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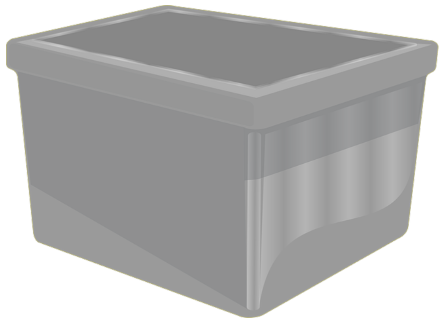
Lecture 20
Linked Lists

FIT 1008
Introduction to Computer Science

MONASH University
Information Technology



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**

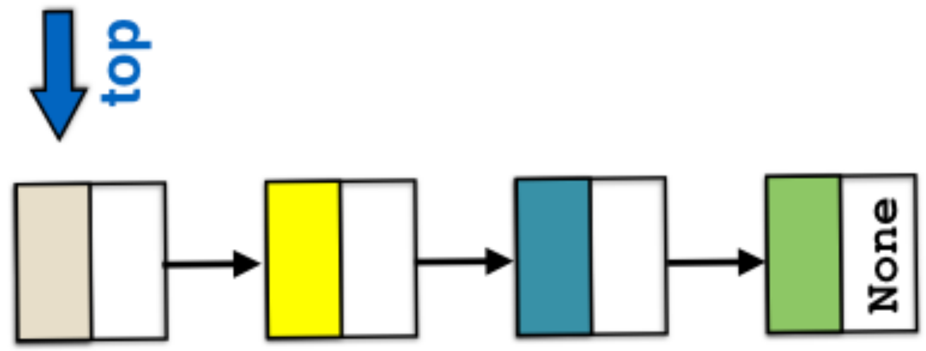
- To be able to:
  - Implement, use and modify linked lists.
  - Decide when is it appropriate to use them (as opposed to using the ones implemented with arrays)

List ADT

- Sequence of items

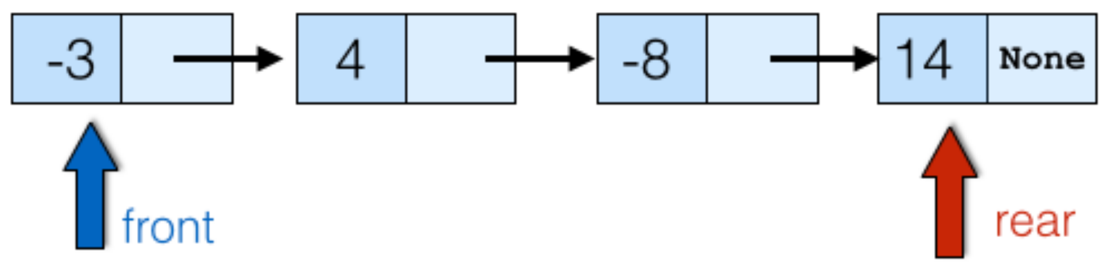
- Possible Operations:
    - ➡ Create a list
    - ➡ Insert an item before a given position in the list
    - ➡ Delete an item at a given position from the list
    - ➡ Check whether the list is empty
    - ➡ Check whether the list is full
    - ➡ Get the length of the list.

Access the top element only




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

Append to rear
Serve front

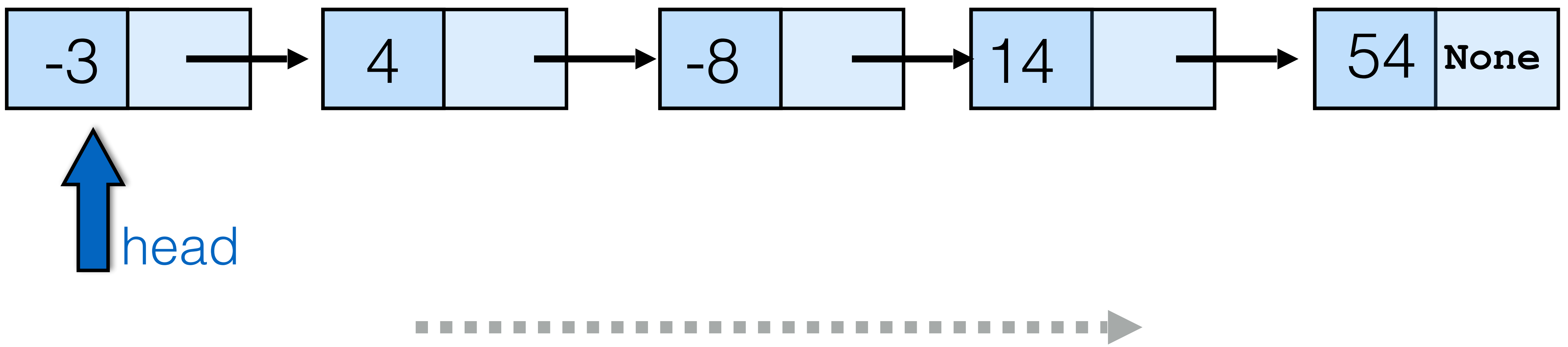



```python
class Queue:
    def __init__(self):
        self.front = None
        self.rear = None
```

Access any Node

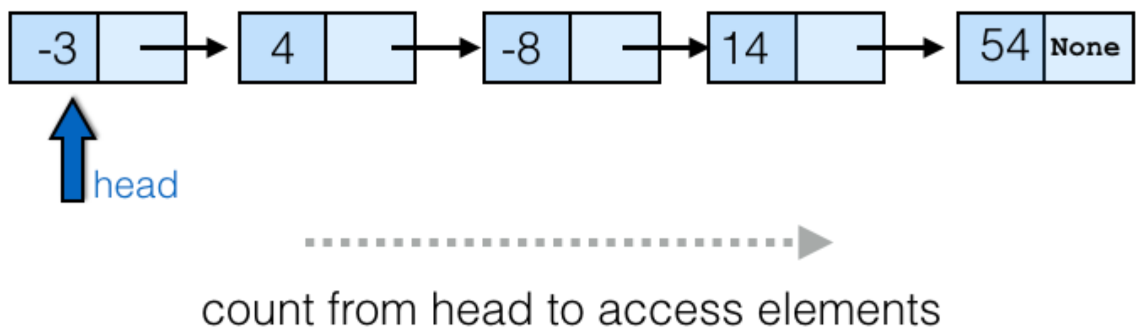
?

?



count from head to access elements

Linked Lists



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

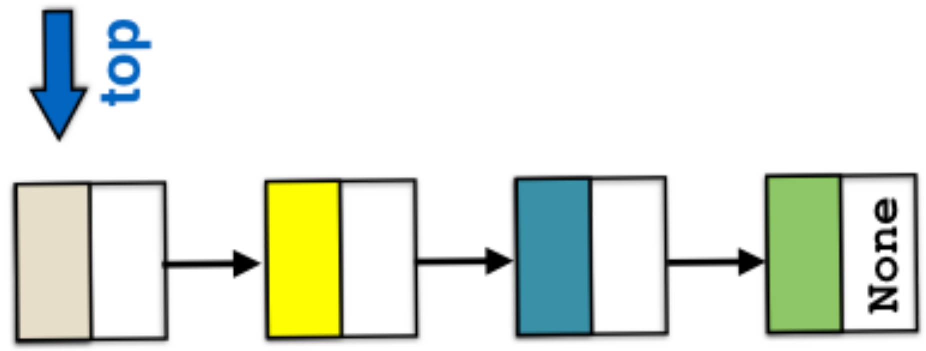
- What instance variables do we need for **lists**?Only one component: a reference to the **head node**

- From there, we can access every other node

No strictly necessary, but it will be useful

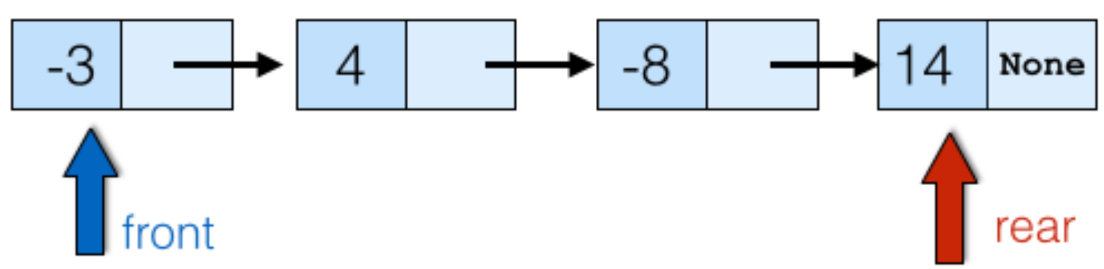
```
class List:
    def __init__(self):
        self.head = None
        self.count = 0
```

Access the top element only



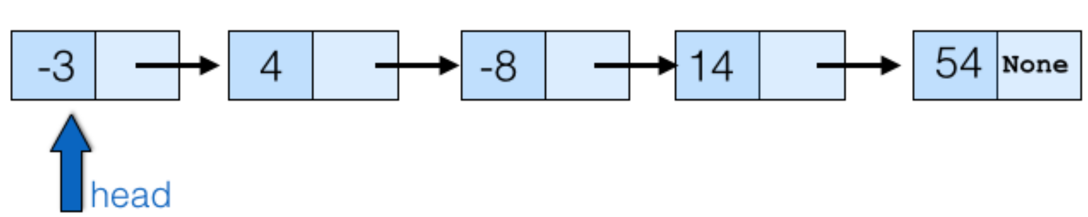

```python
class Stack:
    def __init__(self):
        self.top = None
```

