Problem Solving Techniques and Data Structures

Objectives

In this session, you will:

- **Understand the Operating System basics:**
  - ✓ Hardware
  - ✓ Software
  - ✓ Memory management
  - ✓ Process management

- **Understand the basics of Computer Networks**
  - ✓ Protocols
  - ✓ IP addresses

- **Introduce the need for problem solving and develop the ability to analyze a given problem and understand various techniques to solve problem.**

- **To introduce the concepts of Data Structures**

Session Plan

- To explain the need for problem solving, problem classification
- The need for Data Structure, What is Data Structure, Types of Data Structures and operations permitted in each one of them
- To explain the different ways to solve a given problem

Introduction to Problem Solving Techniques

Skills of Software Developer

- The following are the ten skills to be possessed by a software Developer
  - Analytical ability
  - Analysis
  - Design
  - Technical knowledge
  - Programming ability
  - Testing
  - Quality planning and Practice
  - Innovation
  - Team working
  - Communication

Performance measures

- The following are the five points deciding the performance of a software developer

  - Timeliness
  - Quality of work
  - Customer Orientation
  - Optimal solution
  - Team satisfaction

Problem-Definition

- **Definition:** A *problem* is a puzzle that requires logical thought or mathematics to solve

- What is **Problem solving** ?

  The act of defining a problem; determining its cause; identifying, prioritizing and selecting alternatives for a solution; and implementing that solution.

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Problem Solving-Steps

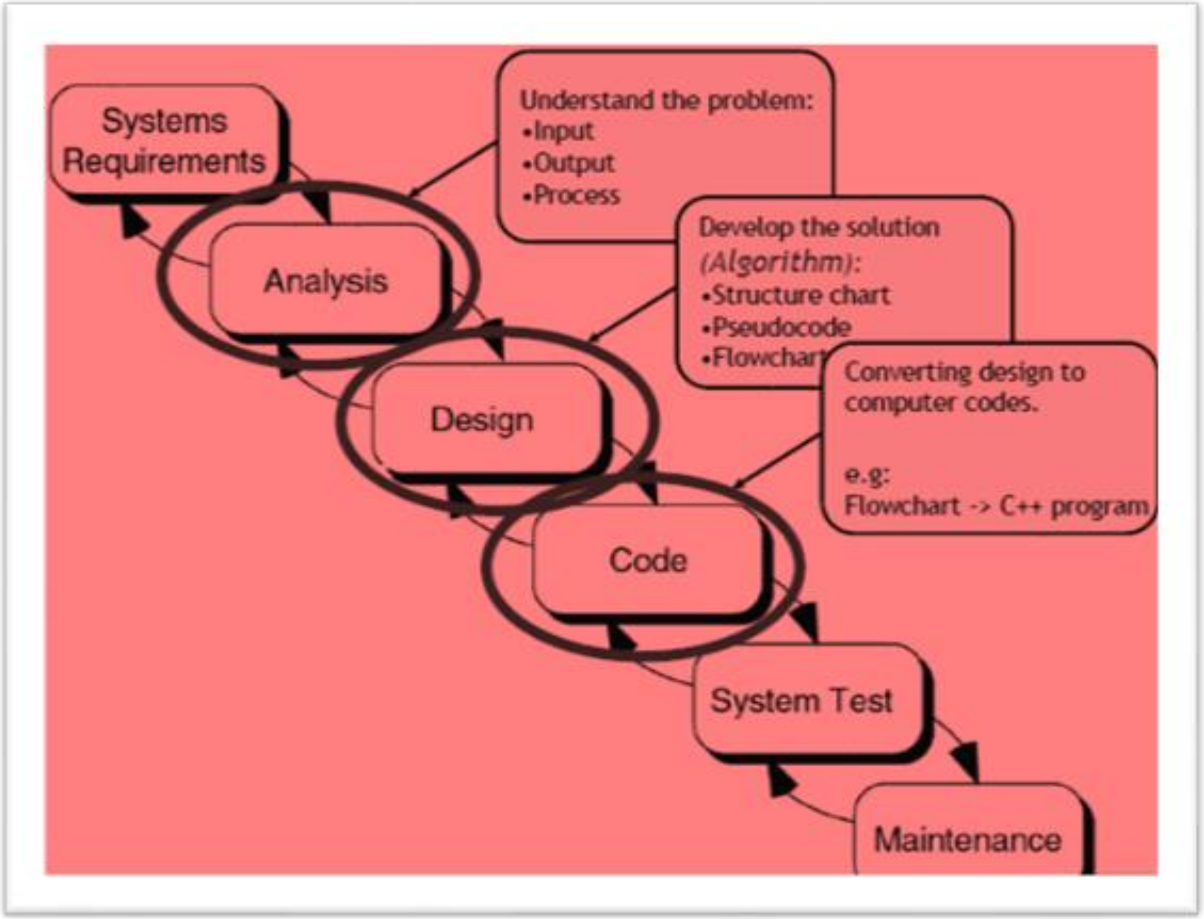
Analyze and understand the Problem

Select a method to solve the problem

Design a solution

Develop the solution

Test the solution



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Problem Classification

- Concurrent: Operations overlap in time
- Sequential: Operations are performed in a step-by-step manner
- Distributed: Operations are performed at different locations
- Event-Based: Operations are performed based on the input

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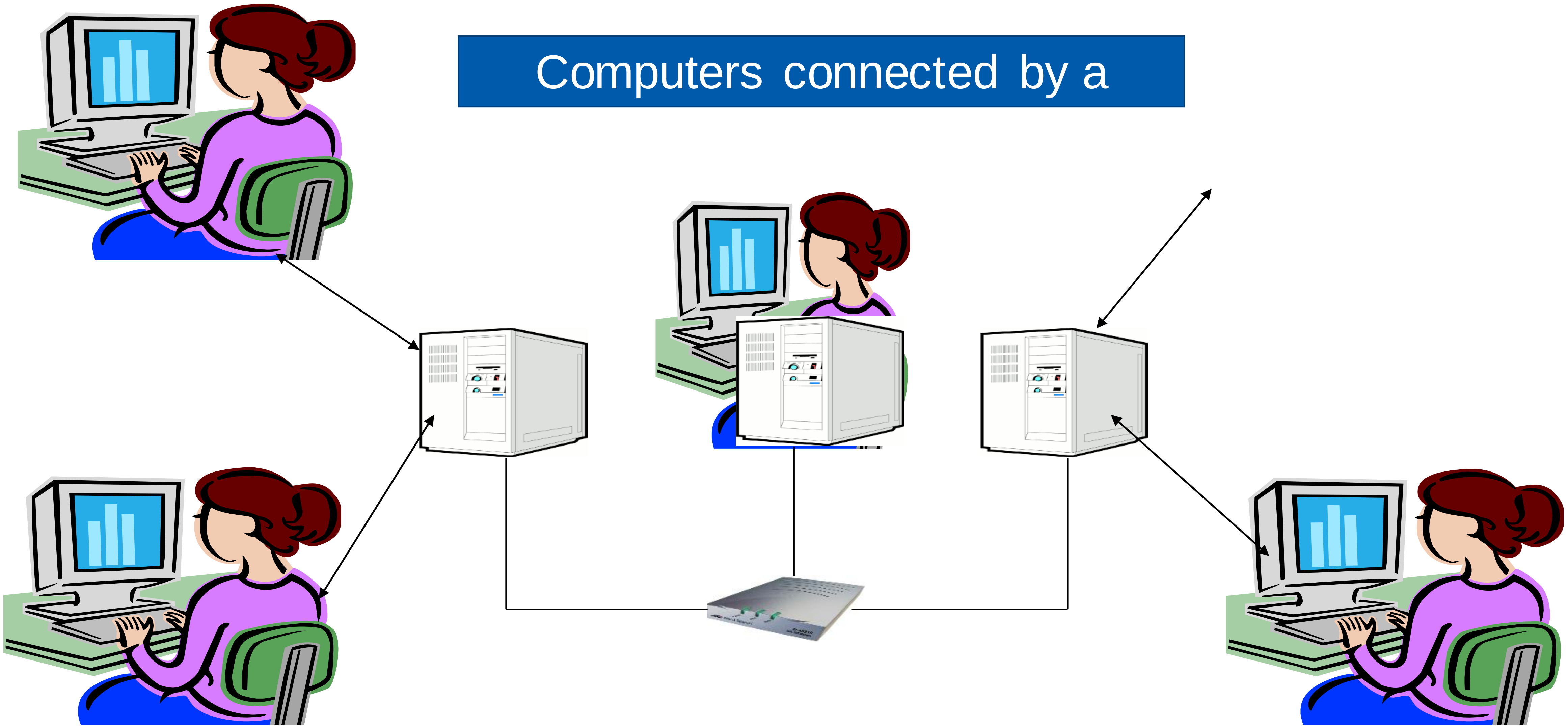
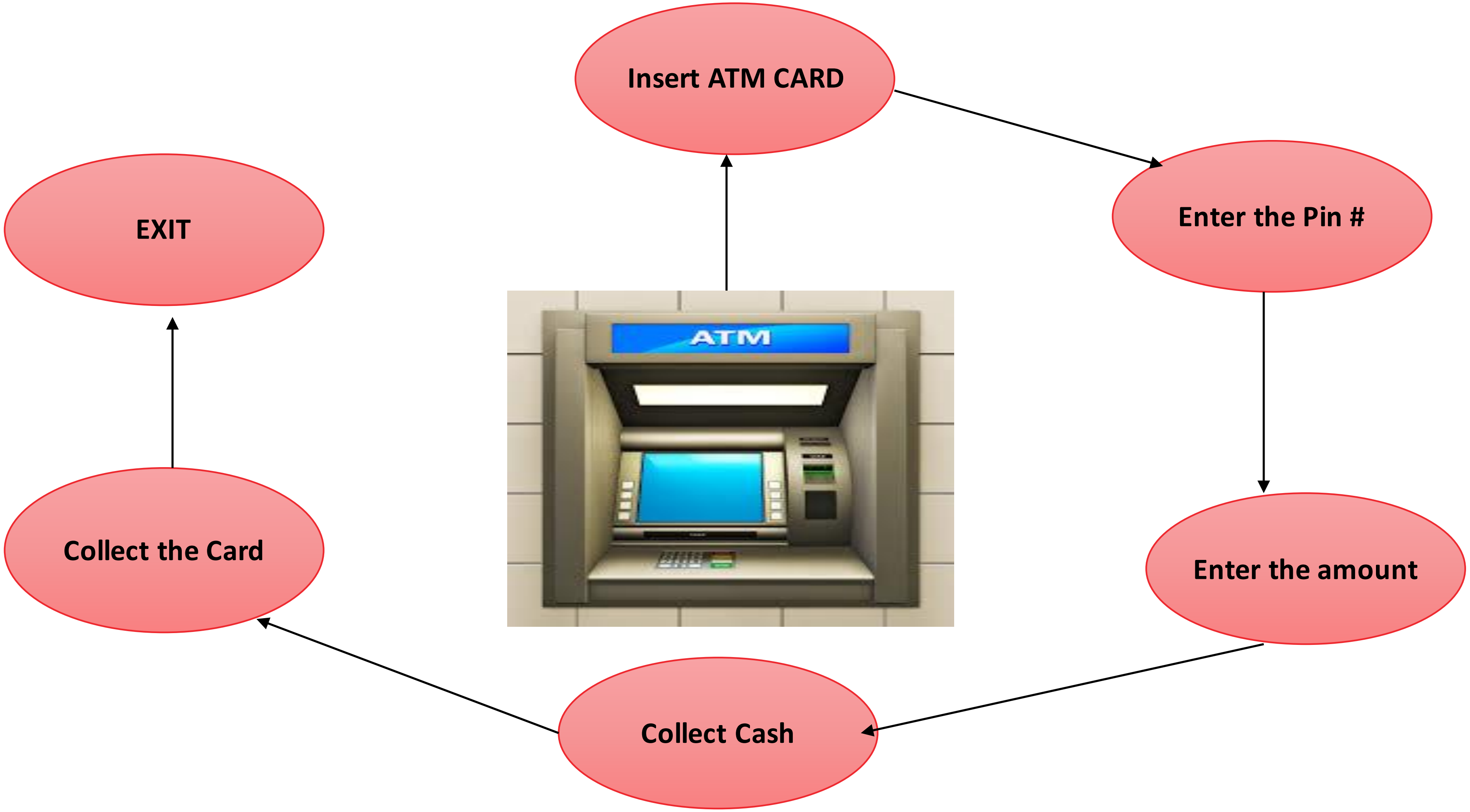
Distributed/Concurrent Problems

Computers connected by a



Sequential/Event based-Example



Problem solving methods

- Heuristic approach/ Brute Force technique
- Greedy approach
- Divide and Conquer technique
- Dynamic Programming technique

Heuristic/ Brute Force approach

- Brute force approach is a straight forward approach to solve the problem. It is directly based on the problem statement and the concepts

- Brute force is a simple but a very costly technique

Example: Breaking Password

Watch the video to get more clarity on Heuristic approach

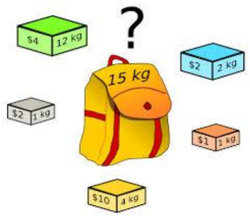
https://www.youtube.com/watch?v=ZINodNt-33g

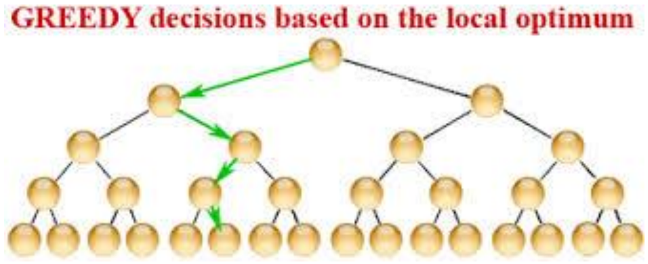
Greedy Approach

- Greedy design technique is primarily used in Optimization problems

- The Greedy approach helps in constructing a solution for a problem through a sequence of steps where each step is considered to be a partial solution. This partial solution is extended progressively to get the complete solution

- The choice of each step in a greedy approach is done based on the following
    - It must be feasible
    - It must be locally optimal
    - It must be irrevocable





Example: TSP- Traveling Salesman Problem

- https://www.youtube.com/watch?v=SC5CX8drAtU

Divide-and-Conquer

The most-well known algorithm design strategy:

1. Divide instance of problem into two or more smaller instances

2. Solve smaller instances recursively

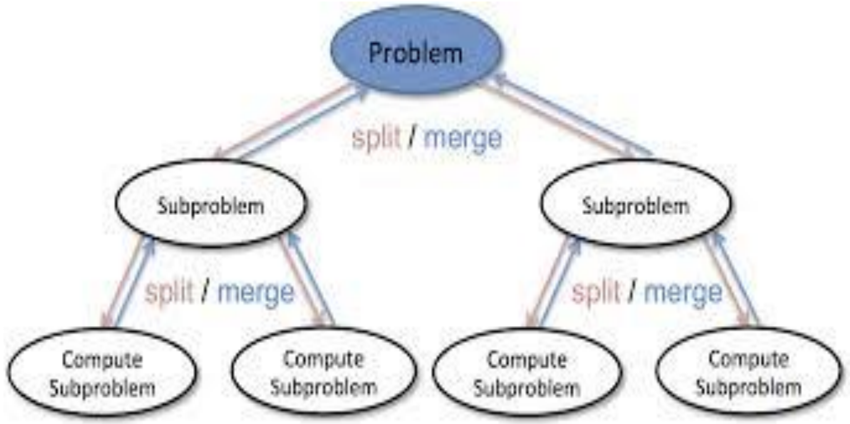
3. Obtain solution to original (larger) instance by combining these solutions

Example:

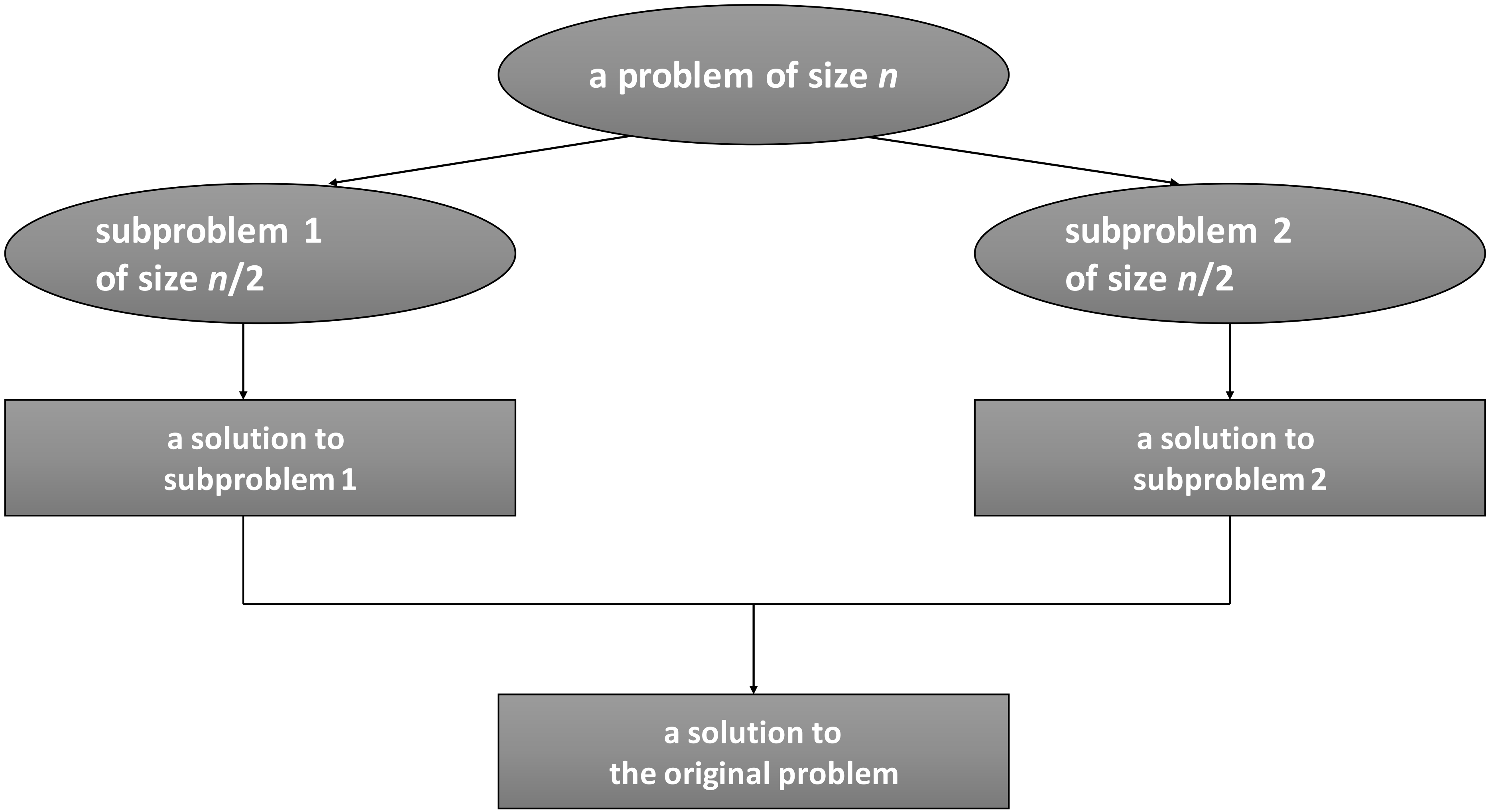
- Binary Search

https://www.youtube.com/watch?v=wVPCT1VjySA

Divide and Conquer



Divide-and-Conquer Technique (cont.)



What's the difference?

Consider the problem of exponentiation: Compute a^n

- Brute Force
- Divide and conquer

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Dynamic Programming

- Dynamic Programming is a design principle which is used to solve problems with overlapping sub problems

- It solves the problem by combining the solutions for the sub problems

- “Programming” here means “planning”

- Main idea:
    - set up a recurrence relating a solution to a larger instance to solutions of some smaller instances
        - solve smaller instances once
    - record solutions in a table
    - extract solution to the initial instance from that table

- The difference between Dynamic Programming and Divide and Conquer is that the sub problems in Divide and Conquer are considered to be disjoint and distinct whereas in Dynamic Programming they are overlapping

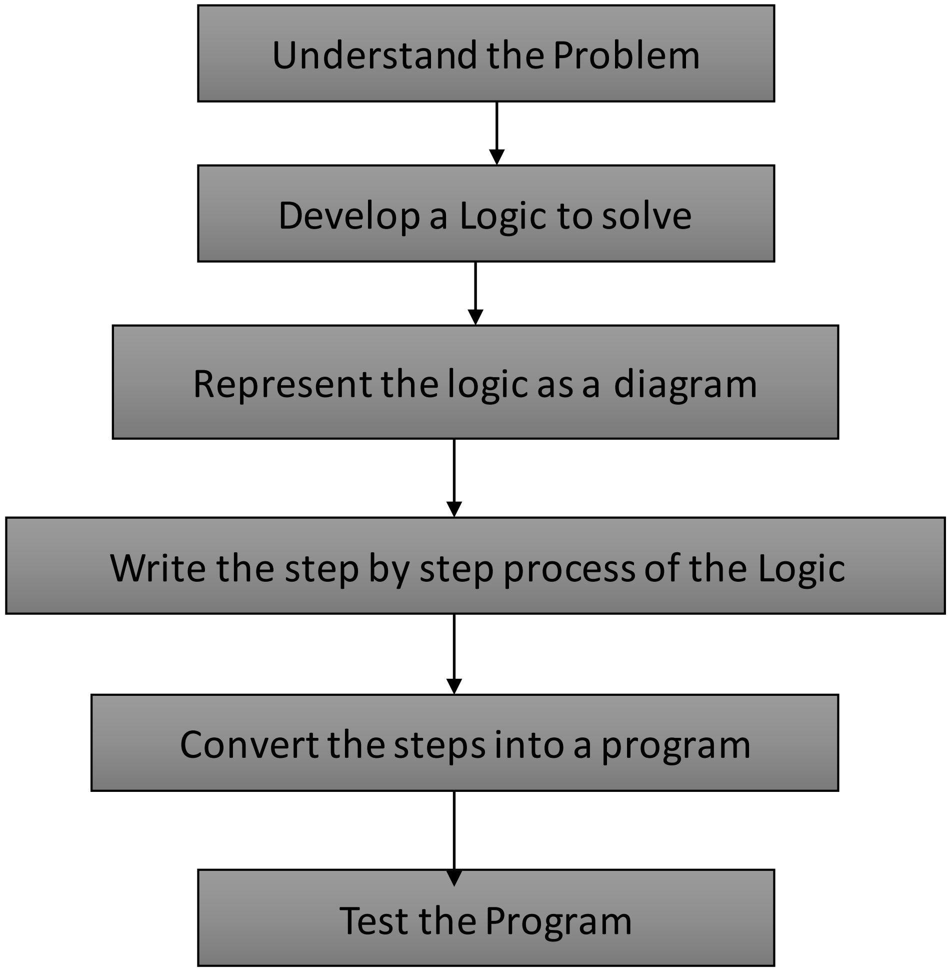
Dynamic Programming-Example

You have three jugs, which we will call A, B, and C. Jug A can hold exactly 8 cups of water, B can hold exactly 5 cups, and C can hold exactly 3 cups. A is filled to capacity with 8 cups of water. B and C are empty. We want you to find a way of dividing the contents of A equally between A and B so that both have 4 cups. You are allowed to pour water from jug to jug.

Solution

- **Step 1:** First fill the 8L bucket full.
- **Step 2:** Pour the water from 8L bucket to 5L bucket. Water remaining in 8L bucket is 3L.
- **Step 3:** Pour the water from 5L bucket to 3L bucket. Water remaining in 5L bucket is 2L.
- **Step 4:** Pour the water from 3L bucket to 8L bucket. Water in 8L bucket is 6L now and 3L bucket gets empty.
- **Step 5:** Pour the water from 5L bucket to 3L bucket. Water in 3L bucket is 2L now and 5L bucket gets empty.
- **Step 6:** Pour the water from 8L bucket to 5L bucket. Water remaining in 8L bucket is 1L 5L bucket gets full.
- **Step 7:** Pour the water from 5L bucket to 3L bucket. Water remaining in 5L bucket is now 4L as 3L bucket already had 2L of water and when we poured water from 5l bucket to 3L bucket we poured 1L of water from 5L bucket and thus the remaining water in 5L bucket is now 4L.

