

# Complex Networks

Social Networks Analysis and Graph Algorithms

Prof. Carlos Castillo — <https://chato.cl/teach>

# Sources

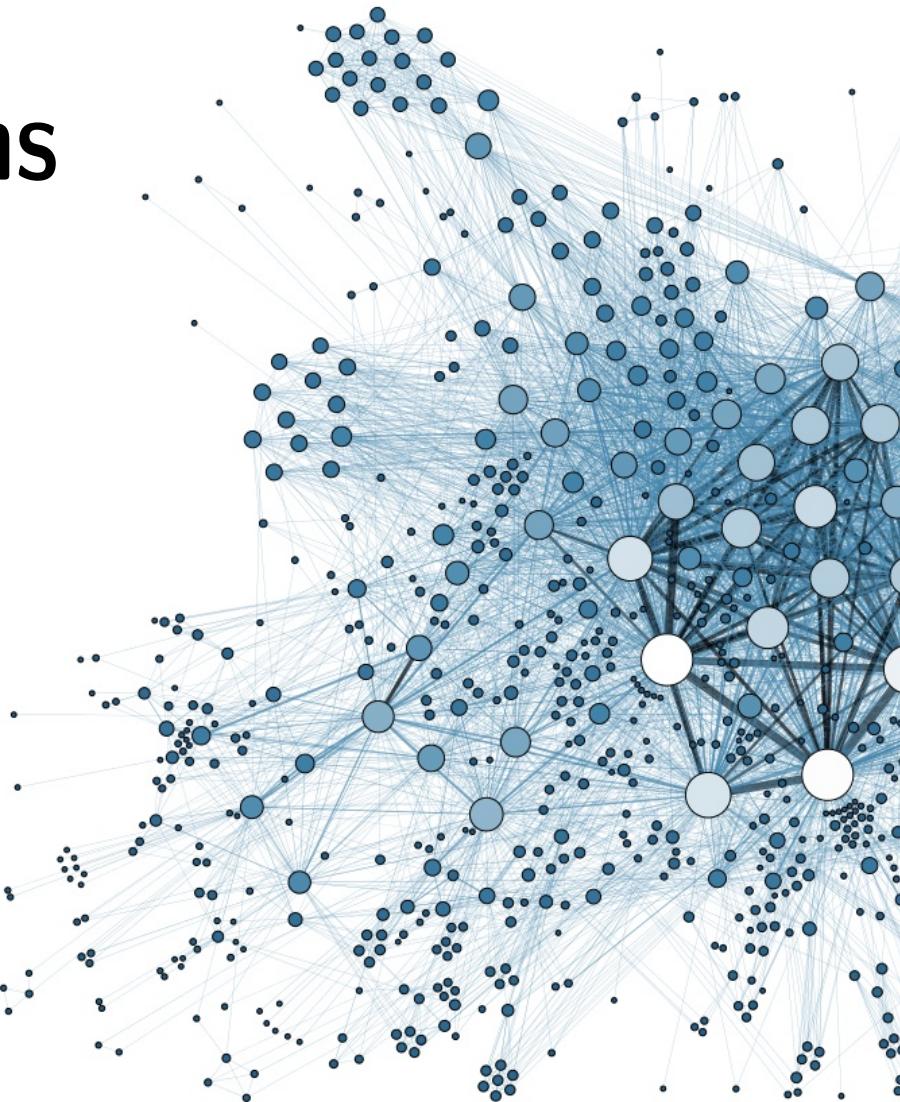
- A. L. Barabási (2016). Network Science - Chapter 01 and Chapter 02
- F. Menczer, S. Fortunato, C. A. Davis (2020). A First Course in Network Science - Chapter 00
- URLs cited in the footer of slides

# What is networks science?

- Network science studies complex networks:
  - Social networks, telecommunication networks, computer networks, biological networks, cognitive and semantic networks
- A network is an interconnected object with:
  - elements or actors represented by nodes
  - connections between them represented as links

# Complex systems

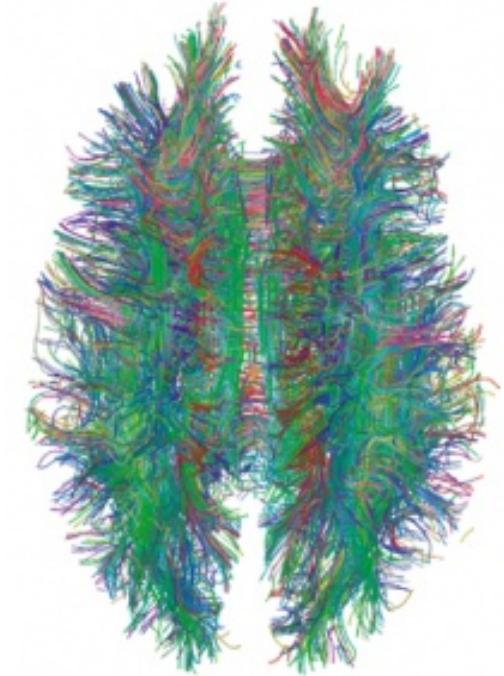
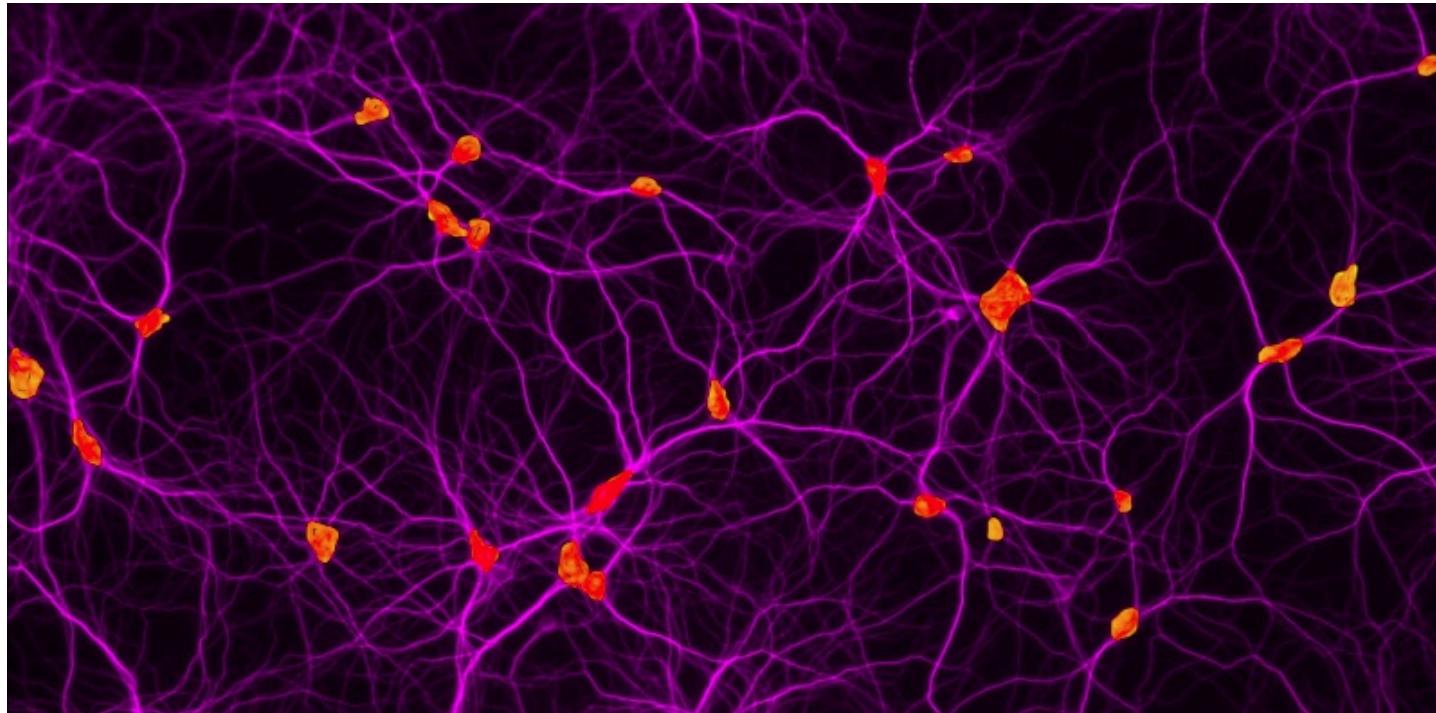
- Many interconnected parts
- Intricate arrangement of connections
- Emerging properties



