Sorting Algorithms

1. Selection
2. Bubble
3. Insertion
4. Merge
5. Quick
6. Shell

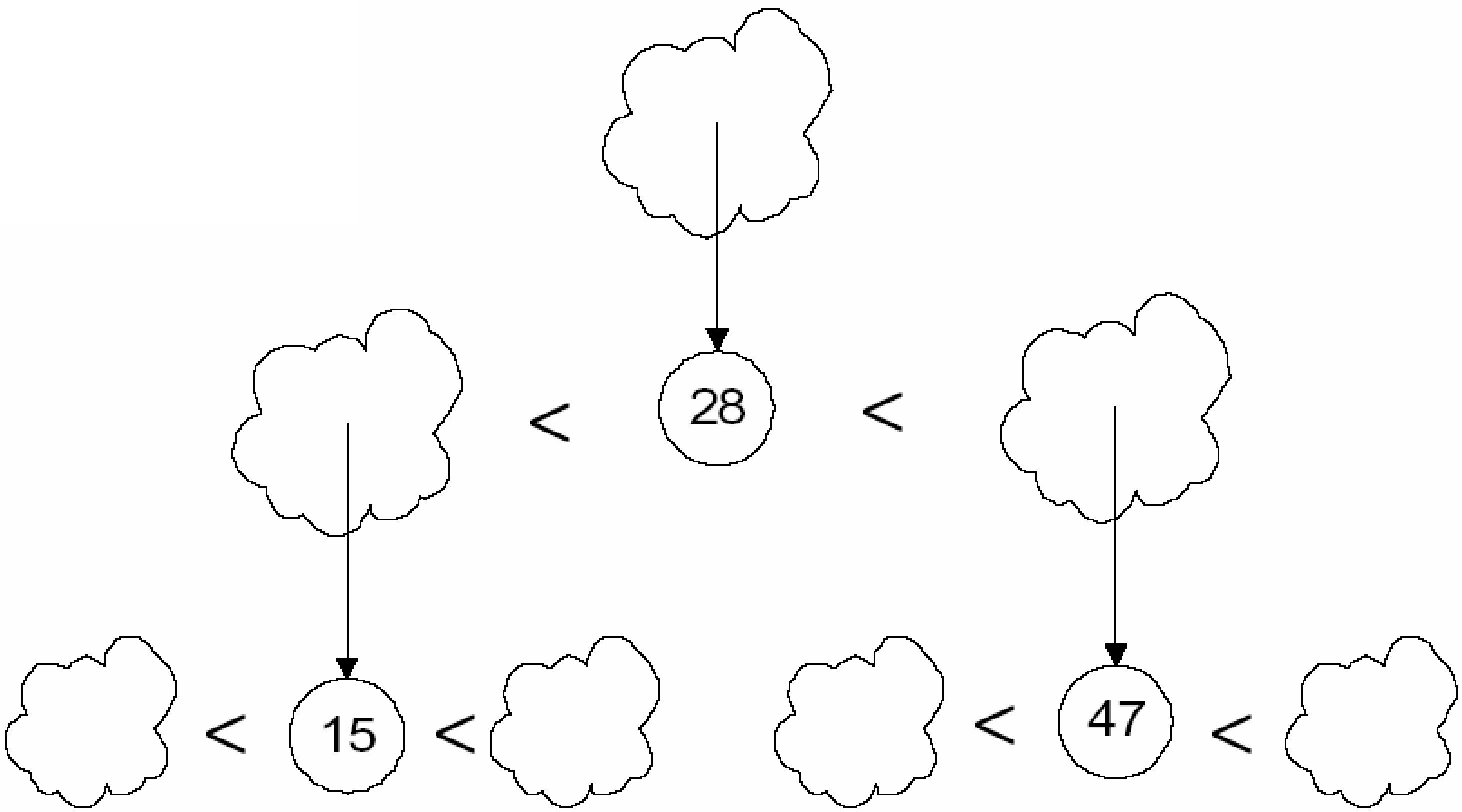
Sorting algorithms

- Metode Insertion, selection dan bubble sort memiliki worst-case performance yang bernilai quadratik
- Apakah algoritma berbasis comparison yang tercepat ?

