Sorting and Searching

ACS-1904 LECTURE 10

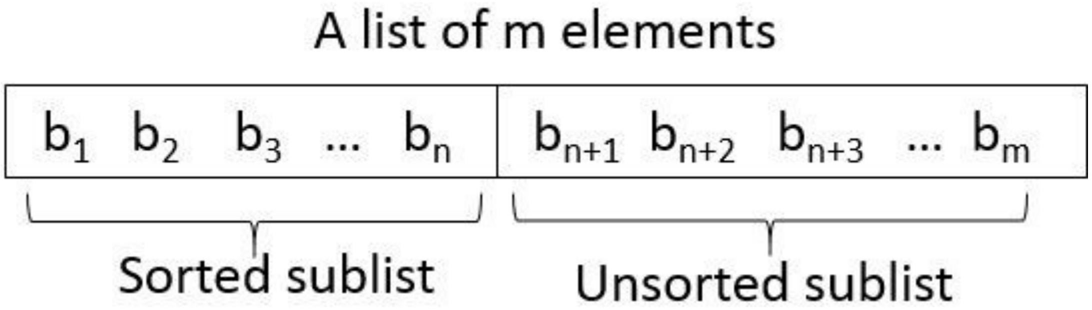
Sorting & searching

- Sorting:
  - Putting lists into sequence

- Searching:
  - Finding things in a list

Sorting

- many algorithms conceptually consider a list that comprises a sorted sublist and an unsorted sublist



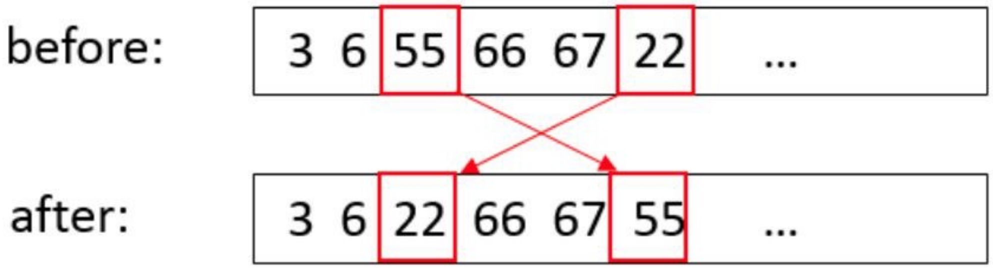
← growing →

→ shrinking ←

Sorting - list operations

Swapping a pair of elements

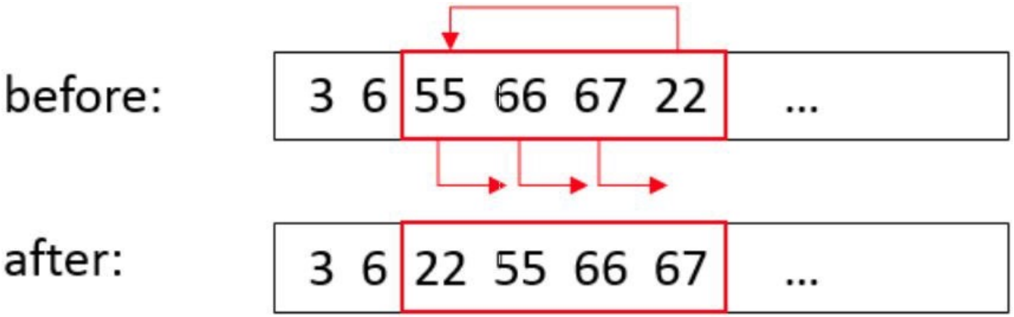
- e.g. 3rd and 6th elements swap positions



Sorting - list operations

Shifting an element into position

- e.g. 6th element moves into 3rd position; others shift right



Sorting algortihms

- Selection sort
- Insertion sort
- Bubble sort
- Quicksort

… many others

e.g. Merge sort, heap sort, bucket sort, radix sort...

