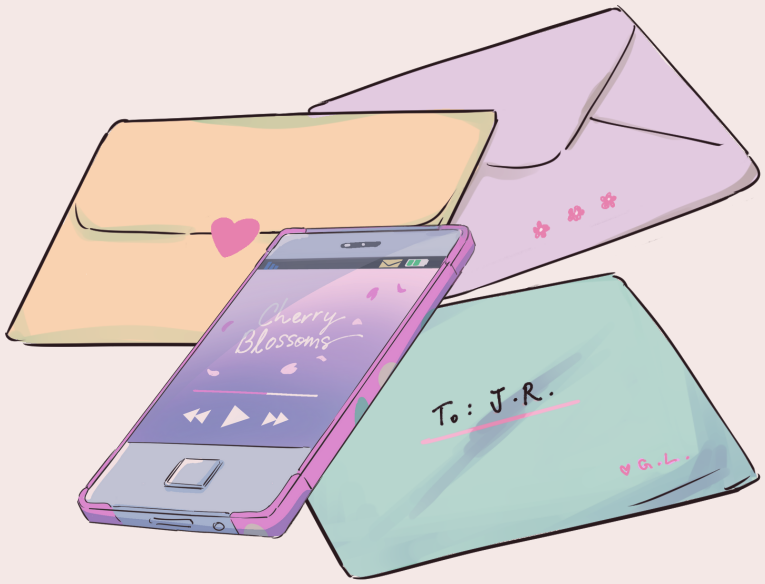
LINKED LIST

Common coding Interview problems



Linkedin problems

1 — Count() Solution

A straightforward iteration down the list — just like Length().

```
int Count(struct node* head, int searchFor) {
   struct node* current = head;
   int count = 0;

   while (current != NULL) {
      if (current->data == searchFor) count++;
      current = current->next;
   }

   return count;
}
```

Alternately, the iteration may be coded with a `for` loop instead of a `while`...

```
int Count2(struct node* head, int searchFor) {
   struct node* current;
   int count = 0;

   for (current = head;   current != NULL;   current = current->next) {
      if (current->data == searchFor) count++;
   }

   return count;
}
```

2 — GetNth() Solution

Combine standard list iteration with the additional problem of counting over to find the right node. Off-by-one errors are common in this sort of code. Check it carefully against a simple case. If it's right for n=0, n=1, and n=2, it will probably be right for n=1000.

```
int GetNth(struct node* head, int index) {
   struct node* current = head;
   int count = 0; // the index of the node we're currently looking at

   while (current != NULL) {
      if (count == index) return(current->data);
      count++;
      current = current->next;
   }

   assert(0);  // if we get to this line, the caller was asking
               // for a non-existent element so we assert fail.
}
```

3 — DeleteList() Solution

Delete the whole list and set the head pointer to NULL. There is a slight complication inside the loop, since we need extract the `.next` pointer before we delete the node, since after the delete it will be technically unavailable.

```
void DeleteList(struct node** headRef) {
   struct node* current = *headRef; // deref headRef to get the real head
   struct node* next;

   while (current != NULL) {
      next = current->next;   // note the next pointer
      free(current);          // delete the node
      current = next;         // advance to the next node
   }

   *headRef = NULL;     // Again, deref headRef to affect the real head back
                        // in the caller.
}
```

4 — Pop() Solution

Extract the data from the head node, delete the node, advance the head pointer to point at the next node in line. Uses a reference parameter since it changes the head pointer.

```
int Pop(struct node** headRef) {
   struct node* head;
   int result;

   head = *headRef;
   assert(head != NULL);

   result = head->data; // pull out the data before the node is deleted

   *headRef = head->next;     // unlink the head node for the caller
                        // Note the * -- uses a reference-pointer
                        //  just like Push() and DeleteList().

   free(head);          // free the head node

   return(result);      // don't forget to return the data from the link
}
```

