Welcome!

DATA STRUCTURES AND ALGORITHMS IN PYTHON

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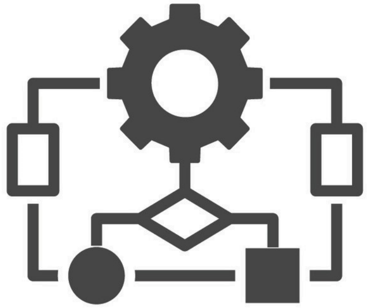
Software Engineer

The importance of algorithms and data structures

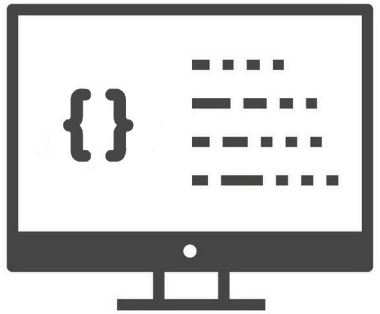
- **Data structures** and **algorithms** enable us to
  - solve **everyday problems**
  - using **efficient code**
- The course could be taught in **any programming language**

Algorithms and data structures

- **Algorithm:** set of instructions that solve a problem
  1. *Design*

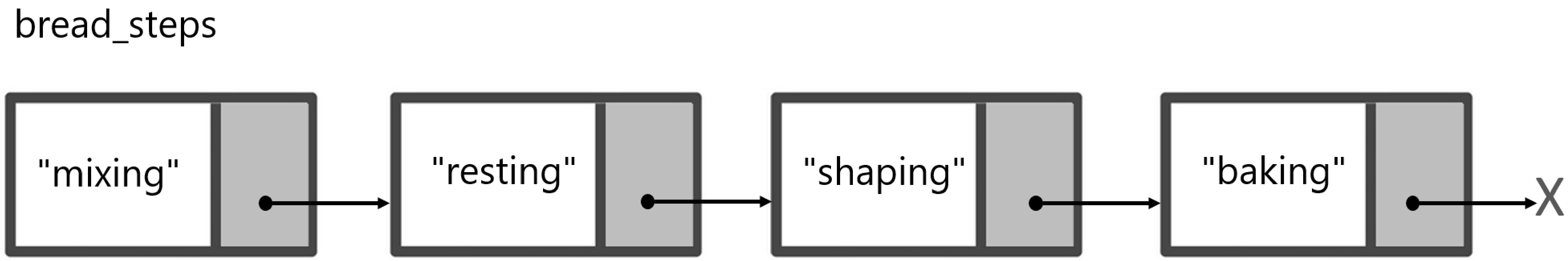


  2. *Code*



- **Data structures:** hold and manipulate data when we execute an algorithm
  - **Advanced** data structures: linked lists, stacks, queues...

Linked lists



- Sequence of data connected through links

Linked lists - structure

NODE

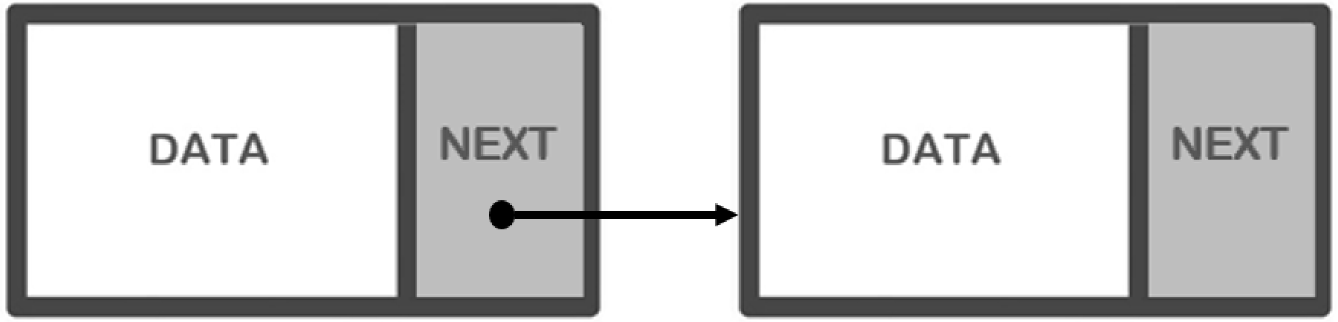
Linked lists - structure

NODE

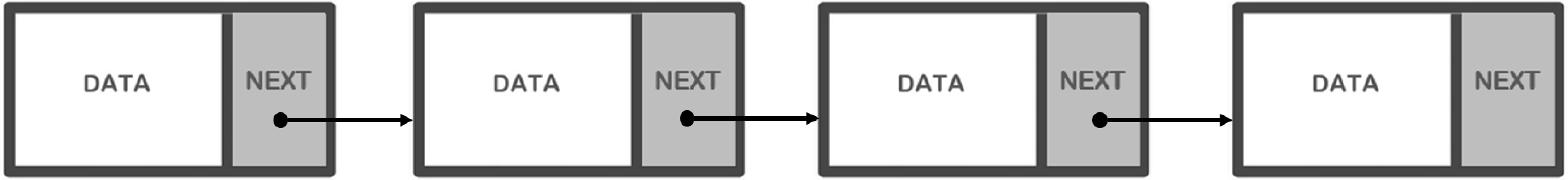
Linked lists - structure

NODE

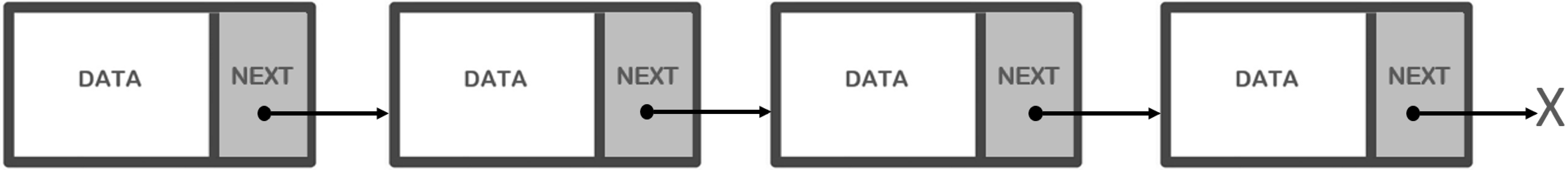
Linked lists - structure



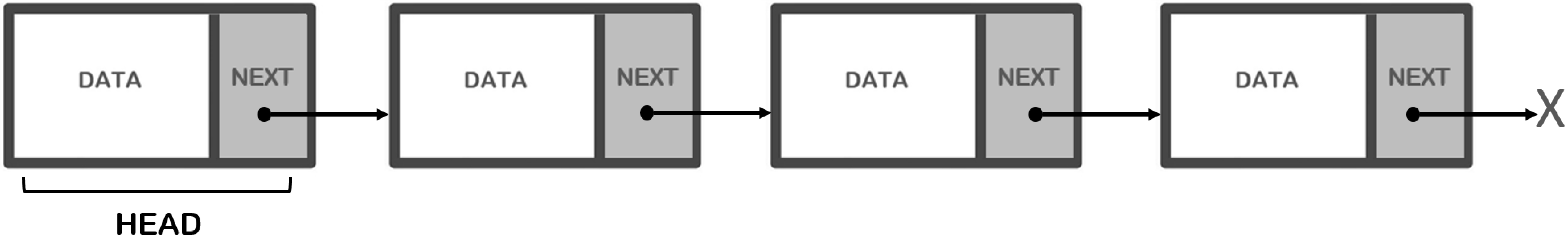
Linked lists - structure



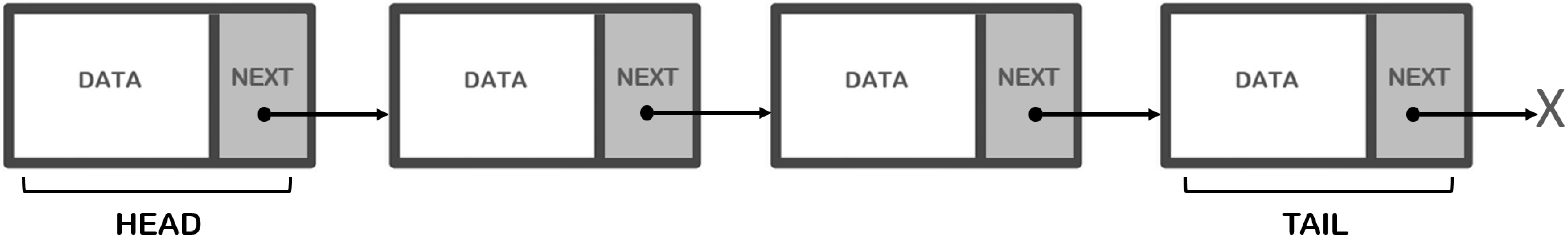
Linked lists - structure



Linked lists - structure

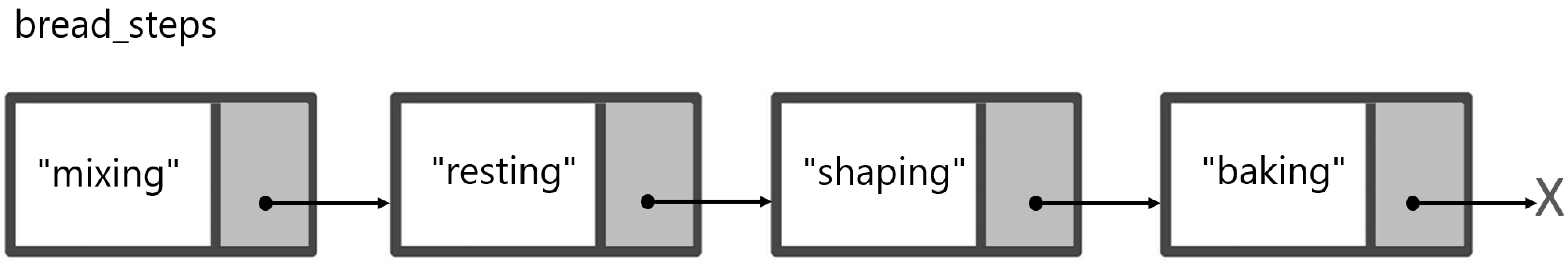


Linked lists - structure



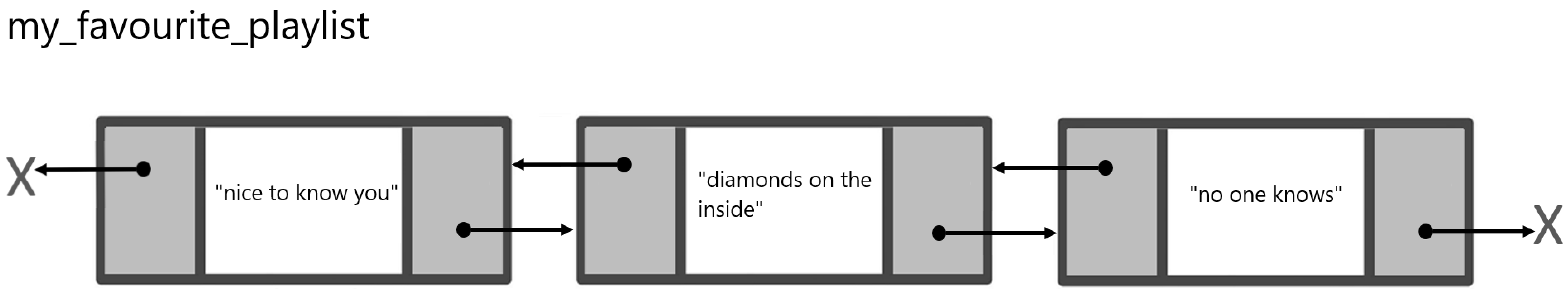
- Data doesn't need to be stored in contiguous blocks of memory
- Data can be located in any available memory address

Singly linked lists



- One link: **singly linked list**

Doubly linked lists



- Two links in either direction: **doubly linked list**

Linked lists - real uses

- Implement other data structures:
  - stacks
  - queues
  - graphs
- Access information by navigating backward and forward
  - web browser
  - music playlist

Linked lists - Node class

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

Linked lists - LinkedList class

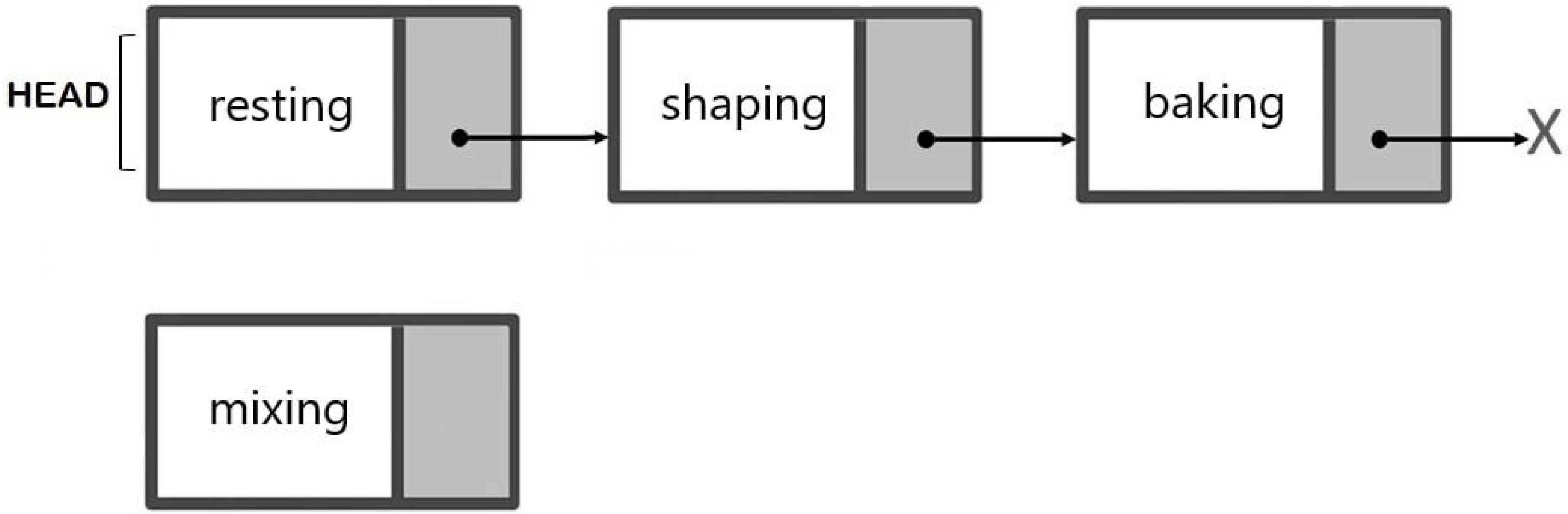
```
class LinkedList:
  def __init__(self):
    self.head = None
    self.tail = None
```

Linked lists - methods

- `insert_at_beginning()`
- `remove_at_beginning()`
- `insert_at_end()`
- `remove_at_end()`
- `insert_at()`
- `remove_at()`
- `search()`
- ...