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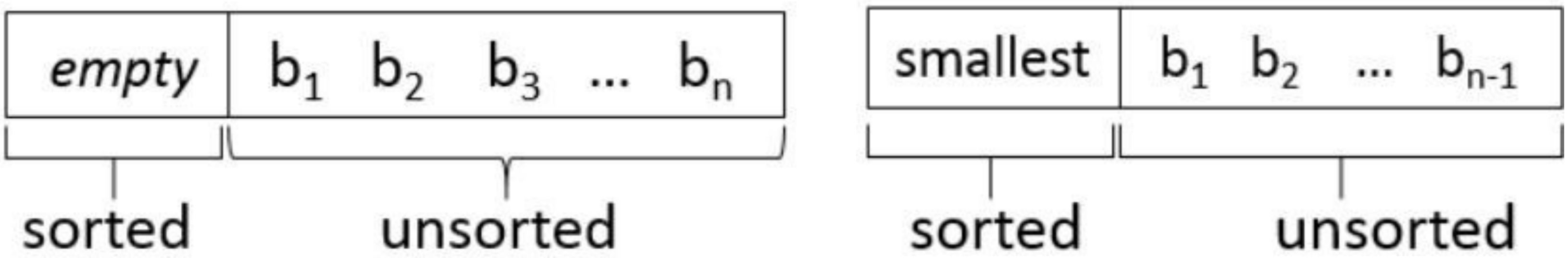
Selection sort

During a series of passes over the unsorted sublist

- the sorted sublist grows larger and
- the unsorted sublist shrinks to nothing

Basic idea: find smallest & move it to beginning of unsorted



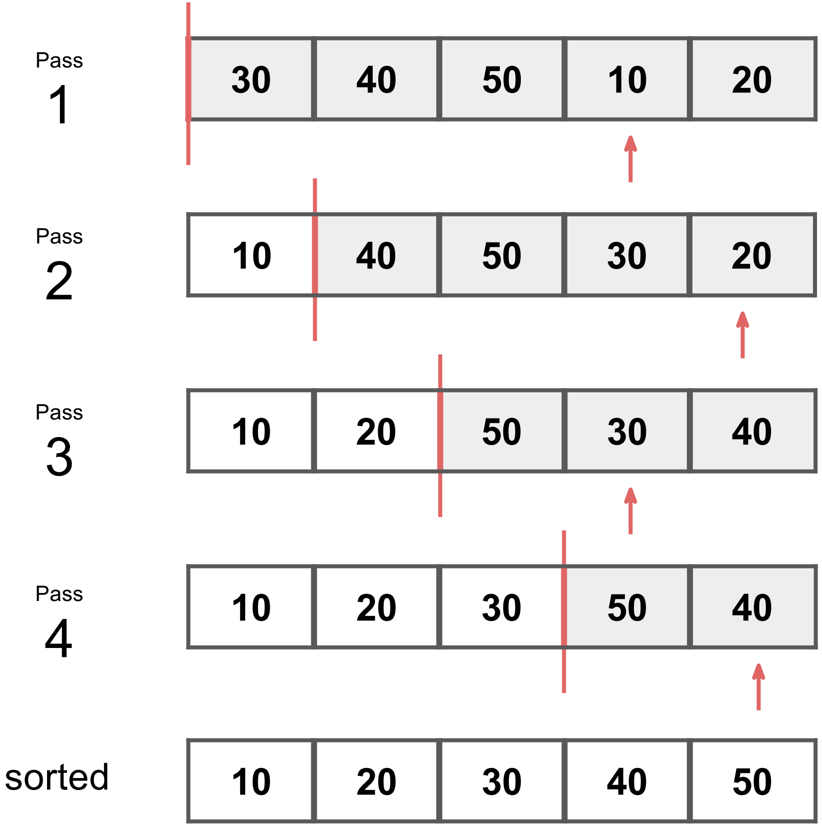
Selection sort

1. Sorted sublist ← empty.
2. Unsorted sublist ← list to be sorted.
3. Iteration:
    a. find the smallest entry (X) in the unsorted sublist
    b. swap X and the first entry of the unsorted sublist
    c. sorted sublist grows by 1 element & unsorted sublist shrinks by 1 element

