



Maastricht University

Department of Knowledge Engineering

Alan Turing, the Imitation Game and Big Data

Frank Thuijsman

March 1, 2016



Alan Turing

June 23 '12, born London

'31 - '34 King's College (S)

'35 - '36 King's College (F)

'36 **computable numbers**

'38 PhD, Princeton

'39 - '45 **Bletchley Park**

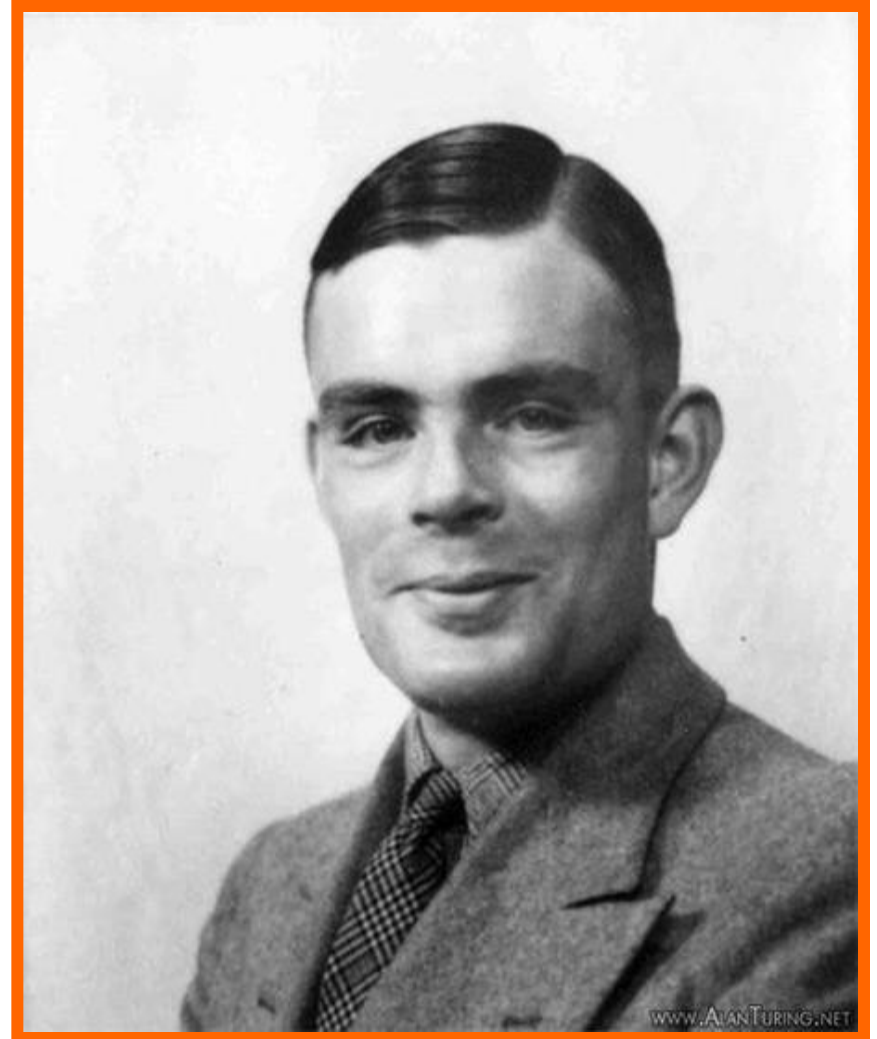
'45 - '47 ACE/NPL, London

'48 - '54 Manchester

'50 **computing machinery**

'52 convicted

June 7 '54, dies Wilmslow



Turing Machines & the Halting Problem

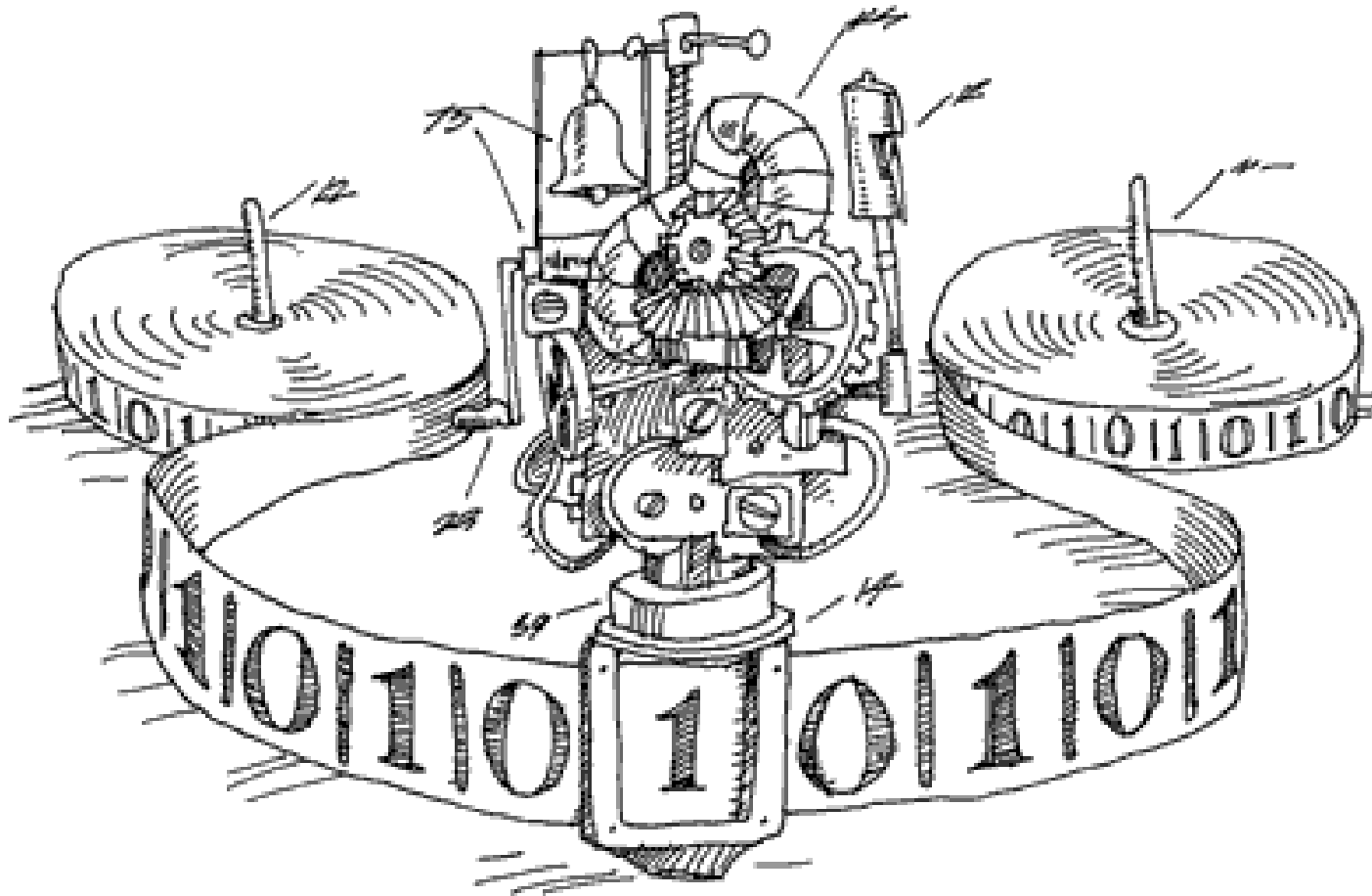
ON COMPUTABLE NUMBERS, WITH AN APPLICATION TO
THE ENTSCHEIDUNGSPROBLEM

By A. M. TURING.

