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Lecture 23
Linked Structures

FIT 1008
Introduction to Computer Science

MONASH University
Information Technology

Container ADTs

- **Stores** and removes items **independent of contents.**
- **Examples** include:
  - List ADT ☑
  - Stack ADT ☑
  - Queue ADT. ☑
- Core **operations**:
  - add item
  - remove item

http://s4.thisnext.com/media/largest_dimension/DFF83835.jpg

Implementation affects time complexity.

Unsorted List: Add

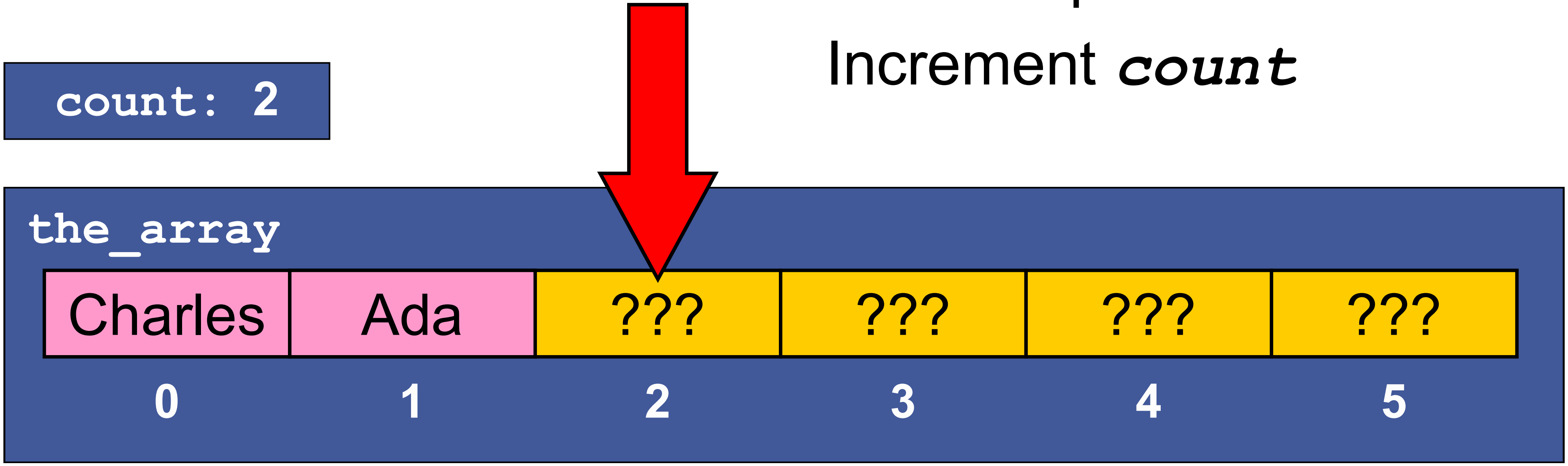
Adding an element

Recall: count indicates the first empty position (if any)

`Example: add “Ada”`

Add the item at position ***`count`***

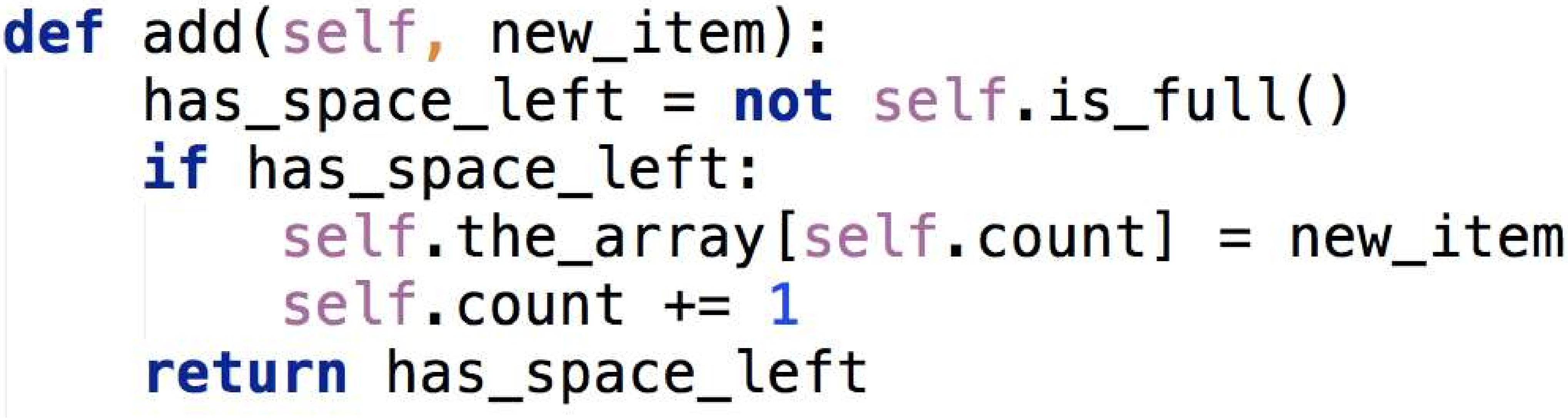
Increment ***`count`***



`count: 2`

`the_array`

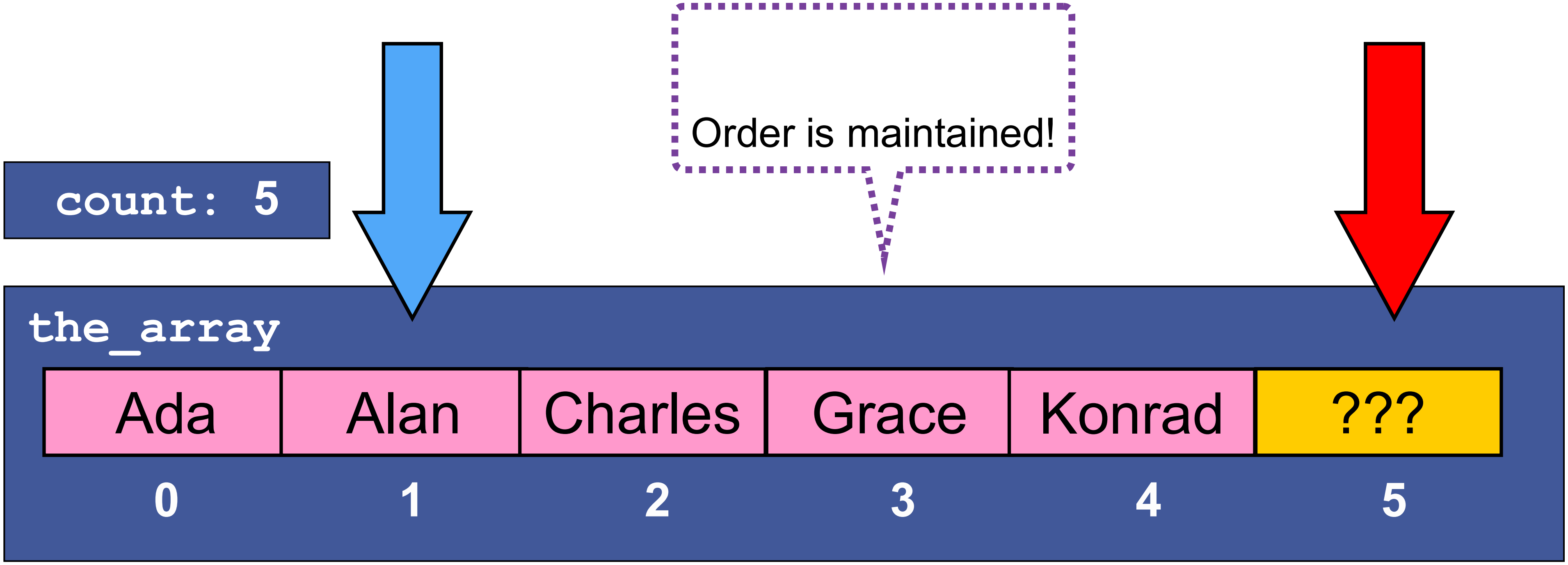
Charles	Ada	???	???	???	???
0	**1**	**2**	**3**	**4**	**5**



```python
def add(self, new_item):
    has_space_left = not self.is_full()
    if has_space_left:
        self.the_array[self.count] = new_item
        self.count += 1
    return has_space_left
```

Sorted List: Add

Example: add "Alan" to the sorted list.



