

Complex Networks (CS60078)

Instructor: Animesh Mukherjee

TAs: Abhik Jana
Soumya Sarkar

Course Directives

- Time: Wednesday (12-1 hrs), Thursday (11-12hrs) & Friday (9-10hrs)
- Room: CSE 107
- Webpage: http://cse.iitkgp.ac.in/~animeshm/course_cnt2016.html
- Marks:
 - Midterm: 20%
 - Term project/ term paper/ scribe: 30%
 - Attendance & class performance: 10%
 - Blog: 5%
 - Endterm: 35%

Blogging ...



- Name: **Filter Bubble**
- Typically of the type of:
<http://betweenness.blogspot.com/> (Betweenness from College of the Atlantic)
- No summary of the class lecture! This is to be done through scribes
- What exactly then:
 - One person each day tries to gather something interesting (in the form of a short summary possibly associated with one figure) and possibly unknown to most of us in this area of research (could be something very old or very contemporary)
 - Others read, comment and discuss on the posted topic
 - You might also post relevant announcements (call for papers, call for participation in summer schools etc. each time explaining why you found it relevant)

Term project

A decorative horizontal row of five circles. From left to right: a solid light purple circle, a hollow light purple circle, a solid light purple circle, a hollow light purple circle, and a solid light purple circle.

- **Term project:** A mini project (topics will be soon circulated among you).
 - Meet your mentor and understand the project,
 - gather data (if reqd.),
 - model/ analyze/ frame and solve eqns.,
 - prepare presentation and tech report (can lead to a paper)

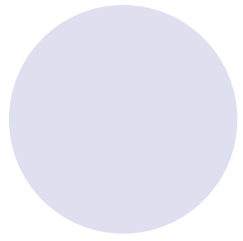
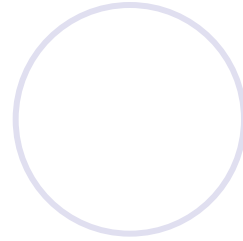
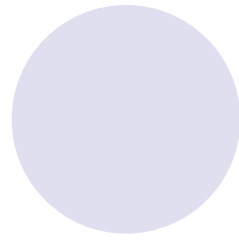
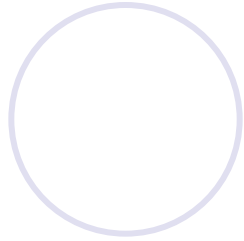
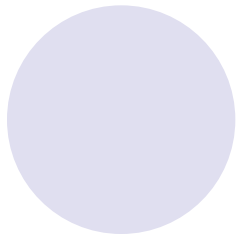
References

- *Networks: An Introduction*, Oxford University Press, Oxford, 2010. (I shall mostly follow this one)
- *Evolution of Networks*, Oxford University Press, Oxford, 2003.
- The structure and function of complex networks, *SIAM Review* **45**, 167-256, 2003.
- Statistical mechanics of complex networks, *Rev. Mod. Phys.*, **74**(1), 2002.
- Further references can be found on the course page of Dr. Niloy Ganguly (facweb.iitkgp.ernet.in/~niloy/)

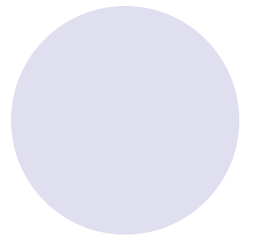
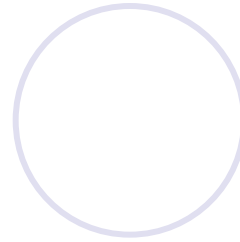
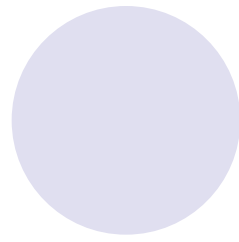
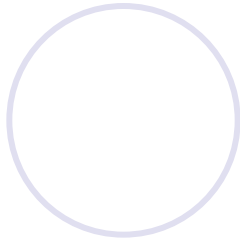


One Credit Micro-Course

- Economic and Financial Network Analytics
 - Instructor: Matteo Marsili, ICTP, Trieste, Italy
- Rough Outline:
 - Introduction to economic and financial networks (1 lecture)
 - Network representation and the basic analysis tools (2 lectures)
 - Economic Networks -- Strategic network formation (1 lecture), Networked markets (1 lecture), Games on networks (1 lecture), Game theoretic modeling of network formation (1 lecture), Allocation rules and cooperative games (1 lecture)
 - Financial Networks -- Systemic Risk (1 lecture), Failure mechanisms and financial stability (1 lecture), Contagion in financial markets (1 lecture), Analysis of empirical financial networks (1 lecture)



Introduction

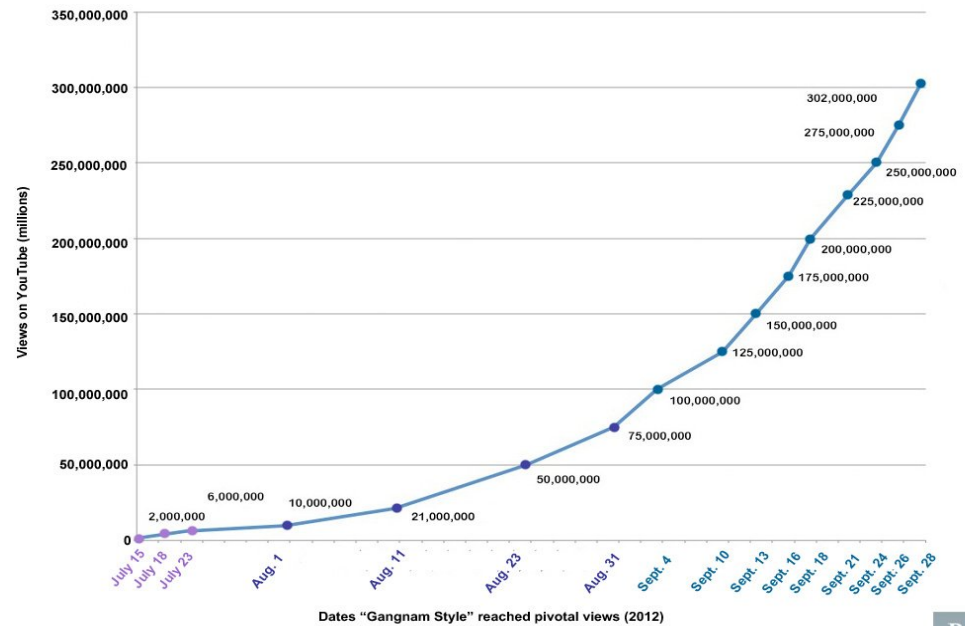


Gangnam Style



ources: Yahoo, NY Times, Korea Times, WSJ

Growth of 'Gangnam Style' Views On YouTube



Dates "Gangnam Style" reached pivotal views (2012)

BUSINESS INSIDER

Why did it go viral? --> Youtube:800 million views, Facebook: 1 billion likes, Twitter: 150 million followers

Any clue how --> **we shall try to explore how such properties emerge in a complex evolving system (in this case the social media)**

Complexity in nature



Complexity in nature



A termite "cathedral" mound produced by a termite colony --> no engineer planned this for them!!!



