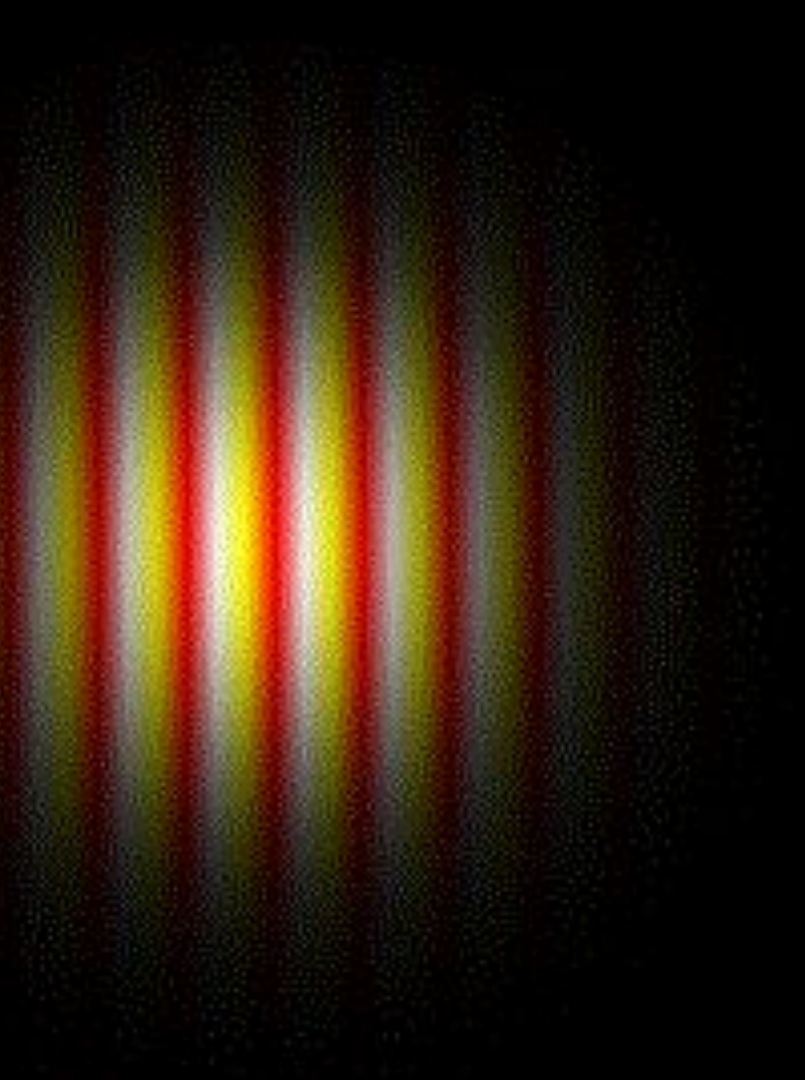
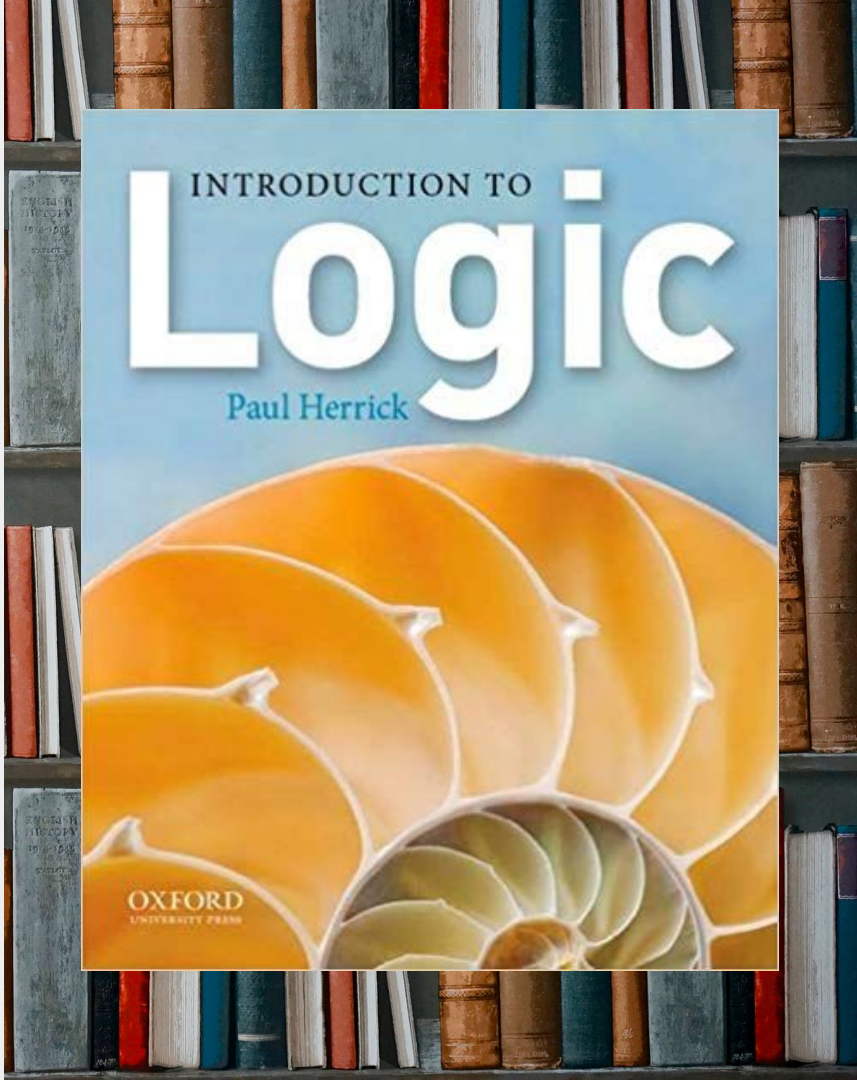


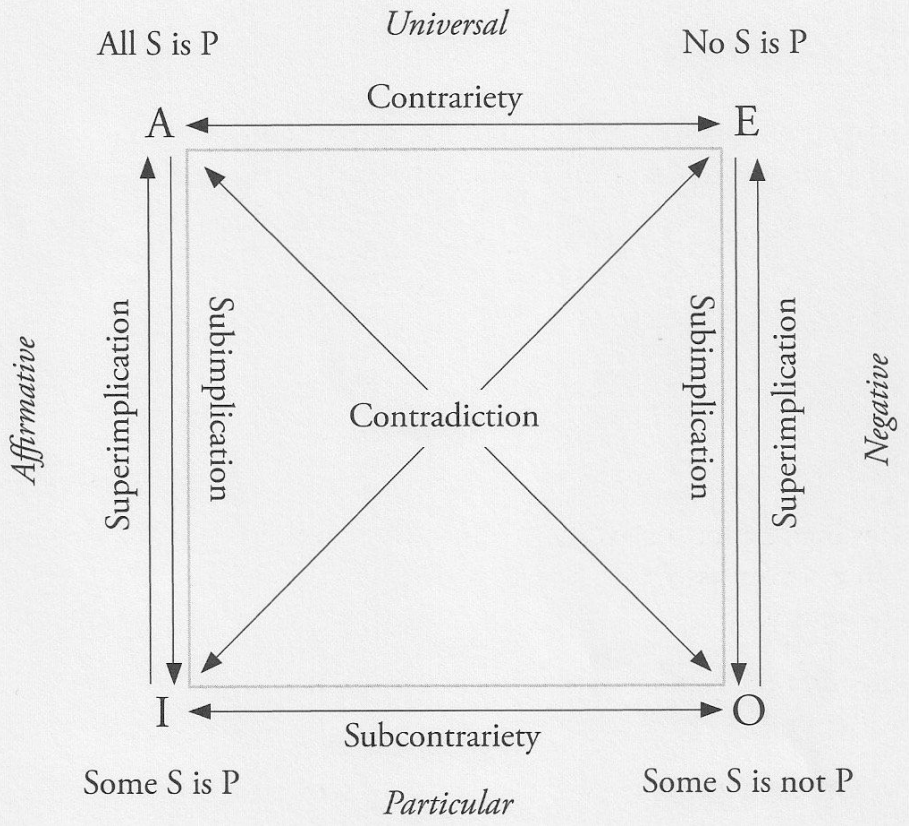
Universal Machines

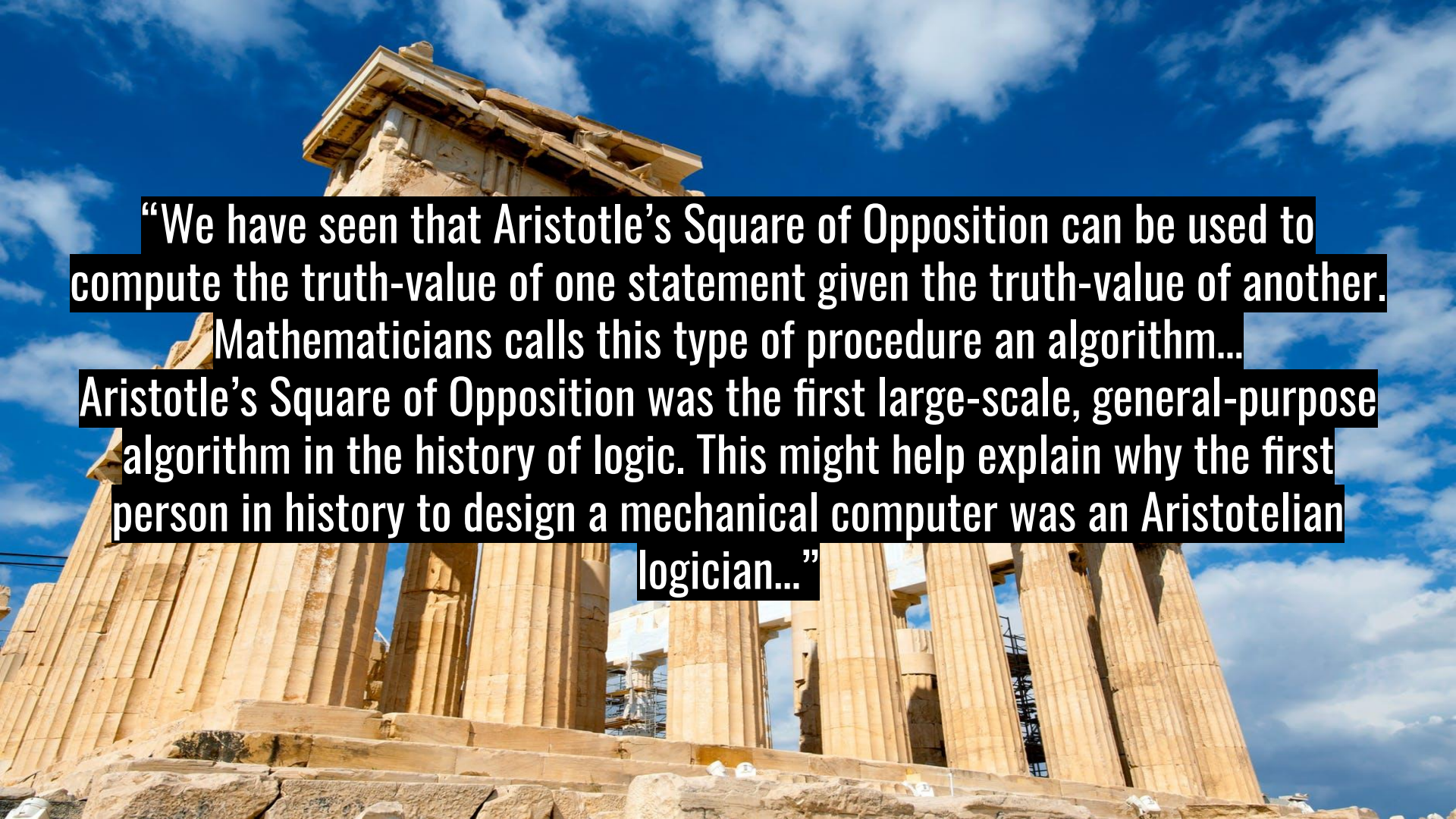
In his magisterial *Introduction to Logic*, Paul Herrick (2013) not only guides the reader through a history of symbolic logic, but he also comments on the various links between logic and the history of computation.



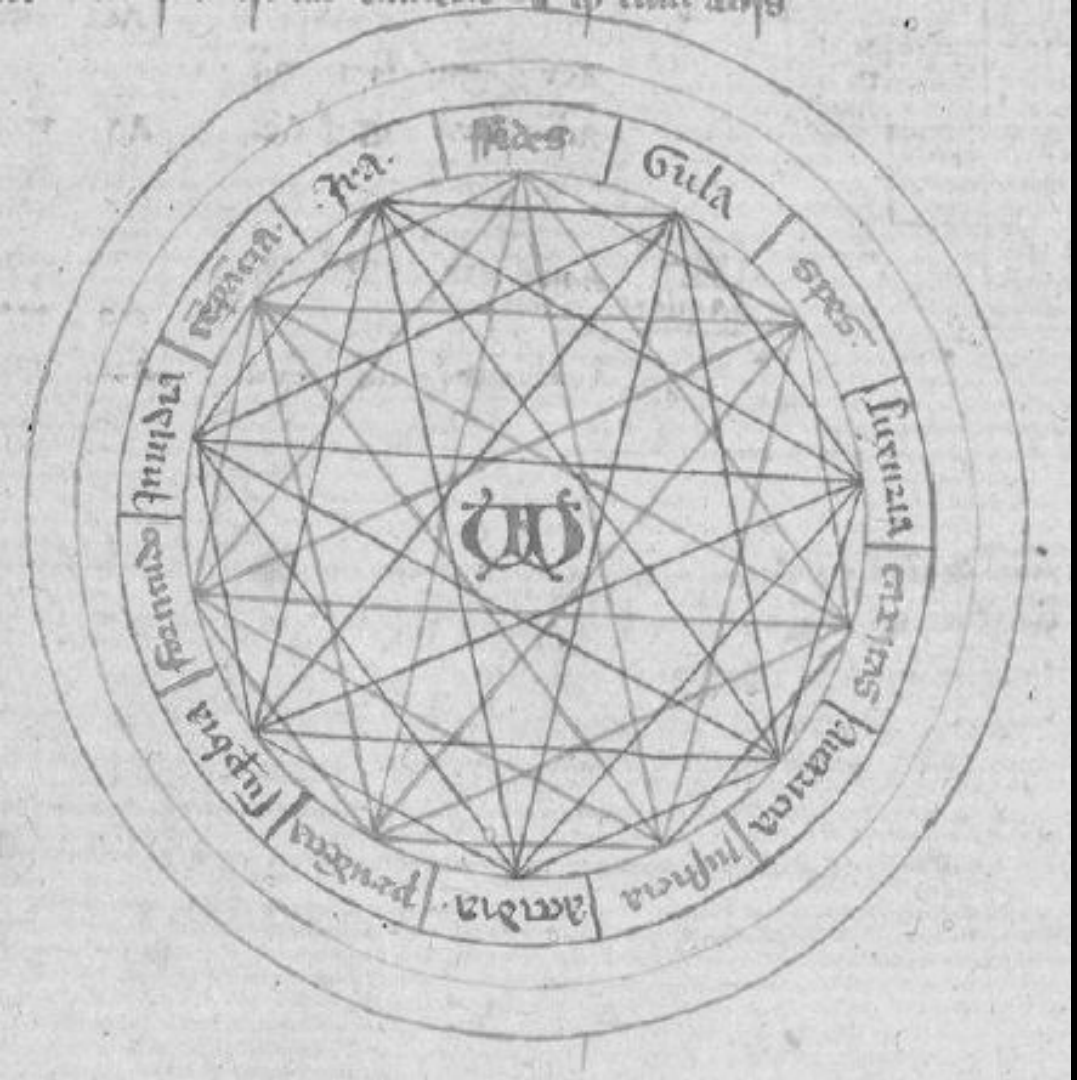

Aristotle, 384-322 BCE

The Square of Opposition



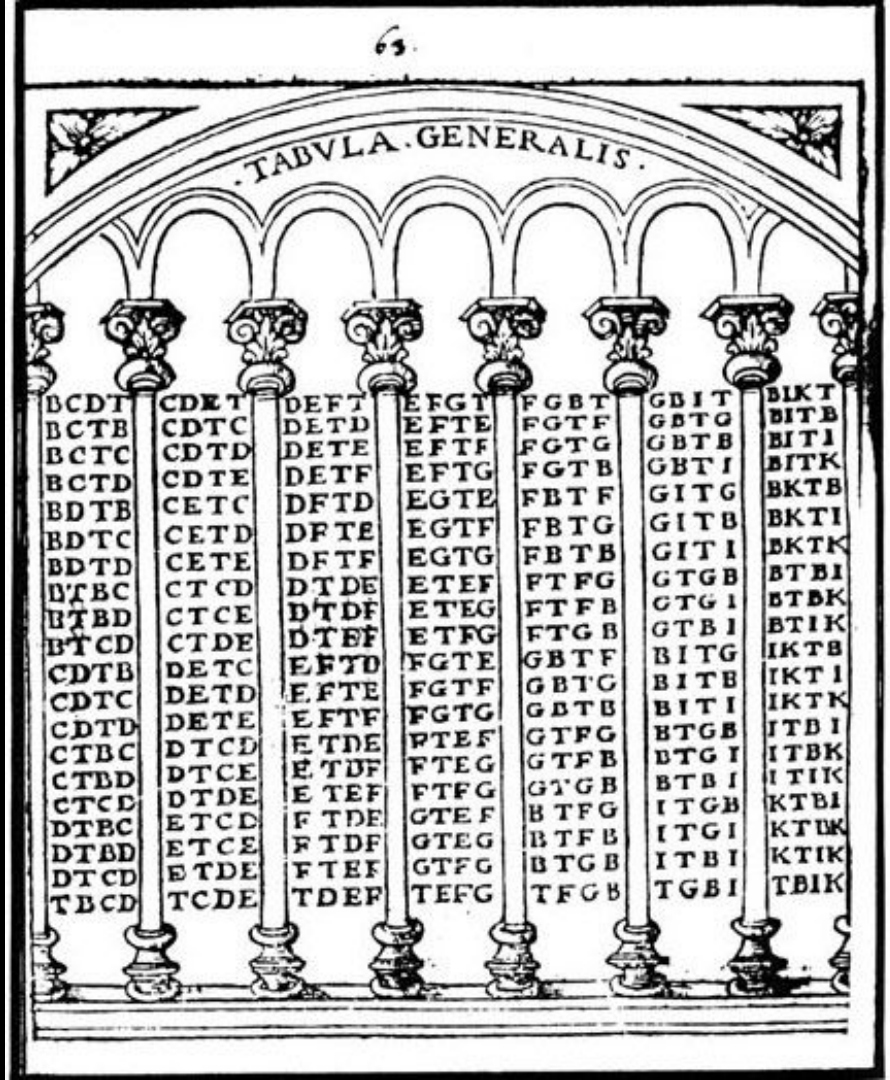

“We have seen that Aristotle’s Square of Opposition can be used to compute the truth-value of one statement given the truth-value of another. Mathematicians calls this type of procedure an algorithm... Aristotle’s Square of Opposition was the first large-scale, general-purpose algorithm in the history of logic. This might help explain why the first person in history to design a mechanical computer was an Aristotelian logician...”