Order is maintained!

count: 5

the_array

Ada	Alan	Charles	Grace	Konrad	???
0	1	2	3	4	5

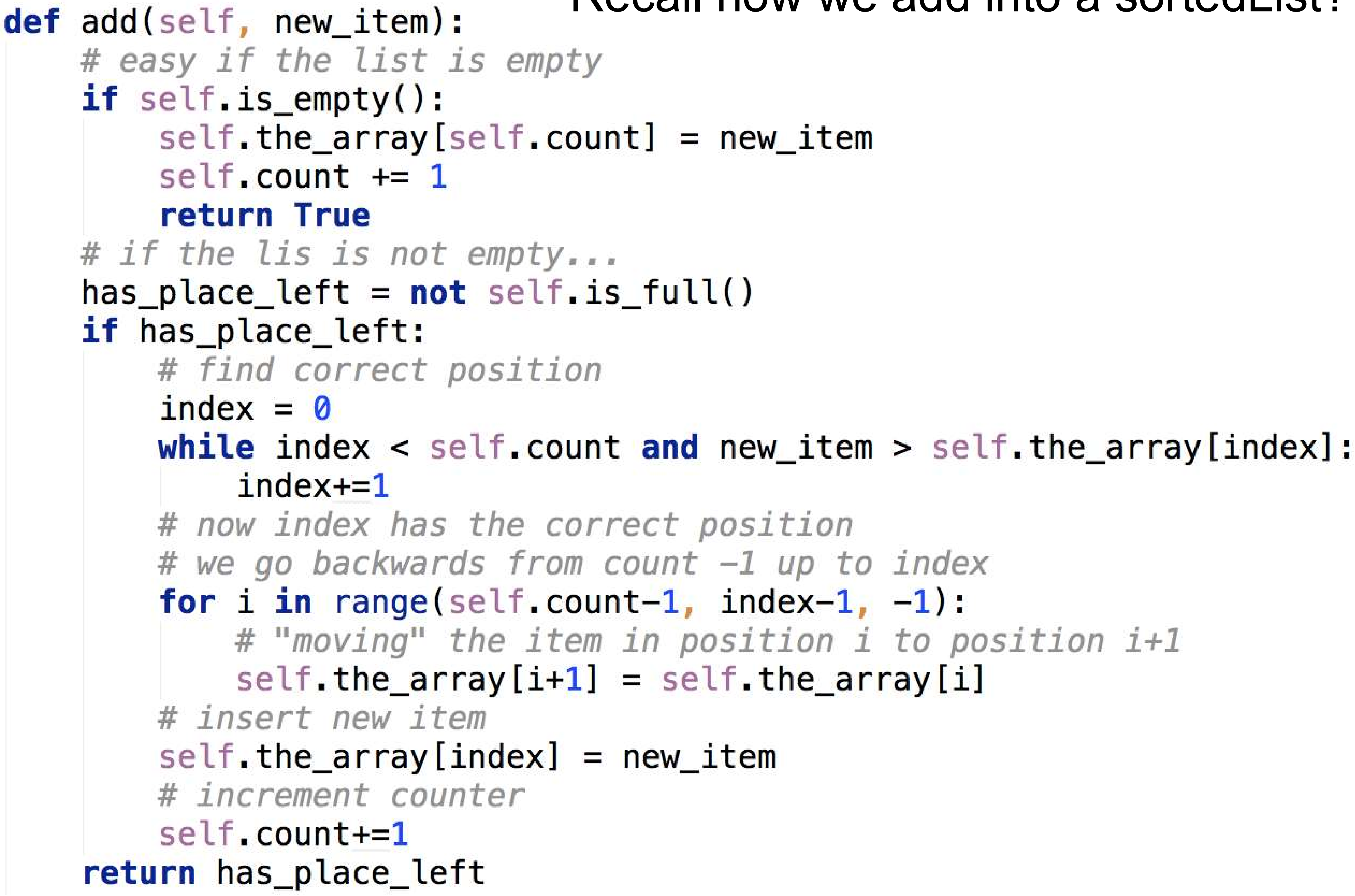
If there is space, find the correct position

Make room by moving all to the right.

Put item in position.

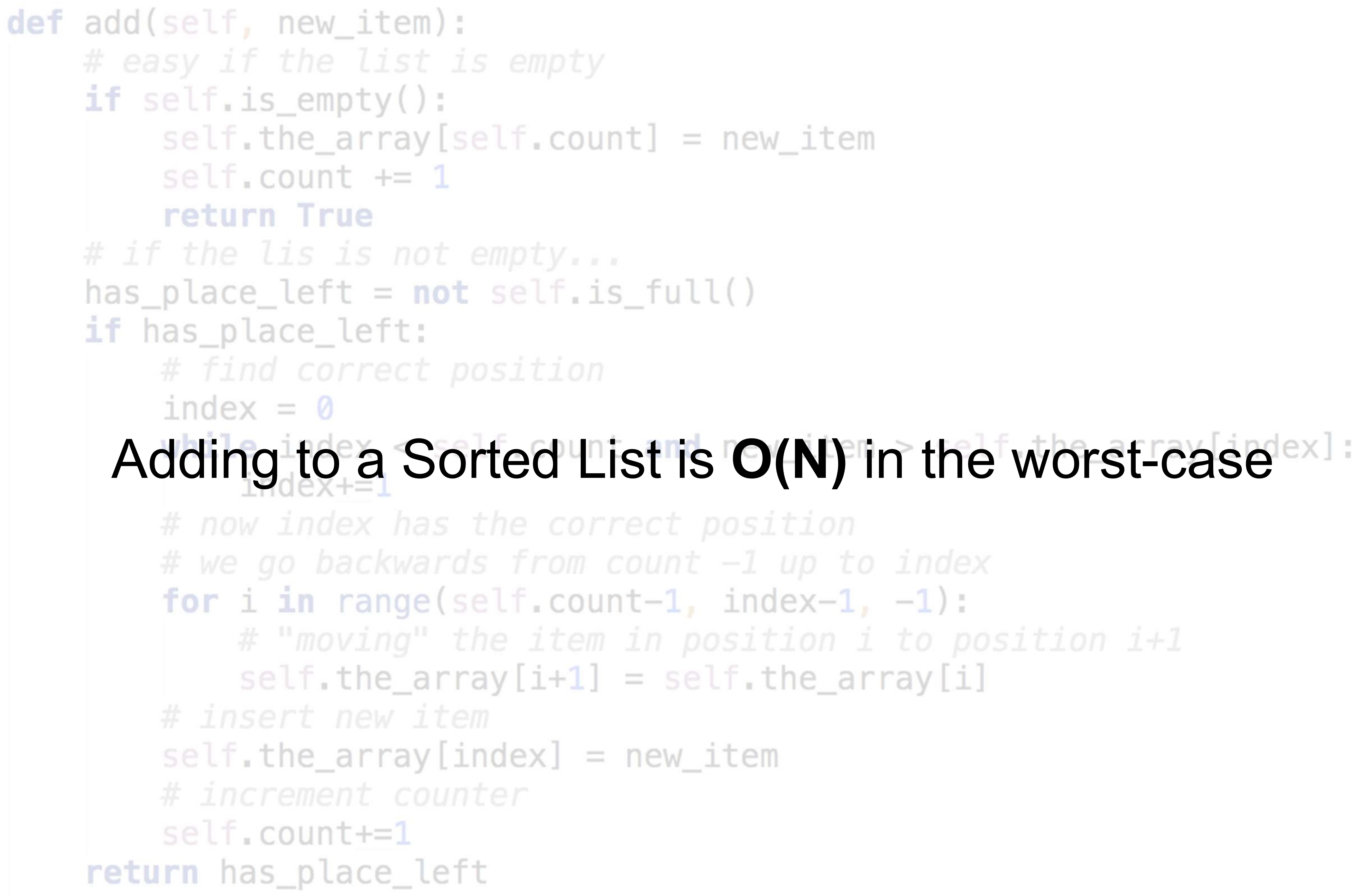
Update count then **return True**

Recall how we add into a sortedList?



```
def add(self, new_item):
    # easy if the list is empty
    if self.is_empty():
        self.the_array[self.count] = new_item
        self.count += 1
        return True
    # if the lis is not empty...
    has_place_left = not self.is_full()
    if has_place_left:
        # find correct position
        index = 0
        while index < self.count and new_item > self.the_array[index]:
            index+=1
        # now index has the correct position
        # we go backwards from count -1 up to index
        for i in range(self.count-1, index-1, -1):
            # "moving" the item in position i to position i+1
            self.the_array[i+1] = self.the_array[i]
        # insert new item
        self.the_array[index] = new_item
        # increment counter
        self.count+=1
    return has_place_left
```

