臺北醫學大學 轉譯影像研究中心 TMU TRANSLATIONAL IMAGING RESEARCH CENTER

Small World of Human Brain
人腦中的小世界：網路分析

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國立陽明大學 物理治療暨輔助科技學系 兼任助理教授

Forest = A Collection of Trees ?

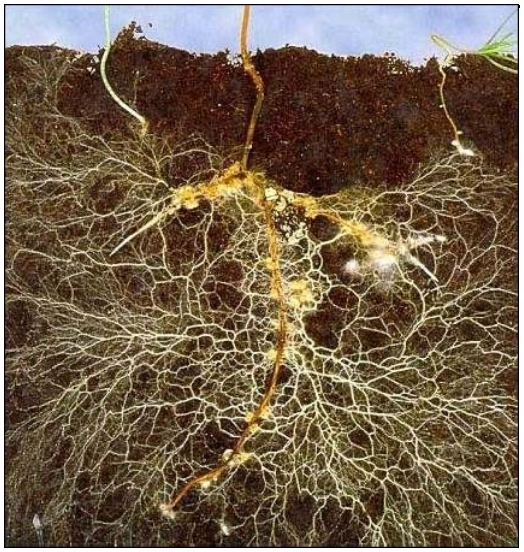
How trees talk to each other ?

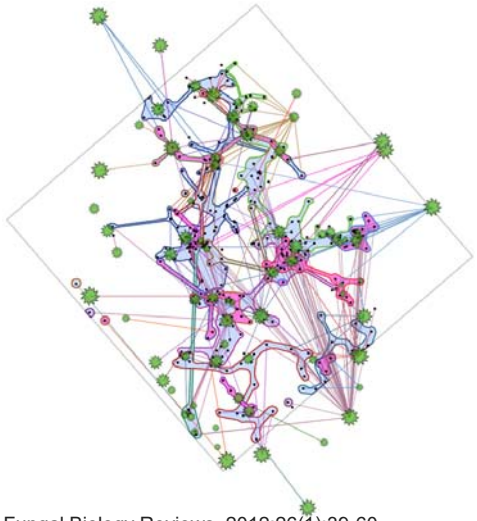
http://www.ted.com/talks/suzanne_simard_how_trees_talk_to_each_other

Underground Mycorrhizal networks

by Shannon Wright

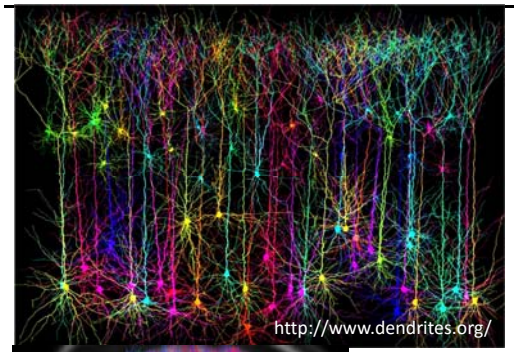
Forest behaves as a single organism

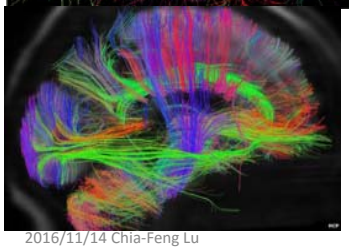


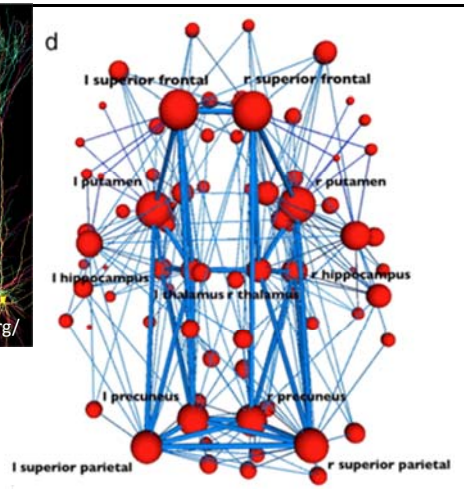


Fungal Biology Reviews. 2012;26(1):39-60.

