Sorting algorithms

Data Structures and Algorithms

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Overview

1. **Sorting concepts**
2. **Insertion Sort**
   - Straight Insertion Sort
   - Shell Sort
3. **Selection Sort**
   - Straight Selection Sort
4. **Exchange Sort**
   - Bubble Sort
5. **Devide-and-Conquer**
   - Quick Sort
   - Merge Sort

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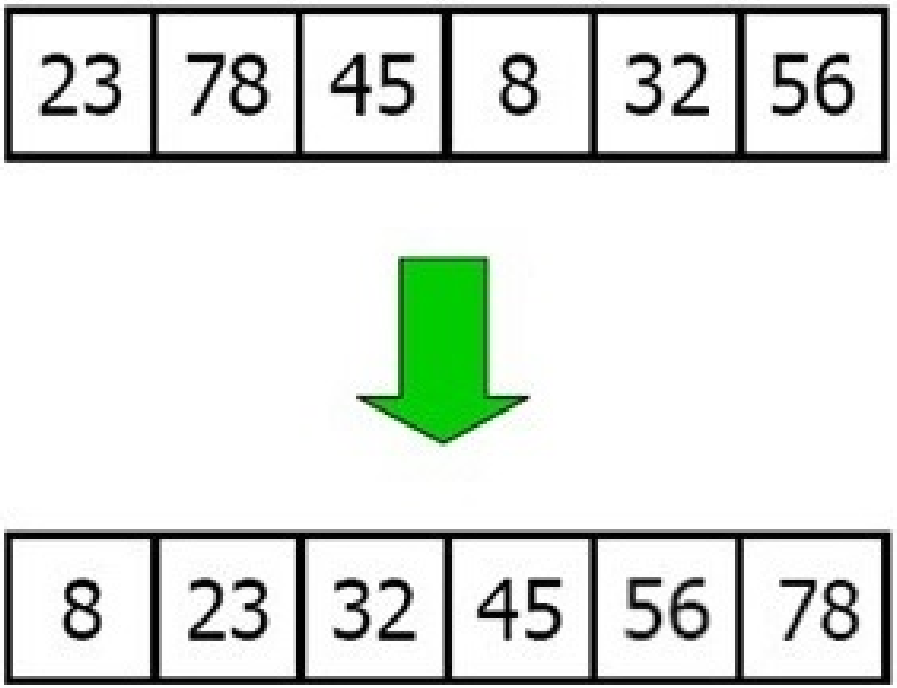
Sorting concepts

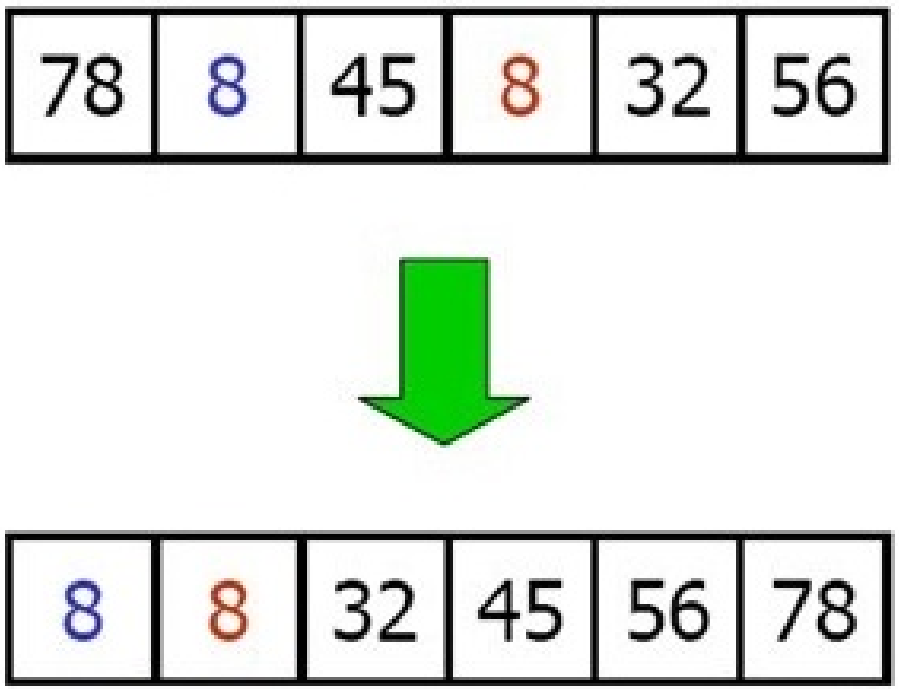
Sorting

One of the most important concepts and common applications in computing.



Sorting

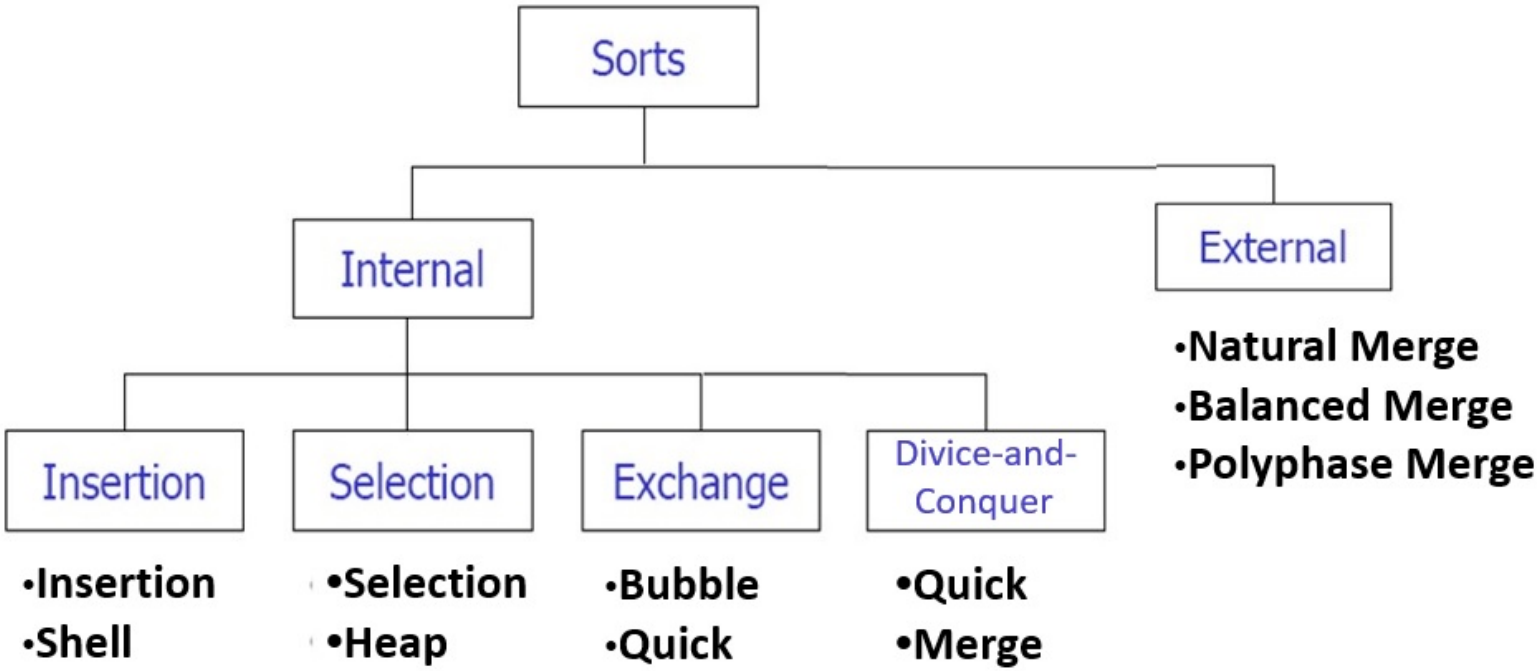
Sort stability: data with equal keys maintain their relative input order in the output.



Sorting

Sort efficiency: a measure of the relative efficiency of a sort = number of comparisons + number of moves.