“Inspired by Aristotle’s Square of Opposition, Raymond Lull (1232-1315), a medieval logician who was also a Catholic priest, designed a computing machine consisting of two rotating disks, each inscribed with symbols for categorical propositions…”

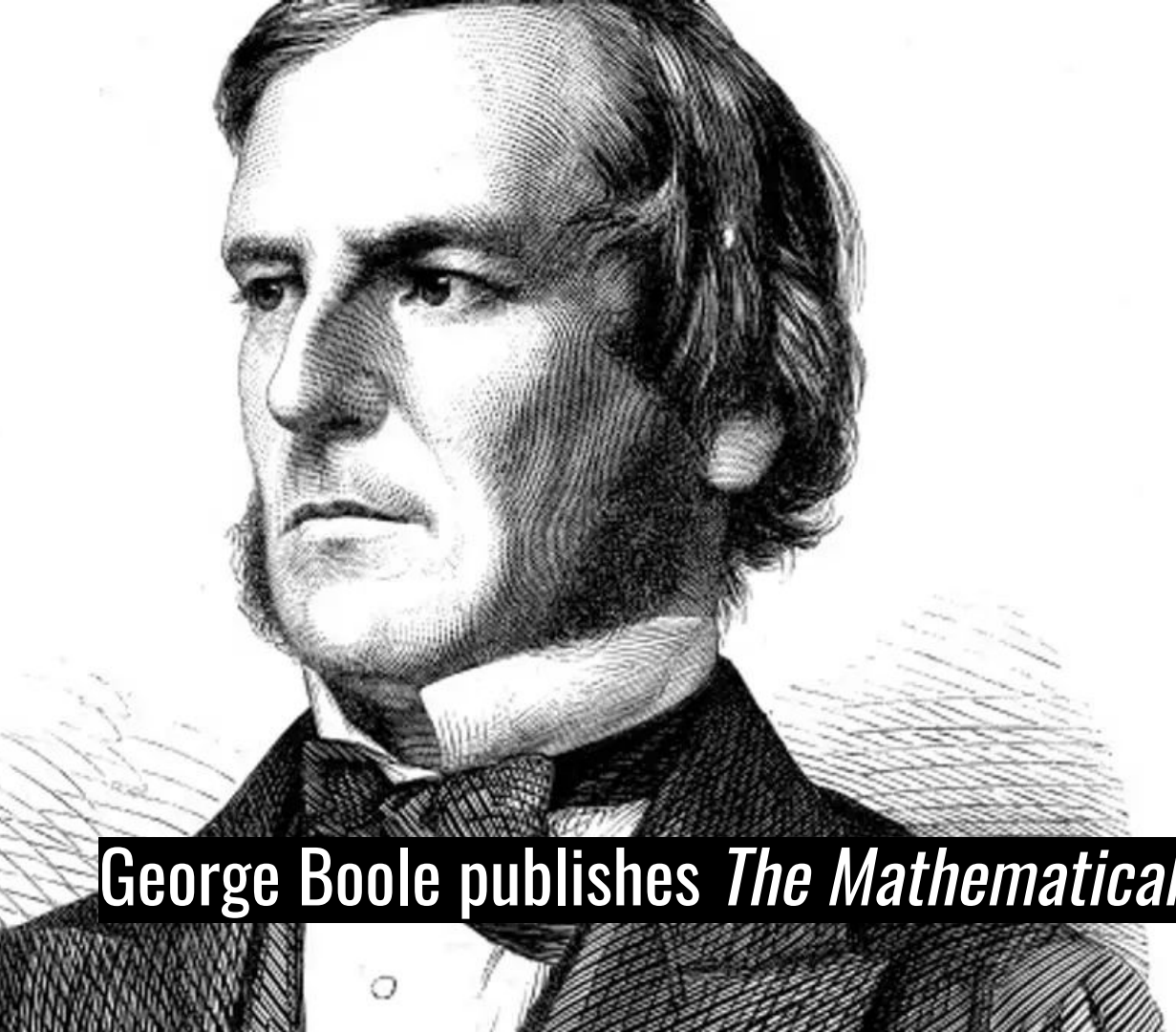


“The disks were aligned in such a way that one could turn a dial and see which statements validly follow from a given statement. Although extremely rudimentary, Lull’s basic idea underlies the modern digital computer…”

“For the first time in history, someone had conceived of a machine that takes inputs of a certain sort and then, on the basis of rules of logic, computes an exact answer, which is then read off some other part of the device...”



“The first designs in history for machines that compute were designs for mechanical devices that would operate according to the exact laws not of mathematics but of logic” (Herrick 2013: 121-2).



THE MATHEMATICAL ANALYSIS

OF LOGIC,

BEING AN ESSAY TOWARDS A CALCULUS
OF DEDUCTIVE REASONING.

BY GEORGE BOOLE.

Ἐπικοινωνοῦσι δὲ πᾶσαι αἱ ἐπιστῆμαι ἀλλήλαις κατὰ τὰ κοινά. Κοινὰ δὲ λέγω, οἷς χρῶνται ὡς ἐκ τούτων ἀποδεικνύντες· ἀλλ' οὐ περὶ ὧν δεικνύουσιν, οὐδὲ ὃ δεικνύουσι.

ARISTOTLE, *Anal. Post.*, lib. I. cap. XI.

CAMBRIDGE:

George Boole publishes *The Mathematical Analysis of Logic*, 1847

BEGRIFFSSCHRIFT,

EINE DER ARITHMETISCHEN NACHGEBILDETE

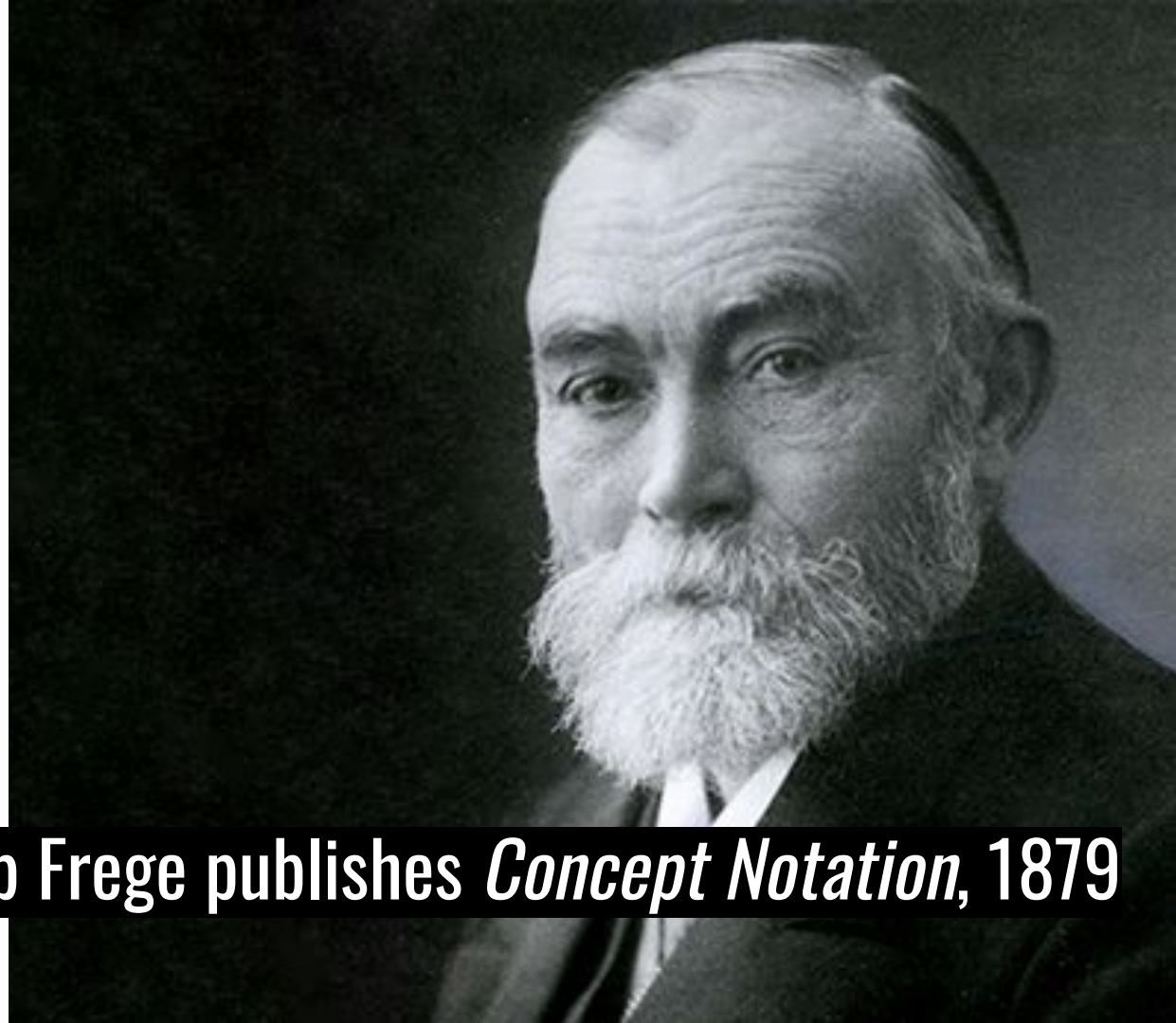
FORMELSPRACHE

DES REINEN DENKENS.

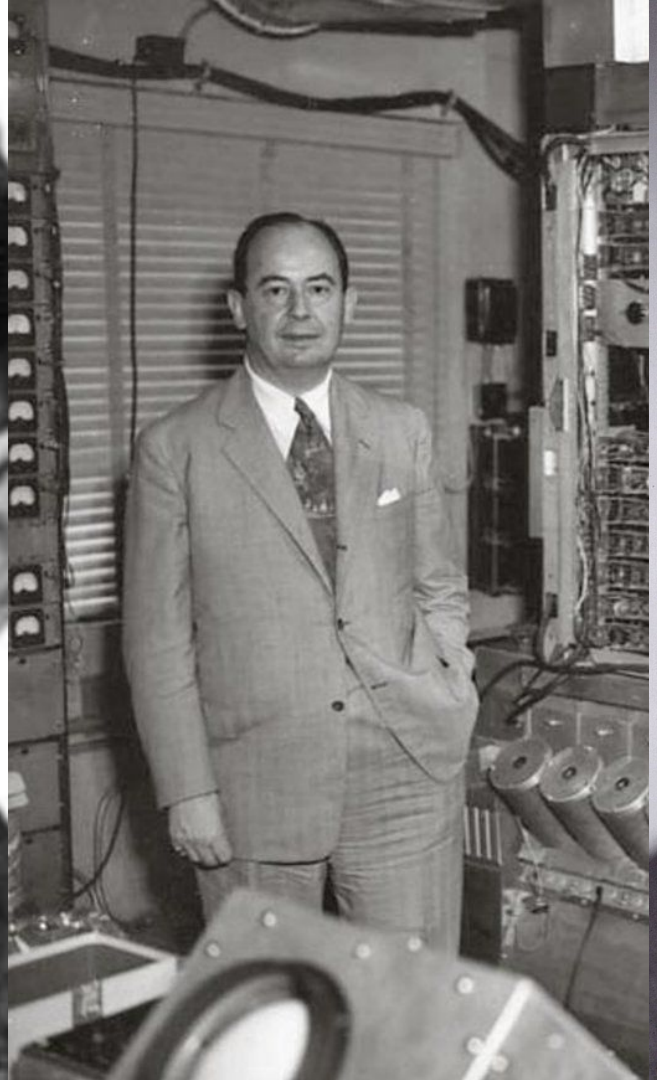
von

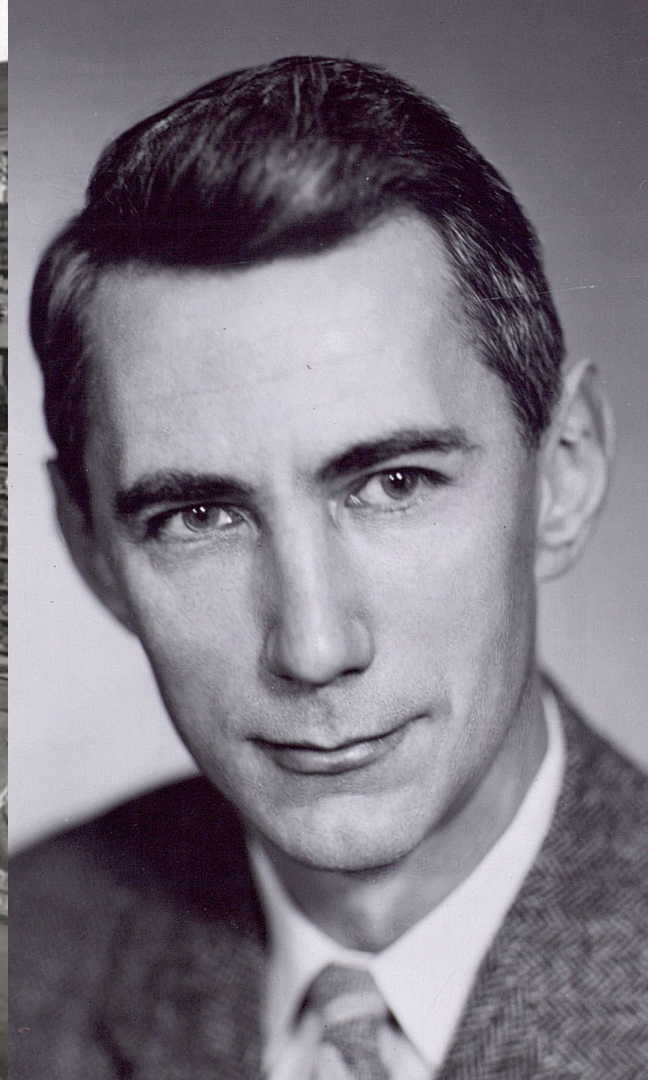
Dr. GOTTLOB FREGE.

HALLE a/S.
VERLAG VON LOUIS NEBERT.
1879.



