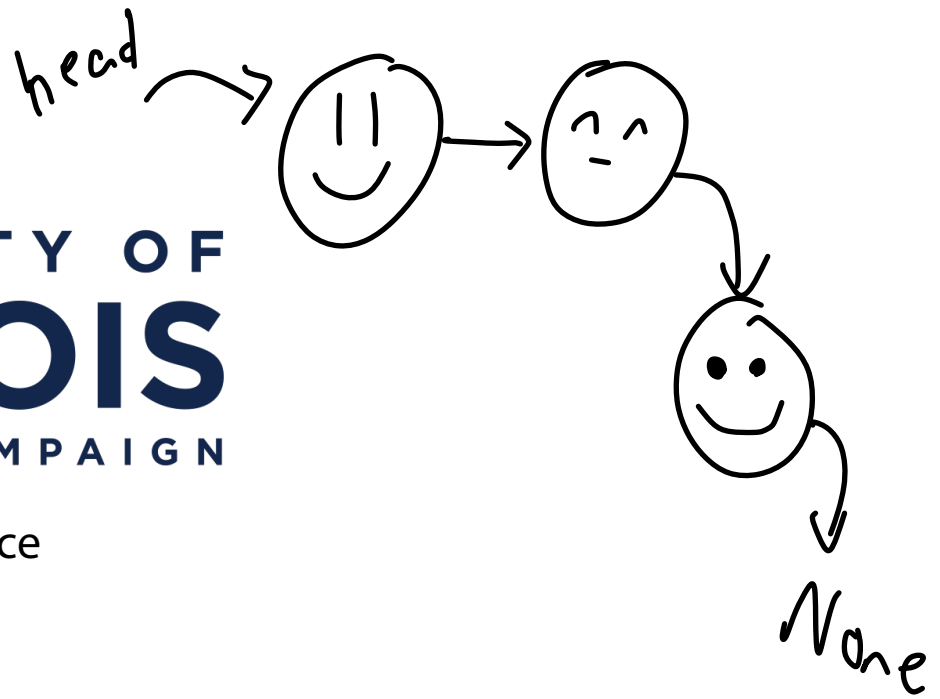
Algorithms and Data Structures for Data Science

Lists Implementation Day 2

CS 277

Brad Solomon

February 7, 2024



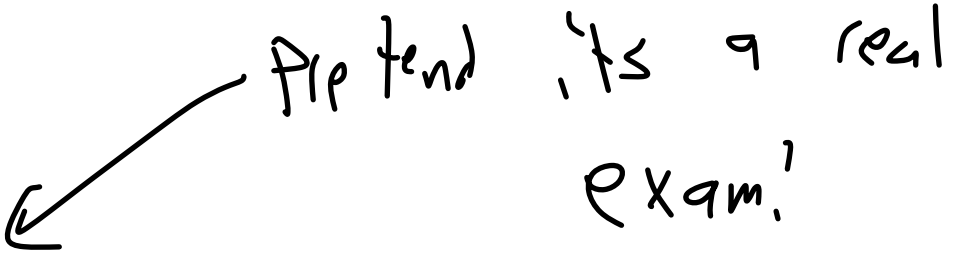
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Department of Computer Science

Exam 0: 2/13 — 2/15

Two coding questions in 50 minutes

Practice exam has four total questions



Content is Python fundamentals and lists

↳ Review the content rather than specifics

Office Hours Time Change

Not available Thursday @ 11 AM

For this week only: Friday @ 10 - 11 AM

Siebel center for Computer Science

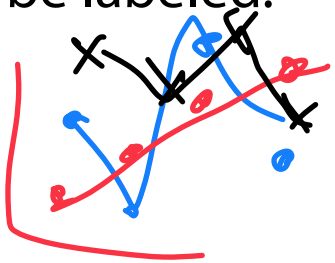
MP Generate: Part 3

```
1  for qlen in [5, 10, 15, 20, 25]:
2      print("For query length: {}".format(qlen))
3      time_list = []
4      for pow in [15, 16, 17, 18, 19, 20]:
5          rowcount = 2**pow
6
7          query =
8  random.sample(string.ascii_uppercase, qlen)
9          random.shuffle(query)
10
11         start = timeit.default_timer()
12         checkPathExists("data/graph_r{}
13 _c8.txt".format(rowcount), query)
14         end = timeit.default_timer()
15
16         time = end-start
17
18         time_list.append(time)
19
20     print("Runtime with increasing edge
21 count:")
22     print(time_list)
23
24
25
```

1. The x-dimension should be the number of rows in the file. (Each plotted line should be run on the same files)

2. The y-dimension should be the timing information for a randomly generated query on a particular file.

3. Each query length should have its own line, which should be labeled.



Learning Objectives

arrays

Discuss list implementation strategies in the context of Big O

Build a linked list implementation in Python

Extend lists to multi-dimensions using built-in and NumPy

Big O Practice: Reading code

```
1  def convert_1D_to_2D(inList, rowSize):
2      listLen = len(inList)
3      numRows = math.ceil(listLen/rowSize)
4
5      outList = []
6      count = 0
7
8      ops = 0
9      for i in range(numRows):
10         tempList = []
11
12         for j in range(rowSize):
13
14             if count >= listLen:
15                 tempList.append(-1)
16             else:
17                 tempList.append(inList[count])
18
19             ops+=1
20             count+=1
21
22         outList.append(tempList)
23
24     print(ops)
25     return outList
```

1) What is my input variables?

n is the size of inList

m is the row size

n / m

O(1)

n

n/m

m x

2) Break down code into runtime

Bis O

O(n)

O(n)