Brain Connects in a Similar Way

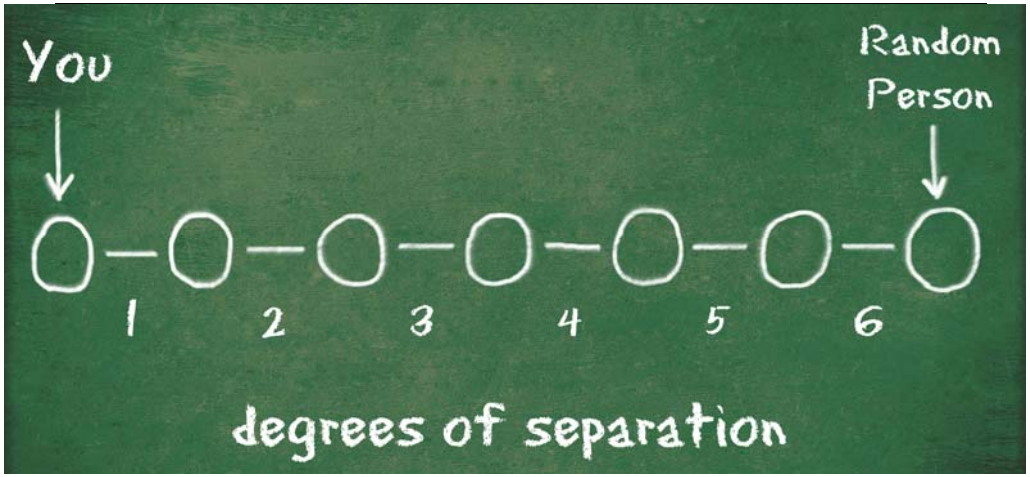






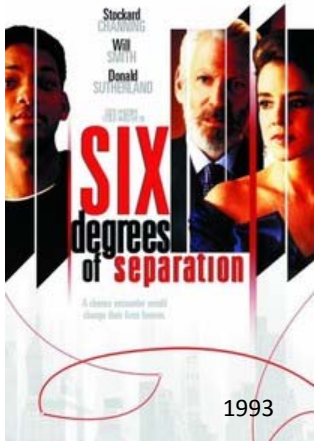
J. Neurosci, 2011;31:15775-86.

Small World?



