

# COMP 250

## INTRODUCTION TO COMPUTER SCIENCE

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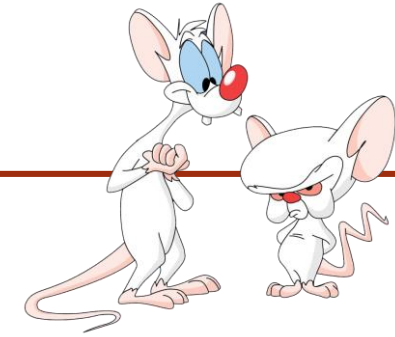
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Week 6-1: Quadratic Sorting a List

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Giulia Alberini, Fall 2020

# WHAT ARE WE GOING TO DO IN THIS VIDEO?



## ■ How to sort a list Assignment Project Exam Help

- 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):

BEFORE

3
17
-5
-2
23
4

AFTER

-5
-2
3
4
17
23

# 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

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Today  $O(N^2)$   
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- Heap Sort
- Merge Sort
- Quick Sort

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

Check out how different algorithms compare:  
<https://www.youtube.com/watch?v=ZZuD6iUe3Pc>

# OBAMA KNOWS ABOUT SORTING!

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[https://www.youtube.com/watch?v=k4RRi\\_ntQc8](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 independent of whether we use an array list or a linked list.

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# BUBBLE SORT

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# BUBBLE SORT

---

- Bubble sort is the simplest sorting algorithm.

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- Goal: order a list of integers in ascending order

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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 -2 {  
        if(list[j] > list[j+1]) {  
            swap(list[j], list[j+1])  
        }  
    }  
}
```

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## EXAMPLE – ONE ITERATION

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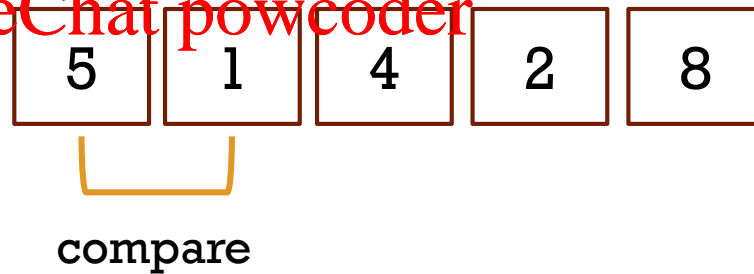
## EXAMPLE – ONE ITERATION

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Iteration #1

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



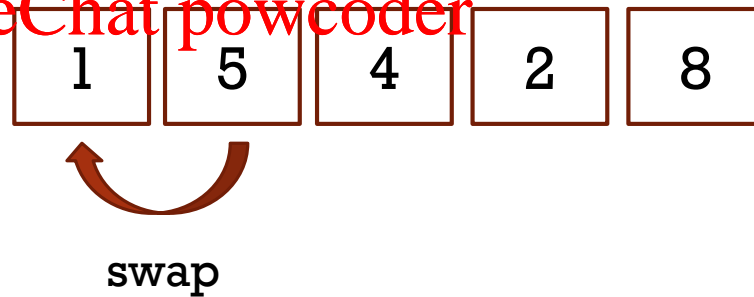
## EXAMPLE – ONE ITERATION

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Iteration #1

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



## EXAMPLE – ONE ITERATION

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Iteration #1

- Compare all adjacent elements.

- If needed, swap!



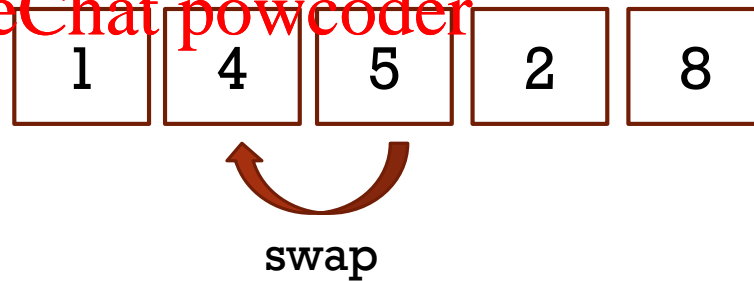
## EXAMPLE – ONE ITERATION

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Iteration #1

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



## EXAMPLE – ONE ITERATION

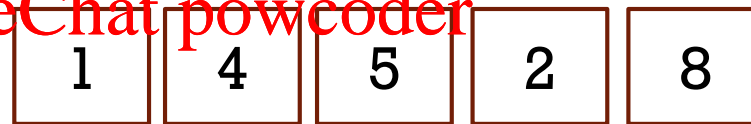
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Iteration #1

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

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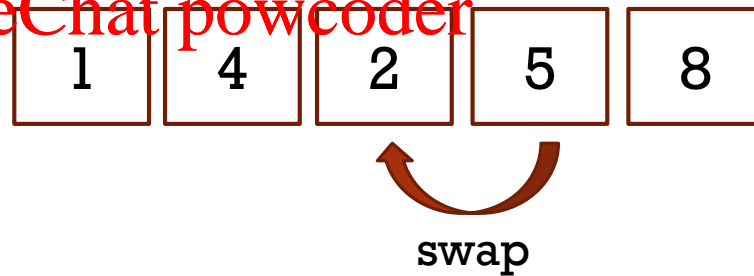
## EXAMPLE – ONE ITERATION

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Iteration #1

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



## EXAMPLE – ONE ITERATION

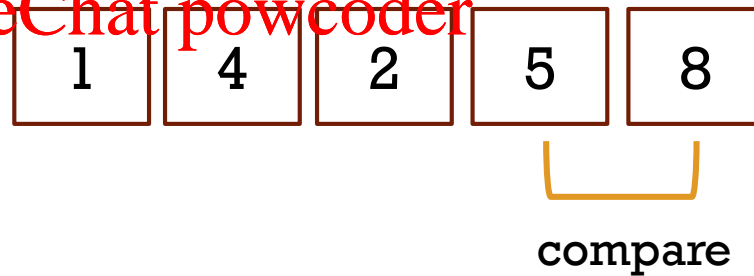
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Iteration #1

- Compare all adjacent elements.

- If needed, swap!



## 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 end of the list (position  $N-1$ )

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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 end of the list (position  $N-1$ )

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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])  
        }  
    }  
}
```

