

Complex networks

Introduction to Network Science

Carlos Castillo

Topic 01

Sources

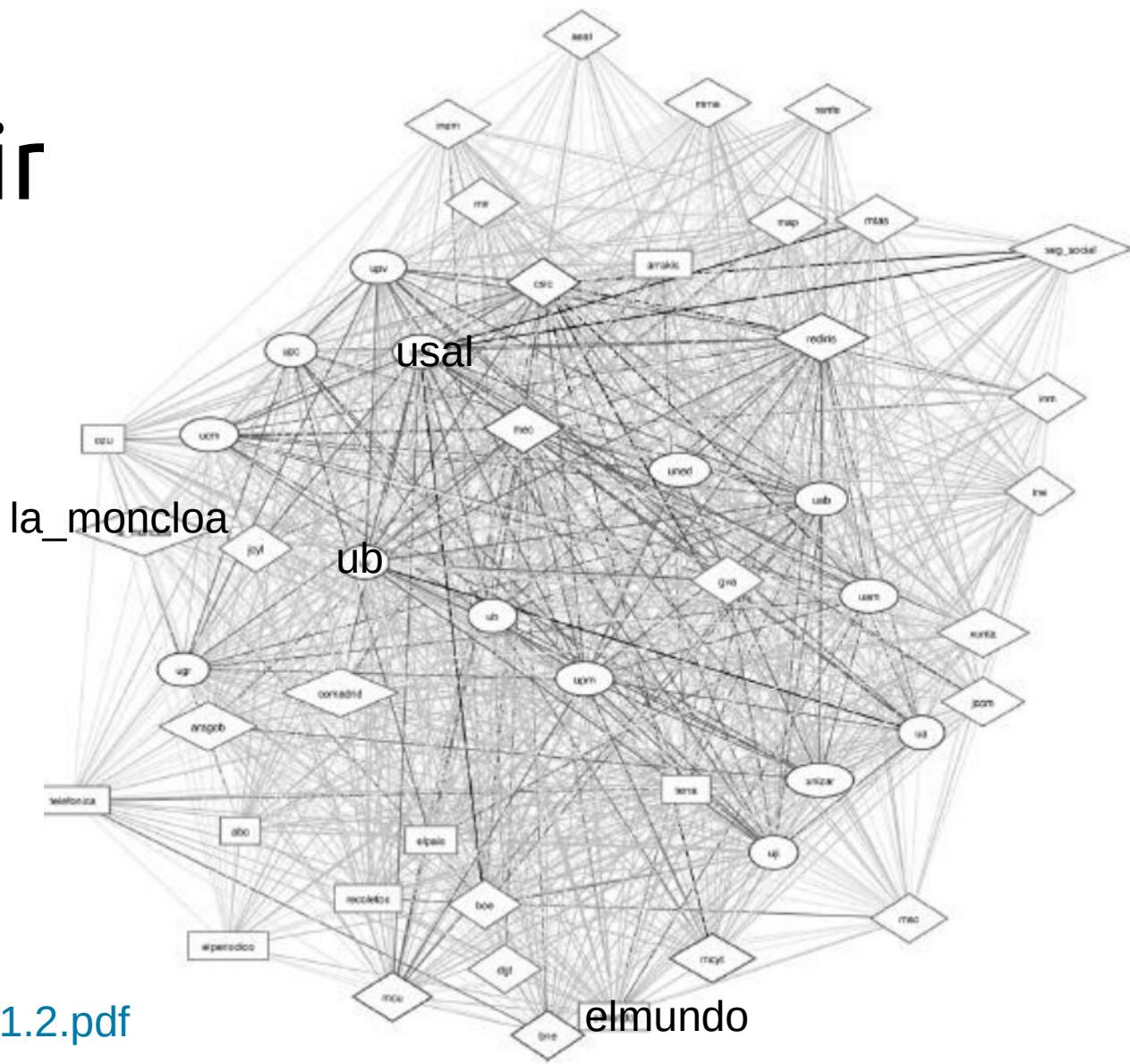
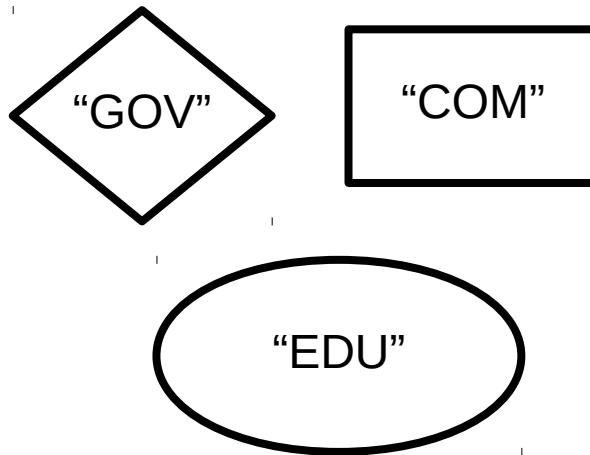
- Albert László Barabási: Network Science.
Cambridge University Press, 2016.
 - Chapters 01-02
- URLs cited in the footer of specific slides

A personal introduction

PhD work (2000-2004)

- Collecting web pages
- Characterizing national web domains
 - Chile, Korea, Greece, Spain ...

Top domains in .es (~2006)



Post-doctoral work (2005-2009)

- Web spam pages
 - Pages created to deceive search engines
 - Attract traffic by stuffing themselves with keywords
 - Increase link score of other pages
 - Methods evolve all the time, how to catch them?

The screenshot shows a web browser window with several tabs open, illustrating various security-related contexts where advertisements are placed.

NIST Computer Security Division's CSRC Home page
CSD publications, events, cryptographic standards and applications. Information on security testing, security management, and research initiatives. Includes links to the national vulnerability cyber
Source: [csrc.nist.gov](http://www.csrc.nist.gov)

Macromedia - Security Resource Center

Auto-generated and/or Plagiarized Content

Test / Event Log
Scan your system for trojans using this free online trojan scanner. Anti trojan software will allow Security Tests Web Site Security Audit. Get a free audit of your Website Security and check if
Source: www.windowsecurity.com

Security Center - PayPal
Welcome to the PayPal Security Center. Here, you'll find the latest information on how to buy and sell safely online. You'll get tools to help keep you protected.
Source: www.paypal.com

ASG Security - Home Security Solutions
We all know the feeling, that nagging concern in the back of our minds What if there's a fire? What if someone breaks in? ASG has a solution for you and your family - to help stop the worrying.
Source: www.asgsecurity.com

Yahoo! Security Center | About Passwords
Passwords. Your password is more than just a key to your online

www.Protect-My-Home.e.c

Security System Reviewed
Top Rated Security Systems Ratings - Security Systems
www.a-SecuritySystems.com

On Pro Pro Sig Det Ships Today
www.NeedDecals.com

Advertise on this site

EPOXY GARAGE FLOOR
BIKE RACKS
BERNINA SEWING MACHINES
PORTABLE AIR CONDITIONERS
DISCOUNT FURNITURE STORES
ELECTRIC FIREPLACE
MASSAGE CHAIRS
FACTORY FURNITURE
PRINTABLE GROCERY COUPONS
LAND IN NORTH CAROLINA
MOEN FAUCETS
DINING FURNITURE
FIBER GLASS
BOYNTON BEACH REAL ESTATE
CHENILLE BEDSPREADS
HOUSE DESIGNS

