

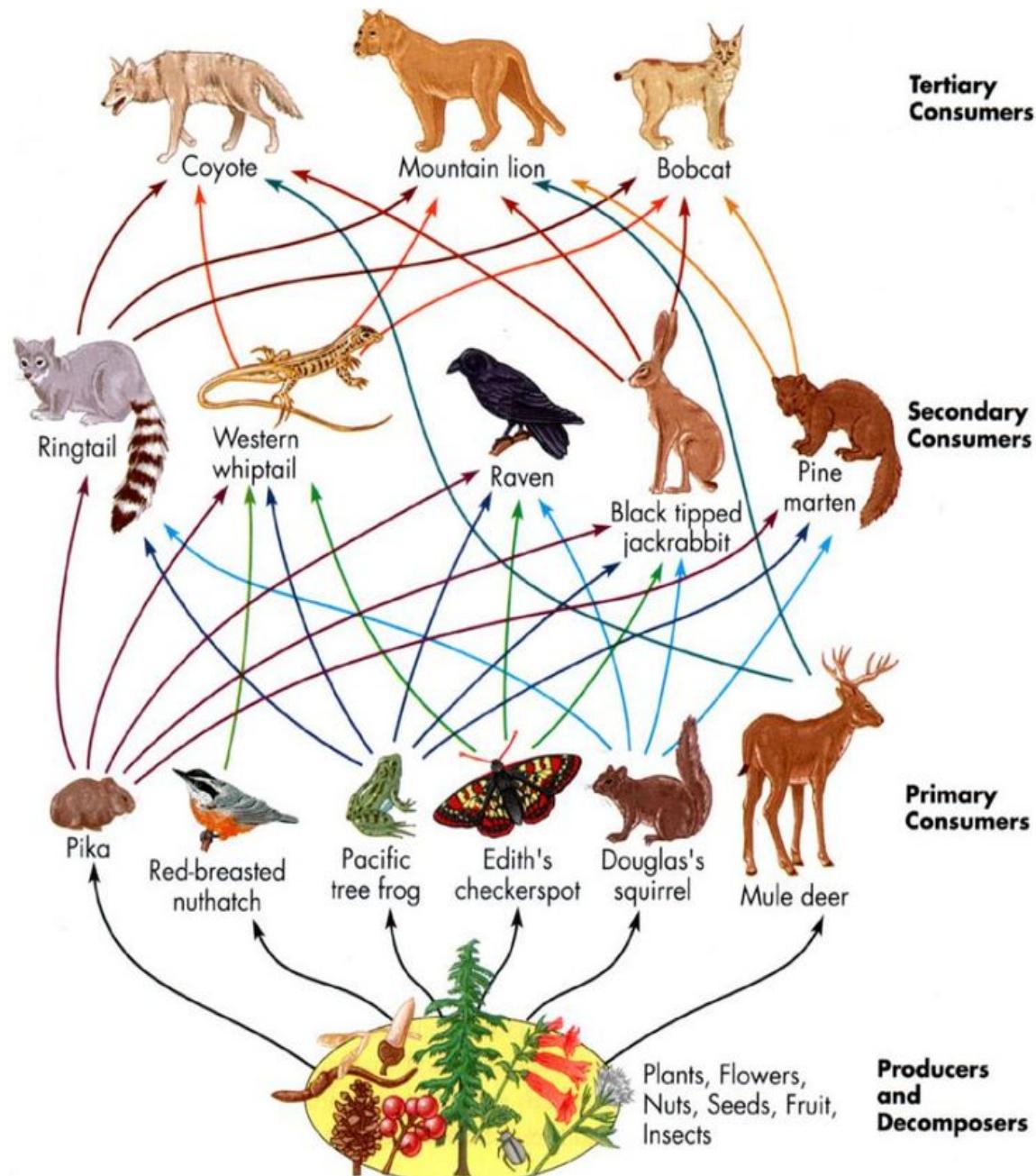


Network theory: 2

Liubov Tupikina (CRI)

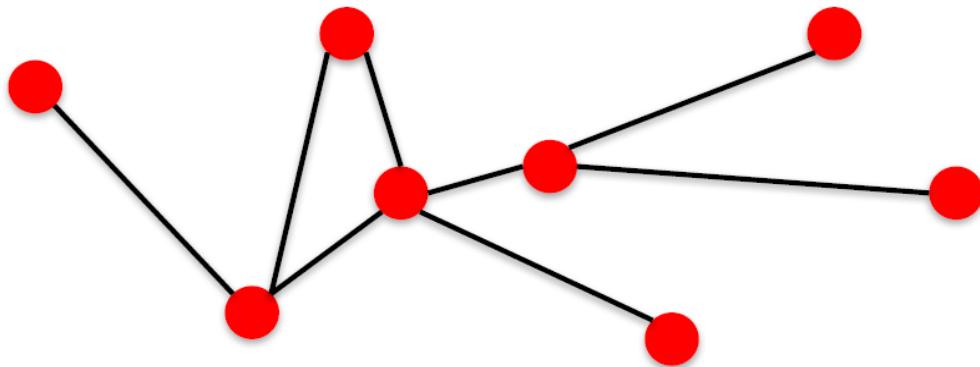
Networks are everywhere.

Do you have any examples of networks?