5 — InsertNth() Solution

This code handles inserting at the very front as a special case. Otherwise, it works by running a current pointer to the node before where the new node should go. Uses a for loop to march the pointer forward. The exact bounds of the loop (the use of < vs <=, n vs. n-1) are always tricky — the best approach is to get the general structure of the iteration correct first, and then make a careful drawing of a couple test cases to adjust the n vs. n-1 cases to be correct. (The so called "OBOB" — Off By One Boundary cases.) The OBOB cases are always tricky and not that interesting. Write the correct basic structure and then use a test case to get the OBOB cases correct. Once the insertion point has been determined, this solution uses Push() to do the link in. Alternately, the 3-Step Link In code could be pasted here directly.

```
void InsertNth(struct node** headRef, int index, int data) {
   // position 0 is a special case...
   if (index == 0) Push(headRef, data);
   else {
      struct node* current = *headRef;
      int i;

      for (i=0; i<index-1; i++) {
         assert(current != NULL);   // if this fails, index was too big
         current = current->next;
      }

      assert(current != NULL);      // tricky: you have to check one last time

      Push(&(current->next), data); // Tricky use of Push() --
                        // The pointer being pushed on is not
                        // in the stack. But actually this works
                        // fine -- Push() works for any node pointer.
   }
}
```

6 — SortedInsert() Solution

The basic strategy is to iterate down the list looking for the place to insert the new node. That could be the end of the list, or a point just before a node which is larger than the new node. The three solutions presented handle the "head end" case in different ways...

```
// Uses special case code for the head end
void SortedInsert(struct node** headRef, struct node* newNode) {
   // Special case for the head end
   if (*headRef == NULL || (*headRef)->data >= newNode->data) {
      newNode->next = *headRef;
      *headRef = newNode;
   }
   else {
      // Locate the node before the point of insertion
      struct node* current = *headRef;
      while (current->next!=NULL && current->next->data<newNode->data) {
         current = current->next;
      }
      newNode->next = current->next;
      current->next = newNode;
   }
}


// Dummy node strategy for the head end
void SortedInsert2(struct node** headRef, struct node* newNode) {
   struct node dummy;
   struct node* current = &dummy;
   dummy.next = *headRef;

   while (current->next!=NULL && current->next->data<newNode->data) {
      current = current->next;
   }

   newNode->next = current->next;
   current->next = newNode;
```

```
   *headRef = dummy.next;
}


// Local references strategy for the head end
void SortedInsert3(struct node** headRef, struct node* newNode) {
   struct node** currentRef = headRef;

   while (*currentRef!=NULL && (*currentRef)->data<newNode->data) {
      currentRef = &((*currentRef)->next);
   }

   newNode->next = *currentRef;     // Bug: this line used to have
                                    // an incorrect (*currRef)->next
   *currentRef = newNode;
}
```

7 — InsertSort() Solution

Start with an empty result list. Iterate through the source list and SortedInsert() each of its nodes into the result list. Be careful to note the `.next` field in each node before moving it into the result list.

```
// Given a list, change it to be in sorted order (using SortedInsert()).
void InsertSort(struct node** headRef) {
   struct node* result = NULL;      // build the answer here
   struct node* current = *headRef; // iterate over the original list
   struct node* next;

   while (current!=NULL) {
      next = current->next;   // tricky - note the next pointer before we change it
      SortedInsert(&result, current);
      current = next;
   }

   *headRef = result;
}
```

8 — Append() Solution

The case where the 'a' list is empty is a special case handled first — in that case the 'a' head pointer needs to be changed directly. Otherwise we iterate down the 'a' list until we find its last node with the test `(current->next != NULL)`, and then tack on the 'b' list there. Finally, the original 'b' head is set to NULL. This code demonstrates extensive use of pointer reference parameters, and the common problem of needing to locate the last node in a list. (There is also a drawing of how Append() uses memory below.)

```
void Append(struct node** aRef, struct node** bRef) {
   struct node* current;

   if (*aRef == NULL) {       // Special case if a is empty
      *aRef = *bRef;
   }
   else {      // Otherwise, find the end of a, and append b there
      current = *aRef;
      while (current->next != NULL) {     // find the last node
         current = current->next;
      }
```

```
      current->next = *bRef;  // hang the b list off the last node
   }

   *bRef=NULL;    // NULL the original b, since it has been appended above
}
```

