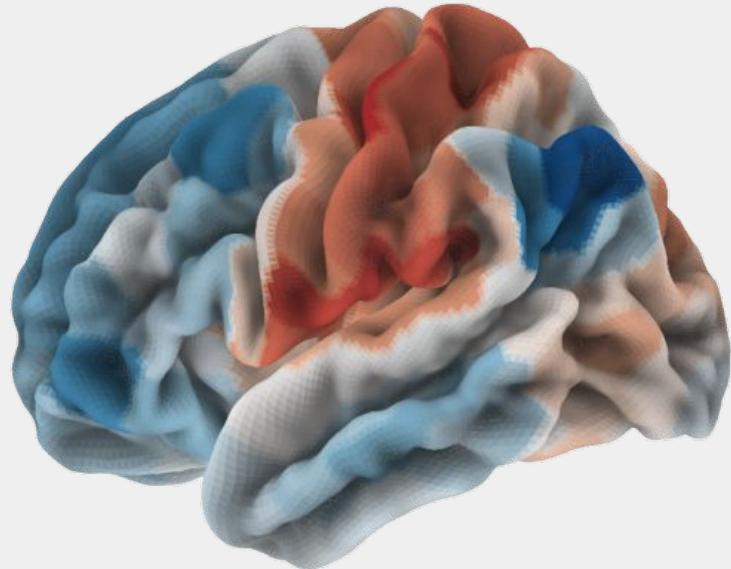


# Neurobiologia / BPZ

... w czasach kryzysu

Karolina Finc

Interdyscyplinarne Centrum Nowoczesnych Technologii  
Uniwersytet Mikołaja Kopernika w Toruniu



Wykład #1: **Wstęp** | 10 kwiecień 2020

# Kim jestem?



## Karolina Finc

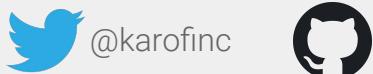
Badacz w ICNT (UMK)

Magister kognitywistyki (2014)

Doktorat z nauk ścisłych i przyrodniczych w dyscyplinie nauki fizyczne (2019)

**Computational Neuroimaging Team**

<http://compneuro.umk.pl/>



@karofinc



@kfinc

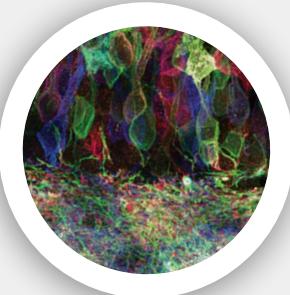


finc@umk.pl

# Zajęcia

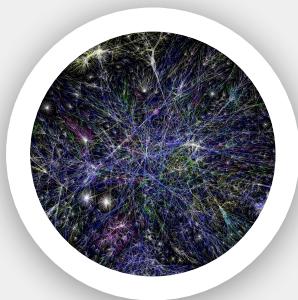
# Zajęcia

Neurobiologia

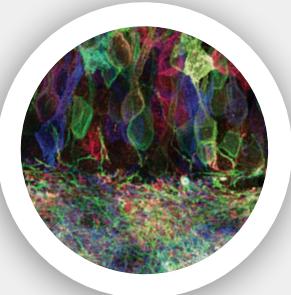


# Zajęcia

Nauka o  
sieciach



Neurobiologia



# Zajęcia

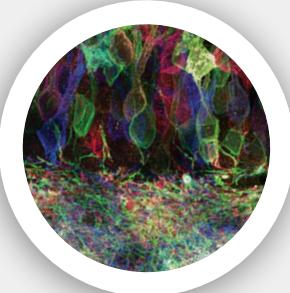
Nauka o sieciach



Zachowanie



Neurobiologia



# Zajęcia

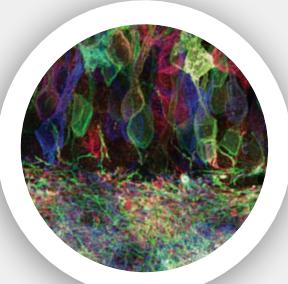
Nauka o sieciach



Zachowanie



Neurobiologia



Ewolucja

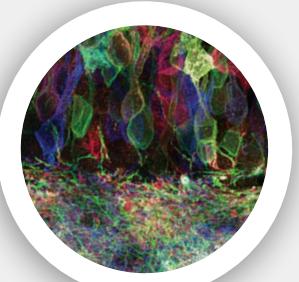


# Zajęcia

Nauka o sieciach



Neurobiologia



Zachowanie



Sztuczna inteligencja



Ewolucja

# Zajęcia

Nauka o sieciach



# Zasady

Egzamin



# Zasady

Egzamin



Aktywność



Prezentacja



# Zasady

Egzamin



Aktywność



Prezentacja



# Zasady

Egzamin



Aktywność



Prezentacja



# Zasady

Egzamin



Aktywność



Prezentacja



Konsultacje:

<https://finc.youcanbook.me>

Email:

finc@umk.pl



Kim jest ten człowiek?

A color painting of Santiago Ramón y Cajal, a Spanish neuroscientist. He is seated at a large wooden desk in a workshop-like laboratory. He wears a light-colored, long-sleeved shirt and a purple turban-like headband. He has a beard and is resting his chin on his hand, looking directly at the viewer. On the desk in front of him are three microscopes of different sizes, some glassware, and various scientific instruments. Behind him is a shelf filled with bottles and jars, and a wall decorated with colorful, abstract murals.

Santiago  
Ramón y Cajal

1852-1934

Kim jest ten człowiek?

A color painting of Santiago Ramón y Cajal, a Spanish neuroscientist. He is seated at a table in a laboratory, wearing a purple turban and a light-colored, button-down shirt. He has a beard and is resting his head on his hand. On the table in front of him are three microscopes of different sizes, along with various glassware, slides, and laboratory tools. Behind him is a shelf filled with bottles and jars. The background features a wall with some colorful, abstract graffiti.

Santiago  
Ramón y Cajal

1852-1934

Co jest dziwnego w tym zdjęciu?

# Camillo Golgi

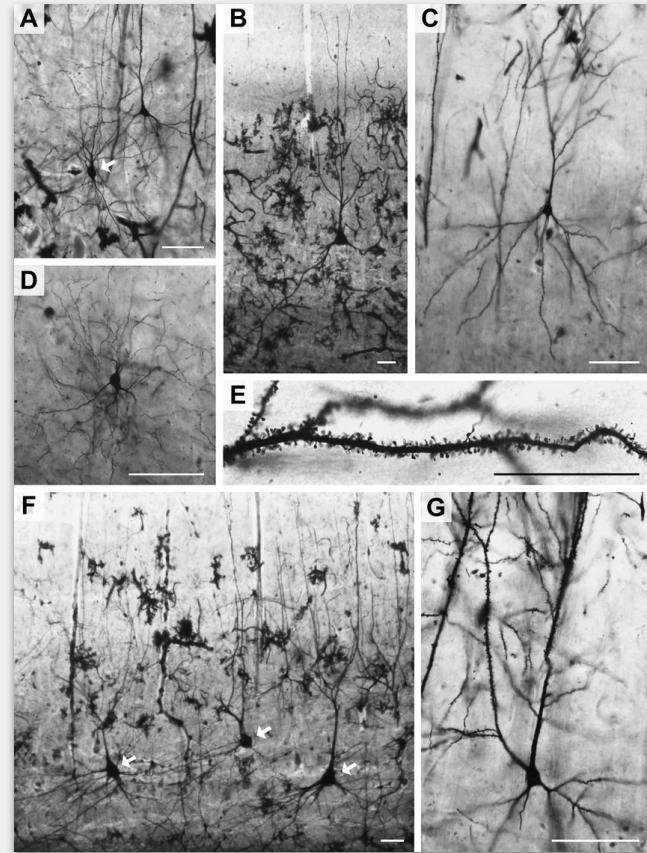


**Camillo Golgi**  
1843-1926

# Camillo Golgi



**Camillo Golgi**  
1843-1926

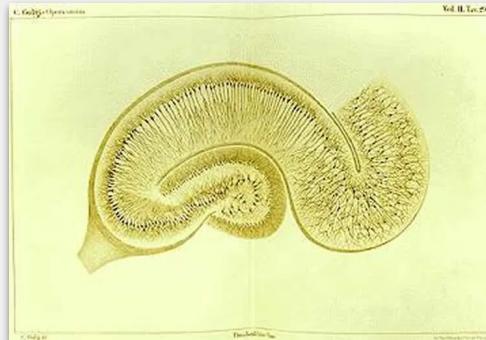


**Metoda Golgiego** - metoda barwienia preparatów neurohistologicznych przy pomocy soli metali ciężkich.

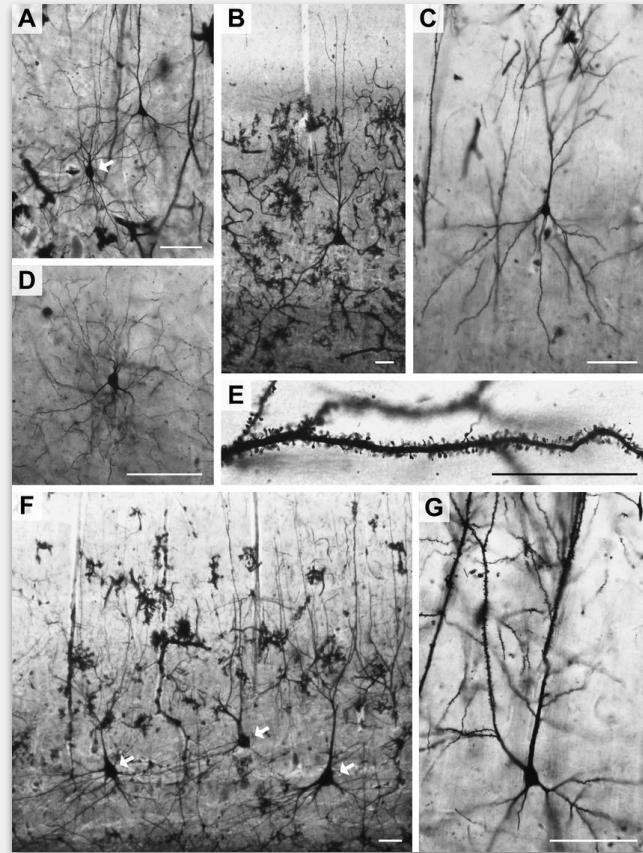
# Camillo Golgi



**Camillo Golgi**  
1843-1926



**Teoria siatkowa (reticular theory)** - neurony tworzą kontynuum.



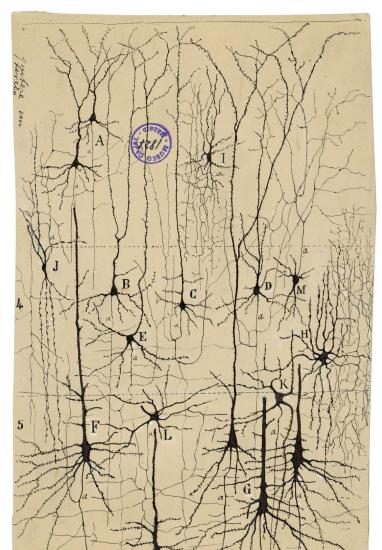
**Metoda Golgiego** - metoda barwienia preparatów neurohistologicznych przy pomocy soli metali ciężkich.