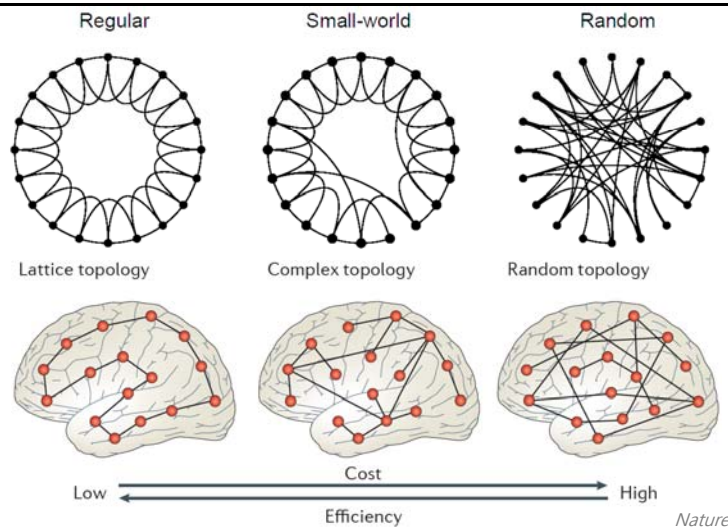
By Stanley Milgram

2008, 5-degree of separation



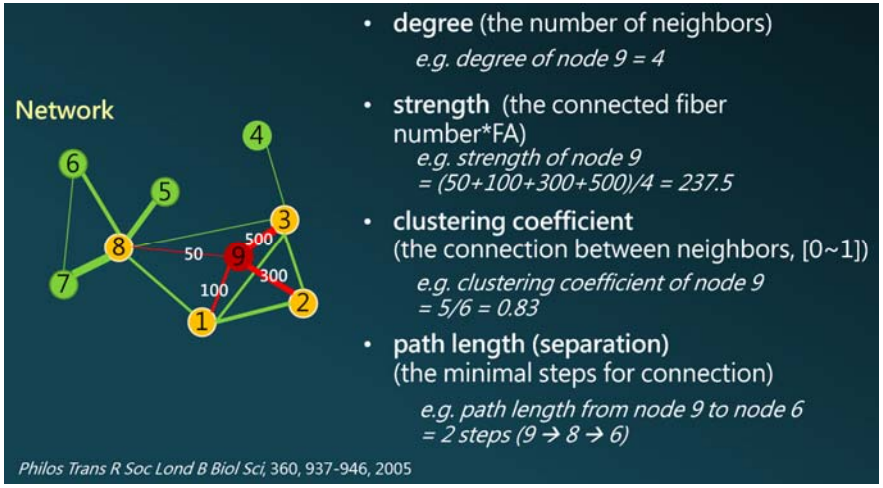
1993

Brain is a Small World



Nature 393:440-442, 1998.
Nature Reviews Neuroscience, 13: 336-349, 2012.