O(nlogn)

- Mergesort dan Quicksort

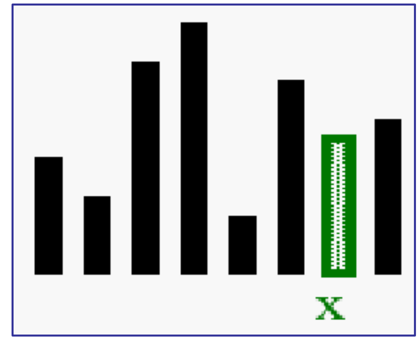
Idea of Quicksort



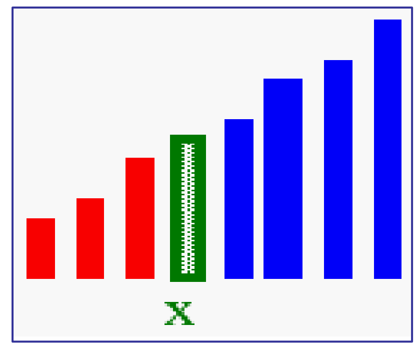
- Ambil sebuah “pivot”.
- Bagi menjadi 2 : bagian yang kurang dari dan bagian yang lebih dari pivot
- Urutkan masing-masing bagian secara rekursif

Idea of Quicksort

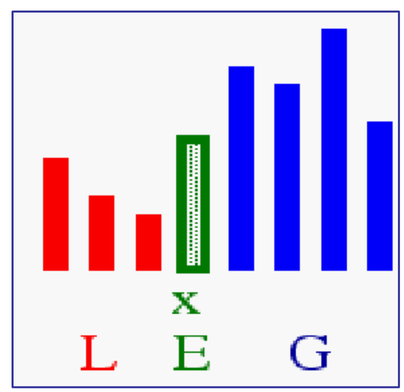
1. **Select**: pick an element



2. **Divide**: rearrange elements so that **x goes to its final position E**



3. **Recur and Conquer**: recursively sort



Quicksort Algorithm

Misal diberikan sebuah array A memiliki n elemen (integer) → p = 0; r = n-1

- Array A[p.. r] dipartisi menjadi dua non-empty subarray : A[p..q] and A[q+1..r]
  - Seluruh elemen dalam array A[p..q] lebih kecil dari seluruh elemen dalam array A[q+1..r]
- Seluruh sub array diurutkan secara rekursif dengan cara memanggil fungsi `quicksort()`

Quicksort Code

```
Quicksort_rekursif(A, p, r)
{
    if (p < r)
    {
        q = Partition(A, p, r);
        Quicksort_rekursif(A, p, q);
        Quicksort_rekursif(A, q+1, r);
    }
}
```

Partition

- Terlihat bahwa, seluruh aksi terjadi dalam fungsi **`partition()`**
  - Rearranges subarray secara in place
  - Hasil akhir:
    - Dua subarray
    - Seluruh elemen pada subarray pertama $\leq$ seluruh elemen pada subarray kedua
  - Return value berupa index dari elemen “pivot” – yang memisahkan kedua subarray tsb
- *How do you suppose we implement this?*

Partition In Words

- Partition(A, p, r):
  - Pilih sebuah elemen yang bertindak sebagai “pivot” (*which?*)
  - Pecah array menjadi dua bagian, A[p..i] and A[j..r]
    - Seluruh element dalam A[p..i] <= pivot
    - Seluruh element dalam A[j..r] >= pivot

    (HOW ?)
  - Increment i until A[i] >= pivot
  - Decrement j until A[j] <= pivot
  - Jika i < j, maka Swap A[i] and A[j]
  - Jika tidak, return j
  - Repeat until i >= j
  - return j

