

COMP 250

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INTRODUCING COMPUTER SCIENCE

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Week 6-1: Quadratic

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Giulia Alberini, Fall 2020

WHAT ARE WE GOING TO DO IN THIS VIDEO?



- How to sort a list

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- Bubble sort
- Selection sort
- Insertion sort

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SORTING

- The process of arranging items in a ordered list following a given criterion.
- For example, sorting a list of integers in ascending order (from smallest to largest):

BEFO

3
17
-5
-2
23
4

-2
3
4
17
23

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SORTING ALGORITHMS

There are many techniques for sorting a list

- Selection Sort
- Bubble Sort
- Insertion Sort
- Random Sort :P
- Heap Sort
- Merge Sort
- Quick Sort

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SORTING ALGORITHMS

There are many techniques for sorting a list

- Selection Sort
- Bubble Sort
- Insertion Sort
- Heap Sort
- Merge Sort
- Quick Sort

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Check out how different algorithms compare:

<https://www.youtube.com/watch?v=ZZuD6iUe3Pc>

Later $O(N \cdot \log N)$

OBAMA KNOWS ABOUT SORTING!

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https://www.youtube.com/watch?v=k4RRi_ntQc8

OBSERVATION

Today we are concerned with algorithms, not data structures.

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The following algorithms are in f whether we use
an array list or a linked list.

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BUBBLE SORT

- Bubble sort is the simplest sorting algorithm.

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- Goal: order a list of int <https://eduassistpro.github.io/>

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- IDEA: repeatedly iterate through the list and swap adjacent elements if they are in the wrong order.

BUBBLE SORT – PSEUDOCODE

```
for i from 0 to list.length-1 {  
    for j from 0 to list.length-i-2 {  
        if(list[j] > list[j+1]) {  
            swap(list[j], list[j+1])  
        }  
    }  
}
```

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EXAMPLE – ONE ITERATION

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5

2

8

EXAMPLE – ONE ITERATION

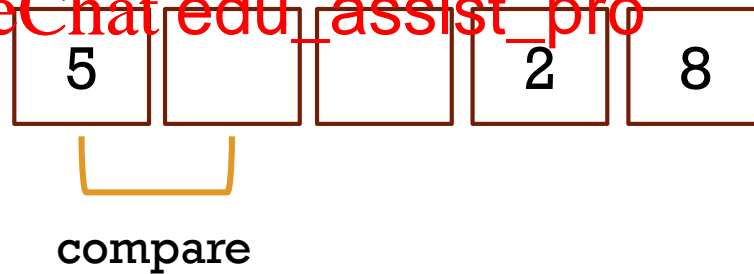
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Iteration #1

- Compare all adjacent elements.

- If needed, swap!



EXAMPLE – ONE ITERATION

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Iteration #1

- Compare all adjacent elements.
- If needed, swap!

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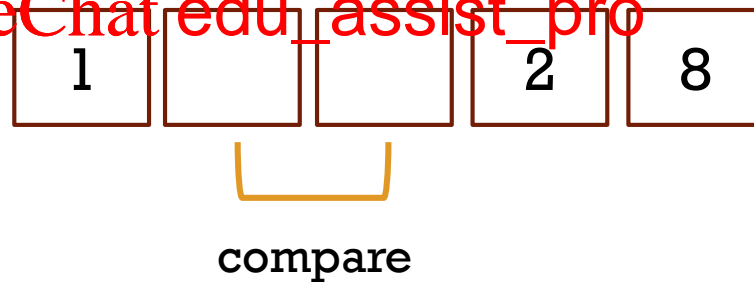
EXAMPLE – ONE ITERATION

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Iteration #1

- Compare all adjacent elements.
- If needed, swap!



EXAMPLE – ONE ITERATION

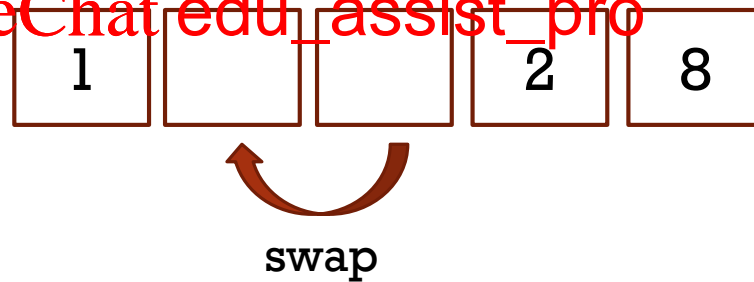
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Iteration #1

- Compare all adjacent elements.
- If needed, swap!

