LINKED LISTS

LECTURE 8–1

JIM FIX, REED COLLEGE CSCI 121

COURSE INFO

- **Midterm:**
  - Graded; check Gradescope for feedback.
  - If you like, you can submit revisions to me and I'll take a look.
    - ➡ Either email me code (or pictures of handwritten code)…
    - ➡ …or just meet with me to go through those revisions.
- **Due Friday:**
  - **Project 2: ciphers**.
- **Posted today:**
  - **Project 3: hawk dove**, a bird simulation, *due three weeks from Friday.*
- **Today's lecture:**
  - We look at our first link-based data structure, *linked lists*.
  - (We will look at another kind, *search trees*, later in the semester.)

LIST DEMO

```
>>> xs = list(range(10000000))
>>> for _ in range(100000):
...     xs.append(1)
...
>>> for _ in range(100000):
...     xs.insert(0,0)
...
```

LIST DEMO

```
>>> xs = list(range(10000000))
>>> for _ in range(100000):
...     xs.append(1)
...
>>> for _ in range(100000):
...     xs.insert(0,0)
...
```

This runs somewhat instantaneously.

LIST DEMO

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>>> xs = list(range(10000000))
>>> for _ in range(100000):
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...
>>> for _ in range(100000):
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```

This loop sure takes a while. Why?

LIST DEMO

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>>> xs = list(range(10000000))
>>> for _ in range(100000):
...     xs.append(1)
...
>>> for _ in range(100000):
...     xs.insert(0,0)
...
```

This loop sure takes a while. Why?

The items stored at 0 onward have to be copied right to make room for the new item #0.

LIST DEMO

```
>>> xs = list(range(10000000))
>>> for _ in range(100000):
...     xs.append(1)
...
>>> for _ in range(100000):
...     xs.insert(0,0)
...
>>> for _ in range(100000):
...     del xs[0]
...
```

This loop also takes a while. Why?

LIST DEMO

```
>>> xs = list(range(10000000))
>>> for _ in range(100000):
...     xs.append(1)
...
>>> for _ in range(100000):
...     xs.insert(0,0)
...
>>> for _ in range(100000):
...     del xs[0]
...
```

This loop also takes a while. Why?

The items stored at 1 onward have to be copied left to when we eliminate item #0.

LINKED DATA STRUCTURES

- Rather than storing data as a sequence in memory…
- …we can house the data into individual storage units called ***nodes.***
- The sequencing happens by having each node* know some successor node.
  - ➡ Each node refers to, or *links to*, some other node*.
- We can change the sequence order, or add things, or remove things, by changing the links.
- You don't have to move the data around.

** NOTE: except the last node in the sequence.*

A NODE CLASS

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

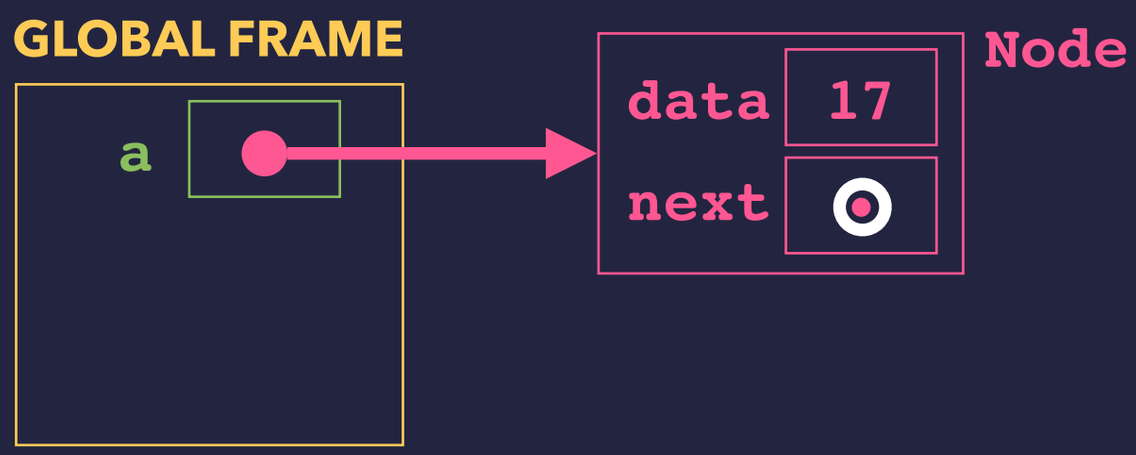
```
>>>
```

GLOBAL FRAME

A NODE CLASS

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

>>> a = Node(17)
>>>
```



A NODE CLASS

```
class Node:
    def __init__(self, value):
        self.value = value
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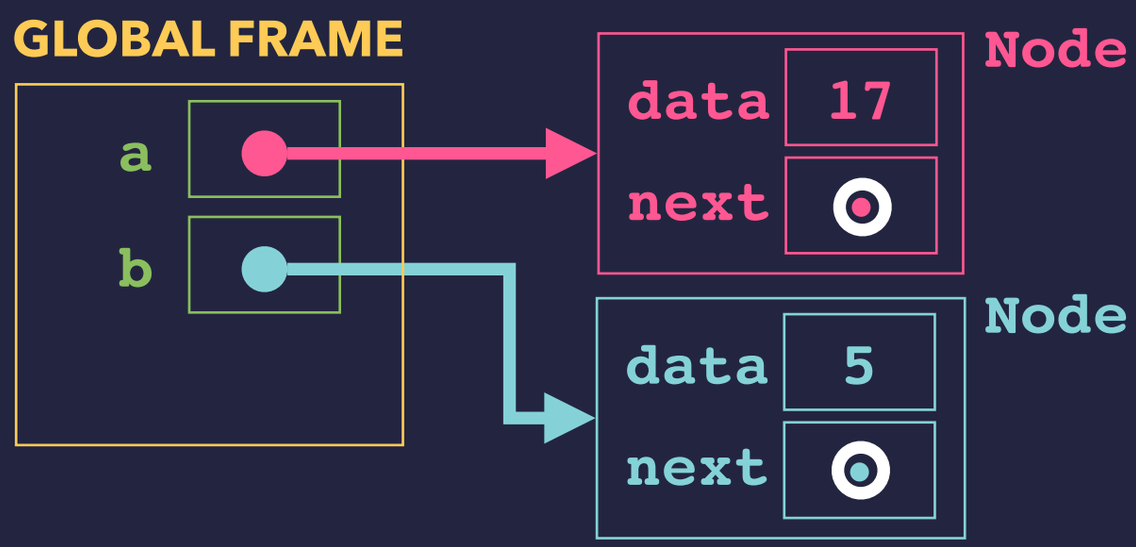
```

```
>>> a = Node(17)
>>> b = Node(5)
>>>
```



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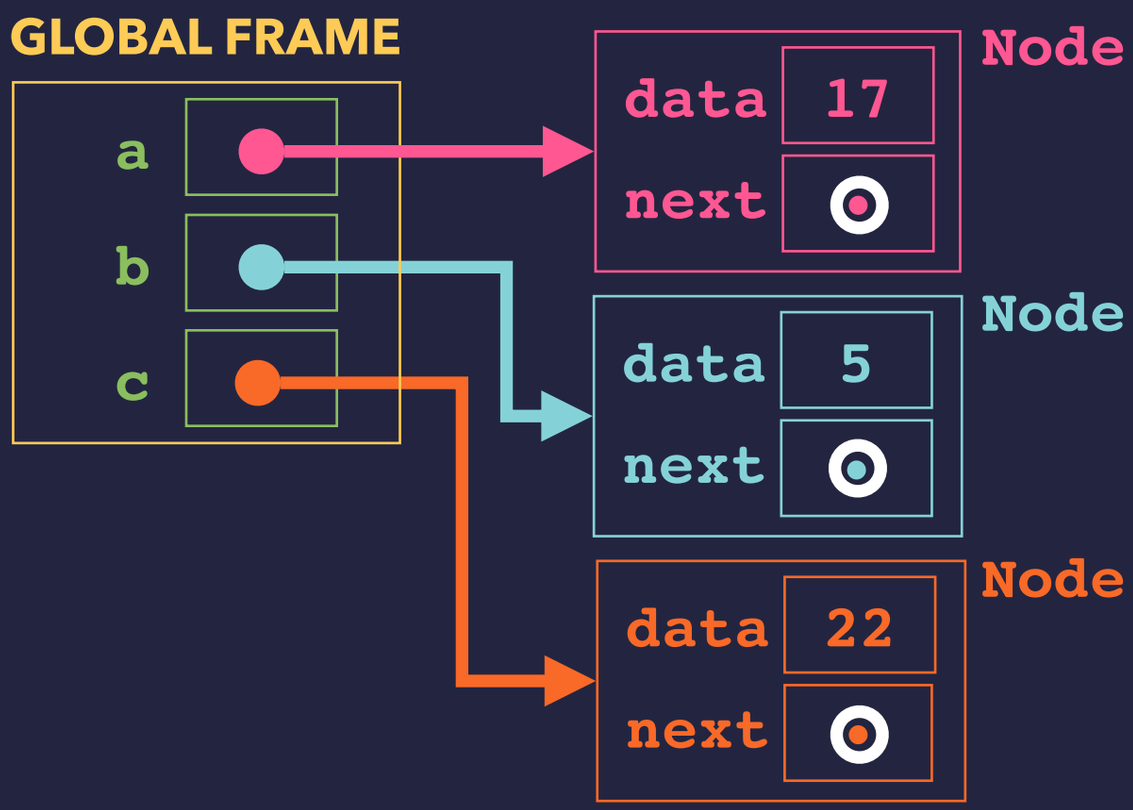
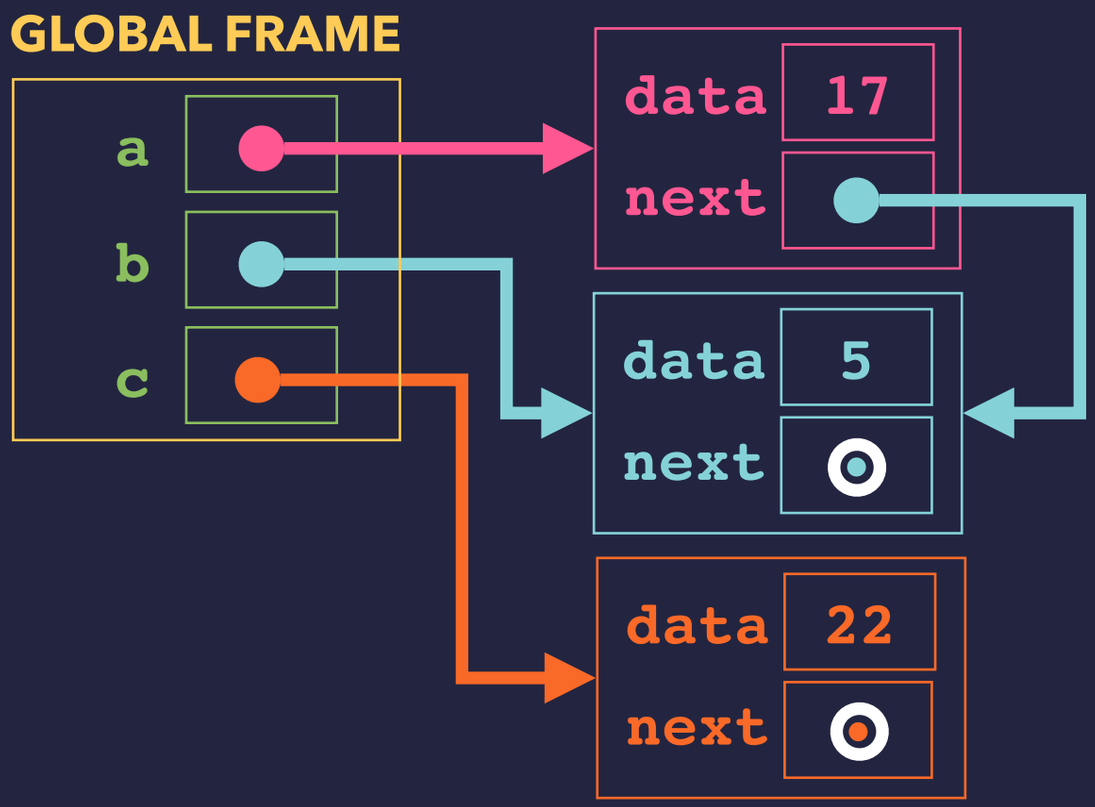


LINKING NODES IN SERIES

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

```
>>> a = Node(17)
>>> b = Node(5)
>>> c = Node(22)
>>> a.next = b
>>>
```



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```

```
>>> a = Node(17)
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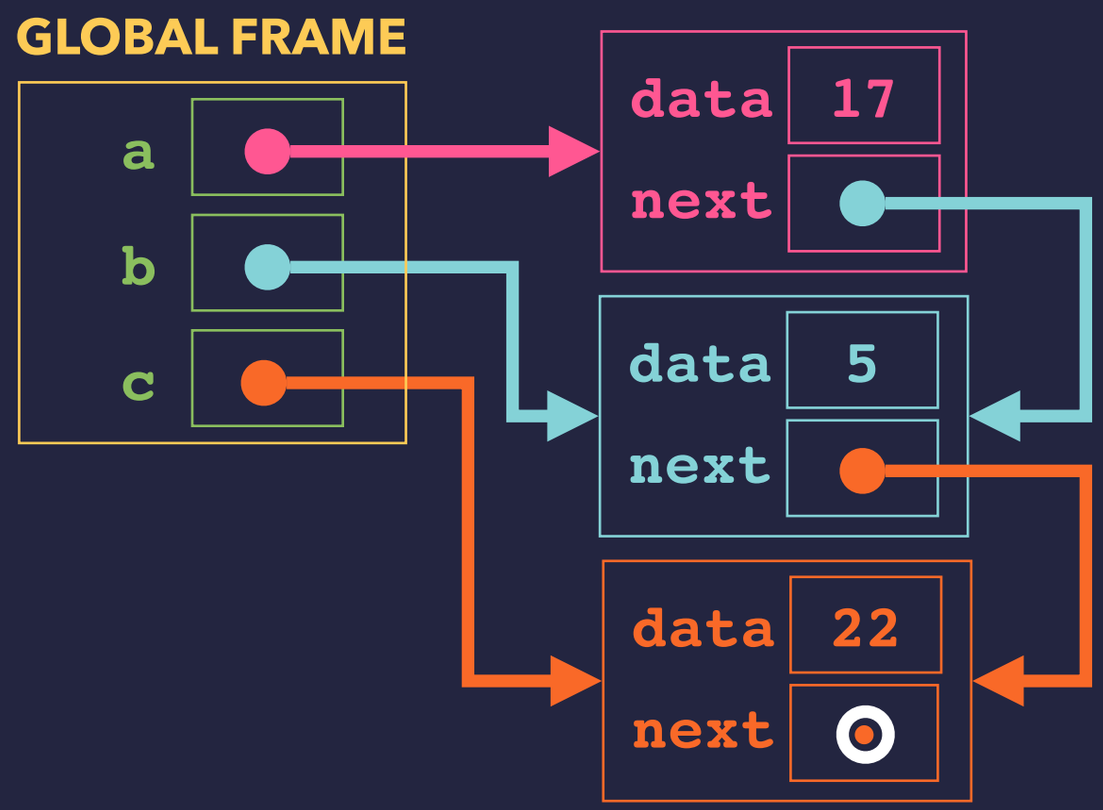
>>> a.next = b
>>> b.next = c
>>>
```



