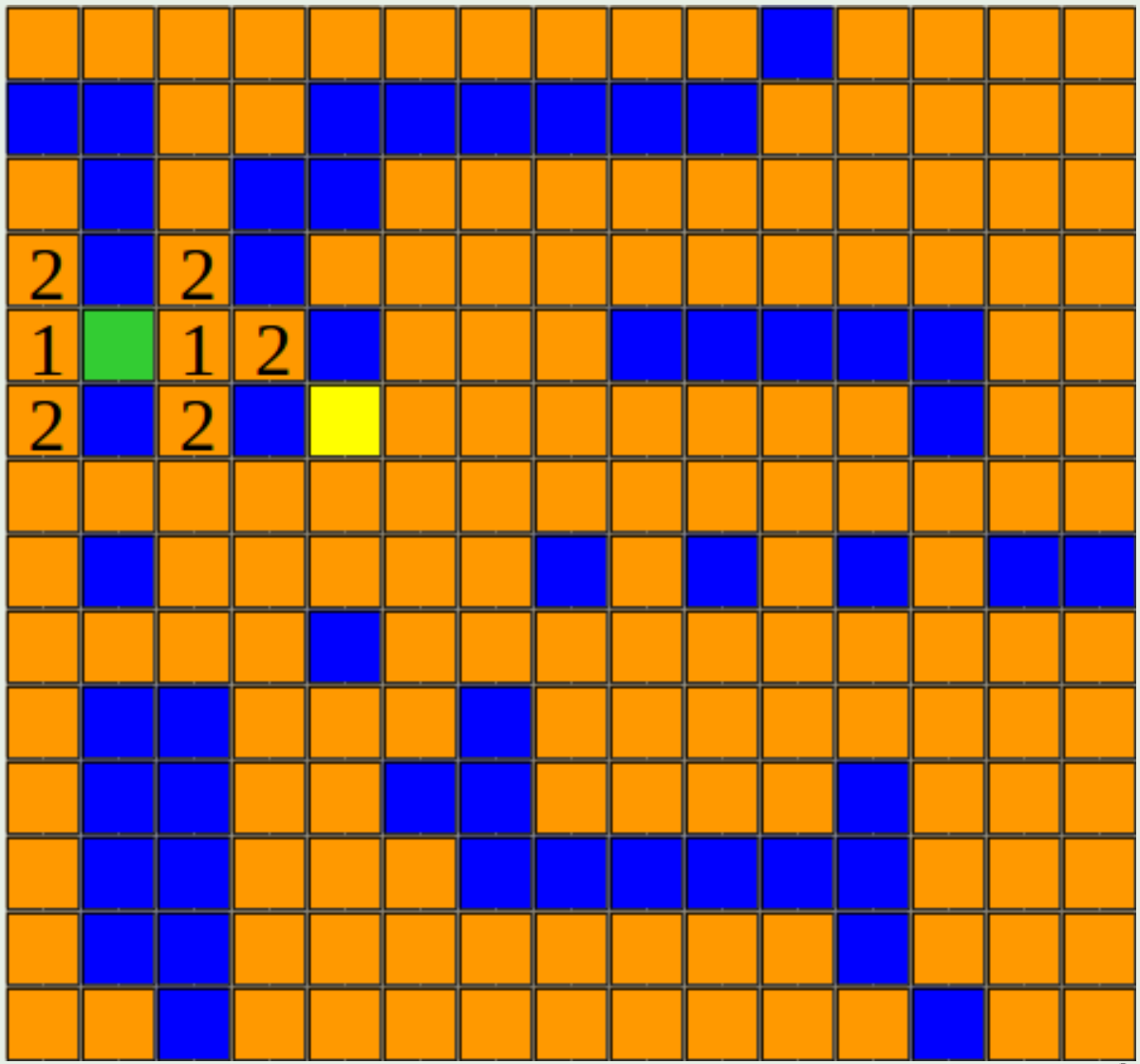


Example

Circuit Board - Label all reachable unlabeled squares 3 units from start.

start pin

end pin

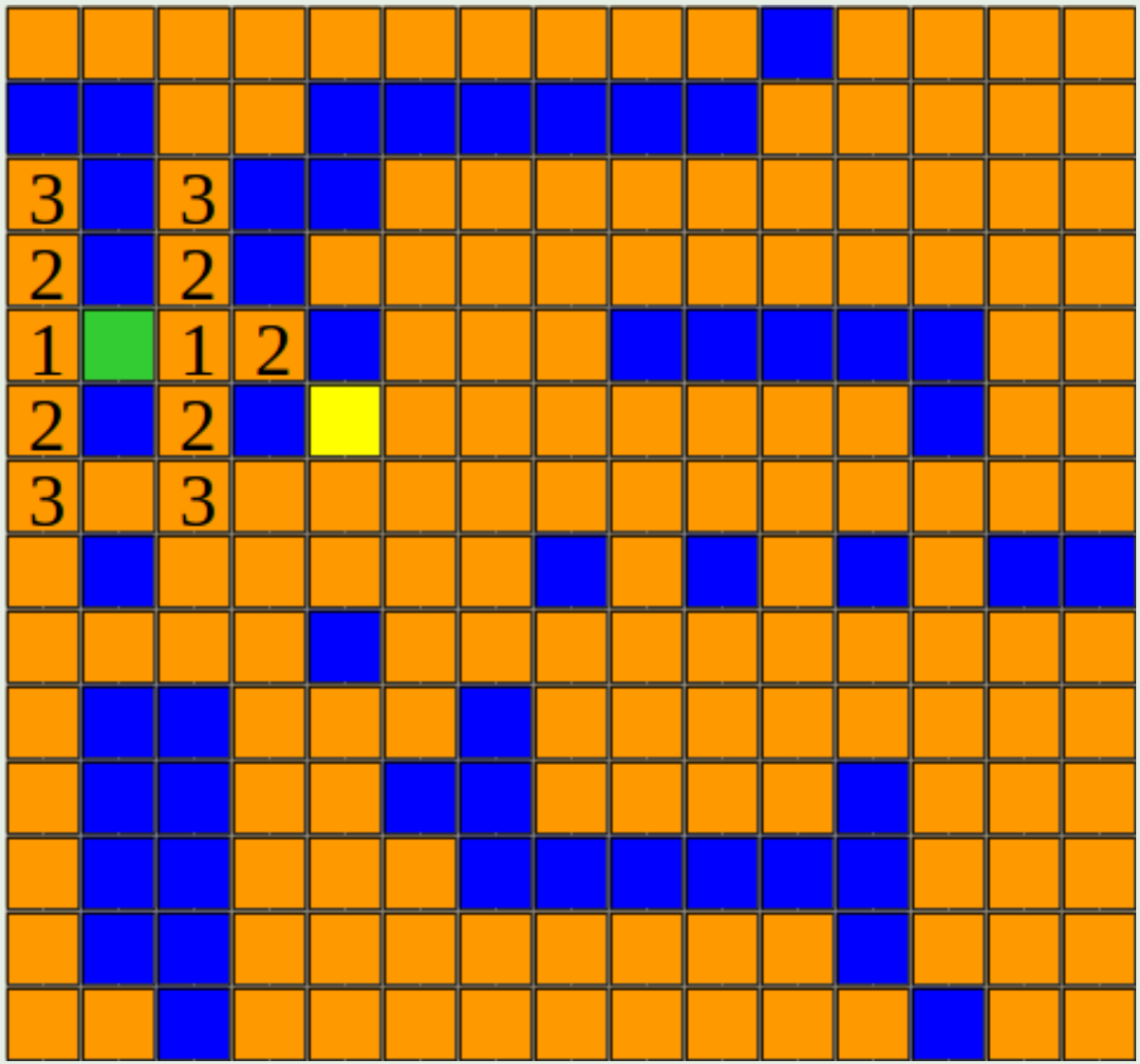


Example

Circuit Board - Label all reachable unlabeled squares 4 units from start.

start pin

end pin

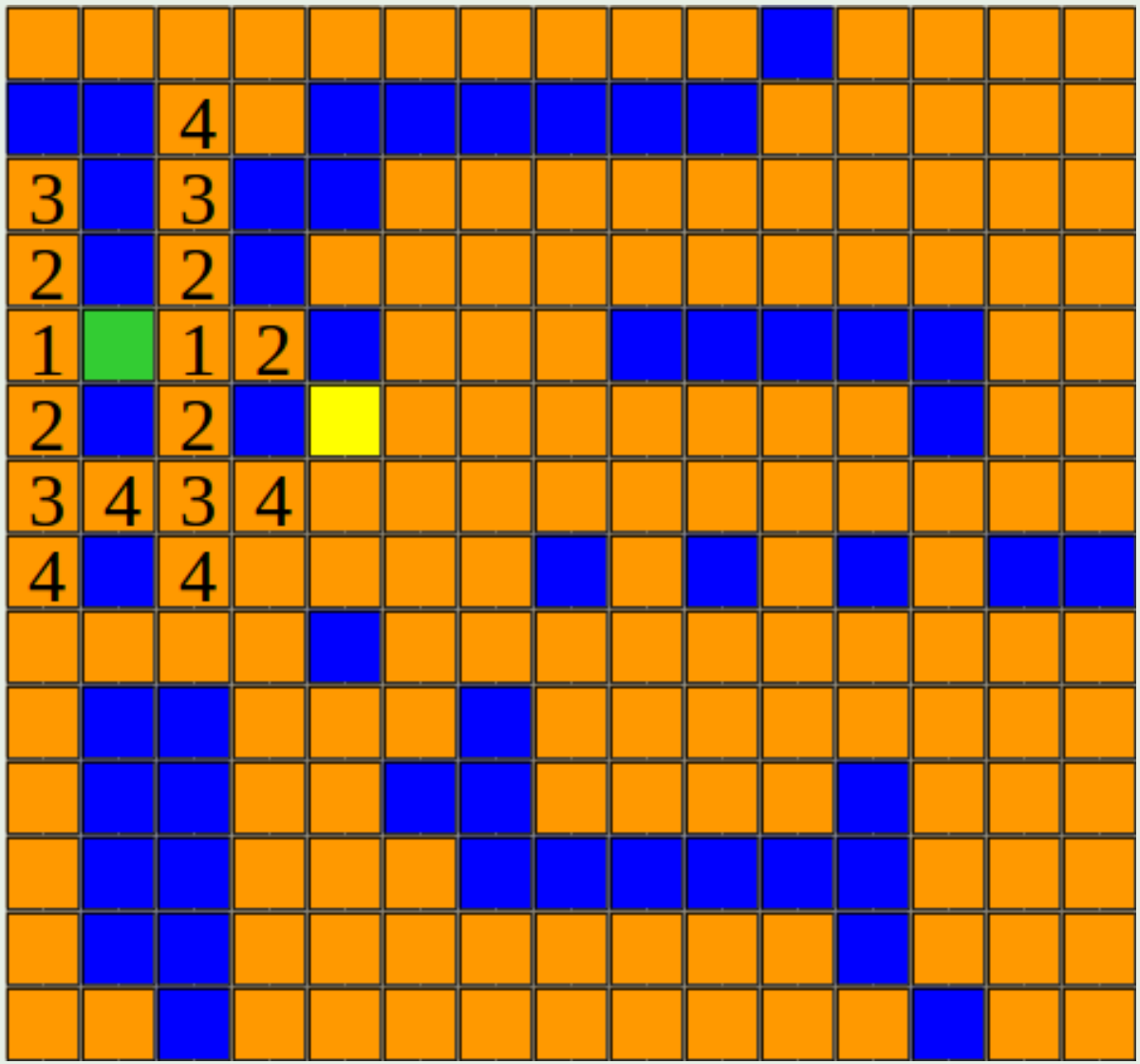


Example

Circuit Board - Label all reachable unlabeled squares 5 units from start.

start pin

end pin



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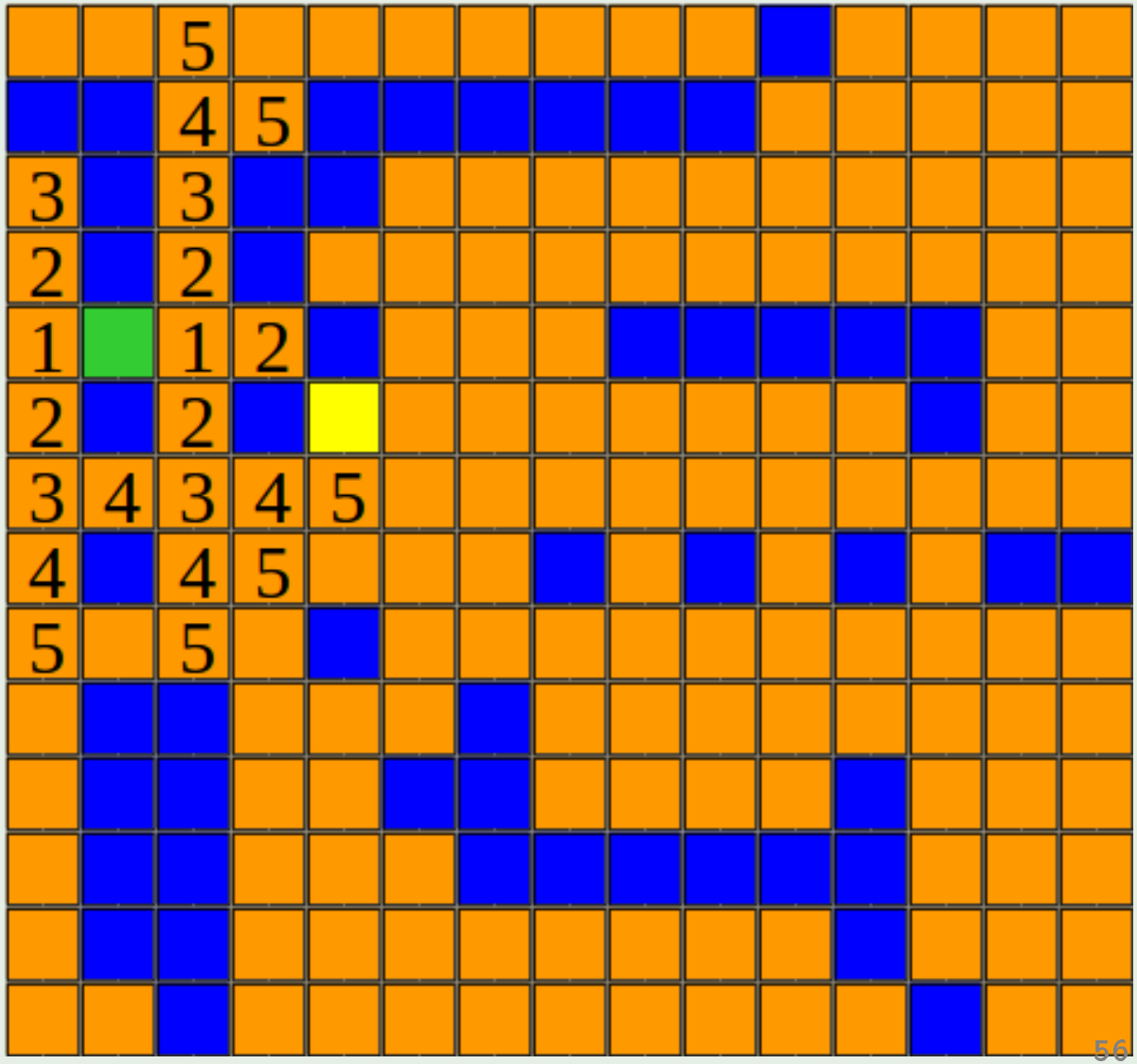
end pin

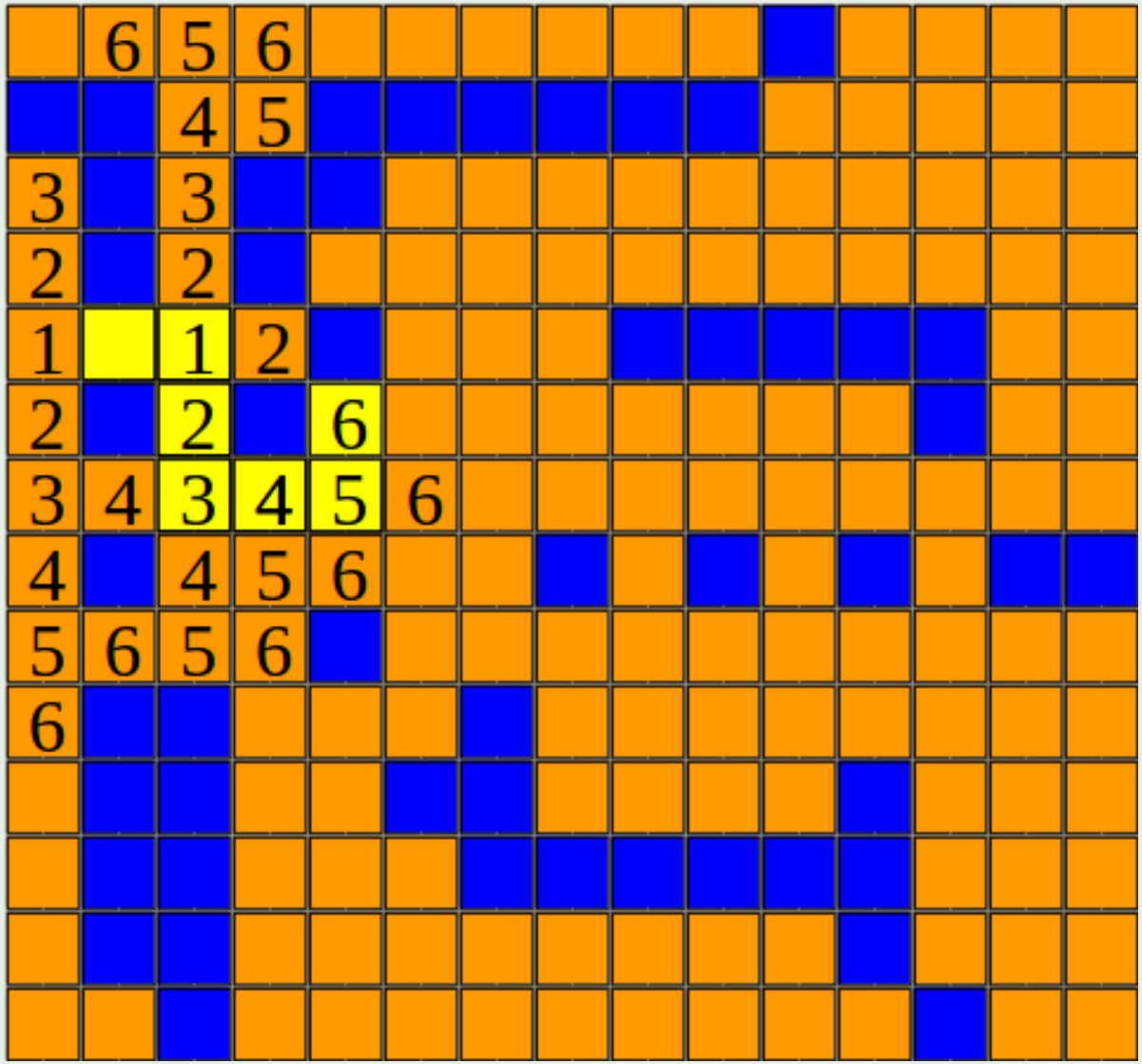


Example

Circuit Board - Traceback.

