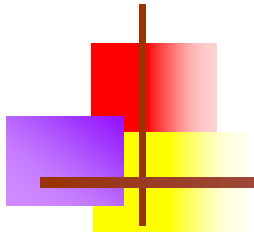
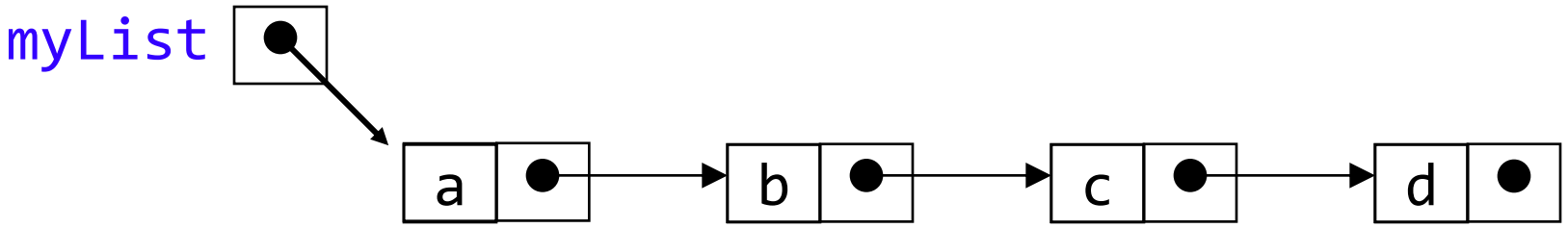


# Linked Lists

# Anatomy of a linked list

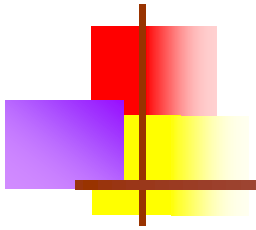
- A linked list consists of:
  - A sequence of nodes




Each node contains a value
and a link (pointer or reference) to some other node

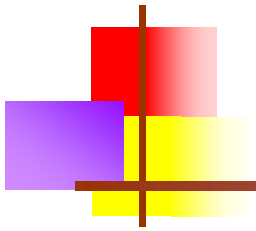
The last node contains a null link

The list may (or may not) have a header



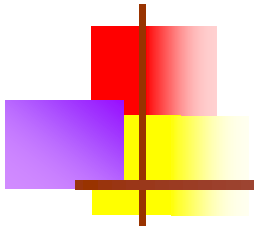
# More terminology

- A node's successor is the next node in the sequence
  - The last node has no successor
- A node's predecessor is the previous node in the sequence
  - The first node has no predecessor
- A list's length is the number of elements in it
  - A list may be empty (contain no elements)



# Pointers and references

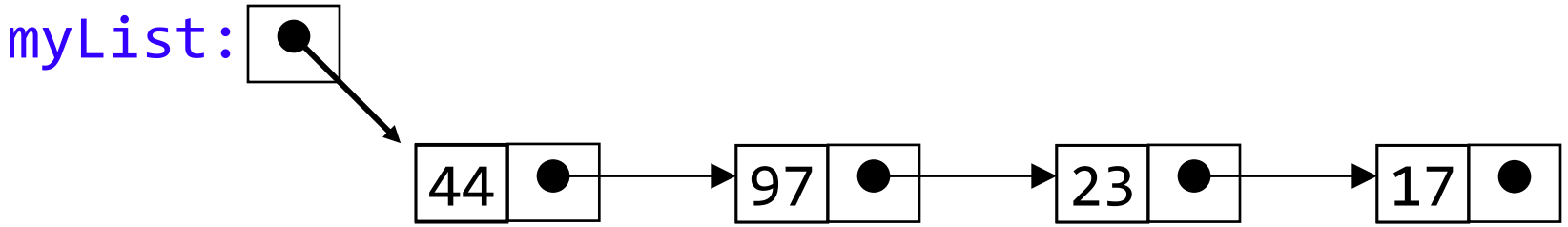
- In C and C++ we have "pointers," while in Java we have "references"
  - These are essentially the same thing
    - The difference is that C and C++ allow you to modify pointers in arbitrary ways, and to point to anything
  - In Java, a reference is more of a "black box," or ADT
    - Available operations are:
      - dereference ("follow")
      - copy
      - compare for equality
    - There are constraints on what kind of thing is referenced: for example, a reference to an `array of int` can *only* refer to an `array of int`