Sorting



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Insertion Sort

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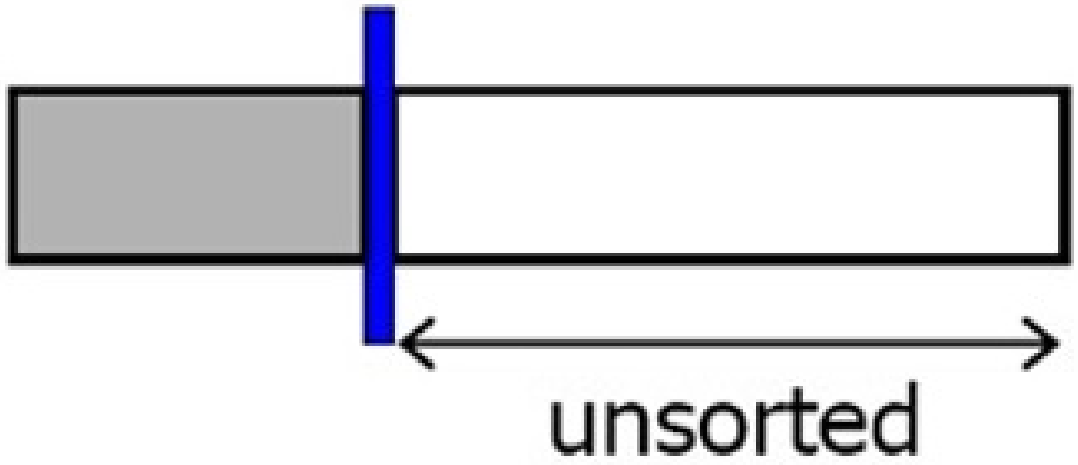
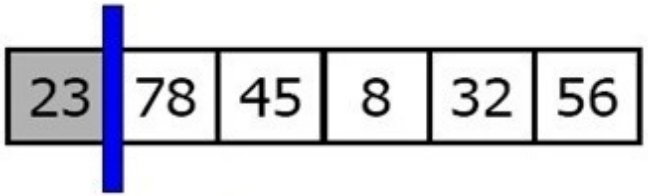
Straight Insertion Sort

- The list is divided into two parts: sorted and unsorted.
- In each pass, the first element of the unsorted sublist is inserted into the sorted sublist.



Straight Insertion Sort



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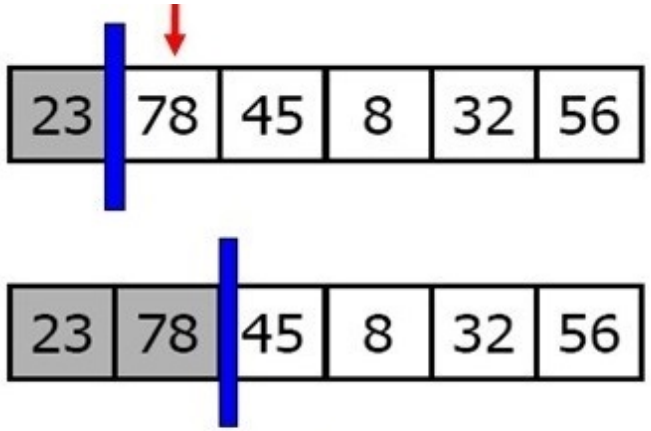
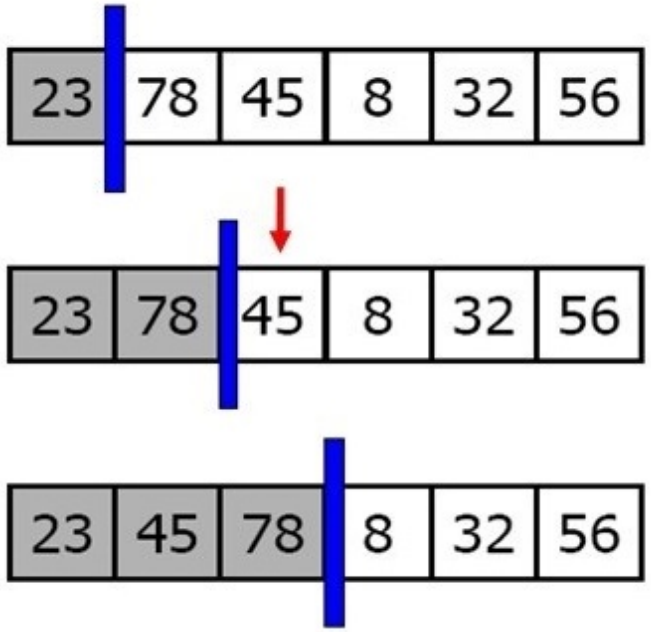
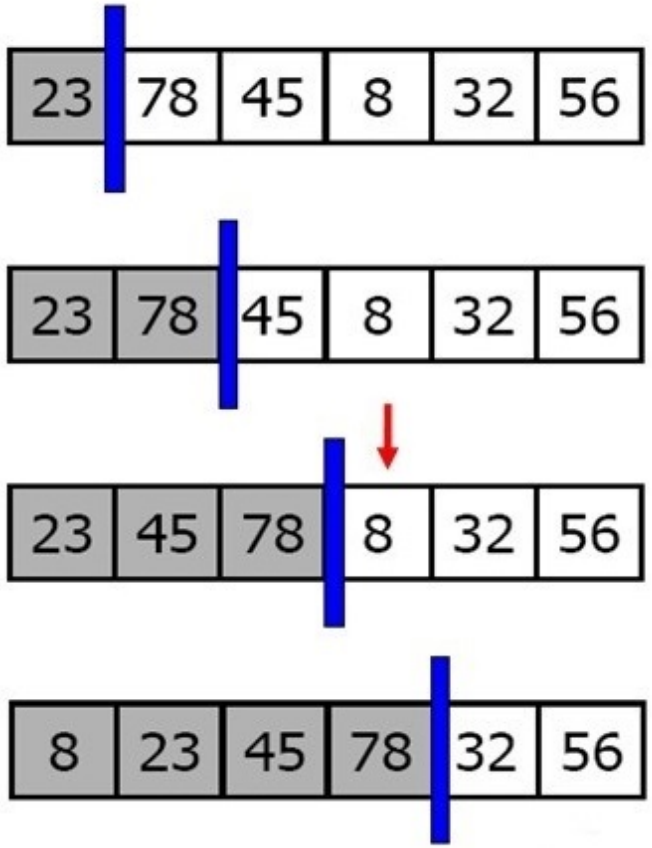
Straight Insertion Sort



