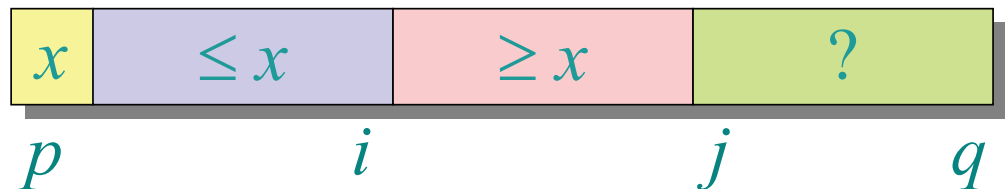


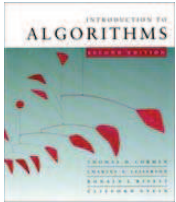
Partitioning subroutine

```
PARTITION( $A, p, q$ )  $\triangleright A[p \dots q]$   
   $x \leftarrow A[p]$   $\triangleright$  pivot =  $A[p]$   
   $i \leftarrow p$   
  for  $j \leftarrow p + 1$  to  $q$   
    do if  $A[j] \leq x$   
      then  $i \leftarrow i + 1$   
          exchange  $A[i] \leftrightarrow A[j]$   
  exchange  $A[p] \leftrightarrow A[i]$   
  return  $i$ 
```

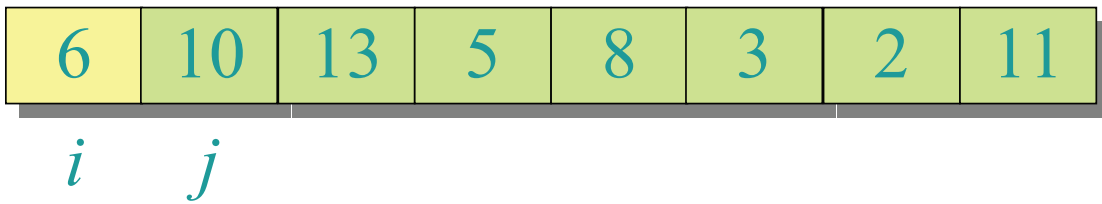
Running time
= $O(n)$ for n
elements.

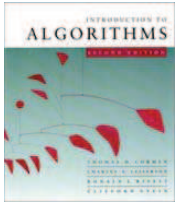
Invariant:



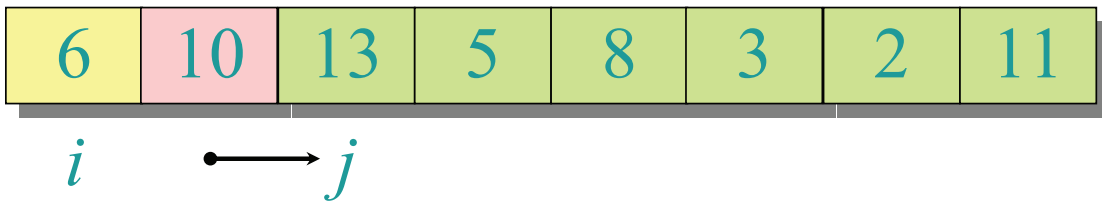


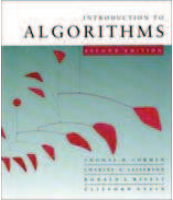
Example of partitioning



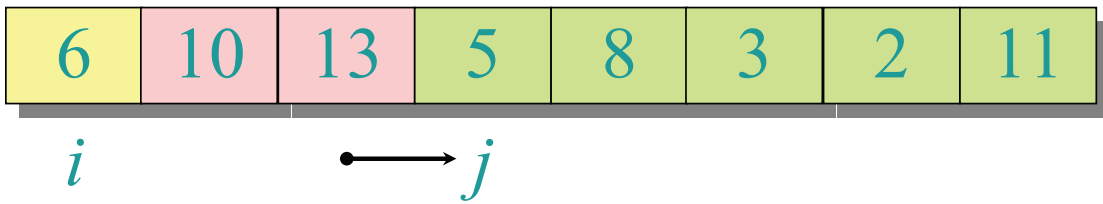


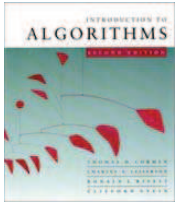
Example of partitioning



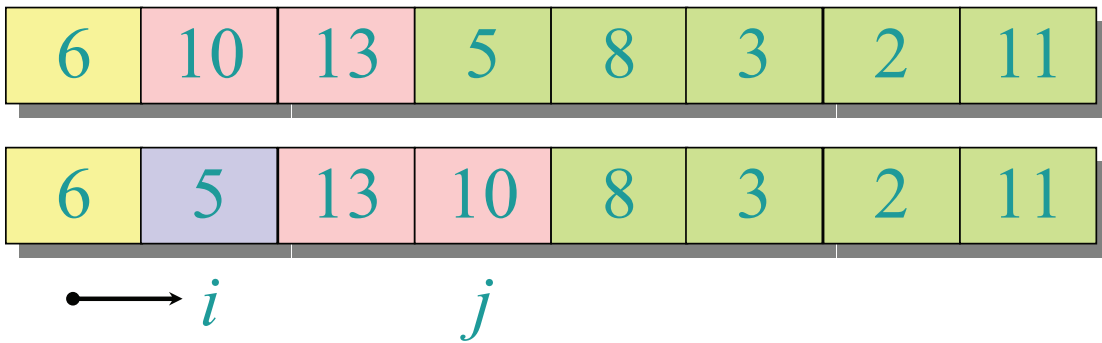


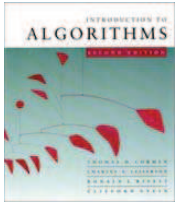
