Complex Networks

Social Networks Analysis and Graph Algorithms

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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

Introductory video (00:00-01:20) by Albert-László Barabási,

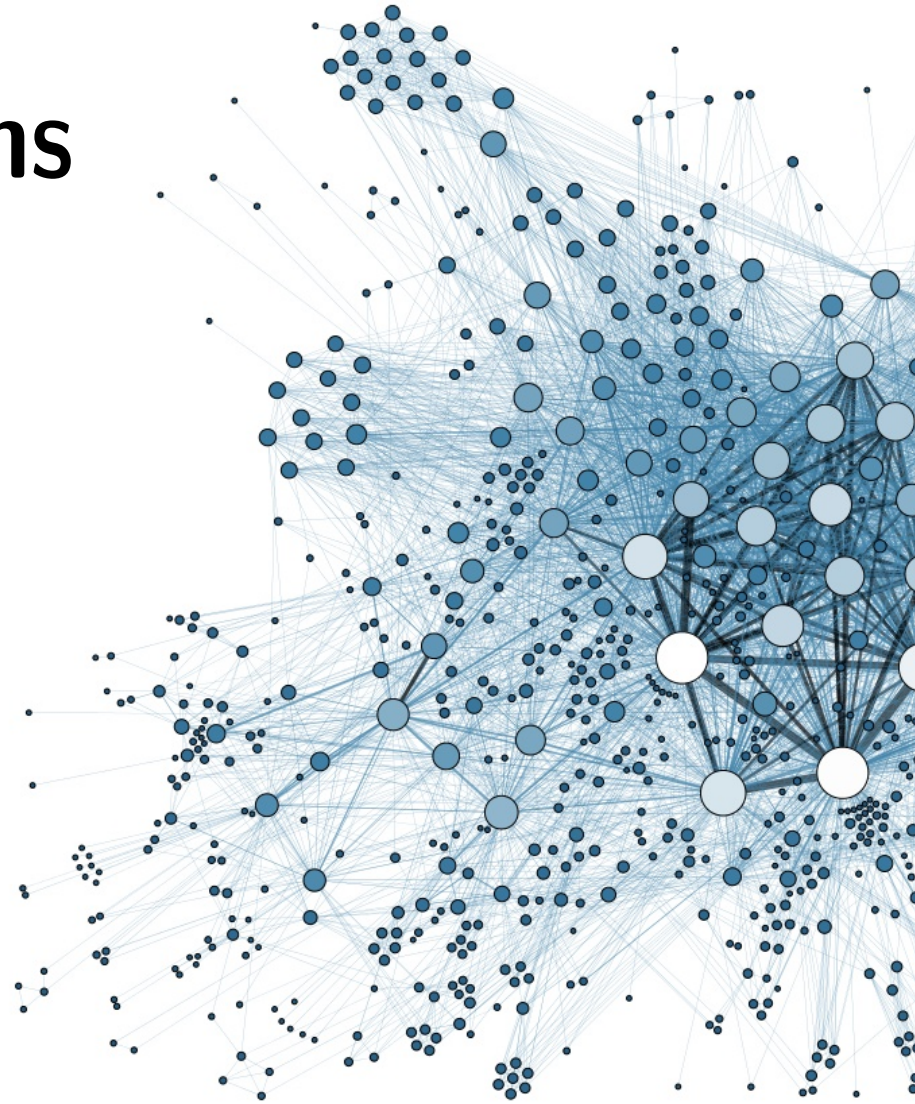
https://www.youtube.com/watch?v=RfgjHoVCZwU

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

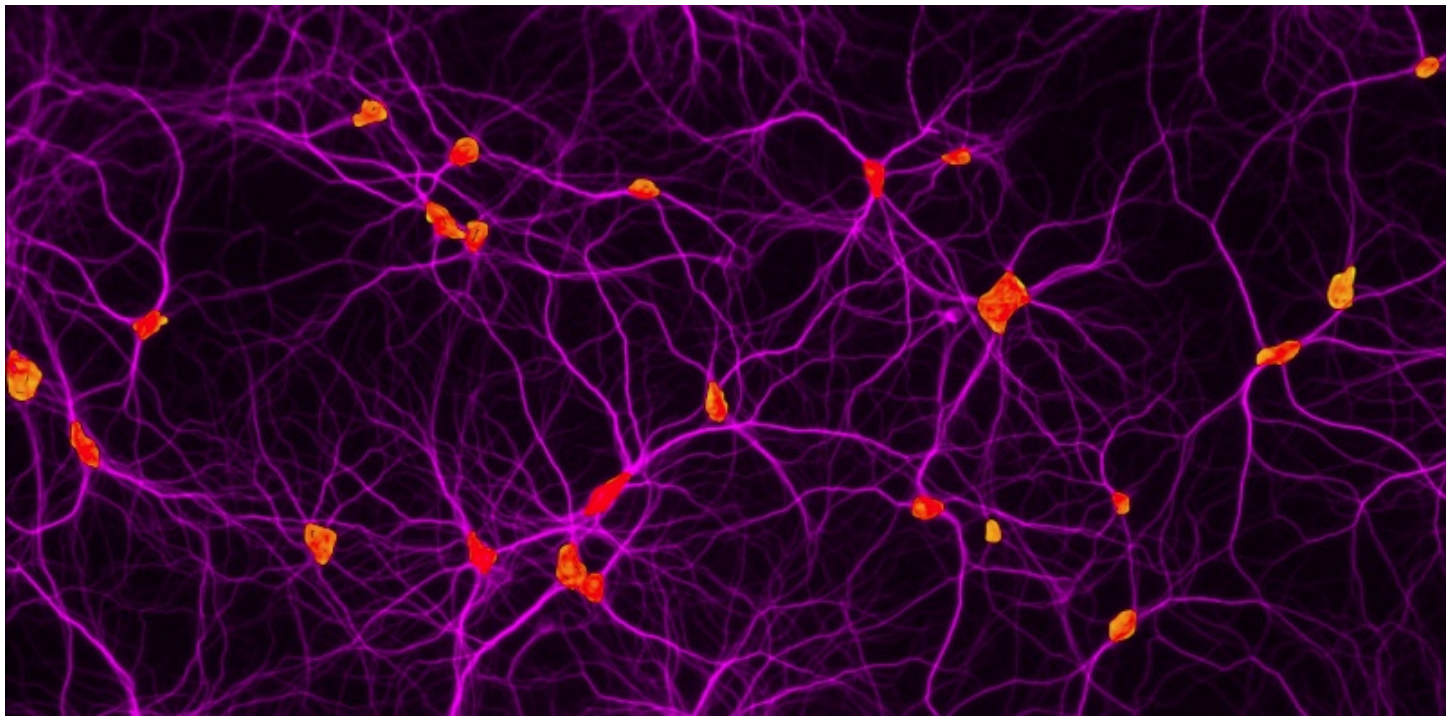
- Many interconnected parts
- Intrincate arrangement of connections
- **Emerging properties**



