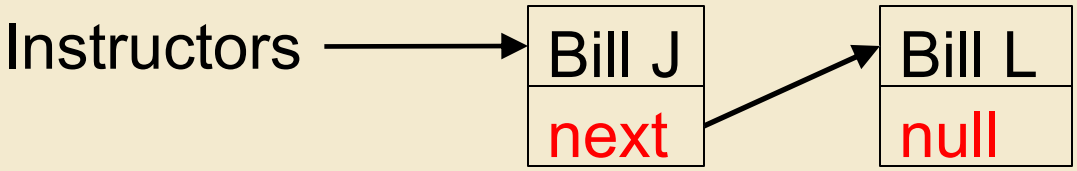
CSCI 136
Data Structures & Advanced Programming

Linked Lists

Fall 2020



Linked Lists

Linked Lists

- List: A general-purpose structure
- Implementing Lists with linked structures
  - Singly Linked Lists
    - A variant: Circularly Linked Lists
  - Doubly Linked Lists

For Maximum Value

If you haven't yet reviewed the implementations of Vector methods, do so before continuing!

Pros and Cons of Vectors

Pros

- Good general purpose list
- Dynamically Resizeable
- Fast access to elements
  - vec.get(387425) finds item 387425 in the same number of operations regardless of vec's size

Cons

- Slow updates to front of list (why?)
- Hard to predict time for add (depends on internal array size)
- Potentially wasted space

Today we look at another way to store data: Linked Lists

But First : List Interface

The Vector class implements many useful methods

```
size()
isEmpty()
contains(e)
get(i)
set(i, e)
add(i, e)
remove(i)
addFirst(e)
getLast()...
```

- Other data structures provide similar methods
- This set of methods is a natural candidate for forming an interface: The List Interface
- We will develop structures that implement the List interface
- They are called *linked structures*

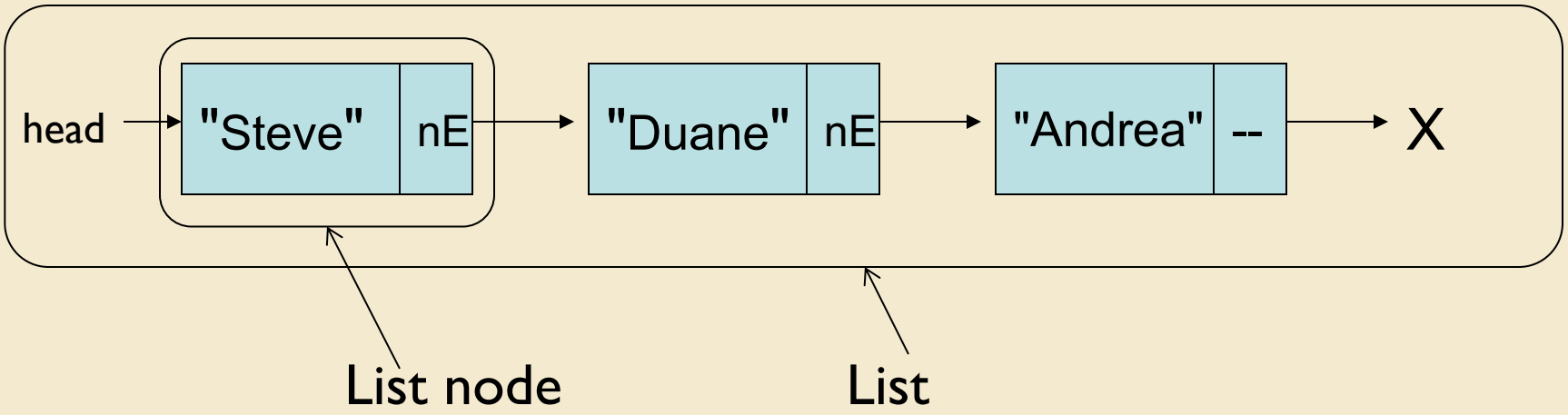
List Interface

```
public interface List<E> extends Structure<E> {

public int size();
public void clear();
public E getFirst();
public E getLast();
public E remove(E value);
public E remove(int i);
public E remove();
public void add(E value);
public E get();
public E get(int i);
public E set(int i, E o);
public boolean isEmpty();
public void addFirst(E value);
public void addLast(E value);
public E removeFirst();
public E removeLast();
public boolean contains(E value);
public int indexOf(E value);
public int lastIndexOf(E value);
public void add(int i, E o);
public Iterator<E> iterator();
}
```

Linked List Basics

- There are two key aspects of Lists
  - The *nodes* of the list
  - The list itself

- Visualizing lists



Linked List Basics

- List nodes are *recursive* data types
  - A node contains an instance variable of type node!
- Each "node" has:
  - A data value
  - A "next" value that identifies next node in the list
    - Could also have "previous" that identifies the previous node ("doubly-linked" lists)
- What state and methods does a Node need?