Adding to a Sorted List is **O(N)** in the worst-case



```
def add(self, new_item):
    # easy if the list is empty
    if self.is_empty():
        self.the_array[self.count] = new_item
        self.count += 1
        return True
    # if the lis is not empty...
    has_place_left = not self.is_full()
    if has_place_left:
        # find correct position
        index = 0
        while index < self.count and new_item > self.the_array[index]:
            index+=1
        # now index has the correct position
        # we go backwards from count -1 up to index
        for i in range(self.count-1, index-1, -1):
            # "moving" the item in position i to position i+1
            self.the_array[i+1] = self.the_array[i]
        # insert new item
        self.the_array[index] = new_item
        # increment counter
        self.count+=1
    return has_place_left
```

Can we improve this by changing the representation?

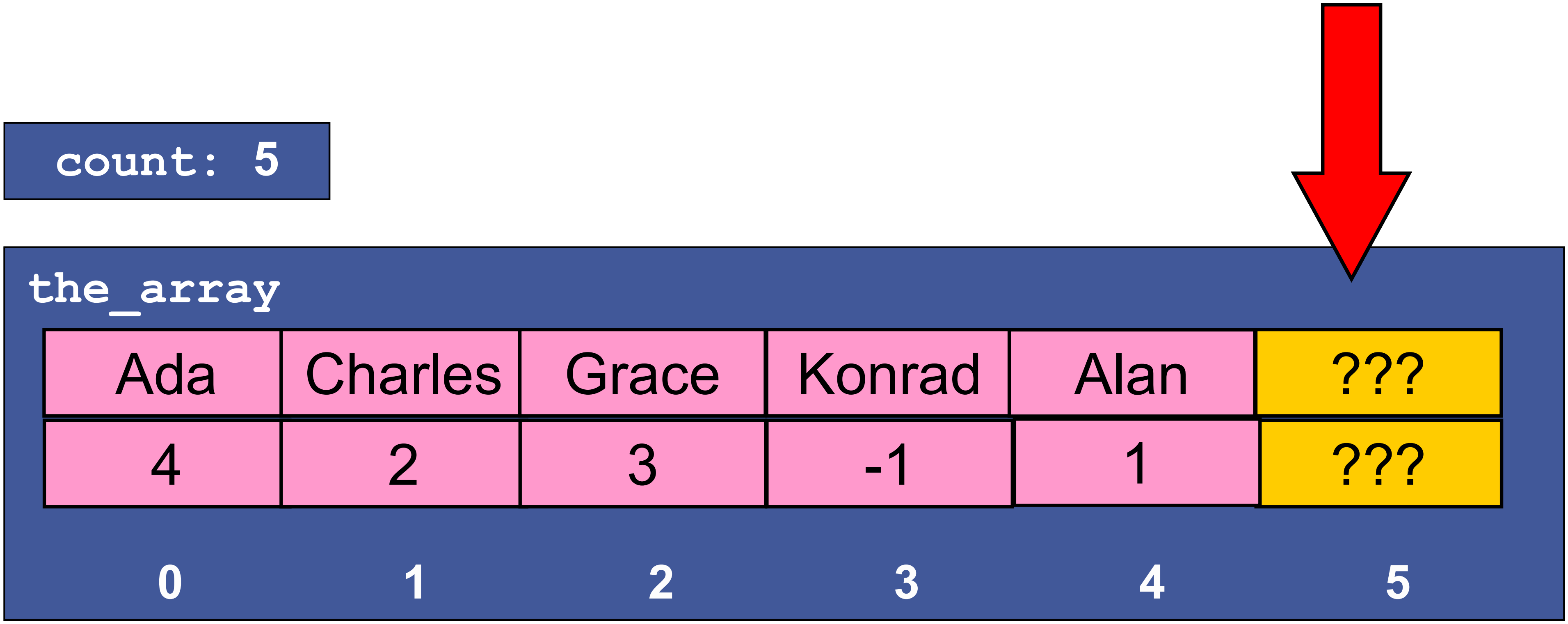
Welcome to the world of

ed structures

Legend of zelda
https://upload.wikimedia.org/wikipedia/en/3/39/Wakerlink.jpg

Array Linked List: Add

Example: add "Alan" to the sorted list.



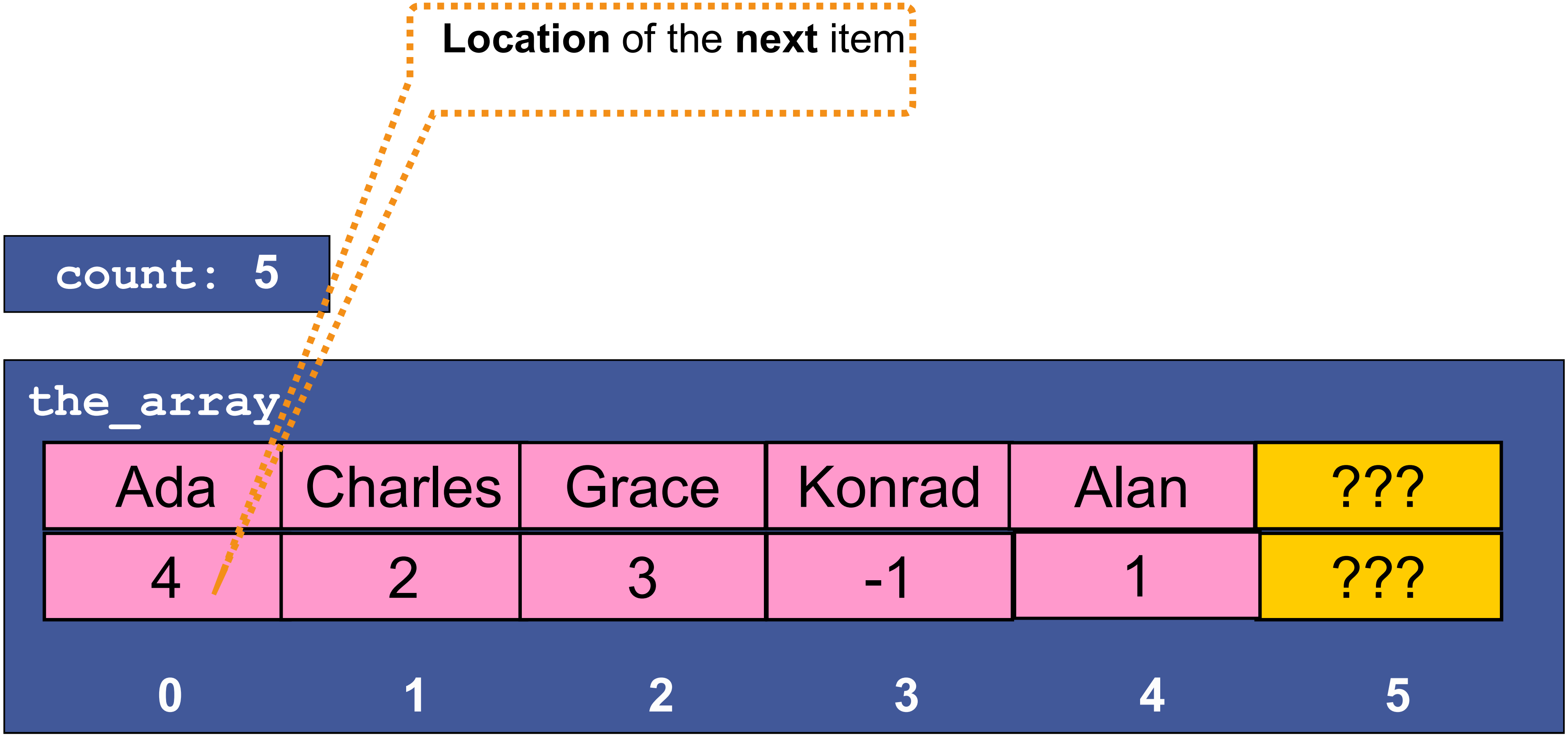
count: 5

the_array

0	1	2	3	4	5
Ada	Charles	Grace	Konrad	Alan	???
4	2	3	-1	1	???

