(Ch 24) Modules for Data Structure

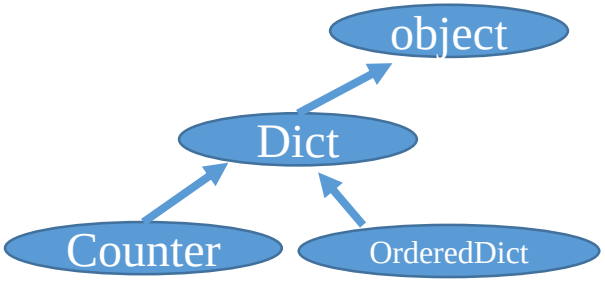
- collections
- array
- queue
- heapq
- bisect

“collections” Module

Object들의 저장소를 보다 더 다양하고 편하게 제공하고자!

- The **collections** module implements specialized container data types
  - providing alternatives to the built-in types **list**, **dict**, **set,** and **tuple**

- **Counter class**
  - **Subclass of “Dict” class**
  - **Counting hashable objects**



- **deque function**
  - list-like container with fast appends and pops on either end
  - a generalization of stacks and queues (the name is pronounced “deck” and is short for “double-ended queue”)
- **OrderedDict class**
  - just like regular dictionaries but they remember the order that items were inserted.

- ChainMap class,, UserDict class, UserList class etc…

“collections” Module – Counter Class [1/2]

- A **Counter** class is a dictionary-like container that tracks how many times equivalent values are added

```
>>> import collections
>>> c = collections.Counter(['eggs', 'ham', 'ham', 'soy'])
>>> print (c['eggs'])
1
>>> print (c['ham'])
2
```

```
>>> print(c)
Counter({'ham': 2, 'eggs': 1, 'soy': 1})
```

Unless using collections module!

```
>>> c = {}
>>> def addCounter(obj):
        if obj not in c:
                c[obj] = 1
        else:
                c[obj] += 1


>>> addCounter('eggs')
>>> addCounter('ham')
>>> addCounter('ham')
>>> addCounter('soy')
>>> print (c['eggs'])
1
>>> print (c['ham'])
2
```

"collections" Module – Counter Class [2/2]

- Counter constructors

```
# a new, empty counter
>>> import collections
>>> c = collections.Counter()
>>> print(c)
Counter()
>>>
```

```
# a new counter from an iterable
>>> c = collections.Counter('gallahad')
>>> print(c)
Counter({'a': 3, 'l': 2, 'h': 1, 'd': 1, 'g': 1})
>>>
```

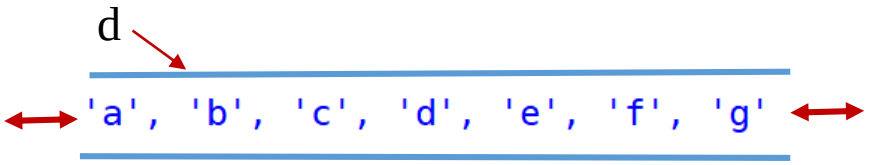
```
# a new counter from a mapping
>>> c = collections.Counter({'red': 4,  'blue': 2 })
>>> print(c)
Counter({'red': 4, 'blue': 2})
>>>
```

```
# a new counter from keyword args
>>> c = collections.Counter(cats = 4, dogs = 8)
>>> print(c)
Counter({'dogs': 8, 'cats': 4})
>>>
```

Functions on deque object [1/3]

- **deque** function returns a list-like object initialized left-to-right
  - supports adding and removing elements from either end
- The more commonly used stacks and queues are forms of **deque**, where the inputs and outputs are restricted to a single end

```
import collections
d = collections.deque('abcdefg')
print ('Deque:', d)
print ('Length:', len(d))
print ('Left end:', d[0])
print ('Right end:', d[-1])

d.remove('c')                   # remove element 'c'
print ('remove(c):', d)

d.append('h')                   # append 'h' at right
print ('append(h):', d)

d.appendleft('X')               # append 'X' at left
print ('appendleft(X):', d)
```



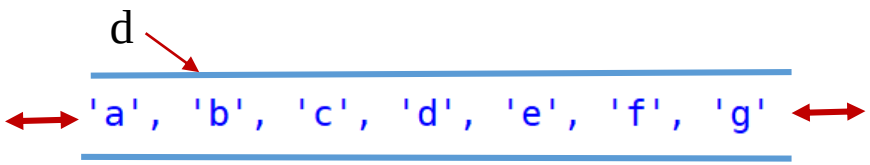
dequeue 양쪽끝에서 element를 insert or delete할수 있고, dequeue의 중간에서 element를 중간에서 remove 가능하다!

Result

```
Deque: deque(['a', 'b', 'c', 'd', 'e', 'f', 'g'])
Length: 7
Left end: a
Right end: g
remove(c): deque(['a', 'b', 'd', 'e', 'f', 'g'])
append(h): deque(['a', 'b', 'd', 'e', 'f', 'g', 'h'])
appendleft(X): deque(['X', 'a', 'b', 'd', 'e', 'f', 'g', 'h'])
```

Functions on deque object [2/3]

```
import collections
d = collections.deque('abcdefg')
print ('Deque:', d)
print ('Length:', len(d))
print ('Left end:', d[0])
print ('Right end:', d[-1])

print (d.pop())      # pop rightmost element
print (d)

print (d.popleft()) # pop leftmost element
print (d)
```



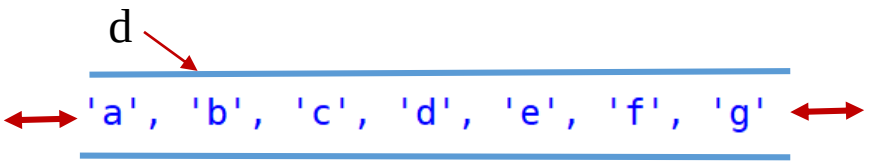
Result

```
Deque: deque(['a', 'b', 'c', 'd', 'e', 'f', 'g'])
Length: 7
Left end: a
Right end: g
g
deque(['a', 'b', 'c', 'd', 'e', 'f'])
a
deque(['b', 'c', 'd', 'e', 'f'])
```

Functions on deque object [3/3]

```
import collections
d = collections.deque('abcdefg')
print ('Deque:', d)
print ('Length:', len(d))
print ('Left end:', d[0])
print ('Right end:', d[-1])

d.rotate(2)     # rotate elements to right
print (d)

d.rotate(-2)    # rotate elements to left
print (d)
```

