

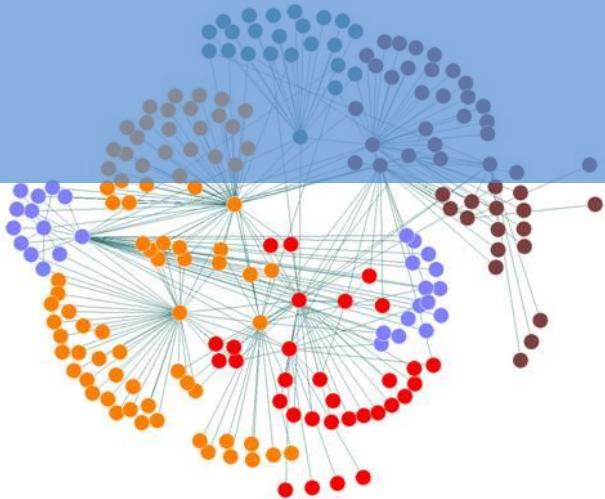


BABEŞ-BOLYAI UNIVERSITY
Faculty of Mathematics and Computer Science



Social Network Analysis

Introduction



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Complex Systems

Complex

[adj., v. kuh m-pleks, kom-pleks; n. kom-pleks]
–adjective

1.

composed of many interconnected parts; compound; composite: a complex highway system.

2.

characterized by a very complicated or involved arrangement of parts, units, etc.: complex machinery.

3.

so complicated or intricate as to be hard to understand or deal with: a complex problem.

Source: Dictionary.com

Complexity, a **scientific theory** which asserts that some systems display behavioral phenomena that are completely inexplicable by any conventional analysis of the systems' constituent parts. These phenomena, commonly referred to as emergent behaviour, seem to occur in many complex systems involving living organisms, such as a stock market or the human brain.

Source: John L. Casti, Encyclopædia Britannica

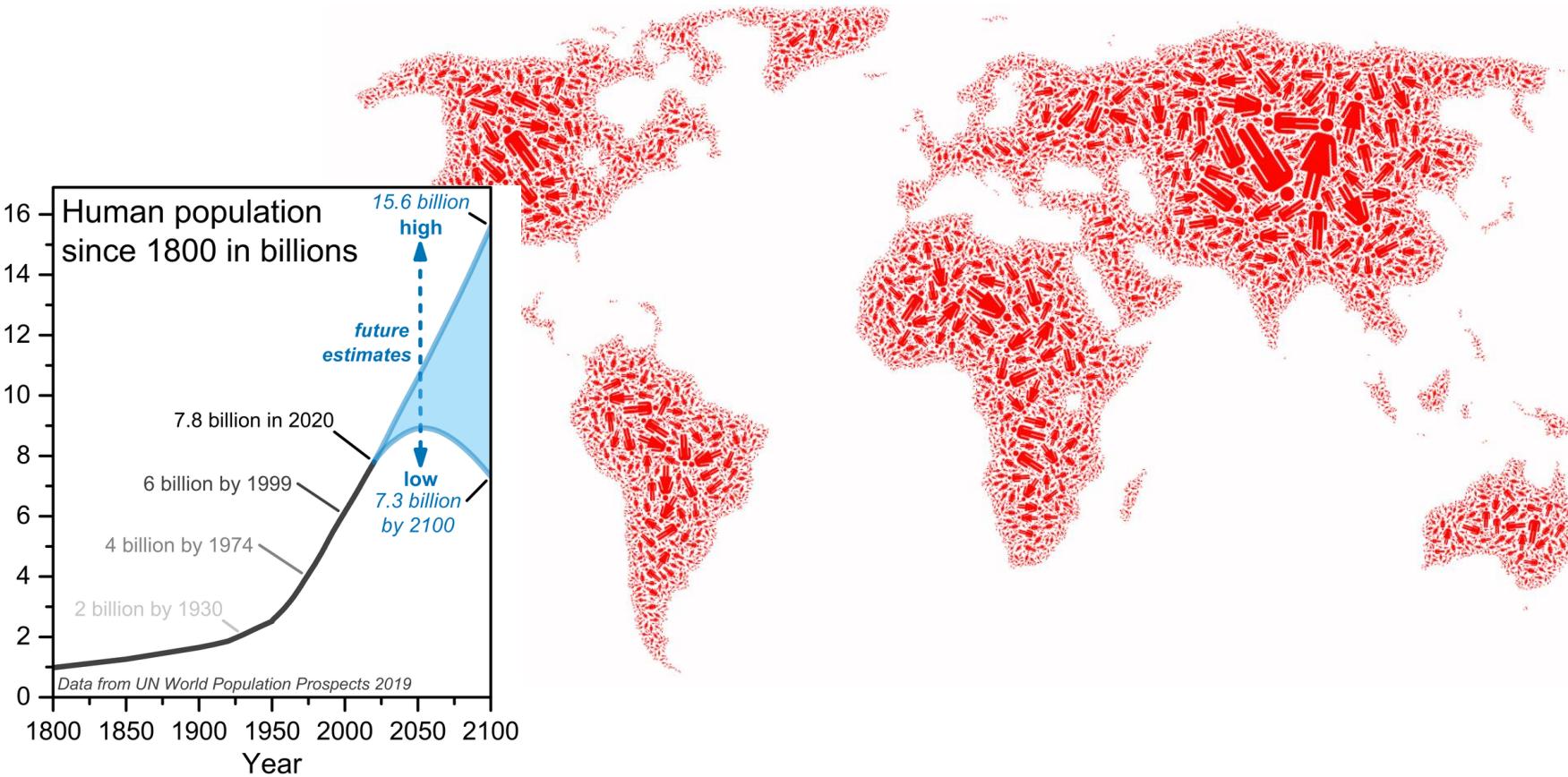
Complexity

Network Science

- Behind each complex system there is a **network**, that defines the interactions between the components.
-
- How network structure affects the robustness of a complex system?
 - Can we asses the interplay between network structure and the dynamical processes on the networks?

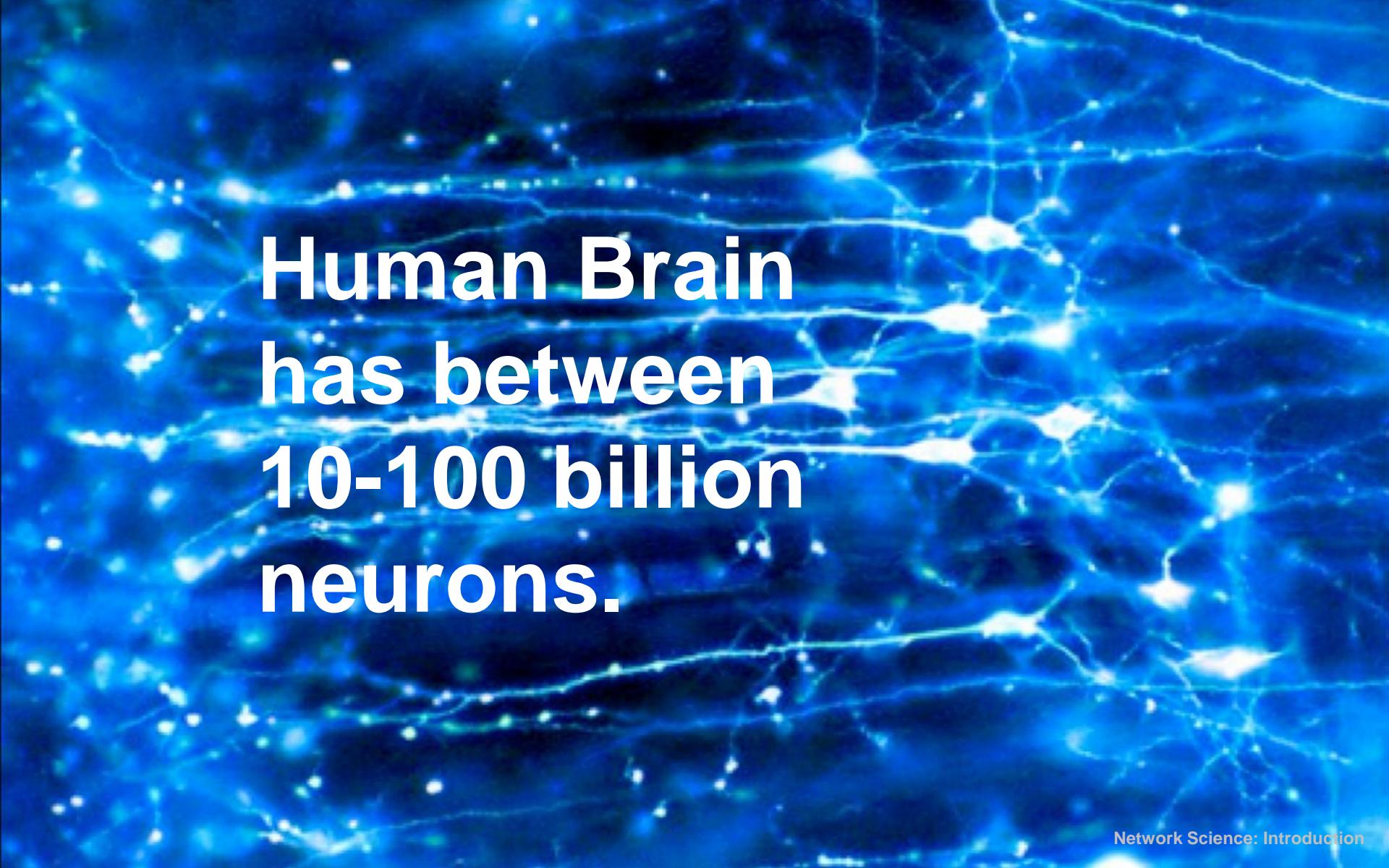
NETWORKS AT THE HEART OF
COMPLEX SYSTEMS

