

CMSC 337

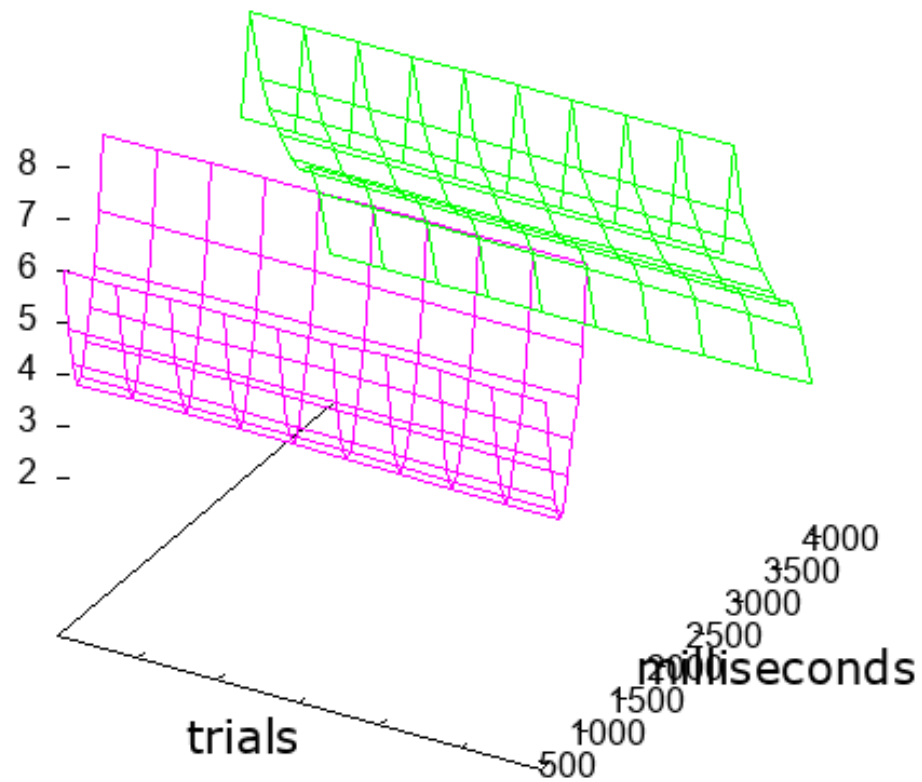
Algorithms: Design & Practice

- Given an array, A of n integers arranged in ascending order, and an integer x :

$$\text{search}(A, n, x) = \begin{cases} i, & \text{such that } A[i] = x \\ -1, & \text{otherwise} \end{cases}$$

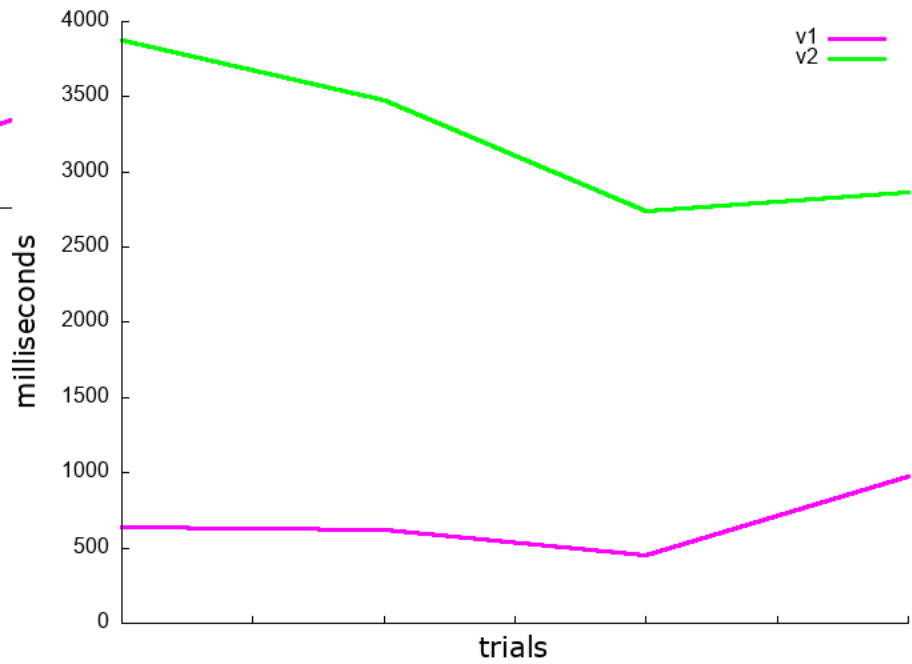
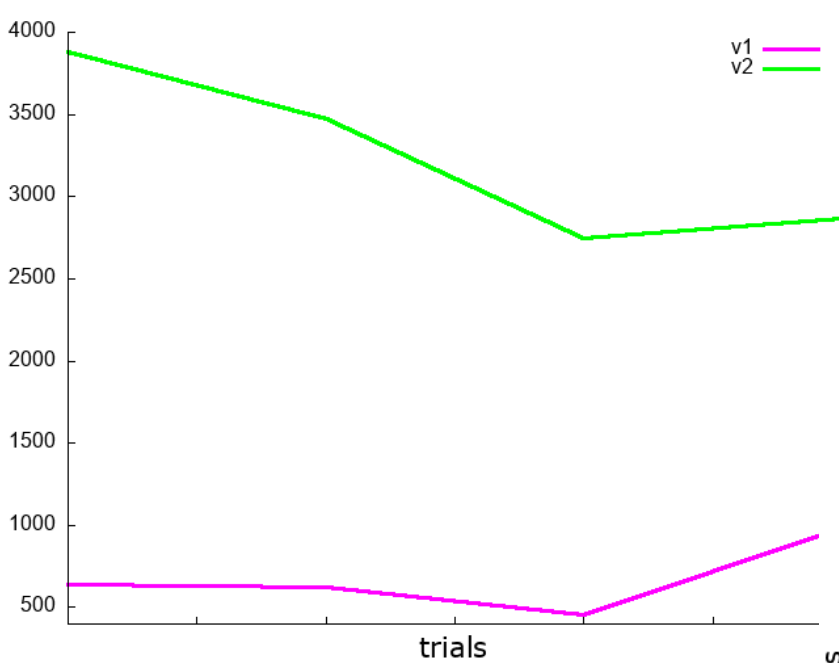
Graphs: Do/Don't

- Simple
- Lies
- Labels
- Appropriate type



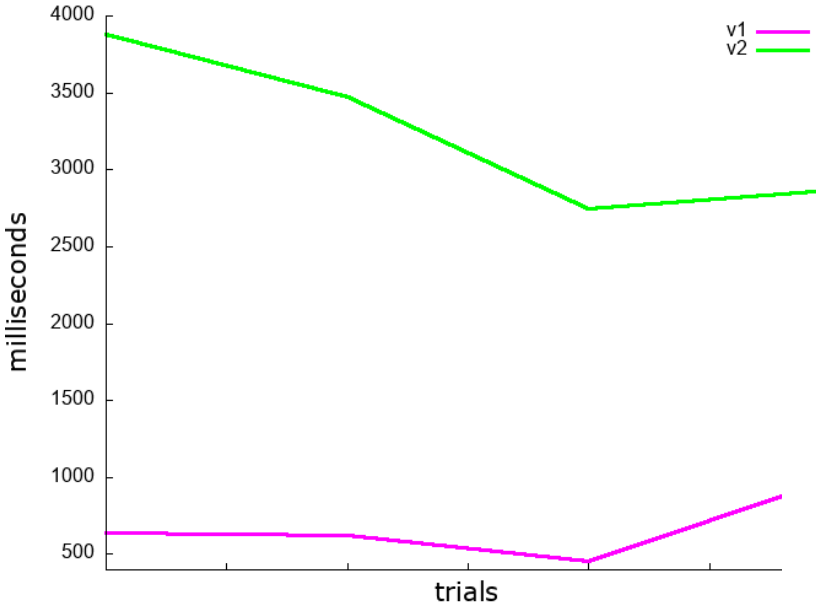
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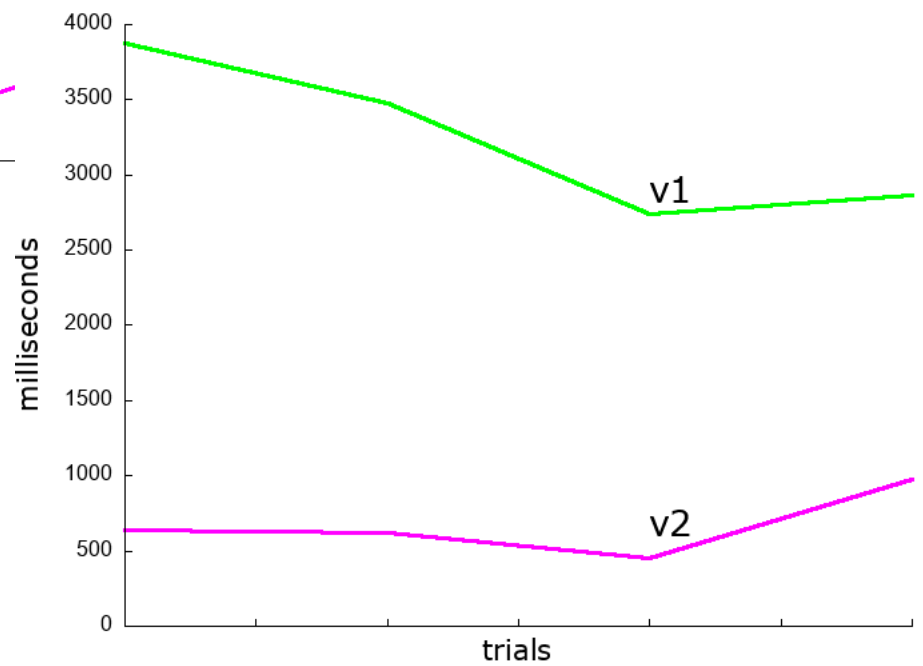