Amortized

~2 operations

~2 operations

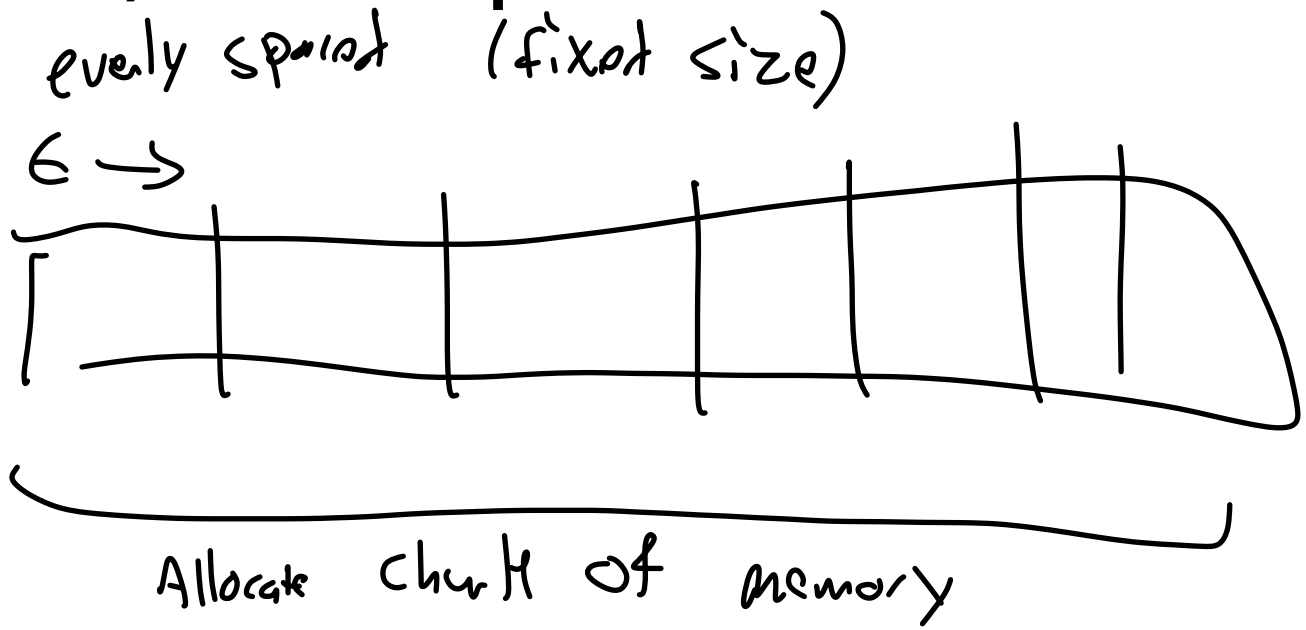
3) Combine Bis O

total # of iterations in for for chunk

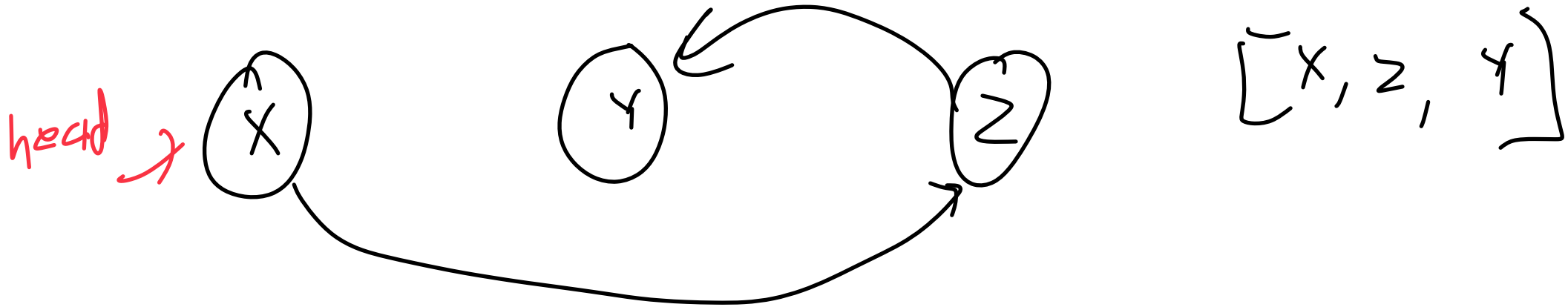
$O(1 + \frac{n}{m} \cdot m \cdot n) \rightsquigarrow O(n^2)$

(Theoretical) List Implementations

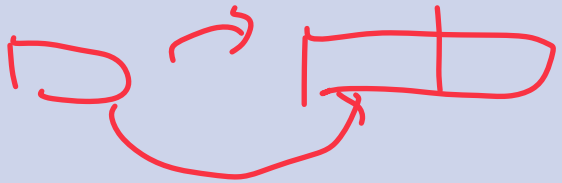
1. Array List



2. Linked List

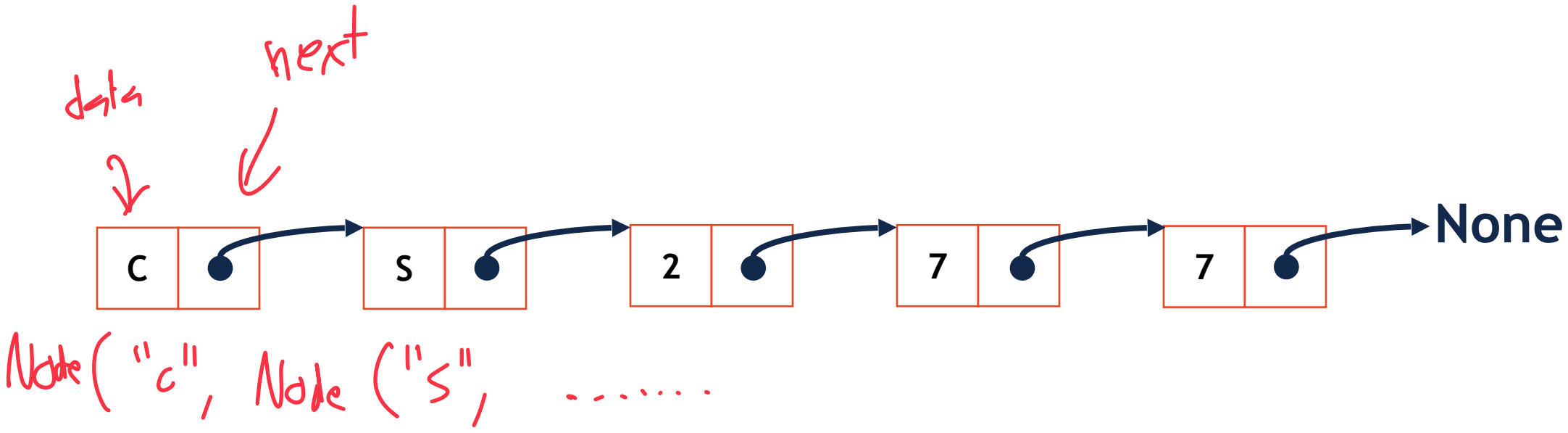


Array Implementation

	Array	Singly Linked List
Look up given an input **position**	$O(1)$	
Search given an input **value** 	$O(n)$	
Insert/Remove at **front** 	$O(n)$	
Insert/Remove at **arbitrary** location	$O(n)$	

