EECE 2560:
Fundamentals of Engineering Algorithms

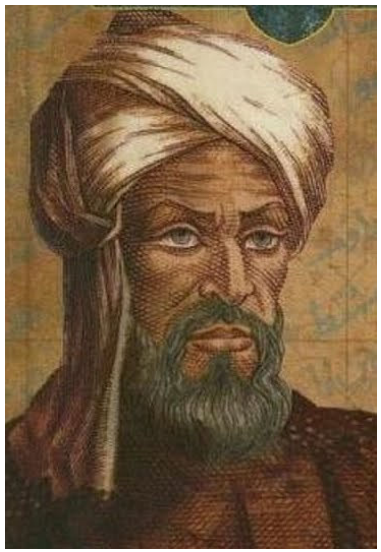
Introduction

What is an Algorithm?

- An algorithm can be viewed as a tool for solving a well-specified ***computational problem***.
  - The statement of the problem specifies the desired input/output relationship.
  - The algorithm describes a specific computational procedure for achieving that input/output relationship.
- An algorithm is said to be ***correct*** if, for every input instance, it ends with the correct output.
- An algorithm can be specified in English, in pseudo code, or as a computer program.

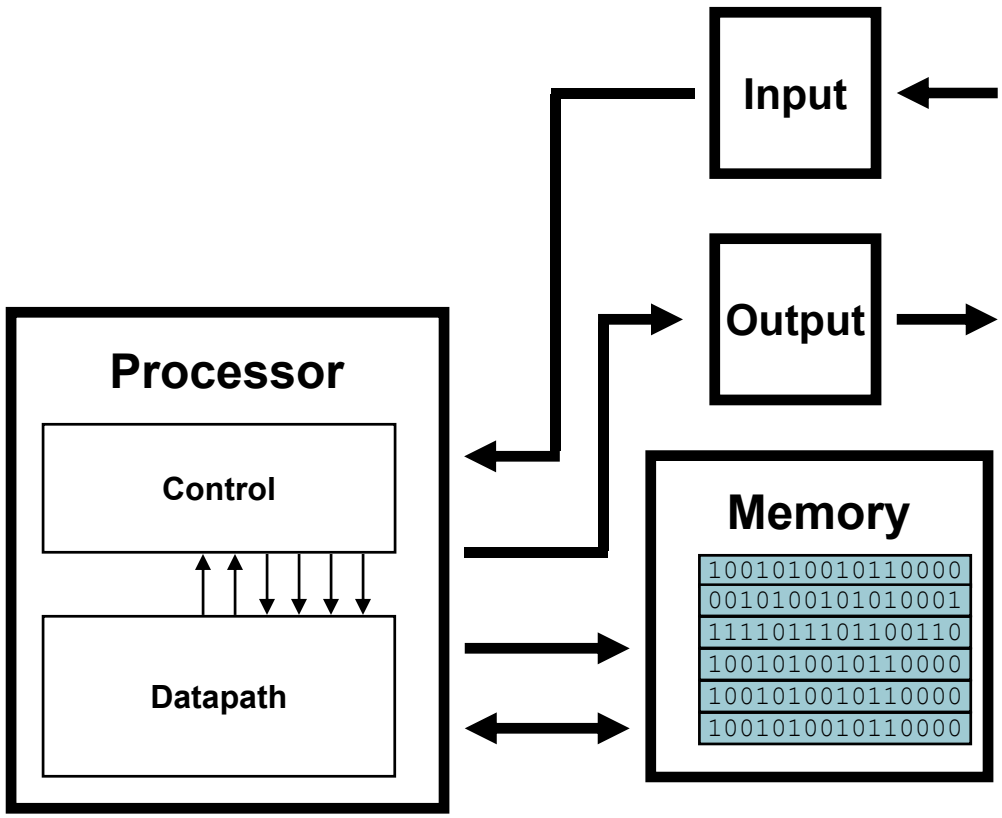
The Origin of the Word Algorithm

- The English word "algorithm" derives from the Latin form of Al-Khwarizmi's name. He developed the concept of an algorithm in mathematics.
- Al-Khwarizmi was born around 800 CE in Khwarizm, now in Uzbekistan and lived in Baghdad (Iraq).



Computer Model

- For most of this course, we shall assume a generic one processor, random-access machine (RAM) model of computation as our implementation technology
- Our algorithms will be implemented as computer programs.
- In this model, instructions are executed one after another, with no concurrent operations.