Computer Based Problem Solving -Steps



- Analysis of the Problem
- Selecting a solution method
- Draw Flowcharts
- Develop Algorithms using Pseudo codes
- Develop Program using Programming language
- Test the program

Modeling Tools

- Diagrammatic Representation of Logic

- Different Types:

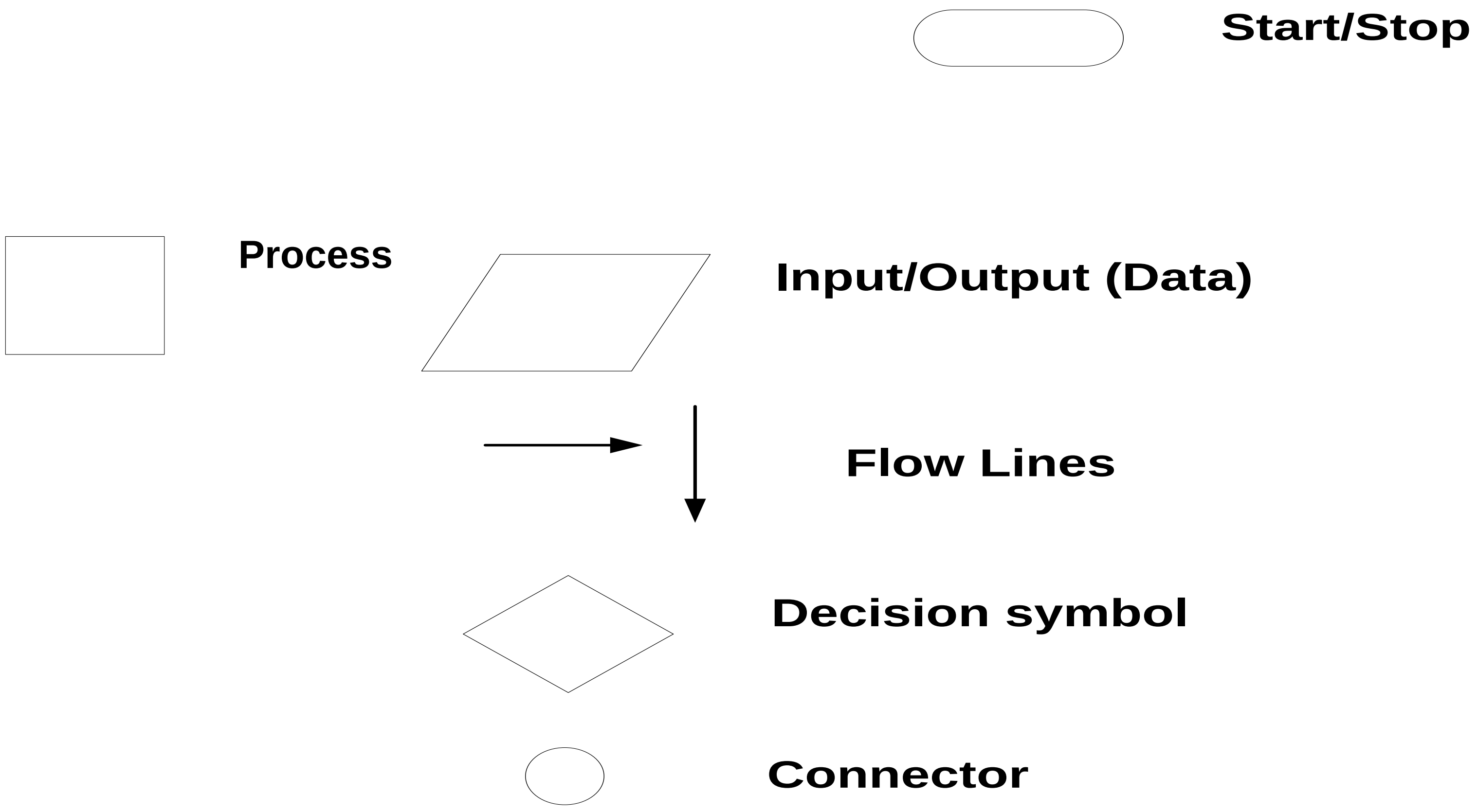
  - Flow Charts
  - Data flow Diagrams
  - Entity Relationship diagram
  - Unified Modeling Language

Flow Charts

- A flowchart is a diagrammatic
  representation of an algorithm

- A flow chart is an organized
  combination of shapes, lines and text that graphically illustrates a process or structure

Symbols used



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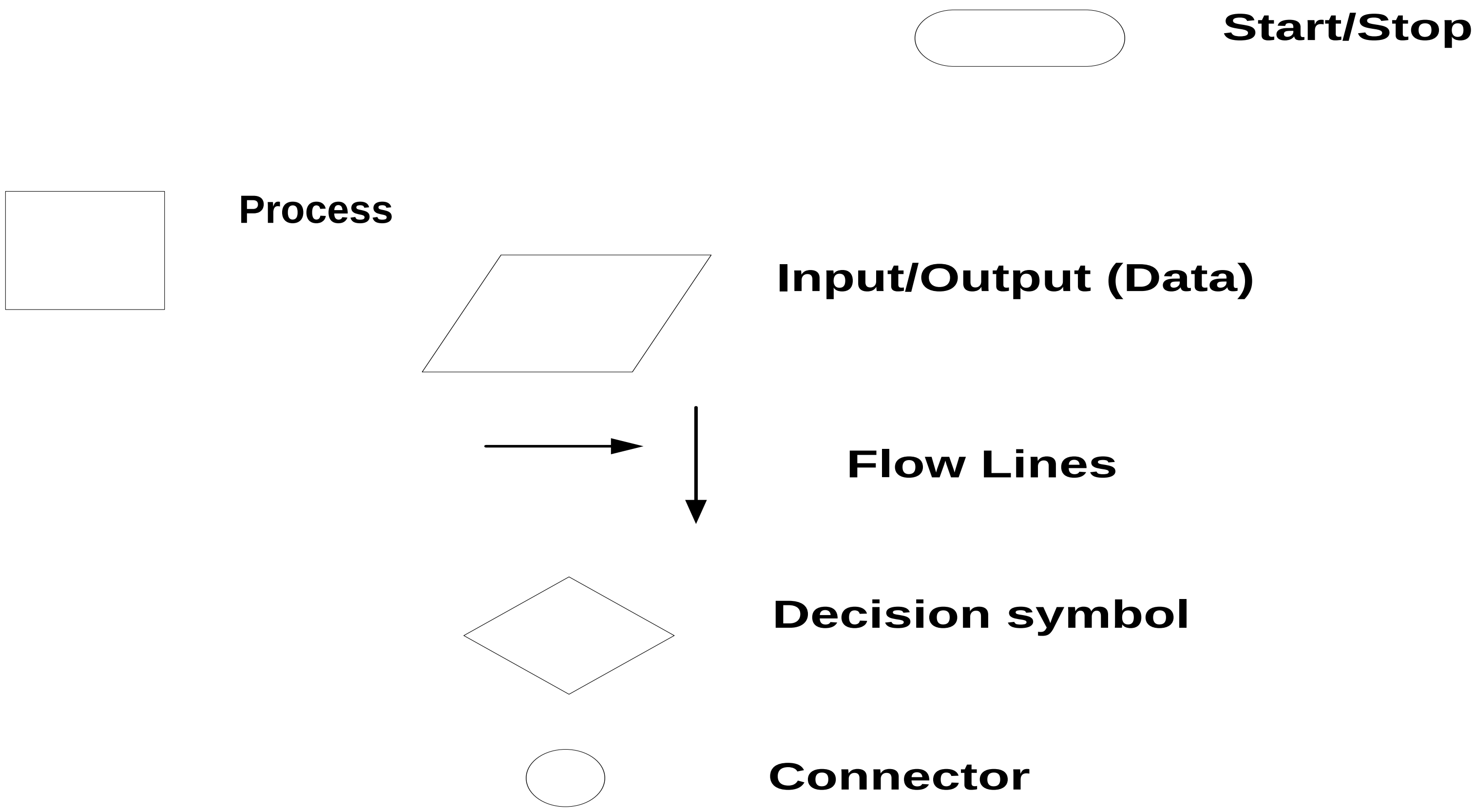
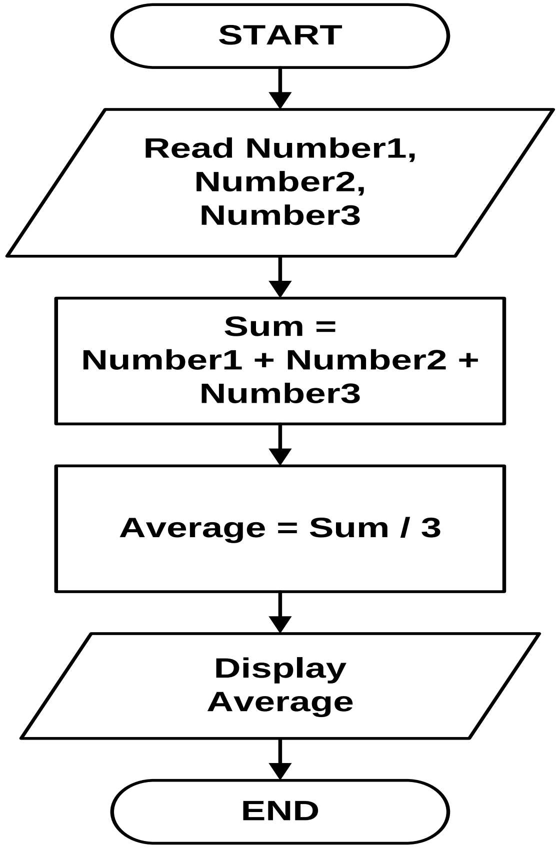
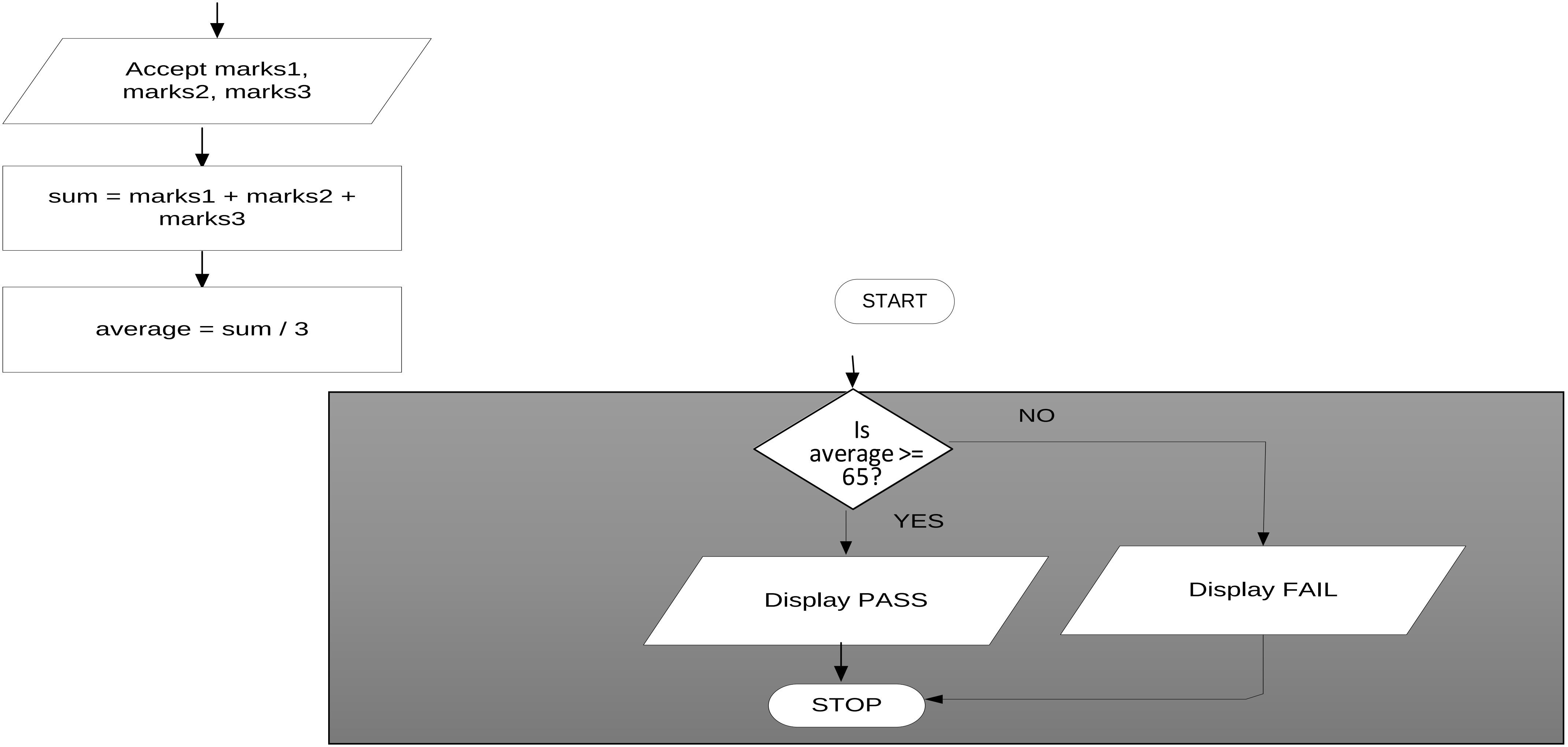


Example: Flow Chart (Sequential)

Find the average of three numbers



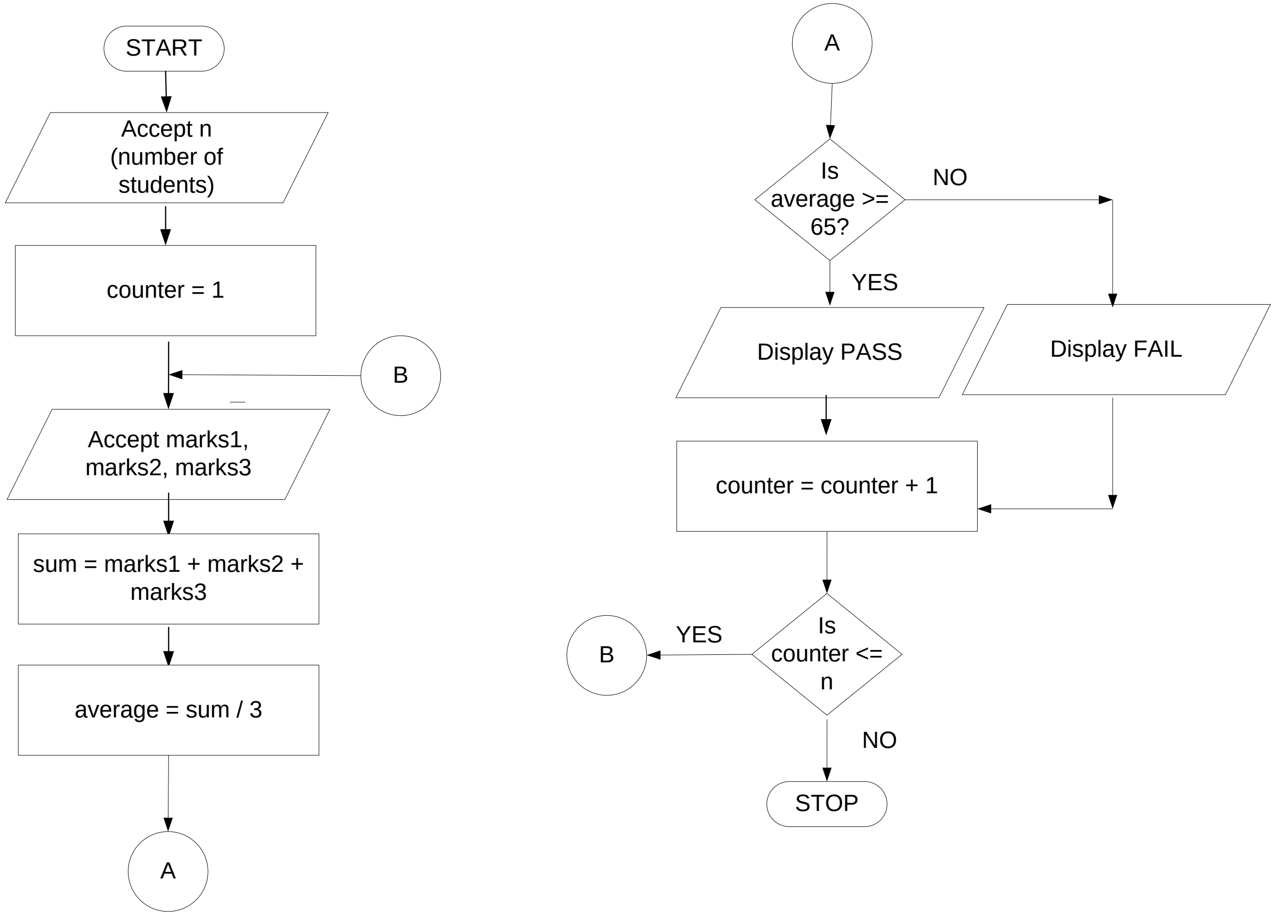
Flow Chart - Selectional



Example (Iterational)

- Do the following for N input values. Read N from user
  - Write a program to find the average of a student given the marks he obtained in three subjects.
  - Then test whether he passed or failed.
  - For a student to pass, average should not be less than 65.

Flow Chart – Example (Iterational)



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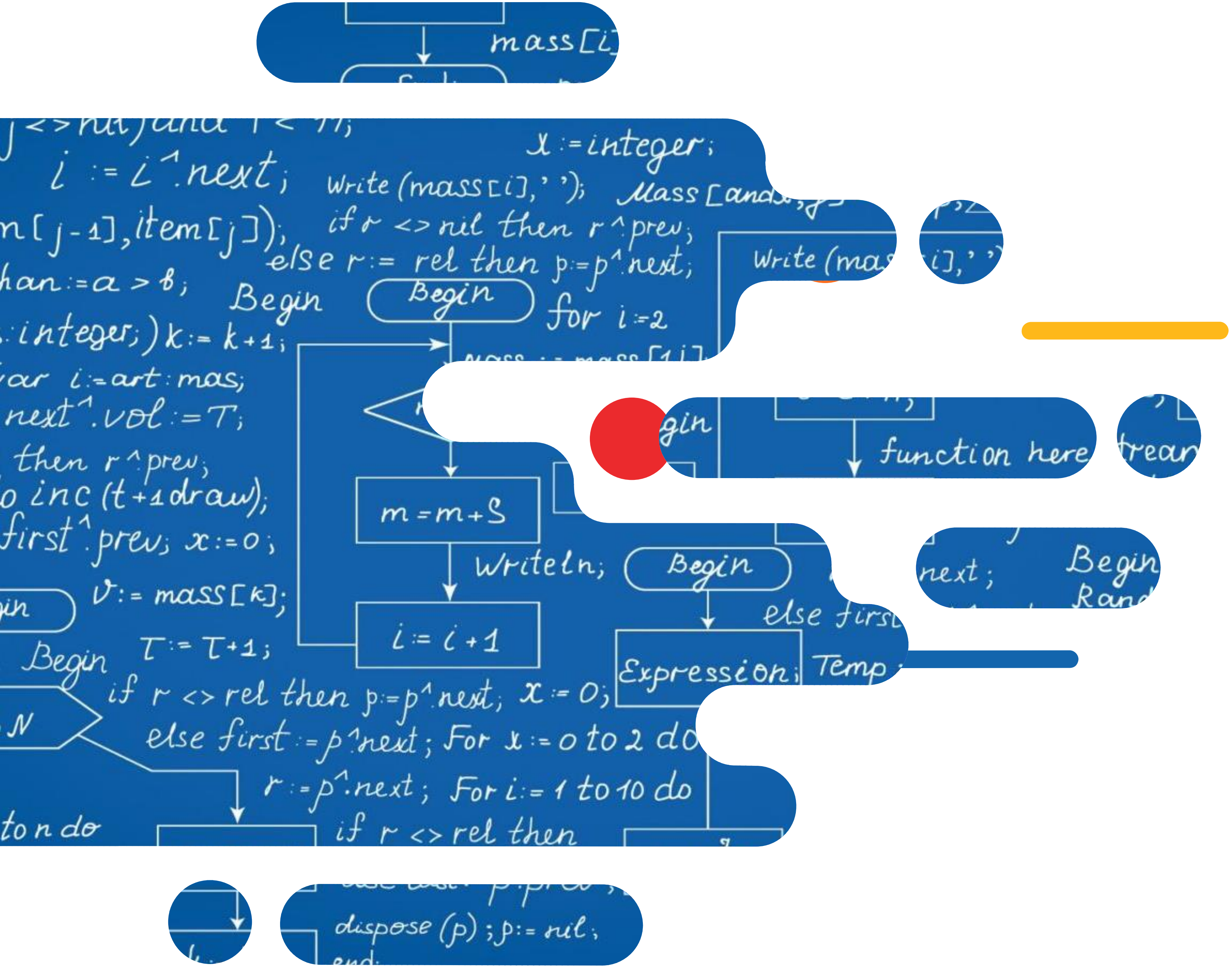

x := integer;
Write (mass[i],' ');
Begin
m = m+S
i := i +1
Writeln;
function here
Expression;
dispose (p) ; p:= nil;

Algorithm

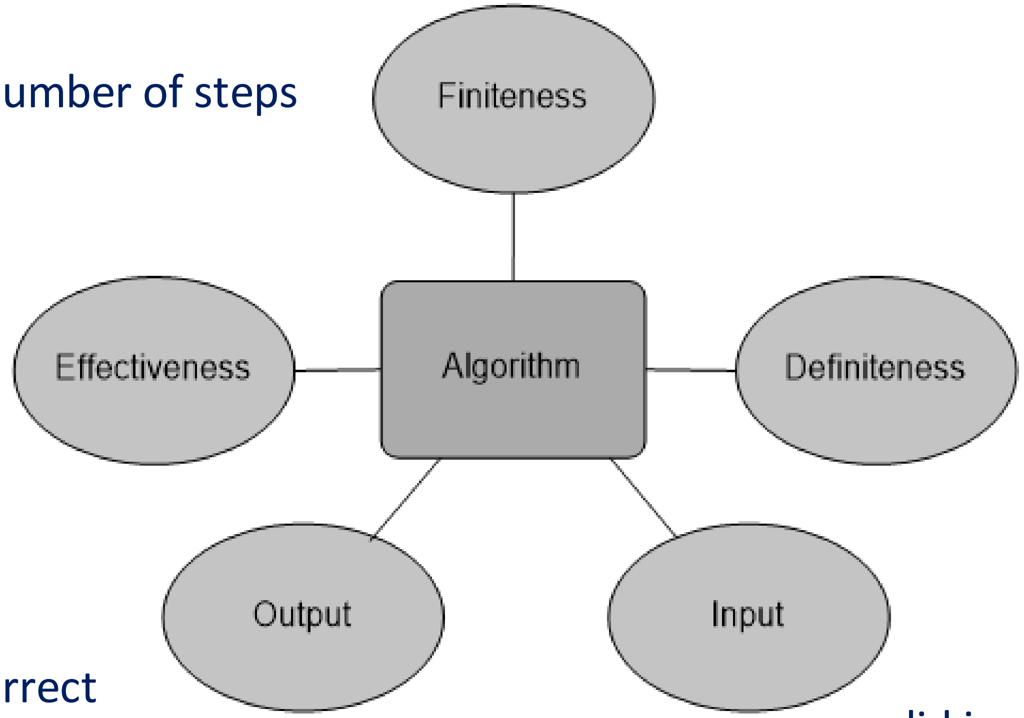
Algorithm

- An ***algorithm*** is a sequence of unambiguous instructions for solving a problem, i.e., for obtaining a required output for any legitimate input in a finite amount of time.
- Recipe, process, method, technique, procedure, routine,… with following requirements:
- The properties of an algorithm are as follows:

terminates after a finite number of steps

steps are sufficiently simple and basic

rigorously and unambiguously specified



can be proved to produce the correct output given a valid input

valid inputs are clearly specified

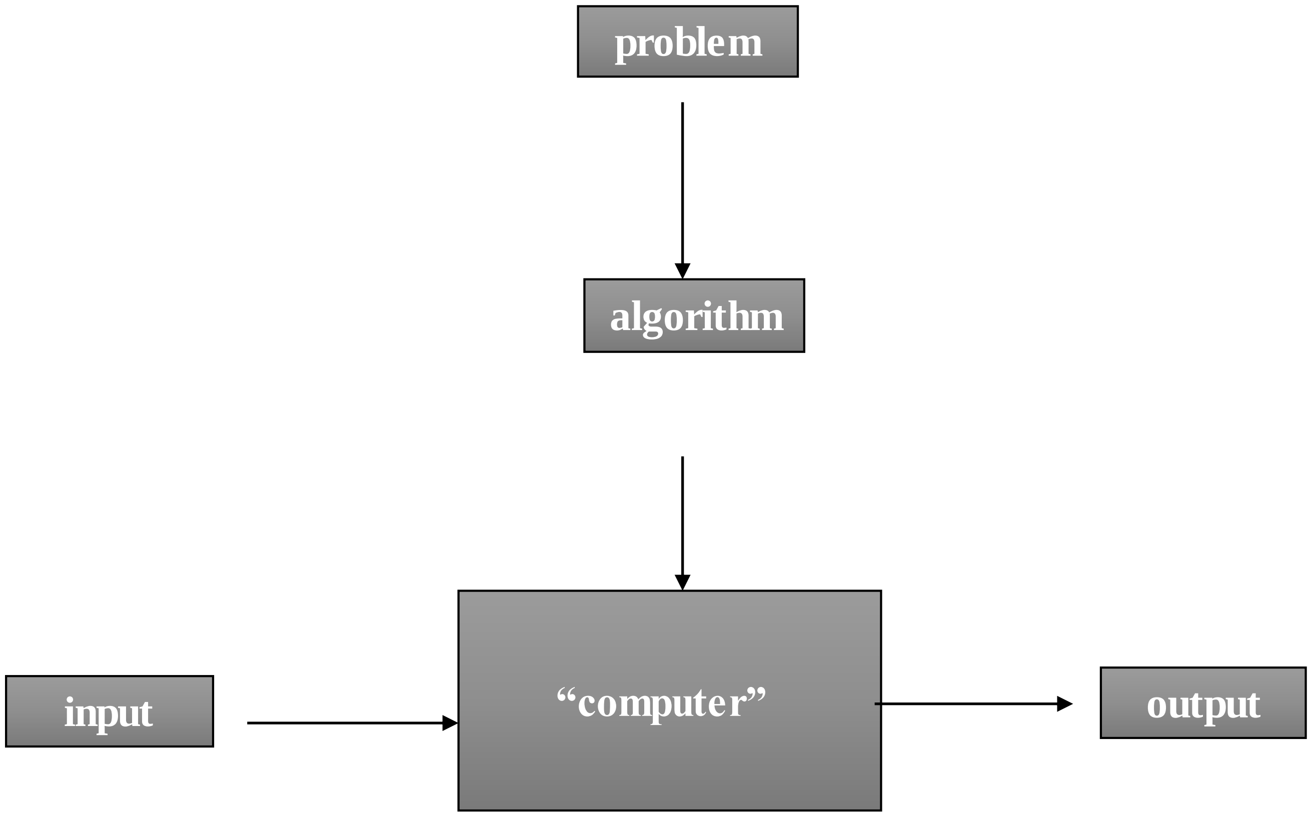
Steps to develop Algorithm

1) Identify the Inputs and Outputs

2) Identify any other data and constants required to solve the problem

3) Identify what needs to be computed

4) Write an algorithm



Algorithm – Example (1 of 2)

Find the average marks scored by a student in 3 subjects:

BEGIN

Step 1 : Accept 3 marks say Marks1, Marks2, Marks3 scored by the student

Step 2 : Add Marks1, Marks2, Marks3 and store the result in Total

Step 3 : Divide Total by 3 and find the Average

Step 4 : Display Average

END

 |

Algorithm-Example (2 of 2)

Find the average marks scored by a student in 3 subjects:

BEGIN

Step 1 : Read Marks1, Marks2, Marks3

Step 2 : Sum = Marks1 + Marks2 + Marks3

Step 3 : Average = Sum / 3

Step 4 : Display Average

END

 |

Different Patterns in Algorithms

- **Sequential**
  - Sequential constructs execute the program in the order in which they appear in the program
- **Selectional (Conditional)**
  - Selectional constructs control the flow of statement execution in order to achieve
    the required result
- **Iterational (Loops)**
  - Iterational constructs are used when a part of the program is to be executed several times

Example - Selectional

- Write an algorithm to find the average marks of a student. Also check whether the student has passed or failed.
- For a student to pass, average marks should not be less than 65.