Graphs: Do/Don't

- Simple
- Lies
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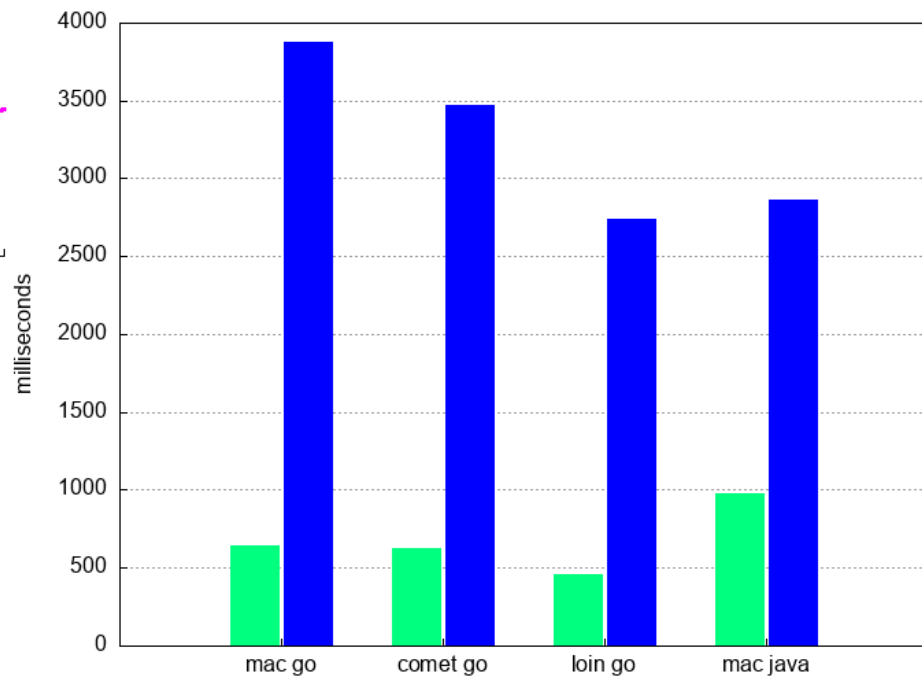
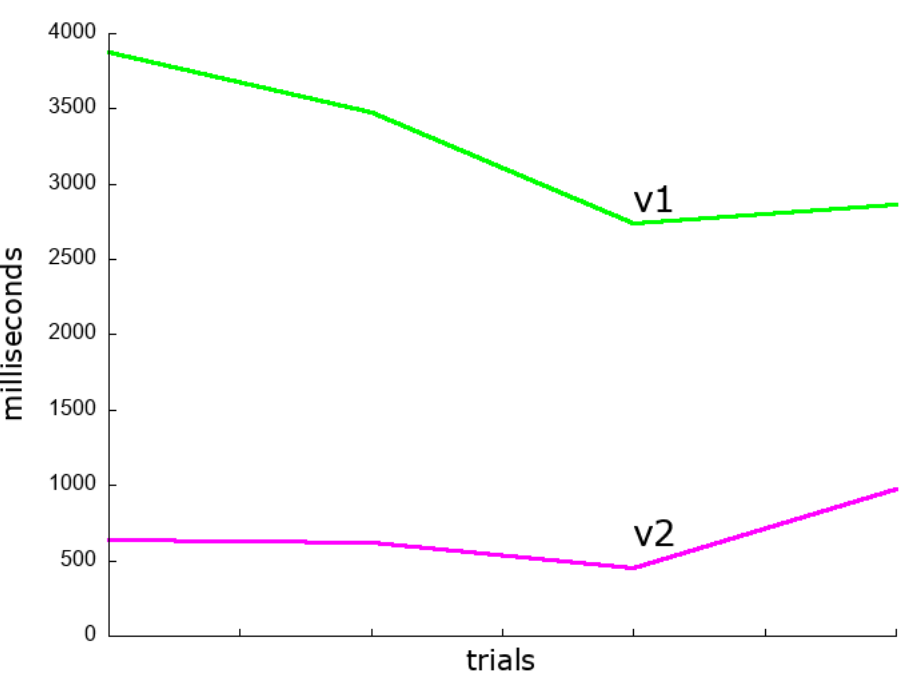
Use labels rather than keys

