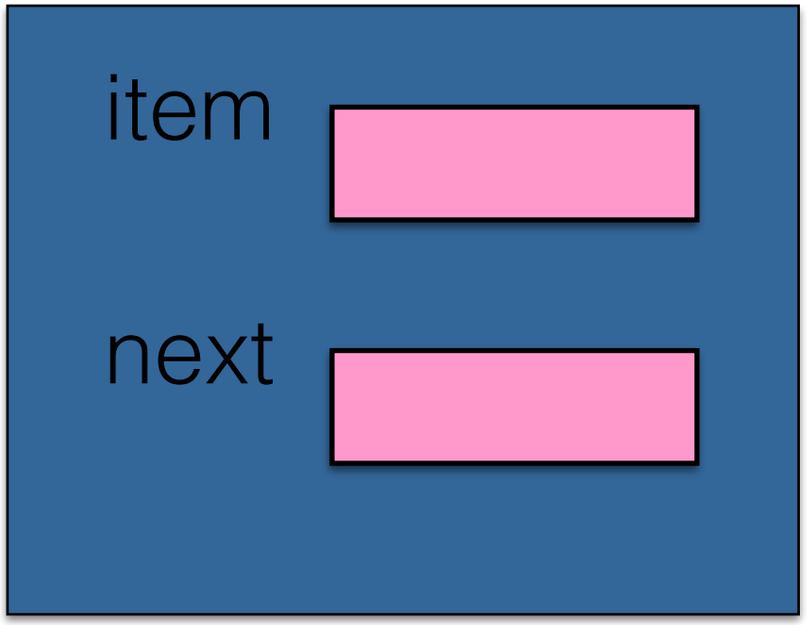
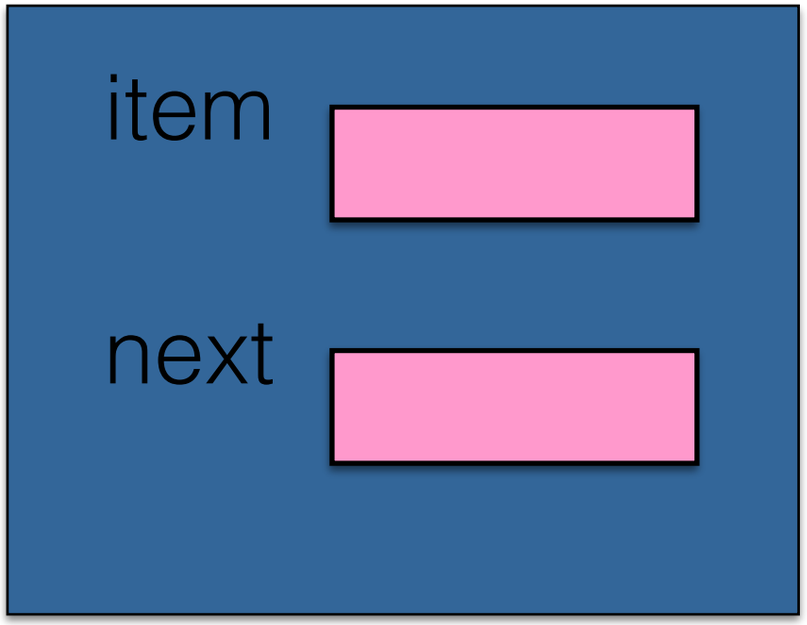
Did you watch the video?

Node

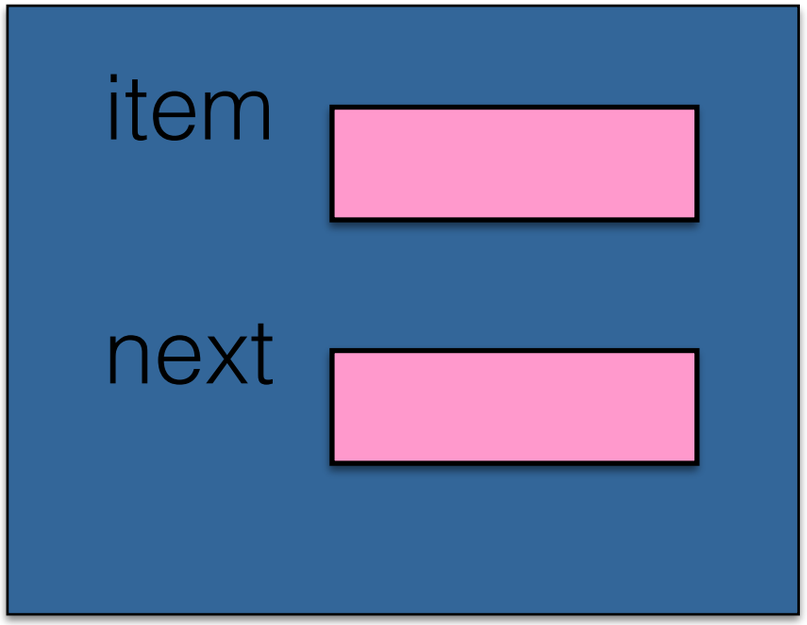


Node



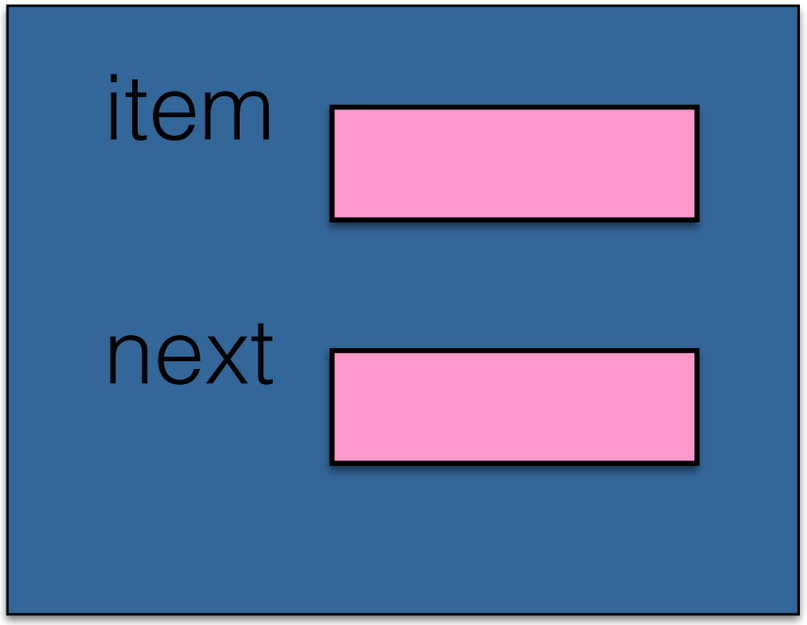

```
class Node:
    def __init__(self, item, link):
        self.item = item
        self.next = link
```

Node




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

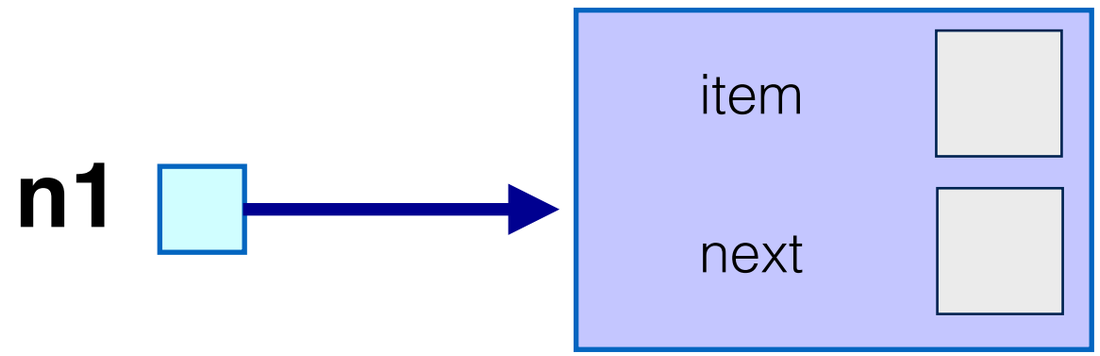
Node



default values, if not supplied

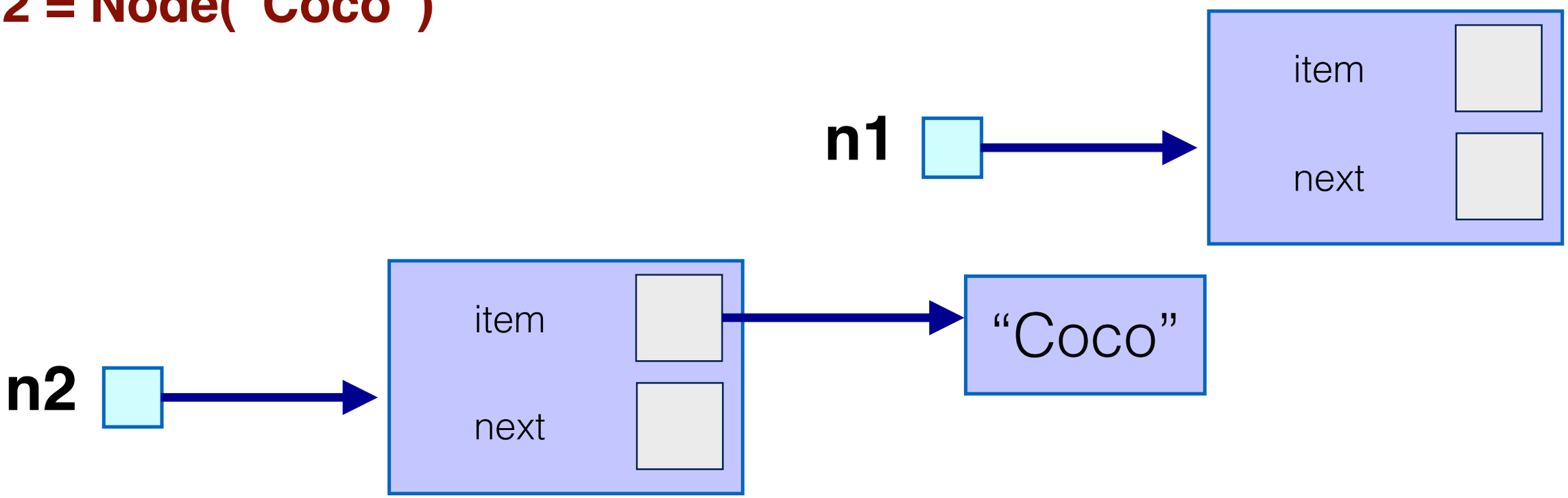
```
class Node:
    def __init__(self, item = None, link= None):
        self.item = item
        self.next = link
```

n1 = Node()



n1 = Node()

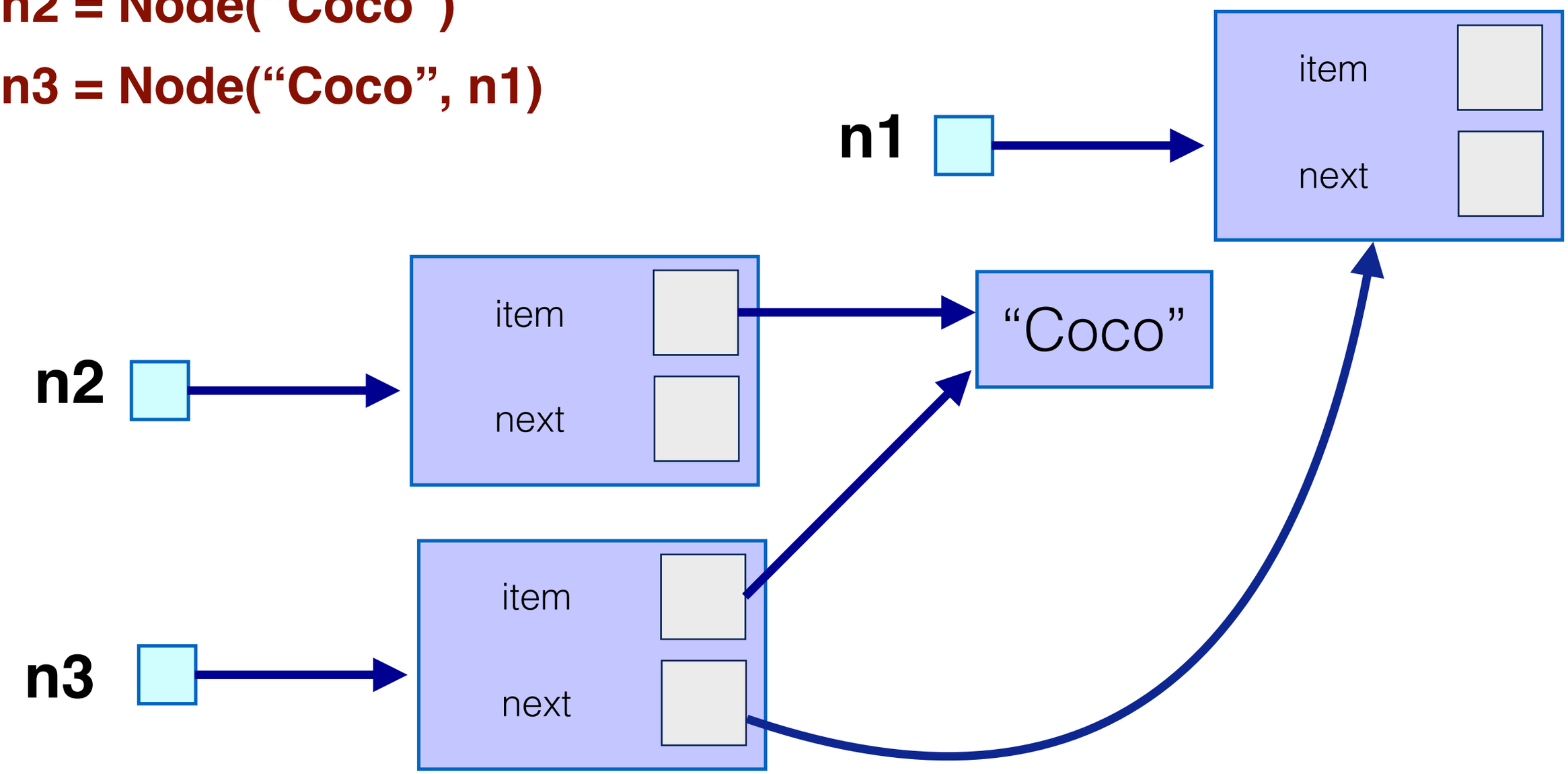
n2 = Node("Coco")



n1 = Node()

n2 = Node("Coco")

n3 = Node("Coco", n1)

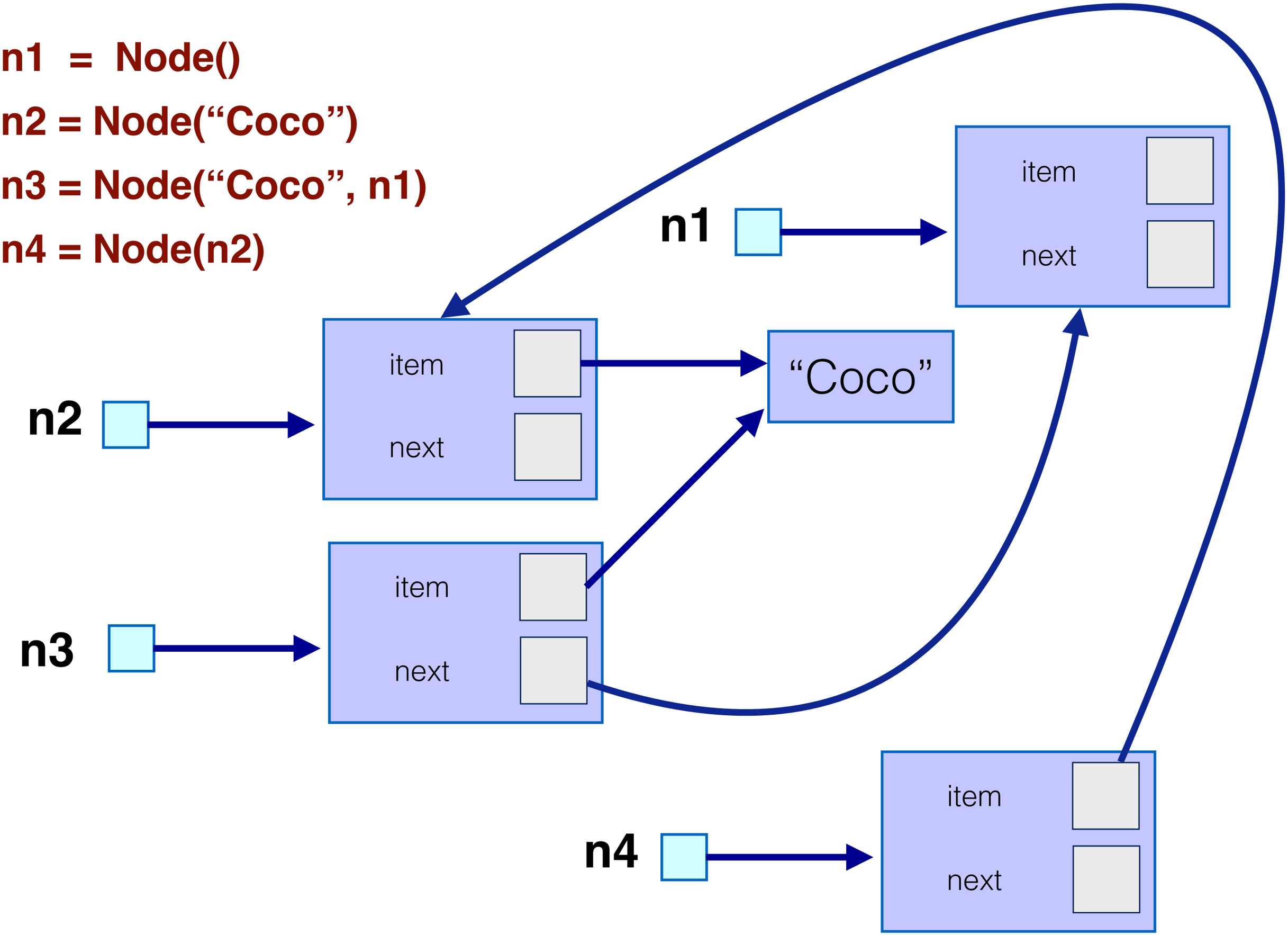


n1 = Node()

n2 = Node("Coco")

n3 = Node("Coco", n1)

n4 = Node(n2)

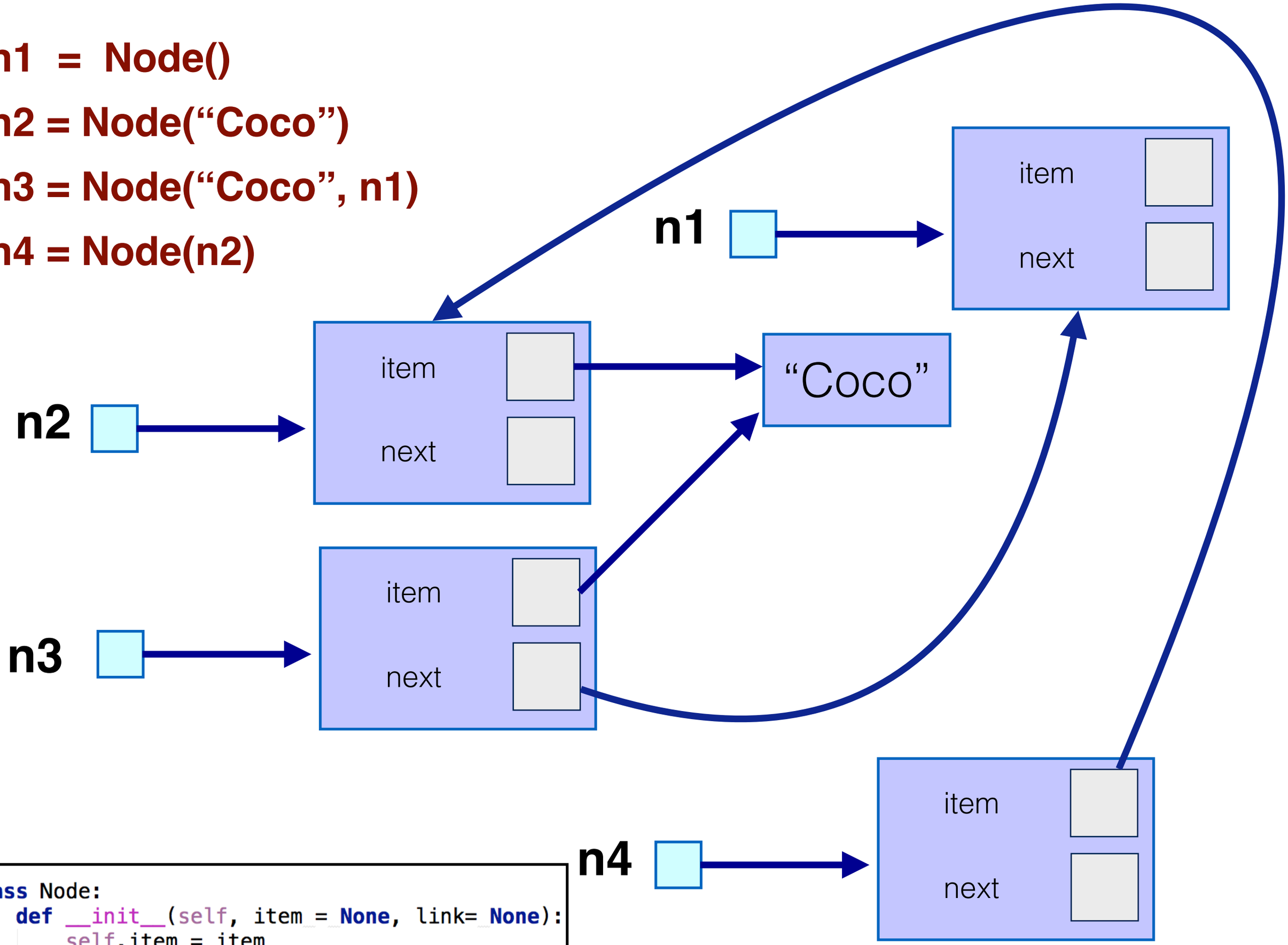


n1 = Node()

n2 = Node("Coco")

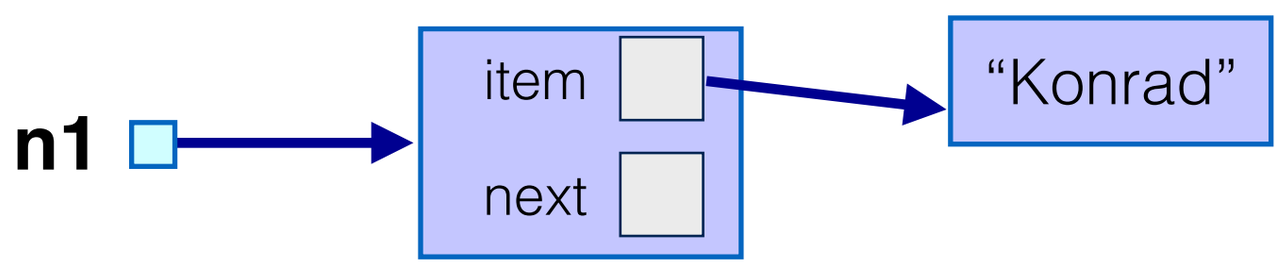
n3 = Node("Coco", n1)

n4 = Node(n2)

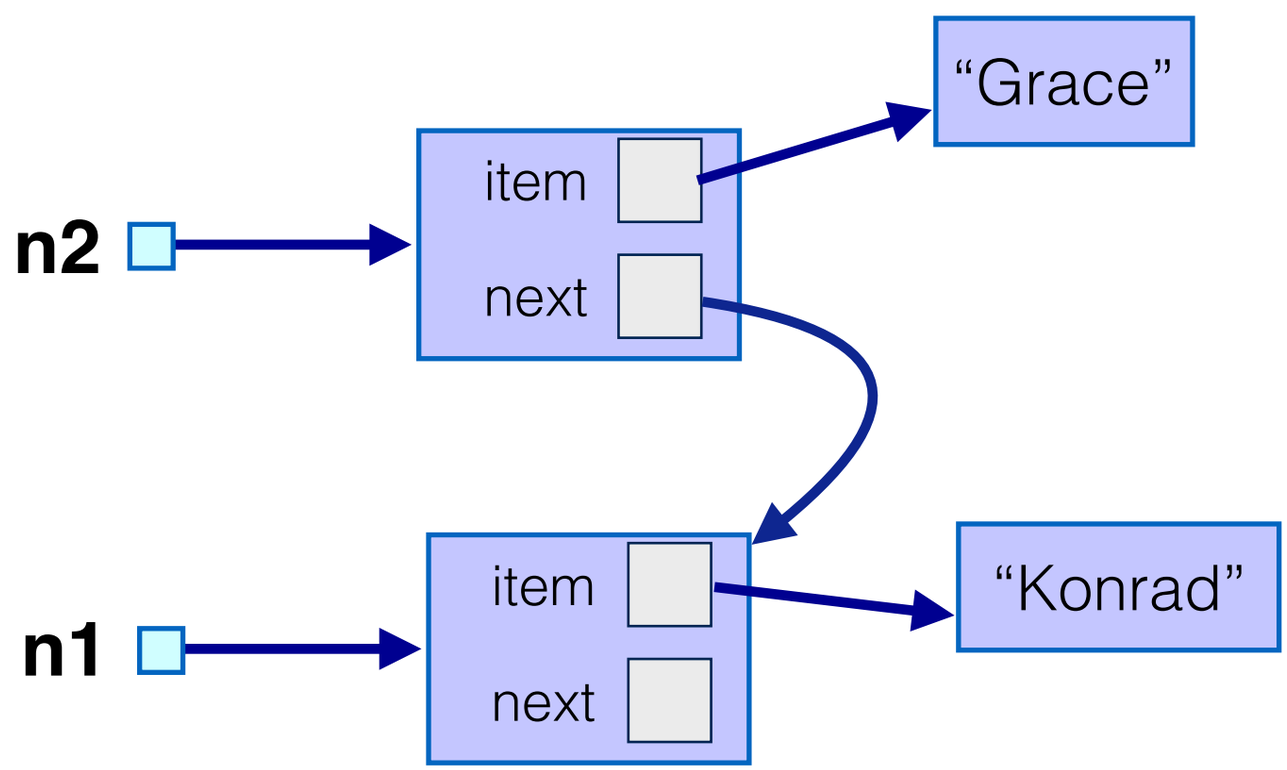



```
class Node:
    def __init__(self, item = None, link= None):
        self.item = item
        self.next = link
```

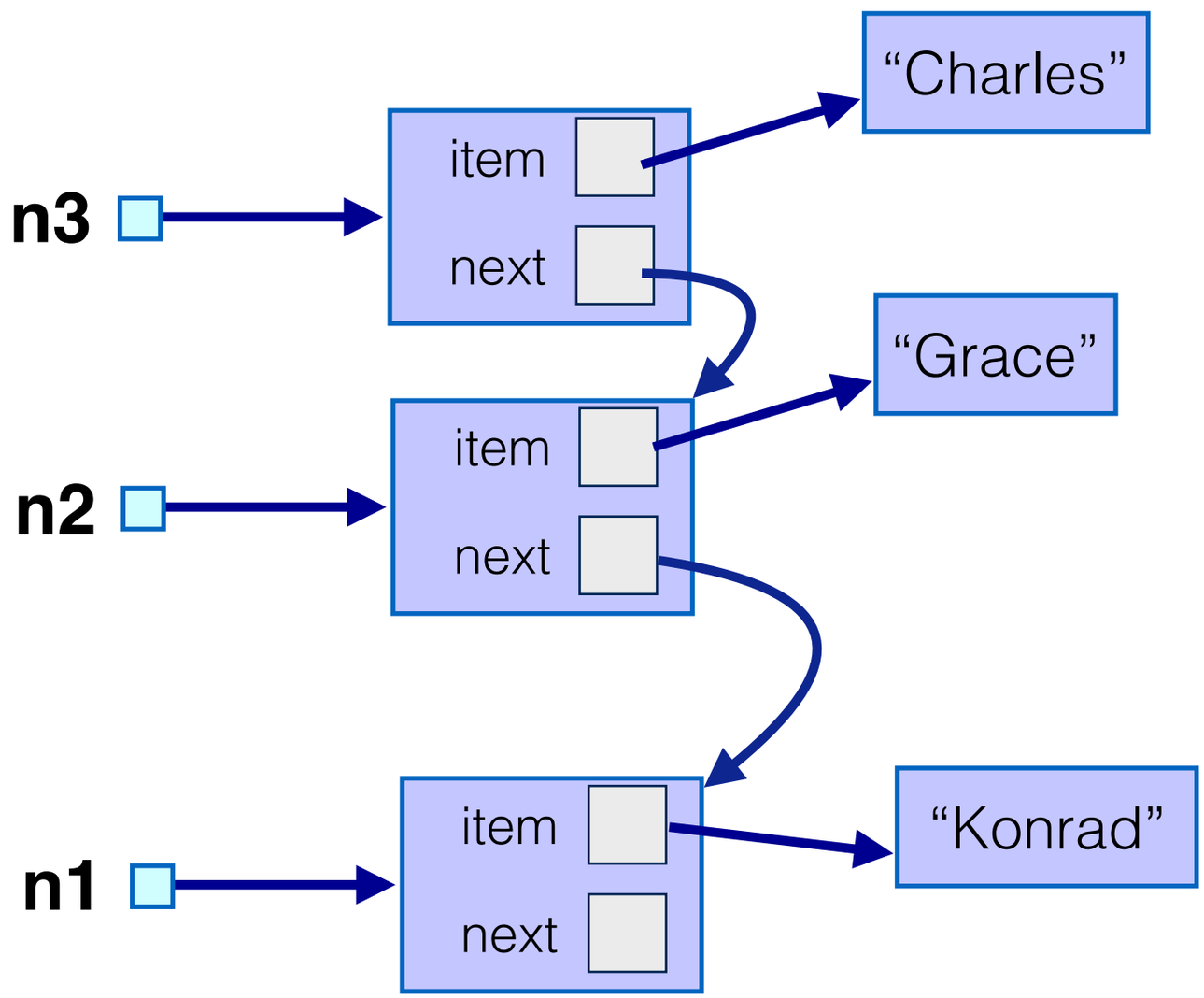
```
>>> n1 = Node("Konrad")
```



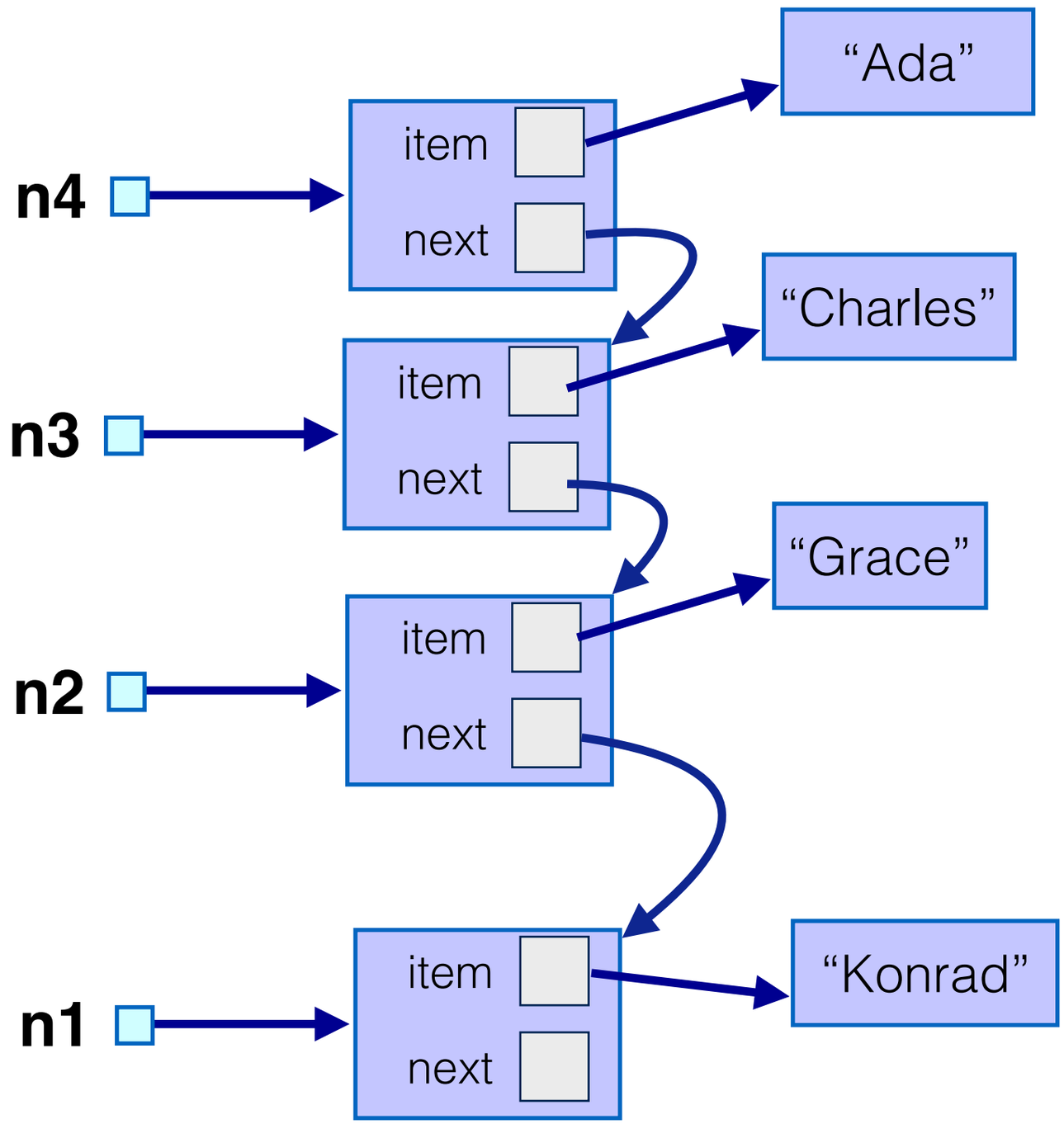
```
>>> n1 = Node("Konrad")
>>> n2 = Node("Grace", n1)
```



