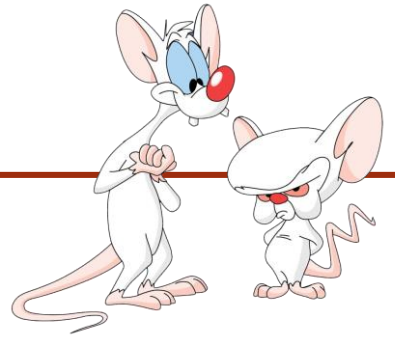
COMP 250
INTRODUCTION TO COMPUTER SCIENCE

Week 5-3 : Doubly Linked Lists

Giulia Alberini, Fall 2020

WHAT ARE WE GOING TO DO IN THIS VIDEO?



- Doubly Linked Lists

LINKED LISTS

IMPLEMENTATIONS

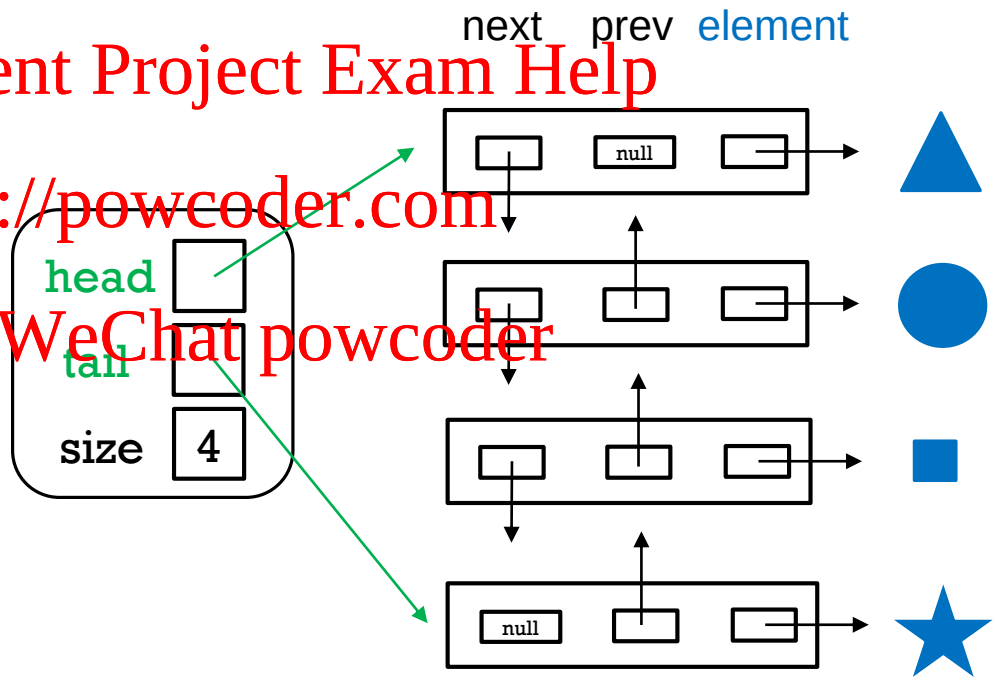
There are different implementations of a list:

- Array list
- Singly linked list
- Doubly linked list

Idea: the elements in the list are linked using pointers

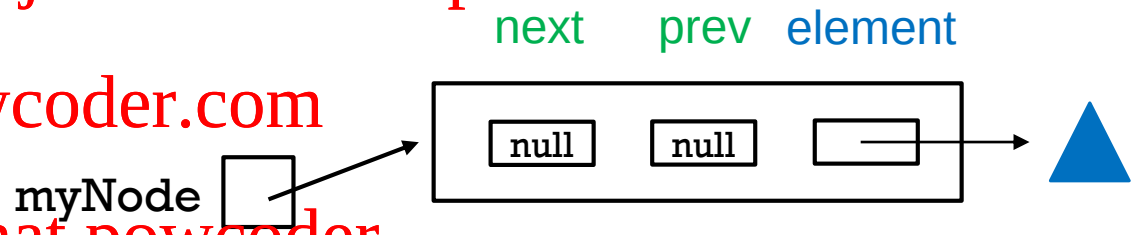
DOUBLY LINKED LIST

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



DOUBLY LINKED LIST NODE

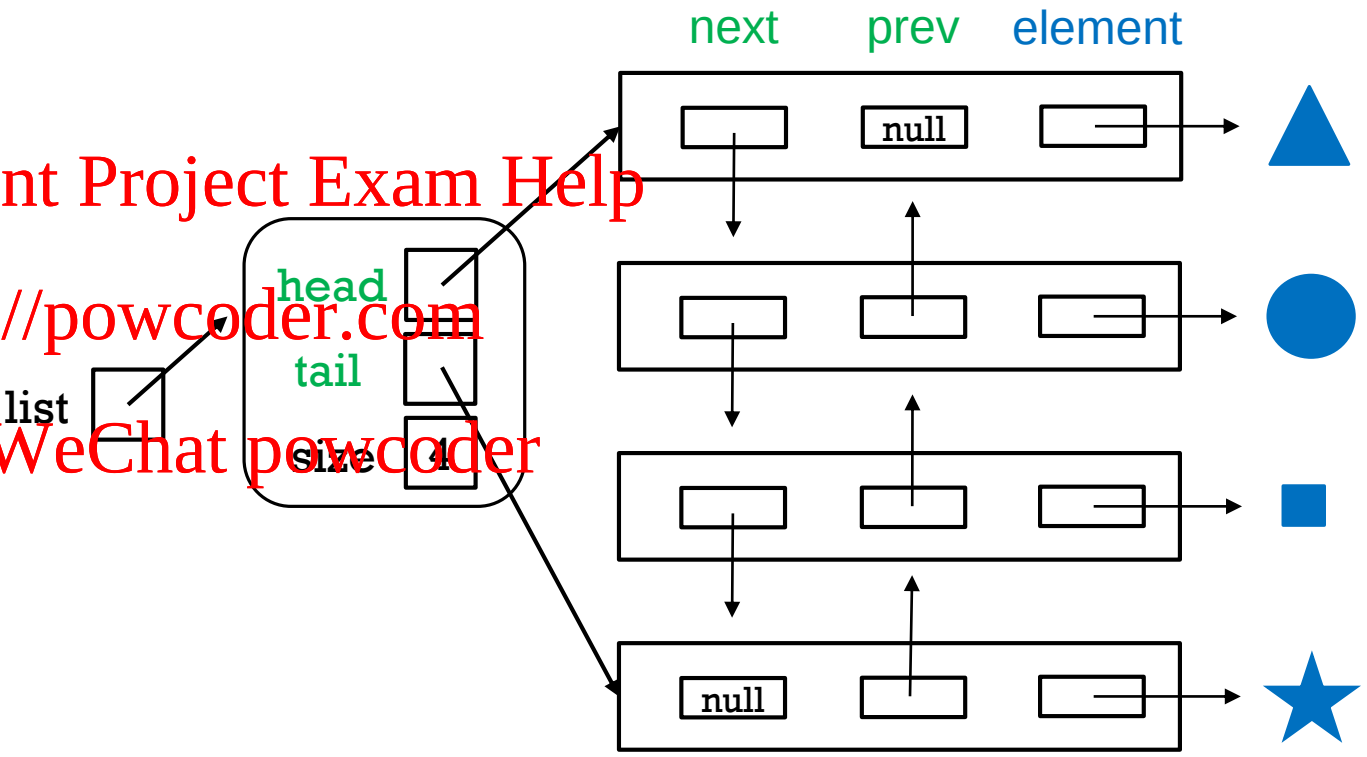
```
class DNode {
    Shape element;
    DNode next;
    DNode prev;
}
```


```
DNode myNode = new DNode();
n.element = new Shape( ▲ );
```

