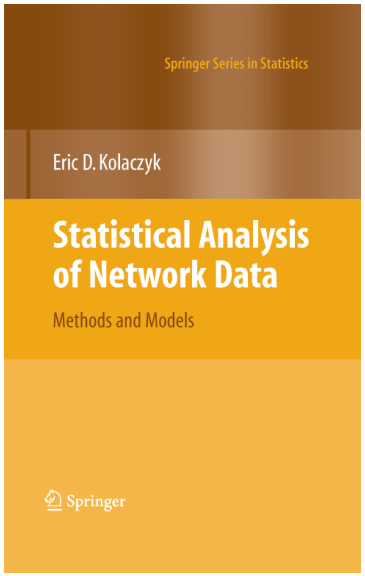
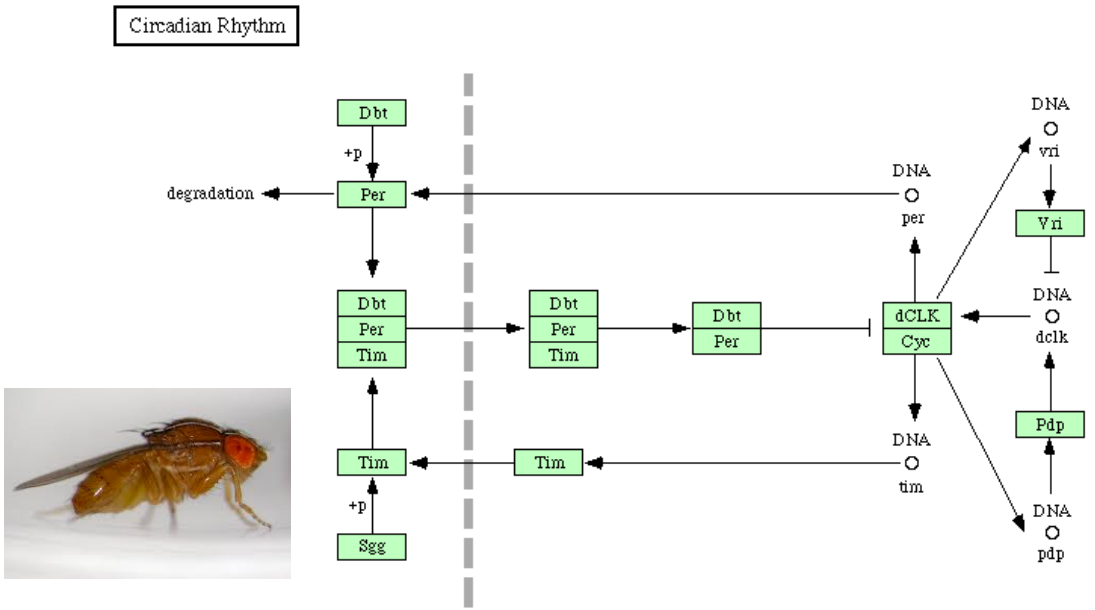
Reading material

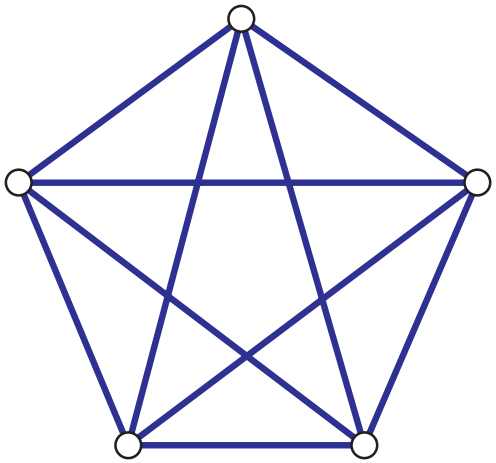
- We will use lecture slides to cover the material
  - $\Rightarrow$ Research papers, tutorials also posted in the class website
- Basic book I will follow is: Eric D. Kolaczyk, *"Statistical Analysis of Network Data: Methods and Models,"* Springer



Networks

- As per the dictionary: *A collection of inter-connected things*
- Ok. There are multiple things, they are connected. Two extremes



