

Complex Networks

Social Networks Analysis and Graph Algorithms

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Sources

- Albert László Barabási: Network Science. Cambridge University Press, 2016.
 - [Chapter 01](#), [Chapter 02](#)
- Filippo Menczer, Santo Fortunato, and Clayton A. Davis. A First Course in Network Science. Cambridge University Press, 2020.
 - [Chapter 00](#)
- URLs cited in the footer of specific 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

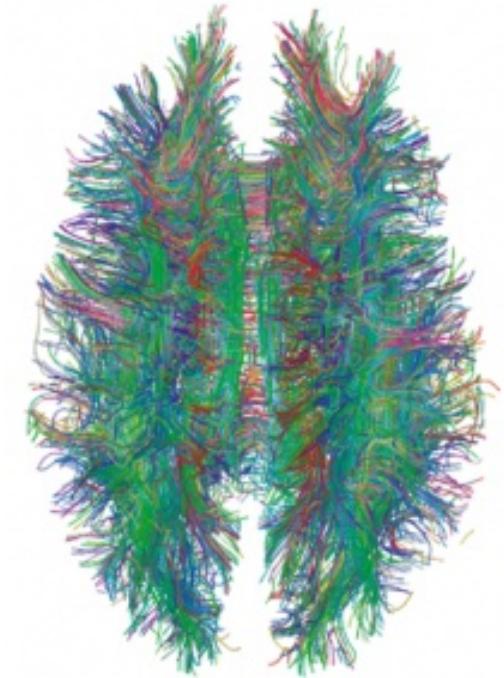
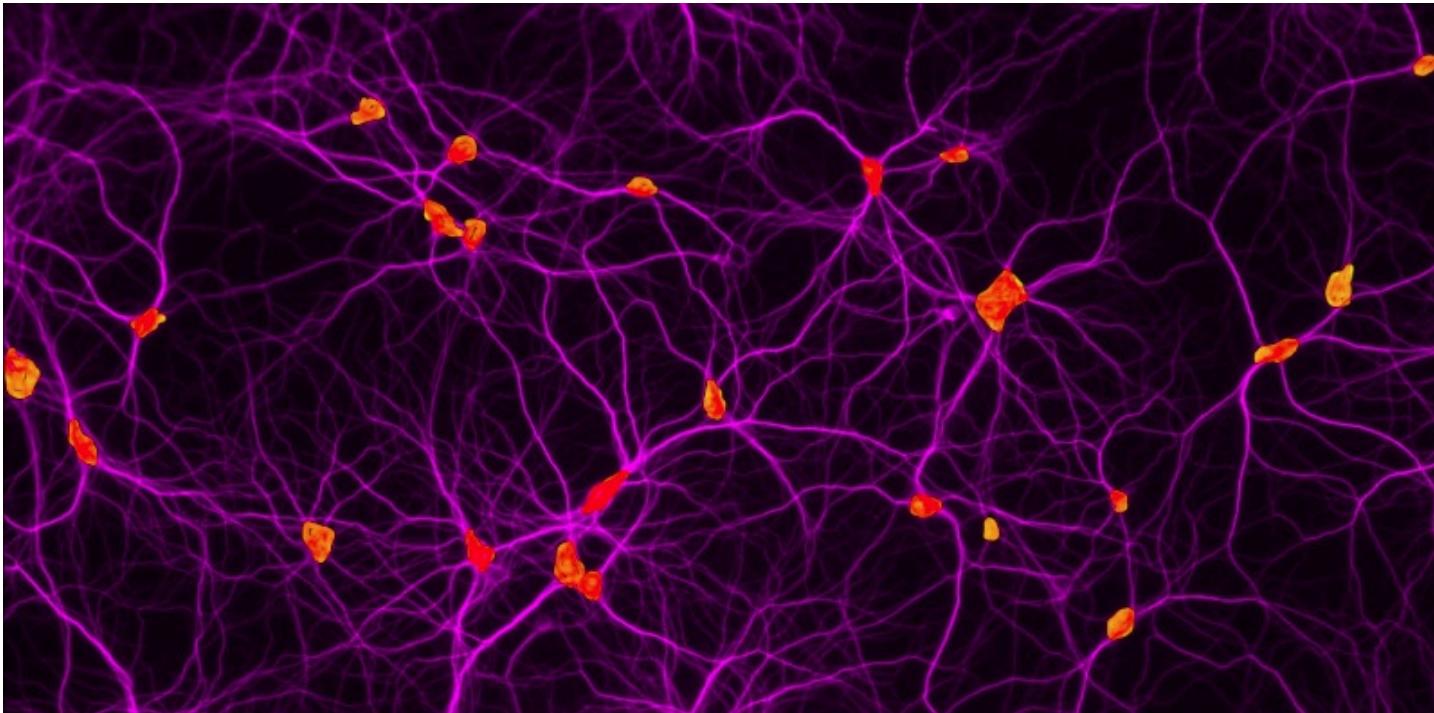
- Many interconnected parts
- Intricate arrangement of connections
- **Emerging properties**



