

# DIGITAL MINDS

SCIENCE FICTION OR NEAR FUTURE REALITY?

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Arlindo Oliveira

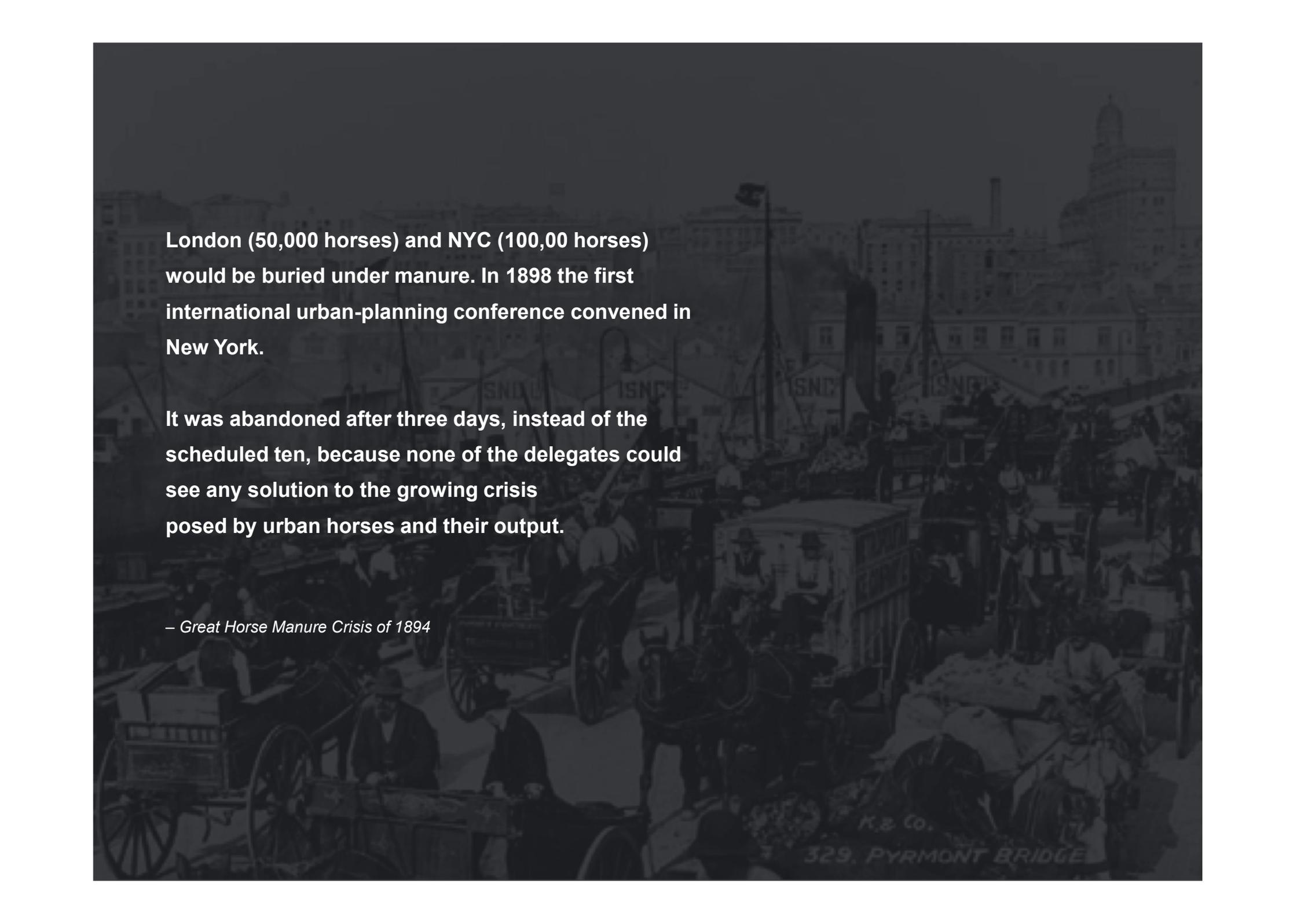




**It is difficult to make predictions,  
especially about the future**

If **trend X** continues, the result will be **disaster**.

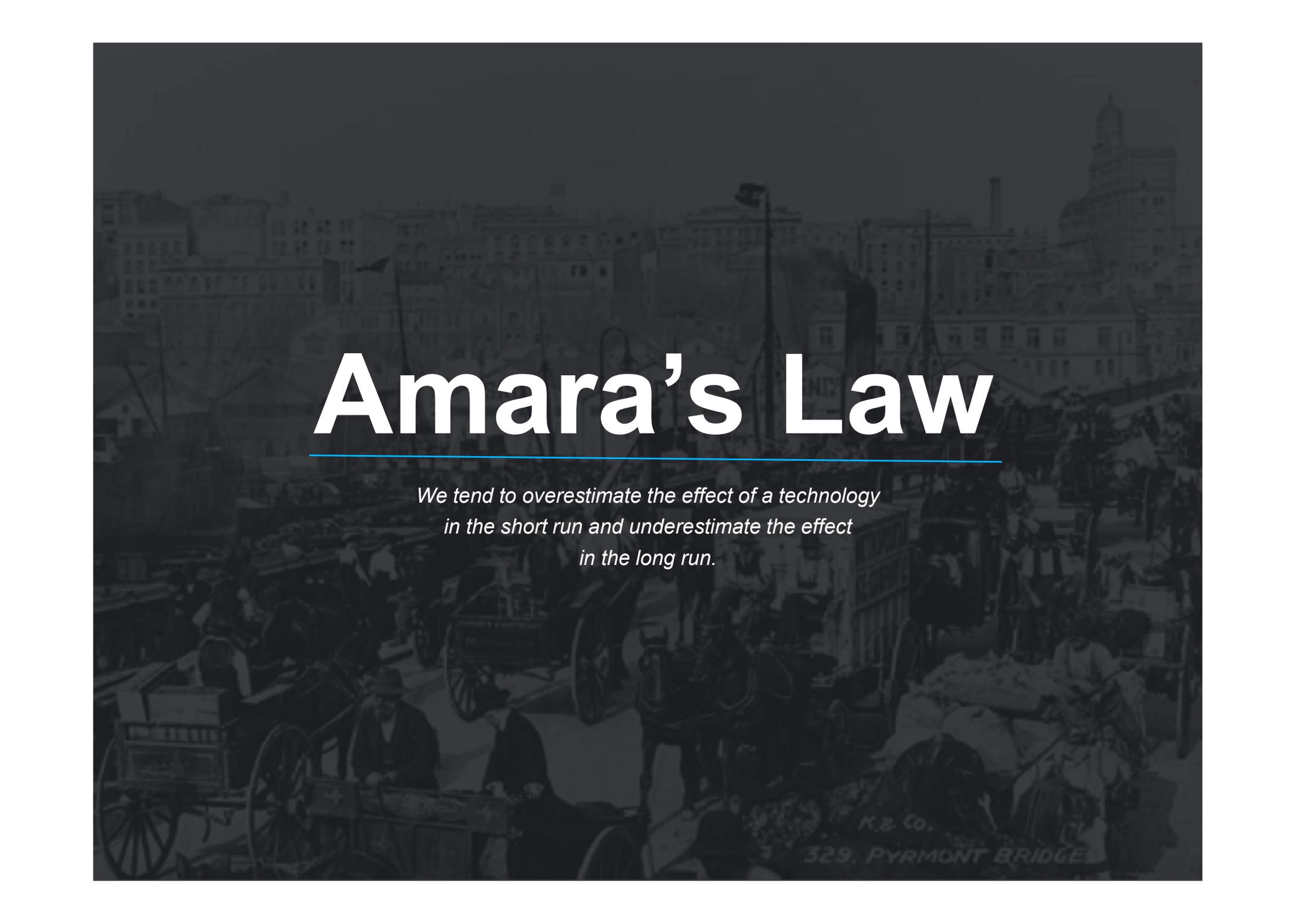




**London (50,000 horses) and NYC (100,00 horses) would be buried under manure. In 1898 the first international urban-planning conference convened in New York.**