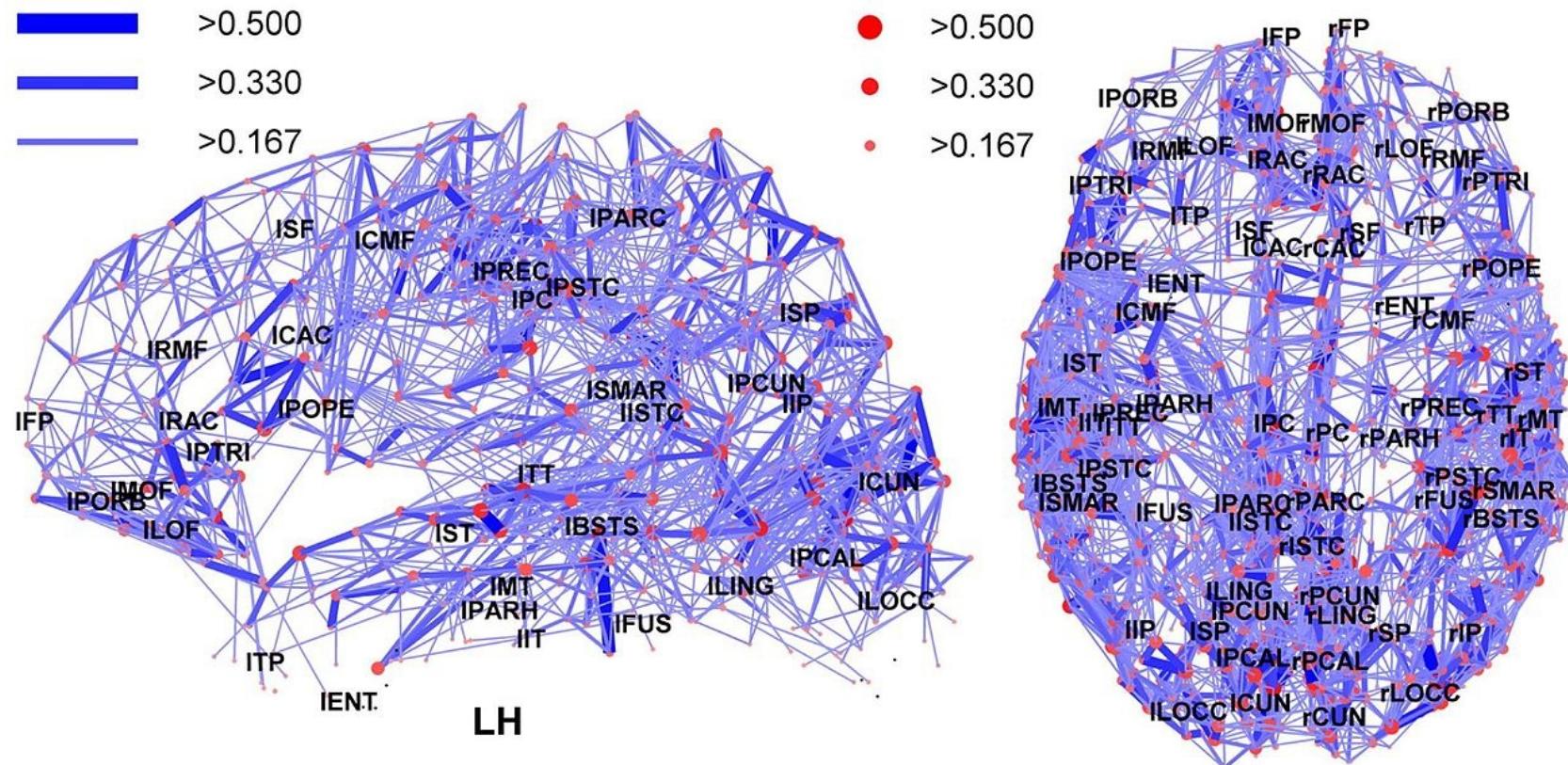
# Behind every complex system there is a complex network

- 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: $|V| \simeq 90 \times 10^9$