Society



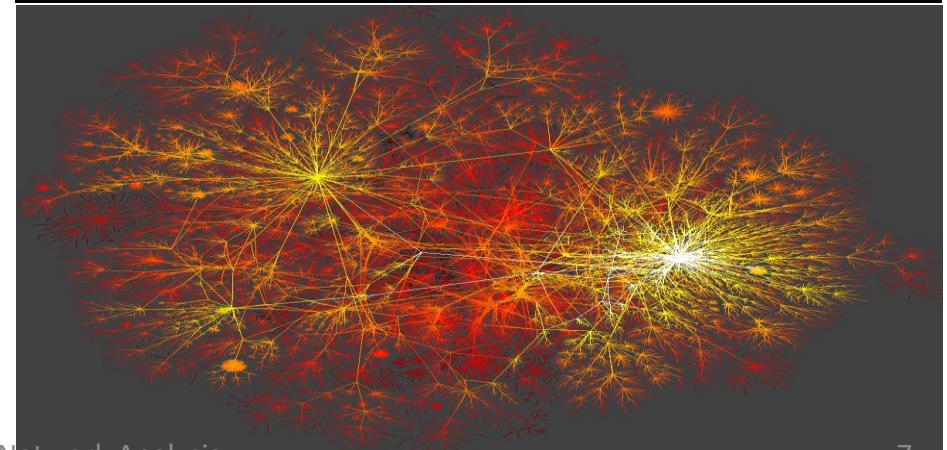
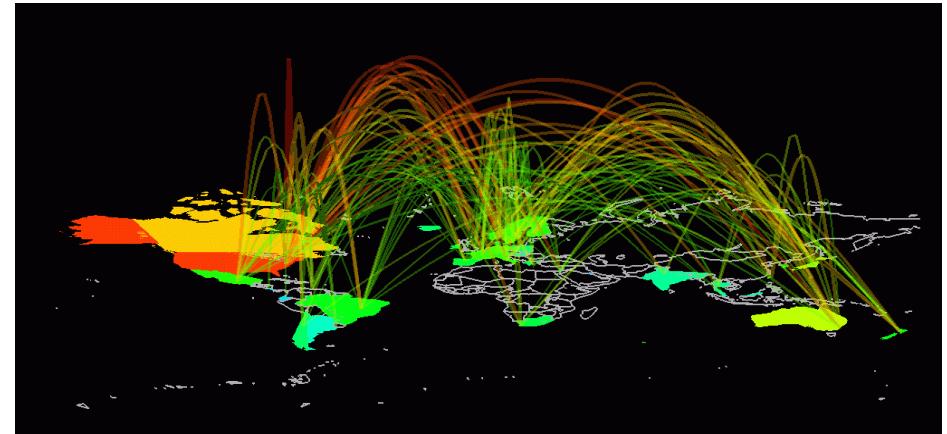
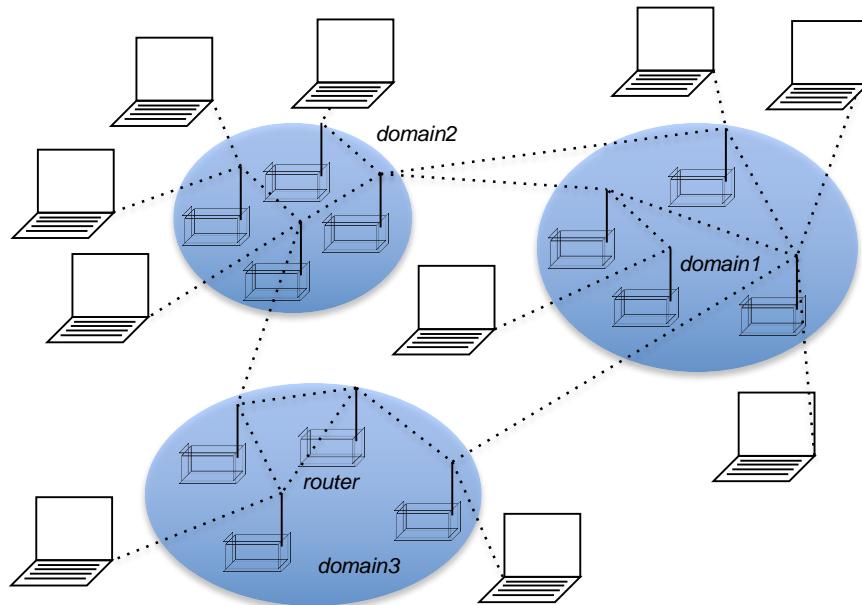


The “Social Graph” behind Facebook



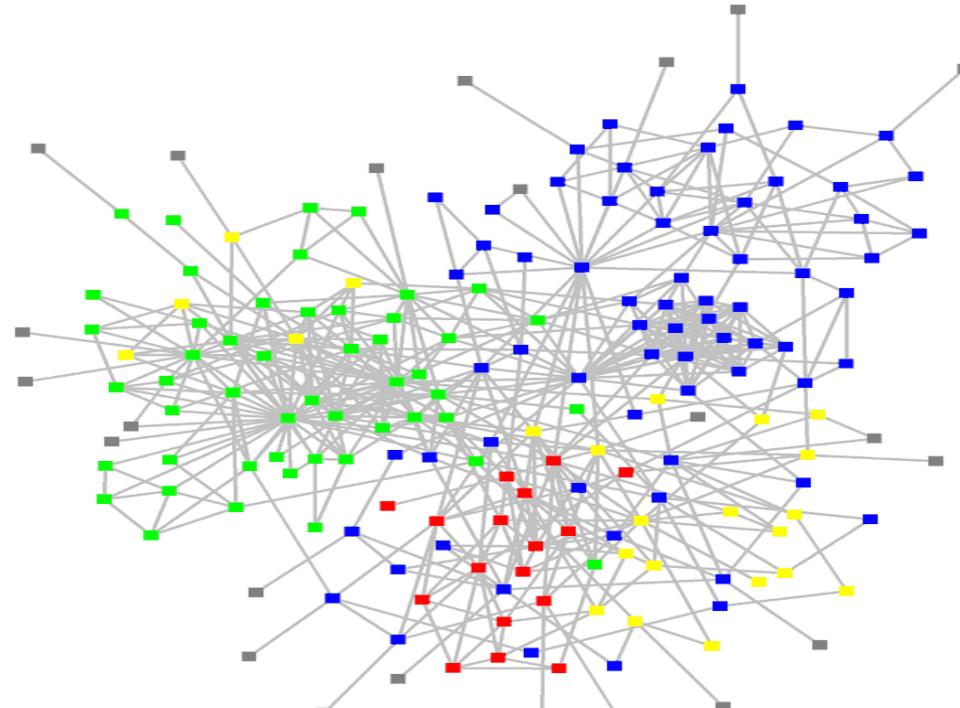
Human Brain
has between
10-100 billion
neurons.

