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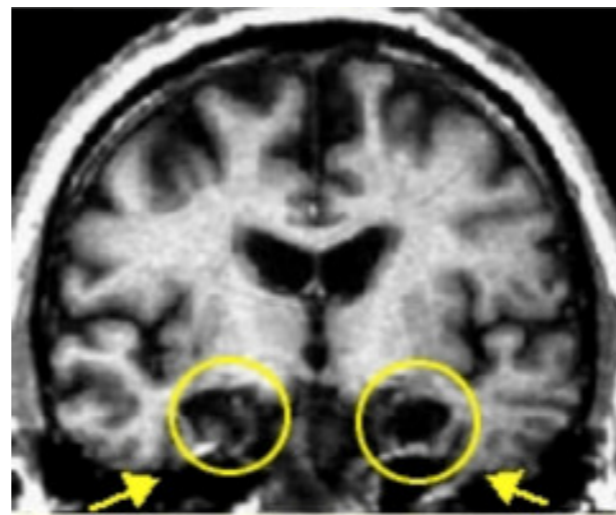
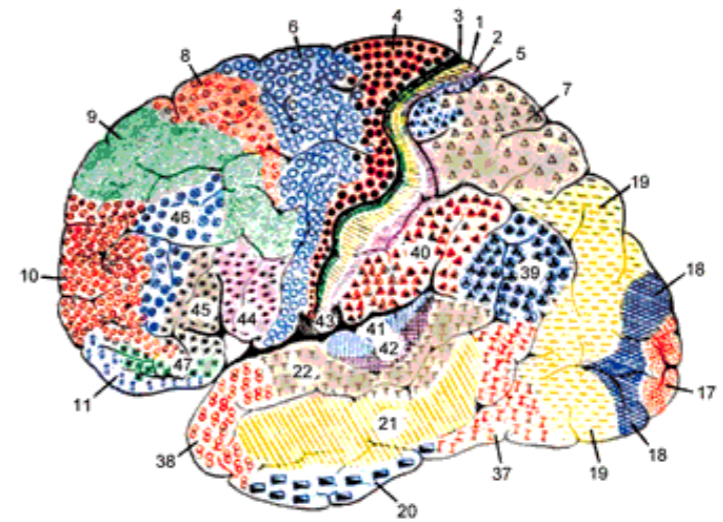
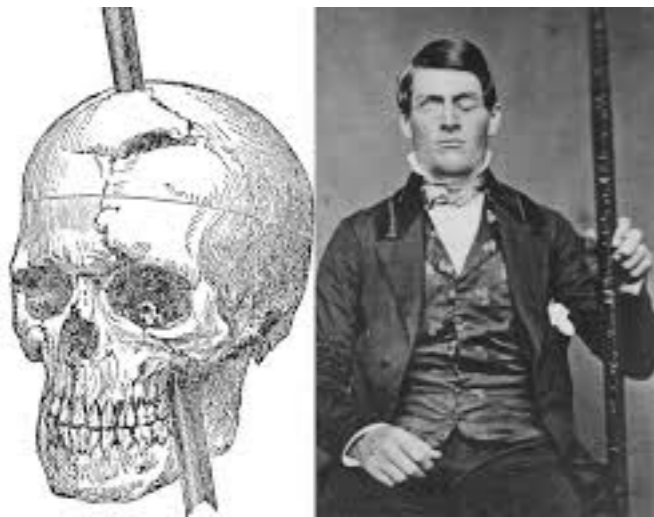
- ❖ Brain mapping: a brief guide
- ❖ The 'quantum leap' of the resting brain
- ❖ Rise of the connectome
- ❖ Neurosurgery: making the connectome 'work'

Chapter 1: The brain mapper



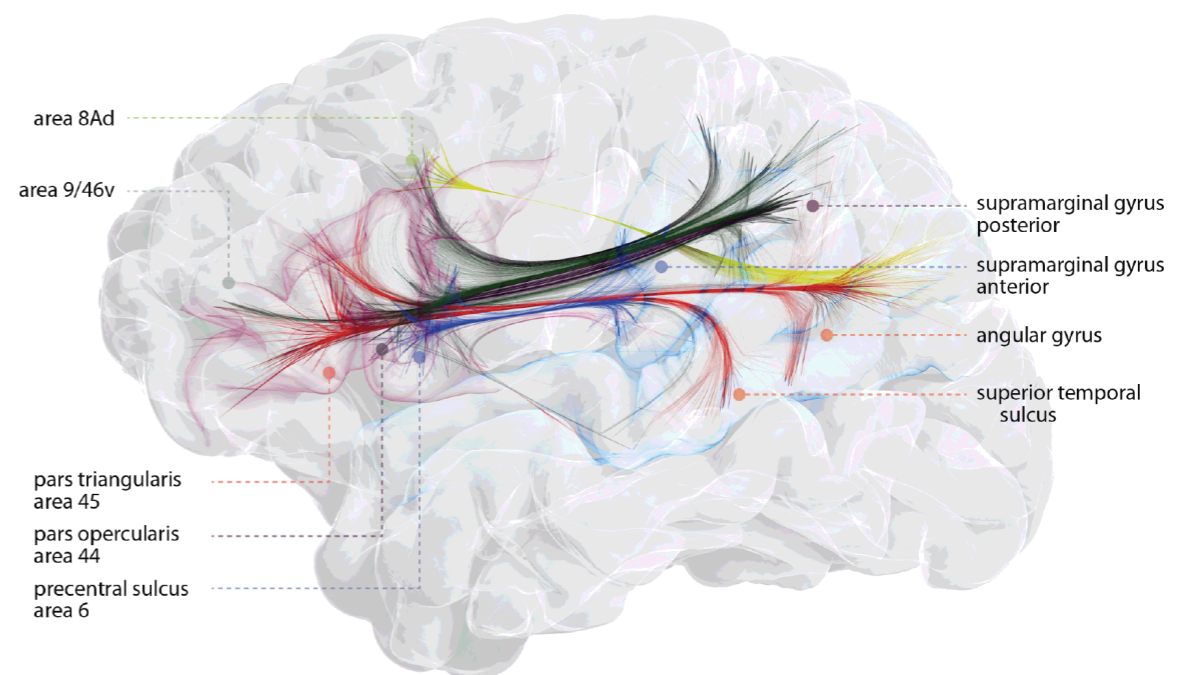
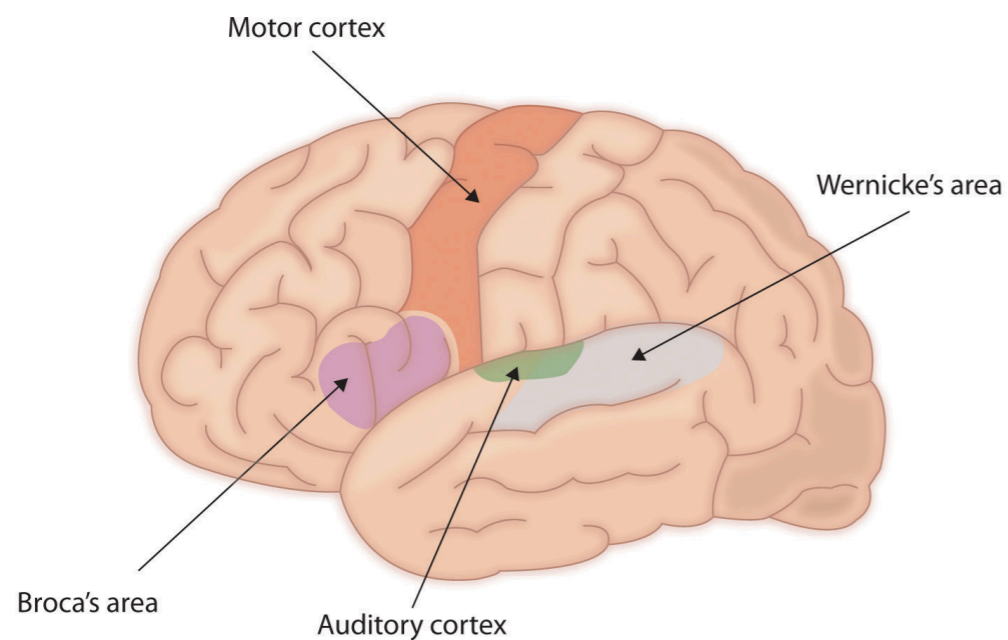
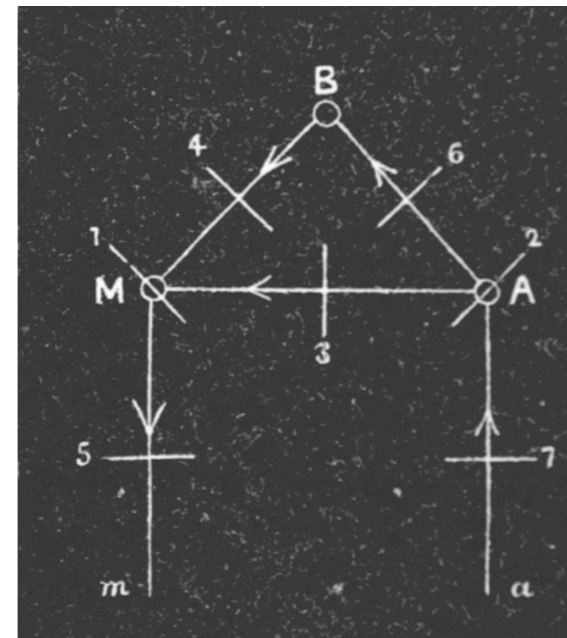
Map of the
world, 1570
Abraham
Ortelius

functional localisation



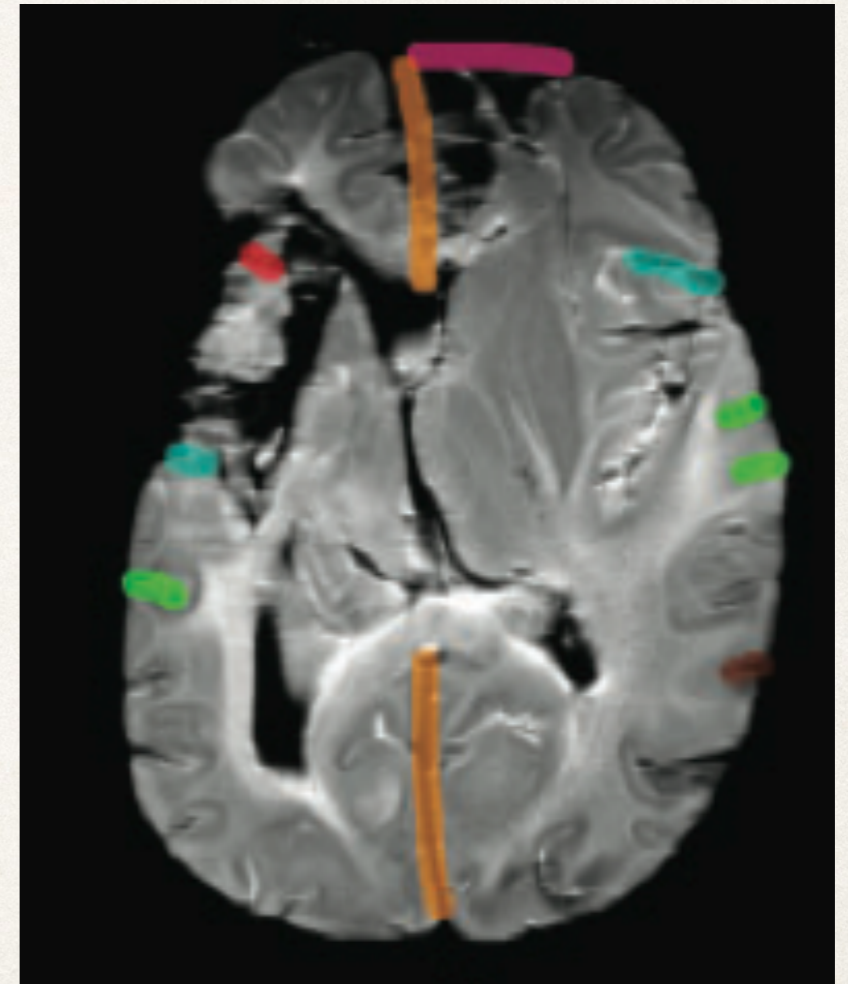
functional integration

- ❖ Geschwind-Wernicke-Lichtheim language circuit
- ❖ Still a 'discrete' model

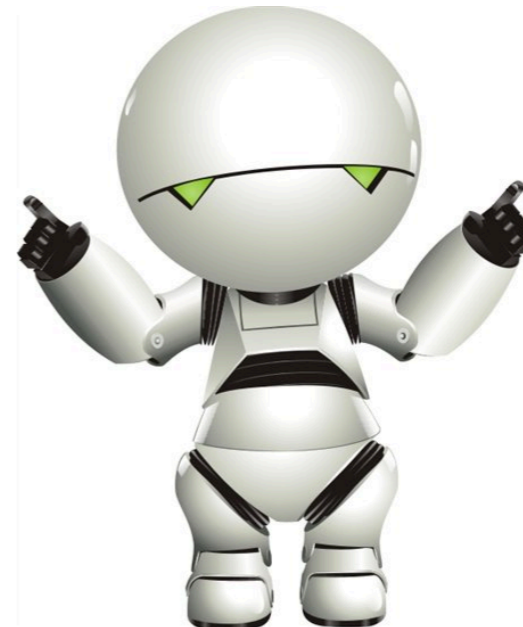


Critique

- ❖ Pros: applicable / practical
- ❖ Cons: limited numbers, not replicable, pathological brains, heterogenous
- ❖ Conclusion: an inevitable 'dead' end