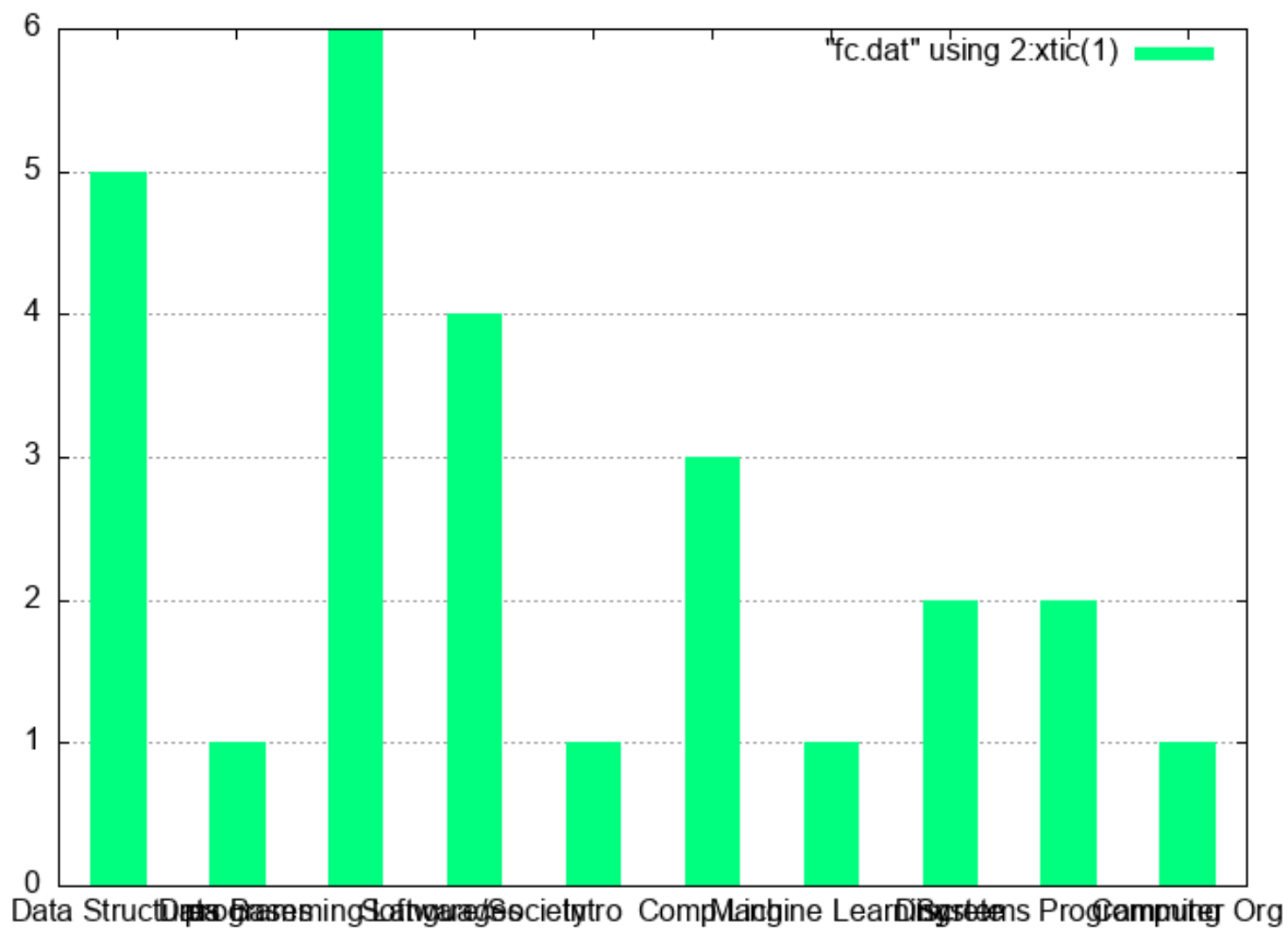


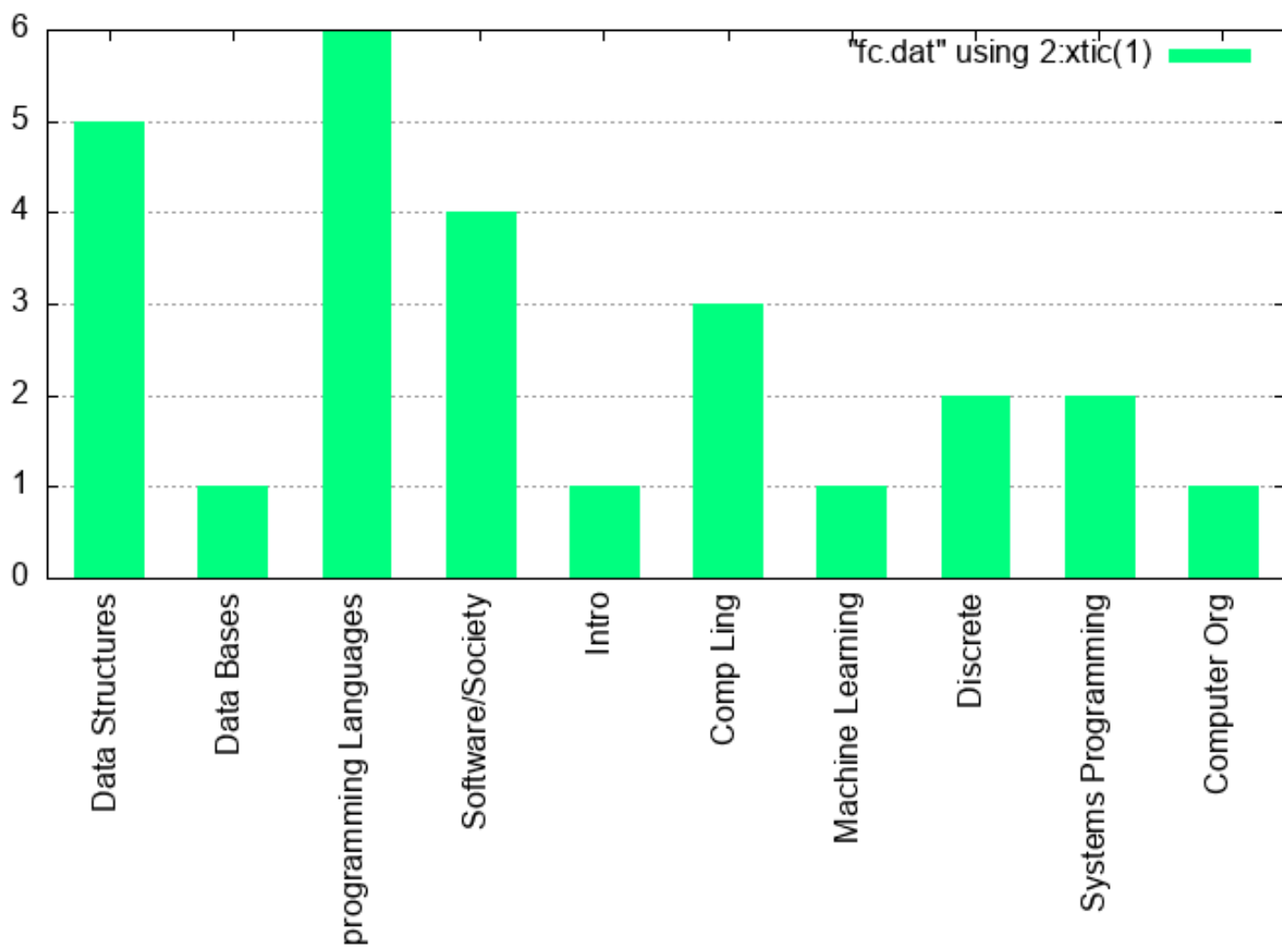
Also, every axis should be labelled

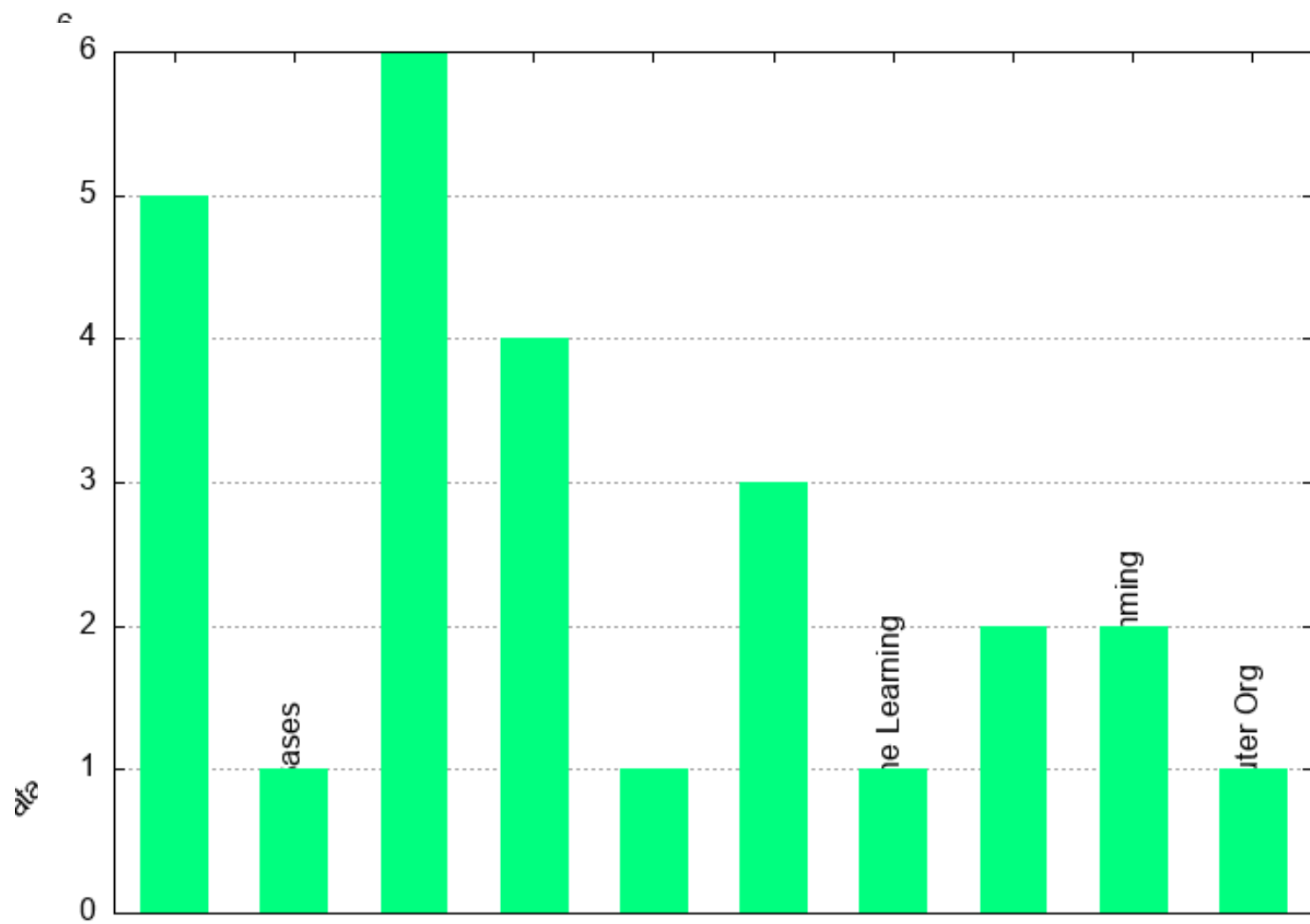