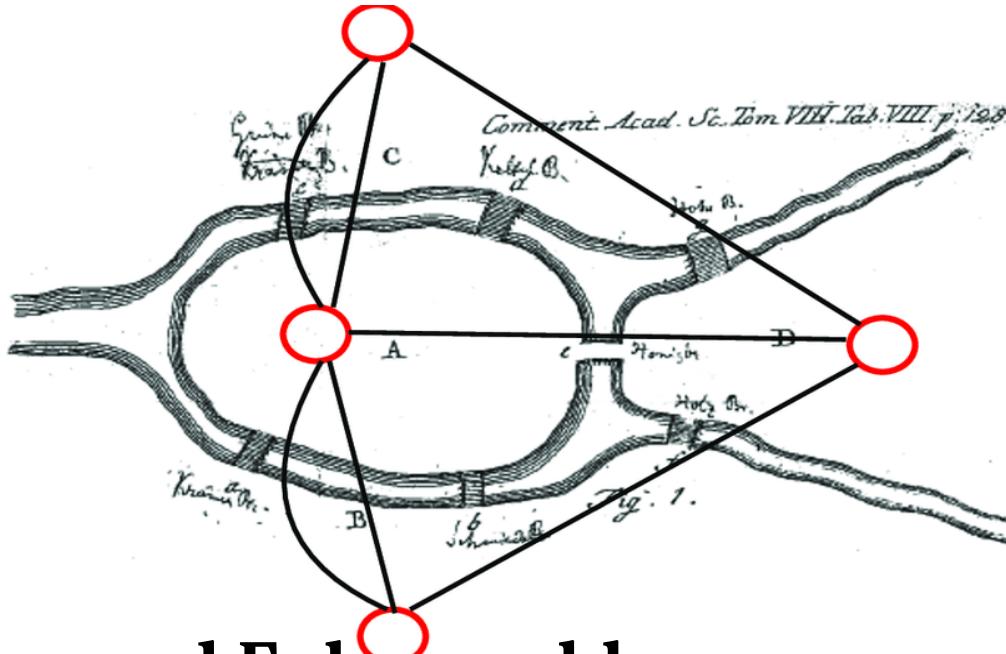


References included in the last slide

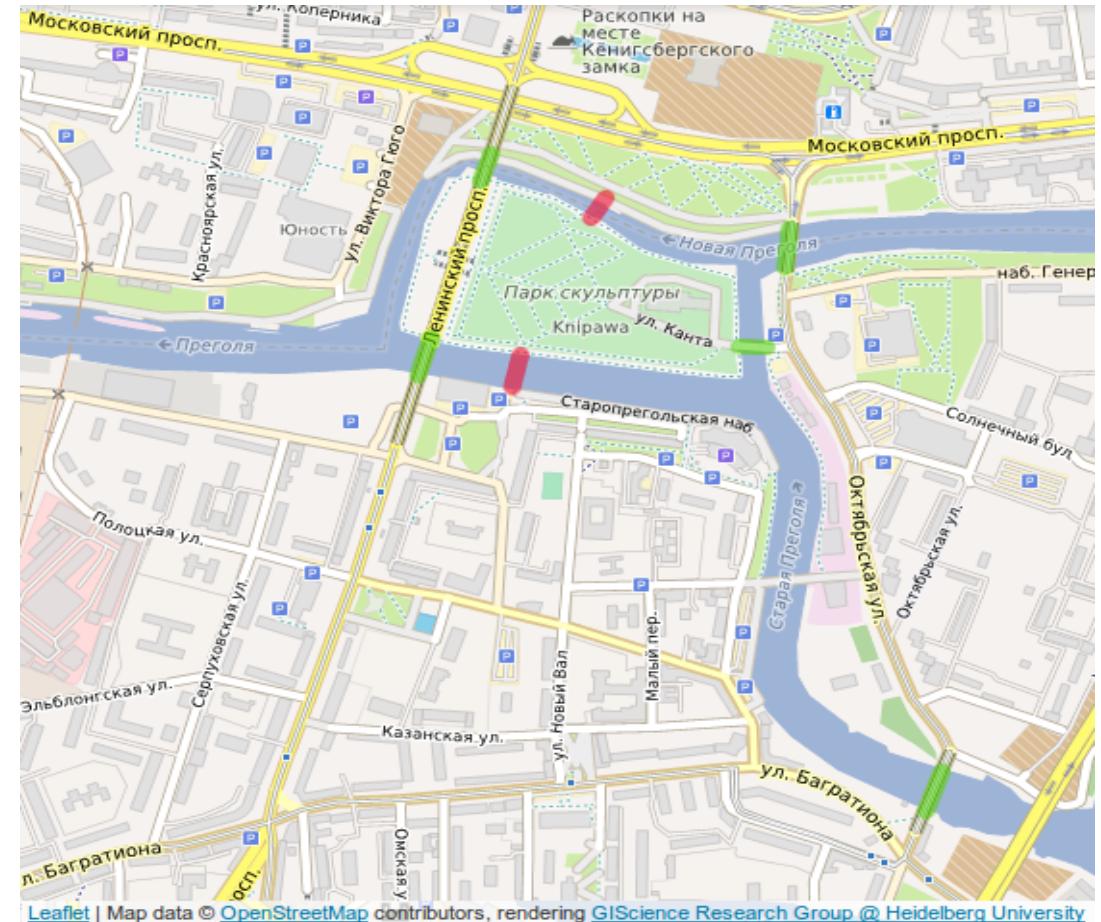
What is a network?



