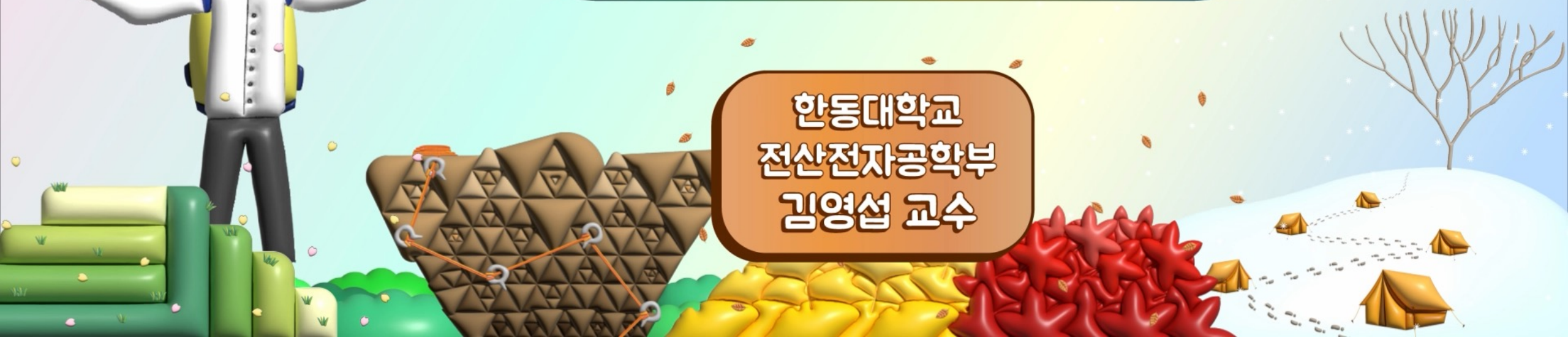


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학습 목표

Deque가 무엇인지 이해하고 직접 구현할 수 있다

Data Structures in Python

Chapter 3 - 2

- Queue
- **Deque**
- Deque Profiling
- Circular Queue

Agenda

- Deque in Python
 - Abstract Data Type
 - Time Complexity: List vs Deque
 - Building Efficient Queues and Stacks

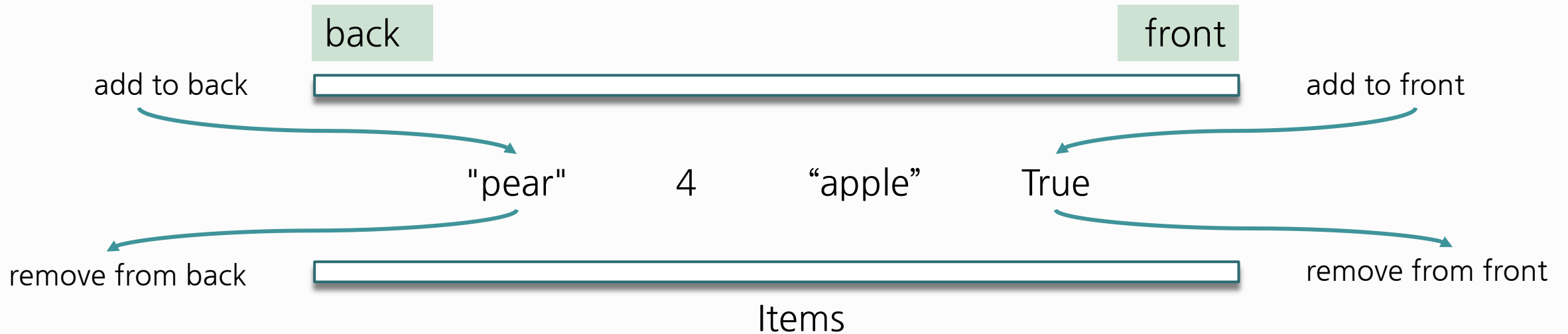
Deque

- **Double Ended Queue (pronounced like 'deck')**
 - A deque is an ordered collection of items where items are added and removed from either end, either front or back(rear).
- The newest item is at one of two ends.
 - It is implemented as a **doubly linked list** internally.