Rotating it in either direction



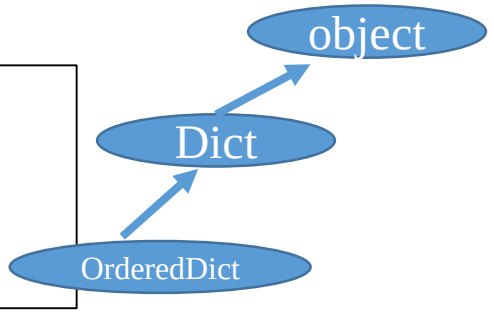
Result

```
Deque: deque(['a', 'b', 'c', 'd', 'e', 'f', 'g'])
Length: 7
Left end: a
Right end: g
deque(['f', 'g', 'a', 'b', 'c', 'd', 'e'])
deque(['a', 'b', 'c', 'd', 'e', 'f', 'g'])
```

OrderedDict Class]1/2]

- A regular **dictionary** does not tract the order of key:value pairs, and iterating over it produces the values in an arbitrary order

```
>>> from collections import OrderedDict
>>> # regular unsorted dictionary
>>> d = {'abc': 3, 'a': 4, 'b': 1, 'cd': 2}
>>> d
{'abc': 3, 'a': 4, 'b': 1, 'cd': 2}
```




```
>>> d.items( )
dict_items([('abc', 3), ('a', 4), ('b', 1), ('cd', 2)])

>>> OrderedDict(d)
OrderedDict([('abc', 3), ('a', 4), ('b', 1), ('cd', 2)])

>>>  OrderedDict(d.items( ))
OrderedDict([('abc', 3), ('a', 4), ('b', 1), ('cd', 2)])
```

OrderedDict Class]2/2]

- Sometimes we want to process the items in the disctionary with a certain order
- We want to give a rule how the items of the orderedDict object should be **ordered**

```
>>> from collections import OrderedDict
>>> # regular unsorted dictionary
>>> d = {'abc': 3, 'a': 4, 'b': 1, 'cd': 2}
>>> d
{'abc': 3, 'a': 4, 'b': 1, 'cd': 2}
```

```
>>> d.items( )
dict_items([('abc', 3), ('a', 4), ('b', 1), ('cd', 2)])
```

t

```
>>> OrderedDict(sorted(d.items( )))
OrderedDict([('a', 4), ('abc', 3), ('b', 1), ('cd', 2)])
```

sorted( ) 로 complex object 들을 sort할때 object들의 index를 key 로 이용할수 있다.

d.items( ) 에서 dictionary items 들이 key:value pair 이므로
t[0] 는 key , t[1]은 value

```
>>>
>>> # dictionary sorted by key
>>> OrderedDict(sorted(d.items(), key=lambda t: t[0]))
OrderedDict([('a', 4), ('abc', 3), ('b', 1), ('cd', 2)])
```

```
>>> # dictionary sorted by value
>>> OrderedDict(sorted(d.items(), key=lambda t: t[1]))
OrderedDict([('b', 1), ('cd', 2), ('abc', 3), ('a', 4)])
```

(Ch 22) Data Structure 관련 Modules

- collections
- array
- queue
- heapq
- bisect

"array" Module

Python의 List기반 2D Array와 3D Array보다 more efficient하게!!

- Purpose : Making array of fixed-type numerical data efficiently
- 1D Array, 2D Array, 3D Array are all emulated with Python List

- For large amounts of data, an **array** may make more efficient use of memory than a **list**

- Since the **array** is limited to a single data type, it can use a more compact memory representation than a general purpose **list**

- Uses the library of C array
  - Needs to define type before using
  - Faster than Python List
    - But if you **really need speed**, consider using pure C

- Python list data type은 다른종류의 item들을 keep할수 있다
  - ["SNU", 59, [10, 20]]

Initialization of Array Object: array( )

typecode : ‘u’ for string, ‘i’ for integer

```
import array

s = 'This is the array.'
a = array.array('u', s)

print ('As string:', s)
print ('As array :', a)
```

Result

```
As string: This is the array.
As array : array('u', 'This is the array.')
```

```
from array import array

# Create an int array of three elements.
a = array('i', [10, 20, 30])

# Display elements in array.
for value in a:
    print (value)
```

Result

```
10
20
30
```

Type code	C Type	Python Type
'b'	signed char	int
'B'	unsigned char	int
'u'	Py_UNICODE	Unicode character
'h'	signed short	int
'H'	unsigned short	int
'i'	signed int	int
'I'	unsigned int	int
'l'	signed long	int
'L'	unsigned long	int
'q'	signed long long	int
'Q'	unsigned long long	int
'f'	float	float
'd'	double	float

Itemize Attribute on Array Object [1/7]

- array.**itemsize** : the length in bytes of one array item in the internal representation

```
import array

s = 'This is the array.'
a = array.array('u', s)

print (a)

b = a.itemsize

print ('size is ', b)
```

a

2 bytes로 표현된다

```
>>> print(a[0])
T
```

Result

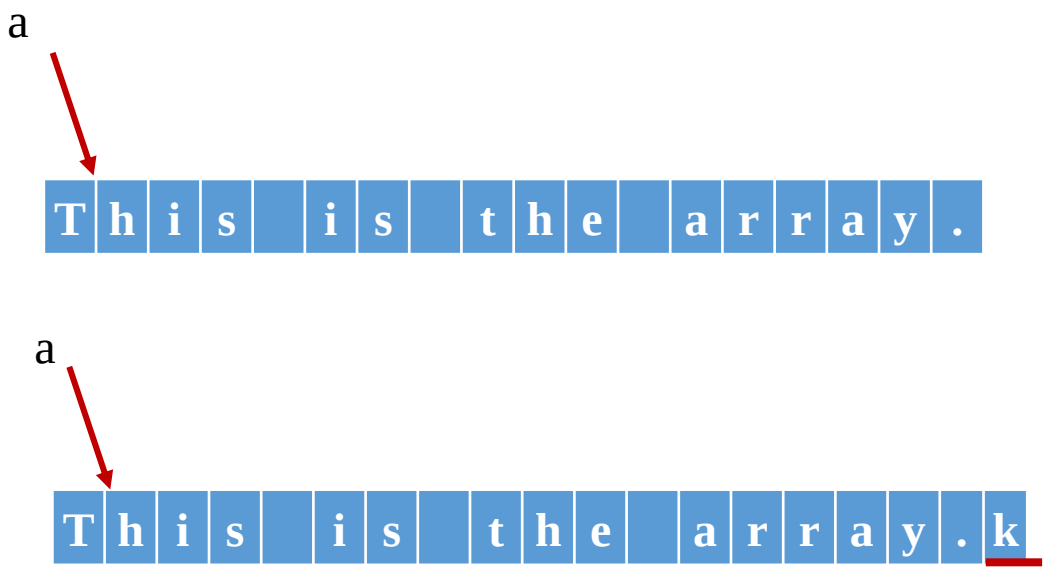
```
array('u', 'This is the array.')
size is  2
```

One array item의 size

append( ) on Array Object [2/7]

- array.**append**(x) : Append new item x to the end of the array (only unicode)

```
import array

s1 = 'This is the array.'
a = array.array('u', s1)

print (a)

a.append('k')

print ('New array:  ', a )
```



