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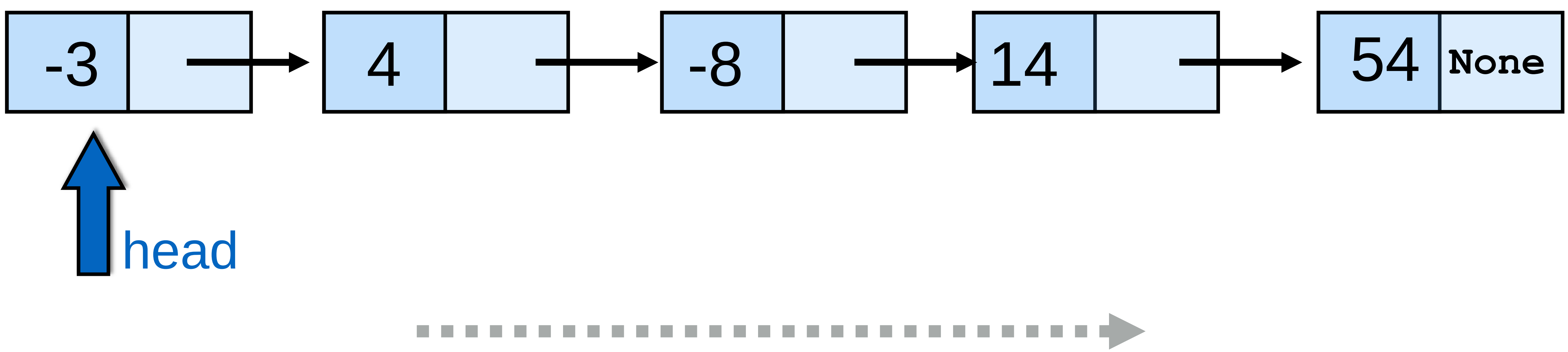
Lecture 28
Iteration vs Recursion

FIT 1008
Introduction to Computer Science

Operation	Class Method
str(obj)	__str__(self)
len(obj)	__len__(self)
item in obj	__contains__(self,item)
y = obj[ndx]	__getitem__(self,ndx)
obj[ndx] = value	__setitem__(self,ndx,value)
obj == rhs	__eq__(self,rhs)
obj < rhs	__lt__(self,rhs)
…	
obj + rhs	__add__(self,rhs)
...	

```python
class List:
    def __init__(self):
        self.head = None
        self.count = 0

    def __len__(self):
        return self.count
```

?



count from head to access elements

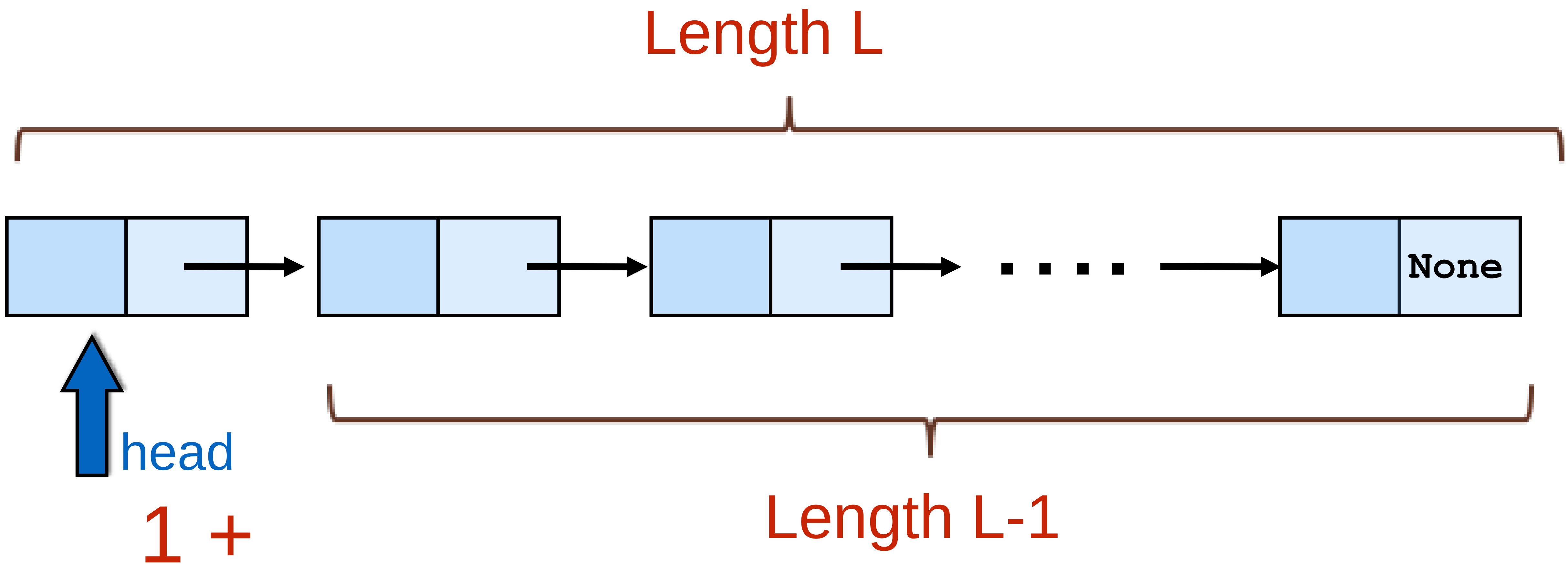
```python
class List:
    def __init__(self):
        self.head = None

    def __len__(self):
```

```python
class List:
    def __init__(self):
        self.head = None

    def __len__(self):
        current = self.head
        count = 0
        while current is not None:
            current = current.next
            count += 1
        return count
```

```python
class List:
    def __init__(self):
        self.head = None

    def __len__(self):
        current = self.head
        count = 0
        while current is not None:
            current = current.next
            count += 1
        return count
```

