



UNIVERSITY of
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Network Science Analytics

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Networks

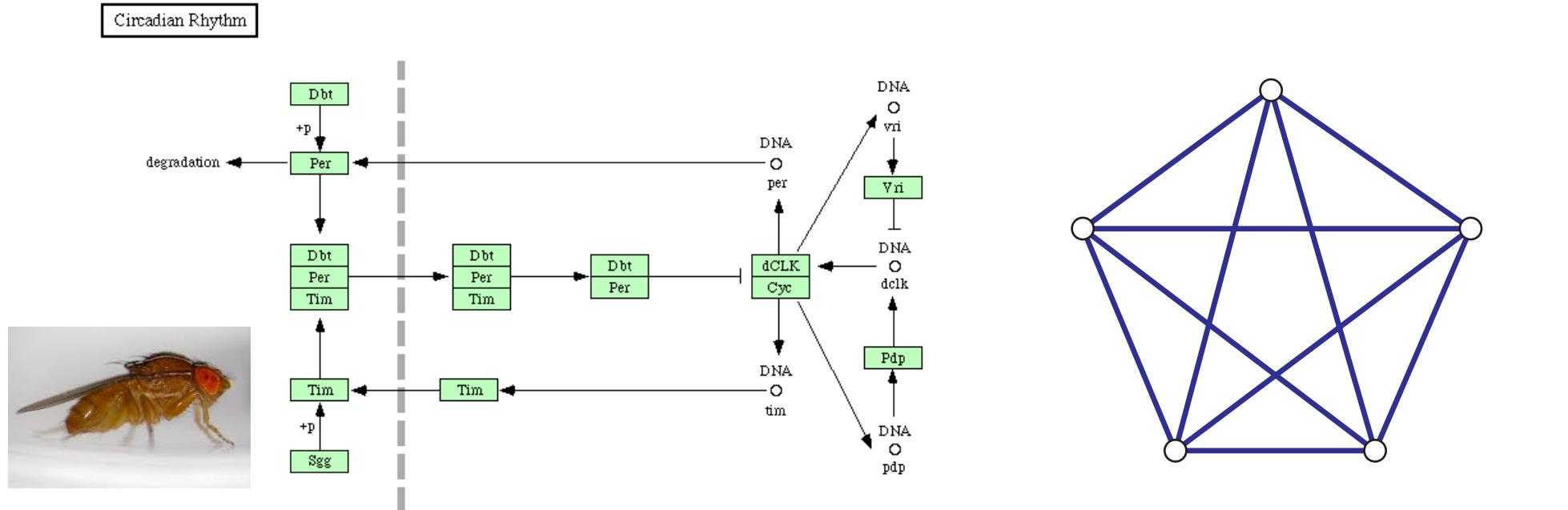
Introductions

Networks - A birds-eye view

Class description and contents

Networks

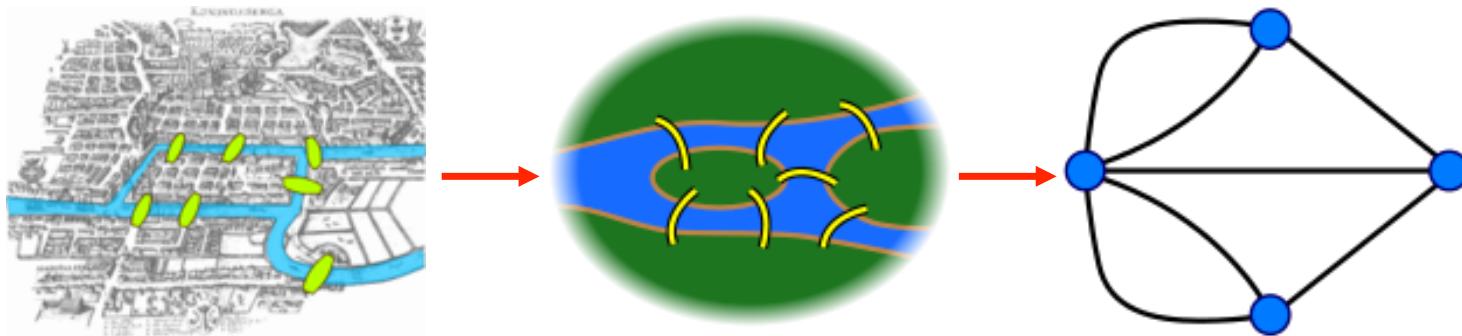
- As per the dictionary: *A collection of inter-connected things*
- Ok. There are **multiple things**, they are **connected**. Two extremes