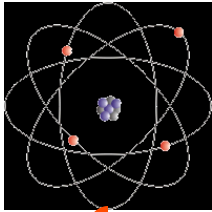
Emergence : What is it?

- *Emergence* resembles the development of a complex organized system
- It refers to the arising of novel & coherent structures, patterns & properties due to the *self-organization* going on in various complex systems
- Self-organization is a process by which a system increases its complexity through *internal re-organization* without being guided by any external source

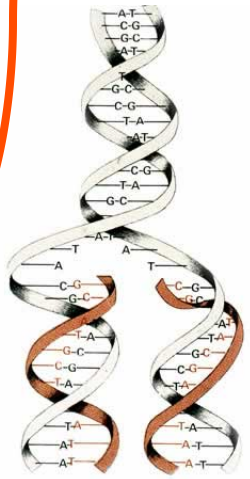
Emergence of networked life

Communities

Atom



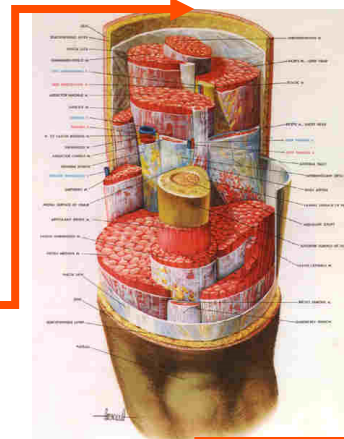
Molecule



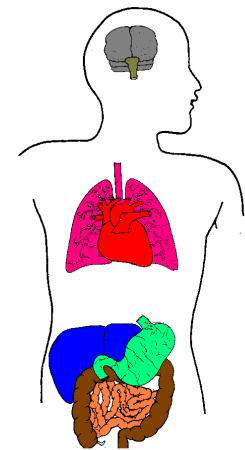
Cell



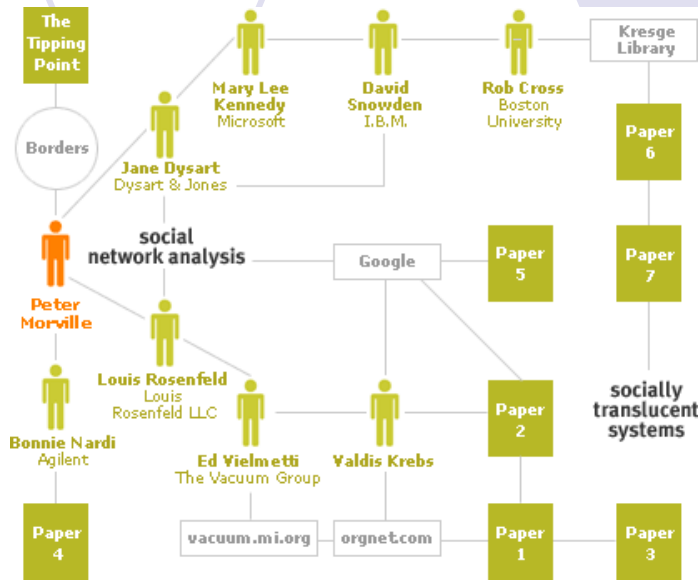
Tissue



Organs



Organisms

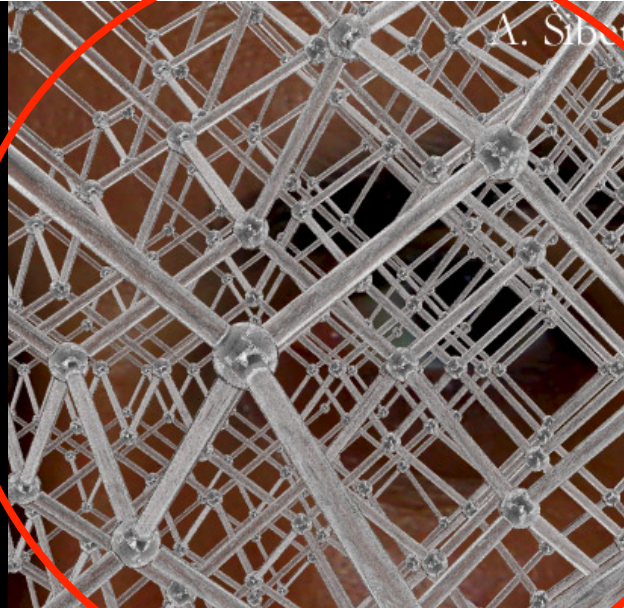


Three Views of a System



MACROSCOPY

