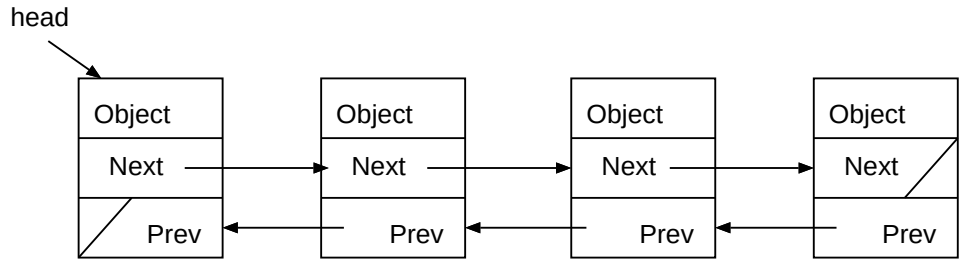
20-0: **Doubly Linked List**

- Deleting from (and inserting into!) a linked list can be challenging because you need to find the node *before* the node you are looking for
- Once you've found the node, it's too late – can't follow pointers backwards to get to the previous node
  - ... unless you keep a pointer to the previous node in the list, too!

20-1: **Doubly Linked List Node**

```
public class DLLNode
{
   Object data;
   DLLNode next;
   DLLNode previous;
   public DLLode (Object data)
   {
      this.data = data;
      this.next = null;
      this.previous = null;
   }
   public DLLNode (Object data, DLLNode next)
   {
      this.data = data;
      this.next = next;
      this.previous = null;
   }
   public DLLNode (Object data, DLLNode next, DLLNode previous)
   {
      this.data = data;
      this.next = next;
      this.previous = previous;
   }
}
```

20-2: **Doubly Linked List**



20-3: **Doubly Linked List**

- Many of the functions for Double-Linked Lists are similar (or event the same) as Singly-Linked versions

20-4: **Double Linked List Find**

```
public class LinkedList
{
   private DLLNode head;

   public LinkedList()
   {
      head = null;
   }

   public boolean find(Object o)
   {
      ...
   }
}
```

20-5: **Double Linked List Find**

```
public class LinkedList
{
   private DLLNode head;

   public LinkedList()
   {
      head = null;
   }
   public boolean find(Object o)
   {
```

```
      DLLNode tmp = head;
      while (tmp != null)
      {
          if (tmp.data.equals(o))
          {
             return true;
          }
      }
      return false;
   }
}
```

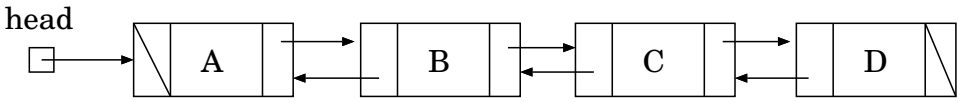
20-6: **Double Linked List removeAt**

```
public class LinkedList
{
   private DLLNode head;

   public LinkedList()
   {
      head = null;
   }

   public Object removeAt(int index)
   {
      ...
   }
}
```

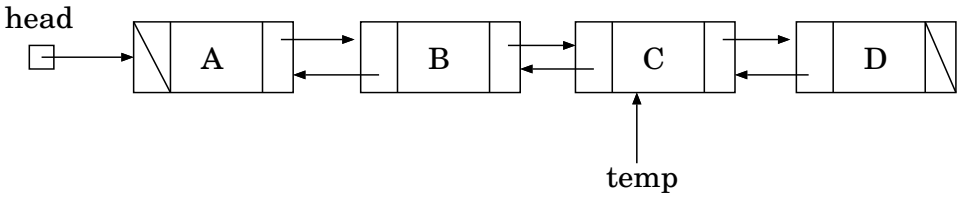
20-7: **Double Linked List removeAt**

- Find the element that you want to remove
  - Don't need to be "one-off", can find the actual element
- Rearrange pointers
  - Removing from middle of list
  - Removing from end