Straight Insertion Sort



Straight Insertion Sort



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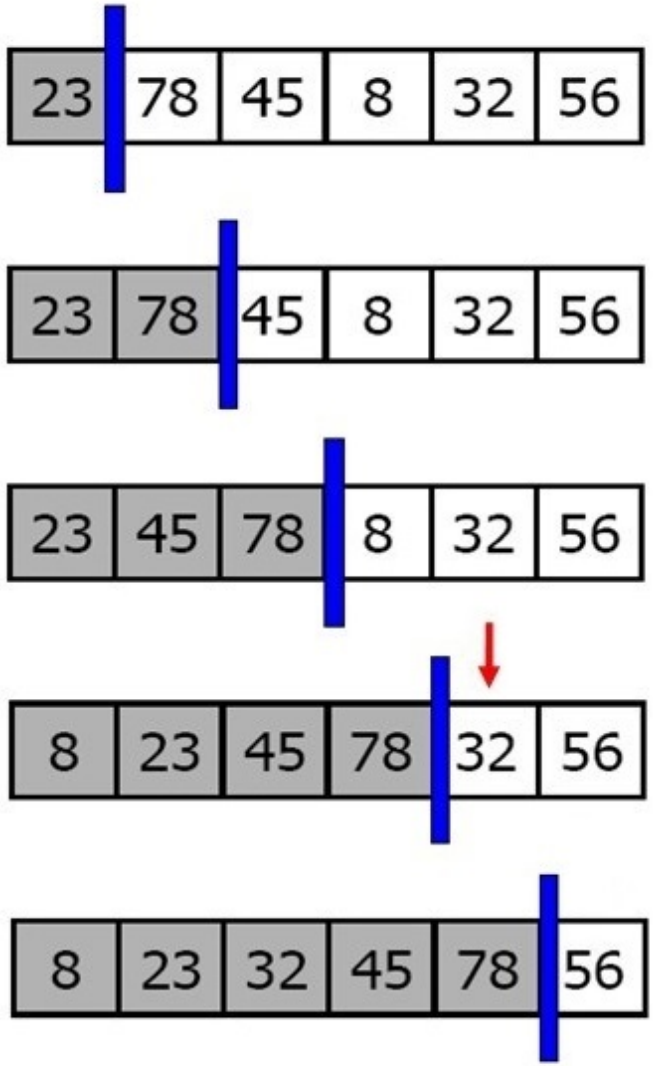
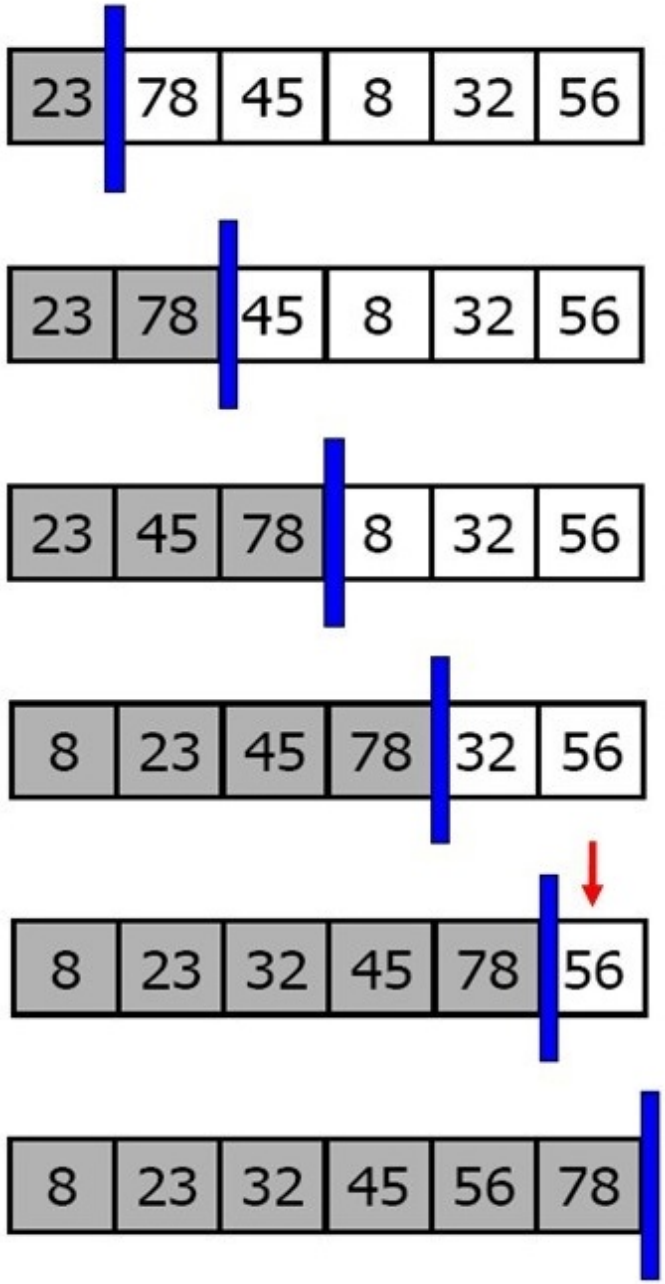
Straight Insertion Sort



Straight Insertion Sort



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Straight Insertion Sort

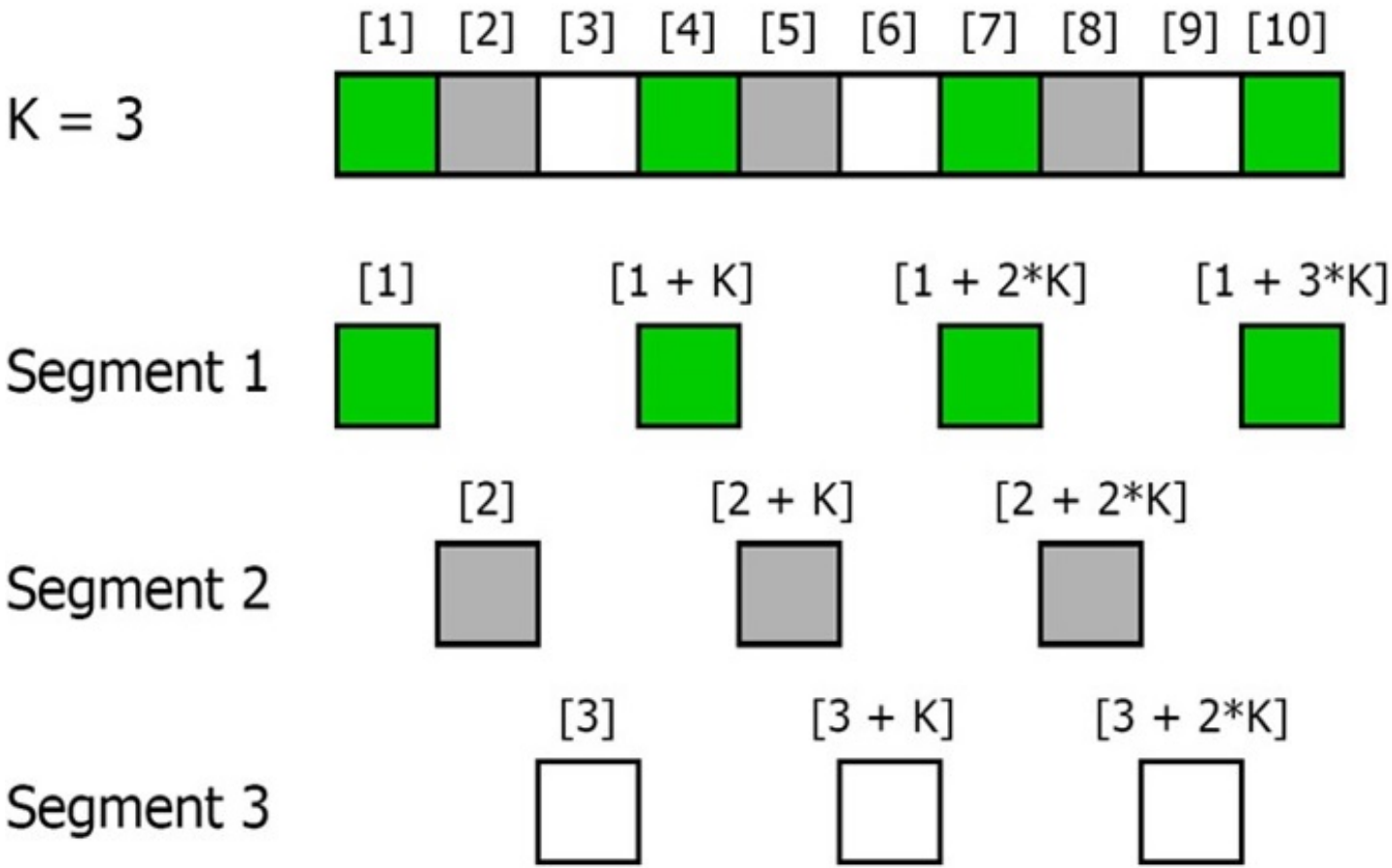
```
1  Algorithm InsertionSort()
2  Sorts the contiguous list using straight insertion
     sort.

3  if count > 1 then
4      current = 1
5      while current < count do
6          temp = data[current]
7          walker = current - 1
8          while walker >= 0 AND temp.key <
             data[walker].key do
9              data[walker+1] = data[walker]
10             walker = walker - 1
11         end
12         data[walker+1] = temp
13         current = current + 1
14     end
15 end
```

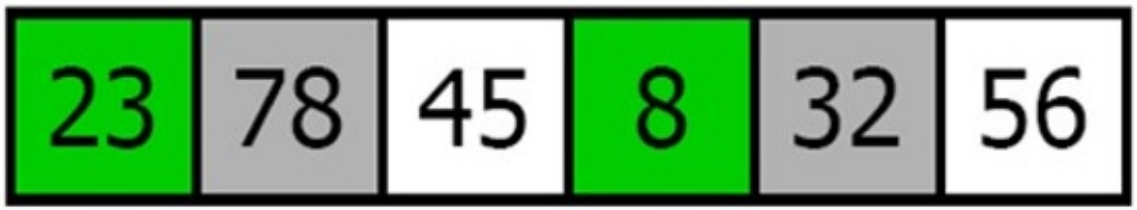

Shell Sort

- Named after its creator Donald L. Shell (1959).
- Given a list of N elements, the list is divided into K segments (K is called the increment).
- Each segment contains N/K or more elements.
- Segments are dispersed throughout the list.
- Also is called diminishing-increment sort.