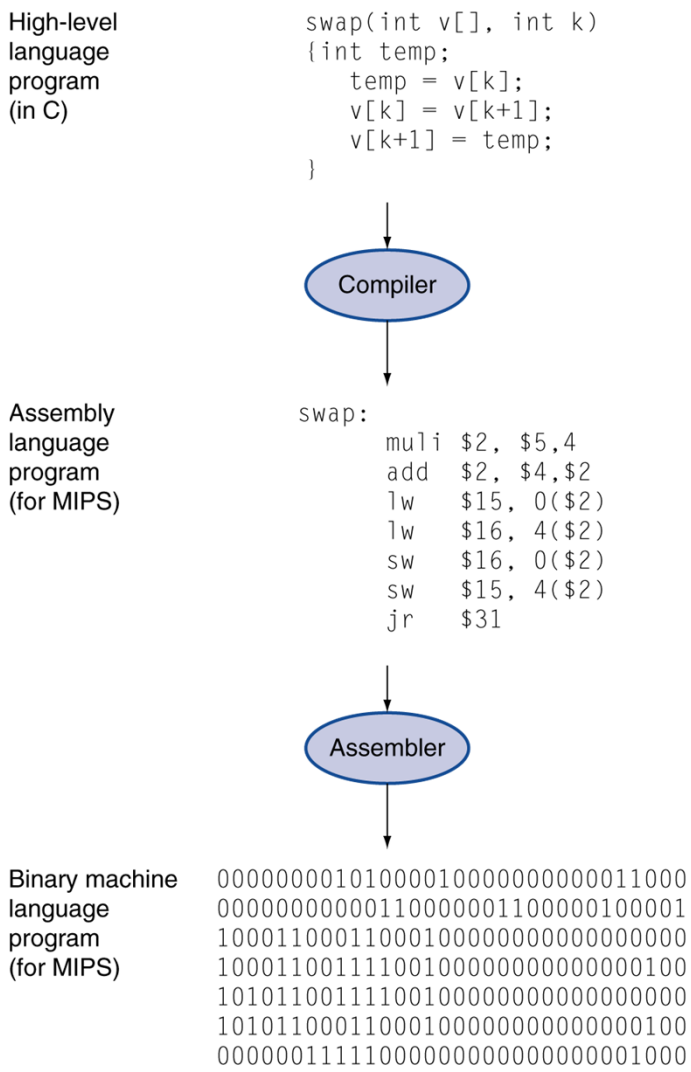
The Von Neumann Computer Model

- Same components for all kinds of computer
  - Desktop, server, embedded
- Input/output includes
  - User-interface devices
    - Display, keyboard, mouse
  - Storage devices
    - Hard disk, CD/DVD, flash
  - Network adapters
    - For communicating with other computers

John von Neumann (1903-1957) was a Hungarian-American mathematician, physicist, inventor, computer scientist

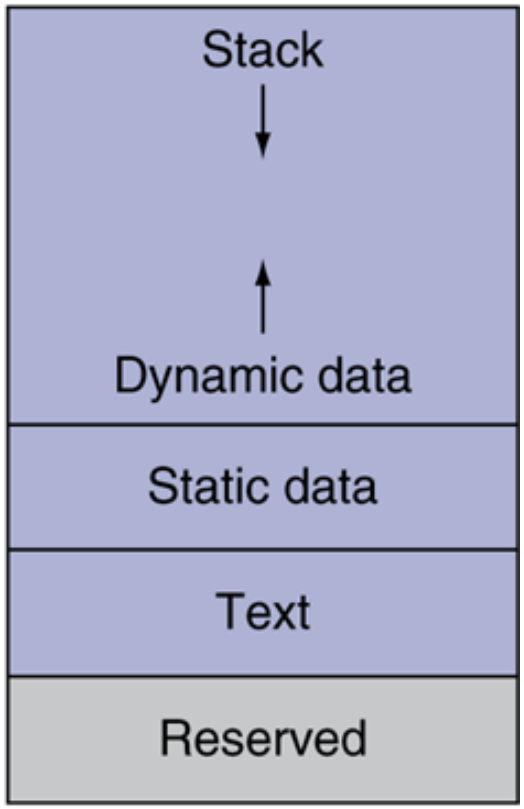
Levels of Program Code

- High-level language
  - Level of abstraction closer to problem domain
  - Provides for productivity and portability
- Assembly language
  - Textual representation of instructions
- Hardware representation
  - Binary digits (bits)
  - Encoded instructions and data



Memory Layout

- Text: program code
- Static data: global variables
  - Example: global and static variables in C.
- Dynamic data: heap
  - Examples: **`malloc`** in C, **`new`** in C++
- Stack: local variables of functions.



