

The background of the slide is a complex network diagram. It consists of numerous small, dark blue circular nodes connected by thin, light blue lines. The nodes are distributed across the entire frame, with a higher density in the center and lower density towards the edges. The lines vary in thickness, suggesting different weights or types of connections between the nodes. The overall appearance is that of a large-scale, interconnected system, likely representing a brain network or a social network.

Intro to Brain networks

COGNESTIC 2023

Isaac Sebenius

<https://www.psychiatry.cam.ac.uk/people/postgraduate-students/isaac-sebenius/>

Overview

Break 

Break 

01

From simple networks to diverse perspectives on brain connectivity (Mostly me talking)

02

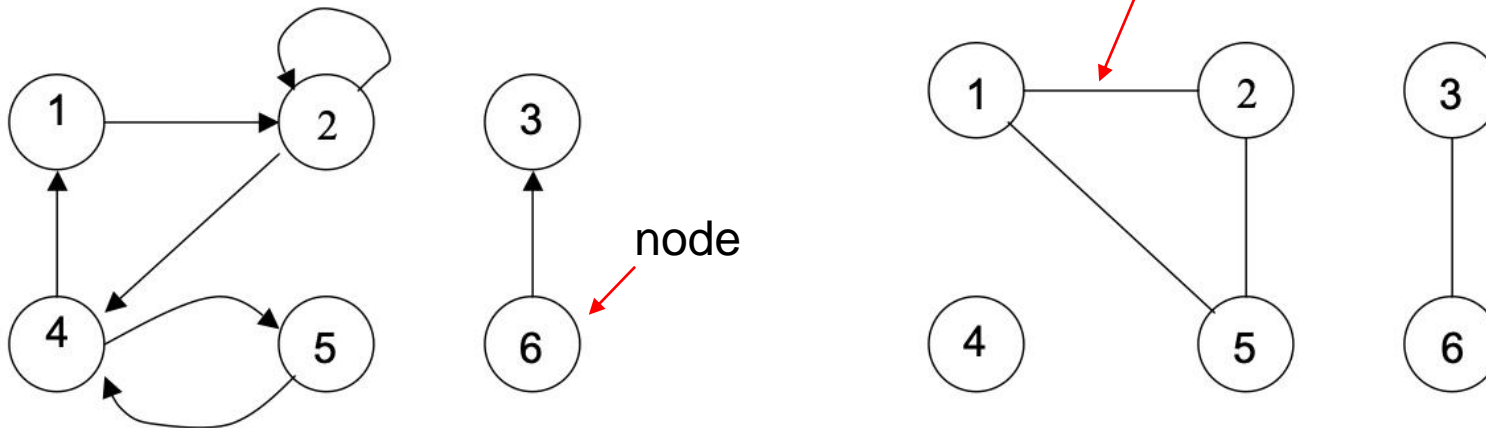
Graph theory of brain networks crash course (We work through the Jupyter notebook together)

03

Mess around with some sample brain network data! (You are off on your own 😊)

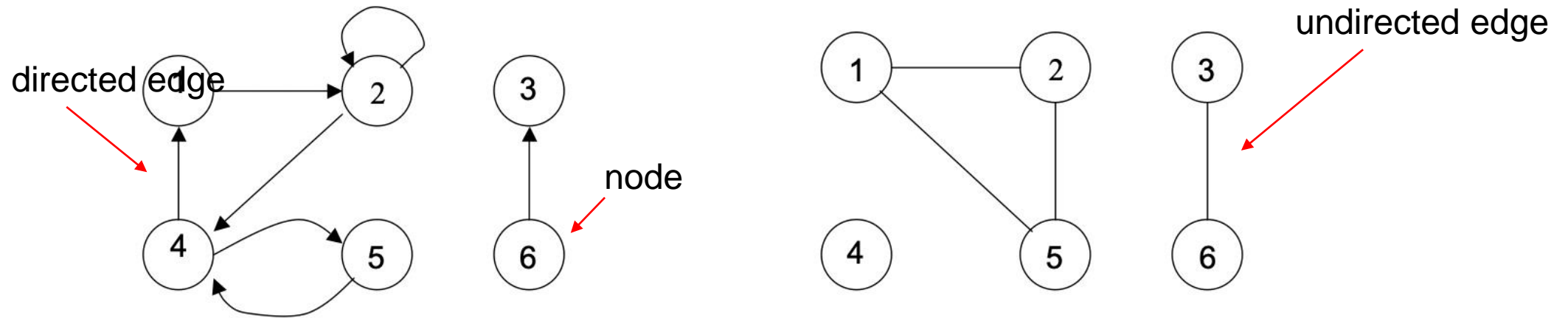
What is a network?

- **Network = Graph**
- **A graph/network is simply a set of nodes (a.k.a vertices) and edges**



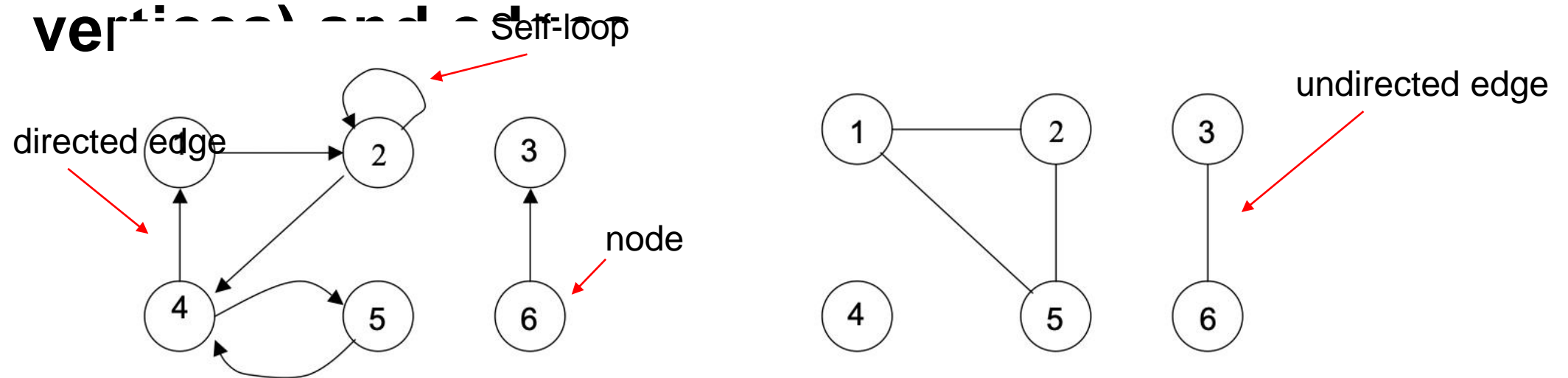
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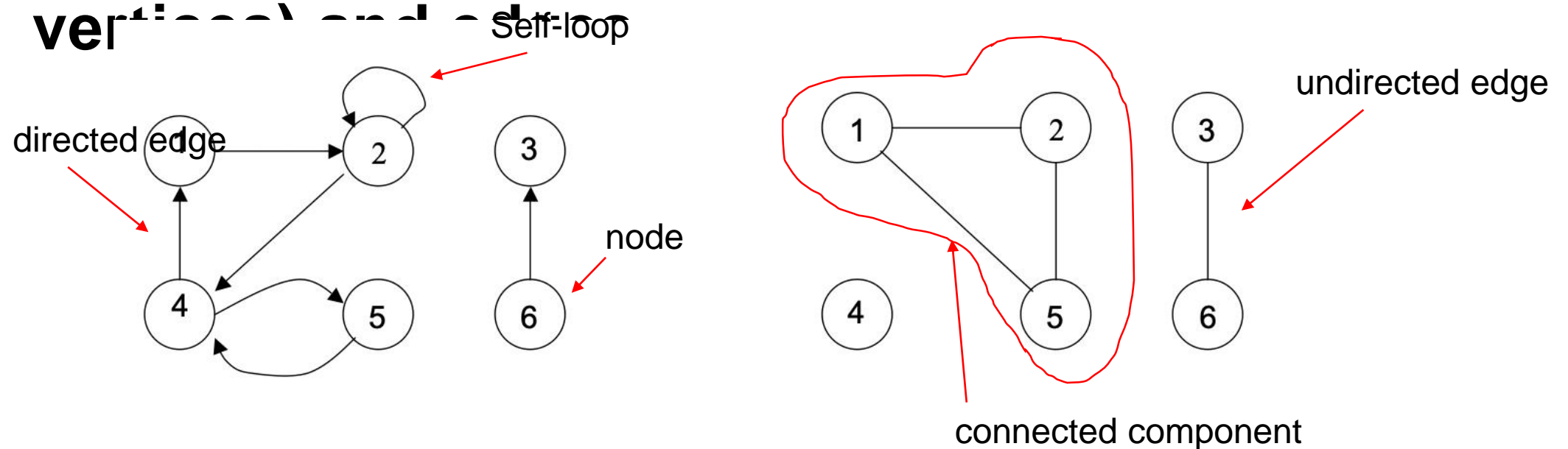
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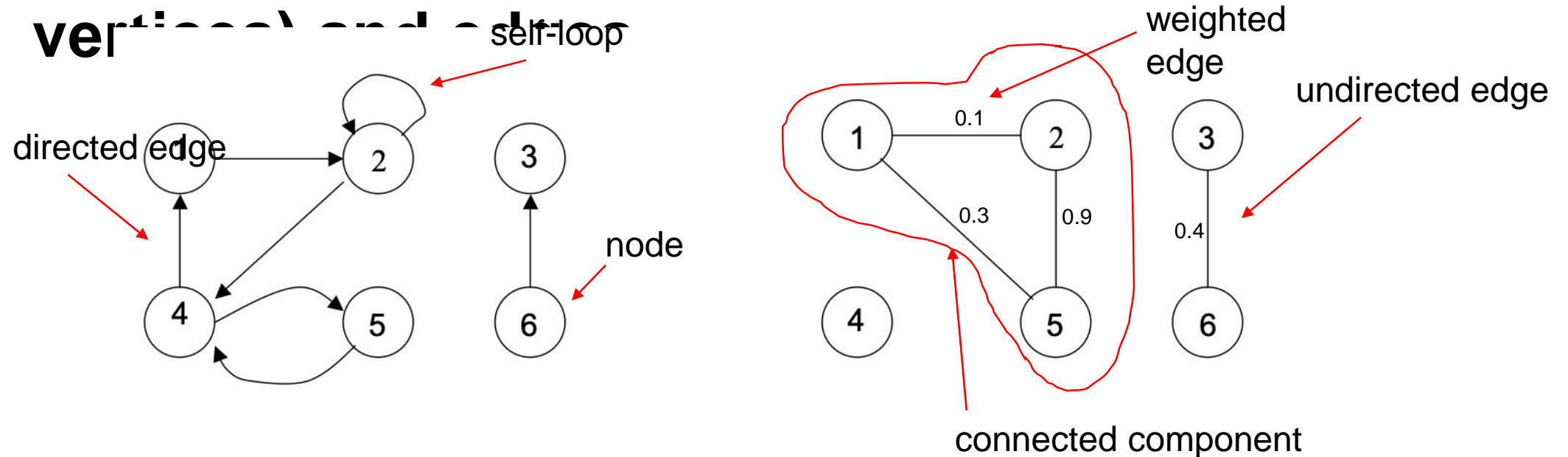
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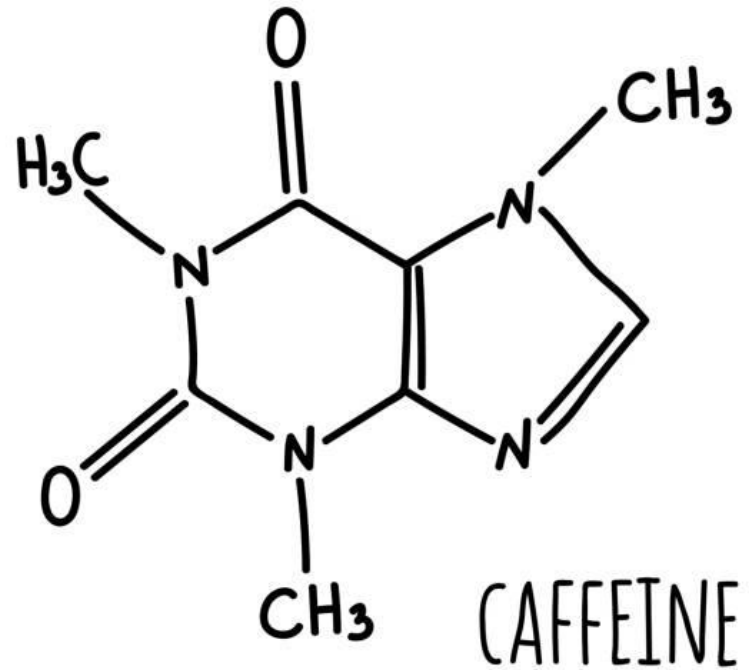