Append to rear Serve front

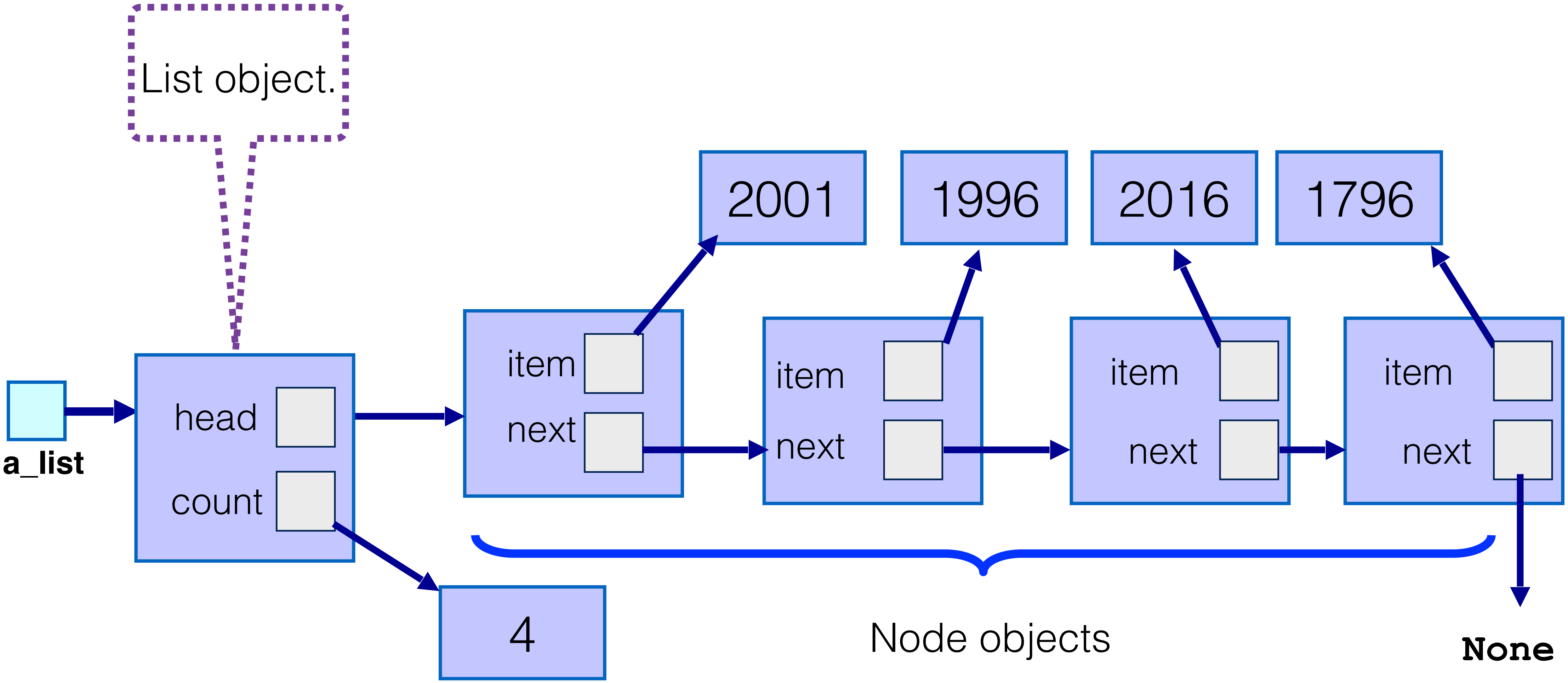



```python
class Queue:
    def __init__(self):
        self.front = None
        self.rear = None
```

