Prepared by Julian García, based on material by
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Lecture 26
Linked Lists

FIT 1008
Introduction to Computer Science

http://giantcontainersales.com/wp-content/uploads/2014/07/1.jpg

Container ADTs

	Array-based implementation	Linked implementation
Stacks	Done	Done
Queues	Done	Done
Lists	Done	?

Objectives

- To understand the use of linked data structures in implementing Linked lists
- To be able to:
  - Implement, use and modify linked lists.
  - Decide when is it appropriate to use them (as opposed to using the ones implemented with arrays)

List ADT

- Sequence of items
- Possible Operations:
  - Create a list
  - Insert an item before a given position in the list
  - Delete an item at a given position from the list
  - Check whether the list is empty
  - Check whether the list is full
  - Get the length of the list.

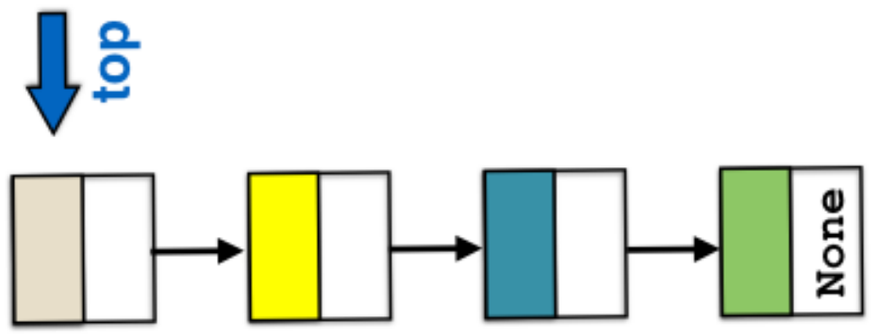
http://giantcontainersales.com/wp-content/uploads/2014/07/1.jpg

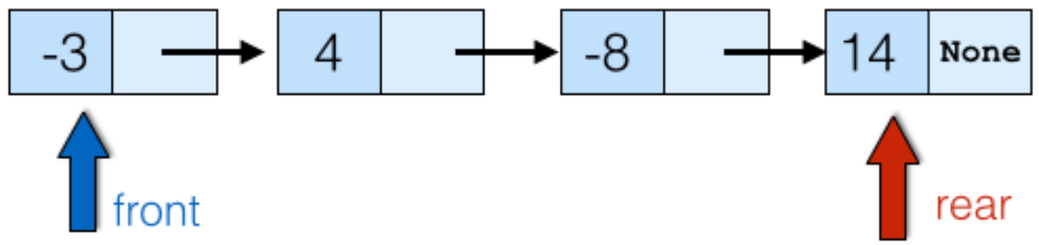
Container ADTs

	Array-based implementation	Linked implementation
Stacks	Done	Done
Queues	Done	Done
Lists	Done	?

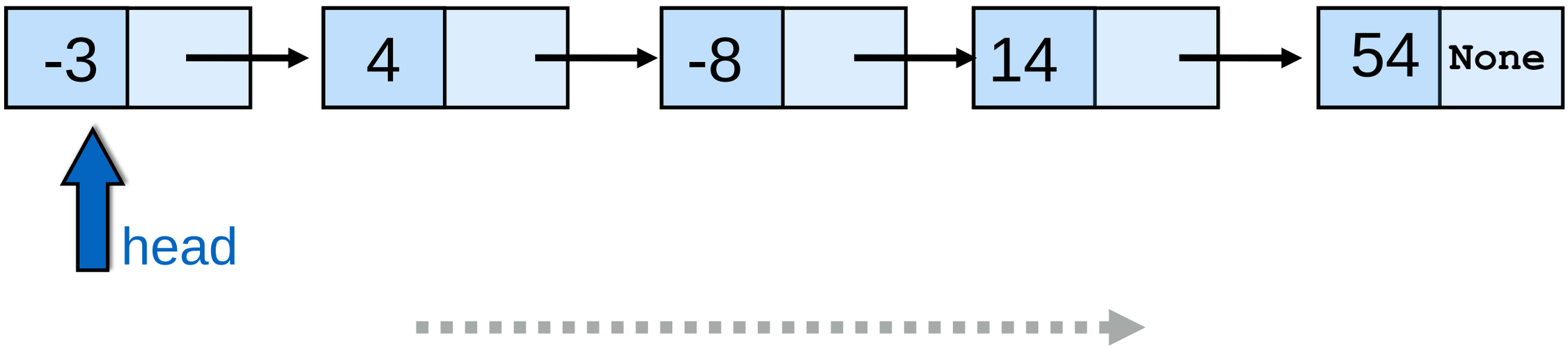
Access elements at specific locations

Access any element

Access the top element only		`class Stack:`
		`  def __init__(self):`
		`  self.top = None`

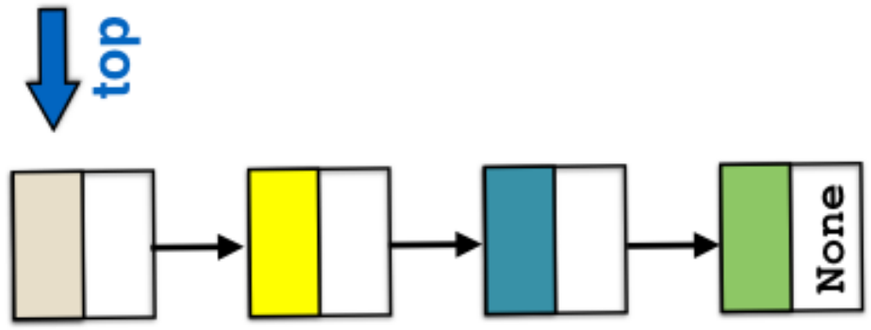
Append to rear Serve front		`class Queue:`
		`  def __init__(self):`
		`  self.front = None`
		`  self.rear = None`

Access any Node	?	?