What is a network?

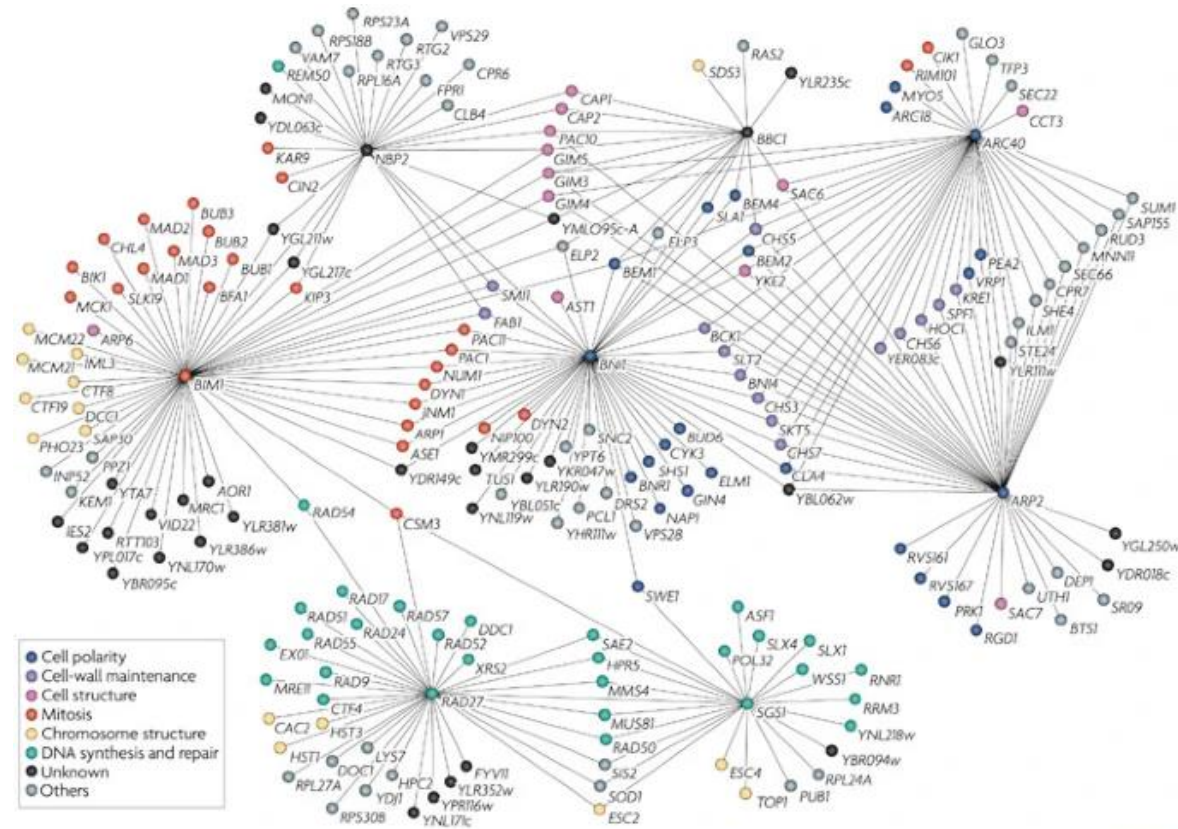
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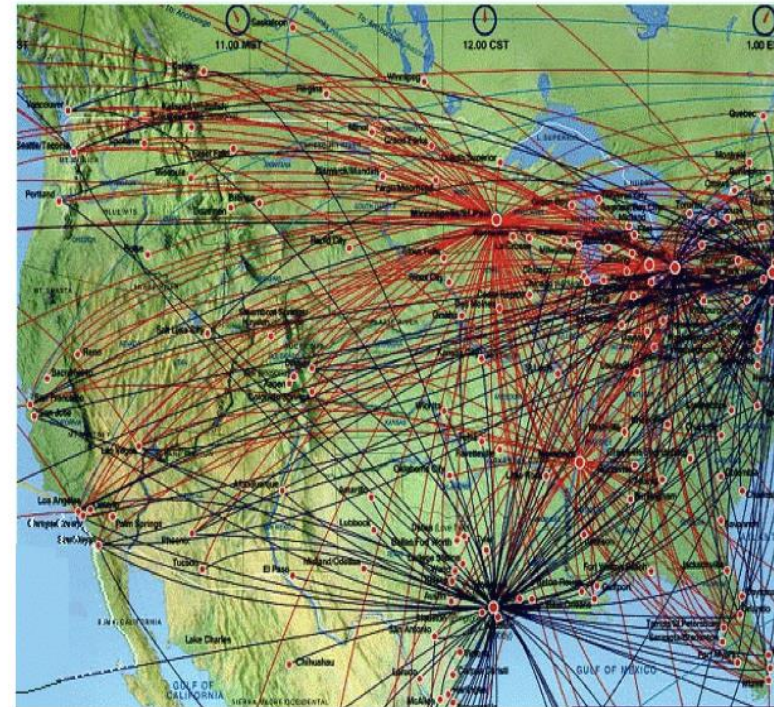
Sample networks: molecules