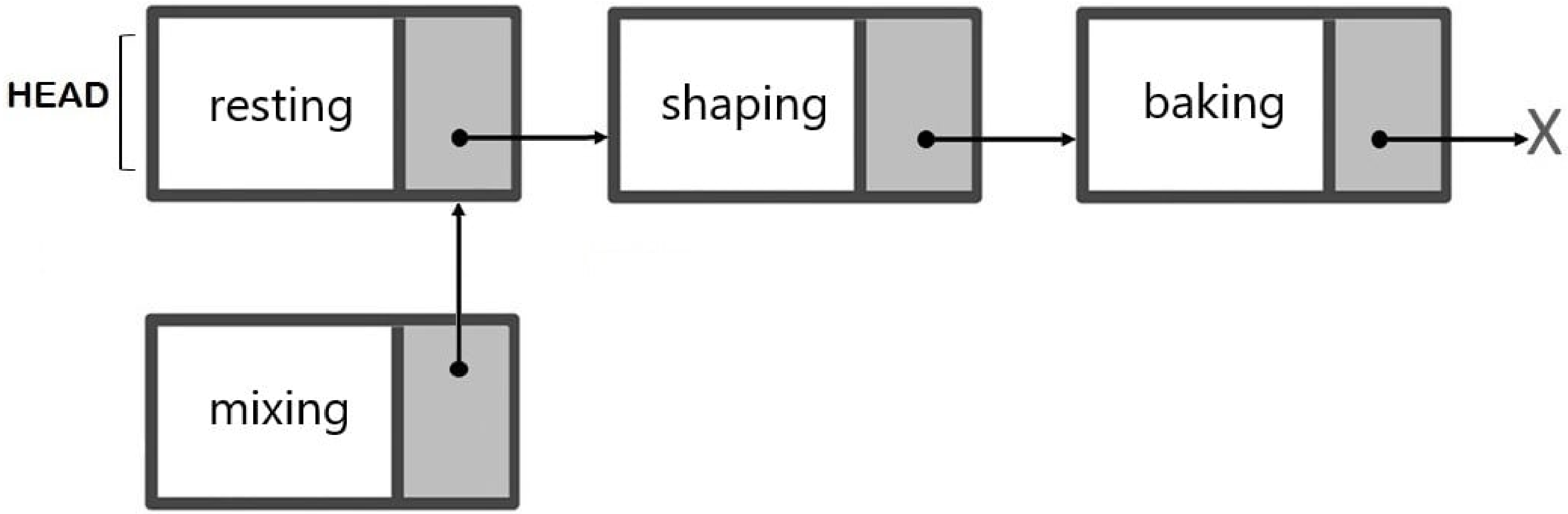
Linked lists - insert_at_beginning

Linked lists - insert_at_beginning



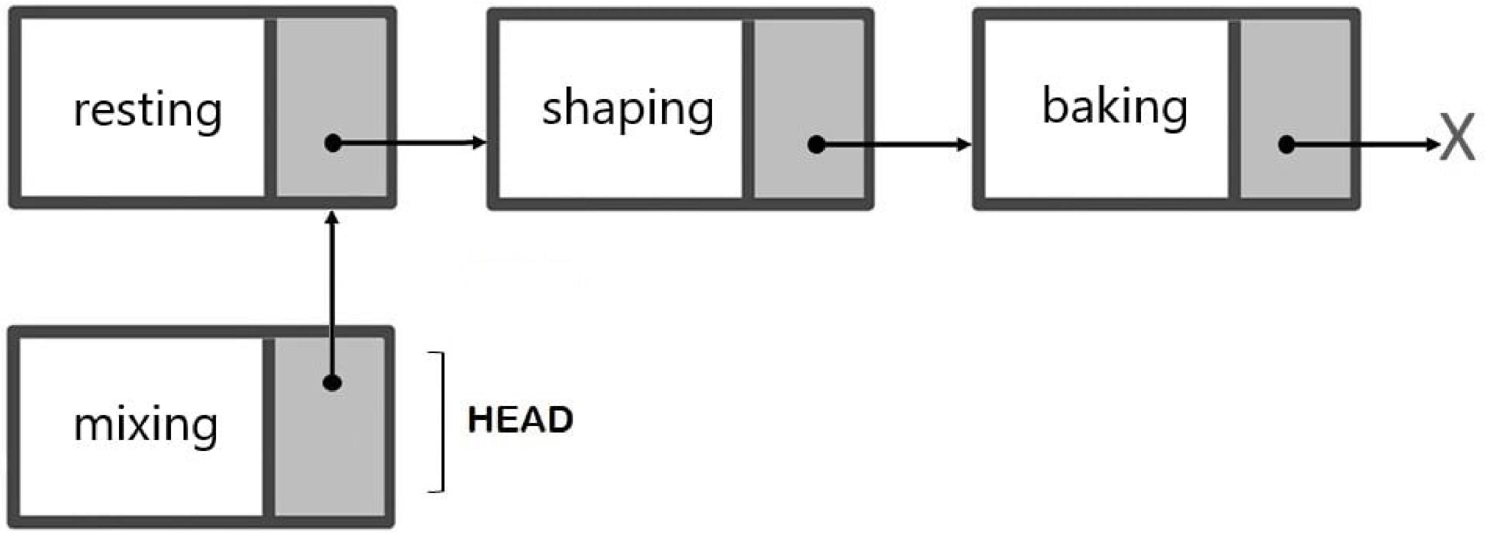

```python
def insert_at_beginning(self, data):
    new_node = Node(data)
    if self.head:
```

Linked lists - insert_at_beginning




```python
def insert_at_beginning(self, data):
    new_node = Node(data)
    if self.head:
      new_node.next = self.head
```

Linked lists - insert_at_beginning




```python
def insert_at_beginning(self, data):
    new_node = Node(data)
    if self.head:
      new_node.next = self.head
      self.head = new_node
```

Linked lists - insert_at_beginning

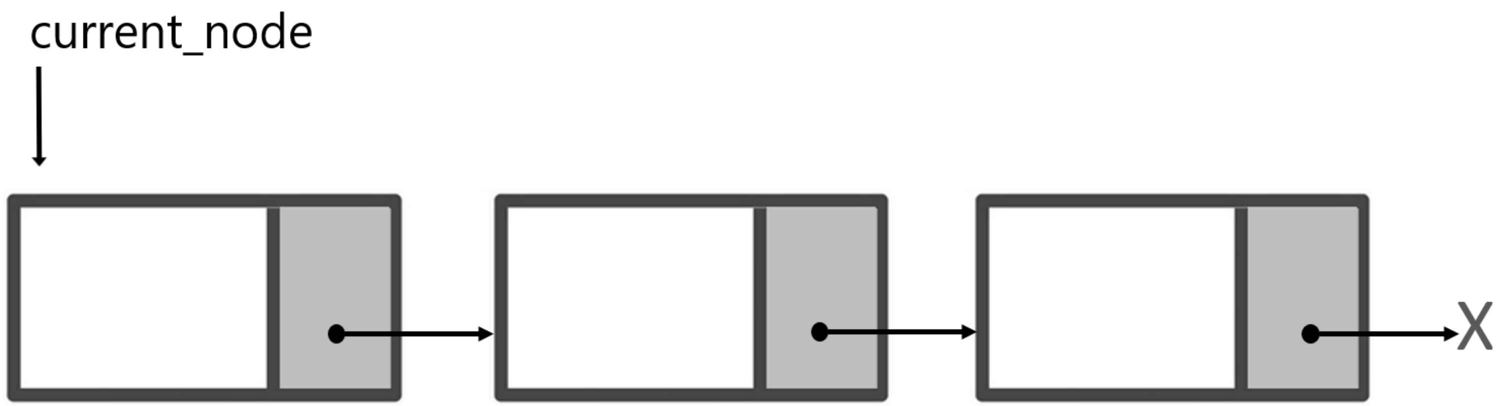

```python
def insert_at_beginning(self, data):
    new_node = Node(data)
    if self.head:
      new_node.next = self.head
      self.head = new_node
    else:
      self.tail = new_node
      self.head = new_node
```

Linked lists - insert_at_end

```
def insert_at_end(self, data):
  new_node = Node(data)
  if self.head:
    self.tail.next = new_node
    self.tail = new_node
  else:
    self.head = new_node
    self.tail = new_node
```

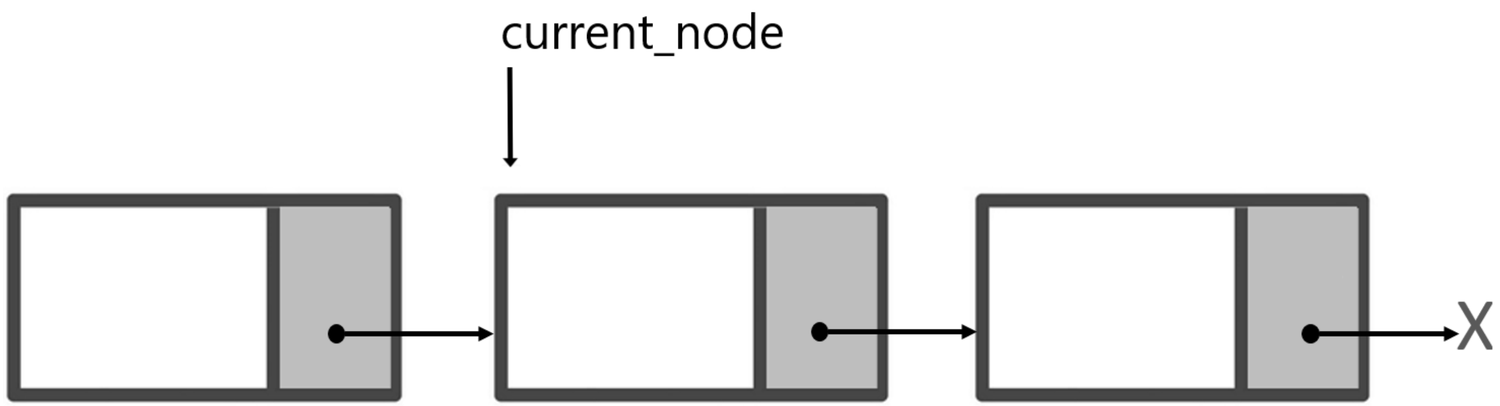
Linked lists - search

```
def search(self, data):
  current_node = self.head
  while current_node:
    if current_node.data == data:
      return True
```



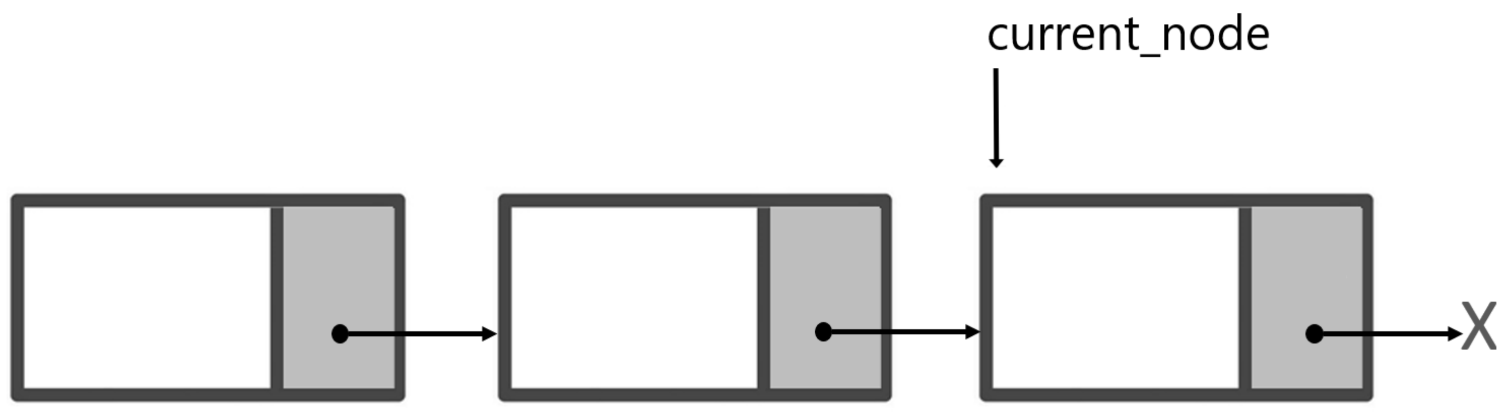
Linked lists - search

```python
def search(self, data):
  current_node = self.head
  while current_node:
    if current_node.data == data:
      return True
    else:
      current_node = current_node.next
```

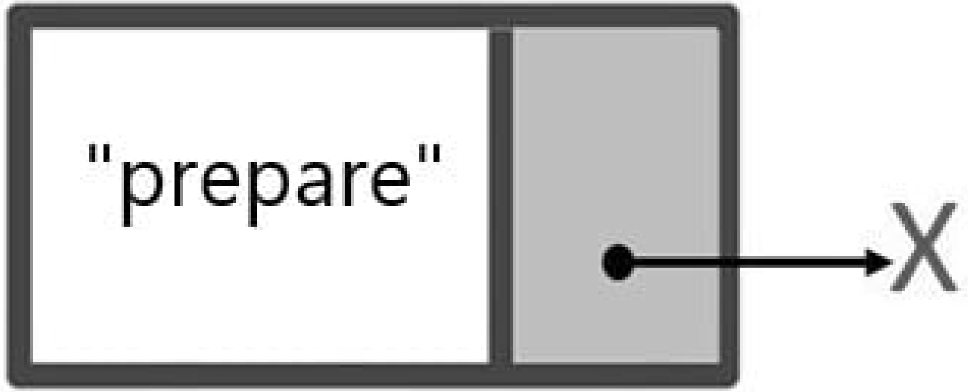


Linked lists - search

```
def search(self, data):
  current_node = self.head
  while current_node:
    if current_node.data == data:
      return True
    else:
      current_node = current_node.next
  return False
```