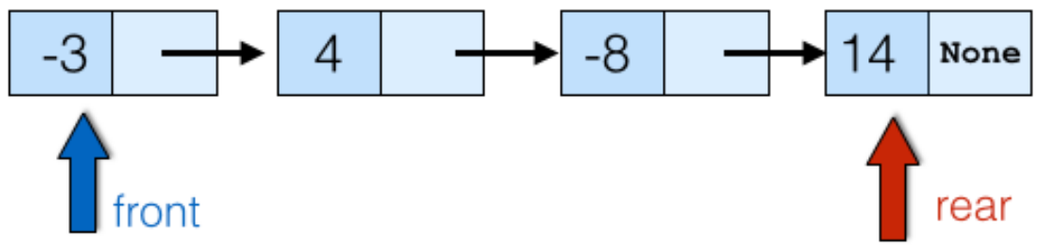
count from head to access elements

Access the top element only



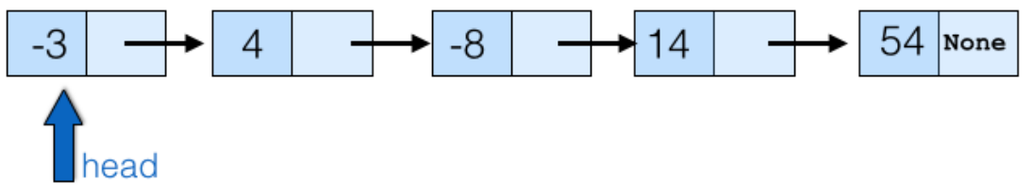

```
class Stack:
    def __init__(self):
        self.top = None
```

Append to rear
Serve front




```
class Queue:
    def __init__(self):
        self.front = None
        self.rear = None
```

Access any Node

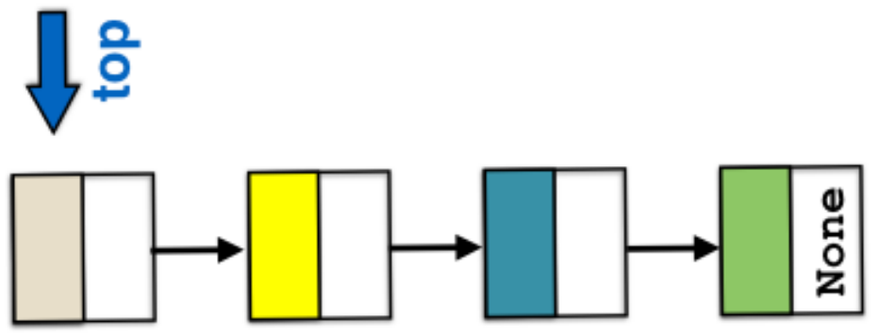


?

No strictly necessary, but it will be useful

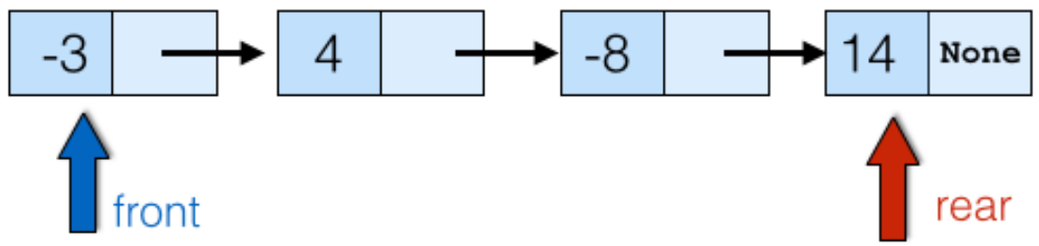
```
class List:
    def __init__(self):
        self.head = None
        self.count = 0
```

Access the top element only



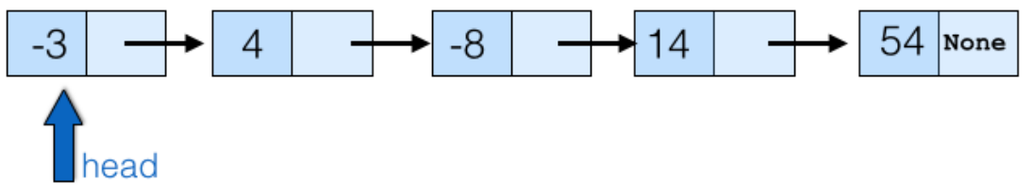

```
class Stack:
    def __init__(self):
        self.top = None
```

Append to rear
Serve front




```
class Queue:
    def __init__(self):
        self.front = None
        self.rear = None
```

Access any Node



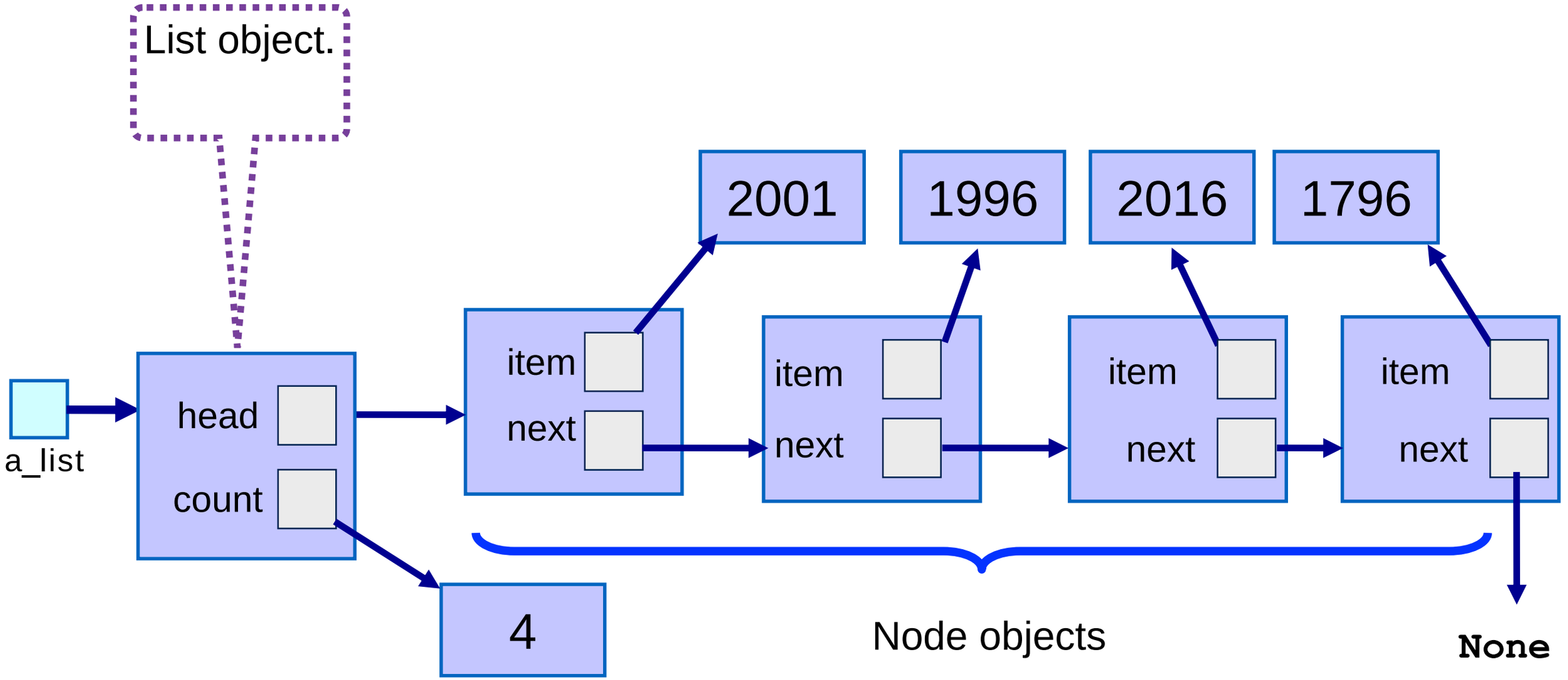

```
class List:
    def __init__(self):
        self.head = None
        self.count = 0
```