Access any Node




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



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

```python
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

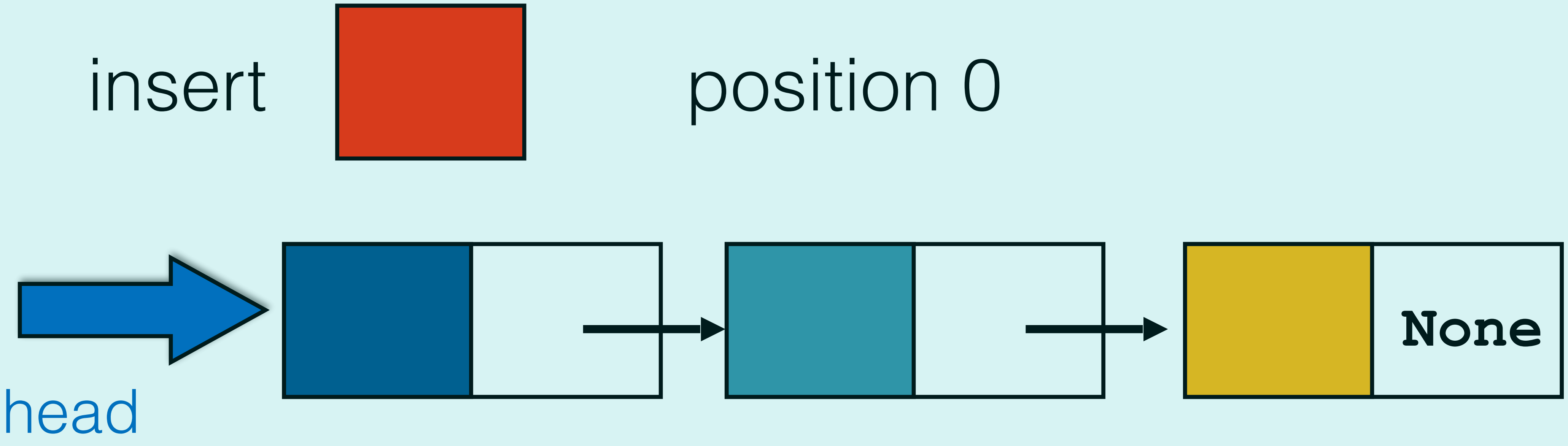
- **insert**(index, item)
  - ➡ Inserts **item** before position **index** in the list
- **delete**(index)
  - ➡ Removes the **item** at position **index** in the list
  - ➡ Raises IndexError if the list is empty or the index is out of range
  - ➡ Similar to pop(index) in Python's list ADT
- Both require **_get_node**(self, index)
  - ➡ Returns a reference to the node at position index.
  - ➡ Internal "private" method

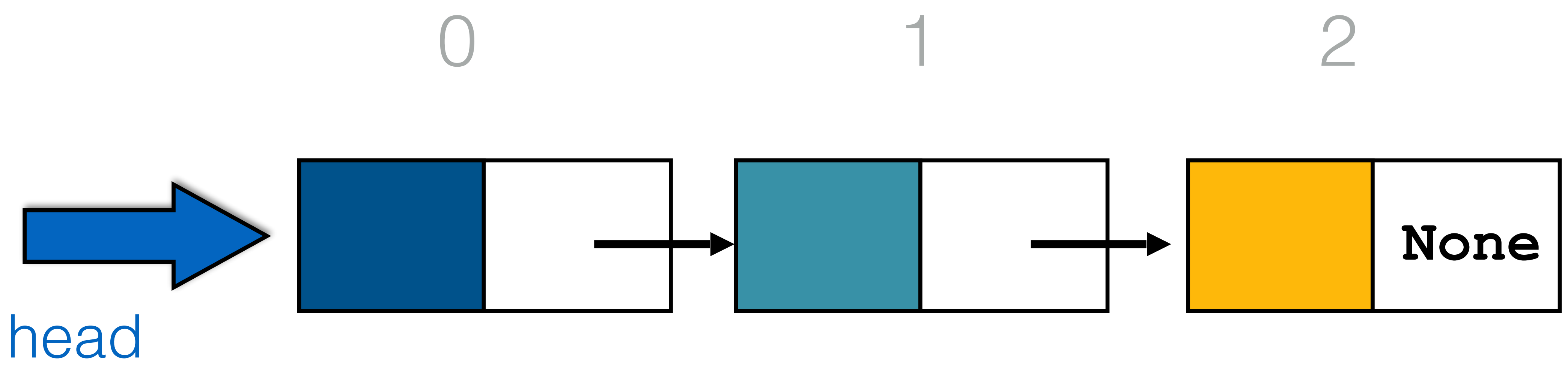