DOUBLY LINKED LIST

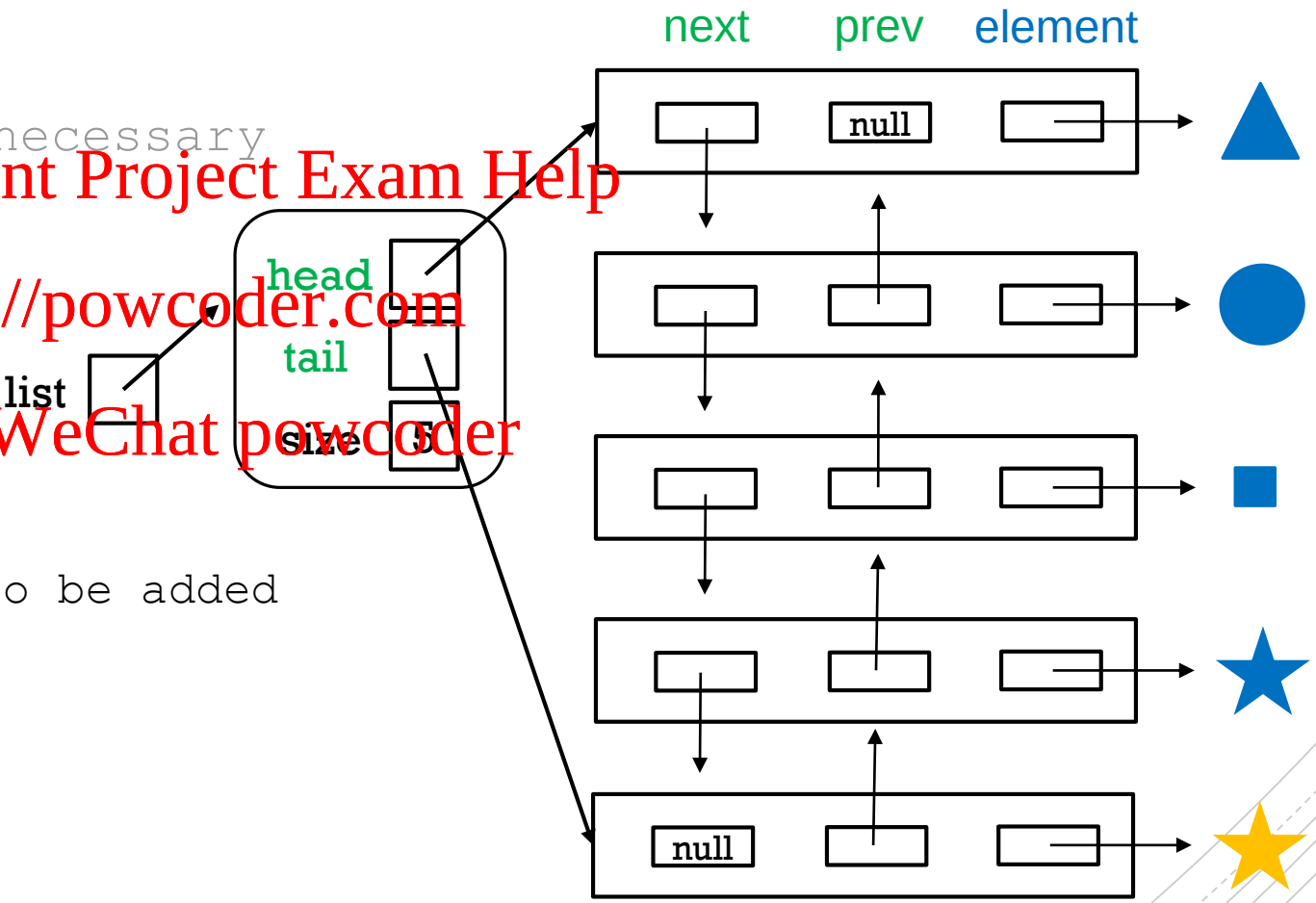
```
public class DLinkedList {
    private DNode head;
    private DNode tail;
    private int size;
    :
    private class DNode {
        Shape element;
        DNode next;
        DNode prev;
    }
}
```


```
DLinkedList list = new DLinkedList();
:
```

DOUBLY LINKED LIST – removeLast()

```
tail = tail.prev;

tail.next.prev = null; // not necessary

tail.next = null;

size = size - 1;

// to return the element,
// you need to do a bit more work

// edge cases for size = 0 and 1 to be added
```

