MODELLING THE RELATIONSHIP BETWEEN STRUCTURAL AND FUNCTIONAL CONNECTOMES

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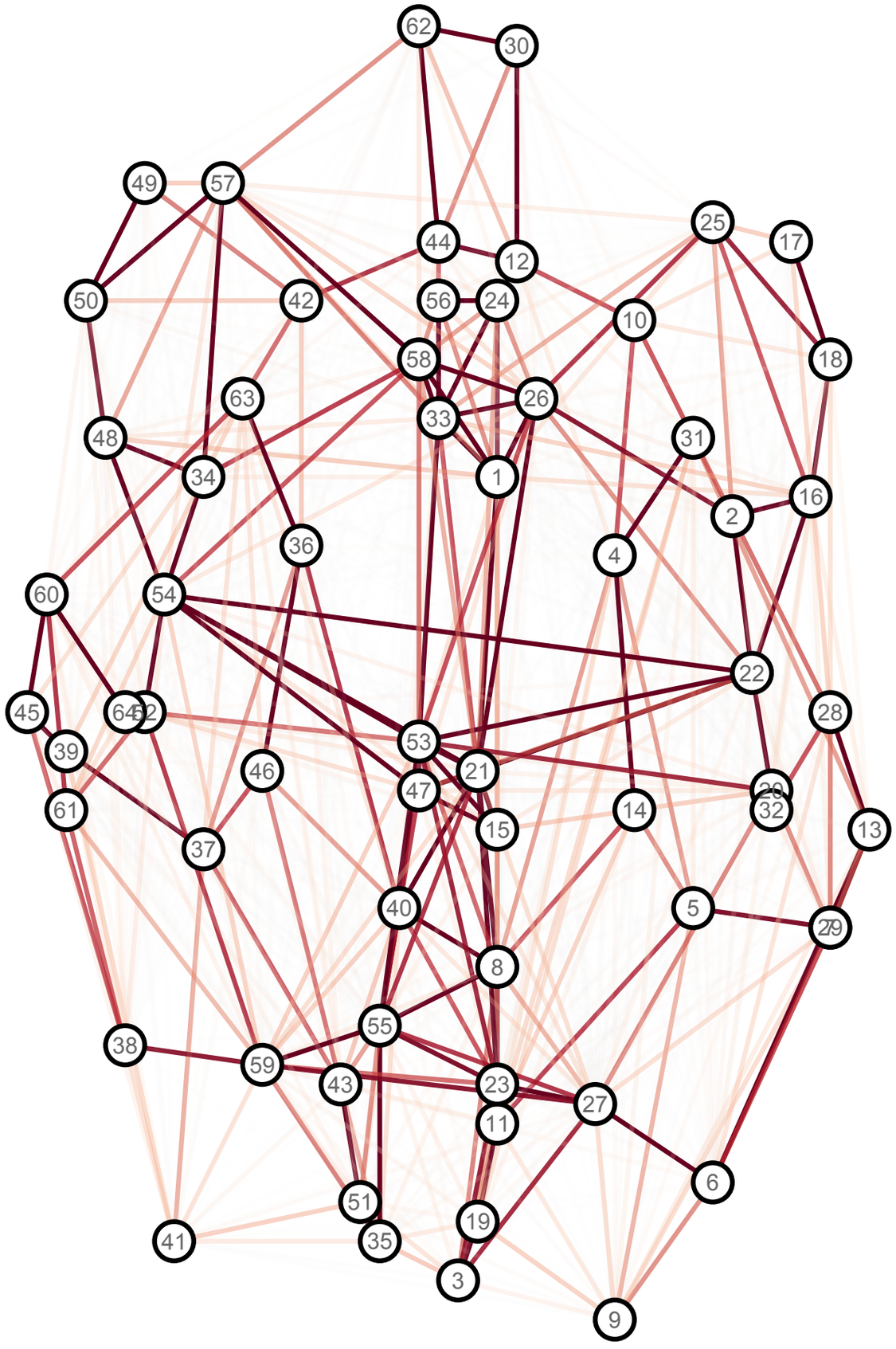
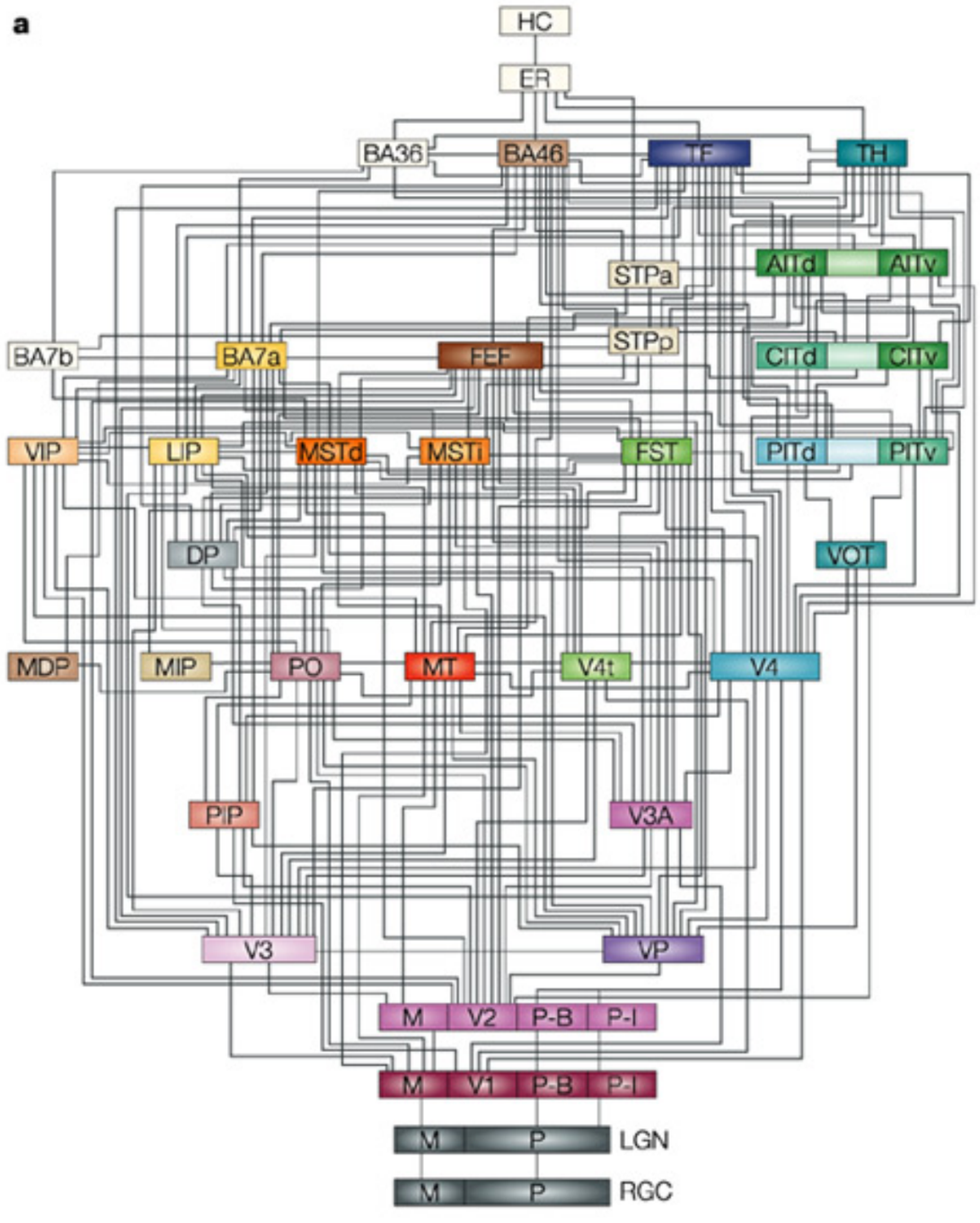
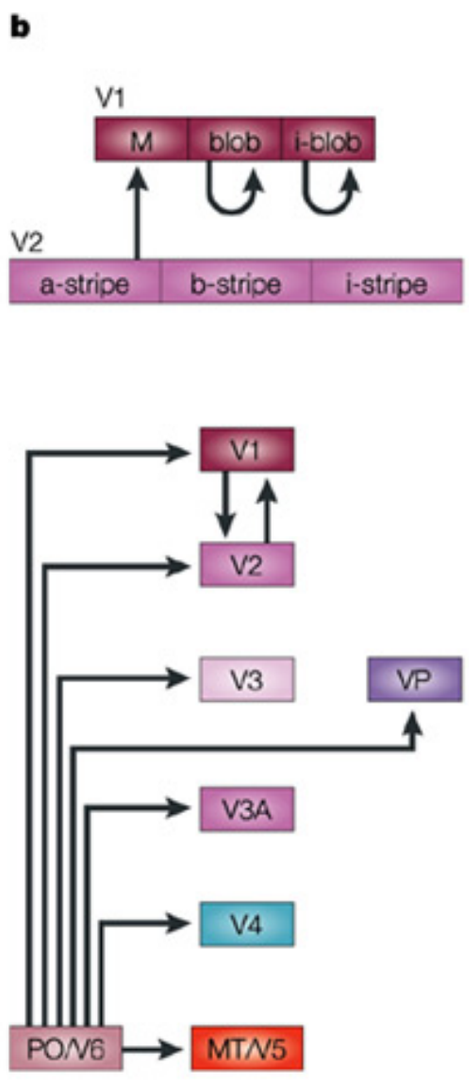


