Linear Lists – Linked Representation

Data structures

Spring 2017

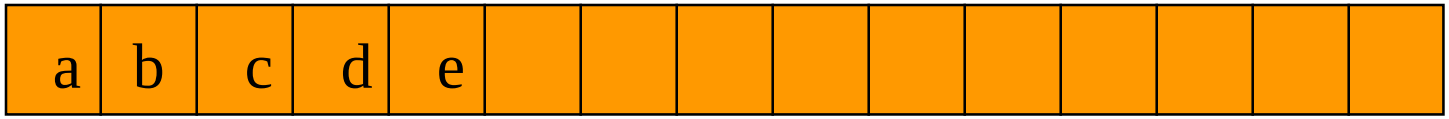
Linked Representation

- list elements are stored, in memory, in an arbitrary order

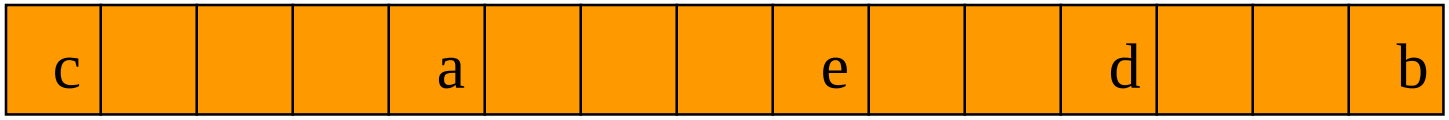
- explicit information (called a ‘link’) is used to go from one element to the next

Memory Layout

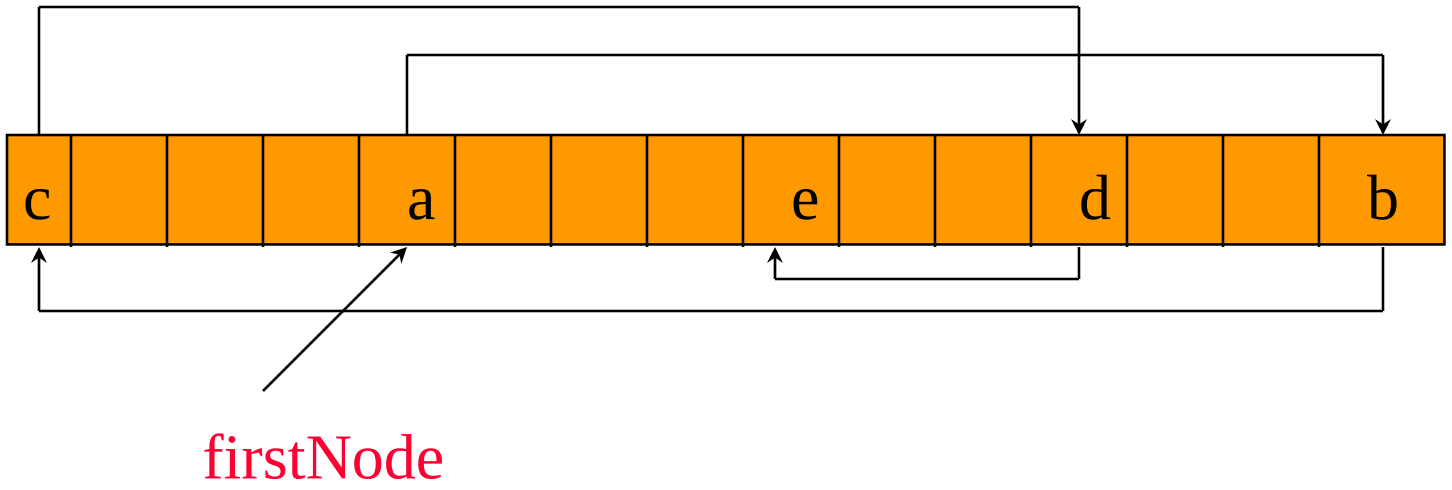
Layout of L = (a,b,c,d,e) using an array representation.



A linked representation uses an arbitrary layout.



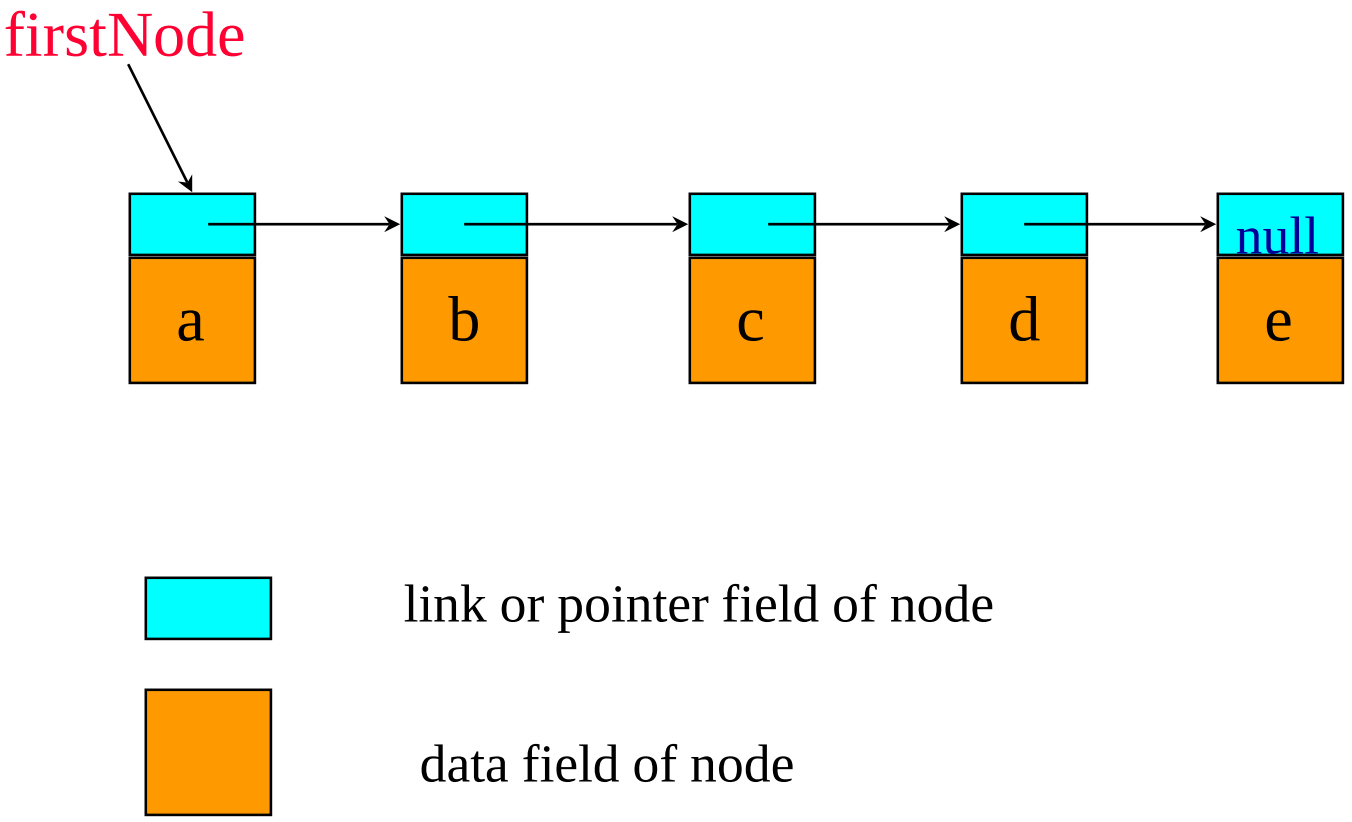
Linked Representation



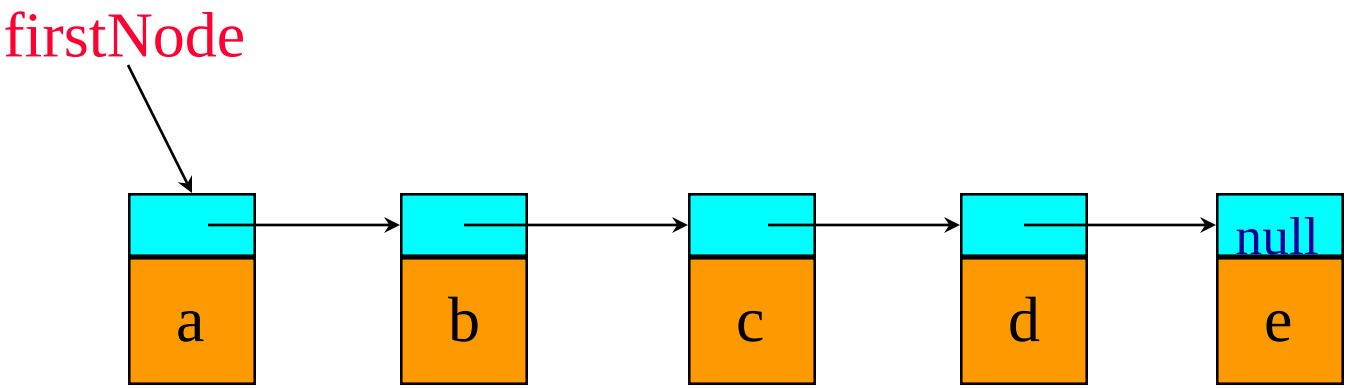
pointer (or link) in e is null

use a variable firstNode to get to the first element a

Normal Way To Draw A Linked List



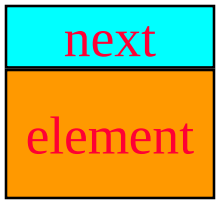
Chain



- A chain is a linked list in which each node represents one element.
- There is a link or pointer from one element to the next.
- The last node has a null pointer.

