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

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**

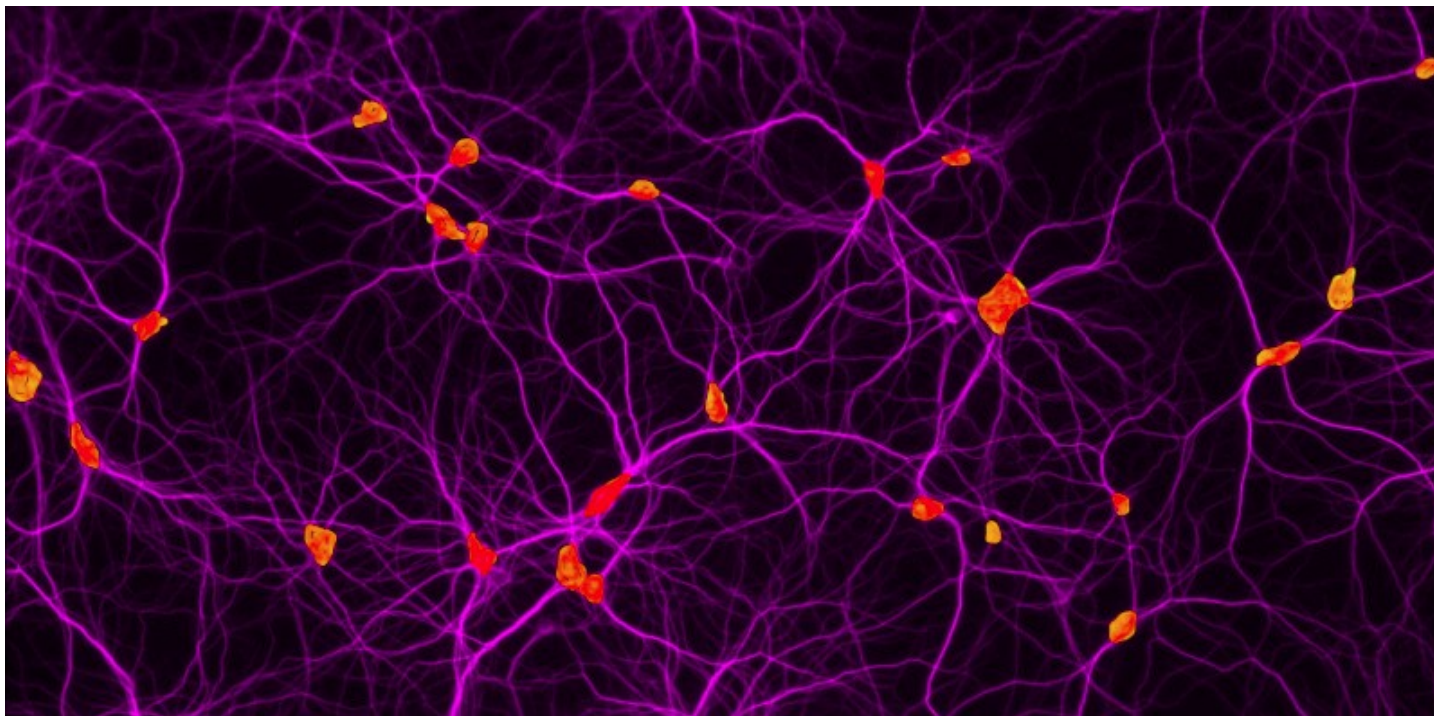 - connections between them represented as **links**

Complex systems

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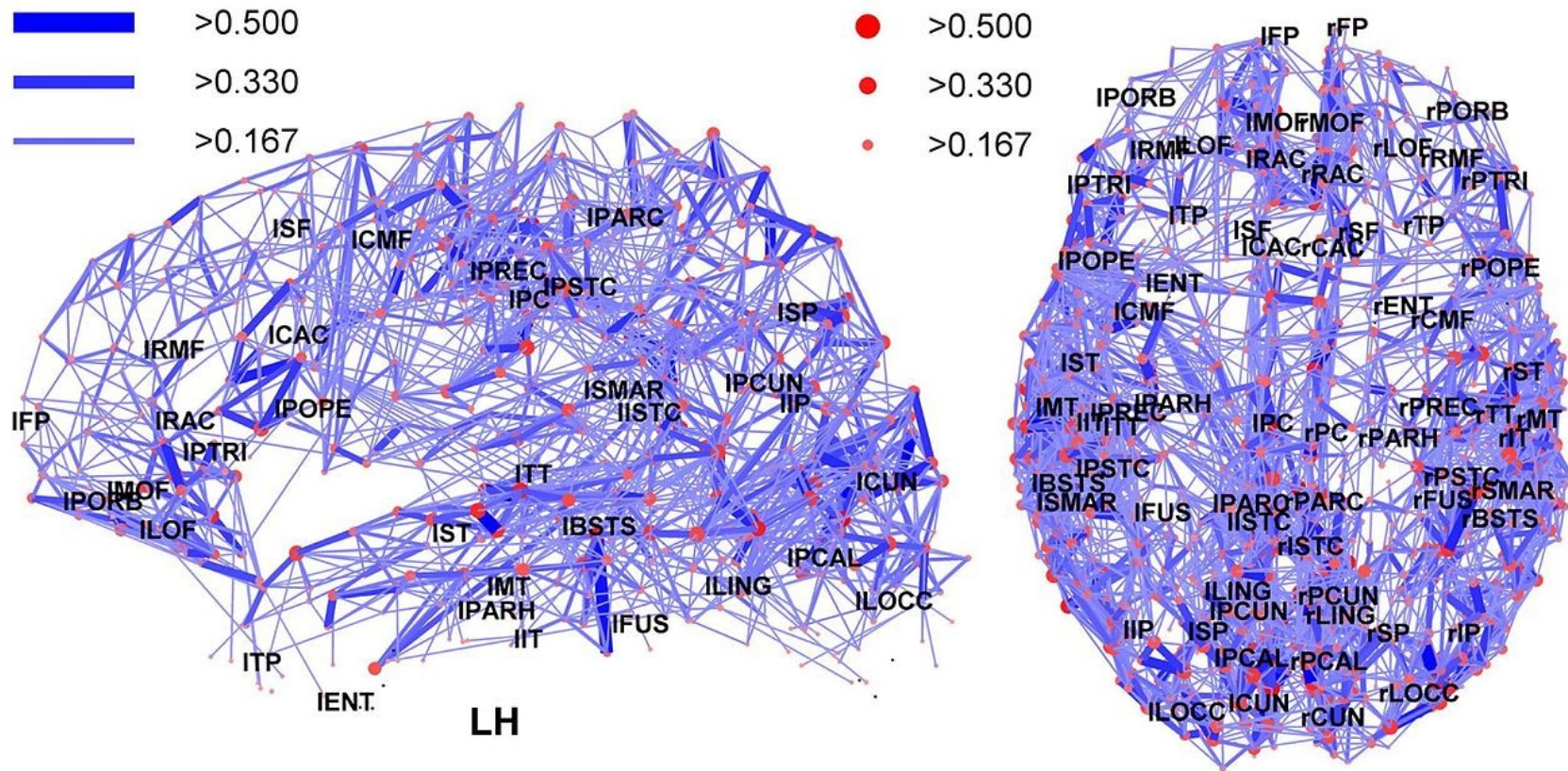- Intrincate arrangement
  of connections
- Emerging properties

