Modeling Cortical Synchronization on Brain-Like Networks

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"As long as our brain is a mystery, the universe, the reflection of the structure of the brain, will also be a mystery."
-Santiago Ramon y Cajal (1852 - 1934)

"The mind is everything. What you think you become."
- Gautama Buddha

Main References

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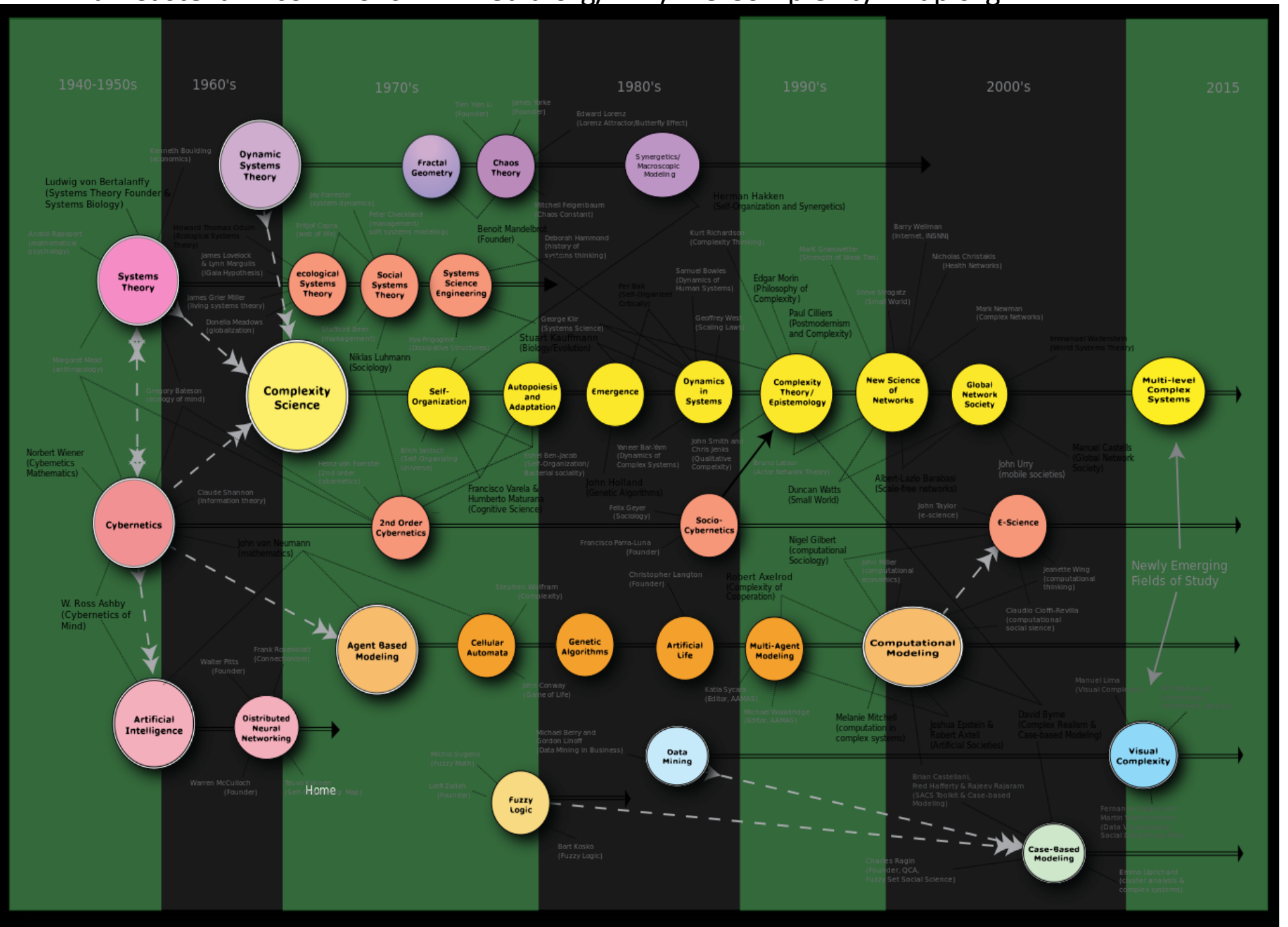
- 2. Strogatz S (2000). "From Kuramoto to Crawford: Exploring the onset of synchronization in populations of coupled oscillators".Physica D 143 (1–4): 1–20
- 3. Bullmore, E.T, Sporns, O. “Complex brain networks: graph-theoretical analysis of structural and functional systems.” Nature Reviews Neuroscience 10, 186-198
- 4. Newman, Mark. Networks: an introduction. Oxford University Press, 2010.

