

# An AI perspective on the Past, Present, and Future of Neuro-AI

Nasir Ahmad, Sander Keemink, Ahmed El-Gazzar

Today, an AI perspective on:

The history of “Neuro” “AI”



Today, an AI perspective on:

The history of “Neuro” “AI”

Neuroscience’s Impact on AI at Present



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The Future of (Neuro)Science and AI



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## **The history of “Neuro” “AI”**

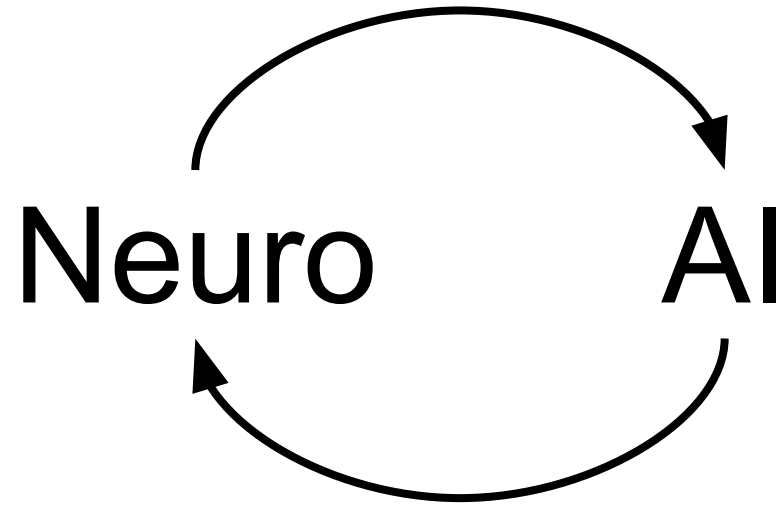
Neuroscience's Impact on AI at Present

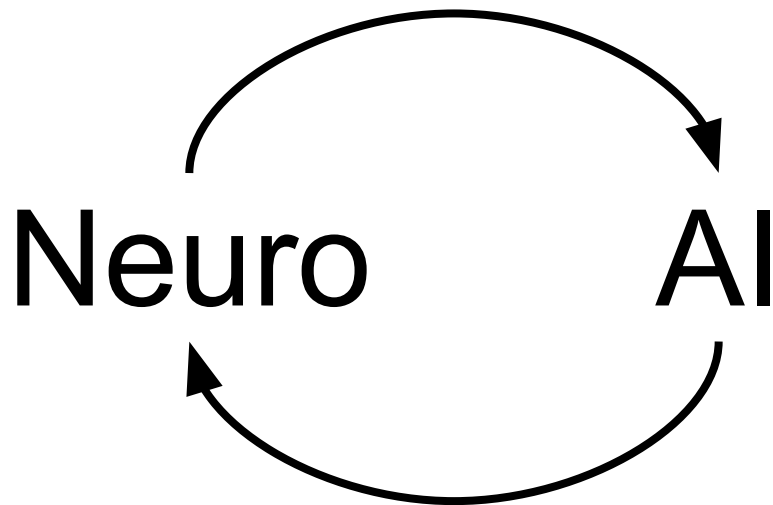
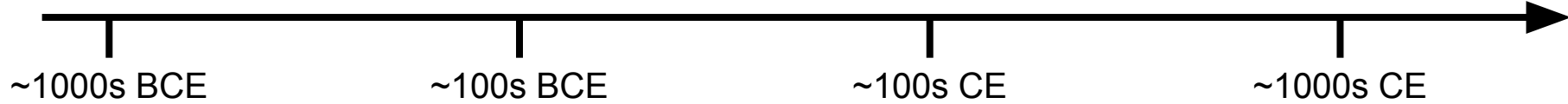
The Future of (Neuro)Science and AI

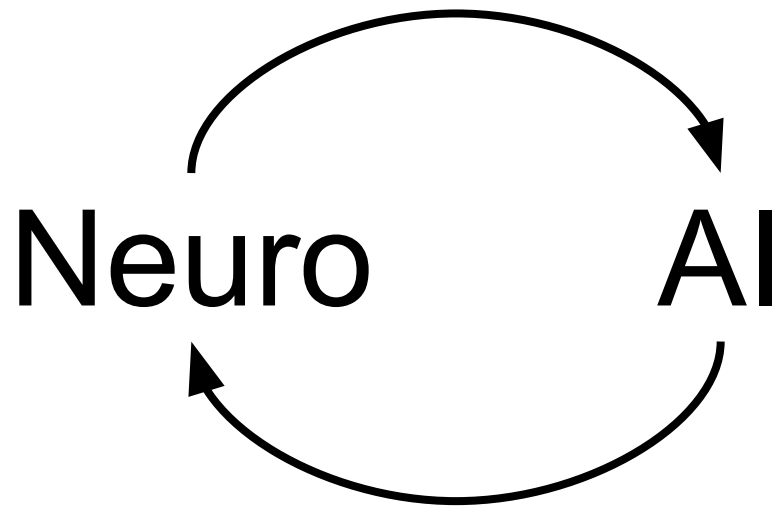
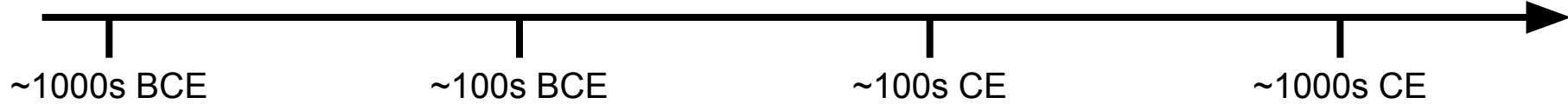


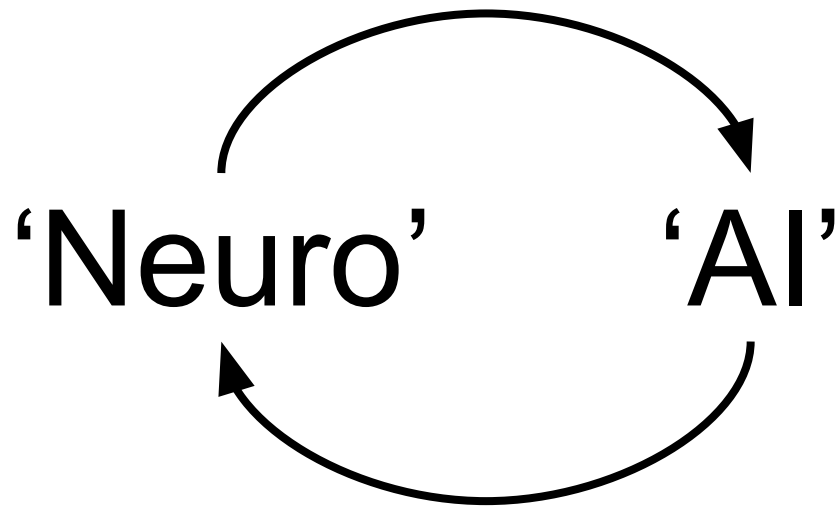
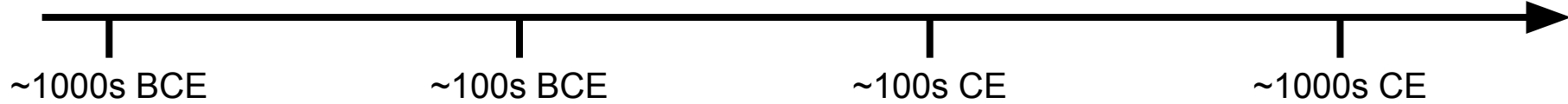
# Neuro AI











~1000s BCE

?

~100s BCE

~100s CE

~1000s CE

‘Neuro’

‘AI’



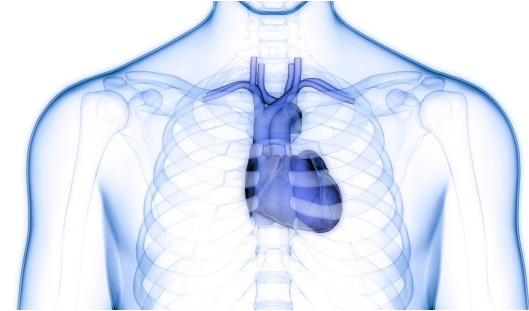
~1000s BCE

~100s BCE

~100s CE

~1000s CE

**“the role of the brain was seen as insignificant, being removed and discarded during the mummification procedures, while the heart was regarded as valuable, envisaged as the seat of consciousness and intelligence.”**



Engelhardt, E. (2018). Cerebral localization of the mind and higher functions The beginnings. *Dementia & Neuropsychologia*, 12, 321–325.  
<https://doi.org/10.1590/1980-57642018dn12-030014>

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~1000s BCE

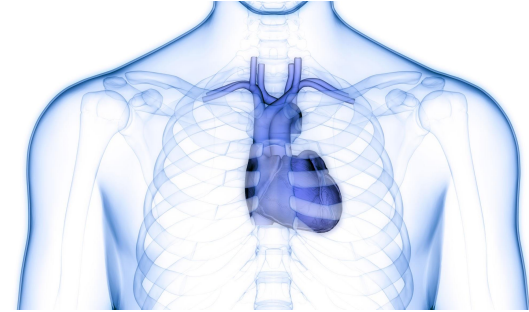
~100s BCE

~100s CE

~1000s CE

**“the role of the brain was seen as insignificant, being removed and discarded during the mummification procedures, while the heart was regarded as valuable, envisaged as the seat of consciousness and intelligence.”**

“A long hiatus followed, and ancient Greek sages, going back to Homer’s time (ca. 900 years BC), took up the theme. The seat of the soul [mind] divided them - **many regarded the heart as the principal organ of the mind (“cardiocentric” doctrine), while others saw the brain as the fundamental organ (“cephalocentric” or “cerebrocentric” doctrine).**”

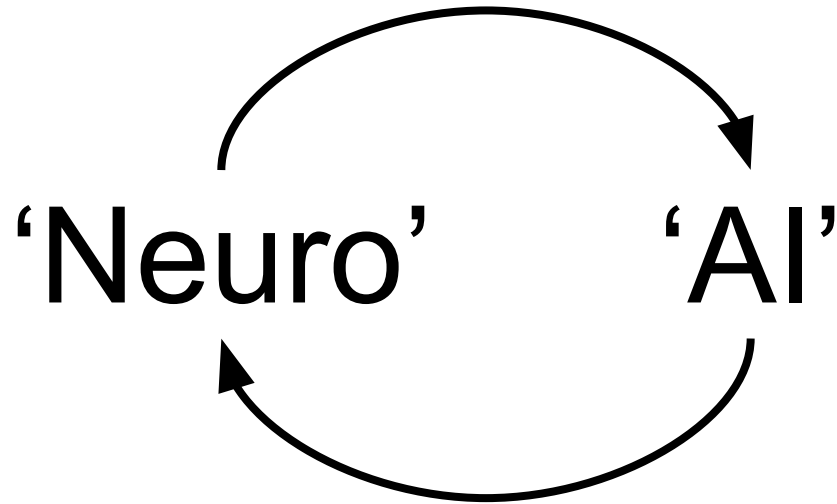


~1000s BCE

~100s BCE

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~1000s CE

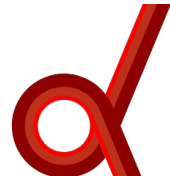
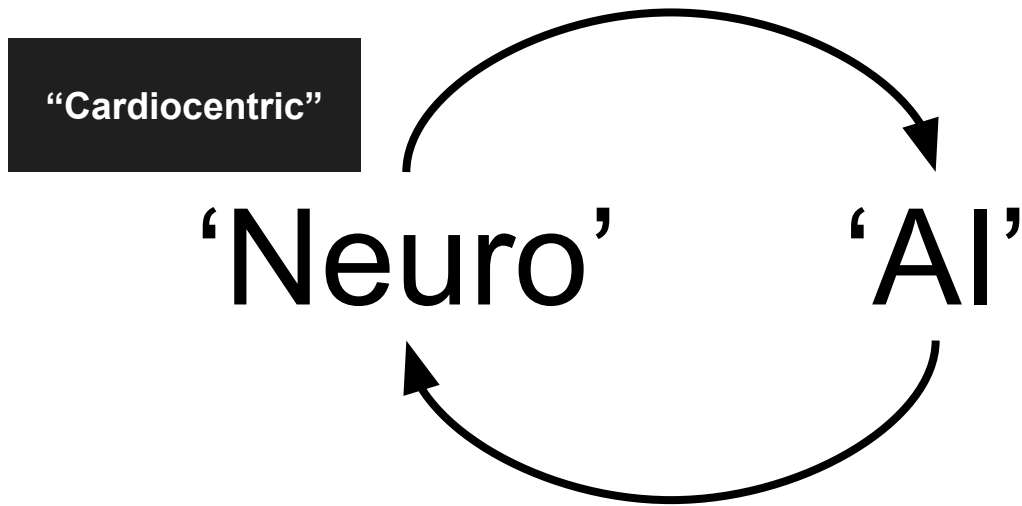


~1000s BCE

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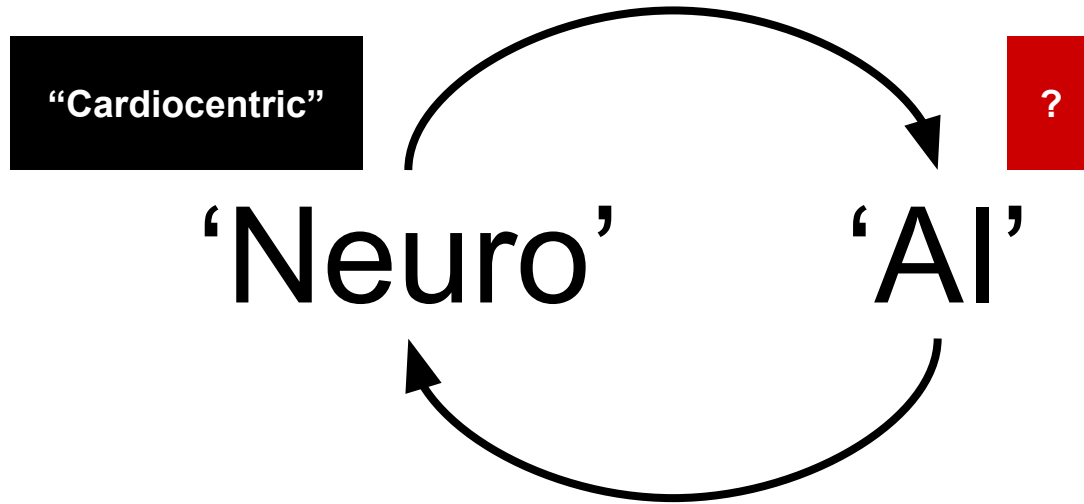


~1000s BCE

~100s BCE

~100s CE

~1000s CE



~1000s BCE

~100s BCE

~100s CE

~1000s CE

Then he [Hephaestus] pulled on a tunic and came limping out, gripping a sturdy staff. At once he was helped along by female **servants made of gold, who moved to him. They look like living servant girls, possessing minds, hearts with intelligence, vocal chords, and strength. They learned to work from the immortal gods.**

Homer's Iliad (Book 18)

<https://johnstoniatexts.x10host.com/homer/iliad18.htm>



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~100s BCE

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**Cardio-Neuro AI-Mythology?**



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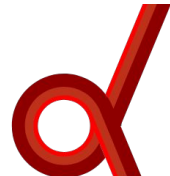
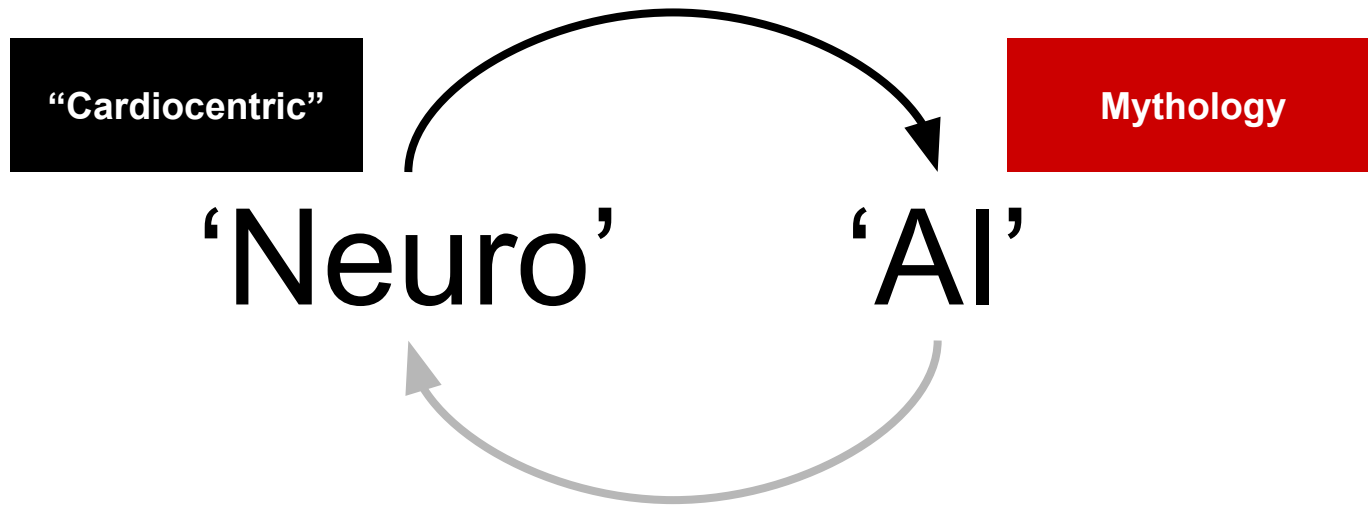


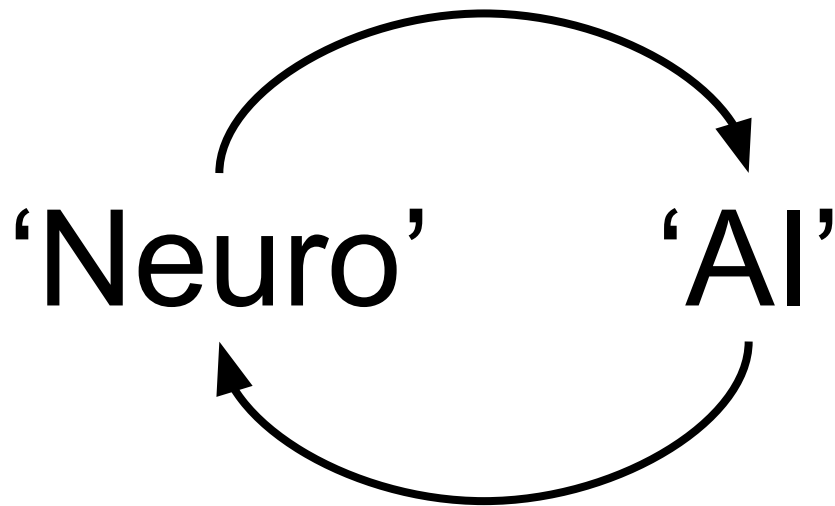
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~100s BCE

~100s CE

~1000s CE





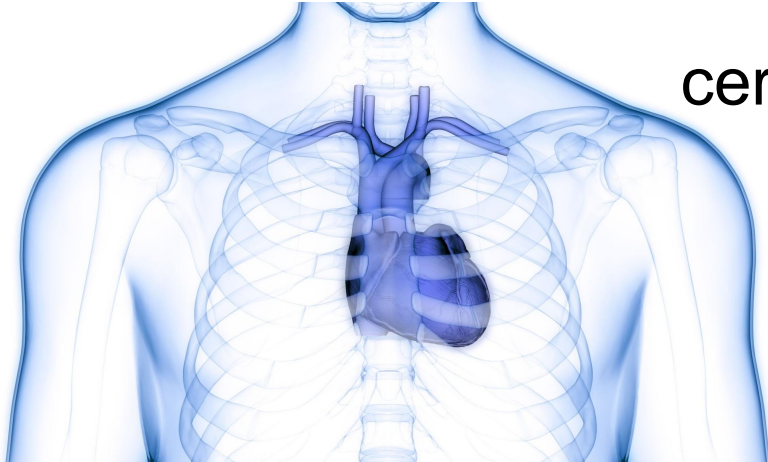
~1000s BCE

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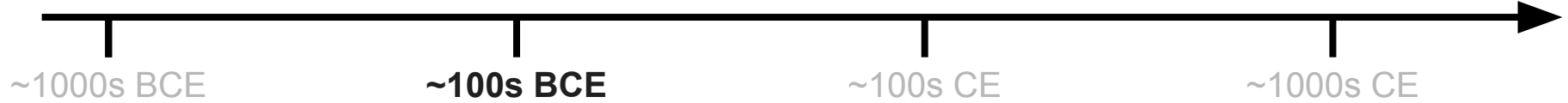
cardiocentrism  
vs  
cereberocentrism





**According to Aristotle, the soul is defined as the substance or the form of a living body [4]. It is indeed the primary cause of living, perceiving and thinking.** He distinguished different soul faculties [4]. The vegetative or nourishing soul belongs to both plants and animals. Sensitive and motor souls pertain only to animal. The intellectual soul (nous) is limited to man. **All soul faculties reside in the heart.** Only the nous is immaterial. Thus the heart occupies the uppermost place in Aristotle's psychological and physiological hierarchy.