AIMS

- Understand the concepts of structural and functional connectivity
- Understand how they can be estimated using biomedical imaging
- Investigate the effects of image processing decisions on connectivity networks
- Explore how the two forms of connectivity are related, and appreciate why there may be a mismatch
- Explicitly model these relationships
- Vary models and assumptions, and compare outcomes

CONNECTIVITY AND THE BRAIN

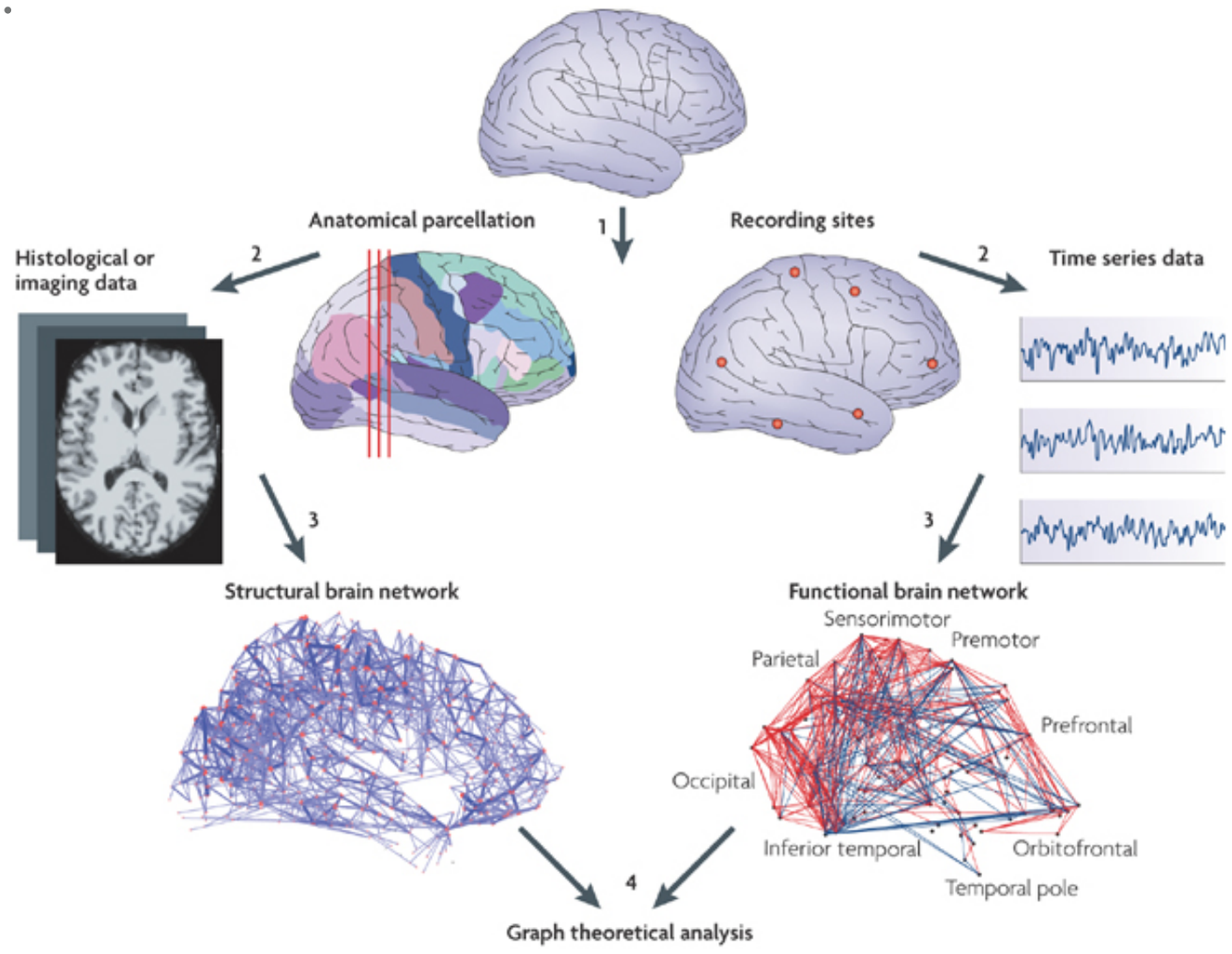




Rees et al., *Nat Rev Neurosci*, 2002 (after Felleman & van Essen, *Cereb Cortex*, 1991)

