ITI 1121. Introduction to Computing II

Queue: concept

by

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Preamble

Preamble

Overview

Overview

Queue: concept

We are interested in all aspects of queues in programming. We examine several examples of their use, including resource sharing, simulation algorithms, and the breadth-first search algorithm. We will see two implementations of queues: either using circular arrays or using chained elements.

General objective :

- This week, you will be able to describe, apply, and implement a queue.

Preamble

Learning objectives

Learning objectives

- **Describe** the concept of a queue in computer science.
- **Implement** a queue using linked elements.

Lectures:

- Pages 177–189 of E. Koffman and P. Wolfgang.

Preamble

Plan

Plan

Definitions

Definitions

A **queue** is a linear **abstract data type** such that adding data is done at one end, the **rear** of the queue, and removing at the other, the **front**.

These data structures are called **FIFO**: *first-in first-out*.

$$\texttt{enqueue()} \Rightarrow \text{Queue} \Rightarrow \texttt{dequeue()}$$

The two **basic operations** are:

- **enqueue:** **adding** an item to the **rear** of the queue...,
- **dequeue:** the **removal** of the **front** element to the queue.

$\Rightarrow$ The queues are therefore data structures similar to the queues at the supermarket, bank, cinema, etc.

Abstract Data Type (ADT): Queue

```java
public interface Queue<E> {
  void enqueue(E element);
  E dequeue();
  boolean isEmpty();
}
```

Applications of queues

- Managing **shared resources**:
  - Accessing the CPU;
  - Access to a disk or other peripherals, e.g. printer;
- **Algorithms** based on queues:
  - Simulations;
  - Breadth-first-search.

Example

```
public class Test {
    public static void main(String[] args) {

        Queue<Integer> q;
        q = new LinkedQueue<Integer>();

        for (int i=0; i<10; i++) {
            q.enqueue(Integer.valueOf(i));
        }

        while (! q.isEmpty()) {
            System.out.println(q.dequeue());
        }

    }
}
```

- **Prints?** 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

```
q = new LinkedQueue();
q.enqueue(a);
q.enqueue(b);
q.enqueue(c);
q.dequeue();
-> a
q.dequeue();
-> b
q.enqueue(d);
q.dequeue();
-> c
q.dequeue();
-> d
```

- The elements are processed in the same order as they were inserted in the queue, here the element **a** is the first to join the queue and it is also the first to leave the queue (***first-come first-serve***).

Implementation

Implementation

Like stacks, there are two families of implementations:

- **Linked lists**;
- **With the help of an array**.

Implementation using linked elements

```
public class LinkedQueue<E> implements Queue<E> {

    public boolean isEmpty() { ... }
    public void enqueue(E o) { ... }
    public E dequeue() { ... }

}
```

Implementation

Elem

Implementation using linked elements

```
public class LinkedQueue<E> implements Queue<E> {

    private static class Elem<T> {
        private T value;
        private Elem<T> next;
        private Elem(T value, Elem<T> next ) {
            this.value = value;
            this.next = next;
        }
    }

    public boolean isEmpty() { ... }
    public void enqueue(E o ) { ... }
    public E dequeue() { ... }
}
```

Implementation

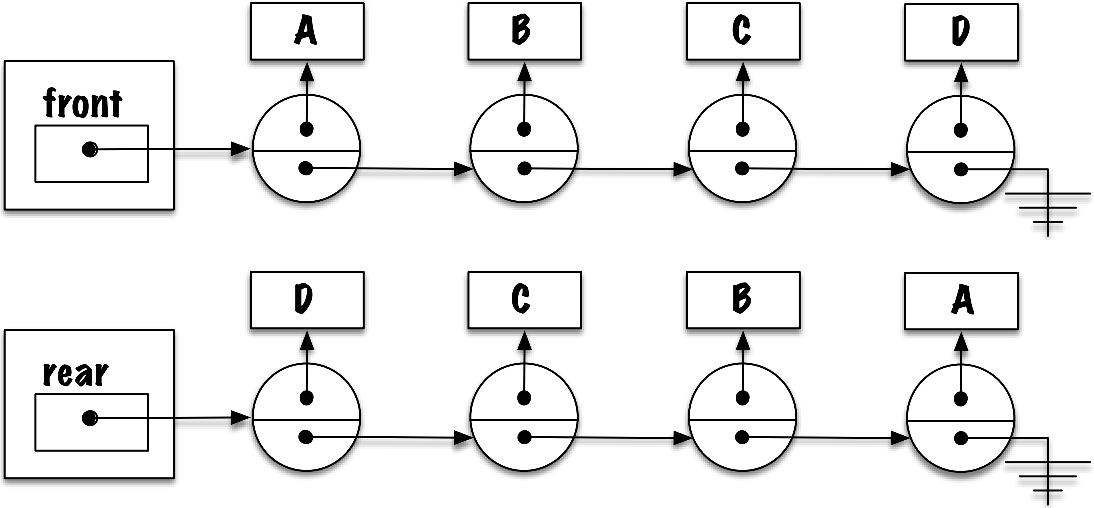
Instance variables

Implementation using linked elements

```
public class LinkedQueue<E> implements Queue<E> {

    private static class Elem<T> {
        private T value;
        private Elem<T> next;
        private Elem(T value, Elem<T> next) {
            this.value = value;
            this.next = next;
        }
    }

    private Elem<E> front; // rear?

    public boolean isEmpty() { ... }
    public void enqueue(E o) { ... }
    public E dequeue() { ... }
}
```

Implementation using linked elements

Which representation do you think is **preferable** and **why**?



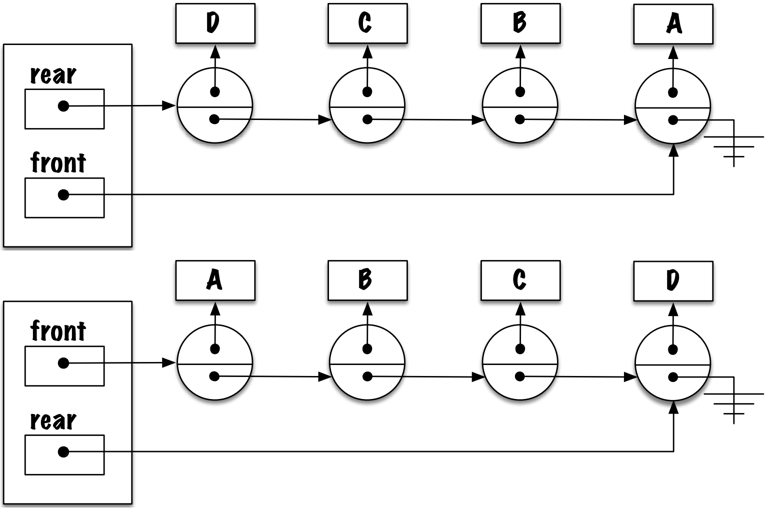
Discussion

- If we choose the first implementation, then the **removal** of an element will be easy (and **fast**) but the **adding** at the rear of the queue will be difficult (and **slow**).
- The other implementation just reverses the situation, the **removal** becomes **costly** while **adding** is **fast**.
- **Is it a dead end?**
- **What is needed to facilitate removal?**
- **What is needed to facilitate adding?**

Implementation using linked elements

Implementation using linked elements

- Will these two implementations be equally **efficient**?