Selection sort

Each pass:

- find smallest of unsorted
- swap with first of unsorted

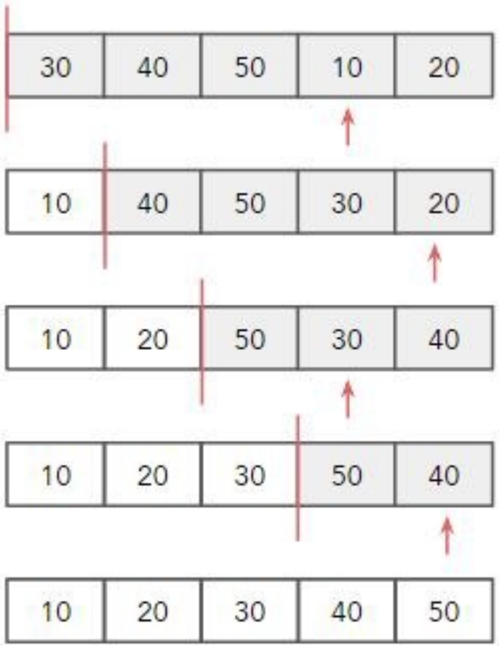


5 elements → 4 passes

Selection sort

SelectionSort.java

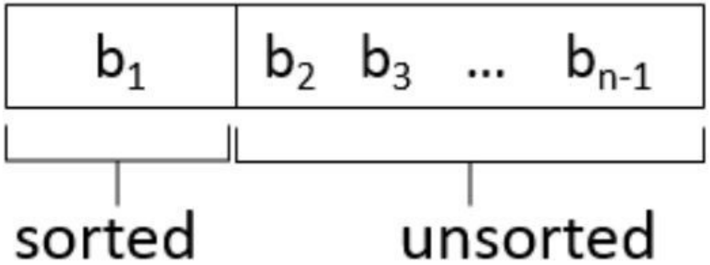
```java
public static void selectionSort(int[] a){
        int n = a.length;
        for (int i=0; i<n-1; i++) {
            int iSmallest = i;
            for (int j=i+1; j<n; j++) {
                if (a[j] < a[iSmallest]) {
                    iSmallest = j;
                }
            }
            if(iSmallest != i) {
                int temp = a[i];
                a[i] = a[iSmallest];
                a[iSmallest] = temp;
            }
        }
 }
```



Insertion sort

Initially first element is part of sorted sublist

Basic idea: move first of the unsorted into proper position of sorted elements … may require some shifting



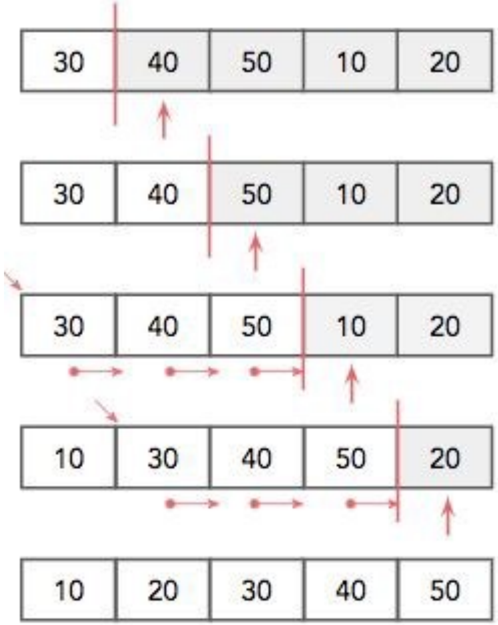
Insertion sort

1. Sorted sublist ← first element of list.
2. Unsorted sublist ← remaining n-1 elements.
3. Iteration: Repeat until the unsorted sublist is empty.
   a. Let X be the first element in the unsorted list
   b. Shift entries that are greater than X to the right making room for X in its proper position in the sorted sublist.
   c. X is now part of the sorted sublist and the unsorted sublist is 1 element shorter