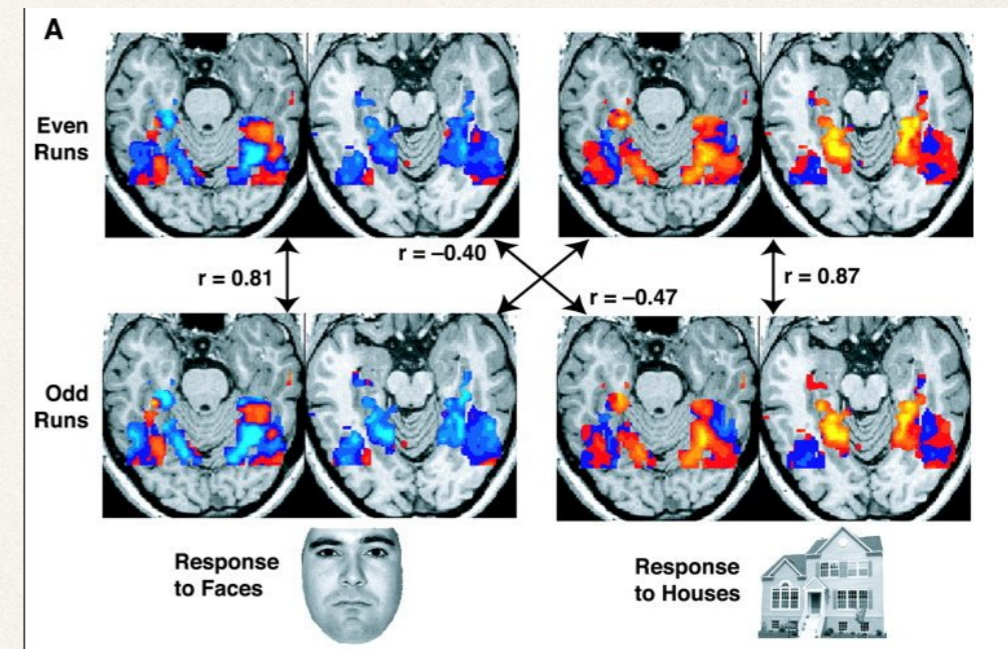


Chapter 2: The resting brain



task based functional MRI

- ❖ Task activity = feature of interest
- ❖ Brain like a computer (processor)
- ❖ Rest = background 'noise'
- ❖ Big advance in neurosciences ~1990s onwards

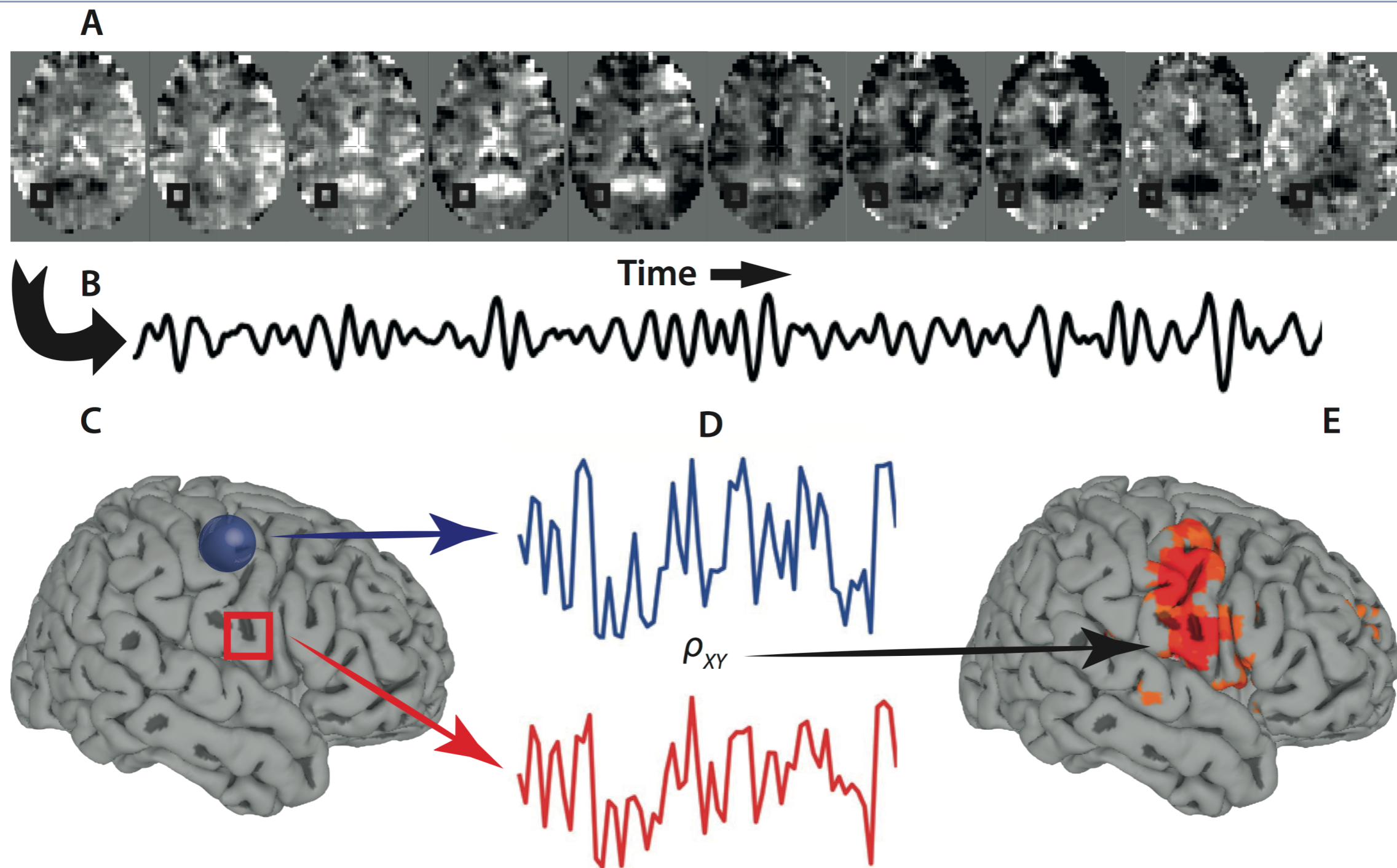


PET & the paradigm shift

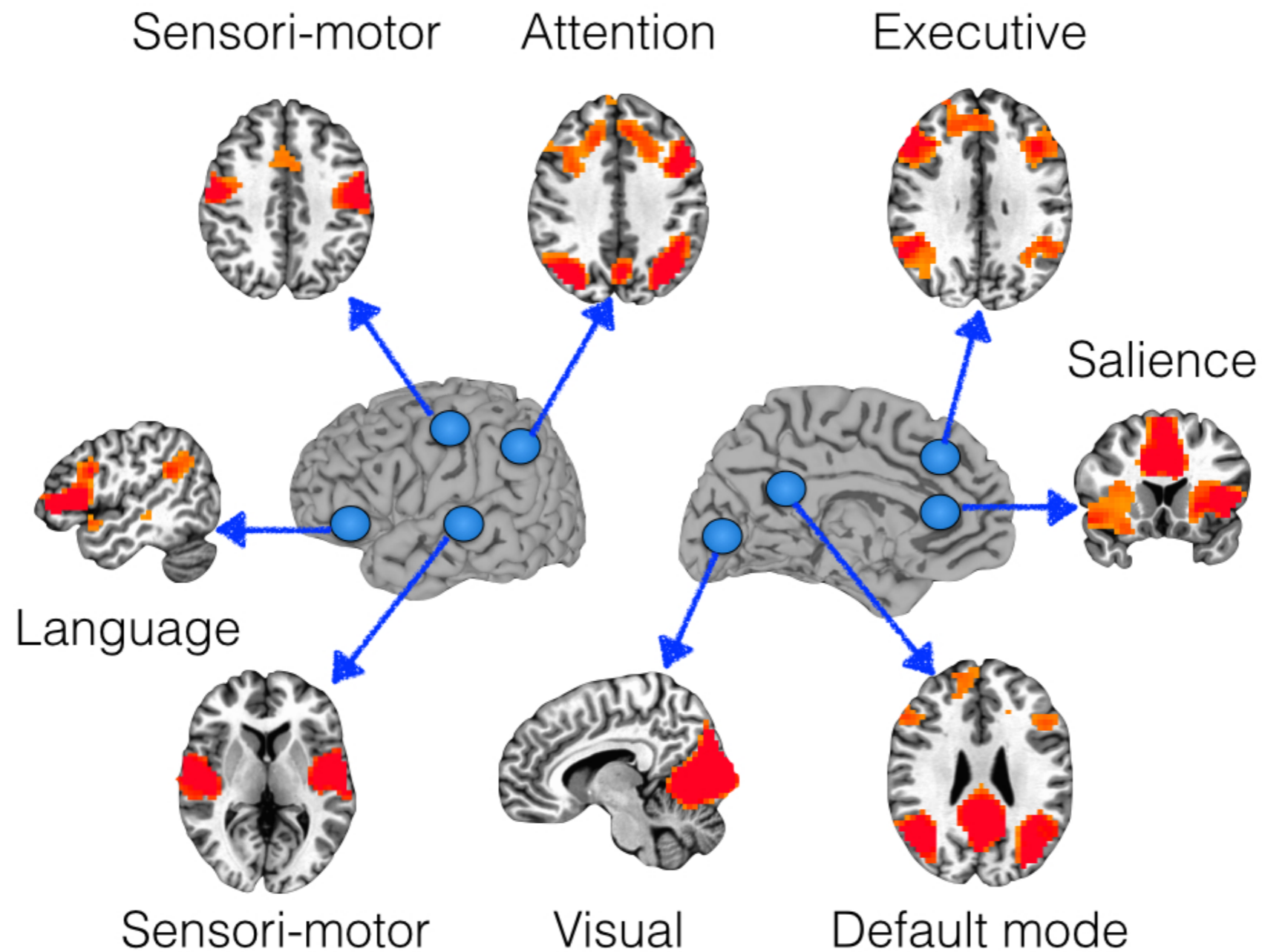
- ❖ Majority of energy (>95%) used at rest)
- ❖ Typical patterns or self-organising activity
- ❖ Characteristic 'task negative' default mode network



