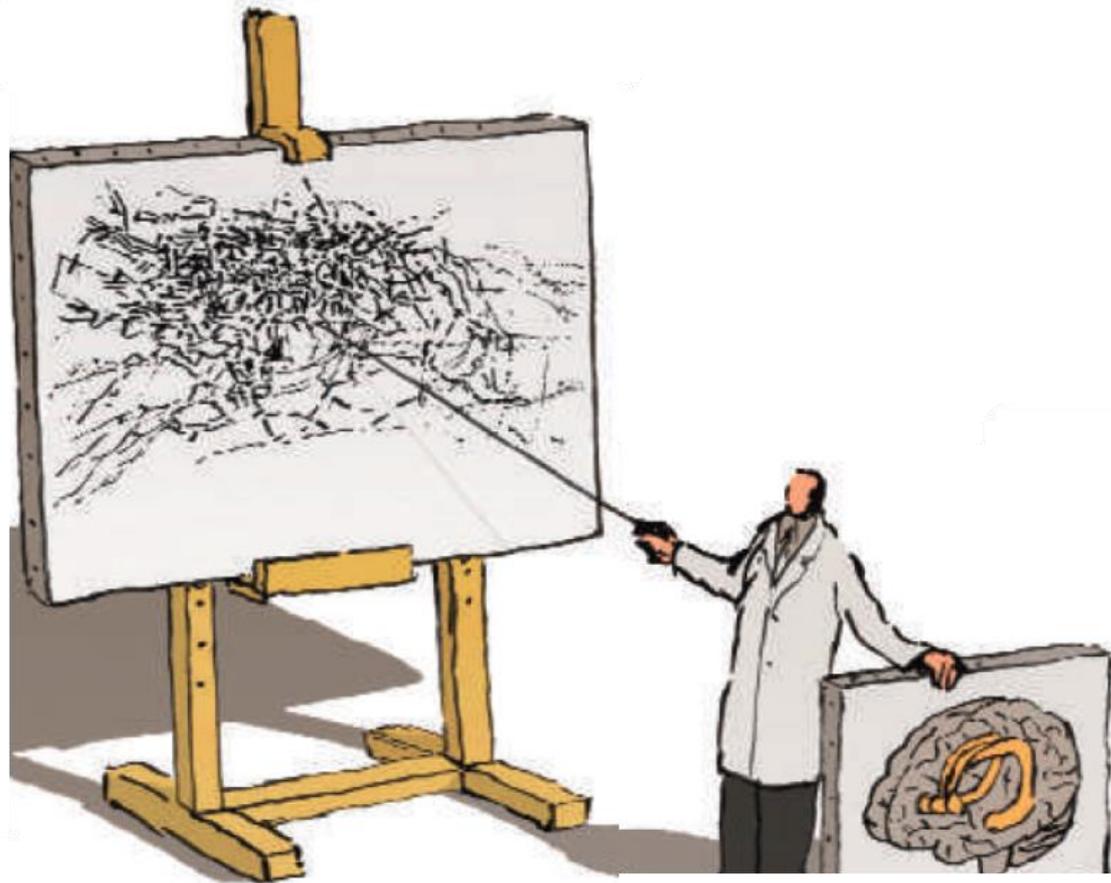


Нейронные гиперсети:

факты и теории об устройстве и динамике высших функций мозга

Константин Анохин

Институт перспективных исследований мозга МГУ



Первая международная конференция

Теоретическая физика и математика мозга:

междисциплинарные контакты

ТЕМЫ

- геометрические и динамические свойства сетей мозга;
- мозг как критическая система;
- информационные и энтропийные аспекты функционирования мозга;
- топологический анализ данных;
- отображения коннектома в пространство стимулов;
- коннектом как статистическая система и его связь с другими направлениями исследований сложных распределенных систем.



ДОКЛАДЧИКИ

- **Константин Анохин** (МГУ, Москва)
- **Антон Айзенберг** (ВШЭ, Москва)
- **Александр Бернштейн** (Сколтех, Москва)
- **Роман Борисюк** (Университет Экзетер, Великобритания)
- **Всеволод Чернышев** (ВШЭ, Москва)
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- **Константин Анохин** (Институт перспективных исследований мозга МГУ)
- **Александр Горский** (Институт проблем передачи информации РАН)
- **Юрий Котелевцев** (Центр нейробиологии и восстановления мозга Сколтех)
- **Сергей Нечаев** (Центр Понселе)

Consciousness & the Brain: John Searle at TEDxCERN

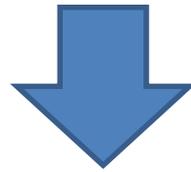


JOHN SEARLE

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

The main idea of the lecture:

**To get deeper into the brain
one needs to reach higher**



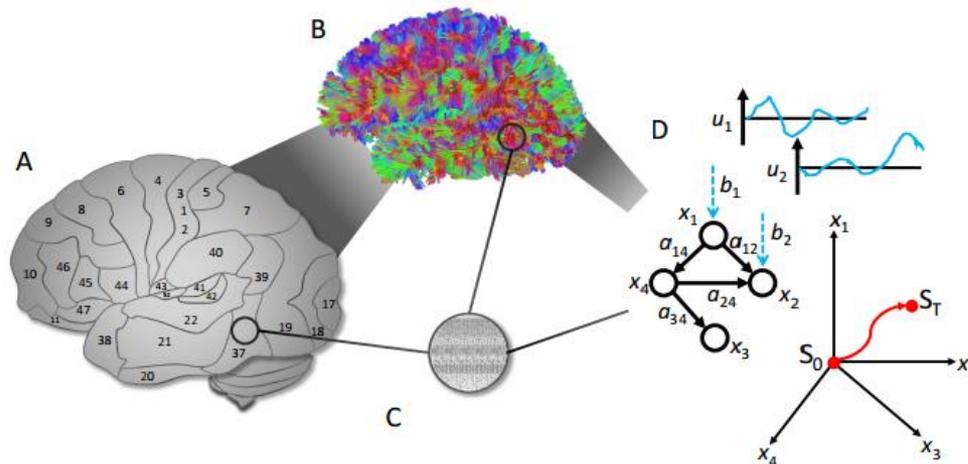
Deep HyperRealism:

- Hyper is real
- Hyper is deep

Current situation

- A burst of neuroscience research
- Leads to huge amount of data
- Is accompanied by lack of understanding
- And a desperate need of fundamental brain theory (**FBT**)

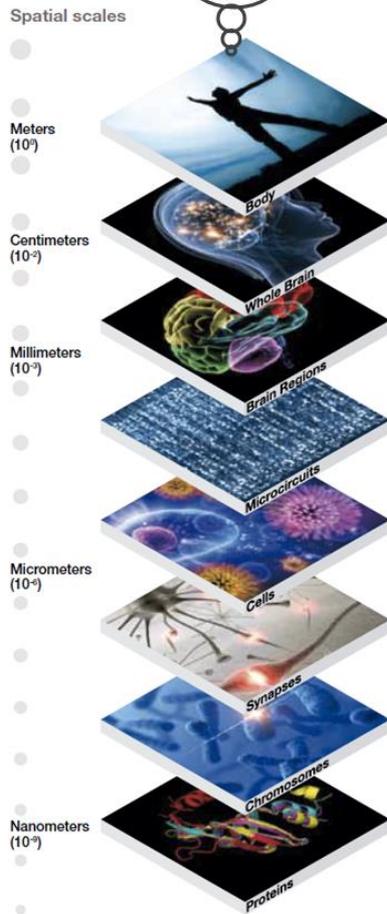
Theoretical physics and mathematics of the brain



The MAIN problem for FBT



B
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• More...

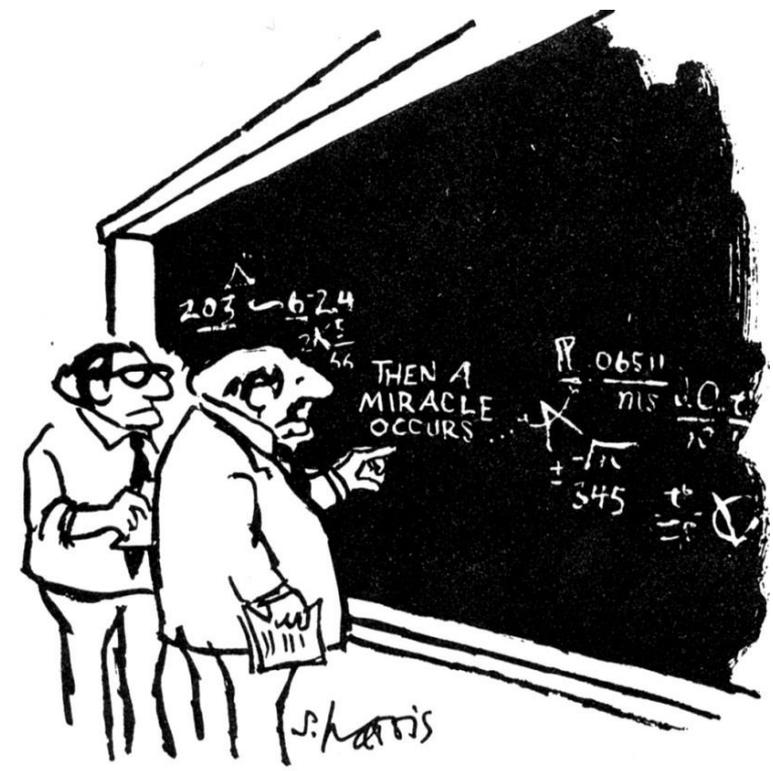
• Biology

• Chemistry

• Physics

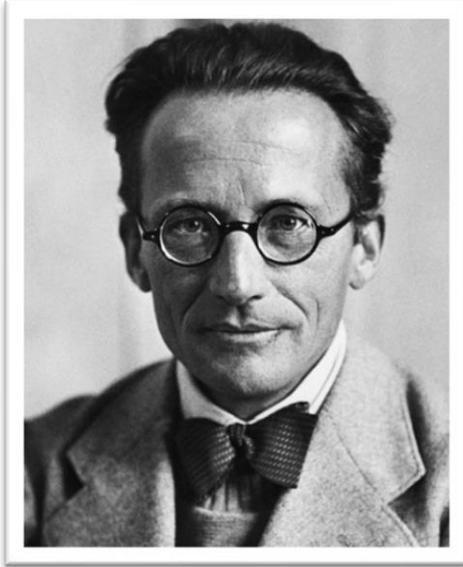
“More is different”

Philip Anderson (1972)



“I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO.”

Attempts (from training in physics)



Chapter 1. The Physical Basis of Consciousness

"A Tentative Answer

I would summarize my general hypothesis thus: consciousness is associated with the **learning** of the living substance."

MIND AND MATTER

BY

ERWIN SCHRÖDINGER

PROFESSOR OF PHYSICS AT THE
UNIVERSITY OF VIENNA

THE TARNER LECTURES

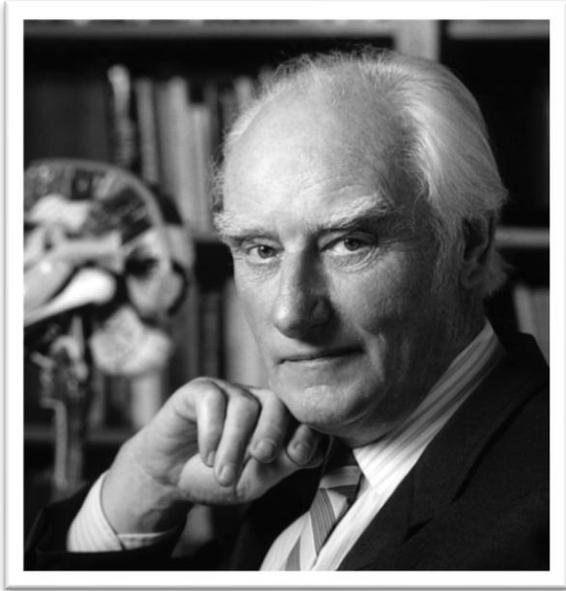
*delivered at
Trinity College, Cambridge, in
October 1956*

CAMBRIDGE
AT THE UNIVERSITY PRESS

1959

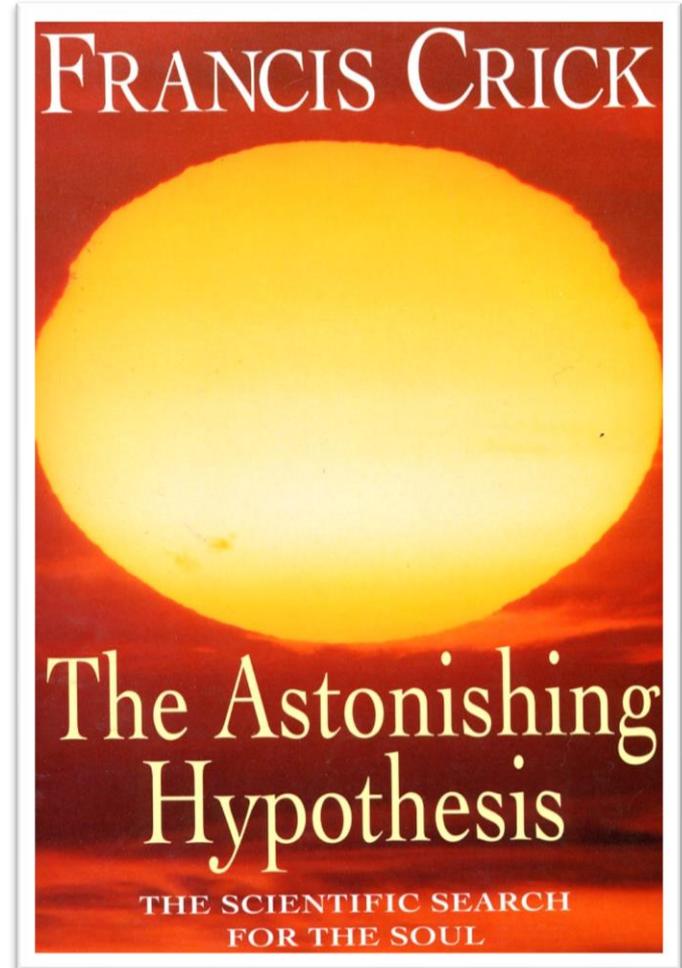
Attempts

(from training in physics)



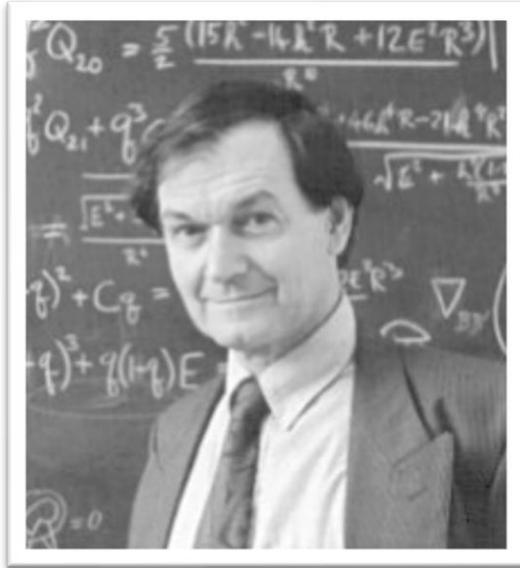
"You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules. As Lewis Carroll's Alice might have phrased it: "you're nothing but a pack of neurons."