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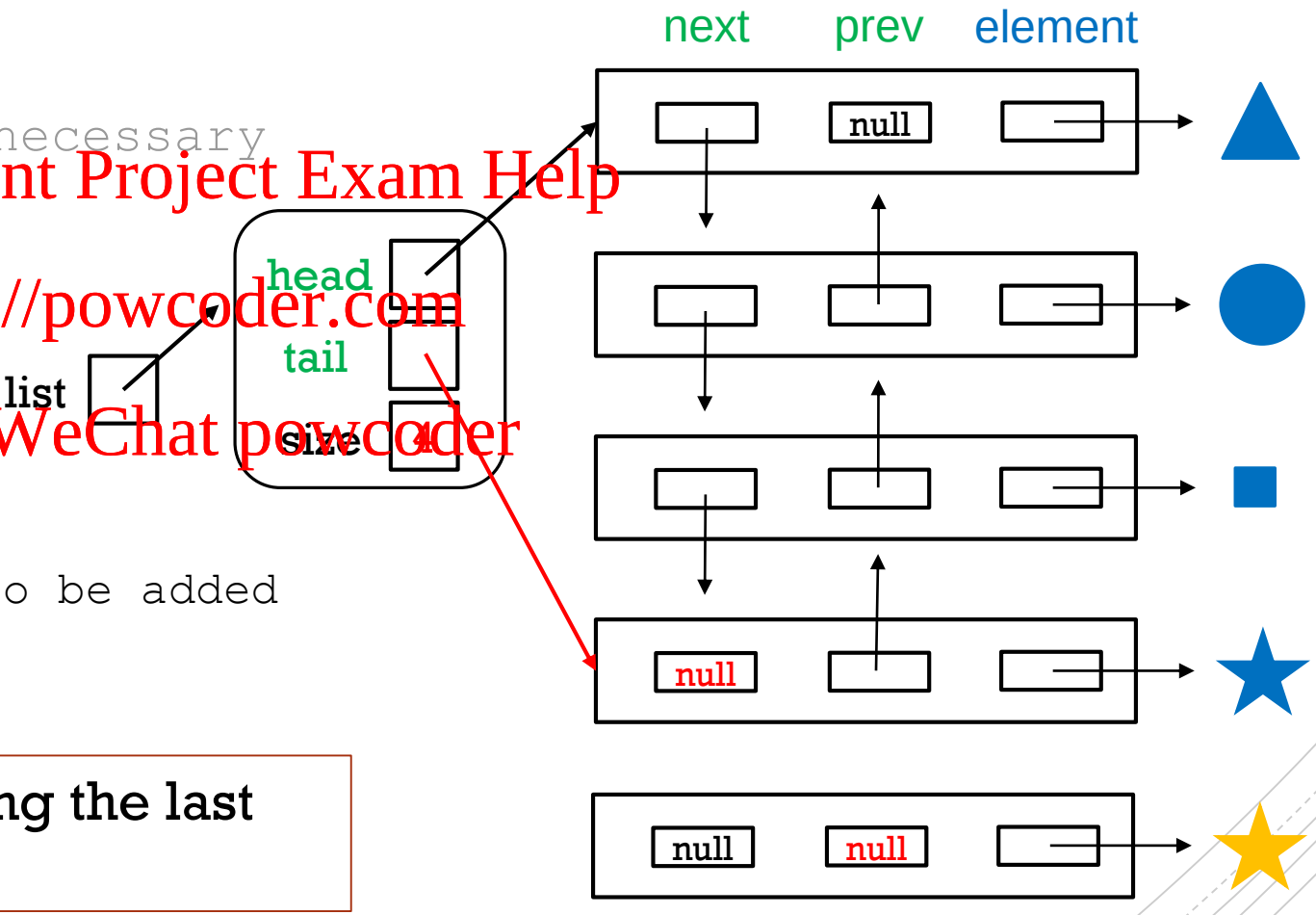


For a doubly linked list, removing the last element is much faster.

WORSE CASE 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)

OTHER LIST OPERATIONS

Many list operations require access to a specific node `i`

get(i)

set(i,e)

add(i,e)

remove(i)

:

LINKED LISTS

Suppose we want to access general node `i` in a linked list.

Two issues arise:

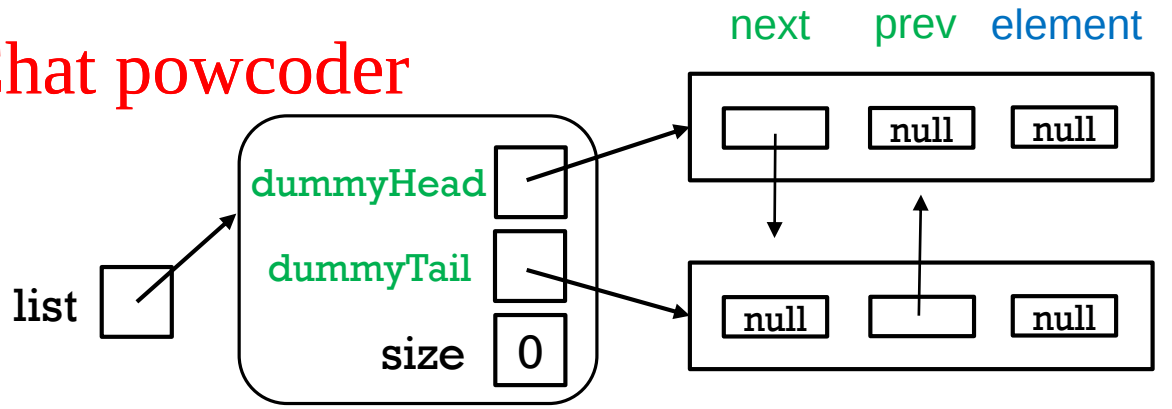
- Edge cases (i = 0, i = size – 1) require extra code.
  This is a pain and can lead to coding errors.

- How long does it take to access node `i`?