Analysing resting state fMRI data

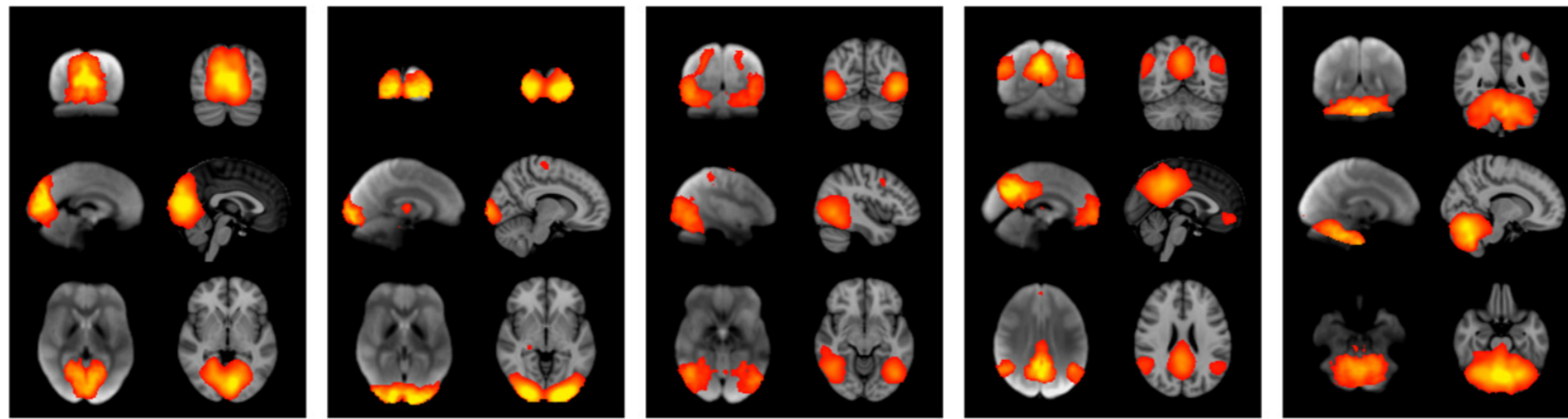


Resting state networks



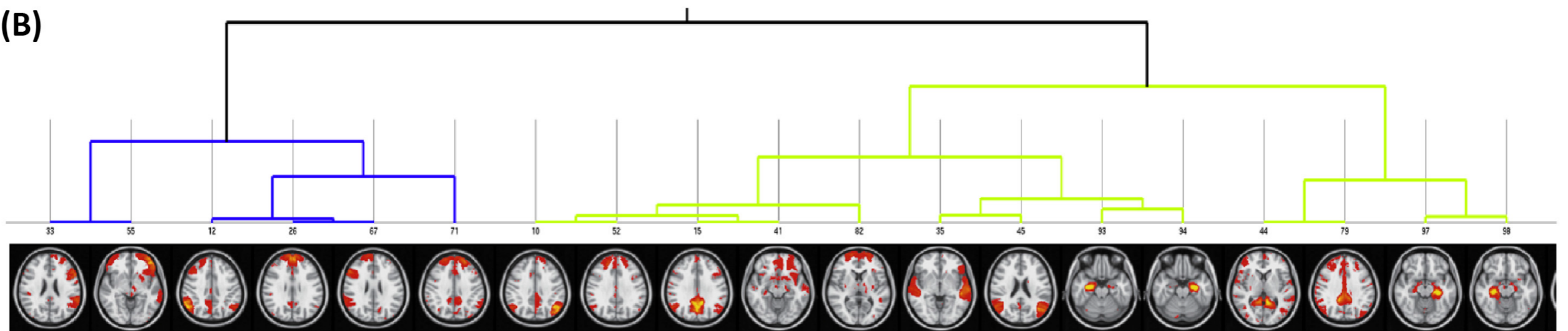
Activation & rest

Resting networks reflect those from task meta-analysis



Resting networks arranged in a hierarchy of sub-networks

(B)



Smith et al, PNAS, 2009

Organisation at rest

- ❖ Majority of energy
- ❖ Correspondence of activation & rest architectures
- ❖ Dynamically active repertoire of networks

“The fact that the body is lying down is no reason for supposing that the mind is at peace.
Rest is far from restful”. Seneca the younger, ~65 AD

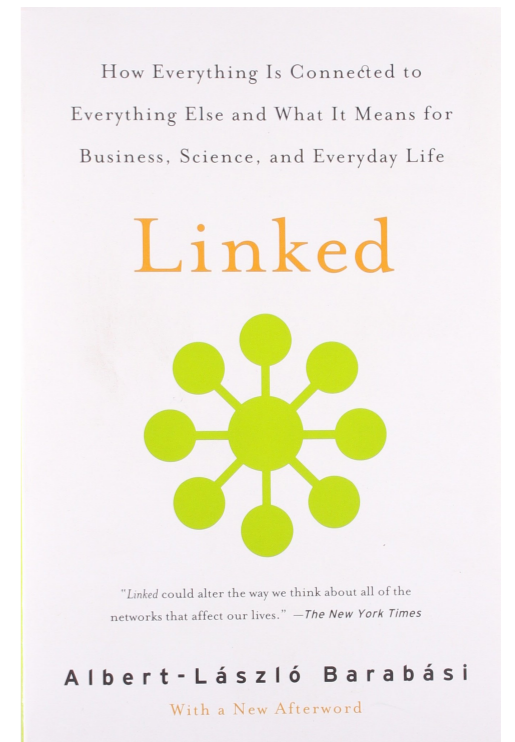
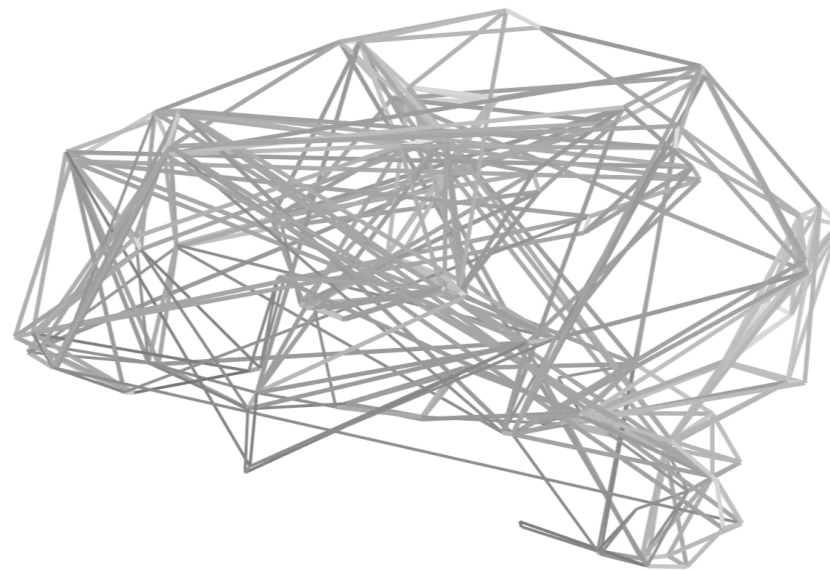
Chapter 3: The Connectome - what, how, why?



Leonhard Euler
1707-1783

What is the connectome?

“wiring diagram of the brain”



HUMAN
Connectome
PROJECT

NIH Blueprint: The Human Connectome Project

NIH Blueprint for Neuroscience Research



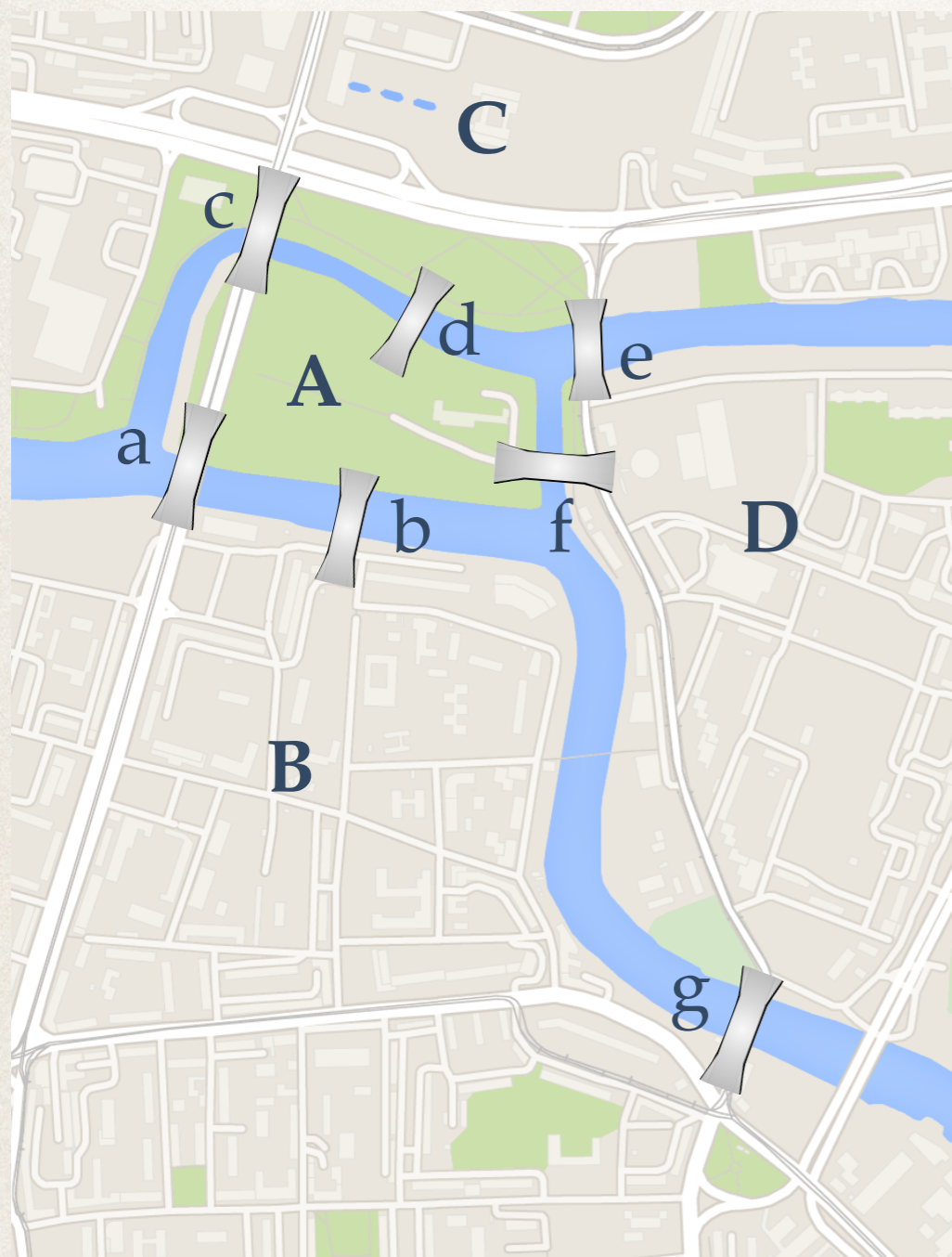
‘Backwardness of human neuroanatomy....new techniques are needed....’

Crick & Jones, Nature, 1993

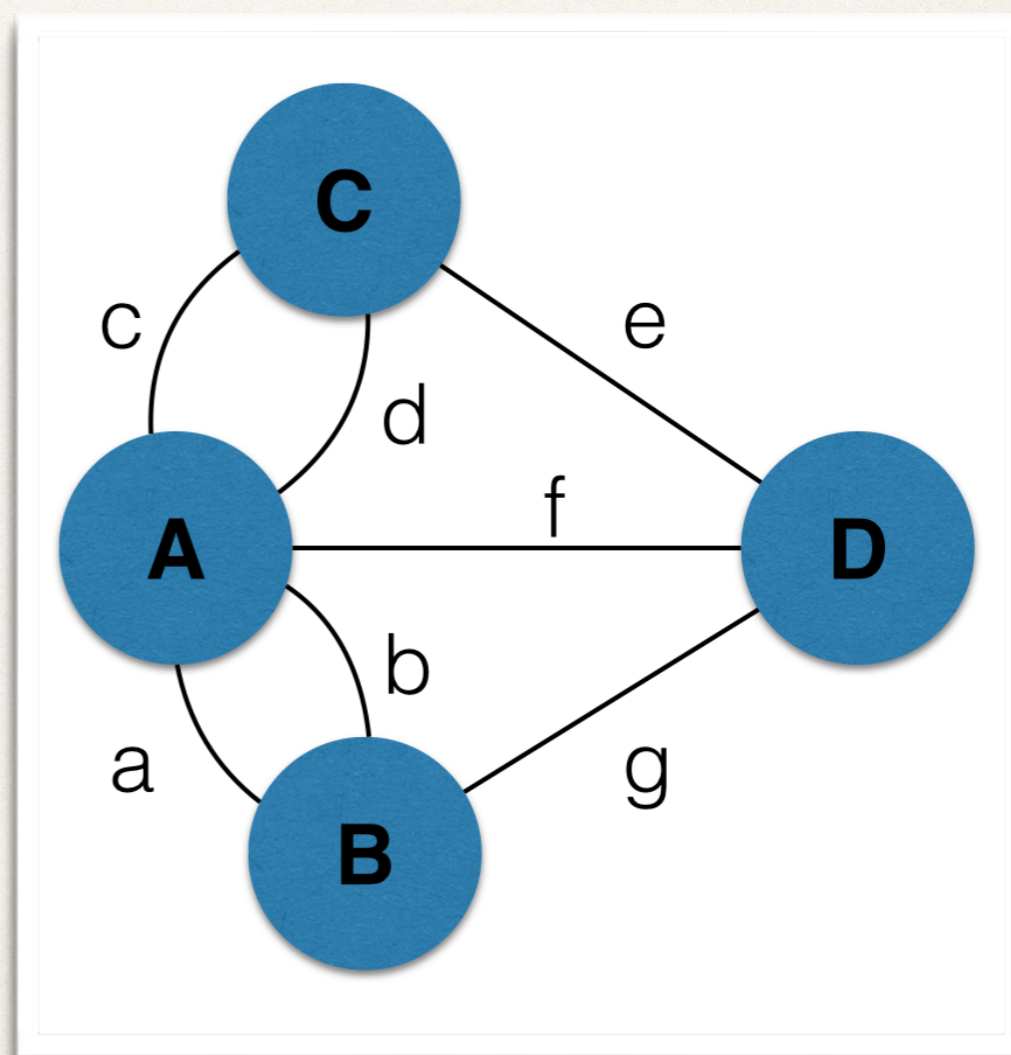
aside 1:

what networks?