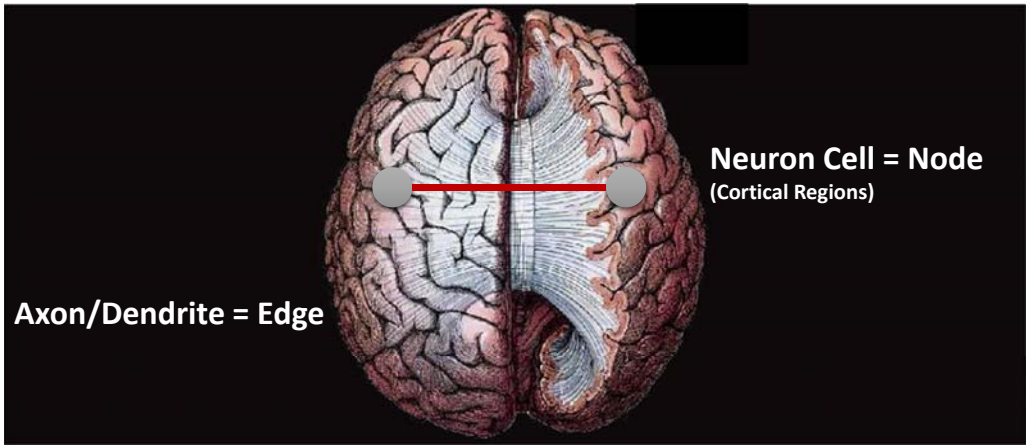
How to Describe a Small World



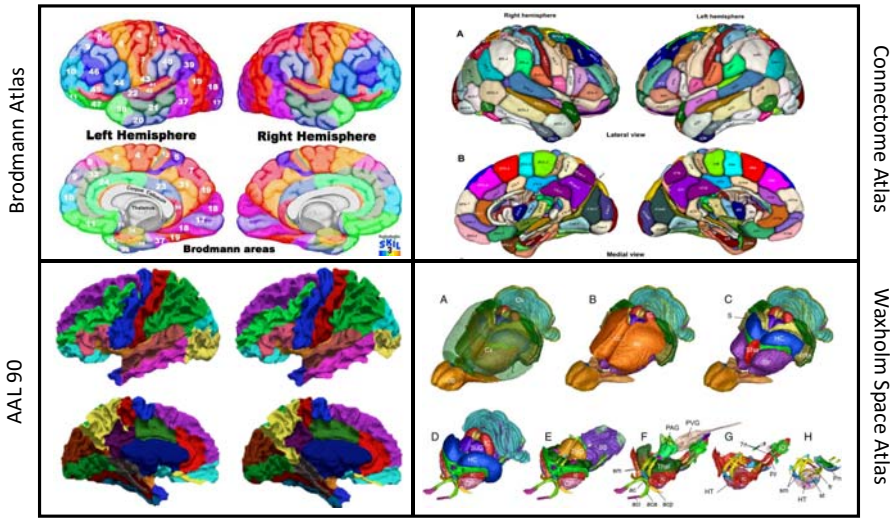
- **degree** (the number of neighbors)
  e.g. degree of node 9 = 4
- **strength** (the connected fiber number*FA)
  e.g. strength of node 9 = (50+100+300+500)/4 = 237.5
- **clustering coefficient** (the connection between neighbors, [0~1])
  e.g. clustering coefficient of node 9 = 5/6 = 0.83
- **path length (separation)** (the minimal steps for connection)
  e.g. path length from node 9 to node 6 = 2 steps (9 → 8 → 6)

Philos Trans R Soc Lond B Biol Sci, 360, 937-946, 2005

Construct Brain Network

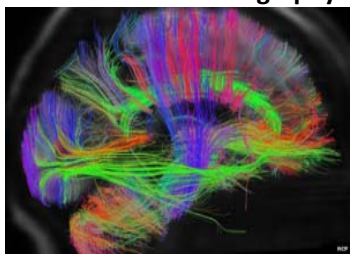


Define Cortical Regions (Nodes)

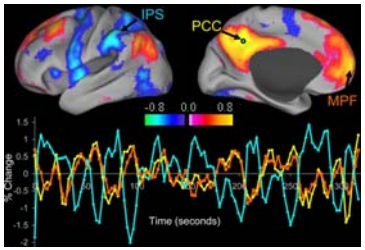


Define Connectivity (Edges)

Axon Bundle Tractography

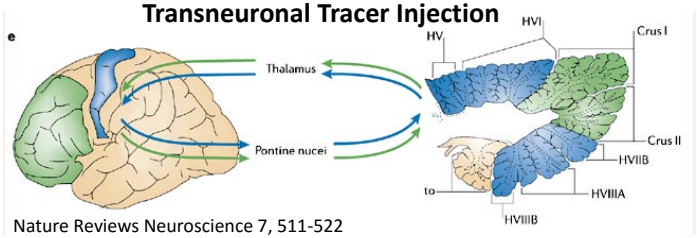


Functional Synchrony



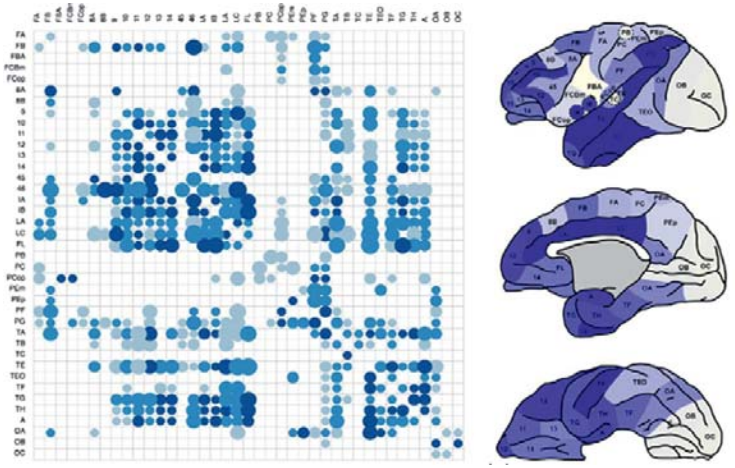
Front. Sys. NeuroSci. 2010;17;4:19.