Computational Problem Example

The problem of sorting

Input: sequence $\langle a_1, a_2, \ldots, a_n \rangle$ of numbers.

Output: permutation $\langle a'_1, a'_2, \ldots, a'_n \rangle$ such that $a'_1 \le a'_2 \le \cdots \le a'_n$.

Example:

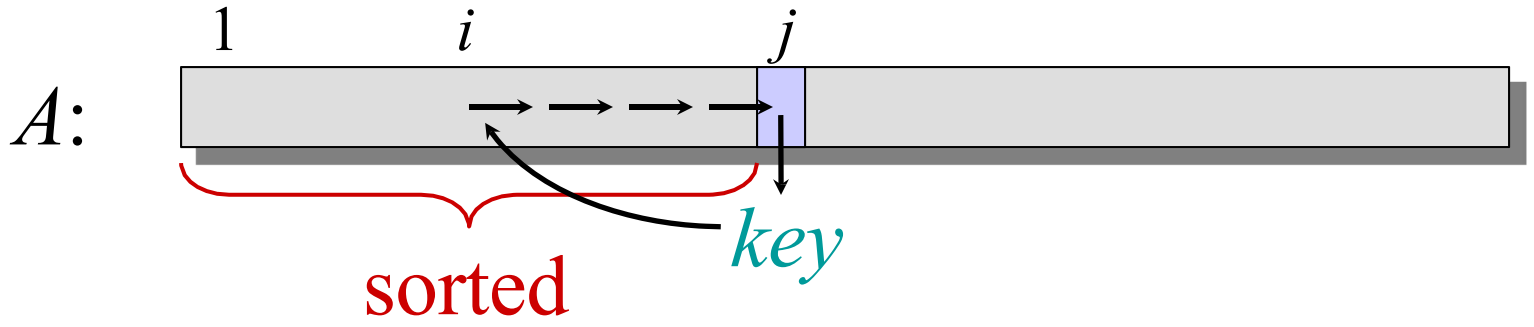
Input: 8 2 4 9 3 6

Output: 2 3 4 6 8 9

Insertion Sort Algorithm

"pseudocode"

```
INSERTION-SORT (array A , int n)
    for j ← 2 to n do
        key ← A[ j]
        i ← j – 1
        while i > 0 and A[i] > key do
                A[i+1] ← A[i]
                i ← i – 1
        A[i+1] = key
```



Example of insertion sort

8 2 4 9 3 6

Example of insertion sort

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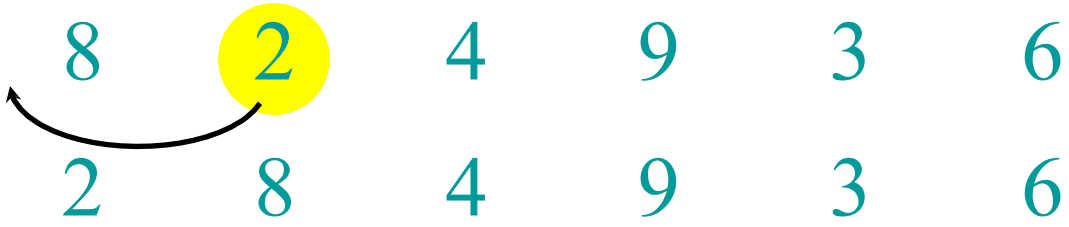