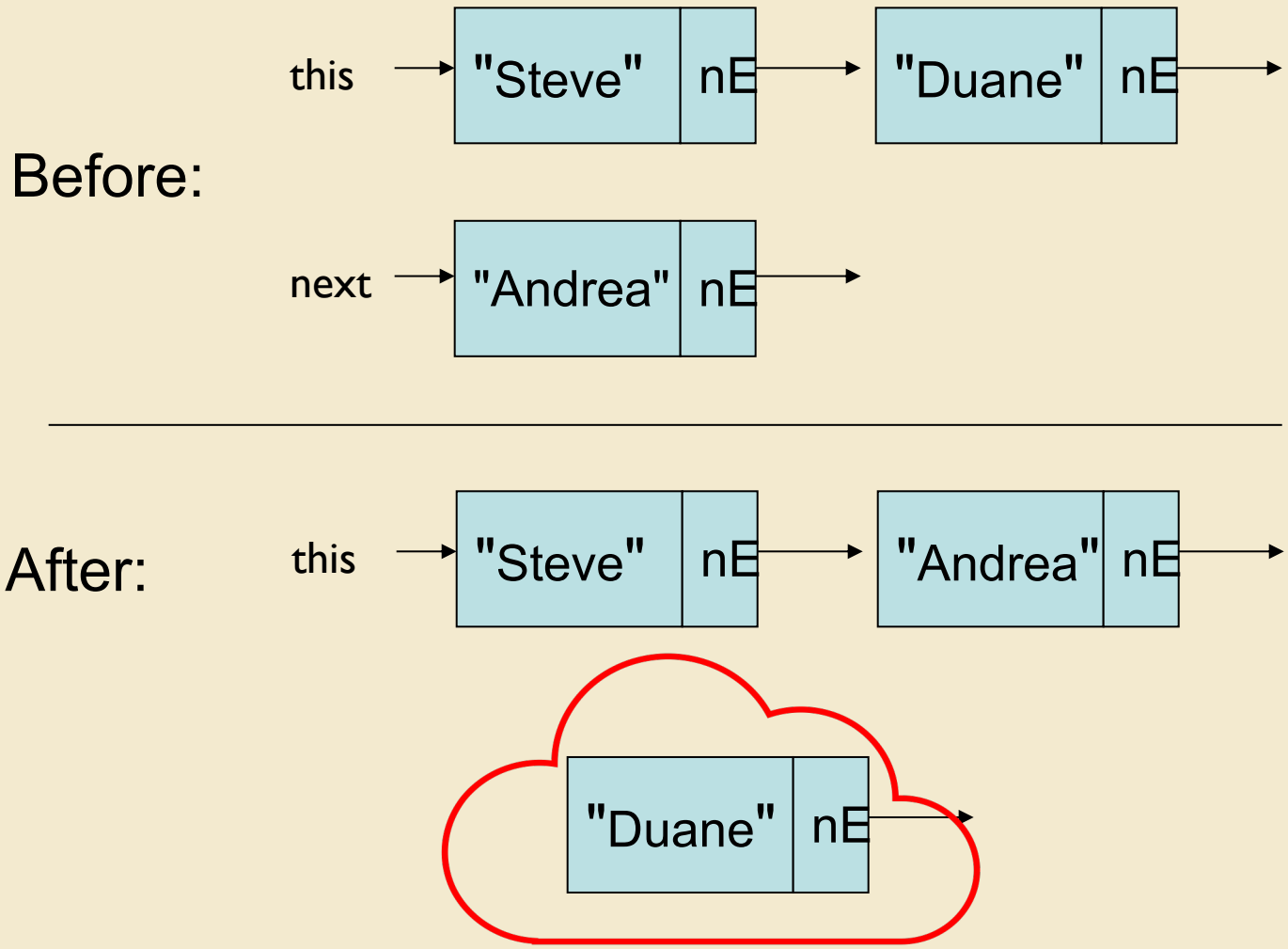
Public Class Node<E>

A singly-linked list node

```
protected E data; // value stored in this node
protected Node<E> nextElement; // ref to next node
public Node(E v, Node<E> next) {
    data = v;
    nextElement = next;
}
public Node(E v) { this(v,null); }

public Node<E> next() { return nextElement; }

public void setNext(Node<E> next){ nextElement = next; }

public E value() { return data; }

public void setValue(E value) { data = value; }

public String toString() { return "<Node: "+value()+">"; }
```

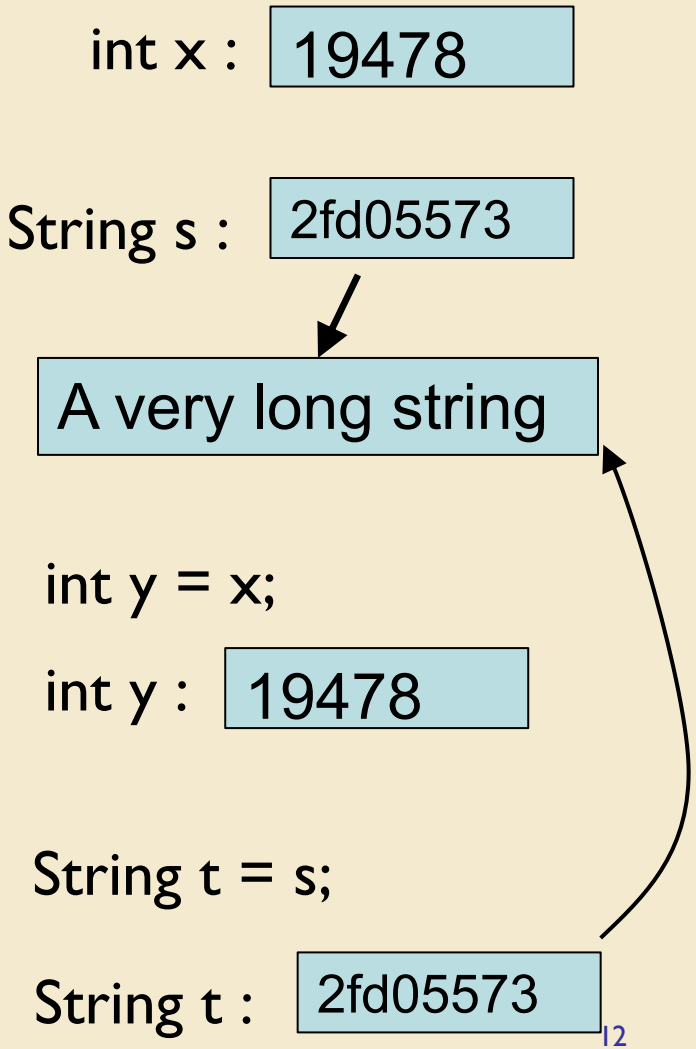
Visualizing setNext

```
public void setNext(Node<E> next){ nextElement = next; }
```



Types and Memory

- Variables of primitive types
  - Hold a value of primitive type
- Variables of class types
  - Hold a *reference* to the location in memory where the corresponding object is stored
- Variable of array type
  - Holds a *reference*, like variables of class type
- Assignment statements
  - For primitive types, copies the value
  - For class/array types, copies the reference



Variables and Memory

- Instance variables
  - Upon declaration are given a default value
  - Primitive types
    - 0 for number types, false for Boolean, \u000 for char
  - Class types and arrays: null
- Local variables
  - Are NOT given a default when declared
- Method parameters
  - Receive values from arguments in method call

Memory Management in Java

- Where do "old" objects go?

```
Track t = new Track("Hey, Jude", "The Beatles", … );
…
t = new Track ("Blowin' in the Wind", "Bob Dylan", … );
```

- What happens to Hey, Jude?
- Java has a *garbage collector*
  - Runs periodically to "clean up" memory that had been allocated but is no longer in use
  - Automatically runs in background
- Not true for many other languages!