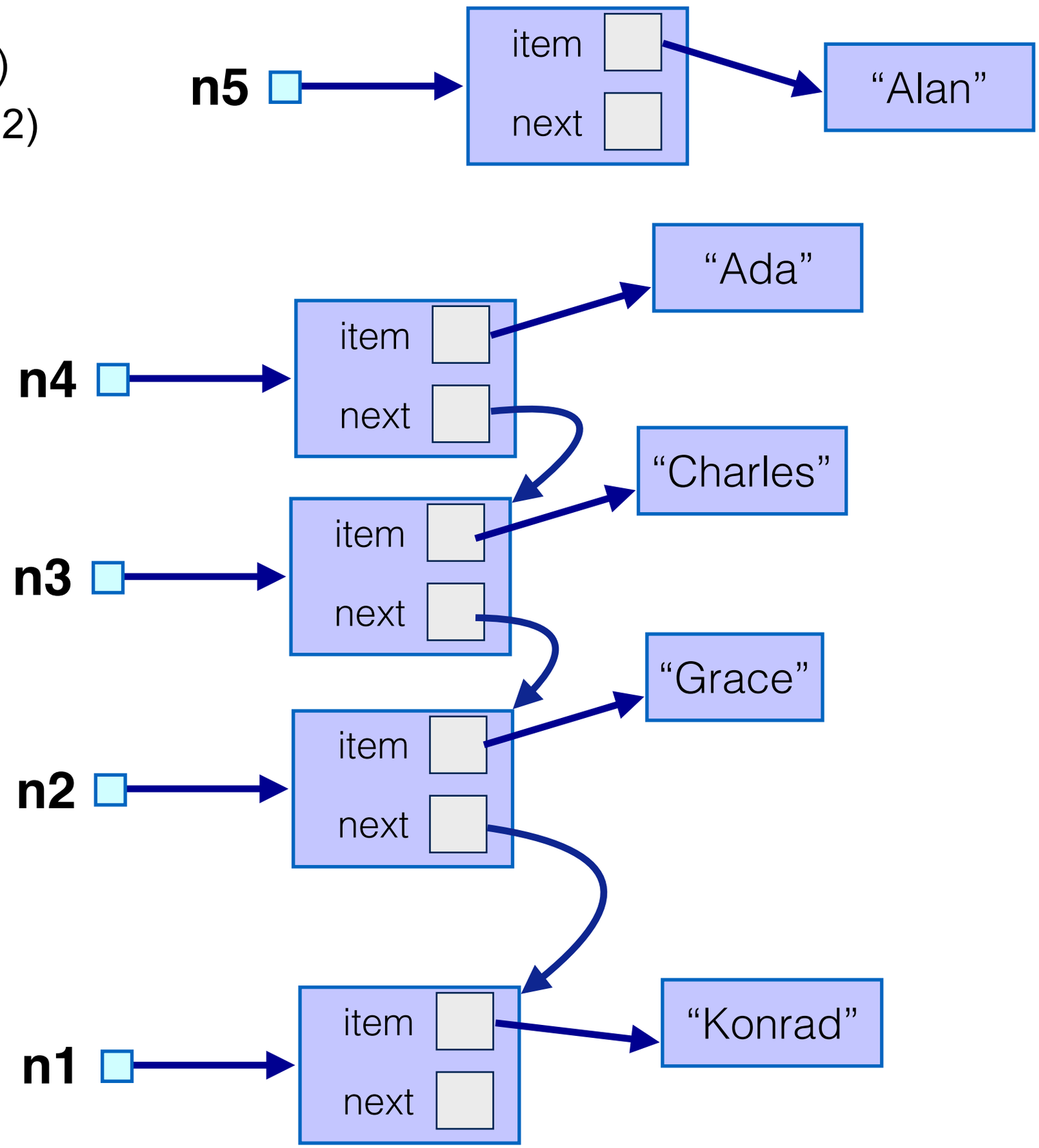
```
>>> n1 = Node("Konrad")
>>> n2 = Node("Grace", n1)
>>> n3 = Node("Charles", n2)
```



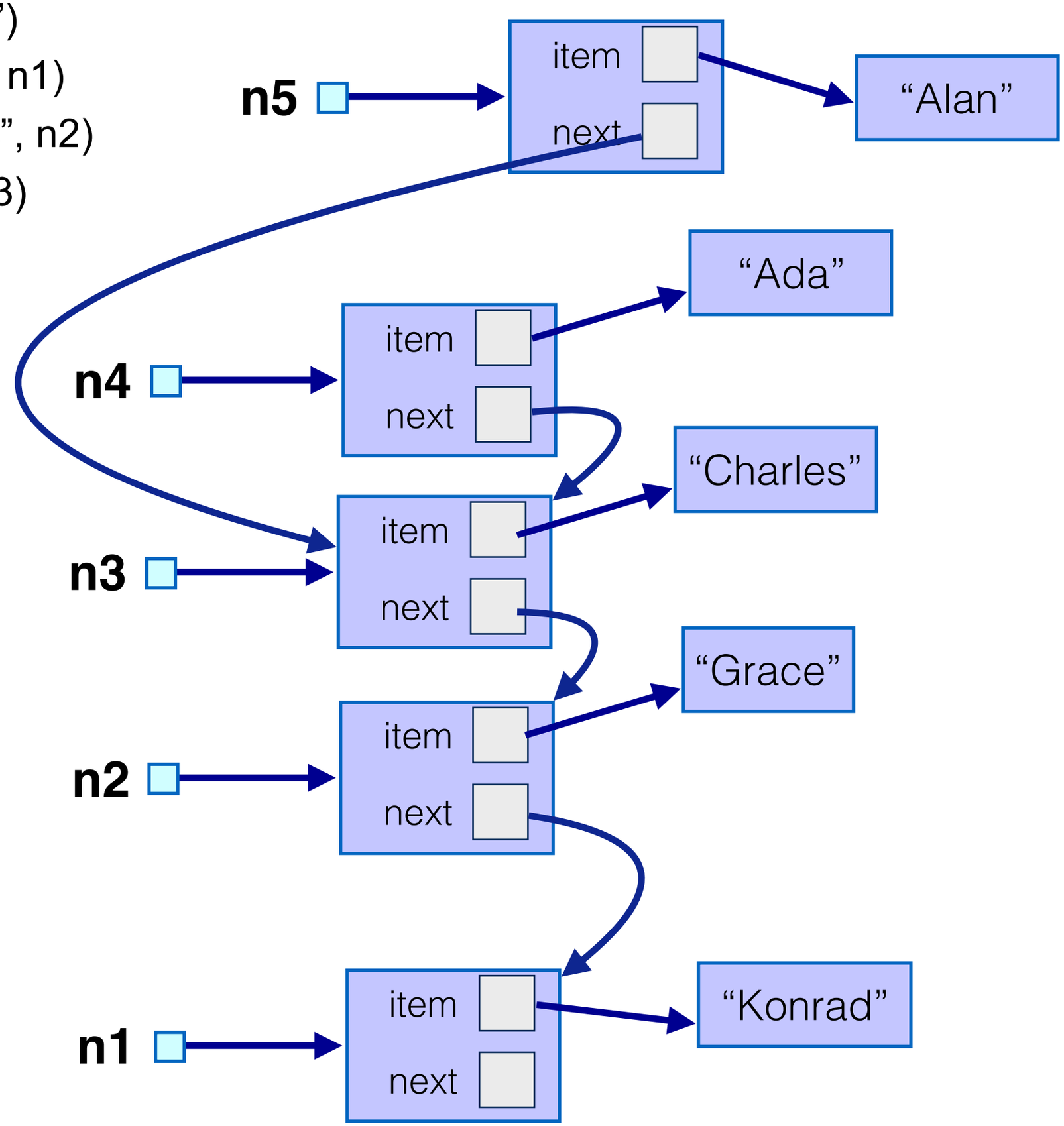
```
>>> n1 = Node("Konrad")
>>> n2 = Node("Grace", n1)
>>> n3 = Node("Charles", n2)
>>> n4 = Node("Ada", n3)
```



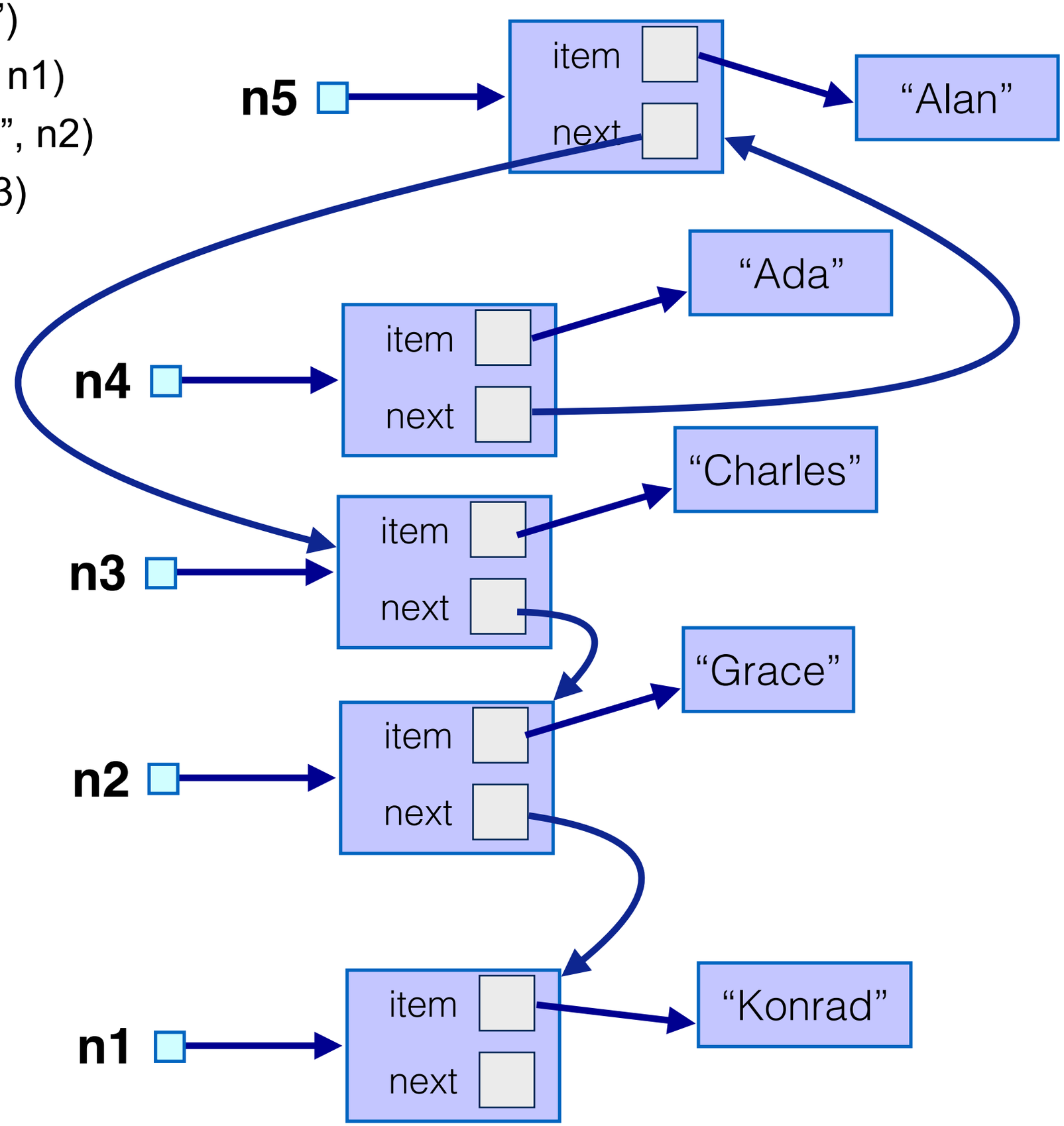
```
>>> n1 = Node("Konrad")
>>> n2 = Node("Grace", n1)
>>> n3 = Node("Charles", n2)
>>> n4 = Node("Ada", n3)
>>> n5 = Node("Alan")
```