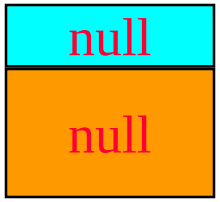
Node Representation

```
package dataStructures;

class ChainNode
{
   // package visible data members
   Object element;
   ChainNode next;

   // constructors come here
}
```

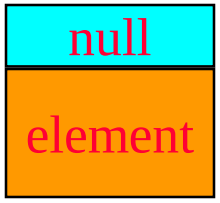


Constructors Of ChainNode

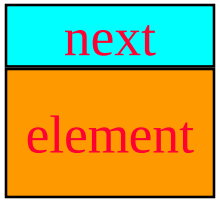
ChainNode() {}



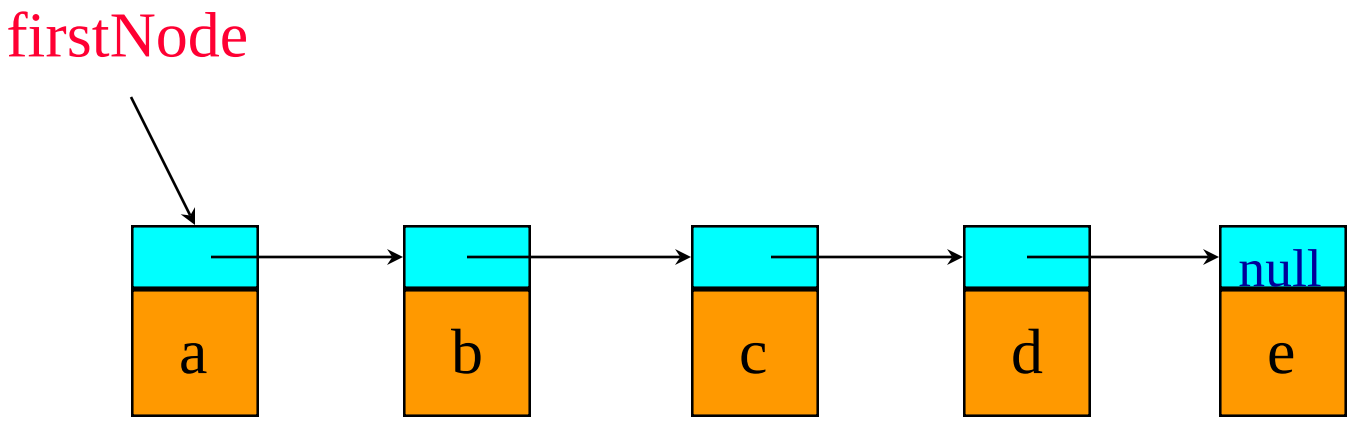
ChainNode(Object element)
{this.element = element;}



ChainNode(Object element, ChainNode next)
{this.element = element;
this.next = next;}

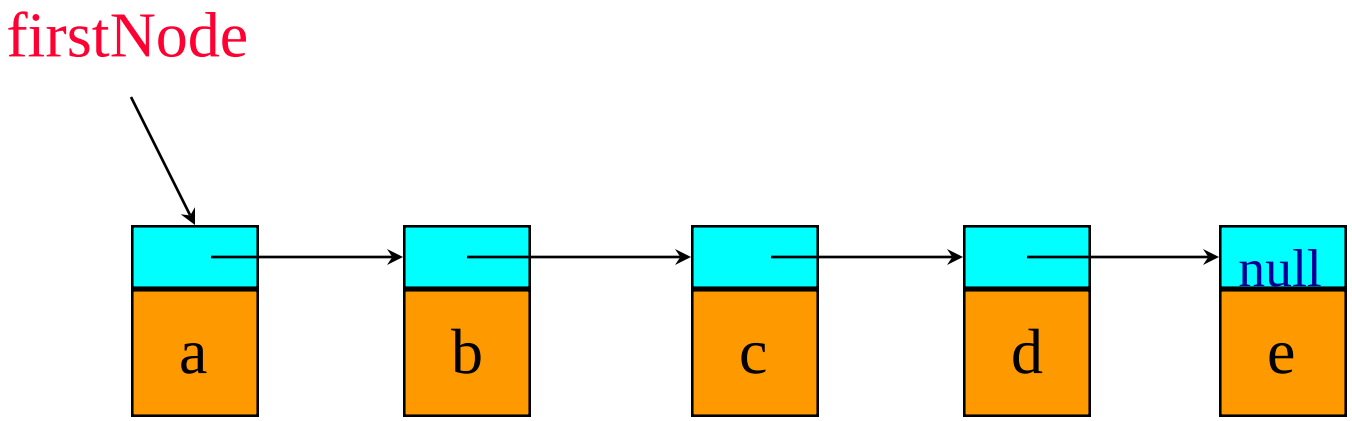


get(0)




```
checkIndex(0);
desiredNode = firstNode; // gets you to first node
return desiredNode.element;
```

get(1)

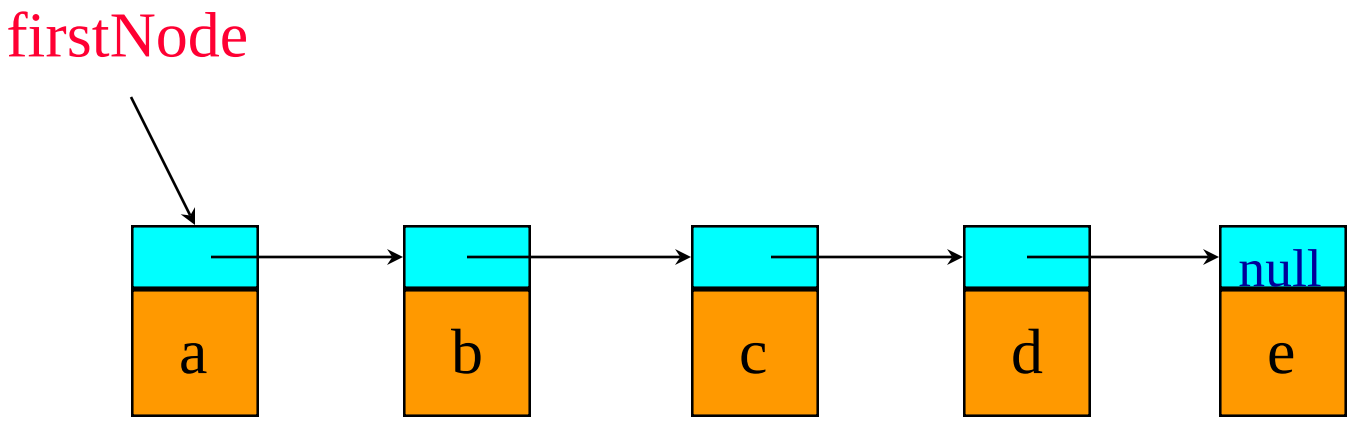


checkIndex(1);

desiredNode = firstNode.next; // gets you to second node

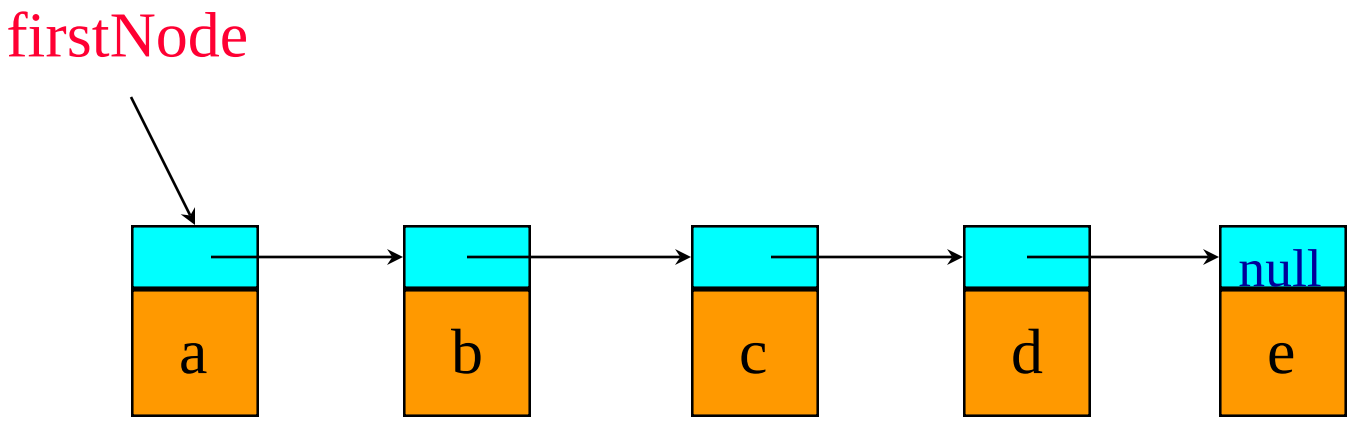
return desiredNode.element;

get(2)