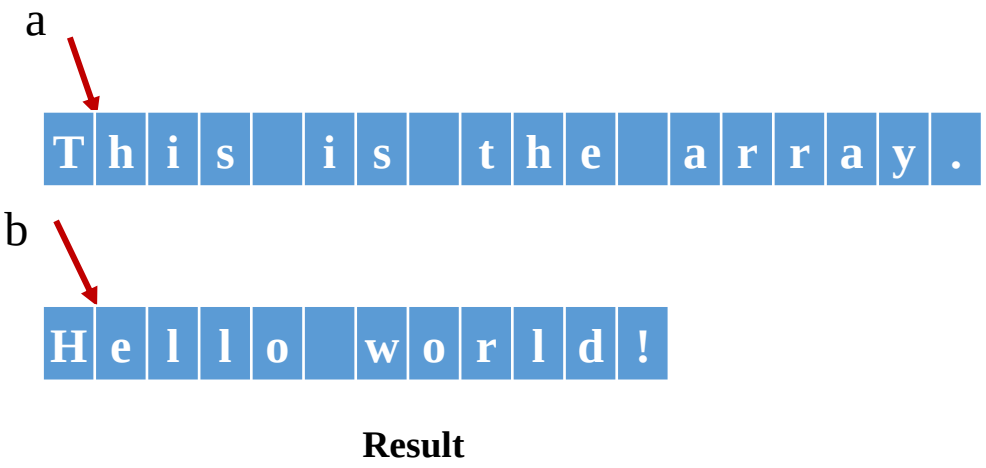
Result

```
array('u', 'This is the array.')
New array: array('u', 'This is the array.k')
```

extend( ) on Array Object [3/7]

- array.**extend( )** : append items from an iterable to the end of the array
- If an iterable is another array, it must have exactly the same type

```
import array

s1 = 'This is the array.'
s2 = 'Hello world!'

a = array.array('u', s1)
b = array.array('u', s2)

print (a)
print (b)

a.extend(b)

print ('extend : ', a)
```



Result

```
array('u', 'This is the array.')
array('u', 'Hello world!')
extend :  array('u', 'This is the array.Hello world!')
```

count( ) on Array Object [4/7]

- array.**count( )** : Return the number of occurrences of x in the array

```
import array

s1 = 'This is the array. Apple'
a = array.array('u', s1)

icount = a.count('i')
Acount = a.count('A')

print ('We have ', icount, ' i in s1')
print ('We have ', Acount, ' A in s1')
```

a

Result

```
We have  2  i in s1
We have  1  A in s1
```

remove( ) on Array Object [5/7]

- array.**remove**(x) : Remove the first occurrence of x from the array

```
import array

s1 = 'This is the array. haha'
a = array.array('u', s1)

print ('Original array : ', a)

a.remove('h')

print ('New array : ', a)
```

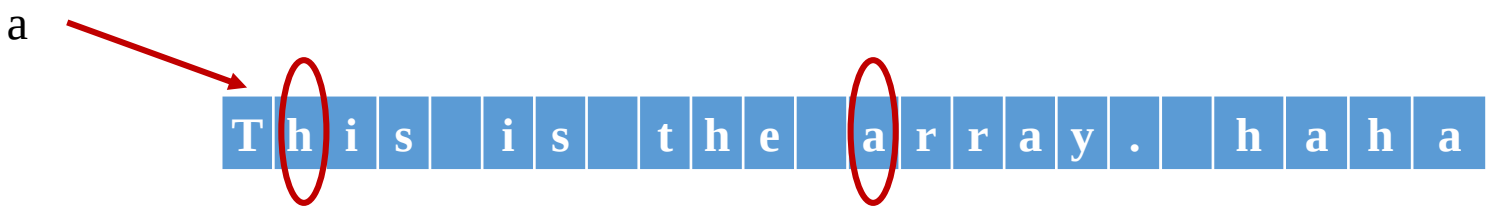
Result

```
Original array :  array('u', 'This is the array. haha')
New array :  array('u', 'Tis is the array. haha')
```

index( ) on Array Object [6/7]

- array.**index(x)** : Return the smallest i such that i is the index of the first occurrence of x in the array

```
import array

s1 = 'This is the array. haha'
a = array.array('u', s1)

print ('Array : ', a)

print (a.index('h'))
print (a.index('a'))
```



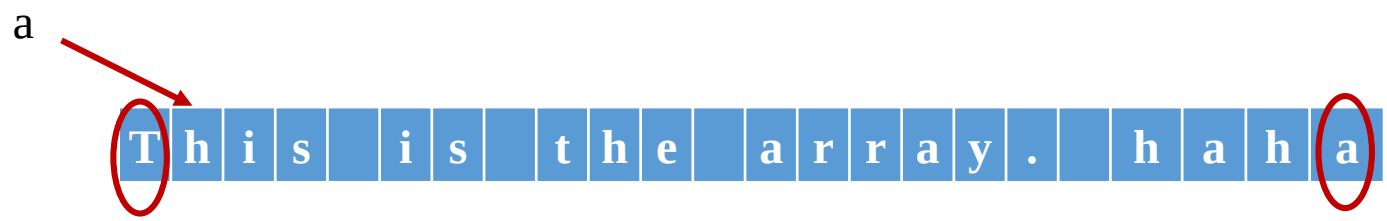
Result

```
Array :  array('u', 'This is the array. haha')
1
12
```

insert( ) on Array Object [7/7]

- array.**insert**(i, x) : insert a new item with value x in the array before position i. Negative values are treated as being relative to the end of the array

```
import array

s1 = 'This is the array. haha'
a = array.array('u', s1)

print ('Array : ', a)

a.insert(0, 'W')
print (a)

a.insert(-1, 'X')
print (a)
```



Result

```
Array :  array('u', 'This is the array. haha')
array('u', 'WThis is the array. haha')
array('u', 'WThis is the array. hahXa')
```