- 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

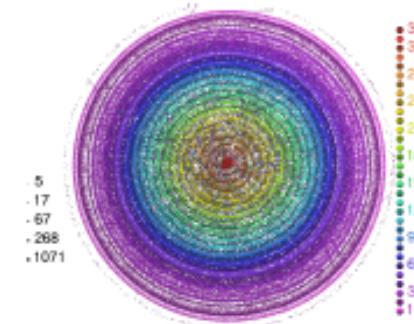
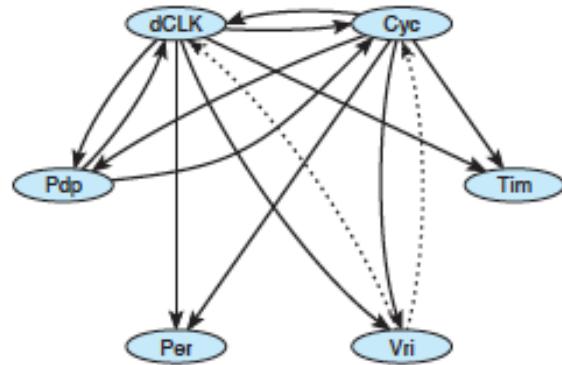
- ▶ Network-based analysis in the sciences has a long history
- ▶ Mathematical foundations of graph theory (L. Euler, 1735)



- ▶ 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?

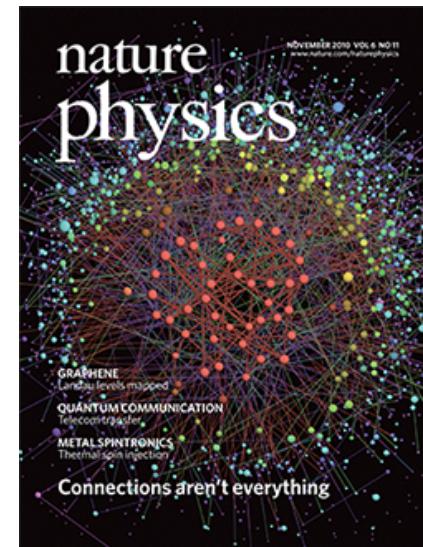
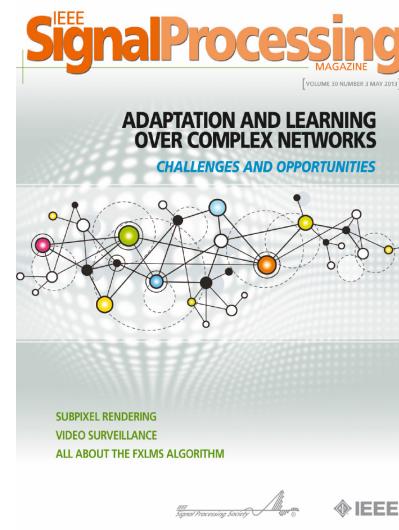
- ▶ Understand **complex systems** \Leftrightarrow Understand **networks** behind them



- ▶ 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, ...

