Abstract Data Types - Lists
Arrays implementation
Linked-lists implementation

Lecture 16

Jérôme Waldispühl

School of Computer Science

McGill University

Slides by Mathieu Blanchette

Recap from last lecture

- ADT: Model of a data structure that specifies:
  - The type of data stored
  - The operations supported on that data
- Application to lists (sequence of objects)
- We reviewed 2 types of implementations
  - Array-based implementation
  - Single-linked lists

Operations on list ADT

- getFirst() : returns the first object of the list
- getLast() : returns the last of object of the list
- getNth(n): returns the n-th object of the list
- insertFirst(Object o) : adds o at the beginning of the list
- insertLast(Object o): adds o the end of the list
- insertNth(n, o): adds the n-th object of the list by o
- removeFirst(): removes the first object of the list
- removeLast(): removes the last object of the list
- removeNth(n): removes the n-th object of the list
- getSize(): returns the number of objects in the list
- concatenate(List l): appends List l to the end of this list

Array-based list ADT

- An 1D array L to store the elements of the list
- An integer size to record the number of objects stored.

L:	O	G	C	N	Ø
	0	1	2	3	4

size = 4

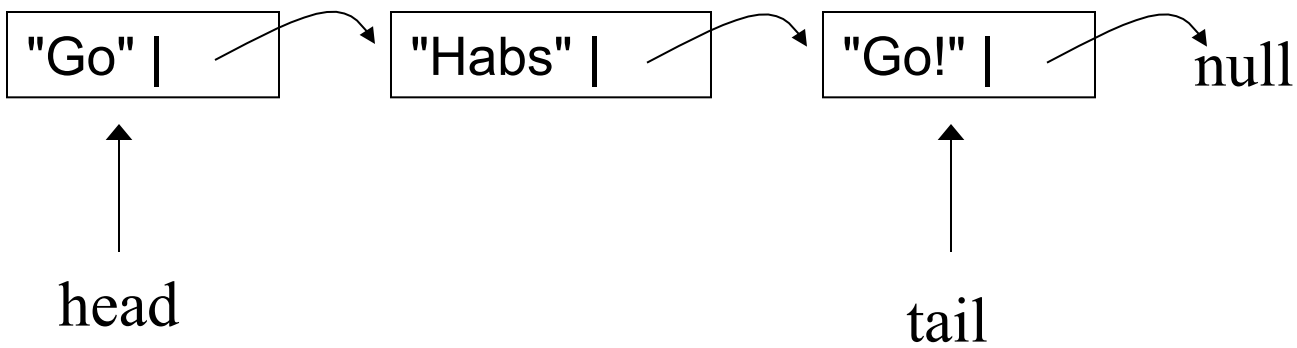
+ Easy to implement
+ Space efficient
- the number of objects to be stored in not known in advance
- the user will need to do a lot of insertions or removals

Linked-list implementation

- Linked-list: Sequence of nodes. Each node stores some data and knows the next node in the list.
- A linked-list is a recursive data structure!