F. Crick *"The Astonishing Hypothesis"*, 1993



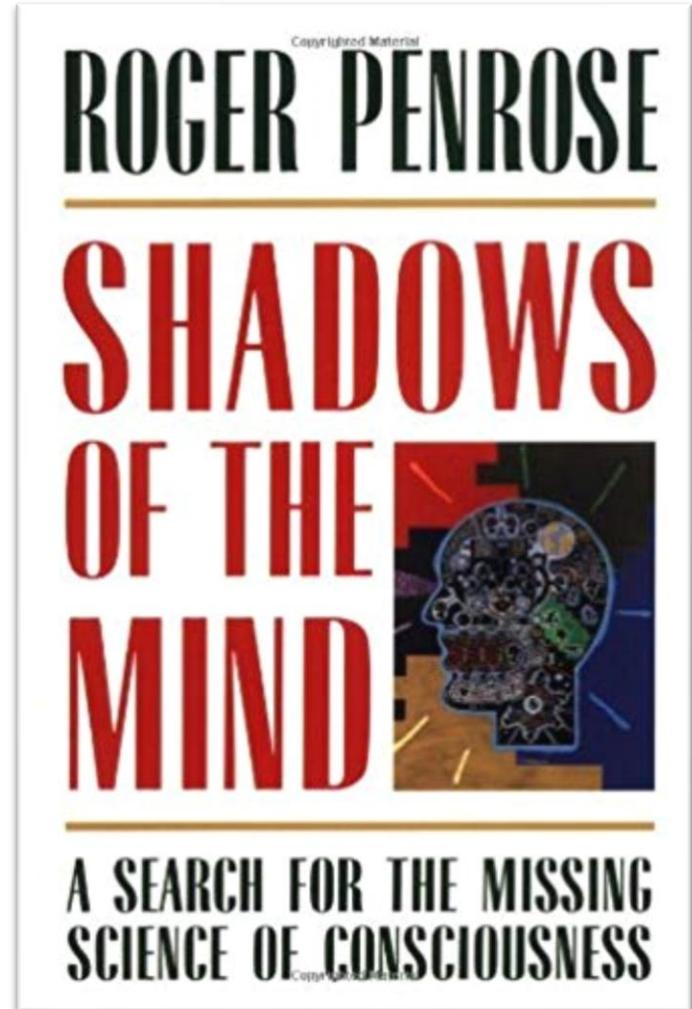
Attempts

(from training in physics)



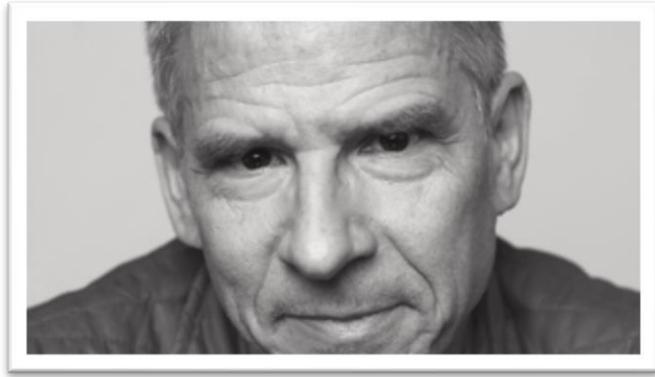
**Orchestrated objective reduction
(Orch OR) theory**
(R. Penrose and S. Hameroff)

Consciousness is based on non-computable quantum processing performed by qubits formed collectively on cellular microtubules, a process significantly amplified in the neurons.



Attempts

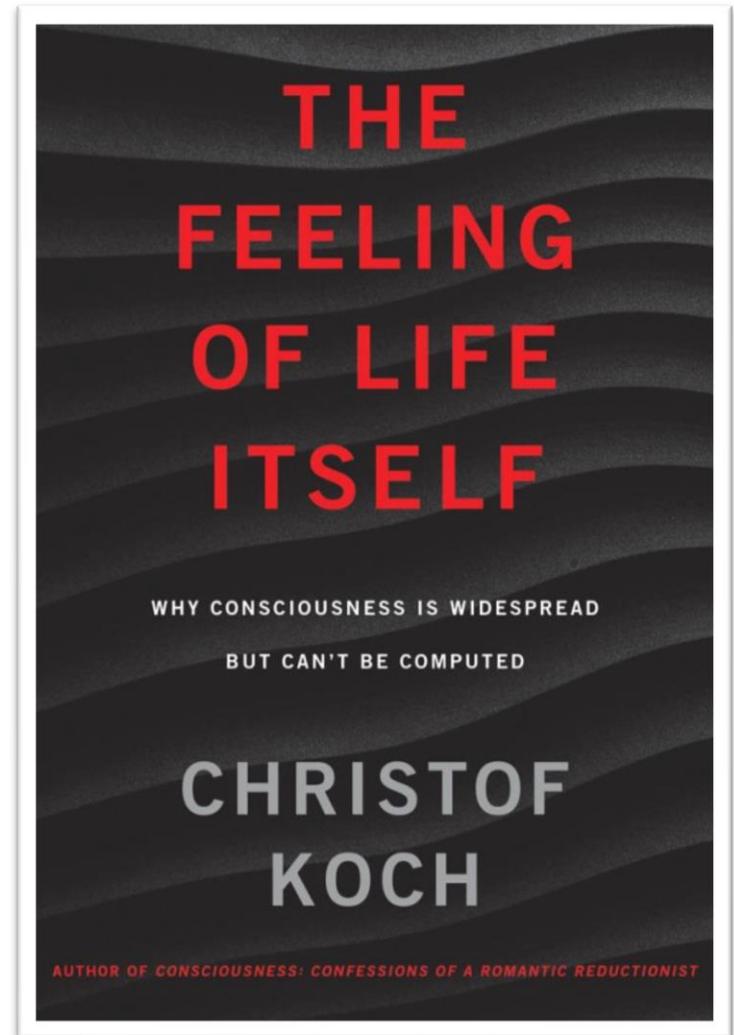
(from training in physics)



Christof Koch

Integrated information theory

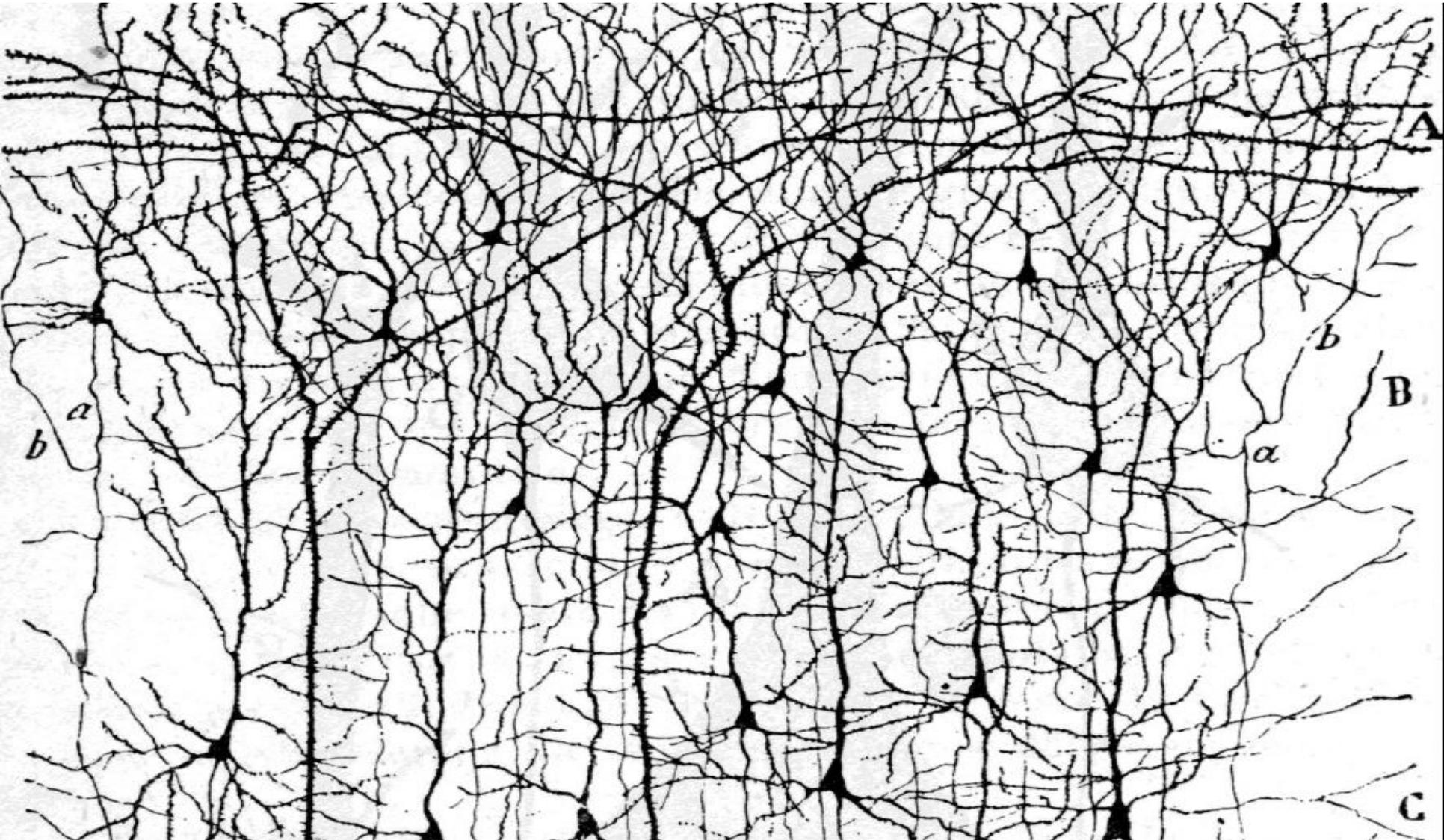
“IIT postulates that conscious experience is a fundamental aspect of reality and is identical to a particular type of information—integrated information. ..Tononi’s theory offers a scientific, constructive, predictive and mathematically precise form of panpsychism for the 21st century. It is a gigantic step in the final resolution of the ancient mind-body problem.”