_get_node(self, **index**)

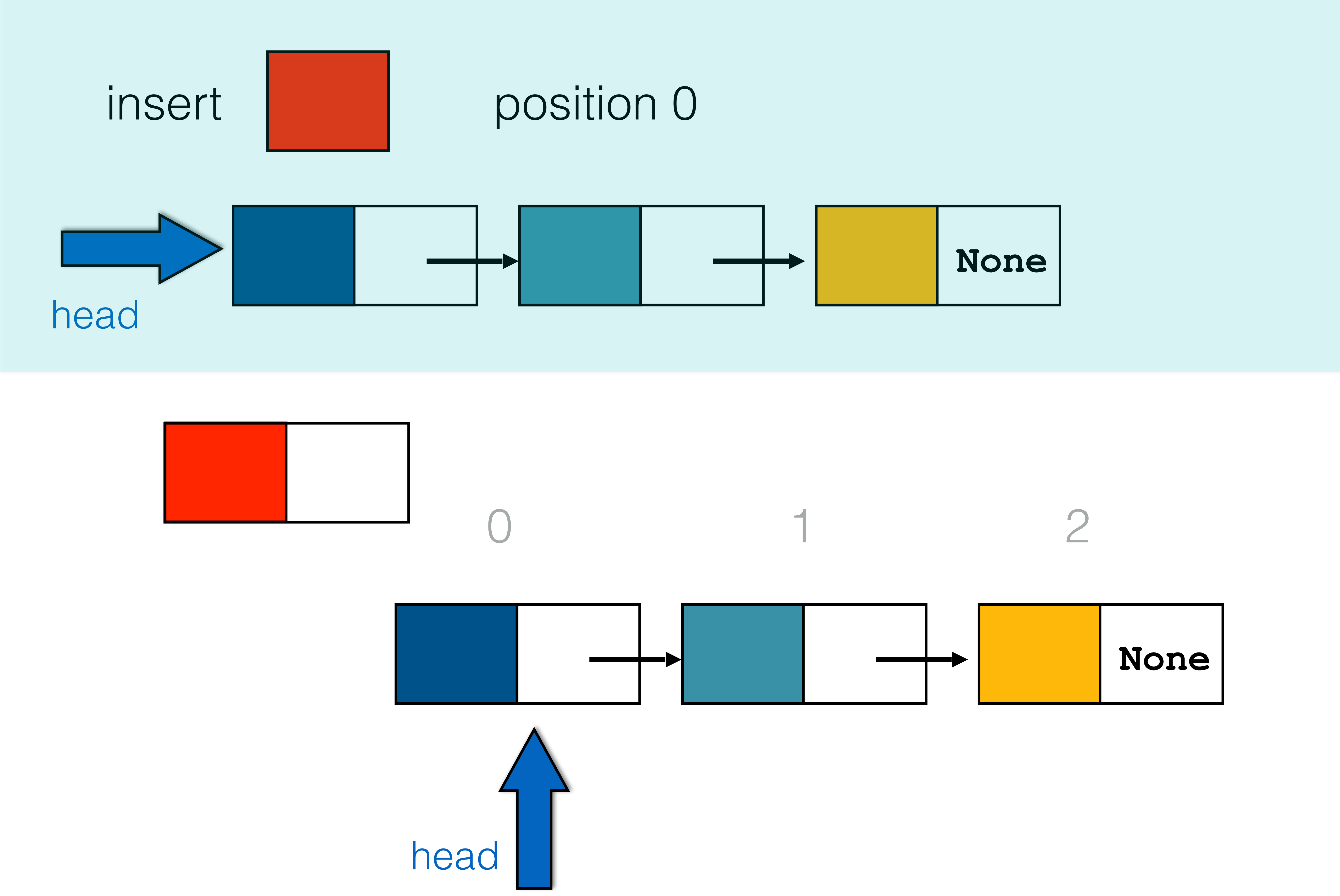
- check if **index** is within range
- set a variable **node**, pointing to Node referred by head
- set a **counter** to 0
- while **counter** is less than **index**
  - follow link to <u>next node</u>
  - increment **counter**
- return **node**

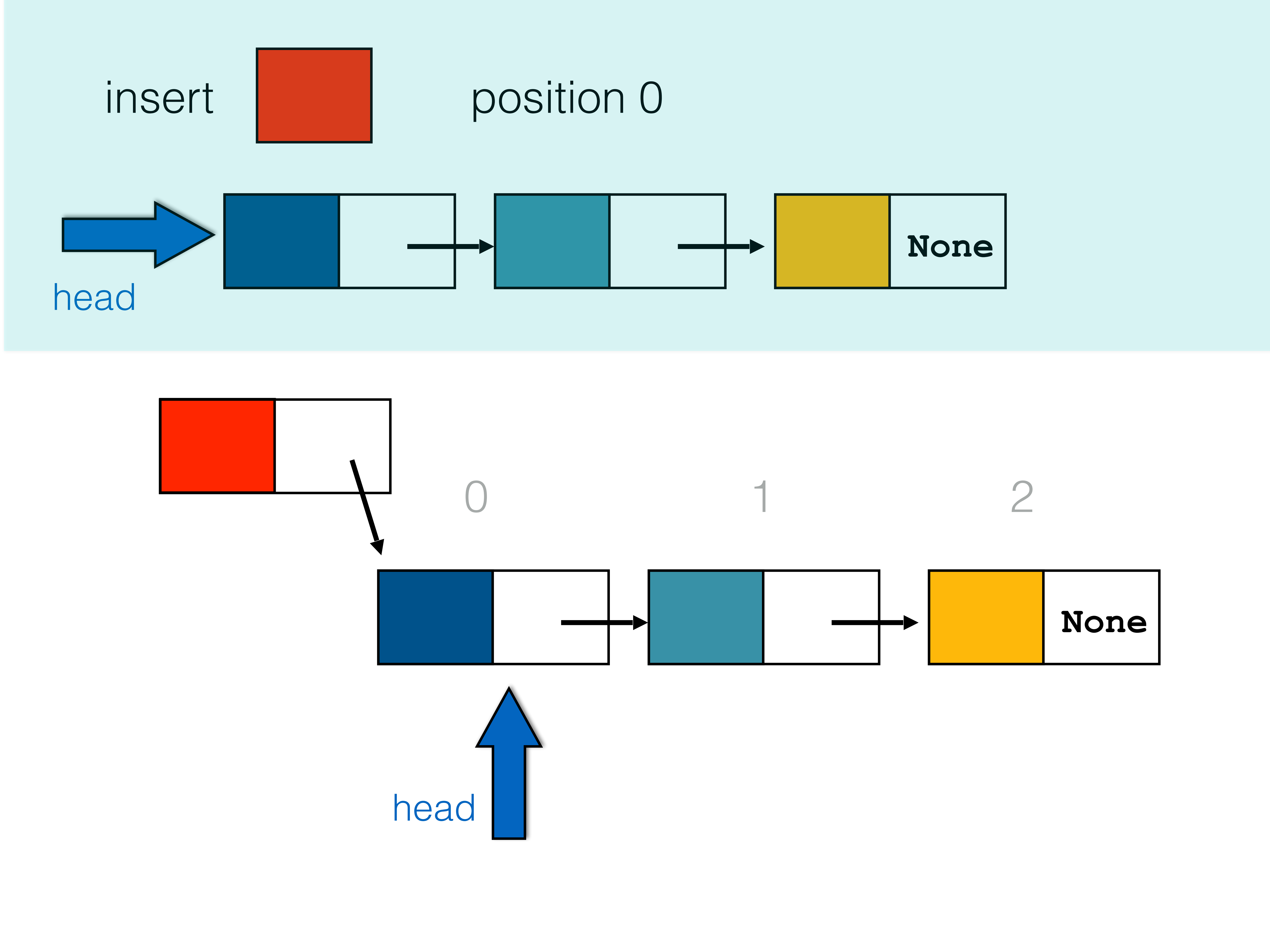
```python
def _get_node(self, index):
    assert 0 <= index < self.count, "Index out of bounds"
    node = self.head
    for _ in range(index):
        node = node.next
    return node
```

Insert

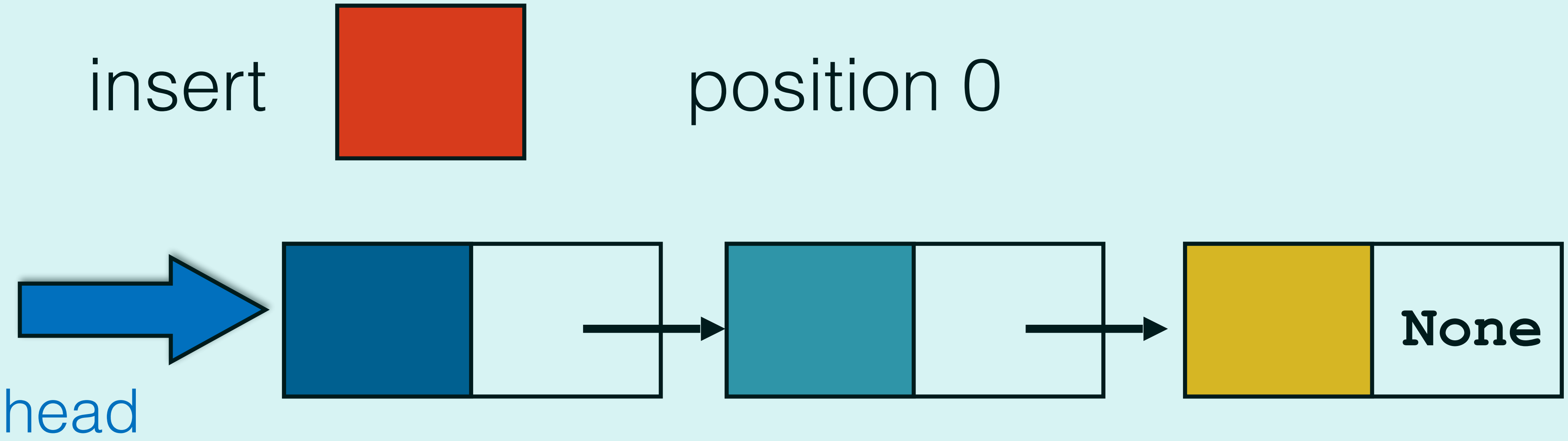

insert
position 0
None
head

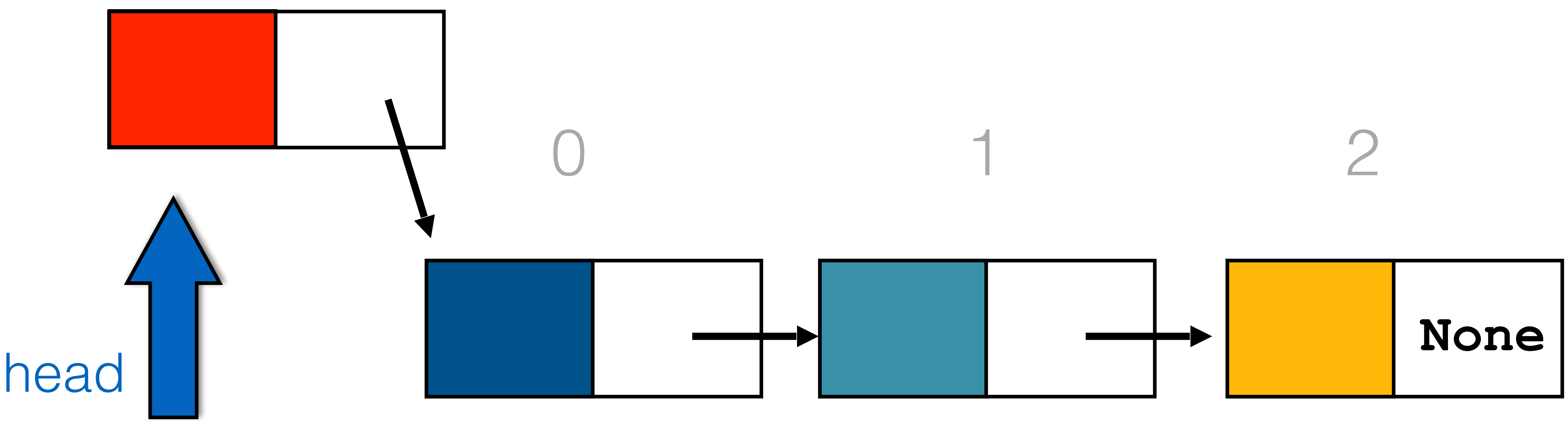

0
1
2
None
head


insert
position 0
head
None
0
1
2
None