Partition Code

```
Partition(A, p, r)
    x = A[p];  //pivot=elemen posisi pertama
    i = p ;    //inisialisasi
    j = r ;
    repeat
        while(A[j] > x)
            j--;
         while(A[i] < x)
               i++;
         if (i < j){
             Swap(A, i, j);
            j--;
           i++
        }
        else
            return j;
    until i >= j
    return j
```

12	35	9	11	3	17	23	15	31	20

QuickSort(0,9)

- X = PIVOT merupakan indeks ke –0
- PIVOT = 12
- terdapat variabel i dan j , i=0 , j=9
- variabel i untuk mencari bilangan yang lebih dari atau sama dengan PIVOT. Cara kerjanya : selama Data[i] < PIVOT maka nilai i ditambah.
- variabel j untuk mencari bilangan yang lebih kecil dari atau sama dengan PIVOT. Cara kerjanya : selama Data[j] > PIVOT maka nilai j dikurangi

q = Partition(0,9)

12	35	9	11	3	17	23	15	31	20

PIVOT = 12

i = 0 j = 4

i < j maka SWAP

SWAP

3	35	9	11	12	17	23	15	31	20

PIVOT = 12

i = 1 j = 3

i < j maka SWAP

SWAP

3	11	9	35	12	17	23	15	31	20

PIVOT = 12

i = 3 j = 2

i < j (False) NO SWAP

Return j = 2

Q = Partisi = 2

QuickSort(0,9)

QuickSort(0,2)

QuickSort(3,9)

QuickSort(0,2)

3	11	9

35	12	17	23	15	31	20

PIVOT = 3

i = 0 j = 0

i < j (False) NO SWAP

Return j = 0

Q = Partisi = 0

QuickSort(0,0)

QuickSort(1,2)

QuickSort(1,2)