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class Node:
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>>> a.next = b
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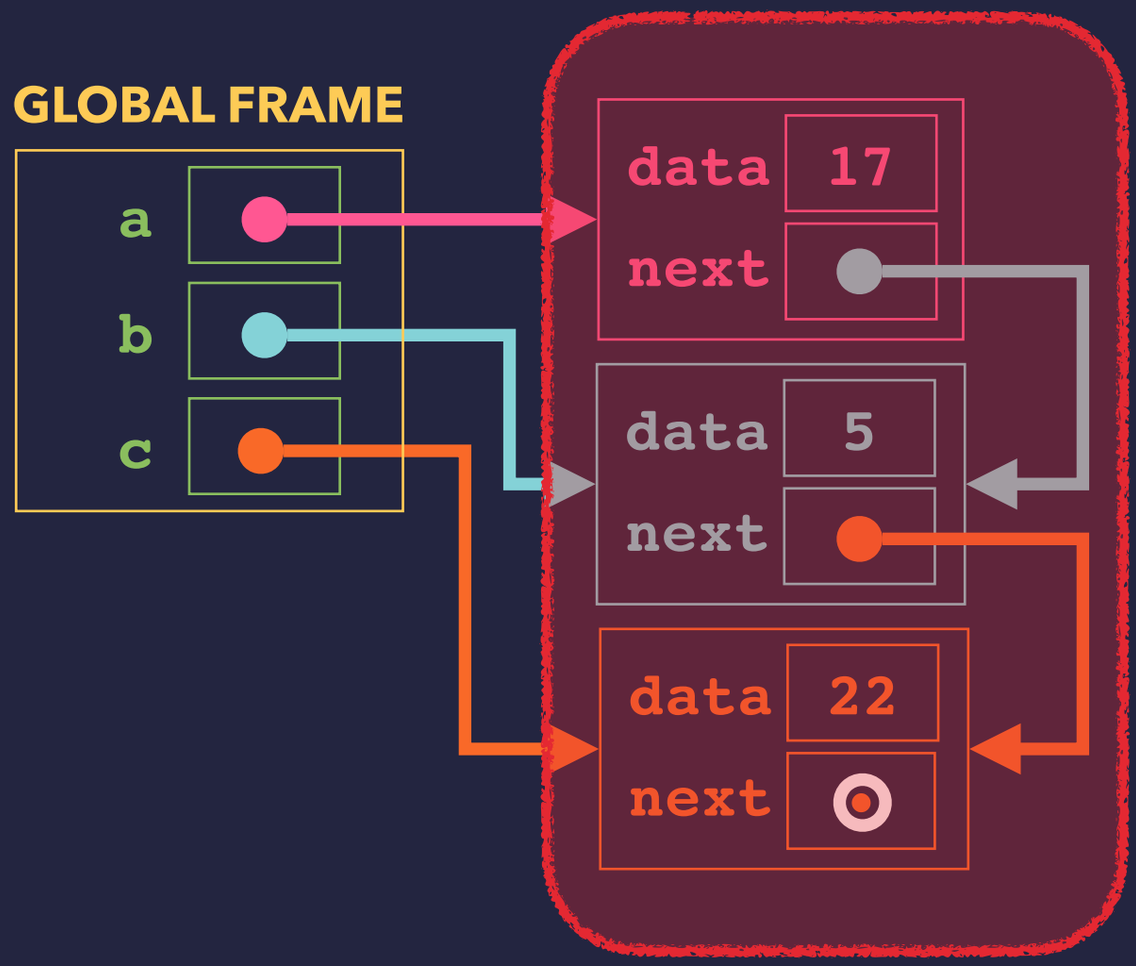
```

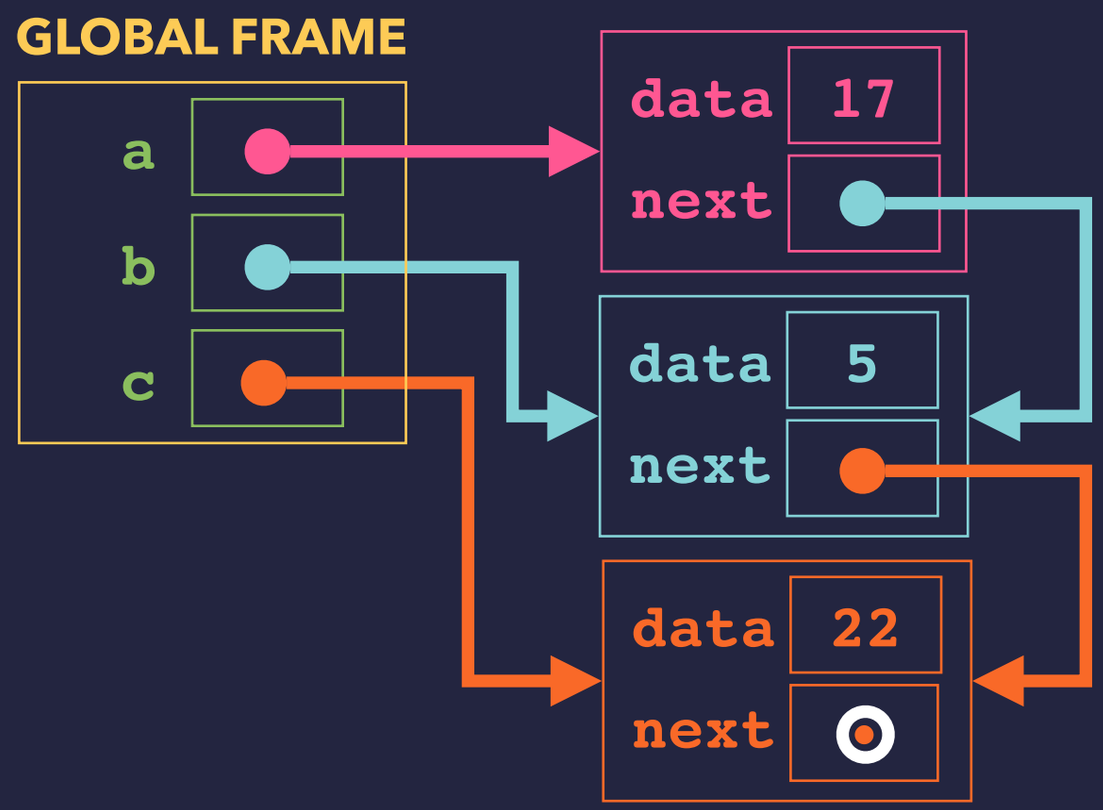


THIS STRUCTURE IS CALLED A LINKED LIST

FOLLOWING LINKS

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

```
>>> a = Node(17)
>>> b = Node(5)
>>> c = Node(22)
>>> a.next = b
>>> b.next = c
>>> a.value
17
>>> b.value
5
>>> c.value
22
>>> a.next.value
5
```



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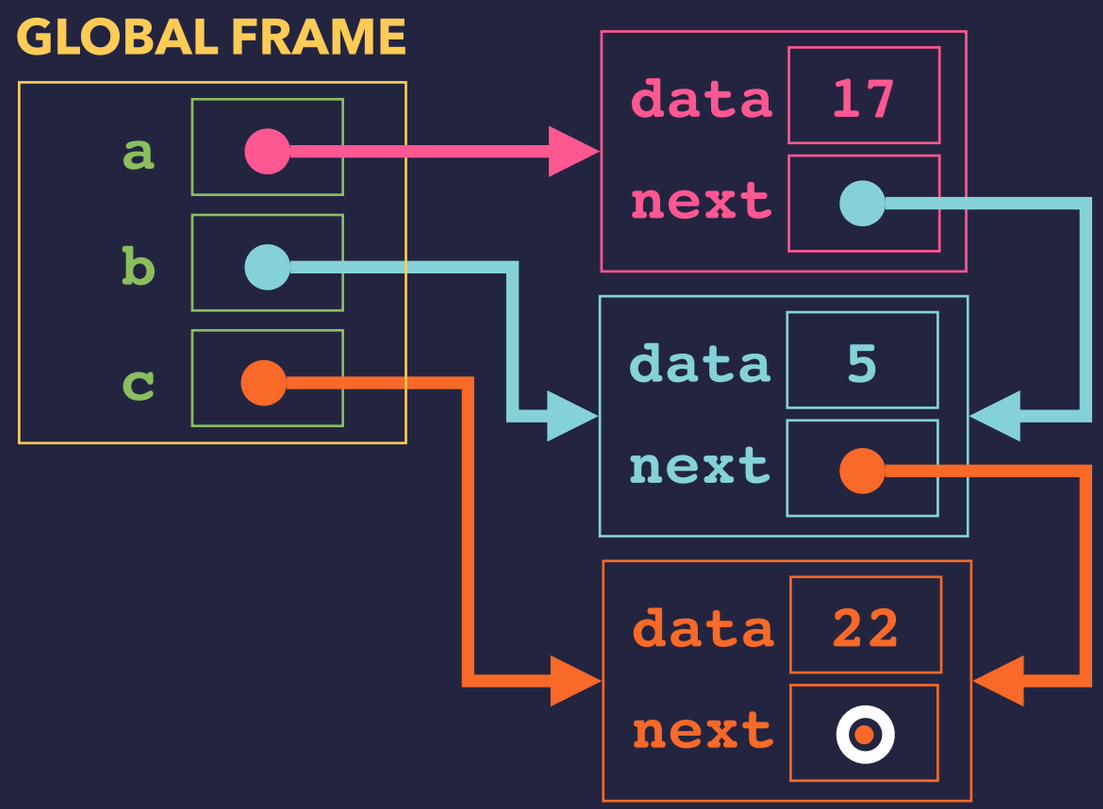
>>> b.next = c
>>> a.value
17
>>> b.value
5
>>> c.value
22
>>> a.next.value
5
>>> a.next.next.value
22
```



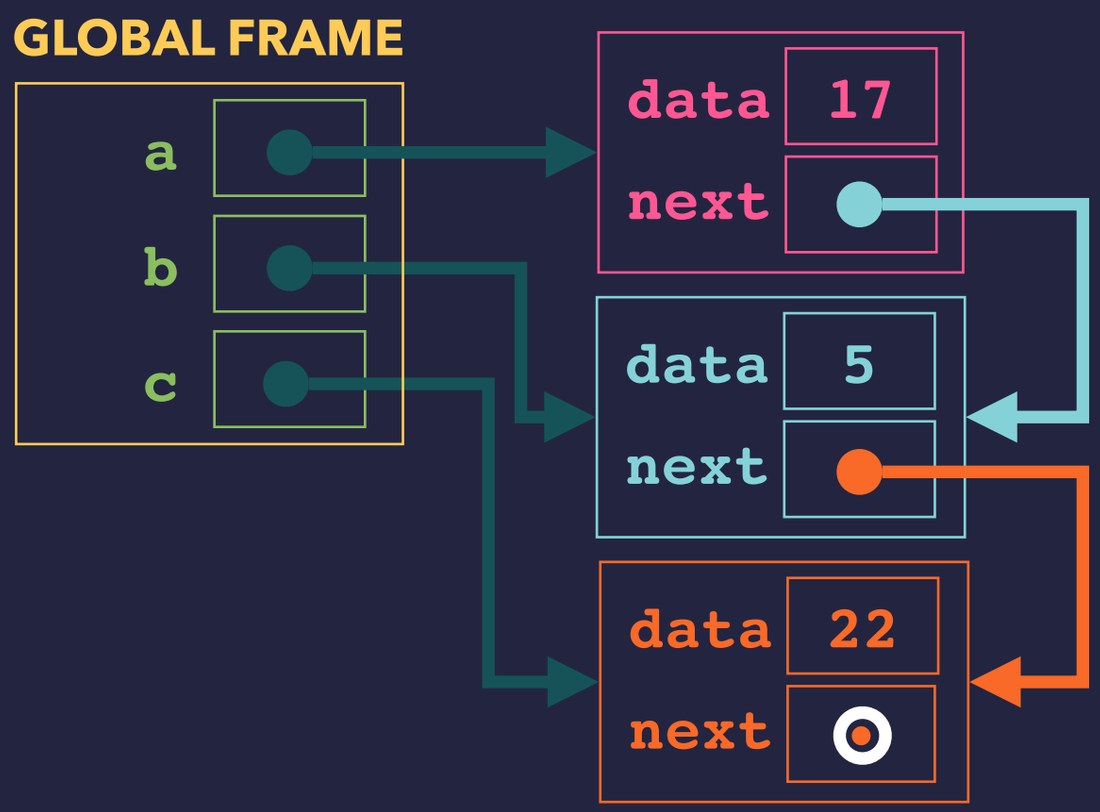
LOOPING THROUGH A LINKED LIST

TRAVERSING A LINKED LIST

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

def traverse(frst):
    curr = frst
    while curr is not None:
        print(curr.value)
        curr = curr.next
```

```
>>> a = Node(17)
>>> b = Node(5)
>>> c = Node(22)
>>> traverse(a)
```



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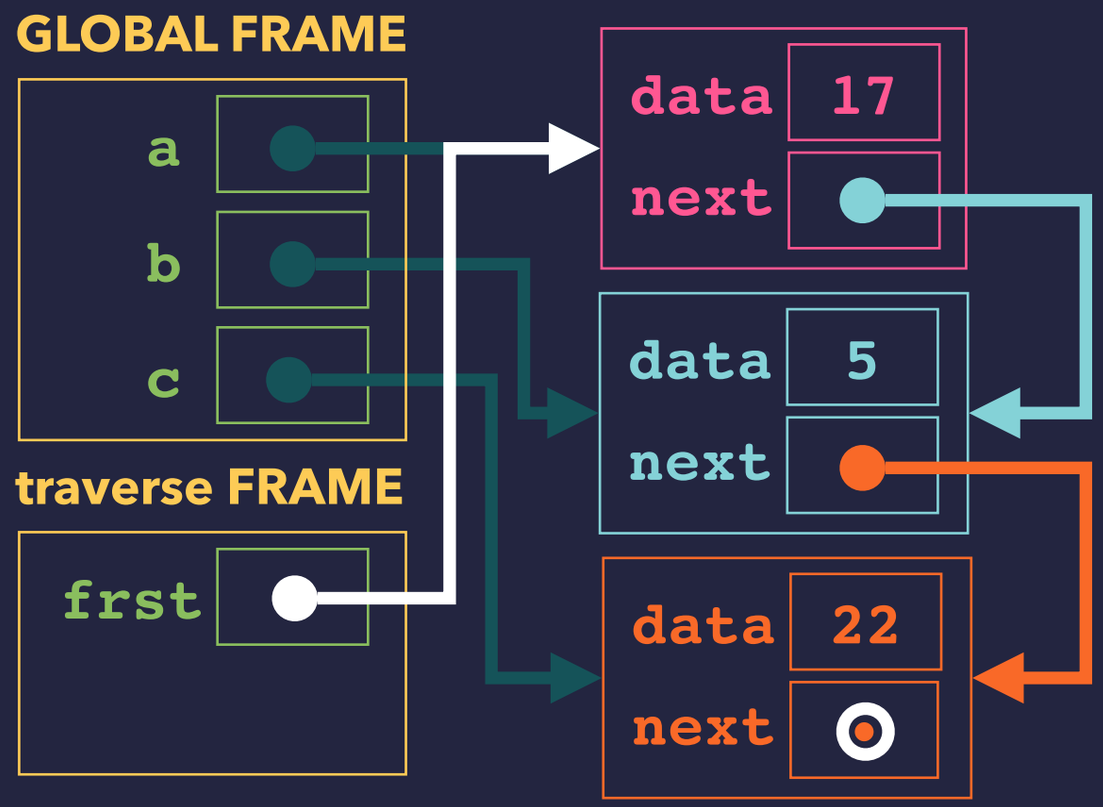

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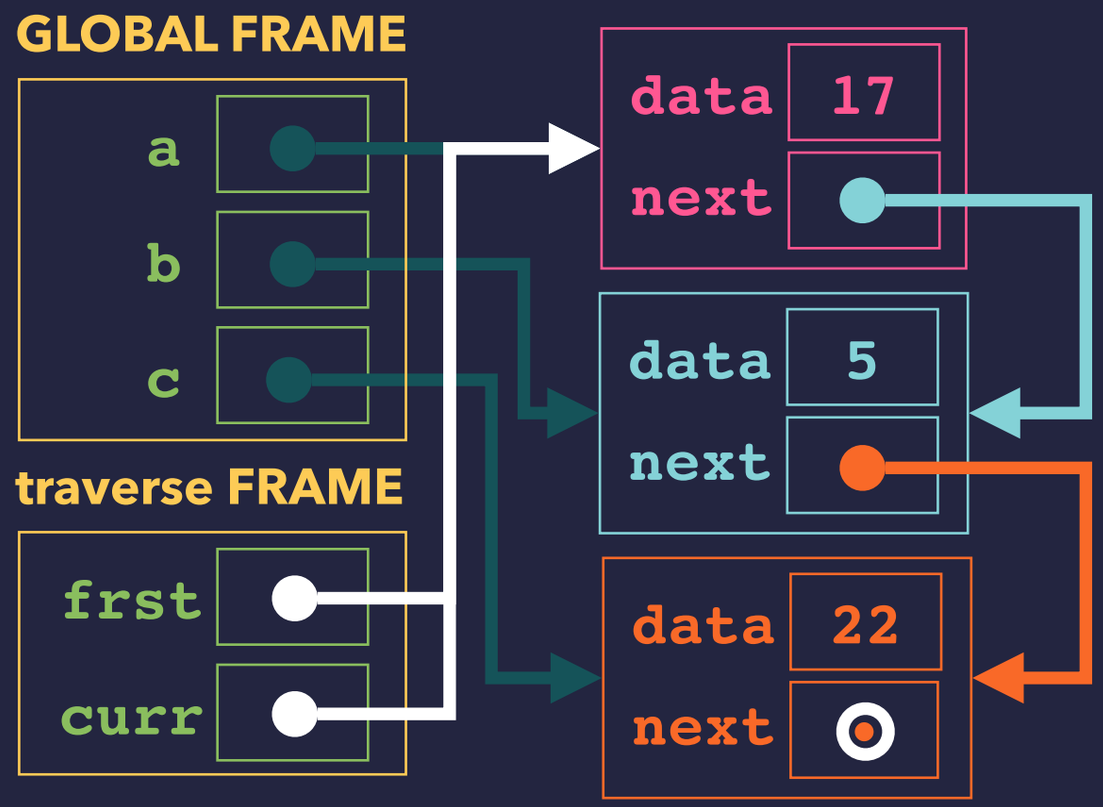

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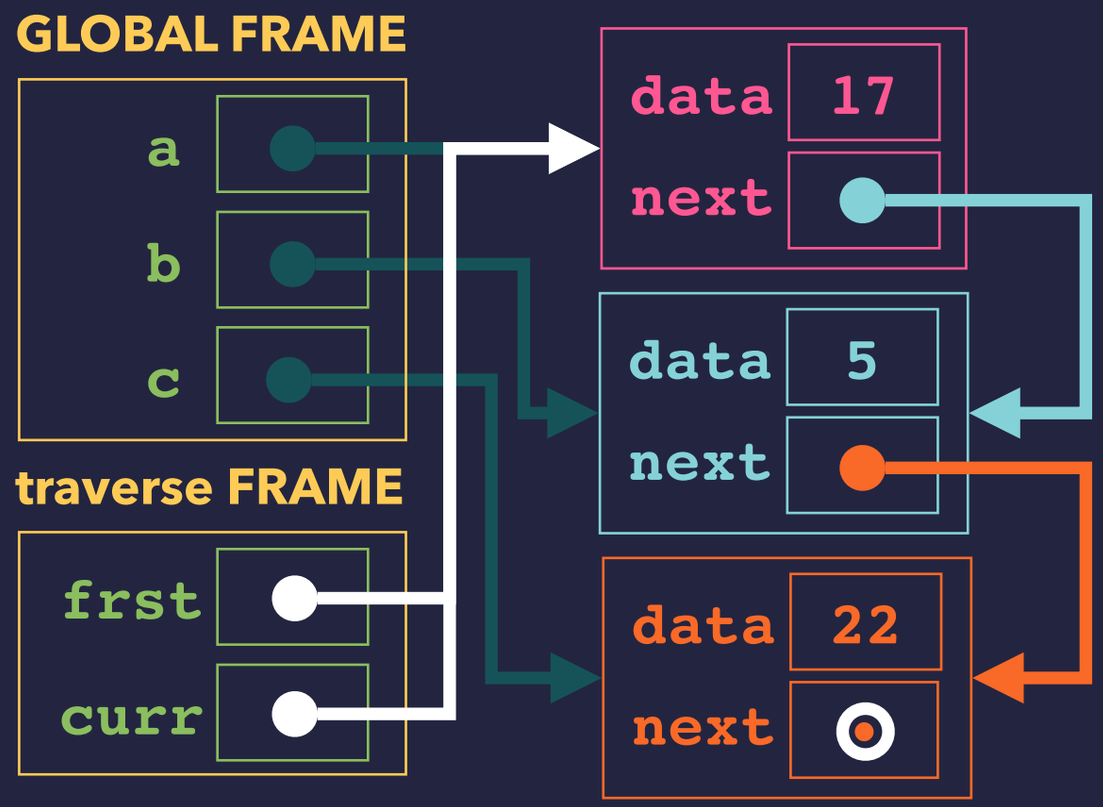
17
```



