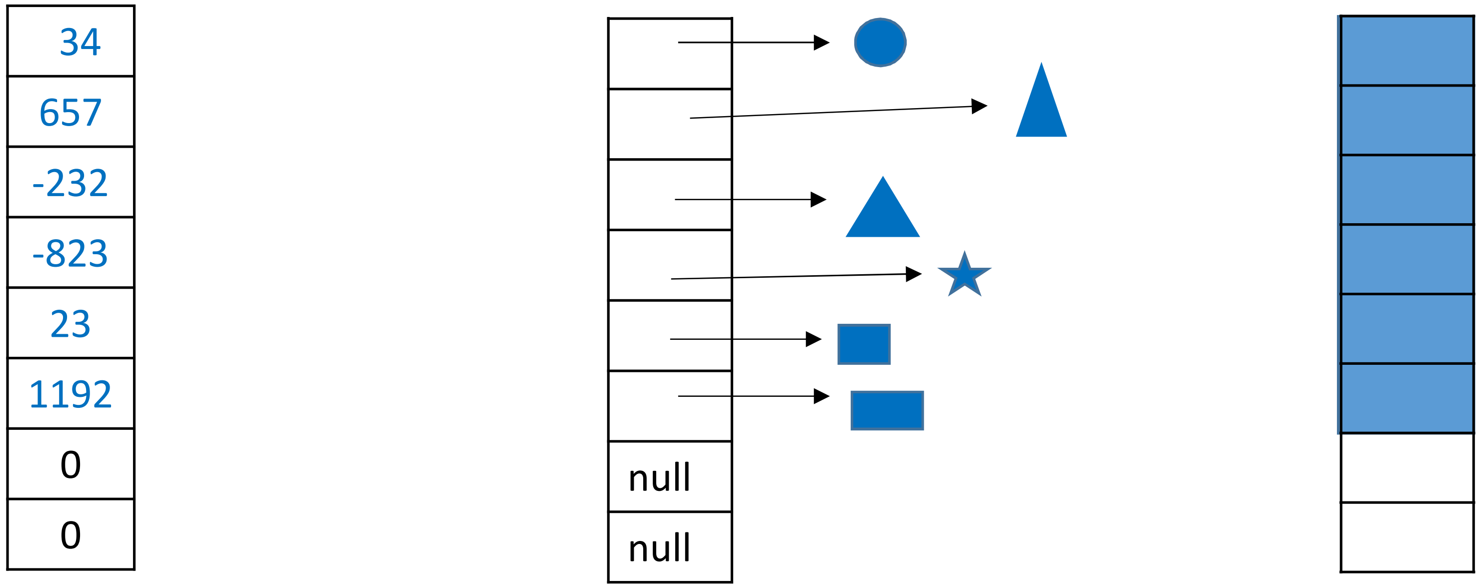
# COMP 250

Lecture 5

# singly linked lists

Sept. 18, 2017

# Recall last lecture:   Java array



array of int

| |
|---|
| 34 |
| 657 |
| -232 |
| -823 |
| 23 |
| 1192 |
| 0 |
| 0 |

array
of Shape
objects

array
(unspecified
type)

I have drawn each of these as array lists.

# Java ArrayList class

https://docs.oracle.com/javase/8/docs/api/java/util/ArrayList.html

It uses an array as the underlying data structure

It grows the array (by 50%, not 100%) when the array is full and a new element is added.

You don't use the usual array notation a[ ]. Instead, use get() and set() and other methods.

# Java generic type

An array of what?     ArrayList<T>

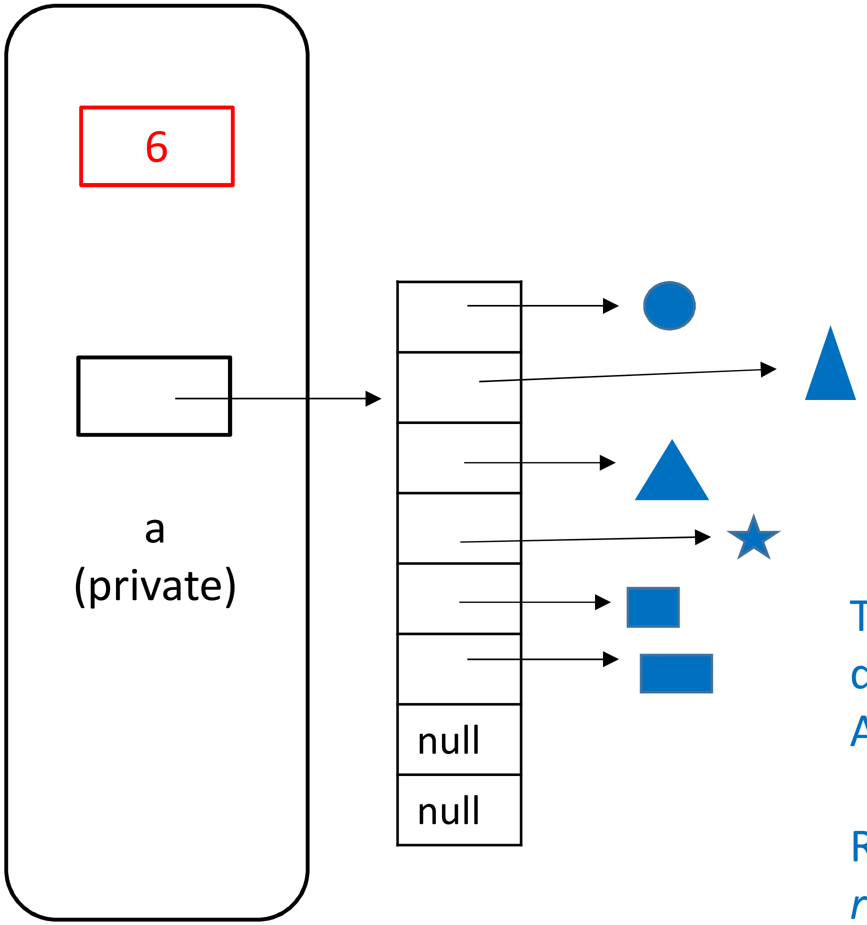
Example:

```
ArrayList< Shape >     shape  =  new ArrayList<  Shape >();

        //  initializes the array length (capacity) to 10

ArrayList<  Shape >    shape  =  new ArrayList<  Shape >( 23 );

        //  initializes the array length to 23
```

# Java ArrayList object

Has private field that holds the number of elements in the list (size).

Has a private field that references an array object.



These Shape objects do not belong to the ArrayList object.