A problem of bridges.....



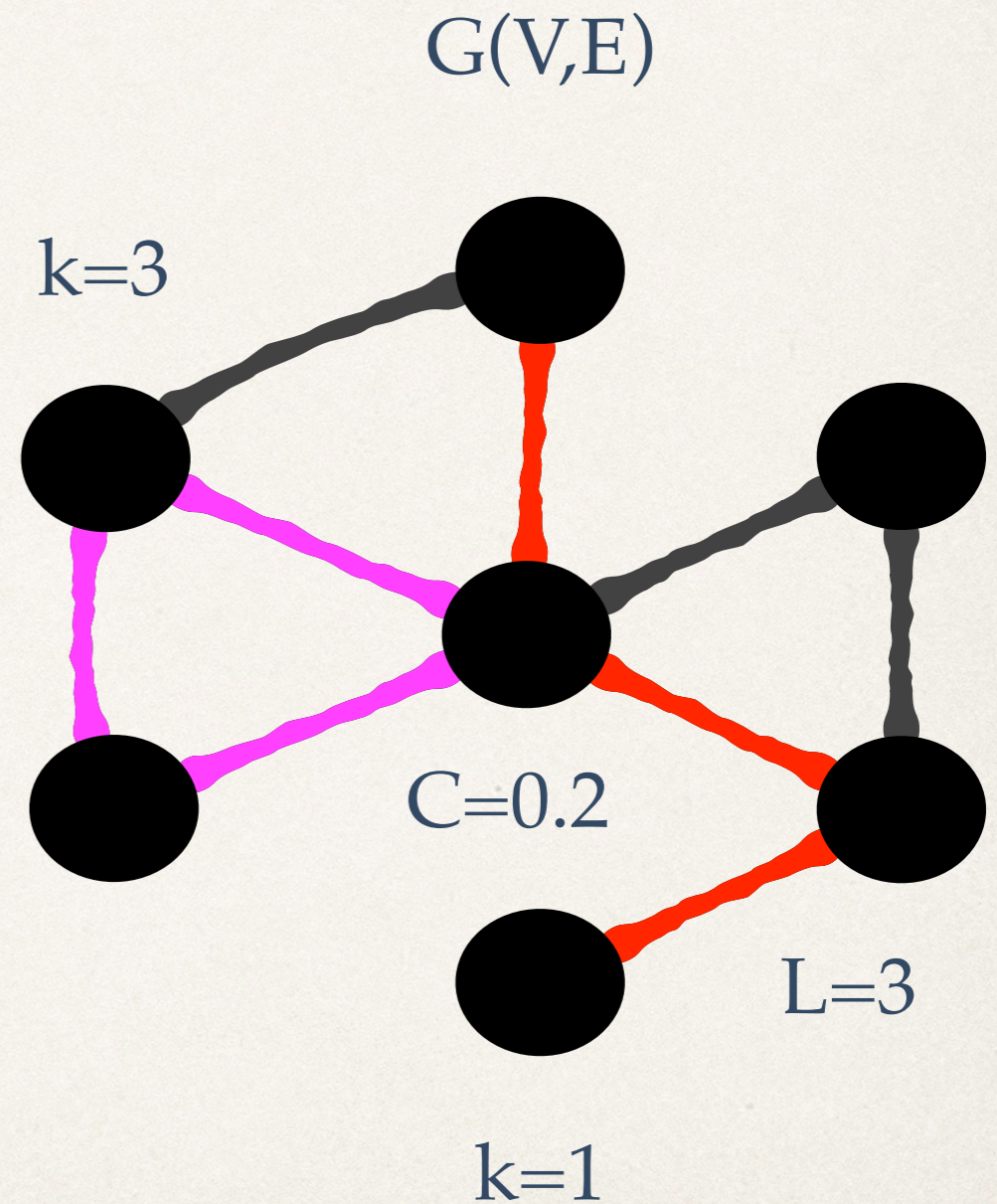
Make a graph.....



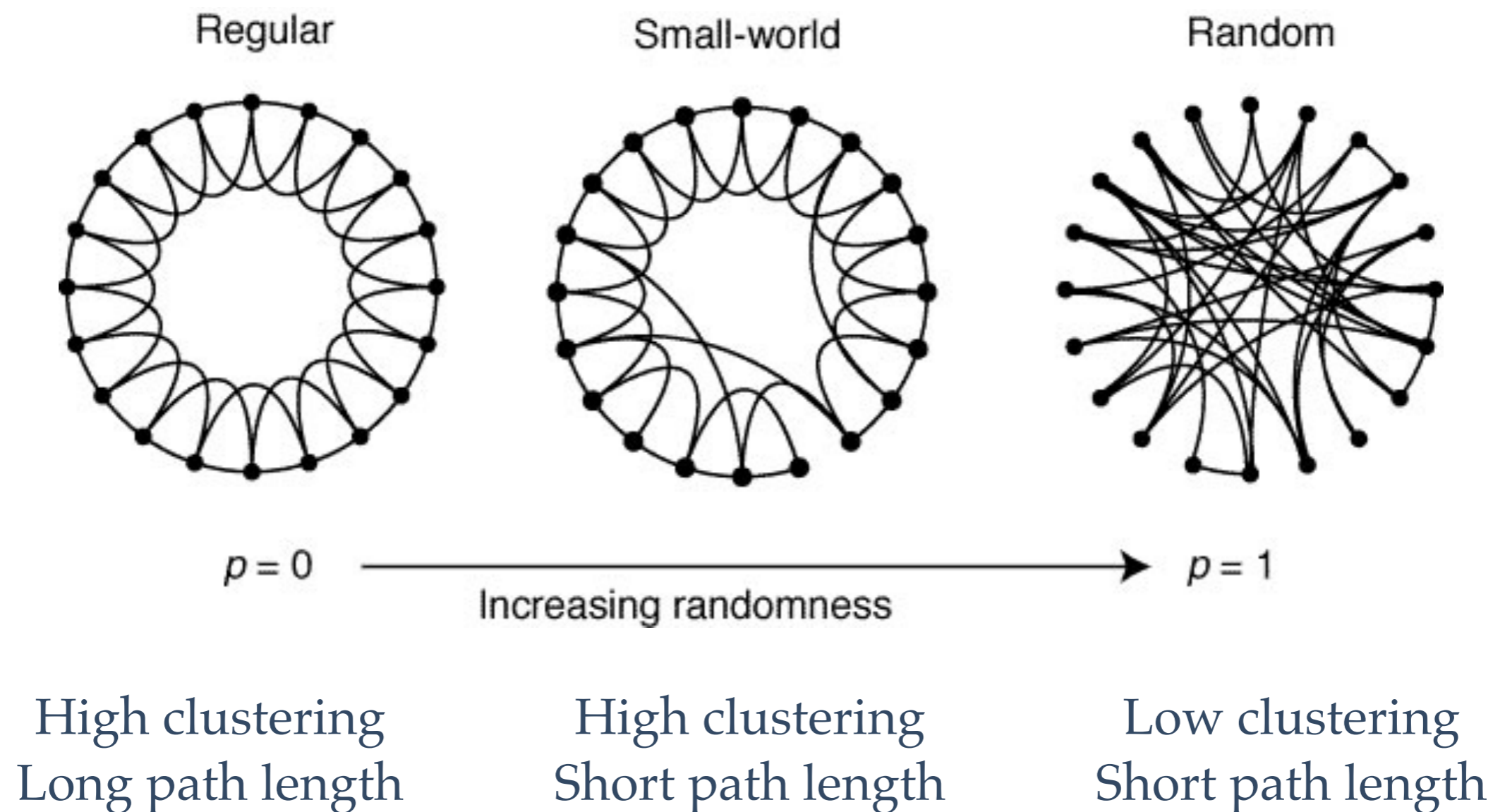
Graph theory - the language of networks

Graph vocabulary

- ❖ $G(V,E)$
 - ❖ Vertices (nodes)
 - ❖ Edges (links)
- ❖ Degree (k)
 - ❖ number of links per node
- ❖ Clustering (C)
- ❖ Path length (L)

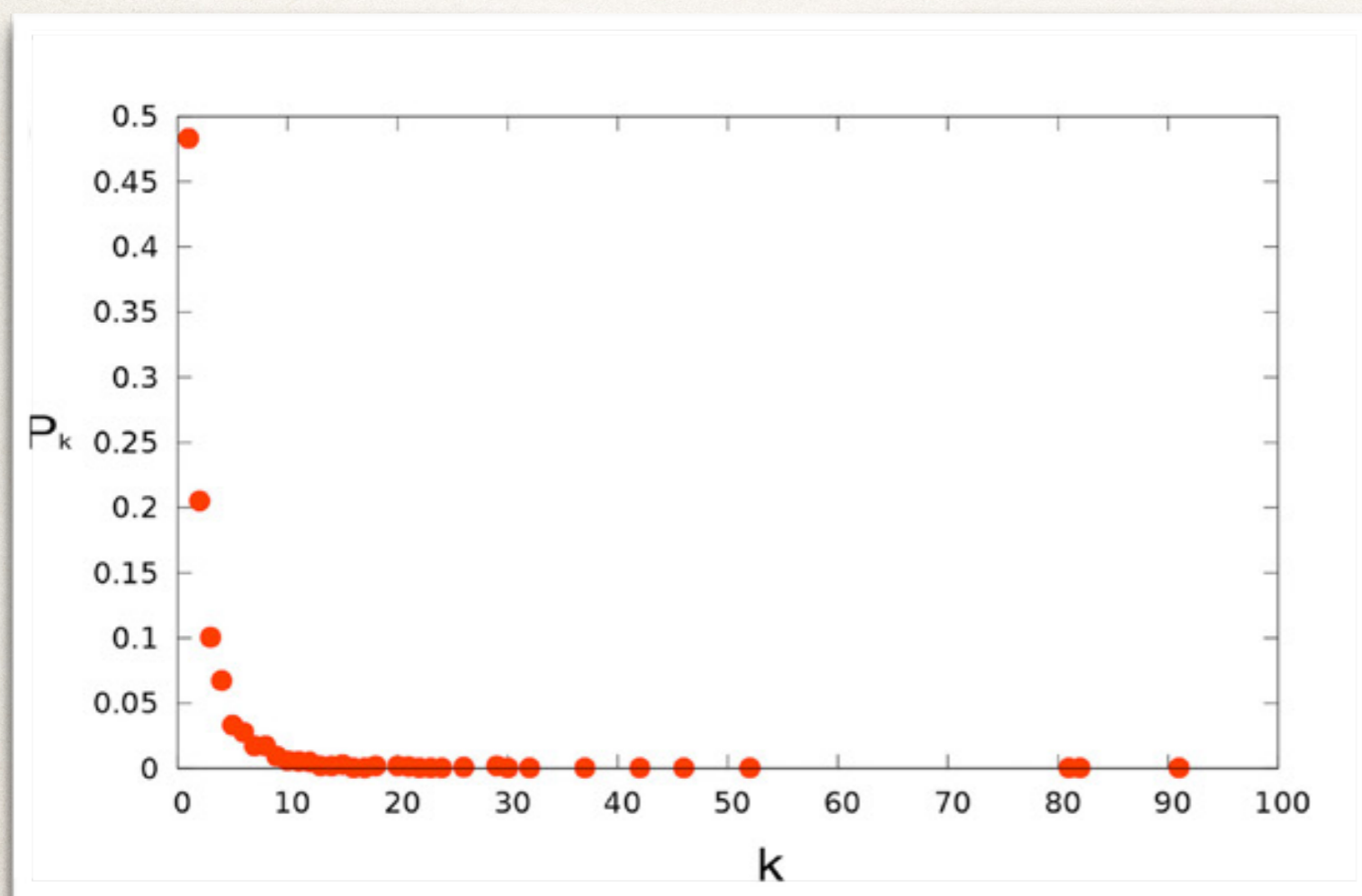


Small world



Watts & Strogatz, Nature, 1998

Scale-free networks & 'hubs'