Advertisements in Profitable Contexts

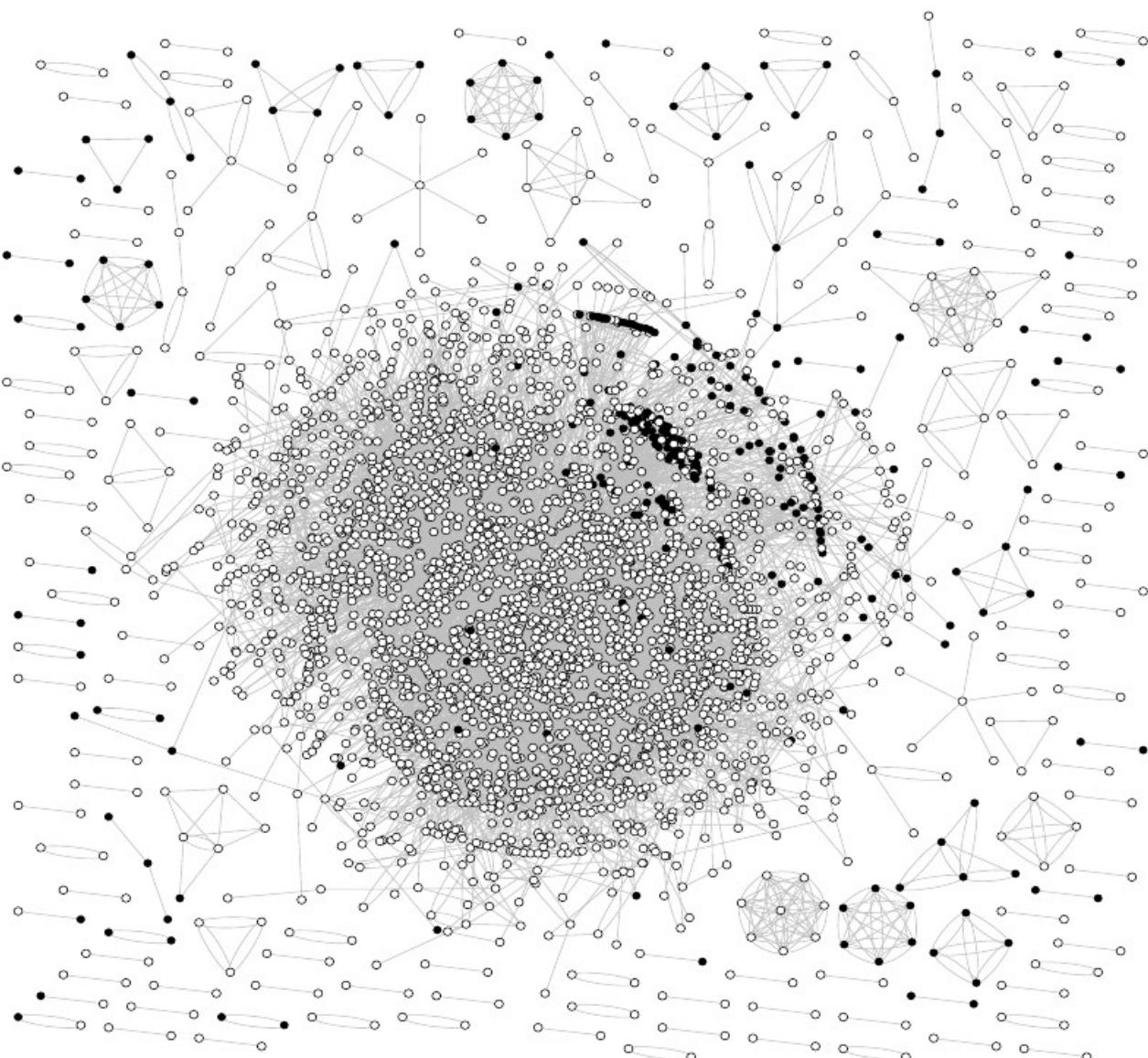
Link Farms to promote other spam pages

Eureka! Moment 2006

Use *gnuplot* to
visualize an
annotated dataset

White: non-spam

Black: spam

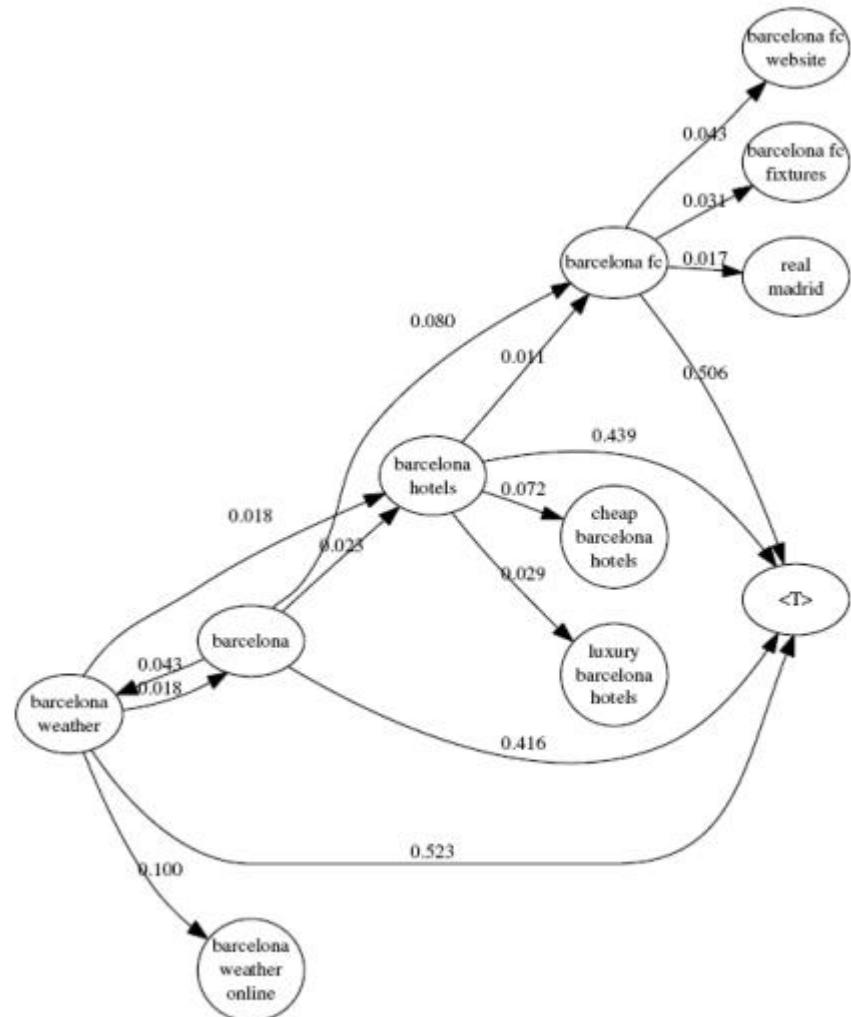


Query flows

2008

What is the most likely query before or after another query?

How are they connected?



Graphs in my own work

- Characterizing national web domains
- Finding web spam pages
- Suggesting queries to searchers
- ...
- Currently:
 - part of a larger toolbox
 - skeptical about structural-only conclusions

Network Science

Wikipedia definition

- **Network science** is an academic field which studies **complex networks** such as
 - telecommunication networks, computer networks, biological networks, cognitive and semantic networks, and social networks,
- considering
 - distinct elements or actors represented by **nodes** and
 - the connections between the elements or actors as **links**.

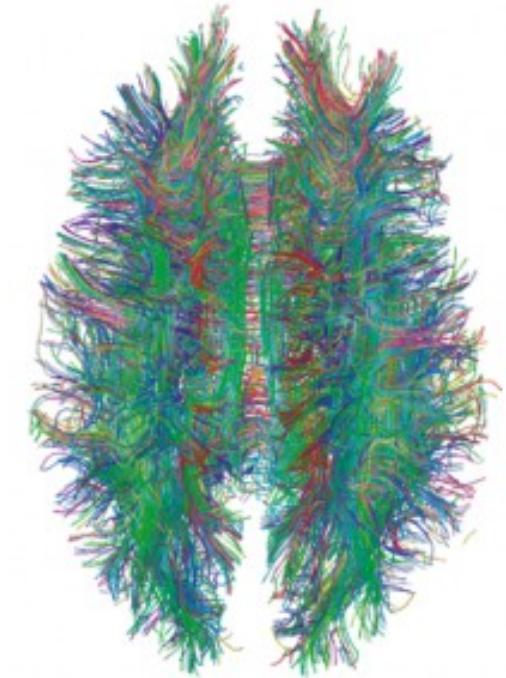
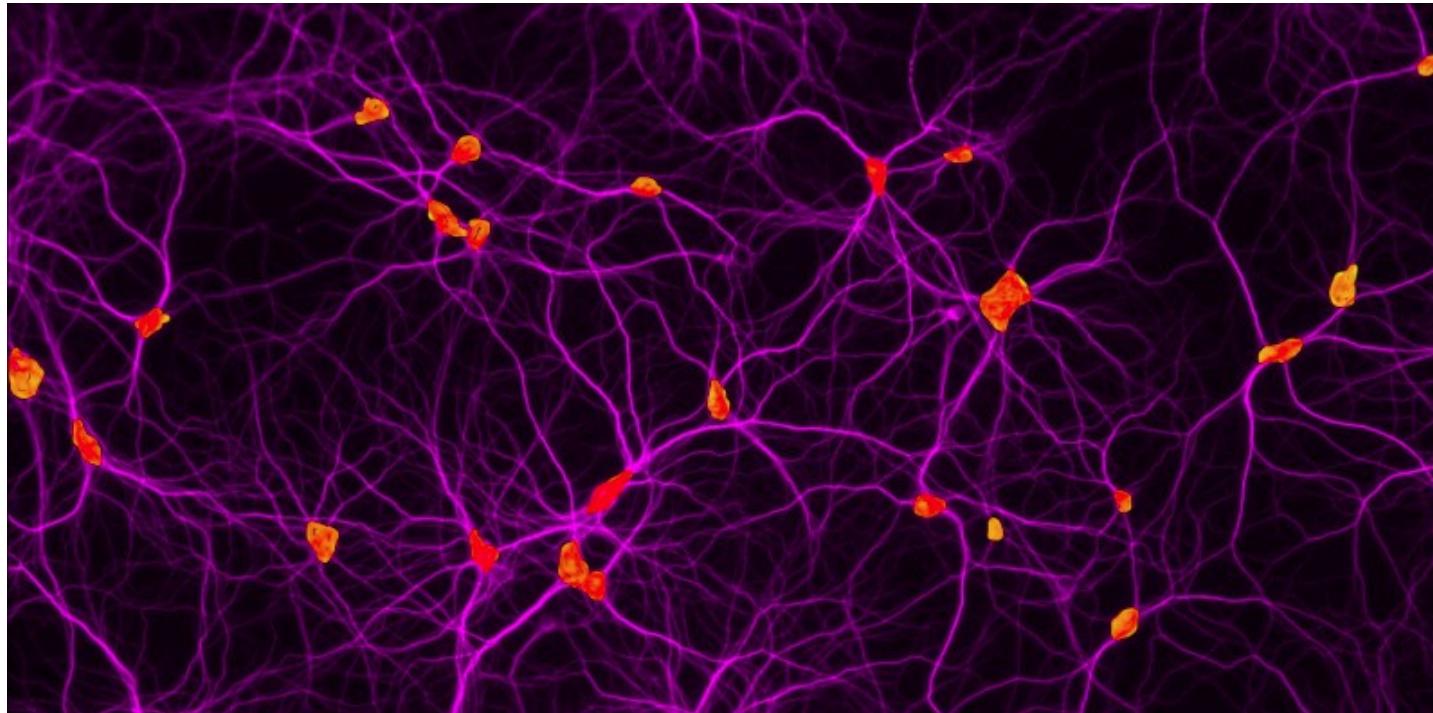
Complex systems