Discussion

- What will be the **impact** of this change?
  - The amount of extra **memory** is **negligible**.
  - The **implementation** of the methods will be **more complex**.

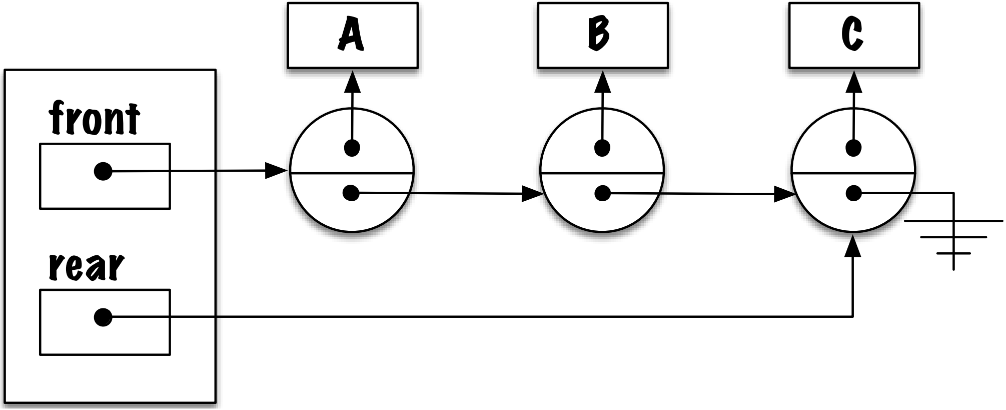
Implementation

Methodology

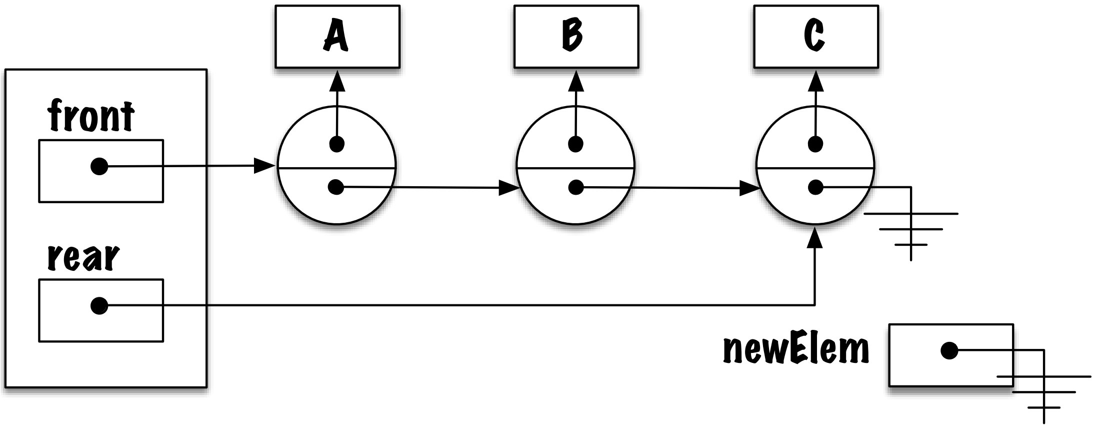
Methodology

- Identify the **general case** as well as the **special case**.
- **General case**, consider a sufficient number of elements so that it represents the majority of the cases.
- **Special cases** are cases where the strategy employed for the general case would not work.
- Queues, stacks, and lists that are **empty** or that have **an element** are often the special cases.

Adding an element (general case)

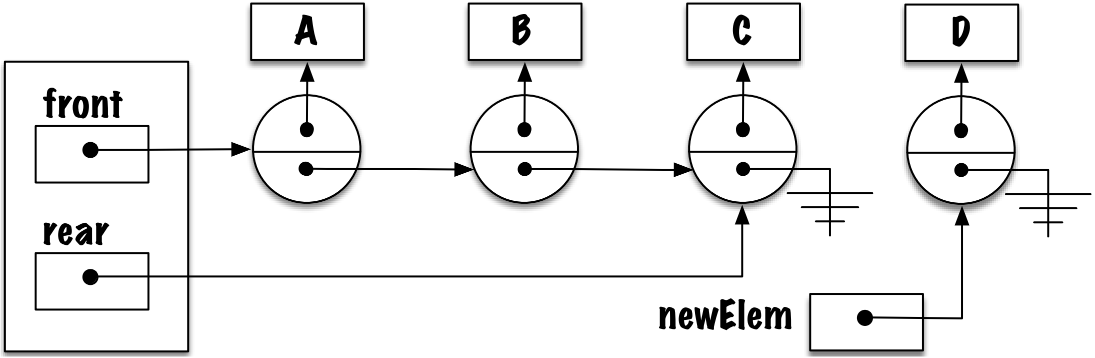


Adding an element (general case)



The use of a **local variable** will make the job easier.