# Creating references

- The keyword `new` creates a new object, but also returns a *reference* to that object
- For example, `Person p = new Person("John")`
  - `new Person("John")` creates the object and returns a reference to it
  - We can assign this reference to `p`, or use it in other ways

# Creating links in Java



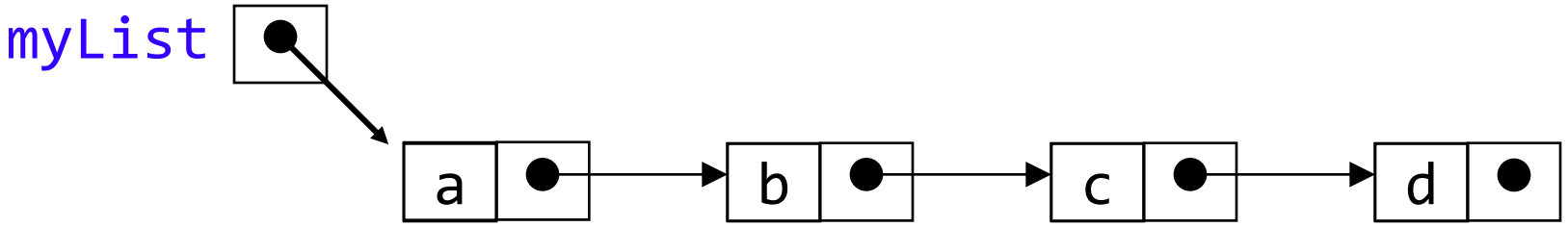

```
class Node {
     int value;
     Node next;

   Node (int v, Node n) { // constructor
        value = v;
        next = n;
   }
}

Node temp = new Node(17, null);
temp = new Node(23, temp);
temp = new Node(97, temp);
Node myList = new Node(44, temp);
```

# Singly-linked lists

- Here is a singly-linked list (SLL):

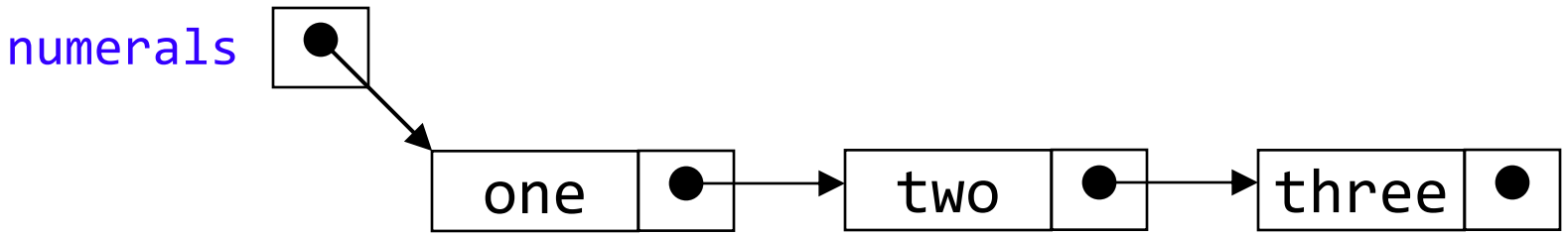


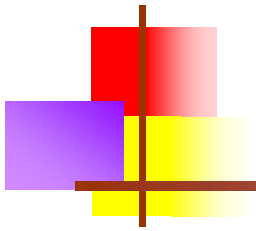

- Each node contains a value and a link to its successor (the last node has no successor)
- The header points to the first node in the list (or contains the null link if the list is empty)

# Creating a simple list

- To create the list ("one", "two", "three"):
- `Node numerals = new Node();`
- `numerals =`

```
    new Node("one",
        new Node("two",
            new Node("three", null)));
```