BEGIN
Step 1 : Read Marks1, Marks2, Marks3
Step 2 : Total = Marks1 + Marks2 + Marks3
Step 3 : Average = Total / 3
Step 4 : Set Output = “Student Passed”
Step 5 : if Average < 65 then Set Output = “Student Failed”
Step 6 : Display Output
END

Example - Iterational

Find the average marks scored by ‘N’ number of students

BEGIN
Step 1 : Read NumberOfStudents
Step 2 : Counter = 1
Step 3 : Read Marks1, Marks2, Marks3
Step 4 : Total = Marks1 + Marks2 + Marks3
Step 5 : Average = Total / 3
Step 6 : Set Output = “Student Passed”
Step 7 : If (Average < 65) then Set Output = “Student Failed”
Step 8 : Display Output
Step 9 : Counter = Counter + 1
Step 10 : If (Counter <= NumberOfStudents) then goto step 3
END

 |

Pseudo Code

- An algorithm is independent of any language or machine whereas a program is dependent on a language and machine

- To fill the gap between these two, we need pseudo codes

- *Pseudo-code* is a way to represent the step by step methods in finding the solution to the given problem

Pseudo code - Example

Here's pseudo-code to add the two numbers:

```
Begin
int a, b, c;
input a, b
Let c= a + b;
output c;
End
```

 |

Pseudo codes (sequential)

```
BEGIN
Int a,b,c,avg;
Input a,b,c;
Let avg = (a+b+c)/3;
Output avg;
END
```

Pseudo codes (conditional)

Determine the largest number of A, B, C

```
Read A, B and C
If A is greater than B Then
        If A is greater than C Then
                Display A
   Else
                Display C
   End If
Else
   If B is greater than C Then
                Display B
        Else
                Display C
        End If
End If
```

 |

Pseudo codes (iteration)

Pseudo code:

```
For emp # 1000 to 1500
Salary = salary + 10000
End for;
```

Recap

- Skills of a software developer
- Problem classification
- Problem solving approaches
- Flow Chart
- Algorithm patterns
- Pseudo codes

Algorithm Design

Searching and Sorting

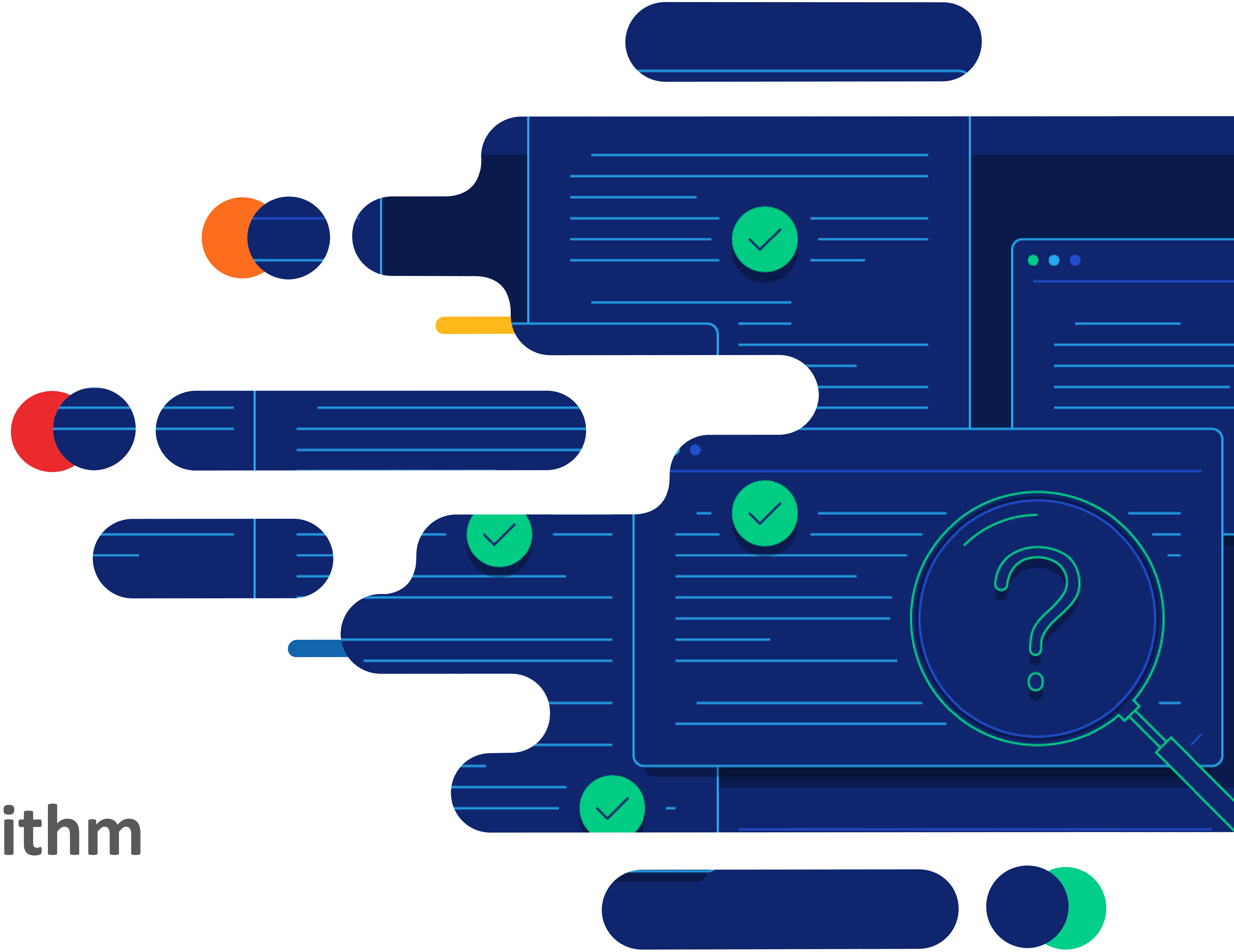
- Searching refers to finding whether a data item is present in the set of items or not
- Sorting refers to the arrangement of data in a particular order. That is, arranging items in a particular way
- Sorting and searching have many applications in the area of computers

Searching Algorithms

- The time required to search depends on the following factors:
  - Whether the data is arranged in a particular order or not
  - The location of the data to be searched
  - The total number of searches to be done

- When the data is arranged in a particular order then, the time taken to search for the item is less.

- Searching algorithms
  - Linear Search
  - Binary Search



Searching Algorithm

Linear Search: A Simple Search

- A search traverses the collection until
  - The desired element is found
  - Or the collection is exhausted

- If the collection is ordered, I might not have to look at all elements
  - I can stop looking when I know the element cannot be in the collection.

The Scenario

- We have a sorted array

- We want to determine if a particular element is in the array
  - Once found, print or return (index, boolean, etc.)
  - If not found, indicate the element is not in the collection

7	12	42	59	71	86	104	212

A Better Search Algorithm

Of course we could use our simpler search and traverse the array.

But we can use the fact that the array is sorted to our advantage.

This will allow us to reduce the number of comparisons.

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Binary Search

- **Requires a sorted array or a *binary search tree*.**

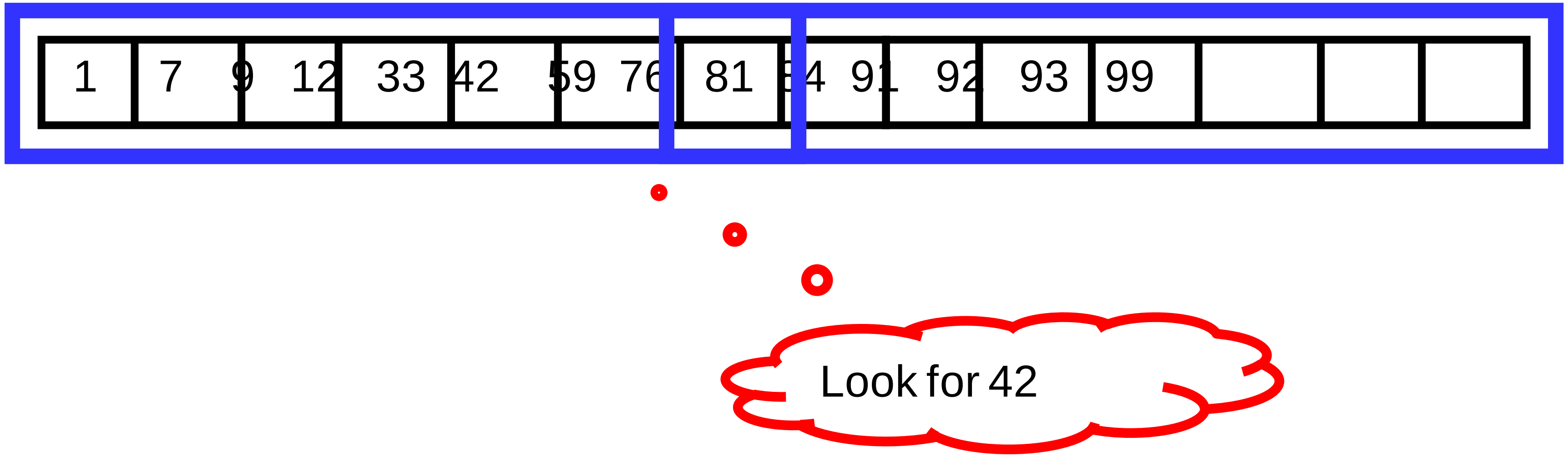
- **Cuts the “search space” in half each time.**

- **Keeps cutting the search space in half until the target is found or has exhausted the all possible locations.**

Binary Search Algorithm

```
look at "middle" element

if no match then
   look left (if need smaller) or
        right (if need larger)
```

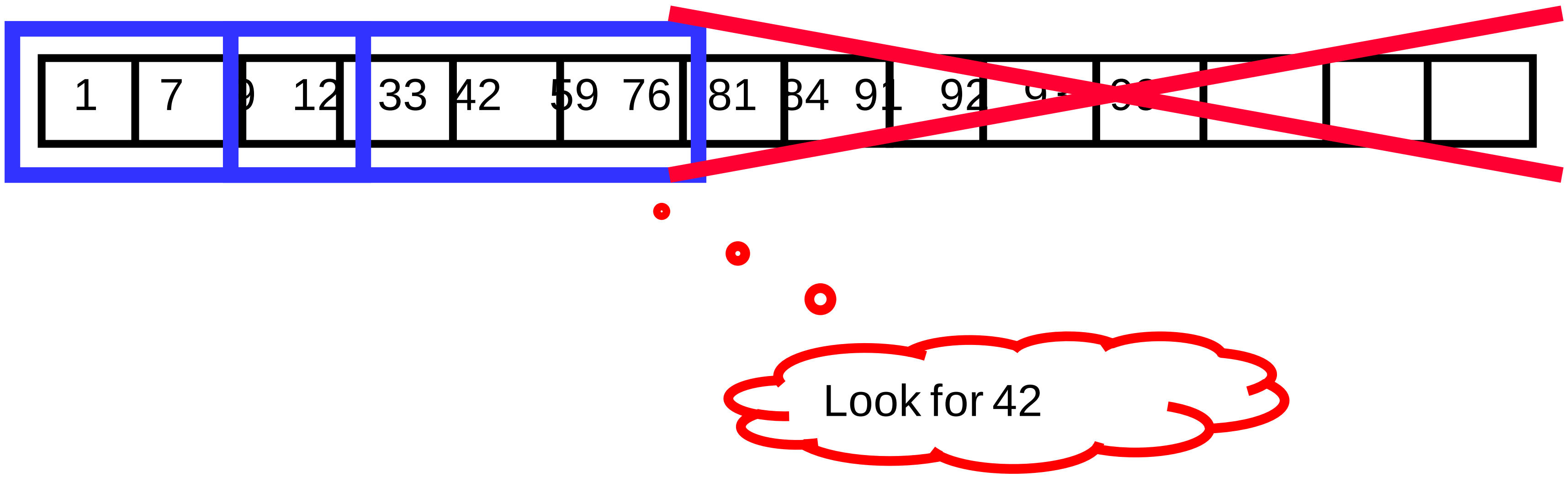


The Algorithm

look at "middle" element

if no match then

look left or right



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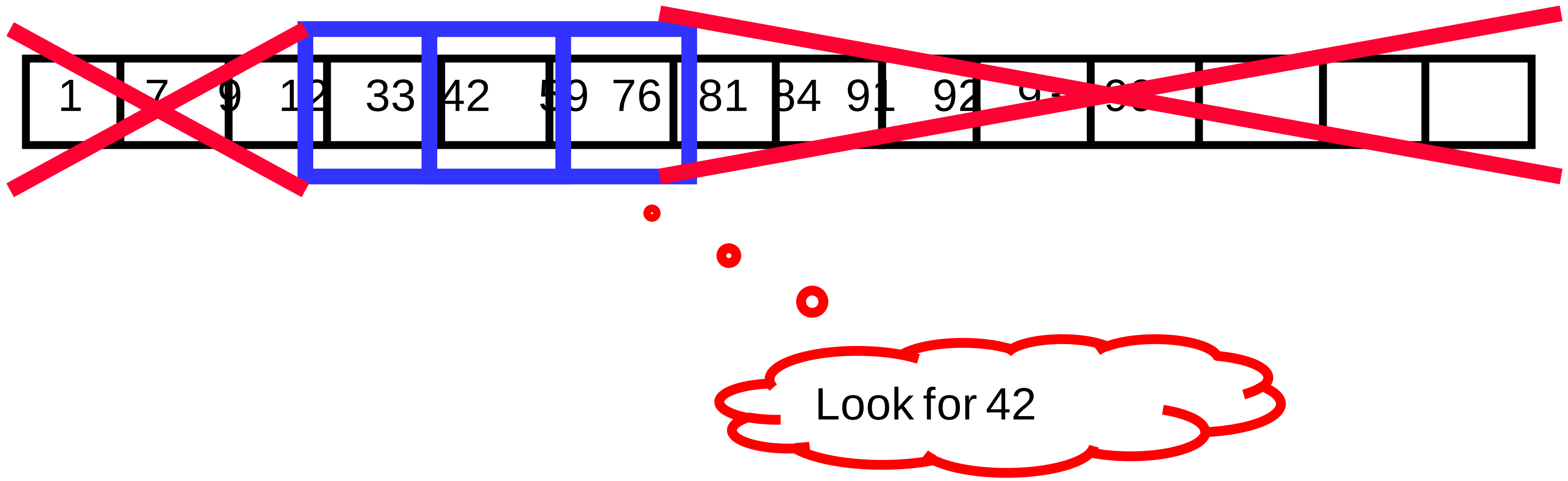

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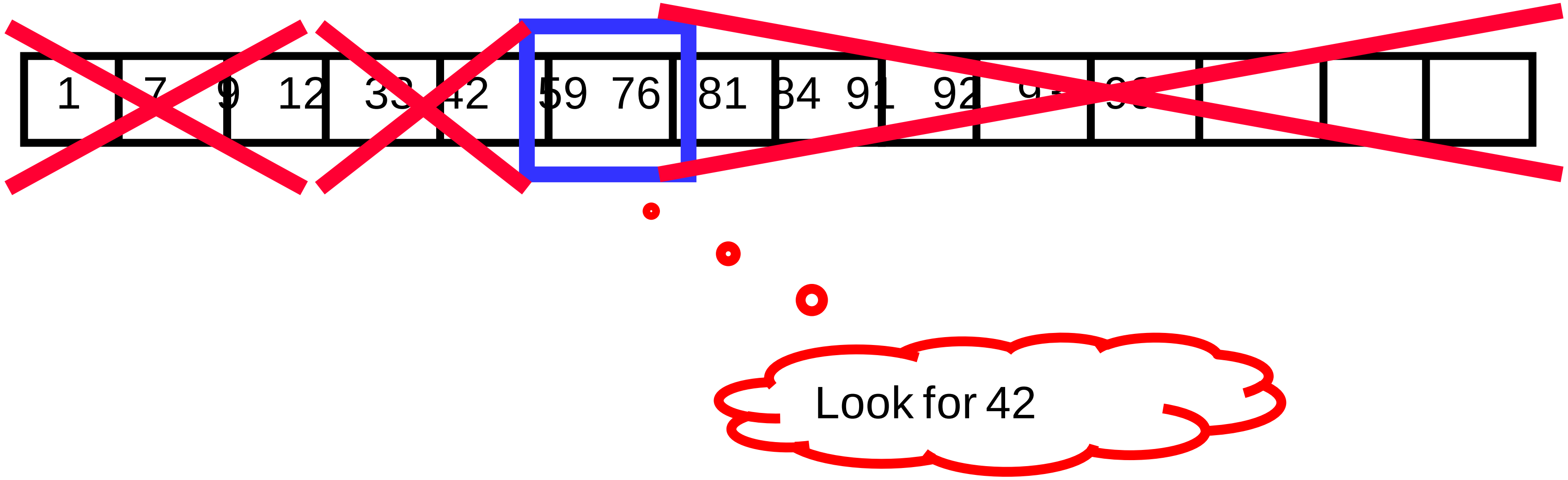


The Binary Search Algorithm

- **Return found or not found (true or false), so it should be a function.**

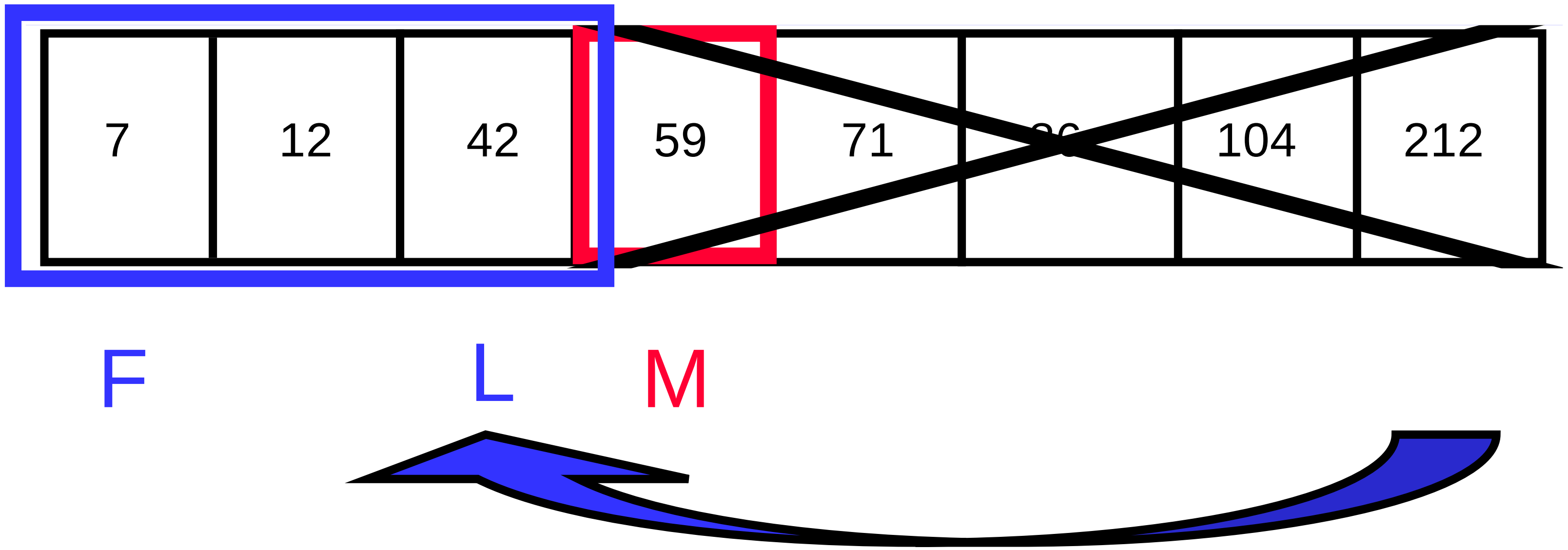
- **When move *left* or *right*, change the array boundaries**
  - **We need a first and last index value.**

The Binary Search Algorithm

```
calculate middle position

if (first and last have "crossed") then
  "Item not found"

elseif (element at middle = to_find) then
  "Item Found"

elseif to_find < element at middle then
  Look to the left

else
  Look to the right
```

Looking Left

- Use indices “**first**” and “**last**” to keep track of where we are looking
- Move **left** by setting **last = middle – 1**



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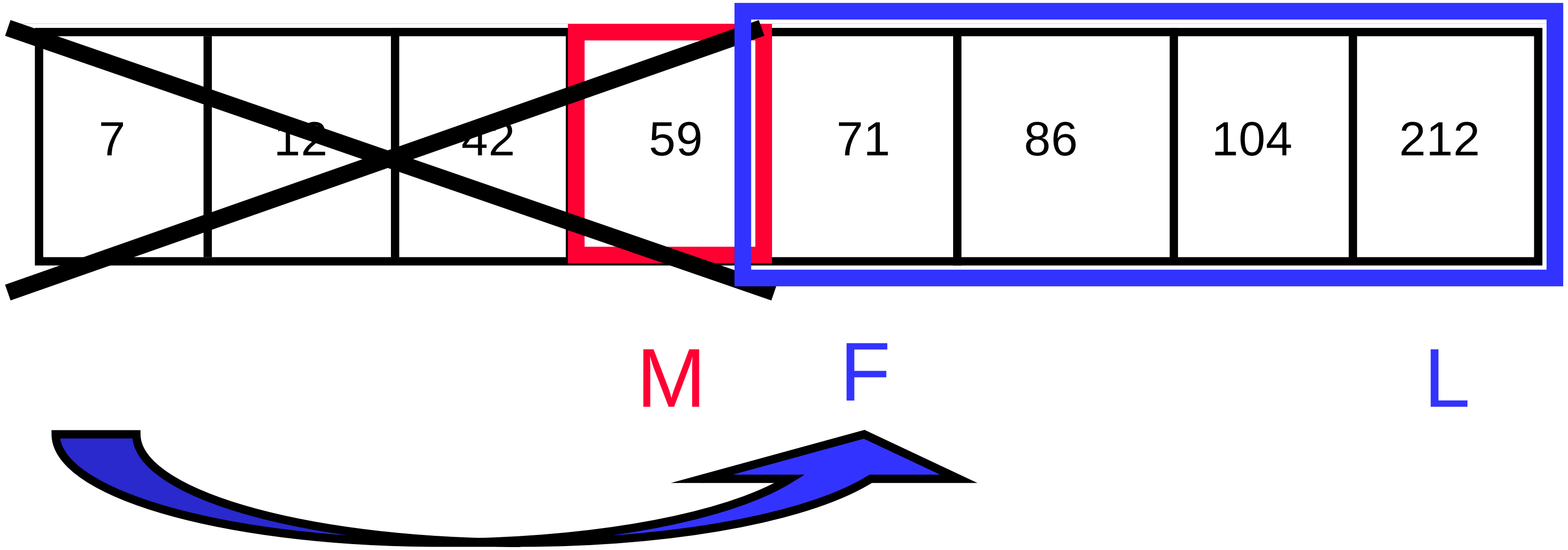
Looking Right

- Use indices "first" and "last" to keep track of where we are looking
- Move right by setting first = middle + 1



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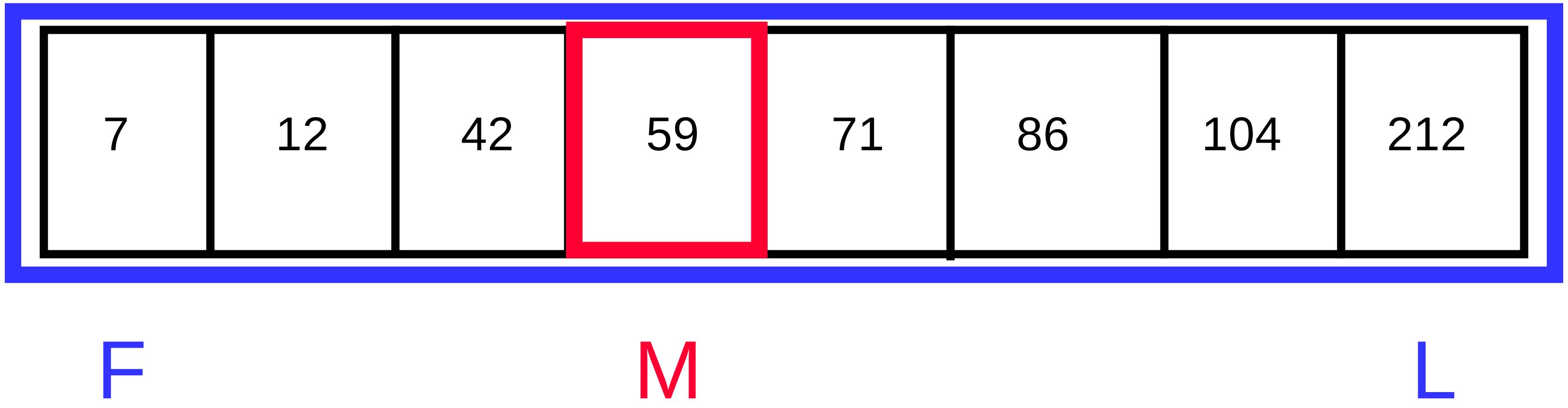
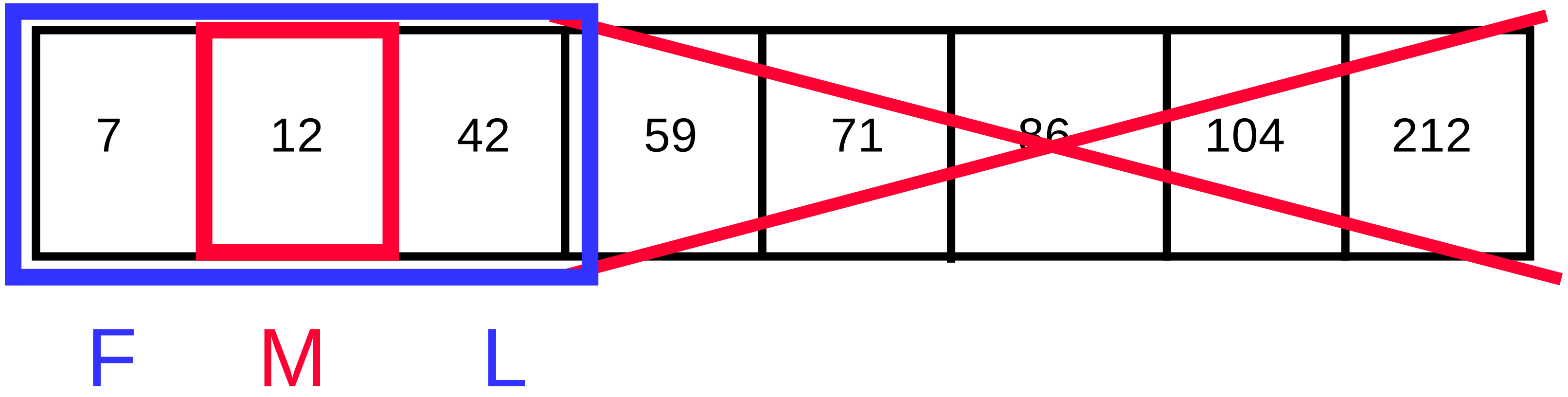
Binary Search Example – Found