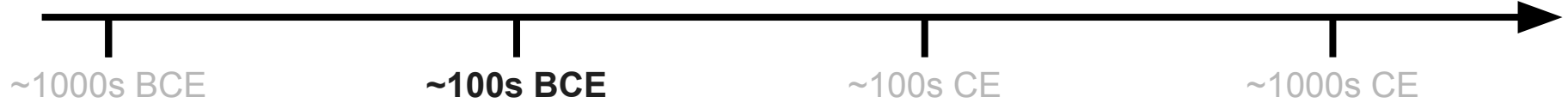




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**Plato (427–347 B.C.E.) supported the concept of the primacy of the brain as the organ of the rational soul.** The most complete formulation of Plato's theory of human soul (psychē) is to be found in Timaeus. According to Plato's view, there are three soul species in the human body. Only the first one was qualified as “immortal” and “divine”, the logos. It was called “the imperishable principle of the deathly animal” [34,35]. **This soul was recognized to be bound to “the head, which is the most divine part and dominates over the rest [of the body] in us. And the gods gave to this part also the whole body as servant” [34,35].**



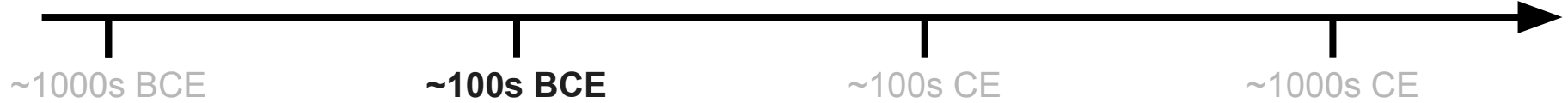


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**So how was this resolved?**

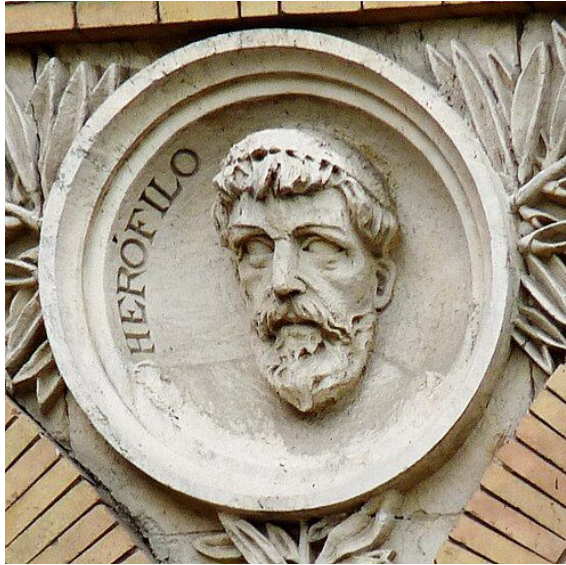


~1000s BCE

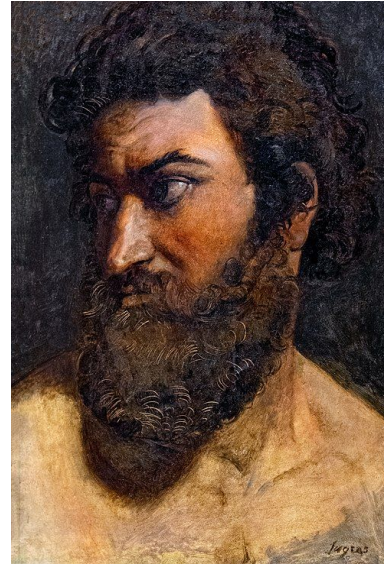
~100s BCE

~100s CE

~1000s CE



<https://en.wikipedia.org/wiki/Herophilus>



<https://en.wikipedia.org/wiki/Erasistratus>

**Enter Herophilos and Erasistratus!  
(+ later Galen)**

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~1000s BCE

~100s BCE

~100s CE

~1000s CE



<https://en.wikipedia.org/wiki/Herophilos>



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**Began Neuroanatomy!**

**Enter Herophilos and Erasistratus!  
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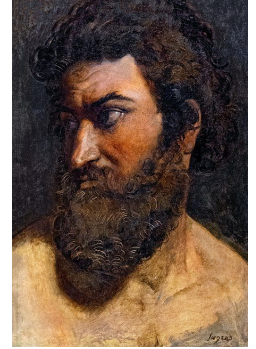
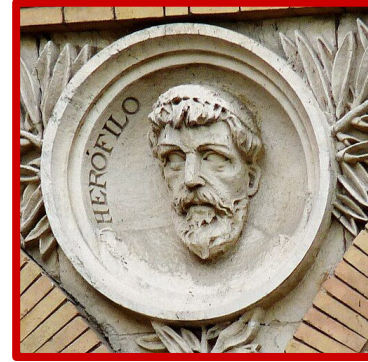
~1000s BCE

~100s BCE

~100s CE

~1000s CE

**Herophilus identified nerves (including cranial nerves) and found that nerves connect the body with the brain. He further discovered the existence of motor and sensory nerves, and realised that motor nerves originate either in the brain or in the spinal cord.**



~1000s BCE

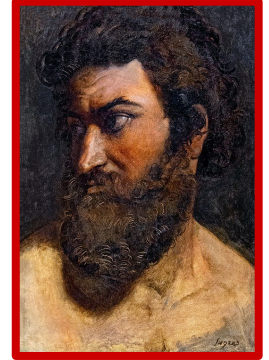
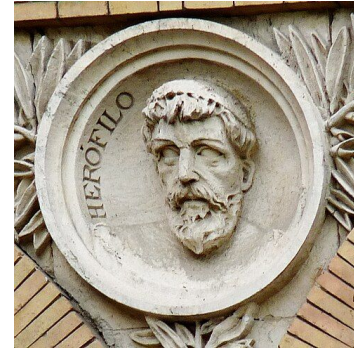
~100s BCE

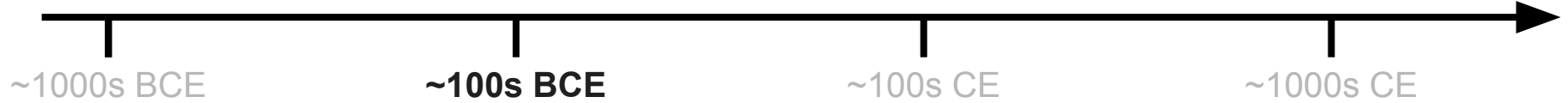
~100s CE

~1000s CE

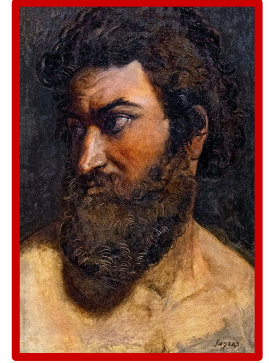
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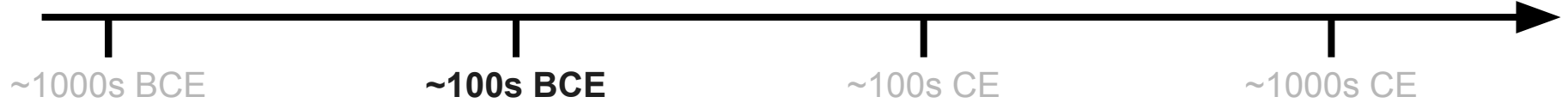
Erasistratus [...] was the first to find the direct relations between complexity of the brain and human intelligence [1,6,7,8]. **Erasistratus was also the first to outline the principles of the ventricular-pneumatic theory of brain function.**





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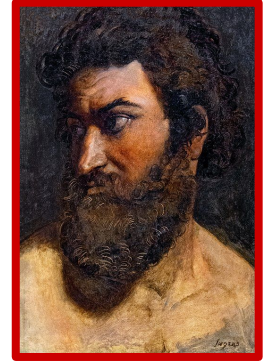


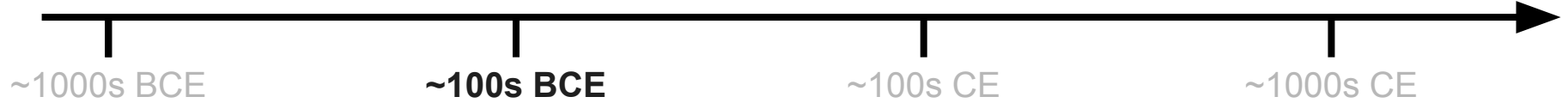


“Erasistratus was also the first to outline the principles of **the ventricular-pneumatic theory of brain function**.

**According to this theory, there are several classes of pneuma; the first type, the vital pneuma, is produced in the lungs from the inhaled air;** this vital pneuma is subsequently distributed throughout the body by blood vessels, the vital pneuma diffuses to the tissues and sustains their life.

**The brain parenchyma converts the vital pneuma into the psychic pneuma, which is concentrated in the ventricles.”**

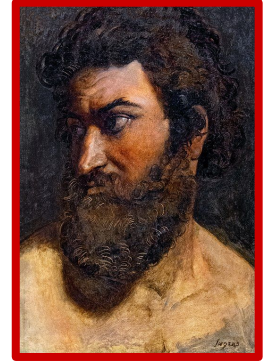




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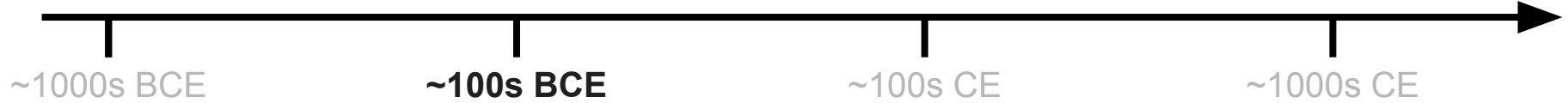
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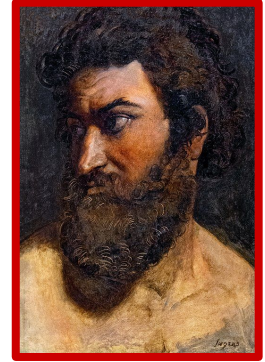
**Psychic pneuma = “animal spirit”**





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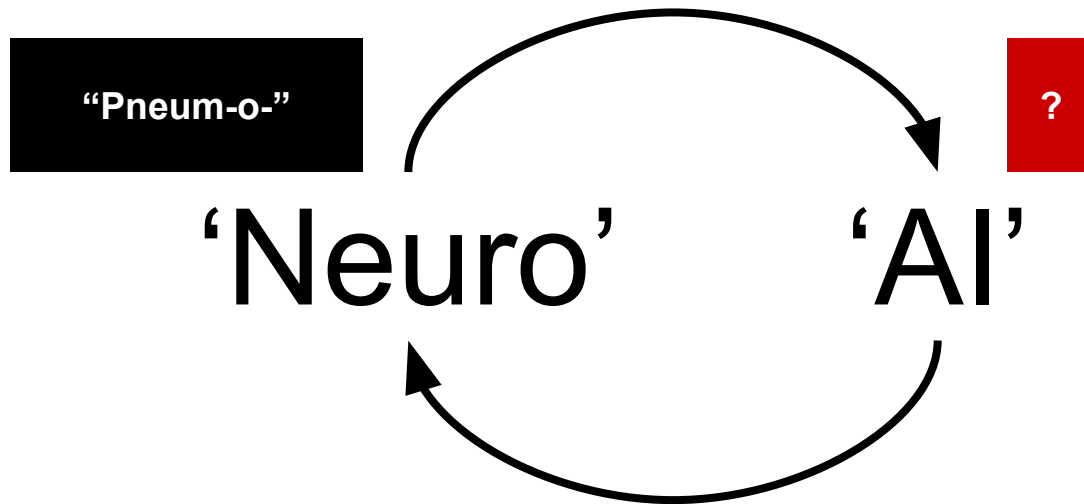


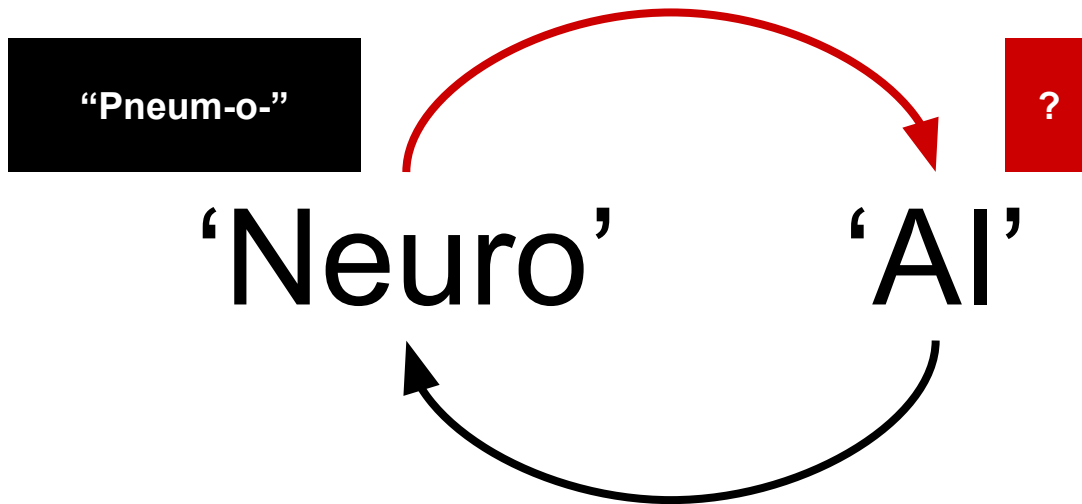
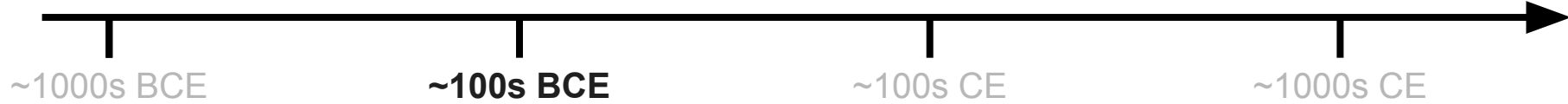
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**Psychic pneuma = “animal spirit”**

**How did this interact with ‘AI’?**





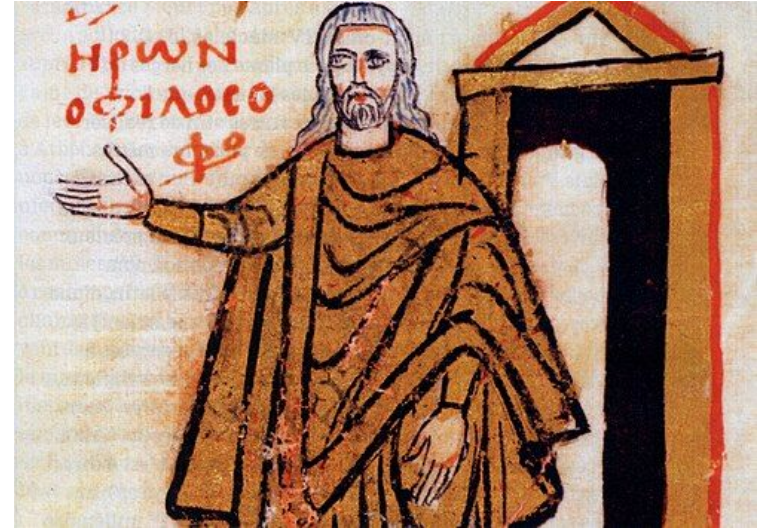


~1000s BCE

~100s BCE

~100s CE

~1000s CE



Hero of Alexandria

[https://en.wikipedia.org/wiki/Hero\\_of\\_Alexandria#/media/File:Heron\\_Alexandrie.jpg](https://en.wikipedia.org/wiki/Hero_of_Alexandria#/media/File:Heron_Alexandrie.jpg)

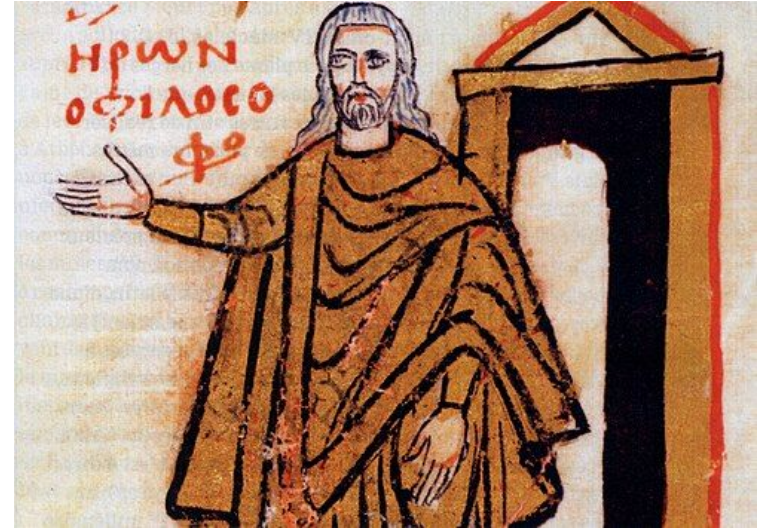
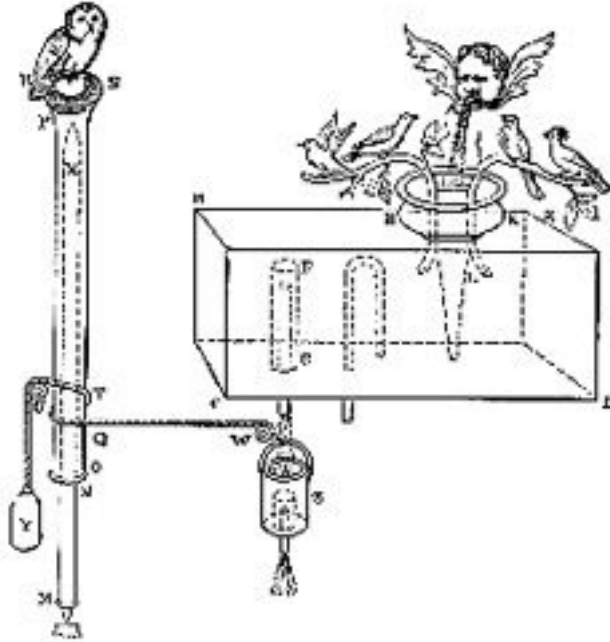