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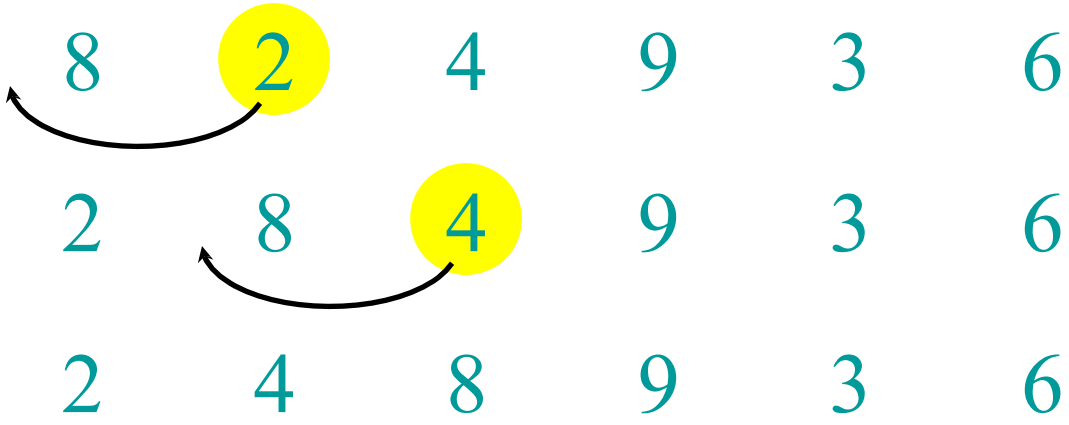

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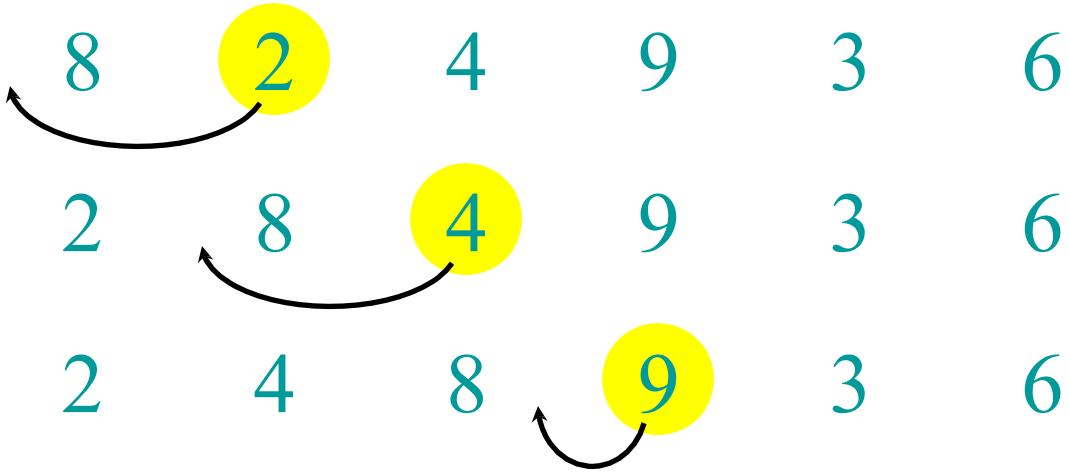

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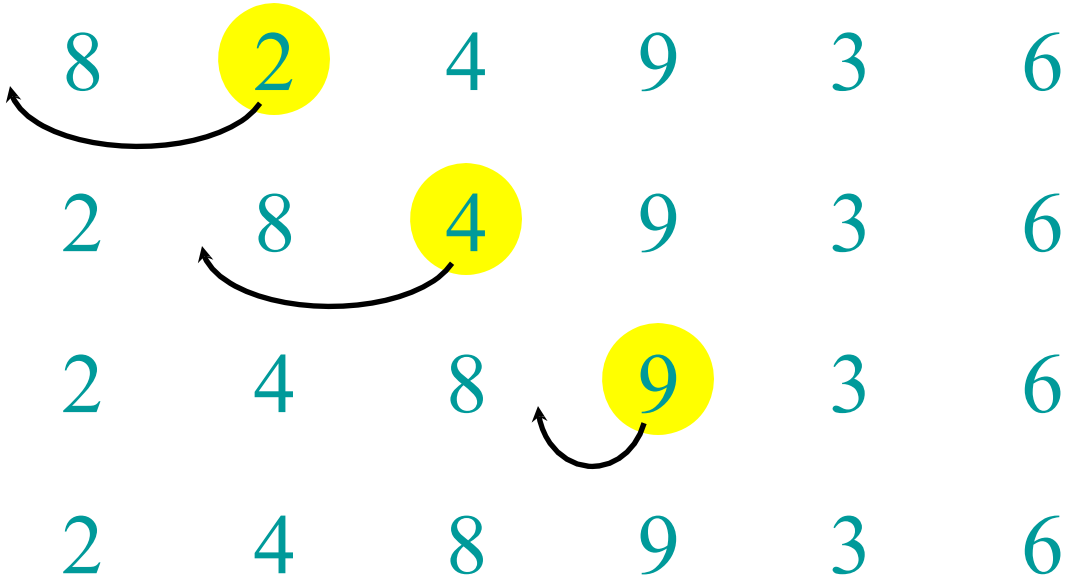

