COMP 250
INTRODUCTION TO COMPUTER SCIENCE

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Week 6-1 : Quadratic Sorting a List

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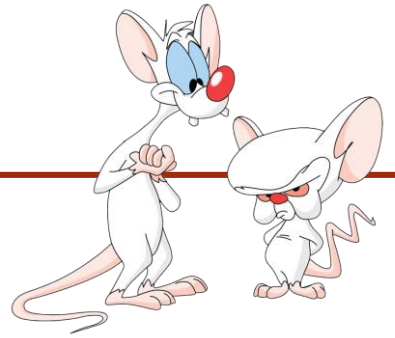
Giulia Alberini, Fall 2020

WHAT ARE WE GOING TO DO IN THIS VIDEO?



- How to sort a list
  - 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):

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BEFORE	AFTER
3	-5
17	-2
-5	3
-2	4
23	17
4	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

Today $O(N^2)$

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

- Heap Sort
- Merge Sort
- Quick Sort

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

OBAMA KNOWS ABOUT SORTING!

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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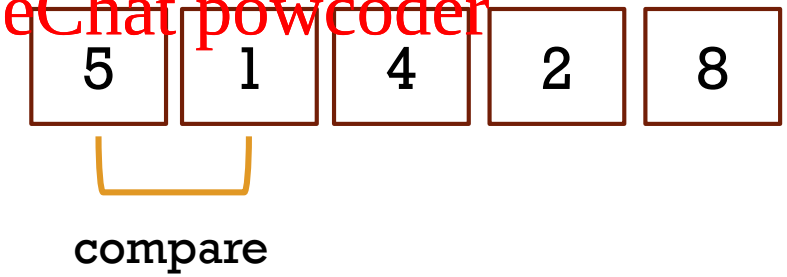
Iteration #1

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



EXAMPLE – ONE ITERATION

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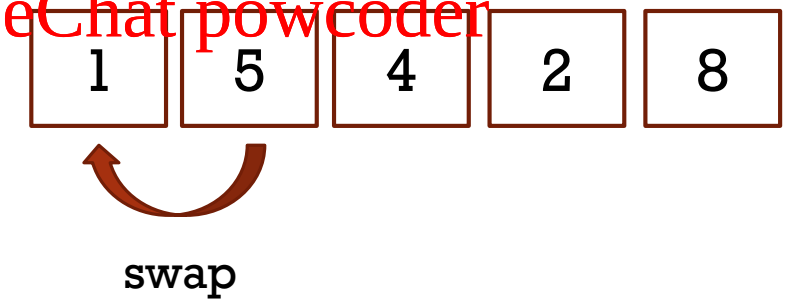

EXAMPLE – ONE ITERATION

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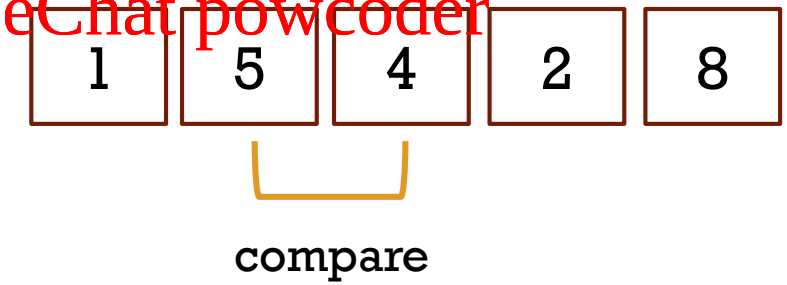

EXAMPLE – ONE ITERATION

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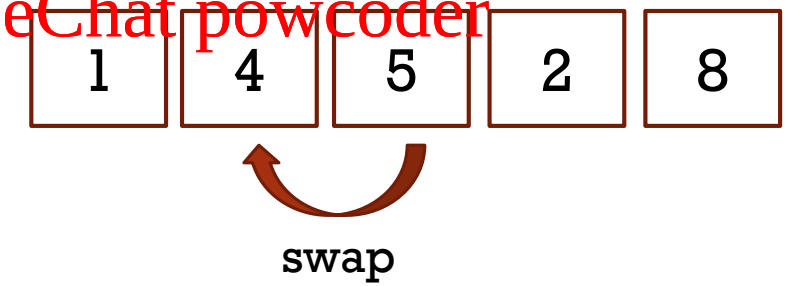

EXAMPLE – ONE ITERATION

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Iteration #1

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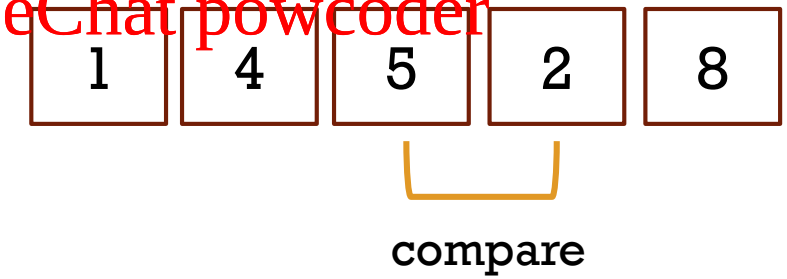

EXAMPLE – ONE ITERATION

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Iteration #1

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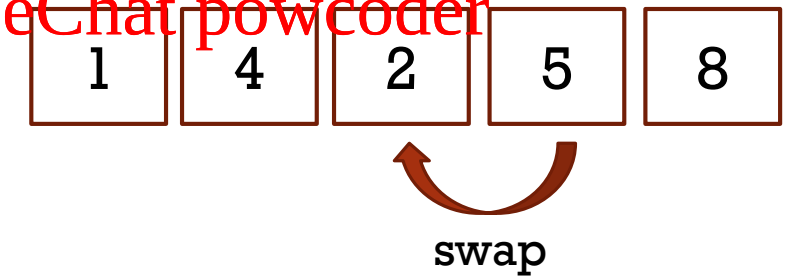

EXAMPLE – ONE ITERATION

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Iteration #1

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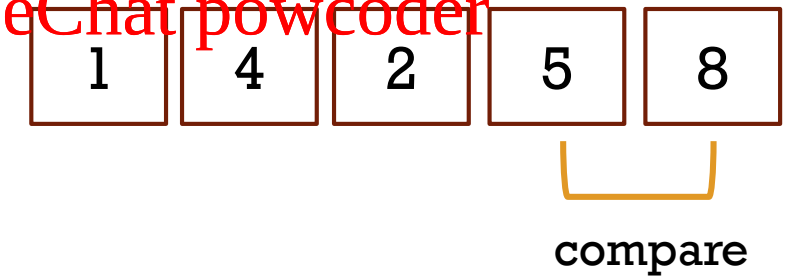

WHAT CAN WE SAY AFTER THE FIRST ITERATION?