May not give a complete picture or explanation of what goes on

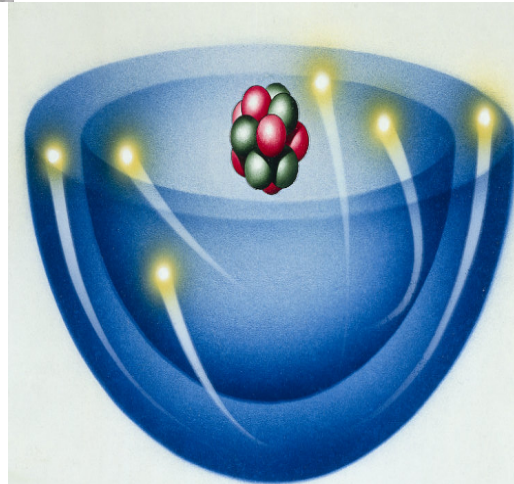


MESOSCOPY

A useful trade-off between the two

MICROSCOPY

May be too difficult to analyze or simulate the macroscopic behavior



Now coming to networks

Complex systems

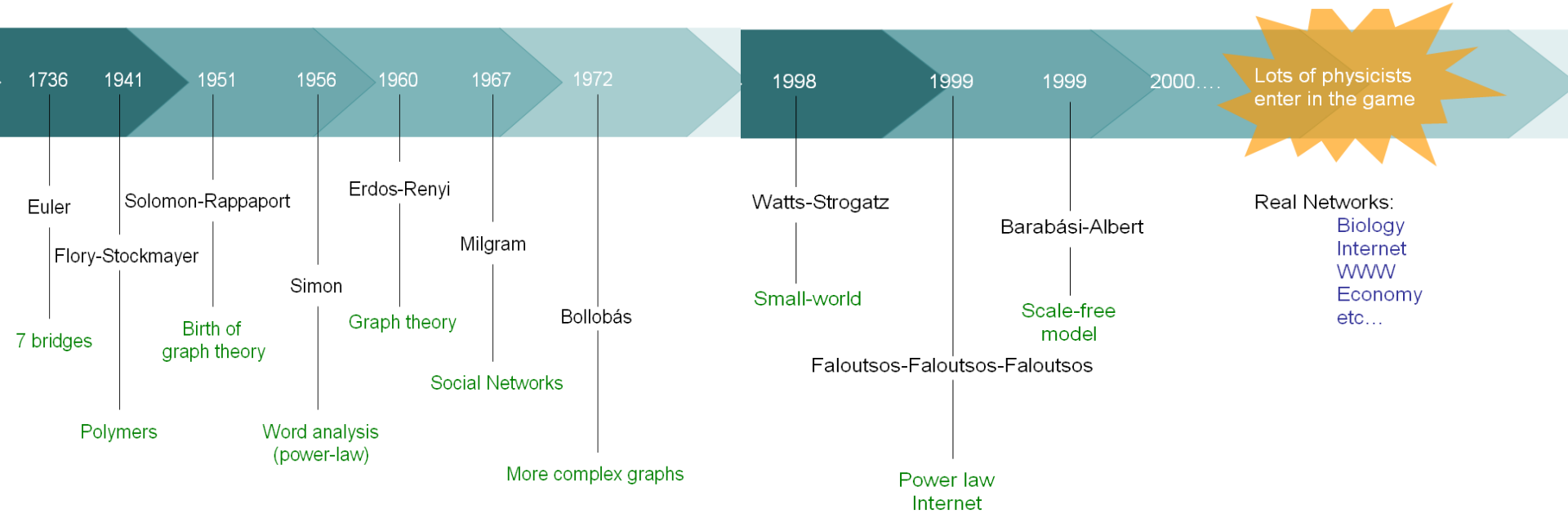
Conception

Made of many non-identical **elements**
connected by diverse **interactions**.

Formulation

NETWORK

Historical Background



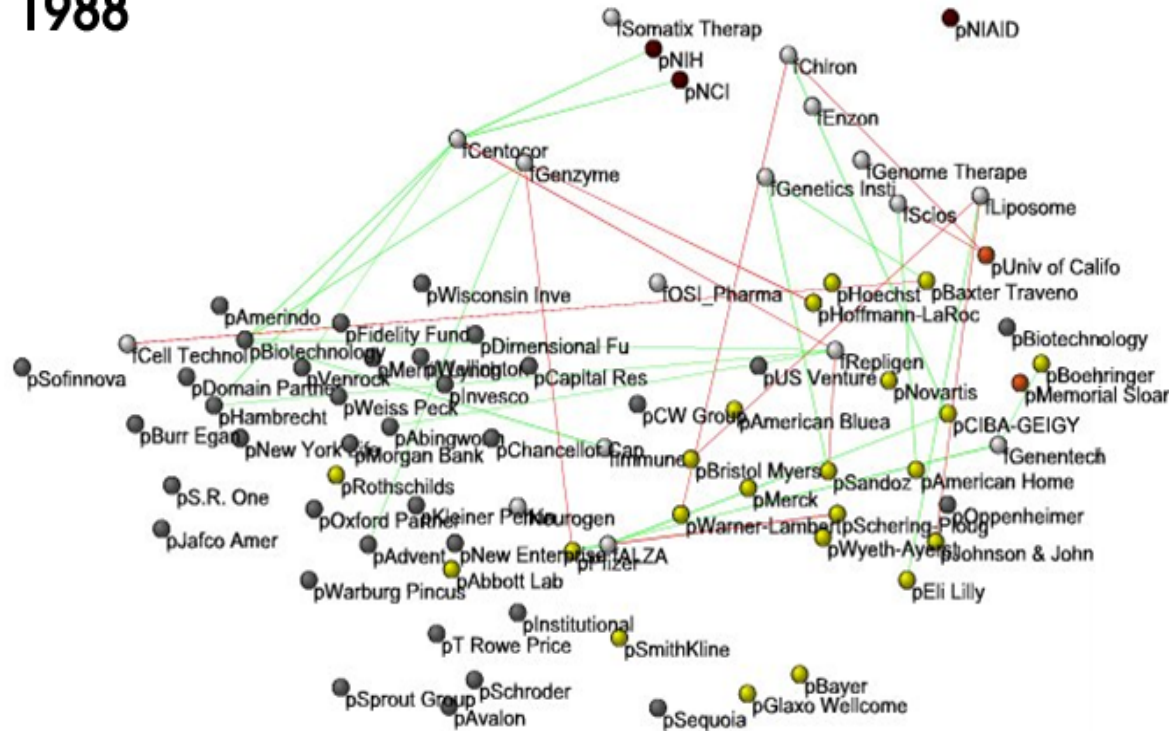
Network Connectivity \neq Complexity

Network Connectivity + Dynamics = Complexity

- **They have a non-trivial topological structure dynamically evolving over time**
- **Buzzwords**
 - **Heavy tail in the degree distribution**
 - **High clustering coefficient**
 - **Preferential attachment**
 - **Community structure**