Small number of highly connected (central) nodes

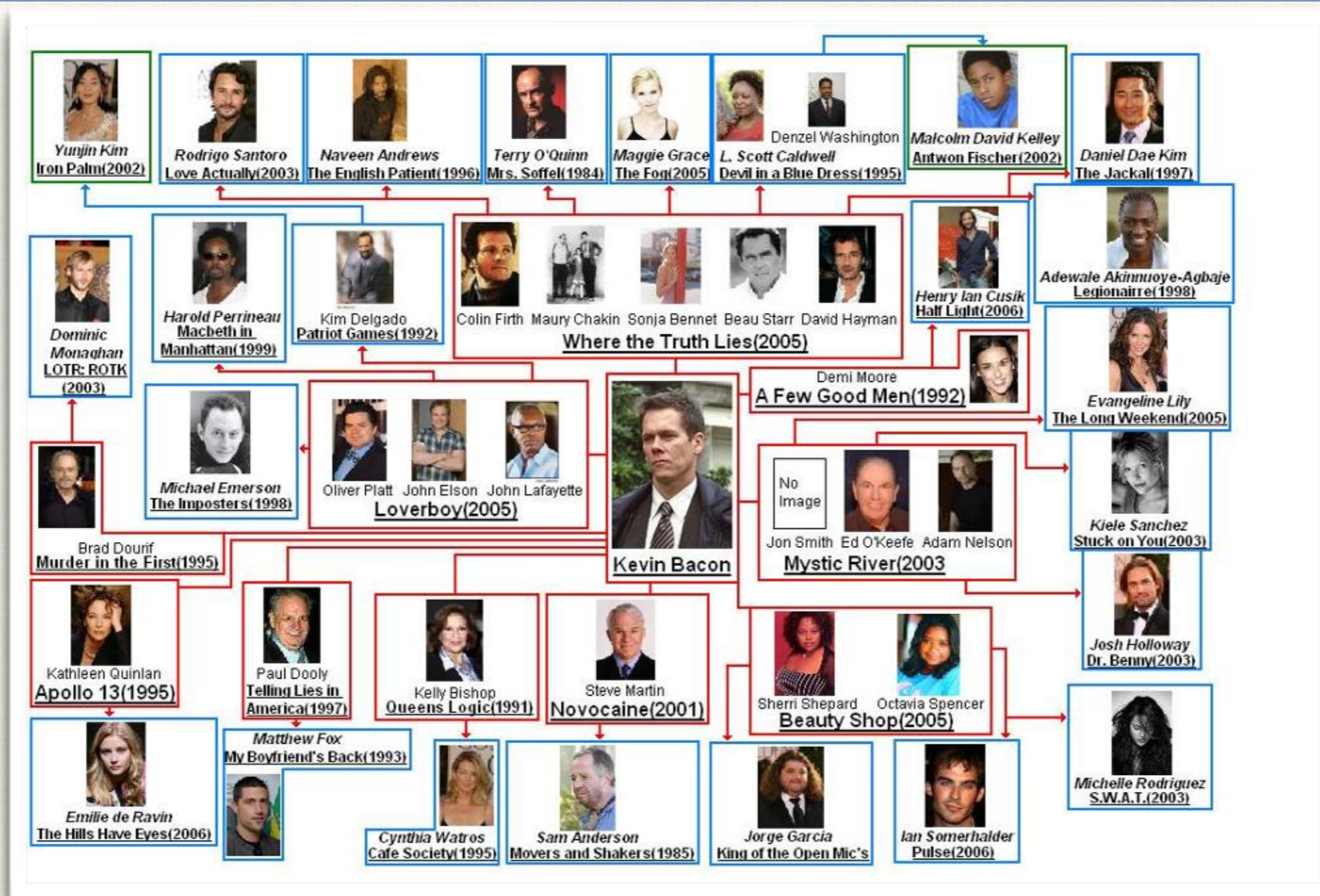
Most nodes have low connectivity (degree)

Defines hubs & rich club

Vulnerably to attack on hubs but robust to random error

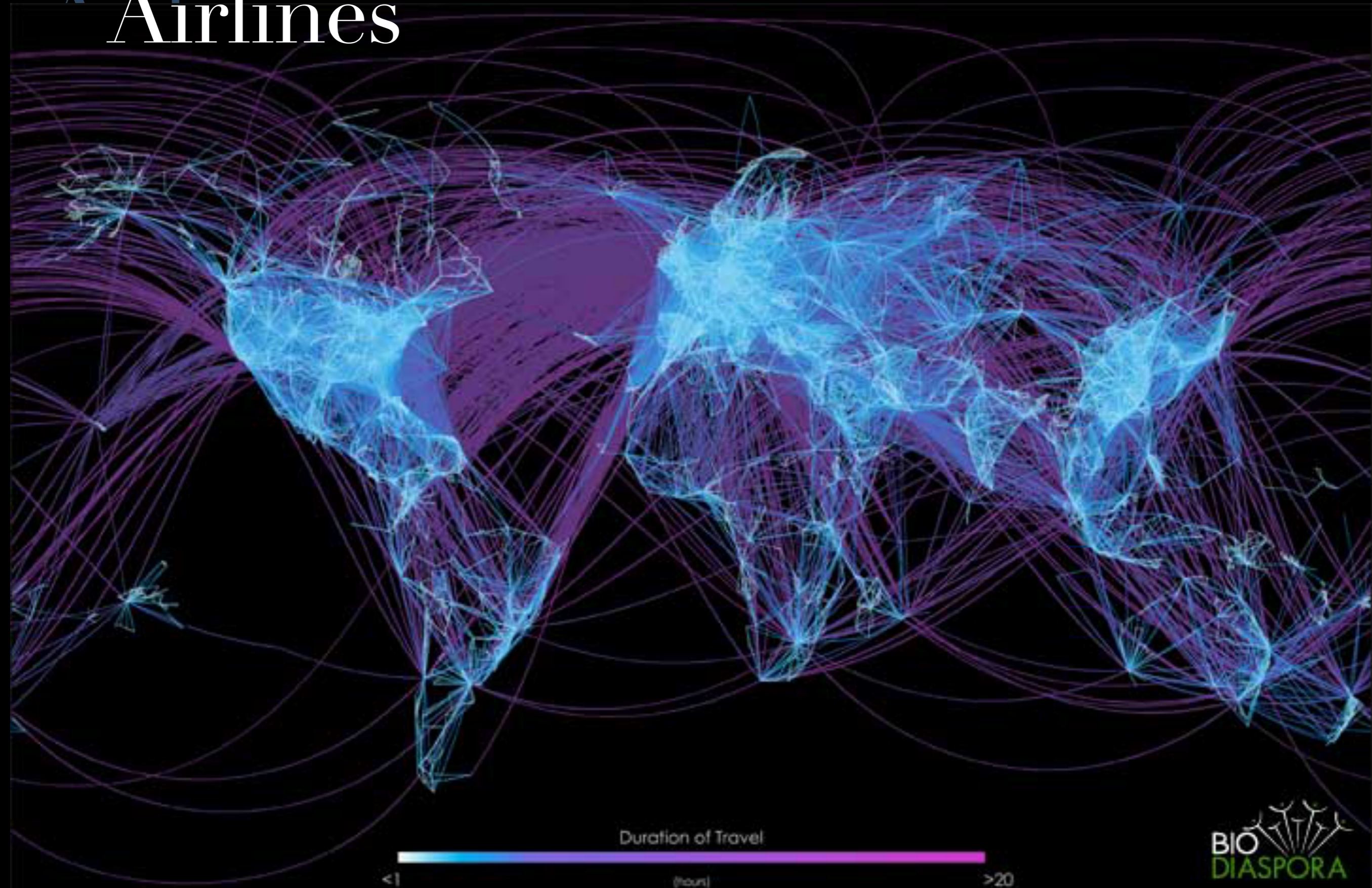
Can be simulated by growth & preferential attachment

Six Degrees of Kevin Bacon



Hollywood actor network (>200,000 nodes, >3 million links): small-world, scale-free, central hubs, rich club

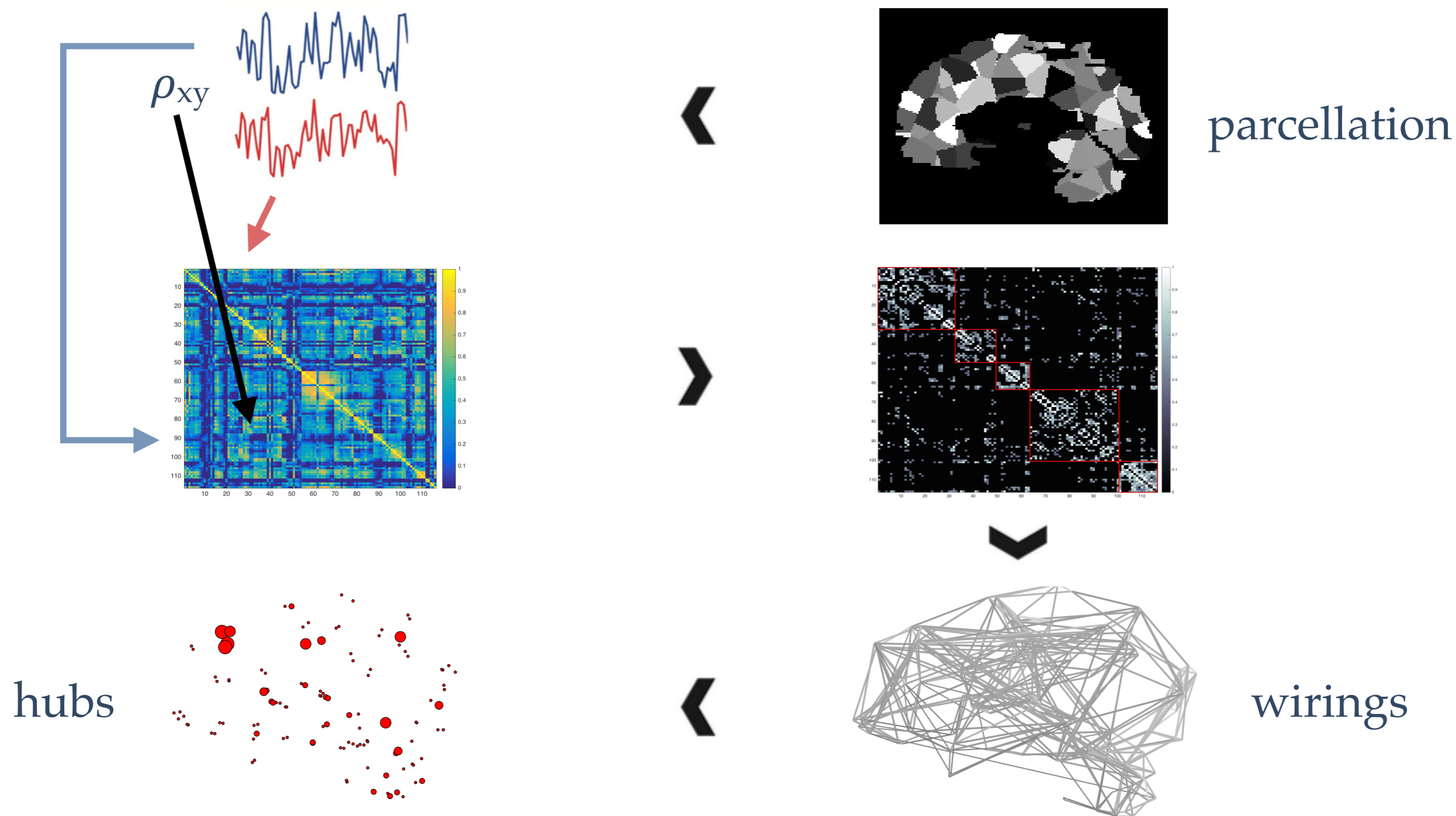
Airlines



aside 2:

how to make brain networks?