~1000s BCE

~100s BCE

~100s CE

~1000s CE



Hero of Alexandria

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<https://www.smithsonianmag.com/arts-culture/a-brief-history-of-robot-birds-77235415/>

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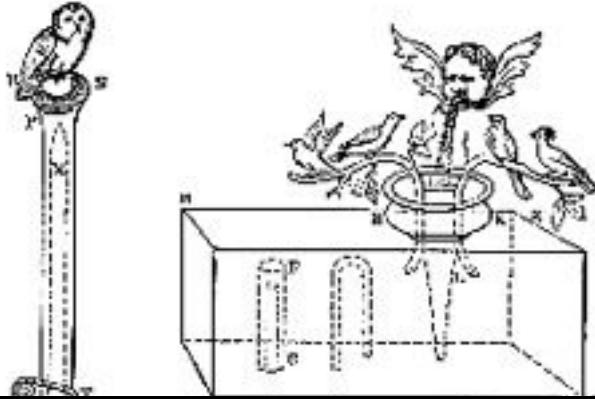


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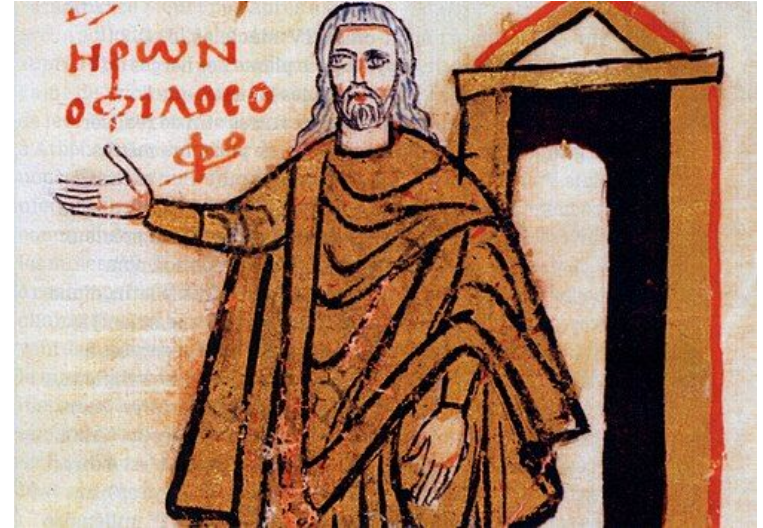
~100s BCE

~100s CE

~1000s CE



**“Singing Birds” using pneumatics!**



**Hero of Alexandria**

[https://en.wikipedia.org/wiki/Hero\\_of\\_Alexandria#/media/File:Heron\\_Alexandrie.jpg](https://en.wikipedia.org/wiki/Hero_of_Alexandria#/media/File:Heron_Alexandrie.jpg)

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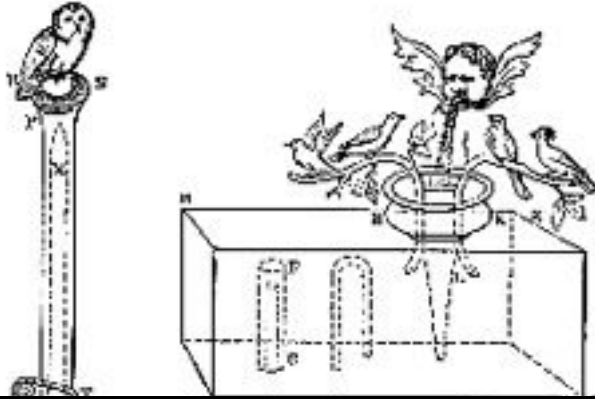


~1000s BCE

~100s BCE

~100s CE

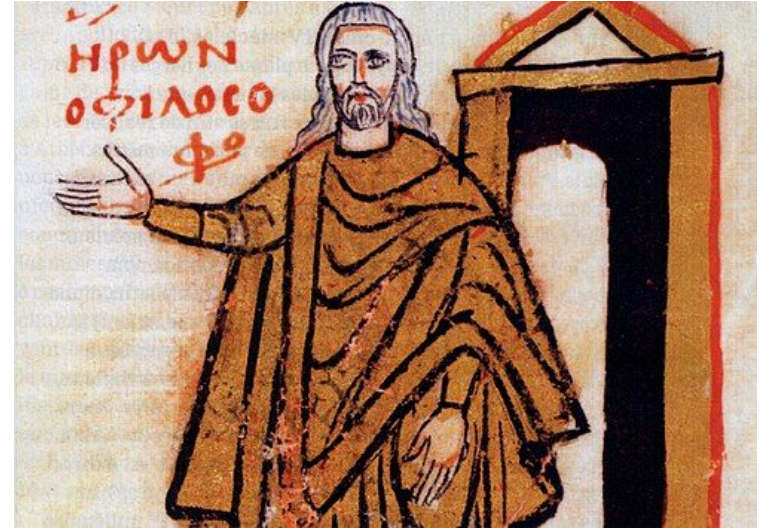
~1000s CE



**“Singing Birds” using pneumatics!**

**But is this an entirely fair causal chain?**

<https://www.smithsonianmag.com/arts-culture/a-brief-history-of-robot-birds-77235415/>

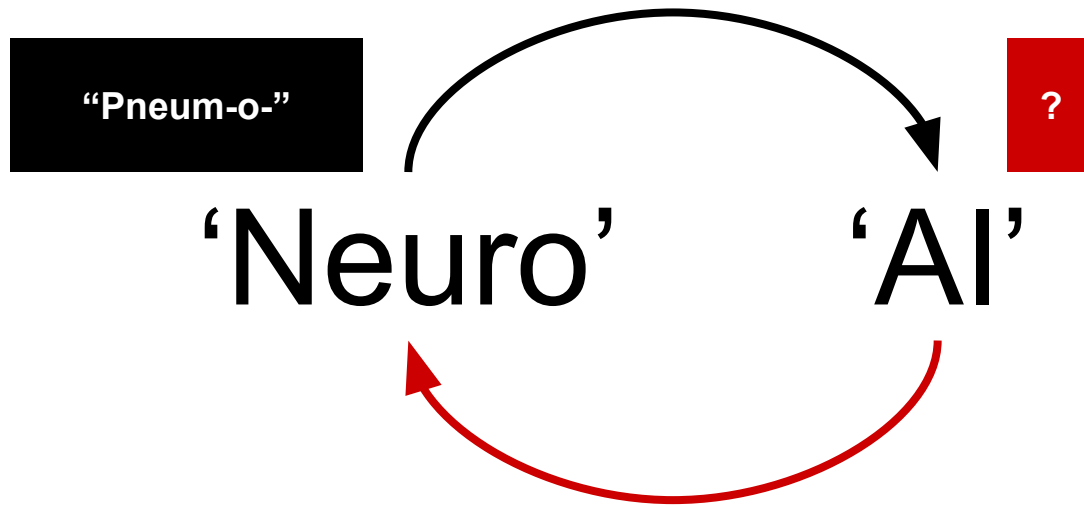


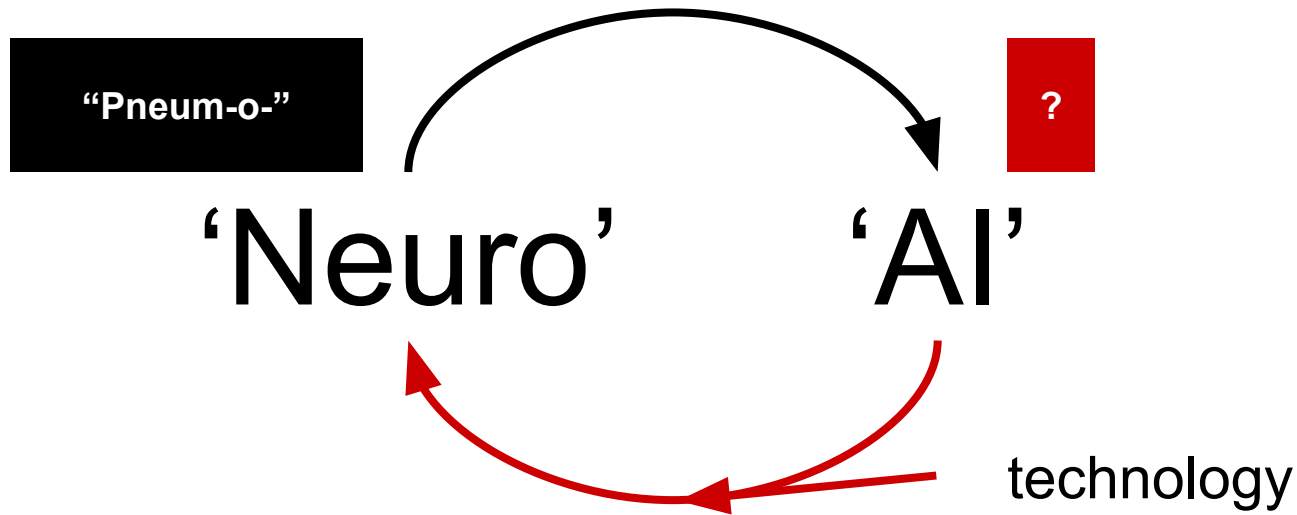
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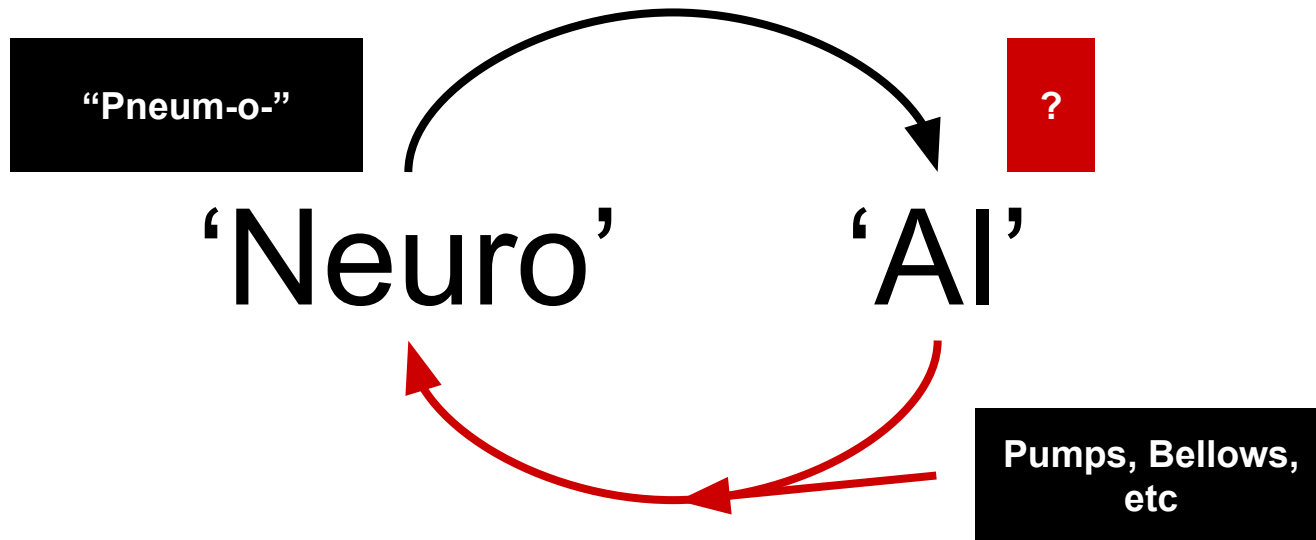
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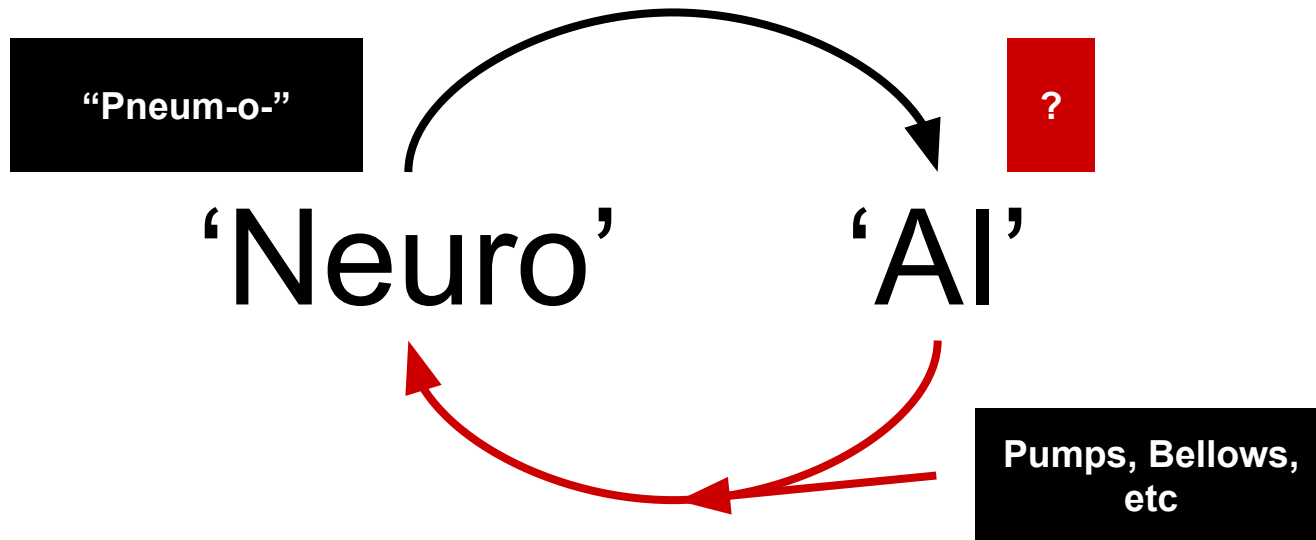
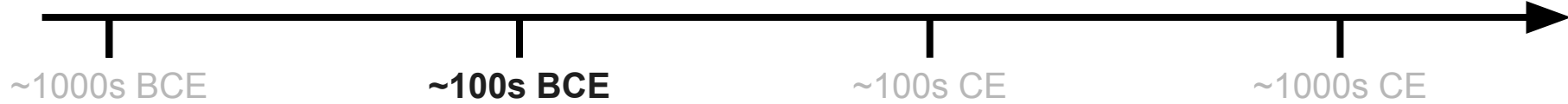
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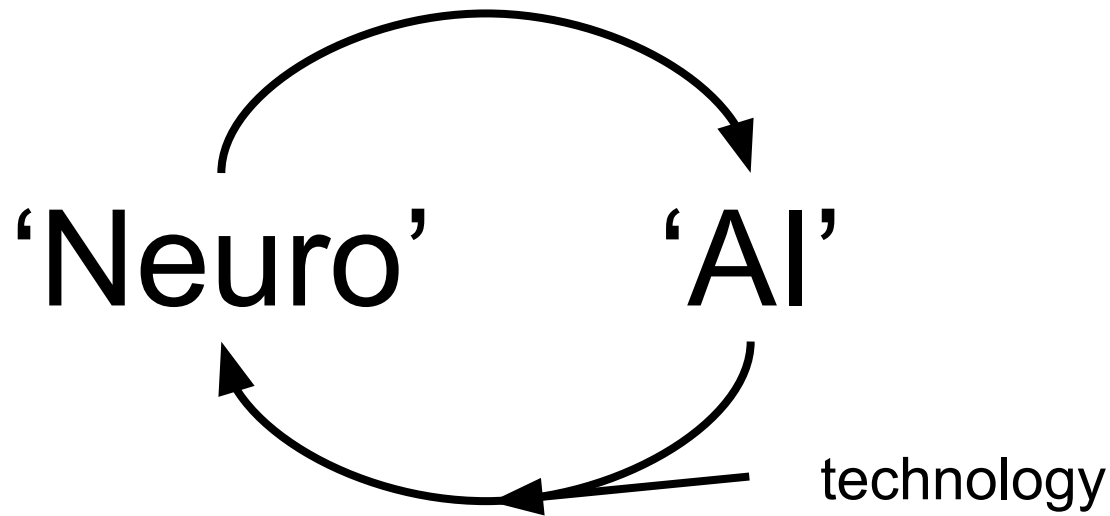






Is this a pattern of interaction?





~1000s BCE

~100s BCE

~100s CE

~1000s CE

“Hydraulic-”

‘Neuro’

‘AI’

Pressure  
Regulators etc

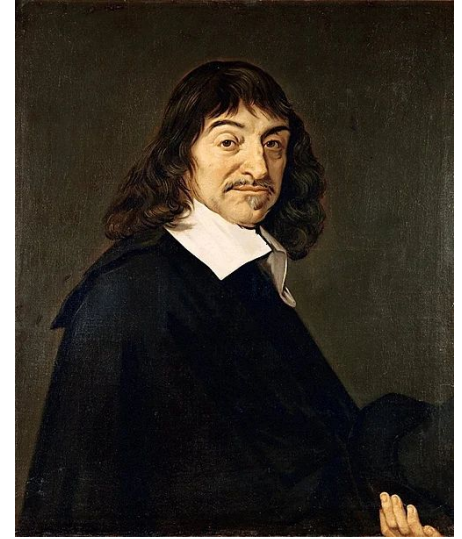


~1000s BCE

~100s BCE

~100s CE

~1000s CE



Renee Descartes

[https://nds-nl.wikipedia.org/wiki/Ren%C3%A9\\_Descartes#/media/Bestaand:Frans\\_Hals\\_-\\_Portret\\_van\\_Ren%C3%A9\\_Descartes.jpg](https://nds-nl.wikipedia.org/wiki/Ren%C3%A9_Descartes#/media/Bestaand:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg)



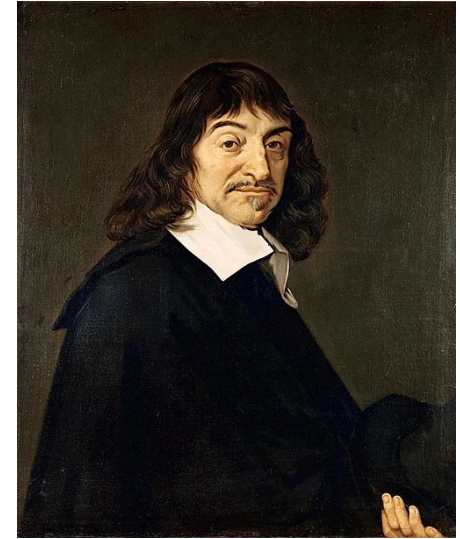
~1000s BCE

~100s BCE

~100s CE

~1000s CE

Regarding the functional aspect, **he devised the brain as a machine, with a fluid, the animal spirits, flowing inside tubes, a hydraulic device.** Such way of thinking may be understood, i.e., the application of physics and its rules, one of the cherished subjects of his studies, to the mechanisms of the animal body functioning [...]