# Santiago Ramón y Cajal



Santiago  
Ramón y Cajal  
1852-1934

# Santiago Ramón y Cajal

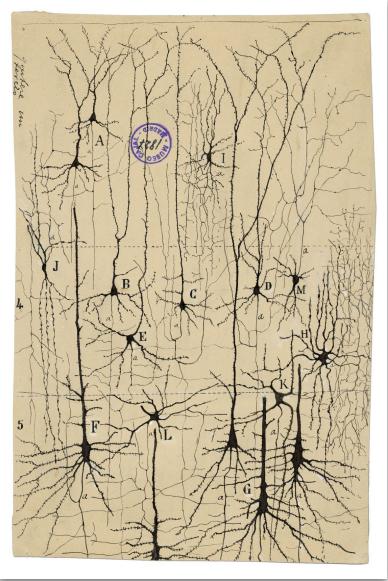


**Doktryna neuronu** - neurony są oddzielnymi komórkami, które kontaktują się ze sobą przez szczeliny synaptyczne.

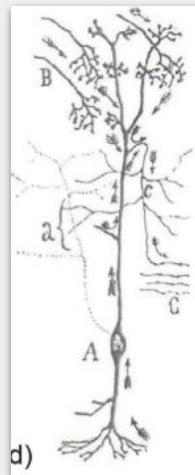


Santiago  
Ramón y Cajal  
1852-1934

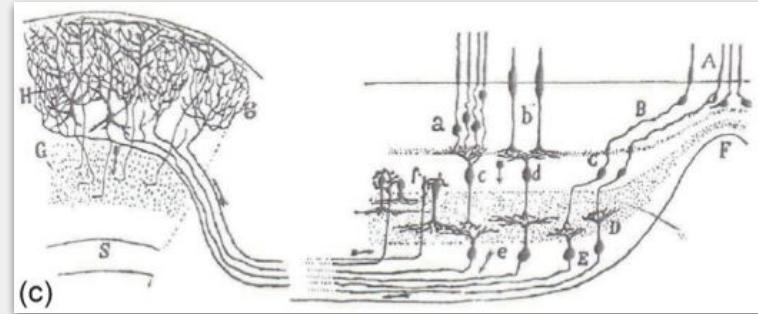
# Santiago Ramón y Cajal



**Doktryna neuronu** - neurony są oddzielnymi komórkami, które kontaktują się ze sobą przez szczeliny synaptyczne.



**Diagram połączeń** (*wiring diagram*)



**Santiago  
Ramón y Cajal**  
1852-1934

# Nagroda Nobla z Fizjologii i Medycyny (1906)



Camillo Golgi



Santiago  
Ramón y Cajal

# Nagroda Nobla z Fizjologii i Medycyny (1906)



Camillo Golgi



Santiago  
Ramón y Cajal

However opposed it may seem to the popular tendency to individualize the elements, I cannot abandon the idea of unitary action of the nervous system.  
(Nobel Prize Lecture, 1906)

# Emergencja

Złożoność powstająca z prostych elementów.



# Emergencja

Złożoność powstająca z prostych elementów.



[Planet Ant: Life Inside the Colony \(BBC\)](#)

# Emergencja

Złożoność powstająca z prostych elementów.



[Planet Ant: Life Inside the Colony \(BBC\)](#)

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Colonies of funnel ants show group personality, which affects their success at collecting food and competing with other colonies. JOHN TANN/Flickr/Creative Commons

**Ants have group-level personalities, study shows**

By Claire Asher | Aug. 28, 2015, 1:45 PM

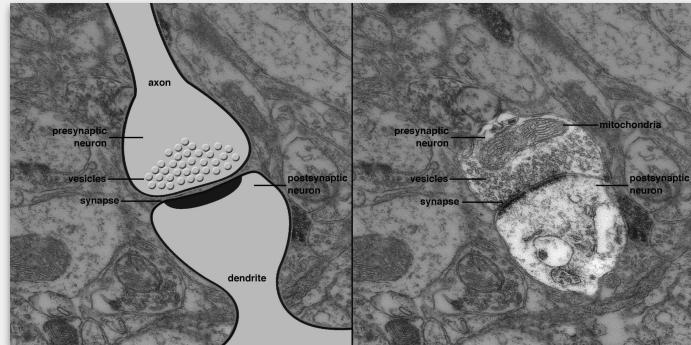
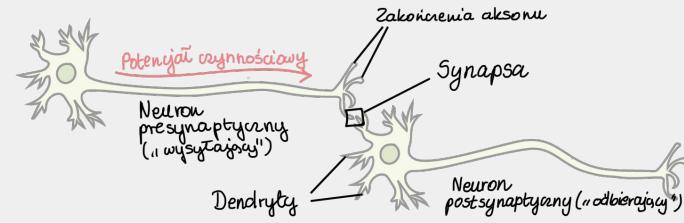
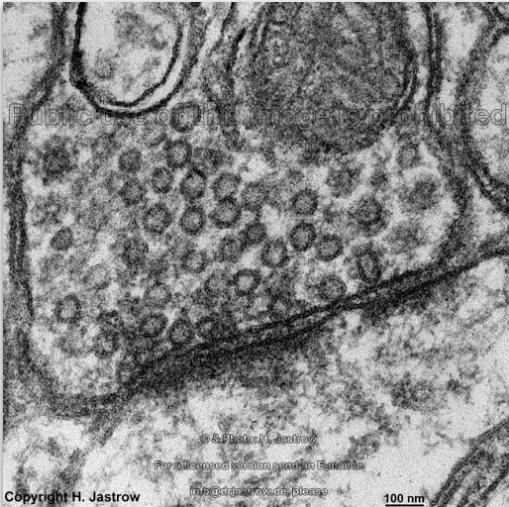
[Ants have group-level personalities, study shows](#)

# EMERGENCE



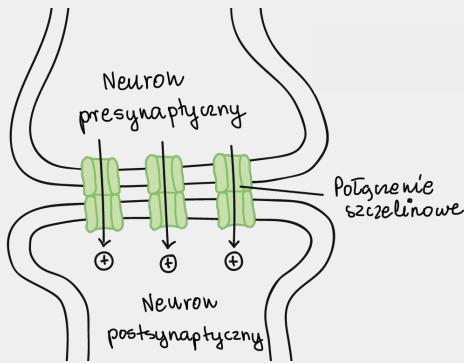
# Synapsy

**1955** - potwierdzenie istnienia synaps z wykorzystaniem mikroskopu elektronowego (DeRobertis i Bennett, 1995).

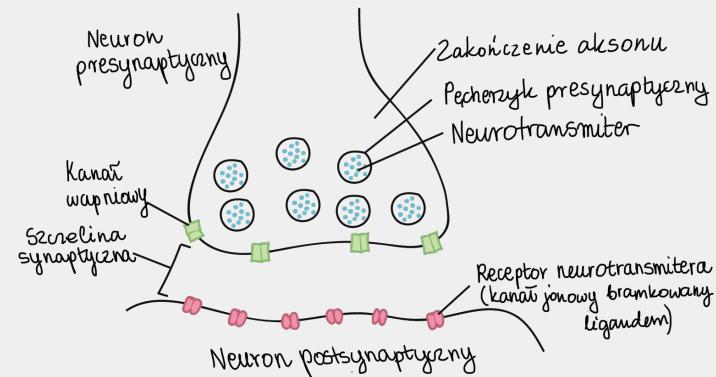


# Rodzaje synaps

## Elektryczna



## Chemiczna



- Szybkie
- Dwukierunkowe
- Przydatne przy synchronizacji

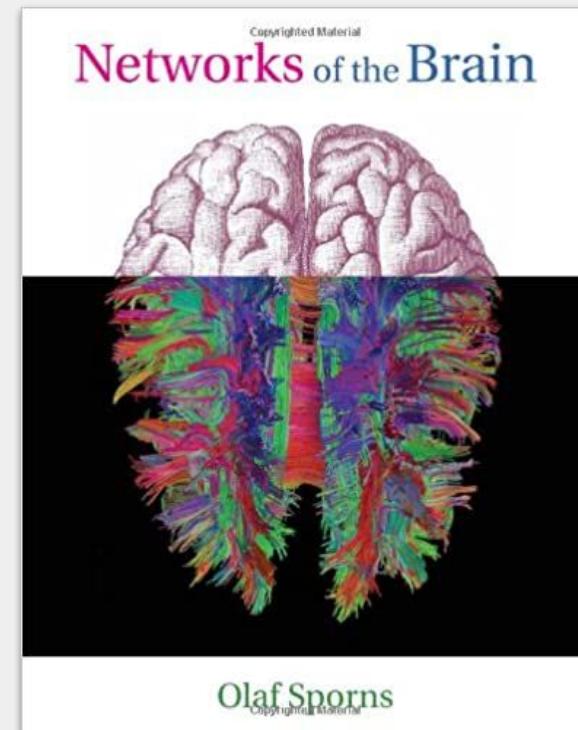
- Różnorodność: mogą zwiększać albo zmniejszać prawdopodobieństwo pobudzenia neuronu
- Specyficzność: jednokierunkowe

# Konektomika

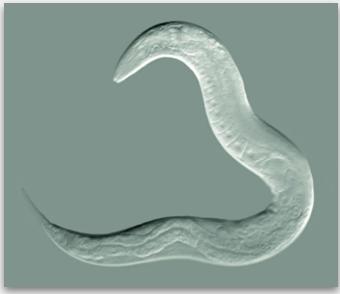
Olaf Sporns, Giulio Tononi, Rald Kötter (2005)  
Patric Hagmann (2005)

**Konektom** - mapa wszystkich możliwych połączeń w mózgu, "wiring diagram" of the brain.

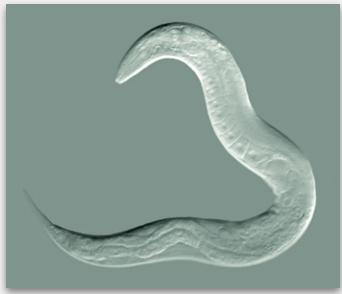
**Konektomika** - dziedzina nauki zajmująca się badaniem organizacji sieci mózgu.