Linked List Node

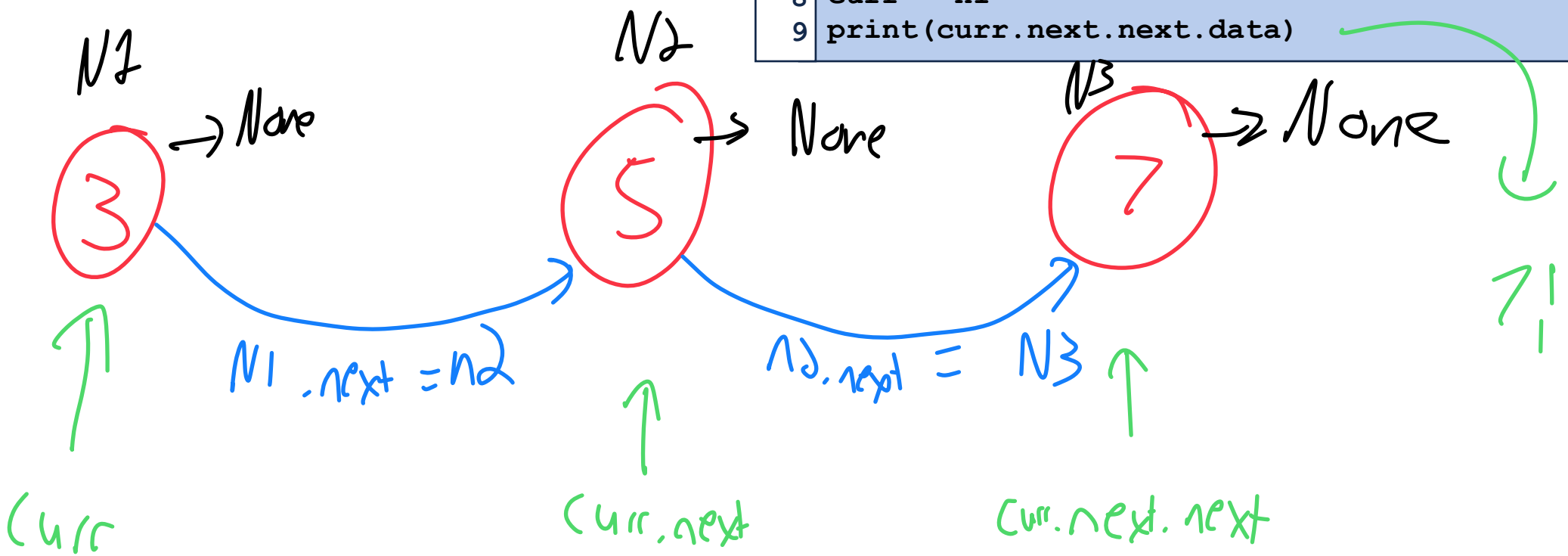
```
1  class Node:
2      def __init__(self, data, next=None):
3          self.data = data
4          self.next = next
5
```



Linked List Node

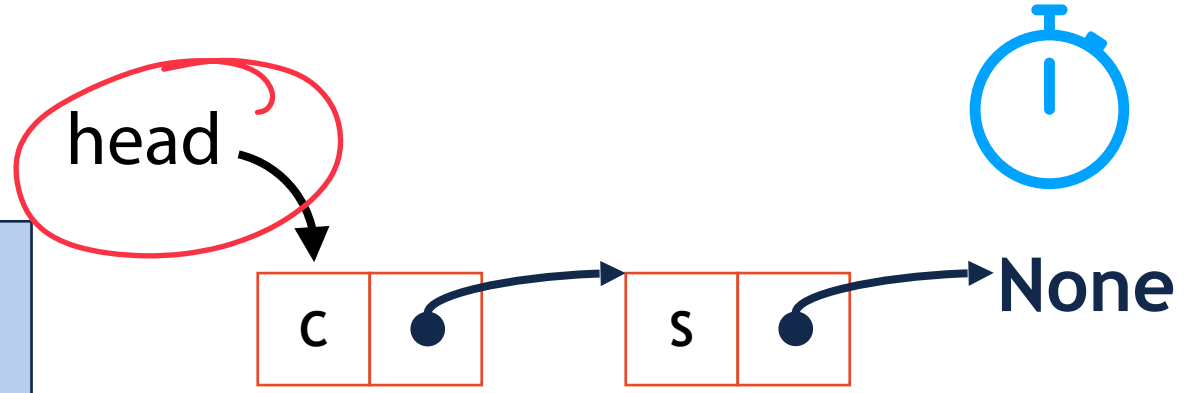
```
1  class Node:
2      def __init__(self, data, next=None):
3          self.data = data
4          self.next = next
5
```

```
1  n1 = Node(3)
2  n2 = Node(5)
3  n3 = Node(7)
4
5  n1.next = n2
6  n2.next = n3
7
8  curr = n1
9  print(curr.next.next.data)
```



Class Linked List

```
1  class Node:
2      def __init__(self, data, next=None):
3          self.data = data
4          self.next = next
5
6  class linkedList:
7      def __init__(self, head=None):
8          self.head = head
9
10     def __str__(self):
11
12     def __len__(self):
13
14     def __getitem__(self):
15
16     def add(self):
17
18     def insert(self):
19
20     def delete(self):
21
22     def remove(self):
23
```

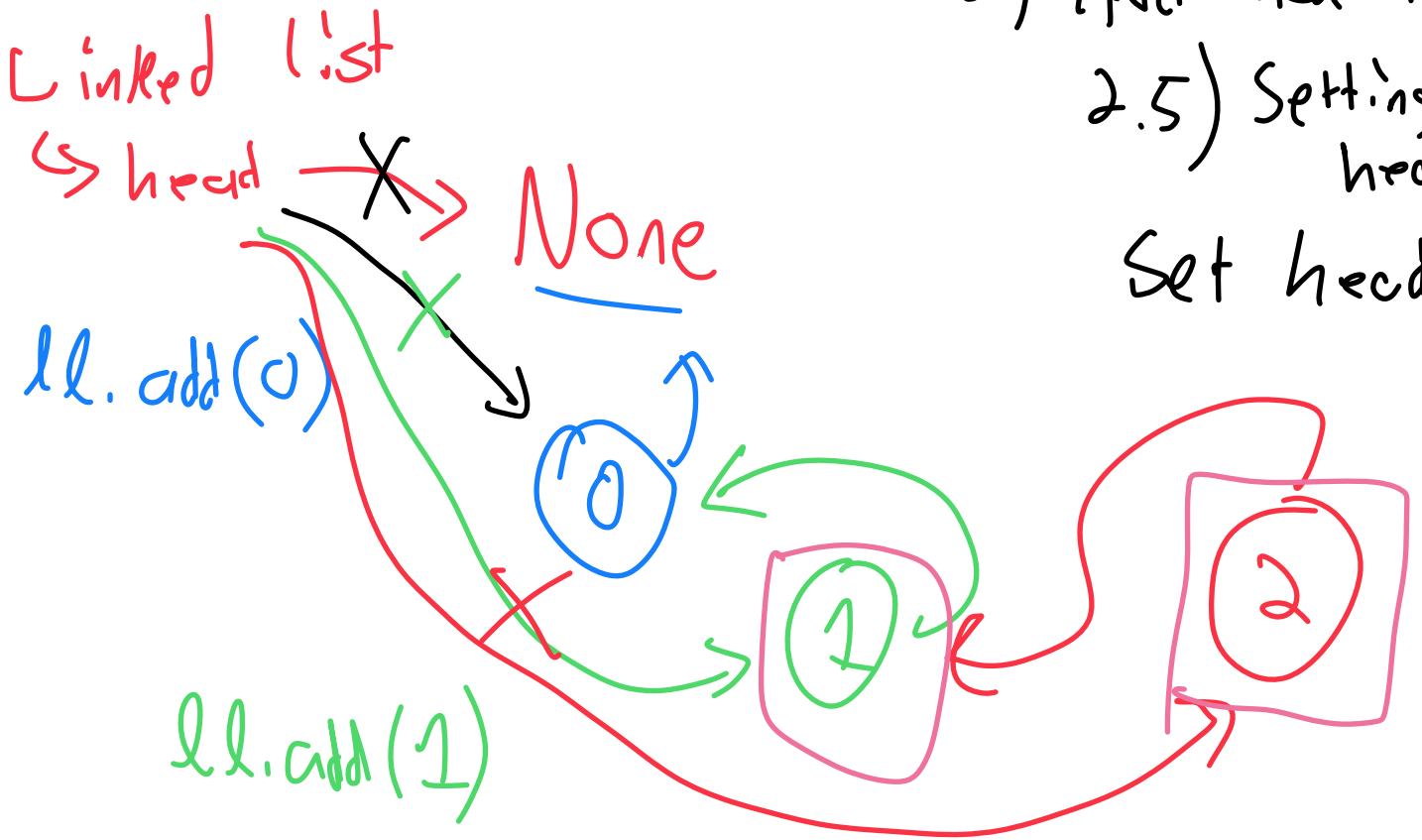


Linked List: add( )

```
1  ll = linkedList()
2
3  for i in range(3):
4      ll.add(i)
5
```