Business ties in US biotech-industry

1988



Nodes: companies: investment

pharma

research labs

public

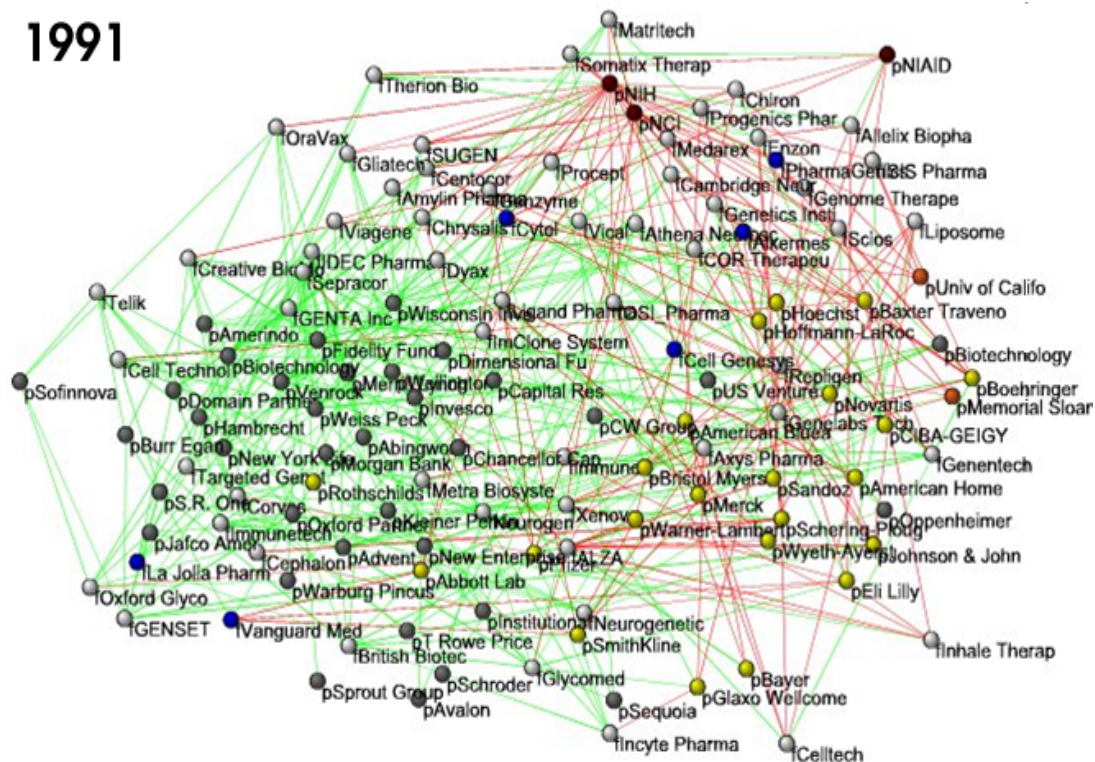
biotechnology

Links: financial

R&D collaborations

Business ties in US biotech- industry

1991