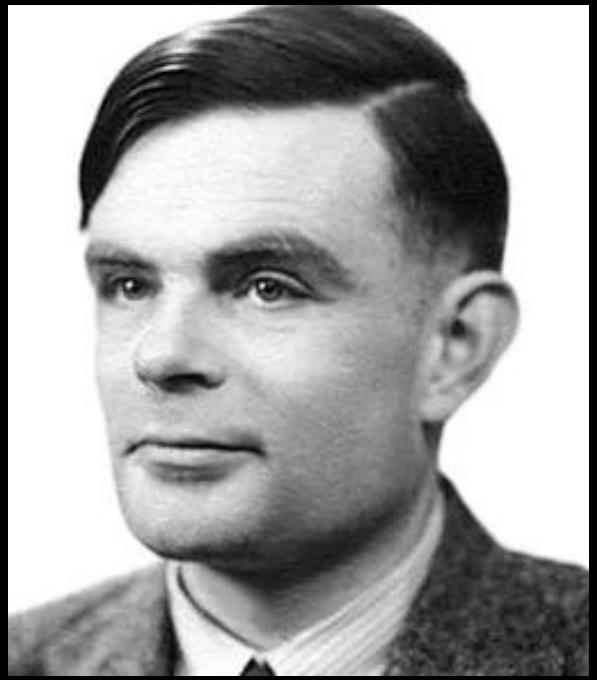
Gottlob Frege publishes *Concept Notation*, 1879






1936

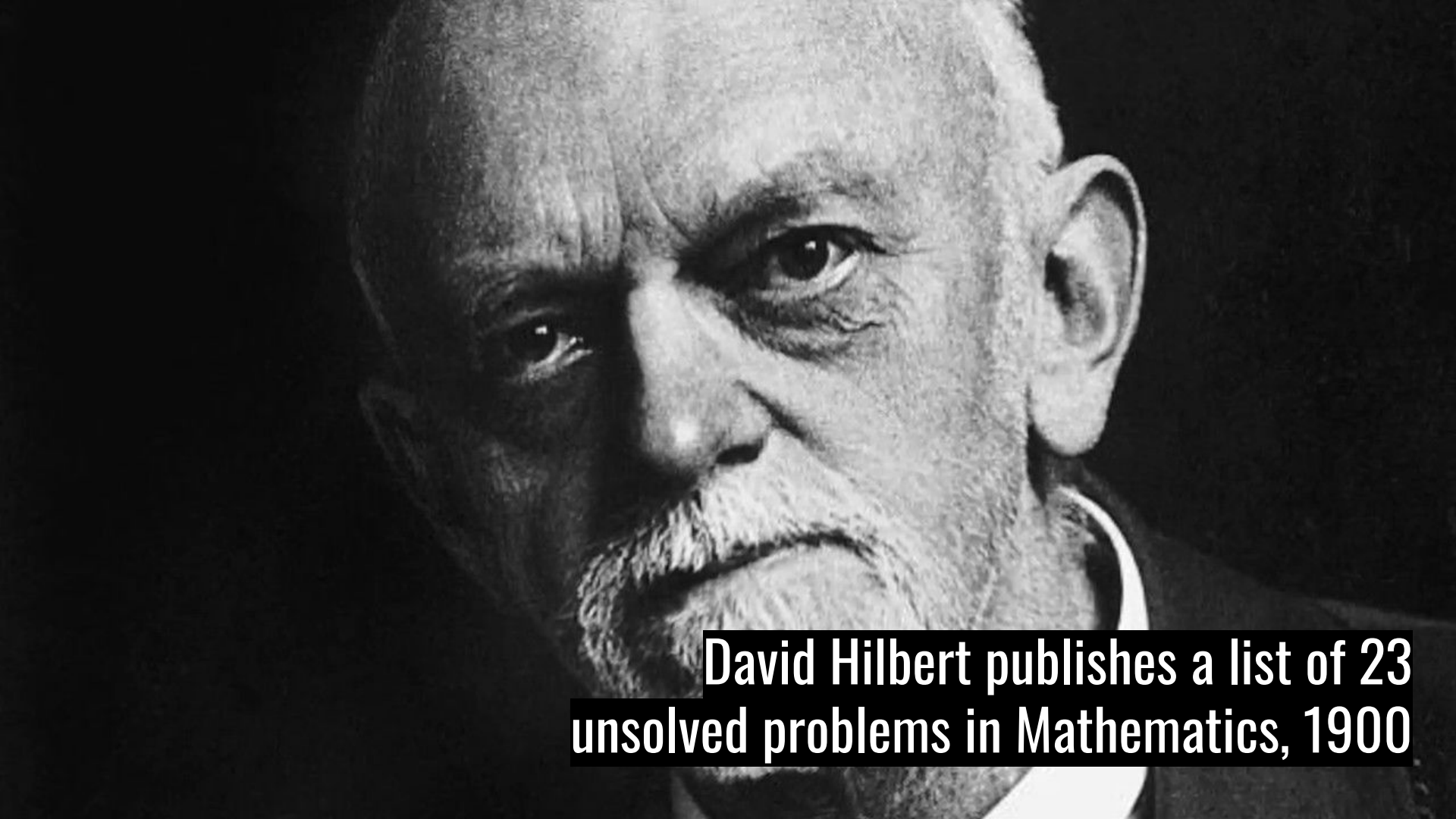
Person of Interest: Alan Turing



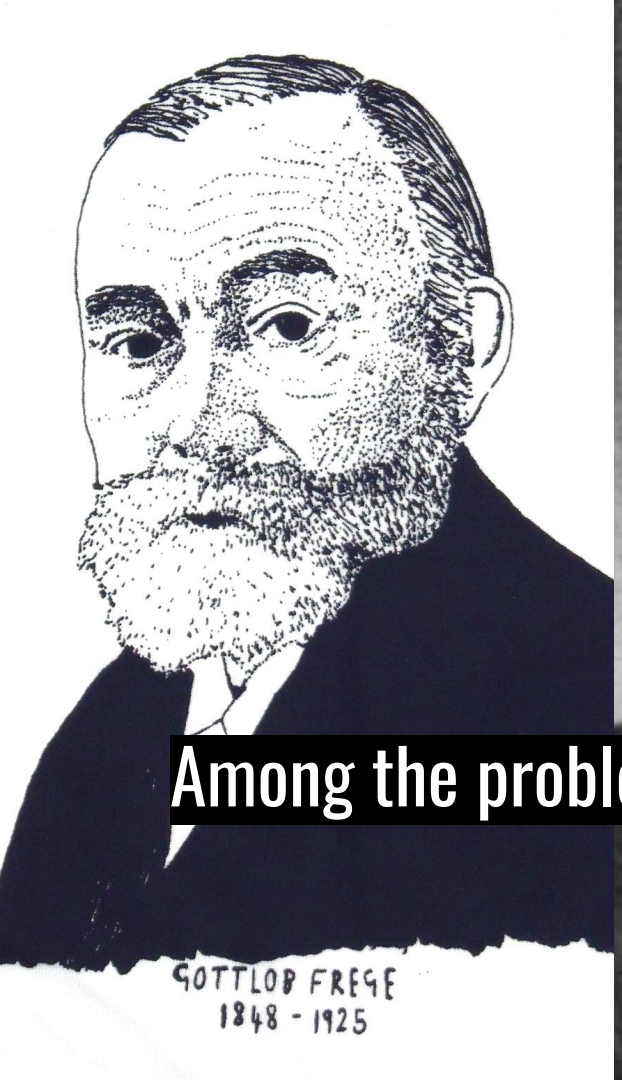
Occupation:
Mathematician
Logician
Philosopher

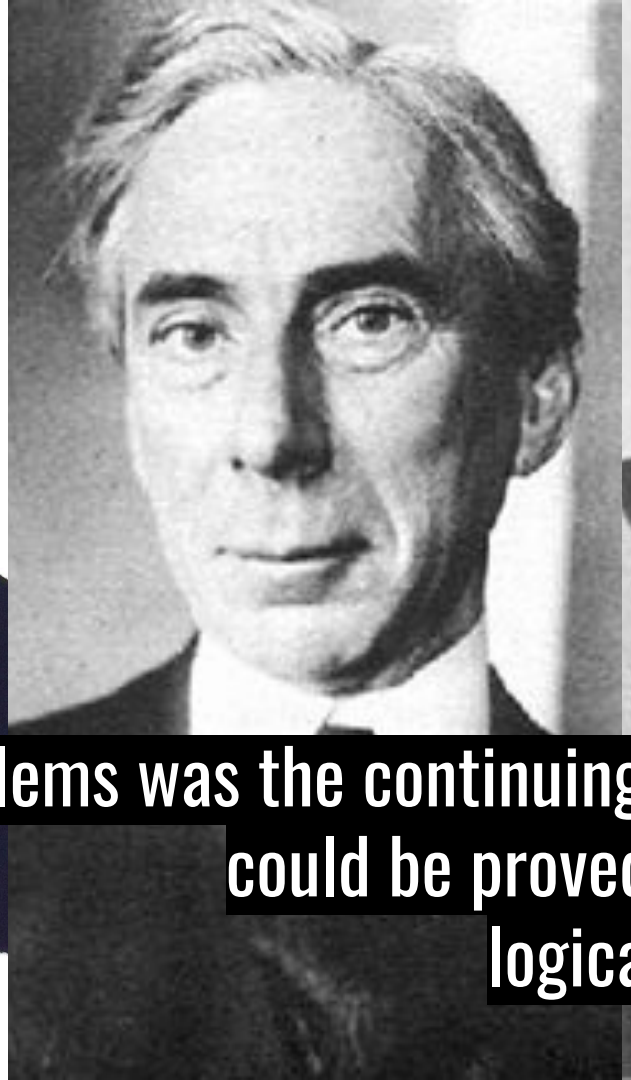
Notable Accomplishments:
Cryptanalysis of Enigma
Church-Turing Thesis
Turing Machines
Turing Tests

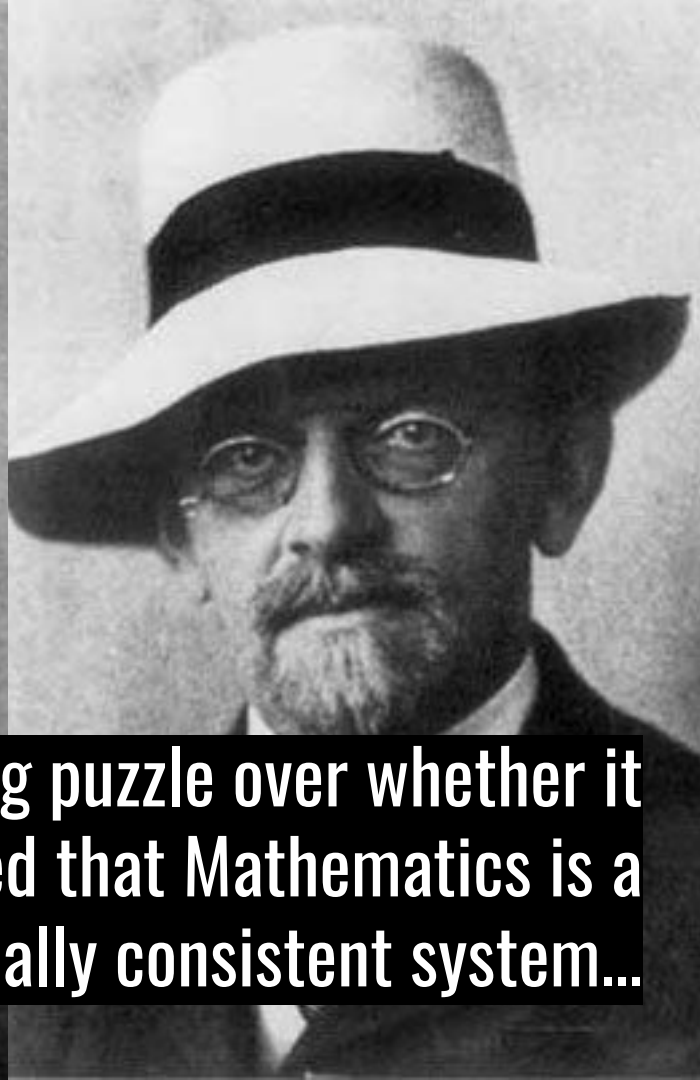
Storytime!



David Hilbert publishes a list of 23 unsolved problems in Mathematics, 1900

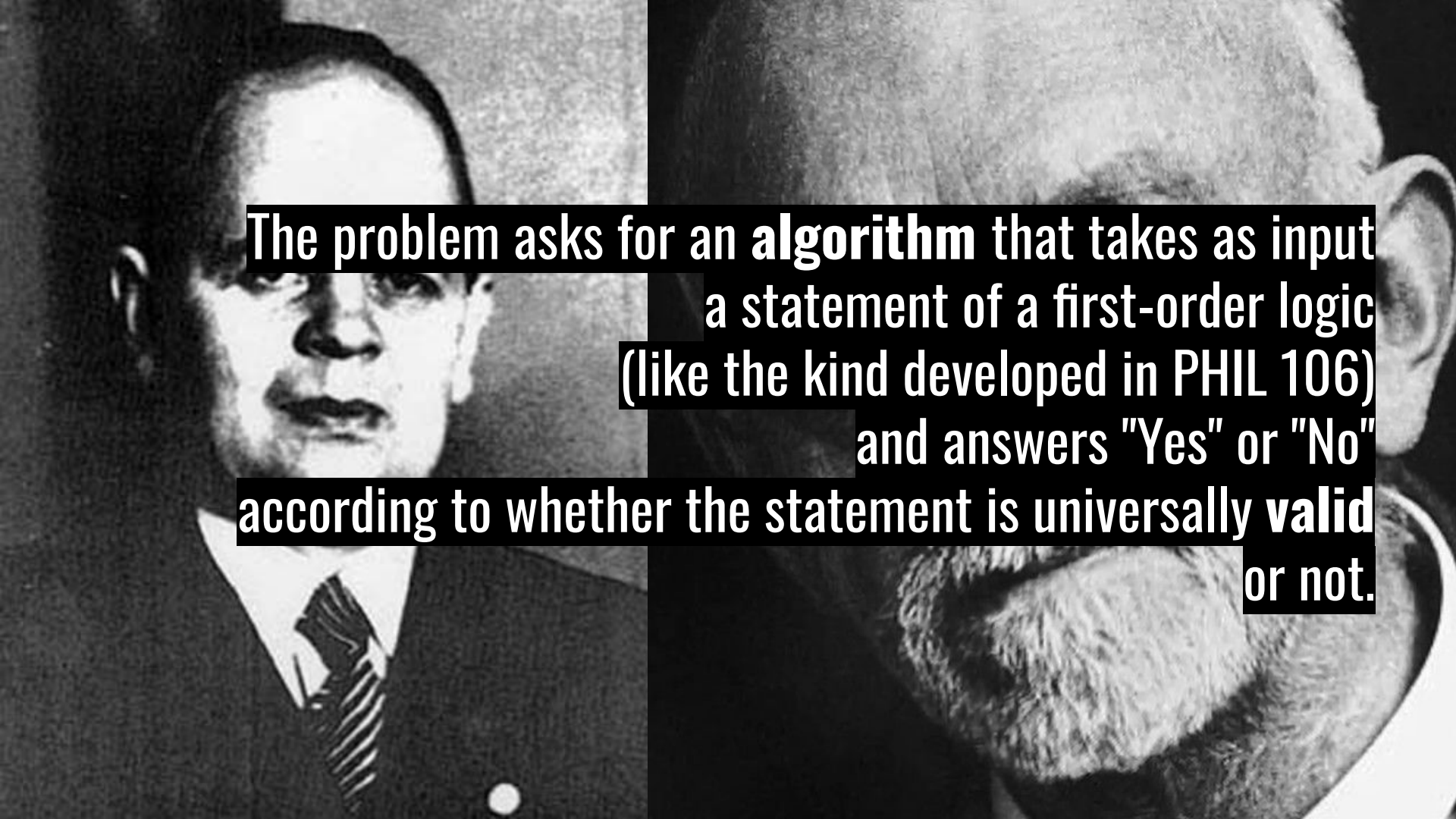






Among the problems was the continuing puzzle over whether it could be proved that Mathematics is a logically consistent system...

David Hilbert and Wilhelm Ackermann propose the **Entscheidungsproblem**, 1928



The problem asks for an **algorithm** that takes as input
a statement of a first-order logic
(like the kind developed in PHIL 106)
and answers "Yes" or "No"
according to whether the statement is universally **valid**
or not.

ON COMPUTABLE NUMBERS, WITH AN APPLICATION TO THE ENTSCHEIDUNGSPROBLEM

By A. M. TURING.

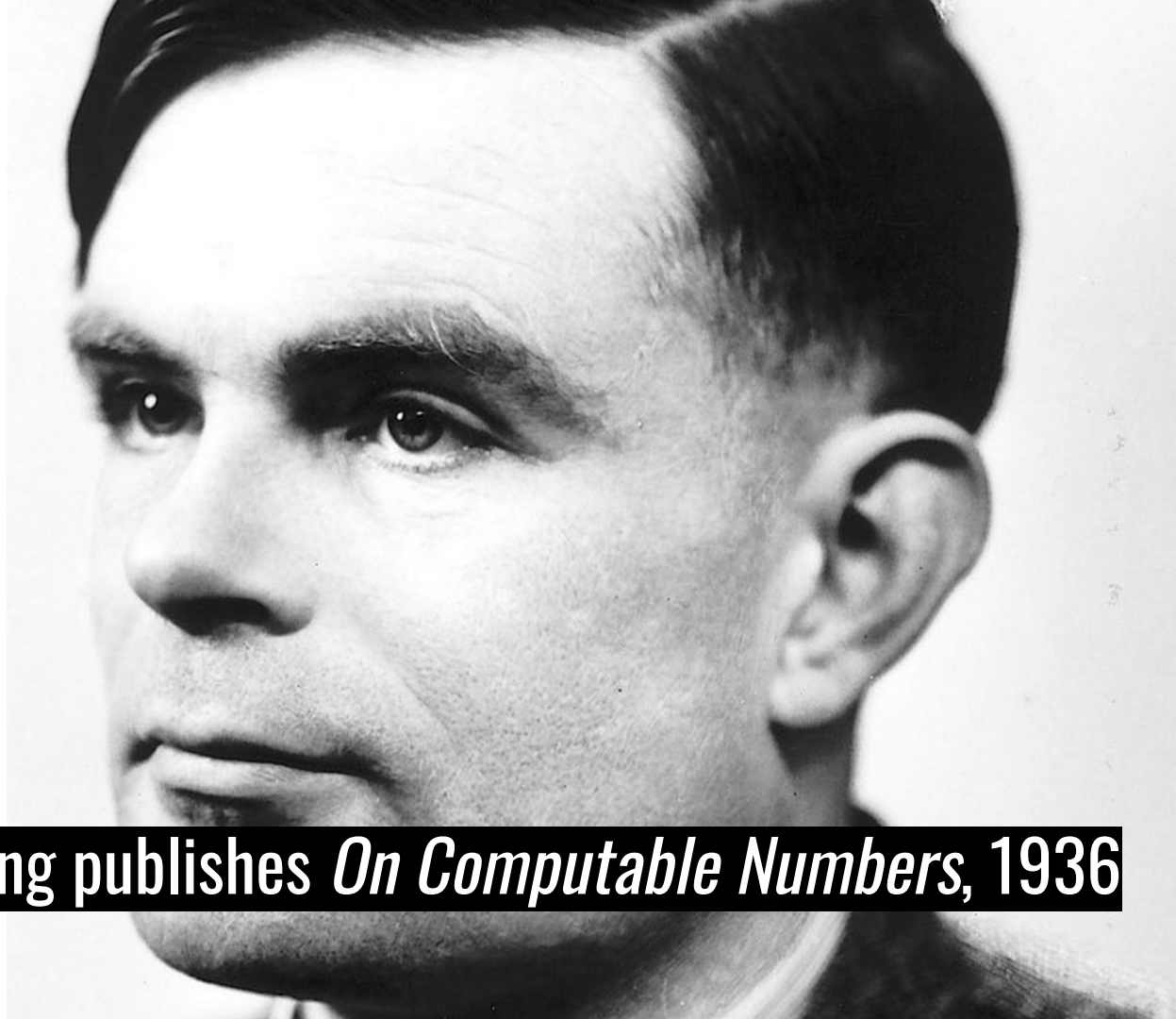
[Received 28 May, 1936.—Read 12 November, 1936.]