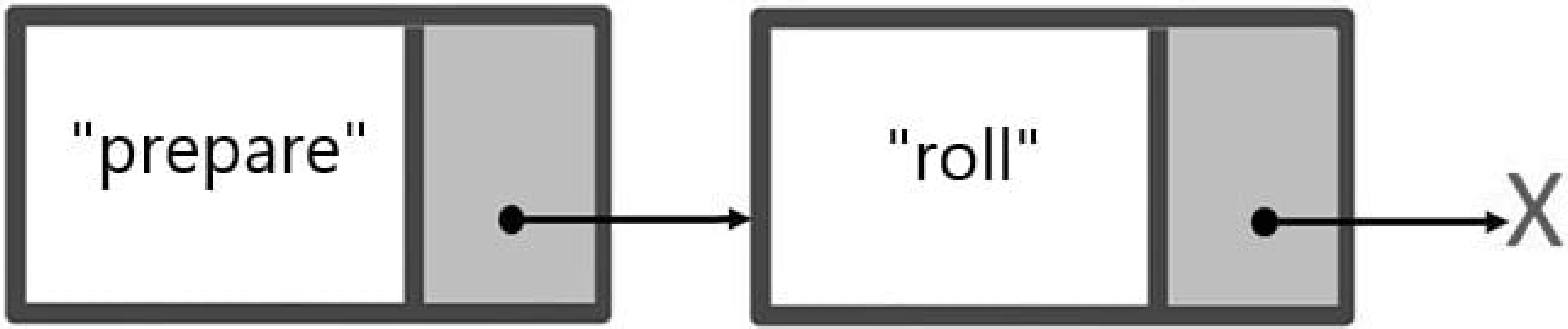


Linked lists - example



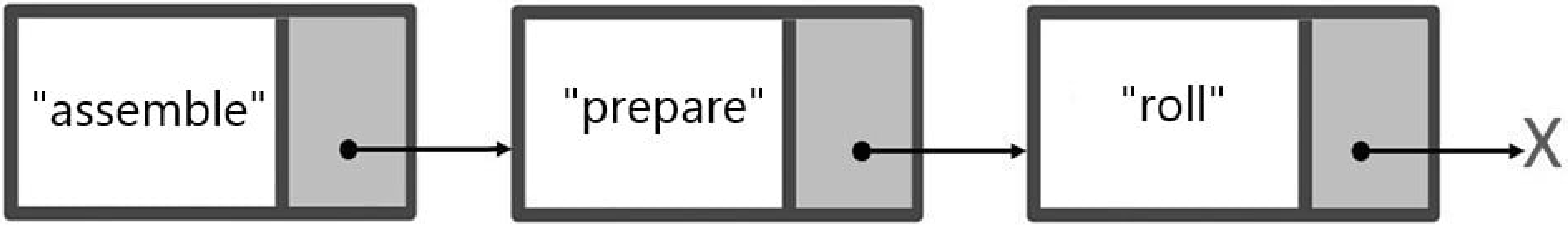

```
sushi_preparation = LinkedList()
sushi_preparation.insert_at_end("prepare")
```

Linked lists - example




```
sushi_preparation = LinkedList()
sushi_preparation.insert_at_end("prepare")
sushi_preparation.insert_at_end("roll")
```

Linked lists - example




```
sushi_preparation = LinkedList()
sushi_preparation.insert_at_end("prepare")
sushi_preparation.insert_at_end("roll")
sushi_preparation.insert_at_beginning("assemble")
```

Linked lists - example


```
sushi_preparation.search("roll")
```

```
True
```

```
sushi_preparation.search("mixing")
```

```
False
```

Let's practice!

DATA STRUCTURES AND ALGORITHMS IN PYTHON

Understanding Big O Notation

DATA STRUCTURES AND ALGORITHMS IN PYTHON

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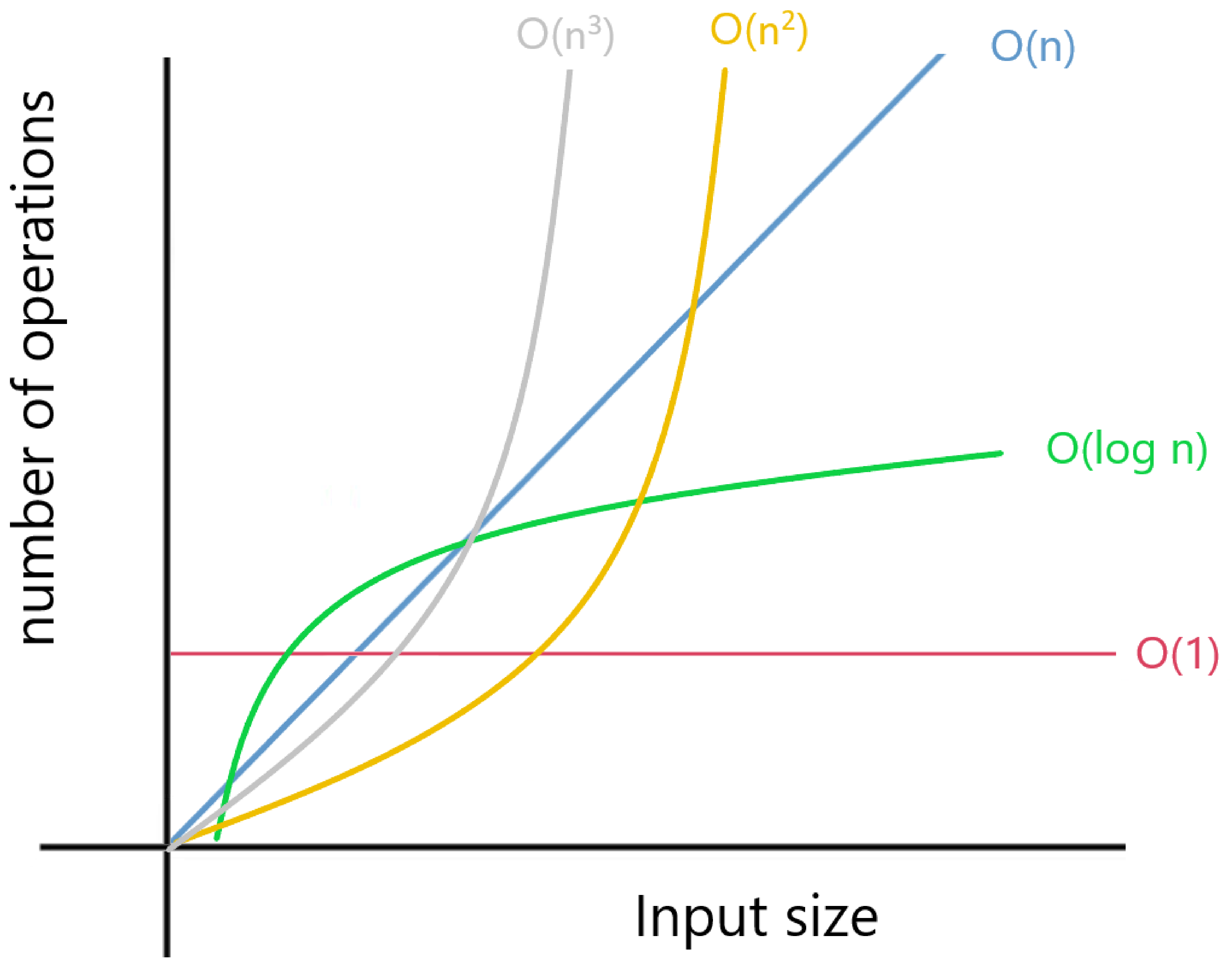
Software Engineer

Big O Notation

- Measures the **worst-case complexity** of an algorithm
    - **Time complexity:** time taken to run completely
    - **Space complexity:** extra memory space
- Doesn't use seconds/bytes
    - Different results depending on the hardware
- **Mathematical expressions:** $O(1)$, $O(n)$, $O(n^2)$...

Big O Notation



$O(1)$

```python
colors = ['green', 'yellow', 'blue', 'pink']

def constant(colors):
    print(colors[2])

constant(colors)
```

```
blue
```

$O(1)$

```python
colors = ['green', 'yellow', 'blue', 'pink', 'black', 'white', 'purple', 'red']

def constant(colors):
    print(colors[2])  # O(1)

constant(colors)
```

```
blue
```

$O(n)$

```python
colors = ['green', 'yellow', 'blue', 'pink']

def linear(colors):
  for color in colors:
    print(color)

linear(colors)
```

```
green
yellow
blue
pink
```

$O(n)$

```python
colors = ['green', 'yellow', 'blue', 'pink'] # n=4

def linear(colors):
  for color in colors:
    print(color)    # O(4)

linear(colors)
```

- `n=4` : 4 operations

$O(n)$

```
colors = ['green', 'yellow', 'blue', 'pink', 'black', 'white', 'purple'] # n=7

def linear(colors):
  for color in colors:
    print(color)    # O(7)

linear(colors)
```

- `n=4` : 4 operations
- `n=7` : 7 operations
- `n=100` : 100 operations
- ...
- $O(n)$ **complexity**

$O(n^2)$

```python
colors = ['green', 'yellow', 'blue']

def quadratic(colors):
  for first in colors:
      for second in colors:
          print(first, second)

quadratic(colors)
```

```
green green
green yellow
green blue
yellow green
yellow yellow
yellow blue
blue green
blue yellow
blue blue
```

- `n=3` : (3 x 3) **9 operations**
- `n=100` : (100 x 100) **10,000 operations**
- quadratic pattern
- $O(n^2)$ **complexity**

$O(n^3)$

```python
colors = ['green', 'yellow', 'blue']

def cubic(colors):
  for color1 in colors:
      for color2 in colors:
          for color3 in colors:
              print(color1, color2, color3)

cubic(colors)
```

- `n=3` : (3 x 3 x 3) **27 operations**
- `n=10` : (10 x 10 x 10) **1,000 operations**
- cubic pattern
- $O(n^3)$ **complexity**

Calculating Big O Notation

```python
colors = ['green', 'yellow', 'blue', 'pink', 'black', 'white', 'purple']
other_colors = ['orange', 'brown']

def complex_algorithm(colors):
  color_count = 0

  for color in colors:
      print(color)
      color_count += 1

  for other_color in other_colors:
      print(other_color)
      color_count += 1

  print(color_count)

complex_algorithm(colors)
```

Calculating Big O Notation

```
colors = ['green', 'yellow', 'blue', 'pink', 'black', 'white', 'purple']  # O(1)
other_colors = ['orange', 'brown']  # O(1)

def complex_algorithm(colors):
  color_count = 0          # O(1)

  for color in colors:
    print(color)           # O(n)
    color_count += 1       # O(n)

  for other_color in other_colors:
    print(other_color)     # O(m)
    color_count += 1       # O(m)

  print(color_count)       # O(1)

complex_algorithm(colors)  # O(4
```

Calculating Big O Notation

```python
colors = ['green', 'yellow', 'blue', 'pink', 'black', 'white', 'purple']  # O(1)
other_colors = ['orange', 'brown']  # O(1)

def complex_algorithm(colors):
  color_count = 0          # O(1)

  for color in colors:
    print(color)           # O(n)
    color_count += 1       # O(n)

  for other_color in other_colors:
    print(other_color)     # O(m)
    color_count += 1       # O(m)

  print(color_count)       # O(1)

complex_algorithm(colors)  # O(4 + 2n
```

Calculating Big O Notation

```python
colors = ['green', 'yellow', 'blue', 'pink', 'black', 'white', 'purple']  # O(1)
other_colors = ['orange', 'brown']  # O(1)

def complex_algorithm(colors):
  color_count = 0          # O(1)

  for color in colors:
    print(color)           # O(n)
    color_count += 1       # O(n)

  for other_color in other_colors:
    print(other_color)     # O(m)
    color_count += 1       # O(m)

  print(color_count)       # O(1)

complex_algorithm(colors)  # O(4 + 2n + 2m)
```

Simplifying Big O Notation

1. Remove constants
   - $O(4 + 2n + 2m)$ -> $O(n + m)$
2. Different variables for different inputs
   - $O(n + m)$
3. Remove smaller terms
   - $O(n + n^2)$

Simplifying Big O Notation

1. Remove constants
   - $O(4 + 2n + 2m)$ -> $O(n + m)$
2. Different variables for different inputs
   - $O(n + m)$
3. Remove smaller terms
   - $O(n + n^2)$ -> $O(n^2)$

Let's practice!