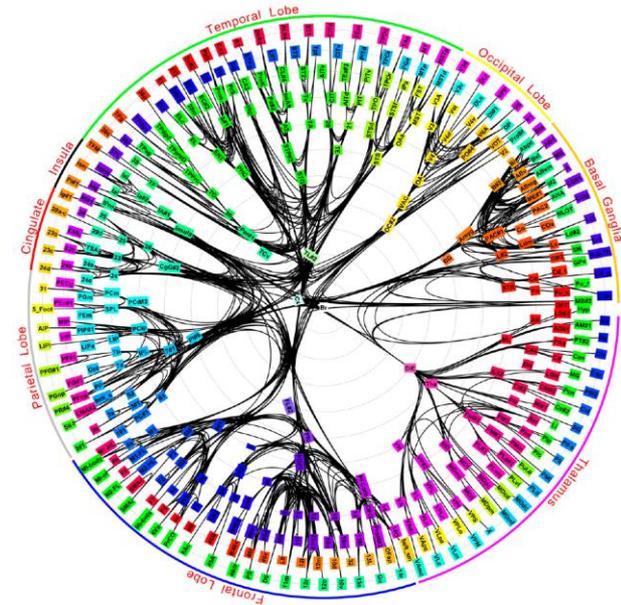
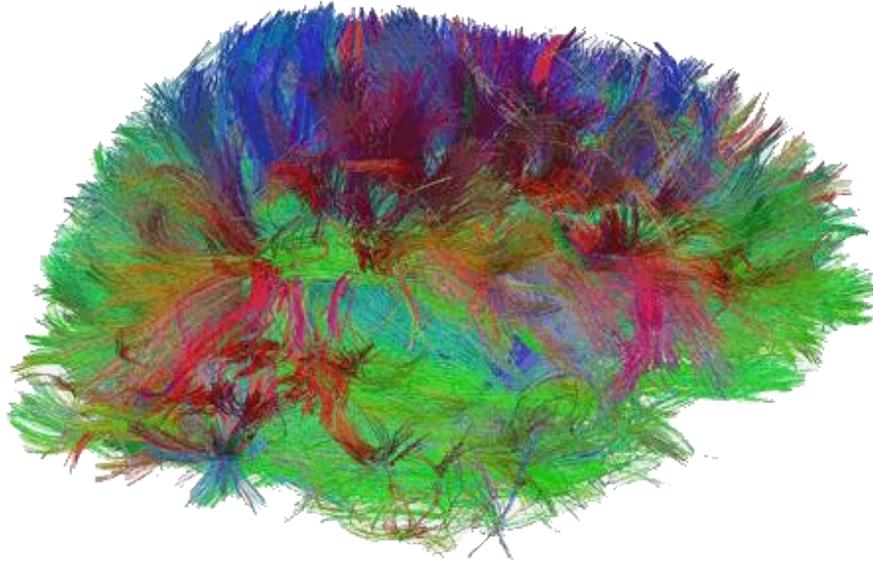
CURRENT KNOWLEDGE

- Brain facts
- MAIN facts –
Mind-brAIN facts

Brain facts



Any brain is connectome



“To understand the functioning of a network, one must know its elements and their interconnections. The purpose of this article is to discuss research strategies aimed at a **comprehensive structural description of the network of elements and connections forming the human brain**. We propose to call this dataset the human “connectome”.”

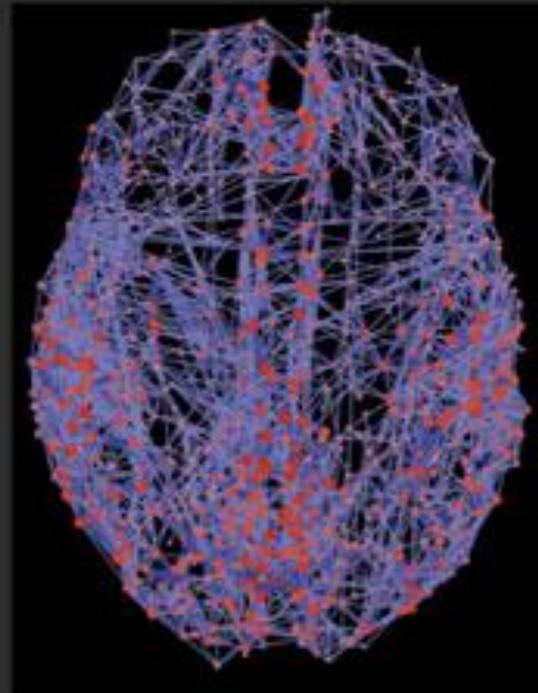
Sporns et al., (2005), "The Human Connectome, a structural description of the human brain"

The Human Connectome



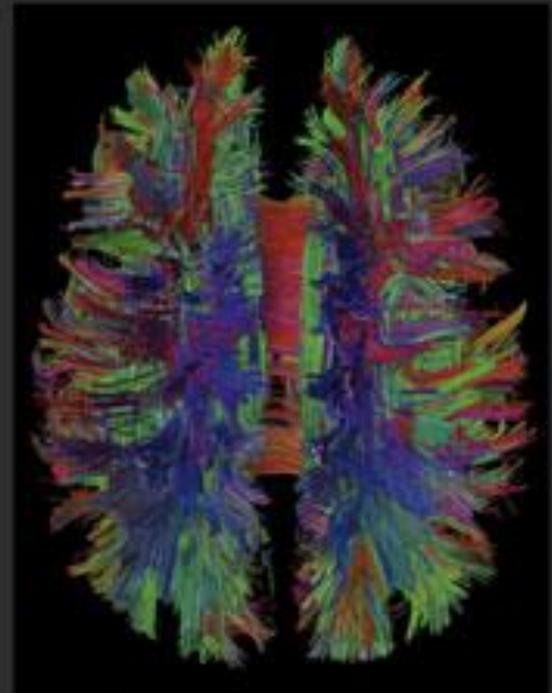
Anatomy

Klinger's method for fiber tract dissection uses freezing of brain matter to spread nerve fibers apart. Afterwards, tissue is carefully scratched away to reveal a relief-like surface in which the desired nerve tracts are naturally surrounded by their anatomical brain areas.



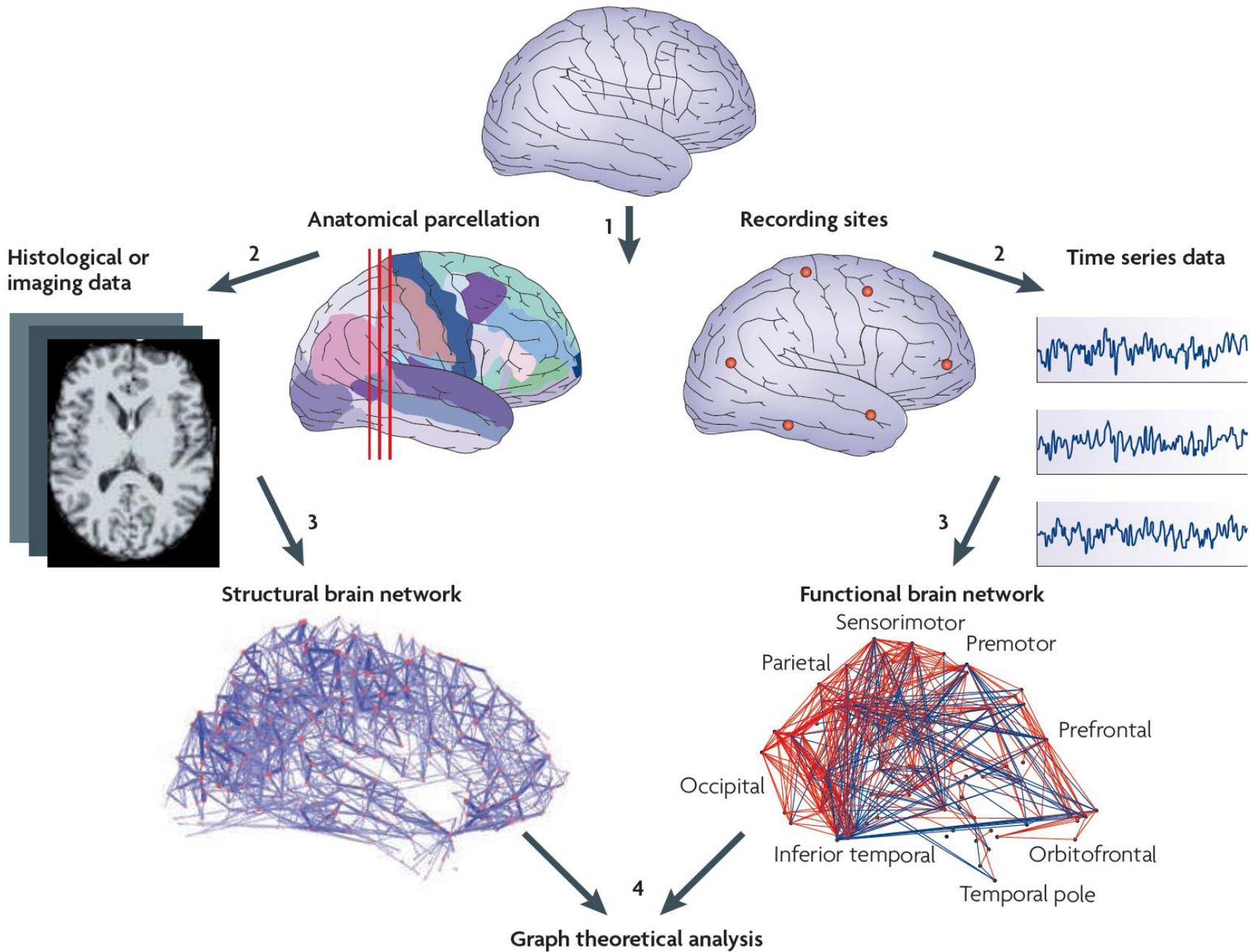
Connectome

Shown are the connections of brain regions together with "hubs" that connect signals among different brain areas and a central "core" or backbone of connections, which relays commands for our thoughts and behaviors.



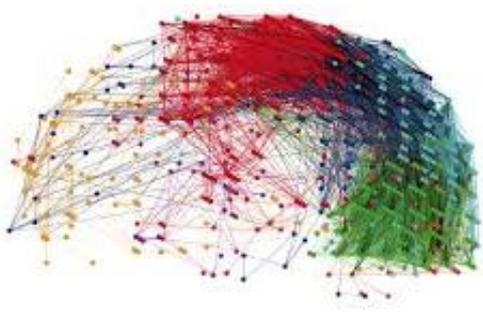
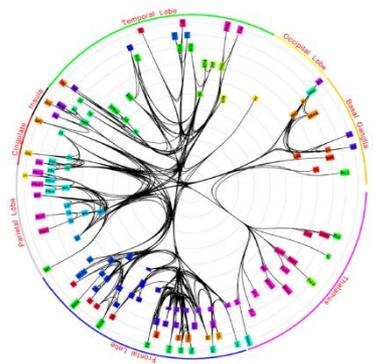
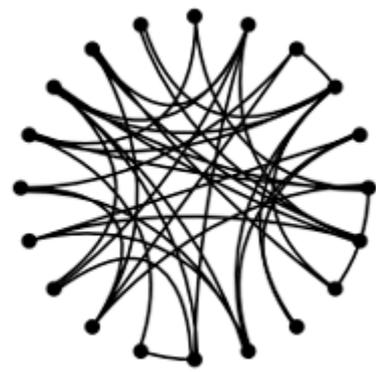
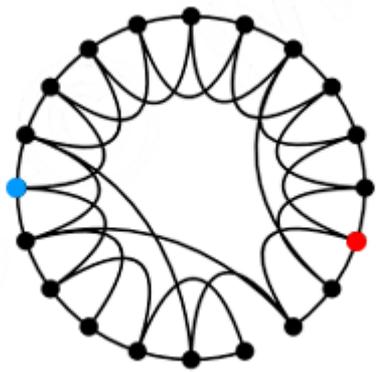
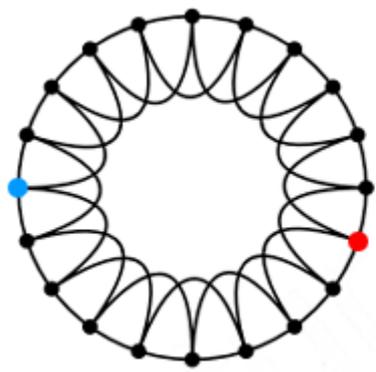
Neuronal Pathways

A new MRI technique called diffusion spectrum imaging (DSI) analyzes how water molecules move along nerve fibers. DSI can show a brain's major neuron pathways and will help neurologists relate structure to function.