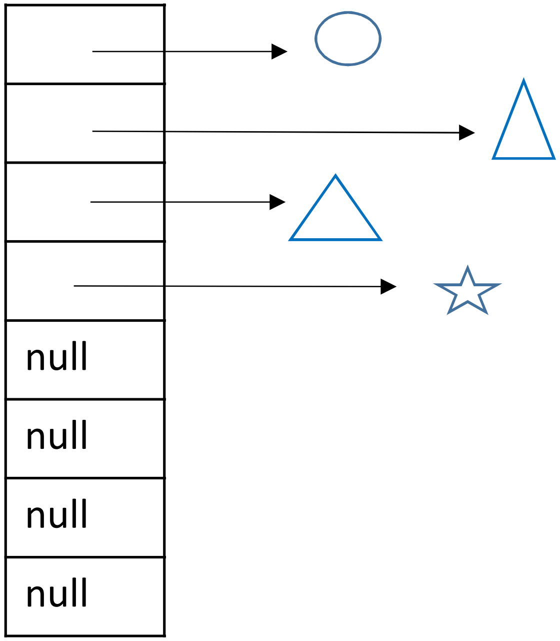
Rather they are *referenced by* it.

# Lists

- array list
- singly linked list (today)
- doubly linked list (next lecture)

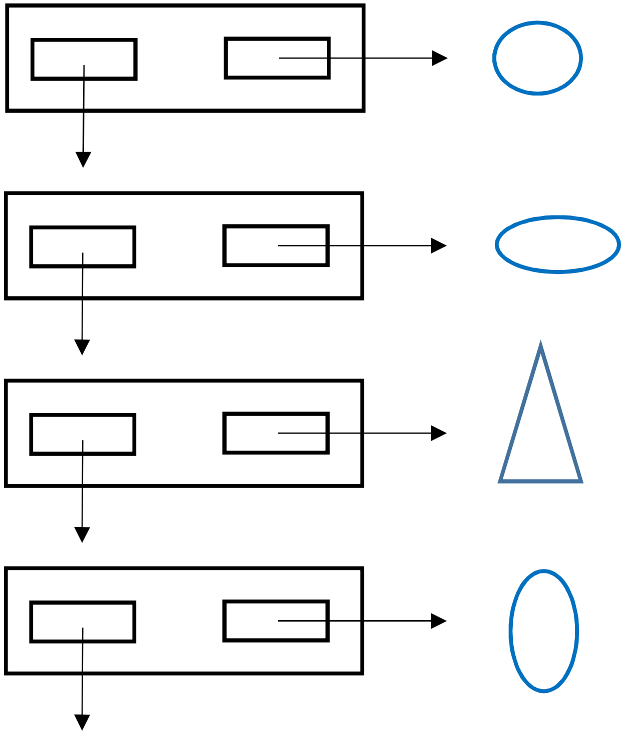
:

# array list



# linked list

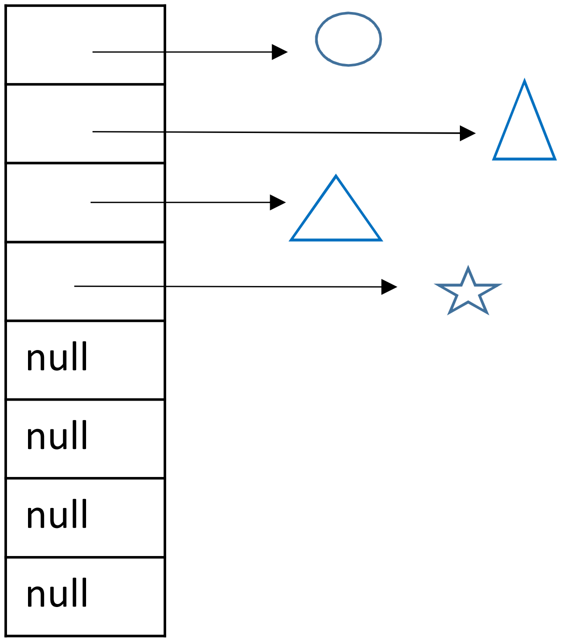
“nodes”

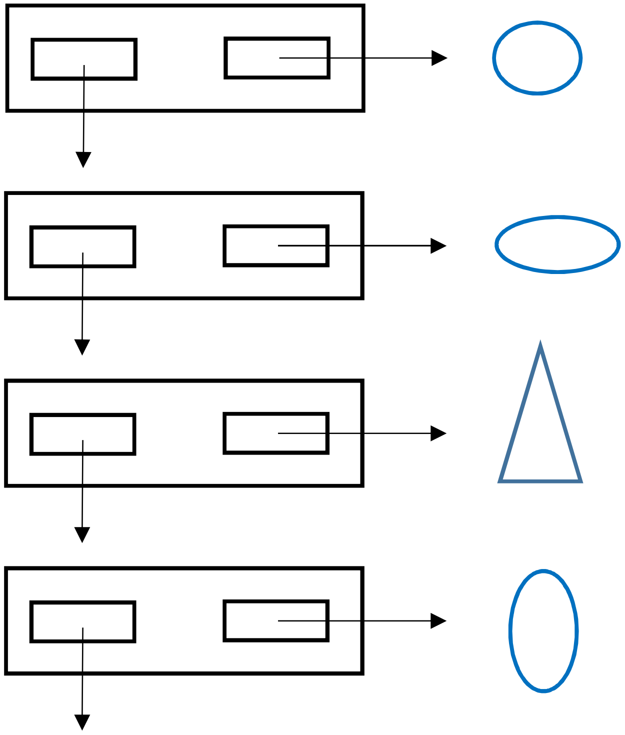


size = 4

# array list

# linked list

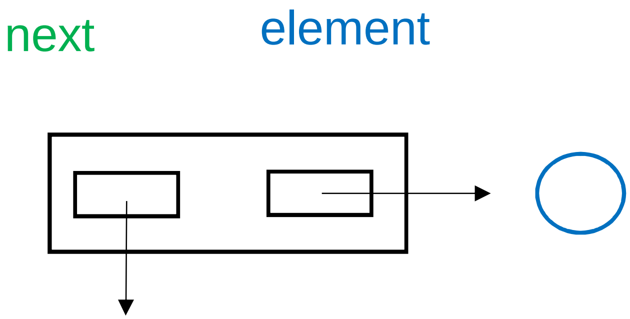




Array slots are in consecutive locations (addresses) in memory, but objects can be anywhere.

Linked list “nodes” and objects can be anywhere in memory.