Shell Sort

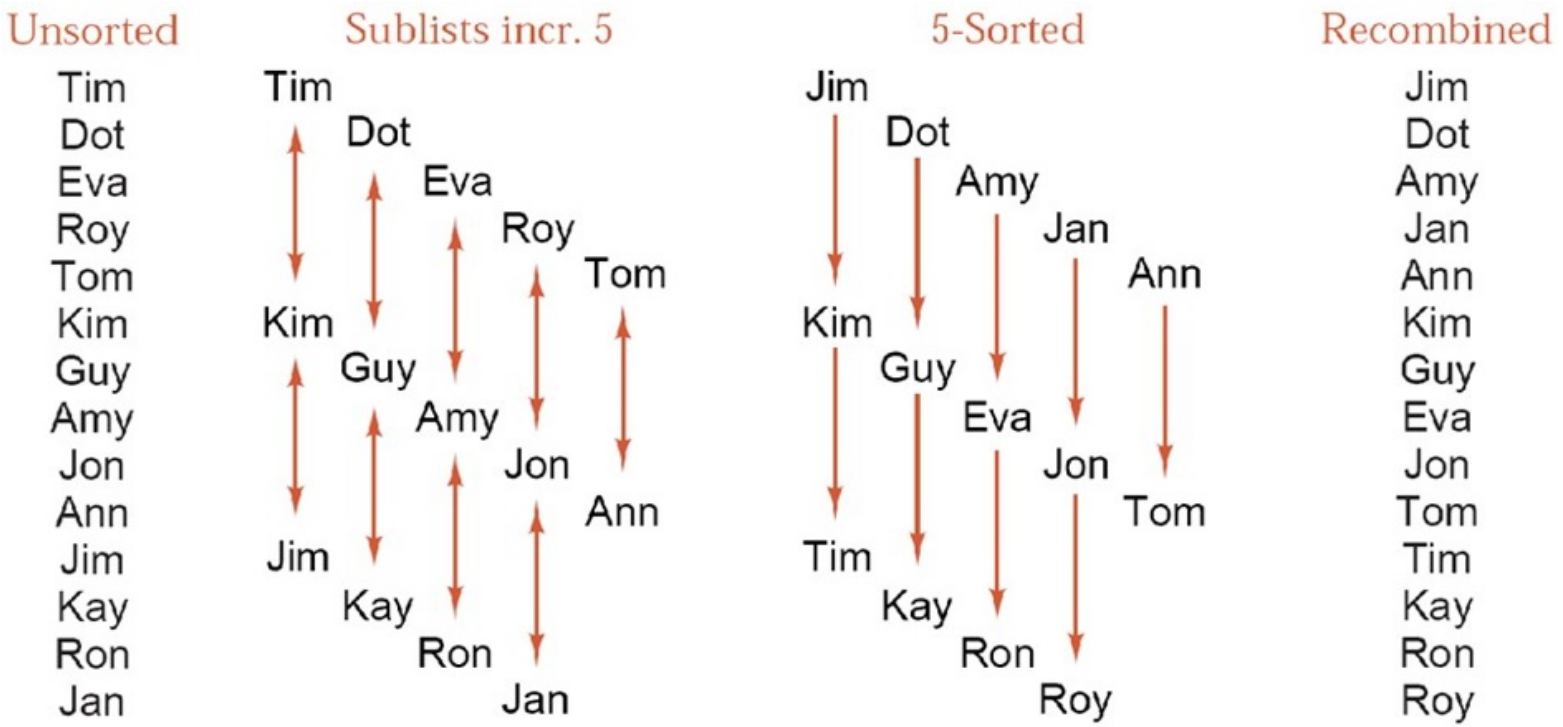


Shell Sort

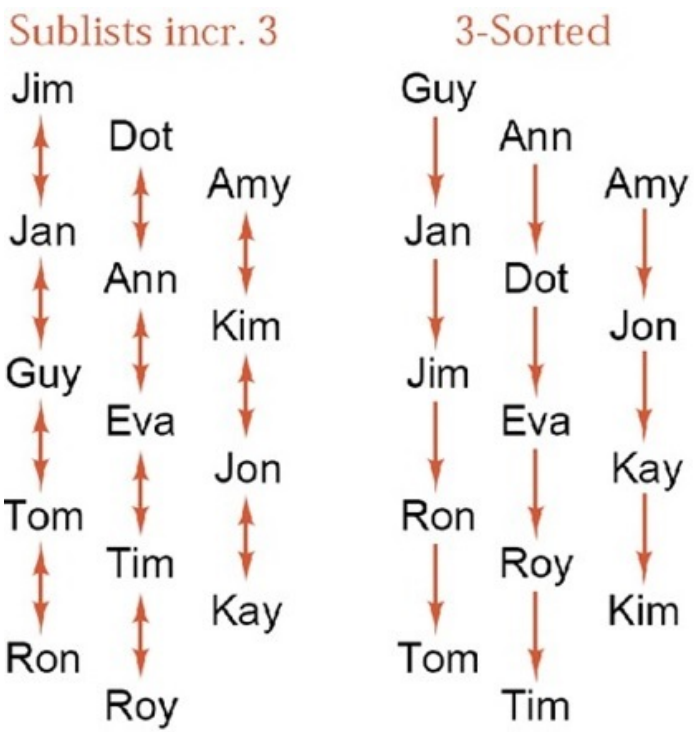


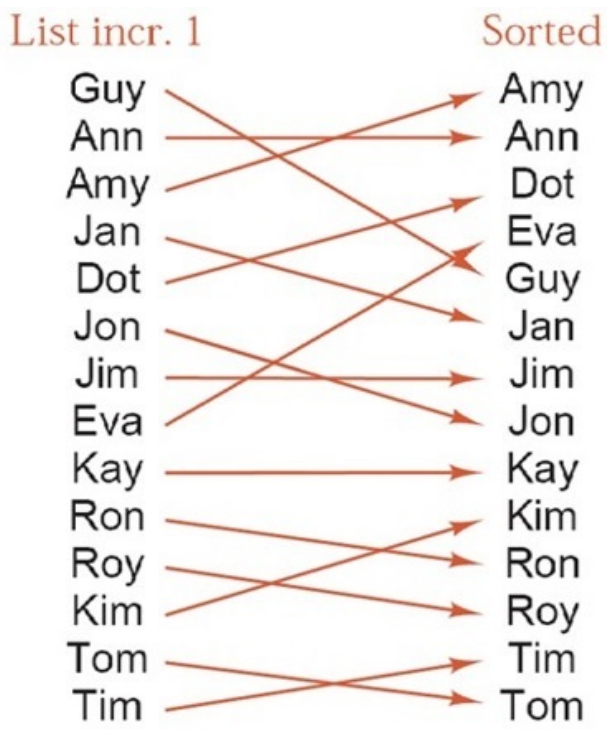
- For the value of K in each iteration, sort the K segments.
- After each iteration, K is reduced until it is 1 in the final iteration.

Example of Shell Sort



Example of Shell Sort





Choosing incremental values

- From more of the comparisons, it is better when we can receive more new information.
- Incremental values should not be multiples of each other, other wise, the same keys compared on one pass would be compared again at the next.
- The final incremental value must be 1.

Choosing incremental values

- Incremental values may be:
  $1, 4, 13, 40, 121, ...$
  $k_t = 1$
  $k_{i-1} = 3 * k_i + 1$
  $t = \lfloor \log_3 n \rfloor - 1$

- or:
  $1, 3, 7, 15, 31, ...$
  $k_t = 1$
  $k_{i-1} = 2 * k_i + 1$
  $t = \lfloor \log_2 n \rfloor - 1$

Shell Sort

```
1  Algorithm ShellSort()
2  Sorts the contiguous list using Shell sort.

3  k = first_incremental_value
4  while k >= 1 do
5  |   segment = 1
6  |   while segment <= k do
7  |   |   SortSegment(segment)
8  |   |   segment = segment + 1
9  |   end
10 |   k = next_incremental_value
11 end
12 End ShellSort
```


Shell Sort

```
1  Algorithm SortSegment(val segment <int>, val k
     <int>)
2  Sorts the segment beginning at segment using
     insertion sort, step between elements in the
     segment is k.

3  current = segment + k
4  while current < count do
5  |   temp = data[current]
6  |   walker = current - k
7  |   while walker >=0 AND temp.key <
   |     data[walker].key do
8  |   |   data[walker + k] = data[walker]
9  |   |   walker = walker - k
10 |   end
11 |   data[walker + k] = temp
12 |   current = current + k
13 end
```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Insertion Sort Efficiency

- Straight insertion sort:
  $f(n) = n(n+1)/2 = O(n^2)$
- Shell sort:
  $O(n^{1.25})$ (Empirical study)

Selection Sort

Selection Sort

In each pass, the smallest/largest item is selected and placed in a sorted list.

