

Examples of Complex Networks

Introduction to Network Science

Carlos Castillo

Topic 02

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

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

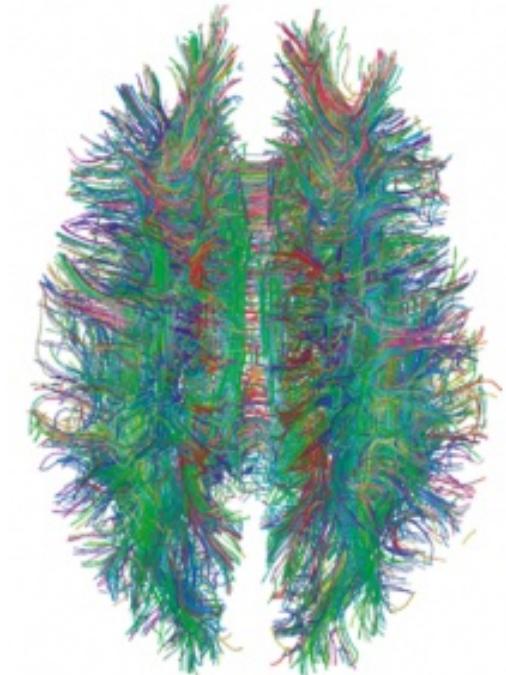
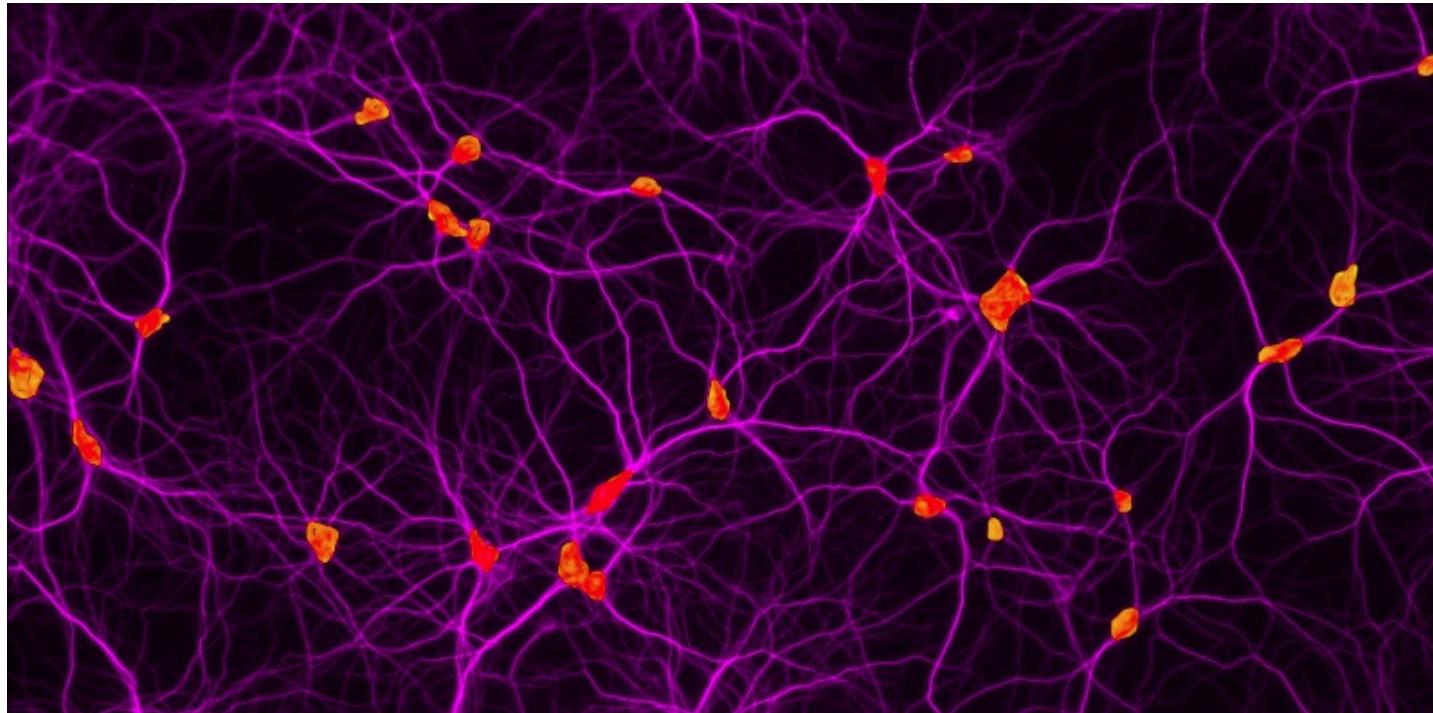
- Many interconnected parts
- Complicated arrangement of connections
- Emerging properties