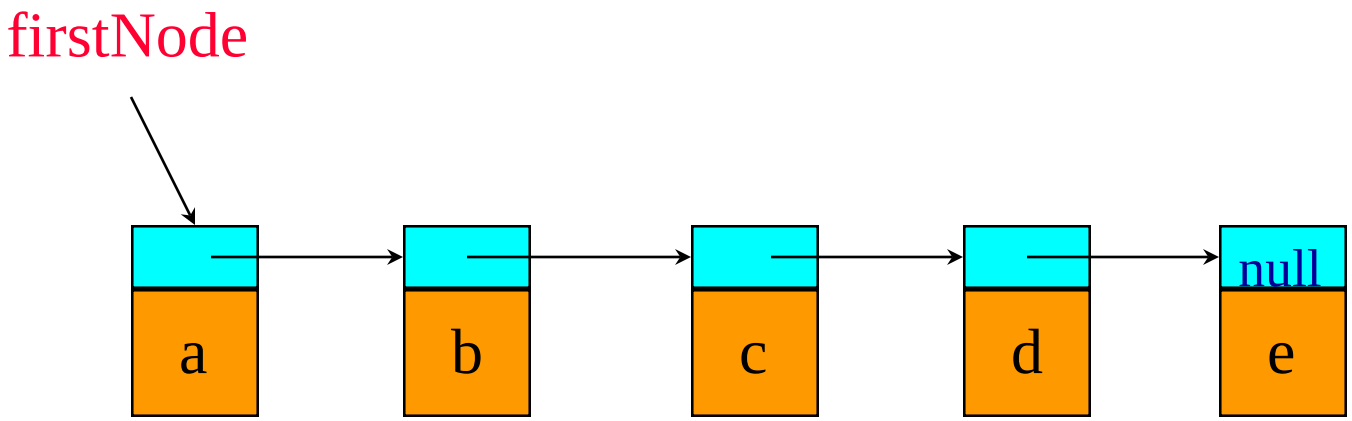

```
checkIndex(2);
desiredNode = firstNode.next.next; // gets you to third node
return desiredNode.element;
```

get(5)



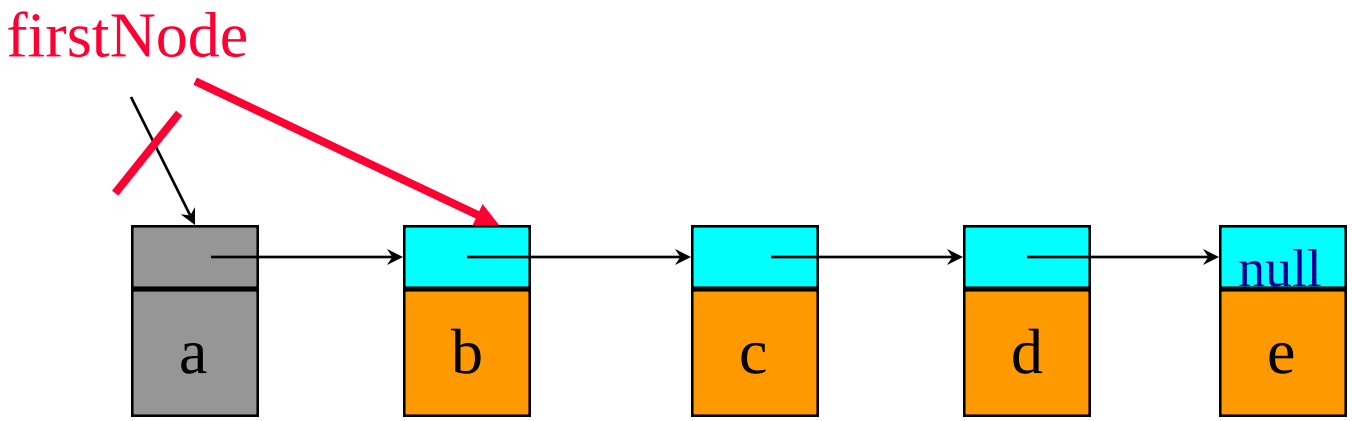

```
checkIndex(5);              // throws exception
desiredNode = firstNode.next.next.next.next.next;
                            // desiredNode = null
return desiredNode.element;   // null.element
```

NullPointerException




```
desiredNode =
    firstNode.next.next.next.next.next.next;
      // you get a NullPointerException
```

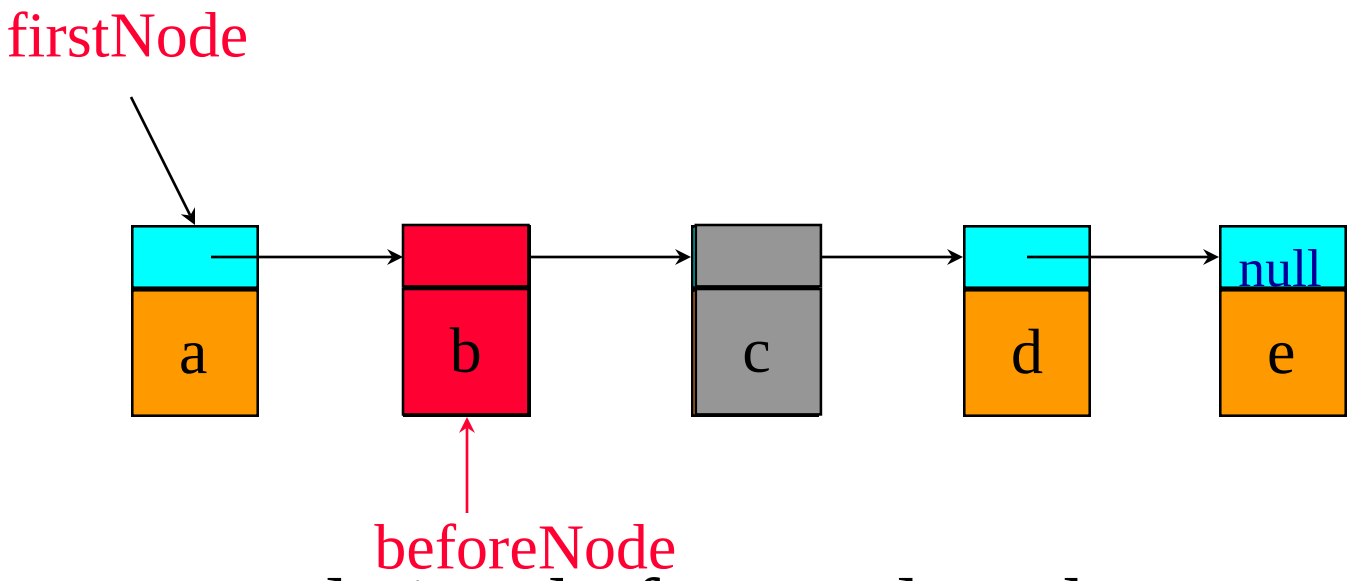
Remove An Element



remove(0):

firstNode = firstNode.next;

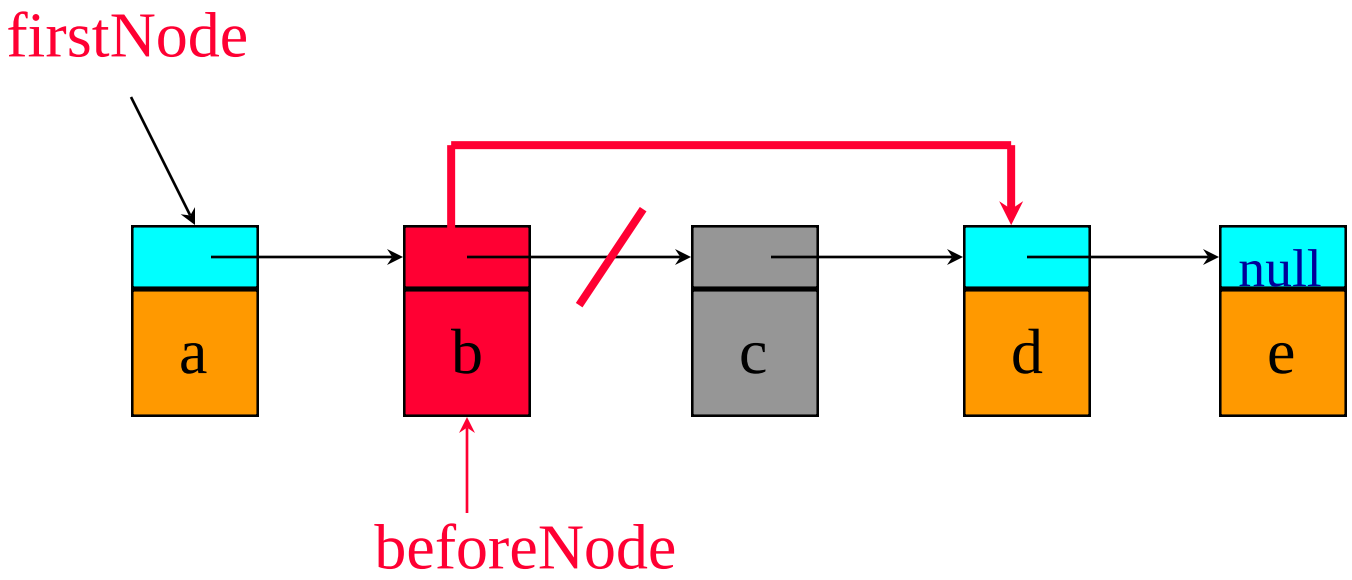
remove(2)



first get to node just before node to be removed

beforeNode = firstNode.next;