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

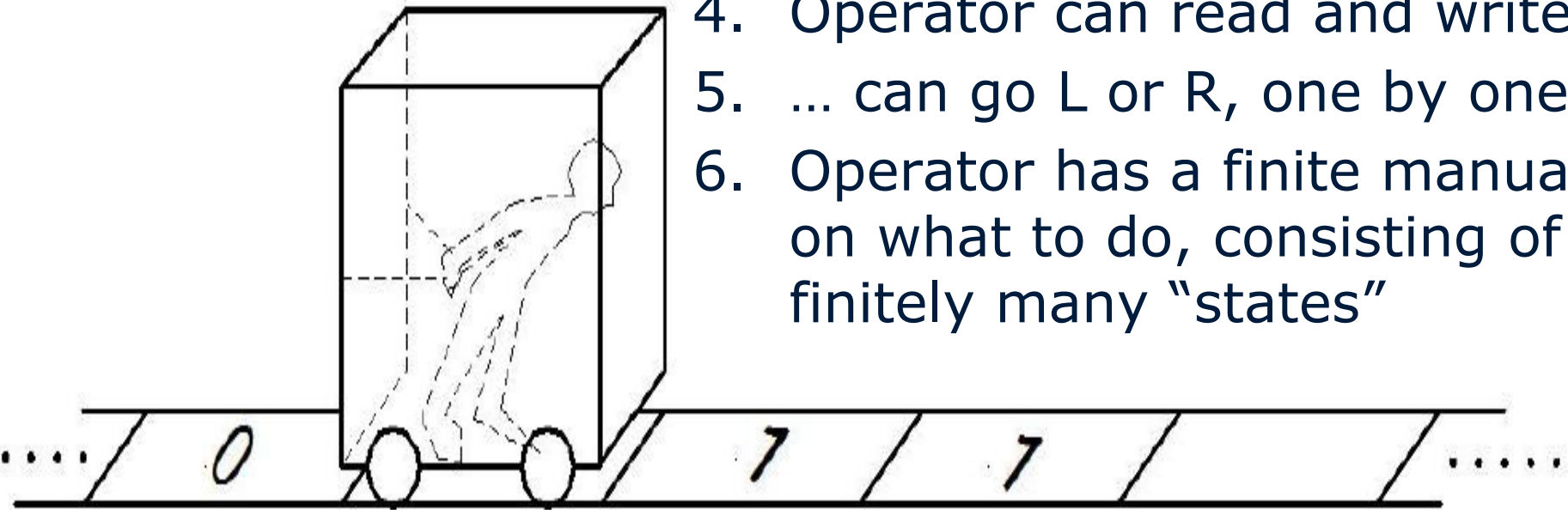
The “computable” numbers may be described briefly as the real numbers whose expressions as a decimal are calculable by finite means.

Turing Machines

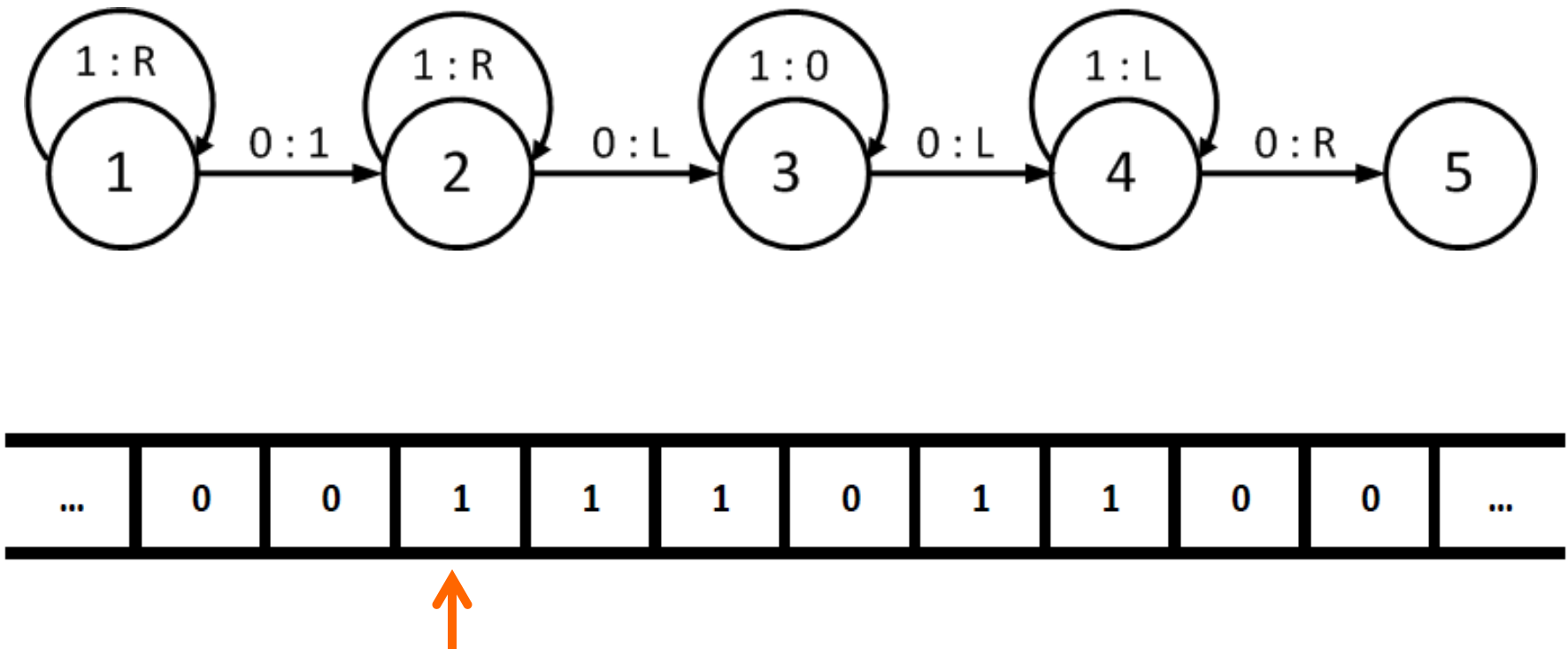


Turing Machines

1. Input: infinite squared tape
2. Finitely many non-empty
3. Finitely many symbols
4. Operator can read and write
5. ... can go L or R, one by one
6. Operator has a finite manual on what to do, consisting of finitely many "states"