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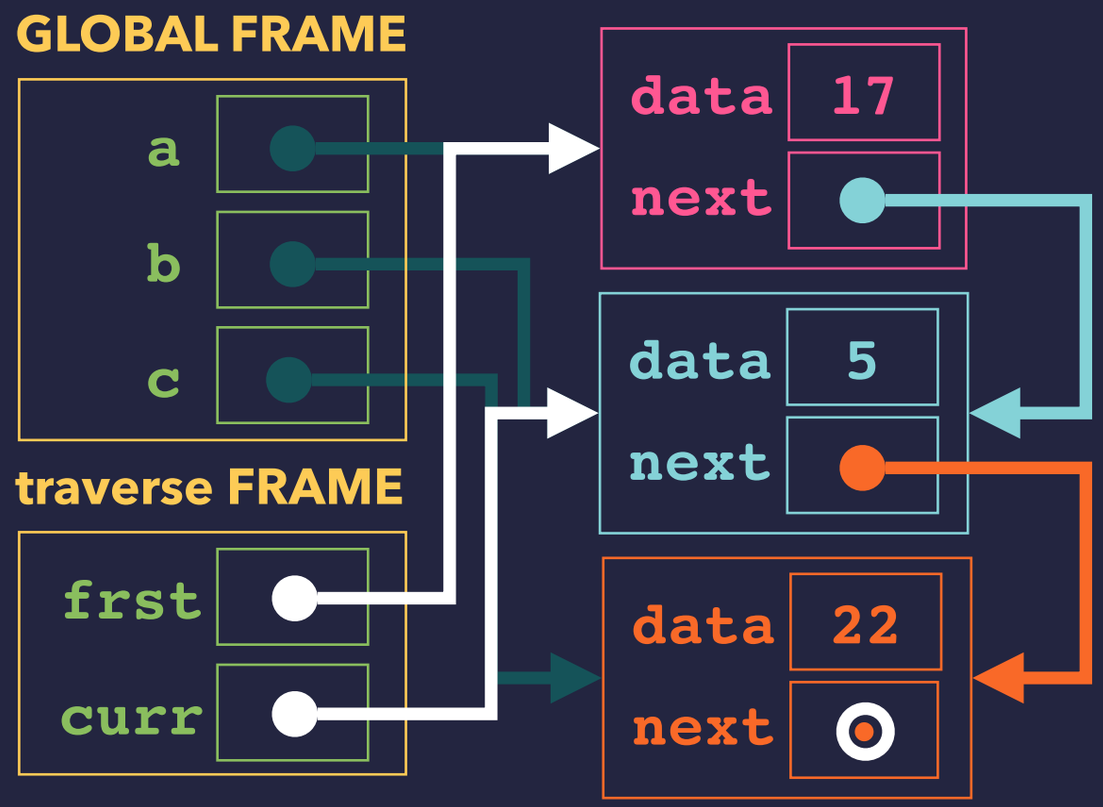
17
```



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```

```
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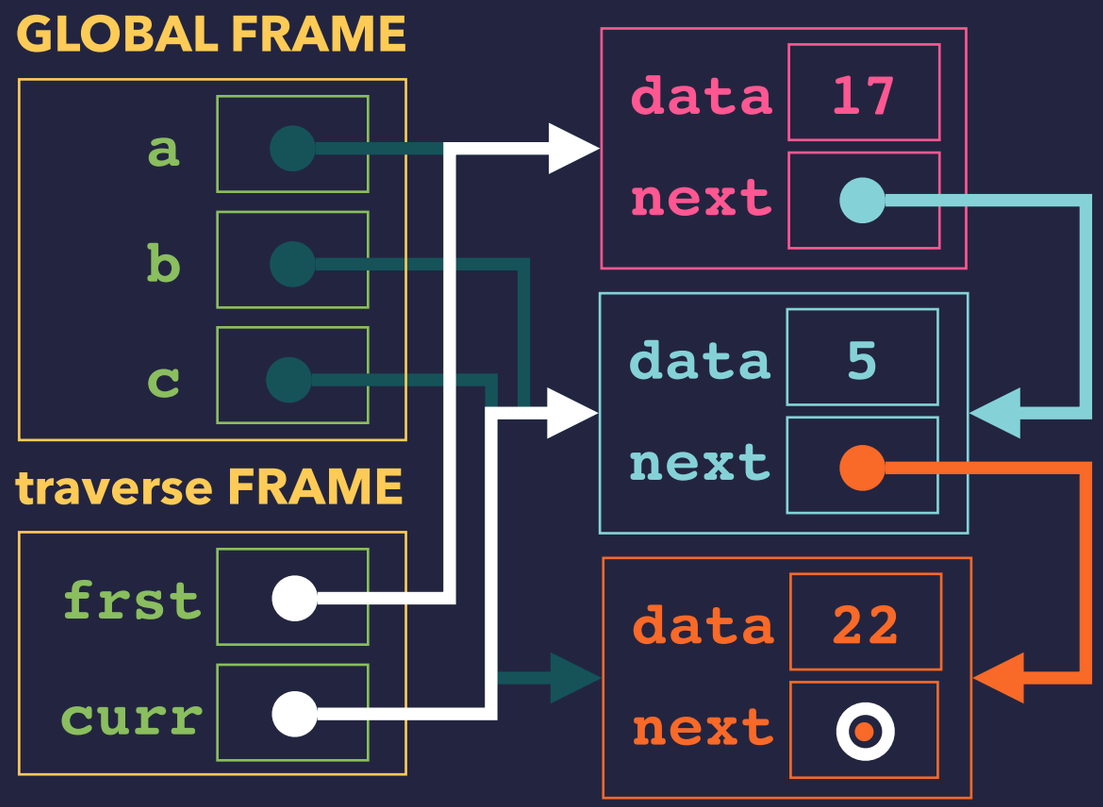
>>> b = Node(5)
>>> c = Node(22)
>>> traverse(a)
17
5
```



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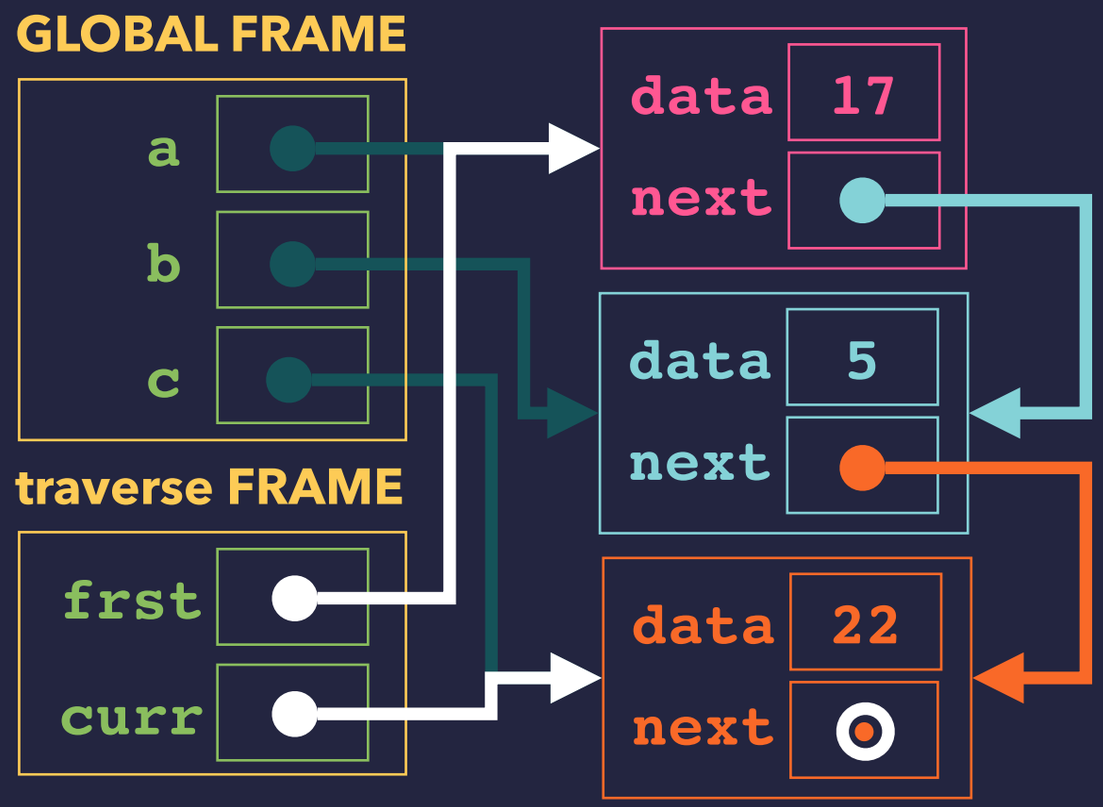
17
5
```



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>>> traverse(a)
17
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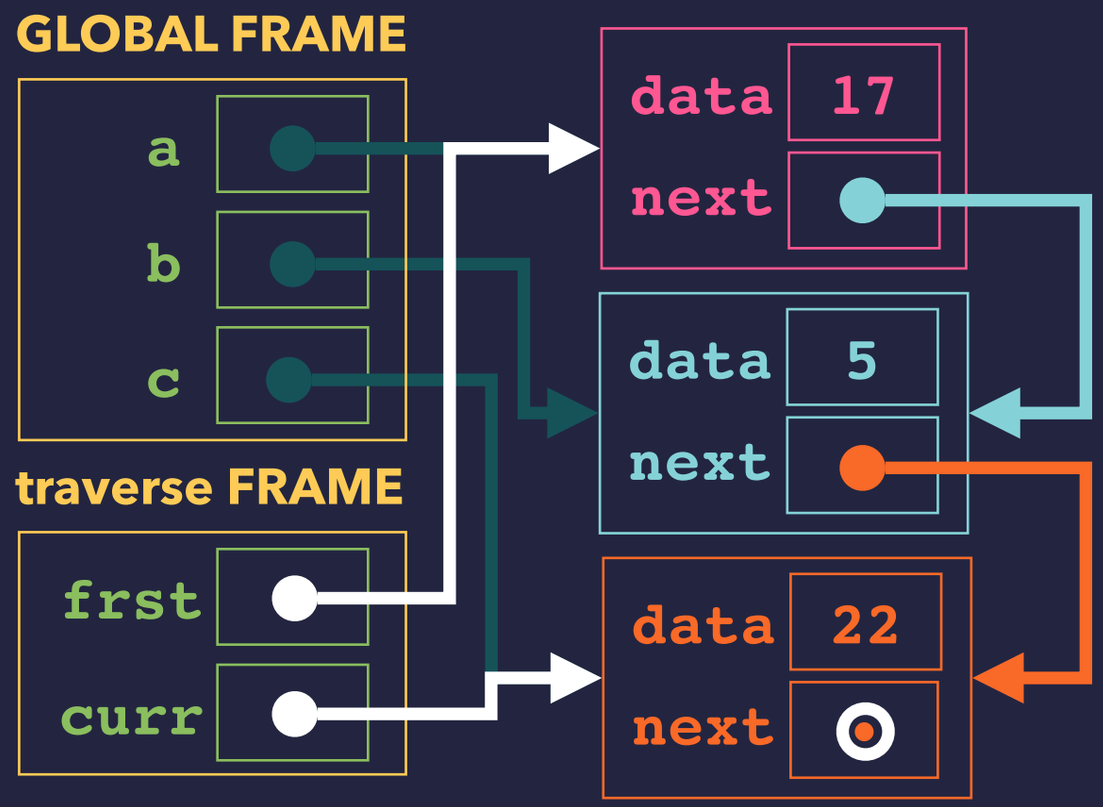
22
```



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```