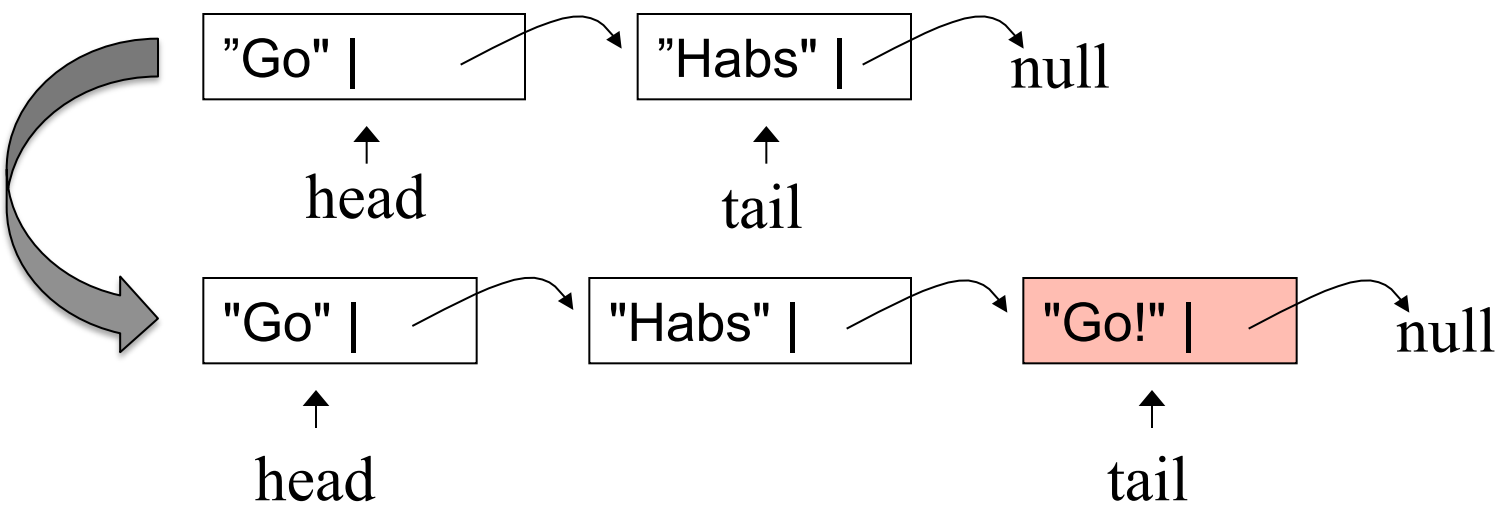
- Node: Value | Next

- List:



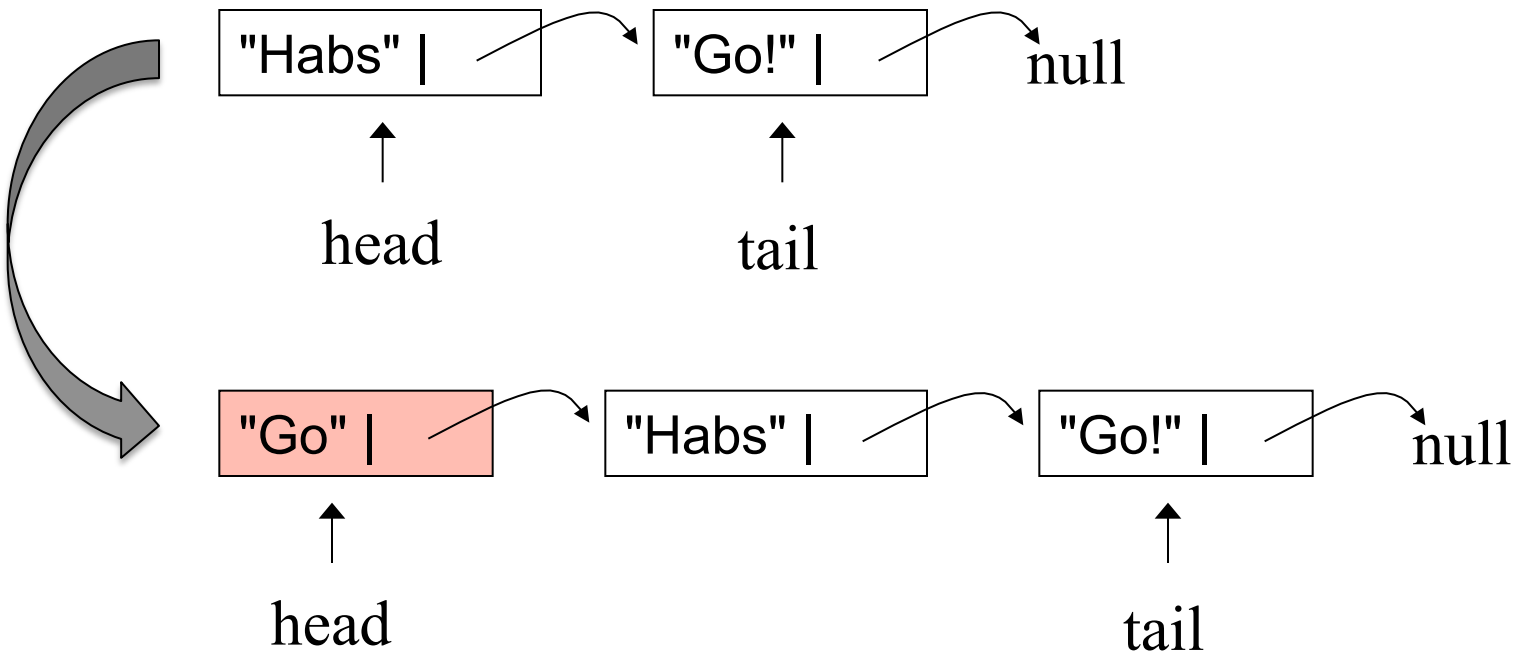
```
/* Add an object at the tail of the list */
    void addLast(Object x) {
        if ( tail == null ) {    // list is empty
            tail = head = new node(x, head);
         }
        else {
            tail.setNext( new node(x,null) );
            tail = tail.getNext();
        } }
```

Example: addLast(“Go!”)



```
/* Add an object at the head of the list */
    void addFirst(Object x) {
        head = new node(x, head);
        if (tail == null) tail = head;
    }
```