Small world networks

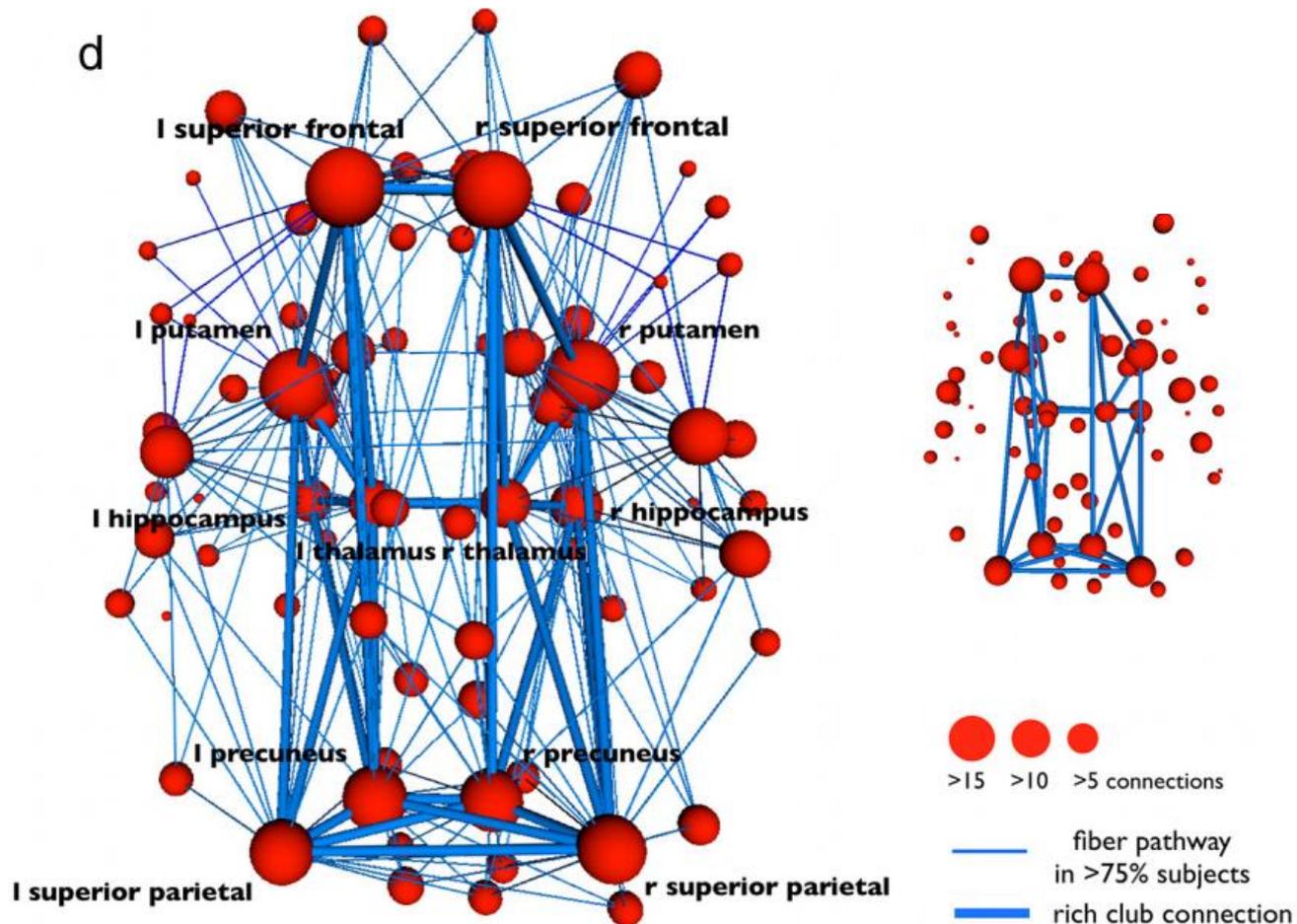


Rich-Club Organization of the Human Connectome

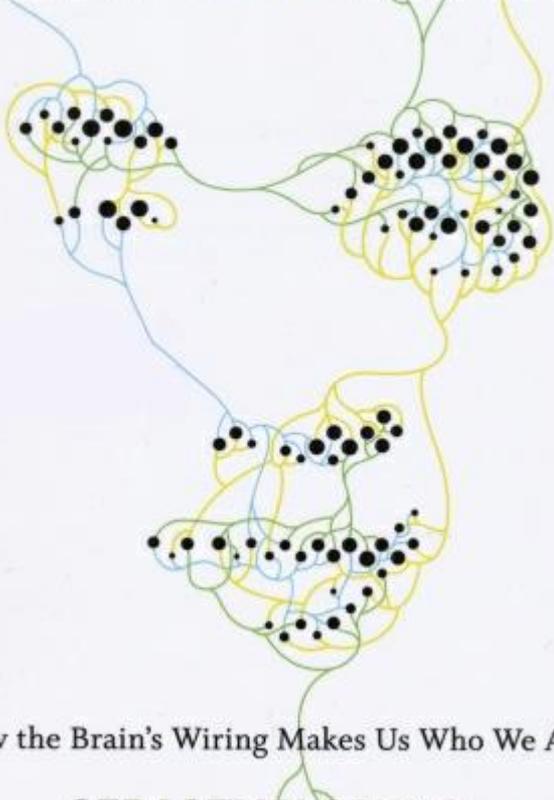
Martijn P. van den Heuvel¹ and Olaf Sporns²

¹Department of Psychiatry, University Medical Center Utrecht, Rudolf Magnus Institute of Neuroscience, 3508 GA Utrecht, The Netherlands, and

²Department of Psychological and Brain Sciences and Program in Cognitive Science, Indiana University, Bloomington, Indiana 47405



CONNECTOME

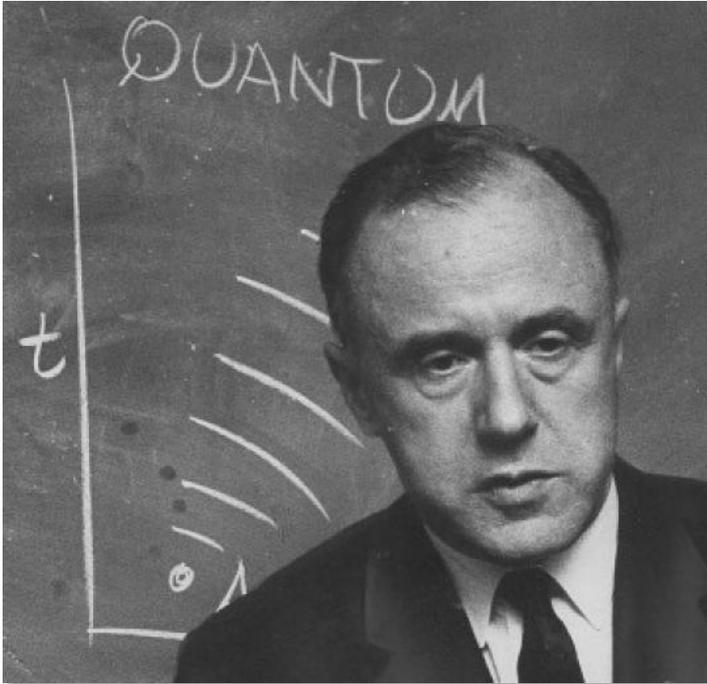


How the Brain's Wiring Makes Us Who We Are

SEBASTIAN SEUNG



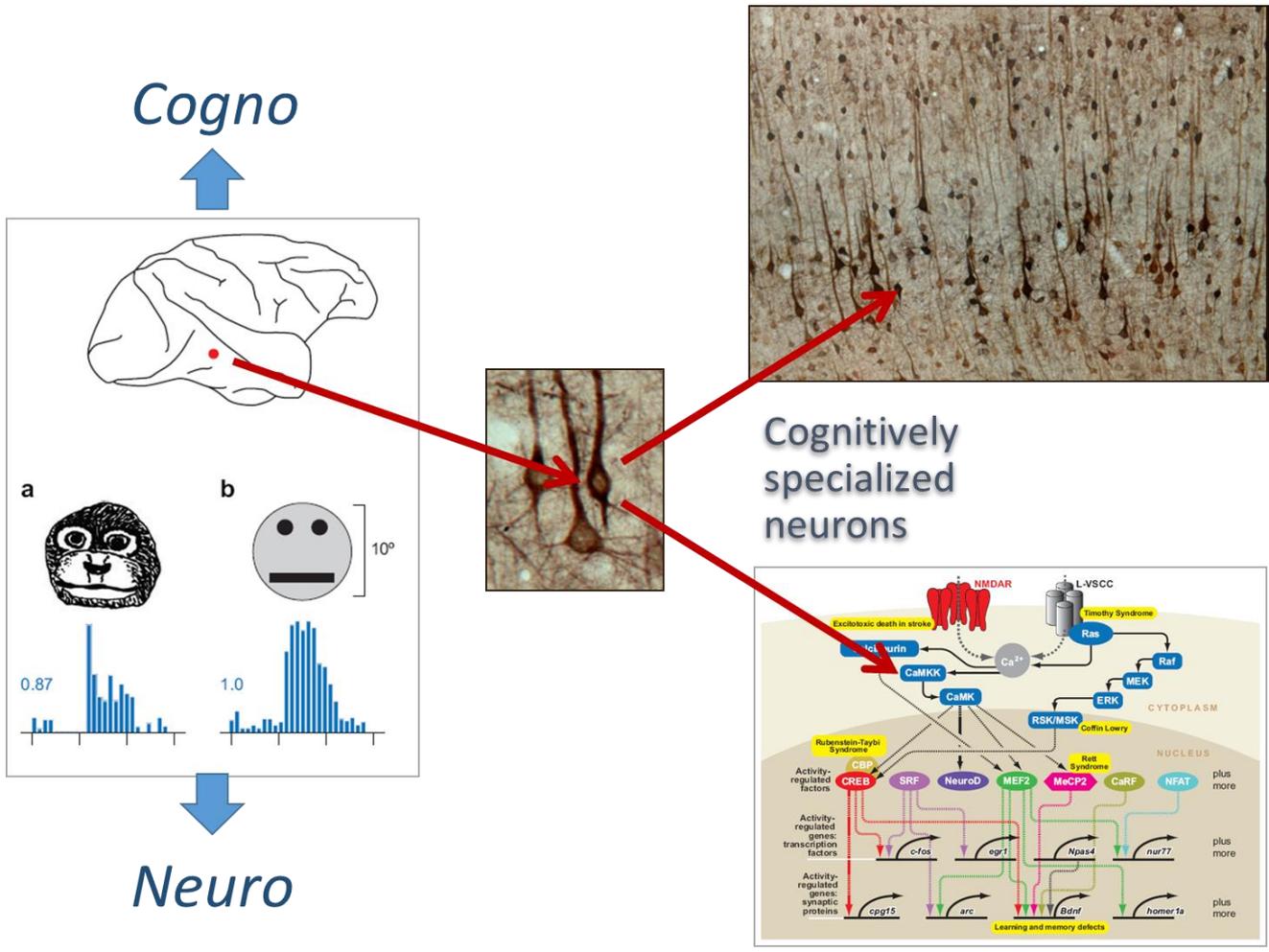
MAIN facts



“In any field find the most unusual fact and then explore it”

J.A. Wheeler

MAIN facts



“In any field find the most unusual fact and then explore it”
 J.A. Wheeler

Deep HyperRealism:

- Hyper is real
- Hyper is deep

What is 'real'?

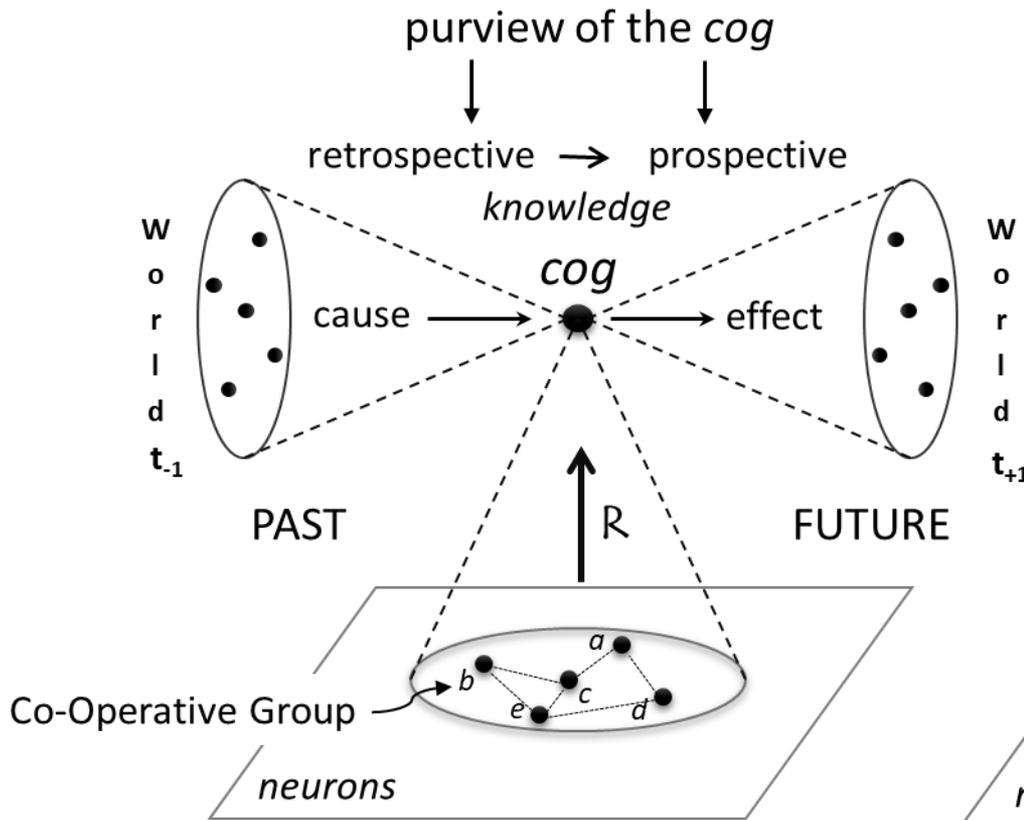
"My notion would be, that anything which possesses any sort of power to affect **another**, or to be affected by another, if only for a single moment, however trifling the cause and however slight the effect, has **real existence**; and I hold that the definition of being is simply **power**."

Plato "Sophist"

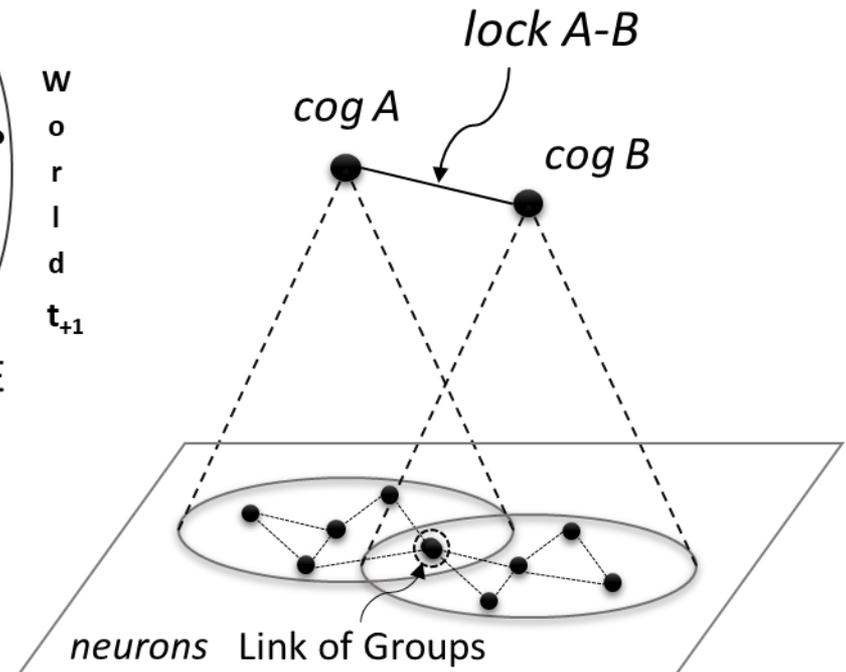
Anything that possess **cause-effect power** (CEP)

What is 'real'?

