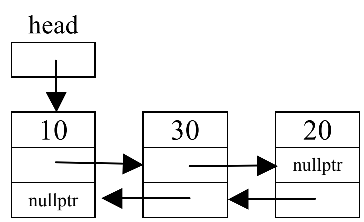
Supplement to Linked List Lecture

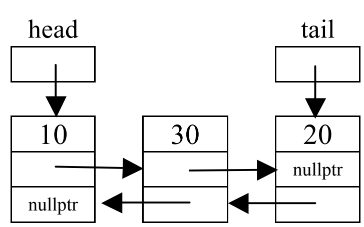
First some notation: When we show a pointer pointing to an object, it's irrelevant where the arrowhead of the pointer touches the object. Thus, these two pictures of a situation where two pointers point to the same object mean the same thing:

If the object were at memory address 1000, we assume both of these pictures mean that the two pointers both contain memory address 1000. (Under a notational convention we're *not* using, one might consider the pointers in the right picture to hold different values, neither being memory address 1000.) The reason we use this convention is that when drawing a doubly-linked list, fewer lines cross each other in the picture.

A straightforward way of representing a doubly-linked list of integers containing 10, 30, and 20 in that order would be



This gives us direct access to the first item in the list, and from there we can reach every other item. But for many applications, a lot of activity occurs at the end of the list, so rather than starting at the beginning of a long list and traversing it to the end every time we needed to do something at the end of the list, it would be faster to have direct access to the end of the list:



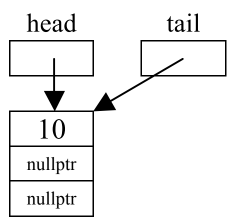
This works, but it makes the implementation of many typical operations a bit tricky. For example, to remove the first item from a list, we might think we could do this:

```
Node* oldHead = head;
head = head->m_next;
head->m_prev = nullptr;
delete oldHead;
```

But this code is wrong. While it works in the general case, it fails when the list is empty (i.e., when head and tail are null pointers). We should have thought of that: How can you remove the first item from a list if there are no items in the list? So let's fix that:

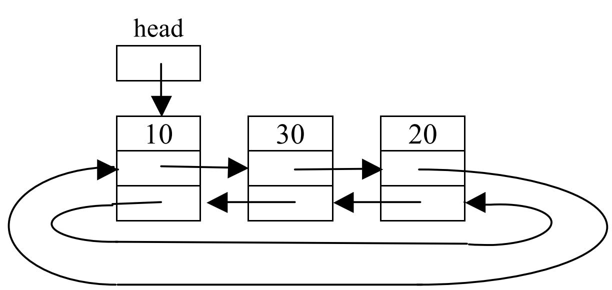
```
if (head != nullptr)
{
      Node* oldHead = head;
      head = head->m_next;
      head->m_prev = nullptr;
      delete oldHead;
}
```

But this code is flawed, too. What if the list has just one element?



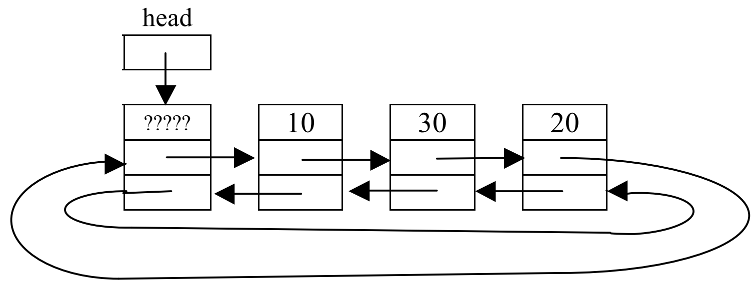
Exercise for the reader: Fix the two bugs.

The representation of a list that we've chosen will lead to a lot of special case checking in code that manipulates the list. One way to reduce some of that checking is to change the representation to one that, for example, will not have the problem of potentially following a null pointer:



This is a *circularly linked list*, or more specifically, a *circular doubly-linked list*. (Note that singly-linked lists can also be circularly-linked.) Notice that we no longer need to keep a separate tail pointer; the tail of the list will be at `head->m_prev`.

While a circular list eliminates some of the special case checking, we'll still have some issues with lists with zero or one element. A technique that might simplify our code is to ensure that there is always at least one node in the linked list:

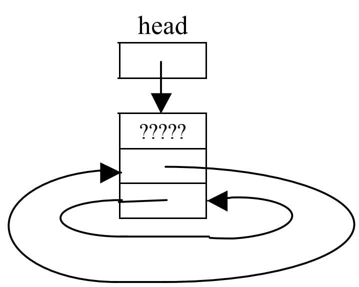


The first node is a *dummy* node, so called because we don't consider its value to be part of the list; in fact we never bother initializing that value, since we will never examine it. The first item we consider to be in the list is at `head->m_next`; the last item we consider to be in the list is at `head->m_prev`. Because there is now *always* a node before and after every item in the list, we've eliminated the special cases in code that manipulates the list.

Here's an example of using a circular doubly-linked list with a dummy node:

```
  // 10 30 20
for (Node* p = head->m_next; p != head; p = p->m_next)
     cout << p->m_data << endl;
  // 20 30 10
for (Node* p = head->m_prev; p != head; p = p->m_prev)
     cout << p->m_data << endl;
```

If the picture above shows what a three-element list looks like with this representation, then what does a zero-element list look like?



If you try writing code to insert and remove items from the list at various positions, you'll find that such code is easiest to write with this representation, because there are no special cases.