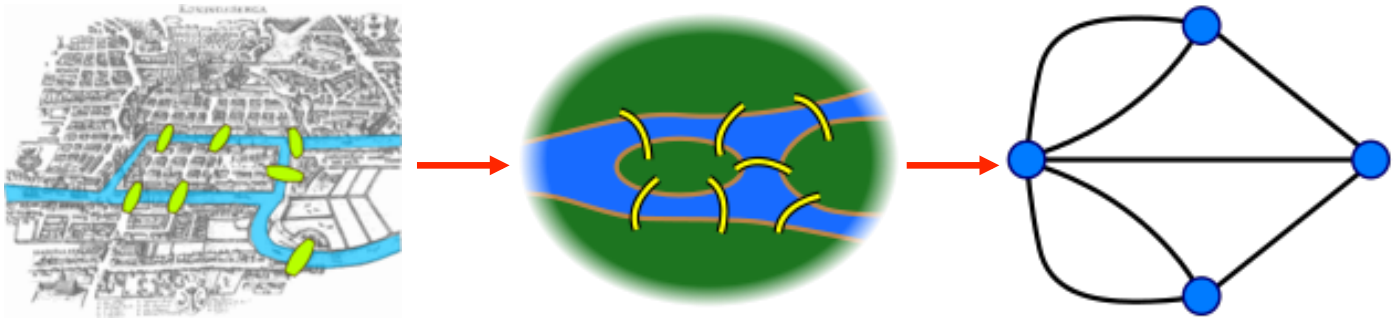


1) A real (complex) system of inter-connected components
2) A graph representing the system

- Understand complex systems $\Leftrightarrow$ Understand networks behind them

Historical background

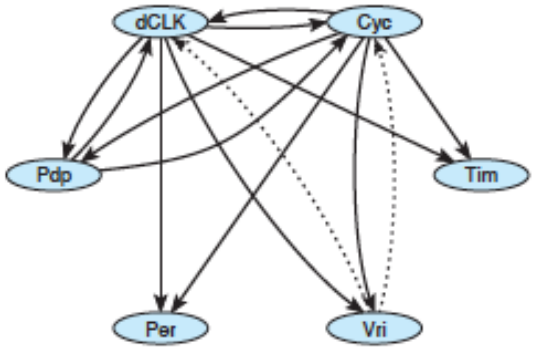
- Network-based analysis in the sciences has a long history
- Mathematical foundations of graph theory (L. Euler, 1735)

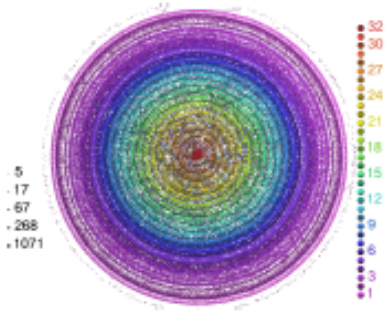


  - The seven bridges of Königsberg
- Laws of electrical circuitry (G. Kirchoff, 1845)
- Molecular structure in chemistry (A. Cayley, 1874)
- Network representation of social interactions (J. Moreno, 1930)
- Power grids (1910), telecommunications and the Internet (1960)
- Google (1997), Facebook (2004), Twitter (2006), ...

Why networks? Why now?