# Konektom *C. elegans*



# Konektom *C. elegans*



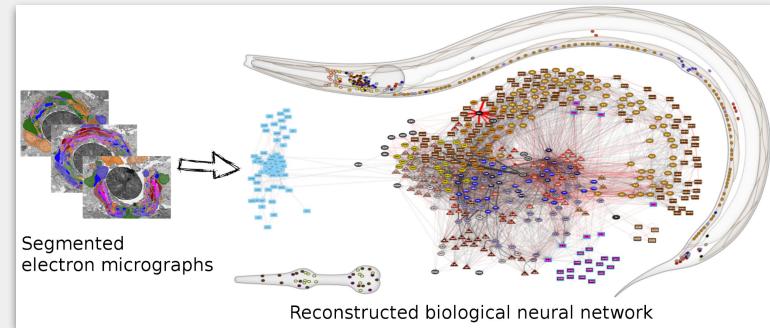
**302** neurony

**5000** chemicznych synaps

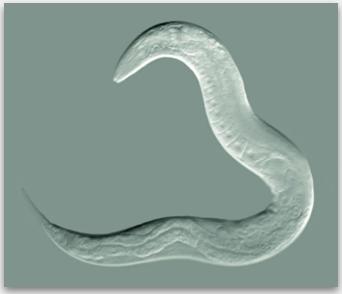
**600** synaps elektrycznych

**2000** synaps

nerwowo-mięśniowych



# Konektom *C. elegans*

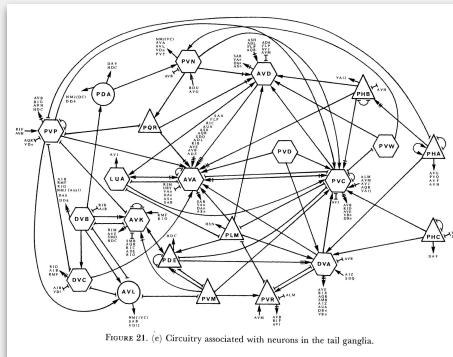
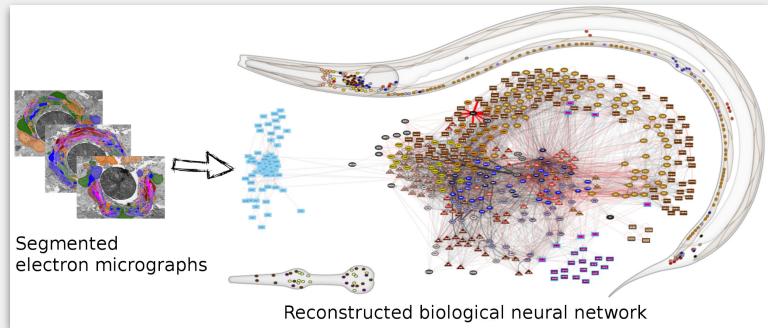


302 neurony

5000 chemicznych synaps

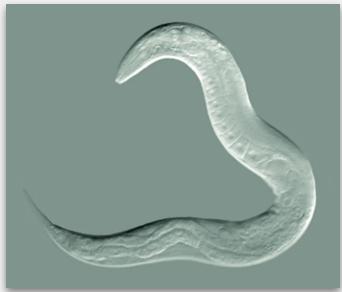
600 synaps elektrycznych

2000 synaps  
nerwowo-mięśniowych



White et al. (1986) [The structure of the nervous system of the nematode \*Caenorhabditis elegans\*.](#)

# Konektom *C. elegans*



302 neurony

5000 chemicznych synaps

600 synaps elektrycznych

2000 synaps  
nerwowo-mięśniowych



[OpenWorm project](#)  
[Documentation](#)

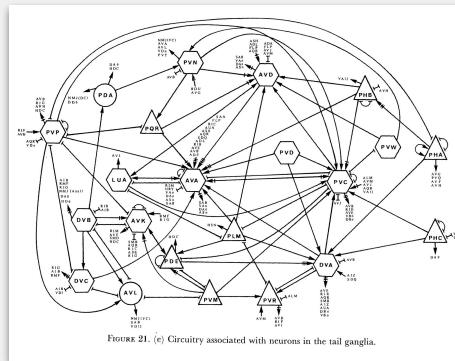
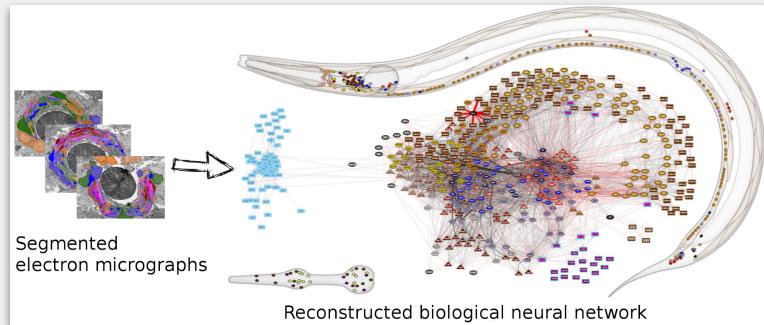


FIGURE 21. (e) Circuitry associated with neurons in the tail ganglia.

White et al. (1986) [The structure of the nervous system of the nematode \*Caenorhabditis elegans\*.](#)

# Konektom muszki owocowej (*Drosophila*)



25 000 neuronów  
20 mln synaps

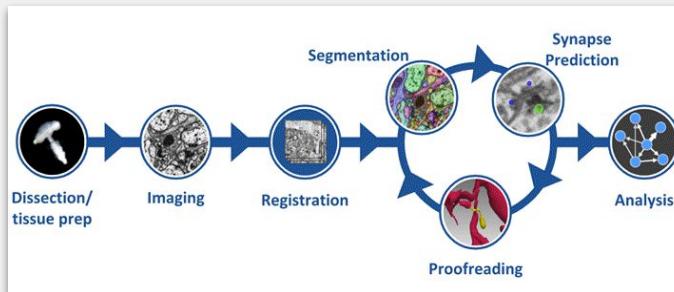
bioRxiv  
THE PREPRINT SERVER FOR BIOLOGY

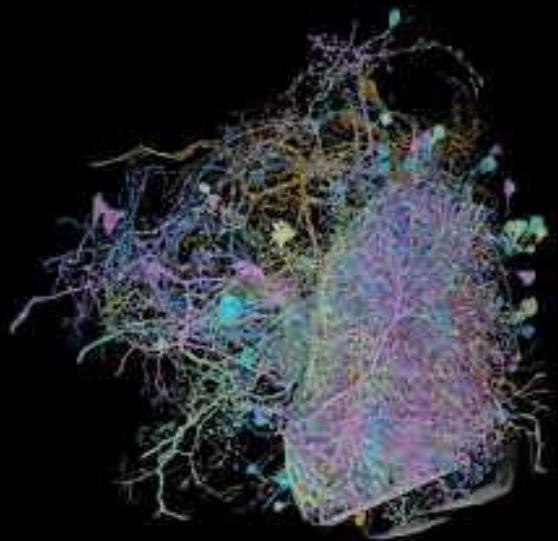
New Results

6 comments

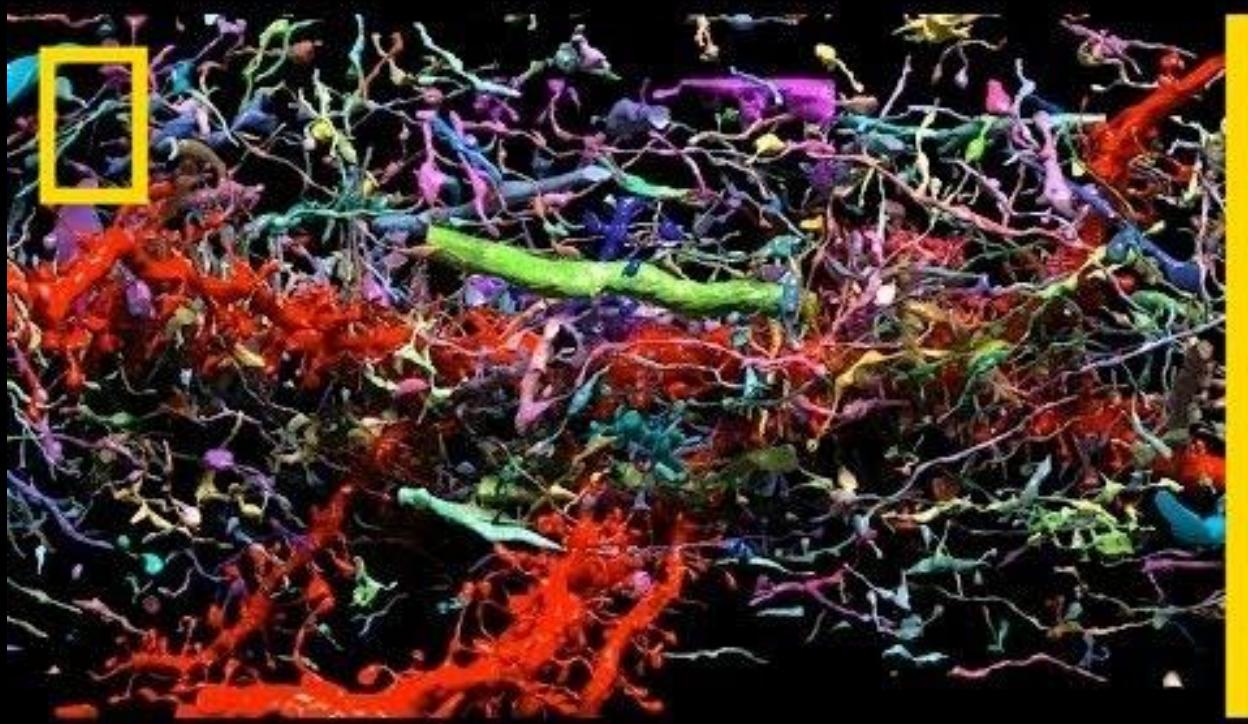
## A Connectome of the Adult *Drosophila* Central Brain

C. Shan Xu, M. Michal Januszewski, Zhiyuan Lu, Shin-ya Takemura, Kenneth J. Hayworth, Gary Huang, Kazunori Shinomiya, Jeremy Maitlin-Shepard, David Ackerman, Stuart Berg, Tim Blakely, John Bogovic, Jody Clements, Tom Dolafi, Philip Hubbard, Dagmar Kainmueller, William Katz, Takashi Kawase, Khaled A. Khairy, Laramie Leavitt, Peter H. Li, Larry Lindsey, Nicole Neubarth, Donald J. Olbris, Hideo Otsuna, Eric T. Troutman, Lowell Umayam, Ting Zhao, Masayoshi Ito, Jens Goldammer, Tanya Wolff, Robert Svirskas, Philipp Schlegel, Erika R. Neace,