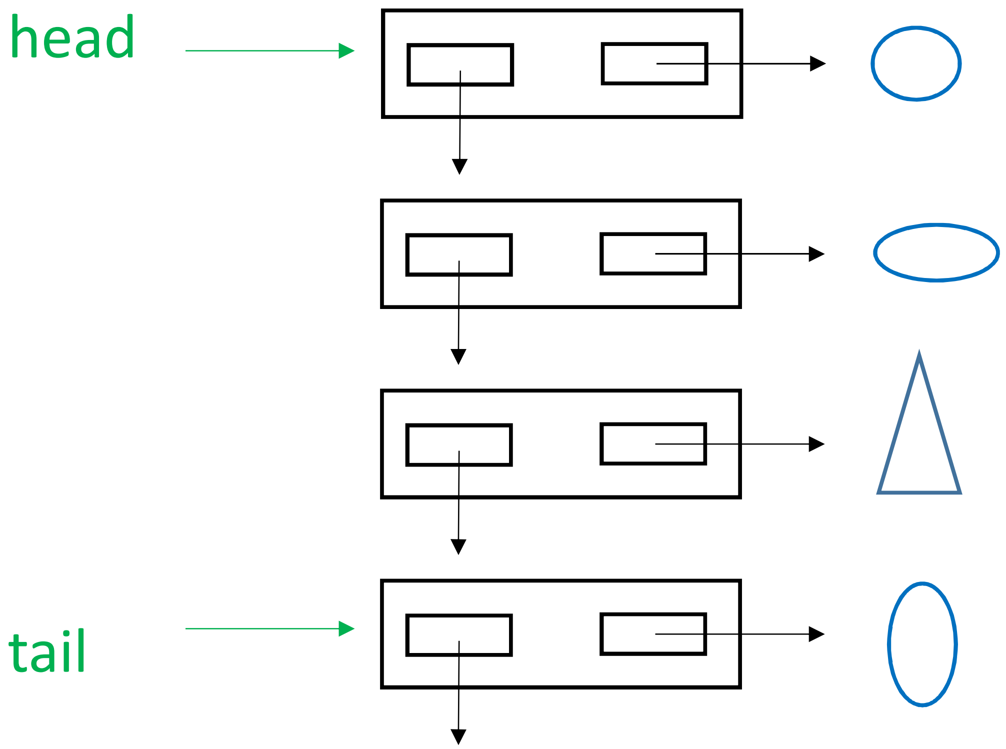
# Singly linked list node  (“S” for singly)



```
class   SNode<E> {

        SNode<E>   next;
        E          element;
        :
}
```

e.g. E might be Shape

A linked list consists of a sequence of nodes, along with a reference to the first (head) and last (tail) node.



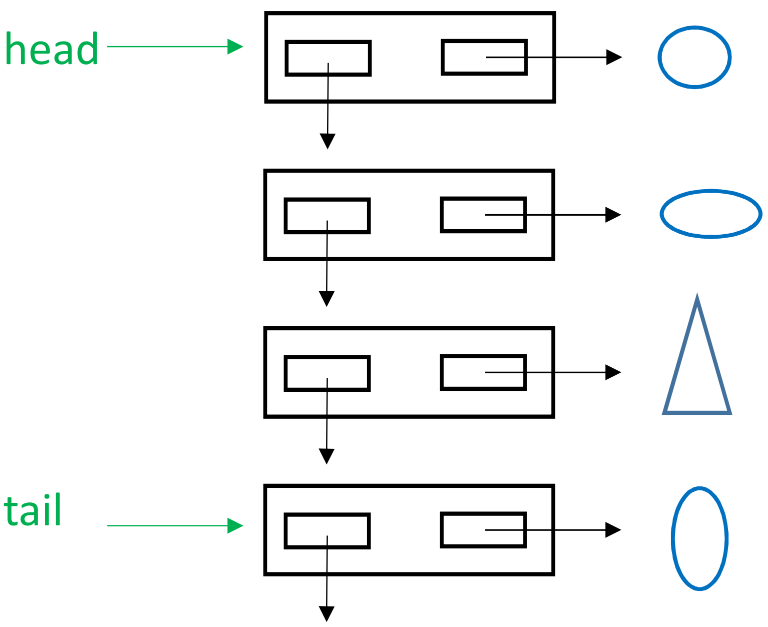
```
class   SLinkedList<E> {

        SNode<E>   head;
        SNode<E>   tail;
        int        size;

         :

         private   class   SNode<E> {        // inner class

                   SNode<E>   next;
                   E          element;
                    :
         }
}
```

# Linked list operations

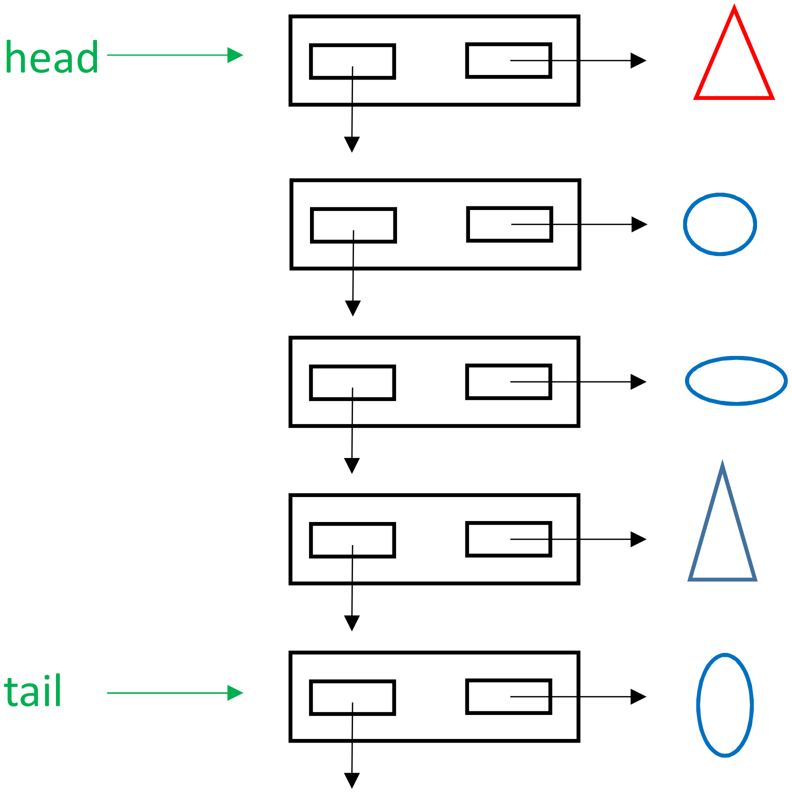
- addFirst ( e )
- removeFirst( )
- addLast ( e )
- removeLast( )
- ……. many other list operations