Example of partitioning



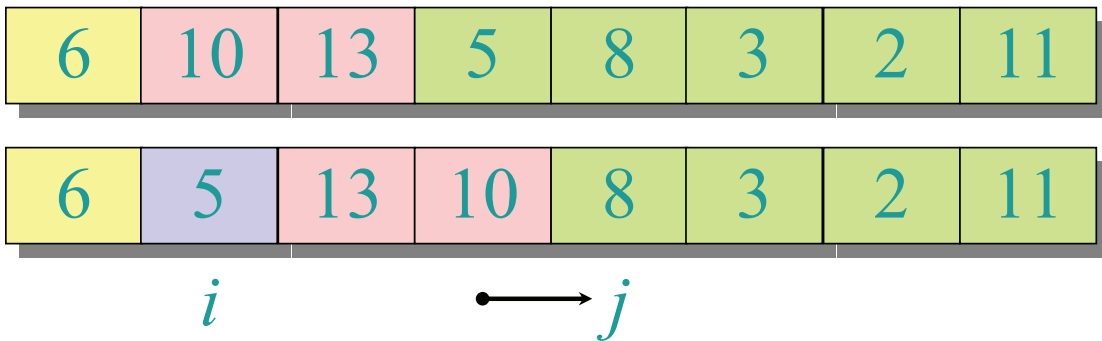


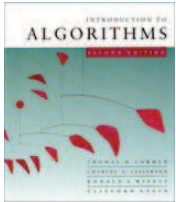
Example of partitioning



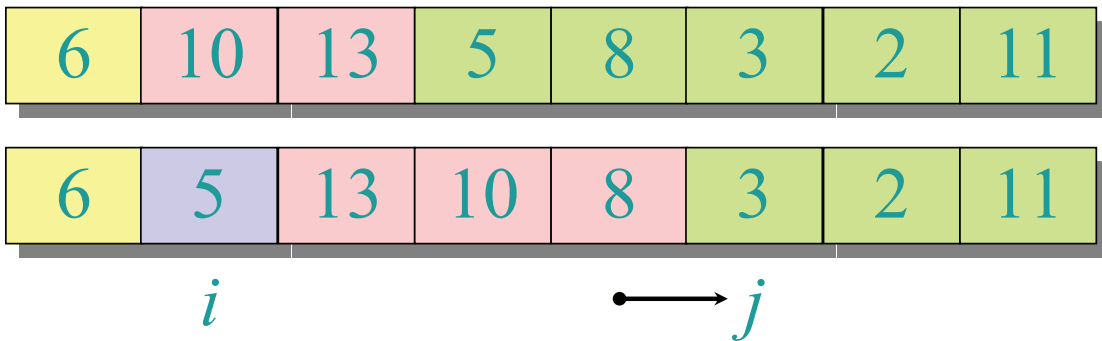


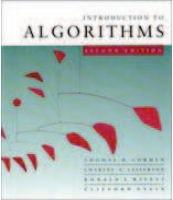
Example of partitioning



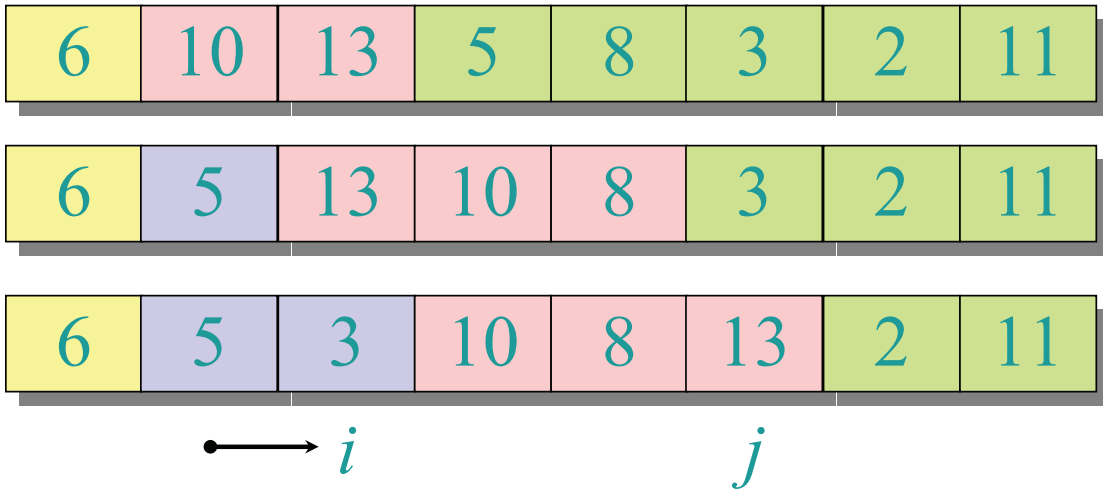