Nodes: companies: investment

pharma

research labs

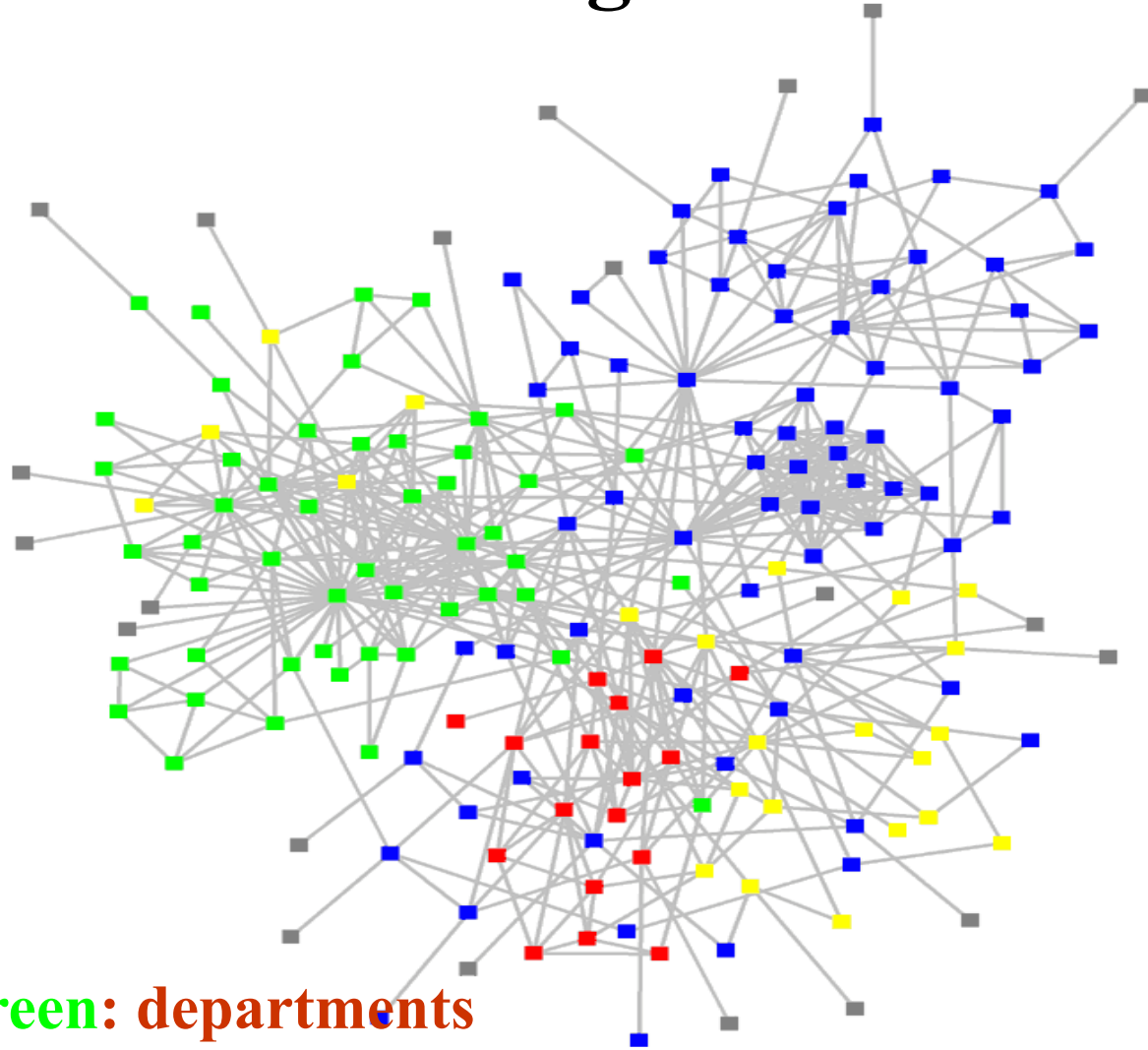
public

biotechnology

Links: financial

R&D collaborations

Structure of an organization

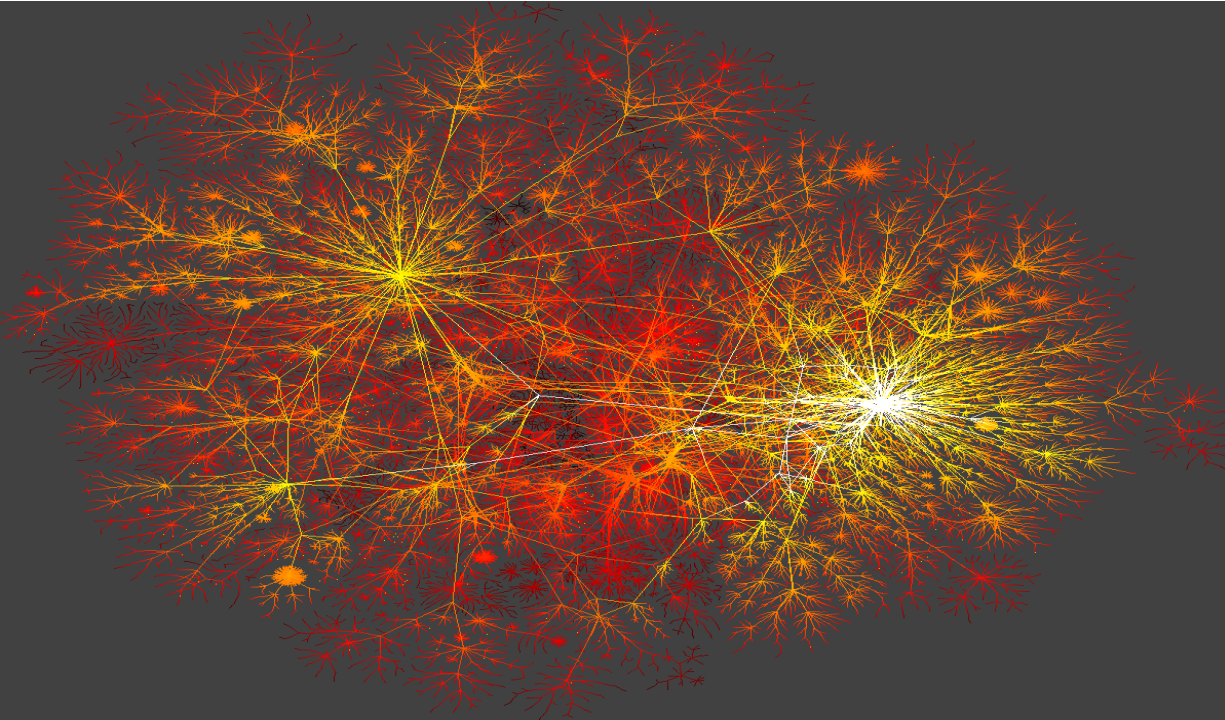
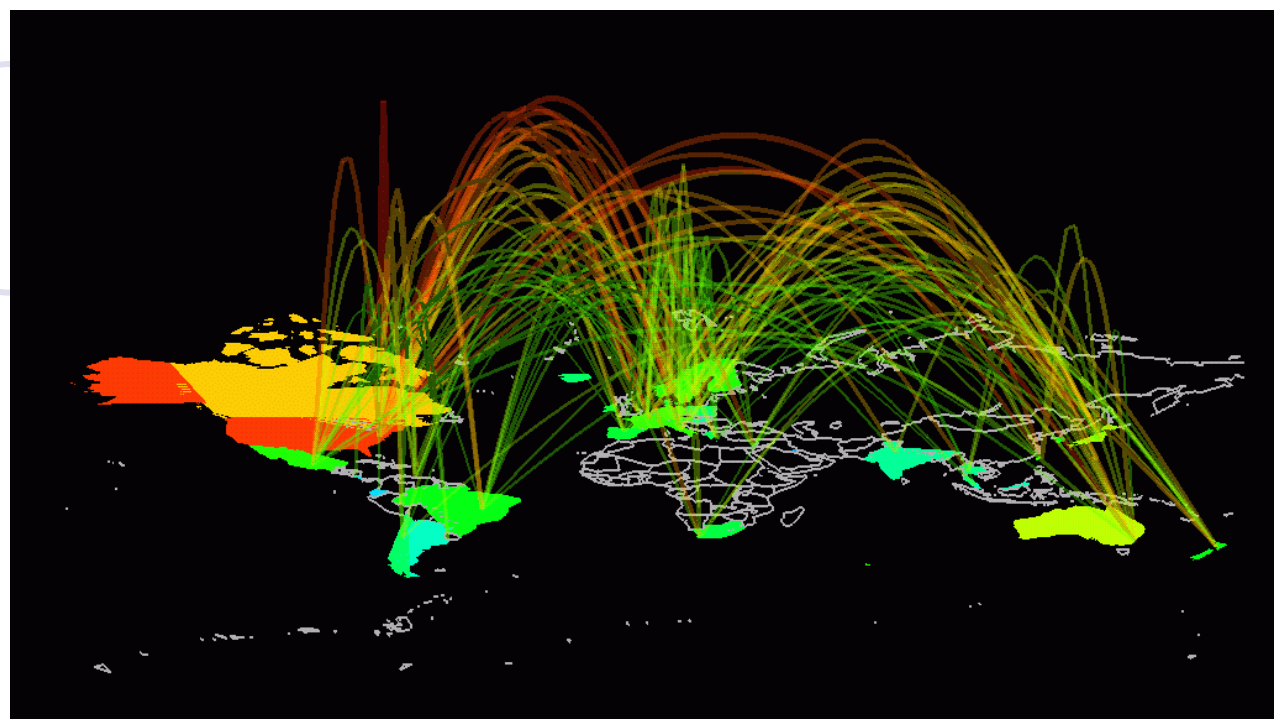


