Consciousness as a natural phenomenon

Paweł M. Boguszewski
p.boguszewski@nencki.edu.pl

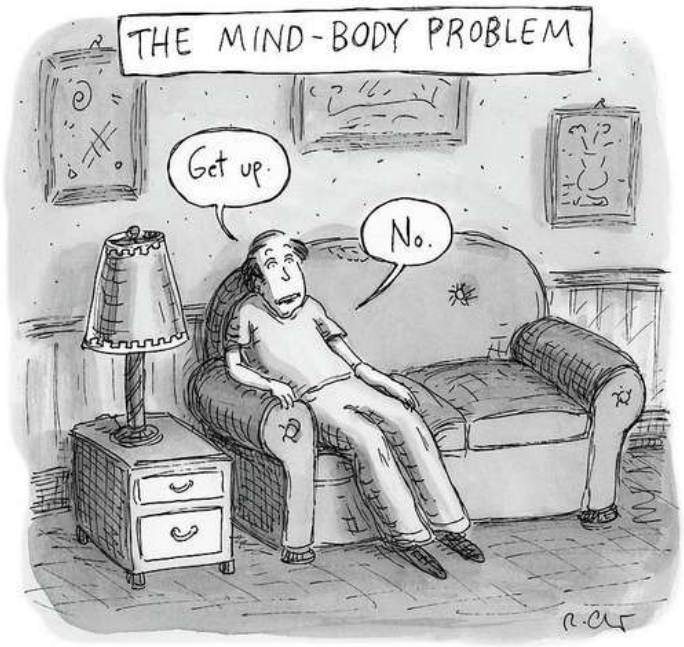
100 years nencki institute of experimental biology

Anesthesia awareness

The 5th National Audit Project (NAP5) on accidental awareness during general anaesthesia: summary of main findings and risk factors

https://associationofanaesthetists-publications.onlinelibrary.wiley.com/doi/full/10.1111/anae.12826
http://www.polanest.webd.pl/pliki/varia/powrot_swiadomosci_stanowisko.pdf
https://www.crazynauka.pl/jak-jest-obudzic-sie-podczas-operacji/

2



https://condenaststore.com/featured/the-mind-body-problem-roz-chast.html

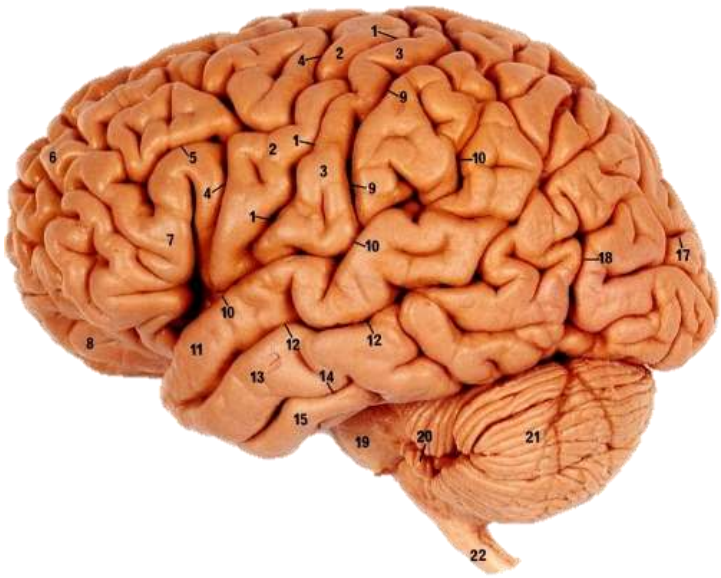
3

Consciousness:

- *The brain*
- *Theories*
- *Neuroscience*
- *Strange cases*
- *Animals*
- *New biology*
- *Artificial systems*

en.wikipedia.org

4



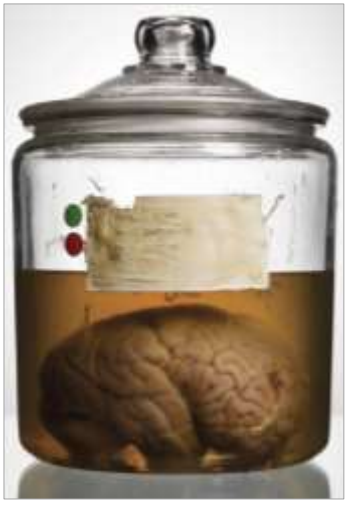
5

The Human Brain

Genes

Evolutionary blueprint

- *Anatomy and connections*
- *Basic reflexes*
- *Face recognition*
- *Language preparedness*
- *Morality*



Plasticity

Environment and experience

- *Learning and Memory*
- *Developmental*
- *Injury-induced Brain Repair*

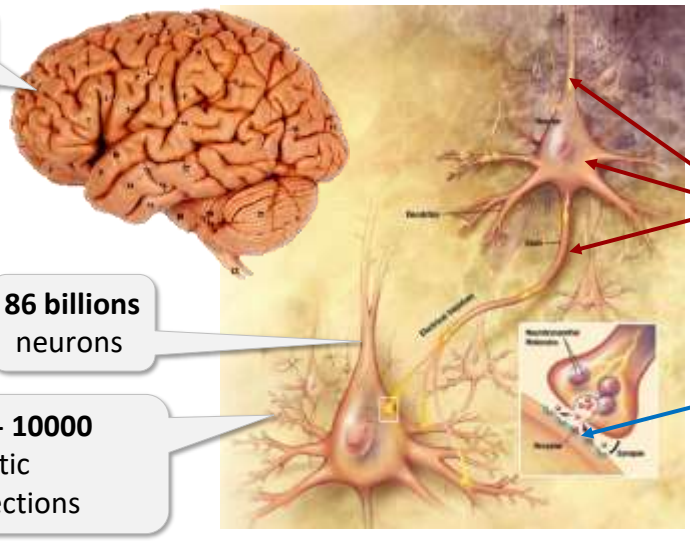
http://www.voorhes.com/MALFORMED-BOOK/2/

6

Nervous system

processing and transmitting information

25% energy
20 Watt



Electrical impulses

86 billions neurons

1000 - 10000 synaptic connections

Chemical impulses

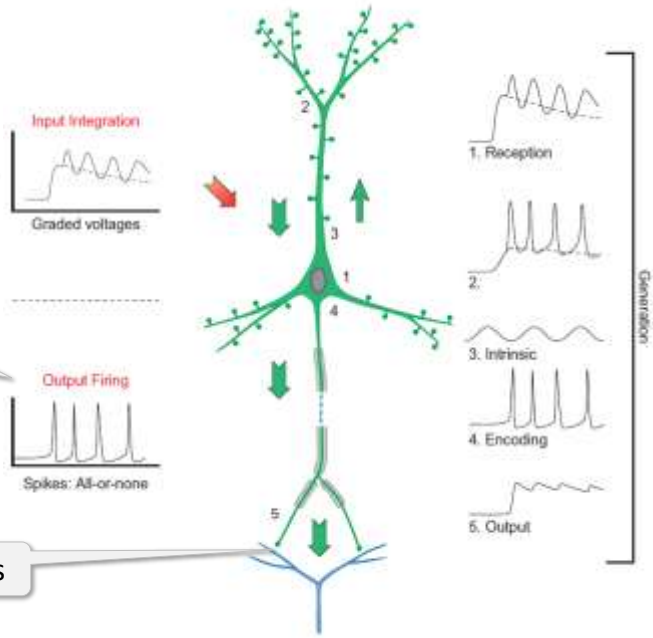
7

Signals in nervous system

Synaptic potential
Processing

Action potential
Transmission

Chemical impulses



8

MATHEMATICS

CHEMISTRY

COMPUTER SCIENCE

PHYSICS

NEUROSCIENCE
Scientific study of nervous system

PSYCHOLOGY

PHILOSOPHY

BIOLOGY

MEDICINE

9

The Nobel Prize in Physics 2024

John Hopfield

"for foundational discoveries and inventions that enable machine learning with artificial neural networks"

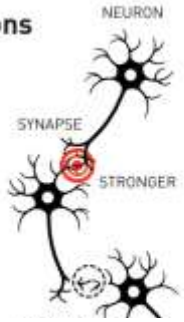
Geoffrey Hinton

"for foundational discoveries and inventions that enable machine learning with artificial neural networks"

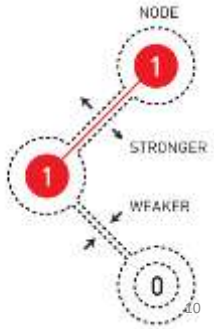
https://www.nobelprize.org/all-nobel-prizes-2024/

Natural and artificial neurons

The brain's neural network is built from living cells, neurons, with advanced internal machinery. They can send signals to each other through the synapses. When we learn things, the connections between some neurons get stronger, while others get weaker.

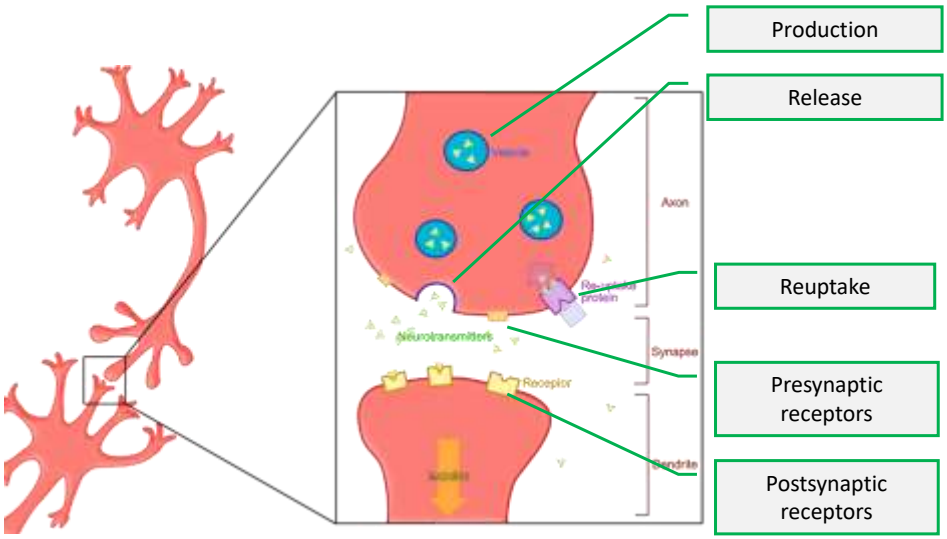


Artificial neural networks are built from nodes that are coded with a value. The nodes are connected to each other and, when the network is trained, the connections between nodes that are active at the same time get stronger, otherwise they get weaker.