No shifting around!

If there is space, add it
then fix indexes…increment count



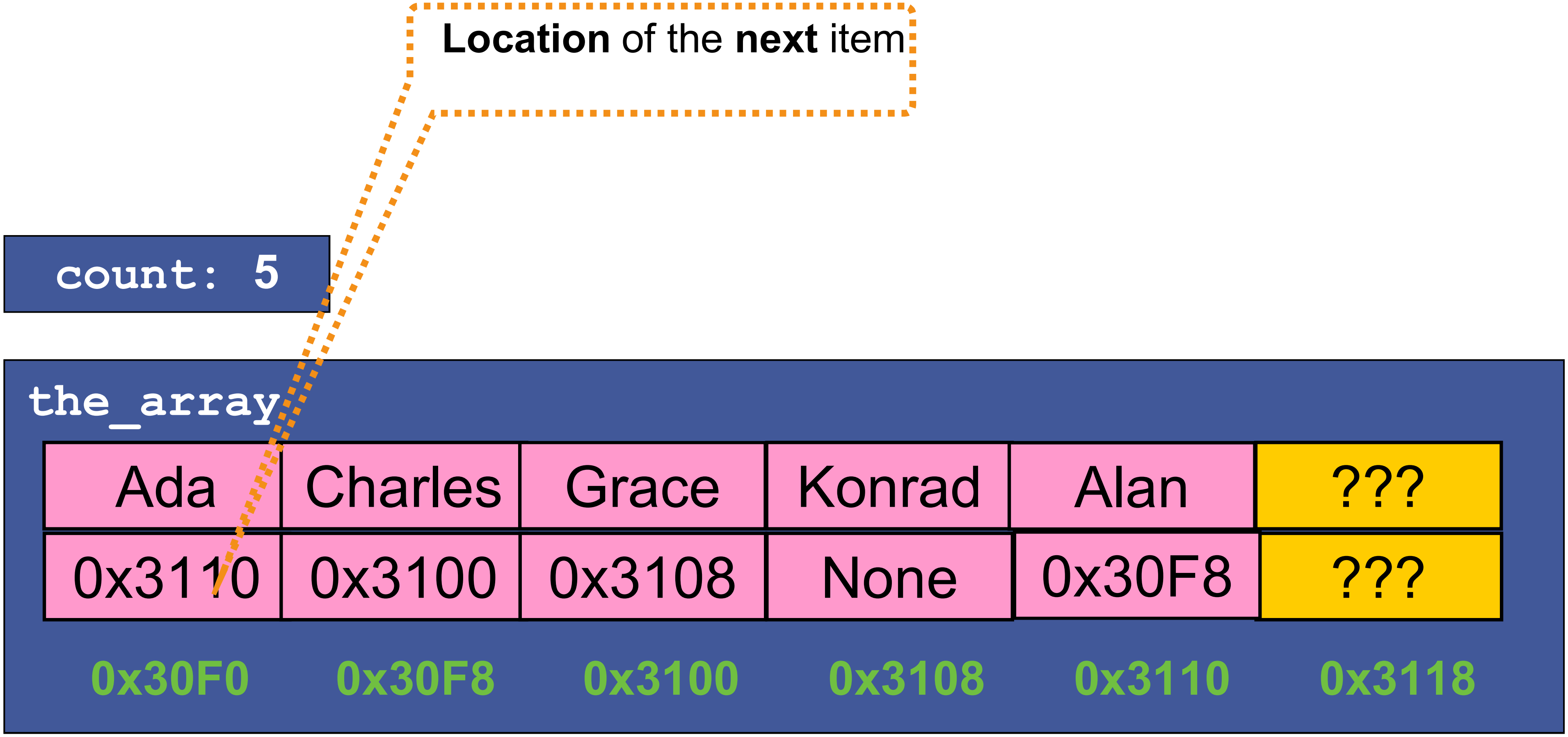
Location of the **next** item

`count: 5`

`the_array`

Ada	Charles	Grace	Konrad	Alan	???
4	2	3	-1	1	???
0	1	2	3	4	5

Why not use a **memory address** instead?

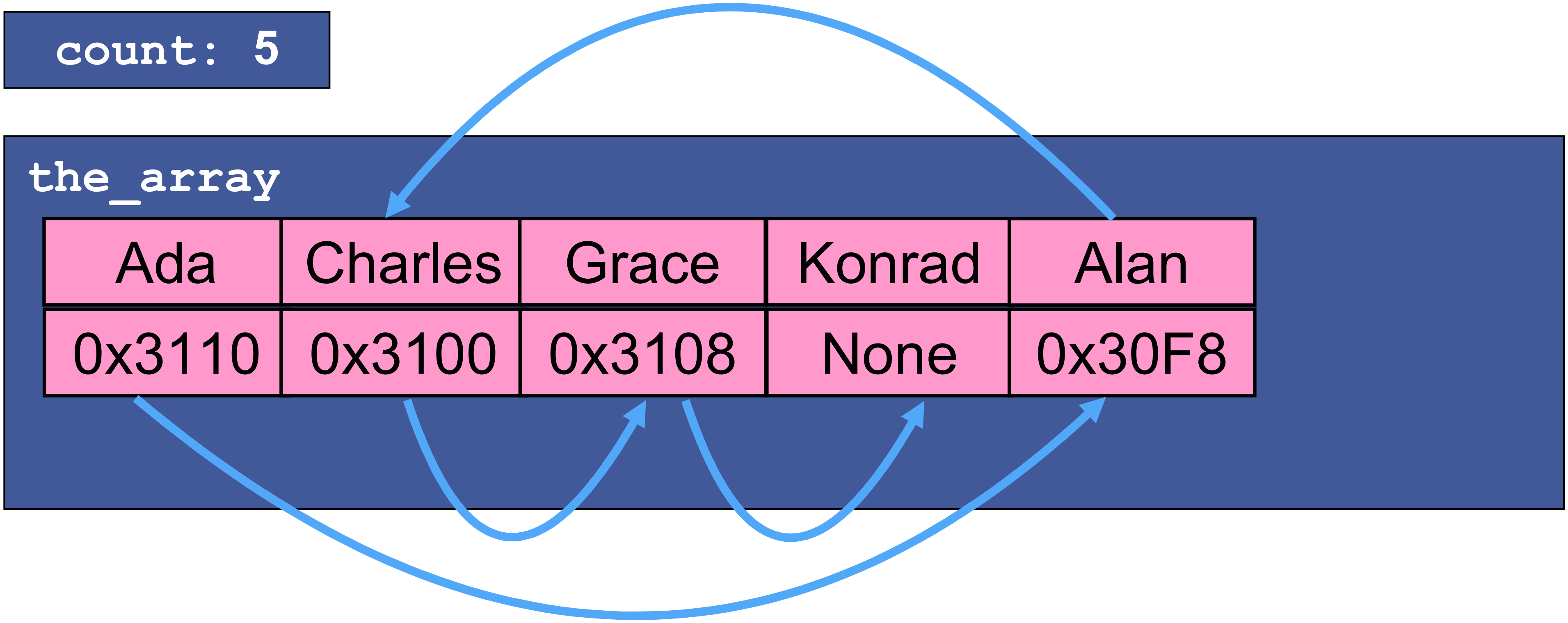


Location of the **next** item

count: 5

the_array

Ada	Charles	Grace	Konrad	Alan	???
0x3110	0x3100	0x3108	None	0x30F8	???
0x30F0	0x30F8	0x3100	0x3108	0x3110	0x3118



