• Given an array, \( A \) of \( n \) integers arranged in ascending order, and an integer \( x \):

\[
\text{search}(A, n, x) = \begin{cases} 
  i, & \text{such that } A[i] = n \\
  -1, & \text{otherwise}
\end{cases}
\]
Graphs: Do/Don't

- Simple
- Lies
- Labels
- Appropriate type
Graphs: Do/Don't

- Simple
- Lies
- Labels
- Appropriate type
Graphs: Do/Don't

- Simple
- Lies
- Labels
- Appropriate type
Also, every axis should be labelled

Use labels rather than keys
Graphs: Do/Don't

• Simple
• Lies
• Labels
• Appropriate type
Programming Language

- Java: know (8), would use (8)
- Go: know (5), would use (1)
- Python: know (9), would use (4)
- Swift: know (2), would use (2)
- R: know (2), would use (2)
- Processing: know (2), would use (2)
- C: know (2), would use (2)
Programming Language

"know"

would use

Java | Go | Python | Swift | R | Processing | C

8

4
Algorithms

A Bird’s Eye View
• Given an array, \( A \) of \( n \) integers arranged in ascending order, and an integer \( x \):

\[
\text{search}(A, n, x) = \begin{cases} 
  i, \text{ such that } A[i] = n \\
  -1, \quad \text{otherwise}
\end{cases}
\]
When Bryn Mawr Froze…

From January 23, 2018. Local NBC TV Station’s Weather Forecast.
Information Processing

Input  Process  Output
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

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?
Information Processing

Program that implements the model that solves the problem.
Information Processing

Program that implements the model that solves the problem.
Given: A Problem

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?
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)

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?
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.

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.

Program that implements the model that solves the problem in $f(n)$ steps.
EXPSPACE \supseteq \mathcal{L} \supseteq \text{EXPTIME} \supseteq \text{PSPACE} \supseteq \text{NP} \supseteq \text{P} \supseteq \text{NL}
The image shows a graph comparing different orders of growth as a function of data input (space) and time. The graph includes lines labeled with Big O notation: O(1), O(log n), O(√n), O(n), O(n^2), O(n^3), and O(n^n). The y-axis represents time, and the x-axis represents data input (space). The lines show how different functions scale with input size.
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

\[
\frac{2 \times (10^7)^2}{10^{10}} \approx 20,000 \text{ s}
\]

\~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?
How long to sort 10 million numbers?

**Computer A**

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

\[
\frac{2 \times (10^7)^2}{10^{10}} \approx 20,000s
\]

~5.5 hours

**Computer B**

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

\[
\frac{50 \times 10^7 \times \log 10^7}{10^7} \approx 1163s
\]

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

\[
\frac{2 \times (10^7)^2}{10^{10}} \approx 20,000 \text{s}
\]

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

\[
\frac{50 \times 10^7 \times \log 10^7}{10^7} \approx 1163 \text{s}
\]

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
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

```python
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: \( \min(\text{abs}(A[i] - B[j])) \)