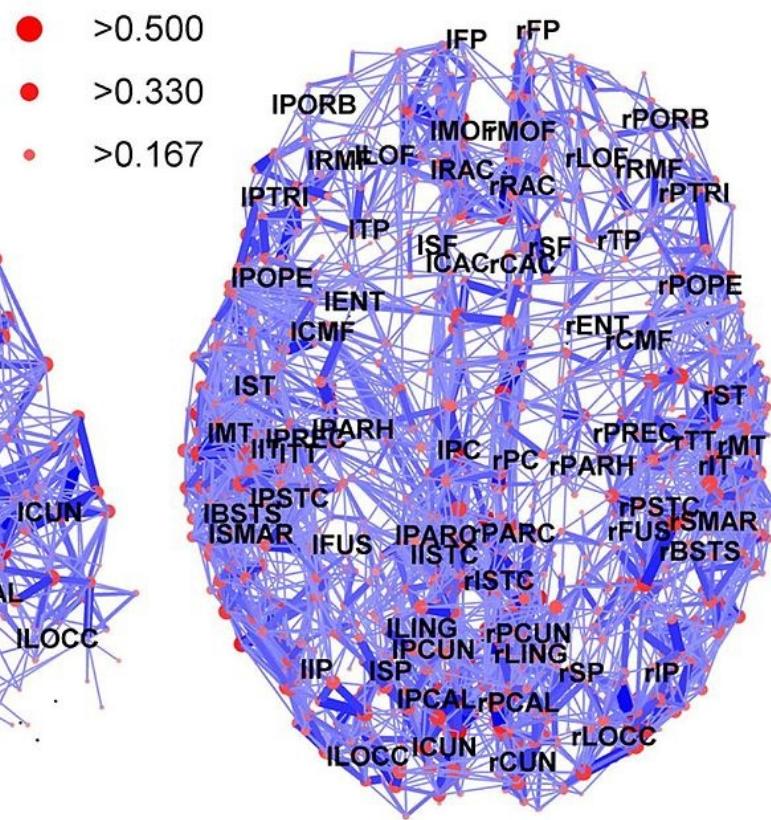
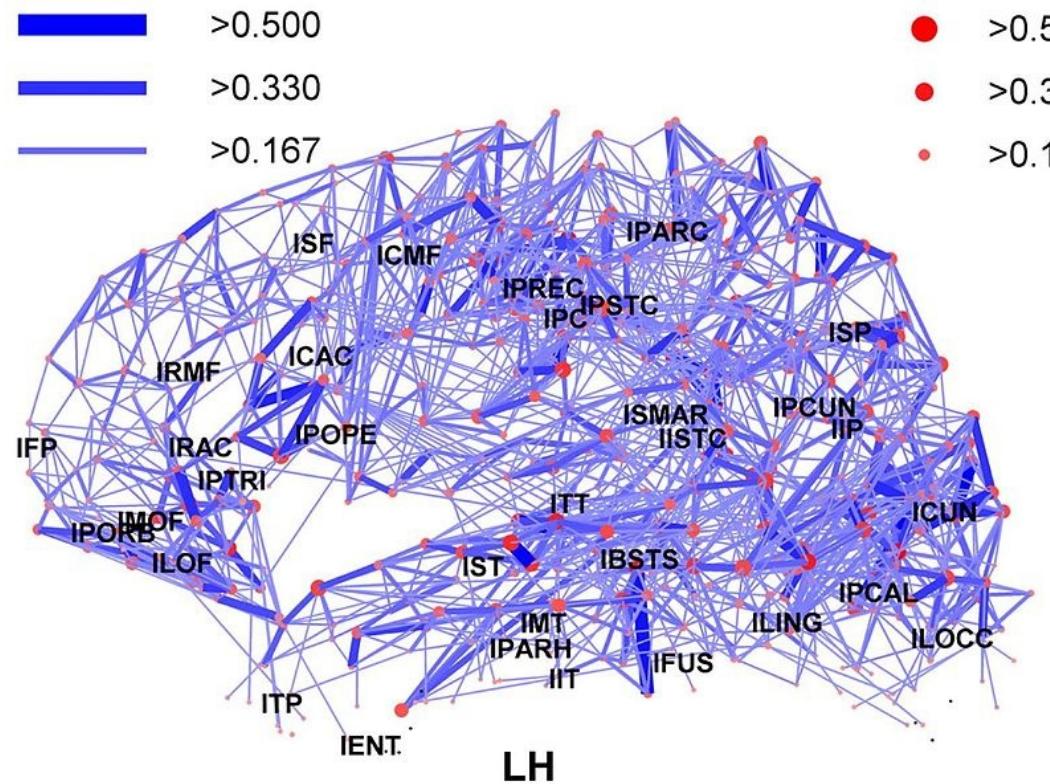
Behind every complex system there is a complex network