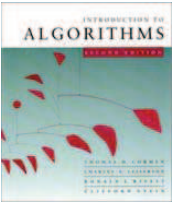
Example of partitioning



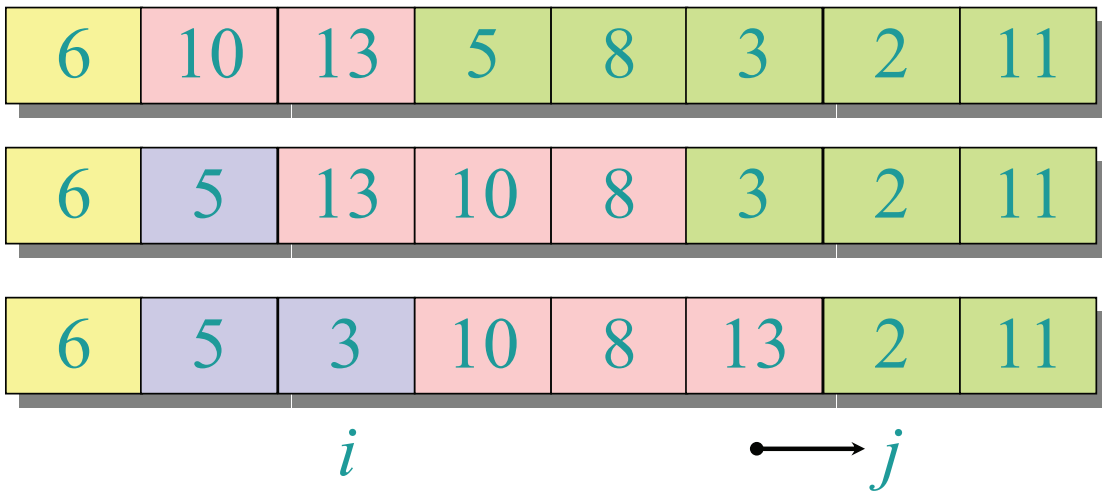


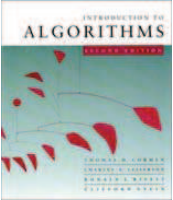
Example of partitioning



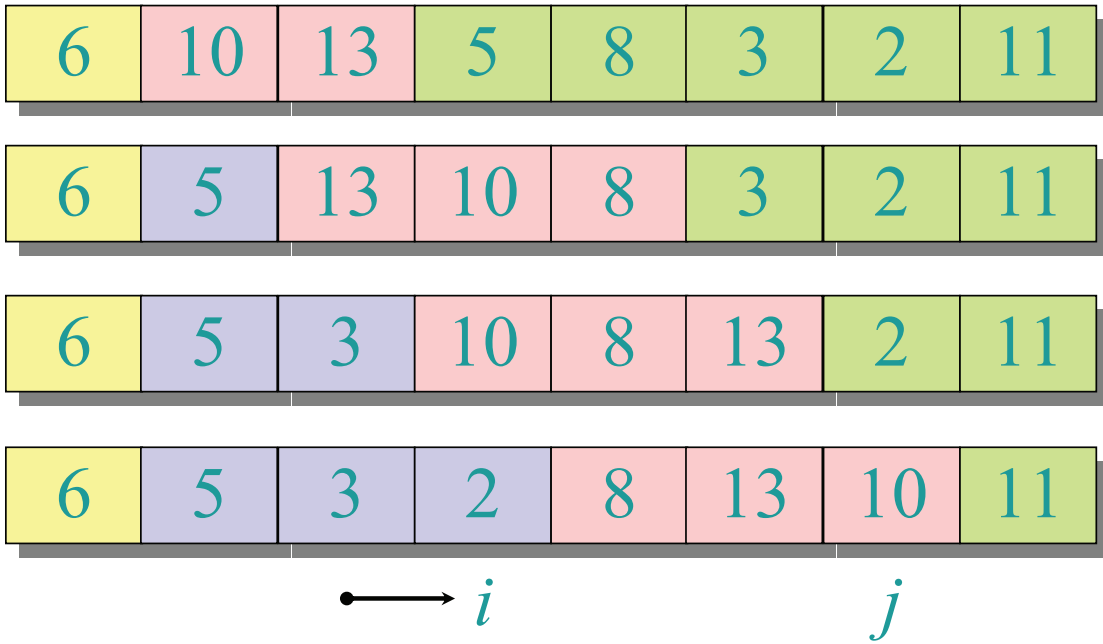


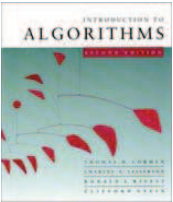
Example of partitioning



