

# Dissertation: Background and Literature

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## 1 Brain Formation

### 1.1 Parsimonious principles

These reach back very far to as Ramon y Cajal (1899).

#### 1.1.1 Network wiring cost

There is overwhelming evidence in favor of this hypothesis (Bullmore and Sporns 2012):

- Cost of building and maintaining axonal connections and speed of transmission increase in wiring volume which is proportional to length (D)
- White matter grows faster than grey-matter as function of brain size, driven by increase in axonal diameter and number synapses per neuron
- Fraction of grey matter neurons that send myelinated axons into white matter slowly reduces with brain size
- The probability distribution of connection distances is skewed towards short distances that will be relatively parsimonious in wiring cost

Factors which potentially explain the deviations from this simple wiring principle (Bullmore and Sporns 2012):

- Volume exclusions = Due to the limited size of the brain, axonal projections must perturbate from the straight line connection
- Functional properties = Example: Monosynaptic vs. Polysynaptic nerves, when you need low latency you would build a high cost long axonal connection

#### 1.1.2 Network running cost

Not part of Cajal's initial principal's, but metabolic cost of running the brain has become an increasingly important principle for network formation.

- Bigger brains are metabolically more expensive

## 2 Generative network models

These models were first developed and applied to connectome data by Betzel et al. (2016).

## 2.1 Evaluation

$$E = \max(KS_k, KS_c, KS_b, KS_e)$$

to quantify the difference between the synthetic and observed data using the Kolmogorov-Smirnov statistic. The corresponding statistic is computed for every vertex, and then the distributions are compared.

- $KS_K$  Nodal degree = Number of edges that are incident to a vertex
- $KS_C$  Clustering (coefficient) = Measure of the degree to which nodes in a graph tend to cluster together, proportion of possible connections realized among the neighbors of a vertex (Where the neighbor of a vertex are all the other connected vertices)
- $KS_b$  Betweenness centrality = Measures the centrality of a vertex by investigating the number of shortest paths that pass through the vertex (For every pair of vertices there exists a shortest path between them minimizing either the number of edges or the summed weights of the edges)
- $KS_e$  Edge length = Sum of all the edge length that are incident to a vertex

## 2.2 Optimization

### 2.3 Rules

#### 2.3.1 Geometric

- Promotion of low cost connections is promoted, but forming only the shortest connections, produces lack of long distance connections, which increases path length, and reduces efficiency
- Problems in reproducing clustering and edge length distributions simultaneously ( $KS_c, KS_e$ ), this is because strong distance penalty required to make high clustering but then lacking long distance connections

#### 2.3.2 Degree

#### 2.3.3 Clustering

#### 2.3.4 Homophilic

##### 2.3.4.1 Matching index

- Normalized measure of the overlap in two vertexes neighborhoods
- that eta and gamma seem to trade off with each other, such that a connectome is either shaped by geometry or non-geometric constraints

## 3 Graphs

### 3.1 Rich clubs

- Measure the extent by which well connected nodes are connected to each other
- Networks of high rich-club coefficients have many connections between nodes of high degree

## 4 Random dictionary

- Gray matter = Composed of the neurons (appears darker due to higher levels of melanin)
- White matter = Mainly made up of myelinated axons also called tracts (light appearance through the lipid content of myelin)

- Monosynaptic reflex = There is only one synapse between the afferent nerve and the efferent nerve (slow latency)
- Polysynaptic reflex = There are more than one synapse between the nerves, such that there is higher latency

## References

- Betzel, Richard F., Andrea Avena-Koenigsberger, Joaquín Goñi, Ye He, Marcel A. De Reus, Alessandra Griffa, Petra E. Vértes, et al. 2016. “Generative Models of the Human Connectome.” *NeuroImage* 124 (January): 1054–64. <https://doi.org/10.1016/j.neuroimage.2015.09.041>.
- Bullmore, Ed, and Olaf Sporns. 2012. “The Economy of Brain Network Organization.” *Nature Reviews Neuroscience* 13 (5): 336–49. <https://doi.org/10.1038/nrn3214>.