CoG (Cognitive Group)



LiG (Link of Groups)

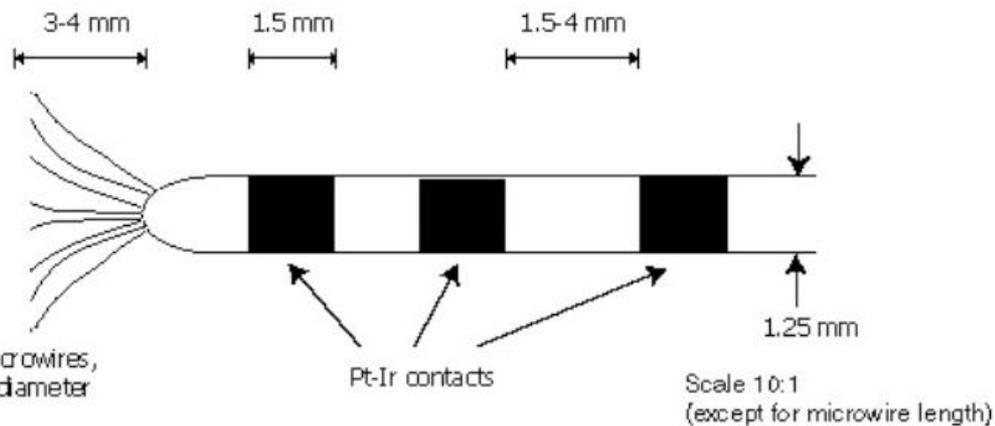


Initial research programs on neuronal bases of human mind

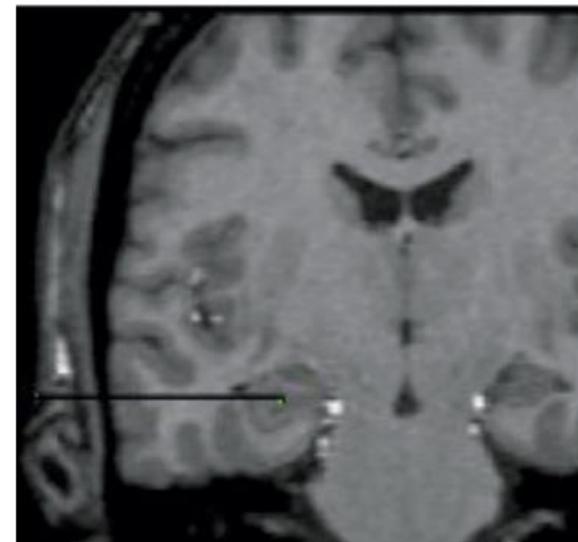


Natalia Bekhtereva in the Laboratory of human neurophysiology (1968)

Around 100 microwires per patient
Data is acquired at 28.7 kHz via 64
electrode Neuralynx system



Fried, I. et al. Cerebral microdialysis combined with single-neuron and electroencephalographic recording in neurosurgical patients. *J. Neurosurg.* **91**: 697-705 (1999).

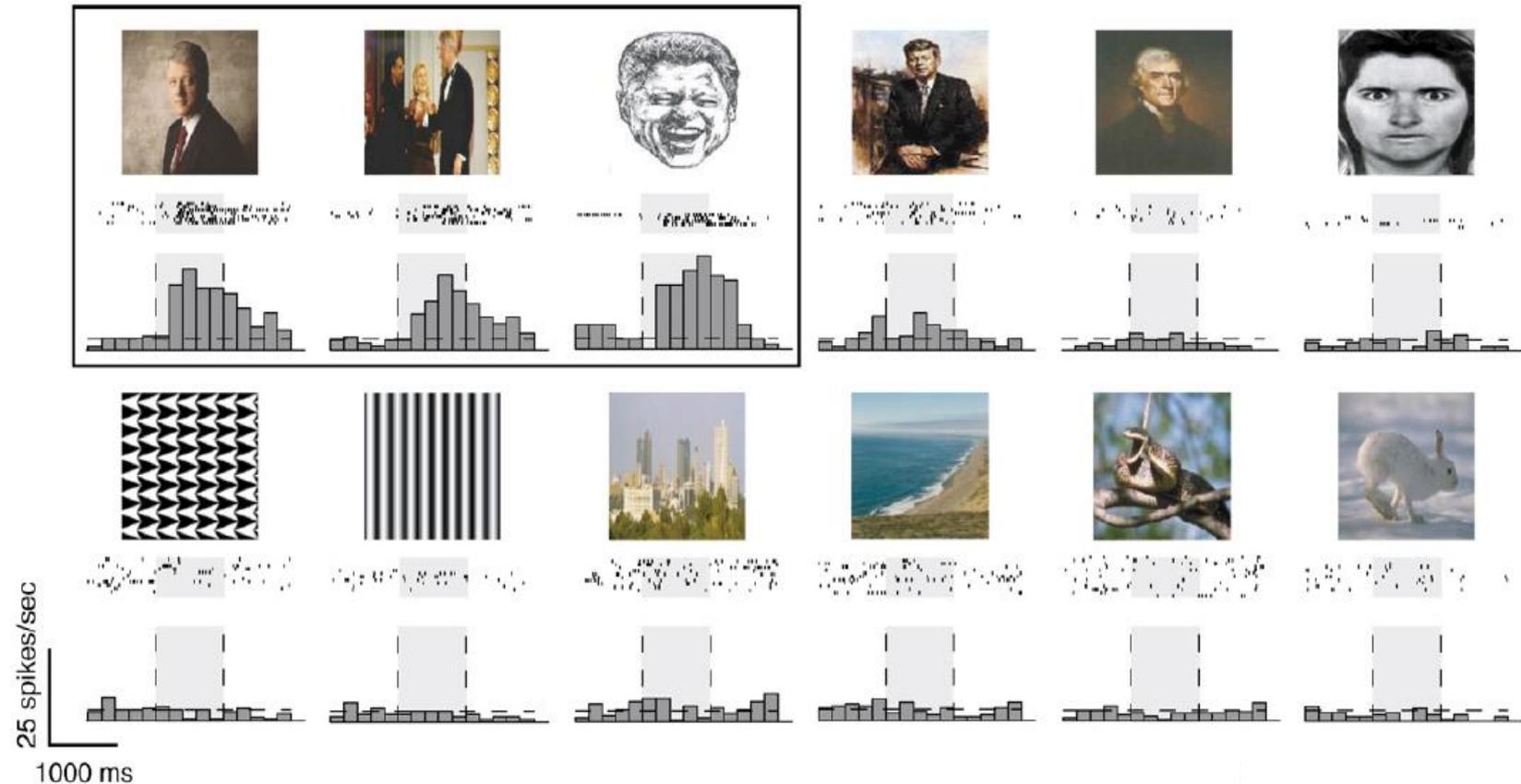


Implantation sites
in the patient brain

From Quiroga et al., 2009

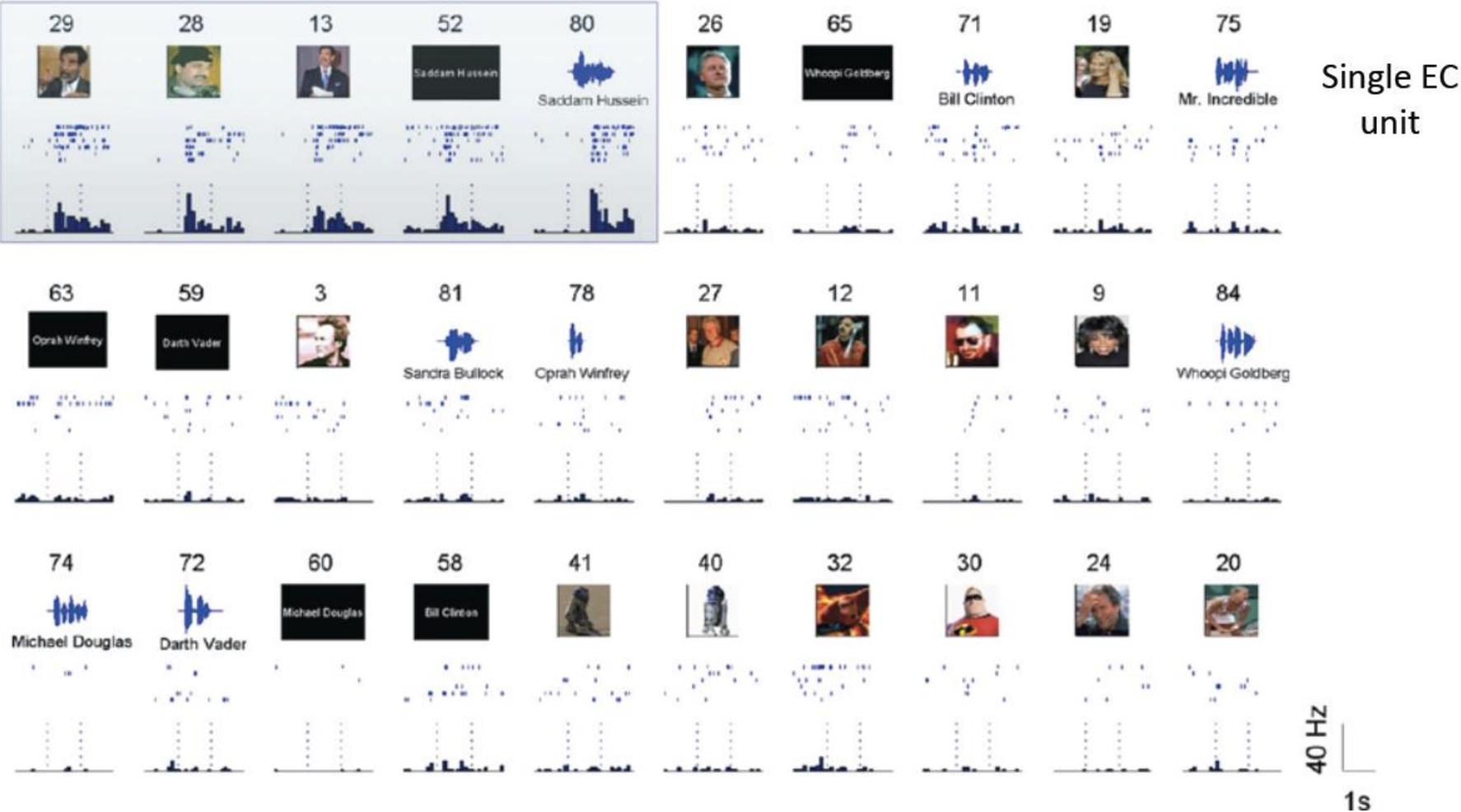
Cognitive specialization of neurons in the human brain

“Bill Clinton neuron”



Cognitive specialization of neurons in the human brain

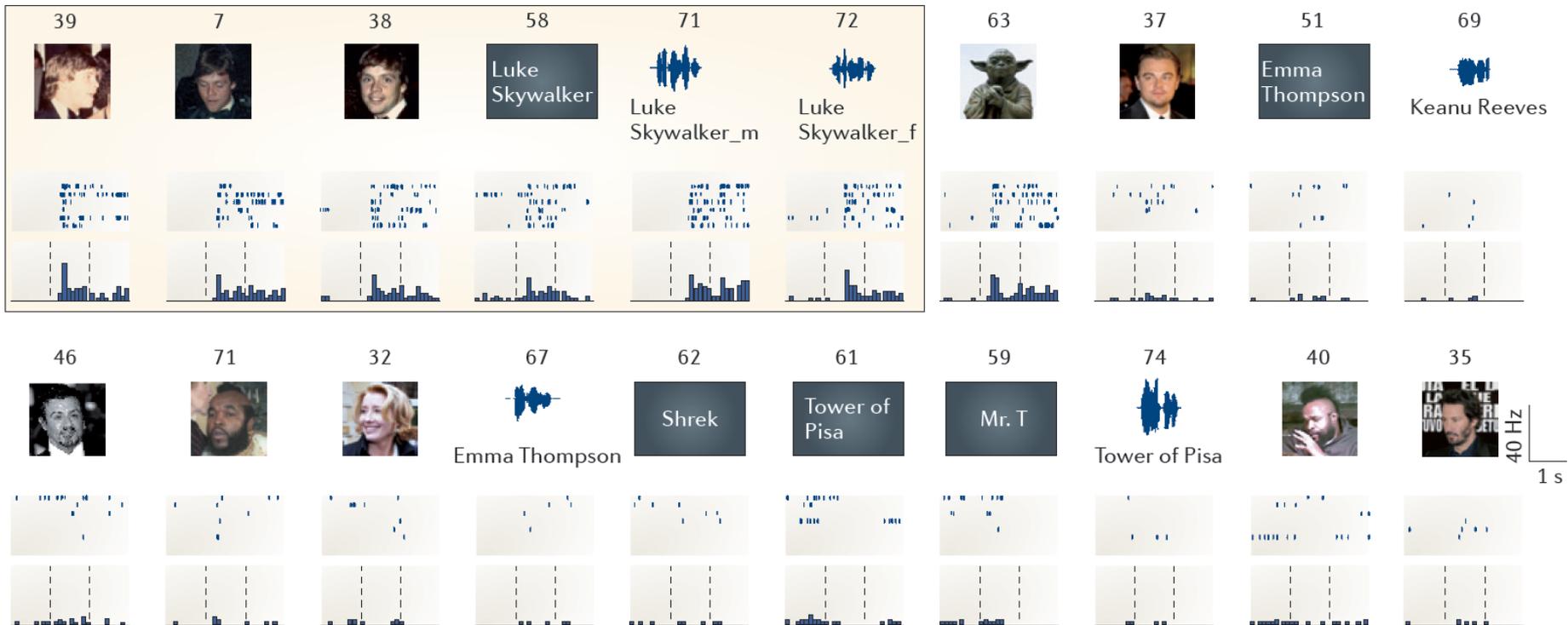
“Saddam Hussein neuron”