Sample Networks: Gene networks



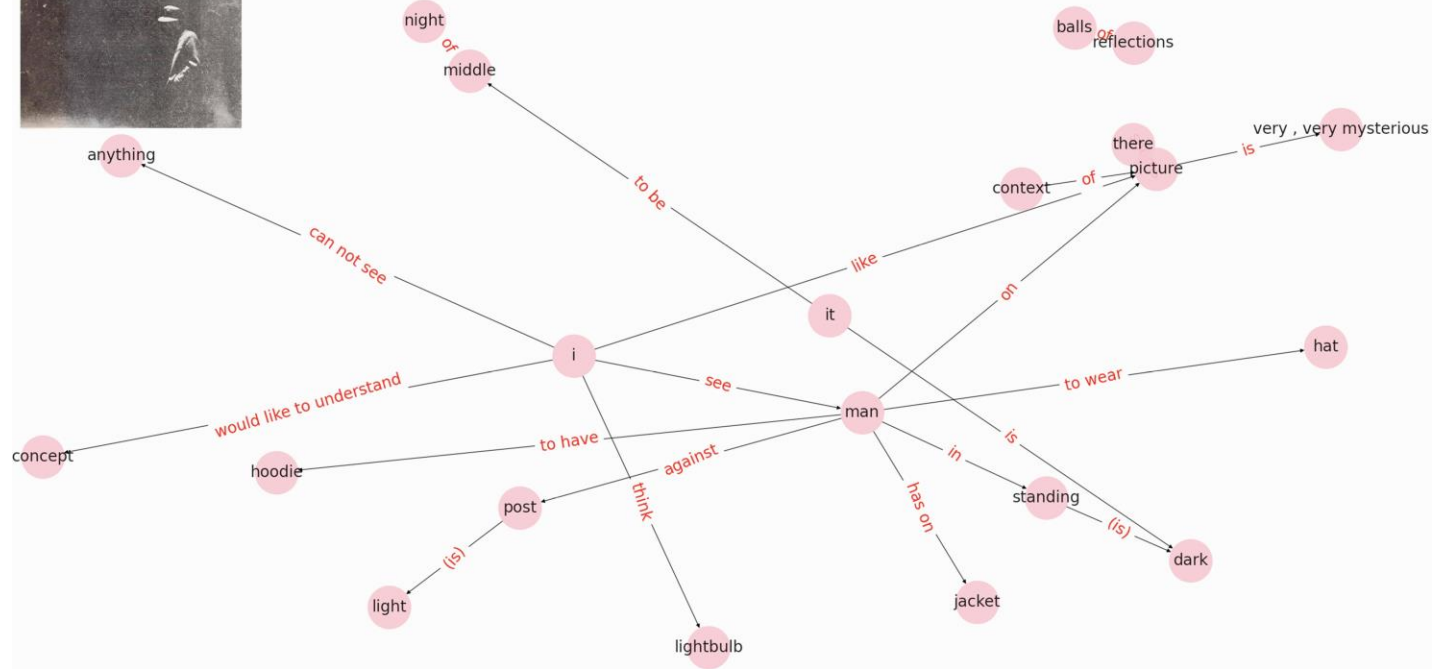
Sample networks: transportation



Sample networks: Speech networks



"I see a man in the dark standing against a light post . It seems to be in the middle of the night ; I think because the lightbulb is working . On the picture there seems to be like a park and ... Or trees but in those trees there are little balls of light reflections as well . I can not see the ... Anything else because it is very dark . But the man on the picture seems to wear a hat and , and has a jacket on and he seems to have a hoodie on as well . The picture is very , very mysterious , which I like about it , but for me I would like to understand more concept , context of the picture ."



Source: Nettekoven et al., Schizophrenia Bulletin (2010)

Brain networks: brief group discussion

Let's say you are interested in studying a brain, parcellated into a set of regions of interest.

How would we turn it into a brain network? What could be the edges?

What are some justifications for turning it into a 'connectome'?



Brain networks: brief group discussion

Let's say you are interested in studying a brain, parcellated into a set of regions of interest.

How would we turn it into a brain network? What could be the edges?

What are some justifications for turning it into a 'connectome'?

- Communication between regions across white matter tracts.
- Harmonized activity patterns between distant regions suggest network-structure of activity.
- Developmental coordination across different areas of the brain.
- Strong genetic and phenotypic covariance between different brain regions.
- More???

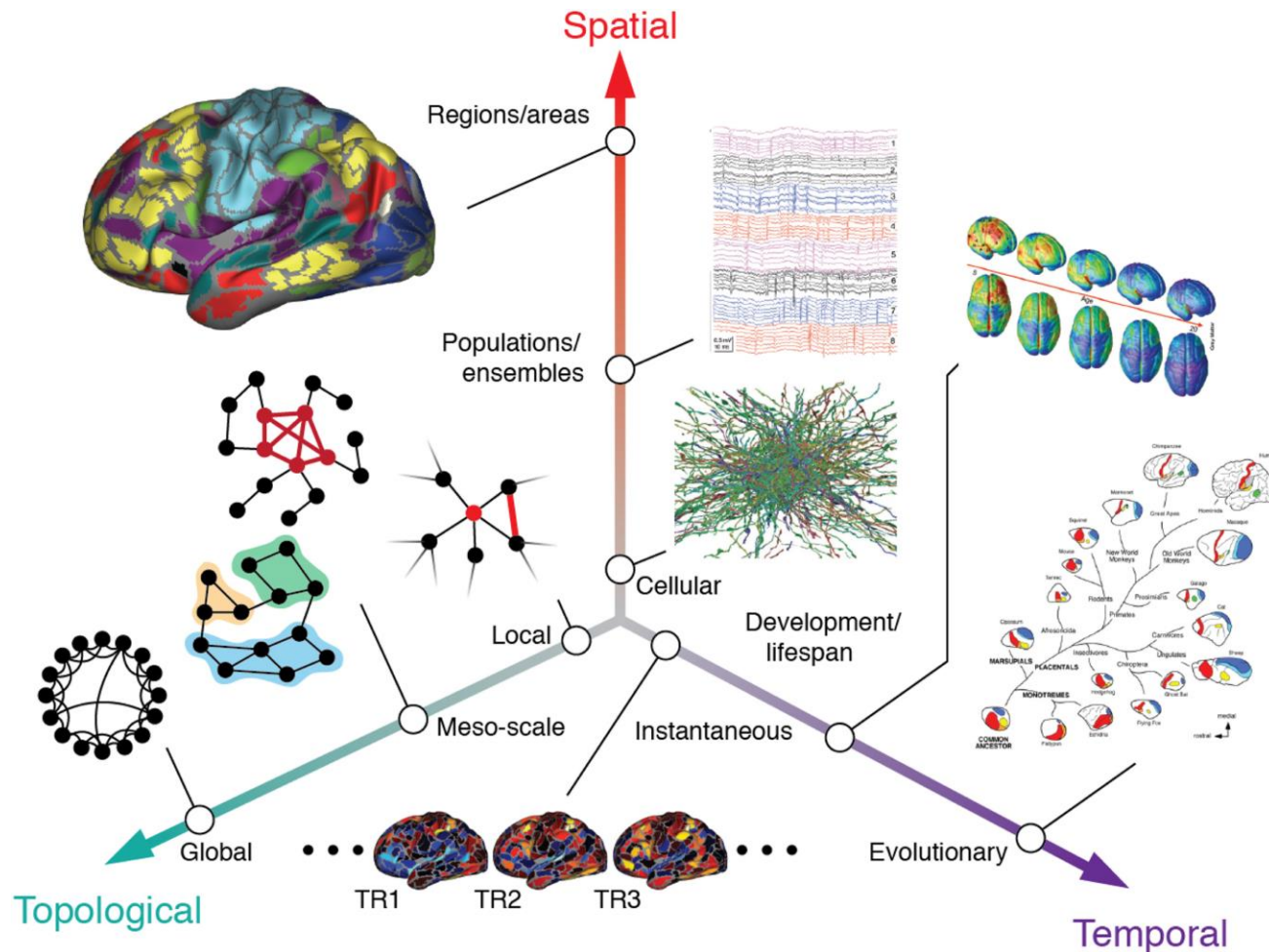


The brain as a multiscale network

Brain networks can be studied at various:

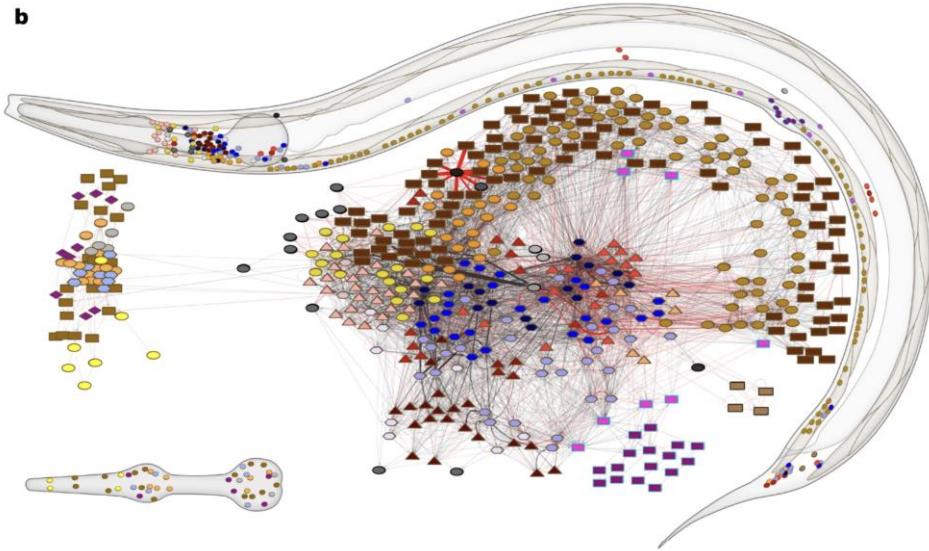
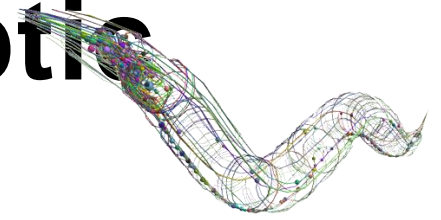
- Temporal scales
- Spatial scales
- Topological scales

(And even within the same scale, multiple types of connections can be considered!)