DATA STRUCTURES AND ALGORITHMS IN PYTHON

Working with stacks

DATA STRUCTURES AND ALGORITHMS IN PYTHON

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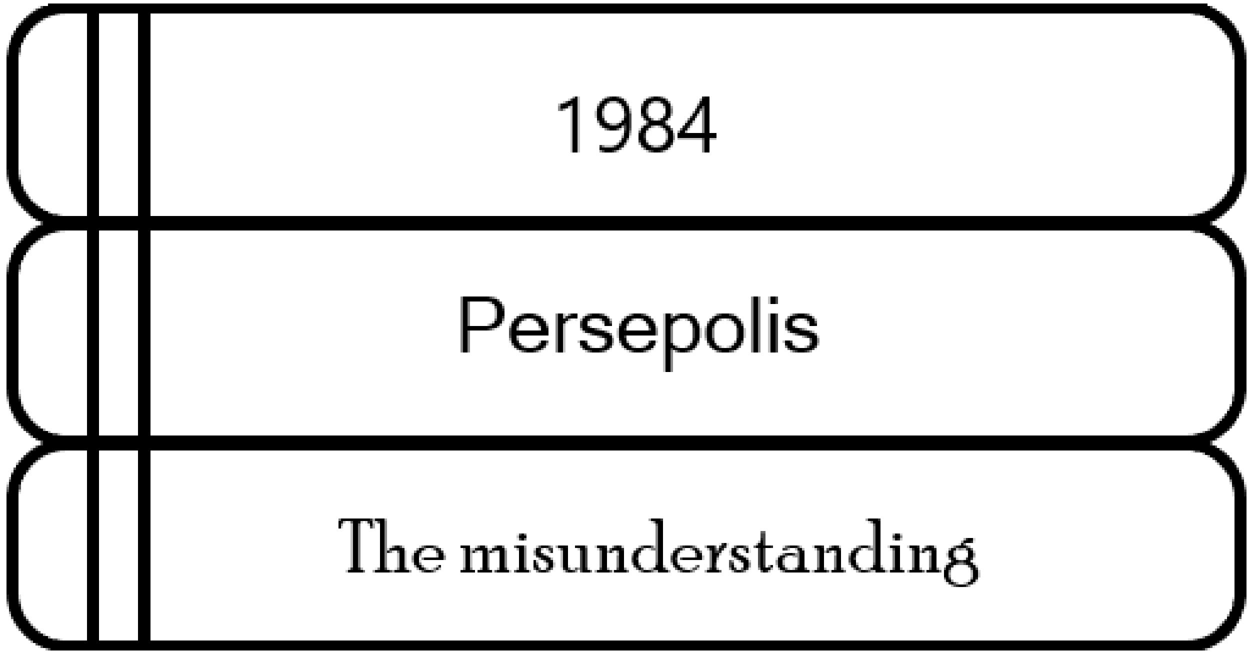
Software Engineer

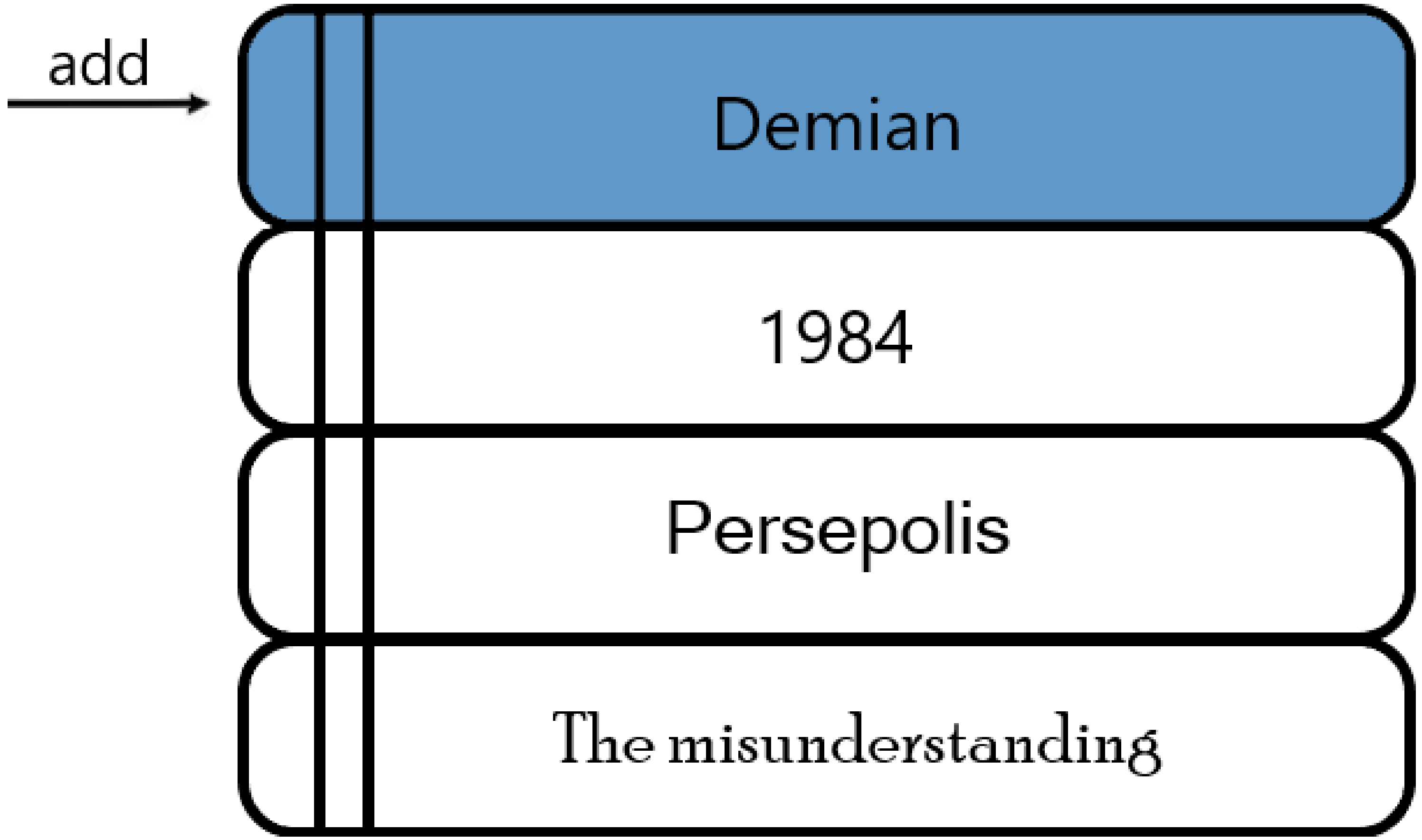
Stacks

- **LIFO:** Last-In First-Out
  - **Last inserted** item will be the **first** item to be **removed**



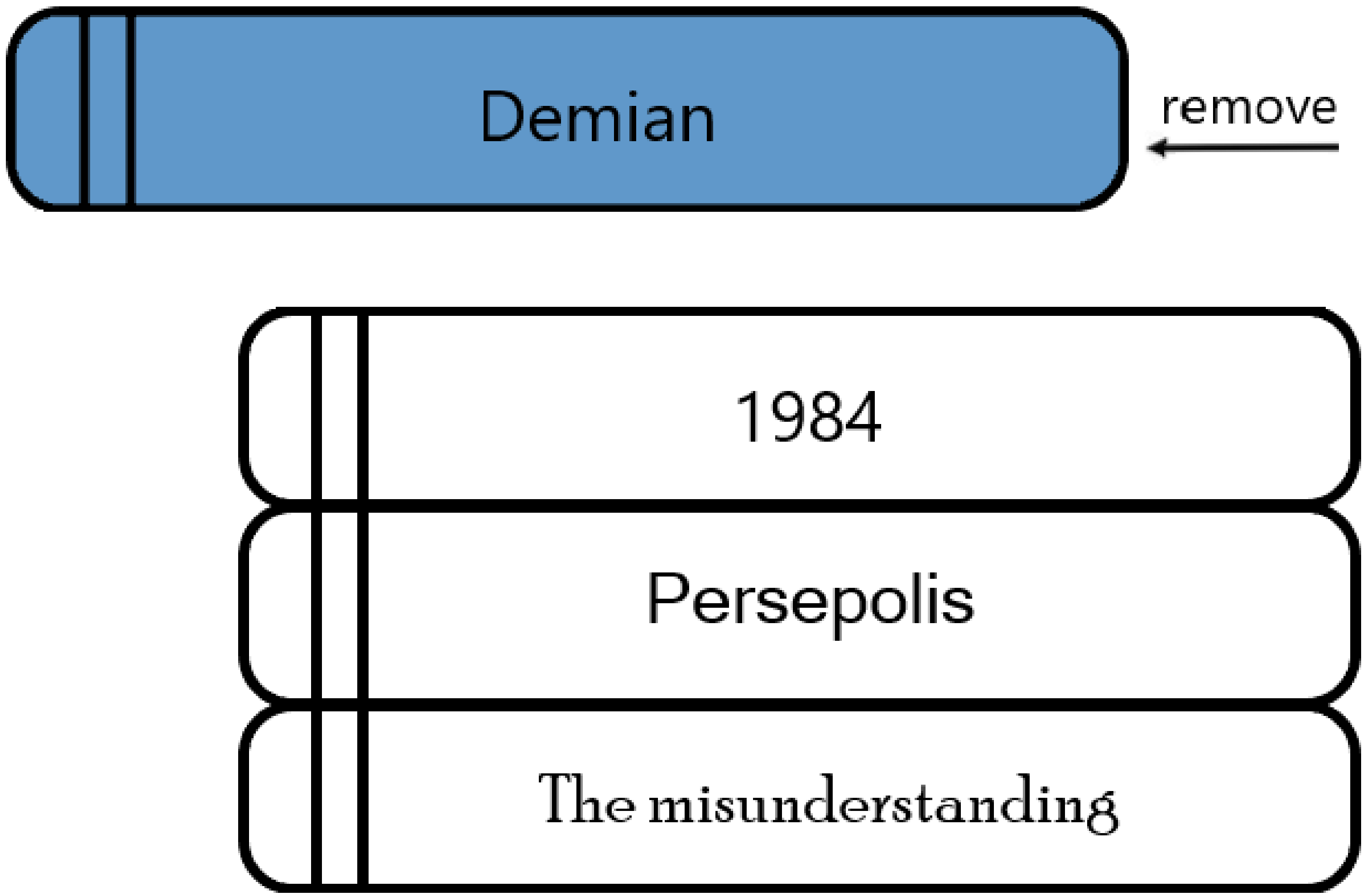
Stacks

- **LIFO:** Last-In First-Out
  - **Last inserted** item will be always the **first** item to be **removed**
- Can only **add** at the **top**
  - *Pushing onto the stack*



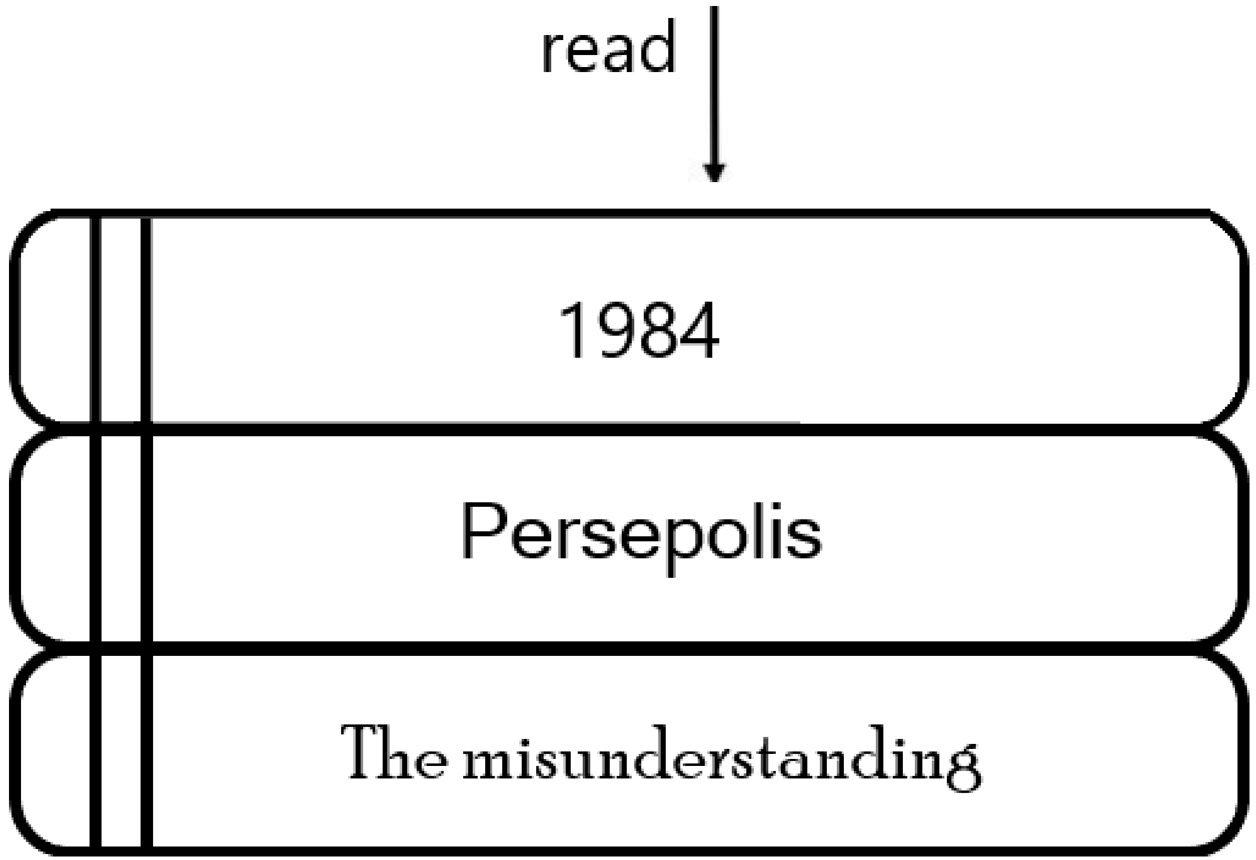
Stacks

- **LIFO:** Last-In First-Out
  - **Last inserted** item will be always the **first** item to be **removed**
- Can only **add** at the **top**
  - ***Pushing** onto the stack*
- Can only **take** from the **top**
  - ***Popping** from the stack*



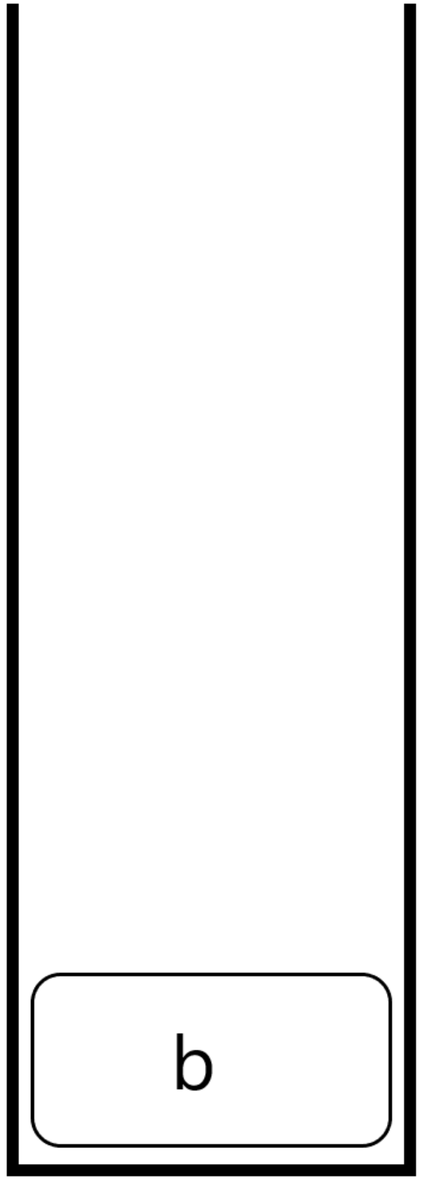
Stacks

- **LIFO:** Last-In First-Out
  - **Last inserted** item will be always the **first** item to be **removed**
- Can only **add** at the **top**
  - ***Pushing** onto the stack*
- Can only **remove** from the **top**
  - ***Popping** from the stack*
- Can only **read** the **last element**
  - ***Peeking** from the stack*