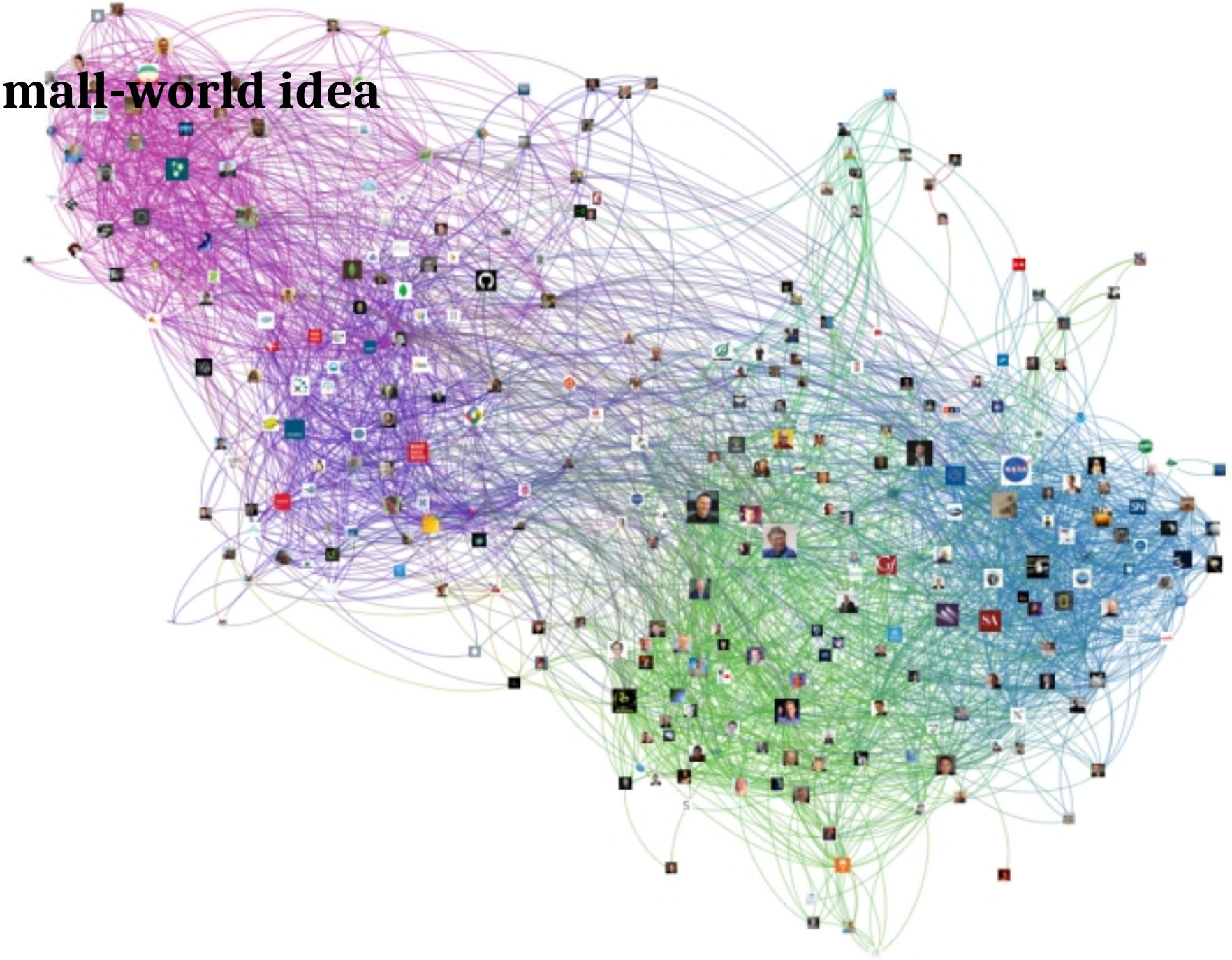
- **components:** nodes, vertices N
- **interactions:** links, edges L
- **system:** network, graph (N,L)



Leonard Euler problem about bridges



Watts-Strogarz small-world idea
Social media
Twitter
Facebook



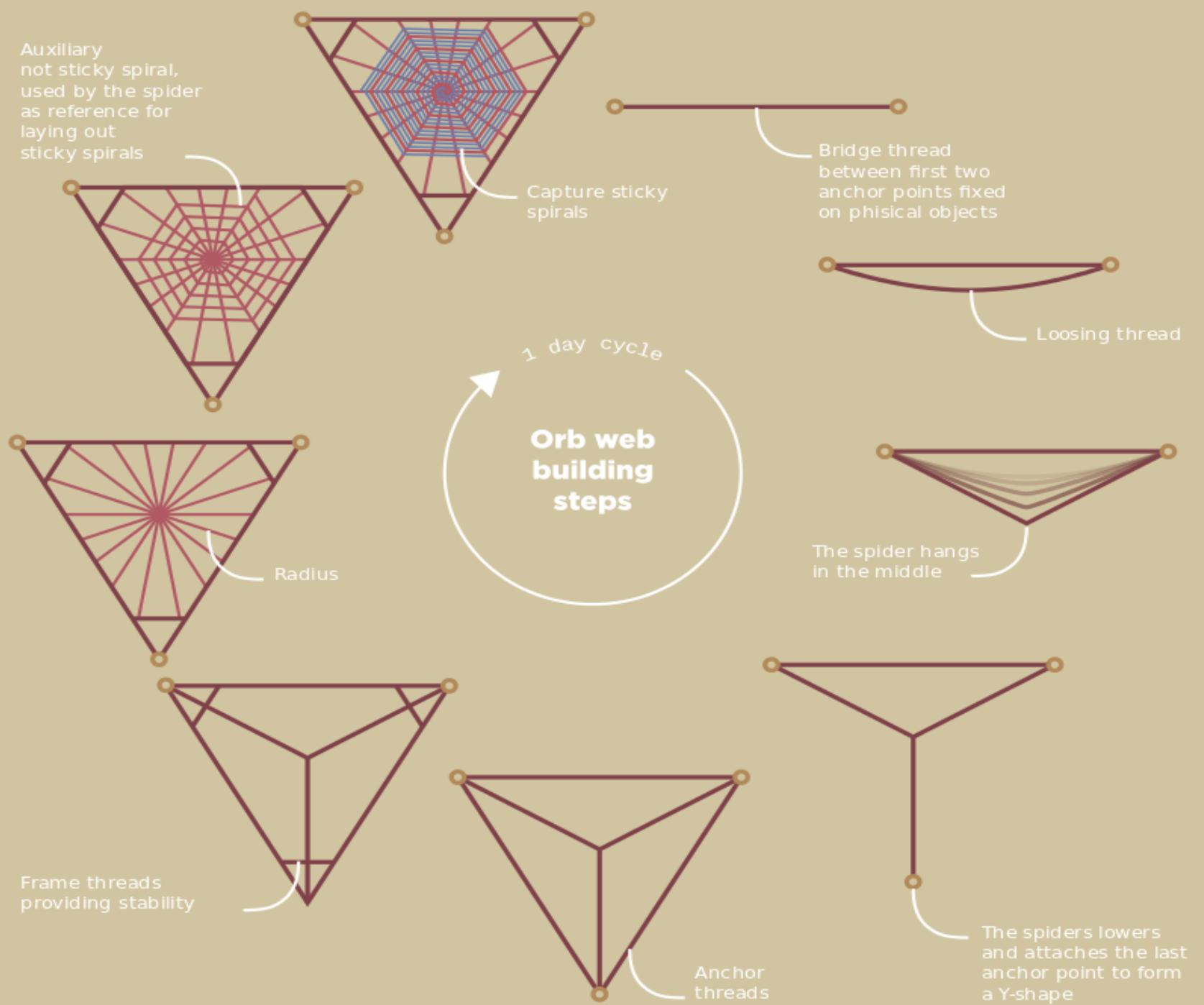


Moovellab





Silk types and properties



Major-ampullate silk

Structural and drag line silk

High tensile strength,
low extensibility,
high loss tangent,
exhibits super contraction
when wetted, higher
hysteresis