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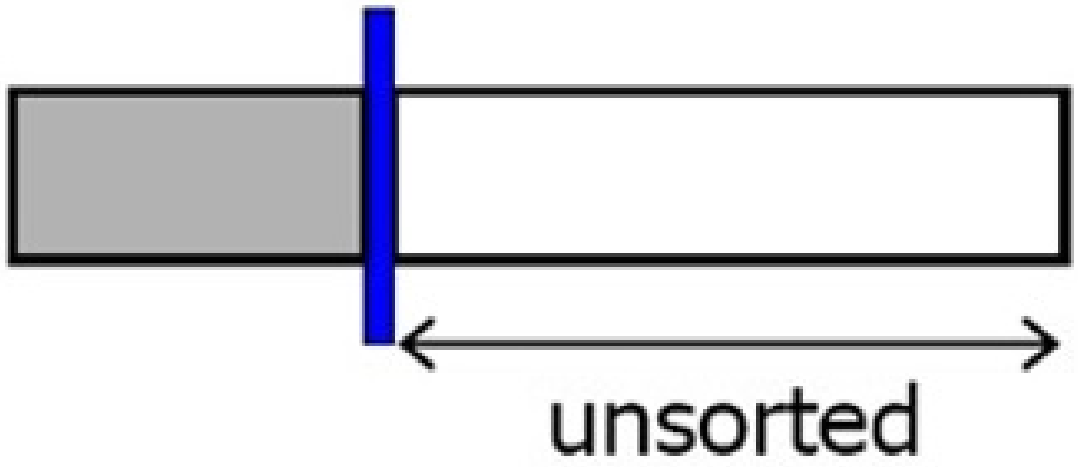
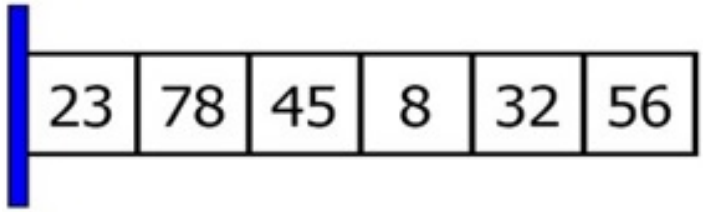
Straight Selection Sort

- The list is divided into two parts: sorted and unsorted.
- In each pass, in the unsorted sublist, the smallest element is selected and exchanged with the first element.



Straight Selection Sort



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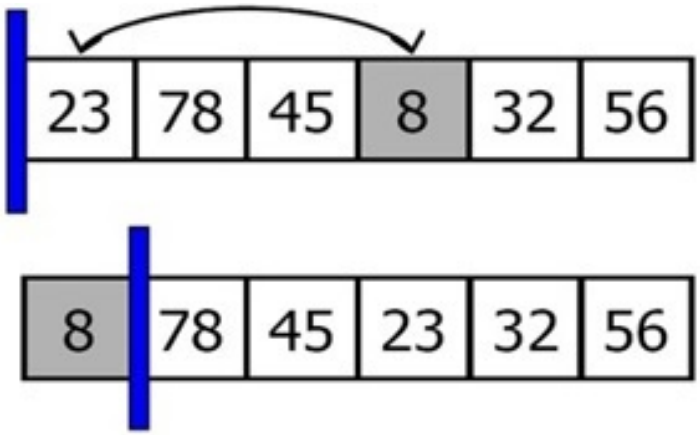
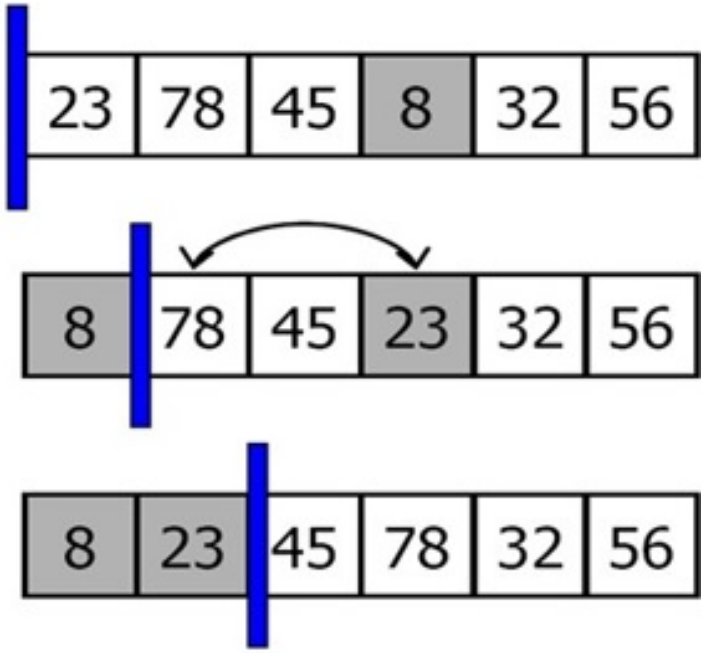
Straight Selection Sort



Straight Selection Sort



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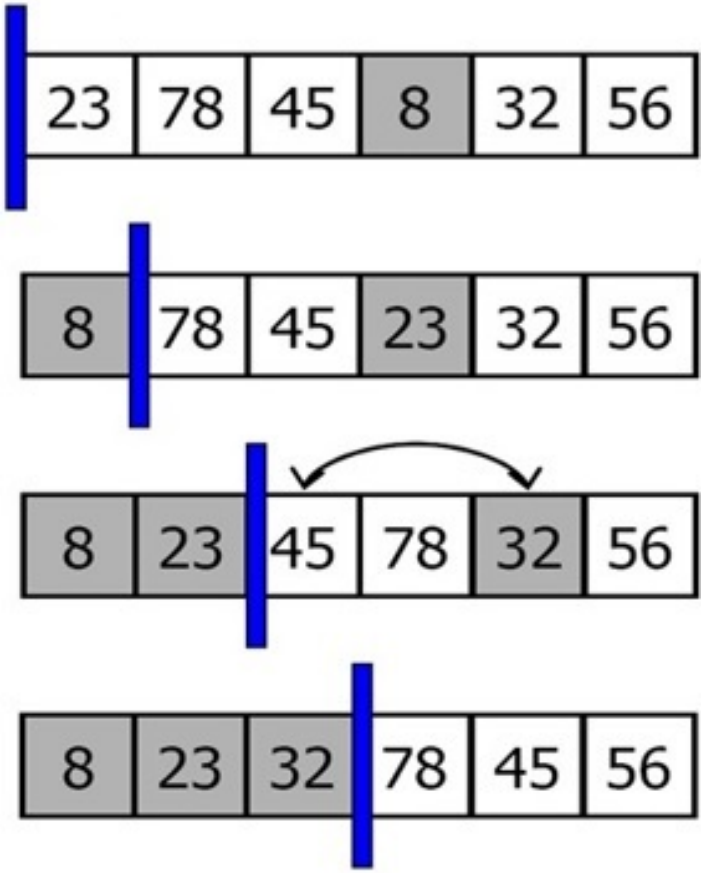
Straight Selection Sort