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

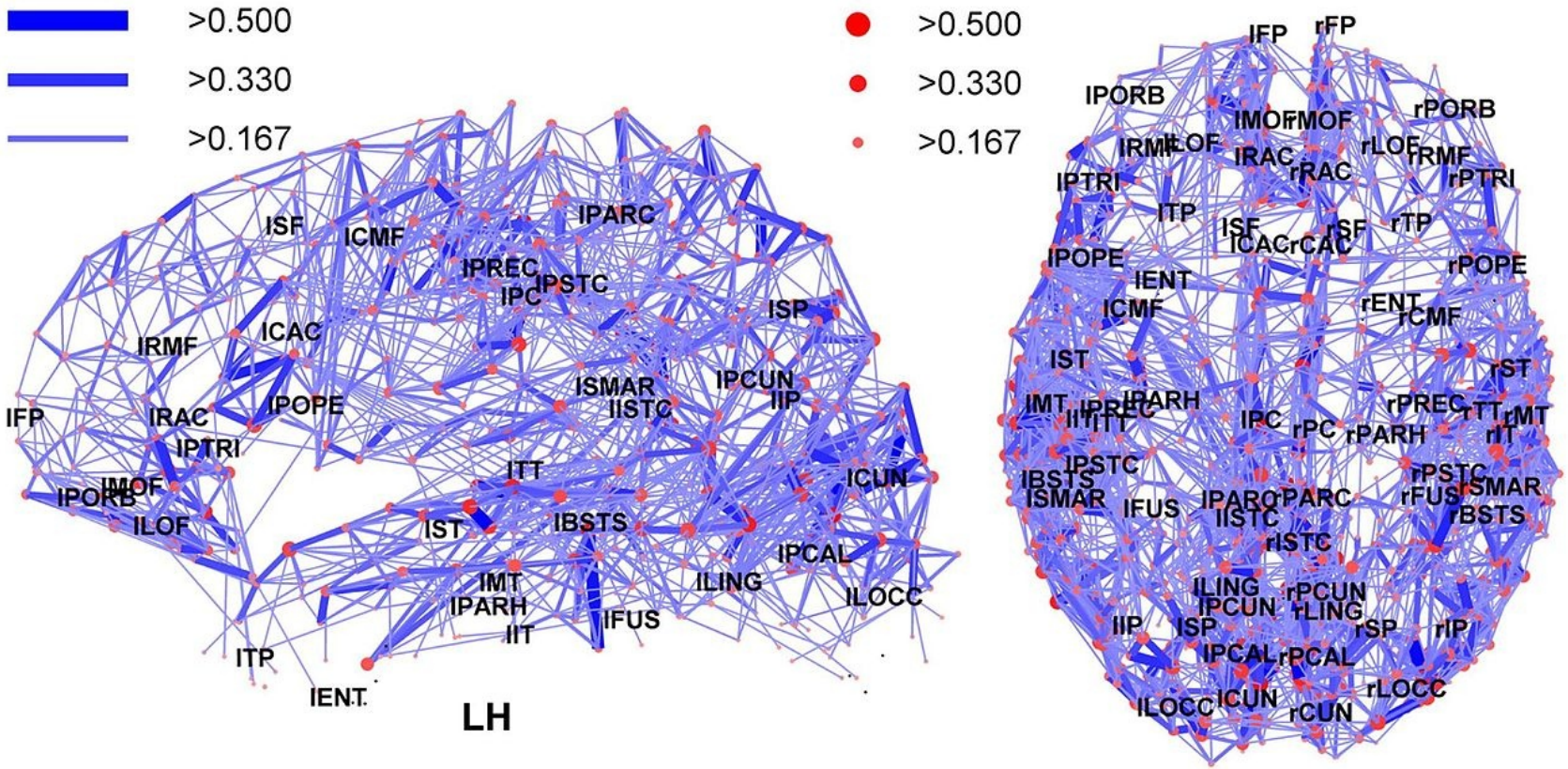
Human brain: $|V| \simeq 90 \times 10^9$