- Understand complex systems $\Leftrightarrow$ Understand networks behind them



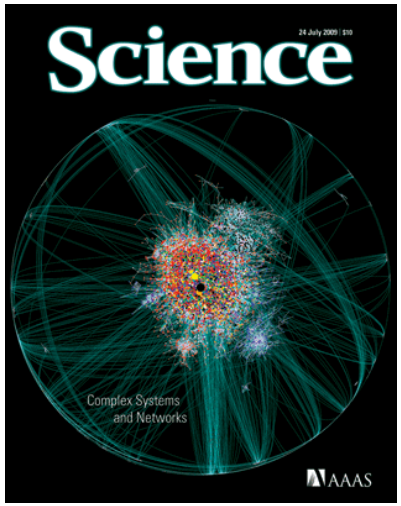


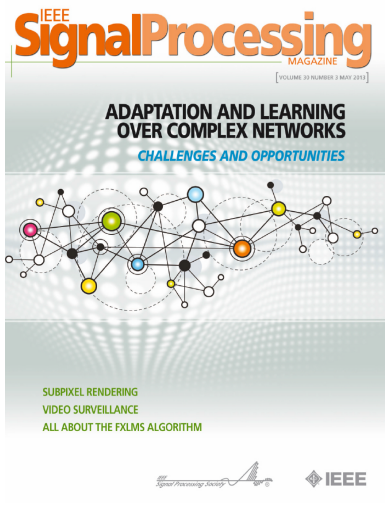
- Relatively small field of study up until $\sim$ the mid-90s
- Epidemic-like explosion of interest recently. A few reasons:
  - Systems-level perspective in science, away from reductionism
  - Ubiquitous high-throughput data collection, computational power
  - Globalization, the Internet, connectedness of modern societies

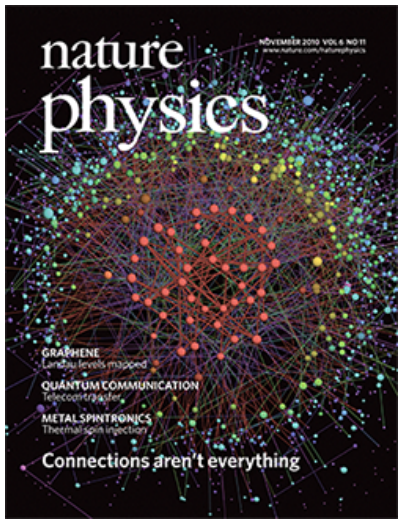
Network Science

- Study of complex systems through their network representations

  Ex: economy, metabolism, brain, society, Web, ...
- Universal language for describing complex systems and data
  - Striking similarities in networks across science, nature, technology
- Shared vocabulary across fields, cross-fertilization
  - From biology to physics, economics to statistics, CS to sociology







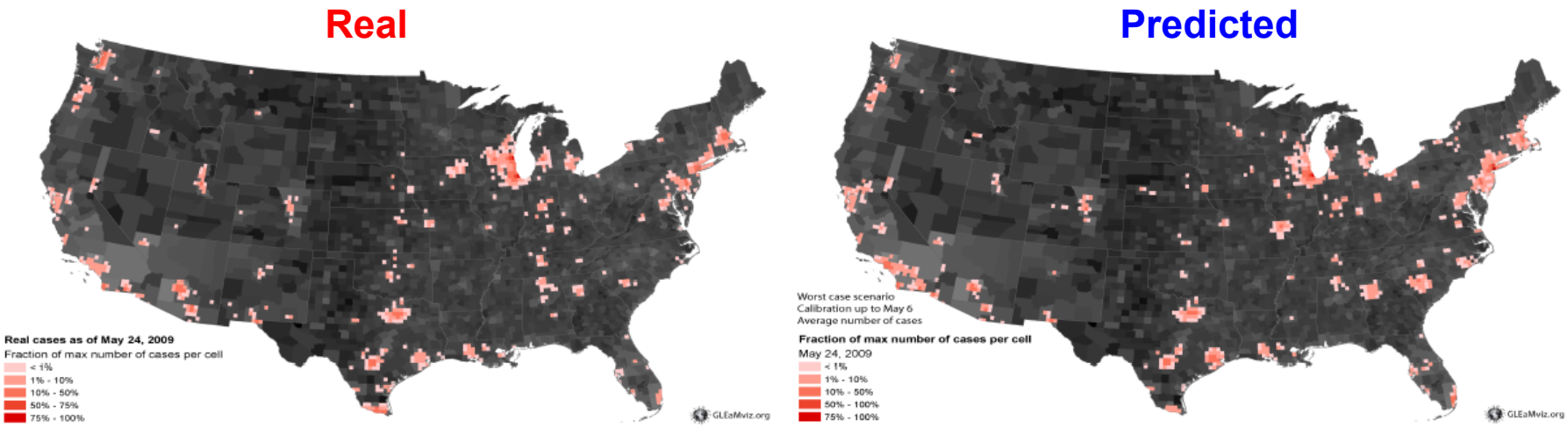
- Impact: social networking, drug design, smart infrastructure, ...