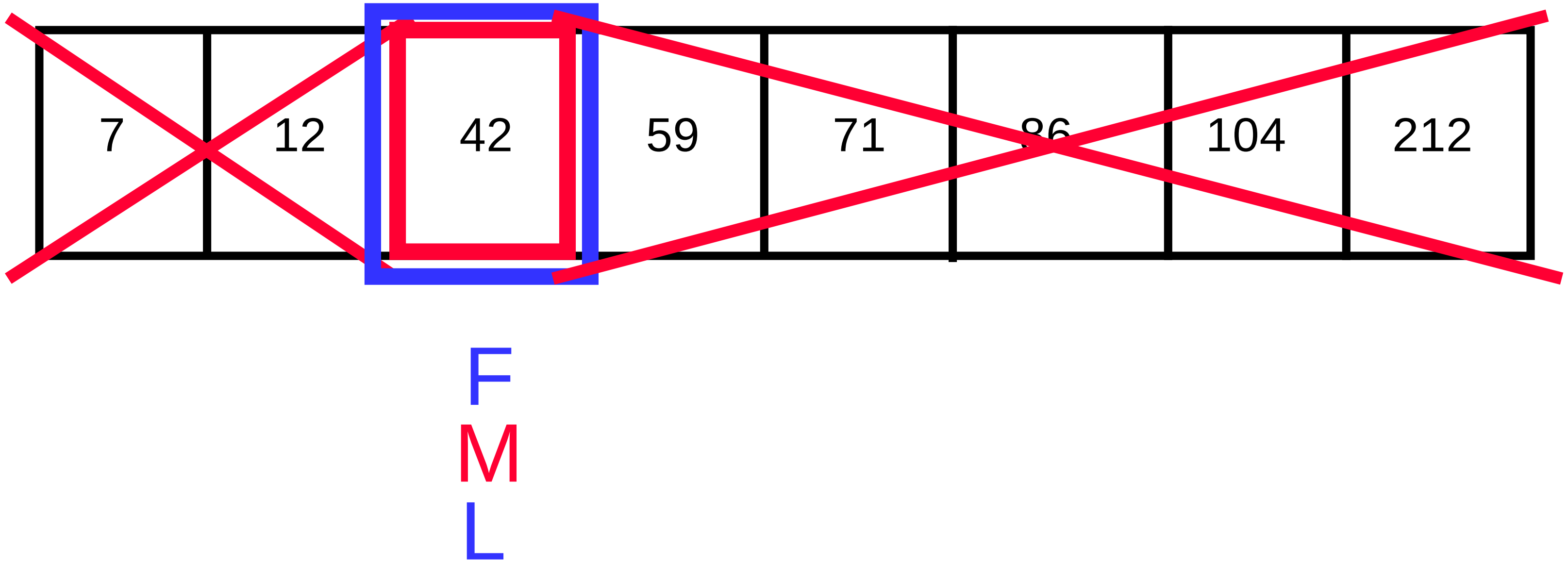
Looking for 42

Binary Search Example – Found



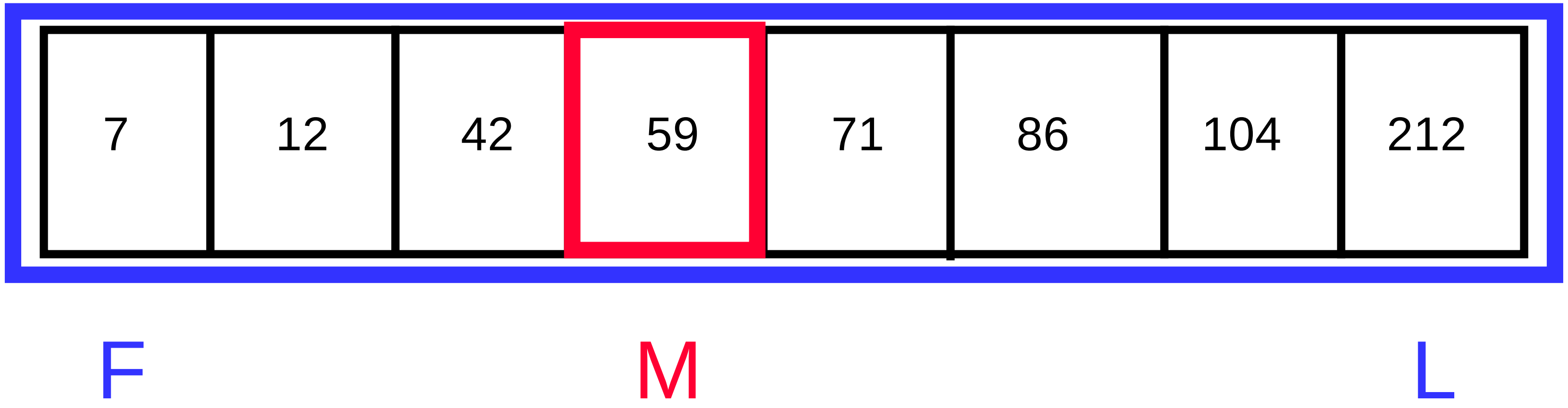
Looking for 42

Binary Search Example – Found



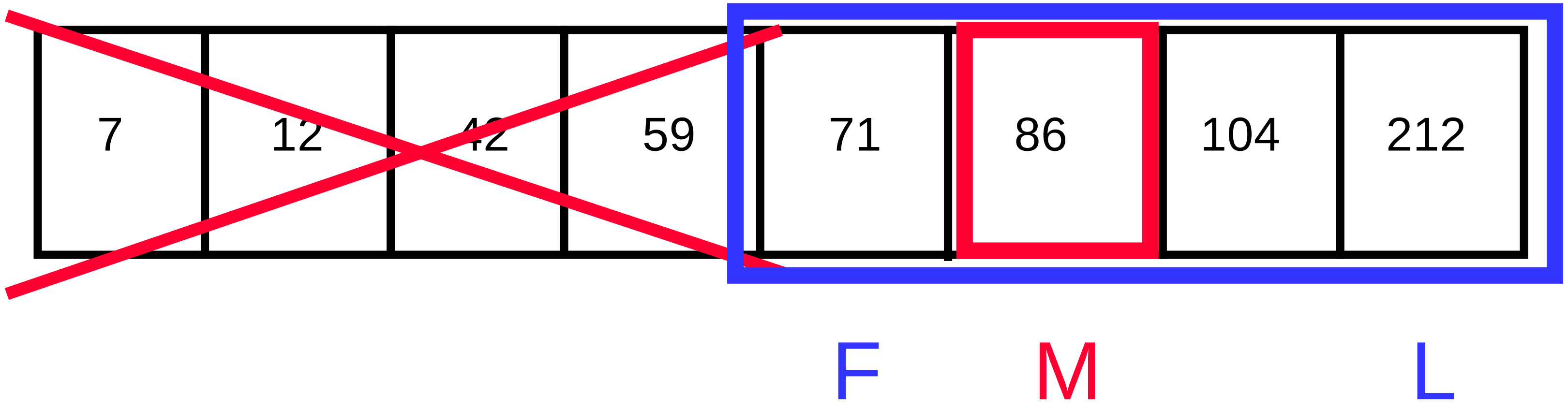
42 found – in 3 comparisons

Binary Search Example – Not Found



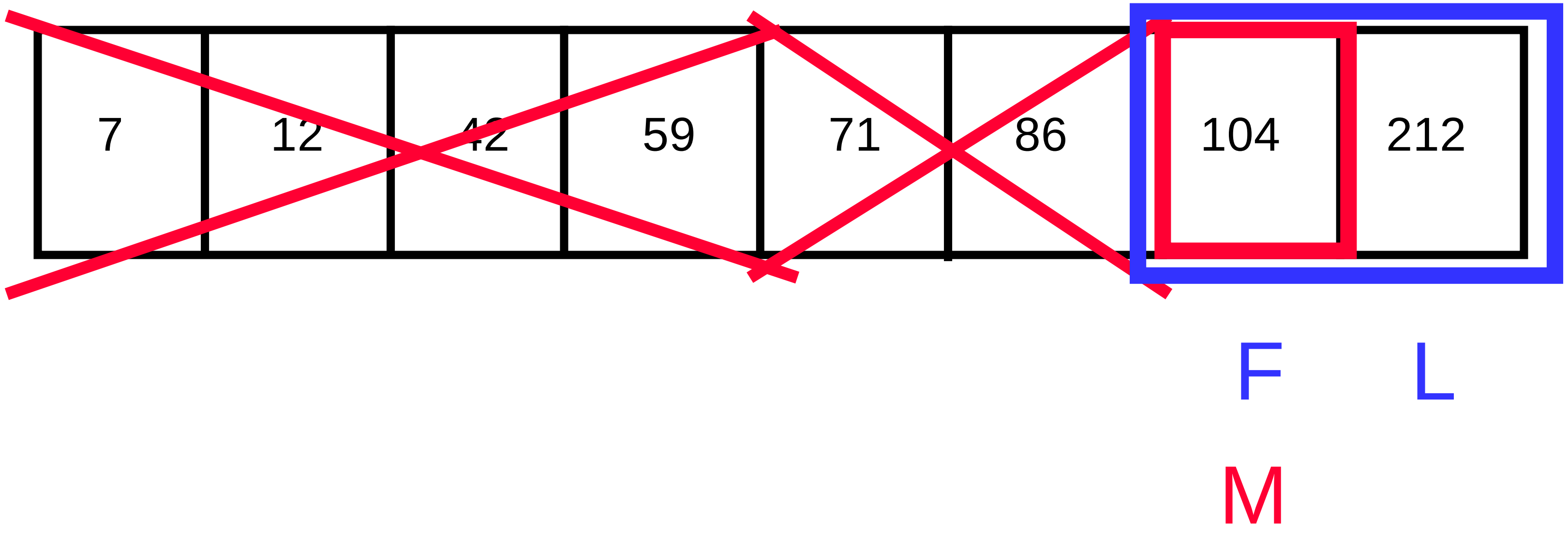
Looking for 89

Binary Search Example – Not Found



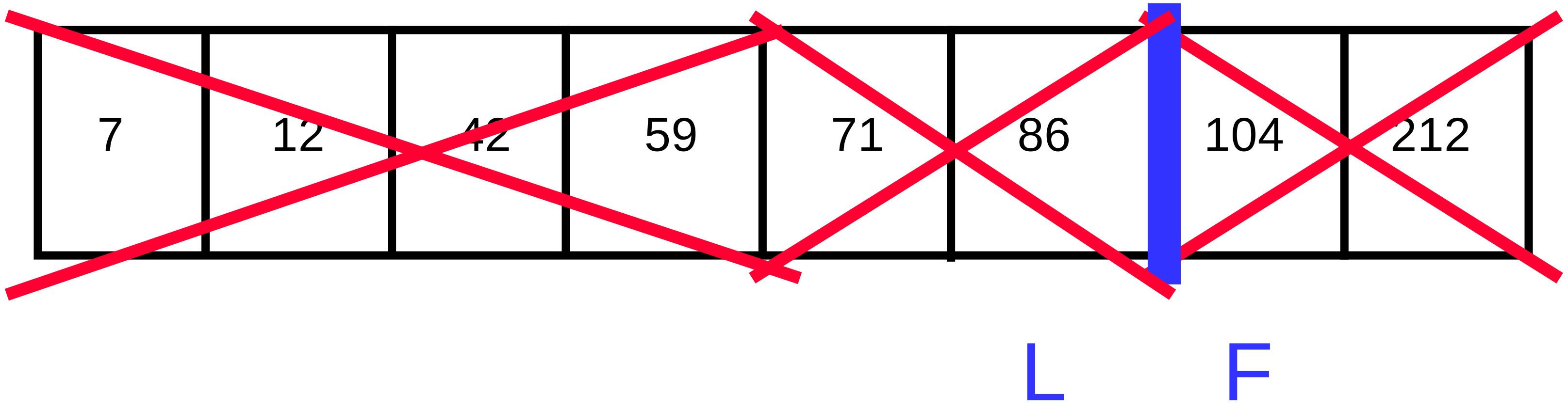
Looking for 89

Binary Search Example – Not Found



Looking for 89

Binary Search Example – Not Found



89 not found – 3 comparisons

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Sorting Techniques

Sorting

- Arranging the data elements in a particular sequence – in the ascending order (increasing order) or in the descending order (decreasing order)

- Sorting Algorithms:
    - Selection Sort
    - Insertion Sort
    - Bubble Sort

 |

Sorting

Sorting is any process of arranging items systematically, and has two common, yet distinct meanings: ordering: arranging items in a sequence ordered by some criterion; categorizing: grouping items with similar properties.

Sorting

- **Sorting takes an unordered collection and makes it an ordered one.**

1	2	3	4	5	6
77	42	35	12	101	5

↓

1	2	3	4	5	6
5	12	35	42	77	101

Complexity of sorting Algorithm

The complexity of sorting algorithm calculates the running time of a function in which 'n' number of items are to be sorted. The choice for which sorting method is suitable for a problem depends on several dependency configurations for different problems. The most noteworthy of these considerations are:

The length of time spent by the programmer in programming a specific sorting program

Amount of machine time necessary for running the program

The amount of memory necessary for running the program

Types of Sorting Techniques

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

Bubble sort - "Bubbling Up" the Largest Element

- Traverse a collection of elements
  - Move from the front to the end
  - “Bubble” the largest value to the end using pair-wise comparisons and swapping

1	2	3	4	5	6
77	42	35	12	101	5

"Bubbling Up" the Largest Element

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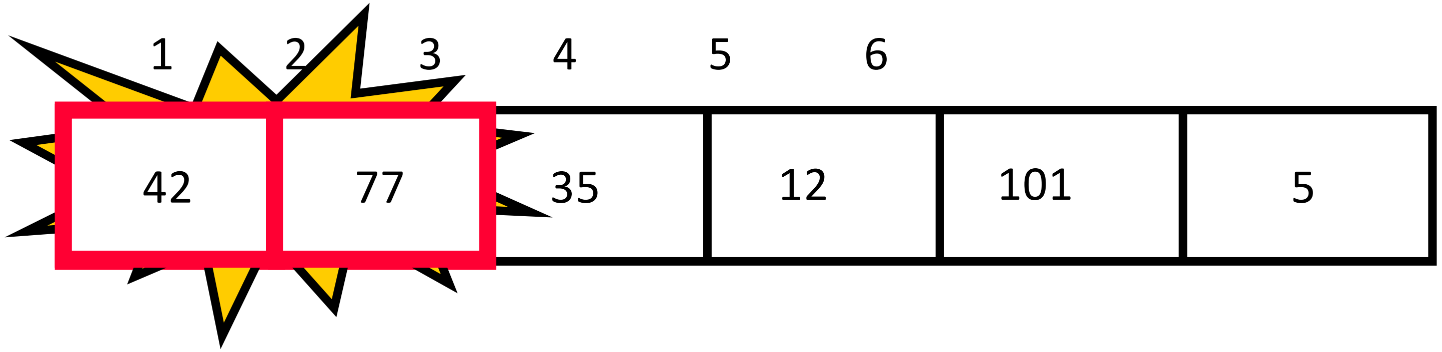

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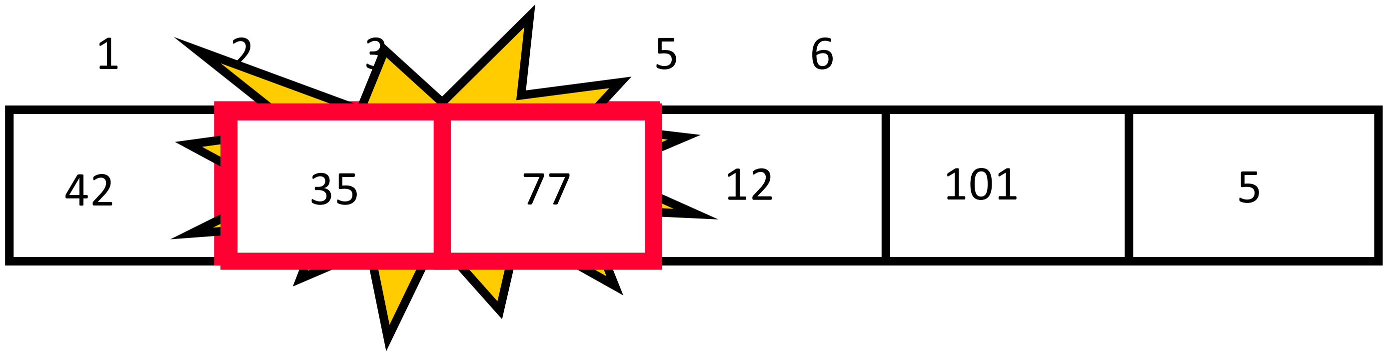

"Bubbling Up" the Largest Element

- **Traverse a collection of elements**
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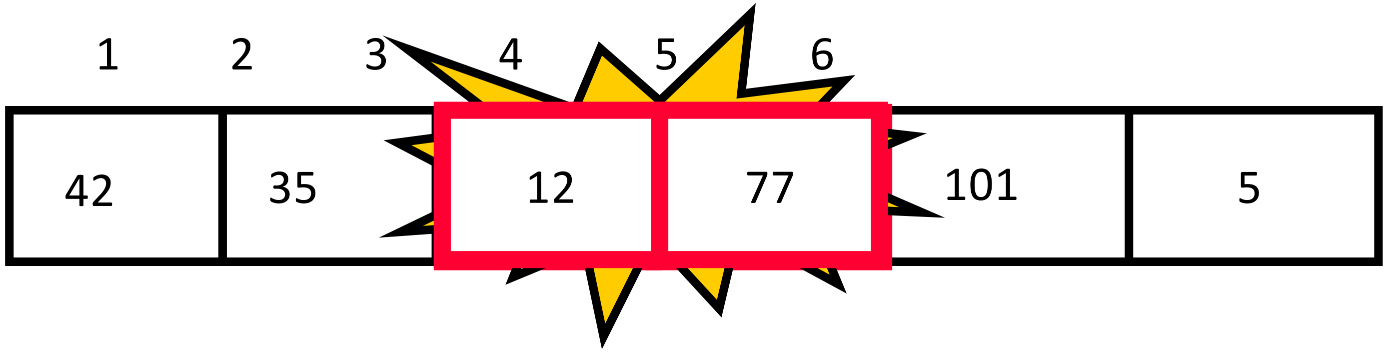

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1	2	3	4	5	6
42	35	12	77	101	5

No need to swap

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"Bubbling Up" the Largest Element

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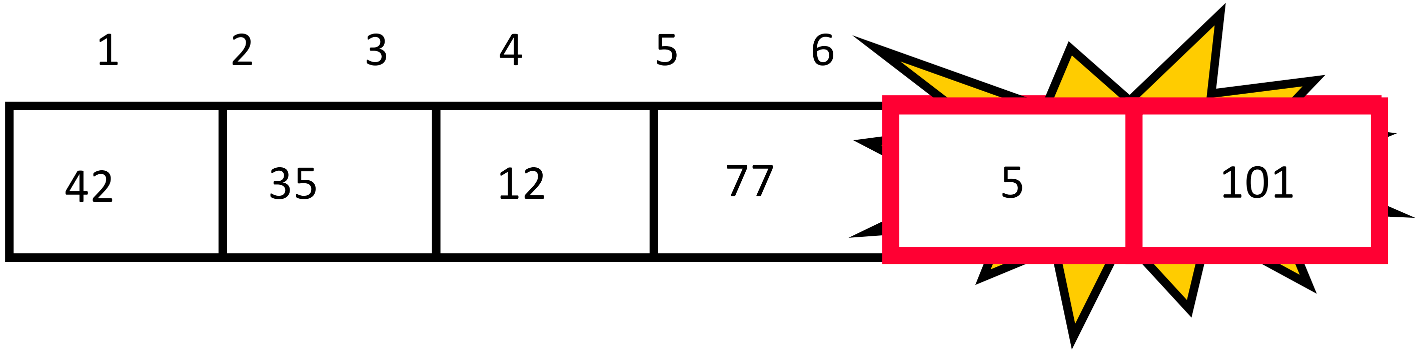

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- Traverse a collection of elements
  - Move from the front to the end
  - “Bubble” the largest value to the end using pair-wise comparisons and swapping

1	2	3	4	5	6
42	35	12	77	5	101

Largest value correctly placed

Items of Interest

- **Notice that only the largest value is correctly placed**
- **All other values are still out of order**
- **So we need to repeat this process**

1	2	3	4	5	6
42	35	12	77	5	101

Largest value correctly placed

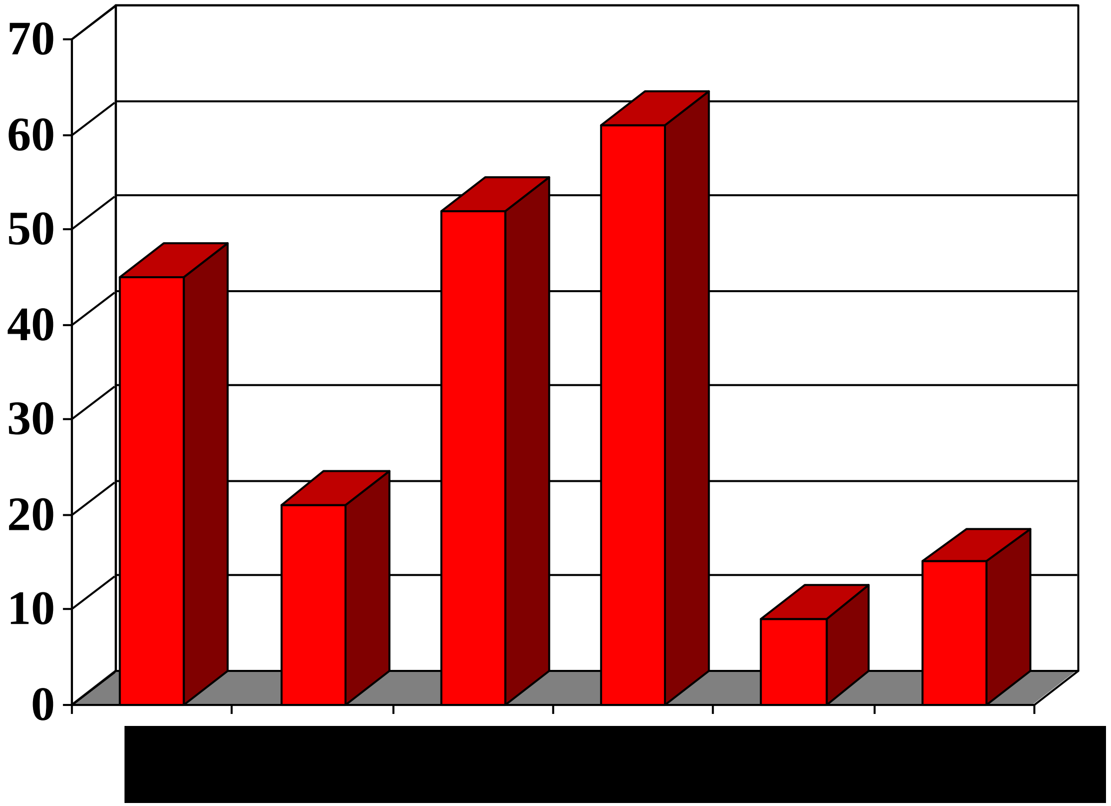
Selection sort

Selection Sort

- Idea:
  - Find the smallest element in the array
  - Exchange it with the element in the first position
  - Find the second smallest element and exchange it with the element in the second position
  - Continue until the array is sorted
- Disadvantage:
  - Running time depends only slightly on the amount of order in the file

Selection Sort

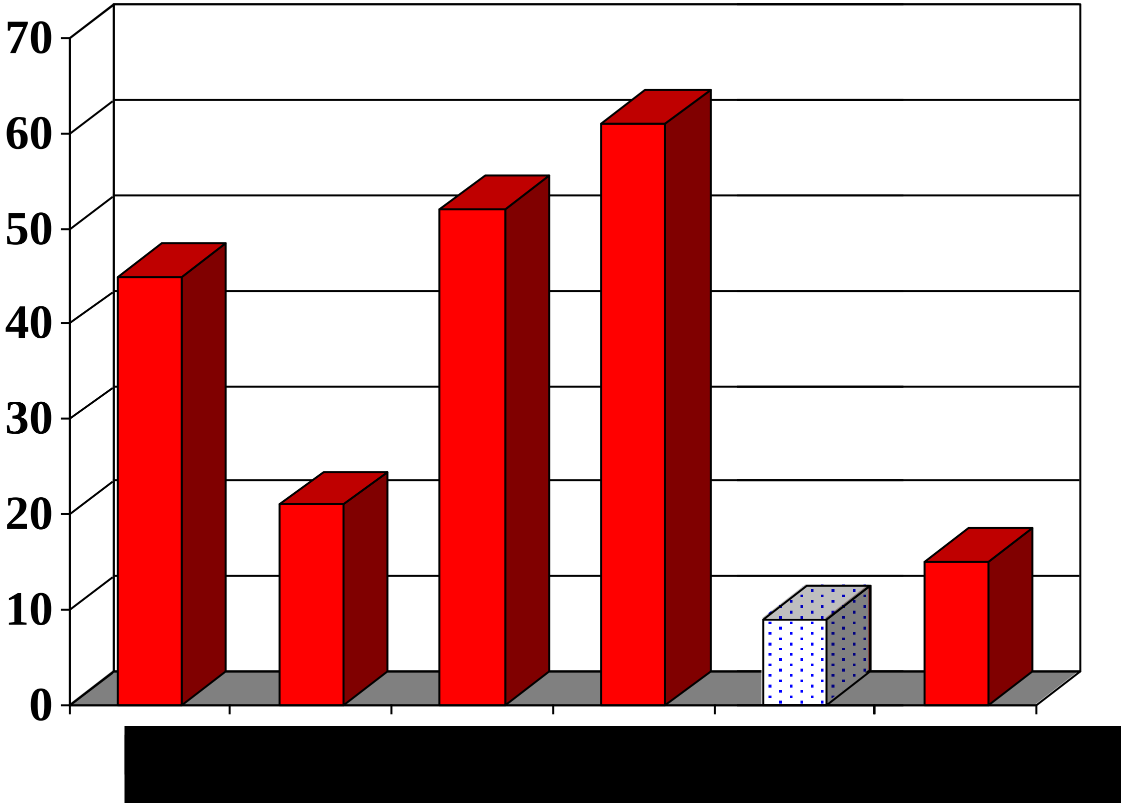
- Example: we are given an array of six integers that we want to sort from smallest to largest



 |

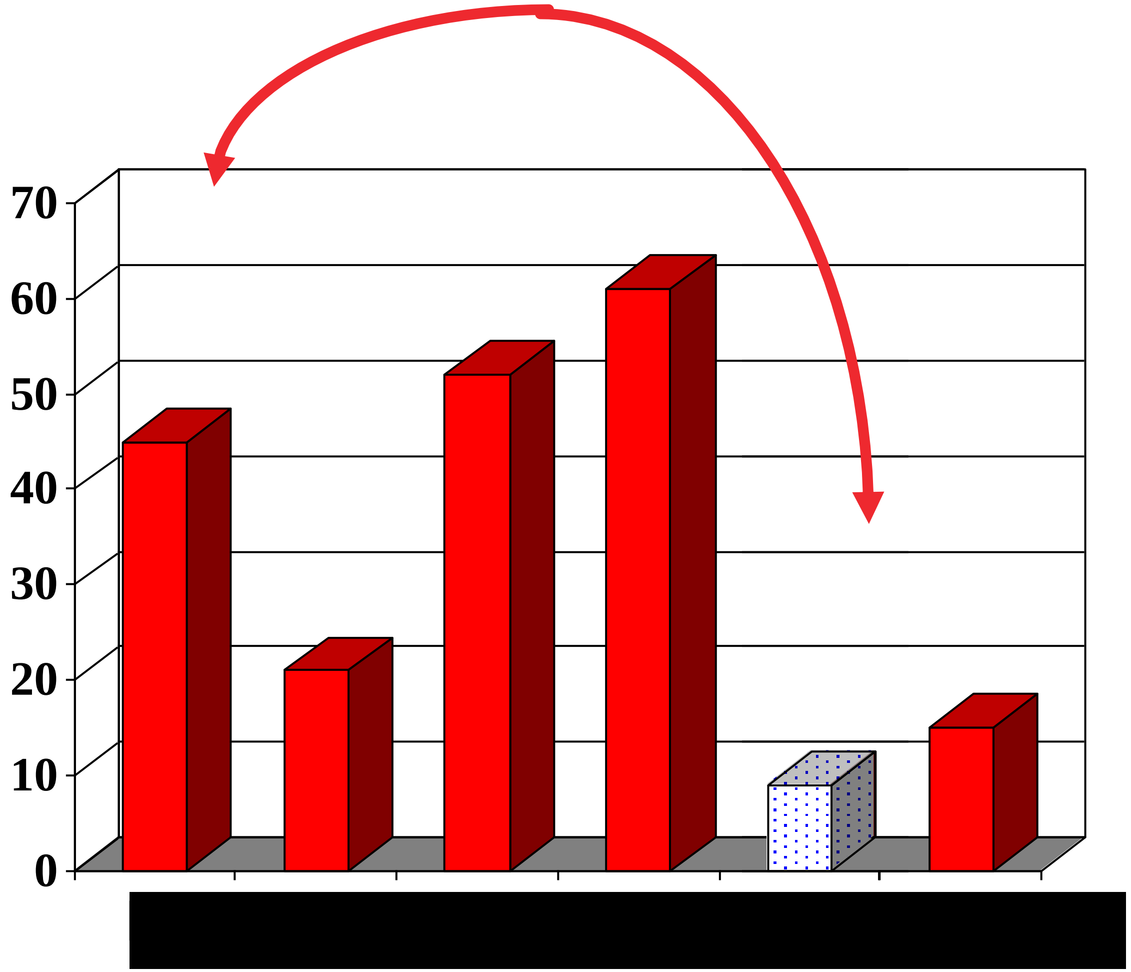
Selection Sort

- Start by finding the **smallest** entry.