```
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>>> b = Node(5)
>>> c = Node(22)
>>> traverse(a)
17
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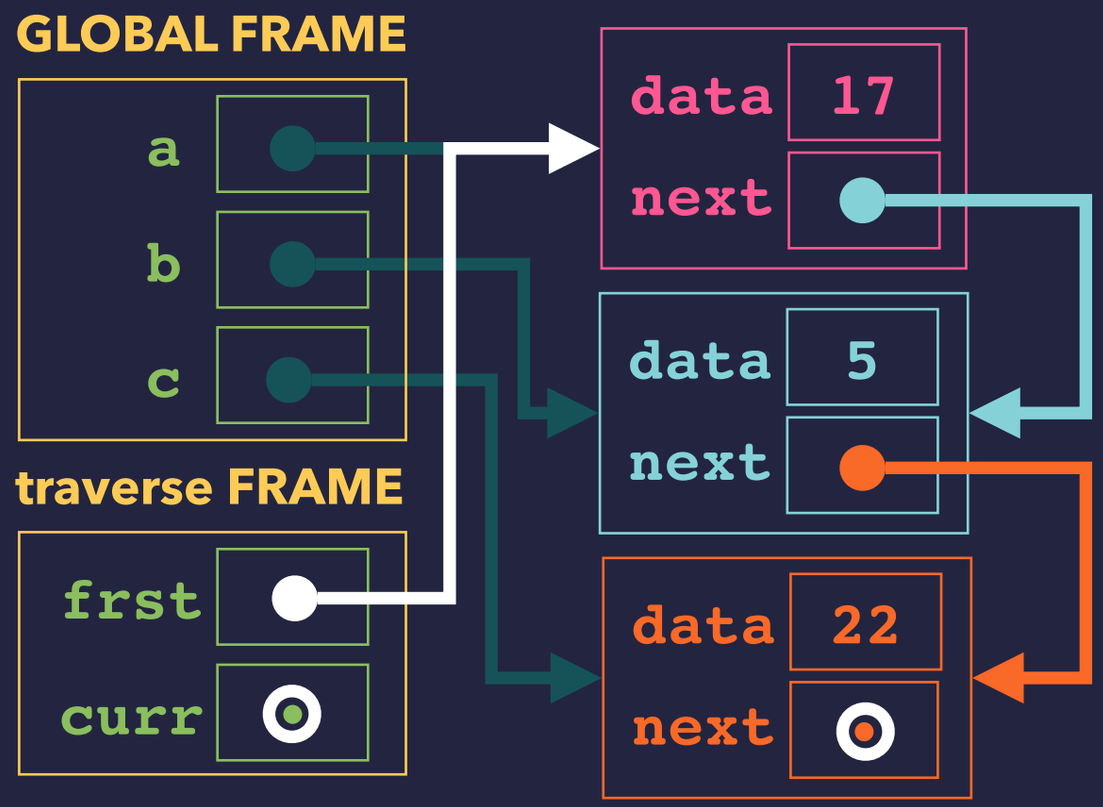
22
```



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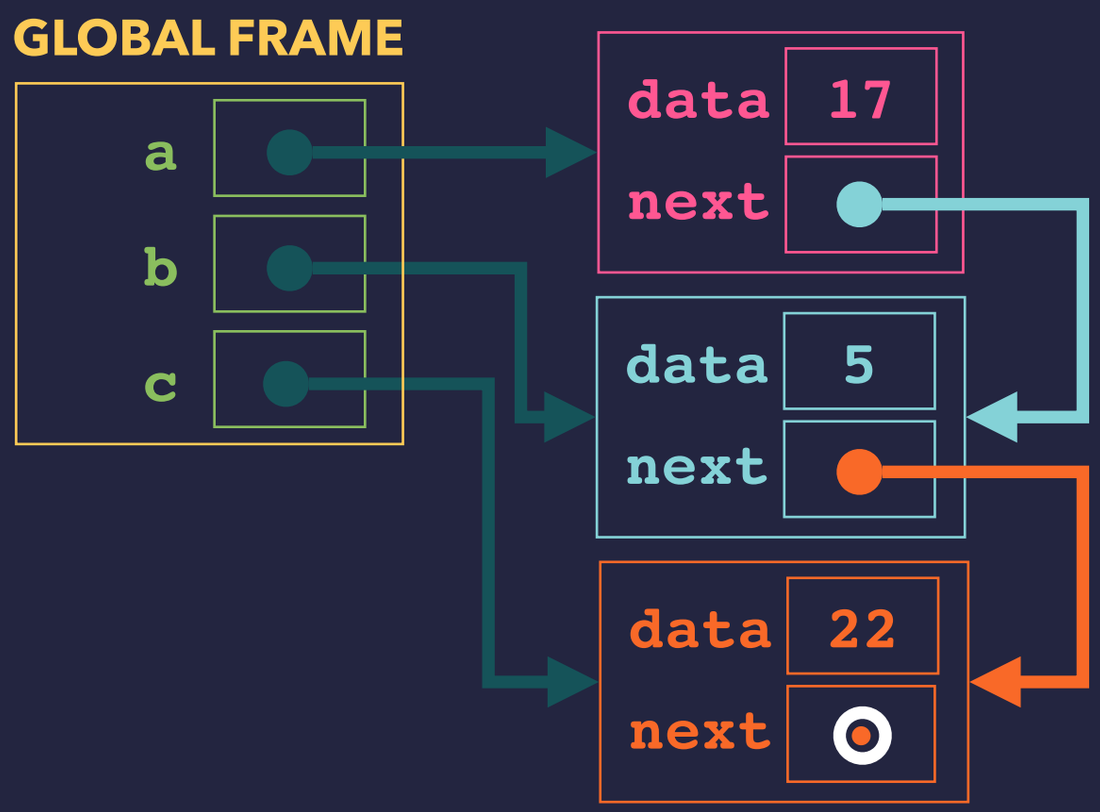
>>> traverse(a)
17
5
22
>>>
```



LINKED LISTS

- Linked lists are a way of keeping a collection of items as a sequence.
- They are used sometimes as the structure for other collection types.

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- They are used sometimes as the structure for other collection types.

More generally:

Linked lists are an example of a ***link-based data structure***.

- Other examples are search trees, expression trees, graphs, ...
- The structure can be edited by just relinking nodes.
- New items can be inserted anywhere with few changes.

A LINKED LIST CLASS

- On the remaining slides, we develop a linked list class.
- **Operations we'll :**
  - Adding an item to the front.
  - Adding an item to the end.
  - Checking for an item.
  - Printing all the items.
  - Removing an item.
- Many of the operations rely on a ***list traversal*** of some sort.

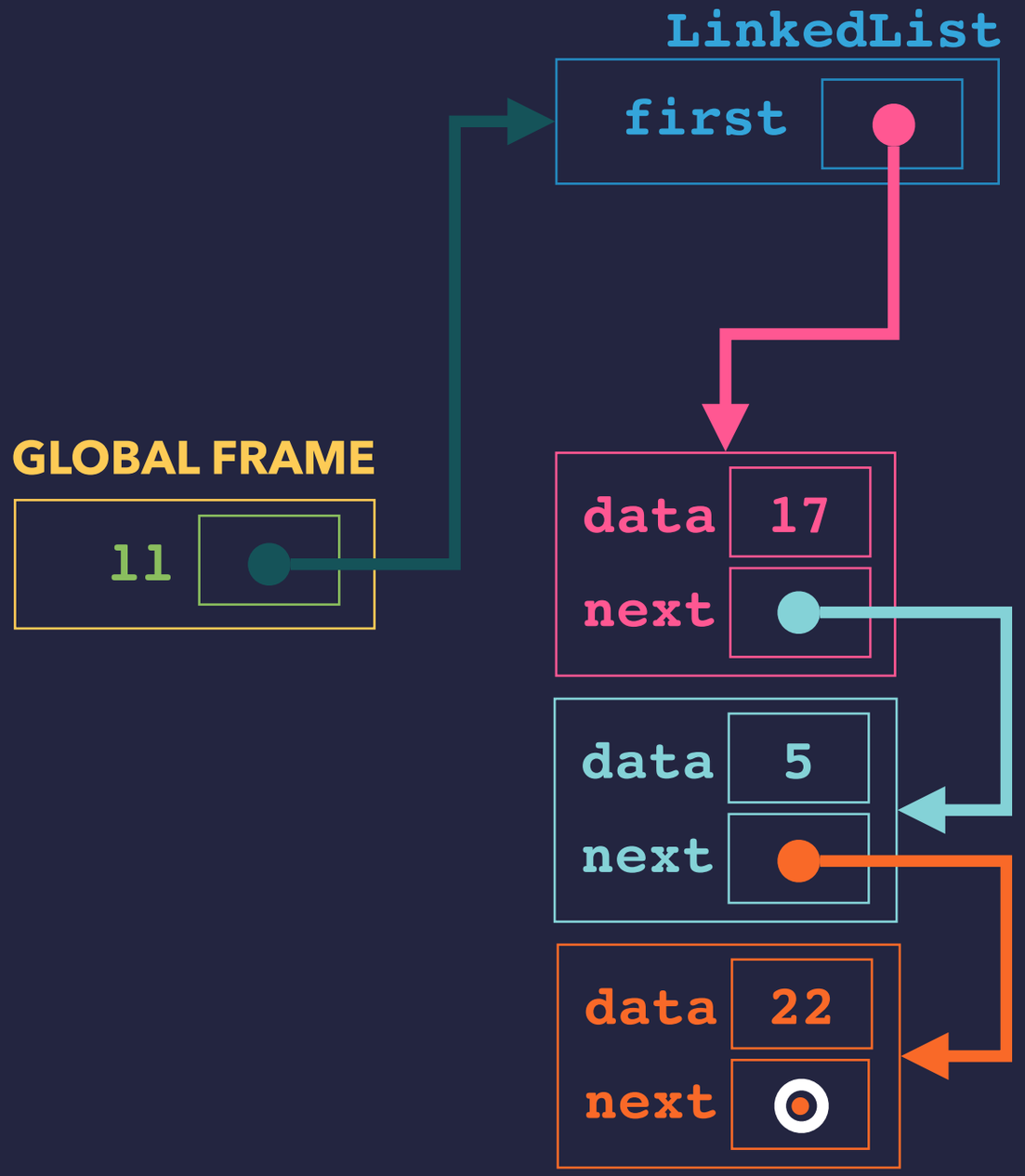
A LINKED LIST CLASS

```
class LLNode:
    def __init__(self, value):
        self.value = value
        self.next  = None

class LinkedList:
    def __init__(self):
        self.first = None

    def prepend(self, value):
        newNode = LLNode(value)
        newNode.next = self.first
        self.first = newNode
```

```
>>> ll = new LinkedList()
>>> ll.prepend(22)
>>> ll.prepend(5)
>>> ll.prepend(17)
```



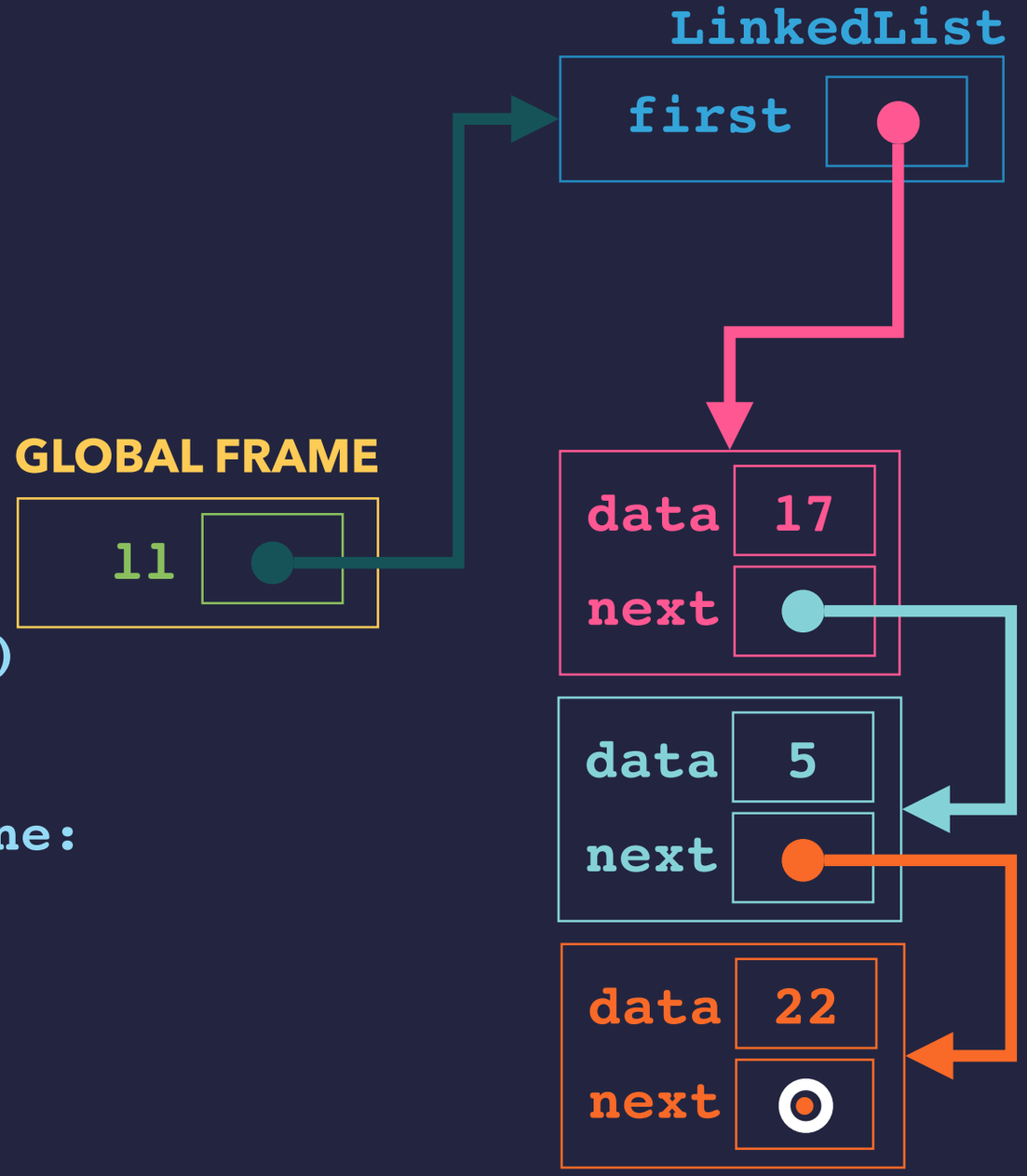
LINKED LIST APPEND

A LINKED LIST CLASS

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

class LinkedList:
    ...
    def append(self, value):
        if self.first is None:
            self.first = LLNode(value)
        else:
            curr = self.first
            while curr.next is not None:
                curr = curr.next
            curr.next = LLNode(value)
```

```
>>> ll = new LinkedList()
>>> ll.append(17)
>>> ll.append(5)
>>> ll.append(22)
>>>
```



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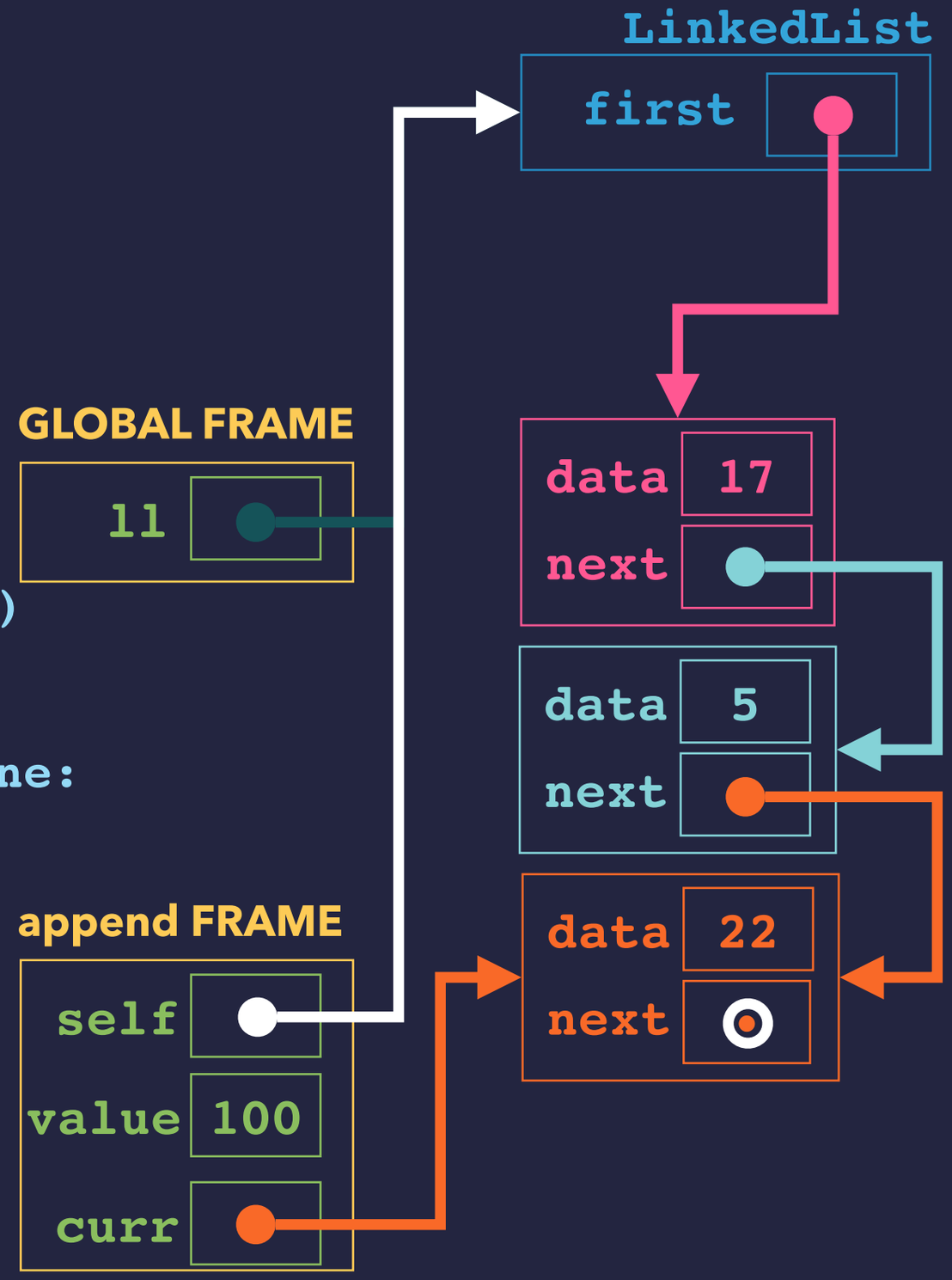
    ...
    def append(self, value):
        if self.first is None:
            self.first = LLNode(value)
        else:
            curr = self.first
            while curr.next is not None:
                curr = curr.next
            curr.next = LLNode(value)
```

```
>>> ll = new LinkedList()
>>> ll.append(17)
>>> ll.append(5)
>>> ll.append(22)
>>> ll.append(100)
```



