Communication

- How to talk about algorithms & computing?

- How to write about it?

- How to do presentations?

- How to exchange ideas?

Strunk & White's Rule 17

Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all sentences short, or avoid all detail and treat subjects only in outline, but that every word tell.

A Problem

Count the number of occurrences of all characters in a file.

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?

A Problem

Count the number of occurrences of all characters in a file.

Kernighan & Pike's Version

```c
unsigned long count[UCHAR_MAX+1];

/* freq main: display byte frequency counts */
int main(void)
{
    int c;

    while ((c = getchar()) != EOF)
        count[c]++;

    for (c = 0; c <= UCHAR_MAX; c++)
        if (count[c] != 0)
            printf("%.2x  %c  %lu\n",
                c, isprint(c) ? c : '-', count[c]);
    return 0;
}
```

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.

```
.def ___main; .scl 2; .type 32; .endef
.text
.align 32
LC0:
    .ascii "I will not Throw paper airplanes in class.\0"
    .globl _main
    .def _main; .scl 2; .type 32; .endef
    _main:
    pushl  %ebp
    movl   %esp, %ebp
    subl   $24, %esp
    andl   $-16, %esp
    movl   $0, %eax
    movl   %eax, -8(%ebp)
    movl   -8(%ebp), %eax
    call   __alloca
    call   ___main
    movl   $1, -4(%ebp)
L10:
    cmpl   $500, -4(%ebp)
    jle L13
    jmp L11
L13:
    movl   $LC0, (%esp)
    call   _printf
    leal   -4(%ebp), %eax
    incl   (%eax)
L11:
    movl   $0, %eax
    leave
    ret
```

Wrong way!!!

```
\documentclass{article}
\begin{document}
\newcount\i
\i1
\loop \ifnum\i<500
    I will not Throw paper airplanes in class.
    \advance\i1
\repeat
```

Ahhh, too many \'s.

```
#include <stdio.h>
int main(void)
{
    int count;

    for (count = 1; count <= 500; count++)
        printf ("I will not Throw paper airplanes in class.");

    return 0;
}
```
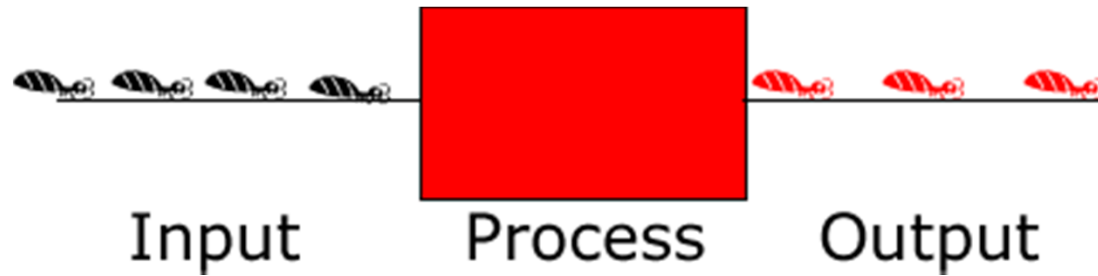
NICE TRY.

```
%!PS-Adobe-2.0
/Times-BoldItalic findfont
12 scalefont
setfont
10 700 moveto
1 1 500 {
/i exch def
  10 700 10 i mul sub moveto
  (I will not Throw paper airplanes in class.\n.) show
} for
```

A little more high-level.

```
print "I will not Throw paper airplanes in class." x 500;
```