start pin

end pin



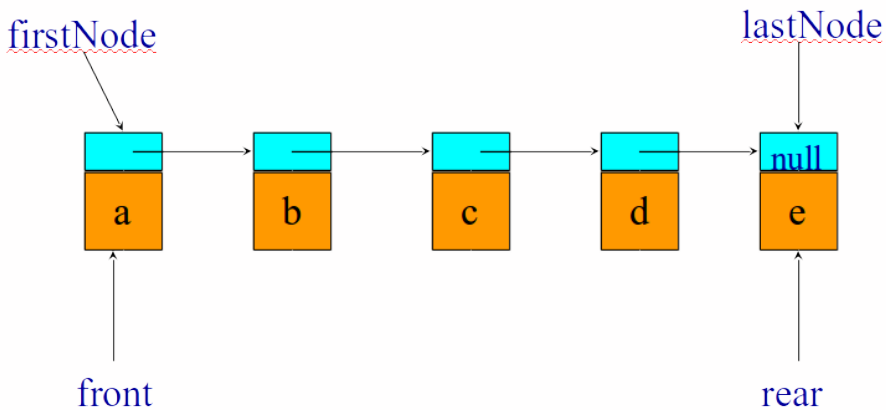
What Implementations

Directly Extending Classes

- From ArrayLinearList

  Note: Not a so good idea!!!

Extending from class but adding some pointers



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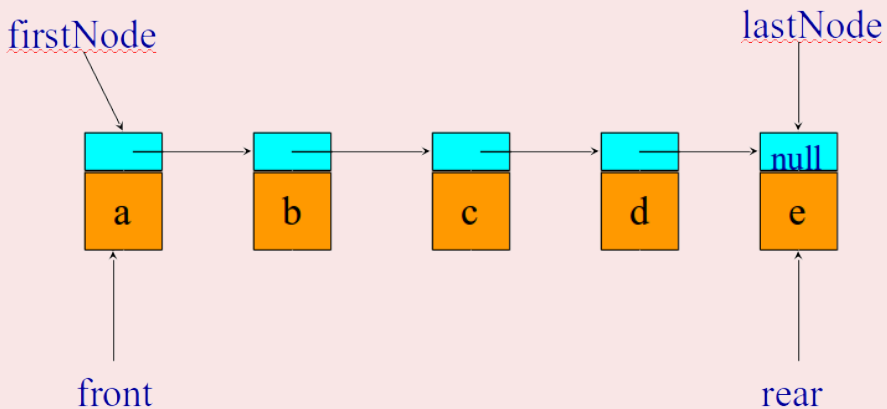

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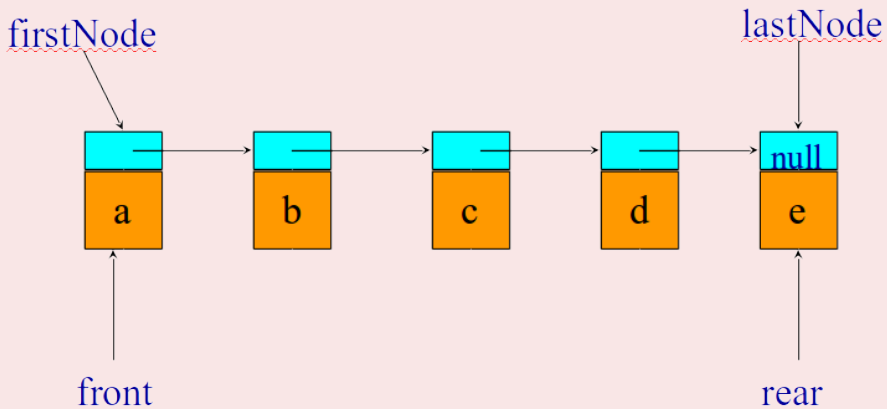

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Outline

Derive from ArrayLinearList

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We do not extend our data structure.

Simply use

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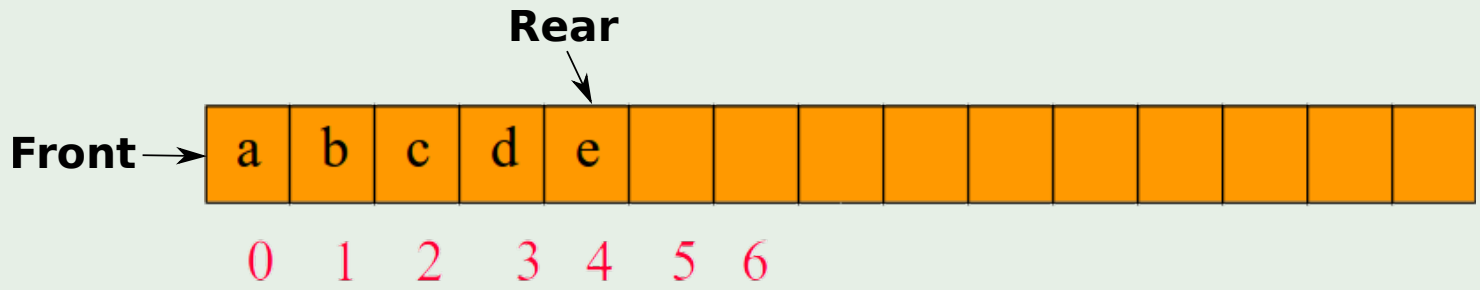

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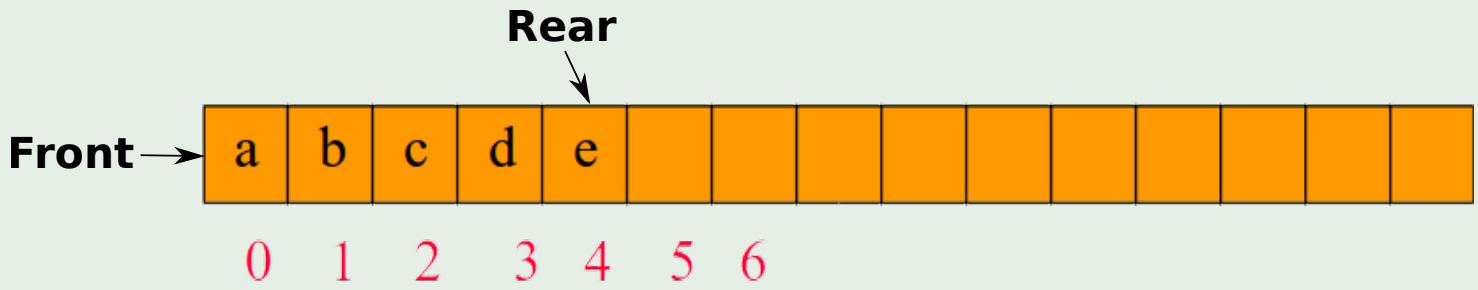

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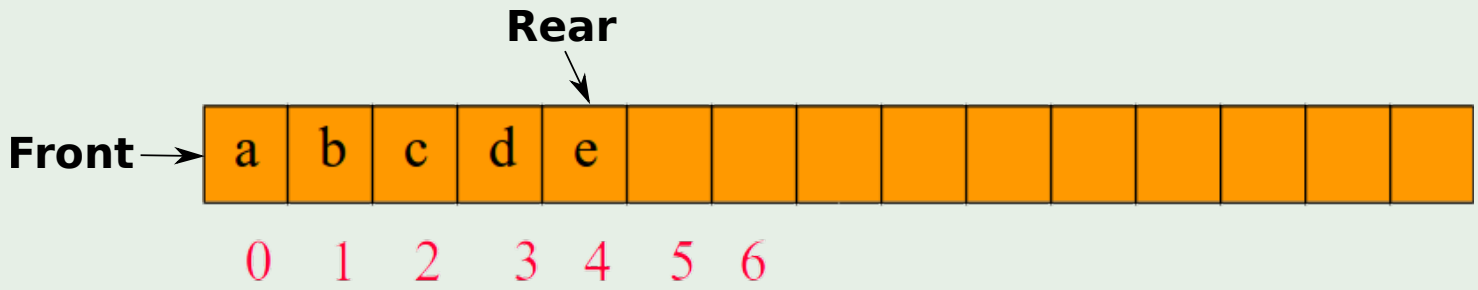

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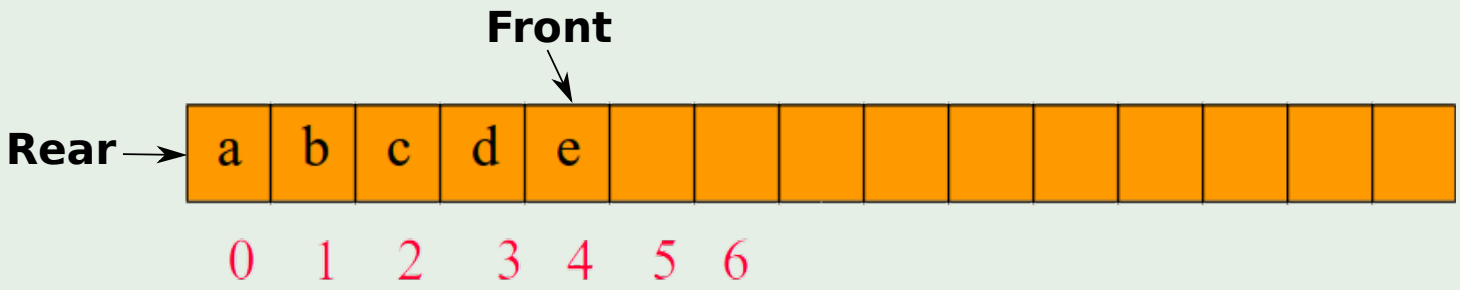

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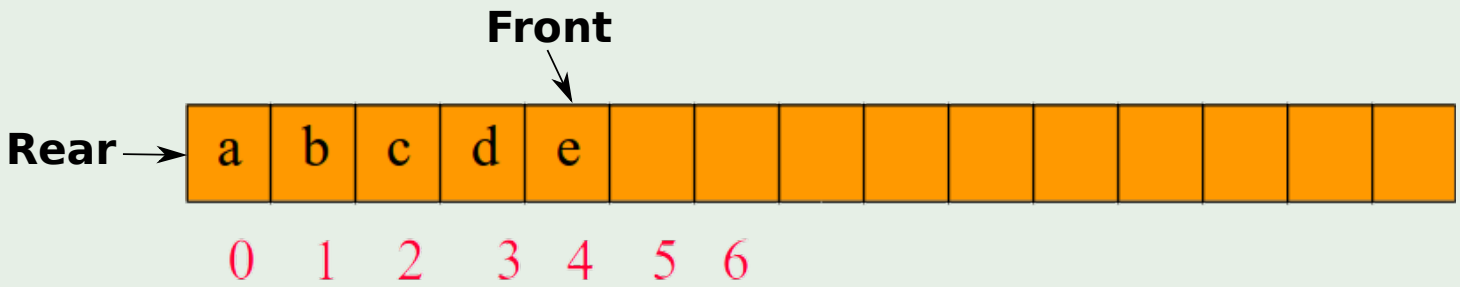

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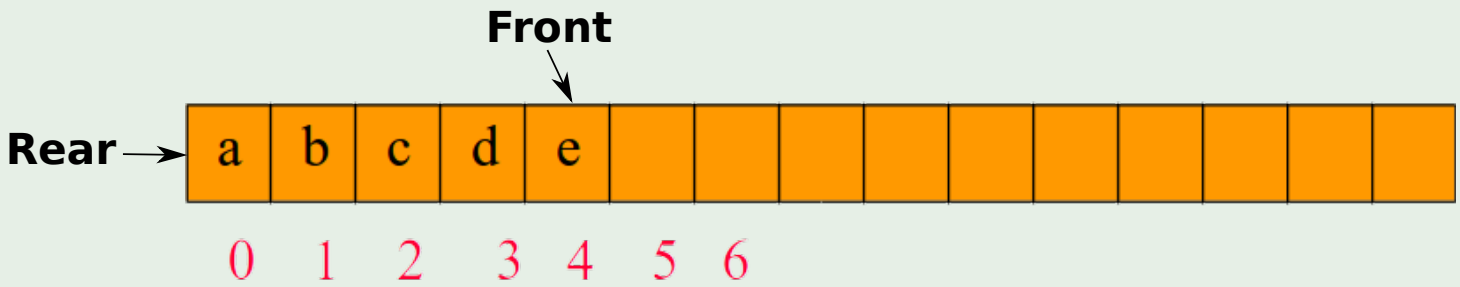

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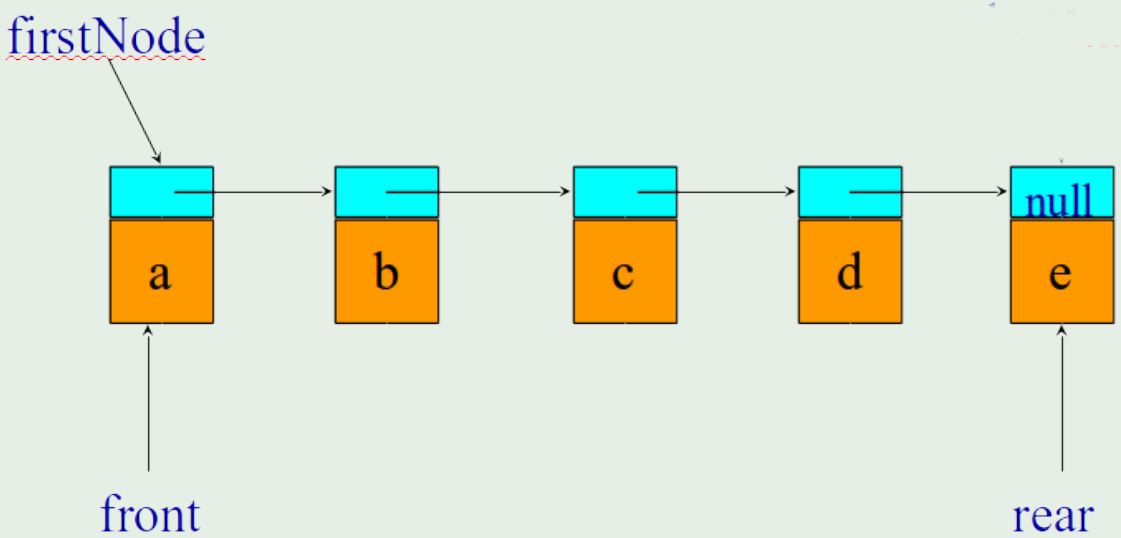

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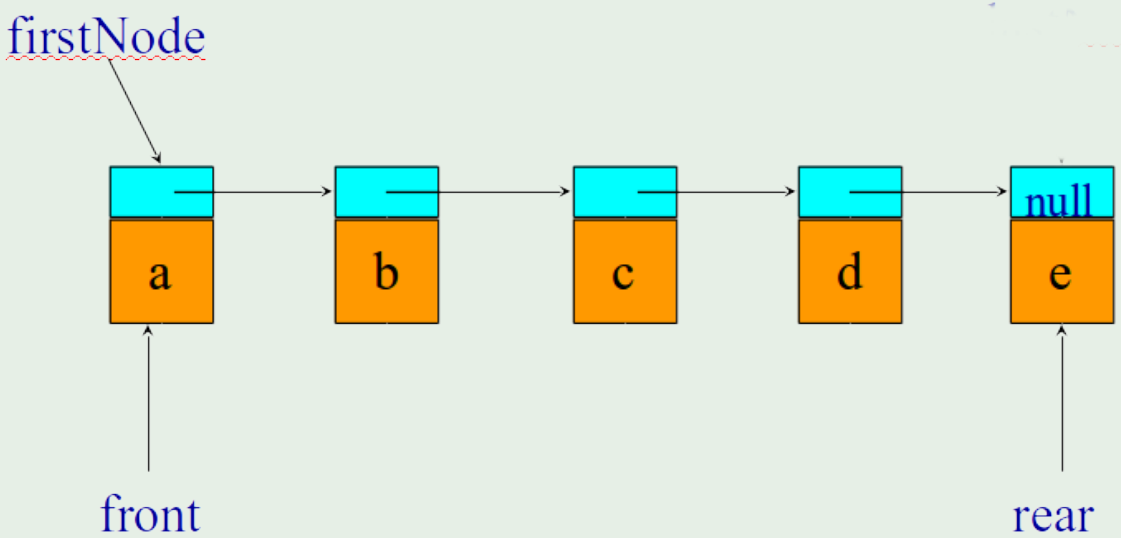

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Not Good At ALL

Even

If we change the front and the rear we do not get the performance we want!!!