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

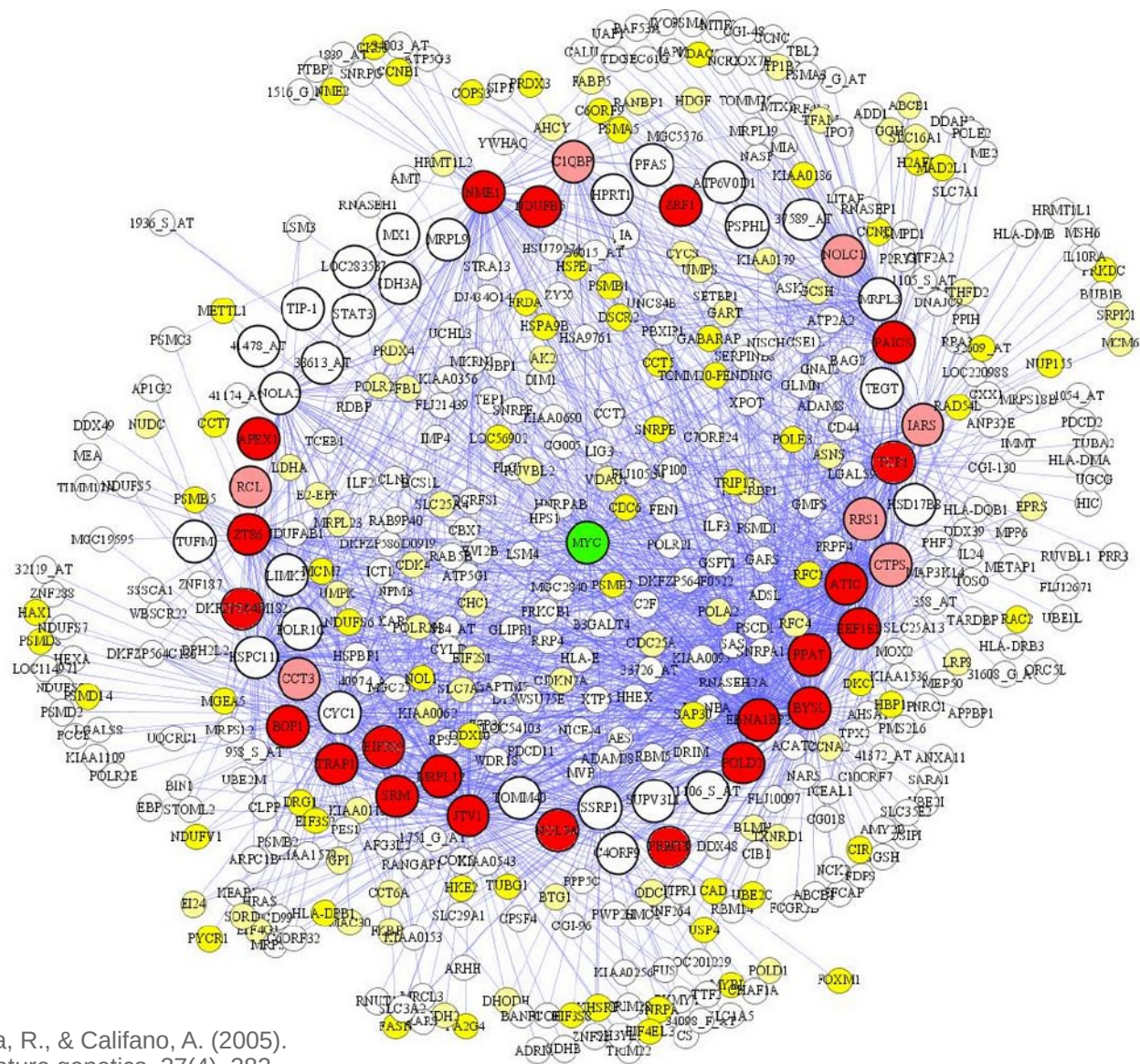# Human brain: $|V| \simeq 90 \times 10^9$

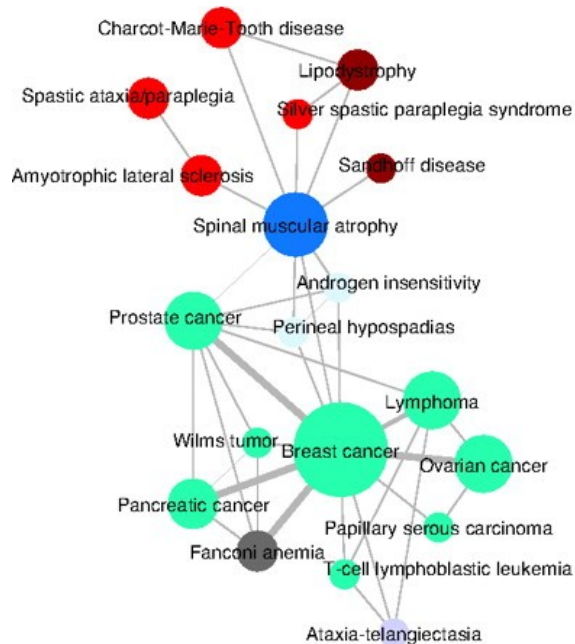https://health.uconn.edu/cell-analysis-modeling/microscopy-facility-2/   https://dx.doi.org/10.1371%2Fjournal.pone.0004006