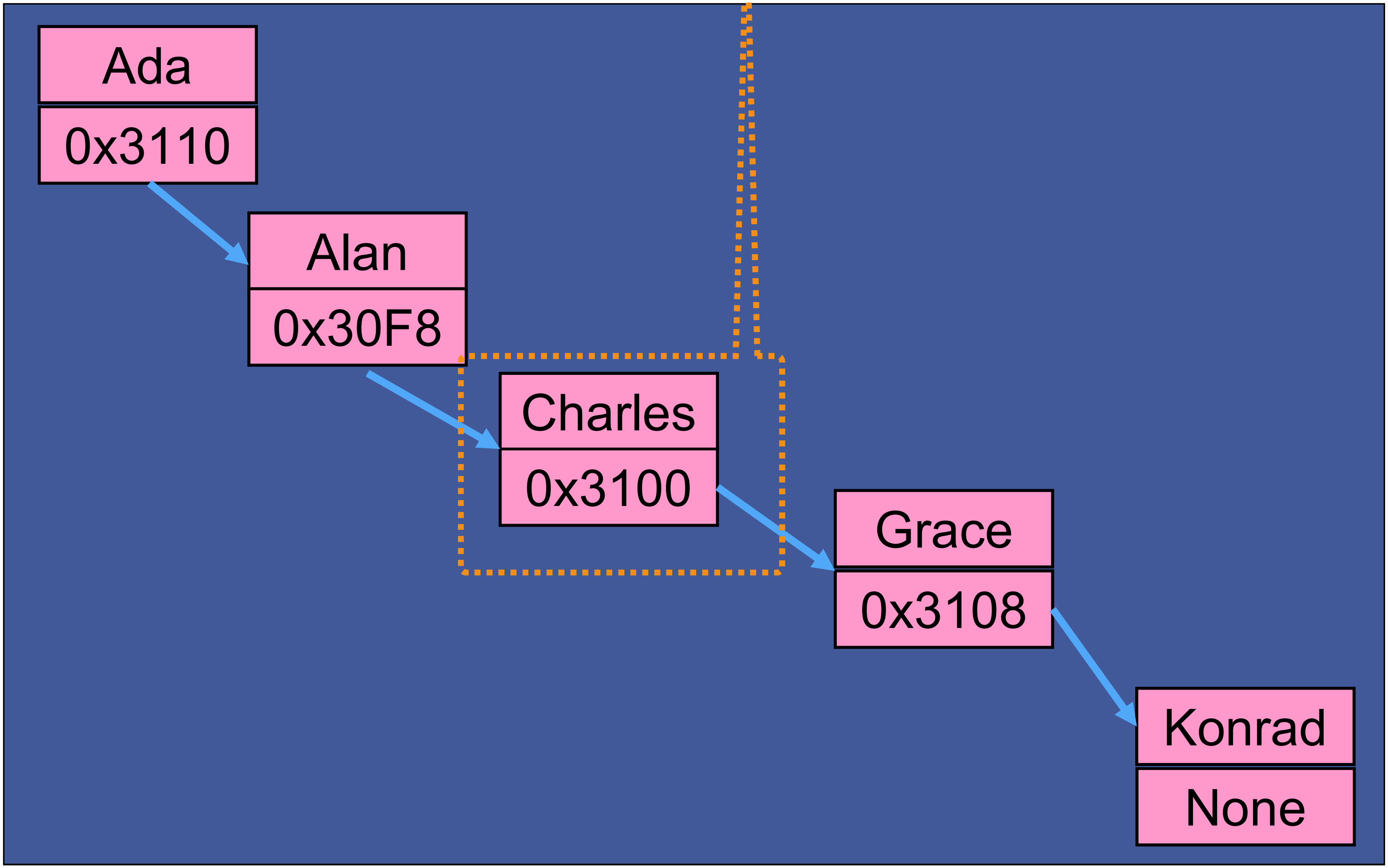
count: 5

the_array

Ada	Charles	Grace	Konrad	Alan
0x3110	0x3100	0x3108	None	0x30F8

`count: 5`

A **node**



Ada
0x3110

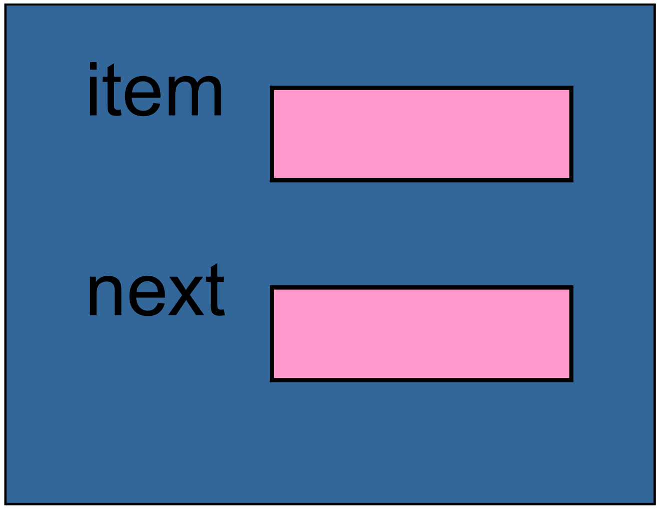
Alan
0x30F8

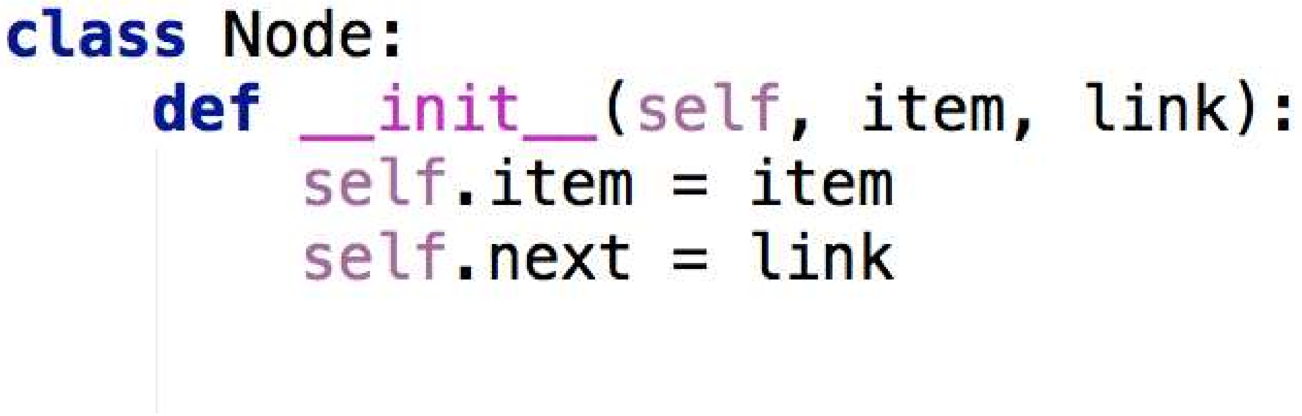
Charles
0x3100

Grace
0x3108

Konrad
None

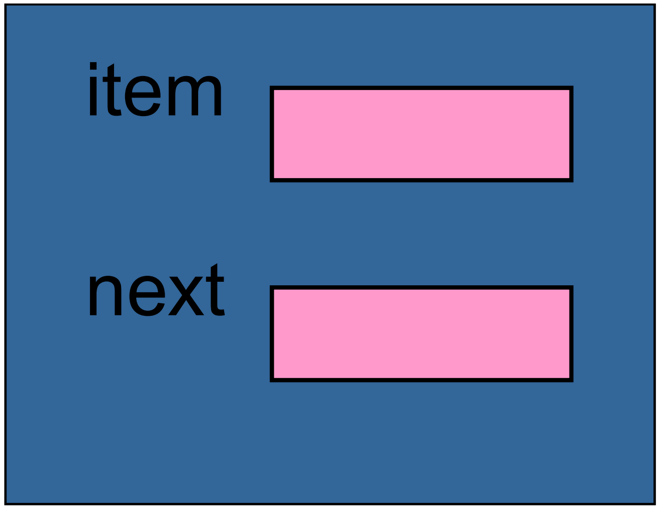
Node



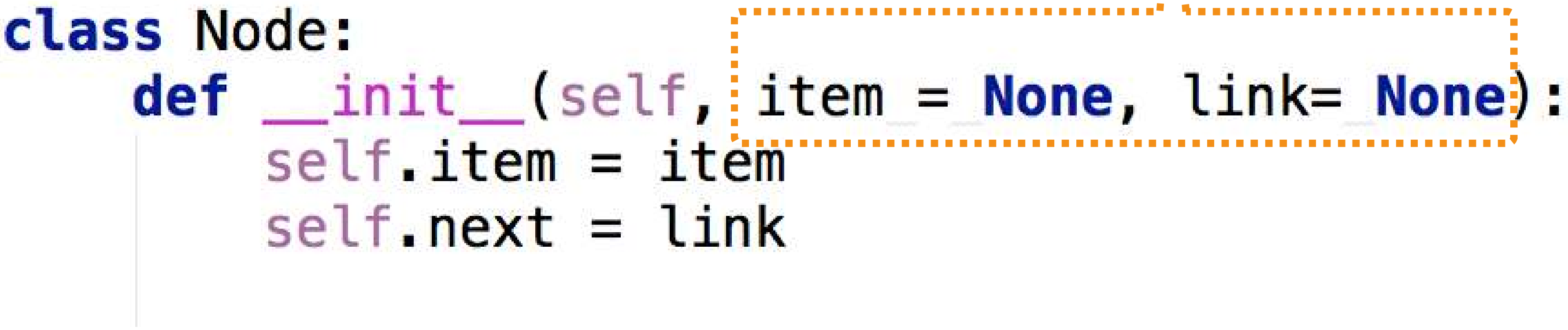