Linked Lists

- What instance variables have we used for stacks and queues?
  - Stacks: top (only place where we push and pop elements from)
  - Queues: front and rear (we append to the rear, serve from the front)

- What instance variables do we need for lists? Only one component: a reference to the head/start/first node

- From there, we can access every other node


List object.
a_list
head
count
4
2001
1996
2016
1796
item
next
item
next
item
next
item
next
Node objects
None

No need for size when initialising the object

Reference to node at the head

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

    def is_empty(self):
        return self.count == 0

    def is_full(self):
        return False

    def reset(self):
        self.__init__()

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

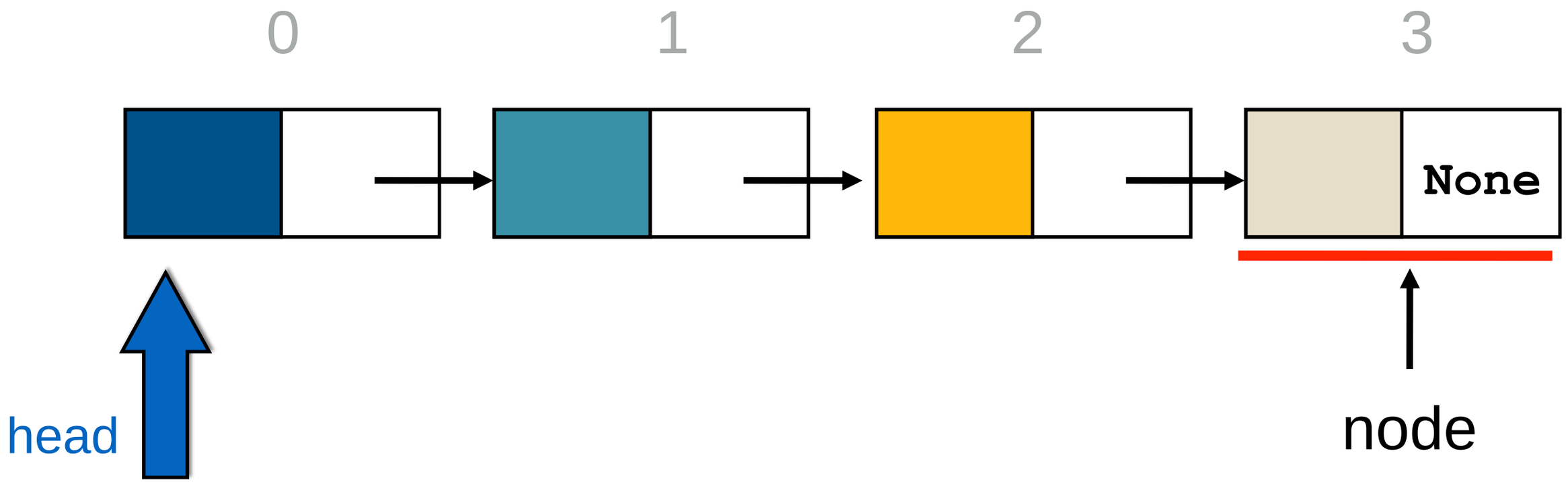
Insert and Delete

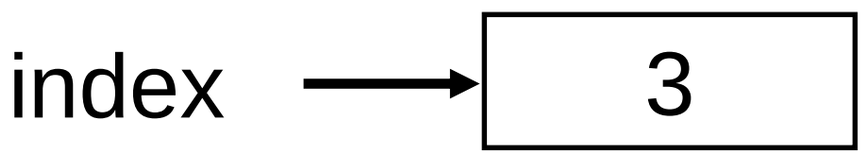
- insert(index, item)
  - Inserts item before position index in the list

- delete(index)
  - Removes the item at position index in the list
  - Raises IndexError if the list is empty or the index is out of range
  - Similar to pop(index) in Python's list ADT

- Both require _get_node(self, index)
  - Returns a reference to the node at position index.
  - Internal "private" method

_get_node(self, index)





_get_node(self, index)

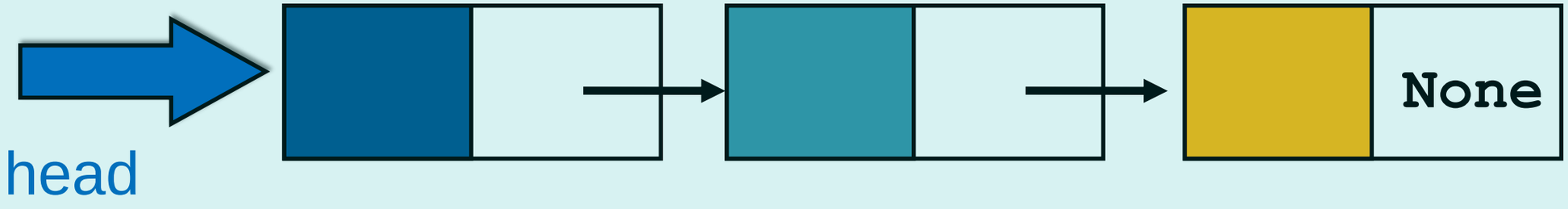
- check if index is within range
- set a variable node, pointing to Node referred by head
- set a counter to 0
- while counter is less than index
  - follow link to next node
  - increment counter
- return node