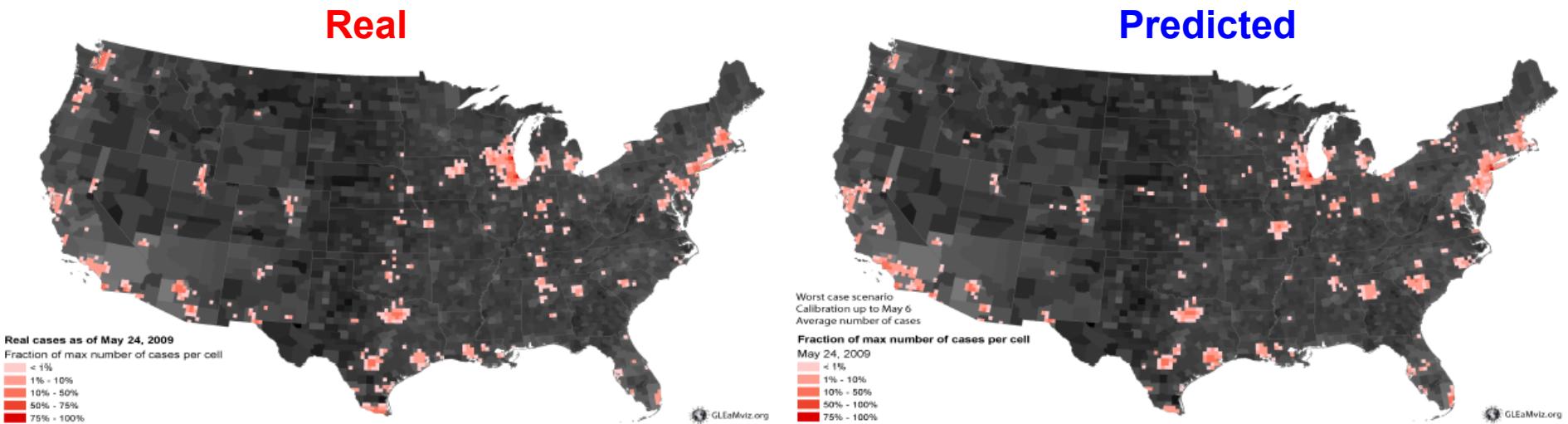
Economic impact

- ▶ Google
Market cap:
\$1.24 trillion
- ▶ Facebook
Market cap:
\$736 billion
- ▶ Cisco
Market cap:
\$188 billion
- ▶ Apple
Market cap:
\$2.22 billion

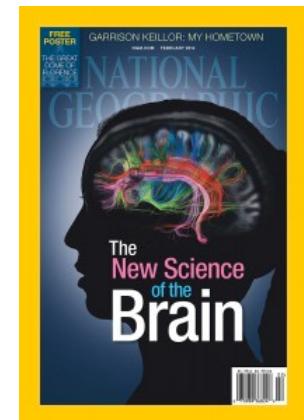
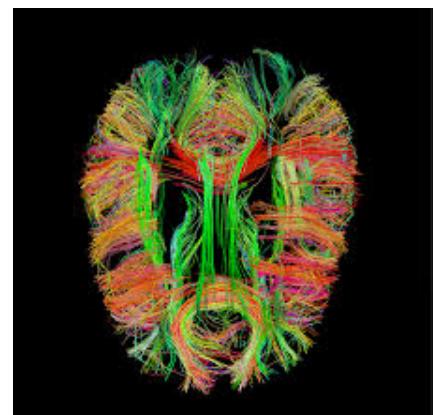