```python
class Node:
    def __init__(self, item, link):
        self.item = item
        self.next = link
```

Node

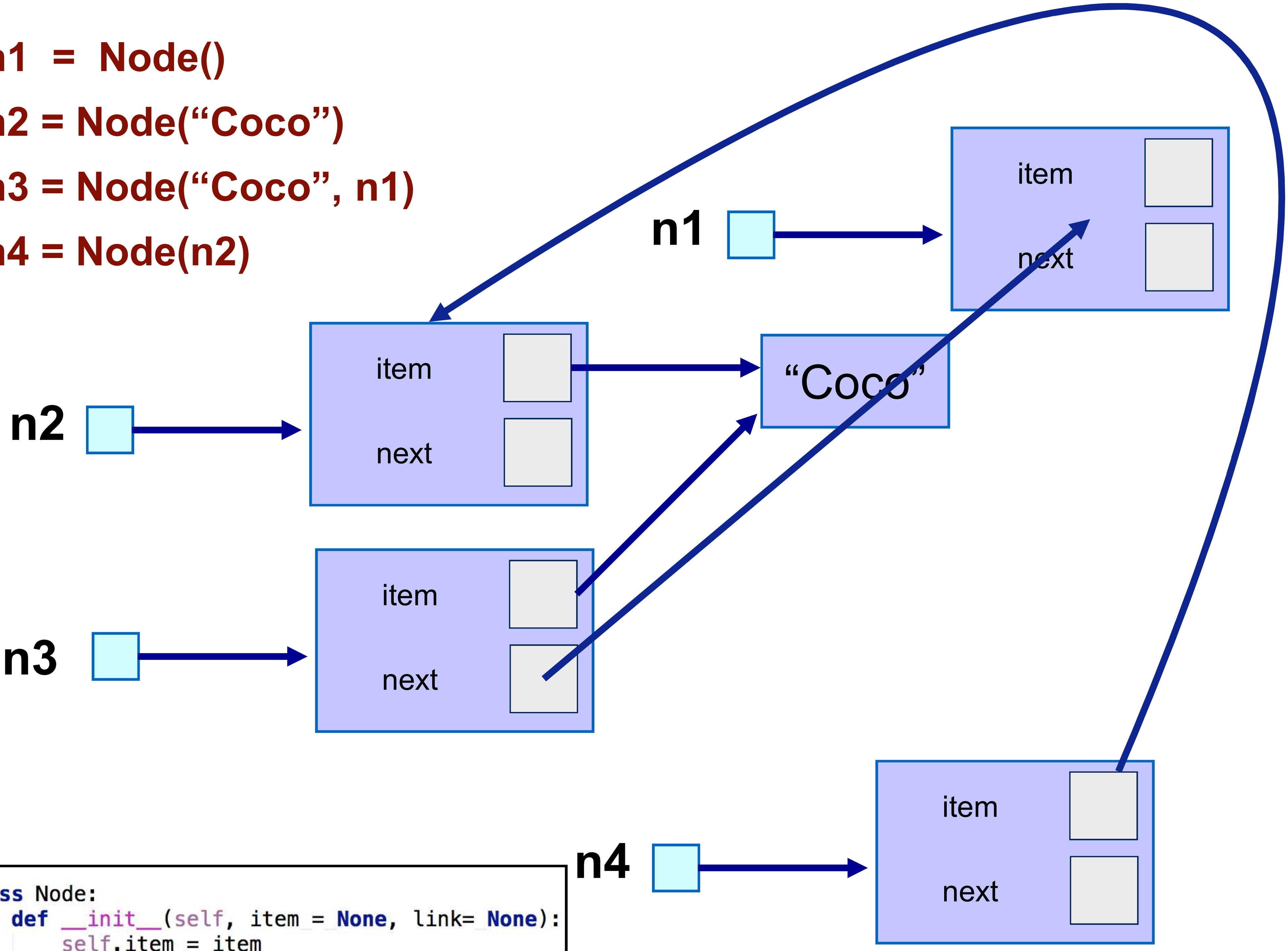


default values, if not supplied



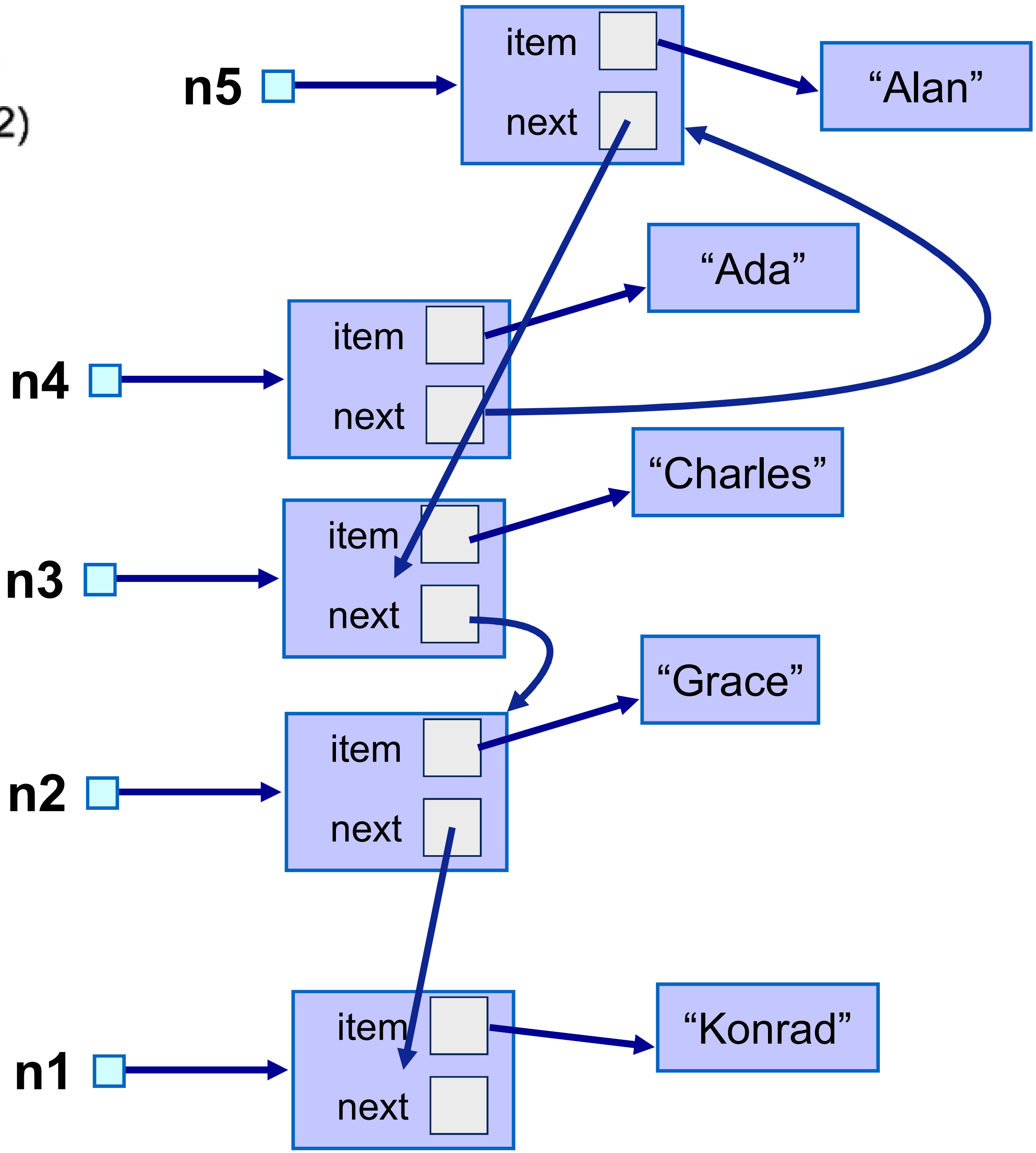
```
class Node:
    def __init__(self, item = None, link= None):
        self.item = item
        self.next = link
```