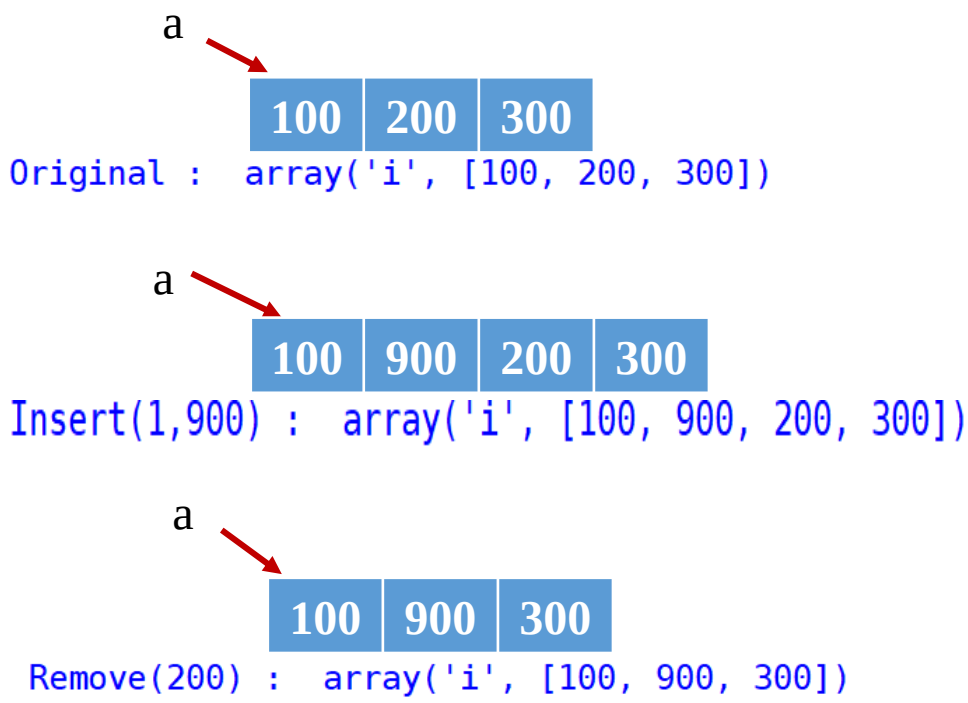
Application of Array Object

Note:

We create an empty int array in the first part. The second argument to the array init method is optional.

Python program that uses append, insert, remove, count

```
from array import array

# New int array.
a = array('i')

# Append three integers.
a.append(100)
a.append(200)
a.append(300)
print('Original : ', a)

# Insert an integer at index 1.
a.insert(1, 900)
print('Insert(1,900) : ', a)

# Remove this element.
a.remove(200)
print('Remove(200) : ', a)

# Count elements with this value.
a.count(900)
```



(Ch 22) Data Structure 관련 Modules

- collections
- array
- queue
- heapq
- bisect

“queue” Python Standard Library

List, Set, Dict같은것으로 Queue를 지원하는것은 불편하고, 세가지 대표 queue종류을 한번에 지원!!

- The queue module provides a safe implementation of FIFO structure
  - Queue class implemented all the required locking semantics

- There are 3 types of Queue, which differ in the order of the entities retrieved
  - FIFO queue ➔ Queue Class
  - LIFO queue (Works like a stack) ➔ LifoQueue Class
  - Priority queue ➔ PriorityQueue Class

```
import queue

a = queue.Queue(5)
b = queue.LifoQueue(5)
c = queue.PriorityQueue(5)

print("Successfully created 3 queues")
```

Result

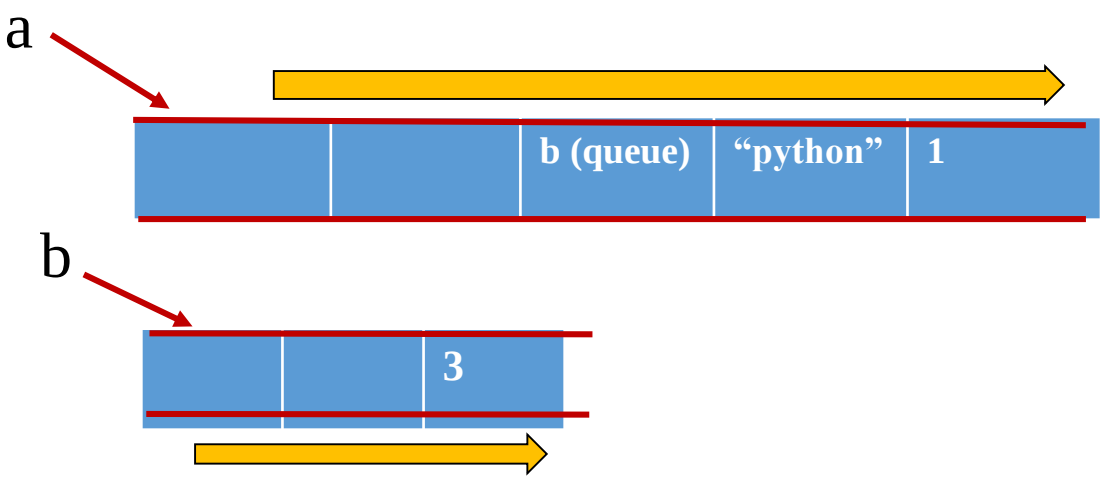
```
>>>
Successfully created 3 queues
```

"queue" Module: Queue Class for Queue [1/2]

- queue.**Queue**(x) : Construct a FIFO queue of size 'x'
- queue.**Queue**() : Construct a FIFO queue of infinite size
- queue.**put**(x) : Put item into the queue. Item can be anything
- queue.**get**(x) : Delete the item and return that item

```
import queue

a = queue.Queue(5)
b = queue.Queue(3)

a.put(1)
a.put("python")
a.put(b)

b.put(3)

print(a.get())
print(a.get())
print(a.get().get())
```

Return the queue 'b'



Result

```
>>>
1
python
3
```

"queue" Module: Queue Class for Queue [2/2]

- queue.**qsize()** : Return the number of items in the queue
- queue.**empty()** : Return True if the queue is empty, False otherwise
- queue.**full()** : Return True if the queue is full, False otherwise

```
import queue

a = queue.Queue(3)
b = queue.Queue()

a.put(1)
a.put(2)
a.put(3)
```

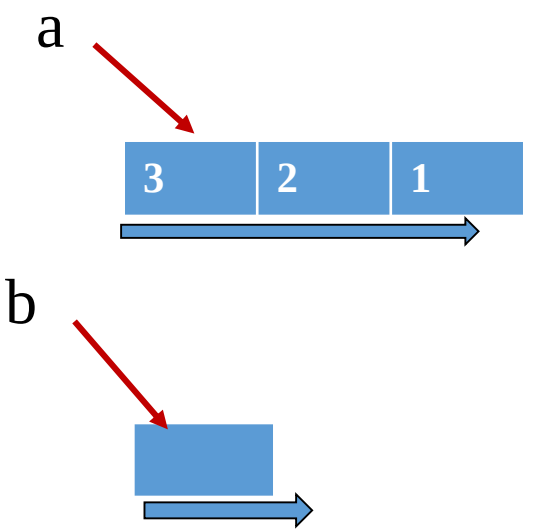
```
print("qsize : ")
print(a.qsize())
print(b.qsize())
print()
```

```
print("Empty?")
print(a.empty())
print(b.empty())
print()
```

```
print("Full?")
print(a.full())
print(b.full())
print()
```