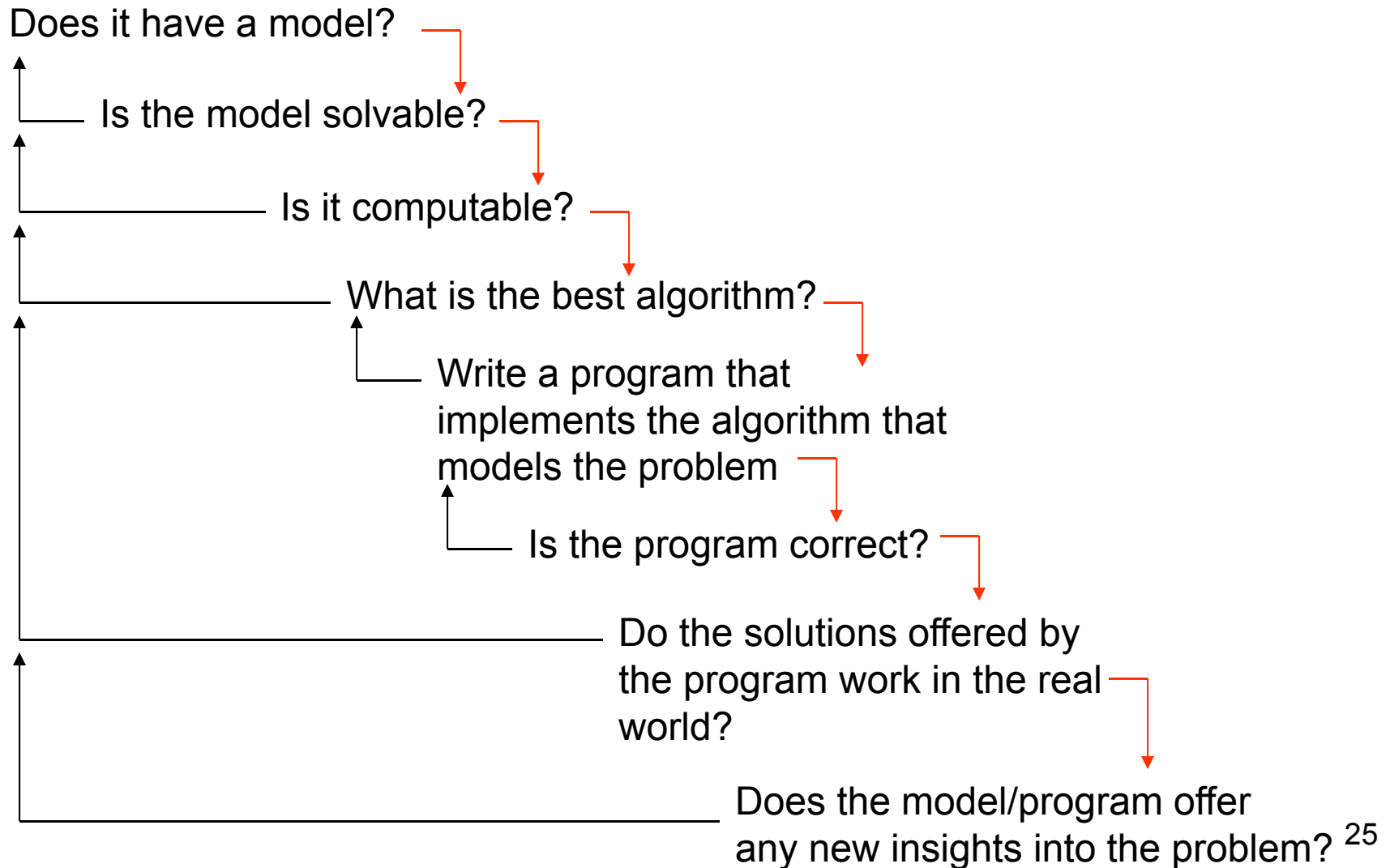Hmmmmmmmmmmm???

14

Information Processing
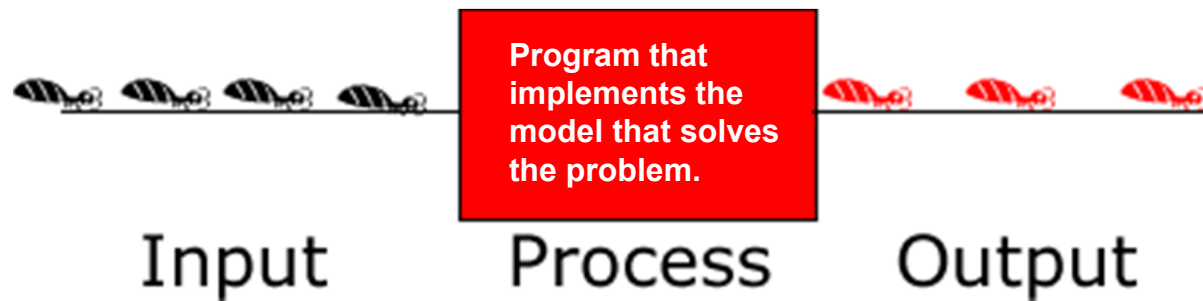

Input   Process   Output

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?