The "computable" numbers may be described briefly as the real numbers whose expressions as a decimal are calculable by finite means. Although the subject of this paper is ostensibly the computable *numbers*, it is almost equally easy to define and investigate computable functions of an integral variable or a real or computable variable, computable predicates, and so forth. The fundamental problems involved are, however, the same in each case, and I have chosen the computable numbers for explicit treatment as involving the least cumbrous technique. I hope shortly to give an account of the relations of the computable numbers, functions, and so forth to one another. This will include a development of the theory of functions of a real variable expressed in terms of computable numbers. According to my definition, a number is computable if its decimal can be written down by a machine.

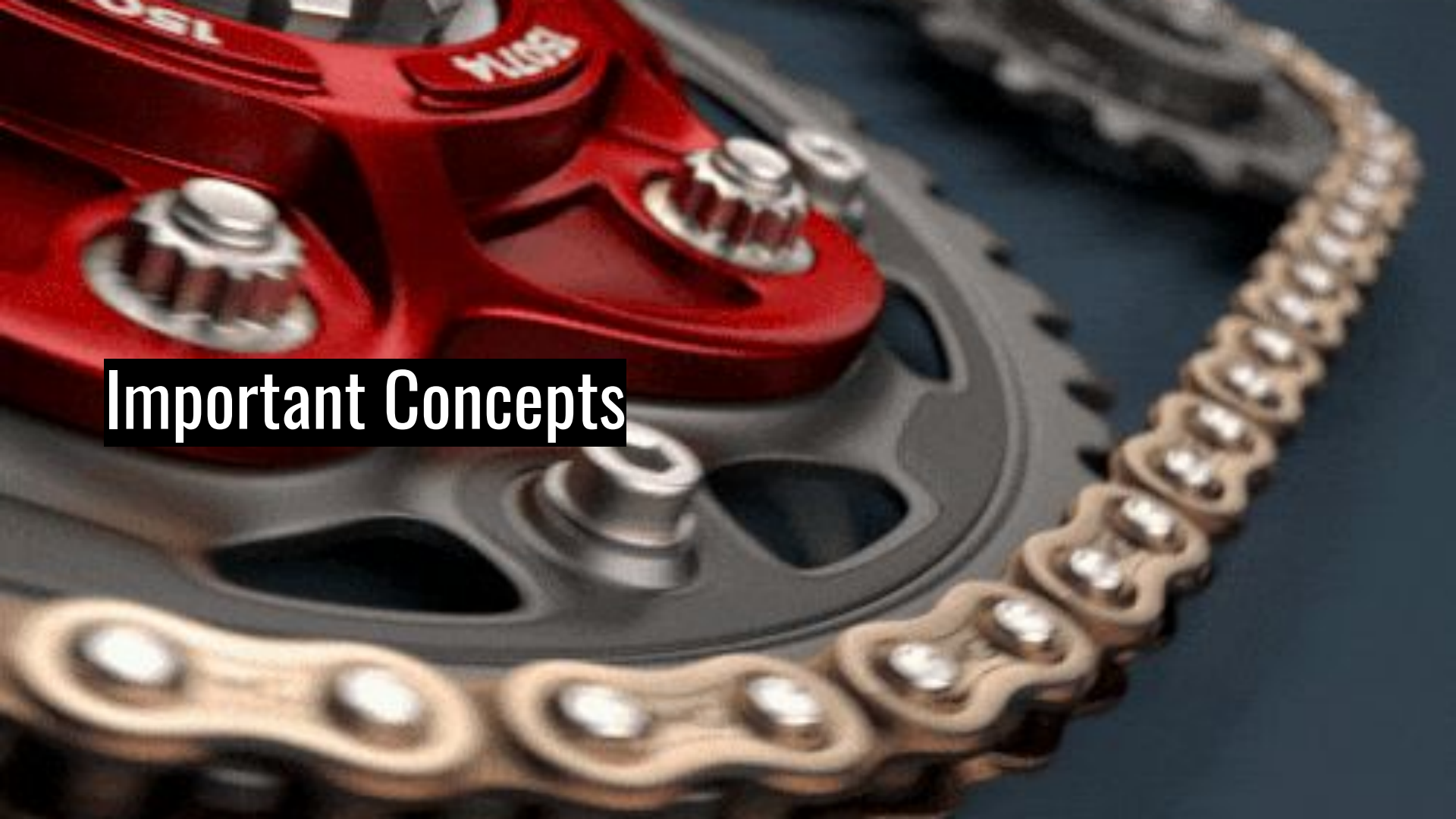
In §§ 9, 10 I give some arguments with the intention of showing that the computable numbers include all numbers which could naturally be regarded as computable. In particular, I show that certain large classes of numbers are computable. They include, for instance, the real parts of all algebraic numbers, the real parts of the zeros of the Bessel functions, the numbers π, e, etc. The computable numbers do not, however, include all definable numbers, and an example is given of a definable number which is not computable.

Although the class of computable numbers
ways similar to the class of real numbers, it is
In § 8 I examine certain arguments which would
By the correct application of one of these a
reached which are superficially similar to those of Gödel†. These results

† Gödel, "Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I", *Monatshefte Math. Phys.*, 38 (1931), 173–198.



Alan Turing publishes *On Computable Numbers*, 1936

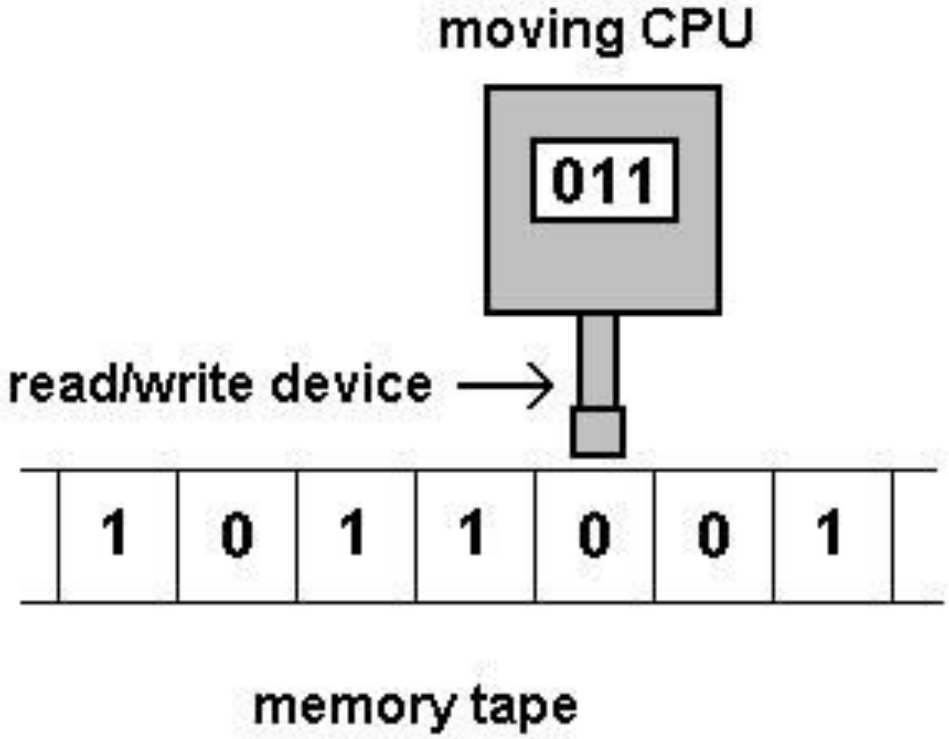


Important Concepts

Turing Machine

A Turing machine is a simple abstract computational device intended to help investigate the extent and limitations of what **can** be computed;
i.e., for any problem that is computable, there exists a Turing machine.

Today, Turing machines are considered to be one of the foundational models of computability and (theoretical) computer science (see De Mol 2018).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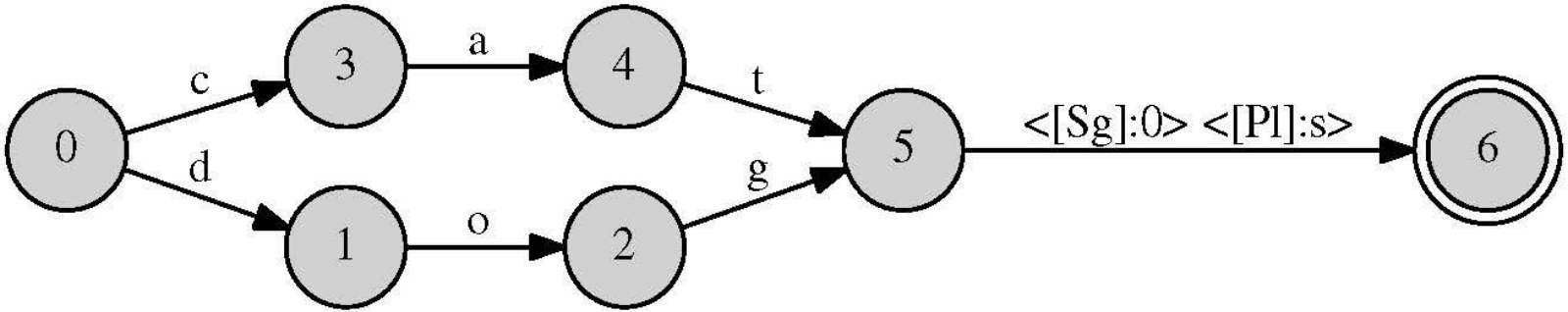
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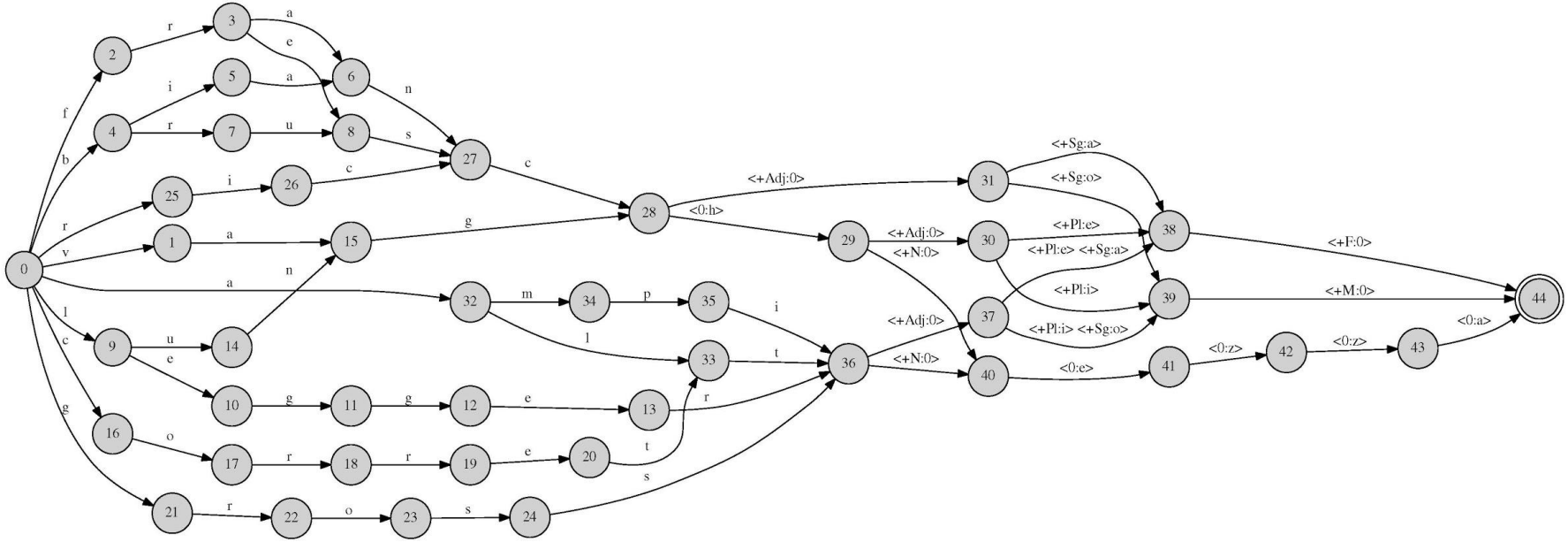
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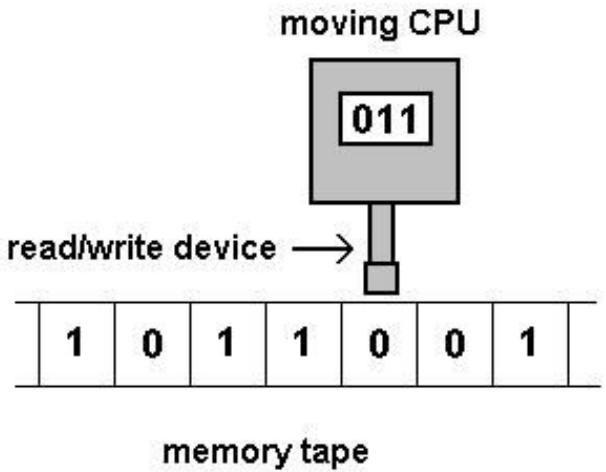
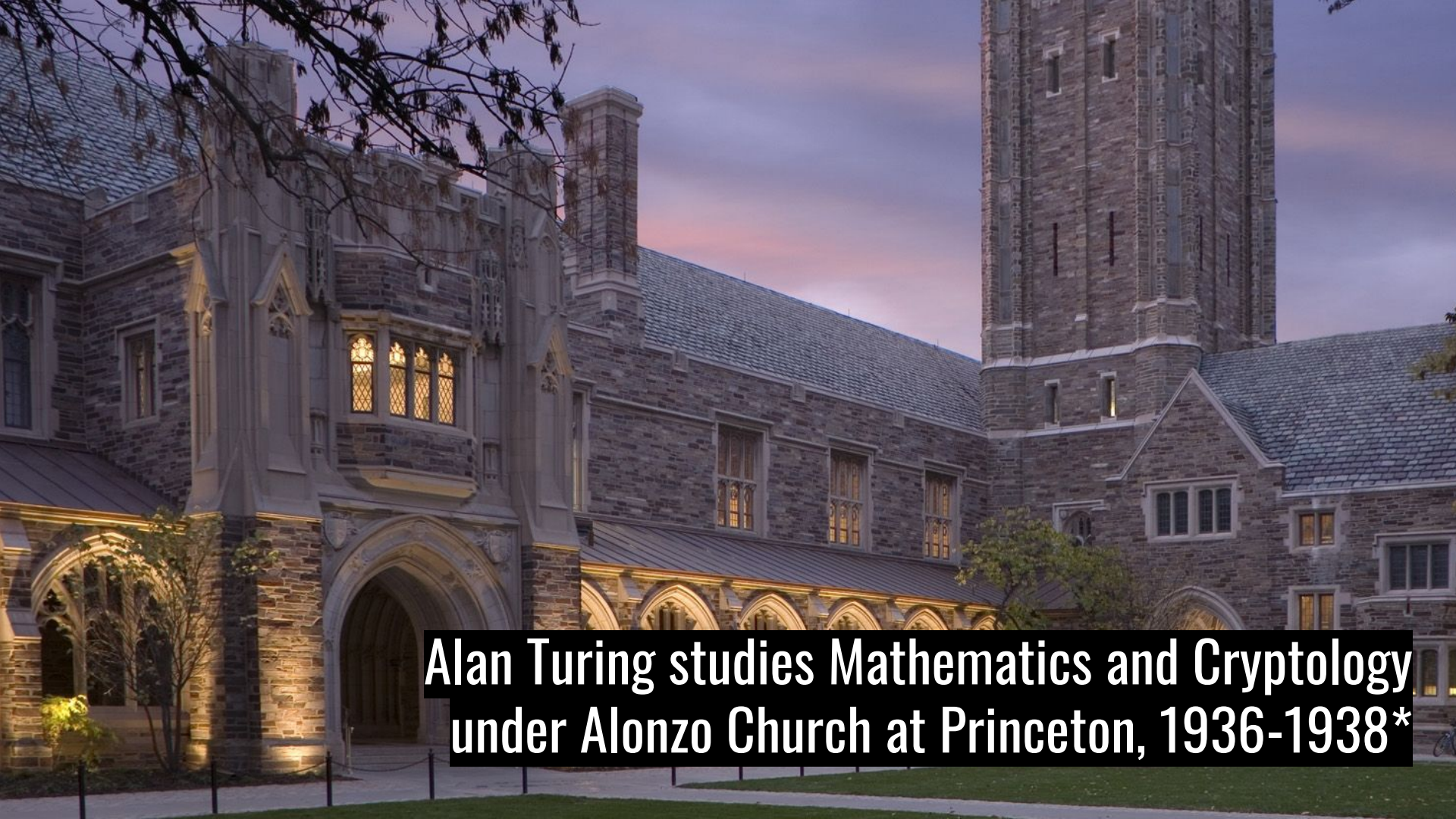


In any case, Turing proved there cannot exist any algorithm that can solve the Entscheidungsproblem; hence, mathematics will always contain **undecidable** (as opposed to *unknown*) propositions.