Internet

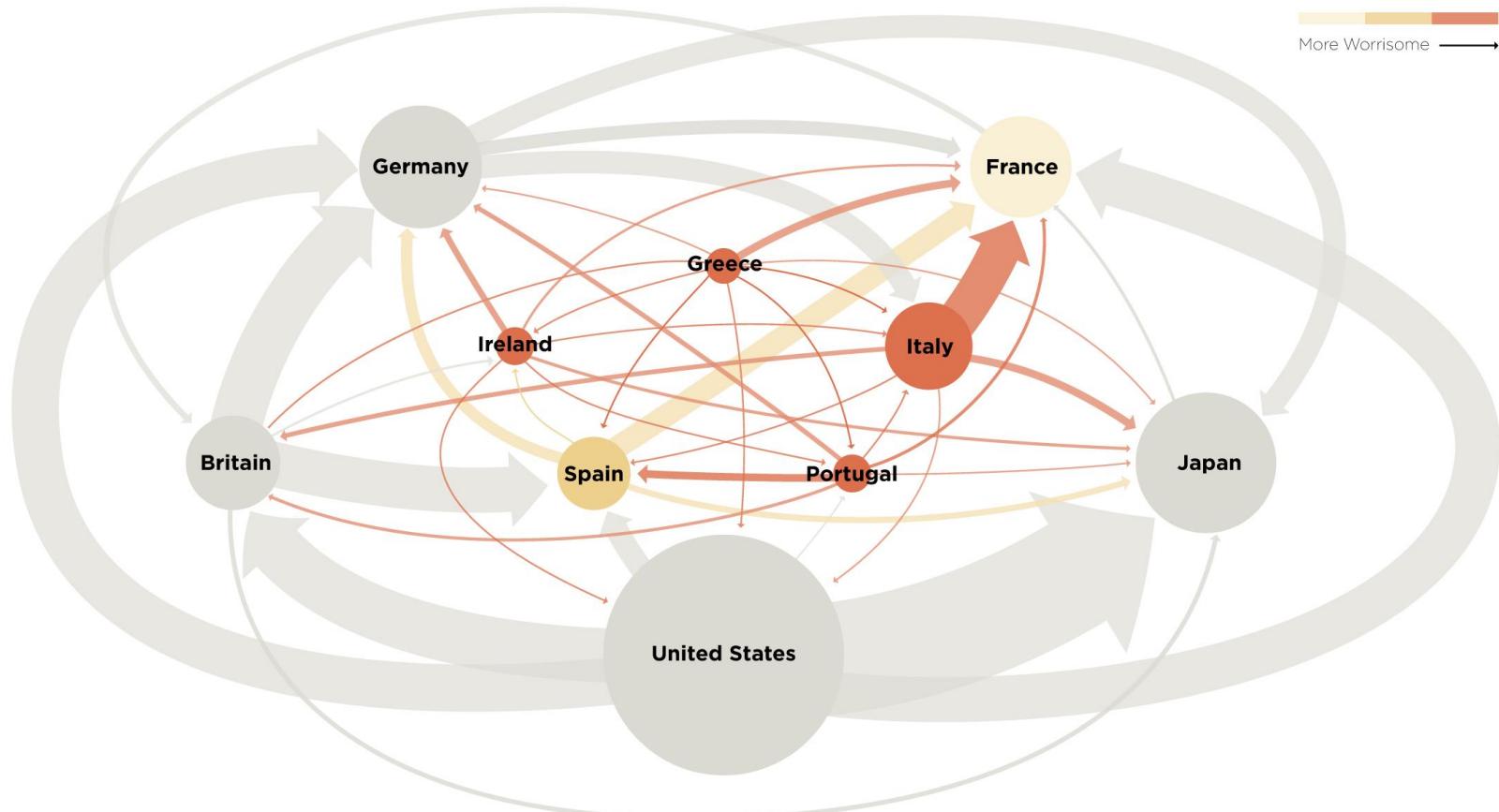


Organizations

- : departments
- : consultants
- : external experts



Finance



Business ties in US biotech-industry

Nodes:

Companies 

Investment 

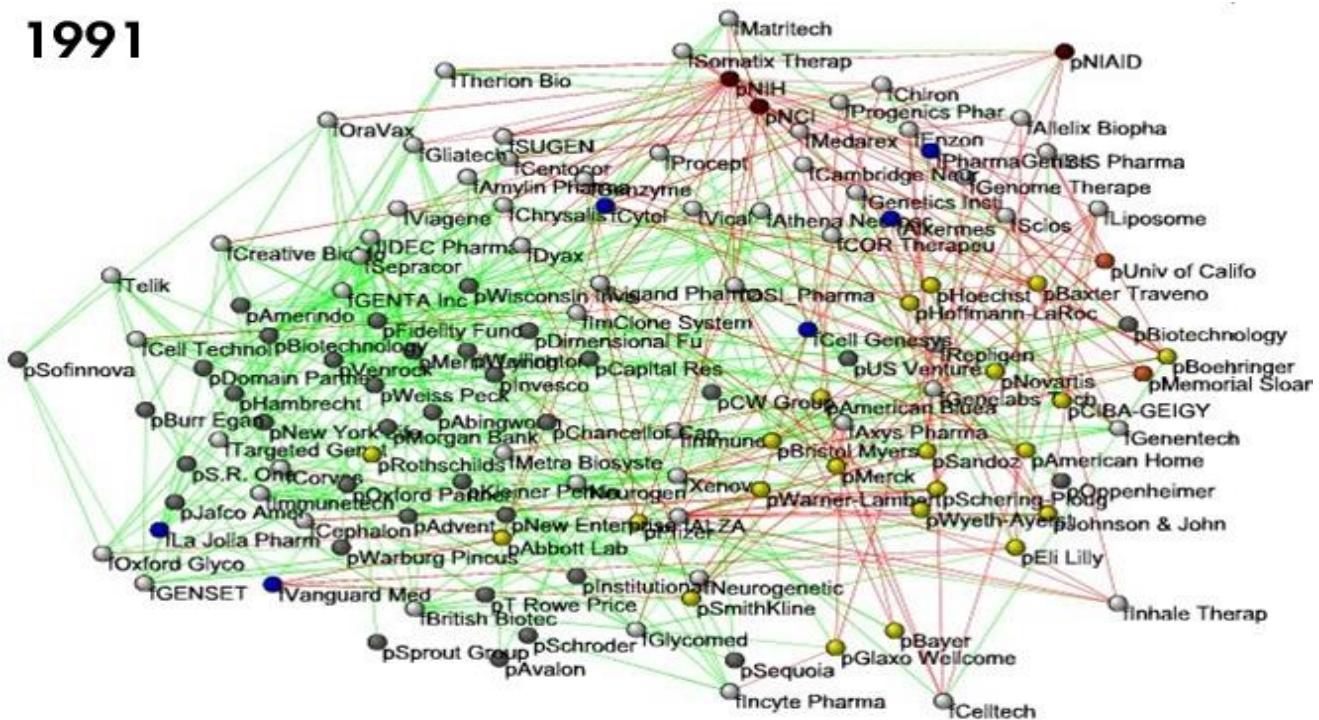
Pharma 

Research Labs 

Public 

Biotechnology 

1991



Links:

Collaborations 

Financial 

R&D 

Camelia Chira

<http://ecclectic.ss.uci.edu/~drwhite/Movie>

The role of networks

Behind each system studied in complexity there is an intricate wiring diagram, or a **network**, that defines the interactions between the component.

We will never understand complex system unless we map out and understand the networks behind them.

Structure and content

1. Introduction
 2. Basic definitions and properties
 3. Introduction to NetworkX
 4. Network metrics and centrality measures
 5. Random networks
 6. Small-world networks
 7. Scale-free networks
 8. Growth and preferential attachment
 9. Communities
 10. Spreading phenomena
 11. Applications
- Invited lectures

Requirements and Evaluation

- Course: **Grade1**
 - Written exam / research paper and presentation
 - Grade should be at least 5
 - 50% of the final grade
- Seminar/Lab: **Grade2**
 - Project implementation and presentation
 - Attendance 75%
 - 50% of the final grade

Evaluation: course (Grade1)

Grade1 (at least 5): 50% of the final grade

Present a research topic from network science
(presentation and written paper)

- Presentation (individual, lectures 12-14)
- Paper (submitted in the exam date)

Grade1 is the average of two grades (one for the presentation and one for the written paper)

Evaluation: course (Grade1)

Choose a research topic from network science, prepare a written paper and a presentation

- Individual work
 - **Deadline for choosing your topic: week 9-10 (exact date to be announced)**
 - Topic should be different than those presented during the course and should represent useful information/knowledge in network analysis
 - The **paper** should detail the topic and have an appropriate structure to present the concepts/definitions/results with relevant references (*recommended length: 5-7 pages*)
 - The **presentation** should cover the topic in 5-6 minutes and explain it
-
- **Presentation:** during the lecture in the last 3 weeks of the semester (schedule will be announced)
 - **The paper:** to be submitted in the date of the exam (**mandatory step**)

=> Grade1 is the average of presentation grade and paper grade

Evaluation: seminar (Grade 2)

Grade2: 50% of the final grade

Project implementation and presentation

- *Analysis of real networks (details given in the seminar)*
- Team of 3-4 students
- Preliminary presentations: seminars 3-4
 - Show what is the data and idea of the project
- Final presentations: seminars 6-7
 - Present network analysis results (each student in the team will present his/her own contribution)
 - Submit code, data and experimental results

Bibliography and materials

Course web page: <http://www.cs.ubbcluj.ro/~cchira/teaching.html>

Content based on the textbook:

A.-L. Barabási, Network Science, Cambridge University Press, 2016.

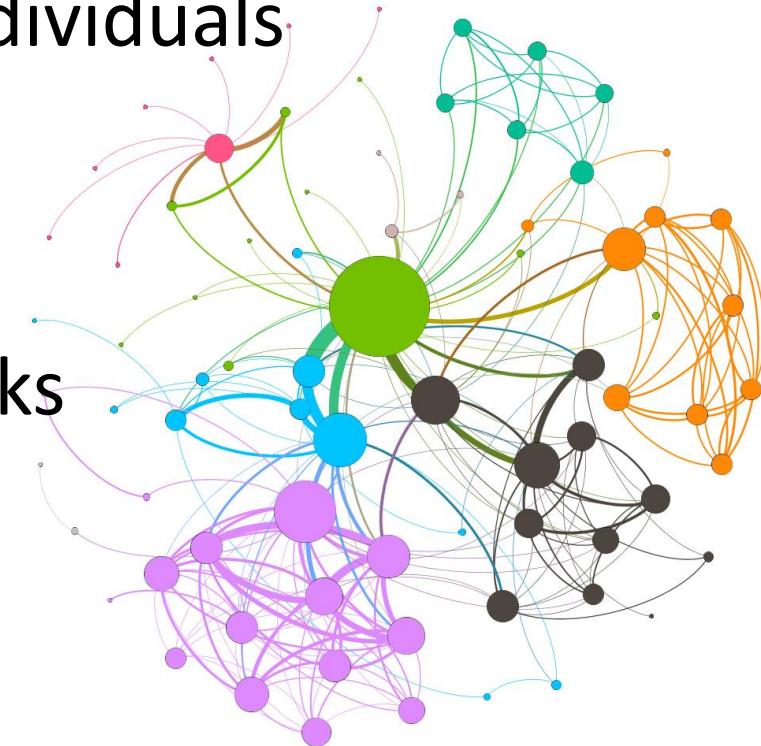
Available online: <http://networksciencebook.com/>

Bibliography

1. Albert-Laszlo Barabasi, Network Science, Cambridge University Press, 2016.
2. Mark Newman, Networks: An Introduction, Oxford University Press, 2010.
3. David Easley, Jon Kleinberg, Networks, Crowds, and Markets: Reasoning About a Highly Connected World, Cambridge University Press, 2010.
4. Ernesto Estrada, The Structure of Complex Networks Theory and Applications, Oxford University Press, 2011.
5. Melanie Mitchell, Complexity: A Guided Tour, Oxford University Press, 2009.
6. Robert A. Hanneman, Mark Riddle. 2005. Introduction to social network methods. Riverside, CA: University of California, Riverside (published in digital form at <http://faculty.ucr.edu/~hanneman>)
7. D. J. Watts, P. S. Dodds, M. E. J. Newman. Identity and Search in Social Networks. *Science*, 296, 1302-1305, 2002.