Insertion sort

InsertionSort.java

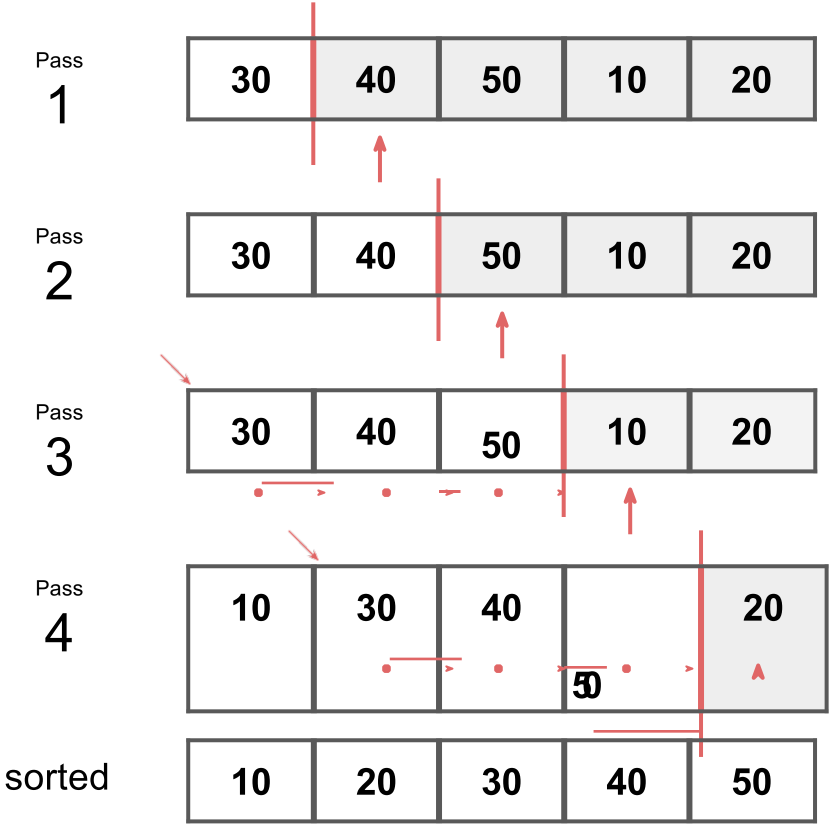
```java
public static void insertionSort(int[] a){
    int n = a.length;
    for (int i=1; i<n; i++) {
        int x = a[i];
        int j=i-1;
        while (j>=0 && a[j]>x){
            a[j+1] = a[j];
            j--;
        }
        a[++j]=x;
    }
}
```



Insertion sort

Each pass:

- move first unsorted element to its proper position in sorted sublist
- shift elements as is necessary



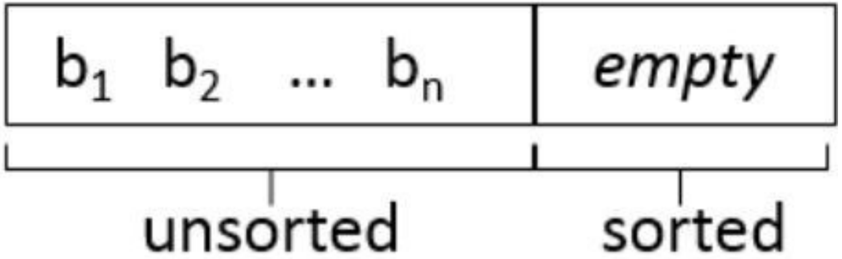
5 elements → 4 passes

Bubble sort

Larger elements bubble to the right

- largest element moved to end of unsorted
- sorted sublist grows by 1, unsorted shrinks by 1