- Many interconnected parts
- Complicated arrangement of connections
- Emerging properties

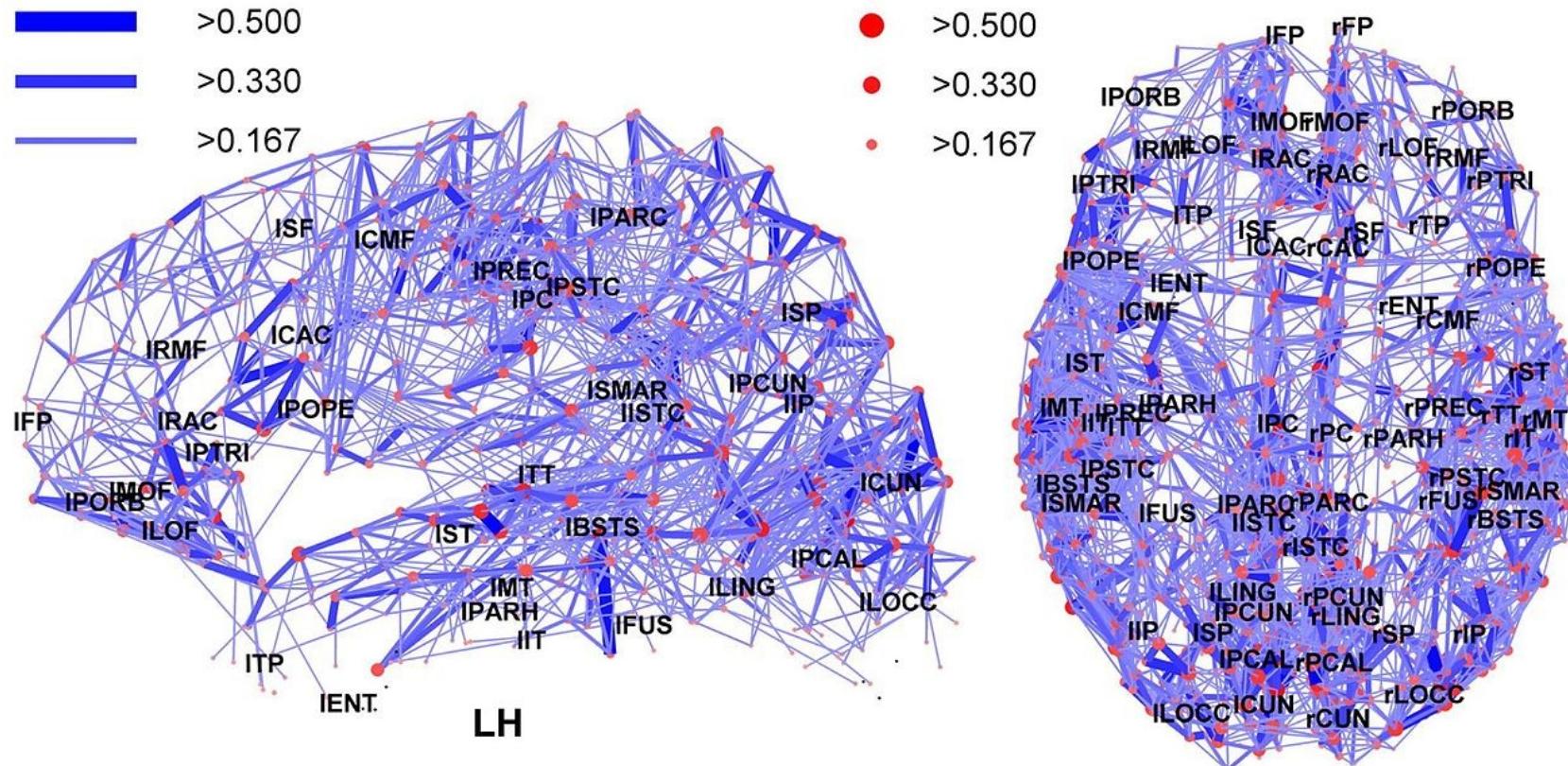
Behind every complex system there is a complex network

- Connections between neurons in the brain
- Interactions between genes and proteins
- Family/friendship links in human and non-human animals
- Infrastructure of telecommunications, electricity
- Commerce/trade networks

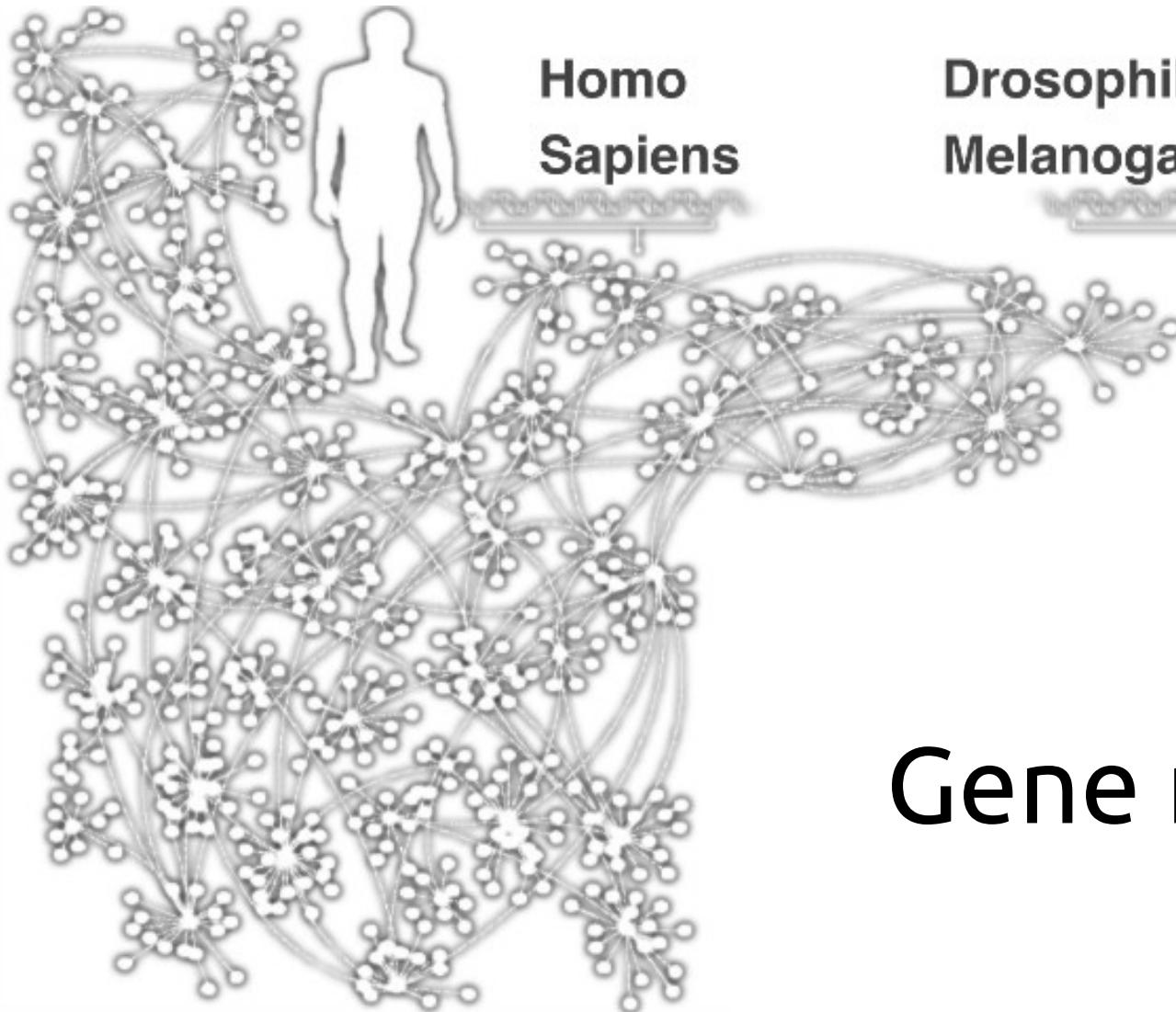
Human brain: $|V| \approx 90 \times 10^9$



Regions in the human brain

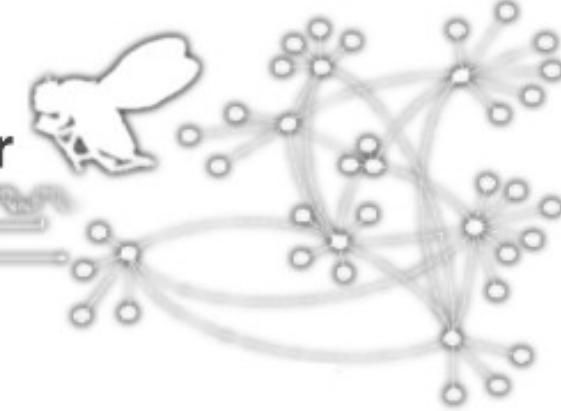


https://en.m.wikipedia.org/wiki/File:Network_representation_of_brain_connectivity.JPG