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])
      }
   }
}
```

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EXAMPLE

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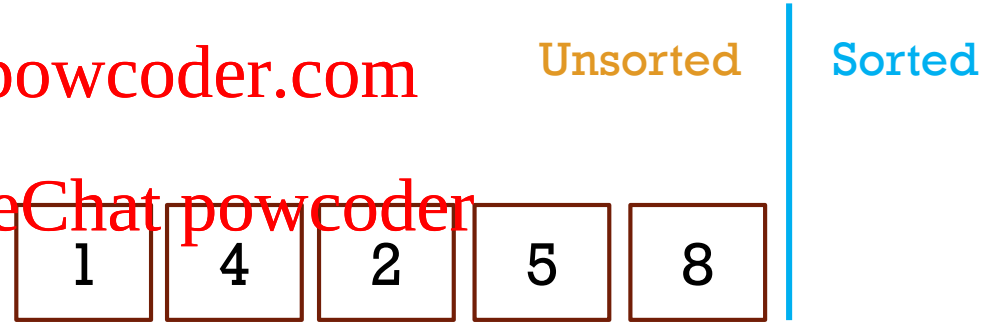
We left off at the end of Iteration #1



EXAMPLE

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Iteration #2

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

EXAMPLE

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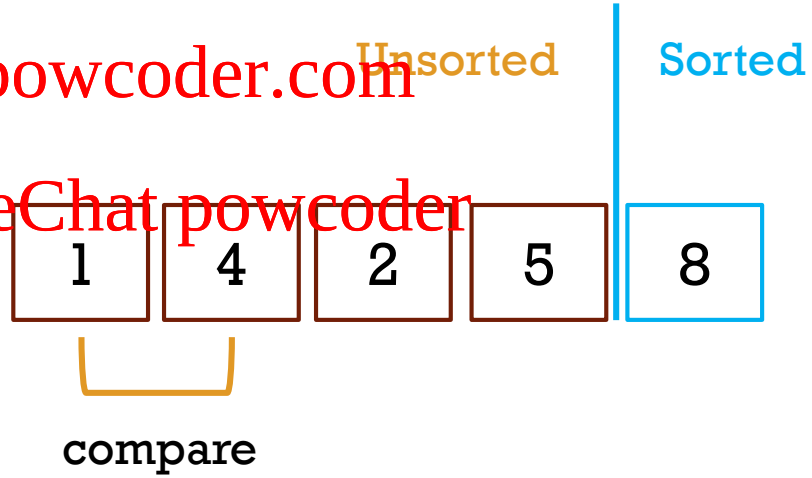
Iteration #2

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



EXAMPLE

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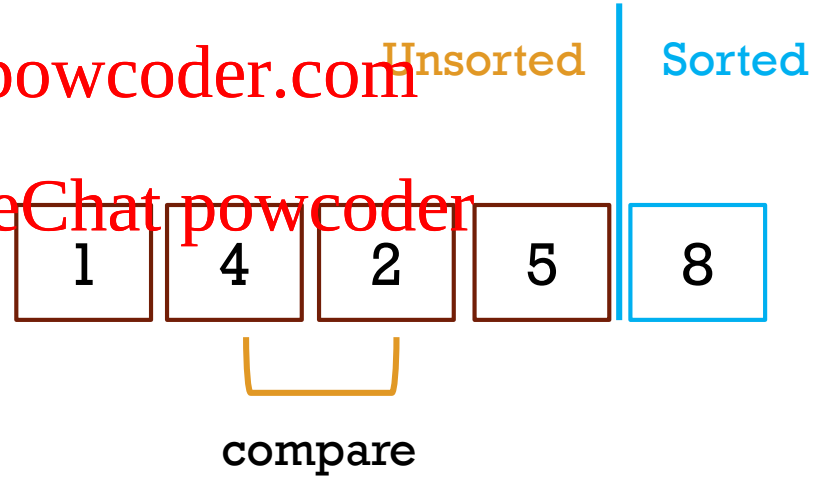
Iteration #2

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



EXAMPLE

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Iteration #2

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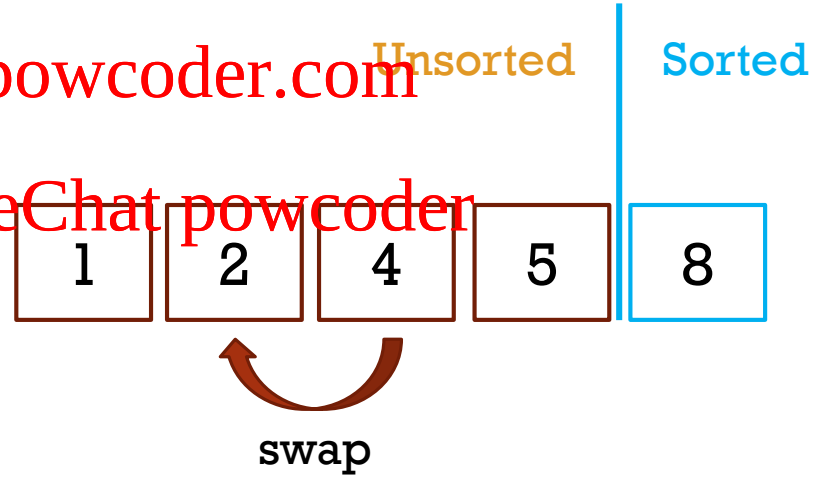