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



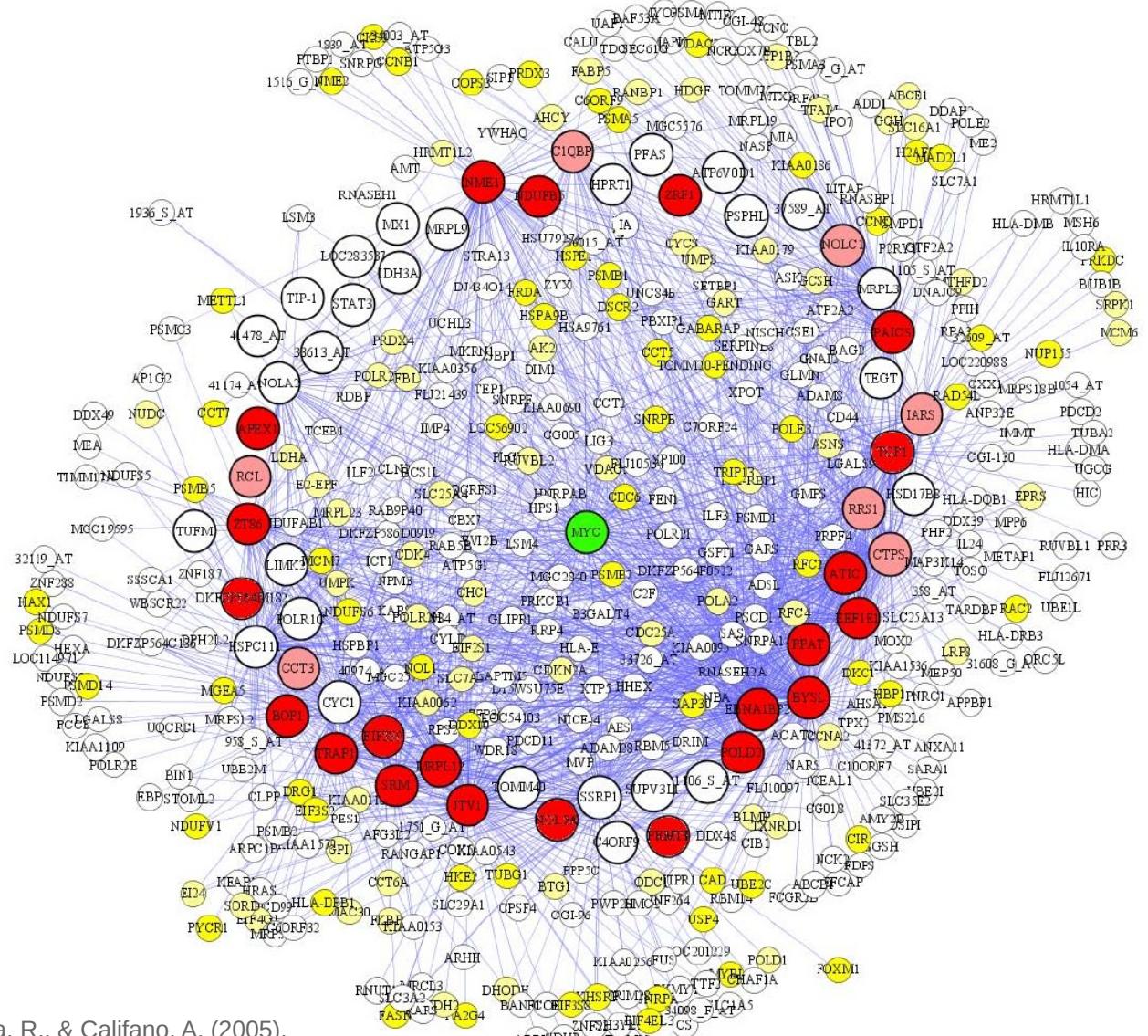
Regions in the human brain



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

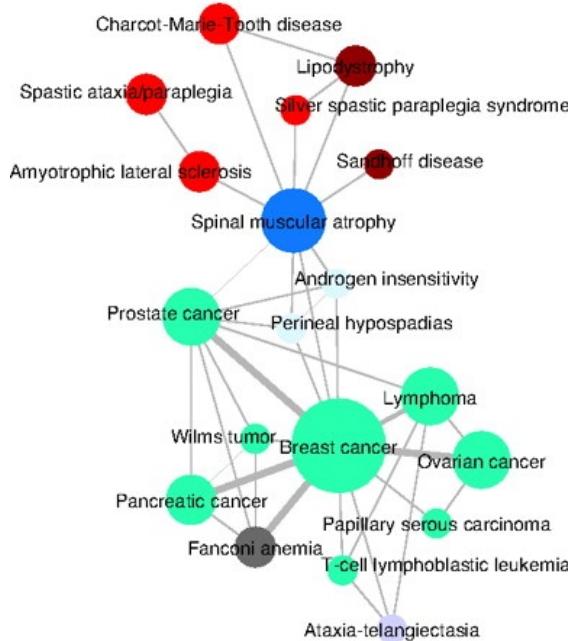
Genes

$|V|=500$ in this plot



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 paraplegia syndrome

Spastic ataxia/paraplegia

Fanconi anemia

disease genome

AR