https://health.uconn.edu/cell-analysis-modeling/microscopy-facility-2/

https://dx.doi.org/10.1371%2Fjournal.pone.0004006

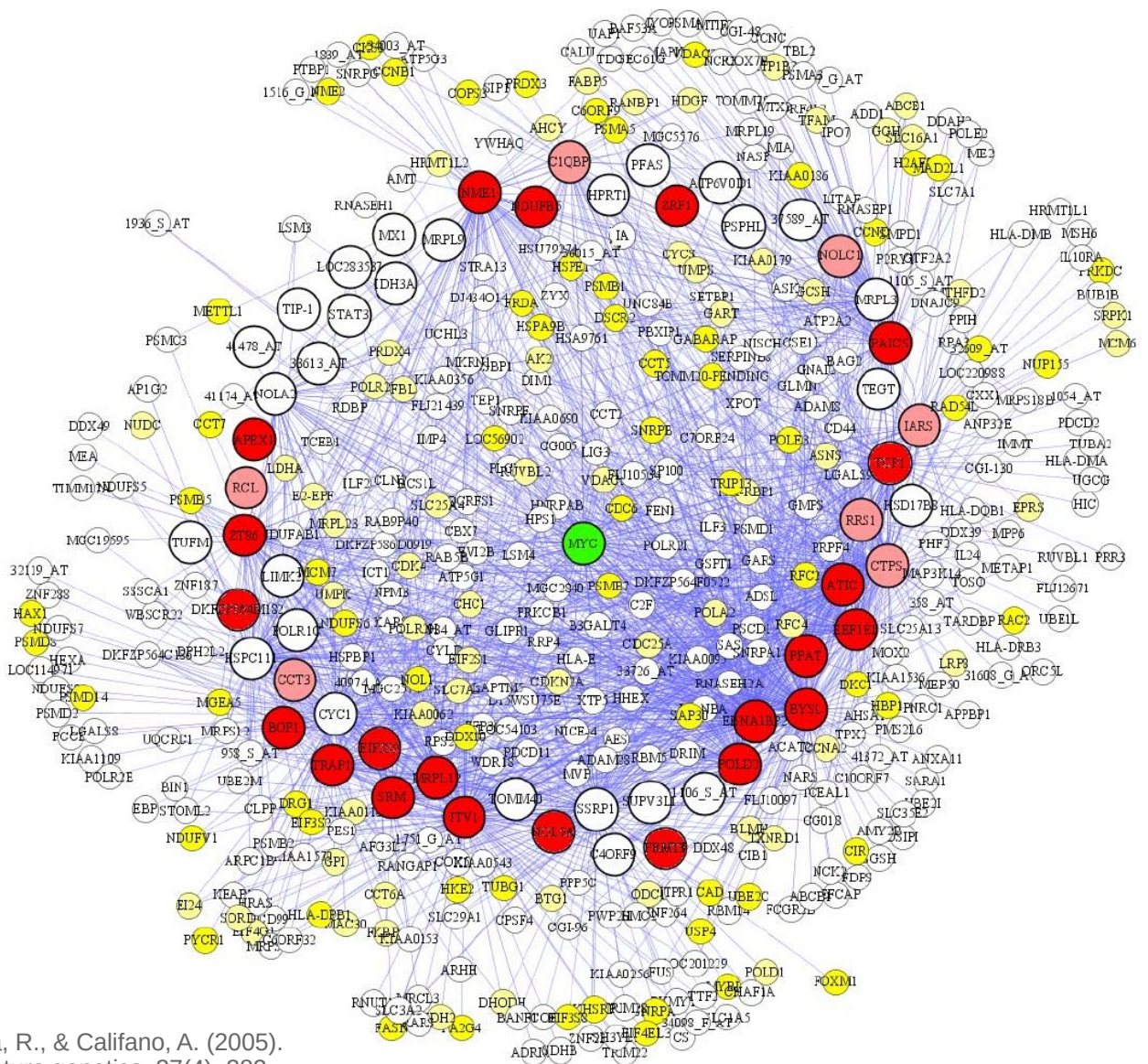
Regions in the human brain



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

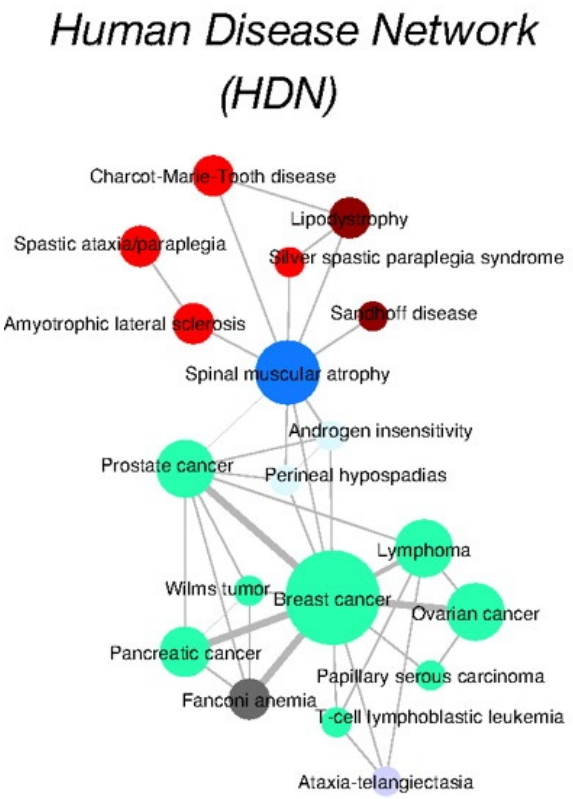
Genes

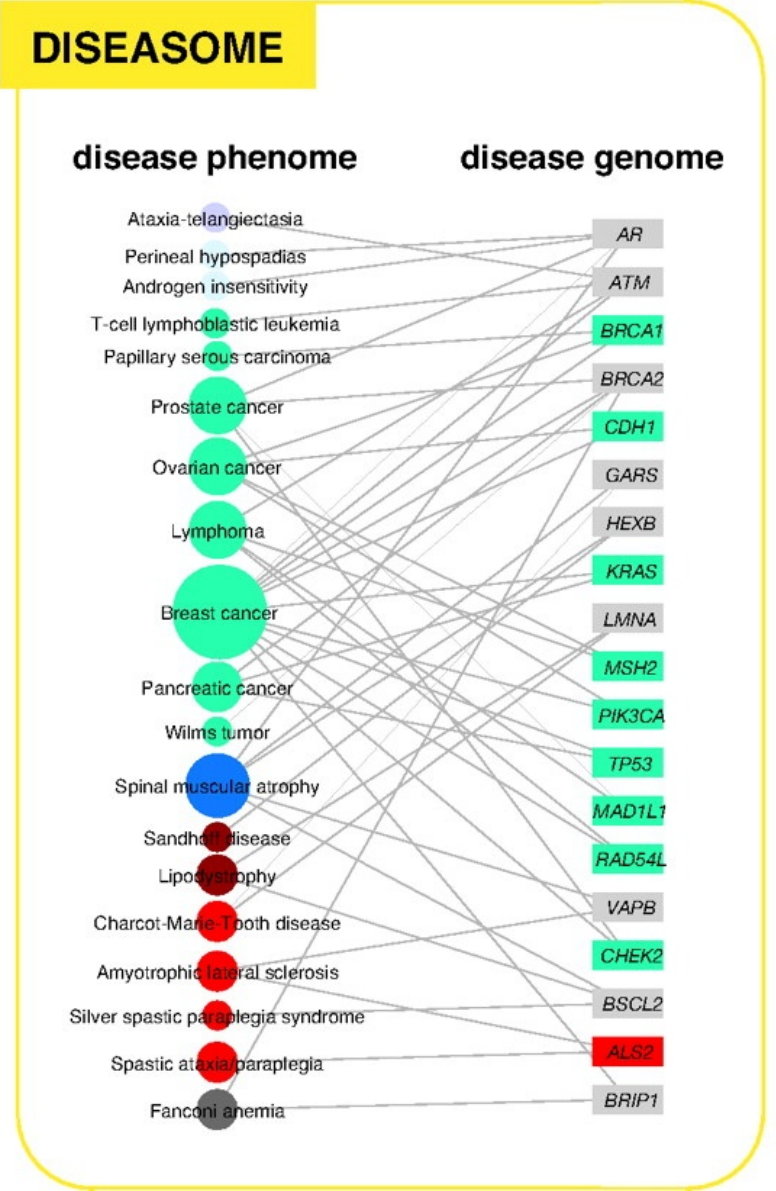
$|V|=500$ in this plot



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

