COMP 250

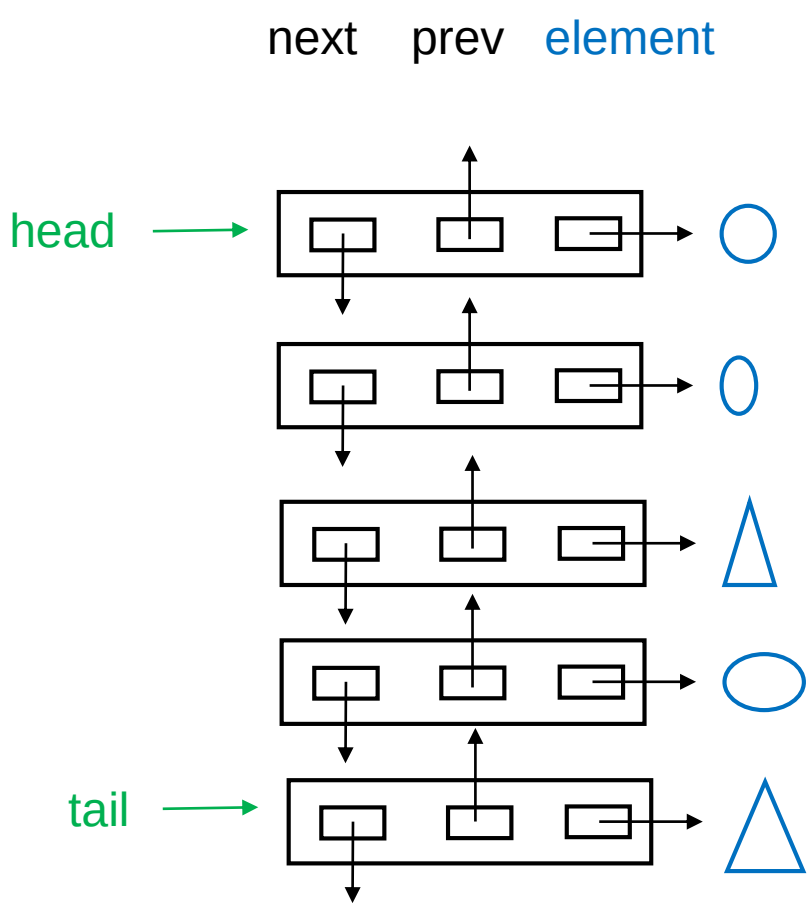
Lecture 5

doubly linked lists
Java LinkedList

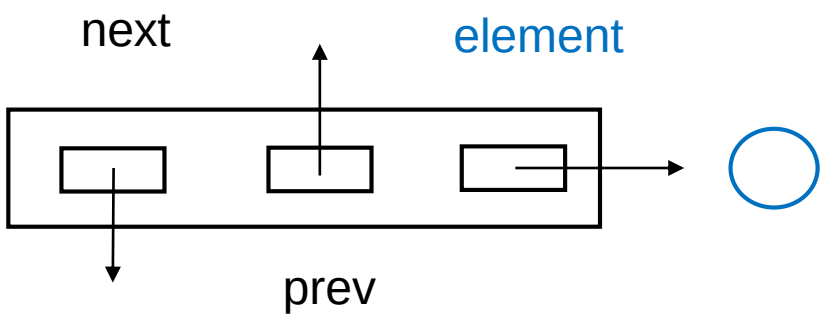
Sept. 16, 2016

Doubly linked lists

Each node has a reference to the next node and to the previous node.