Minor-ampullate silk

Auxiliary spiral

High modulus and
extensibility, moderate
tensile strength
and toughness

Capture silk

Capture core threads

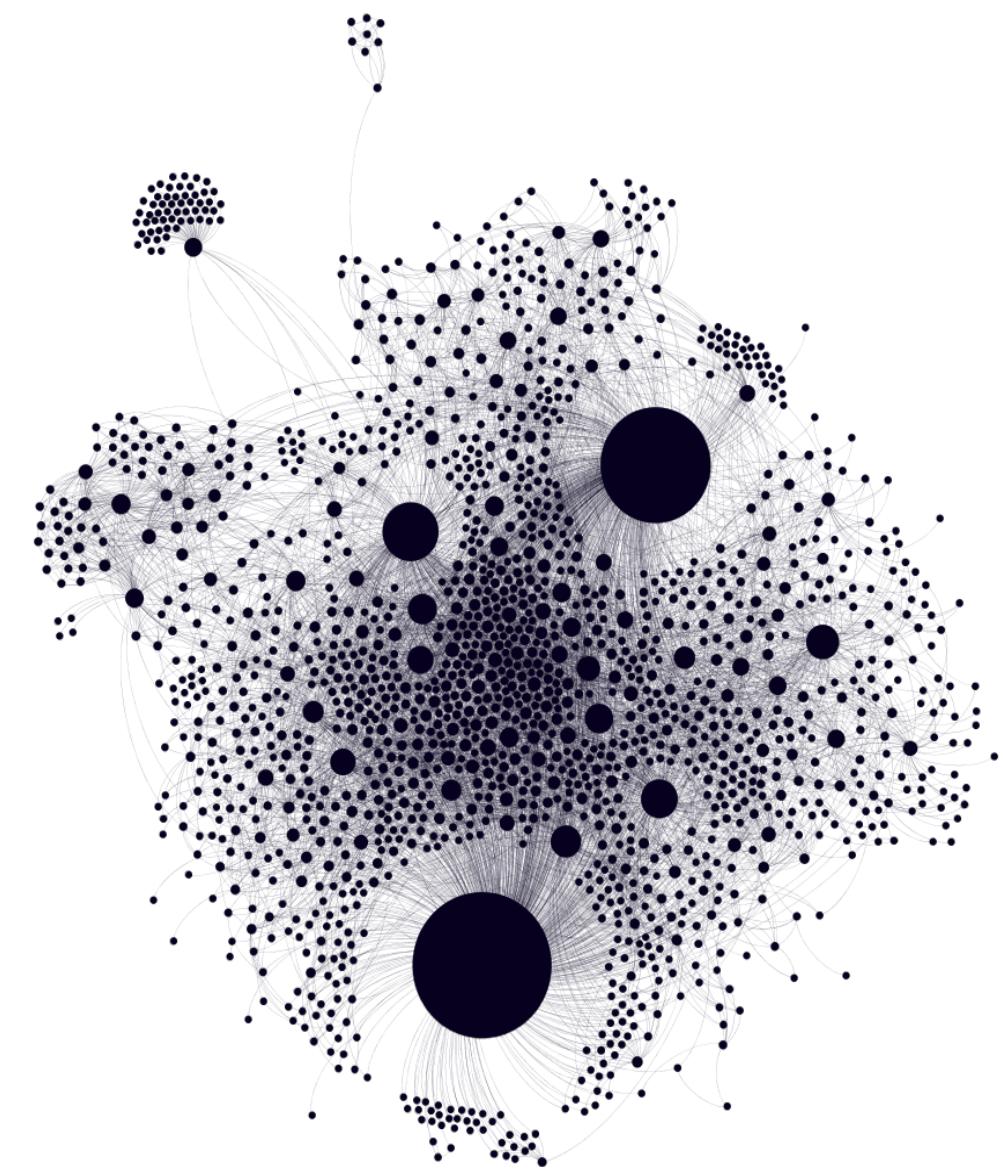
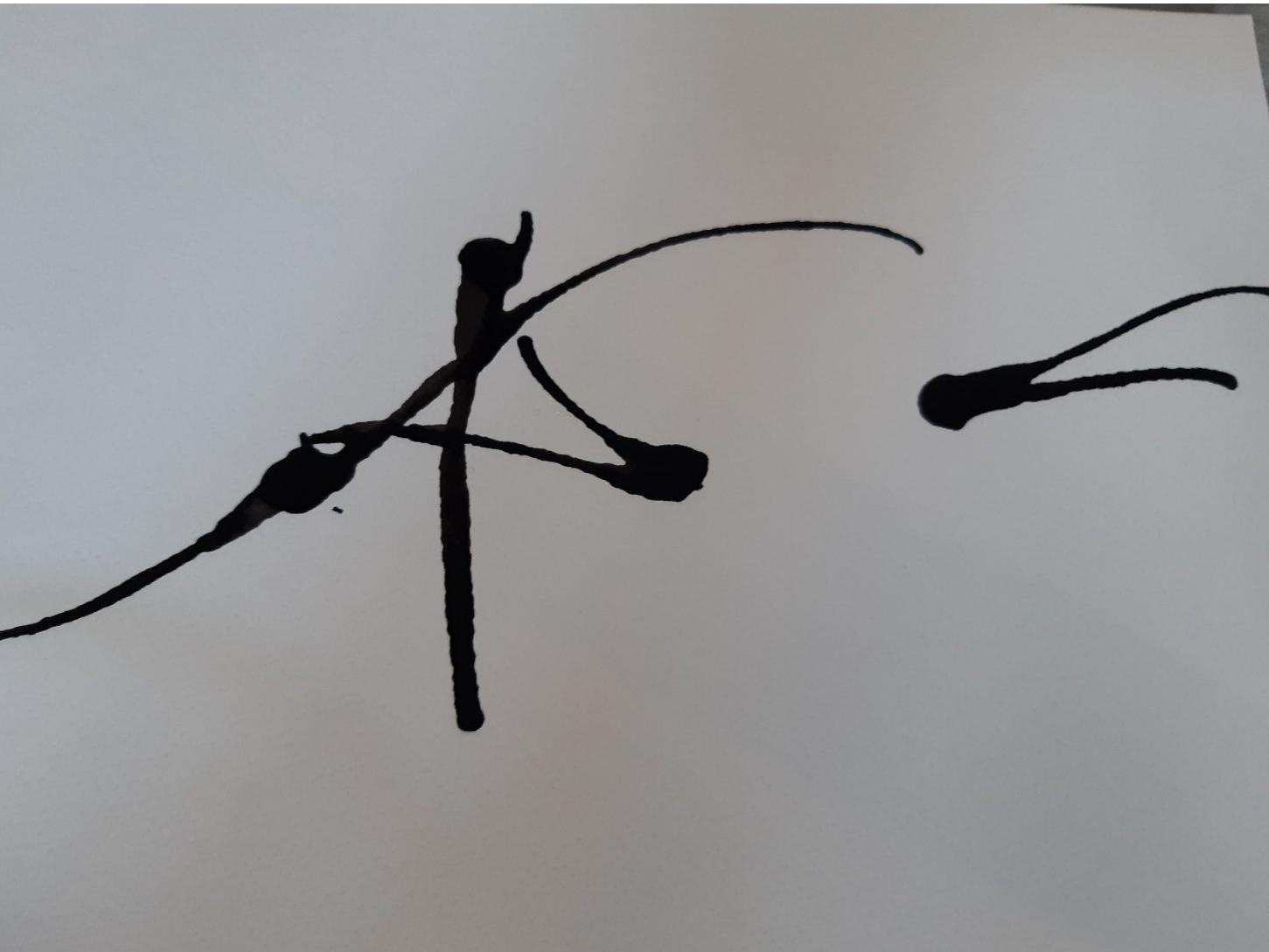
Extremely extensible
and resilient, highly
compliant, glue-coated wet
fiber