Example: addFirst(“Go”)

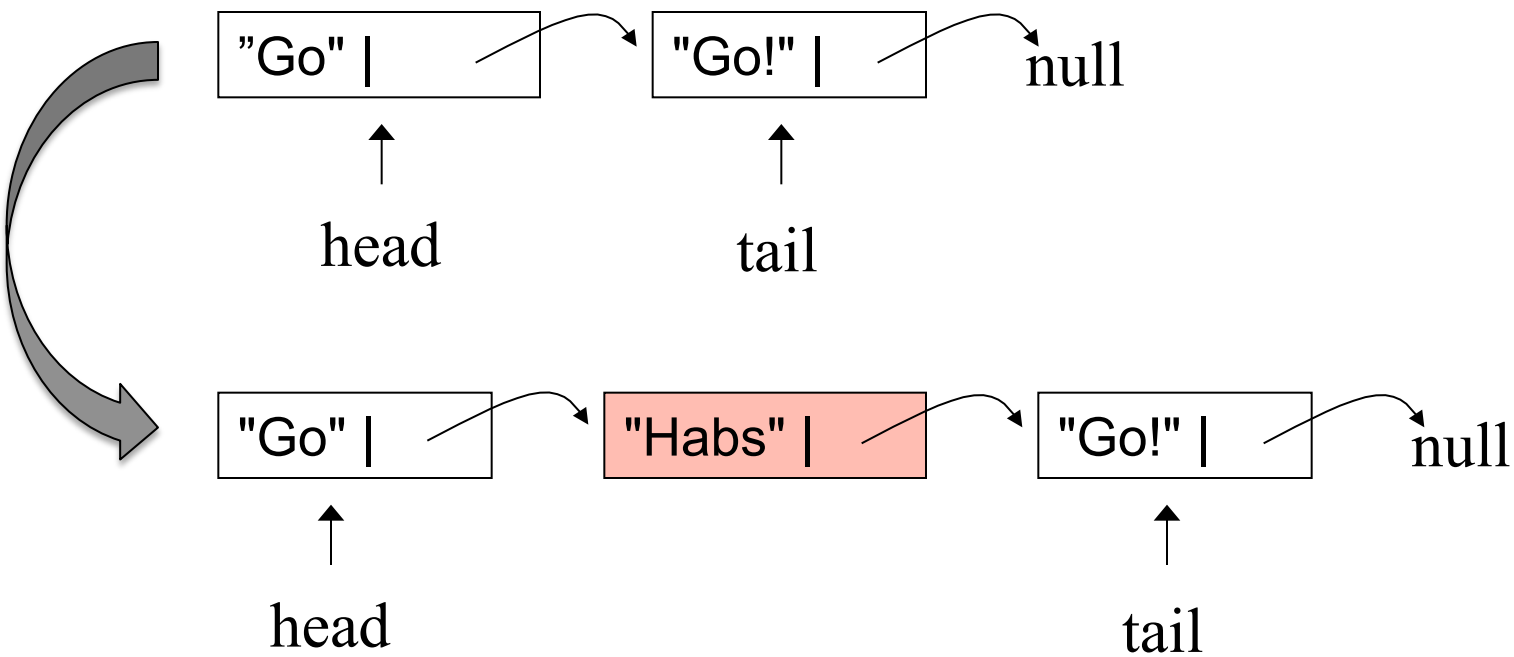


insertNth(n,Object x) is more complicated…

Why? How to code it?