Complexity: O(n) where n is the size of the list.

What about recursively?



Convergence: Call recursion with L-1. Use variable *current*.

Base case: Empty? Size of empty list is 0.

Combining solutions: Add up result of recursive call +

```python
def __len__(self):
```

```python
def __len__(self):
    if self.head is None:
        return 0
    else:
        return 1  + self.__len__(self.head.next)
```

https://c3.thejournal.ie/media/2013/11/awkward-moment-sign1-230x150.jpg


```
def __len__(self):
    if self.head is None:
        return 0
    else:
        return 1  + self.__len__(self.head.next)
```

```
TypeError: __len__() takes 1 positional argument but 2 were given
```

```python
def length(self, current):
```

```python
def _length(self, current):
    if self.current is None: # base case
        return 0
    else:
        return 1  + self._length(current.next)

def __len__(self):
    return self._length(self.head)
```

Base case

Convergence

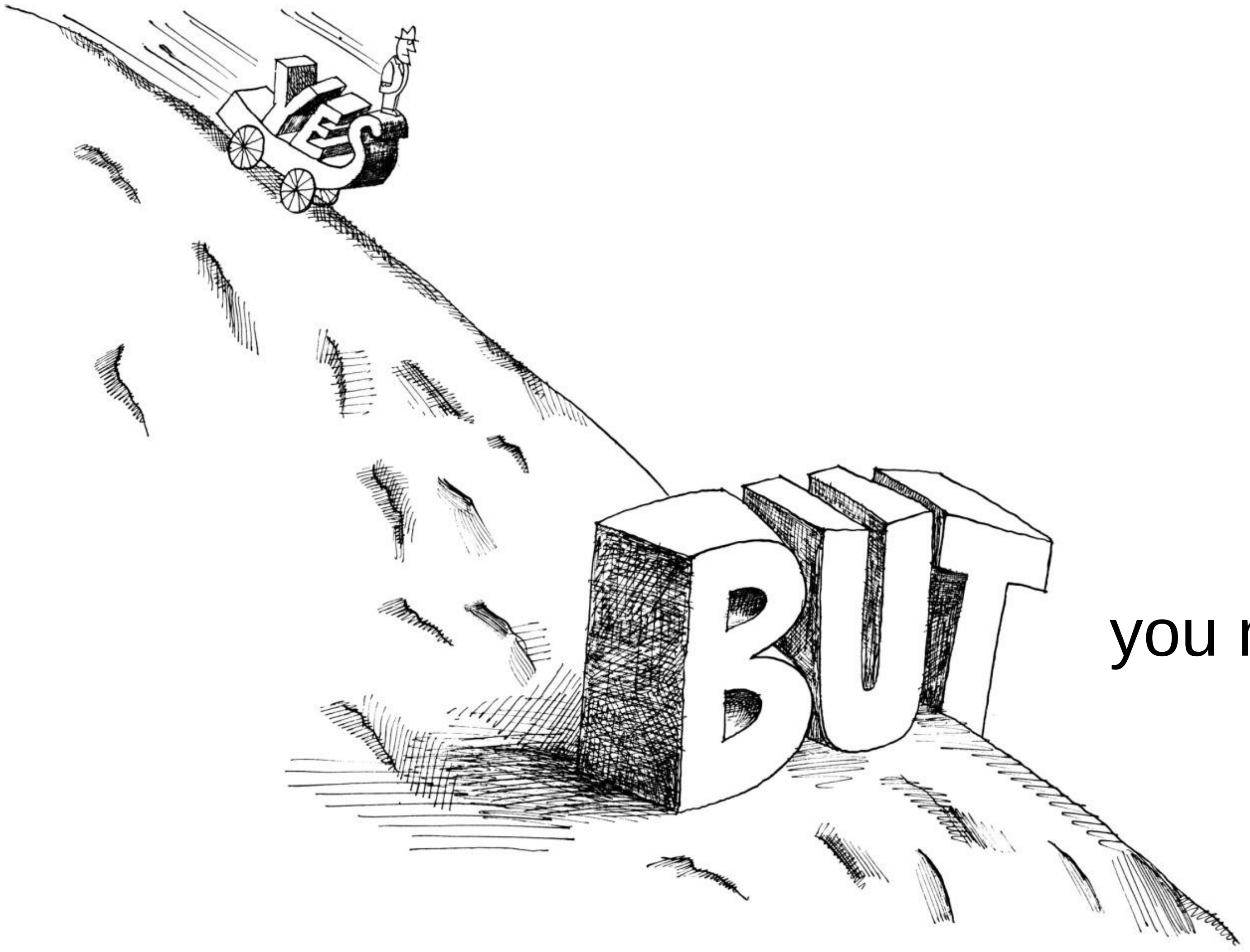
Combination

Auxiliary method sets up the initial parameters

Recursion vs Iteration

- Can every **iterative function** be implemented using **recursion**?
  Yes, it is straightforward.

- Can every **recursive function** be implemented using **iteration**?



you might also need to store past results.

Lovingly stolen from:
https://66.media.tumblr.com/3f1bb6a13c96f90cb332b385a6363b2e/tumblr_nkaavk9owg1qz6f4bo2_1280.jpg

Operation	Class Method
str(obj)	__str__(self)
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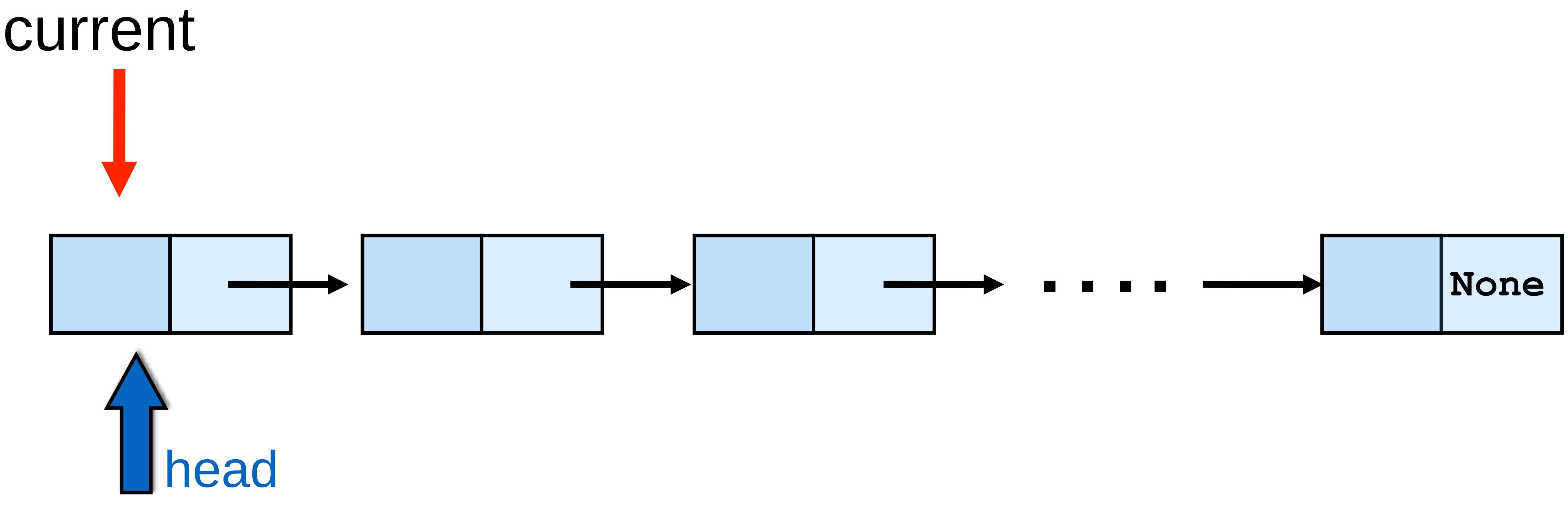
...	

__contains__



__contains__

```python
def __contains__(self, item):
```

__contains__

```
def __contains__(self, item):
    current = self.head
    while current is not None:
        if current.item == item:
            return True
        current = current.next
    return False
```

Complexity: Worst case - O(n) where n is the size of the list.