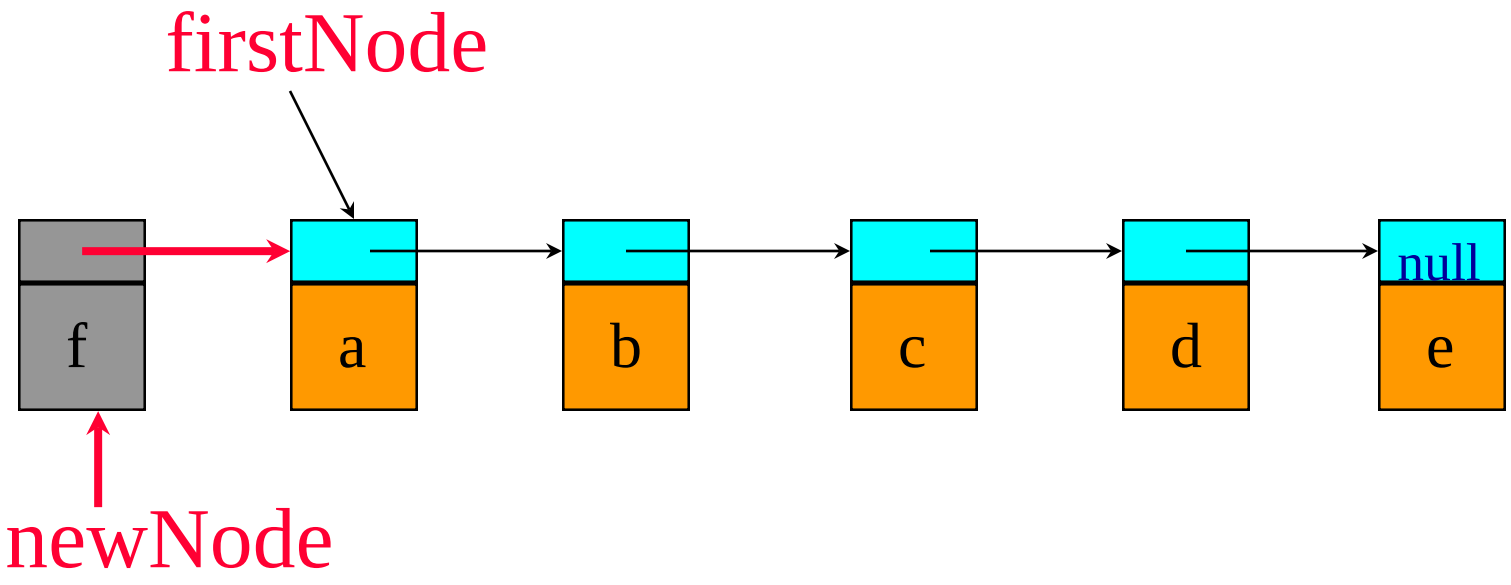
remove(2)



now change pointer in beforeNode

beforeNode.next = beforeNode.next.next;

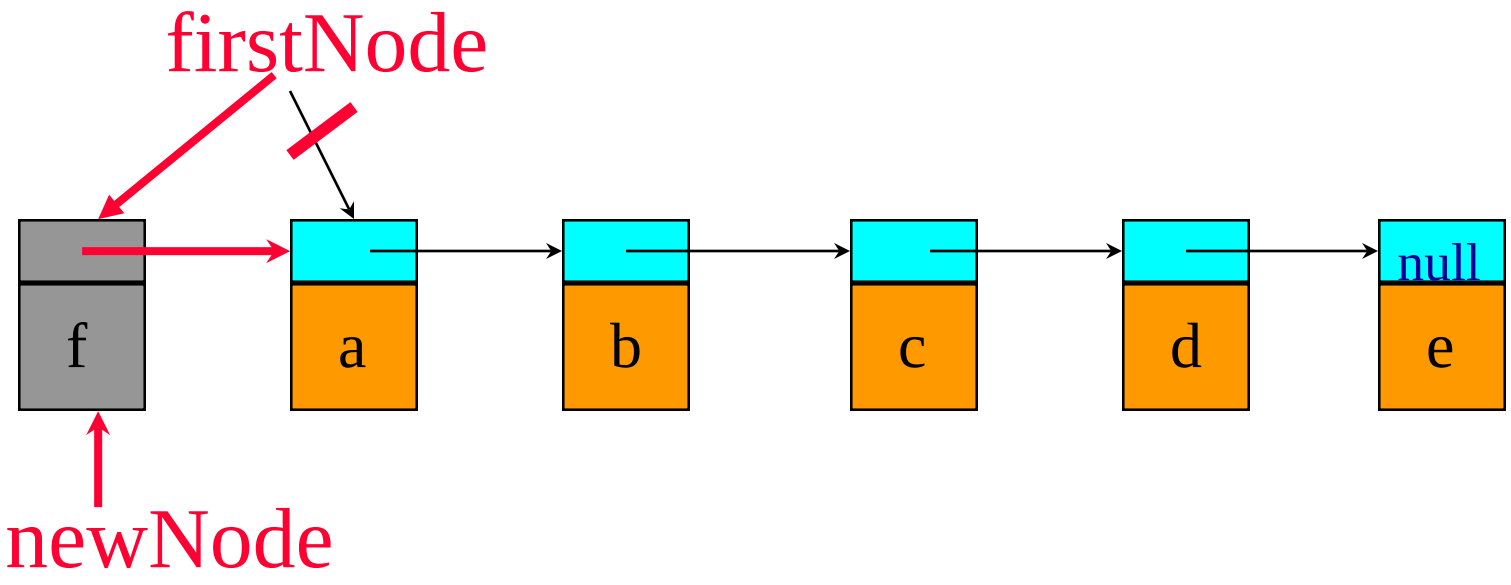
add(0,'f')



Step 1: get a node, set its data and link fields

```
ChainNode newNode =
    new ChainNode(new Character('f'), firstNode);
```

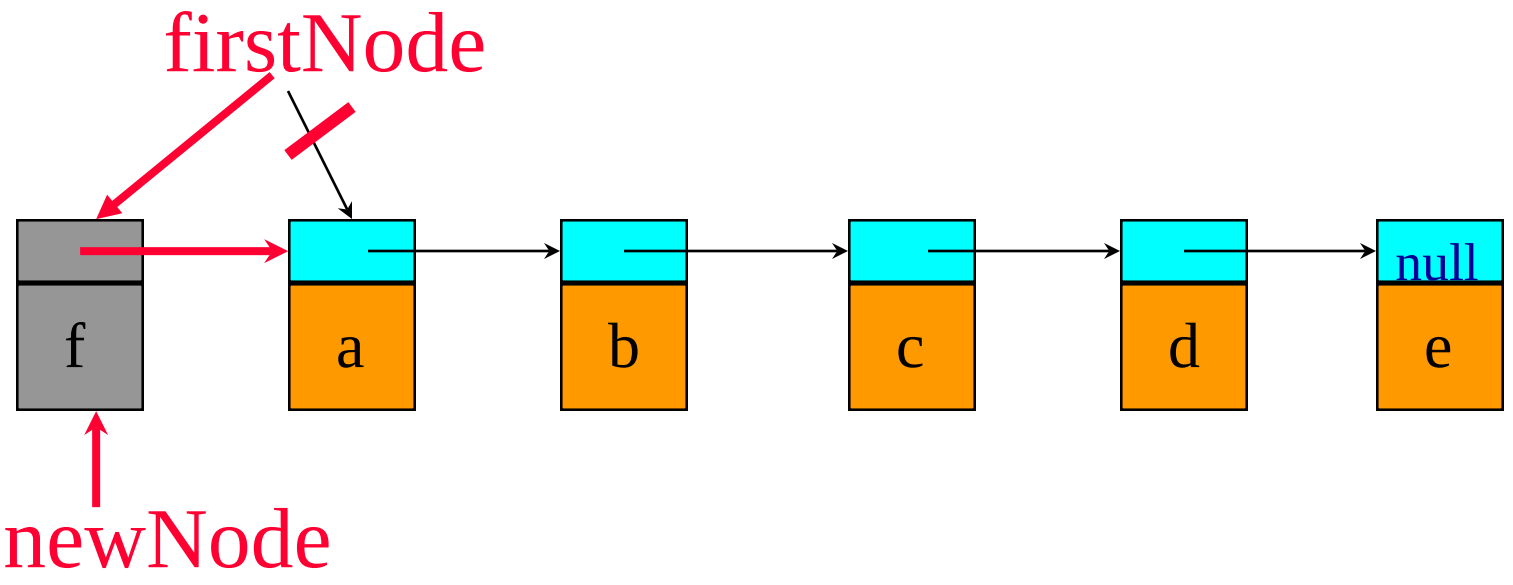
add(0,'f')