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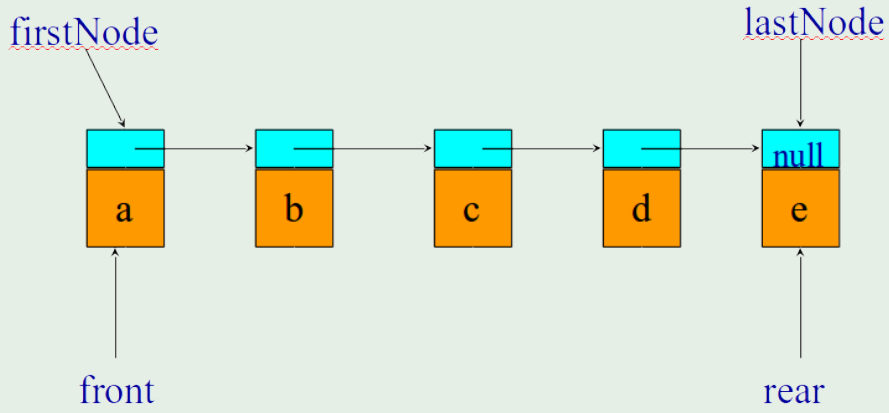

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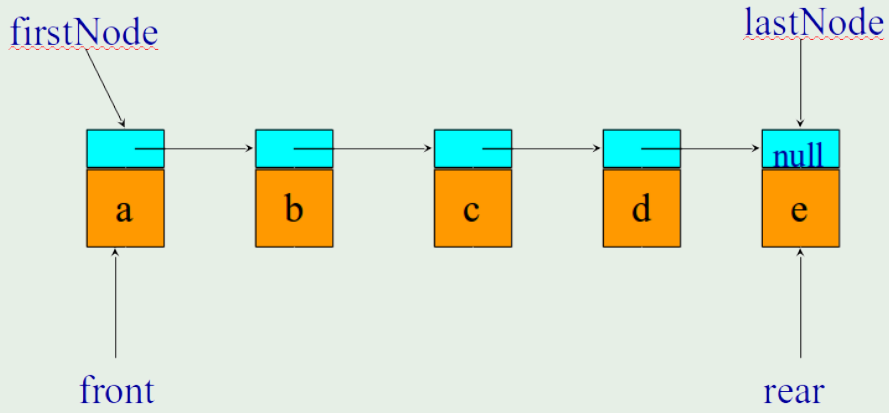

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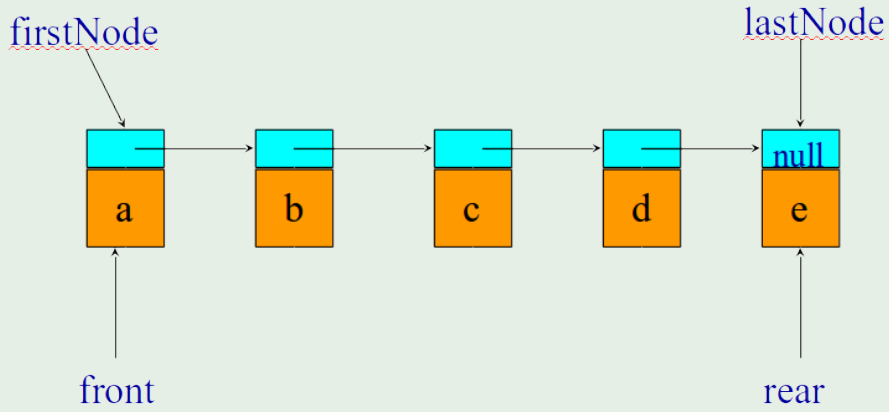

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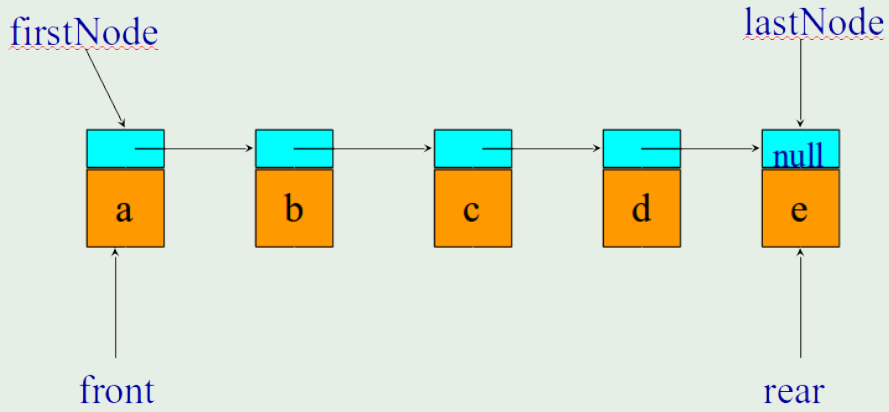

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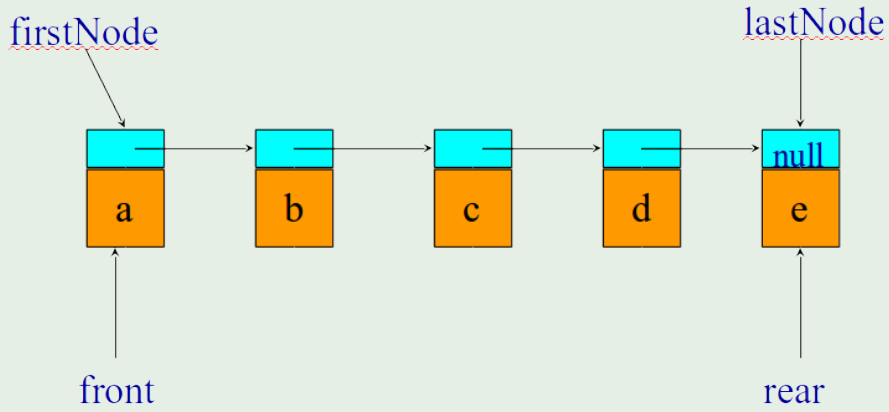

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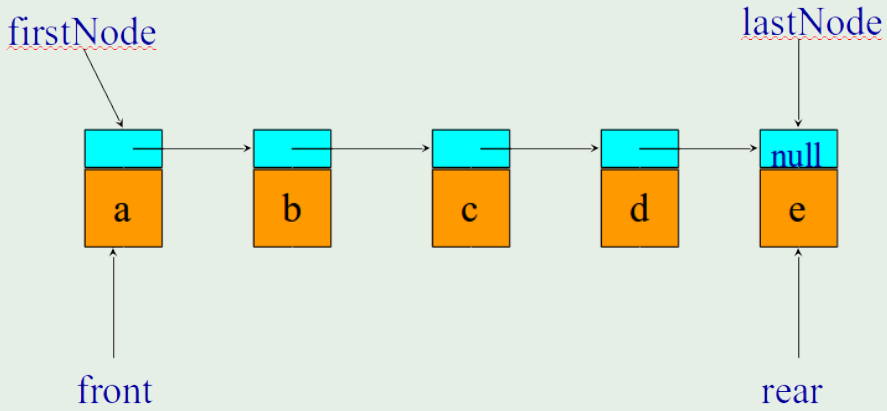

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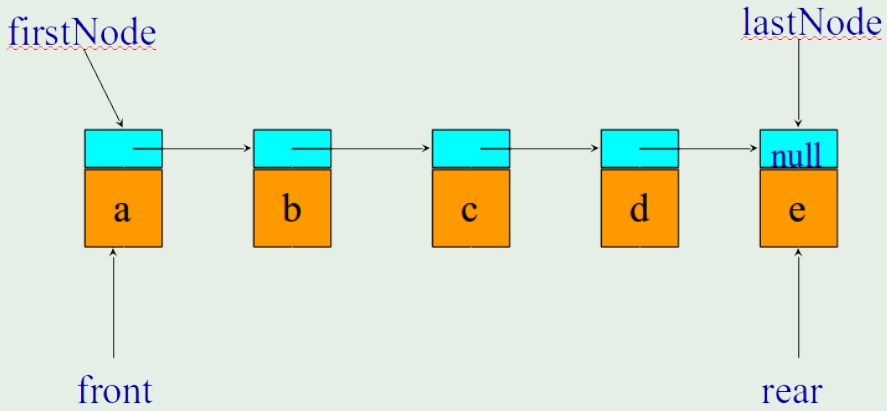

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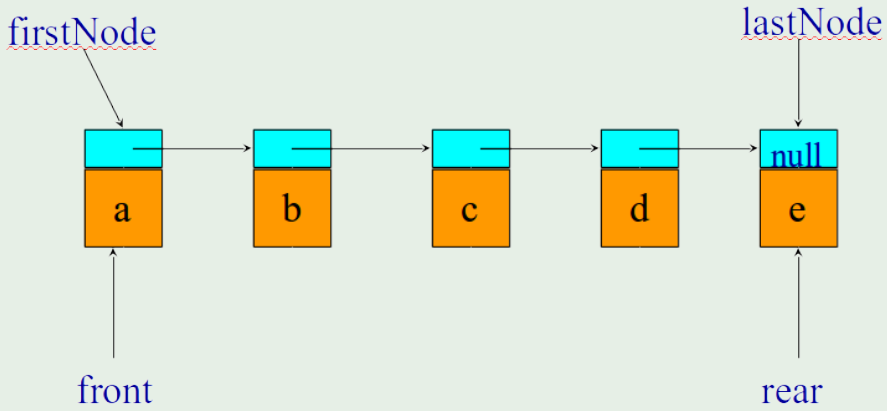

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Derive From Chain

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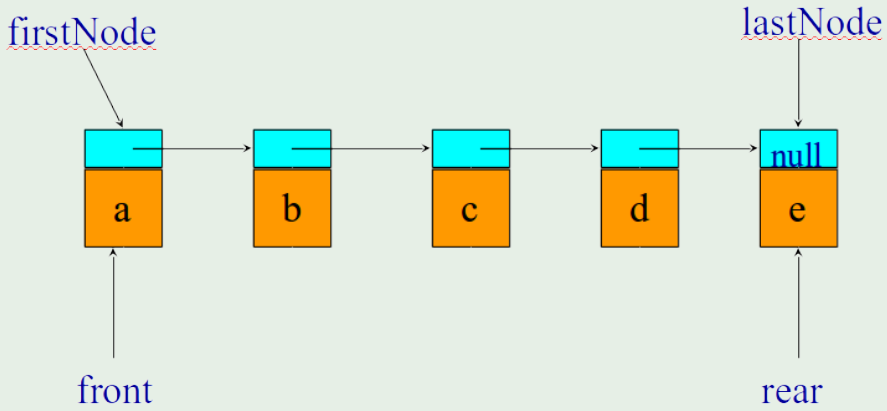

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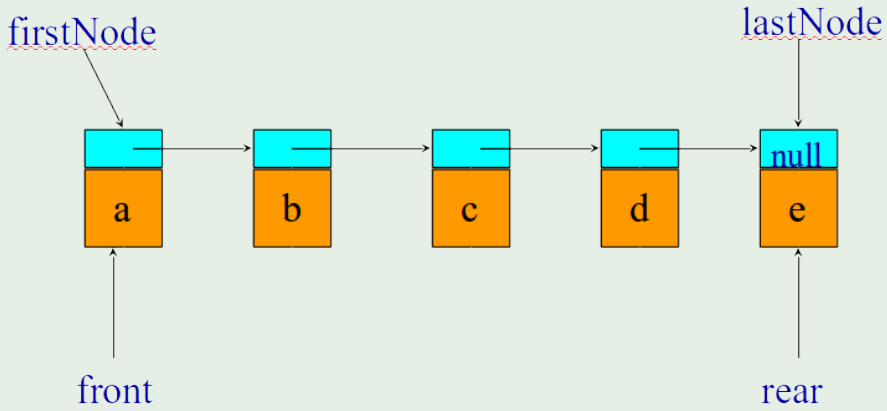

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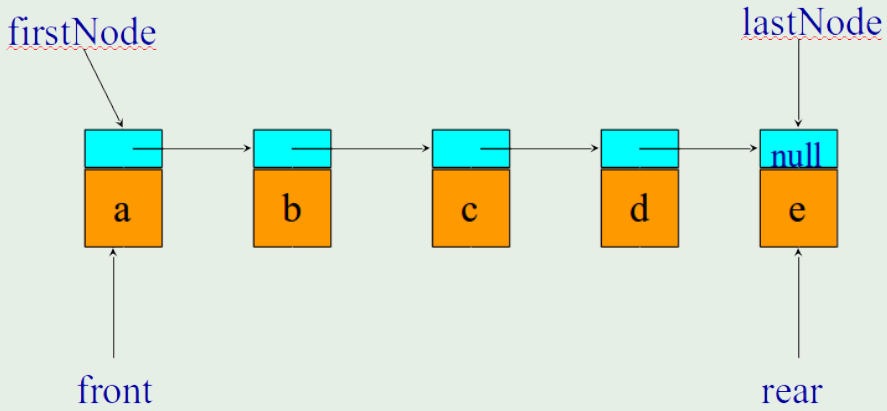

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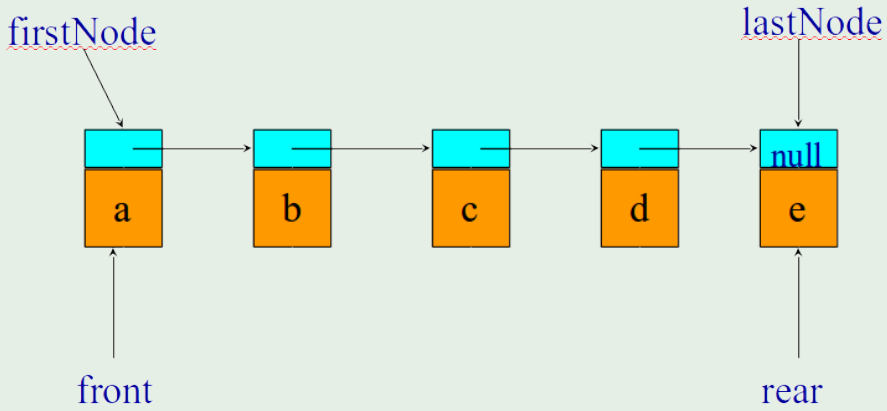

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We have do still some code that does not belong to the ADT queue!!!

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Example

For example the idea of index checking!!!

But even with this implementation

Problems

We have do still some code that does not belong to the ADT queue!!!

Example

For example the idea of index checking!!!

Moral of the Story

Better to implement from scratch... **when possible**!!!

Outline

A Linked Implementation of a Queue

From our experience extending the Chain Class

- We use two pointer for the front and the back of the chain:
  - firstNode == at the beginning of the Chain
  - lastNode == the end of the Chain

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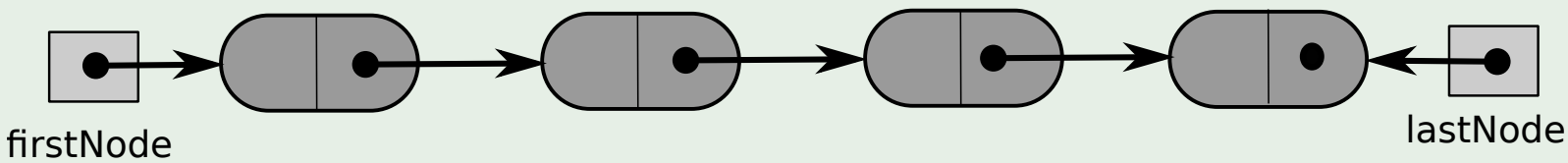

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Thus...

The Code For this Implementation

Sketch of the Code - Question: What is the problem with private class Node?

```
public class LinkedQueue<Item> implements Queue<Item>
{
   private Node firstNode;
   private Node lastNode;
   private int size;
   public LinkedQueue(){
      firstNode = null;
      lastNode = null;
      size = 0;
   } // end default constructor

   private class Node
   {
      private Item data; // entry in queue
      private Node next; // link to next node
    } // end Node
} // end LinkedQueue
```

Yes!!!

With private fields

It is necessary to have public methods to access them!!!

- setDataNode(Item Object)
- setNextNode(Node newNode);

Yes!!!