ATM

BRCA1

BRCA2

CDH1

GARS

HEXB

KRAS

LMNA

MSH2

PIK3CA

TP53

MAD1L1

RAD54L

VAPB

CHEK2

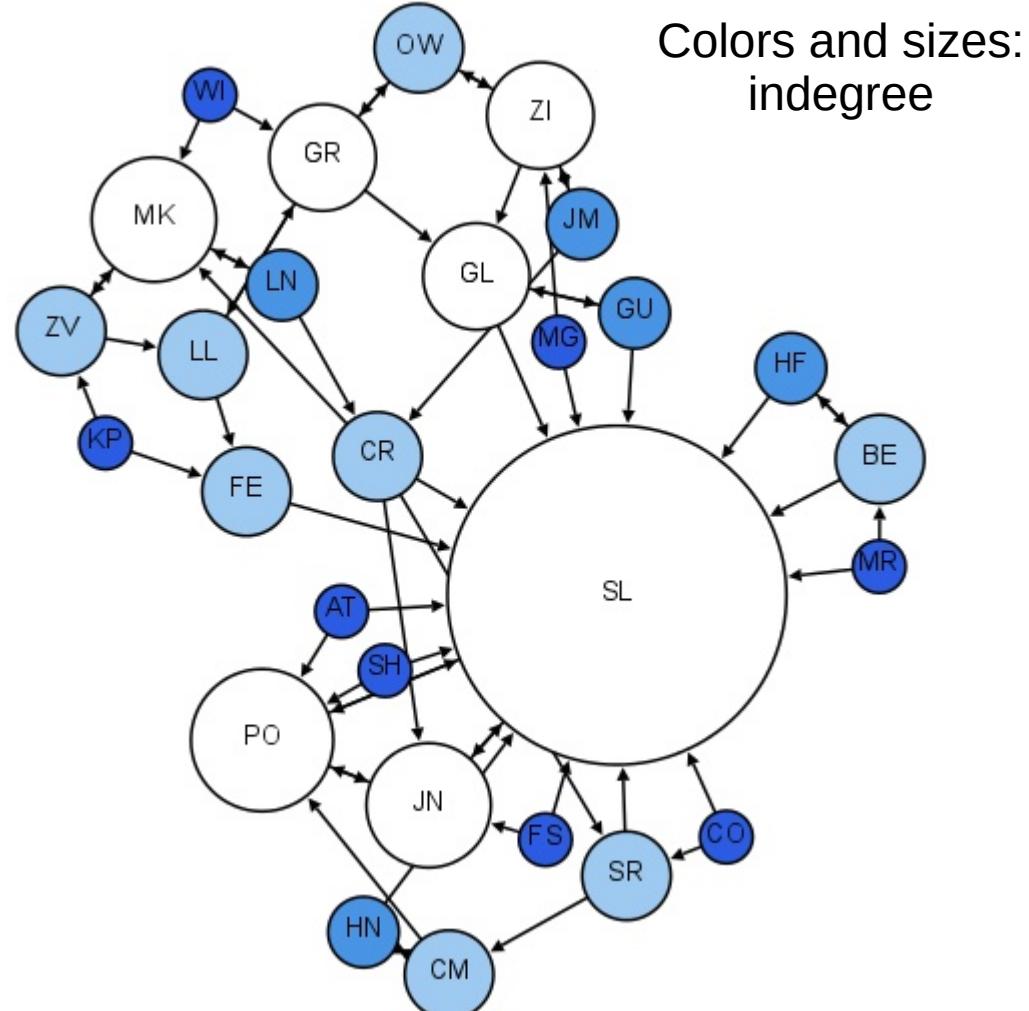
BSCL2

ALS2

BRIP1

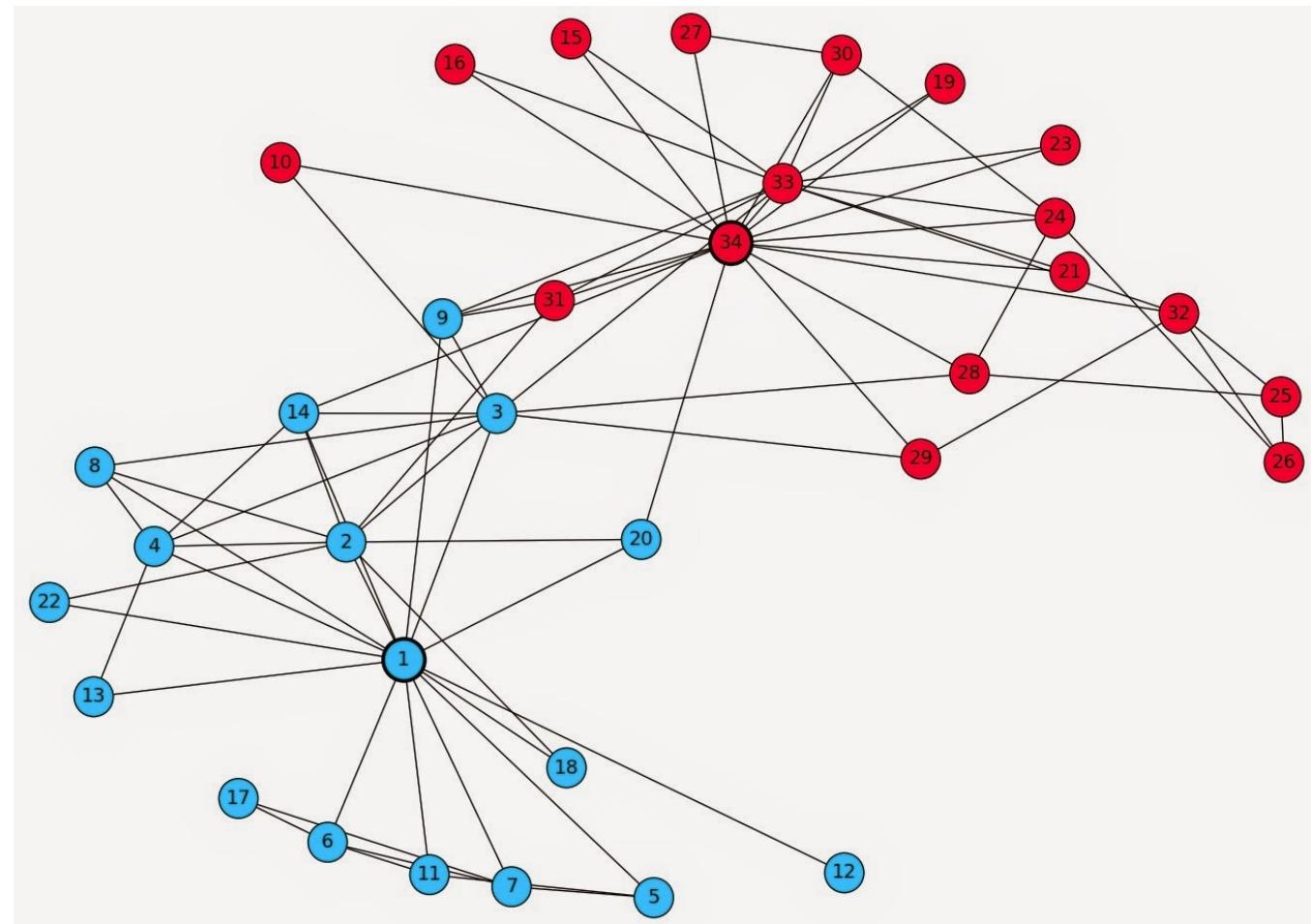
Moreno's sociograms

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



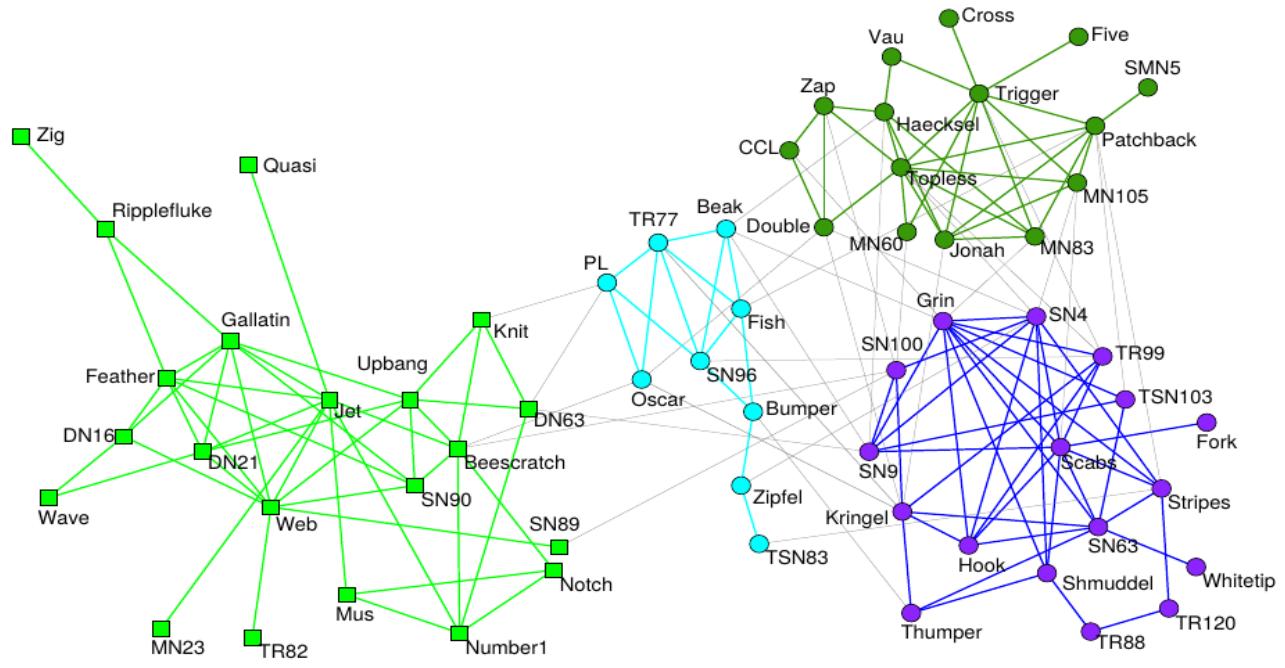
Zachary's Karate Club

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)



