Singly Linked lists

Revised based on textbook author's notes.

Consider this problem

- Given a sorted list of numbers, insert a new number into this sorted list
  - [3, 5, 7, 10, 12, 20]
  - insert 6 into this list to become
  - [3, 5, 6, 7, 10, 12, 20]
- How do YOU accomplish this seemly simple task? Take 5 min to work it out.

Here is a possible solution

n steps

n steps

n steps

```
def insert_sorted(k, my_list):
    """ Insert k into a sorted list my_list"""
    new_list = [x for x in my_list] + [k]  # have k to occupy a spot!
    i = find_pos(k, my_list)
    for j in range(len(new_list)-1, i-1, -1):  # shift each element right
        new_list[j] = new_list[j-1]
    # now put k where it belongs to
    new_list[j] = k

    return new_list

def find_pos(k, my_list):
    """ Find where k should be in the sorted list my_list"""
    i = 0
    while i < len(my_list) and k > my_list[i]:
        i += 1
    return i    # i could be len(my_list)!
```

How many steps to complete this work?

It takes 3*n steps to do this.

Can we do better? How?

Let's look at one issue at a time

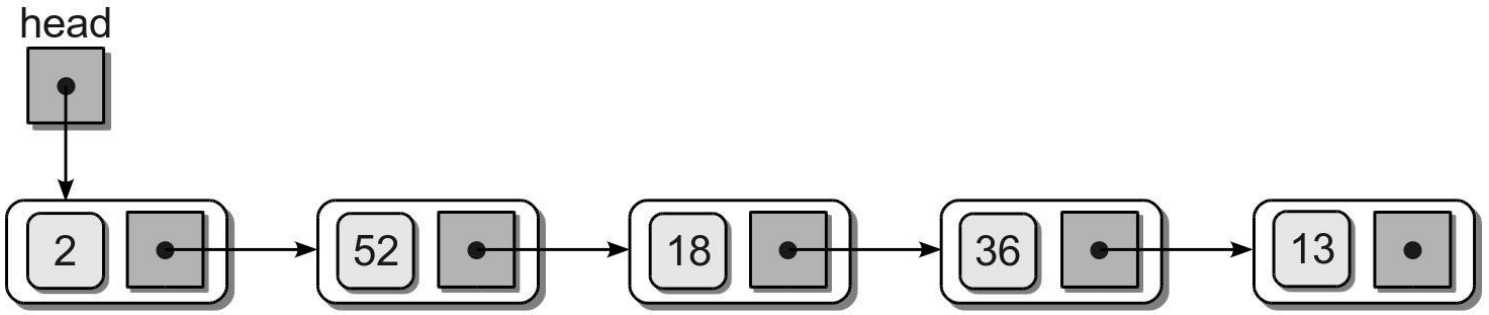
- new_list = [x for x in my_list] + [k]
  - We need to increase the capacity of the list to hold the new element. Weather the list is implemented as a Python list or an array, this would take n steps.
- i = find_pos(k, my_list)
  - We need to find the right spot for the new number, which takes n steps
- for j in range(len(new_list)-1, i-1, -1):
  - Shifting elements to the right takes n steps

Linked lists

- Use linked list we can make two of the three operations in constant time!

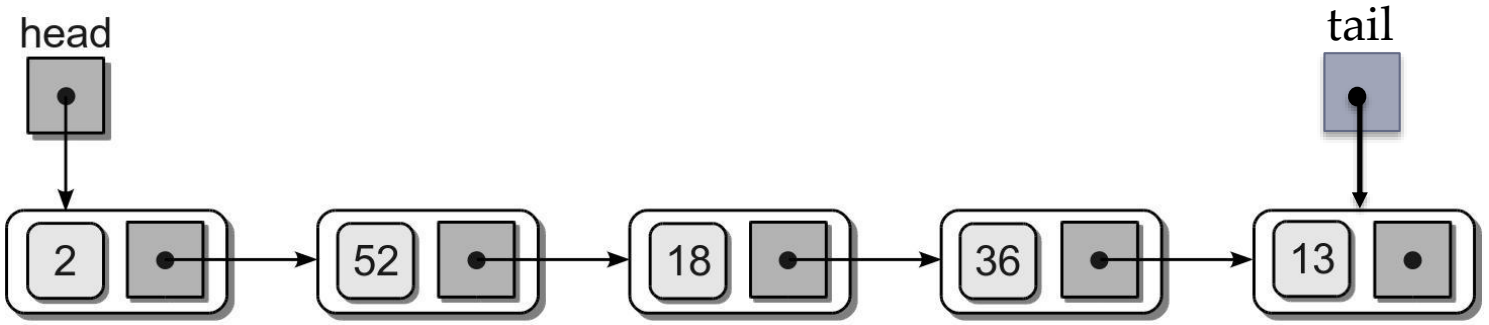
Linked Structure

- Constructed using a collection of objects called **nodes**.
- Each node contains data and at least one reference or **link** to another node.
- **Linked list** – a linked structure in which the nodes are linked together in linear order.