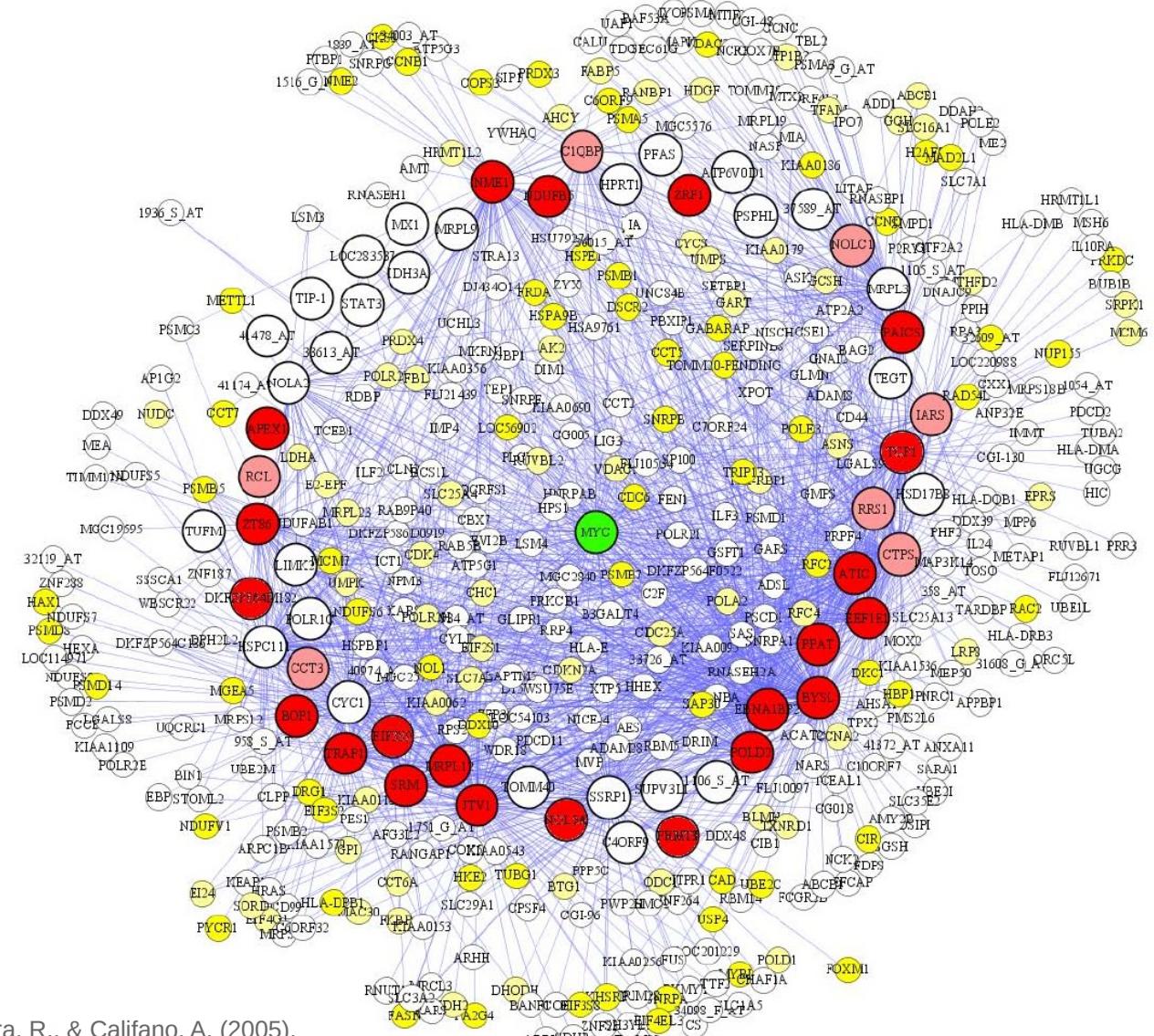
# Regions in the human brain



[https://en.m.wikipedia.org/wiki/File:Network\\_representation\\_of\\_brain\\_connectivity.JPG](https://en.m.wikipedia.org/wiki/File:Network_representation_of_brain_connectivity.JPG)