**Homo
Sapiens**

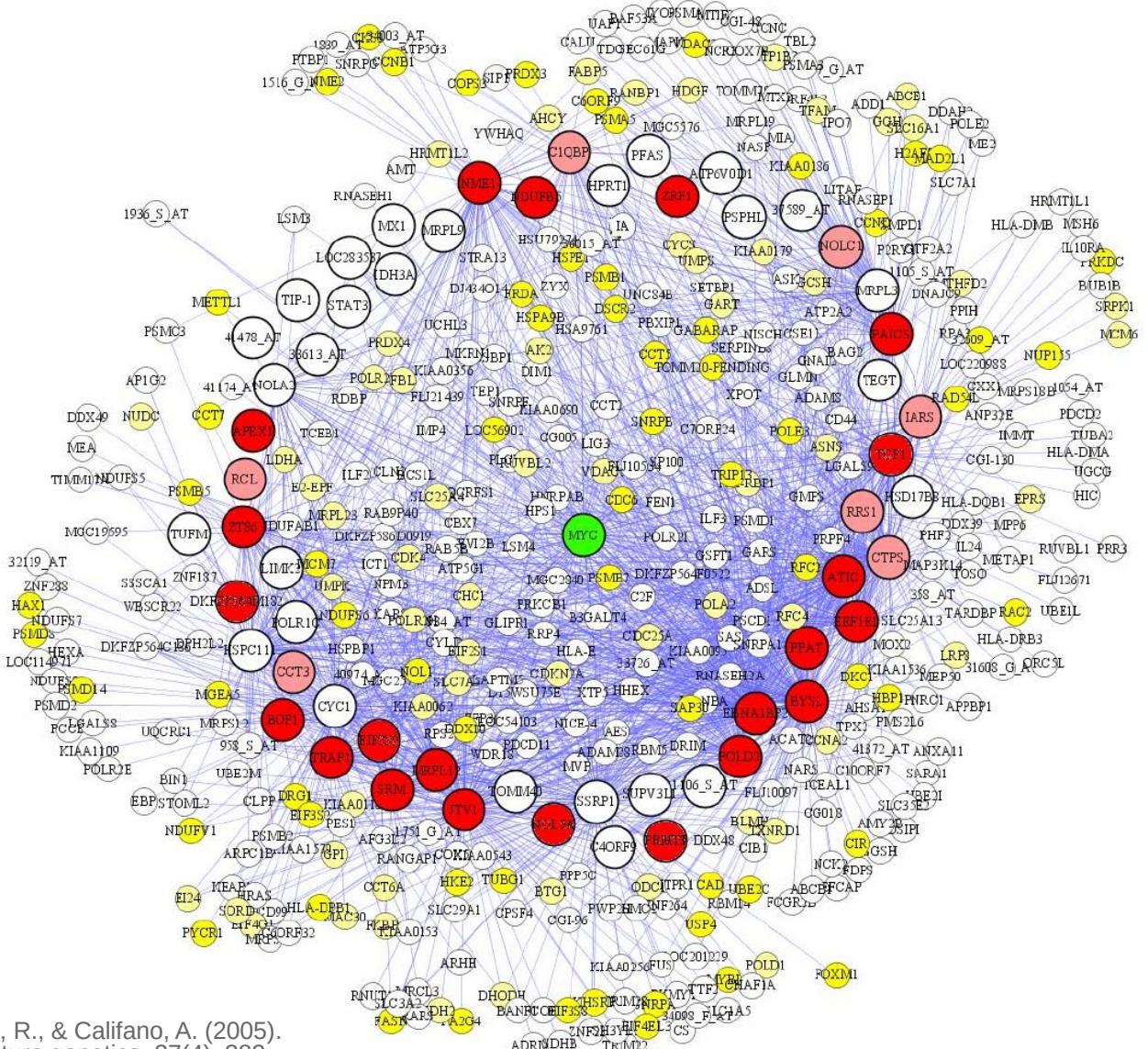
**Drosophila
Melanogaster**



Gene networks

Co-expression of Genes

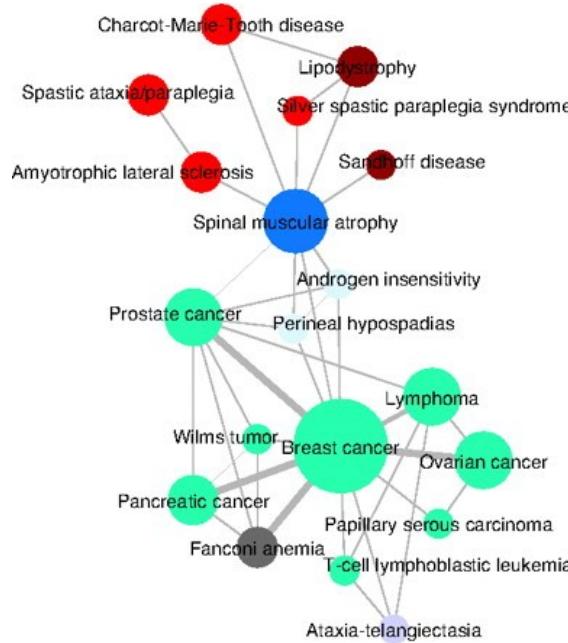
|V|=500 in this plot



Basso, K., Margolin, A. A., Stolovitzky, G., Klein, U., Dalla-Favera, R., & Califano, A. (2005). Reverse engineering of regulatory networks in human B cells. *Nature genetics*, 37(4), 382.