Adding an element (general case)



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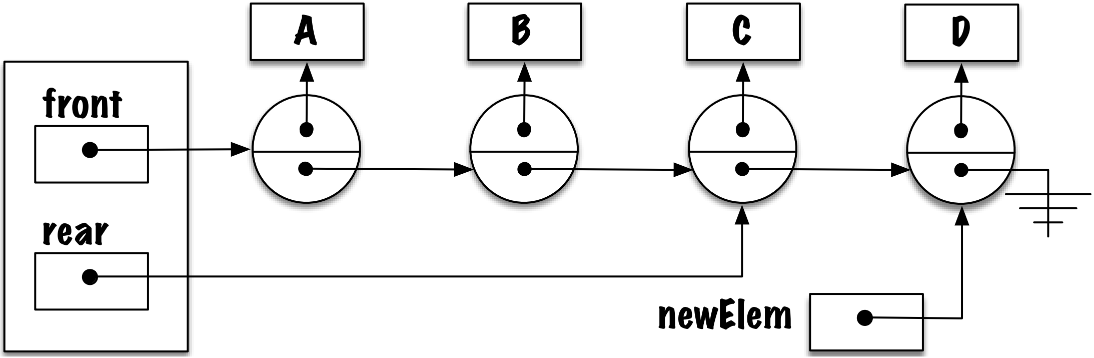

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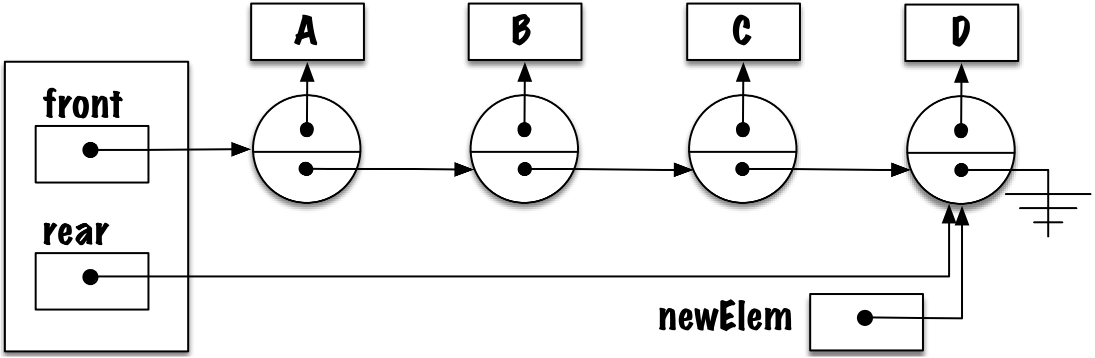

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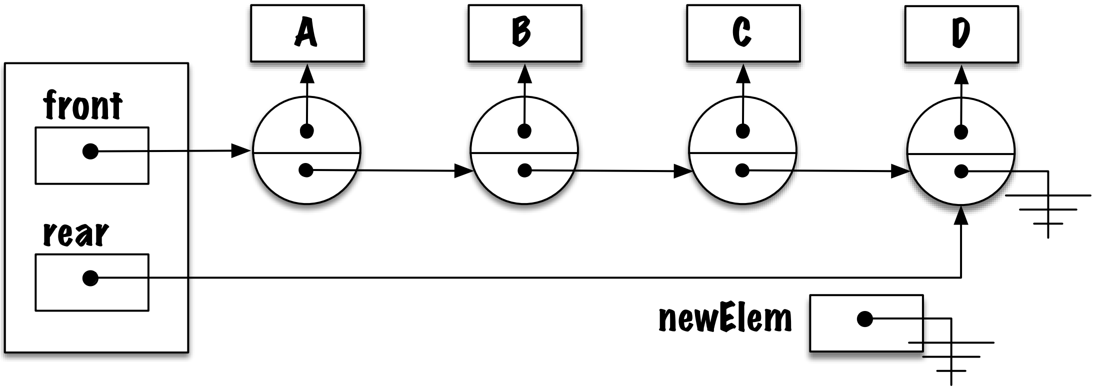

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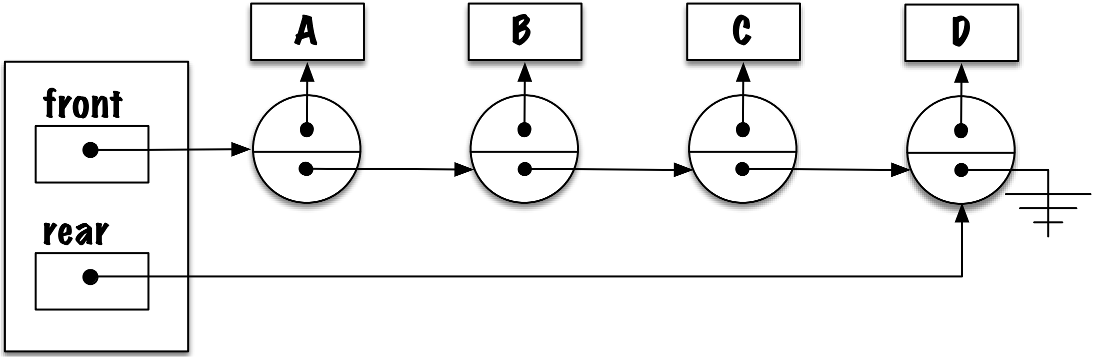
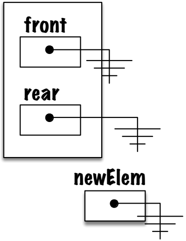


Adding an element (special case)

Draw the **memory diagram** representing the **empty** queue.

- What **expression** is used to identify the **empty queue**?

Adding an element (special case)



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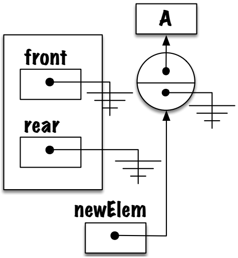

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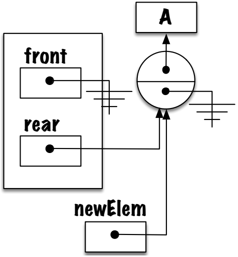

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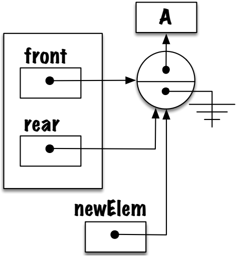

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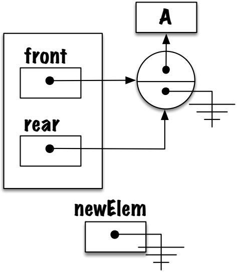