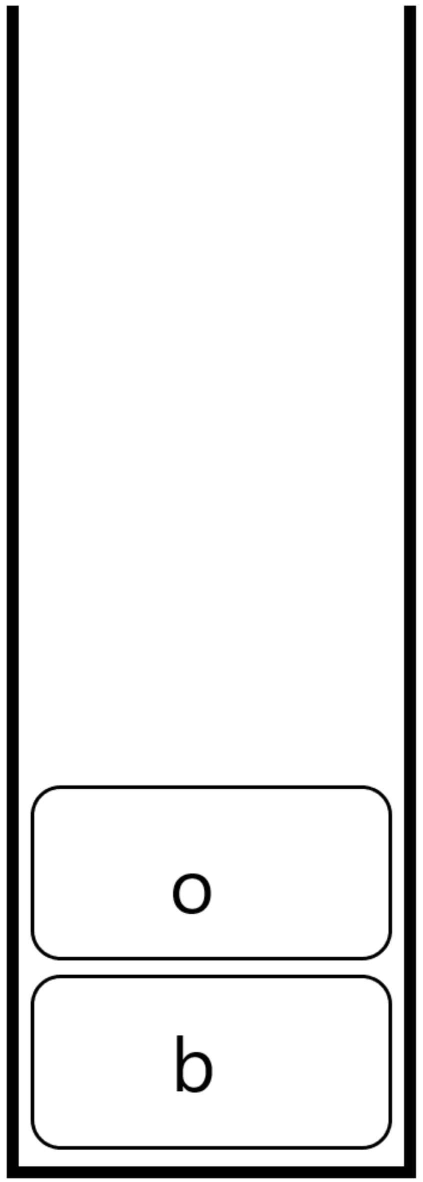
Stacks - real uses

- Undo functionality



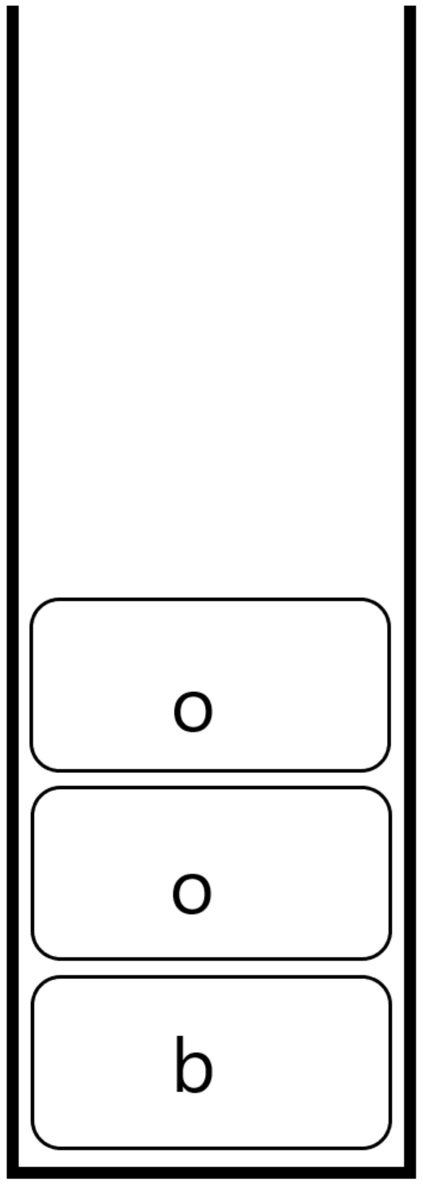
Stacks - real uses

- Undo functionality
  - **push** each keystroke



Stacks - real uses

- Undo functionality
  - **push** each keystroke



Stacks - real uses

- Undo functionality
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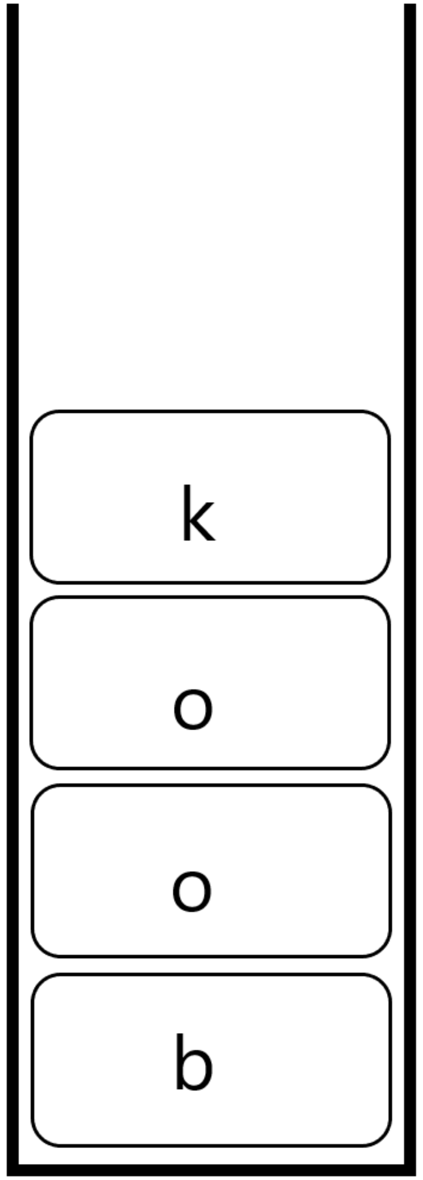

Stacks - real uses

- Undo functionality
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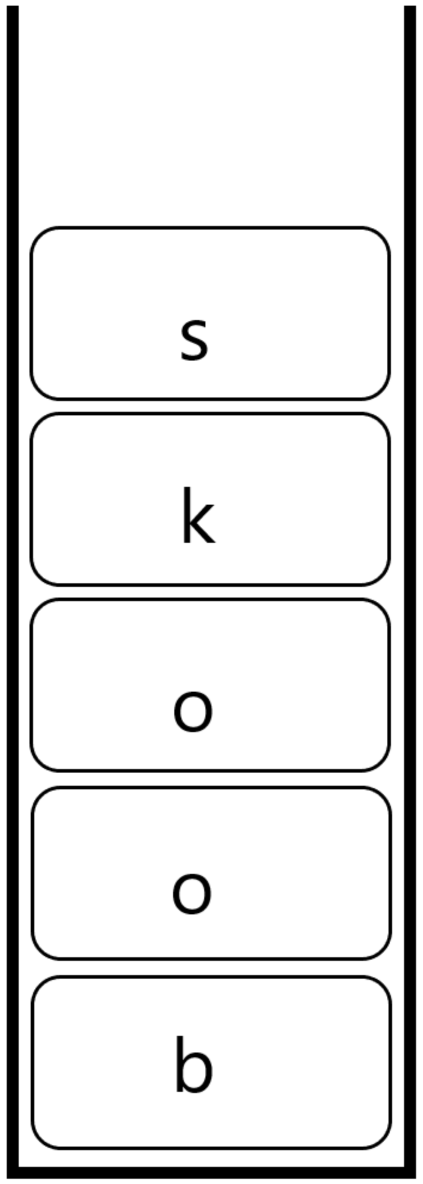
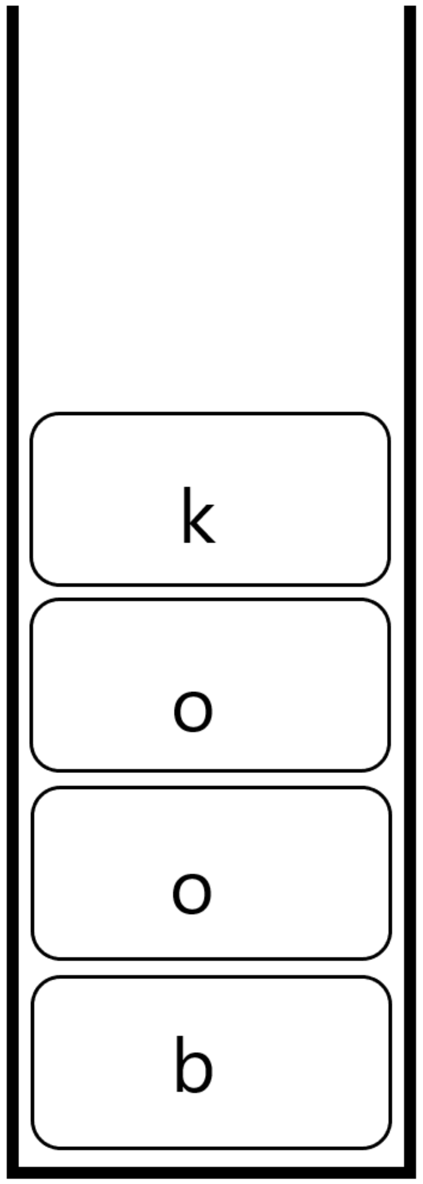


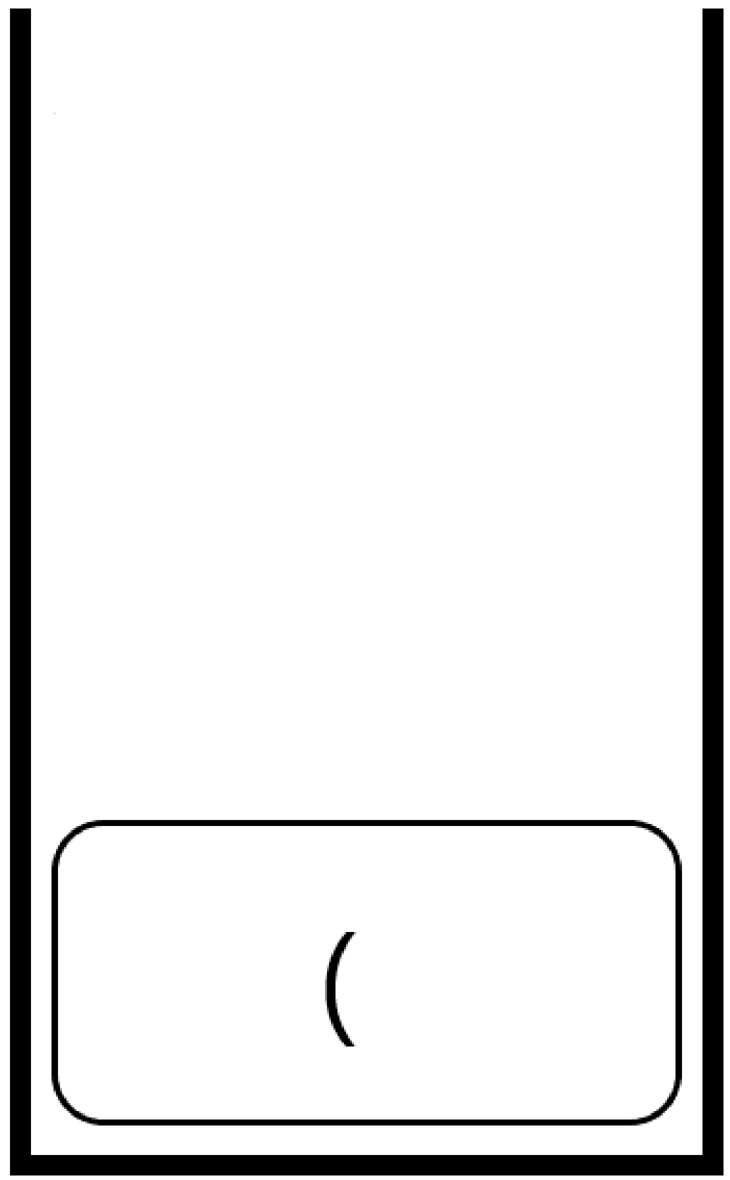
Stacks - real uses

- Undo functionality
  - **push** each keystroke
  - **pop** last inserted keystroke