Append() Test and Drawing

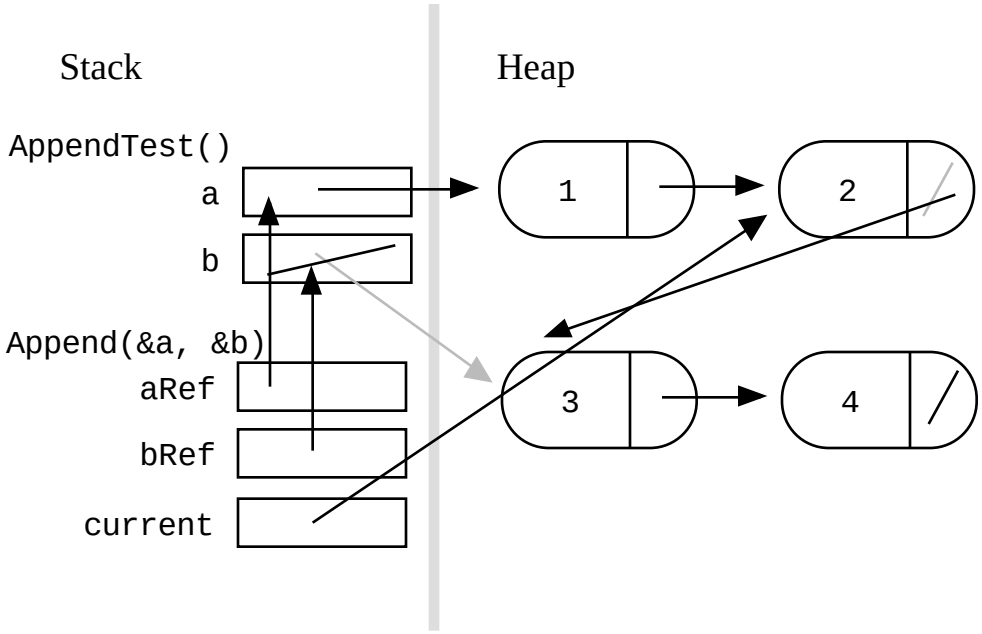
The following AppendTest() code calls Append() to join two lists. What does memory look like just before the call to Append() exits?

```
void AppendTest() {
   struct node* a;
   struct node* b;

   // set a to {1, 2}
   // set b to {3, 4}

   Append(&a, &b);
}
```

As an example of how reference parameters work, note how reference parameters in Append() point back to the head pointers in AppendTest()...



9 — FrontBackSplit() Solution

Two solutions are presented...

```
// Uses the "count the nodes" strategy
void FrontBackSplit(struct node* source,
                    struct node** frontRef, struct node** backRef) {

   int len = Length(source);
   int i;
   struct node* current = source;
```

```
   if (len < 2) {
      *frontRef = source;
      *backRef = NULL;
   }
   else {
      int hopCount = (len-1)/2;     //(figured these with a few drawings)
      for (i = 0; i<hopCount; i++) {
         current = current->next;
      }

      // Now cut at current
      *frontRef = source;
      *backRef = current->next;
      current->next = NULL;
   }
}


// Uses the fast/slow pointer strategy
void FrontBackSplit2(struct node* source,
                  struct node** frontRef, struct node** backRef) {
   struct node* fast;
   struct node* slow;

   if (source==NULL || source->next==NULL) {    // length < 2 cases
      *frontRef = source;
      *backRef = NULL;
   }
   else {
      slow = source;
      fast = source->next;

      // Advance 'fast' two nodes, and advance 'slow' one node
      while (fast != NULL) {
         fast = fast->next;
         if (fast != NULL) {
            slow = slow->next;
            fast = fast->next;
         }
      }

      // 'slow' is before the midpoint in the list, so split it in two
      // at that point.
      *frontRef = source;
      *backRef = slow->next;
      slow->next = NULL;
   }
}
```