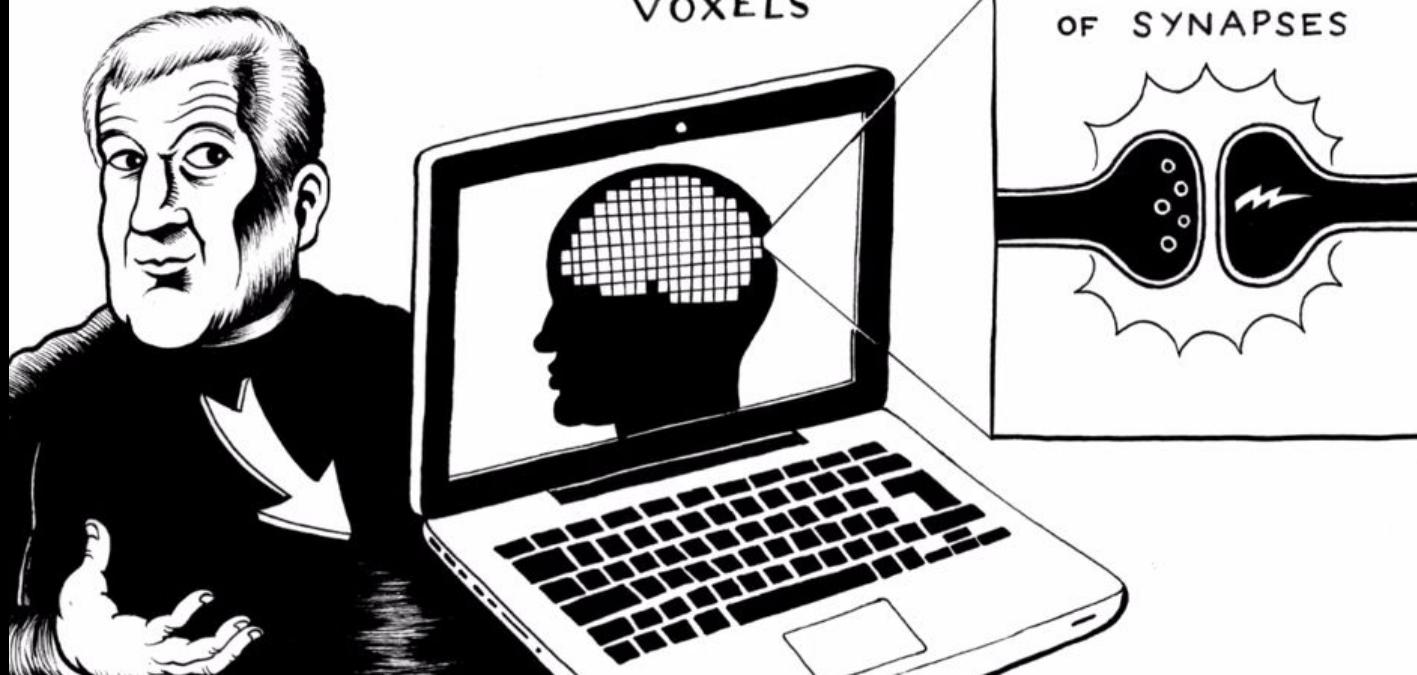
Visual



**1 BRAIN = 1 MILLION X 2000 TERA BYTES**

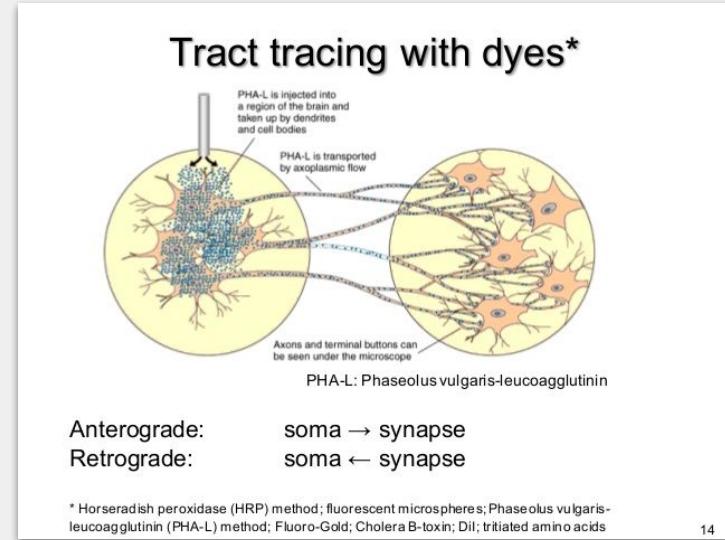
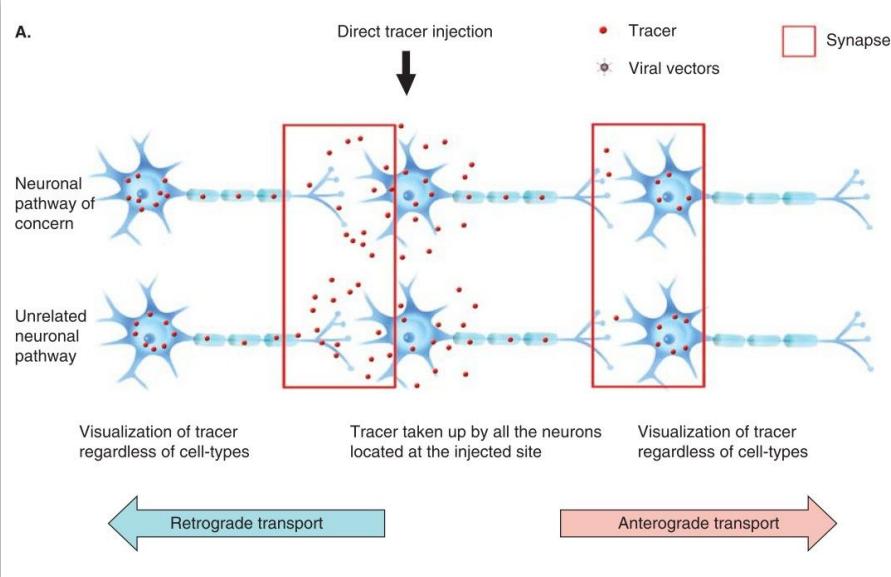
VOXELS

OF SYNAPSES



Connectomics: Big Microscopes & Tiny Synapses

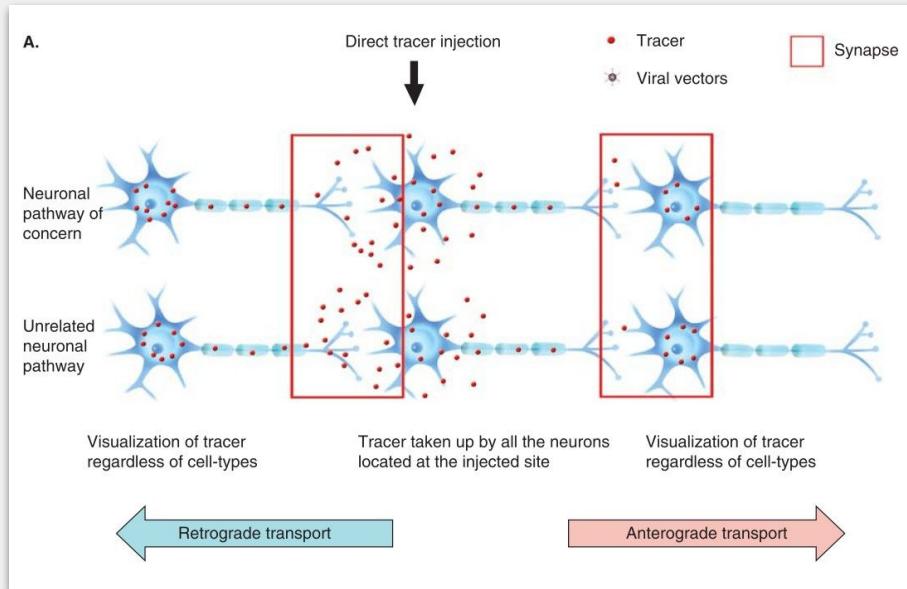
# Tract-tracing



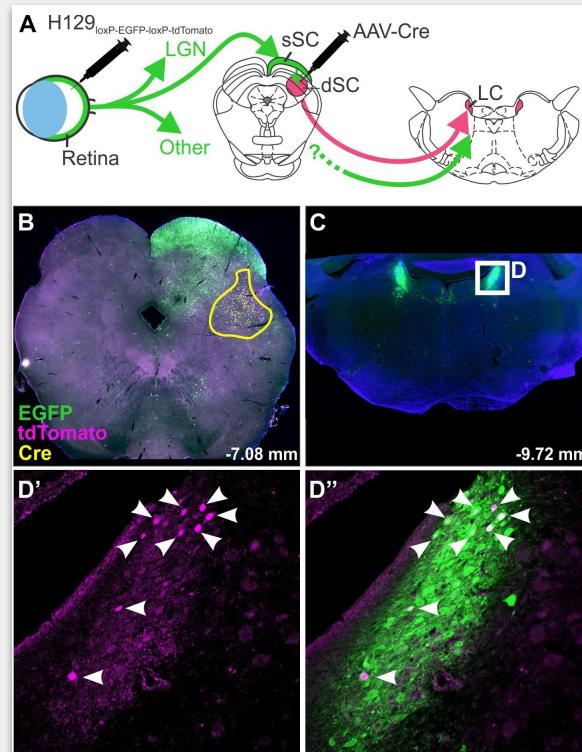
**Retrograde tracing** - śledzenie połączeń od synapsy do ciała komórki.

**Anterograde tracing** - śledzenie połączeń od ciała komórki do synapsy.

# Tract-tracing

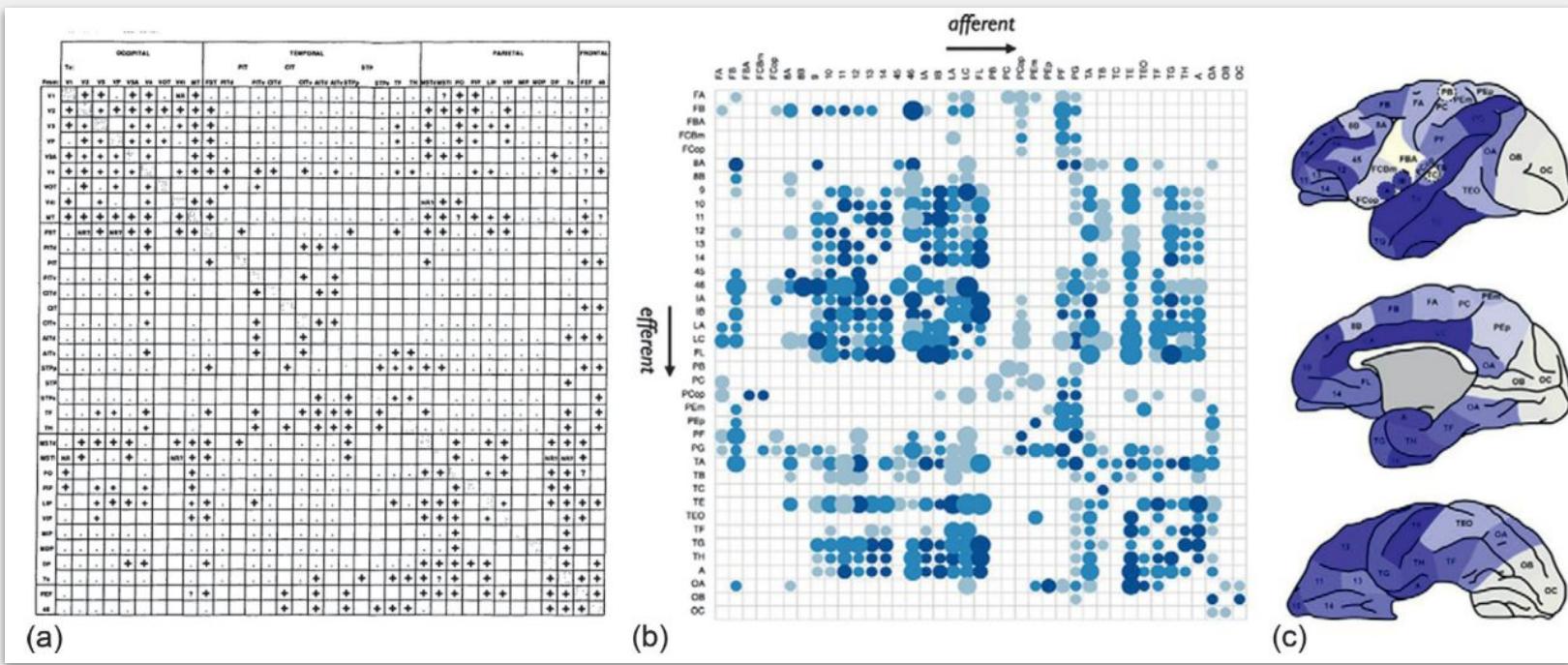


**Retrograde tracing** - śledzenie połączeń od synapsy do ciała komórki.



**Anterograde tracing** - śledzenie połączeń od ciała komórki do synapsy.

# Konektom makaka



Felleman i Van Essen (1991), Scholtens et al. (2014)

[CoCoMac database](#) (Stephan et al., 2001).