Piriform silk

Attachment cement

Low extensibility and high
toughness



If you have questions?

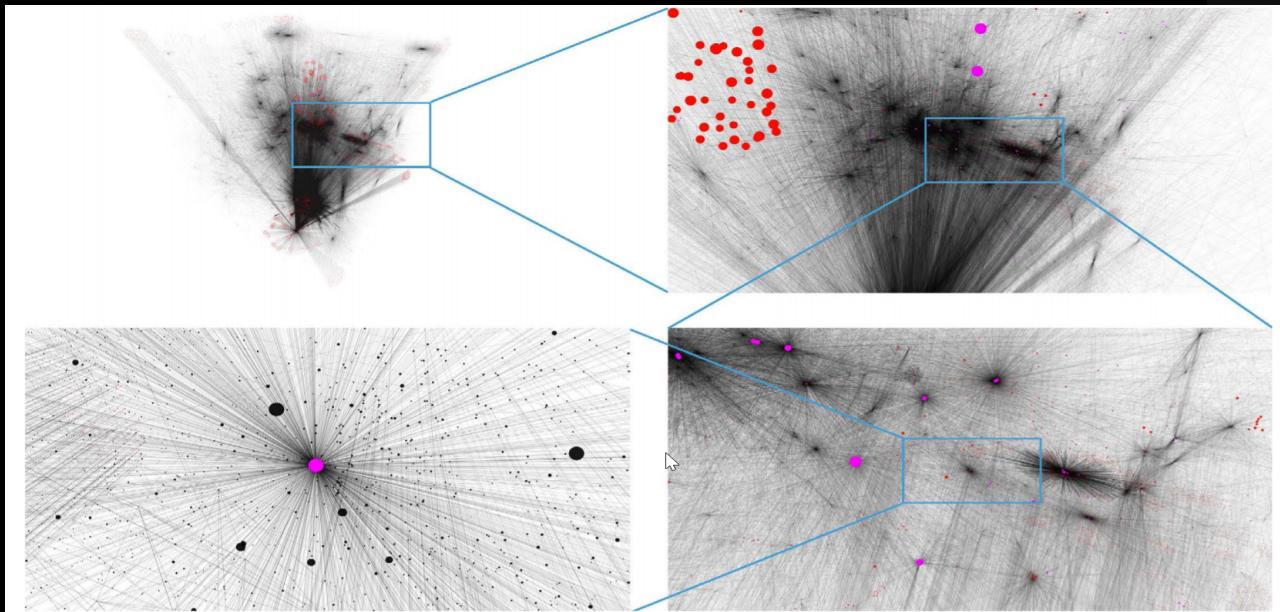
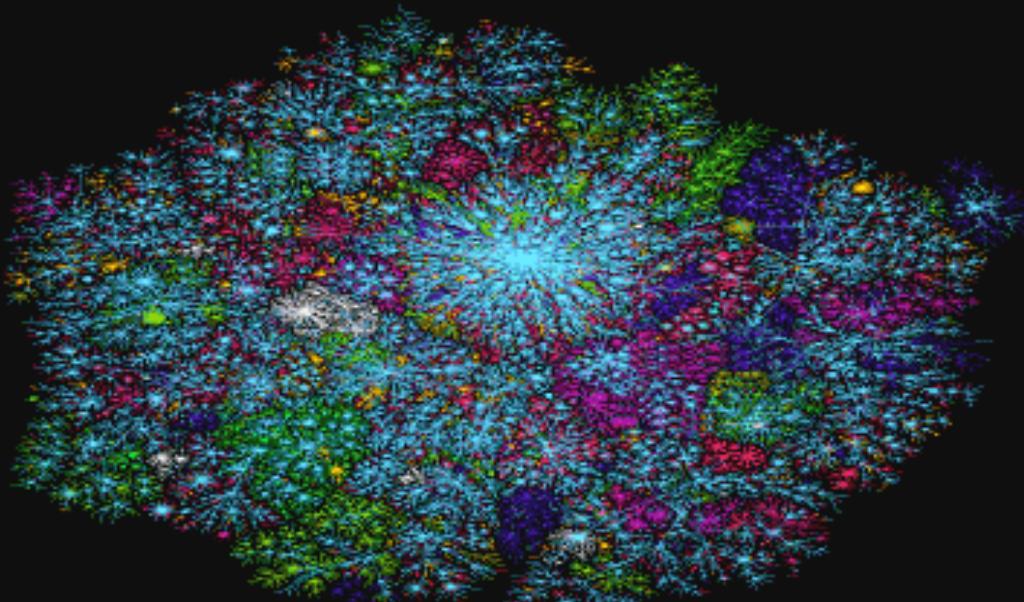
My email liubov.tupikina@cri-paris.org
Twitter @luyibov