Linked List

- Terms:
  - **node** – each element in the list.
  - **head** – first node in the list.
  - **tail** – last node in the list; link field has a null reference.



How does it look like in Python?

- The nodes are constructed from a simple storage class:

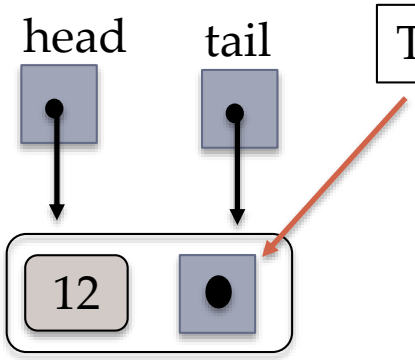
```
class ListNode:
  def __init__( self, data ):
    self.data = data
    self.next = None
```

- List contains two nodes, a head and a tail

```
class UserList:
  def __init__( self ):
    self.head = None
    self.tail = None
```

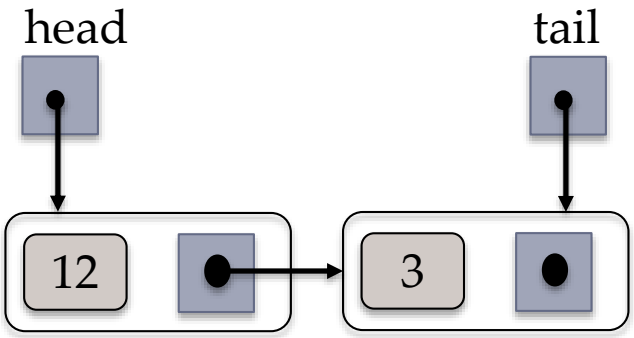
How to build a list?

```
my_list = UserList()  # initial list head == None
a_node = ListNode(12) # create a node
my_list.insert_after(node)  # insert the node to list
my_list.insert_after(ListNode(3))# another node
```



The 'next' field has a value of None

```
def insert_after(self, node):
    """ Insert a node with data at the end of the list
    """
    if self.is_empty():    # the node will be the first one in list
        self.head = node
        self.tail = node
    else:                  # insert after the current tail
        self.tail.next = node
        self.tail = node
```



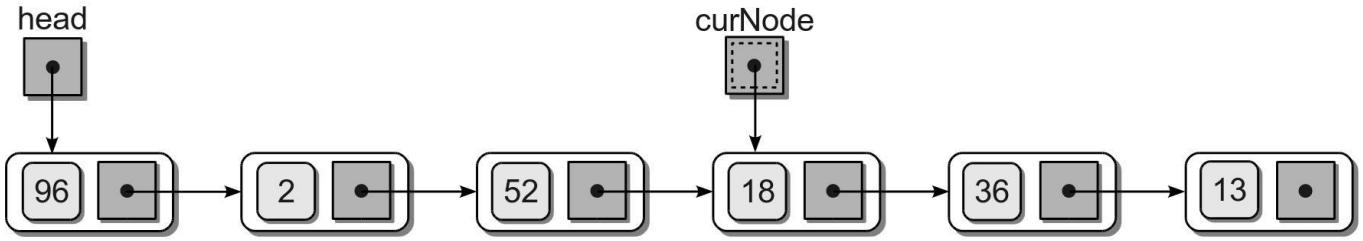
Try out an example

```
from random import *
from userlist import *

def test_list():
    """ A test program for singly linked list """
    my_list = UserList()
    nums = [randint(1, 100) for i in range(10)]
    for x in nums:
        my_list.insert_after(ListNode(x))

    print(my_list)


test_list()
```

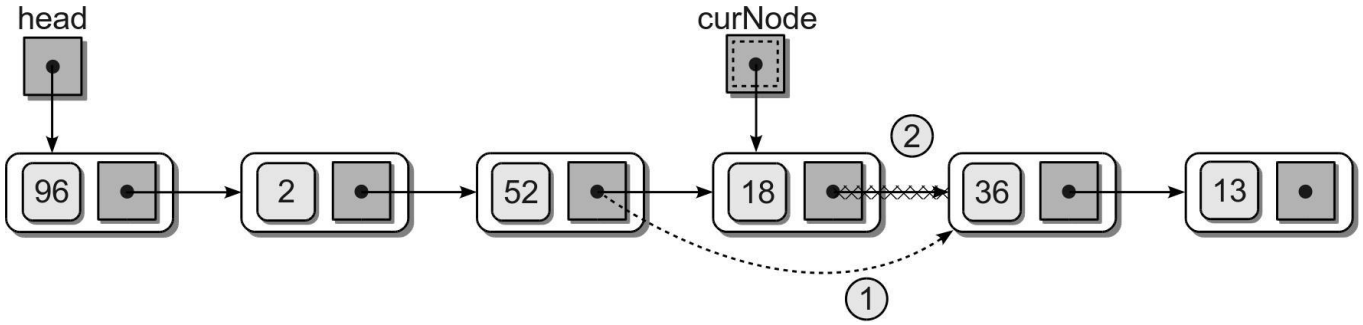
Exercise: write the function `insert_before()` that inserts the node before the head.