**It was abandoned after three days, instead of the scheduled ten, because none of the delegates could see any solution to the growing crisis posed by urban horses and their output.**

*– Great Horse Manure Crisis of 1894*



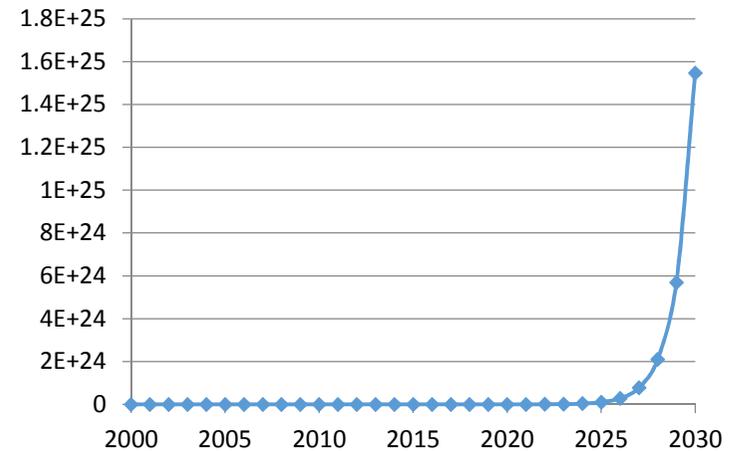
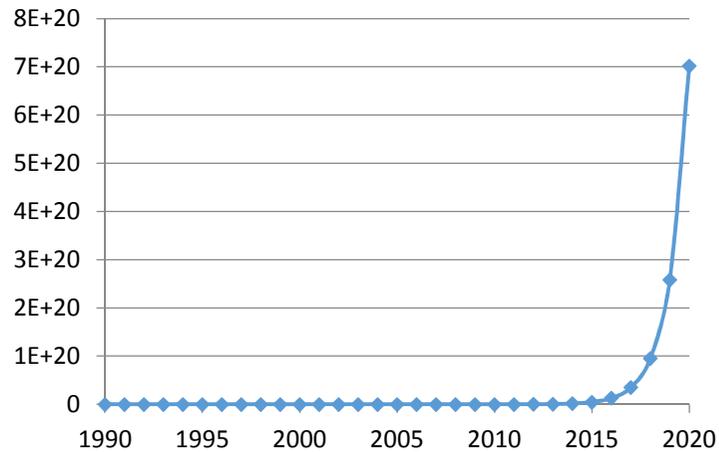
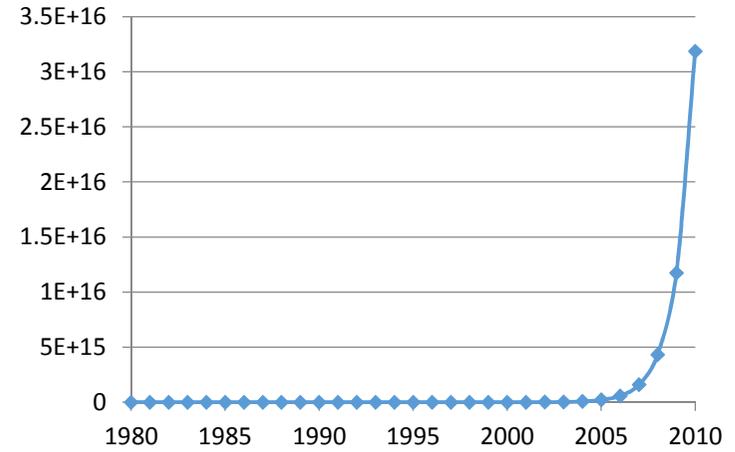
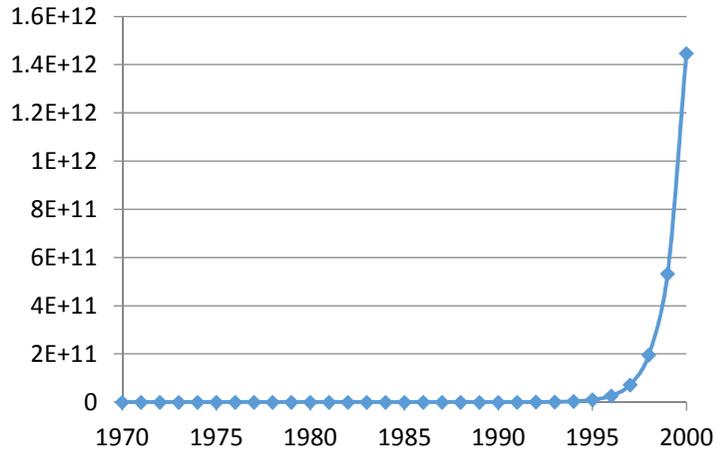
# Amara's Law

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*We tend to overestimate the effect of a technology  
in the short run and underestimate the effect  
in the long run.*

K & Co.  
329, PYRMONT BRIDGE

# Example: Number of Transistors



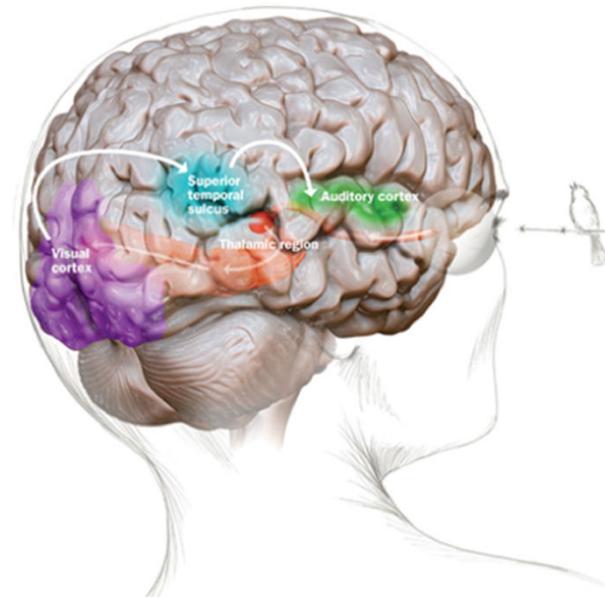
# The Church-Turing Thesis

All forms of computation are equivalent



**CPU running a program**

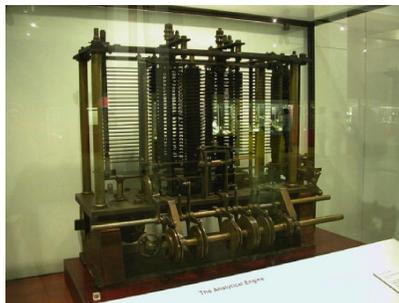
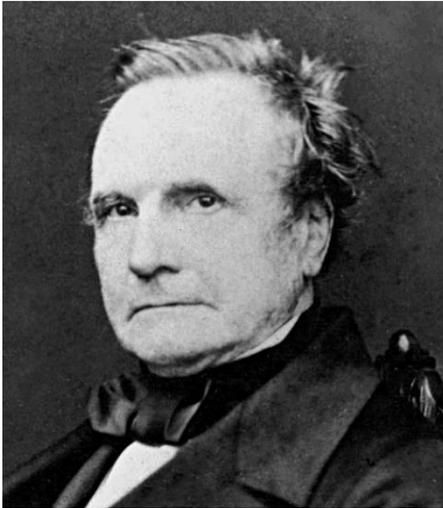
Electrical signals