<http://networksciencebook.com/>

<http://networkrepository.com/graph-vis.php>

<http://www.complexity-explorables.org/explorables/neighbors/>

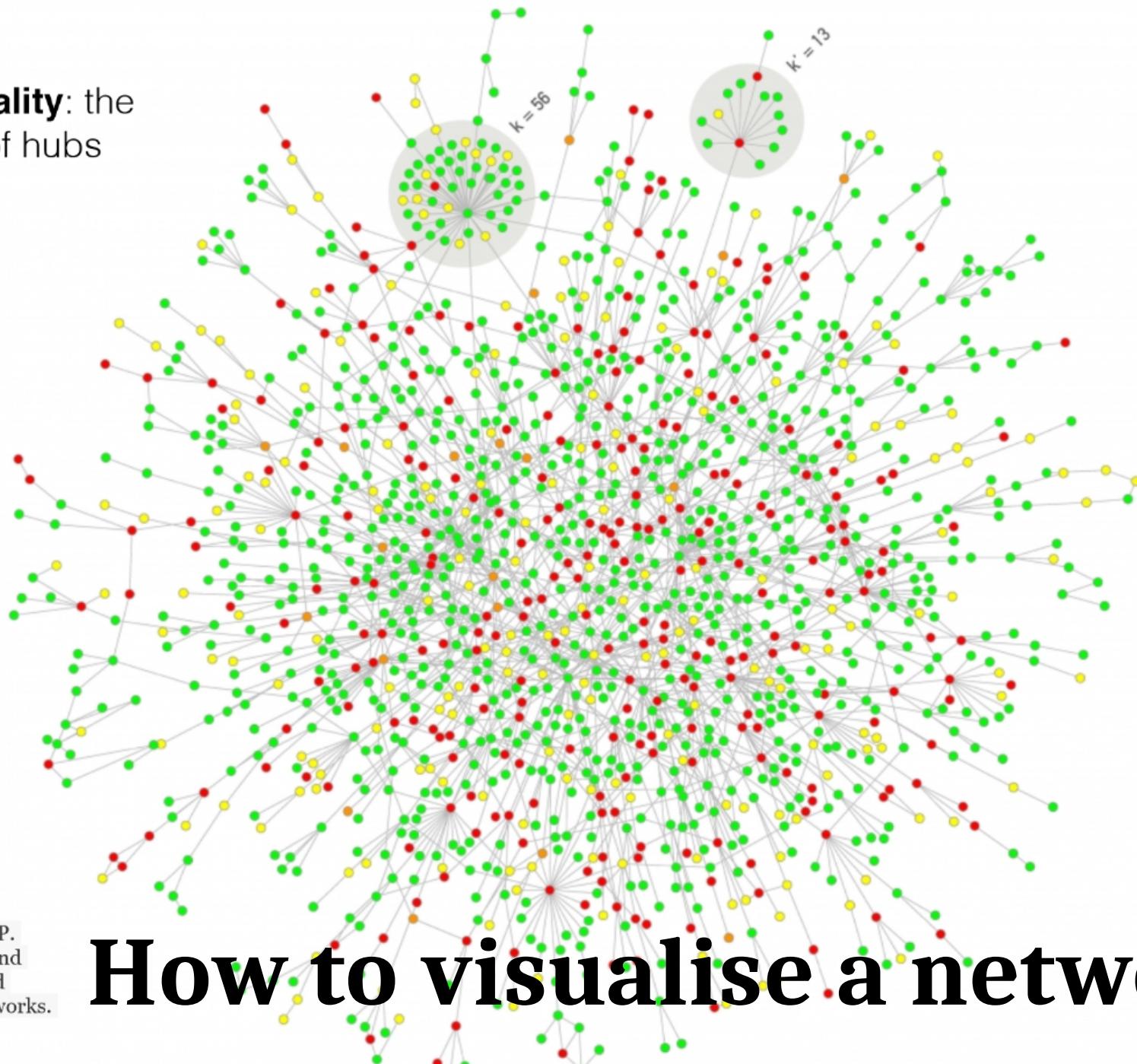
THE WHOLE INTERNET



<https://snap.stanford.edu/data>

<https://sites.google.com/a/binghamton.edu/netscied/teaching-learning/network-concepts>

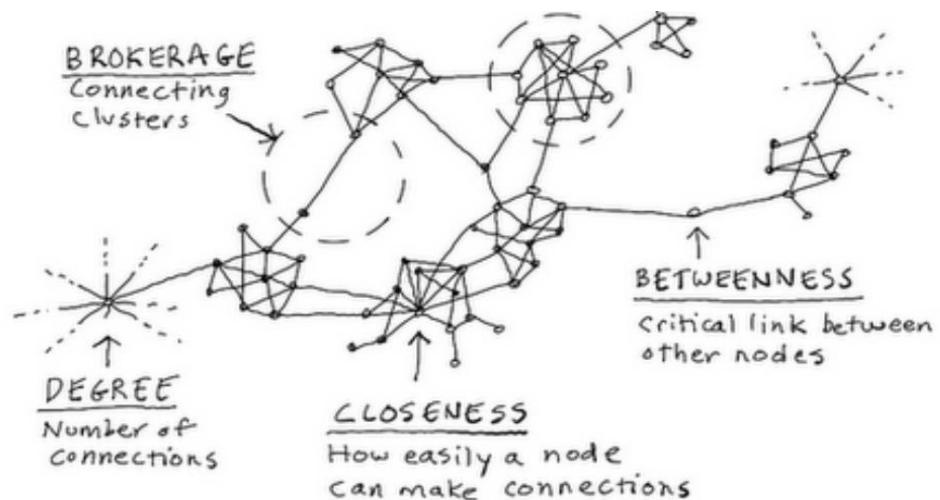
centrality-lethality: the importance of hubs



How to visualise a network?