DEFINITIONS OF CONNECTIVITY

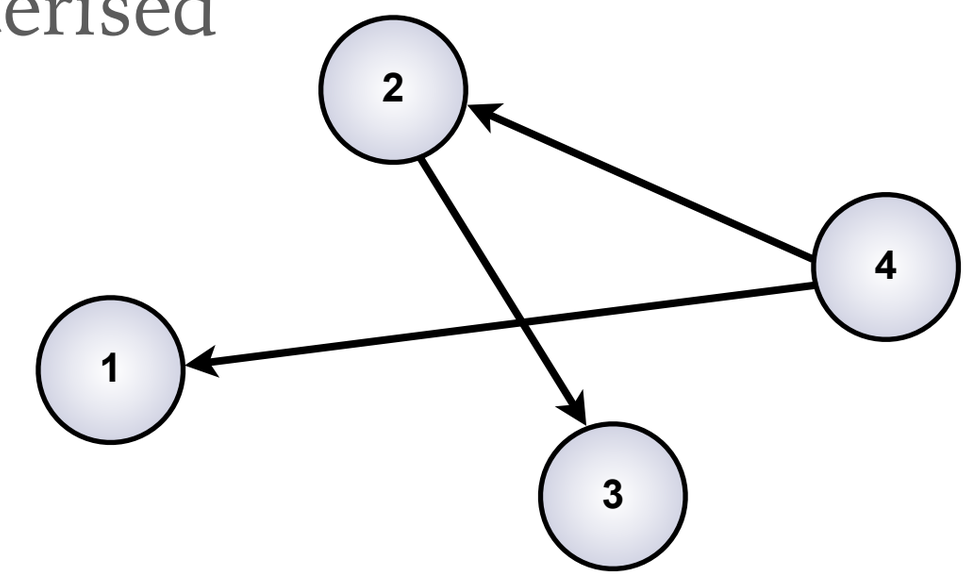
- **Structural connectivity**: the physical axon bundles connecting brain regions together
- **Functional connectivity**: associations between neural activity in spatially remote regions of grey matter
- **Effective connectivity**: patterns of influence by some neural systems over others



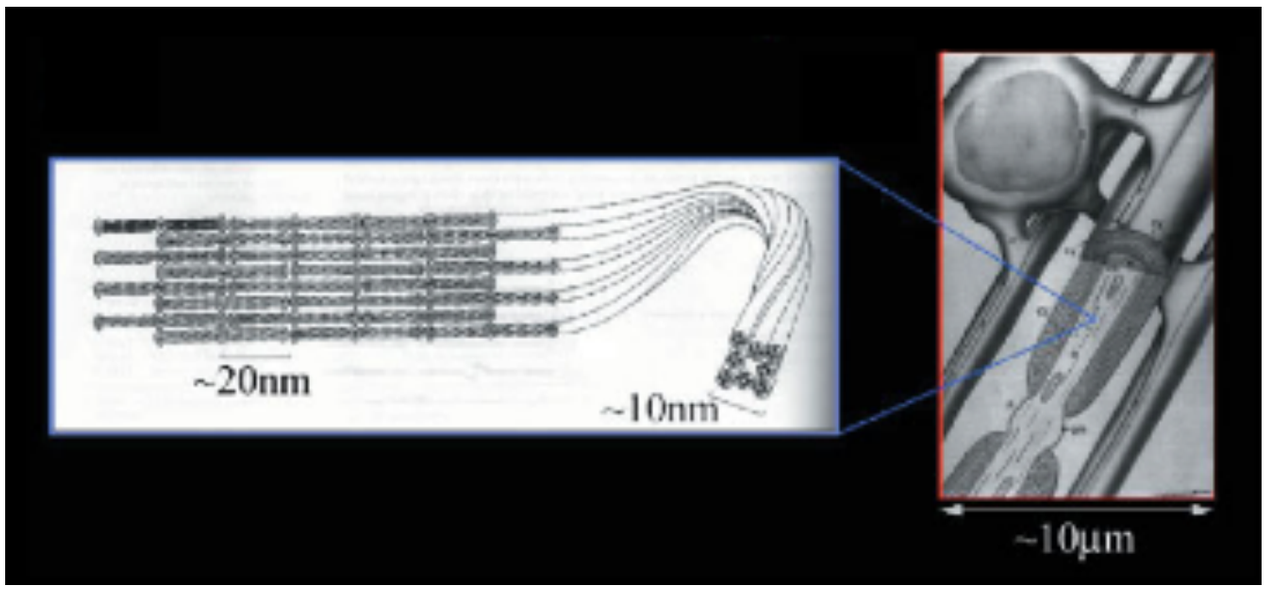
Bullmore & Sporns, *Nat Rev Neurosci*, 2009

GRAPHS

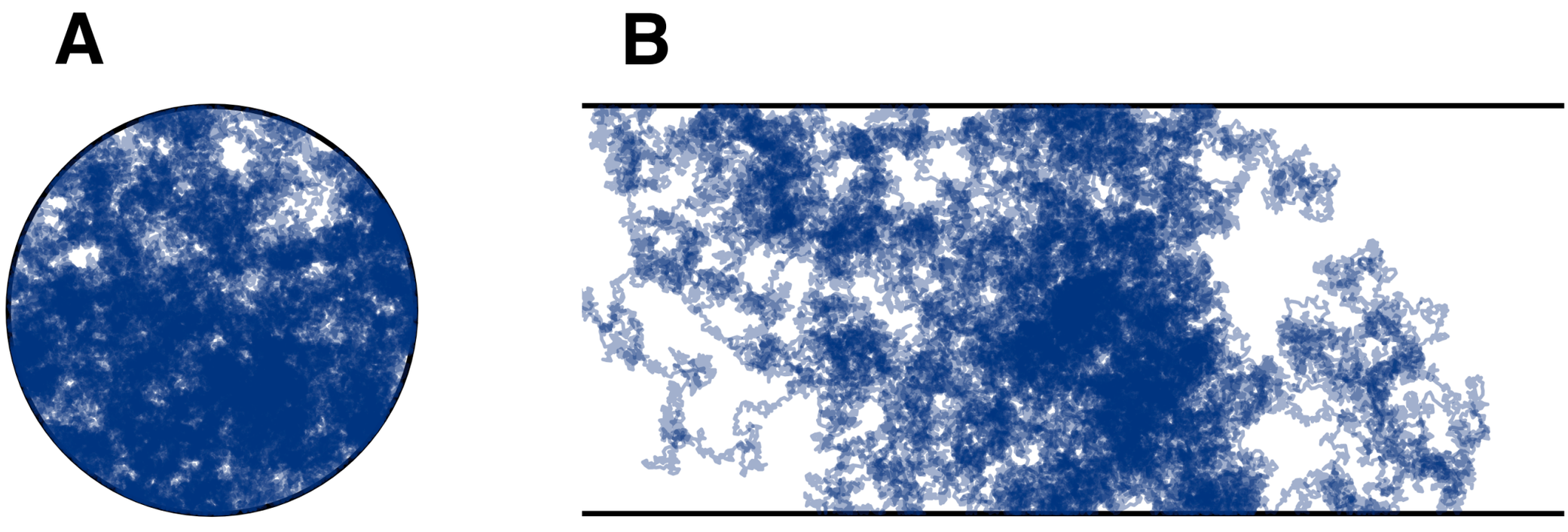
- A highly abstract representation of a set of vertices connected by edges
- Edges may be directed or undirected, and may have associated weights or costs
- A natural representation of connected systems
- Theoretically very well characterised
- Broad range of applications