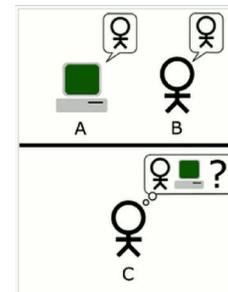
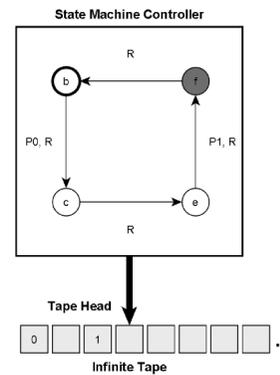
**Image processing, reasoning**

Electrical and biochemical signals

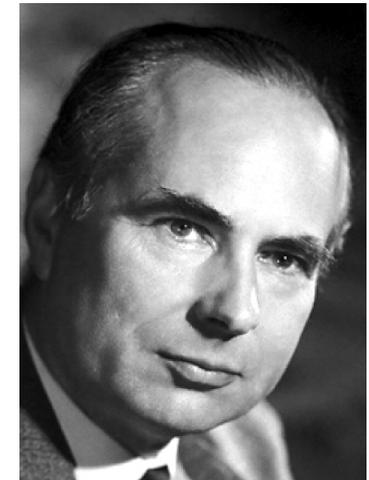
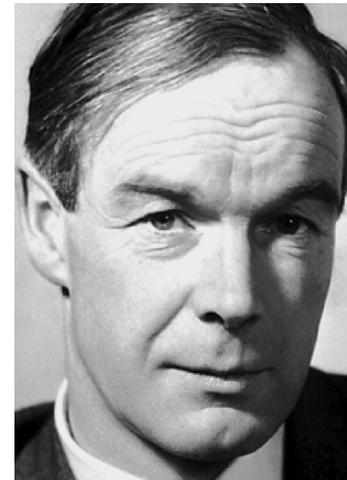
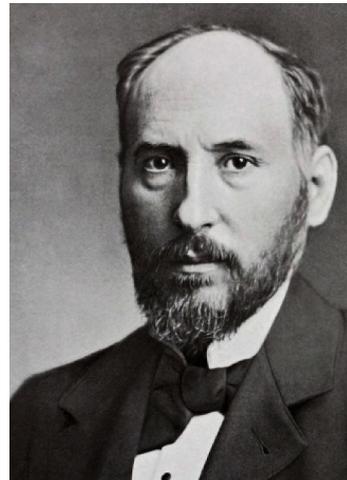
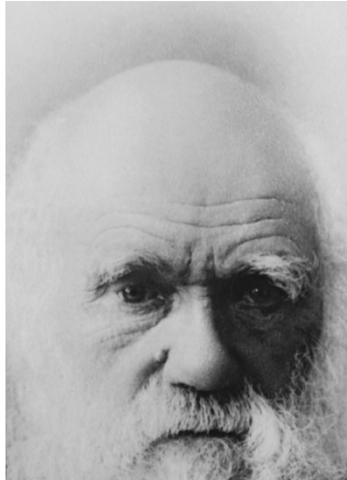
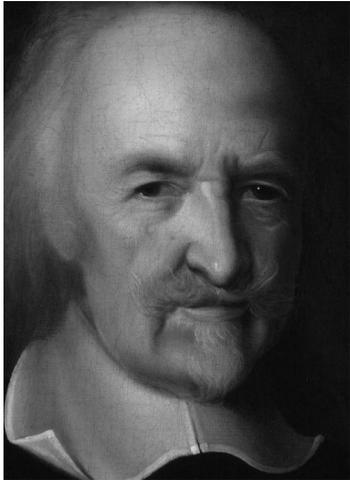
# Babbage, Lovelace, Turing, Bardeen, Shockley & Brattain



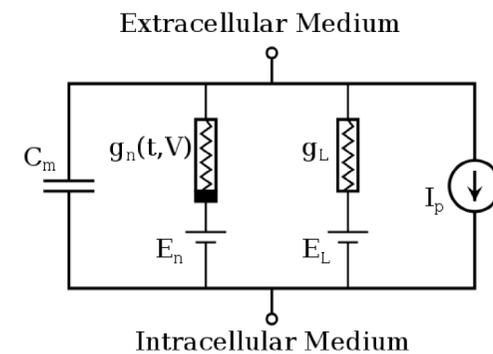
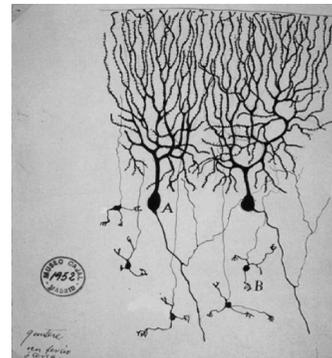
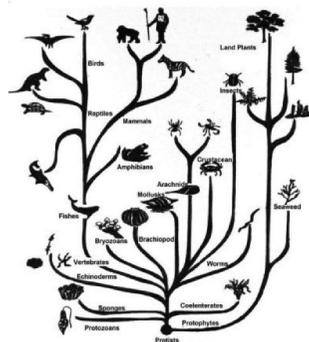
*(...) it might act upon other things besides number, were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations (...)*



# Hobbes, Darwin, Ramon y Cajal, Hodgkin & Huxley



*(...) he does nothing else but conceive a sum total, from addition of parcels; or conceive a remainder, from subtraction of one sum from another (...)*