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Some Operations: Enqueue

We have always two cases

1. Adding to an empty Queue
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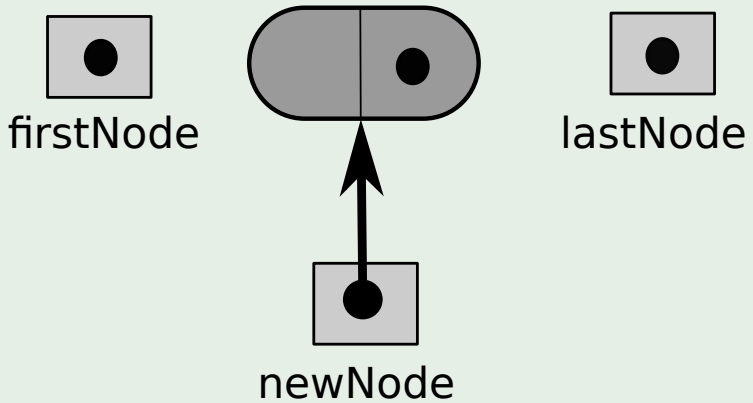
Example: Adding to an Empty List

Before Inserting



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Example: Adding to an Empty List

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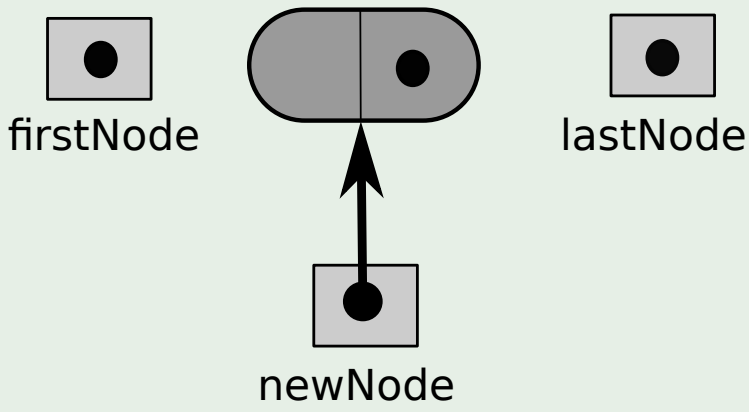

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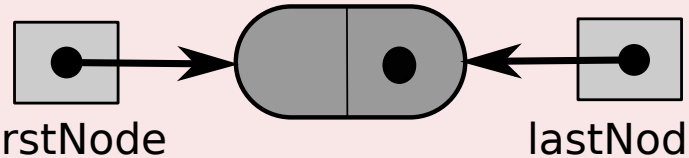
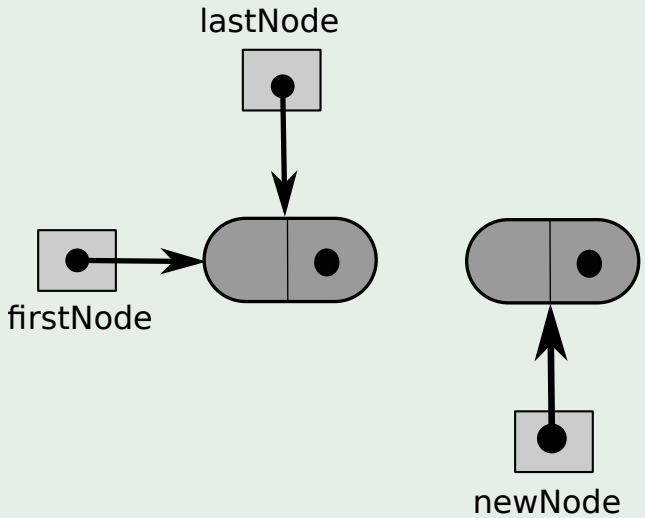


Example: Adding to a Non-Empty List

Create New Node



Make next from lastNode...

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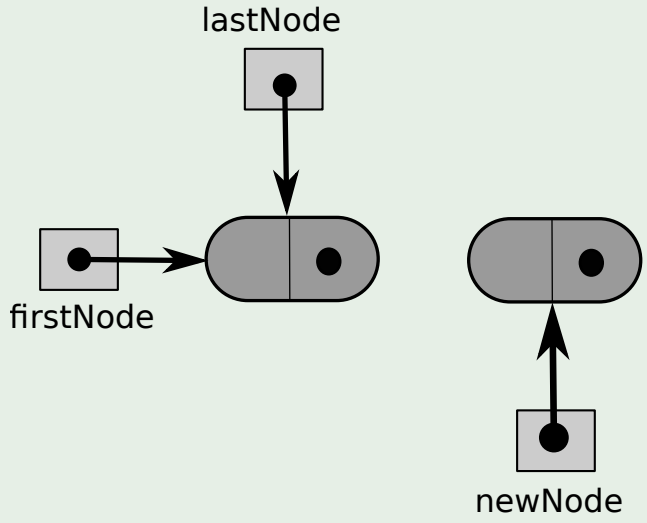

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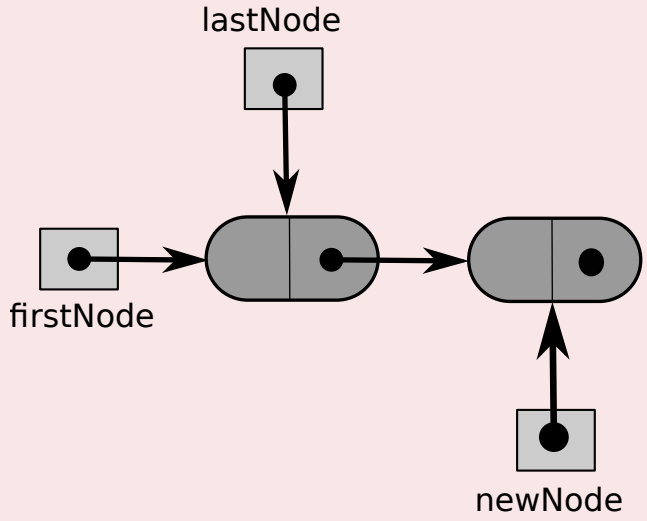
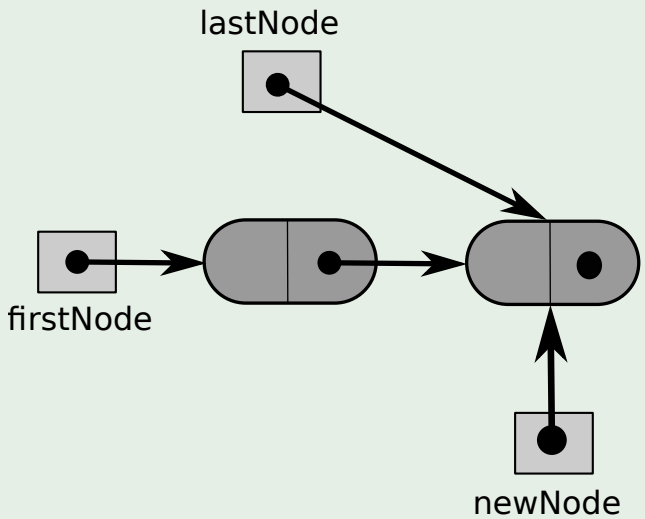


Example: Adding to a Non-Empty List

Move lastNode



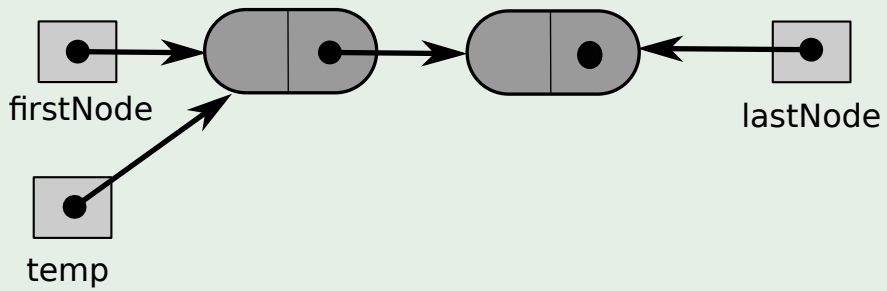
Final Code

Code

```
public void enqueue(Item newEntry)
{
    Node newNode = new Node(newEntry, null);
    if (empty())
            firstNode = newNode;
    else
            lastNode.setNextNode(newNode);
    lastNode = newNode;
} // end enqueue
```

What about Dequeue?

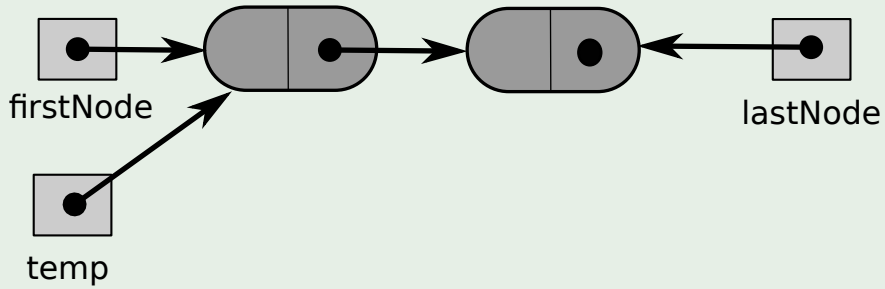
Point a temporary node to the front node



Point firstNode to temp.next

What about Dequeue?

Point a temporary node to the front node



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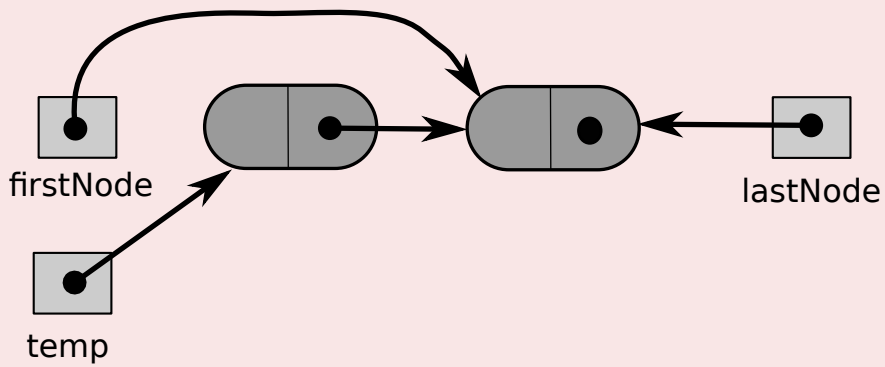
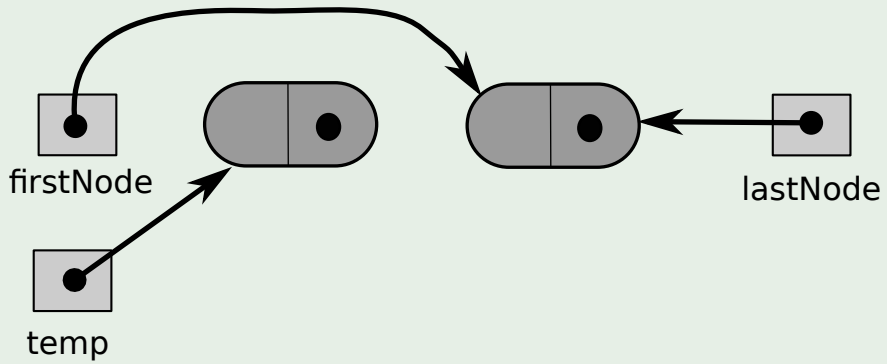


Empty

Make temp.next = null



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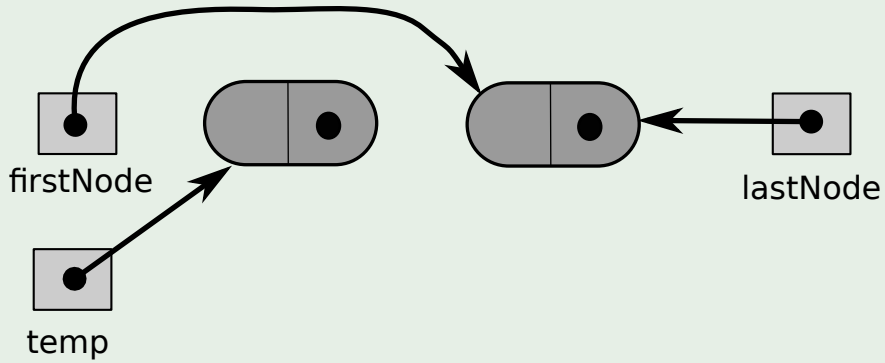

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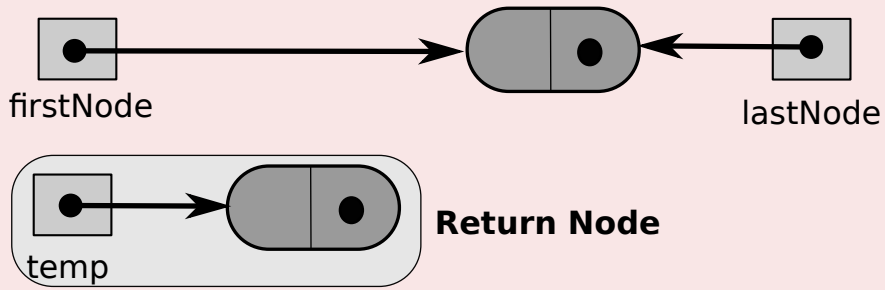

Thus...

The Rest of Operations

You can think about them... they are not complex...

Complexities

Operation in Scratch Queue using Chains	Complexity
empty()	O(1)
front()	O(1)
rear()	O(1)
Enqueue(TheObject)	O(1)
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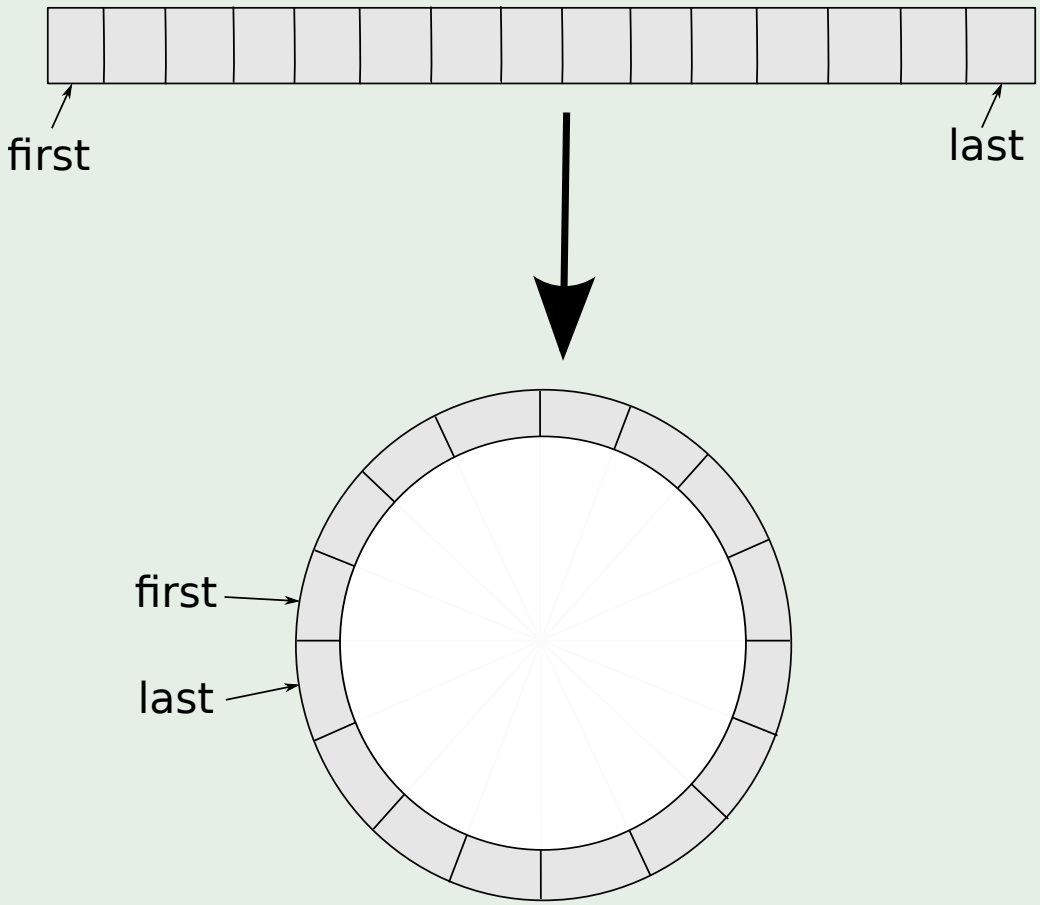
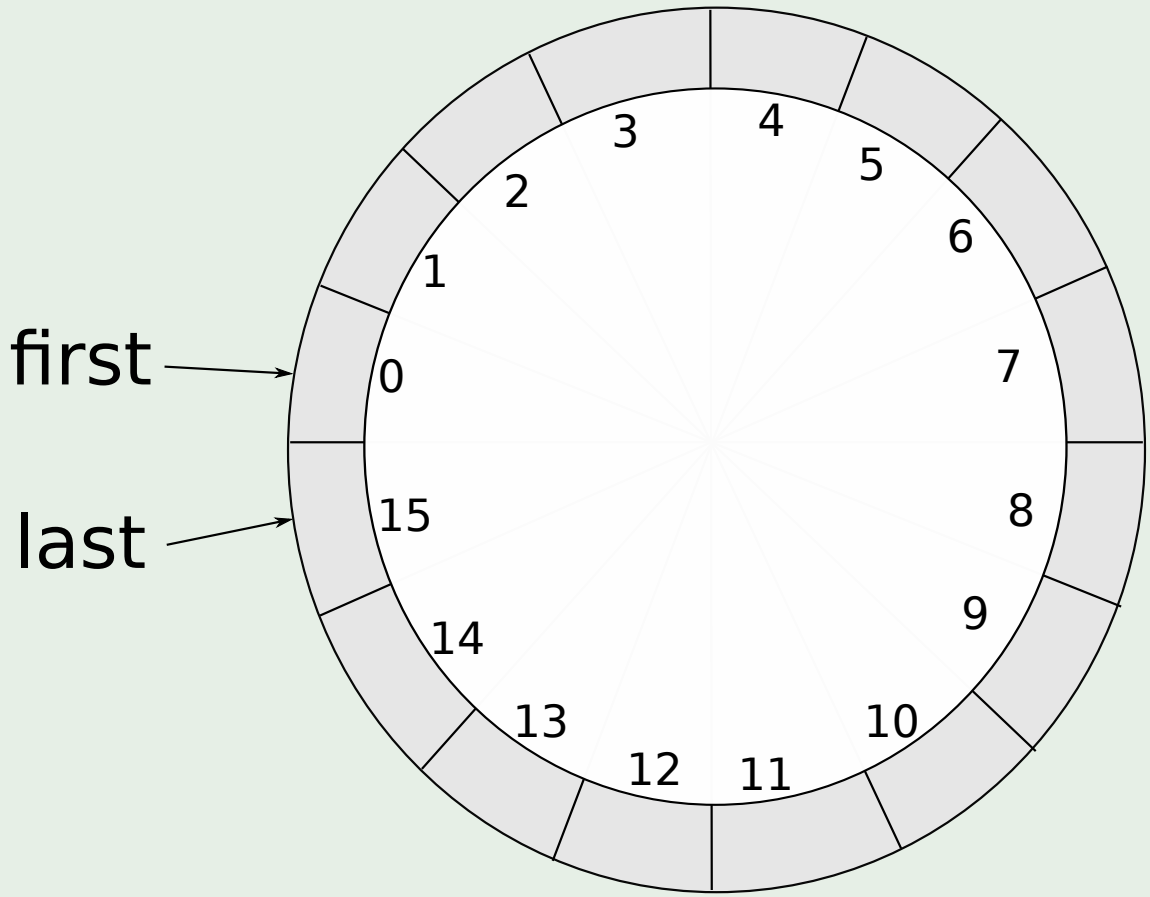
From Scratch Using an Array!!!