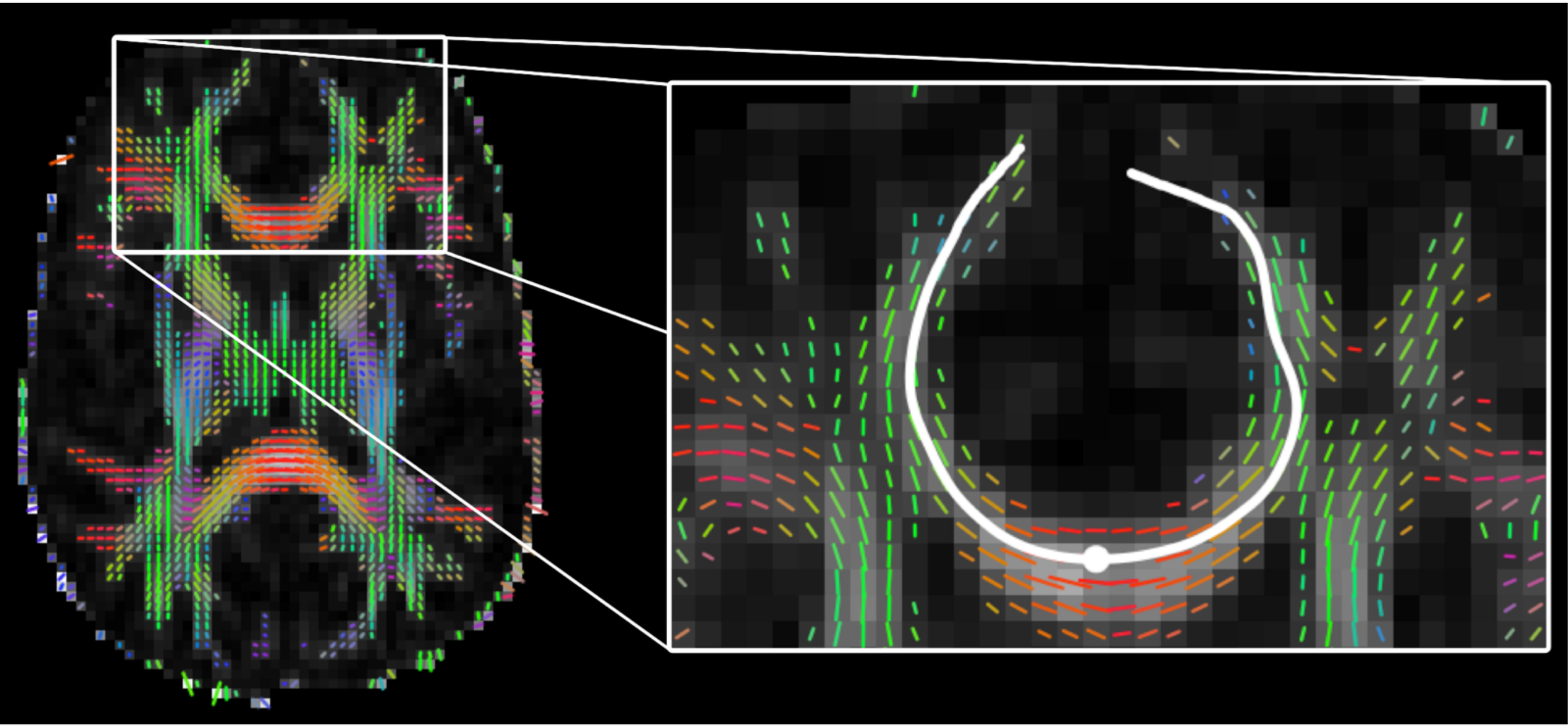
DIFFUSION ANISOTROPY IN TISSUE



Mori & van Zijl, NMR Biomed, 2002

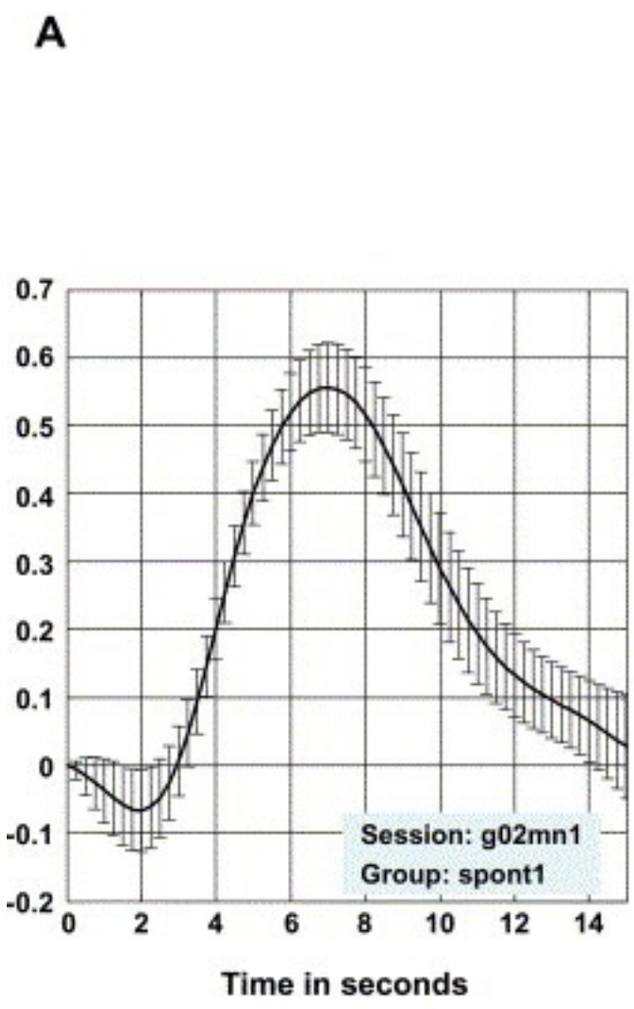


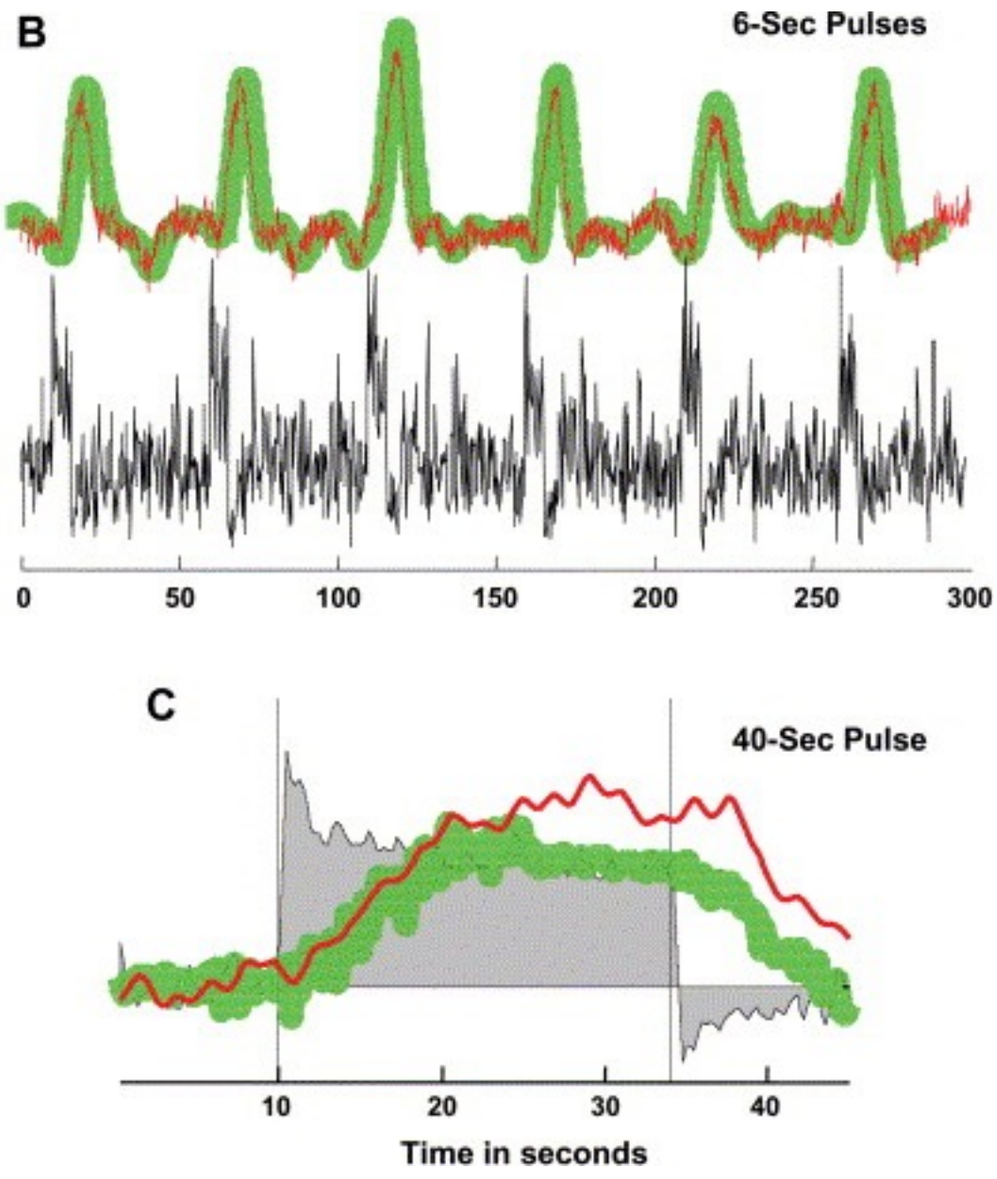
STRUCTURAL CONNECTIVITY: TRACTOGRAPHY