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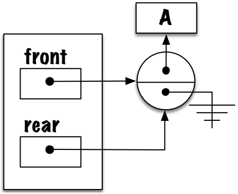
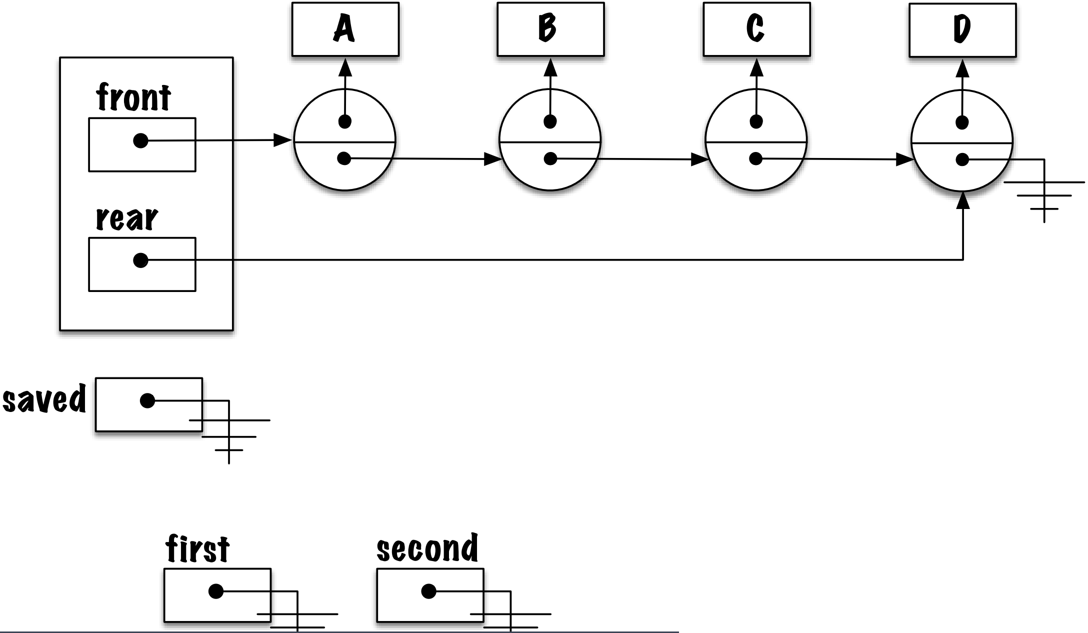


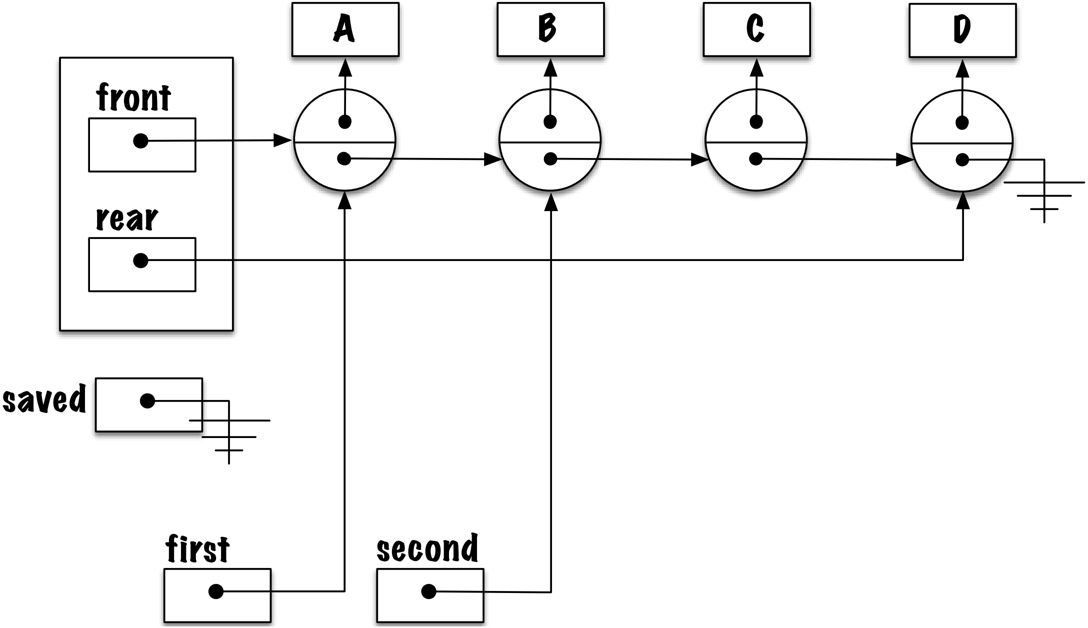
Methodology: removing an element

- Identify the **general case** as well as the **special case(s)**.
- Is the **empty queue** a **special case**?
  - **No**, this is a **illegal** case, for which we'll need to **throw an exception**.
- The queue containing **only one element** is the **special case**.

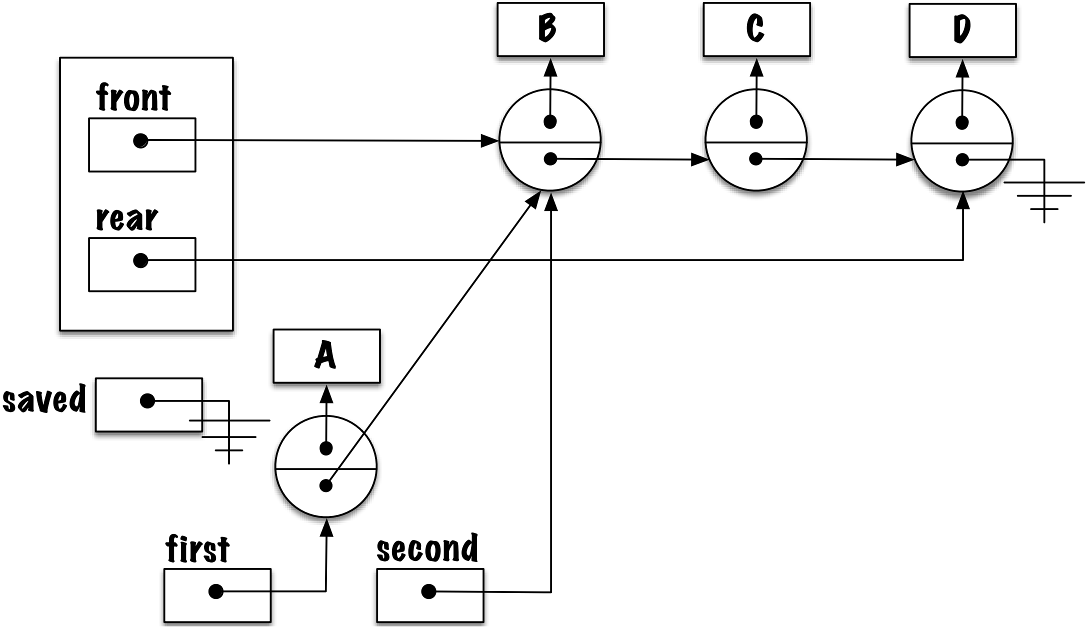
Removal of an element (general case)