A little bit about me

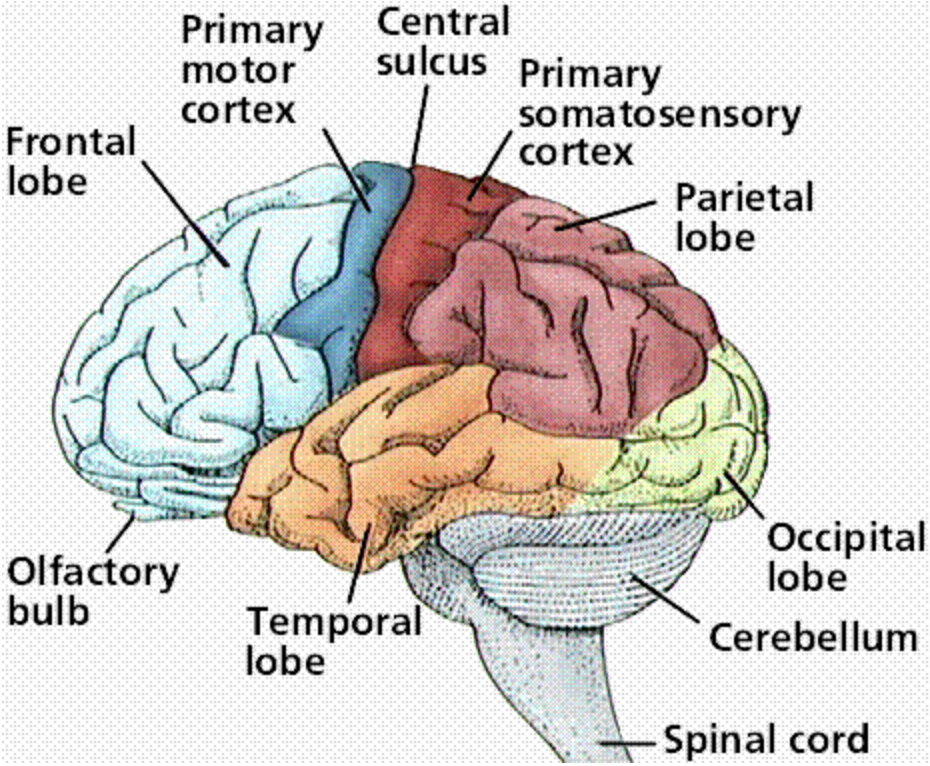
- Woodstock School, Sarah Lawrence College
- http://www.complex-systems.meduniwien.ac.at/about/
- Bard Ermentrout

Brian Castellani: commons.wikimedia.org/wiki/File:Complexity_Map.svg

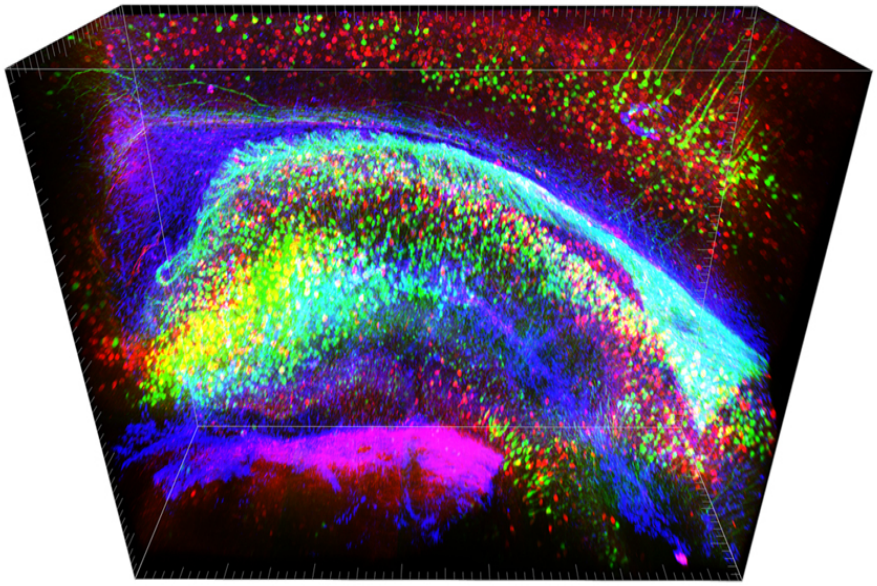


Fireflies in the Brain

- http://www.youtube.com/watch?v=sROKYelaWbo
- http://www.youtube.com/watch?v=tRPuVAVXk2M