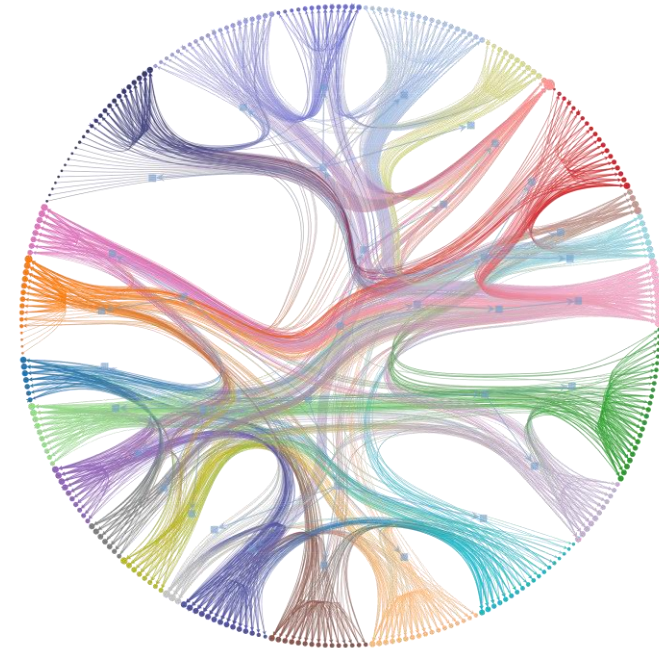


Source: Betzel and Bassett, NeuroImage 2017

The complete *c. Elegans* synaptic connectome



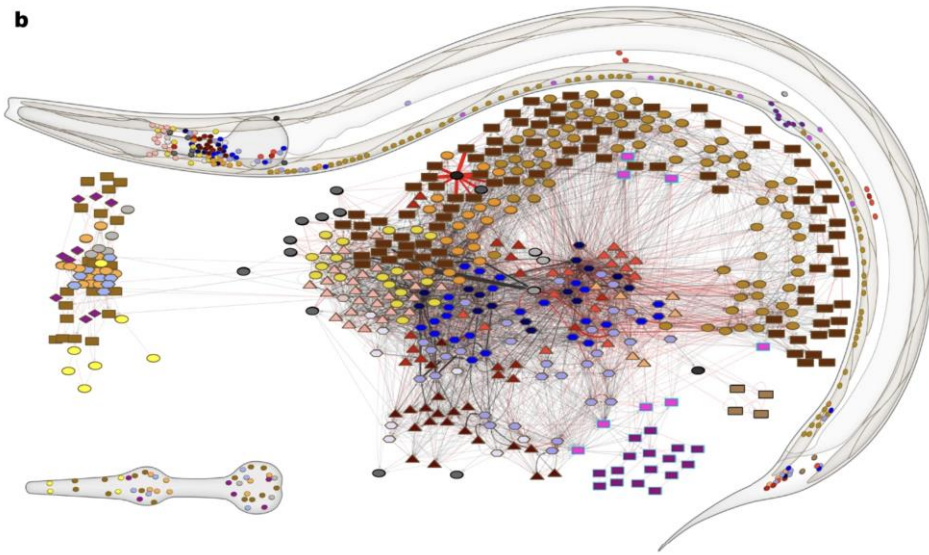
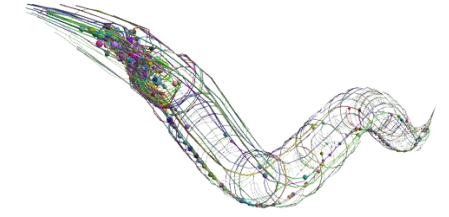
Source: Cook et al., Nature (2019)



Source: Tiago Peixoto, graph-tool document

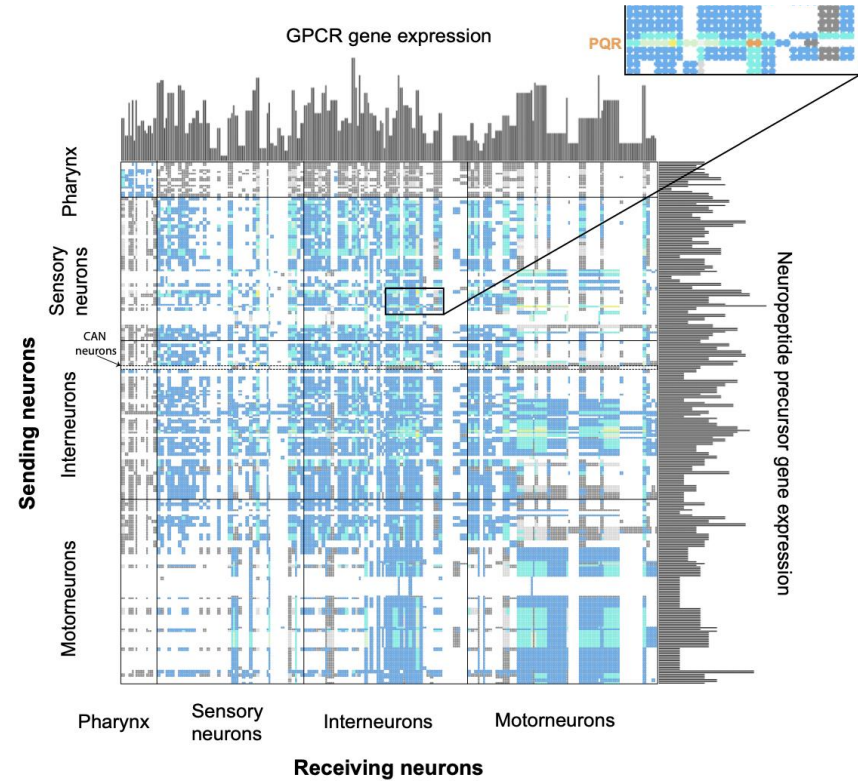
Alternate views on *c. elegans* connectivity

Synaptic connectome



Source: Cook et al., Nature (2023)

Neuropeptidergic connectome

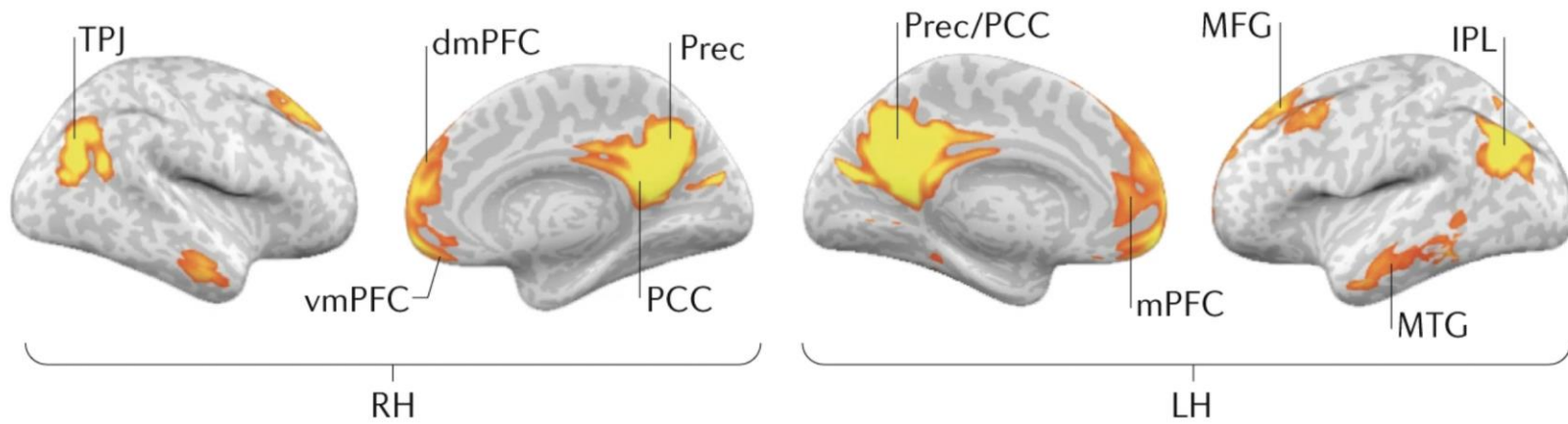


Source: Ripoll-Sanchez et al., biorxiv (2022)