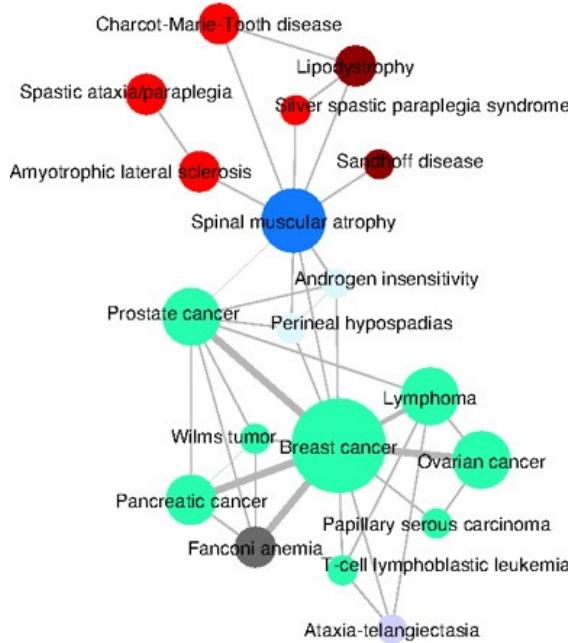
# Genes

$|V|=500$  in this plot

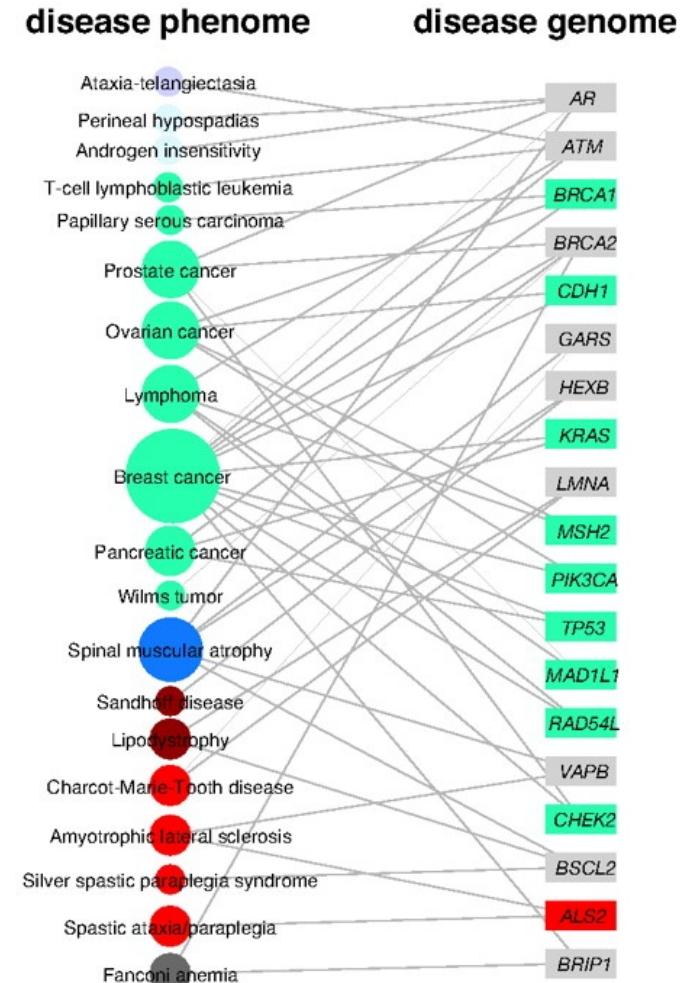


# Human disease network

*Human Disease Network (HDN)*

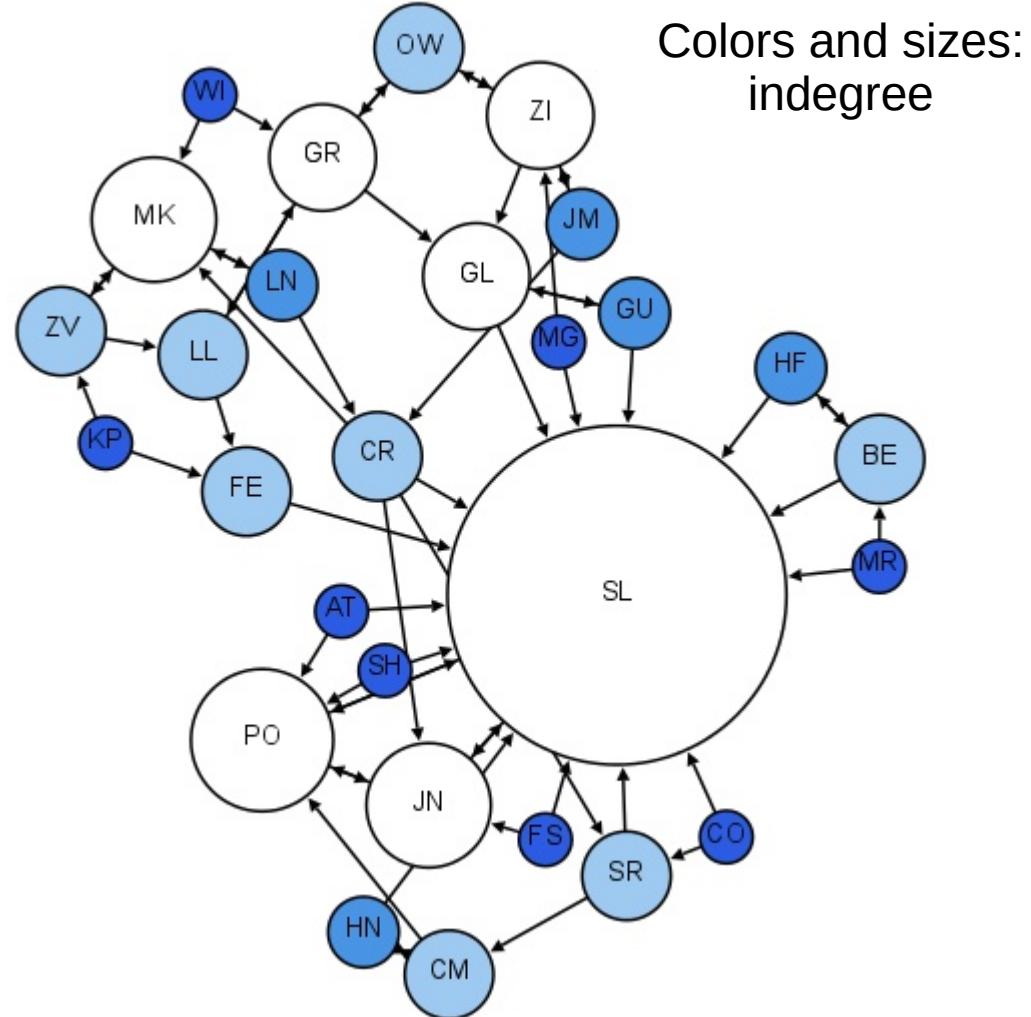


## DISEASOME



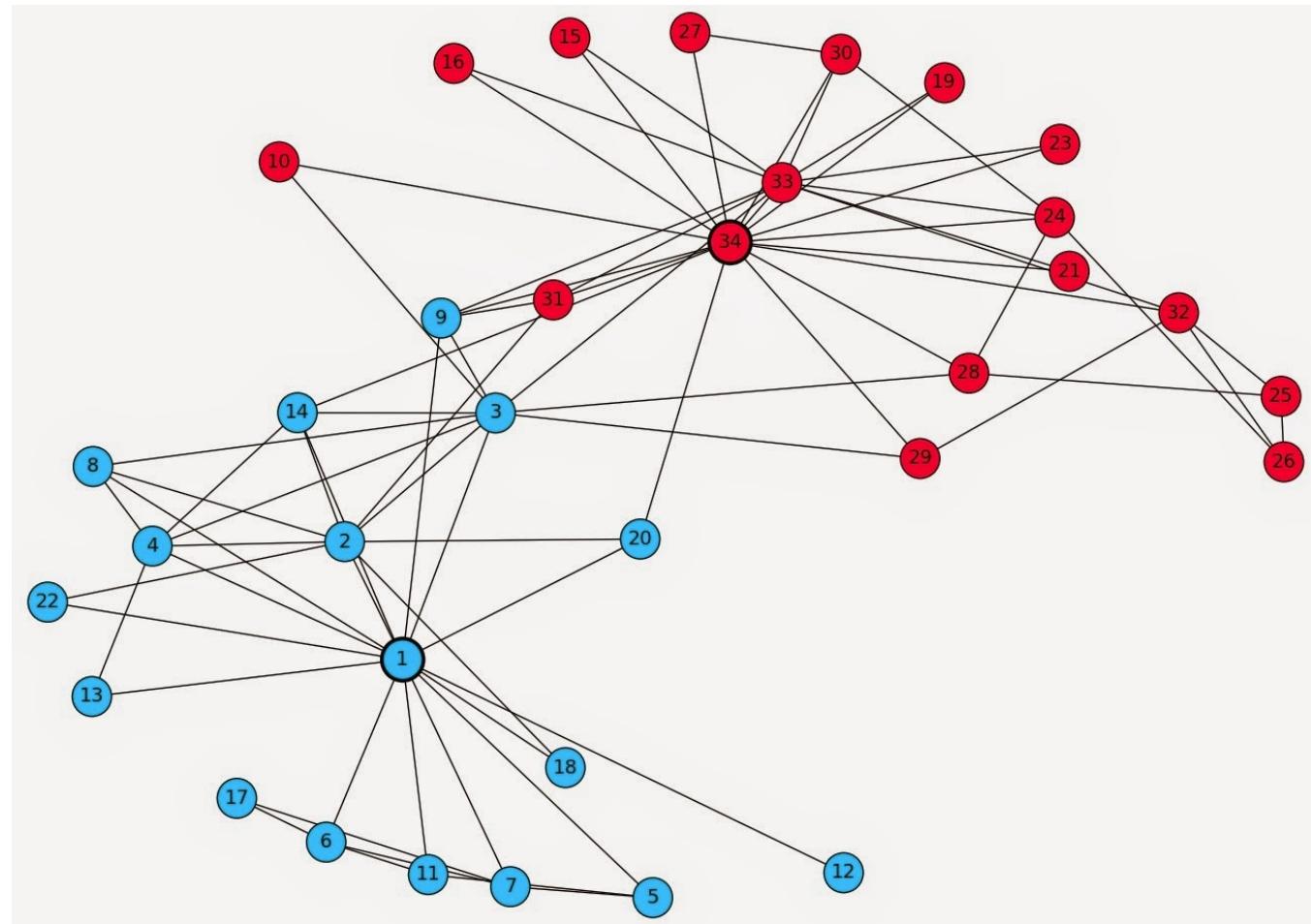
# Moreno's sociograms

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



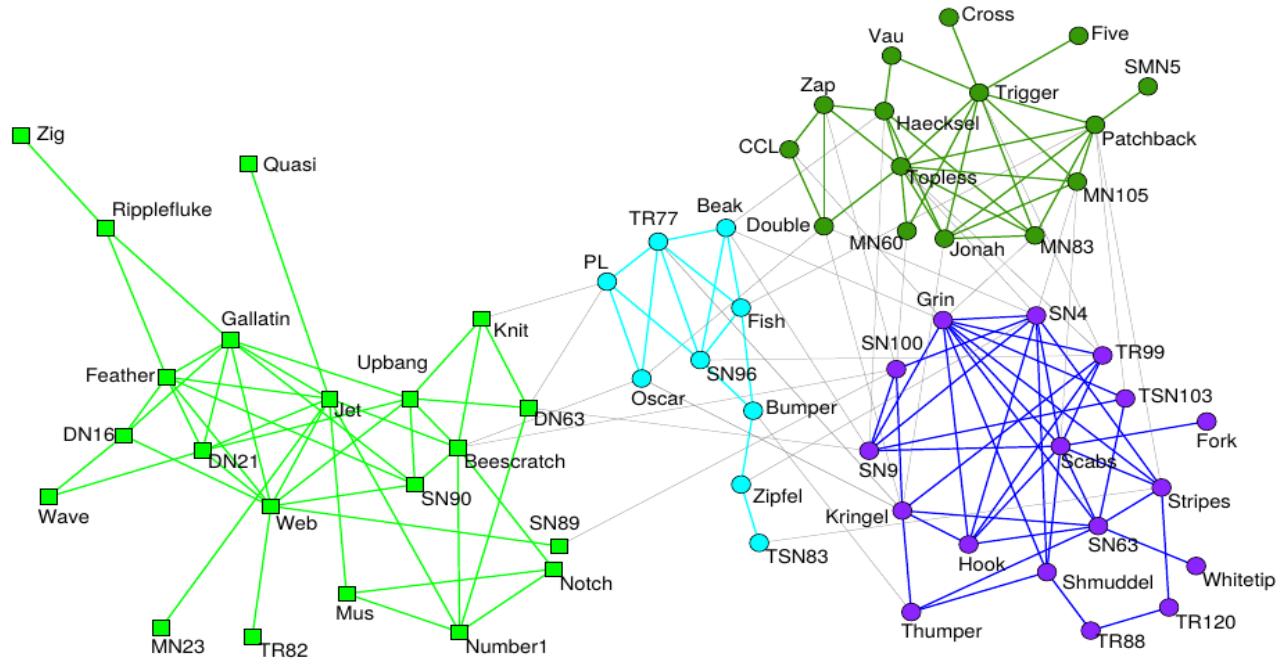
# Zachary's Karate Club

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)