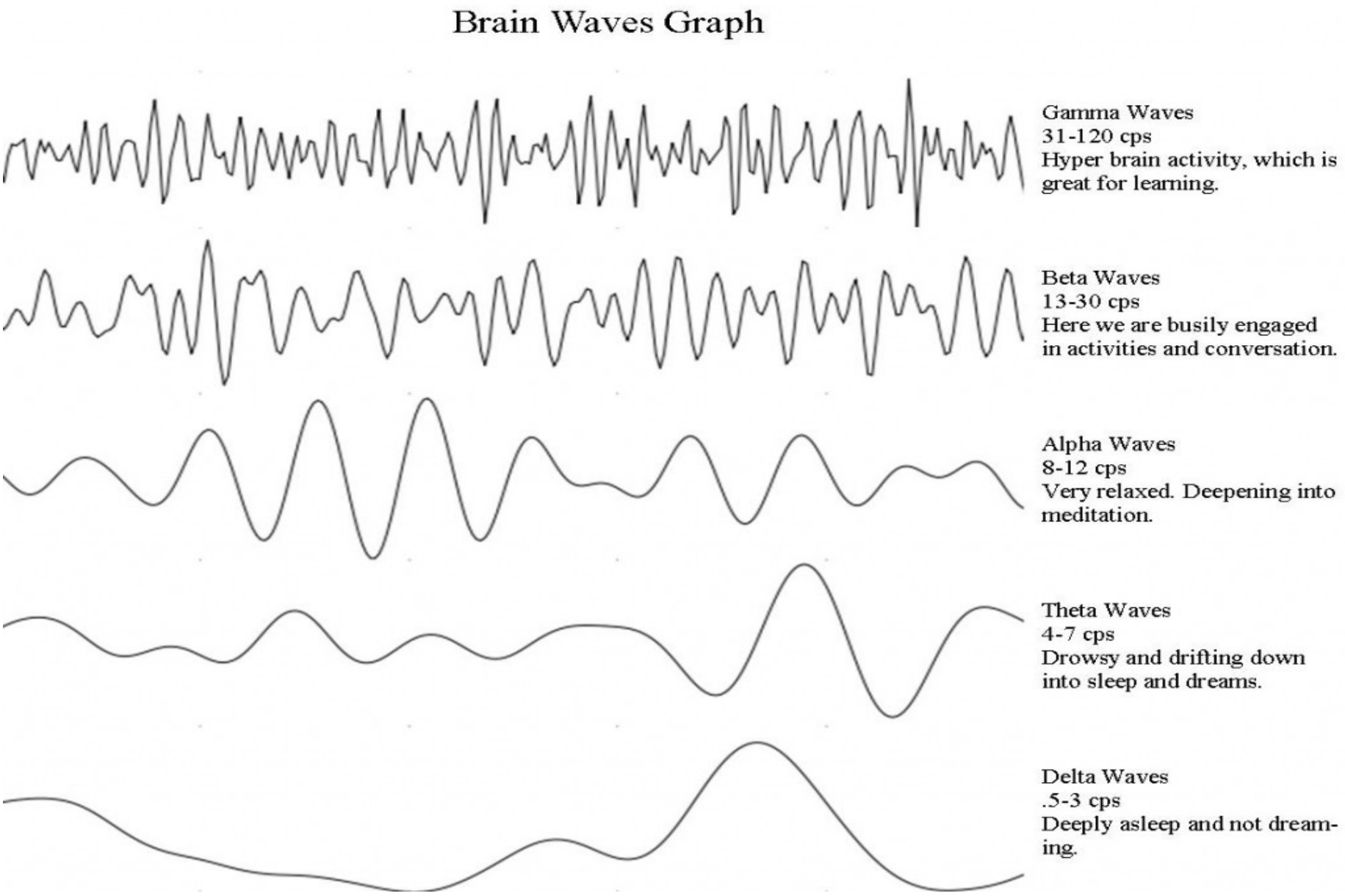


http://www2.estrellamountain.edu/faculty/farabee/biobk/biobooknerv.html



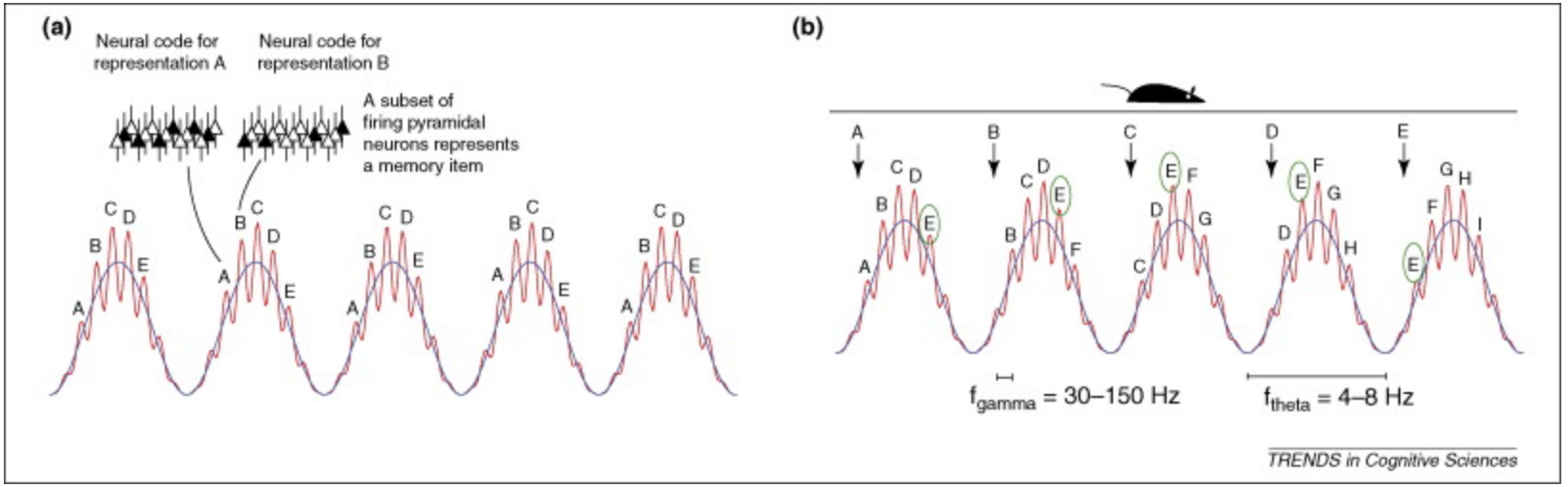
http://clarityresourcecenter.