# Digital Minds

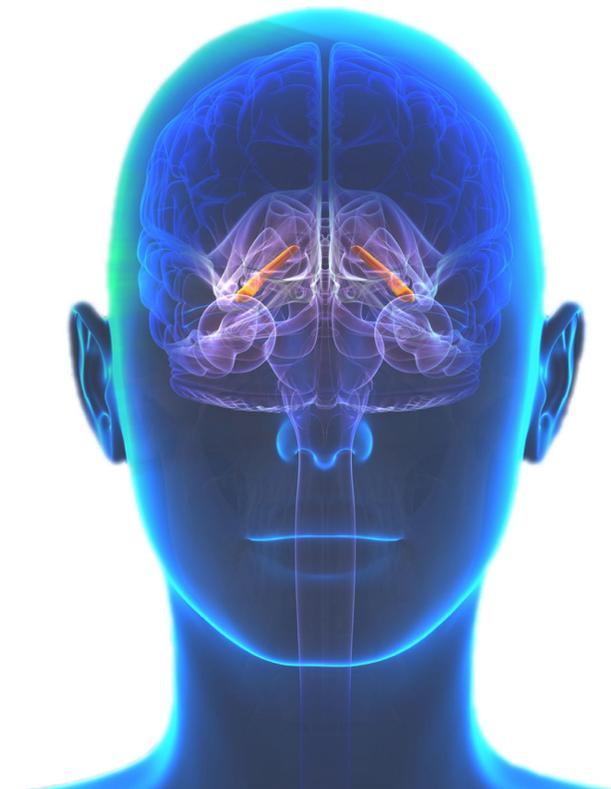
## Synthetic

Artificial Intelligence



## Natural

Whole brain simulation



# Digital Minds

## Synthetic

Artificial Intelligence



## Natural

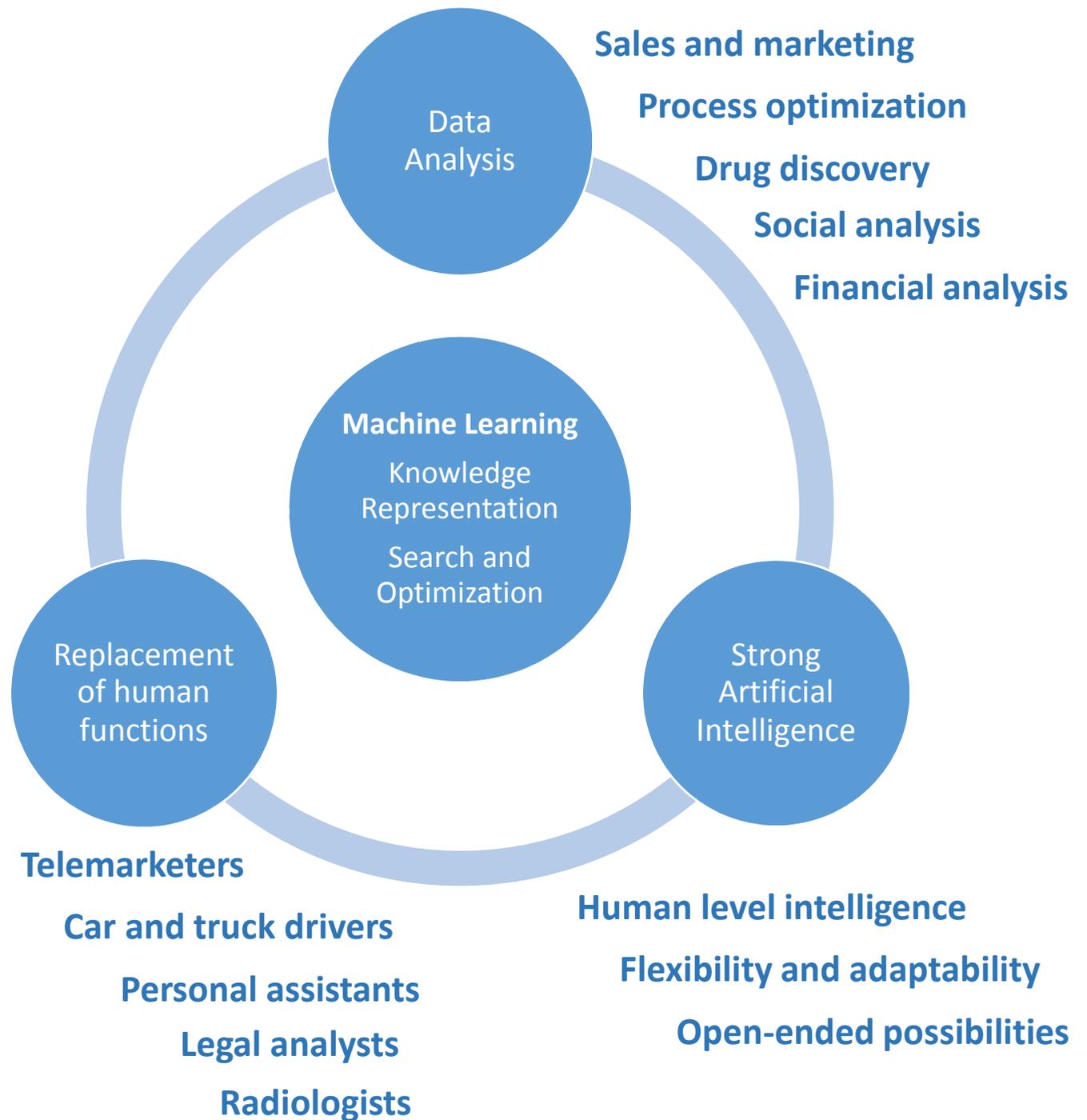
Whole brain simulation





# Modern Artificial Intelligence

# Artificial Intelligence

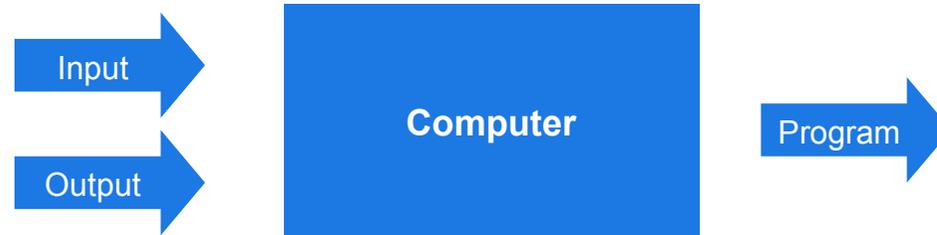


# Machine Learning

## Traditional programming

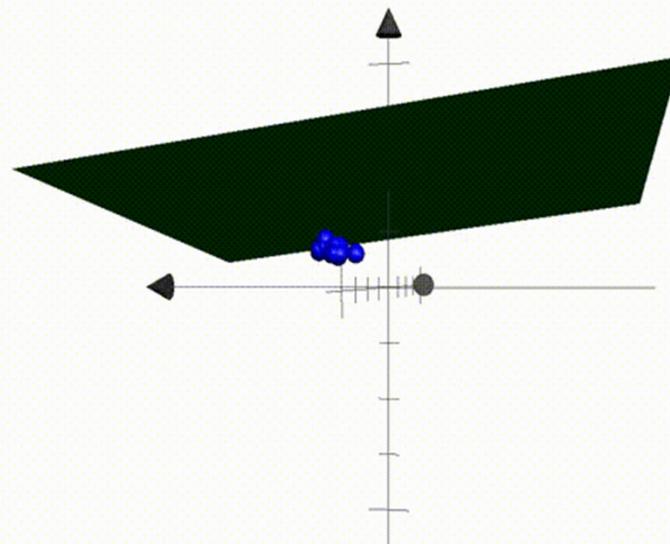
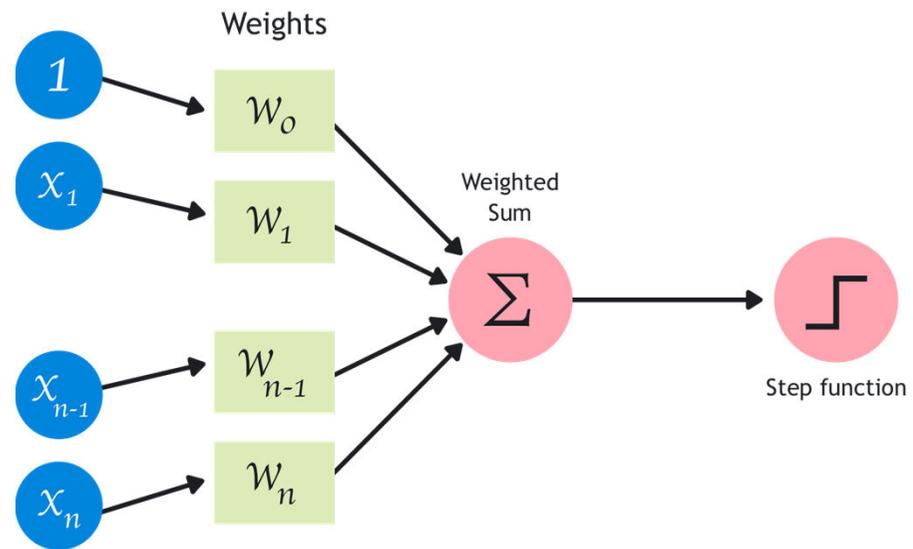