Alan Turing studies Mathematics and Cryptology
under Alonzo Church at Princeton, 1936-1938*

LATEST PRICES

LATE NIGHT FINAL

Evening Standard

To-morrow's Weather—Bright periods.

Lighting-up Time To-night 8.47

No. 35,880 LONDON, FRIDAY, SEPTEMBER 1, 1939 ONE PENNY

GERMANS INVADE AND BOMB POLAND BRITAIN MOBILISES

Warsaw, Cracow, Nine Other Towns Bombed: Danzig is "Annexed"

FRANCE DECLARES "STATE OF SIEGE"

GERMANY INVADED POLAND TO-DAY. COMPLETE MOBILISATION HAS BEEN ORDERED IN BRITAIN.

Orders in Council for the complete mobilisation of the Navy, Army and Air Force were signed by the King at a Privy Council to-day. The King also approved other Orders in Council dealing with the emergency.

Warsaw has been bombed. Other German aircraft raided Kursk, Gdynia, Thorn, Bialystock, Grodno, Dihivô and Bydgoszoz. A few hours later, Cracow, Katowice and Czenstowice were bombed.

THE EVENING STANDARD LEARNS THAT THE POLISH AMBASSADOR SAW

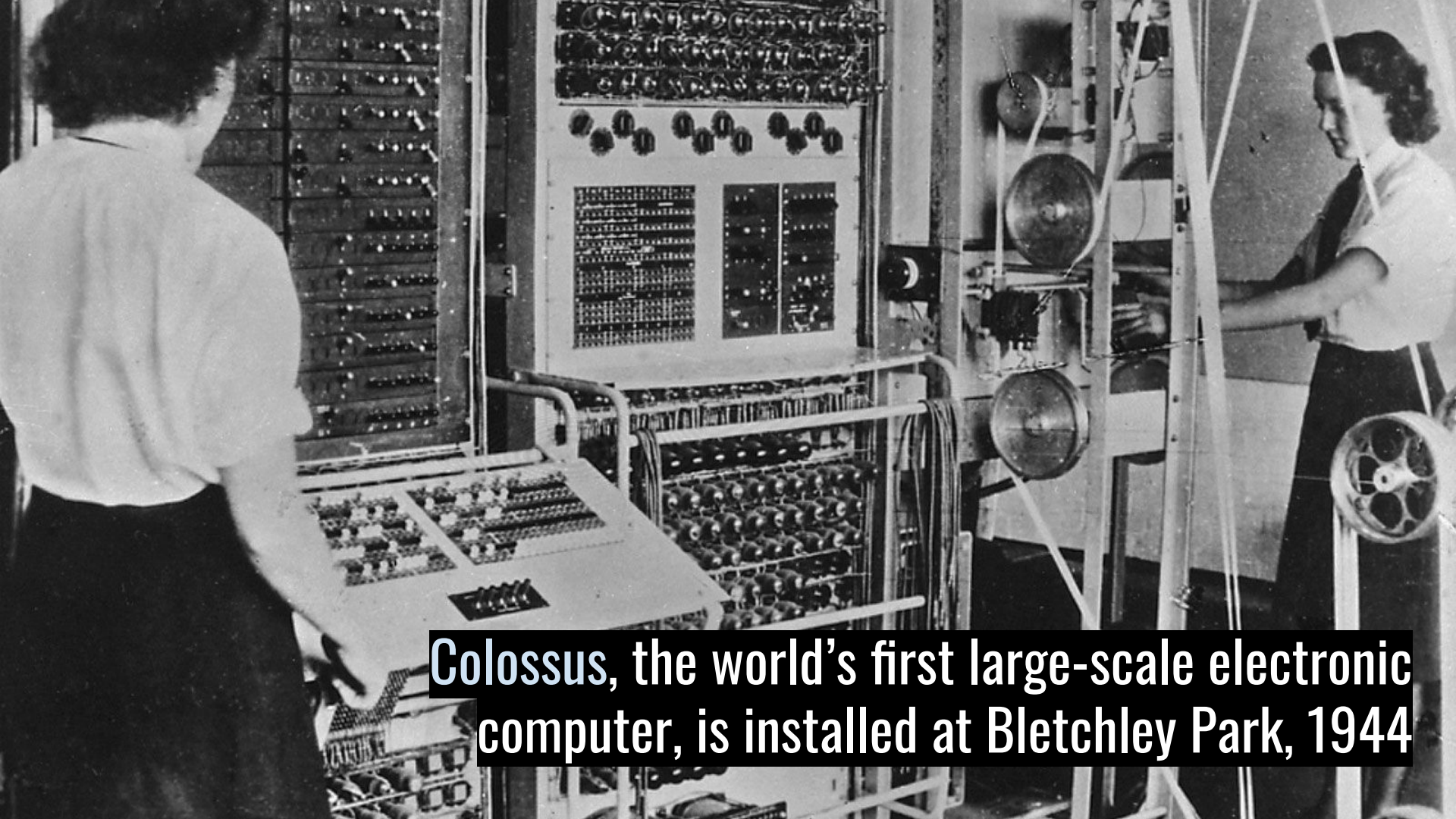
'BRITAIN WILL FULFIL HER OBLIGATIONS'

Parliament Meeting To-night

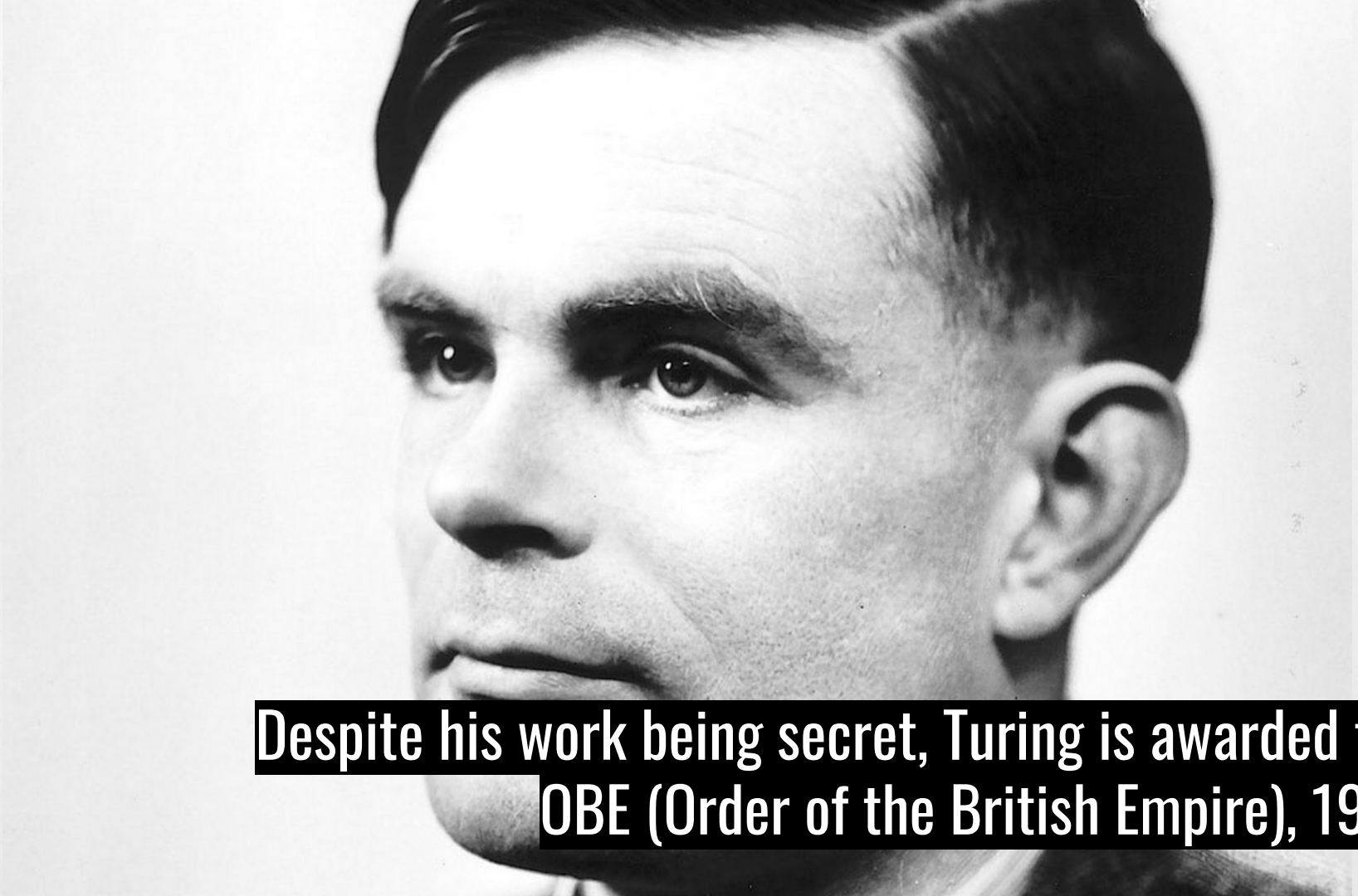
THE BRITISH CABINET MET TO-DAY. THEY BROKE UP AFTER ONE HOUR AND FIFTY

Turing is asked to join the Government Codes and Ciphers School at Bletchley Park, September 1939*


Europe at the height of German expansion, 1941-1942
Nazi Germany*
Areas under German occupation
German allies*, co-belligerents, and puppet states*
Nominally unoccupied
Retaken during Soviet 1941-1942 winter-offensive
Allied-held areas
Neutral countries
*: Including annexed and occupied territories
Iceland (British-occupied)
Faroe Islands (British-occupied)
Sweden
Finland
Finnish Military Admin.
Reichs-kommissariat Norwegen
Soviet Union
Reichskommissariat Ostland
Denmark
Under Military Administration
Ireland
United Kingdom
RK Niederlande
German Reich
General Government
Reichskommissariat Ukraine
Under Military Admin.
Bohemia and Moravia
Slovakia
Zone occupée (Under Military Admin.)
Hungary
Liechtenstein
Vichy France
Switzerland
Romania
Zone libre
Independent State of Croatia
Under Military Admin.
San Marino
Monaco
Bulgaria
Italy
Montenegro (Italy)
Andorra
Portugal
Spain
Albania (Italy)
Turkey
Vatican City
Italian Military Admin.
Syria (Free France) (From July 1941)
Iraq (Br.-oc.)
Dodecanese (Italy)
Cyprus (Britain)
Tangier
Morocco (Spain)
Malta (Britain)
Trans-Jordan (Britain)
Saudi Arabia
Algeria (Vichy France)
Tunisia (Vichy Fr.)
Morocco (Vichy Fr.)



Colossus, the world's first large-scale electronic computer, is installed at Bletchley Park, 1944



Despite his work being secret, Turing is awarded the OBE (Order of the British Empire), 1945

Public unveiling of the ENIAC (USA), 1948

Vol. lix. No. 236.] [October, 1950

MIND

A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. *The Imitation Game.*

I propose to consider the question, 'Can machines think?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

The new form of the problem can be described in terms of a game which we call the 'imitation game'. It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either 'X is A and Y is B' or 'X is B and Y is A'. The interrogator is allowed to put questions to A and B thus:

C: Will X please tell me the length of his or her hair?

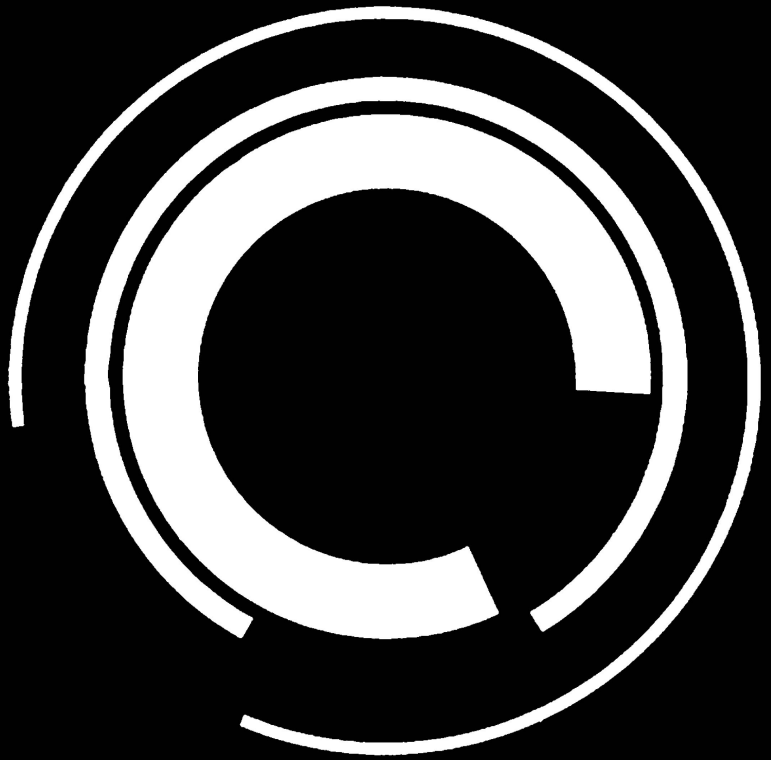
Now suppose X is actually A, then A must answer. It is A's

Alan Turing publishes *Computing Machinery and Intelligence*, 1950

Turing Test

A Turing test is a **test** of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human.
This suggests that a **positivist methodology** is the best course of action on the question of whether machines can think.