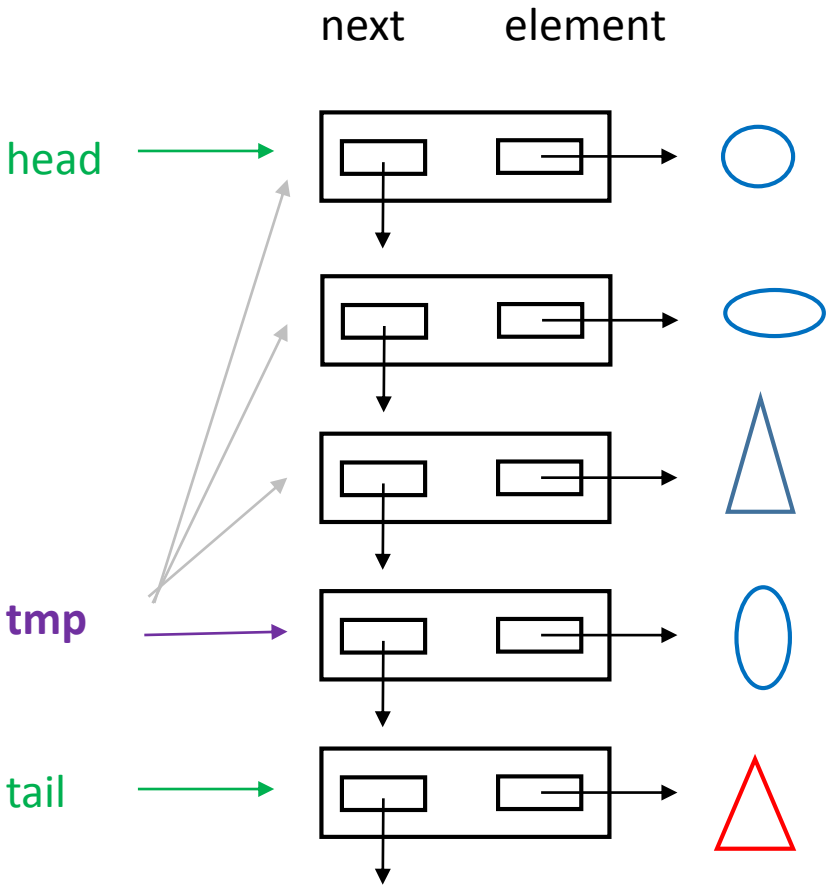
```
class DNode< E > {

      DNode< E >          next;
      Dnode<  E >         prev;
      E                   element;

     // constructor

      DNode( E    e ) {
          element = e;
          prev = null;
          next = null;
       }

}
```



Motivation:

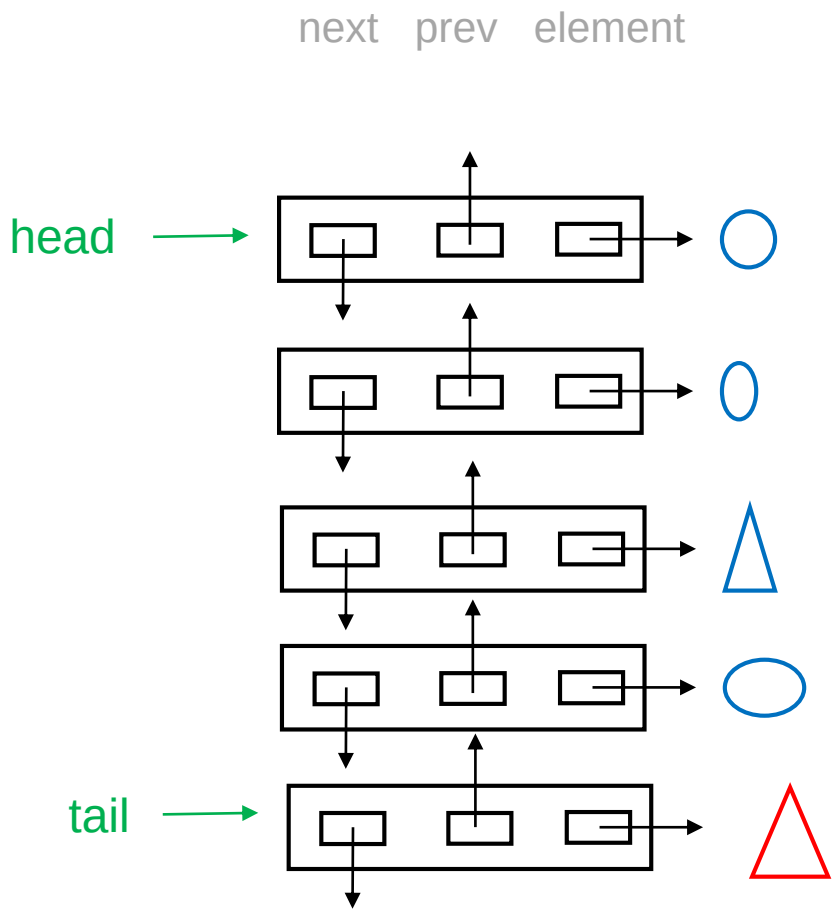
recall removeLast ( ) for singly linked lists

The only way to access the element before the tail was to loop through all elements from the head. This took time O(N) where N is the size of the list.