Initially:

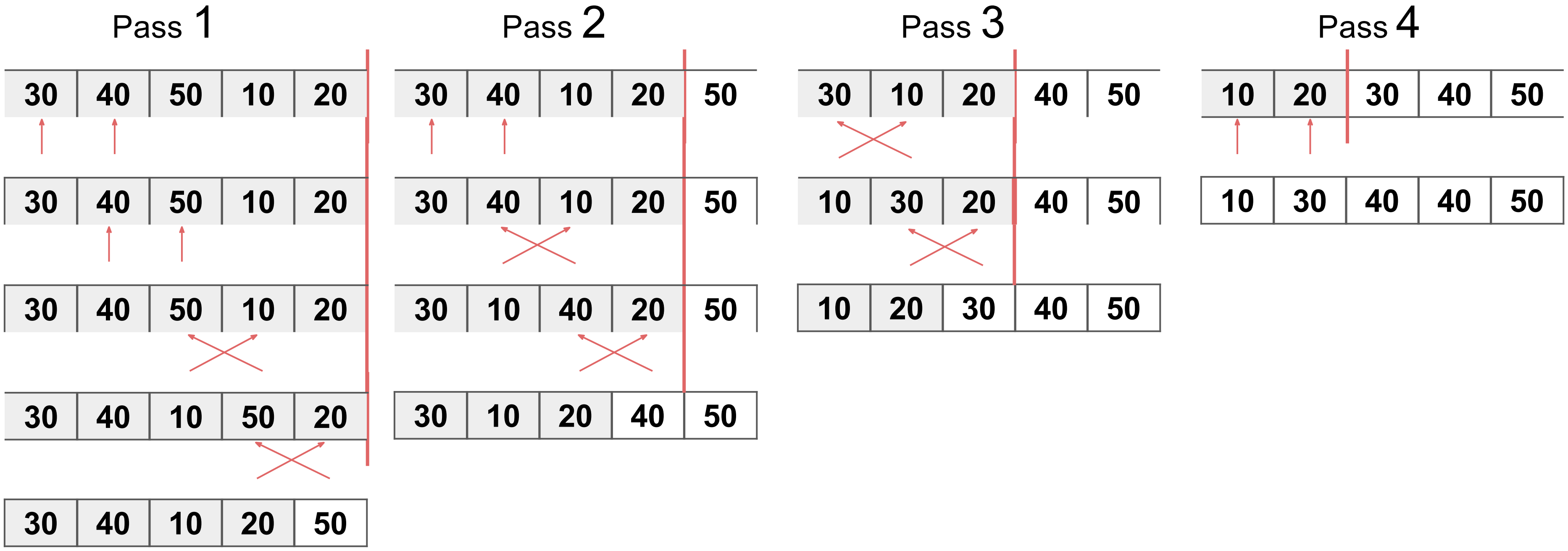


Bubble sort

1. Unsorted sublist ← the original list.
2. Sorted sublist ← an empty list.
3. Iteration:
   a. Scanning forward from the beginning of the unsorted list, consider the elements pairwise: a_1 and a_2, then a_2 and a_3, ... For each pair where $a_i > a_{i+1}$, swap a_i and a_{i+1}.
   After a scan the largest element has moved to the end of the unsorted list.
   b. The unsorted sublist shrinks by 1 element; sorted sublist increases by 1 element.