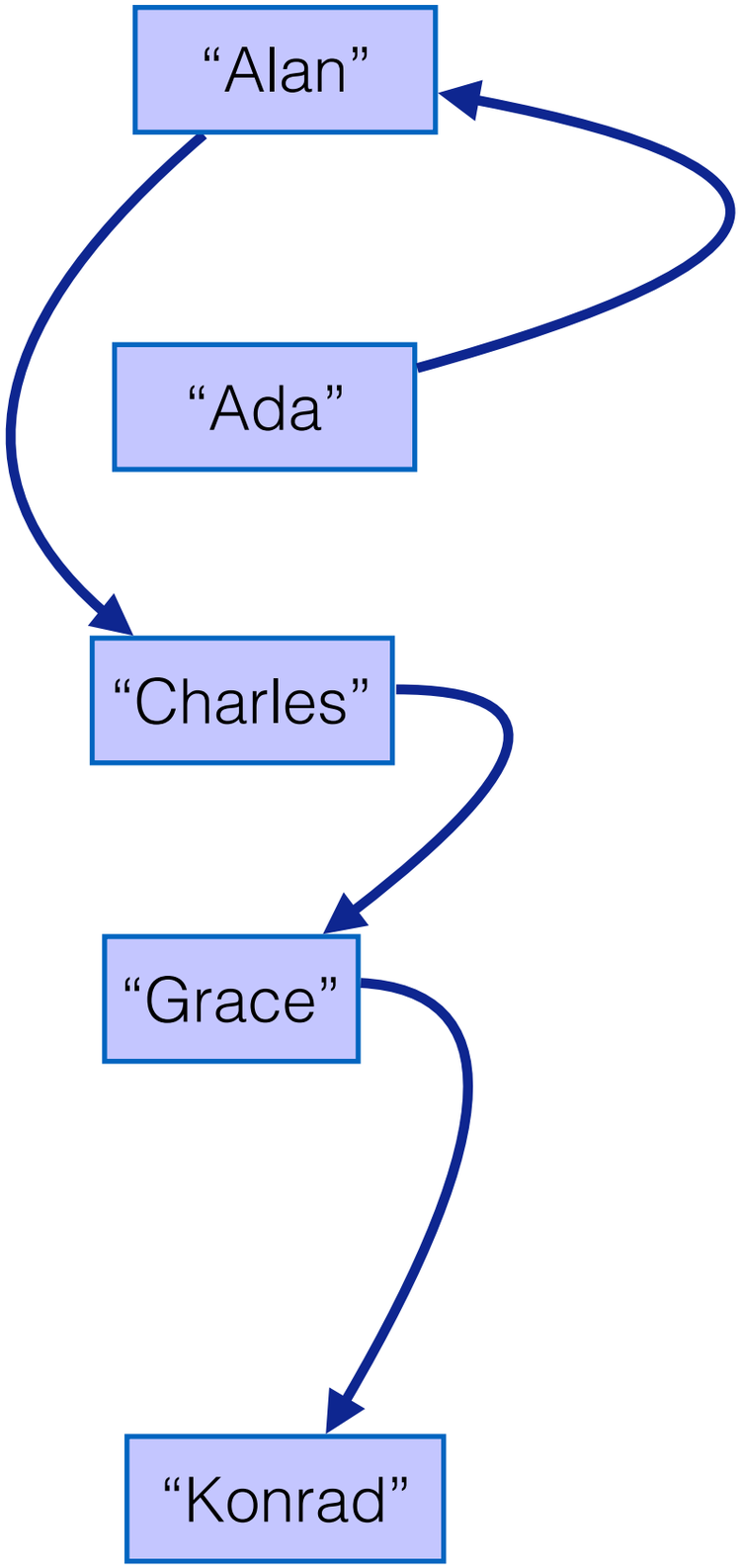


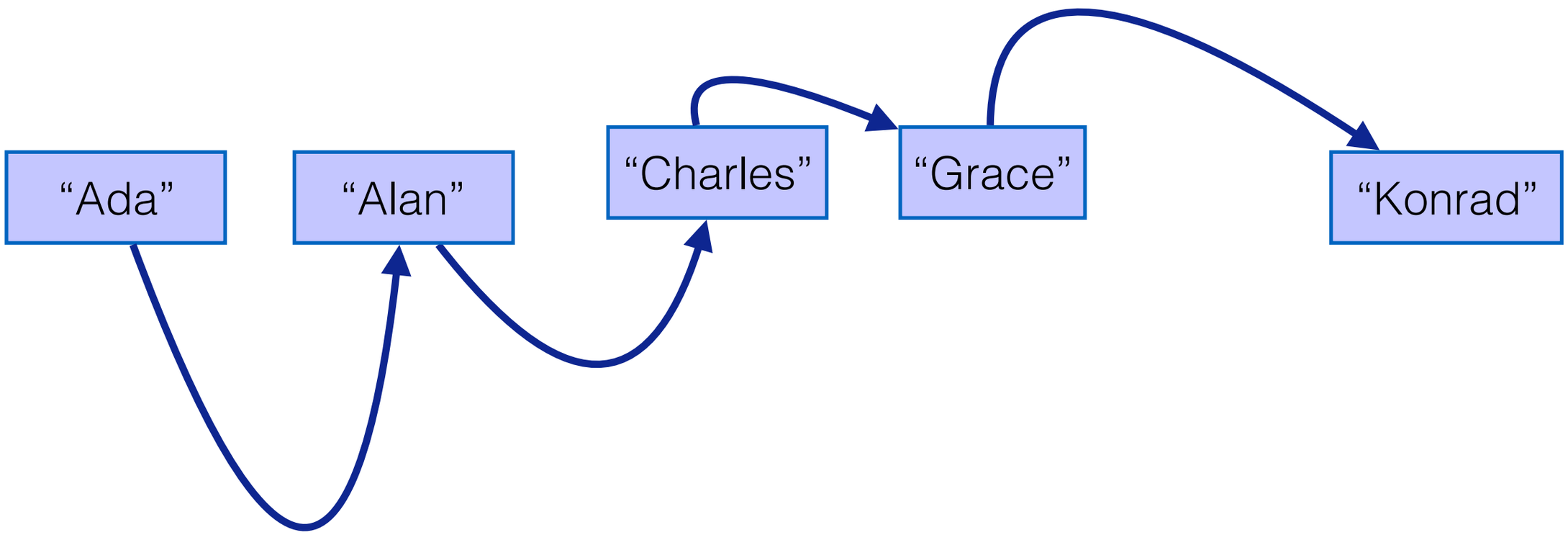
```
>>> n1 = Node("Konrad")
>>> n2 = Node("Grace", n1)
>>> n3 = Node("Charles", n2)
>>> n4 = Node("Ada", n3)
>>> n5 = Node("Alan")
>>> n5.next = n3
```



```
>>> 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”

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

Check if two things are **the same ,** use **is**

Check if two things are **identical,** use **==**

calls `__eq__(self, other)`

Prepared by Julian García, based on material by
David Albrecht and María García de la Banda

Lecture 24
Linked Stacks

FIT 1008
Introduction to Computer Science

MONASH University
Information Technology

Objectives for these this lecture

- To understand:
  - The concept of **linked data structures**
  - Their use in **implementing stacks**

- To be able to:
  - Implement, use and modify linked stacks
  - Decide when it is appropriate to use them (rather than arrays)

Where are we at?

- Implemented container ADT using arrays
- Know about Linked Structures
- Have implemented Nodes

How many of the following characteristics does a linked data structure has?

- Fixed size
- Data stored sequentially
- Each item occupies the same amount of space

A) 0

B) 1

C) 2

D) 3

How many of the following characteristics does a linked data structure has?

- Fixed size
- Data stored sequentially
- Each item occupies the same amount of space

A) 0

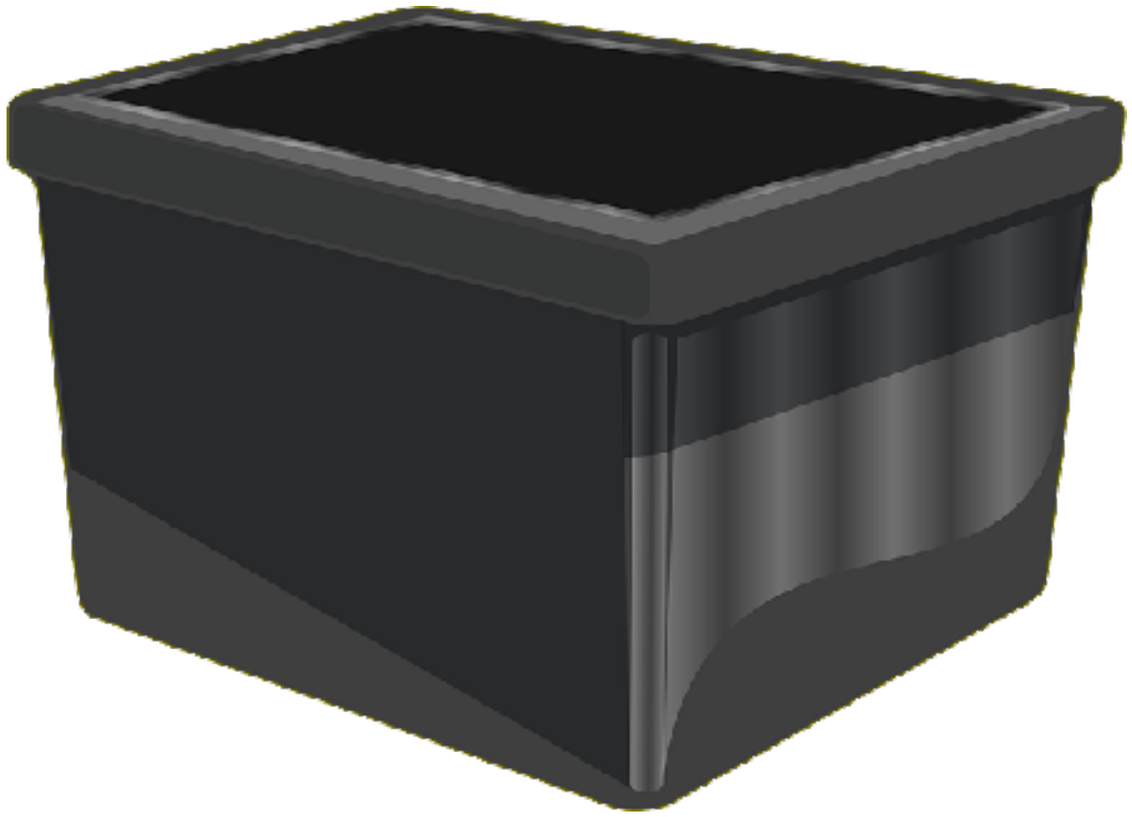
B) 1

C) 2

D) 3

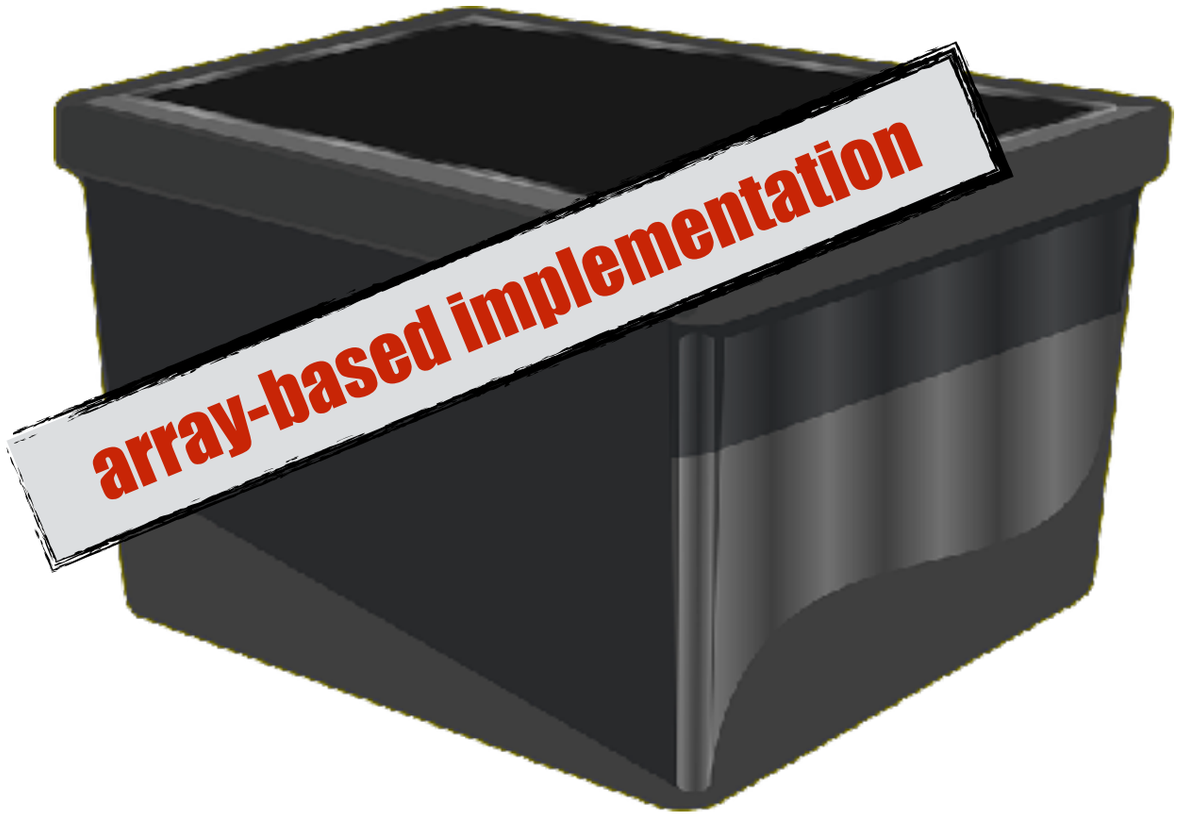
Container ADTs

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



Container ADTs

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

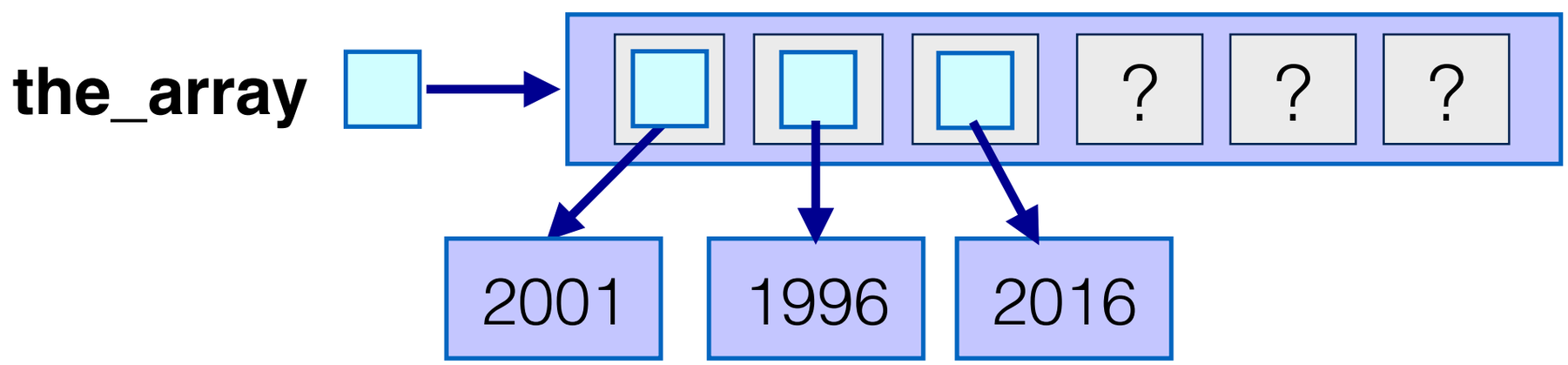


Array implementation

- Array **characteristics**:
  - Fixed size
  - Data items are stored sequentially
  - Each item occupies exactly the same amount of space

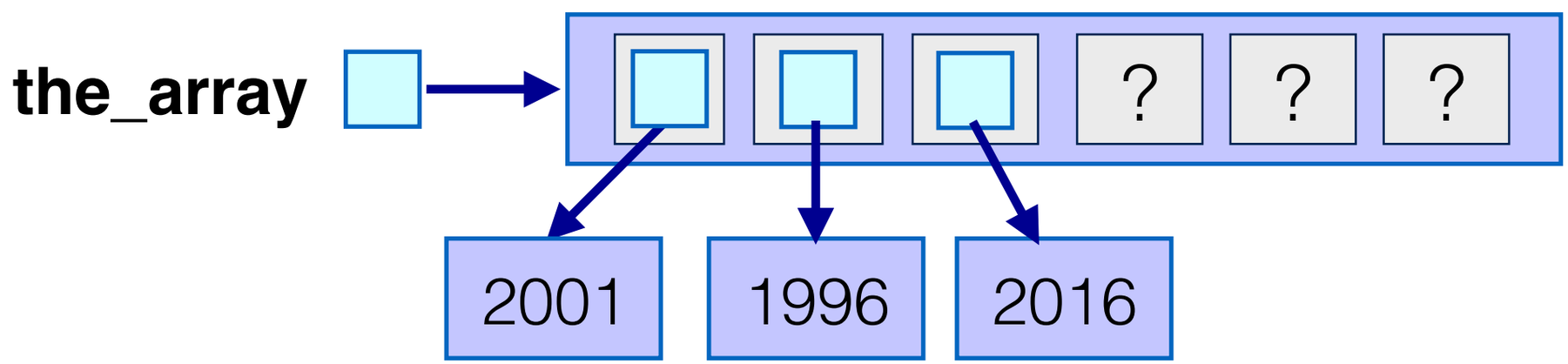
Array implementation

- Array **characteristics**:
  - Fixed size
  - Data items are stored sequentially
  - Each item occupies exactly the same amount of space



Array implementation

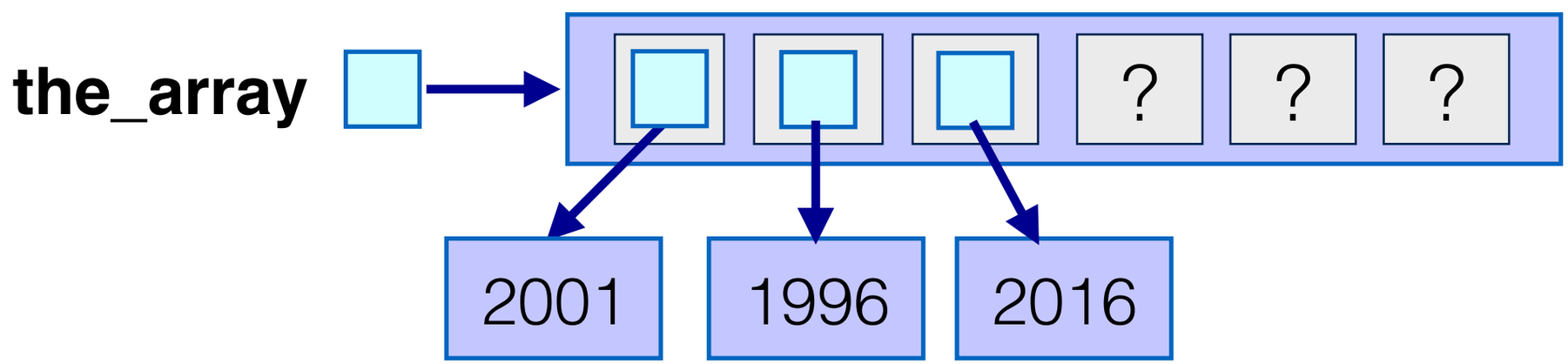
- Array **characteristics**:
  - Fixed size
  - Data items are stored sequentially
  - Each item occupies exactly the same amount of space



- Main **advantages**:
  - Very **fast** access O(1)
  - Very **compact** representation if the array is full

Array implementation

- Array **characteristics**:
  - Fixed size
  - Data items are stored sequentially
  - Each item occupies exactly the same amount of space

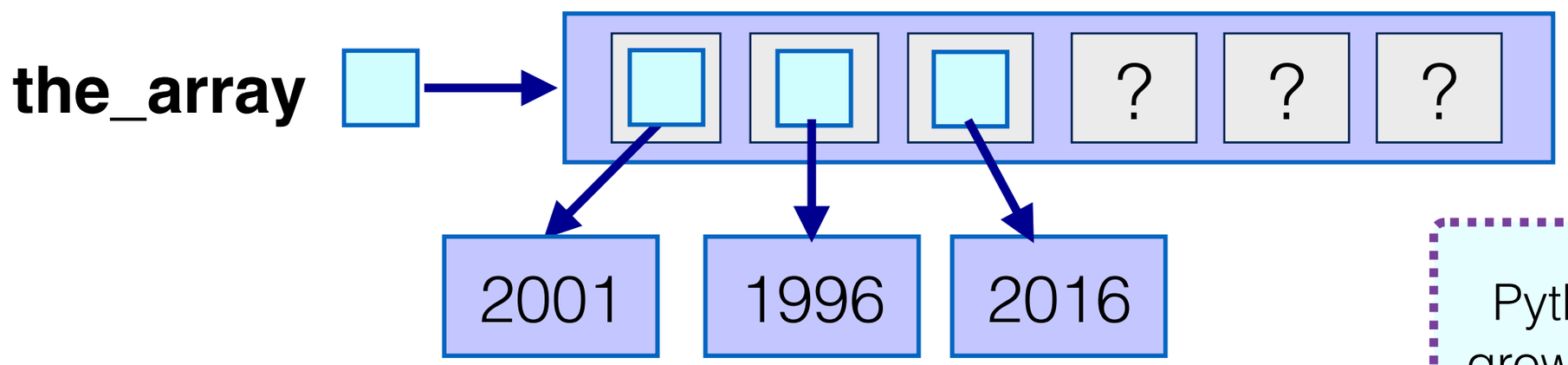


- Main **advantages**:
  - Very **fast** access O(1)
  - Very **compact** representation if the array is full

- Main **disadvantages**:
  - Non-resizable: maximum size specified on creation
  - Changing size is costly: **create a new array + copy all items**
  - Slow operations if shuffling elements is required

Array implementation

- Array **characteristics**:
  - Fixed size
  - Data items are stored sequentially
  - Each item occupies exactly the same amount of space

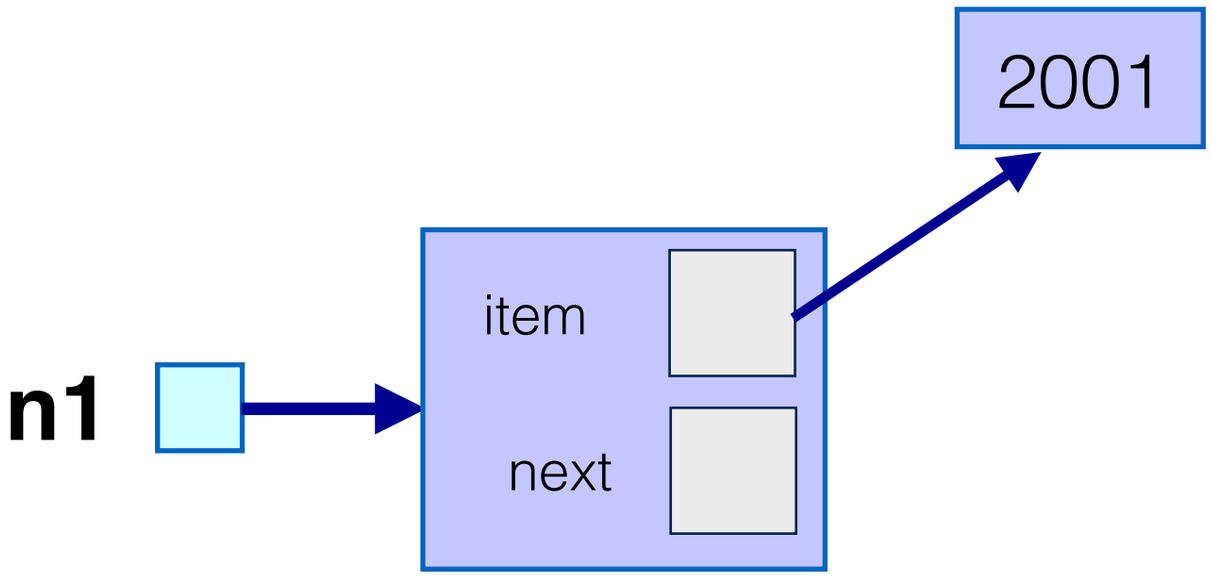


Python lists: array growth pattern is 0, 4, 8, 16, 25, 35, 46, 58, 72, 88,…

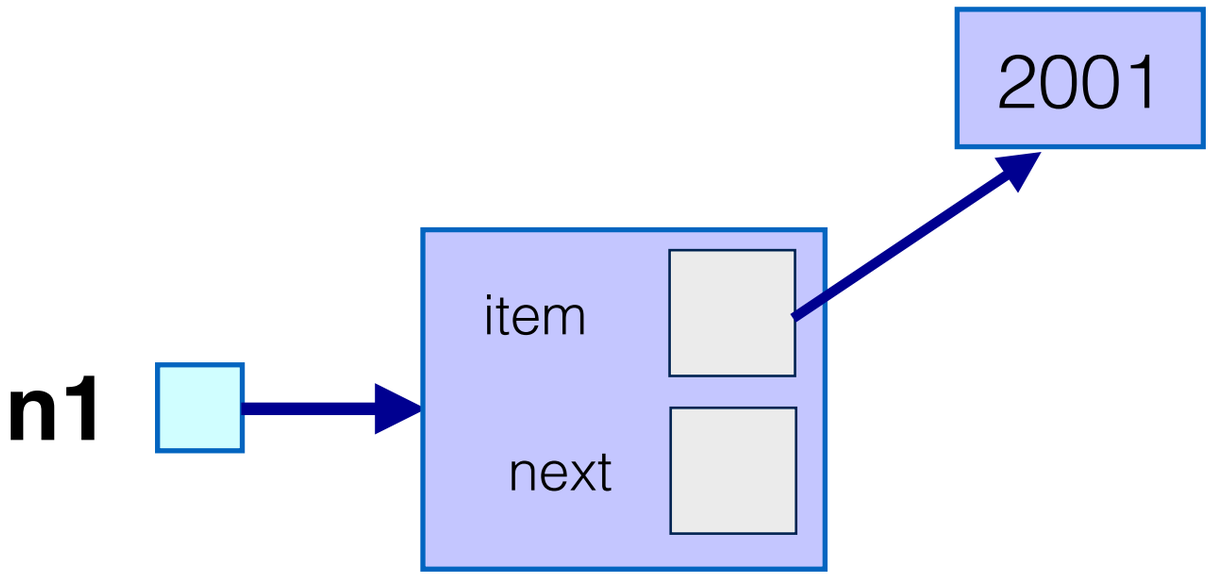
- Main **advantages**:
  - Very **fast** access O(1)
  - Very **compact** representation if the array is full

- Main **disadvantages**:
  - Non-resizable: maximum size specified on creation
  - Changing size is costly: **create a new array + copy all items**
  - Slow operations if shuffling elements is required

Linked Data Structures

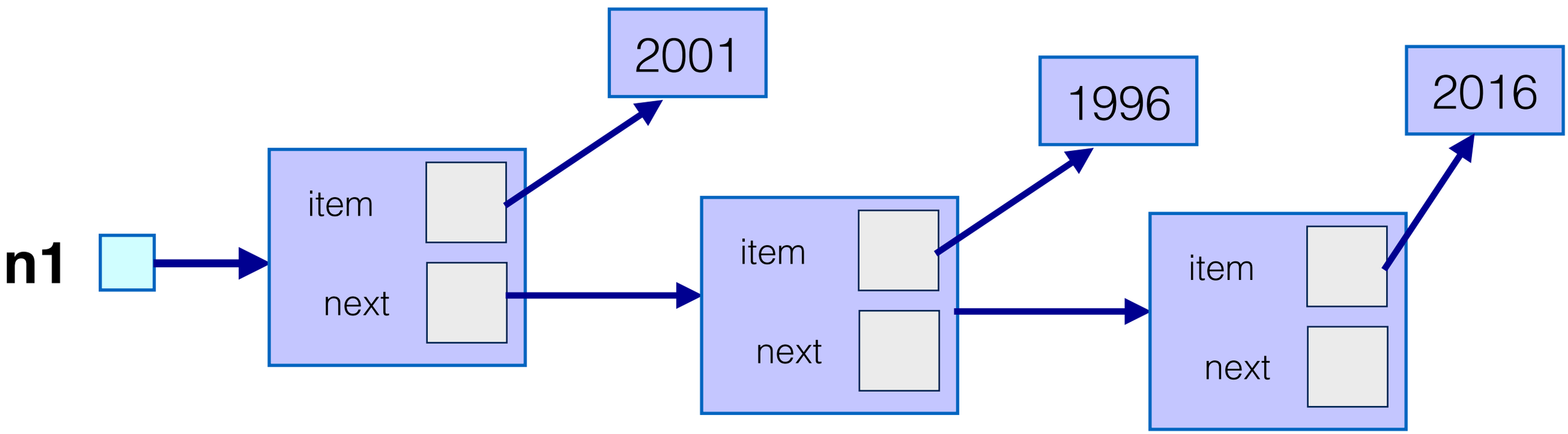


Linked Data Structures



- <u>Collection</u> of nodes
- Each node contains:
  - One or more **data items**
  - One or more **links to other nodes**

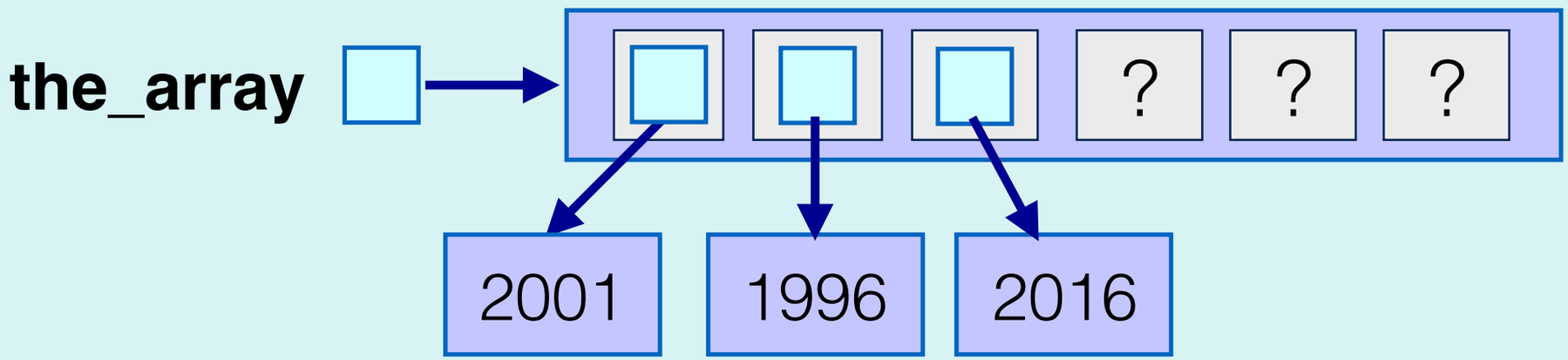
Linked Data Structures