Red, blue, or green: departments

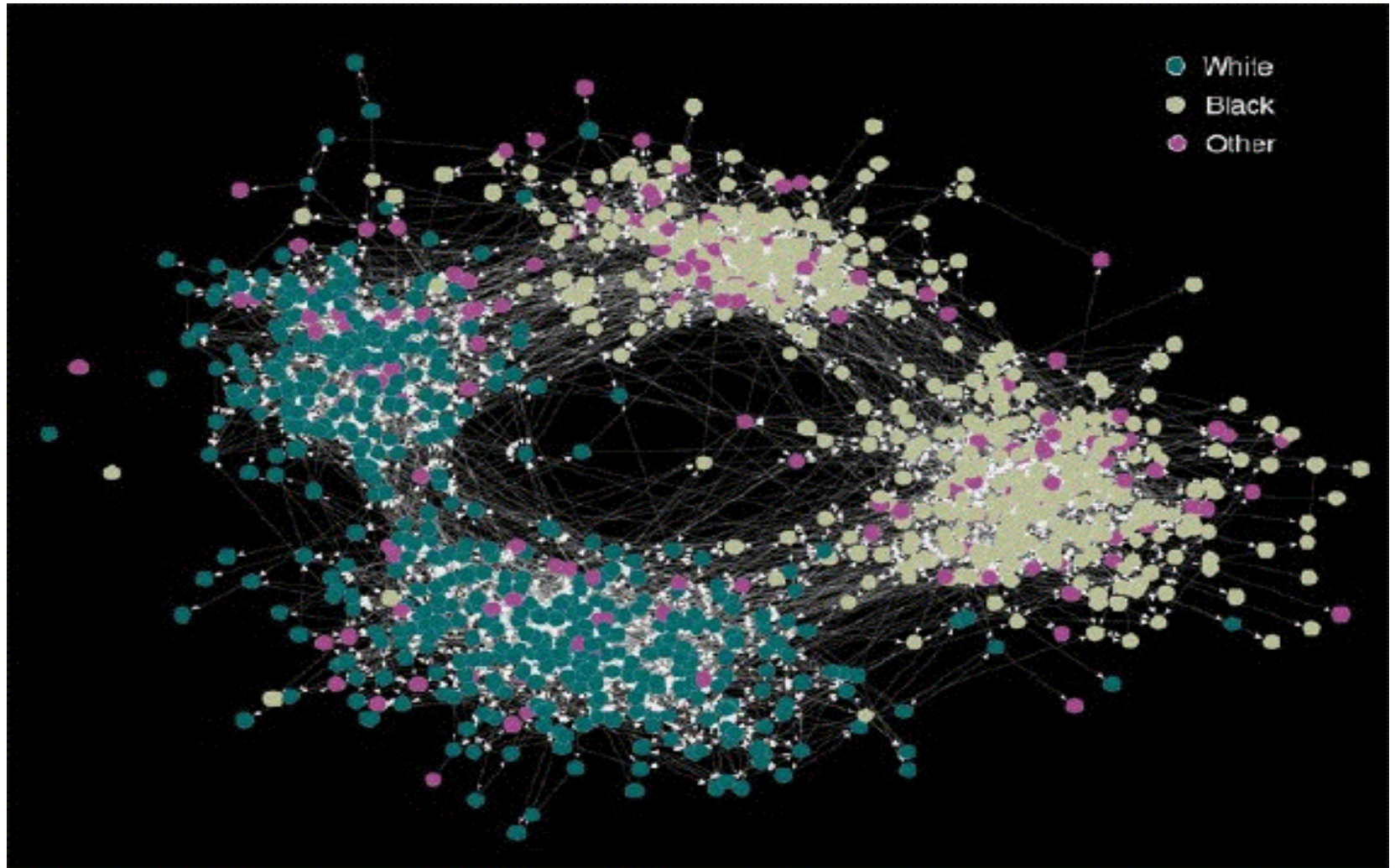
Yellow: consultants

Grey: external experts

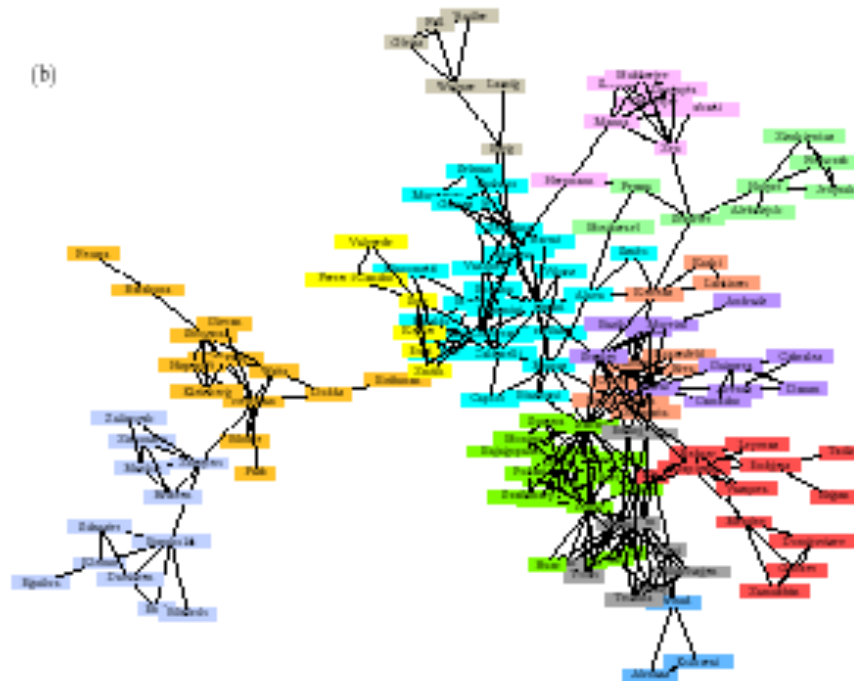
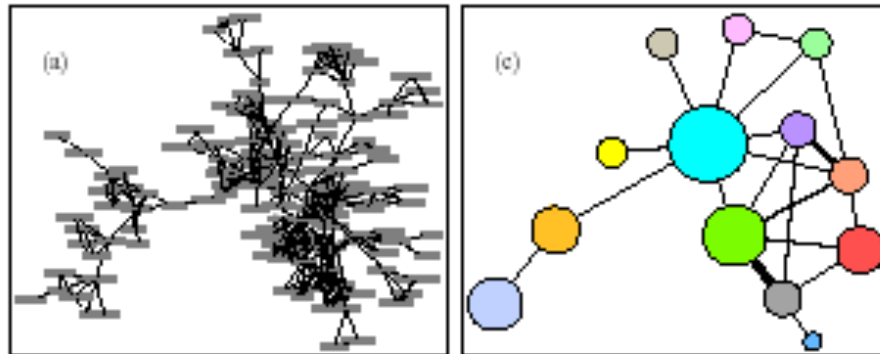
Internet