10

Neurotransmitter System

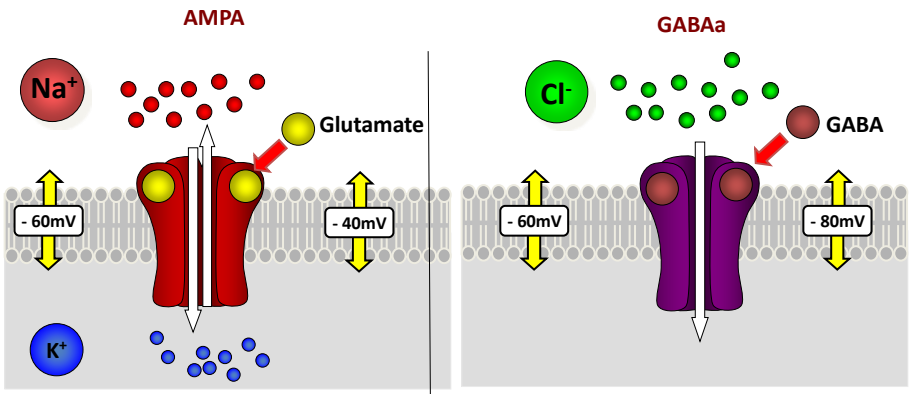


Ligand-gated ion channels

receptor and ion channel in a single protein

EPSP: excitatory
Depolarization

IPSP: inhibitory
Hiperpolarization

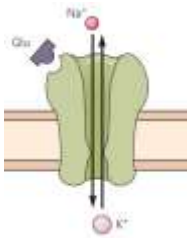


13

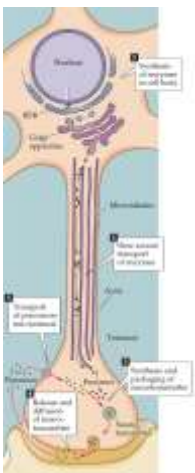
Neurotransmitter System

Molecule
Neurotransmitter

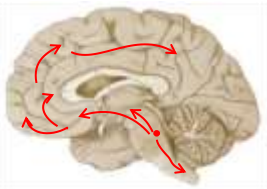
Transmitter
receptor



Synthesis
vesicular packaging
release
Reuptake /degradation

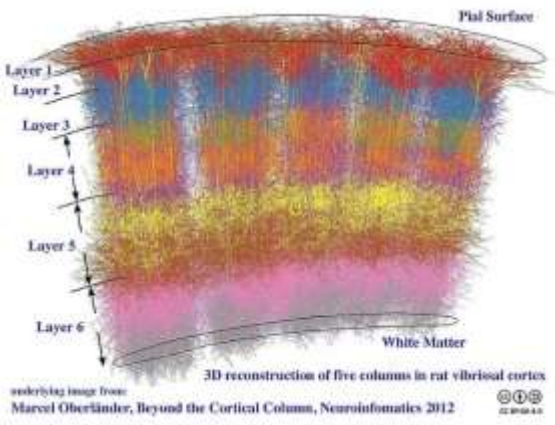


Anatomy



14

Cortical columns



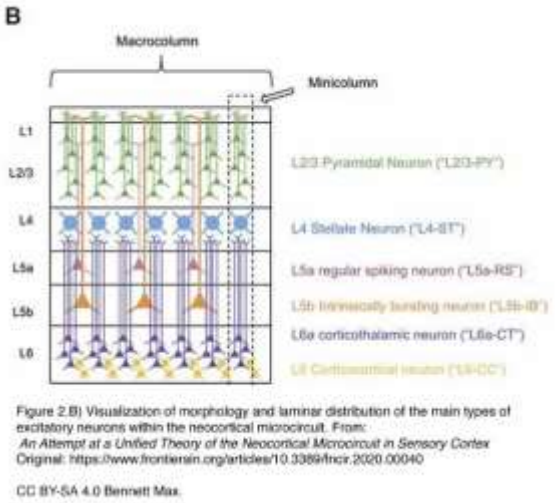
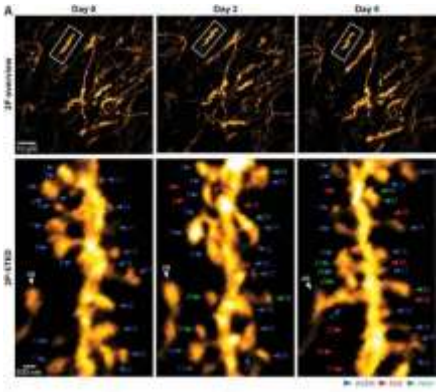


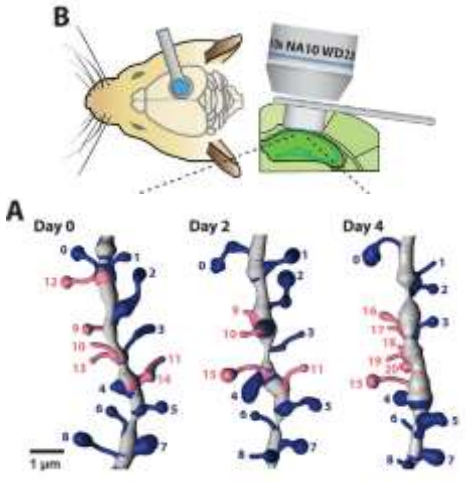
Figure 2.B) Visualization of morphology and laminar distribution of the main types of excitatory neurons within the neocortical microcircuit. From:
An Attempt at a Unified Theory of the Neocortical Microcircuit in Sensory Cortex
Original: https://www.frontiersin.org/articles/10.3389/fncir.2020.00040

https://en.wikipedia.org/

Chronic 2P-STED imaging reveals high turnover of dendritic spines in the hippocampus in vivo

Turnover ~40% within 4 days





Thomas Pfeiffer, Stefanie Poll, Stephane Bancelin, Julie Angibaud, VVG Krishna Inavalli, Kevin Keppler, Manuel Mittag, Martin Fuhrmann, U Valentin Nägerl (2018) Chronic 2P-STED imaging reveals high turnover of dendritic spines in the hippocampus in vivo eLife 7:e34700 https://elifesciences.org/articles/34700/figures

https://www.youtube.com/watch?v=iqPYwf2r37Y

Map of the entire brain of an adult fruit fly

(*Drosophila melanogaster*).

- Observe the environment
- Walk and fly
- Navigate in 3D
- Memorize information
- Make decisions
- Social interactions
- Sing to females

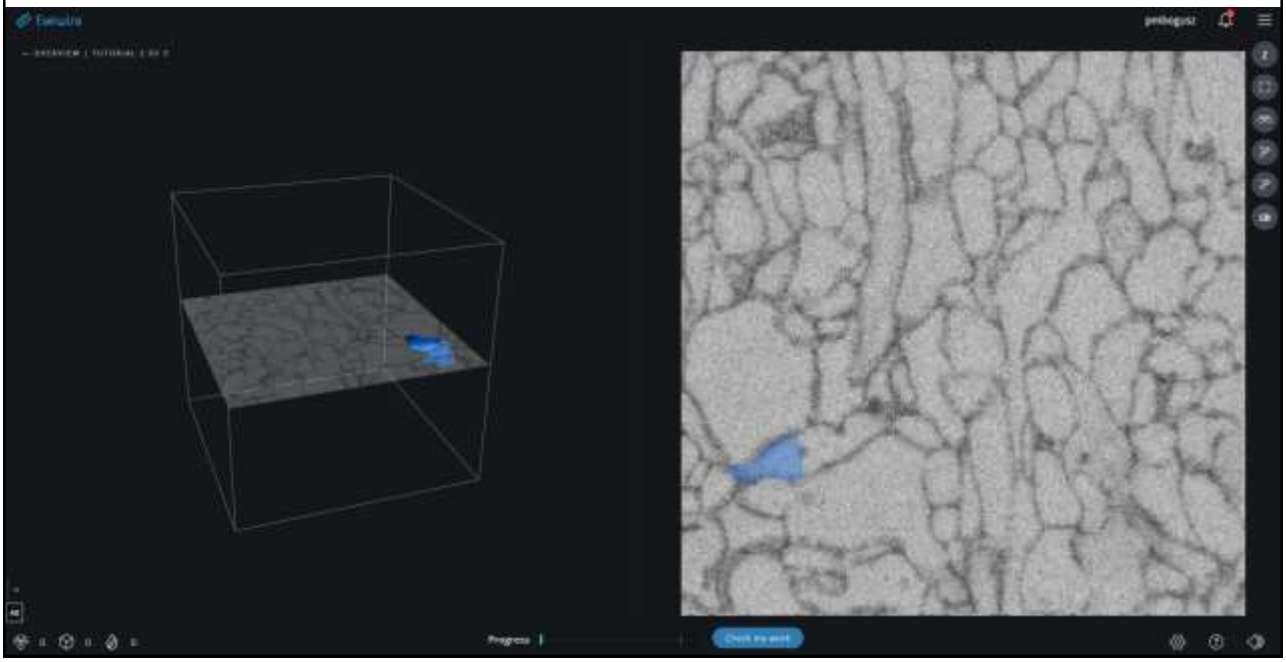
- 139 255 neurons
- 50 million connections
- 8 453 types of nerve cells
- 4 581 new ones

- FlyWire Consortium (Princeton University)
- 76 Labs / 287 Researchers
- Players online - Krzysztof Kruk (PL)

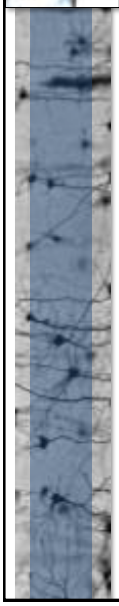
https://www.nature.com/articles/s41586-024-07686-5
https://medicalxpress.com/news/2024-10-entire-brain-adult-fruit-fly.html
https://naukawpolsce.pl/aktualnosci/news%2C104832%2Ccale-okablowanie-mozgu-muszki-opisane-polak-ma-publikacje-w-nature-bo-gral

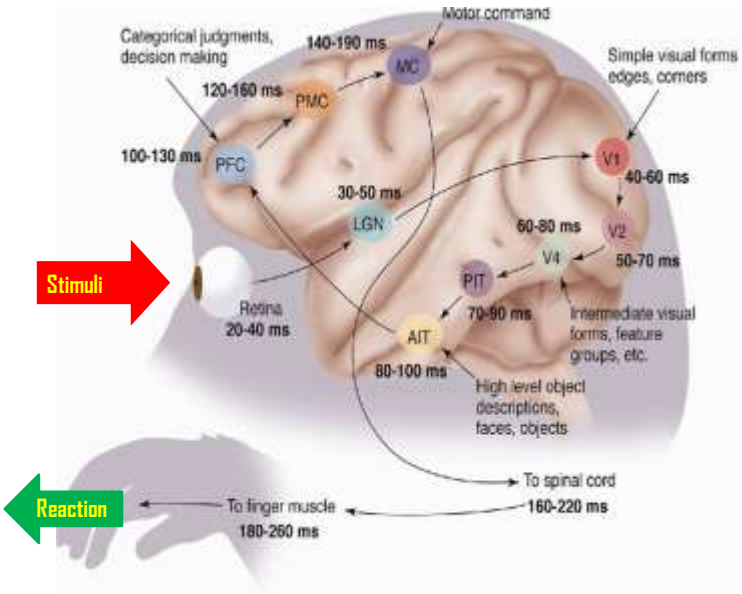
18

https://eyewire.org/



Brain - reactive machine?



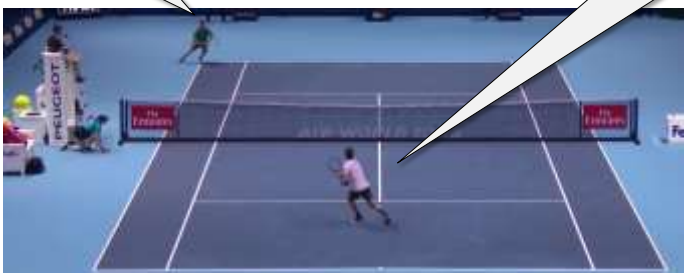


20

Brain - prediction machnie

40 ms - retina
100 ms - recognition
180 ms - reaction time:

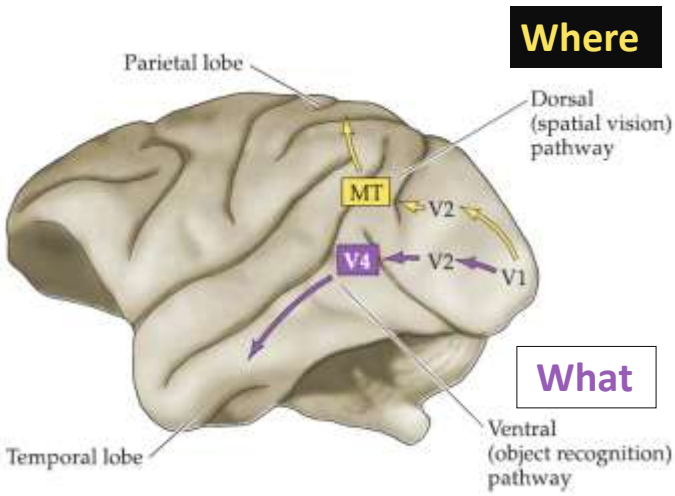
Ball distance for 40 ms:
50 km/h = 56 cm
263 km/h = 293 cm



https://www.quora.com/How-long-does-a-tennis-match-go-for

21

Visual system



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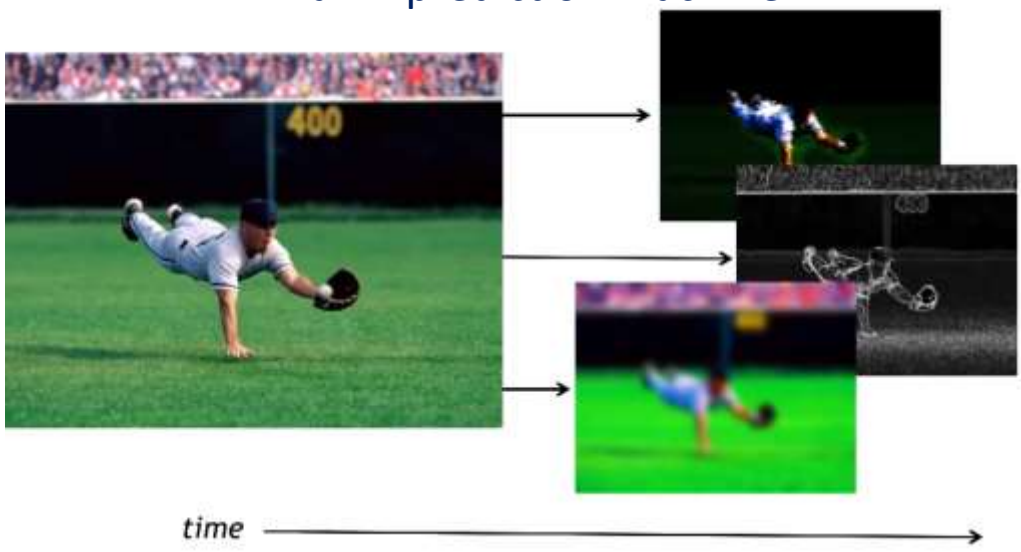
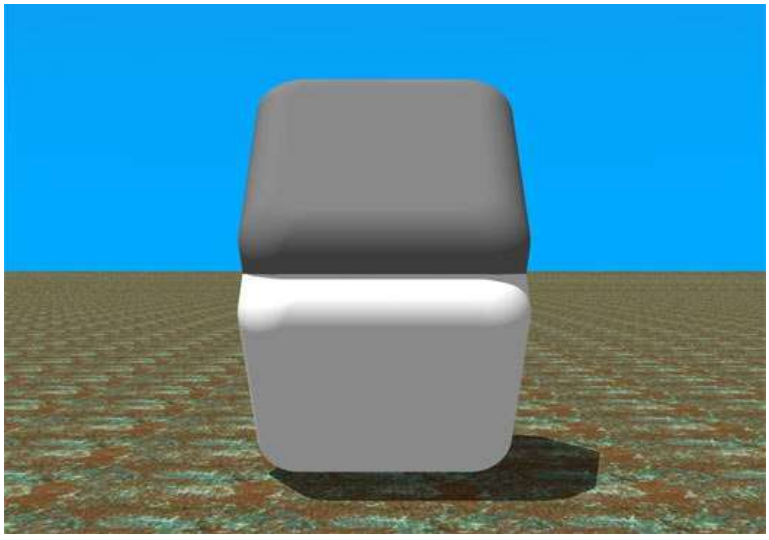
Brain - prediction machine



Time and the brain: the illusion of now | Hinze Hogendoorn | TEDxUtrechtUniversity
https://youtu.be/BEuNa1Vp_b0?t=551

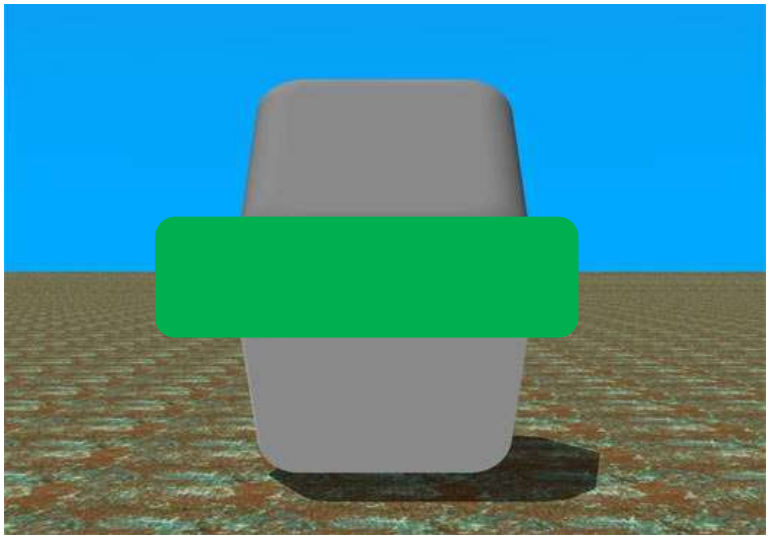
23

Illusions caused by knowledge about the environment



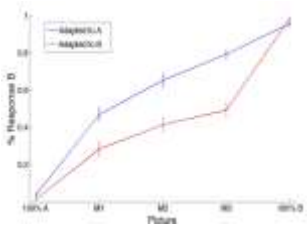
24

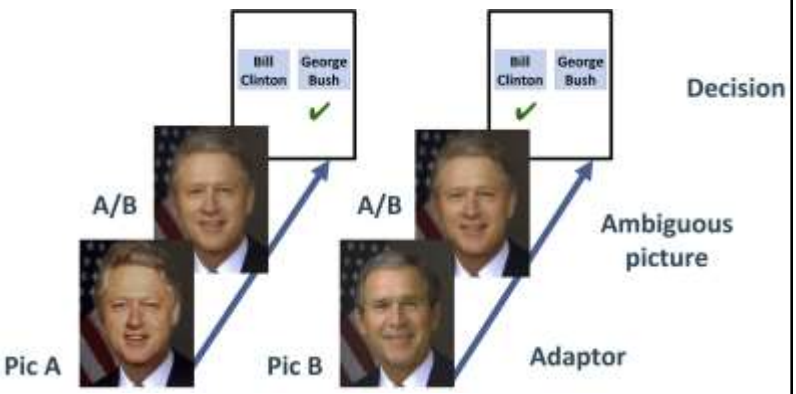
Illusions caused by knowledge about the environment



25

Illusions caused by knowledge about the environment





http://theness.com/neurologicablog/index.php/how-our-brains-respond-to-ambiguous-images/
https://static.scientificamerican.com/sciam/assets/Image/prez(1).jpg

26

Consciousness:

en.wikipedia.org

- *The brain*
- *Theories*
- *Neuroscience*
- *Strange cases*
- *Animals*
- *New biology*
- *Artificial systems*

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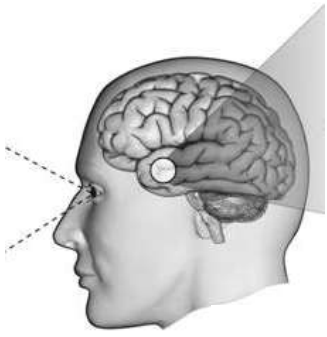
Consciousness



A natural, pre-scientific, and culturally conditioned concept

Awareness of:
- The external environment
- One's own thoughts
- Self-awareness of existence

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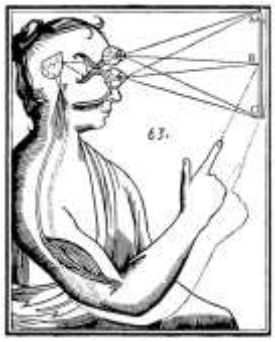
Descartes (1596 – 1650)

Cogito ergo sum
Dualism
Animal machine



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Descartes

Elizabeth of Bohemia

1643

THE CORRESPONDENCE BETWEEN
PRINCESS ELISABETH OF BOHEMIA
AND RENÉ DESCARTES

https://www.google.pl/books/edition/The_Correspondence_between_Princess_Elis/nUqHckXFyxUC?hl=en&gbpv=0

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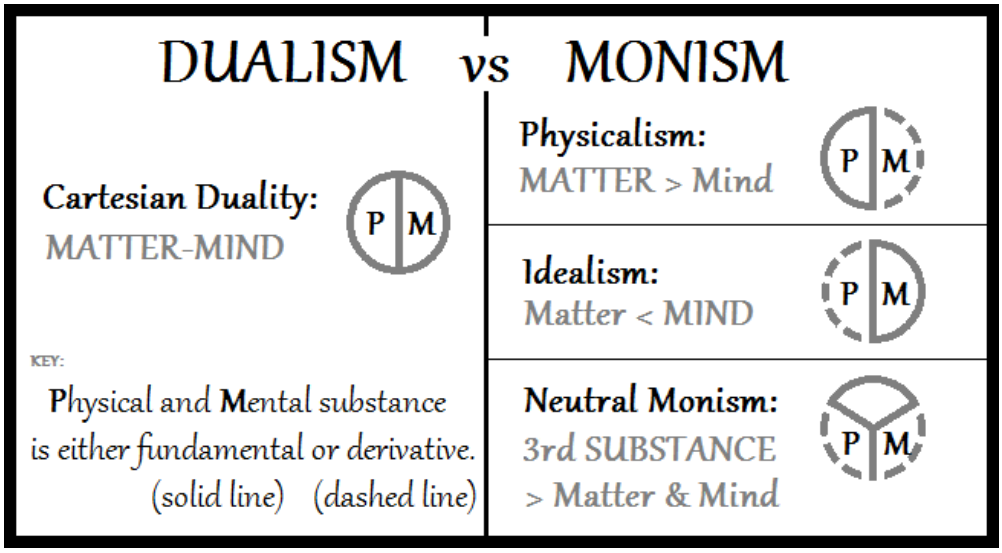
The mind–body problem



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Consciousness

Daniel Dennett

Consciousness as an Illusion

consciousness is more like a virtual interface - the desktop on a computer

Sir Roger Penrose

Consciousness as Non-Computational Processes

quantum mechanics plays a crucial role in consciousness - consciousness arises from quantum computations in microtubules

http://fizyka.umk.pl/publications/kmk/02-neuro.pdf

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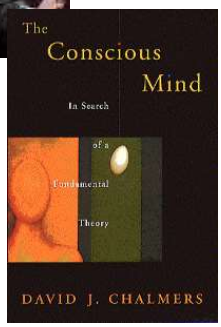
The hard problem of consciousness

David Chalmers, 1996



Easy problem

- how we process information and act

Hard problem:

- Why do we have a sense of self, a first-person perspective, a narrator.
- Why do we feel anything – not „philosophical zombies“
- Qualia – experiences have a qualitative aspect
- Inner experiences – the sense of self does not reduce to brain function

33

The neuronal correlates of consciousness (NCC)

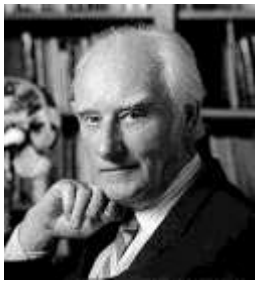
seminars in THE NEUROSCIENCES, Vol 2, 1990 : pp 263-275

Towards a neurobiological theory of consciousness

Francis Crick and Christof Koch

Visual awareness is a favorable form of consciousness to study neurobiologically. We propose that it takes two forms: a very fast form, linked to iconic memory, that may be difficult to

are undoubtedly important but we doubt whether they will, by themselves, ever be sufficiently compelling to explain consciousness in a convincing



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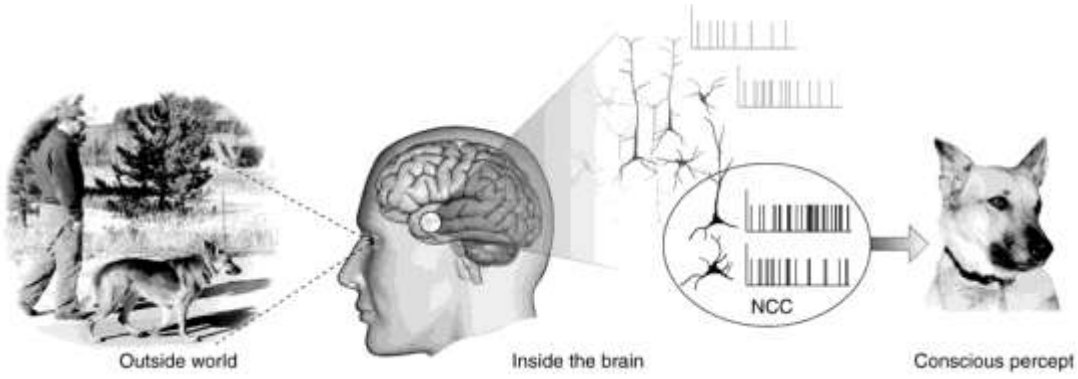
The neuronal correlates of consciousness (NCC)



https://upload.wikimedia.org/wikipedia/commons/6/6c/Neural_Correlates_Of_Consciousness.jpg