Human disease network

*Human Disease Network
(HDN)*



DISEASOME

disease phenotype

Ataxia-telangiectasia
Perineal hypospadias
Androgen insensitivity

T-cell lymphoblastic leukemia
Papillary serous carcinoma

Prostate cancer

Ovarian cancer

Lymphoma

Breast cancer

Pancreatic cancer

Wilms tumor

Spinal muscular atrophy

Sandhoff disease

Lipodystrophy

Charcot-Marie-Tooth disease

Amyotrophic lateral sclerosis

Silver spastic paraparesis syndrome

Spastic ataxia/paraparesis

Fanconi anemia

disease genome

AR

ATM

BRCA1

BRCA2

CDH1

GARS

HEXB

KRAS

LMNA

MSH2

PIK3CA

TP53

MAD1L1

RAD54L

VAPB

CHEK2

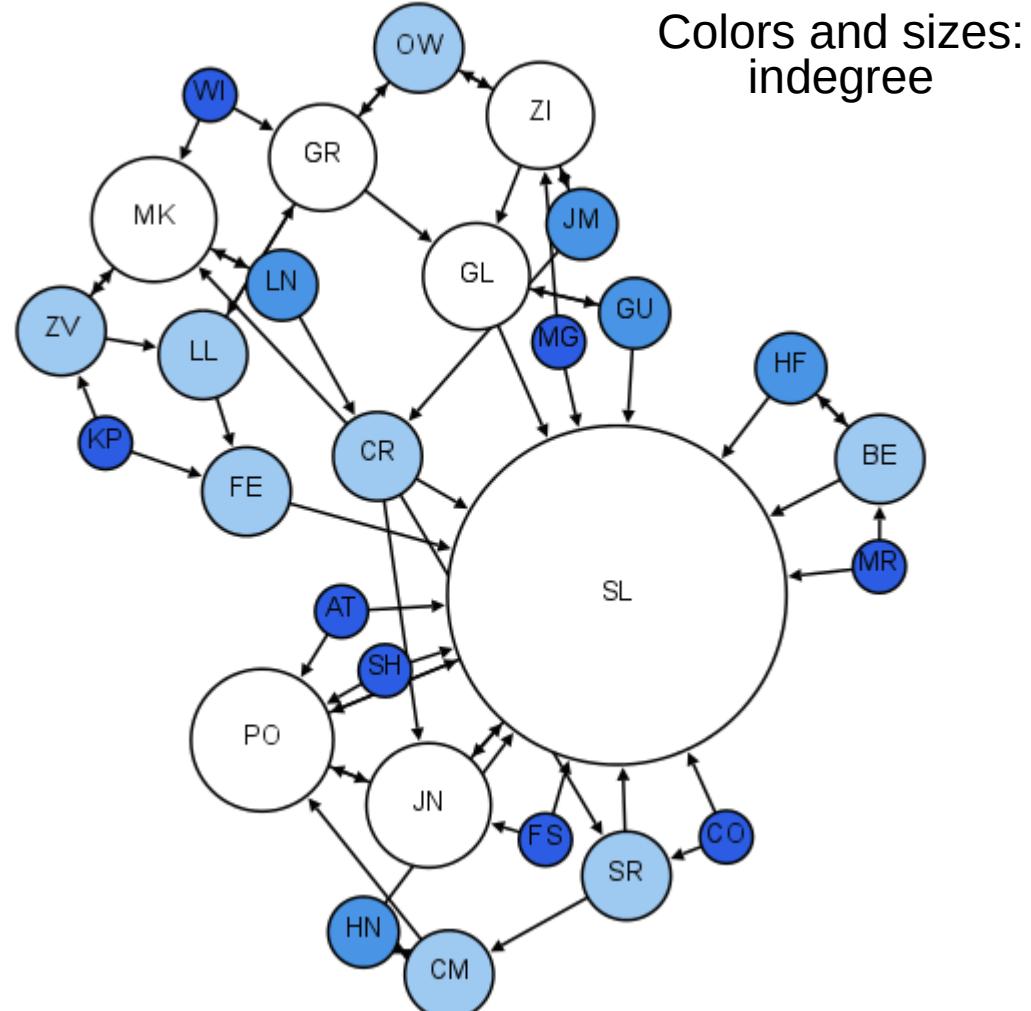
BSCL2

ALS2

BRIP1

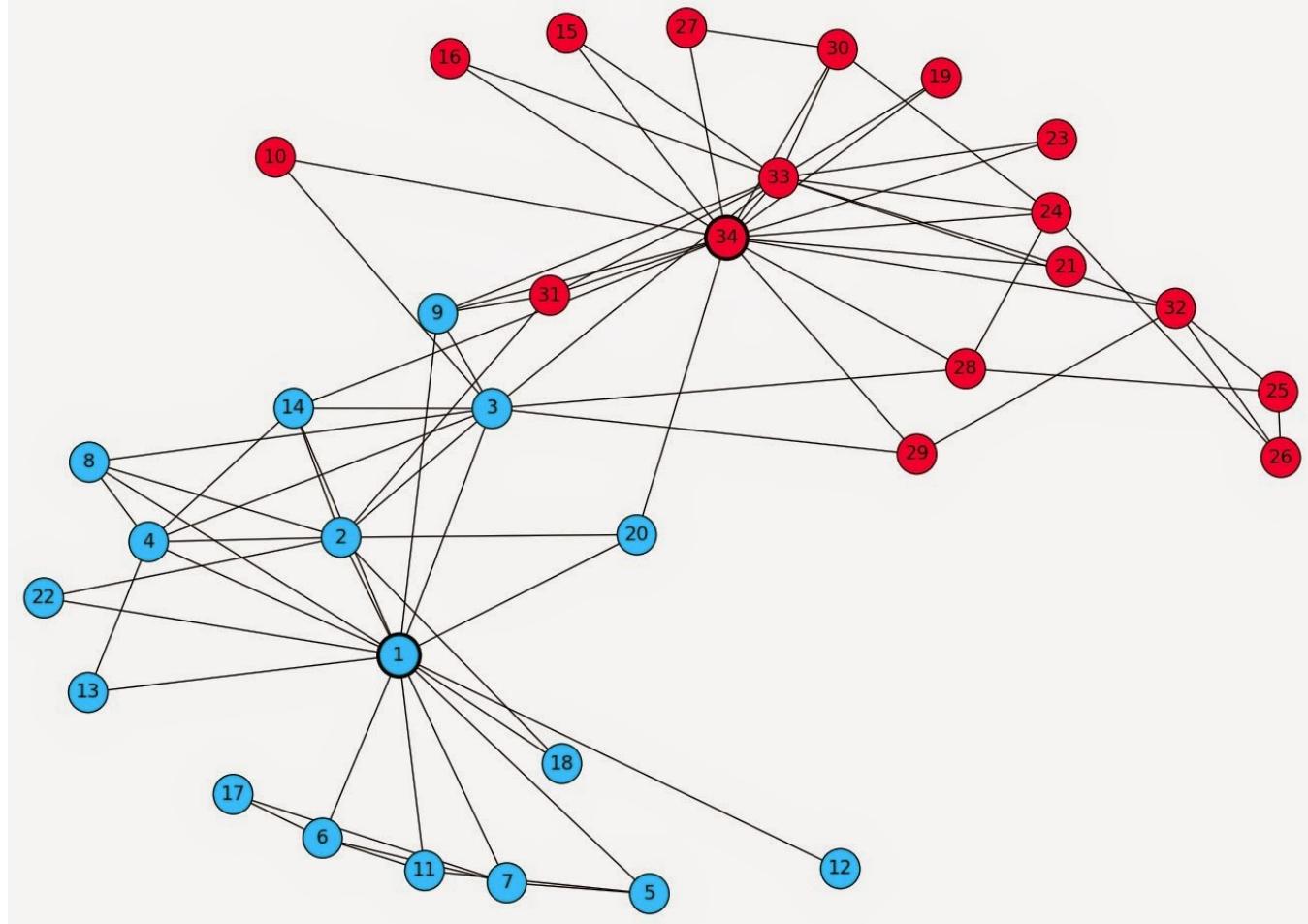
Moreno's sociograms

- Early 1930s
- Children in 2nd grade
- Who would you like to sit with?



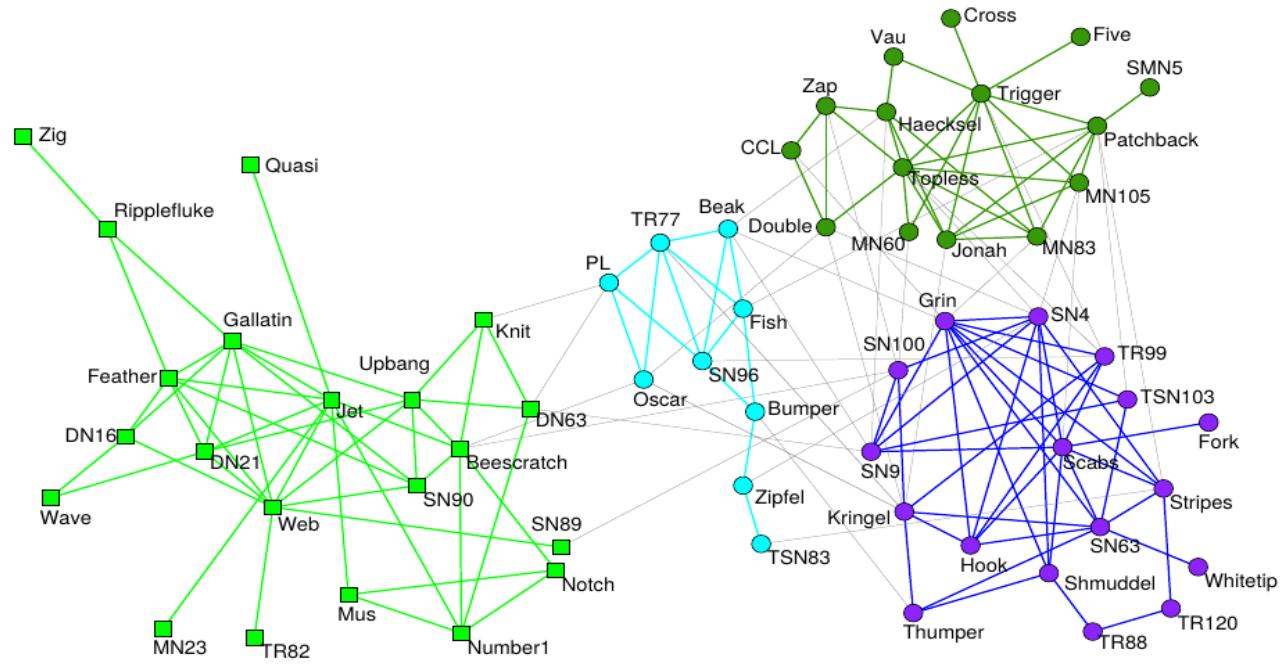
Zachary's Karate Club

Karate club that split into two clubs
(led by 1 and 34)



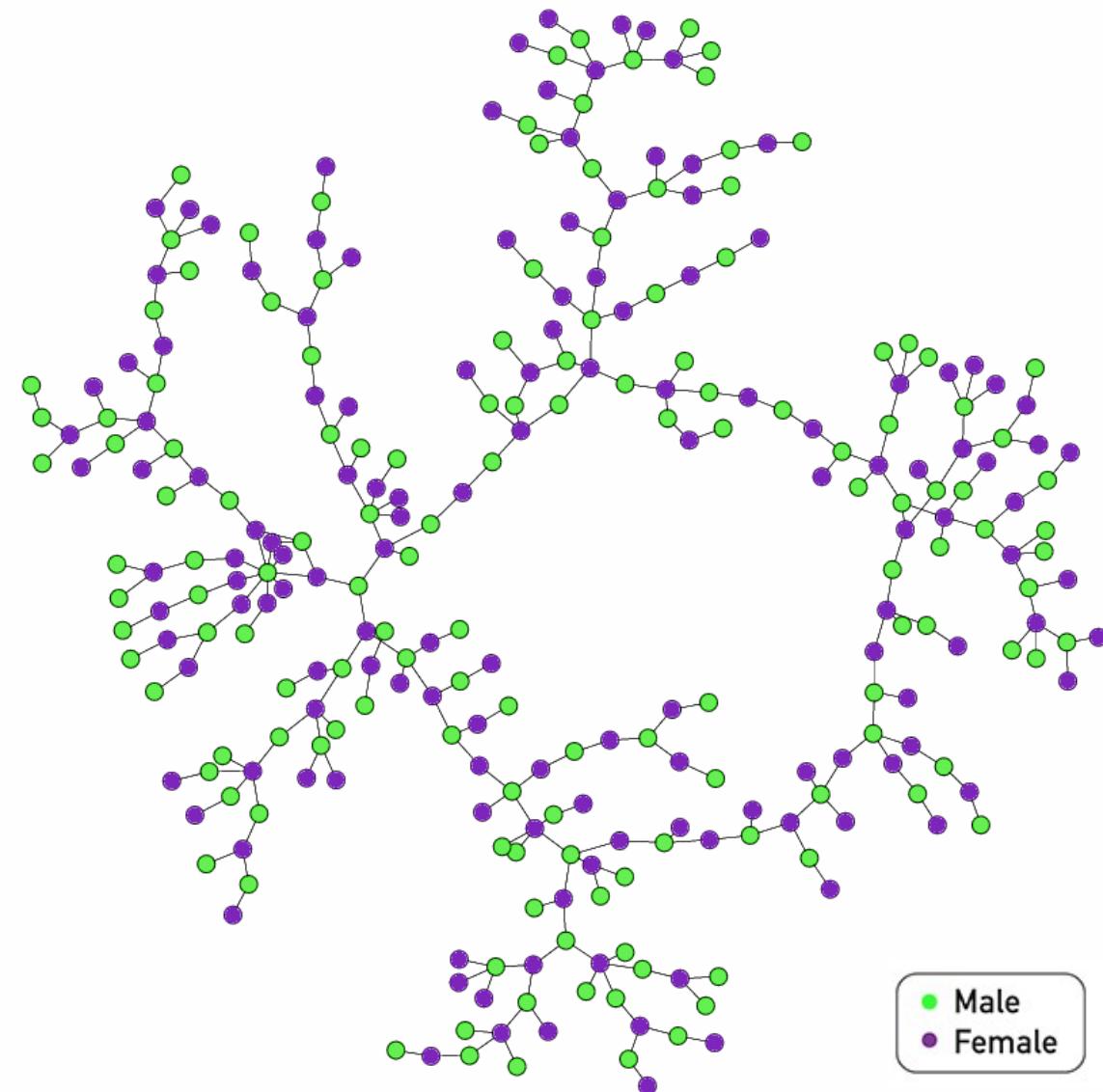
Dolphins in a fjord in New Zealand

- Research following a school of dolphins in the wild (2003)
- Look for dolphins swimming together
- Found **long-lasting associations**; research has been repeated with other non-human animals (e.g., sheep)