A Deque of Python Data Objects

Deque

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A Deque of Python Data Objects

Deque Time Complexity

- **Double Ended Queue (pronounced like 'deck')**
 - It is specially designed to provide fast and memory-efficient ways to append and pop item from both ends of the underlying data structure.
 - It is useful for implementing elegant, efficient, and Pythonic queues and stacks,

Operation	deque	list
Pop and append items on the left end	$O(1)$	$O(n)$
Pop and append items on the right end	$O(1)$	$O(1)$ + reallocation
Insert and delete items in the middle	$O(n)$	$O(n)$
Access arbitrary items through indexing	$O(n)$	$O(1)$

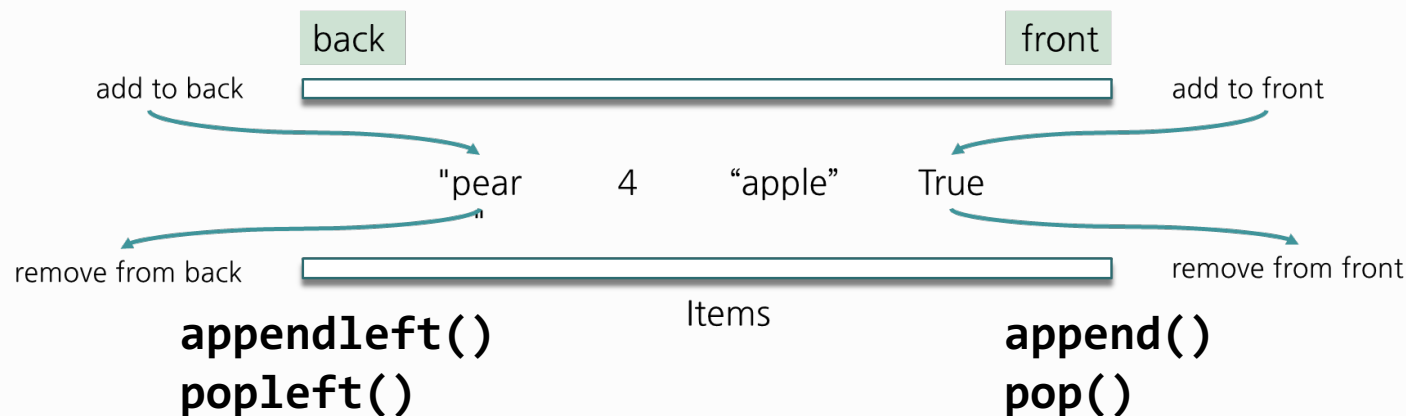
a doubly linked list

an array

Time Complexity of Python Deque Implementation

Deque ADT

- Create an empty deque:
- Determine whether a deque is empty:
- Add a new item to the deque:
 - **append()** - adds a new item to the right end (front) of the deque.
 - **appendleft()** - adds a new item to the left end (rear, back) of the deque.
- Remove a new item from the deque:
 - **pop()** - remove an argument from the right end of the deque.
 - **popleft()** - remove an argument from the left end of the deque.
- **count()** - counts the number of occurrences of the value passed by an argument.
- **insert(i, a)** - inserts the value mentioned in arguments(a) at index(i) specified in arguments.



Deque - Implementing using Python list

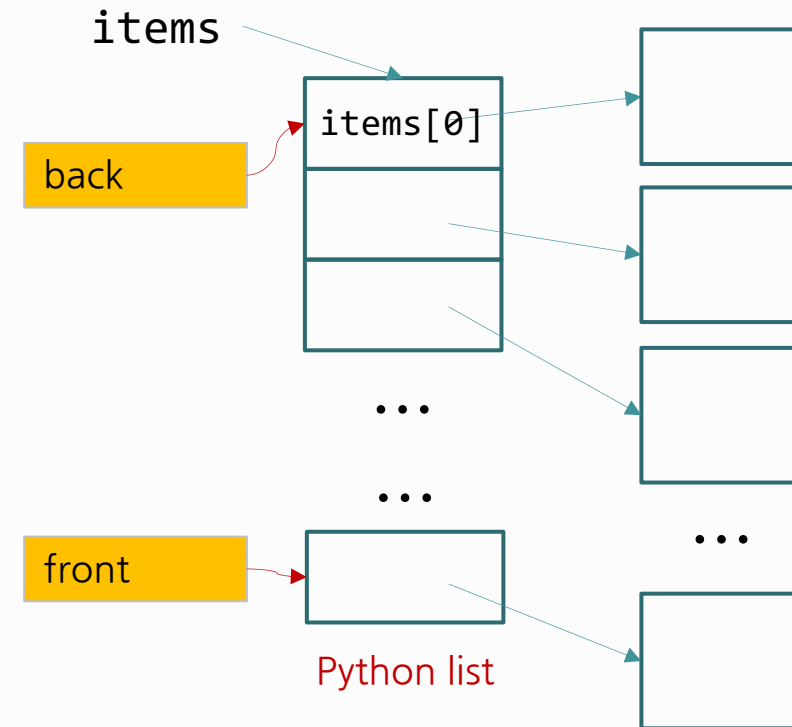
- If we use Python **list** class to implement the **deque**, ...

```
class Deque:
    def __init__(self):
        self.items = []
    ...
    def append(self, item):
        self.items.append(item)

    def appendleft(self, item):
        self.items.insert(0, item)

    def pop(self):
        return self.items.pop()

    def popleft(self):
        return self.items.pop(0)
```