For a doubly linked list, removing the last element is much faster.

```
removeLast(){

        tail      = tail.prev
        tail.next = null
        size = size – 1

              :
}
```



Time Complexity (N = list size)

	array list	SLinkedList	DLinkedList
addFirst	O(N)	O(1)	O(1)
removeFirst	O(N)	O(1)	O(1)
addLast	O(1)	O(1)	O(1)
removeLast	O(1)	**O(N)**	**O(1)**

List Operations

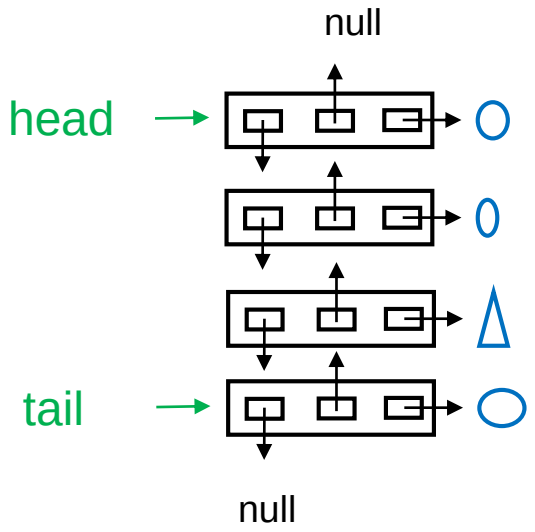
get(i)

set(i,e)

add(i,e)

remove(i)

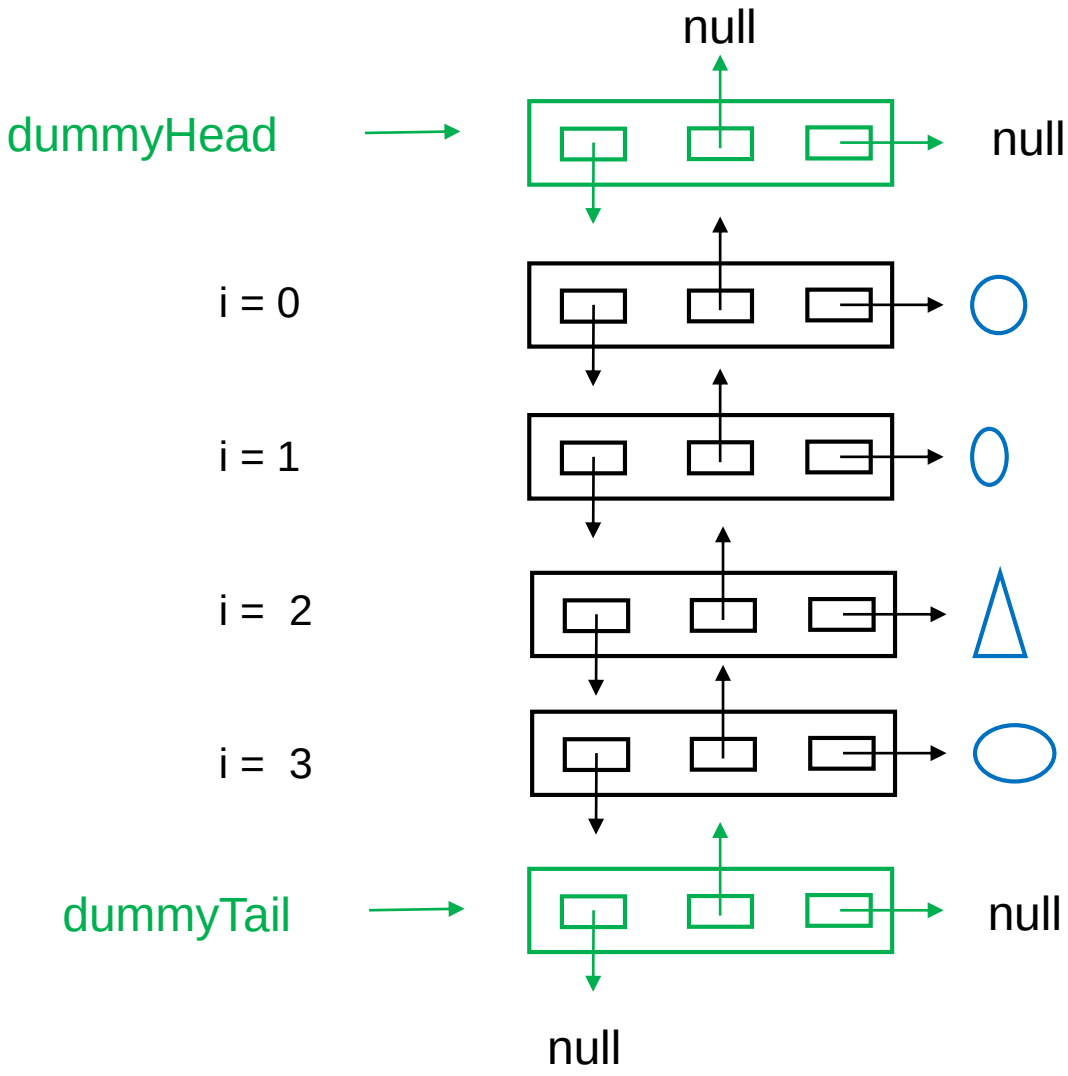
:



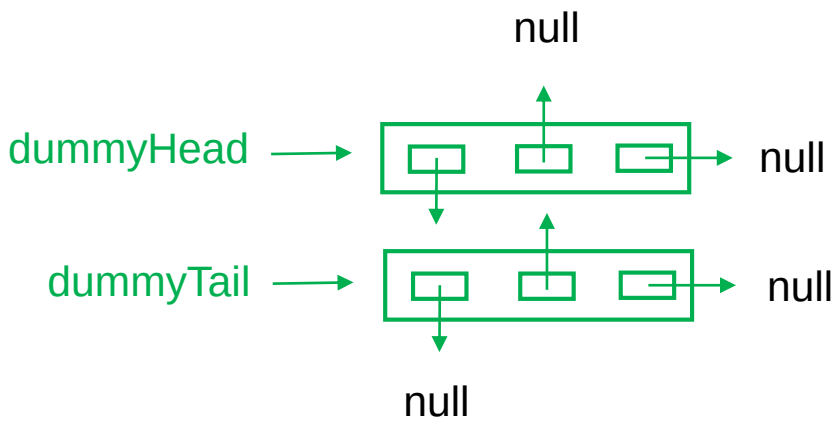
For a linked list, many operations require access to node i.

The “edge cases” (i = 0, i = size – 1) usually require extra code, *which can lead to coding errors*.

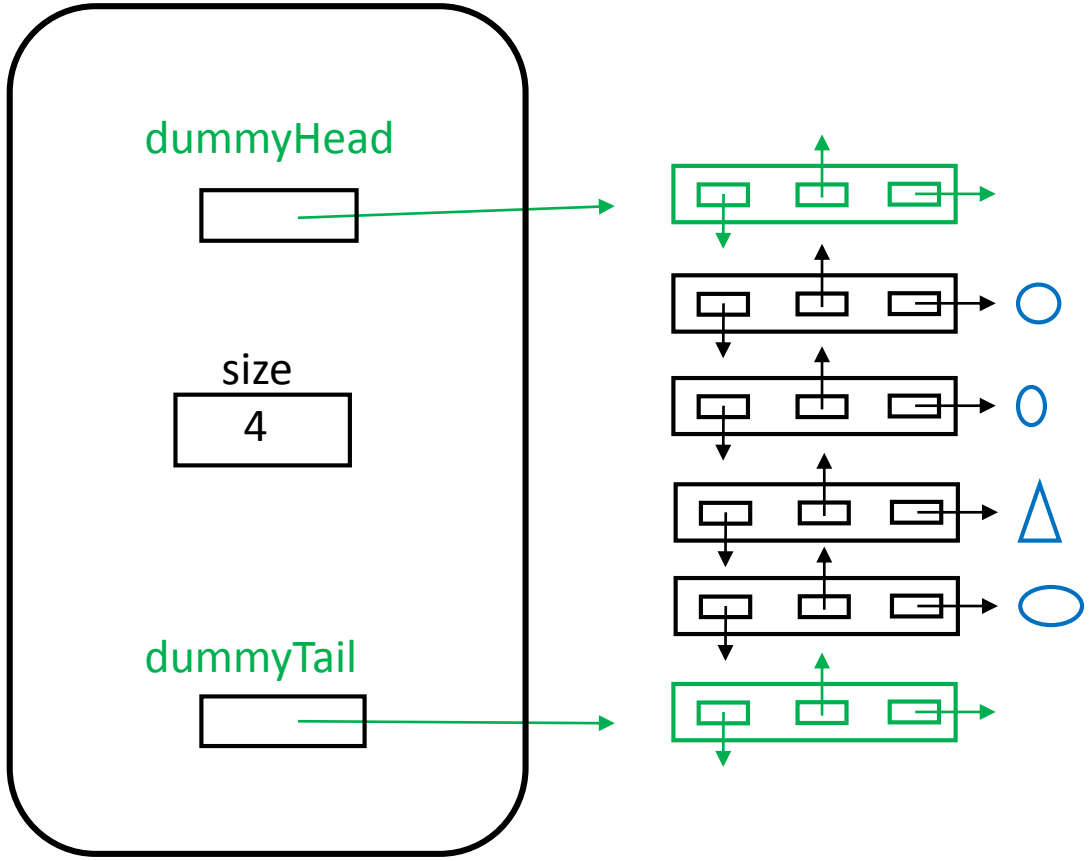
Common linked list trick: avoid edge cases with “dummy nodes”



```
class  DLinkedList<E>{

    DNode<E>      dummyHead;
    DNode<E>      dummyTail;

    int           size;
     :

    //  constructor

    DLinkedList<E>(){
        dummyHead =   new   DNode<E>();
        dummyTail   =   new   DNode<E>();
        dummyHead.next   =   dummyTail;
        dummyTail.prev     =   dummyHead;
        size     = 0;
}
```