We will come back on that a bit later…

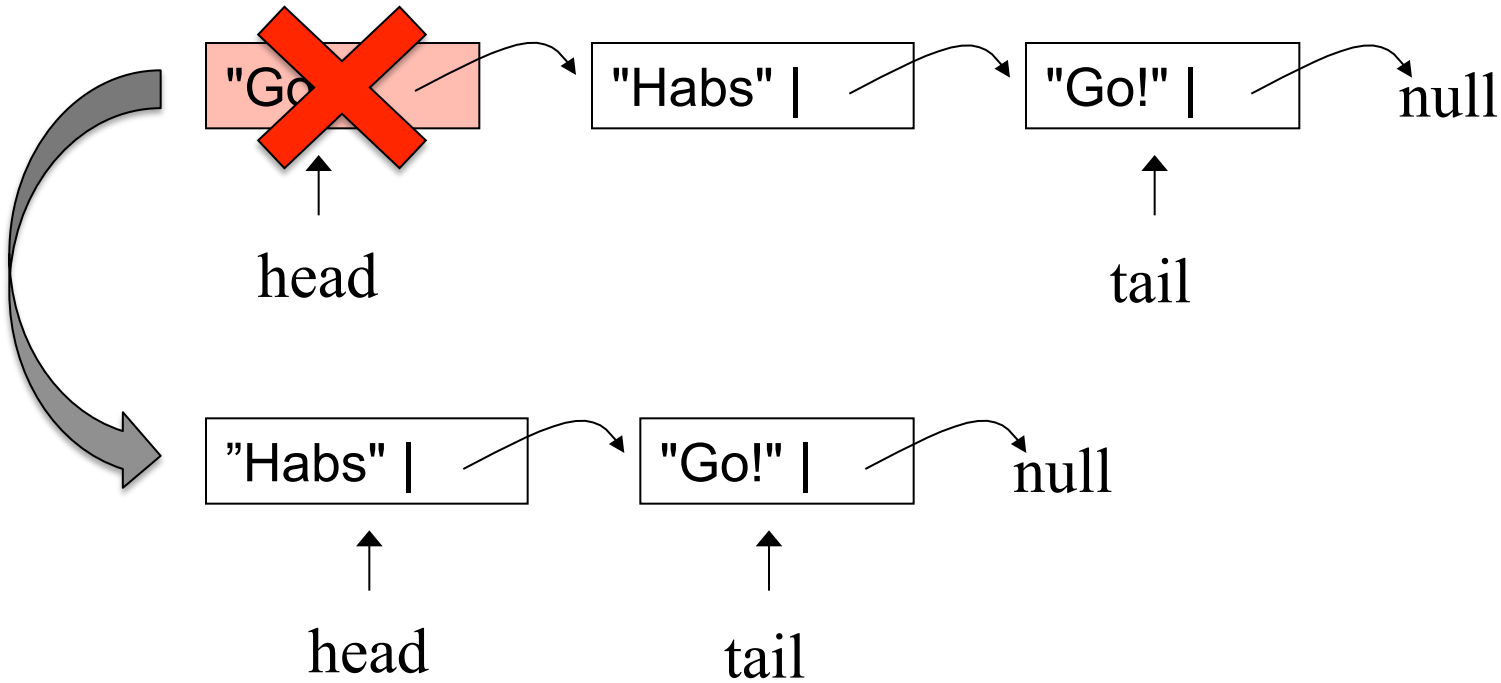
Example: insertNth(1,“Habs”)



Example of utilization of linkedList

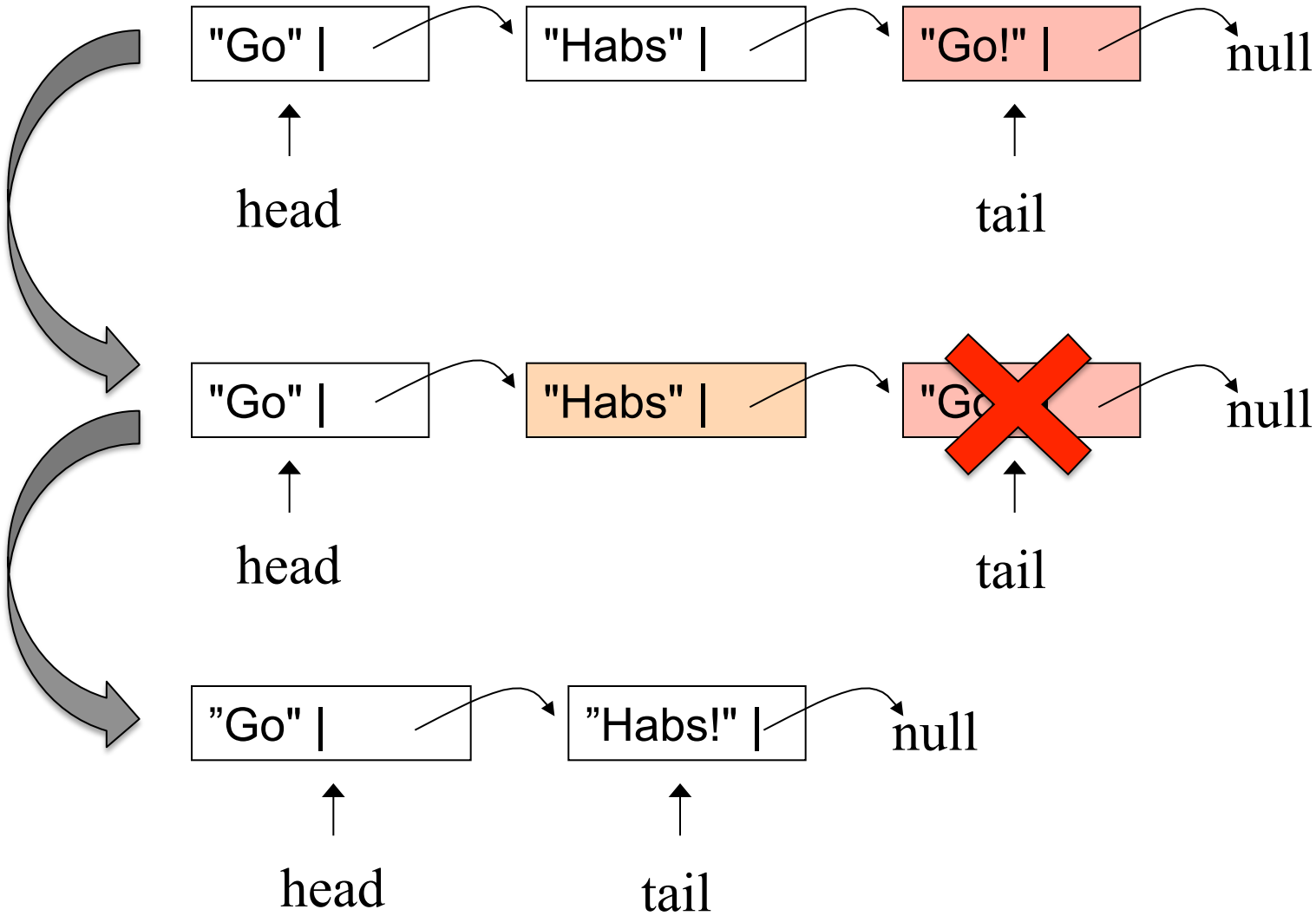
```
public class testLists {

    public static void main(String args[])  {

        linkedList l = new linkedList(); // the list is empty for now
        l.addFirst("Roses");
        l.addLast(”are");
        l.addLast(“red”);
        System.out.println( l.getFirst() ); // prints Roses
        System.out.println( l.getLast() ); // prints red

        ...
```