Transneuronal Tracer Injection



Nature Reviews Neuroscience 7, 511-522

Brain Connectivity Matrix

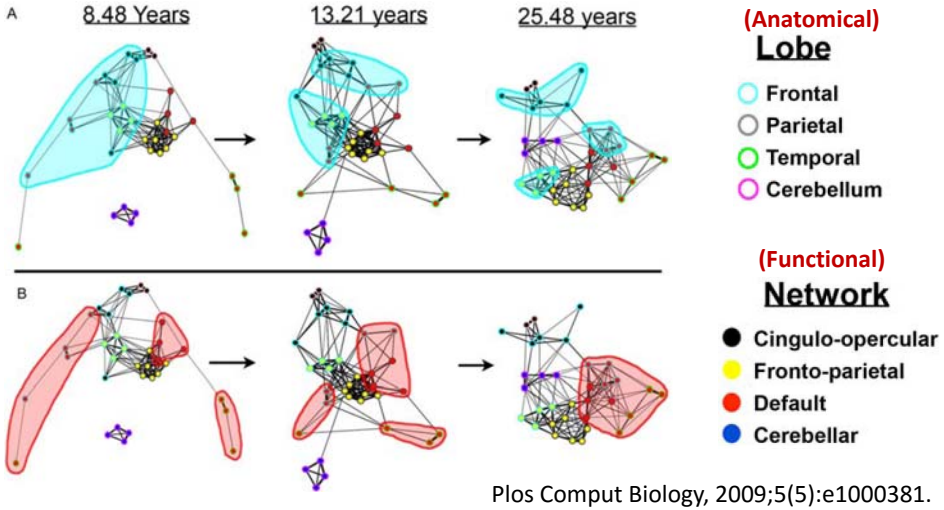


Fundamentals of Brain Network Analysis

Example #1

Brain Networks in Development

(8.48~25.48 years)

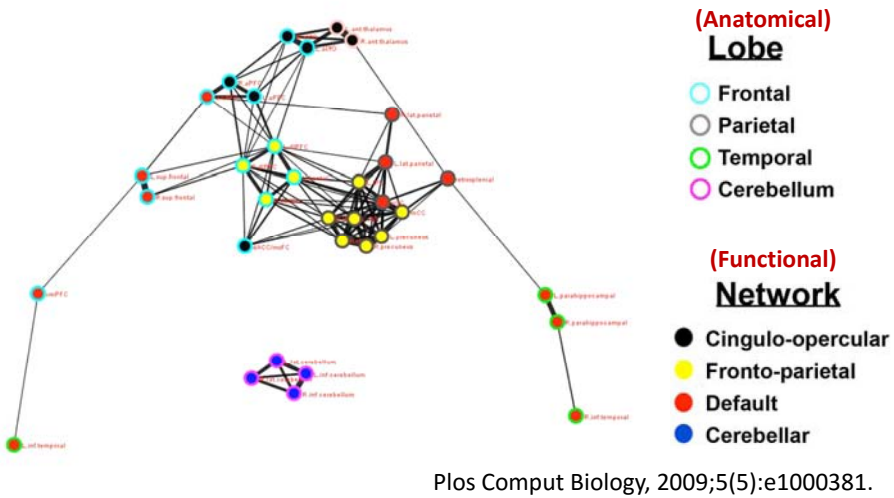


Plos Comput Biology, 2009;5(5):e1000381.