Bubble sort

Each iteration: bubble larger elements to the right



50 in its final position

40 & 50 in final positions

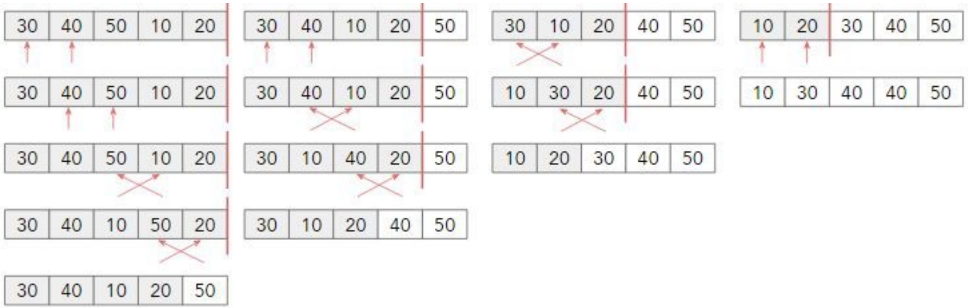
30, 40, 50 in final positions

sorted

Bubble sort

BubbleSort.java

```java
public static void bubbleSort(int[] a){
    int n = a.length;
    for (int i=0; i<n-1; i++) {
        for (int j=0; j<n-i-1; j++){
            if (a[j] > a[j+1]) {
                int temp = a[j];
                a[j] = a[j+1];
                a[j+1] = temp;
            }
        }
    }
}
```



Quick sort

Different: Recursive

- Continuously subdivide a list into 2 sublists based on a ***pivot*** value
- Variations on how the pivot value is chosen

  → the pivot can be any value in the list, first, last, middle, or any other random index.

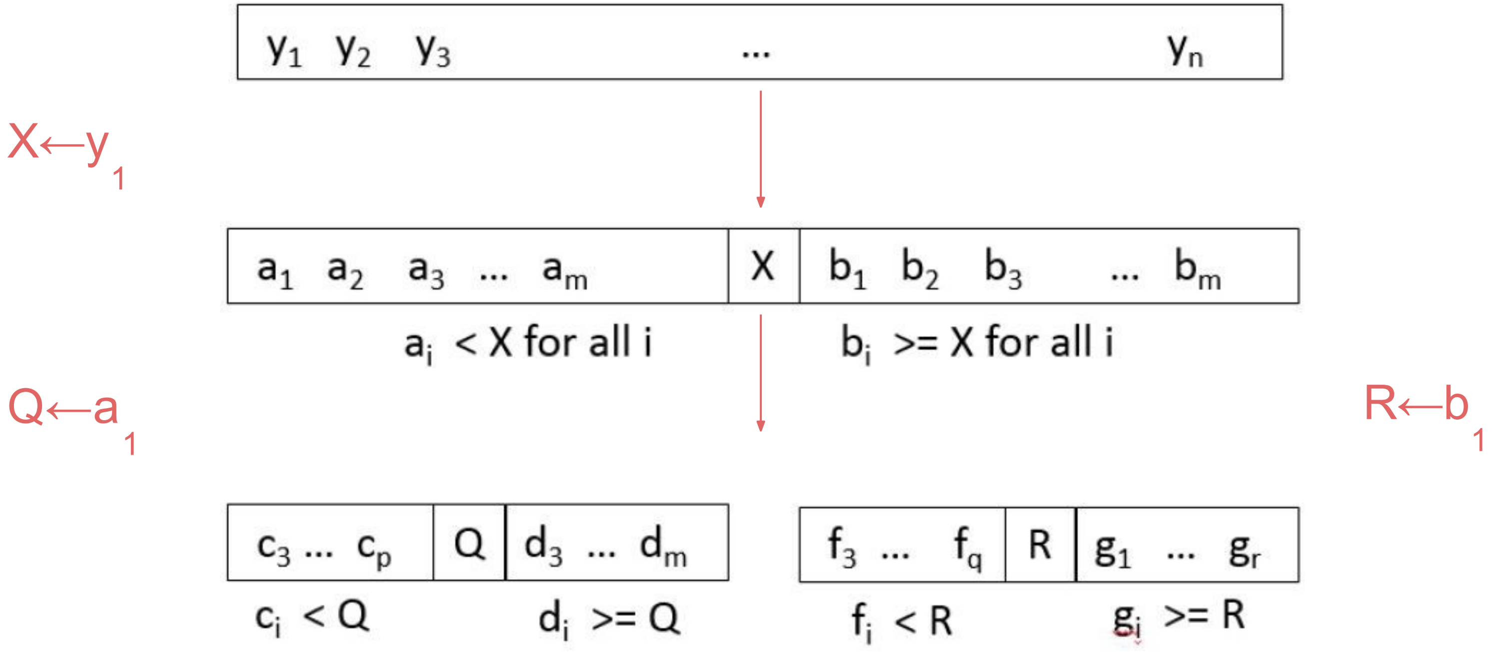
- Left sublist has elements with values < pivot
- Right sublist has elements with values >= pivot

