

# DATA STRUCTURES & ALGORITHMS

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Sorting – Quick Sort

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# Algorithm

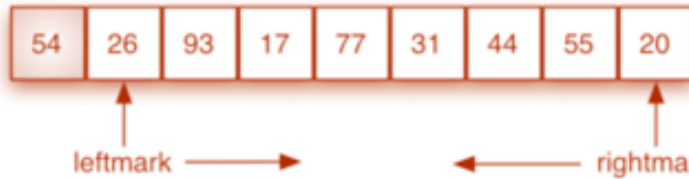
1. Choose the lowest index value as pivot
2. Take two variables to point left and right of the list excluding pivot
3. left points to the low index
4. right points to the high
5. while value at left is less than pivot move right
6. while value at right is greater than pivot move left
7. if both step 5 and step 6 does not match swap left and right Step 8 – if  $\text{left} \geq \text{right}$ , the point where they met is new pivot

1



54 will be the first pivot value

2



leftmark and rightmark will converge on split point

4



now rightmark  $20 < 54$  stop

3



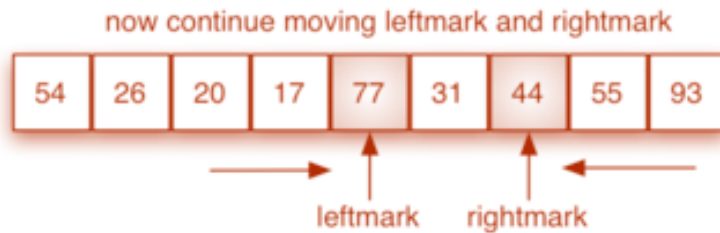
$26 < 54$  move to right  
 $93 > 54$  stop

5



exchange 20 and 93

6



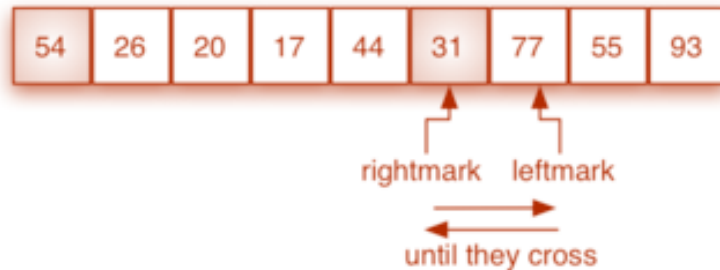
$77 > 54$  stop  
 $44 < 54$  stop  
exchange 77 and 44

8

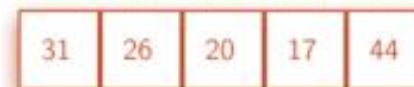


54 is in place

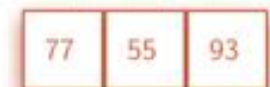
7



$77 > 54$  stop  
 $31 < 54$  stop  
rightmark < leftmark  
split point found  
exchange 54 and 31



quicksort left half



quicksort right half

# Worst Case Partitioning

- Worst-case partitioning
  - One region has one element and the other has  $n - 1$  elements
  - Maximally unbalanced

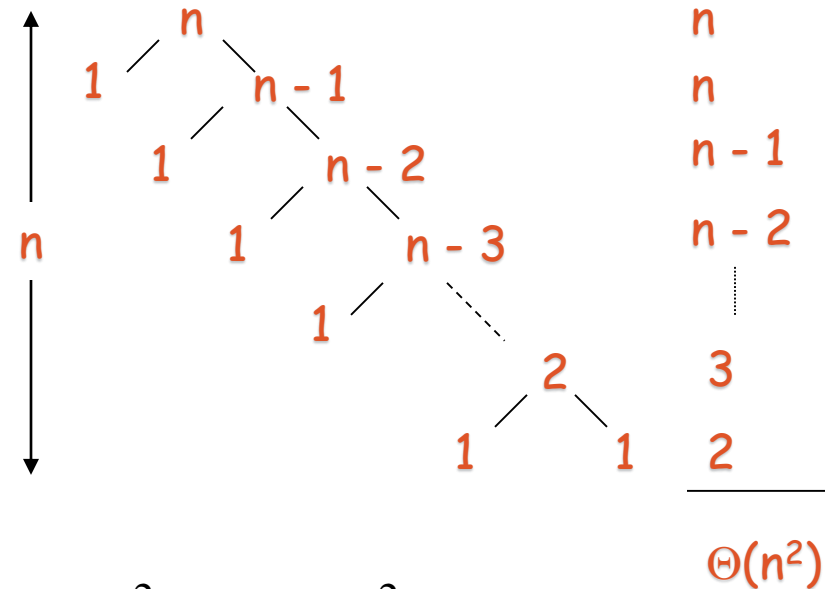
- Recurrence:  $q=1$

$$T(n) = T(1) + T(n - 1) + n,$$

$$T(1) = \Theta(1)$$

$$T(n) = T(n - 1) + n$$

$$n + \left( \sum_{k=1}^n k \right) - 1 = \Theta(n) + \Theta(n^2) = \Theta(n^2)$$



# How does partition affect performance?

- **Any splitting of constant proportionality** yields  $\Theta(n \lg n)$  time !!!

- Consider the  $(1 : n - 1)$  splitting:

ratio =  $1/(n - 1)$  not a constant !!!

- Consider the  $(n/2 : n/2)$  splitting:

ratio =  $(n/2)/(n/2) = 1$  it is a constant !!

- Consider the  $(9n/10 : n/10)$  splitting:

ratio =  $(9n/10)/(n/10) = 9$  it is a constant !!

# Choice of Pivot

Choosing the first element as pivot can cause worst case behavior on already sorted arrays.

For improvement in selecting pivot, pick the median value of three elements (first, mid and last) from data array as a pivot.

# Practice

Given the following list of numbers [14, 17, 13, 15, 19, 10, 3, 16, 9, 12] which answer shows the contents of the list after the second partitioning according to the quicksort algorithm?

- a) [9, 3, 10, 13, 12]
- b) [9, 3, 10, 13, 12, 14]
- c) [9, 3, 10, 13, 12, 14, 17, 16, 15, 19]
- d) [9, 3, 10, 13, 12, 14, 19, 16, 15, 17]

# Practice

Which of the following methods is the most effective for picking the pivot element?

- a) first element
- b) last element
- c) median-of-three partitioning
- d) random element



# Practice

Find the pivot element from the given input using median-of-three partitioning method.

8, 1, 4, 9, 6, 3, 5, 2, 7, 0.

- a) 8
- b) 7
- c) 9
- d) 6