AVOID EDGE CASES WITH "DUMMY NODES"

```
public class DLinkedList {
    private DNode dummyHead;
    private DNode dummyTail;
    private int size;
    :
    public DLinkedList(){
        dummyHead = new DNode();
        dummyTail = new DNode();
        dummyHead.next = dummyTail;
        dummyTail.prev = dummyHead;
        size =0;
    }
}
```

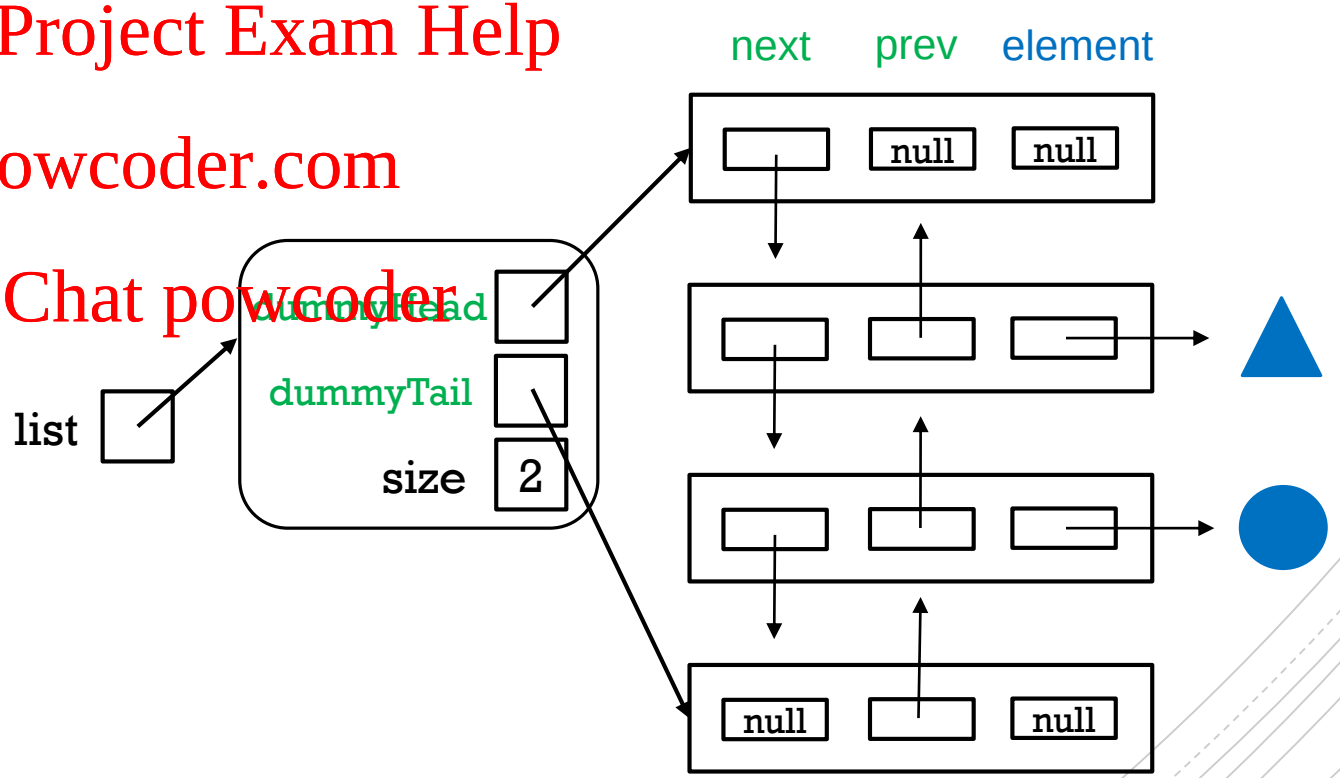
```
// empty list
DLinkedList list = new DLinkedList();
```

AVOID EDGE CASES WITH "DUMMY NODES"

```
public class DLinkedList {
    private DNode dummyHead;
    private DNode dummyTail;
    private int size;
    :
    public DLinkedList(){
        dummyHead = new DNode();
        dummyTail = new DNode();
        dummyHead.next = dummyTail;
        dummyTail.prev = dummyHead;
        size =0;
    }
}
```