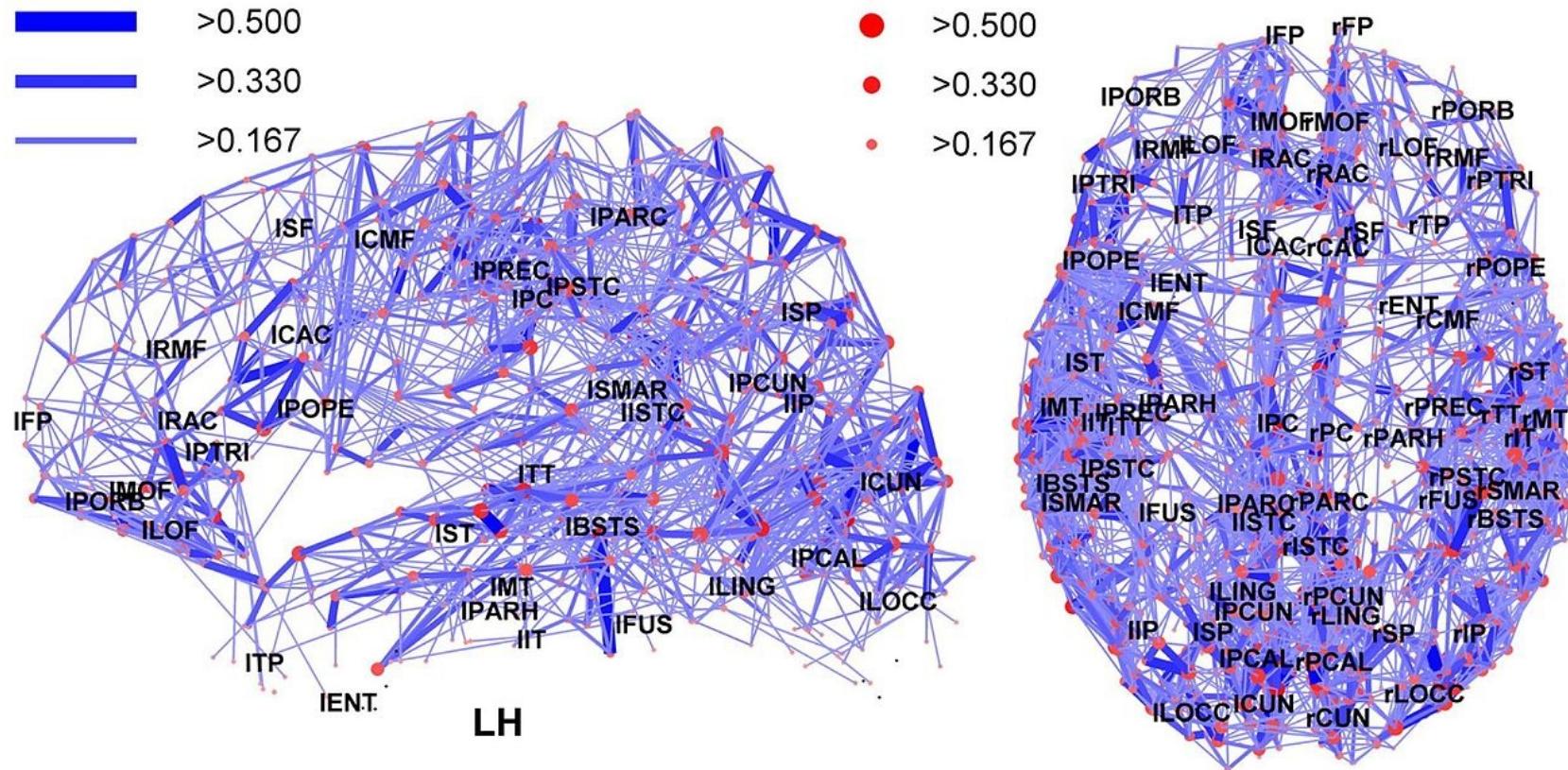
Behind every complex system there is a complex network

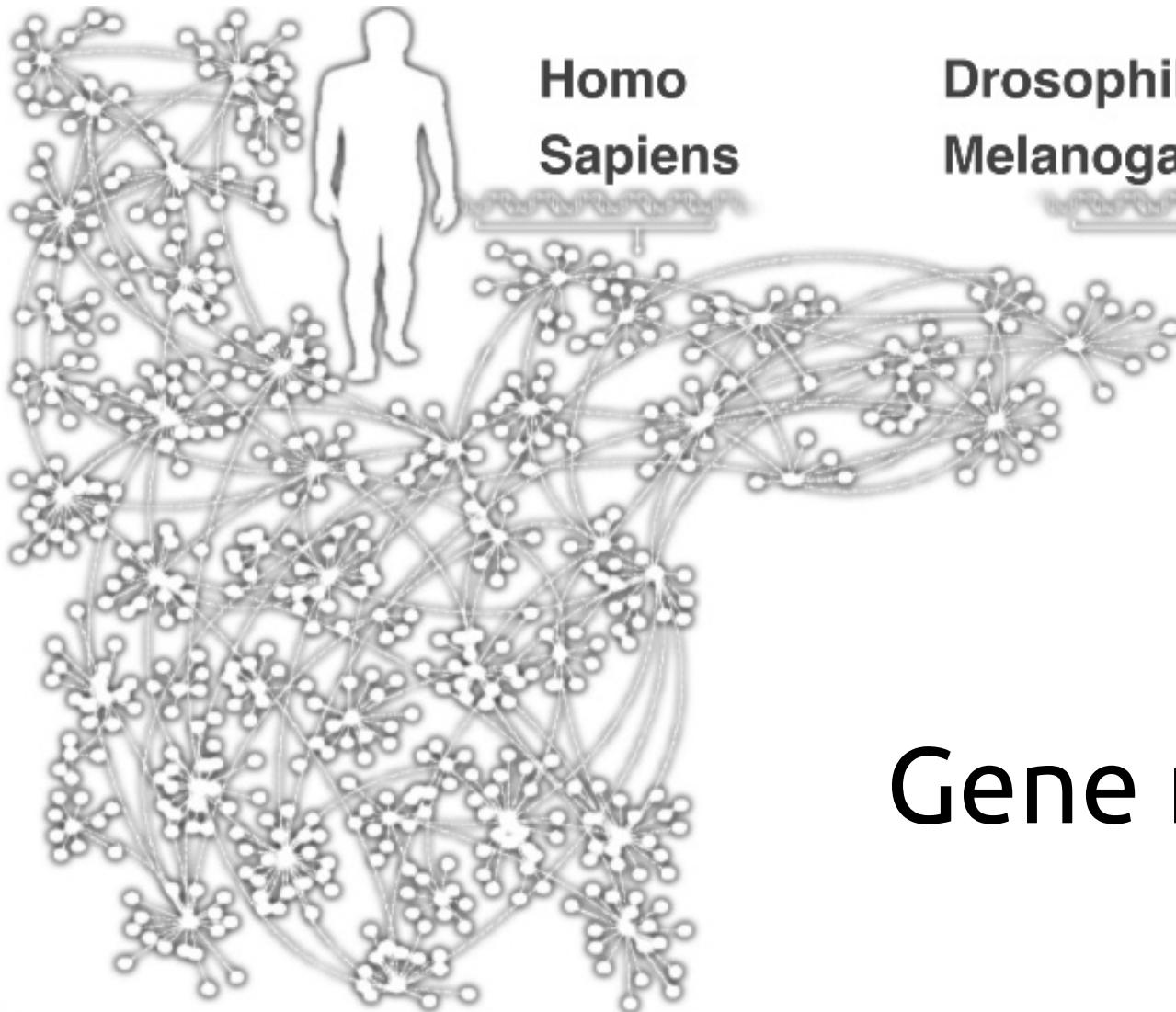
- Connections between neurons in the brain
- Interactions between genes and proteins
- Family/friendship links in human and non-human animals
- Infrastructure of telecommunications, electricity
- Commerce/trade networks

