

# Quicksort

## ① Choose a "pivot."

In this note, our pivot-picking strategy chooses first element as pivot.

|    |    |    |    |   |   |    |    |    |
|----|----|----|----|---|---|----|----|----|
| 14 | 33 | 43 | 21 | 5 | 9 | 18 | 67 | 30 |
| p  |    |    |    |   |   |    |    |    |

## ② Partition: run Tony Hoare's In-place Partitioning scheme

- Partition = place all items less than or equal to the pivot to the left and all items greater than pivot to the right.
- Tony Hoare: accomplishes this in  $\Theta(N)$  time and  $\Theta(1)$  space.

a) Place L pointer at index 1.

b) Place G pointer at end.

) Move pointers towards each other until L lands on an item that is greater than pivot and when G lands on an item less than or equal to pivot.

Swap items L and G are pointing to.

c) Repeat (a) until L is on right side of G.

) Swap pivot and item at G.

|    |    |    |    |   |   |    |    |    |
|----|----|----|----|---|---|----|----|----|
| 14 | 33 | 43 | 21 | 5 | 9 | 18 | 67 | 30 |
| p  | L  |    |    |   |   |    |    | G  |

↓↓

|    |    |    |    |   |   |    |    |    |
|----|----|----|----|---|---|----|----|----|
| 14 | 33 | 43 | 21 | 5 | 9 | 18 | 67 | 30 |
| p  | L  |    |    |   | G |    |    |    |

↓↓

|    |   |    |    |   |    |    |    |    |
|----|---|----|----|---|----|----|----|----|
| 14 | 9 | 43 | 21 | 5 | 33 | 18 | 67 | 30 |
| p  | L |    |    | G |    |    |    |    |

*Step 5:*

↓↓

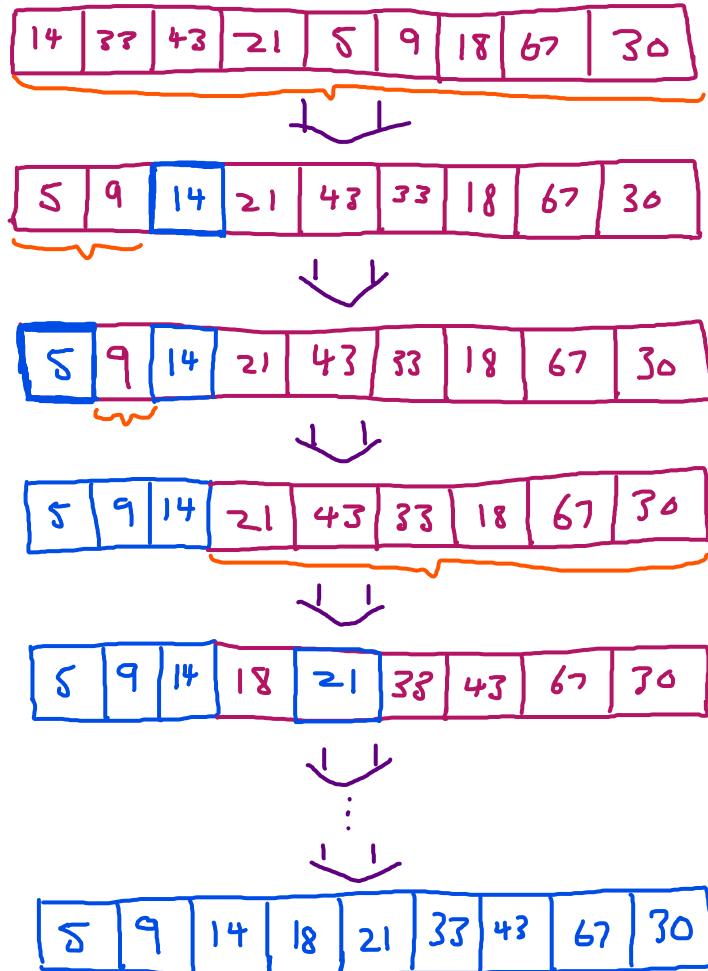
|    |   |   |    |    |    |    |    |    |
|----|---|---|----|----|----|----|----|----|
| 14 | 9 | 5 | 21 | 43 | 33 | 18 | 67 | 30 |
| p  | G | L |    |    |    |    |    |    |