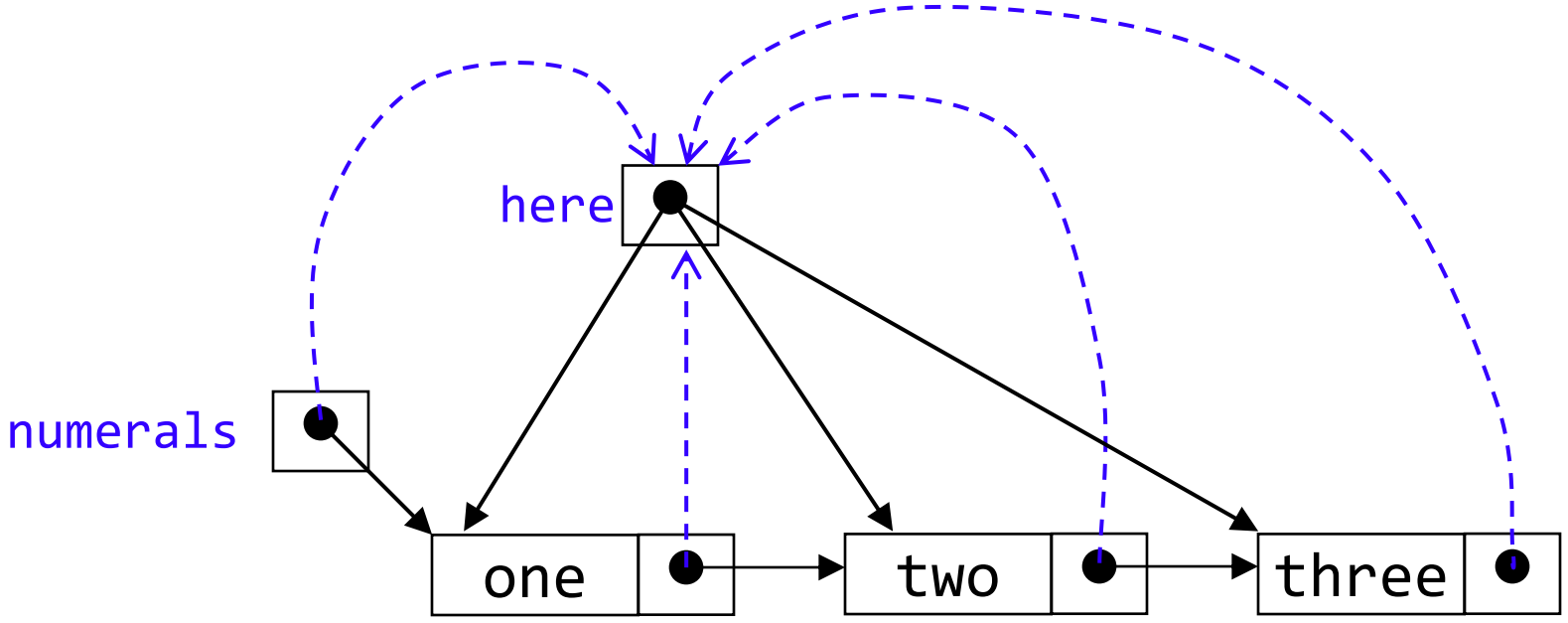
# Traversing a SLL

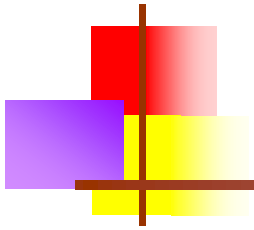
- The following method traverses a list (and prints its elements):

```
public void printFirstToLast(Node here) {
   while (here != null) {
      System.out.print(here.value + "  ");
      here = here.next;
    }
}
```

- You would write this as an instance method of the `Node` class

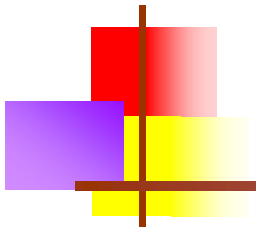
# Traversing a SLL (animation)





# Inserting a node into a SLL

- There are many ways you might want to insert a new node into a list:
  - As the new first element
  - As the new last element
  - Before a given node (specified by a *reference*)
  - After a given node
  - Before a given value
  - After a given value
- All are possible, but differ in difficulty



# Inserting as a new first element

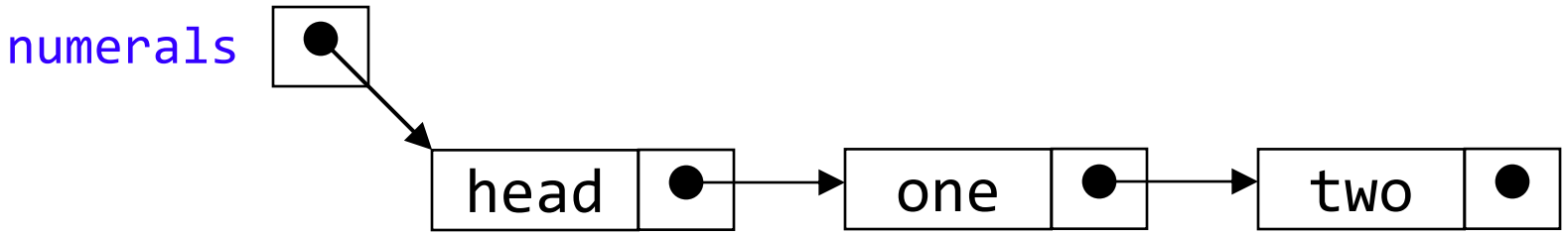
- This is probably the easiest method to implement
- In class `Node`:

```
Node insertAtFront(Node oldFront, Object value) {
     Node newNode = new Node(value, oldFront);
     return newNode;
}
```