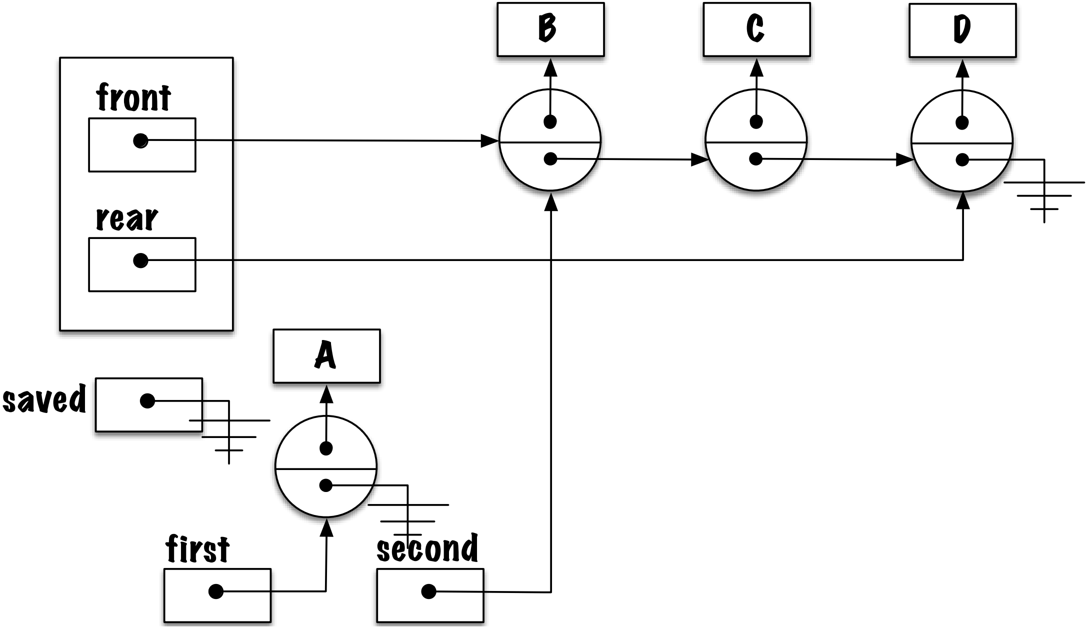
Removal of an element (general case)



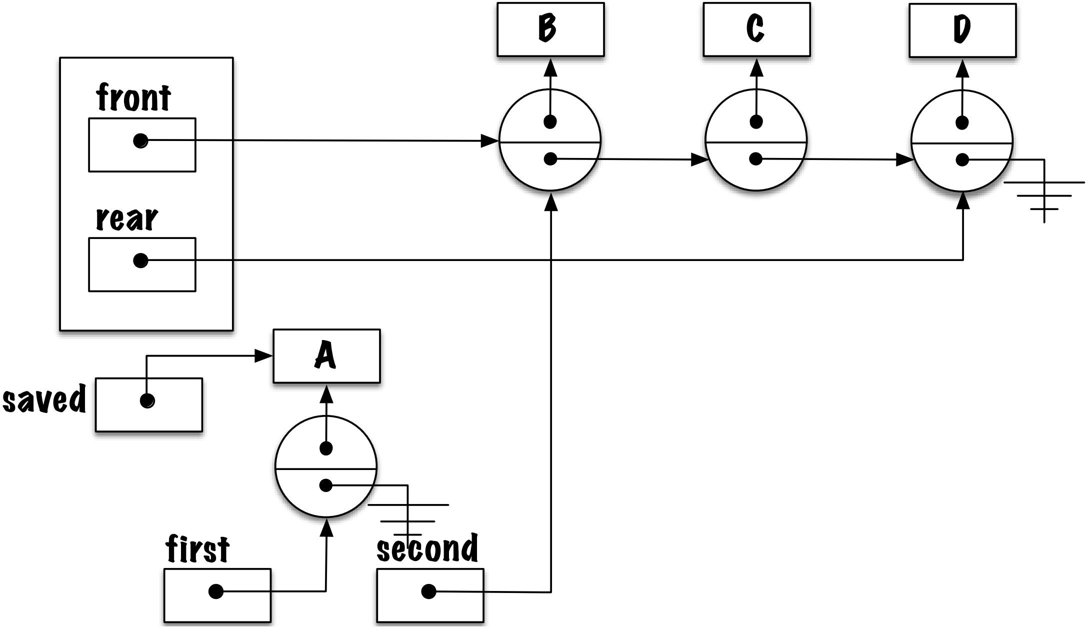
Removal of an element (general case)



Removal of an element (general case)



Removal of an element (general case)



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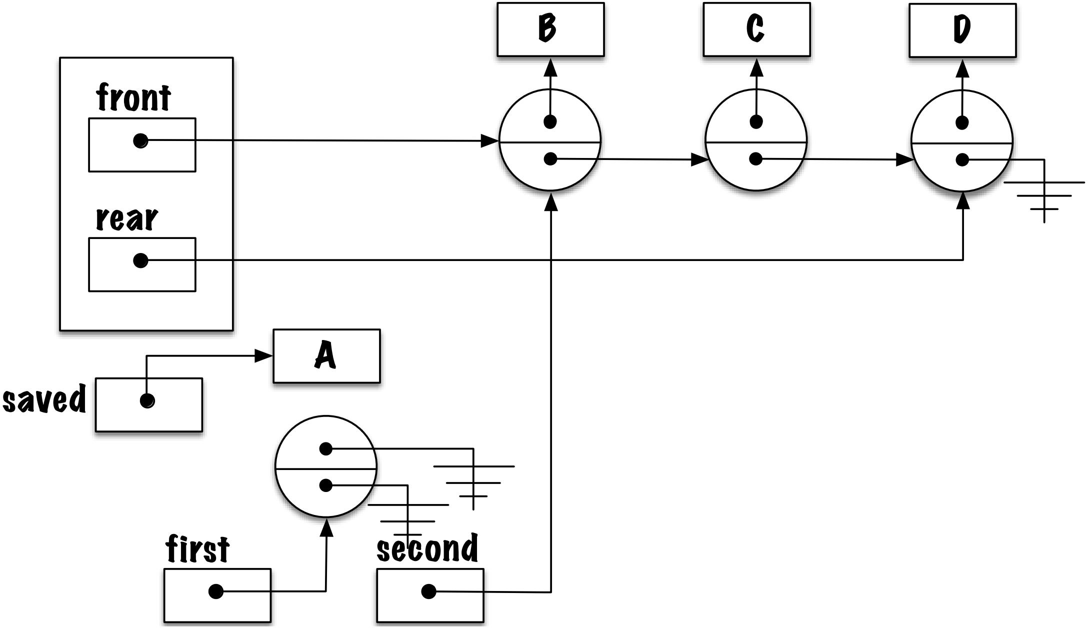