Graphs: Do/Don't

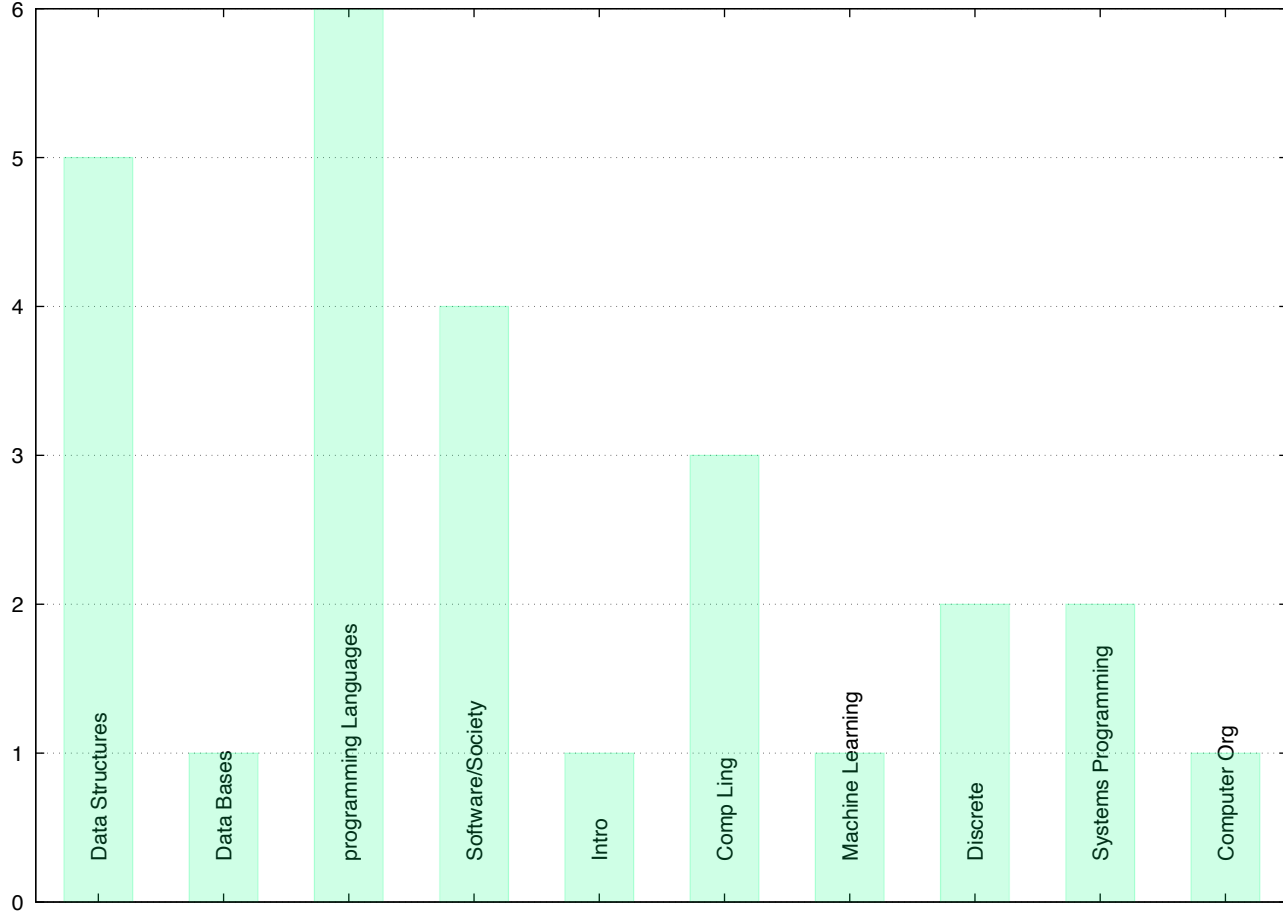
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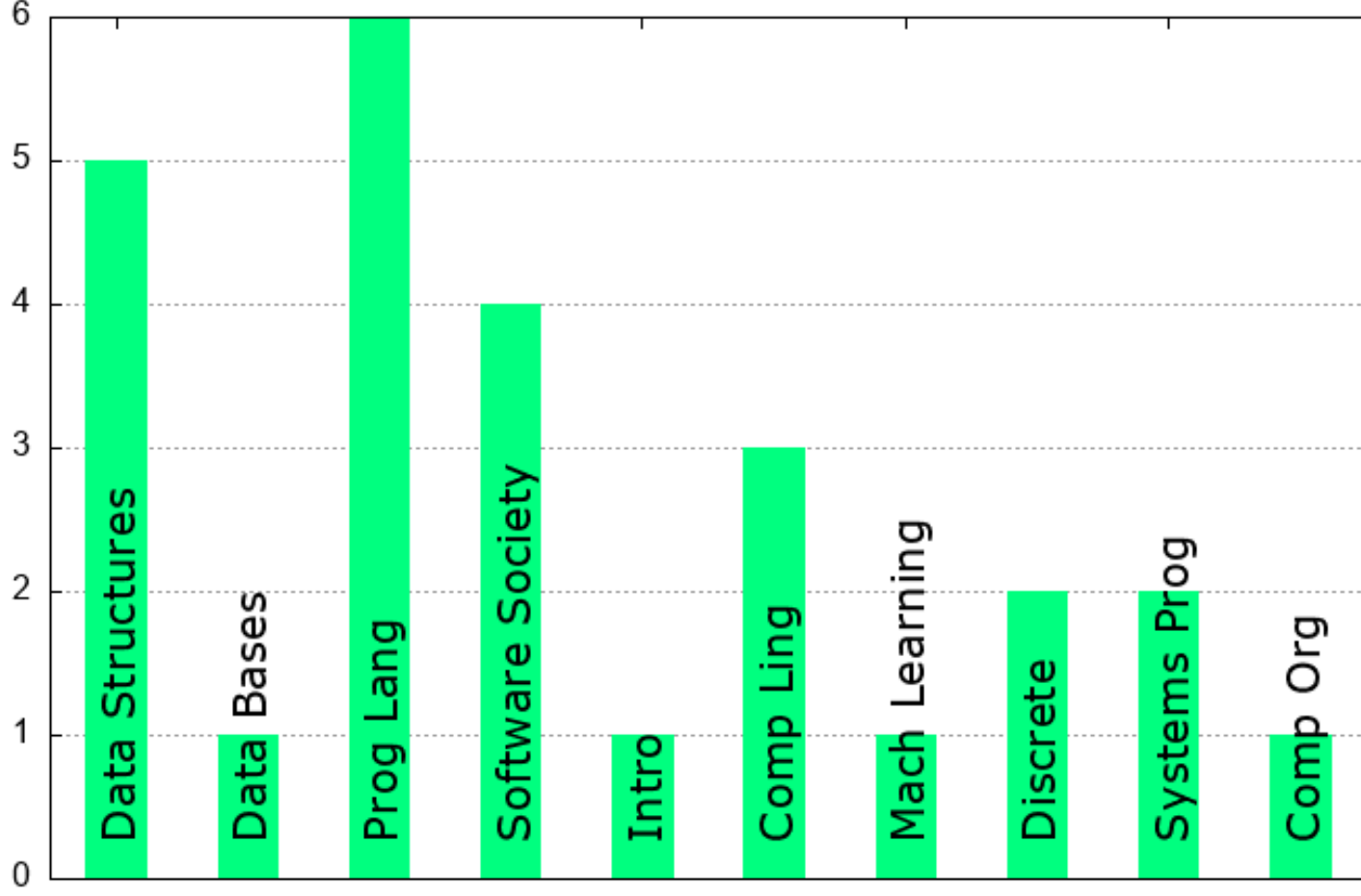