Cognitive specialization of neurons in the human brain

“Luke Skywalker neuron”

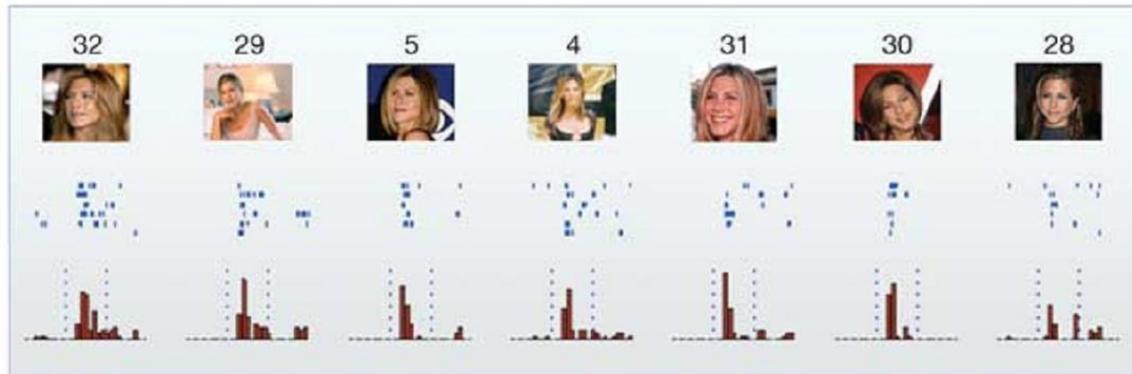
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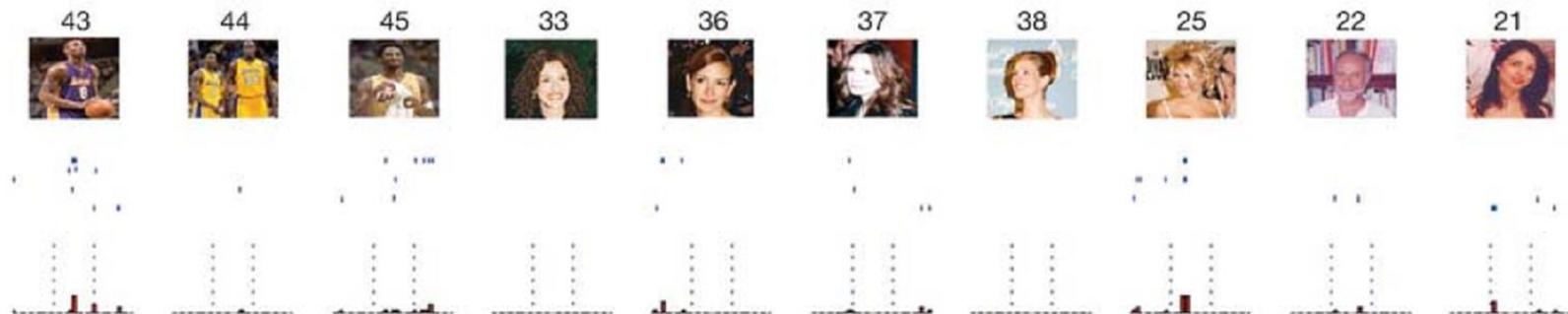
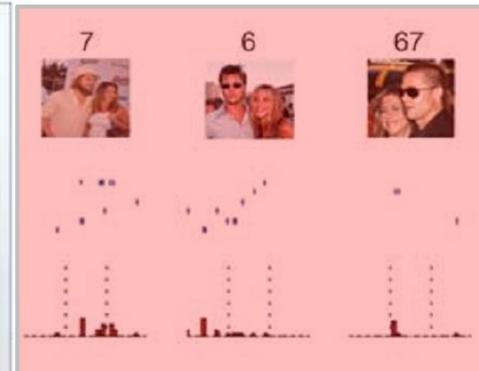
Cognitive specialization of neurons in the human brain

“Jennifer Aniston neuron”

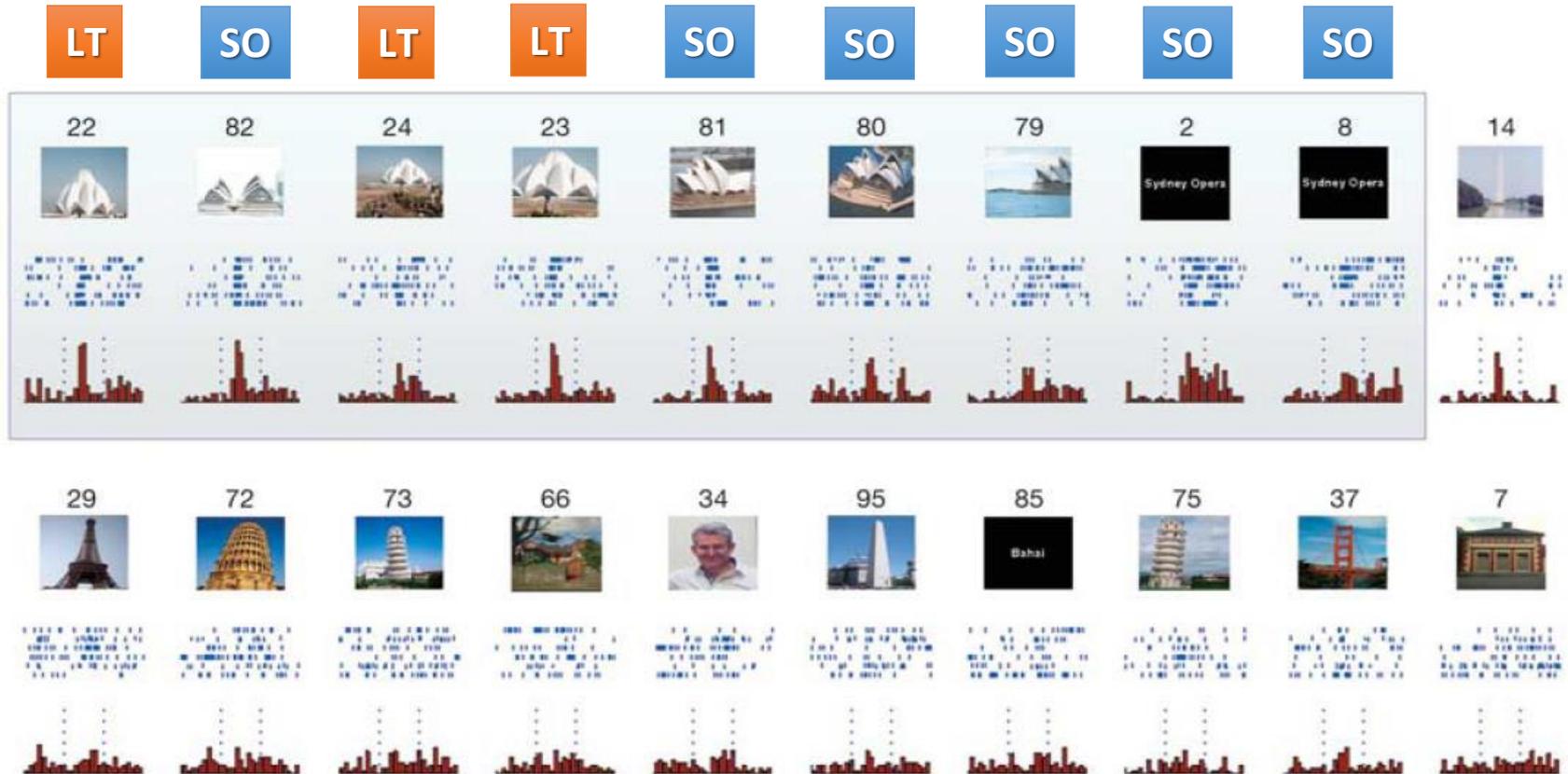
J. Aniston alone



J. Aniston with a
Husband – Brad Pitt



Cognitive specialization of neurons in the human brain



SO Sydney Opera

LT Lotus Temple New Delhi

Cognitive specialization of neurons in the human brain

Supplementary Movie S1a
viewing session

accompanying
demonstration for Fig. 1

Firing of a single entorhinal
cortex neuron while watching
short video episodes

Beeps represent single spikes

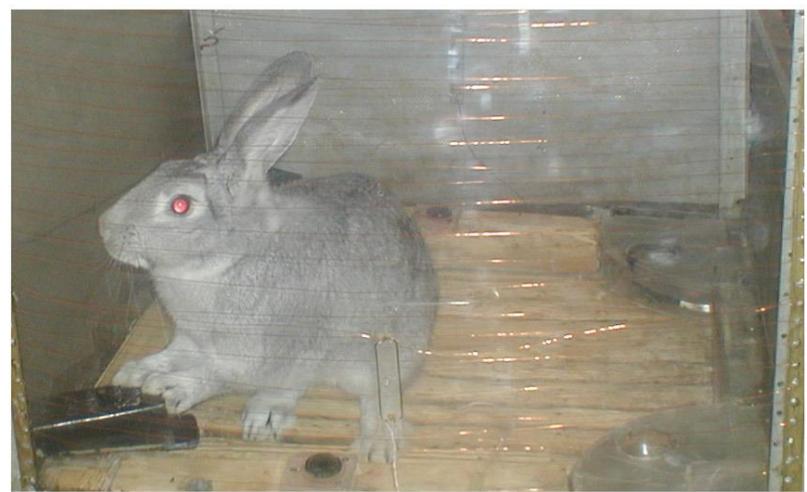
H. Gelbard-Sagiv, R. Mukamel, M. Harel, R. Malach, I. Fried, *Science* (2008)

Cognitive specialization of neurons in the animal brain

- It is extremely difficult to study these processes in the human brain.
- However, similar phenomena exists in the animal brain.

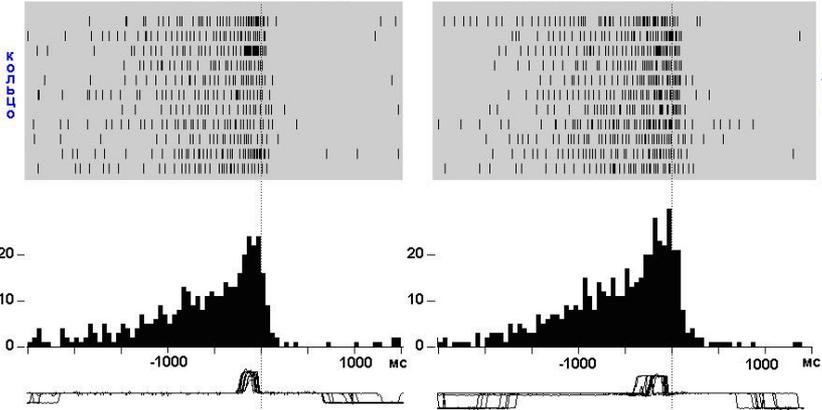


V.B.Shvyrkov, "Systems determination of neuronal activity during behavior"
Adv.Physiol.Sci, **14** (1983) 1-27.