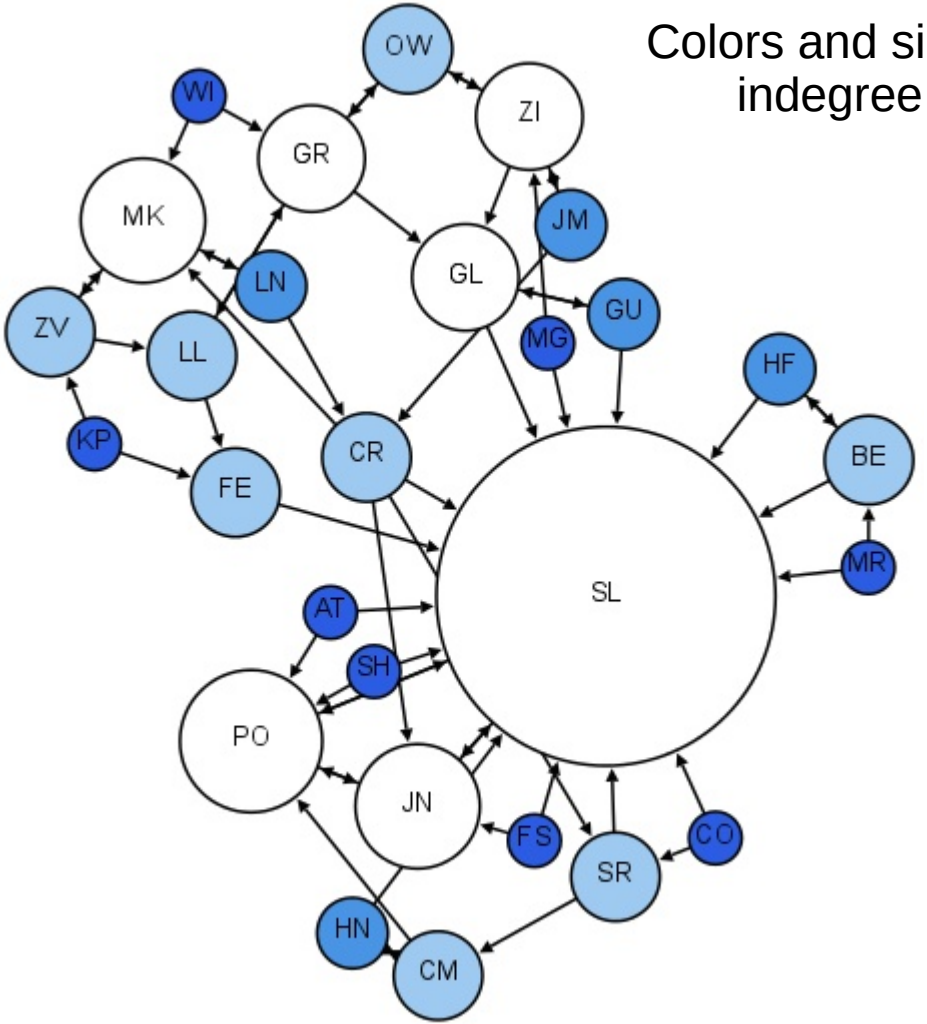




http://www.pnas.org/content/104/21/8685

Moreno's sociograms

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

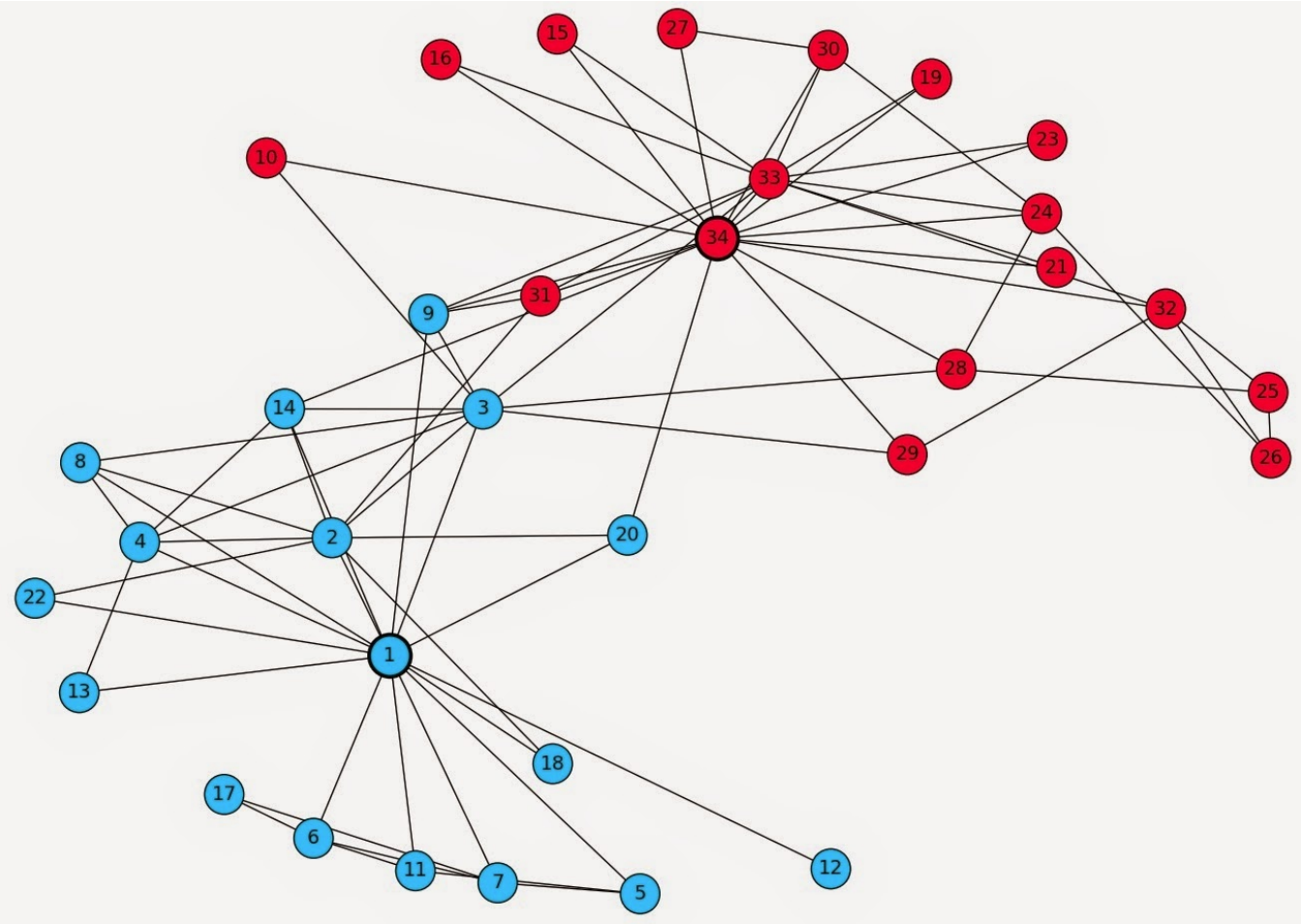


http://www.martingrandjean.ch/social-network-analysis-visualization-morenos-sociograms-revisited/

Zachary's Karate Club

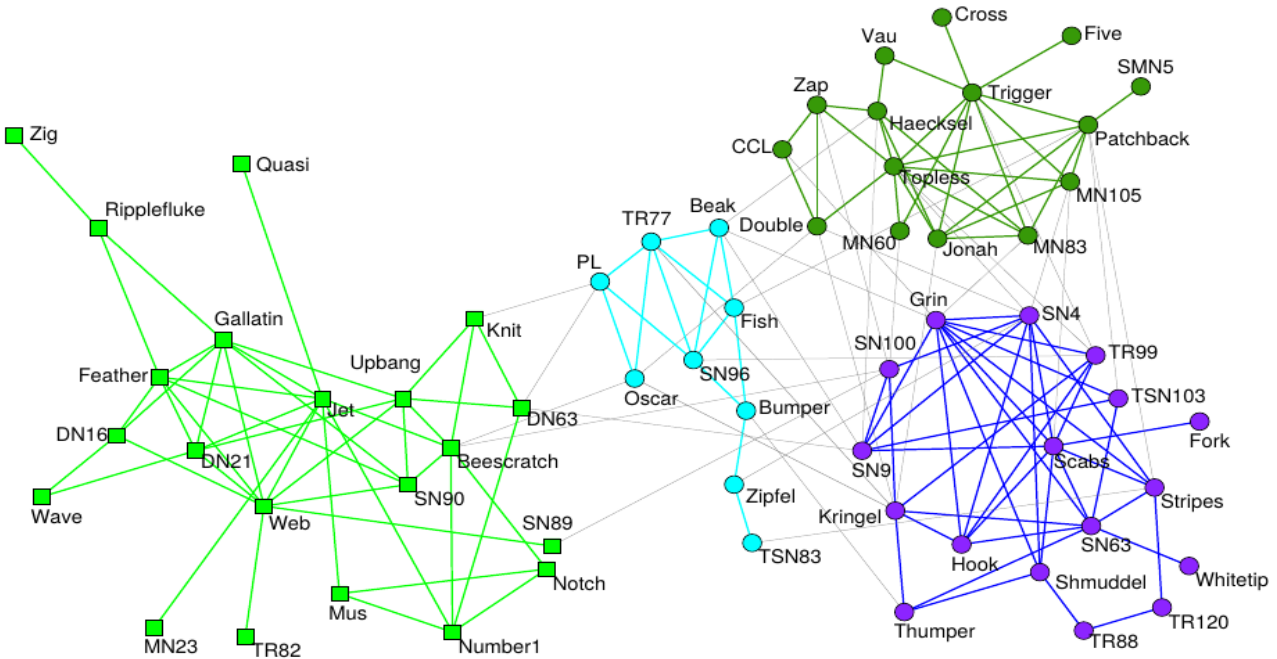
Karate club that split into two clubs

(led by 1 and 34)