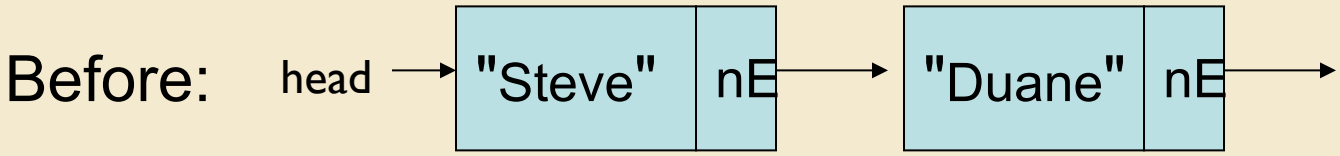
SinglyLinkedLists

- A SinglyLinkedList object stores only two values

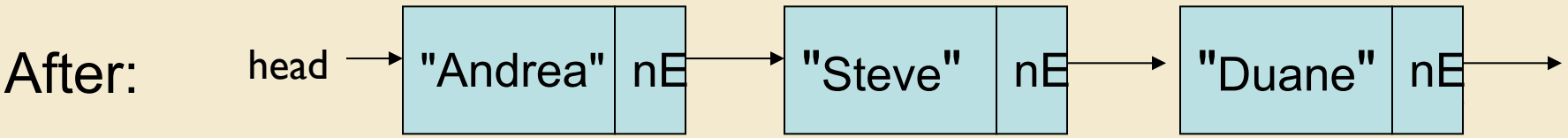
```
// list size
protected int count;
// ref. to first element
protected Node<E> head;
```

- What would addFirst(E d) look like?

```
public void addFirst(E value) {
    head = new Node<E>(value, head);
    count++;}
```



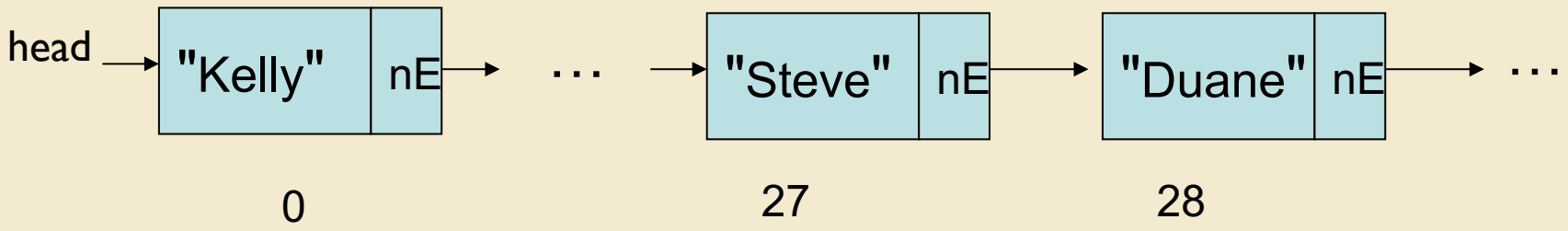

```
myList.addFirst("Andrea");
```



More SLL Methods

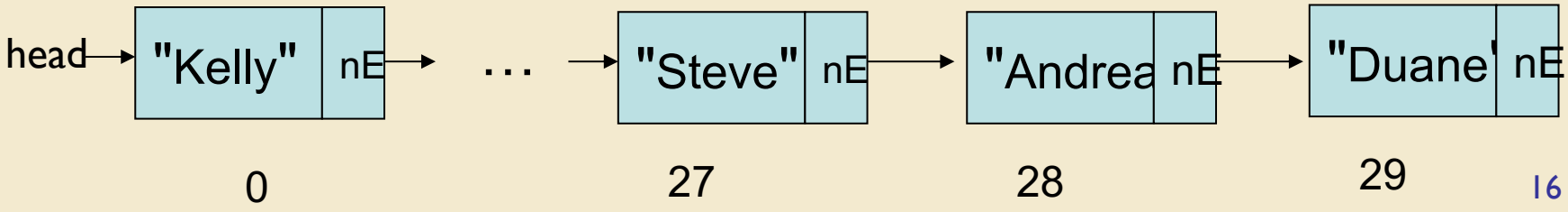
- How would we implement `add(int i, E o)`?