- If needed, swap!



EXAMPLE

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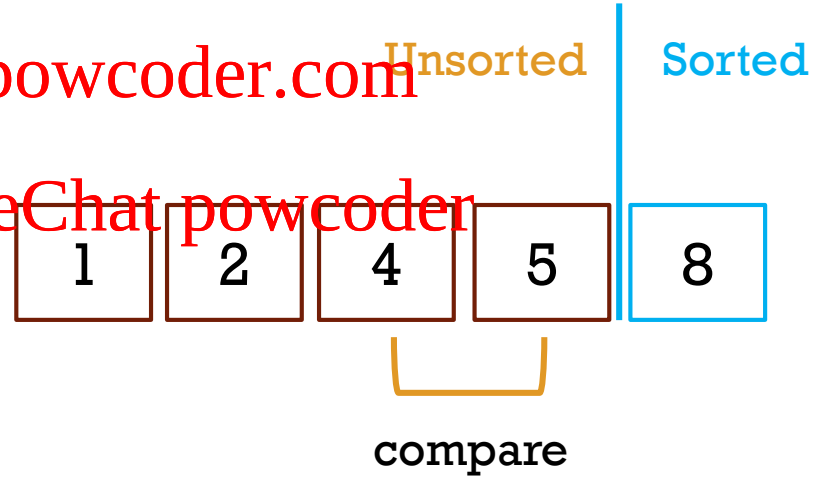
Iteration #2

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



EXAMPLE

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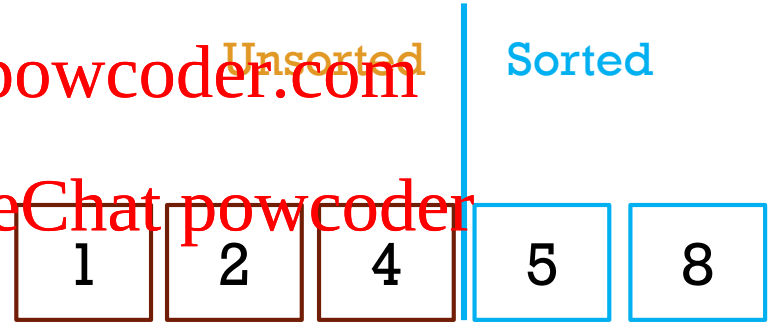
Iteration #3

- 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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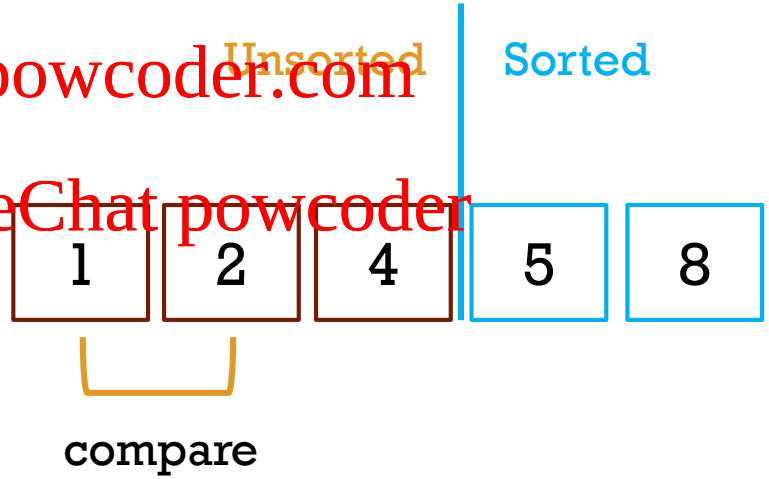
Iteration #3

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



EXAMPLE

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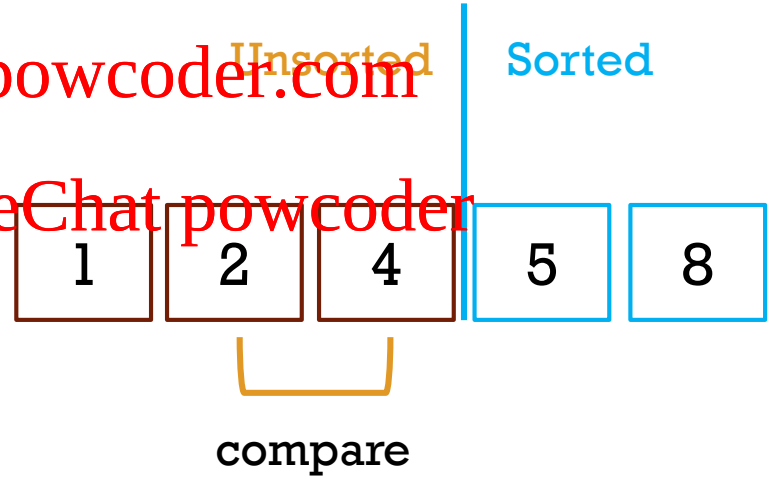
Iteration #3

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



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

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

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)