Example: removeFirst()



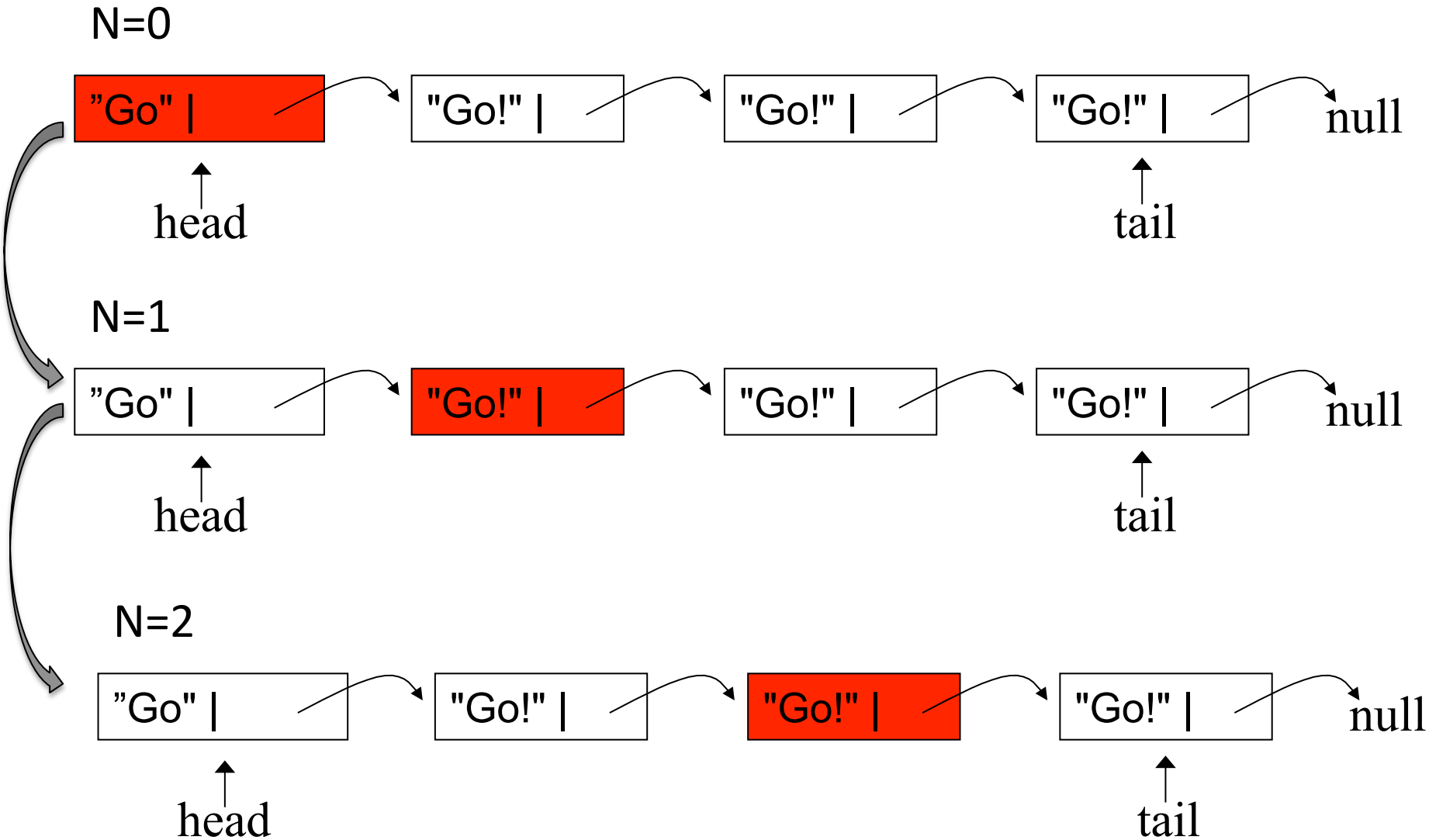
```
class linkedList {
  node head, tail;
  ...  // see previously defined methods
  removeFirst() {   // You do it!
      if (head==null) return false;   // the list was already empty
      head = head.getNext();
  }
  removeLast() {   // You do it!





  }
```