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



Regions in the human brain





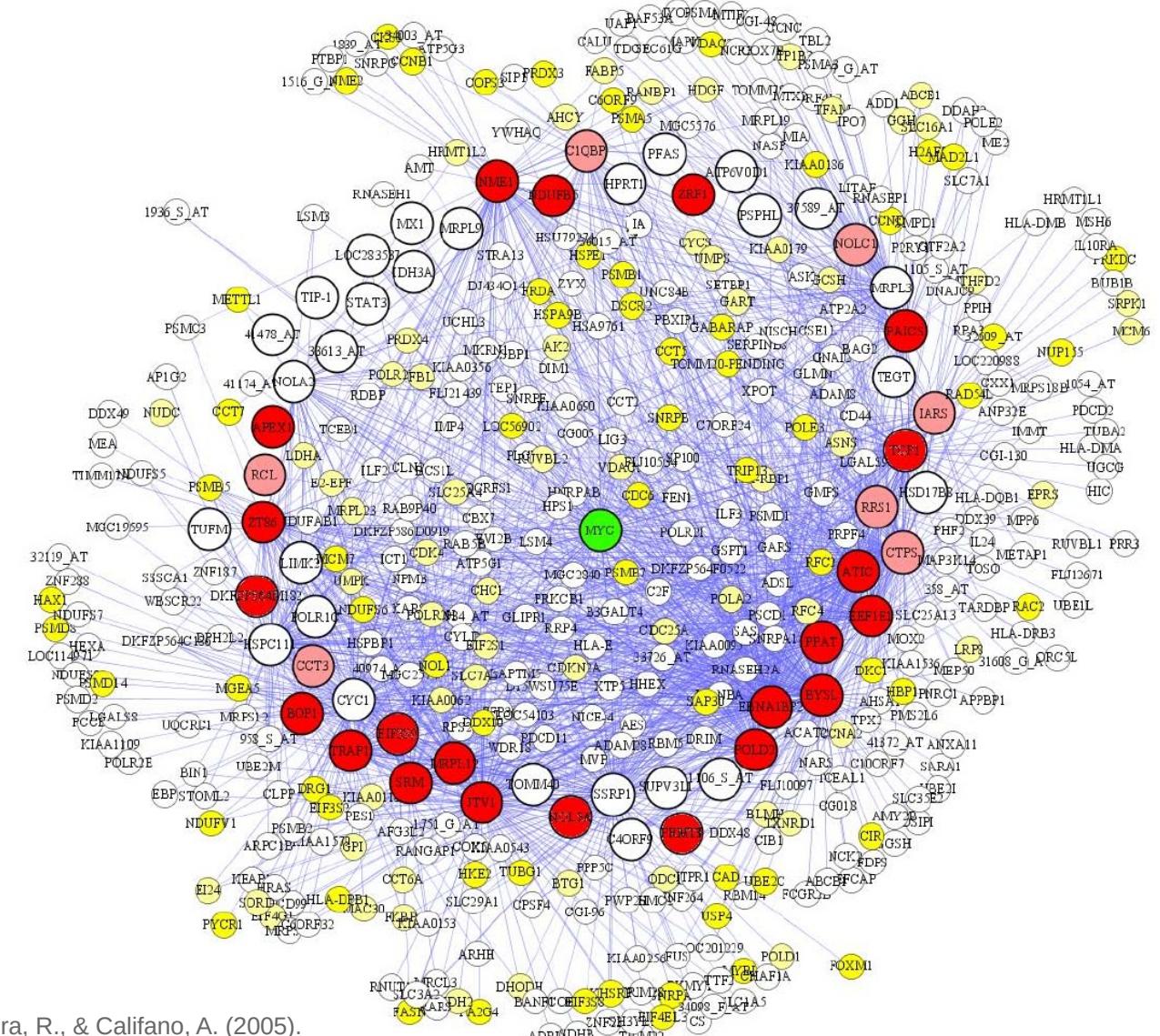
**Drosophila
Melanogaster**



Gene networks

Co-expression of Genes

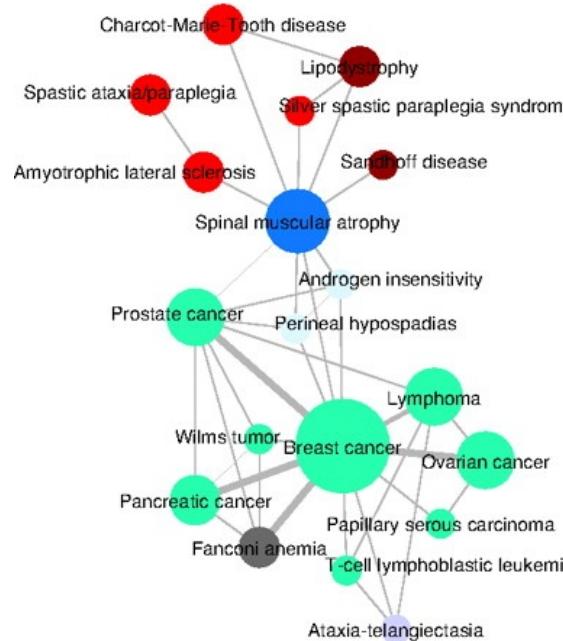
|V|=500 in this plot