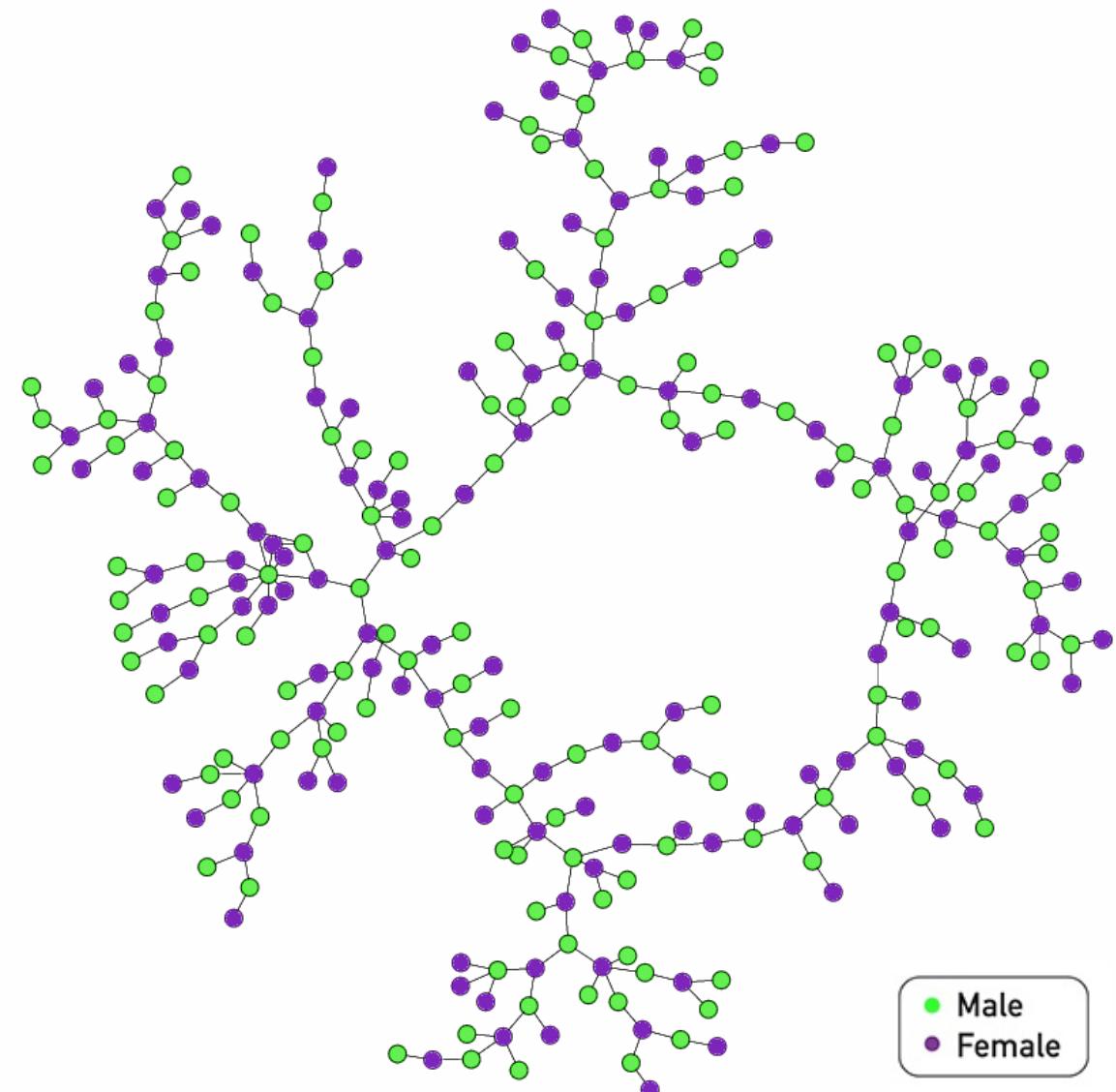
<https://doi.org/10.1007/s00265-003-0651-y>

