

# CS 4884: Projects

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# Project 1: Small-Worldness of Fly Connectome

## A Connectome of the Adult *Drosophila* Central Brain

① C. Shan Xu, ② Michal Januszewski, ③ Zhilyuan Lu, Shin-ya Takemura, ④ Kenneth J. Hayworth, Gary Huang, Kazunori Shinomiya, ⑤ Jeremy Mattin-Shepard, David Ackerman, Stuart Berg, Tim Blakely, ⑥ John Bogovic, Jody Clements, Tom Dolafi, ⑦ Philip Hubbard, ⑧ Dagmar Kalnmueller, ⑨ William Katz, Takashi Kawase, Khaled A. Khairy, Laramie Leavitt, ⑩ Peter H. Li, Larry Lindsey, ⑪ Nicole Neubarth, Donald J. Olbris, Hideo Otsuna, Eric T. Troutman, Lowell Umayam, Ting Zhao, Masayoshi Ito, Jens Goldammer, Tanya Wolff, Robert Svirskas, ⑫ Philipp Schlegel, ⑬ Erika R. Neace, ⑭ Christopher J. Knecht Jr., ⑮ Chelsea X. Alvarado, ⑯ Dennis A. Bailey, ⑰ Samantha Ballinger, ⑱ Jolanta A Borycz, ⑲ Brandon S. Canino, Natasha Cheatham, ⑳ Michael Cook, Marisa Dreher, ㉑ Octave Duclos, ㉒ Bryon Eubanks, Kelli Fairbanks, ㉓ Samantha Finley, ㉔ Nora Forknall, ㉕ Audrey Francis, ㉖ Gary Patrick Hopkins, ㉗ Emily M. Joyce, ㉘ SungJin Kim, ㉙ Nicole A. Kirk, ㉚ Julie Kovalyak, ㉛ Shirley A. Lauchle, ㉜ Alanna Lohff, ㉝ Charli Maldonado, ㉞ Emily A. Manley, ㉟ Sari McLin, ㊱ Caroline Mooney, ㊲ Miatta Ndama, ㊳ Omotara Ogundeyi, ㊴ Nneoma Okeoma, ㊵ Christopher Ordish, ㊶ Nicholas Padilla, ㊷ Christopher Patrick, Tyler Paterson, Elliott E. Phillips, ㊸ Emily M. Phillips, ㊹ Neha Rampally, ㊺ Caitlin Rbelro, ㊻ Madelaine K Robertson, ㊼ Jon Thomson Rymer, ㊽ Sean M. Ryan, ㊾ Megan Sammons, Anne K. Scott, ㊿ Ashley L. Scott, ① Aya Shinomiya, Claire Smith, Kelsey Smith, ② Natalie L. Smith, ③ Margaret A. Sobeski, ④ Alla Suleiman, Jackie Swift, ⑤ Satoko Takemura, ⑥ Iris Talebi, ⑦ Dorota Tarnogorska, ⑧ Emily Tenshaw, ⑨ Temour Tokhi, ⑩ John J. Walsh, Tansy Yang, ⑪ Jane Anne Horne, Feng LJ, ⑫ Ruchi Parekh, ⑬ Patricia K. Rivlin, ⑭ Vivek Jayaraman, Kel Ito, Stephan Saalfeld, Reed George, ⑮ Ian Meinertzhagen, ⑯ Gerald M. Rubin, Harald F. Hess, ⑰ Louis K. Scheffer, ⑱ Viren Jain, ⑲ Stephen M. Plaza

doi: <https://doi.org/10.1101/2020.01.21.911859>

- Goal: Determine if this network has the small-world property.
- Challenge: network has 25K nodes and 3M edges

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- Goal: Determine if this network has the small-world property.
- Challenge: network has 25K nodes and 3M edges  $\Rightarrow$  need to compute 625M shortest paths.
- Devise sampling strategies to estimate average shortest path length efficiently.
- Do the same for clustering coefficient.
- How will you know that your estimates are accurate?

# Project 2: Clustering in Fly Connectome

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- Goal: Determine clusters in this network and connect them to functional regions in the fly brain.
- Challenge: network has 25K nodes and 3M edges  $\Rightarrow$  clustering algorithms are likely to be slow.

# Project 3: Routing in Connectomes 1

- How are signals propagated efficiently in brain networks?
- Does the brain use Dijkstra's algorithm?

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- How are signals propagated efficiently in brain networks?
- Does the brain use Dijkstra's algorithm?
- How does the brain route signals given a node's limited knowledge of entire network?