Step 2: update firstNode

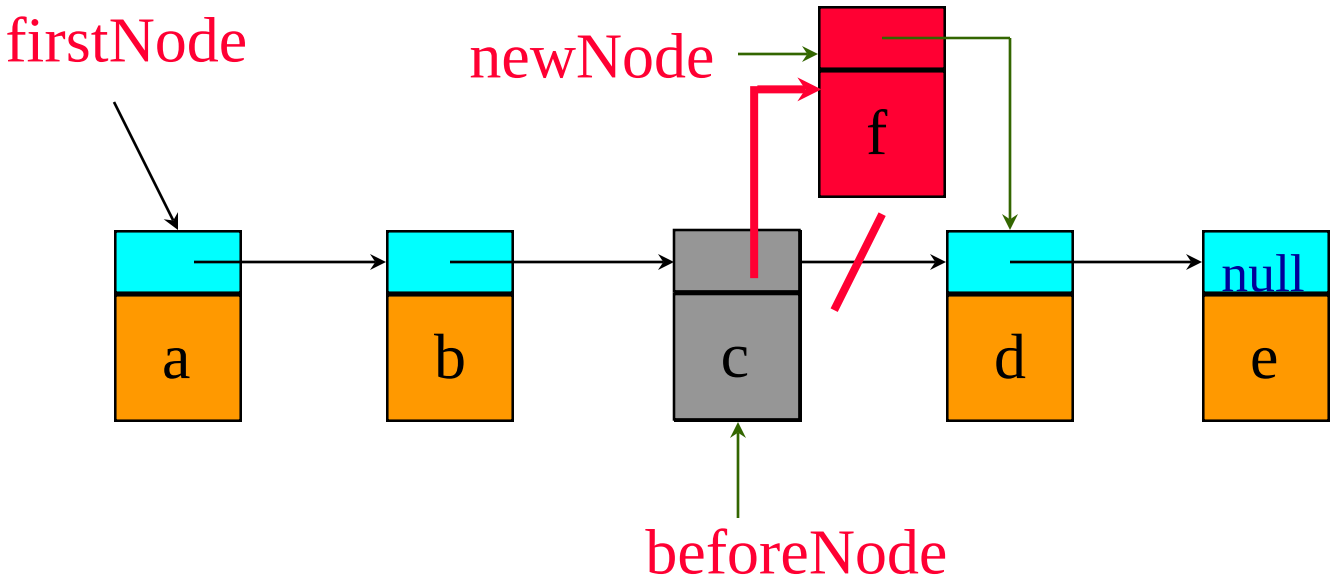
firstNode = newNode;

One-Step add(0,'f')



firstNode = new ChainNode(new Character('f'),
firstNode);

add(3,'f')



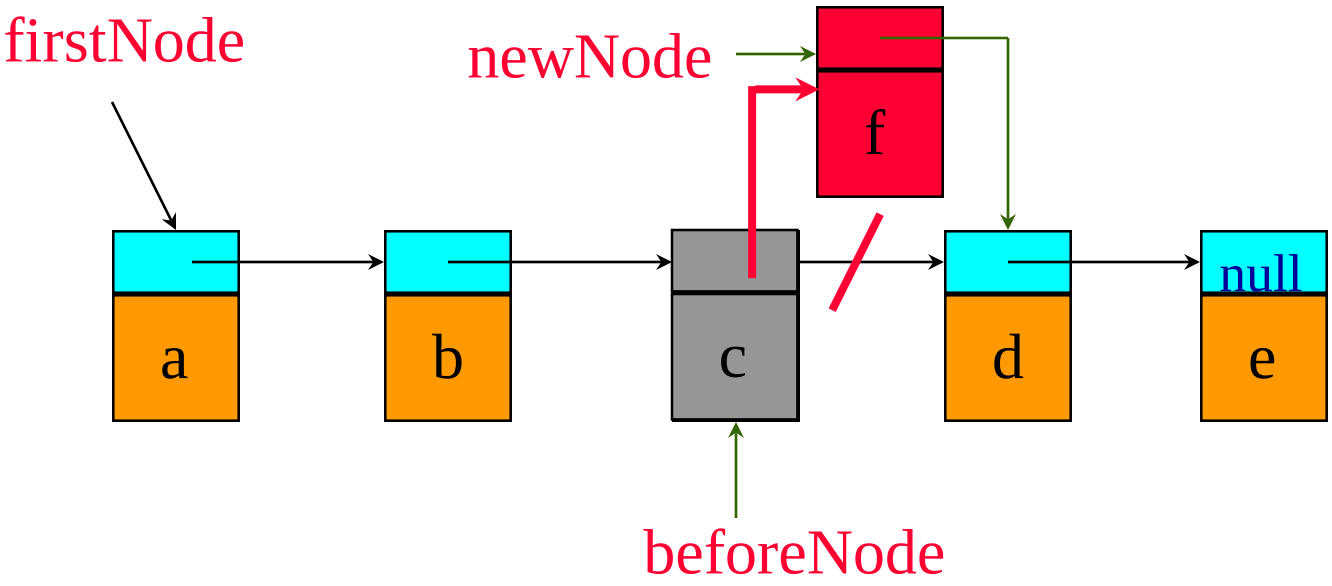
- first find node whose index is 2
- next create a node and set its data and link fields

```
ChainNode newNode = new ChainNode(new Character('f'),
                                  beforeNode.next);
```

- finally link beforeNode to newNode

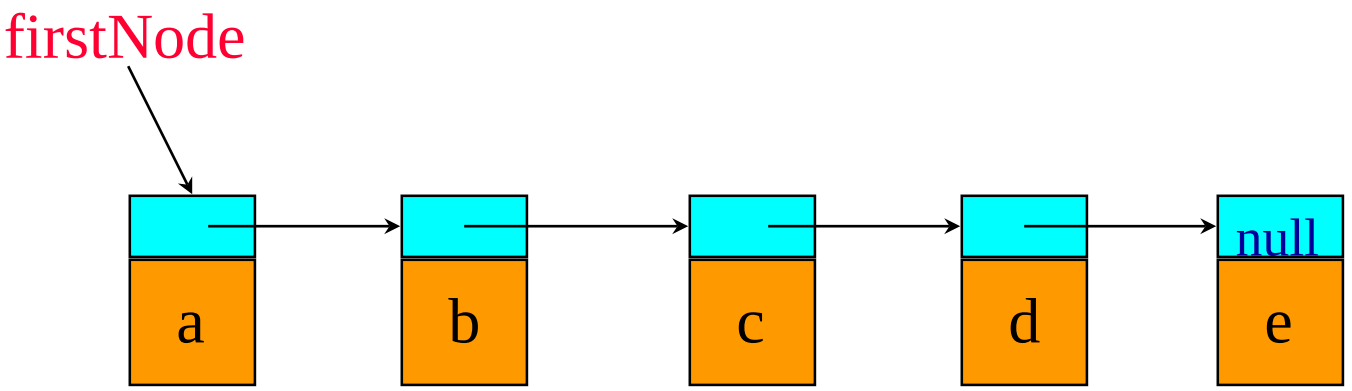
```
beforeNode.next = newNode;
```

Two-Step add(3,'f')




```
beforeNode = firstNode.next.next;
beforeNode.next = new ChainNode(new Character('f'),
                                beforeNode.next);
```

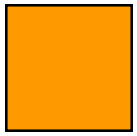
The Class Chain



size = number of elements

Use ChainNode

next (datatype ChainNode)



element (datatype Object)

The Class Chain

```
/** linked implementation of LinearList */
package dataStructures;
import java.util.*;  // has Iterator
public class Chain implements LinearList
{
   // data members
   protected ChainNode firstNode;
   protected int size;

   // methods of Chain come here
}
```

Constructors

```
/** create a list that is empty */
public Chain(int initialCapacity)
{
      // the default initial values of firstNode and size
      // are null and 0, respectively
}

public Chain()
   {this(0);}
```

The Method isEmpty

```
/** @return true iff list is empty */
public boolean isEmpty()
   {return size == 0;}
```

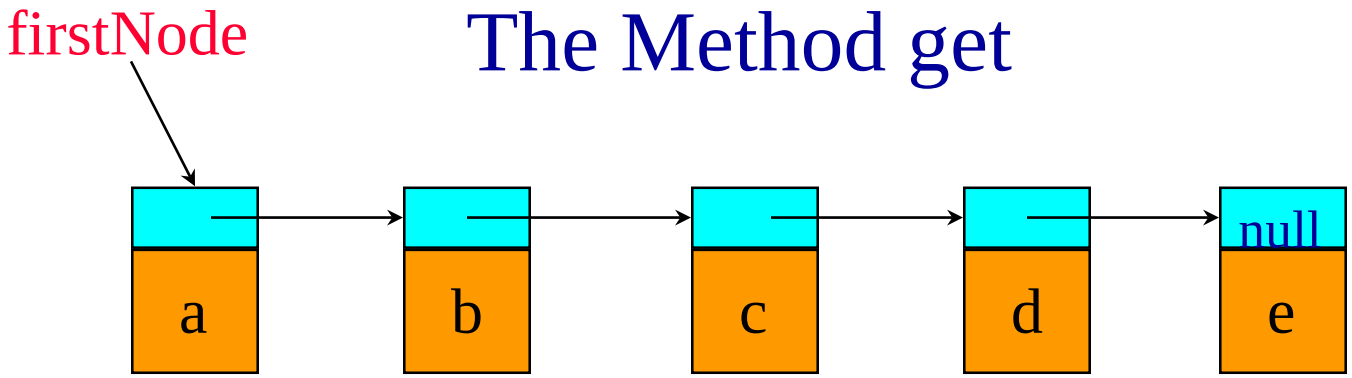
The Method size()

```
/** @return current number of elements in list */
public int size()
   {return size;}
```