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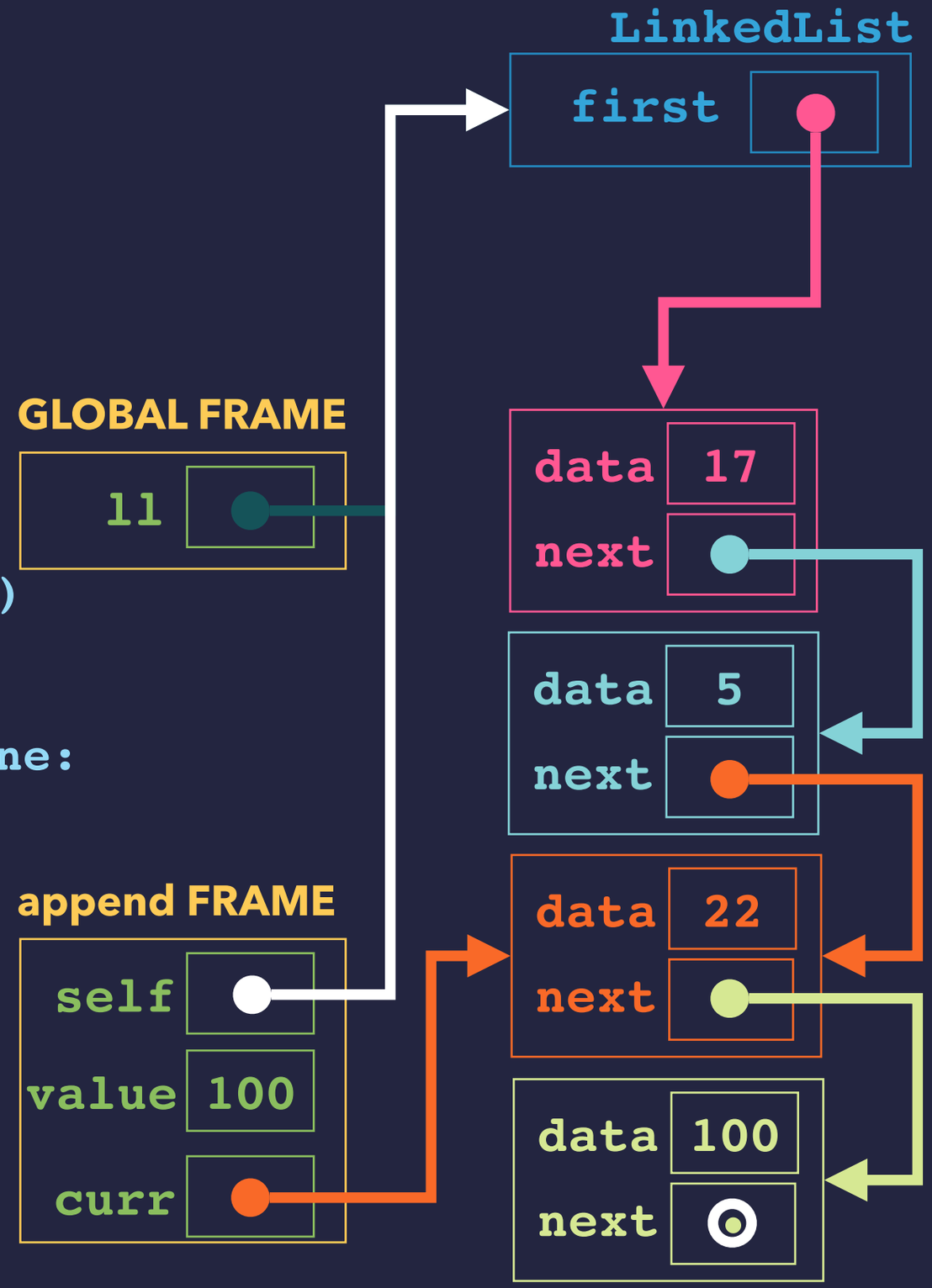
    ...
    def append(self, value):
        if self.first is None:
            self.first = LLNode(value)
        else:
            curr = self.first
            while curr.next is not None:
                curr = curr.next
            curr.next = LLNode(value)
```

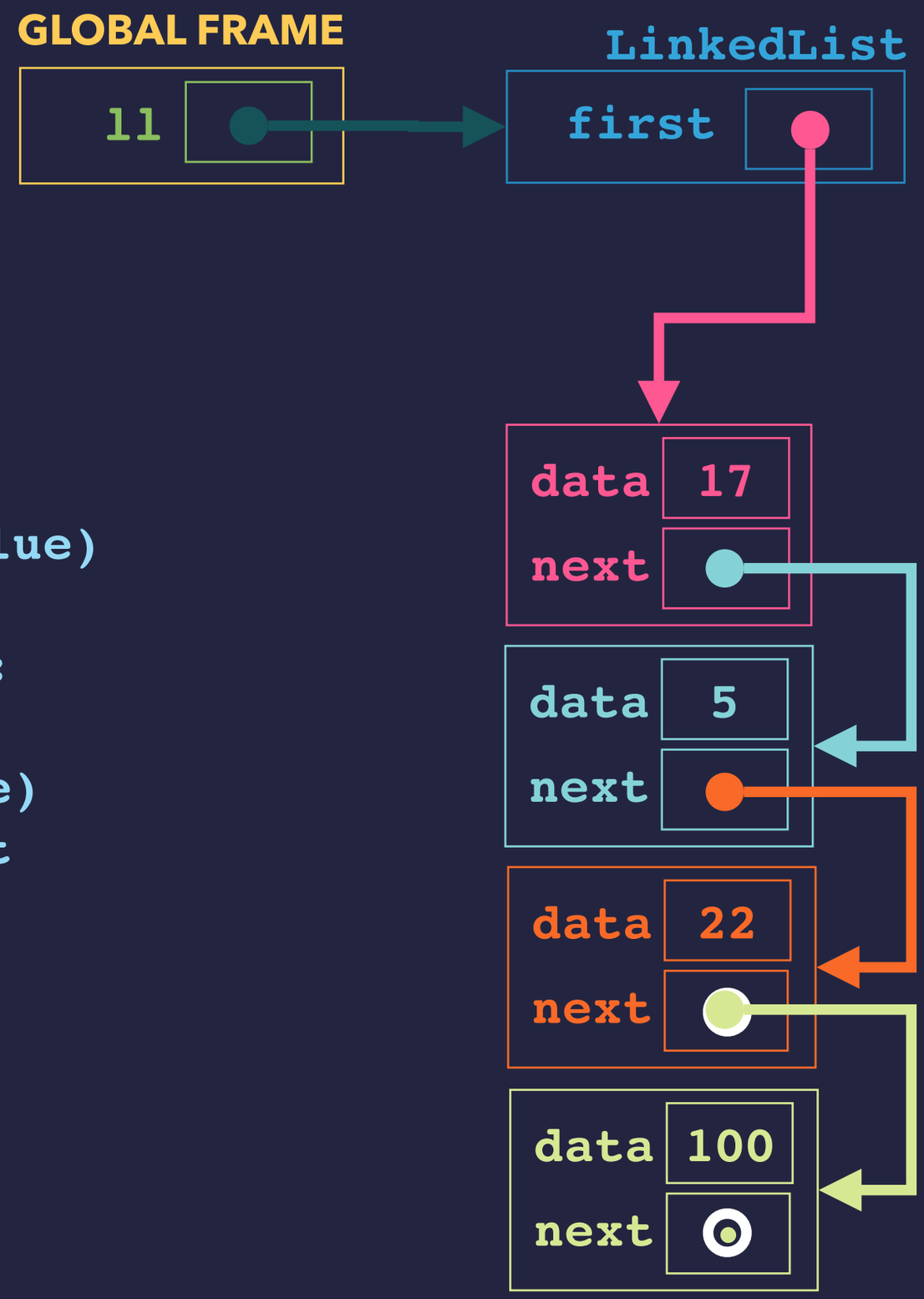
```
>>> ll = new LinkedList()
>>> ll.append(17)
>>> ll.append(5)
>>> ll.append(22)
>>> ll.append(100)
```



A LINKED LIST CLASS

```
class LinkedList:
    ...
    def asString(self):
        if self.first is None:
            return "<>"
        else:
            s = "<"
            s += str(self.first.value)
            curr = self.first.next
            while curr is not None:
                s += ", "
                s += str(curr.value)
                current = curr.next
            s += ">"
            return s
```

```
>>> ll.asString()
'<17, 5, 22, 100>'
>>>
```

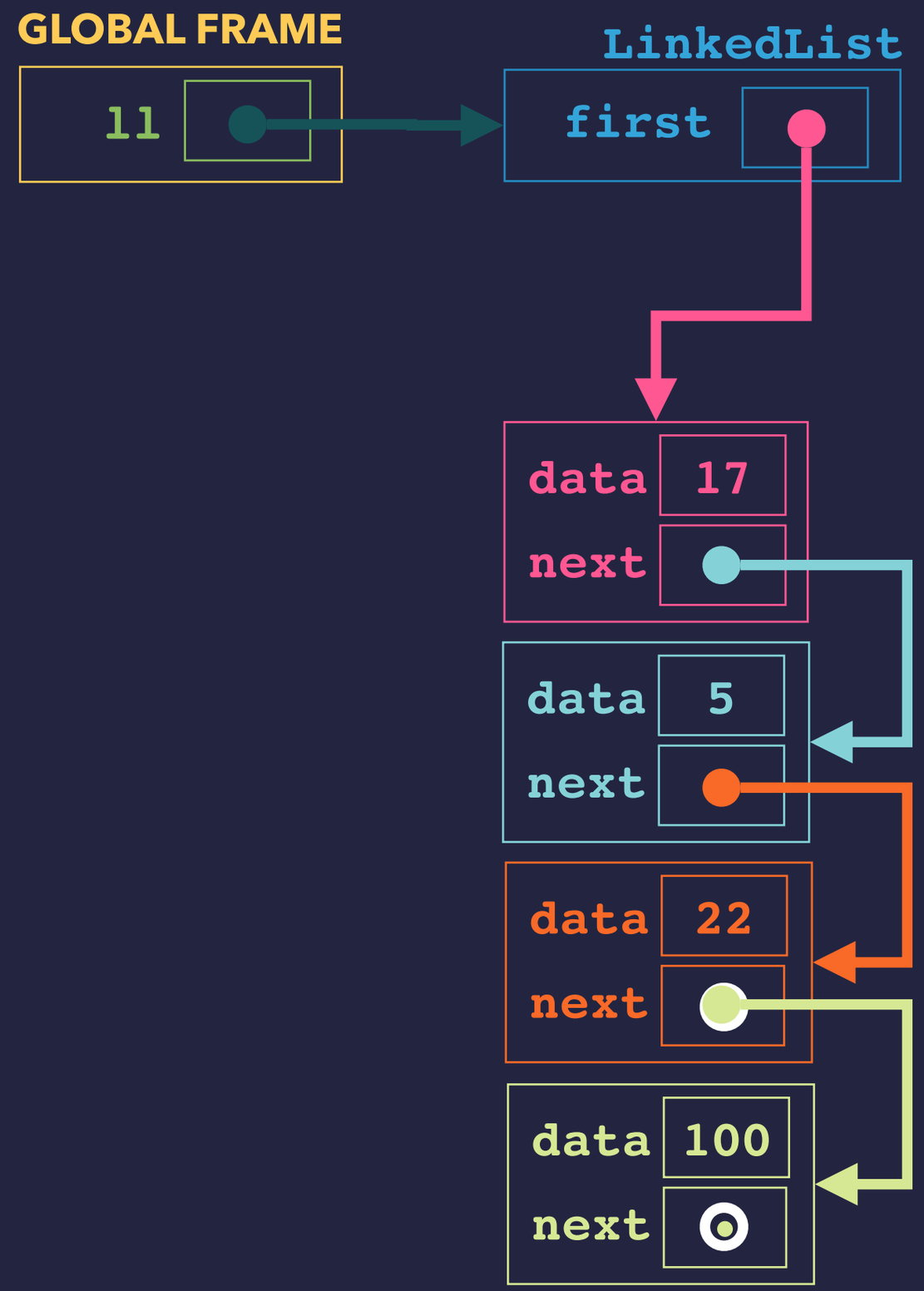


LINKED LIST DELETION

A LINKED LIST CLASS

```
class LinkedList:
    ...
    def delete(self, value):
        prev = None
        curr = self.first
        while curr.value != value:
            prev = curr
            curr = curr.next
        if prev is None:
            self.first = curr.next
        else:
            prev.next = curr.next
```