10 — RemoveDuplicates() Solution

Since the list is sorted, we can proceed down the list and compare adjacent nodes. When adjacent nodes are the same, remove the second one. There's a tricky case where the node after the next node needs to be noted before the deletion.

```
// Remove duplicates from a sorted list
void RemoveDuplicates(struct node* head) {
   struct node* current = head;
```

```
   if (current == NULL) return;     // do nothing if the list is empty

   // Compare current node with next node
   while(current->next!=NULL) {
      if (current->data == current->next->data) {
         struct node* nextNext = current->next->next;
         free(current->next);
         current->next = nextNext;
      }
      else {
         current = current->next;   // only advance if no deletion
      }
   }
}
```

11 — MoveNode() Solution

The MoveNode() code is most similar to the code for Push(). It's short — just changing a couple pointers — but it's complex. Make a drawing.

```
void MoveNode(struct node** destRef, struct node** sourceRef) {
   struct node* newNode = *sourceRef;     // the front source node
   assert(newNode != NULL);

   *sourceRef = newNode->next;      // Advance the source pointer

   newNode->next = *destRef;  // Link the old dest off the new node
   *destRef = newNode;        // Move dest to point to the new node
}
```

12 — AlternatingSplit() Solution

The simplest approach iterates over the source list and use MoveNode() to pull nodes off the source and alternately put them on 'a' and b'. The only strange part is that the nodes will be in the reverse order that they occurred in the source list.

AlternatingSplit()

```
void AlternatingSplit(struct node* source,
                      struct node** aRef, struct node** bRef) {
   struct node* a = NULL;     // Split the nodes to these 'a' and 'b' lists
   struct node* b = NULL;

   struct node* current = source;
   while (current != NULL) {
      MoveNode(&a, &current); // Move a node to 'a'
      if (current != NULL) {
         MoveNode(&b, &current);    // Move a node to 'b'
      }
   }
   *aRef = a;
   *bRef = b;
}
```

AlternatingSplit() Using Dummy Nodes

Here is an alternative approach which builds the sub-lists in the same order as the source list. The code uses a temporary dummy header nodes for the 'a' and 'b' lists as they are being built. Each sublist has a "tail" pointer which points to its current last node — that way new nodes can be appended to the end of each list easily. The dummy nodes give the tail pointers something to point to initially. The dummy nodes are efficient in this case because they are temporary and allocated in the stack. Alternately, the "local references" technique could be used to get rid of the dummy nodes (see Section 1 for more details).

```
void AlternatingSplit2(struct node* source,
                       struct node** aRef, struct node** bRef) {
   struct node aDummy;
   struct node* aTail = &aDummy;    // points to the last node in 'a'
   struct node bDummy;
   struct node* bTail = &bDummy;    // points to the last node in 'b'
   struct node* current = source;

   aDummy.next = NULL;
   bDummy.next = NULL;

   while (current != NULL) {
      MoveNode(&(aTail->next), &current); // add at 'a' tail
      aTail = aTail->next;                // advance the 'a' tail
      if (current != NULL) {
         MoveNode(&(bTail->next), &current);
         bTail = bTail->next;
      }
   }

   *aRef = aDummy.next;
   *bRef = bDummy.next;
}
```

13 SuffleMerge() Solution

There are four separate solutions included. See Section 1 for information on the various dummy node and reference techniques.