Renee Descartes

[https://nds-nl.wikipedia.org/wiki/Ren%C3%A9\\_Descartes#/media/Bestaand:Frans\\_Hals\\_-\\_Portret\\_van\\_Ren%C3%A9\\_Descartes.jpg](https://nds-nl.wikipedia.org/wiki/Ren%C3%A9_Descartes#/media/Bestaand:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg)



~1000s BCE

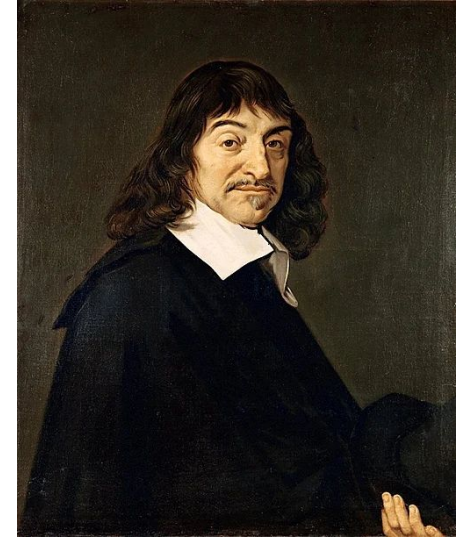
~100s BCE

~100s CE

~1000s CE

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**The pineal gland is especially important in Descartes' project. There is lodged the main part of the soul ("rational soul") [mind], source of all thoughts and wills (volitions, motivations, wishes), as well as the common sense and imagination.** The gland centralizes most activities through its movements, directing the spirits that it releases to different parts of the brain, as necessary.



Renee Descartes

[https://nds-nl.wikipedia.org/wiki/Ren%C3%A9\\_Descartes#/media/Bestaand:Frans\\_Hals\\_-\\_Portret\\_van\\_Ren%C3%A9\\_Descartes.jpg](https://nds-nl.wikipedia.org/wiki/Ren%C3%A9_Descartes#/media/Bestaand:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg)



~1000s BCE

~100s BCE

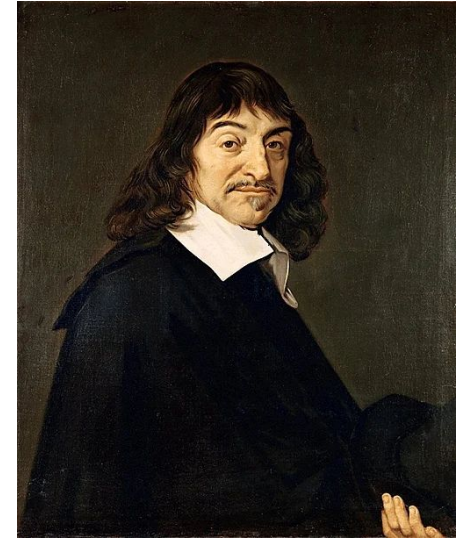
~100s CE

~1000s CE

Regarding the functional aspect, **he devised the brain as a machine, with a fluid, the animal spirits, flowing inside tubes, a hydraulic device.** Such way of thinking may be understood, i.e., the application of physics and its rules, one of the cherished subjects of his studies, to the mechanisms of the animal body functioning [...]

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**Hydraulic system with a pressure regulator!**



Renee Descartes

[https://nds-nl.wikipedia.org/wiki/Ren%C3%A9\\_Descartes#/media/Bestaand:Frans\\_Hals\\_-\\_Portret\\_van\\_Ren%C3%A9\\_Descartes.jpg](https://nds-nl.wikipedia.org/wiki/Ren%C3%A9_Descartes#/media/Bestaand:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg)



~1000s BCE

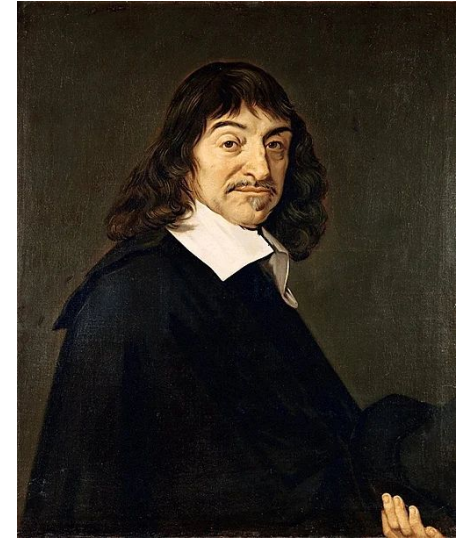
~100s BCE

~100s CE

~1000s CE



<https://www.metmuseum.org/art/collection/search/697113>

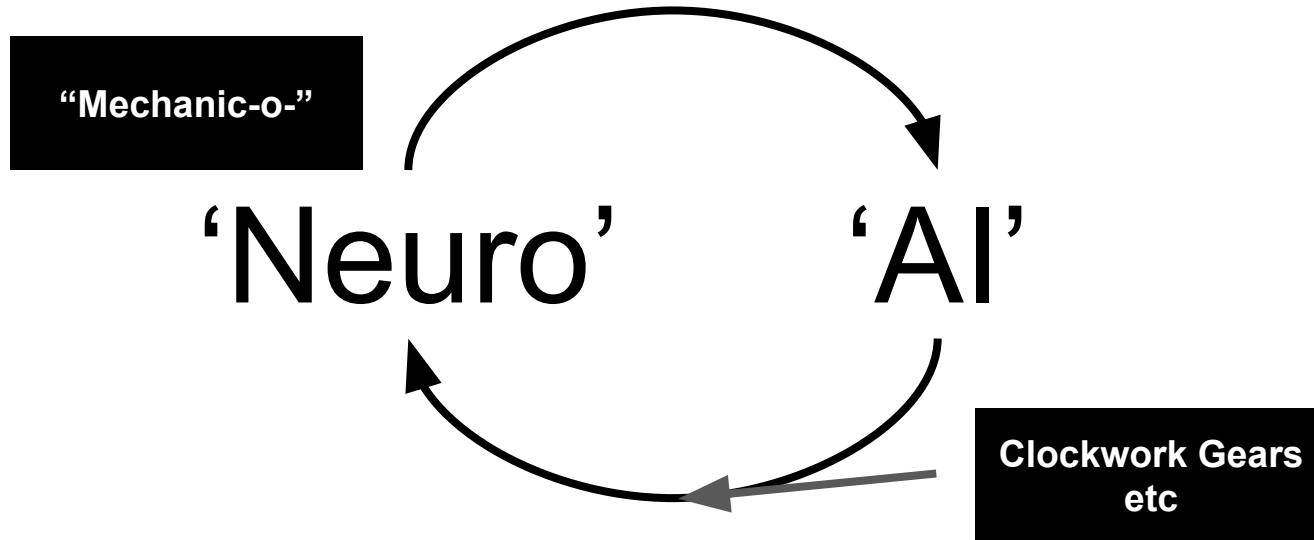


Renee Descartes

[https://nds-nl.wikipedia.org/wiki/Ren%C3%A9\\_Descartes#/media/Bestaand:Frans\\_Hals\\_-\\_Portret\\_van\\_Ren%C3%A9\\_Descartes.jpg](https://nds-nl.wikipedia.org/wiki/Ren%C3%A9_Descartes#/media/Bestaand:Frans_Hals_-_Portret_van_Ren%C3%A9_Descartes.jpg)

nasir.ahmad@donders.ru.nl



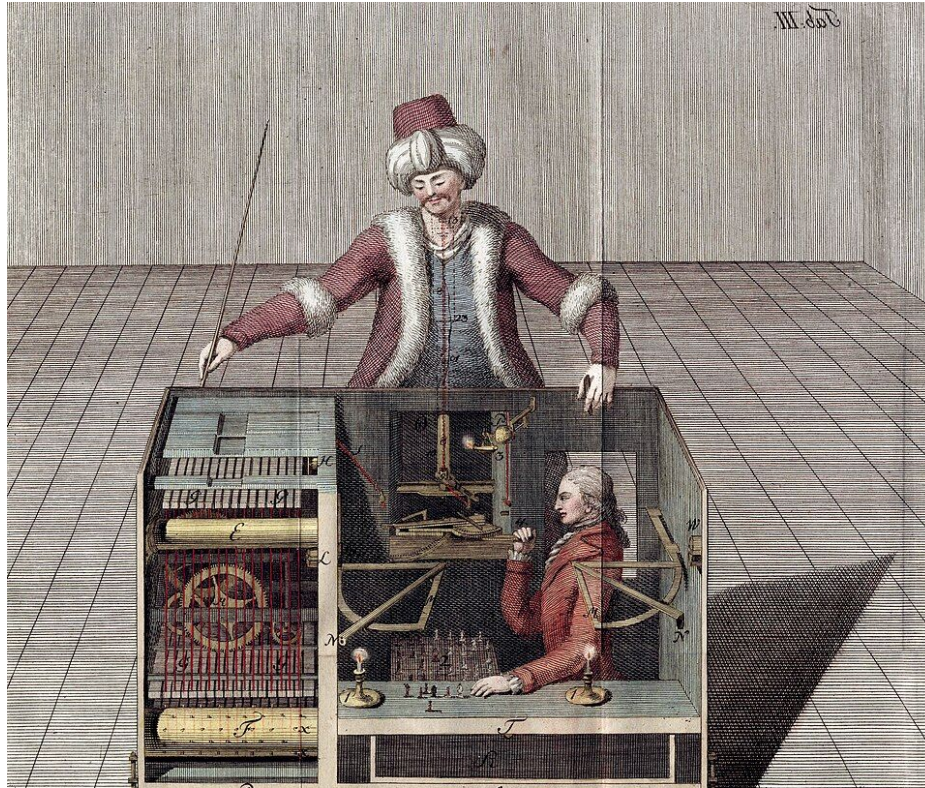


~1000s BCE

~100s BCE

~100s CE

~1000s CE



Standage, Tom (2002). The Turk: The Life and Times of the Famous Eighteenth-Century Chess-Playing Machine. New York: Walker. ISBN 978-0-8027-1391-9.

## The 'Mechanical' Turk

ad@donders.ru.nl

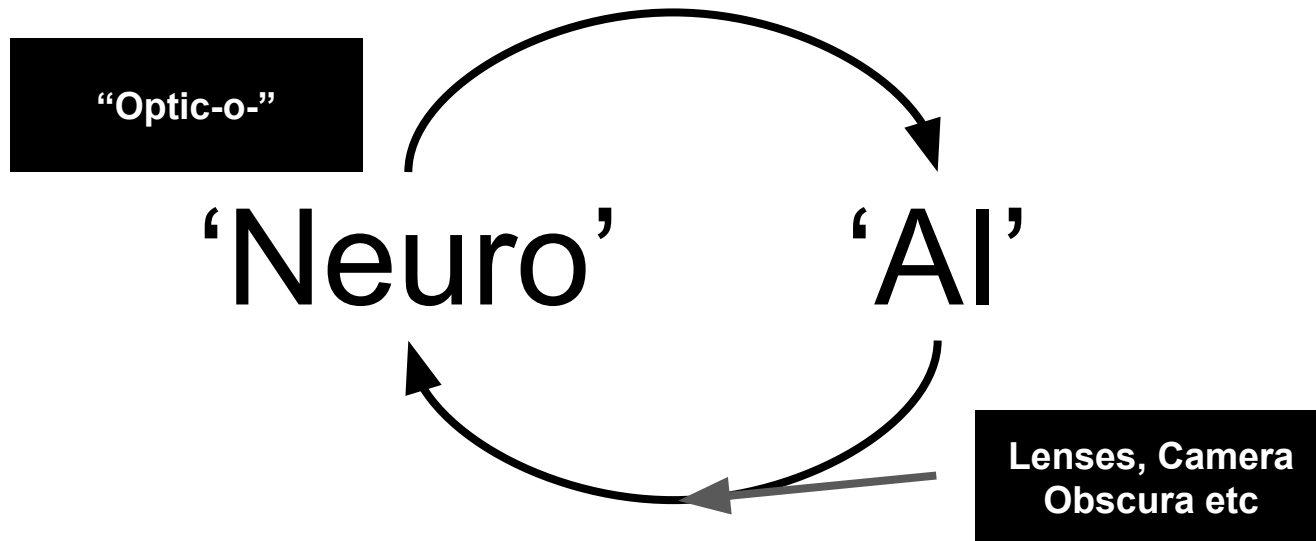


~1000s BCE

~100s BCE

~100s CE

~1000s CE

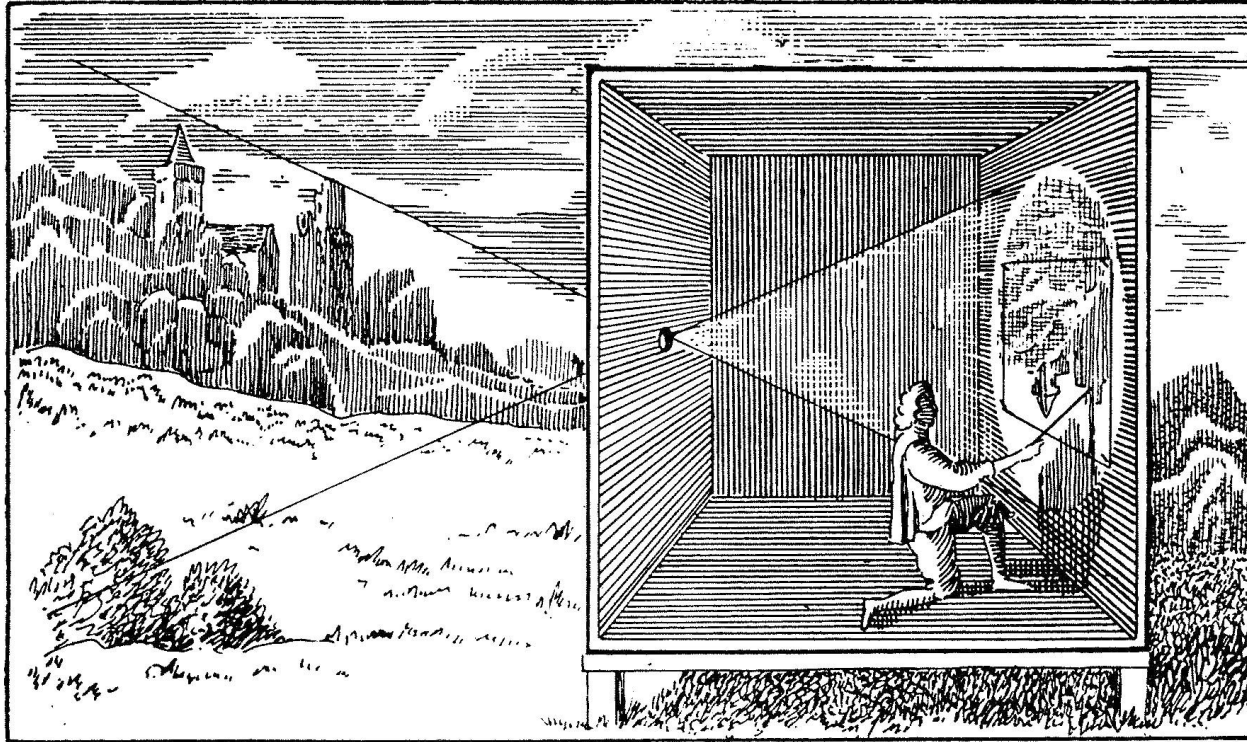


~1000s BCE

~100s BCE

~100s CE

~1000s CE



<https://bigdanzblog.wordpress.com/2013/10/27/camera-obscura/>

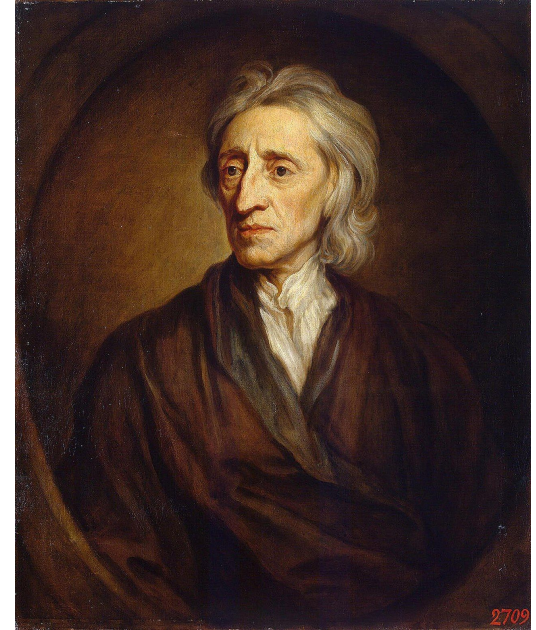


~1000s BCE

~100s BCE

~100s CE

~1000s CE



John Locke

[https://en.wikipedia.org/wiki/John\\_Locke#/media/File:Godfrey\\_Kneller\\_-\\_Portrait\\_of\\_John\\_Locke\\_\(Hermitage\).jpg](https://en.wikipedia.org/wiki/John_Locke#/media/File:Godfrey_Kneller_-_Portrait_of_John_Locke_(Hermitage).jpg)

nasir.ahmad@donders.ru.nl



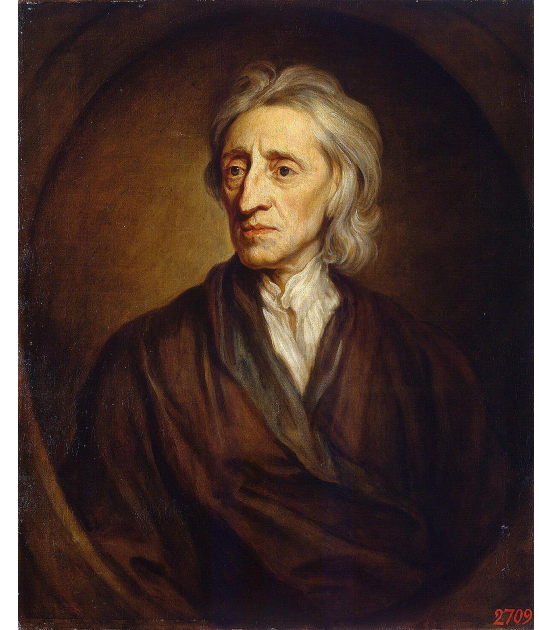
~1000s BCE

~100s BCE

~100s CE

~1000s CE

**“Methinks the understanding is not much unlike a closet wholly shut from light, with only some little openings left, to let in external visible resemblances, or ideas of things without; Would the pictures in such a room but stay there, and lie so orderly as to be found upon occasion, it would very much resemble the mind of man, in reference to all objects of sight and our ideas of them”**



John Locke

[https://en.wikipedia.org/wiki/John\\_Locke#/media/File:Godfrey\\_Kneller\\_-\\_Portrait\\_of\\_John\\_Locke\\_\(Hermitage\).jpg](https://en.wikipedia.org/wiki/John_Locke#/media/File:Godfrey_Kneller_-_Portrait_of_John_Locke_(Hermitage).jpg)





The larger scale pattern then seems:

- 1) Our cutting edge technology is projected on to the brain
- 2) Neuroscience + Technology leads to biomimicry