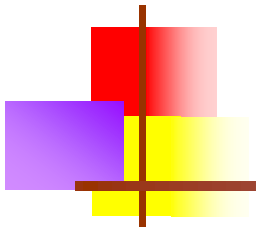
- Use this as: `myList = insertAtFront(myList, value);`
- Why can't we just make this an instance method of `Node`?

# Using a header node

- A header node is just an initial node that exists at the front of every list, even when the list is empty
- The purpose is to keep the list from being `null`, and to point at the first element



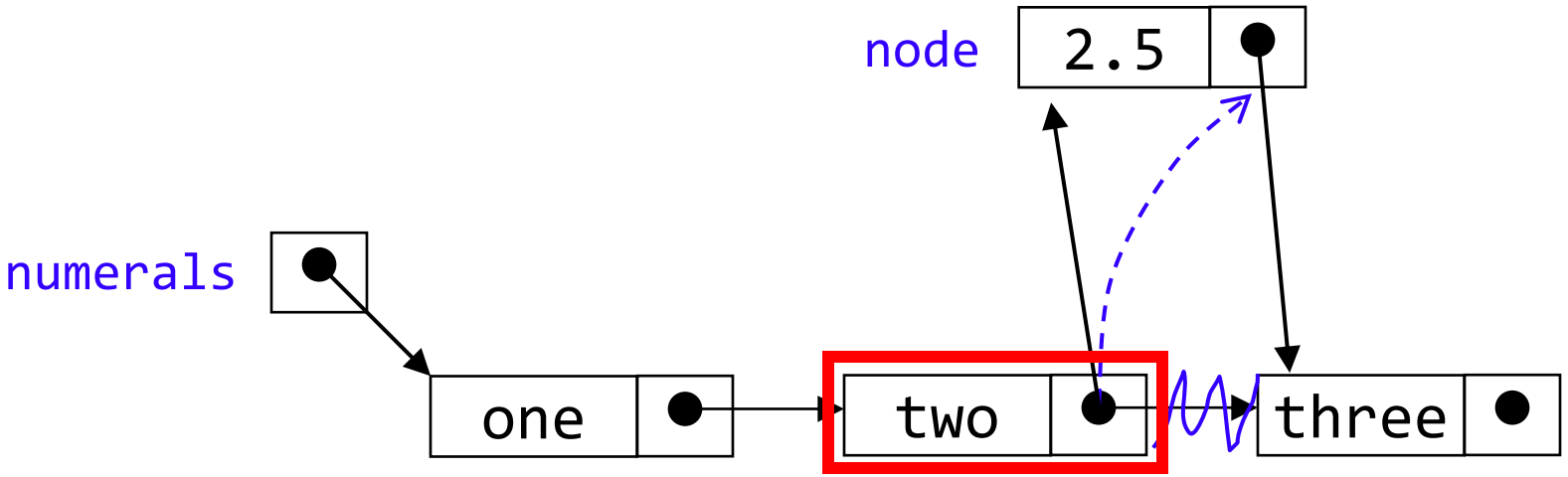

```
void insertAtFront(Object value) {
    Node front = new Node(value, this);
    this.next = front;
}
```



# Inserting a node after a given value

```
void insertAfter(Object target, Object value) {
    for (Node here = this; here != null; here = here.next)
   {
          if (here.value.equals(target)) {
              Node node = new Node(value, here.next);
              here.next = node;
              return;
          }
   }
    // Couldn't insert--do something reasonable here!
}
```

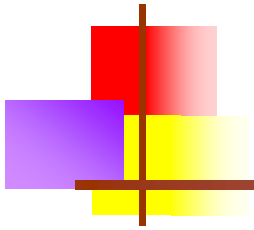
# Inserting after (animation)