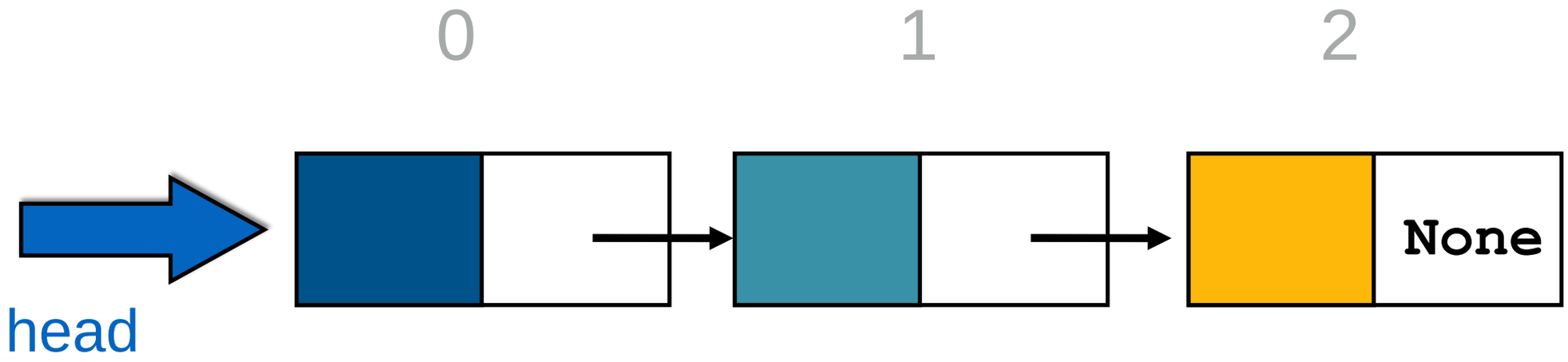
count index times

```
def _get_node(self, index):
    assert 0 <= index < self.count, "Index out of bounds"
    node = self.head
    for _ in range(index):
        node = node.next
    return node
```