com/images/lineH_PV_GFAP_hipp.jpg

- This is where the magic happens



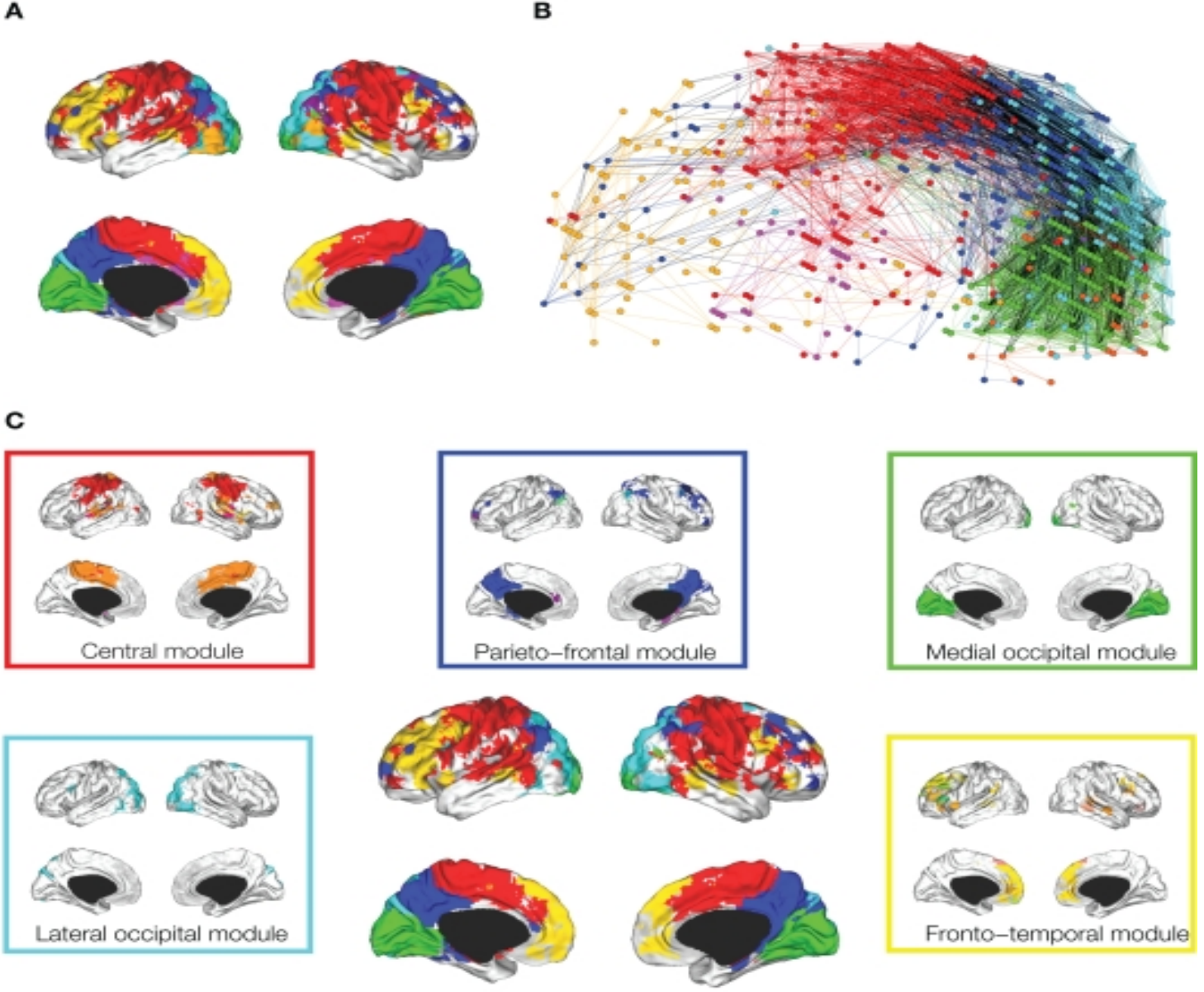
- http://blog.world-mysteries.com/science/the-unity-of-life-consciousness/