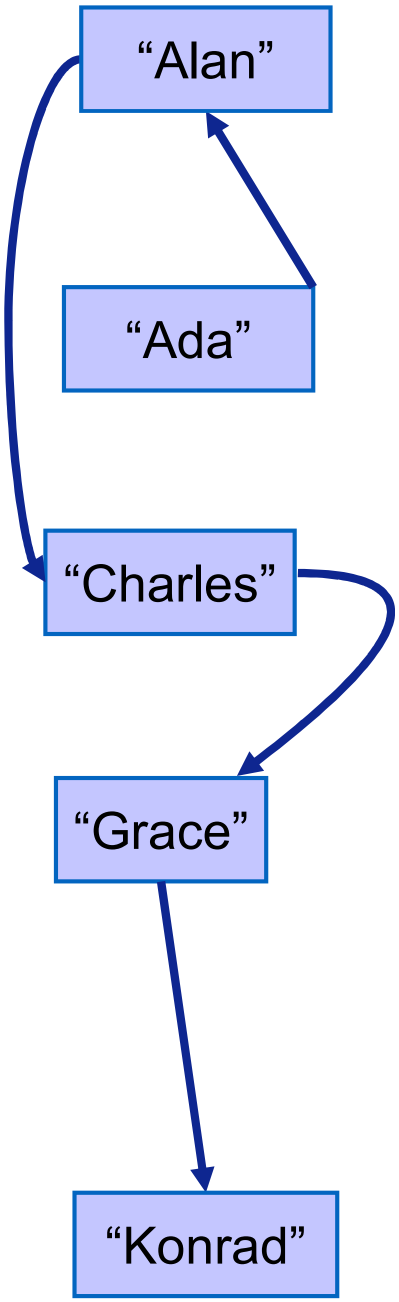
```
n1  =  Node()
n2 = Node(“Coco”)
n3 = Node(“Coco”, n1)
n4 = Node(n2)
```



```
class Node:
    def __init__(self, item = None, link= None):
        self.item = item
        self.next = link
```

```
>>> n1 = Node(“Konrad”)
>>> n2 = Node(“Grace”, n1)
>>> n3 = Node(“Charles”, n2)
>>> n4 = Node(“Ada”, n3)
>>> n5 = Node(“Alan”)
>>> n5.next = n3
>>> n4.next = n5
```





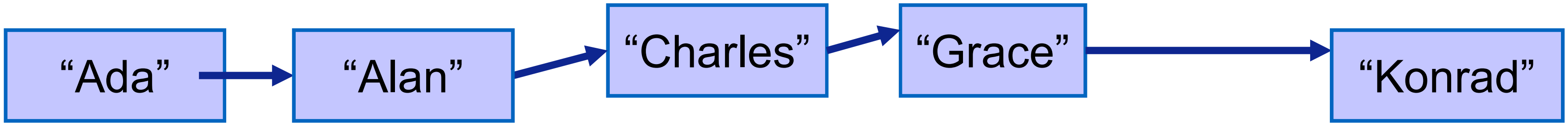
“Alan”

“Ada”

“Charles”

“Grace”

“Konrad”



“Ada”

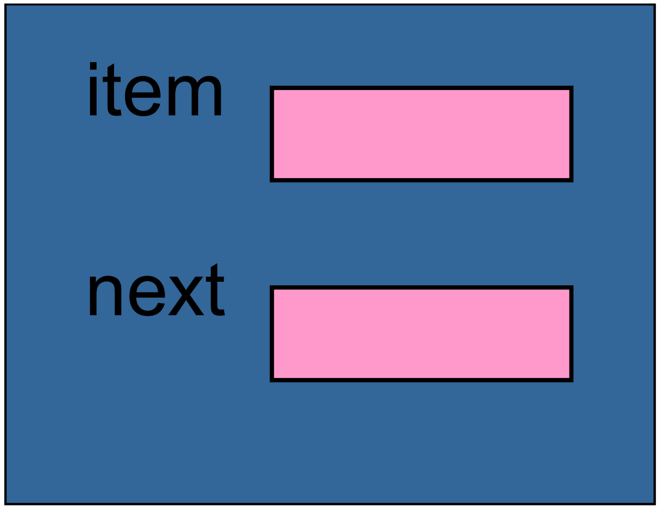
“Alan”

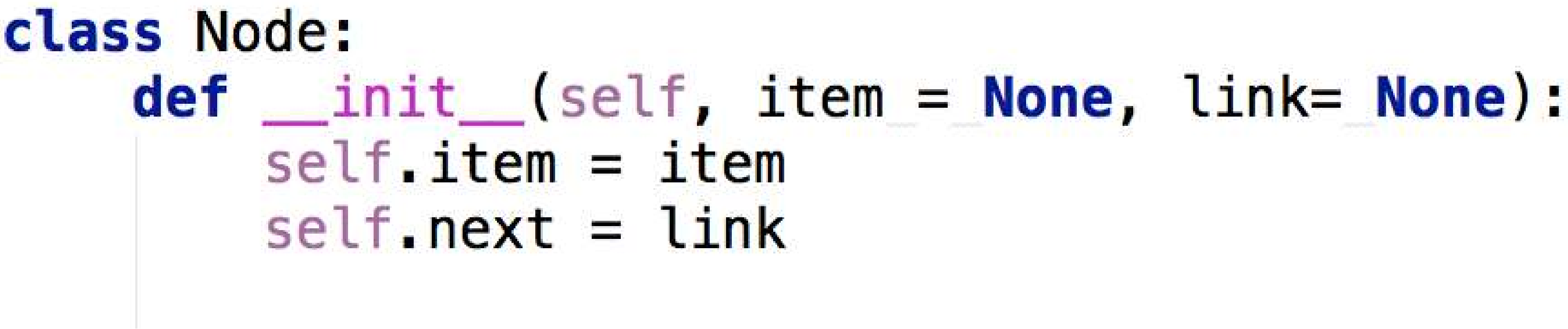
“Charles”

“Grace”

“Konrad”

Node



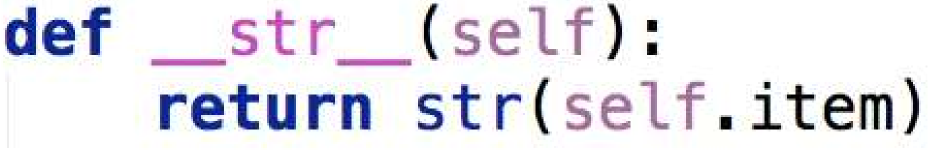


```python
class Node:
    def __init__(self, item = None, link= None):
        self.item = item
        self.next = link
```

Nodes

- Basic <u>building blocks</u> for simple **linked structures**.
- Allow easy addition of items
- Allow easy deletion of items
- Allow dynamic structures