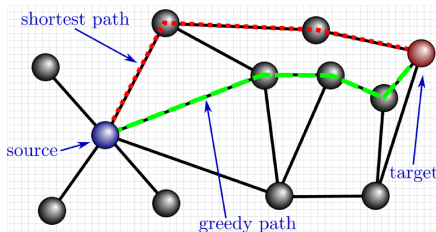
## Navigable maps of structural brain networks across species

Antoine Allard, M. Ángeles Serrano

Version 2



Published: February 3, 2020 • <https://doi.org/10.1371/journal.pcbi.1007584>



# Project 4: Routing in Connectomes 2

- Local-global strategy: combine diffusion and shortest-path approaches to routing.
- Changing one parameter smoothly transitions from one extreme to another.

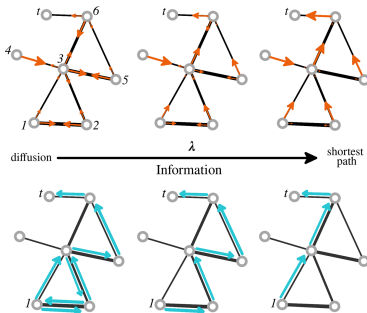
## A spectrum of routing strategies for brain networks

Andrea Avena-Koenigsberger , Xiaoran Yan, Artemy Kolchinsky, Martijn P. van den Heuvel, Patric Hagmann, Olaf Sporns

Version 2



Published: March 8, 2019 • <https://doi.org/10.1371/journal.pcbi.1006833>



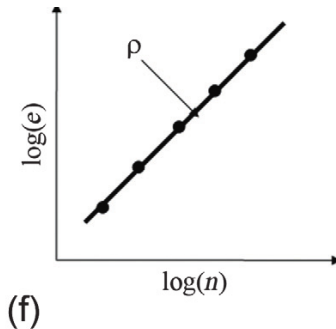
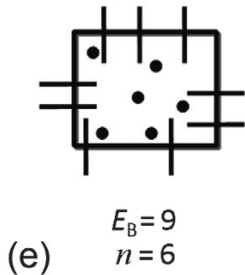


## Project 5: Rentian Scaling

- Brain networks are (believed to be) modular.
- How are connections between modules distributed within a network?

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- Brain networks are (believed to be) modular.
- How are connections between modules distributed within a network?
- Rentian scaling: Power-law relationship between number of nodes in a module and number of edges leaving module.
- Goal: Determine the Rentian scaling laws for different brain networks.
- Challenge: implement algorithms for topological/geometric Rentian scaling.



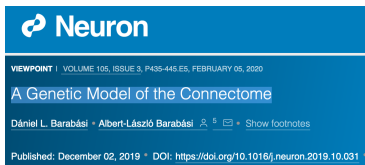
## Project 6: A Mouse Connectome

- Organizing principles for the cerebral cortex network of commissural and association connections: publication and analysis of a comprehensive connectome of the mouse brain, collected from findings in over 185 publications that appeared in the literature since 1974.
- Goal: Analyze the structural properties of this connectome.
  - ▶ Small-worldness
  - ▶ Efficiency
  - ▶ Clustering
- Additional challenge: correlate this network with the mouse connectome created independently by the Allen Institute for Brain Science.

# Project 7: Generative Models of Connectomes

- Connectomes arise from experimental observations of the brains of different organisms.
- What types of evolutionary processes in nature can generate the types of connectomes that exist in organisms?
- Several mathematical models that have been proposed for connectomes.
- Goal: test these models for their ability to generate artificial networks with properties that match those of real connectomes such as the small world property and modularity.
  - ▶ Resolving Structural Variability in Network Models and the Brain
  - ▶ Box 10.1: Growth Connectomics: Generative Models for Brain Networks
- Important question: should models incorporate geometric constraints imposed by the structure of the brain?

# Project 8: Genetic Model of the Connectome




- Why do connectomes of individuals of the same species show considerable architectural and wiring similarity?
- How is neuronal connectivity encoded at the protein level?

# Project 8: Genetic Model of the Connectome

## Neuron

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### A Genetic Model of the Connectome

Dániel L. Barabási • Albert-László Barabási   • [Show footnotes](#)

Published: December 02, 2019 • DOI: <https://doi.org/10.1016/j.neuron.2019.10.031> •

- Why do connectomes of individuals of the same species show considerable architectural and wiring similarity?
- How is neuronal connectivity encoded at the protein level?
- Hypothesis: genetic identity of neurons guides synapse formation.
- Predict the existence of specific biclique motifs in the connectome.

### 3x6 Biclique

Random:  $0.911 \pm 1.214$   
C. elegans: 173  
Z-Score: 142