Before:



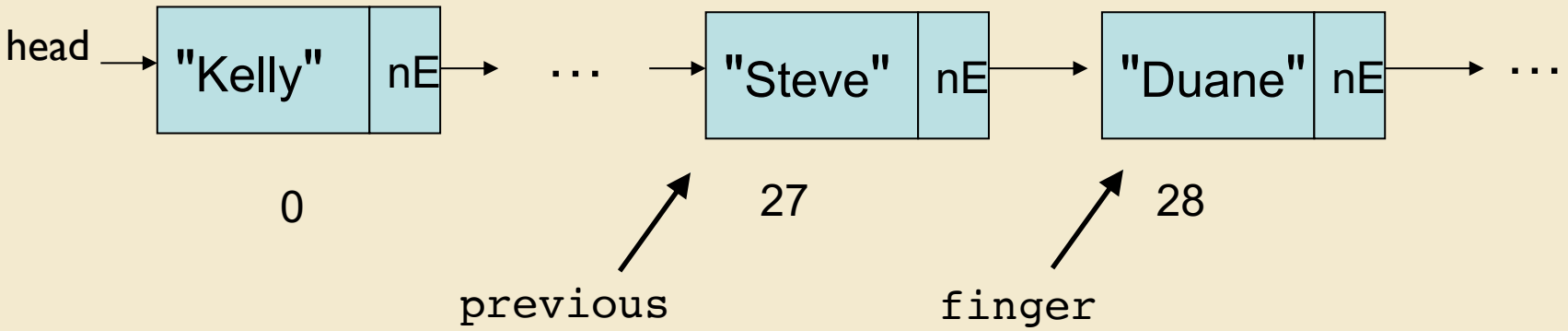

```
myList.add(28, "Andrea");
```

After:

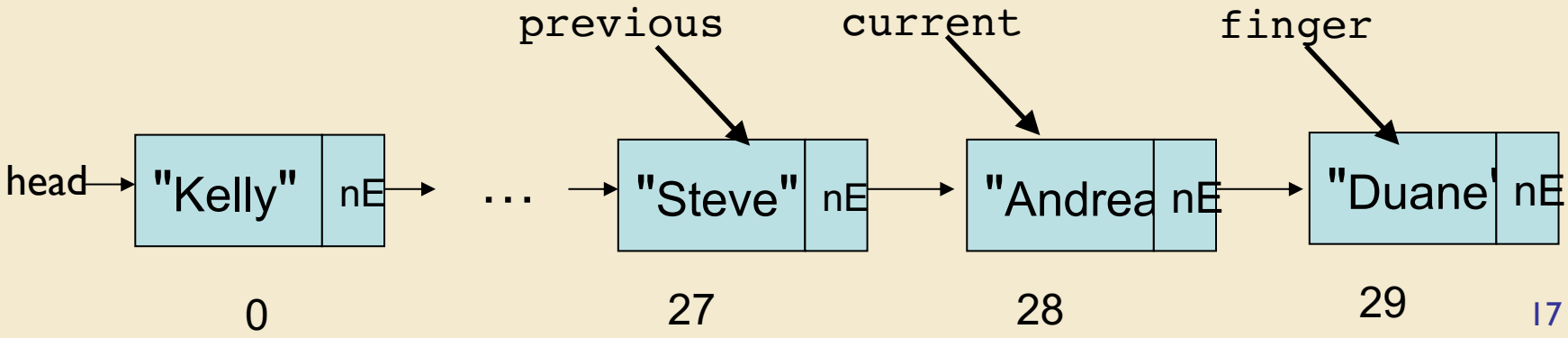


Add(int i, E o)

```
Node<E> previous = null;
Node<E> finger = head;
```




```
Node<E> current = new Node<E>(o,finger);
previous.setNext(current);
```