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 paraplegia syndrome

Spastic ataxia/paraparesis

Fanconi anemia

disease genome

AR

ATM

BRCA1

BRCA2

CDH1

GARS

HEXB

KRAS

LMNA

MSH2

PIK3CA

TP53

MAD1L1

RAD54L

VAPB

CHEK2

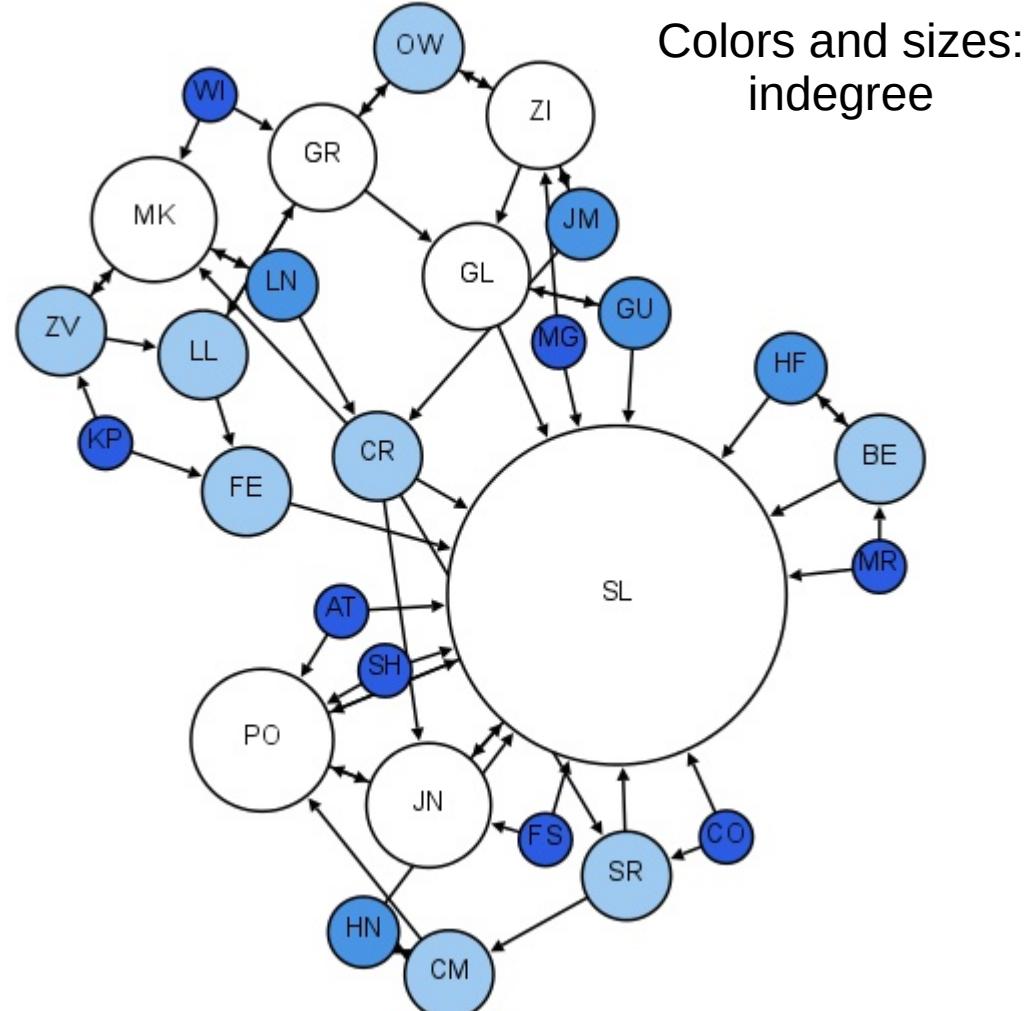
BSCL2

ALS2

BRIP1

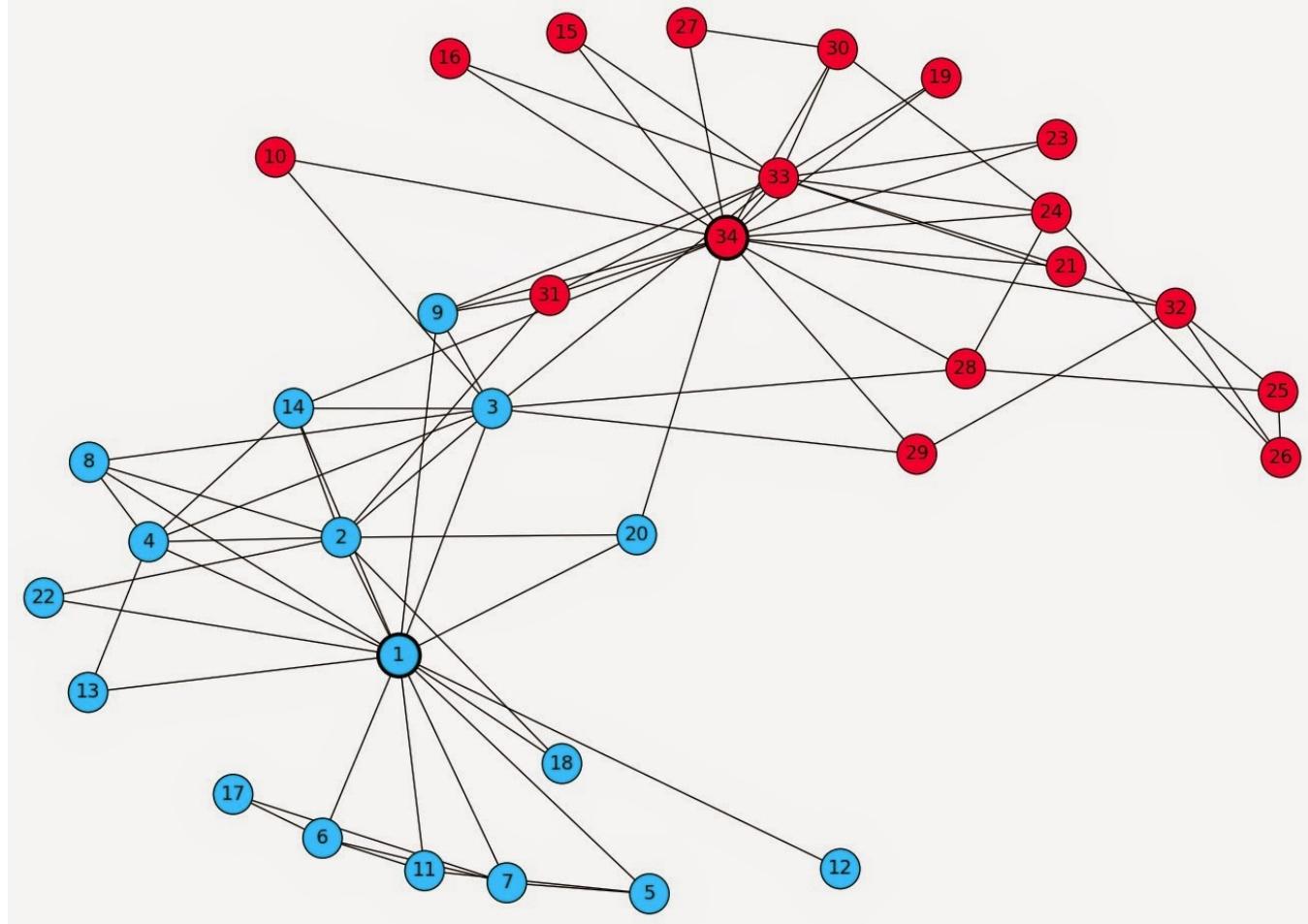