PIVOT = 11

i = 1 j = 2

i < j   SWAP

SWAP

3		9	11		35	12	17	23	15	31	20

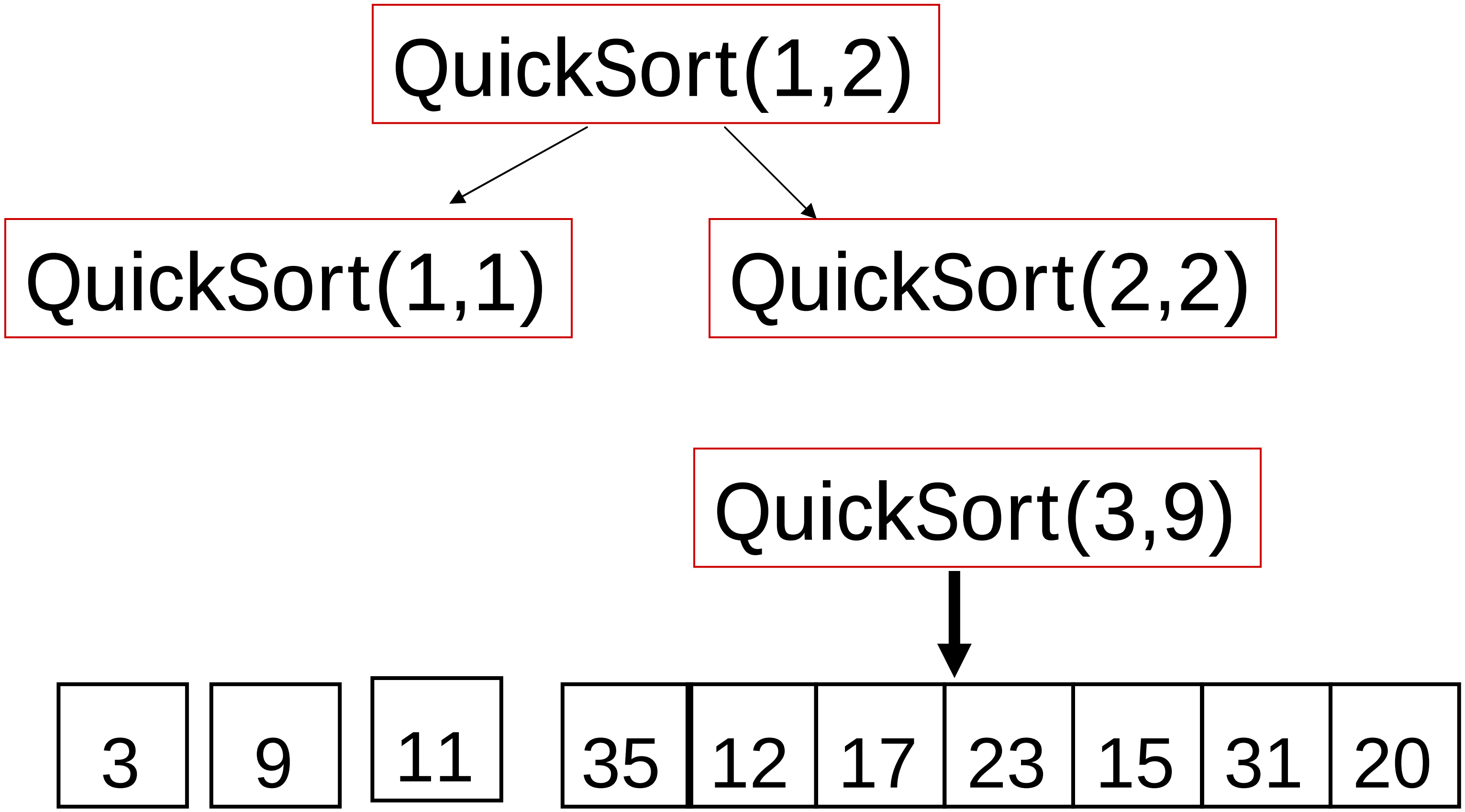
PIVOT = 11

i = 2 j = 1

i < j   NO SWAP

Return j = 1

Q = Partisi = 1



PIVOT = 35

i = 3 j = 9

i < j SWAP

3	9	11	20	12	17	23	15	31	35

PIVOT = 35

i = 9 j = 8

i < j   NO SWAP

Return j = 8

Q = Partisi = 8

QuickSort(3,9)

QuickSort(3,8)

QuickSort(9,9)

3	9	11	20	12	17	23	15	31	35

QuickSort(3,8)