Temporal Encoding



- Jensen, O, Colgin, L.L. "Cross-frequency coupling between neuronal oscillations." Trans in Cog. Sci. 11 (7), 267-269

- Interspike Intervals
- Long-range communication by slow waves
- Intracortical communication by fast waves
- Why do we have 7 digit telephone numbers?



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Synchrony in the Brain

- Perception Binding Problem (γ)
- Working Memory (γ & θ)
- Selective Attention (α suppression, γ processing)
- Multi-tasking (γ, α, β, cross frequency coupling)

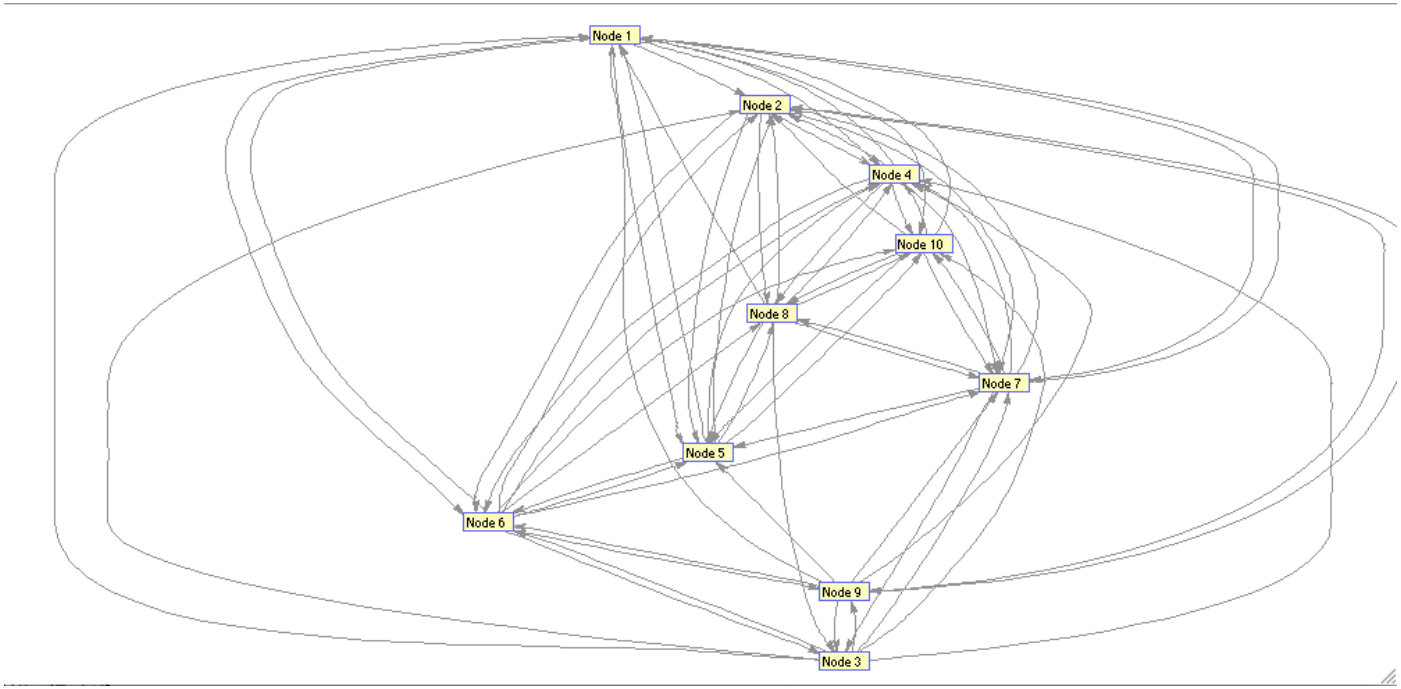
Dynamics approach to Brain

- complex (adj.): … from Latin complexus "surrounding, encompassing,"…from com- "with" (see com-) + plectere "to weave, braid, twine, entwine," from PIE *plek-to-, from root *plek- "to plait" (etymonline.com)
- Cognitive "Phase Space" & associated notions – E.g Churchland Lab, Gotham Brain Dynamics, **Walter Freeman** @ Berkeley
- Robustness
- Self-Organization