# addFirst ( △ )

## BEFORE

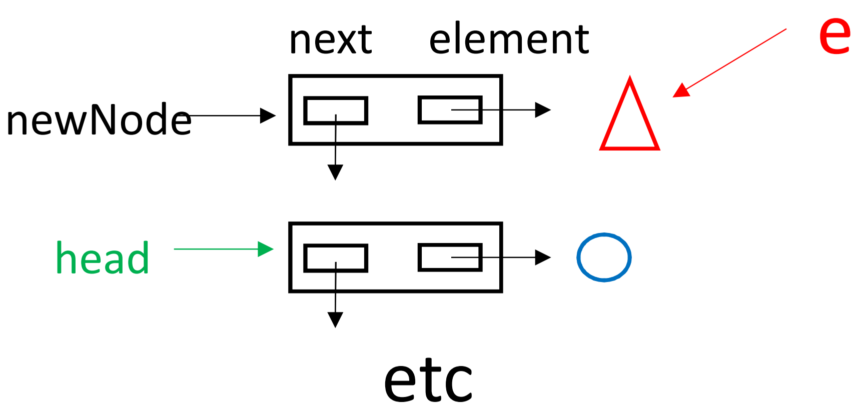


## AFTER



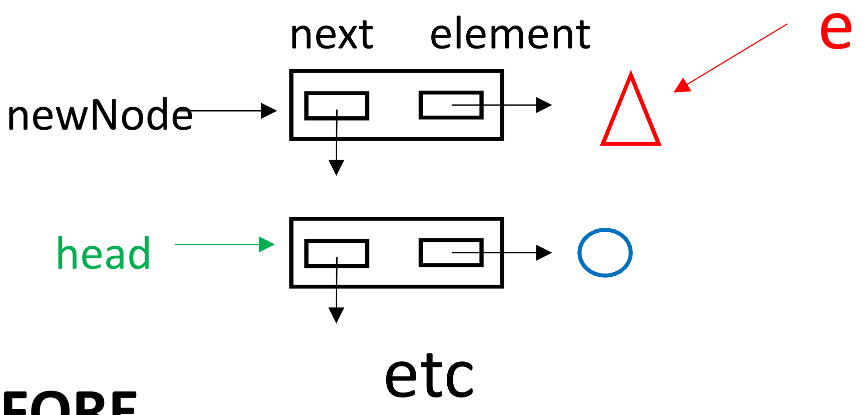
# addFirst ( e ) pseudocode

```
construct newNode
newNode.element = e
newNode.next    = head
```



# addFirst ( e ) pseudocode

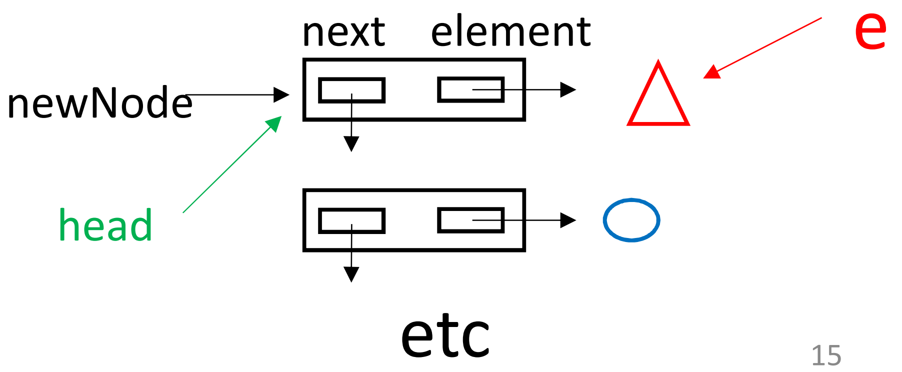
```
construct  newNode
newNode.element  =  e
newNode.next     =  head

//  edge case
if head == null
    tail = newNode
```



**BEFORE**

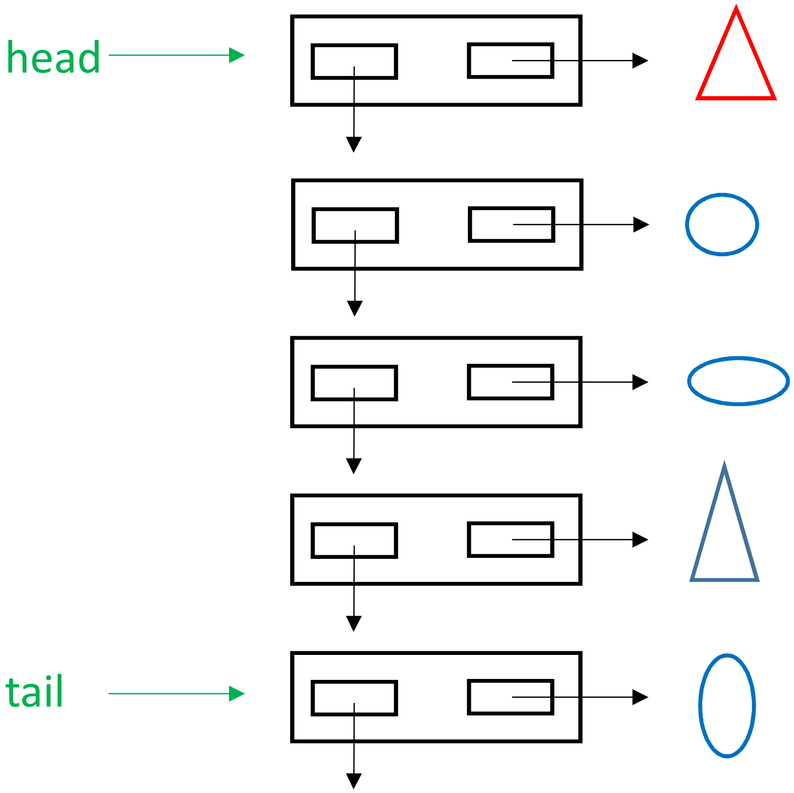
**AFTER**

```
head =  newNode
size = size+1
```