Social Networks

- Friendships between individuals
- Professional contacts
- Collaboration networks
- Communication networks
- Business networks
- Disease transmission



Complex networks

- Social networks
- Biological networks
- Technological networks
- Information networks
- Networks used in study of:
 - protein interactions, epidemiology, computer viruses, genetics, human transportation and communication, human language, books, movies, music, etc.

Interest in networks

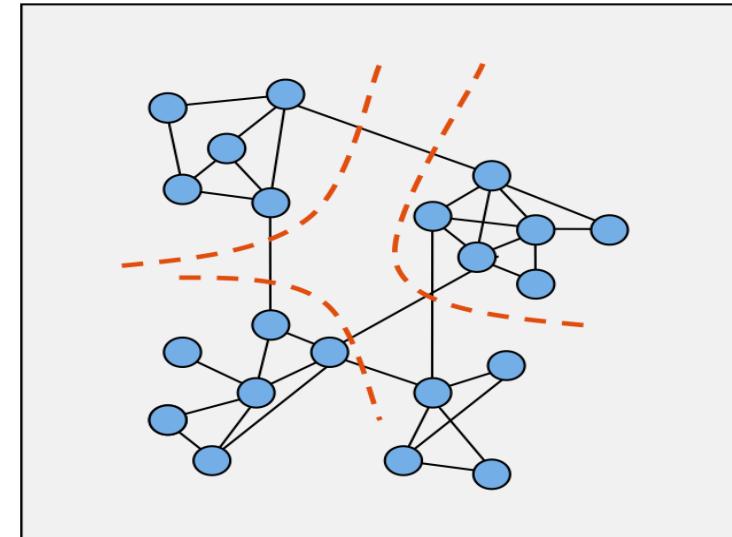
- Mathematicians
 - L. Euler: graph theory, solution of the famous Königsberg bridge problem (1765)
 - K. Appel, W. Haken, four-colour theorem (1976)
- Social scientists
 - Moreno (1930)
- Physicists
 - Statistical properties of networks
 - 1998 onward
- Computer scientists, social scientists, biologists

Social Network Analysis

- The process of investigating social structures through the use of networks and graph theory

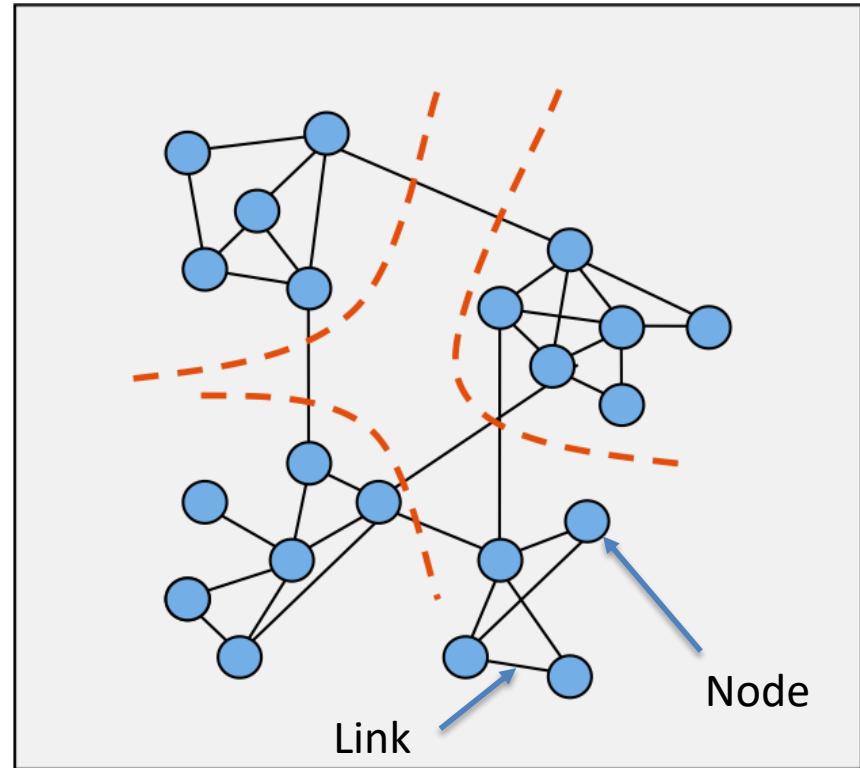
Terminology

- Network (graph)
- Nodes (vertices, actors)
- Edges (links, relations)
- Communities (clusters)



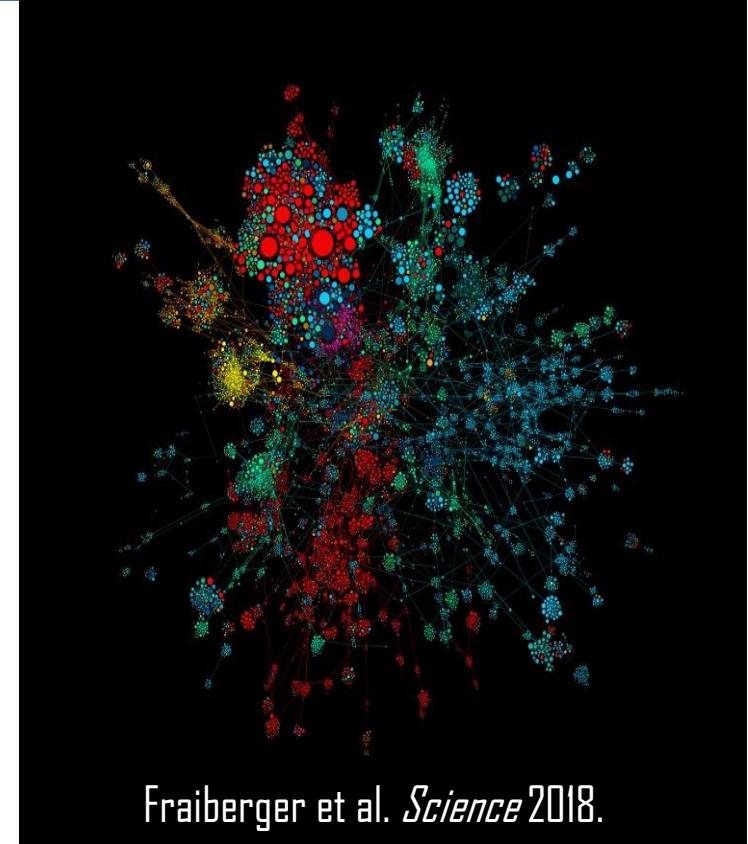
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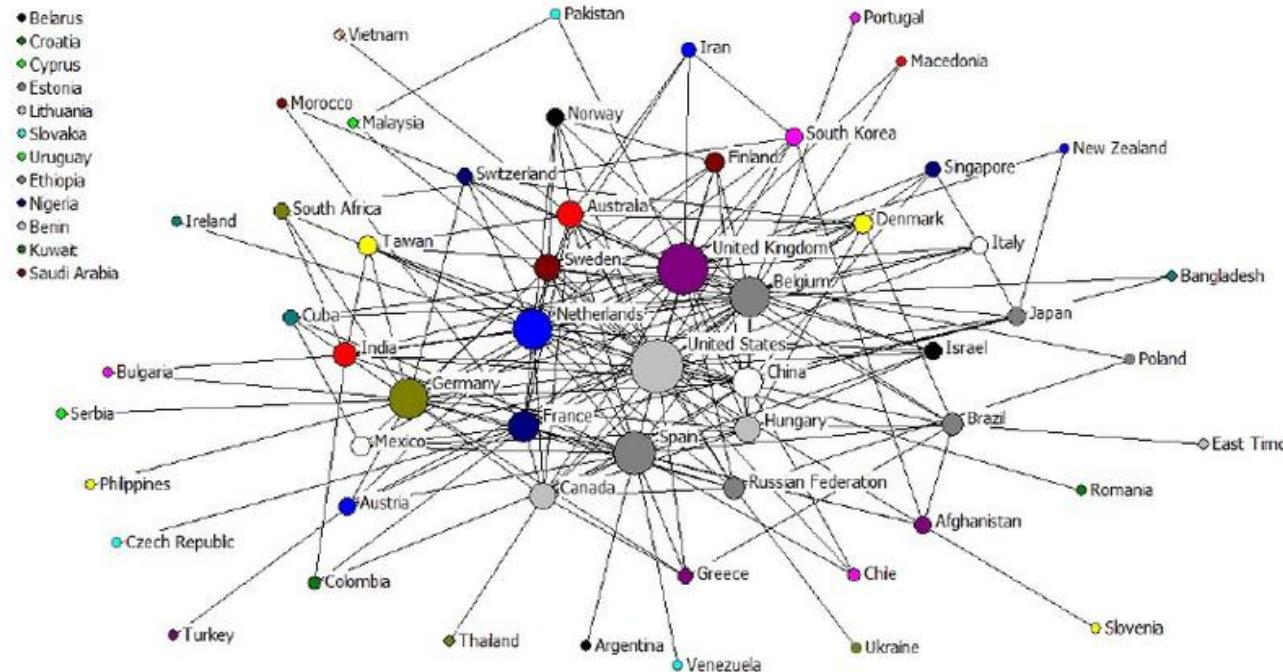
Complex Networks