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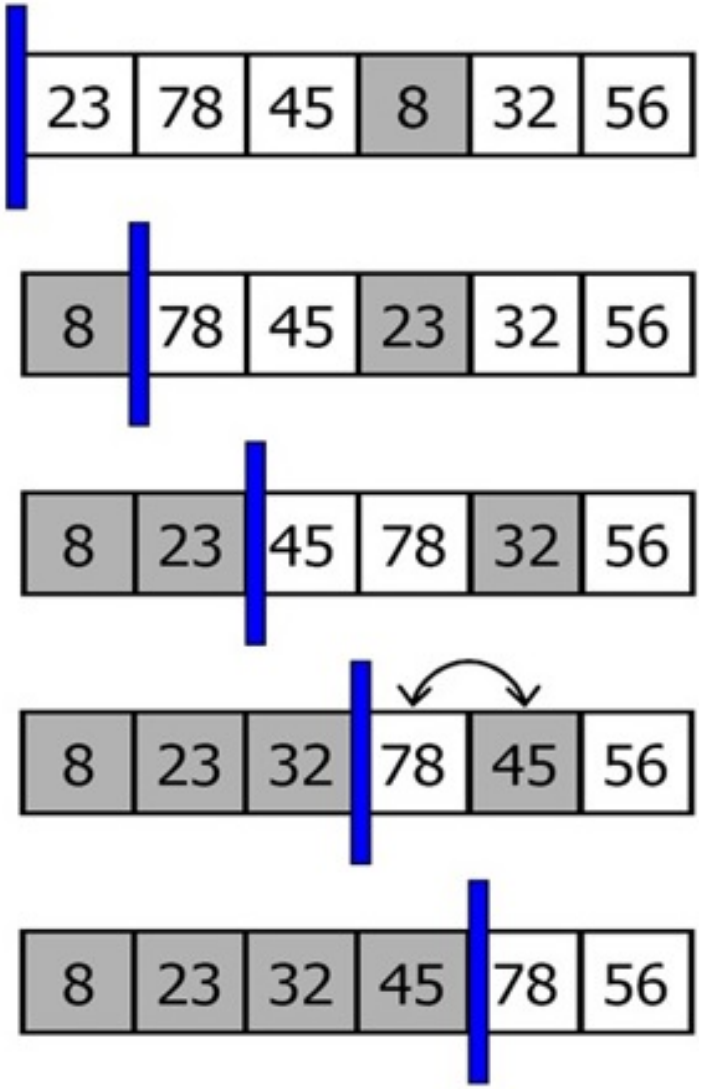
Straight Selection Sort



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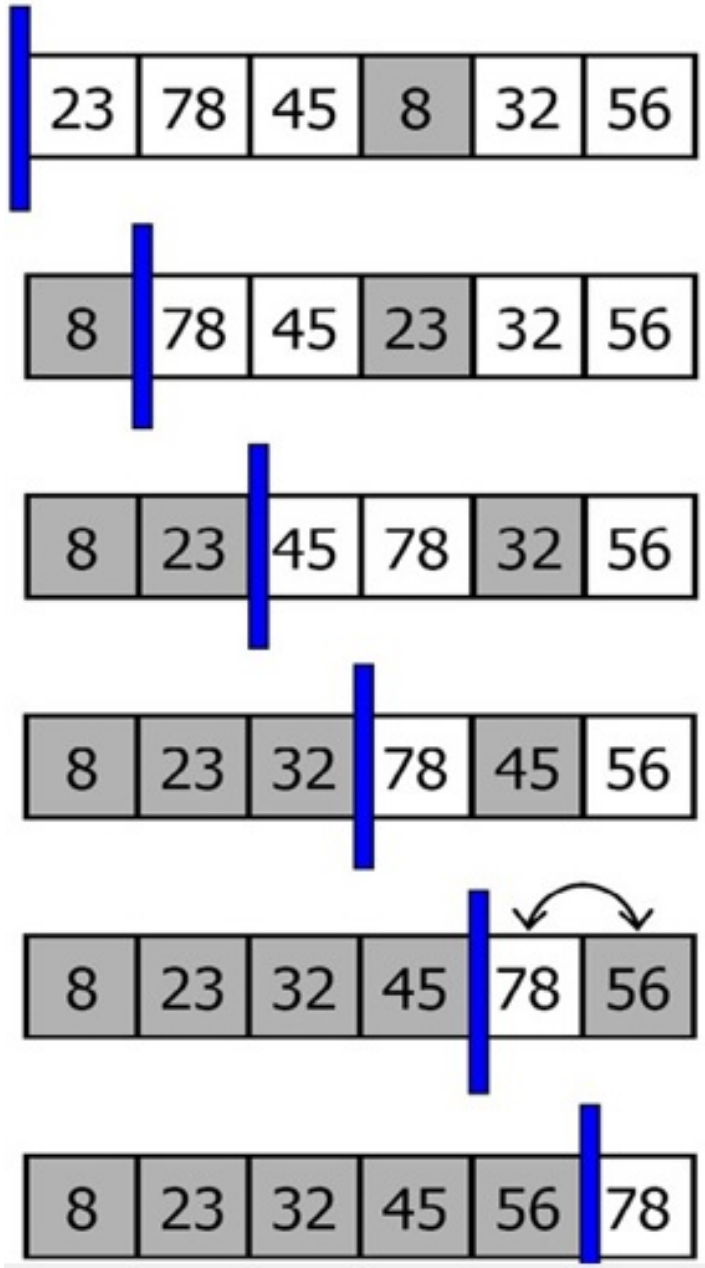
Straight Selection Sort



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Straight Selection Sort

```
1  Algorithm SelectionSort()
2  Sorts the contiguous list using straight selection
     sort.

3  current = 0
4  while current < count - 1 do
5  |    smallest = current
6  |    walker = current + 1
7  |    while walker < count do
8  |    |    if data [walker].key < data [smallest].key
   |    |      then
9  |    |    |    smallest = walker
10 |    |    end
11 |    |    walker = walker + 1
12 |    end
13 |    swap(current, smallest)
14 |    current = current + 1
15 end
```


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Selection Sort Efficiency

- Straight selection sort: $O(n^2)$

Exchange Sort

Exchange Sort

- In each pass, elements that are out of order are exchanged, until the entire list is sorted.
- Exchange is extensively used.

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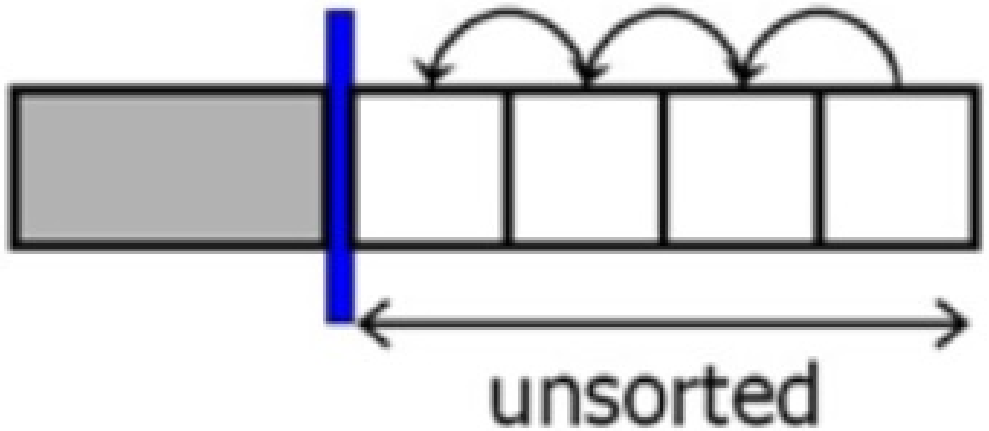
Bubble Sort

- The list is divided into two parts: sorted and unsorted.
- In each pass, the smallest element is bubbled from the unsorted sublist and moved to the sorted sublist.



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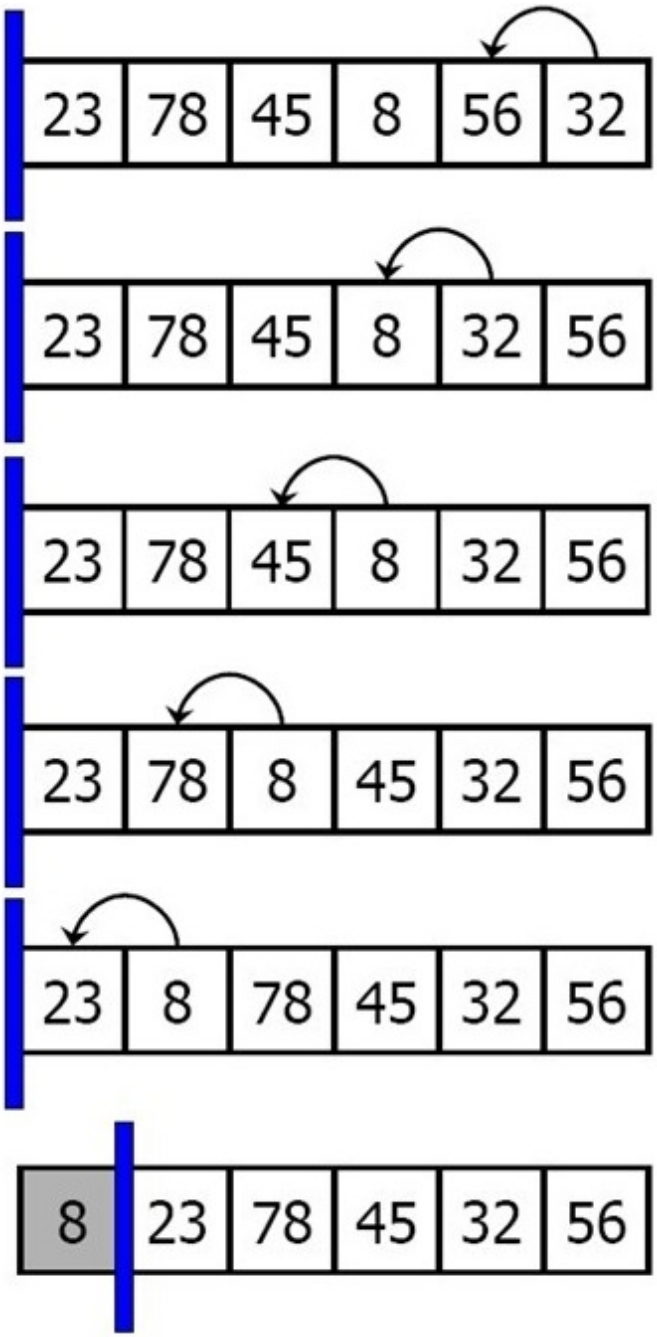
Bubble Sort