Regions in the human brain

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
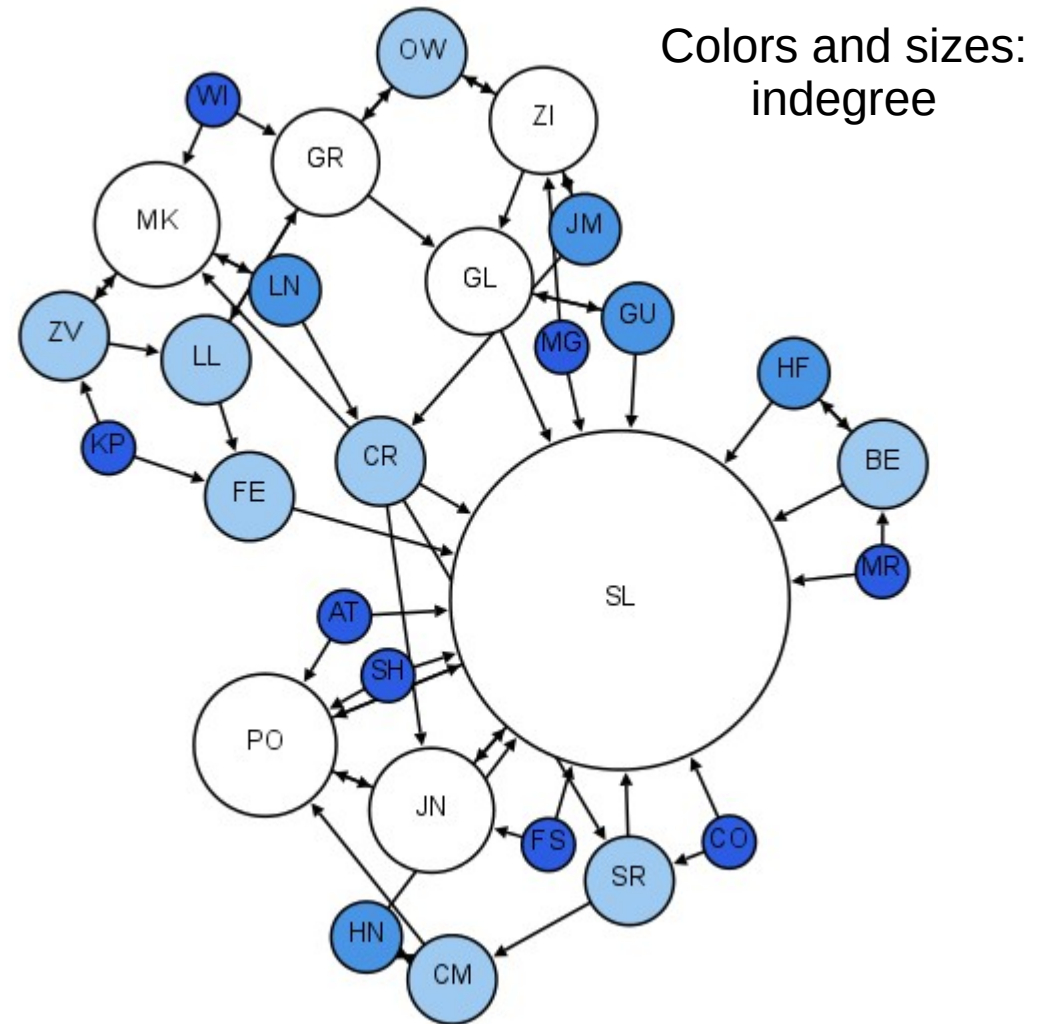

Human Disease Network (HDN)

DISEASOME

http://www.pnas.org/content/104/21/8685
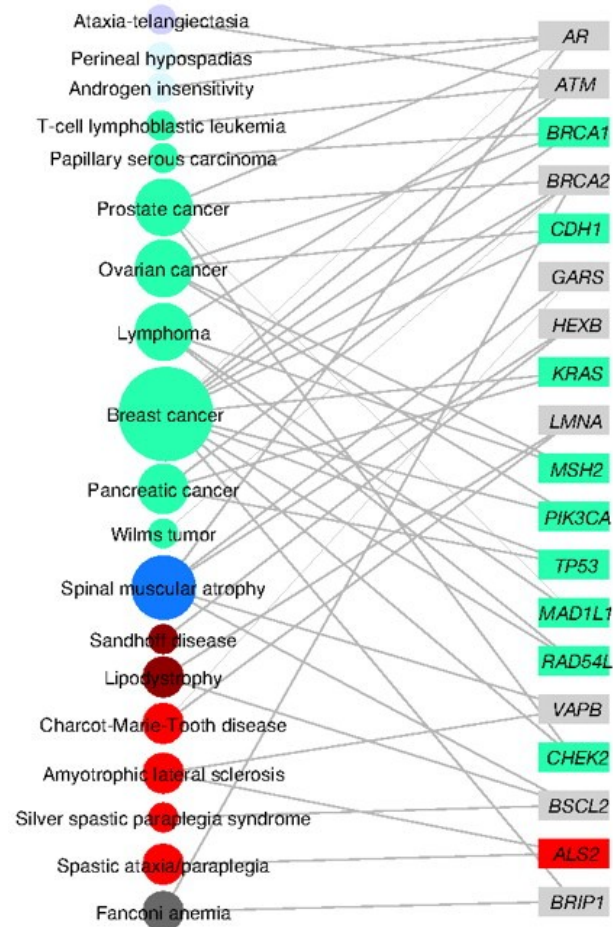
Moreno's sociograms

- Early 1930s

- Children in 2nd grade

- Who would you like to sit with?
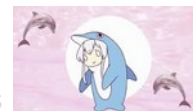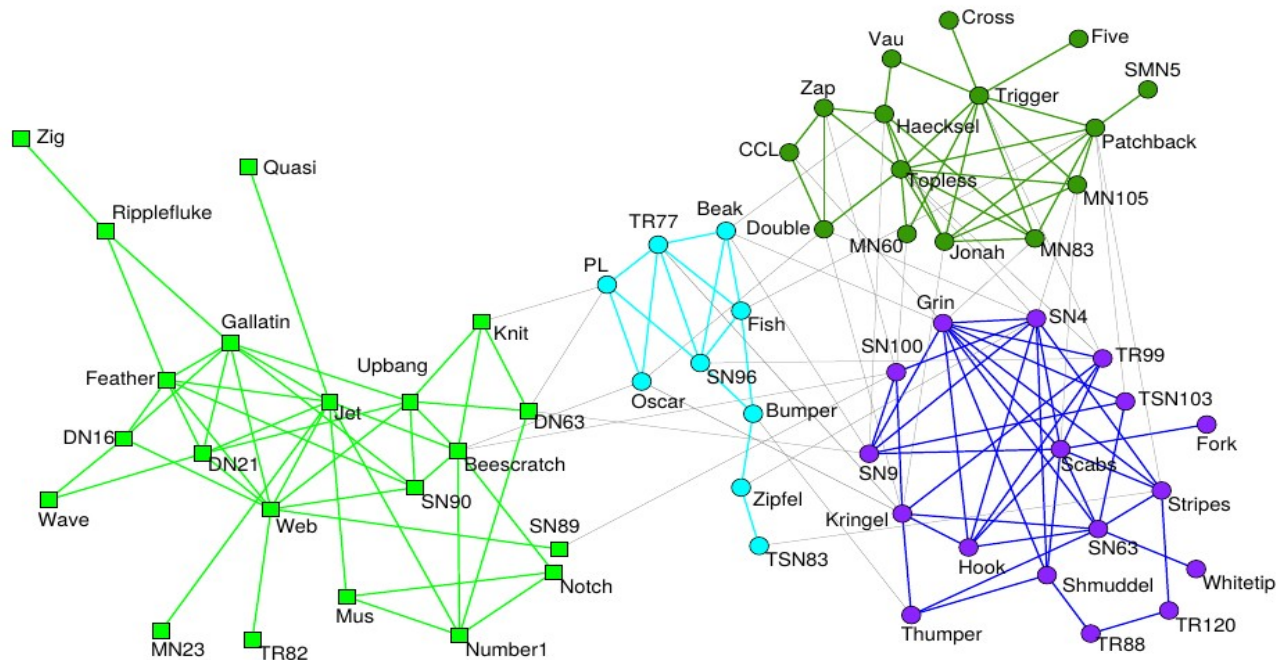