Matrices and Measures of Networks

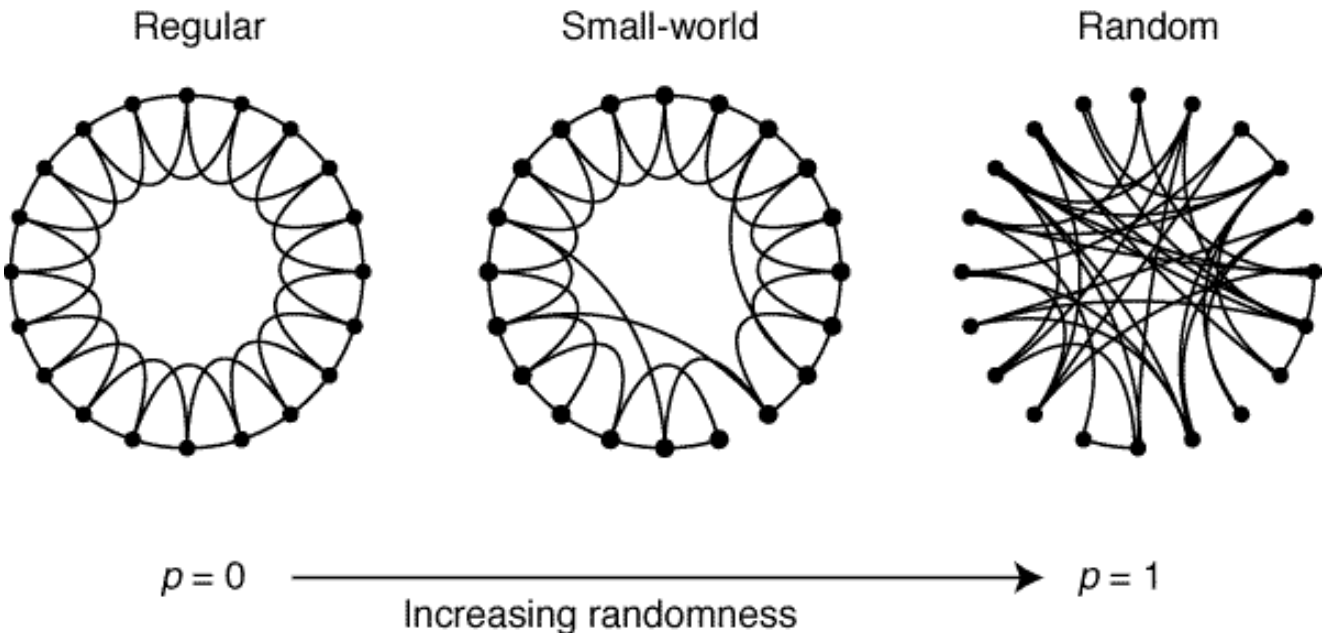
- The Adjacency Matrix
  - Edges and Nodes
  - Degree of a node
  - Path length
  - Clustering
  - Modularity