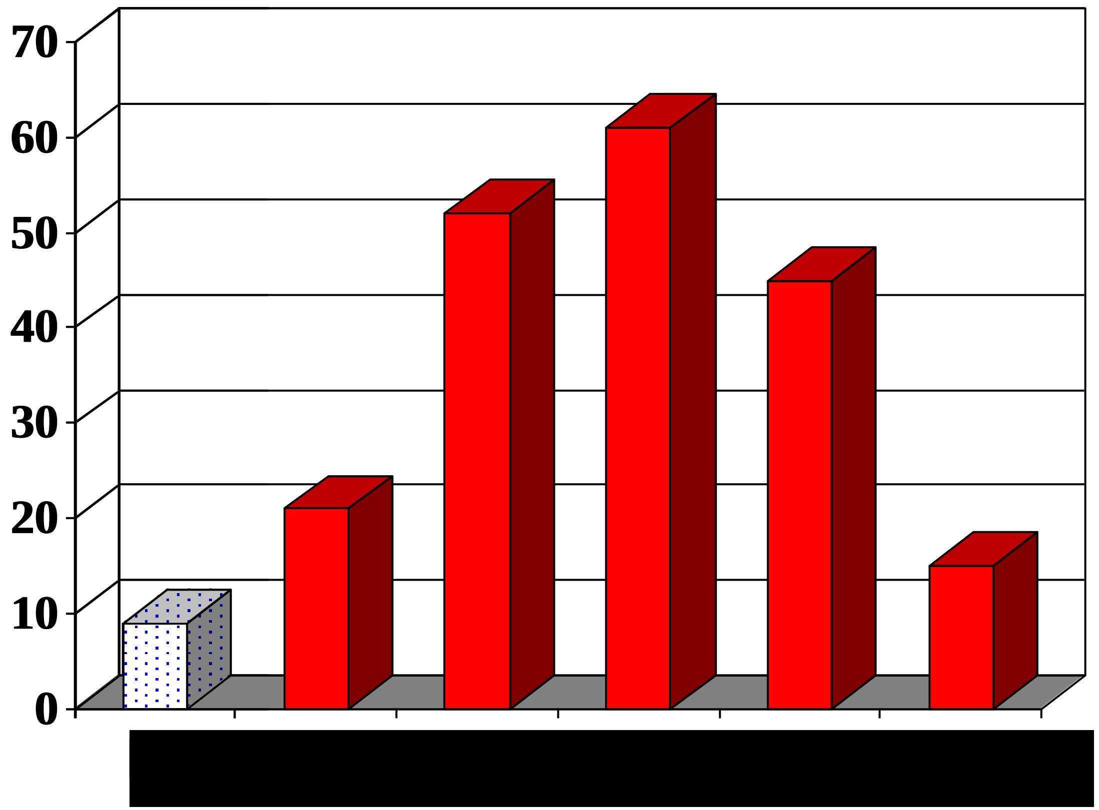
Selection Sort

- Swap the smallest entry with the **first entry**.



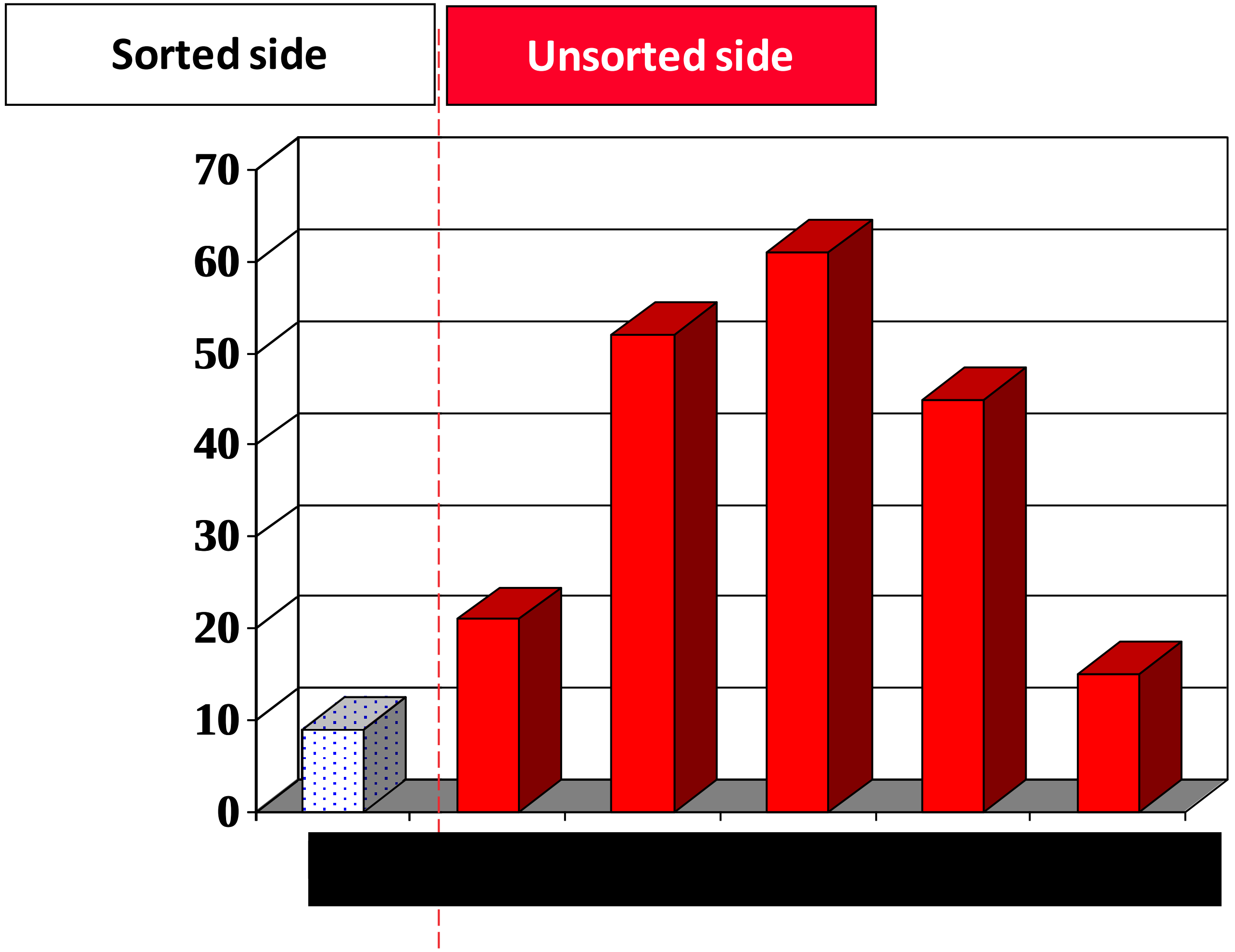
Selection Sort

- Swap the smallest entry with the **first entry**.



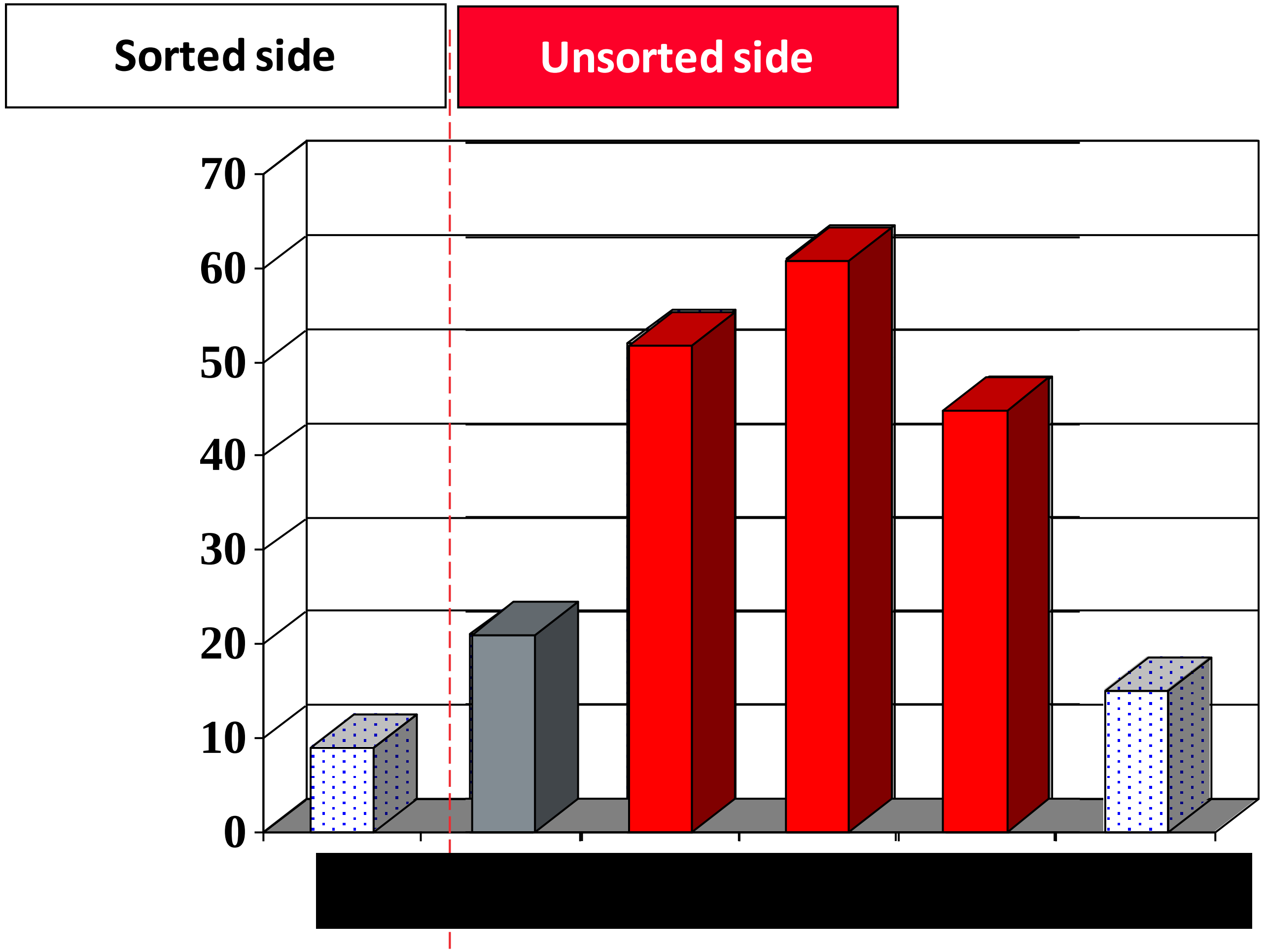
Selection Sort

- Part of the array is now sorted.



Selection Sort

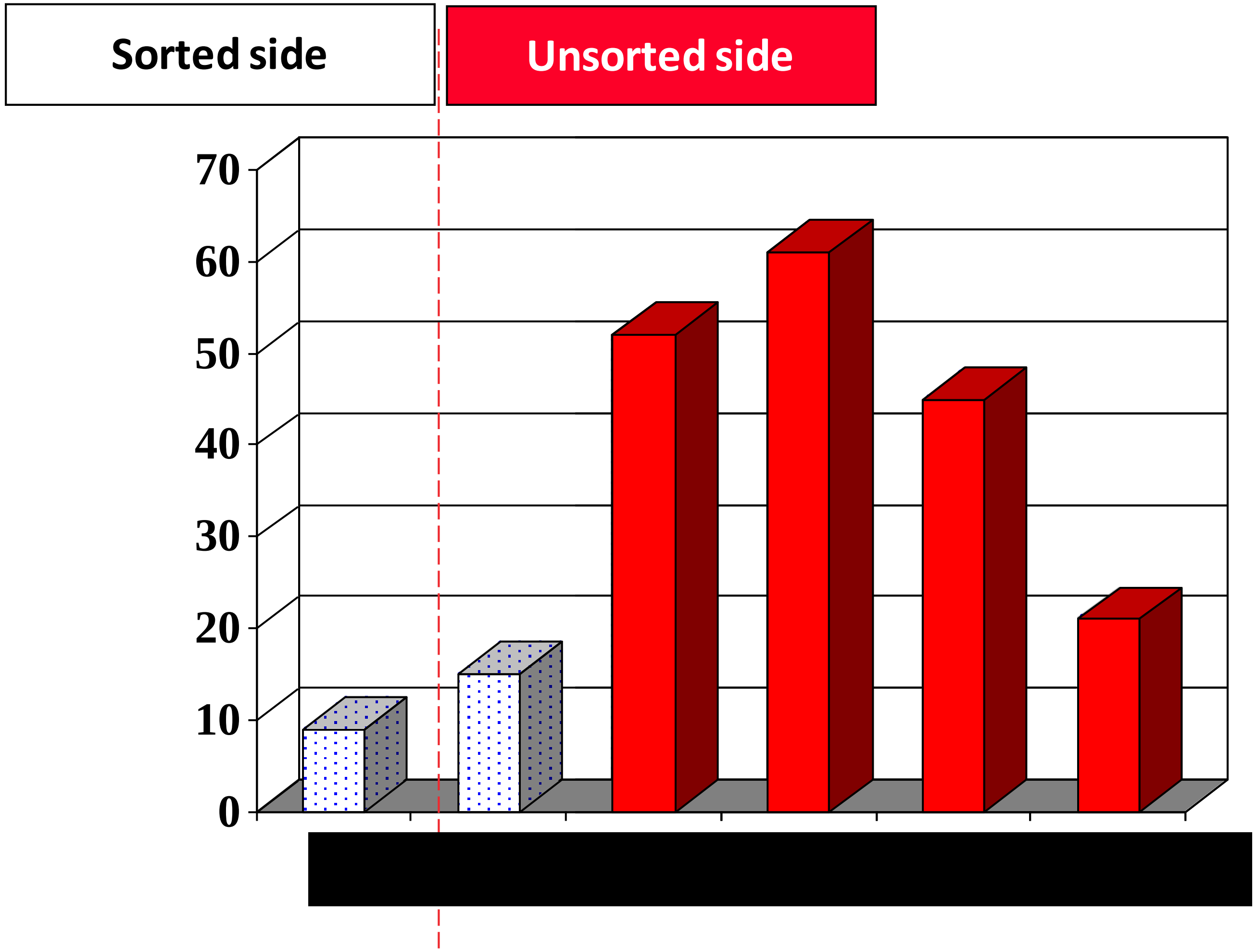
- Find the smallest element in the unsorted side.



 |

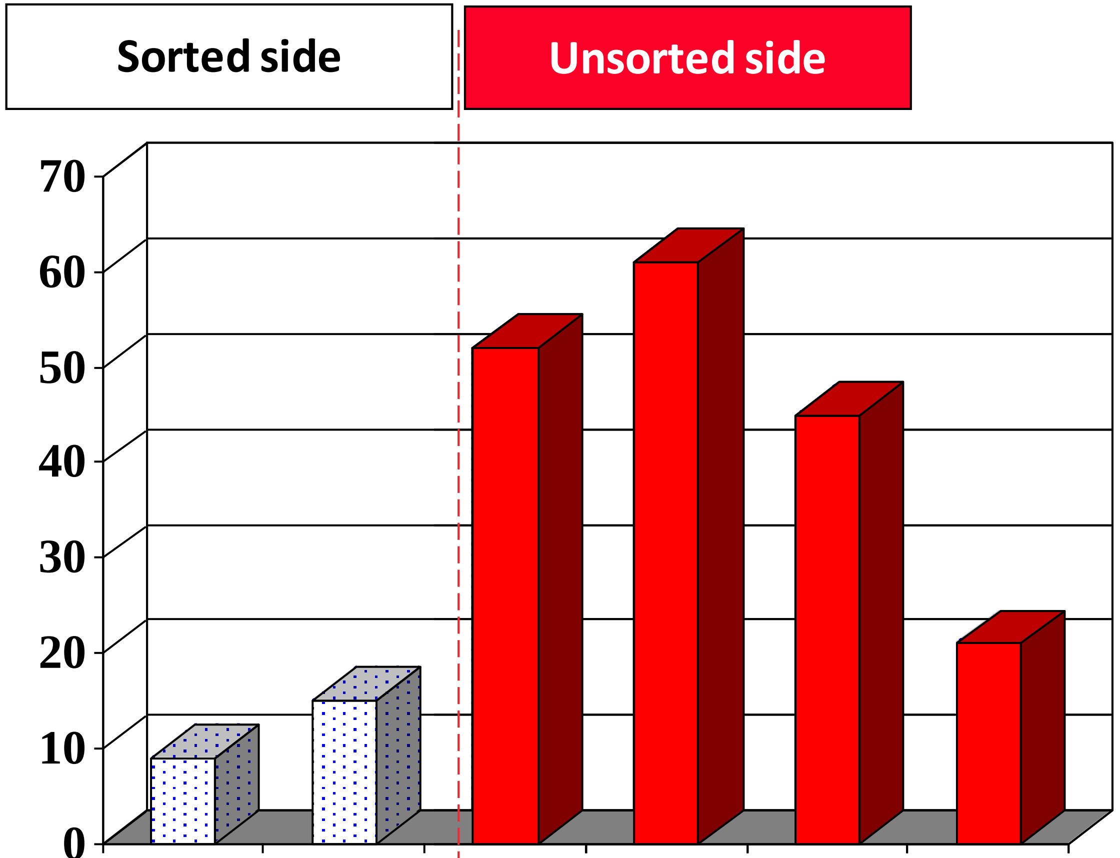
Selection Sort

- Swap with the front of the unsorted side.



Selection Sort

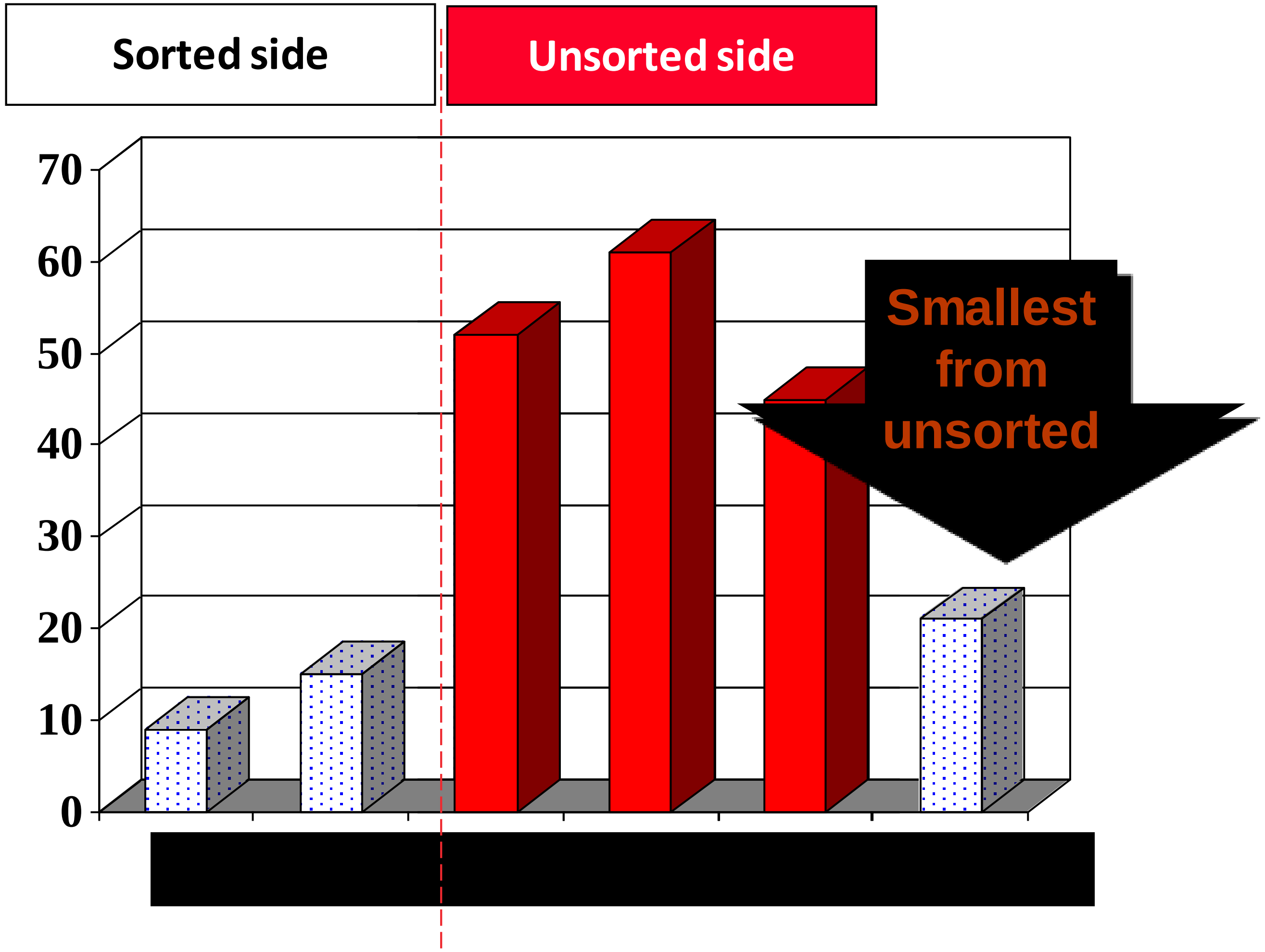
- We have increased the size of the sorted side by one element.



 |

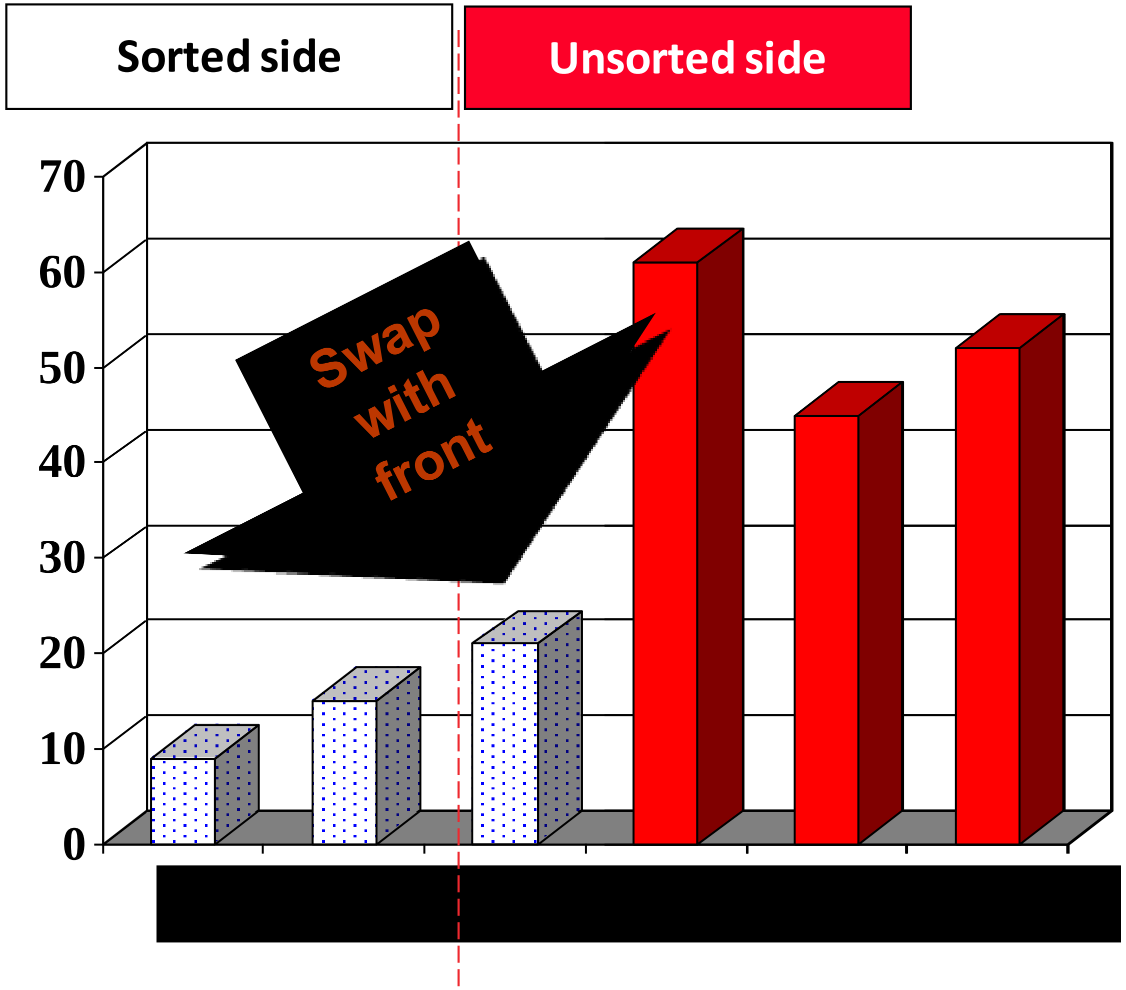
Selection Sort

- The process continues...