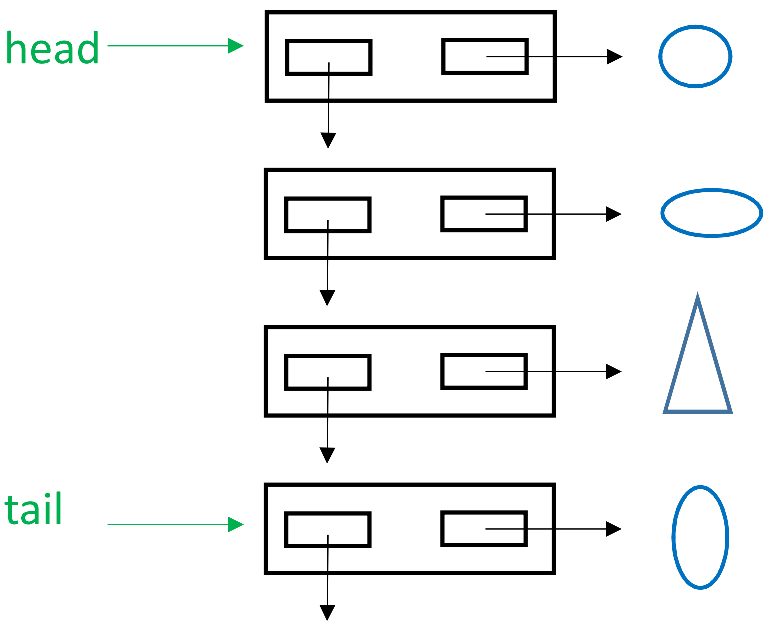


# removeFirst ( )

## BEFORE

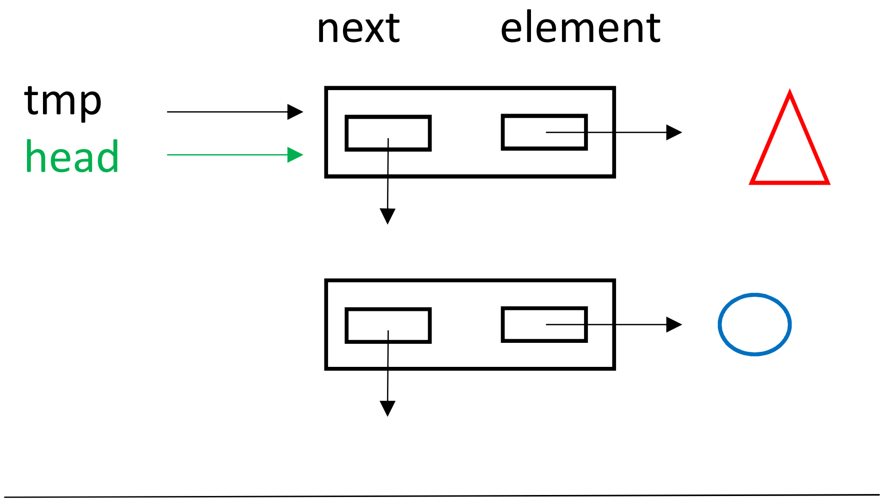


## AFTER



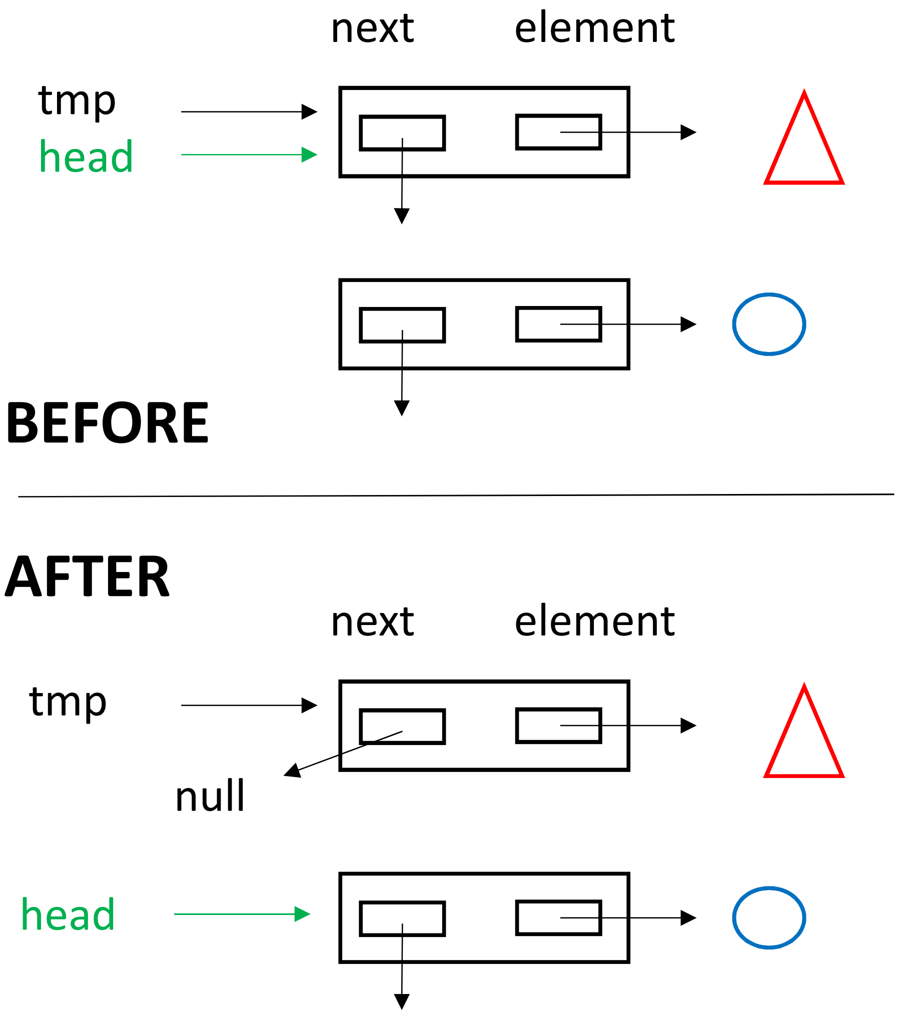
# removeFirst ( )    pseudocode

```
tmp = head
```



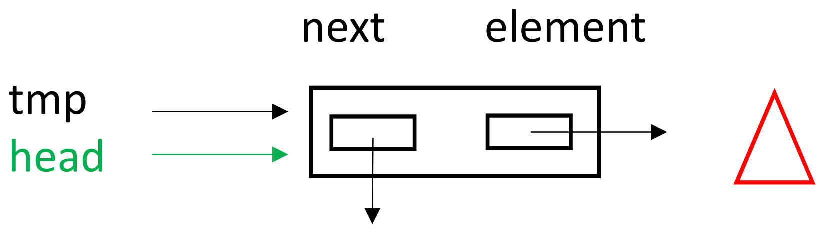
# removeFirst ( )    pseudocode

```
tmp  =  head
head     =  head.next
tmp.next =  null
size = size – 1
```



# removeFirst() edge cases   (size is 0 or 1)

```
tmp  =  head

if (size == 0)
   throw exception
head     =  head.next
tmp.next =  null
size = size – 1

if  (size == 0)  // size was 1
    tail = null
```



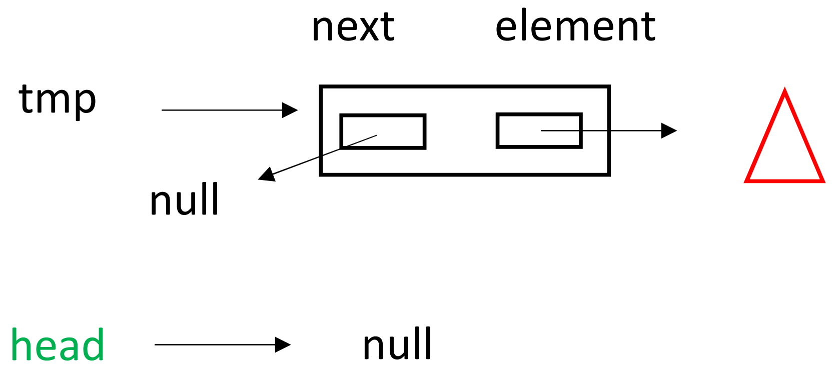
next element

tmp

head

**BEFORE**

**AFTER**



next element

tmp

null

head

null

# Worse Case Time Complexity (N = size)

| | array list | linked list |
|---|---|---|
| addFirst | O( N ) | O( 1 ) |
| removeFirst | O( N ) | O( 1 ) |