Erdos-Renyi Random Nets



Erdos Renyi Random Network with wiring probability 70%, n = 10

Small-World Networks



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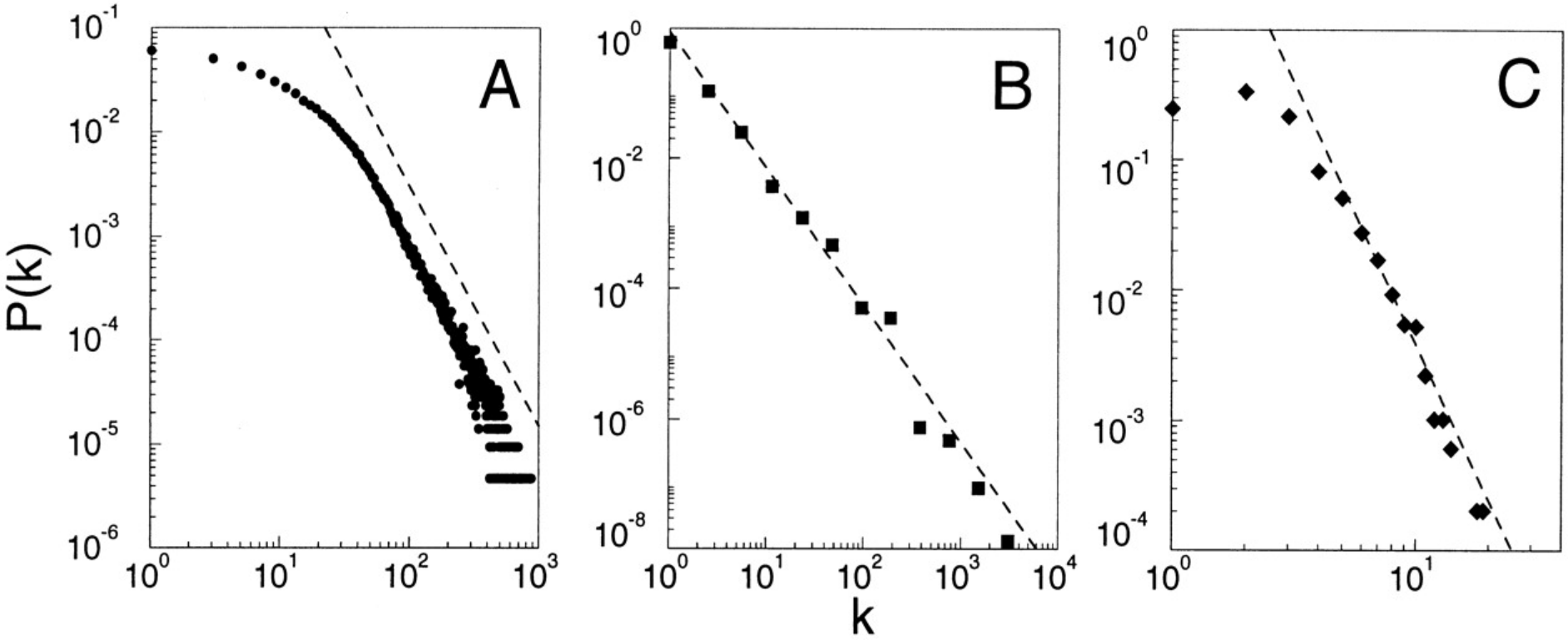
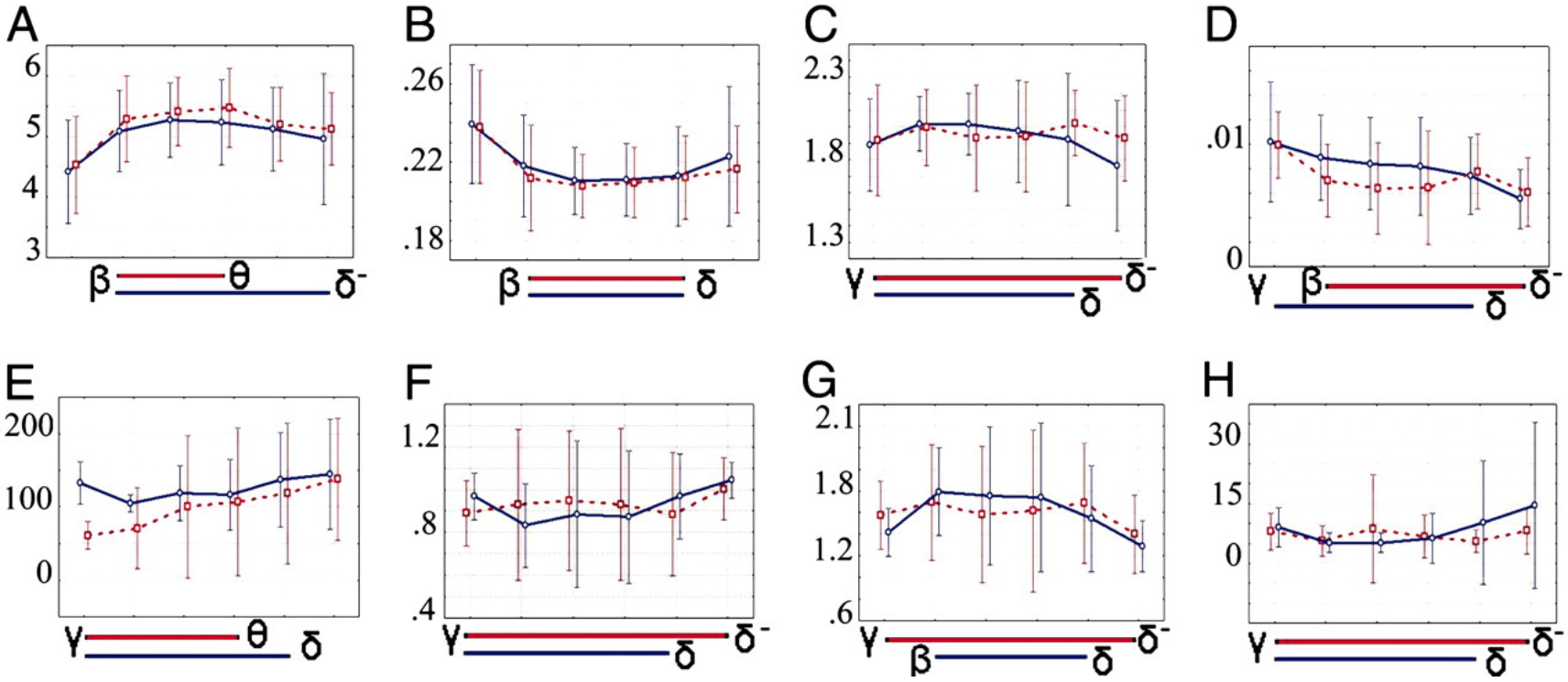
Scale-Free Networks