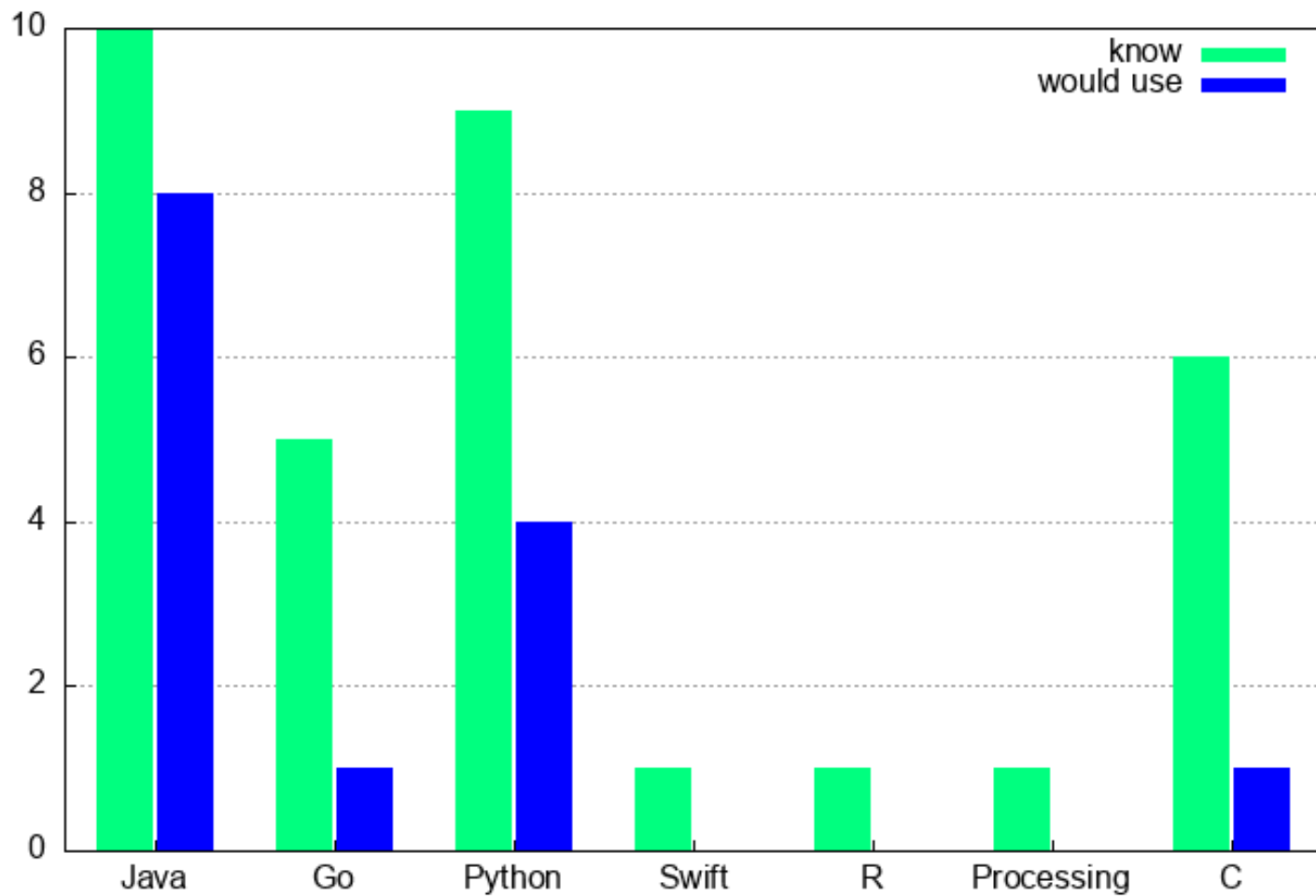




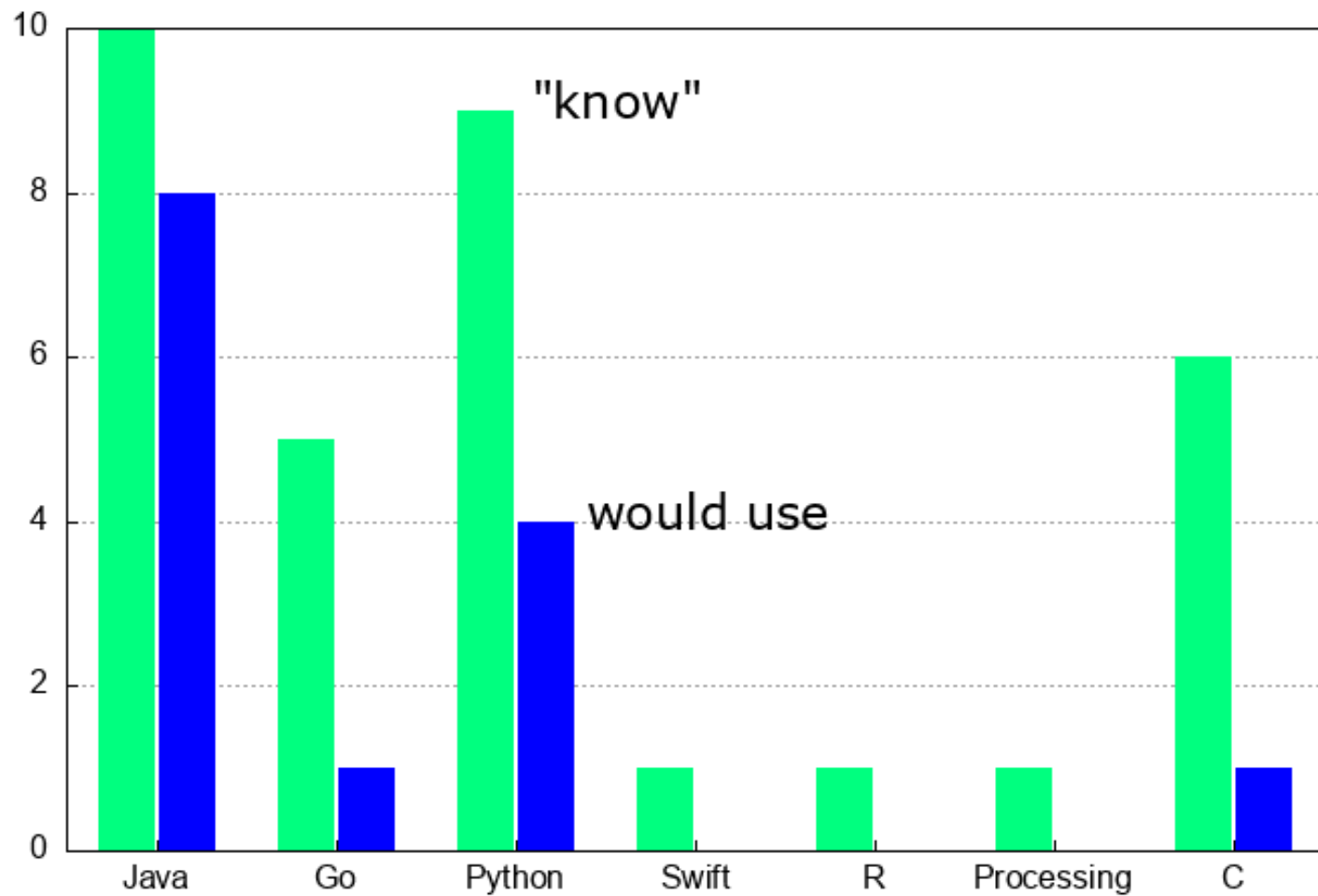
Favorite Class



Programming Language



Programming Language



Algorithms

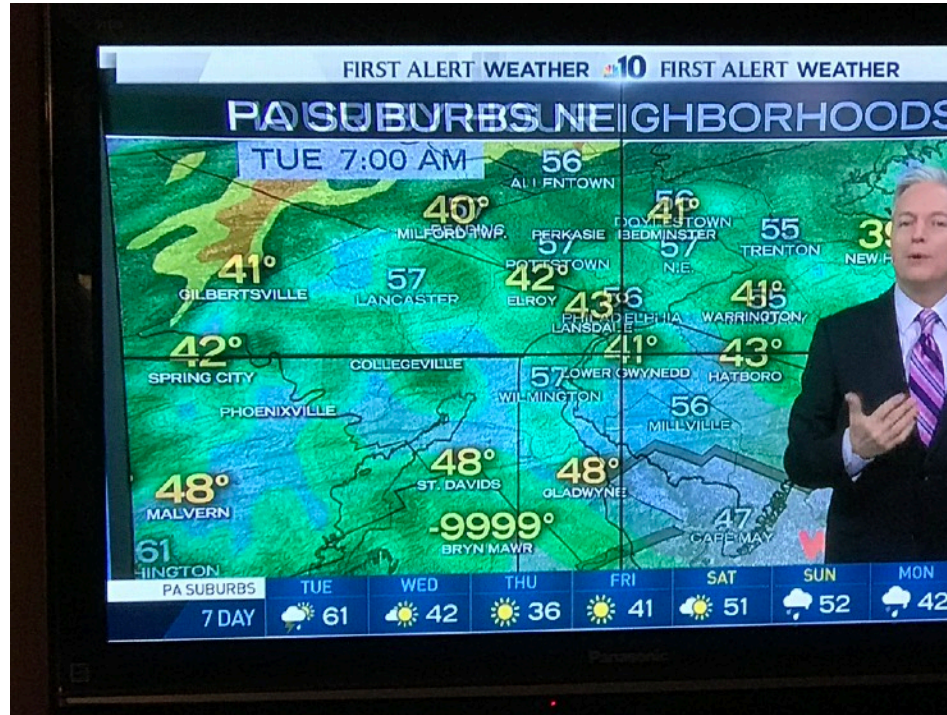


A Bird's Eye View

- Given an array, A of n integers arranged in ascending order, and an integer x :

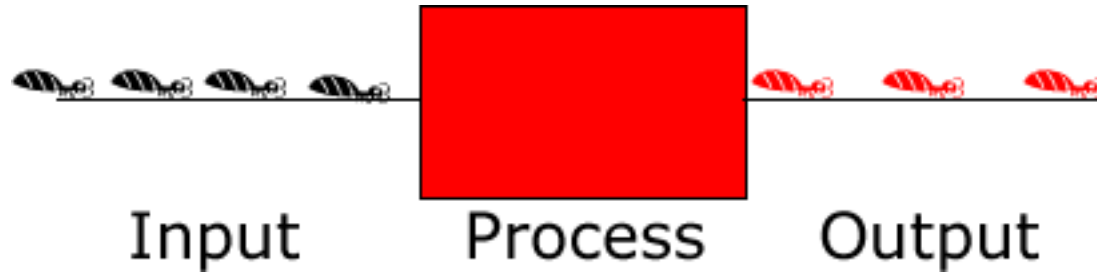
$$\text{search}(A, n, x) = \begin{cases} i, & \text{such that } A[i] = x \\ -1, & \text{otherwise} \end{cases}$$

When Bryn Mawr Froze...



From January 23, 2018. Local NBC TV Station's Weather Forecast.

Information Processing



Problem Solving (Investigation of Processes)

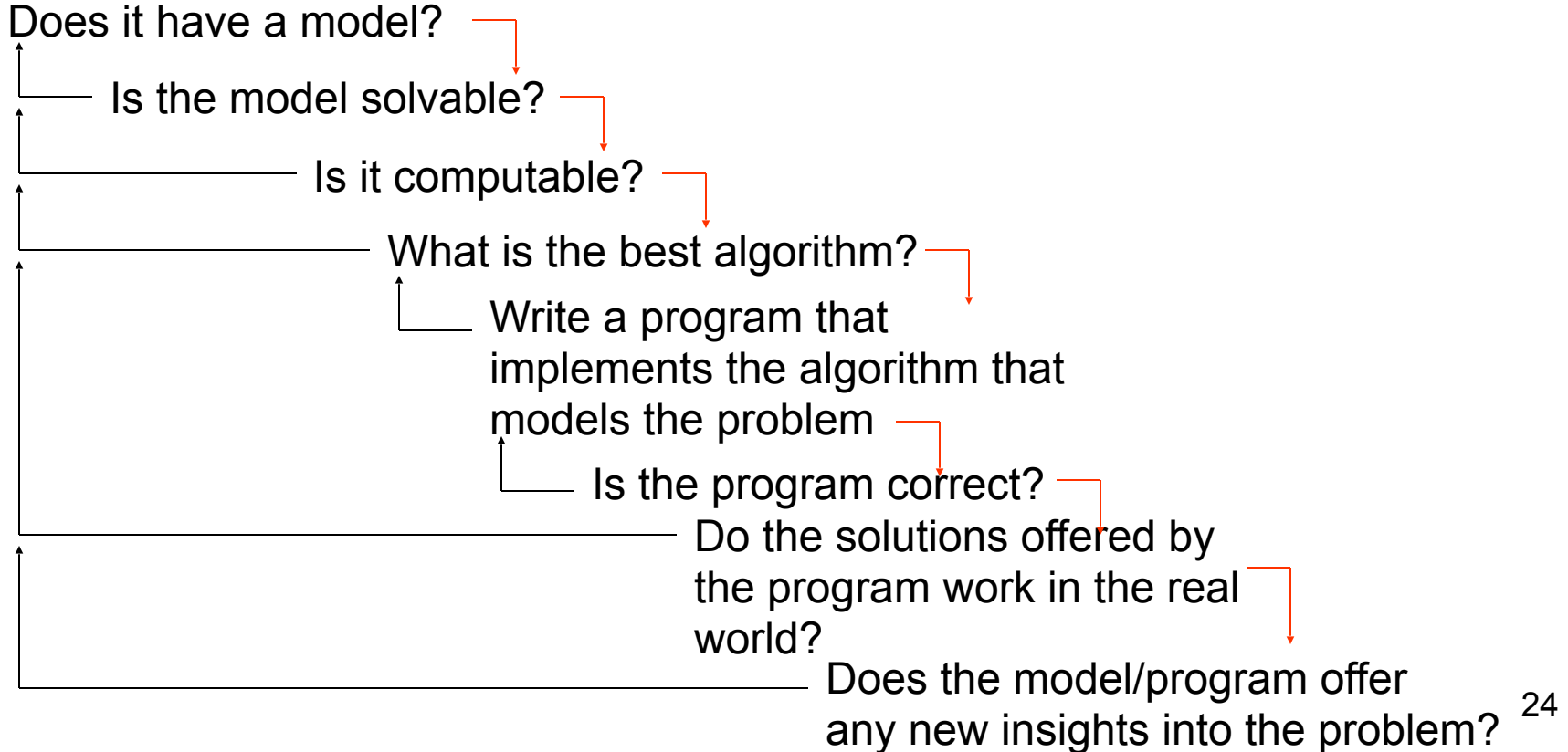
- Given a dictionary of english words, what are all the anagram classes? (e.g. earthling, haltering, lathering)
- Given the details of a tropical depression, can you predict if it will become a hurricane? What path will it take?
- Can you play the game of chess in a way that guarantees a win or a draw?
- How does the mind work?
- What is the most optimal way to get from here to there?
- What is the square root of 42?
- What impact will the Fed raising short term interest rates have on international currencies?
- What is the meaning of life?

Investigation: Asking Questions

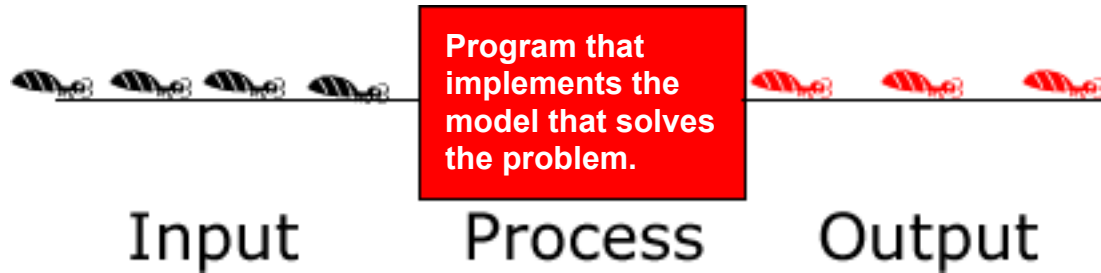
Given: A problem/process.