Economic impact

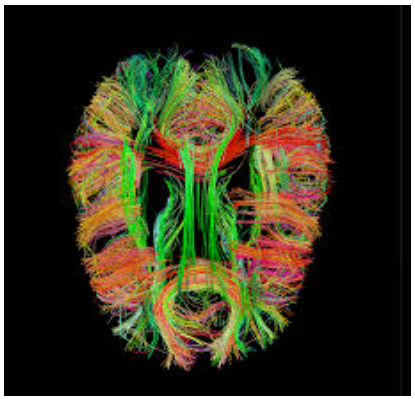
- Google
  Market cap:
  $547 billion
- Facebook
  Market cap:
  $326 billion
- Cisco
  Market cap:
  $150 billion
- Apple
  Market cap:
  $529 billion

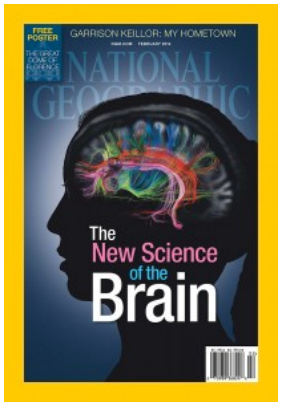
Healthcare impact

- Prediction of epidemics, e.g. the 2009 H1N1 pandemic



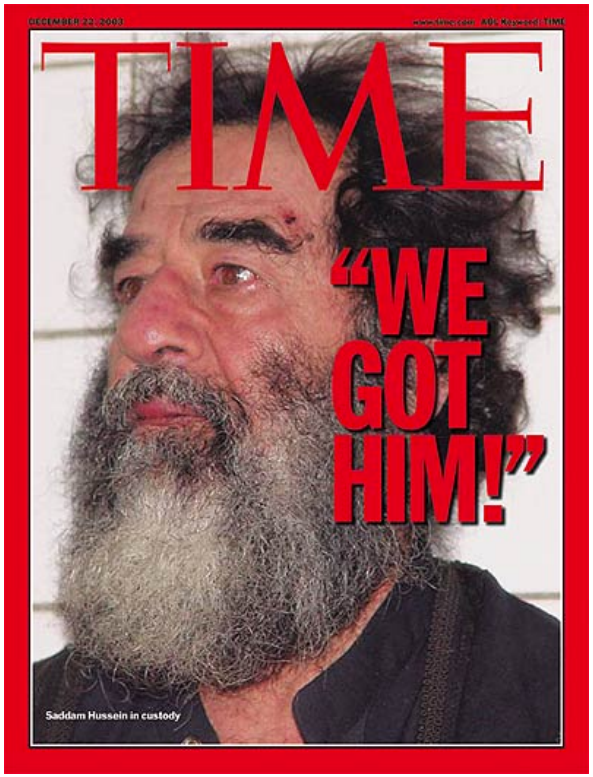
- Human Connectome Project to map-out brain circuitry