35

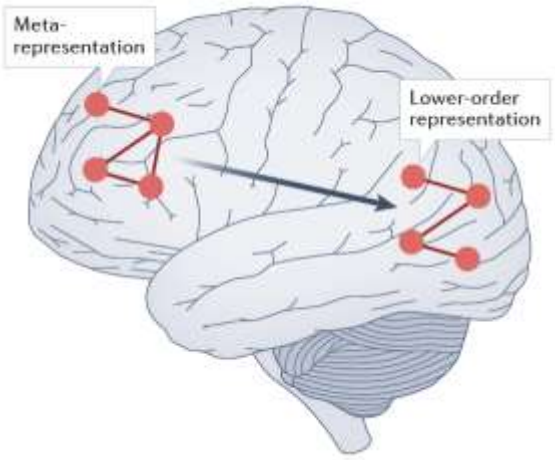
A selection of neurobiological theories of consciousness

1. **Higher-order thought theory**
2. Self-organising metarepresentational theory
3. Attended intermediate representation theory
4. **Neuronal global workspace theory**
5. **Integrated information theory**
6. Information closure theory
7. Dynamic core theory
8. Neural Darwinism
9. Local recurrency
10. **Predictive processing**
11. Neurorepresentationalism
12. Active inference
13. Beast machine theory
14. Neural subjective frame
15. Self comes to mind theory
16. Attention schema theory
17. Multiple drafts model
18. Sensorimotor theory
19. Unlimited associative learning
20. Dendritic integration theory
21. Electromagnetic field theory
22. **Orchestrated objective reduction**

Seth AK, Bayne T. Theories of consciousness. Nat Rev Neurosci. 2022 Jul;23(7):439-452. doi: 10.1038/s41583-022-00587-4. Epub 2022 May 3. PMID: 35505255.

36

Higher-order theories (HOT).



Higher-order theories. The core claim in higher-order theories (HOTs) of consciousness is that mental states are conscious in virtue of being the target of specific kinds of meta-representation.

Seth AK, Bayne T. Theories of consciousness. Nat Rev Neurosci. 2022 Jul;23(7):439-452. doi: 10.1038/s41583-022-00587-4. Epub 2022 May 3. PMID: 35505255.

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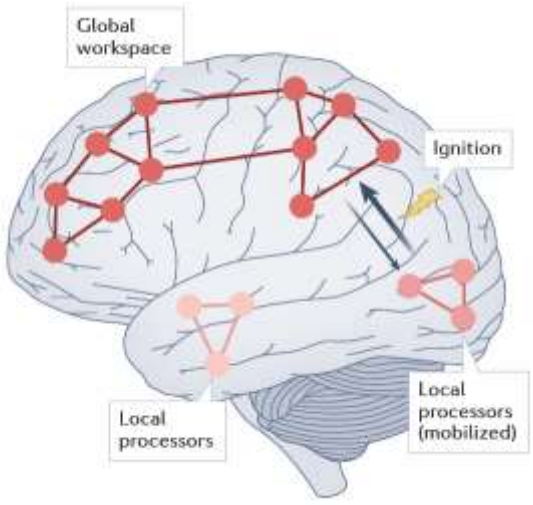
Global workspace theories (GWT).



Global workspace theories. The core claim of global workspace theories (GWTs) of consciousness is that mental states are conscious when they are broadcast within a global workspace in which fronto-parietal networks play a central hub-like role.

Seth AK, Bayne T. Theories of consciousness. Nat Rev Neurosci. 2022 Jul;23(7):439-452. doi: 10.1038/s41583-022-00587-4. Epub 2022 May 3. PMID: 35505255.

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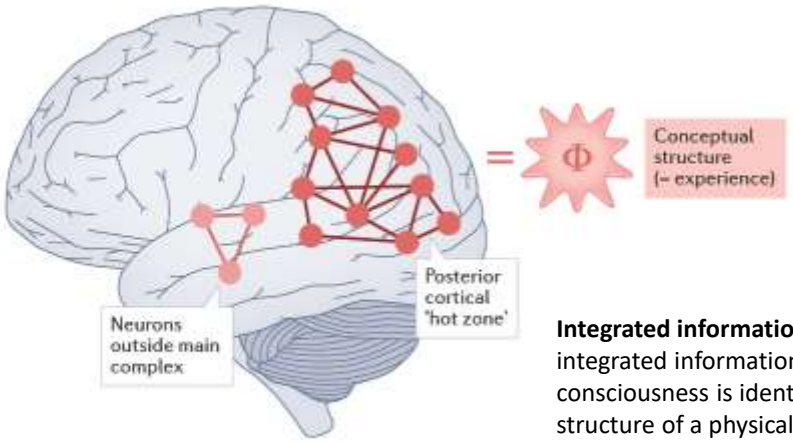
Integrated information theory (IIT).



Integrated information theory. The core claim of integrated information theory (IIT) is that consciousness is identical to the cause-effect structure of a physical system that specifies a maximum of irreducible integrated information.

Seth AK, Bayne T. Theories of consciousness. Nat Rev Neurosci. 2022 Jul;23(7):439-452. doi: 10.1038/s41583-022-00587-4. Epub 2022 May 3. PMID: 35505255.

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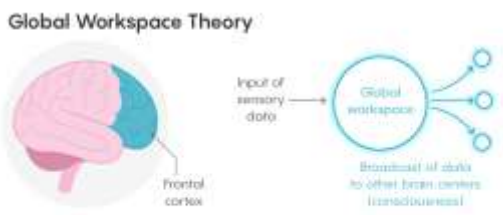
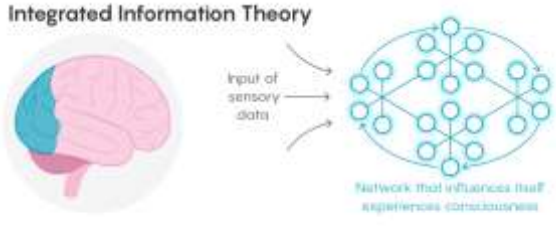
An adversarial collaboration to critically evaluate theories of consciousness

Global workspace theory



According to one theory, consciousness is a form of information processing. It occurs when sensory data for an experience go to a "global workspace" and are distributed to other centers. The architecture for this process in the brain may be in the frontal cortex.

Integrated Information Theory



The integrated information theory argues that consciousness is intrinsic to cognitive networks that exert a "causal power" on themselves. The back of the brain might have the right architecture for this capacity.

Quanta magazine

https://www.quantamagazine.org/neuroscience-readies-for-a-showdown-over-consciousness-ideas-20190306/
https://www.biorxiv.org/content/10.1101/2023.06.23.546249v2

40

The Integrated Information Theory of Consciousness as Pseudoscience

nature

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nature > news > article

NEWS | 20 September 2023

Consciousness theory slammed as 'pseudoscience' – sparking uproar

Researchers publicly call out theory that they say is not well supported by science, but that gets undue attention.

Mariana Lenharo

A letter, signed by 124 scholars and posted online last week, has caused an uproar in the consciousness-research community. It argues that a prominent theory describing what makes someone or something conscious – called the integrated information theory (IIT) – should be labelled as pseudoscience. Since its publication on 15 September in the preprint repository PsyArXiv[1], the letter has resulted in some researchers arguing over the label and others worrying that it will increase polarization in a field that has grappled with issues of

https://www.nature.com/articles/d41586-023-02971-1
https://osf.io/preprints/psyarxiv/zsr78

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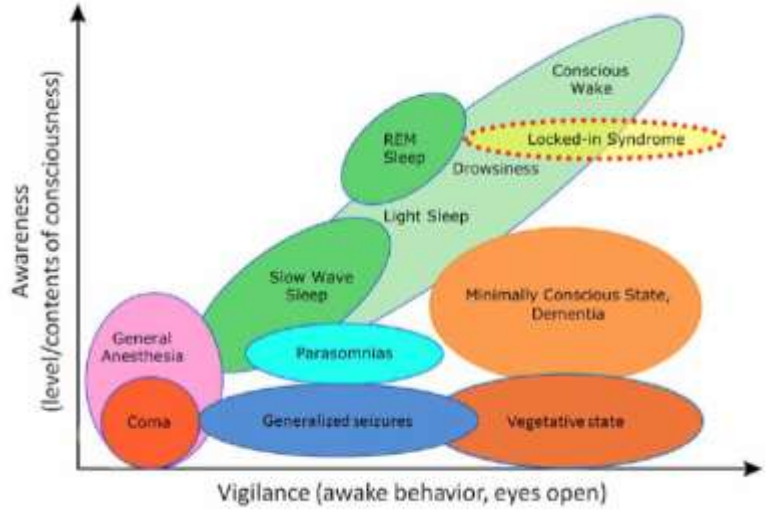
Consciousness:

- *The brain*
- *Theories*
- *Neuroscience*
- *Strange cases*
- *Animals*
- *New biology*
- *Artificial systems*

en.wikipedia.org

42

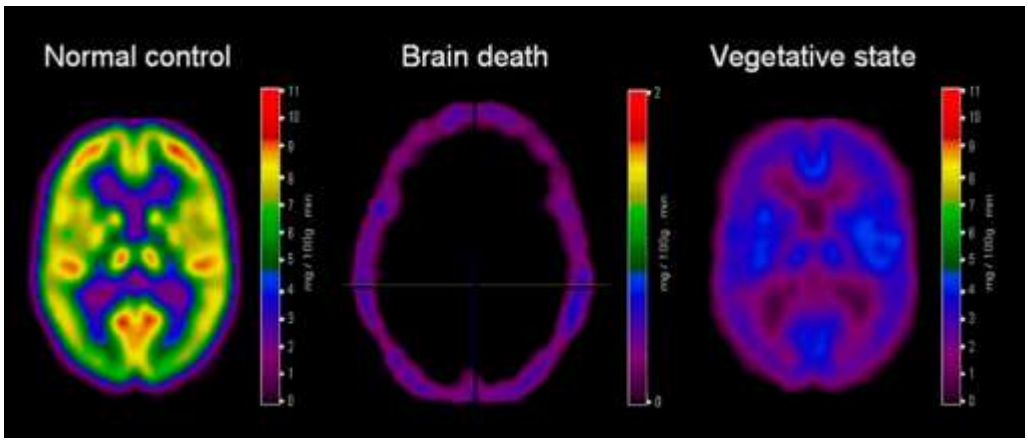
Level and contents of consciousness.