Selection Sort

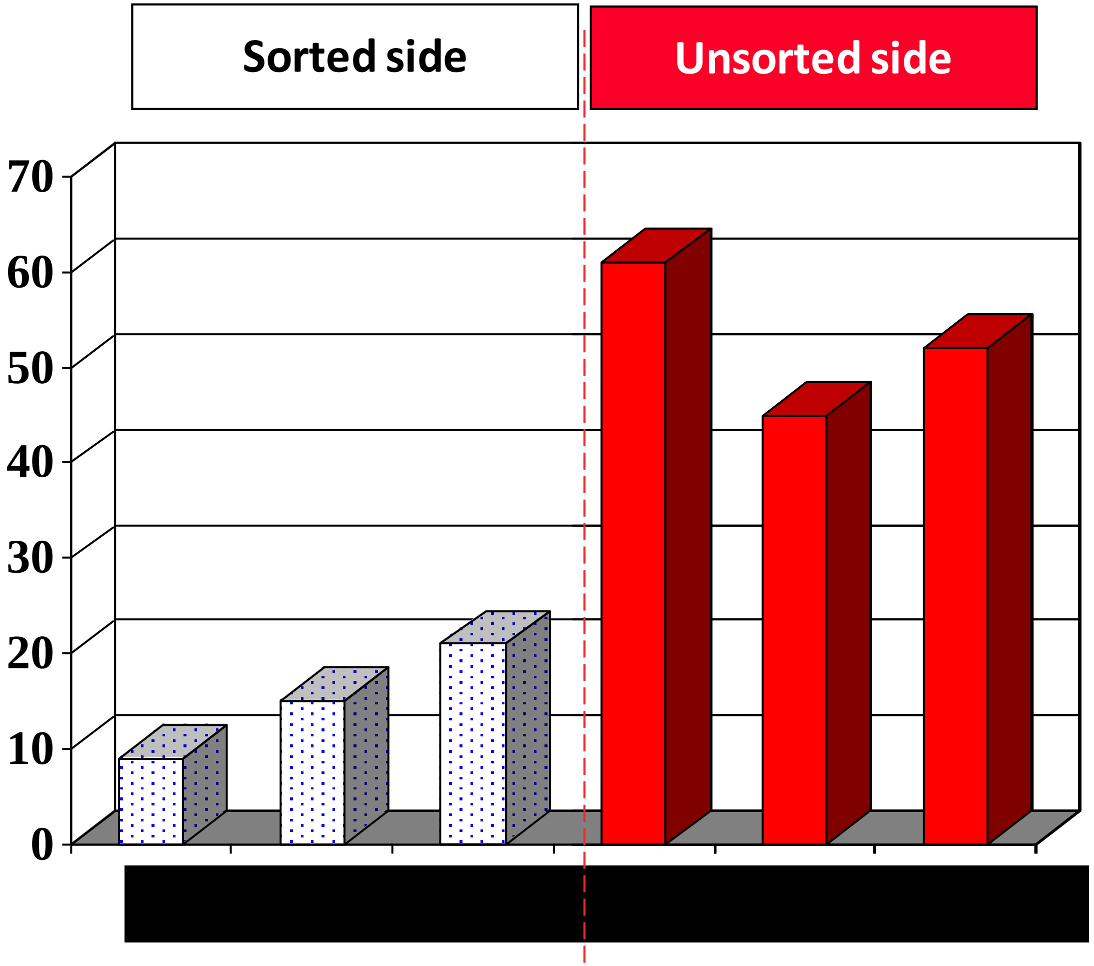
- The process continues...



Selection Sort

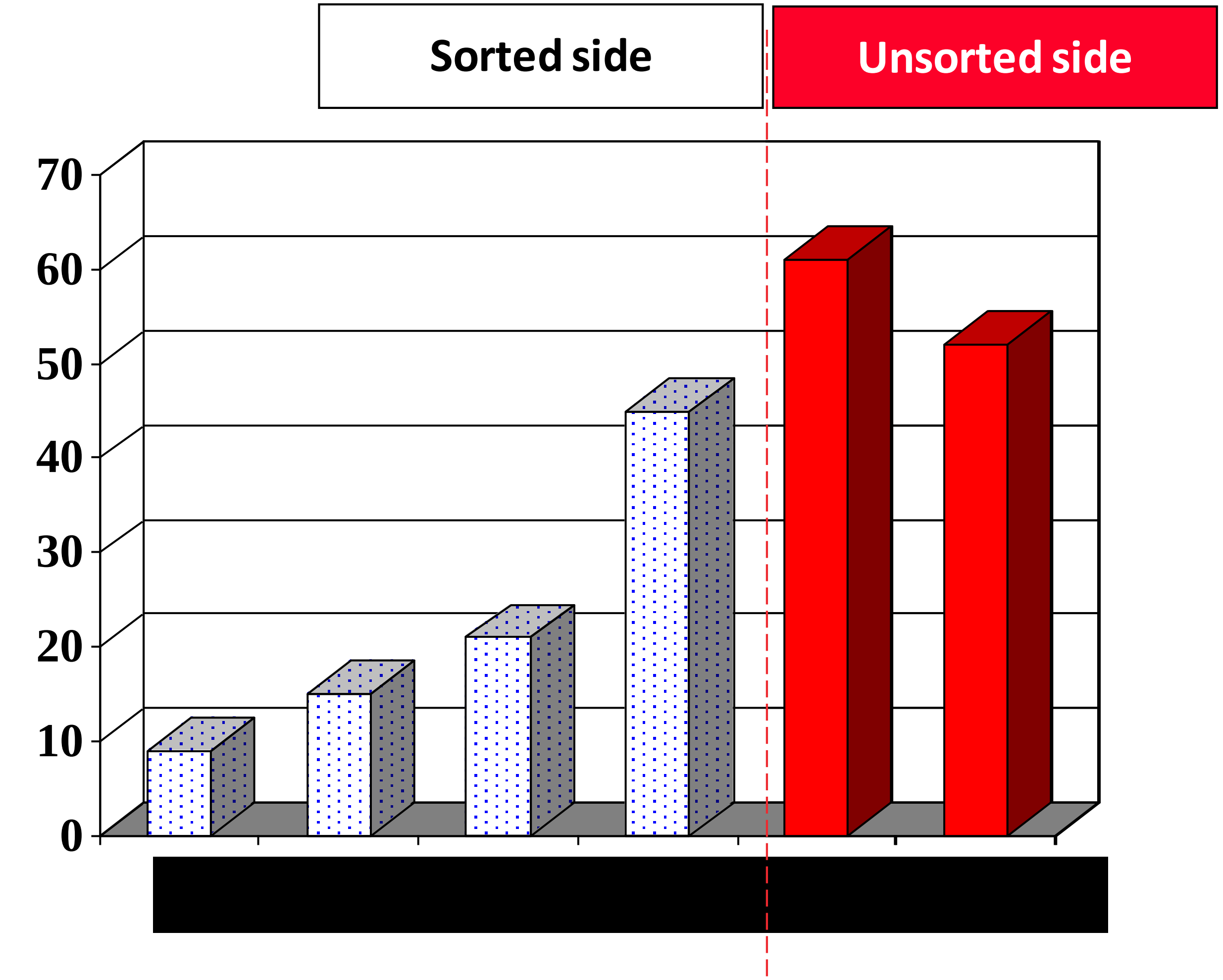
- The process continues...

Sorted side is bigger



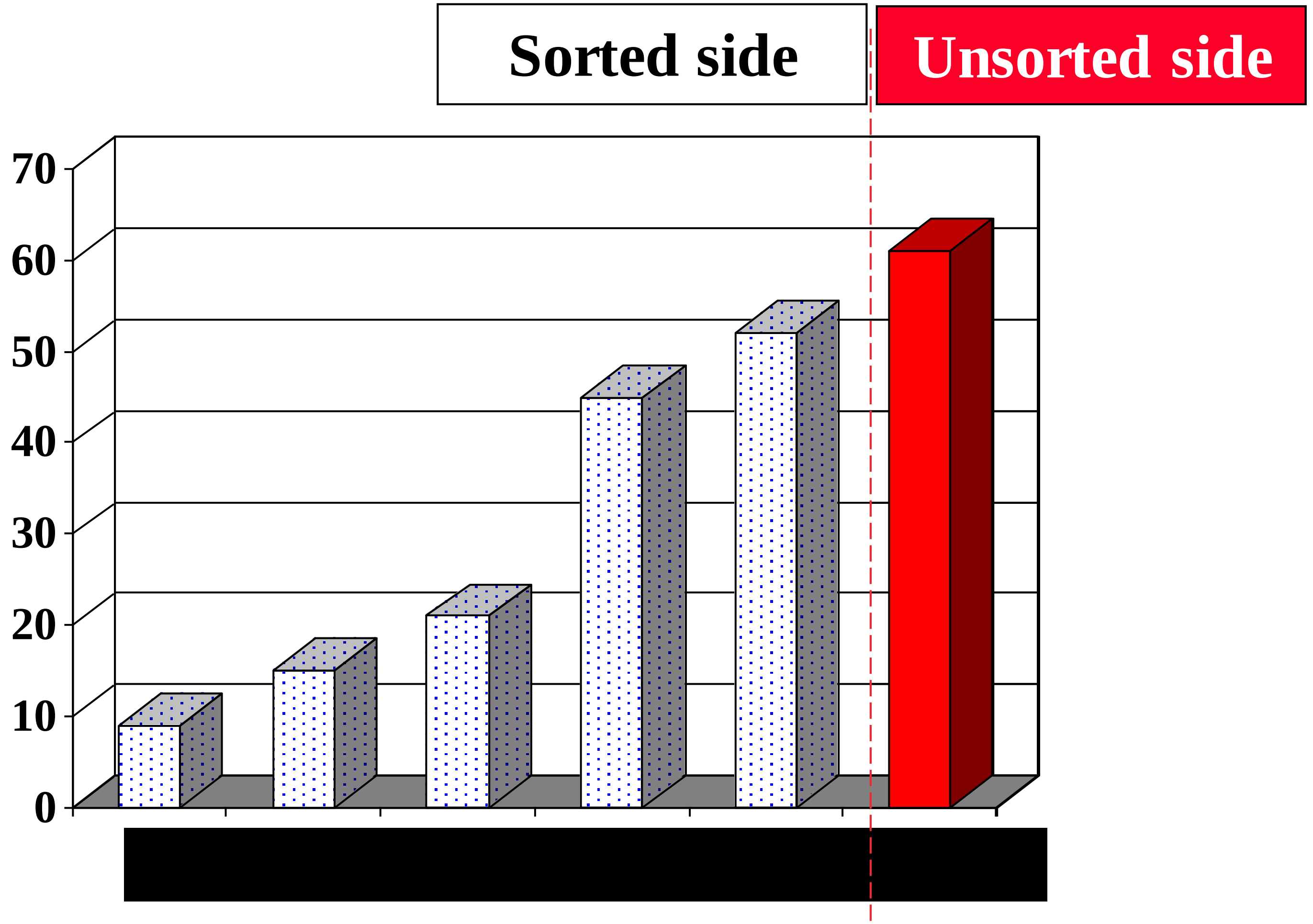
Selection Sort

- The process keeps adding one more number to the sorted side.
- The sorted side has the smallest numbers, arranged from small to large.



Selection Sort

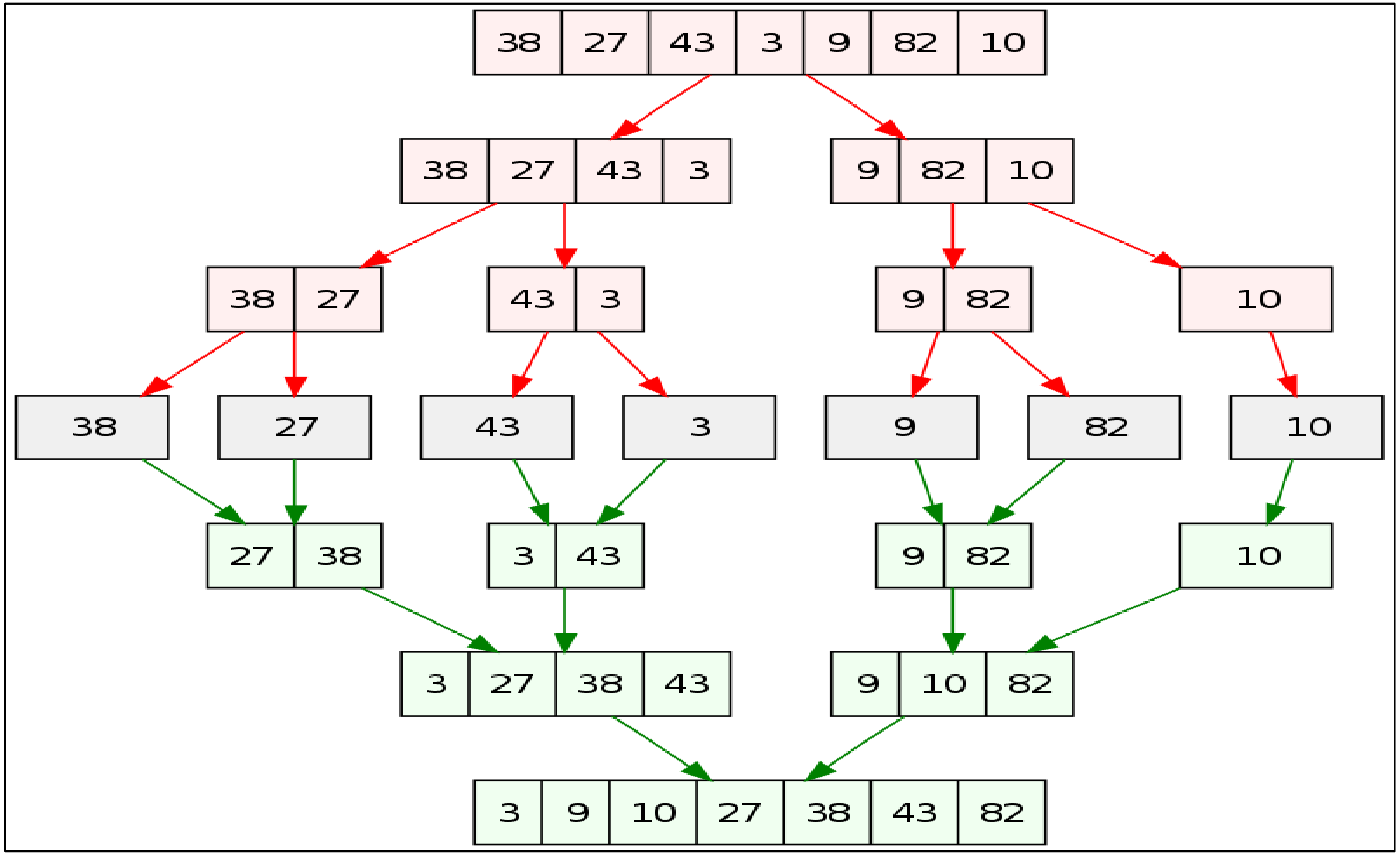
- We can stop when the unsorted side has just one number, since that number must be the largest number.



"Divide and Conquer"

- Very important strategy in computer science:
  - Divide problem into smaller parts
  - Independently solve the parts
  - Combine these solutions to get overall solution
- **Idea 1**: Divide array into two halves, *recursively* sort left and right halves, then *merge* two halves → Mergesort
- **Idea 2 :** Partition array into items that are "small" and items that are "large", then recursively sort the two sets → Quicksort

Mergesort



38 27 43 3 9 82 10
38 27 43 3
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38
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43
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10
27 38
3 43
9 82
10
3 27 38 43
9 10 82
3 9 10 27 38 43 82

Quick Sort

- Quick Sort is based on the **Divide and Conquer rule.**
- It is also called **partition-exchange sort**. This algorithm divides the list into three main parts:
- Elements less than the **Pivot** element
- Pivot element(Central element)
- Elements greater than the pivot element

 |

Quick Sort

Pivot element can be any element from the array, it can be the first element, the last element or any random element. In this tutorial, we will take the rightmost element or the last element as pivot.

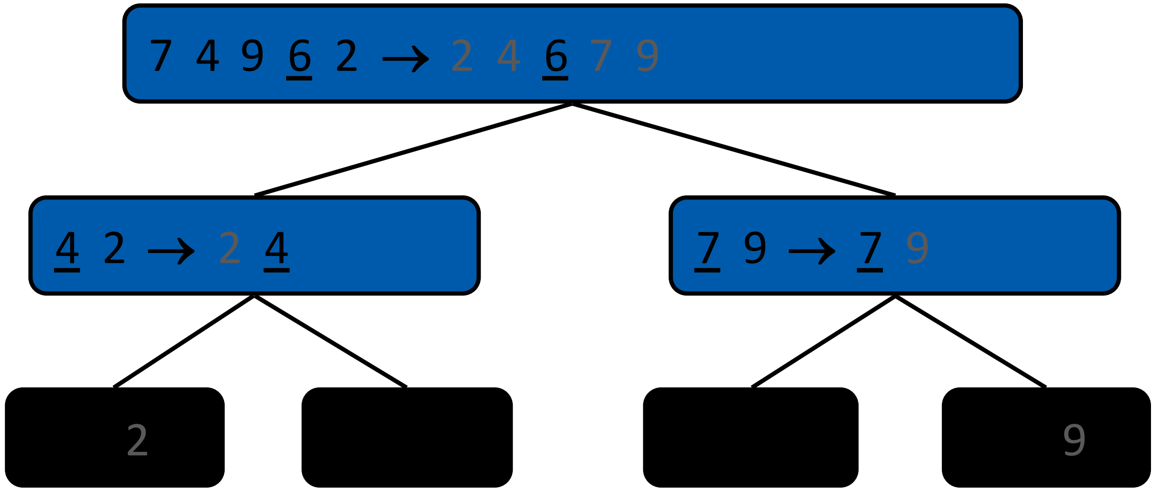
For example: In the array {52, 37, 63, 14, 17, 8, 6, 25}, we take 25 as pivot. So after the first pass, the list will be changed like this.

{6 8 17 14 25 63 37 52}

 |

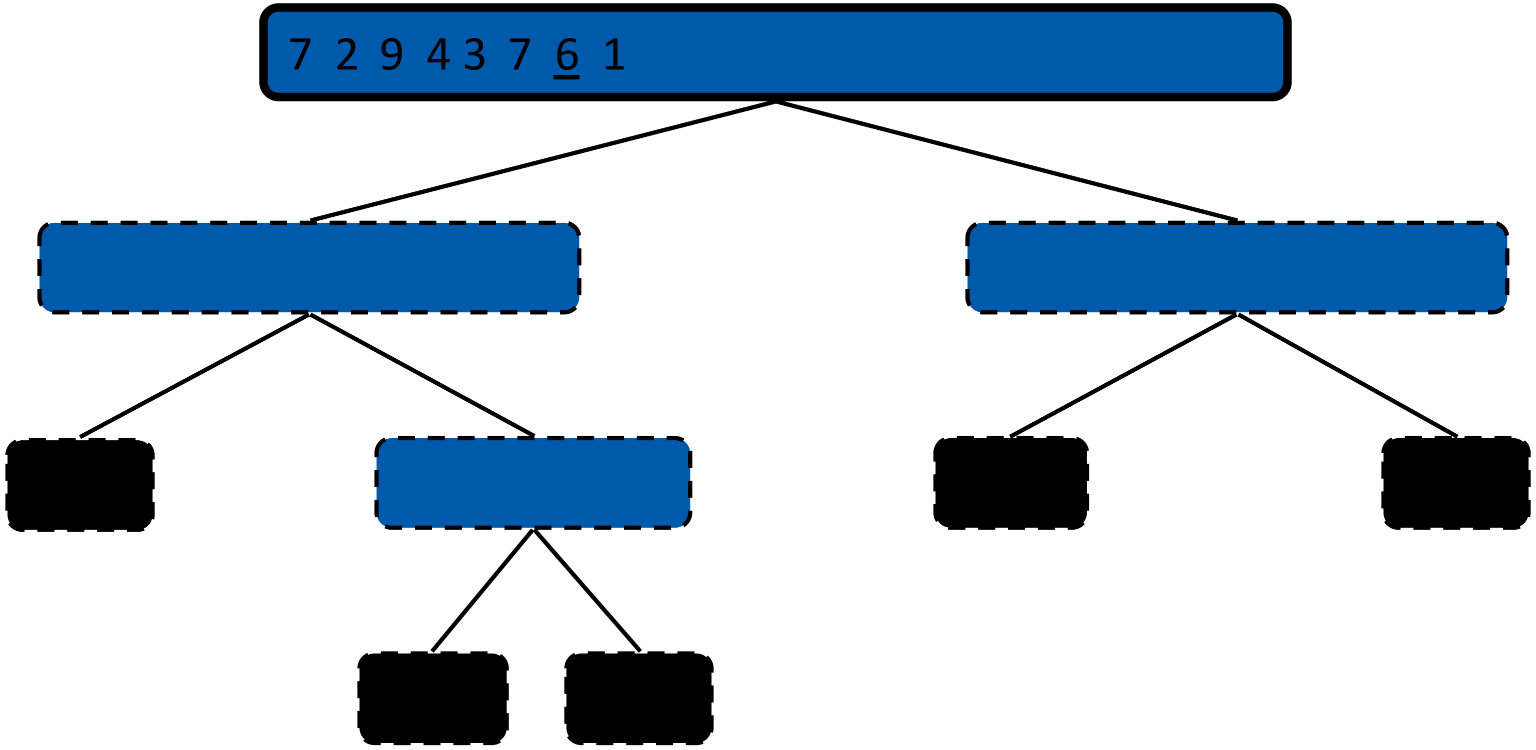
Quick-Sort Tree

- An execution of quick-sort is depicted by a binary tree
  - Each node represents a recursive call of quick-sort and stores
    - Unsorted sequence before the execution and its pivot
    - Sorted sequence at the end of the execution
  - The root is the initial call
  - The leaves are calls on subsequences of size 0 or 1