Notice: the pivot is now in the correct position of the sorted array

↓↓

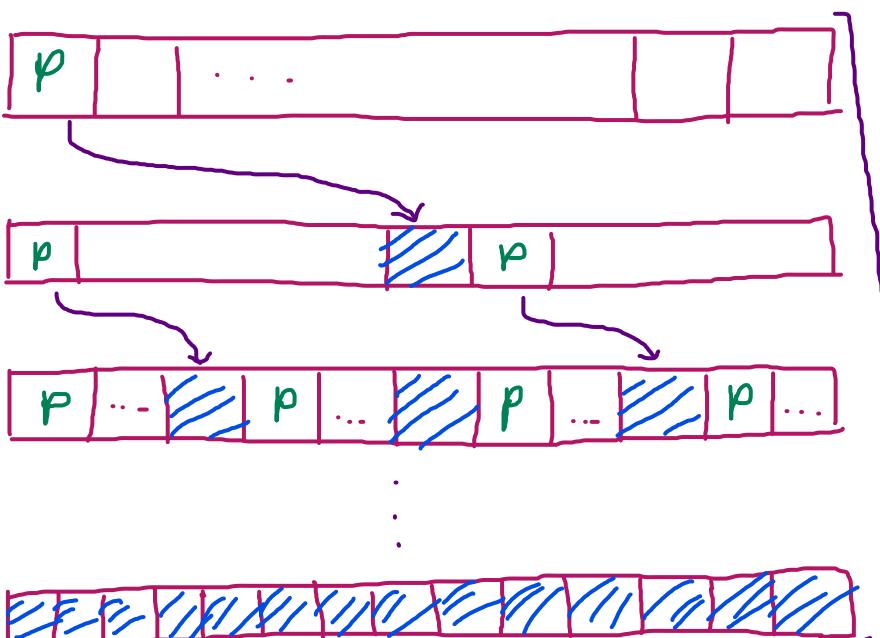
|   |   |    |    |    |    |    |    |    |
|---|---|----|----|----|----|----|----|----|
| 5 | 9 | 14 | 21 | 43 | 33 | 18 | 67 | 30 |
| p |   |    |    |    |    |    |    |    |

③ Recursion: repeat steps 1 and 2 on left and right subarrays of pivot.



Runtime?

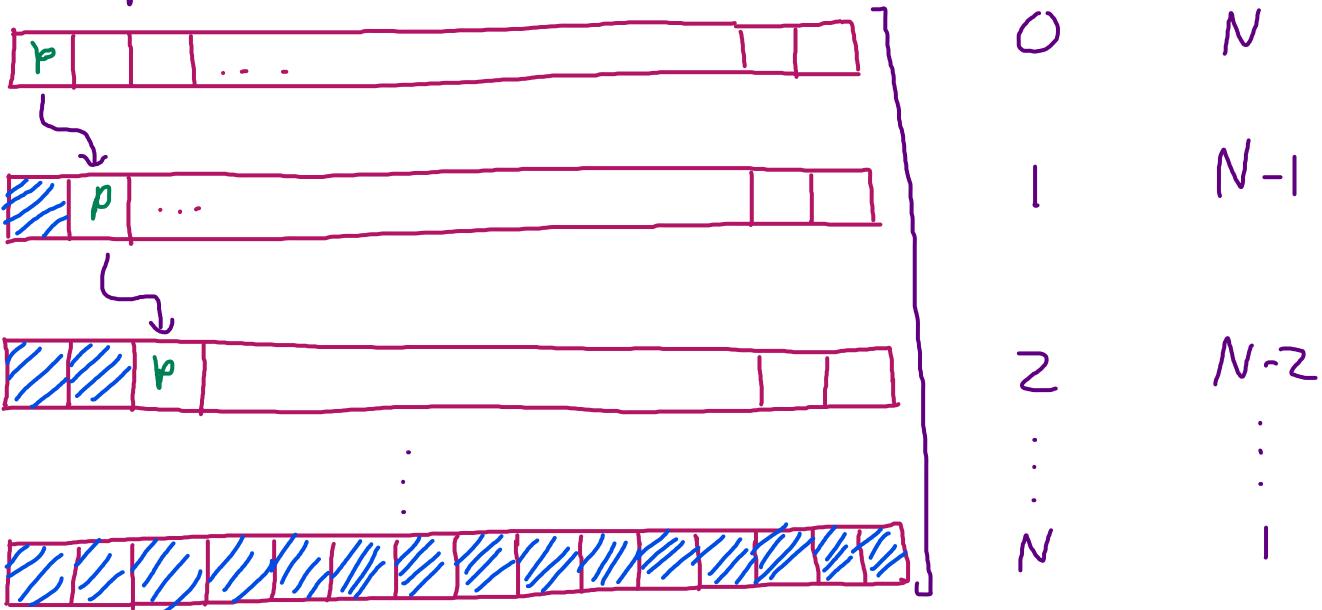
Best case:  $\Theta(N \log N)$



| <u>Level</u> | <u>Work</u>           |
|--------------|-----------------------|
| 0            | $N$                   |
| 1            | $\frac{N}{2} * 2 = N$ |
| 2            | $\frac{N}{4} * 4 = N$ |
| :            | $< N$                 |
| $\log N$     | $< N$                 |

$$\underbrace{N + N + \dots + N}_{\log N} = \Theta(N \log N)$$

Worst case?  $\Theta(N^2)$



$$N + (N-1) + (N-2) + \dots + 2 + 1 = \Theta(N^2)$$













