Chapter 2: Arrays

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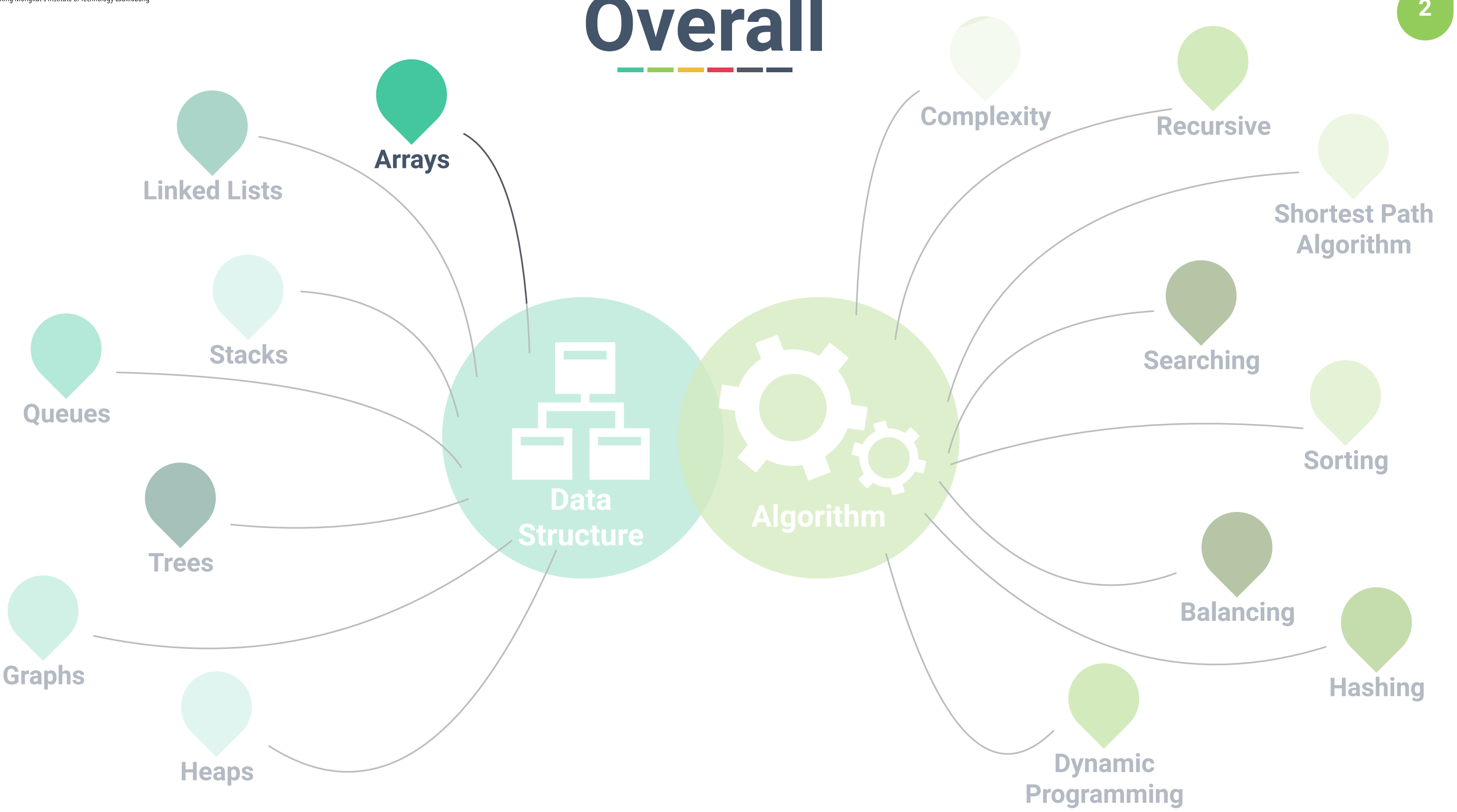
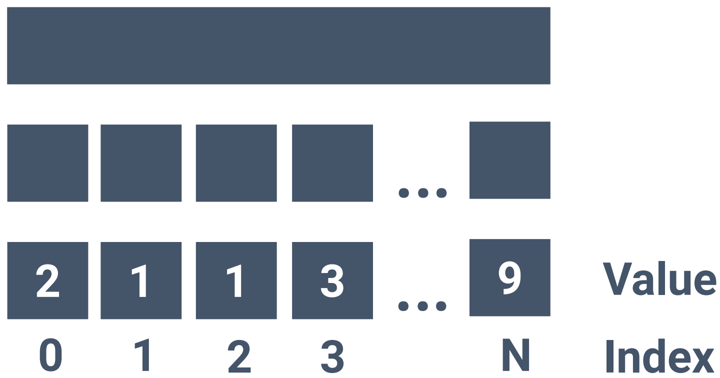
Overall