SuffleMerge() — Dummy Node Not Using MoveNode()

```
struct node* ShuffleMerge(struct node* a, struct node* b) {
   struct node dummy;
   struct node* tail = &dummy;
   dummy.next = NULL;

   while (1) {
      if (a==NULL) {          // empty list cases
         tail->next = b;
         break;
      }
      else if (b==NULL) {
         tail->next = a;
         break;
      }
      else {                  // common case: move two nodes to tail
         tail->next = a;
         tail = a;
         a = a->next;
```

```
         tail->next = b;
         tail = b;
         b = b->next;
      }
   }

   return(dummy.next);
}
```

SuffleMerge() — Dummy Node Using MoveNode()

Basically the same as above, but use MoveNode().

```
struct node* ShuffleMerge(struct node* a, struct node* b) {
   struct node dummy;
   struct node* tail = &dummy;
   dummy.next = NULL;

   while (1) {
      if (a==NULL) {
         tail->next = b;
         break;
      }
      else if (b==NULL) {
         tail->next = a;
         break;
      }
      else {
         MoveNode(&(tail->next), &a);
         tail = tail->next;
         MoveNode(&(tail->next), &b);
         tail = tail->next;
      }
   }

   return(dummy.next);
}
```

SuffleMerge() — Local References

Uses a local reference to get rid of the dummy nodes entirely.

```
struct node* ShuffleMerge(struct node* a, struct node* b) {
   struct node* result = NULL;
   struct node** lastPtrRef = &result;

   while (1) {
      if (a==NULL) {
         *lastPtrRef = b;
         break;
      }
      else if (b==NULL) {
         *lastPtrRef = a;
         break;
      }
      else {
         MoveNode(lastPtrRef, &a);
         lastPtrRef = &((*lastPtrRef)->next);
         MoveNode(lastPtrRef, &b);
         lastPtrRef = &((*lastPtrRef)->next);
```

```
      }
   }

   return(result);
}
```

SuffleMerge() — Recursive

The recursive solution is the most compact of all, but is probably not appropriate for production code since it uses stack space proportionate to the lengths of the lists.

```
struct node* ShuffleMerge(struct node* a, struct node* b) {
   struct node* result;
   struct node* recur;

   if (a==NULL) return(b);          // see if either list is empty
   else if (b==NULL) return(a);
   else {
      // it turns out to be convenient to do the recursive call first --
      // otherwise a->next and b->next need temporary storage.

      recur = ShuffleMerge(a->next, b->next);

      result = a;       // one node from a
      a->next = b;      // one from b
      b->next = recur;  // then the rest
      return(result);
   }
}
```

14 — SortedMerge() Solution

SortedMerge() Using Dummy Nodes

The strategy here uses a temporary dummy node as the start of the result list. The pointer `tail` always points to the last node in the result list, so appending new nodes is easy. The dummy node gives `tail` something to point to initially when the result list is empty. This dummy node is efficient, since it is only temporary, and it is allocated in the stack. The loop proceeds, removing one node from either 'a' or 'b', and adding it to `tail`. When we are done, the result is in dummy.next.

```
struct node* SortedMerge(struct node* a, struct node* b) {
   struct node dummy;   // a dummy first node to hang the result on
   struct node* tail = &dummy;      // Points to the last result node --
                                    // so tail->next is the place to add
                                    // new nodes to the result.

   dummy.next = NULL;

   while (1) {
      if (a == NULL) {  // if either list runs out, use the other list
         tail->next = b;
         break;
      }
      else if (b == NULL) {
         tail->next = a;
         break;
      }
```

```
      if (a->data <= b->data) {
         MoveNode(&(tail->next), &a);
      }
      else {
         MoveNode(&(tail->next), &b);
      }
      tail = tail->next;
   }

   return(dummy.next);
}
```

SortedMerge() Using Local References

This solution is structurally very similar to the above, but it avoids using a dummy node. Instead, it maintains a struct node** pointer, `lastPtrRef`, that always points to the last *pointer* of the result list. This solves the same case that the dummy node did — dealing with the result list when it is empty. If you are trying to build up a list at its tail, either the dummy node or the struct node** "reference" strategy can be used (see Section 1 for details).

```
struct node* SortedMerge2(struct node* a, struct node* b) {
   struct node* result = NULL;
   struct node** lastPtrRef = &result;    // point to the last result pointer

   while (1) {
      if (a==NULL) {
         *lastPtrRef = b;
         break;
      }
      else if (b==NULL) {
         *lastPtrRef = a;
         break;
      }

      if (a->data <= b->data) {
         MoveNode(lastPtrRef, &a);
      }
      else {
         MoveNode(lastPtrRef, &b);
      }
      lastPtrRef = &((*lastPtrRef)->next);      // tricky: advance to point to
                                                // the next ".next" field

   }

   return(result);
}
```