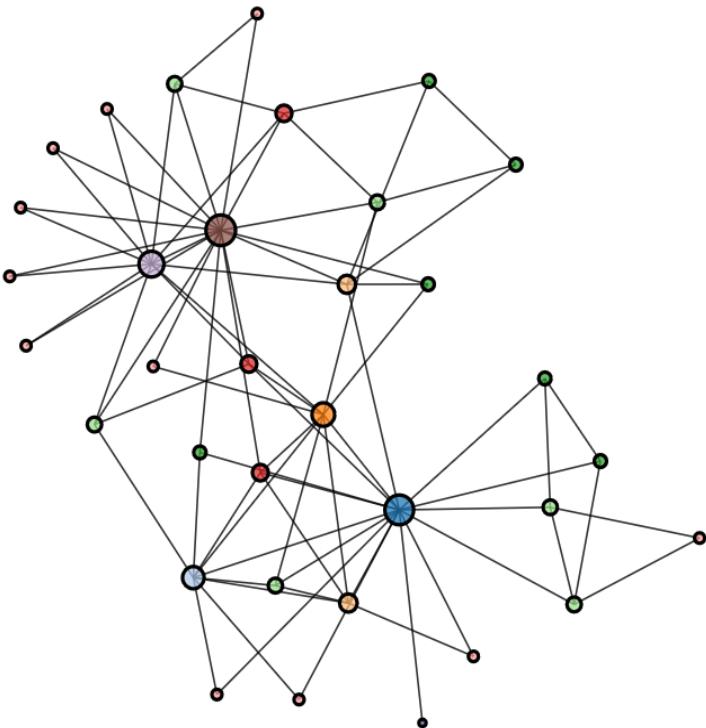
H. Jeong, B. Tombor, S. P.
Mason, A.-L. Barabási, and
Z.N. Oltvai. Lethality and
centrality in protein networks.
Nature 411: 41-42, 2001.

Network measures: How to describe a network?



How to describe a real network?

What is degree distribution of larger network? (Liuba-hands on session)
How to visualise a network in a nice way? (Marc- visualisation)

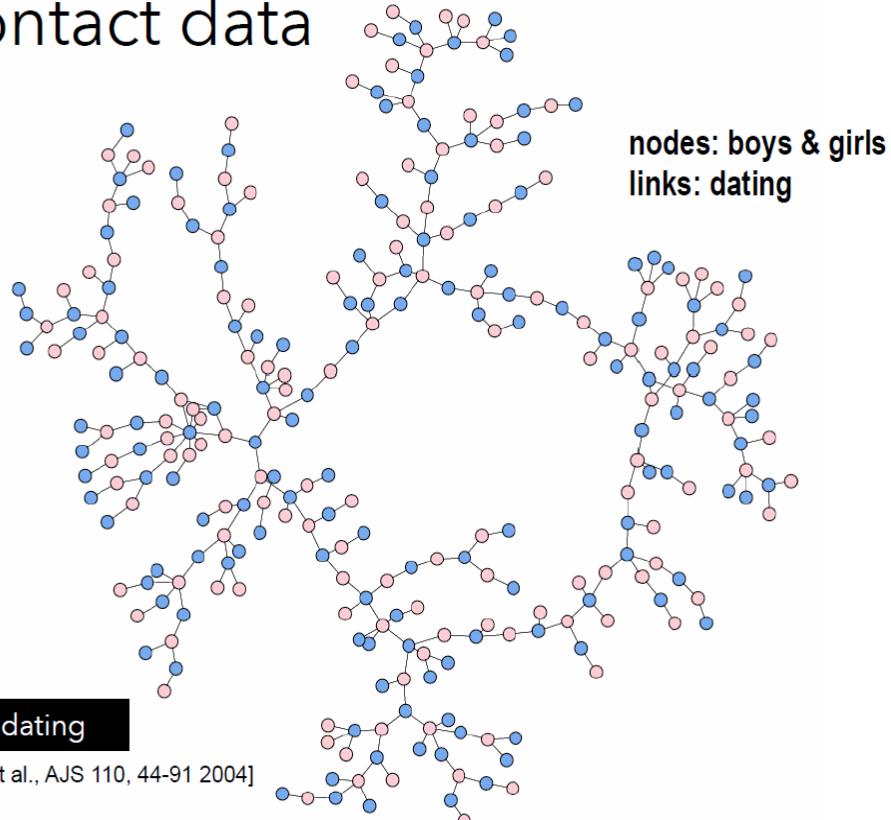


<http://networkrepository.com/so-c-karate.php>

Network Data Statistics	
Nodes	34
Edges	78
Density	0.139037
Maximum degree	17
Minimum degree	1
Average degree	4
Assortativity	-0.475613
Number of triangles	135
Average number of triangles	3
Maximum number of triangles	18
Average clustering coefficient	0.570638
Fraction of closed triangles	0.255682
Maximum k-core	5
Lower bound of Maximum Clique	5

For your projects: How to analyze networks with network measures?

contact data



High school dating

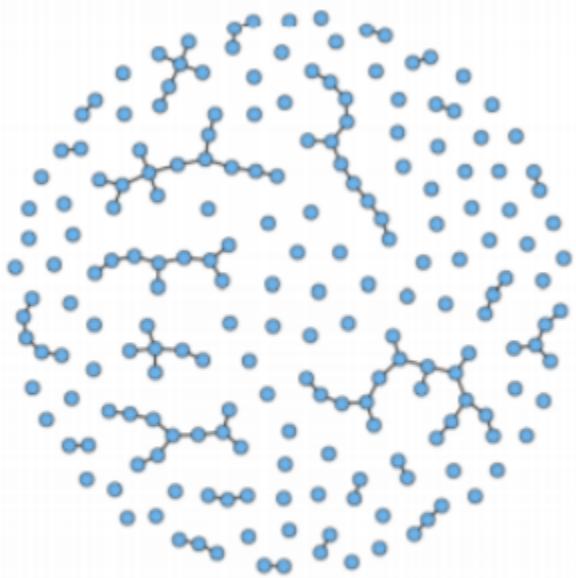
[P. S. Bearman, et al., AJS 110, 44-91 2004]

Network	Nodes	Links	Directed / Undirected	N	L	$\langle k \rangle$
Internet	Routers	Internet connections	Undirected	192,244	609,066	6.34
WWW	Webpages	Links	Directed	325,729	1,497,134	4.60
Power Grid	Power plants, transformers	Cables	Undirected	4,941	6,594	2.67
Mobile-Phone Calls	Subscribers	Calls	Directed	36,595	91,826	2.51
Email	Email addresses	Emails	Directed	57,194	103,731	1.81
Science Collaboration	Scientists	Co-authorships	Undirected	23,133	93,437	8.08
Actor Network	Actors	Co-acting	Undirected	702,388	29,397,908	83.71
Citation Network	Papers	Citations	Directed	449,673	4,689,479	10.43