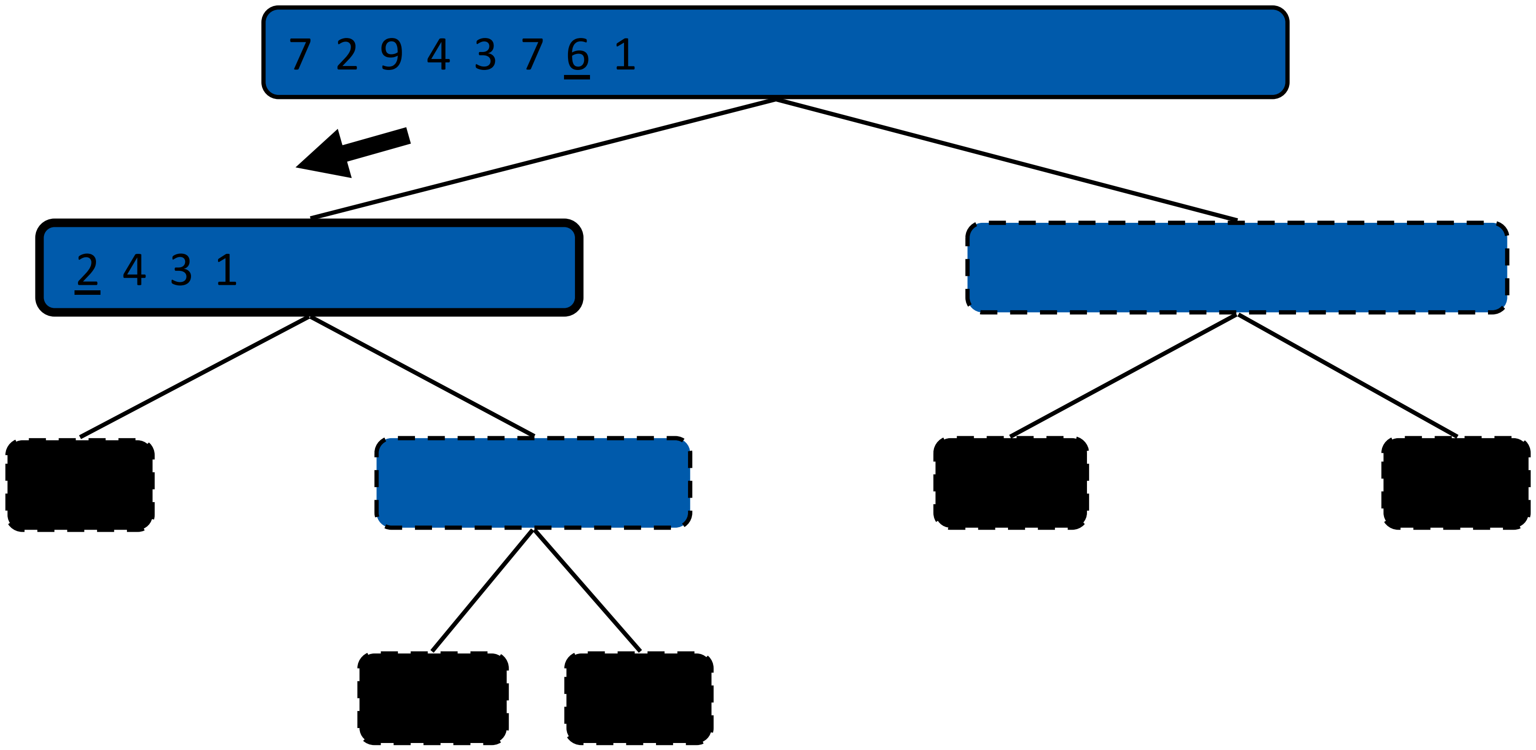
Execution Example

- Pivot selection



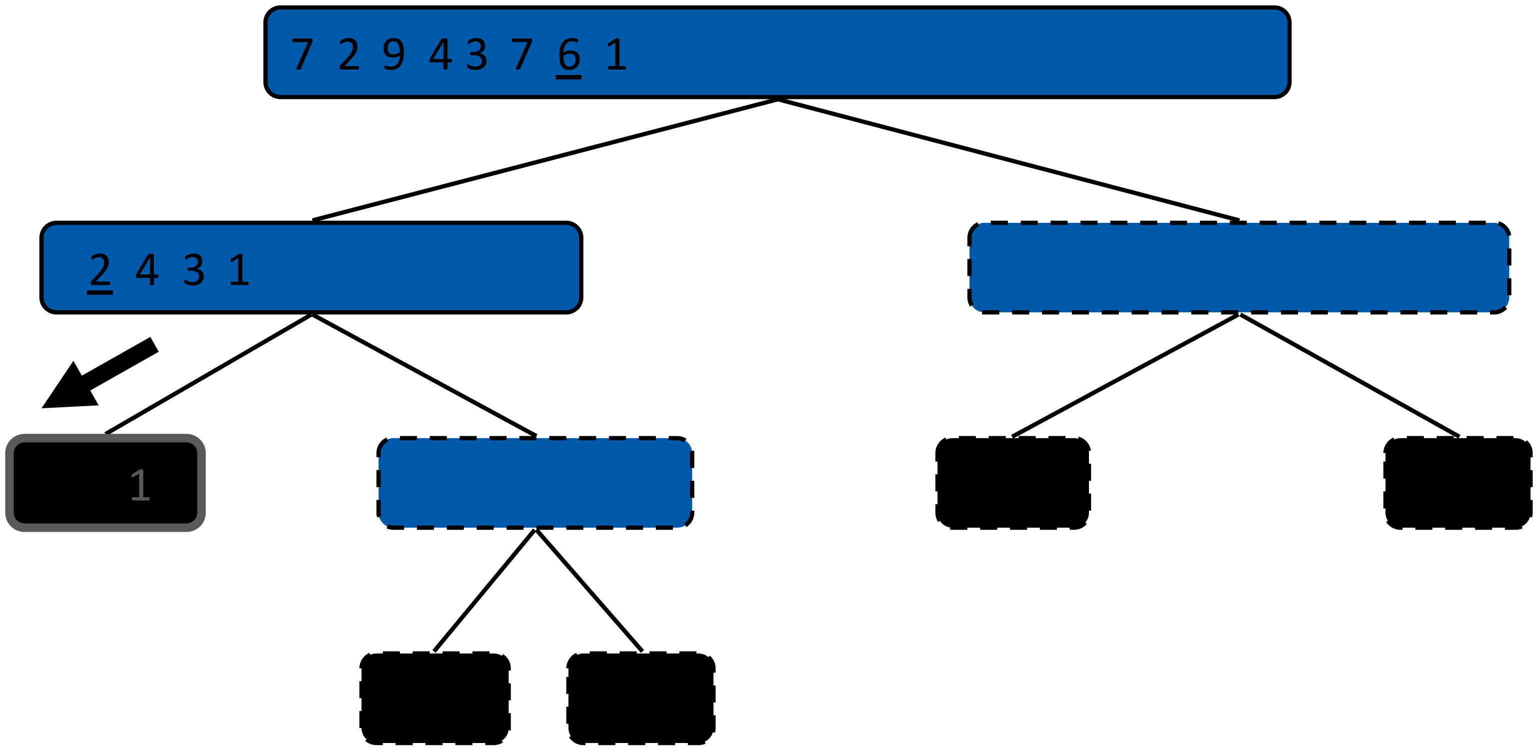
Execution Example (cont.)

- Partition, recursive call, pivot selection



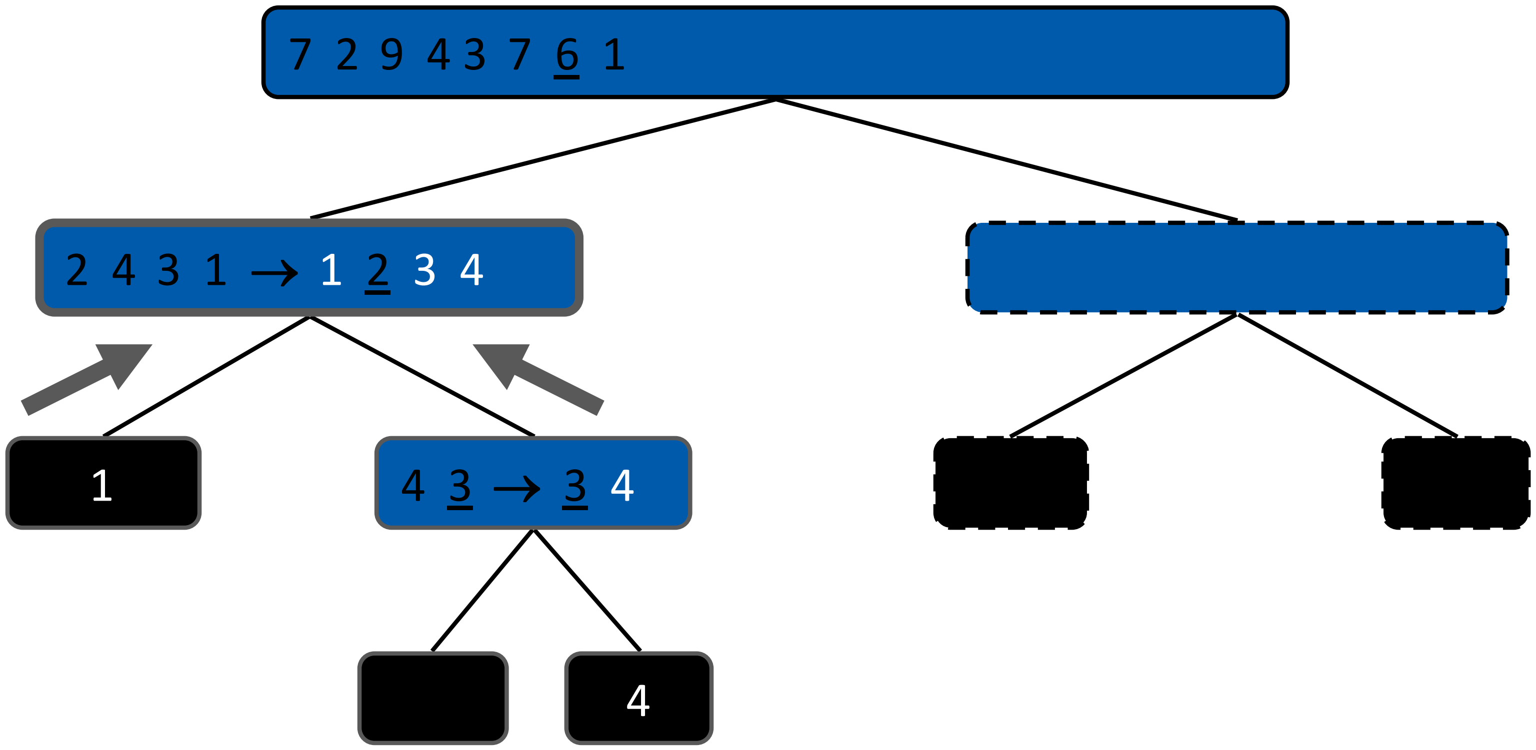
Execution Example (cont.)

- Partition, recursive call, base case



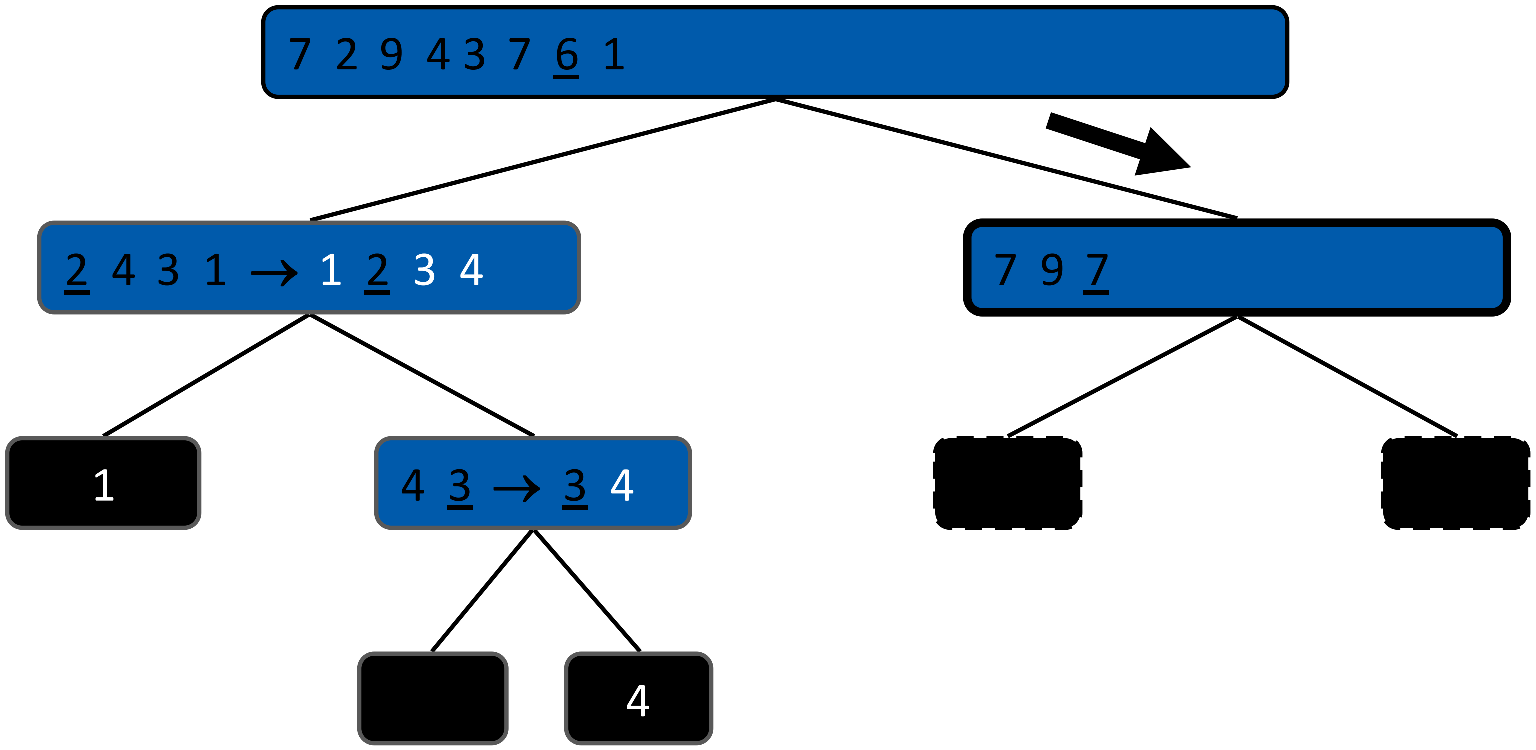
Execution Example (cont.)

- Recursive call, …, base case, join



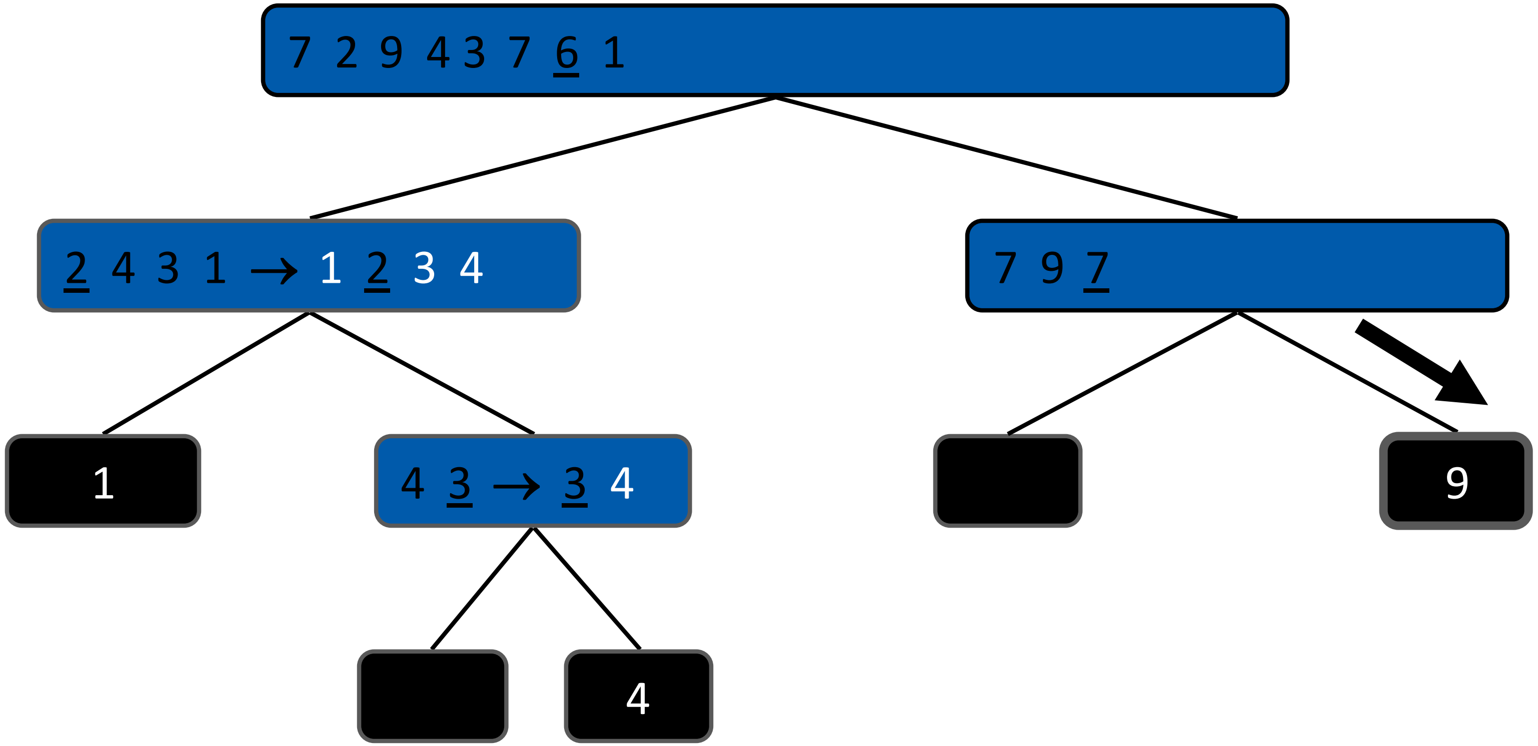
Execution Example (cont.)

- Recursive call, pivot selection



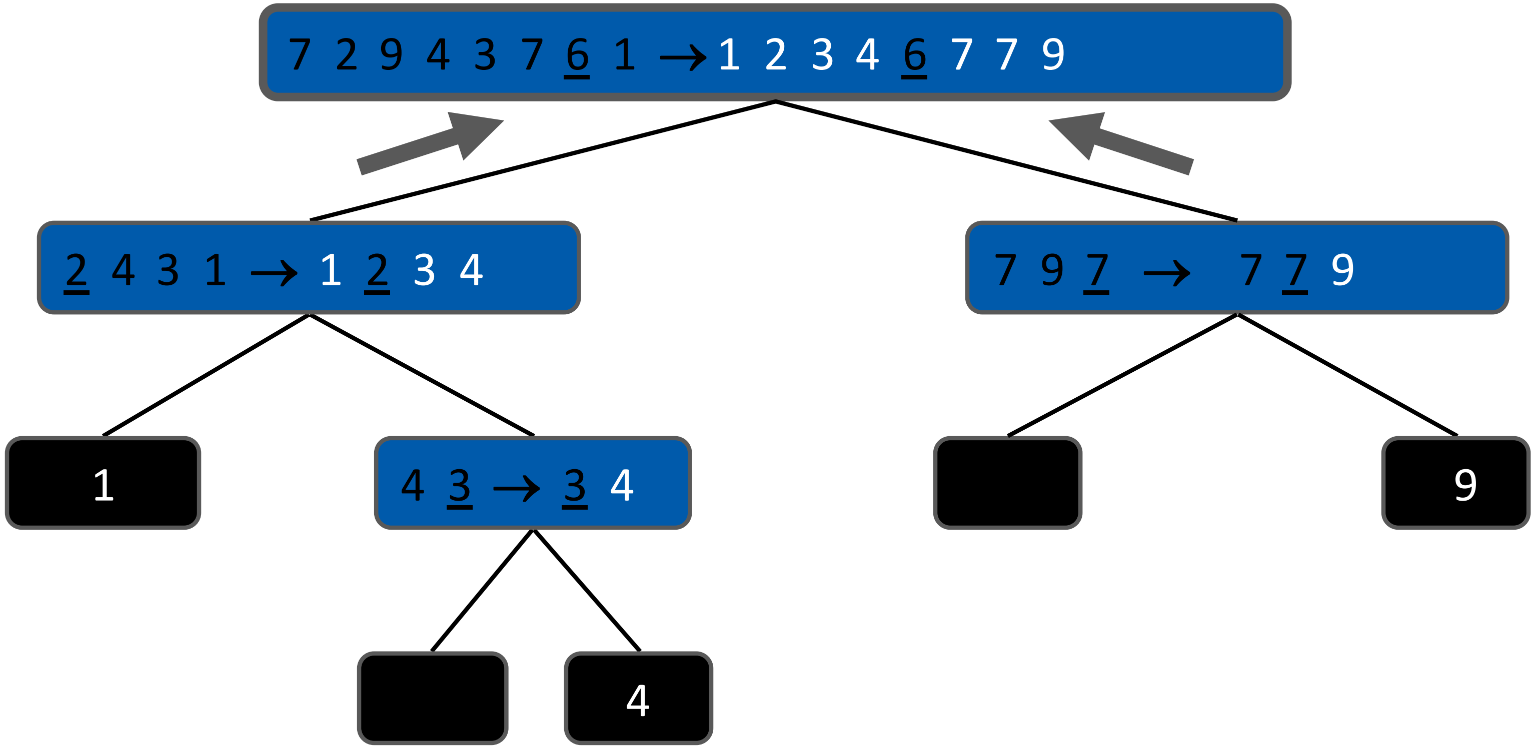
Execution Example (cont.)

- Partition, …, recursive call, base case



Execution Example (cont.)

- Join, join



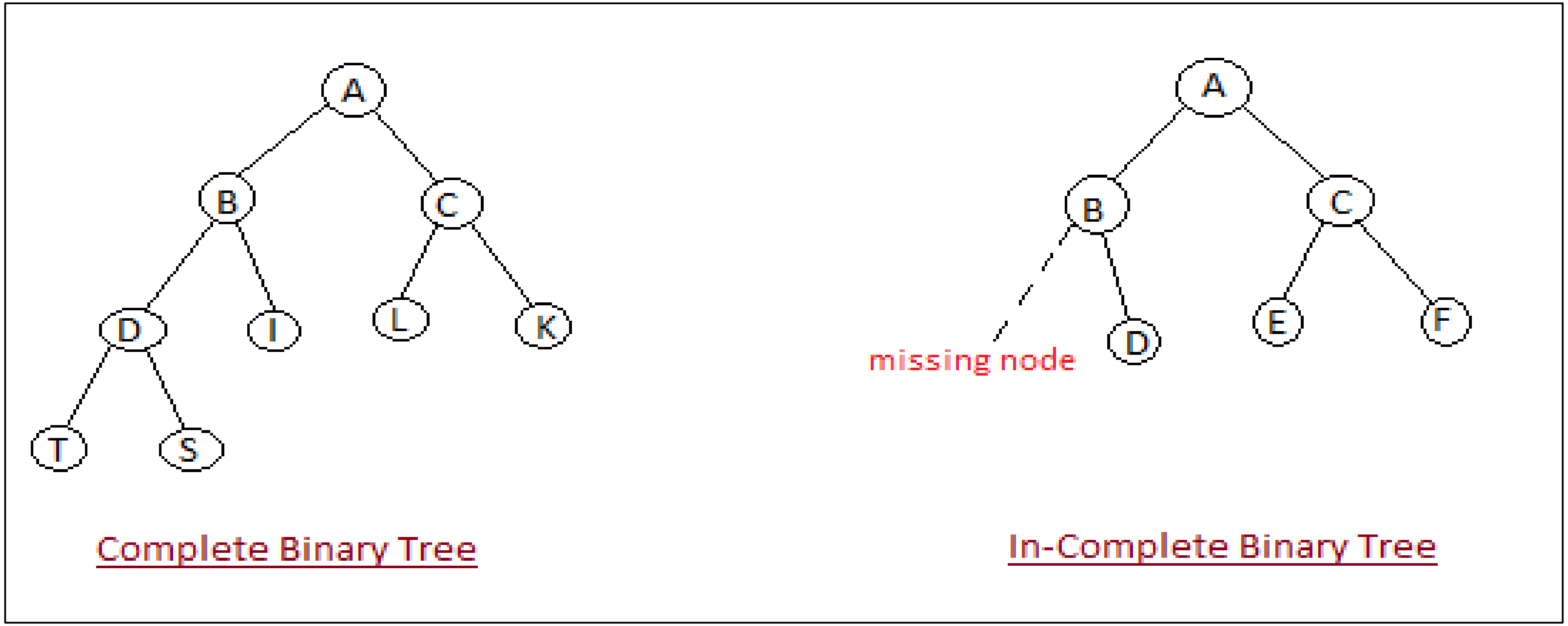
Heap Sort

Heap sort involves building a Heap data structure from the given array and then utilizing the Heap to sort the array.

- Heap is a special tree-based data structure, that satisfies the following special heap properties:

Heap Sort

- Shape Property: Heap data structure is always a Complete Binary Tree, which means all levels of the tree are fully filled.



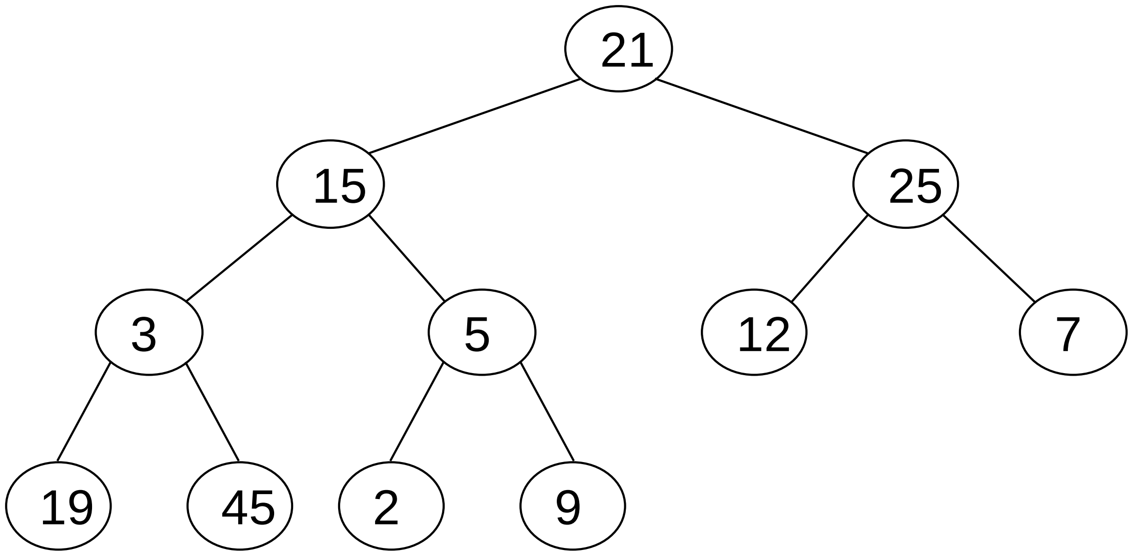
Sample Run

- Start with unordered array of data

Array representation:

	21	15	25	3	5	12	7	19	45	2	9

Binary tree representation:



Additional References

Heap Sort - Video link:
https://www.youtube.com/watch?v=H5kAcmGOn4Q

Merge Sort Vs Quick Sort – Video:
link:https://www.youtube.com/watch?v=es2T6KY45cA

https://www.youtube.com/watch?v=WaNLJf8xzC4

Data Structures

Why Data structure?