Example #1

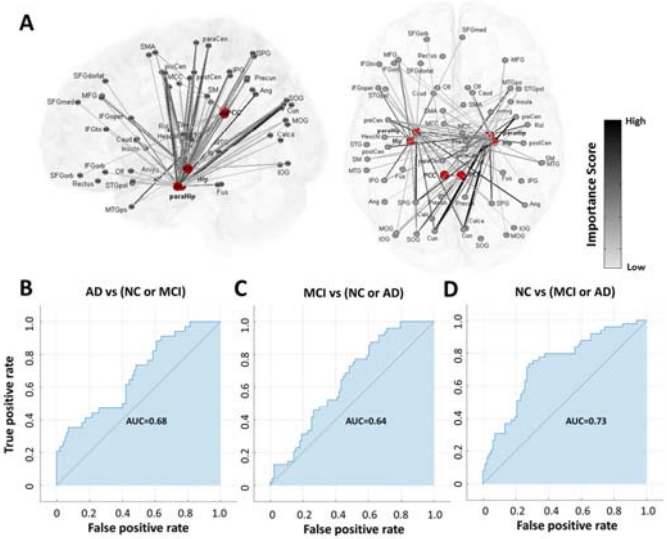
Brain Networks in Development

(8.48~25.48 years)

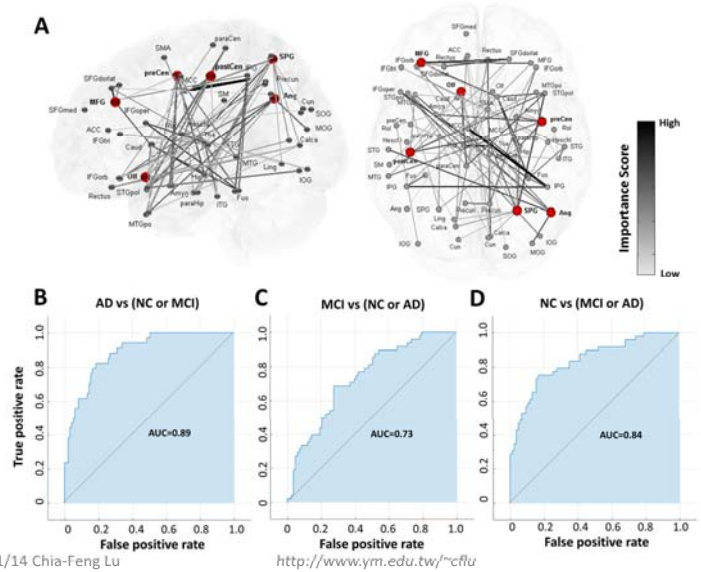


Plos Comput Biology, 2009;5(5):e1000381.