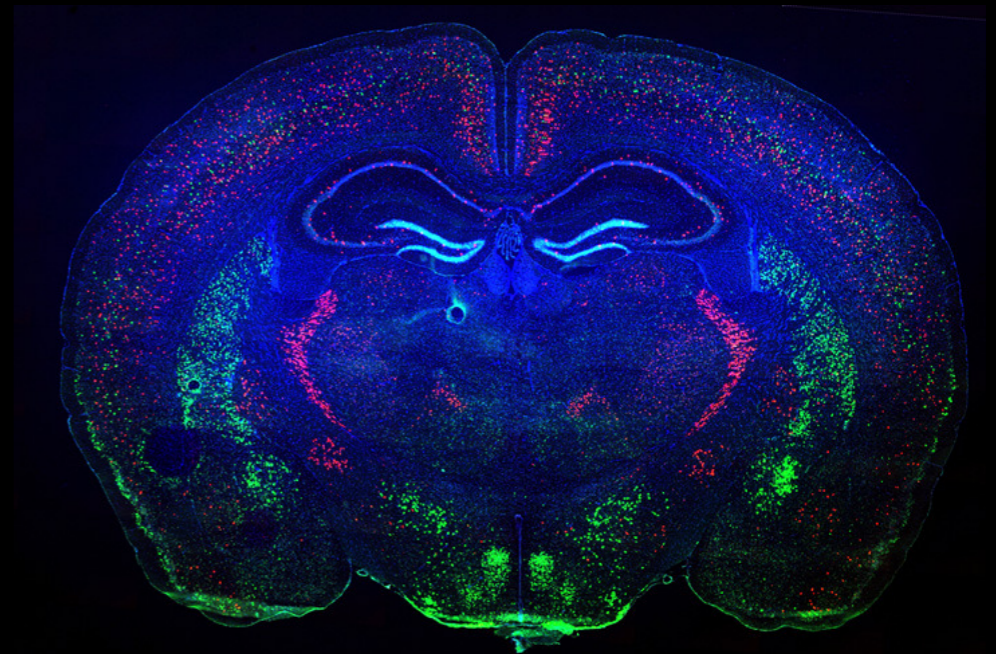
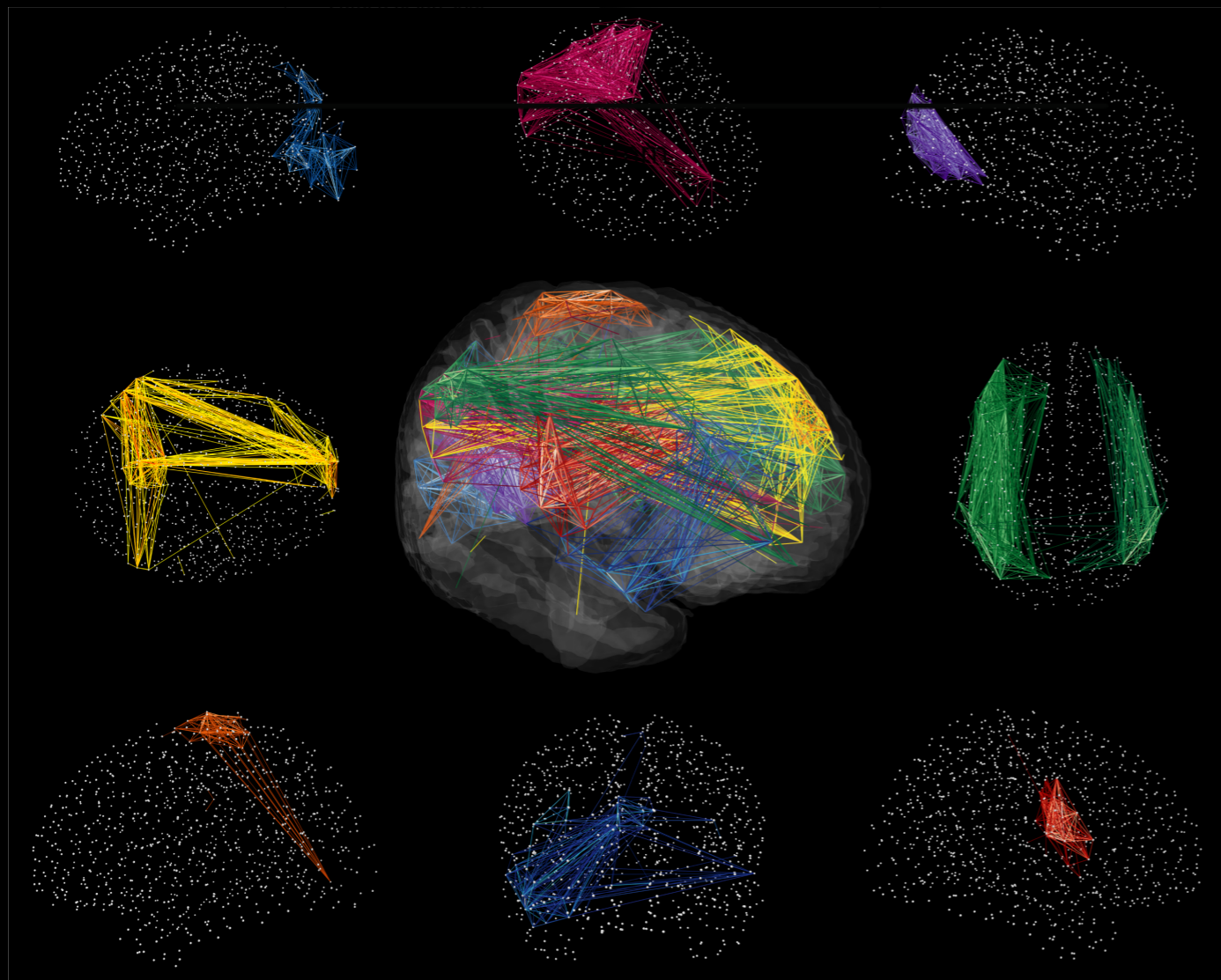
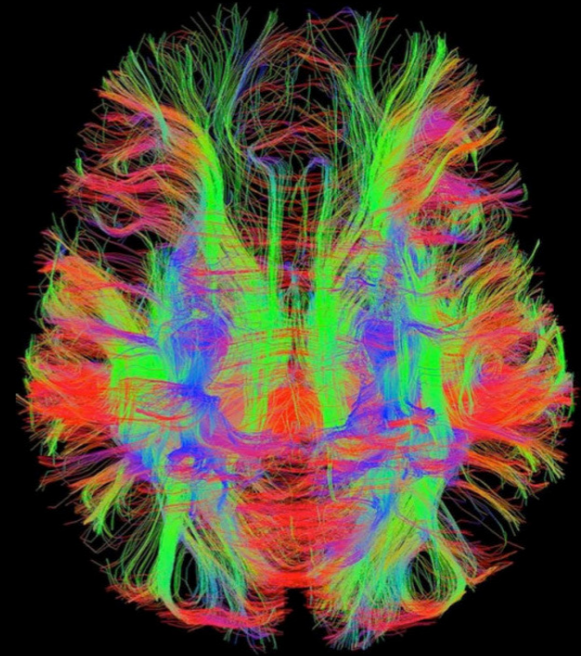
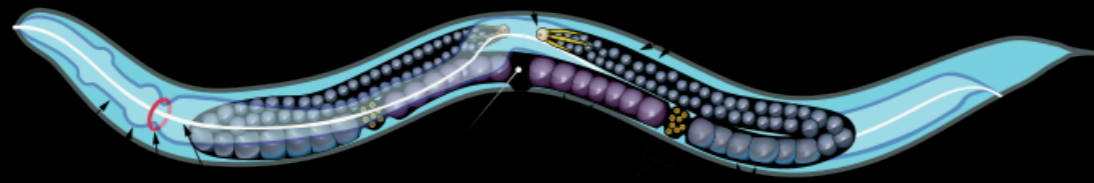
Connectome making



aside 3:

why networks?

Brains are networks



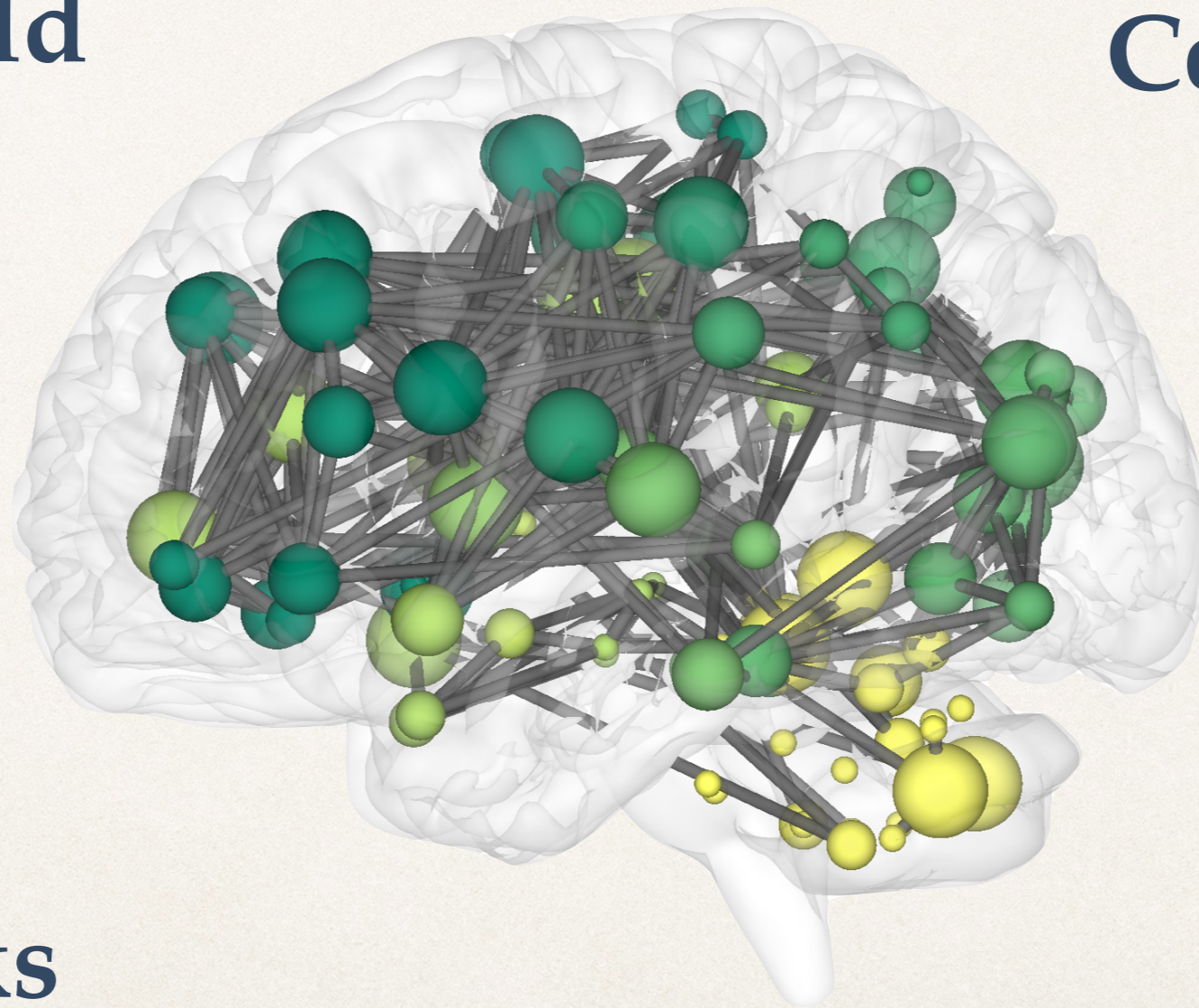
Appraising a new theory

- ❖ Explain current models | consistent
- ❖ Resolves conflicts | clarifying
- ❖ Offer new approaches | motivating

Universal principles

Small world

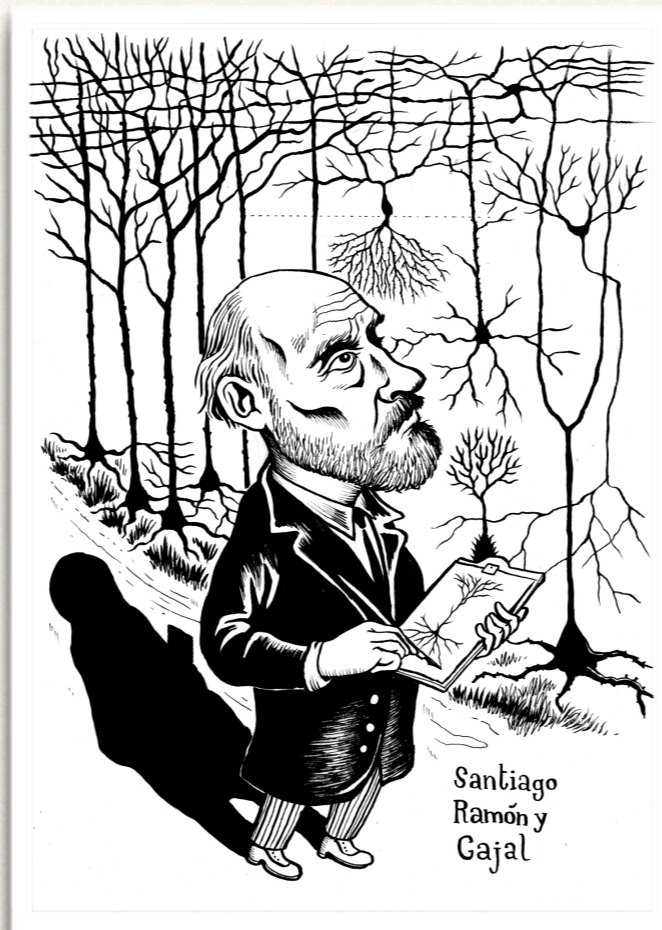
Communities



Weak links
“Achille’s heel”