## Machine Learning



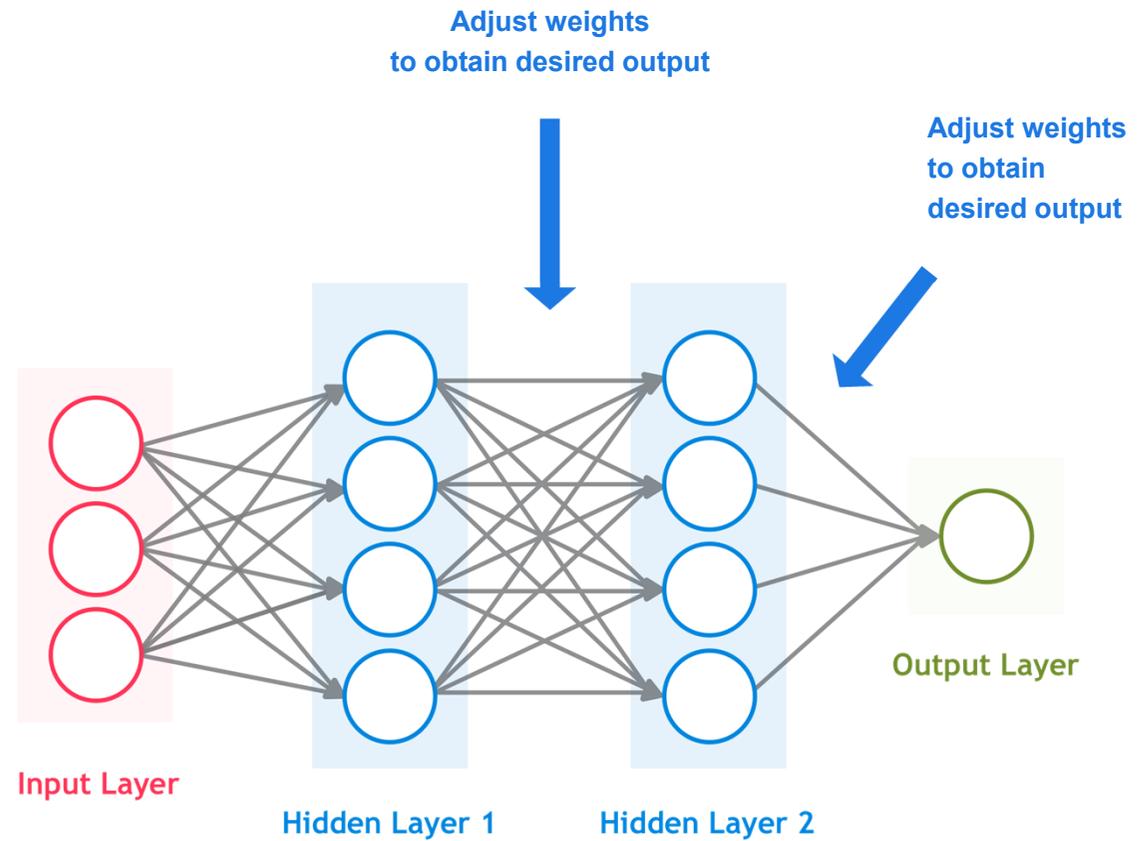
# Neural Networks

Artificial  
Neuron-Perceptron

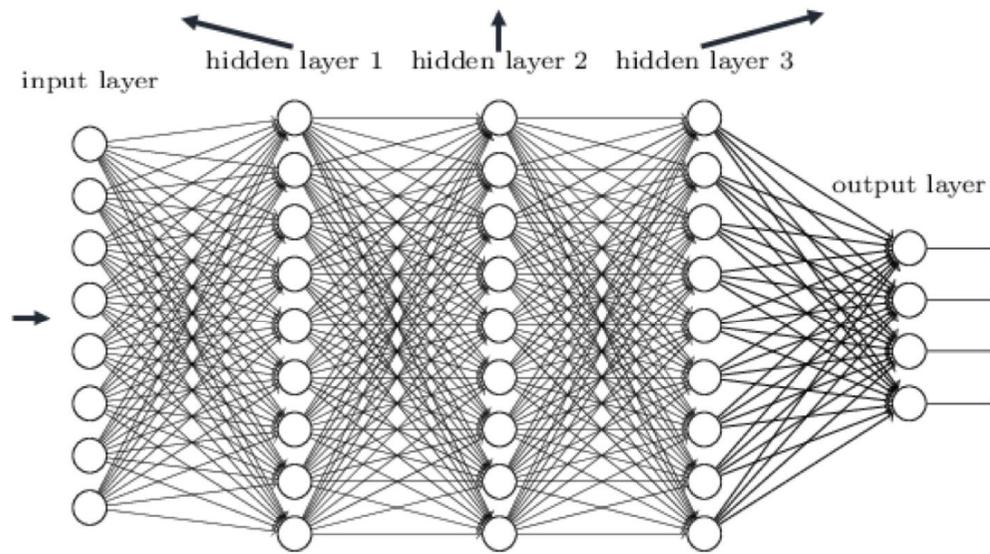
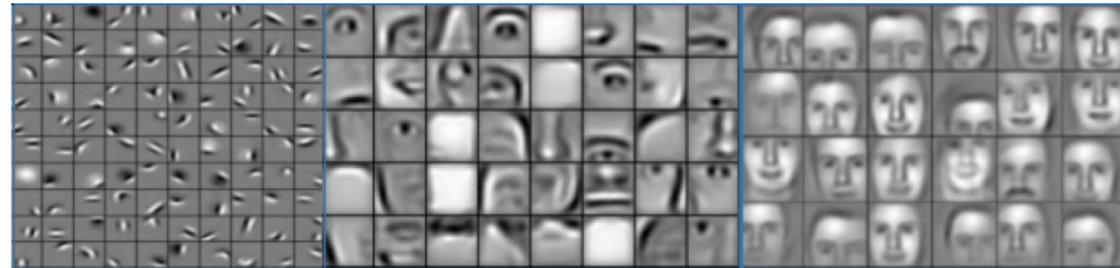