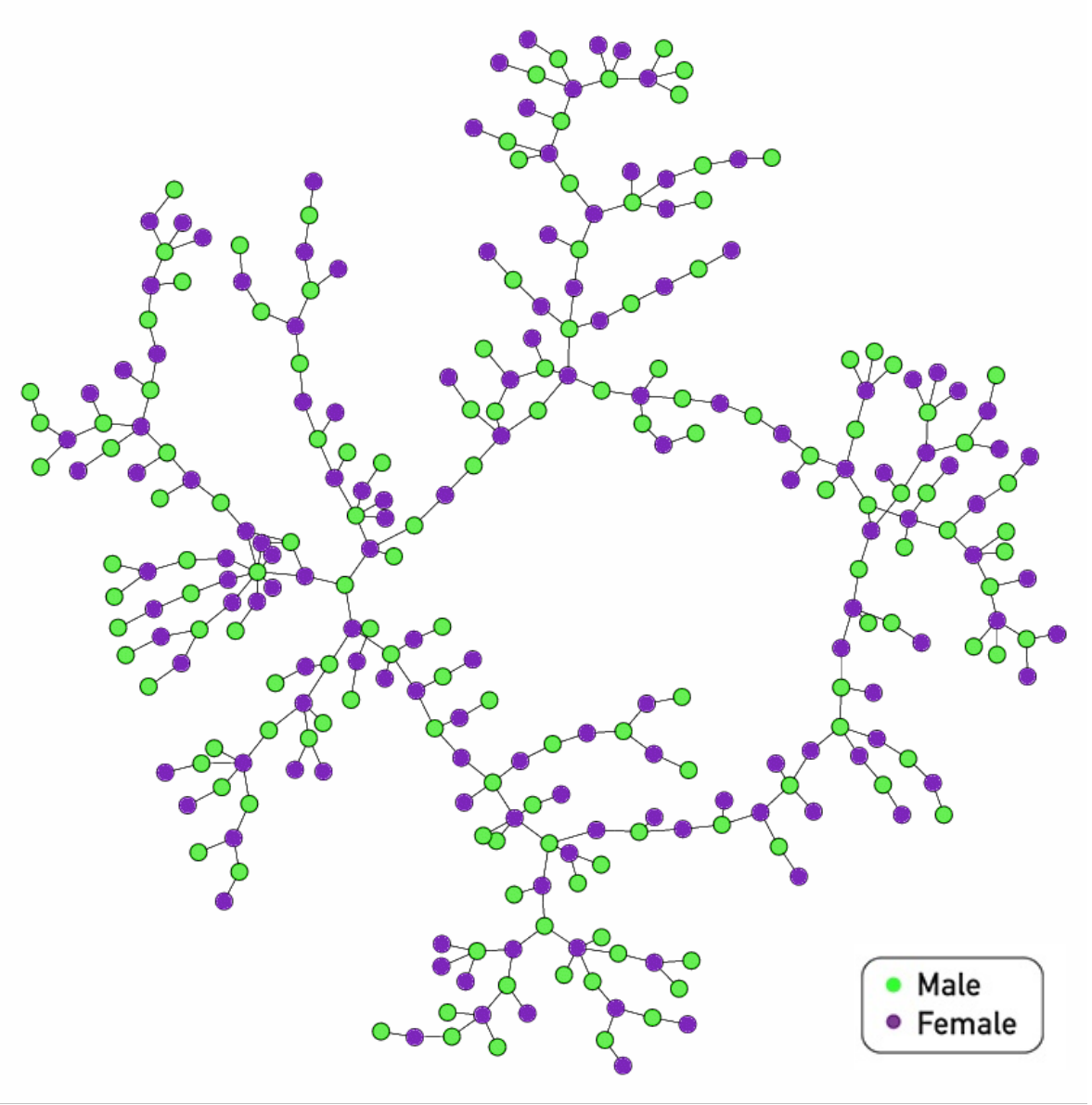


Dolphins in a fjord in New Zealand

- 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)



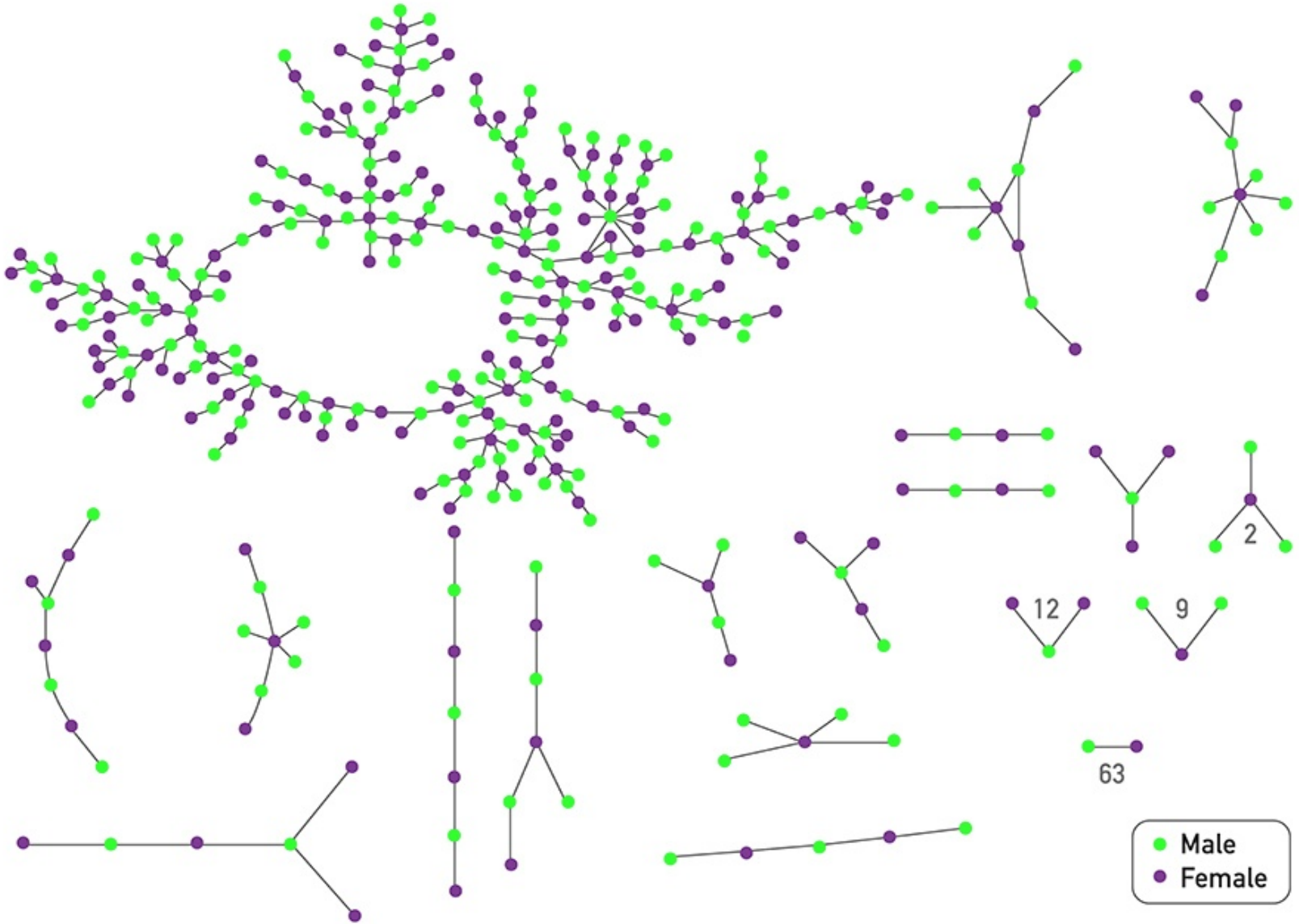
https://doi.org/10.1007/s00265-003-0651-y