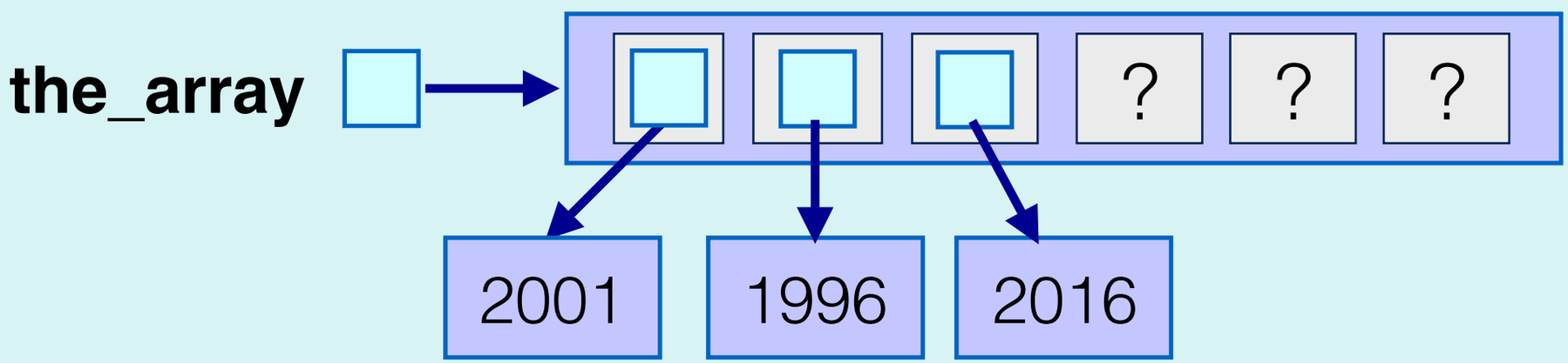
- <u>Collection</u> of nodes

- Each node contains:
  - One or more **data items**
  - One or more **links to other nodes**

Array-based Data Structures:

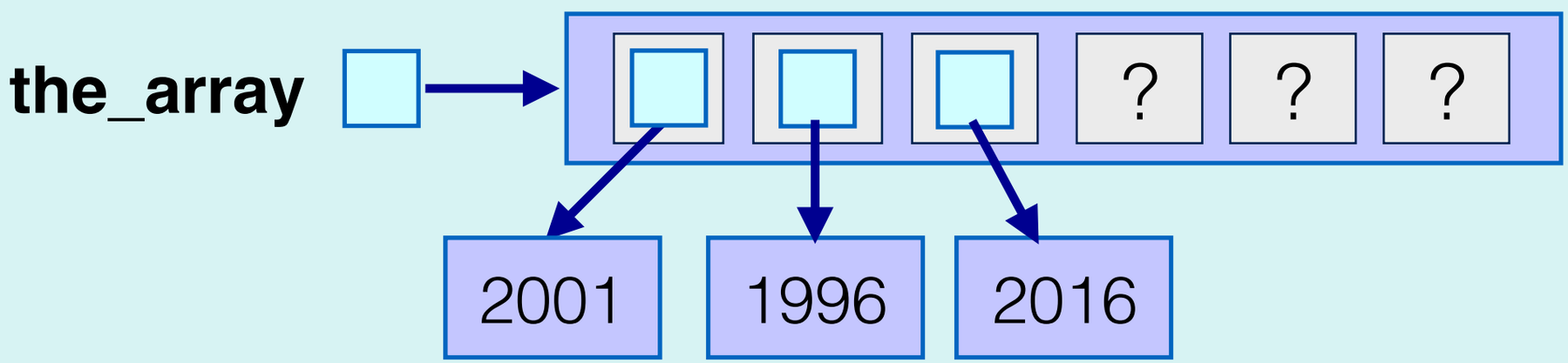


Array-based Data Structures:

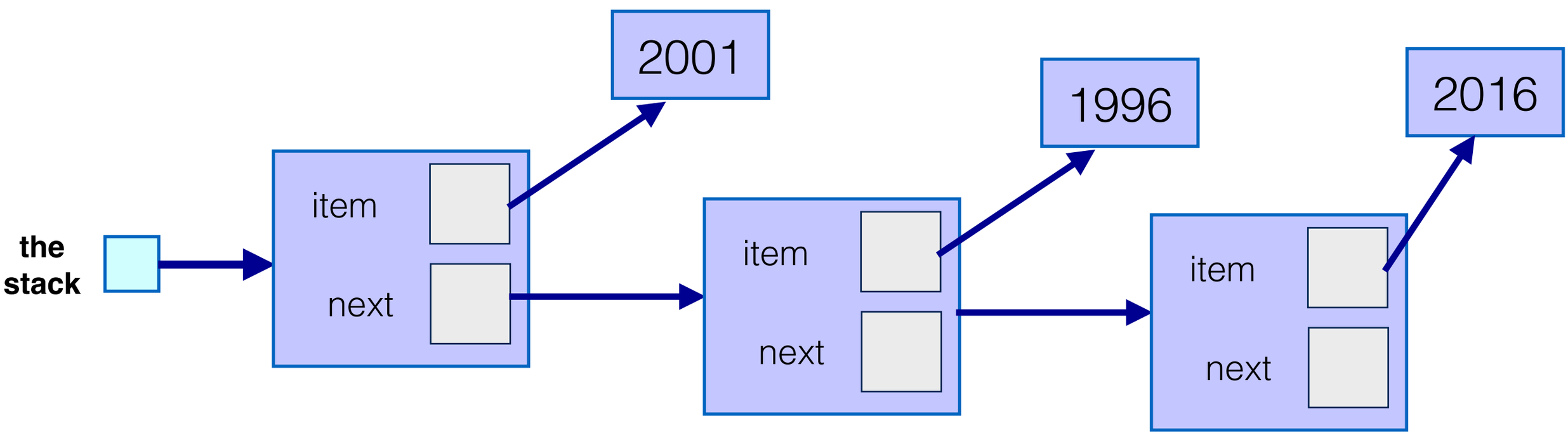


Linked Data Structures:

Array-based Data Structures:



Linked Data Structures:



Linked Data Structures: **Advantages**

Linked Data Structures: **Advantages**

- **Fast** insertions and deletions of items
  (no need for reshuffling)

Linked Data Structures: **Advantages**

- **Fast** insertions and deletions of items (no need for reshuffling)
- Easily **resizable**: just create/delete node

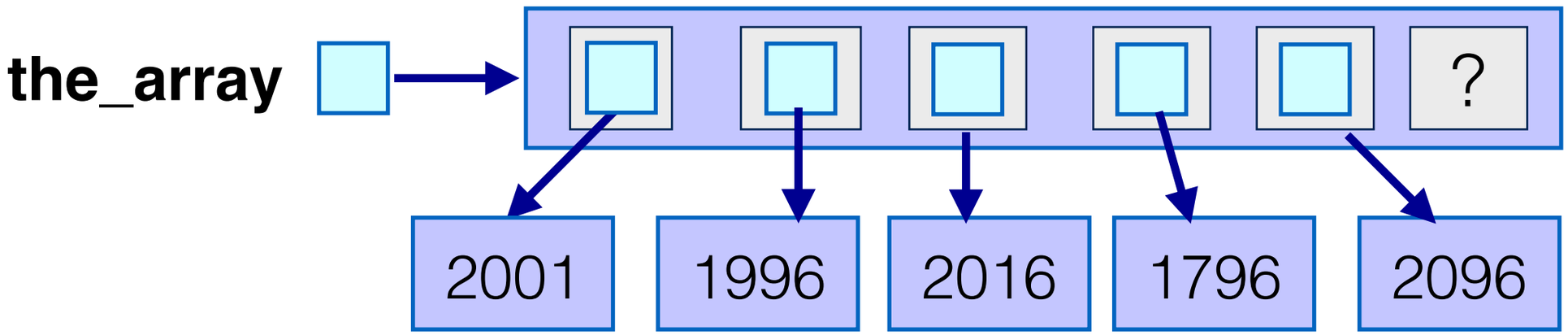
Linked Data Structures: **Advantages**

- **Fast** insertions and deletions of items (no need for reshuffling)
- Easily **resizable**: just create/delete node
- Never full (only if no more memory left)

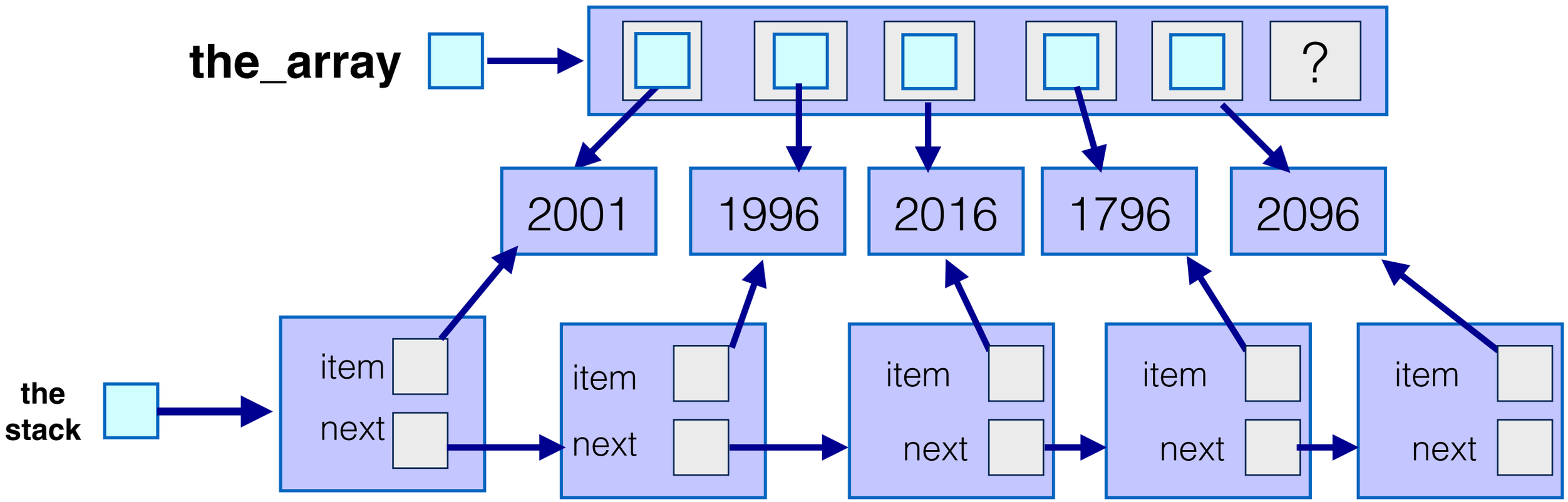
Linked Data Structures: **Advantages**

- **Fast** insertions and deletions of items (no need for reshuffling)
- Easily **resizable**: just create/delete node
- Never full (only if no more memory left)
- Less memory used than an array if the array-based implementation is relatively empty

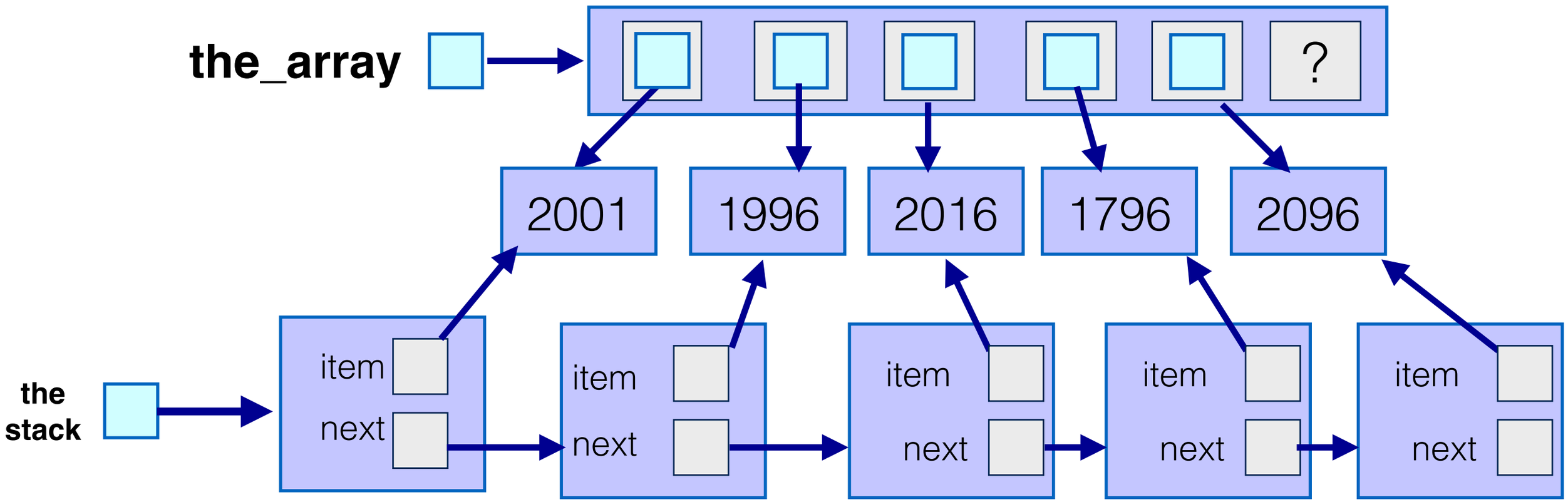
Linked Data Structures: **Disadvantages**



Linked Data Structures: **Disadvantages**

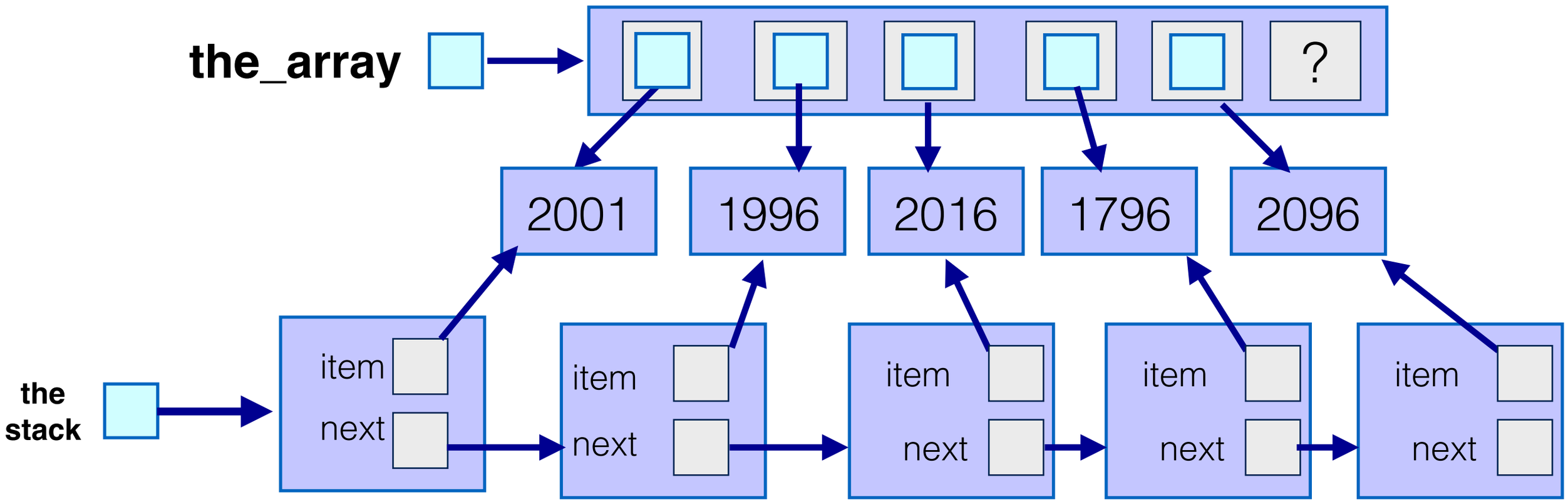


Linked Data Structures: **Disadvantages**



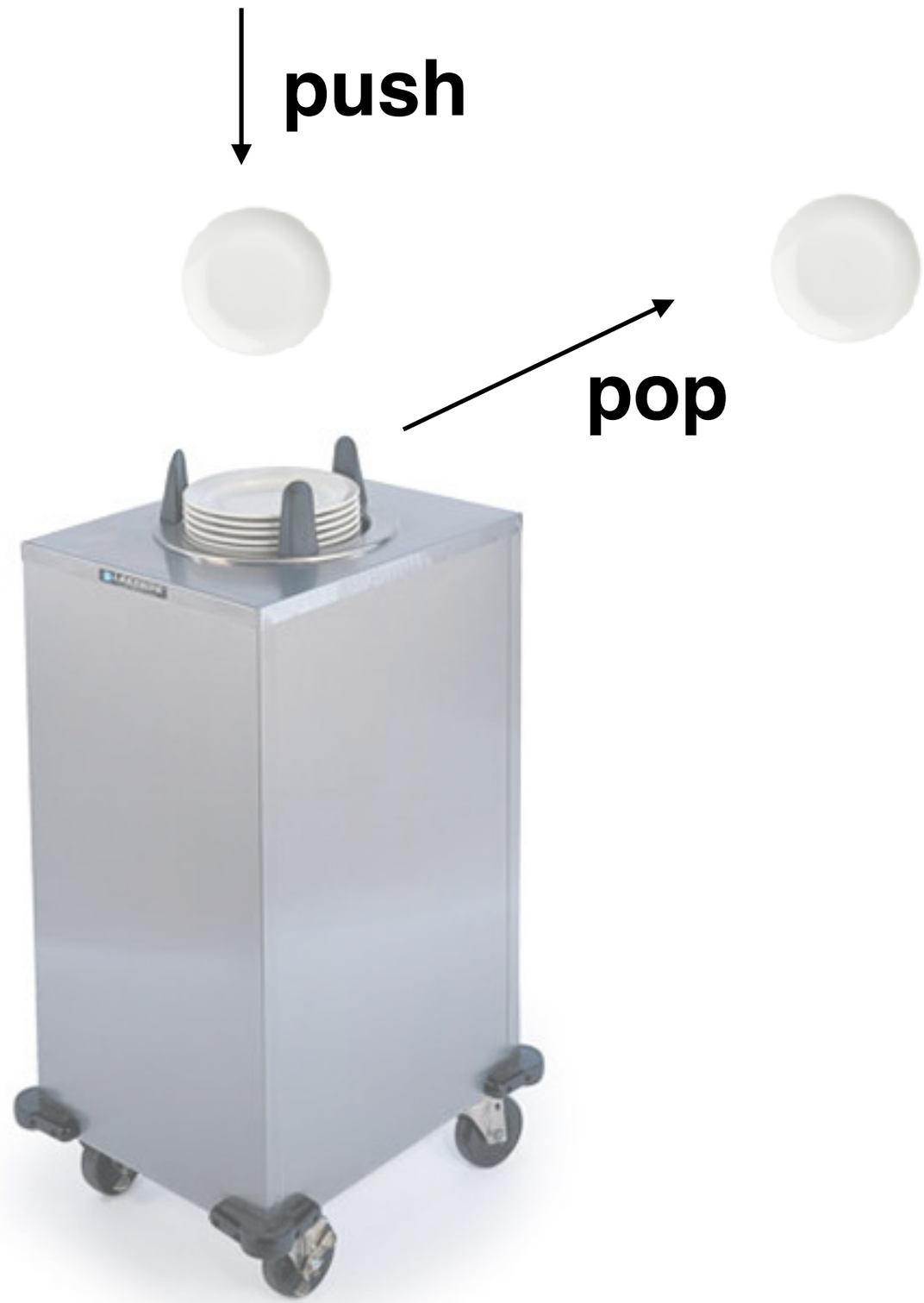
- More **memory** used than an array if the array is relatively full (Reason: every data item has an associated link)

Linked Data Structures: **Disadvantages**



- More **memory** used than an array if the array is relatively full (Reason: every data item has an associated link)

- For some data types certain operations are more time consuming (e.g., no random access)


push
pop

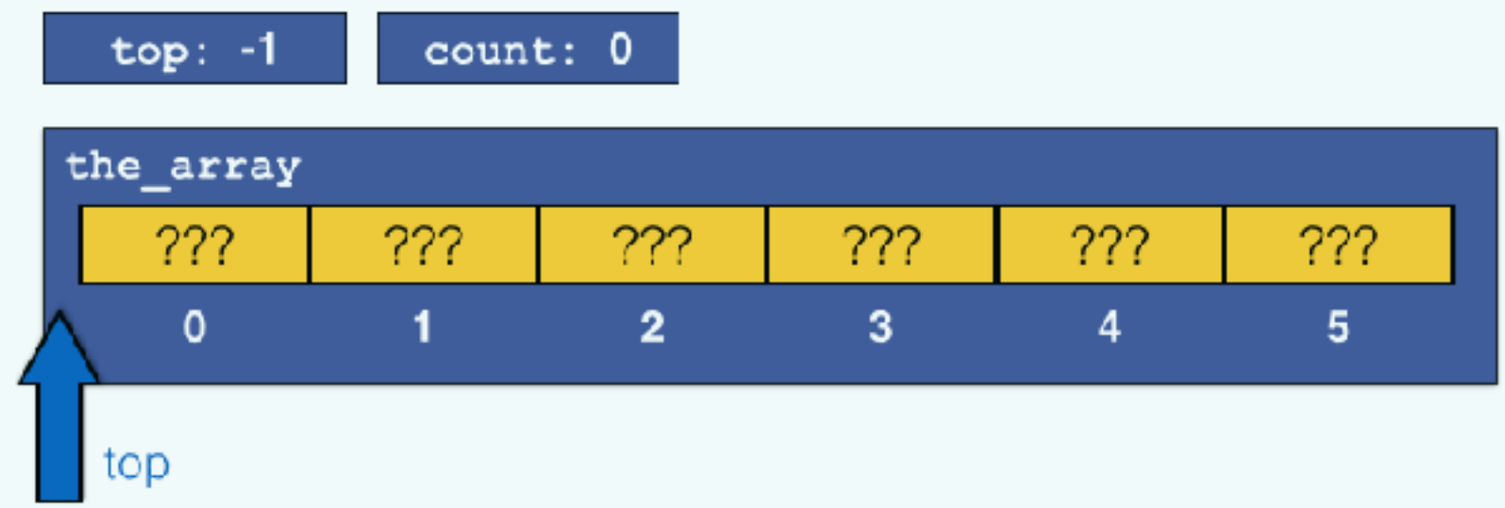
Stack Data Type

- Follows a **LIFO model**

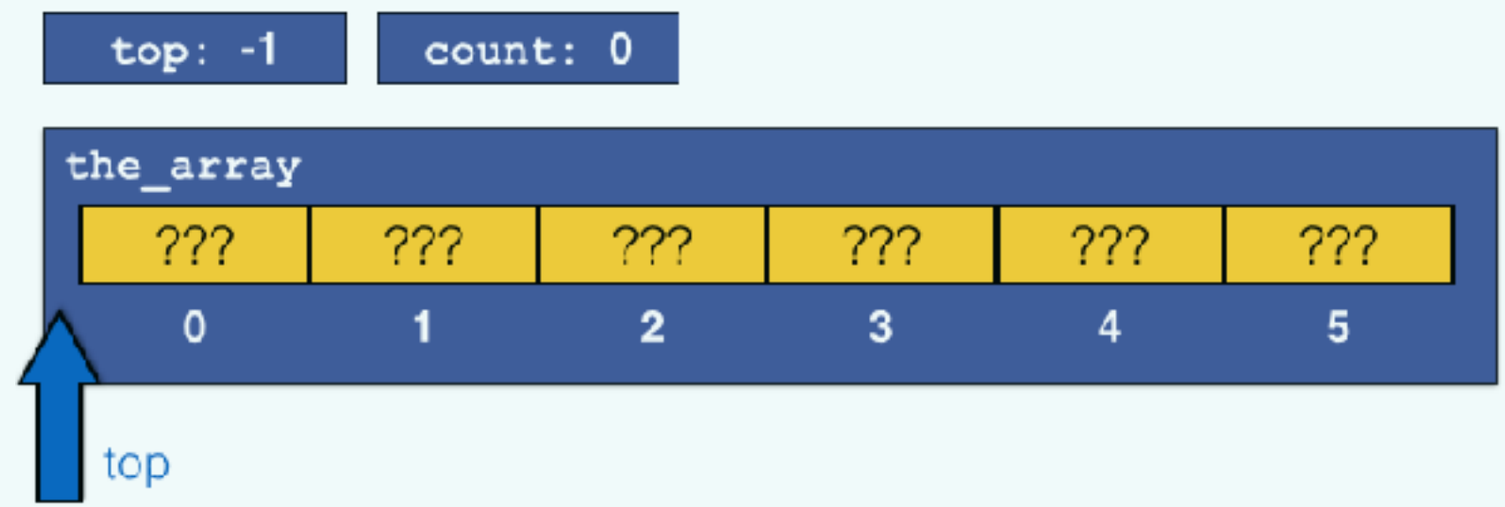
- Its **operations** (interface) are :
    - **Create** a stack (Stack)
    - Add an item to the top (**push**)
    - Take an item off the top (**pop**)
    - Look at the item on top, don't alter the stack (top/**peek**)
    - Is the stack **empty**?
    - Is the stack **full**?
    - Empty the stack (**reset**)

Remember: it only provides access to the element at the top of the stack (last element added)

Array Stack Implementation



Array Stack Implementation

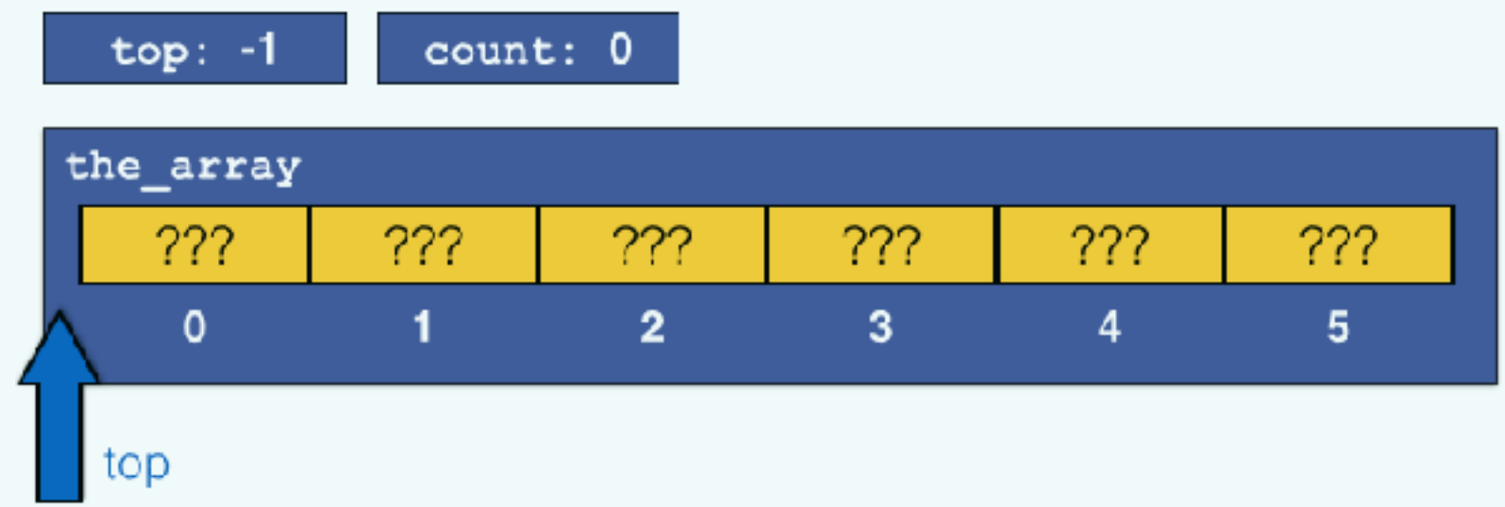


What do we need for a linked implementation?

Nodes!

Linked Stack Implementation

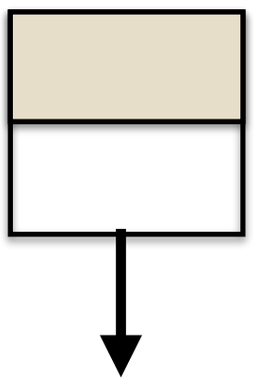
Array Stack Implementation



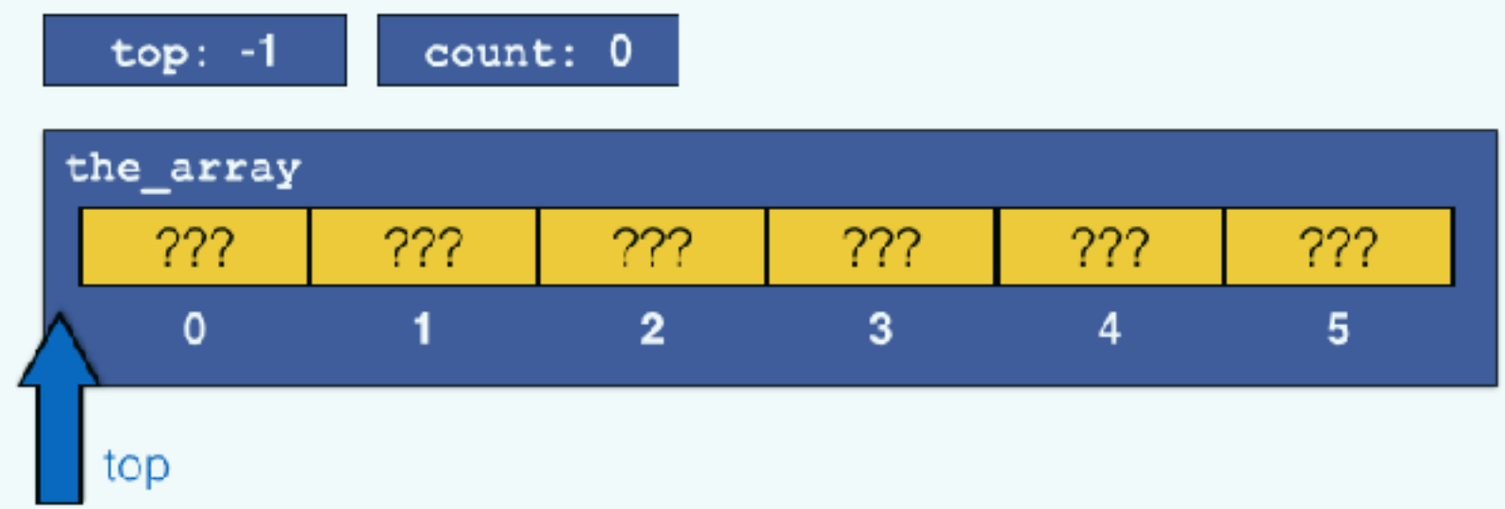
What do we need for a linked implementation?

Nodes!

Linked Stack Implementation



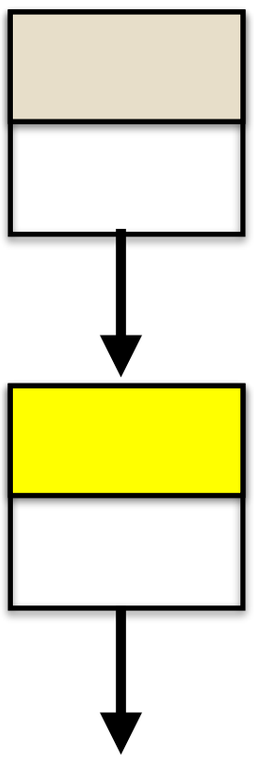
Array Stack Implementation



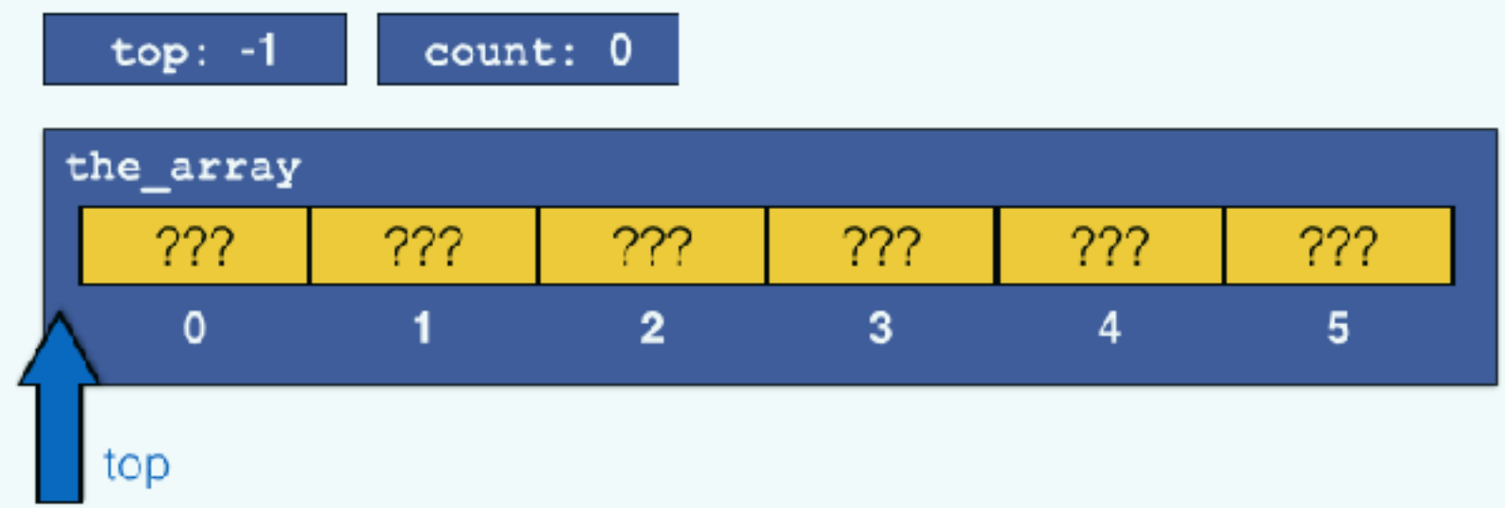
What do we need for a linked implementation?

Nodes!

Linked Stack Implementation



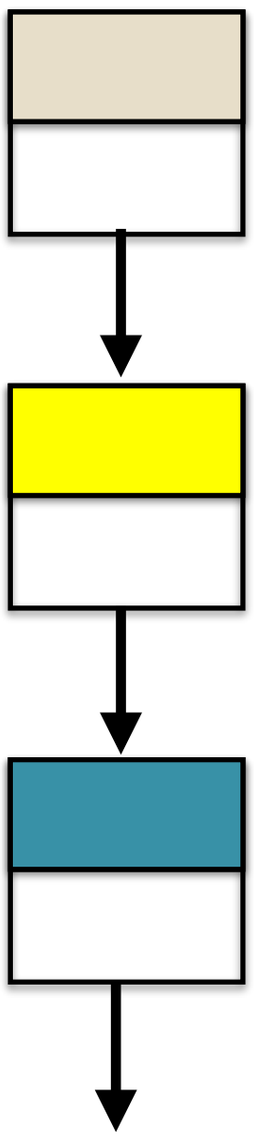
Array Stack Implementation



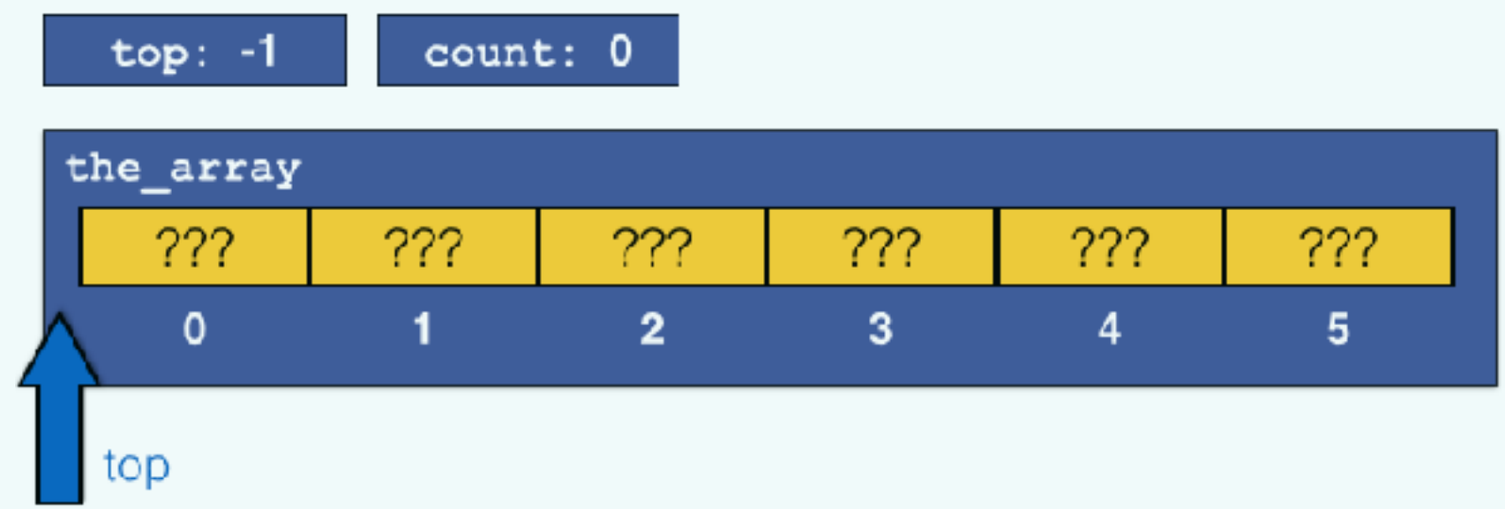
What do we need for a linked implementation?

Nodes!

Linked Stack Implementation



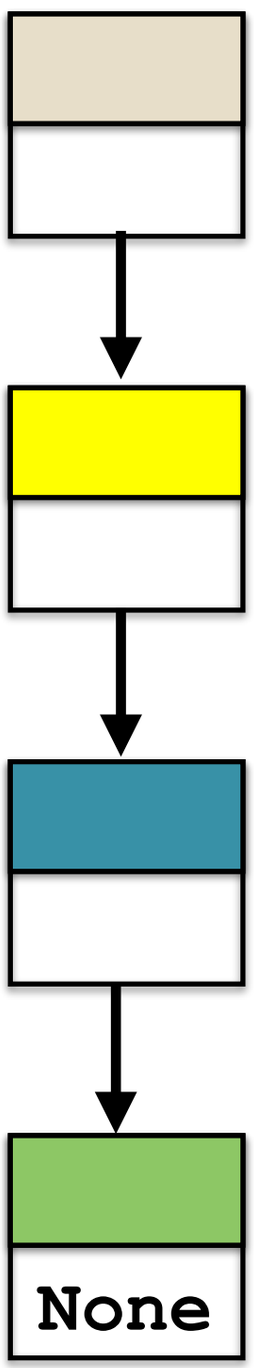
Array Stack Implementation



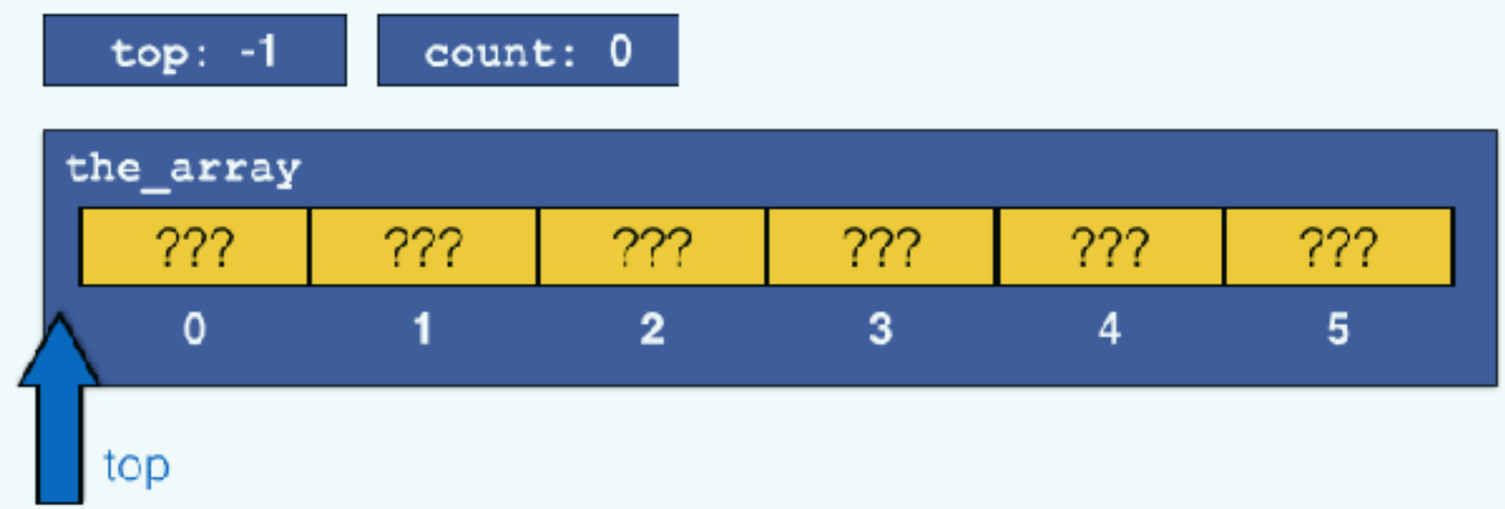
What do we need for a linked implementation?

Nodes!

Linked Stack Implementation



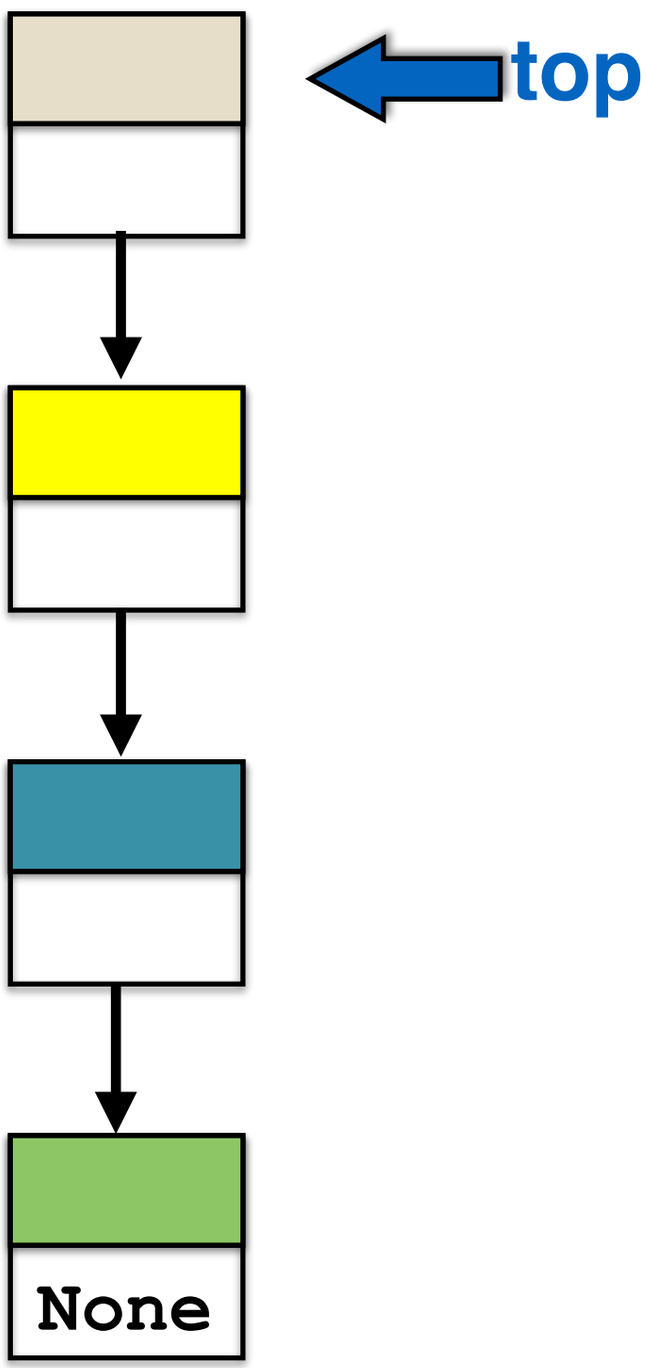
Array Stack Implementation



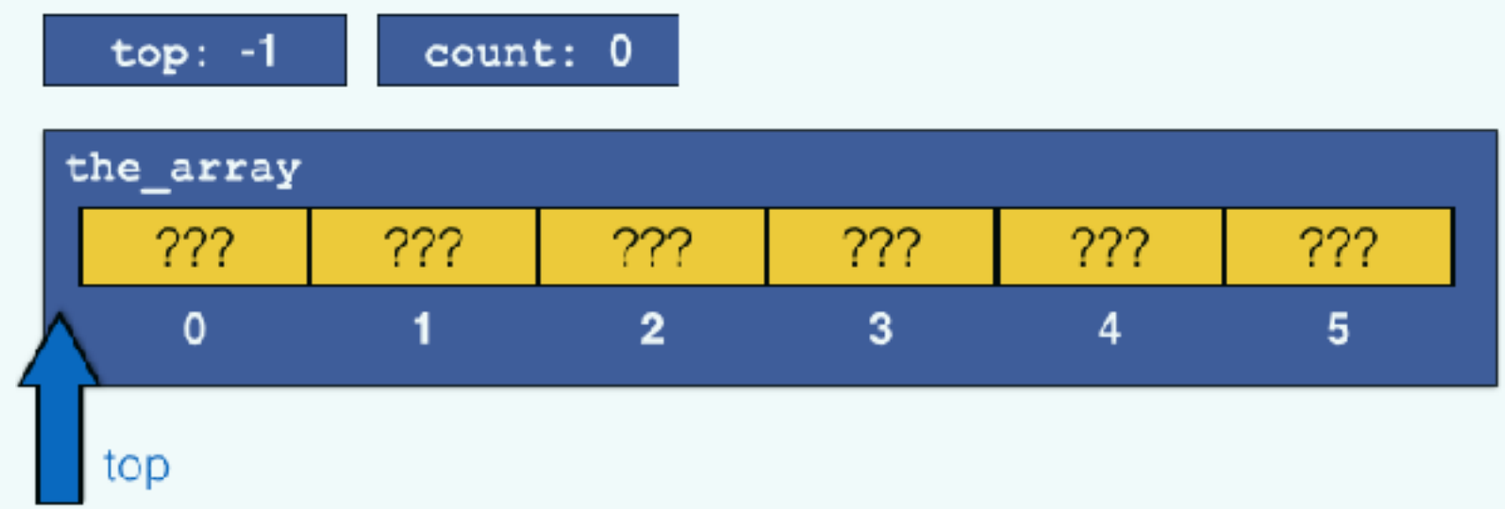
What do we need for a linked implementation?

Nodes!

Linked Stack Implementation



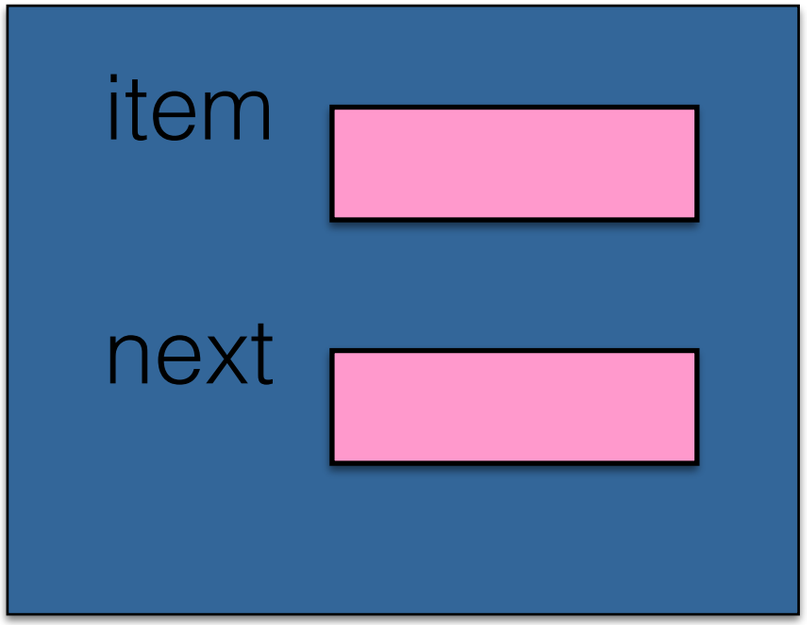
Array Stack Implementation



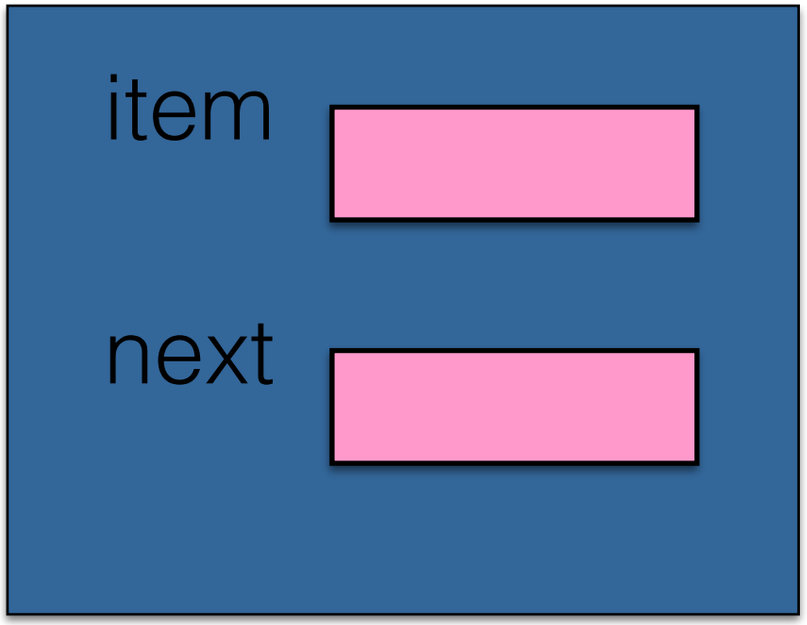
What do we need for a linked implementation?

Nodes!

Node



Node




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