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EXAMPLE – ONE ITERATION

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Iteration #1

- Compare all adjacent elements.
- If needed, swap!



EXAMPLE – ONE ITERATION

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Iteration #1

- Compare all adjacent elements.
- If needed, swap!

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swap

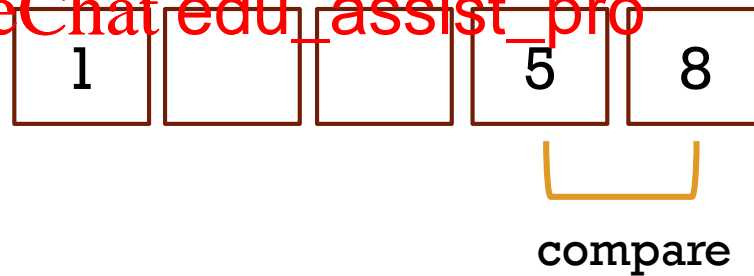
EXAMPLE – ONE ITERATION

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Iteration #1

- Compare all adjacent elements.
- If needed, swap!



WHAT CAN WE SAY AFTER THE FIRST ITERATION?

Q: Where is the largest element ?

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A:

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Q: Where is the smallest element?

A:

WHAT CAN WE SAY AFTER THE FIRST ITERATION?

Q: Where is the largest element ?

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A: It must be at the en <https://eduassistpro.github.io/>

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Q: Where is the smallest element?

A: Anywhere (except position N-1)

WHAT CAN WE SAY AFTER THE FIRST ITERATION?

Q: Where is the largest element ?

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A: It must be at the en <https://eduassistpro.github.io/>

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- Since each time we iterate through the list we ensure that the largest element is in the correct position. → at each iteration we can stop comparing adjacent elements one step earlier.

BUBBLE SORT – PSEUDOCODE

```
for i from 0 to list.length-1 {  
    for j from 0 to list.length-i-2 {  
        if(list[j] > list[j+1]) {  
            swap(list[j], list[j+1])  
        }  
    }  
}
```

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EXAMPLE

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We left off at the end of
Iteration #1

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Unsorted

Sorted

EXAMPLE

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Iteration #2

- Compare all adjacent elements up to index 3.
- If needed, swap!



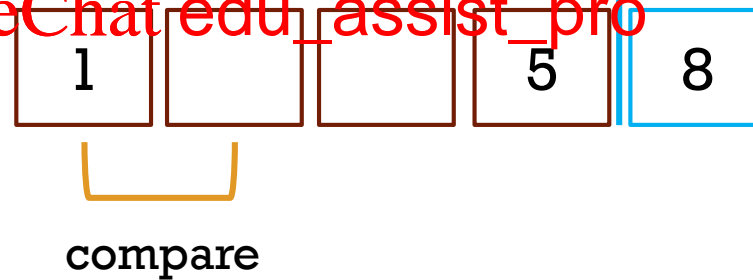
EXAMPLE

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Iteration #2

- Compare all adjacent elements up to index 3.
- If needed, swap!



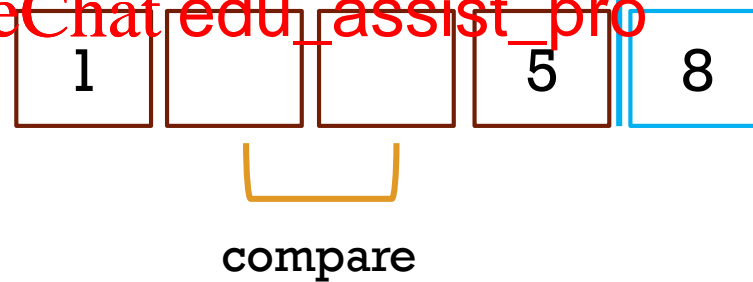
EXAMPLE

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Iteration #2

- Compare all adjacent elements up to index 3.
- If needed, swap!