Result

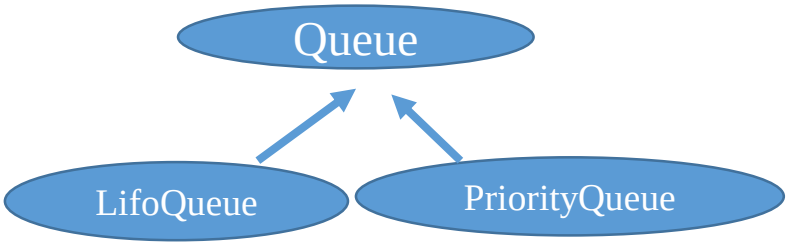
```
>>>
qsize :
3
0

Empty?
False
True

Full?
True
False
```

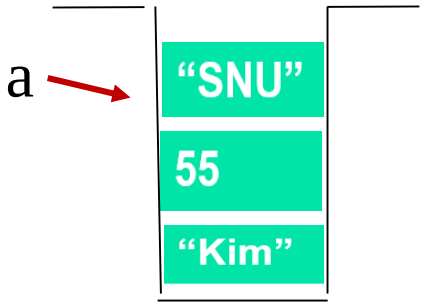


"queue" Module: LiFoQueue Class for Stack

- Subclass of Queue class
- put(x), get(x), qsize(), empty(), full() are all similar with that of Queue class

```
>>> import queue
>>> a = queue.LifoQueue(3)
>>> a.put("Kim")
>>> a.put(55)
>>> a.put("SNU")
>>> a.qsize()
3
>>> a.get()
'SNU'
>>> a.qsize()
2
```

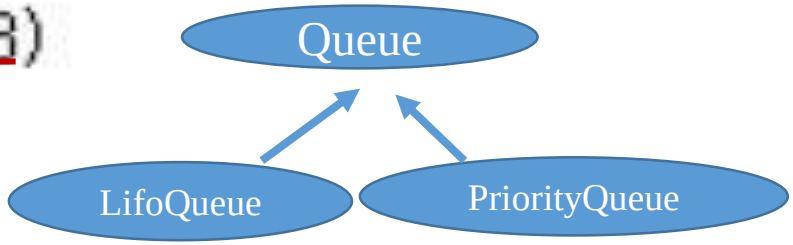


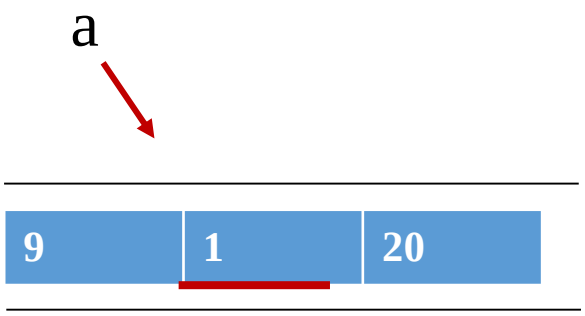


“queue” Module : PriorityQueue Class

- A subclass of Queue class, retrieves entries in priority order (lowest first)
- put(x), get(x), qsize(), empty(), full() are all similar with that of Queue class

```
>>> import queue
>>> a = queue.PriorityQueue(3)
>>> a.put(20)
>>> a.put(1)
>>> a.put(9)
>>> a.qsize()
3
>>> a.get()
1
>>> a.qsize()
2
```





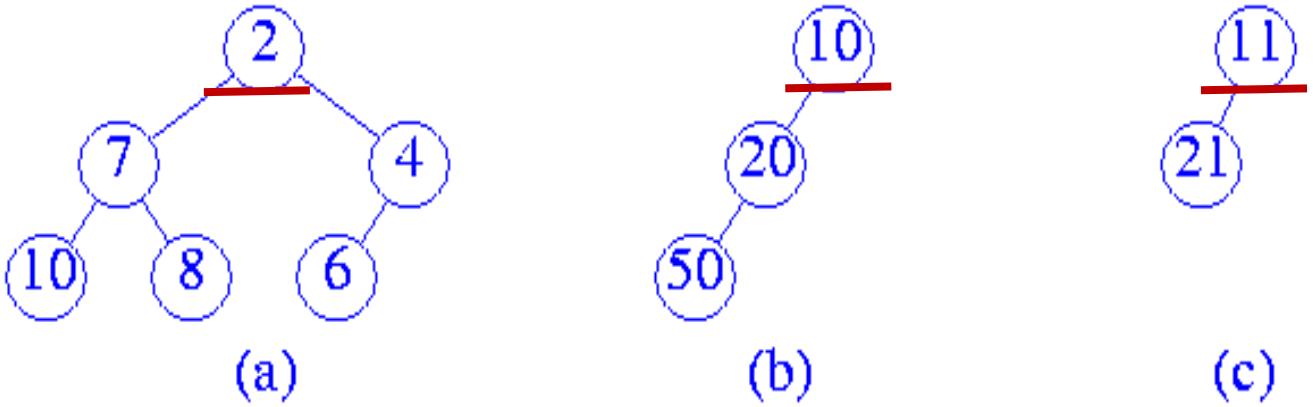
(Ch 22) Data Structure 관련 Modules

- collections
- array
- queue
- heapq
- bisect

“heapq” Module

- **heapq** module provides an implementation of the **heap queue** algorithm, also known as the priority queue algorithm
  - Class는 없고, Heap 관련 function들을 지원