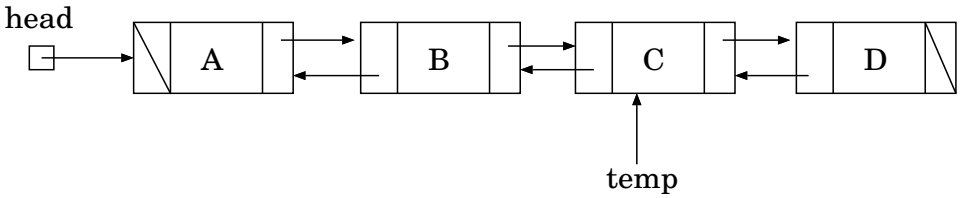
20-8: **Doubly Linked List**



20-9: **Doubly Linked List**

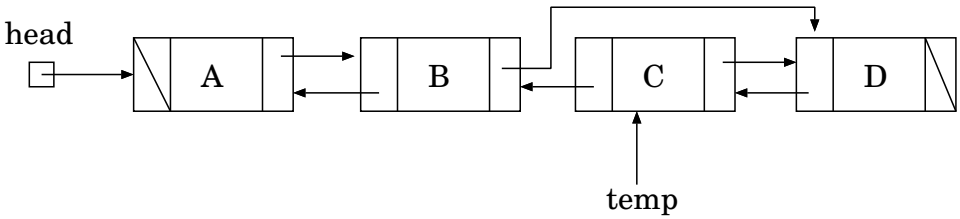


20-10: **Doubly Linked List**



temp.previous.next = temp.next

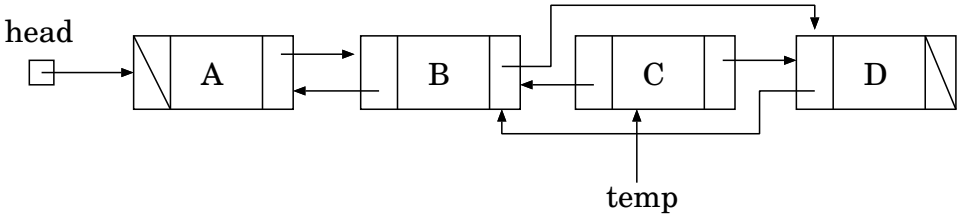
20-11: **Doubly Linked List**



temp.previous.next = temp.next

temp.next.previous = temp.previous

20-12: **Doubly Linked List**



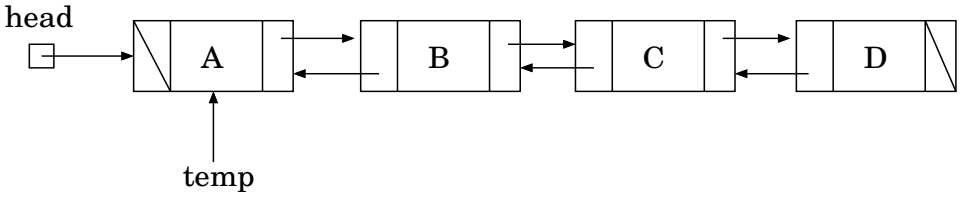
temp.previous.next = temp.next

temp.next.previous = temp.previous

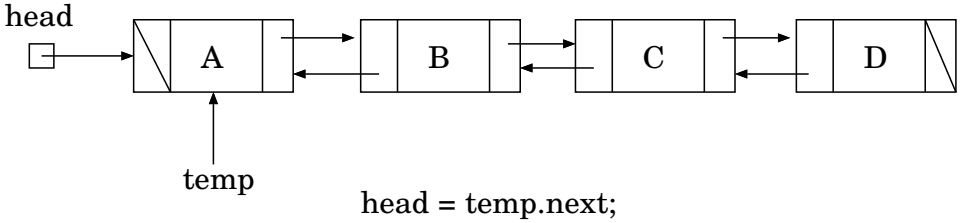
20-13: **Double Linked List removeAt**

```
public class LinkedList
{
   private DLLNode head;

   public Object removeAt(int index)
   {
      DLLNode tmp = head;
      for (int i = 0; i < index; i++)
      {
         tmp = tmp.next;
      }
      // Removing from the midle of list
      //  (won't work for removing 1st/last element
      tmp.prev.next = tmp.next;
      tmp.next.prev = tmp.prev;
      return tmp.data;
   }
}
```