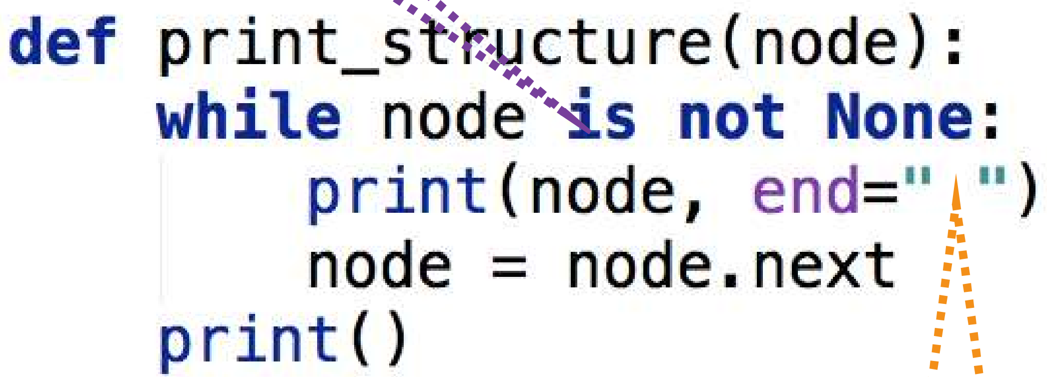
Print Node



```
def __str__(self):
    return str(self.item)
```

Print Linked Structure

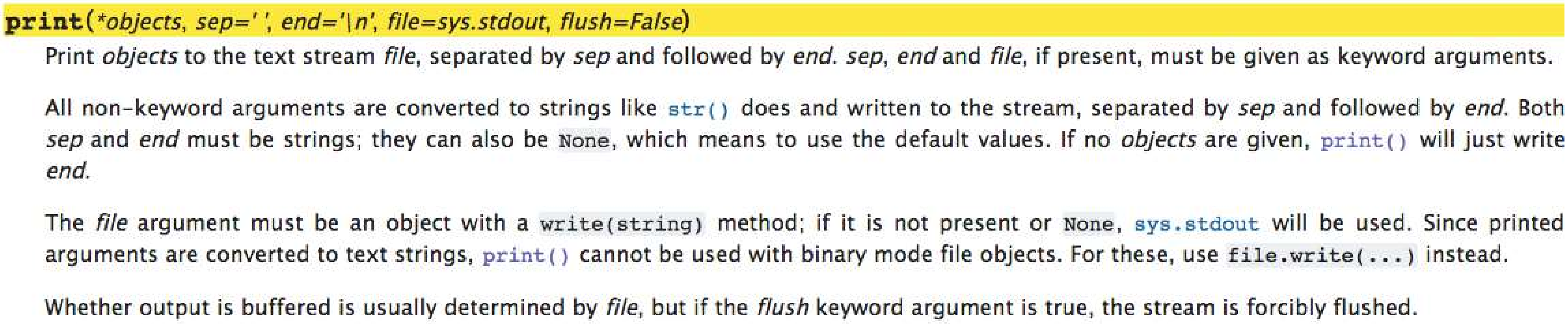
a is b, True if variables a and be point to the same object



```python
def print_structure(node):
    while node is not None:
        print(node, end=" ")
        node = node.next
    print()
```

by default end of **print** is a new line, we just want a space here

a == b, true if the objects referred to by variables a and b are equal.



`print`(**objects, sep=' ', end='\n', file=sys.stdout, flush=False*)

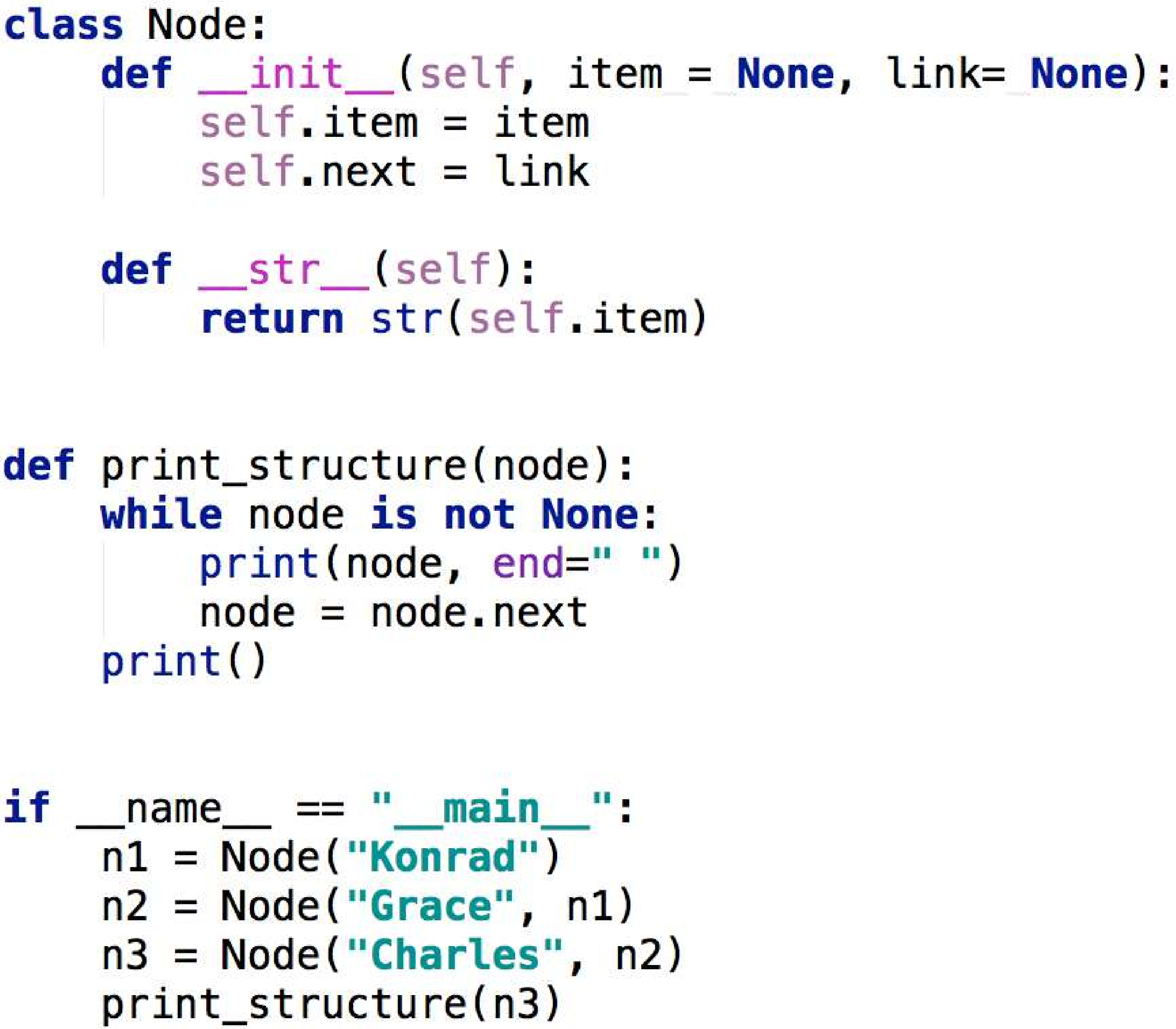
Print *objects* to the text stream *file*, separated by *sep* and followed by *end*. *sep*, *end* and *file*, if present, must be given as keyword arguments.

All non-keyword arguments are converted to strings like `str()` does and written to the stream, separated by *sep* and followed by *end*. Both *sep* and *end* must be strings; they can also be `None`, which means to use the default values. If no *objects* are given, `print()` will just write *end*.

The *file* argument must be an object with a `write(string)` method; if it is not present or `None`, `sys.stdout` will be used. Since printed arguments are converted to text strings, `print()` cannot be used with binary mode file objects. For these, use `file.write(...)` instead.

Whether output is buffered is usually determined by *file*, but if the *flush* keyword argument is true, the stream is forcibly flushed.

https://docs.python.org/3/library/functions.html#print



```python
class Node:
    def __init__(self, item = None, link= None):
        self.item = item
        self.next = link

    def __str__(self):
        return str(self.item)


def print_structure(node):
    while node is not None:
        print(node, end=" ")
        node = node.next
    print()


if __name__ == "__main__":
    n1 = Node("Konrad")
    n2 = Node("Grace", n1)
    n3 = Node("Charles", n2)
    print_structure(n3)
```

Summary

- Linked Structures
- Nodes