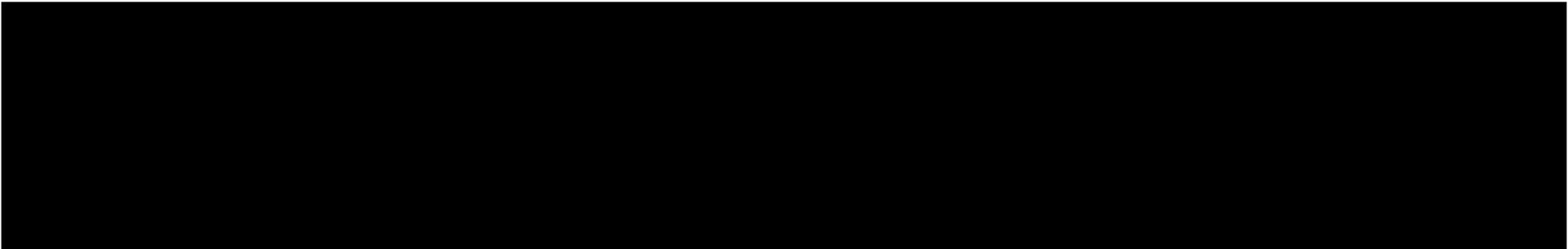
# Neural Networks

Multi Layer  
Perceptron



# Deep Neural Networks

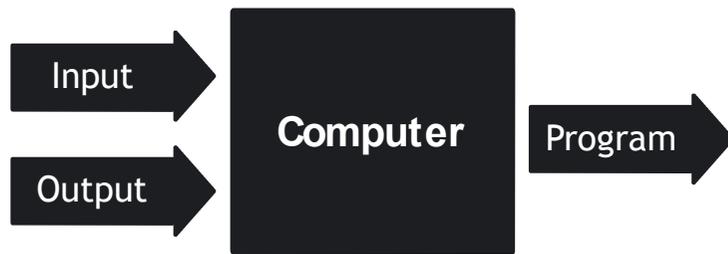




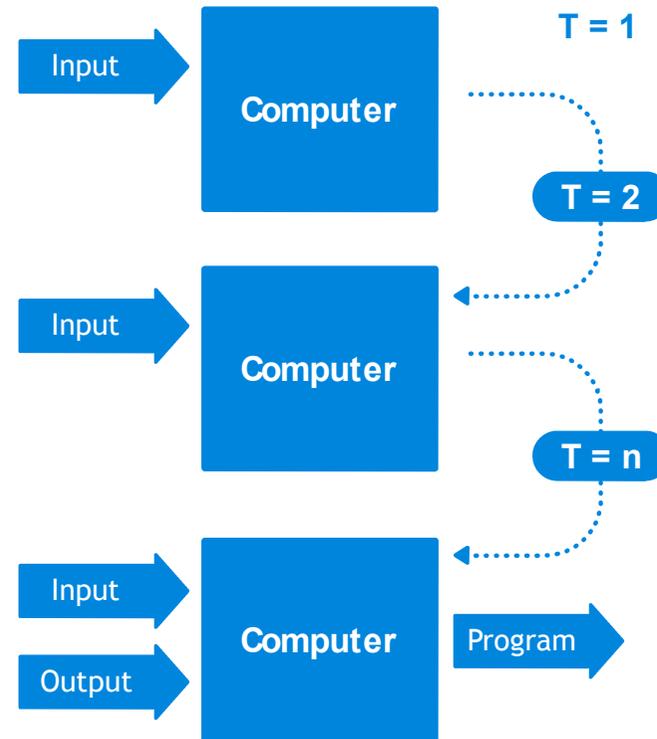
[www.cybercontrols.org](http://www.cybercontrols.org)

# More Machine Learning

Supervised Learning

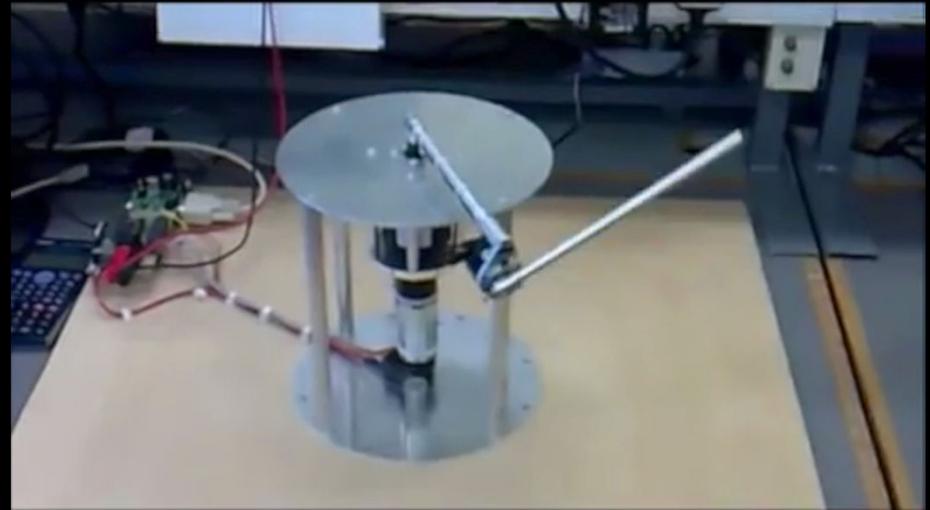
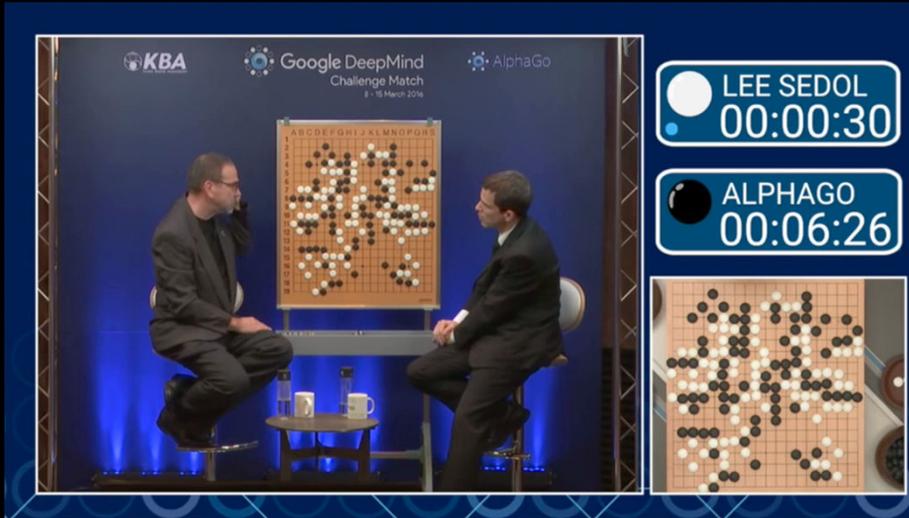


Reinforcement Learning



The image features a dark blue background with a network of glowing red nodes connected by thin, light-colored lines. The nodes are scattered across the frame, with a denser cluster in the upper-middle section. The text "Synthetic Minds" is centered in a bold, white, sans-serif font.

# Synthetic Minds



# Digital Minds

## Synthetic

Artificial Intelligence



## Natural

Whole brain simulation



# Digital Minds

## Synthetic

Artificial Intelligence



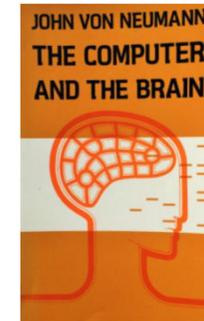
## Natural

Whole brain simulation



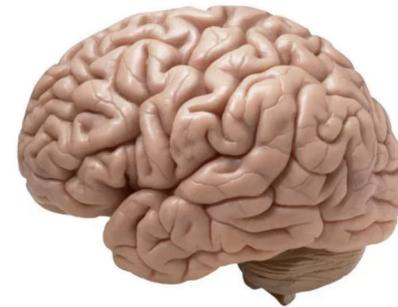
# Could a computer ever simulate the network of neurons in a human brain?

John von Neumann first compared the processing power of brains and computers



## Human Brain

- $\sim 10^{11}$  neurons (86 billion)
- $10^{14} - 10^{15}$  synapses (100-1000 trillion)
- $10^{-3}$  seconds (milliseconds)
- $\sim 10^{18}$  operations / second