# Atlas Allena

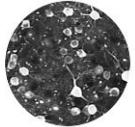
## Allen Brain Atlases and Data



### CELL TYPES DATABASE

A database of biological features derived from single cells, from both human and mouse.

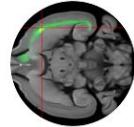
[View Data →](#)



### BRAIN OBSERVATORY

A new approach to open data, featuring a survey of *in vivo* recordings from the mouse visual cortex.

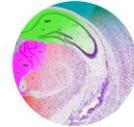
[View Data →](#)



### MOUSE BRAIN CONNECTIVITY ATLAS

A brain-wide map of neural projections, including cell class-specific data.

[View Atlas →](#)

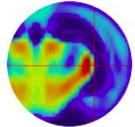


### REFERENCE ATLASES

High resolution anatomical reference atlases and histology for mouse and human.

[View Atlases →](#)

<https://portal.brain-map.org/>



### MOUSE BRAIN ATLAS

A unique multimodal atlas of the adult mouse brain, featuring anatomic and genomic data.

[View Atlas →](#)



### DEVELOPING MOUSE BRAIN ATLAS

A detailed atlas of gene expression across 7 stages of development.

[View Atlas →](#)



### MOUSE SPINAL CORD ATLAS

A detailed atlas of gene expression across the adult and juvenile mouse spinal cord.

[View Atlas →](#)

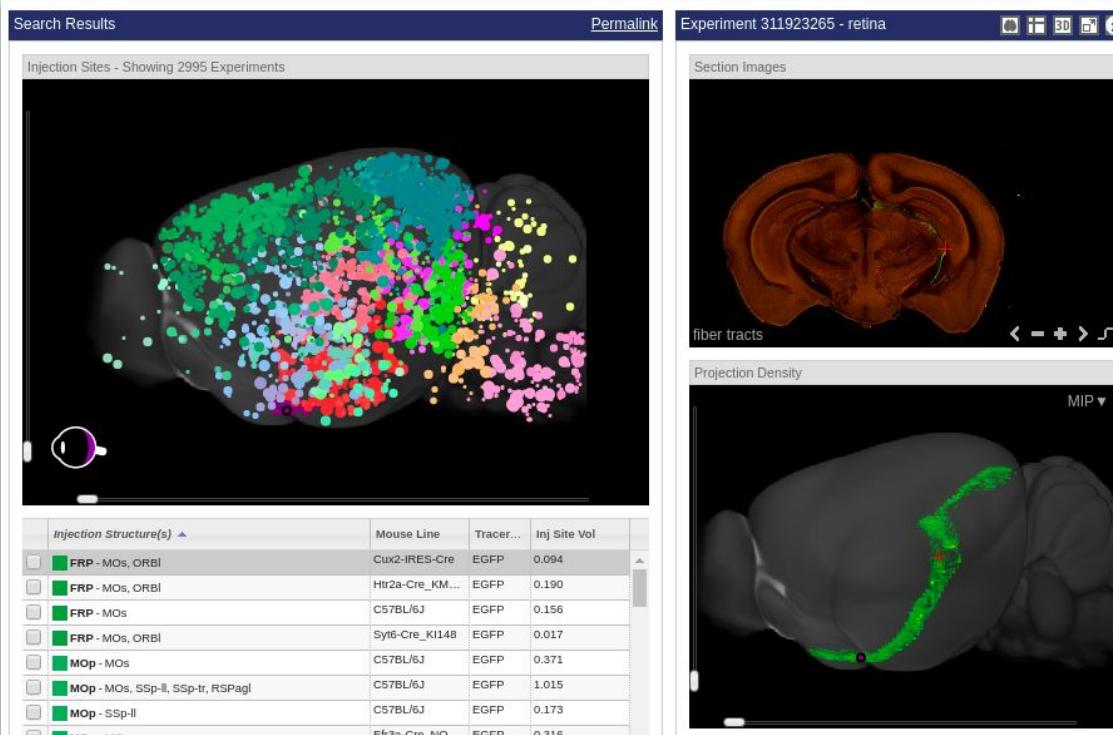


### ADULT AND DEVELOPING NHP ATLAS

The NIH Blueprint Non-Human Primate Atlas characterizes the developing rhesus macaque brain.

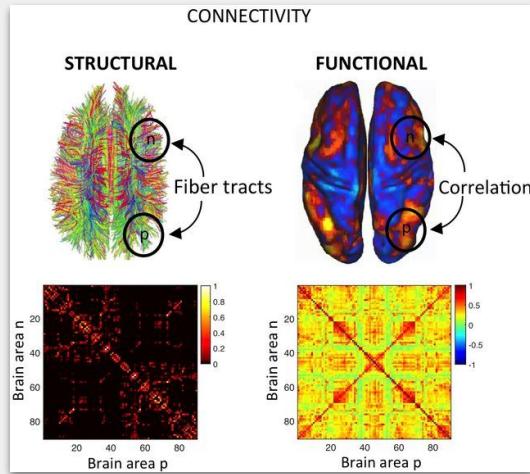
[View Atlas →](#)

# Konektom myszy



<http://connectivity.brain-map.org/>

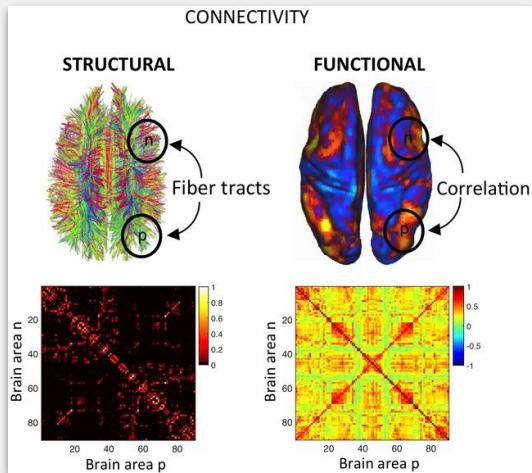
# Konektom człowieka



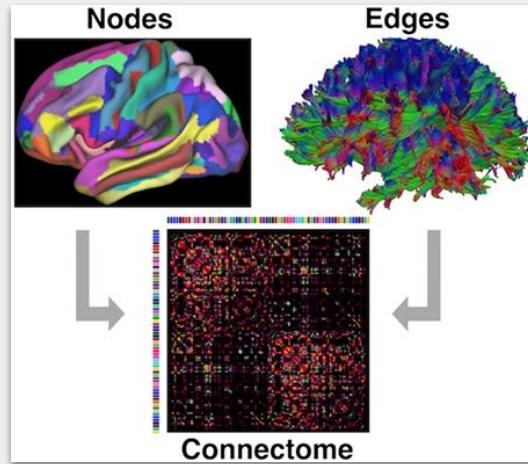
Funkcjonalny rezonans magnetyczny (fMRI)



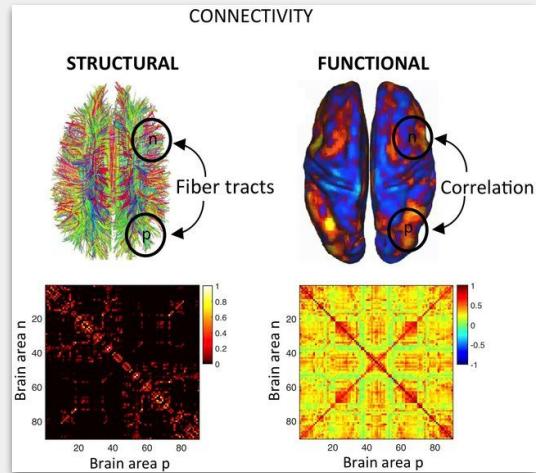
# Konektom człowieka



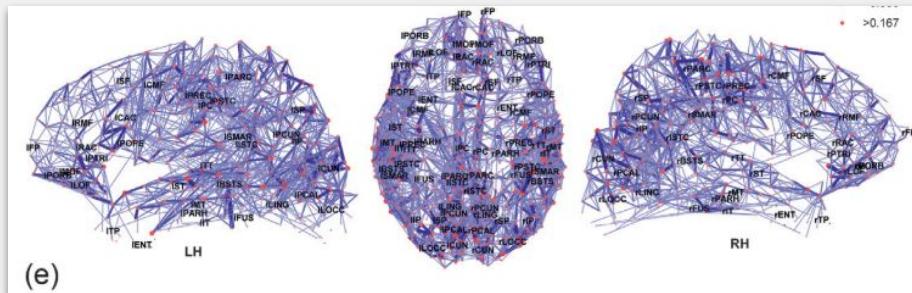
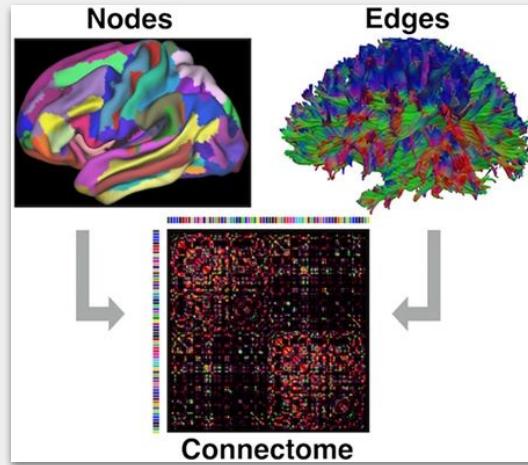
Funkcjonalny rezonans magnetyczny (fMRI)