Healthcare impact

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

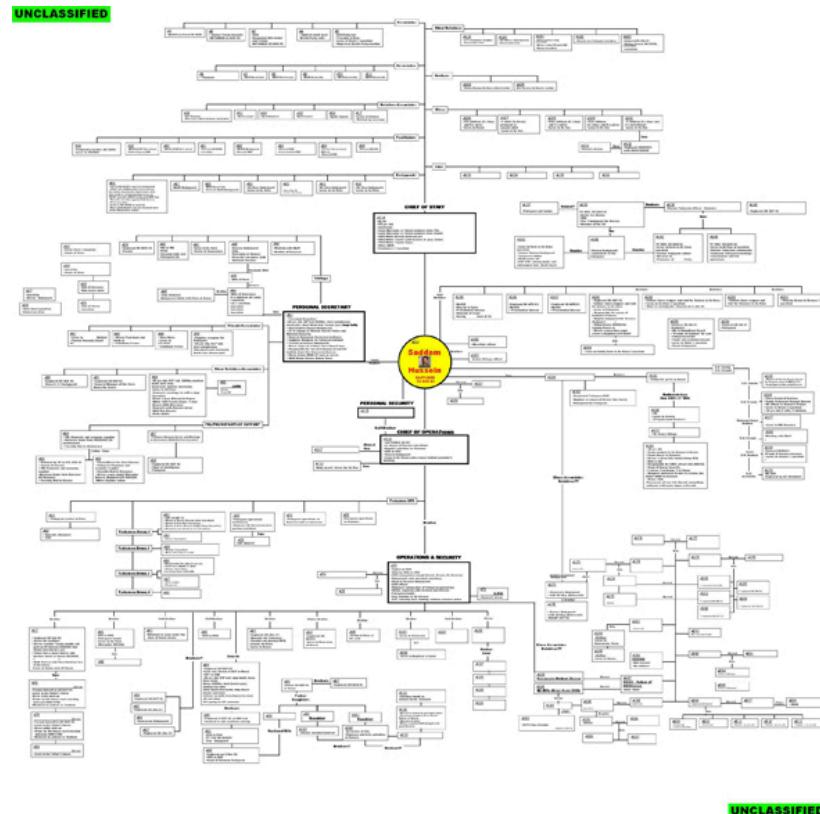
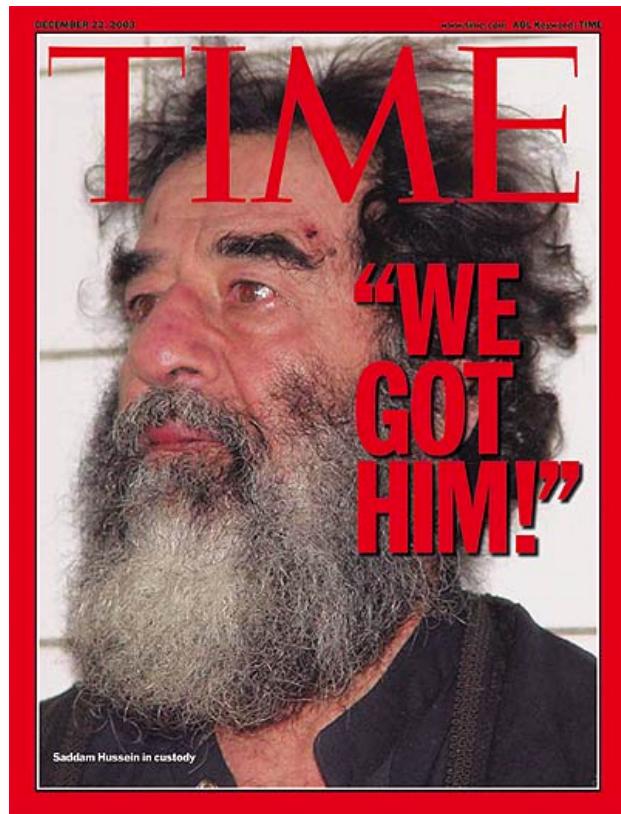


- ▶ Human Connectome Project to map-out **brain** circuitry



Homeland security impact

- Social network analysis key to capturing S. Hussein



Desiderata and Network Science characteristics

- ▶ What are the **goals** of Network Science?
 - ▶ Reveal patterns and statistical properties of network data
 - ▶ Understand the underpinnings of network behavior and structure
 - ▶ Engineer more resource-efficient, robust, socially-intelligent networks
- ▶ **Characteristics:** interdisciplinary, empirical, quantitative, computational
- ▶ **Empirical** study of graph-valued data to find patterns and principles
 - ▶ Collection, measurement, summarization, visualization?
- ▶ Mathematical **models**. Graph theory meets statistical inference
 - ▶ Understand, predict, discern nominal vs anomalous behavior?
- ▶ **Algorithms** for graph analytics
 - ▶ Computational challenges, scalability, tractability vs optimality?