## EXAMPLE

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Unsorted

Sorted

We left off at the end of  
Iteration #1

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1	4	2	5	8
---	---	---	---	---

## EXAMPLE

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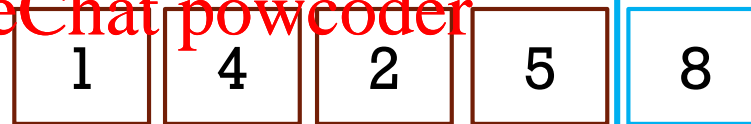
Unsorted

Sorted

Iteration #2

- Compare all adjacent elements up to index 3.

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- If needed, swap!



## EXAMPLE

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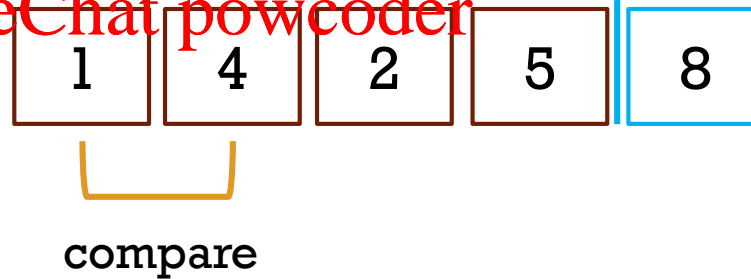
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Unsorted