DLinkedList< Shape >
object

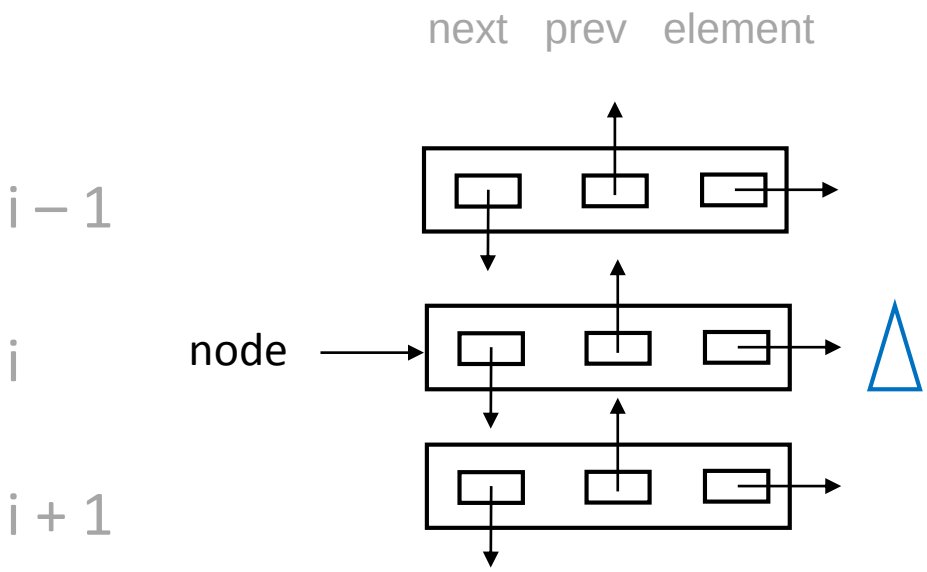


Q: How many objects in total in this figure?

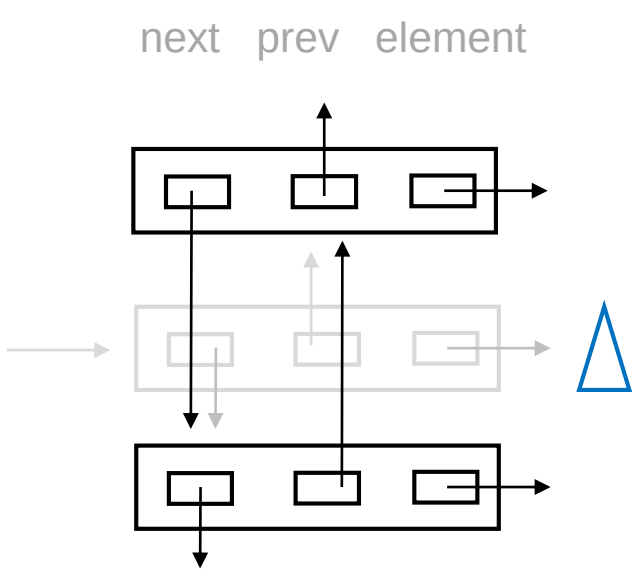
A: 1 + 6 + 4 = 11

```
remove( i ) {          //  recall end of lecture 3 on arrays

    node = getNode( i )          //  next slide
    node.next.prev  =  node.prev
    node.prev.next  =  node.next
    size = size - 1
}
```