Boly M et al. 2013 - Consciousness in humans and non-human animals- recent advances and future

43

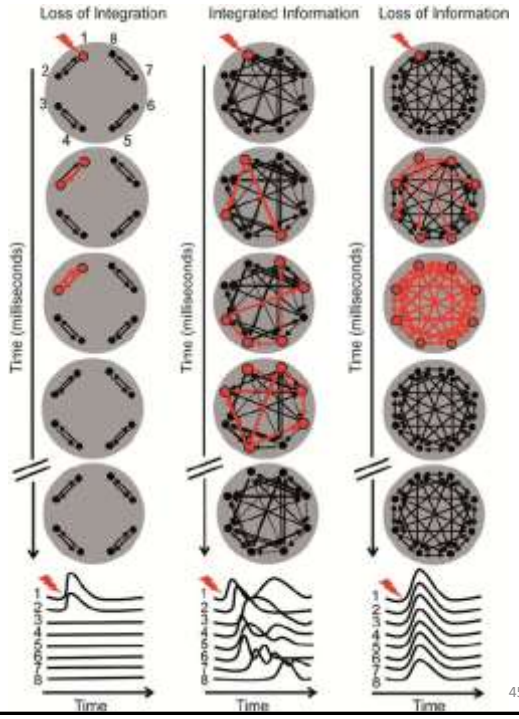
PET - Positron emission tomography



http://www.scholarpedia.org/article/Vegetative_state

44

Zapping and Zipping

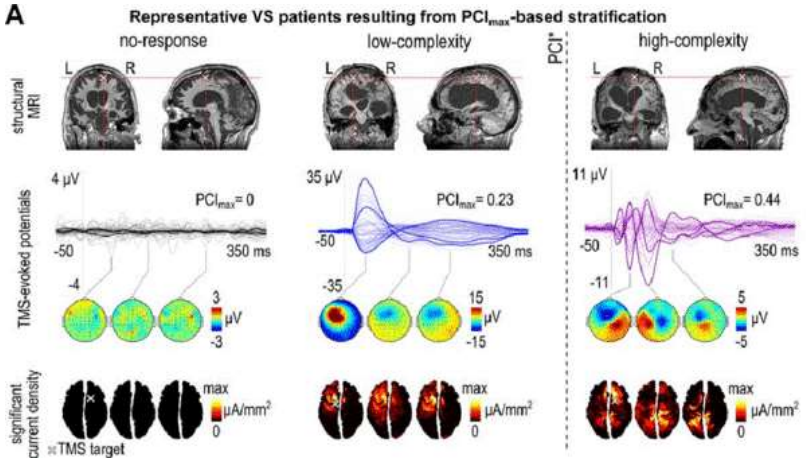


https://www.researchgate.net/publication/259631006_Quantifying_Cortical_EEG_Responses_to_TMS_in_Unconsciousness

2014 Quantifying Cortical EEG Responses to TMS in (Un)consciousness, Simone Sarasso, Clinical EEG and Neuroscience, DOI: 10.1177/1550059413513723

45

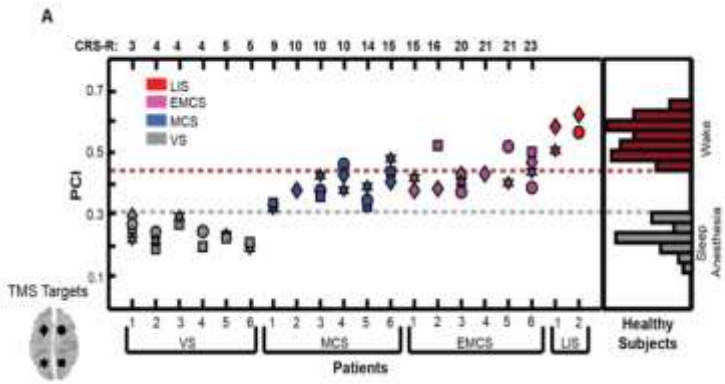
Stratification of unresponsive patients by an independently validated index of brain complexity



https://www.researchgate.net/publication/308946803_Stratification_of_unresponsive_patients_by_an_independently_validated_index_of_brain_complexity. September 2016, Annals of Neurology 80(5) DOI: 10.1002/ana.24779

46

Zapping and Zipping – assesment

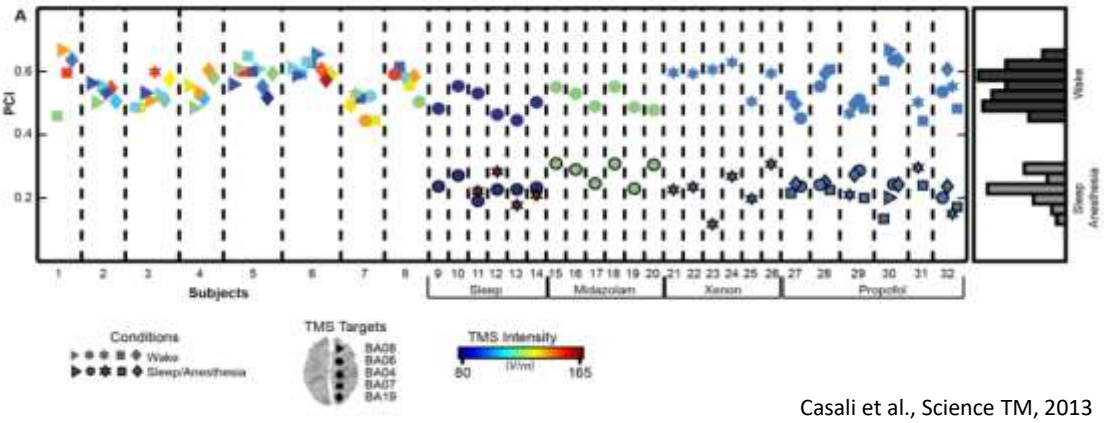


Casali et al., Science TM, 2013

https://www.researchgate.net/publication/255955267_A_Theoretically_Based_Index_of_Consciousness_Independent_of_Sensory_Processing_and_Behavior

https://na.eventscloud.com/file_uploads/8bc655dc99e026910acc75535876e917_GuillioTononi.pdf

Zapping and Zipping - anestetics

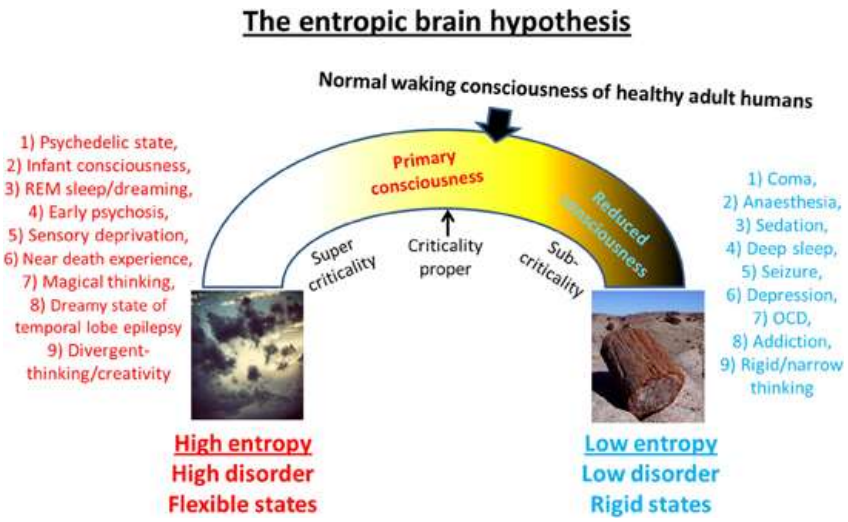


Casali et al., Science TM, 2013

https://www.researchgate.net/publication/255955267_A_Theoretically_Based_Index_of_Consciousness_Independent_of_Sensory_Processing_and_Behavior

https://na.eventscloud.com/file_uploads/8bc655dc99e026910acc75535876e917_GuillioTononi.pdf

Spectrum of cognitive states

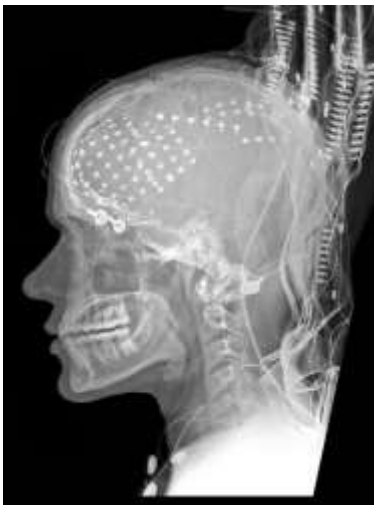


Carhart-Harris RL, Leech R, Hellyer PJ, Shanahan M, Feilding A, Tagliazucchi E, Chialvo DR, Nutt D. The entropic brain: a theory of conscious states informed by neuroimaging research with psychedelic drugs. Front Hum Neurosci. **2014** Feb 3;8:20. doi: 10.3389/fnhum.2014.00020. PMID: 24550805;

https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2014.00020/full

49

ECoG and deep electrodes

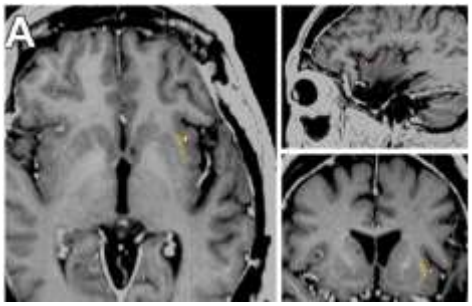


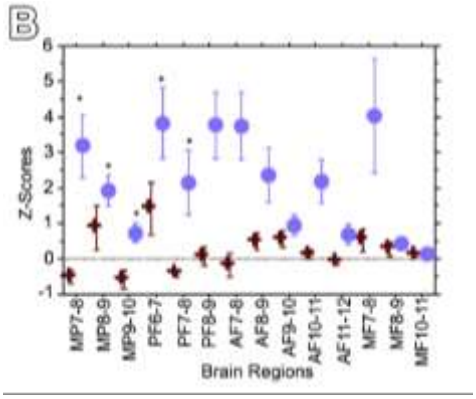
http://www.nedsahin.com/methods/ice/

http://www.livescience.com/5780-speed-thought-speech-traced-brain.html

50

Electric stimulation block consciousness

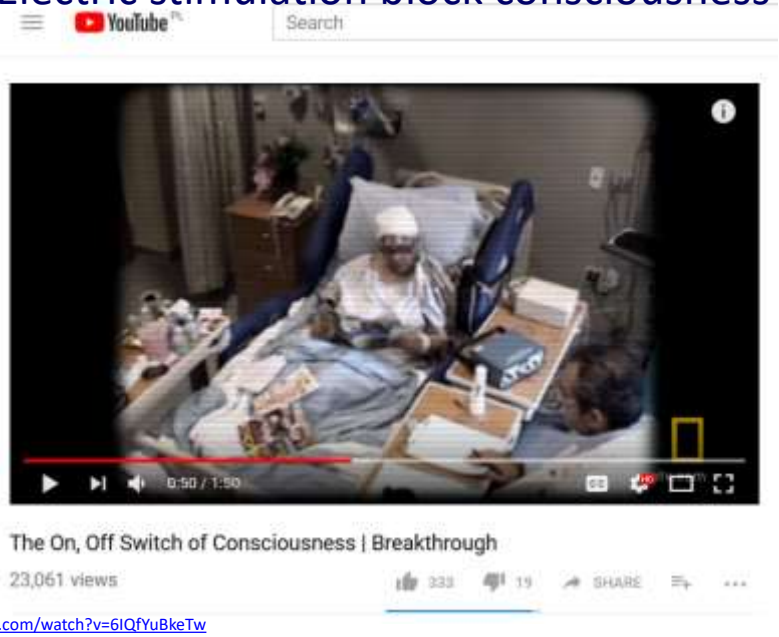




Koubeissi MZ et al. 2014 - Electrical stimulation of a small brain area reversibly disrupts consciousness

51

Electric stimulation block consciousness

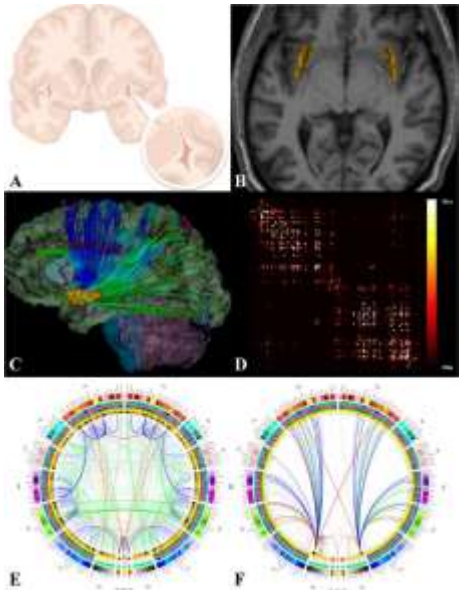


https://www.youtube.com/watch?v=6IQfYuBkeTw

52

53

Clastrum.



http://www.nature.com/news/a-giant-neuron-found-wrapped-around-entire-mouse-brain-1.21539

Torgerson, C. M. *et al*. Hum. Brain Mapp. 36, 827–838 (2015).