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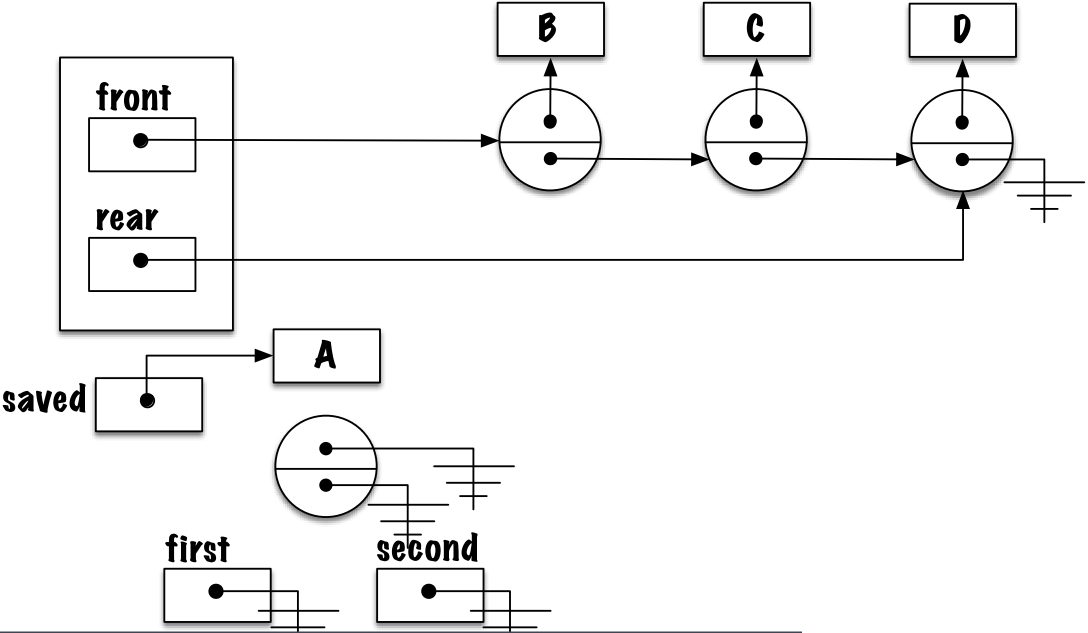
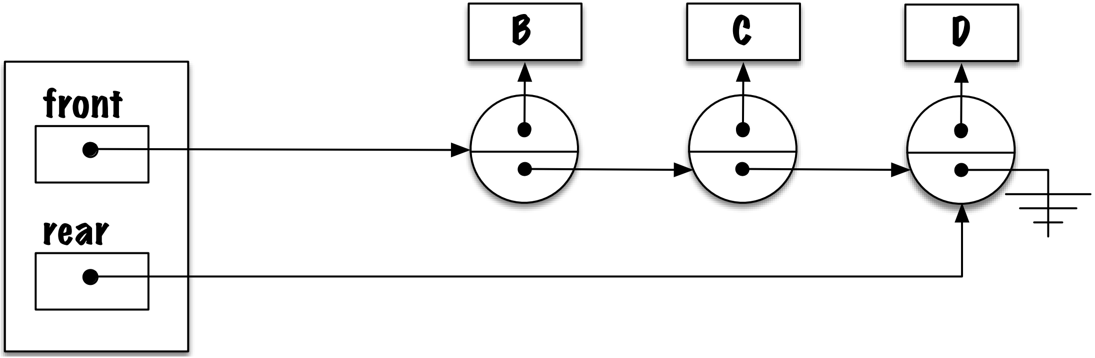
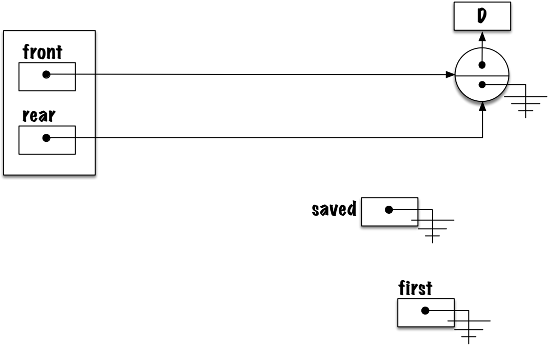


Removal of an element (general case)



Removal of an element (special case)

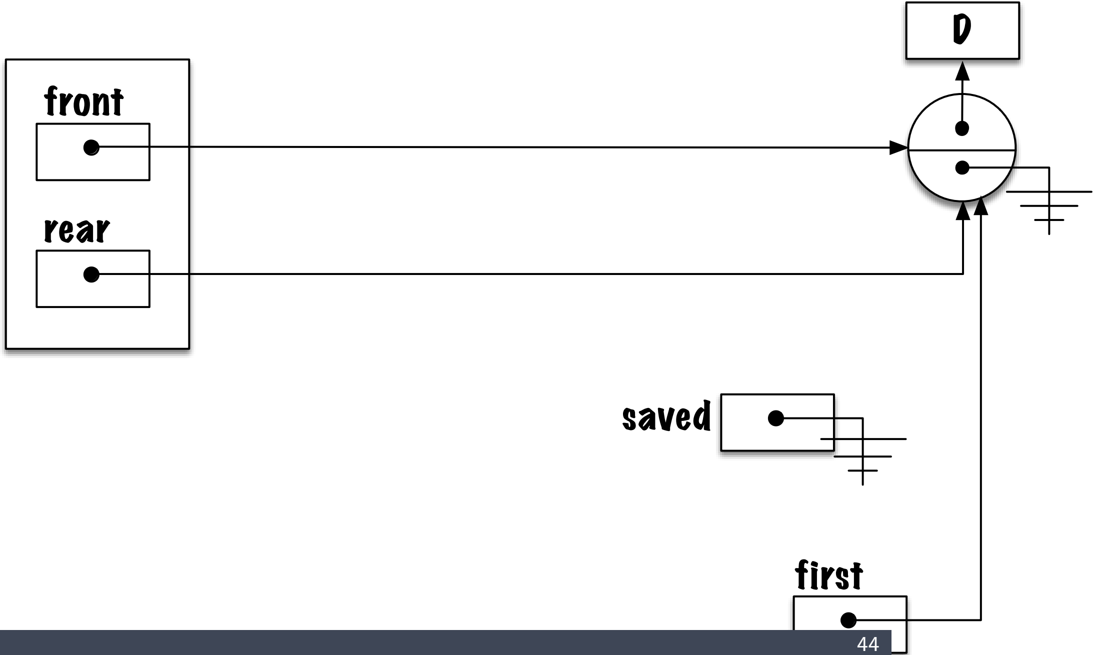


- What **expression** can be used to recognize a queue containing **only one element**?
  - **what do you think** of the following?