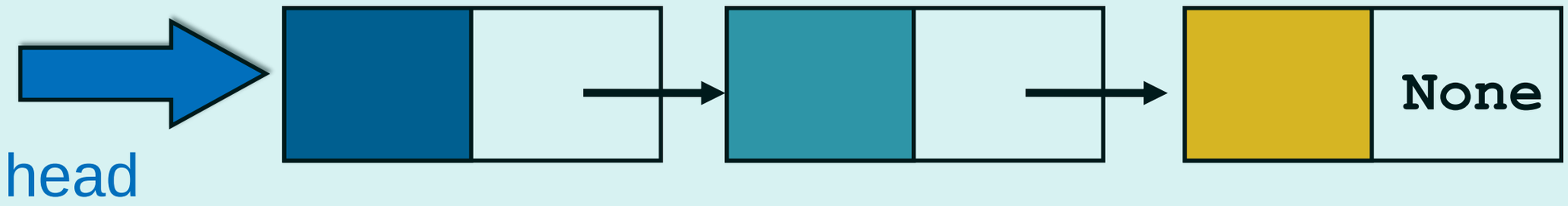
Insert

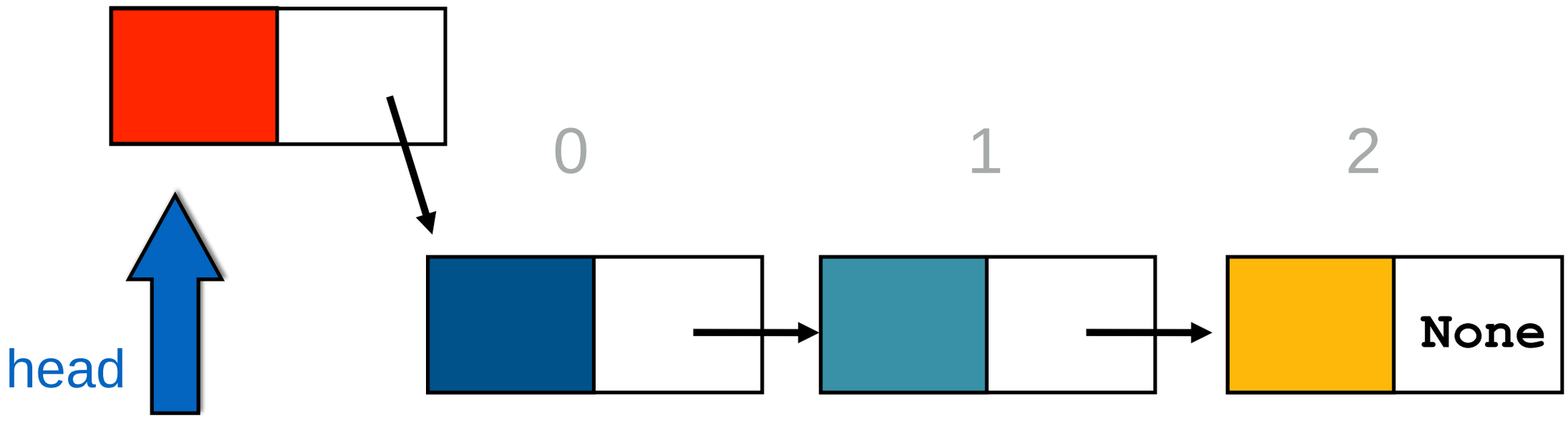
insert position 0





insert  position 0

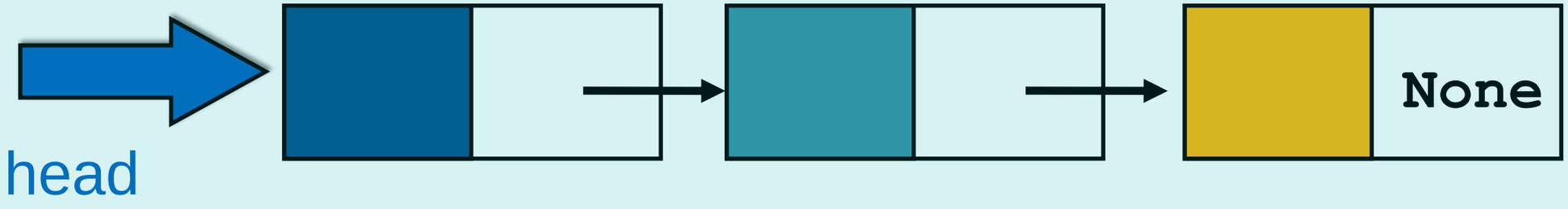


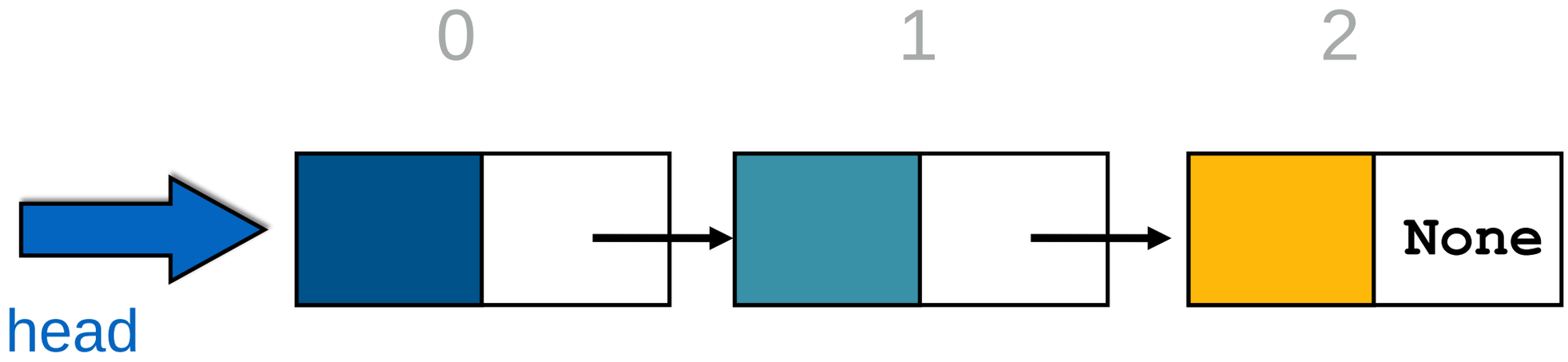


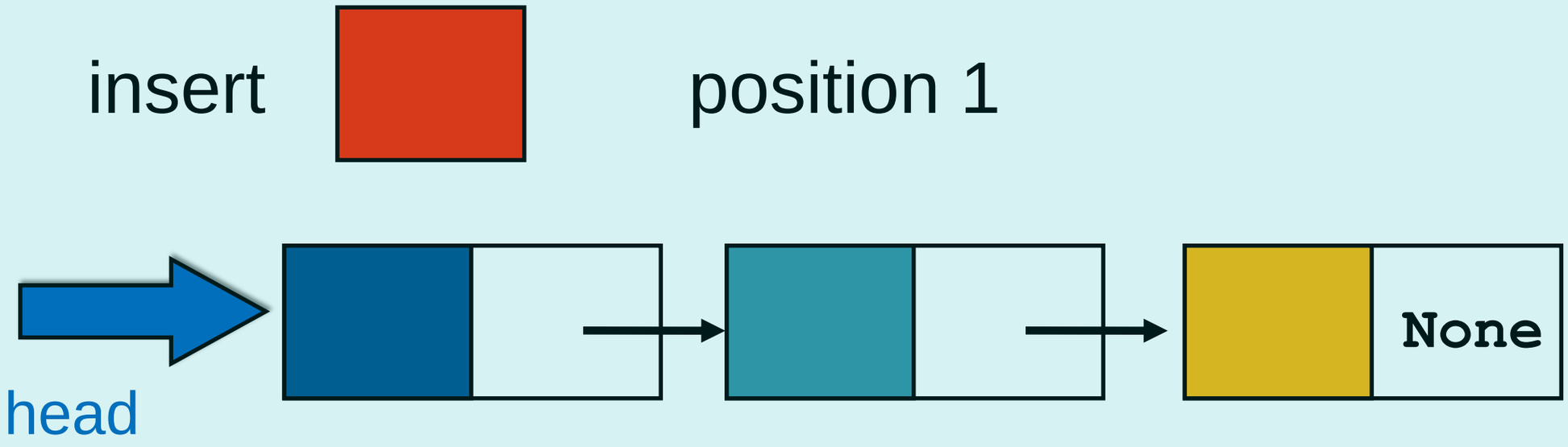
Very similar to push in a Stack, if position is 0