If we can do the following...



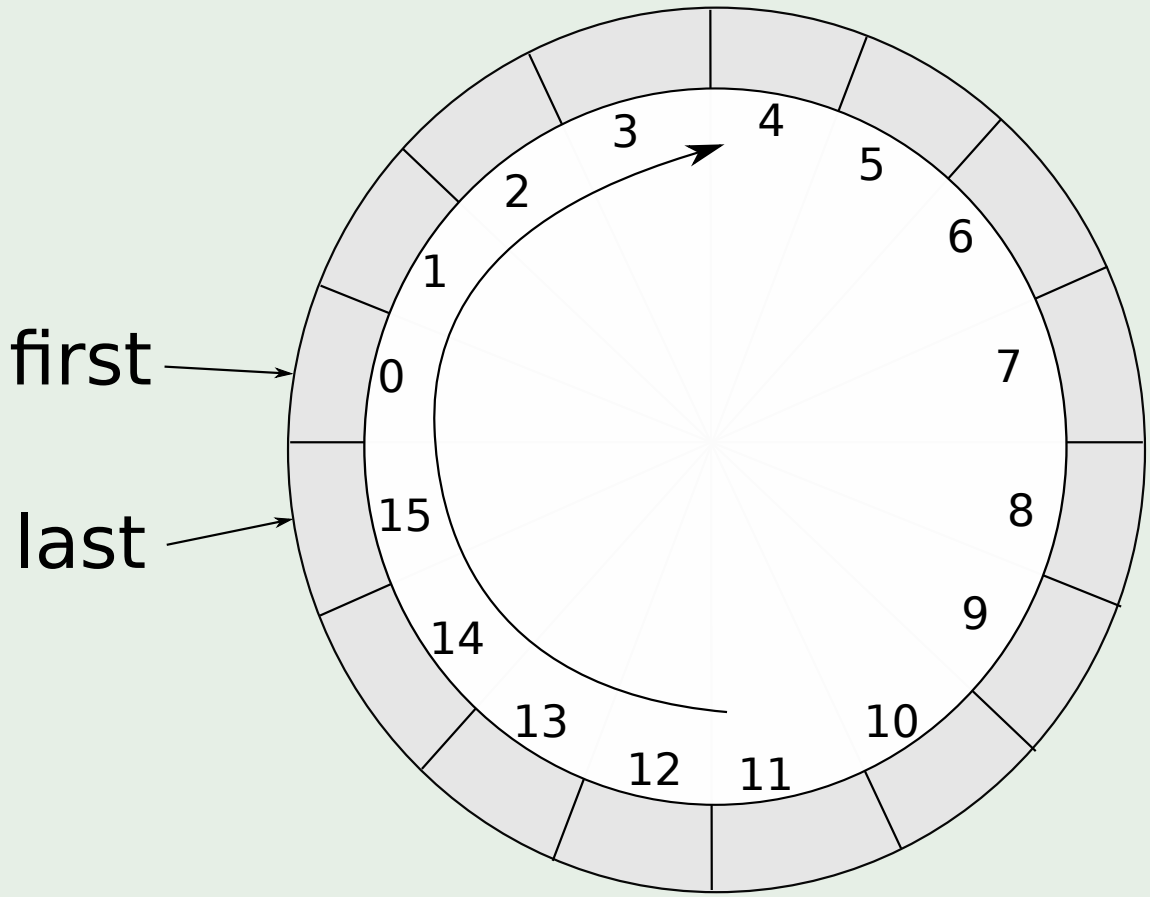
A closer Look...

Somebody can notice something?



Direction of Reading

Repeating numbers in a certain range



How we can simulate this number repetition?

Actually there is function that can help

$$\mod m : \mathbb{N} \to \{0, 1, 2, ..., m-1\} \tag{1}$$

Example for $m = 5$

n	$n \mod m$
0	0
1	1
2	2
3	3
4	4
5	0
6	1
7	2
8	3
etc...	...

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etc...	...

Thus, we still we have two indexes

frontIndex

We need to know where to remove!!!

backIndex

We need to know where to add!!

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Thus

If we want to add

backIndex = (backIndex + 1)% queue.length

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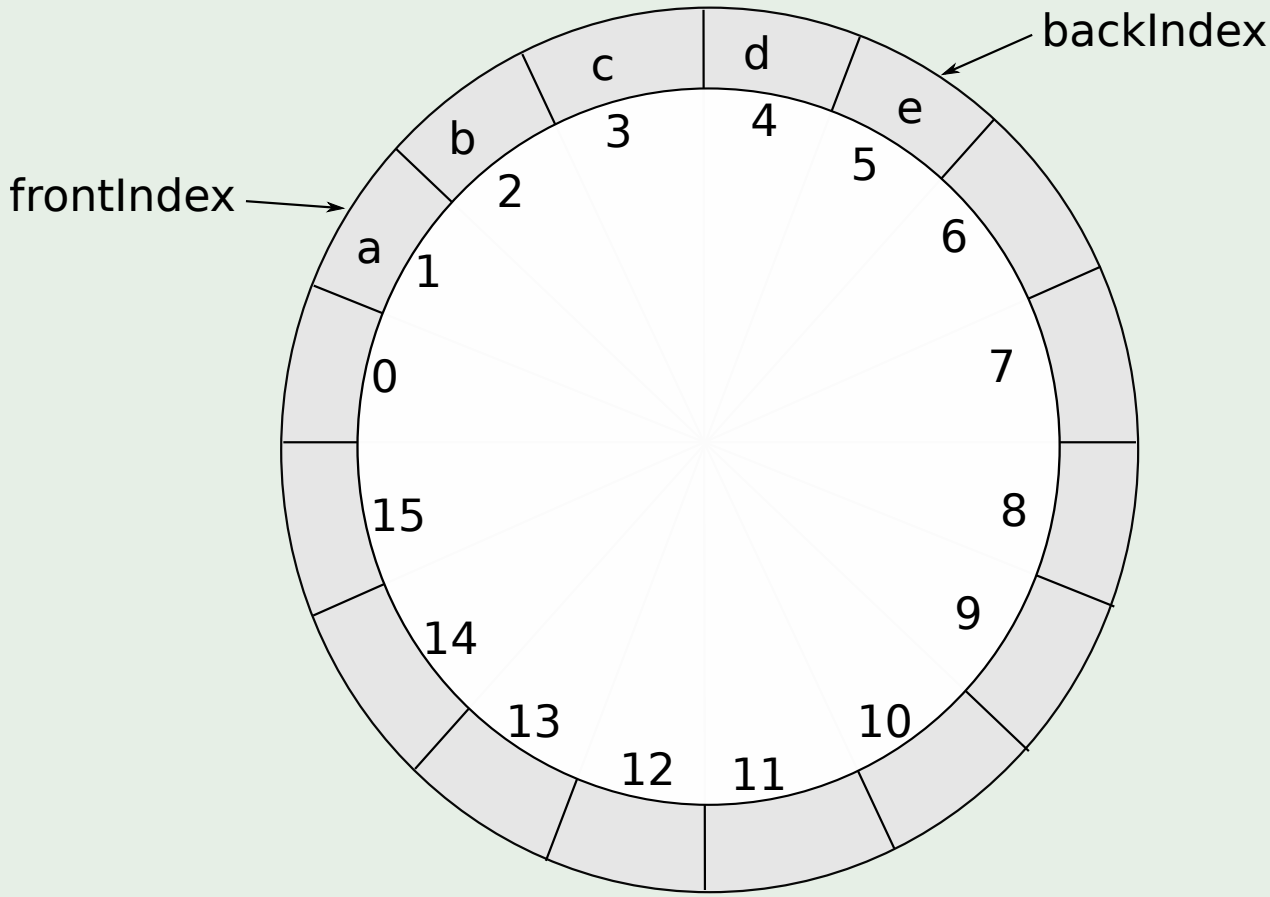
Example

Adding stuff into the back



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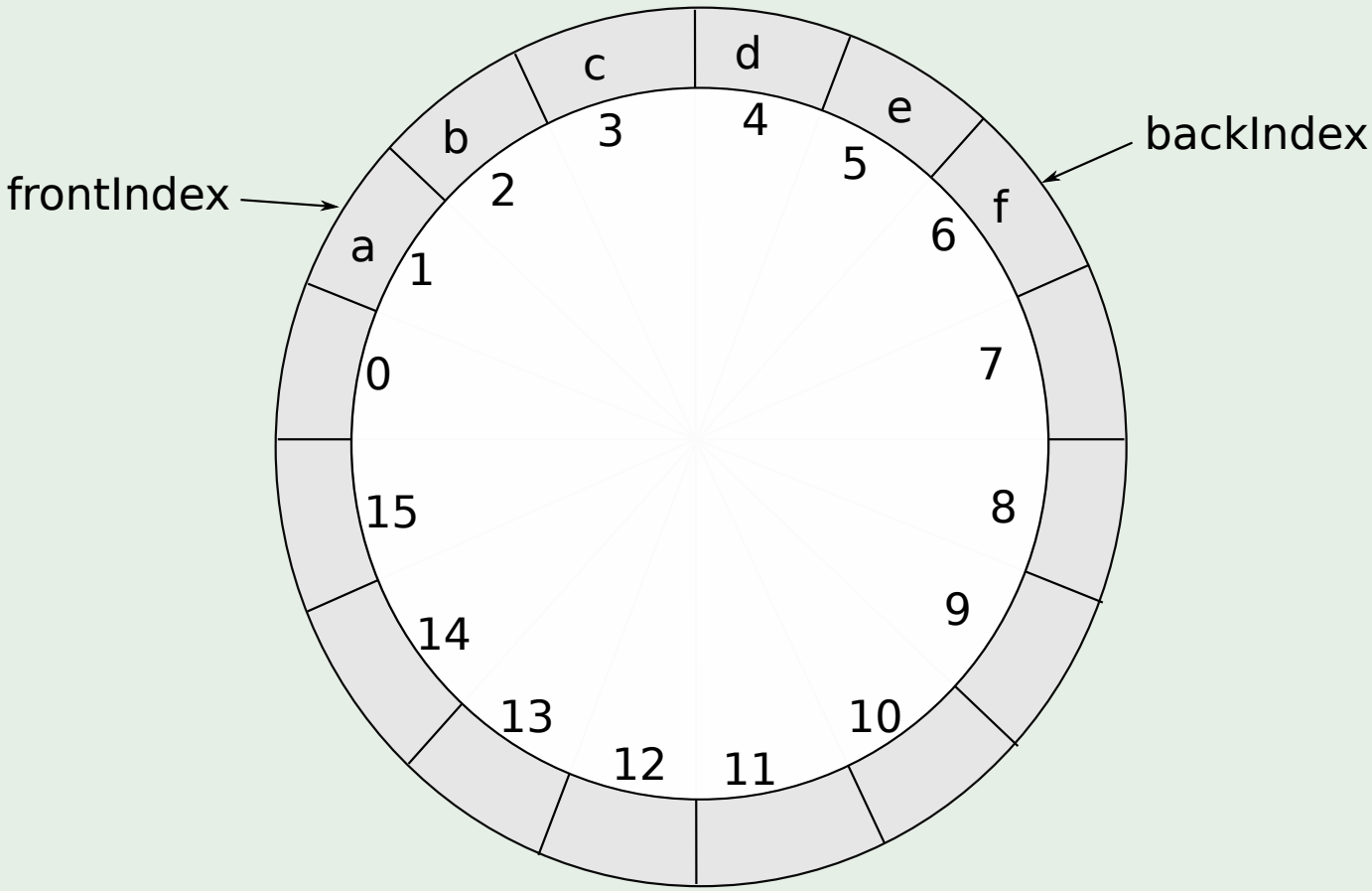

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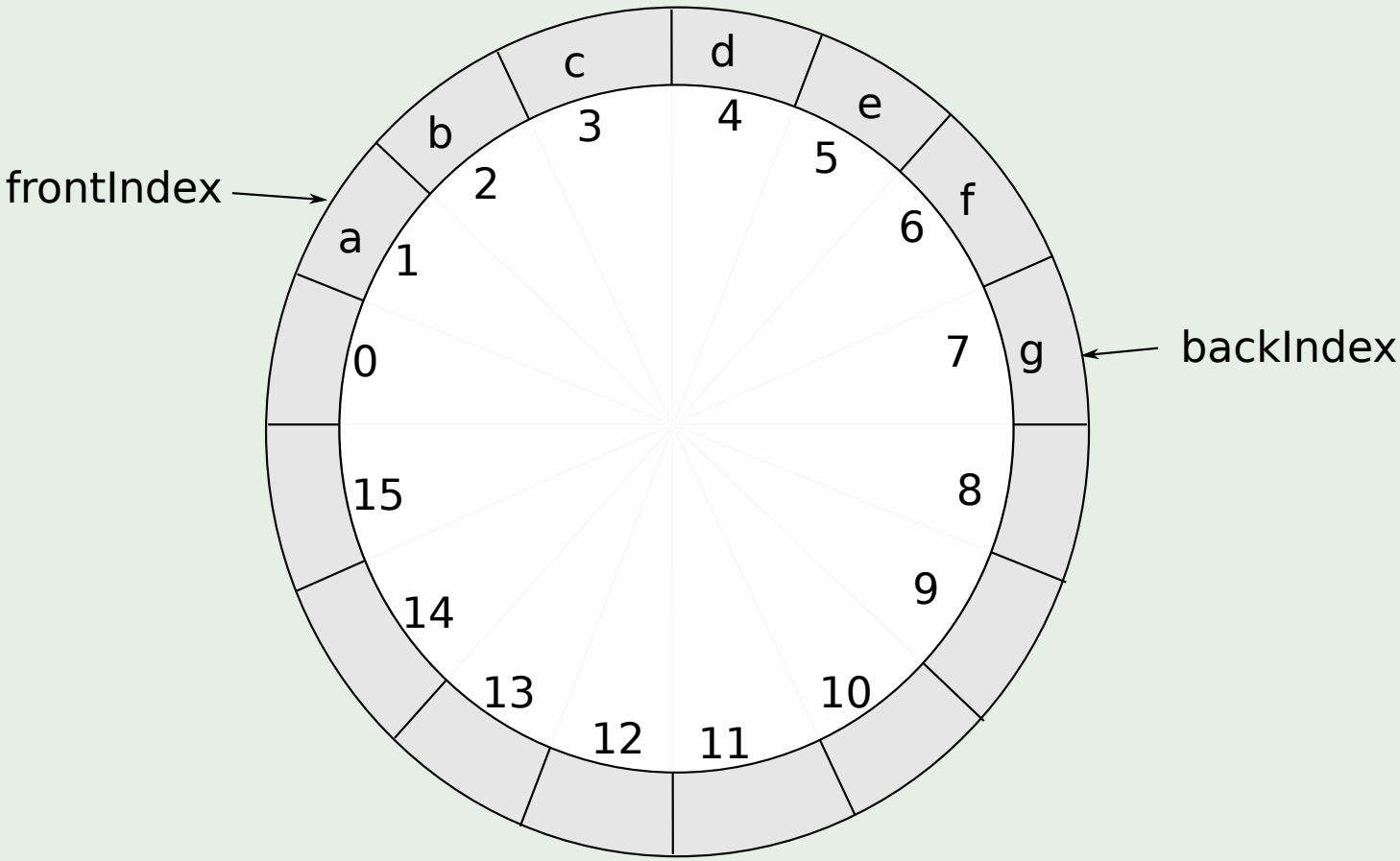
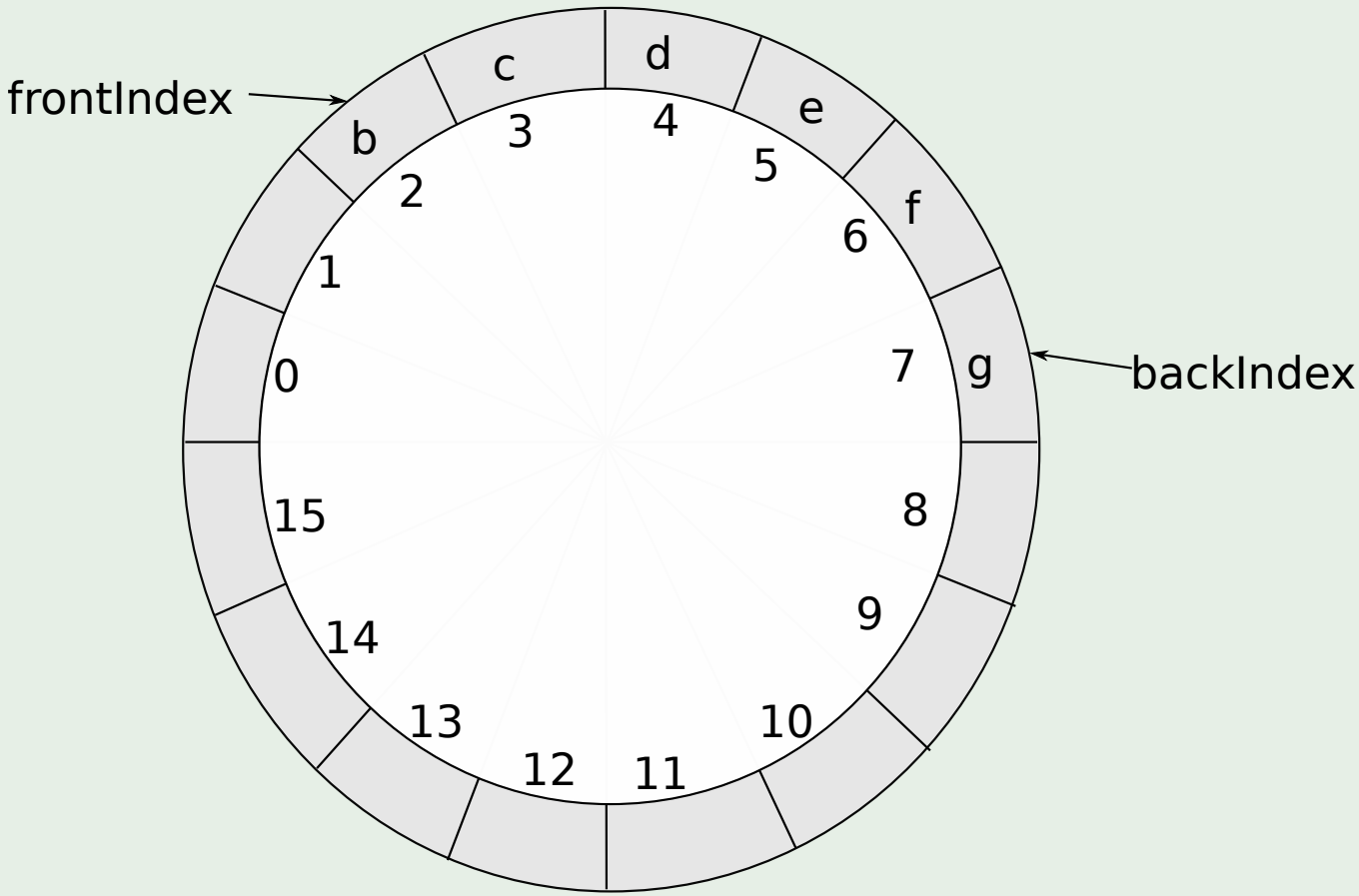