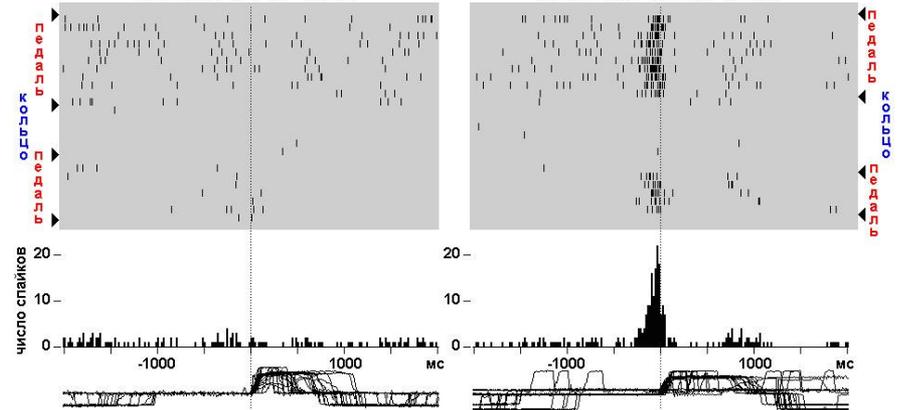
ЛЕВАЯ СТОРОНА

ПРАВАЯ СТОРОНА



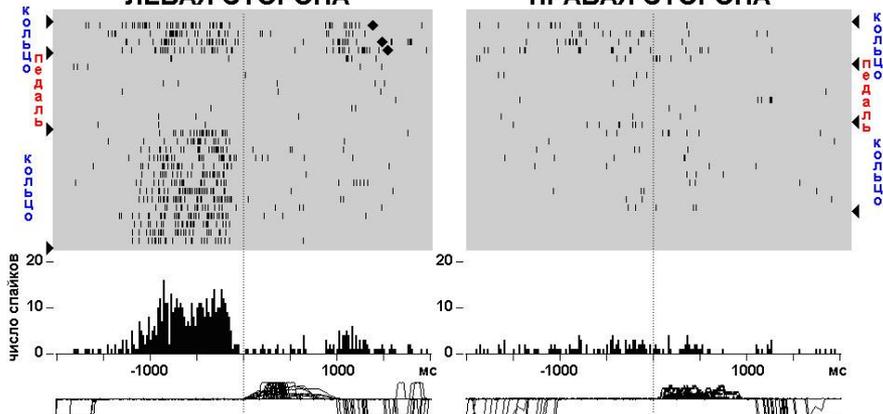
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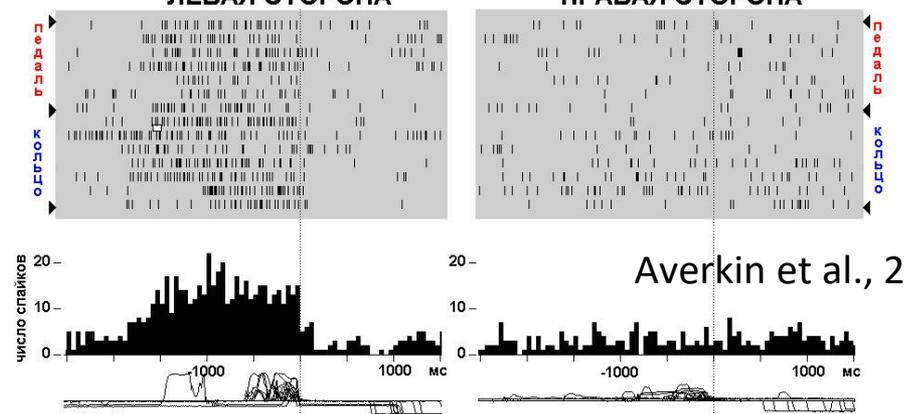
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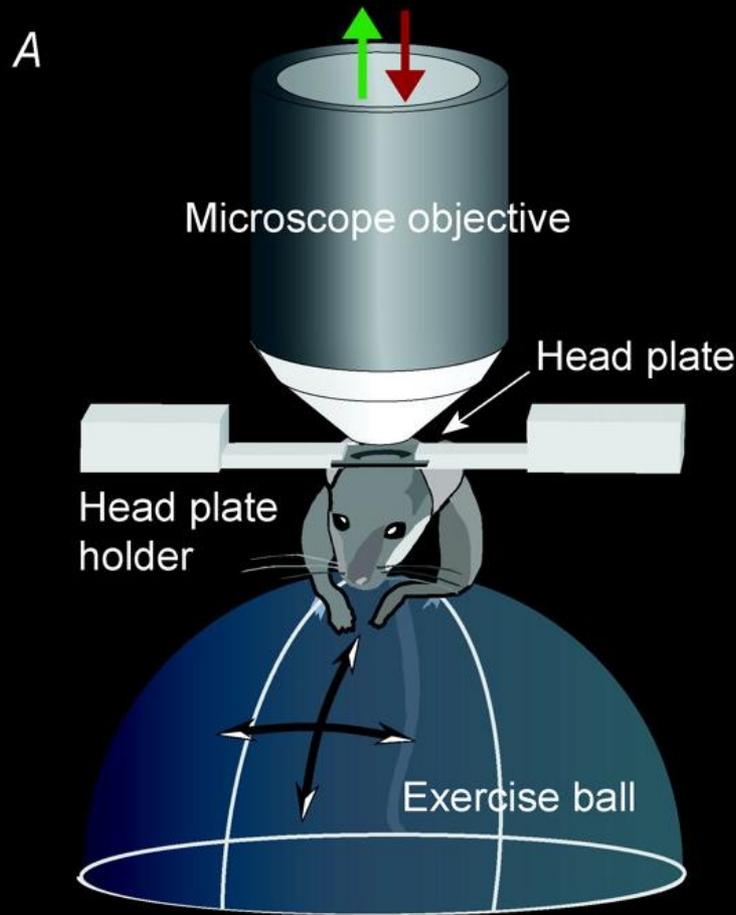
ПРАВАЯ СТОРОНА



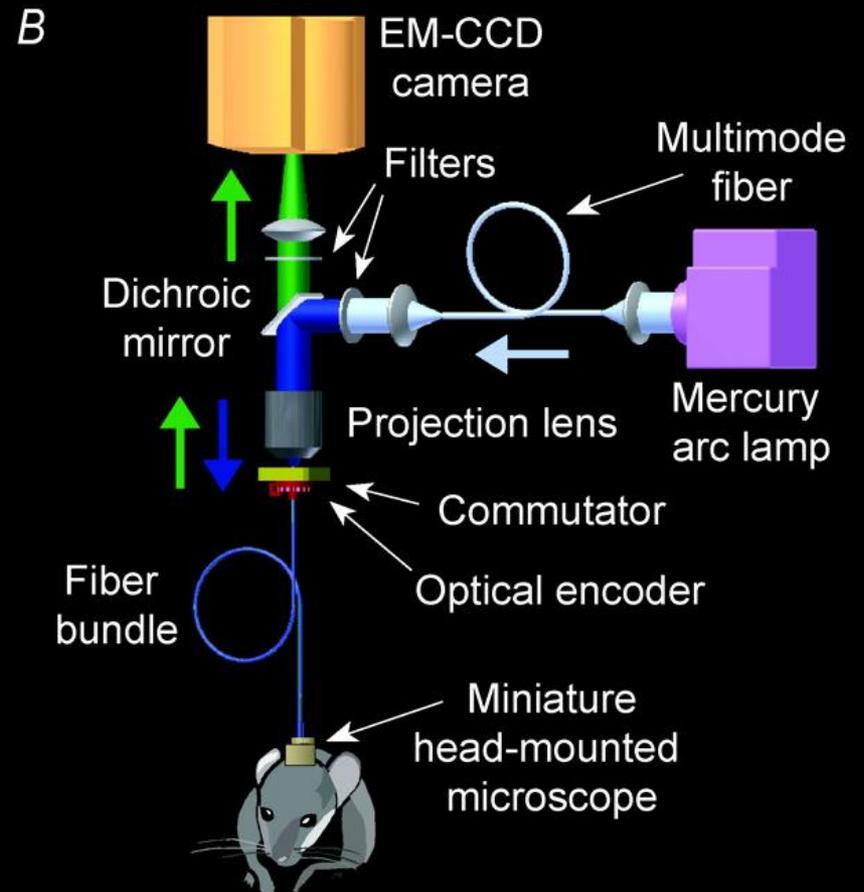
Averkin et al., 2002

In vivo imaging of cognitively indexed neurons

Two-photon microscopy

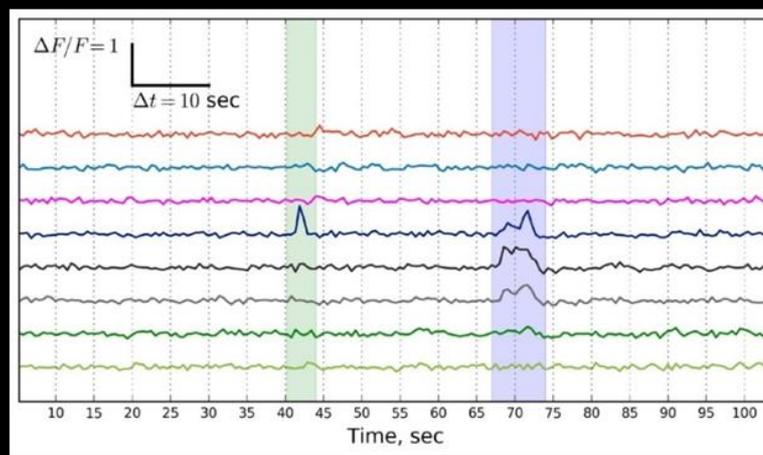
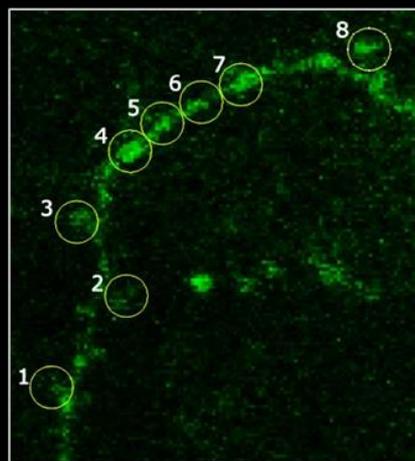
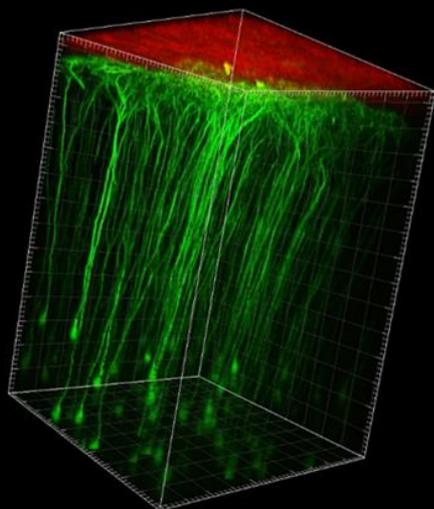
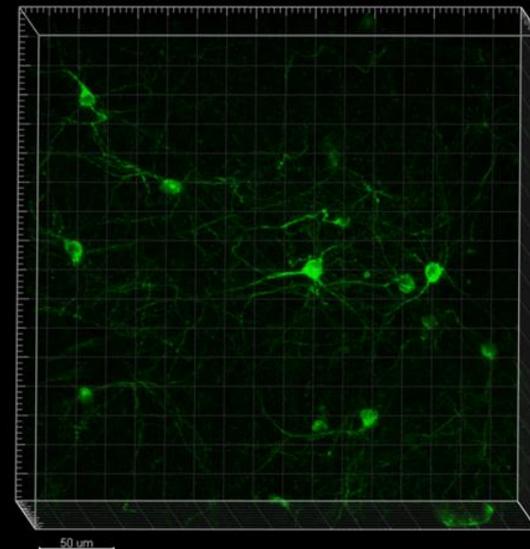
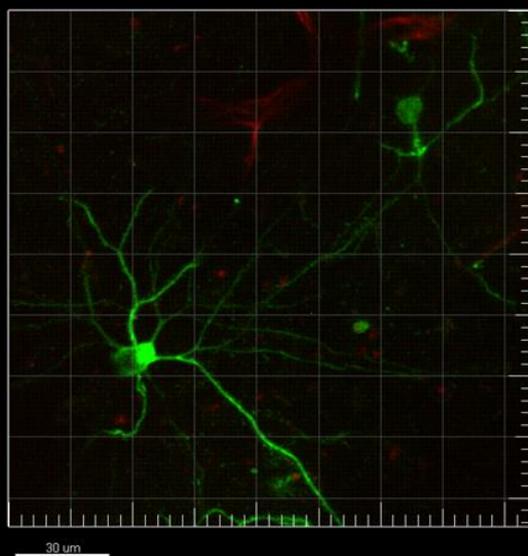
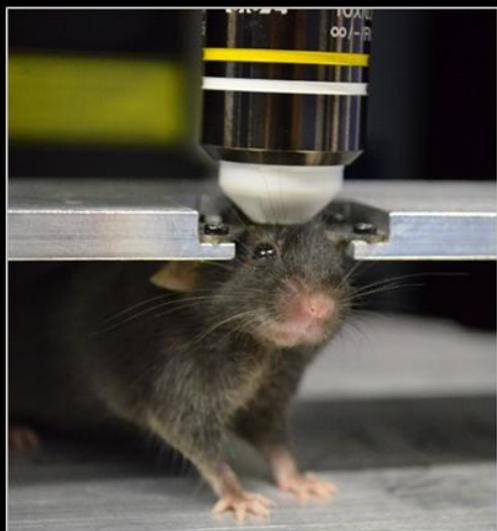


Fiber-optic microscopy



Two-photon imaging of responses of cognitively indexed neurons

Two-photon imaging of Fos-GFP neuronal activity after repeated learning and retrieval episodes

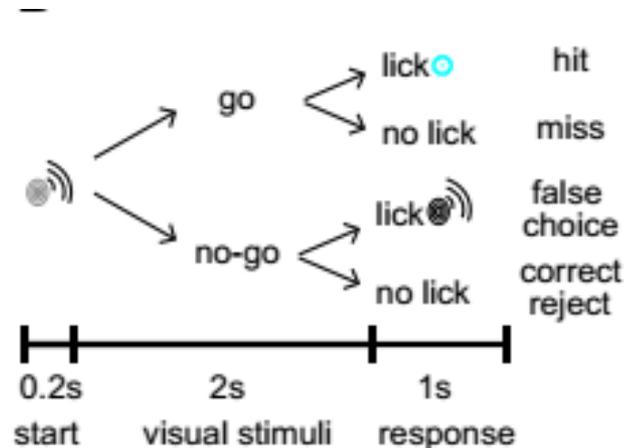
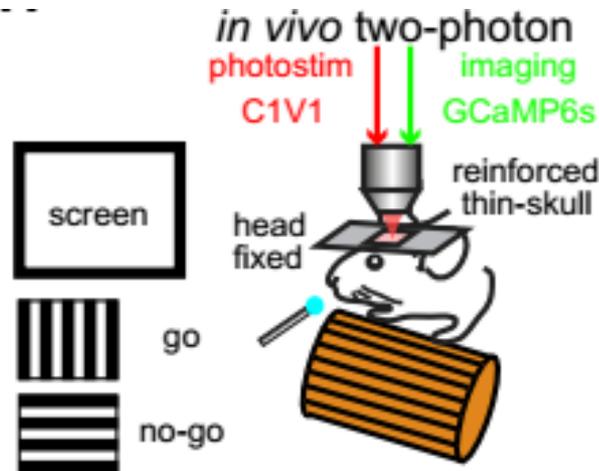