BEFORE



AFTER



[SLIDE WAS ADDED AFTER LECTURE]

```
getNode( i ) {

    //   check that 0 <= i < size   (omitted)

    node = dummyHead.next
    for (k = 0; k < i;   k ++)
        node = node.next
    return node
}
```

More efficient (half the time)…

```
getNode( i ) {

    if ( i < size/2 ){                          //  iterate from head
        node = dummyHead.next
        for (k = 0; k < i;   k ++)
            node = node.next;
         }
     else{                                      //  iterate from  tail
        node = dummyTail.prev
        for ( k = size-1;   k >  i;   k -- )
            node = node.prev
         }
     return node
}
```

Time Complexity (N = list size)

	array list	SLinkedList	DLinkedList
addFirst	O(N)	O(1)	O(1)
removeFirst	O(N)	O(1)	O(1)
addLast	O(1)	O(1)	O(1)
removeLast	O(1)	**O(N)**	**O(1)**
remove(i)	?	?	?

Time Complexity (N = list size)

	array list	SLinkedList	DLinkedList
addFirst	O(N)	O(1)	O(1)
removeFirst	O(N)	O(1)	O(1)
addLast	O(1)	O(1)	O(1)
removeLast	O(1)	O(N)	O(1)
remove(i)	**O(N)**	**O(N)**	**O(N)**

As I will discuss that later, "O( )" ignores constant factors.

Java LinkedList class

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

It uses a *doubly linked list* as the underlying data structure.

It has some methods that ArrayList doesn't have e.g.:

- addFirst()
- removeFirst()

- addLast()
- removeLast()

Q: What is the time complexity of the following ?

```
LinkedList< E >    list =   new  LinkedList< E >( ) ;

for (k = 0; k < N;   k ++)                    //  N is some constant
        list.addFirst(  new  E( …. )   );      // or addLast(..)


for (k = 0; k < k < list.size();   k ++)
        list.get(  k  );
```

Q: What is the time complexity of the following ?

```
LinkedList< E >   list =   new  LinkedList< E >( ) ;

for (k = 0; k < N;   k ++)                    //  N is some constant
        list.addFirst(  new  E( …. )   );     // or addLast(..)
```

A: $\mathbf{1 + 1 + 1 + \ldots . \ 1 = N}$ $\boldsymbol{O(N)}$

```
for (k = 0; k < k < list.size();   k ++)
        list.get(  k  );
```

I am omitting what I would do with this element since that's not the point here e.g. I could print it.

Q: What is the time complexity of the following ?

```
LinkedList< E >   list =   new  LinkedList< E >( ) ;

for (k = 0; k < N;   k ++)                    //  N is some constant
        list.addFirst(  new  E( …. )   );   // or addLast(..)
```

A: $\mathbf{1 + 1 + 1 + \ \ldots .\ 1 = N}$ $\boldsymbol{O(N)}$

```
for (k = 0; k < k < list.size();   k ++)          //  size == N
        list.get(  k  );
```

A: $\mathbf{1 + 2 + 3 + \ \ldots .\ N = \frac{N\,(N+1)}{2}}$ $\boldsymbol{O(N^2)}$

Here I am assuming the first getNode(i) is used, which always starts at the head. See the Exercises for the expression when the more efficient getNode(i) method is used.