SortedMerge() Using Recursion

Merge() is one of those nice recursive problems where the recursive solution code is much cleaner than the iterative code. You probably wouldn't want to use the recursive version for production code however, because it will use stack space which is proportional to the length of the lists.

```
struct node* SortedMerge3(struct node* a, struct node* b) {
   struct node* result = NULL;
```

```
   // Base cases
   if (a==NULL) return(b);
   else if (b==NULL) return(a);

   // Pick either a or b, and recur
   if (a->data <= b->data) {
      result = a;
      result->next = SortedMerge3(a->next, b);
   }
   else {
      result = b;
      result->next = SortedMerge3(a, b->next);
   }

   return(result);
}
```

15 — MergeSort() Solution

The MergeSort strategy is: split into sublists, sort the sublists recursively, merge the two sorted lists together to form the answer.

```
void MergeSort(struct node** headRef) {
   struct node* head = *headRef;
   struct node* a;
   struct node* b;

   // Base case -- length 0 or 1
   if ((head == NULL) || (head->next == NULL)) {
      return;
   }

   FrontBackSplit(head, &a, &b);    // Split head into 'a' and 'b' sublists
                                    // We could just as well use AlternatingSplit()

   MergeSort(&a); // Recursively sort the sublists
   MergeSort(&b);

   *headRef  = SortedMerge(a, b);   // answer = merge the two sorted lists together
}
```

(Extra for experts) Using recursive stack space proportional to the length of a list is not recommended. However, the recursion in this case is ok — it uses stack space which is proportional to the *log* of the length of the list. For a 1000 node list, the recursion will only go about 10 deep. For a 2000 node list, it will go 11 deep. If you think about it, you can see that doubling the size of the list only increases the depth by 1.

16 — SortedIntersect() Solution

The strategy is to advance up both lists and build the result list as we go. When the current point in both lists are the same, add a node to the result. Otherwise, advance whichever list is smaller. By exploiting the fact that both lists are sorted, we only traverse each list once. To build up the result list, both the dummy node and local reference strategy solutions are shown...

```
// This solution uses the temporary dummy to build up the result list
struct node* SortedIntersect(struct node* a, struct node* b) {
   struct node dummy;
```

```
   struct node* tail = &dummy;

   dummy.next = NULL;

   // Once one or the other list runs out -- we're done
   while (a!=NULL && b!=NULL) {
      if (a->data == b->data) {
         Push((&tail->next), a->data);
         tail = tail->next;
         a = a->next;
         b = b->next;
      }
      else if (a->data < b->data) { // advance the smaller list
         a = a->next;
      }
      else {
         b = b->next;
      }
   }

   return(dummy.next);
}


// This solution uses the local reference
struct node* SortedIntersect2(struct node* a, struct node* b) {
   struct node* result = NULL;
   struct node** lastPtrRef = &result;

   // Advance comparing the first nodes in both lists.
   // When one or the other list runs out, we're done.
   while (a!=NULL && b!=NULL) {
      if (a->data == b->data) {     // found a node for the intersection
         Push(lastPtrRef, a->data);
         lastPtrRef = &((*lastPtrRef)->next);
         a=a->next;
         b=b->next;
      }
      else if (a->data < b->data) { // advance the smaller list
         a=a->next;
      }
      else {
         b=b->next;
      }
   }

   return(result);
}
```