- 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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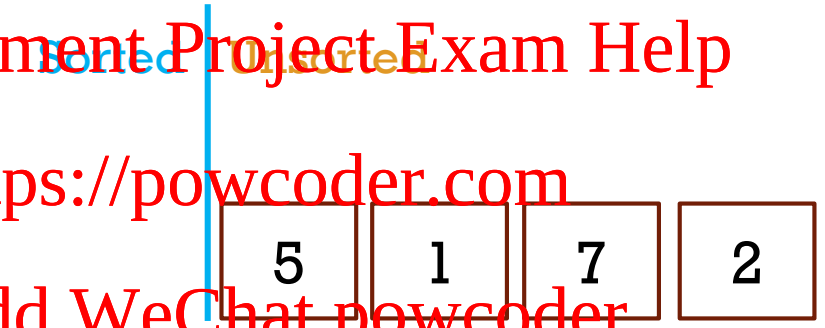

EXAMPLE

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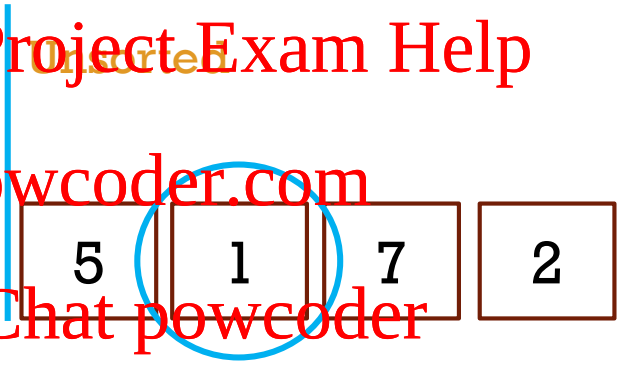
- Select



EXAMPLE

- Select
- Swap

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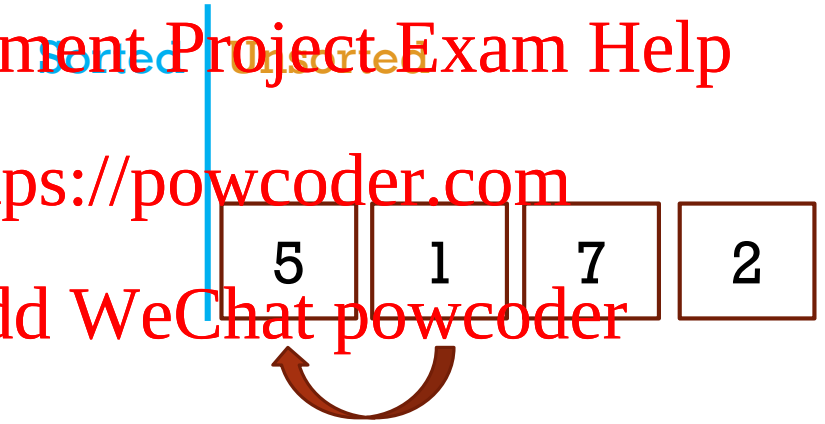

EXAMPLE

- Select
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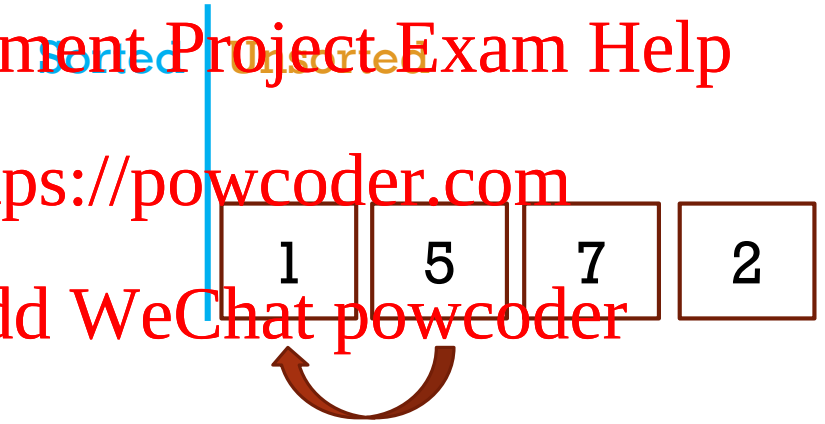

EXAMPLE

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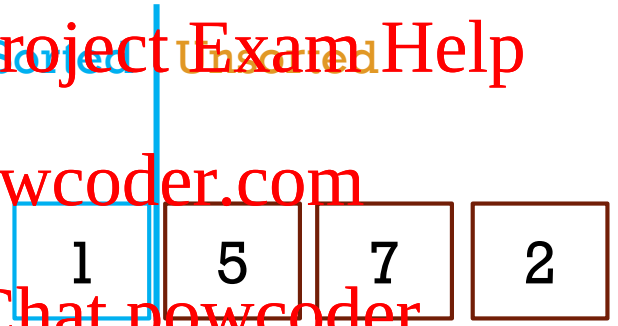
- Select
- Swap
- Update delimiter



EXAMPLE

- Select

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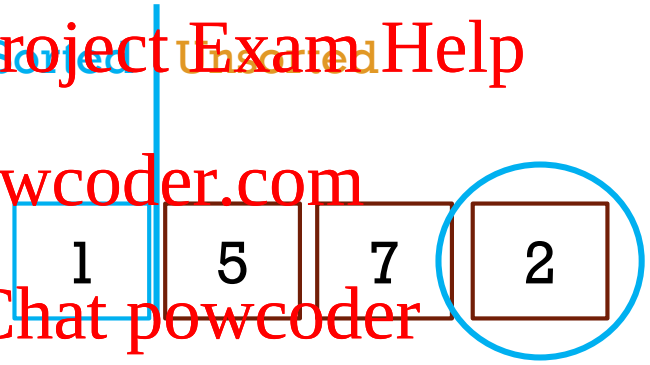

EXAMPLE

- Select
- Swap

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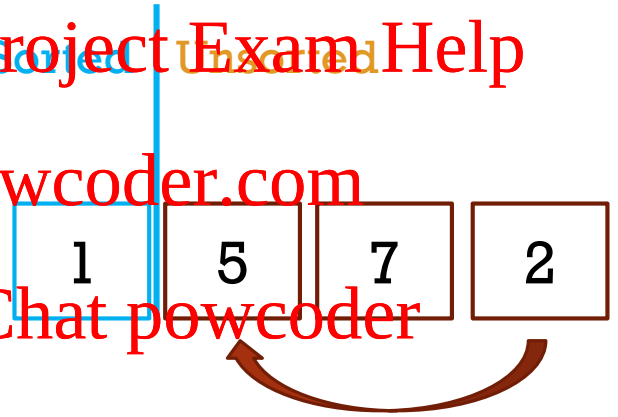