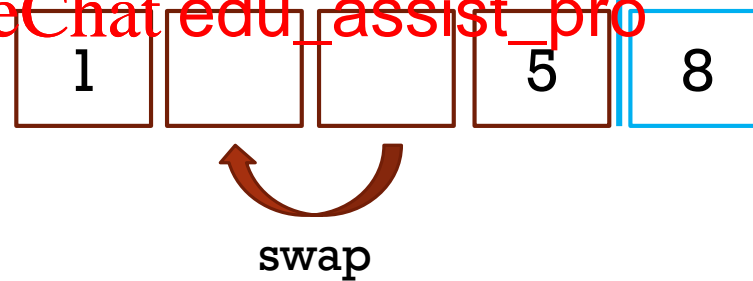
EXAMPLE

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Iteration #2

- Compare all adjacent elements up to index 3.
- If needed, swap!



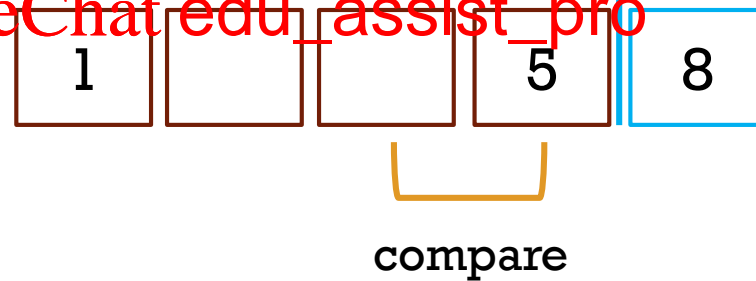
EXAMPLE

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Iteration #2

- Compare all adjacent elements up to index 3.
- If needed, swap!



EXAMPLE

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Iteration #3

- Compare all adjacent elements up to index 2.
- If needed, swap!



Note: now the list is sorted, but the algorithm does not know that.
When can the algorithm infer that the list is sorted?

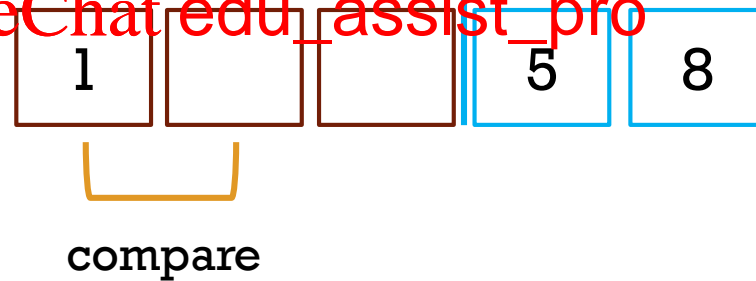
EXAMPLE

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Iteration #3

- Compare all adjacent elements up to index 2.
- If needed, swap!



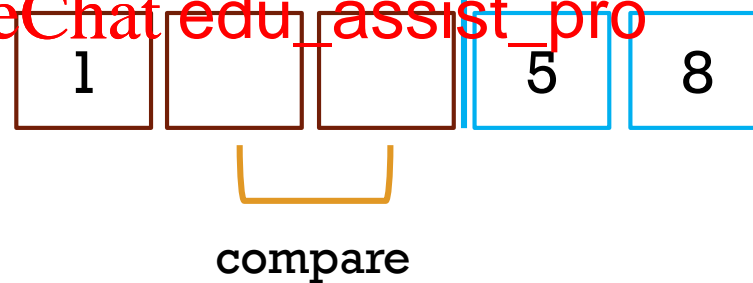
EXAMPLE

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Iteration #3

- Compare all adjacent elements up to index 2.
- If needed, swap!



No swap was needed in this iteration → the list is sorted!

EXAMPLE

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No swap was needed in the last iteration. We can stop comparing. The list is sorted!

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BUBBLE SORT – PSEUDOCODE

```
sorted = false
i = 0
while (!sorted) {
    sorted =
    for j from 1 to n-2 {
        if(list[j] > list[j+1])
            swap(list[j], list[j+1])
        sorted = false
    }
    i++
}
```

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SELECTION SORT

- Goal: order a list of integers in ascending order
- Idea: consider the list as if it was divided into two parts, one sorted and the other unsorted (the sorted part is empty)
- Procedure:
 - Select the smallest element in the unsorted part of the list
 - Swap that element with the element in the initial position of the unsorted array
 - Change where you divide the array from the sorted part to the unsorted part.