Arrays



An array is a chunk of memory, consisting of equal-size elements.
Each of those elements have an integer index, which uniquely refers to the value stored. The values are all of the same type (integer, character, etc.).

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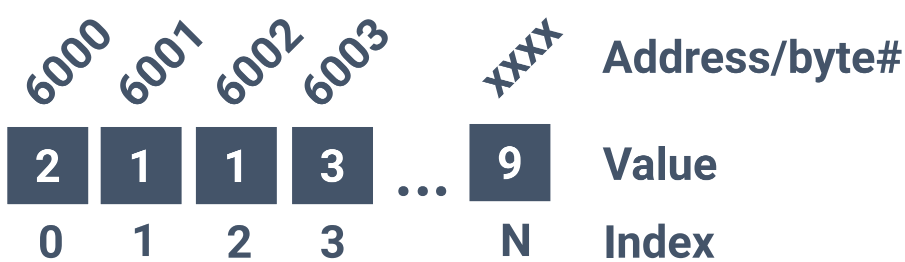
Physical Level Arrays



- A computer will have a large number of bytes of memory.
- It has a memory address to keep track of where a data is stored.
- Each byte has a unique number as its address.
- Although the number is sequential, any byte/element in a RAM can be accessed to read or write with a constant time O(1).

Array of Characters

6000 6001	6002 6003	6004 6005	**Address/byte#**
C	**A**	**R**	**Value**
0	**1**	**2**	**Index**

- In Python, it represents a unicode character with 16 bits (i.e. 2 bytes).
- Each element/cell in array is index with an integer starting with 0, 1, 2, and so on.
- Since each cell has an equal-size bytes, any element can be accessed constantly with this formula:
    - start_address + elem_size * index

Exercise

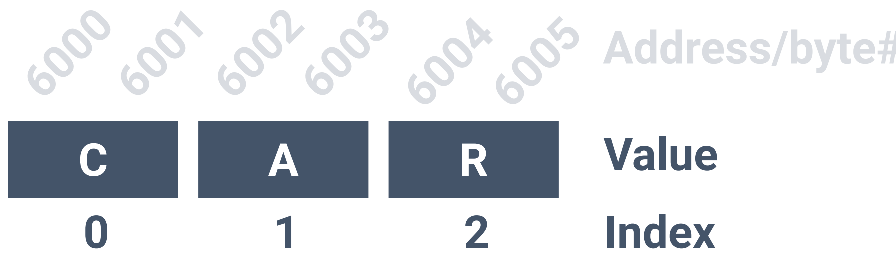
Given an array:

Start Address is 6000,
element size is 8,

What is the address of the element at index 6?