- Networks = nodes + links
- Not regular
- Not random
- Complex topology
- Universal properties
- Scale-free networks



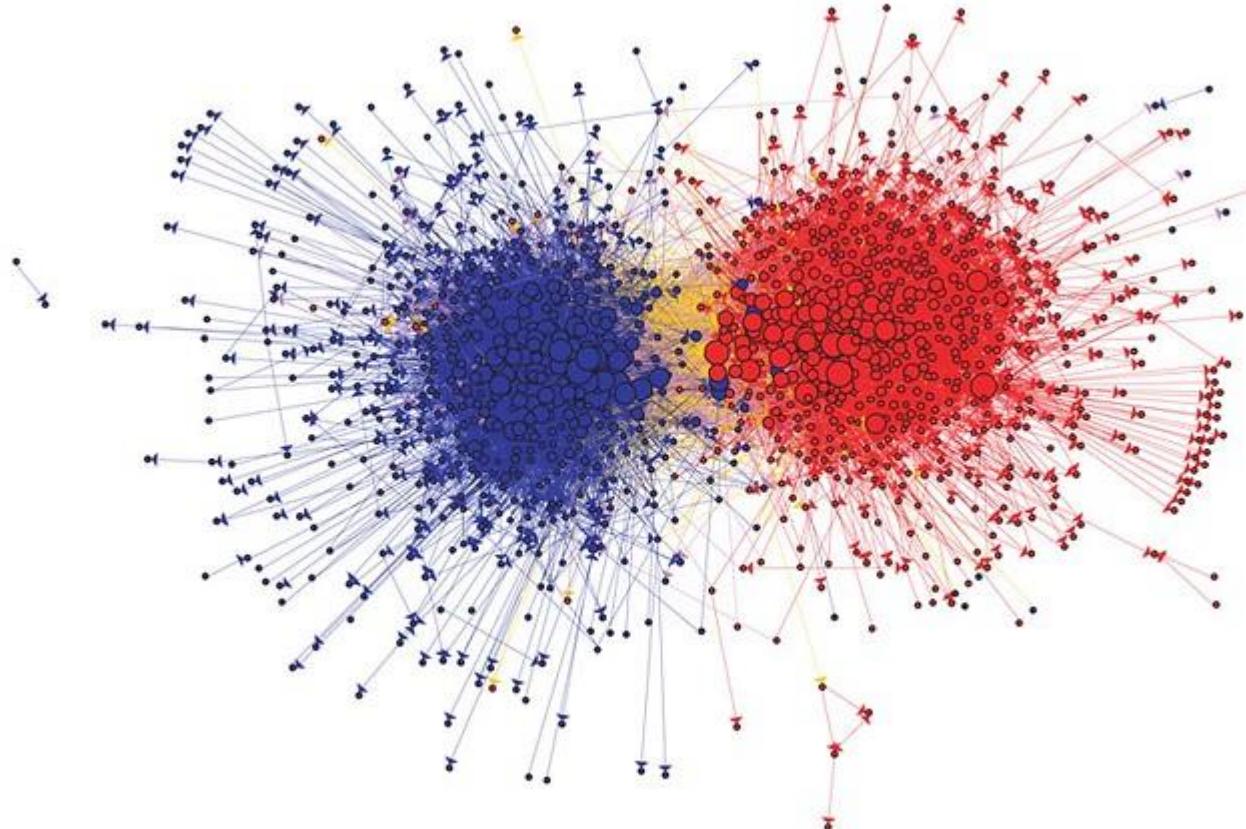
Fraiberger et al. *Science* 2018.