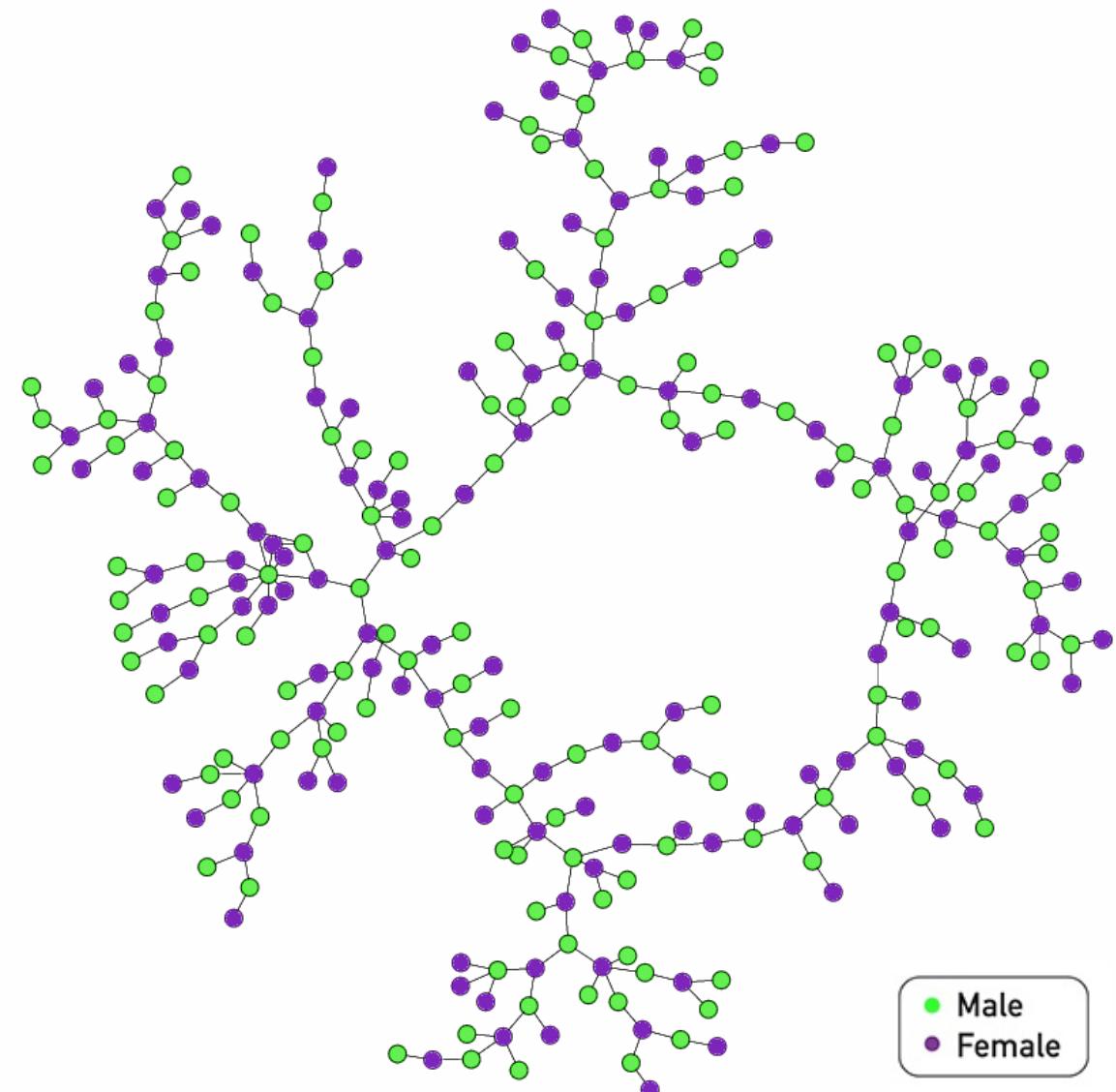
<https://doi.org/10.1007/s00265-003-0651-y>