20-14: **Doubly Linked List**

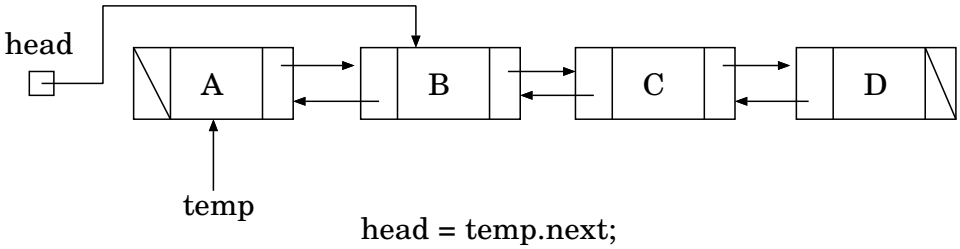


20-15: **Doubly Linked List**



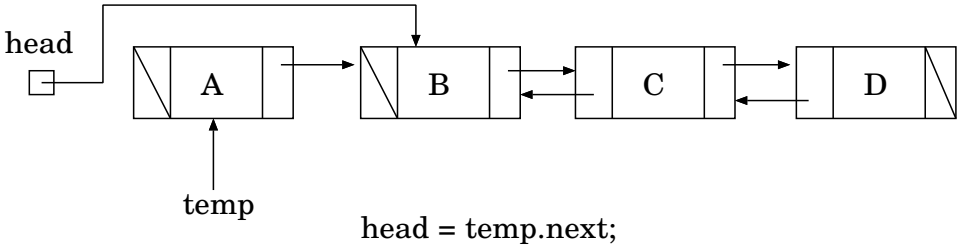
head = temp.next;