Sorted

Iteration #2

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



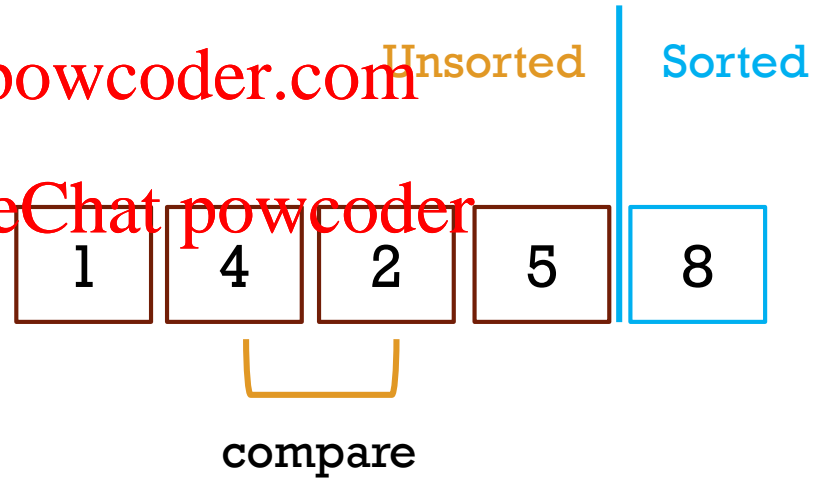
## EXAMPLE

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Iteration #2

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



## EXAMPLE

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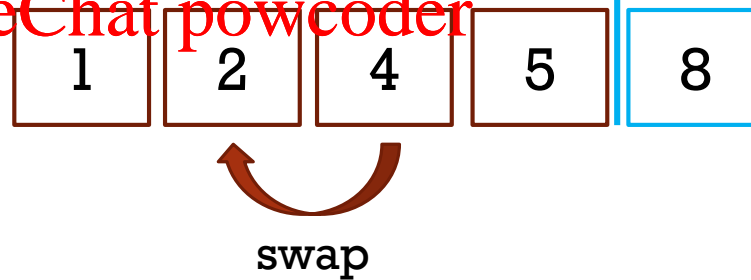
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Unsorted

Sorted

Iteration #2

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



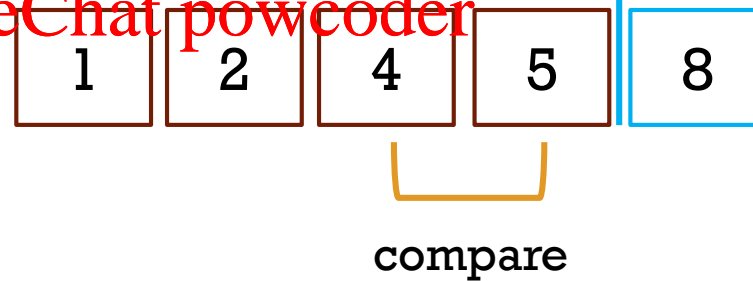
## EXAMPLE

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Iteration #2

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



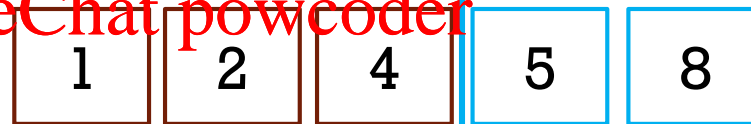
## EXAMPLE

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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?