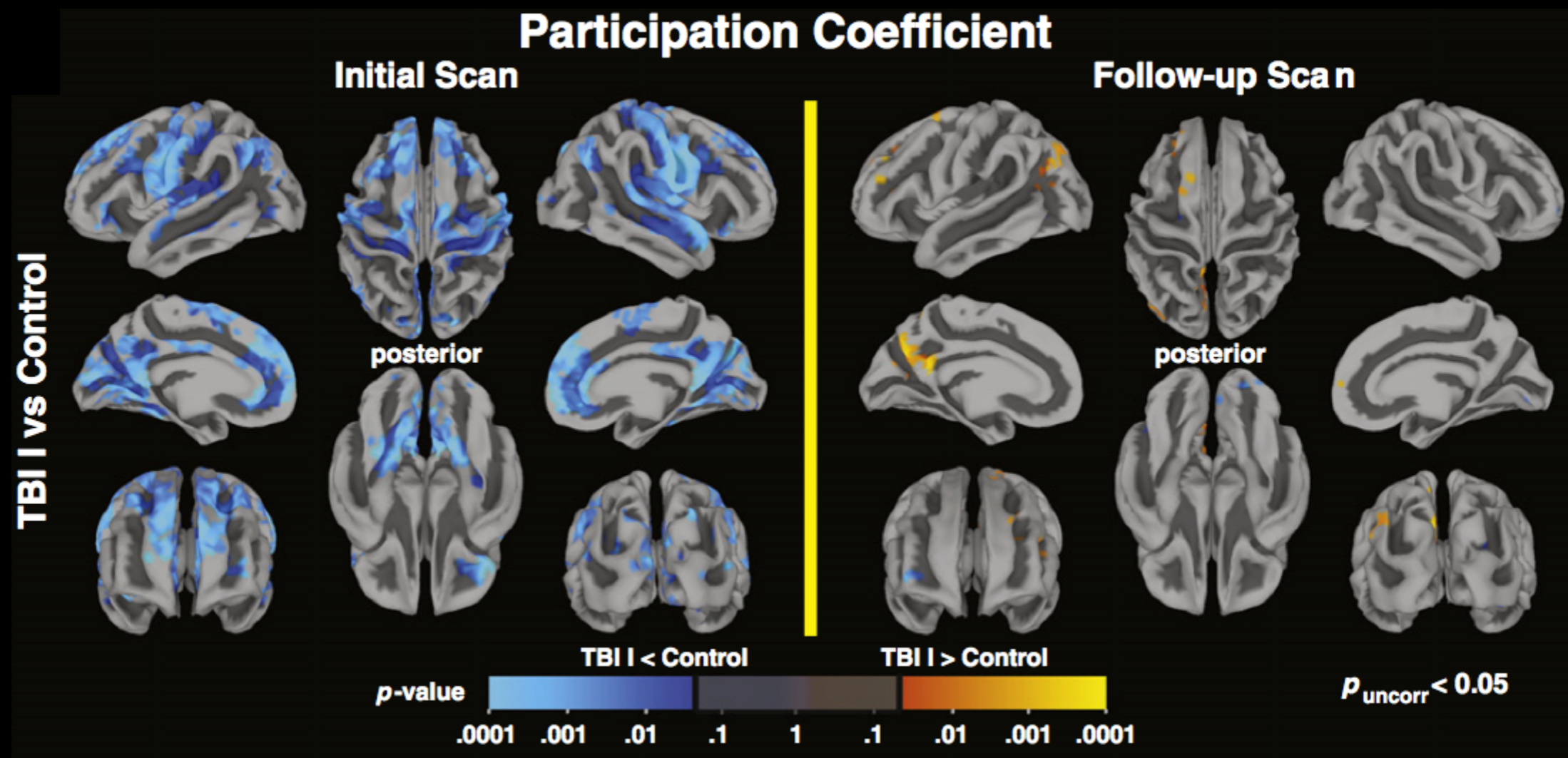
Hubs

Chapter 4: the neurosurgeon & real world connectomics



Biomarkers: 'blast injury'

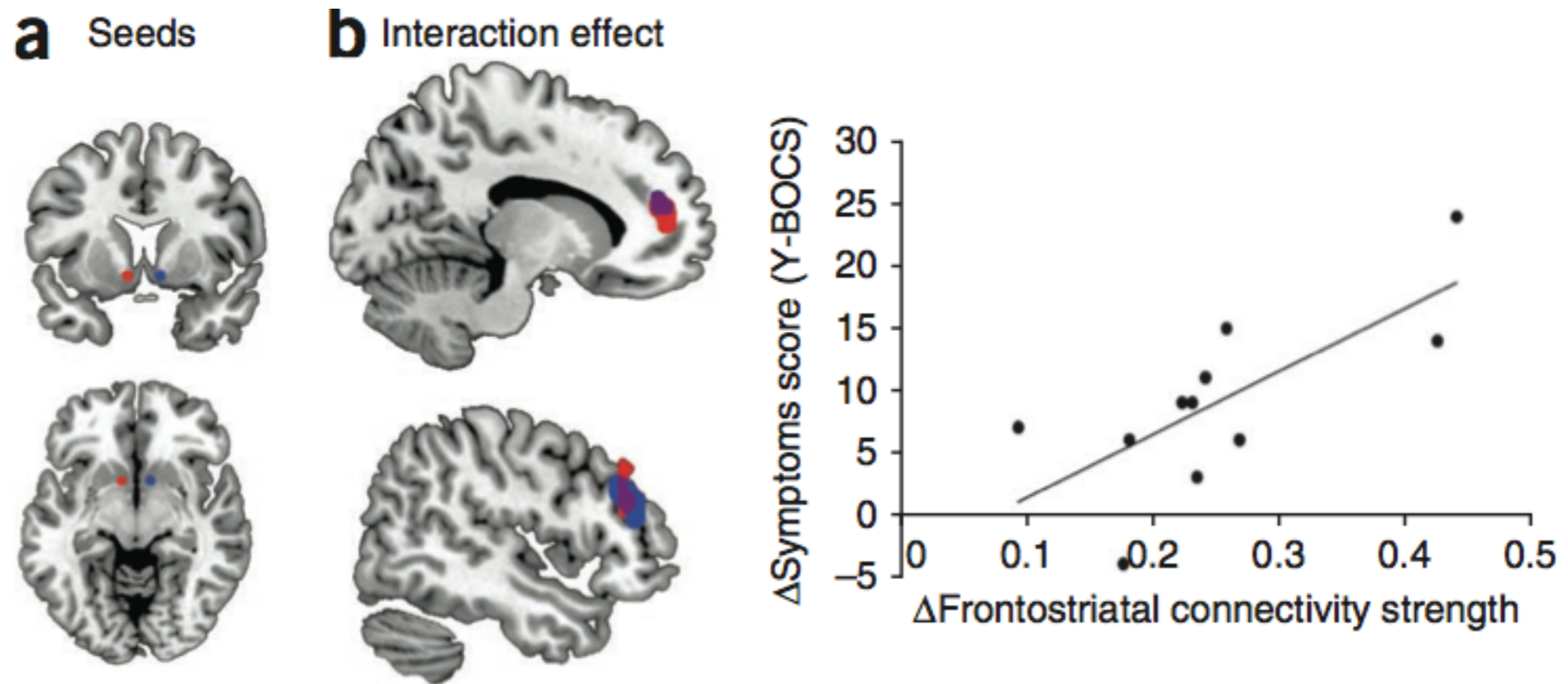
Reduced between module communication



Han et al, Neuroimage, 2014

Functional neurosurgery

DBS for obsessive compulsive disorder normalises fronto-striatal connectivity



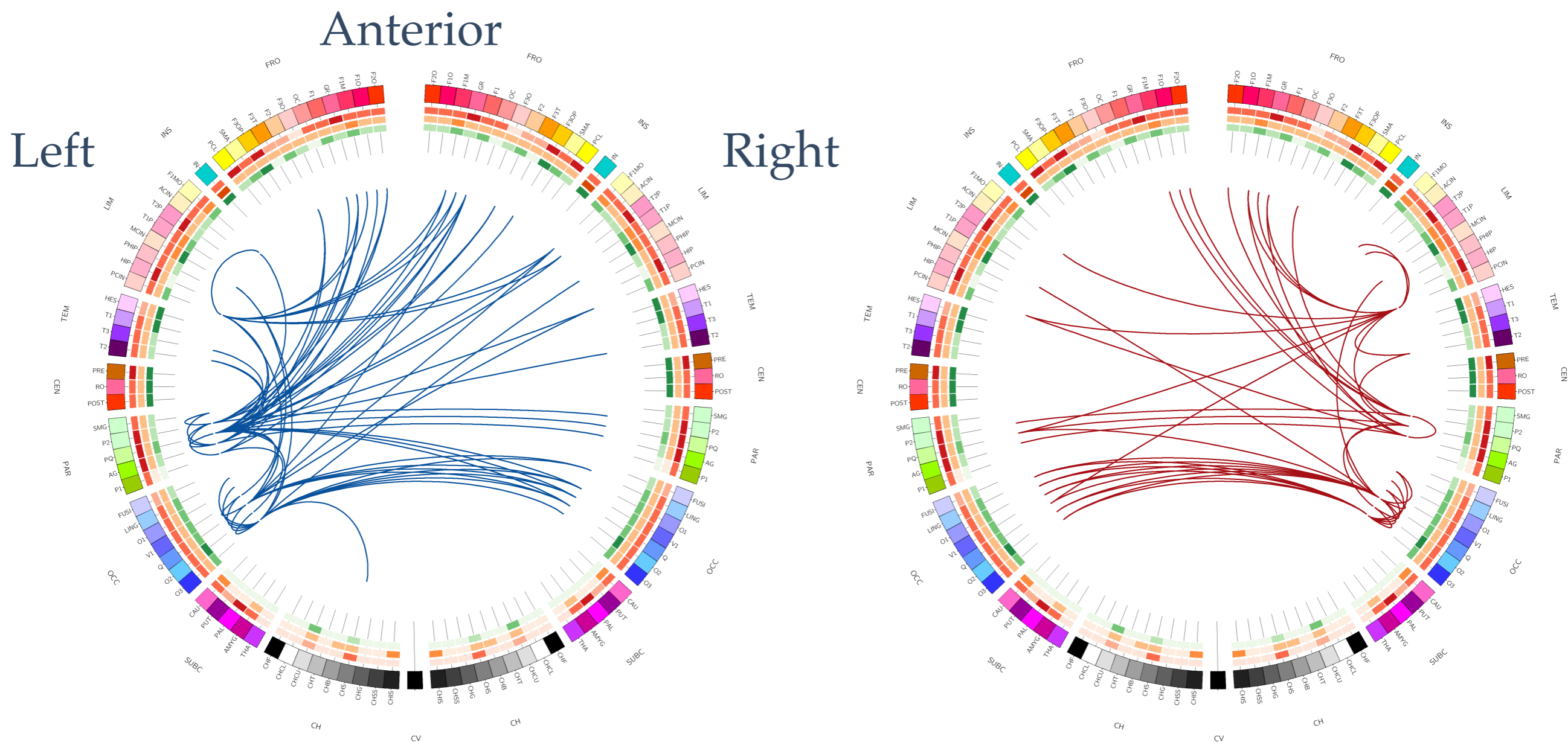
Figeet et al, Nature Neuroscience, 2013

What are the questions?

- ❖ Is function local or long distance?
- ❖ What is the localisation of cognition?
- ❖ Can we see what is going to happen?

“....and can we use this to plan what we do at surgery?”