EXAMPLE

- Select
- Swap

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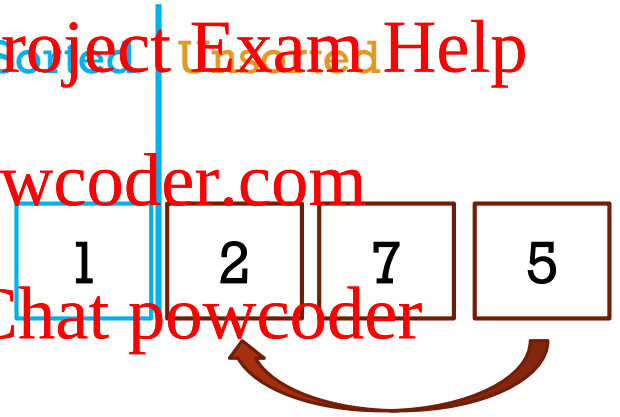

EXAMPLE

- Select
- Swap
- Update

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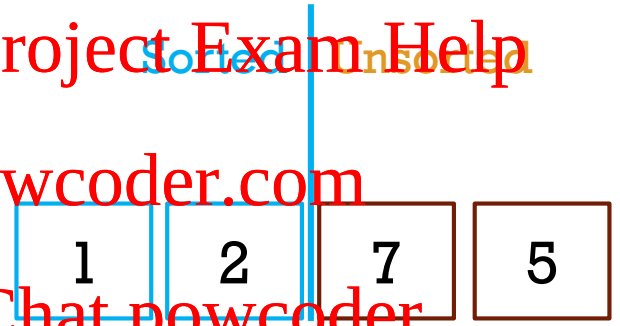

EXAMPLE

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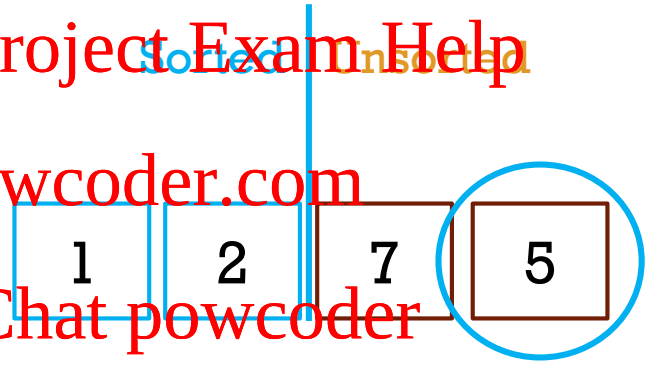
- Select



EXAMPLE

- Select
- Swap

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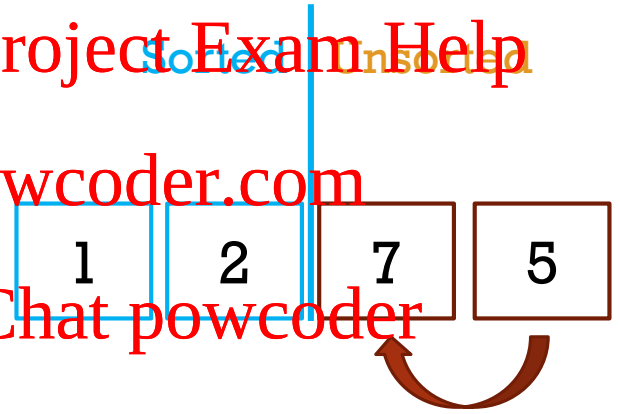

EXAMPLE

- Select
- Swap

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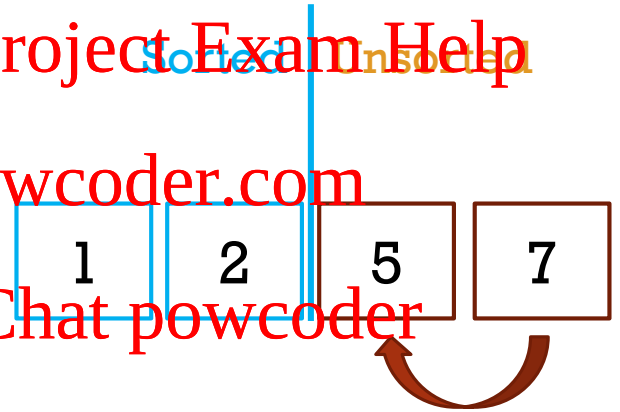

EXAMPLE

- Select
- Swap
- Update

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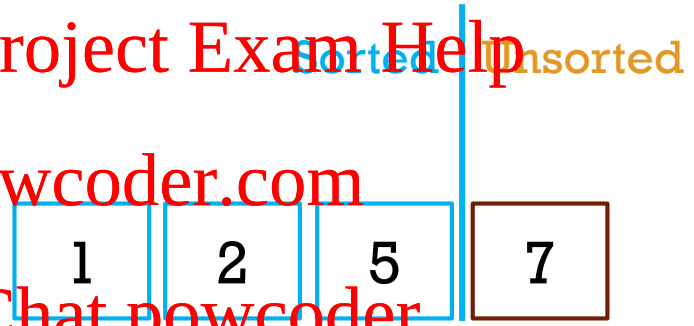

EXAMPLE

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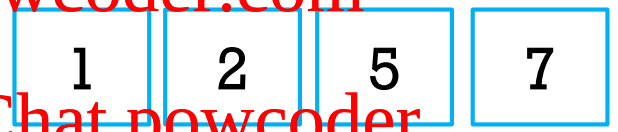
- Done!



SELECTION SORT – PSEUDOCODE