The Method checkIndex

```
/** @throws IndexOutOfBoundsException when
   * index is not between 0 and size - 1 */
void checkIndex(int index)
{
  if (index < 0 || index >= size)
    throw new IndexOutOfBoundsException
          ("index = " + index + "  size = " + size);
}
```

The Method get




```
public Object get(int index)
{
   checkIndex(index);

   // move to desired node
   ChainNode currentNode = firstNode;
   for (int i = 0; i < index; i++)
      currentNode = currentNode.next;

   return currentNode.element;
}
```

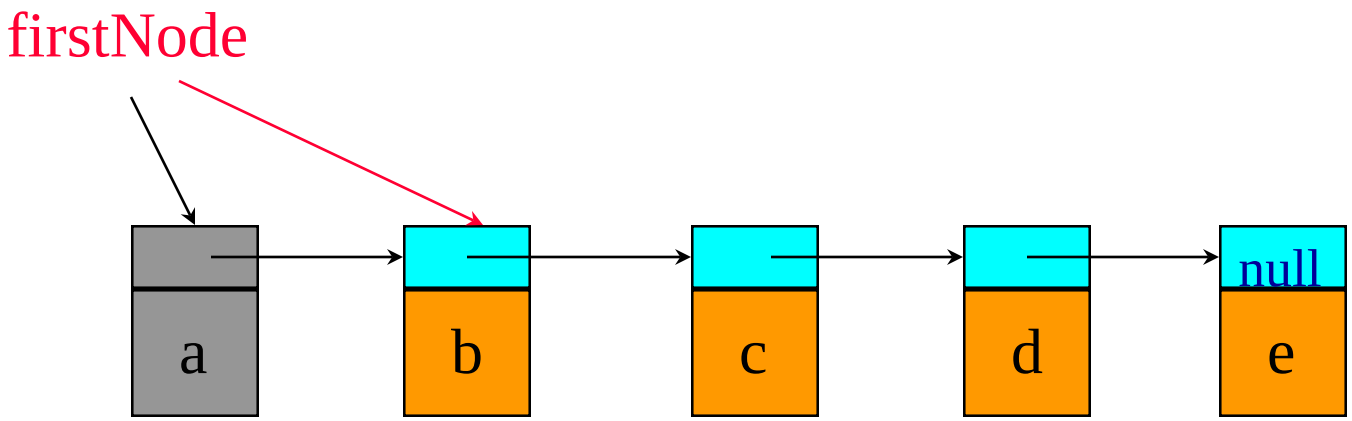
The Method indexOf

```
public int indexOf(Object theElement)
 {
   // search the chain for theElement
   ChainNode currentNode = firstNode;
   int index = 0;  // index of currentNode
   while (currentNode != null &&
          !currentNode.element.equals(theElement))
   {
     // move to next node
     currentNode = currentNode.next;
     index++;
   }
```

The Method indexOf

```
    // make sure we found matching element
    if (currentNode == null)
        return -1;
    else
        return index;
}
```

Removing An Element



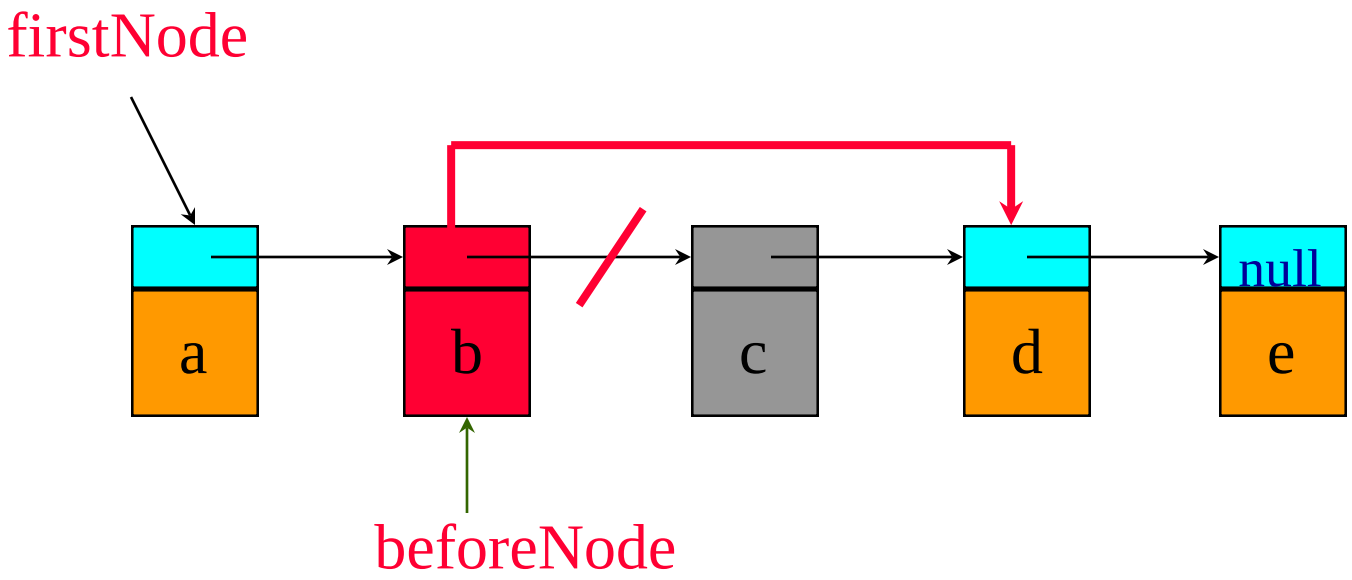
remove(0)

firstNode = firstNode.next;

Remove An Element

```
public Object remove(int index)
{
  checkIndex(index);

  Object removedElement;
  if (index == 0) // remove first node
  {
    removedElement = firstNode.element;
    firstNode = firstNode.next;
  }
```

remove(2)



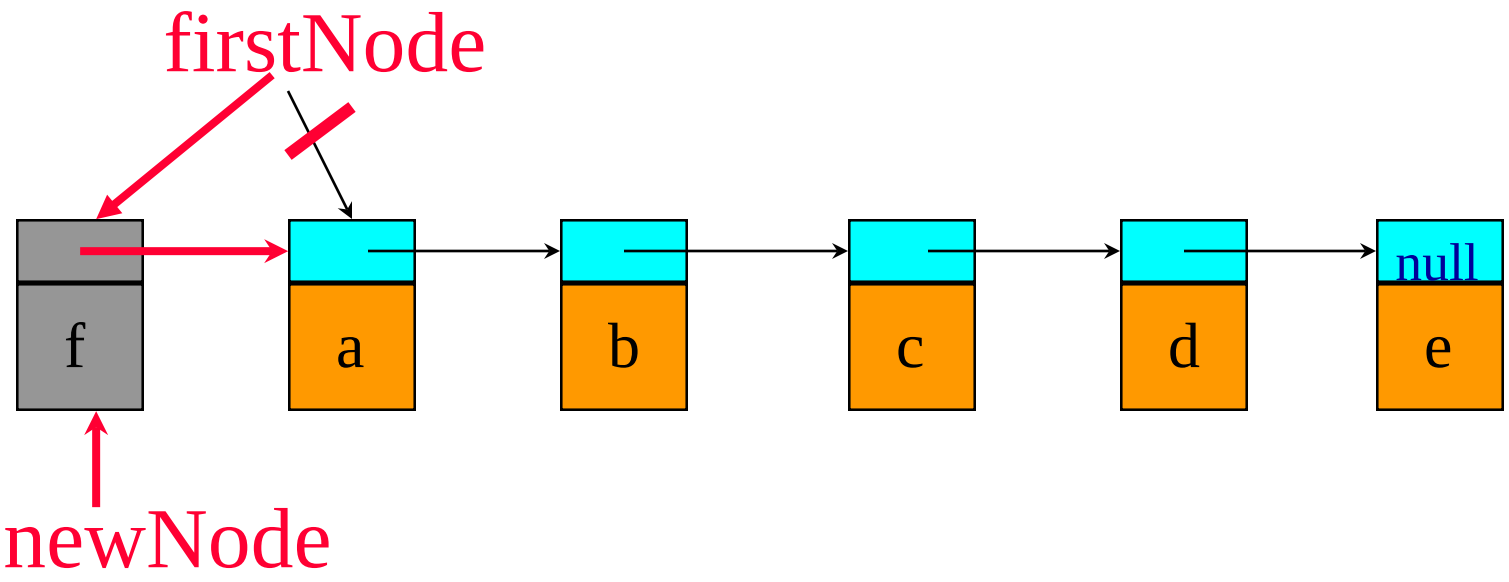
Find beforeNode and change its pointer.

beforeNode.next = beforeNode.next.next;

Remove An Element

```
else
   {  // use q to get to predecessor of desired node
      ChainNode q = firstNode;
      for (int i = 0; i < index - 1; i++)
         q = q.next;

      removedElement = q.next.element;
      q.next = q.next.next; // remove desired node
   }
   size--;
   return removedElement;
}
```

One-Step add(0,'f')