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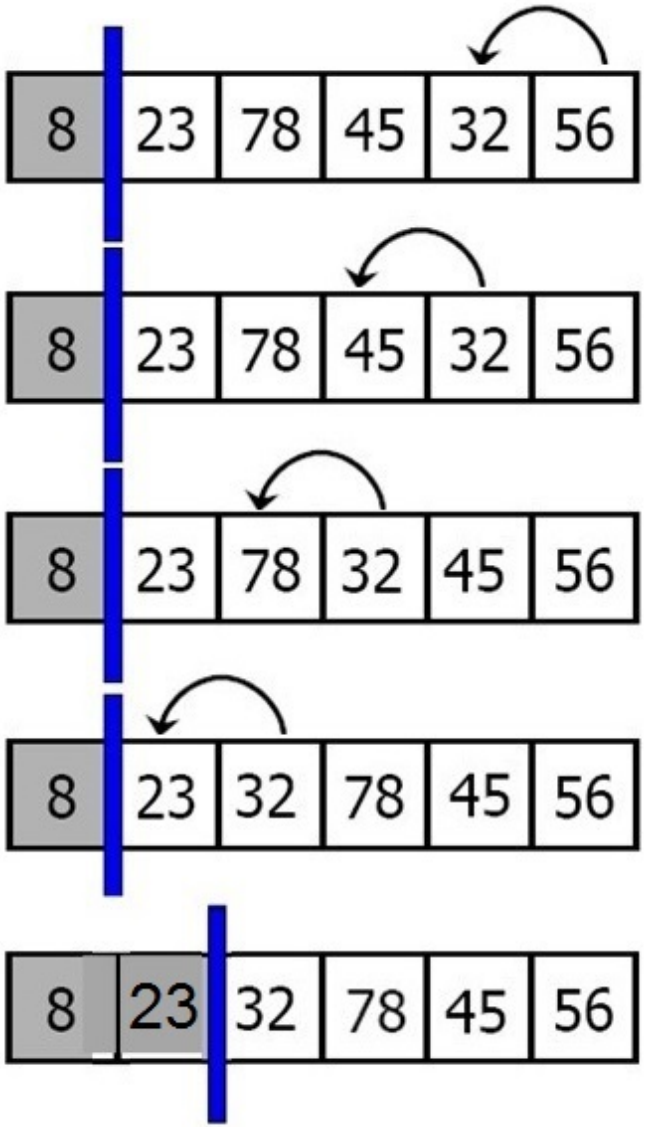
Bubble Sort



Bubble Sort

```
1  Algorithm BubbleSort()
2  Sorts the contiguous list using bubble sort.

3  current = 0
4  flag = False
5  while current < count AND flag = False do
6  |   walker = count - 1
7  |   flag = True
8  |   while walker > current do
9  |   |   if data [walker].key < data [walker-1].key
   |   |     then
10 |   |   |   flag = False
11 |   |   |   swap(walker, walker - 1)
12 |   |   end
13 |   |   walker = walker - 1
14 |   end
15 |   current = current + 1
16 end
```


Exchange Sort Efficiency

- Bubble sort:
  $f(n) = n(n+1)/2 = O(n^2)$

Devide-and-Conquer

Devide-and-Conquer Sort

```
1 Algorithm DevideAndConquer()
2 if the list has length > 1 then
3 |   partition the list into lowlist and
  |     highlist
4 |   lowlist.DevideAndConquer()
5 |   highlist.DevideAndConquer()
6 |   combine(lowlist, highlist)
7 end
8 End DevideAndConquer
```


Devide-and-Conquer Sort

	Partition	Combine
Merge Sort	easy	hard
Quick Sort	hard	easy

Quick Sort

```
1 Algorithm QuickSort()
2 Sorts the contiguous list using quick sort.

3 recursiveQuickSort(0, count - 1)
4 End QuickSort
```

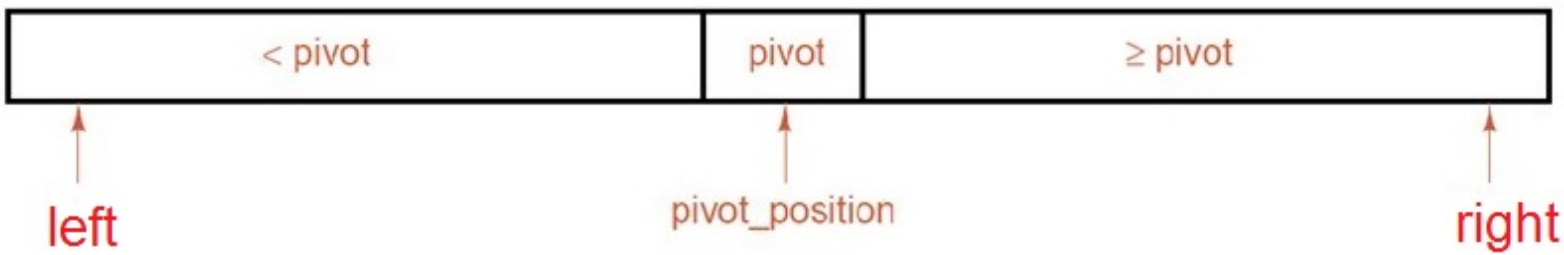

Quick Sort

```
1 Algorithm recursiveQuickSort(val left
    <int>, val right <int>)
2 Sorts the contiguous list using quick sort.
3 Pre: left and right are valid positions
    in the list
4 Post: list sorted

5 if left < right then
6 |   pivot_position = Partition(left, right)
7 |   recursiveQuickSort(left,
  |     pivot_position - 1)
8 |   recursiveQuickSort(pivot_position +
  |     1, right)
9 end
```


Quick Sort

Given a pivot value, the partition rearranges the entries in the list as the following figure:



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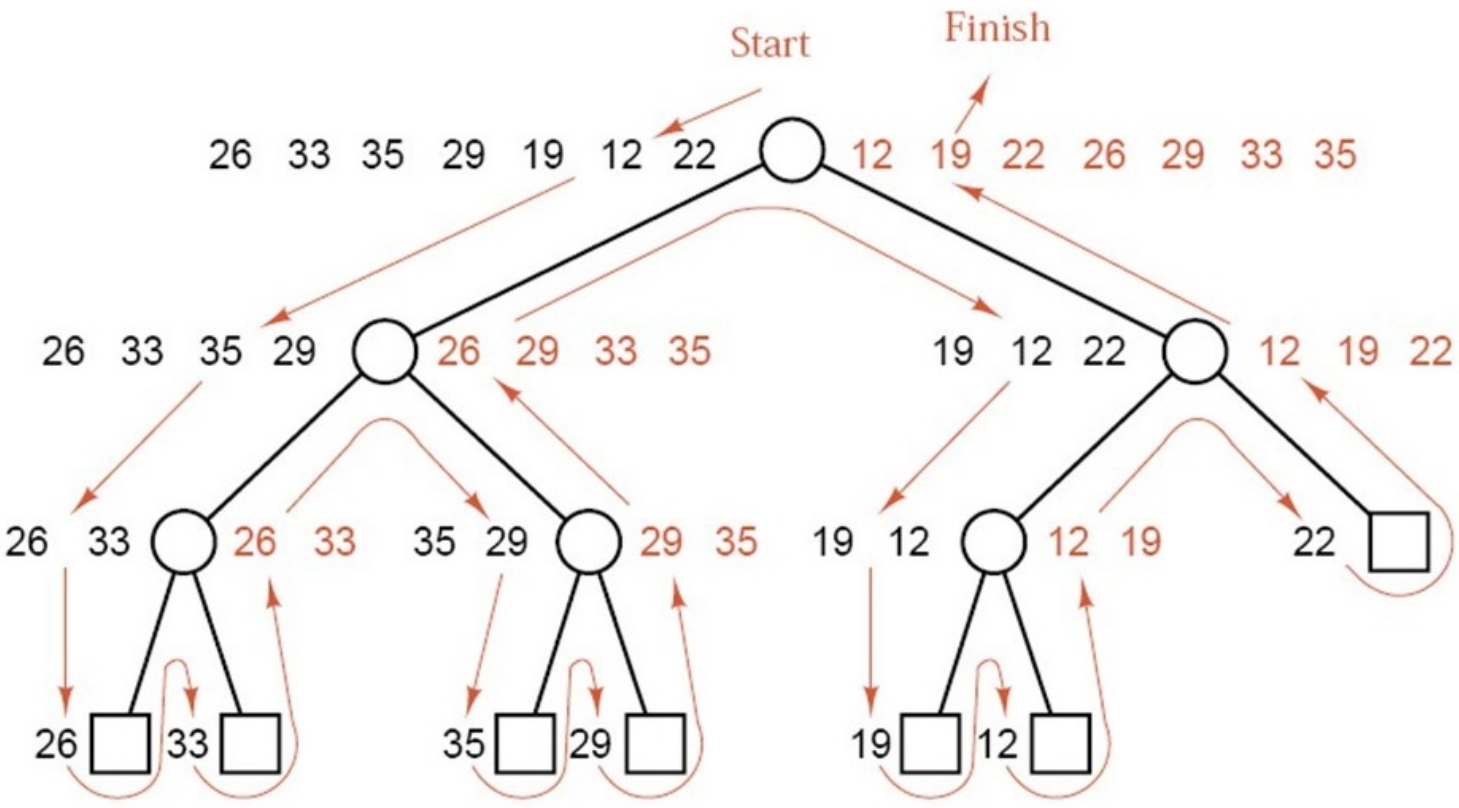
Quick Sort Efficiency

- Quick sort: $O(nlog_2n)$

Merge Sort



Merge Sort

```
1 Algorithm MergeSort()
2 Sorts the linked list using merge sort.

3 recursiveMergeSort(head)
4 End MergeSort
```


Merge Sort

```
1 Algorithm recursiveMergeSort(ref sublist <pointer>)
2 Sorts the linked list using recursive merge sort.

3 if sublist is not NULL AND sublist->link is not NULL then
4 |   Divide(sublist, second_list)
5 |   recursiveMergeSort(sublist)
6 |   recursiveMergeSort(second_list)
7 |   Merge(sublist, second_list)
8 end
9 End recursiveMergeSort
```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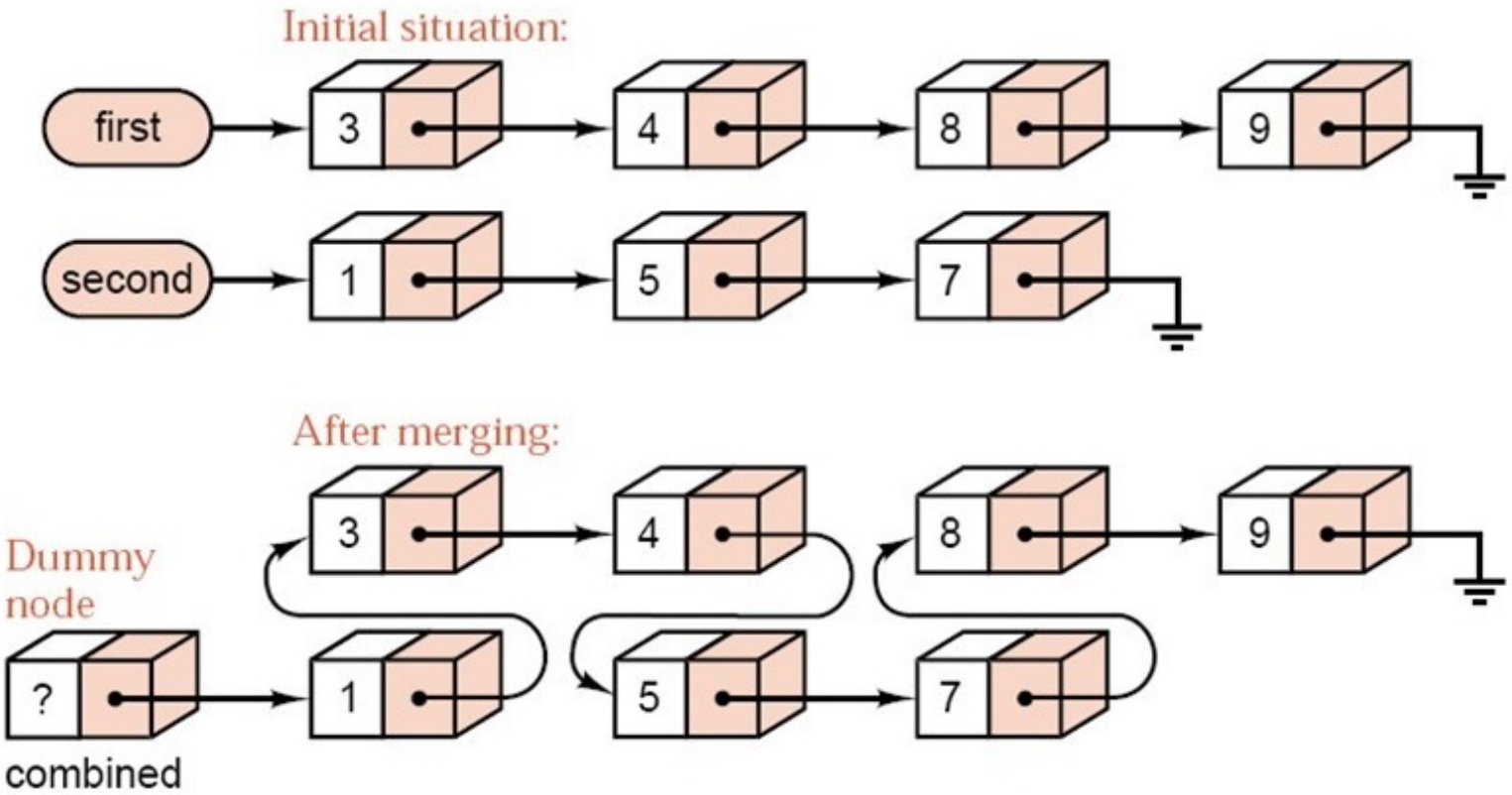
Merge Sort

```
1  Algorithm Divide(val sublist <pointer>, ref
     second_list <pointer>)
2  Divides the list into two halves.

3  midpoint = sublist
4  position = sublist->link
5  while position is not NULL do
6  |    position = position->link
7  |    if position is not NULL then
8  |    |    midpoint = midpoint->link
9  |    |    position = position->link
10 |    end
11 end
12 second_list = midpoint->link
13 midpoint->link = NULL
14 End Divide
```


Merge two sublists



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Merge two sublists

```
1  Algorithm Merge(ref first <pointer>, ref second
     <pointer>)
2  Merges two sorted lists into a sorted list.

3  lastSorted = address of combined
4  while first is not NULL AND second is not NULL
     do
5  |    if first->data.key <= second->data.key then
6  |    |    lastSorted->link = first
7  |    |    lastSorted = first
8  |    |    first = first->link
9  |    else
10 |    |    lastSorted->link = second
11 |    |    lastSorted = second
12 |    |    second = second->link
13 |    end
14 end
```


Merge two sublists

```
1 // ...

2 if first is NULL then
3 |   lastSorted->link = second
4 |   second = NULL
5 else
6 |   lastSorted->link = first
7 end
8 first = combined.link
9 End Merge
```


THANK YOU.