Big-O?

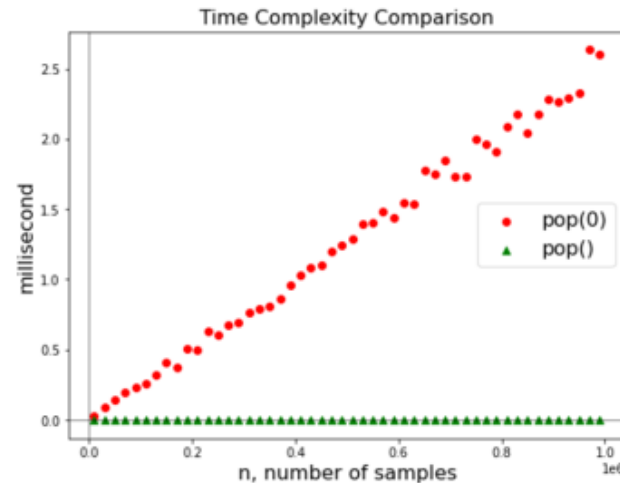
- `append()/pop()`: $O(1)$
- `appendleft()/popleft()`: $O(n)$

Deque - Implementing using Python list

- If we use Python **list** class to implement the **deque**, ...

1 Performance of Python Lists - Pop() vs Pop(0)

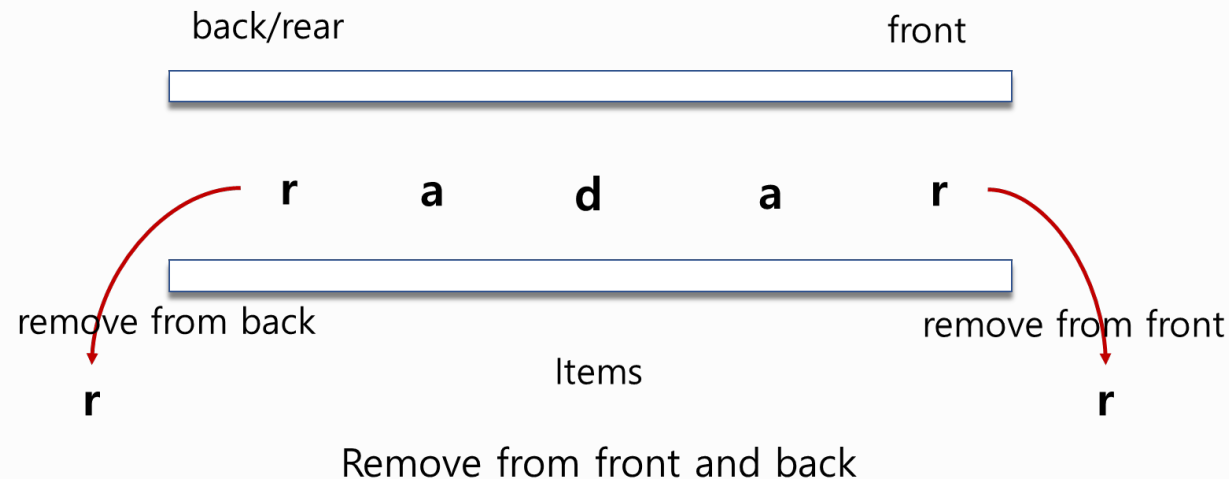
- From the results of our experiment:
 - As the list gets longer and longer the time it takes to pop(0) also increases
 - the time for pop stays very flat.
 - pop(0): Big-O is $O(n)$
 - pop(): Big-O is $O(1)$
 - Why?