PIVOT = 20

i = 3 j = 7

i < j SWAP

SWAP

3	9	11	15	12	17	23	20	31	35

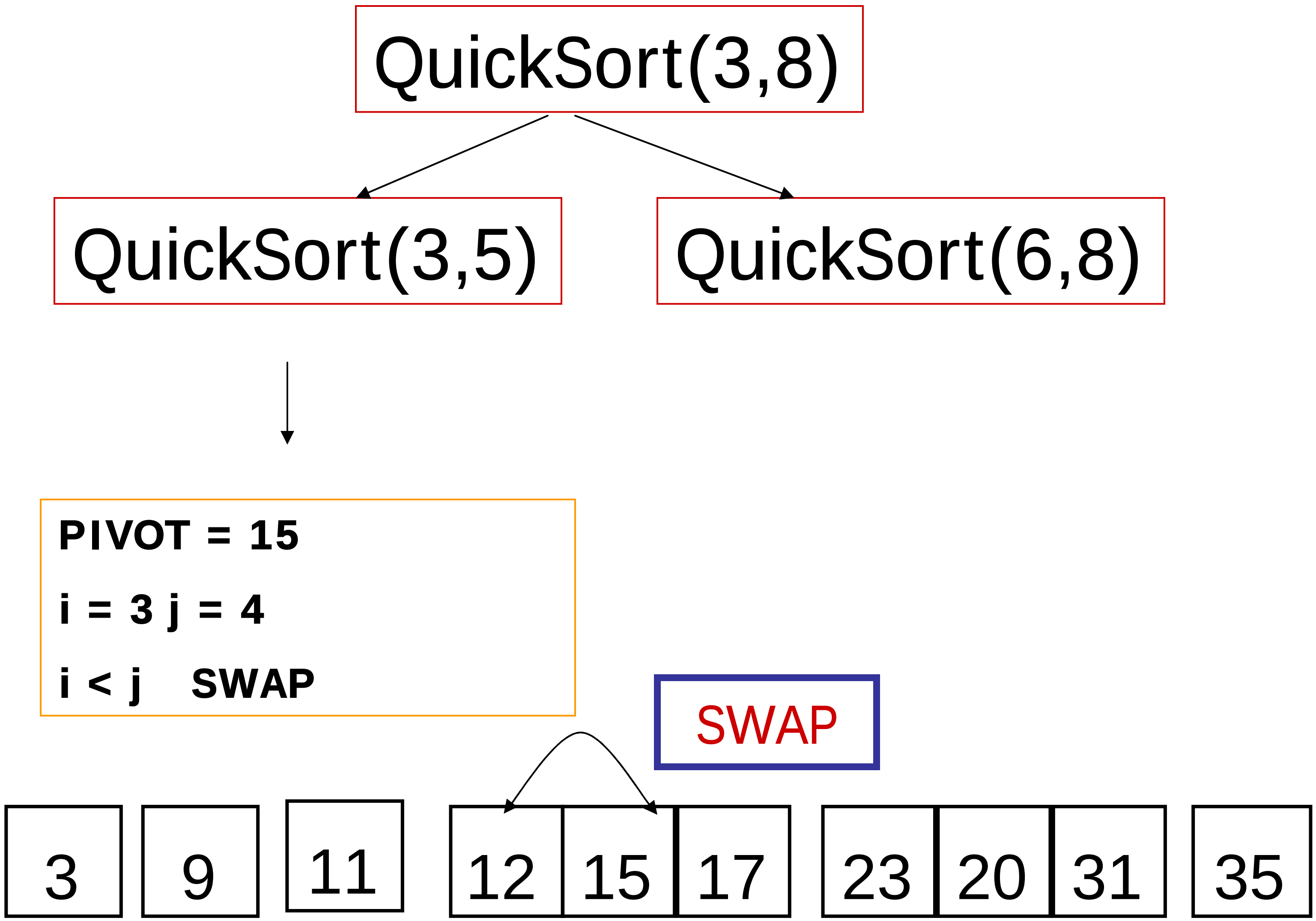
PIVOT = 20

i = 6 j = 5

i < j NO SWAP

Return j = 5

Q = Partisi = 5


QuickSort(3,8)
QuickSort(3,5)
QuickSort(6,8)
PIVOT = 15
i = 3 j = 4
i < j SWAP
SWAP
3
9
11
12
15
17
23
20
31
35

PIVOT = 15

i = 4 j = 3

i < j NO SWAP

Return j = 3

Q = Partisi = 3

q = 3

QS(3,5)

QS(3,3)   QS(4,5)

3	9	11	12	15	17	23	20	31	35

QS(4,5)

PIVOT = 15

i = 4 j = 4

i < j NO SWAP

Return j = 4

Q = Partisi = 4

q = 4

QS(4,5)

QS(4,4) QS(5,5)

3	9	11	12	15	17	23	20	31	35

QuickSort(6,8)

PIVOT = 23

i = 6 j = 7

i < j SWAP

3	9	11	12	15	17	20	23	31	35

PIVOT = 23

i = 7 j = 6

i < j NO SWAP

Return j = 6

Q = Partisi = 6

QS(6,8)

q = 6

QS(6,6) QS(7,8)

3	9	11	12	15	17	20	23	31	35

QS(7,8)