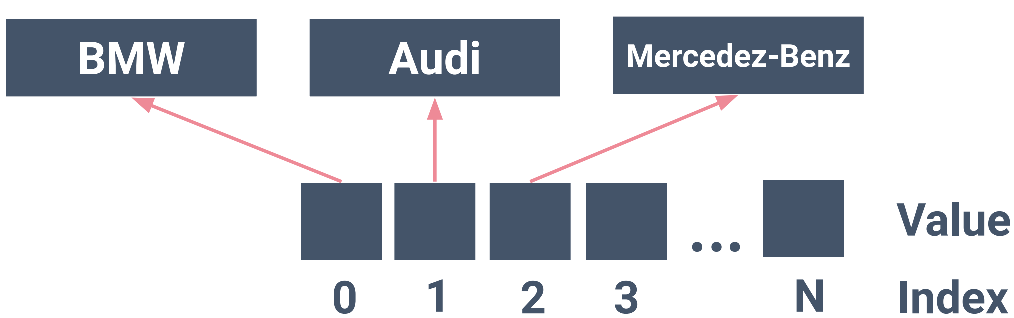
- start_address + elem_size * index

Array of Characters



- Luckily, a programming language calculate memory addresses of an array automatically, so we can focus on values and indexes.

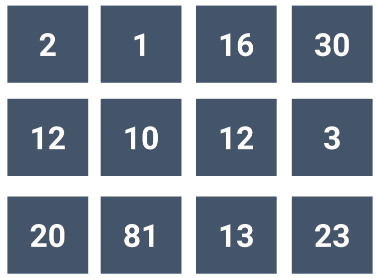
Python List



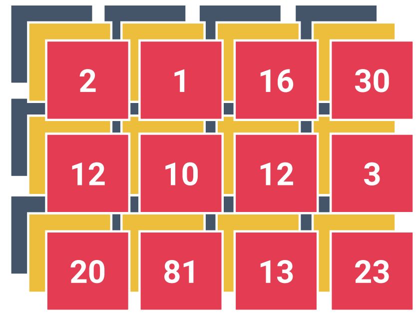
- Python list is a referential-type array that stores the memory addresses (references) of a value instead of the value itself.
- Strings can be in any length, but memory addresses are fixed-size.