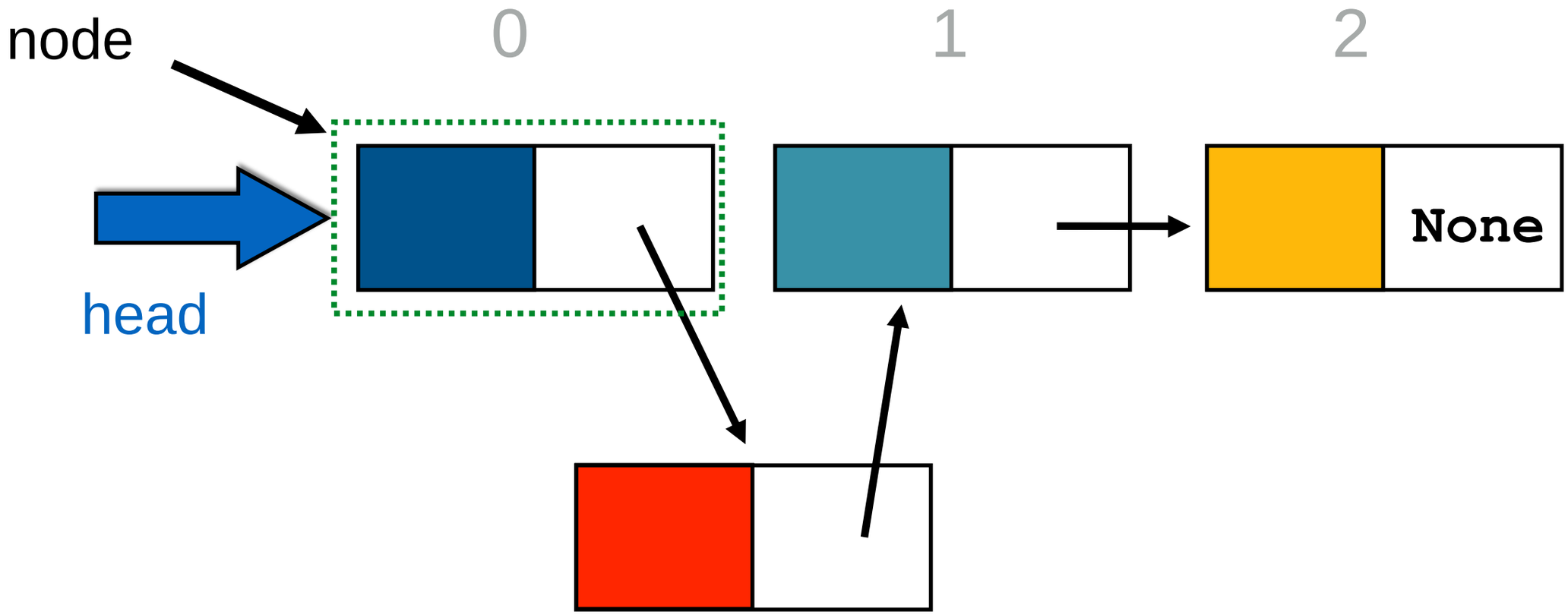
position i > 0

insert position 1






insert
position 1
head
None


node
0
1
2
head
None

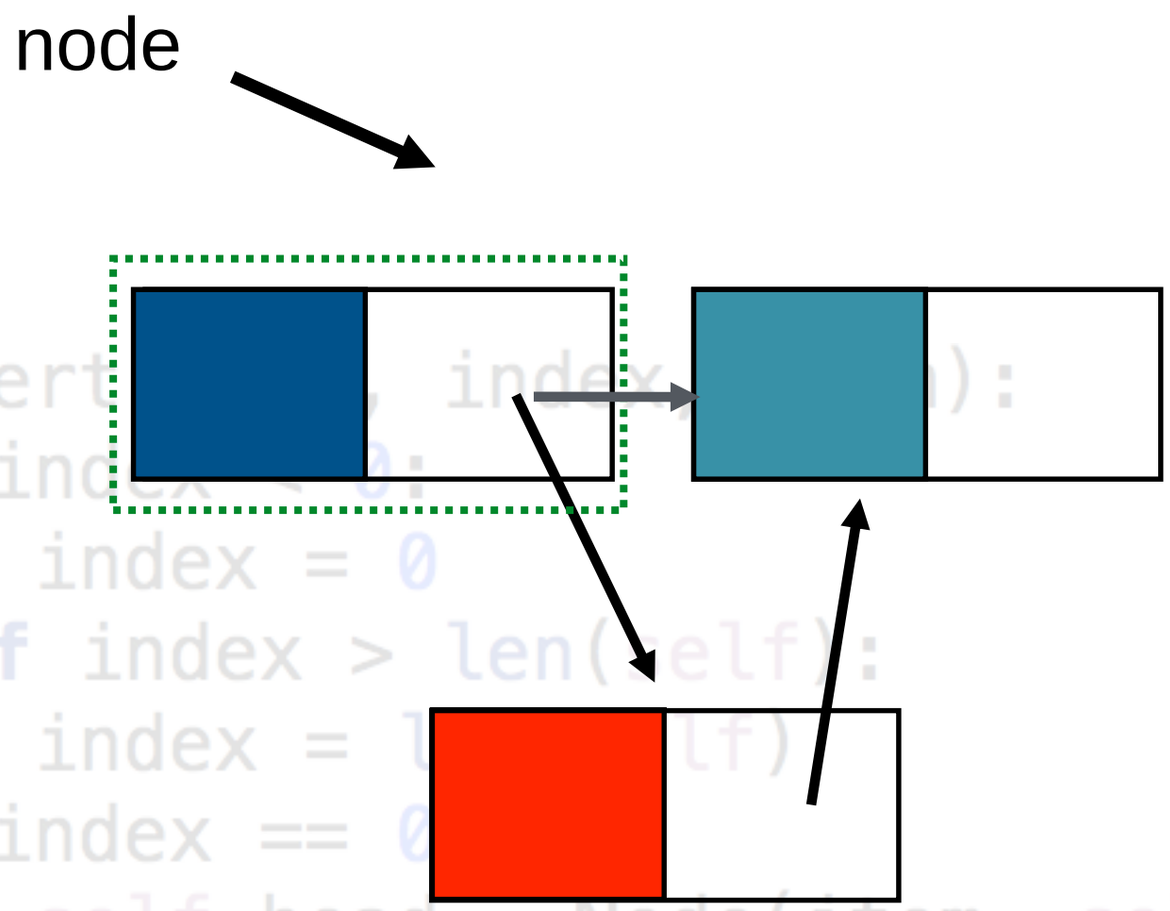
insert

```
def insert(self, index, item):
    if index < 0:
        index = 0
    elif index > len(self):
        index = len(self)
    if index == 0:
        self.head = Node(item, self.head)
    else:
        node = self._get_node(index-1)
        node.next = Node(item, node.next)
    self.count += 1
```

insert it at the end

just like push
if position is 0

index -1



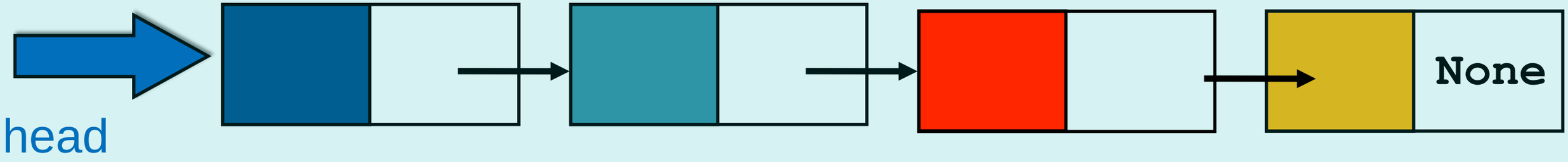

```
        node = self._get_node(index-1)
        node.next = Node(item, node.next)
```