Example

Remove stuff from the front



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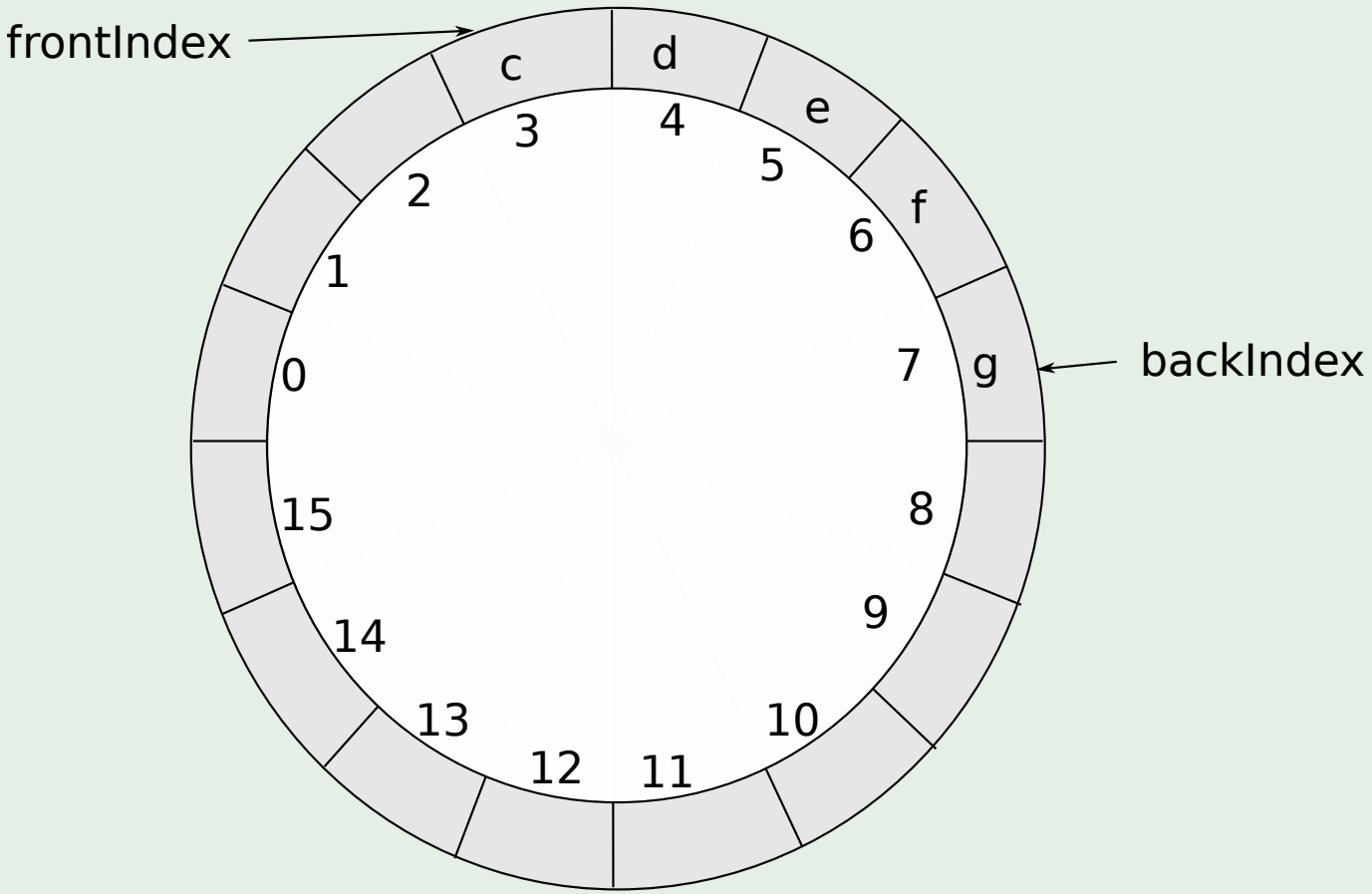
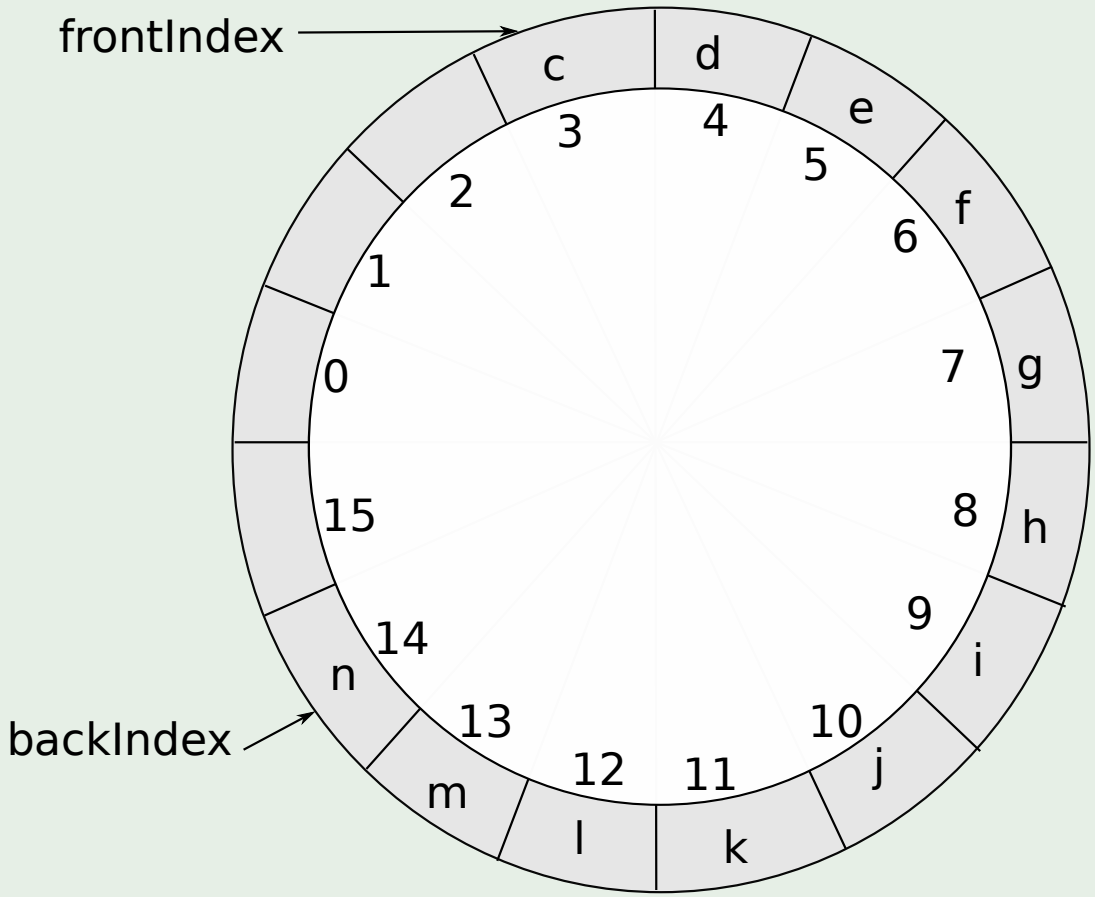