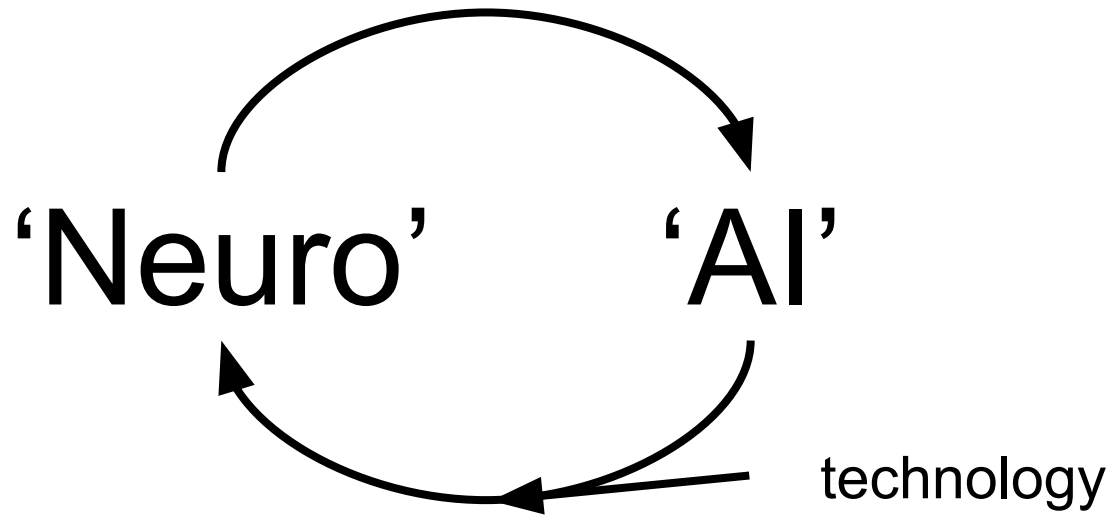


The larger scale pattern then seems:

- 1) Our cutting edge technology is projected on to the brain
- 2) Neuroscience + Technology leads to biomimicry

**Recently, this loop has become even tighter!**







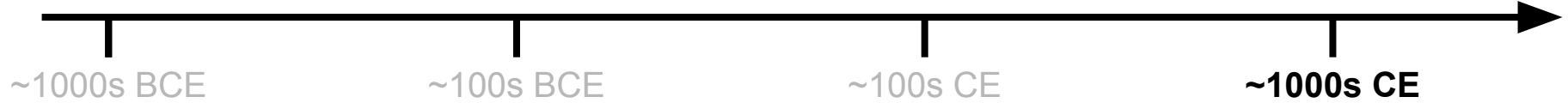
**“Electrico-”**

**‘Neuro’**

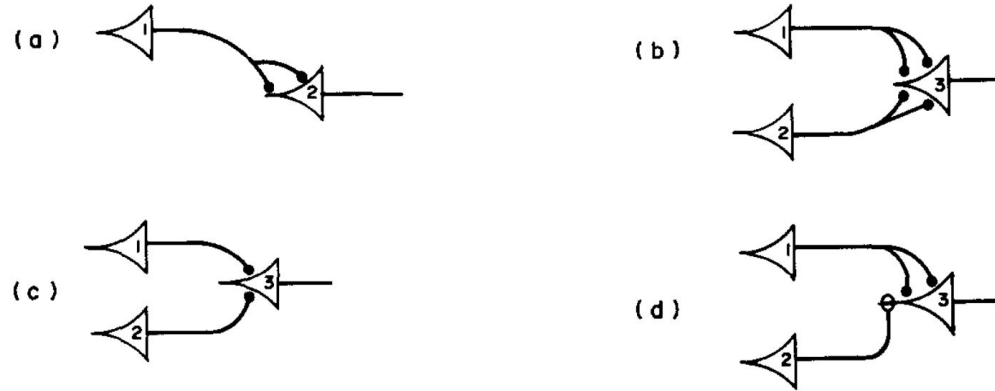
**‘AI’**

**Binary Signals,  
Boolean Logic ++**



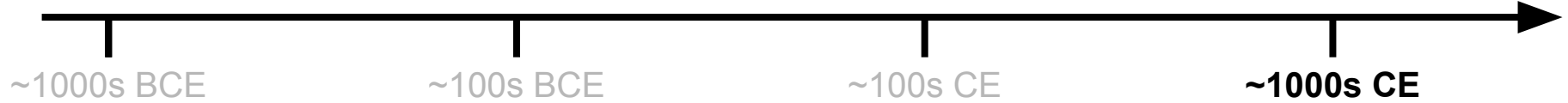


### LOGICAL CALCULUS FOR NERVOUS ACTIVITY

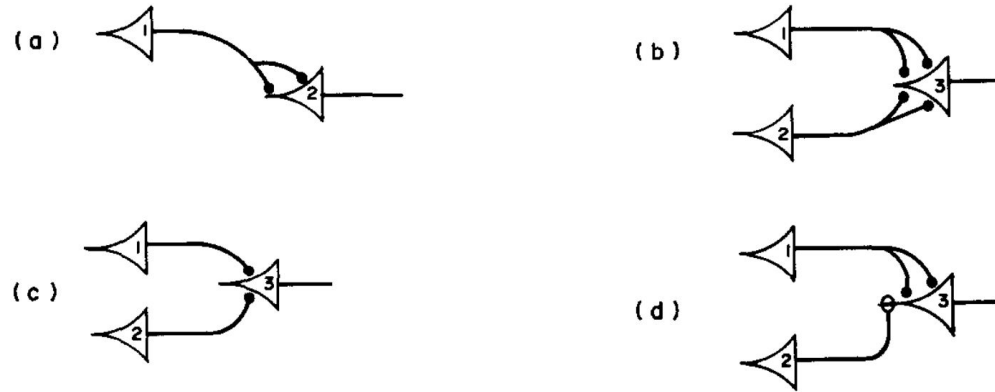


McCulloch, W. S., & Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *The Bulletin of Mathematical Biophysics*, 5(4), 115–133.  
<https://doi.org/10.1007/BF02478259>





### LOGICAL CALCULUS FOR NERVOUS ACTIVITY



**A translation of (then recent) boolean and logic ideas to biology!**



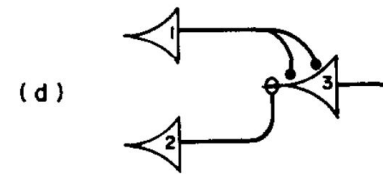
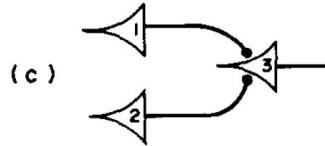
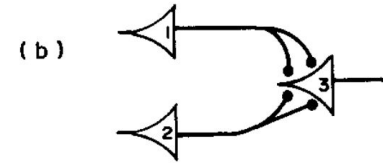
~1000s BCE

~100s BCE

~100s CE

~1000s CE

### LOGICAL CALCULUS FOR NERVOUS ACTIVITY

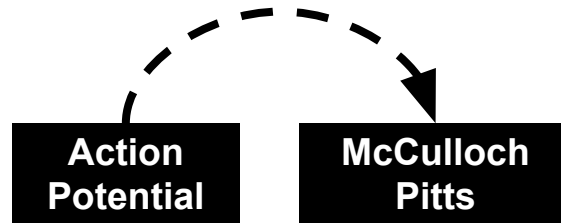


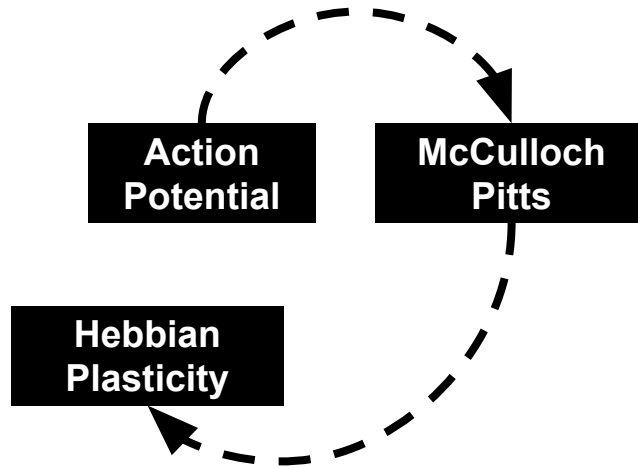
A translation of (then recent) boolean and logic ideas to biology!

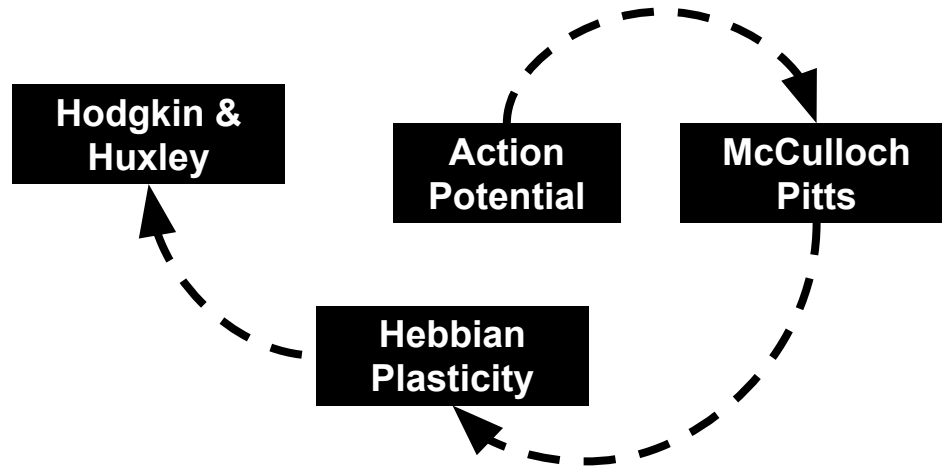
McCulloch & Pitts' Neurons are not accurate but useful!