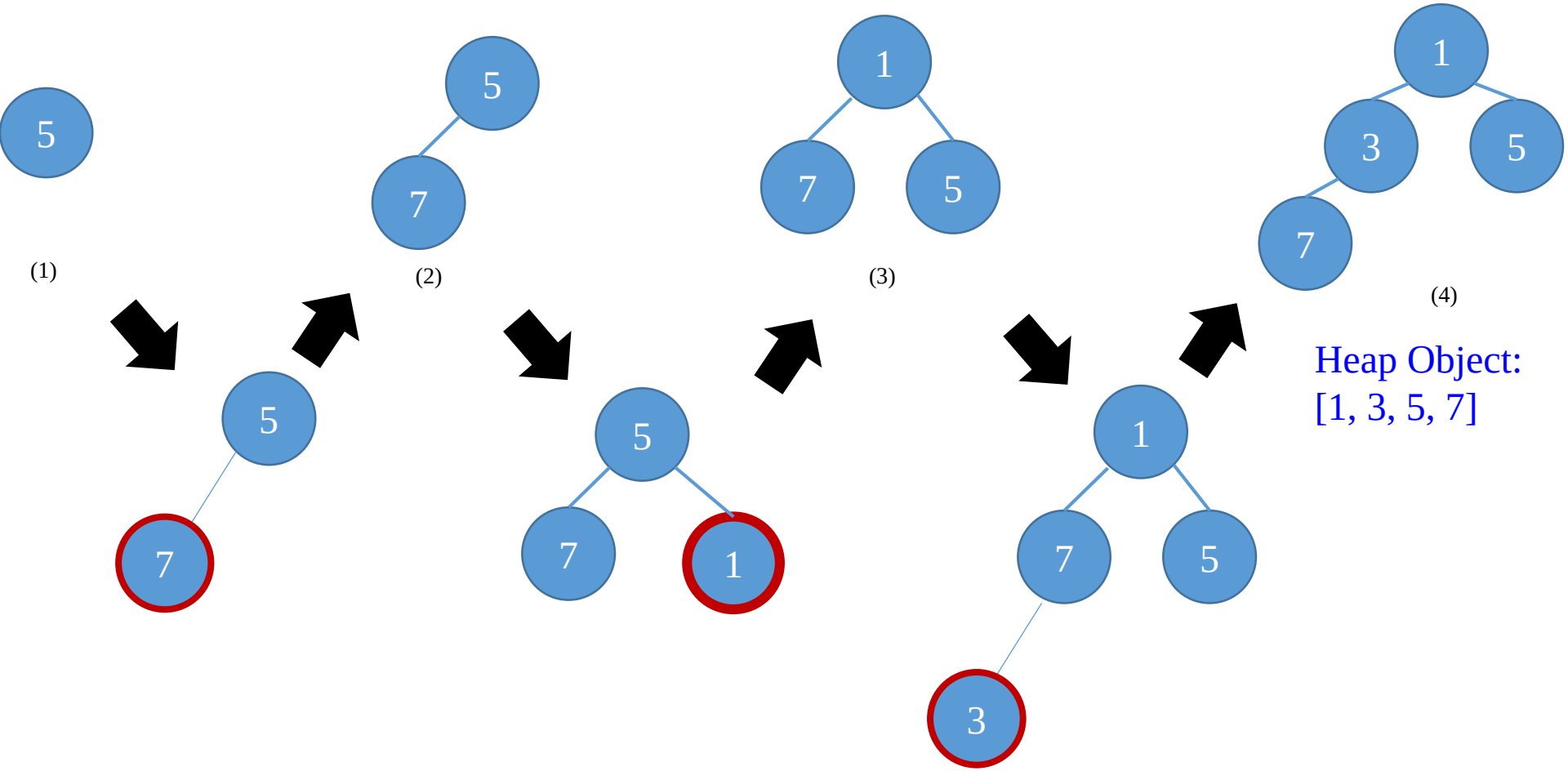
- **Heaps** are **complete binary trees** for which every parent node has a value less than or equal to any of its children
  - Sometimes called, Min Heap or Priority Queue
  - smallest element is always the root, heap[0]



- Heap Object 는 complete binary tree 이므로 list로 표현이 충분하다!

Constructing Heap

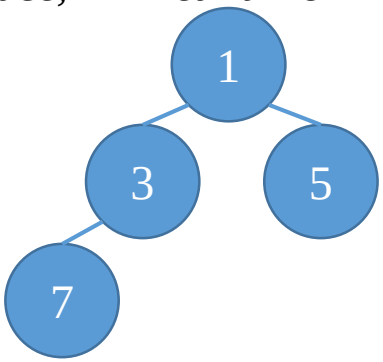
- Suppose the data is arrived in the following sequence [5, 7, 1, 3]



Functions on heapq Module [1/5]

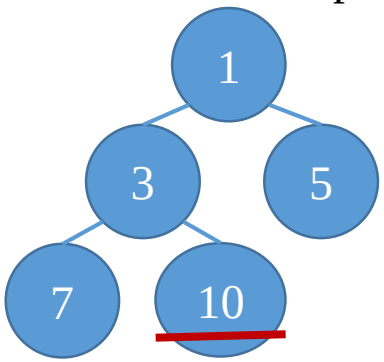
- heapq.**heapify**(*x*): transform list x into a heap, in-place, in linear time

```
>>> from heapq import *
>>> qdata = [5, 7, 1, 3]
>>> heapify(qdata)
>>> qdata
[1, 3, 5, 7]
```



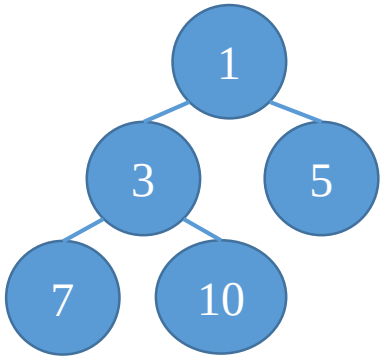
- heapq.**heappush**(*heap*, *item*): push the value item onto the heap

```
>>> heappush(qdata, 10)
>>> qdata
[1, 3, 5, 7,10]
```



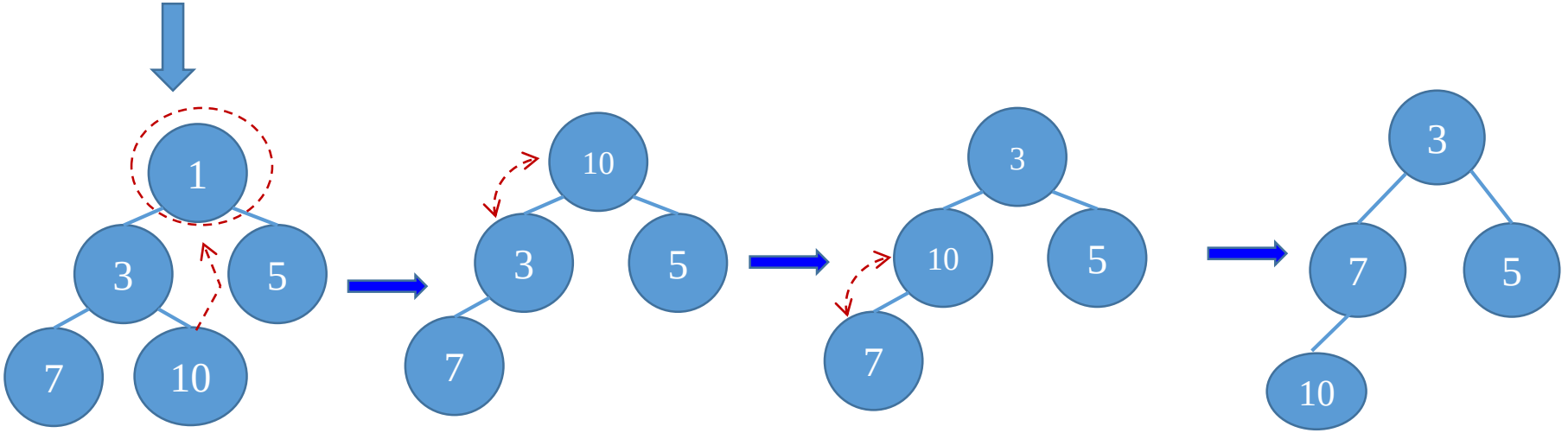
Functions on heapq Module [2/5]

- heapq.**heappop**(*heap*): pop and return the smallest item from the heap




```
>>> from heapq import *
>>> heappop(qdata)
>>> qdata
[3, 7, 5, 10]
```

qdata = [1, 3, 5, 7, 10]



qdata = [3, 7, 5, 10]