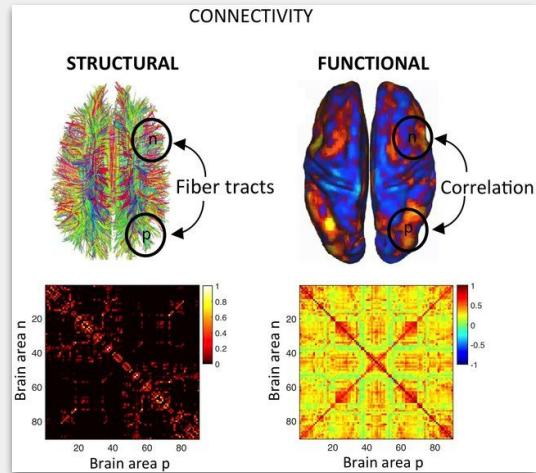
# Konktem człowieka



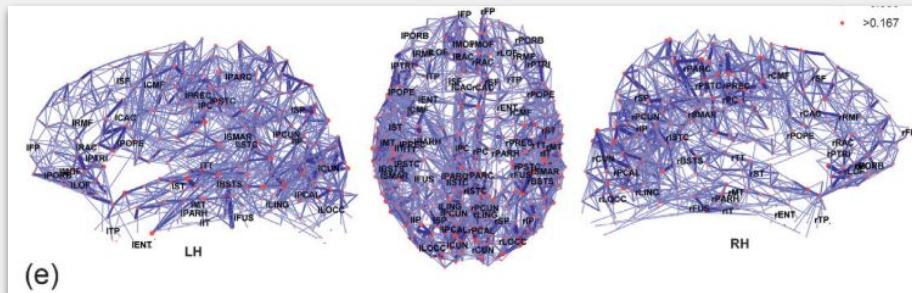
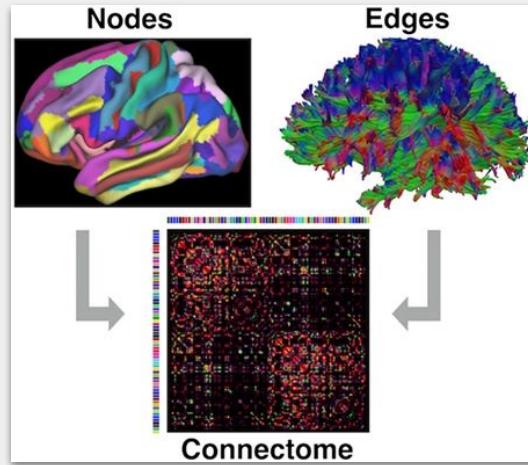
## Funkcjonalny rezonans magnetyczny (fMRI)



# Konktem człowieka



## Funkcjonalny rezonans magnetyczny (fMRI)

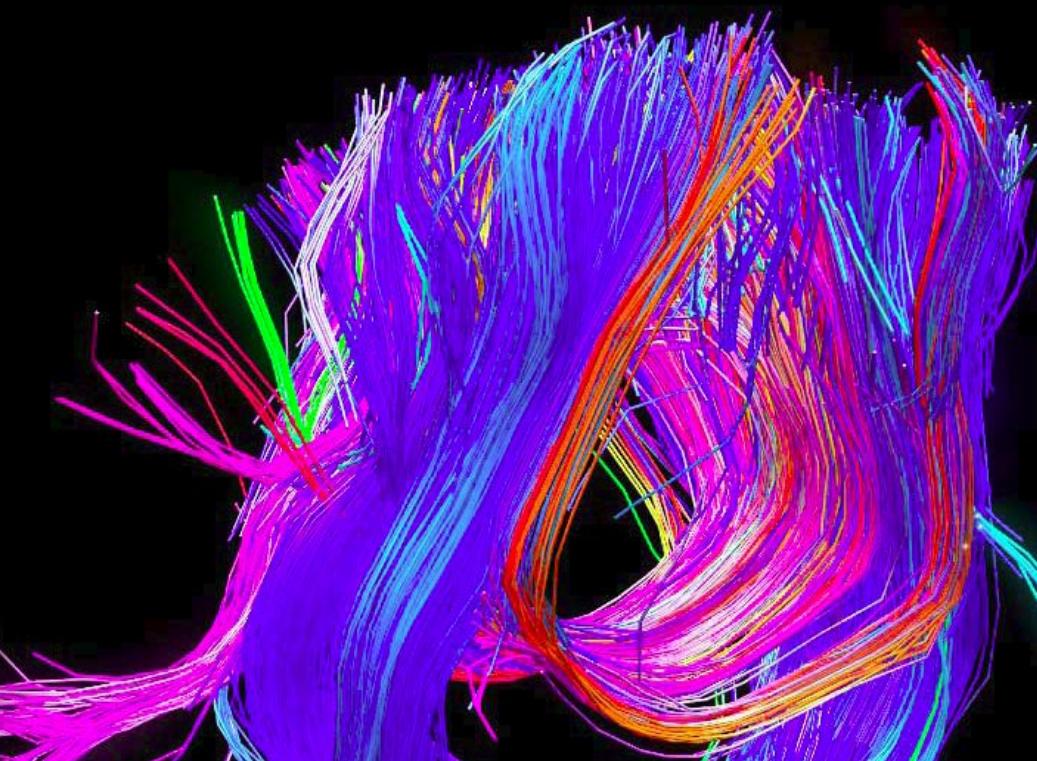


# Human Connectome Project

Enter search keyword



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## The Human Connectome Project

Navigate the brain in a way that was never before possible; fly through major brain pathways, compare essential circuits, zoom into a region to explore the cells that comprise it, and the functions that depend on it.

The Human Connectome Project aims to provide an unparalleled compilation of neural data, an interface to graphically navigate this data and the opportunity to achieve never before realized conclusions about the living human brain.

[Download Data](#)

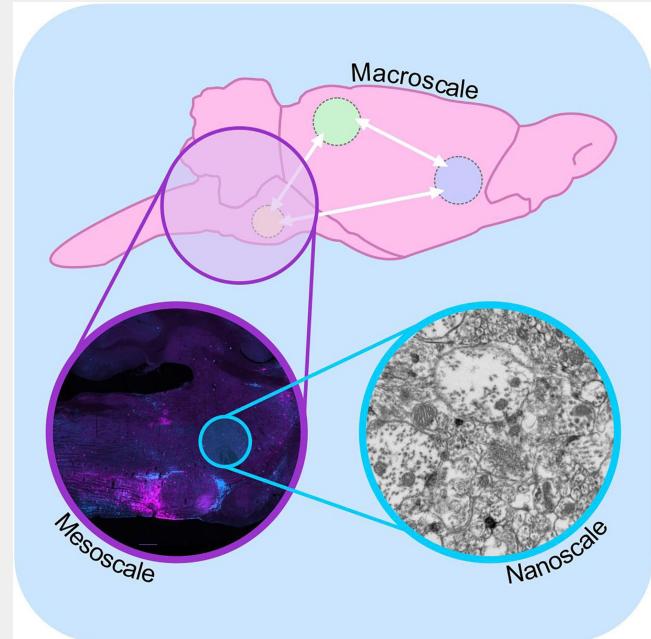
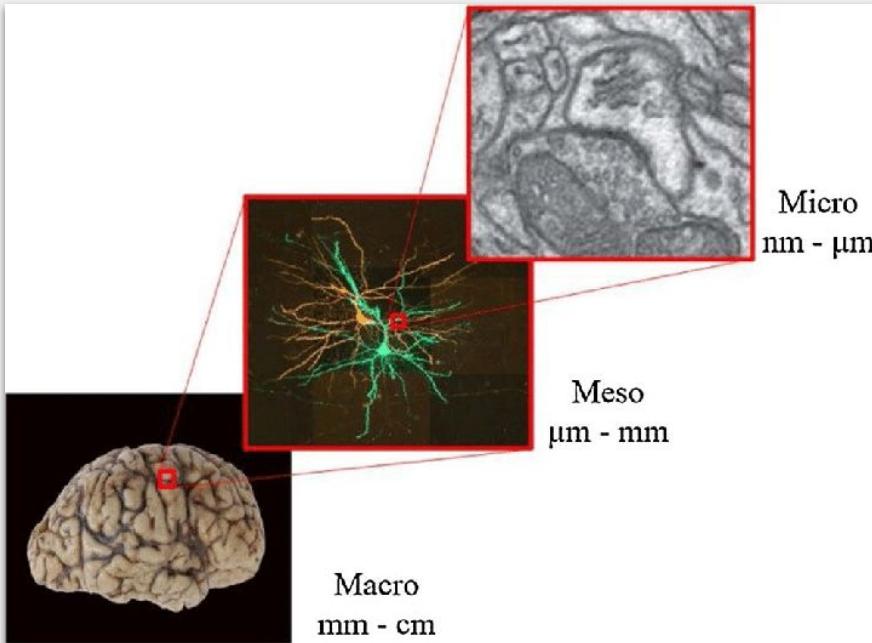
Laboratory of Neuro Imaging

News

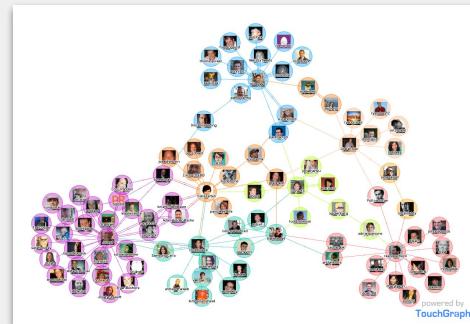
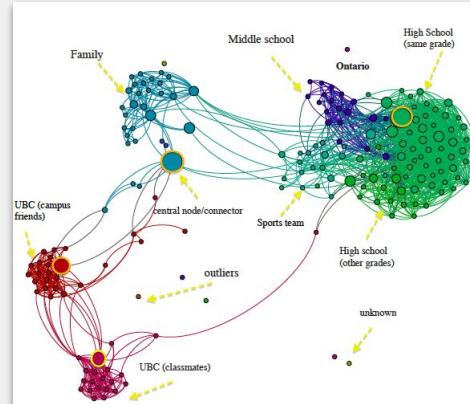
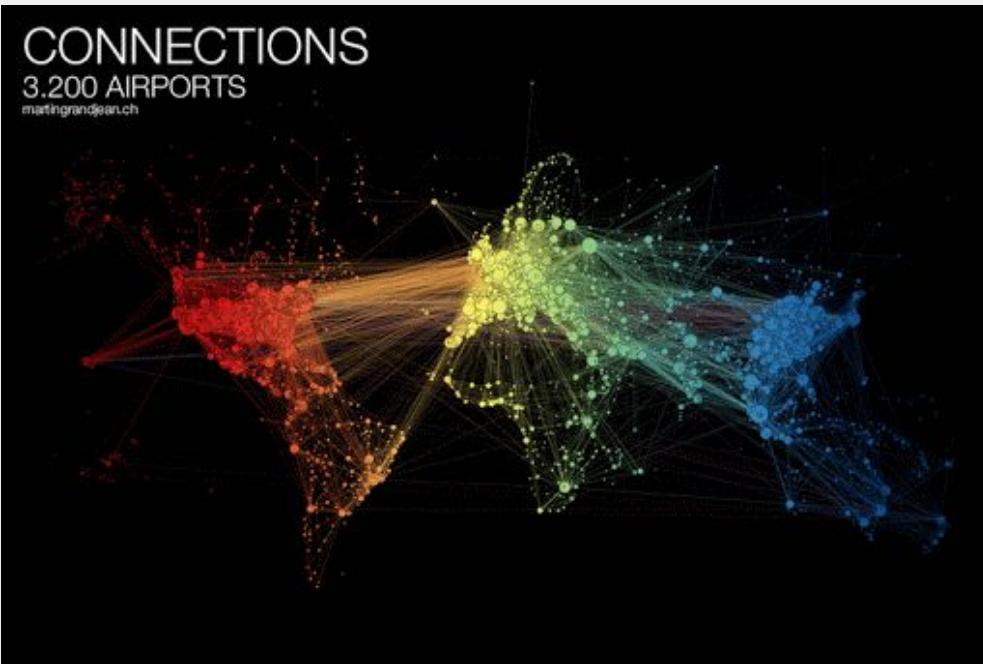
RSS News