Examples: Co-authorship data

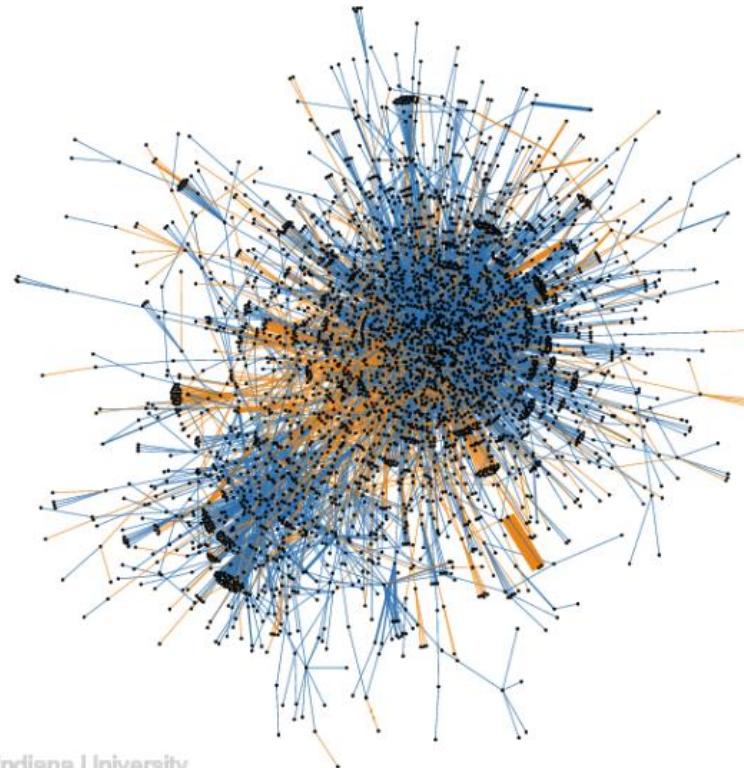


Co-authorship Network of Countries

Examples: Political blogs



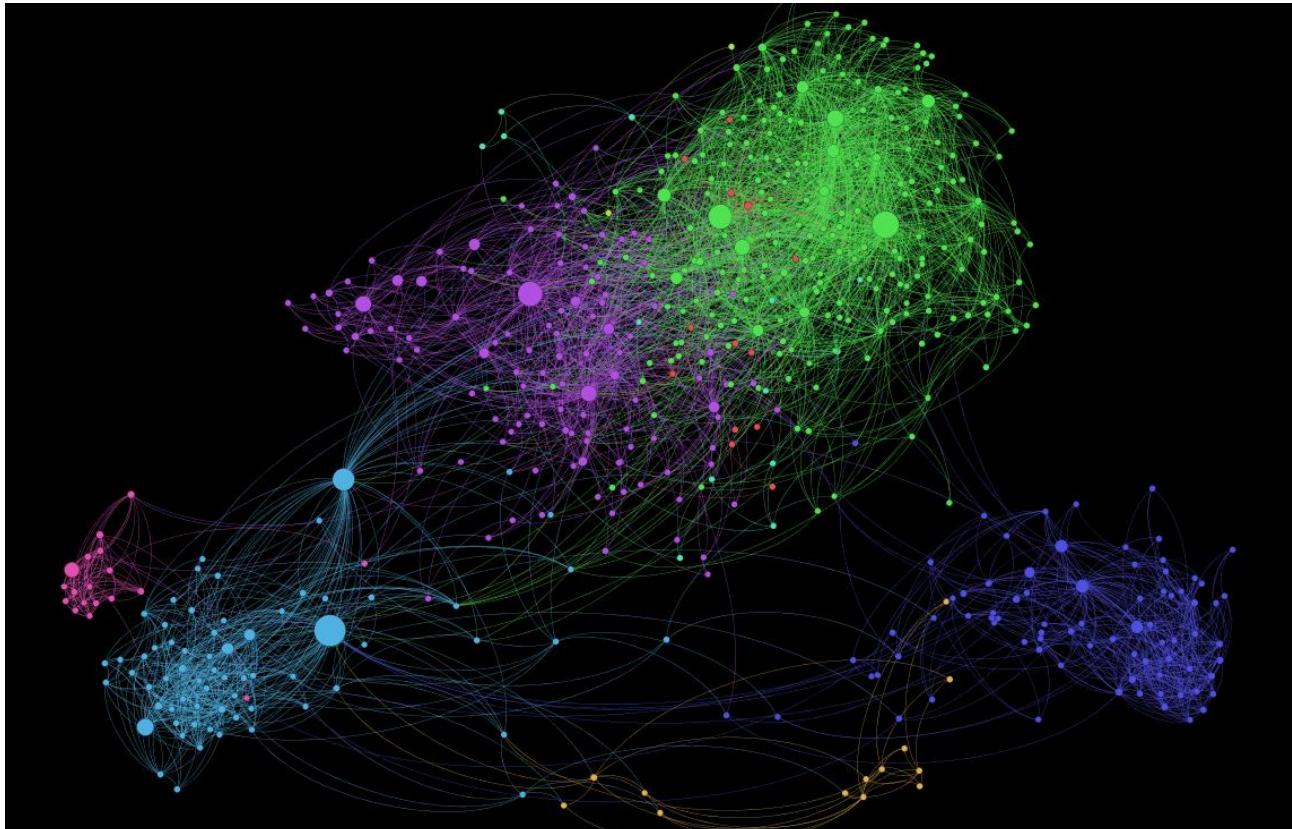
Examples: Twitter



Copyright 2010 Indiana University

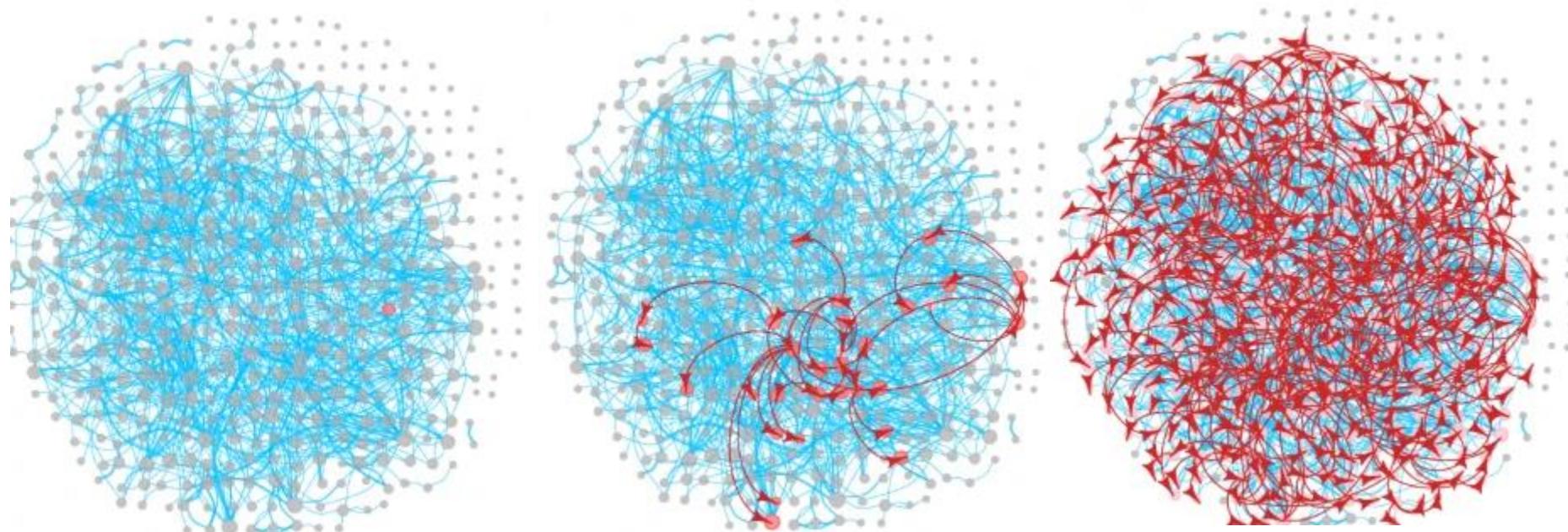
[truthy.indiana.edu](http://Truthy.indiana.edu)

Examples: Facebook



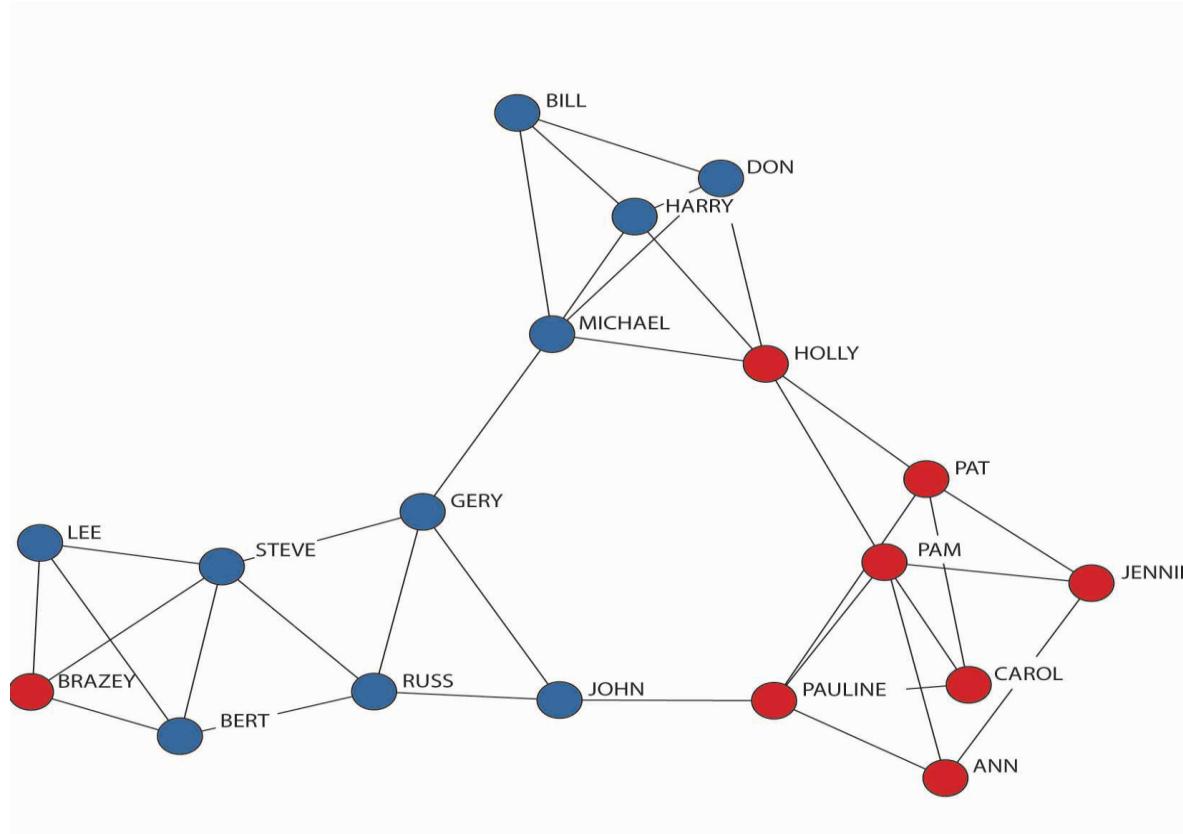
Examples: contact networks

epidemic simulation predictions



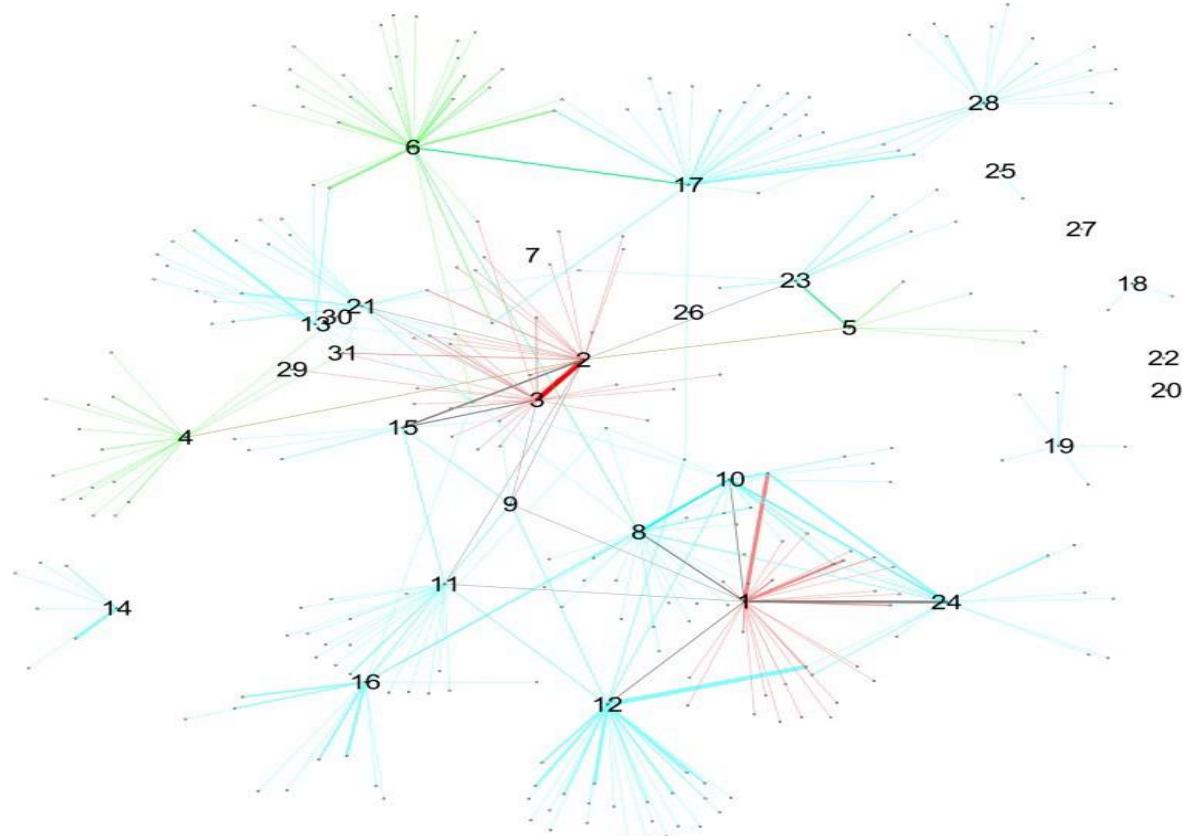
Firth, J.A., Hellewell, J., Klepac, P. et al. Using a real-world network to model localized COVID-19 control strategies. *Nat Med* (2020).