Operation	deque	list
Pop and append items on the left end	$O(1)$	$O(n)$
Pop and append items on the right end	$O(1)$	$O(1)$ + reallocation

Deque - Palindrome Checker

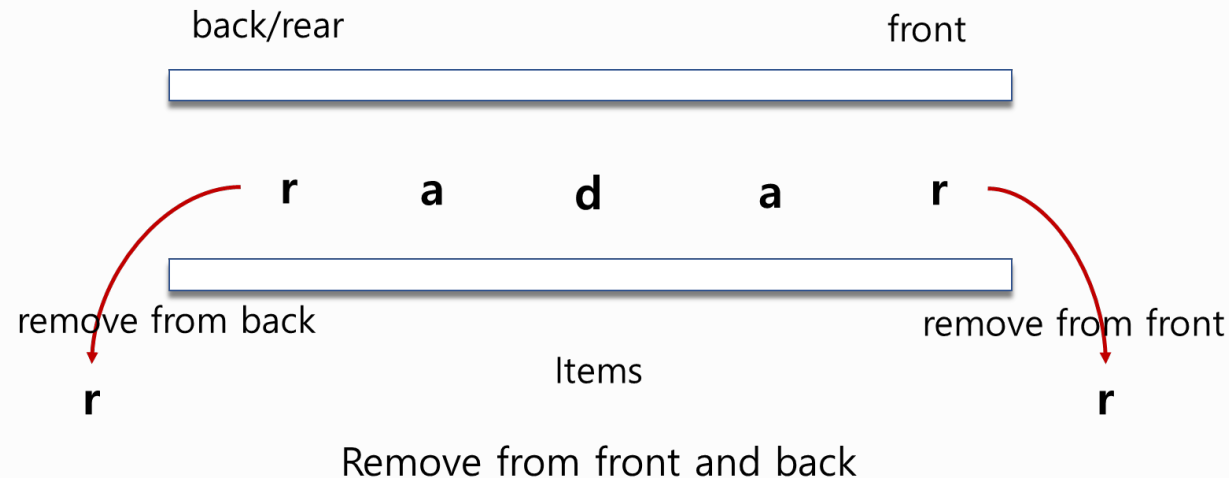
- A string which reads the same either left to right, or right to left is known as a palindrome.
 - Radar
 - deed
 - a dog, a plan, a canal:pagoda



Deque - Palindrome Checker

Algorithm:

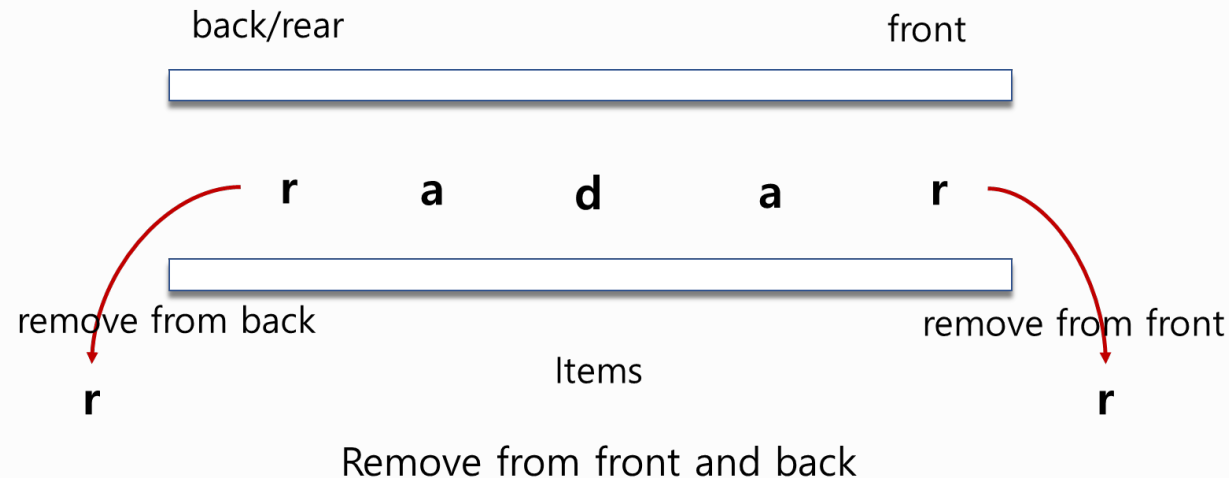
- Create a **deque** to store the characters of the string.
 - The front of the deque will hold the first character of the string and the back of the deque will hold the last character.
- Remove both of them directly, we can compare them and continue only if they match.
 - If we can keep matching first and the last items, we will eventually either run out of characters or be left with a deque of size 1.
 - In either case, the string must be a palindrome