```python
from node import Node
```

```python
from node import Node

class Stack:
```

```python
from node import Node


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

No need for size when initialising the object

```python
from node import Node


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

    def is_empty(self):
        return self.top is None
```

```python
from node import Node


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

    def is_empty(self):
        return self.top is None
```

True if pointing to the same object.

```python
from node import Node


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

    def is_empty(self):
        return self.top is None
```

True if pointing to the same object.

self.top == **None** ?
== can be overloaded implementing __eq__(self, rhs)

```python
from node import Node


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

    def is_empty(self):
        return self.top is None

    def is_full(self):
        return False
```

```python
from node import Node


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

    def is_empty(self):
        return self.top is None

    def is_full(self):
        return False

    def reset(self):
        self.top = None
```

Push: algorithm

Array implementation:

Push: algorithm

Array implementation:

- If the array is full raise exception
- Else
  - Add item in the position marked by top
  - Increase top

Push: algorithm

Array implementation:

- If the array is full raise exception
- Else
  - Add item in the position marked by top
  - Increase top

Linked implementation:

Push: algorithm

Array implementation:

- If the array is full raise exception
- Else
  - Add item in the position marked by top
  - Increase top

Linked implementation:

- Create a **new node** that contains the new item and is linked to the current top
- Make the **new node** the **new top**

Push: algorithm

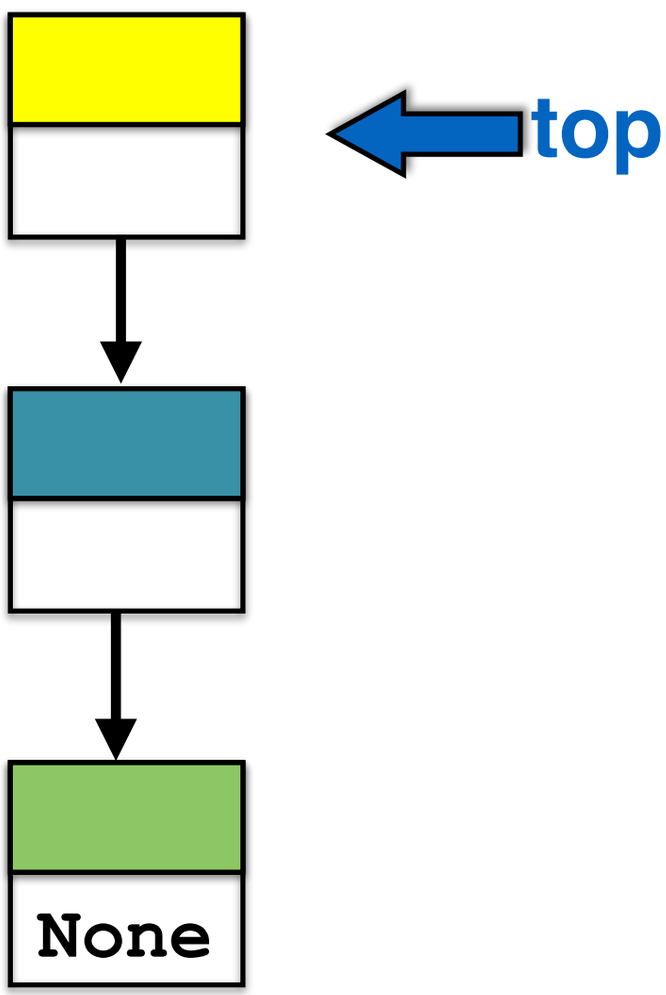
Array implementation:

- If the array is full raise exception
- Else
  - Add item in the position marked by top
  - Increase top

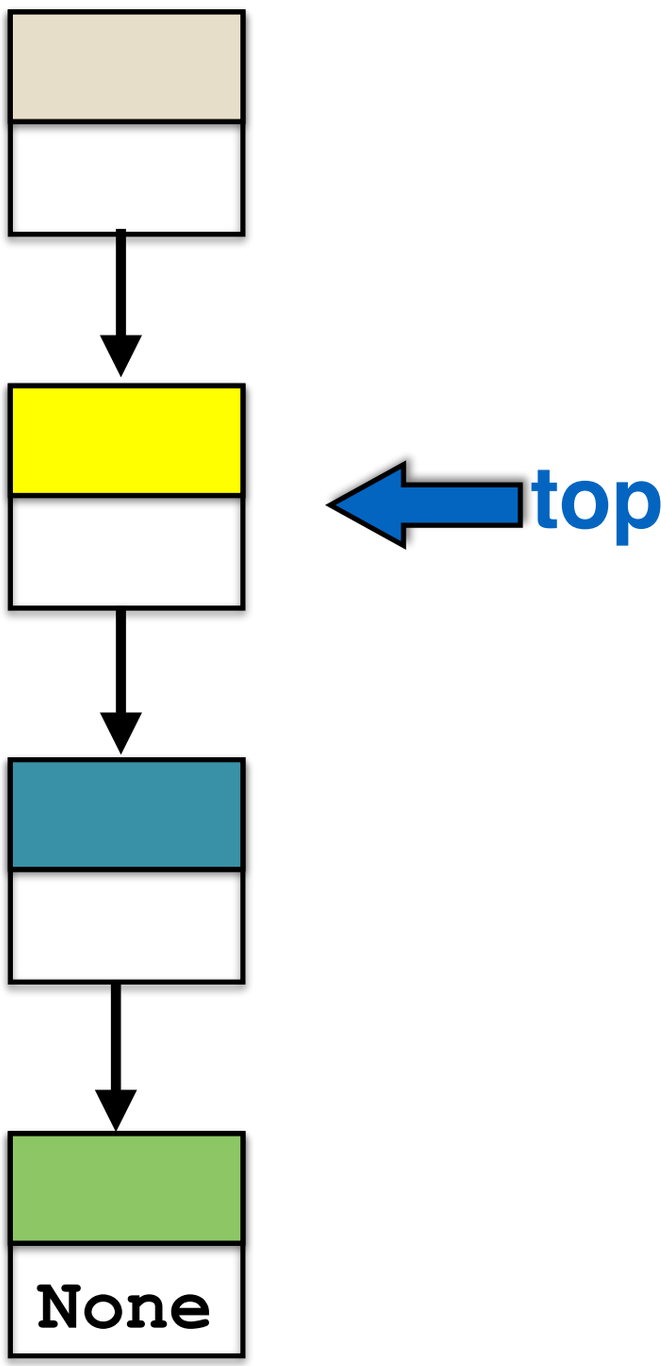
No need for is_full check.
If no more memory can be allocated the system will raise an exception.

Linked implementation:

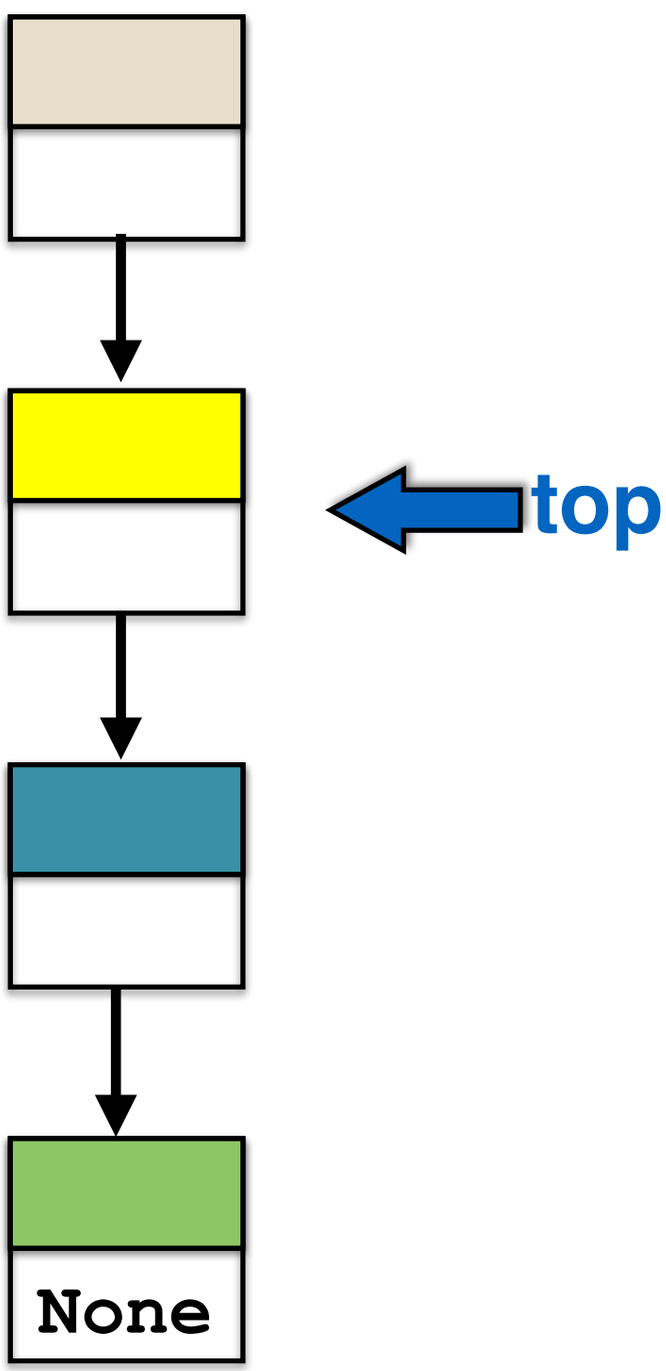
- Create a **new node** that contains the new item and is linked to the current top
- Make the **new node** the **new top**


top
None

Create a new node with the new item.
linked to the current top

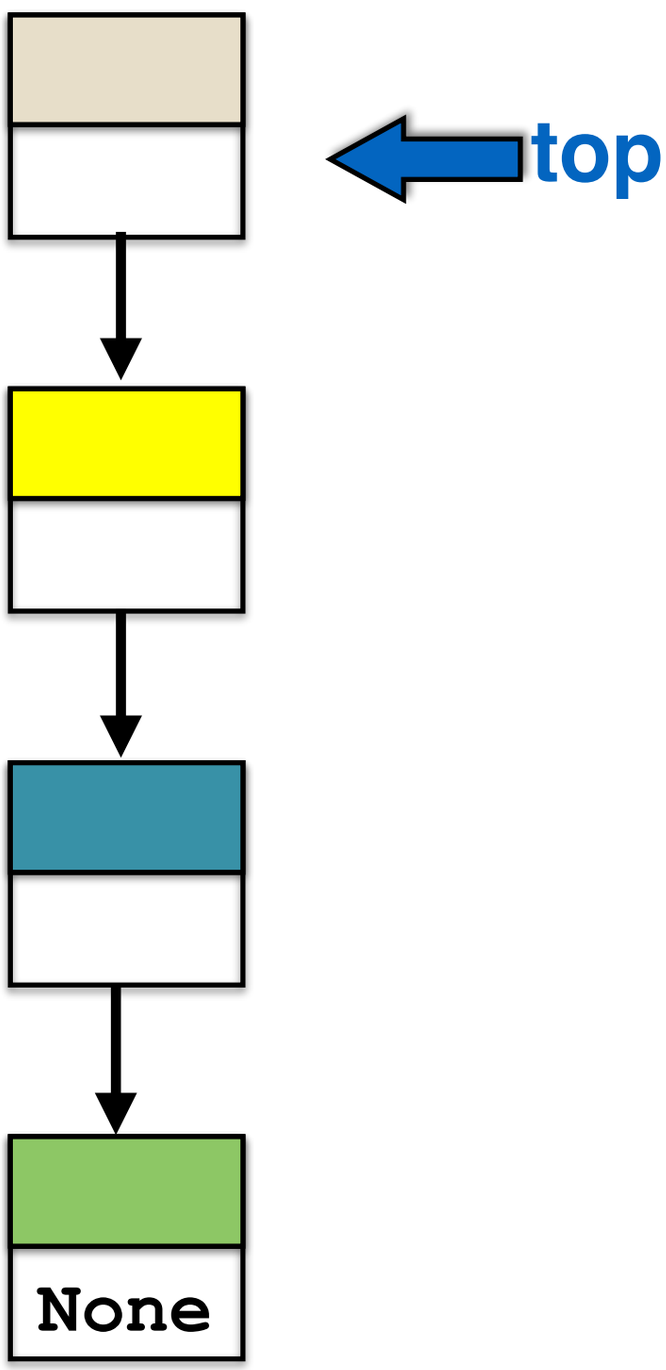


Create a new node with the new item.
linked to the current top



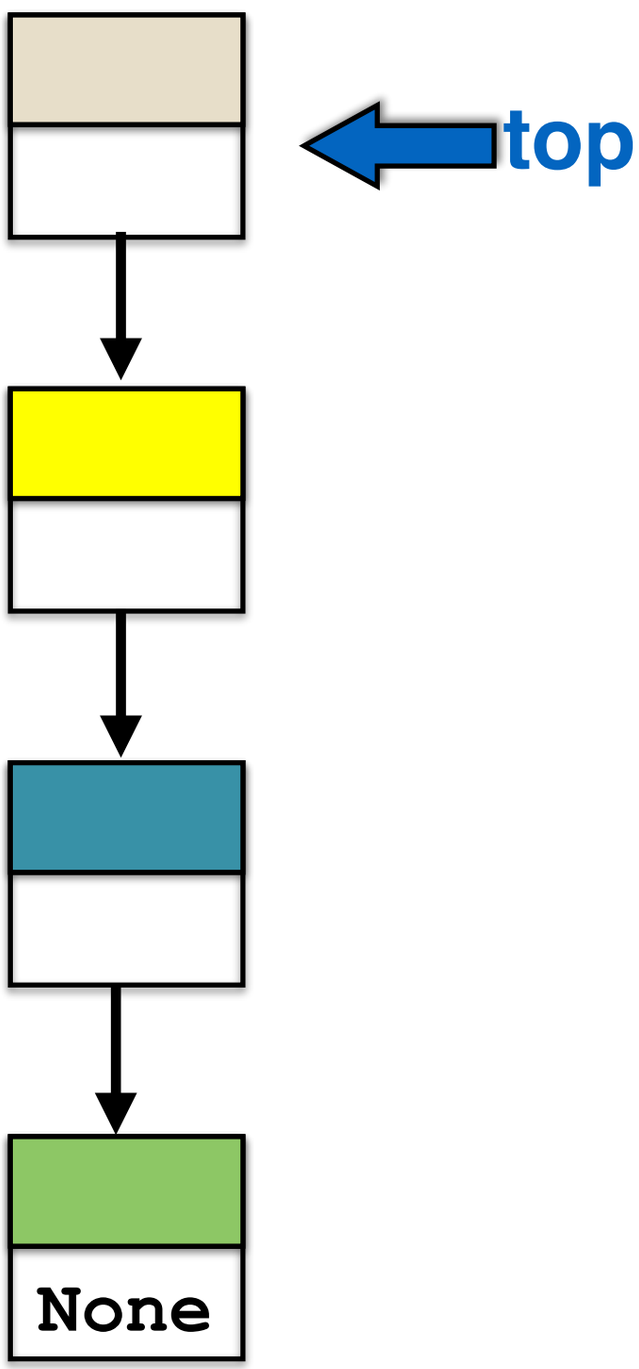
Make the new node the new **top**

Create a new node with the new item.
linked to the current top



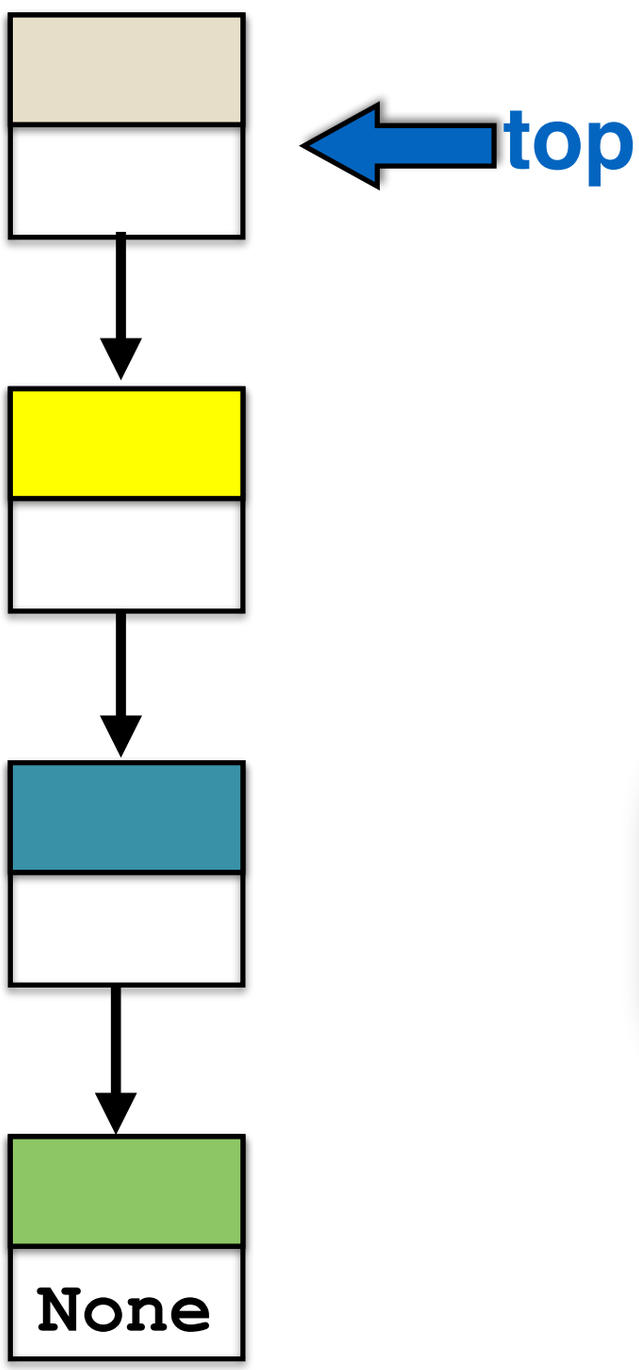
Make the new node the new **top**

Create a new node with the new item.
linked to the current top



Make the new node the new **top**

Create a new node with the new item.
linked to the current top



Make the new node the new **top**

```
def push(self, item):
    self.top = Node(item, self.top)
```

Consider a stack with **7** on top

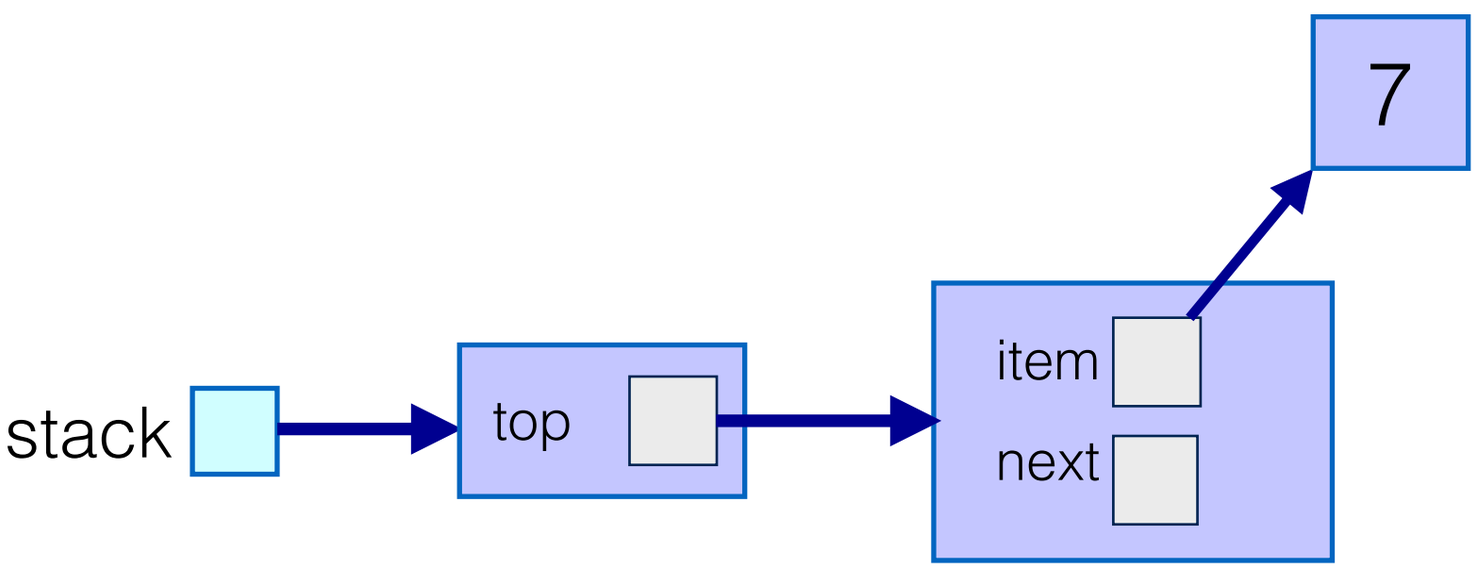
`stack.push(41)`

```
def push(self, item):
    self.top = Node(item, self.top)
```

Consider a stack with **7** on top

`stack.push(41)`

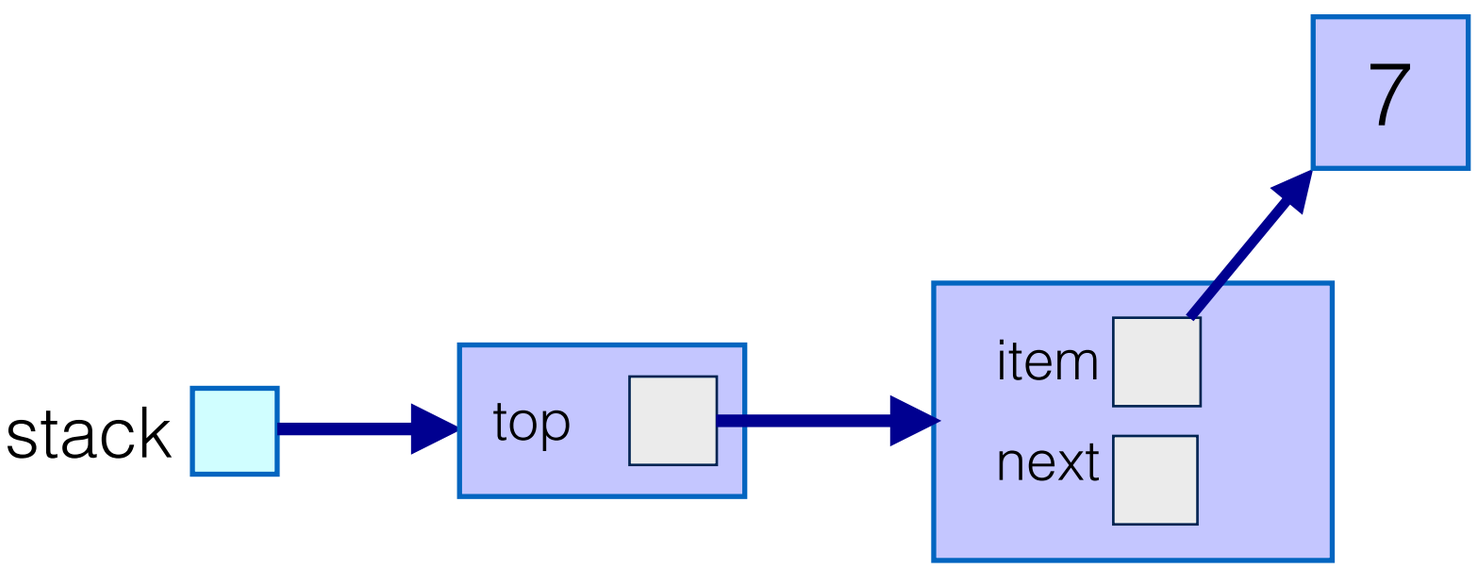
```
def push(self, item):
    self.top = Node(item, self.top)
```



Consider a stack with **7** on top

`stack.push(41)`

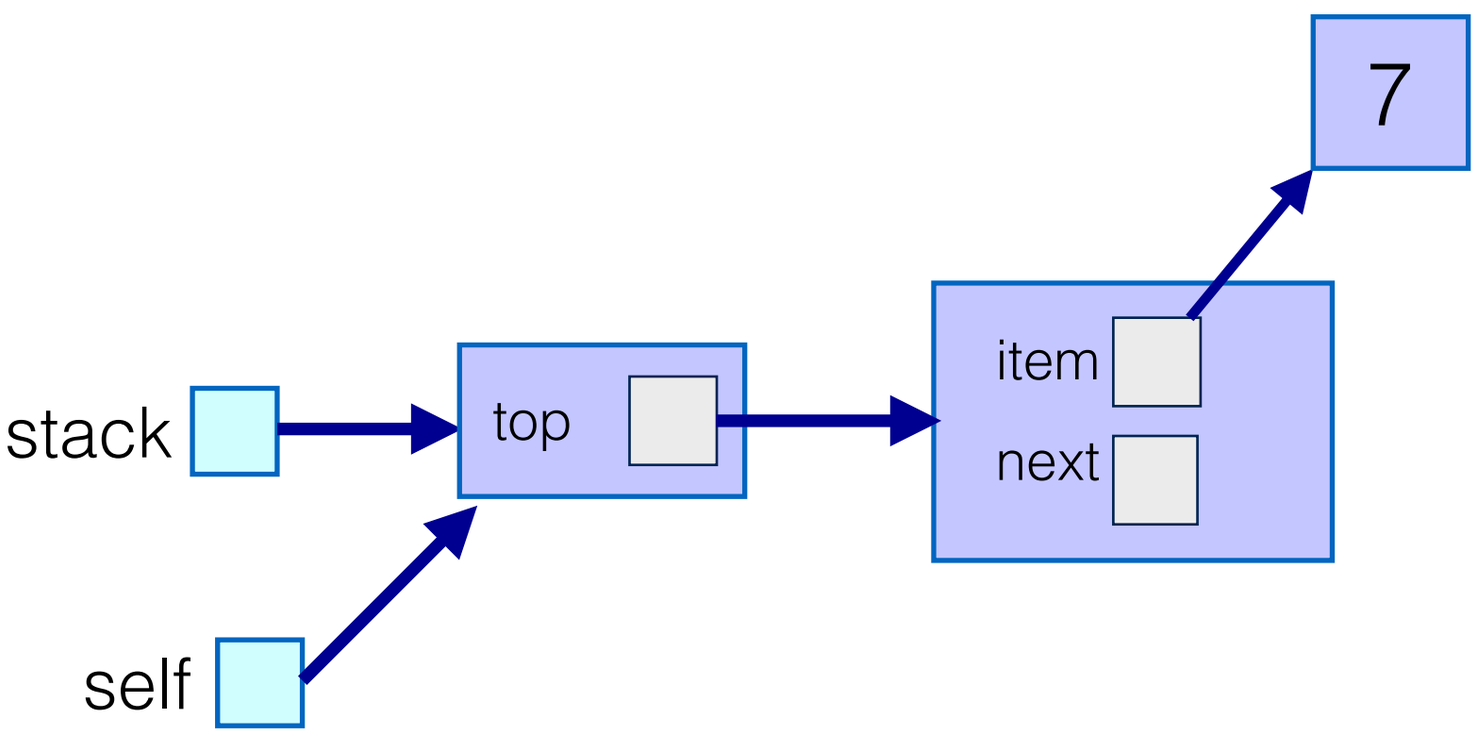
```
def push(self, item):
    self.top = Node(item, self.top)
```



Consider a stack with **7** on top

`stack.push(41)`

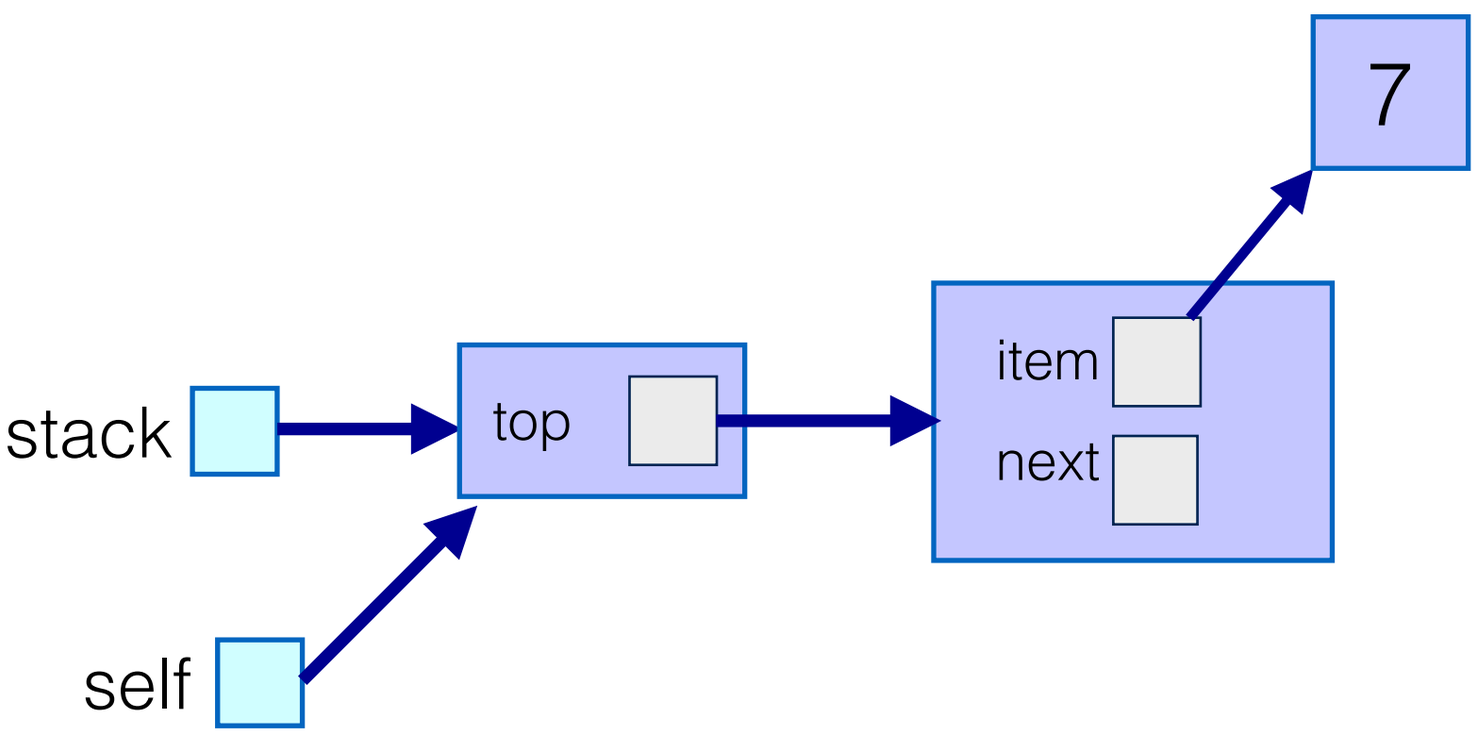
```
def push(self, item):
    self.top = Node(item, self.top)
```



Consider a stack with **7** on top

`stack.push(41)`

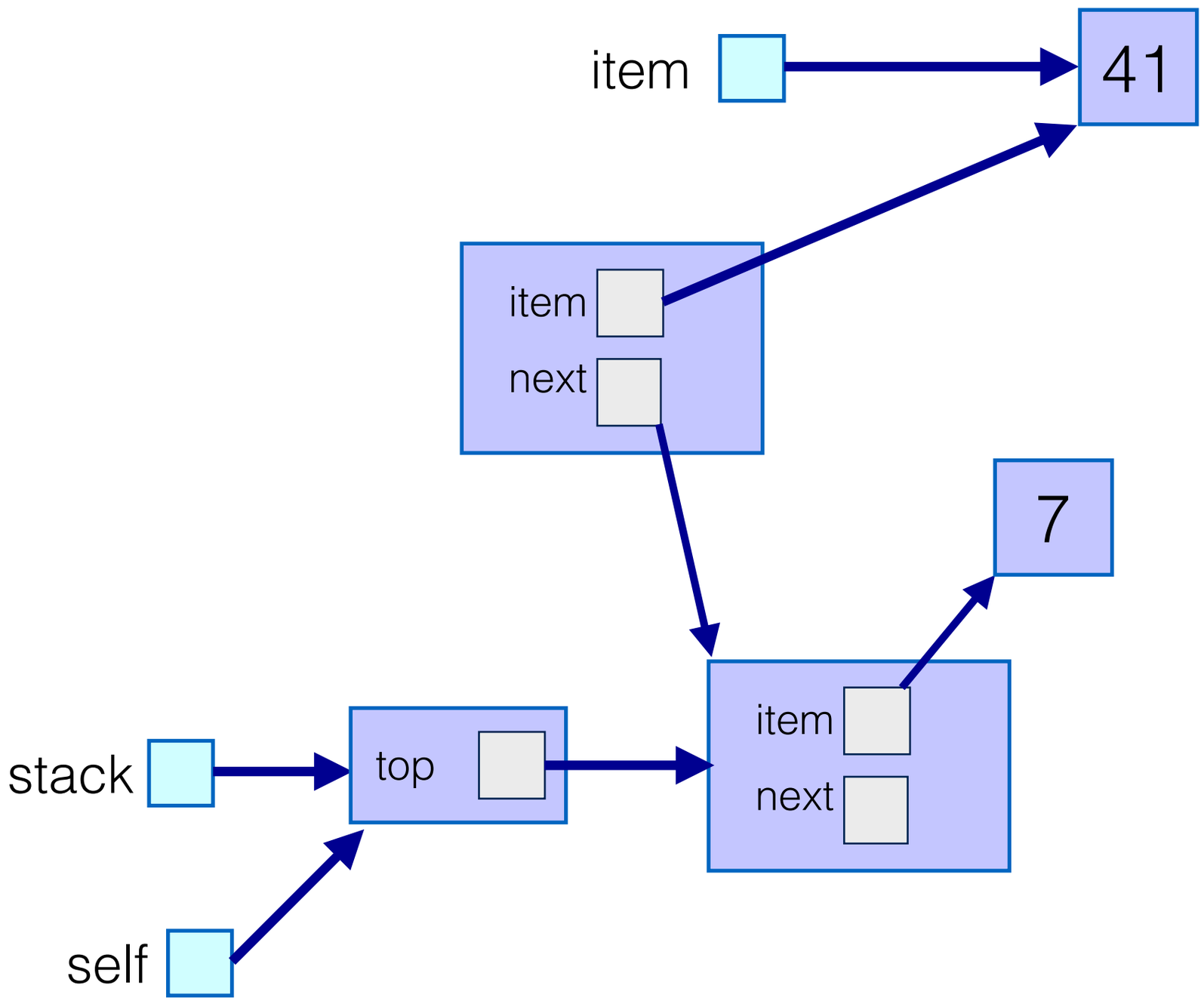
```
def push(self, item):
    self.top = Node(item, self.top)
```