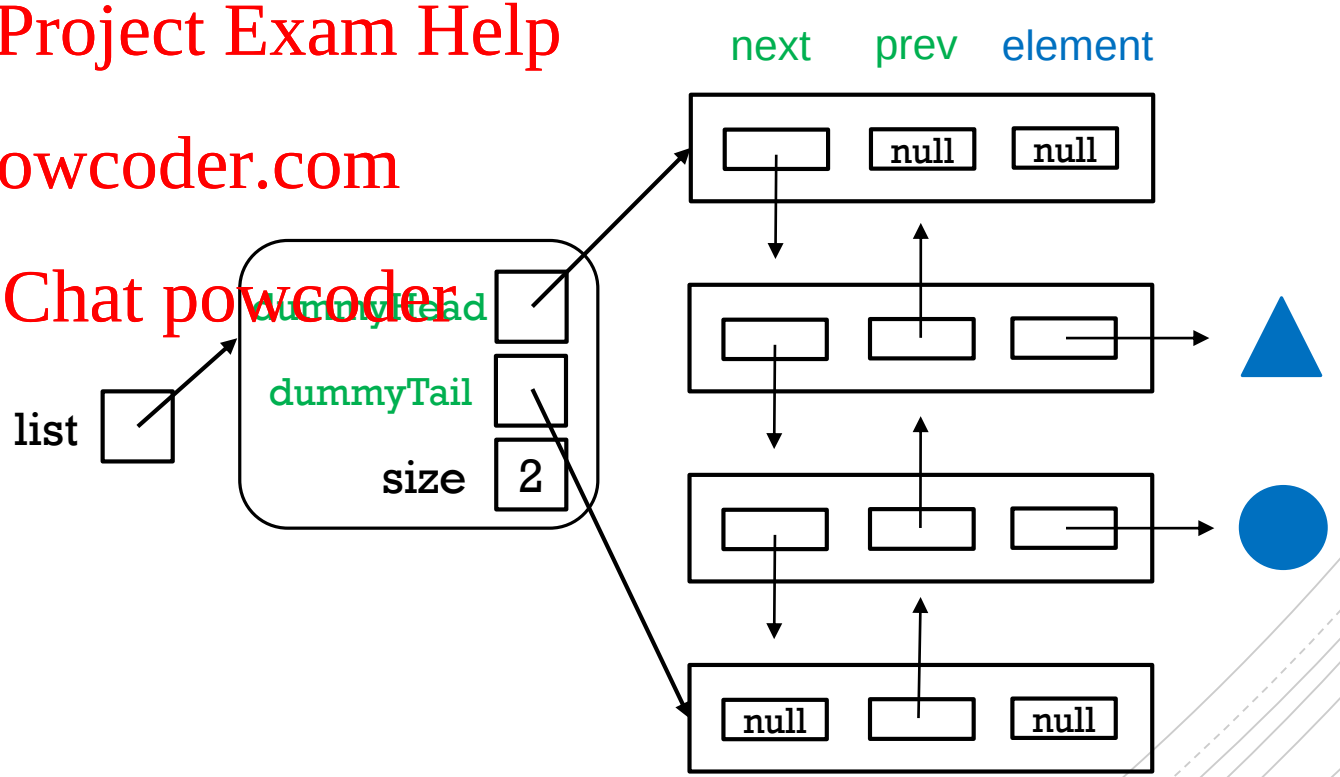
```
DLinkedList list = new DLinkedList();
// add 2 elements…
```

HOW DO WE ACCESS A NODE? – get()