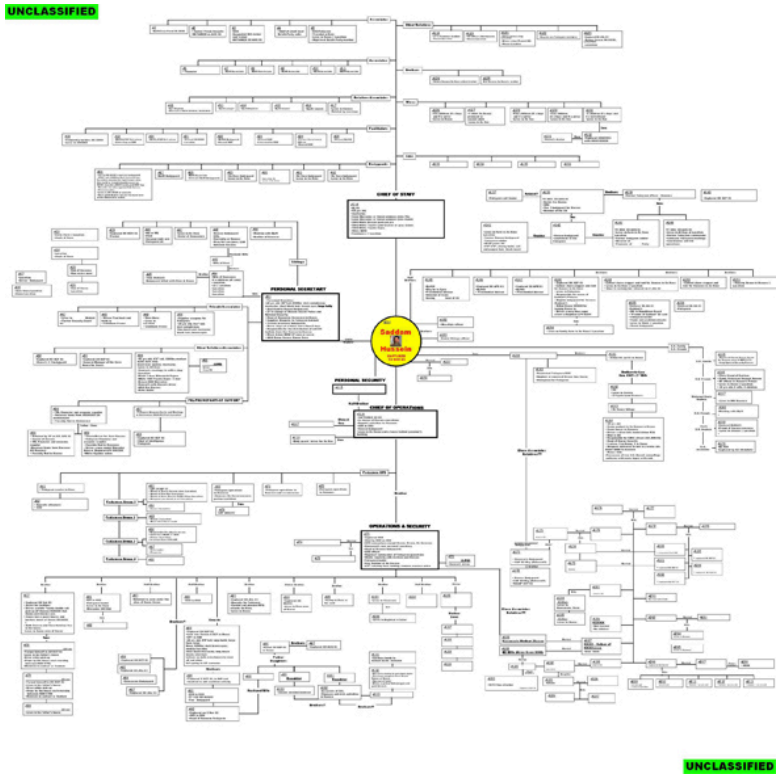




Homeland security impact

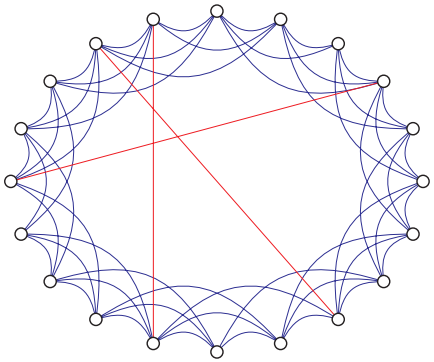
- Social network analysis key to capturing S. Hussein

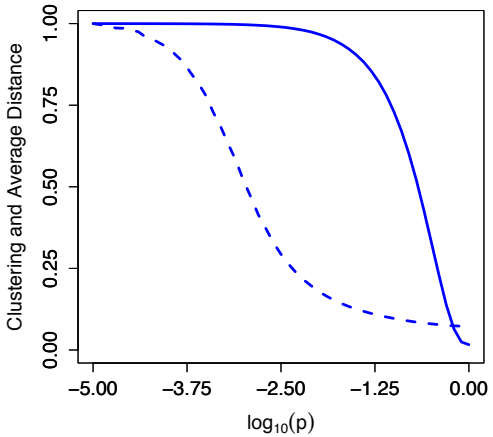




Sampling, modeling and inference of networks

- Watts-Strogatz model captures small-world structure in real graphs
  - Highly structured locally (like social groups); and
  - "Small" globally (like purely random graphs)

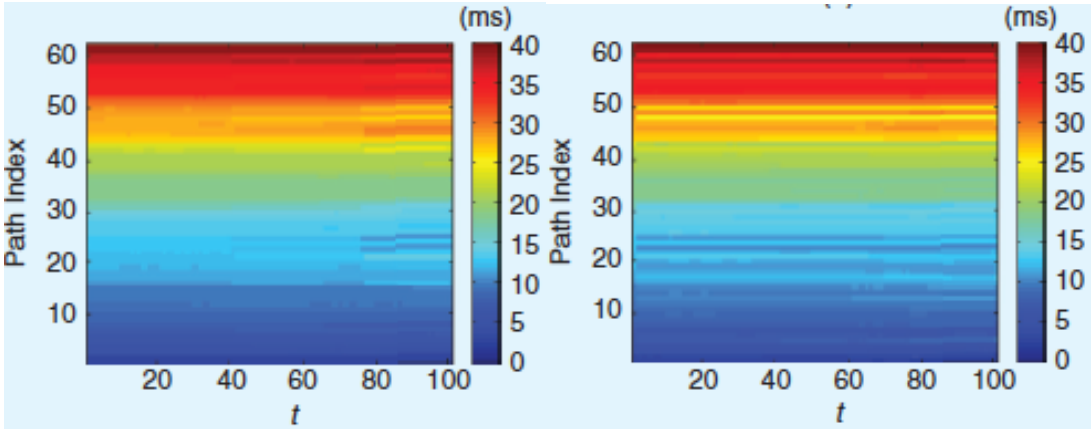




- Of interest: random graph models, network topology inference, growth models for evolving networks, preferential attachment
- Applications: detecting motifs, inferring gene-regulatory interactions, mapping the Internet, predicting popularity in Twitter

Processes evolving over network graphs

- Tracking of end-to-end delay in the Internet
  - Only 30 out of 62 paths sampled, routing induces spatial correlations
  - "Ground-thruth" delays compared to real-time estimates



- Of interest: Markov random fields, kernel regression on graphs, epidemic modeling, network flow models, traffic matrix estimation
- Applications: computer network health monitoring, electric load data cleansing, information cascades in social media, viral marketing