- Does it have a model?
- Is the model solvable?
- Is it computable?
- What is the best algorithm for it?
- Write a computer program that implements the algorithm.
- Is the program equivalent to the model?
- Does the model lend any new insights into the problem/process?

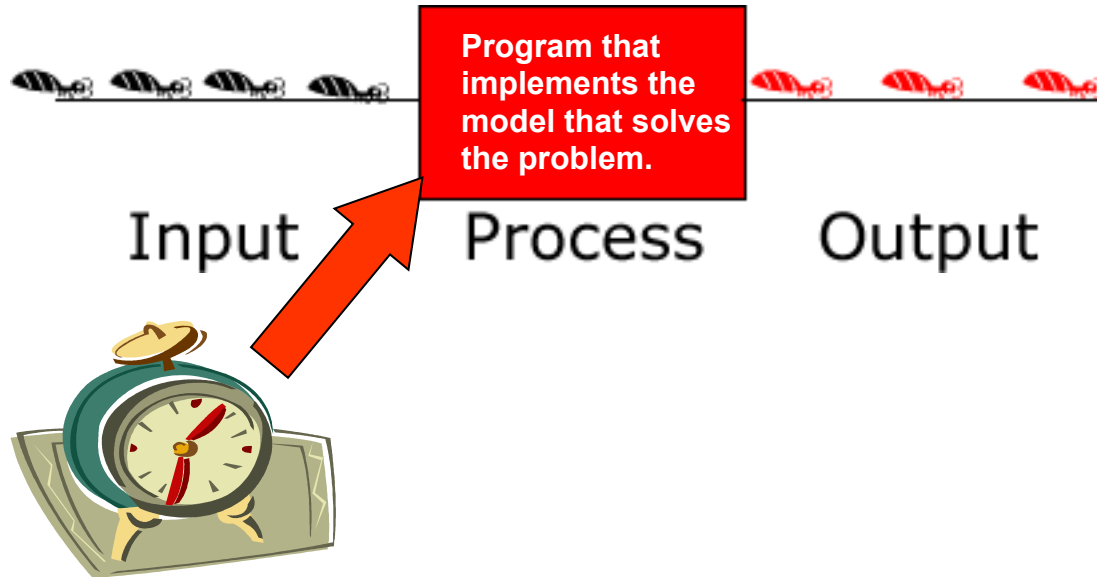
Given: A Problem



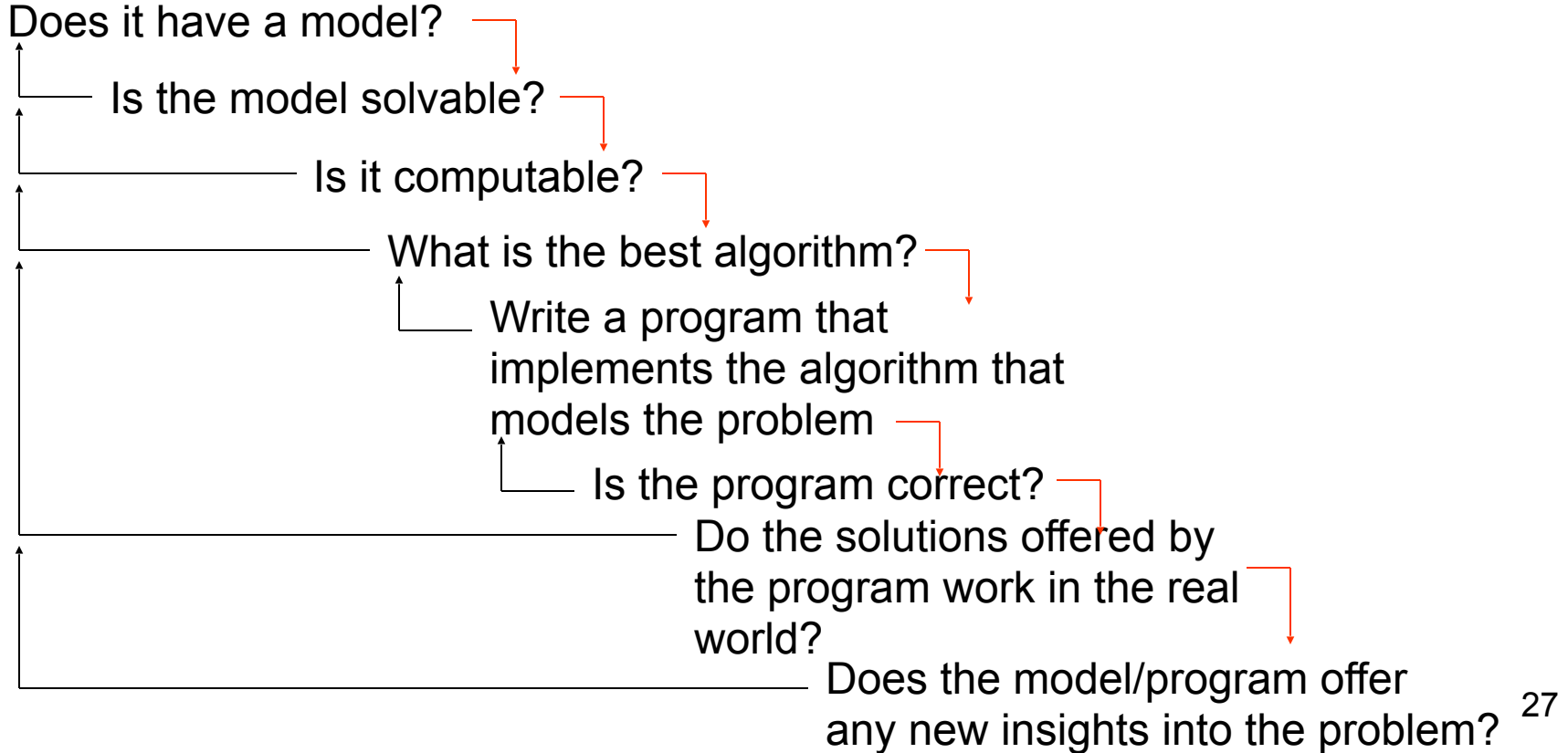
Information Processing



Information Processing



Given: A Problem



Computability:

Problems that can be solved by algorithms (Turing Machines)

Does it have a model?

Is the model solvable?

Is it computable?

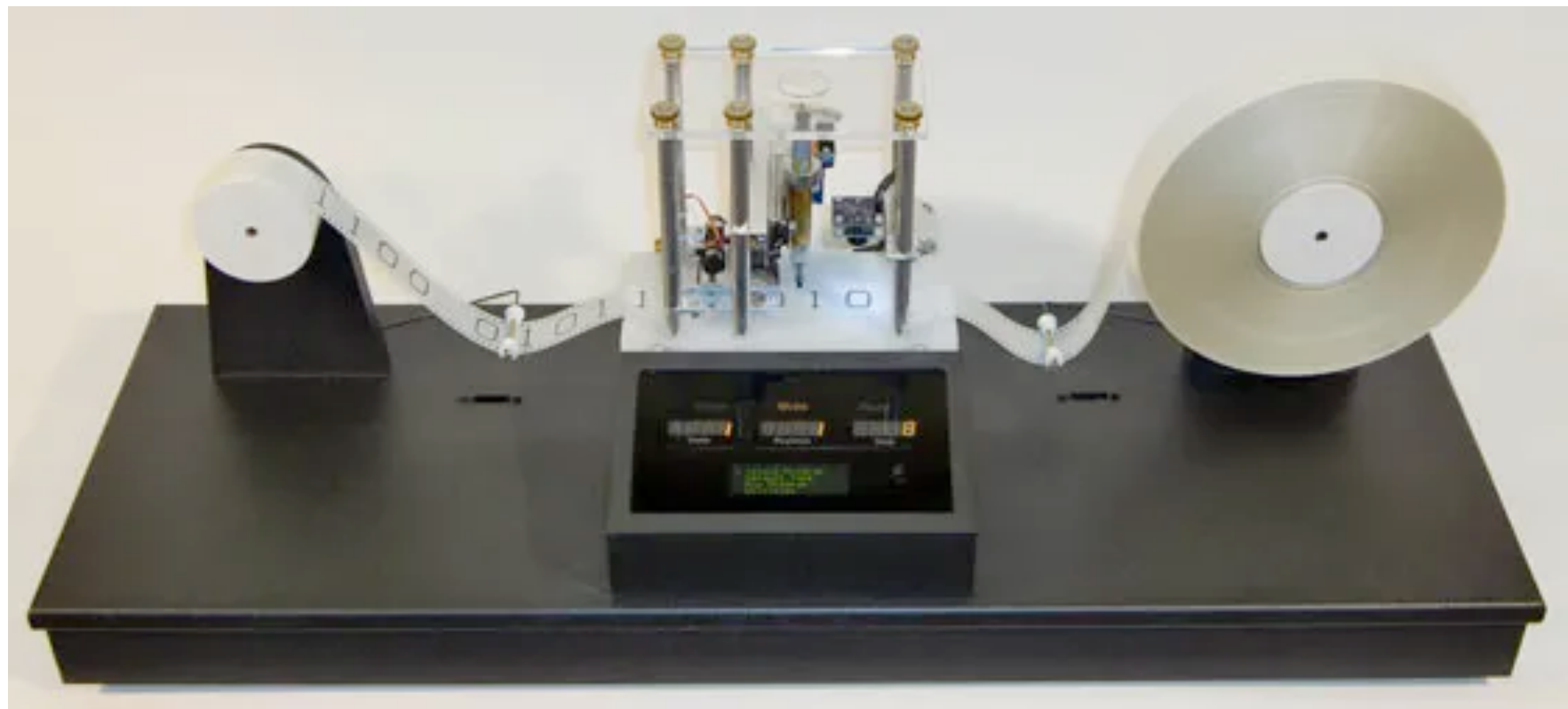
What is the best algorithm?

Write a program that
implements the algorithm that
models the problem

Is the program correct?