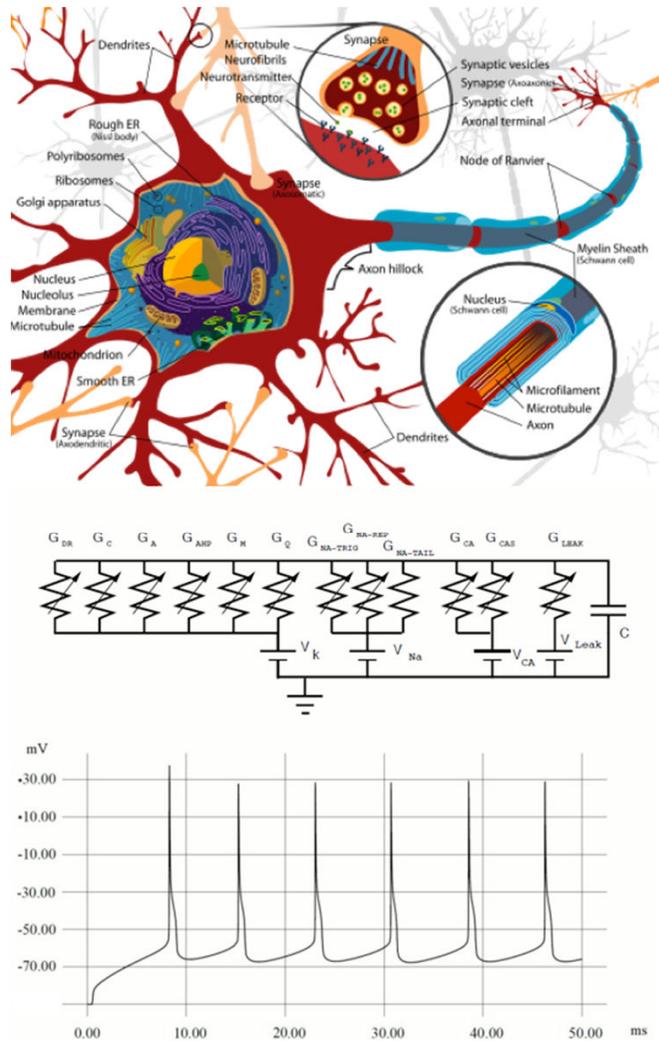


## Modern Processor: Intel Core i7

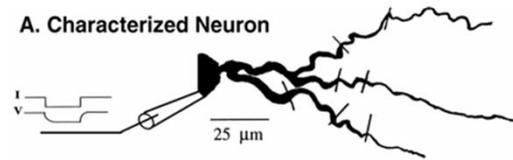
- $10^9$  transistors (1 billion)
- $10^{-9}$  seconds (nanoseconds)
- $\sim 10^{18}$  operations / second



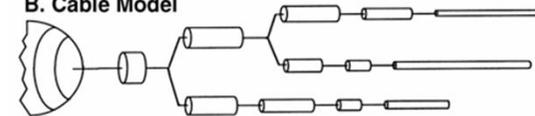
# Simulating Neurons



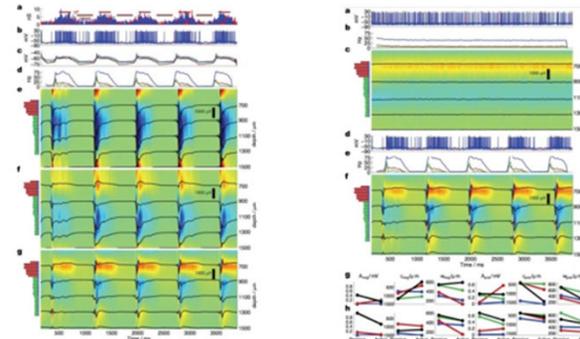
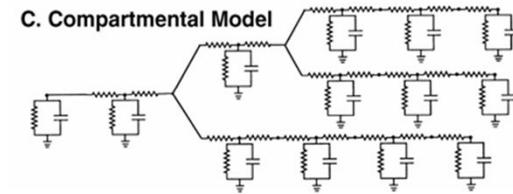
A. Characterized Neuron



B. Cable Model



C. Compartmental Model



Reimann et al. 2013. 12,000 neuron simulation

# Large Scale Simulations



## Blue Gene P Supercomputer

- 12,000 neurons
- 4096 cores
- 14 TFLOPS ( $1.4 \times 10^{13}$ )
- 3 hours for 4 seconds of one cortical column
- 2,700 times slower than real time



## Sunway TaihuLight

- 10,000,000 cores
- 93 PFLOPS ( $9.3 \times 10^{16}$ )
- 2 seconds for a cortical column
- 2 times faster than real time



## Scale up to a whole brain?

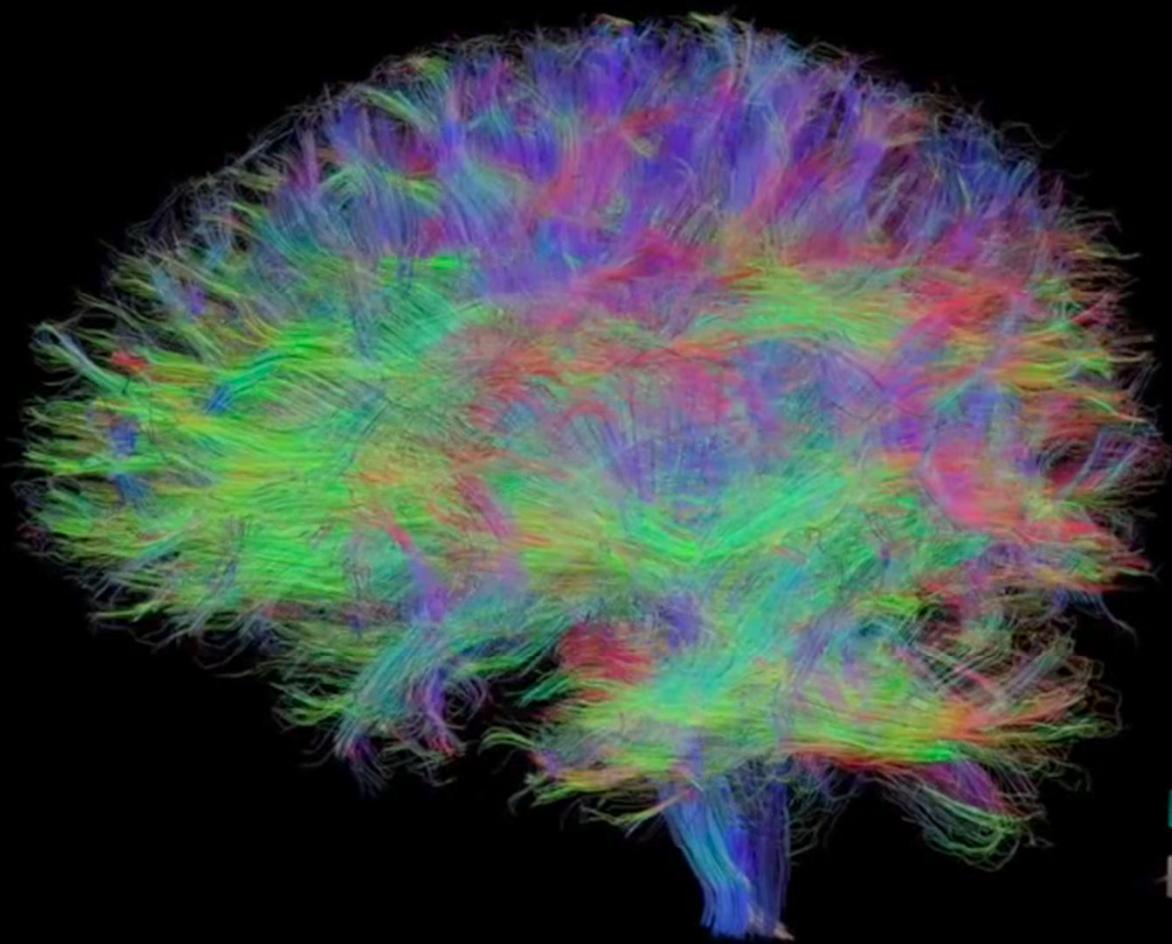
- 86 billion neurons
- 3 million times slower than real time
- 2 trillion times as much energy!