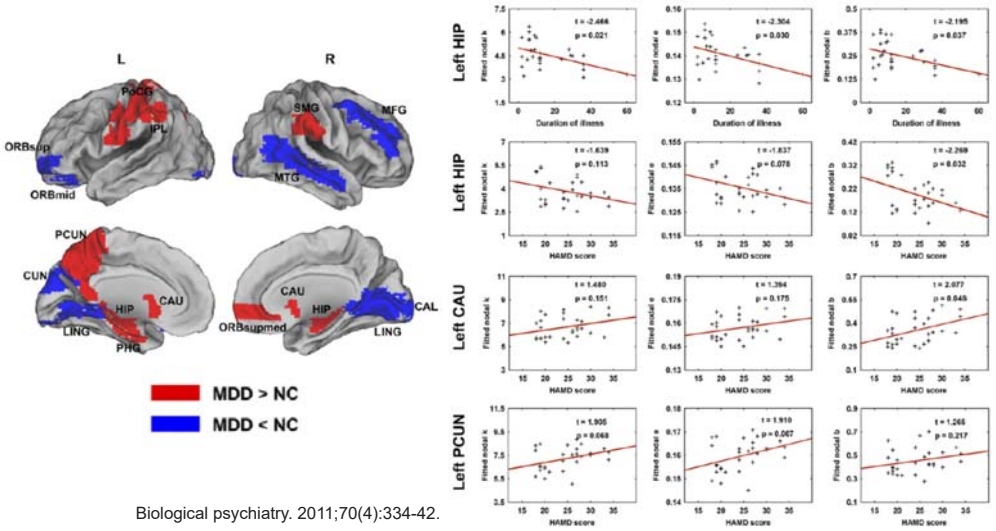
Brain Networks in AD



Brain Networks in AD



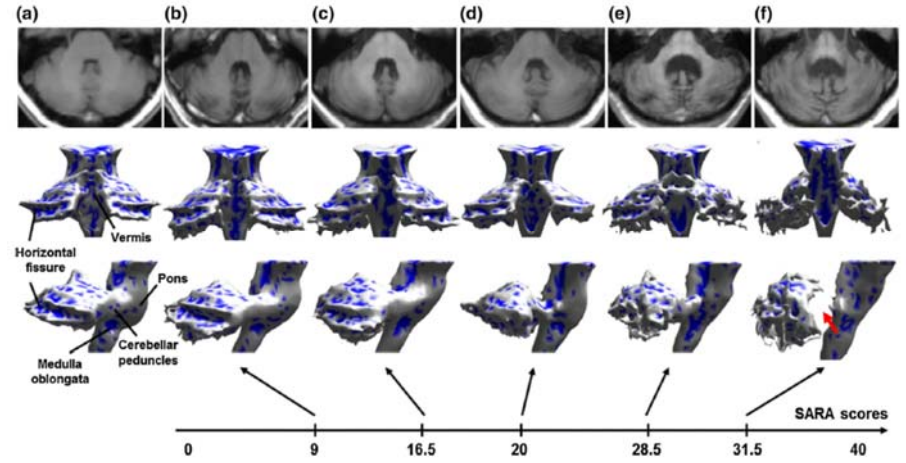
Brain Networks in Depression



Biological psychiatry. 2011;70(4):334-42.

Brain Networks in Cerebellar Atrophy

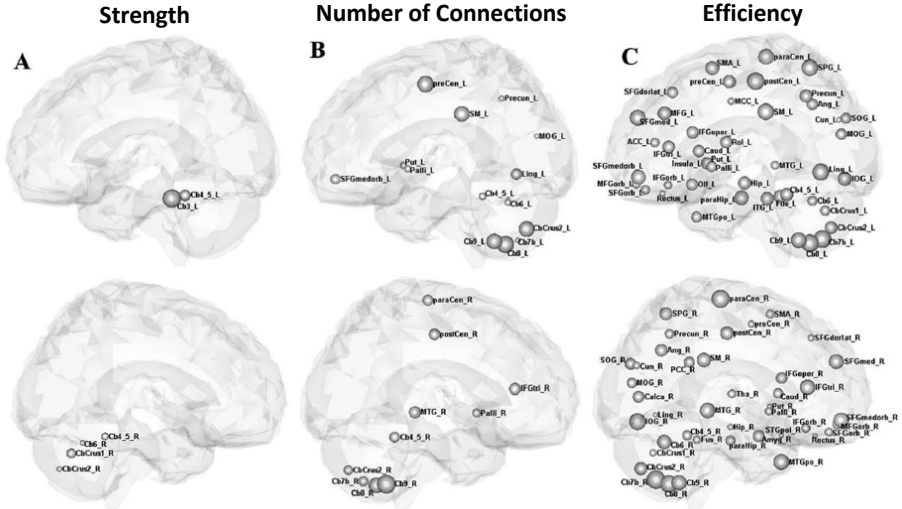
(focal or global?)



Example #4

Brain Networks in Cerebellar Atrophy

(focal or global?)