Find the node you want to insert after

***First,*** copy the link from the node that's already in the list

***Then,*** change the link in the node that's already in the list

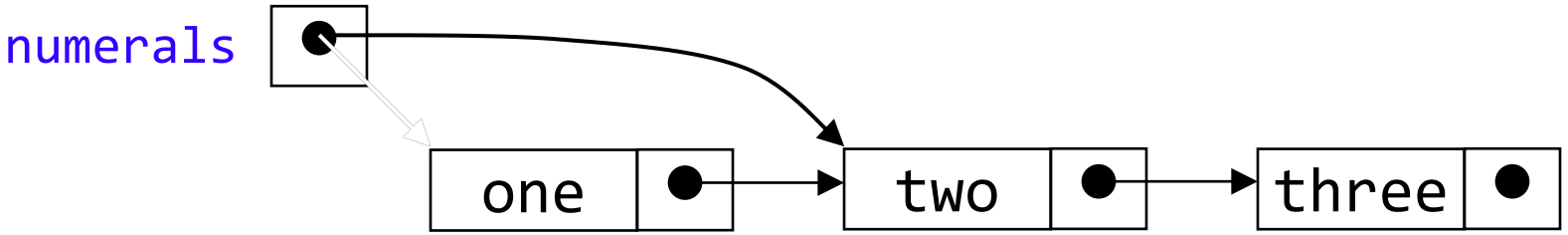


# Deleting a node from a SLL

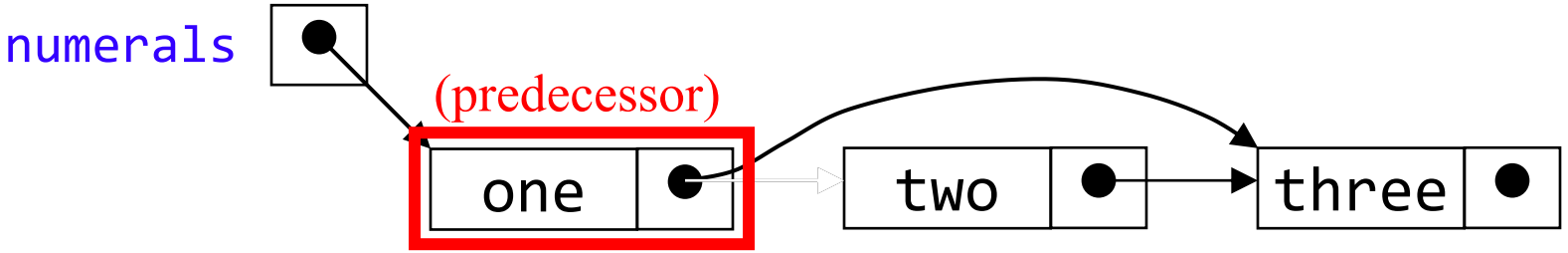
- In order to delete a node from a SLL, you have to change the link in its *predecessor*
- This is slightly tricky, because you can't follow a pointer backwards
- Deleting the first node in a list is a special case, because the node's predecessor is the list header