[ ] [0] [1,0] [2,1,0]

1) Make a new Node object
   ↳ Node(value, head)
2) Add node to LL by:
   2.5) Setting new Nodes next equal to head
   Set head to new node



Linked List: add( )

O(1)

X = 5

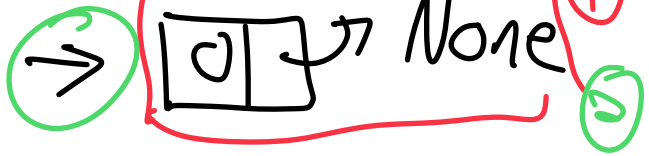
```
1  ll = linkedList()
2
3  for i in range(3):
4      ll.add(i)
5
```

```
1  class linkedList:
2      def add(self, data):
3
4
5
6
7
```

head → None

B: 50

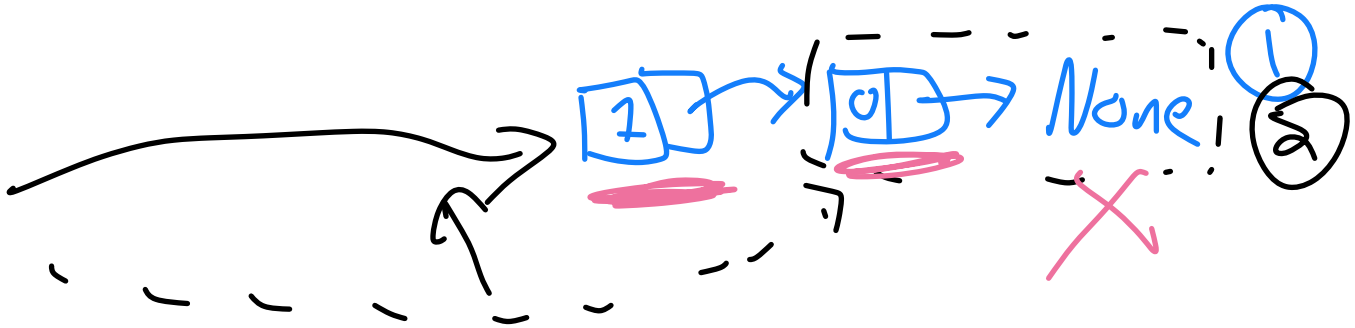
add(0)



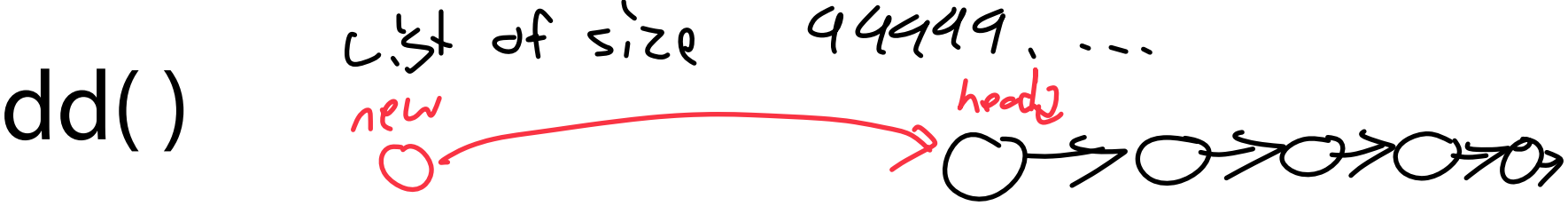
① Created new Node(data, head) — O(1)

② Set head to new Node — O(1)

add(1)



Linked List: add( )




```
1  ll = linkedList()
2
3  for i in range(3):
4      ll.add(i)
5
```

```
1  class linkedList:
2      def add(self, data):
3          temp = self.head
4          self.head = Node(data, temp)
5
```

Line 3:
Keep track of old head node

Line 4:
Create new Node object w/ data & next pointing to old head
&
we assign to head

Linked List: __len__( )

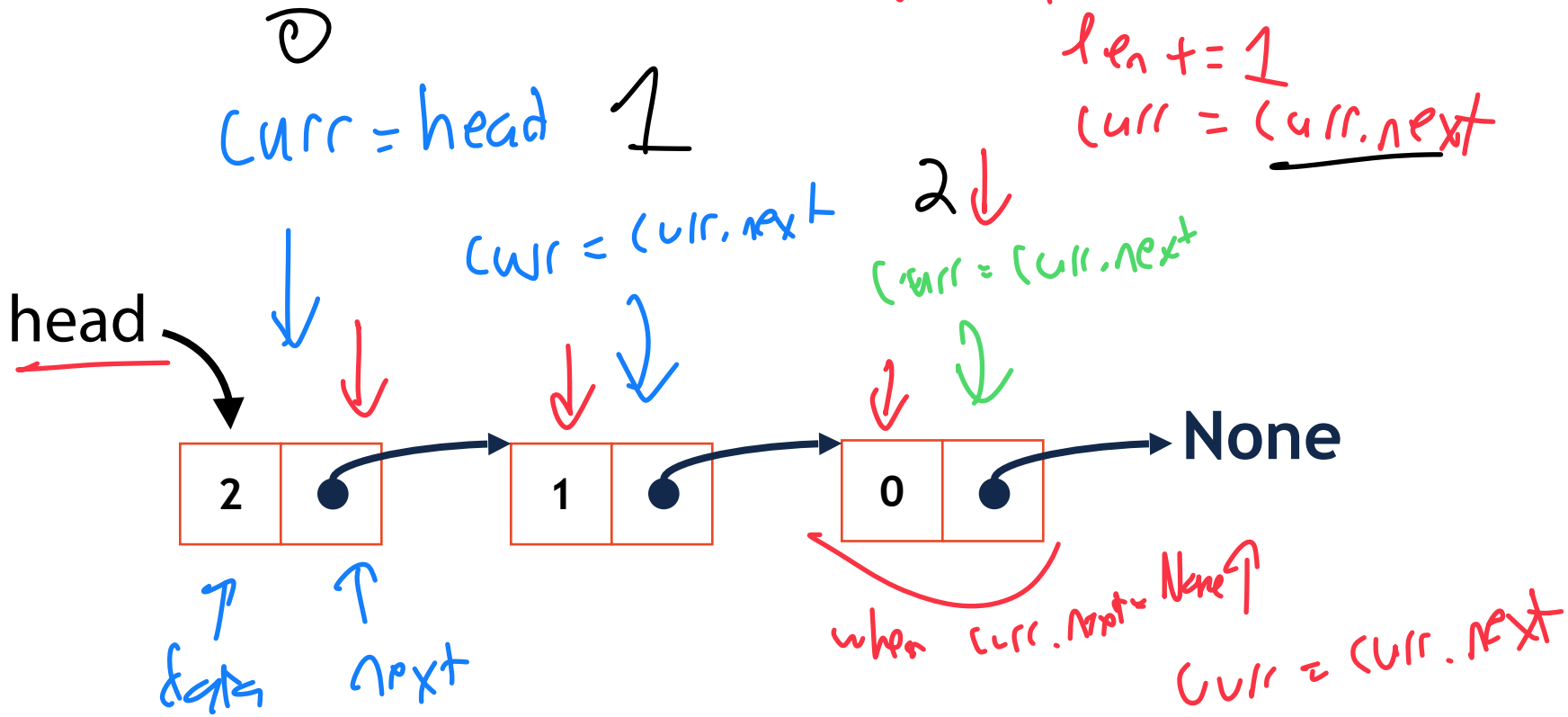
```
1 ll = linkedList()
2 for i in range(3):
3     ll.add(i)
4
5 print(len(ll))
```