Reverse engineering a famous human brain network

What are the nodes? What are the edges?

c Regions of the DMN



Source: Yeshurun et al., Nature Rev

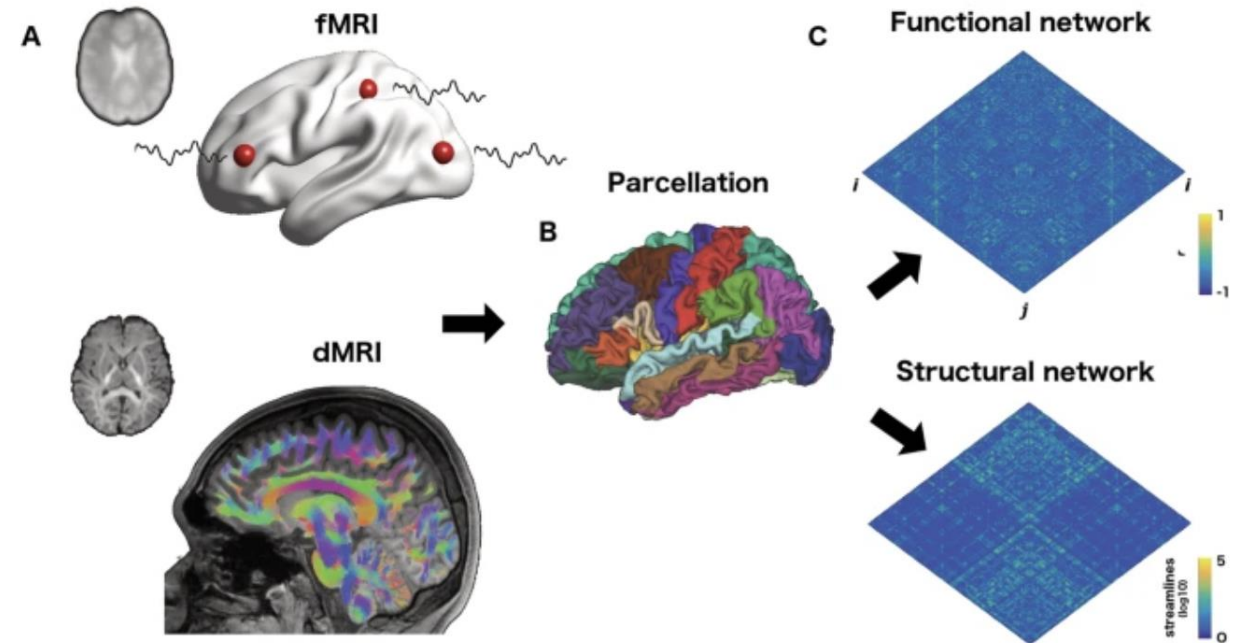
Classic views on human brain networks

Steps:

1. Parcellate brain into regions (ROIs)
2. Define pairwise metric of connectivity
3. Calculate it for all pairs of ROIs

Common types of brain connectivity:

1. fMRI-derived estimates of functional connectivity
2. dMRI-derived estimates of structural connectivity.

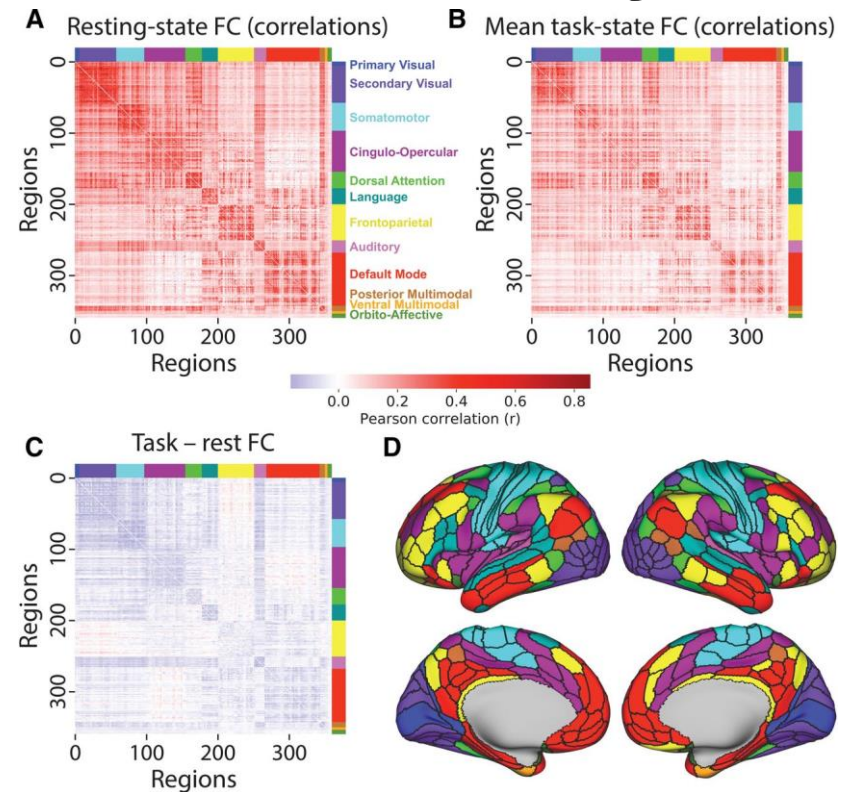


Source: Perry et al, Molecular Psy

Functional brain connectivity

Different paradigms:

- Task-based vs. resting-state



Functional brain connectivity

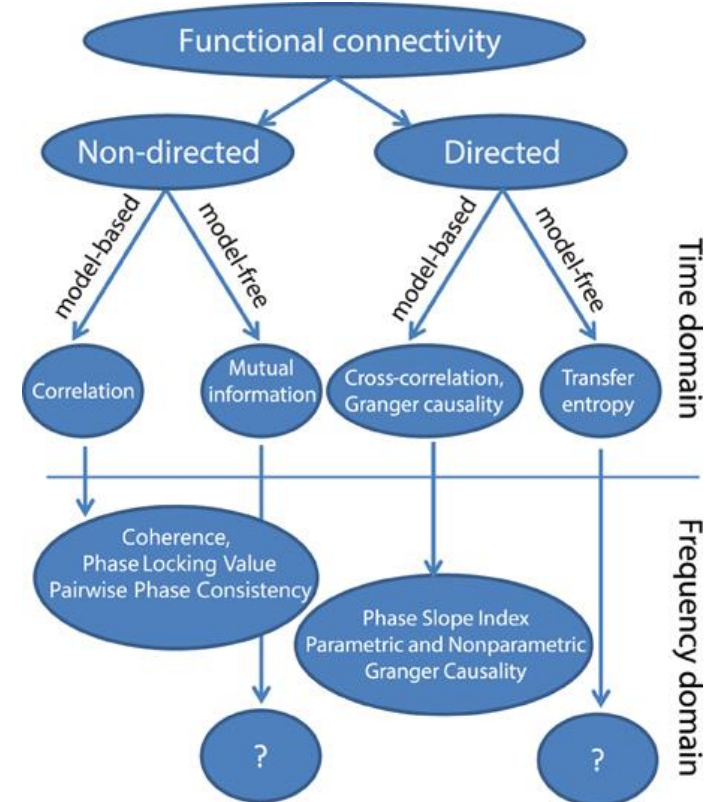
Various metrics of functional connectivity

Different paradigms:

- Task-based vs. resting-state

Different metrics of connectivity:

- Pearson correlation (most common!), partial correlation, Granger causality, etc...



Source: Bastos et al., Front. Sys

Functional brain connectivity

Various metrics of functional connectivity

Different paradigms:

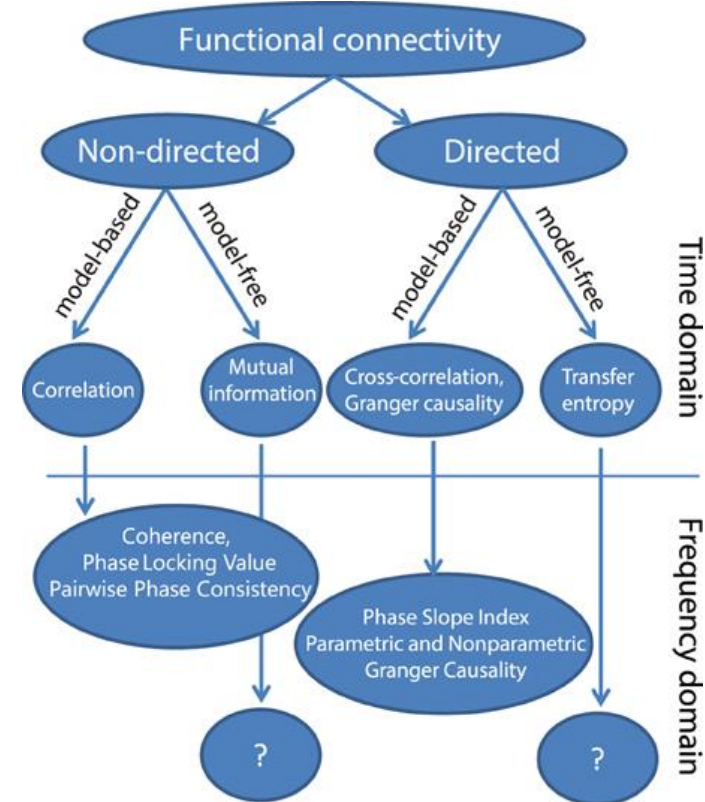
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Different metrics of connectivity:

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Different modalities:

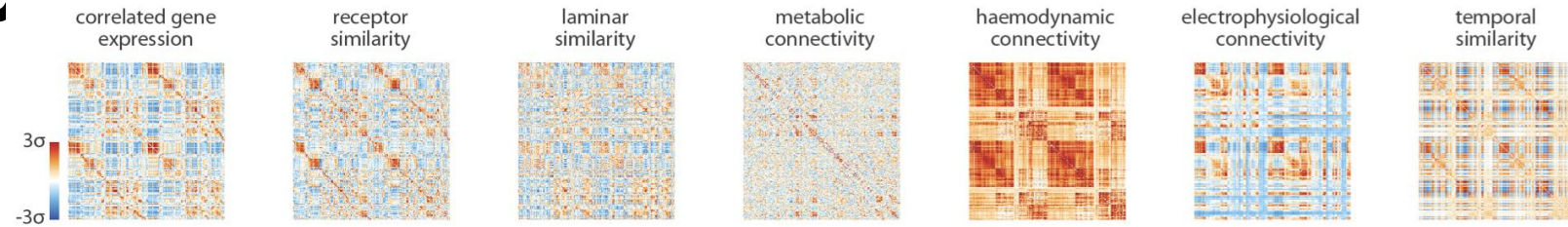
- fMRI, EEG, etc.



Source: Bastos et al., Front. Sys

Alternate conceptions of brain

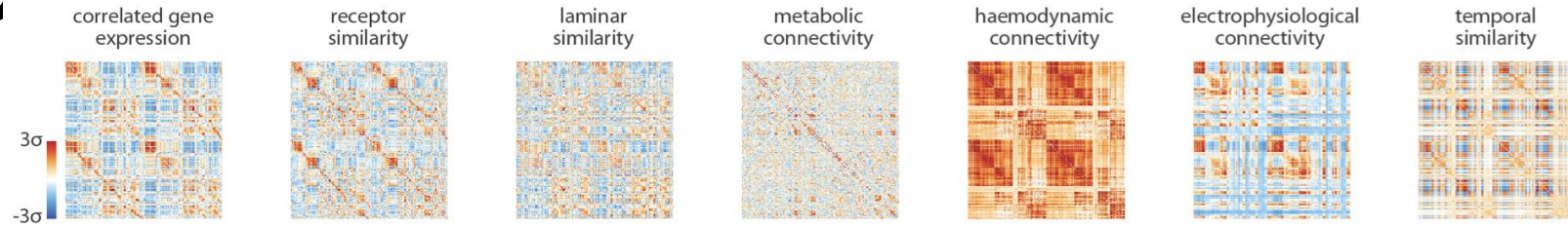
CC^a



Hansen et al., PloS Biology (2023).

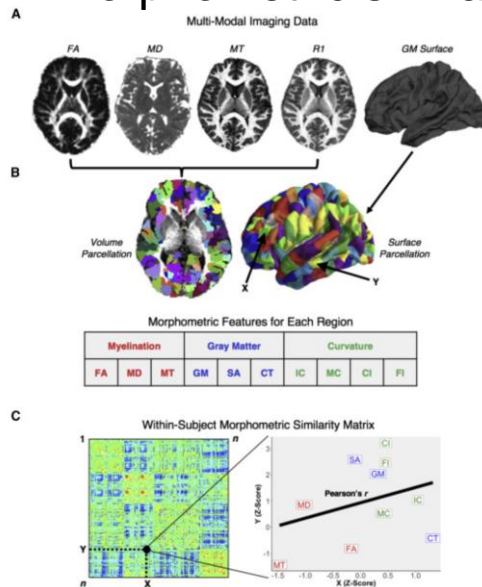
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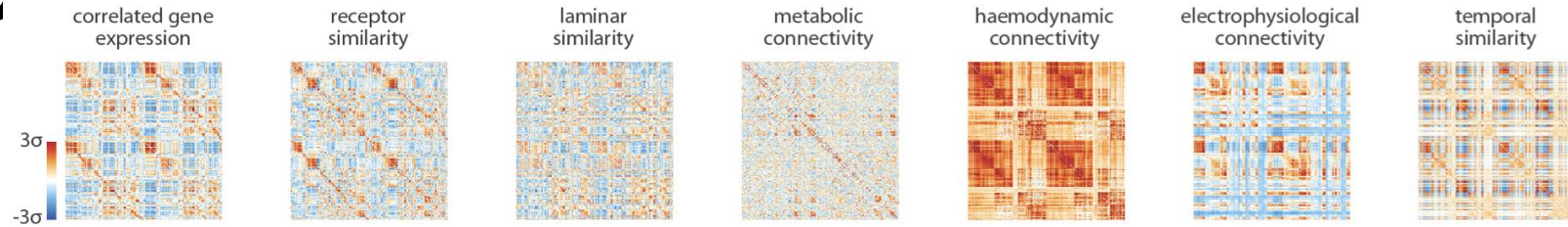
Morphometric similarity networks



Seidlitz et al., Neuron (2018)

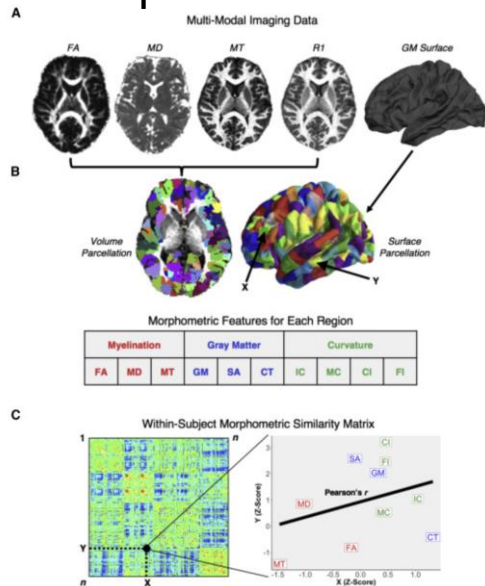
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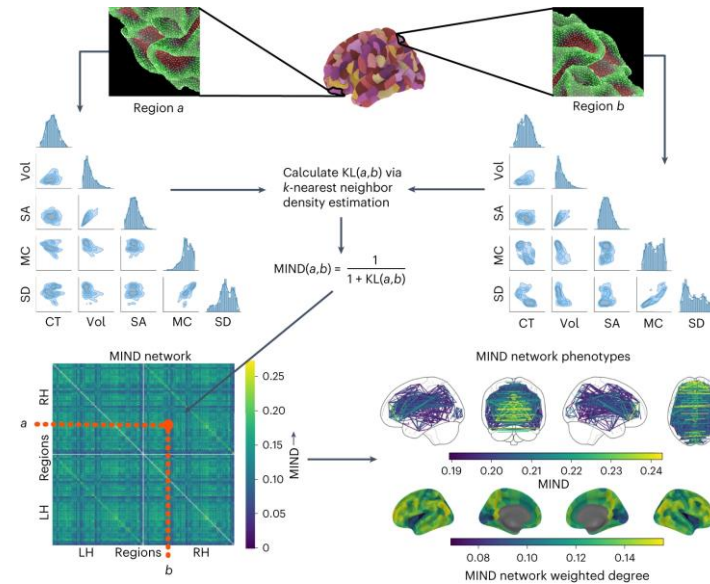
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Morphometric similarity networks



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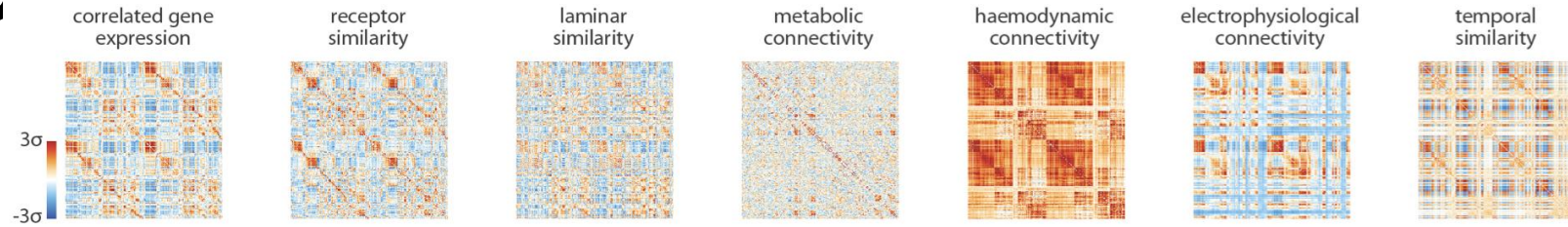
MIND networks



Sebenius et al., Nat. Neuro. (2023)