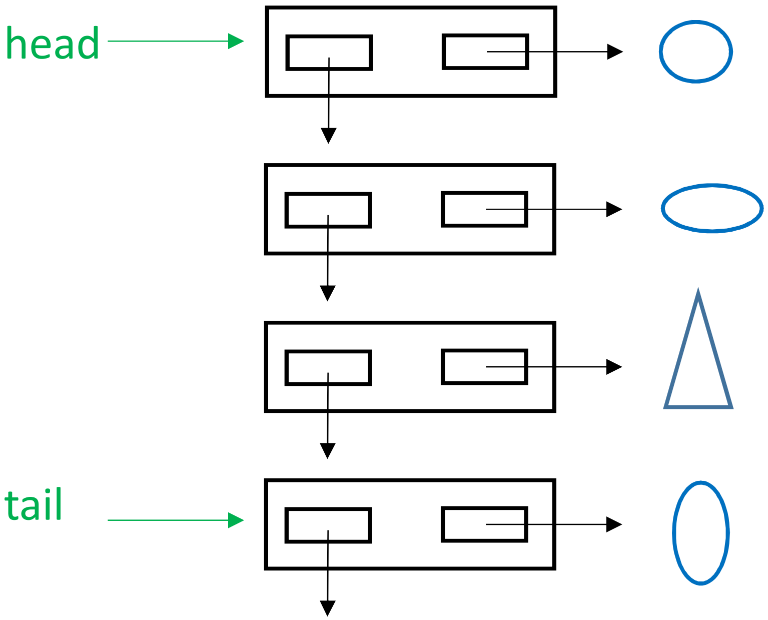
# Worse Case Time Complexity (N = size)

| | array list | linked list |
|---|---|---|
| addFirst | O( N ) | O( 1 ) |
| removeFirst | O( N ) | O( 1 ) |
| addLast | O( 1 )* | ? |
| removeLast | O( 1 ) | ? |