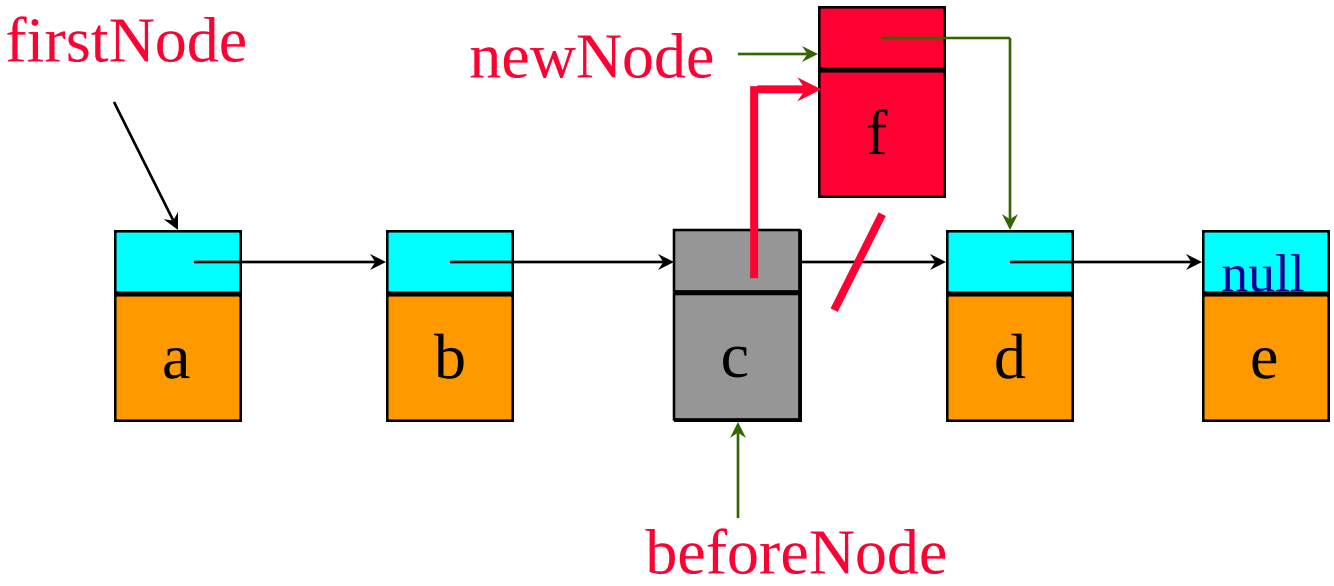


firstNode = new ChainNode('f', firstNode);

Add An Element

```
public void add(int index, Object theElement)
 {
   if (index < 0 || index > size)
      // invalid list position
      throw new IndexOutOfBoundsException
            ("index = " + index + "  size = " + size);


   if (index == 0)
      // insert at front
      firstNode = new ChainNode(theElement, firstNode);
```

Two-Step add(3,'f')

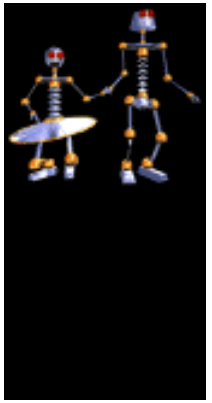



```
beforeNode = firstNode.next.next;
beforeNode.next = new ChainNode('f', beforeNode.next);
```

Adding An Element

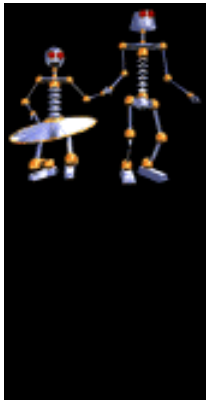
```
else
   { // find predecessor of new element
     ChainNode p = firstNode;
     for (int i = 0; i < index - 1; i++)
        p = p.next;

     // insert after p
     p.next = new ChainNode(theElement, p.next);
   }
   size++;
 }
```

Performance



40,000 operations of each type

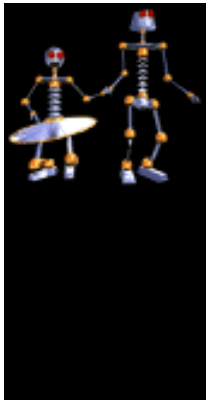
Performance



40,000 operations of each type

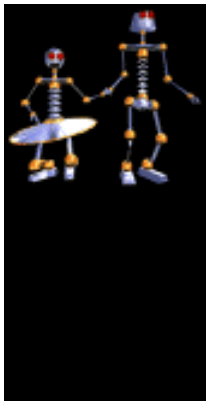
Operation	FastArrayLinearList	Chain
get	5.6ms	157sec
best-case adds	31.2ms	304ms
average adds	5.8sec	115sec
worst-case adds	11.8sec	157sec
best-case removes	8.6ms	13.2ms
average removes	5.8sec	149sec
worst-case removes	11.7sec	157sec

Performance



Indexed AVL Tree (IAVL)

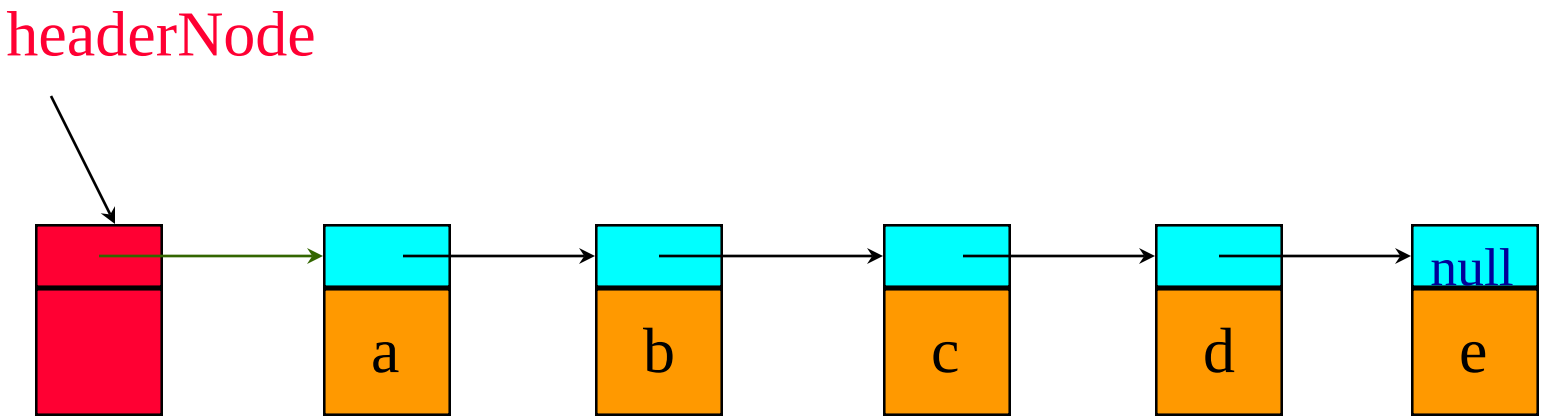
Performance



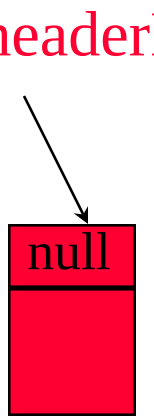
Indexed AVL Tree (IAVL)

Operation	FastArrayLinearList	Chain	IAVL
get	5.6ms	157sec	63ms
best-case adds	31.2ms	304ms	253ms
average adds	5.8sec	115sec	392ms
worst-case adds	11.8sec	157sec	544ms
best-case removes	8.6ms	13.2ms	1.3sec
average removes	5.8sec	149sec	1.5sec
worst-case removes	11.7sec	157sec	1.6sec