- If the Fed. Raises the short term interest rates? What impact will it have on international currencies?
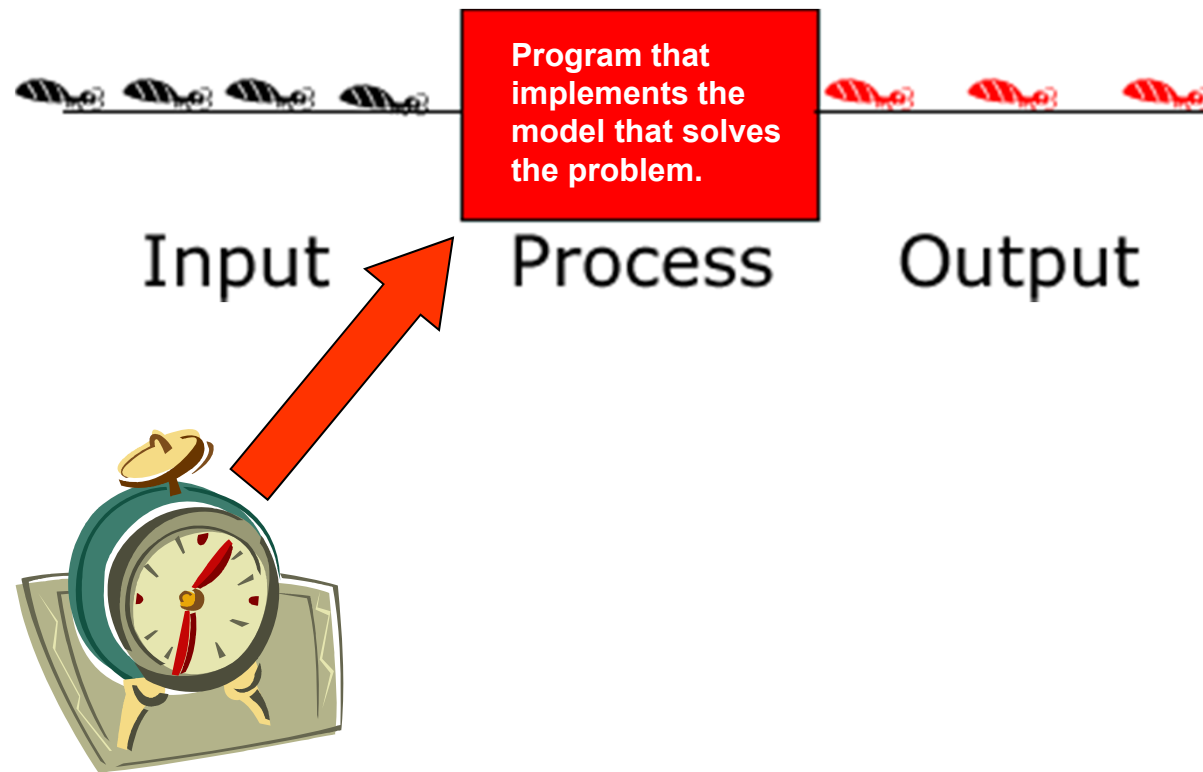
- What is the meaning of life?

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? 25

Information Processing

Program that implements the model that solves the problem.

Input   Process   Output

Information Processing

Computability:
Problems that can be solved by algorithms (Turing Machines)