Example: removeLast()



```
class linkedList {
  node head, tail;
  ...  // see previously defined methods
  removeFirst() {   // You do it!
      if (head==null) return false;   // the list was already empty
      head = head.getNext();
  }

  removeLast() {   // You do it!

      if (head==null) return false;   // the list was already empty
      node newtail = head;
      while (newtail.getNext()!=tail) { newtail = newtail.getNext(); }
      newtail.setNext(null);
      tail = newtail;

  }
```

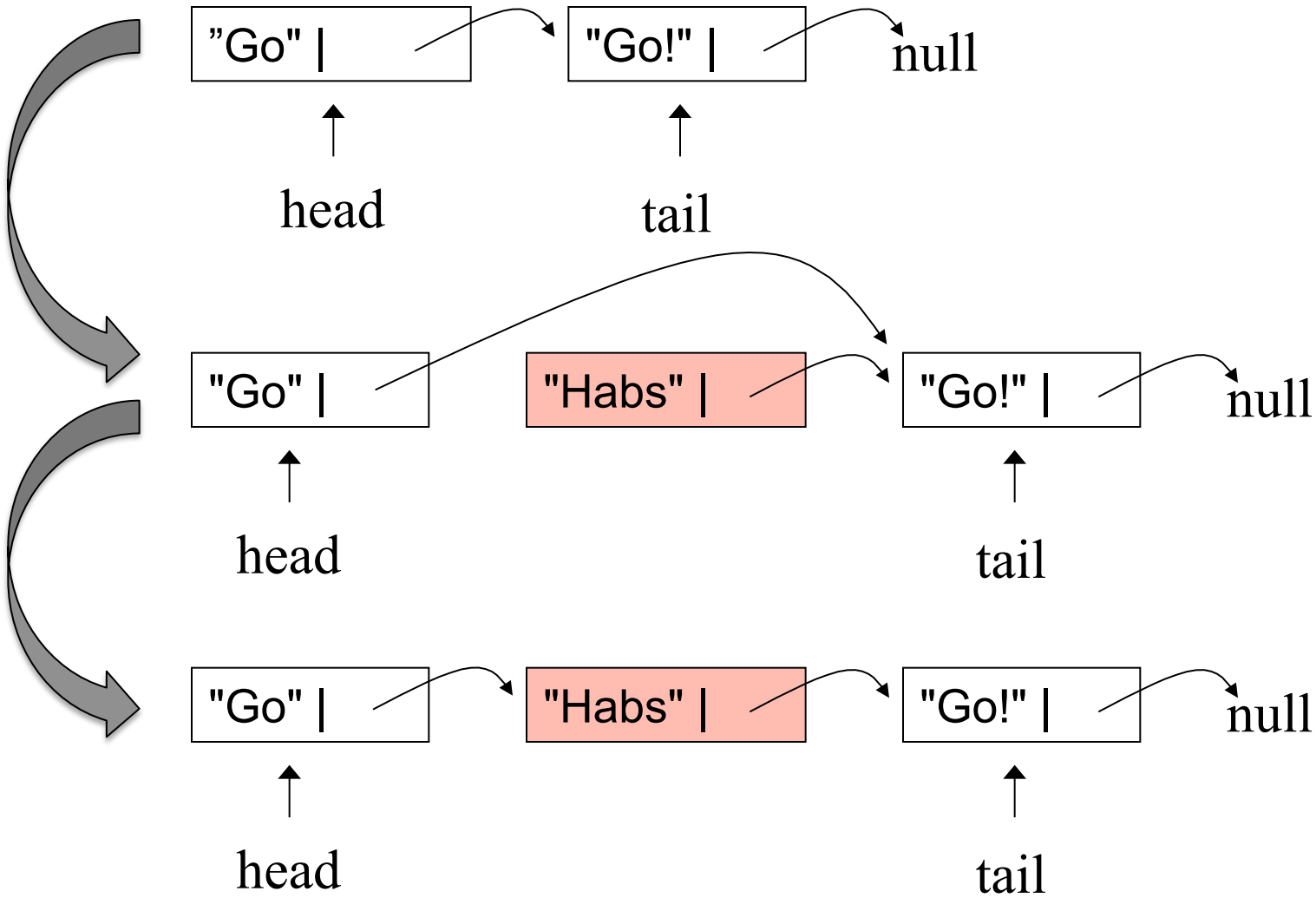
Example: getNth(2)



```
/*Returns the first element of the list */

Object getFirst() {
    if (head==null) throw new Exception("getFirst: List empty!");
    return head.getValue();
}

/* Returns the n-th elements of the list */
/* Runs in time O(n) */

Object getNth(int n) throws IndexOutOfBoundsException {
    if (n>=size()) throw new IndexOutOfBoundsException(”n is too big!");
   node current=head;
   while (n>0) {
      current = current.getNext();
      n--;
    }
    return current;
}
```