I really like dolphins

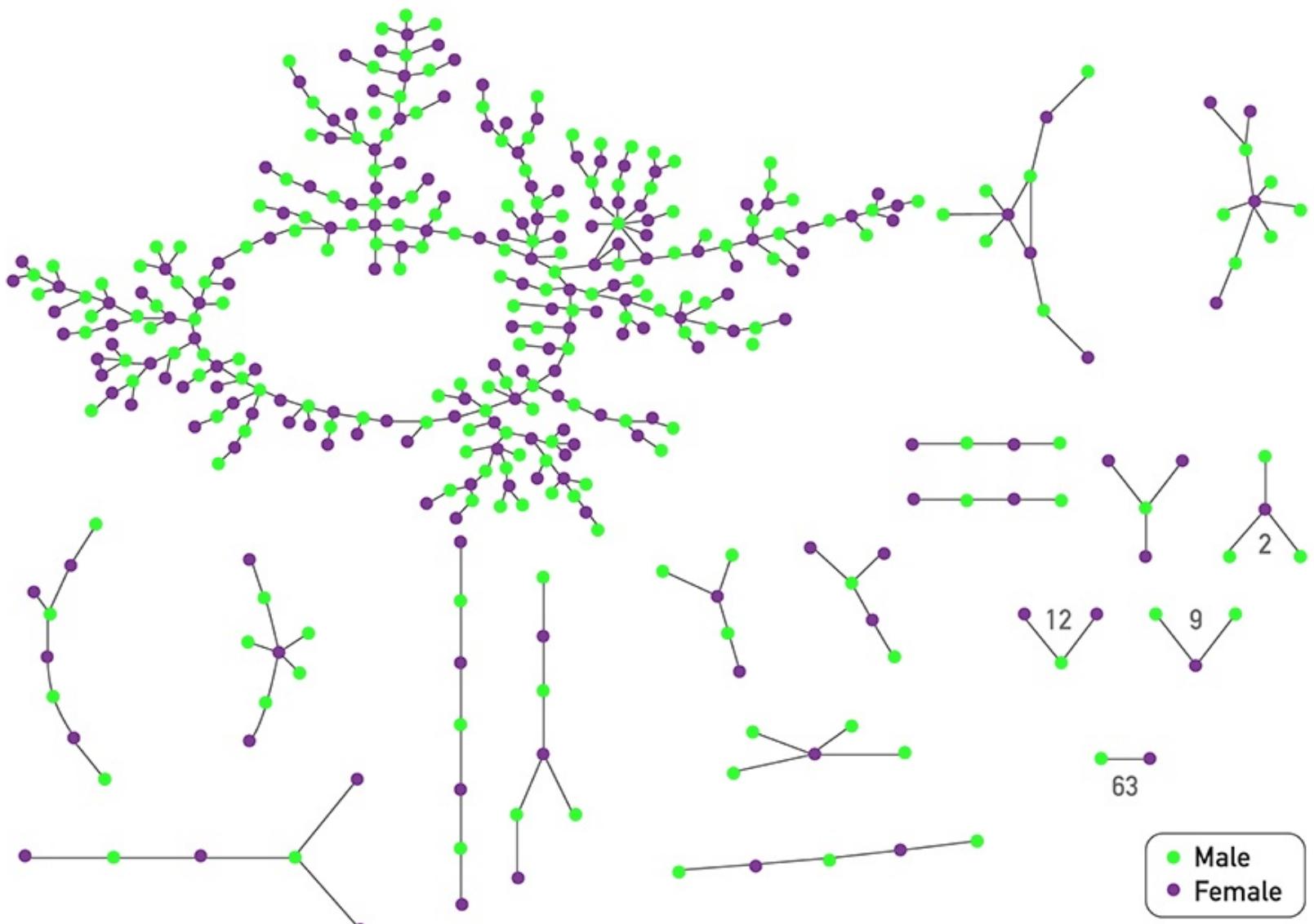


# Chains of affection

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

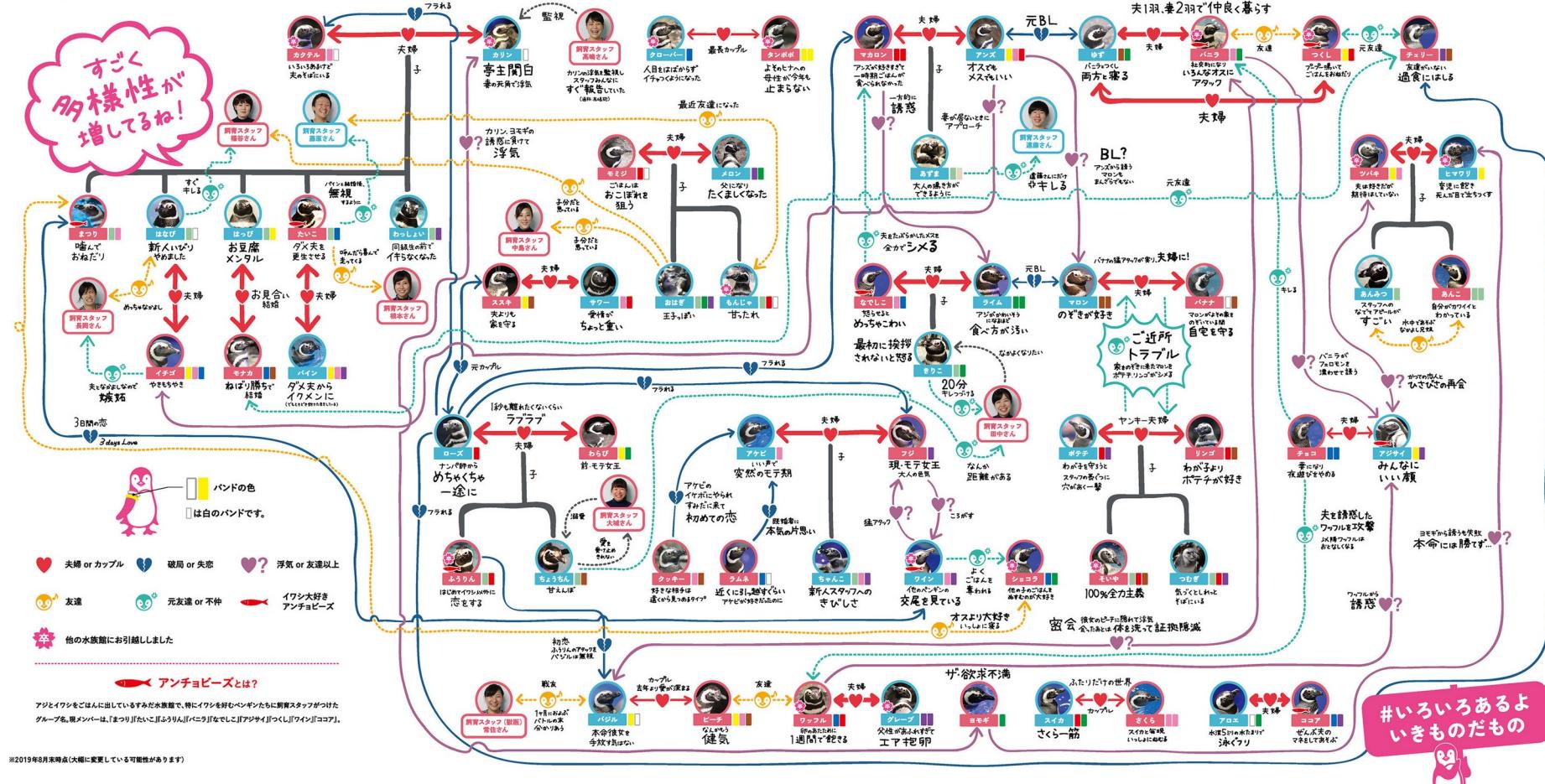


Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American journal of sociology, 110(1), 44-91.