I really like dolphins

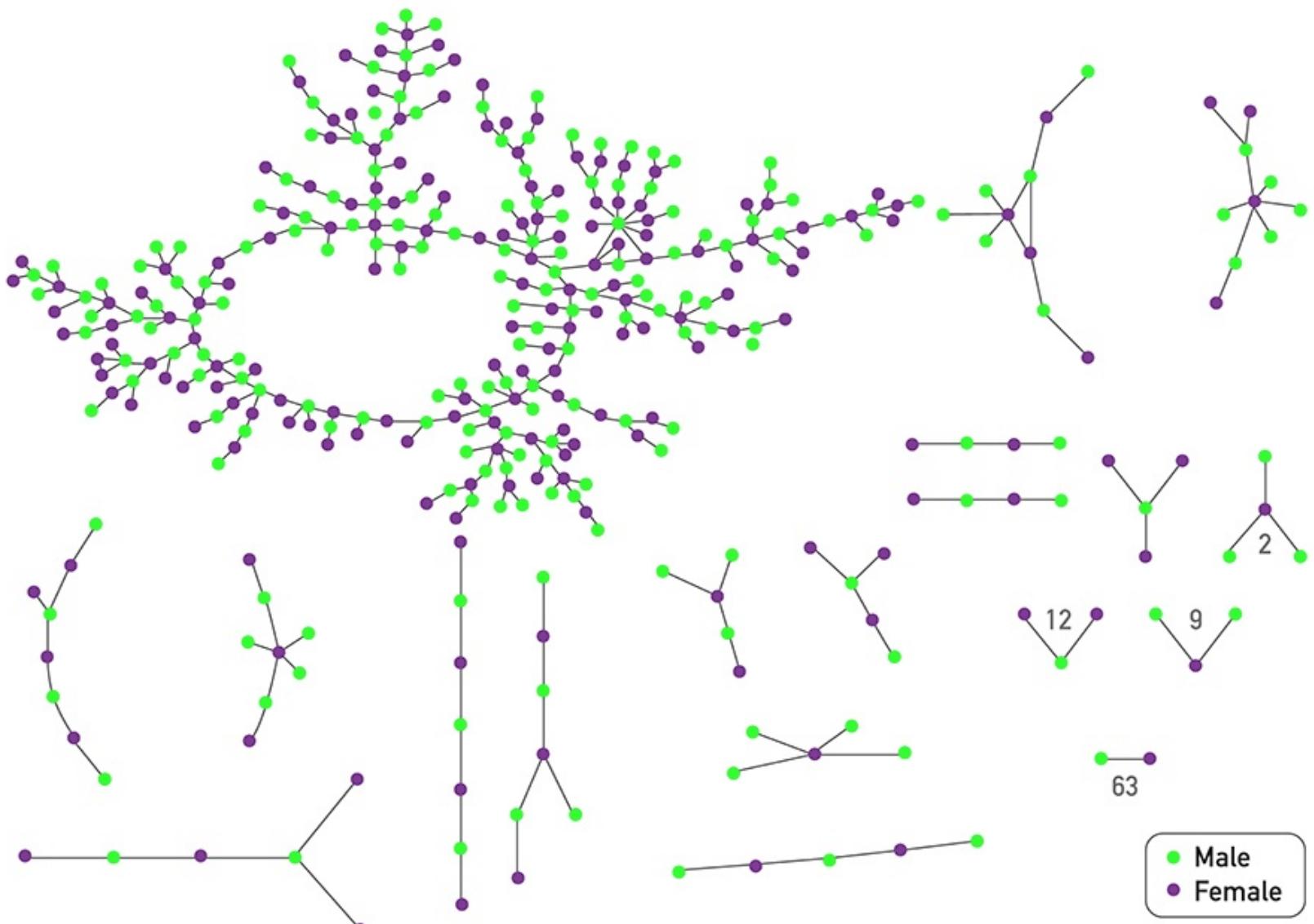


Chains of affection

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

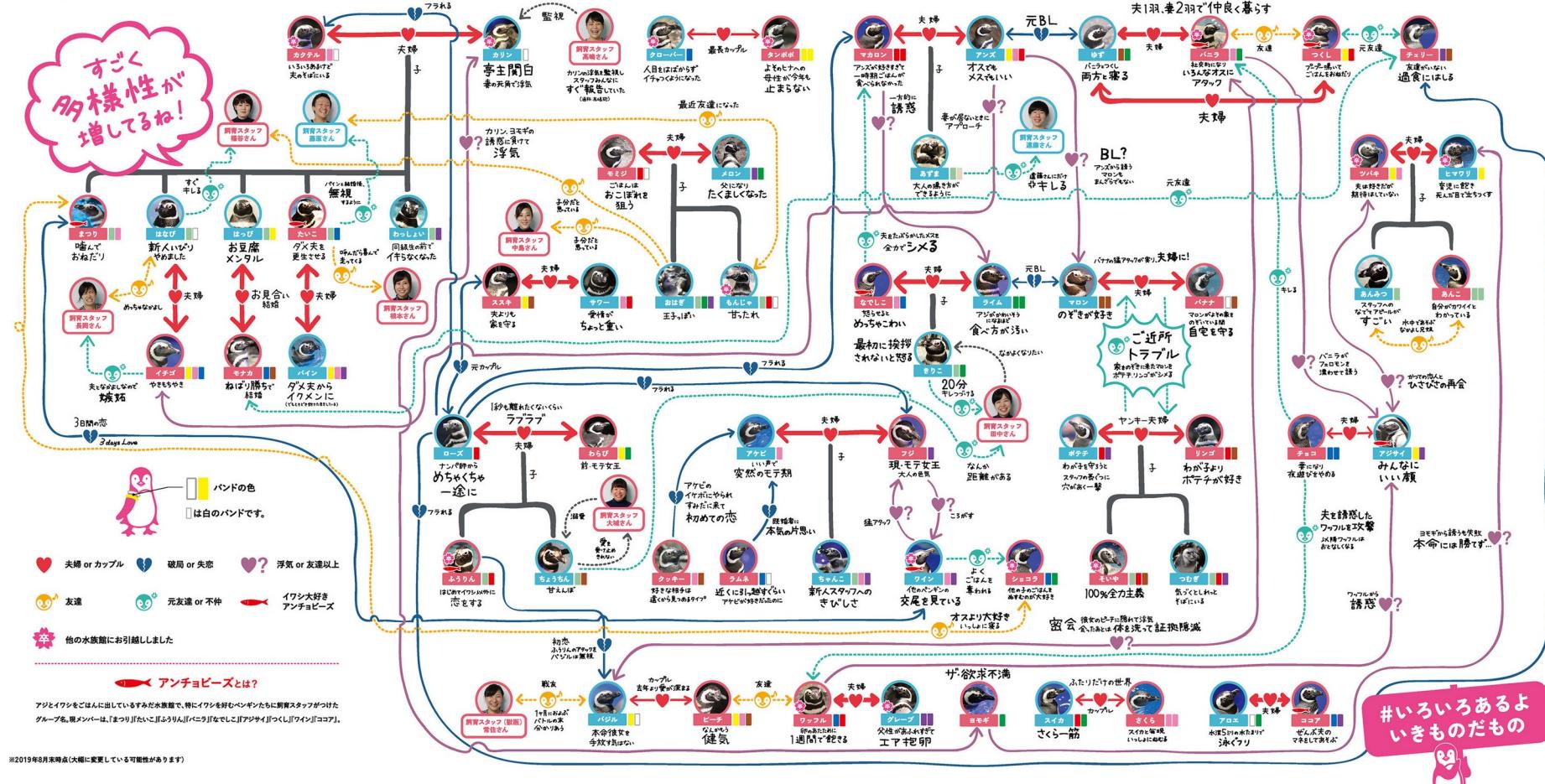


Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American journal of sociology, 110(1), 44-91.