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31
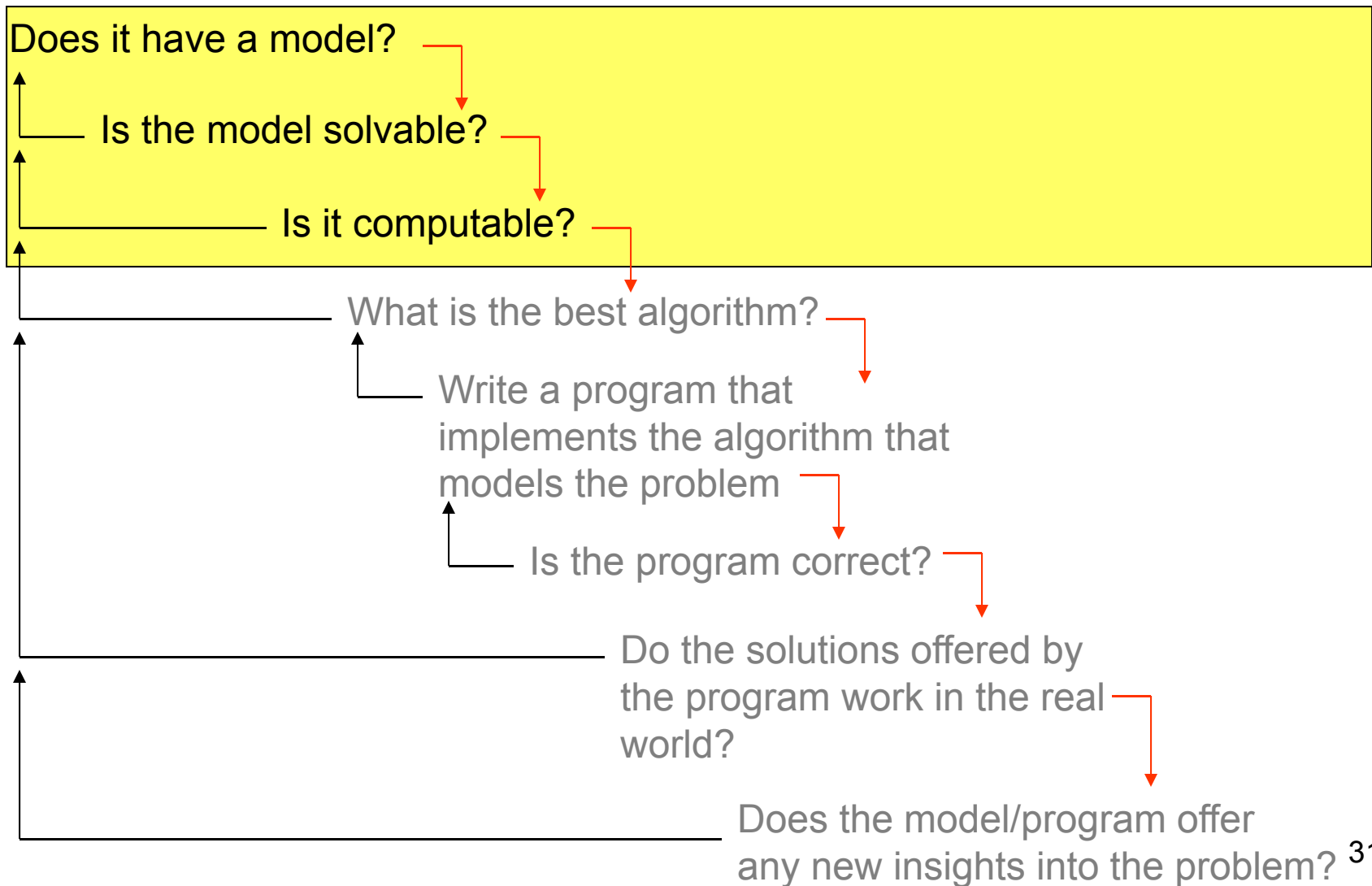
Complexity Theory:
Computational Resources required to solve a given problem (time & space)
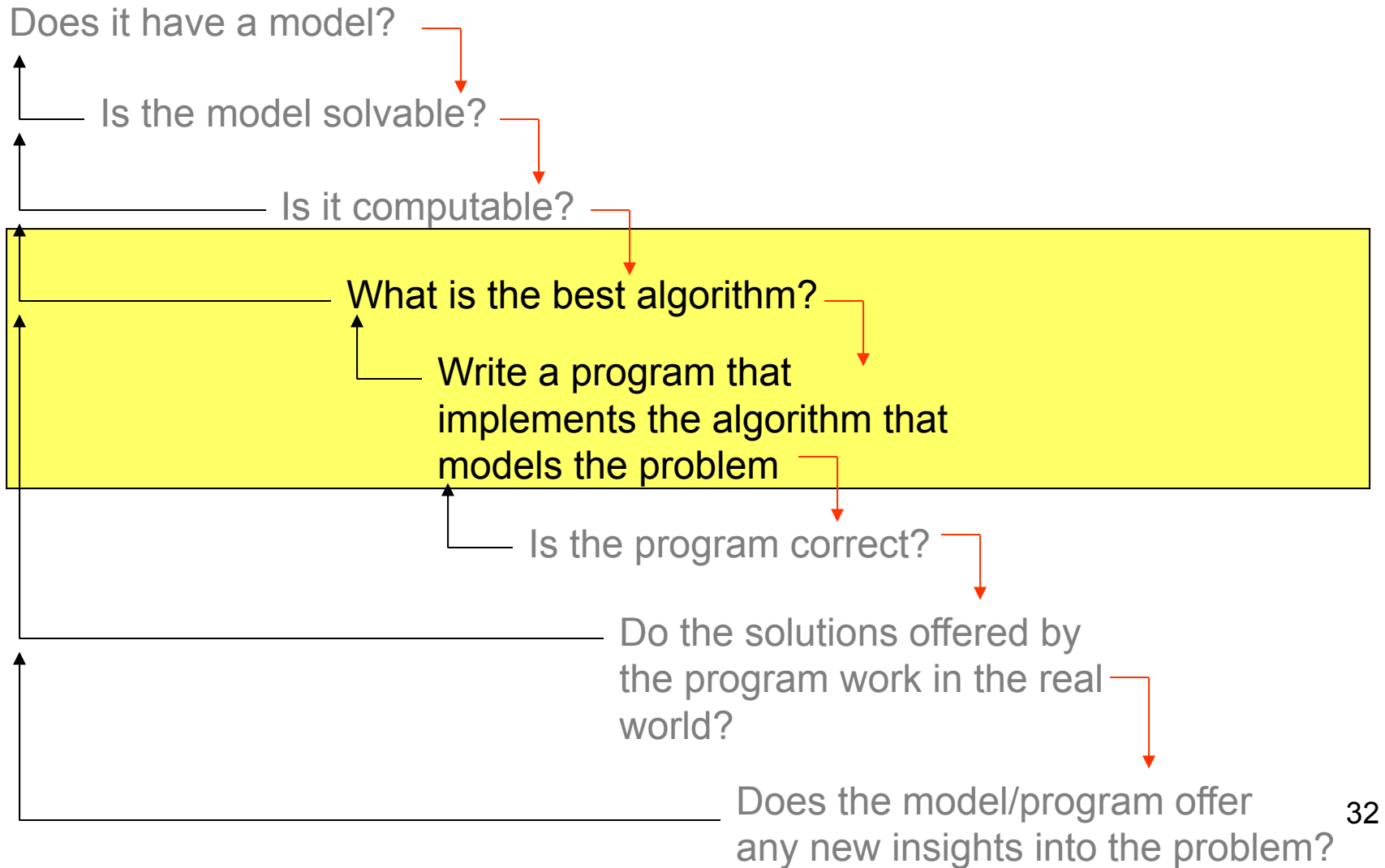
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32