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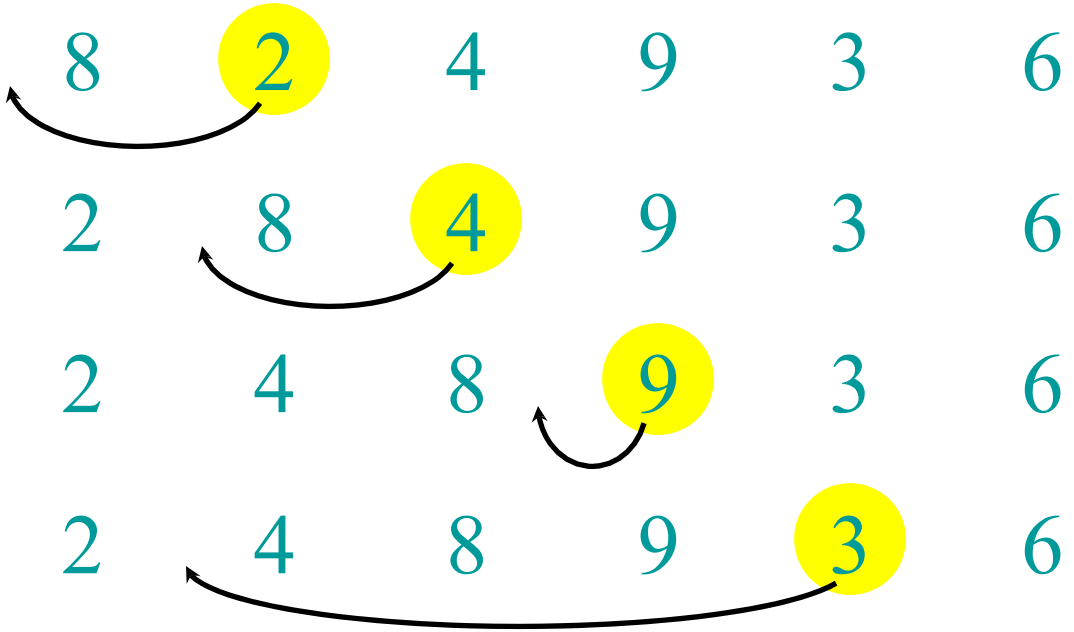

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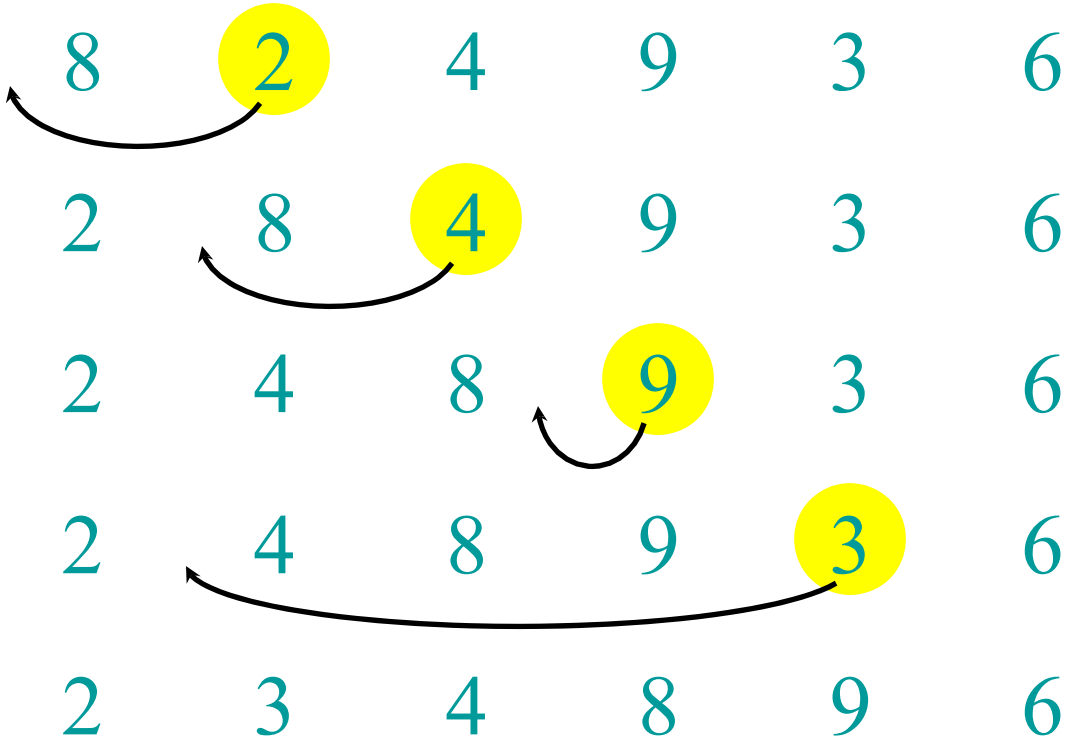