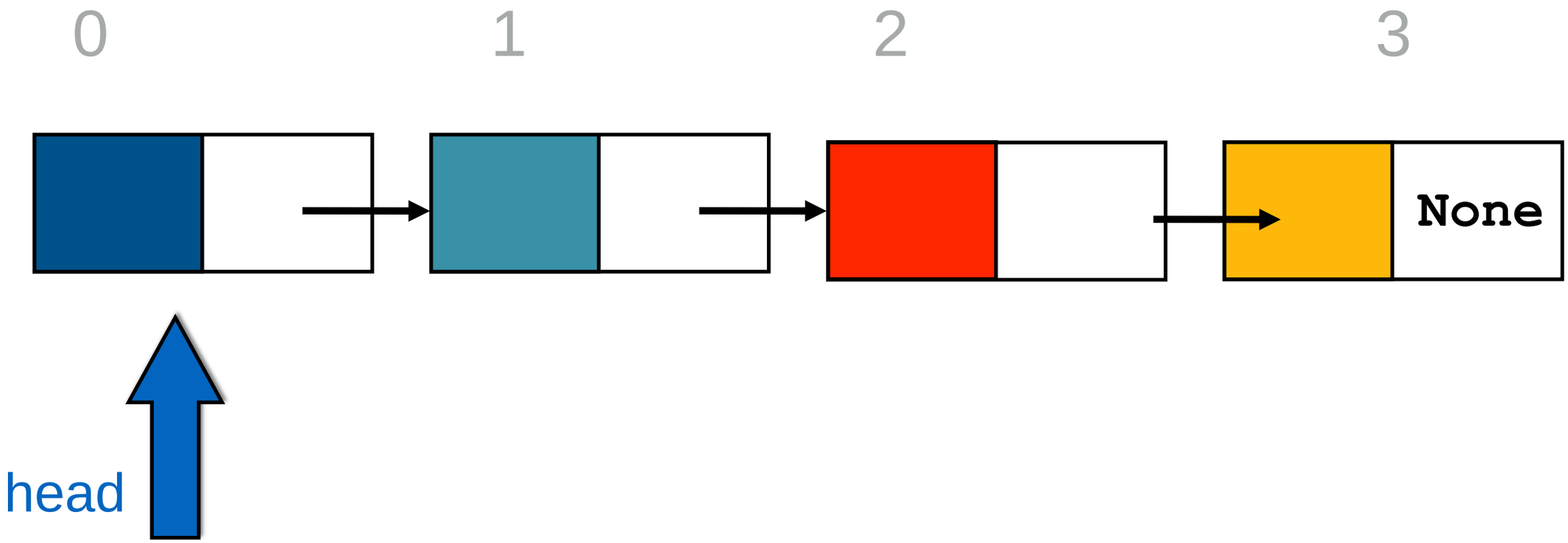
insert

```
def insert(self, index, item):
    if index < 0:
        index = 0
    elif index > len(self):
        index = len(self)
    if index == 0:
        self.head = Node(item, self.head)
    else:
        node = self._get_node(index-1)
        node.next = Node(item, node.next)
    self.count += 1
```

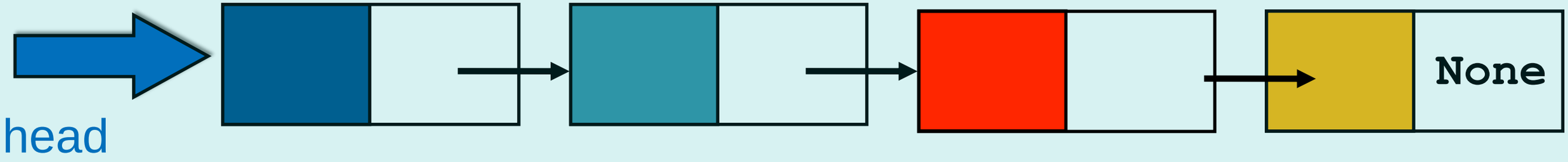
delete

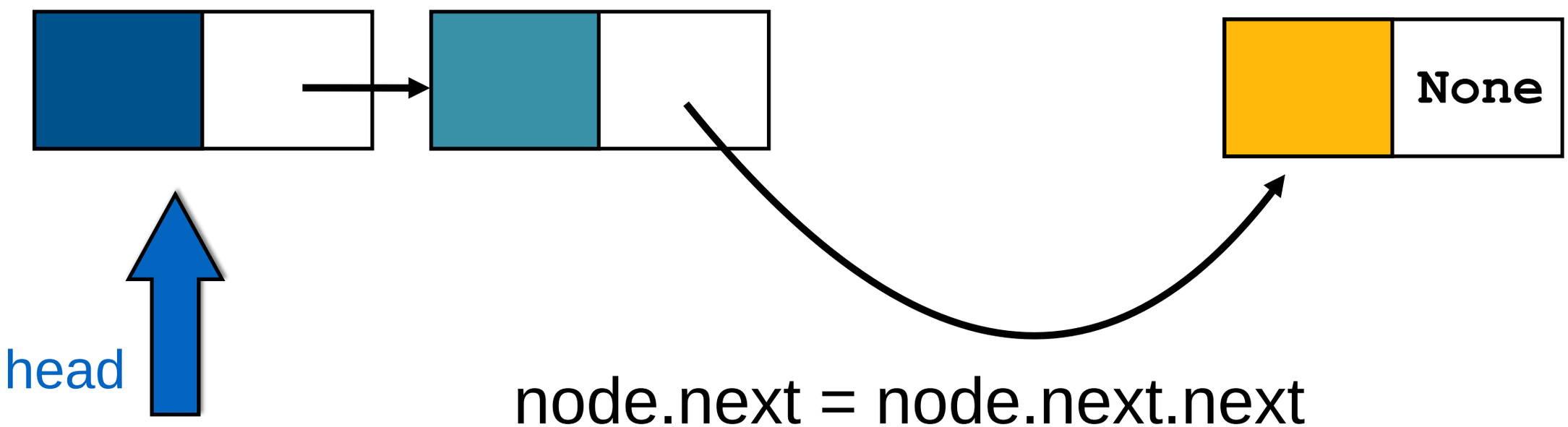
delete item in position 0





delete item in position 2





Boundary cases?