Chains of affection

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

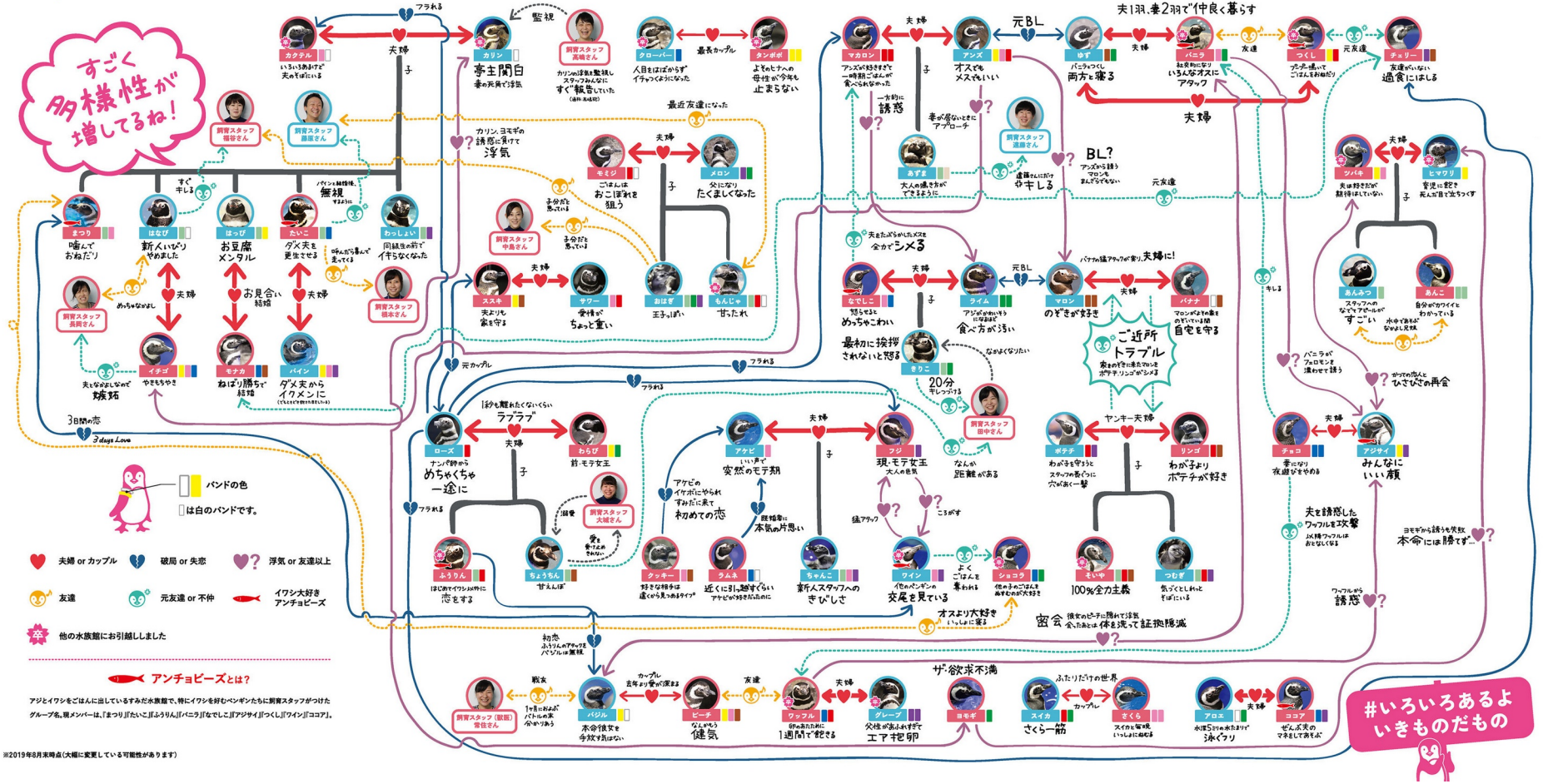
Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American journal of sociology, 110(1), 44-91.