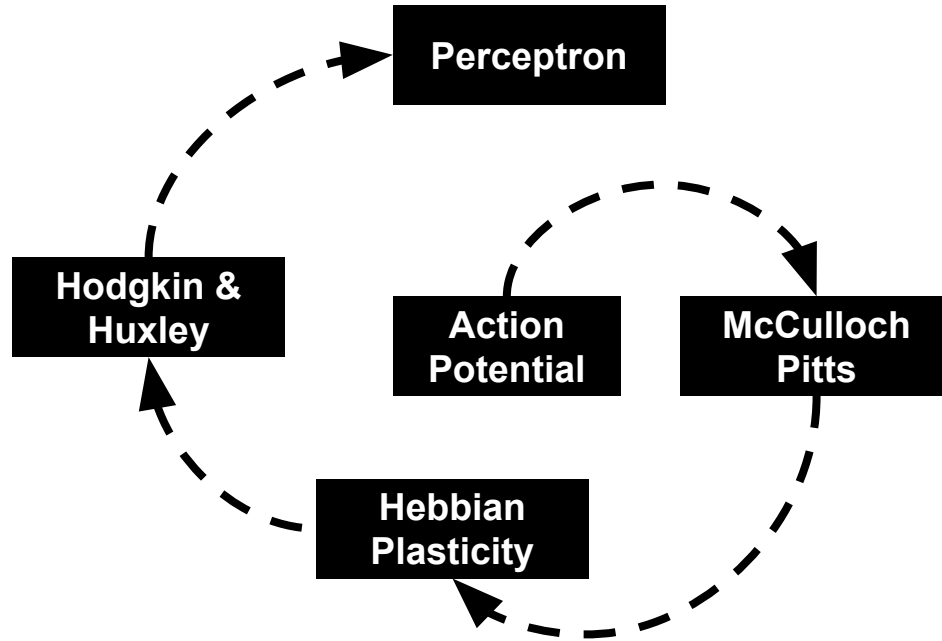
Present

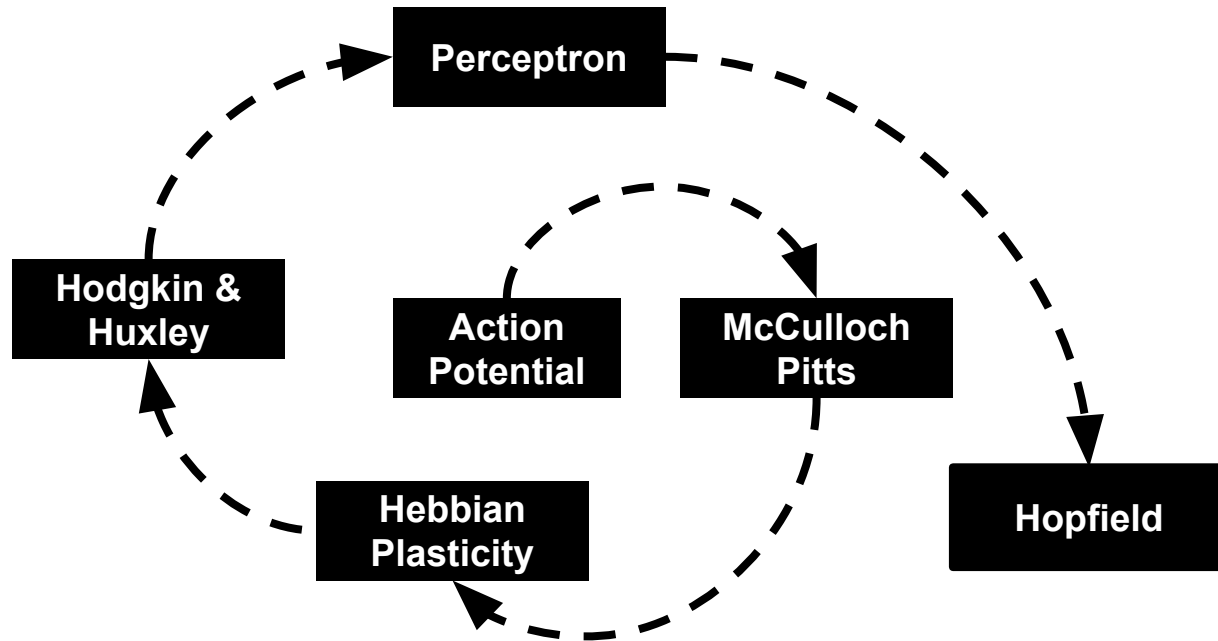


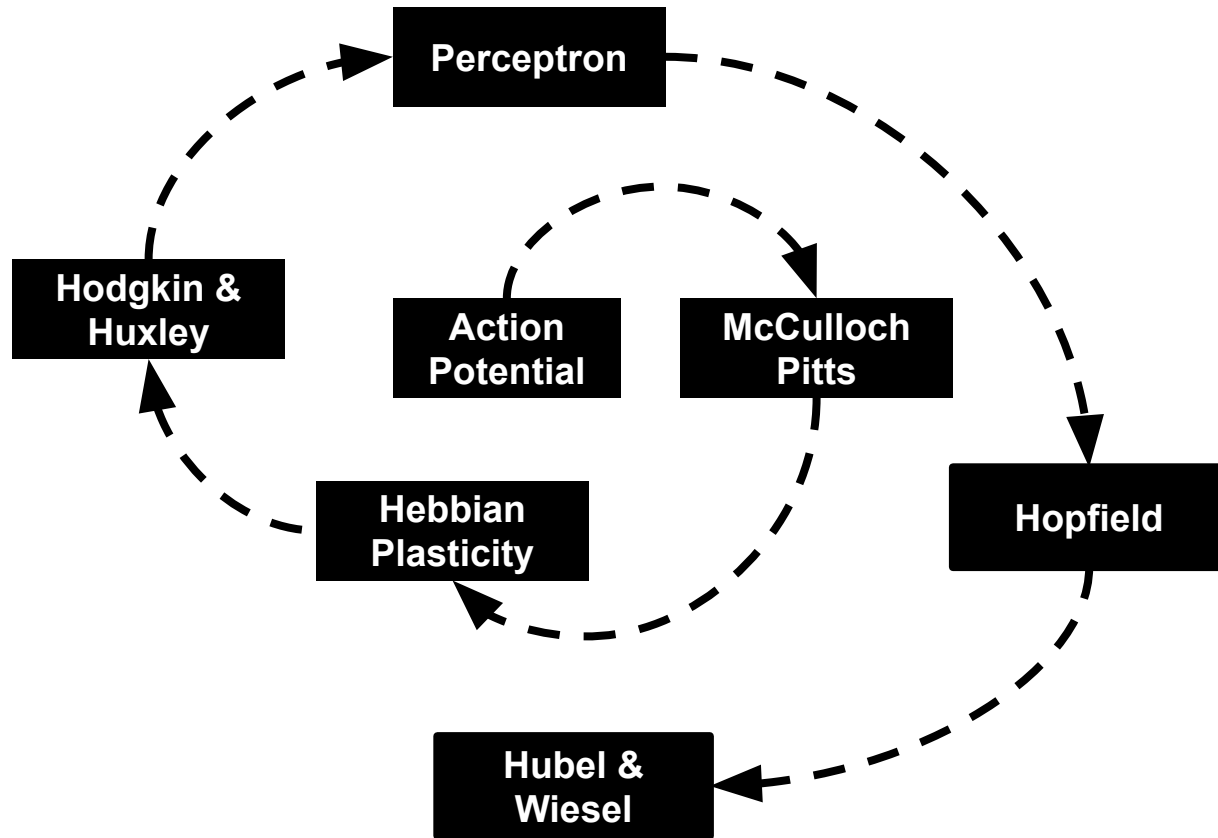


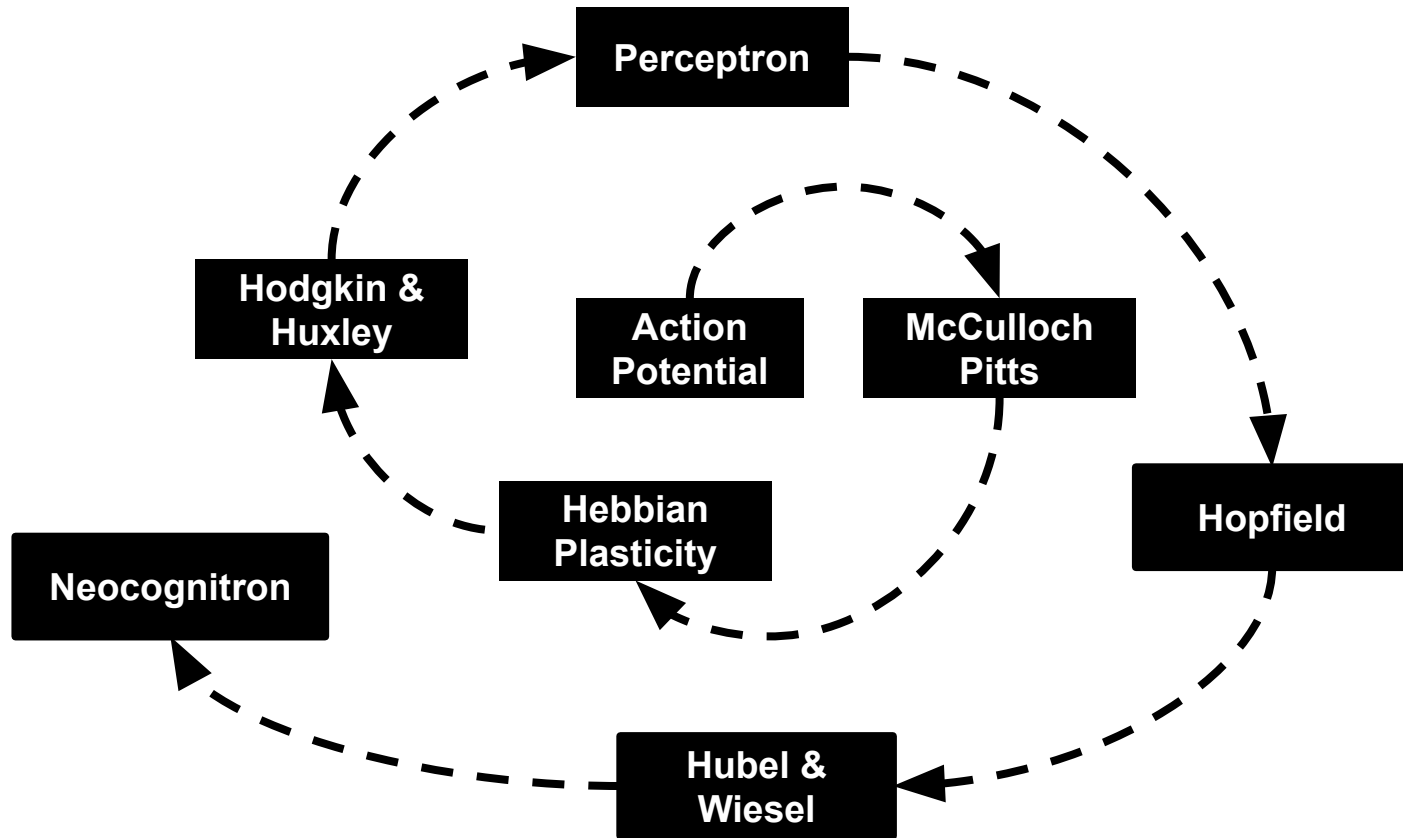


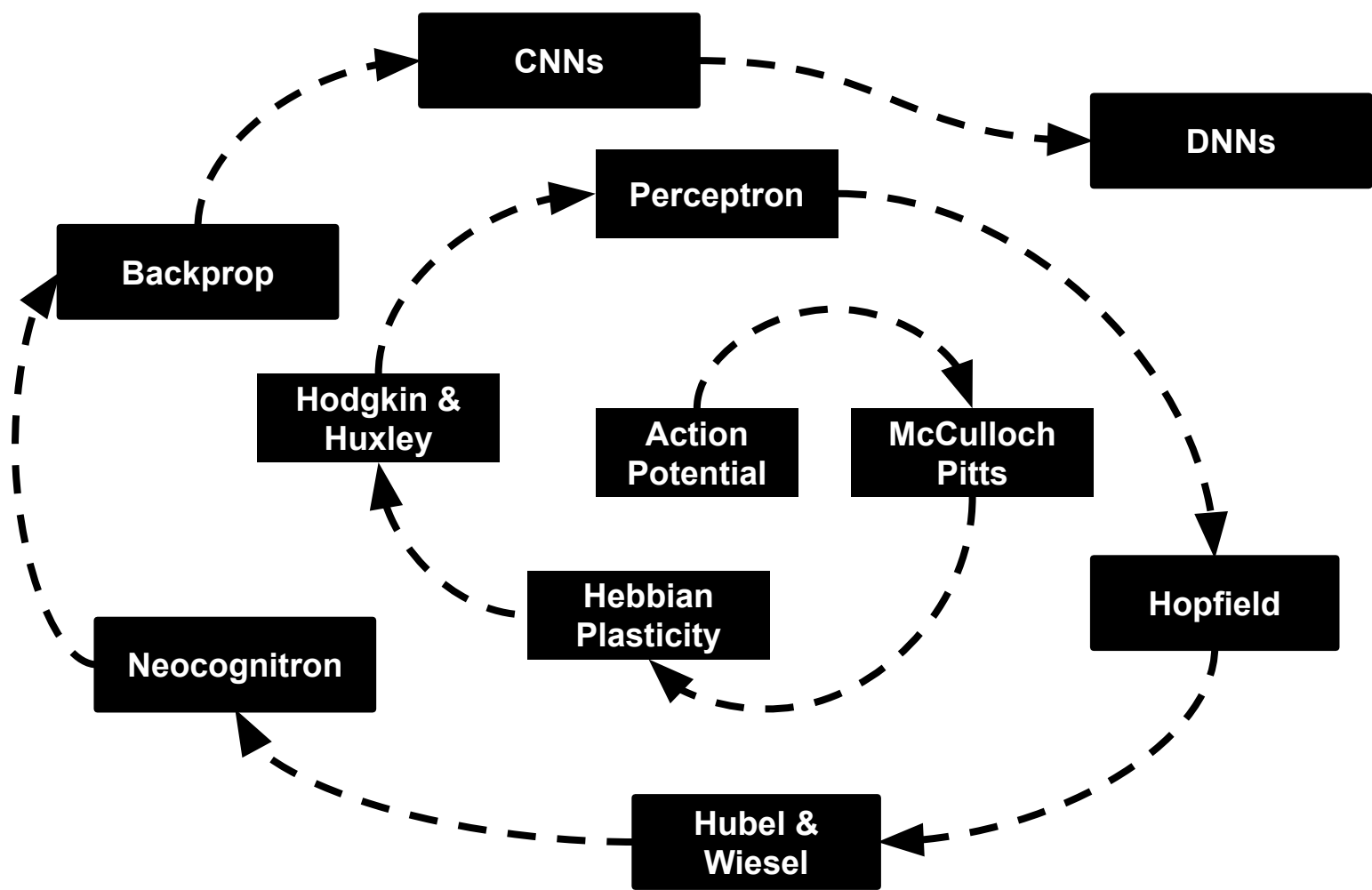


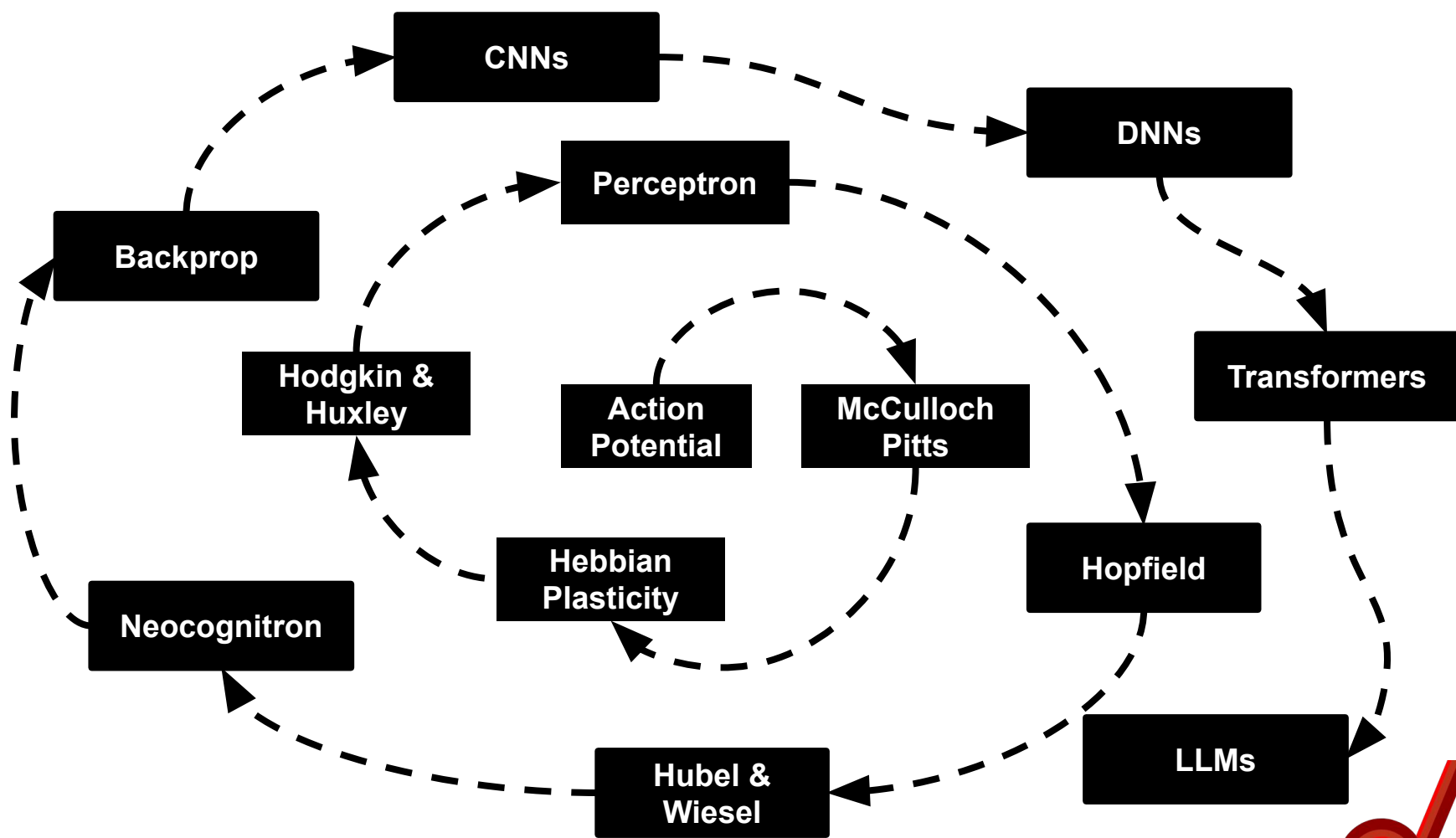


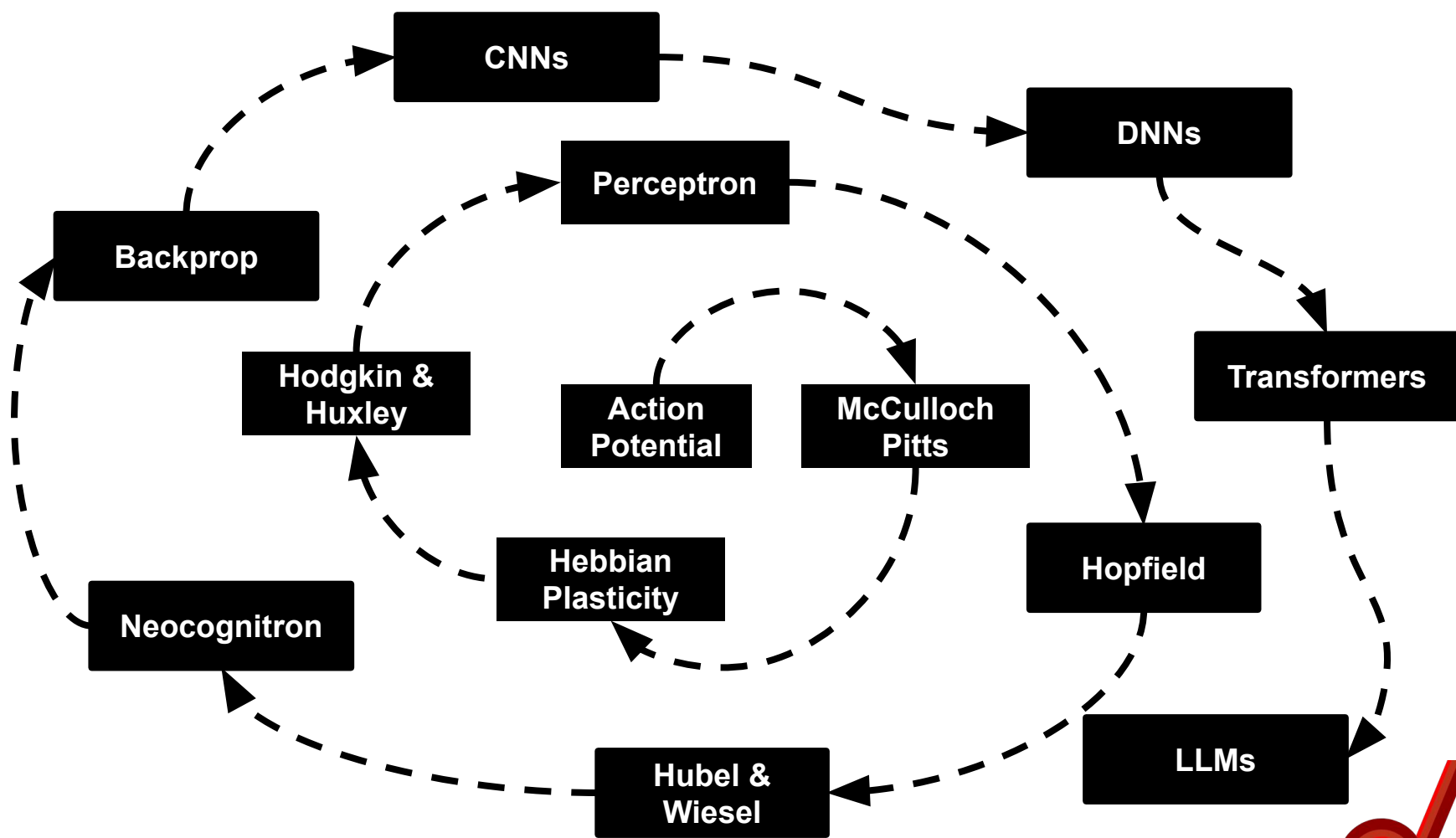


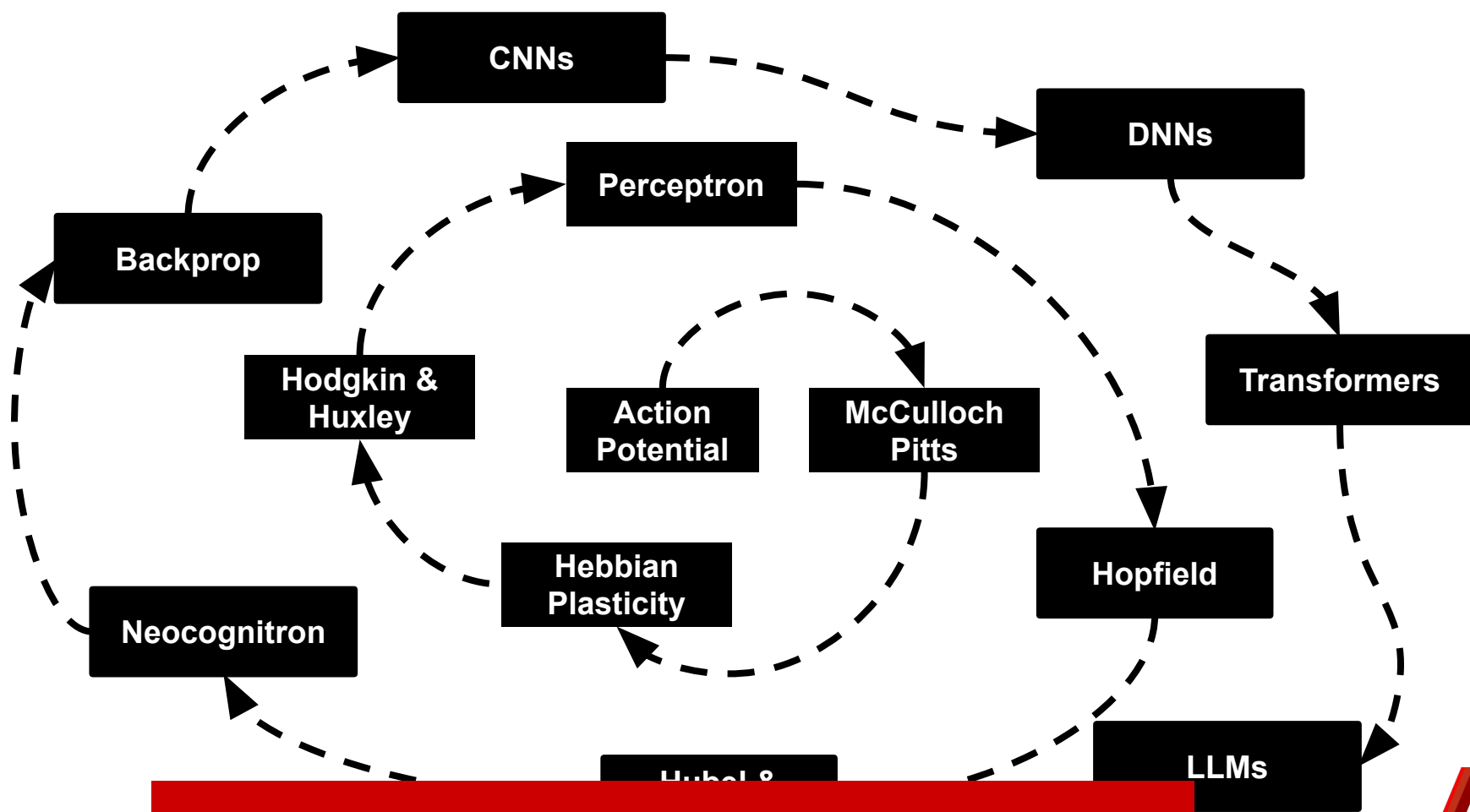












At some point the Neuro-AI division is hard to distinguish ...



# What a journey!

And yet, I missed:

- Reinforcement Learning
- Attention
- Robotics
- Dynamical Systems
- +, +, +



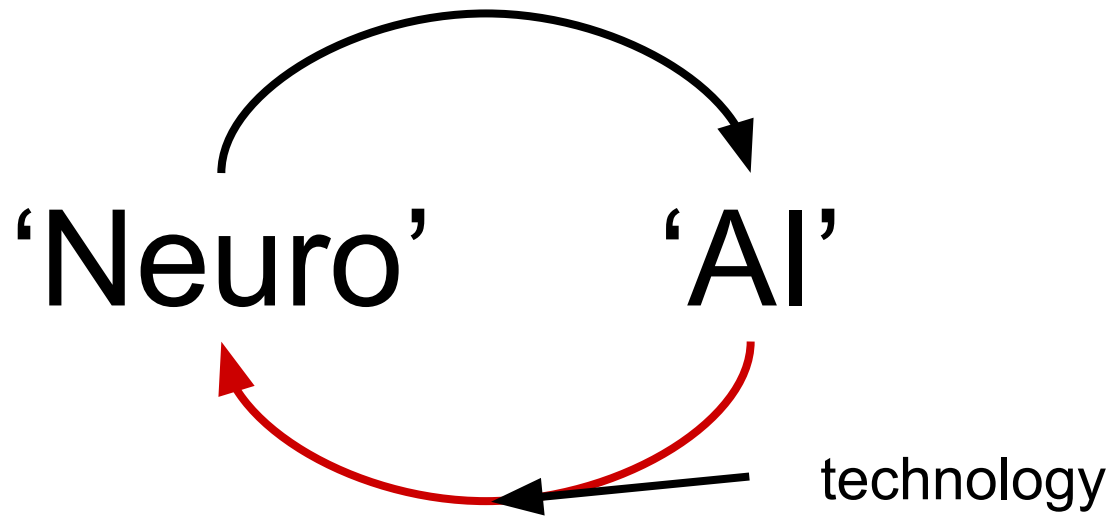
Today, an AI perspective on:

The history of “Neuro” “AI”

## **Neuroscience’s Impact on AI at Present**

The Future of (Neuro)Science and AI







In what ways is AI taking serious input from neuroscience now?





In what ways is AI taking serious input from neuroscience now?

- 1) Spiking Neural Networks
- 2) Neuromorphic Computing
- 3) +





So in what ways is AI taking serious input from neuroscience?

- 1) **Spiking Neural Networks**
- 2) Neuromorphic Computing
- 3) +





**<Enter Sander Keemink>**





So in what ways is AI taking serious input from neuroscience?