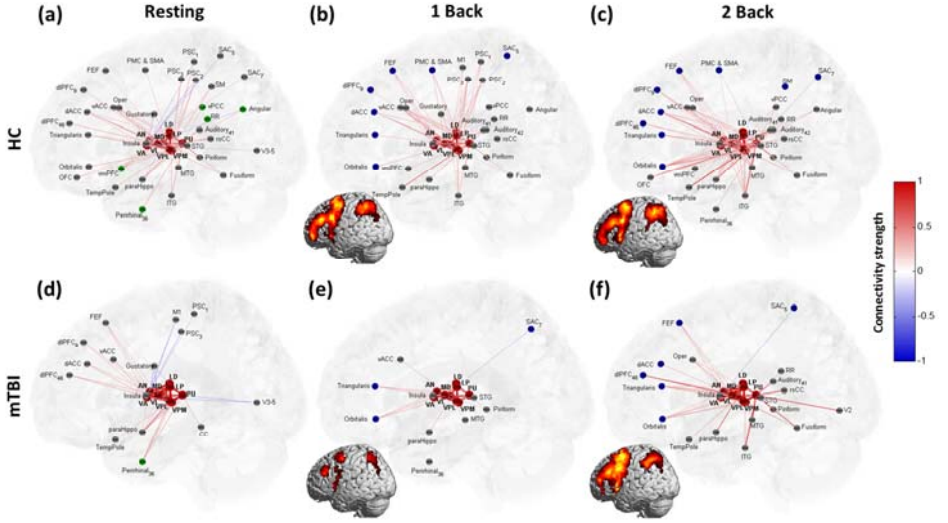


Significant correlations with SARA scores

Example #5

Brain Networks in Brain Trauma

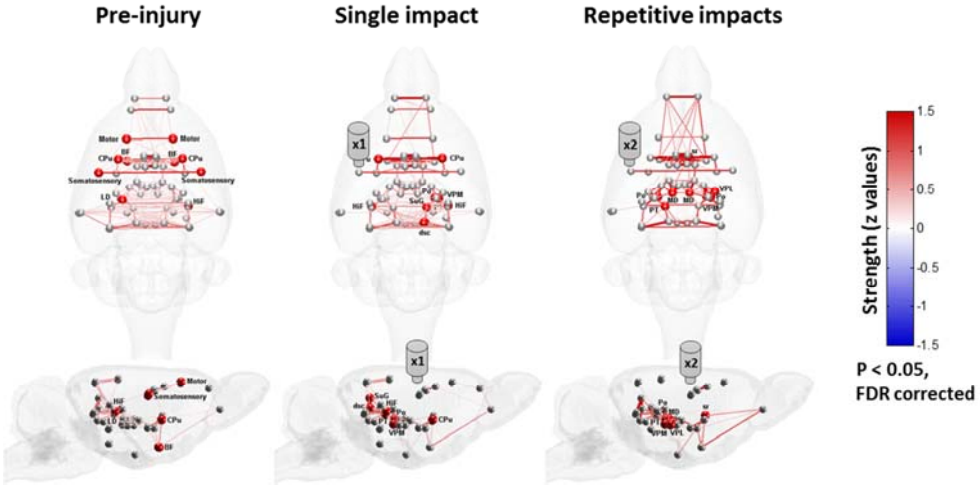
(Thalamocortical circuits)



Example #5

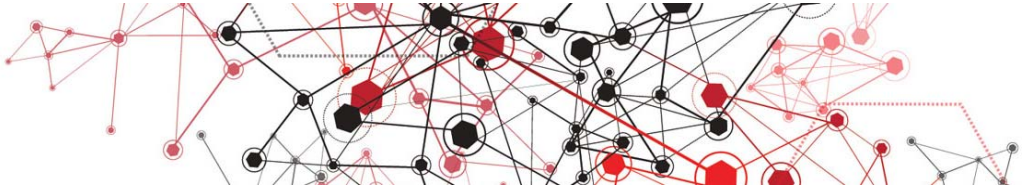
Brain Networks in Brain Trauma

(Thalamocortical circuits)



Summary

- Brain is a complex but organized network.
- Balance between segregation ⇔ integration.
- Development, Aging, Mental State and Disease can alter brain organization.
- Disruption or reorganization can reflect disease progression and severity.



THE END

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