2
12
9
63
Male
Female

もっと！かわいい！たのしい！ややこしい！

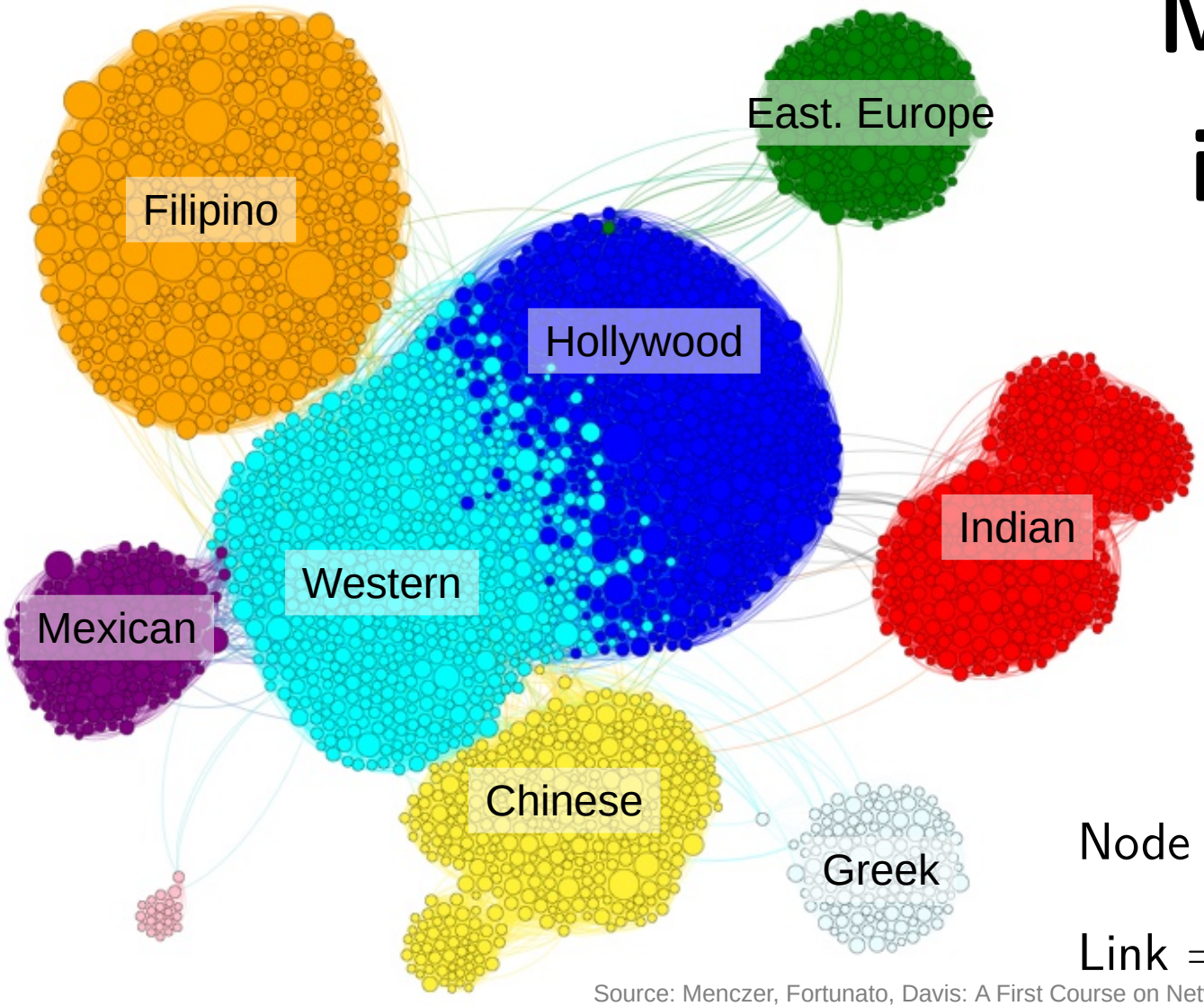
3分くらいでなんとなく分かって、1時間くらい見ていられる！

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

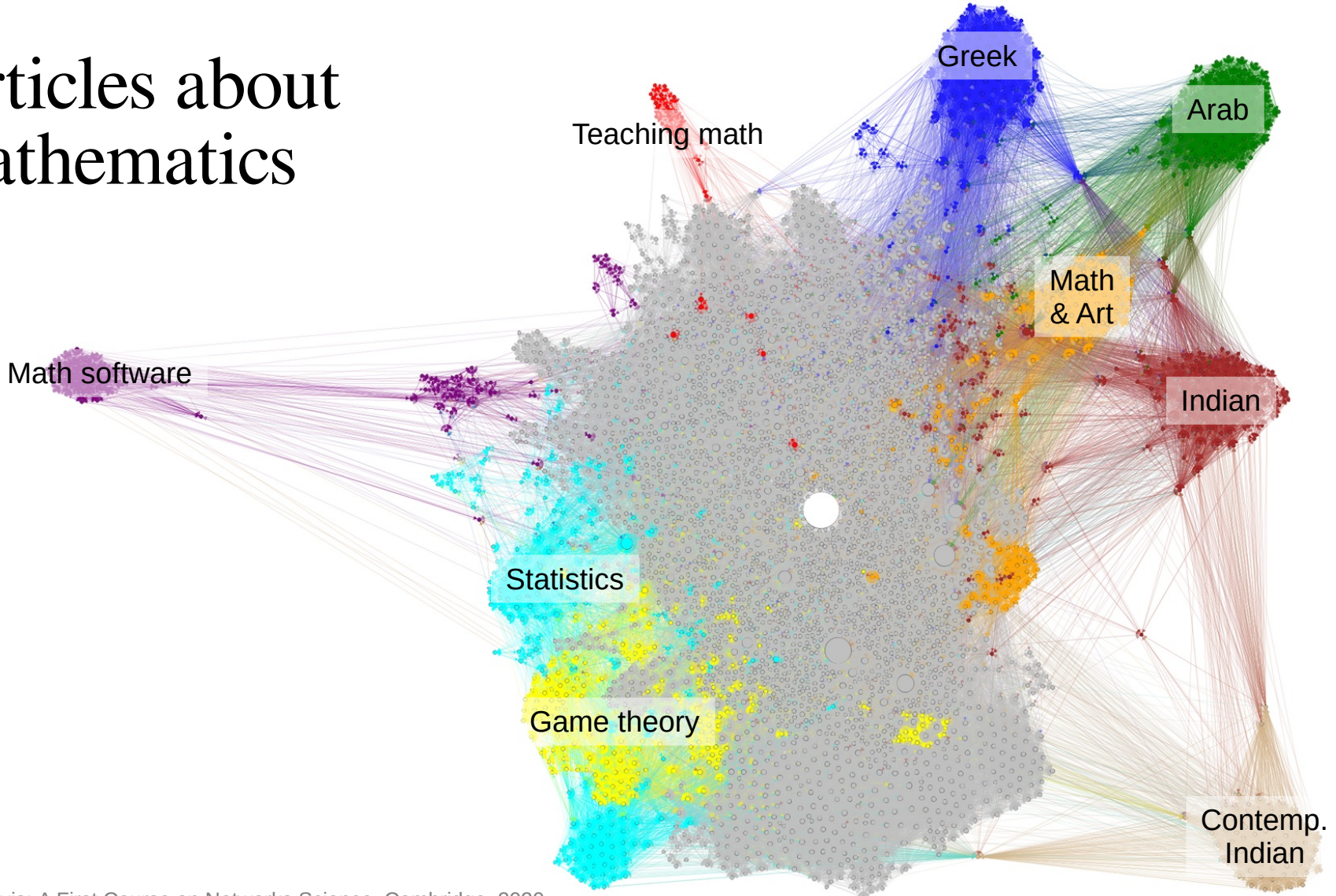


Node = actor/actress

Link = appear in the same movie

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

Articles about mathematics

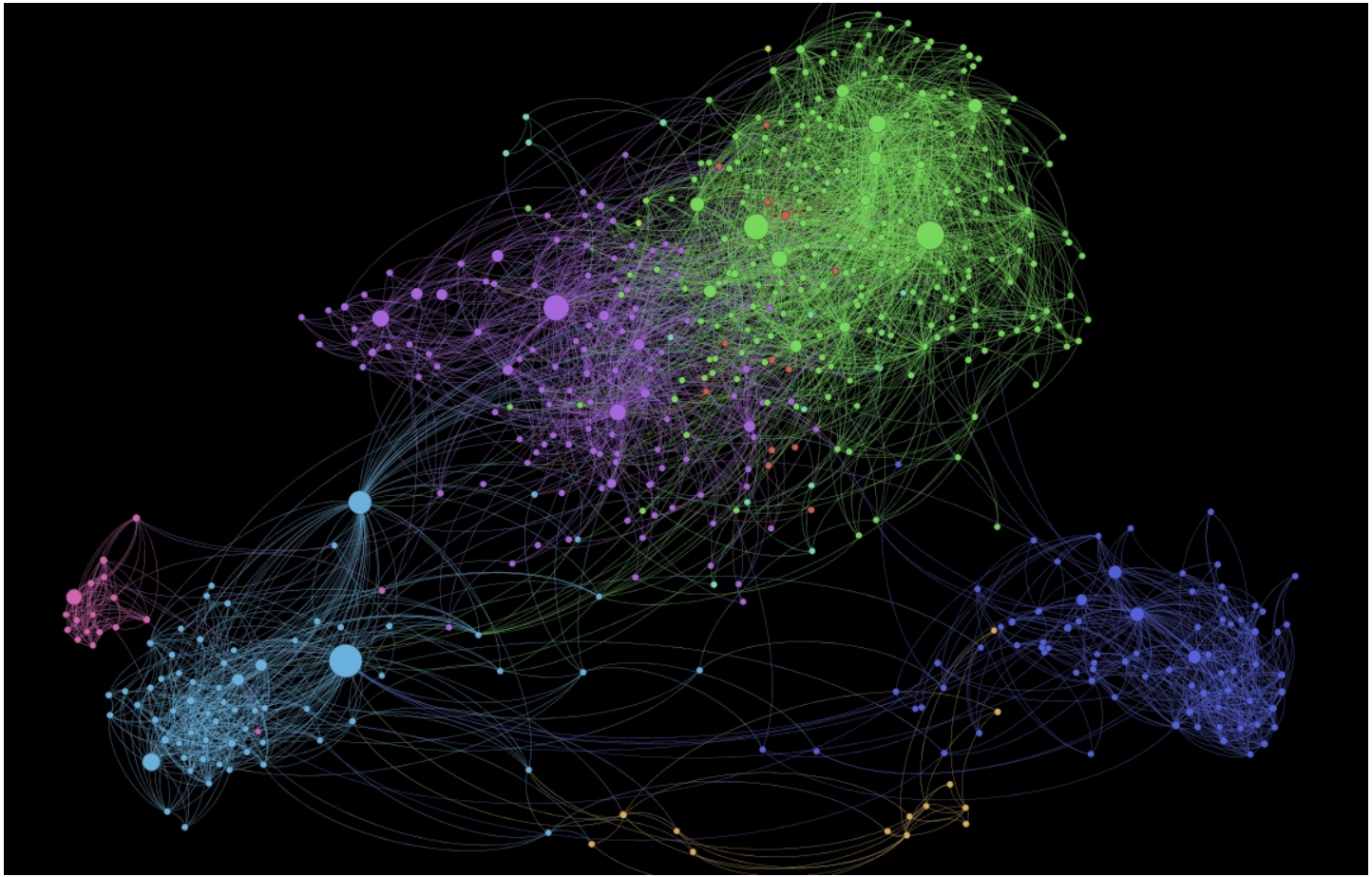


Node = article

Link = link

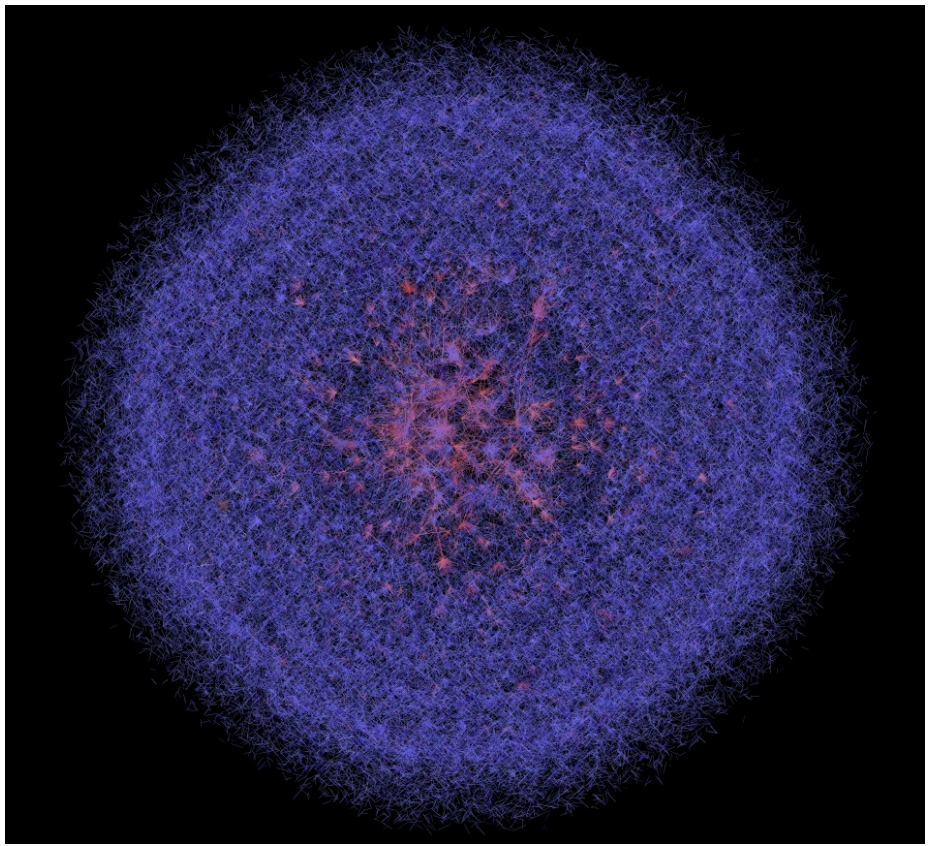
Source: Menczer, Fortunato, Davis: A First Course on Networks Science. Cambridge, 2020.