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Consciousness:

- *The brain*
- *Theories*
- *Neuroscience*
- *Strange cases*
- *Animals*
- *New biology*
- *Artificial systems*

en.wikipedia.org

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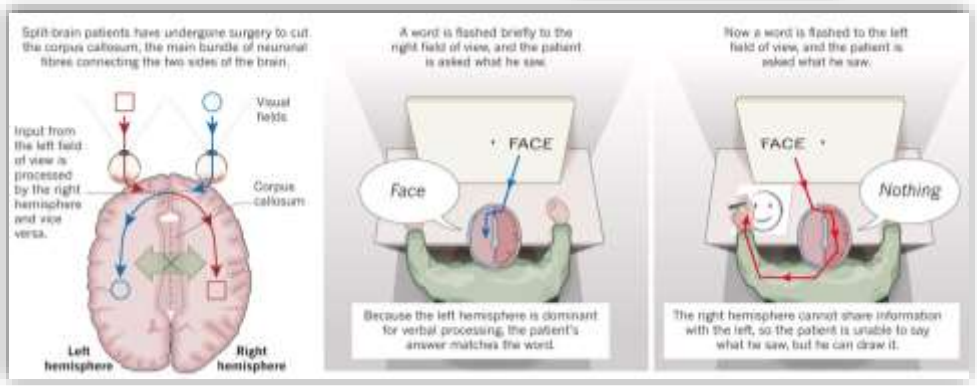
Split brain

Michael S. Gazzaniga

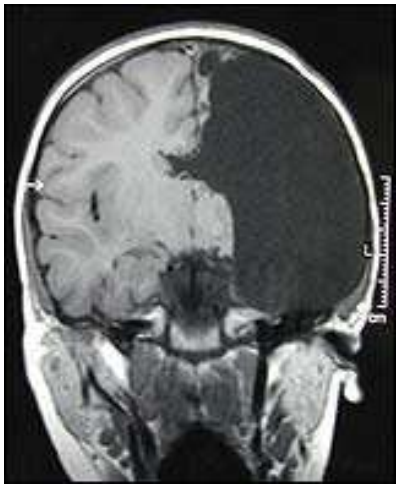


http://knowingneurons.com/2014/07/23/the-split-brain-making-two-hemispheres-whole/

http://www.nature.com/news/the-split-brain-a-tale-of-two-halves-1.10213

56

Rasmussen syndrome



http://media3.s-nbcnews.com/j/MSNBC/Components/Video/100325/tdy_curry_brain2_100325.standard.jpg

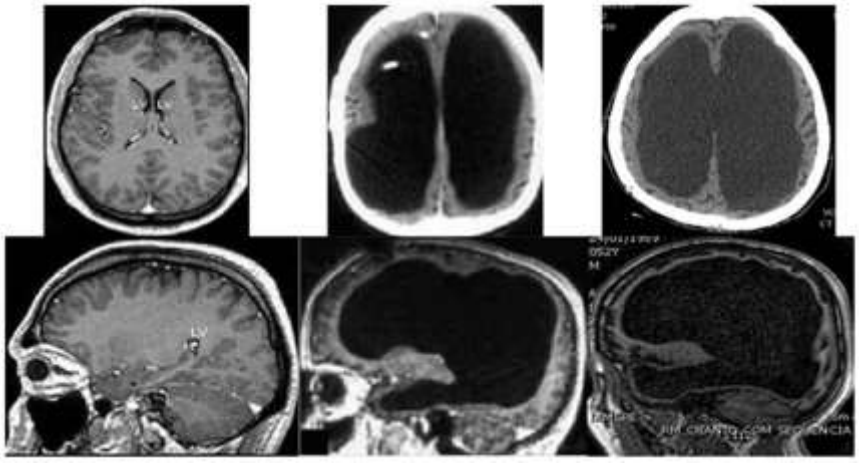
57

Rasmussen syndrome

02.10.2017, 19:06 (http://www.tvn24.pl)

58

The white collar brain



http://journal.frontiersin.org/Journal/10.3389/fnhum.2011.00181/full

59

Krista and Tatiana Hogan
Two persons – common brain

https://www.youtube.com/watch?v=WKwT1Ol3nY0
https://www.cbc.ca/cbcdocspov/features/the-hogan-twins-share-a-brain-and-see-out-of-each-others-eyes

60

Consciousness:

en.wikipedia.org

- *The brain*
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- *Animals*
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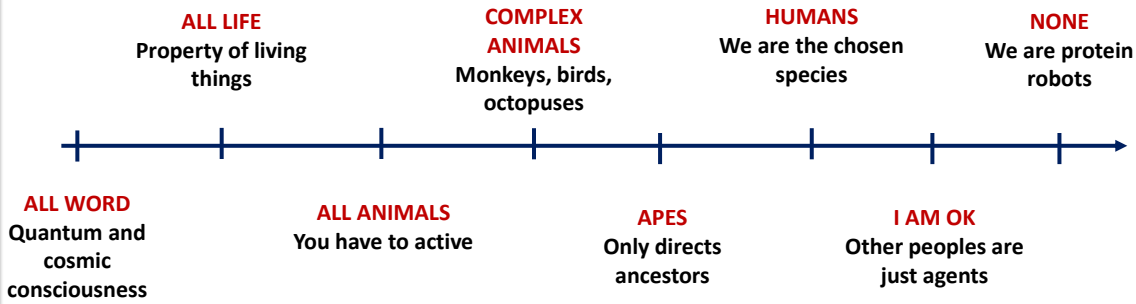
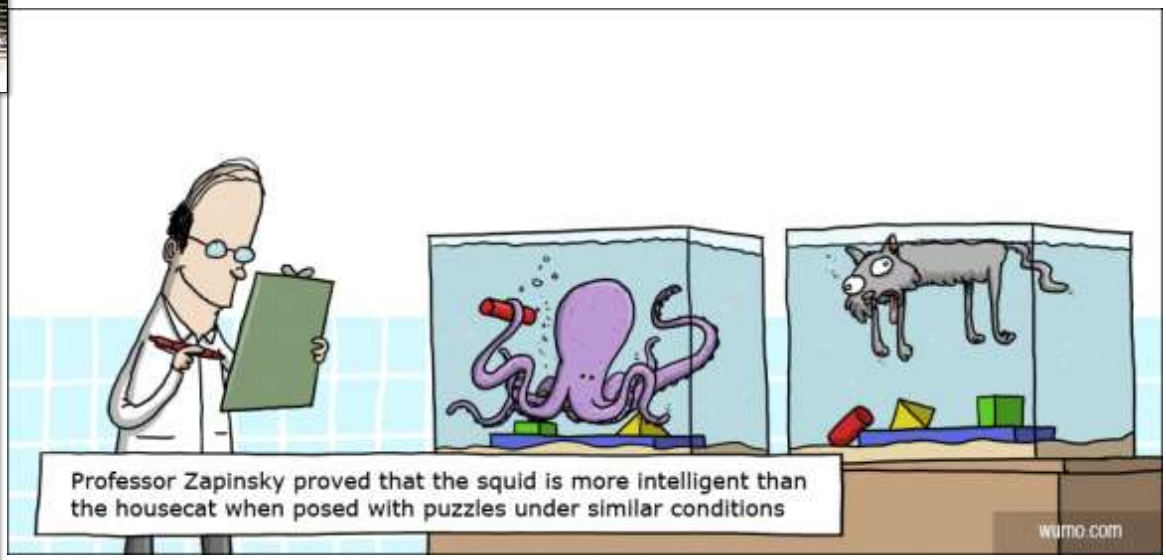
Consciousness



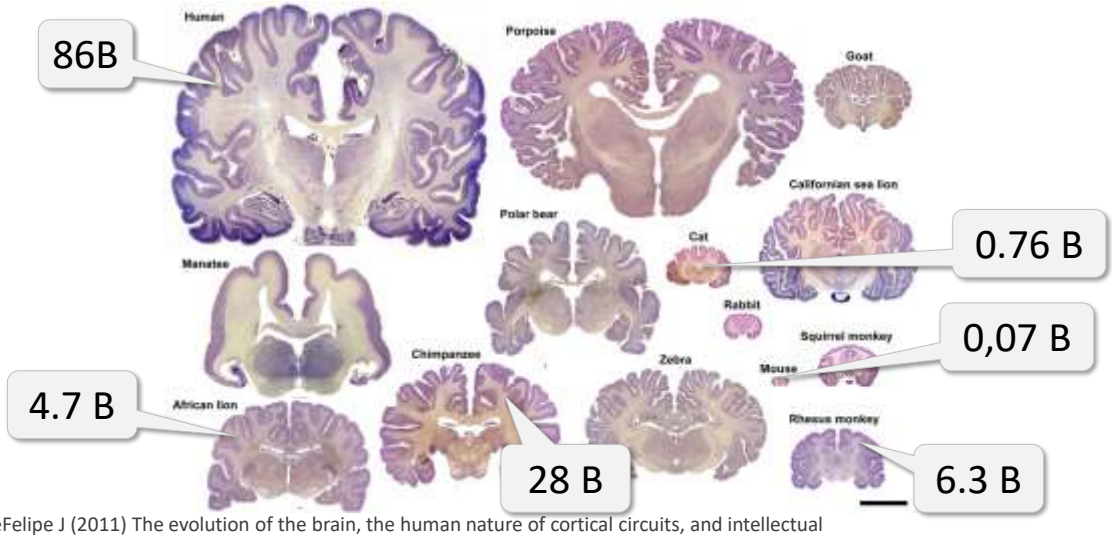
62



http://wumo.com/wumo/2013/02/25

63

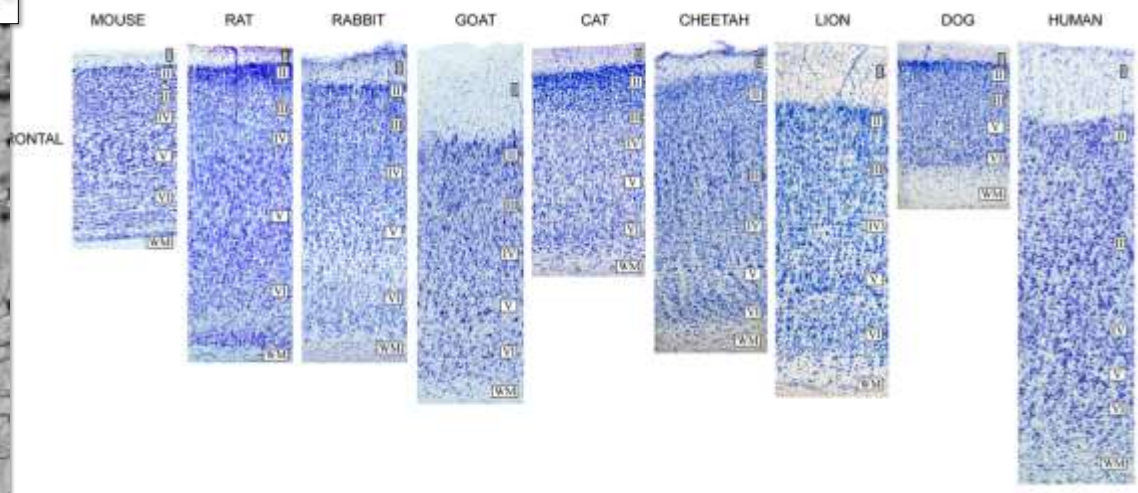
Mammalian brains



DeFelipe J (2011) The evolution of the brain, the human nature of cortical circuits, and intellectual creativity. *Front. Neuroanat.* **5**:29. doi: 10.3389/fnana.2011.00029
https://www.frontiersin.org/articles/10.3389/fnana.2011.00029/full