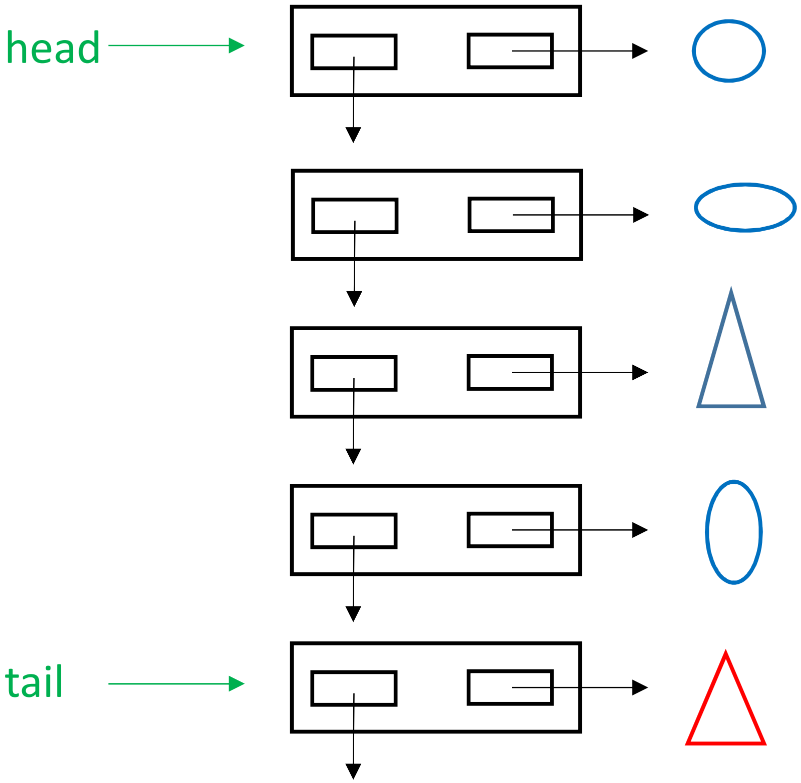
*if array is not full

# addLast ( △ )

## BEFORE

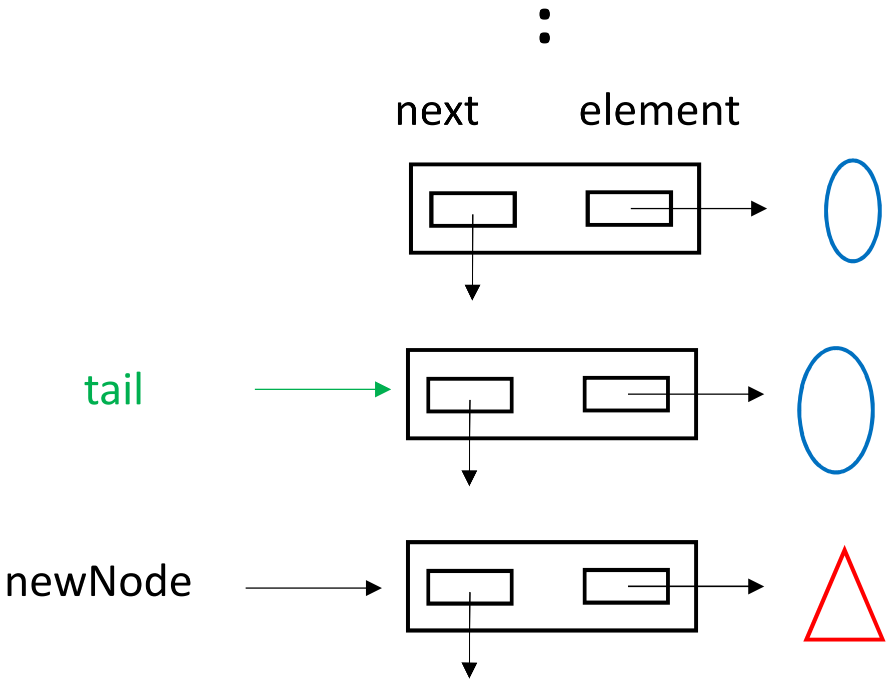


## AFTER

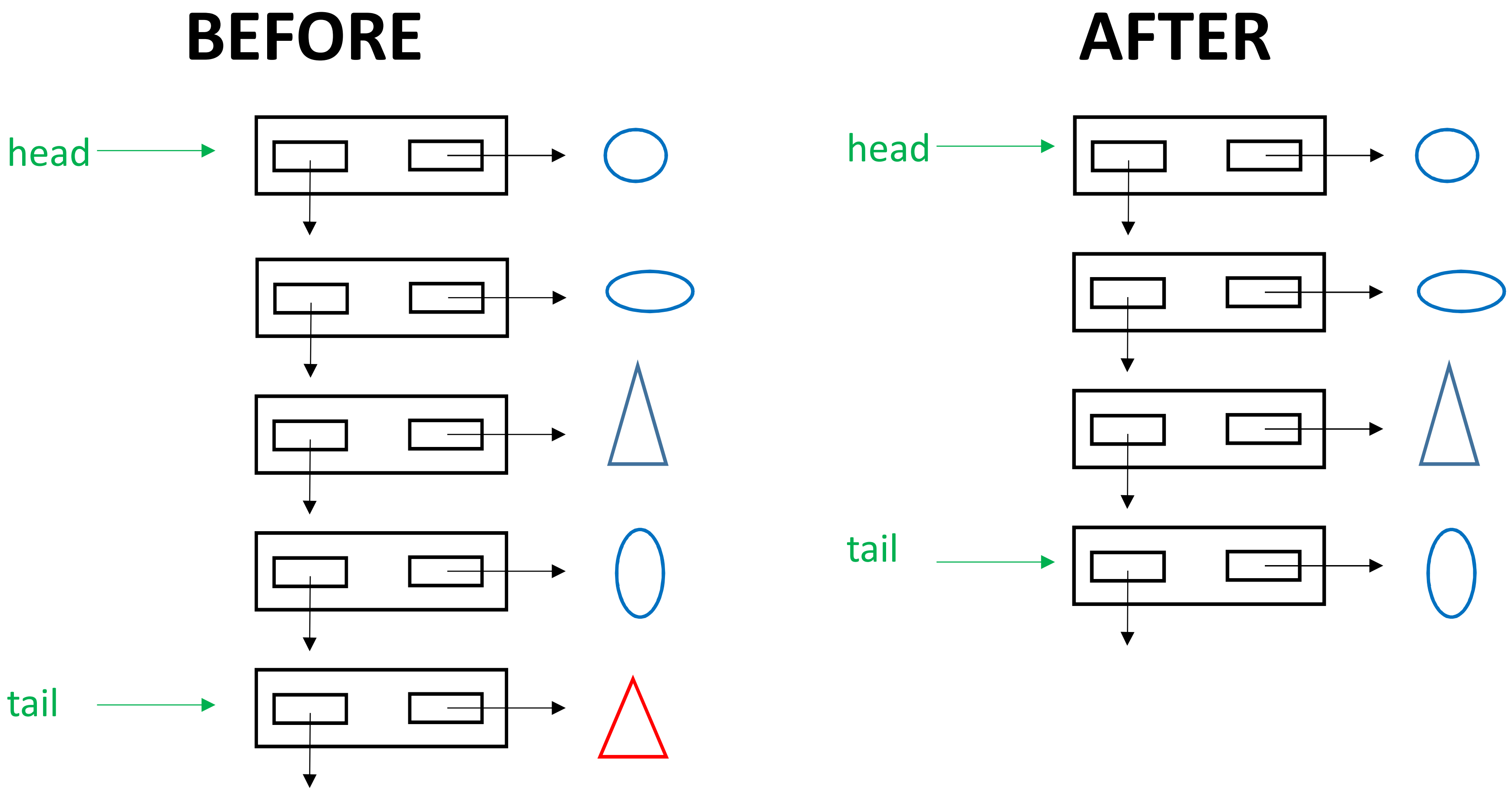


# addLast ( △ )

```
newNode = construct a new node
newNode.element  =  the new list element
tail.next        =  newNode

//  ... and then after what
//  figure shows we do:

tail =  tail.next
size = size+1
```



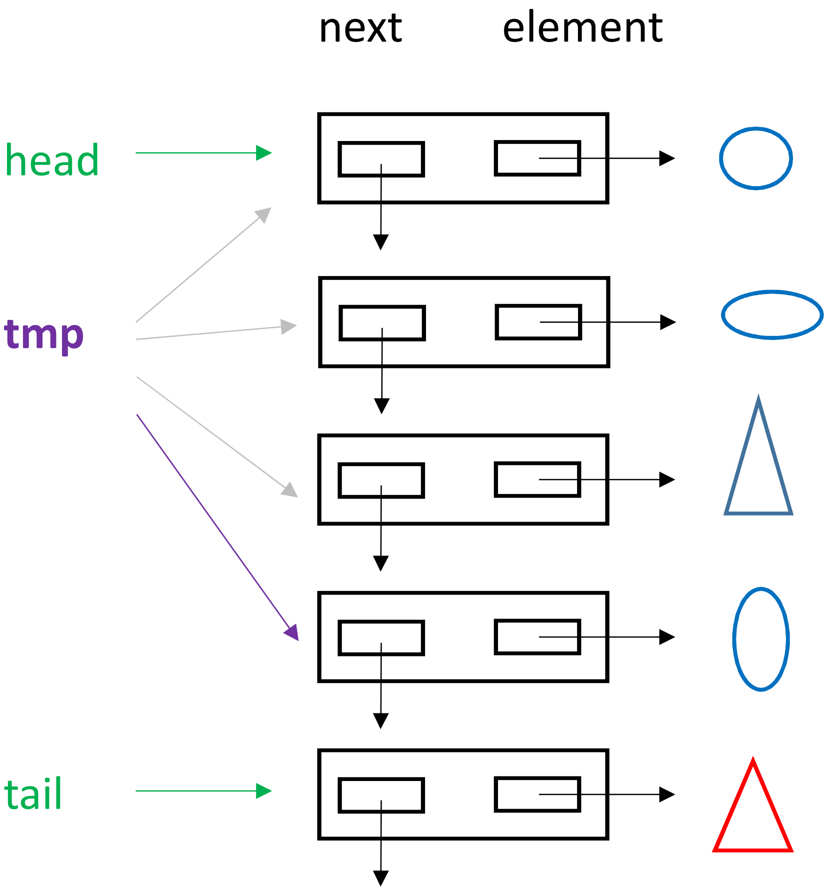
# removeLast ( )



Problem: we have no *direct* way to access the node before tail.

# removeLast (   )

```
if  (head == tail){
     head = null
     tail     = null
}
else {

    tmp  = head
    while (tmp.next  != tail)
            tmp = tmp.next

    tail = tmp
    tail.next = null
}
size = size - 1
//   to return the element,  you need to do a bit more
```



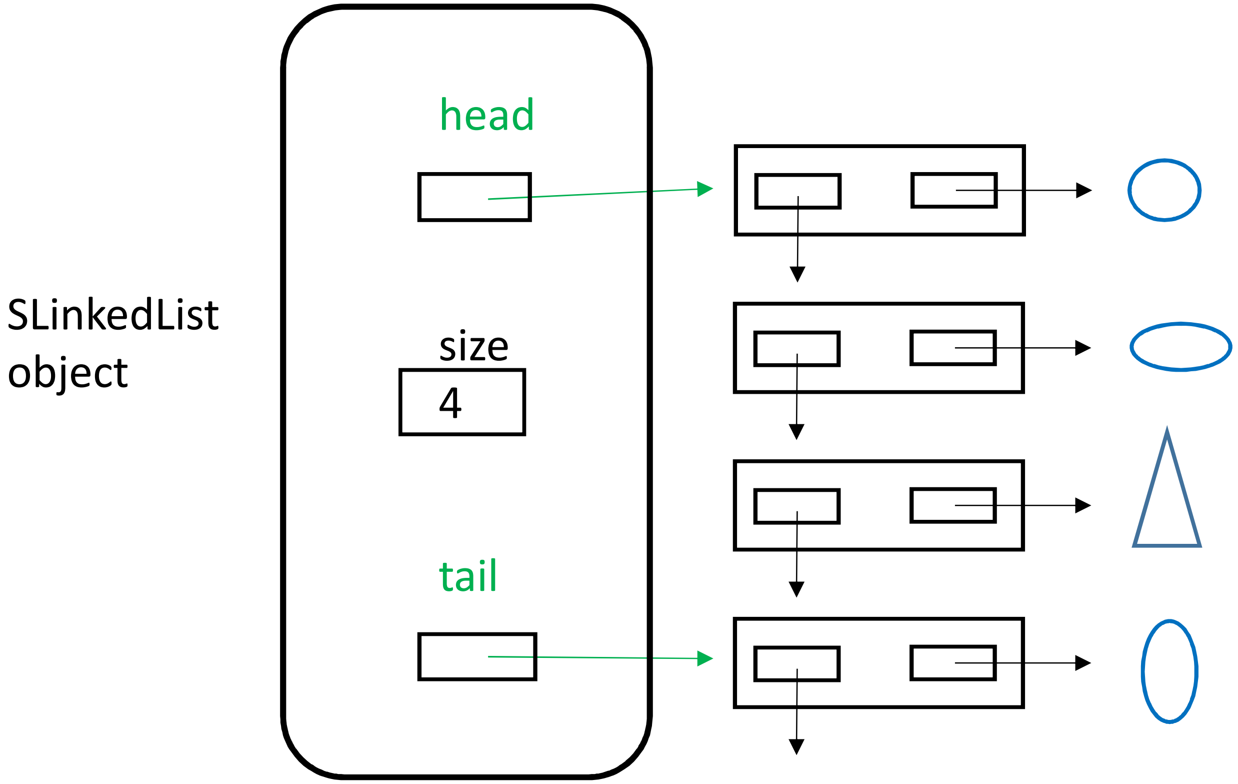
# Time Complexity (N = list size)