head

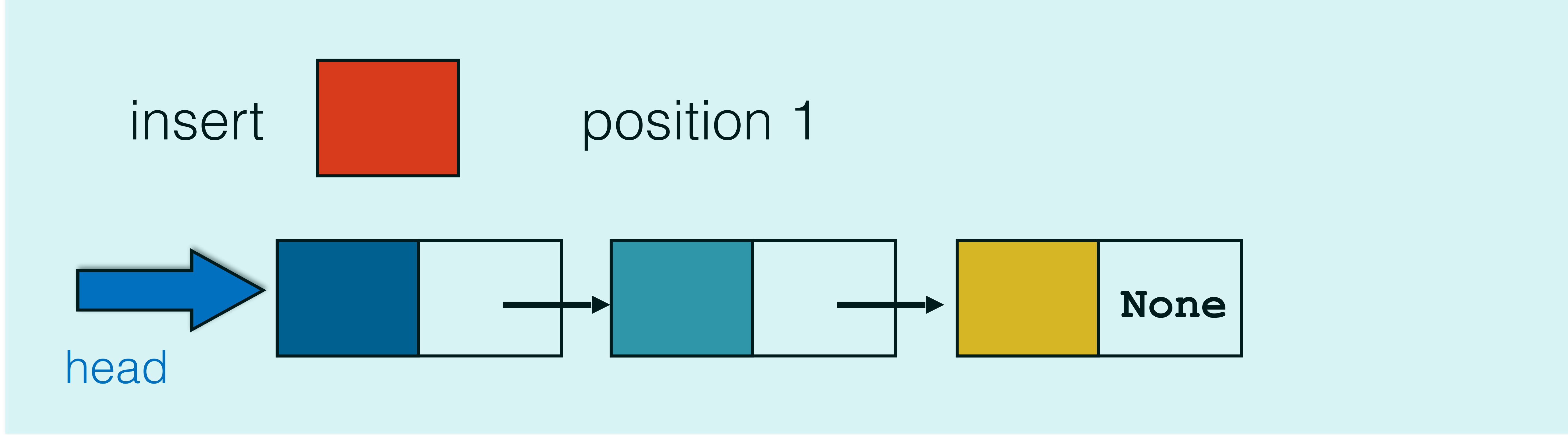


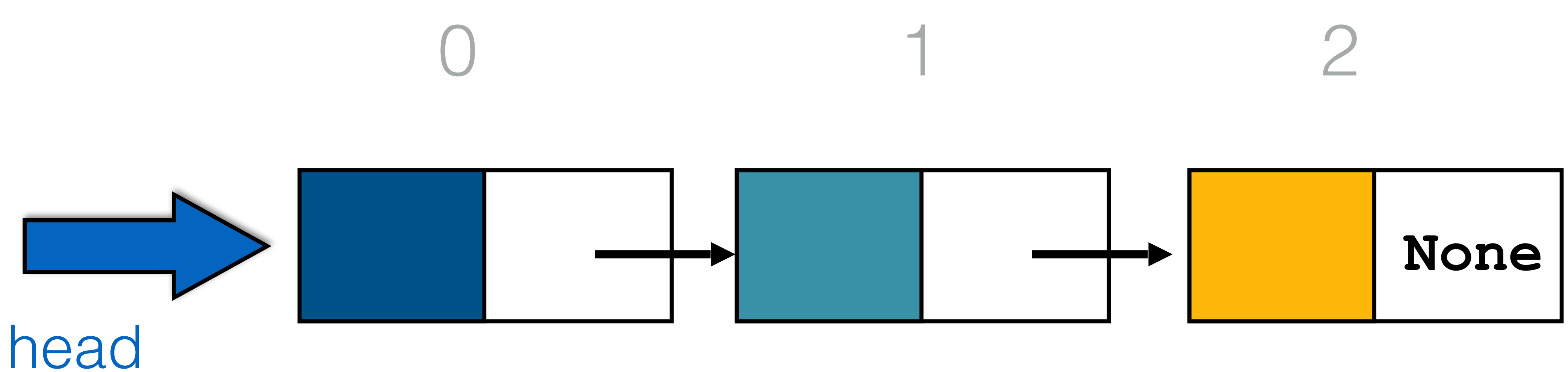
insert
position 0
head
None
0
1
2
None
head

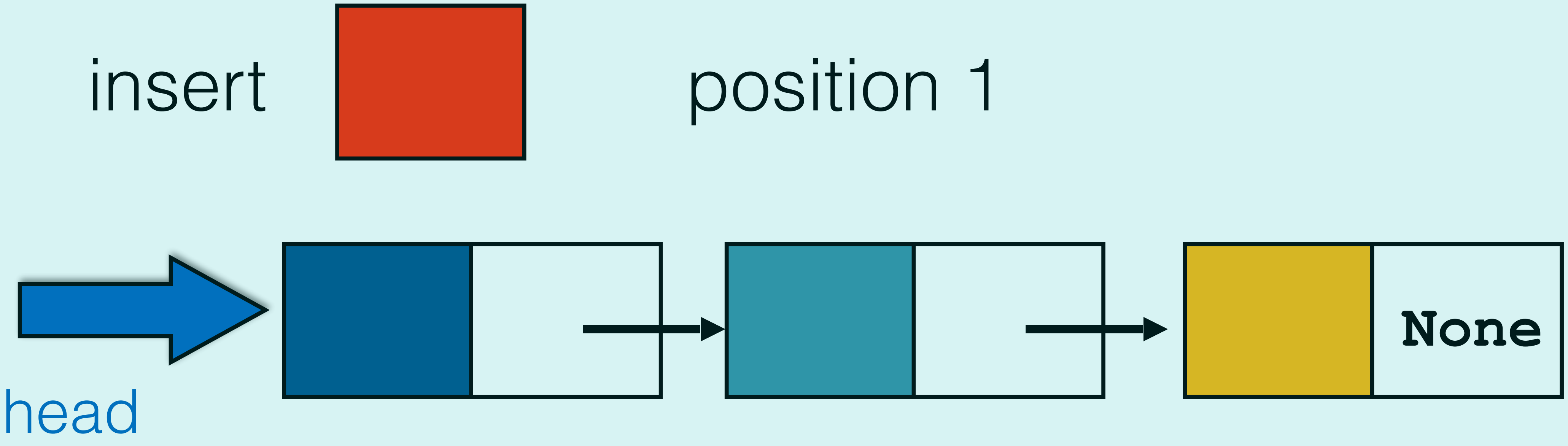


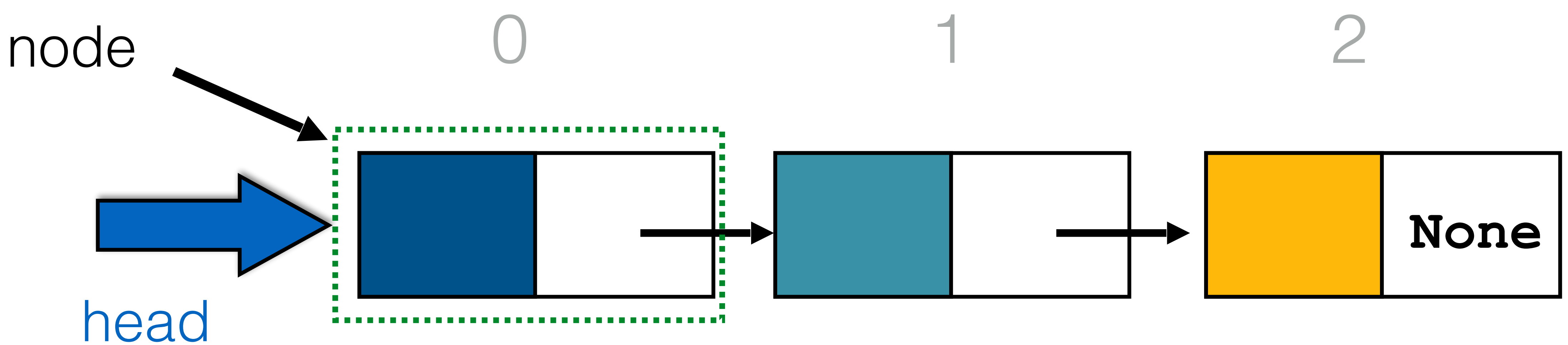


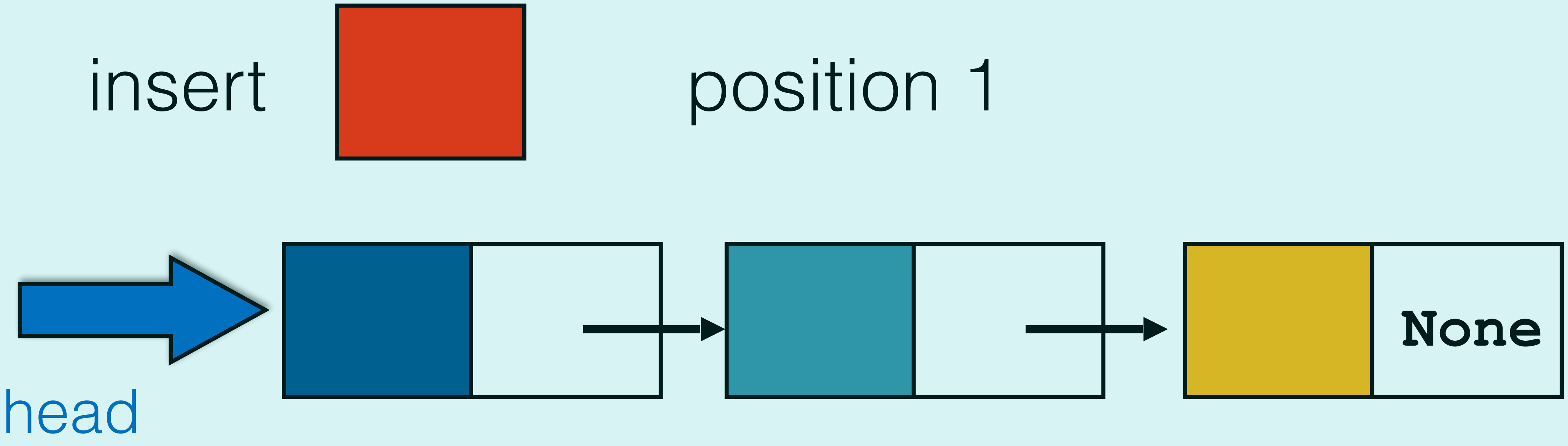
Very similar to **push** in a Stack, if position is 0 position $i > 0$

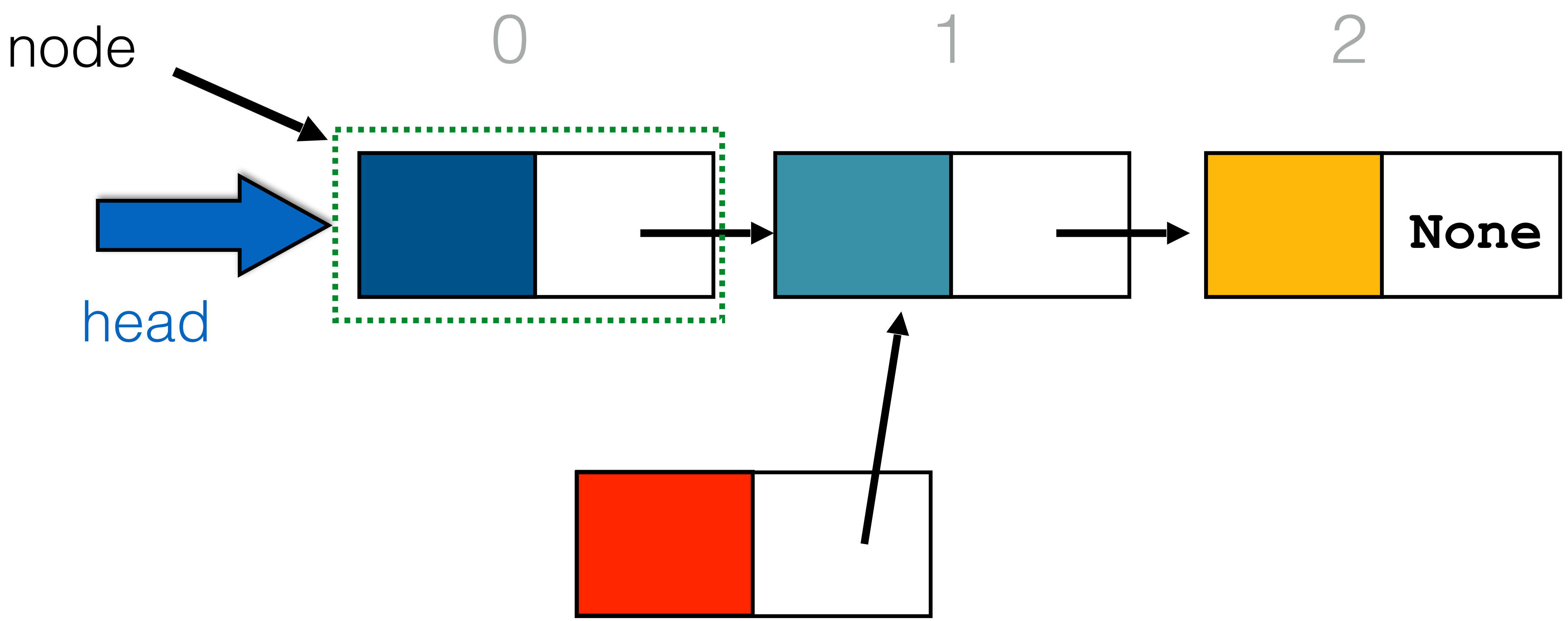

insert
position 1
head
None

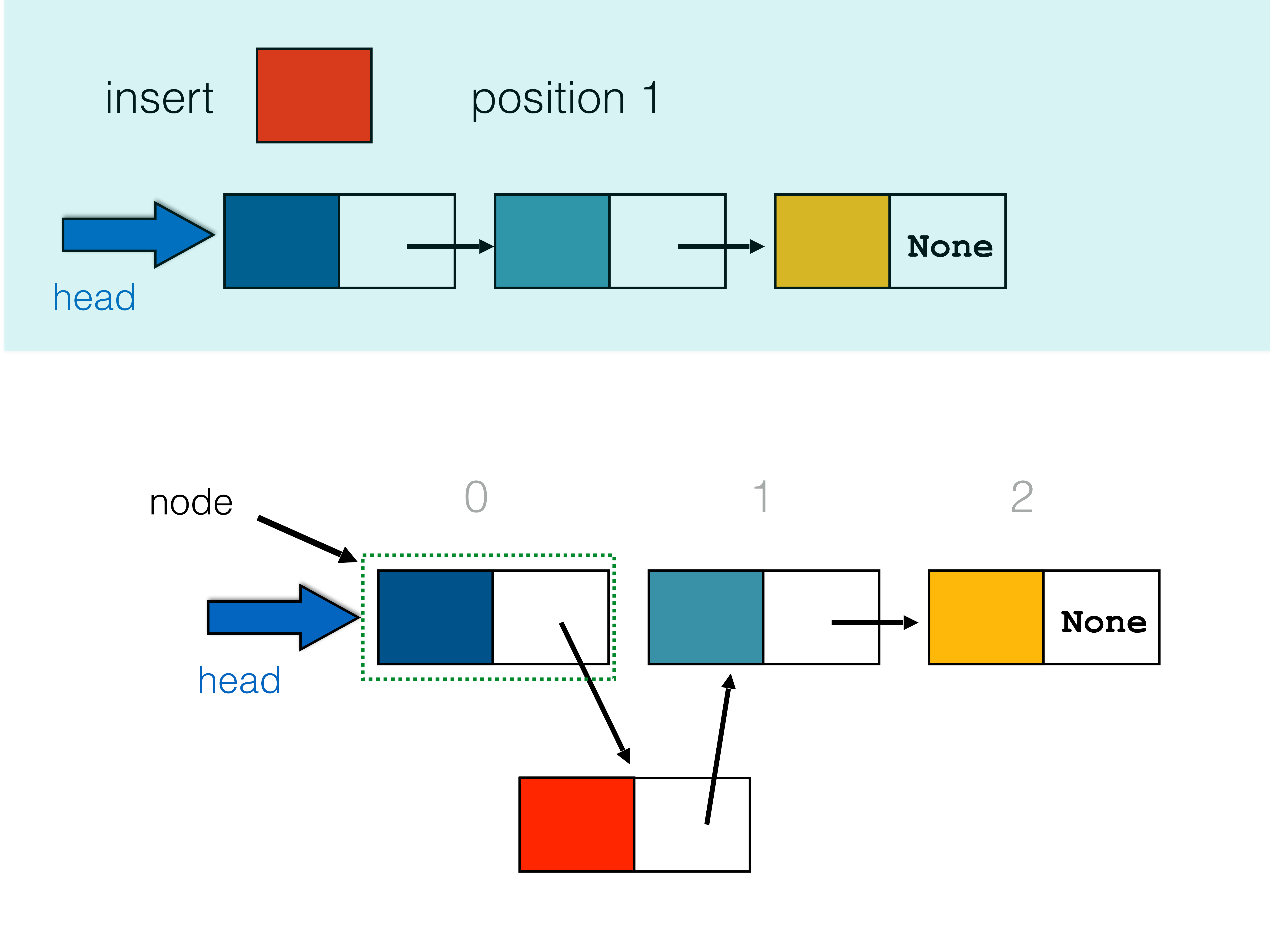

0
1
2
head
None


insert
position 1
None
head


node
0
1
2
None
head


insert
position 1
head
None


node
0
1
2
head
None

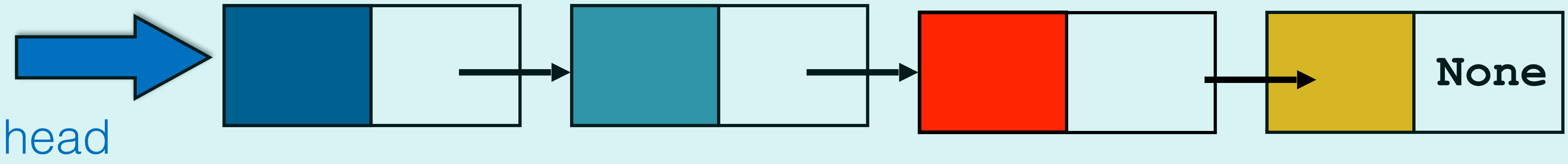

insert
position 1
None
head
node
0
1
2
None
head

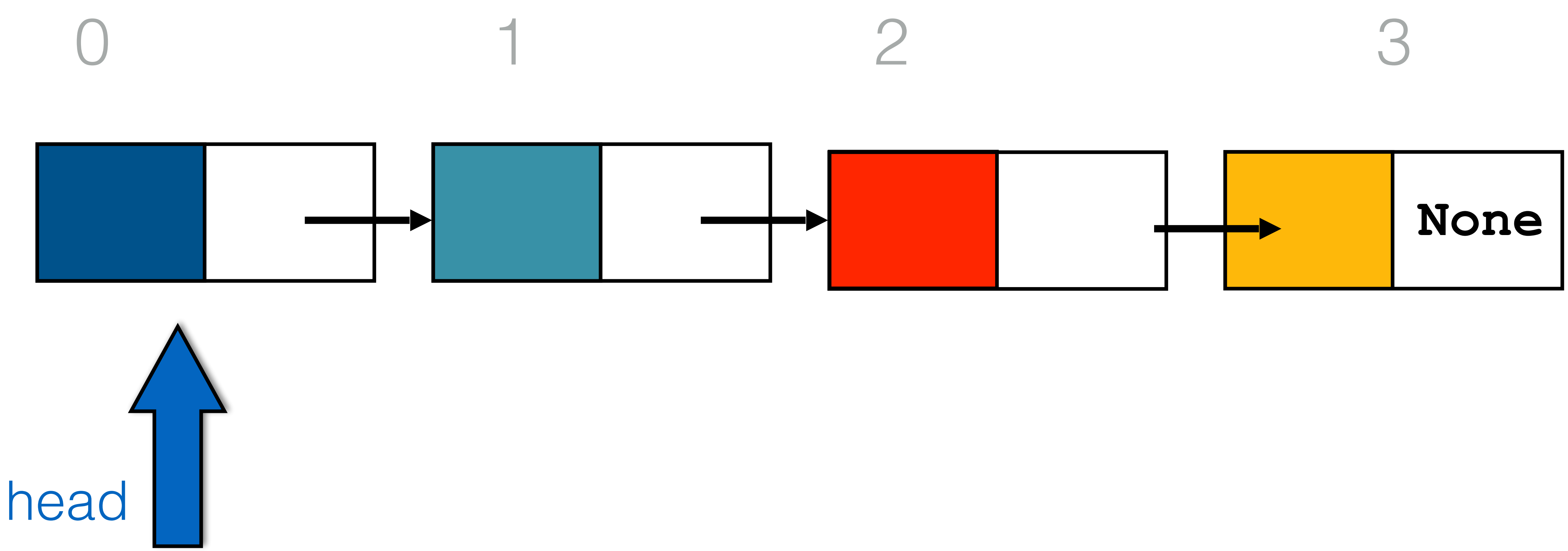
insert