20-16: **Doubly Linked List**



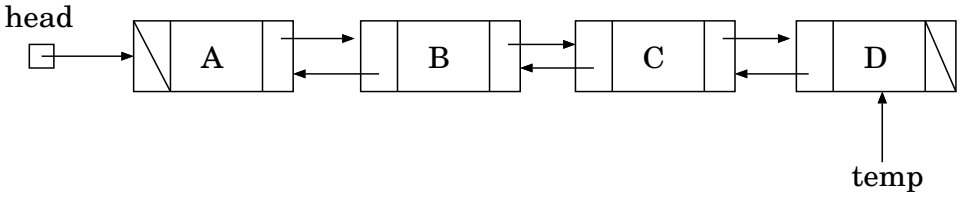
head = temp.next;
head.previous = null

20-17: **Doubly Linked List**

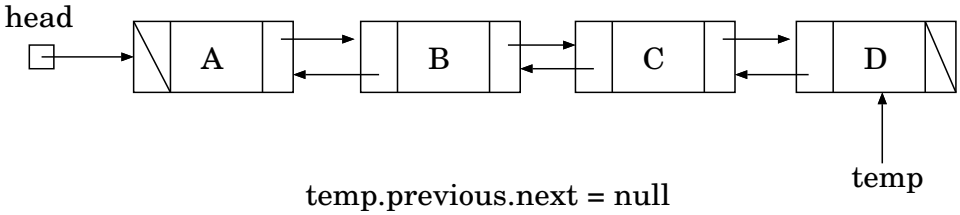


head = temp.next;
head.previous = null

20-18: **Doubly Linked List**

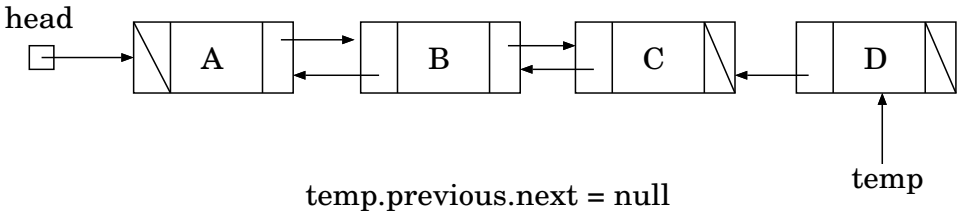


20-19: **Doubly Linked List**



temp.previous.next = null

20-20: **Doubly Linked List**



temp.previous.next = null

20-21: **Double Linked List removeAt**

```
public Object removeAt(int index)
{
   DLLNode tmp = head;
   for (int i = 0; i < index; i++)
   {
      tmp = tmp.next;
   }
   if (tmp.prev != null)
   {
       tmp.prev.next = tmp.next;
   }
   else
   {
```

```
            head = tmp.next;
        }
        if (tmp.next != null)
        {
            tmp.next.prev = tmp.prev;
        }
        return tmp.data;
    }
}
```

20-22: **Reverse**

- Back to single linked lists
- How could we reverse a linked list?
- Function reverse
    - Takes as input parameter a list to reverse
    - Returns a reversed version of the list
    - OK to destroy original list

20-23: **Reverse**

- Go through how to reverse on board, with diagrams

20-24: **Reverse**

```
LinkedListNode reverse(LinkedListNode l)
{
    LinkedListNode newFront = null;
    LinkedListNode tmp = null;
    while (l != null)
    {
        tmp = l.next;
        l.next = newFront;
        newFront = l;
        l = tmp;
     }
     return newFront;
}
```

20-25: **Recursive Reverse**

- Let’s look at doing reverse recursively
- This one is a little tricky ...

20-26: **Recursive Reverse**

- Base case:
    - Easy List to reverse
- Recursive Case:
    - Make list smaller, by removing first element
    - Recursively reverse smaller list
    - Add first element back into correct location

20-27: **Recursive Reverse**

- What is an easy list to reverse?
    - There are actually 2 lists that are easy to reverse ...

20-28: **Recursive Reverse**

```
private StringLinkedListNode reverse(LinkedListNode l)
{
   if (l == null || l.next == null)
   {
      return l;
   }
   ...
}
```

20-29: **Recursive Reverse**

```
private StringLinkedListNode reverse(LinkedListNode l)
{
   if (l == null || l.next == null)
   {
      return l;
   }
   LinkedListNode reversed = reverse(l.next);

   // What does reversed look like now?
   // How should we modify it?
}
```

20-30: **Recursive Reverse**

```
private StringLinkedListNode reverse(LinkedListNode l)
{
   if (l == null || l.next == null)
   {
      return l;
   }
   LinkedListNode reversed = reverse(l.next);
   appendToEnd(reversed, l);
   return reversed;
}
```

20-31: **Recursive Reverse**

```
void appendToEnd(LinkedListNode list, LinkedListNode elem)
{
   while (list.next != null)
   {
      list = list.next;
   }
   elem.next = null;
   list.next = elem;
}
private StringLinkedListNode reverse(LinkedListNode l)
{
   if (l == null || l.next == null)
   {
      return l;
   }
   LinkedListNode reversed = reverse(l.next);
   appendToEnd(reversed, l);
   return reversed;
}
```

20-32: **Recursive Reverse**

- Previous reverse was *very* inefficient.
- Why?

20-33: **Recursive Reverse**

- Previous reverse was *very* inefficient.
  - Need to traverse entire list to append an element to the end
  - We will do this traversal *over and over again* (examples)

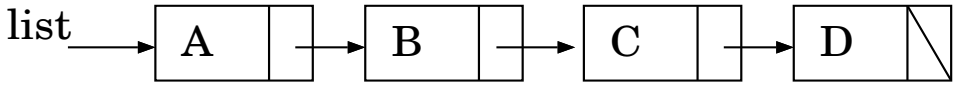
20-34: **Recursive Reverse**

- Problem is that we need to traverse the entire list to get to the last element
- If only there was some way of getting to that last element without traversing the list ...