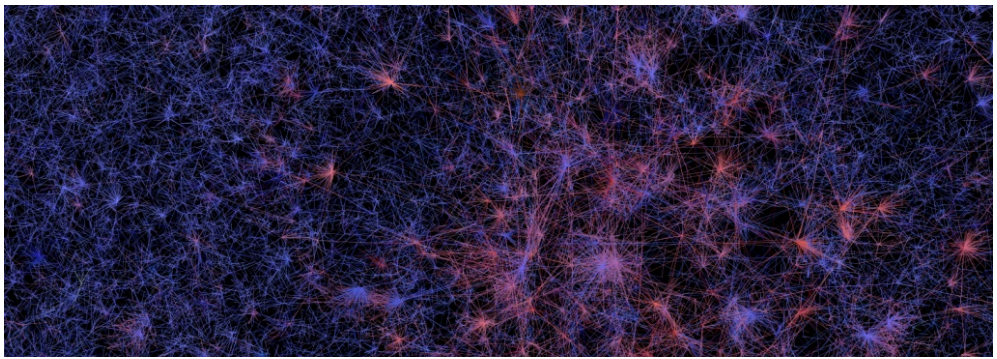
1,000 Somali Users of Facebook

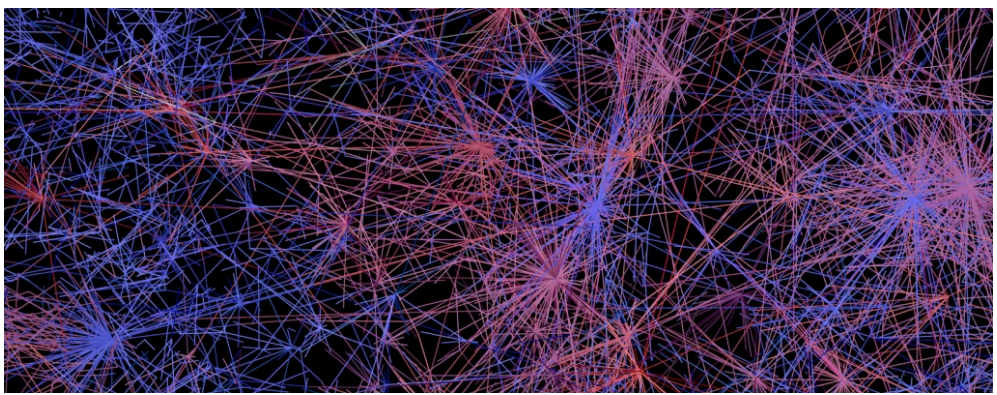


https://kimoquaintance.com/2011/08/22/what-can-we-learn-about-somalis-from-their-facebook-networks/

400,000 Twitter Users







https://dhs.stanford.edu/gephi-workshop/twitter-network-gallery/

Emergent characteristics

- Birds $\rightarrow$ Flocks
- Ants $\rightarrow$ Colonies
- People $\rightarrow$ Cities
- Neurons $\rightarrow$ Consciousness

https://www.science.org/content/article/how-bird-flocks-are-liquid-helium

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