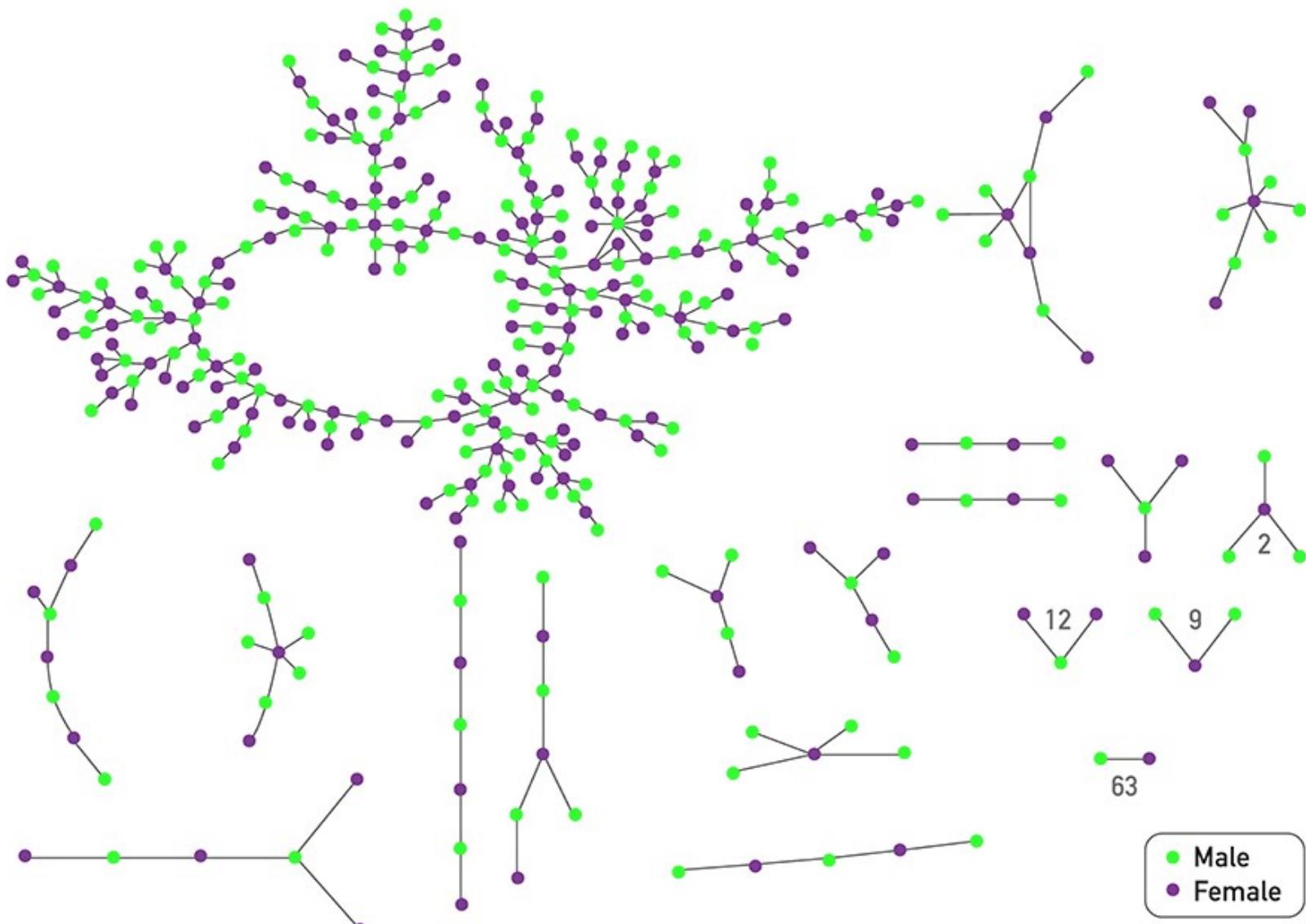


Chains of affection

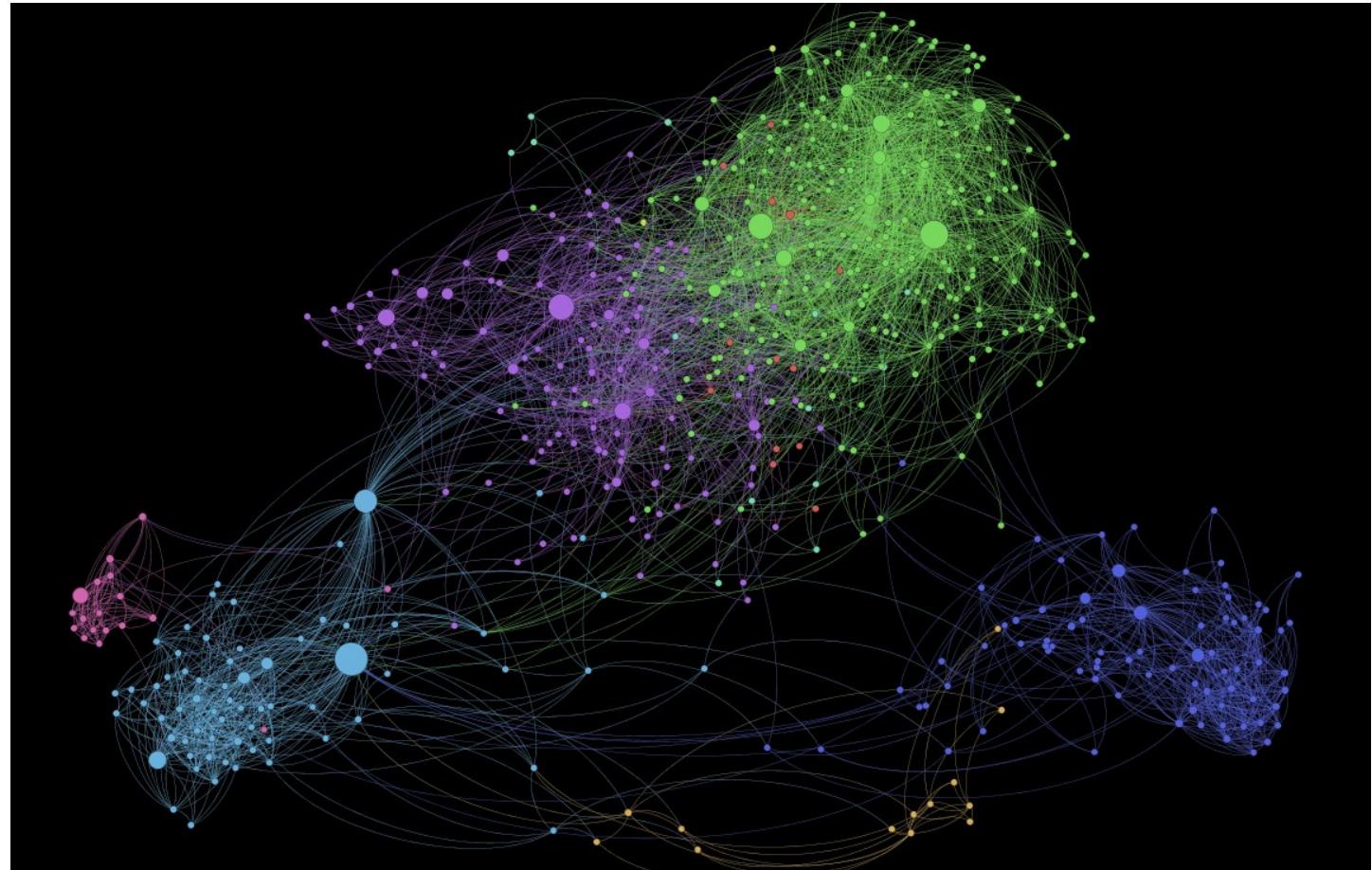
- Early 2000s
- Adolescents in high school
- A “*special romantic relationship*” or a “*nonromantic sexual relationship*” in the past 18 months