Browse all nodes from head to n in order to find the desired node.

Example: insertNth(1,“Habs”)



```
/* insert Object at the n-th position of the list */
/* Runs in time O(n) */
boolean insertNth(int n, Object x) throws IndexOutOfBoundsException {
    if (n>=size()) throw new IndexOutOfBoundsException("n too big!");
    node predecessor = head;
    while (n>1) {
        predecessor = predecessor.getNext();
        n--;
    }

    node newelem = new node(x, predecessor.getNext() );

    predecessor.setNext( newelem );

    return true;

}
```

Visit the (n-1)-th first nodes in order to find the predecessor of n-th

Examples of utilization

```
public class testLists {
    public static void main(String args[]) throws Exception {
        /* after the code listed before */
          System.out.println("The size is " + l.size());
```

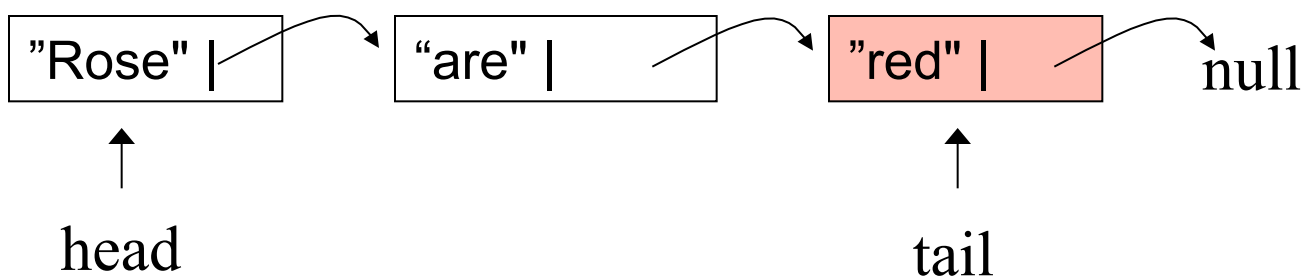
The size is 3

```
        /* Since the get* methods return an Object, it needs to be cast
           to the correct type */
          String s = (String) l.getFirst();
          System.out.println( "The zero-th element is " + s );
```