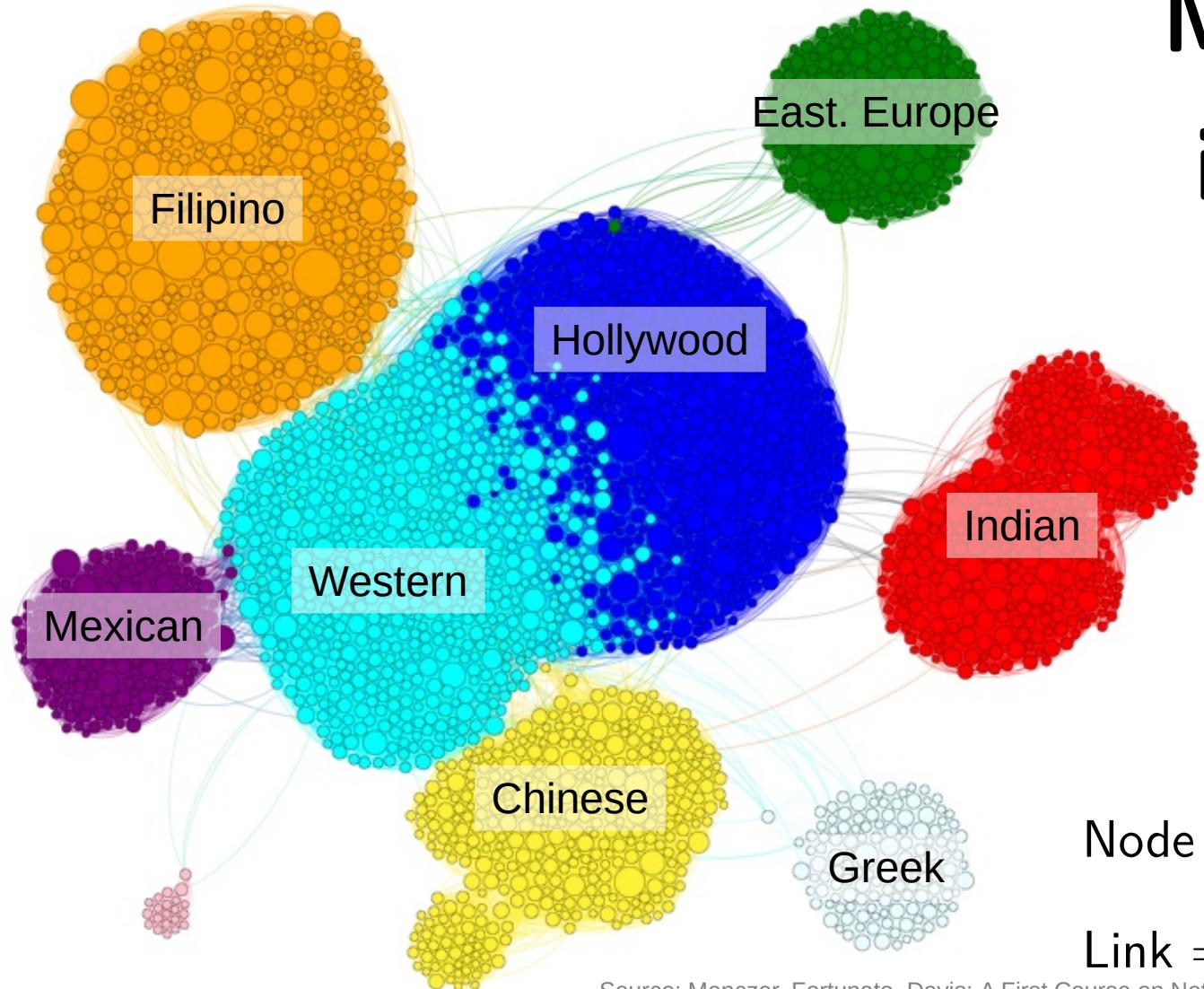
~~もっと!~~  
かわいい!  
たのしい!  
ややこしい

# 3分くらいでなんとなく分かって、1時間くらい見てていられる! すみだペンギン相関図 2020



Complex relationships between penguins  
Image: <https://www.sumida-aquarium.com/>

# Movie stars in international cinema



Node = actor/actress

Link = appear in the same movie

Source: Menczer, Fortunato, Davis: A First Course on Networks Science. Cambridge, 2020.