Controlling Visually Guided Behavior by Holographic Recalling of Cortical Ensembles

Luis Carrillo-Reid,^{1,2,*} Shuting Han,¹ Weijian Yang,¹ Alejandro Akrouh,¹ and Rafael Yuste¹

¹NeuroTechnology Center, Department of Biological Sciences, Columbia University, New York, NY, 10027, USA

Cell 178, 447–457, July 11, 2019

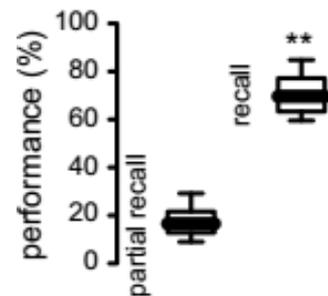
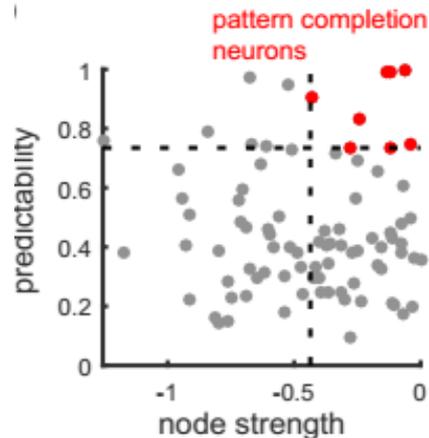
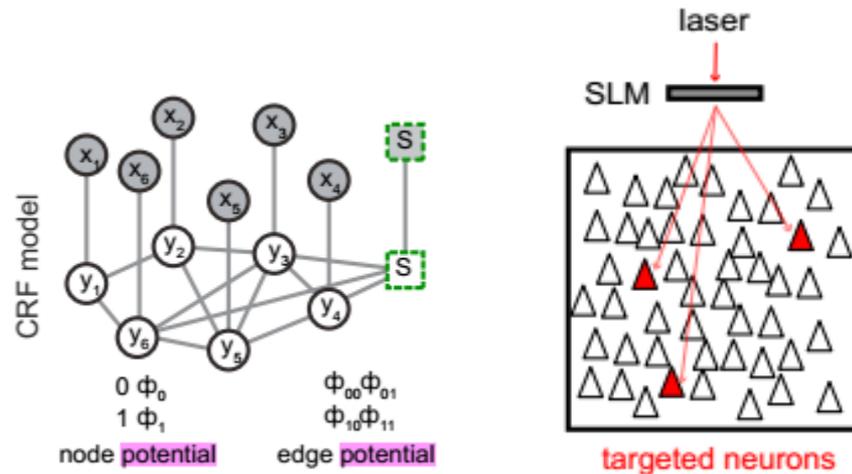


Controlling Visually Guided Behavior by Holographic Recalling of Cortical Ensembles

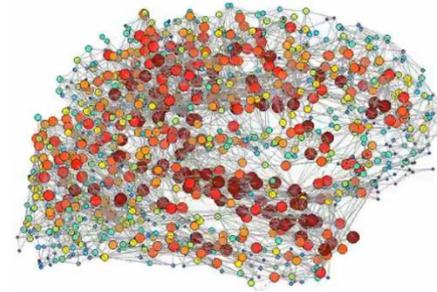
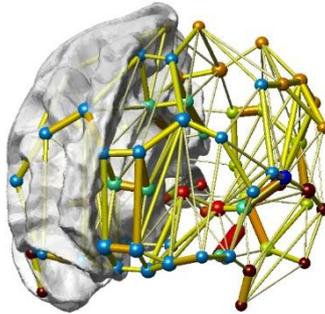
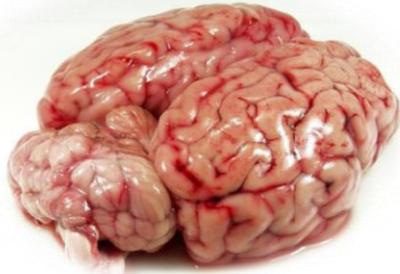
Luis Carrillo-Reid,^{1,2,*} Shuting Han,¹ Weijian Yang,¹ Alejandro Akrouh,¹ and Rafael Yuste¹

¹NeuroTechnology Center, Department of Biological Sciences, Columbia University, New York, NY, 10027, USA

Cell 178, 447–457, July 11, 2019



What is brain?



Tissue

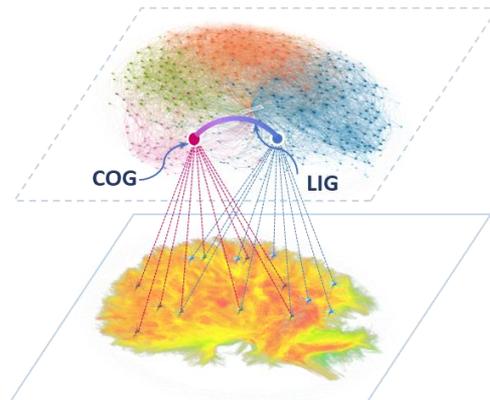
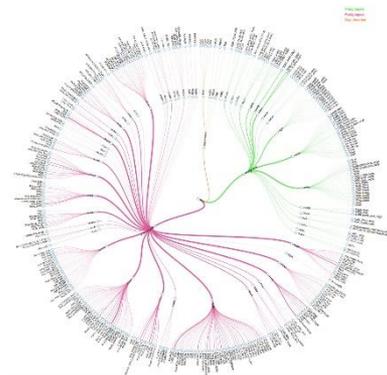
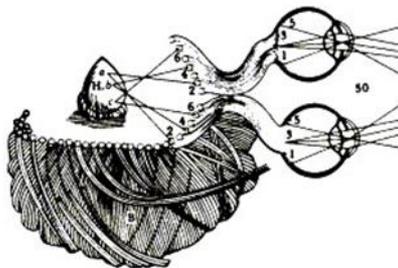
Network

Hypernetwork

Yesterday

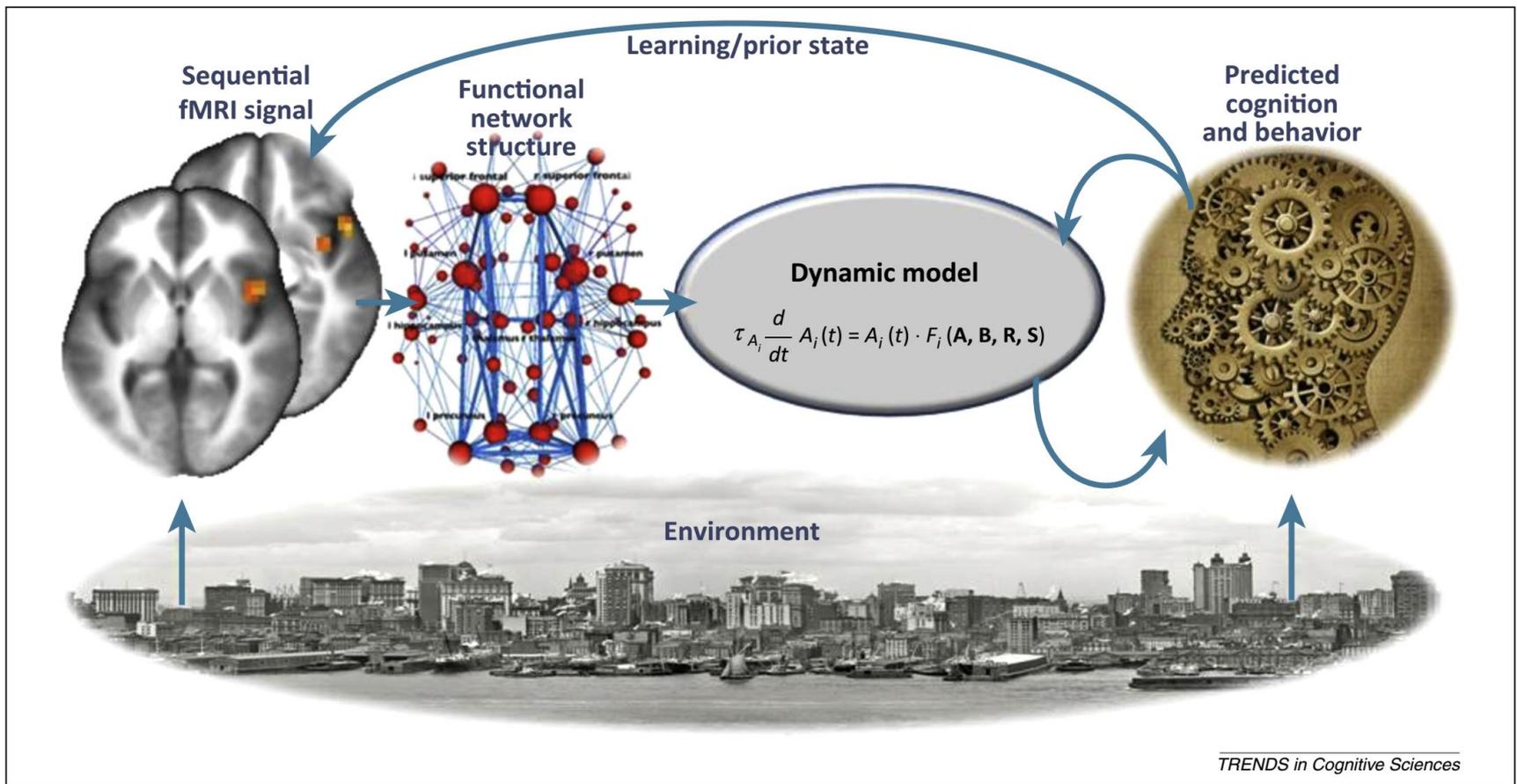
Today

Tomorrow



Dynamical bridge between brain and mind

Mikhail I. Rabinovich¹, Alan N. Simmons^{2,3}, and Pablo Varona⁴



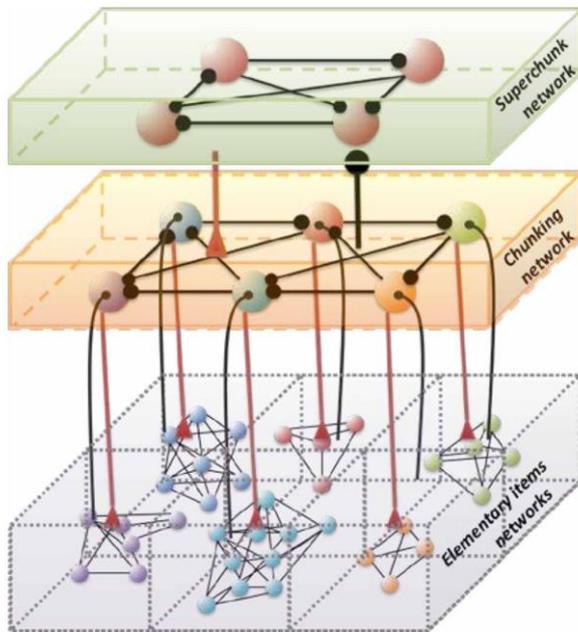


Chunking dynamics: heteroclinics in mind

Mikhail I. Rabinovich¹, Pablo Varona^{2*}, Irma Tristan¹ and Valentin S. Afraimovich³

Table 2 | Heteroclinics in mind.

Phenomenon	Network formalism*	Phase portrait	Time series
Sequential heteroclinic switching	$\dot{X}_i = X_i \left(\sigma_i - \sum_{j=1}^N \rho_{ij} X_j \right)$		
Sequential heteroclinic binding and information flow	$\dot{X}_i^l = X_i^l \left(\sigma_i^l - \sum_{j=1}^N \rho_{ij}^l X_j^l - \sum_{m=1}^L \sum_{j=1}^N \xi_{ij}^{lm} X_j^m \right)$		
Heteroclinic cooperation	$\tau_i^m \dot{X}_i^m = X_i^m \cdot \left[\sigma_i^m - \sum_{j=1}^{K^m} \rho_{ij}^m X_j^m + \sum_{k=1}^M \sum_{j=1}^{K^k} \xi_{ij}^{mk} X_j^k \right]$		
Hierarchical chunking memory and learning	$\begin{aligned} \dot{X}_i^k &= X_i^k \left(\sigma_i^k \cdot \gamma^k - \sum_j \rho_{ij}^k X_j^k \right) \\ \tau \dot{\gamma}^k &= \gamma^k \left(\left(1 - \beta \sum_i X_i^k \right) - Z^k \right) \\ \theta \dot{Z}^k &= \sum_{m=1}^M \xi^{km} \gamma^m - Z^k \end{aligned}$		



Thank you for attention!