Moreno's sociograms

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



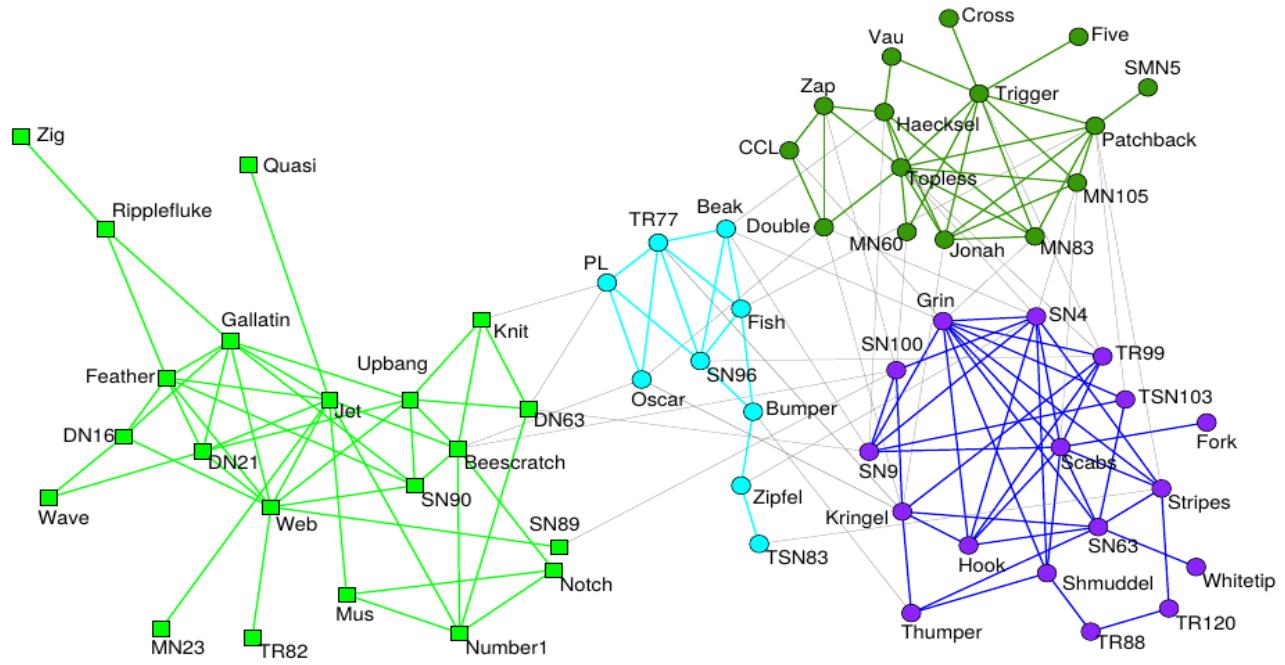
Zachary's Karate Club

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)



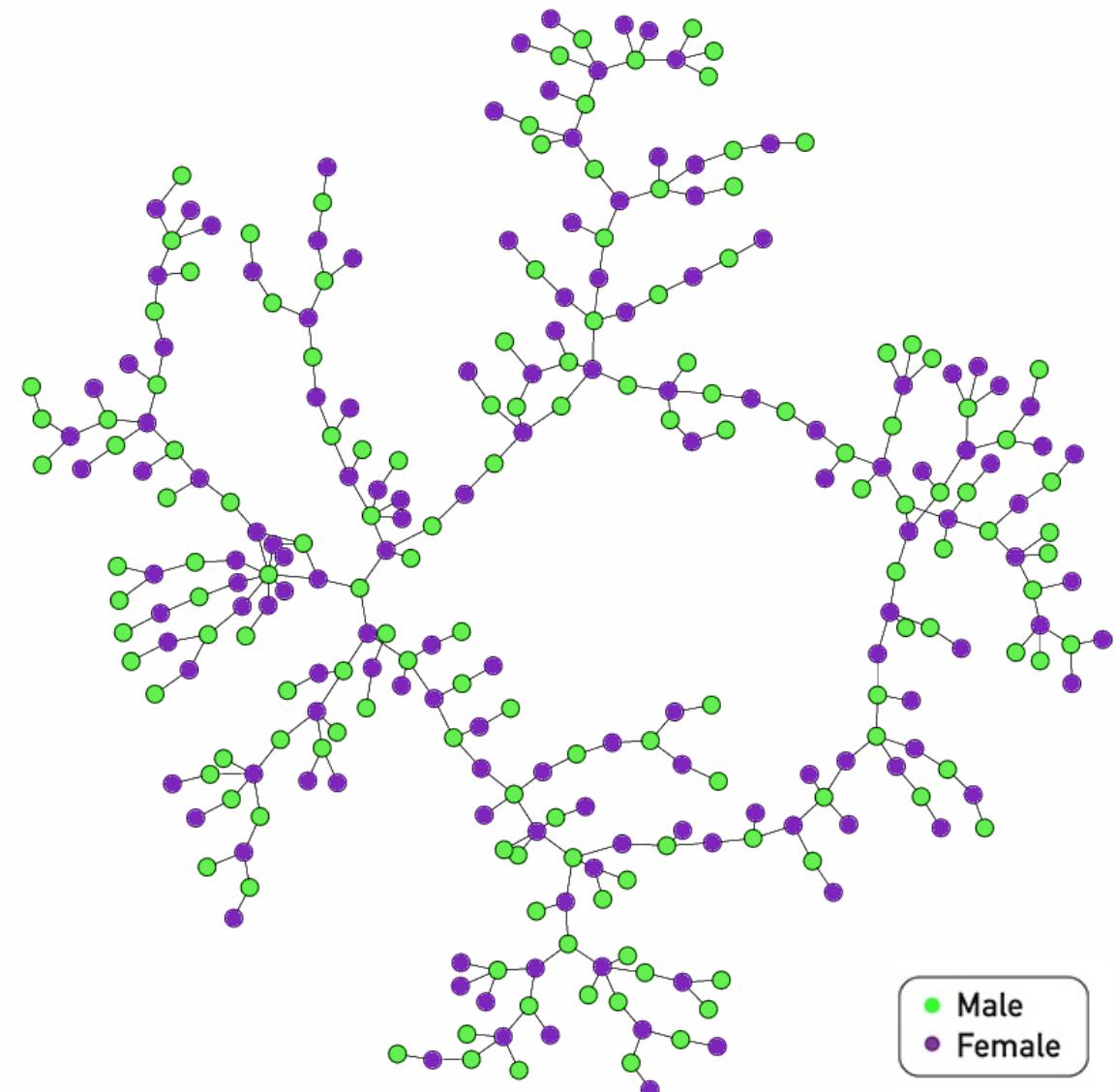
<https://doi.org/10.1007/s00265-003-0651-y>