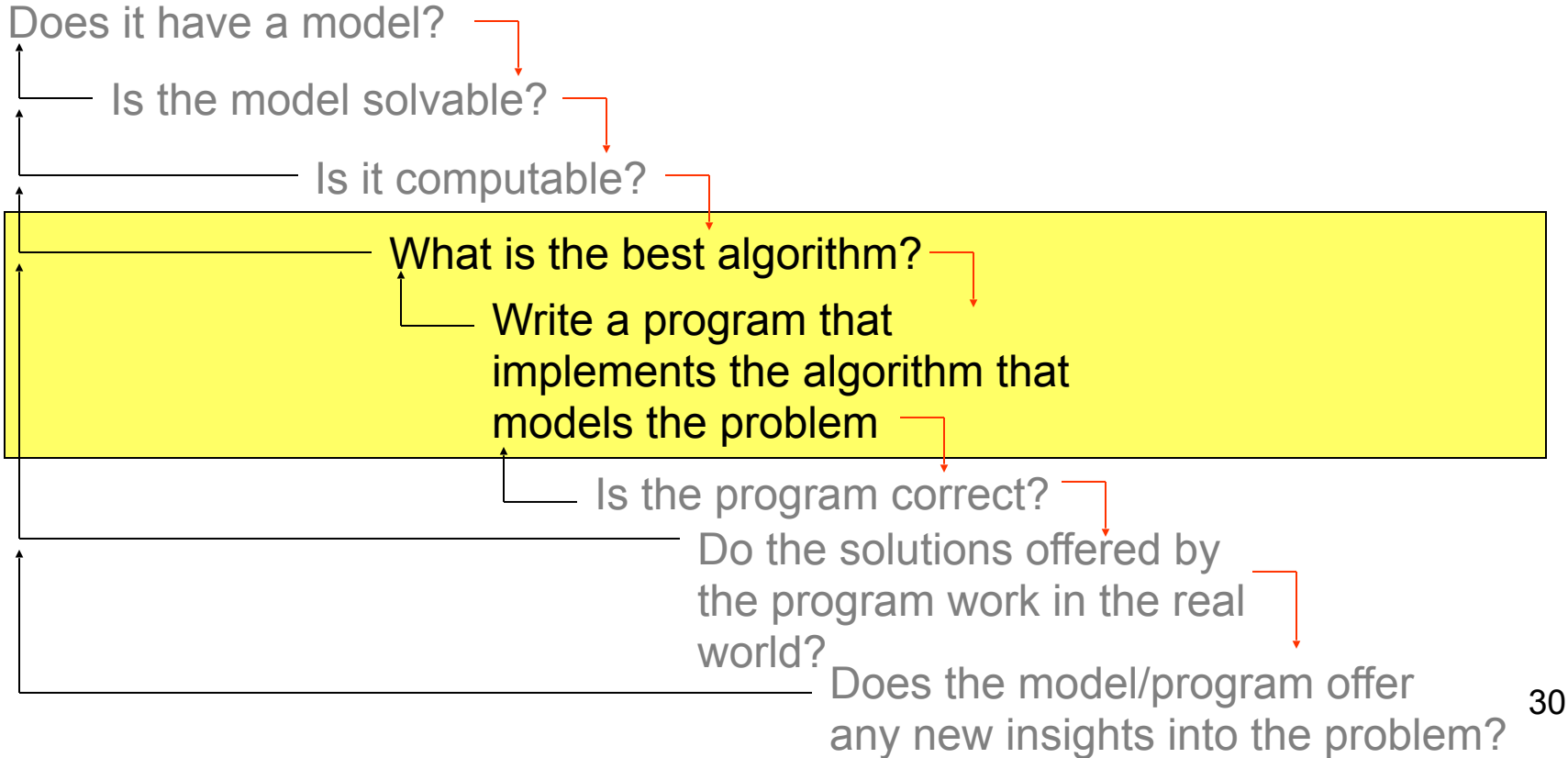
Do the solutions offered by
the program work in the real
world?

Does the model/program offer
any new insights into the problem?



Complexity Theory:

Computational Resources required (time & space)

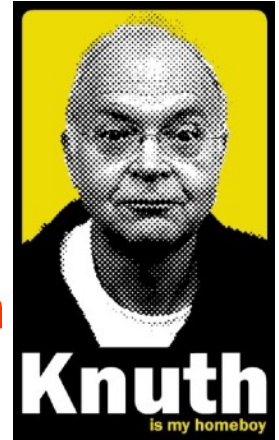


What is an *algorithm*?

A set of instructions arranged in a specific order is a *procedure*.

Similar to a *recipe*, *process*, *method*, *technique*, *procedure*, *routine*, *rigmarole*, except the word “algorithm” connotes just a little something different.

An algorithm is a finite, definite, effective procedure, with some output.



Donald Knuth: The Art of Computer Programming, Volume 1: Fundamental Algorithms, 3rd edition, 1997.

Algorithm (properties)

Finite

There must be an end to it within a reasonable time

Definite

Precisely definable in clearly understood terms, no “pinch of salt” type vagaries, or possible ambiguities

Effective

It must be possible to actually carry out the steps

Procedure

The sequence of specific steps

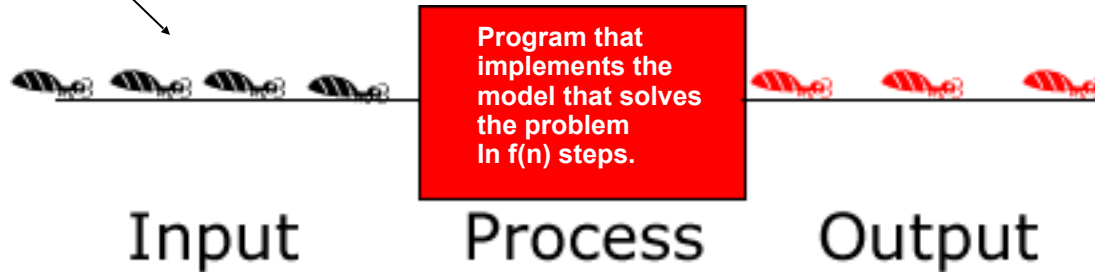
Output

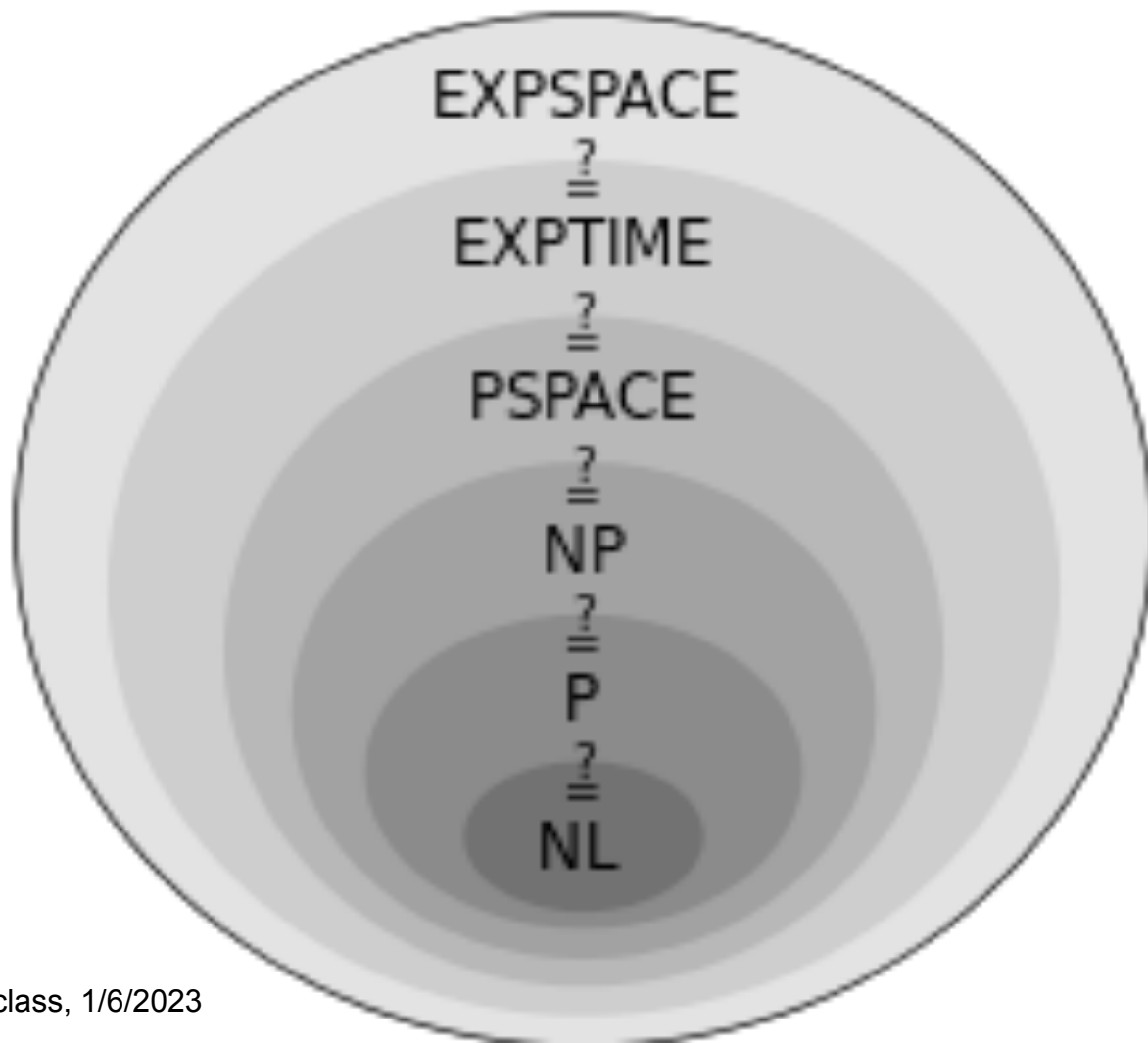
Unless there is something coming out of the computation, the result will be unknown!