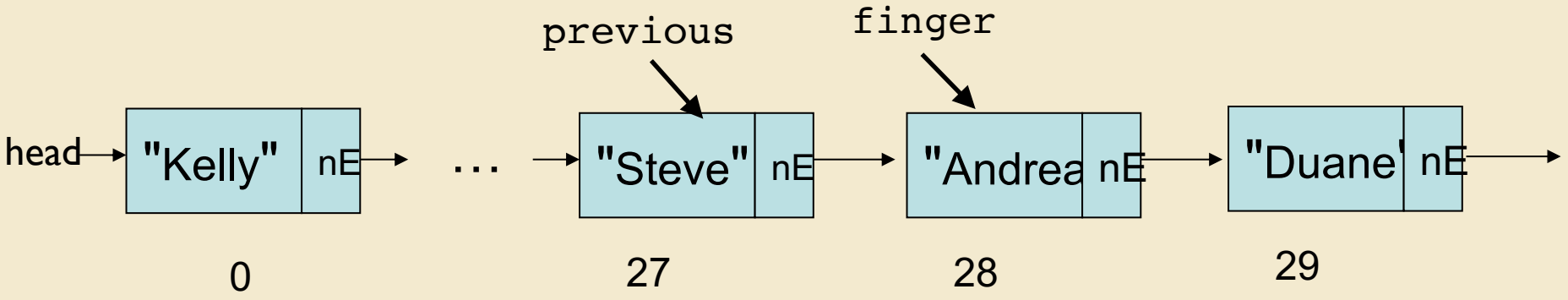


Add(int I, E o)

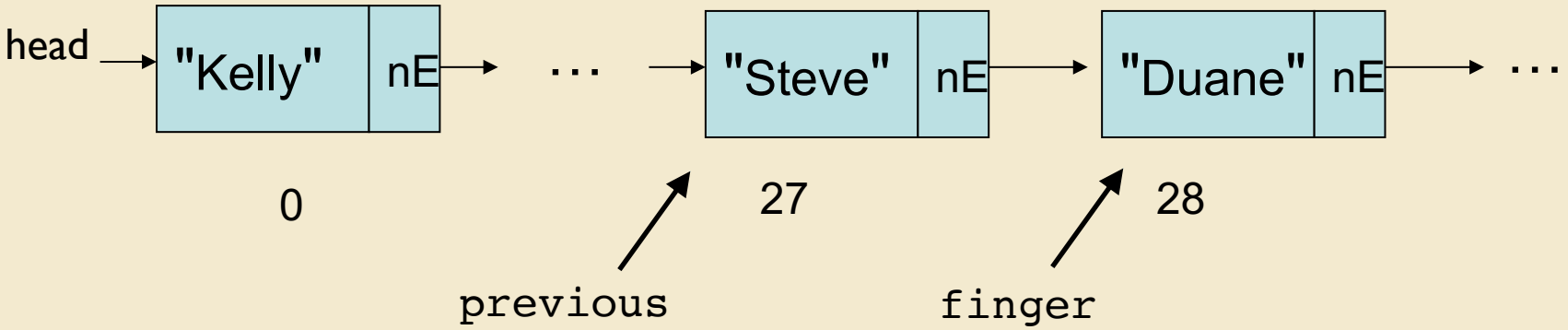
```
public void add(int i, E o) {
   Assert.pre((0 <= i)  && (i <= size()), "Index in range.");
   if (i == size()) {
        addLast(o);
   } else if (i == 0) {
        addFirst(o);
   } else {
        Node<E> previous = null;
        Node<E> finger = head;
        // search for ith position, or end of list
        while (i > 0) {
               previous = finger;
               finger = finger.next();
               i--;
        }
        // create new value to insert in correct position
        Node<E> current = new Node<E>(o,finger);
        count++;
        // make previous value point to new value
        previous.setNext(current);
   }
}
```

Remove(int i)

```
myList.remove(28);

Node<E> previous = null;
Node<E> finger = head;
```




```
previous.setNext(finger.next());
count--;
```



Remove

```
public E remove(int i) {

   Assert.pre((0 <= i) && (i < size()), "Index in range.");

   if (i == 0) return removeFirst();
   else if (i == size()-1) return removeLast();

   Node<E> previous = null;
   Node<E> finger = head;

   // search for value indexed, keep track of previous
   while (i > 0) {
        previous = finger;
        finger = finger.next();
        i--;
   }
   // in list, somewhere in middle
   previous.setNext(finger.next());
   count--;
   // finger's value is old value, return it
   return finger.value();
   }
```

Linked Lists Summary

- Recursive data structures used for storing data
- More control over space use than Vectors
  - No hidden costs like Vector.ensureCapacity()
  - No "empty slots" like Vector
  - But: Keeps an extra reference for each value
- Adding objects to front of list is fast 😄
  - Adding to end of list is slow 😢
- Components of SinglyLinkedList
  - head, count
- Components of Node
  - data, nextElement