```
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
```

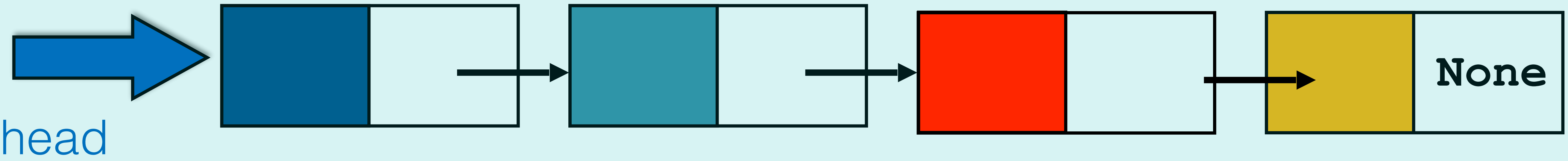
delete

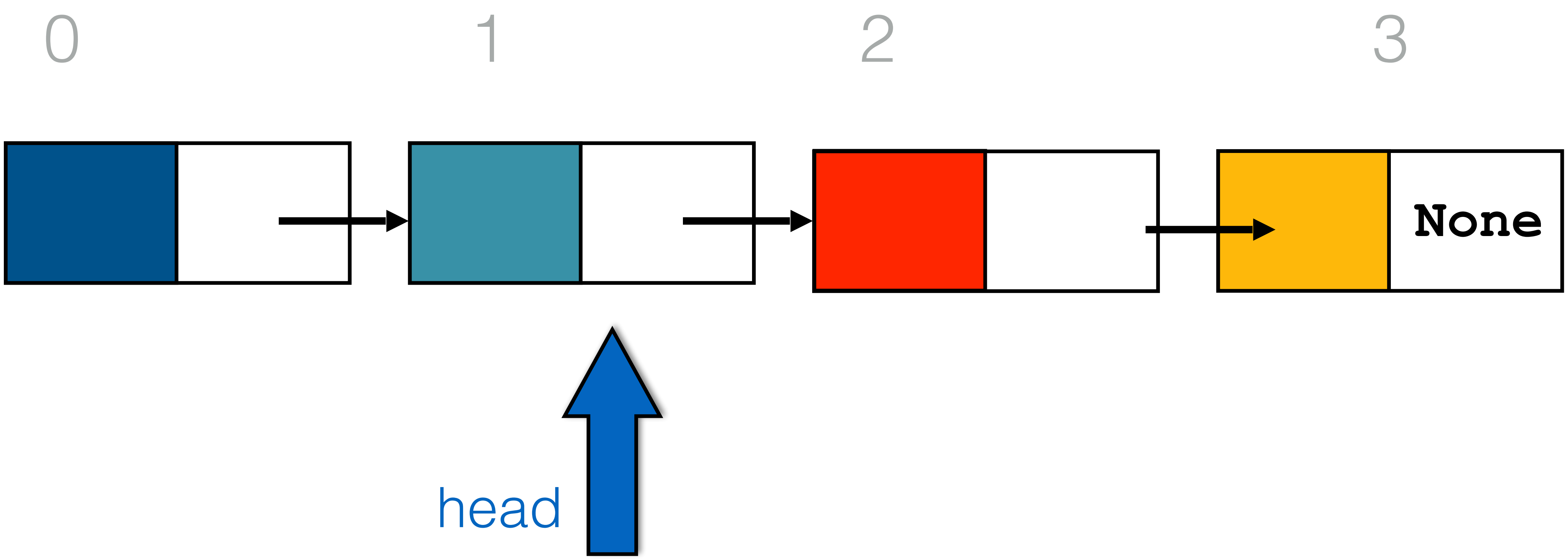
delete item in position 0



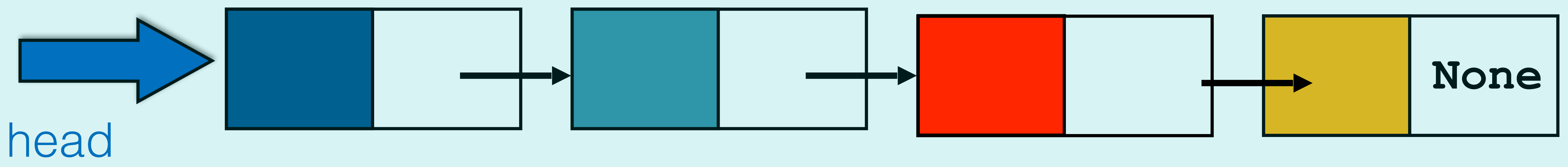


delete item in position 0

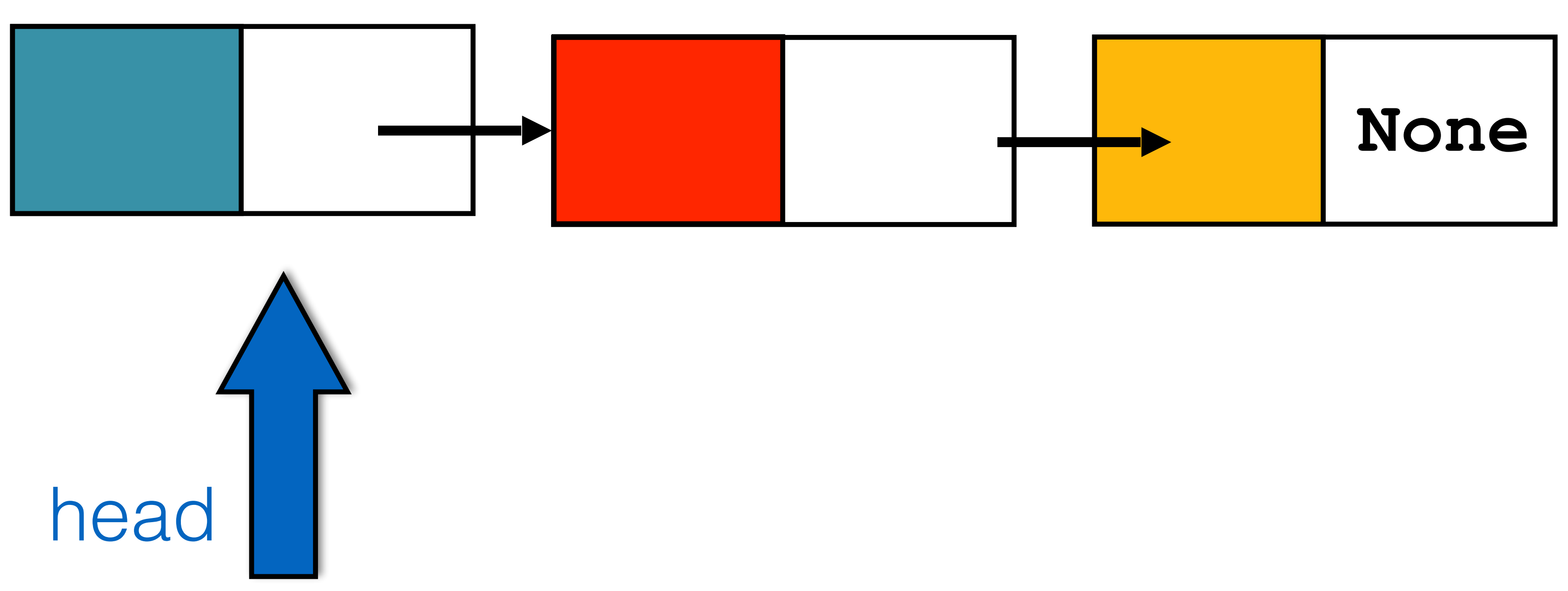




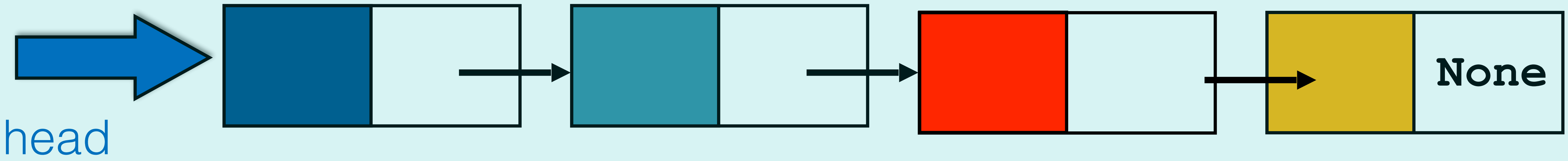
delete item in position 0

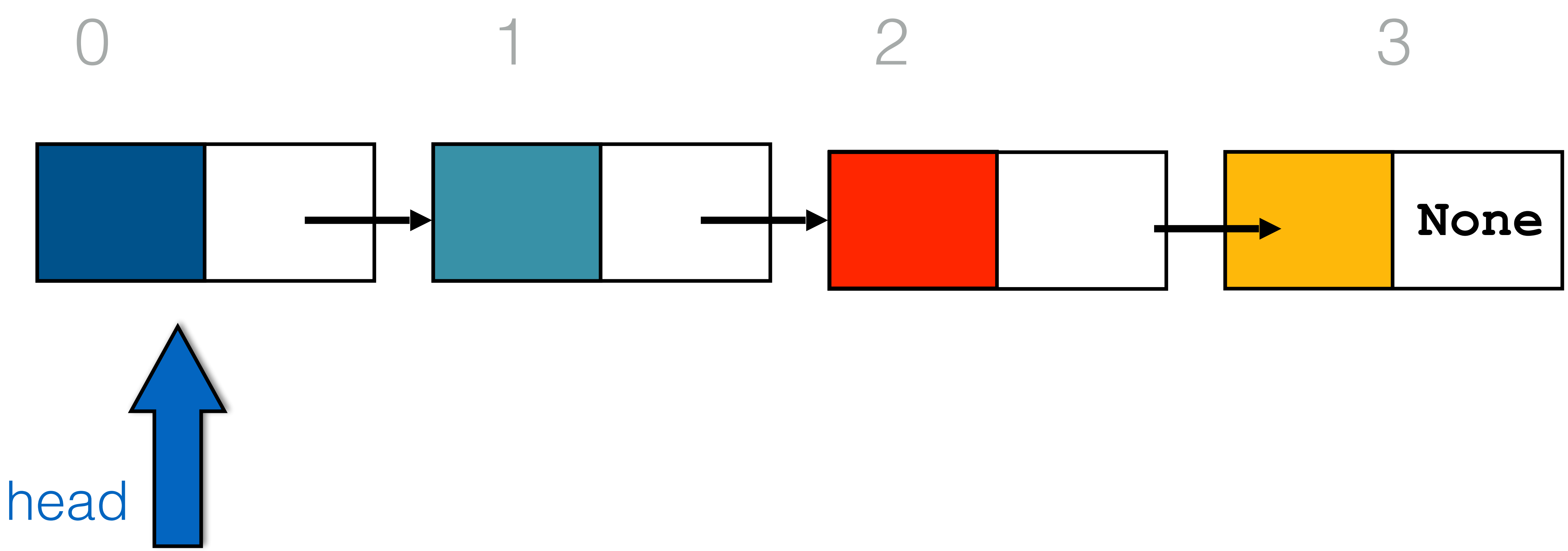


Just like pop.

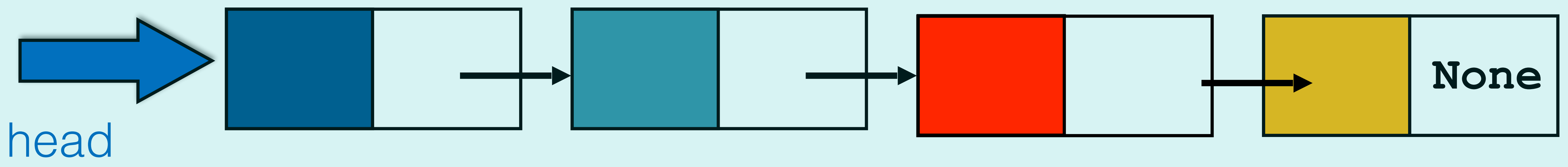