Arrays

(a) One dimension

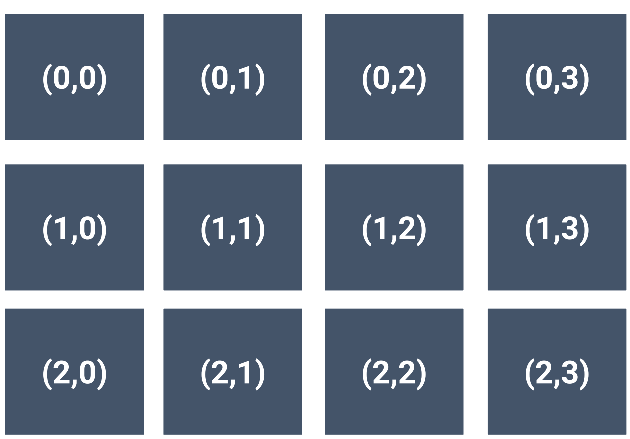


(b) Two dimensions



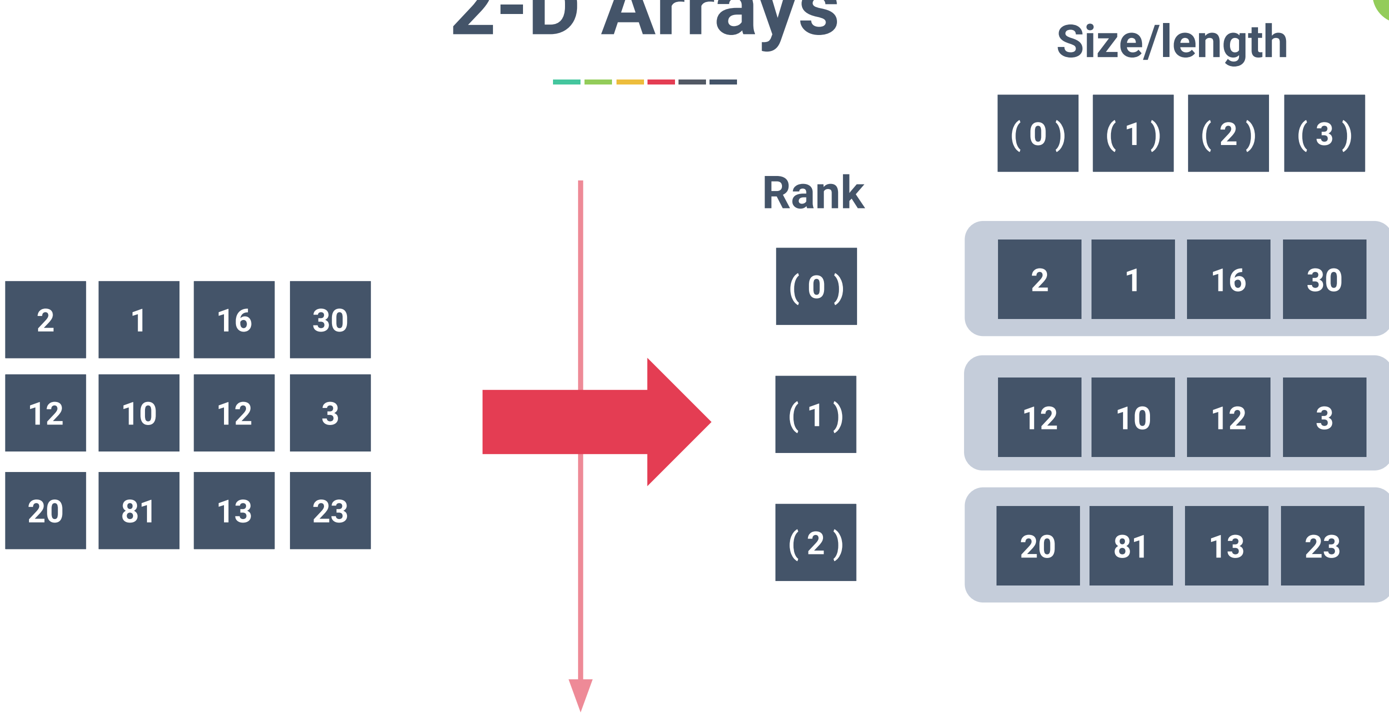
(c) Three dimensions

2-Dimensional Arrays



2-Dimensional Arrays

2-D Arrays



(a) Two dimensions

(b) Nested-one dimension

Example

Python Code: 2-D Arrays

```
c = np.array([['h','e','l','l','o'],['w','o','r','l','d']])
```

Rank					
	6000 6001	6002 6003	6004 6005	6006 6007	6008 6009
(0)	h	e	l	l	o
	(0,0)	(0,1)	(0,2)	(0,3)	(0,4)
	6010 6011	6012 6013	6014 6015	6016 6017	6018 6019
(1)	w	o	r	l	d
	(1,0)	(1,1)	(1,2)	(1,3)	(1,4)

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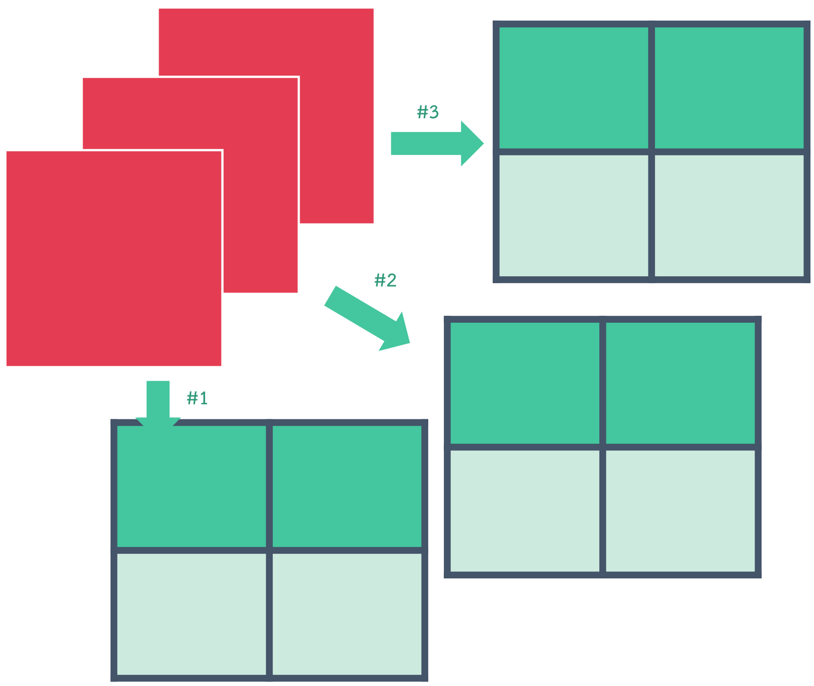
Exercise