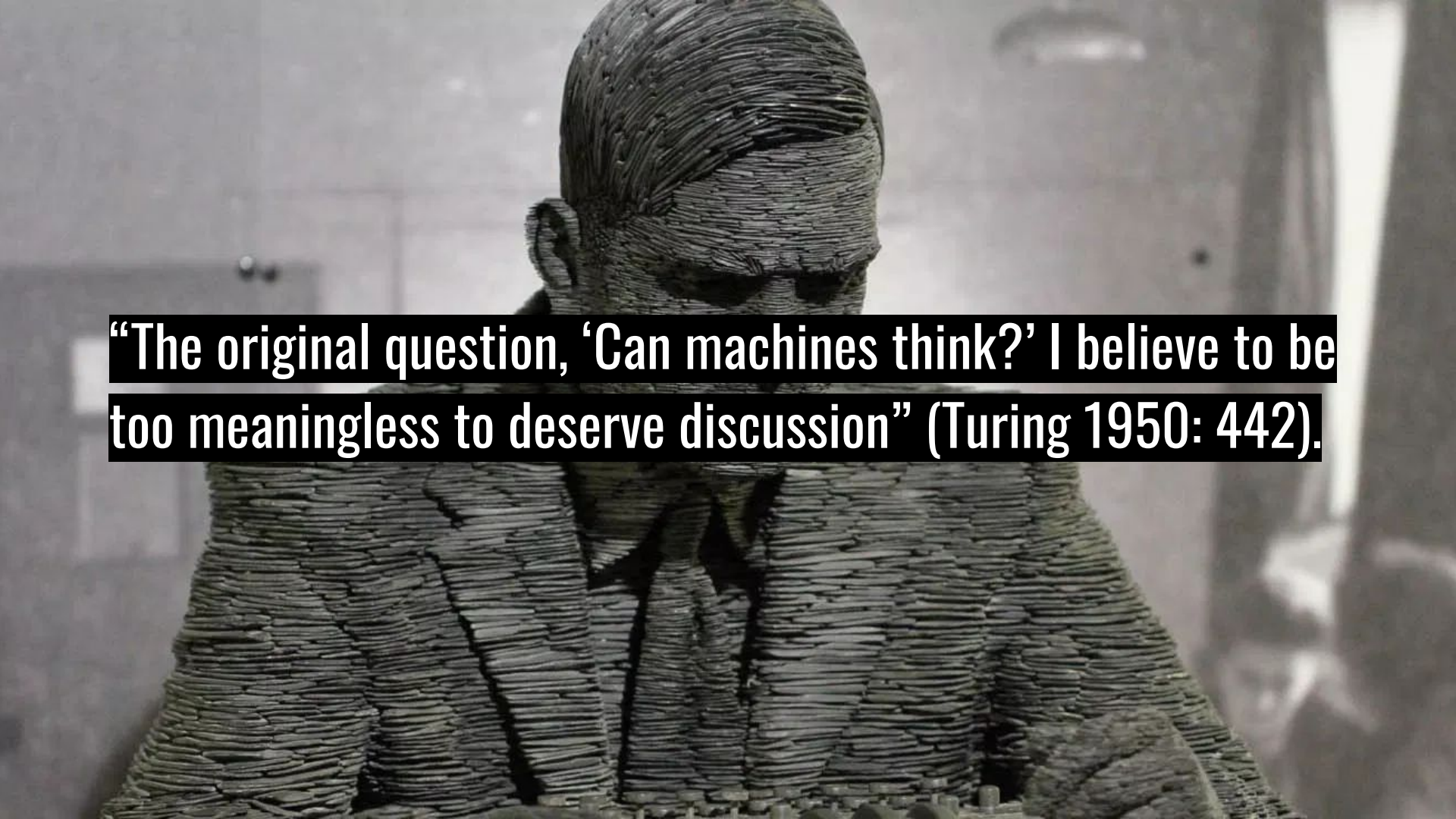

SIDEBAR

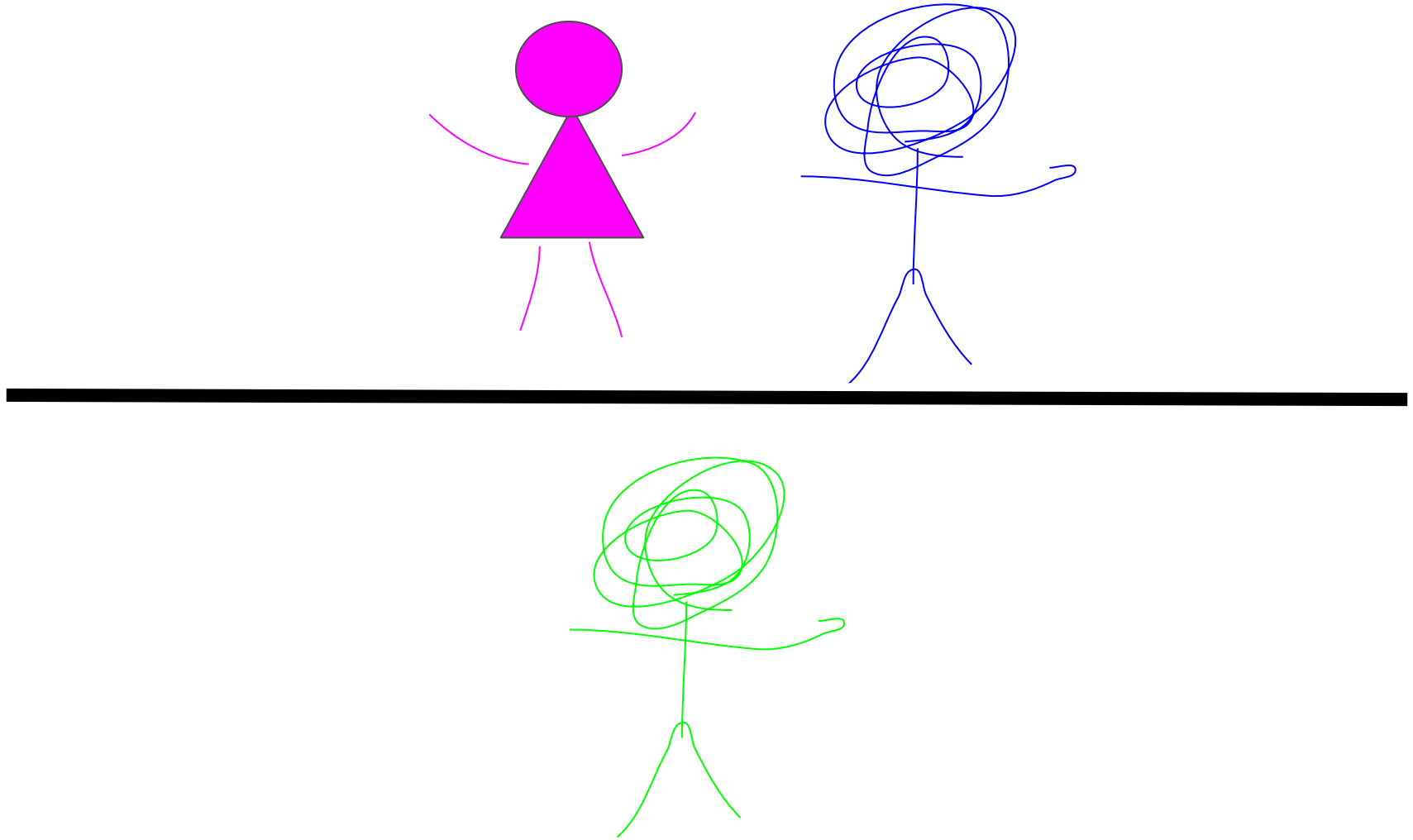


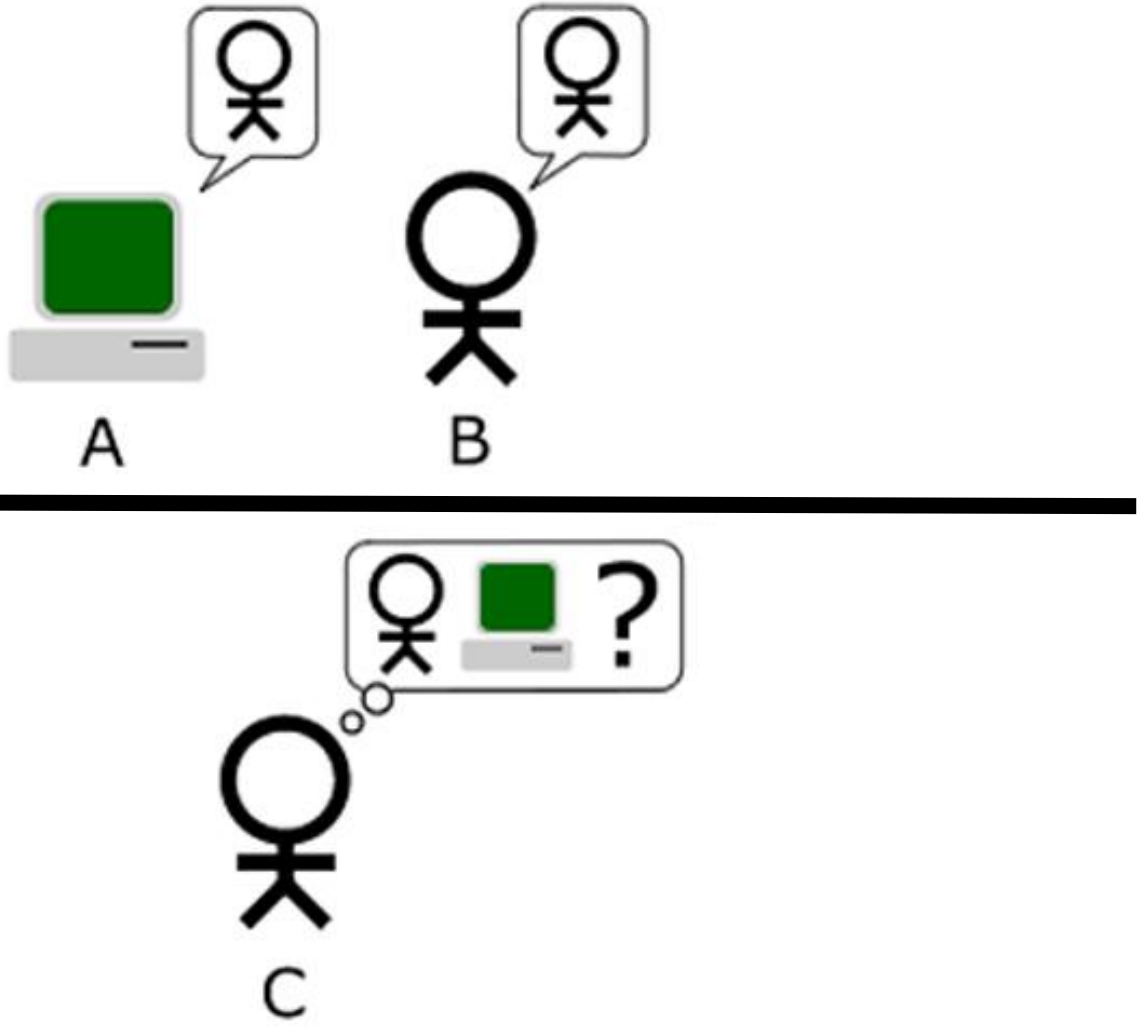
Other philosophers believe that Philosophy as a field is by and large **done**.
Various sciences have been extracted from it throughout its history, and **logic** was the last scientific extraction.
Almost all that's left now is pseudo-problems.

Most of the members of the **Vienna Circle**, for example, subscribed to the verification theory of meaning, which claimed that a statement is meaningful if and only if it can be proved true or false, at least in principle, by means of the experience.

As such, all metaphysics was worse than false; it was meaningless.


“The original question, ‘Can machines think?’ I believe to be too meaningless to deserve discussion” (Turing 1950: 442).




A
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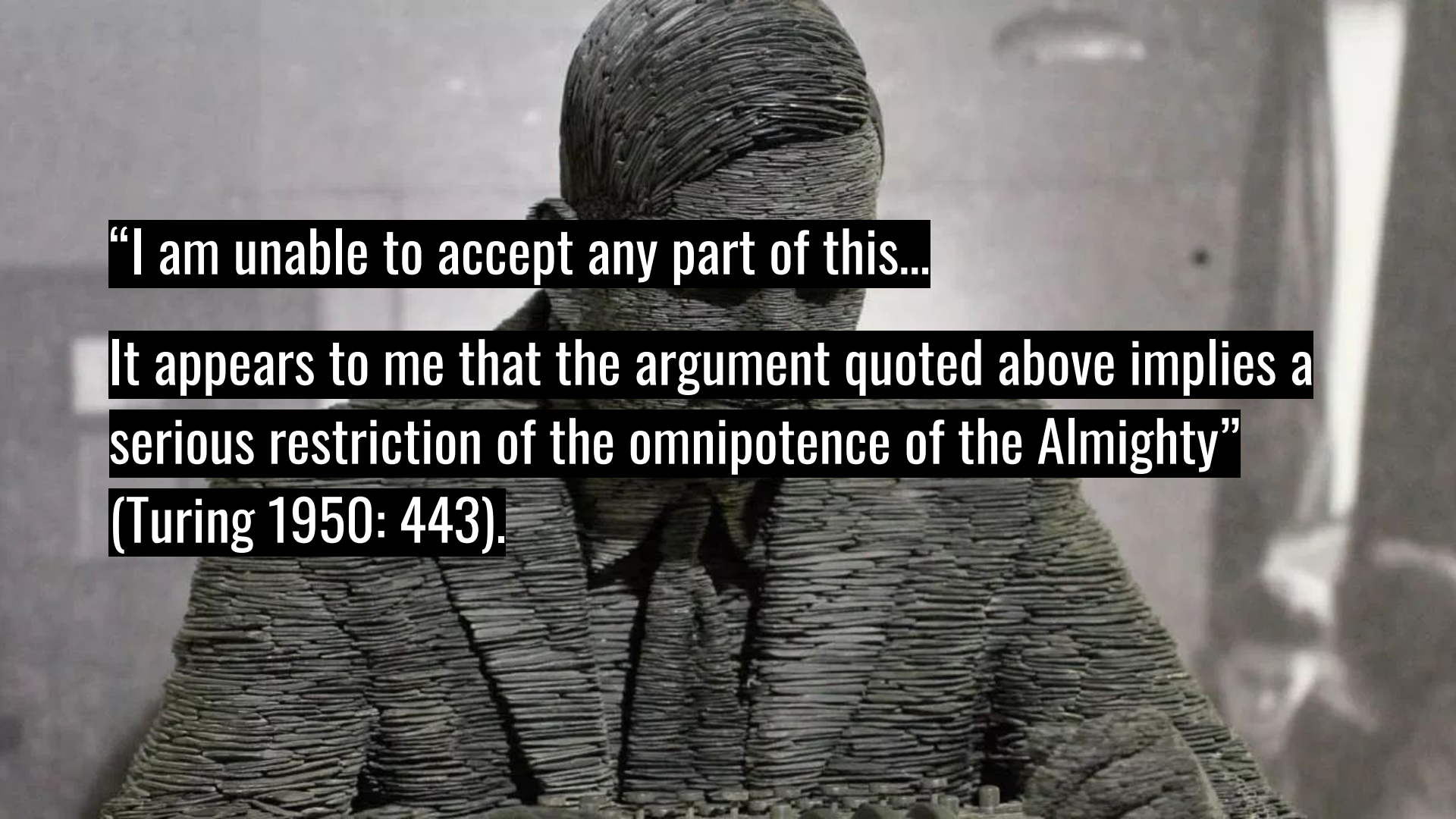
Some of the objections that Turing entertains...

The Theological Objection

“Thinking is a function of man's immortal soul. God has given an immortal soul to every man and woman, but not to any other animal or to machines. Hence no animal or machine can think.”

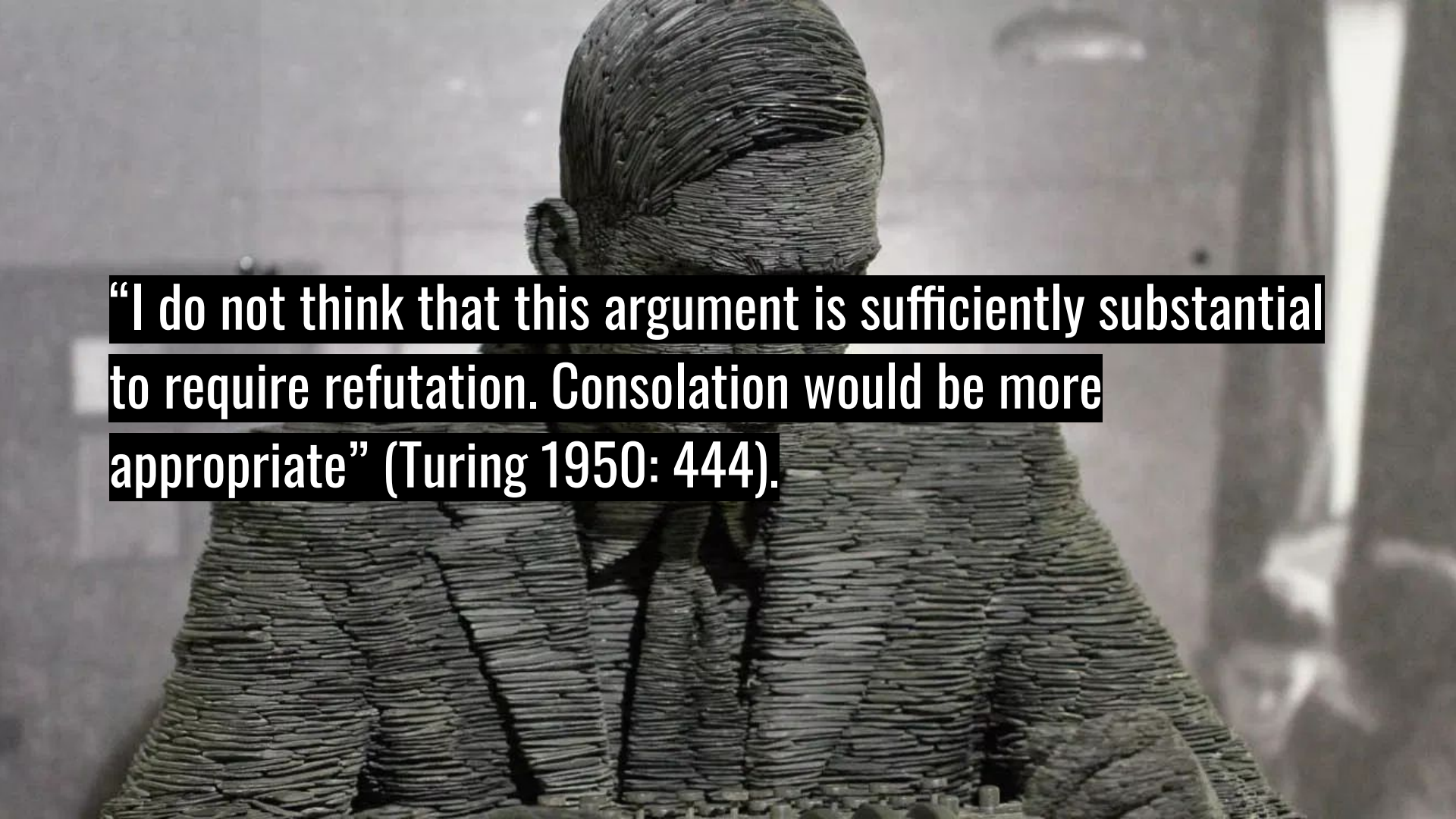


“I am unable to accept any part of this...

It appears to me that the argument quoted above implies a serious restriction of the omnipotence of the Almighty” (Turing 1950: 443).