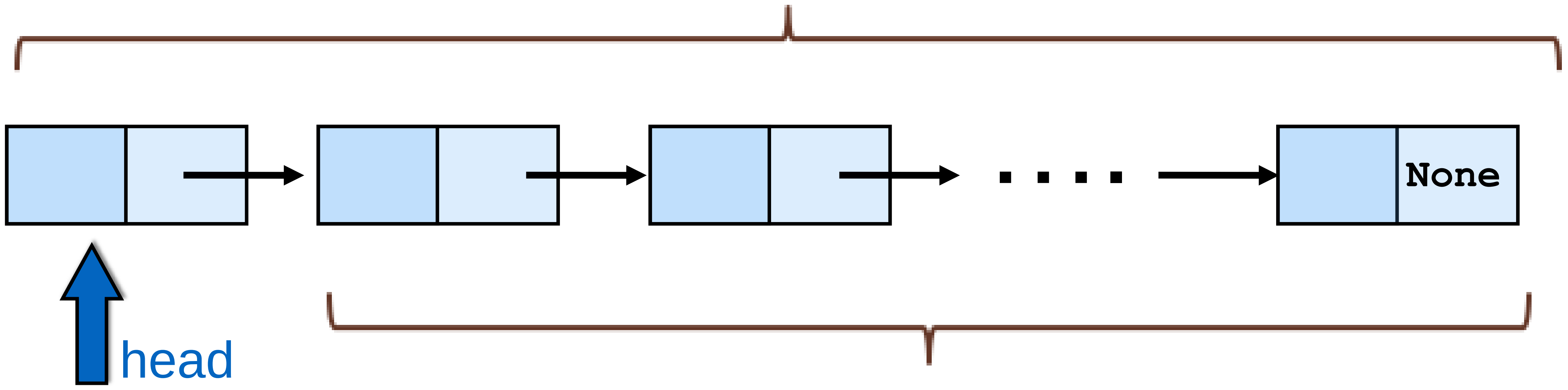
__contains__

```
def __contains__(self, item):
    current = self.head
    while current is not None:
        if current.item == item:
            return True
        current = current.next
    return False
```

- **Best case** complexity when found first: **O(1)***CompEq where CompEq is the complexity of == (or __eq__)
- **Worst case** when not found: **O(n)***CompEq where n is the length of the list.

What about recursively?

__contains__(6) in L



6 ==head.item **or** __contains__(6) in L-1

Convergence: Call recursion with L-1. Use variable *current*.

Base case: Empty or Element Found. We need both.

Combining solutions: it's in the head **or** in the remaining list.

```python
def __contains__(self, item):
```

Auxiliary method sets up the initial parameters

```
def __contains__(self, item):
    return self._contains_aux(self.head, item)

def _contains_aux(self, current, item):
    if current is None:
        return False
    return current.head == item or self._contains_aux(current.next, item)
```

Convergence

Base case

Combination

Alternative coding

```
def __contains__(self, item):
    return self._contains_aux(self.head, item)
```

The Simpsons… but I stole the picture from here: https://i.imgur.com/KQnegLL.jpg

Alternative coding

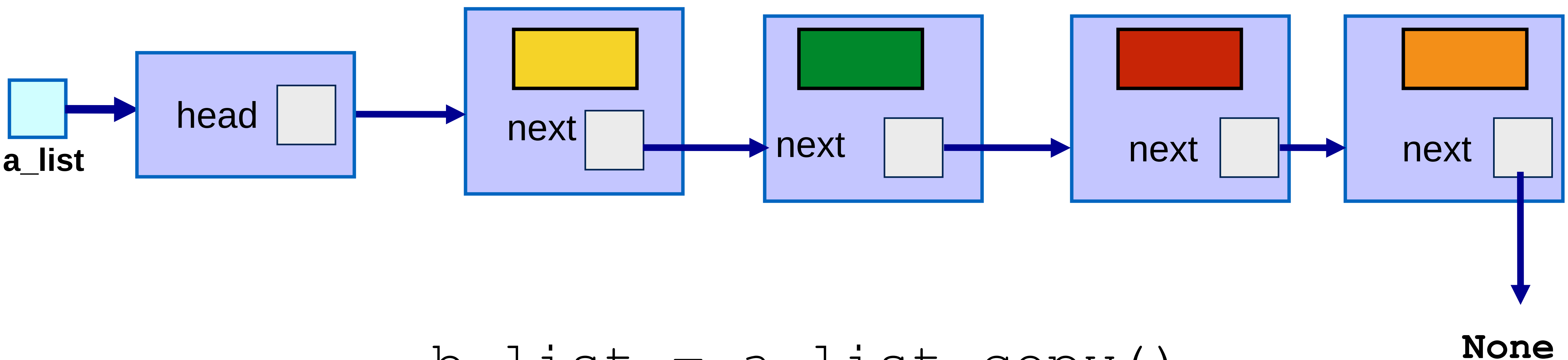
```
def __contains__(self, item):
    return self._contains_aux(self.head, item)

def _contains_aux(self, current, item):
    if current is None:
        return False
    elif current.head == item:
        return True
    else:
        return self._contains_aux(current.next, item)
```