PIVOT = 23

i = 7 j = 7

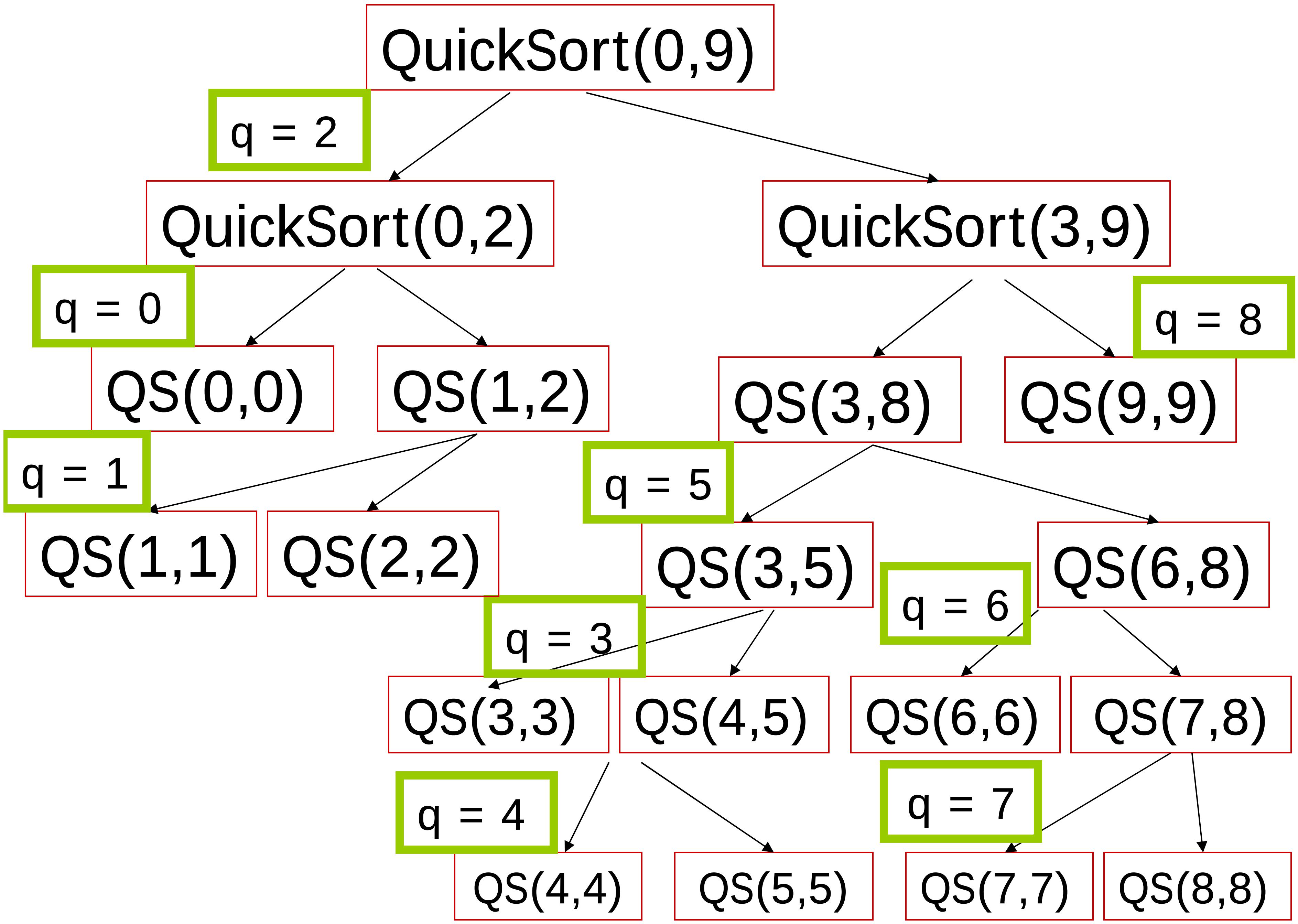
i < j NO SWAP

Return j = 7

Q = Partisi = 7

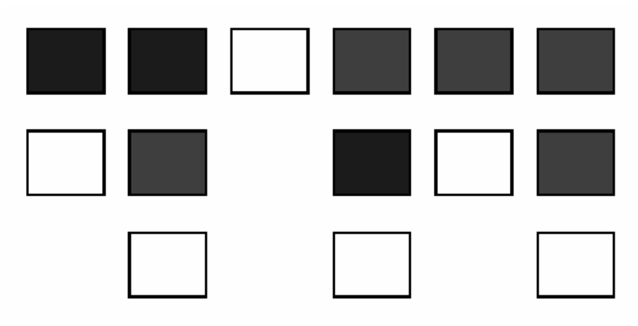
QS(7,8)

QS(7,7) QS(8,8)


QuickSort(0,9)
q = 2
QuickSort(0,2)
QuickSort(3,9)
q = 0
q = 8
QS(0,0)
QS(1,2)
QS(3,8)
QS(9,9)
q = 1
q = 5
QS(1,1)
QS(2,2)
QS(3,5)
q = 6
QS(6,8)
q = 3
QS(3,3)
QS(4,5)
QS(6,6)
QS(7,8)
q = 4
q = 7
QS(4,4)
QS(5,5)
QS(7,7)
QS(8,8)

Quicksort Analysis

- Jika diasumsikan pivot diambil secara random, terdistribusi secara uniform
- **Best case running time: $O(n \log_2 n)$**
  - Pada setiap pemanggilan rekursif, posisi elemen pivot selalu persis di tengah, array dipecah menjadi dua bagian yang sama, elemen-elemen yang lebih kecil dan yang lebih besar dari pivot



Quicksort Analysis

Worst case: O(N^2)

- Pada setiap pemanggilan rekursif, pivot selalu merupakan elemen terbesar (atau terkecil); array dipecah menjadi satu bagian yang semua elemennya lebih kecil dari pivot, pivot, dan sebuah bagian lagi array yang empty

Summary of Sorting Algorithms

Algorithm	Time	Notes
selection-sort	$O(n^2)$	• in-place • slow (good for small inputs)
insertion-sort	$O(n^2)$	• in-place • slow (good for small inputs)
quick-sort	$O(n \log n)$ expected	• in-place, randomized • fastest (good for large inputs)
merge-sort	$O(n \log n)$	• sequential data access • fast (good for huge inputs)

Mergesort X Quicksort

- **Mergesort**
  - Splits partitions in half
  - Merges smaller lists back into larger list
  - Requires overhead when sorting arrays