Deque - Palindrome Checker

Examples:

- `print(pal_checker("hello world"))`
 - Queue: h, e, l, l, o, w, o, r, l, d
 - 1st round: compare h and d => FALSE, STOP
- `print(pal_checker("radar"))`
 - Queue: r, a, d, a, r
 - 1st round: compare r (front) and r (back)
 - 2nd round: compare a (front) and a (back)
 - 3rd round: `size() = 1`, STOP, return TRUE



Deque - Palindrome Checker

Coding:

- Check:

- The front of the deque (the first character of the string)
- The back of the deque (the last character of the string)

```
still_equal = True
while char_deque.size() > 1 and still_equal:
    first = char_deque.pop()
    last = char_deque.popleft()
    if first != last:
        still_equal = False
return still_equal
```

- It would be **a good coding exercise** if you rewrite the code such that it accepts the following list of words as palindromes.
 - Radar
 - deed
 - a dog, a plan, a canal:pagoda

Deque - maxlen

- Specify the maximum length of a given deque using the **maxlen** argument when you're instantiating the class.
 - If you supply a value to **maxlen**, then your deque will only store up to maxlen items.
 - In this case, you have a **bounded deque**.
 - Once a bounded deque is full of the specified number of items, adding a new item at either end automatically removes and discards the item at the opposite end:
- Having the option to restrict the maximum number of items allows you to use deques for tracking the latest elements in a given sequence of objects or events. For example, you can
 - **track the last five transactions** in a bank account,
 - **the last ten** open text files in an editor,
 - **the last five pages** in a browser, and more.

Deque - maxlen example

- In this example, pages keeps a list of the last three sites your application visited.
- Once pages is full, adding a new site to an end of the deque automatically discards the site at the opposite end.
- This behavior keeps your list **up to date with the last three sites** you used.

```
from collections import deque

sites = ("google.com", "yahoo.com", "bing.com")
pages = deque(maxlen=3)
print(pages.maxlen)           # 3
for site in sites:
    pages.appendleft(site)

print(pages)                   # deque(['bing.com', 'yahoo.com', 'google.com'], maxlen=3)
pages.appendleft("handong.edu")
print(pages)                   # deque(['handong.edu', 'bing.com', 'yahoo.com'], maxlen=3)
pages.appendleft("mit.edu")
print(pages)                   # deque(['mit.edu', 'handong.edu', 'bing.com'], maxlen=3)
```


Deque - Exercise

- Define **DequeQue** class using deque such that the test code works as shown:

```
if __name__ == '__main__':  
    numbers = DequeQue()          # DequeQue([])  
    print(numbers)  
    for number in range(1, 5):  
        numbers.enqueue(number)  
    print(len(numbers))          # 4  
    print(2 in numbers)          # True  
    print(10 in numbers)         # False  
    numbers.dequeue()  
    print(numbers)               # Queue([2, 3, 4])  
    print('Numbers:', end = ' ')  
    for number in numbers:  
        print(f"{number}", end = ' ')
```

```
PS C:\GitHub\DSpyx\jupyter> python dequeQue.py  
DequeQue([])  
4  
True  
False  
DequeQue([2, 3, 4])  
Numbers: 2 3 4  
PS C:\GitHub\DSpyx\jupyter> 
```

Deque - Exercise Hints

- Read about deque in Python document
 - Define a **DequeQue** class in a file called **dequeQue.py** :

```
#!/usr/bin/env python
from collections import deque

class DequeQue:
    def __init__(self):
        self.items = deque()
        ...

    ...

    ...
    def __iter__(self):
        yield from self.items

if __name__ == '__main__':
    numbers = DequeQue()          # DequeQue([])
    ...
```

Summary

- The **deque (double ended queue)** in Python was designed to guarantee efficient **append and pop** operations on either end of the sequence in $O(1)$.
- The **deque** in Python is ideal for implementing **queue and stack** data structures.
- Now, you may decide when to use **deque** instead of **list**.

학습 정리

- 1) Deque(Double-ended queue)는 Stack과 Queue의 장점들을 활용한 자료 구조이다
- 2) Deque의 메소드에는 `appendleft()`, `popleft()` 등이 있다
- 3) Deque는 `stack`, `queue`와 다르게 `maxlen`을 사용하여 자동으로 요소의 수를 제한할 수 있다

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