# Deleting an element from a SLL

- To delete the first element, change the link in the header



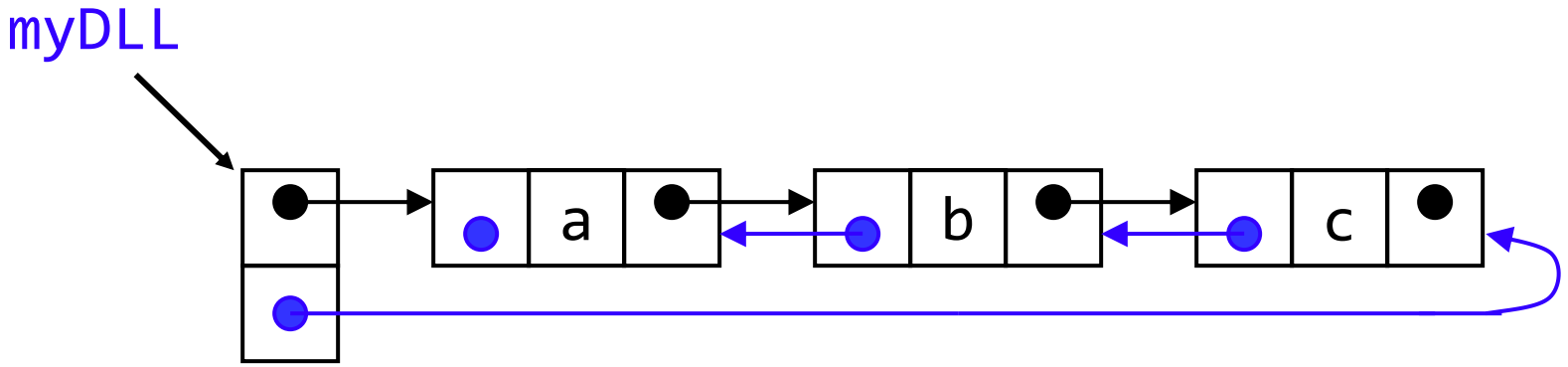

- To delete some other element, change the link in its predecessor



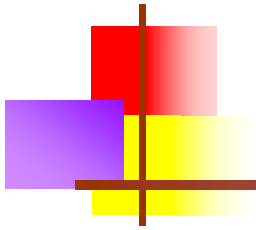

- Deleted nodes will eventually be garbage collected

# Doubly-linked lists

- Here is a doubly-linked list (DLL):




  - Each node contains a value, a link to its successor (if any), *and* a link to its predecessor (if any)
  - The header points to the first node in the list *and* to the last node in the list (or contains null links if the list is empty)

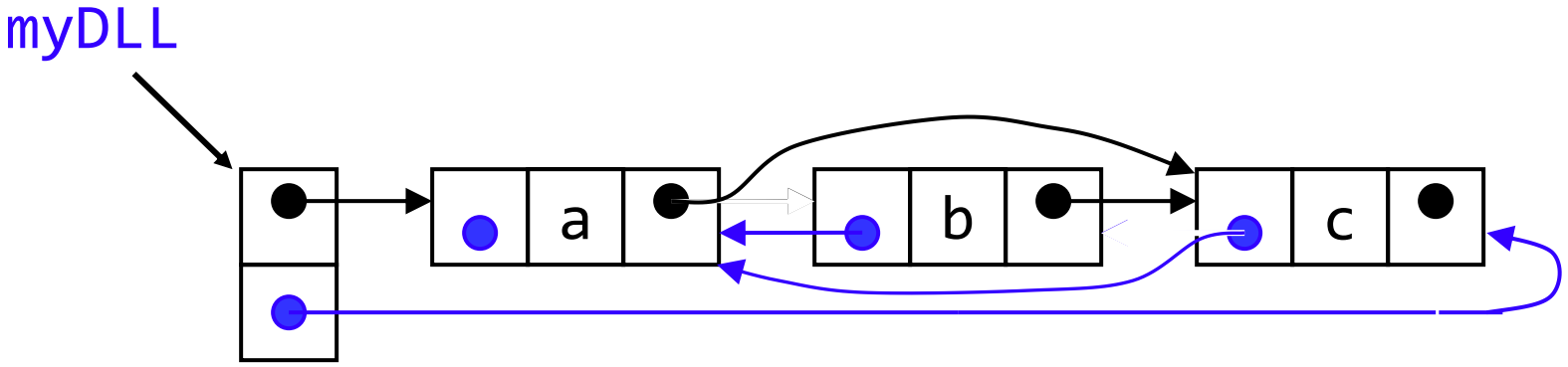


# DLLs compared to SLLs

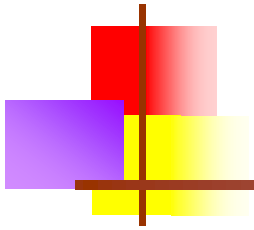
- Advantages:
  - Can be traversed in either direction (may be essential for some programs)
  - Some operations, such as deletion and inserting before a node, become easier
- Disadvantages:
  - Requires more space
  - List manipulations are slower (because more links must be changed)
  - Greater chance of having bugs (because more links must be manipulated)

# Deleting a node from a DLL

- Node deletion from a DLL involves changing *two* links
- In this example,we will delete node b

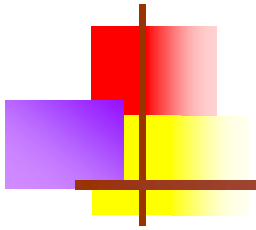



- We don't have to do anything about the links in node b
- Garbage collection will take care of deleted nodes
- Deletion of the first node or the last node is a special case



# Other operations on linked lists

- Most "algorithms" on linked lists—such as insertion, deletion, and searching—are pretty obvious; you just need to be careful
- Sorting a linked list is just messy, since you can't directly access the $n^{th}$ element—you have to count your way through a lot of other elements



# The End

I had written a starfield screensaver, much like many other screensavers of the time, and it was running on my Mac. A co-worker walked by and saw the screensaver, and he asked me, “Is that a real program, or is that something somebody wrote?”

The Evolution of a Programmer
http://lists.canonical.org/pipermail/kragen-tol/2007-March/000849.html