FUNCTIONAL MRI

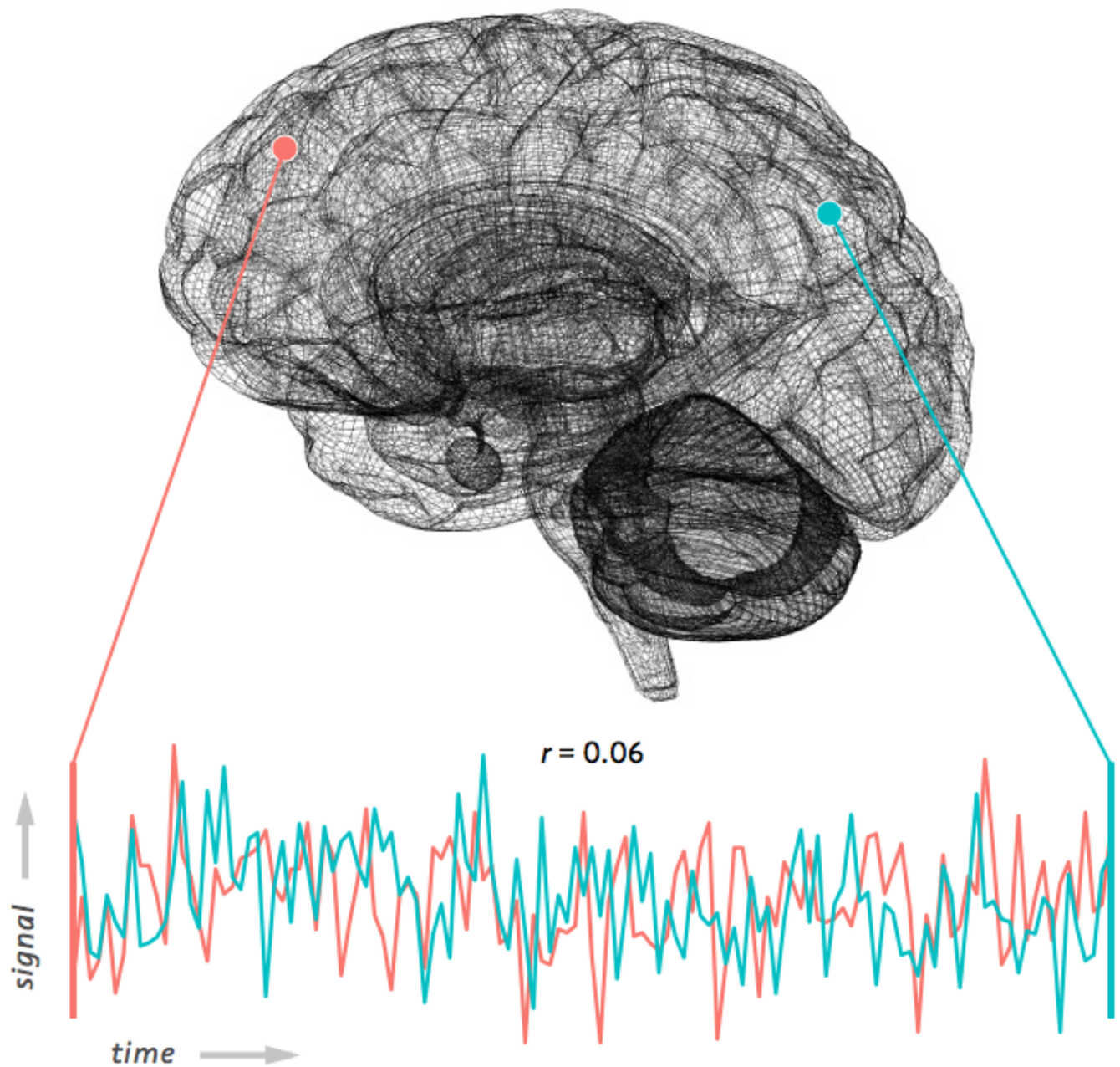
- Brain activity linked to increased demand for oxygenated blood
- Associated via a haemodynamic response function
- Functional activity estimated by deconvolution