Colors and sizes: indegree

Zachary's Karate Club

Karate club that split into two clubs

(led by 1 and 34)
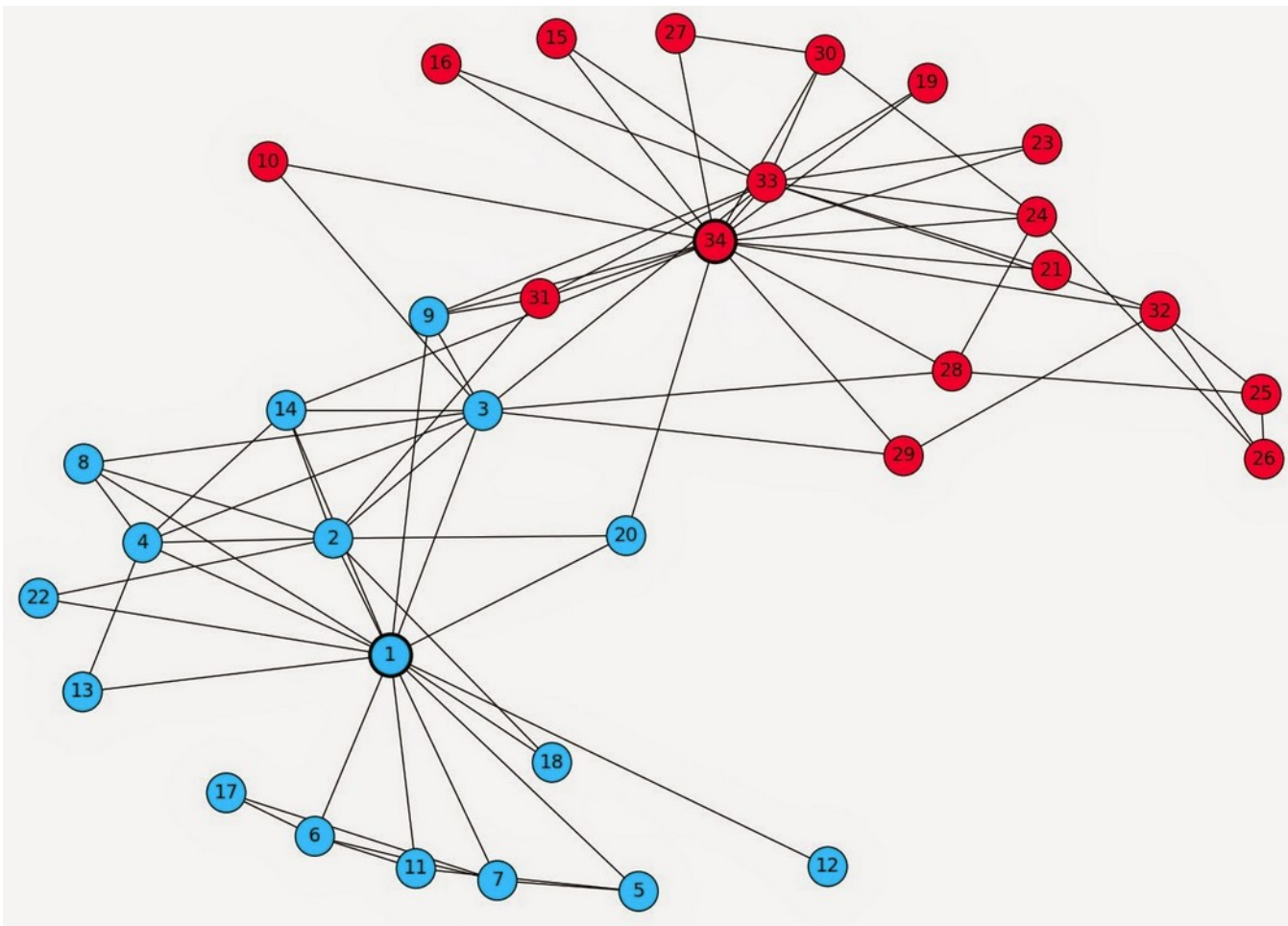
Dolphins in a fjord in New Zealand

- 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)
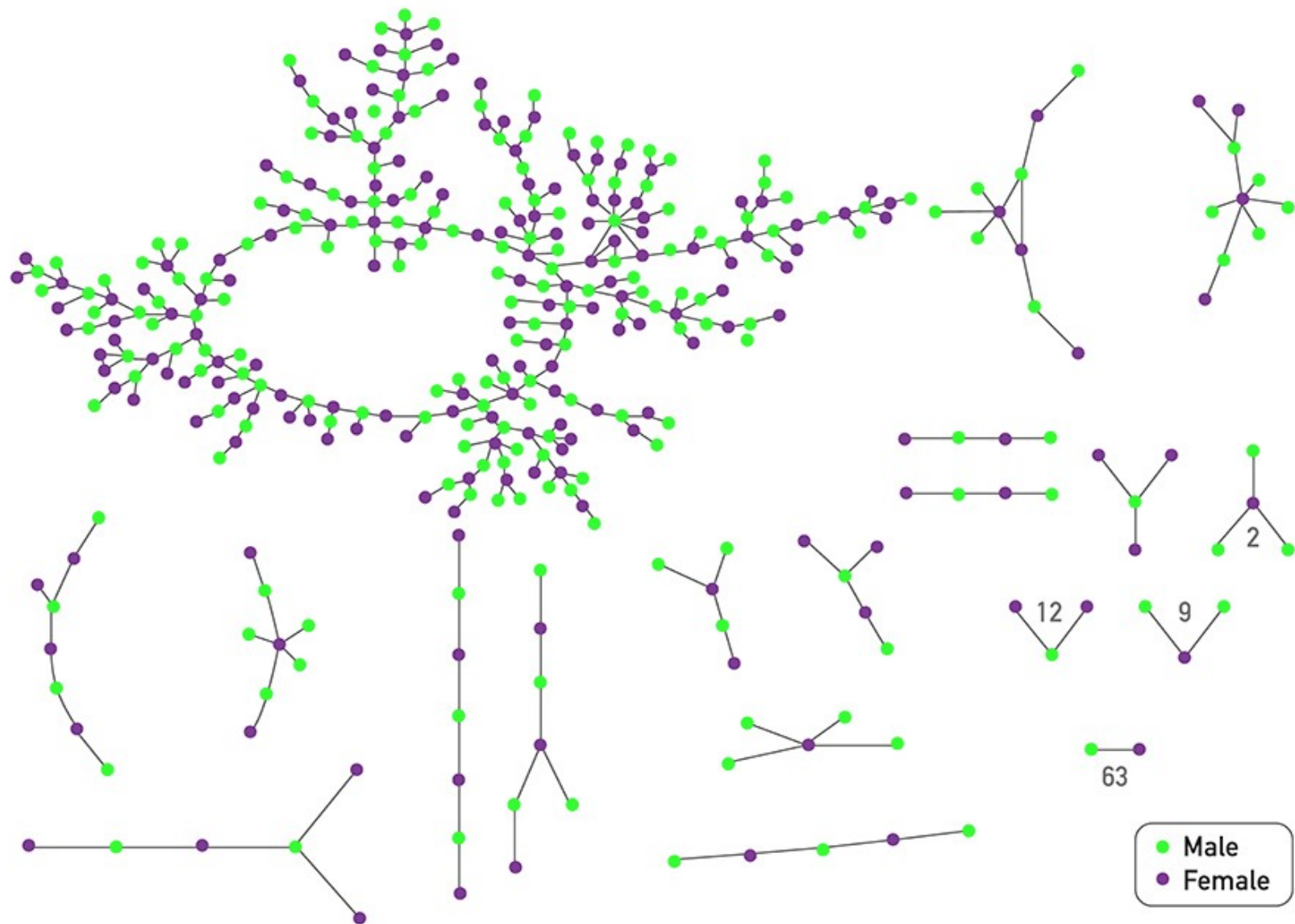
I really like dolphins