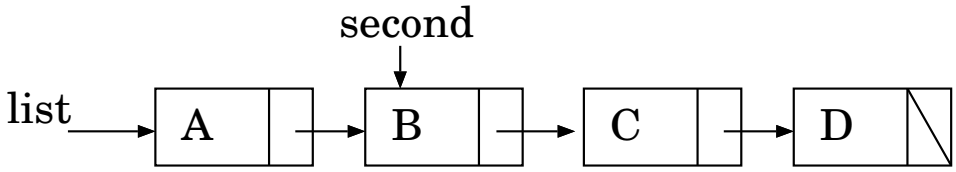
20-35: **Recursive Reverse**

- Problem is that we need to traverse the entire list to get to the last element
- If only there was some way of getting to that last element without traversing the list ...
  - Right before we reverse the list, the first element in the smaller list is the last element in the reversed list!

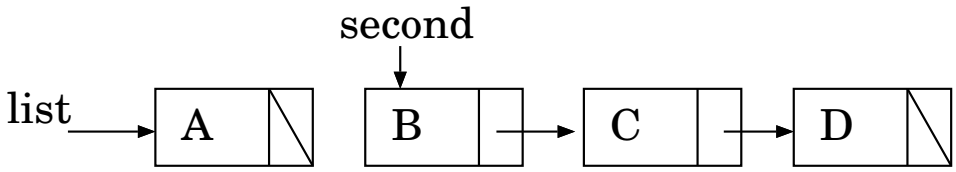
20-36: **Doubly Linked List**



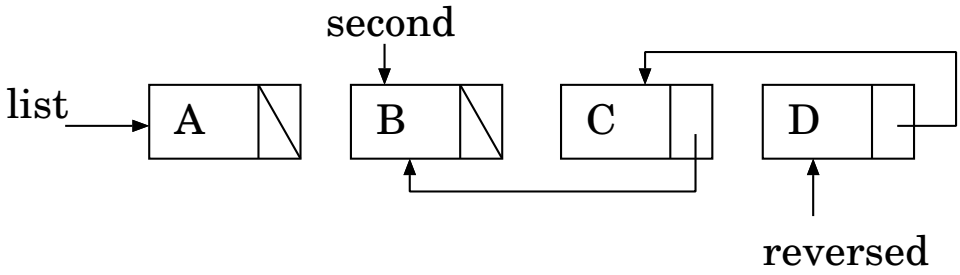
20-37: **Doubly Linked List**



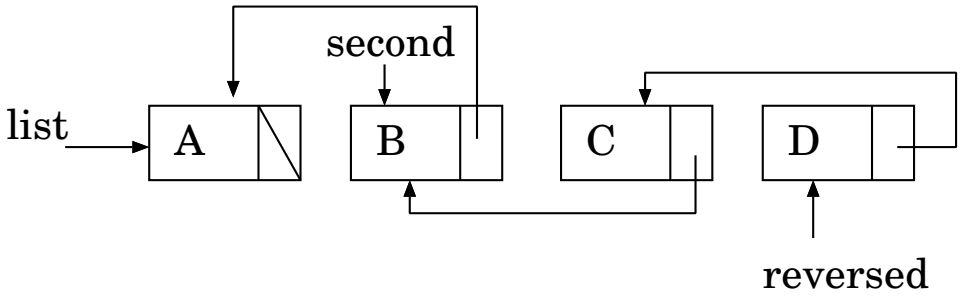
20-38: **Doubly Linked List**



20-39: **Doubly Linked List**



20-40: **Doubly Linked List**



20-41: **Recursive Reverse**

```
private LinkedListNode reverse(LinkedListNode list)
{
  if (list == null || list.next == null)
  {
     return list;
```

```
  }
  LinkedListNode second = list.next;
  list.next = null;
  StringLinkedListNode reversed = reverse(second);
  second.next = list;
  return reversed;
}
```

20-42: **Recursive Reverse**

```
public class LinkedList
{
   private LinkedListNode head;

   public void reverse()
   {
      head = reverse(head);
   }
}
```

20-43: **Hands-On**

- Work on lab/project
-