Algorithm (origins)

Abu 'Abd Allah Muhammad ibn Musa al-Khwarizmi, ~780-850 A.D.
   (Father of Abdullah, Mohammad, son of Moses, native of Khwarizm)

Was a member of Dar Al Hikmah (House of Wisdom) in Baghdad.

Kitab al jabr wa'l-muqabala (Rules of restoring and equating)

35

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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
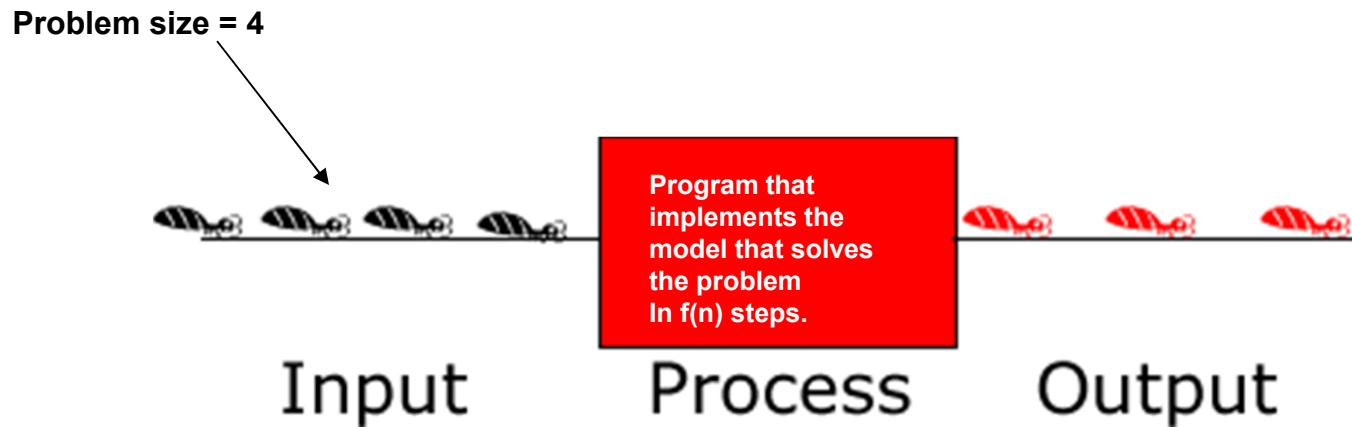It must be possible to actually carry out the steps