64

Neurons are similar

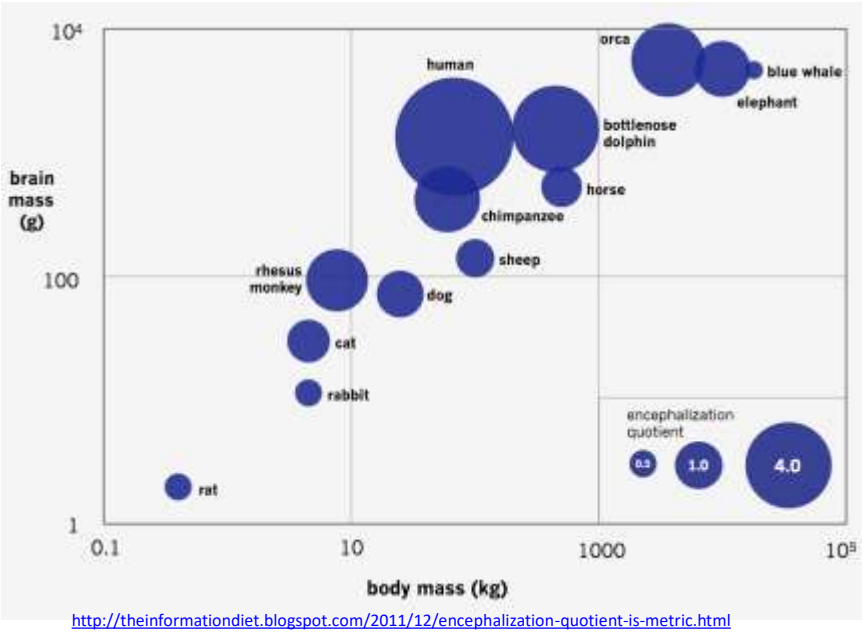


DeFelipe J (2011) The evolution of the brain, the human nature of cortical circuits, and intellectual creativity. *Front. Neuroanat.* **5**:29. doi: 10.3389/fnana.2011.00029

https://www.frontiersin.org/articles/10.3389/fnana.2011.00029/full

65

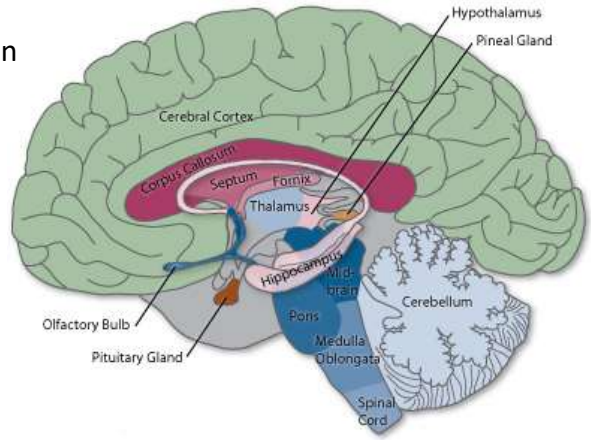
Animal Brain vs. Body Mass - The encephalization quotient



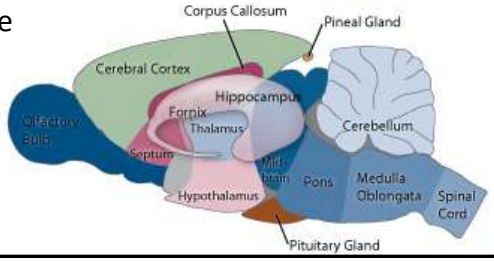
http://theinformationdiet.blogspot.com/2011/12/encephalization-quotient-is-metric.html

66

Human



Mouse

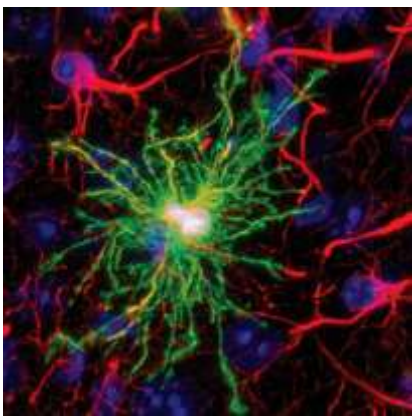


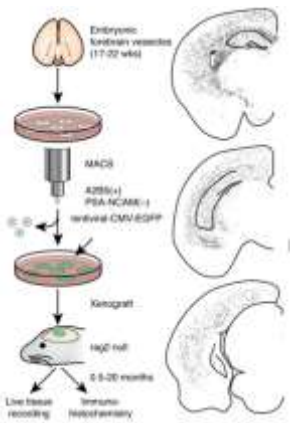
67

Forebrain engraftment by human glial progenitor cells enhances synaptic plasticity and learning in adult mice.

Cell Stem Cell. 2013 Mar 7;12(3):342-53. doi: 10.1016/j.stem.2012.12.015.

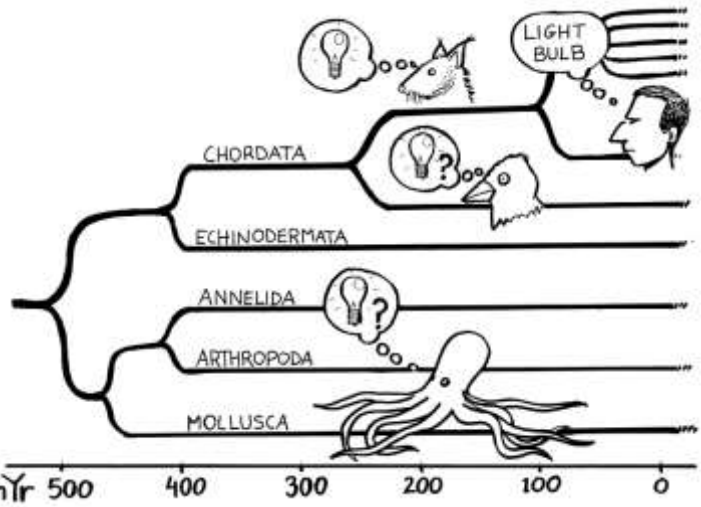
Han X, Chen M, Wang F, Windrem M, Wang S, Shanz S, Xu Q, Oberheim NA, Bekar L, Betstadt S, Silva AJ, Takano T, Goldman SA, Nedergaard M.





68

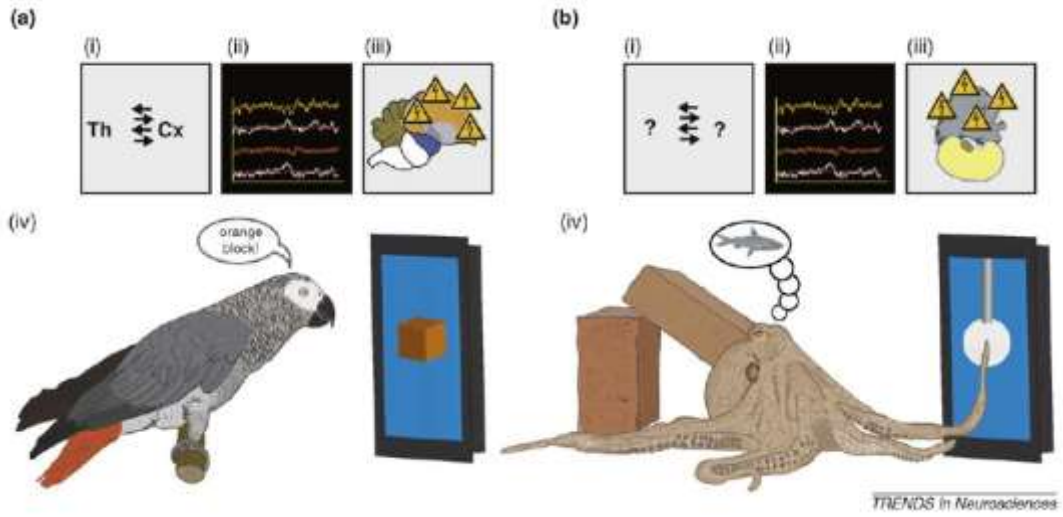
The phylogeny of consciousness – TOP DOWN.



Edelman DB et al. 2005 - Identifying hallmarks of consciousness in non-mammalian species.

69

Consciousness in animals

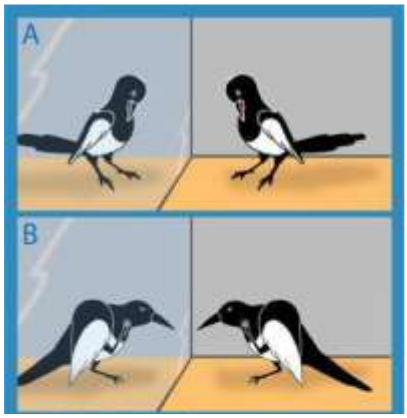


Edelman DB and Seth 2009 - Animal consciousness- a synthetic approach.

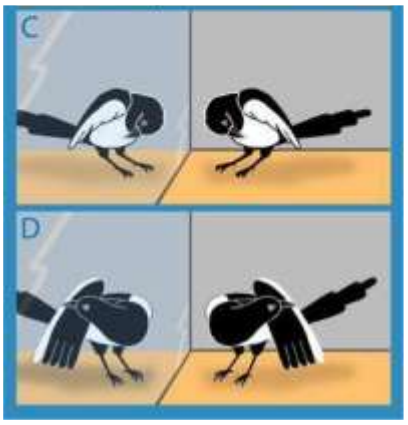
70

Mirror self-recognition (MSR) test

Chimpanzees, bonobos, orangutans, dolphins, elephants, european magpie



Mark-directed behavior



Self-directed, but not related to the mark

Prior et al. (2008).

71

Bluestreak cleaner wrasse (*Labroides dimidiatus*)

https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3000021
https://www.mpg.de/12704402/cleaner-wrasse-self-awareness

72

Bluestreak cleaner wrasse (*Labroides dimidiatus*)

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The Cambridge Declaration on Consciousness

"The absence of a neocortex does not appear to preclude an organism from experiencing affective states. Convergent evidence indicates that non-human animals have the neuroanatomical, neurochemical, and neurophysiological substrates of conscious states along with the capacity to exhibit intentional behaviors. Consequently, the weight of evidence indicates that humans are not unique in possessing the neurological substrates that generate consciousness. Nonhuman animals, including all mammals and birds, and many other creatures, including octopuses, also possess these neurological substrates."

July 7, 2012

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Consciousness:

en.wikipedia.org

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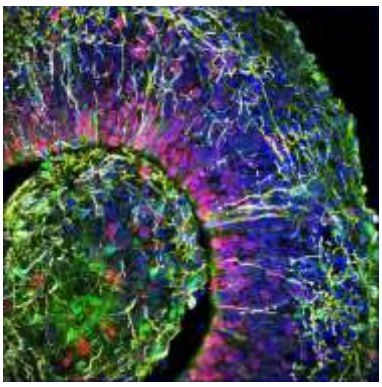
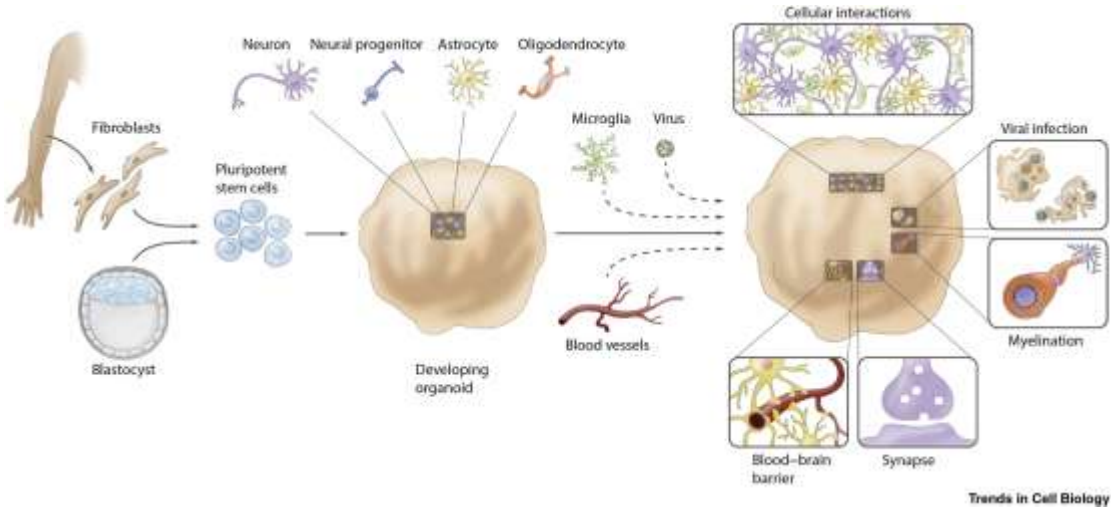
Organoids



https://www.technologynetworks.com/neuroscience/articles/cutting-through-the-headlines-are-scientists-really-growing-sentient-mini-brains-328000