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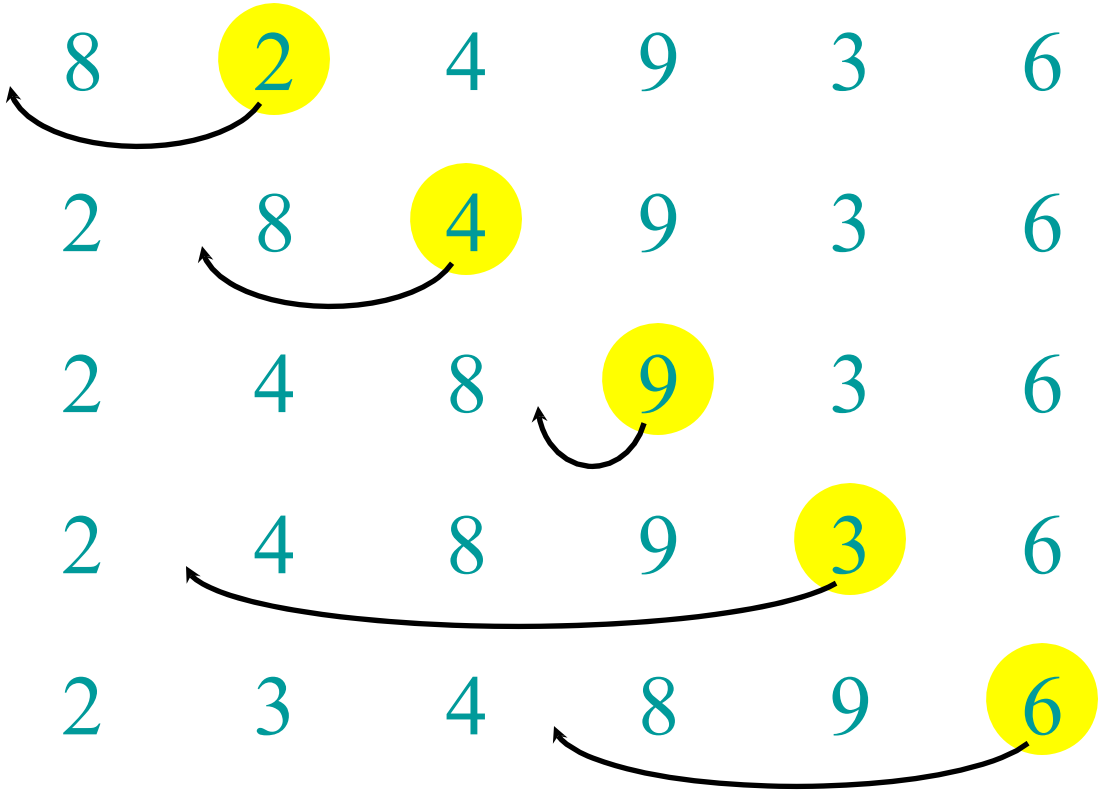