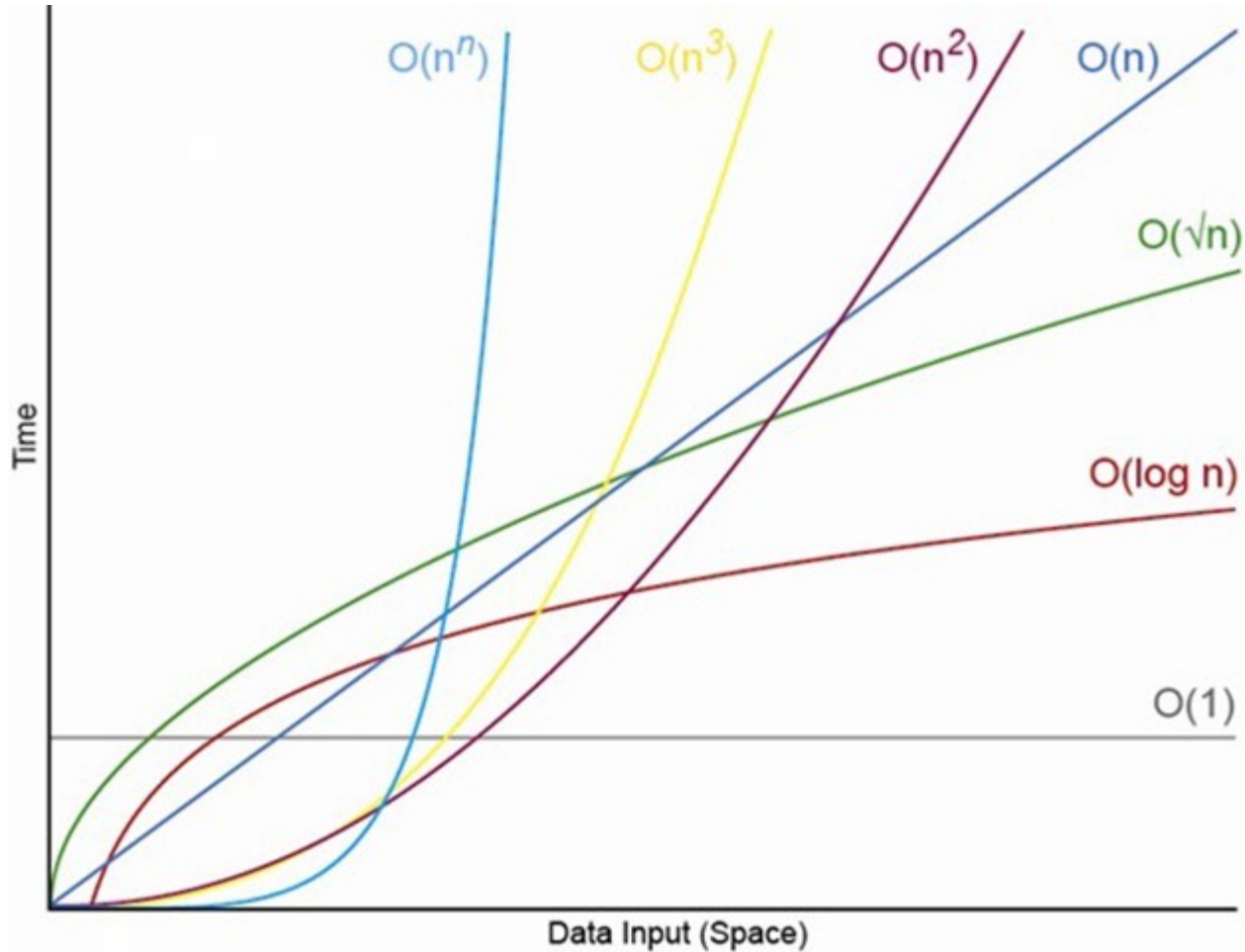
Problem Size

- Time complexity of a problem is the number of steps that it takes to solve an instance of the problem as a function of the size of the input. i.e. if the input is of size, n , it will take $f(n)$ steps to solve it.

Problem size = 4







How long to sort 10 million numbers?

Computer A

Speed: 10^{10} instructions/sec

Running $O(n^2)$ sort

Requires $2n^2$ instructions

How long will it take?

Computer B

Speed: 10^7 instructions/sec

Running $O(n \log n)$ sort

Requires $50 n \log n$ instructions

How long will it take?

How long to sort 10 million numbers?

Computer A

Speed: 10^{10} instructions/sec
Running $O(n^2)$ sort
Requires $2n^2$ instructions

$$\frac{2 * (10^7)^2}{10^{10}} \approx 20,000s$$

~5.5 hours

Computer B

Speed: 10^7 instructions/sec
Running $O(n \log n)$ sort
Requires $50 n \log n$ instructions

How long will it take?

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Computer B

Speed: 10^7 instructions/sec

Running $O(n \log n)$ sort

Requires $50 n \log n$ instructions

$$\frac{50 * 10^7 * \log 10^7}{10^7} \approx 1163s$$

under 20 minutes!

How long to sort 10 million numbers?

Computer A

Speed: 10^{10} instructions/sec

Running $O(n^2)$ sort

Requires $2n^2$ instructions

$$\frac{2 * (10^7)^2}{10^{10}} \approx 20,000s$$

If running $50 n \log n$ program: < 2s!!

Computer B

Speed: 10^7 instructions/sec

Running $O(n \log n)$ sort

Requires $50 n \log n$ instructions

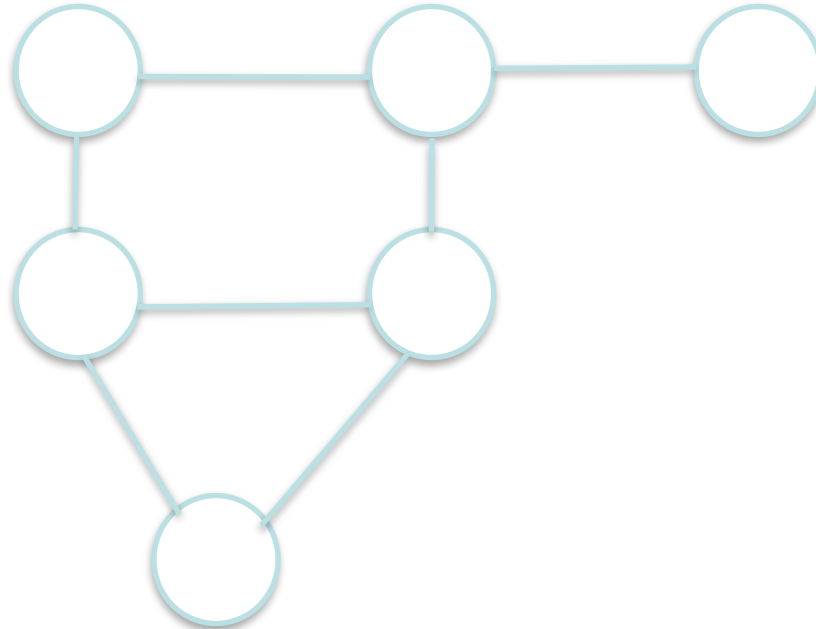
$$\frac{50 * 10^7 * \log 10^7}{10^7} \approx 1163s$$

under 20 minutes!

P = NP?



- vertex cover of a graph is a set of vertices that includes at least one endpoint of every edge.



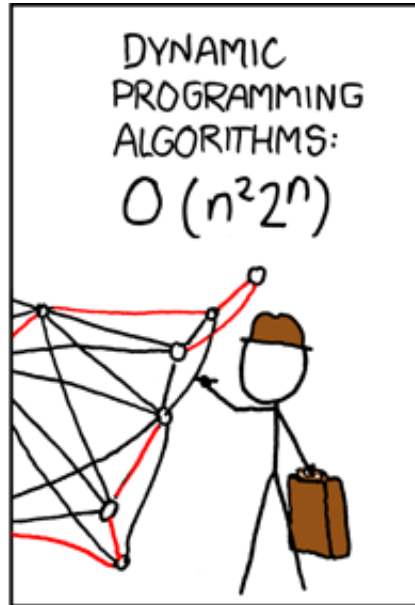
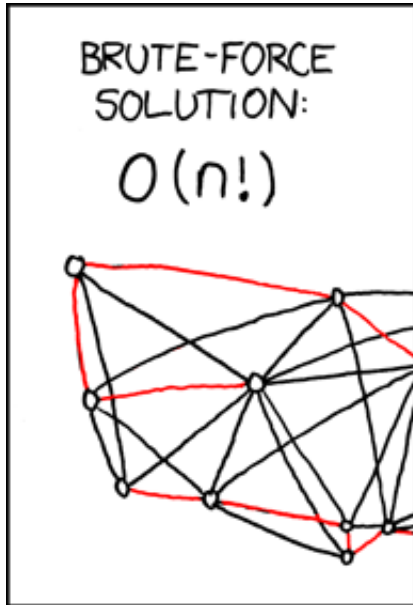
Vertex Cover Algorithm

- Find the minimum vertex cover of a graph
 - We will discuss graph representations, just make something up for now

NP-Complete

- NP = Non-deterministic Polynomial
- in NP == Solution is verifiable in P time
- problem is provably equivalent to other NP complete problems

xkcd??



- More on xkcd.com

Algorithm for Algorithm Development

```
def algorithmDevelopment(problemSpec):  
    correct = false  
    while not correct or not fastEnough(runningTime):  
        algorithm = deviseAlgorithm(problemSpec)  
        correct = analyzeCorrectness(algorithm)  
        runningTime = analyzeEfficiency(algorithm)  
return algorithm
```

Algorithm for Program Development

```
def programDevelopment(algorithm, testSuite):  
    language = pickLanguage(algorithm)  
    program = code(algorithm, program)  
    do:  
        check = false  
        while not check:  
            program = debug(program)  
            check = verifyProgram(program, testSuite)  
  
        performance = measure(performance)  
        while not acceptable(performance)
```



An algorithm to consider

- Given two lists of integers
 - call these A and B
- Find: $\min(\text{abs}(A[i]-B[j]))$