76

Organoids

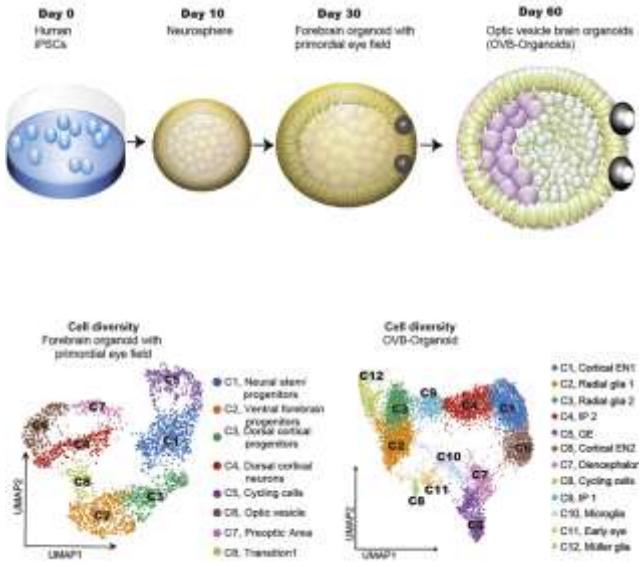


Organoid and Assembloid Technologies for Investigating Cellular Crosstalk in Human Brain Development and Disease, Rebecca M. Marton Sergiu P. Paşca 2020

https://www.cell.com/trends/cell-biology/fulltext/S0962-8924(19)30200-4#relatedArticles

77

Human organoids with eyes

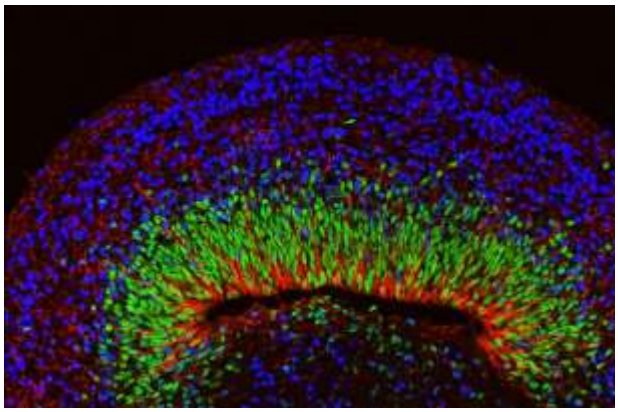


Human brain organoids assemble functionally integrated bilateral optic vesicles, Gabriel et al. 2021 (7 October 2021)

https://doi.org/10.1016/j.stem.2021.07.010

78

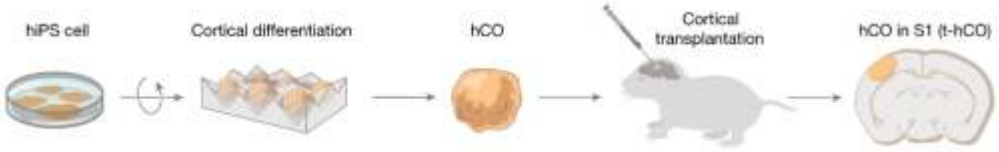
Brain organoid with electrical activity

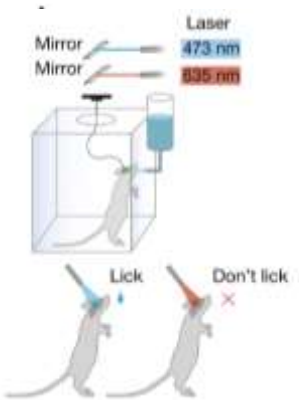


- Donor – a person with Rett syndrome
- Point mutation in the MECP2 gene
- Organoids from body cells
- Epileptic EEG – similar to that in patients

https://newsroom.ucla.edu/releases/brain-organoids-complex-neural-activity

Grafting human organoid in to rat brain



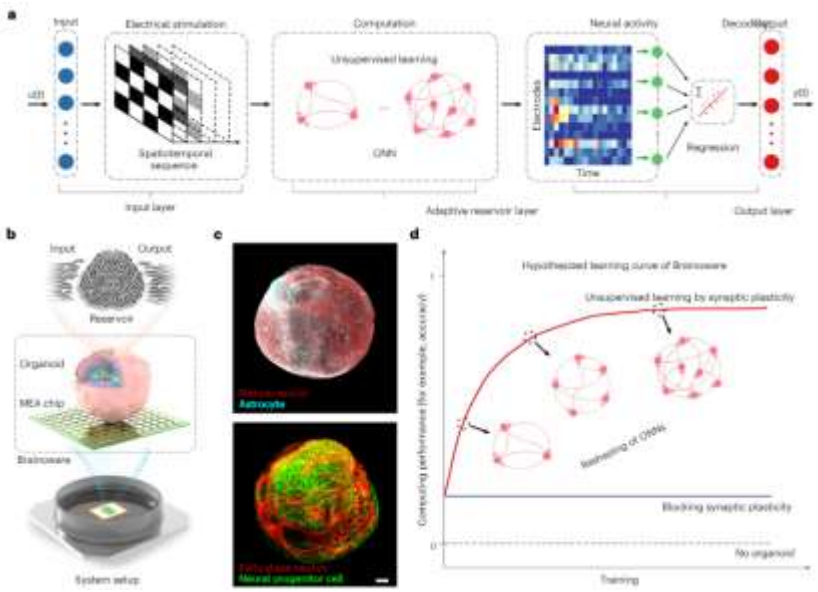


https://www.nature.com/articles/s41586-022-05277-w

https://www.the-scientist.com/news-opinion/researchers-transplant-human-neurons-into-rat-brains-70615

Brain organoid reservoir computing for AI

2023.12.11



https://www.nature.com/articles/d41586-023-03975-7#ref-CR1

Cai, H. et al. Nature Electron. https://doi.org/10.1038/s41928-023-01069-w (2023).

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Consciousness:

- *The brain*
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- *New biology*
- *Artificial systems*

en.wikipedia.org

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- ChatGPT - Chat Generative Pre-trained Transformer
- Large language model LLM
- Transformer - deep learning architecture

what is artificial intelligence?

Artificial Intelligence (AI) is a branch of computer science focused on creating systems capable of performing tasks that typically require human intelligence. These tasks can include problem-solving, decision-making, learning, understanding natural language, recognizing patterns, and even creative processes like generating art or composing music.

https://openai.com/chatgpt

83

Any sufficiently advanced technology is indistinguishable from magic

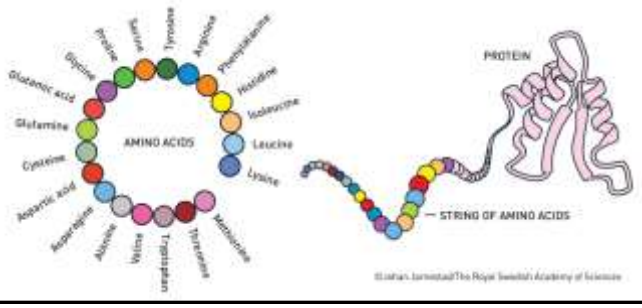
Arthur C. Clarke, “Profiles of the Future: An Inquiry into the Limits of the Possible”, 1962.

https://en.wikipedia.org/wiki/Arthur_C._Clarke

84

The Nobel Prize in Chemistry 2024

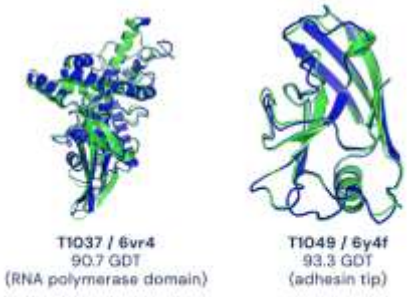
David Baker	Demis Hassabis	John Jumper
"for computational protein design"	"for protein structure prediction"	"for protein structure prediction"



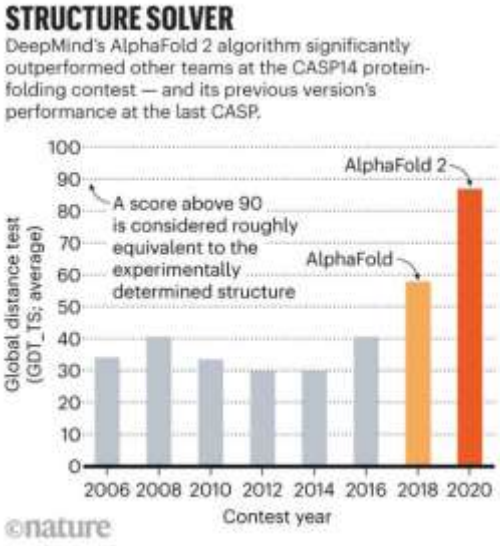
https://www.nobelprize.org/all-nobel-prizes-2(

85

AlphaFold 2, won CASP14 2020.11



https://deepmind.com/blog/article/alphafold-a-solution-to-a-50-year-old-grand-challenge-in-biology



https://www.nature.com/articles/d41586-020-03348-4

86

- **LaMDA** - Language Model for Dialogue Applications

https://www.washingtonpost.com/technology/2022/06/11/google-ai-lamda-blake-lemoine/

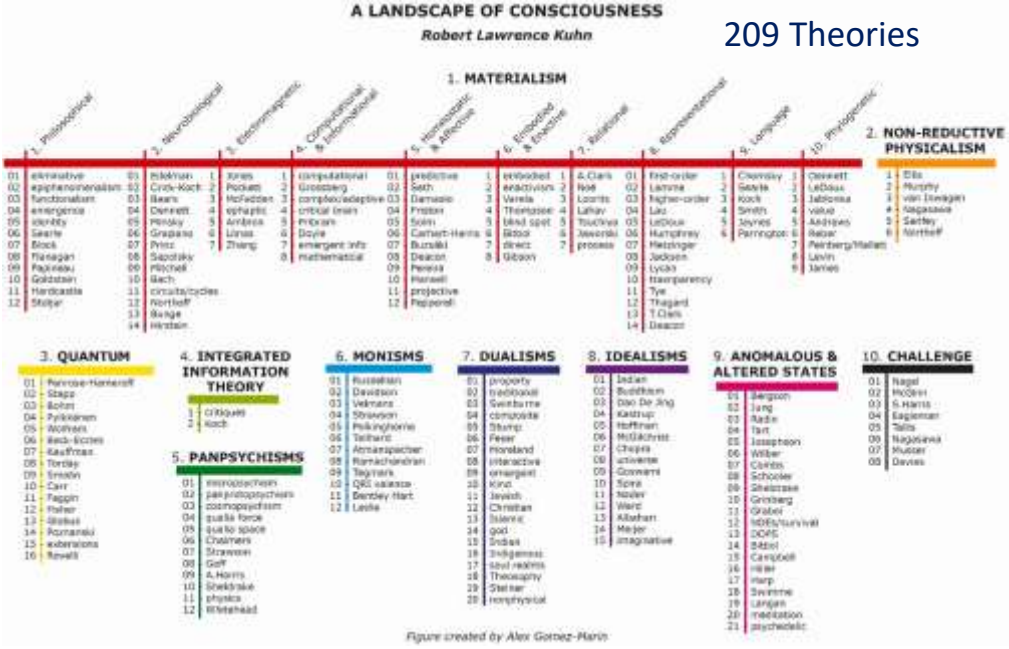
87

CLOSER TO TRUTH 2000 - 2024

Robert Lawrence Kuhn

https://www.closertotruth.com/episodes/why-consciousness-so-mysterious
https://en.wikipedia.org/wiki/List_of_Closer_to_Truth_episodes

88



https://www.sciencedirect.com/science/article/pii/S0079610723001128?via%3Dihub

Kuhn RL. A landscape of consciousness: Toward a taxonomy of explanations and implications. Prog Biophys Mol Biol. 2024 Aug;190:28-169. doi: 10.1016/j.pbiomolbio.2023.12.003. Epub 2024 Jan 26. PMID: 38281544.

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Consciousness as a natural phenomenon

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p.boguszewski@nencki.edu.pl

100 years nencki institute of experimental biology