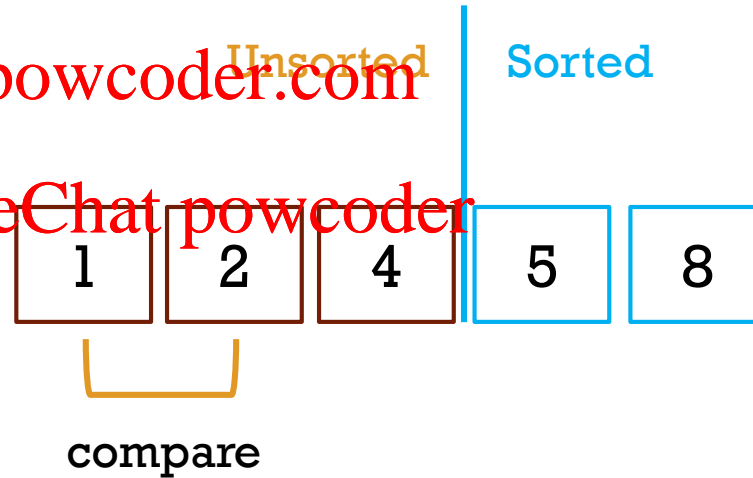
## EXAMPLE

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Iteration #3

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



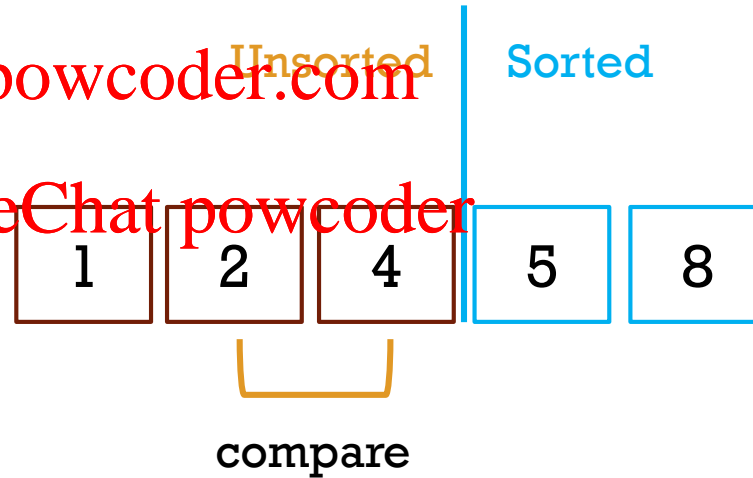
## EXAMPLE

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

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SELECTION SORT

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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. (note: at the beginning the sorted part is empty)  
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- Procedure:  
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  - 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.

## EXAMPLE

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5	1	7	2
---	---	---	---

## EXAMPLE

- Select

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5	1	7	2
---	---	---	---

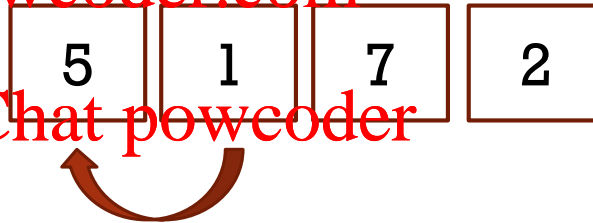
## EXAMPLE

- Select
- Swap

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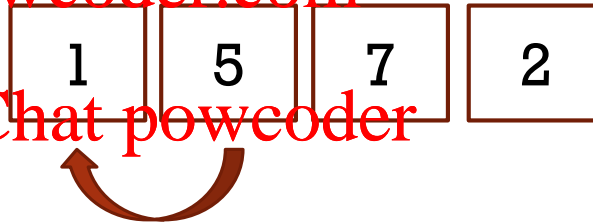
## EXAMPLE

- Select
- Swap

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## EXAMPLE

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- Select
- Swap
- Update delimiter

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1	5	7	2
---	---	---	---



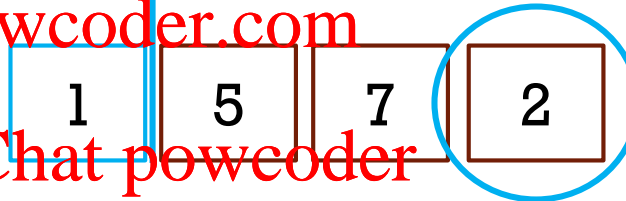
## EXAMPLE

- Select

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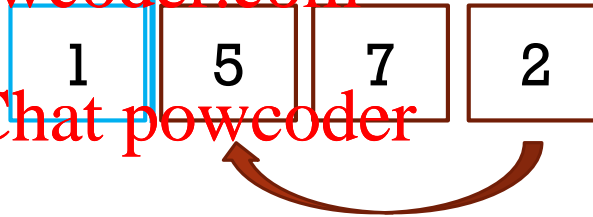
## EXAMPLE

- Select
- Swap

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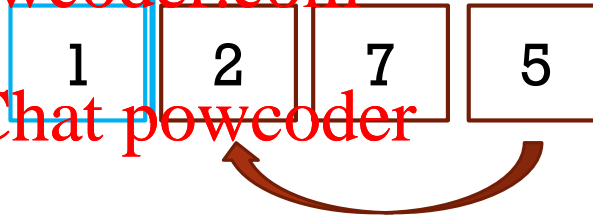
## EXAMPLE

- Select
- Swap

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## EXAMPLE

- Select
- Swap
- Update

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<https://powcoder.com>

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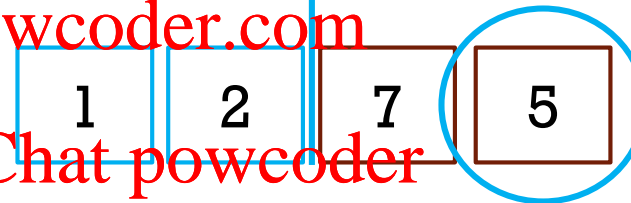
## EXAMPLE

- Select

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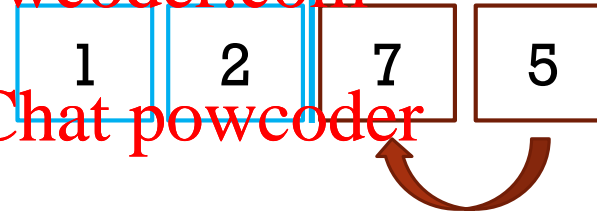
## EXAMPLE