Male
Female

Chains of affection

- Early 2000s

- Adolescents in high school

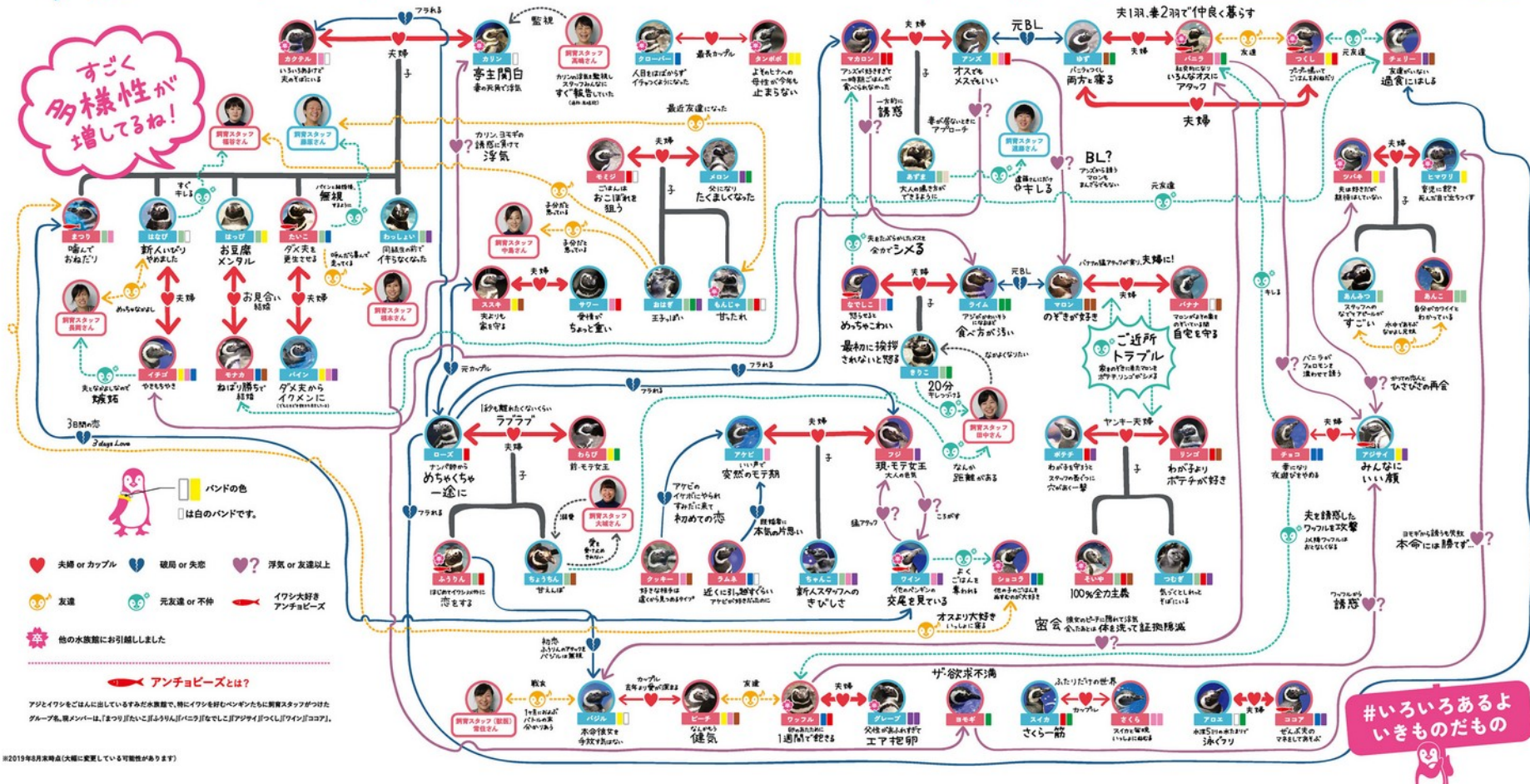- A "*special romantic relationship*" or a "*nonromantic sexual relationship*" in the past 18 months