How to walk down chain?

Create a new var "current"

len = 0
curr = head
while (curr .next != None):
    len += 1
    curr = curr.next

x = []
y = x



Linked List: __len__( )

```
1  ll = linkedList()
2  for i in range(3):
3      ll.add(i)
4
5  print(len(ll))
```

```
1  class linkedList:
2      def __len__(self):
3          i = 0
4          curr = self.head
5          while(curr):
6              curr = curr.next
7              i+=1
8          return i
```

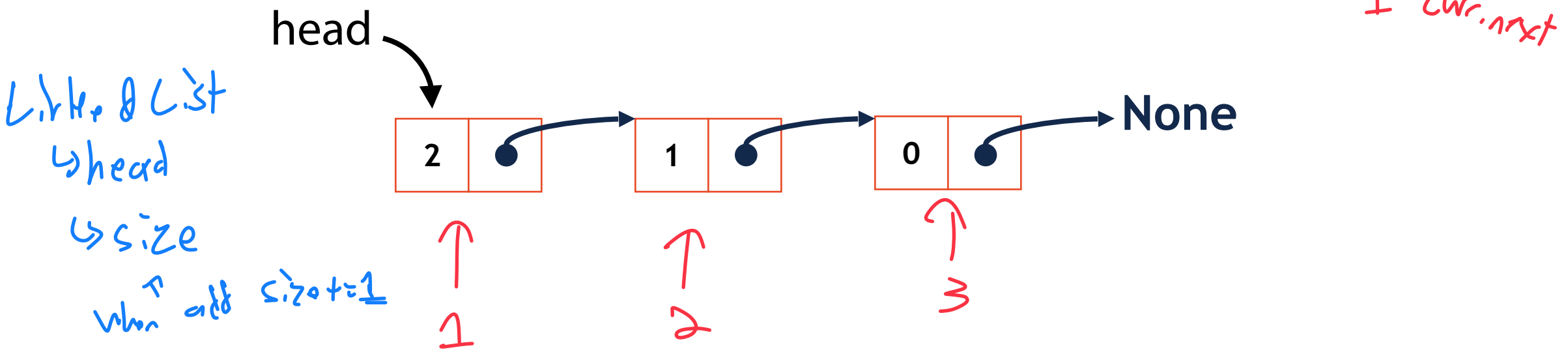
1) Start w/ curr

Big O is O(n)!

↳ we could store length directly

Stop when curr = None

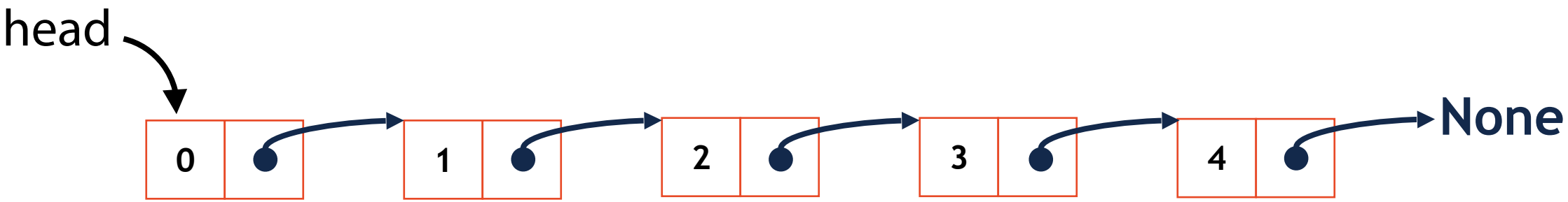
2) To loop I curr.next



Linked List
↳ head
↳ size
↑ when add size+=1

In-Class Exercise: Linked List __getitem__( )

```
1 ll = linkedList()
2 for i in range(5):
3     ll.add(i)
4
5 print(ll[3])
```

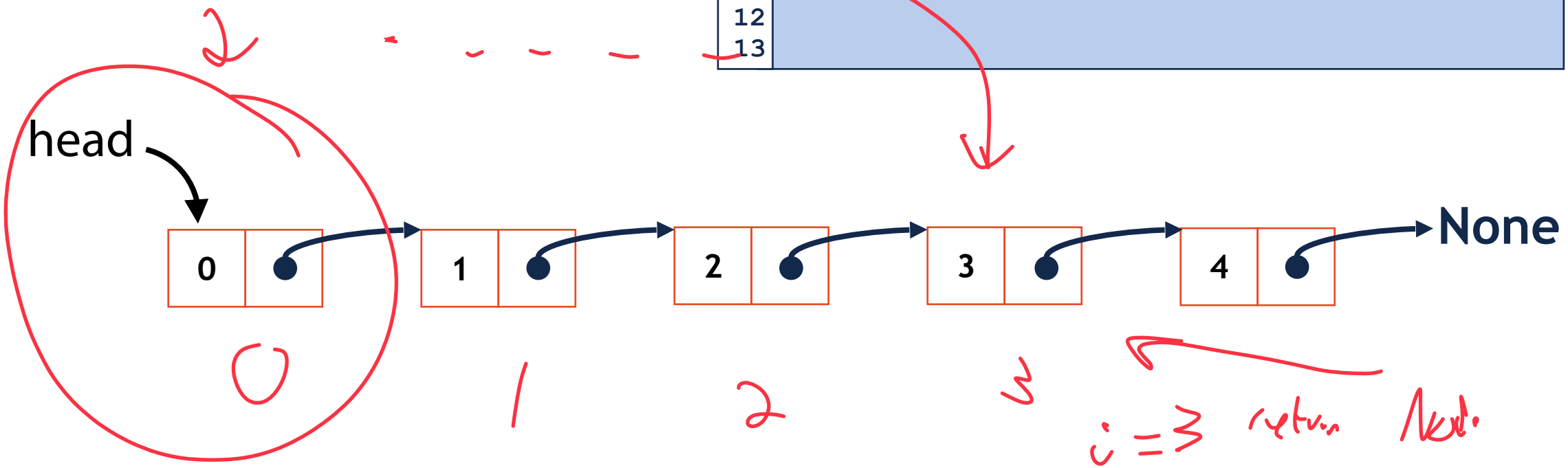


In-Class Exercise: Linked List __getitem__( )

```
1  ll = linkedList()
2  for i in range(5):
3      ll.add(i)
4
5  print(ll[3])
```

```
1
2
3
4
5
6
7
8
9
10
11
12
13
```