- Select
- Swap

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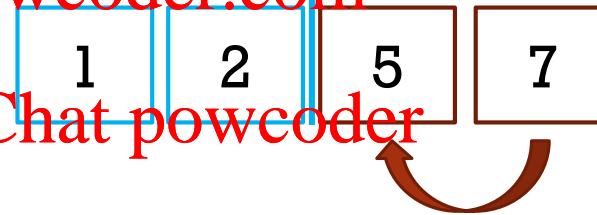
## EXAMPLE

- Select
- Swap

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## EXAMPLE

- Select
- Swap
- Update

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## EXAMPLE

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- Done!

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1

2

5

7

## 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] < list[min]) {
```

```
            min = i
```

```
        }
```

```
    }
```

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

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

```
    }
```

```
}
```

Find the index of the min element in the unsorted part of the list

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
```

```
        ...
```

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- How many times does the inner loop iterate?

## 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 loop iterate?

➤  $N-1 + N-2 + N-3 + \dots + 2 + 1$

## 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 loop iterate?

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

# COMPARISON

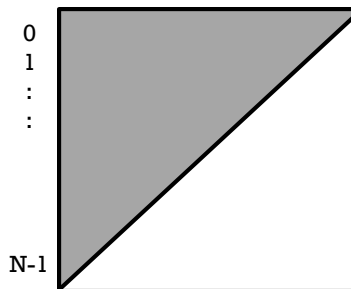
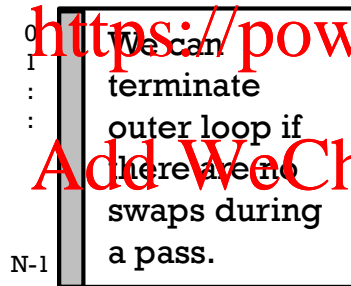
## Bubblesort

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

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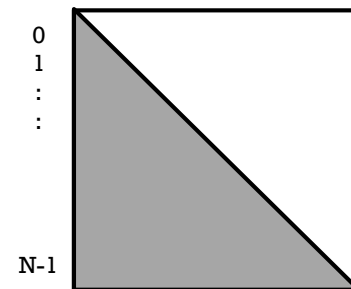
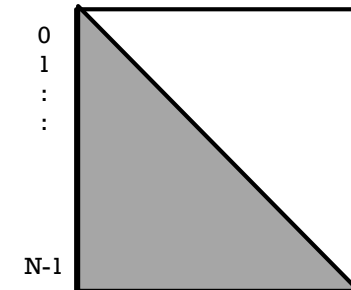
Dark area denotes which elements of the list need to be examined at each iteration of the outer loop.



Outer loop

## Selection sort

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



Outer loop

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INSERTION SORT

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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. (note: at the beginning the sorted part is empty)  
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- Procedure:  
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  - 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.



## EXAMPLE

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5	1	7	2
---	---	---	---

## EXAMPLE

- Select

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5	1	7	2
---	---	---	---

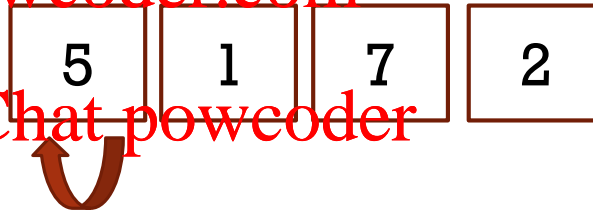
## EXAMPLE

- Select
- Insert

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## EXAMPLE

- Select
- Insert
- Update

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5	1	7	2
---	---	---	---

## EXAMPLE

- Select

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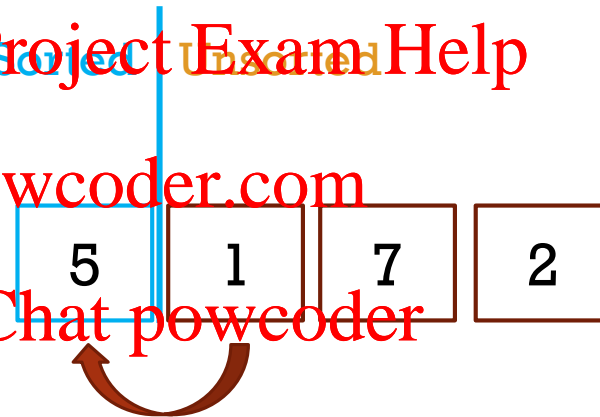
## EXAMPLE