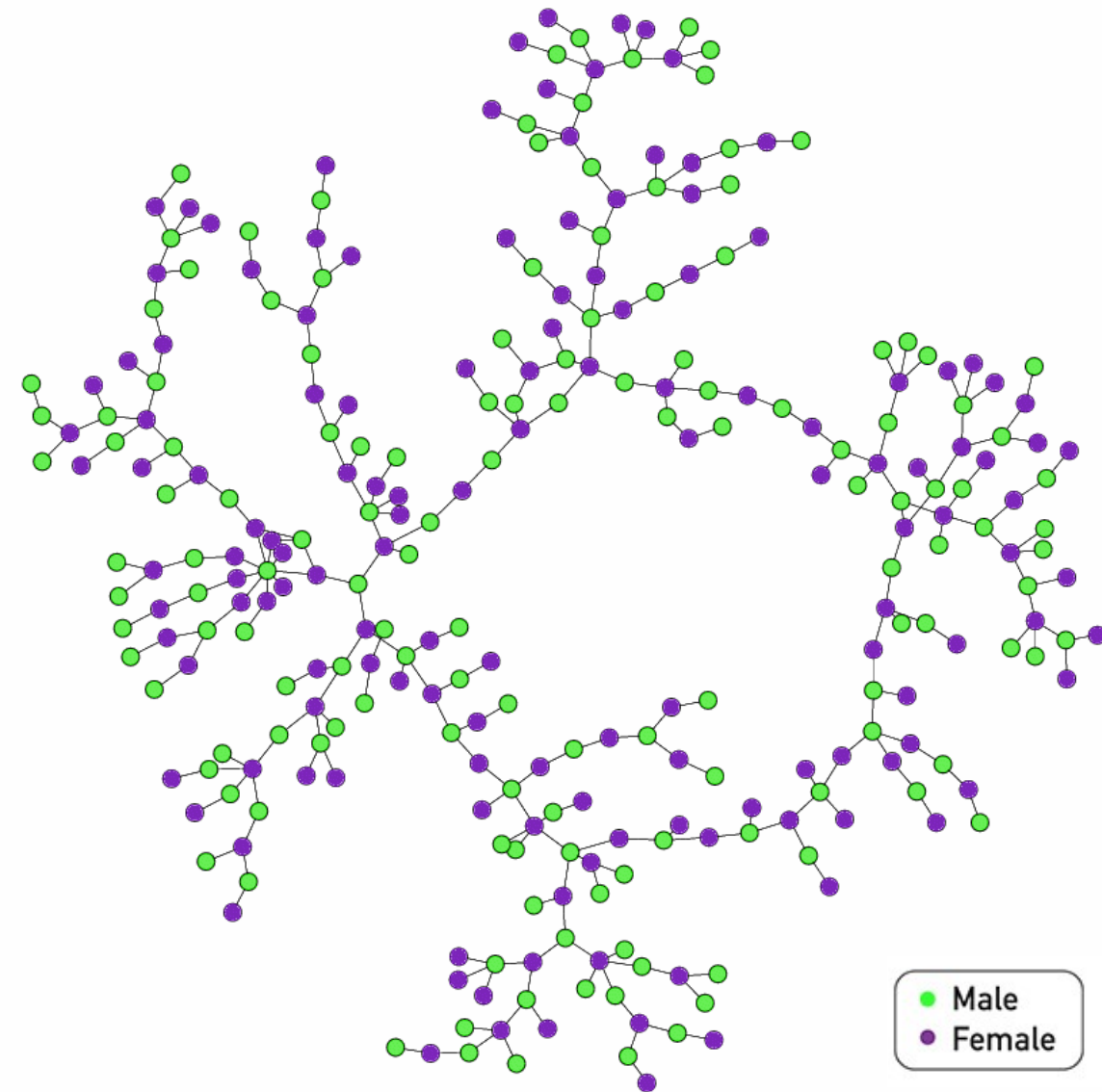
Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American journal of sociology, 110(1), 44-91.
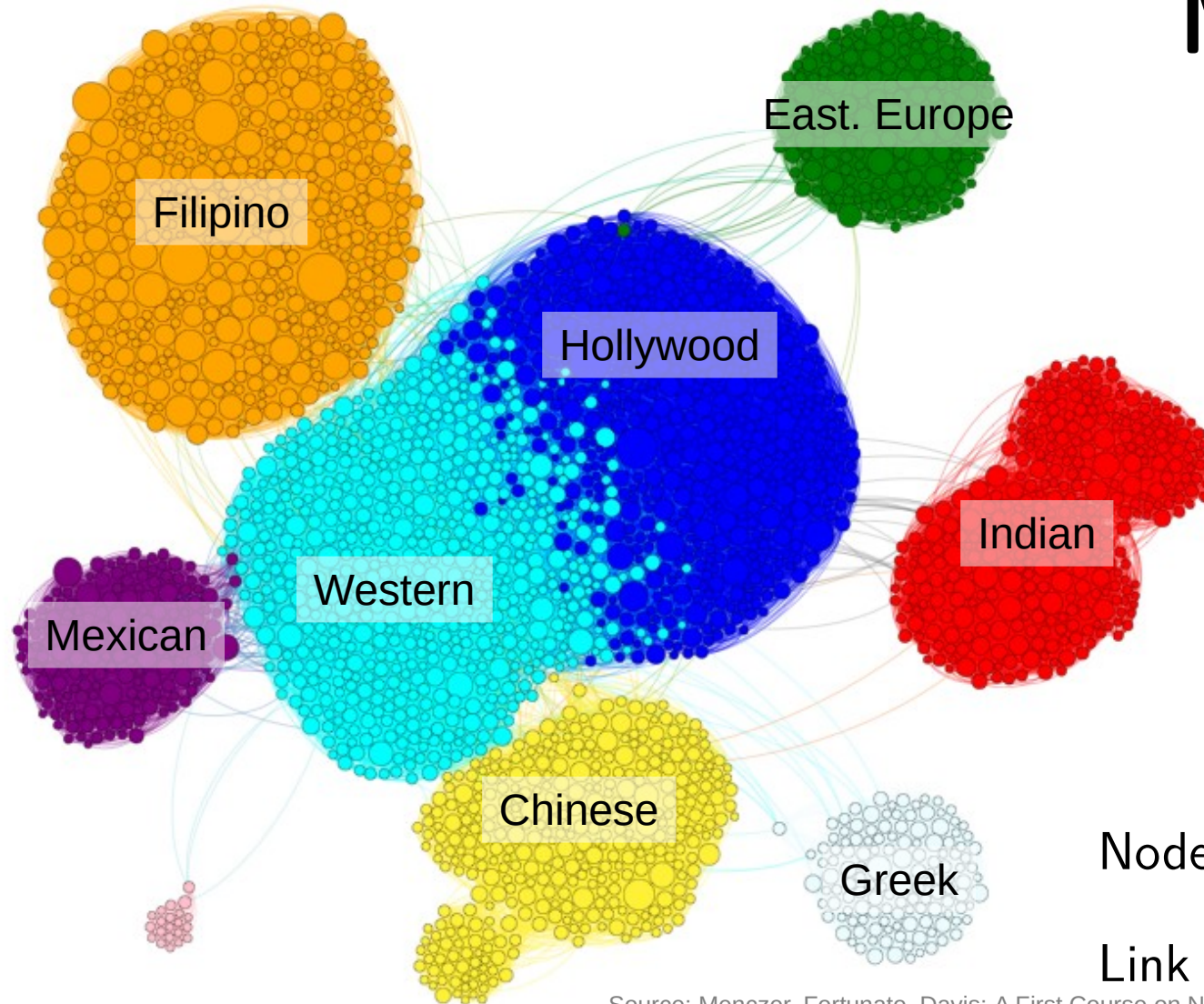
Male
Female