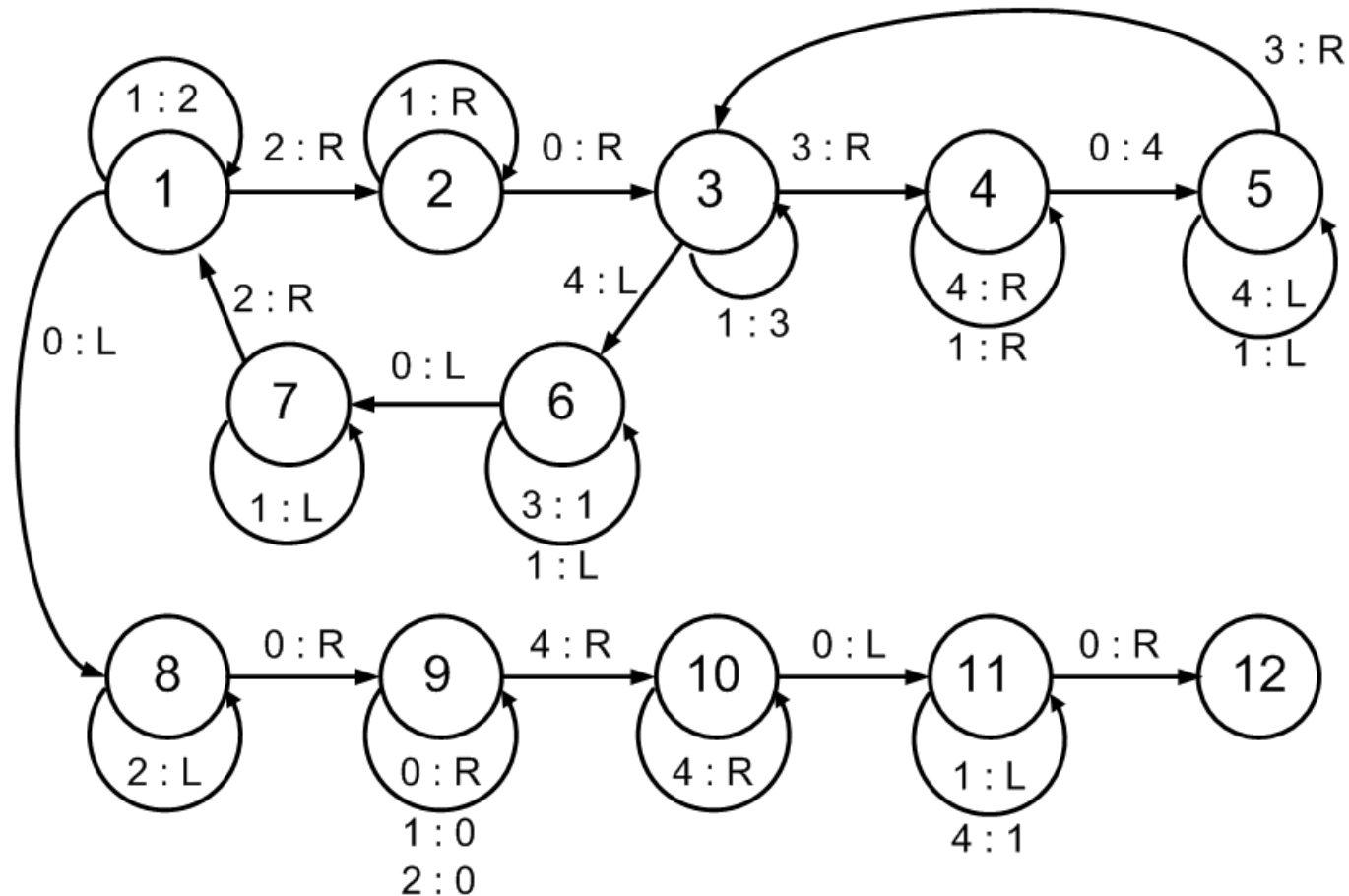


Turing Machines: $x + y$

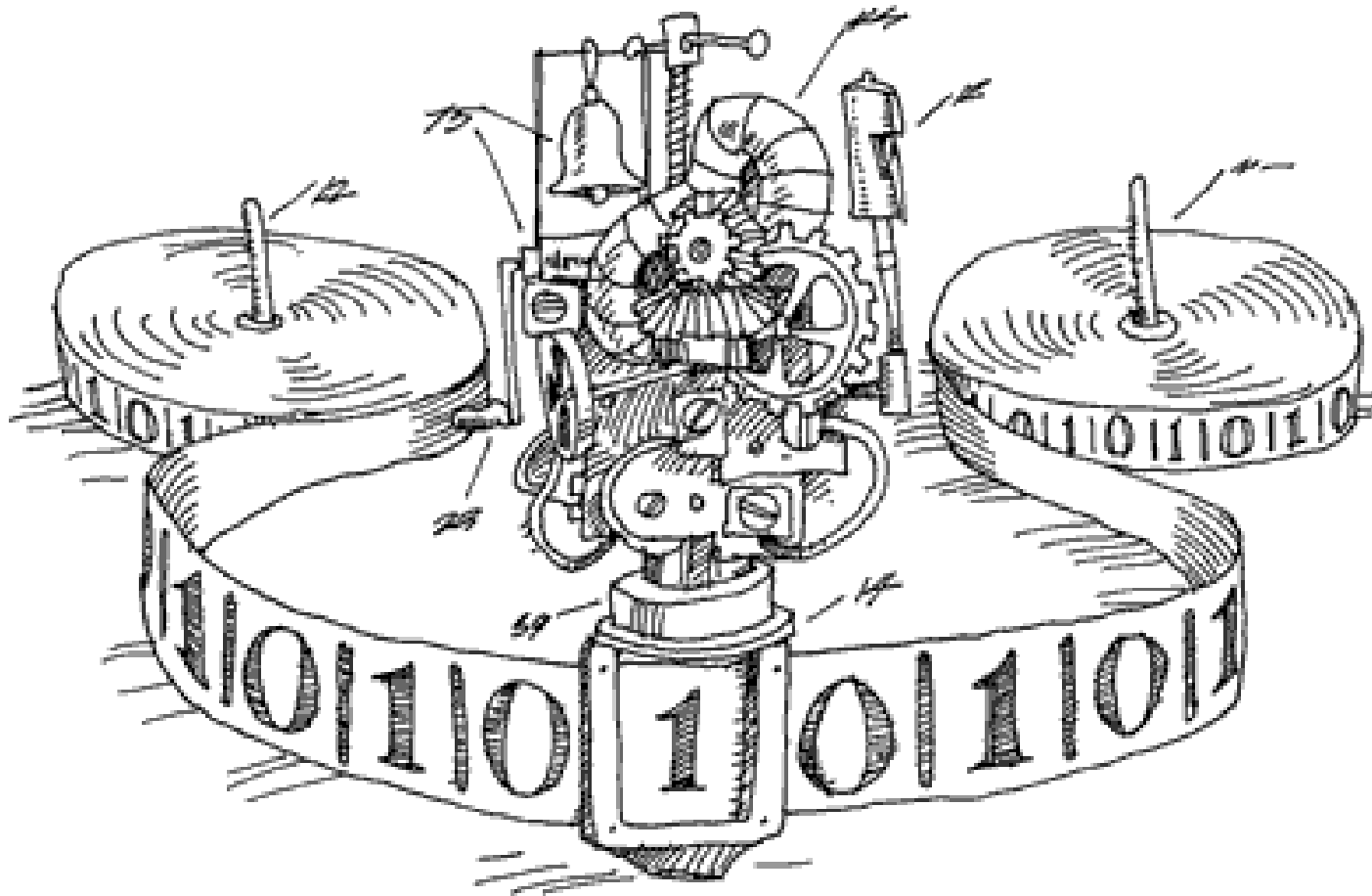


Starting here in state **1**

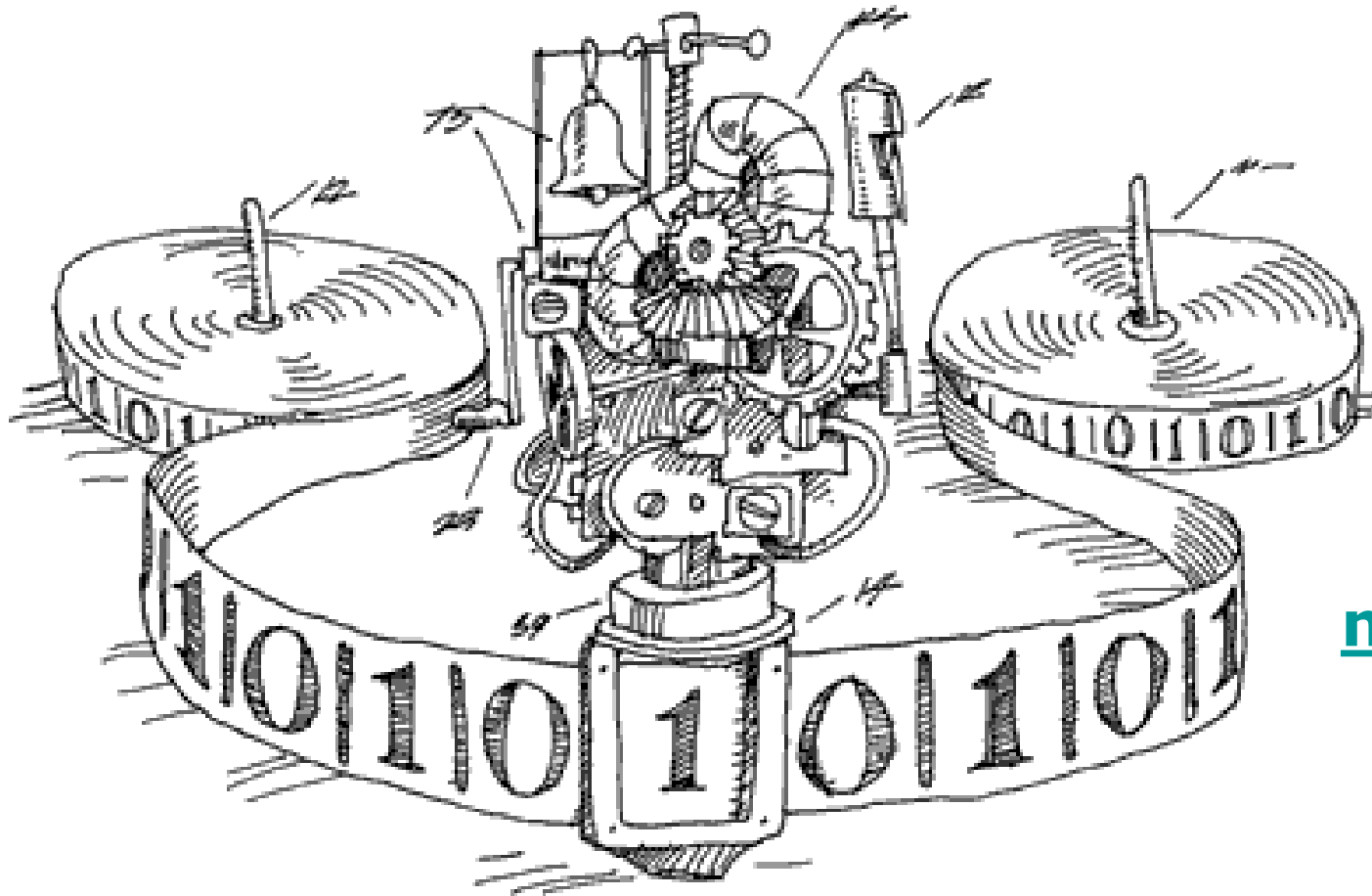
Turing Machines: $x \cdot y$



Turing Machines: how many?



Turing Machines: countably many



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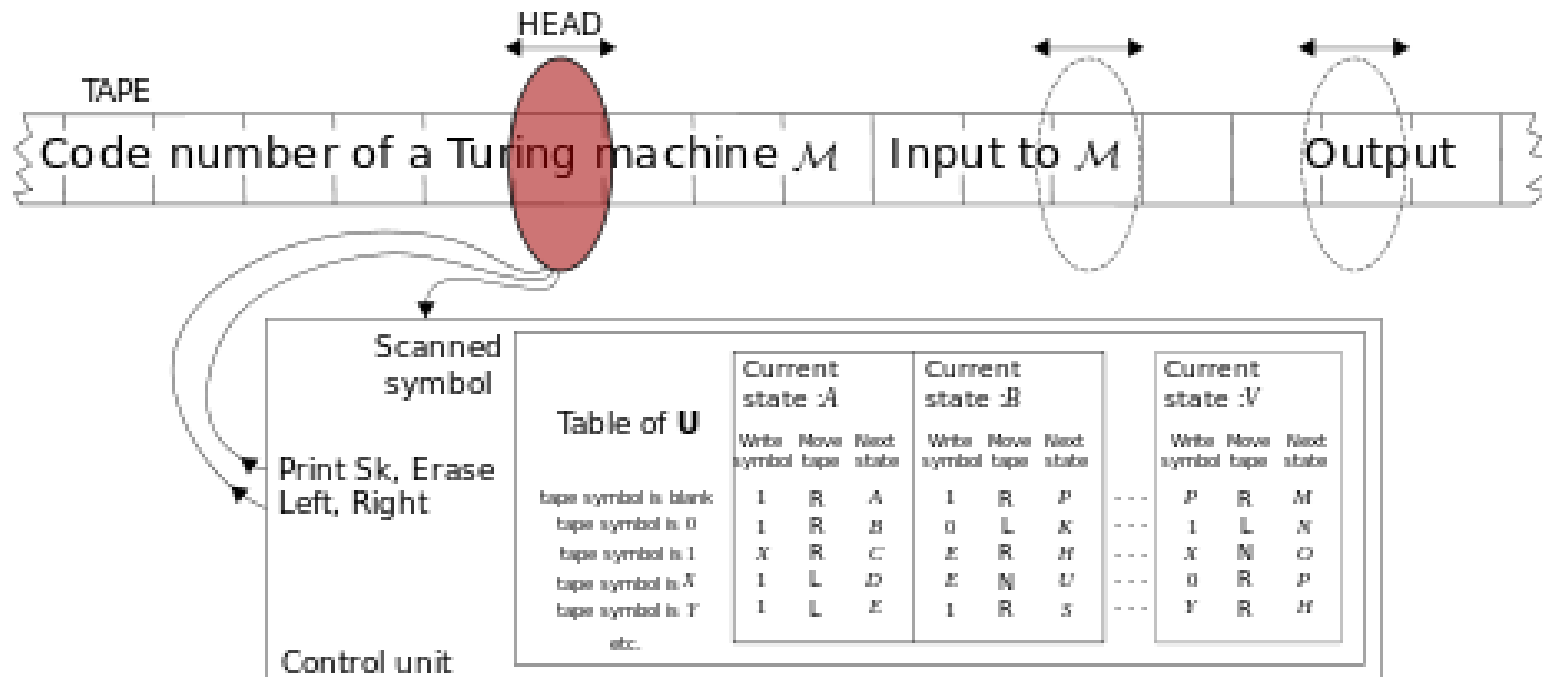
Turing: the Universal Machine



6. *The universal computing machine.*

It is possible to invent a single machine which can be used to compute any computable sequence. If this machine $\mathcal{U}$ is supplied with a tape on the beginning of which is written the S.D of some computing machine $\mathcal{M}$,

Turing: the Universal Machine



Turing Machines & the Halting Problem

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Published 1936

Turing Machines & the Halting Problem

There is **NO** program P that can check for any program Q and any input I , whether or not Q halts on I .

Argument: Suppose program P exists, then P would:

- print **YES** if Q halts on I , and next P halts;
- print **NO** if Q doesn't halt on I , and next P halts.

If P exists, then we can also make a program P^* which:

- prints **YES** if Q halts on Q and next P^* prints $0,0,0,\dots$;
- prints **NO** if Q doesn't halt on Q , and next P^* halts.

Does P^* halt on P^* ? Answers YES and NO both fail!