```
for delim from 0 to N-2 {
   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])
   }
}
```

Repeat until list is all sorted (~N times)

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 +…+ 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 +…+ 2 + 1 = **N*(N-1)/2**

COMPARISON

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

Bubblesort

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

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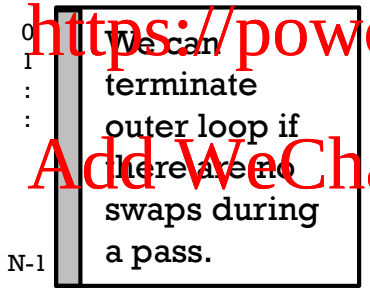
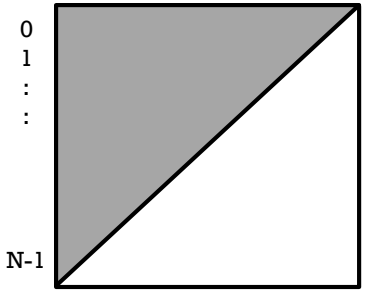


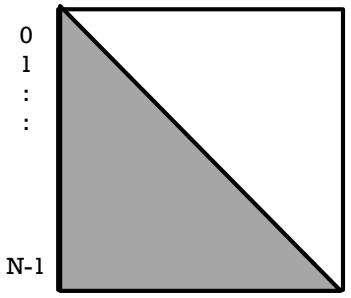
Best case

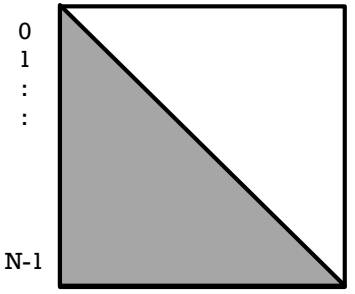


Worst case

Selection sort

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





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INSERTION SORT

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)
- 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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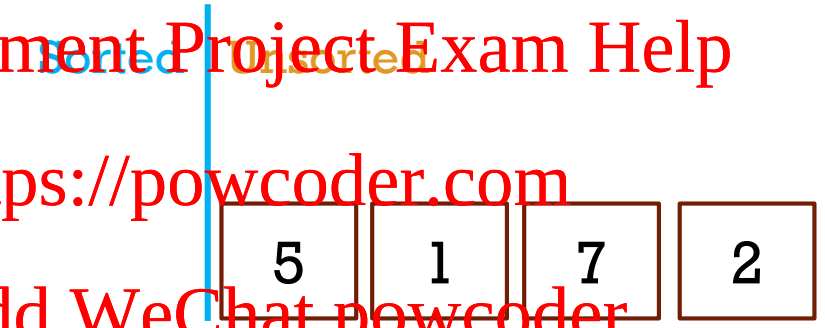

EXAMPLE

- Select

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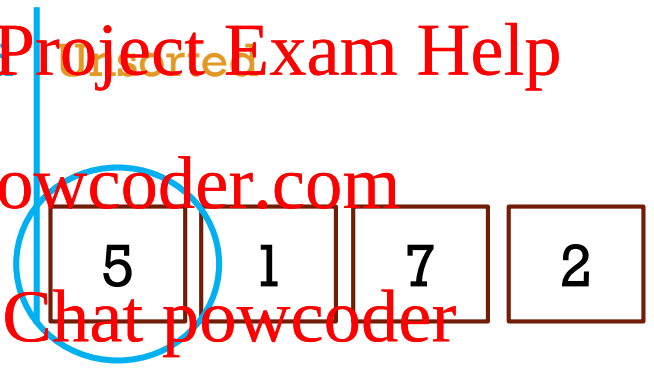

EXAMPLE

- Select
- Insert

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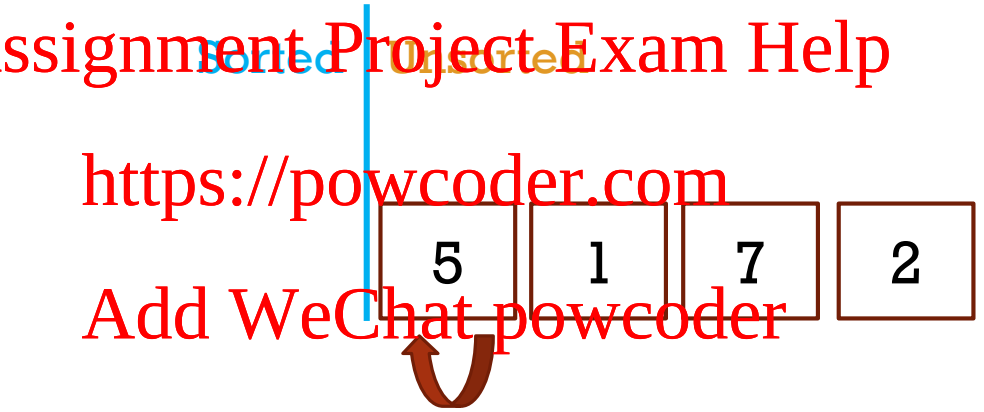

EXAMPLE

- Select
- Insert
- Update