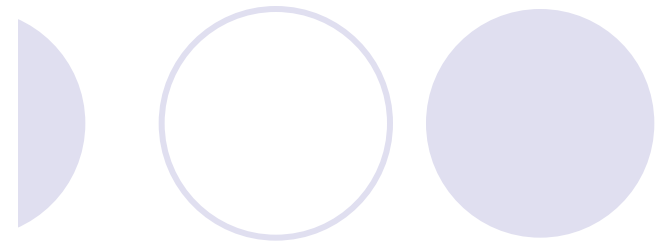


Friendship Network



Collaboration Network





9-11 Terrorist Network

Social Network Analysis is a mathematical methodology for *connecting the dots* -- using science to fight terrorism. Connecting multiple pairs of dots soon reveals an emergent *network* of organization.



Swedish sex-web

Nodes: people (Females; Males)

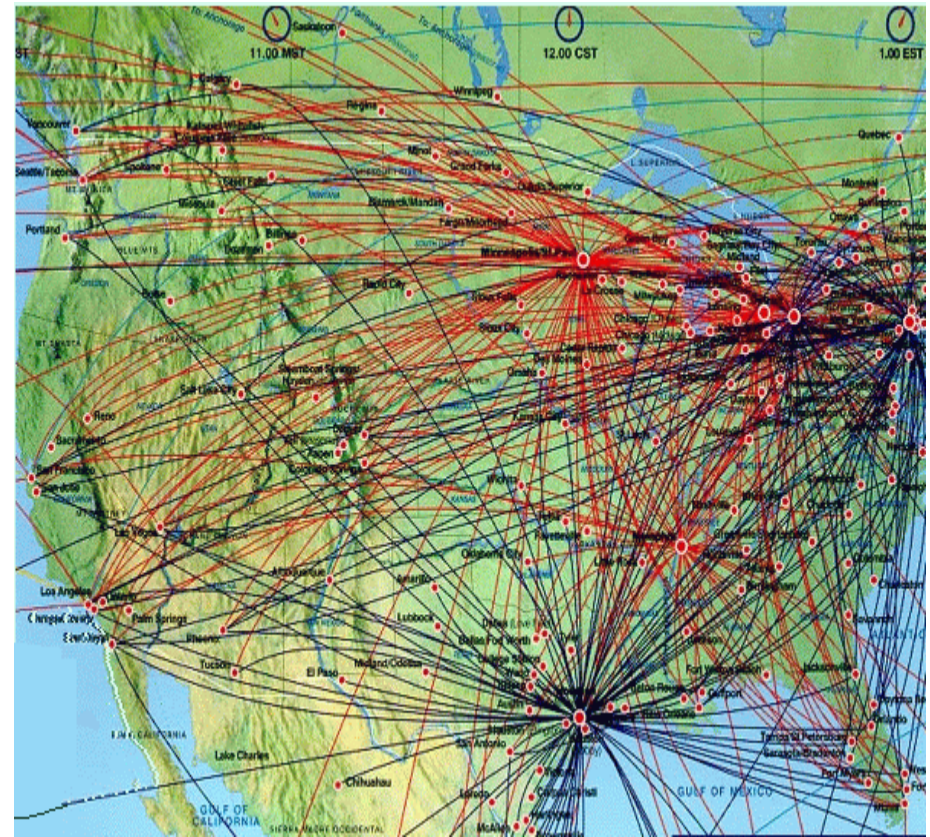
Links: sexual relationships



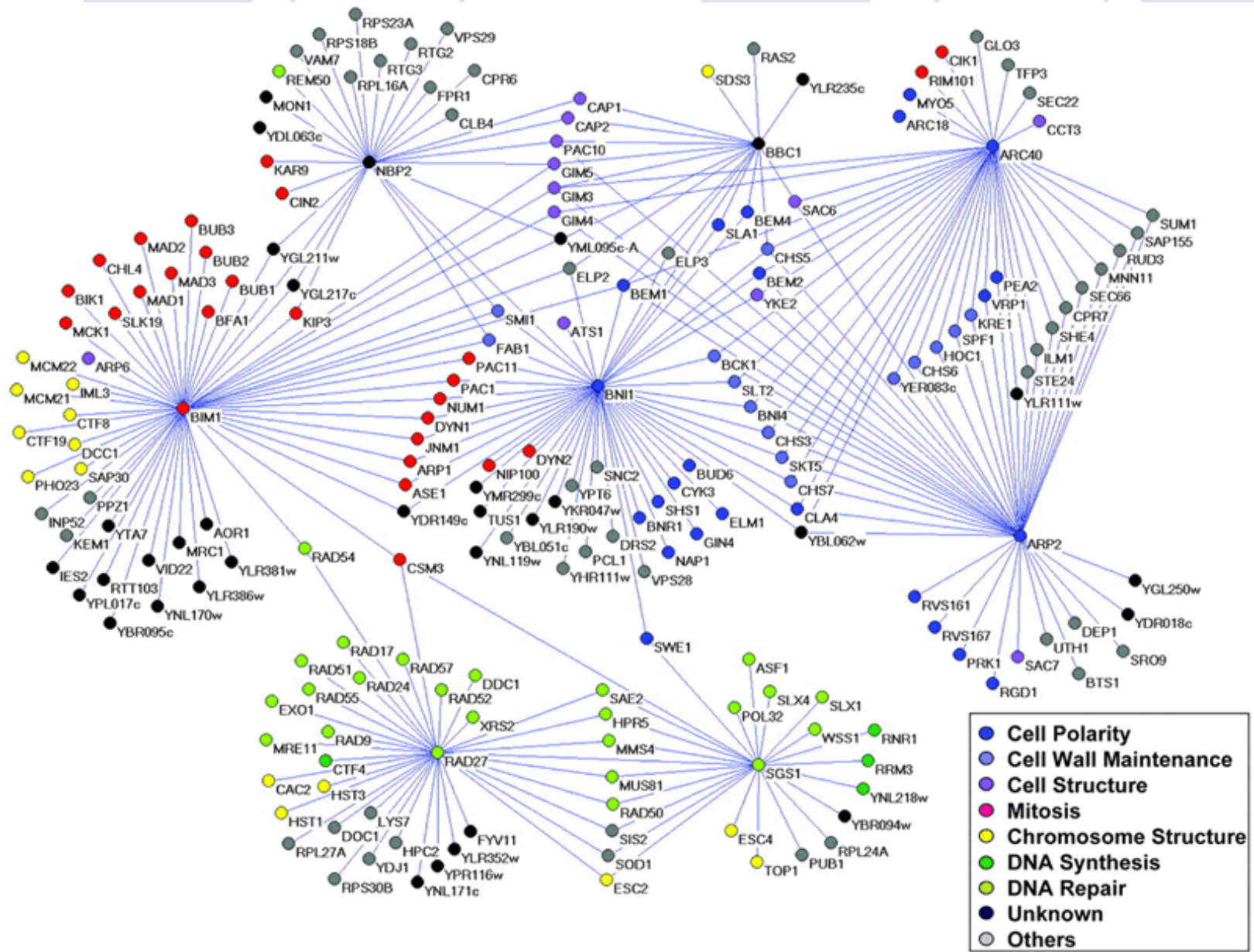
4781 Swedes; Age: 18-74;
59% response rate.