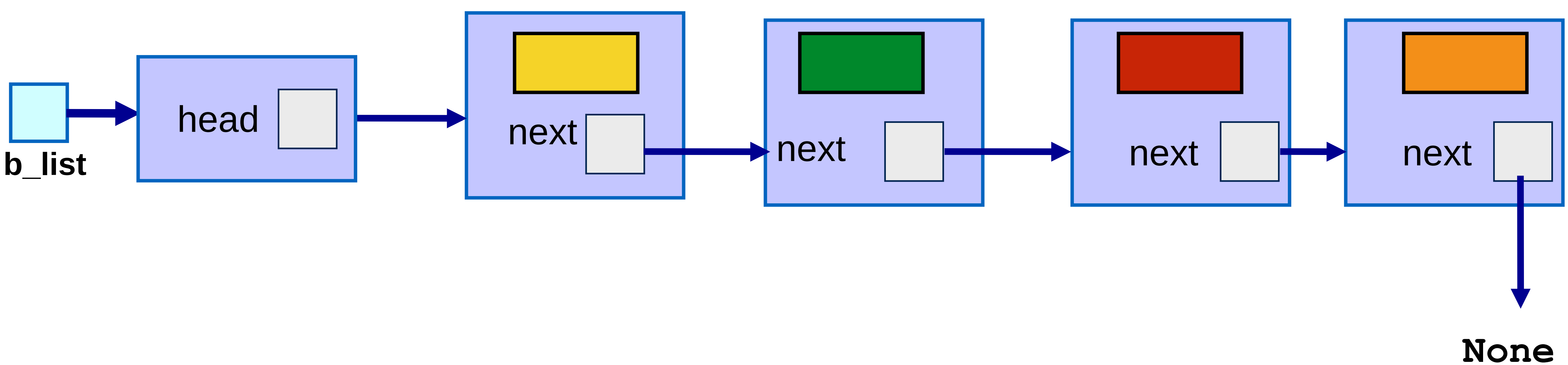
or is implicit

If complexity is the same, why bother with recursive implementations?

Copy Linked Lists




```
b_list = a_list.copy()
```

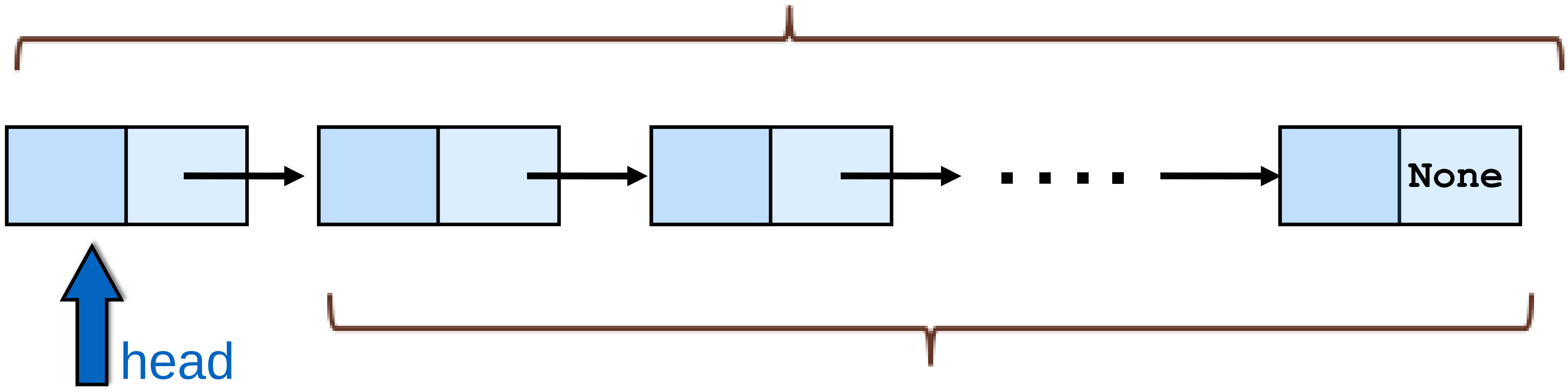


```python
def copy(self):
```

```python
def copy(self):
    new_list = List()
    for item in self:
        new_list.insert(len(new_list), item)
    return new_list
```

What about recursively?