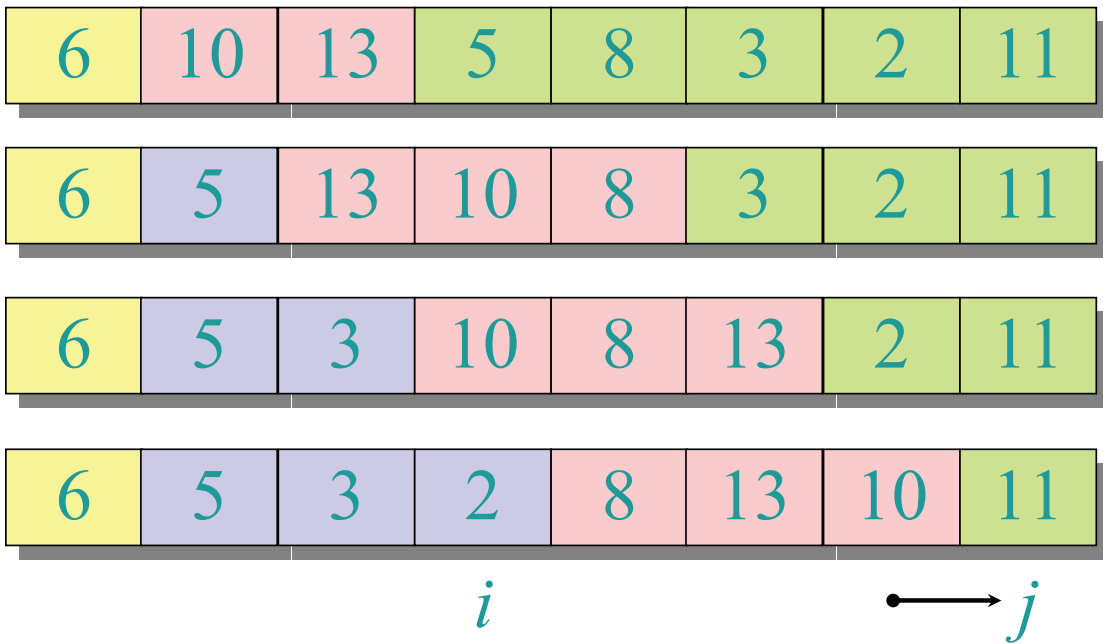


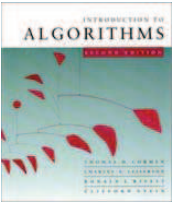
Example of partitioning



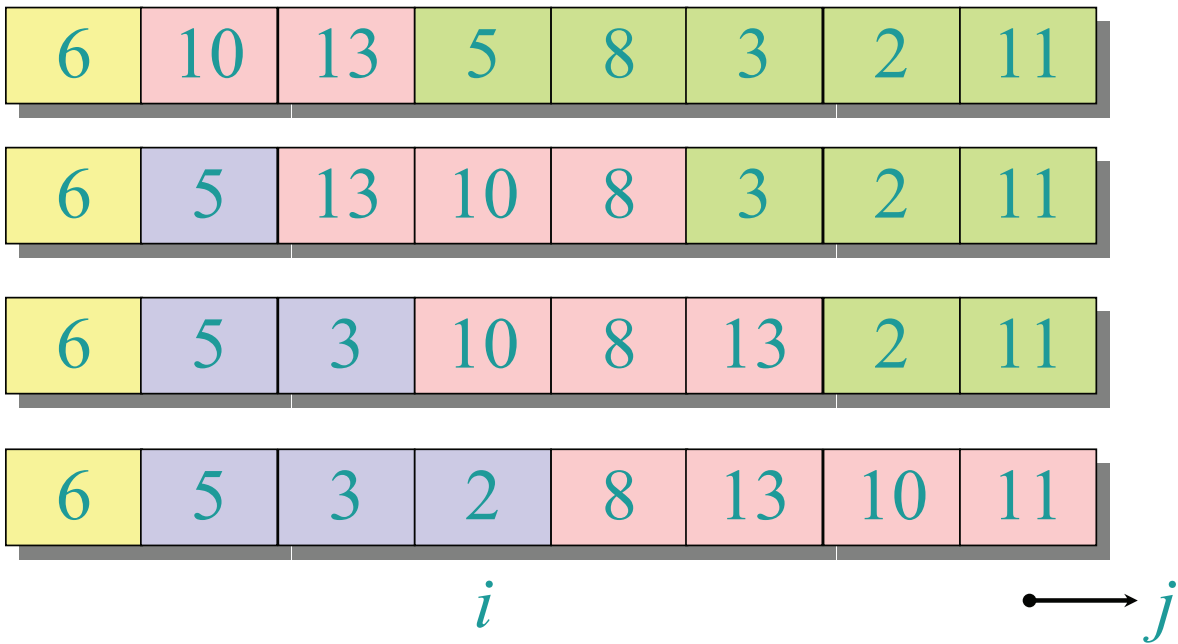


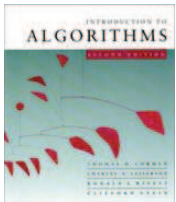
Example of partitioning



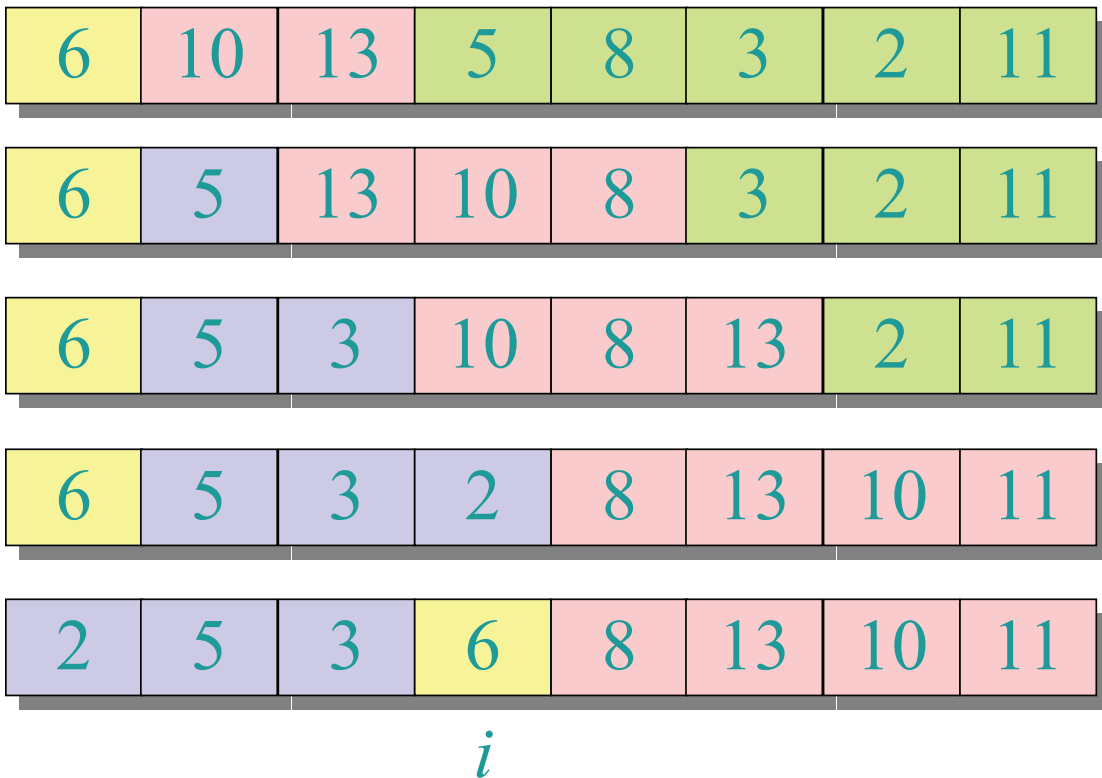


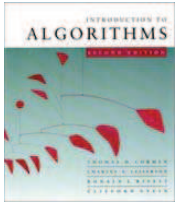
Example of partitioning





Example of partitioning





Pseudocode for quicksort

```
QUICKSORT( $A, p, r$ )  
  if  $p < r$   
    then  $q \leftarrow$  PARTITION( $A, p, r$ )  
        QUICKSORT( $A, p, q-1$ )  
        QUICKSORT( $A, q+1, r$ )
```

Initial call: QUICKSORT($A, 1, n$)