Consider a stack with **7** on top

`stack.push(41)`

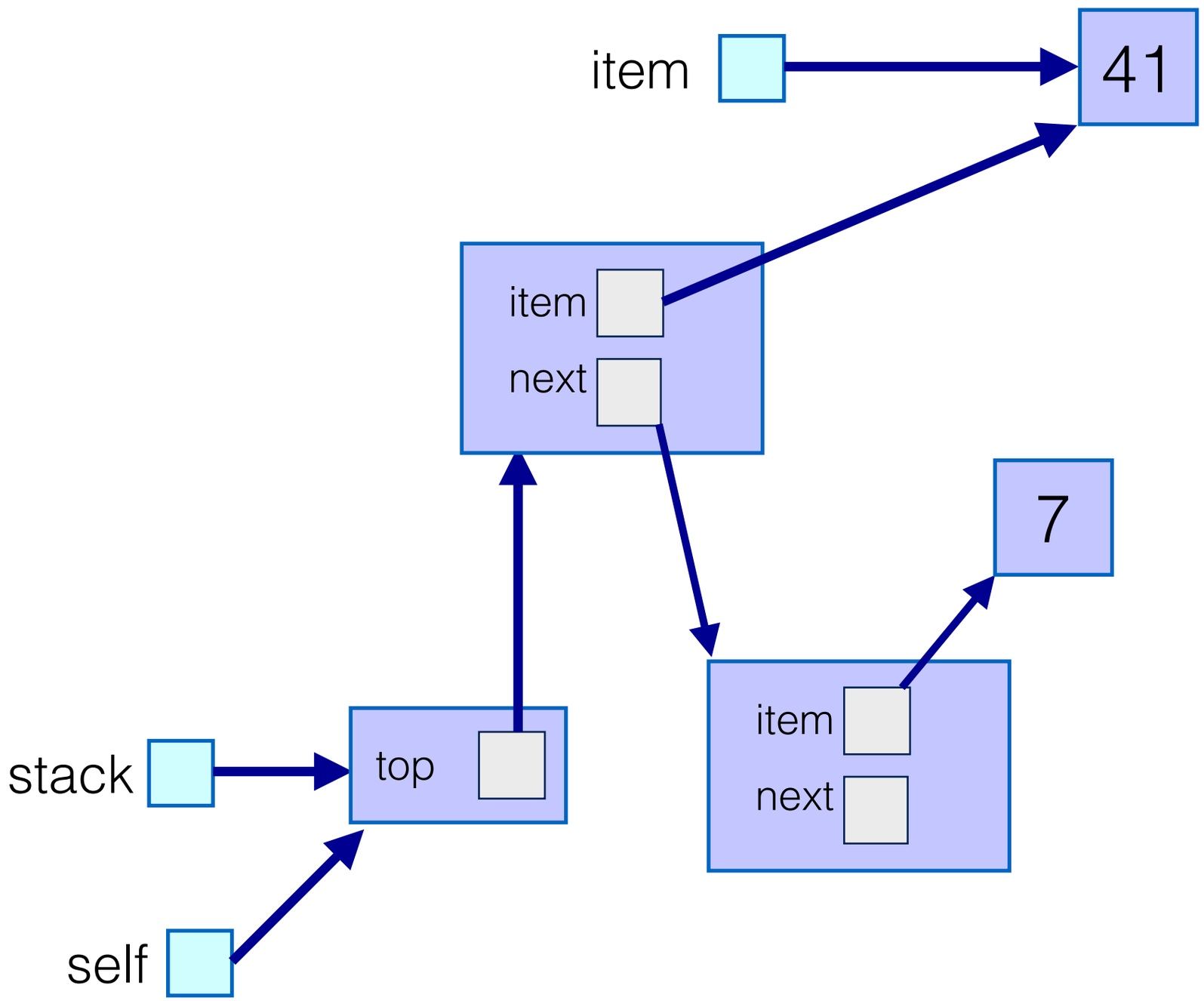
```
def push(self, item):
    self.top = Node(item, self.top)
```

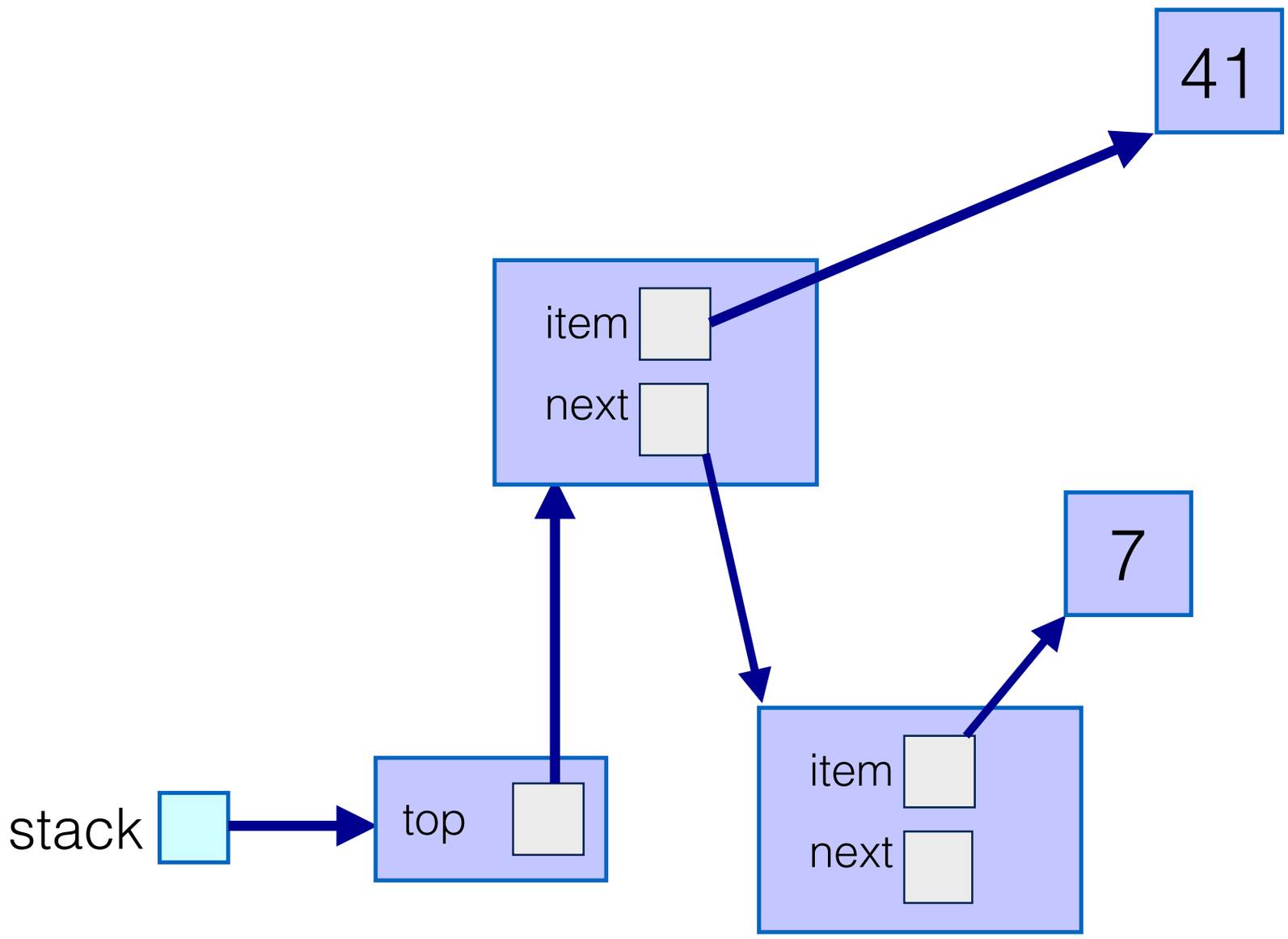


Consider a stack with **7** on top

`stack.push(41)`

```
def push(self, item):
    self.top = Node(item, self.top)
```

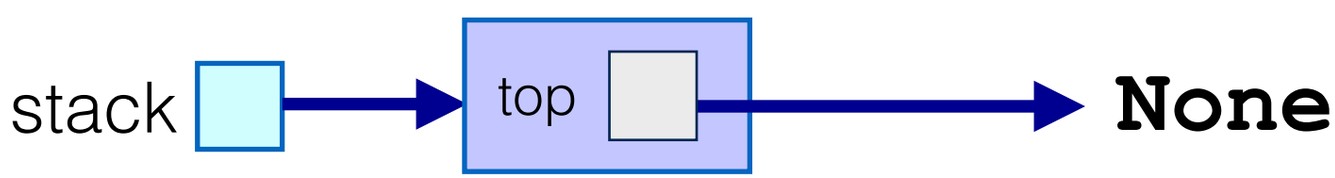



41
item
next
7
item
next
stack
top

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

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

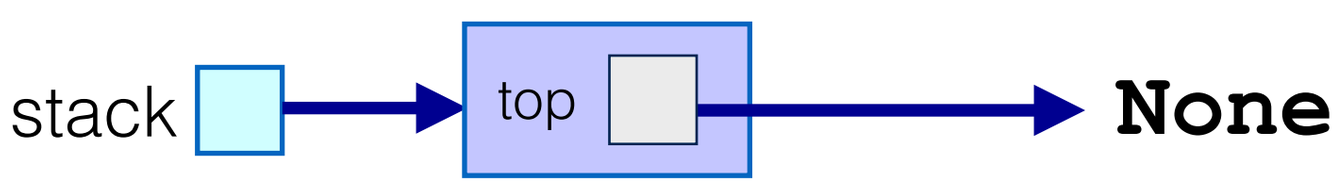


```python
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

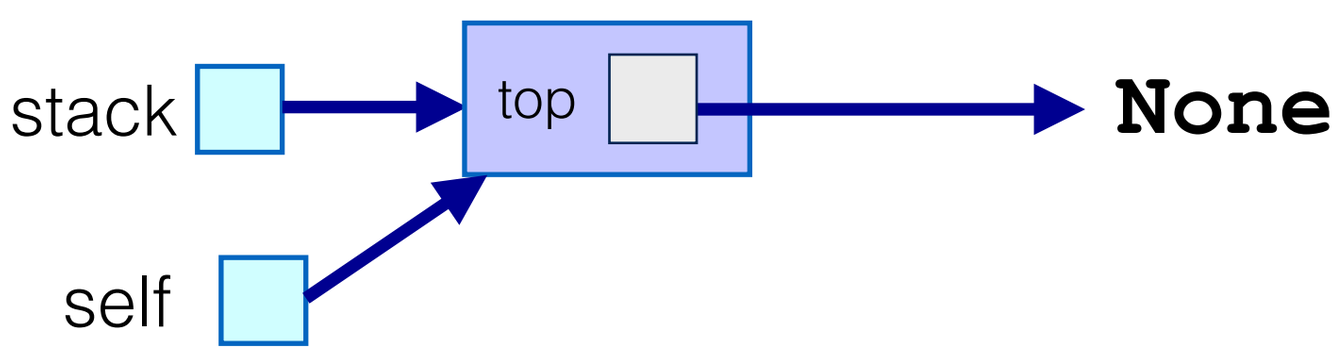


```
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

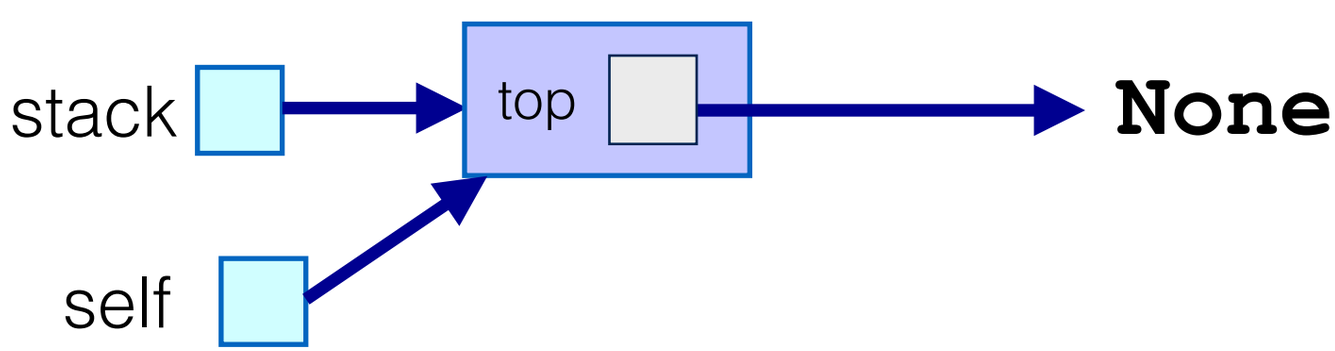


```
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

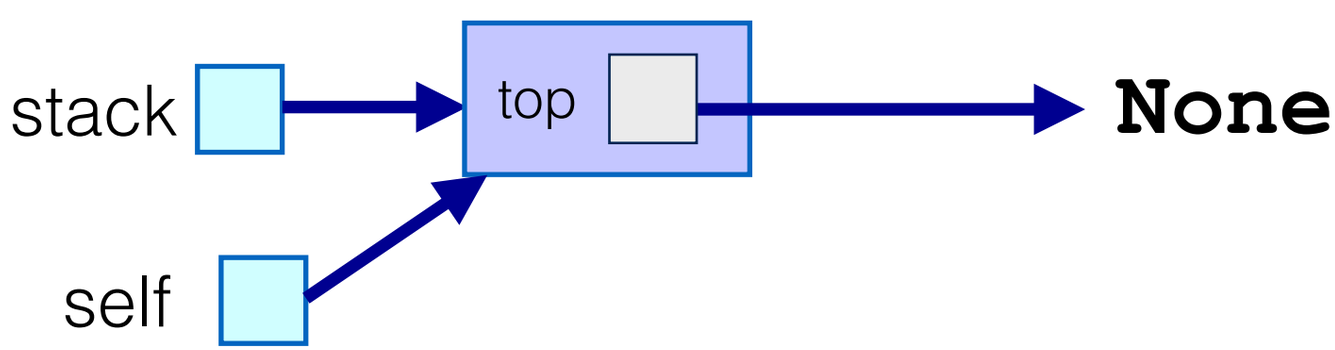


```
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

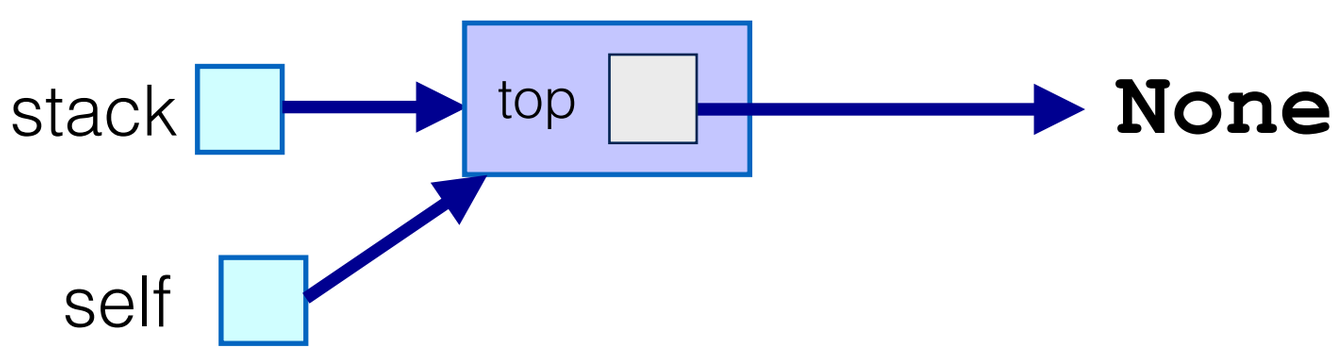


```
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

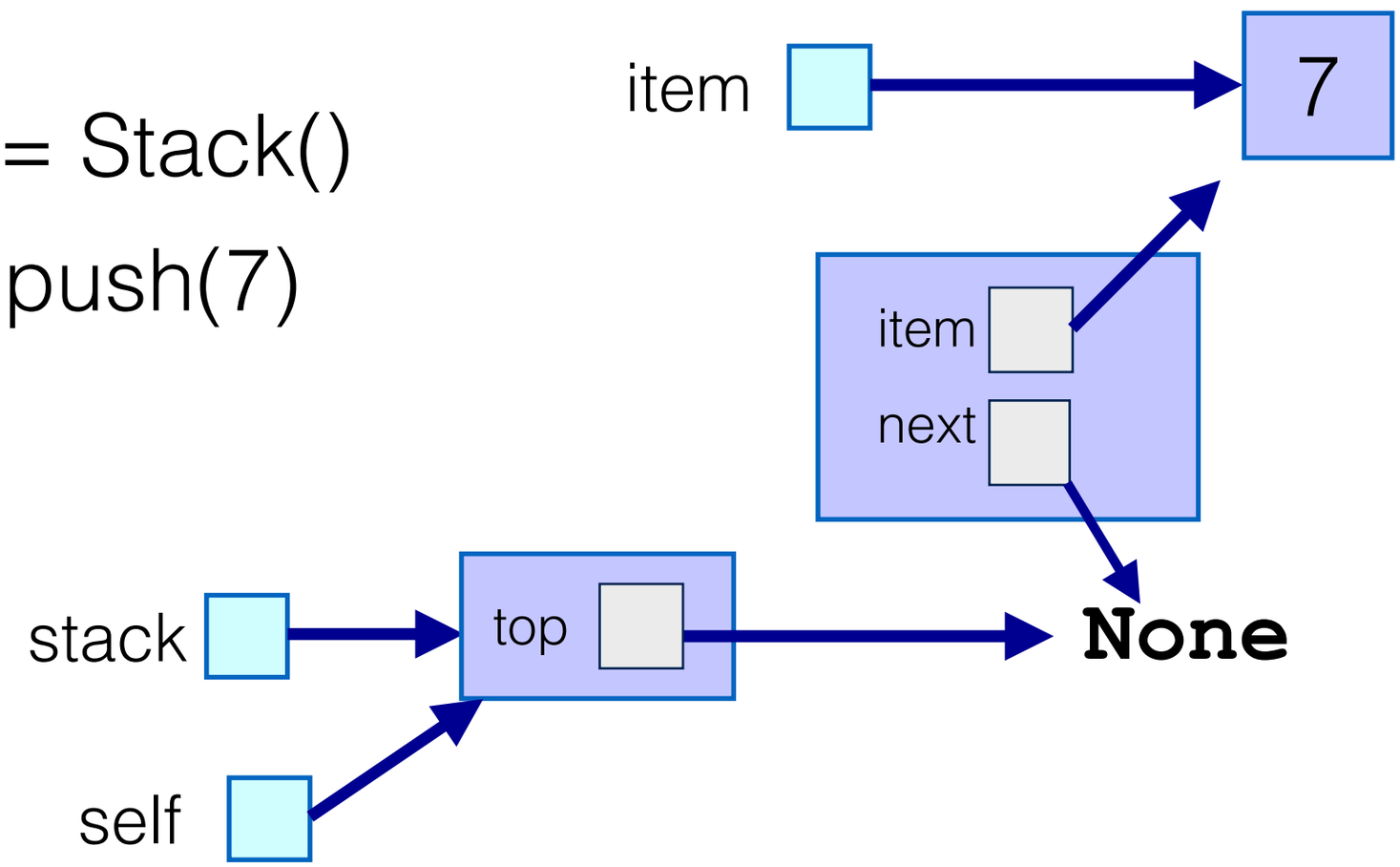


```
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

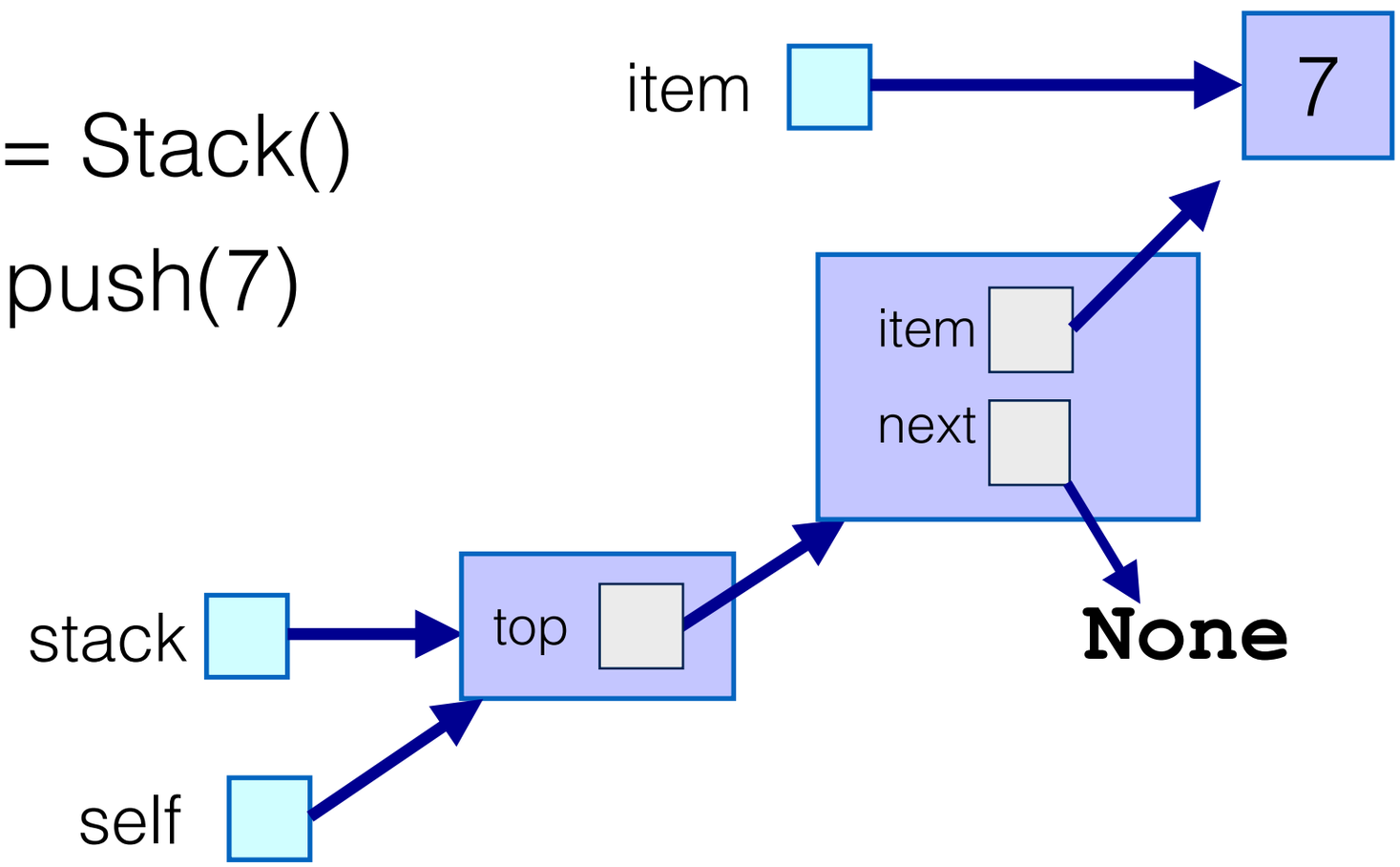


```python
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

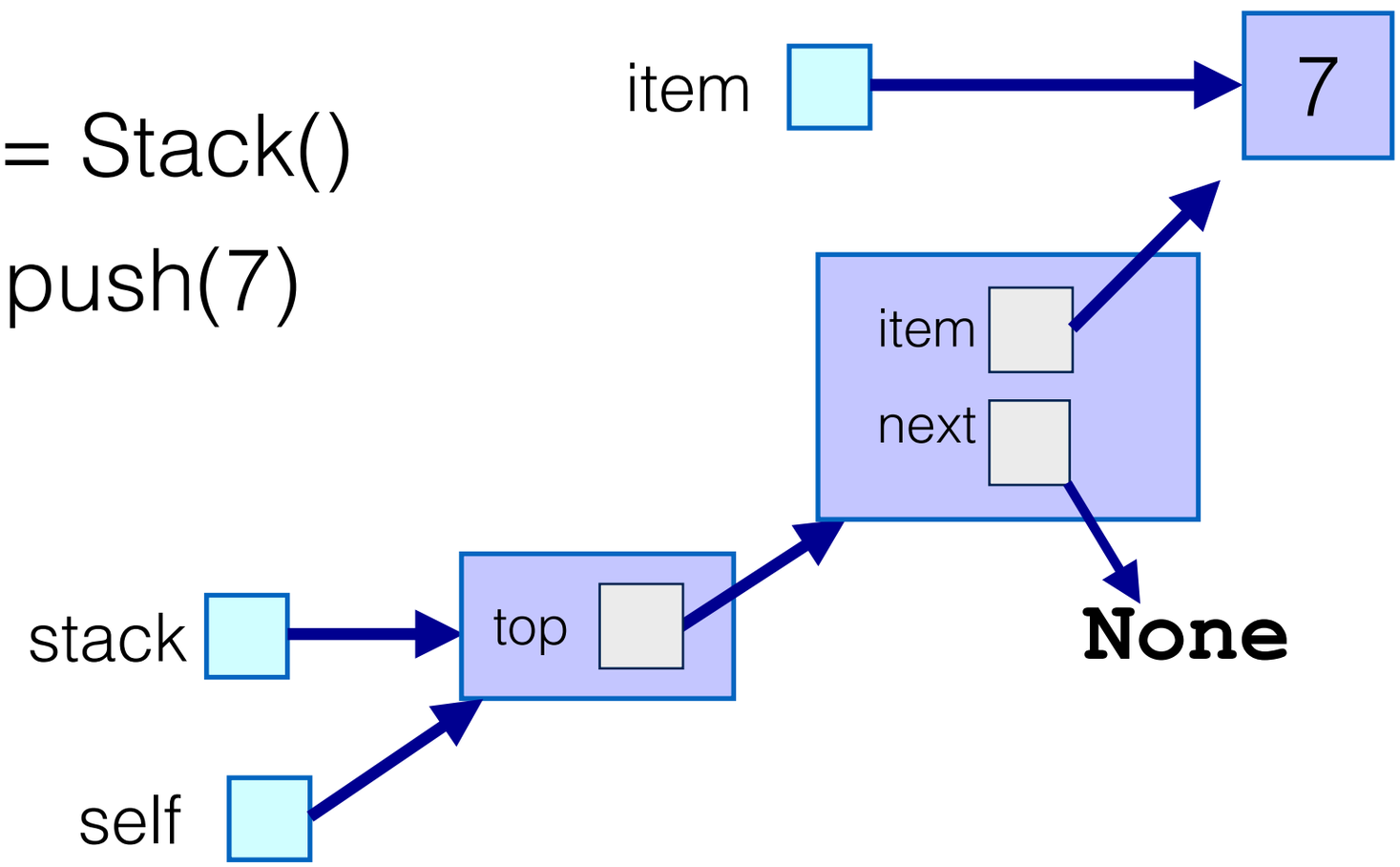