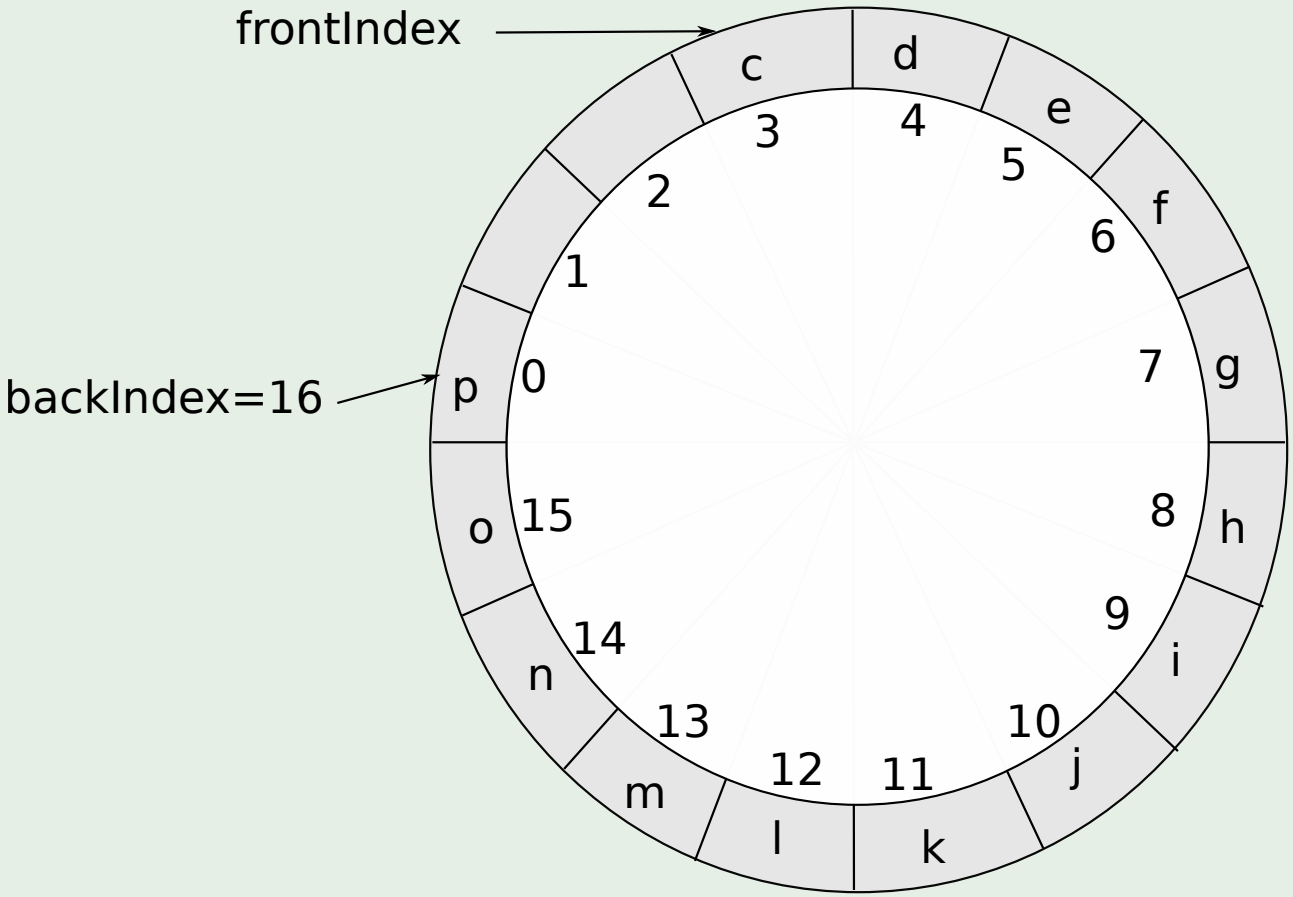
Example

Keep Adding



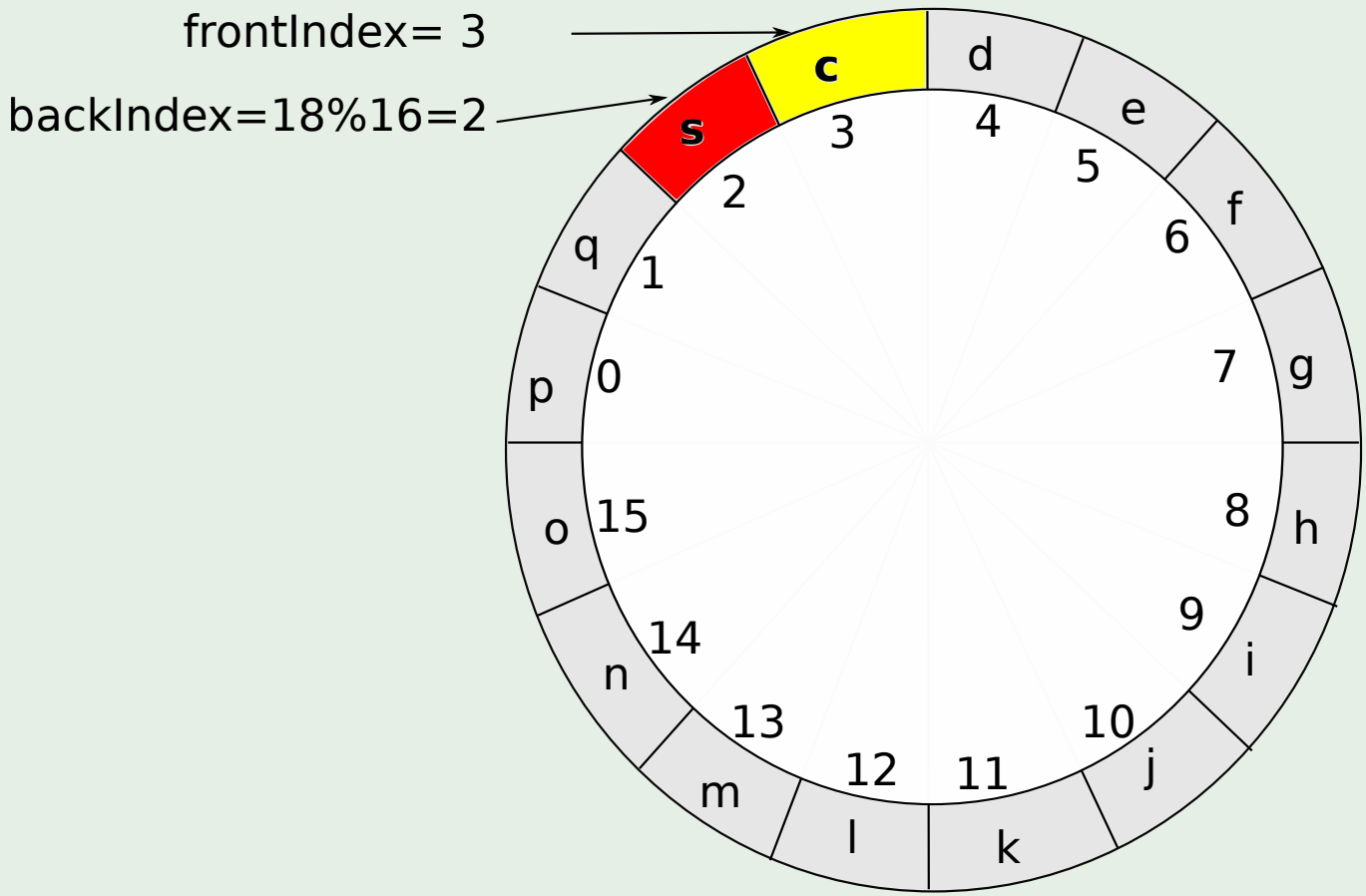
Example

The modulo helps here



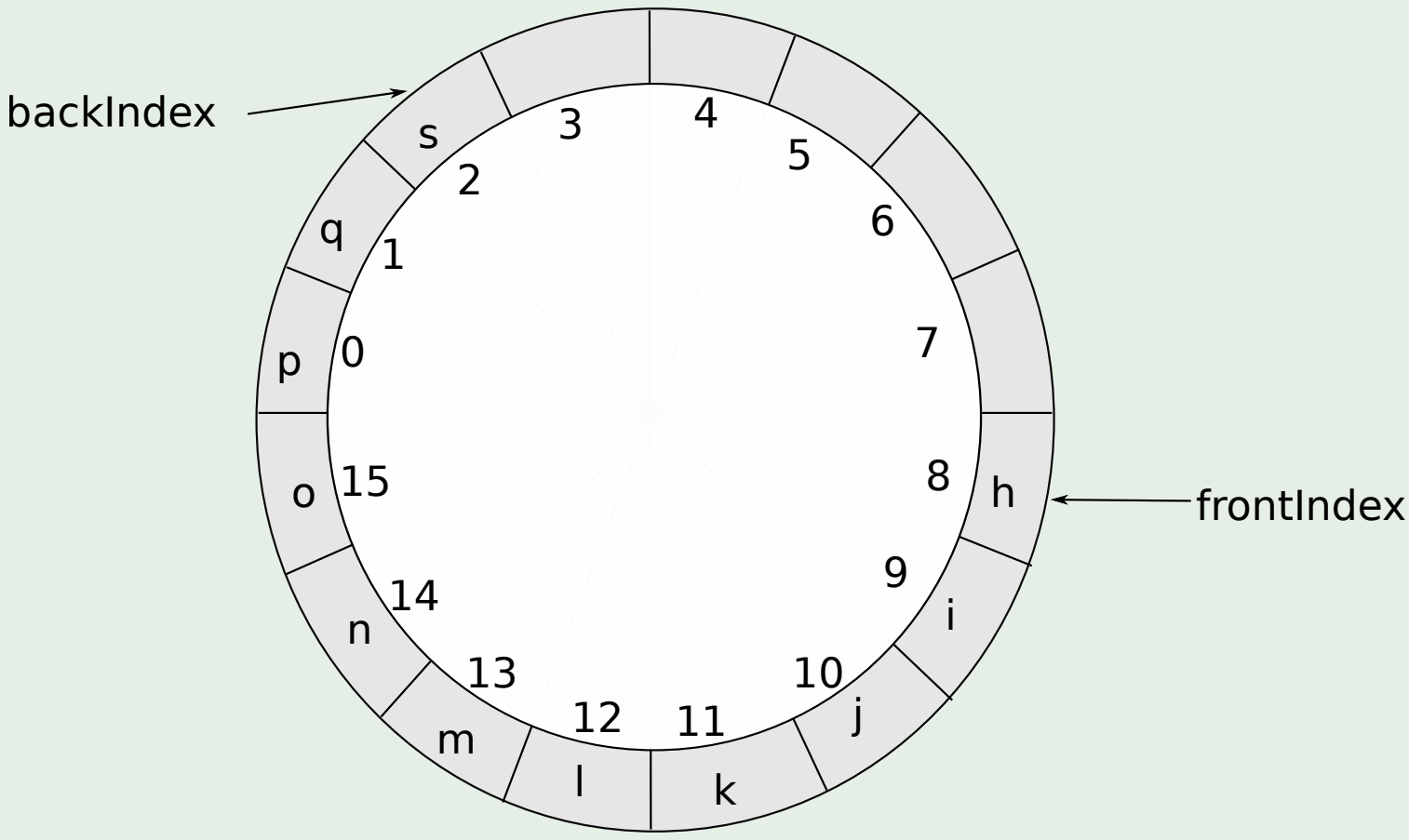
It looks Cool, but...

Problem 1 when full



But when we remove all elements

We go...



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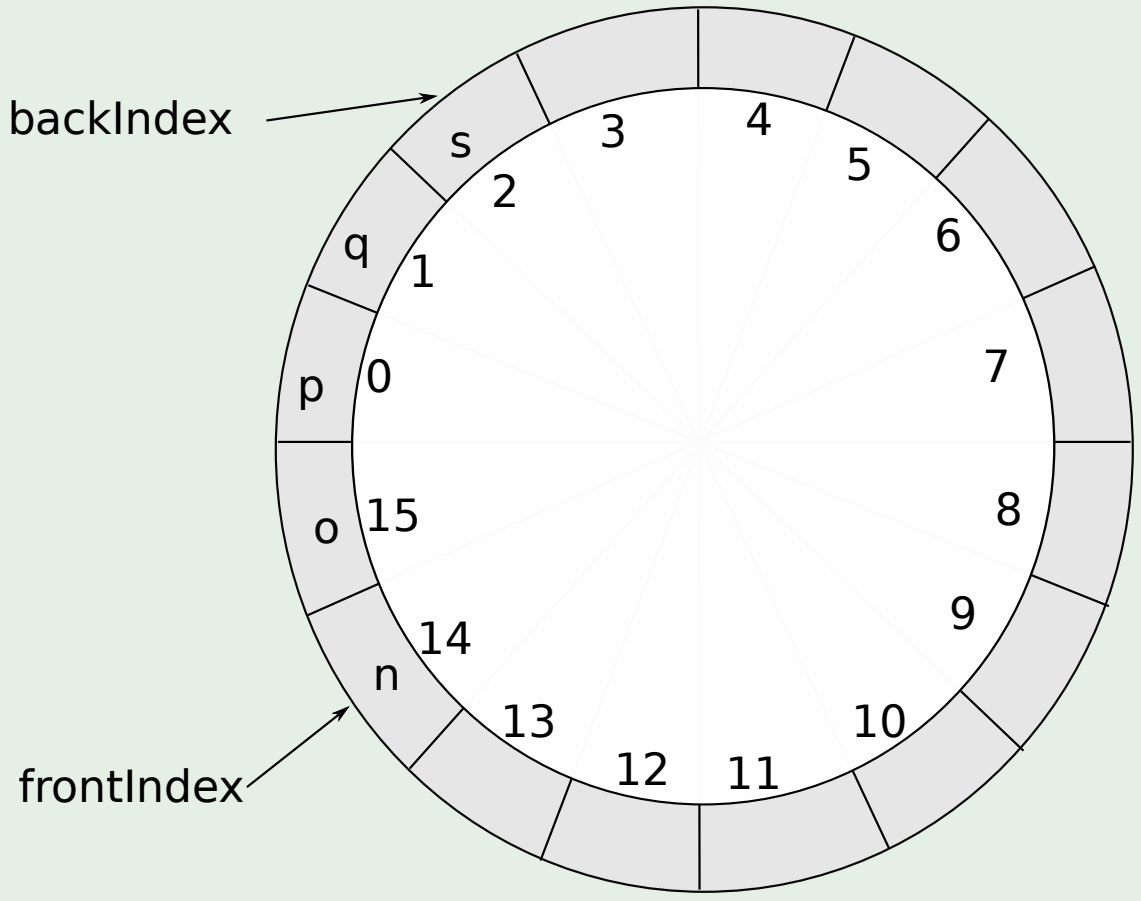
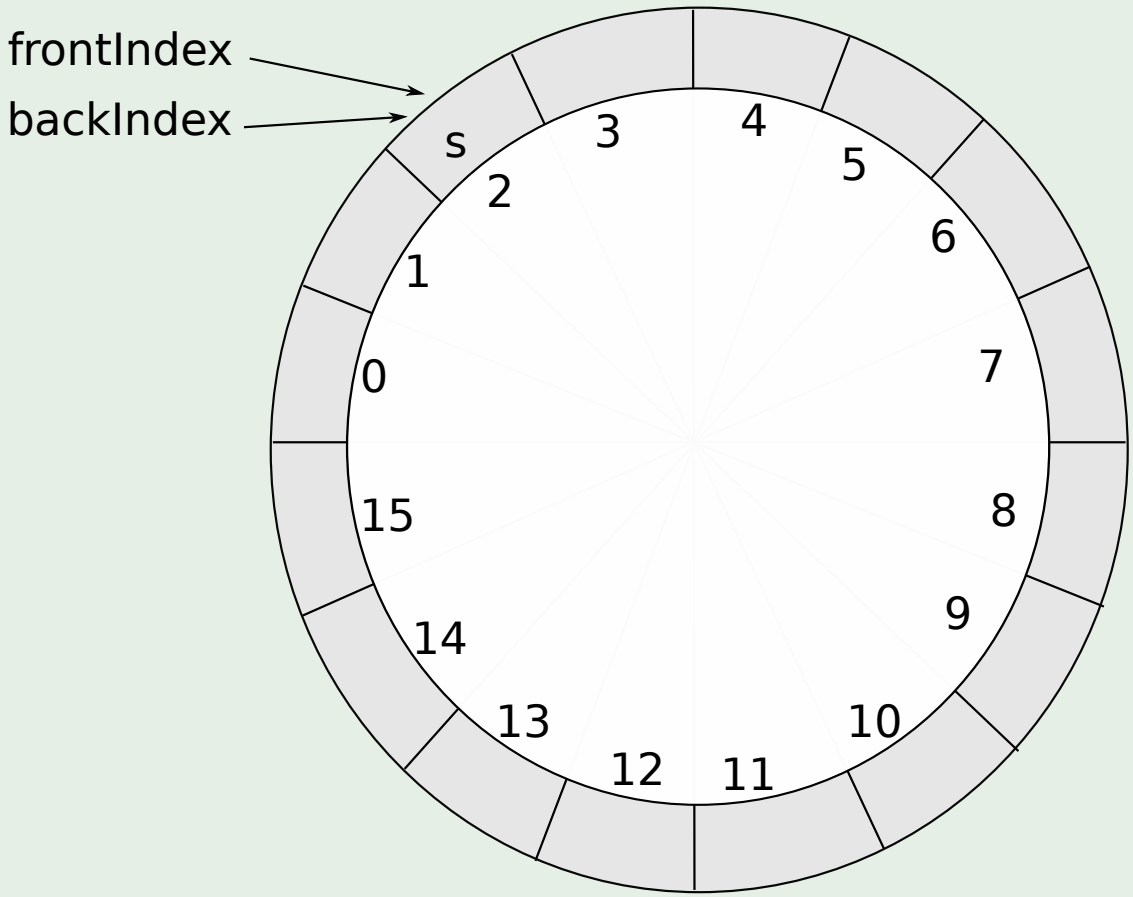


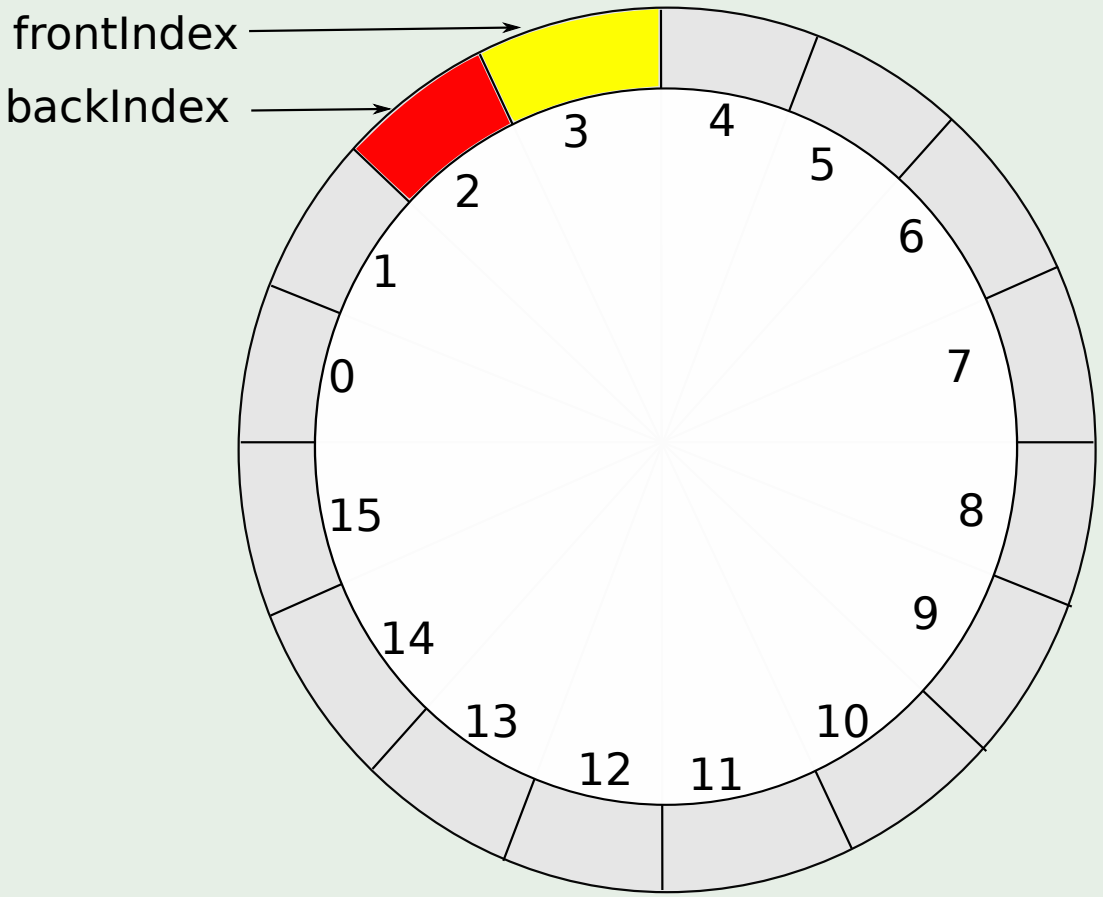
This is the main problem

And here is the problem when removing s



This is the main problem

Then full an empty cases cannot be identified!!!



Thus

The Problem

frontIndex == (backIndex + 1) % queue.length

A possible solution

Somewhat simple

- Use an extra field "**size**"

Then each time

- If frontIndex === (backIndex + 1) % queue.length ⇒ check size
  - Then do something what?

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Somewhat simple

- Use an extra field "**size**"

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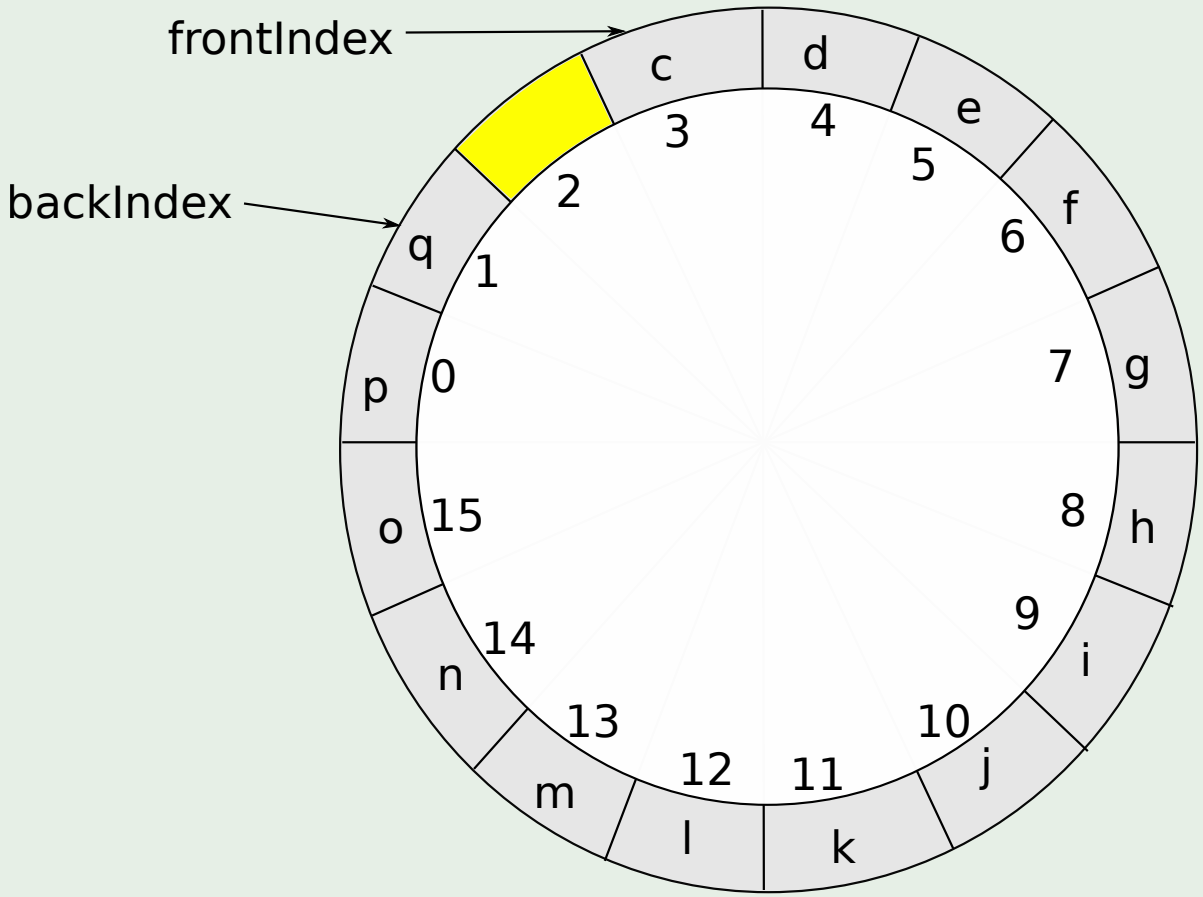
  - Then do something what?