Examples: Organization



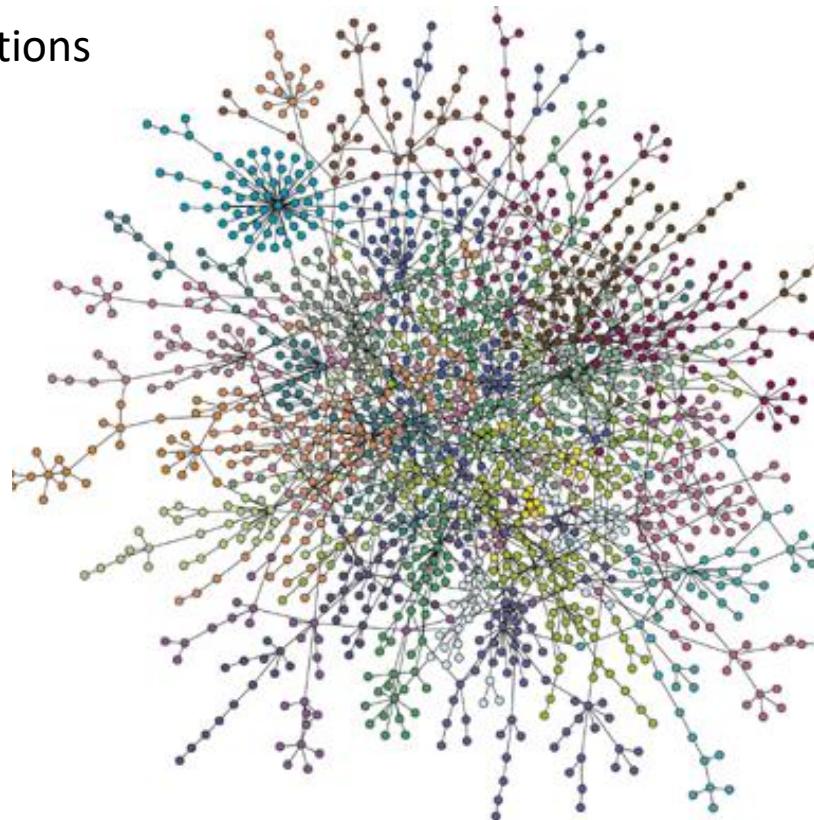
Examples: co-offending network

*Fight crime with
social network analysis*

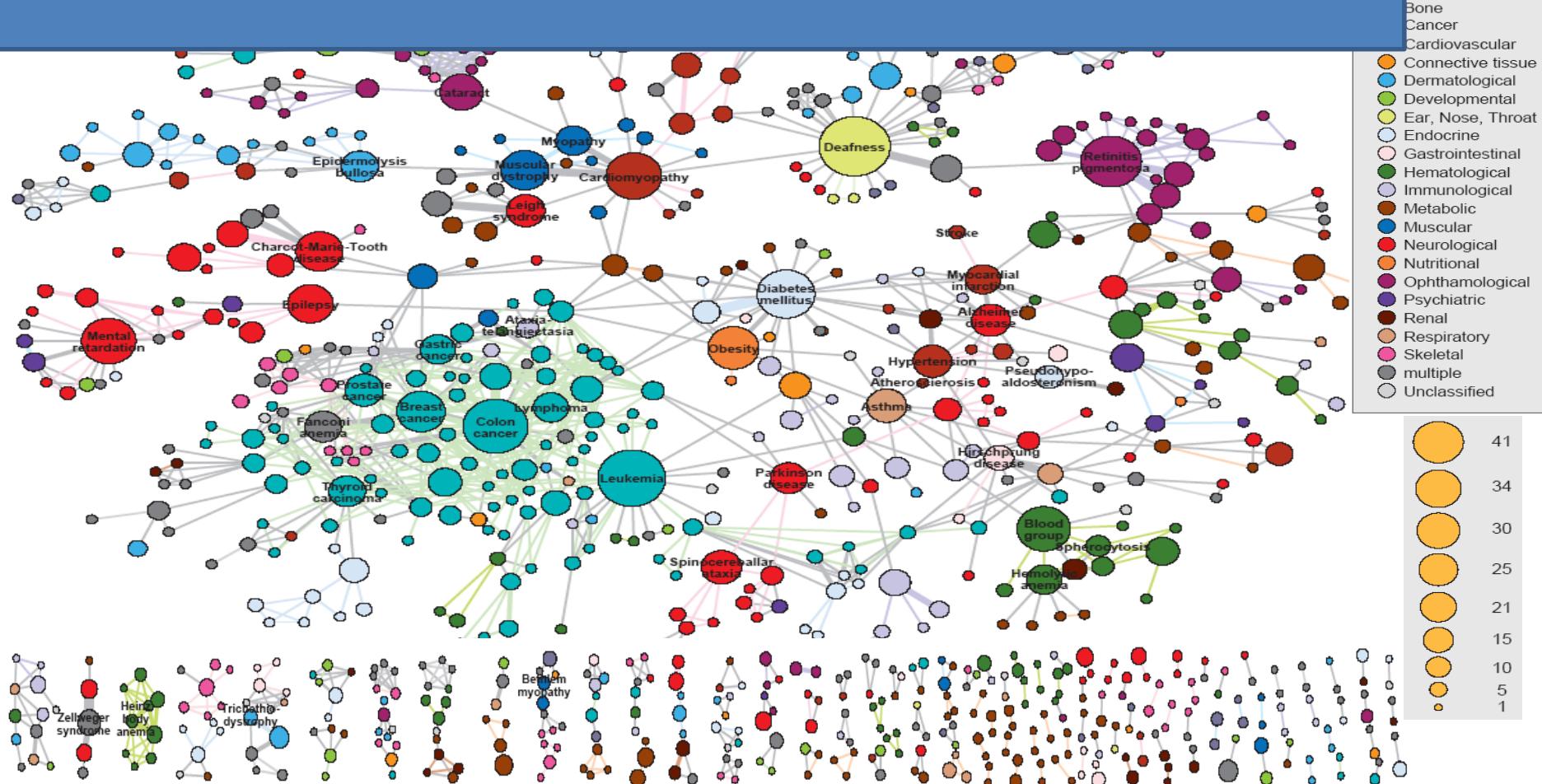


Examples: Biology

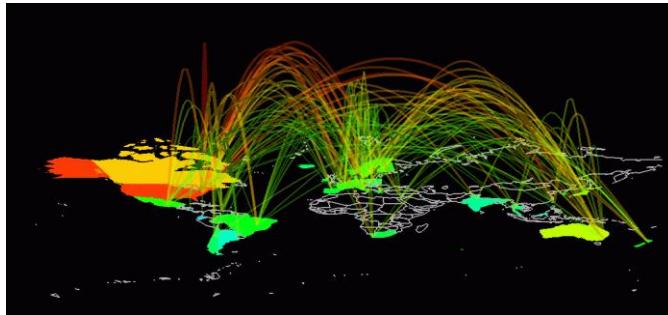
Protein-protein interactions



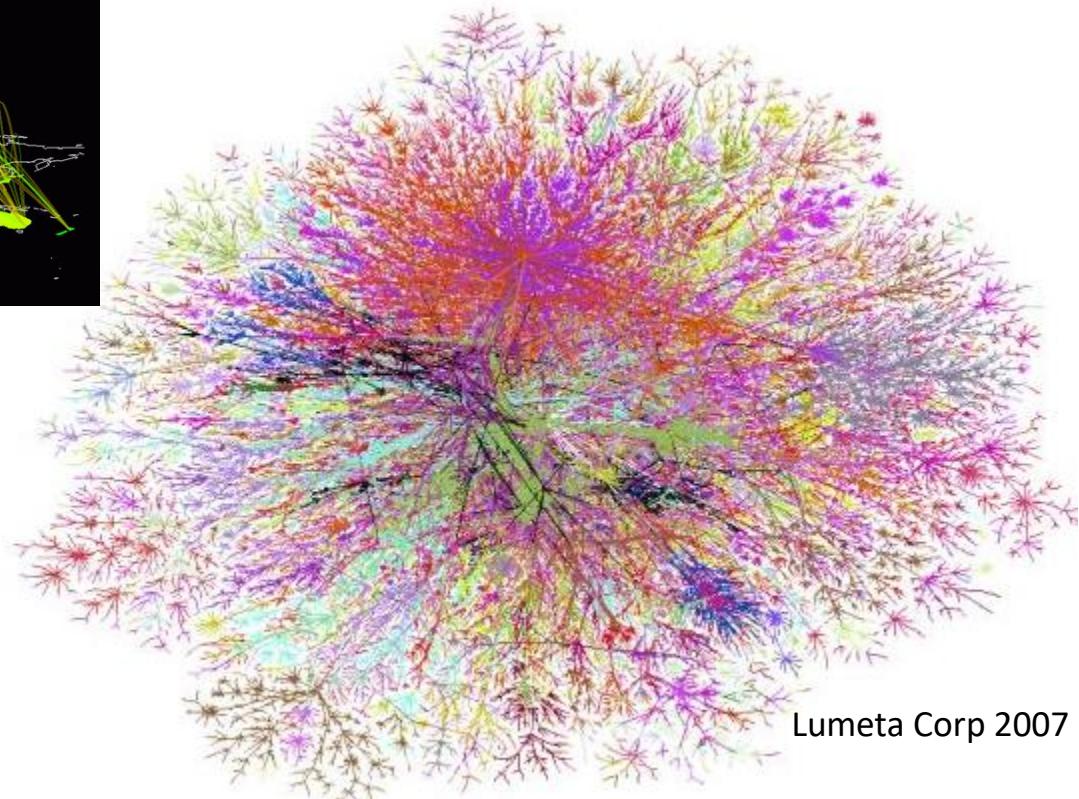
Examples: Human Disease network



Examples: Technology



Network
representation
of the
Internet



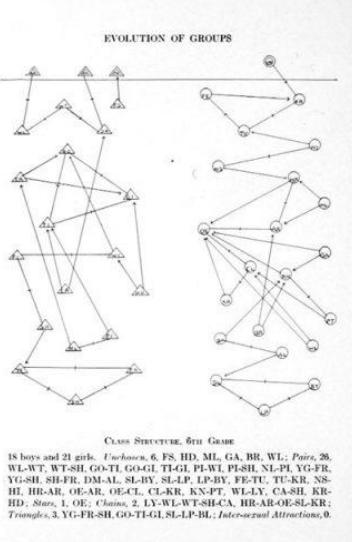
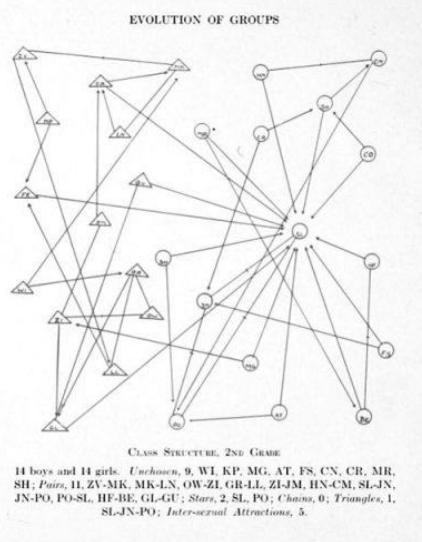
Lumeta Corp 2007

The history of network analysis

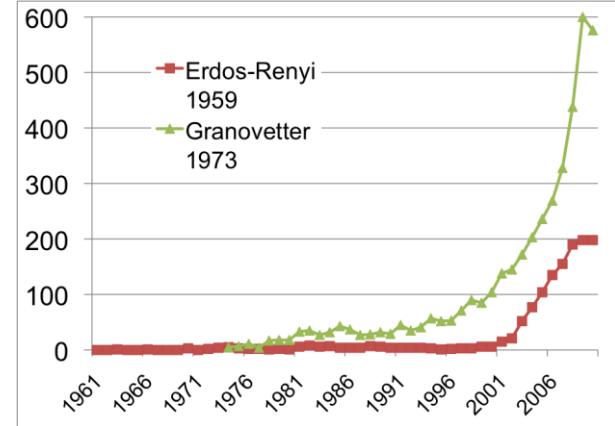
Graph theory: 1735, Euler

Social Network Research: 1930s, Moreno

Origins



Moreno (1934) *Who Shall Survive?*
Copyright: Nervous and Mental Disease Publishing Co.



Emergence of network science

Data availability: the emergence of network maps

Movie Actor Network, 1998

World Wide Web, 1999

C elegans neural wiring diagram 1990

Citation Network, 1998

Metabolic Network, 2000

PPI network, 2001

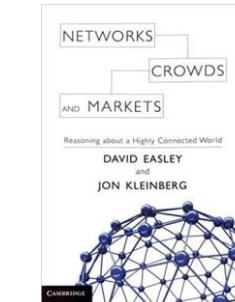
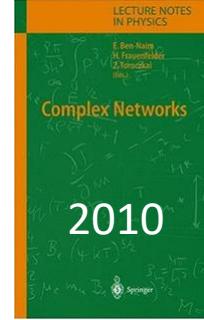
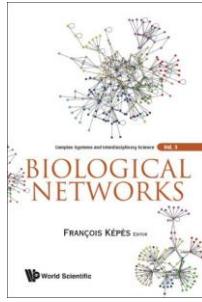
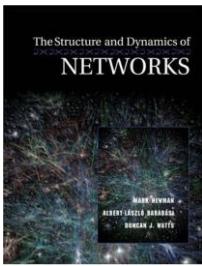
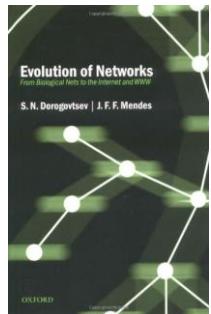
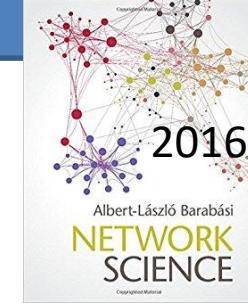
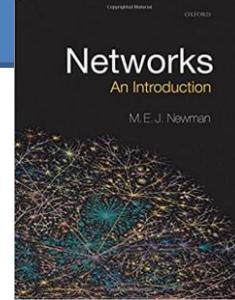
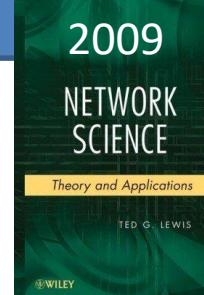
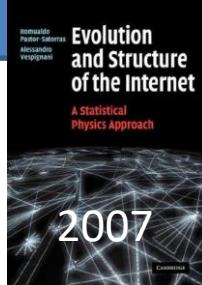
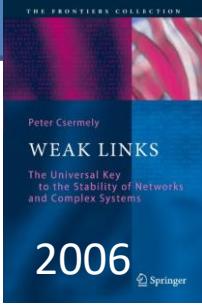
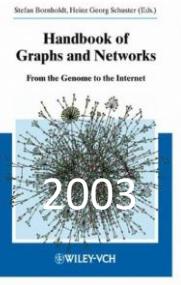
The universality of network characteristics

The architecture of networks emerging in various domains of science, nature, and technology are more similar to each other than one would have expected.

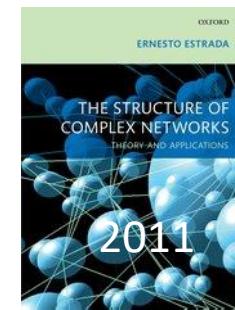
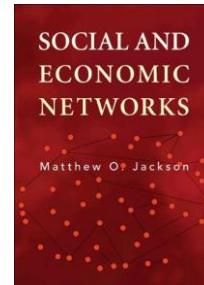