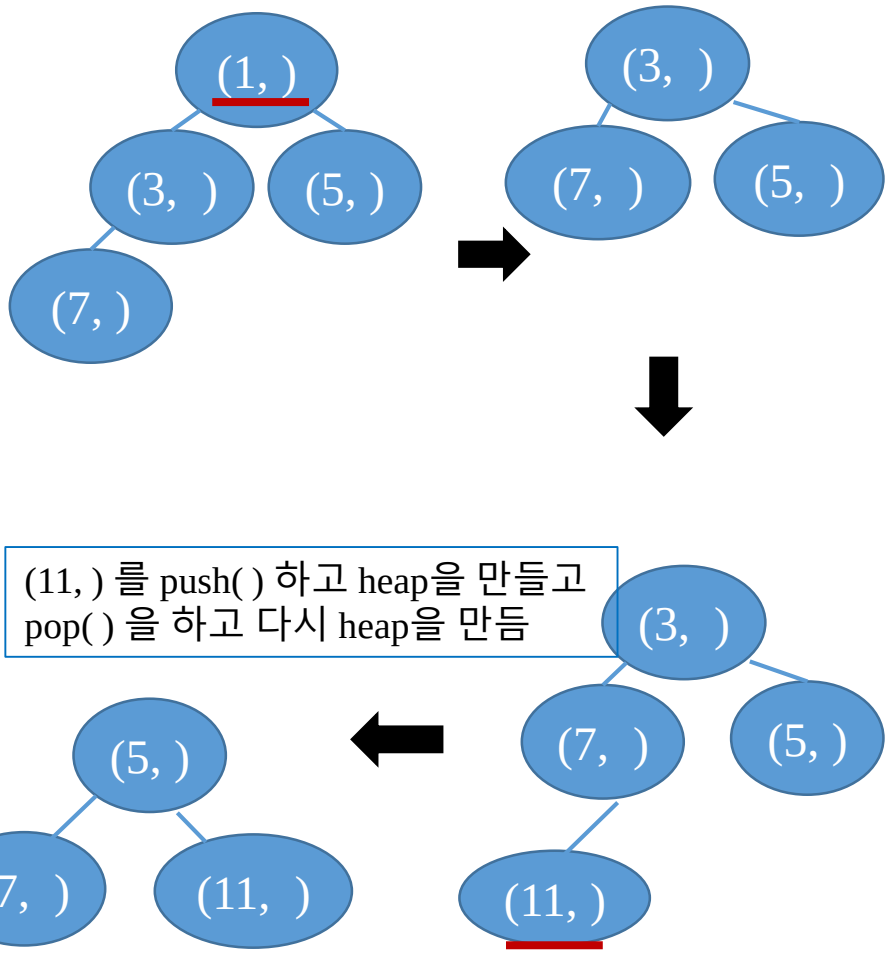
Functions on heapq Module [3/5]

- heapq.**heappushpop**(*heap*, *item*): push item on the heap, then pop and return the smallest item from the heap.

source

```
from heapq import *

h = []
heappush(h, (5, 'write code'))
heappush(h, (7, 'release product'))
heappush(h, (1, 'write sepc'))
heappush(h, (3, 'create tests'))

print(heappop(h))
print(heappushpop(h, (11, 'push pop')))

print(h)
```

Uses Python's Default List



result

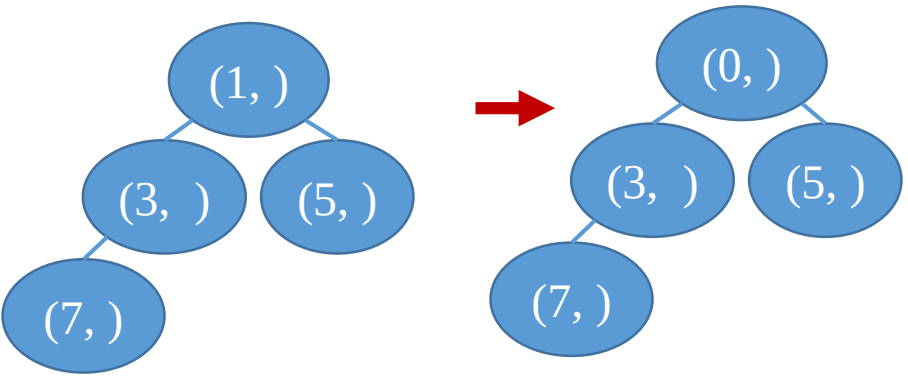
```
(1, 'write sepc')
(3, 'create tests')
[(5, 'write code'), (7, 'release product'), (11, 'push pop')]
```

Functions on heapq Module [4/5]

- heapq.**heapreplace**(*heap, item*): pop and return the smallest item from the heap, and also push the new item to the heap

```
from heapq import *

h = []
heappush(h, (5, 'write code'))
heappush(h, (7, 'release product'))
heappush(h, (1, 'write sepc'))
heappush(h, (3, 'create tests'))

print(heapreplace(h, (0, 'heap')))
print(h)
```

```
(1, 'write sepc')
[(0, 'heap'), (3, 'create tests'), (5,
'write code'), (7, 'release product')]
```

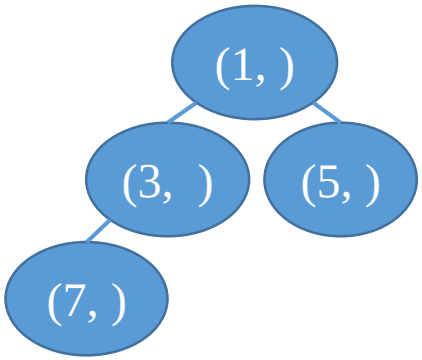


(1,) 를 pop( ) 하고 그자리에 (0,) 를 넣은후에 children들과 비교

Functions on heapq Module [5/5]

- heapq.**nlargest**(*n, iterable, key=None*): return a list with the n largest elements from the dataset defined by *iterable*
- heapq.**nsmallest**(*n, iterable, key=None*): return a list with the n smallest elements from the dataset defined by *iterable*

```
from heapq import *

h = []
heappush(h, (5, 'write code'))
heappush(h, (7, 'release product'))
heappush(h, (1, 'write sepc'))
heappush(h, (3, 'create tests'))

print(nlargest(3, h))
print()
print(nsmallest(3, h))
```




```
[(7, 'release product'), (5, 'write code'), (3, 'create tests')]

[(1, 'write sepc'), (3, 'create tests'), (5, 'write code')]
```