I really like dolphins

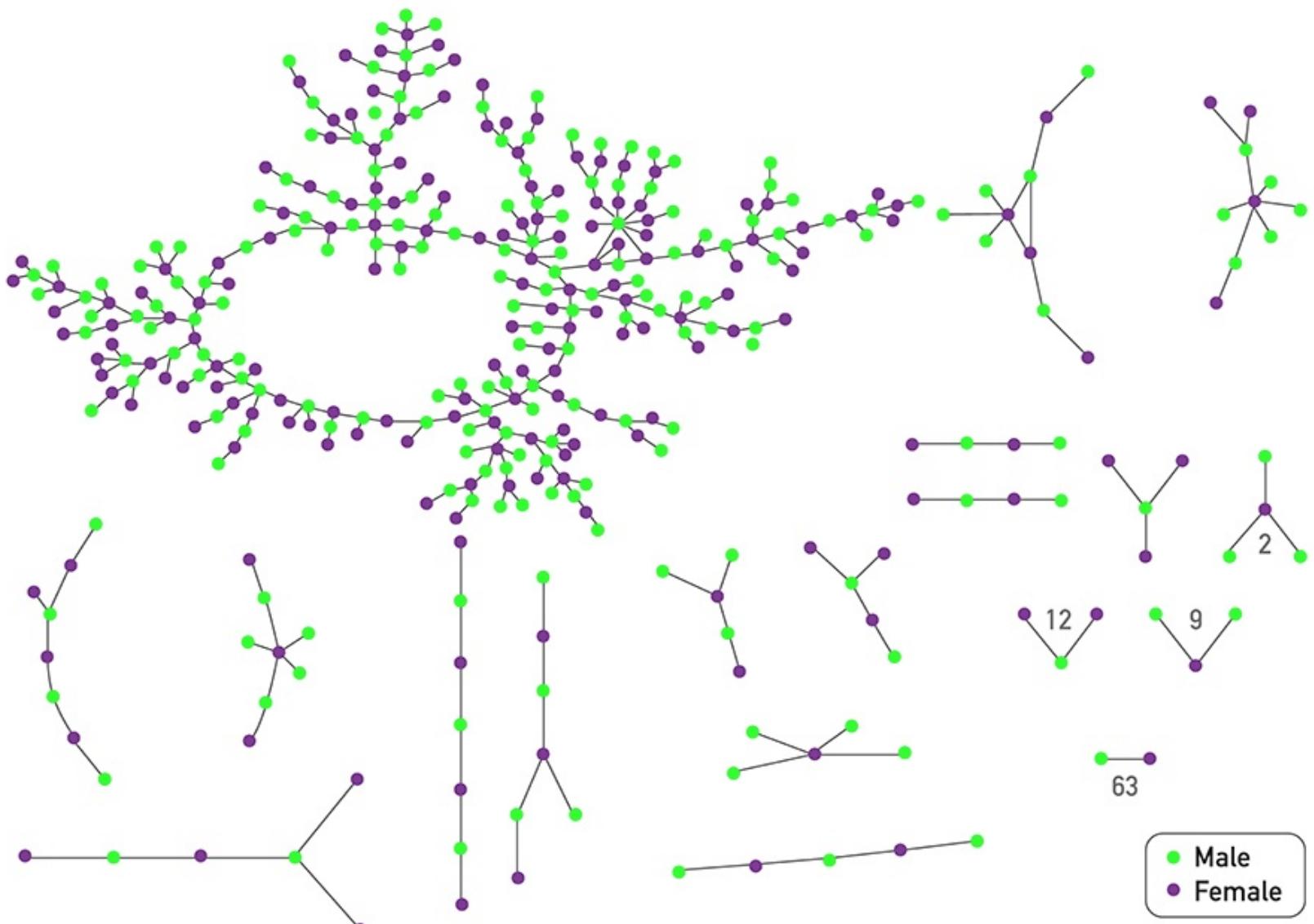


Chains of affection

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

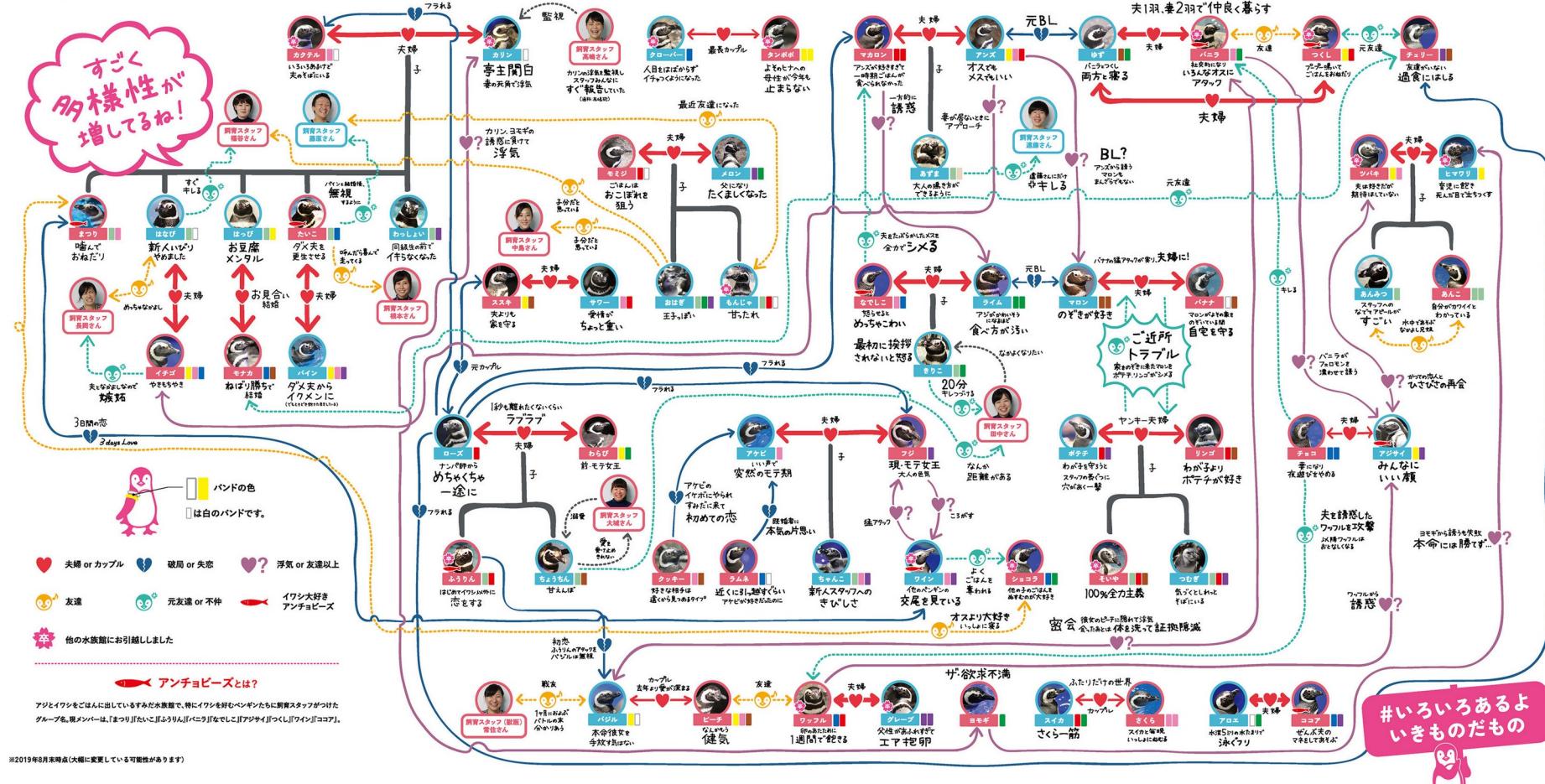


Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American journal of sociology, 110(1), 44-91.