- **Quicksort**
  - Relies on a pivot point for sorting
  - Smaller sets are sorted based on pivot point
  - Can perform slowly if a bad pivot point is used

Mergesort X Quicksort

- **Mergesort**
  - Use extra space
  - Is guaranteed to have O(n log n) performance in the worst case

- **Quicksort**
  - Does **not** use extra space
  - Is **not** guaranteed to have O(n log n) performance in the worst case, unlike merge sort

Mergesort X Quicksort

- **Advantages of quicksort over mergesort**
  - Quicksort doesn’t require an extra array
  - the hidden constant in the average case for quicksort is smaller than the hidden constant for merge sort.

- **Advantage of mergesort over quicksort:**
  - better worst case behavior

- **Quicksort and mergesort are optimal, in the sense that a general sorting algorithm cannot do better than average case O(nlog n).**

Mergesort X Quicksort

- Both QuickSort and MergeSort are O(n log n) for their average cases.
- However, the characteristic of 'O' notation is that you drop all constant factors.
- Therefore, one O(n) algorithm could take 1000 times as long as another O(n) algorithm, and as long as the complexity isn't dependant on the size on 'n', they're both O(n) algorithms.

Mergesort X Quicksort

- The advantage of QSort over MergeSort is that it's constant factor is smaller than MergeSort's, and so therefore, on the average case, it is faster (but not less complex).

- Empirically, QSort is best, especially if the 'pivot' value has been properly selected