National Geographic features the Human Connectome Project

# Skale obrazowania konektomu



# Sieci



# Conservation of space, time, and material



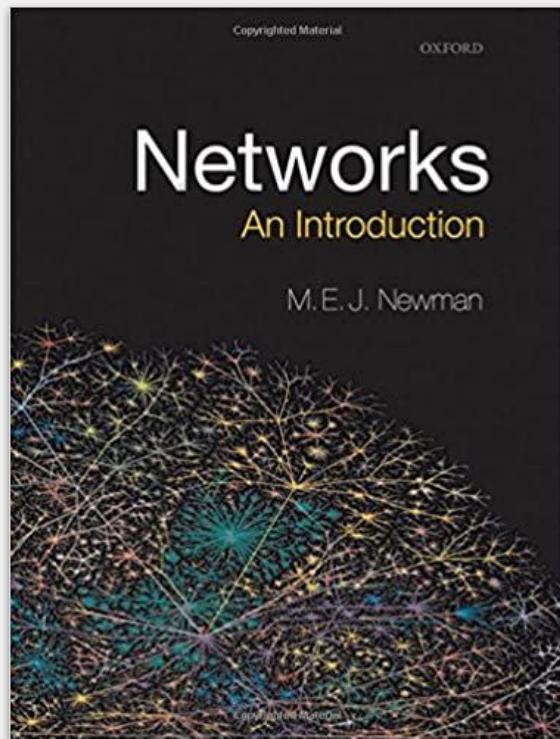
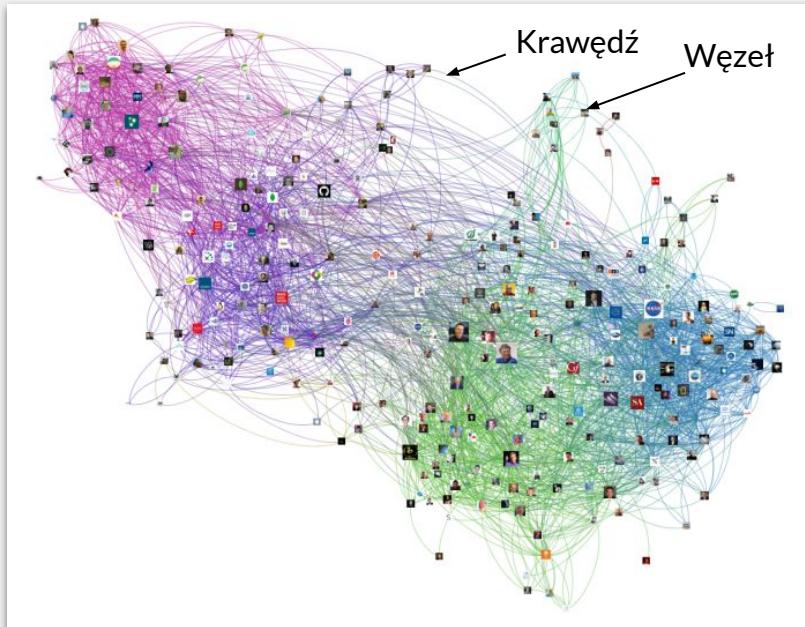
Doubt for us is unacceptable, and all of the morphological features displayed by neurons appear to obey precise rules that are accompanied by useful consequences. What are these rules and consequences? We have searched in vain for them over the course of many years... Finally however we realized that all of the various conformations of the neuron... are simply **morphological adaptations governed by laws of conservation for time, space and material**... which must be considered the final cause of all variations in the shape of neurons, [and] should in our view be immediately obvious to anyone thinking about or trying to verify them.

Santiago  
Ramón y Cajal  
1852-1934

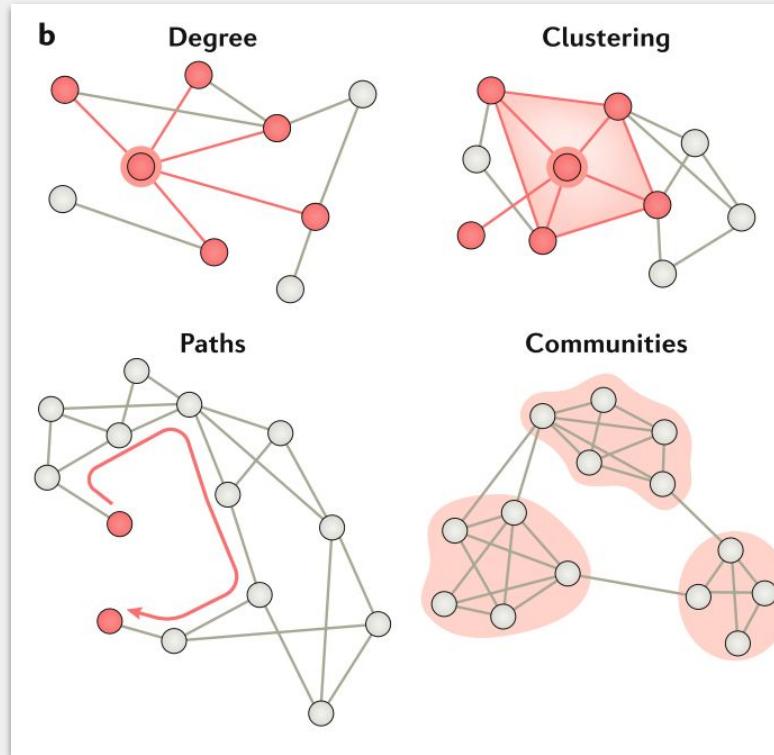




# Nauka o sieciach (*network science*)



# Nauka o sieciach (*network science*)



# Jaki ten świat jest mały!



Stanley Milgram

# Jaki ten świat jest mały!



x 100  
✉ ➡

A graphic showing a large arrow pointing from a small envelope icon to a map of the United States, indicating a significant reduction in physical distance or time through communication.

Stanley Milgram

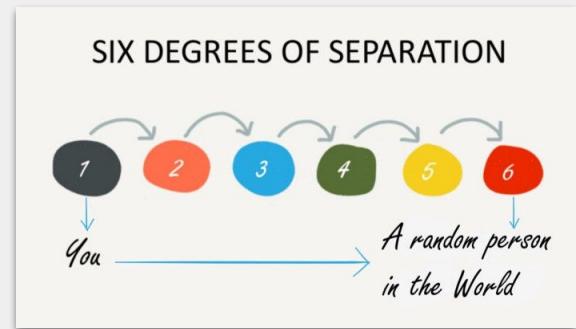
# Jaki ten świat jest mały!



x 100  
 →



Stanley Milgram



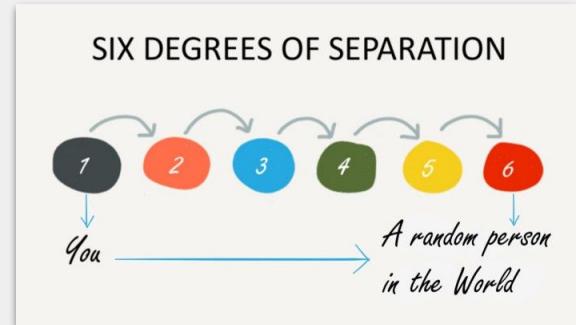
# Jaki ten świat jest mały!



x 100  
✉

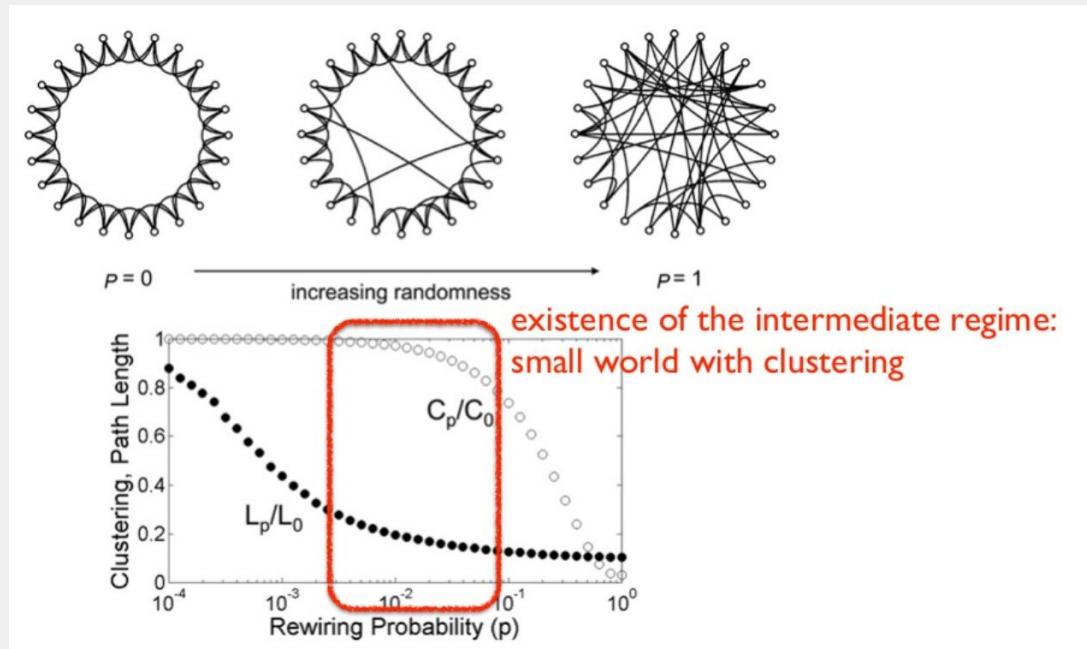


Stanley Milgram



Facebook

# Sieć small-world



Watts and Strogatz (1998), *Nature*.