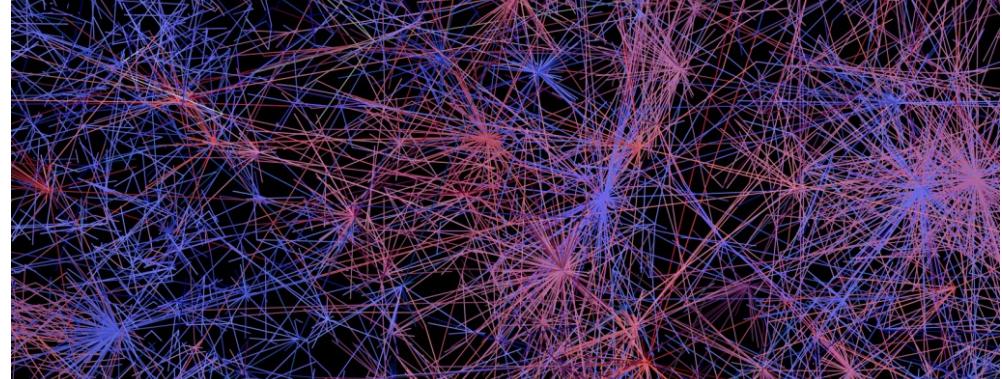
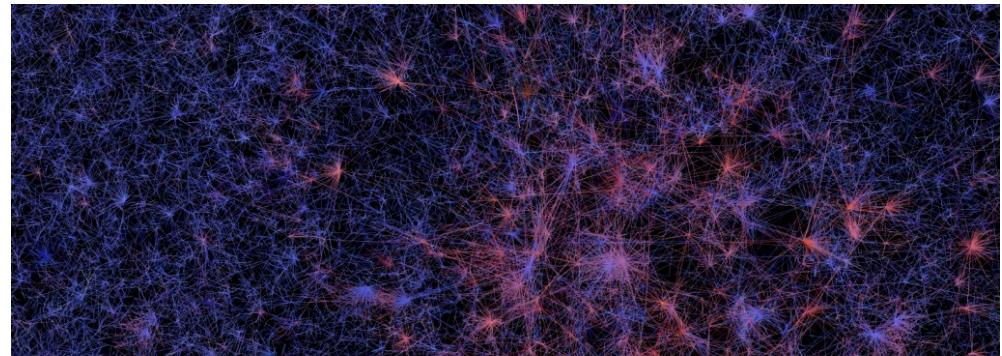
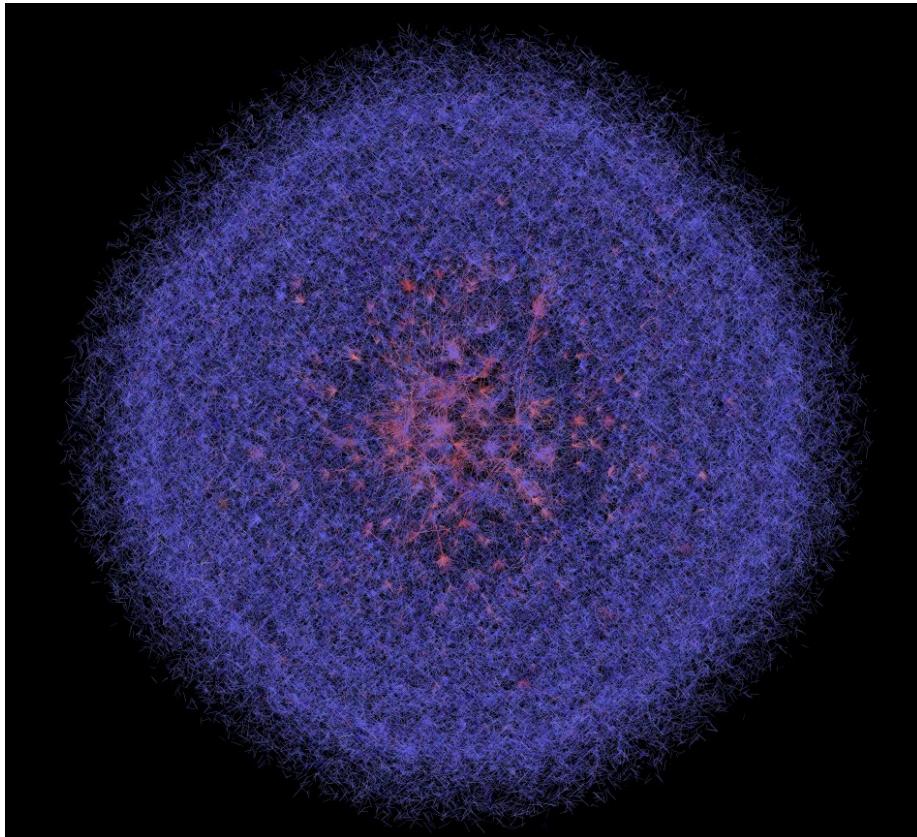
Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American journal of sociology, 110(1), 44-91.



1,000 Somali Users of Facebook



400,000 Twitter Users



What could these networks have in common? Why those regularities could be relevant? How would you find out what they are?

Universality of complex networks

"A key discovery of network science is that the architectures of networks emerging in various domains of science, nature and technology are similar to each other, a consequence of being governed by the same organizing principles."

(Barabási 2016)

Characteristics of network science

- **Interdisciplinary**; indeed we often address problems from disciplines other than CS
- **Empirical** and data-driven; it is based on the observation of networks
- Quantitative, mathematical, **computational**

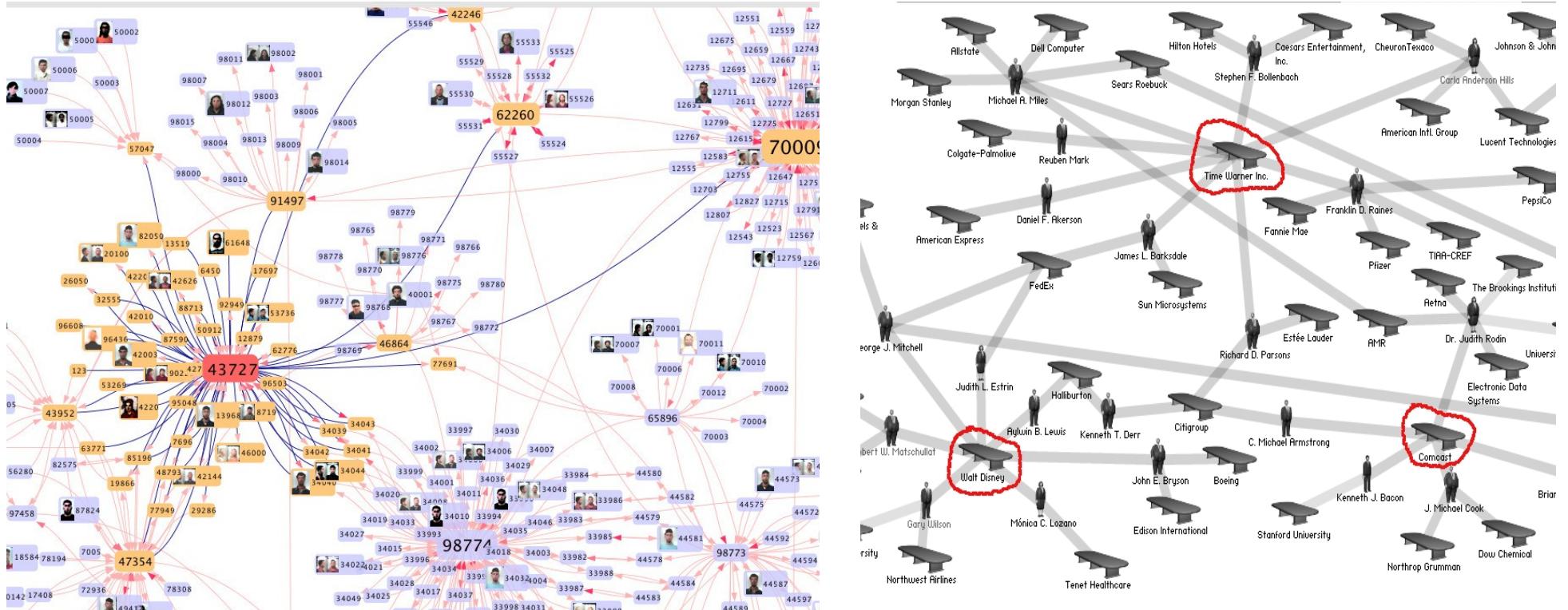
What can you do with this?

- Help design new treatments and drugs
- ...



<https://www.youtube.com/watch?v=wadBvDPeE4E>

Help fight organized crime and collusion



<https://itnews.iu.edu/articles/2014/complex-networks-researcher-at-iu-fighting-crime-with-mobile-phone-data.php>