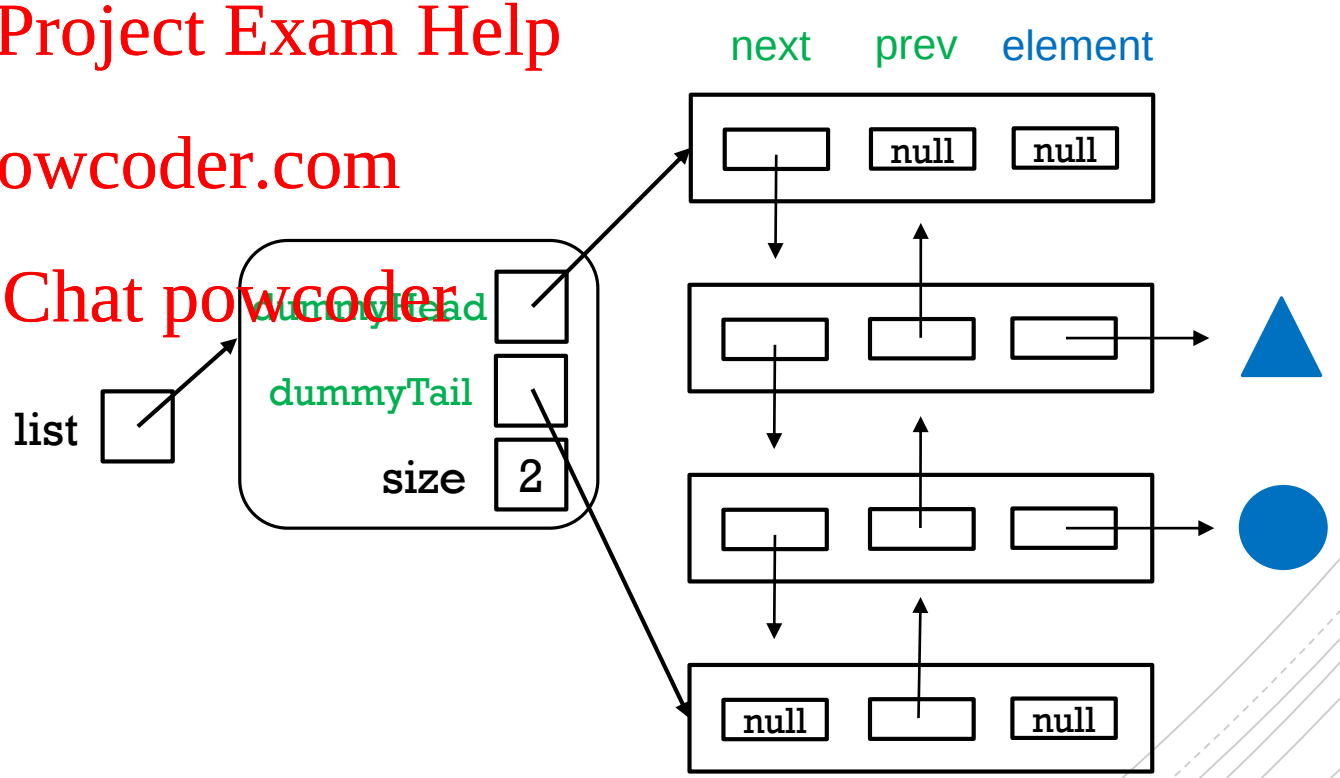
```
public Shape get(int i) {
    DNode node = getNode(i);
    return node.element;
}
```

```
private DNode getNode(int i) {
    // verify that 0<=i<size omitted
    DNode node = dummyHead.next;
    for(int k=0; k<i; k++)
        node = node.next;
    return node;
}
```

CAN WE SPEED THIS UP? – getNode()

```
private DNode getNode(int i) {
    // verify that 0<=i<size omitted
    DNode node;
    if (i < size/2) {
        node = dummyHead.next;
        for(int k=0; k<i; k++)
            node = node.next;
    }
    else {
        node = dummyTail.prev;
        for(int k=size -1; k>i; k--)
            node = node.prev;
    }
    return node;
}
```

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()

Why ?

Q: What is the time complexity of the following ?

```
DLinkedList list =   new  DLinkedList( ) ;

for (k = 0; k < N;   k ++) // N is some constant
        list.addFirst(...);
```

Q: What is the time complexity of the following ?

```
DLinkedList list =   new  DLinkedList( ) ;
for (k = 0; k < N;   k ++) // N is some constant
        list.addFirst(...);
```


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

where ‘1’ means constant.

Q: What is the time complexity of the following ?

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


Assuming here that `getNode(i)` *always starts at the head.*

Q: What is the time complexity of the following ?