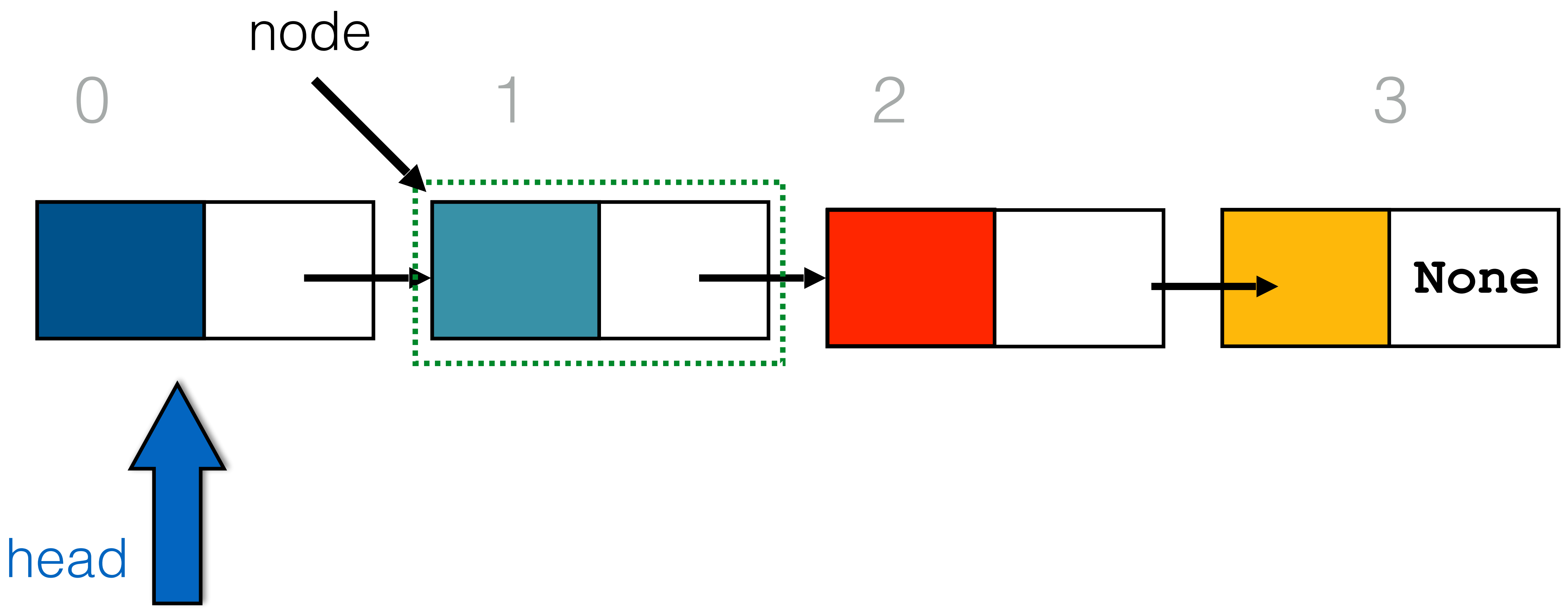
delete item in position 2



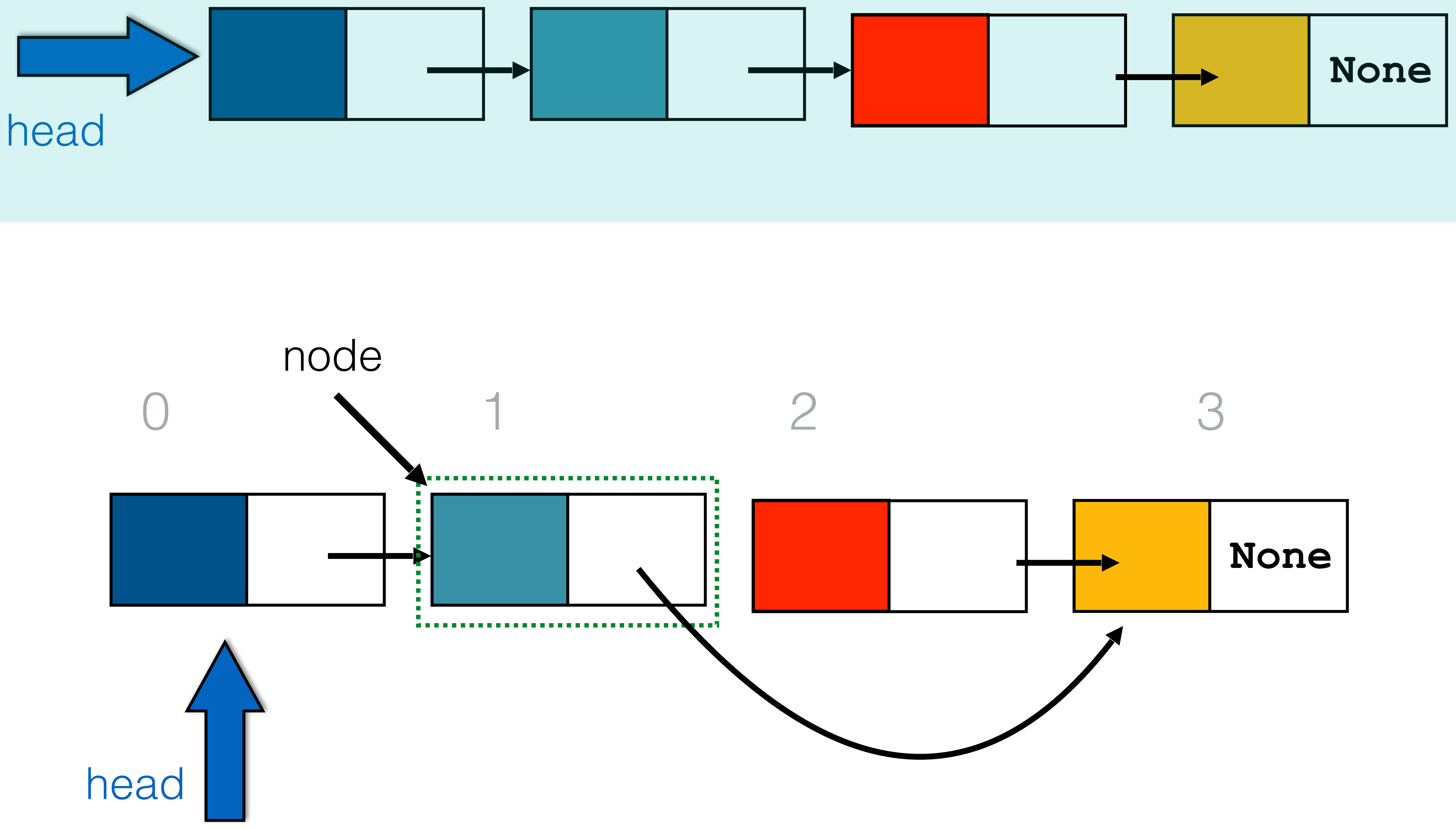


delete item in position 2

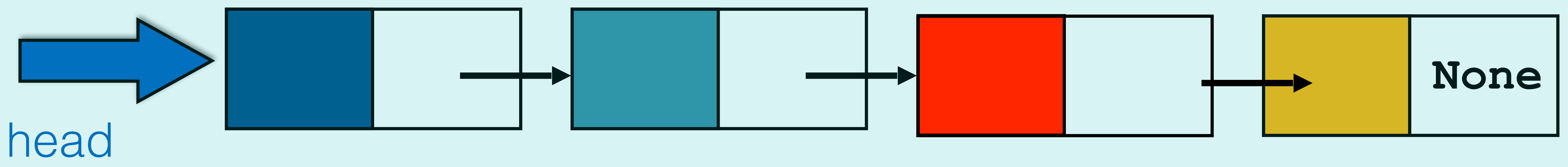


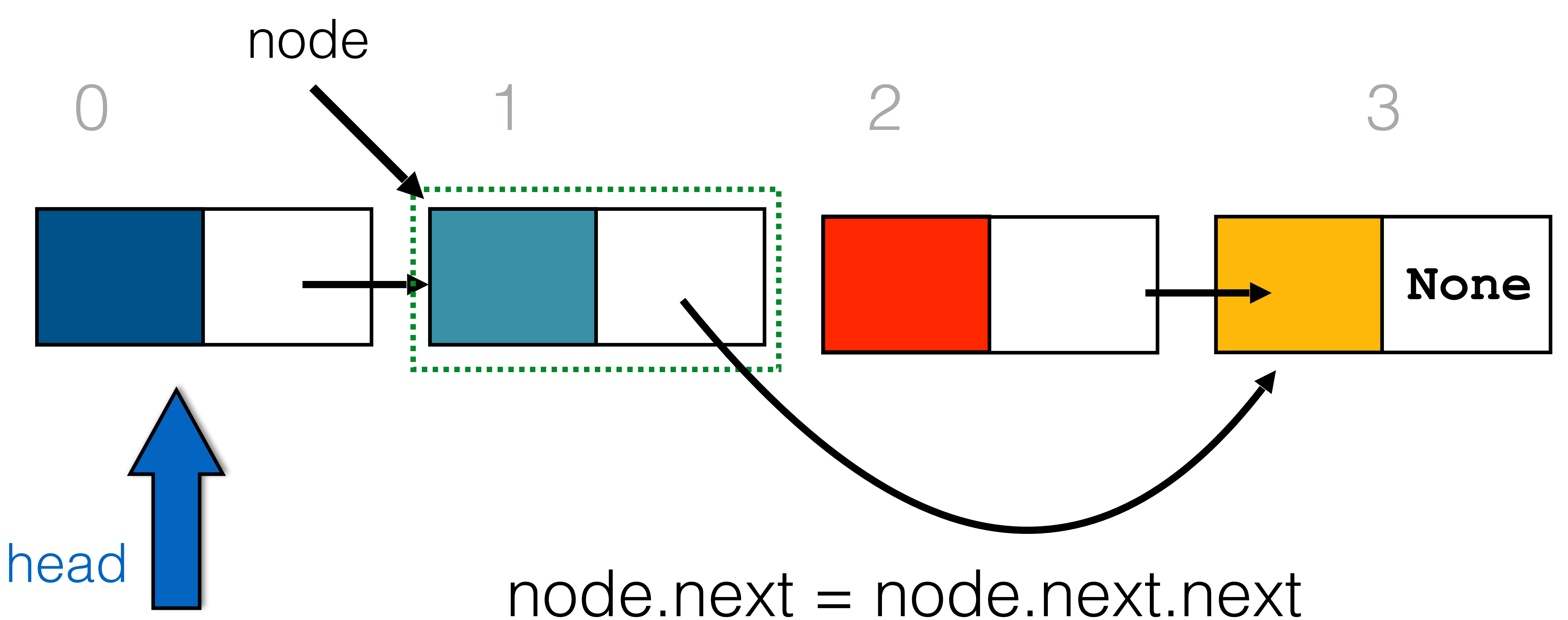


delete item in position 2



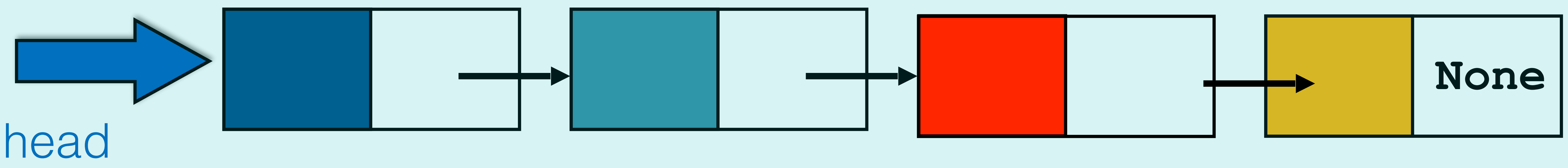
delete item in position 2

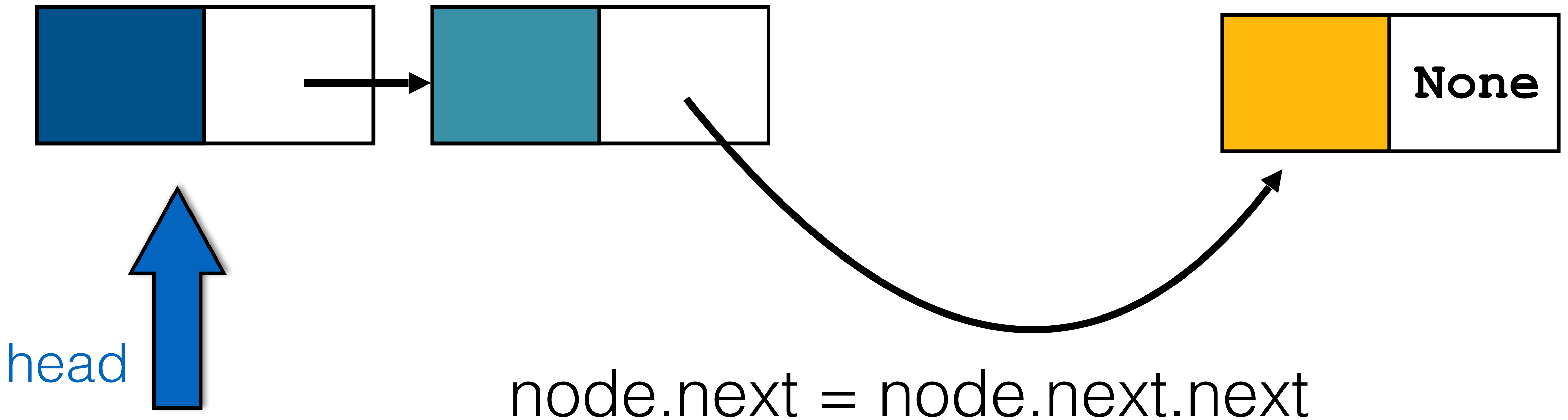




node.next = node.next.next

delete item in position 2





node.next = node.next.next

Boundary cases?

Empty List or Index out of Bounds