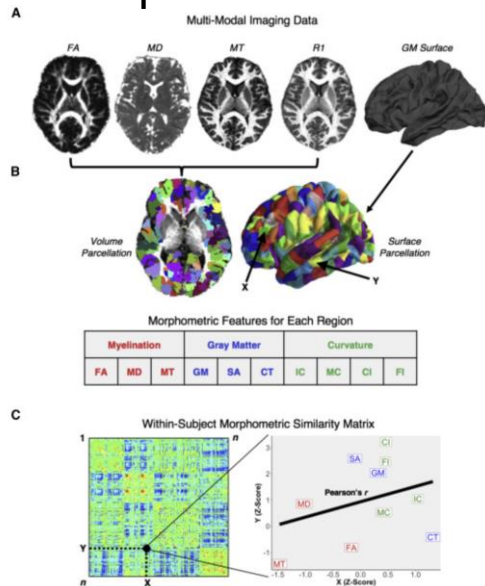
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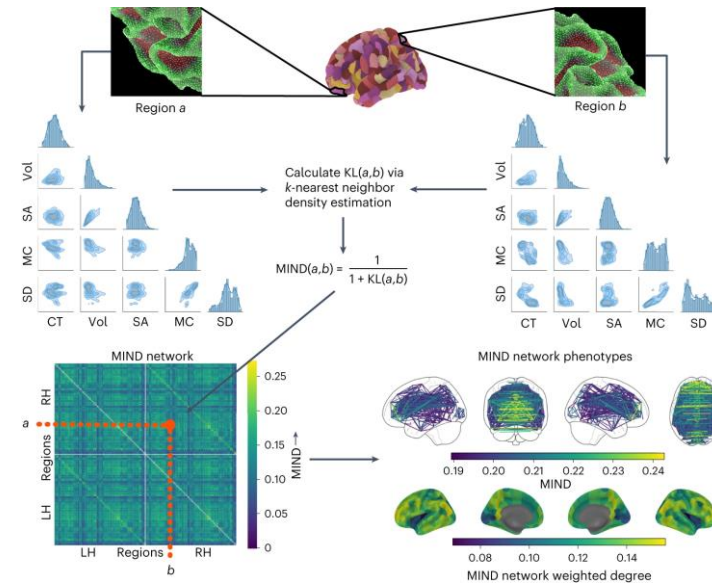
Hansen et al., PloS Biology (2023).
MPC networks

Morphometric similarity networks



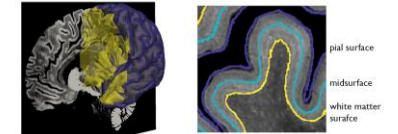
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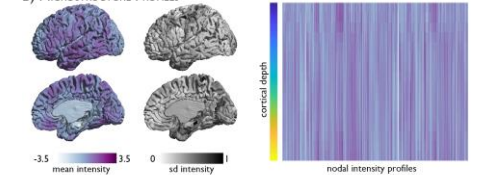


Sebenius et al., Nat. Neuro. (2023)

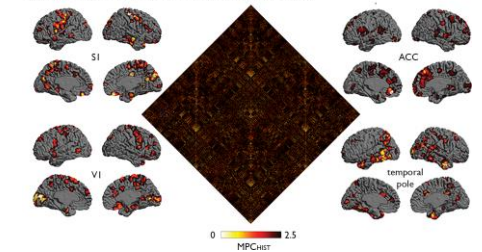
A) CONSTRUCTION OF INTRACORTICAL SURFACES



B) MICROSTRUCTURE PROFILES



C) MICROSTRUCTURE PROFILE COVARIANCE (MPC_{HIST})

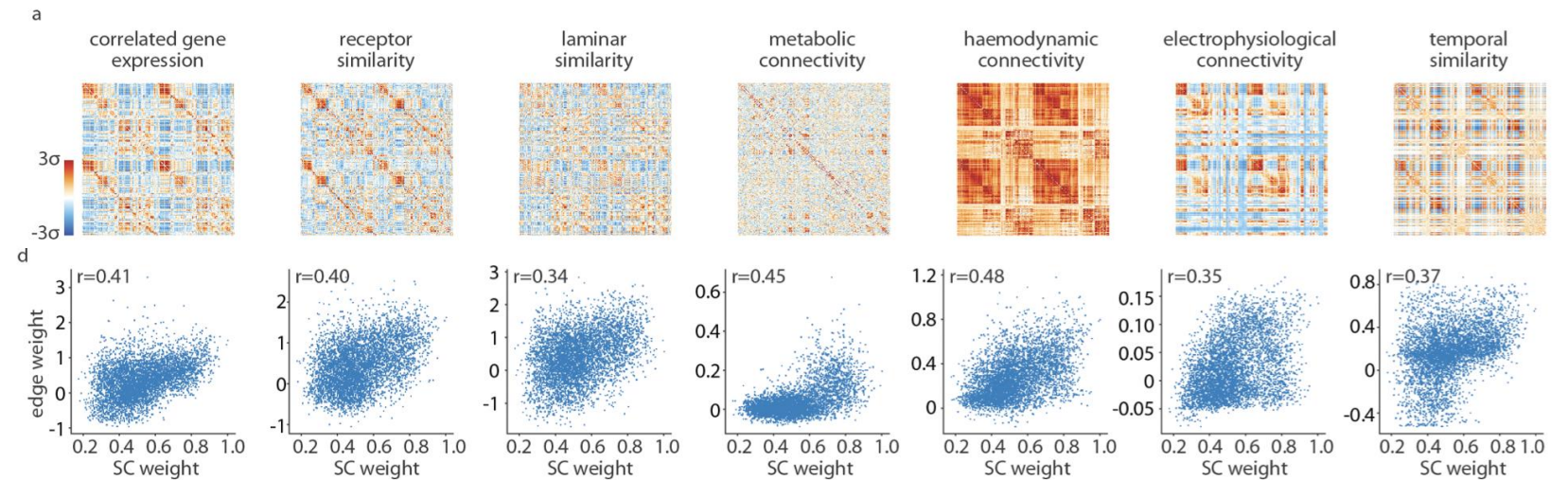


Paquola et al., PLoS ONE

Network neuroscience can bridge multiscale connectivity

Axonally-connected brain regions tend to be more similar across a wide range of definitions of biological similarity.

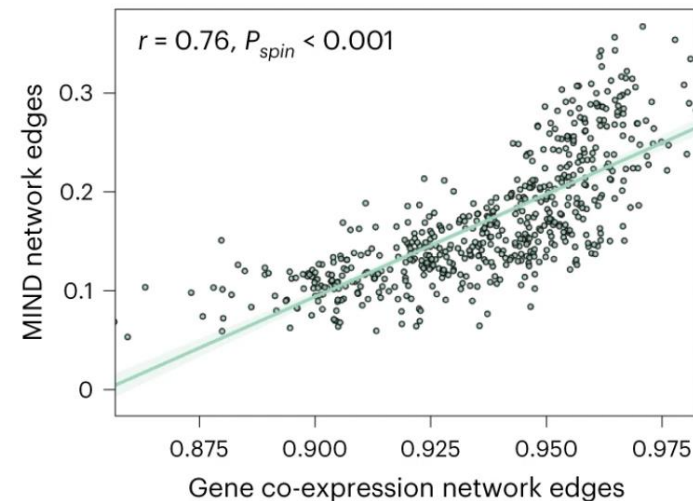
Brain regions with



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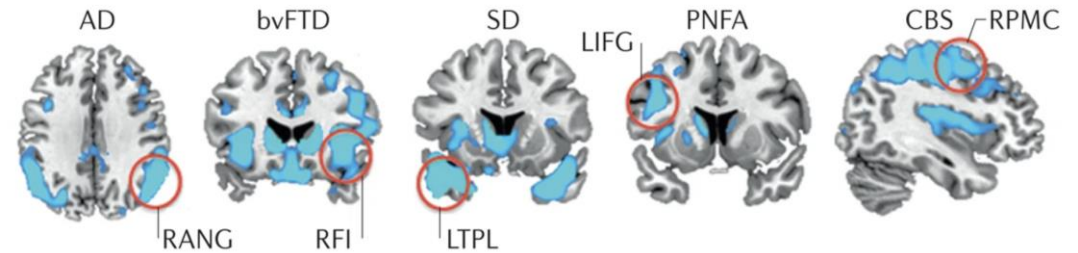
Brain regions with similar gene expression have similar structure, tend to be more connected by white matter, and are more likely to be functionally connected



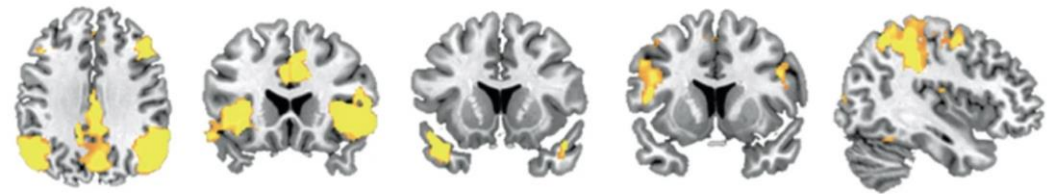
Selected Insights from brain network connectivity

Brain networks constrain patterns of degeneration in psychiatric and neurodegenerative diseases.