```
>>> ll.delete(22)
```

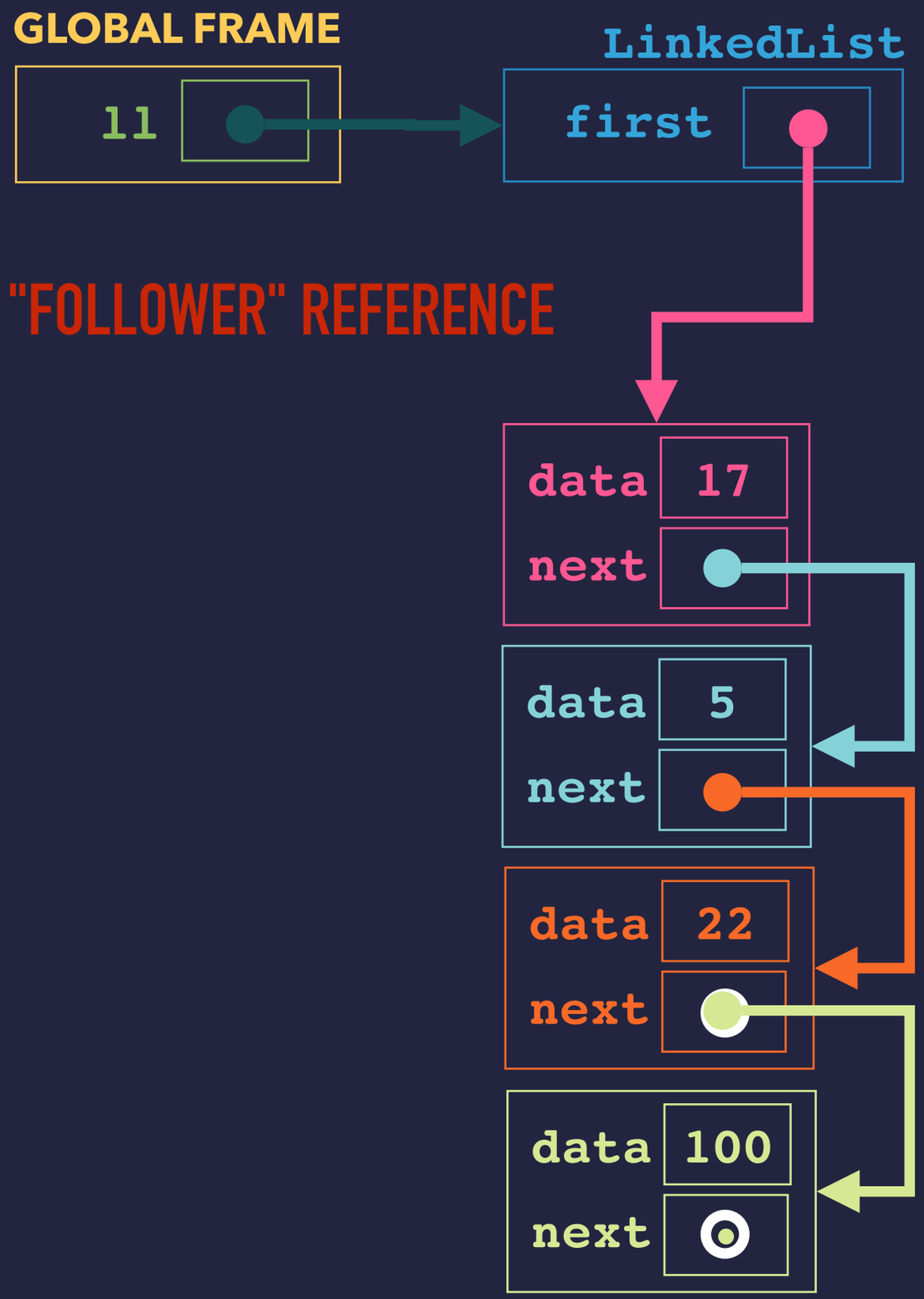


A LINKED LIST CLASS

```
class LinkedList:
    ...
    def delete(self, value):
        prev = None
        curr = self.first
        while curr.value != value:
            prev = curr
            curr = curr.next
        if prev is None:
            self.first = curr.next
        else:
            prev.next = curr.next
```

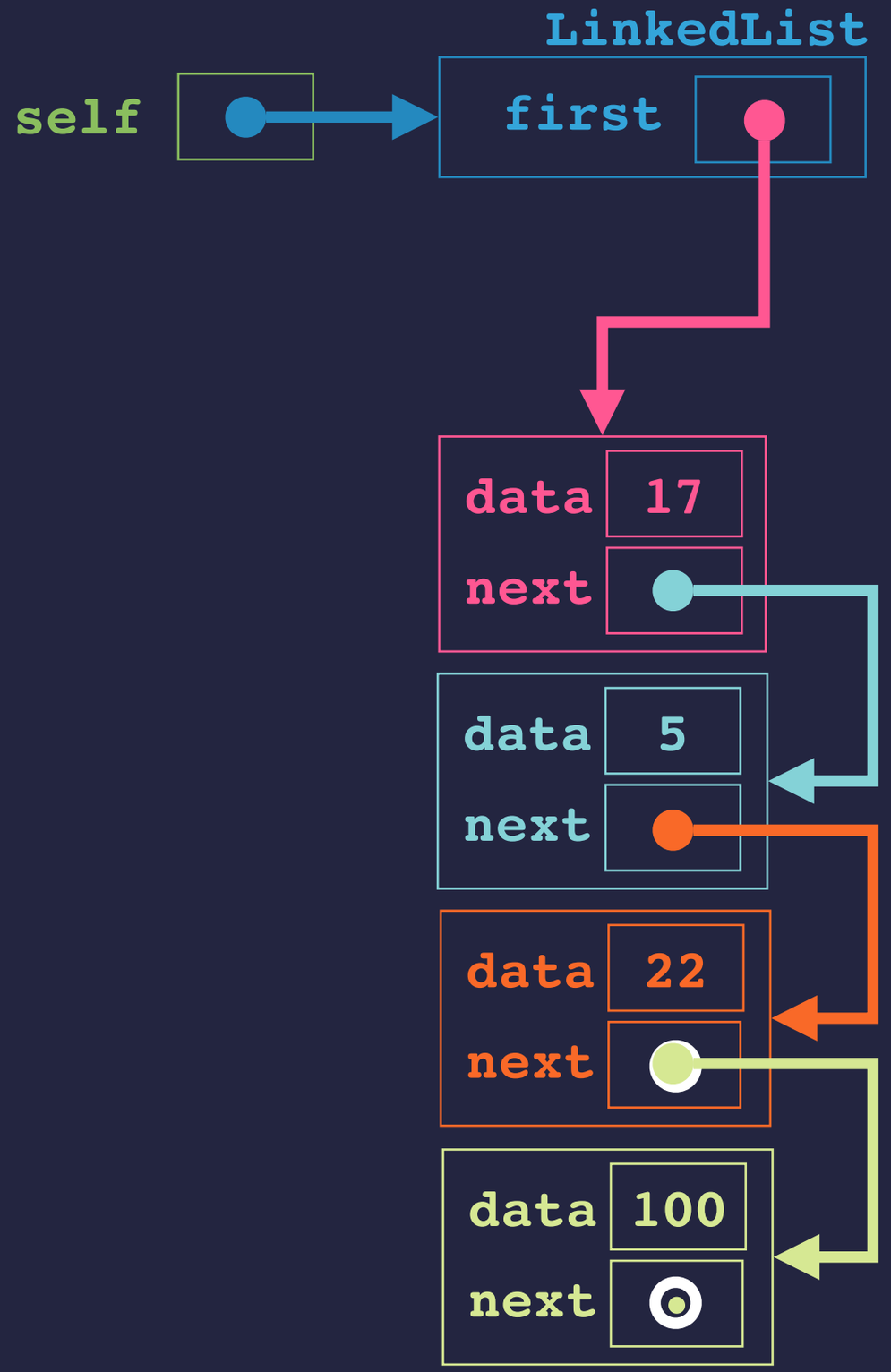
```
>>> ll.delete(22)
```

THIS USES A "FOLLOWER" REFERENCE



FOLLOWER POINTER TRAVERSAL

```
prev = None
curr = self.first
while curr.value != value:
    prev = curr
    curr = curr.next
```



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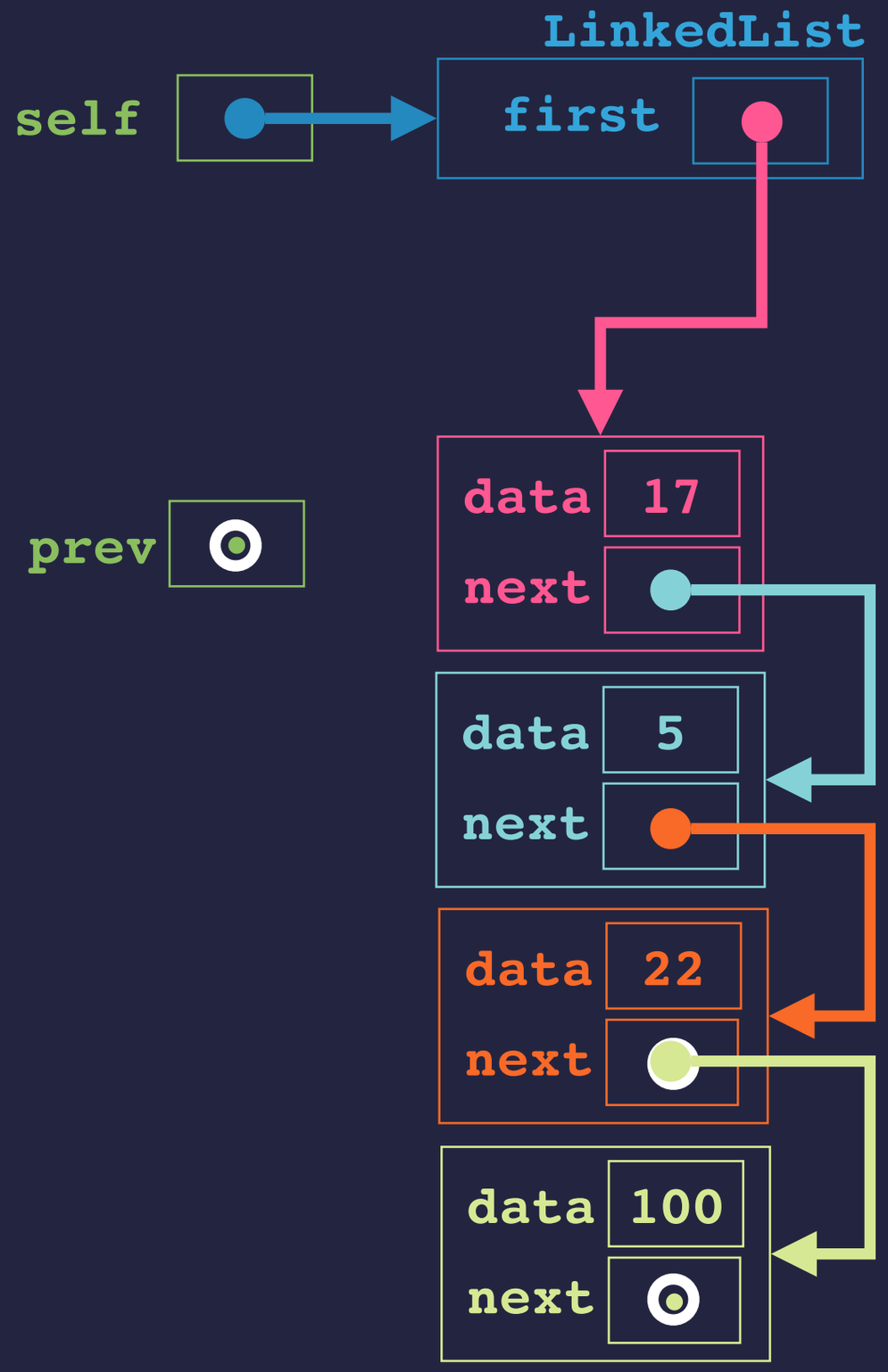
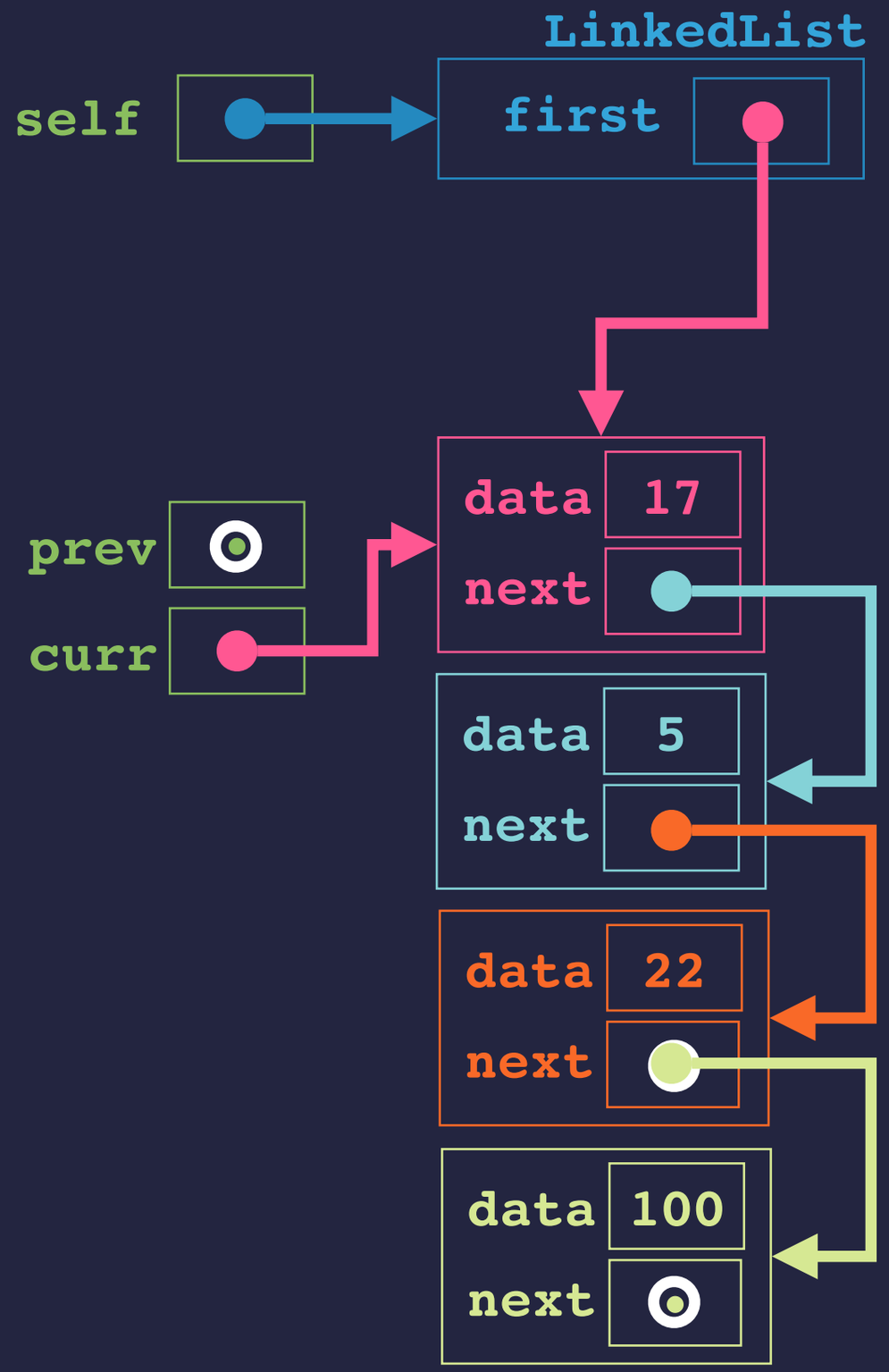
```



FOLLOWER POINTER TRAVERSAL

```
prev = None
curr = self.first
while curr.value != value:
    prev = curr
    curr = curr.next
```



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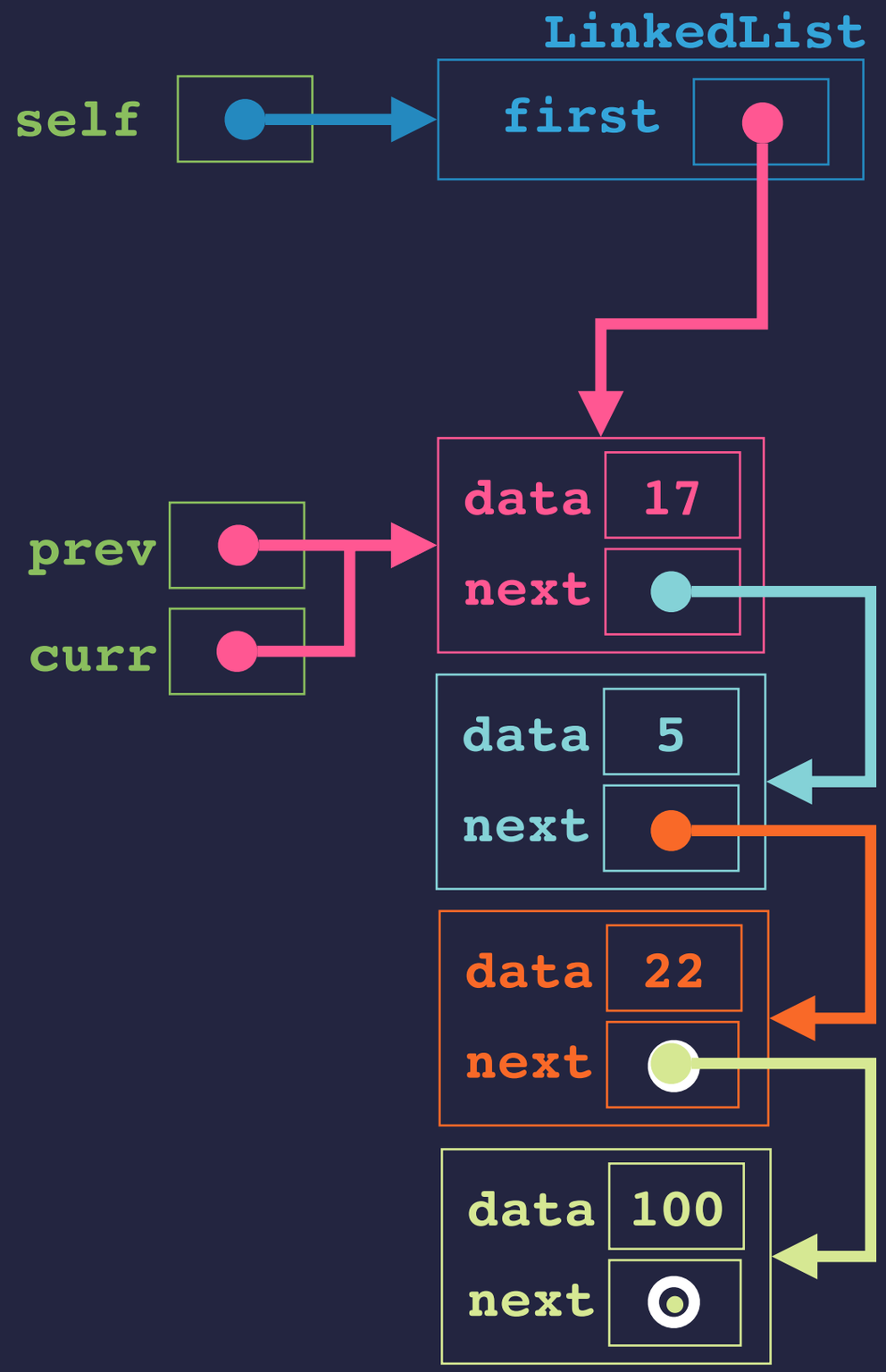