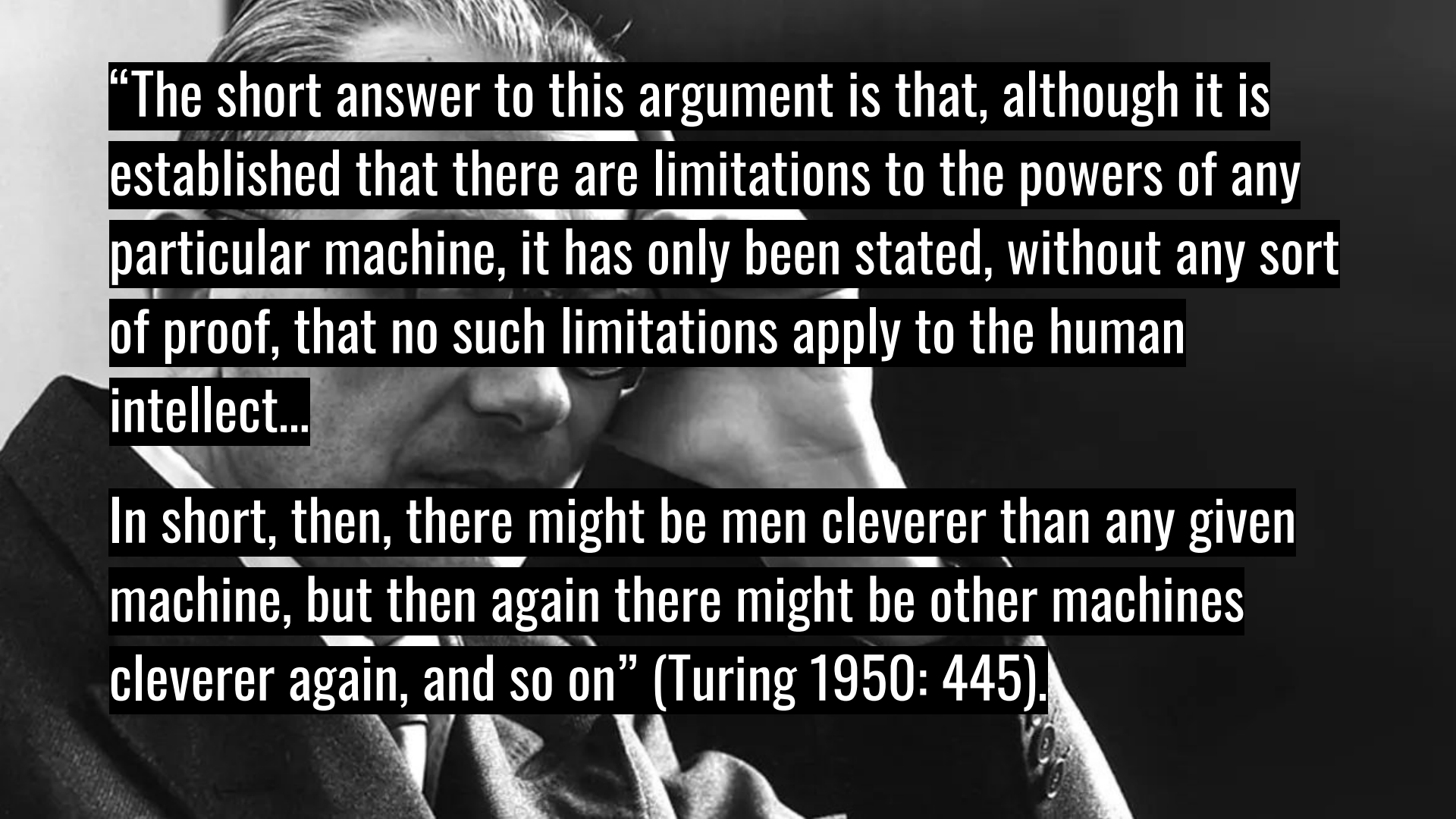
The “Heads in the Sand” Objection

“The consequences of machines thinking would be too dreadful. Let us hope and believe that they cannot do so."


“I do not think that this argument is sufficiently substantial to require refutation. Consolation would be more appropriate” (Turing 1950: 444).

The Mathematical Objection

“There are a number of results of mathematical logic which can be used to show that there are limitations to the powers of discrete-state machines.”

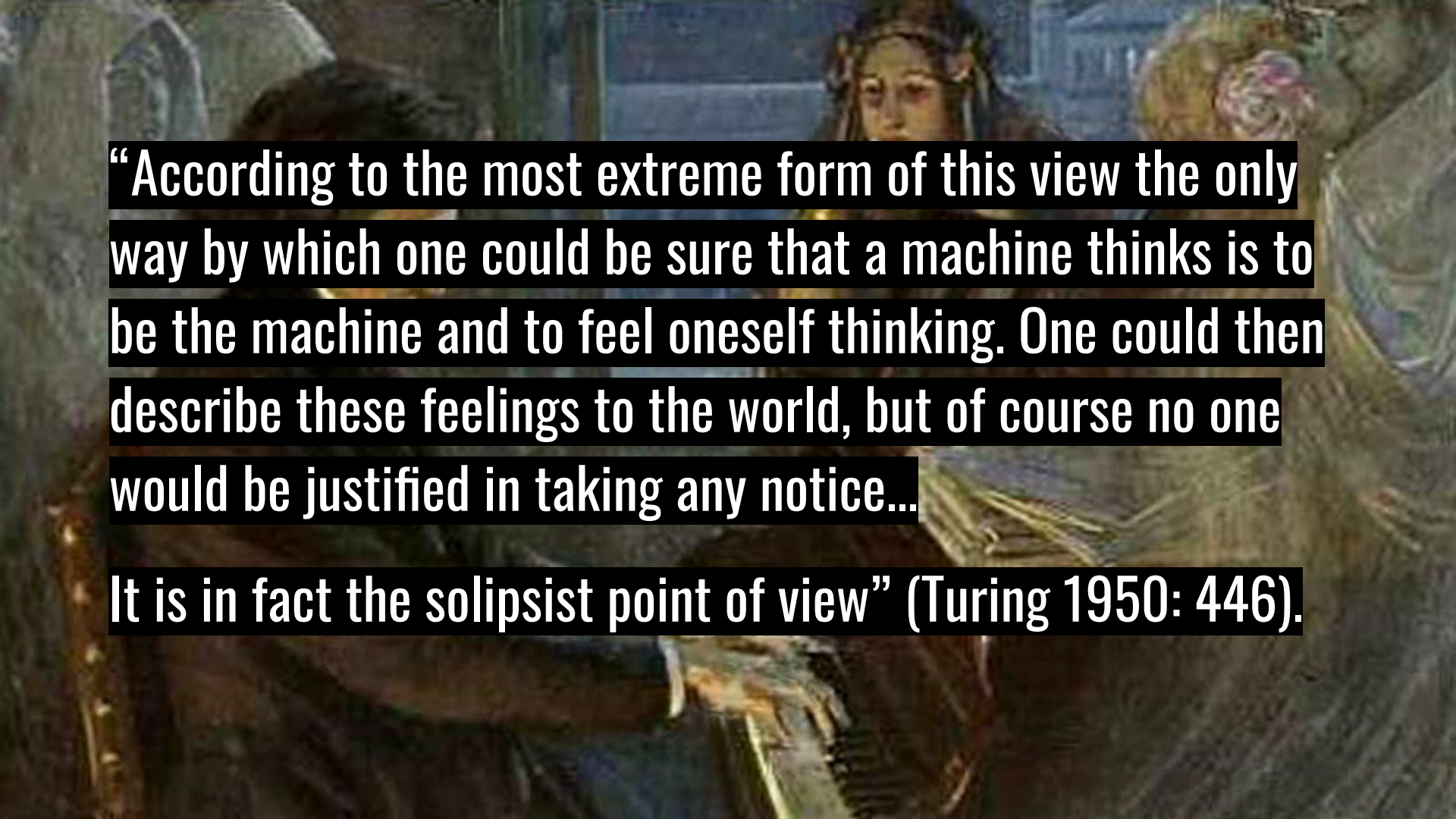


“The short answer to this argument is that, although it is established that there are limitations to the powers of any particular machine, it has only been stated, without any sort of proof, that no such limitations apply to the human intellect...

In short, then, there might be men cleverer than any given machine, but then again there might be other machines cleverer again, and so on” (Turing 1950: 445).

The Argument from Consciousness

“Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain---that is, not only write it but know that it had written it.”



“According to the most extreme form of this view the only way by which one could be sure that a machine thinks is to be the machine and to feel oneself thinking. One could then describe these feelings to the world, but of course no one would be justified in taking any notice...

It is in fact the solipsist point of view” (Turing 1950: 446).

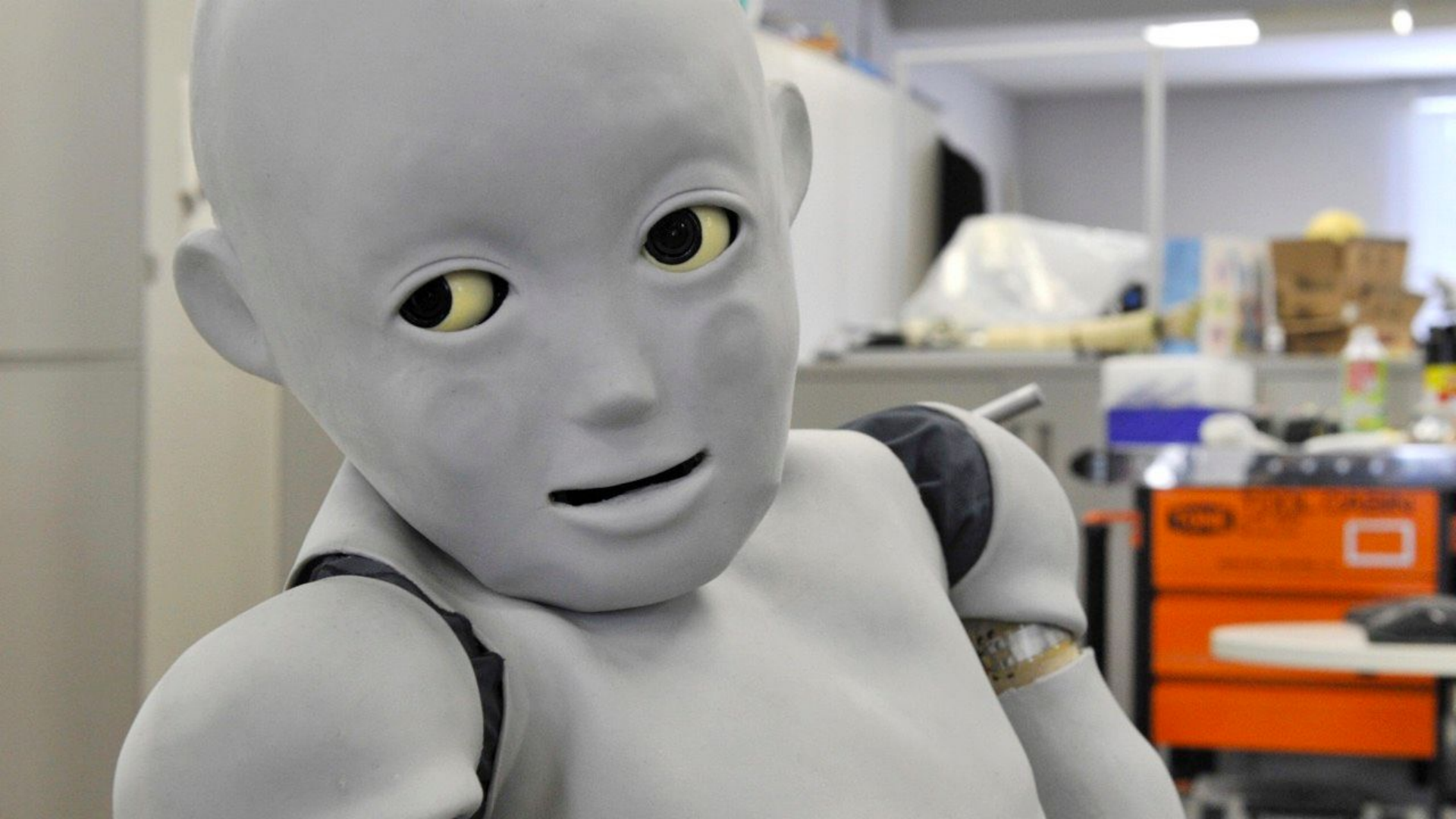
Lady Lovelace's Objection

"The Analytical Engine has no pretensions to originate anything. It can do whatever we know how to order it to perform"

“Who can be certain that ‘original work’ that [anyone] has done was not simply the growth of the seed planted in him by teaching, or the effect of following well-known general principles.

A better variant of the objection says that a machine can never ‘take us by surprise’...

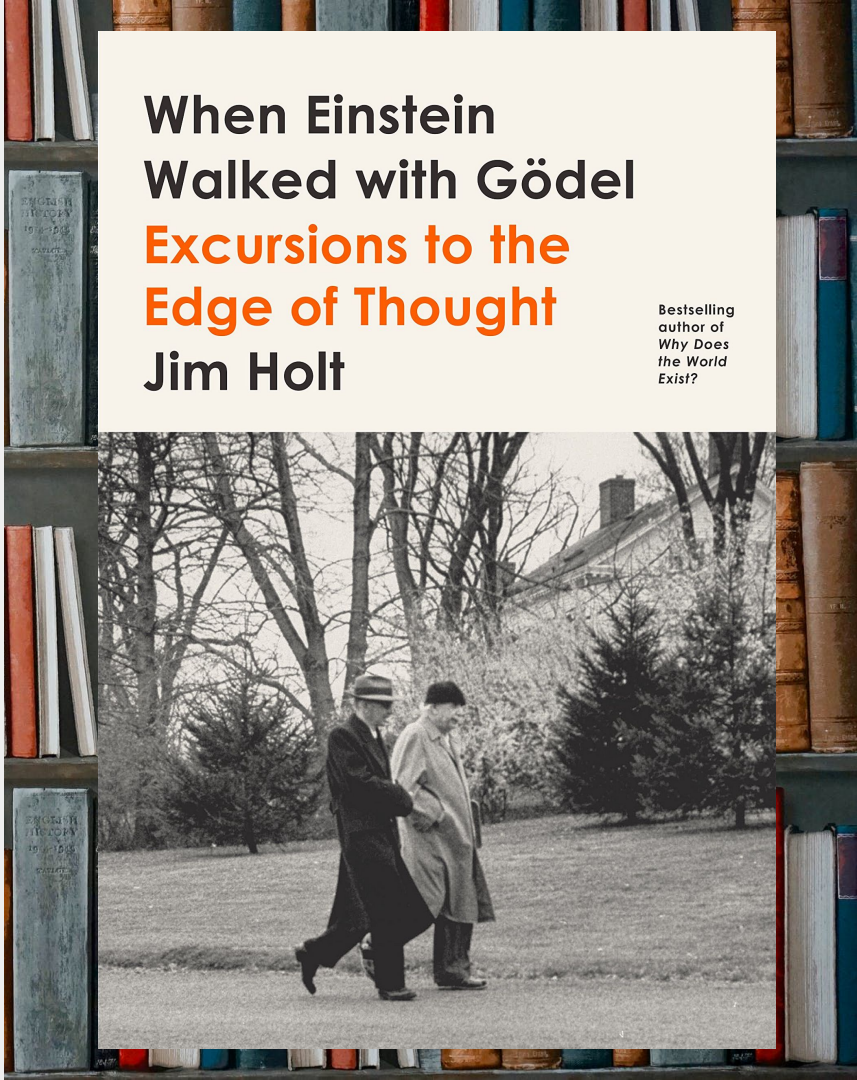
[But] Machines take me by surprise with great frequency” (Turing 1950: 450; interpolation is mine).