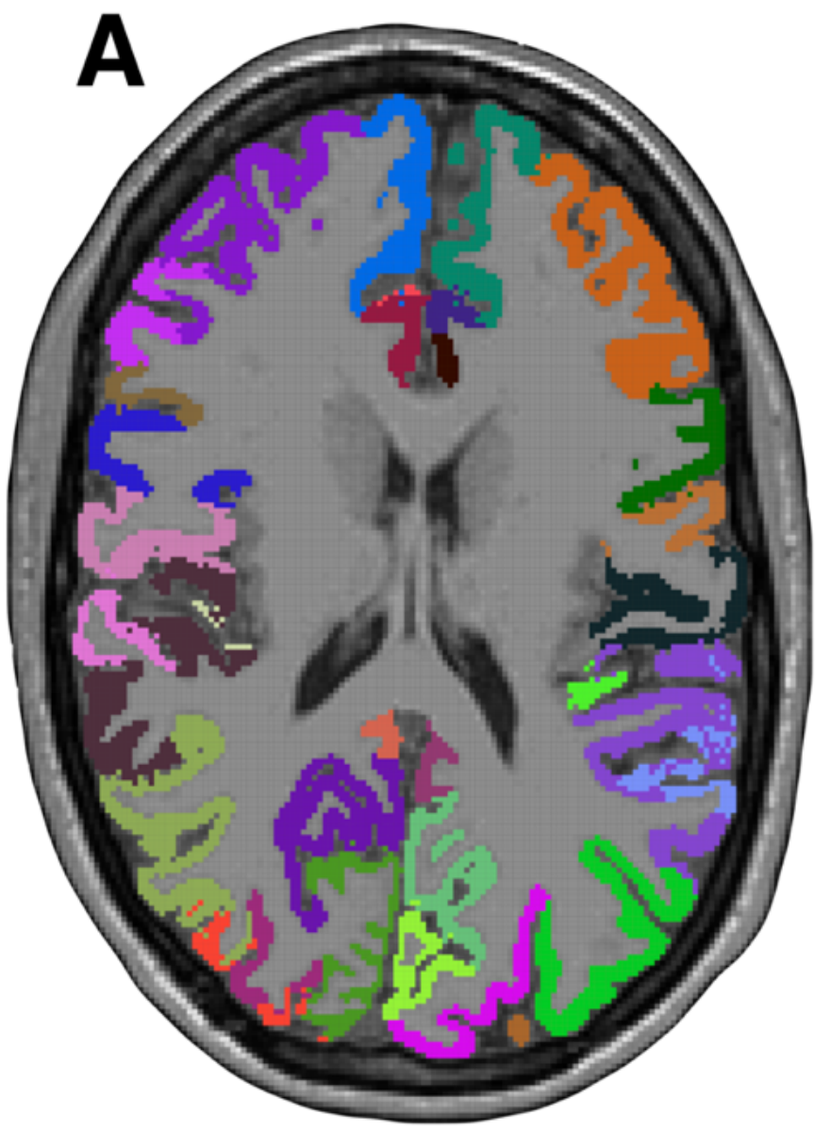


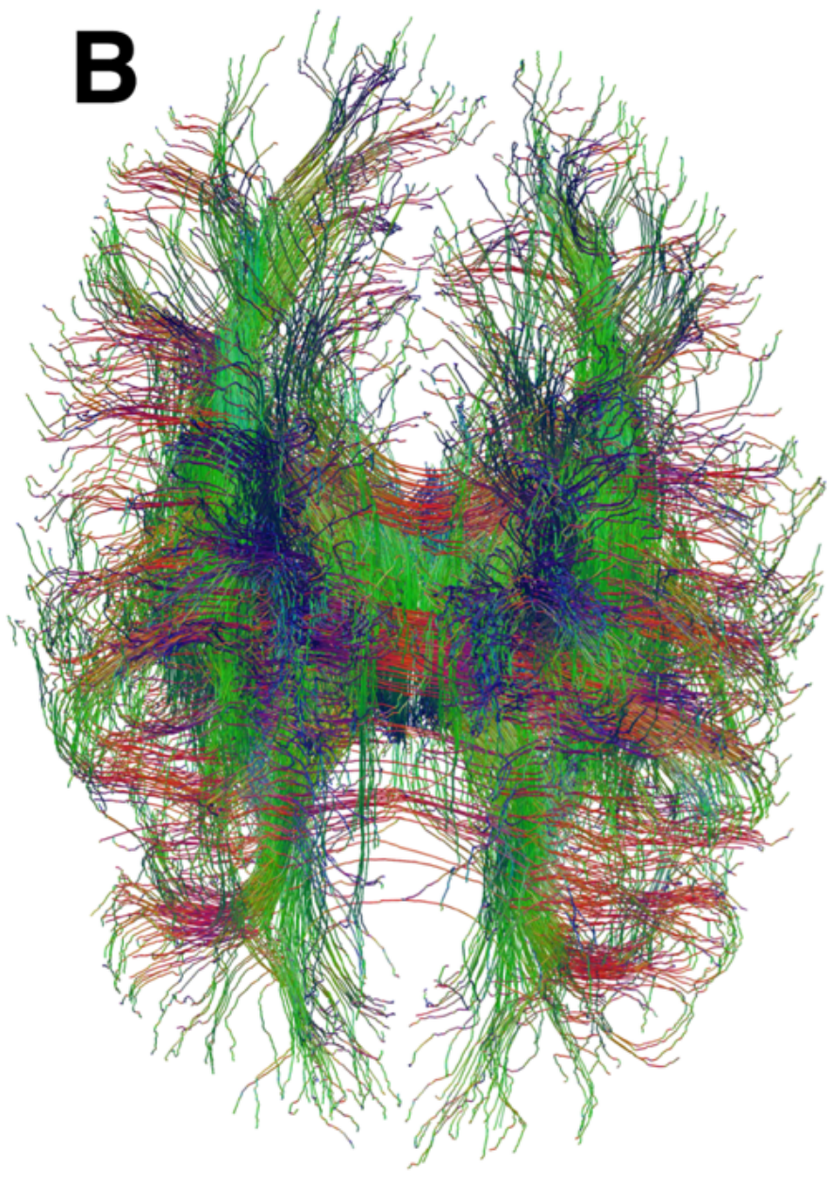
Logothetis & Pfeuffer, Magn Reson Imag, 2004