Turing and Code Breaking

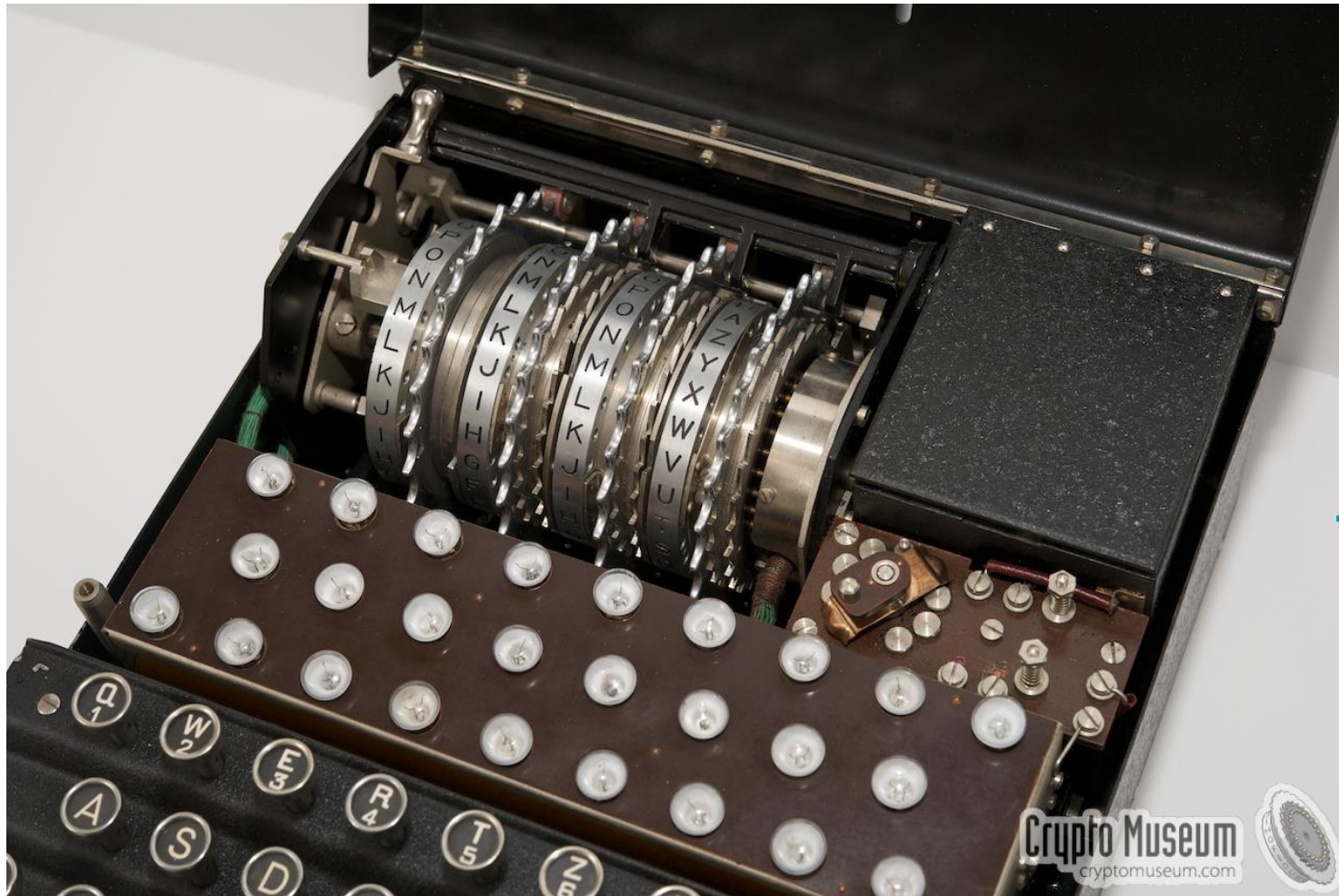


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The Enigma Machine



The Enigma Machine



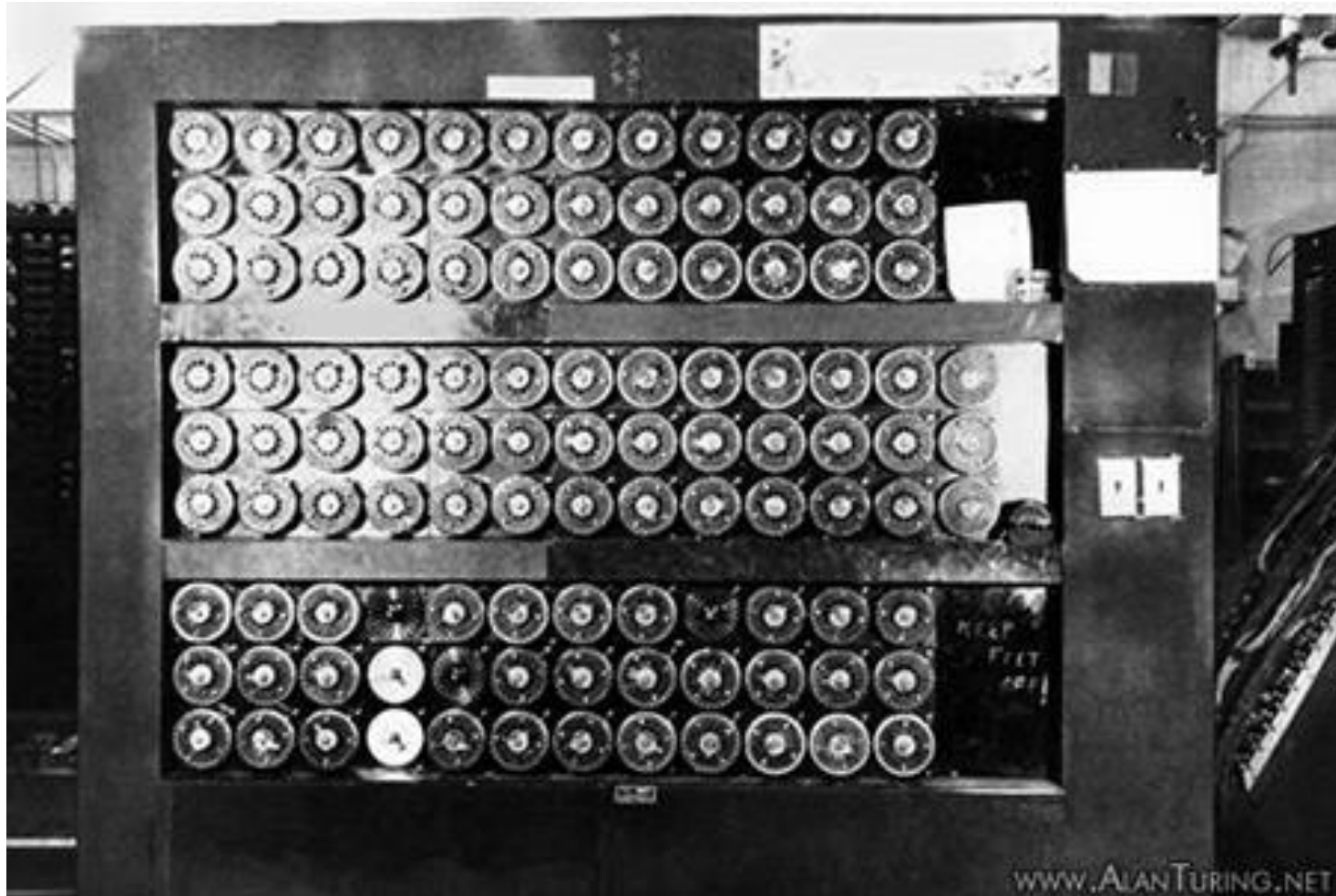
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Crypto Museum
cryptomuseum.com



The Bombe



The Imitation Game



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The Imitation Game

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

The Imitation Game

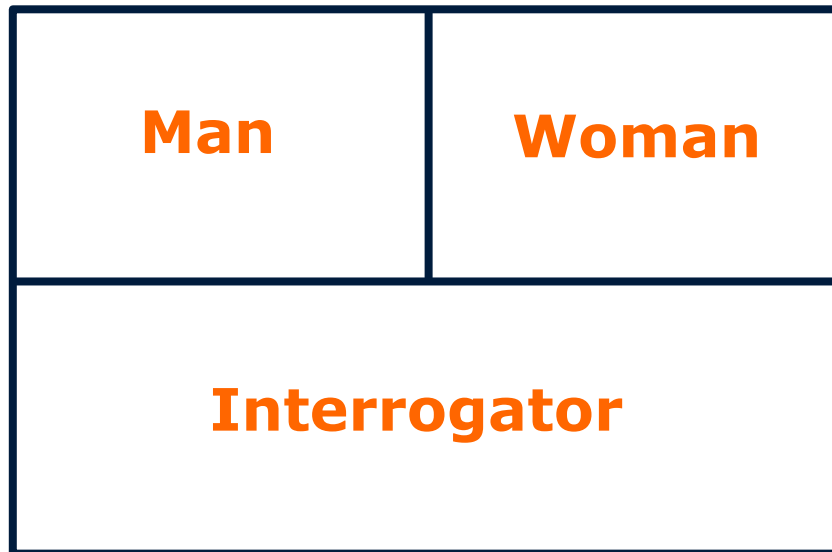
The new form of the problem can be described in terms of a game which we call the 'imitation game'. It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator 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 ?
object in the game to try and cause C to make the wrong identification. His answer might therefore be

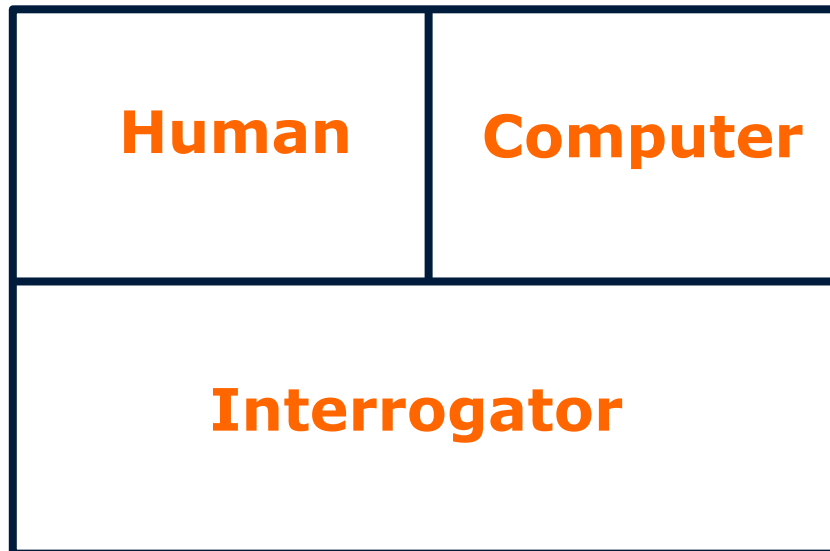
'My hair is shingled, and the longest strands are about nine inches long.'