- 1) Spiking Neural Networks
- 2) **Neuromorphic Computing**
- 3) +





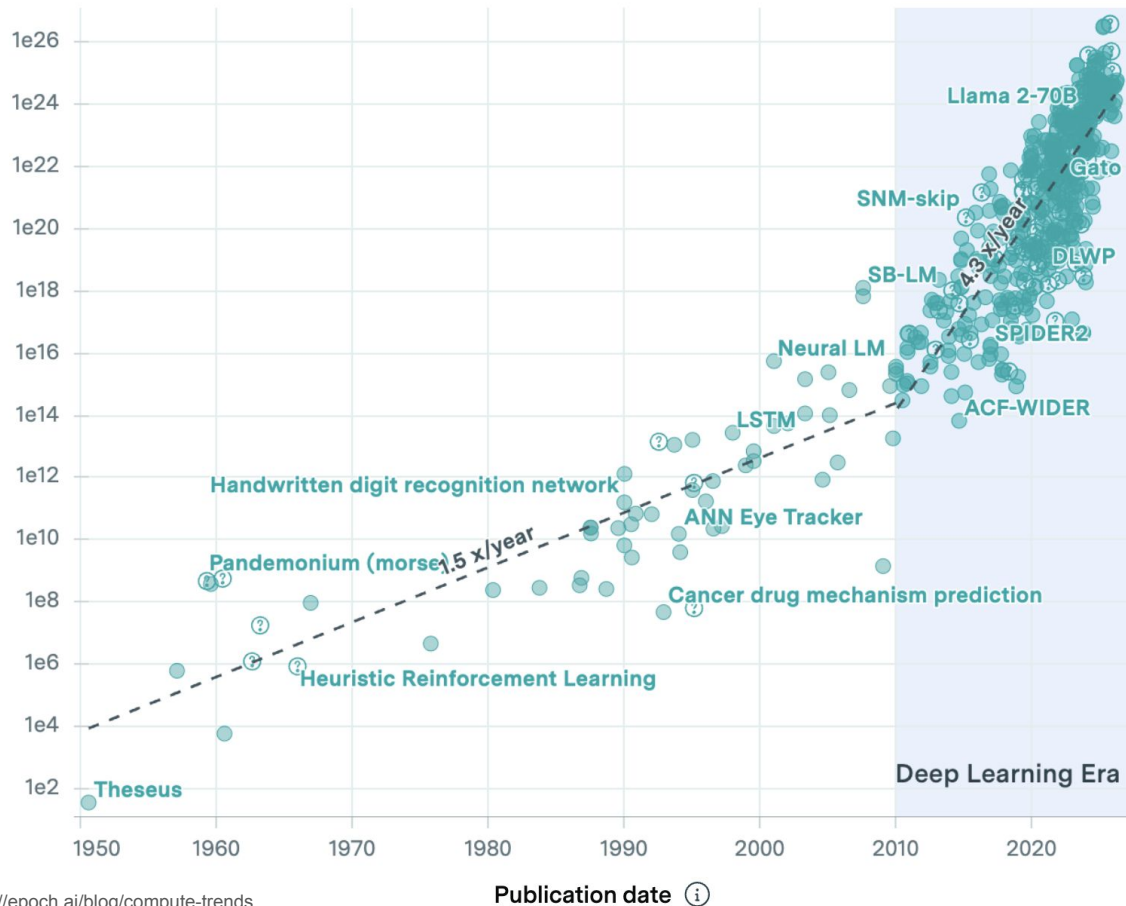
## Why neuromorphic computing?



# Notable AI models ⓘ

Training compute (FLOP) ⓘ

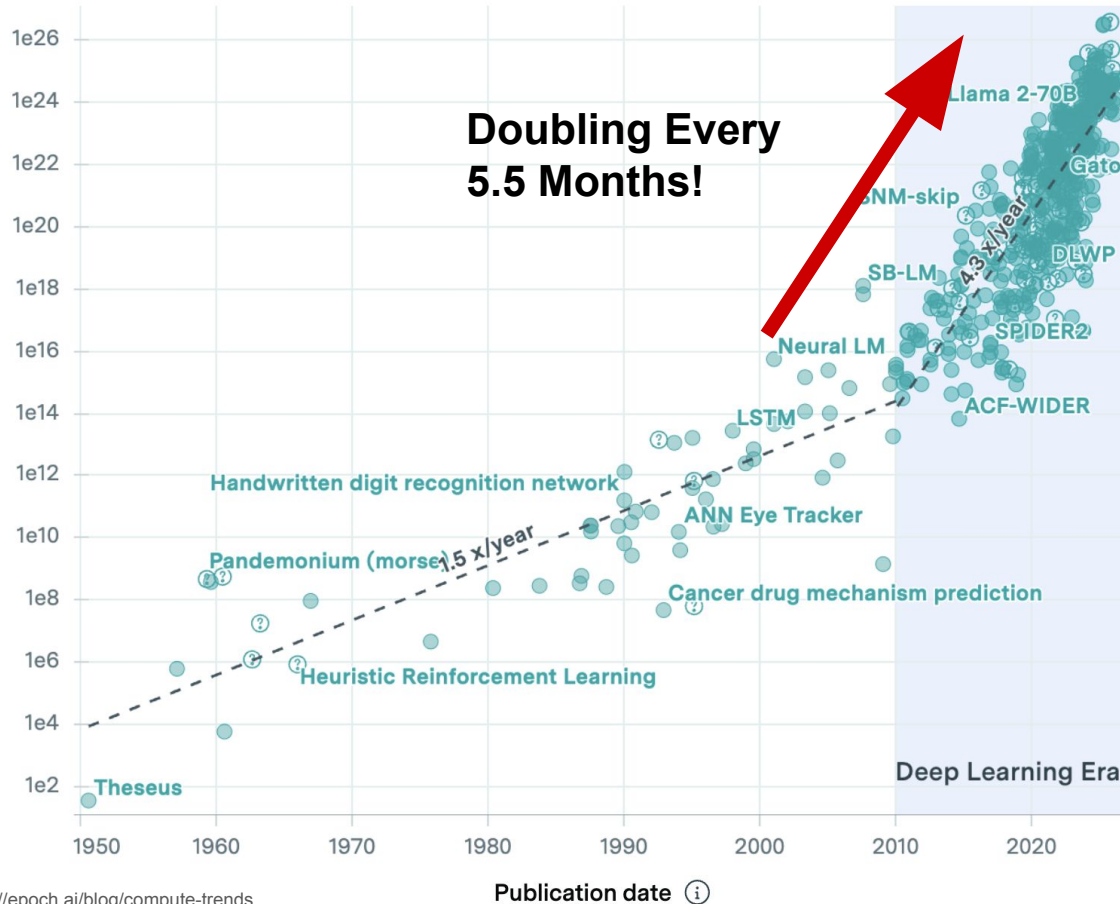
ⓘ : Speculative data ⓘ 546 Results ⓘ



# Notable AI models ⓘ

Training compute (FLOP) ⓘ

ⓘ : Speculative data ⓘ 546 Results ⓘ



# Notable AI models ⓘ

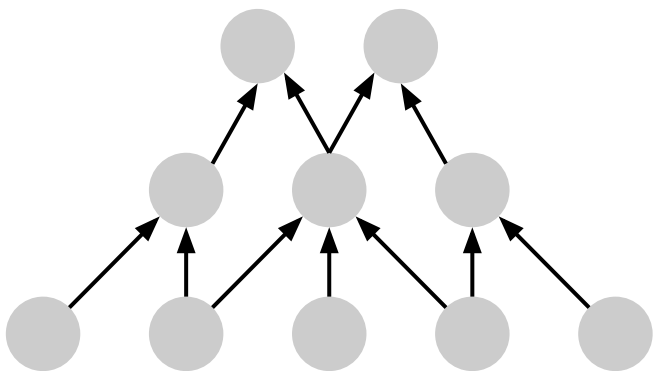
Training compute (FLOP) ⓘ

? : Speculative data ⓘ 546 Results ⓘ



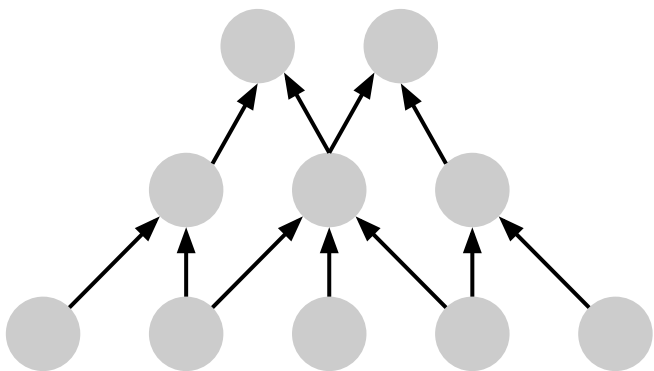
**And inference needs are increasing MUCH faster!**



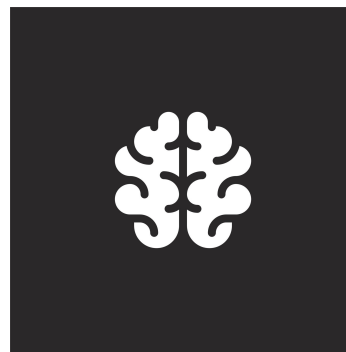


**Training GPT4: ~7200MWh**



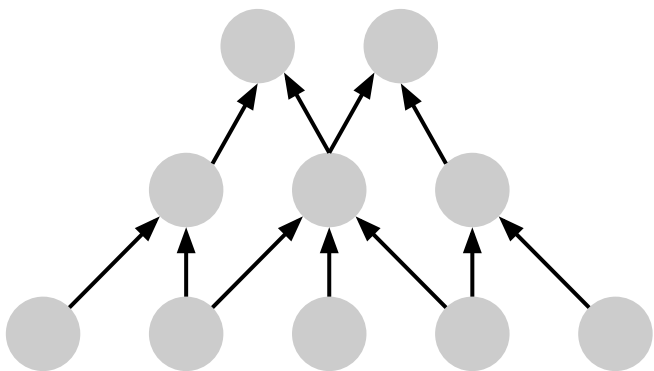


**Training GPT4: ~7200MWh**

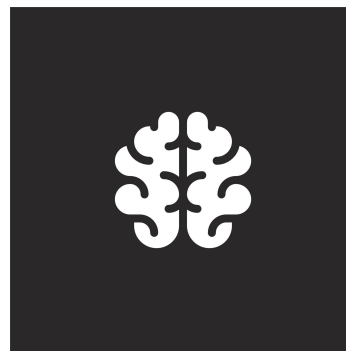


**Training (18y/o): ~16MWh\***



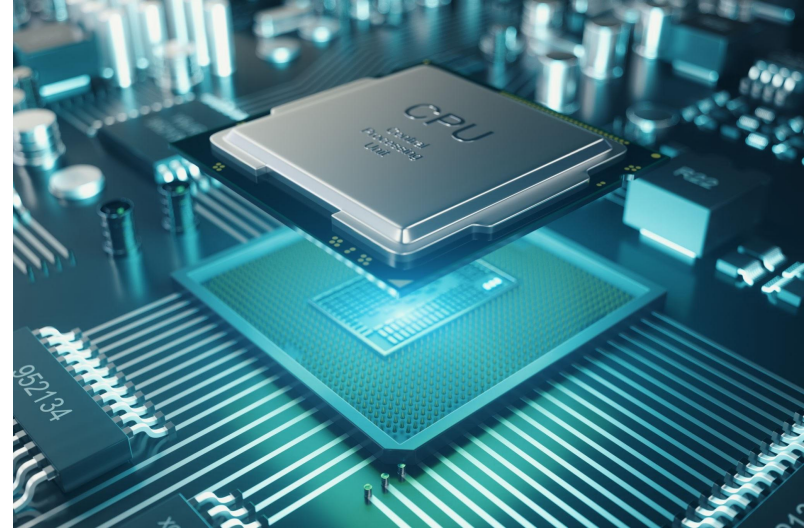


**Training GPT4: ~7200MWh**



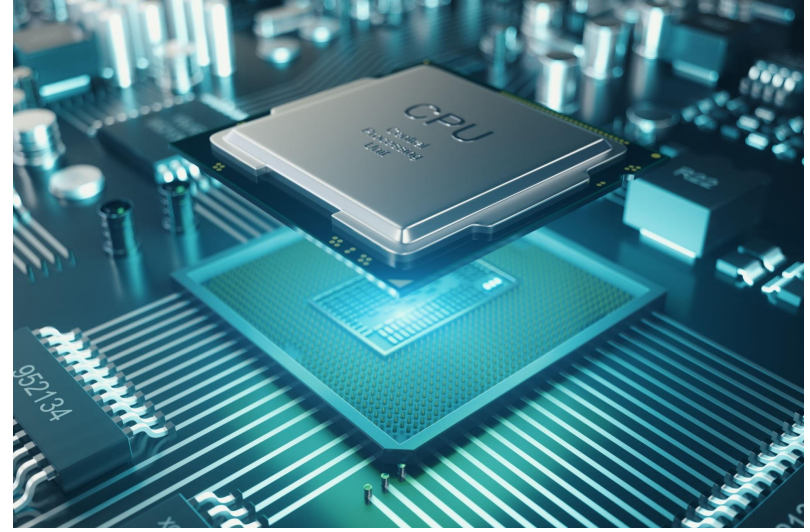
**Training (18y/o): ~16MWh\***





**The fundamental principle then is to gather the brain's efficiency  
into hardware**





**The fundamental principle then is to gather the brain's efficiency  
into hardware**





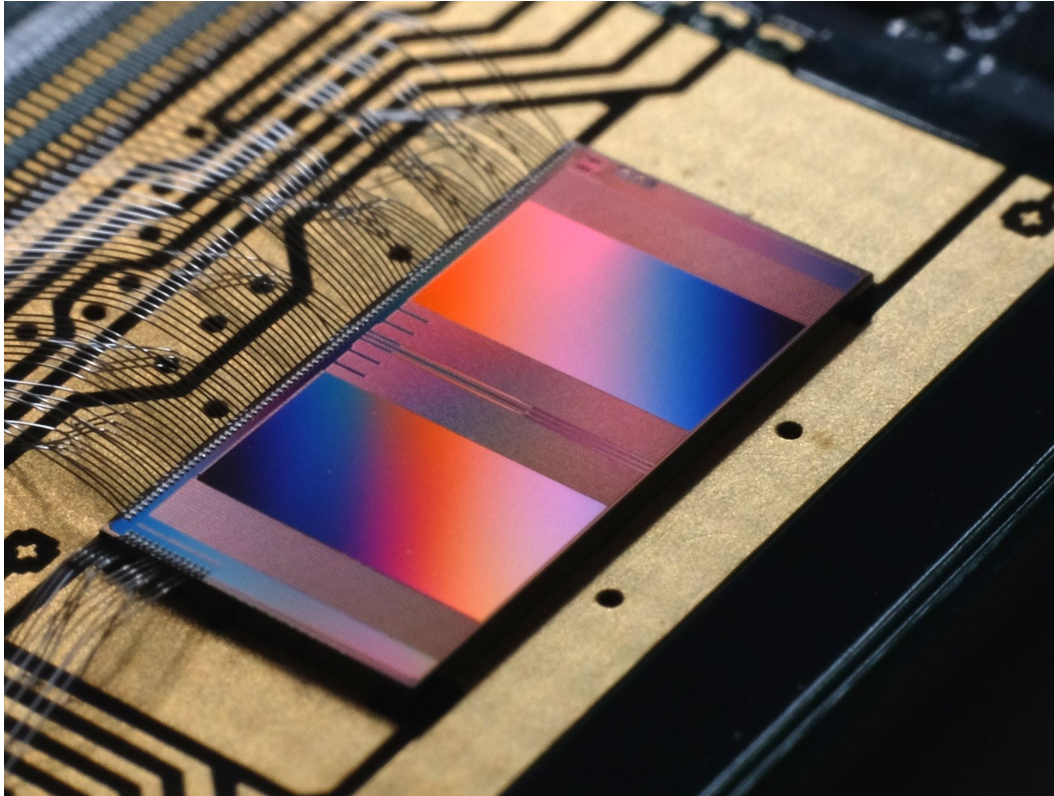
~ 1W





~ 2W

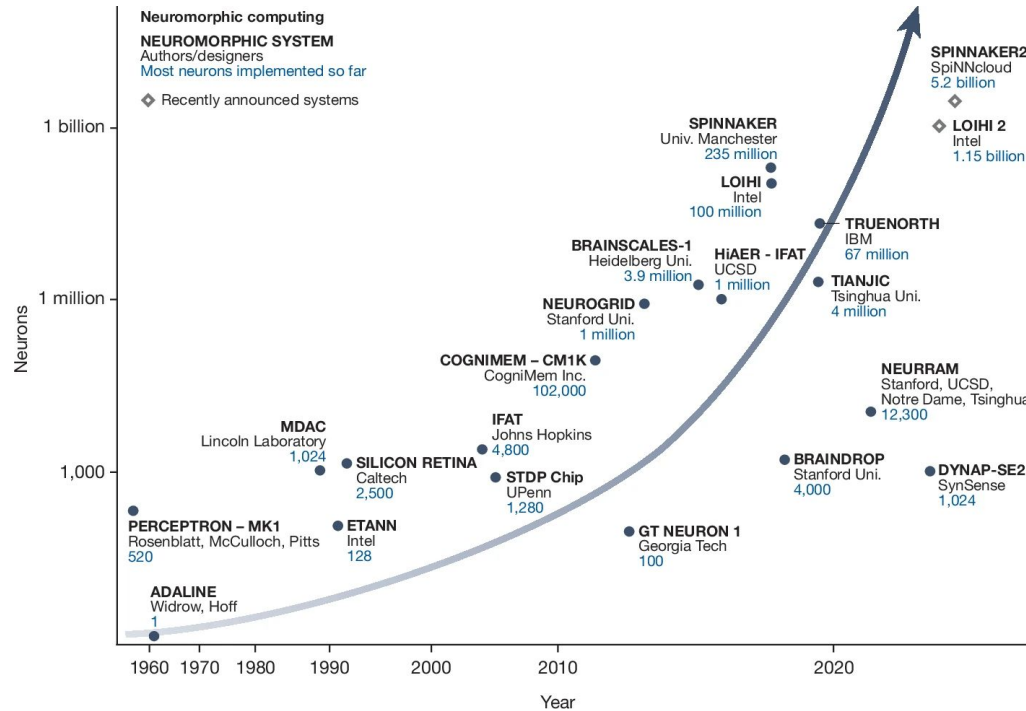




~ 1W



# Neuromorphic Computing



Kudithipudi, D., Schuman, C., Vineyard, C. M., Pandit, T., Merkel, C., Kubendran, R., Aimone, J. B., Orchard, G., Mayr, C., Benosman, R., Hays, J., Young, C., Bartolozzi, C., Majumdar, A., Cardwell, S. G., Payvand, M., Buckley, S., Kulkarni, S., Gonzalez, H. A., ... Furber, S. (2025). Neuromorphic computing at scale. *Nature*, 637(8047), 801–812.