Quick sort

- Once the pivot is chosen the list is ‘*partitioned’* in a (you guessed it) partition method
- Partition moves all of the values smaller than the pivot to the left of the pivot and all of the values larger to the left
- Check out these two algorithms for partitioning
  - Lomuto partition scheme
  - Hoare partition scheme

Quick sort

A list of n elements



Quick sort

QuickSort (list):

1. If list of length <= 1 return.
2. Choose a pivot value X.
3. Rearrange the elements of list:

    Left sublist L with elements < X;

    Right sublist R with elements >= X.

4. **QuickSort** (L)
   QuickSort (R)

Quick sort

Unsorted →	[**6**, 5, 9, 0, 11, 8, 4, 10, 2, 1, 12, 7, 3]
Pivot=6	[3, 5, 1, 0, 2, 4] [**6**] [10, 8, 11, 12, 7, 9]
Pivots 3, 10	[2, 0, 1] [**3**] [5, 4] [9, 8, 7] [**10**] [12, 11]
Pivots 2, 5, 9, 12	[1, 0] [**2**] [4][**5**] [7, 8] [**9**] [11][**12**]
Pivots 1, 7	[0] [**1**] [**7**] [8]
Final result sorted →	[0][1][2][3][4][5][6][7][8][9][10][11][12]

```java
public static void quicksort(int[] a, int start, int end){
    if (start >= end) return;
    int pivot = a[start];
    int left = start;
    int right = end;
    while (left < right){
        while (right > left && a[right]>=pivot){
            right--;
        }
        if(left==right) break;
        a[left]=a[right];
        left++;
        while (right > left && a[left] <= pivot){
            left++;
        }
        if(left == right) break;
        a[right]=a[left];
        right--;
    }
    a[right]=pivot;
    quicksort(a, start,  right-1);
    quicksort(a, right+1, end    );
}
```

Quicksort.java
QuickSortAlternate.java

Sorting Objects

Duck.java
SelectionSortForObjects.java

Example

- Objects (ducks) must implement `Comparable`

    i.e. compareTo method
- Array passed in to `sort` method is of type `Comparable`
- Object holding a temporary is of type `Comparable`

Searching

Unordered list?

Ordered list?

- i.e. sorted

Searching - unordered list

To determine that a search value is not present must scan the whole array

Searching an **Unordered** List

Search(list, X):

1. Let i reference the start of the list
2. While i <= end of list
   a. If $list_i$ equals X then return *found at position i*
   b. Increment i to reference the next element of the list
3. Return *not found*

Searched to the end of list

Searching – ordered list (Sequential Search)

Searching an **Ordered** List

SequentialSearch (list, X):

1. Let i reference the first element of the list.
2. While i <= end of list
   a. If $list_i > X$ then return *not found*
   b. If $list_i$ equals X then return *found at position i*
   c. Increment i to reference the next element of the list
3. Return *not found*

Don't always need to go to end of list to determine the search value is not there

Searching – ordered list (Binary Search)

BinarySearch.java

Searching an Ordered List

BinarySearch (list, X):

1. If the list L is empty then return *not found*
2. Determine the midpoint of the list
3. Determine the value at the midpoint of the list
4. if X < *midpoint value* call BinarySearch (left sublist, X)

   else if X > *midpoint value* call BinarySearch (right sublist, X))

   else if X = *midpoint value* then return *found at position midpoint*