_copy(self.head, new_list)



_copy(self.head.next, new_list)

new_list.insert(0, head.item)

copy

```
def copy(self):
```

copy

Auxiliary method se
up the initial paramete

```
def copy(self):
    new_list = List()
    self._copy_aux(self.head, new_list)
    return new_list
```

Convergence

```
def _copy_aux(self, node, new_list):
    if node is not None:
        self._copy_aux(node.next, new_list)
        new_list.insert(0, node.item)
```

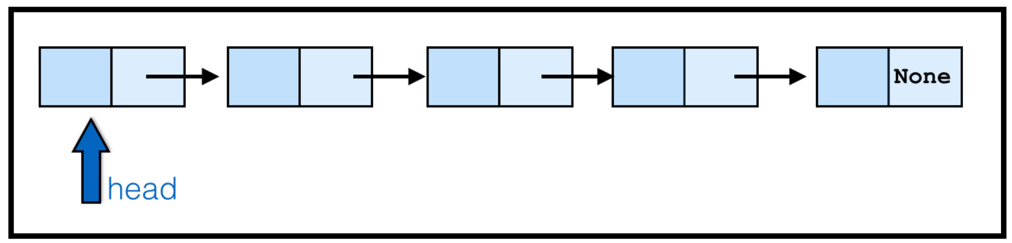
Combination

Base case

```python
def copy(self):
    new_list = List()
    self._copy_aux(self.head, new_list)
    return new_list

def _copy_aux(self, node, new_list):
    if node is not None:
        self._copy_aux(node.next, new_list)
        new_list.insert(0, node.item)
```

O(n)

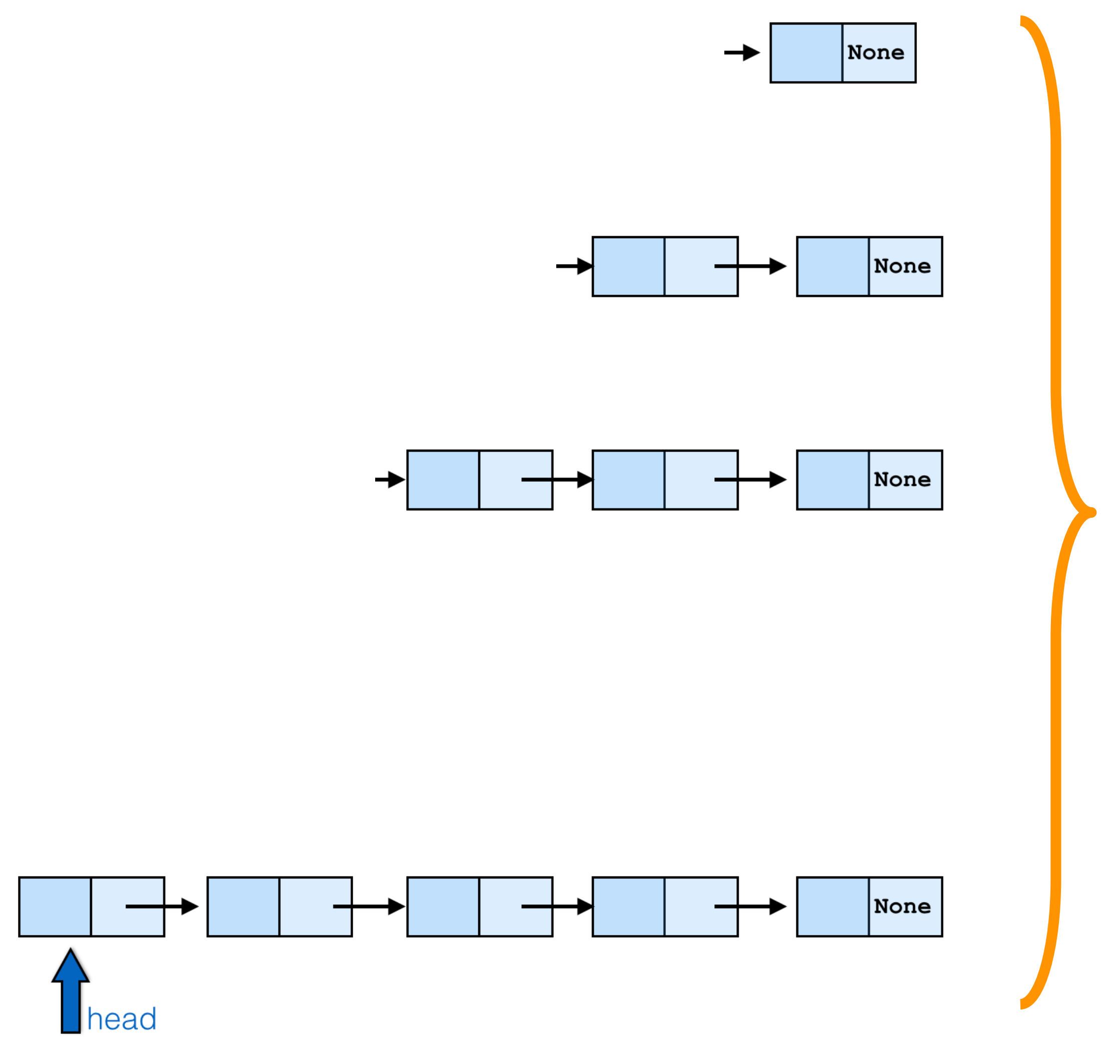


_copy_aux O(1)