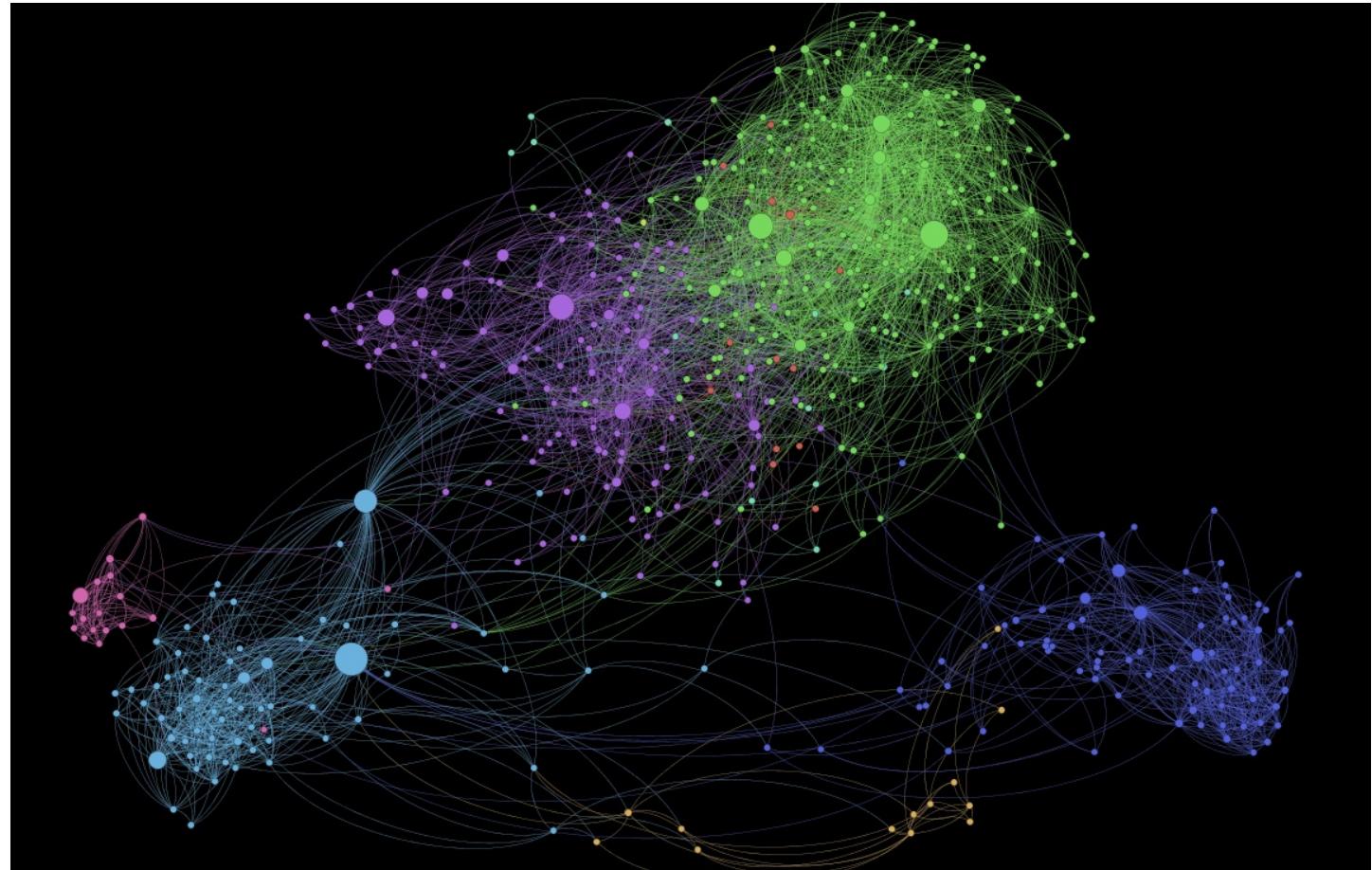
~~もっと!~~
かわいい!
たのしい!
ややこしい

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

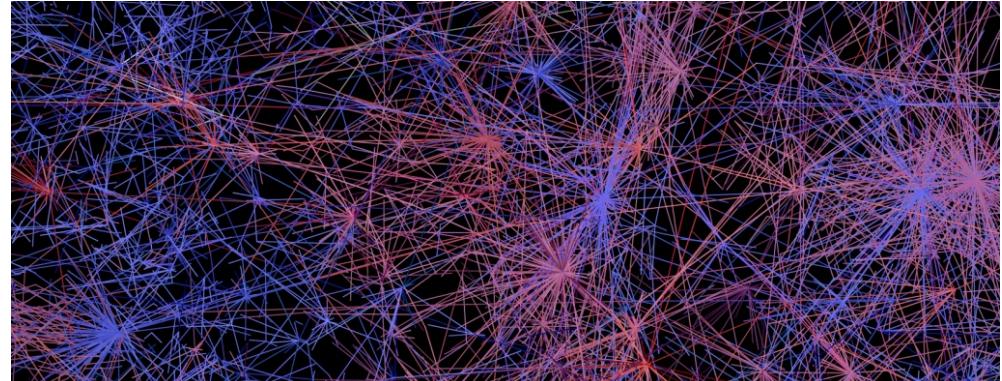
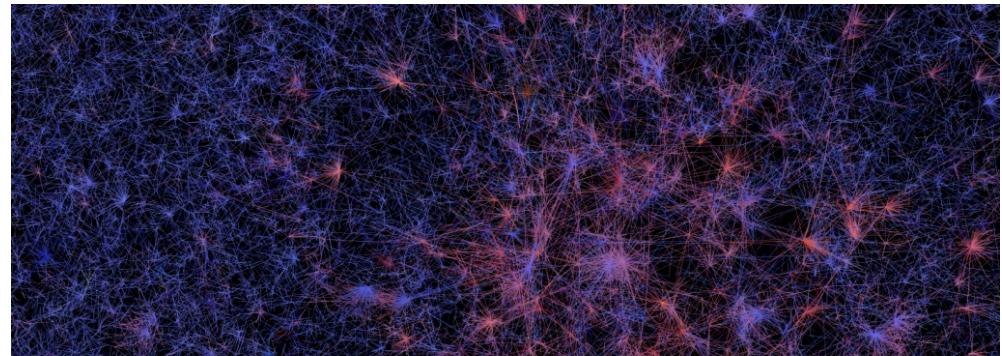