## Case closed? Maybe not.

- Hierarchical simulation
- Moore's law...
- Special purpose hardware
- EuroHPC initiative: 2 exascale by 2023

# Reverse Engineering the Brain



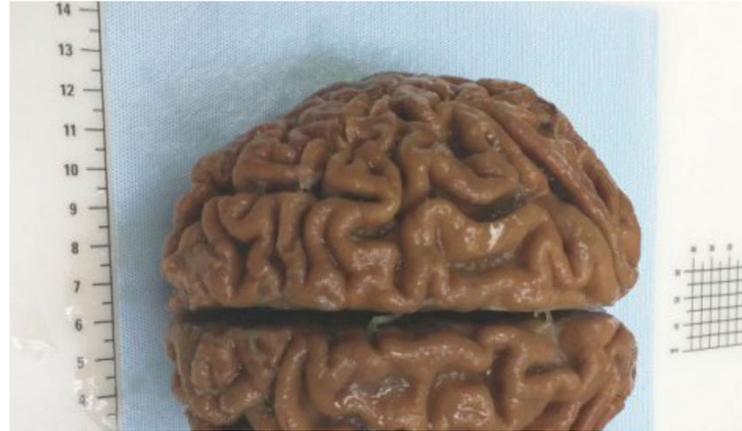
NEURO  
DOME

# Whole Brain Simulation

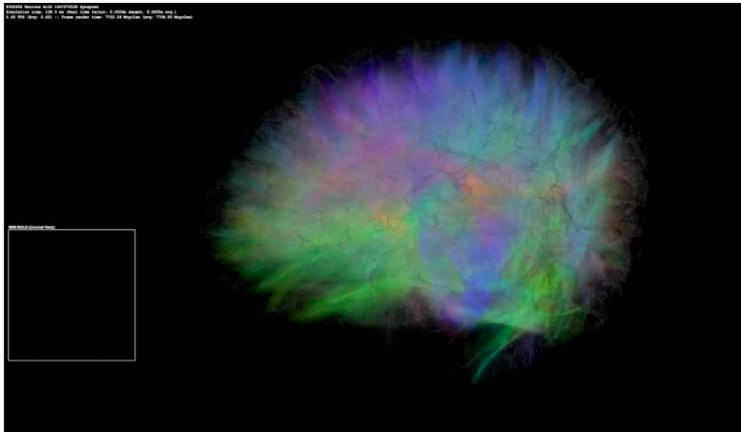
*Simulation of the 302 neurons of C. Elegans*



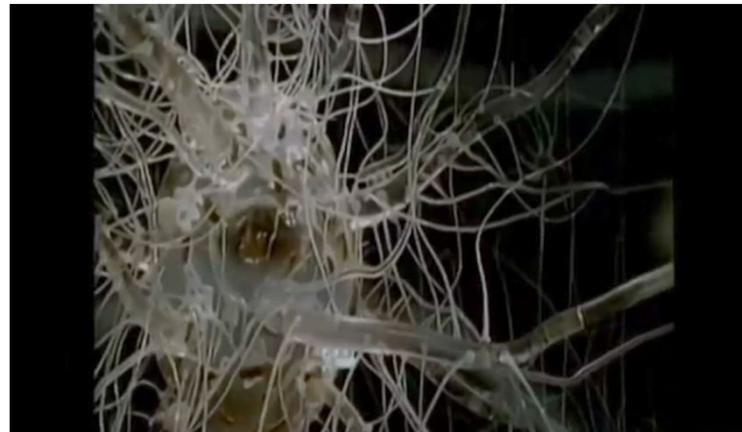
*Brain Preservation by Nectome – Y Combinator*



*Simulation of the mammal thalamocortical system*



*HBP – Simulation of a cortical column*



# Objections

- **The immortal soul objection:**  
Man is the sole owner of an immortal soul, and no machine can ever have one.
- **The consciousness objection:**  
Only humans can be conscious.
- **The technological impossibility objection:**  
It is outside the reach of human technology, forever.
- **The physical support objection:**  
Nervous systems are continuous, use quantum mechanics to function, are chaotic
- **The mathematical objection:**  
Brains are not Turing equivalent
- **Various disabilities objection**  
Cannot create anything new  
Cannot love or be loved  
Cannot feel pain or joy

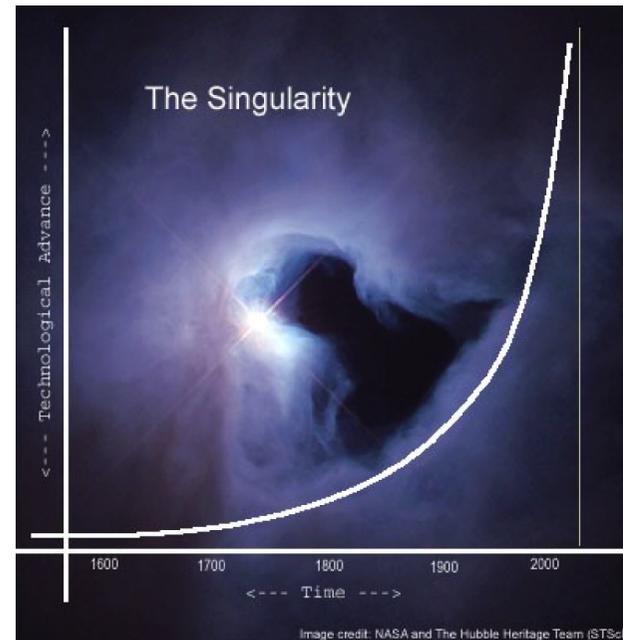
# Legal and Social Challenges

- “(...) whereas, ultimately, robots’ autonomy raises the question of their nature in the light of the existing legal categories - of whether **they should be regarded as natural persons, legal persons, animals or objects - or whether a new category should be created** (...)”
- “(...) creating a **specific legal status for robots**, so that at least the most sophisticated autonomous robots could be established as having the status of electronic persons with specific rights and obligations (...)”
- “(...) consideration should be given to the possible need to introduce corporate reporting requirements on the extent and proportion of the contribution of robotics and AI to the economic results of a company for the purpose of taxation and social security contributions; takes the view that **in the light of the possible effects on the labour market of robotics and AI a general basic income should be seriously considered**, and invites all Member States to do so; (...)”
- “(...) a system of registration of advanced robots should be introduced, and calls on the Commission to establish criteria for the classification of robots with a view to **identifying the robots that would need to be registered**; (...)”

# Speculations

“The ever-accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential **singularity** in the history of the race beyond which human affairs, as we know them, could not continue”

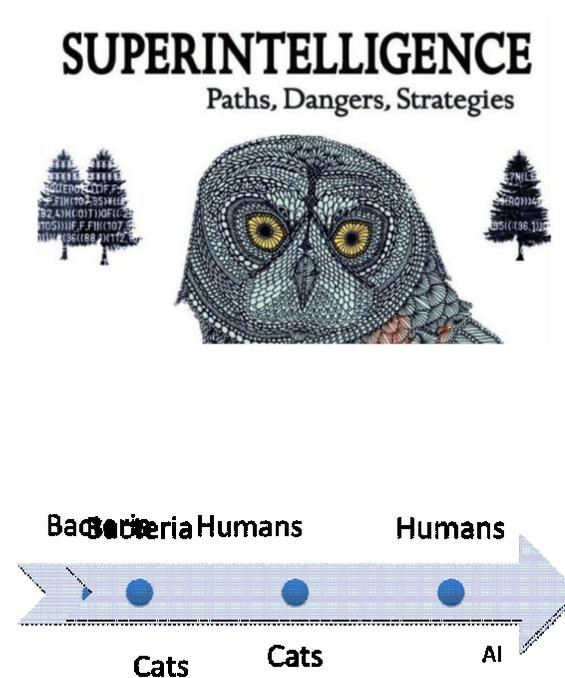
- Von Neuman, quoted by Stanislaw Ulam, 1952



# Speculations

Let an ultraintelligent machine be defined as a machine that can far surpass all the intellectual activities of any man however clever. Since the design of machines is one of these intellectual activities, an ultraintelligent machine could design even better machines; there would then unquestionably be an ‘intelligence explosion’, and the intelligence of man would be left far behind. Thus the first ultraintelligent machine is the **last invention** that man need ever make, provided that the machine is docile enough to tell us how to keep it under control.

- Irving John Good, 1965



# The Future of Intelligence