_copy_aux O(1)

_copy_aux O(1)

_copy_aux O(1)



n times

Using iterators…

```
def copy(a_list):
        new_list = List()
        copy_aux(iter(a_list), new_list)
        return new_list

def copy_aux(iter, new_list):
    try:
        item = next(iter)
        copy_aux(iter, new_list)
        new_list.insert(0, item)
    except StopIteration:
        pass
```

copy

```
def copy(self):
    new_list = List()
    for item in self:
        new_list.insert(len(new_list), item)
    return new_list
```

$O(n^2)$

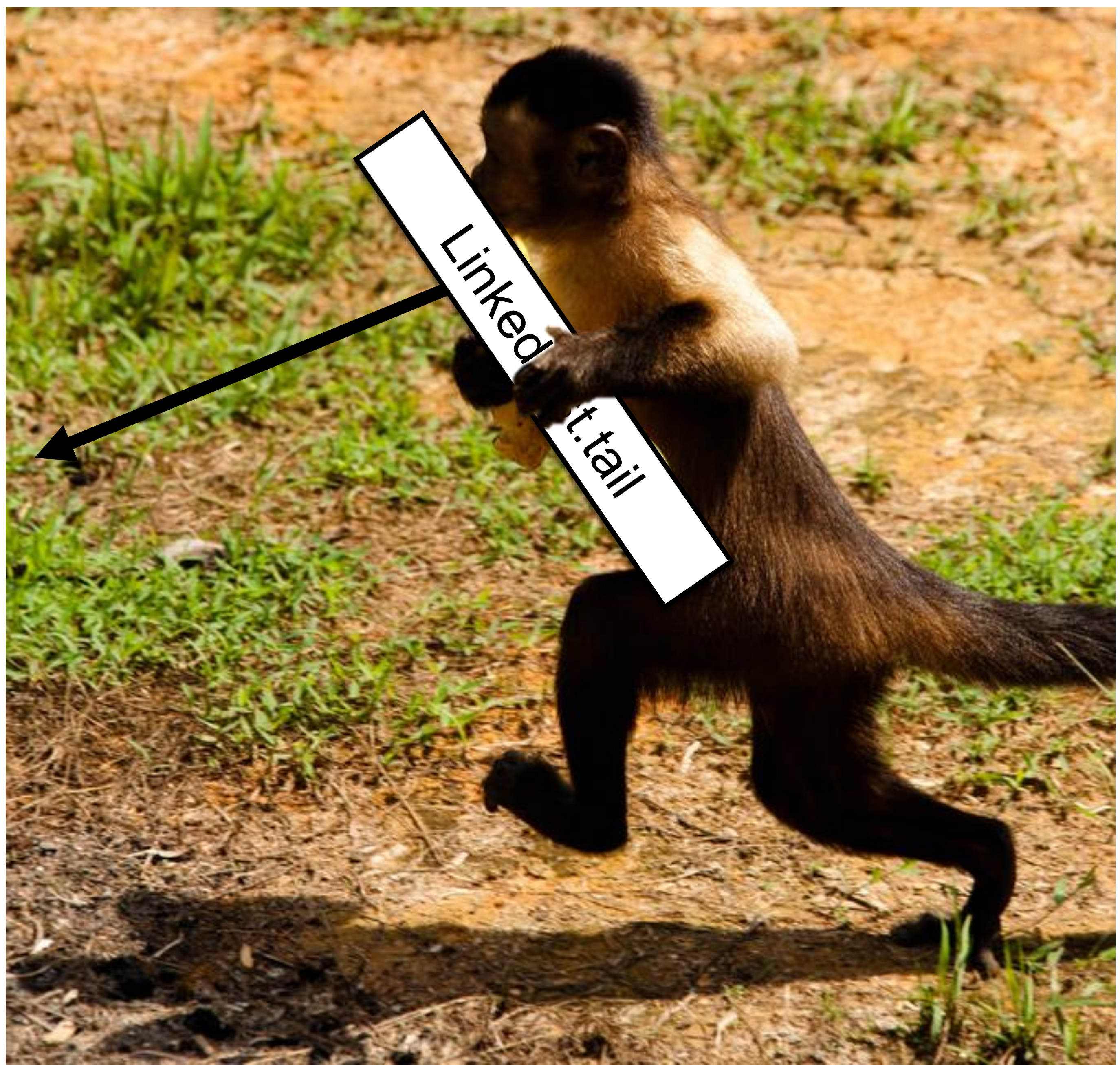
```
def copy(self):
    new_list = List()
    self._copy_aux(self.head, new_list)
    return new_list

def _copy_aux(self, node, new_list):
    if node is not None:
        self._copy_aux(node.next, new_list)
        new_list.insert(0, node.item)
```

$O(n)$

Or….