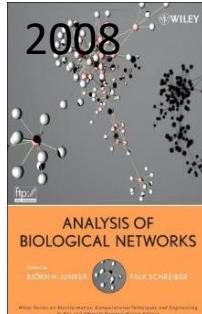
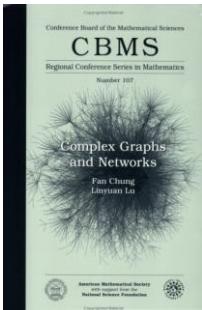
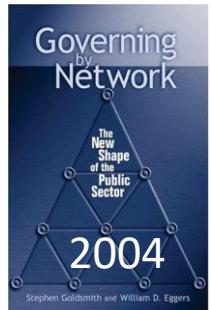
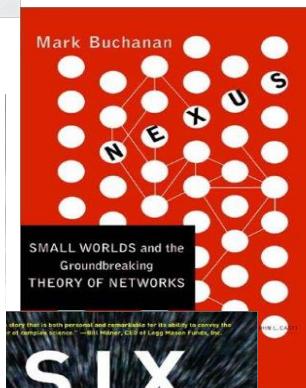
Original papers

- **1998:** Watts-Strogatz paper in the most cited **Nature** publication from 1998; highlighted by ISI as one of the ten most cited papers in physics in the decade after its publication.
- **1999:** Barabasi and Albert paper is the most cited **Science** paper in 1999;highlighted by ISI as one of the ten most cited papers in physics in the decade after its publication.
- **2001:** Pastor-Satorras and Vespignani is one of the two most cited papers among the papers published in 2001 by **Physical Review Letters**.
- **2002:** Girvan-Newman is the most cited paper in 2002 **Proceedings of the National Academy of Sciences**.

BOOKS

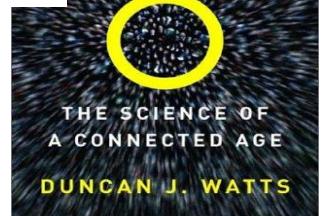


How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life



"Linked could alter the way we think about all of the networks that affect our lives." —The New York Times

Albert-László Barabási
With a New Afterword



Camelia Chira

Social Network Analysis

DOCUMENTARY

Connected, by Australian filmmaker Annamaria Talas



<https://youtu.be/zK1Cb9qj3qQ>

Camelia Chira

<http://cs.ubbcluj.ro/~cchira>

Content based on the textbook:

A.-L. Barabási, Network Science, Cambridge University Press, 2016.

<http://networksciencebook.com/>

References

- A.-L. Barabási, Network Science, Cambridge University Press, 2016. (Chapter 1)
- Mark Newman, The Physics of Networks., Physics Today, November 2008, pp. 33–38.
- A.-L. Barabási, Scale-Free Networks: A Decade and Beyond, Science 325, 412-413, 2009.
- Mark Newman, Networks: An Introduction, Oxford University Press, 2010.