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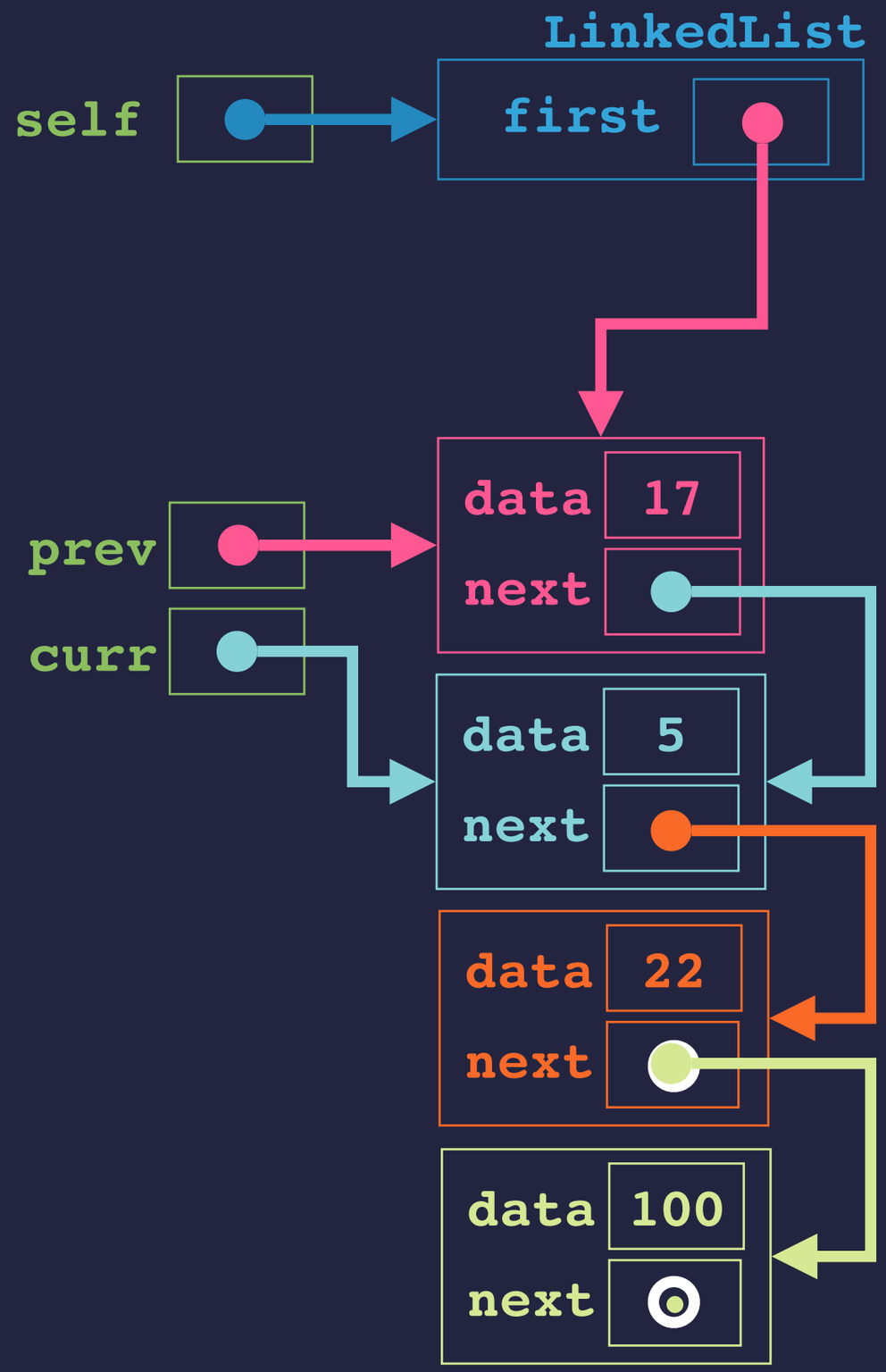

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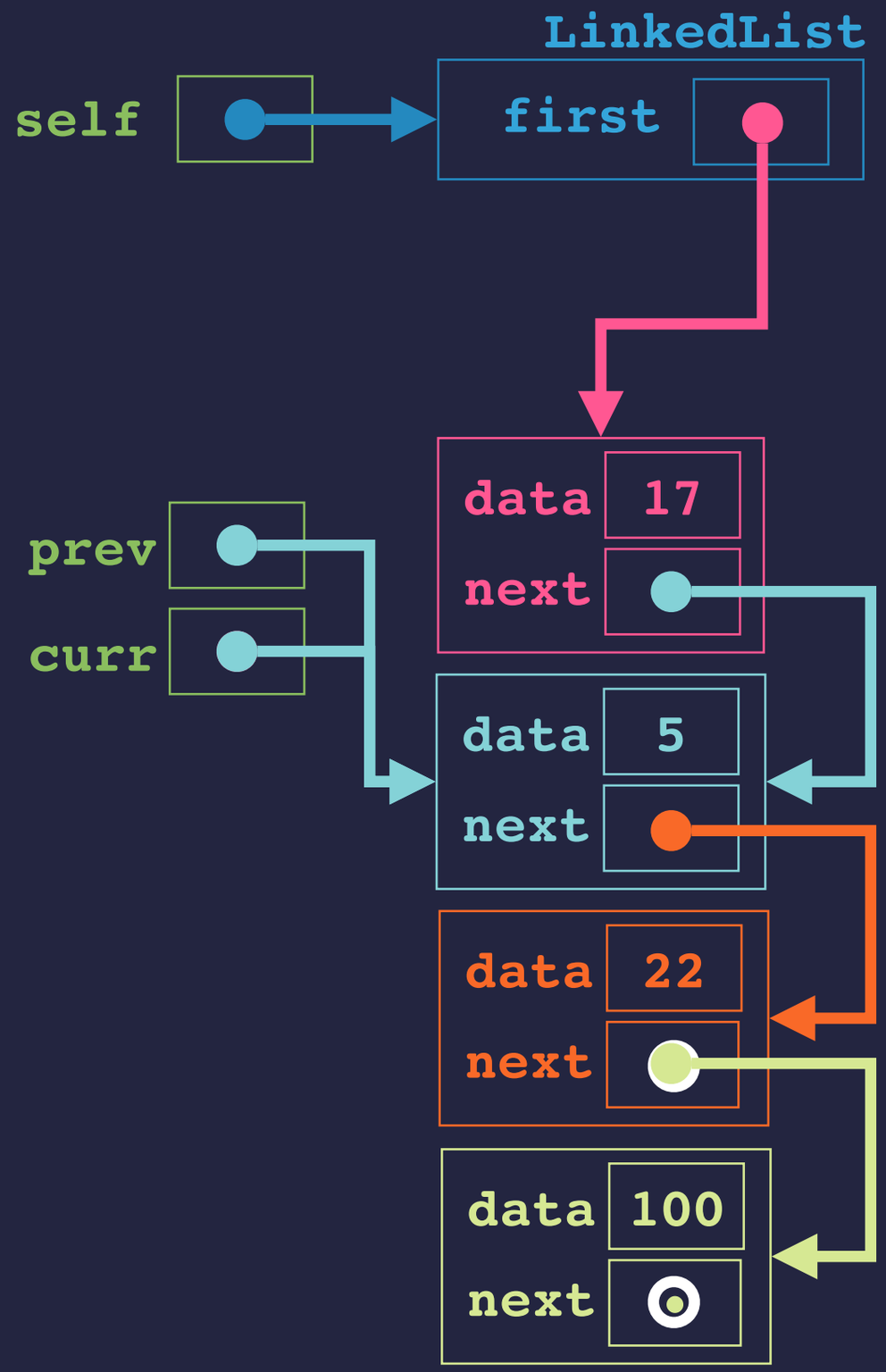

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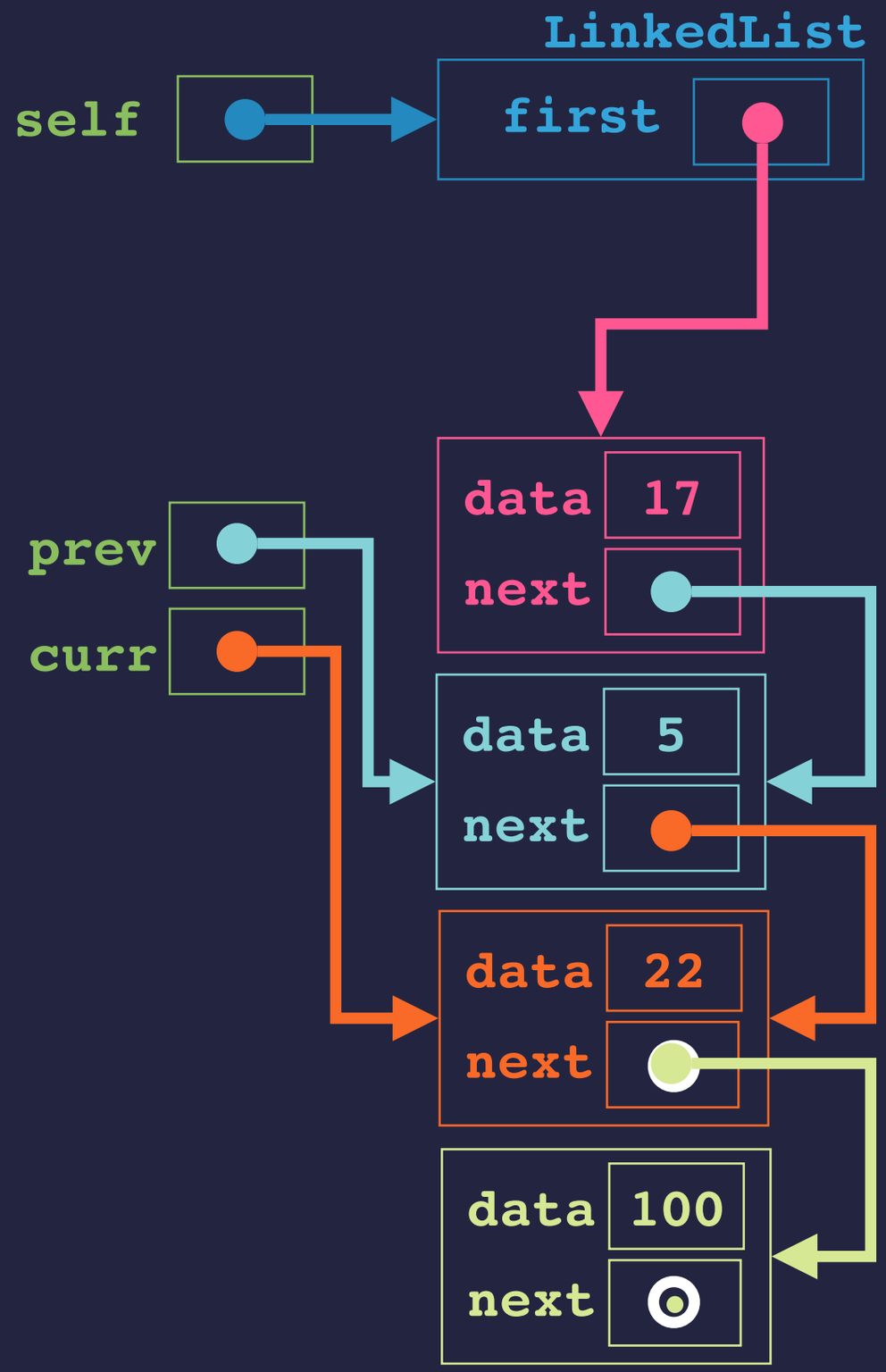
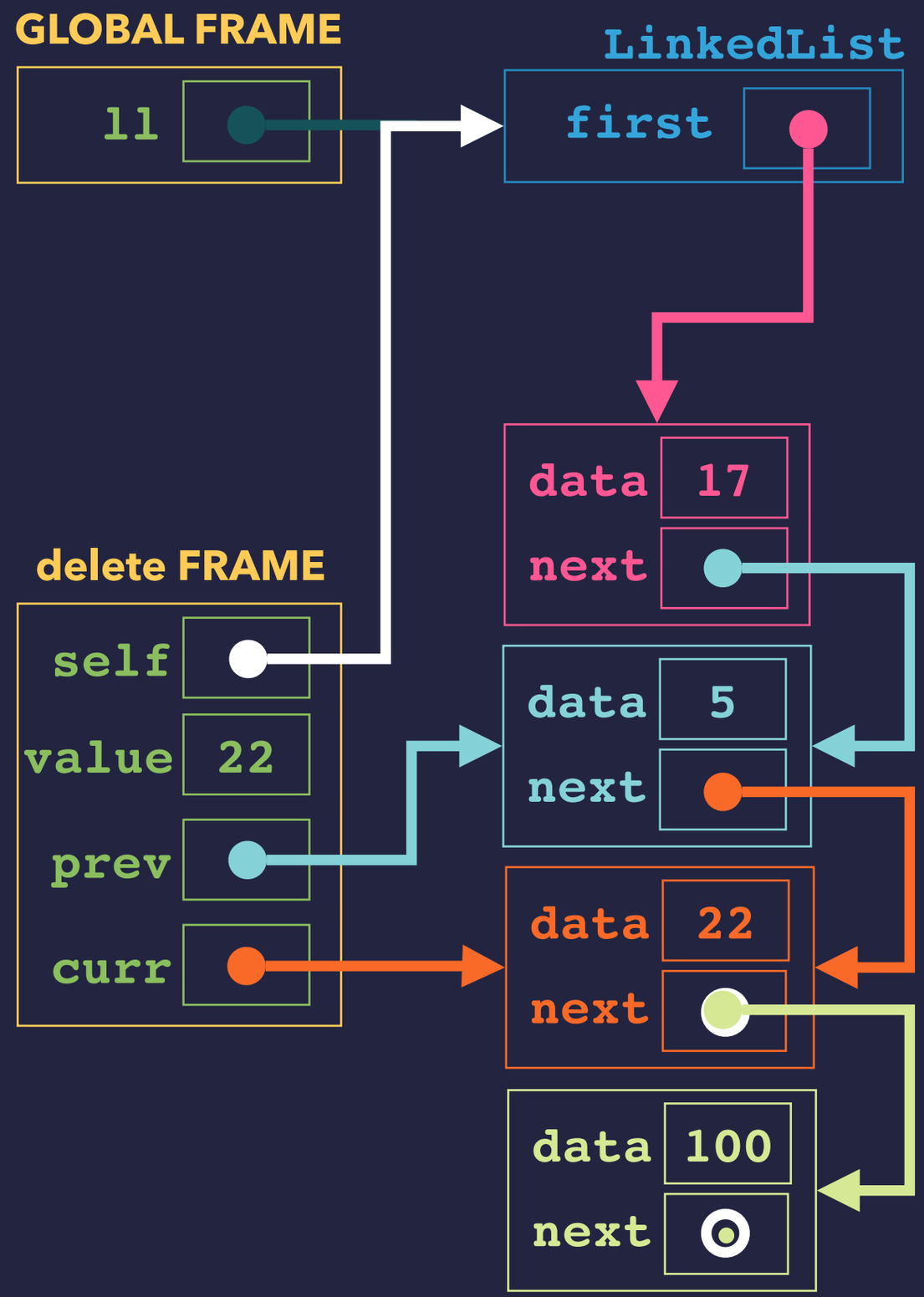