すみだペンギン相関図2020

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

15/23

Movie stars in international cinema

Labels: Filipino, East. Europe, Hollywood, Indian, Western, Mexican, Chinese, Greek
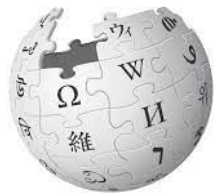
Node = actor/actress
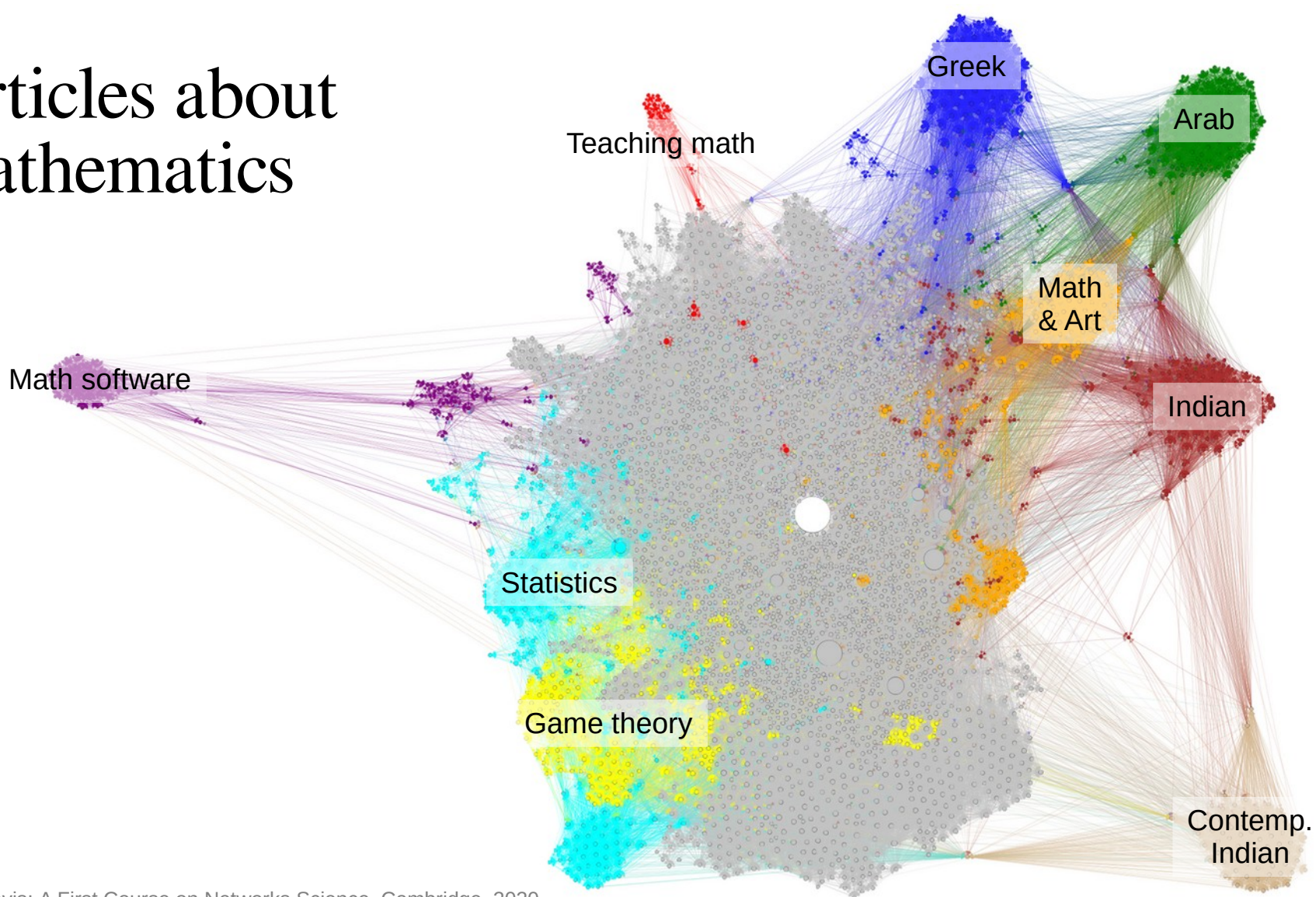
Link = appear in the same movie

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

Articles about mathematics

WIKIPEDIA
The Free Encyclopedia
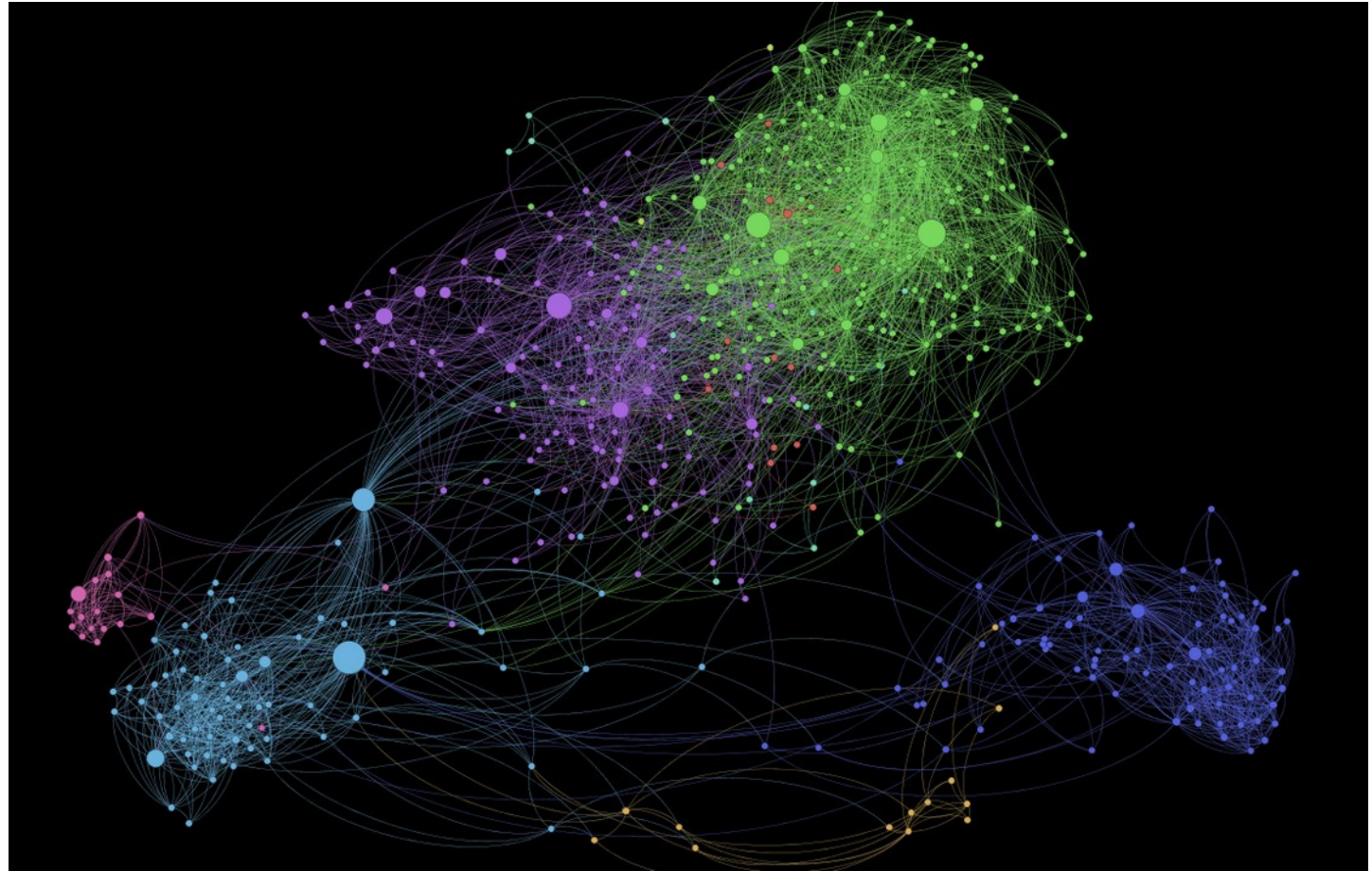
Teaching math