Watch the Video

https://www.youtube.com/watch?v=-q-3b_093do

Data Structures

- Data structures is concerned with the representation and manipulation of data
- All programs manipulate data
- So, all programs represent data in some way
- Data manipulation requires an algorithm
- The study of Data Structure is fundamental to computer programming

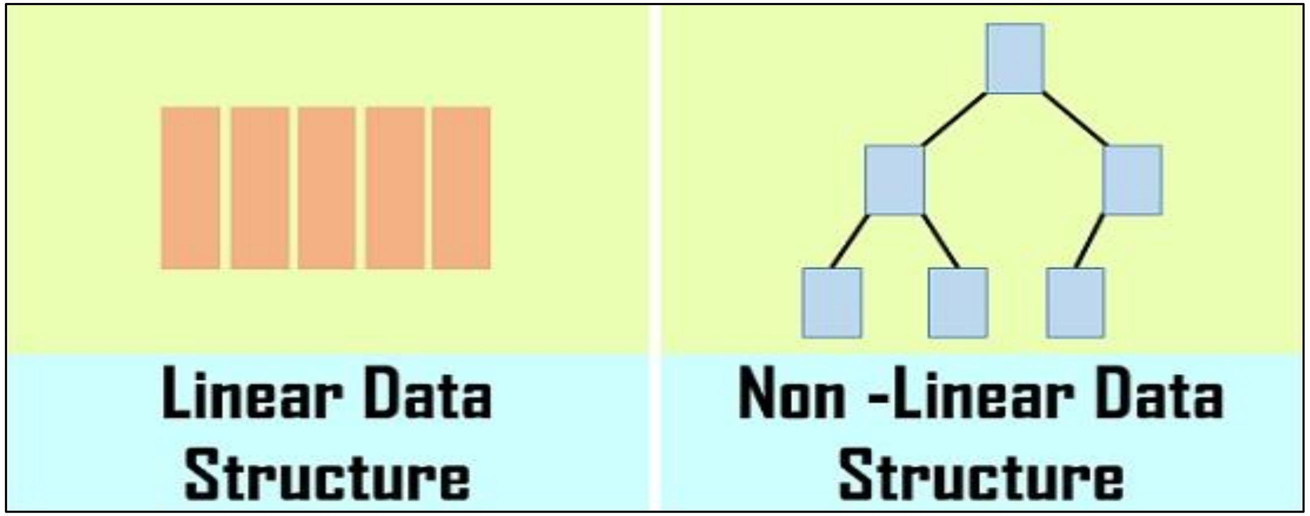
 |

Types of Data Structure

There are basically two types of data structure

1. Linear Data Structure

2. Non-Linear Data Structure.



Basic data structures: *data collections*

- Linear structures
  - Array: Fixed-size
  - Linked List: Add to top, bottom or in the middle
  - Stack: Add to top and remove from top
  - Queue: Add to back and remove from front
  - Priority queue: Add anywhere, remove the highest priority

- Non- Linear Data Structure
  - Tree: A branching structure with no loops
  - Graph: A more general branching structure, with less stringent connection conditions than for a tree

Static vs. Dynamic Structures

- A static data structure has a fixed size

  This meaning is different from the meaning of the static modifier (variable shared among all instances of a class)

- Arrays are static; once you define the number of elements it can hold, the number doesn't change

- A dynamic data structure grows and shrinks at execution time as required by its contents

- A dynamic data structure is implemented using links

 |

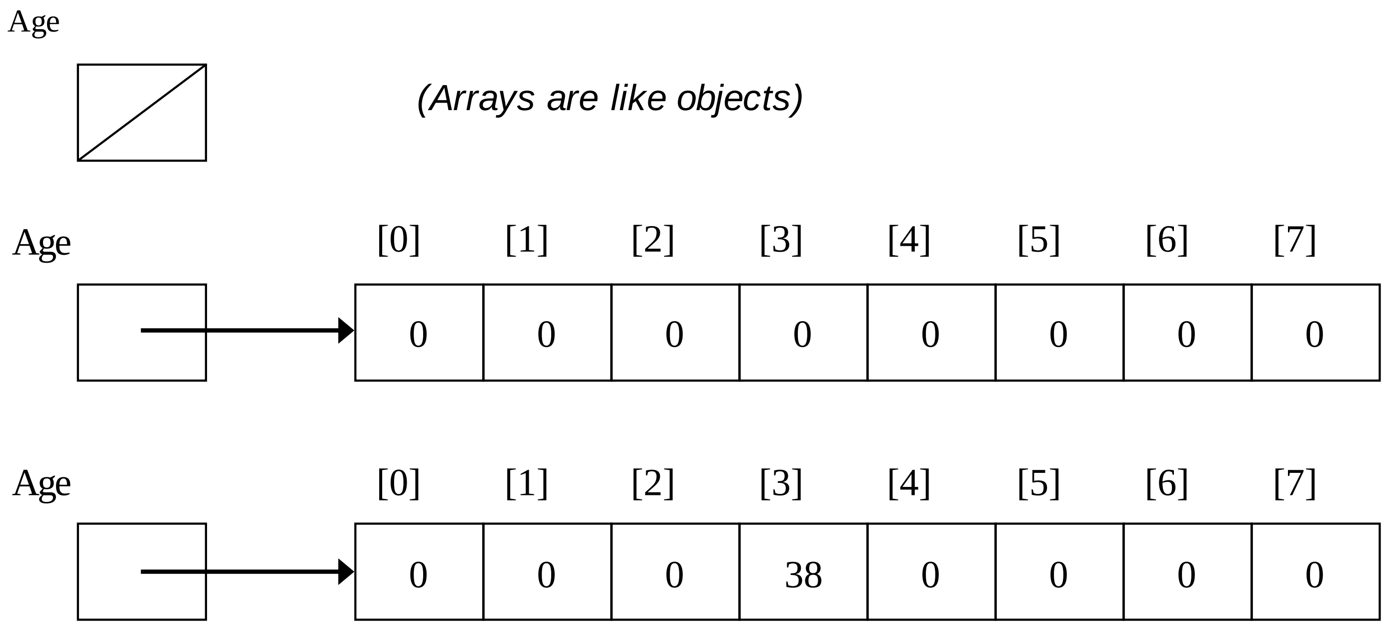
Array

An array of integers

1 int [ ] Age;

2 Age= new int[8];

3 Age [3] = 38;



Declaration — Allocation — Initialization

Linked List

- a **linked list** is a linear collection of data elements, in which linear order is not given by their physical placement in memory.

- Elements may be added in front, end of list as well as middle of list.
- Linked List may be use for dynamic implementation of stack and queue.

 |

Stack

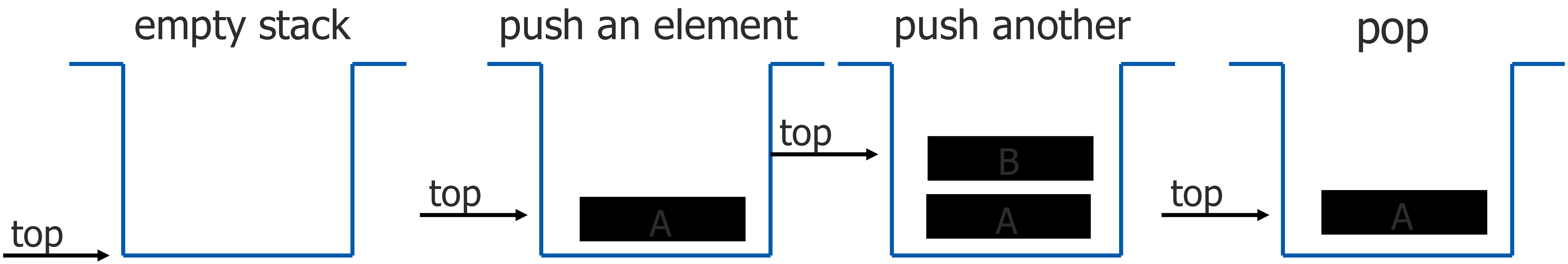
- Stack is a linear data structure which works on LIFO order. So that Last In First Out
.

- In stack element is always added at top of stack and also removed from top of the stack.

- Stack is useful in recursive function, function calling, mathematical expression calculation, reversing the string etc.

Data Structure -- Stacks

- LIFO (Last In, First Out) in Stack:
  The last element inserted will be the first to be retrieved, using Push and Pop
- Push
  - Add an element to the *top* of the stack
- Pop
  - Remove the element at the *top* of the stack



Data Structures -- Stacks

Attributes of `Stack`

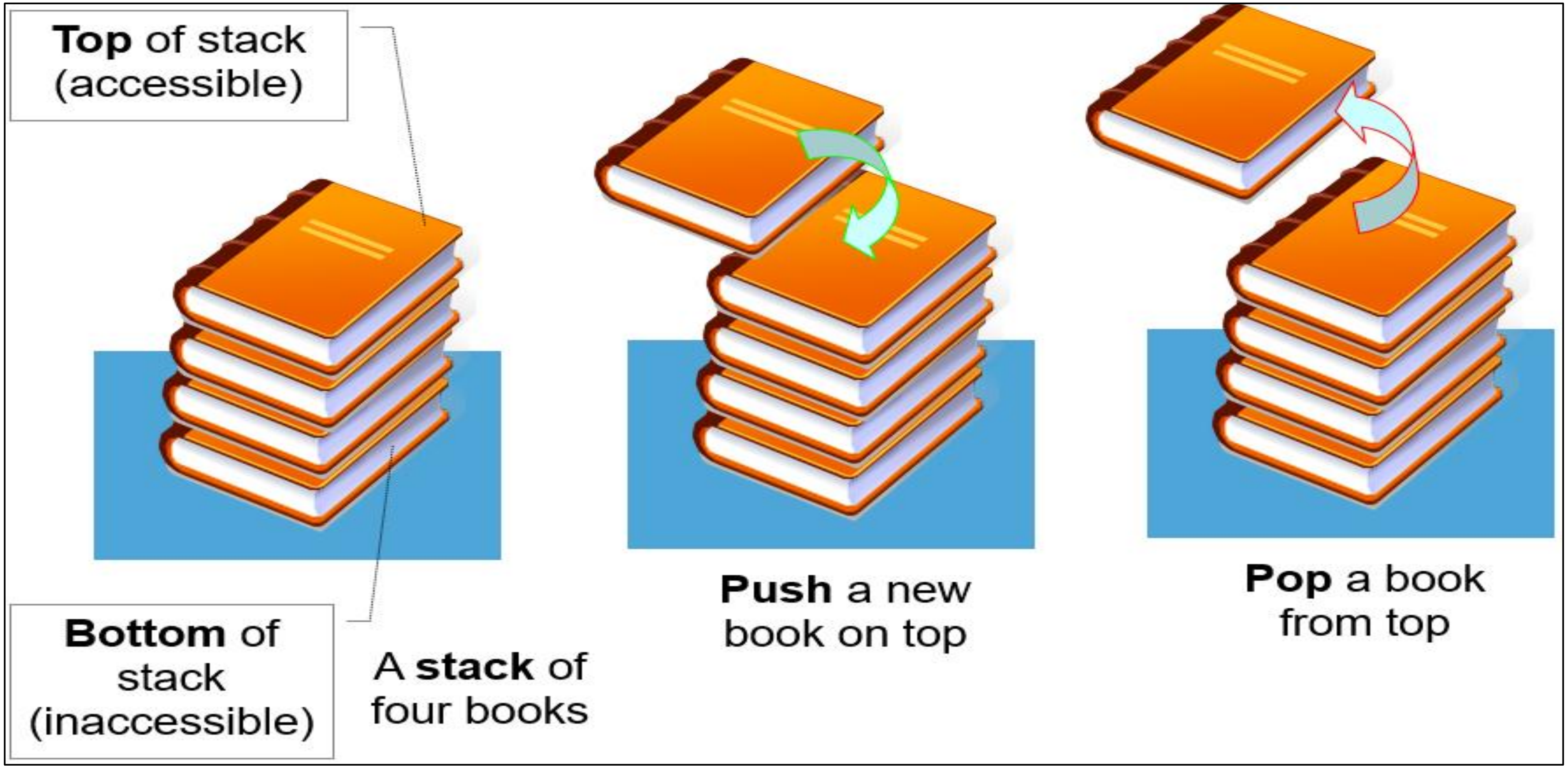
- `maxTop`: the max size of stack
- `top`: the index of the top element of stack

- Operations of `Stack`
  - `empty`: return true if stack is empty, return false otherwise
  - `full`: return true if stack is full, return false otherwise
  - `top`: return the element at the top of stack
  - `push`: add an element to the top of stack
  - `pop`: delete the element at the top of stack
  - `displayStack`: print all the data in the stack

Data Structure -- Stacks

- Real life analogy:
  - Elevator
  - Dish holders (stacks)
- Typical uses of stacks:
  - Prefix-/Postfix- calculators
- Any list implementation could be used to implement a stack
  - Arrays (static: the size of stack is given initially)
  - Linked lists (dynamic: never becomes full)

Data Structure -- Stacks



Data Structure -- Queues

- Like a stack, a *queue* is also a list. However, with a queue, insertion is done at one end, while deletion is performed at the other end
  - The insertion end is called *rear*
  - The deletion end is called *front*

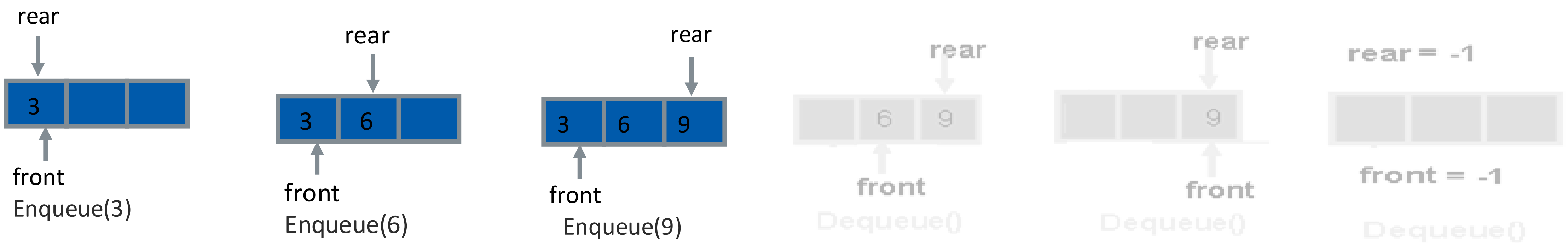
 |

Data Structure -- Queues

- Attributes of `Queue`
  - `front/rear`: front/rear index
  - `counter`: number of elements in the queue
  - `maxSize`: capacity of the queue
- Operations of `Queue`
  - `IsEmpty`: return true if queue is empty, return false otherwise
  - `IsFull`: return true if queue is full, return false otherwise
  - `Enqueue`: add an element to the rear of queue
  - `Dequeue`: delete the element at the front of queue
  - `DisplayQueue`: print all the data

Data Structure -- Queues

- Accessing the elements of queues follows a FIFO (First In, First Out) order
  The first element inserted will be the first to be retrieved, using Enqueue and Dequeue
  - Enqueue
    - Add an element after the *rear* of the queue
  - Dequeue
    - Remove the element at the *front* of the queue



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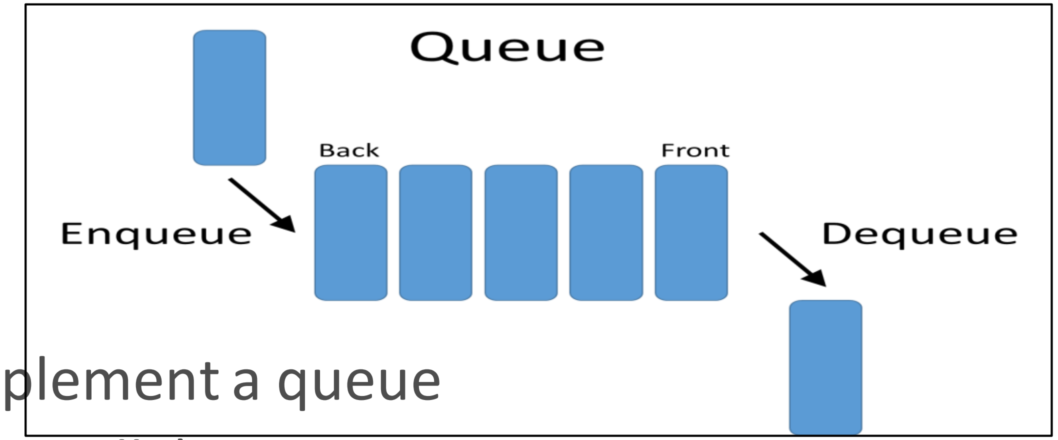
Data Structure -- Queues

- Real life analogy:
  - Check-out lines in a store (queuing up)
- Typical uses of queues:
  - Waiting lists of course registration
  - Simple scheduling in routers
- Any list implementation could be used to implement a queue
  - Arrays (static: the size of queue is given initially)
  - Linked lists (dynamic: never becomes full)



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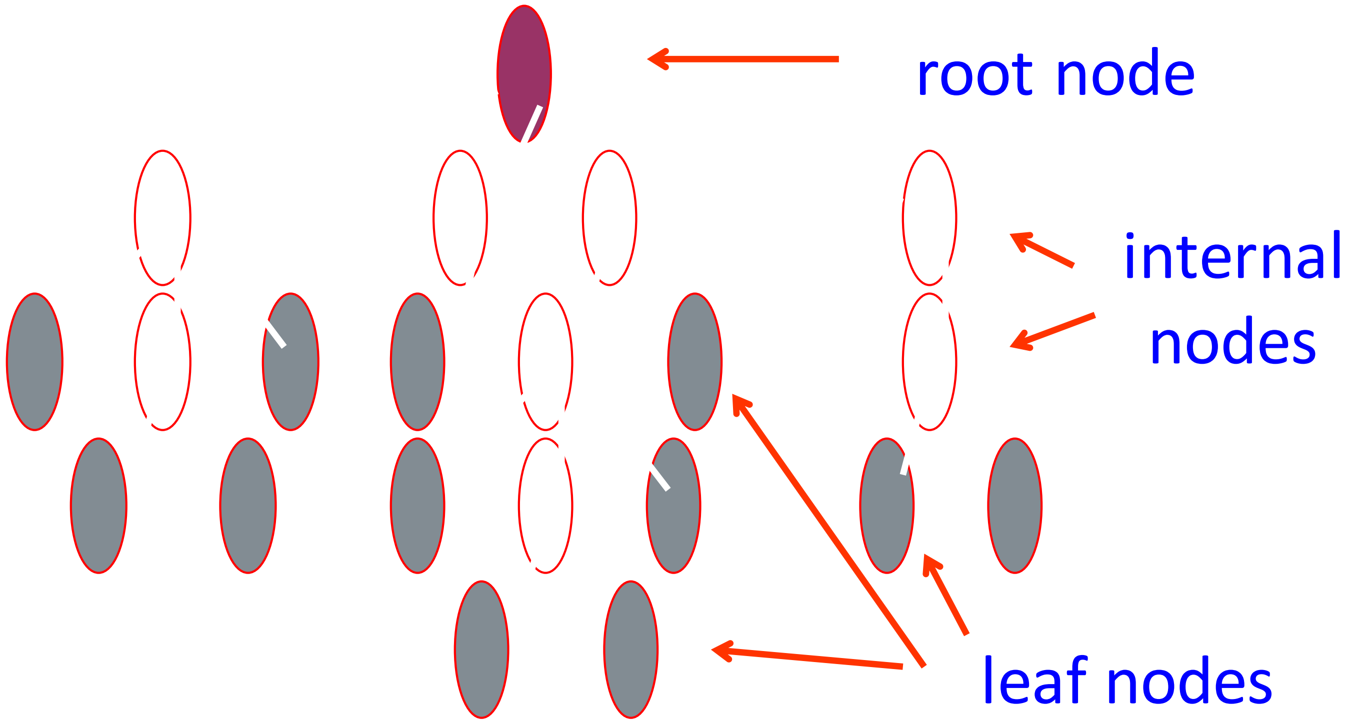
Trees

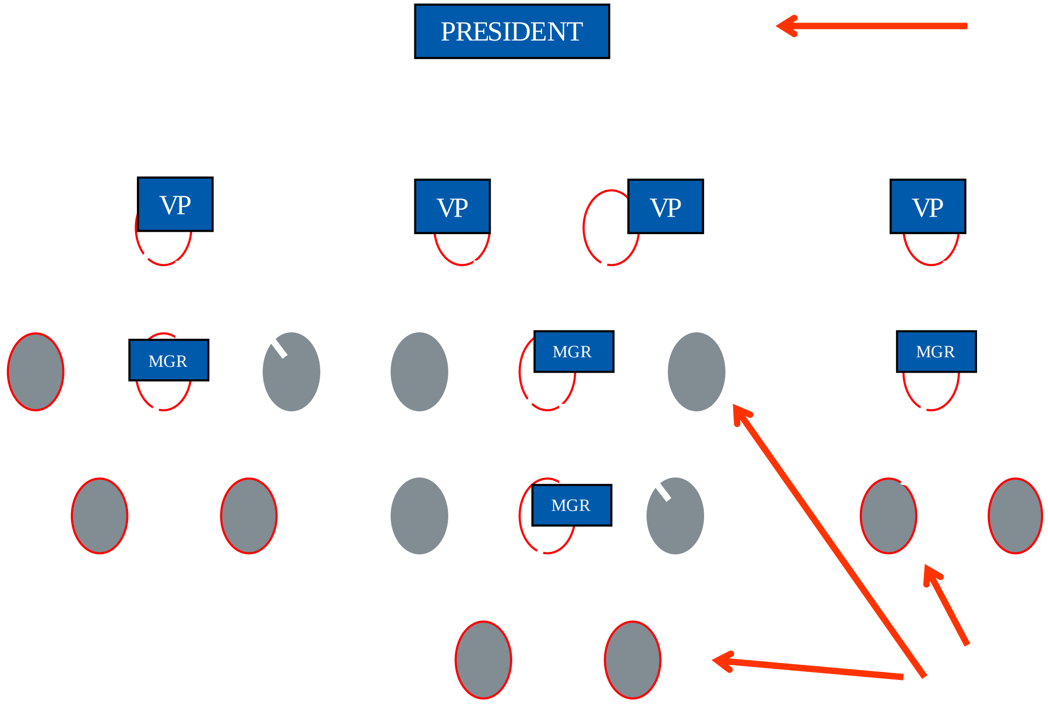
- A tree is a non-linear data structure that consists of a root node and potentially many levels of additional nodes that form a hierarchy
- Nodes that have no children are called leaf nodes
- Non-root and non-leaf nodes are called internal nodes

imagine an upside down tree



A tree data structure

Organization chart represented via a tree data structure



Tree Traversal

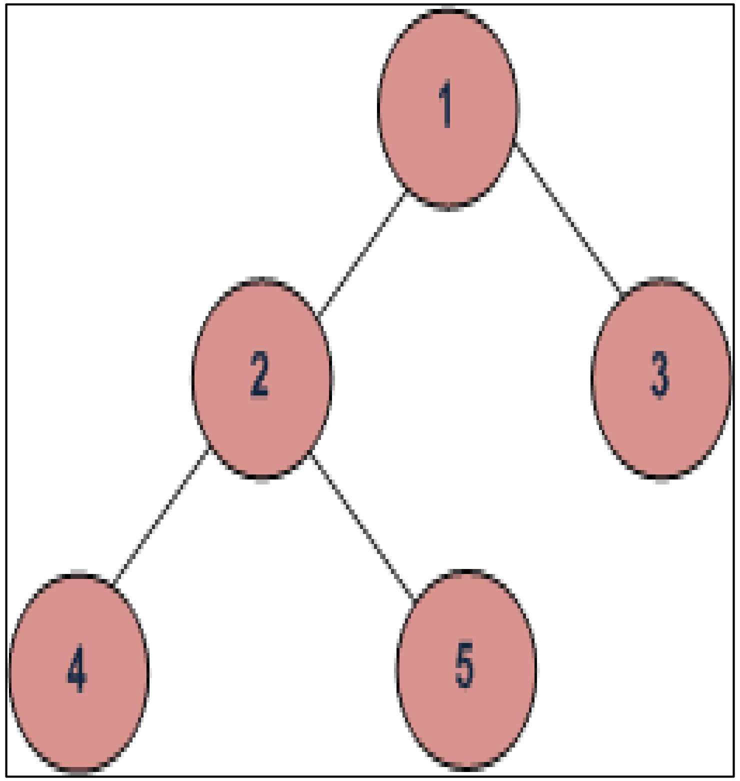
- Two main methods:
  - Inorder
  - Preorder
  - Postorder
- Recursive definition

- Inorder

- Preorder:
  - visit the root
  - traverse in preorder the children (subtrees)

- Postorder
  - traverse in postorder the children (subtrees)
  - visit the root

Tree traversal (cont..)



BFS and DFSs of the Tree

– Breadth First Traversal : 1 2 3 4 5

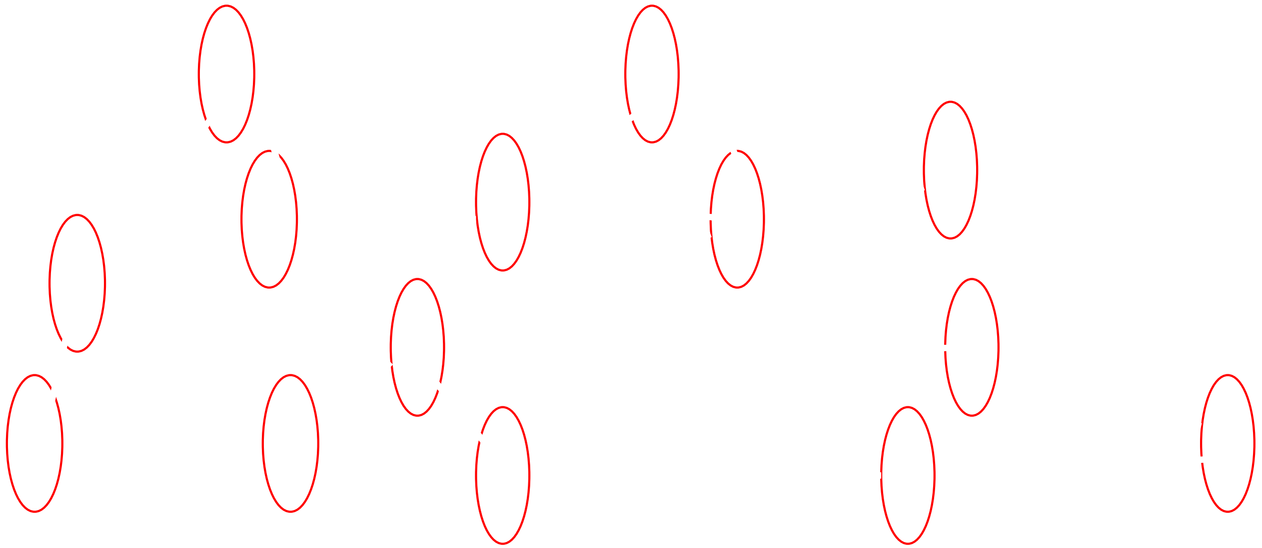
– Depth First Traversals:
– Preorder Traversal : 1 2 4 5 3
– Inorder Traversal : 4 2 5 1 3
– Postorder Traversal : 4 5 2 3 1

Graph

- A graph is a non-linear structure (also called a network)
- Unlike a tree or binary tree, a graph does not have a root – no primary entry point.
- Any node can be connected to any other node by an edge
- Can have any number of edges and nodes

- Analogy: the highway system connecting cities on a map

a graph data structure



Summary

- Qualities of a software Developer
- Problem solving approaches
- Problem classification
- Flow chart design
- Algorithms-Pseudo codes
- Algorithm Patterns
- Data Structures

Learning material references

- Books
  - “Introduction to Algorithms”, Thomas H Cormen, Charles Leiserson, Ronald Rivest and Clifford Stein, 3rd edition, MIT, July 2009
  - “Problem Solving Using C: Structured Programming Techniques”, Yuksel Uckan , McGraw-Hill Inc.,1998
  - "Data Structures and Algorithms Made Easy in Java: Data Structure and Algorithmic Puzzles", Narasimha Karumanchi, areerMonk Publications, 2014

- Web
  - http://www.slideshare.net/dokka/program-design-and-problem-solving-techniques

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