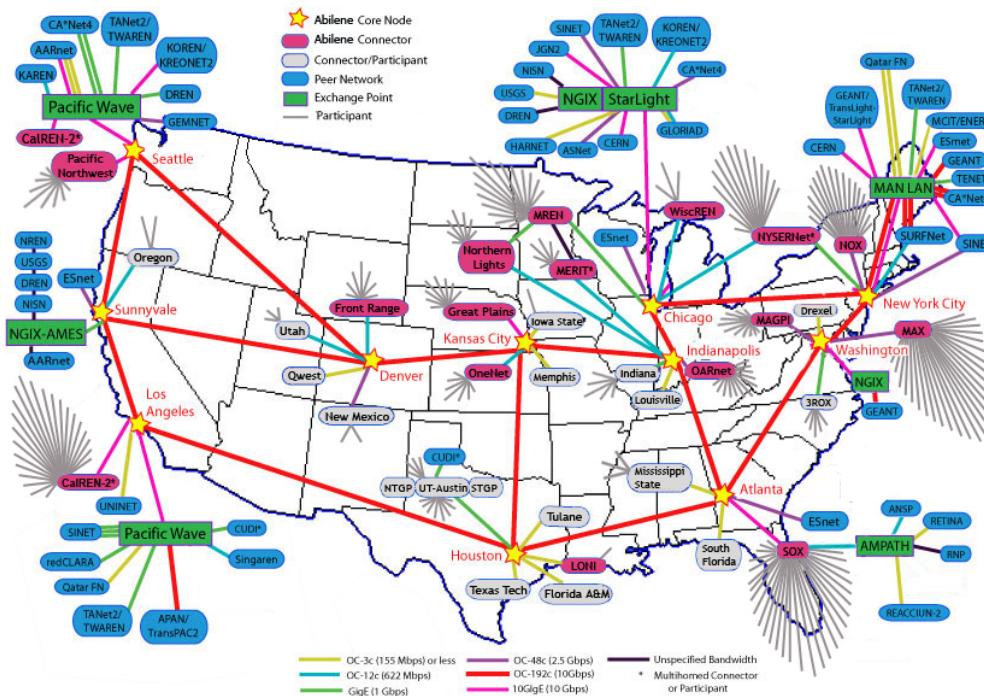


Examples of networks

- ▶ Network analysis spans the sciences, humanities and arts
- ▶ Let's see a few examples from four general areas
 - ▶ Technological
 - ▶ Biological
 - ▶ Social
 - ▶ Informational
- ▶ Standard taxonomy, by no means the only one
 - ⇒ “Soft” classification, networks may fall in multiple categories

Technological networks

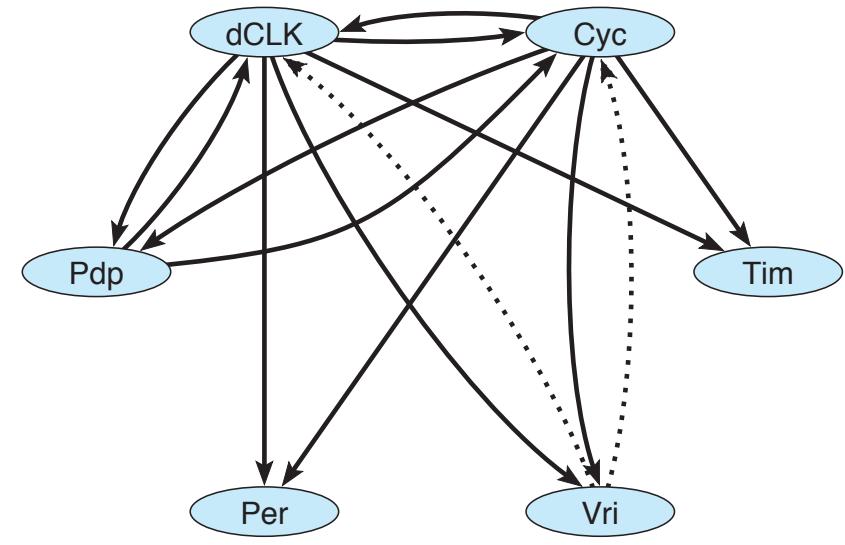
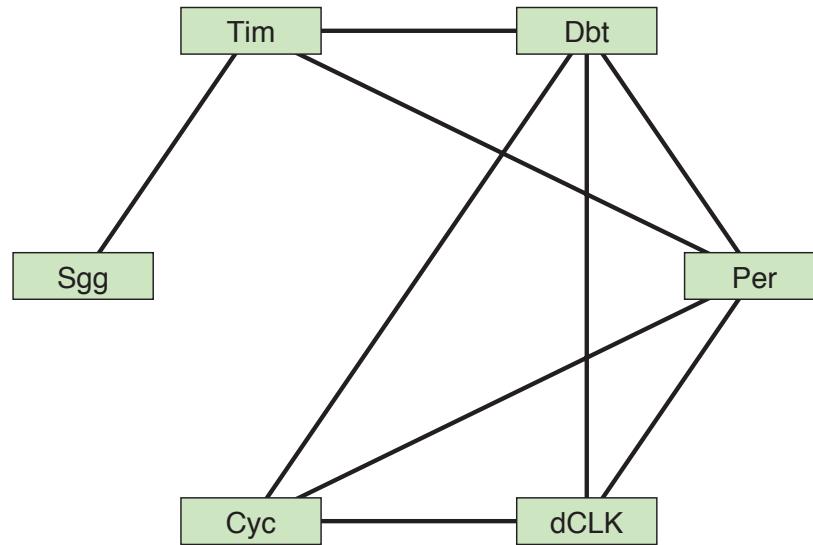
- Ex: communication, transportation, energy, sensor networks