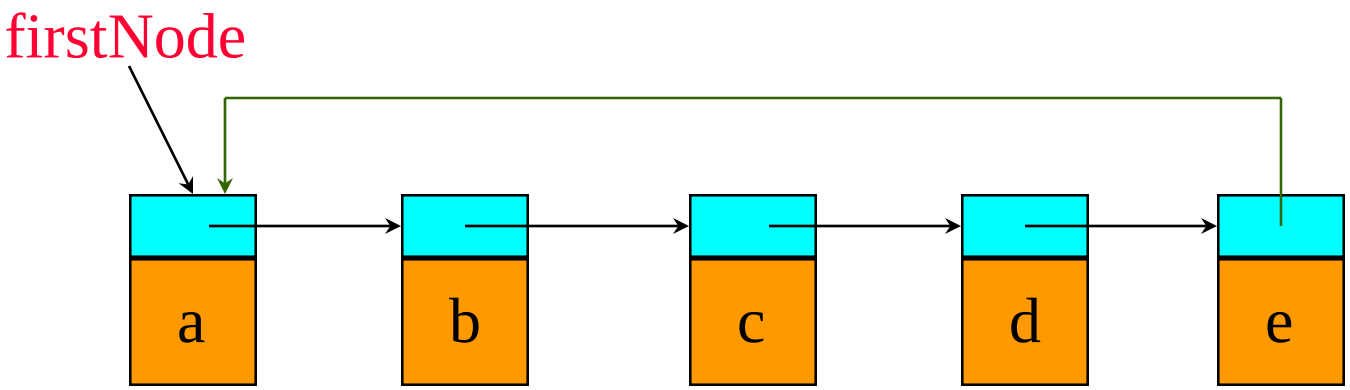
Chain With Header Node



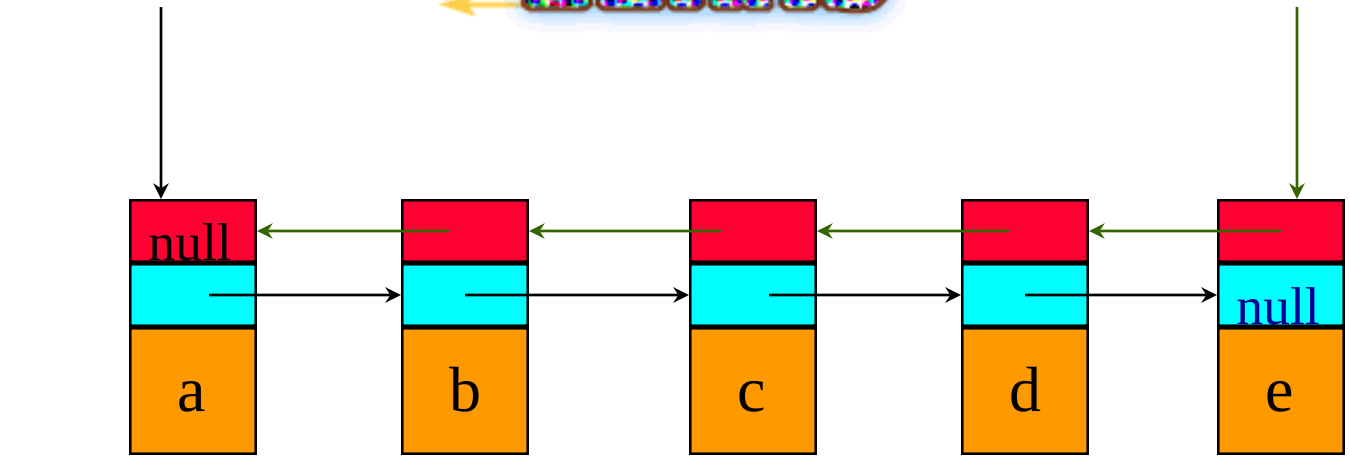
Empty Chain With Header Node



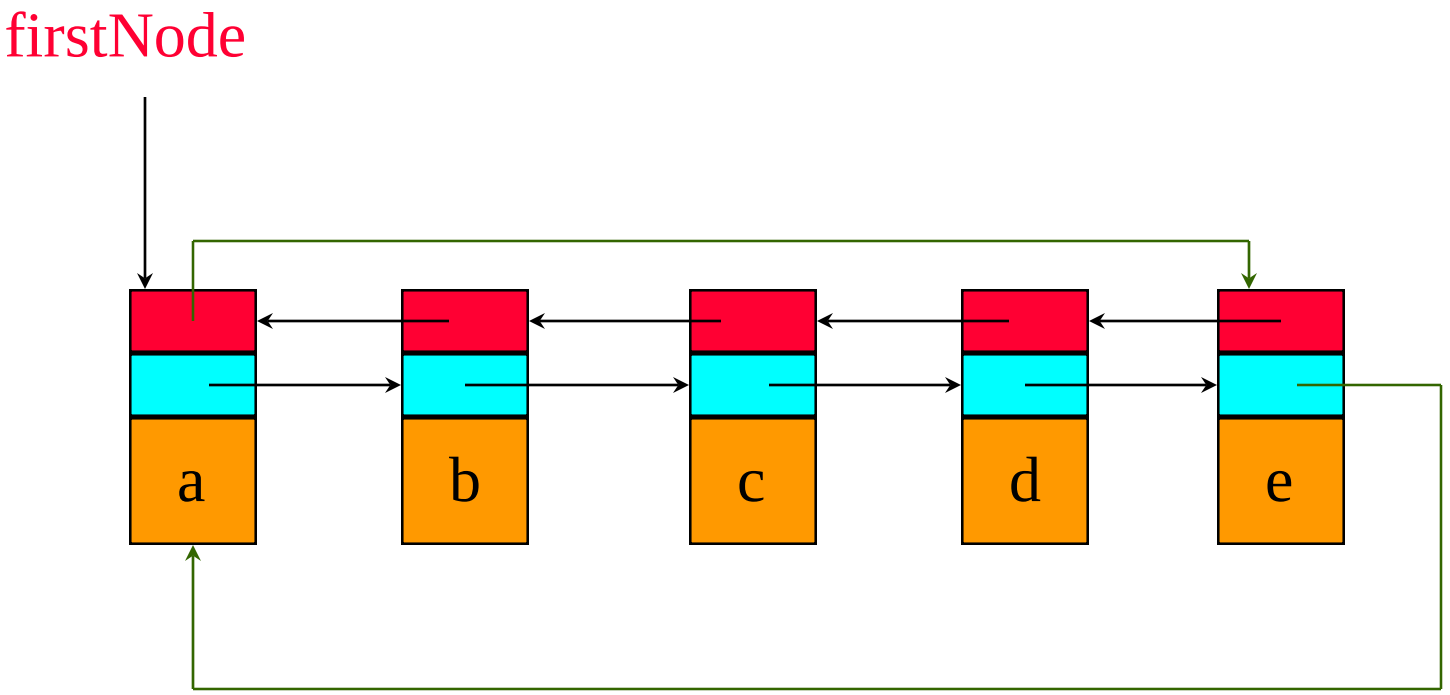
Circular List



Doubly Linked List

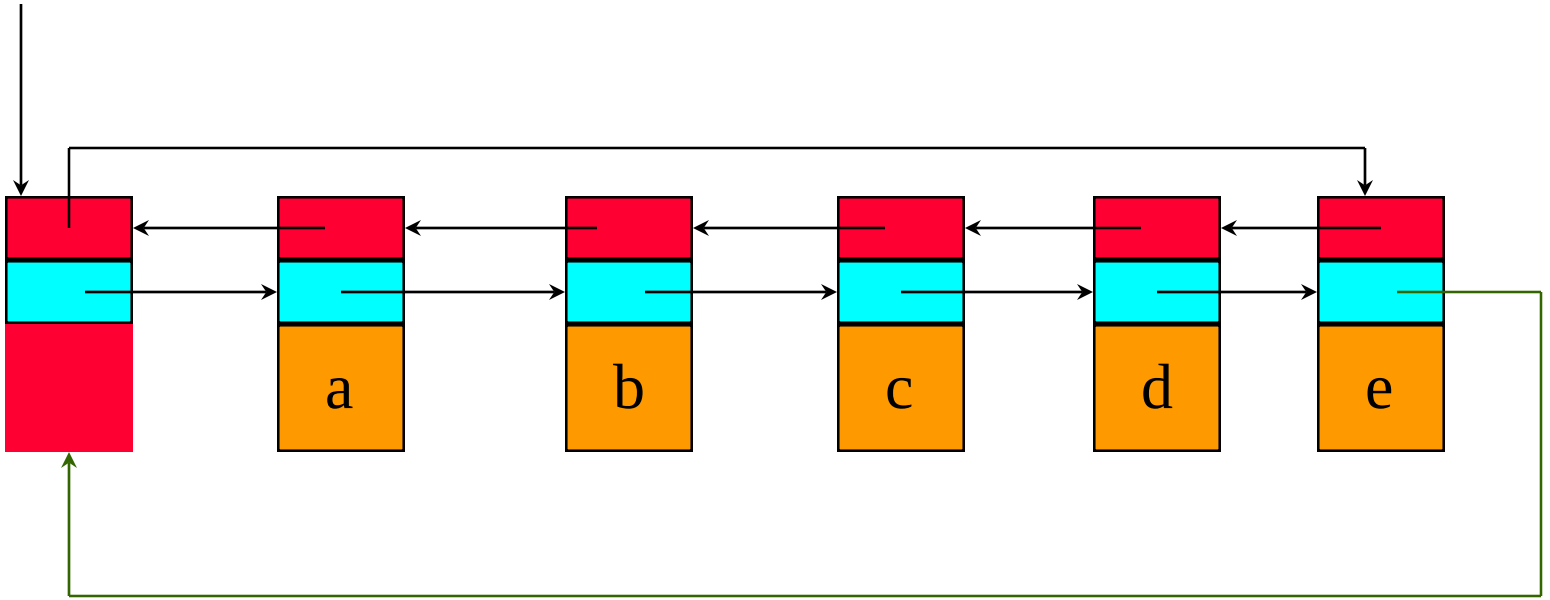


Doubly Linked Circular List

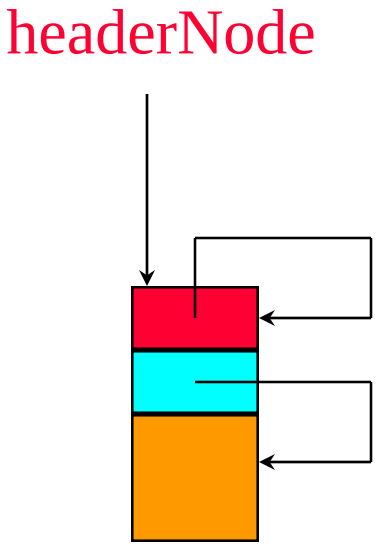


Doubly Linked Circular List With Header Node

headerNode



Empty Doubly Linked Circular List With Header Node



 java.util.LinkedList 

- Linked implementation of a linear list.
- Doubly linked circular list with header node.
- Has all methods of LinearList plus many more.