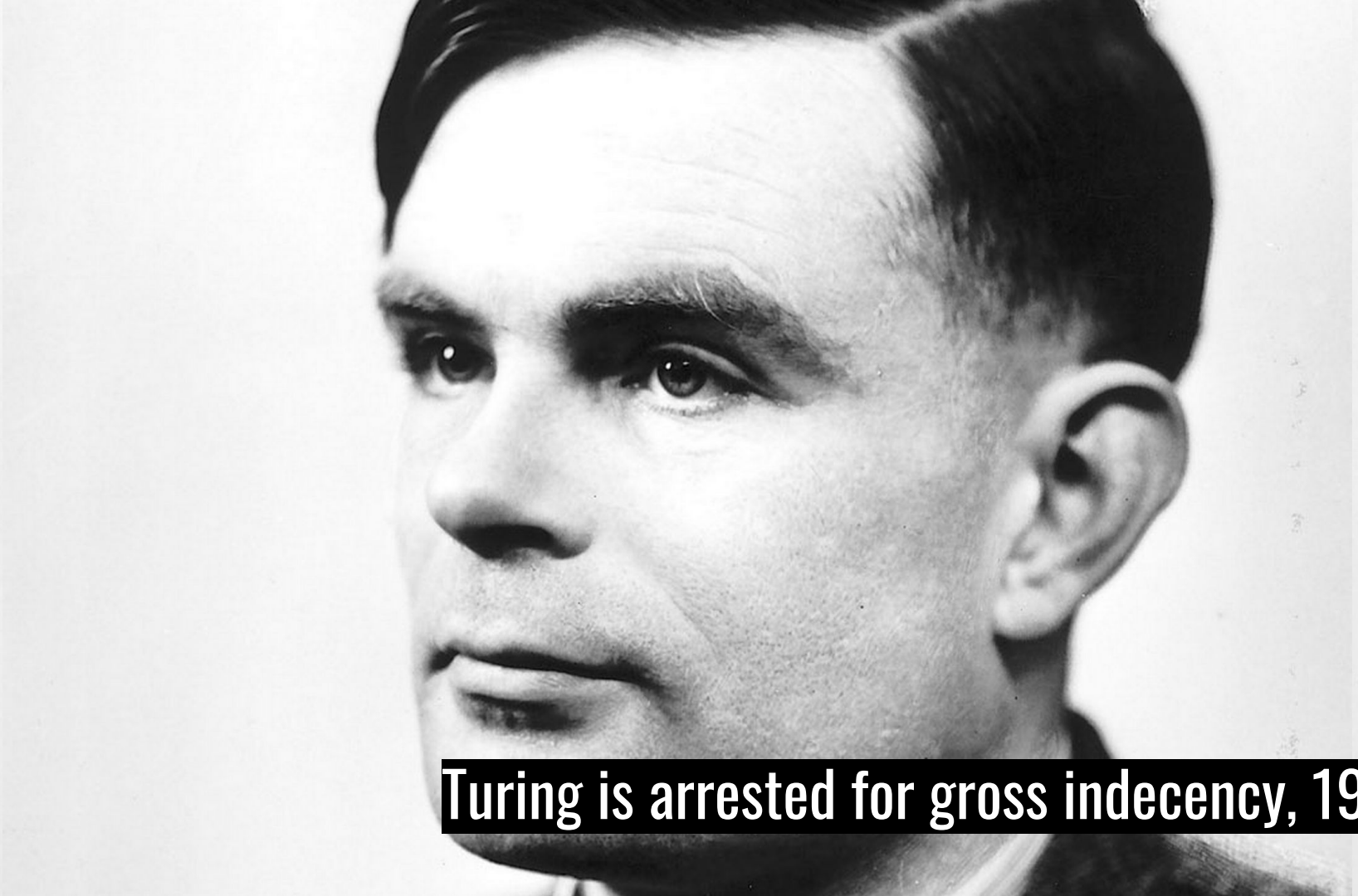

SIDEBAR

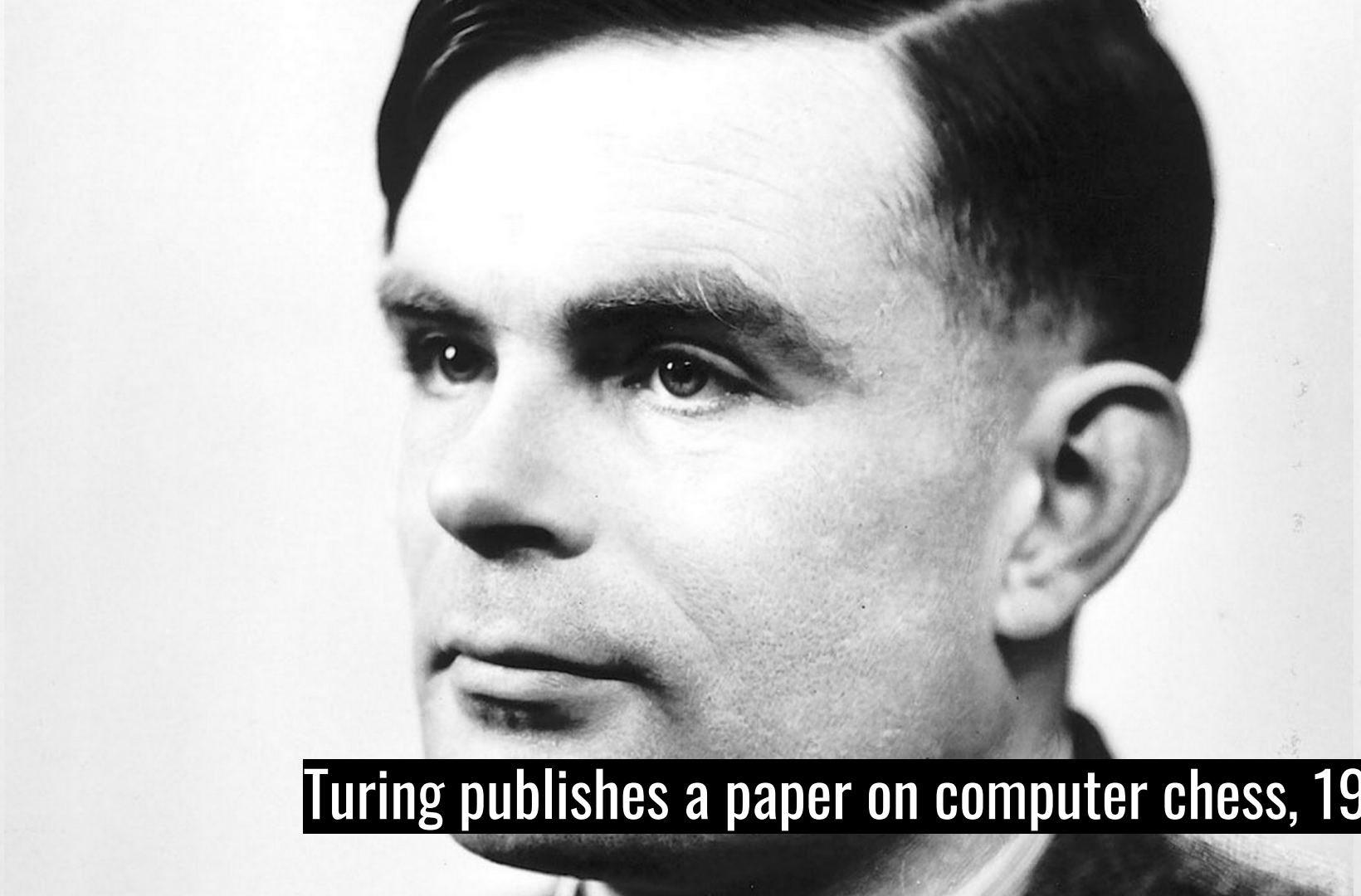
Even though she was given credit for some of the technical aspects of the "program" on which Charles Babbage's Analytical Engine operated, she was not the true author of the material; Babbage was.

Babbage primarily wanted her fame to help him garner funds for his contraption (see Holt 2019, ch. 14).

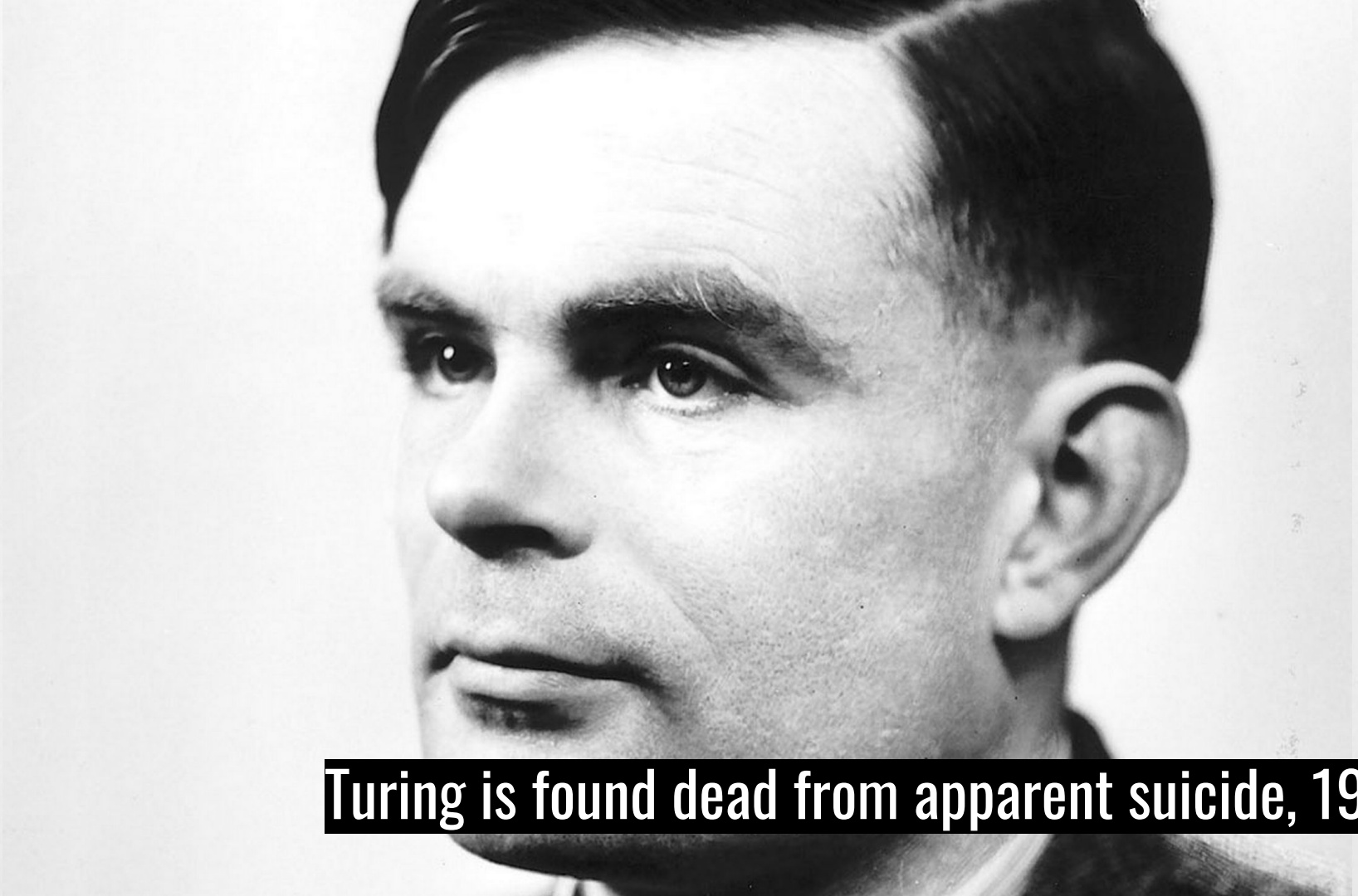


Question:
If not via the Turing Test, how **would** we know if a machine is conscious?


Turing is arrested for gross indecency, 1952



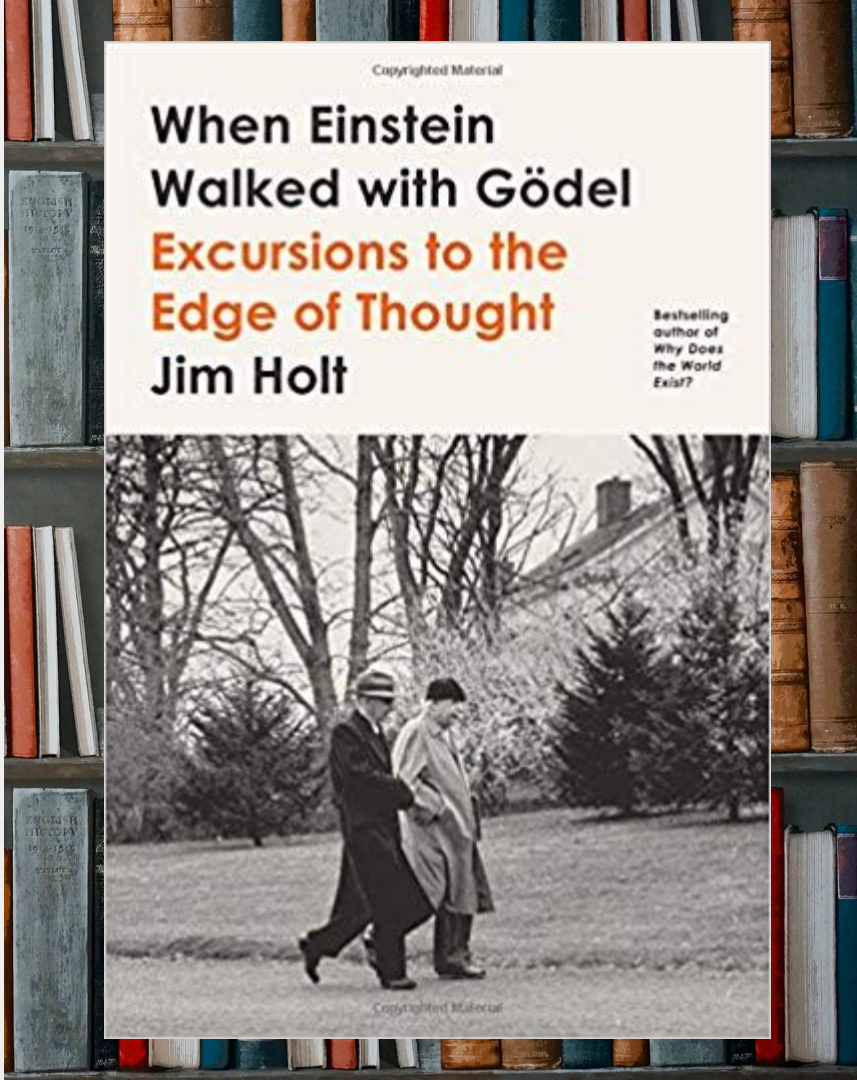
Turing publishes a paper on computer chess, 1953



Turing is found dead from apparent suicide, 1954

There are some theorists who suspect that it was not a suicide but an assassination by the Soviets.

Any intellectual with the capacity of Turing, who had previously collaborated with both the UK and USA governments, was a threat to the Soviet Union (see Holt 2018, Ch. 15).



Food for thought...

According to a recent study, about 47% of US employment is at risk of being robotized (Frey & Osborne 2013).

Both high-skill
and low-skill jobs are at risk...


WE LOVE

This is a long-term trend...

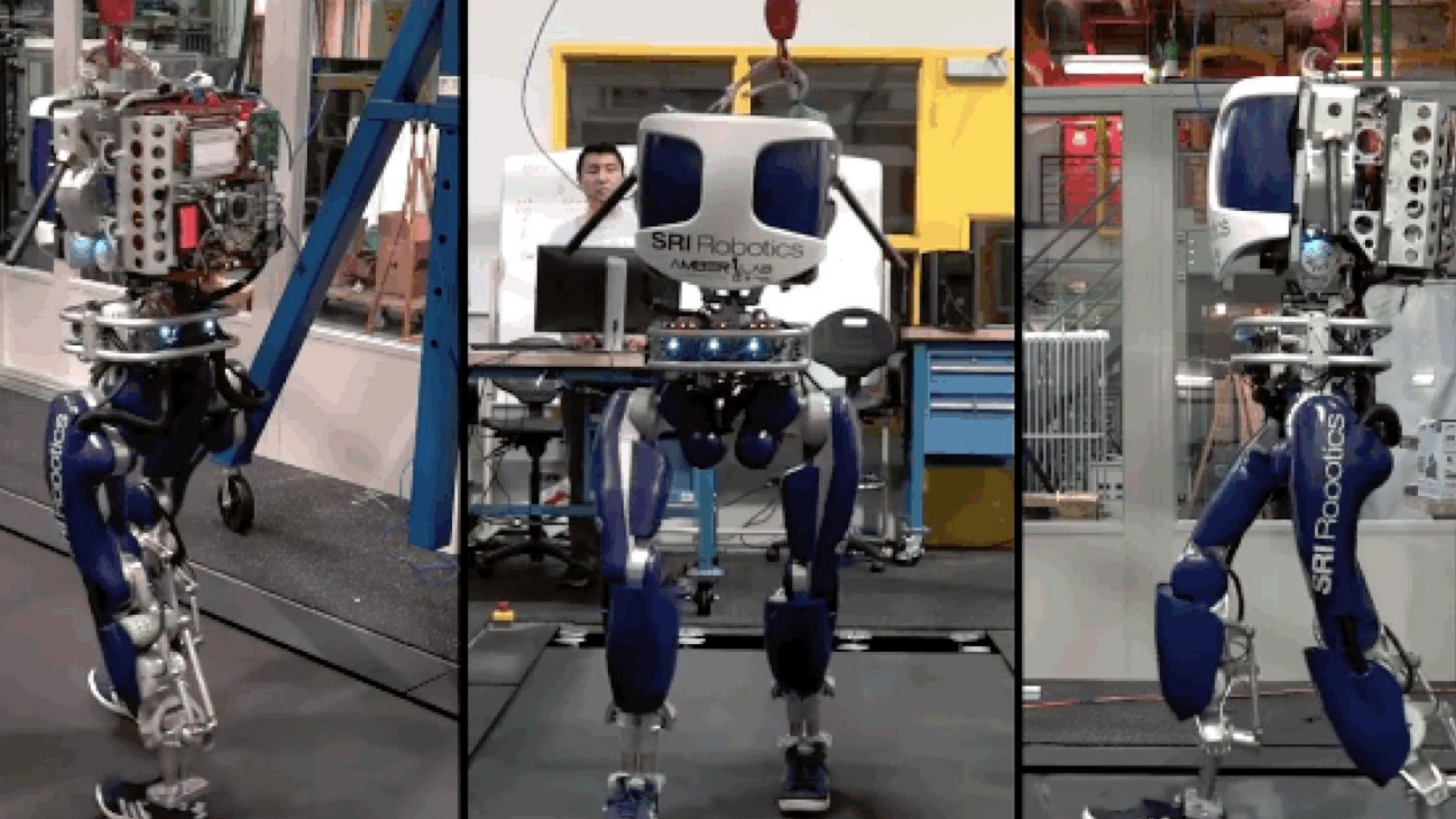
Individuals employed by Kodak at its peak:
145,300

Current Instagram employees:
550

Overreacting?

Another study says it's only 38%...

And other researchers are more worried about A.I. starting nuclear war by 2040.


SRI Robotics
SRI Robotics

DILEMMA #9

Can computers think?