```python
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

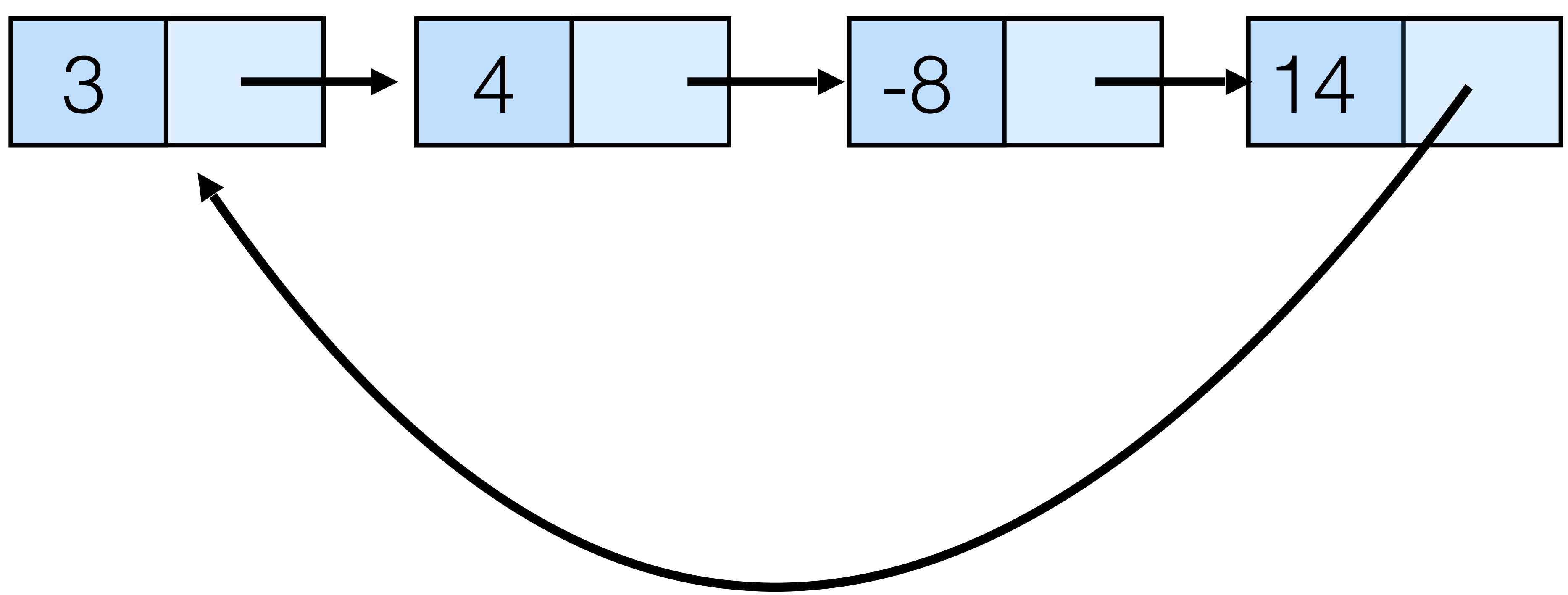
Linked Storage

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

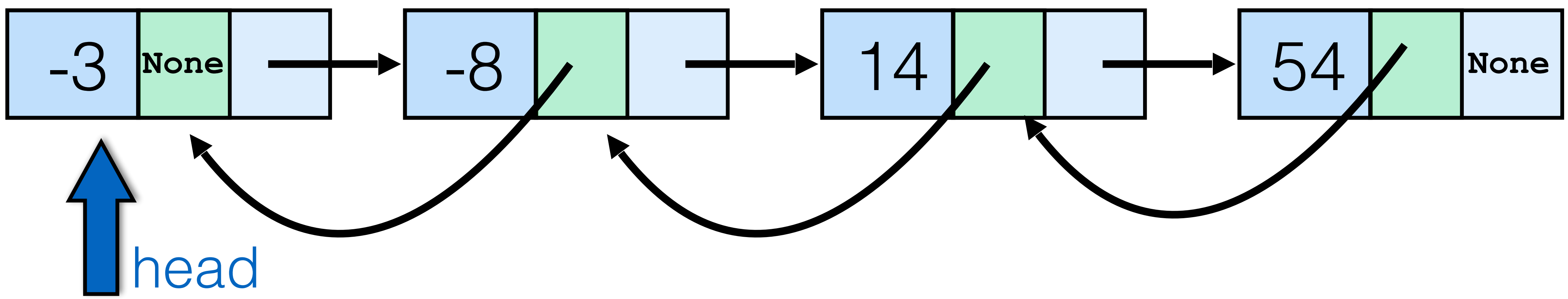
Contiguous Storage

- Known list size.
- Few insertions and deletions.
- <u>Random access</u>

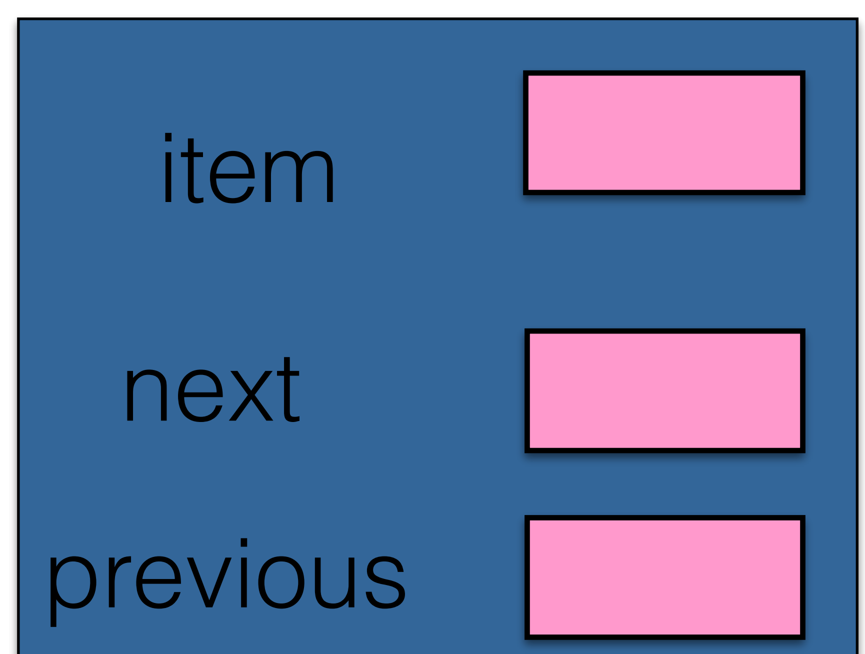
Circular linked list



Double linked list



Node



0	0	1	0	1	1	0
1	0	0	1	0	0	1
0	1	1	0	0	1	0
1	0	0	1	0	0	0
0	1	0	0	0	0	1
0	0	0	1	1	0	1

Find a set of rows in which
exactly one 1 will appear for each column…

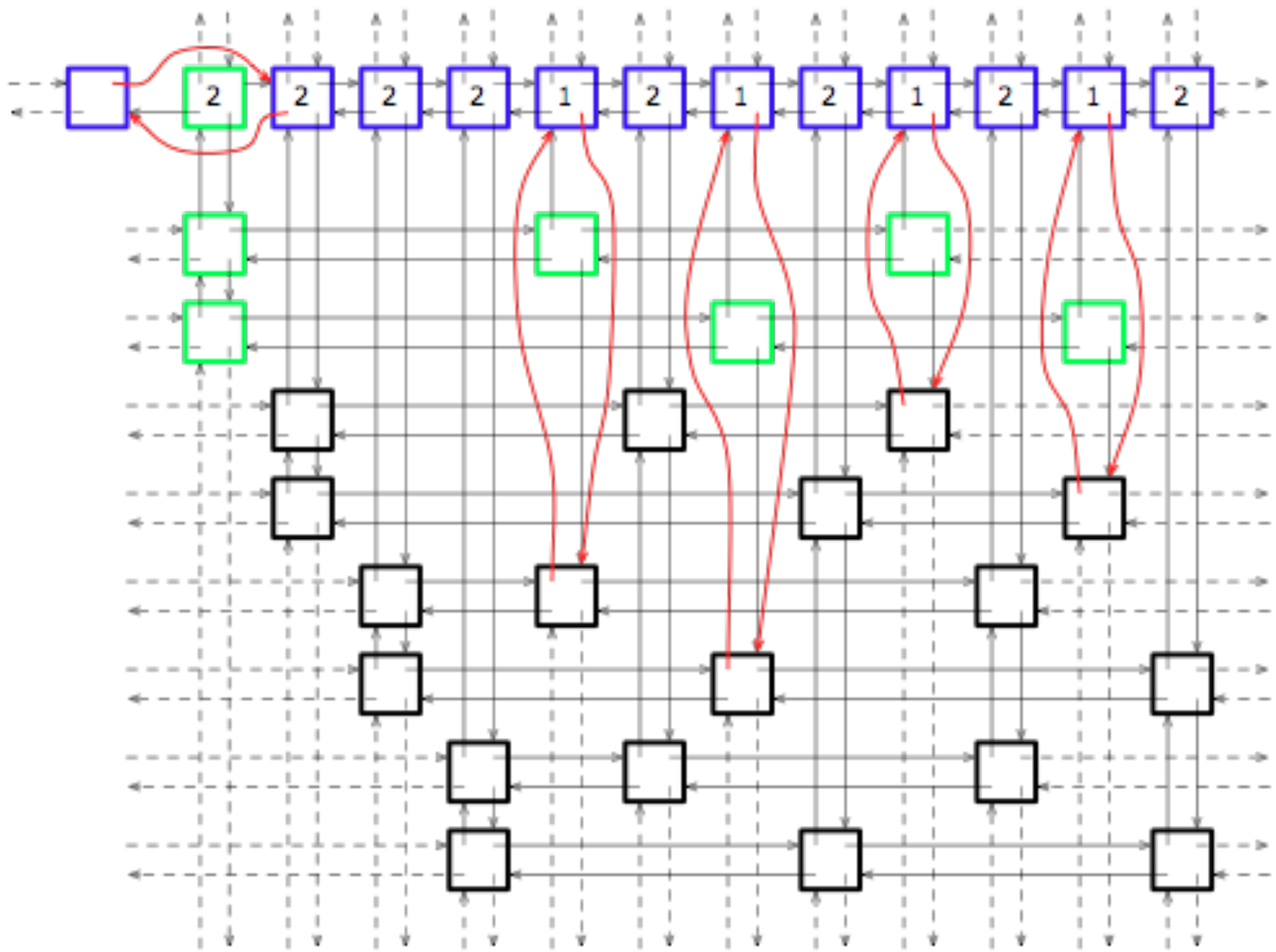
Exact cover problem

(NP-complete)

0	0	0	1	0	1	1	0
	1	0	0	1	0	0	1
	0	1	1	0	0	1	0
3	1	0	0	1	0	0	0
4	0	1	0	0	0	0	1
	0	0	0	1	1	0	1

Find a subset of rows in which
exactly one 1 will appear for each column…

Knuth’s dancing links…



A grid of circular double-linked lists…

http://garethrees.org/2007/06/10/zendoku-generation/dancing-links-2.png

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