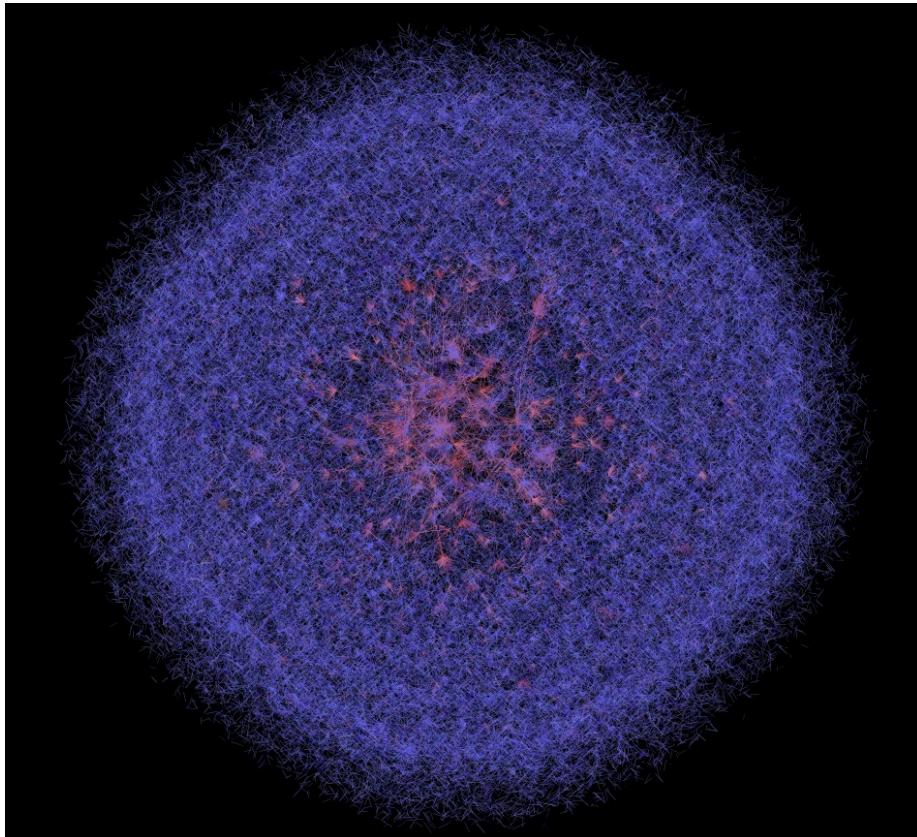


Complex relationships between penguins
Image: <https://www.sumida-aquarium.com/>

1,000 Somali Users of Facebook



400,000 Twitter Users



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