We now ask the question, 'What will happen when a machine takes the part of A in this game ?' Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman ? These questions replace our original, 'Can machines think ?'

The Imitation Game

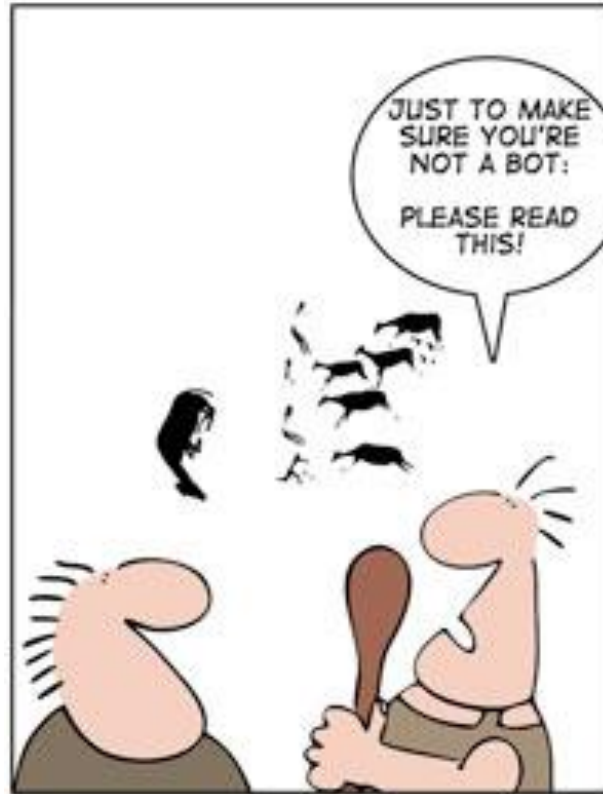


The Imitation Game



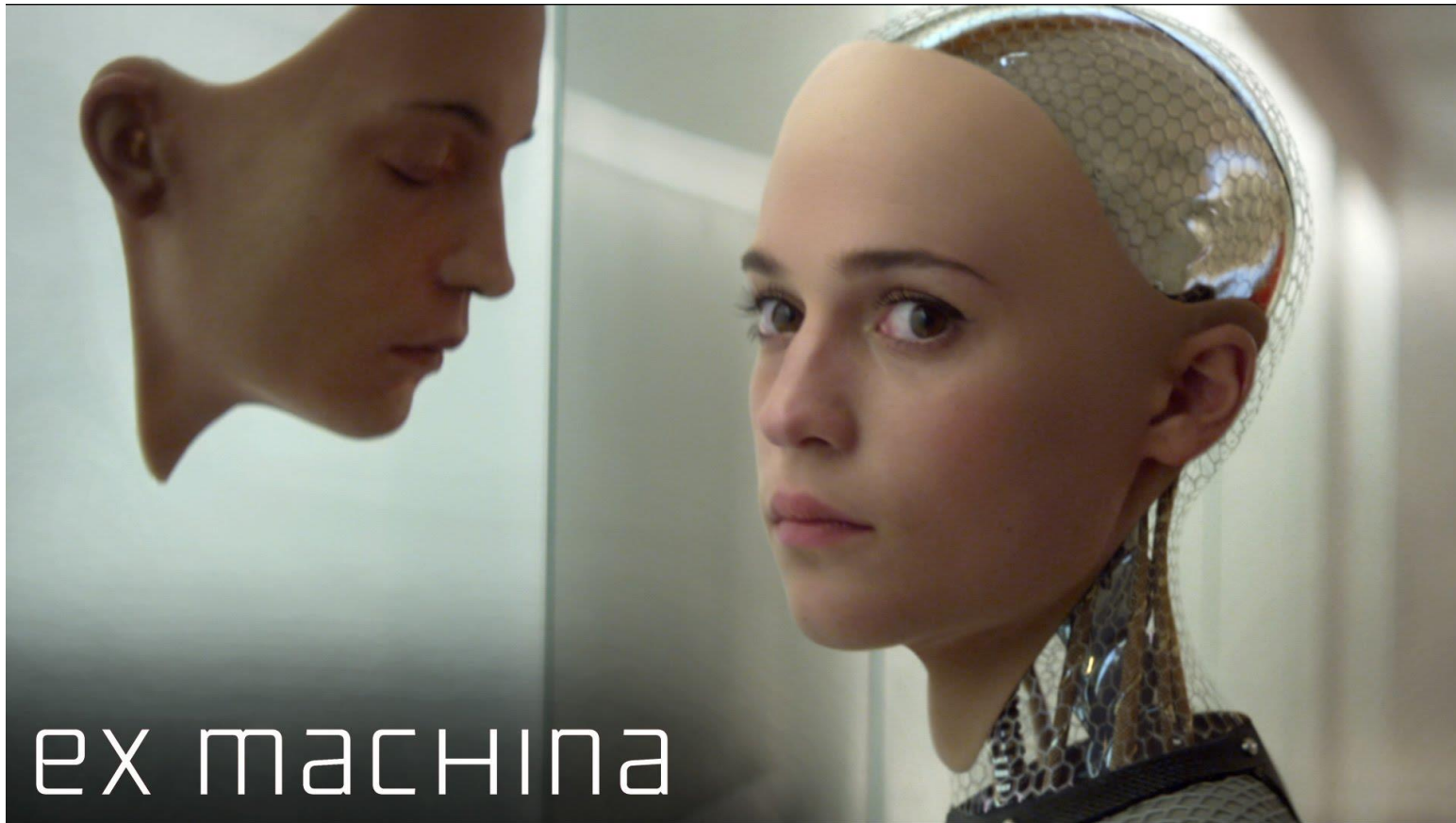
The Imitation Game

CAPTCHA



Completely **A**utomated **P**ublic **T**uring test
to tell **C**omputers and **H**umans **A**part

Ex Machina



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movie](#)

What happened after Turing?

Alan Mathison Turing
1912-1954

Father of Computer Science
Mathematician, Logician
Wartime Codebreaker
Victim of Prejudice

*"Mathematics, rightly viewed, possesses not only truth
but supreme beauty, a beauty cold and austere
like that of sculpture." - Bertrand Russell*



What happened after Turing?