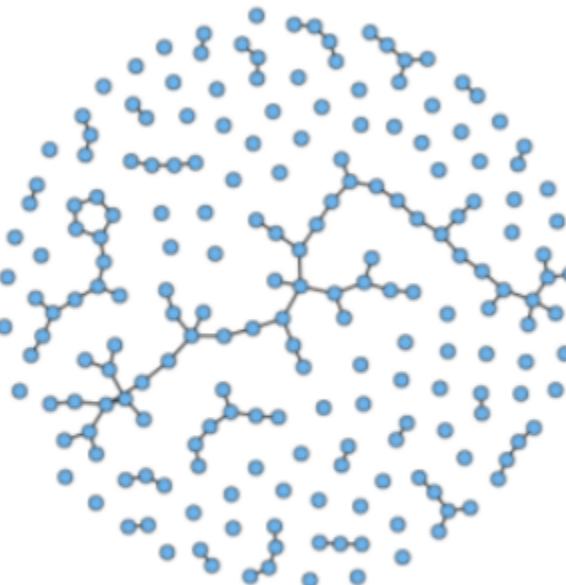
Erdos-Renyi random network

Erdos-Renyi networks

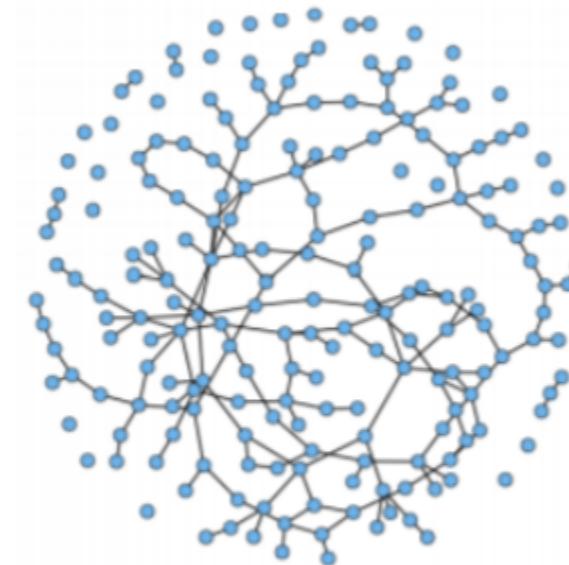
$G(N,p)$, N number of nodes
p is probability to have link between nodes



$$p < p_c$$



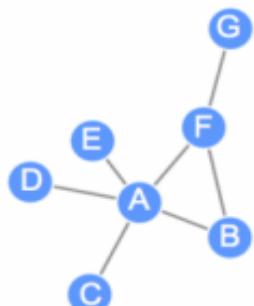
$$p = p_c$$



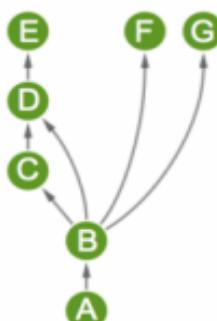
$$p > p_c$$

How to describe a network?

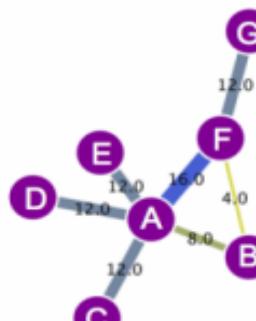
Undirected



Directed



Weighted



	A	B	C	D	E	F	G	Degree
A	0	1	1	1	1	1	0	5
B	1	0	0	0	0	1	0	2
C	1	0	0	0	0	0	0	1
D	1	0	0	0	0	0	0	1
E	1	0	0	0	0	0	0	1
F	1	0	0	0	0	1	0	3
G	0	0	0	0	0	1	0	1

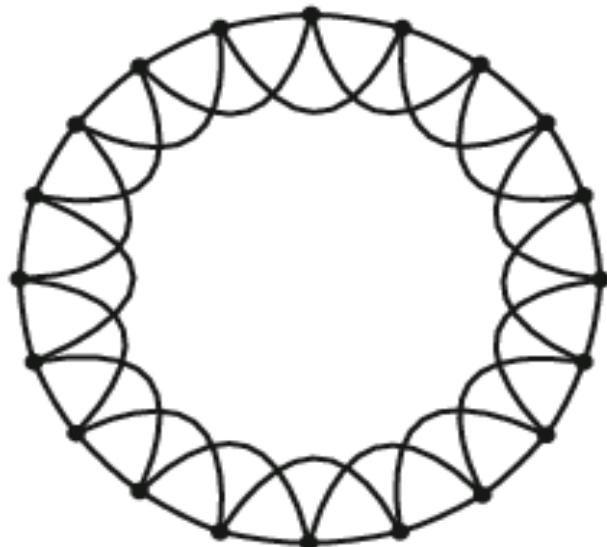
Adjacency matrices

	A	B	C	D	E	F	G	Out-degree
A	0	1	0	0	0	0	0	1
B	0	0	1	1	0	1	1	4
C	0	0	0	1	0	0	0	1
D	0	0	0	0	1	0	0	1
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	1	0
G	0	0	0	0	0	0	0	0

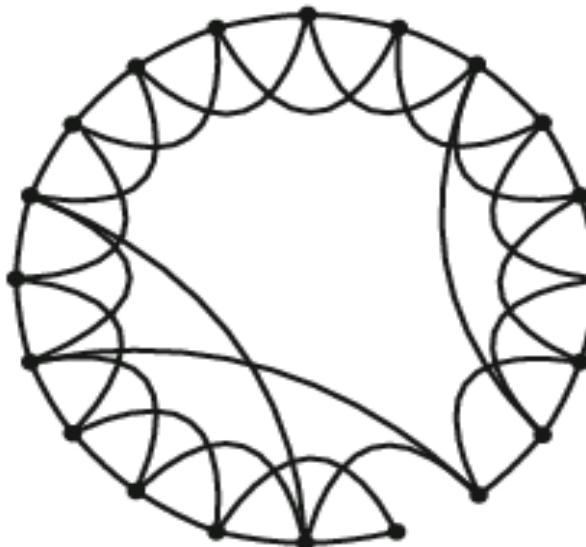
Barabasi book on network science

Watts-Strogarz small-world model

Regular Network



Small-world Network



Random Network



$\beta = 0$



$\beta = 1$