Suppose start address is 6000, find the address of index (1,4)

- start_address + elem_size * index
- Where index = (rank * array_length) + target_index

3-D Arrays

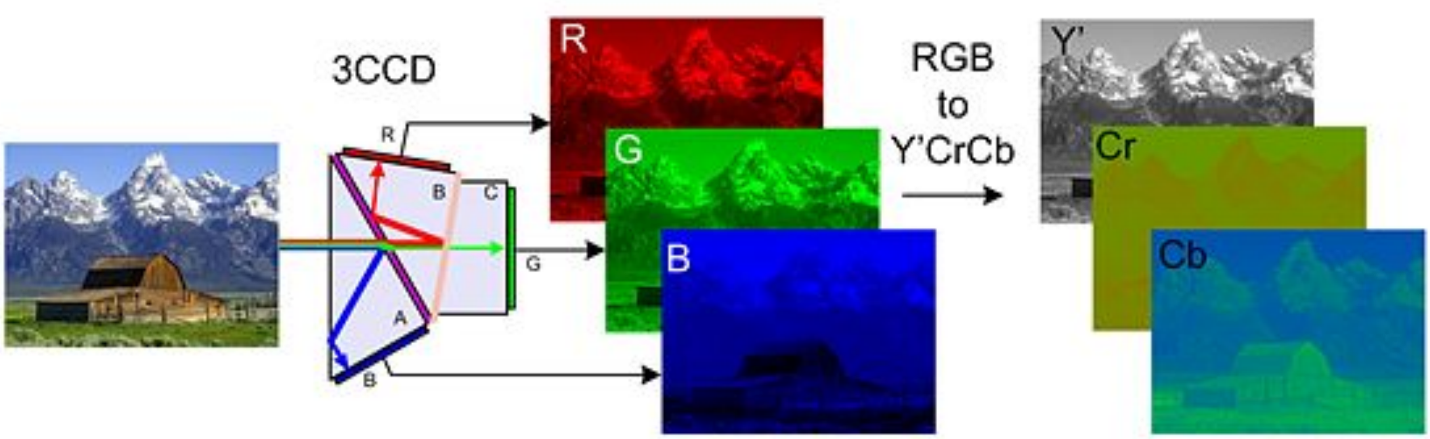


Python Code: 3-D Arrays

```
e = np.array([
[[1,2,3],[4,5,6]],
[[7,8,9],[10,11,12]],
[[13,14,15],[16,17,18]]])
```

Dimension
#1
#2
#3

3-D Arrays



Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning				
End				
Between				

Data								
	10	5	8	7	1			

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Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning				
End	data.append(val)	$O(1)$		
Between				

Data								
	10	5	8	7	1	20		

Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning				
End	data.append(val)	$O(1)$	data.pop()	$O(1)$
Between				

Data								
	10	5	8	7	1			

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Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning			data.pop(0) Del data[0]	$O(n)$
End	data.append(val)	$O(1)$	data.pop()	$O(1)$
Between				

Data								
		5	8	7	1			

Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning			data.pop(0) Del data[0]	*O*(n)
End	data.append(val)	*O*(1)	data.pop()	*O*(1)
Between				

Data								
	5	8	7	1				

Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning	data.insert(0, val)	*O*(n)	data.pop(0) Del data[0]	*O*(n)
End	data.append(val)	*O*(1)	data.pop()	*O*(1)
Between				

Data								
	9	5	8	7	1			

Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning	data.insert(0, val)	*O*(n)	data.pop(0) Del data[0]	*O*(n)
End	data.append(val)	*O*(1)	data.pop()	*O*(1)
Between			data.remove(val)	*O*(n)