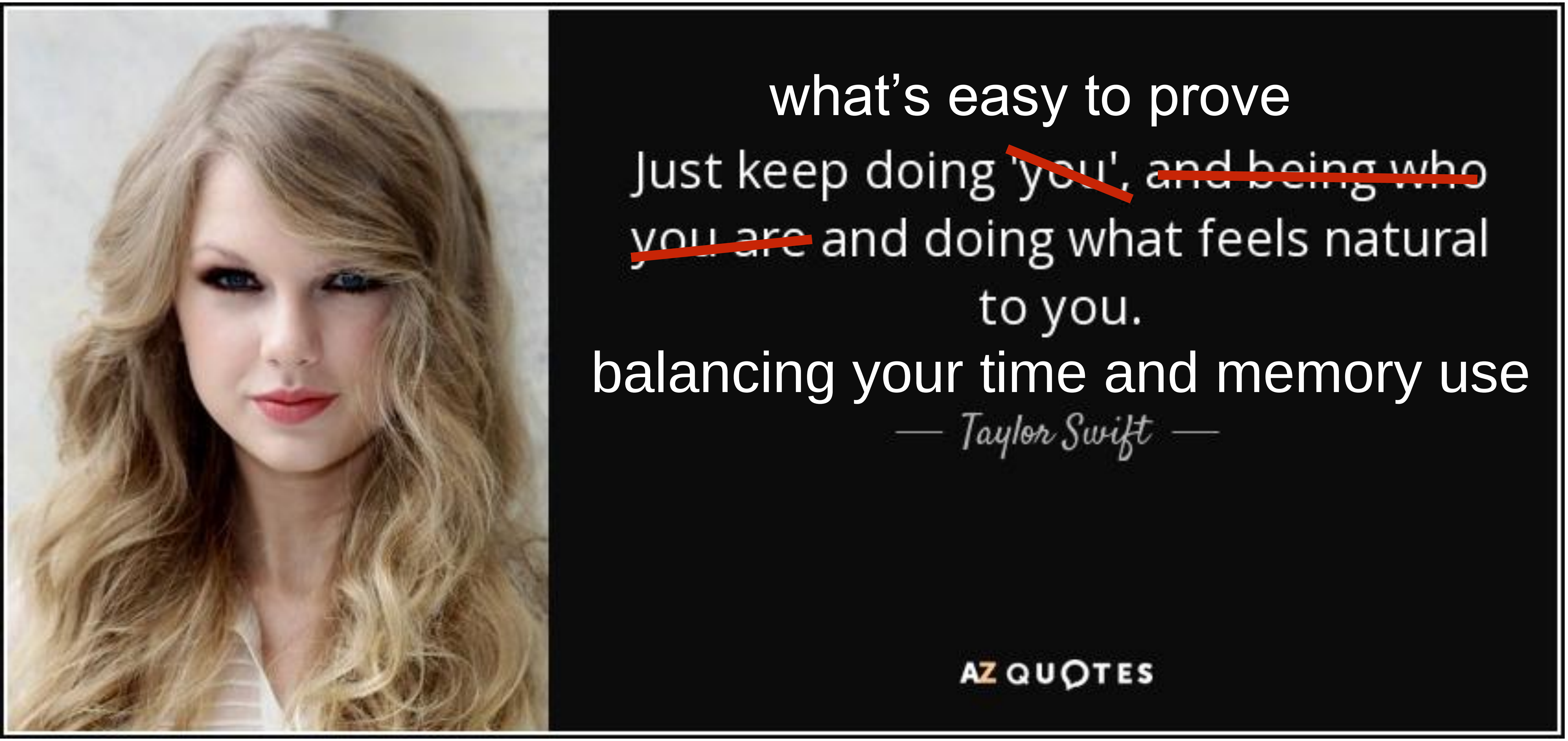
Have a tail attribute and you can have O(1) append and hence O(n) copy



Advantages/Disadvantages of Recursion

- Advantages:
  - More natural
  - Easier to prove correct
  - Easier to analyse

- Disadvantages:
  - Run-time overhead depending on the quality of the compiler
  - Memory overhead (fewer local variables versus stack space for function call)



I stole this quote from TayTay from here: http://www.azquotes.com/quote/863077

Summary

- Recursive algorithms are characterised by:
  1. Existence of base cases
  2. Decomposition into simpler subproblems
  3. Combination of solutions to subproblems

- Recursive methods require:
  1. One or more base cases
  2. One or more recursive calls
  3. Convergence in the recursive calls
  4. Combination of sub-solutions