(Ch 22) Data Structure 관련 Modules

- collections
- array
- queue
- heapq
- bisect

“bisect” Module

- The bisect(list_of_breakpoints, point) function is generally useful for categorizing point (numeric data) among the list of breakpoint
  - It uses a basic bisection algorithm to do its work
- For long lists of items with expensive comparison operations, this can be an improvement over the more common approach

```
from bisect import bisect

lst = [10, 20, 30, 40, 50]

print (lst)
print ('20 fits into group #:', bisect(lst, 20))
print ('10 fits into group #:', bisect(lst, 10))
```

bisect( ) returns

50 ~ +∞ :	➔	5
40 ~ 49 :	➔	4
30 ~ 39 :	➔	3
20 ~ 29 :	➔	2
10 ~ 19 :	➔	1
-∞ ~ 9 :	➔	0

```
[10, 20, 30, 40, 50]
20 fits into group #: 2
10 fits into group #: 1
```

categorizing 20 among lst

bisect( ) [1/4]

- bisect.**bisect**(*a, x, lo=0, hi=len(a)*)
  - The returned insertion point i partitions the array a into two halves so that all **(val <= x for val in a[lo:i])** for the left side and all **(val > x for val in a[i:hi])** for the right side.

```
>>> from bisect import bisect
>>> grades = 'FEDCBA'
>>> breakpoints = [30, 44, 66, 75, 85]
>>> def grade(total):
        return grades[bisect(breakpoints, total)]

>>> grade(66)
'C'
>>> grade_map = map(grade, [33, 99, 77, 44, 12, 88])
>>> grade_map # in Python 3.X, map object is not visible
<map object at 0x03F29FF0>
>>> list(grade_map) # Wrap with list() to see inside
['E', 'A', 'B', 'D', 'F', 'A']
```

grades = “FEDCBA”

grades[0] ➔ F
grades[1] ➔ E
grades[2] ➔ D
grades[3] ➔ C
grades[4] ➔ B
grades[5] ➔ A

bisect( ) returns

80 ~ +∞ :	➔	5	(A)
75 ~ 84 :	➔	4	(B)
66 ~ 74 :	➔	3	(C)
44 ~ 65 :	➔	2	(D)
30 ~ 43 :	➔	1	(E)
-∞ ~ 29 :	➔	0	(F)

bisect_left( ) [2/4]

- bisect.**bisect_left**(*a*, *x*, *lo=0*, *hi=len(a)*)
  - Locate the insertion point for *x* in *a* to maintain sorted order
  - The returned insertion point *i* partitions the array a into two halves so that **all (val < x for val in a[*lo*:*i*])** for the left side and **all (val >= x for val in a[*i*:*hi*])** for the right side

```
from bisect import bisect_left, bisect

lst = [10, 20, 30, 40, 50]

print (lst)
print ('20 bisect_left group #:', bisect_left(lst, 20))
print ('20 bisect group #:', bisect(lst, 20))
print ('10 bisect_left group #:', bisect_left(lst, 10))
print ('10 bisect group #:', bisect(lst, 10))
```

```
[10, 20, 30, 40, 50]
20 bisect_left group #: 1
20 bisect group #: 2
10 bisect_left group #: 0
10 bisect group #: 1
```

bisect( ) returns

50 ~ +∞ :	➔	5
40 ~ 49 :	➔	4
30 ~ 39 :	➔	3
20 ~ 29 :	➔	2
10 ~ 19 :	➔	1
-∞ ~ 9 :	➔	0

bisect_left( ) returns

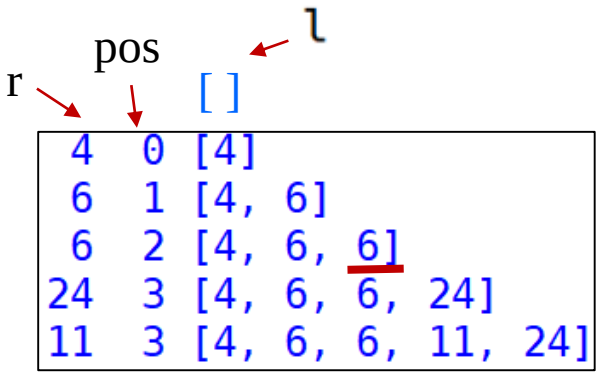
51 ~ +∞ :	➔	5
41 ~ 50 :	➔	4
31 ~ 40 :	➔	3
21 ~ 30 :	➔	2
11 ~ 20 :	➔	1
-∞ ~ 10 :	➔	0

insort( ) [3/4]

- bisect.**insort**(*a, x, lo=0, hi=len(a)*): inserting *x* into *a* after any existing entries of *x*

```
import bisect
import random
random.seed(2)
l = []
for i in range(5):
    r = random.randint(1, 50)
    pos = bisect.bisect(l, r)
    bisect.insort(l, r)
    print ('%2d %2d' % (r, pos), l)
```

In order to get the same result

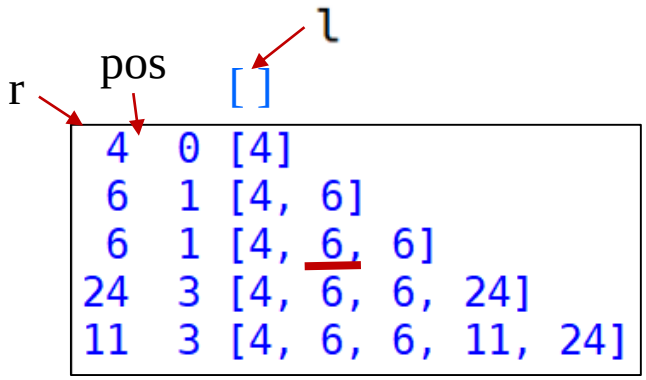


insort([ ], 4) ➔ [4] : based on bisect([ ], 4) is 0
insort([4], 6) ➔ [4, 6] : based on bisect([4], 6) is 1
insort([4, 6], 6) ➔ [4, 6, 6] : based on bisect([4, 6,], 6) is 2
insort([4, 6, 6], 24] ➔ [4, 6, 6, 24] : based on bisect([4, 6, 6], 24) is 3
insort([4, 6, 6, 24], 11) ➔ [4, 6, 6, 11, 24] : based on bisect([4, 6, 6, 24], 11) is 3

insort_left( ) [4/4]

- bisect.**insort_left**(*a, x, lo=0, hi=len(a)*): insert *x* into *a* in sorted order

```
import bisect
import random
random.seed(2)
l = []
for i in range(5):
    r = random.randint(1, 50)
    pos = bisect.bisect_left(l, r)
    bisect.insort_left(l, r)
    print ('%2d %2d' % (r, pos), l)
```



insort_left([ ], 4)	➔ [4]	: based on bisect_left([ ], 4) is 0
insort_left([4], 6)	➔ [4, 6]	: based on bisect_left([4], 6) is 1
insort_left([4, 6], 6)	➔ [4, 6, 6]	: based on bisect_left([4, 6,], 6) is 1
insort_left([4, 6, 6], 24	➔ [4, 6, 6, 24]	: based on bisect_left([4, 6, 6], 24) is 3
insort_left([4, 6, 6, 24], 11)	➔ [4, 6, 6, 11, 24]	: based on bisect_left([4, 6, 6, 24], 11) is 3