Empty List or Index out of Bounds

```
def delete(self, index):
    if self.is_empty():
        raise IndexError("The list is empty")
    if index < 0 or index >= len(self):
        raise IndexError("Index is out of range")
    if index == 0:
        self.head = self.head.next
    else:
        node = self._get_node(index-1)
        node.next = node.next.next
    self.count -= 1
```

Comparison

(When to use)

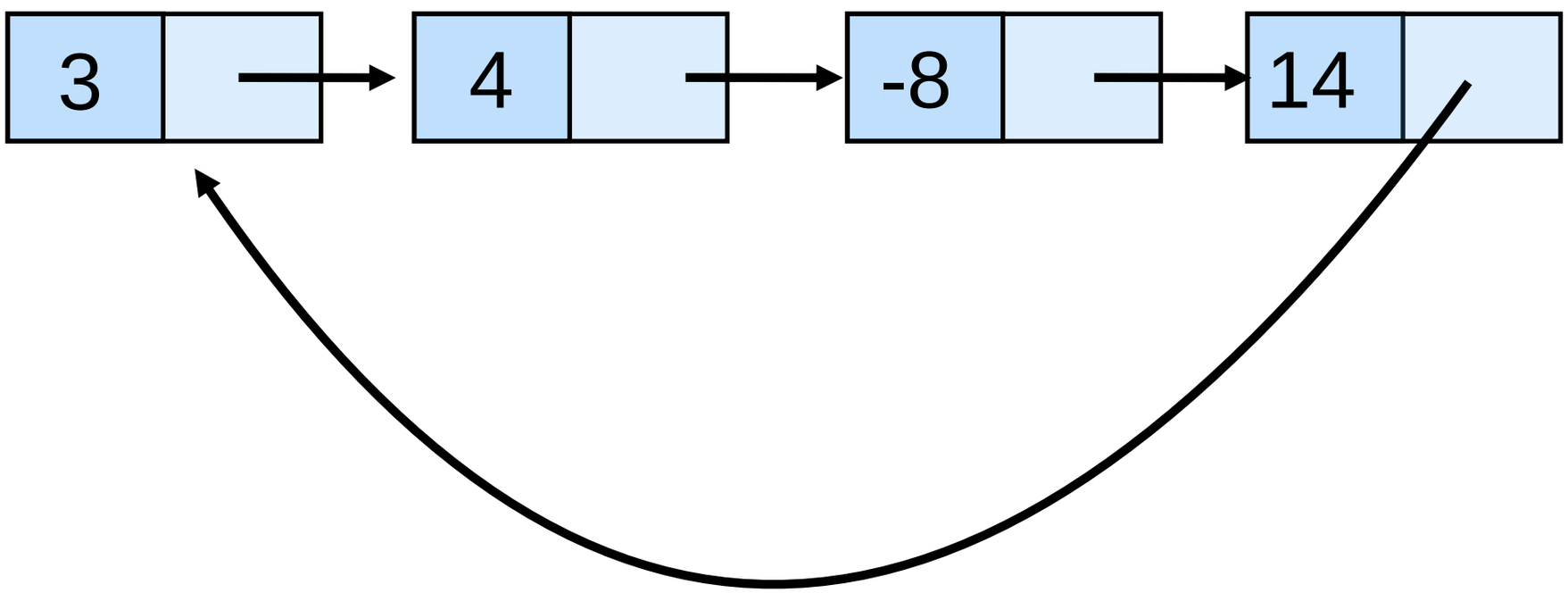
Linked Storage

- Unknown list size.
- Flexibility is needed: lots of insertions and deletions.

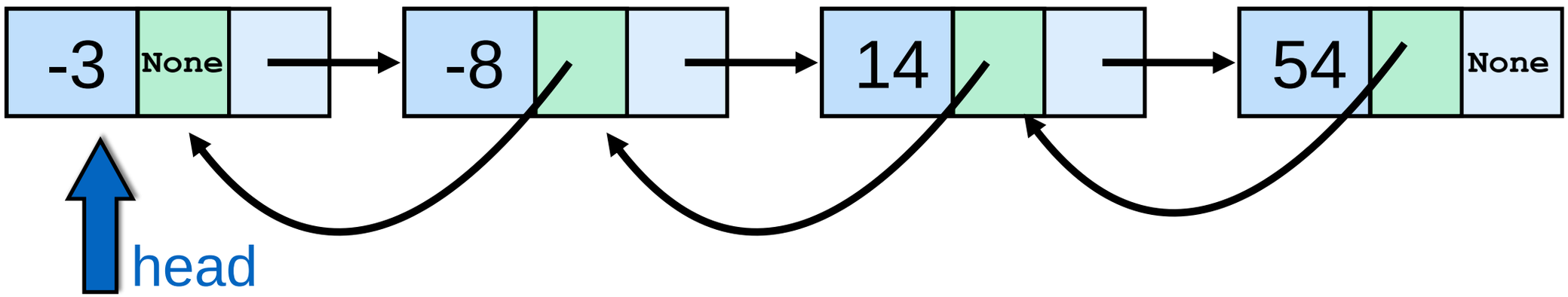
Contiguous Storage

- Known list size.
- Few insertions and deletions.
- Random access

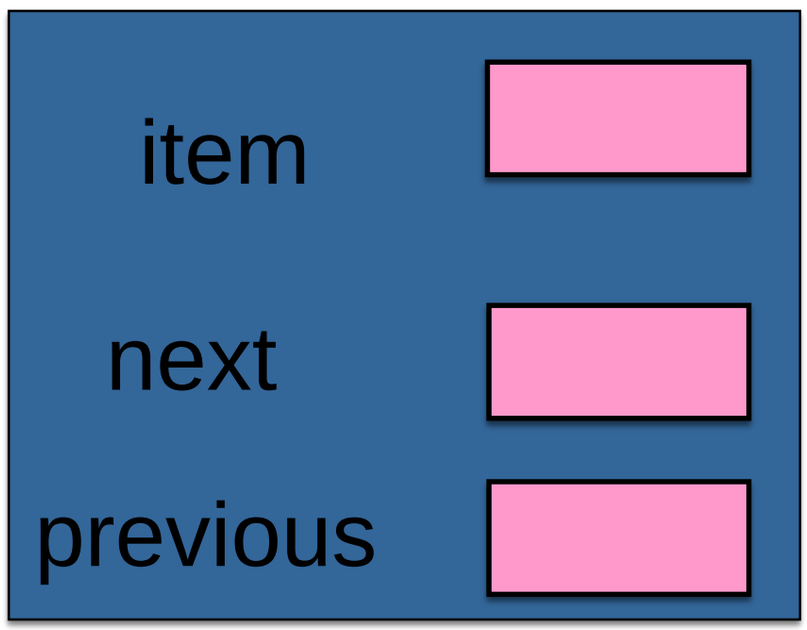
Circular linked list



Double linked list



Node



Make a table with all containers and their complexities for different operations.

Summary

- Seen how to implement a Linked List
- In particular
  - Inserting an item
  - Deleting an item