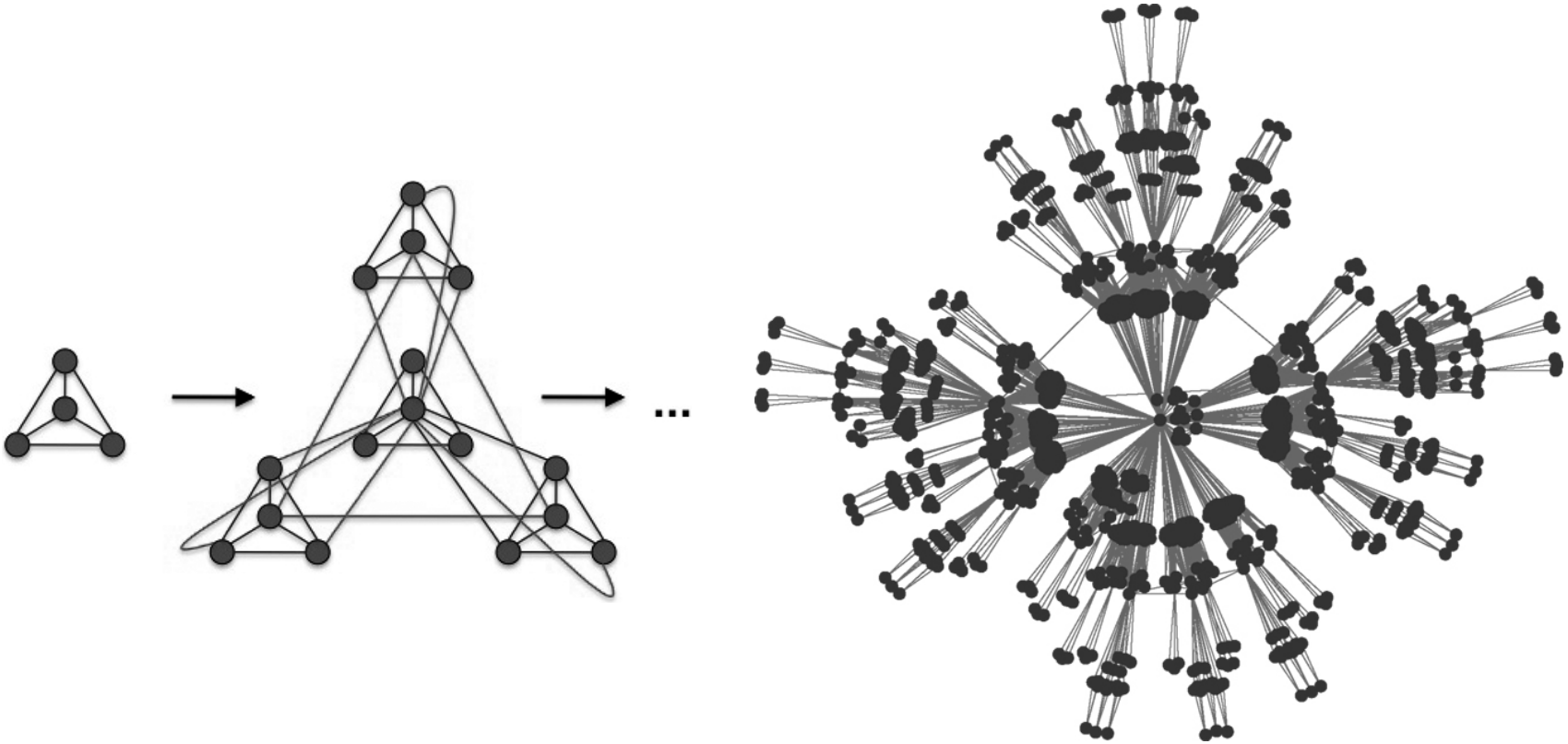
Barabasi, A.L., Albert, R. “Emergence of scaling in random networks.” 1999, Science 286, 509

Functional Cortical Systems



- Bassett, D. S., et al. "Adaptive reconfiguration of fractal small-world human brain functional networks." Proc. Natl Acad. Sci. USA 103, 19518–19523 (2006).

Modularity and Hierarchical Organization



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The Kuramoto Model

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- Kuramoto Y. “Chemical Oscillations, Waves, and Turbulence” Springer-Verlag Berlin 1984

Simulations

The FUTURE