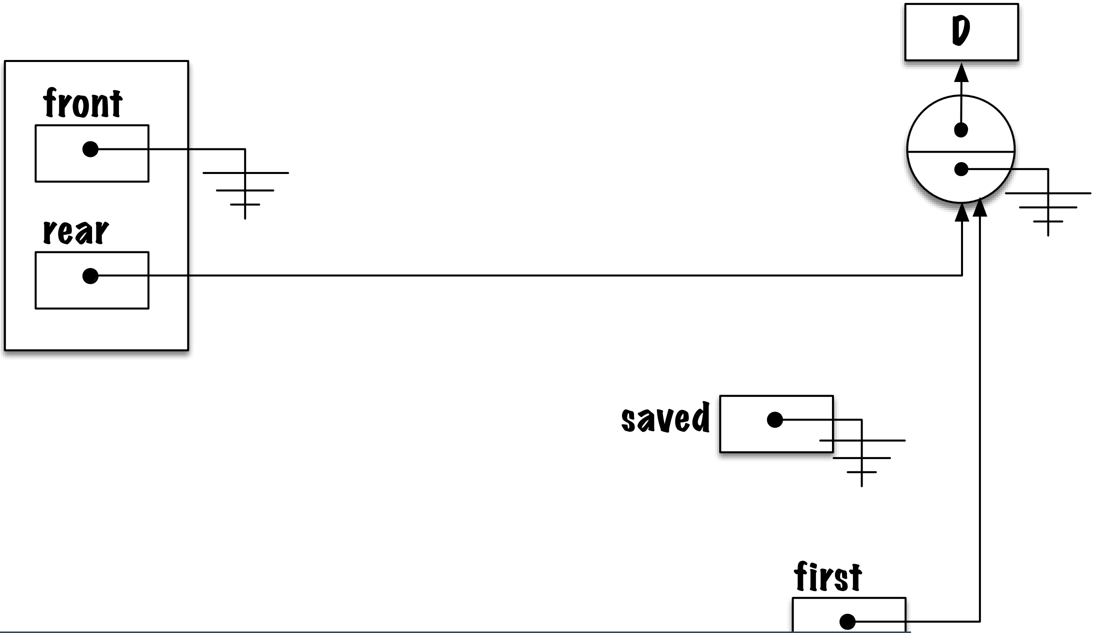
```
front == rear
```

Removal of an element (special case)

Removal of an element (special case)



Removal of an element (special case)



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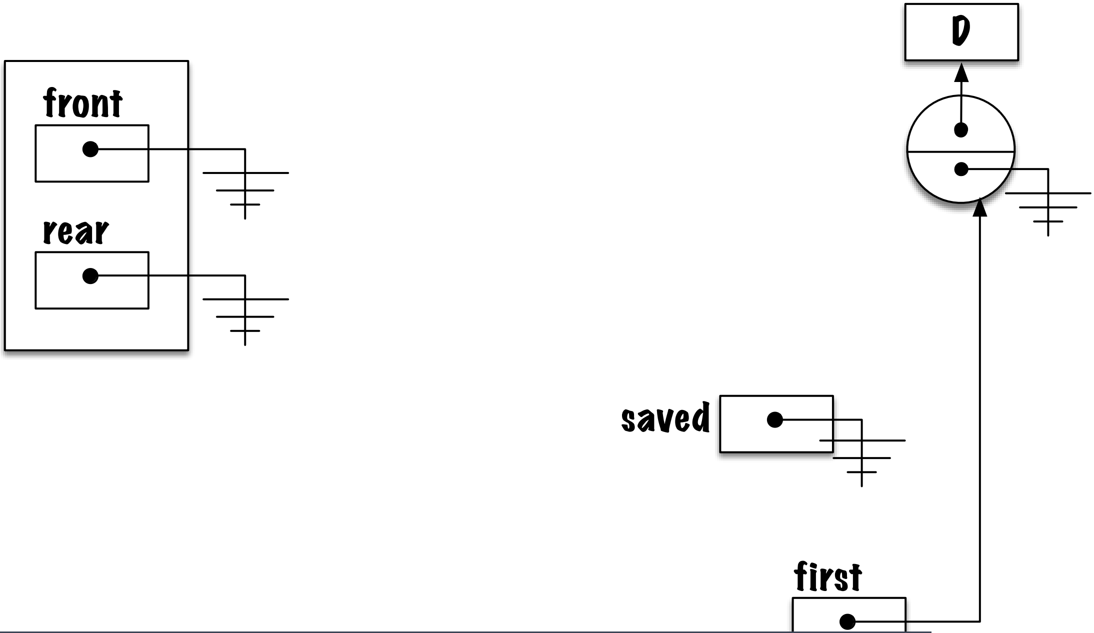