Another solution!!!

Assume an space between the frontIndex and backIndex



Thus,

When the queue is full

frontIndex == (backIndex + 2) % queue.length

When the queue is empty

frontIndex === (backIndex + 1) % queue.length

Thus,

When the queue is full

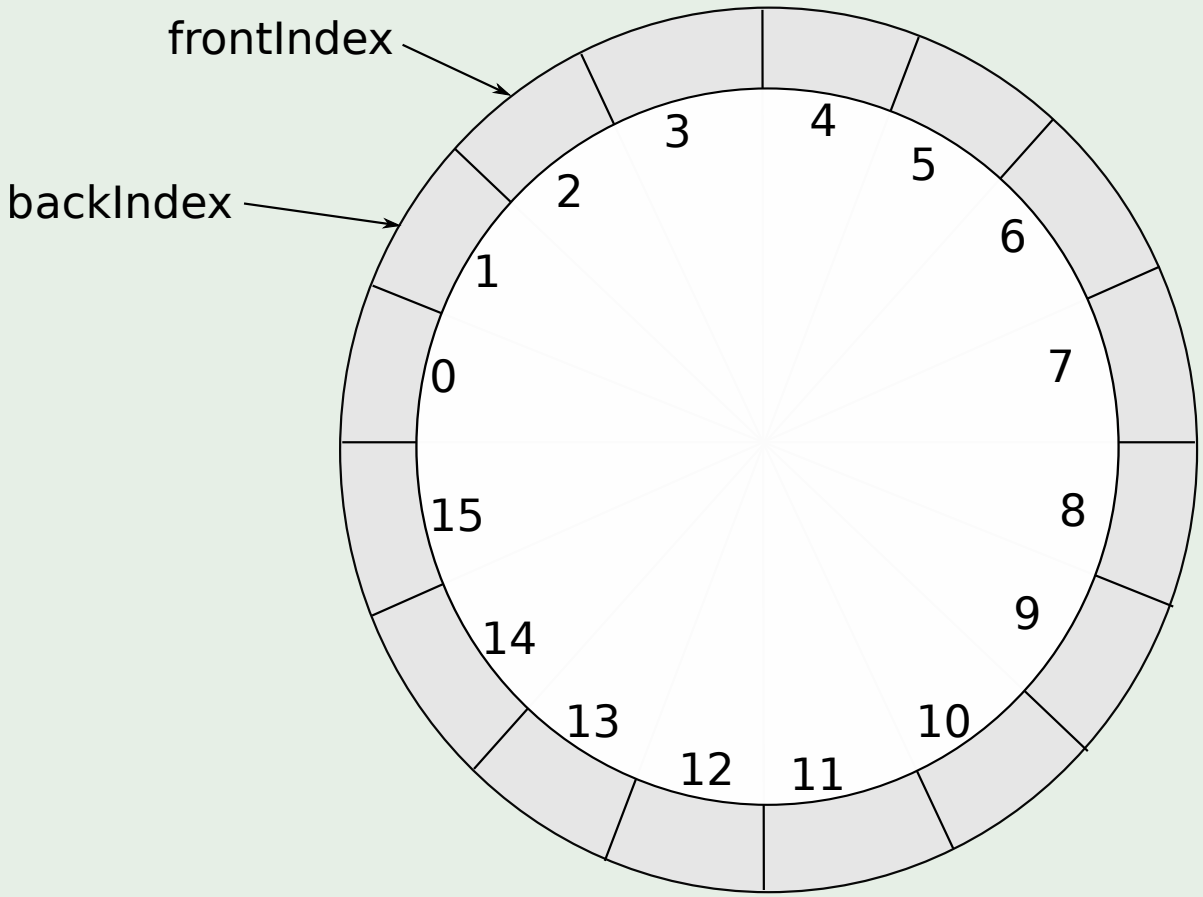
frontIndex == (backIndex + 2) % queue.length

When the queue is empty

frontIndex == (backIndex + 1) % queue.length

A solution!!!

Then for an empty queue



Class Members

Code

```
public class ArrayQueue<Item> implements QueueInterface<Item>
{
    private Item[] queue; // circular array of queue entries
                          // and one unused location
    private int frontIndex;
    private int backIndex;
    private static final int DEFAULT_INITIAL_CAPACITY = 50;
}
```

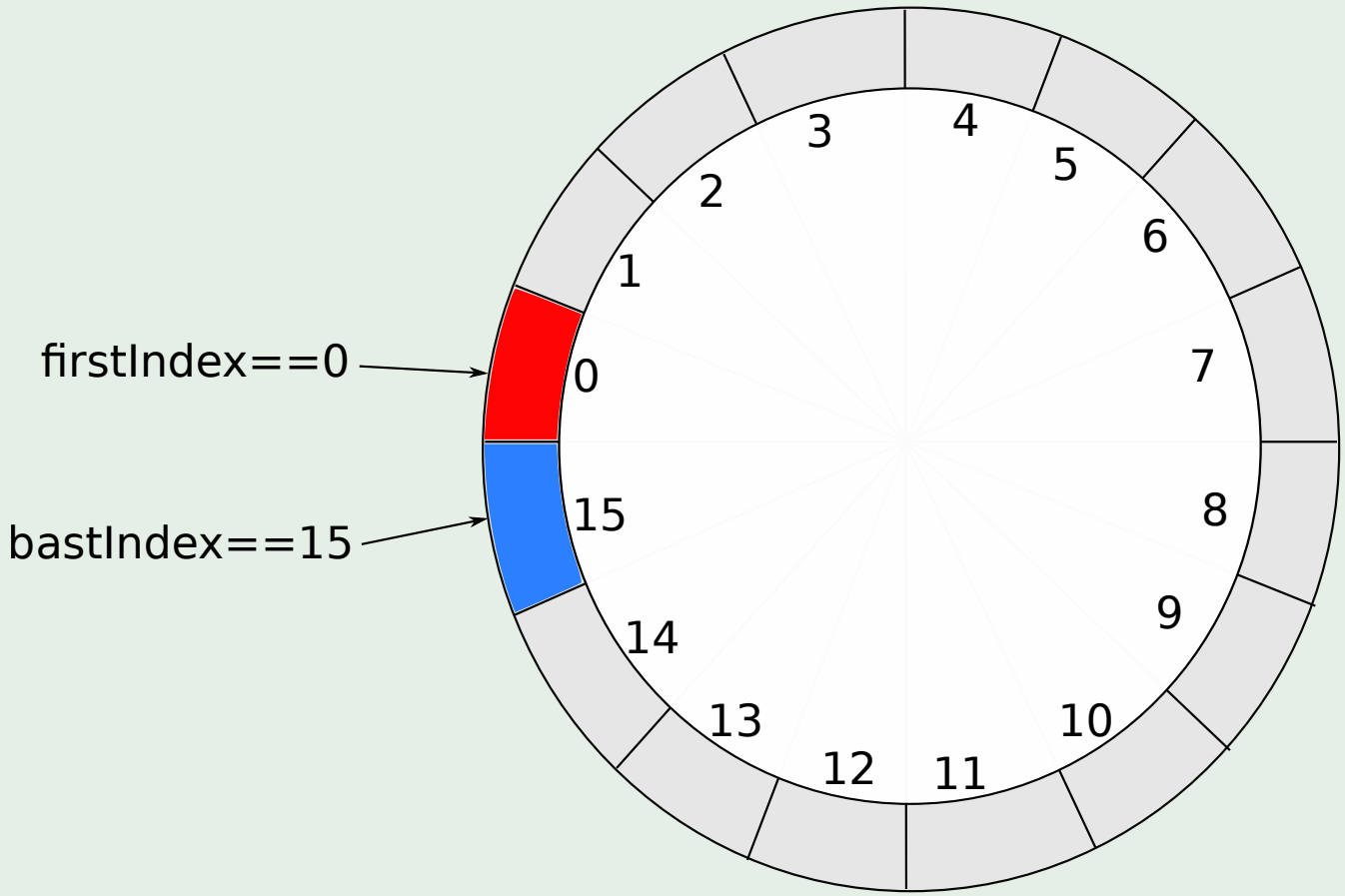
Basic Constructors

Code

```
public ArrayQueue()
{
  this(DEFAULT_INITIAL_CAPACITY);
} // end default constructor

public ArrayQueue(int initialCapacity)
{
// the cast is safe because the new
// array contains null entries
// The 1 is for empty entry
Item[] tempQueue = (Item[]) new Object[initialCapacity + 1];
queue = tempQueue;

frontIndex = 0;
backIndex = initialCapacity;

} // end constructor
```

At the Beginning

At the Instantiation of the Object Queue



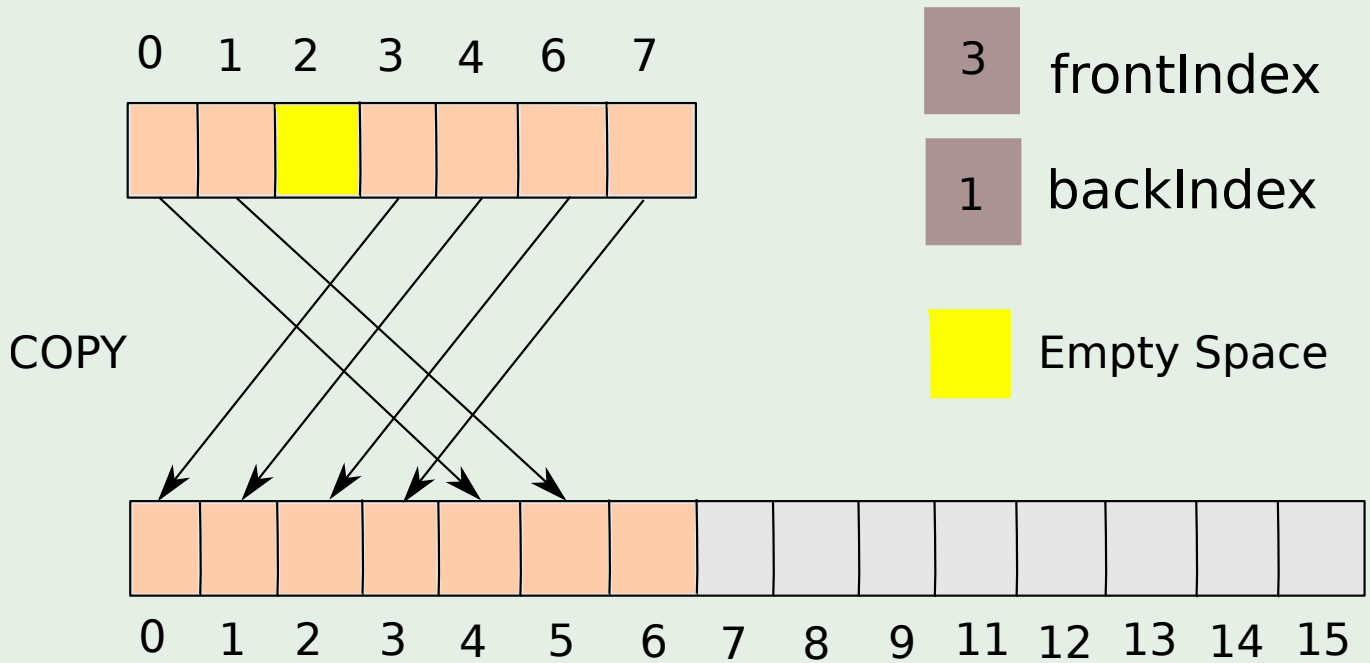
Enqueue in a circular array

Code

```
public void enqueue(Item newEntry)
{
    if (frontIndex == ((backIndex + 2) % queue.length))
    {

     <Something Here....>

    }
    backIndex = (backIndex + 1) % queue.length;
    queue[backIndex] = newEntry;

} // end enqueue
```

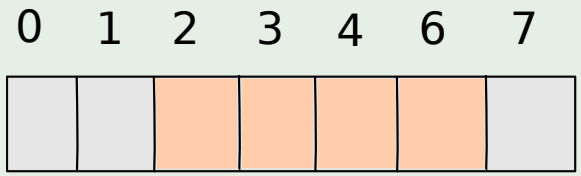
What is this "Something Here"?

Expanding Array and Copying values



Dequeue

At the beginning

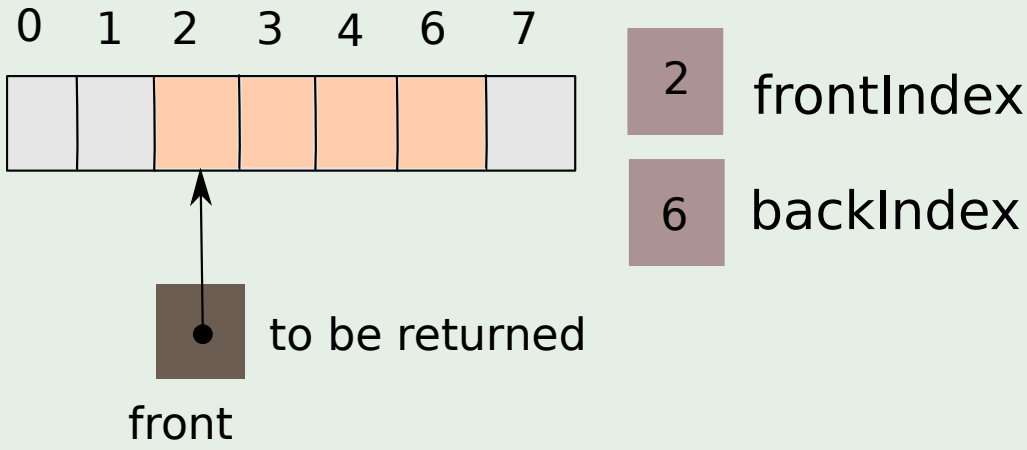


2 frontIndex

6 backIndex

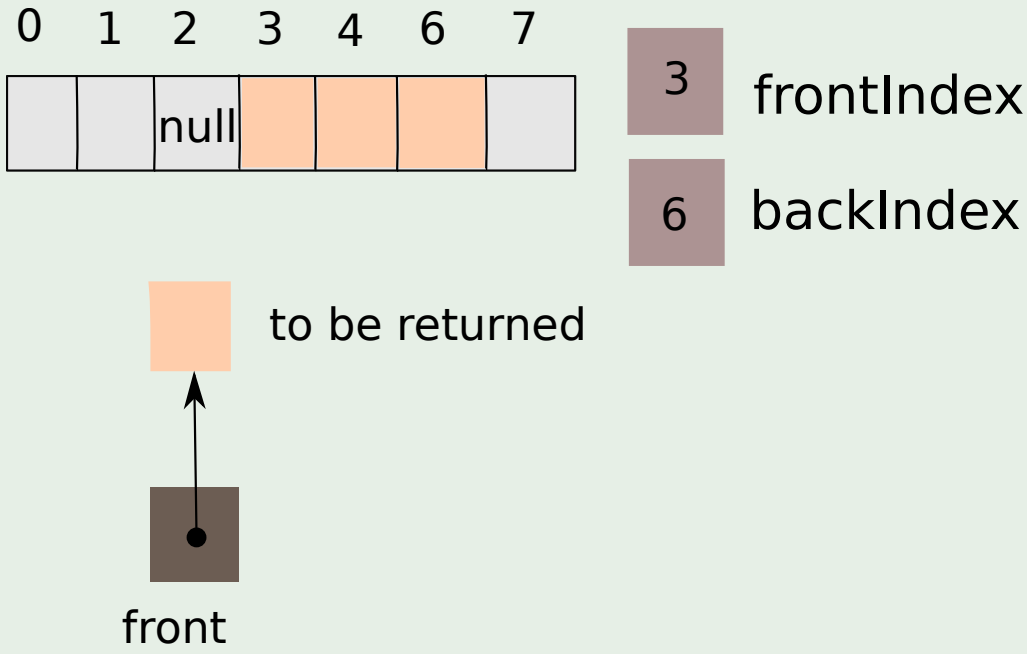
Dequeue

Use a temporary pointer "front"



Dequeue

Remove the element



Enqueue in a circular array

Code

```
public Item dequeue()
{
    Item front = null;
    if (!empty())
    {
        front = queue[frontIndex];
        queue[frontIndex] = null;
        frontIndex = (frontIndex + 1) % queue.length;
    } // End If
    return front;
} // end dequeue
```

Thus...

The Rest of Operations

You can think about them... they are not so complex...

Complexities

Operation in Scratch Queue using Chains	Complexity
empty()	O(1)
front()	O(1)
rear()	O(1)
Enqueue(TheObject)	O(1)
Dequeue()	O(1)

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