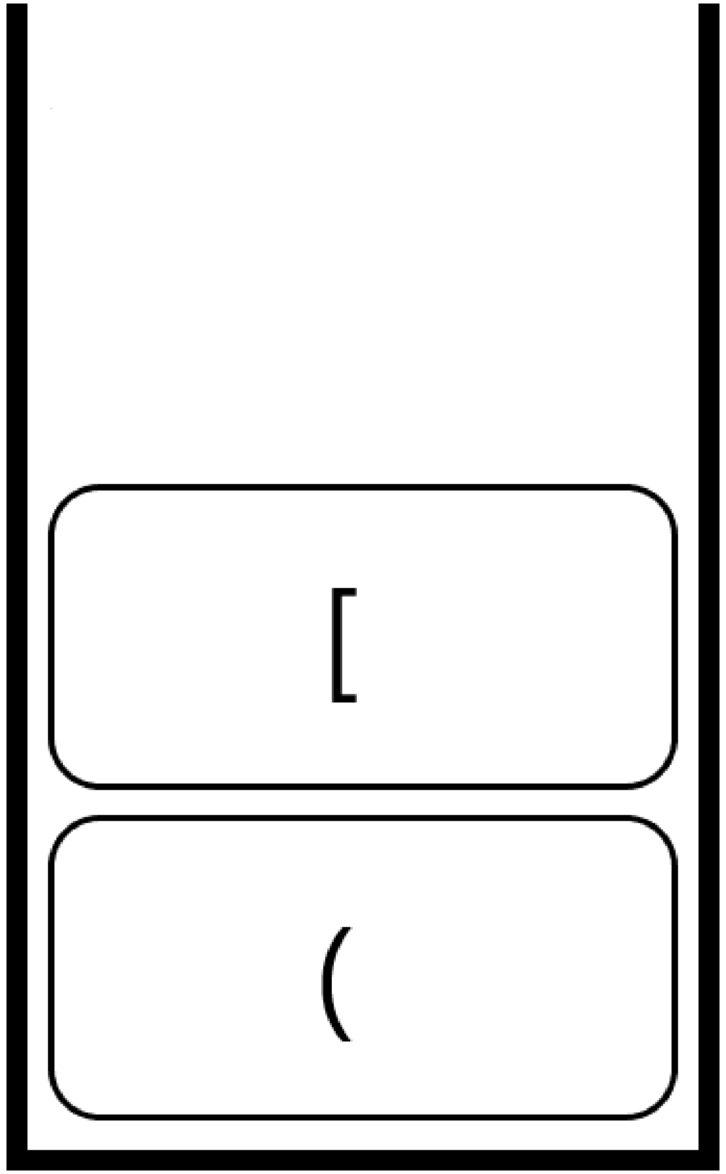
Stacks - real uses

- Symbol checker: ([{ }])
  - **push** opening symbols



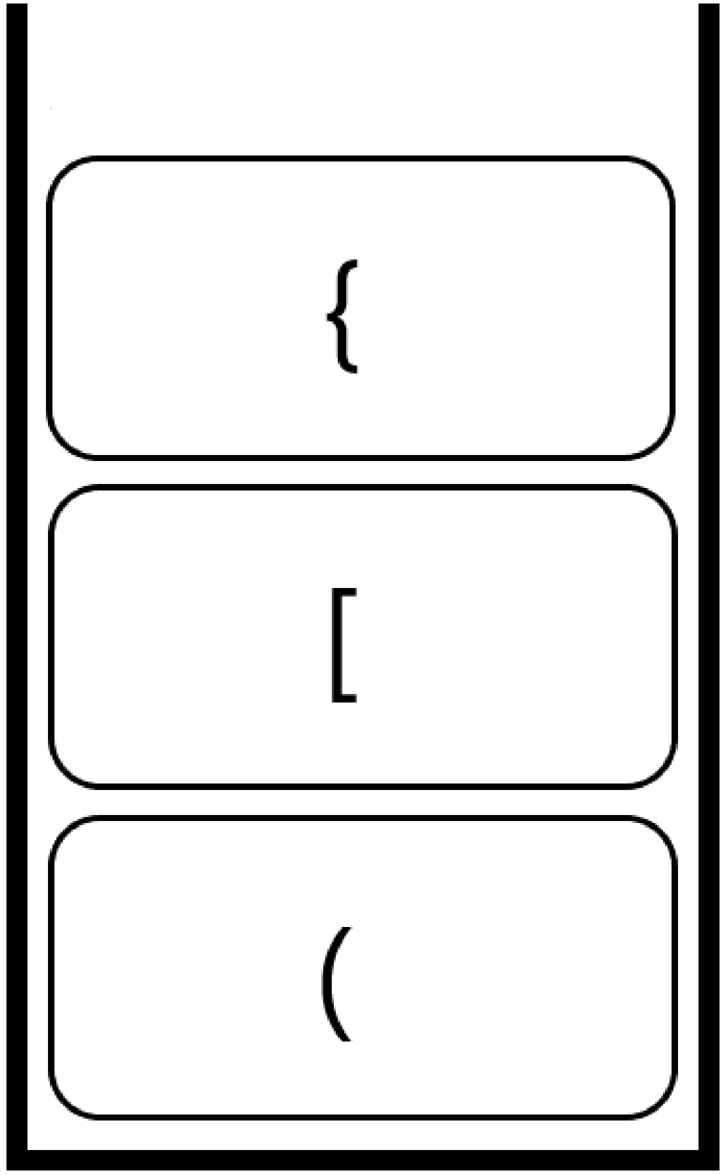
Stacks - real uses

- Symbol checker: ([{ }])
  - **push** opening symbols



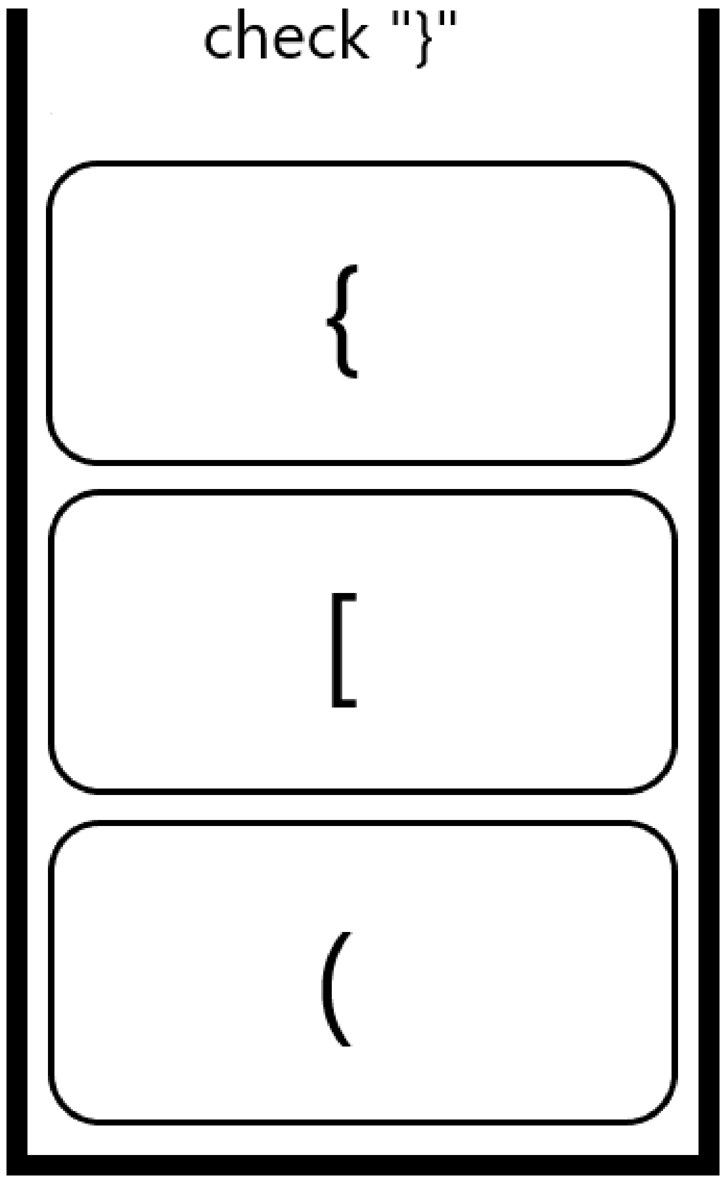
Stacks - real uses

- Symbol checker: ([{ }])
  - **push** opening symbols



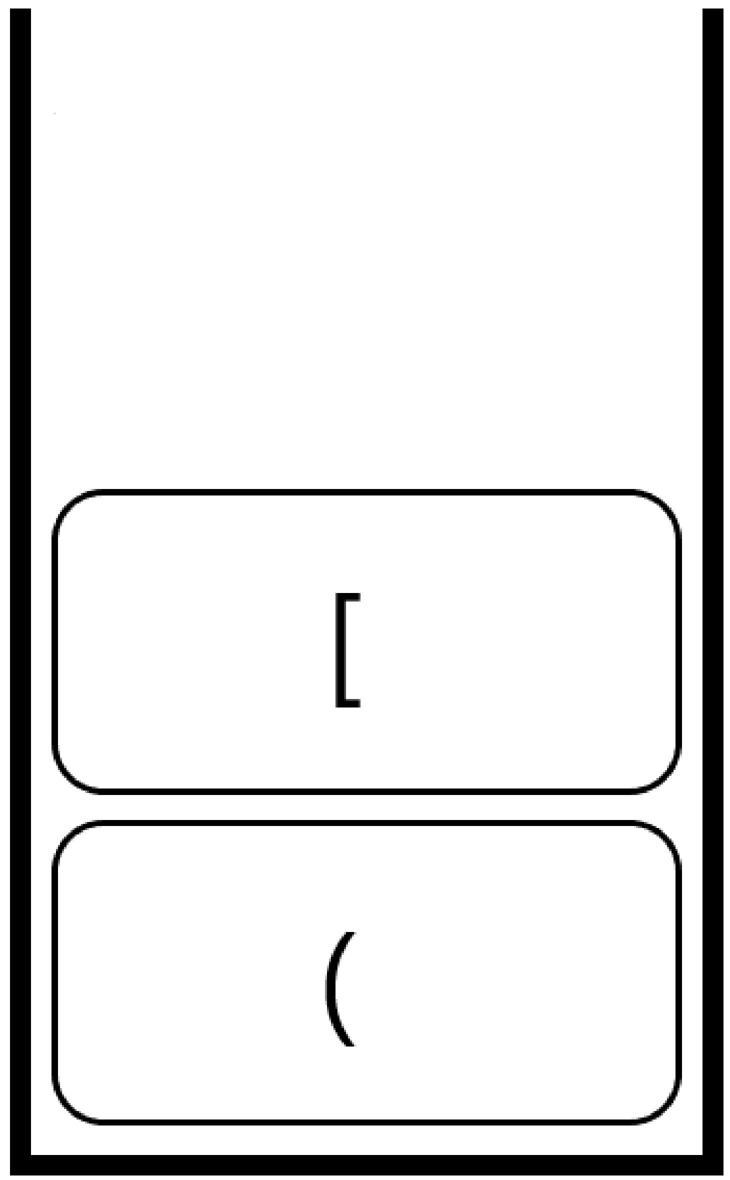
Stacks - real uses

- Symbol checker: ([{ }])
  - **push** opening symbols
  - **check** closing symbol



Stacks - real uses

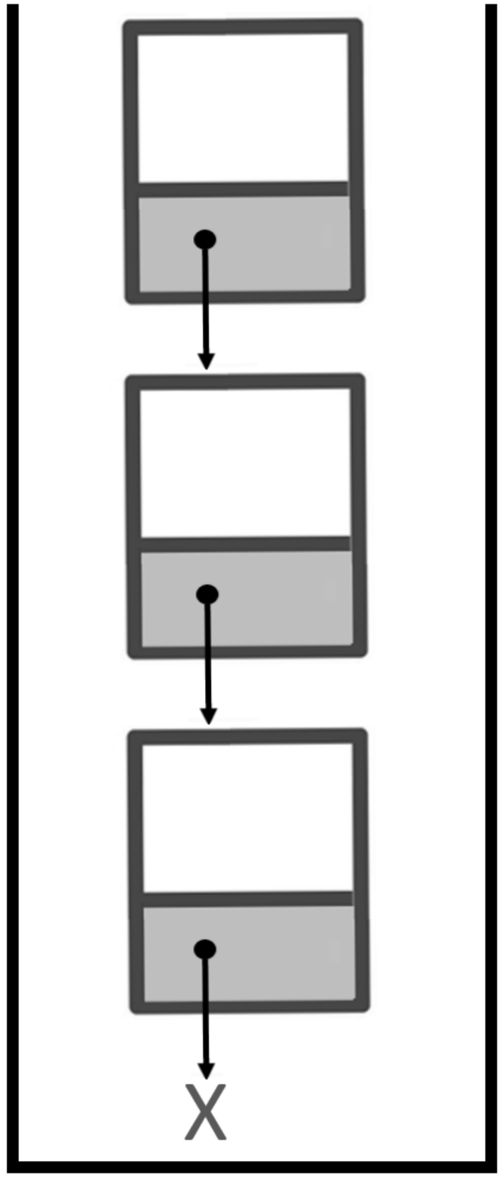
- Symbol checker: ([{ }])
  - **push** opening symbols
  - **check** closing symbol
  - **pop** matching opening symbol



Stacks - real uses

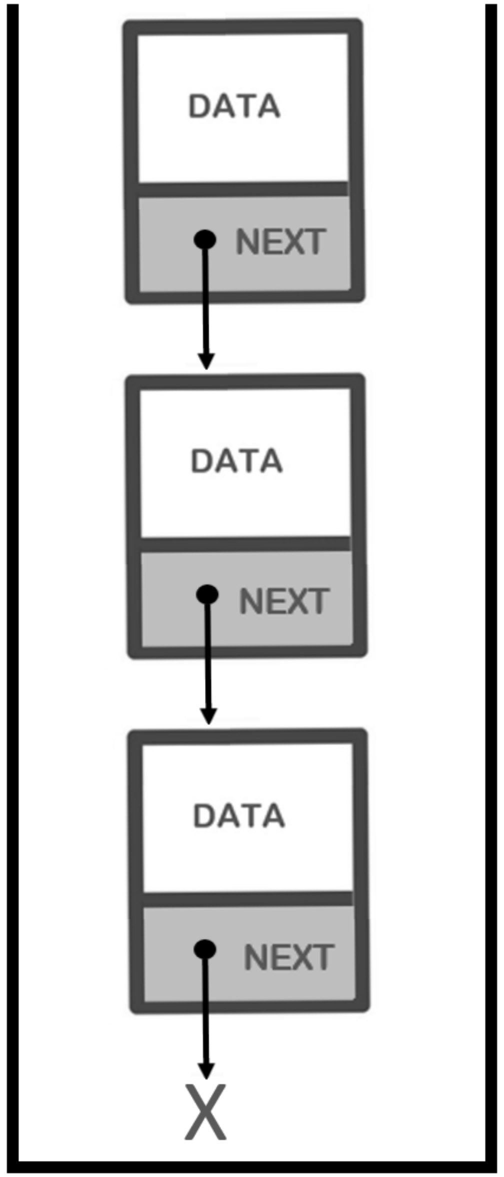
- Function calls
  - **push** block of memory
  - **pop** after the execution ends