<https://doi.org/10.1038/s41586-024-08253-8>

[nasir.ahmad@donders.ru.nl](mailto:nasir.ahmad@donders.ru.nl)



# Neuromorphic Computing



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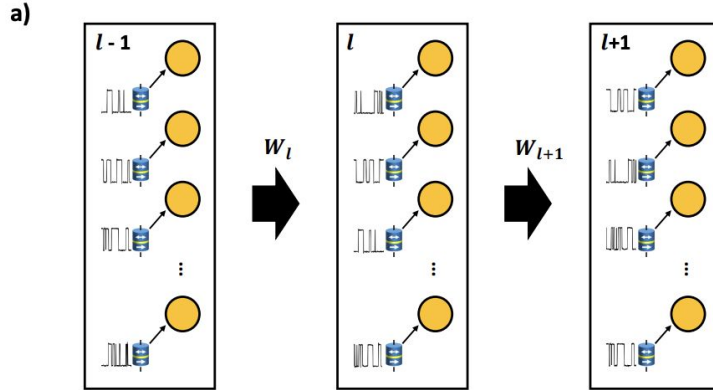
[nasir.ahmad@donders.ru.nl](mailto:nasir.ahmad@donders.ru.nl)



# Using noisy hardware to train neuromorphic chips



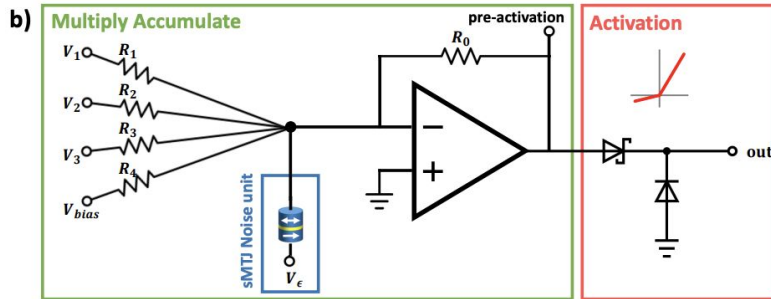
# Using noisy hardware to train neuromorphic chips



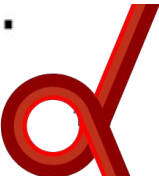
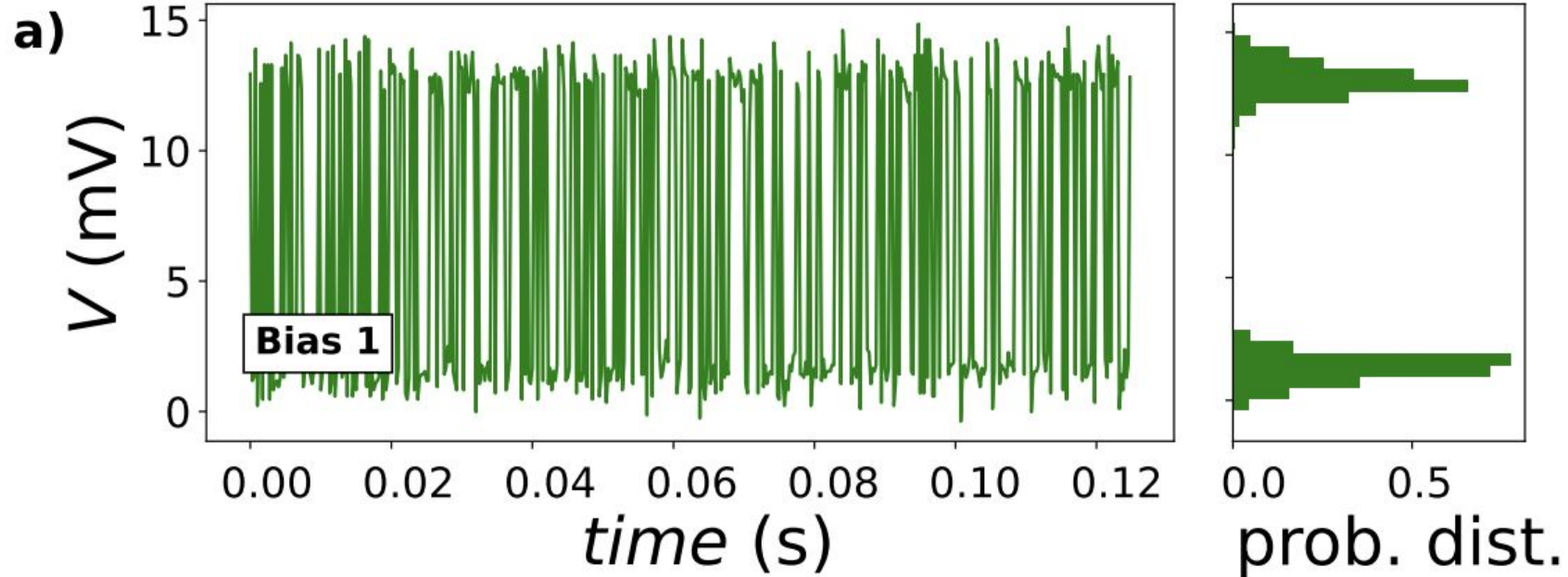
Koenders, K., Schnitzpan, L., Kammerbauer, F., Shu, S., Jakob, G., Kläui, M., Mentink, J. H., Ahmad, N., & van Gerven, M. (2025).

**Noise-based local learning using stochastic magnetic tunnel junctions.** *Physical Review Applied*, 23(5), 054035.

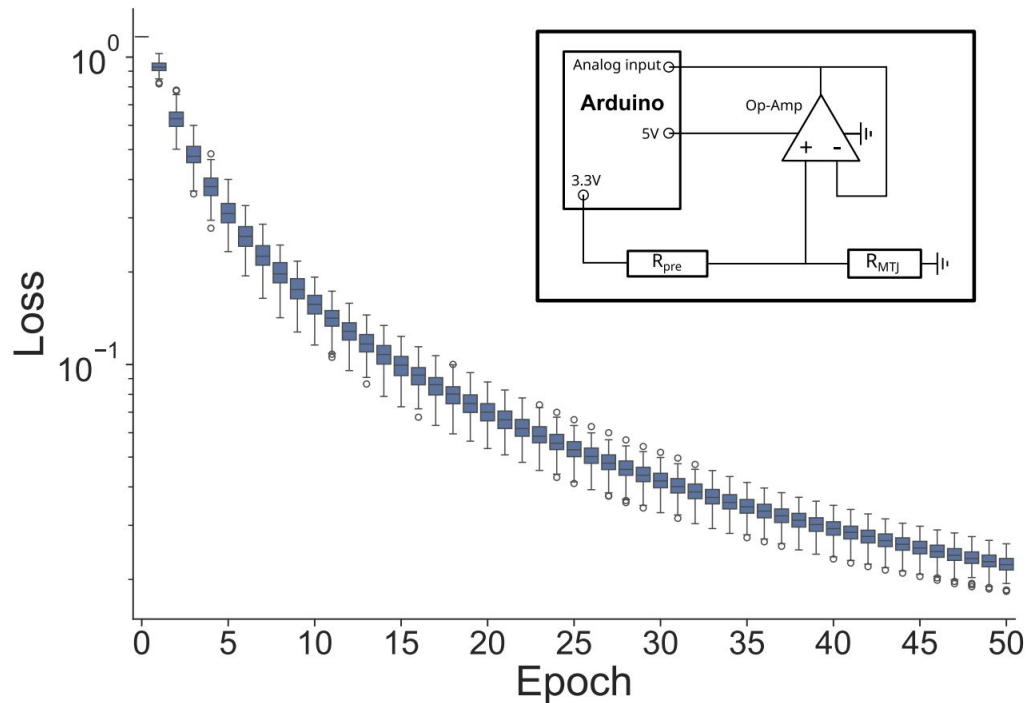
<https://doi.org/10.1103/PhysRevApplied.23.054035>  
5



# Using noisy hardware to train neuromorphic chips



# Using noisy hardware to train neuromorphic chips



# The brain as noisy inference hardware

## Ornstein-Uhlenbeck Adaptation as a Mechanism for Learning in Brains and Machines

Jesús García Fernández<sup>1</sup>, Nasir Ahmad<sup>1</sup>, and Marcel van Gerven<sup>1</sup>

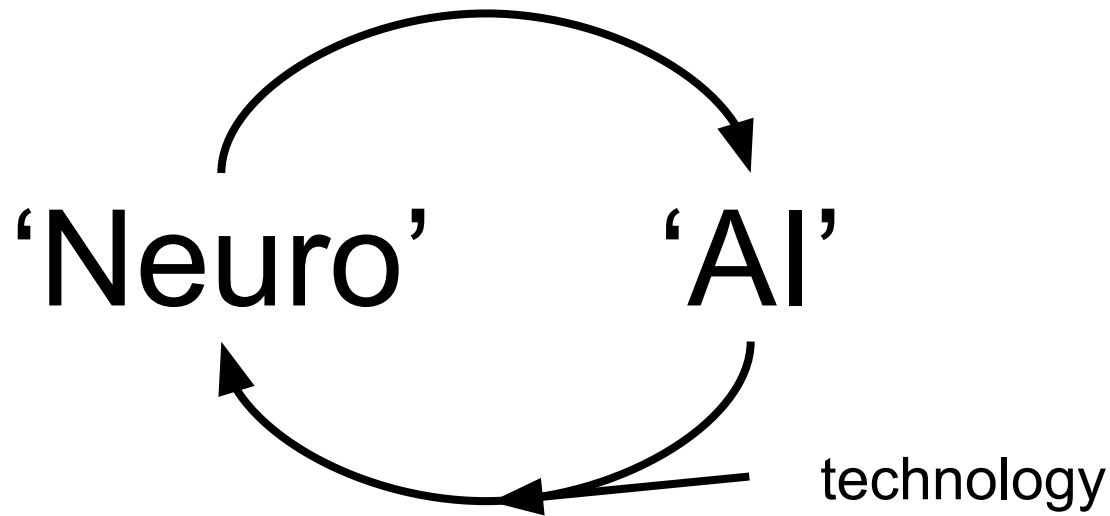
<sup>1</sup>Department of Machine Learning and Neural Computing, Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands



García Fernández, J., Ahmad, N., & van Gerven, M. (2024). **Ornstein-Uhlenbeck adaptation as a mechanism for learning in brains and machines.** *Entropy (Basel, Switzerland)*, 26(12), 1125. <https://doi.org/10.3390/e26121125>

[nasir.ahmad@donders.ru.nl](mailto:nasir.ahmad@donders.ru.nl)





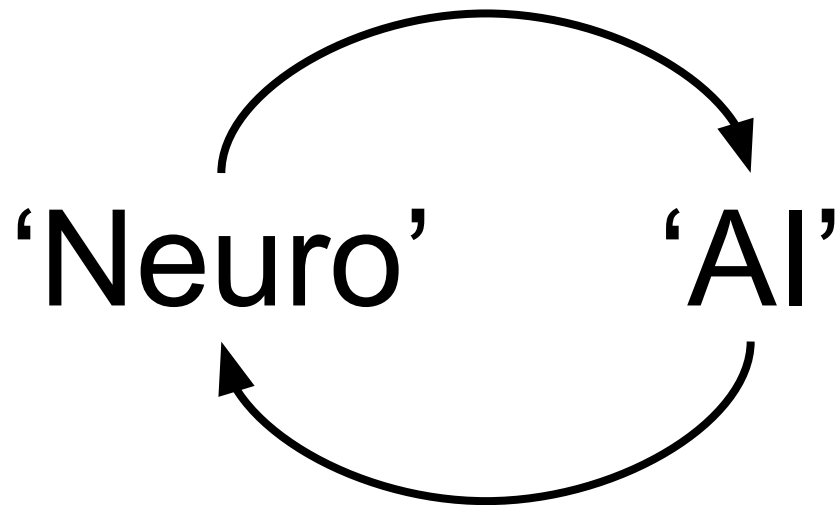
Today, an AI perspective on:

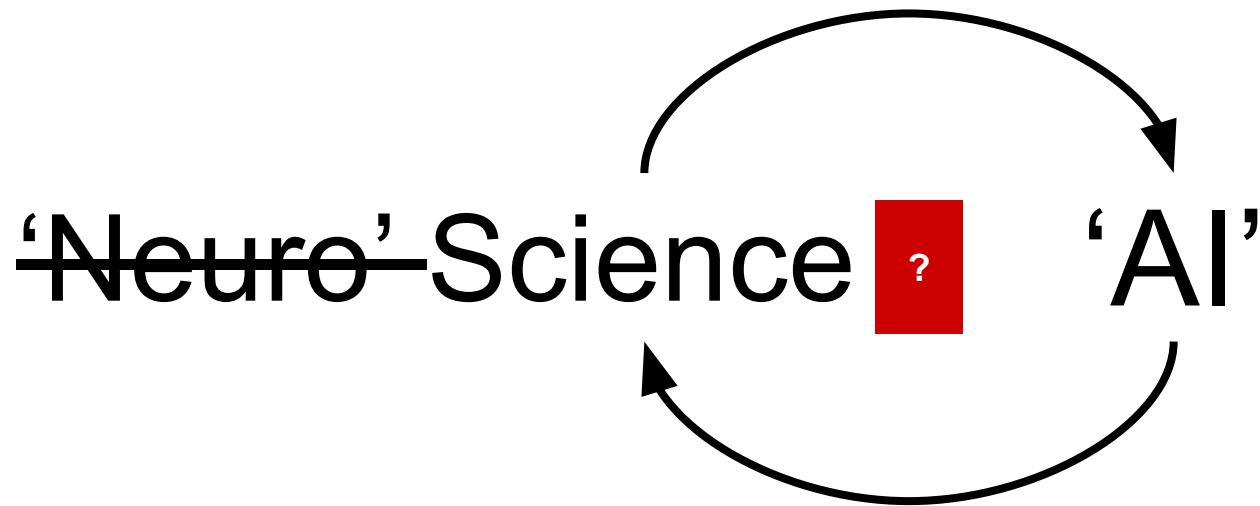
The history of “Neuro” “AI”

Neuroscience’s Impact on AI at Present

**The Future of (Neuro)Science and AI**









**<Enter Ahmed El Gazzar>**





What is next?

How will Neuroscience impact AI as we move forward?

How will AI impact Neuroscience?





We might imagine:

- Neuromorphic BCIs
- Automated (Neuro)Scientific Discovery
- Beyond AI Science





We might imagine:

- Neuromorphic BCIs
- Automated (Neuro)Scientific Discovery

... Beyond Science-AI



# Thank you!

## An AI perspective on the Past, Present, and Future of Neuro-AI

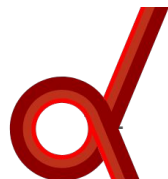
Nasir Ahmad, Sander Keemink, Ahmed El-Gazzar

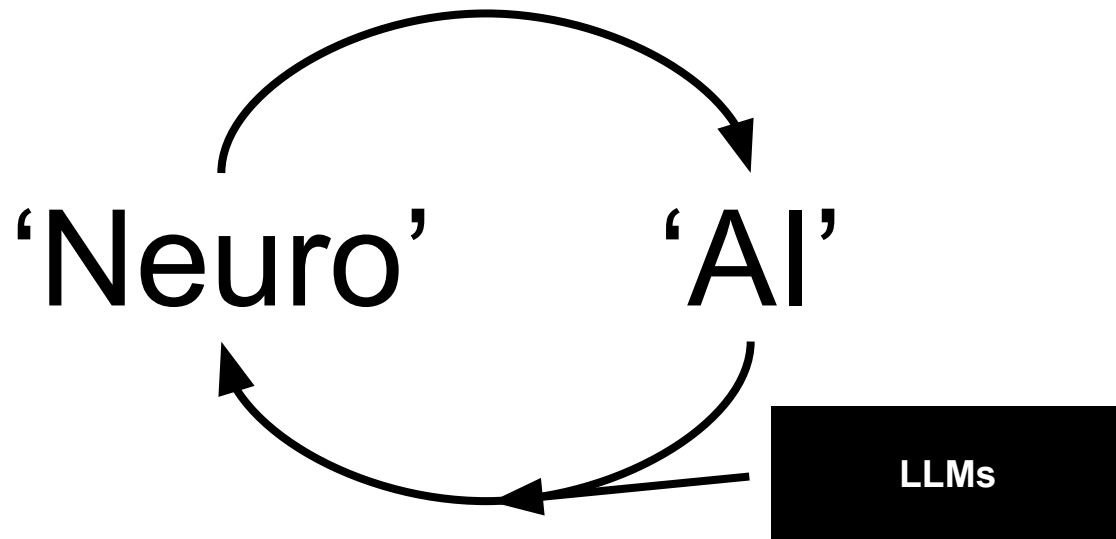
Radboud Universiteit

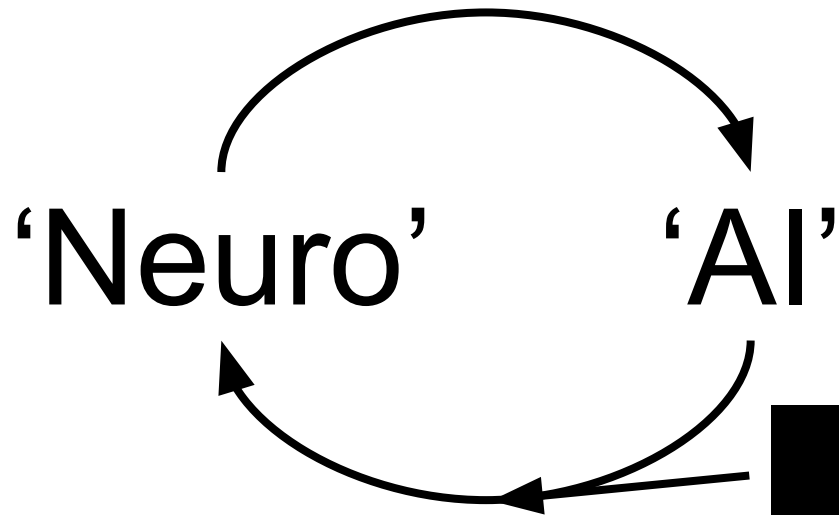
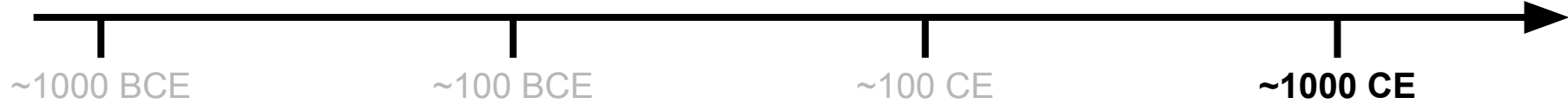


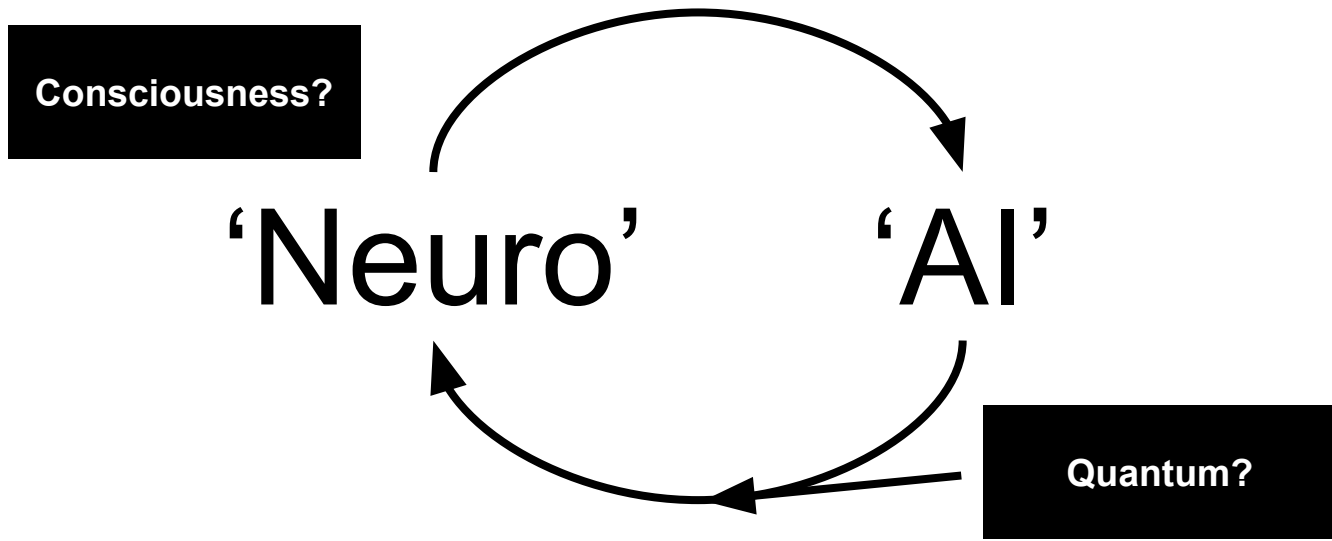
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Consciousness?

‘Neuro’

‘AI’

Quantum?

**The next cardio-neuro-ai-mythology? OR  
Neuro AI? - We should be careful!**