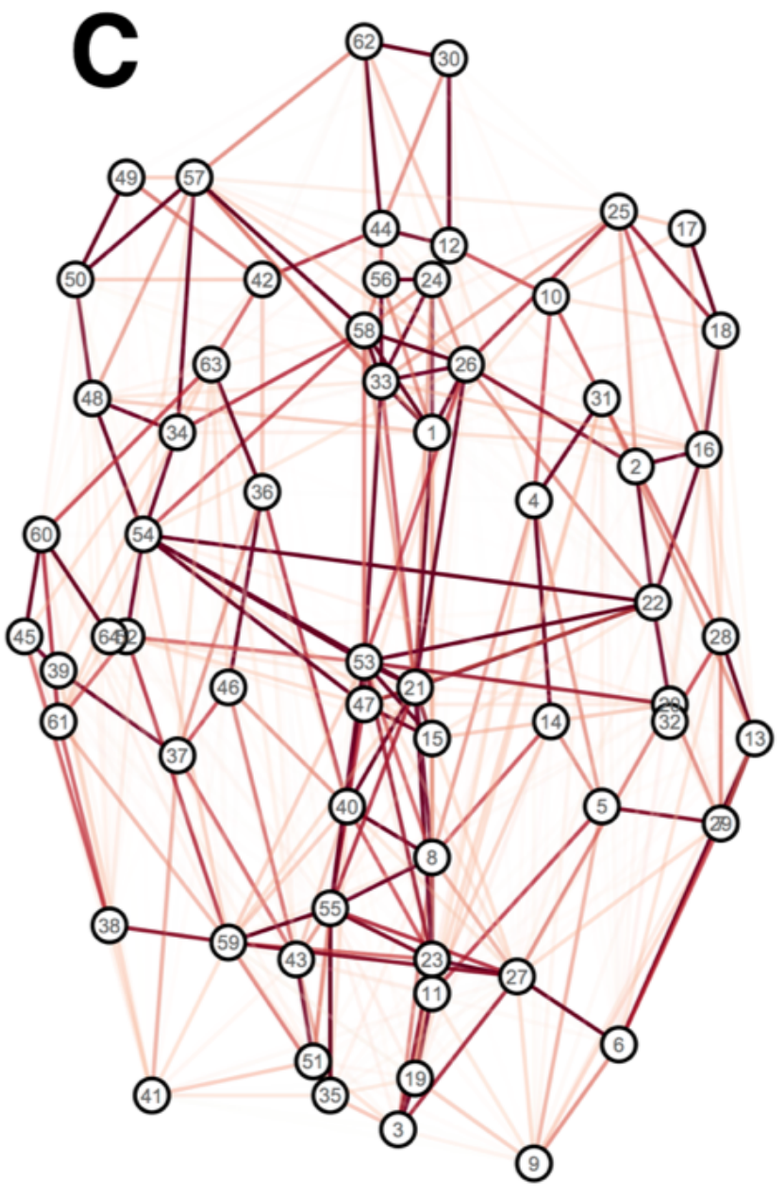
FUNCTIONAL CONNECTIVITY: CORRELATED TIME-COURSES



IN VIVO CONNECTOMICS



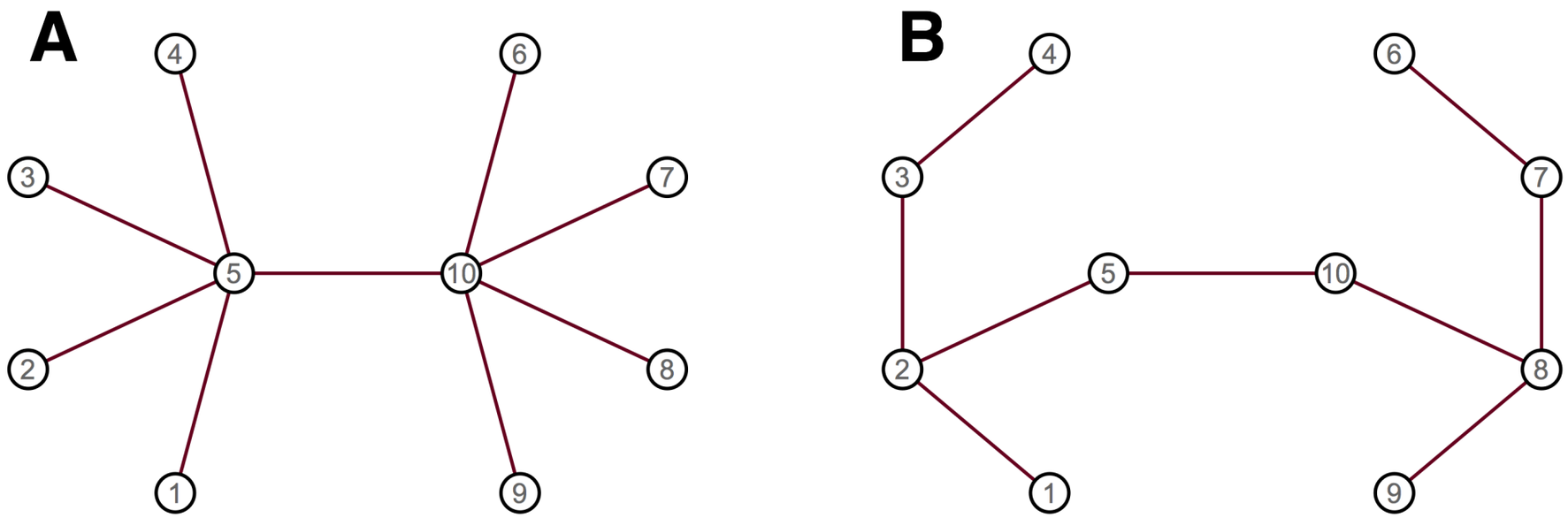




GRAPH CHARACTERISTICS

- A range of measures have been developed in graph theory to describe characteristics of graphs and their vertices
- Connection density: the proportion of all possible edges which are present in the graph (cost)
- Average path length: the mean shortest path length between pairs of vertices (efficiency)
- Betweenness centrality: the number of shortest paths between other vertices which pass through a particular vertex (hubs)