Stacks - implementation using singly linked lists




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

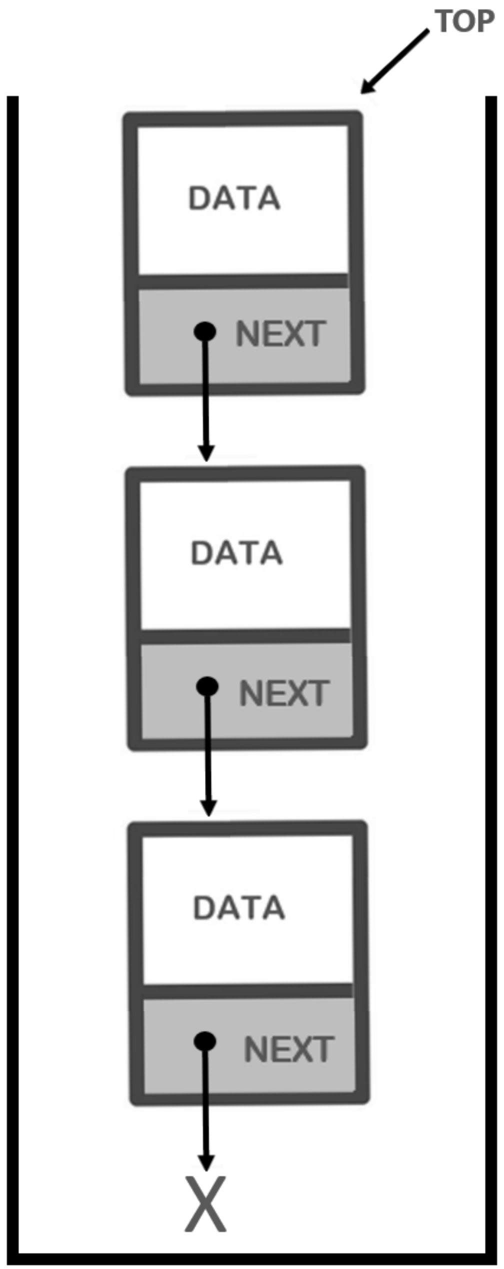
Stacks - implementation using singly linked lists




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

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

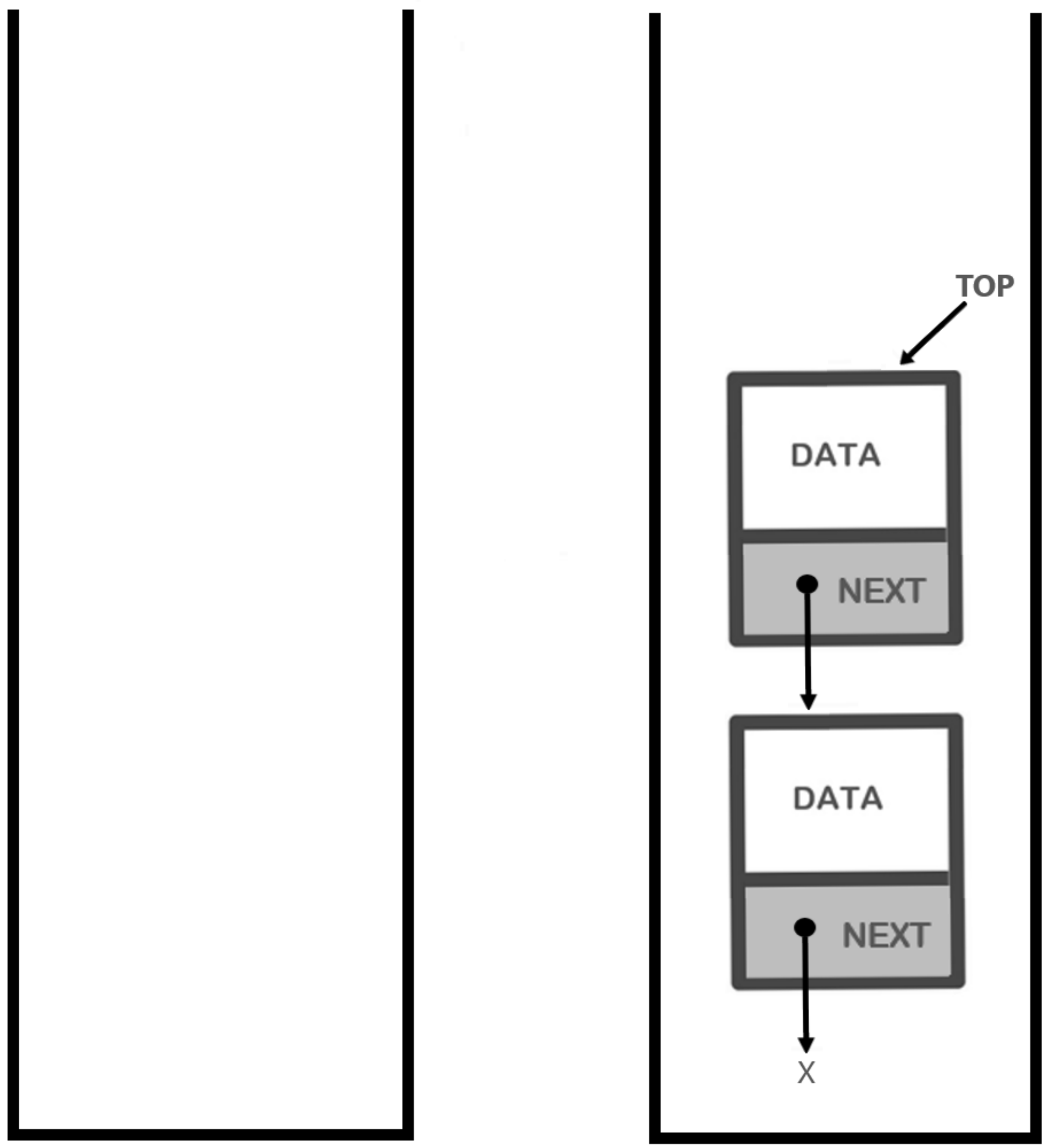
Stacks - implementation using singly linked lists




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

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

Stacks - push

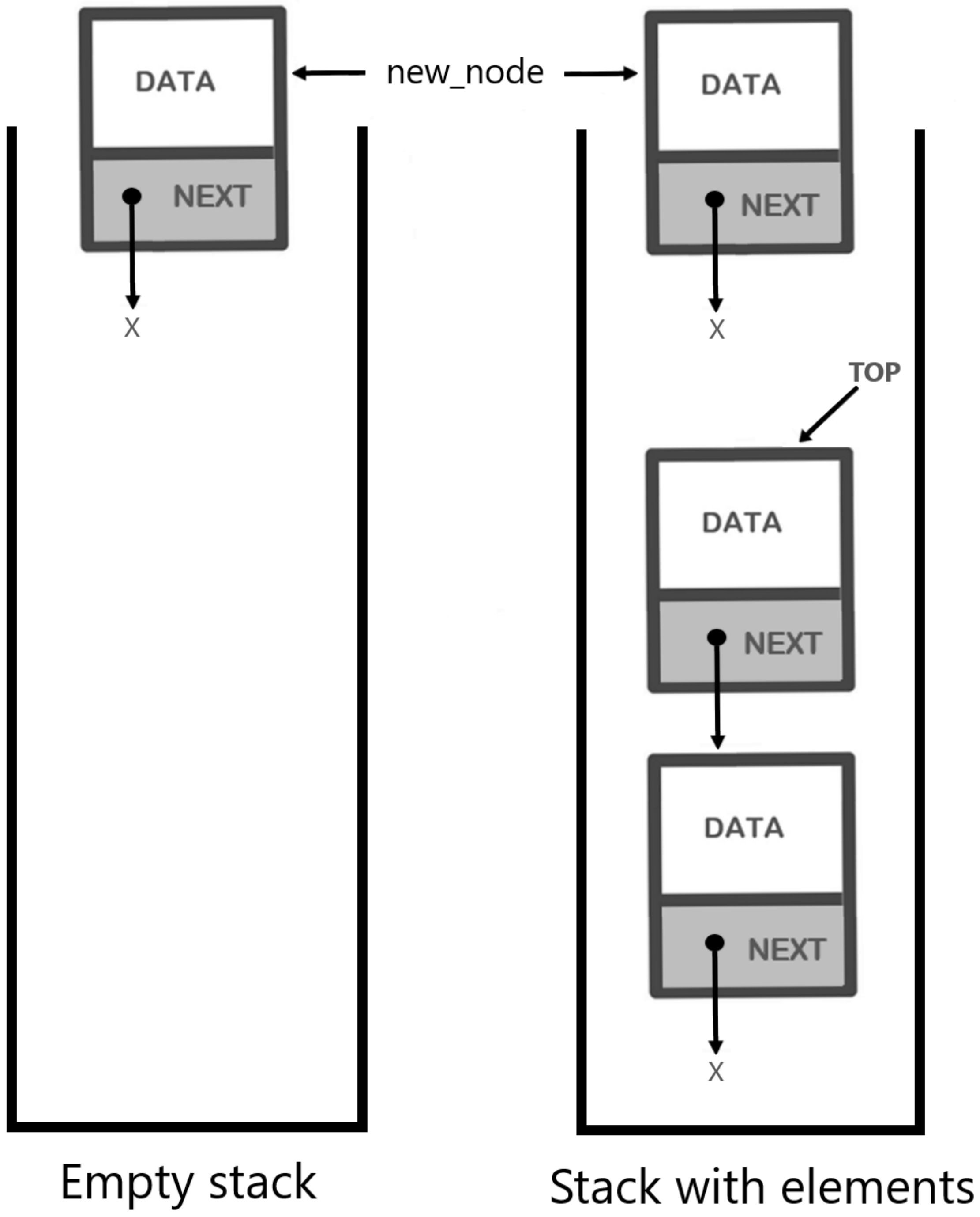


Empty stack

Stack with elements

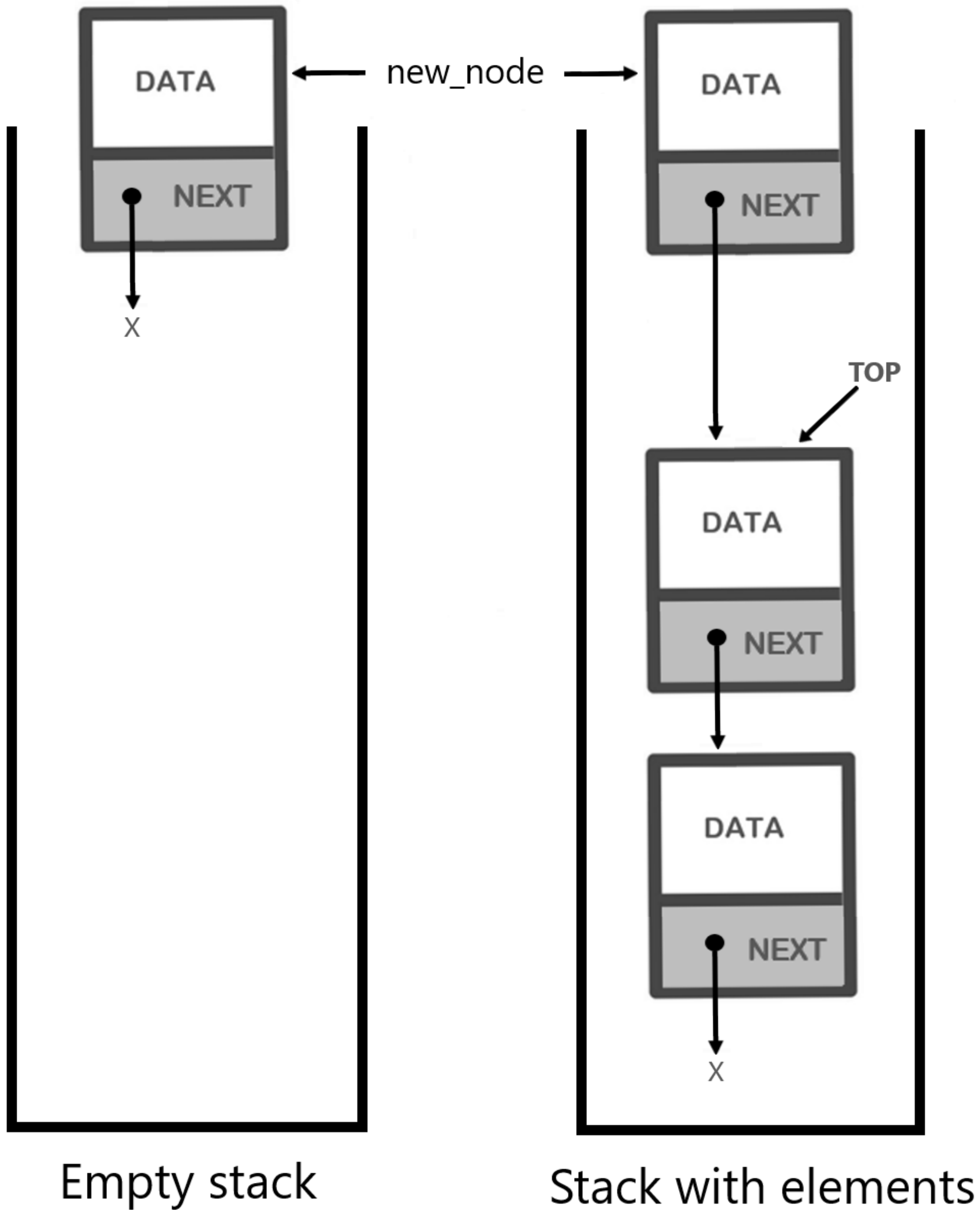
```
def push(self, data):
```

Stacks - push



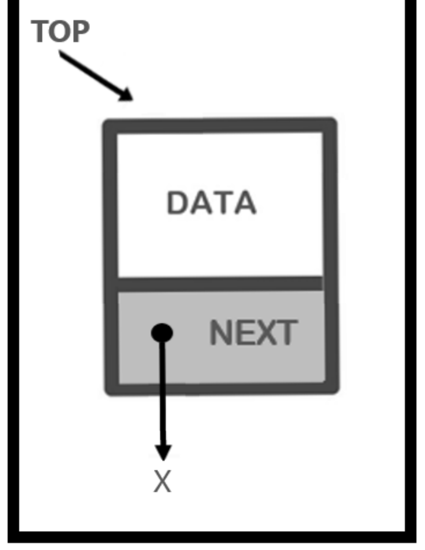

```python
def push(self, data):
  new_node = Node(data)
  if self.top:
```