- Q1: What does the Internet look like today? How big is it?
- Q2: How will the traffic from New York to Chicago look tomorrow?
- Q3: How can we unveil anomalous traffic patterns?

Biological networks

- Ex: neurons, gene regulatory, protein interaction, metabolic paths, predator-prey, ecological networks



- Q1: Are certain gene interactions more common than expected?
- Q2: Which parts of the brain “communicate” during a given task?
- Q3: Can we predict biological function of proteins from interactions?

Social networks

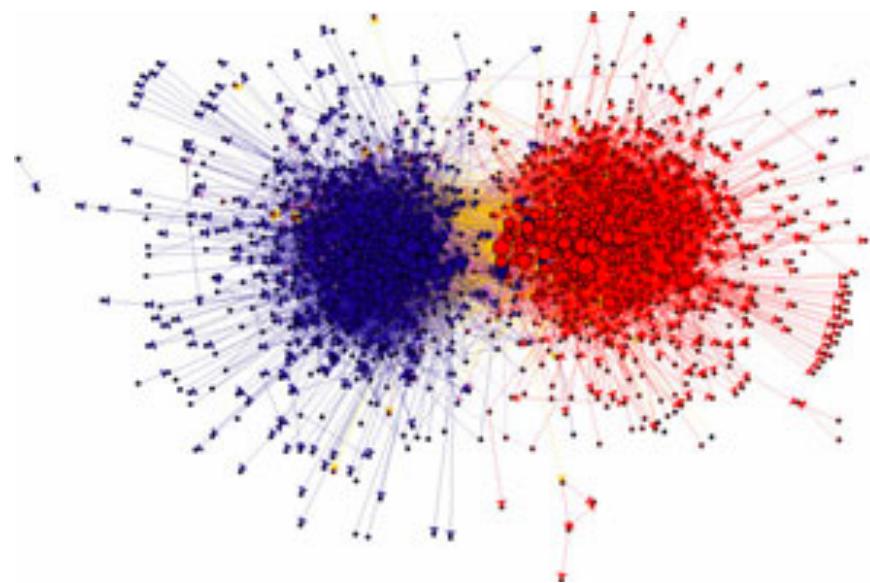
- **Ex:** friendship, corporate, email exchange, international relations, financial networks



- **Q1:** What are the mechanisms underpinning friendship formation?
- **Q2:** Which actors are central to the network and which peripheral?
- **Q3:** Can we identify overlapping communities?

Informational networks

- **Ex:** WWW, Twitter, co-citation between academic journals, blogosphere, paper co-authorship, peer-to-peer networks



- **Q1:** How does the size and structure of the WWW change in time?
- **Q2:** How can we use network analysis for authorship attribution?
- **Q3:** Can we track information cascades in online social media?