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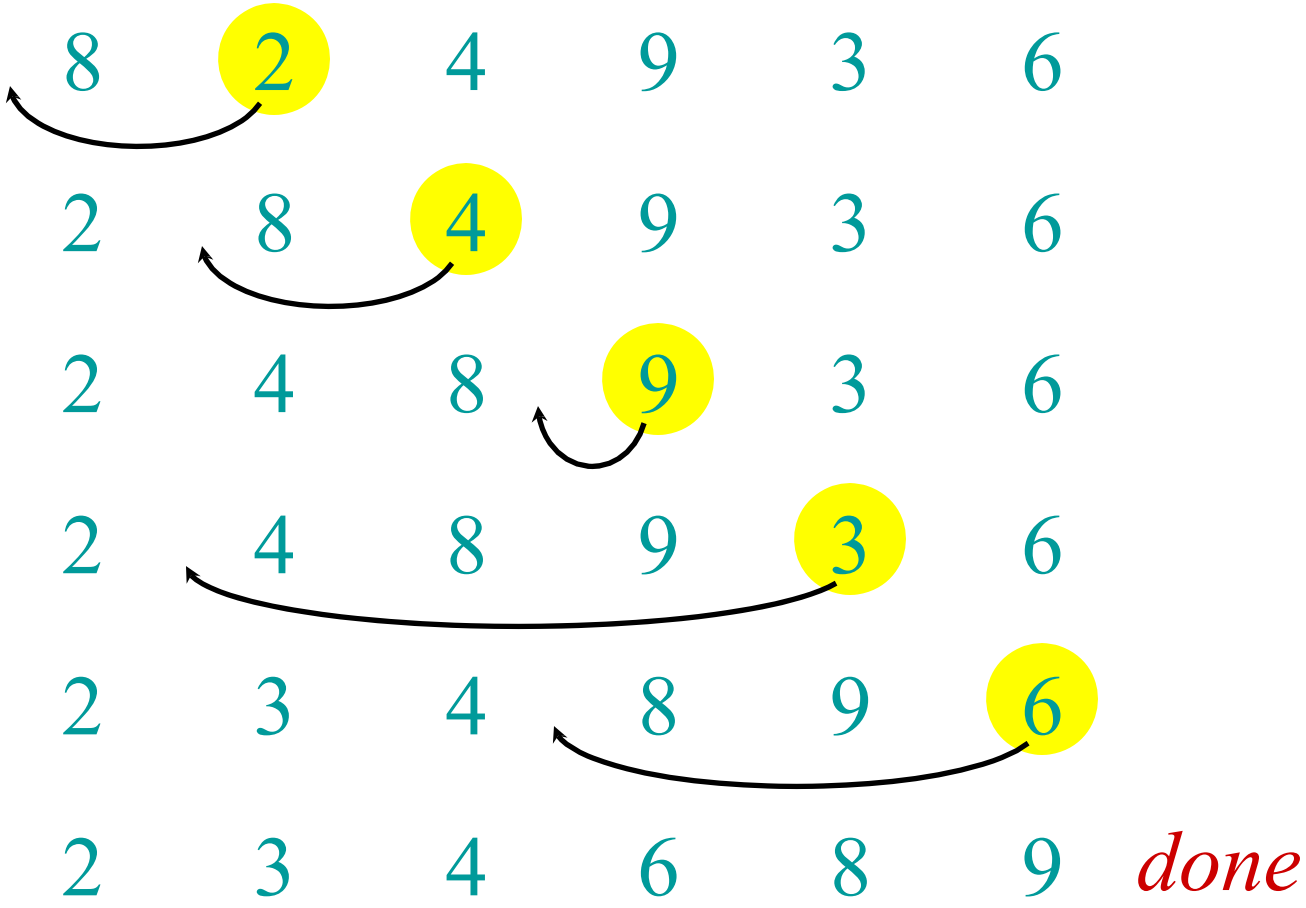

Analysis of Algorithms

- Analyzing an algorithm has come to mean predicting the resources that the algorithm requires.
  - Resources such as memory, communication bandwidth, or computer hardware.
  - Most often it is computational time that we want to measure.
- Less computational time results in better computer-program performance.

Only Performance?

- What are other important features of a computer-program beside performance?
  - modularity
  - maintainability
  - robustness
  - simplicity (for programmers)
  - extensibility
  - reliability
  - memory space requirement
  - locality (for cache memory)

Performance Factors

- Algorithm
  - Determines number of operations executed
- Programming language, compiler, architecture
  - Determine number of machine instructions executed per operation
- Processor and memory system
  - Determine how fast instructions are executed
- I/O system (including OS)
  - Determines how fast I/O operations are executed

Data Structures

- A ***data structure*** is a way to store and organize data in order to facilitate access and modifications.
- No single data structure works well for all purposes, and so it is important to know the strengths and limitations of several of them.
- We will cover different data structures in this course.

Reasons to Study Algorithms

- Studying algorithms will allow you to:
  - Find an efficient solution to a new computational problem.
  - Compare different available solutions to a problem.
  - Understand different techniques used in many computing systems (e.g., operating systems, computer networks, computer architecture).
  - Finally studying algorithms will allow you to answer many interviews questions.