Stacks - push

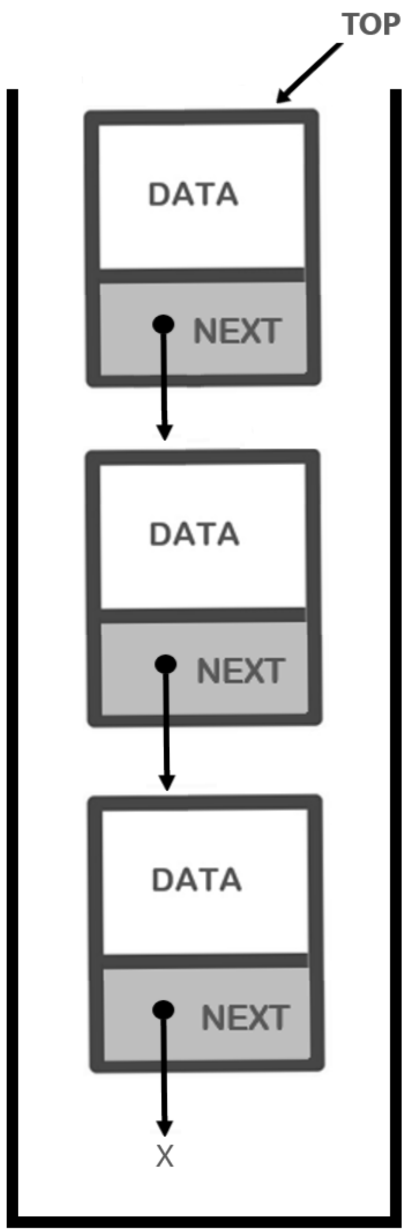



```python
def push(self, data):
  new_node = Node(data)
  if self.top:
    new_node.next = self.top
```

Stacks - push



Empty stack

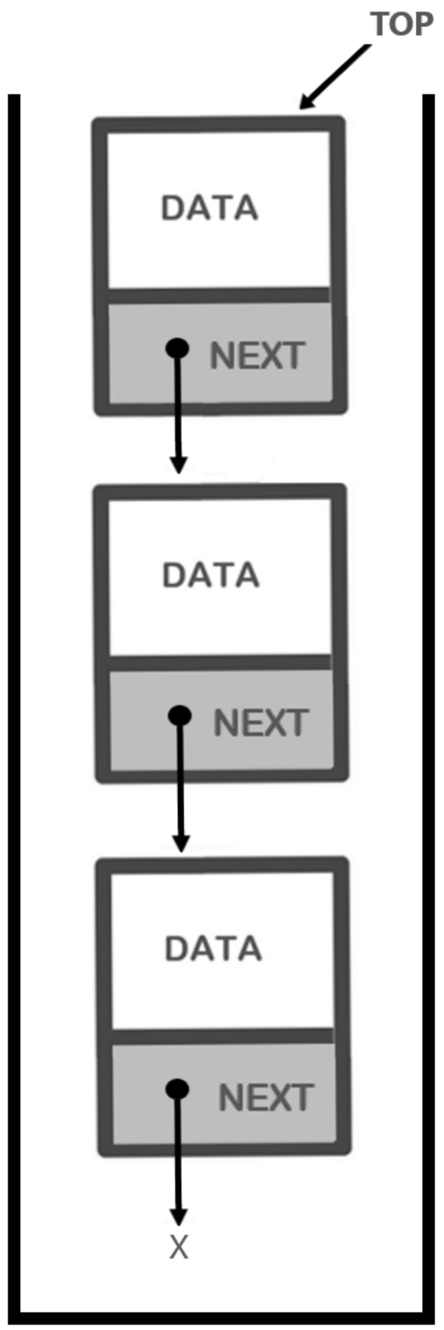


Stack with elements

```
def push(self, data):
  new_node = Node(data)
  if self.top:
    new_node.next = self.top
  self.top = new_node
```

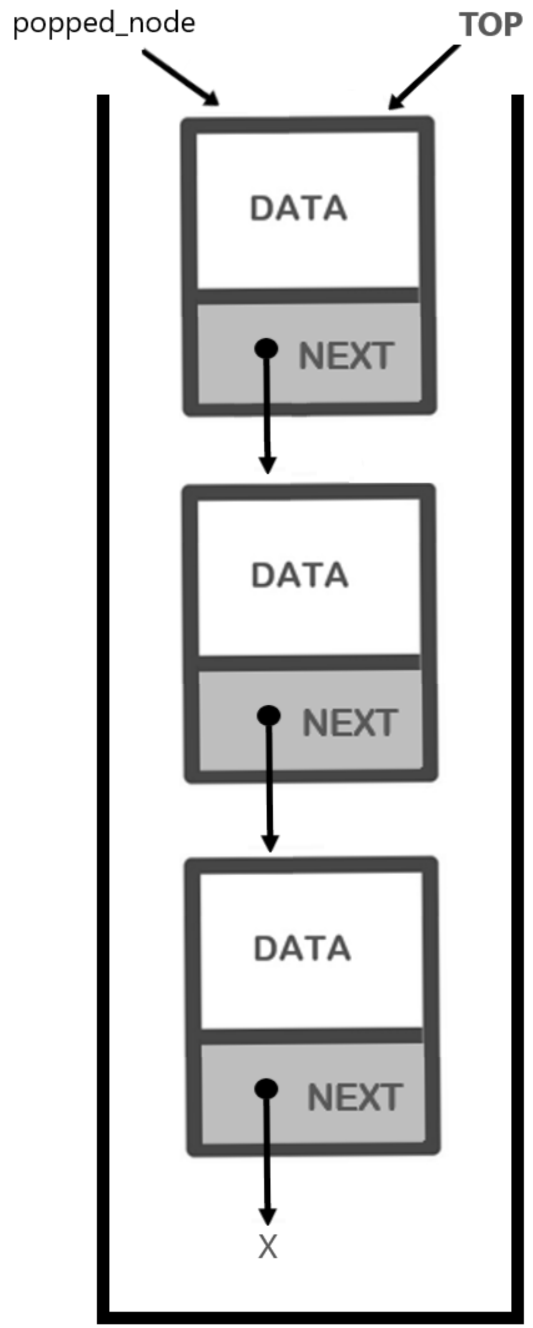
Stacks - pop

```
def pop(self):
  if self.top is None:
    return None
  else:
```



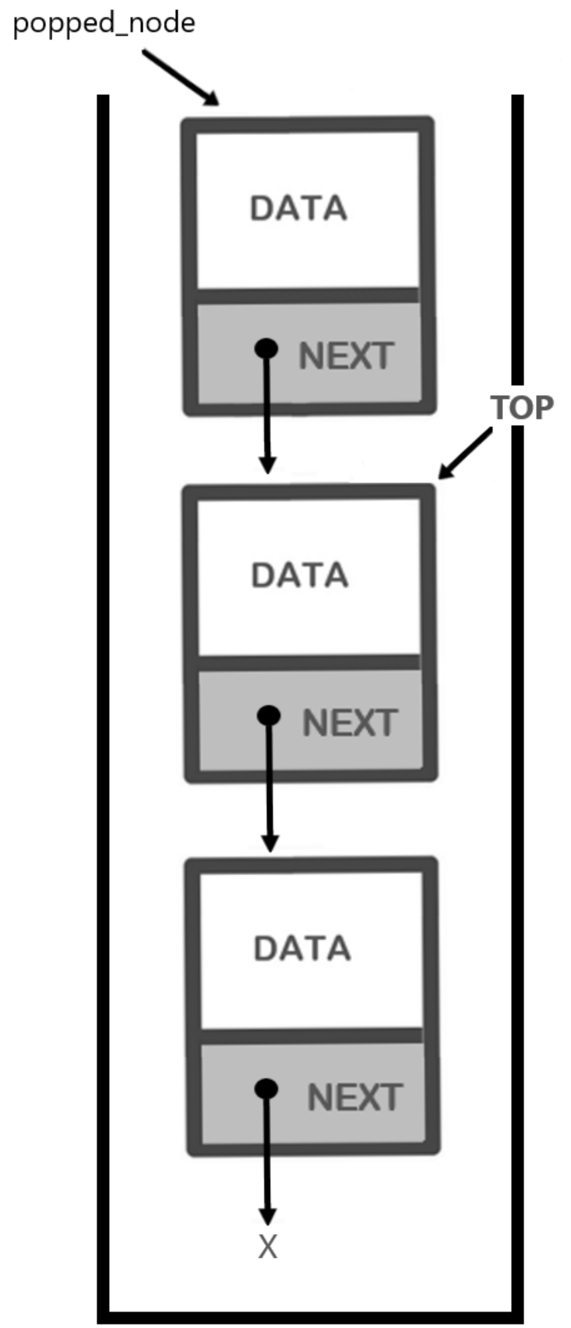
Stacks - pop

```
def pop(self):
  if self.top is None:
    return None
  else:
    popped_node = self.top
```



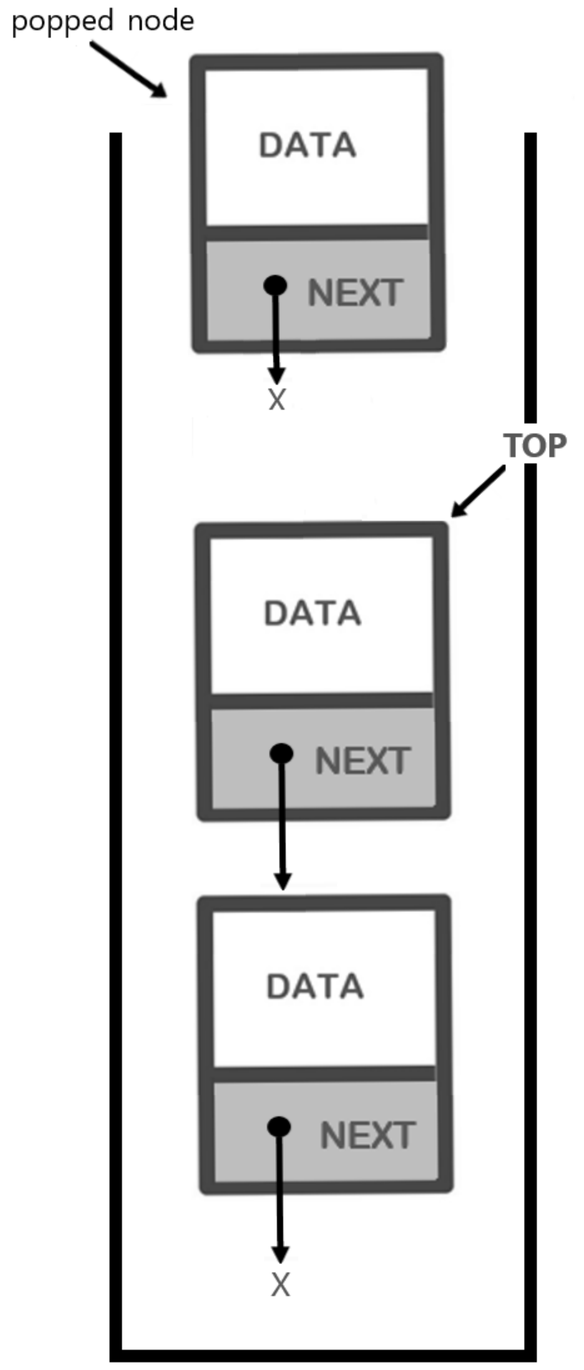
Stacks - pop

```python
def pop(self):
  if self.top is None:
    return None
  else:
    popped_node = self.top
    self.top = self.top.next
```



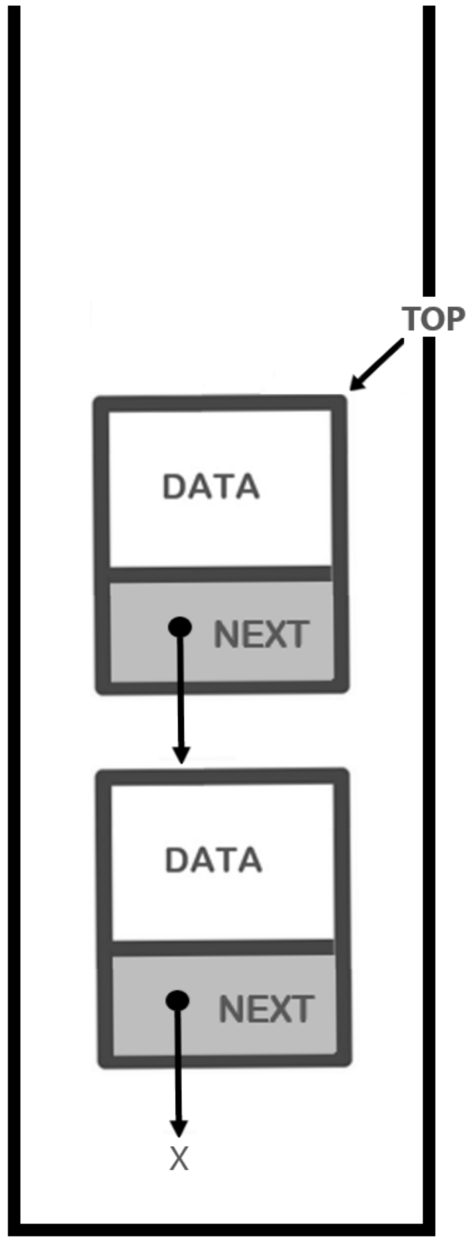
Stacks - pop

```
def pop(self):
  if self.top is None:
    return None
  else:
    popped_node = self.top
    self.top = self.top.next
    popped_node.next = None
```



Stacks - pop

```
def pop(self):
  if self.top is None:
    return None
  else:
    popped_node = self.top
    self.top = self.top.next
    popped_node.next = None
    return popped_node.data
```



Stacks - peek

```
def peek(self):
  if self.top:
    return self.top.data
  else:
    return None
```

LifoQueue in Python

- **LifoQueue:**
  - Python's **queue** module
  - behaves like a stack

```python
import queue

my_book_stack = queue.LifoQueue(maxsize=0)
my_book_stack.put("The misunderstanding")
my_book_stack.put("Persepolis")
my_book_stack.put("1984")

print("The size is: ", my_book_stack.qsize())
```

```
The size is: 3
```

```python
print(my_book_stack.get())
print(my_book_stack.get())
print(my_book_stack.get())
```

```
1984
Persepolis
The misunderstanding
```

```python
print("Empty stack: ", my_book_stack.empty())
```

```
Empty stack: True
```

Let's practice!

DATA STRUCTURES AND ALGORITHMS IN PYTHON