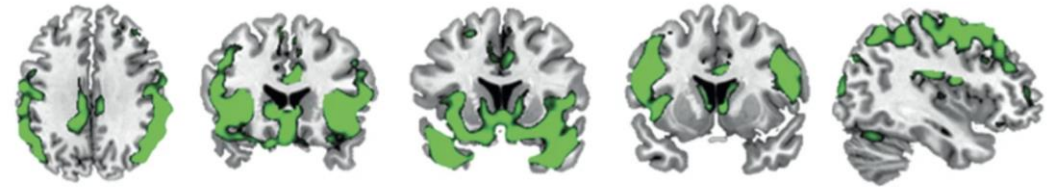
a Syndrome-specific grey-matter atrophy



b Spontaneous functional connectivity in controls



c Structural covariance in controls





Selected Insights from brain network connectivity

Brain networks constrain patterns of degeneration in psychiatric and neurodegenerative diseases.

Article | [Open Access](#) | [Published: 14 August 2023](#)

Regional, circuit and network heterogeneity of brain abnormalities in psychiatric disorders

[Ashlea Segal](#) , [Linden Parkes](#), [Kevin Aquino](#), [Seyed Mostafa Kia](#), [Thomas Wolfers](#), [Barbara Franke](#), [Martine Hoogman](#), [Christian F. Beckmann](#), [Lars T. Westlye](#), [Ole A. Andreassen](#), [Andrew Zalesky](#), [Ben J. Harrison](#), [Christopher G. Davey](#), [Carles Soriano-Mas](#), [Narcís Cardoner](#), [Jeggan Tiego](#), [Murat Yücel](#), [Leah Braganza](#), [Chao Suo](#), [Michael Berk](#), [Sue Cotton](#), [Mark A. Bellgrove](#), [Andre F. Marquand](#) & [Alex Fornito](#) 

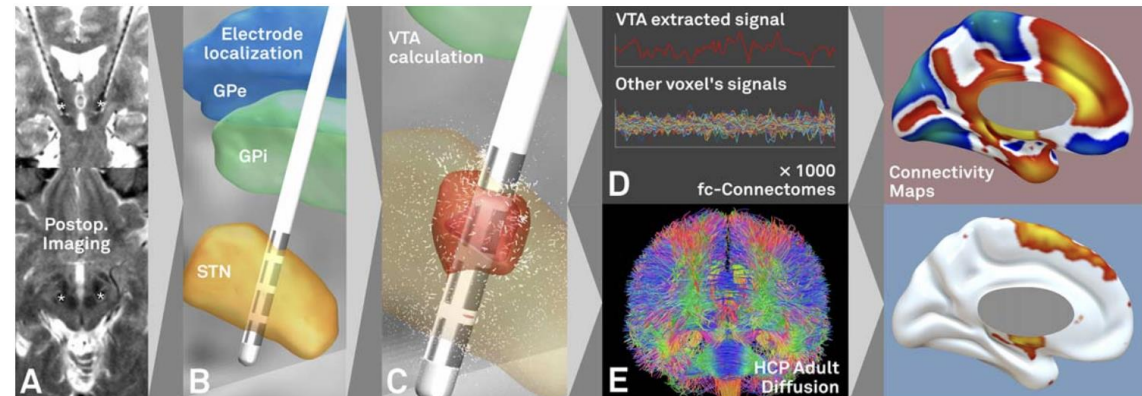
[Nature Neuroscience](#) **26**, 1613–1629 (2023) | [Cite this article](#)

20k Accesses | **1** Citations | **391** Altmetric | [Metrics](#)

From this summer – this st

Selected Insights from brain network connectivity

Brain networks can help guide the placement of electrodes for deep brain stimulation.

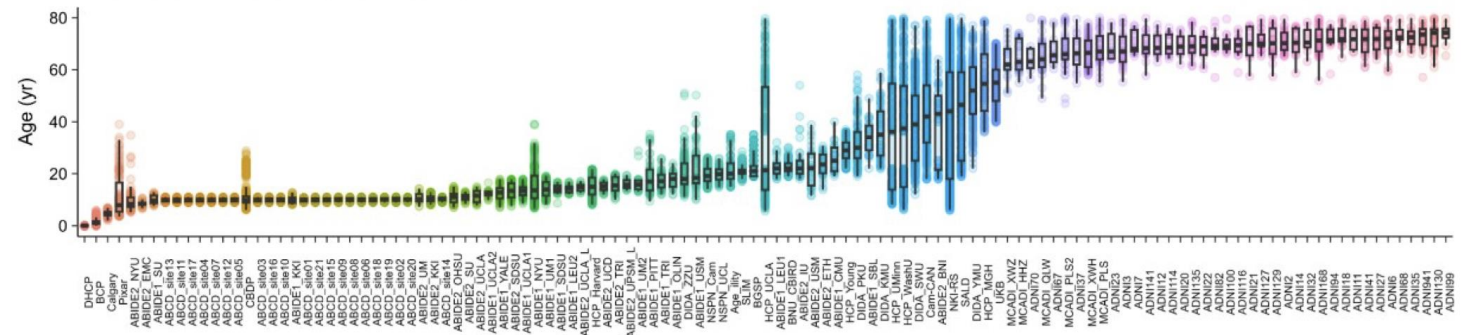


Source: Horn et al.,

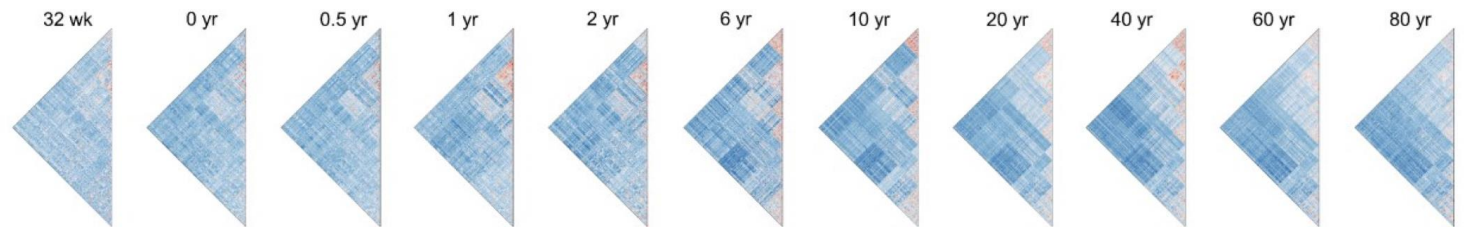
Selected Insights from brain network connectivity

Brain network analysis can shed light on development of the human brain and its relationship to cognition and psychiatric disorders

a Aggregated data across 119 sites (after quality control)



b FC of subjects at different developmental ages





Break!



**Digging into network
measures**

properties of brain networks

Special properties of
networks:



which must therefore often
be applied).

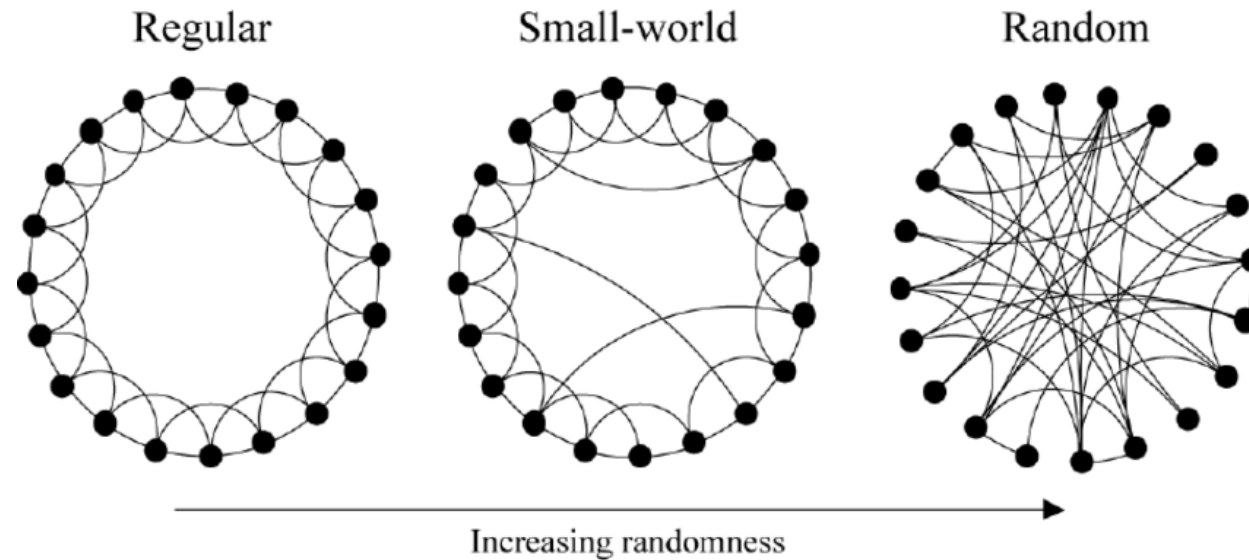
properties of brain networks

Special properties of nodes:

- **Spatially-embedded**
- **Nodes are not interchangeable**
- **Tend to be fully-connected (thresholding often must therefore often be applied).**



The cost-efficiency tradeoff of 'small-world' brain networks



Based on: Watts & Strogatz, Nature (1998).