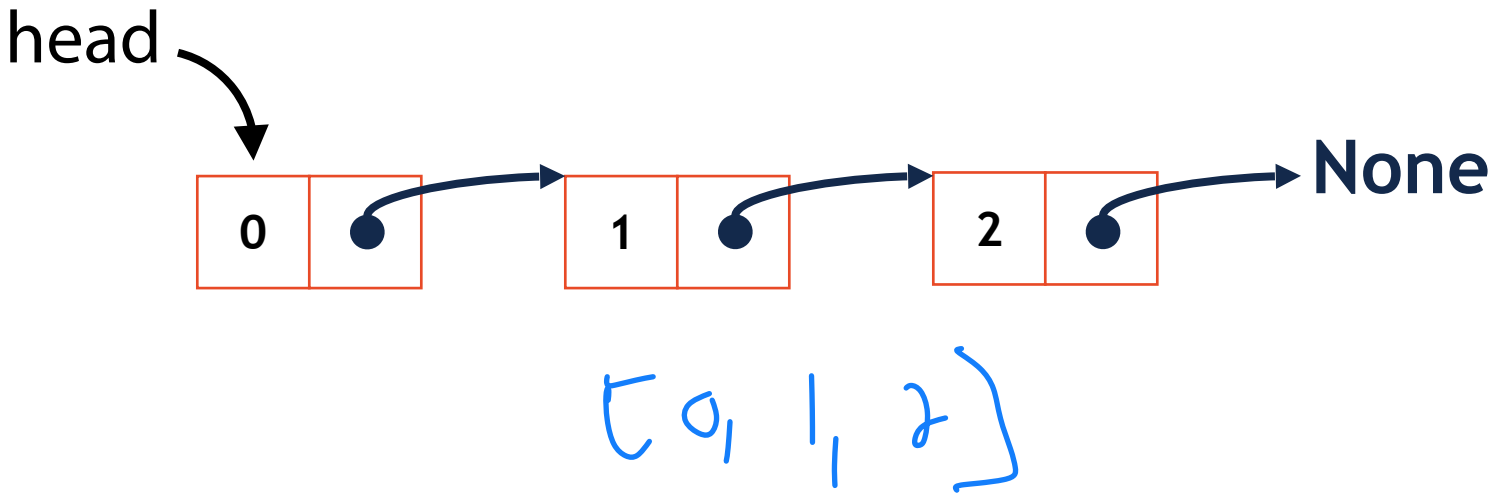
while loop



Linked List: __str__( )

```
1 ll = linkedList()
2 for i in range(3):
3     ll.add(i)
4
5 print(ll)
```

```
1  class linkedList:
2      def __str__(self):
3          curr = self.head
4          out="["
5          while(curr):
6              out+="{},".format(curr.data)
7              curr = curr.next
8
9          if out[-1]==",":
10             out = out[:-1]
11         out = out +"]\n"
12         return out
13
```

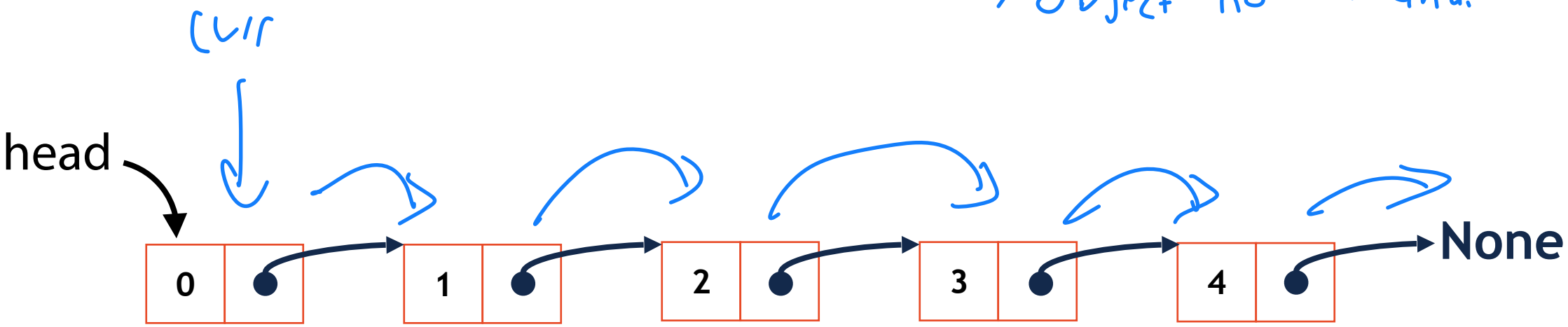


On your own: Linked List find()

```
1  #initialize ll
2
3  node = ll.find("B")
4
5  if(node):
6      print("Exists!")
7  else:
8      print("Doesnt exist!")
```

1) If find object of interest
   ↳ done! return node

2) curr == None
   ↳ object not found!



Linked List: insert( )

```
1  for i in range(5):
2      ll.add(i)
3
4  ll.insert("Value", 2)
5  print(ll)
```

O(n)!