WIKIPEDIA  
The Free Encyclopedia

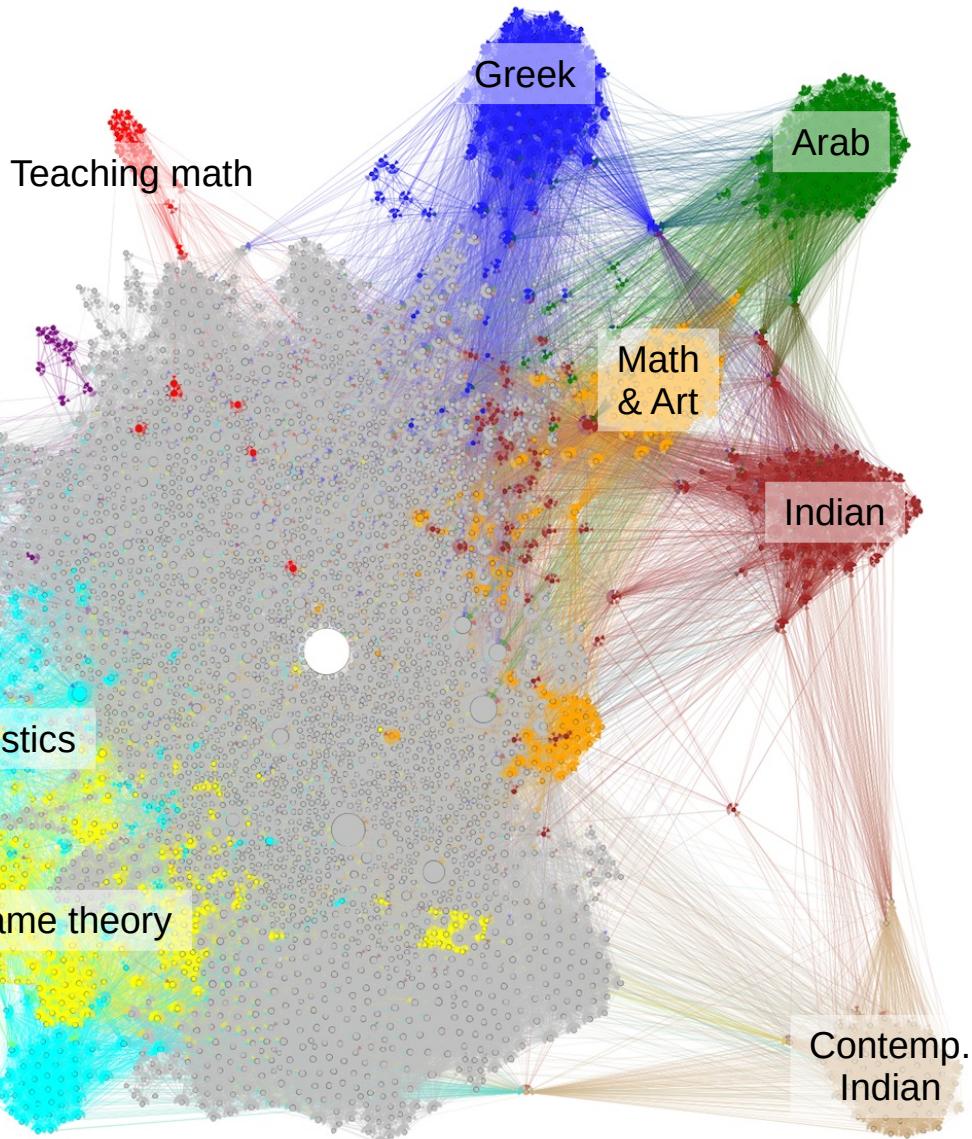
# Articles about mathematics

Math software

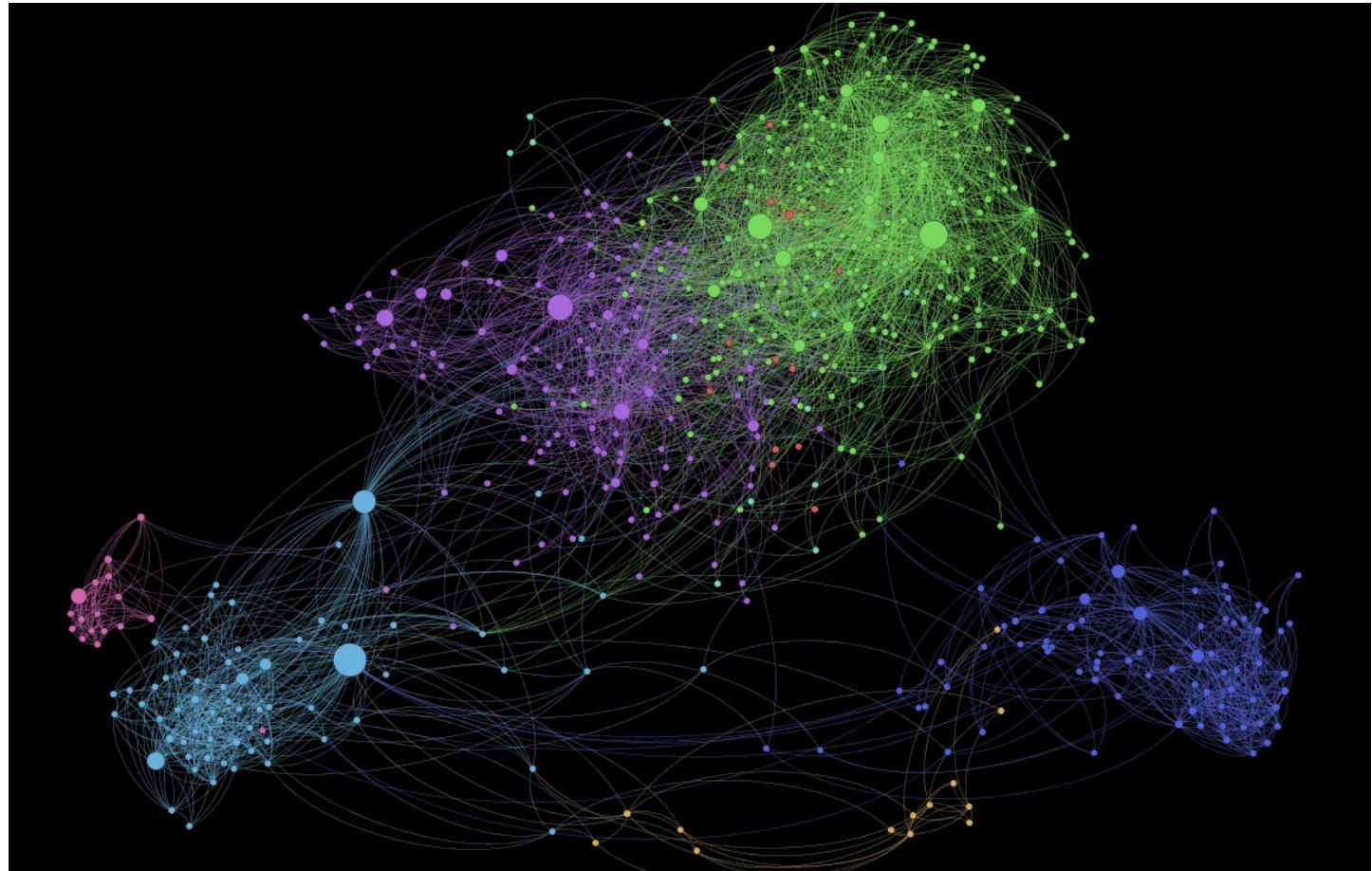
Node = article

Link = link

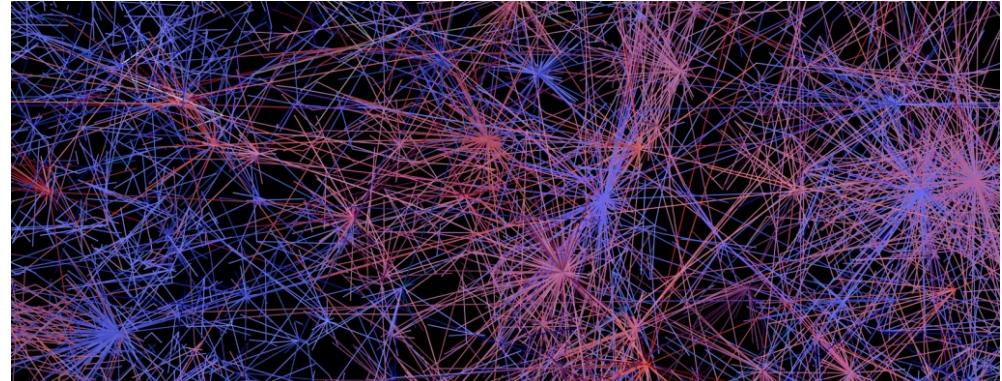
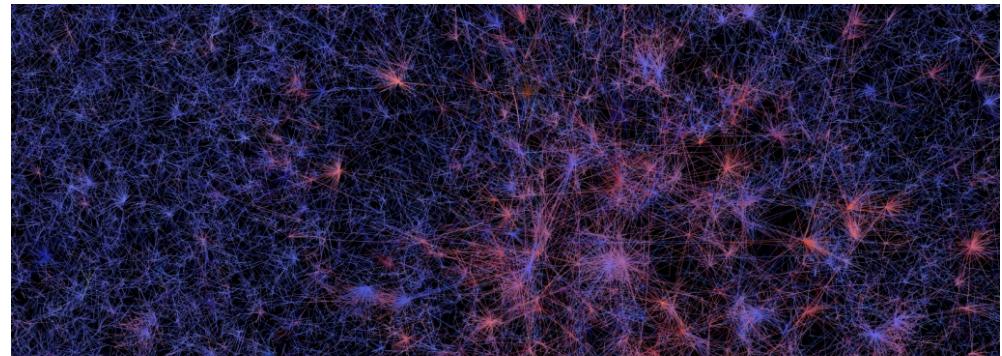
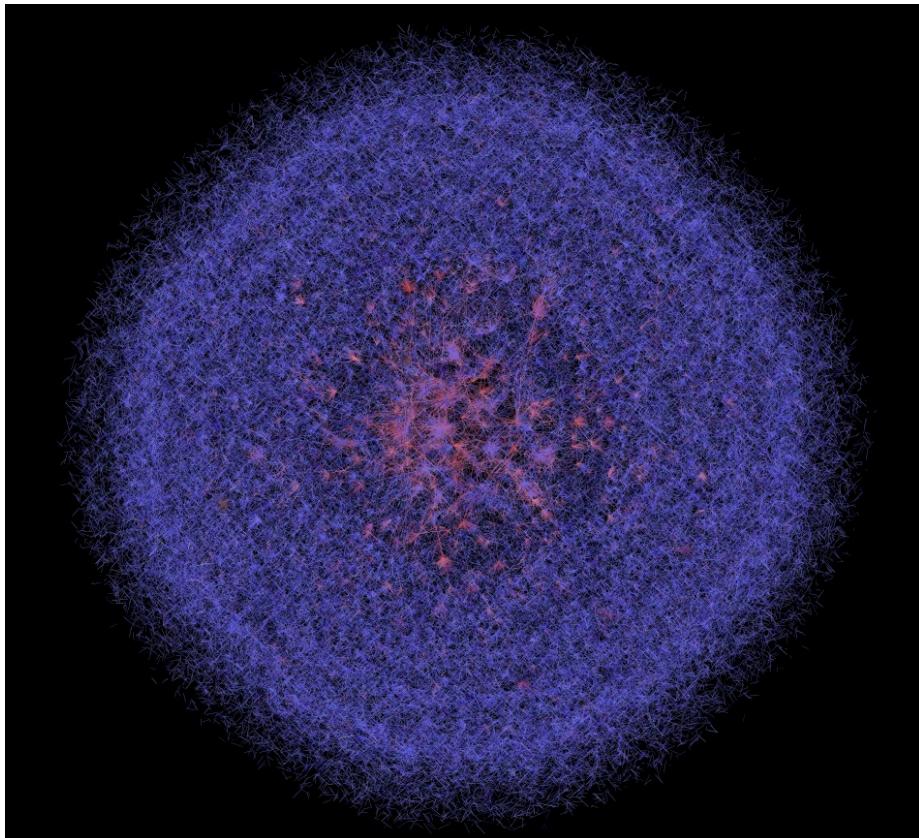
Source: Menczer, Fortunato, Davis: A First Course on Networks Science. Cambridge, 2020.



# 1,000 Somali Users of Facebook



# 400,000 Twitter Users



# Emergent characteristics

- Birds → Flocks
- Ants → Colonies
- People → Cities
- Neurons → Consciousness



What could complex 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)*

# Exercise

## Find examples of networks

- Find examples of networks, just indicating:
  - Name
  - Number of nodes (approximately)
  - Number of edges (approximately)

Pin board: <https://upfbarcelona.padlet.org/chato/xr8sktik56mnftuj>



# Things to remember

- Definitions
  - complex system, complex network, emergent property
- Examples of complex networks