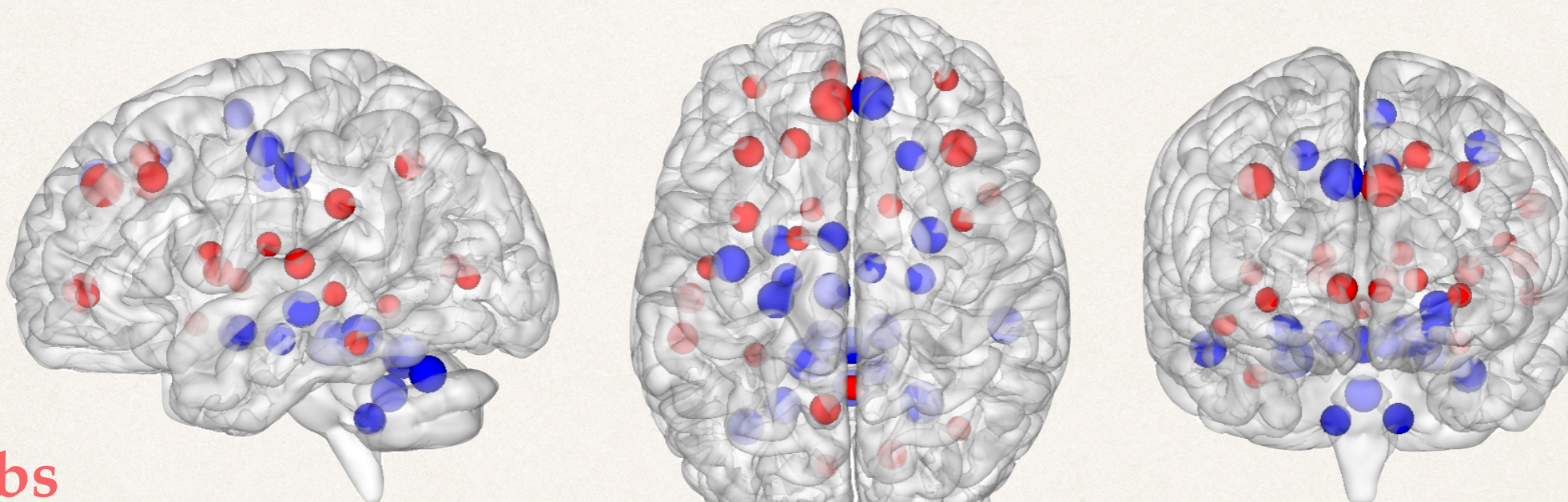
Distant effects of brain tumours



Healthy hemisphere
(contralateral to tumour)

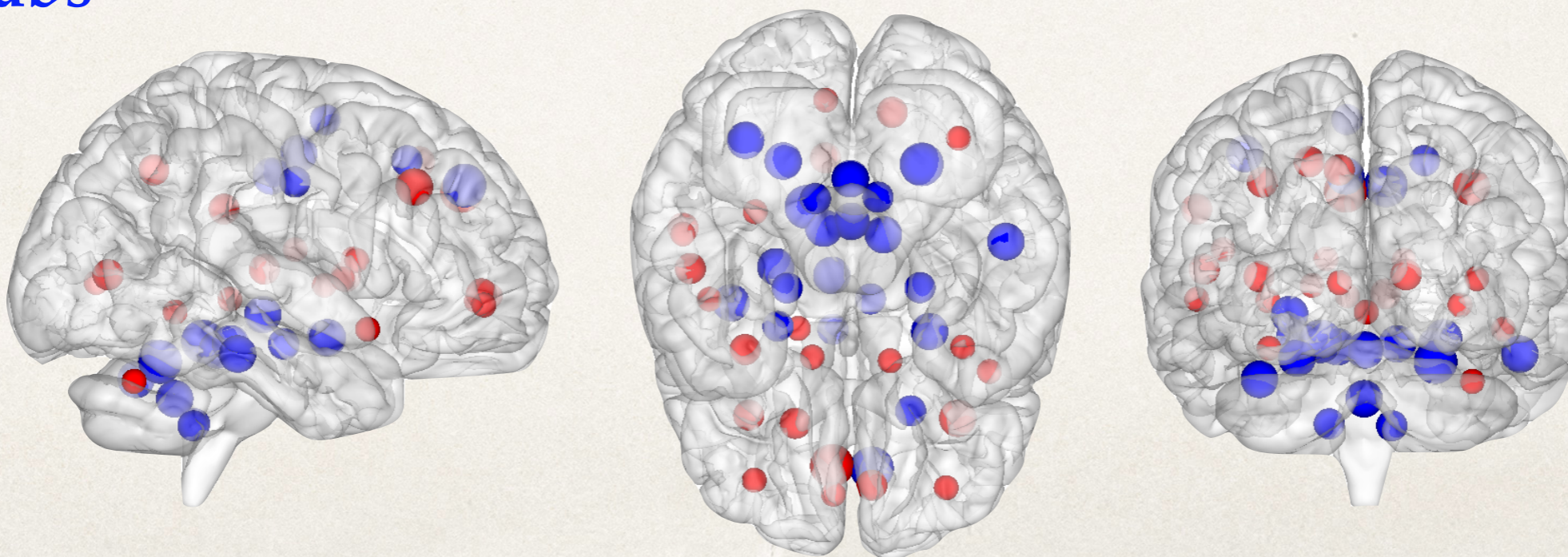
Peri-tumoural regions
“connections at risk”

Plasticity: new & absent hubs



new hubs

absent hubs

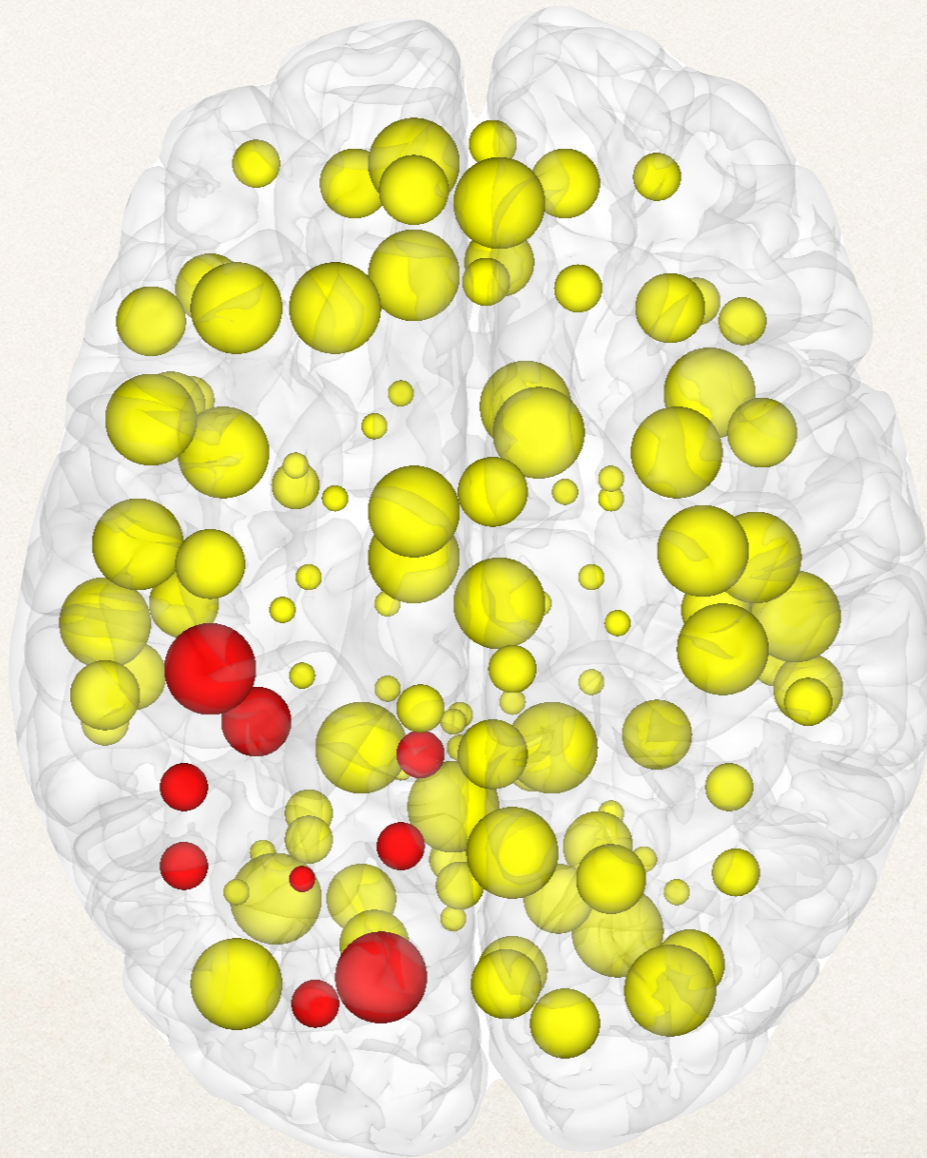


Predicted robustness / resilience

Spheres = nodes /
parcels / brain regions

Red = peri-tumoural
regions

Yellow = brain region
not adjacent to tumour

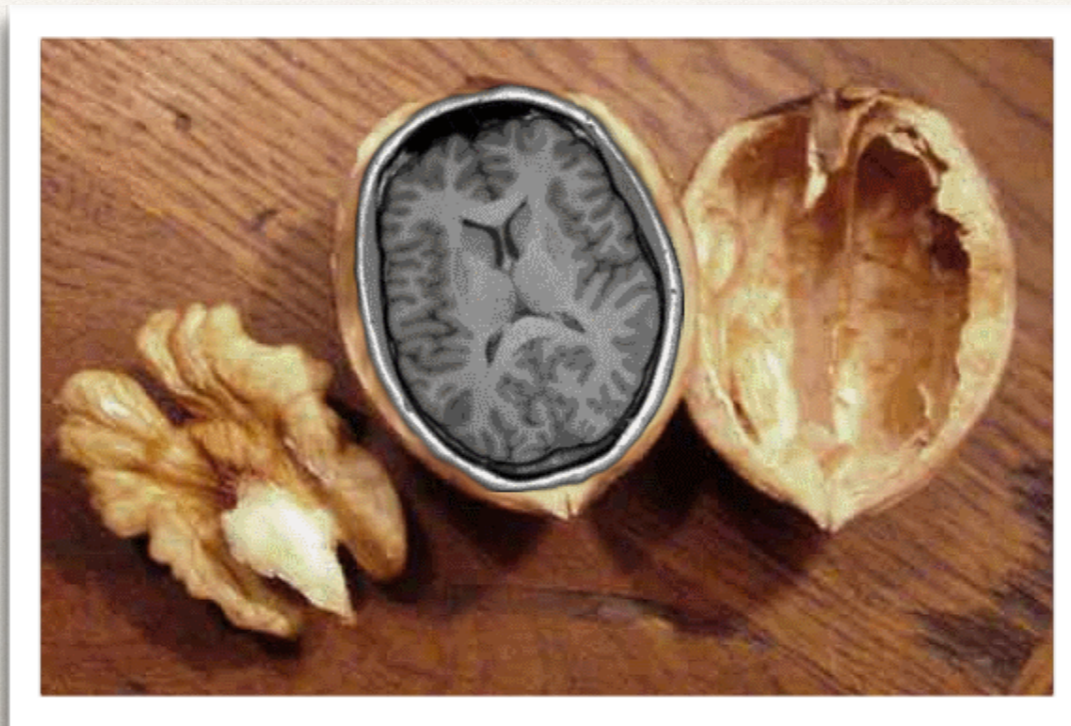


Size = reduction in
network efficiency on
node removal

Small = little effect

Big = larger effect
(‘network hubs’ or
‘central nodes’)

epilogue



The Connectome

- ❖ Paradigm shift in neuroscience
- ❖ Small world encompassing connectivity *and* localisation
- ❖ Hubs & 'cognitive eloquence'
- ❖ New 'graph theory' language for:
 - ❖ functional brain mapping
 - ❖ lesion modelling
 - ❖ dynamic changes & plasticity

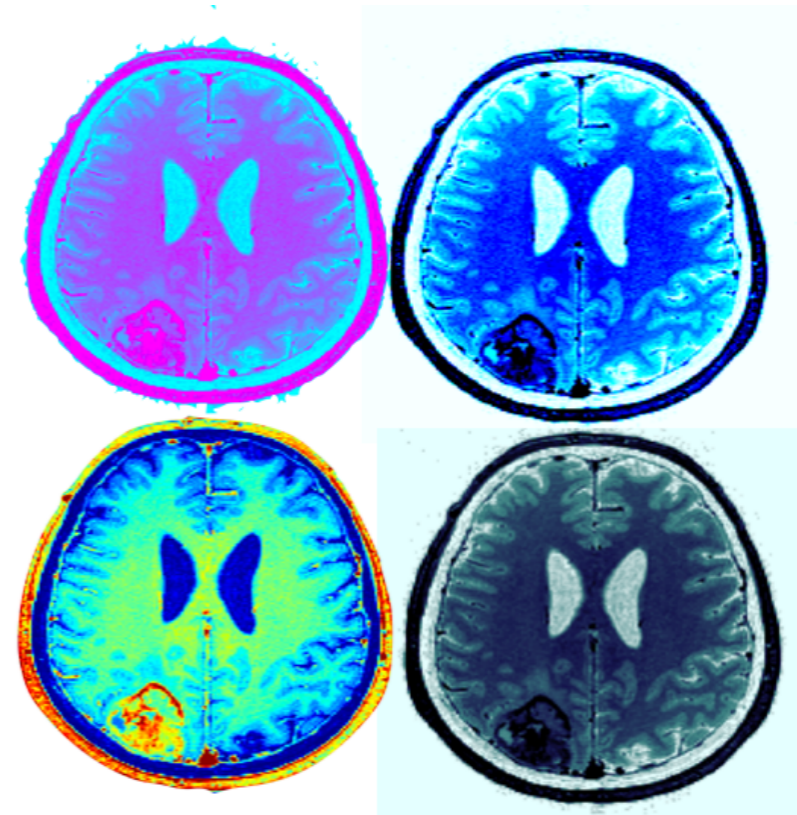
The End



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