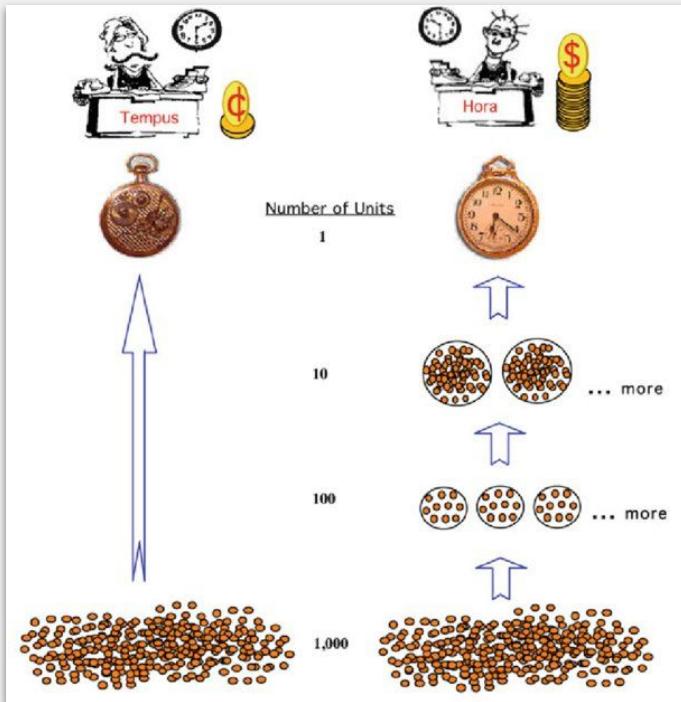
***"In the face of complexity, an in-principle reductionist may be at the same time a pragmatic holist."***

**Herbert A. Simon**, Architecture of Complexity

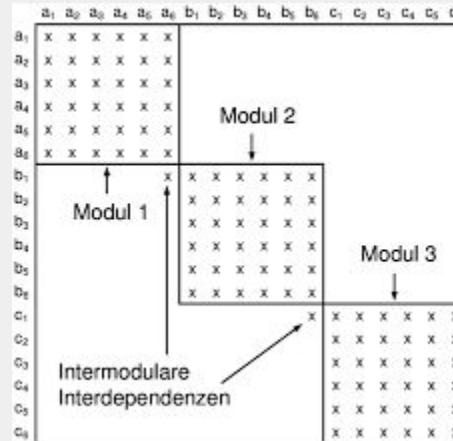
Laureat Nagrody Nobla z Ekonomii (1978)



# Architektura złożoności

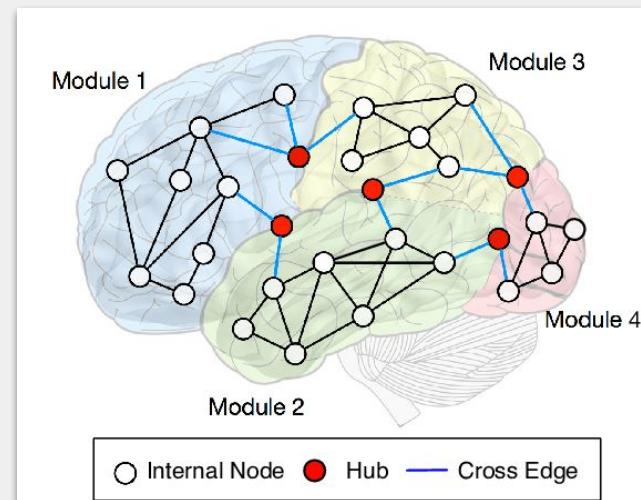
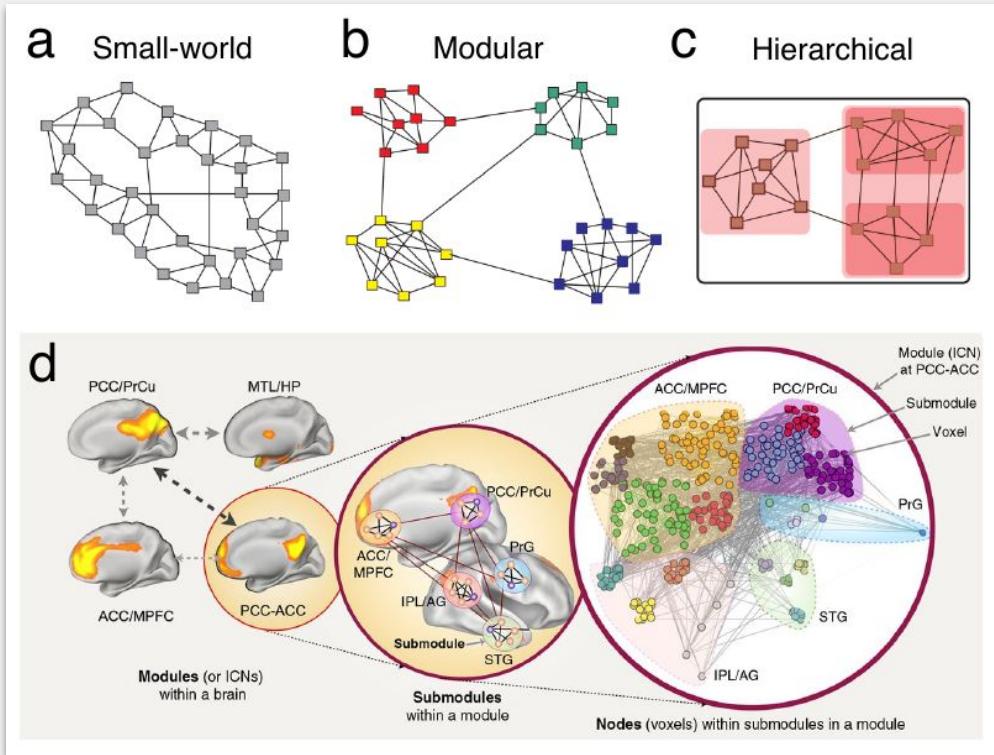


System prawie rozkładalny (nearly decomposable system)

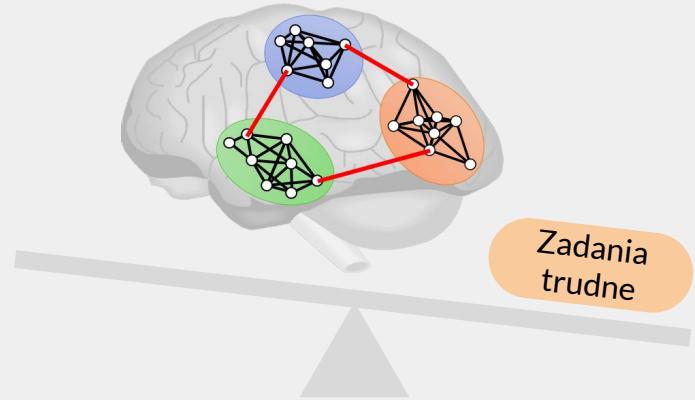
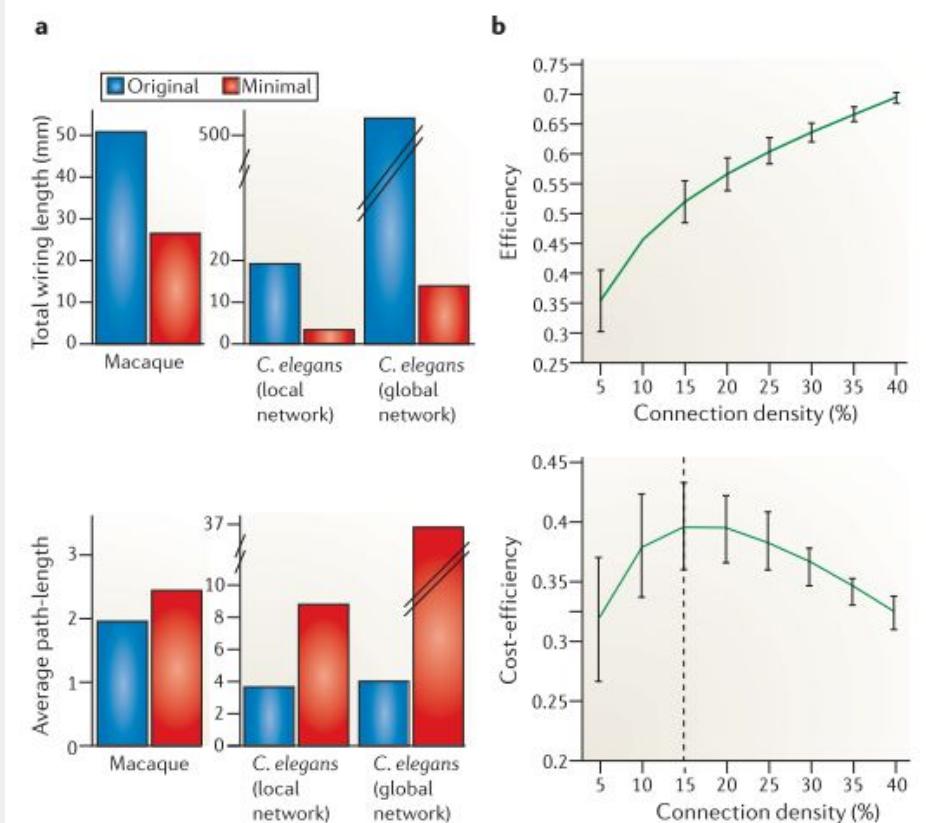


Herbert A. Simon, Architecture of Complexity (1962)

# Modularność



# Ekonomiczny kompromis



**SEGREGACJA**  
Grupowanie  
Modularność  
Niski koszt połączeń

**INTEGRACJA**  
Krótka ścieżka  
Zaangażowanie hubów  
Wysoki koszt połączeń

Bullmore & Sporns (2012)

(Kaiser and Hilgetag, 2006)

# Zalety modularności

- Szybka adaptacja do zmian środowiska
- Odporność na uszkodzenia i zakłócenia
- Umożliwia dynamiczne zmiany funkcjonowania sieci

**PLOS** COMPUTATIONAL BIOLOGY

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RESEARCH ARTICLE

## Neural Modularity Helps Organisms Evolve to Learn New Skills without Forgetting Old Skills

Kai Olav Ellefsen<sup>1</sup>, Jean-Baptiste Mouret<sup>2,3</sup>, Jeff Clune<sup>4\*</sup>

<sup>1</sup> Department of Computer and Information Science, Norwegian University of Science and Technology, Trondheim, Norway, <sup>2</sup> Sorbonne Universités, UPMC Univ Paris 06, UMR 7222, ISIR, Paris, France, <sup>3</sup> CNRS, UMR 7222, ISIR, Paris, France, <sup>4</sup> Computer Science Department, University of Wyoming, Laramie, Wyoming, United States of America

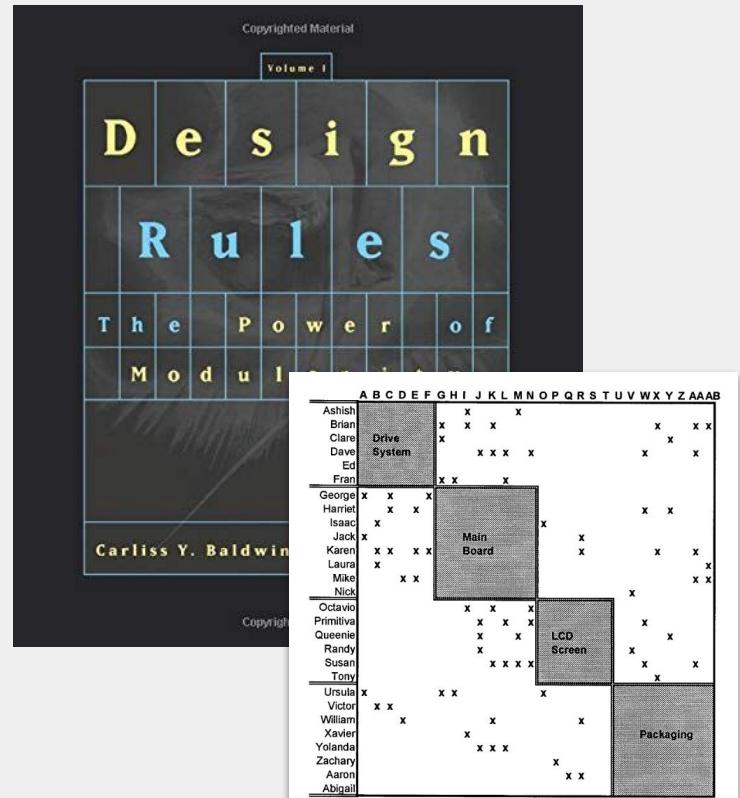


Figure 2.7 Mapping people to tasks: the organizational reflection of a complex task structure.

# Topologia sieci a funkcje poznawcze