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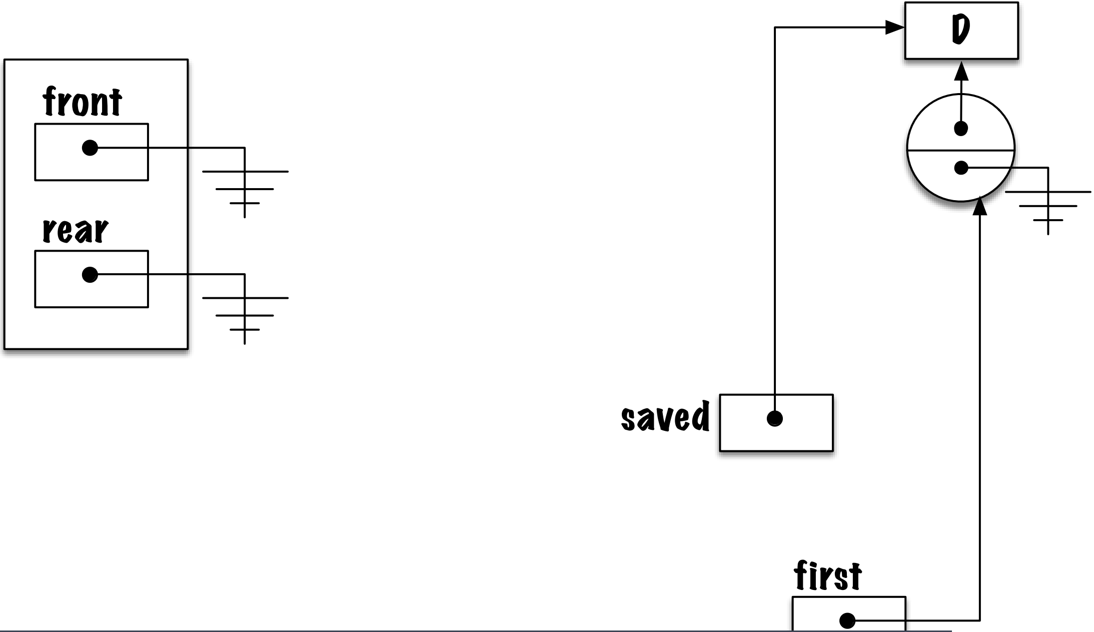

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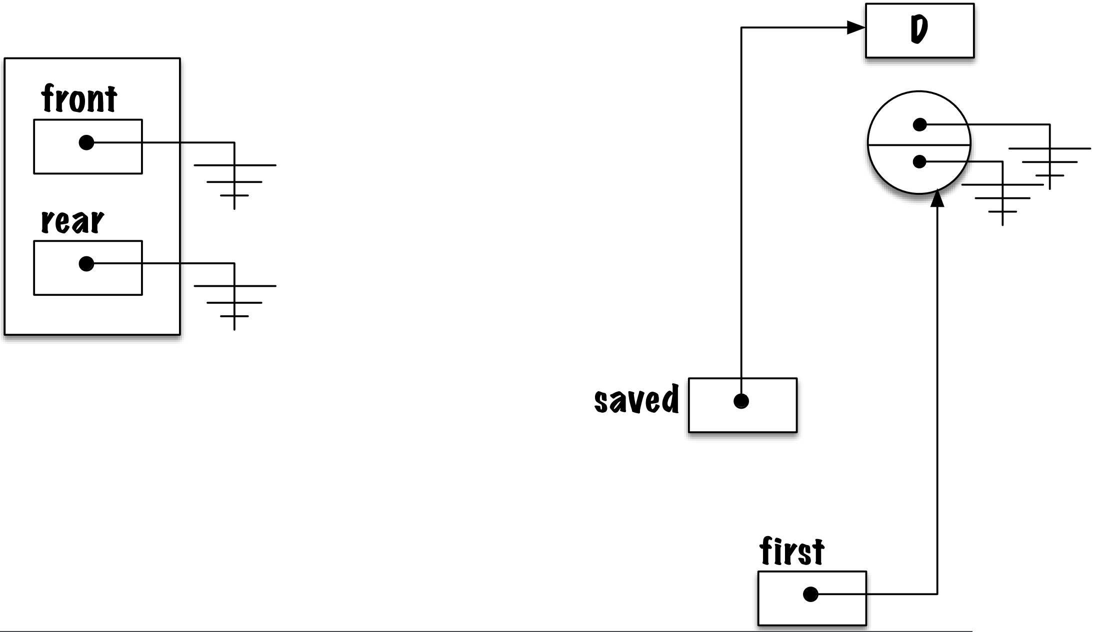

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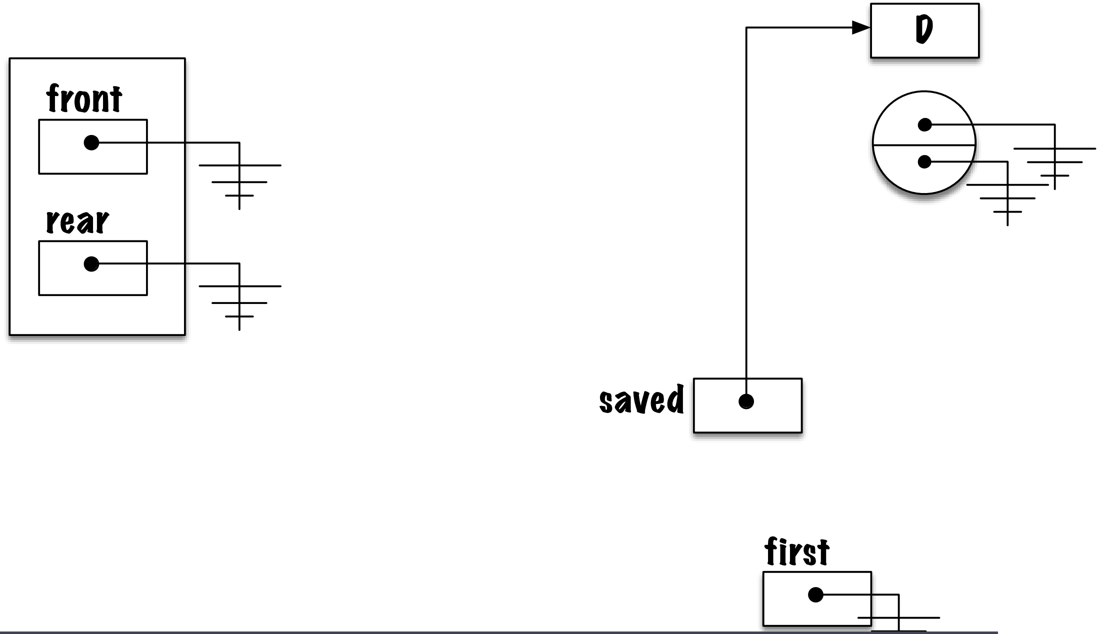

Piège

Pitfall!

- Here's a common problem. The **link to the rear element hasn't been severed**.
- What **kinds of problems** might arise?
- **What will happen** if we use the following expression to detect the empty queue? `front == null && rear == null`.

Prologue

Summary

- A **queue** is a linear **abstract data type** such that adding data is done at one end, the **rear** of the queue, and removing at the other, the **front**.
- The **linked implementation** requires a reference to the **front** element as well as the **rear** element.

Next module

- **Queue** : applications

References I

E. B. Koffman and Wolfgang P. A. T.
***Data Structures: Abstraction and Design Using Java*.**
John Wiley & Sons, 3e edition, 2016.

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