Removing nodes

- An item can be removed from a linked list by removing or unlinking the node containing the item.
  - Find the node containing the item.

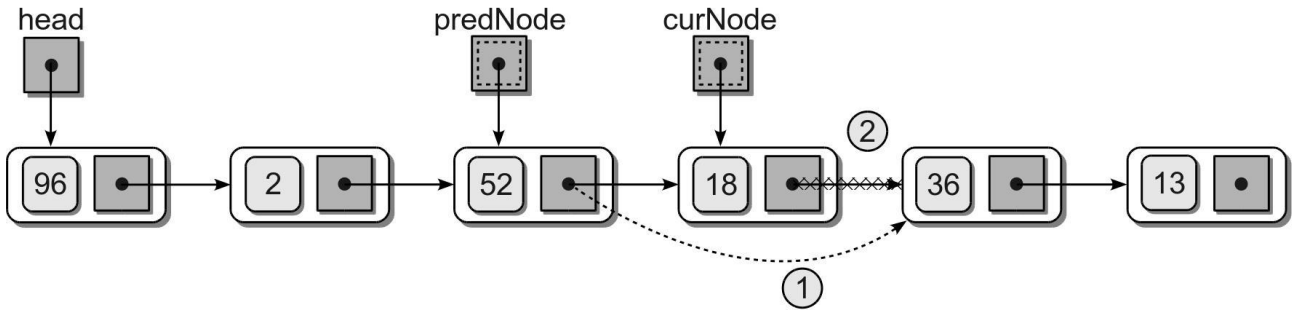


  - Unlink it from the list.

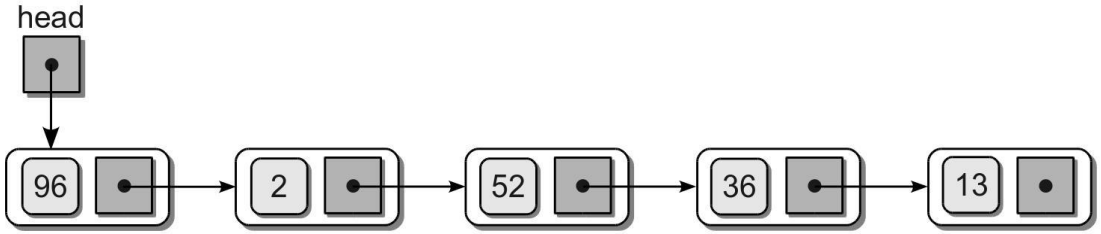


Removing nodes

- Removing a node from the middle of the list requires a second external reference.

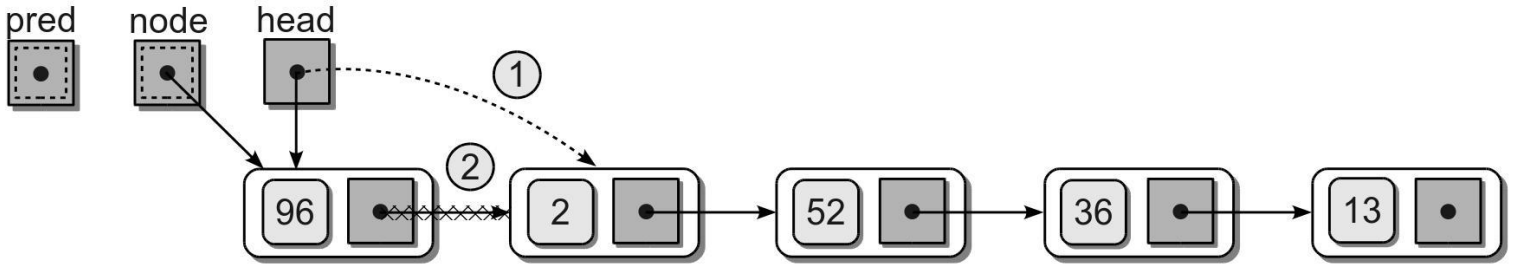


- Resulting list.



Removing Nodes

- Removing the first node is a special case.
- The head reference must be reposition to reference the next node in the list.



Removing nodes

- Given the head reference, we can remove a target from a linked list.

```
def remove_node(self, target):
    """ Remove the node containing the target
    """
    prev = None
    cur  = self.head
    while cur != None and cur.data != target:
        prev = cur
        cur  = cur.next

    if cur != None:     # found it and remove it
        if cur == self.head:
            self.head = cur.next  # head is removed, reset head
        else:
            prev.next = cur.next  # remove a middle node
```