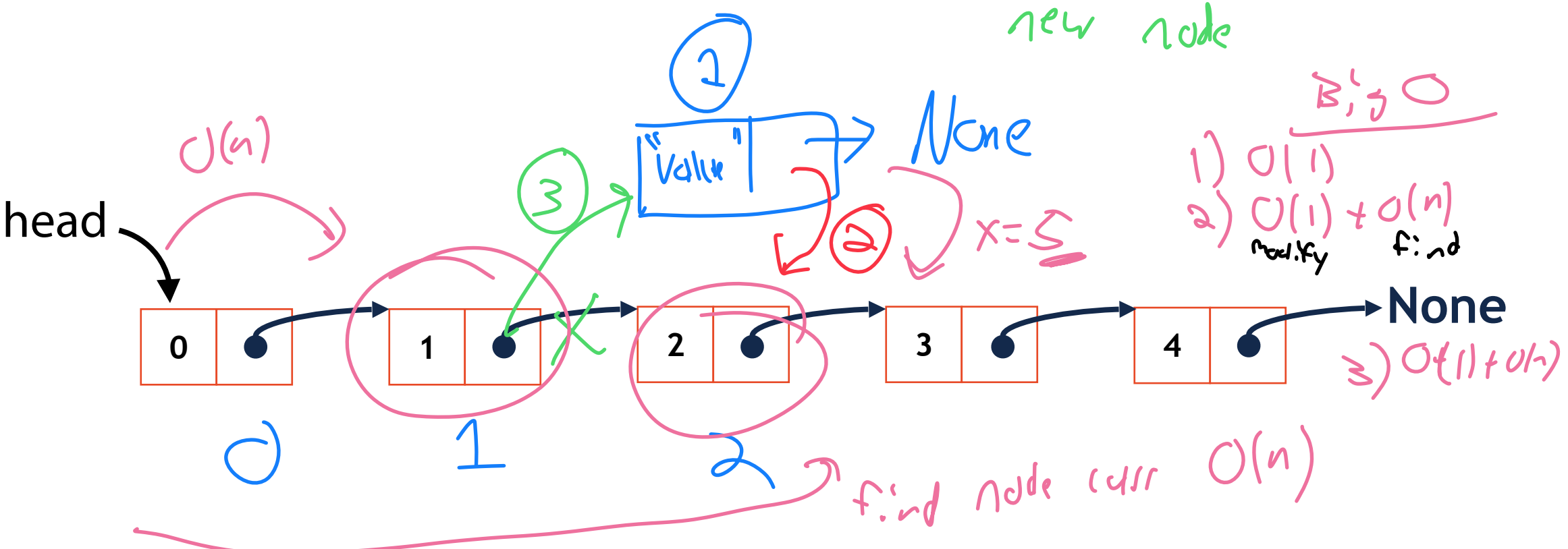
1) Make new Node

[0, 1, 2, 3, 4]

[0, 1, "value", 2, 3, 4]

2) Set new Node next = current node at position i

3) Change previous node's next to be new node



Big O

1) O(1)

2) O(1) + O(n)

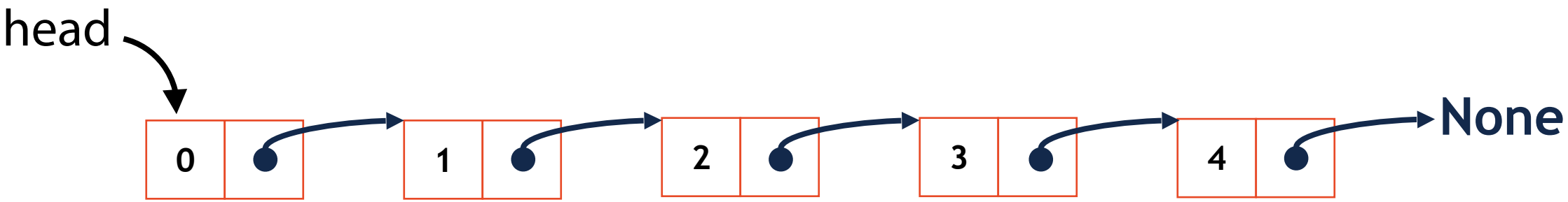
modify find

3) O(1 + n)

In-Class Exercise: Linked List insert( )

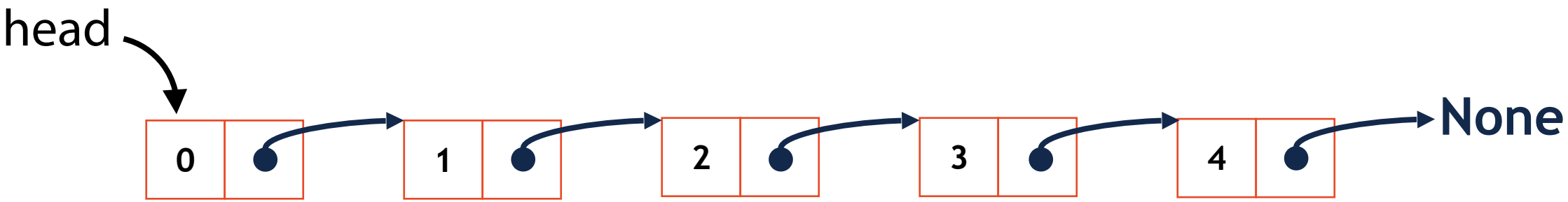
```
1  for i in range(5):
2      ll.add(i)
3
4  ll.insert("Value", 2)
5  print(ll)
```

```
1
2
3
4
5
6
7
```



Linked List: delete( )

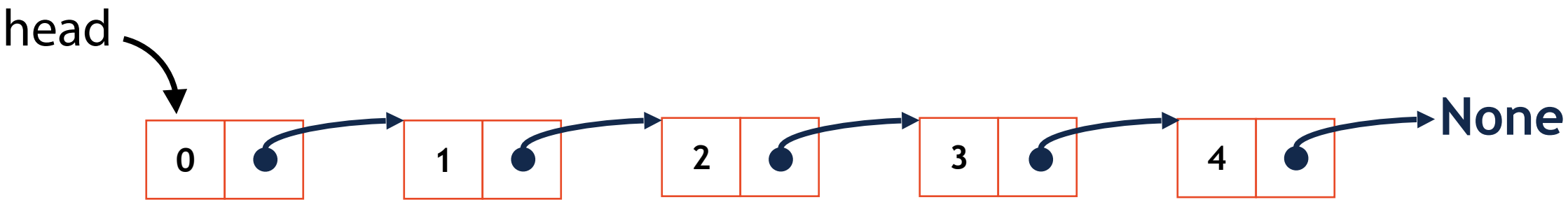
```
1 for i in range(5):
2     ll.add(i)
3
4 ll.delete(1)
5 print(ll)
```



Linked List: delete( )

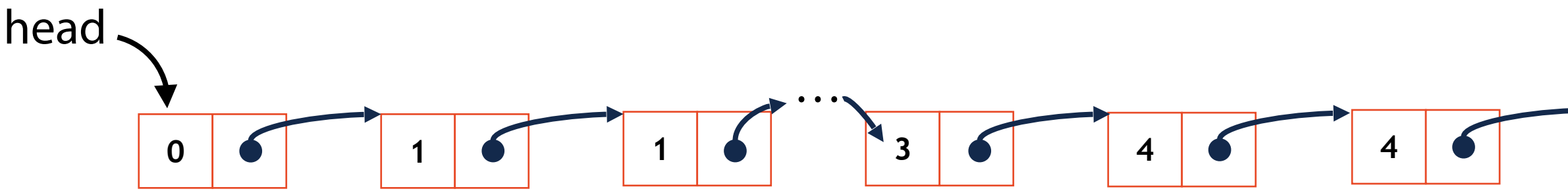
```
1  for i in range(5):
2      ll.add(i)
3
4  ll.delete(1)
5  print(ll)
```

```
1
2
3
4
5
6
7
```



Linked List: remove( )

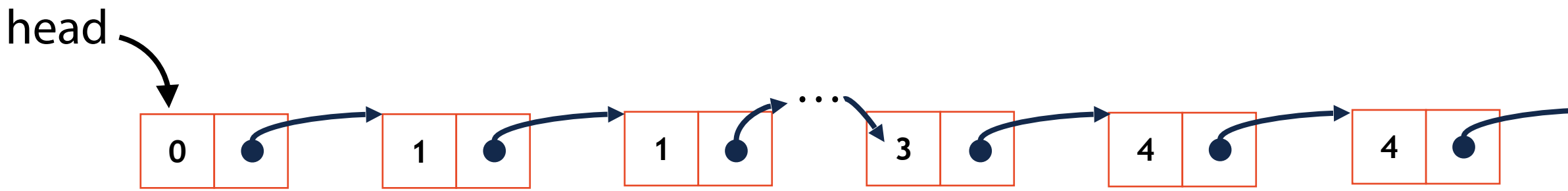
```
1  ll = linkedList()
2
3  for i in range(5):
4      ll.add(i)
5      ll.add(i)
6
7  ll.remove(4)
```