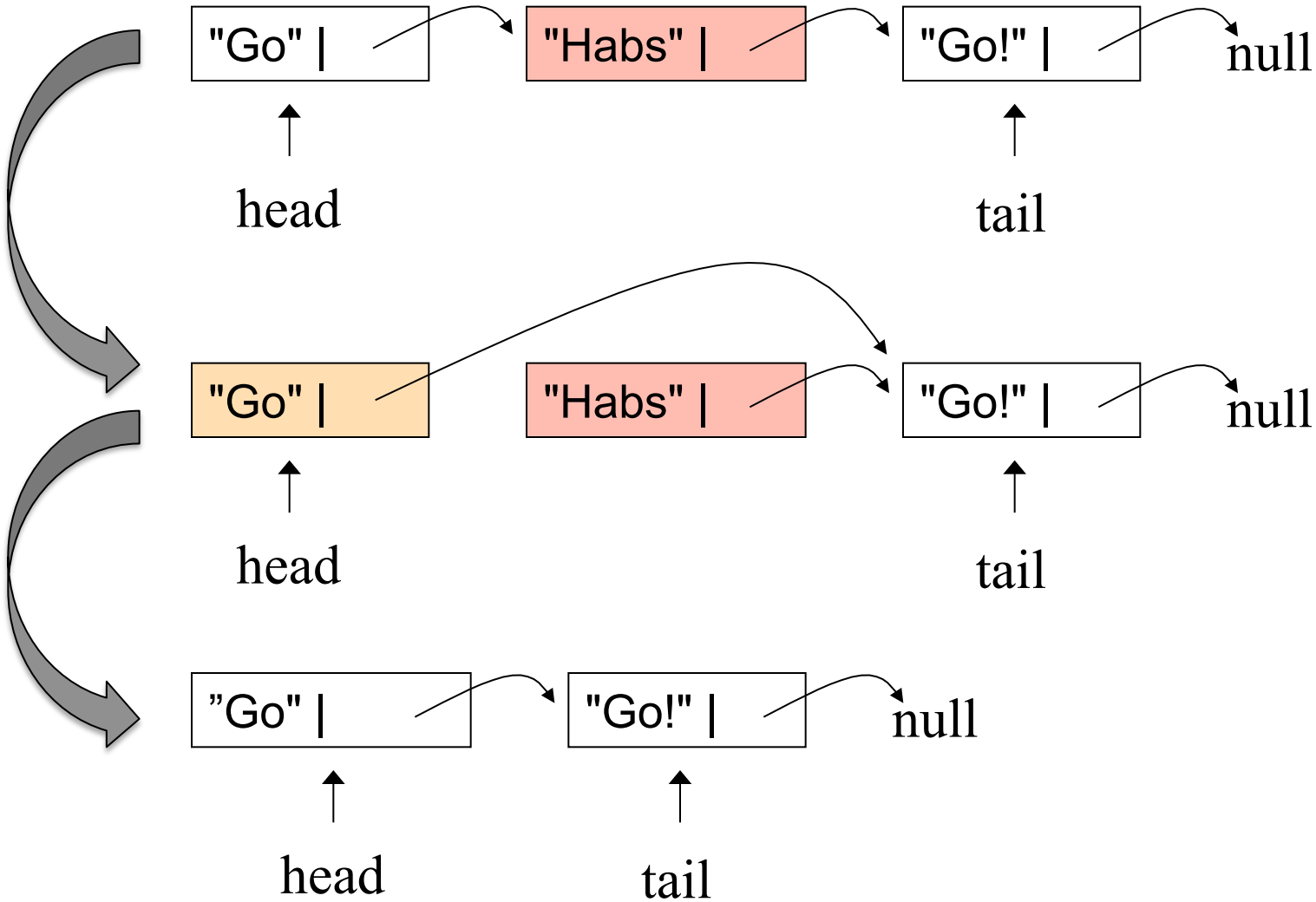
The zero-th element is Rose

```
          System.out.println( "The second element is " + l.getNth(1) );
    }
}
```

The second element is are



Example: remove(“Habs”)



```
/* Removes from the list the first occurrence of object x. Returns true if x was
   removed. */
boolean remove(Object x) throws NoSuchElementException {
    if (head==null) throw new NoSuchElementException("List is empty!");
    if (head.getValue().equals(x)) {
      head=head.getNext();
        if (head==null) tail=null;
        return true;
    }
    node current = head;
    while (current.getNext()!=null &&
                        !current.getNext().getValue().equals(x))
      current = current.getNext();
    if (current.getNext()==null) return false;
    else {
        current.setNext(current.getNext().getNext());
        if (current.getNext()==null) tail=current;
    }
    return true;
}
```

Is the list empty?

Check first element. Remove and return true if object == x

Not found. Return false.

Scan items. Stop iff object == x or all items are scanned. Remove object from list and return true.

Next Lectures

- **Stack ADT**: list that allows only operations at one end of the list
  - push(object): inserts an element at the top of the stack
  - object pop(): removes the object at the top of the stack
  - object top(): returns the last inserted element
  - integer size(): returns the number of elements stored
  - boolean isEmpty(): indicates if stack is empty
- **Queues ADT**: List where insertion & removal are done on
  - enqueue(object): inserts an element at the end of the queue
  - object dequeue(): removes the object at the frontof the queue
  - object front(): returns the element at the front
  - integer size(): returns the number of elements stored
  - boolean isEmpty(): indicates if queue is empty