A LINKED LIST CLASS

```
...
def delete(self, value):
    prev = None
    curr = self.first
    while curr.value != value:
        prev = curr
        curr = curr.next
    if prev is None:
        self.first = curr.next
    else:
        prev.next = curr.next
```

```
>>> ll.delete(22)
```



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    else:
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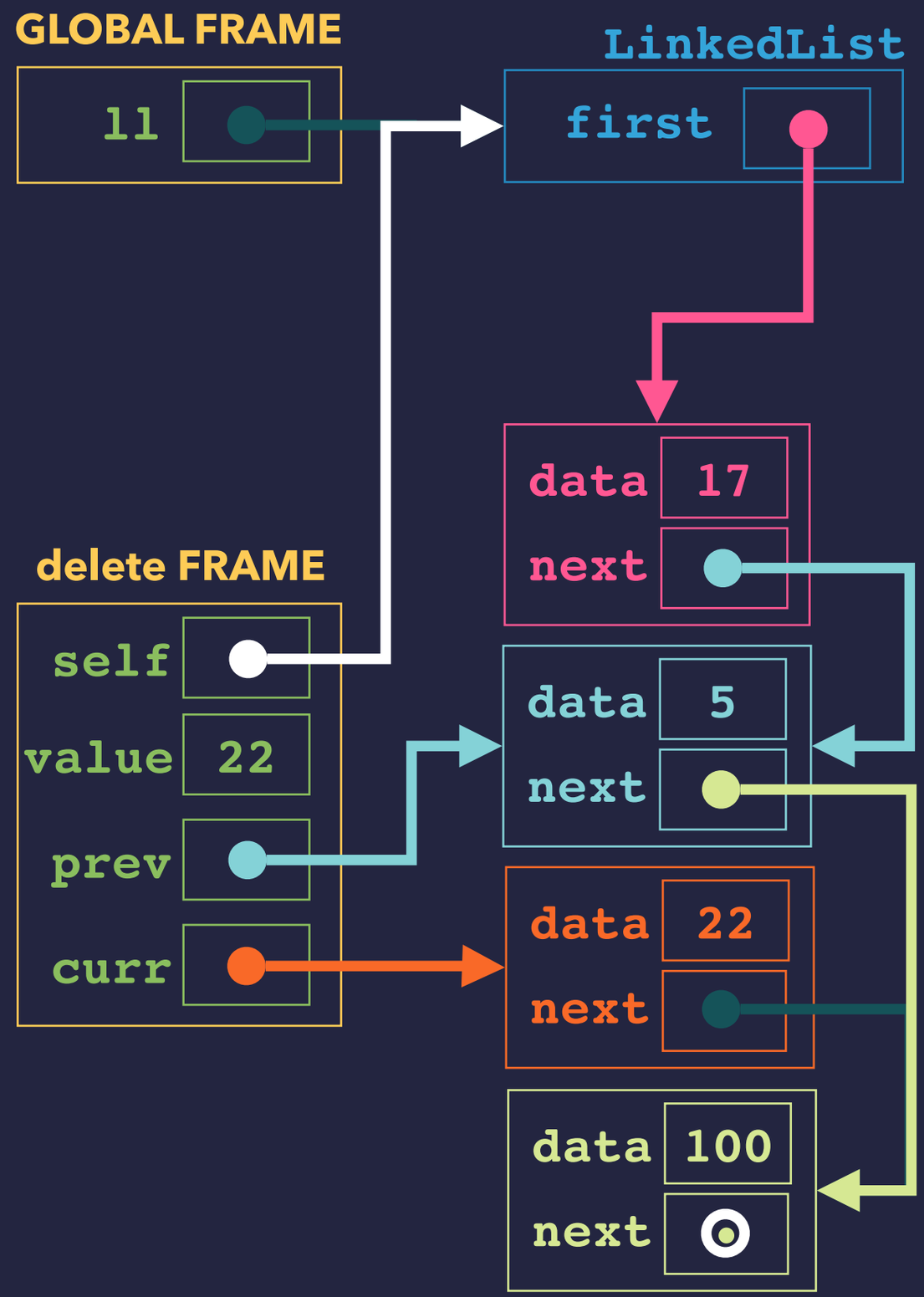
```

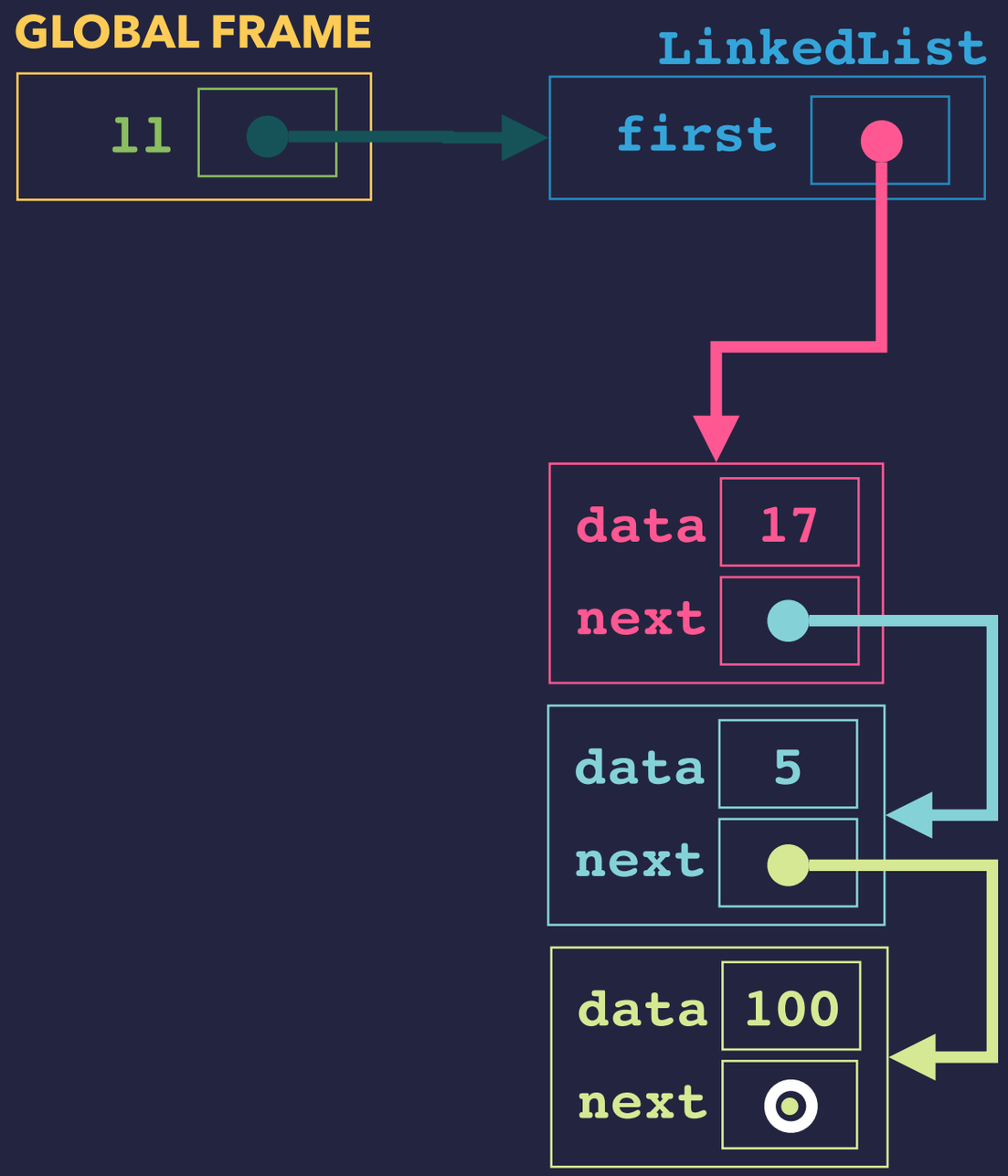
```
>>> ll.delete(22)
```



A LINKED LIST CLASS

```
class LinkedList:
    ...
    def delete(self, value):
        prev = None
        curr = self.first
        while curr.value != value:
            prev = curr
            curr = curr.next
        if prev is None:
            self.first = curr.next
        else:
            prev.next = curr.next
```

```
>>> ll.delete(22)
>>> ll.delete(17)
```



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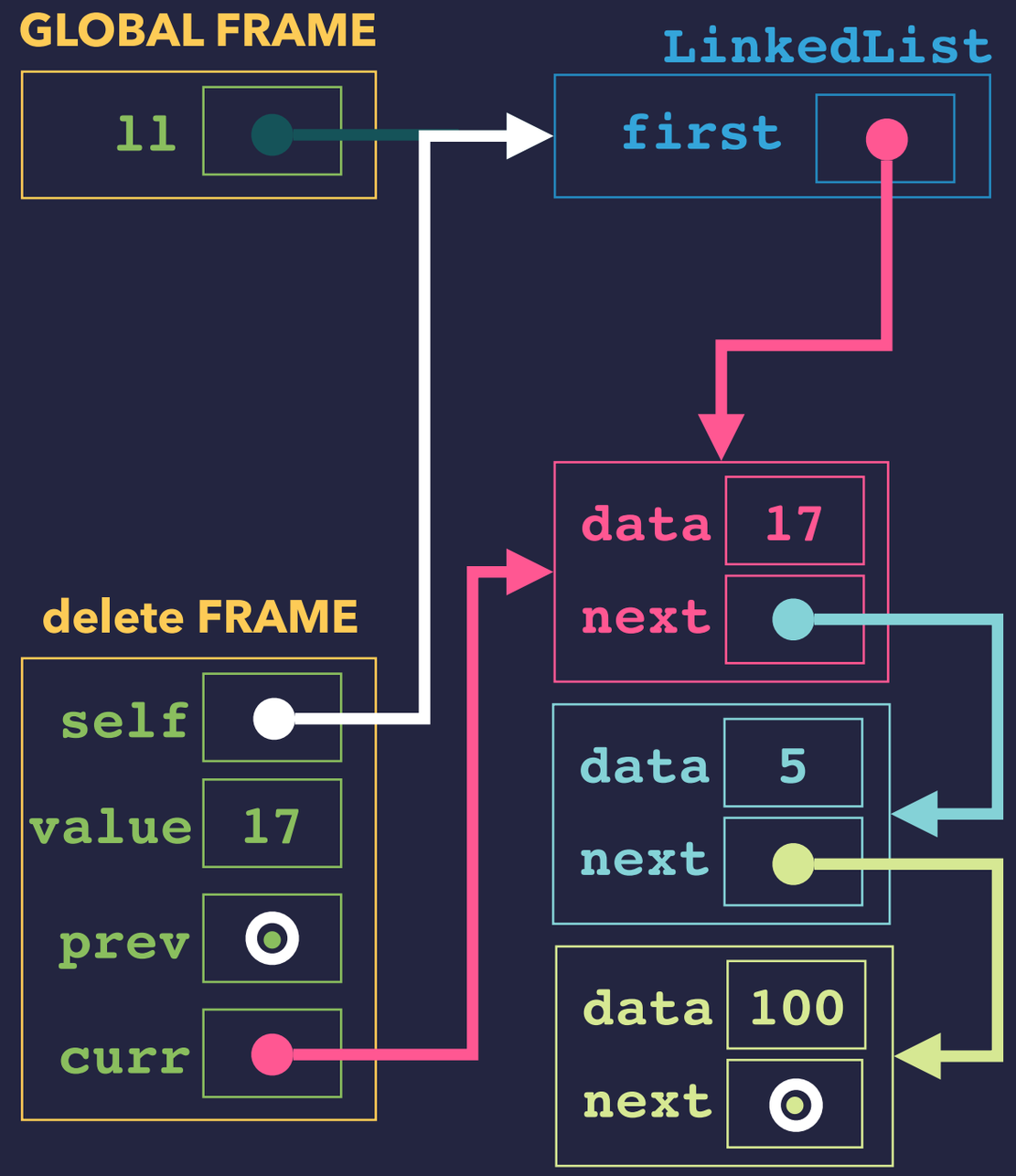

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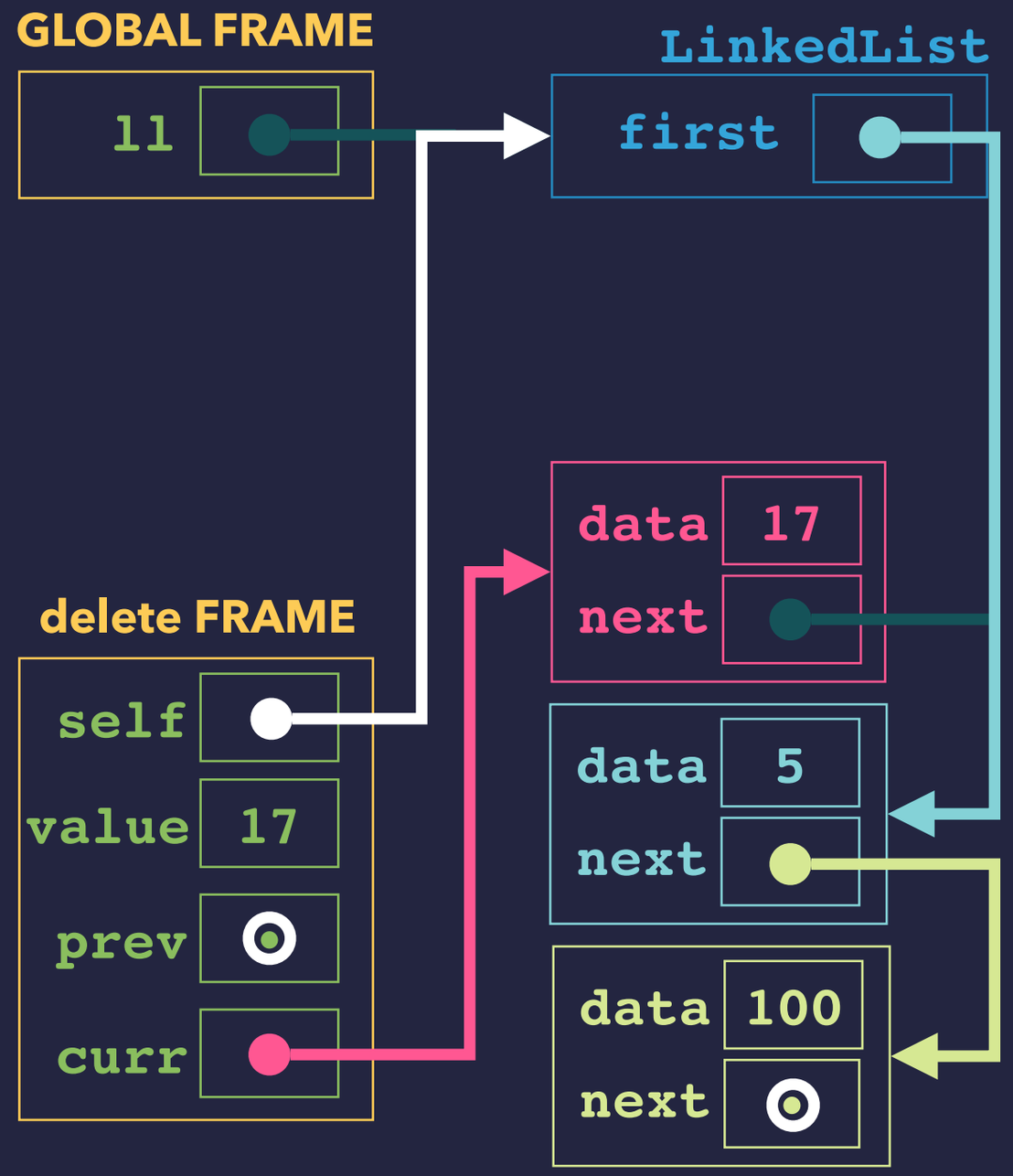

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        if prev is None:
            self.first = curr.next
        else:
            prev.next = curr.next
```

```
>>> ll.delete(22)
>>> ll.delete(17)
>>>
```