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EXAMPLE

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EXAMPLE

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- Select

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EXAMPLE

- Select
- Swap

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5

2



EXAMPLE

- Select
- Swap

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EXAMPLE

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- Select
- Swap
- Update delimiter

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EXAMPLE

Assignment Project Exam Help

- Select

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EXAMPLE

- Select
- Swap

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1

2



EXAMPLE

- Select
- Swap

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1

5



EXAMPLE

- Select
- Swap
- Update

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EXAMPLE

Assignment Project Exam Help

- Select

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EXAMPLE

- Select
- Swap

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1

5



EXAMPLE

- Select
- Swap

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1

7



EXAMPLE

- Select
- Swap
- Update

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EXAMPLE

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- Done!

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SELECTION SORT – PSEUDOCODE

```
for delim from 0 to N-2 {
```

Repeat until list is all sorted (~N times)

```
    min = delim
```

```
    for i from delim+1 to N-1 {
```

```
        if(list[i]
```

```
            min = i
```

```
        }
```

```
    }
```

```
    if(min != delim) {
```

```
        swap(list[min], list[delim])
```

```
    }
```

```
}
```

Swap the min element in the first position of the unsorted part of the list.

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SELECTION SORT

```
for delim from 0 to N-2
```

```
    for i from delim+1 to N-1
```

```
        ...
```

- How many times does the inner lo

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SELECTION SORT

```
for delim from 0 to N-2  
    for i from delim+1 to N-1  
        ...
```

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- How many times does the inner lo

➤ $N-1 + N-2 + N-3 + \dots + 2 + 1$

SELECTION SORT

```
for delim from 0 to N-2
```

```
    for i from delim+1 to N-1
```

```
        ...
```

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- How many times does the inner lo

➤ $N-1 + N-2 + N-3 + \dots + 2 + 1 = \mathbf{N*(N-1)/2}$

COMPARISON

Bubblesort

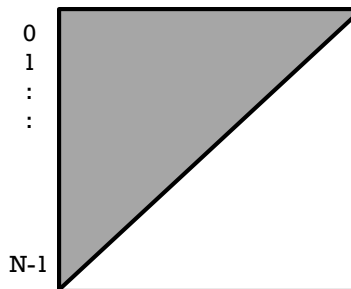
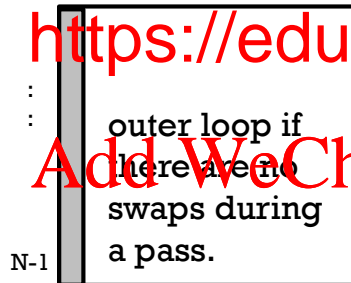
```
while(!sorted)
  for i from 0 to N - 2 - i
```

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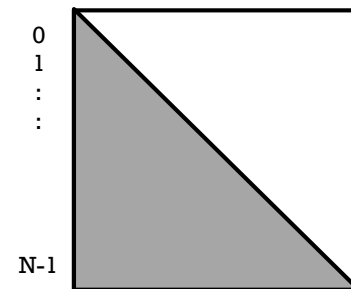
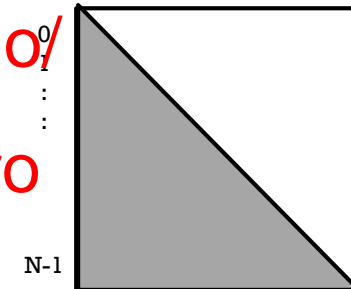
Dark area denotes which elements of the list need to be examined at each iteration of the outer loop.



Outer loop

Selection sort

```
for delim from 0 to N-2
  for i from delim+1 to N-1
```



Outer loop

Worst case

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|

RT

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INSERTION SORT

- Goal: order a list of integers in ascending order
- Idea: consider the list as if it was divided into two parts, one sorted and the other unsorted (the sorted part is empty)
- Procedure:
 - Select the first element of the unsorted part of the list
 - Insert such element into its correct position in the sorted part of the list.
 - Change where you divide the array from the sorted part to the unsorted part.