https://en.wikipedia.org/wiki/File:Media_corporation_interlocks_-_2004.jpg

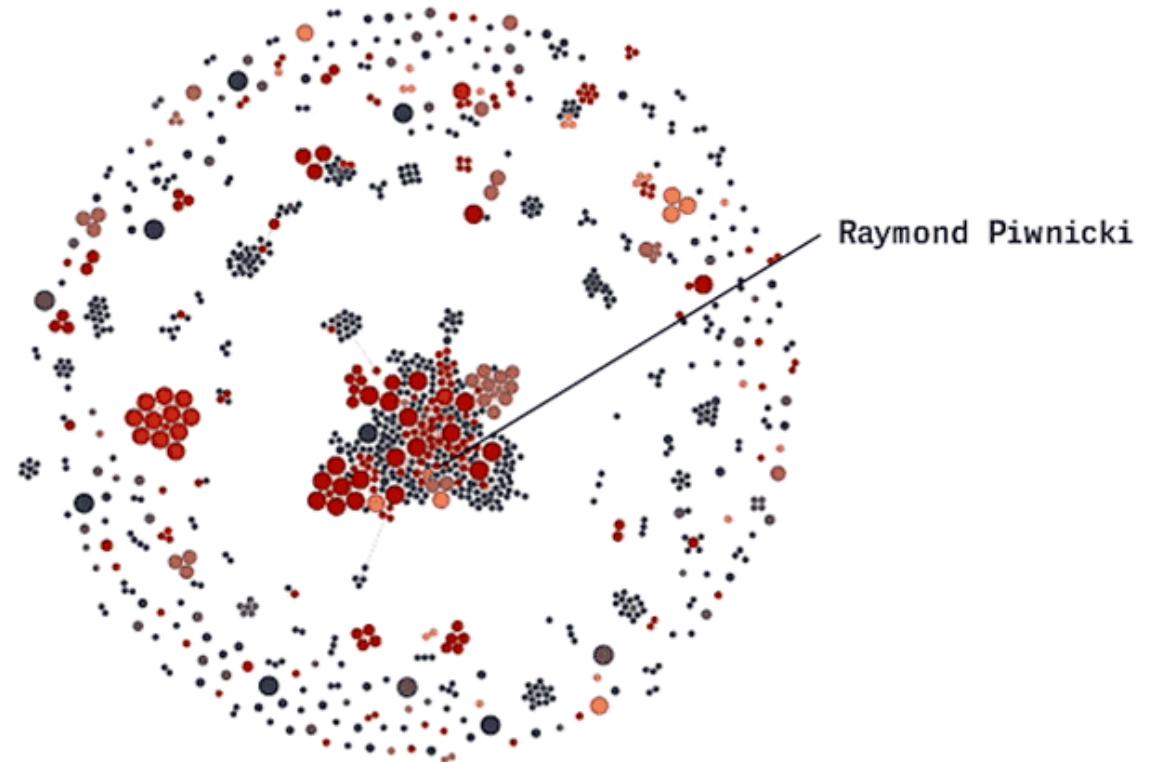
Help fight corruption

The Intercept

BAD CHICAGO COPS SPREAD THEIR MISCONDUCT LIKE A DISEASE

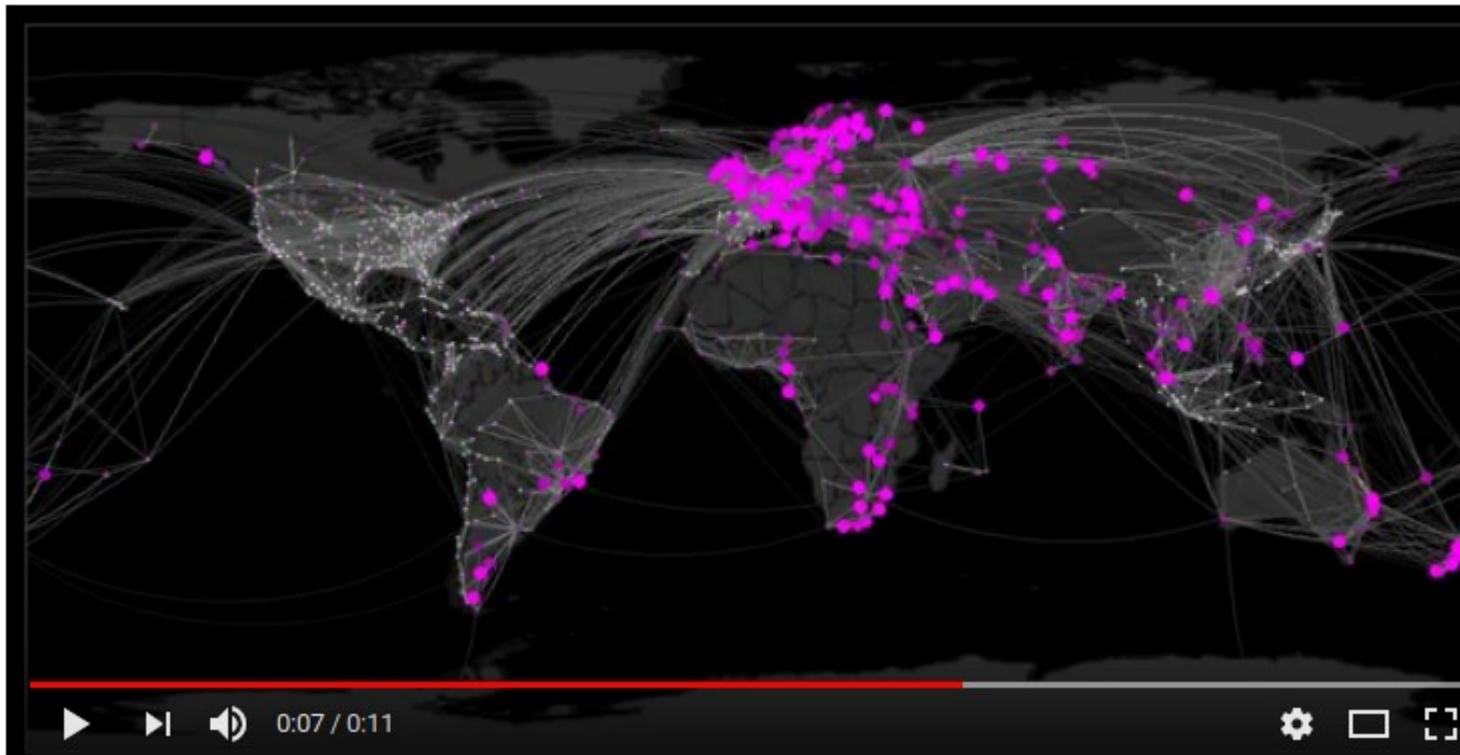
Rob Arthur

August 16 2018, 3:03 p.m.



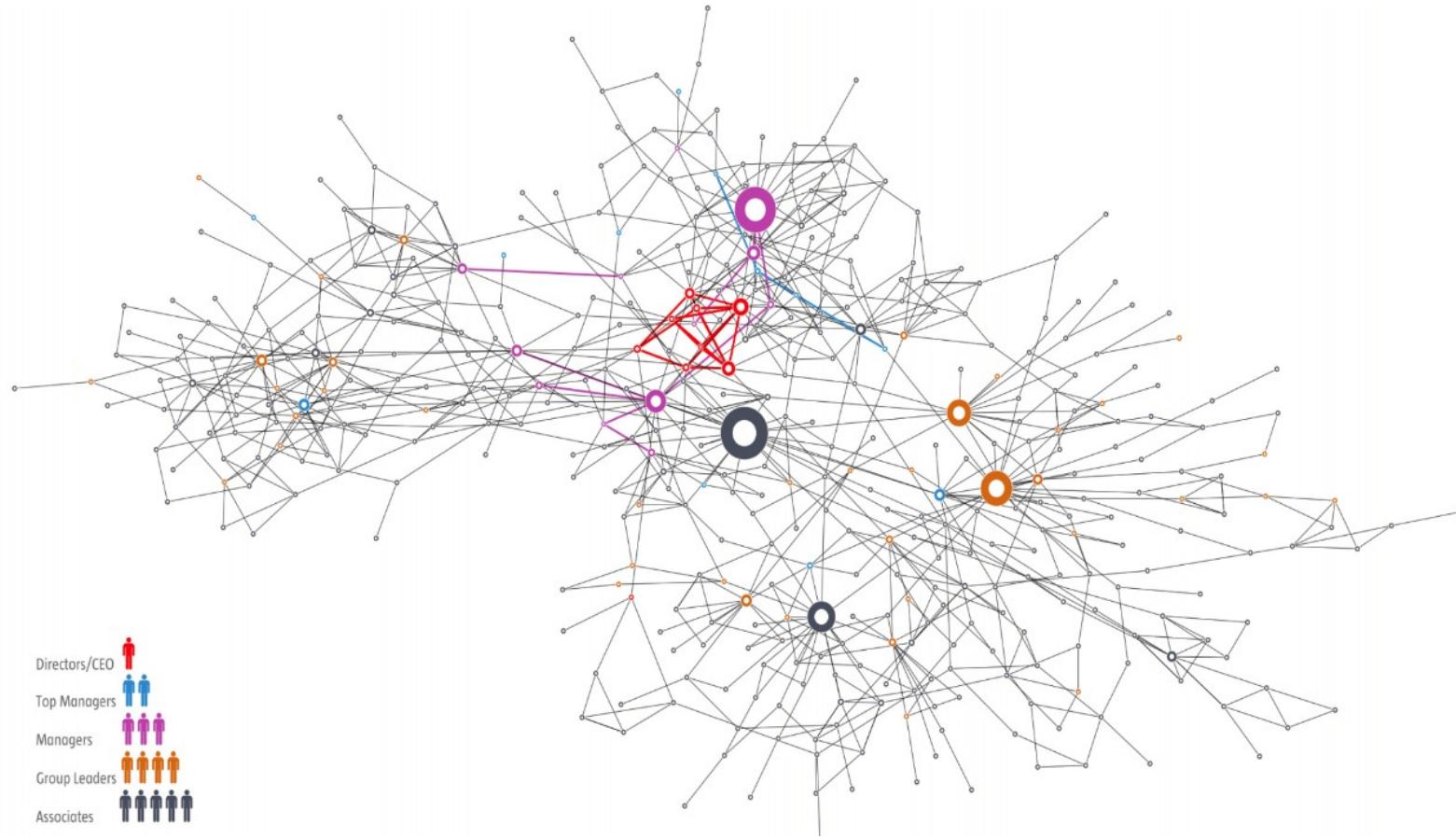
<https://theintercept.com/2018/08/16/chicago-police-misconduct-social-network/>

Help to forecast epidemics



<https://www.youtube.com/watch?v=mm2u9RKwgsY>

Help understand an organization, a society, or a brain



What can you do with this?

- Help design new treatments and drugs
- Help fight organized crime and corruption
- Help to forecast epidemics
- Help to understand an organization, a society, or a brain

What you can learn in this course

- To describe a network in formal terms
- To identify it as such and characterize it
- To visualize different networks
- To operate with networks programmatically
- To find important nodes and communities
- To make discoveries or help others make them
- **Much more (to a large extent, it's up to you!)**

Organization of the course

- Theory sessions:
 - Help you understand how to model complex networks
 - Help you find important nodes, communities, and track influence
 - Do some simple (and not so simple) exercises to check that you understood correctly each concept, and to help you remember
 - Follow “Network Science” by Barabási
- Practice sessions:
 - Help you work with complex networks
 - Manage and analyze graphs in Python
 - New material
- **My focus is on what I think has value for you as a data scientist**