Liljeros et al. *Nature* 2001

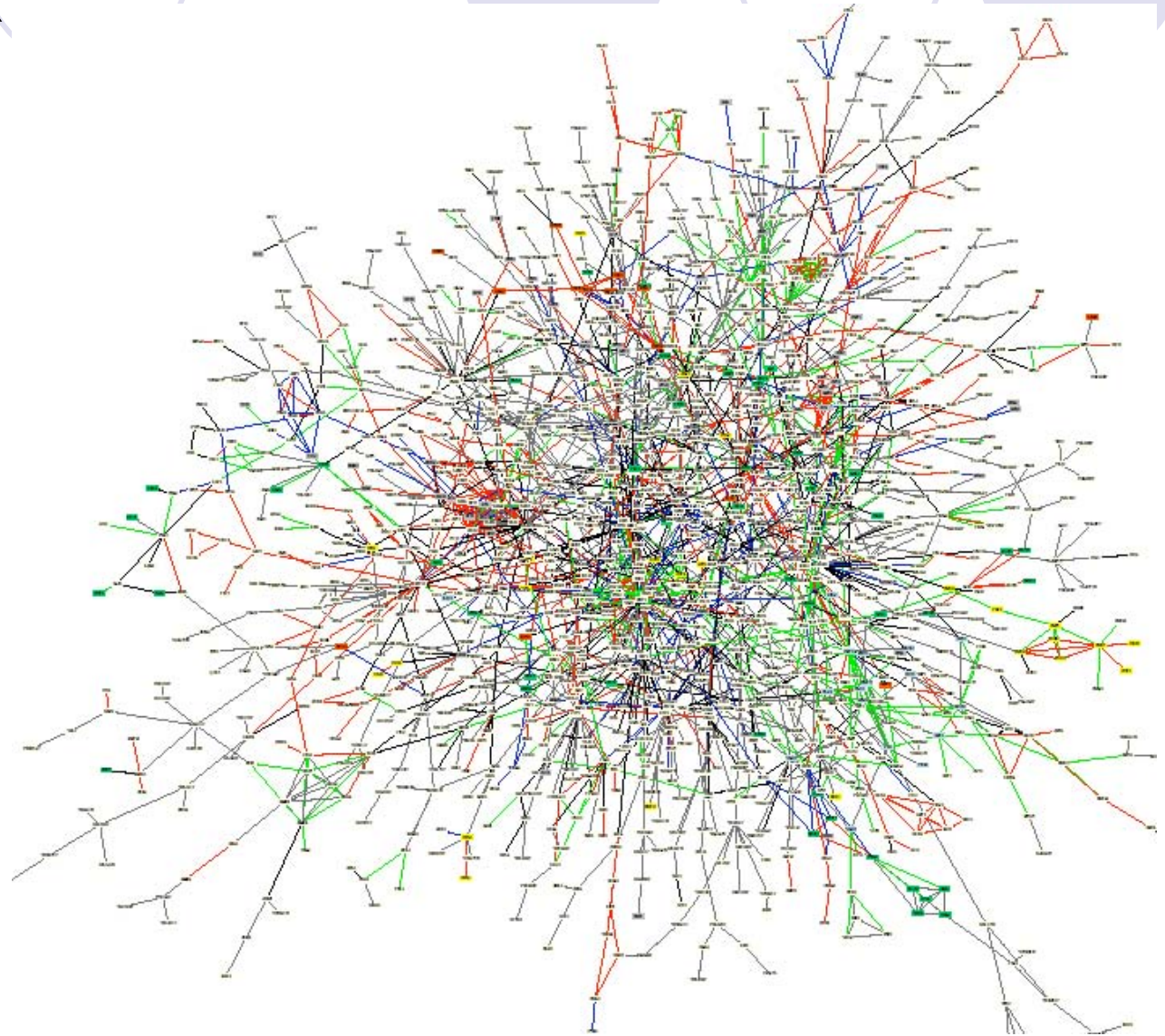
Road and Airlines Network



Genetic interaction network



Yeast protein-protein interaction network





What Questions can be asked

- Does these networks display some symmetry
- Are these networks creation of intelligent objects or they have emerged.
- How have these networks emerged
 - Underlying simple rules leading to their complex formation

2 Way Approach



- Analysis of the real-world networks
 - Degree Distribution
 - Clustering Coefficient
 - Centrality
 - Small-world effect
- Synthesis of the network by means of some simple rules
 - Preferential attachment models
 - Small-world models

The title is centered at the top of the slide. Above the text are five circles of varying shades of light purple. The first, third, and fifth circles are solid, while the second and fourth are hollow with a thin outline. The text "Things that we shall cover ..." is written in a large, black, sans-serif font.

Things that we shall cover ...

- Basic measurement metrics
- Social network analysis metrics
- Community analysis
- Case study (tentatively citation networks)
- Graph mining
- Models of n/w growth
- Epidemics/Percolation