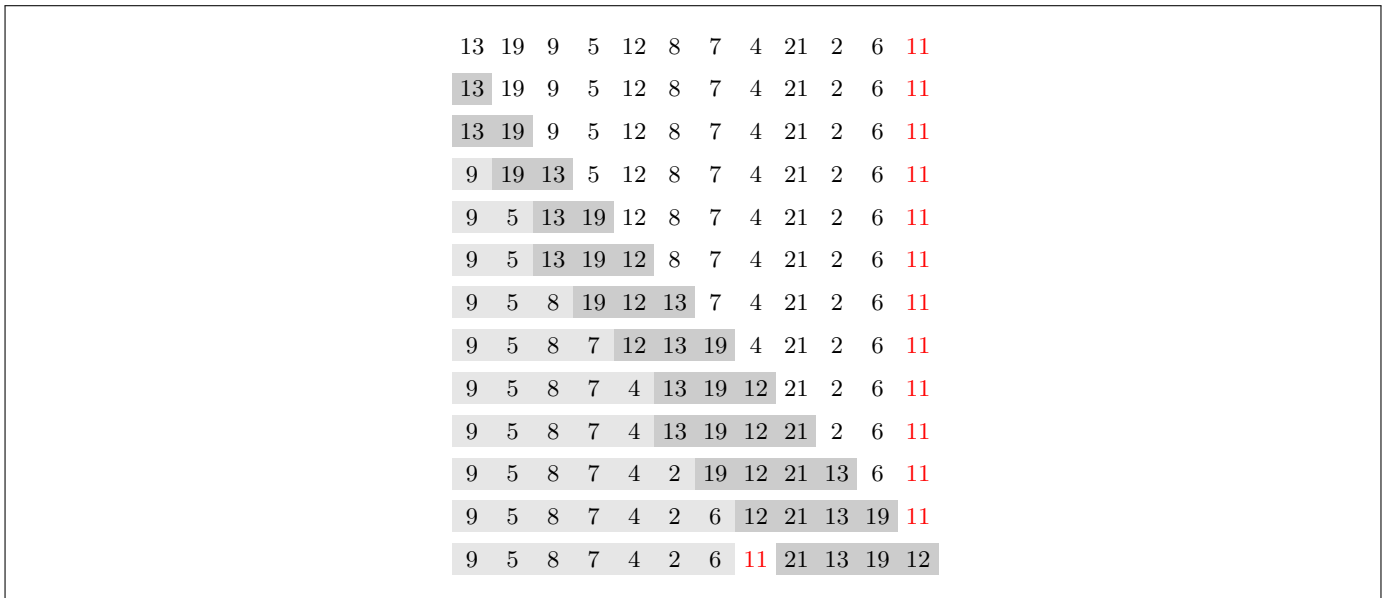


Section 7.1 – Description of quicksort

7.1-1 Using Figure 7.1 as a model, illustrate the operation of PARTITION on the array $A = \langle 13, 19, 9, 5, 12, 8, 7, 4, 21, 2, 6, 11 \rangle$.



7.1-2 What value of q does PARTITION return when all elements in the array $A = [p, \dots, r]$ have the same value? Modify PARTITION so that $q = \lfloor (p+r)/2 \rfloor$ when all elements in the array $A[p, \dots, r]$ have the same value.

It will return $q = r$. We can update PARTITION to split elements that are equal to the pivot on both sides as follows:

- Count the number of elements y such that $y = x$ and set this value to c ;
- Subtract the final pivot index by $\lfloor c/2 \rfloor$.

The updated pseudocode is stated below.

```

Partition-Improved( $A, p, r$ )
1   $x = A[r]$ 
2   $i = p - 1$ 
3   $c = 0$ 
4  for  $j = p$  to  $r - 1$  do
5      if  $A[j] \leq x$  then
6          if  $A[j] == x$  then
7               $c = c + 1$ 
8               $i = i + 1$ 
9          exchange  $A[i]$  with  $A[j]$ 
10 exchange  $A[i + 1]$  with  $A[r]$ 
11 return  $(i + 1) - \lfloor c/2 \rfloor$ 

```

7.1-3 Give a brief argument that the running time of PARTITION on a subarray of size n is $\Theta(n)$.

The **for** loop of lines 3–6 iterates $n - 1$ times and each iteration does a constant amount of work. Thus, it is $O(n)$.

7.1-4 How would you modify QUICKSORT to sort into nonincreasing order?

We just need to update the condition

$$A[j] \leq x,$$

to

$$A[j] \geq x.$$