ARPANET: 1969

Internet: 1983/1993

Microsoft: 1975, Bill Gates, Paul Allen

Apple: 1976, Steve Jobs, Steve Wozniak, Ronald Bayne

WorldWideWeb: 1989/1991, Tim Berners-Lee

Yahoo: 1994, David Filo, Jerry Yang

Amazon: 1994, Jeff Bezos

eBay: 1995, Pierre Omidyar

Google: 1997, Larry Page, Sergey Brin

Wikipedia: 2001, Jimmy Wales

LinkedIn: 2002, Reid Hoffman

Facebook: 2004, Mark Zuckerberg

Twitter: 2006, Noah Glass, Jack Dorsey

The World Wide Web



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Cycling in New York City



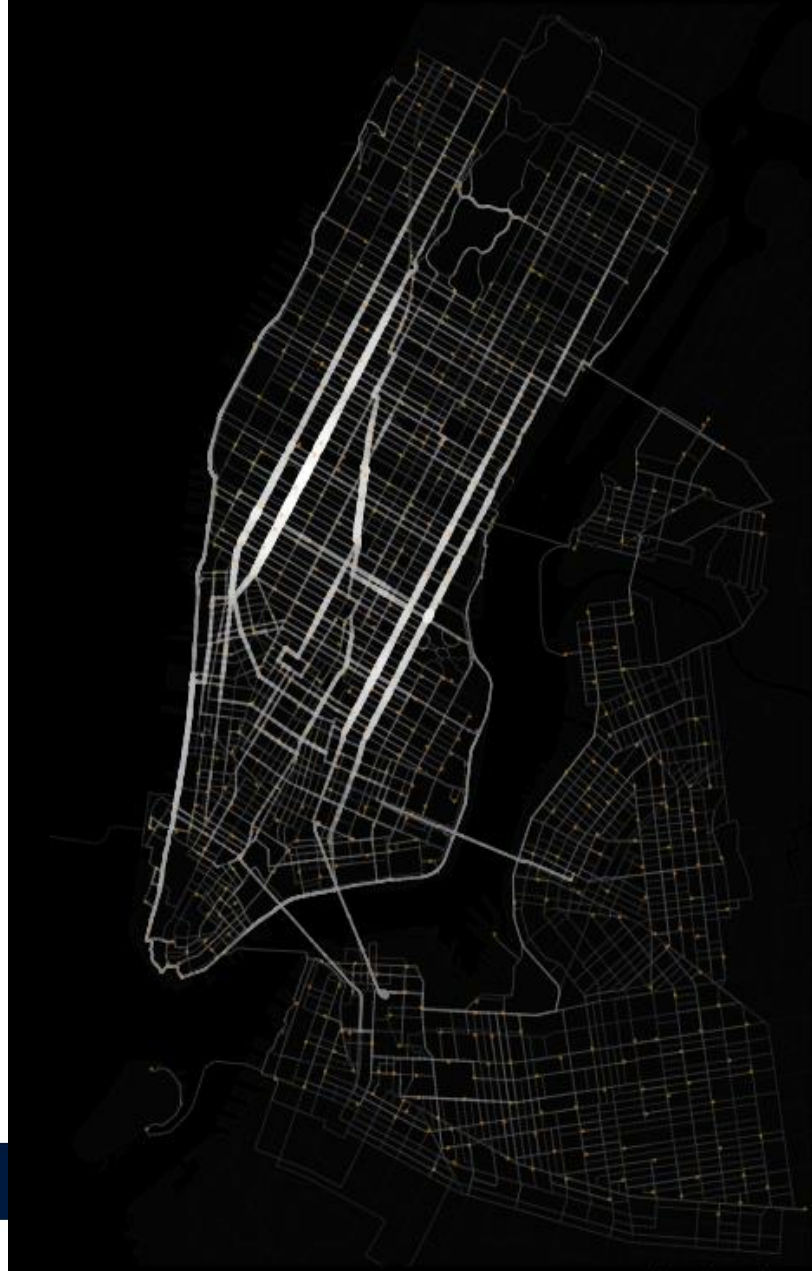
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Cycling in New York City



NYC Citi Bike Most Popular Roads

Sep–Nov 2015



What are we looking at?

What are we looking at?

	PIN	Freq
#1	1234	10.713%
#2	1111	6.016%
#3	0000	1.881%
#4	1212	1.197%
#5	7777	0.745%
#6	1004	0.616%
#7	2000	0.613%
#8	4444	0.526%
#9	2222	0.516%
#10	6969	0.512%
#11	9999	0.451%
#12	3333	0.419%
#13	5555	0.395%
#14	6666	0.391%
#15	1122	0.366%
#16	1313	0.304%
#17	8888	0.303%
#18	4321	0.293%
#19	2001	0.290%
#20	1010	0.285%

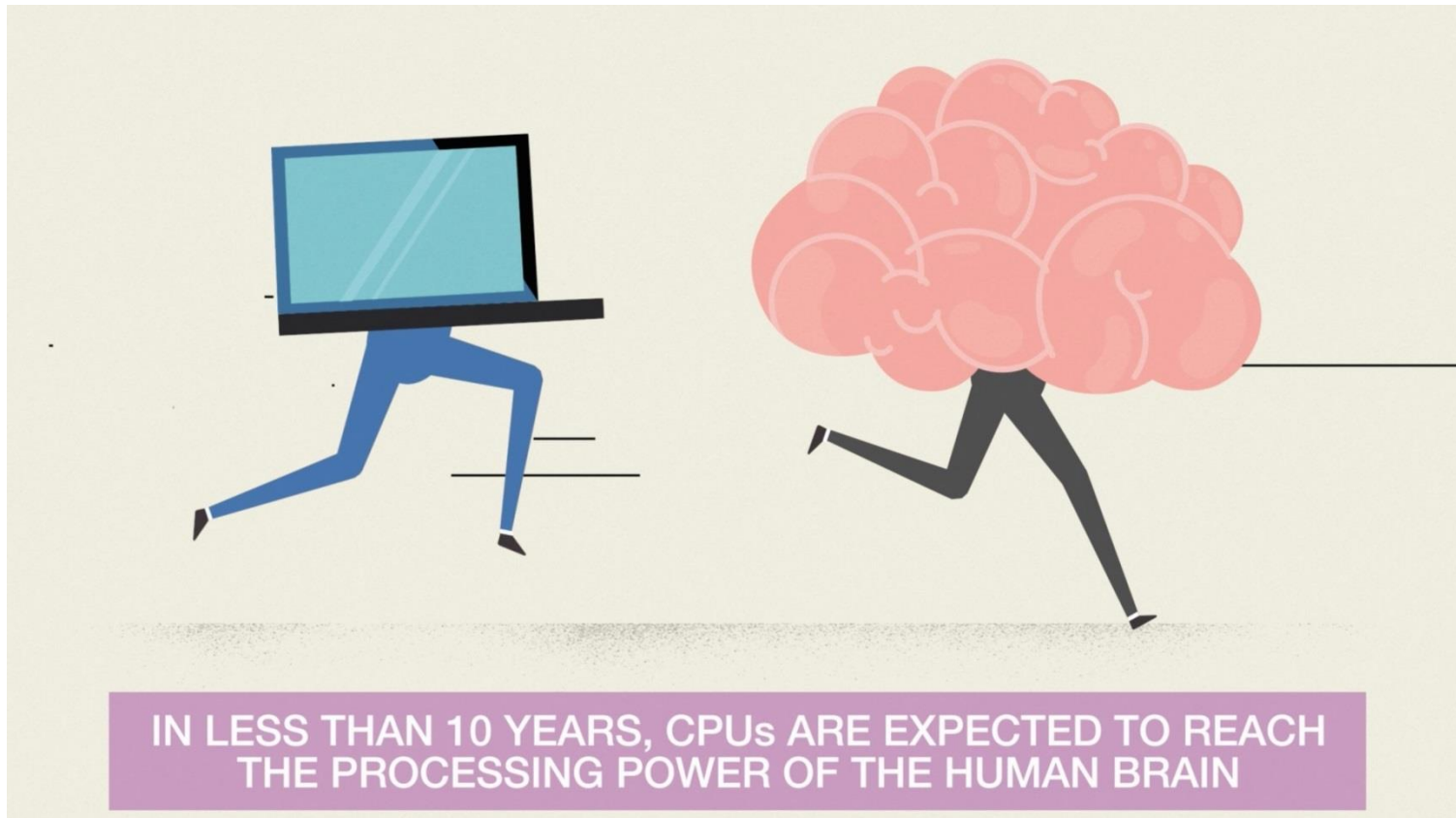
What are we looking at?