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EXAMPLE

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EXAMPLE

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- Select

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EXAMPLE

- Select
- Insert

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EXAMPLE

- Select
- Insert
- Update

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EXAMPLE

- Select

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EXAMPLE

- Select
- Insert

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5

2



EXAMPLE

- Select
- Insert
- Update

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EXAMPLE

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- Select

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EXAMPLE

- Select
- Insert

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1

2



EXAMPLE

- Select
- Insert
- Update

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EXAMPLE

- Select

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1

2

EXAMPLE

- Select
- Insert

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1

2



EXAMPLE

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- Done!

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INSERTING

Mechanism is similar to inserting (adding) an element to an array list:

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Shift all elements ahead by one make a hole,
and then fill the hole.

INSERTION SORT – PSEUDOCODE

```
for i from 0 to N-1 {
```

```
    element = list[i]
```

```
    k = i
```

```
    while(k > 0 && e
```

```
        list[k] = list[k-1]
```

```
        k--
```

```
    }
```

```
    list[k] = element
```

```
}
```

Repeat until list is all sorted (~N times)

Find where the element should be inserted in the sorted part of the list + make space for it (shift all the larger elements to the right)

Insert the element in the sorted part of the list.

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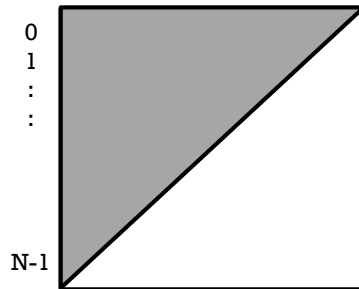
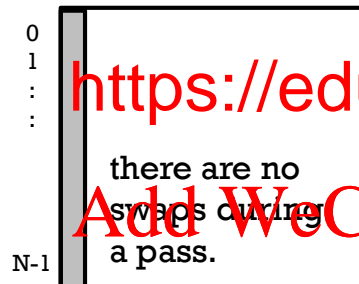
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COMPARISON OF THE THREE ALGORITHMS

Bubblesort

```
while(!sorted)
  for j from 0 to N - 2 - i
```

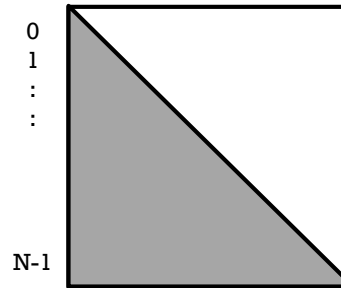
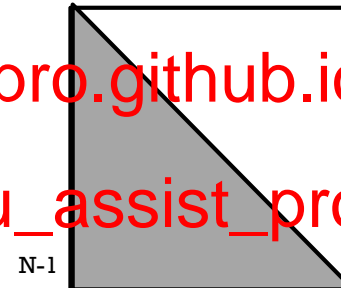
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Outer loop

Selection sort

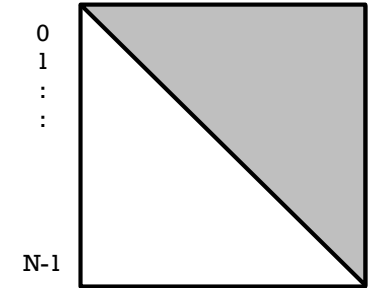
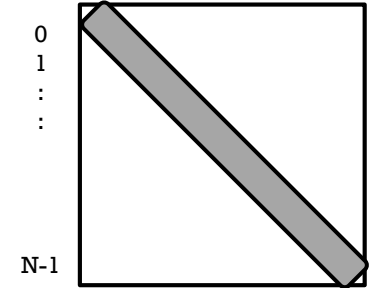
```
for delim from 0 to N-2
  for i from delim+1 to N-1
```



Outer loop

Insertion sort

```
for i from 0 to N-1
  while ....
```



Outer loop

Performance depends highly on initial data. Also, it depends on implementation (array vs. linked list), e.g. what is cost of swap and 'shift'.

Best case

Worst case

An orange paint roller with a red handle, positioned horizontally. The roller is partially filled with orange paint, and there are orange paint splatters and drips around it. The text "Coming Soon" is written in white on the orange part of the roller.

Coming Soon

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In the next

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