- Select
- Insert

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## EXAMPLE

- Select
- Insert
- Update

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## EXAMPLE

- Select

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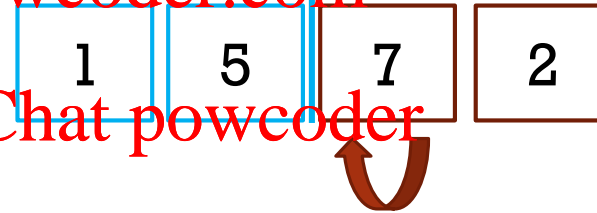
## EXAMPLE

- Select
- Insert

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## EXAMPLE

- Select
- Insert
- Update

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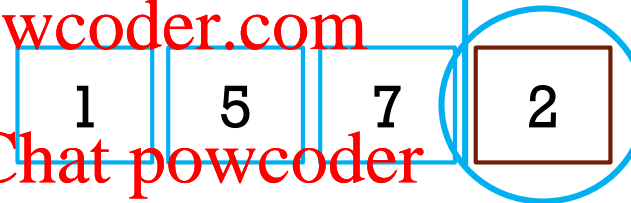
## EXAMPLE

- Select

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## EXAMPLE

- Select
- Insert

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## EXAMPLE

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- Done!

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1

2

5

7

## INSERTING

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

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Shift all elements ahead by one position to 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 && element < list[k-1]) {  
        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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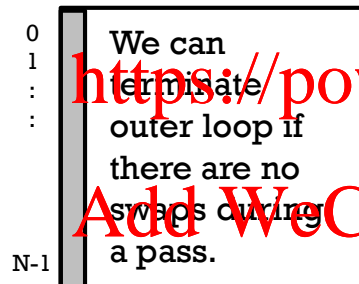
# COMPARISON OF THE THREE ALGORITHMS

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

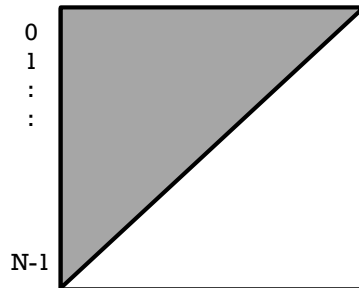
## Bubblesort

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

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Best case

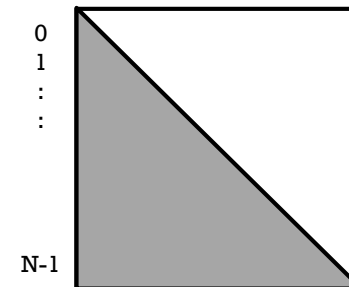
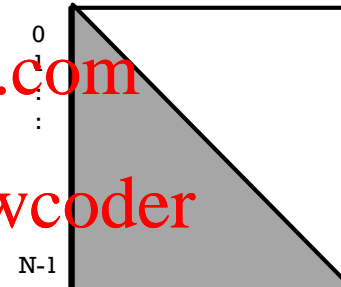


Worst case

Outer loop

## Selection sort

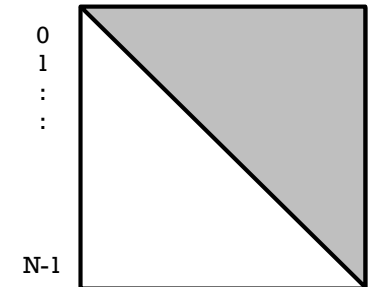
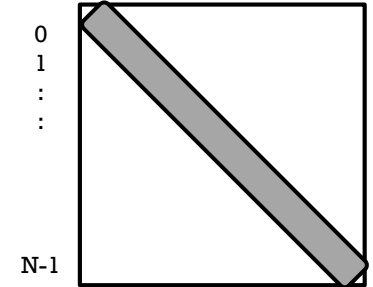
```
for delim from 0 to N-2
  for i from delim+1 to N-1
```



Outer loop

## Insertion sort

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



Outer loop





# Coming Soon

## Assignment Project Exam Help

In the next video:

<https://powcoder.com>

- Asymptotic notations

Add WeChat powcoder