GRAPH TOPOLOGY

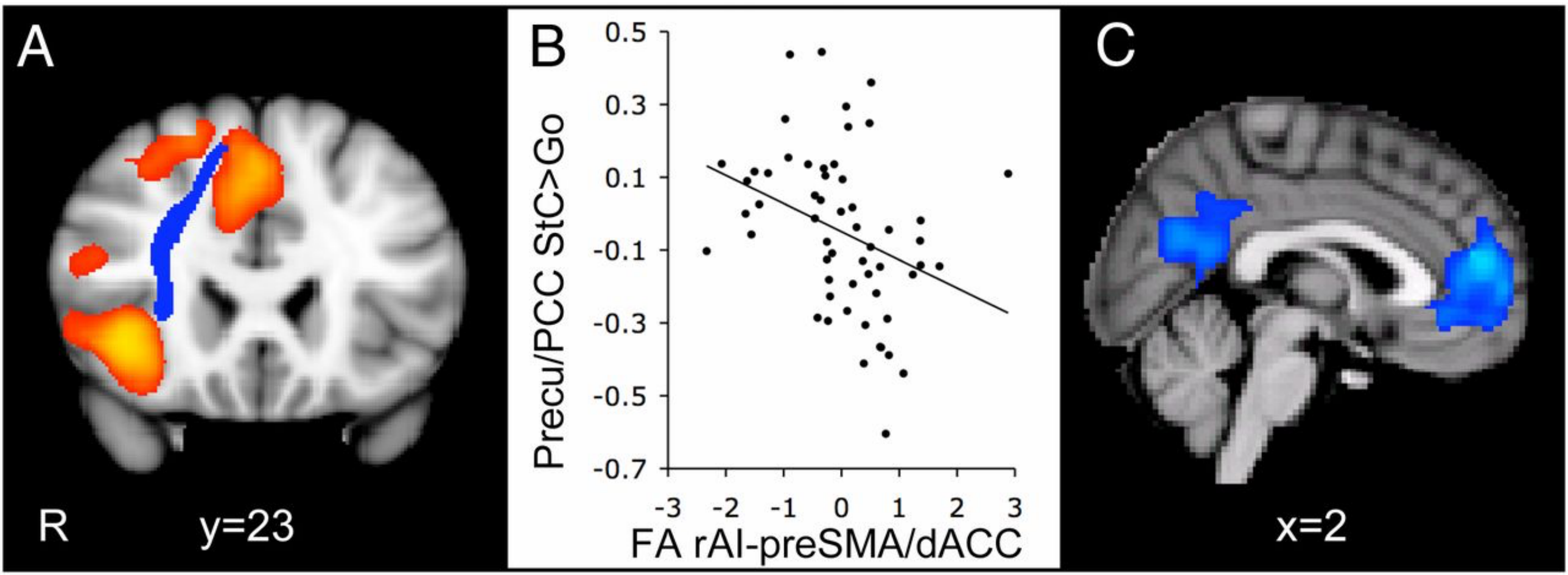


	Graph A	Graph B
Nodes/Vertices	10	10
Edges	9	9
Degree distribution	*d* = 1 (8) *d* = 5 (2)	*d* = 1 (4) *d* = 2 (4) *d* = 3 (2)
Mean path length	2.2	3.1

- What happens if an edge disappears?

STRUCTURE–FUNCTION RELATIONSHIPS

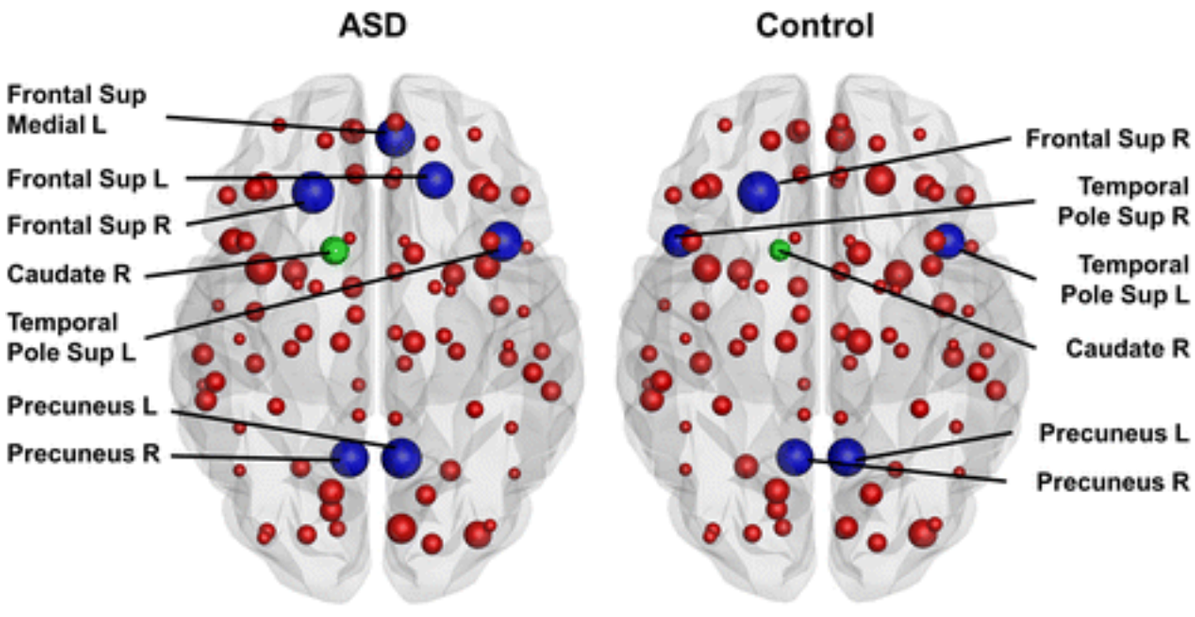
- Integrity of a particular white matter tract predicts de-activation of the default-mode functional network after injury



Bonnelle et al., *PNAS*, 2012

APPLICATION TO ASD

- Global network differences between ASD and control groups, e.g. in network efficiency
- Also local differences in centrality and hub structure

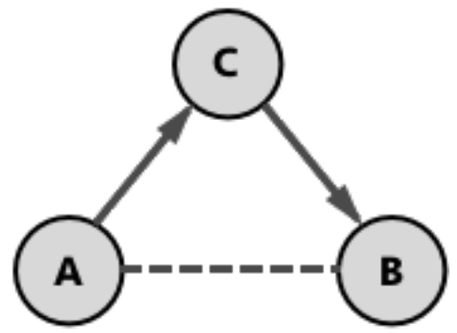


Roine et al., *Mol Autism*, 2015

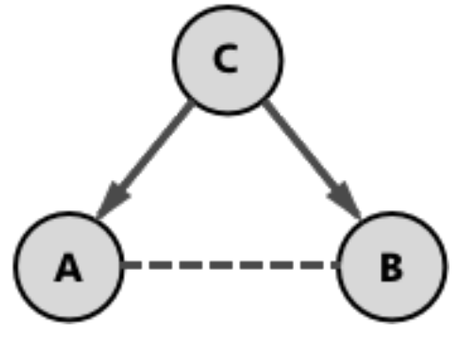
INDIRECT CONNECTIONS

- Correlated activity may indicate a direct physical connection …

- … or an indirect one …



- … or top-down influence from a third region



OUTLINE OF THE TASKS

- Construct a functional connectome from an individual dataset
- Explore the effect of certain parameters on the graph-theoretical properties of structural and functional connectomes
- Directly model the relationship between structural connection weights and the equivalent functional connection weights
- Incorporate indirect structural connections, and investigate their influence
- Predict functional connectomes from structural ones, and compare different models for doing so