```
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

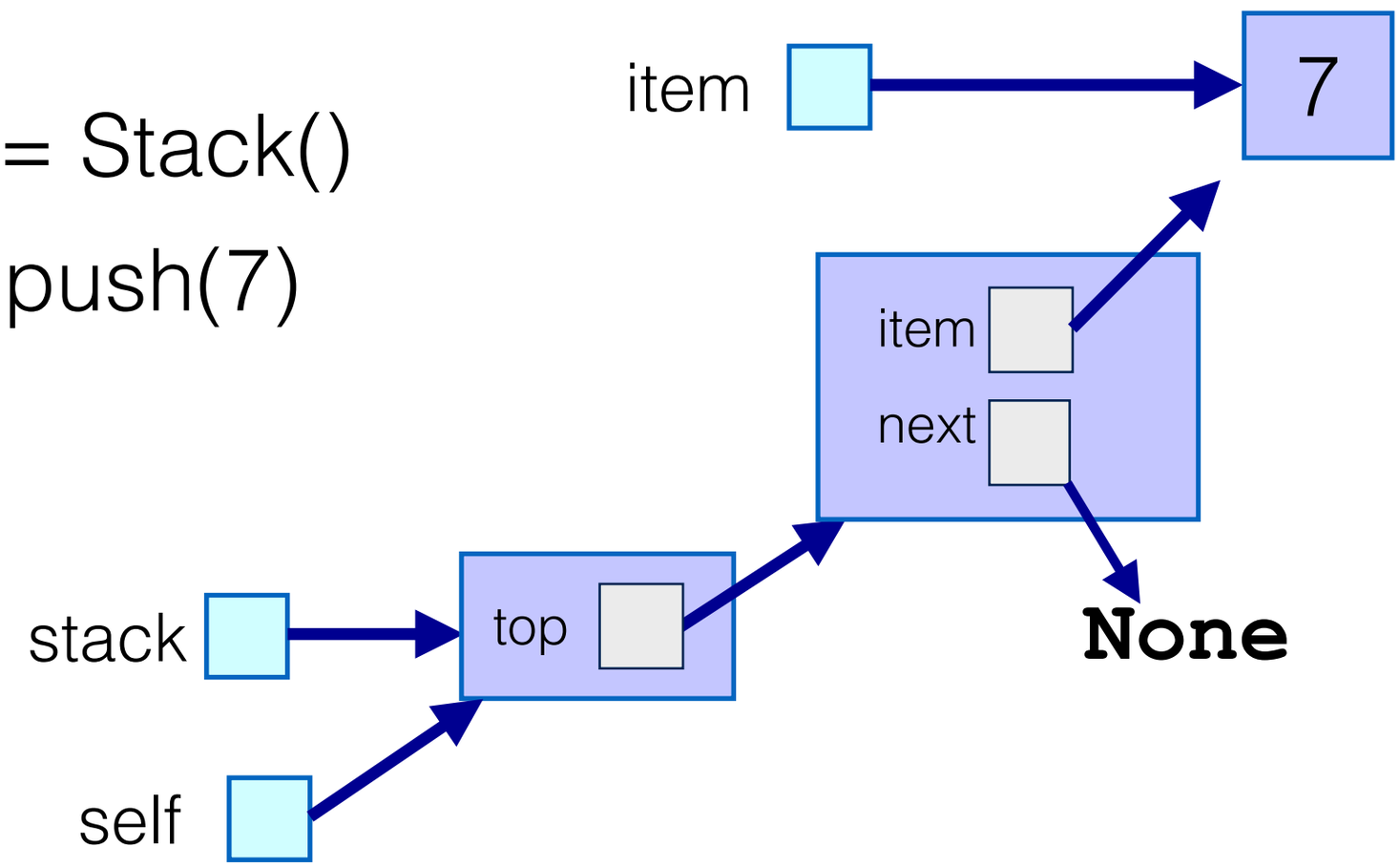


```python
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

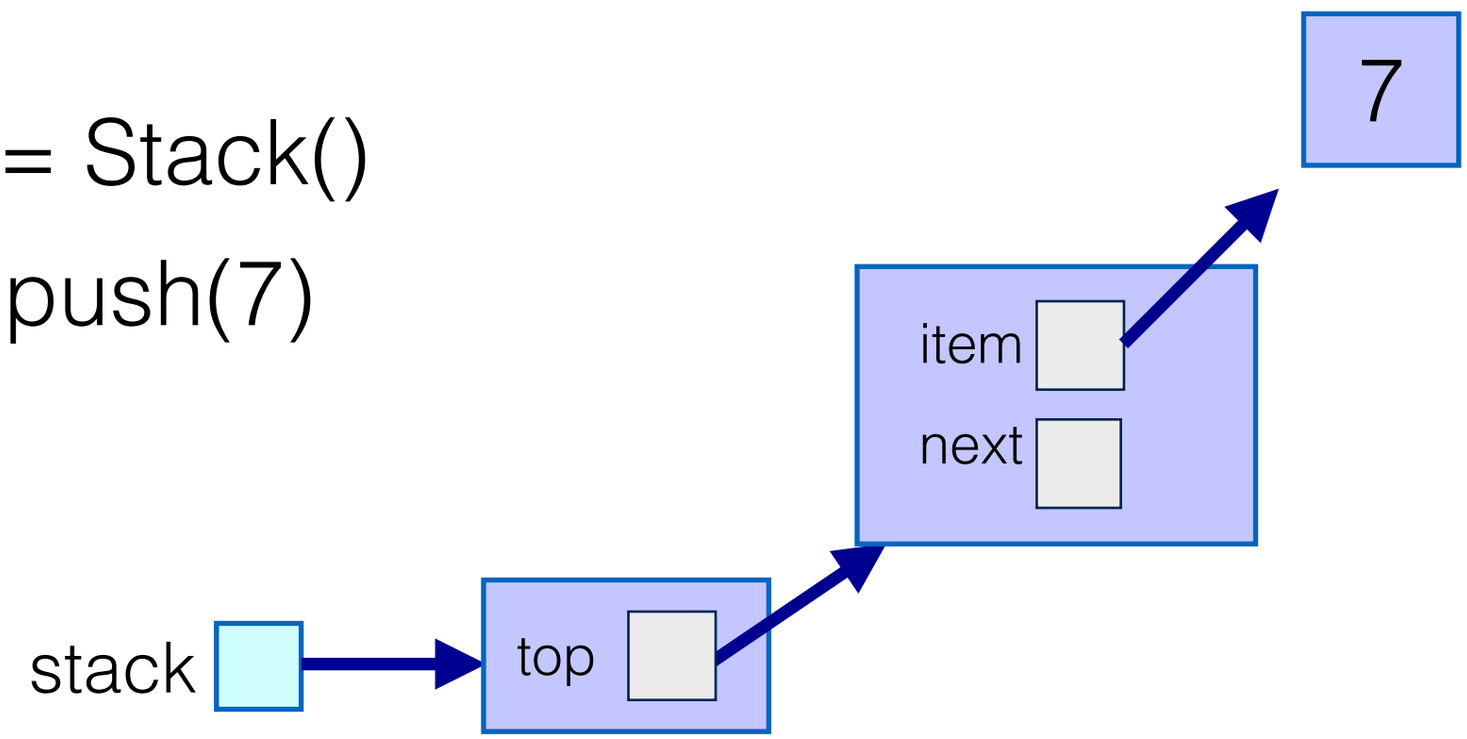


```python
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

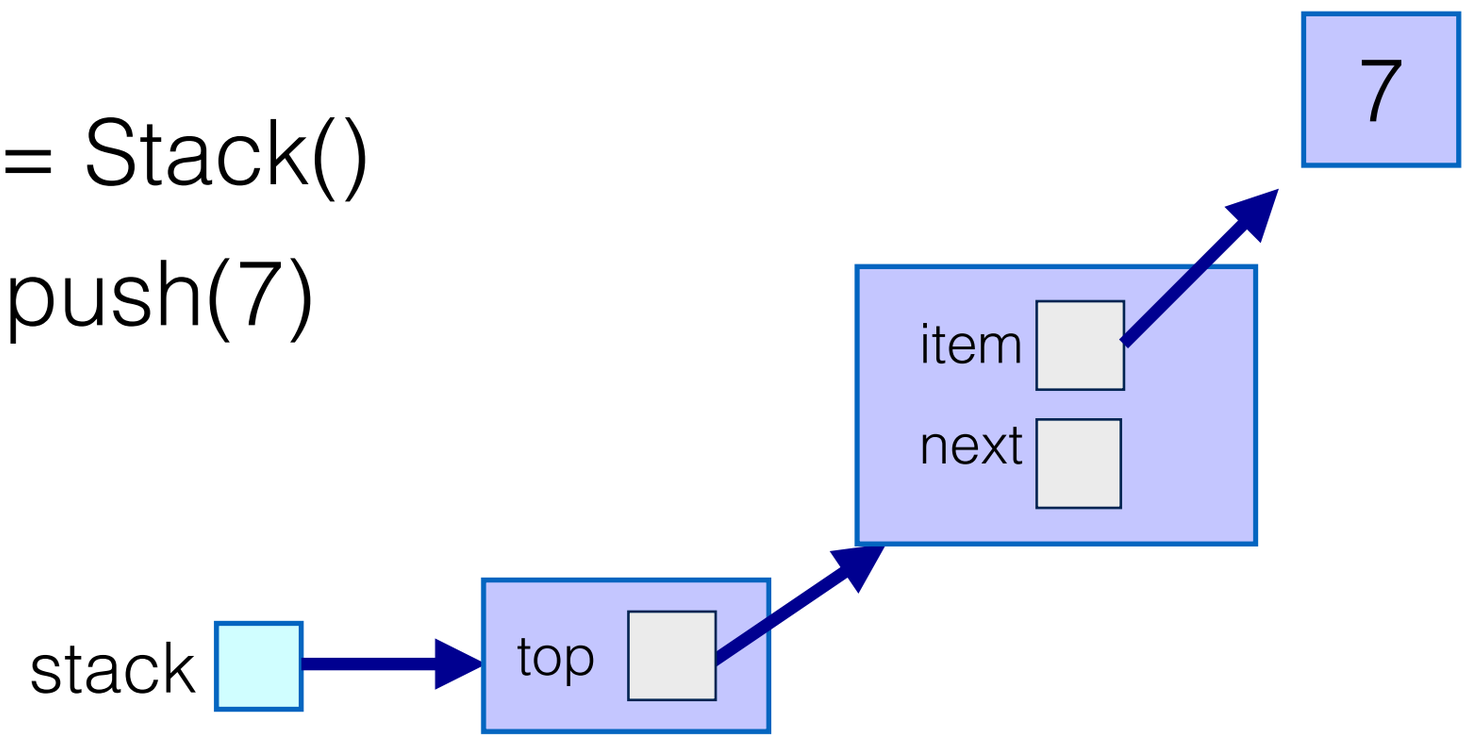


```python
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)

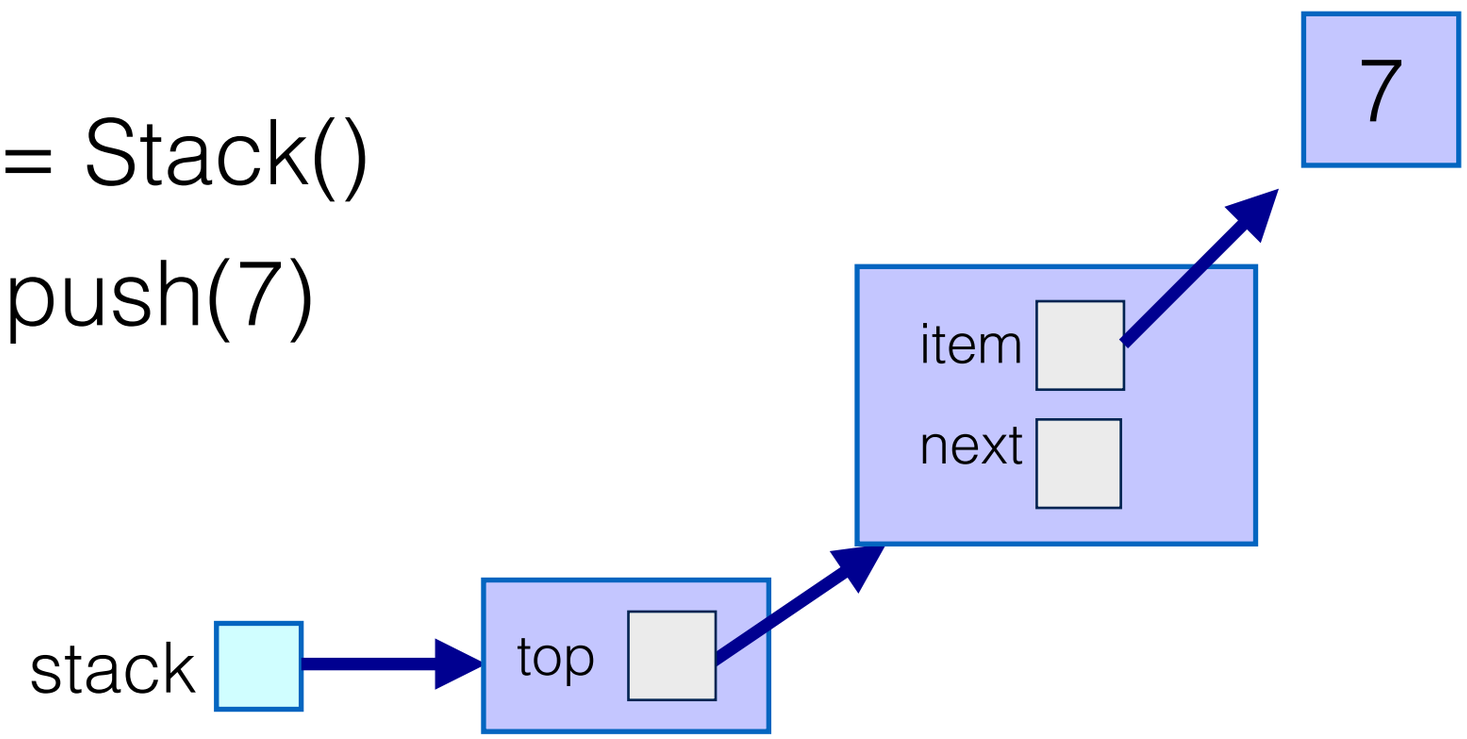


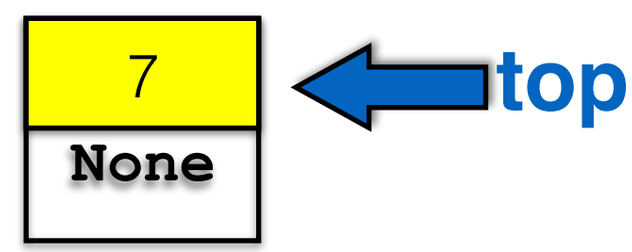
```python
class Stack:
    def __init__(self):
        self.top = None

    def push(self, item):
        self.top = Node(item, self.top)
```

stack = Stack()

stack.push(7)





Pop: algorithm

Array implementation:

Pop: algorithm

Array implementation:

- If the array is empty raise exception
- Else
  - Remember the top item
  - Decrease top
  - Return the item

Pop: algorithm

Array implementation:

- If the array is empty raise exception
- Else
  - Remember the top item
  - Decrease top
  - Return the item

Linked implementation:

Pop: algorithm

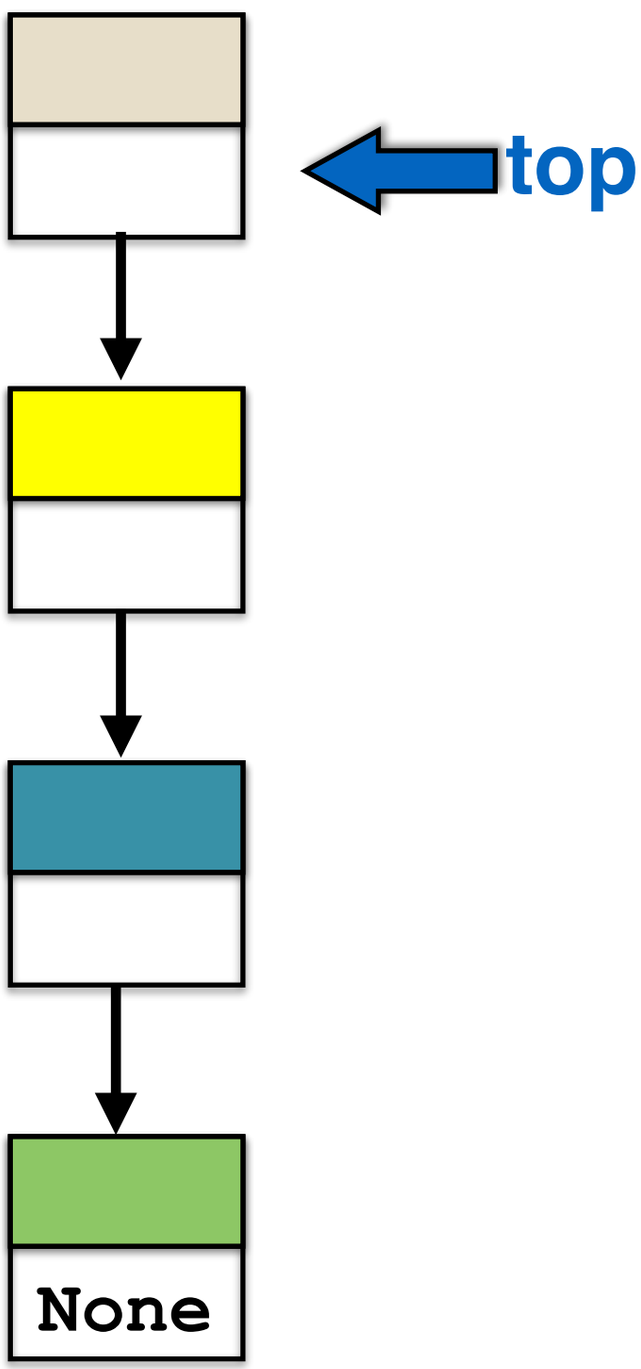
Array implementation:

- If the array is empty raise exception
- Else
  - Remember the top item
  - Decrease top
  - Return the item

Linked implementation:

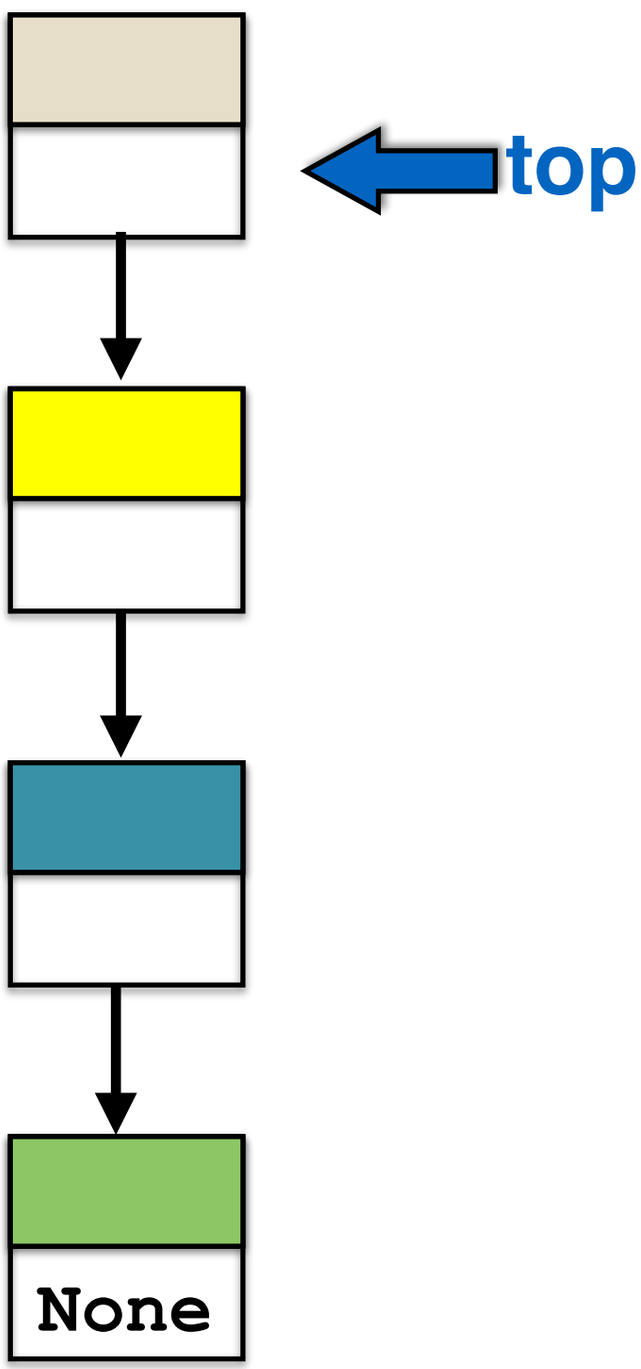
- If the stack is empty raise exception
- Else
  - Remember the top item
  - **Change top to point to the next node**
  - Return the item

Pop: algorithm



Check if the stack is empty

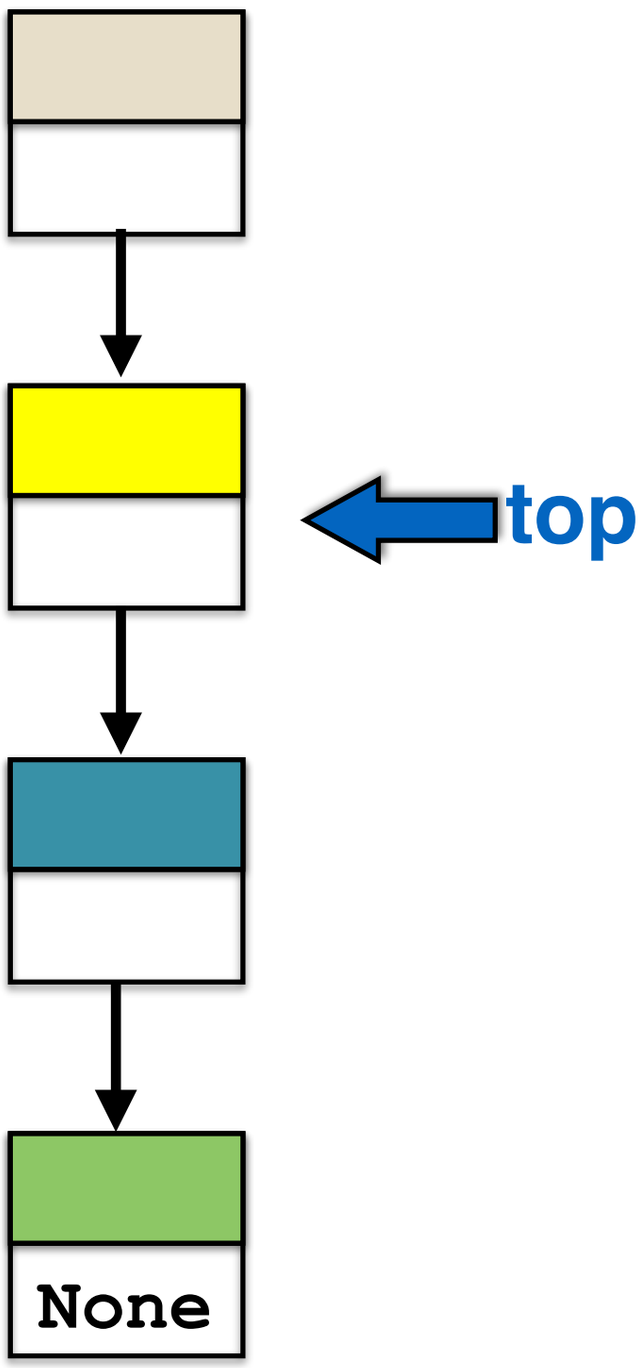
Pop: algorithm



Check if the stack is empty

Remember the item in the top node 

Pop: algorithm



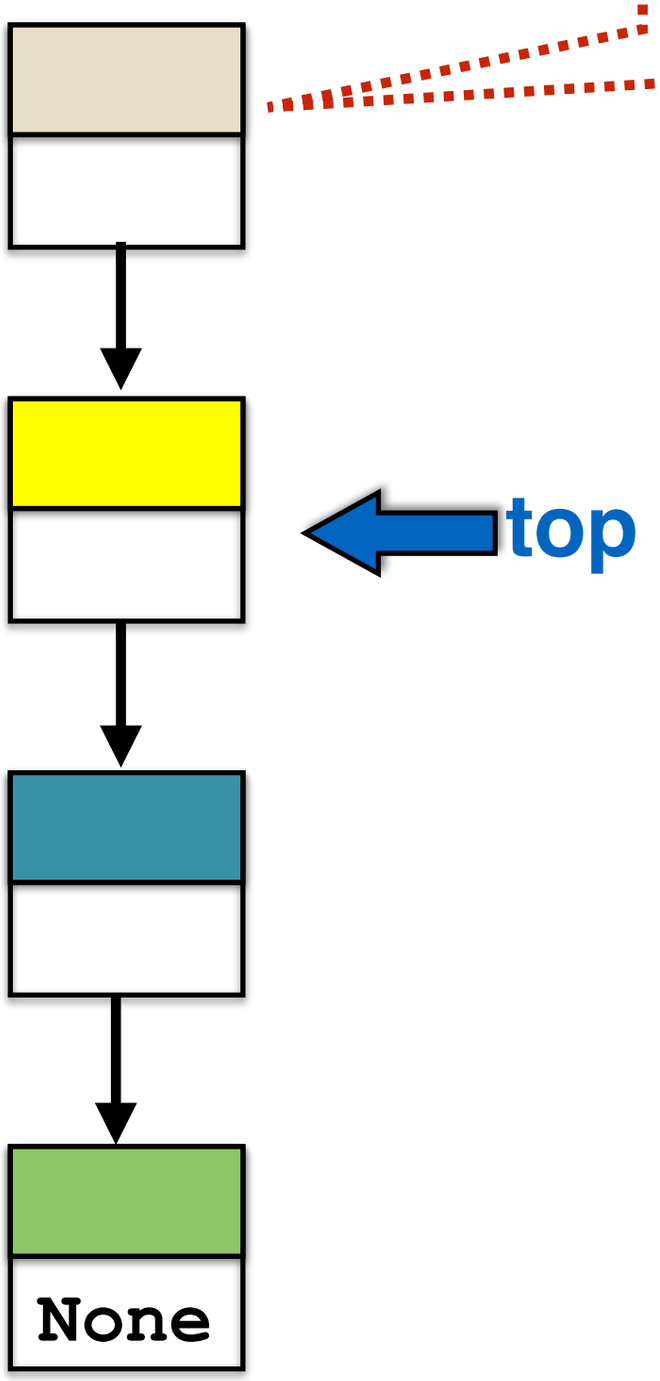
Check if the stack is empty

Remember the item in the top node

Make the next node the new top

Pop: algorithm

This node will be collected by the garbage collector

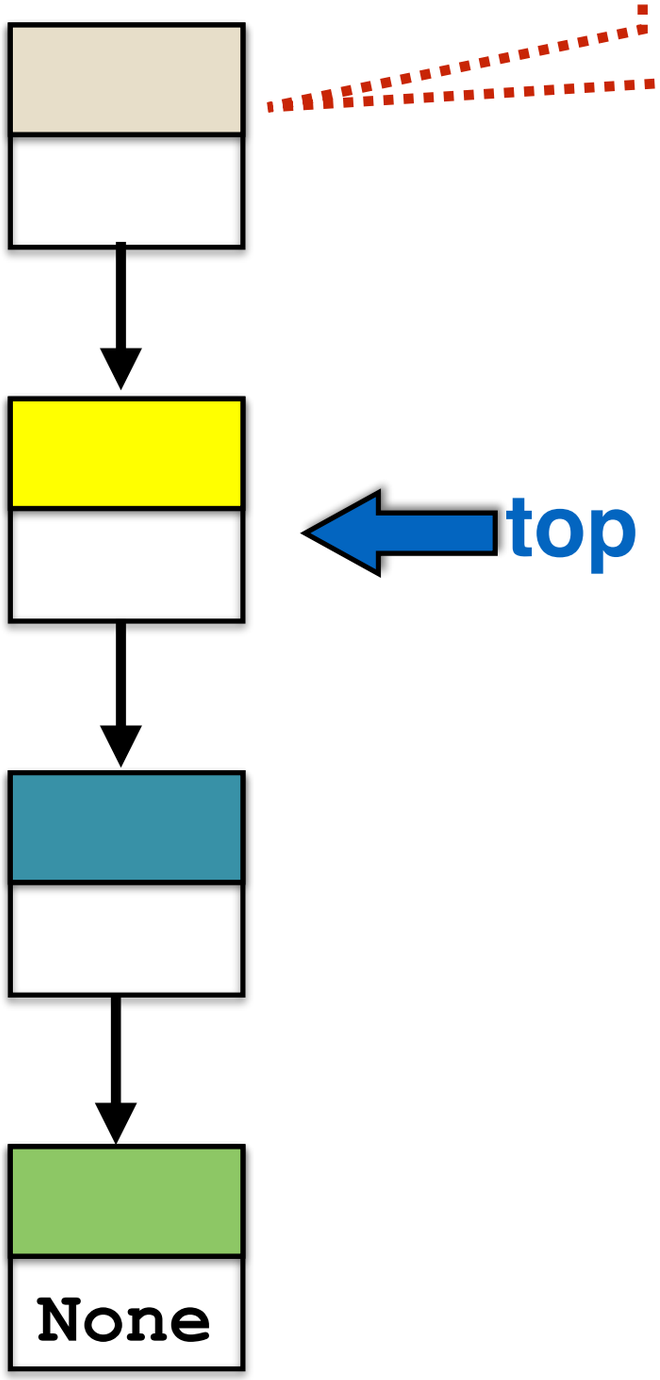


Check if the stack is empty

Remember the item in the top node

Make the next node the new top

Pop: algorithm



This node will be collected by the garbage collector

Check if the stack is empty

Remember the item in the top node

Make the next node the new top

Return the item

```
def pop(self):
```

```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
```

```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
```

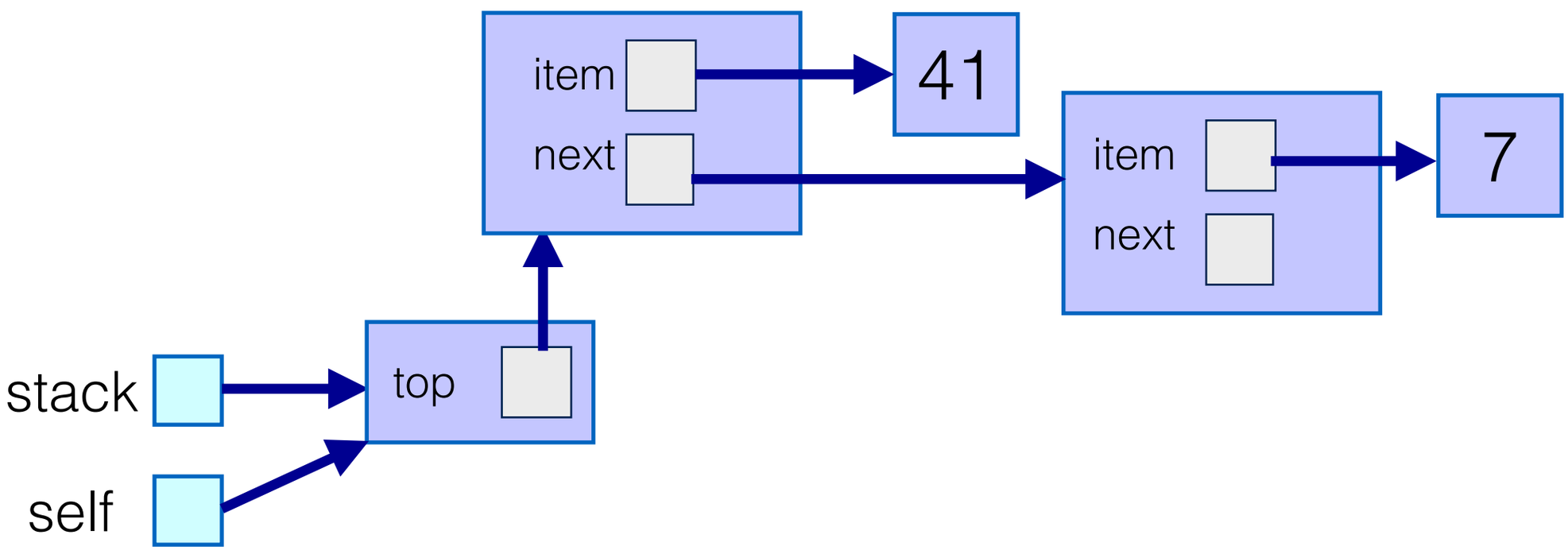
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
```

Note: it is **self.top.item** not **self.top**

```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
```

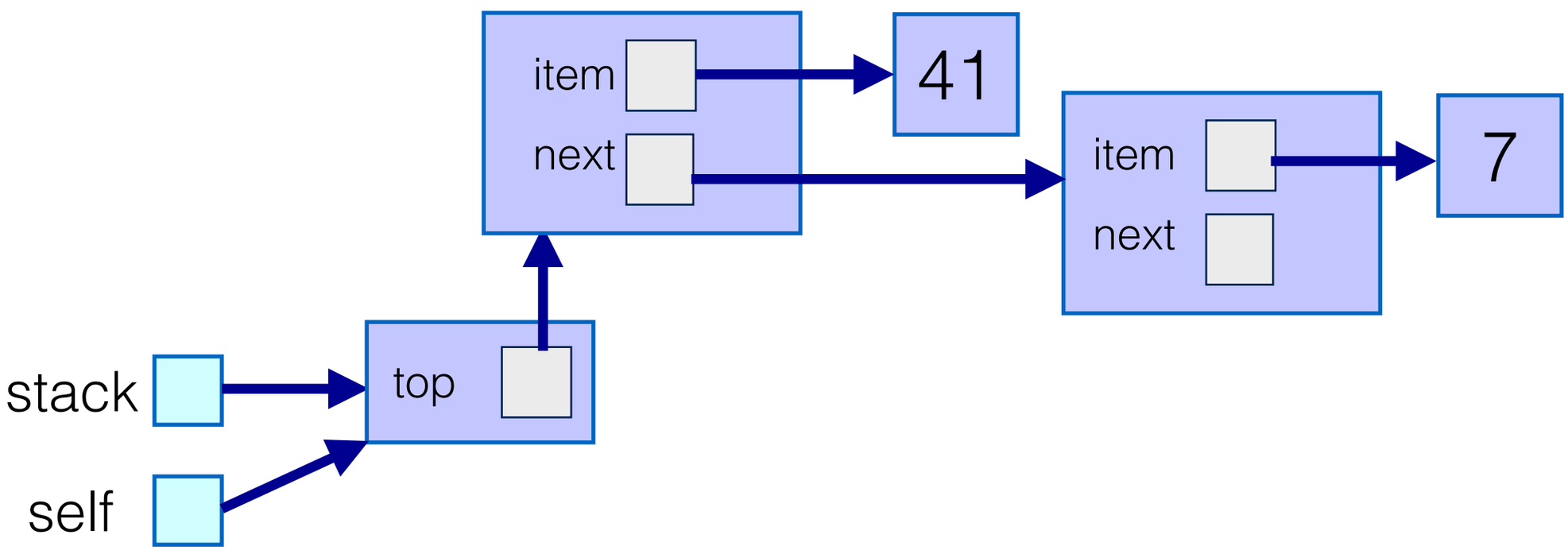
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```