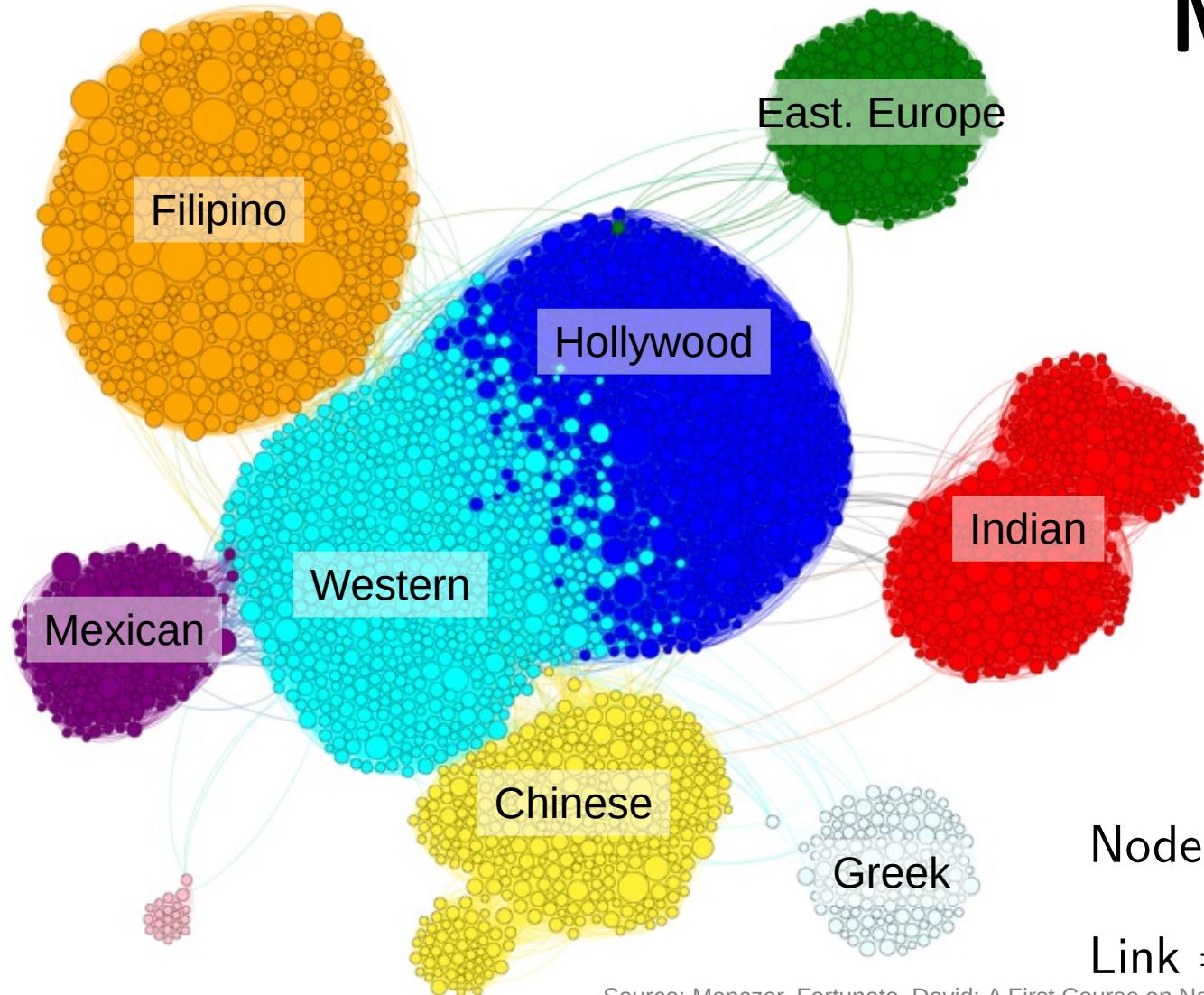
~~もっと!~~
かわいい!
たのしい!
ややこしい

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



WIKIPEDIA
The Free Encyclopedia

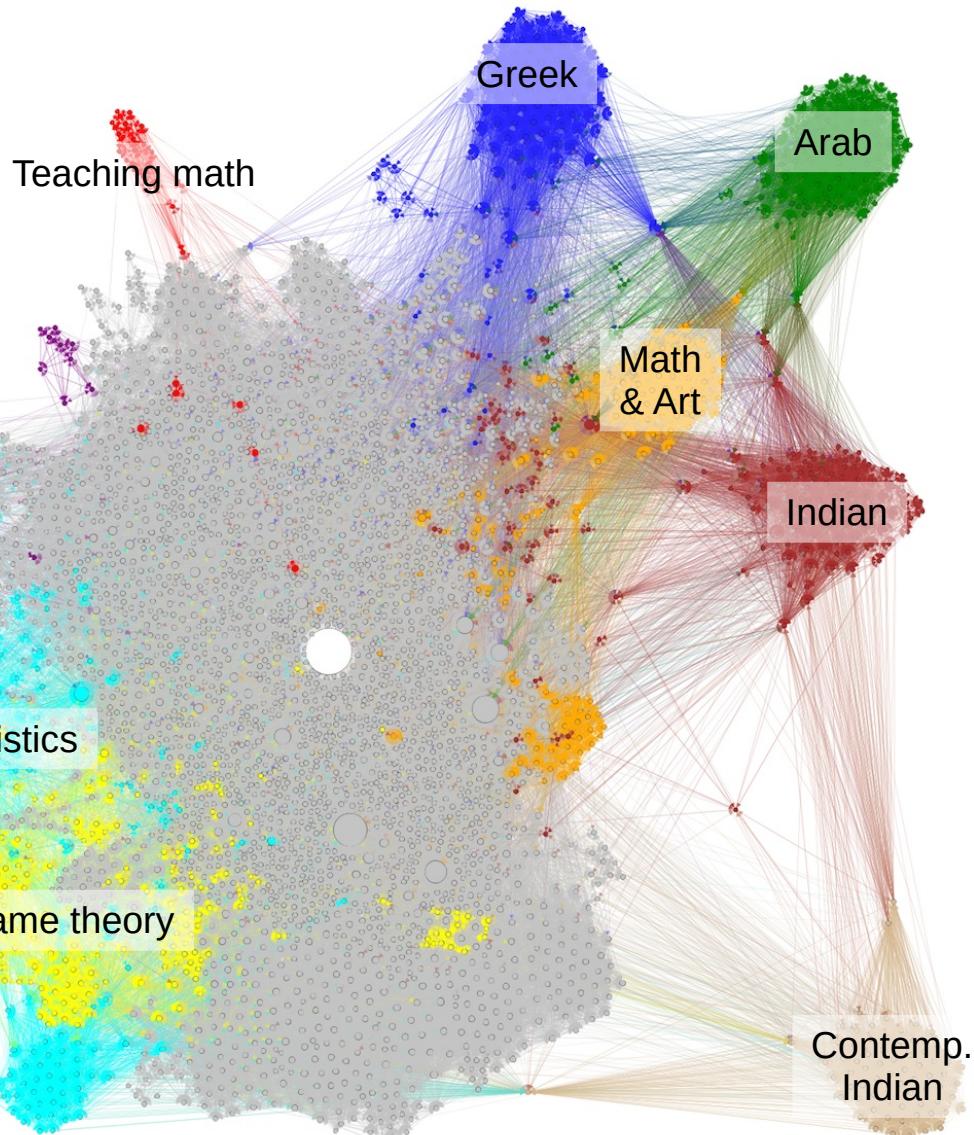
Articles about mathematics

Math software

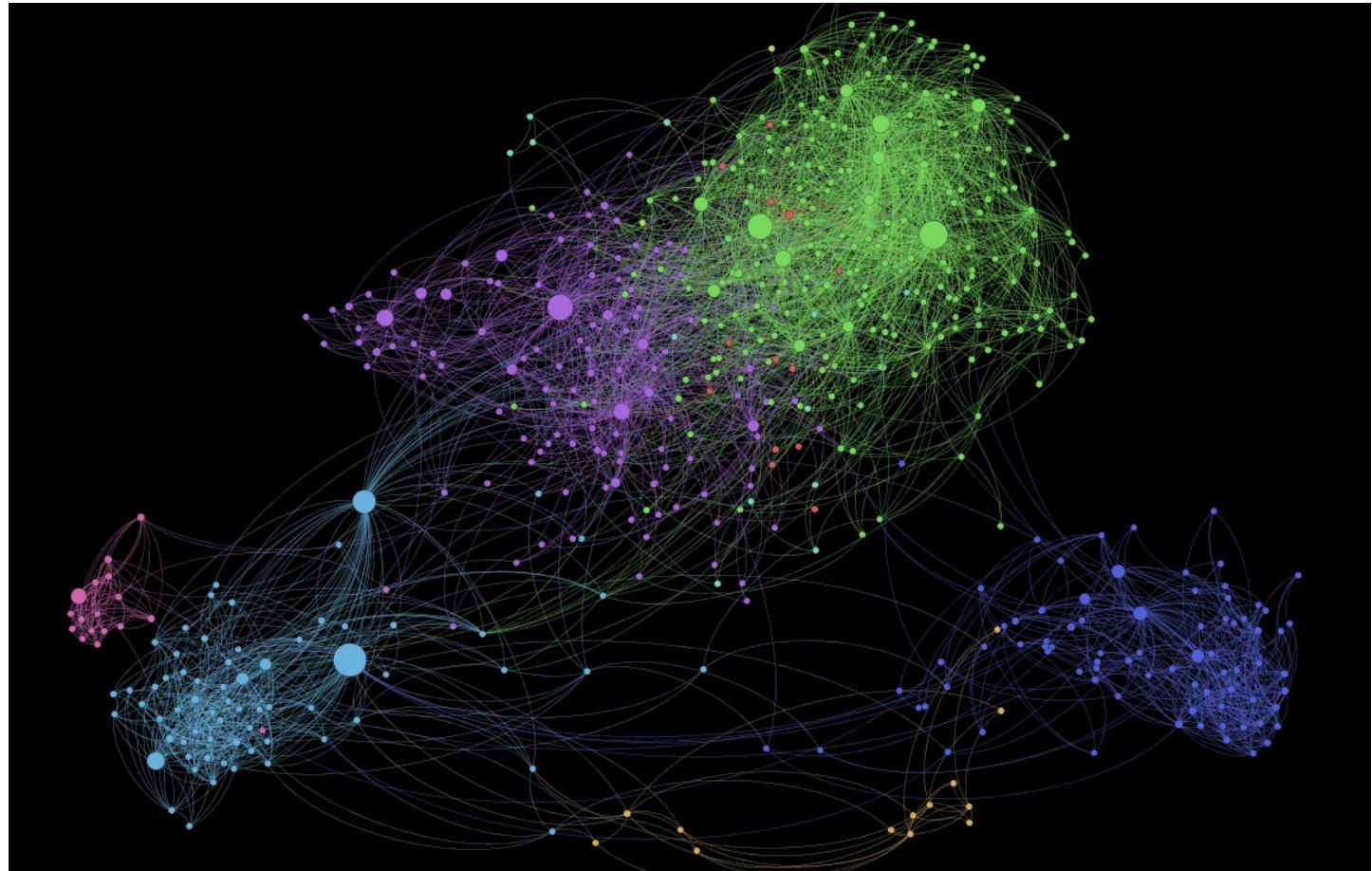
Node = article

Link = link

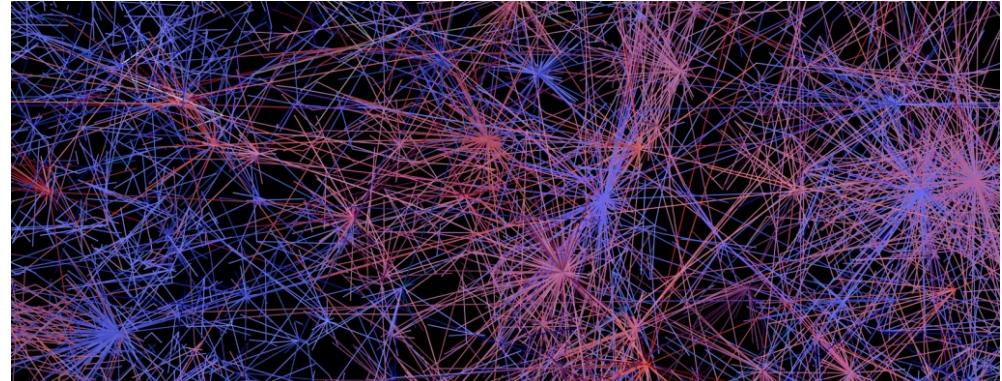
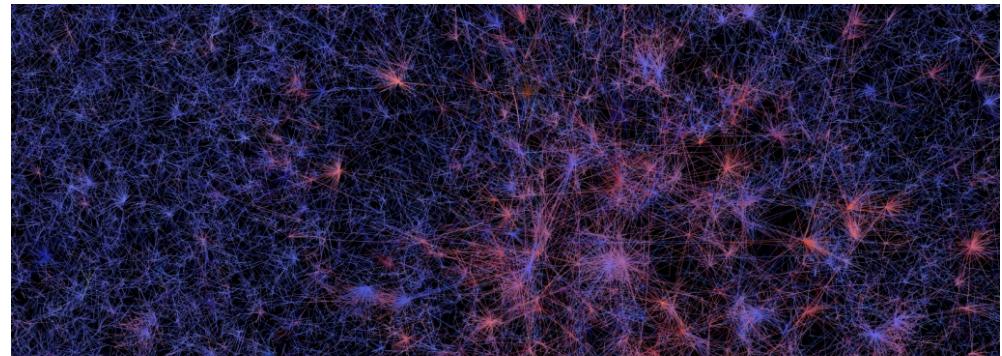