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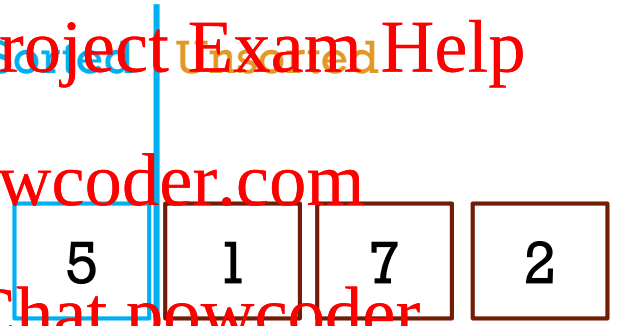

EXAMPLE

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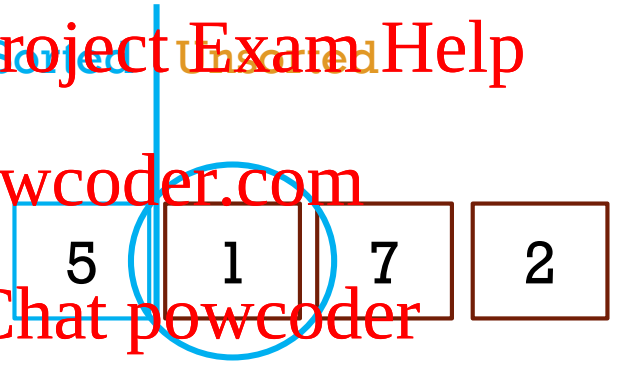
- Select



EXAMPLE

- Select
- Insert

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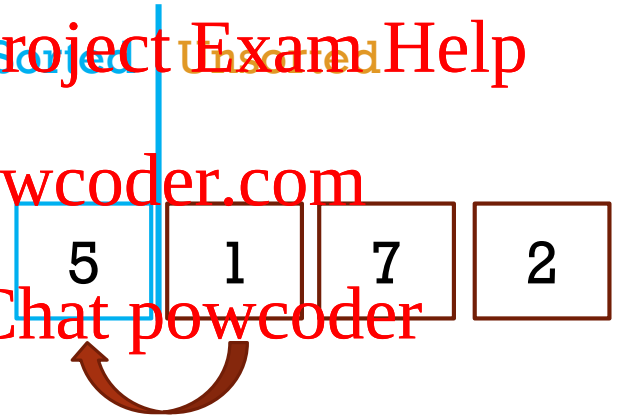

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EXAMPLE

- Select
- Insert
- Update

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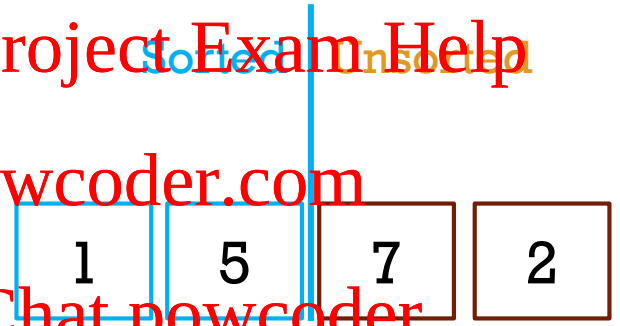

EXAMPLE

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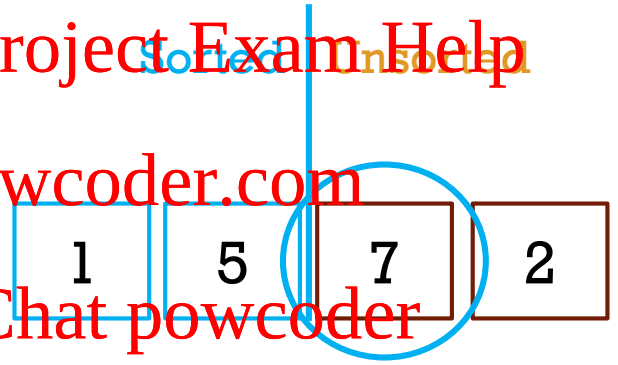
- Select



EXAMPLE

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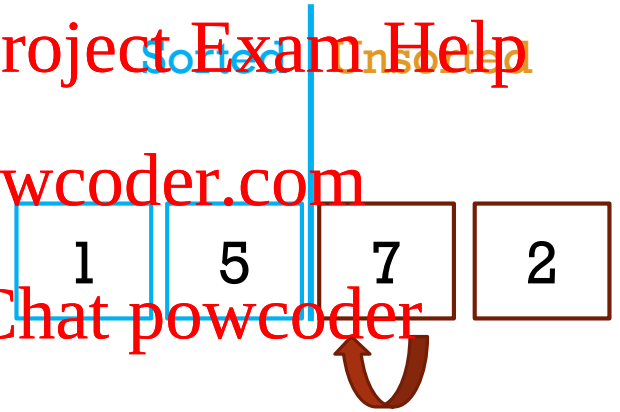

EXAMPLE

- Select
- Insert
- Update

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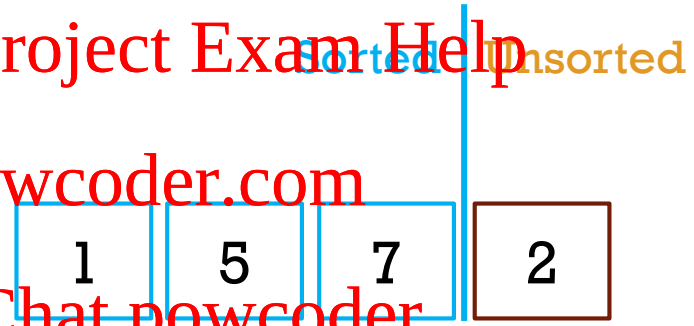

EXAMPLE

- Select

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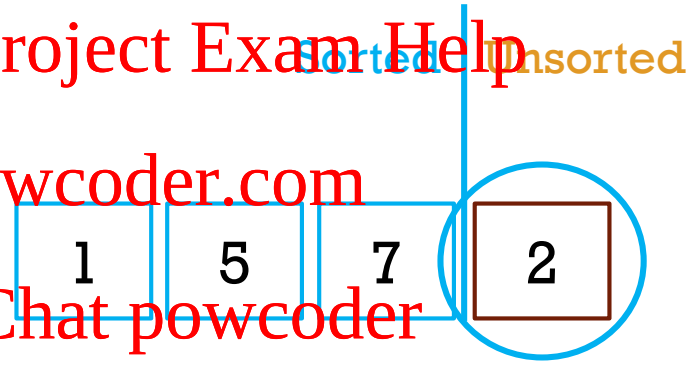

EXAMPLE

- Select
- Insert

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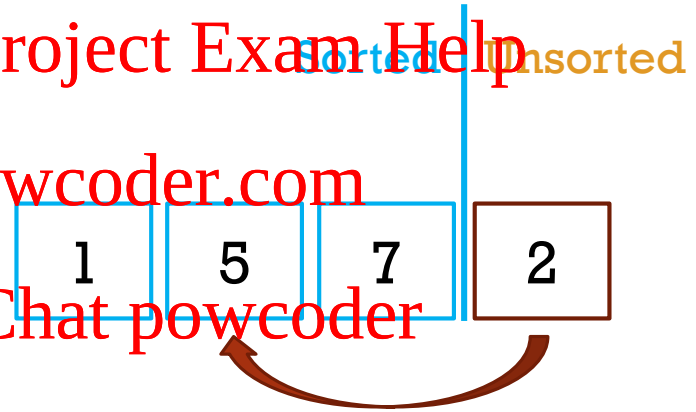

EXAMPLE

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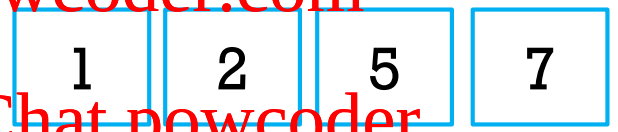
- Done!



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
}
```