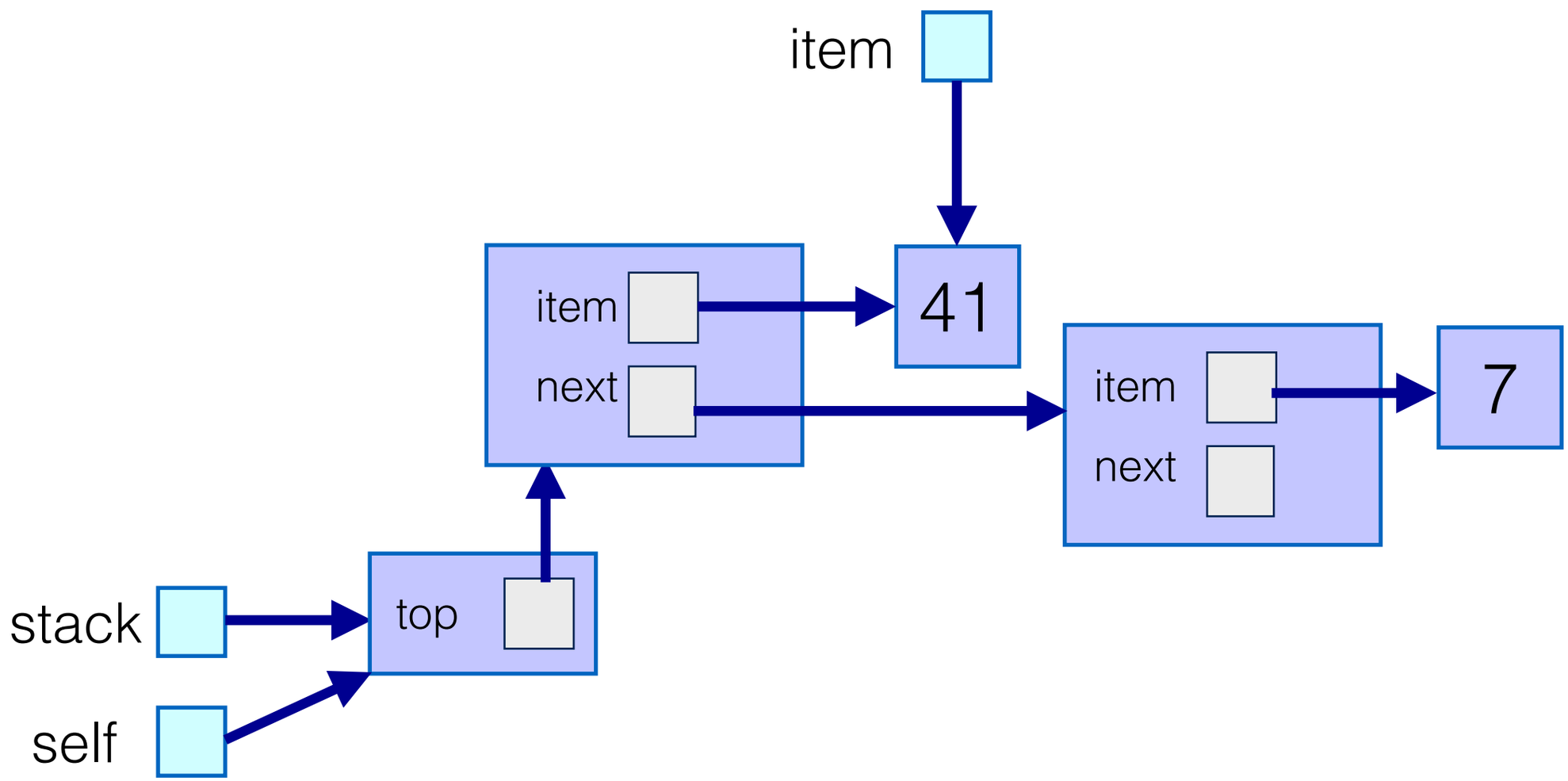
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



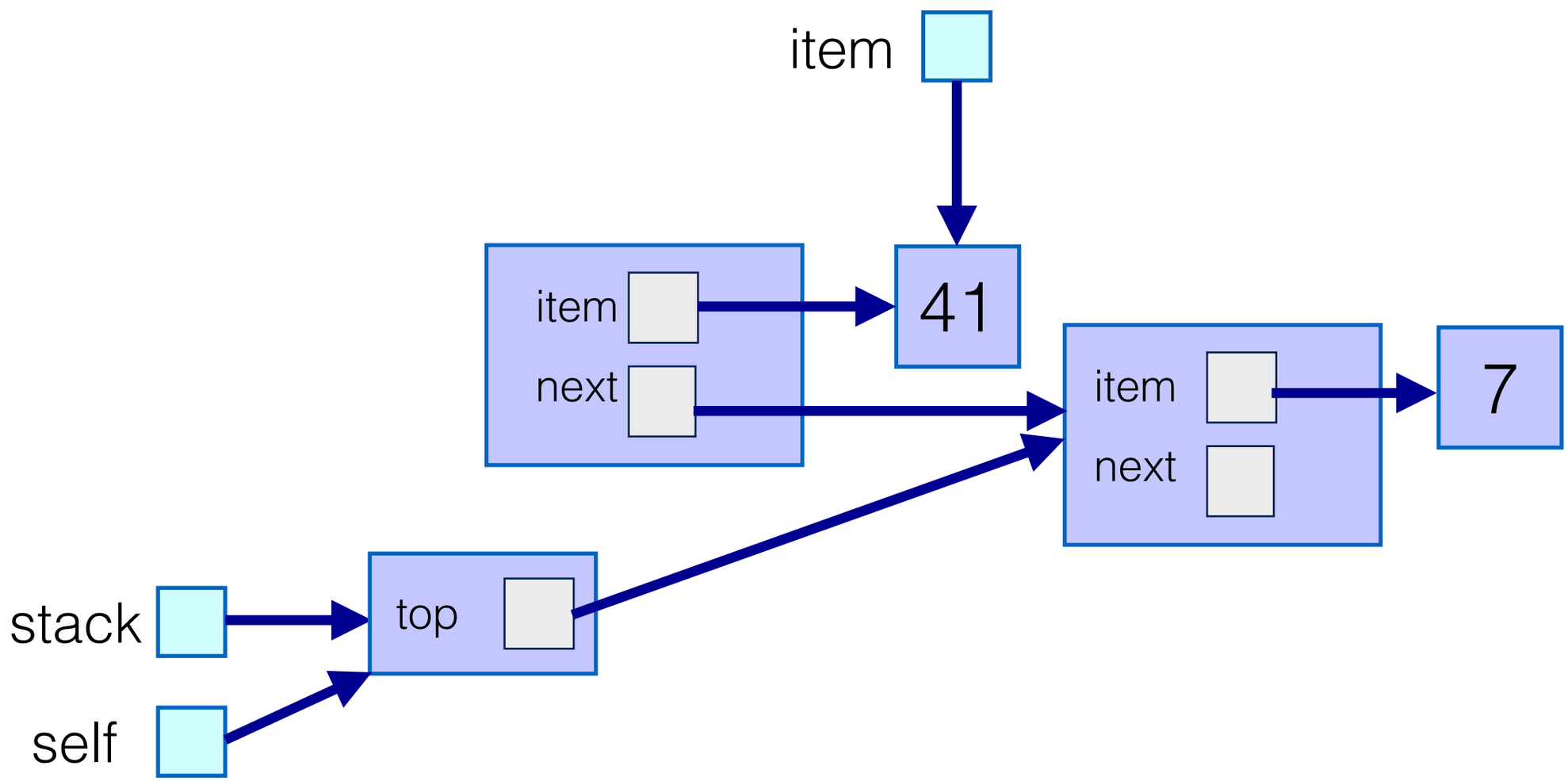
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



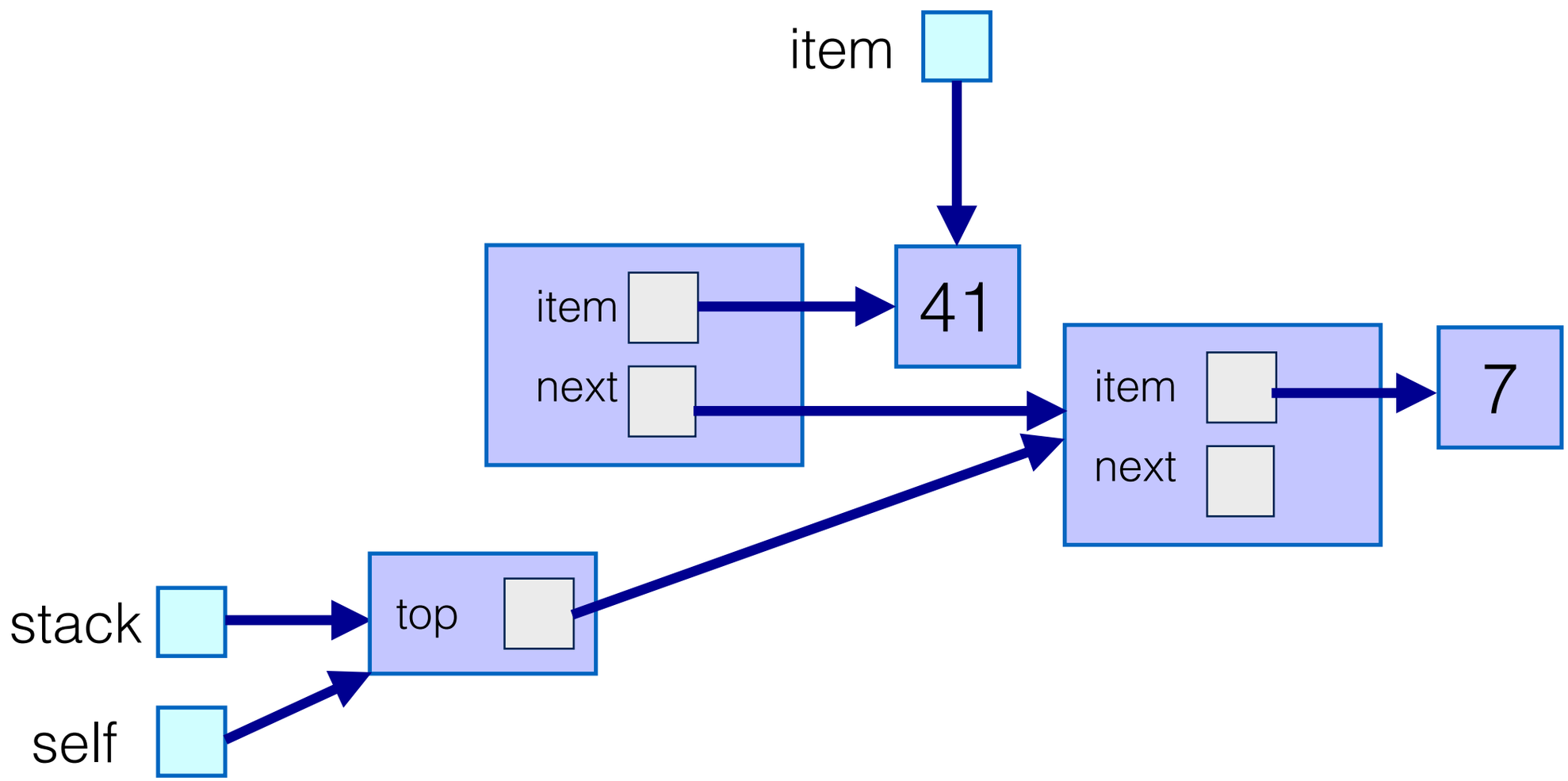
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



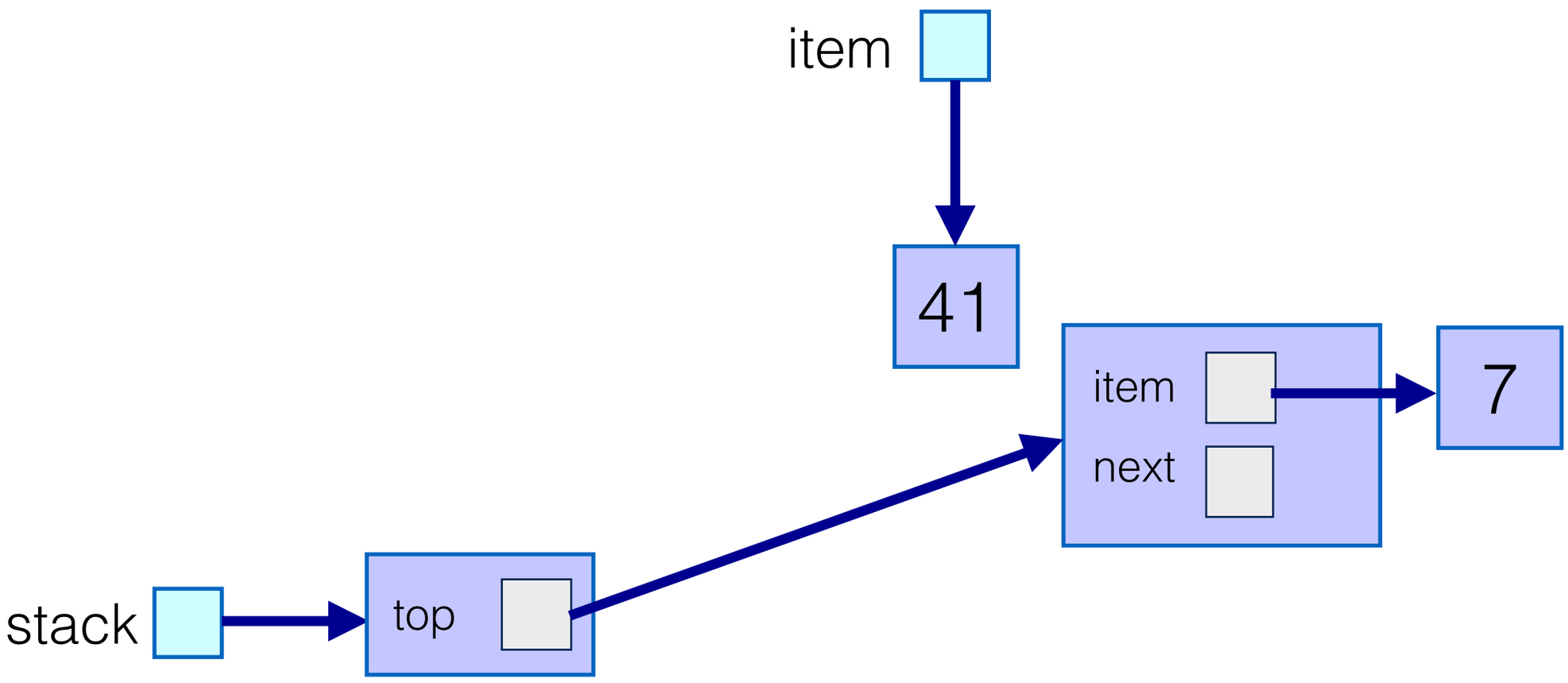
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



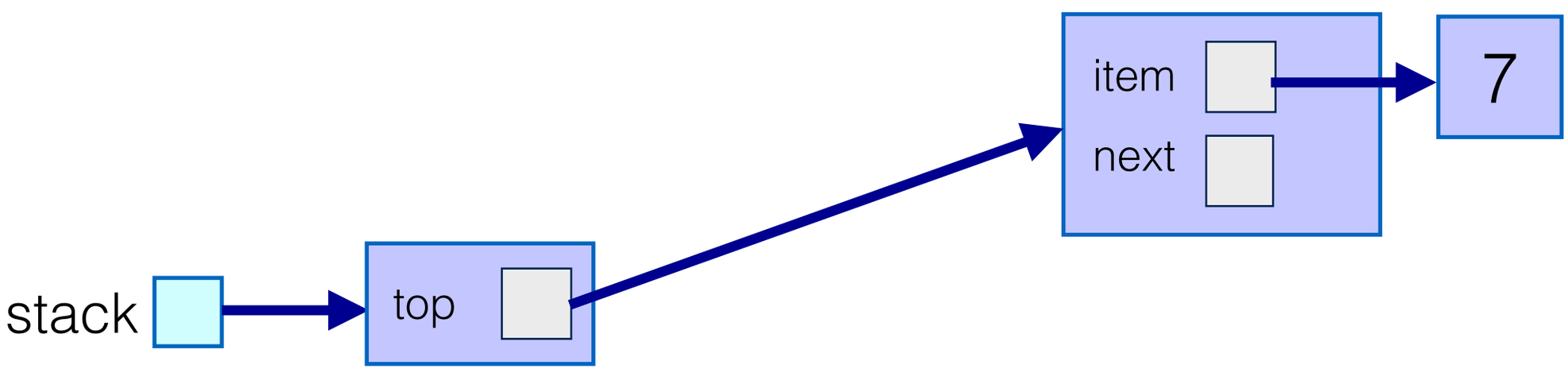
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



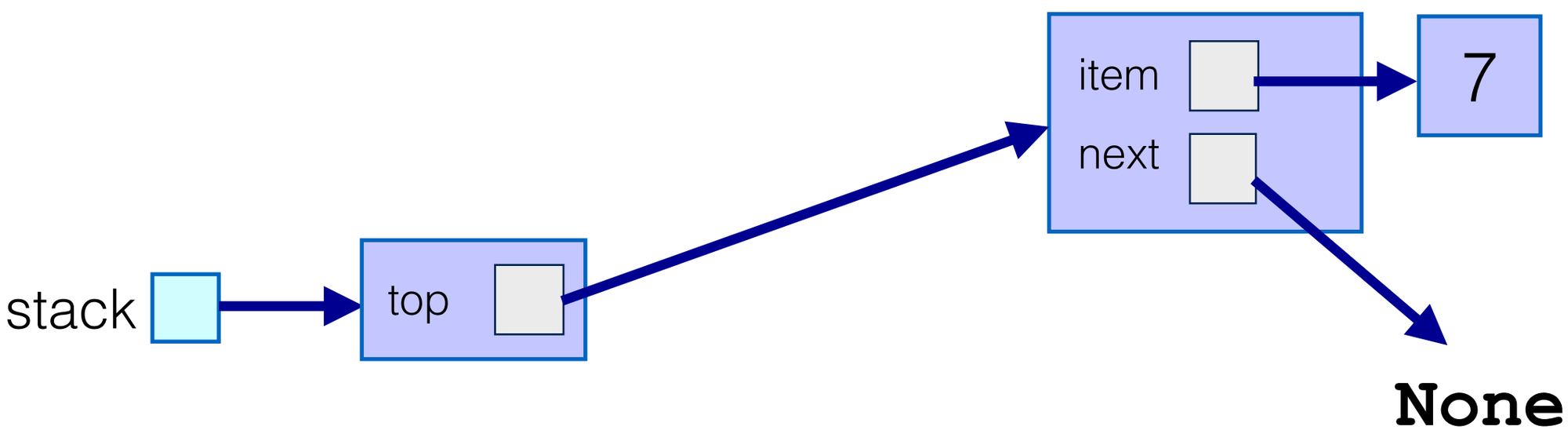
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



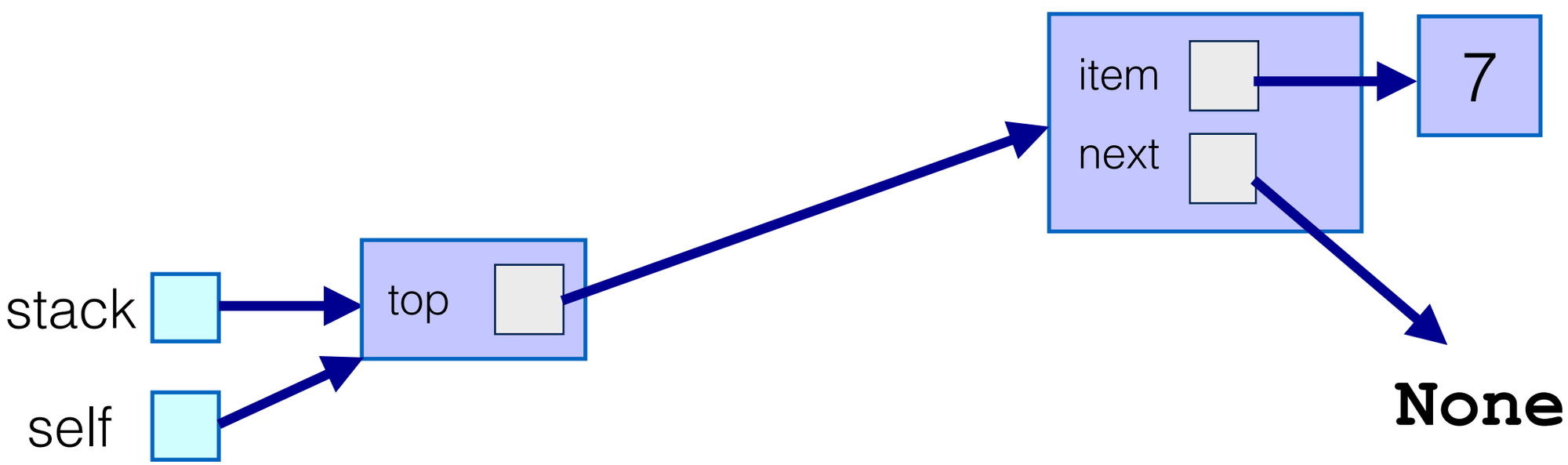
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



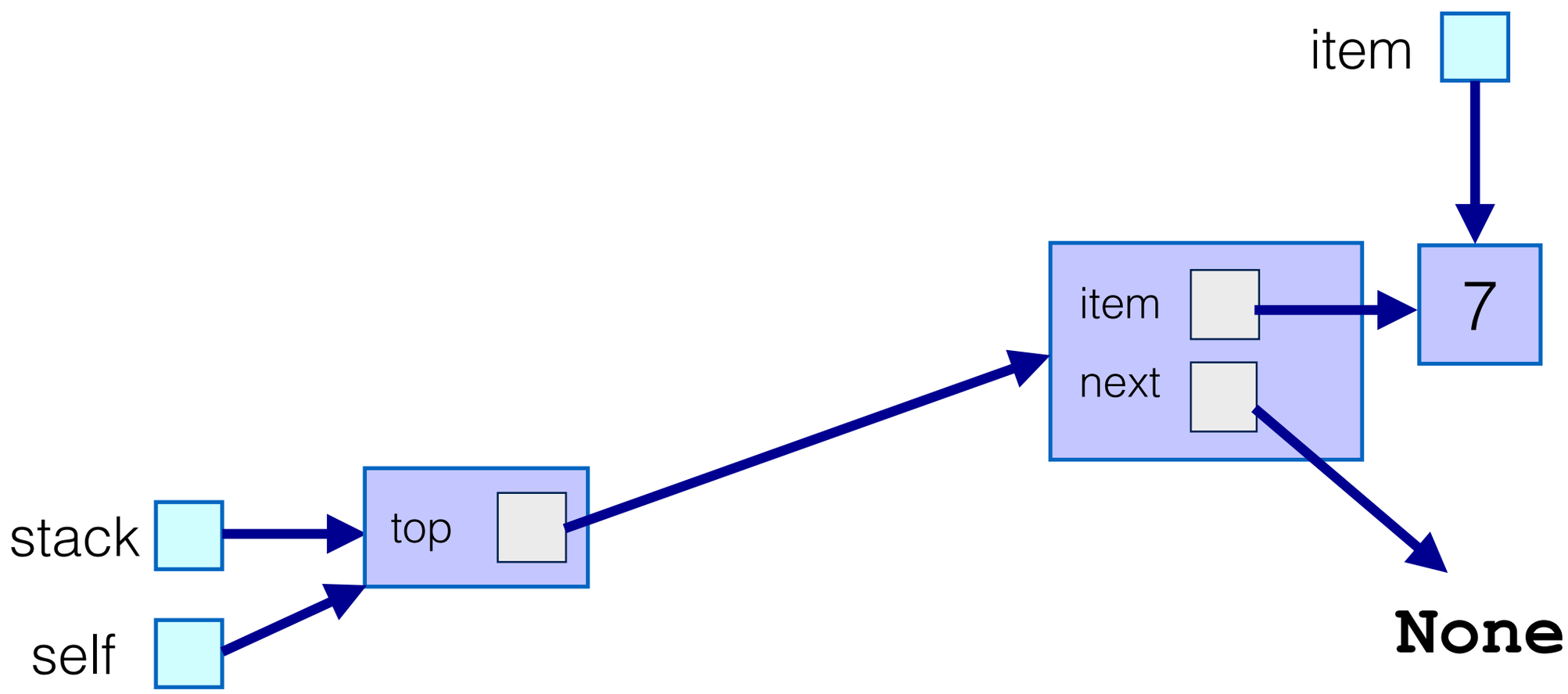
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



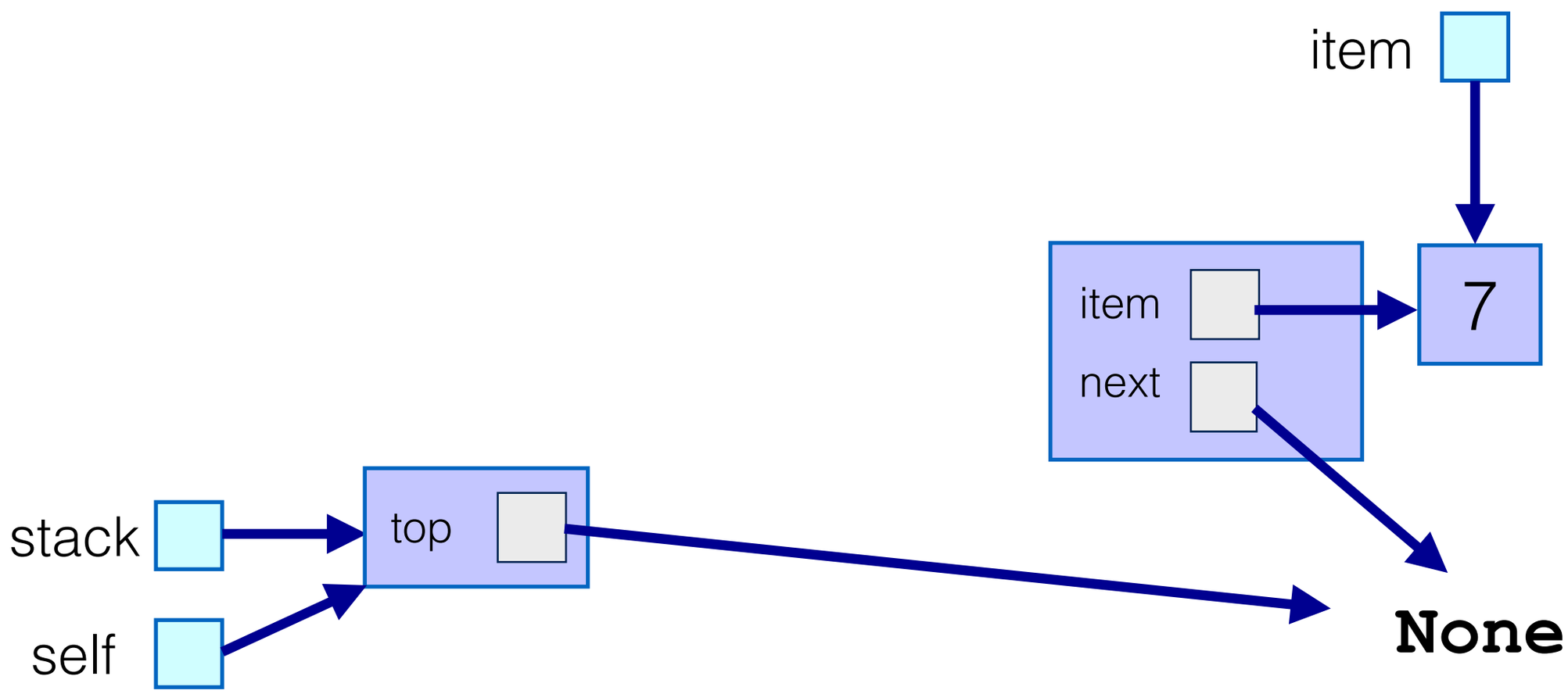
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



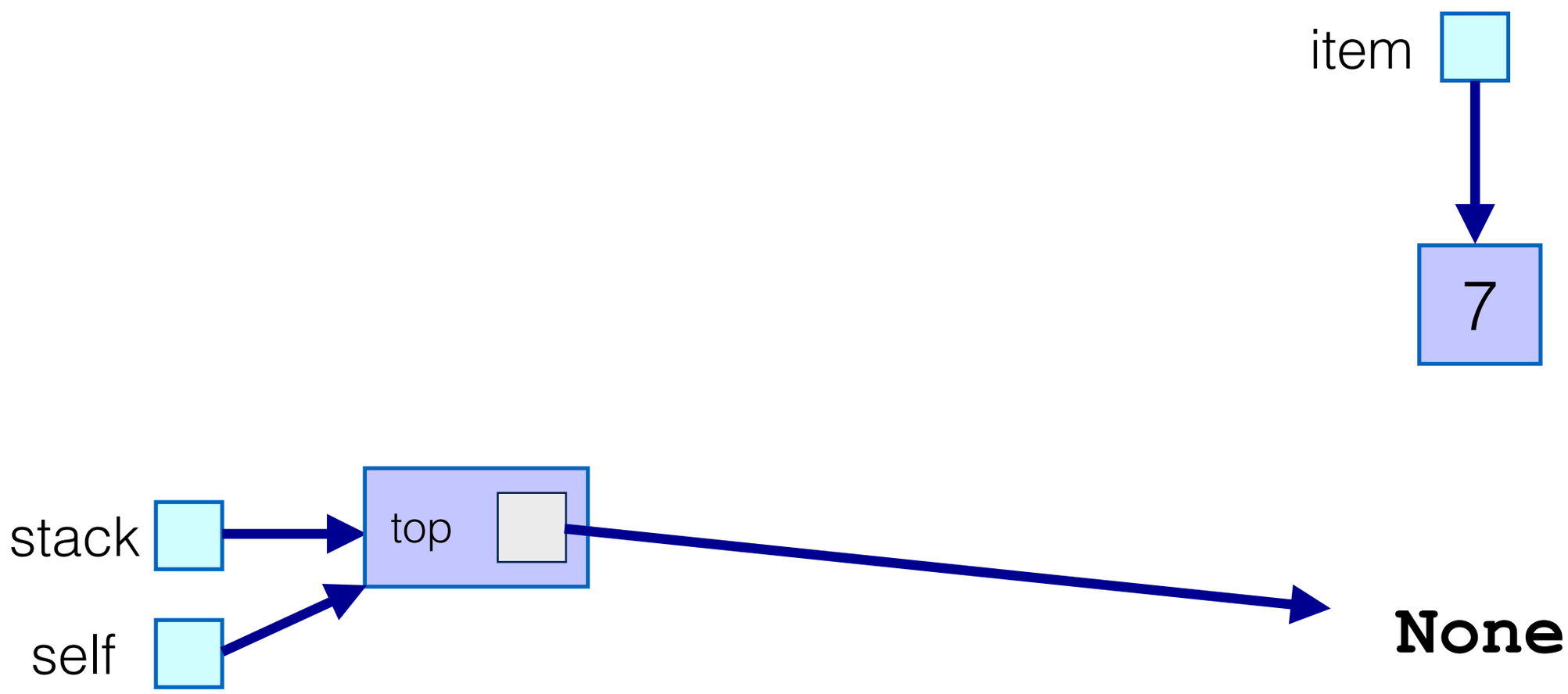
```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )



```python
def pop(self):
    assert not self.is_empty(), "Stack is empty"
    item = self.top.item
    self.top = self.top.next
    return item
```

stack.pop( )

```python
def reverse(a_string):
    the_stack = Stack()
    for item in a_string:
        the_stack.push(item)

    output = ""
    while not the_stack.is_empty():
        item = the_stack.pop()
        output += str(item)
    return output


if __name__ == "__main__":
    input_string = input("Enter a string: ")
    print(reverse(input_string))
```

Summary

- Advantages and disadvantages of linked data structures
- Stacks implemented with linked data structures