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.
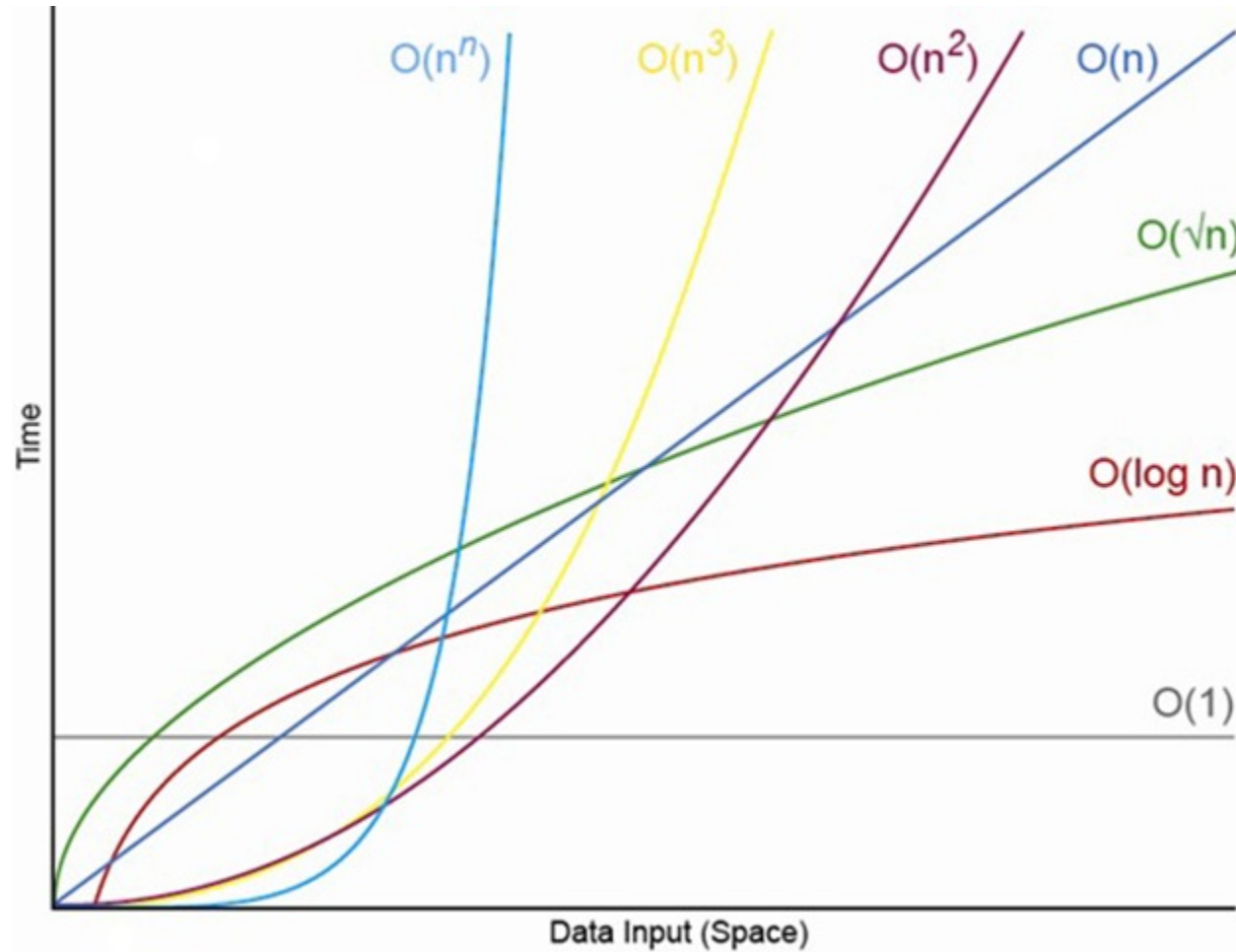
Problem size = 4