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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.

COMPARISON OF THE THREE ALGORITHMS

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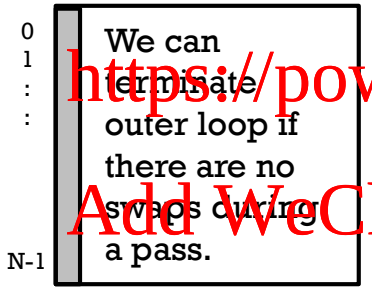
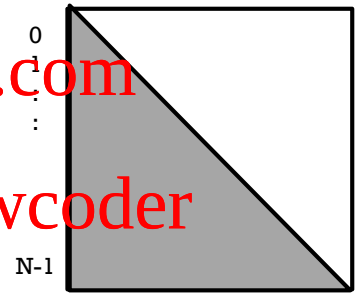
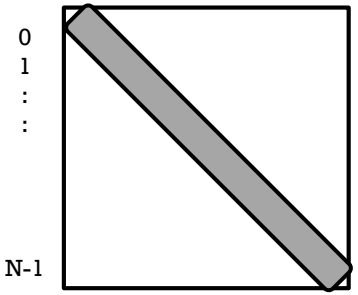
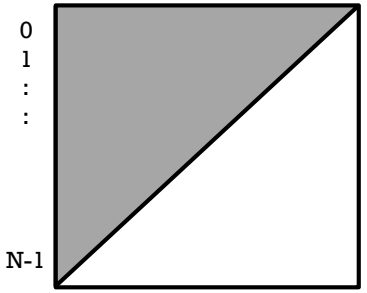
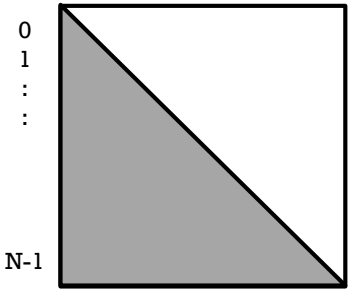
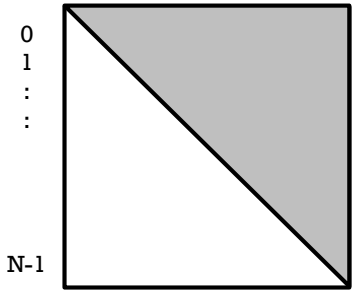
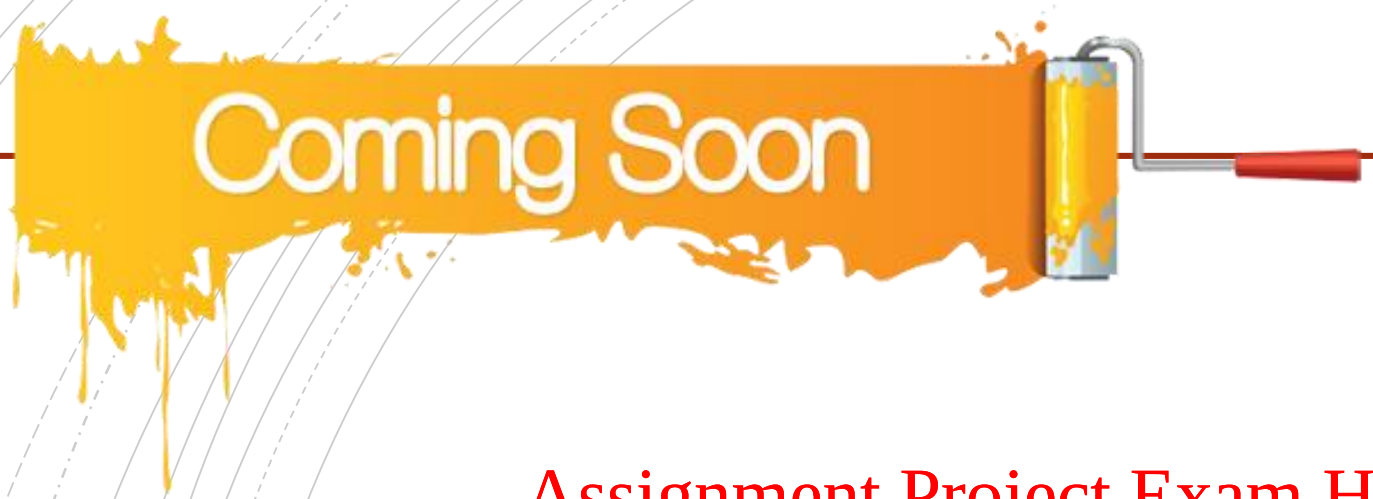
Performance depends highly on initial data. Also, it depends on implementation (array vs. linked list), e.g. what is cost of swap and 'shift'.

	Bubblesort	Selection sort	Insertion sort
	while(!sorted) for j from 0 to N – 2 – i	for delim from 0 to N-2 for i from delim+1 to N-1	for i from 0 to N-1 while ….
Best case			
Worst case			
	Outer loop	Outer loop	Outer loop



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In the next video:

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- Asymptotic notations

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