Optional Exercise: remove( )

```
1  ll = linkedList()
2
3  for i in range(5):
4      ll.add(i)
5      ll.add(i)
6
7  ll.remove(4)
```

```
1
2
3
4
5
6
7
```

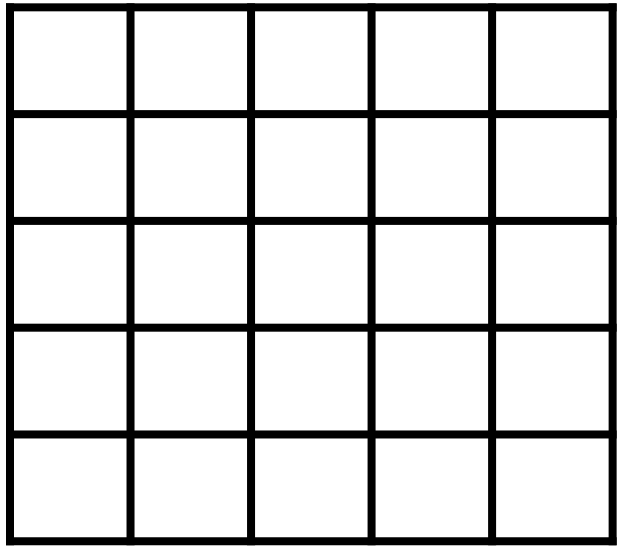


Array Implementation

	Singly Linked List	Array
Look up given an input **position**		
Search given an input **value**		
Insert/Remove at **front**		
Insert/Remove at **arbitrary** location		

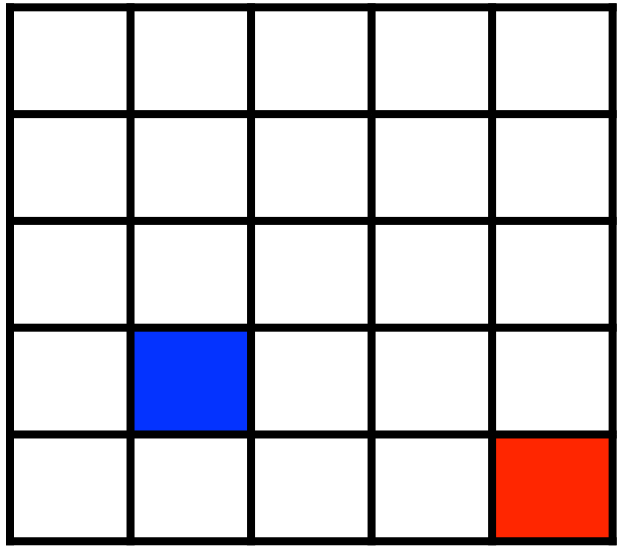
Programming Toolbox: Multidimensional Lists

How can we make a matrix in Python?

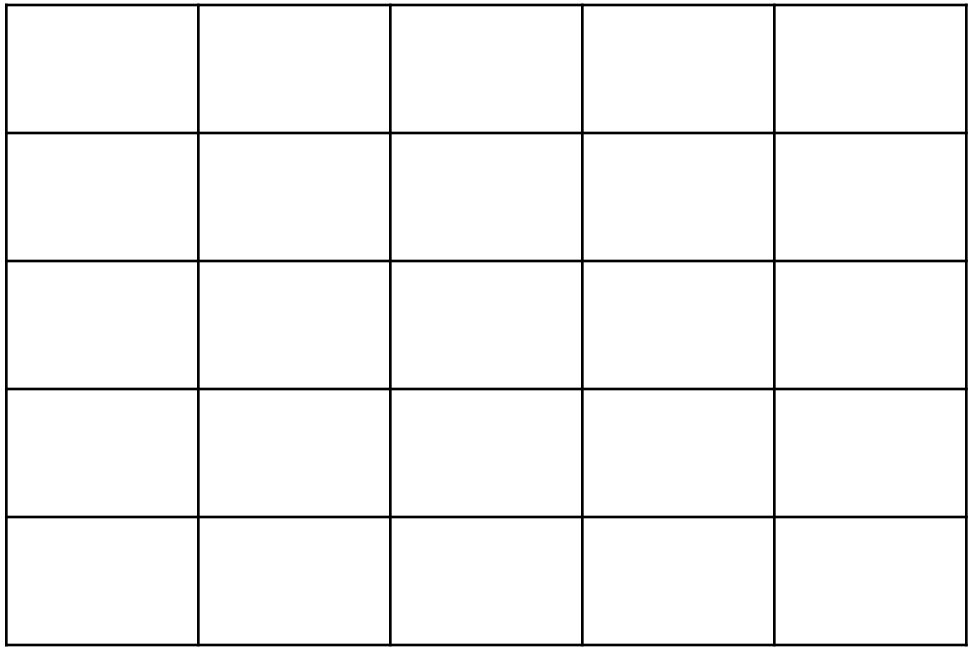


Programming Toolbox: Multidimensional Lists

How is a matrix in Python indexed?



Python 2D lists



```
1  outerList = []
2
3  for i in range(5):
4      innerList = []
5
6      for j in range(5):
7          innerList.append(i+j)
8
9      outerList.append(innerList)
10
11 print(outerList)
12
13 print(outerList[3][1])
14
15
16
17
18
```

Python 2D lists

0	1	2	3	4
1	2	3	4	5
2	3	4	5	6
3	4	5	6	7
4	5	6	7	8

```
1  outerList = []
2
3  for i in range(5):
4      innerList = []
5
6      for j in range(5):
7          innerList.append(i+j)
8
9      outerList.append(innerList)
10
11 print(outerList)
12
13 print(outerList[3][1])
14
15
16
17
18
```

Programming Toolbox: NumPy

NumPy is optimized for multidimensional arrays of numbers

```
1  import numpy as np
2
3  # Convert list to np list
4  nl = np.array([1, 2, 3, 4, 5, 6])
5  print(nl)
6
7  print(nl.shape)
8
9  # Modify list shape
10 nl2 = nl.reshape(3, 2)
11
12 print(nl)
13 print(nl2)
14
15 # Create a new list
16 nl3 = np.arange(15).reshape(5, 3)
17 nl4 = np.zeros((2, 5))
18
19 print(nl3)
20 print(nl4)
21
22
23
```

Programming Toolbox: NumPy

Basic operations are applied **elementwise** (to each item of a list)

```
1  nl = np.arange(4).reshape(2, 2)
2
3  print(nl)
4
5  nl2 = nl * 2
6
7  print(nl2)
8
9  # Matrix multiplication
10 # 0*0+1*4      0*0+1*6
11 # 2*0+3*4      2*2+3*6
12 print(nl.dot(nl2))
```

Explore on your own: https://numpy.org/devdocs/