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

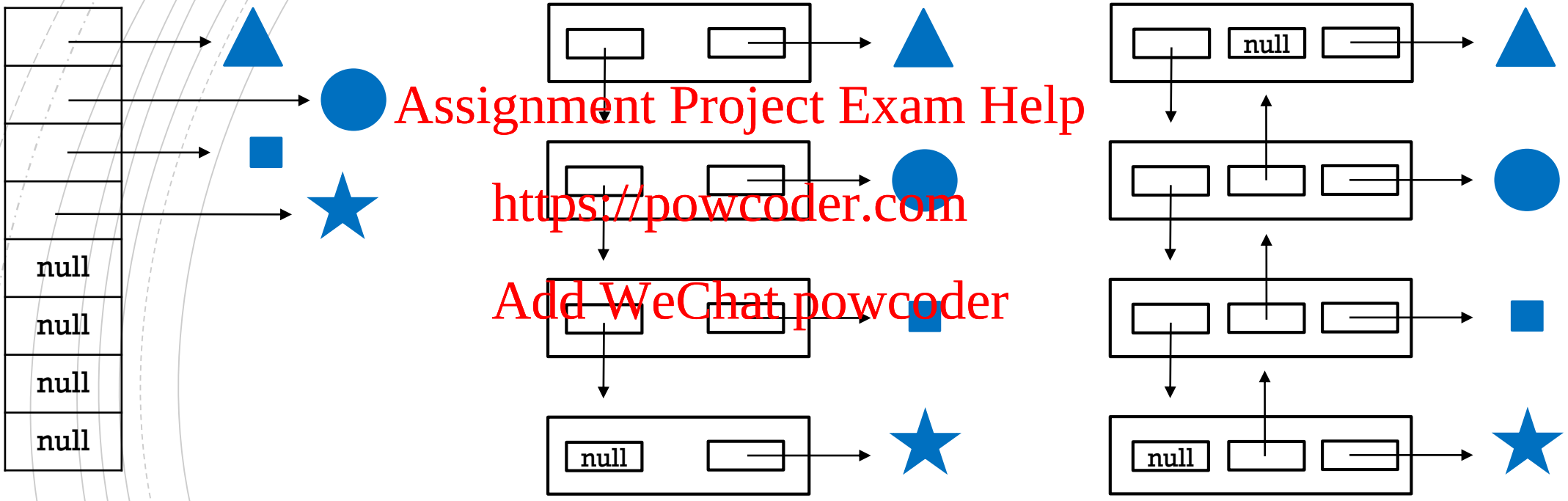

Assuming here that `getNode(i)` *always starts at the head.*

A: $\mathbf{1 + 2 + 3 + \ldots . N}$

$$= \frac{N\,(N+1)}{2} \quad \Rightarrow \quad O(N^2)$$

In 3 weeks we'll talk about a more efficient way to iterate through elements in a (Java) LinkedList!

WHAT ABOUT "SPACE COMPLEXITY" ?



All three data structures use space O(N) for a list of size N.
But linked lists use 2x (single) or 3x (double).

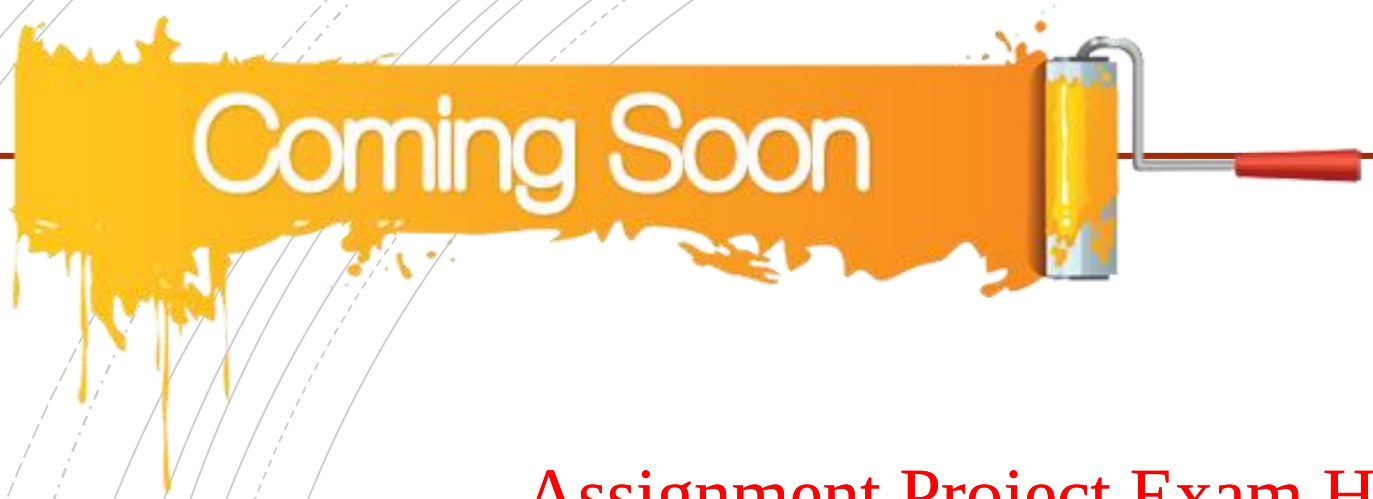
ARRAY LIST VERSUS LINKED LIST ?

Array lists and linked lists both take O(N) time to add or remove from an arbitrary position in the list.

In practice and when N is large, array lists are faster. But the reasons are subtle and have to do with how computer memory works, in particular, how caches exploit contiguous memory allocation. You will learn about that topic in COMP 273.

DO YOU EVER NEED LINKED LISTS ?

Yes. Even if you prefer ArrayLists, you still need to understand LinkedLists. Linked lists are special cases of a general and widely used data structure called a *tree* which we will be discussing extensively.



In the next videos:

- Quadratic sorting algorithms
- Asymptotic notations