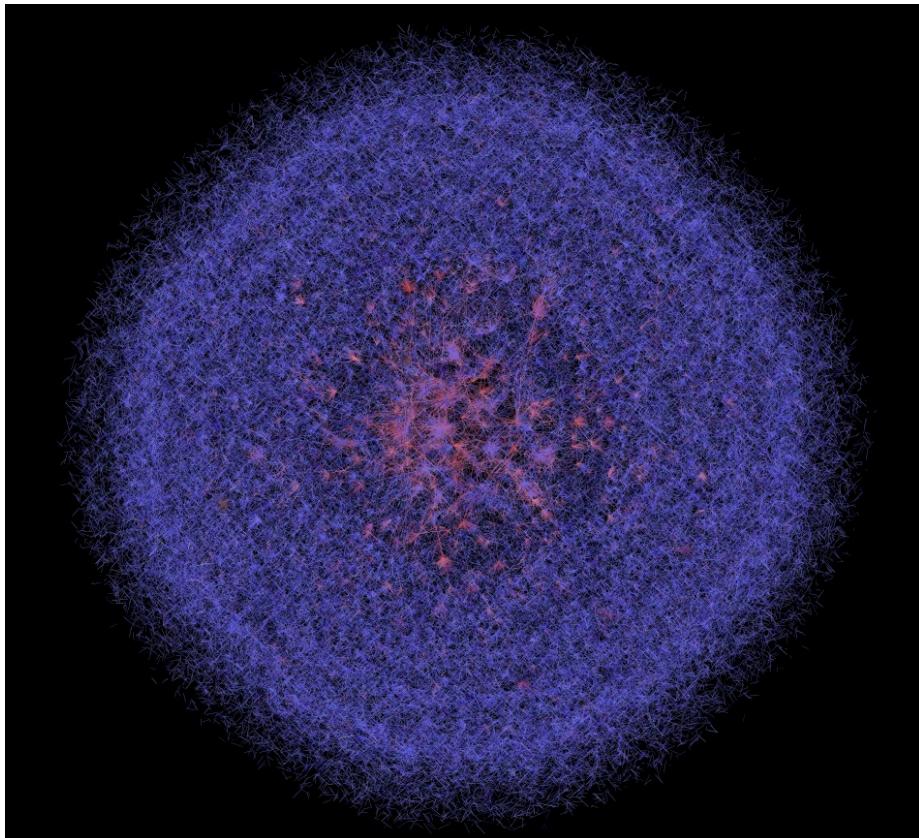
Source: Menczer, Fortunato, David: A First Course on Networks Science. Cambridge, 2020.



1,000 Somali Users of Facebook



400,000 Twitter Users



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

Answer in Nearpod Collaborate
<https://nearpod.com/student/>
Code to be given during class

Things to remember

- Definitions: complex system, complex network
- Examples of complex networks