17 — Reverse() Solution

This first solution uses the "Push" strategy with the pointer re-arrangement hand coded inside the loop. There's a slight trickyness in that it needs to save the value of the "current->next" pointer at the top of the loop since the body of the loop overwrites that pointer.

```
/*
 Iterative list reverse.
 Iterate through the list left-right.
```

```
 Move/insert each node to the front of the result list --
 like a Push of the node.
*/
static void Reverse(struct node** headRef) {
   struct node* result = NULL;
   struct node* current = *headRef;
   struct node* next;

   while (current != NULL) {
      next = current->next;         // tricky: note the next node

      current->next = result;       // move the node onto the result
      result = current;

      current = next;
   }

   *headRef = result;
}
```

Here's the variation on the above that uses MoveNode() to do the work...

```
static void Reverse2(struct node** headRef) {
   struct node* result = NULL;
   struct node* current = *headRef;

   while (current != NULL) {
      MoveNode(&result, &current);
   }

   *headRef = result;
}
```

Finally, here's the back-middle-front strategy...

```
// Reverses the given linked list by changing its .next pointers and
// its head pointer. Takes a pointer (reference) to the head pointer.
void Reverse(struct node** headRef) {
   if (*headRef != NULL) {          // special case: skip the empty list

/*
 Plan for this loop: move three pointers: front, middle, back
 down the list in order. Middle is the main pointer running
 down the list. Front leads it and Back trails it.
 For each step, reverse the middle pointer and then advance all
 three to get the next node.
*/

      struct node* middle = *headRef;           // the main pointer

      struct node* front = middle->next;  // the two other pointers (NULL ok)
      struct node* back = NULL;


      while (1) {
         middle->next = back;       // fix the middle node

         if (front == NULL) break;  // test if done
```

```
         back = middle;             // advance the three pointers
         middle = front;
         front = front->next;
      }

      *headRef = middle;      // fix the head pointer to point to the new front
   }
}
```

18 — RecursiveReverse() Solution

Probably the hardest part is accepting the concept that the `RecursiveReverse(&rest)` does in fact reverse the rest. Then then there's a trick to getting the one front node all the way to the end of the list. Make a drwaing to see how the trick works.

```
void RecursiveReverse(struct node** headRef) {
   struct node* first;
   struct node* rest;

   if (*headRef == NULL) return;          // empty list base case

   first = *headRef;    // suppose first = {1, 2, 3}
   rest = first->next;  //         rest = {2, 3}

   if (rest == NULL) return;        // empty rest base case

   RecursiveReverse(&rest);   // Recursively reverse the smaller {2, 3} case
                              // after: rest = {3, 2}

   first->next->next = first; // put the first elem on the end of the list
   first->next = NULL;        // (tricky step -- make a drawing)

   *headRef = rest;     // fix the head pointer
}
```

The inefficient soluition is to reverse the last n-1 elements of the list, and then iterate all the way down to the new tail and put the old head node there. That solution is very slow compared to the above which gets the head node in the right place without extra iteration.

Appendix

Basic Utility Function Implementations

Here is the source code for the basic utility functions.

Length()

```
// Return the number of nodes in a list
int Length(struct node* head) {
   int count = 0;
   struct node* current = head;

   while (current != NULL) {
      count++;
      current=current->next;
   }

   return(count);
}
```

Push()

```
// Given a reference (pointer to pointer) to the head
// of a list and an int, push a new node on the front of the list.
// Creates a new node with the int, links the list off the .next of the
// new node, and finally changes the head to point to the new node.
void Push(struct node** headRef, int newData) {
   struct node* newNode =
      (struct node*) malloc(sizeof(struct node));     // allocate node
   newNode->data = newData;                           // put in the data
   newNode->next = (*headRef);      // link the old list off the new node
   (*headRef) = newNode;            // move the head to point to the new node
}
```

BuildOneTwoThree()

```
// Build and return the list {1, 2, 3}
struct node* BuildOneTwoThree() {
   struct node* head = NULL;  // Start with the empty list
   Push(&head, 3);      // Use Push() to add all the data
   Push(&head, 2);
   Push(&head, 1);

   return(head);
}
```

FOLLOW

ANKIT PANGASA