Data								
	9	5		7	1			

Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning	data.insert(0, val)	*O*(n)	data.pop(0) Del data[0]	*O*(n)
End	data.append(val)	*O*(1)	data.pop()	*O*(1)
Between			data.remove(val)	*O*(n)

Data								
	9	5	7	1				

Asymptotic Performance

	Add Operation	Running Time	Remove Operation	Running Time
Beginning	data.insert(0, val)	*O*(n)	data.pop(0) Del data[0]	*O*(n)
End	data.append(val)	*O*(1)	data.pop()	*O*(1)
Between	data.insert(index, val)	*O*(n)	data.remove(val)	*O*(n)

Data	9	0	5	7	1			

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Asymptotic Performance

Operation	Running Time
len(data)	*O*(1)
data[i]	*O*(1)
Data[i] = val	*O*(1)
c * data	*O*(n)
data.reverse()	*O*(n)
data.sort()	*O*(n log n)

Searching in Array

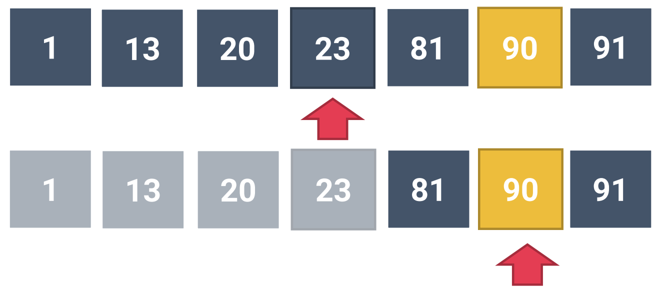
Sequence

1. Search (element by element)

Binary

1. Sort

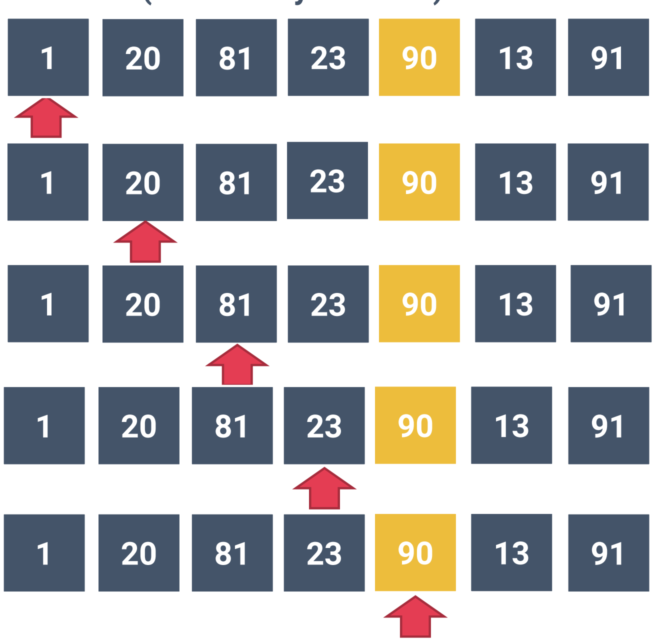
2. Search



Searching in Array

Sequence

1. Search (element by element)



Pseudocode: Sequential/linear search

```
linear_search (list, target_value)
  for each item in the list
    if item value == target_value
      return the item's location
    end if
  end for
  return 'no match'
END
```

Binary Search

- Binary Search
  - Locate a target value in a sequence of *n* elements that are sorted.
  - mid = (low + high) / 2
  - Initially, low = 0, high = n-1
- For instance, find number 5.

Data	1	5	7	9	10	11	20
Index	0	1	2	3	4	5	6

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Binary Search

- Binary Search
  - If target value < data[mid], next interval is from low to mid-1.
  - If target value > data[mid], next interval is from mid + 1 to high.

	low			mid			high	
Data	1	5	7	9	10	11	20	mid = (0 + 6) / 2 = 3
Index	0	1	2	3	4	5	6	

	low	mid	high					
Data	1	5	7	9	10	11	20	mid = (0 + 2) / 2 = 1
Index	0	1	2	3	4	5	6	