Program that implements the model that solves the problem In f(n) steps.

Input   Process   Output

38

Complexity Classes

(# steps it takes to solve a problem)

- Constant time: O(1)
- Logarithmic time: O($\log n$)
- Linear time: O(n)
- Quadratic Time: O(n^2)
- Polynomial time (P): O(n^k)
- Non-deterministic Polynomial Time (NP): O(n^k) on *some* inputs.
- Exponential time: O(2^n)
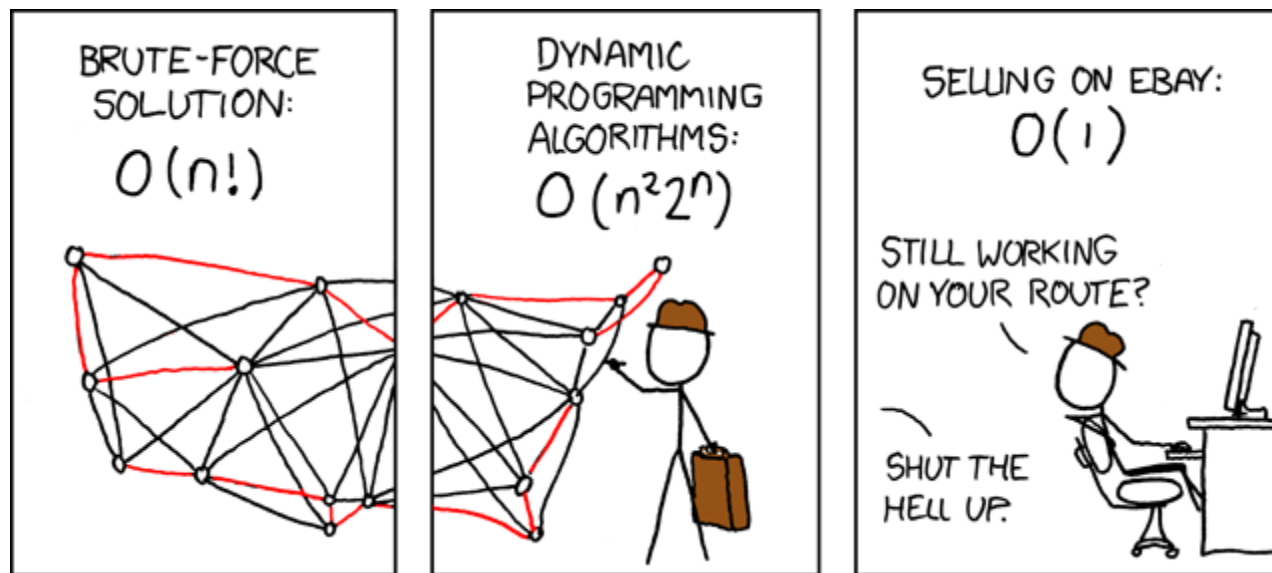- Exponential time (in general): O($2^{p(n)}$)
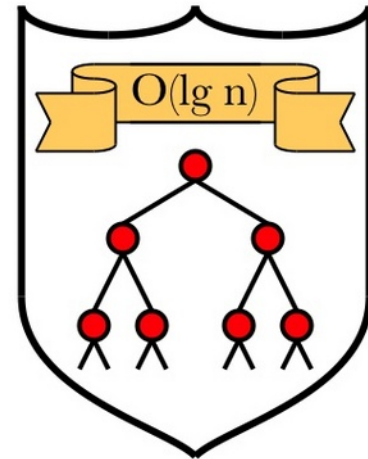
Algorithms: Performance

P = NP?

xkcd??

- [More on xkcd.com](http://xkcd.com)