Greek

Arab

Math & Art

Indian

Math software

Statistics

Game theory

Contemp. Indian

Node = article

Link = link

1,000 Somali Users of Facebook

400,000 Twitter Users

https://dhs.stanford.edu/gephi-workshop/twitter-network-gallery/
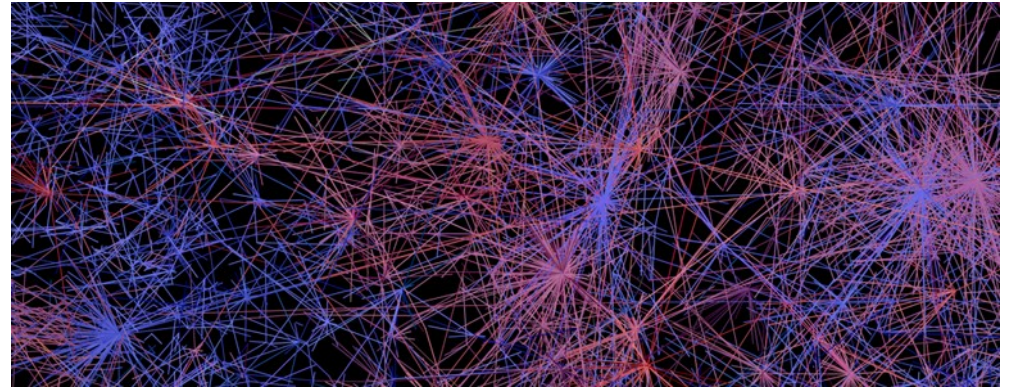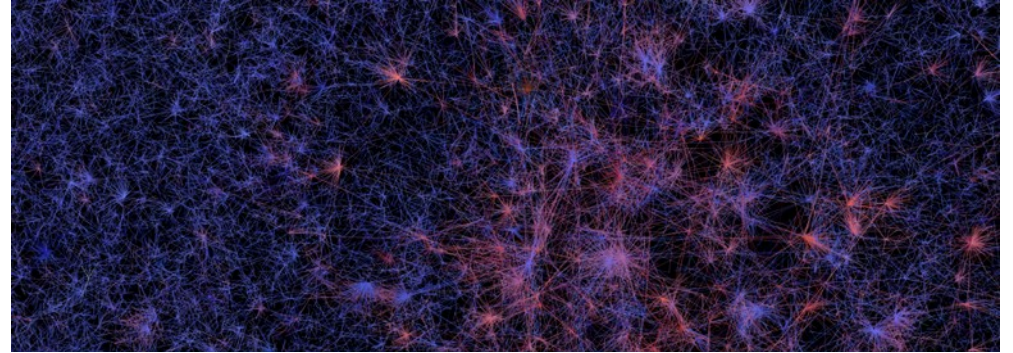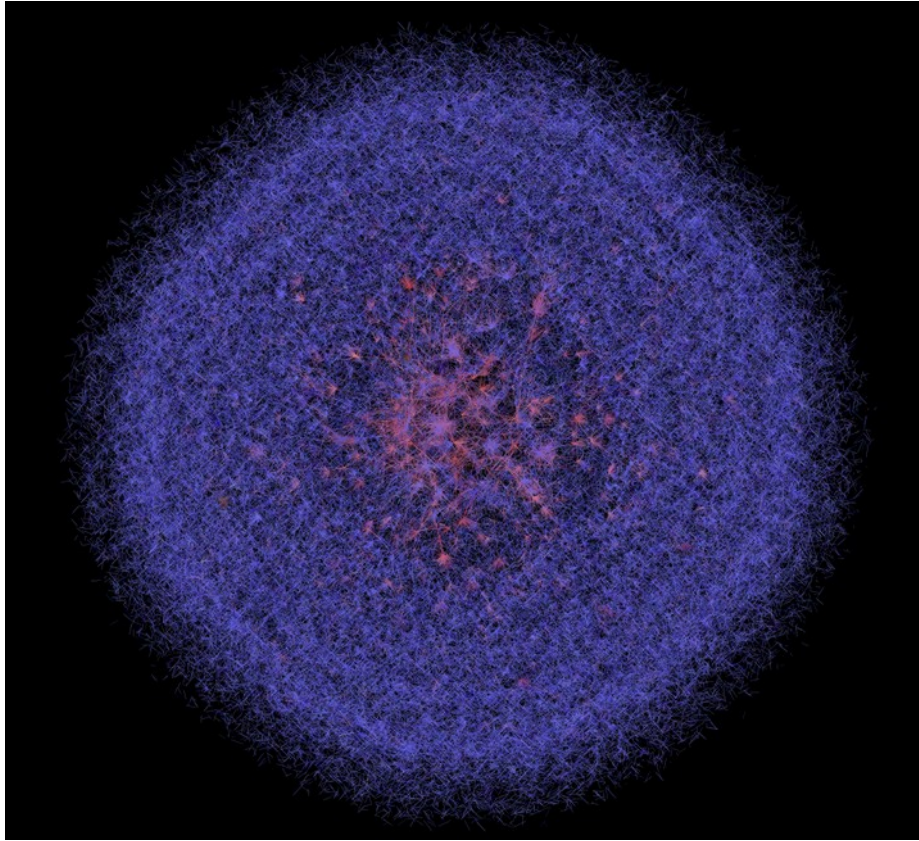
What could complex networks have in common? Why those regularities could be relevant? How would you find out what they are?

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)

Things to remember

- Definitions: complex system, complex network

- Examples of complex networks