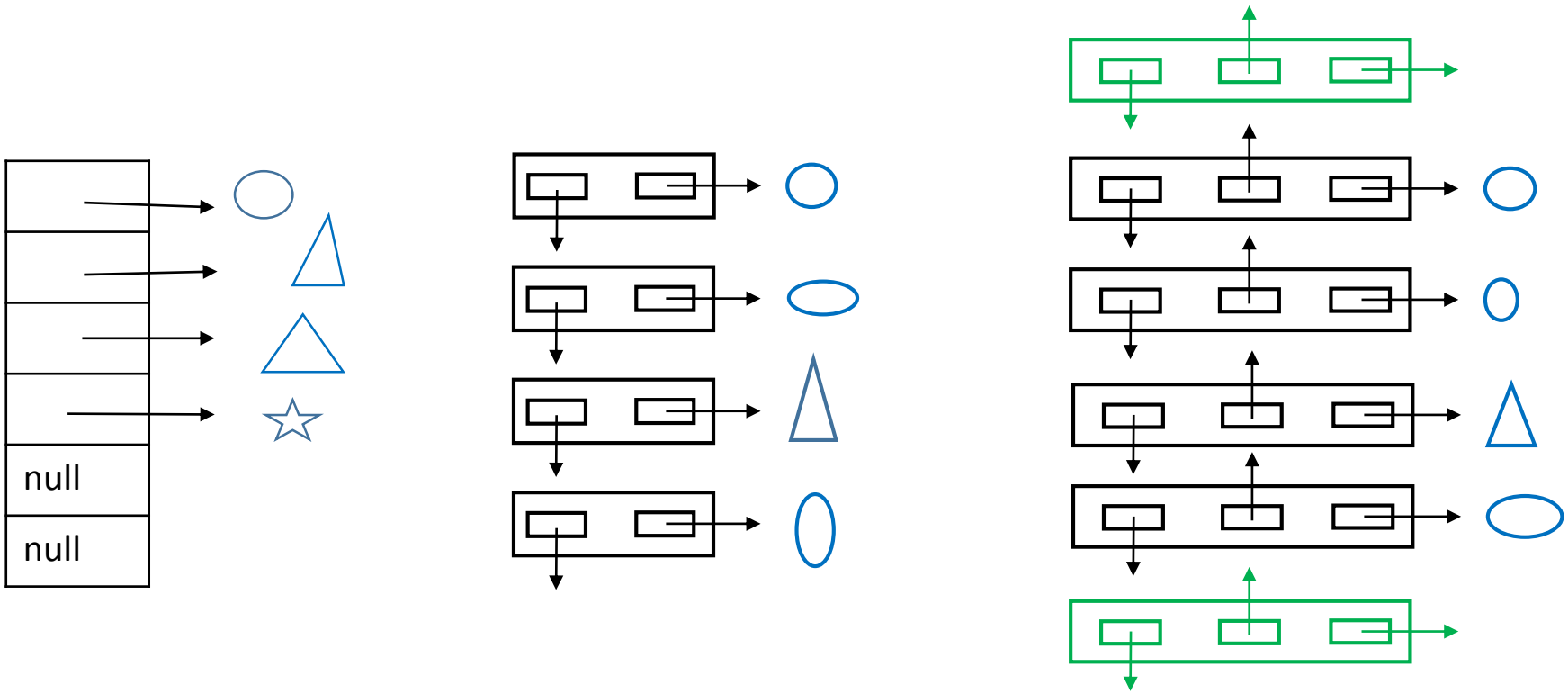
ASIDE: Java 'enhanced for loop'

```
for (k = 0; k < list.size();   k ++)
        ……..
```

A more efficient way to iterate through elements in a LinkedList object is to use:

```
for  (E    e :   list)

     //    'list' references the LinkedList< E >  object
     //     Do something with each element e in list
```

What about “Space Complexity” ?



All three data structures use space O(N) for a list of N elements.

Java terminology (time permitting)

- method “signature”
  - name
  - number and type of parameters,
  - ~~return type~~

- method “overloading”
  - add(int index, E element)
  - add(E element)

  - remove(E element)
  - remove(int i)

Java terminology

What is method “overloading” vs. “overriding” ?

Classes can “inherit” methods from other classes.

Sometimes you do not want a class to inherit the method, however, and so you “override” it by writing a more suitable one.

We will learn about inheritance formally at the end of the course…..

Announcements

- Assignment 1 posted (due in ~2 weeks)
- Exercises for singly linked lists *(practice coding)*
- Eclipse (IDE) tutorials next week.

  Goodbye DrJava ! Hello Eclipse !

I asked the TA's which IDE they use:

- Eclipse or sublime
- jetbrains, IntelliJ
- Eclipse
- Eclipse, also IntelliJ
- Eclipse
- Simple text editor / vim + command line. (However I had to use Eclipse and DrJava in the past.)
- Eclipse, but I like using text editor + command line for small things.
- Eclipse (netbeans for GUIs)