| | array list | linked list |
|---|---|---|
| addFirst | O( N ) | O( 1 ) |
| removeFirst | O( N ) | O( 1 ) |
| addLast | O( 1 )* | **O( 1 )** |
| removeLast | O( 1 ) | **O( N )** |

*if array is not full

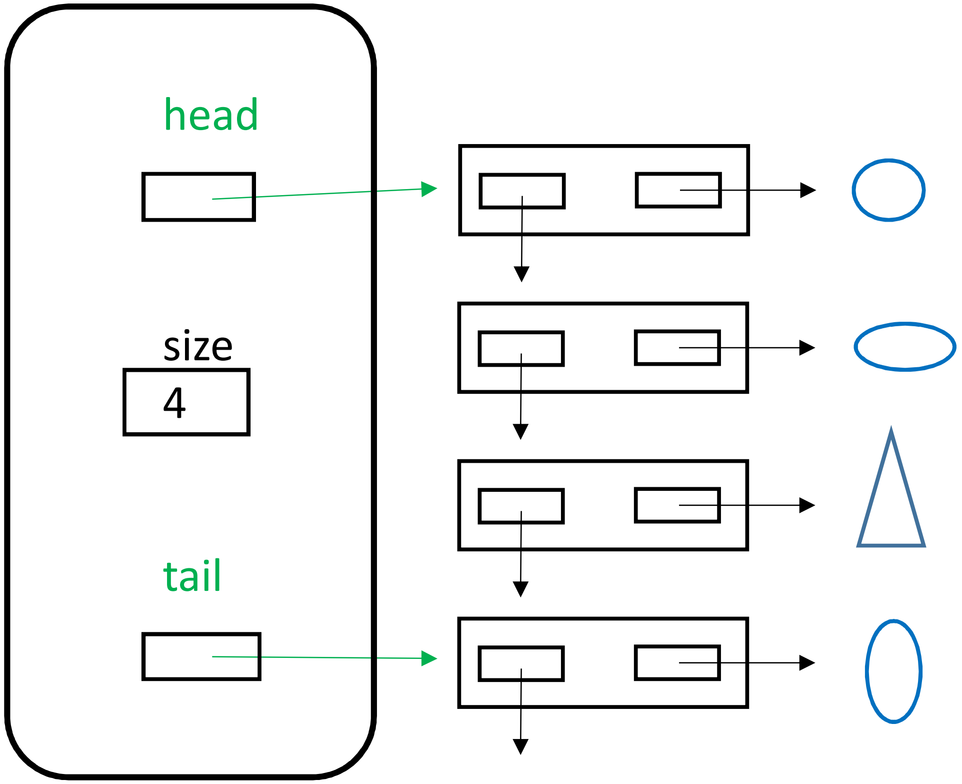
```
class   SLinkedList<E> {

    SNode<E>   head;
    SNode<E>   tail;
    int        size;

     :    //   various methods

    private   class   SNode<E> {        // inner class

          SNode<E>   next;
          E          element;
           :
    }
}
```

```
class   SLinkedList<E> {

        SNode<E>   head;
        SNode<E>   tail;
        int        size;

         :
}
```

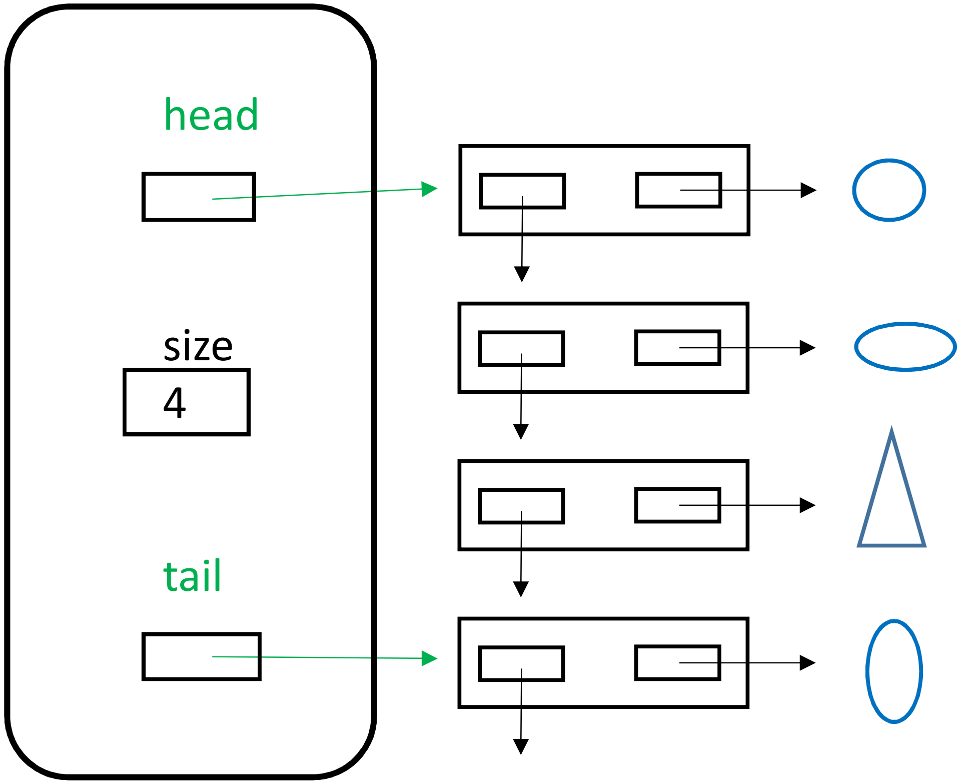


# How many objects?

SLinkedList
object



# How many objects?



1 + 4 + 4 = 9

SLinkedList SNode Shape

# Announcements

- When I make mistakes on slides/lecture notes/exercises, please email me rather posting on discussion board.

  (However, compare the date on your version with the one on the public web page. I may have already corrected it.)

- Assignment 1 should be posted tomorrow (due in 2 weeks)

- Quiz 1 on Monday, Sept 25 (lectures 1-2, 4-6). Online.

- Coding tutorials on lists (coming soon)