Computing, Communication and Storage



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AI and Big Data



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The Internet of Things



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People and the Internet



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Digitisation of Matter



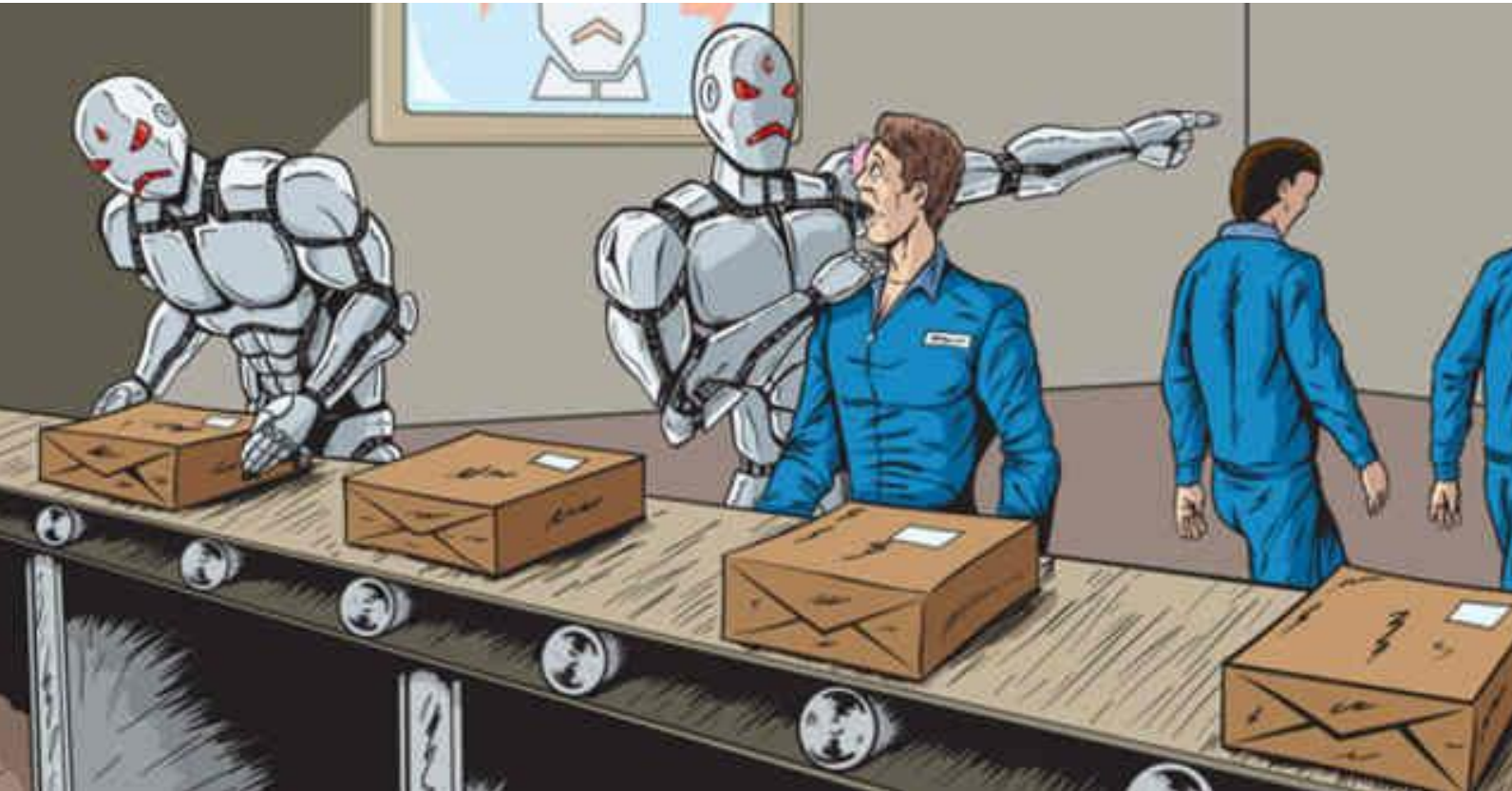
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What will our future bring?



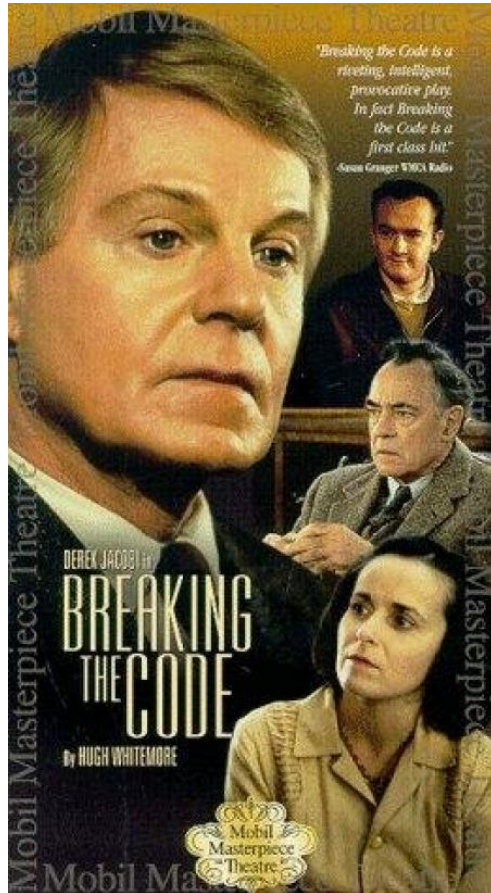
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Humans need not apply ...

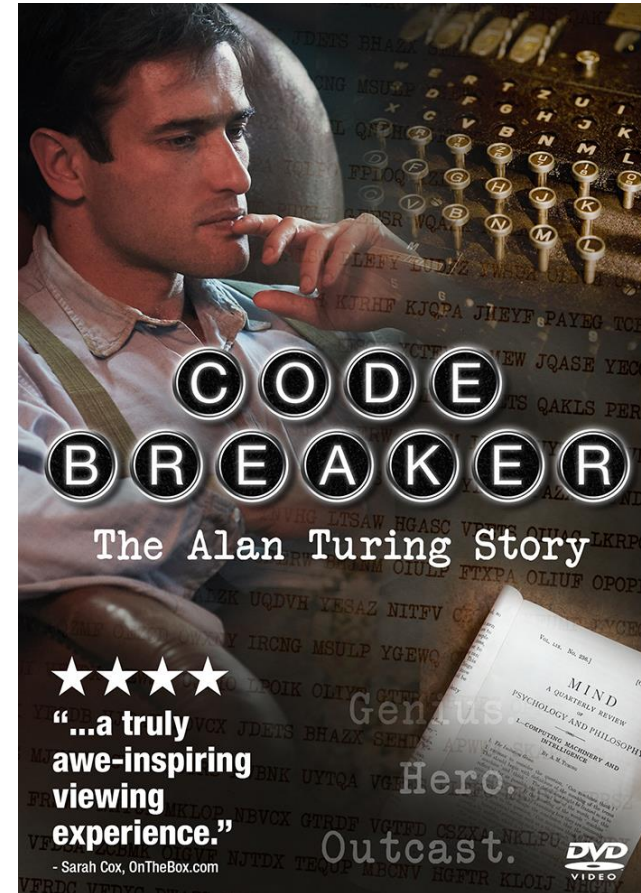


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Further Viewing

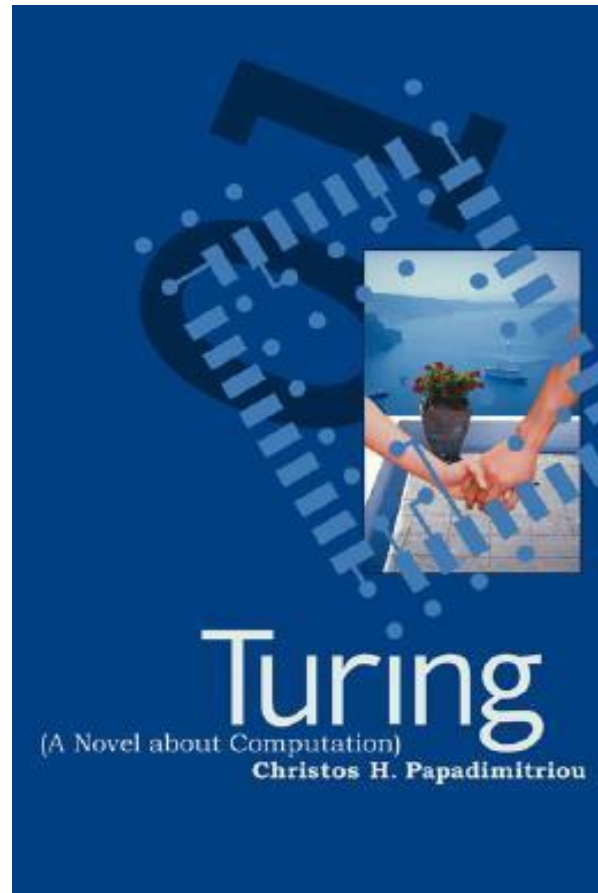


1996



2011

Further Reading



Papadimitriou, 2003

Meet Papadimitriou next Summer!



5th World Congress of the Game Theory Society



24-28 JULY 2016
MAASTRICHT
THE NETHERLANDS
GAMES2016.NL



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Many thanks for your attention!



This presentation will be available at my website!