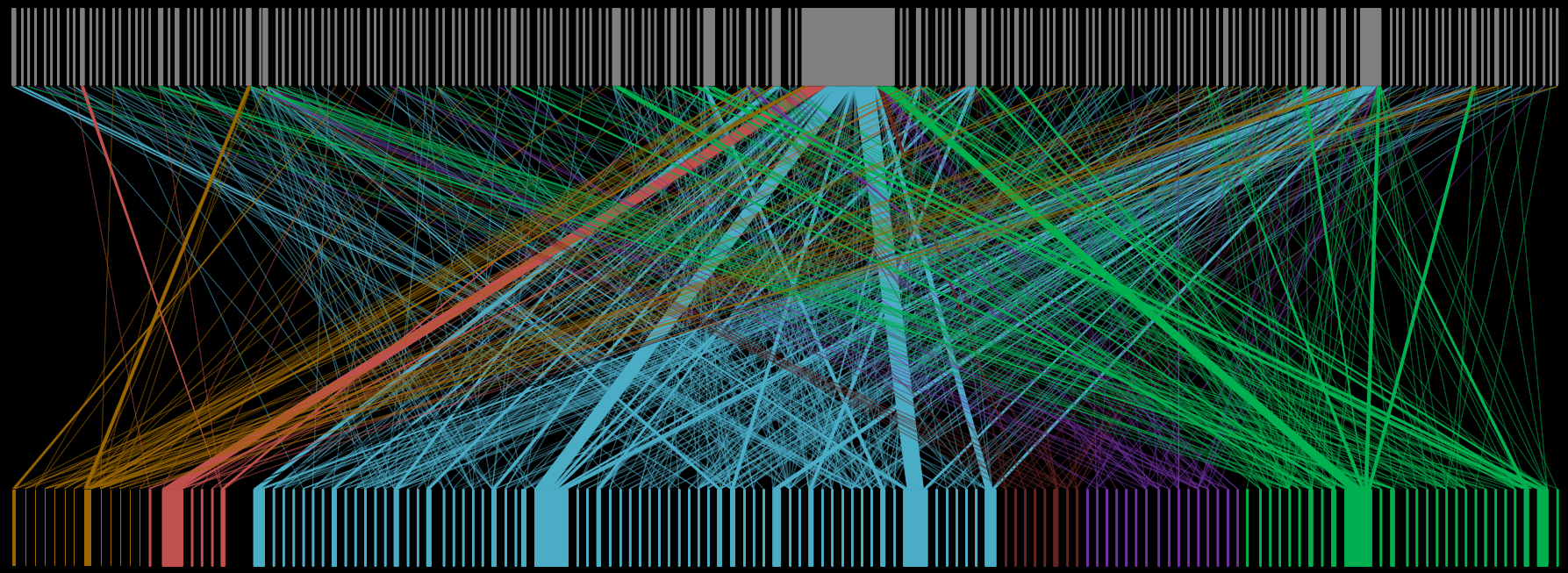
Ecological networks

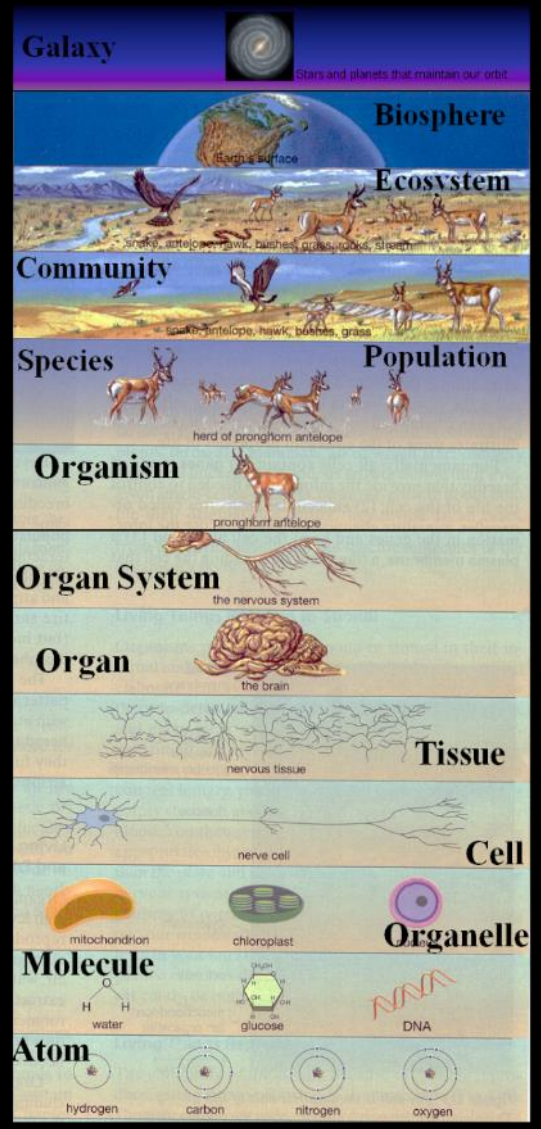


Ruben Heleno - rheleno@uc.pt


Zakaria: The new al-Qaeda threat / Ted Cruz / Fareed: Yellen over Summers for Fed chief / Low Rolling in Vegas
TIME
A
WORLD
WITHOUT
BEES
THE PRICE WE'LL PAY IF WE DON'T FIGURE OUT WHAT'S KILLING THE HONEYBEE
BY BRYAN WALSH

Levels of biological organization

Ecology



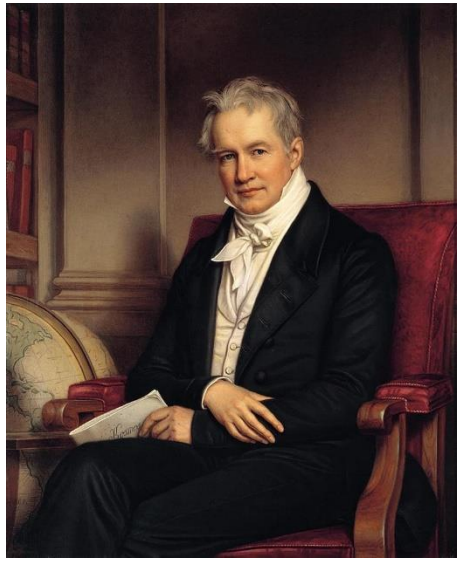
Complexity

Predictability

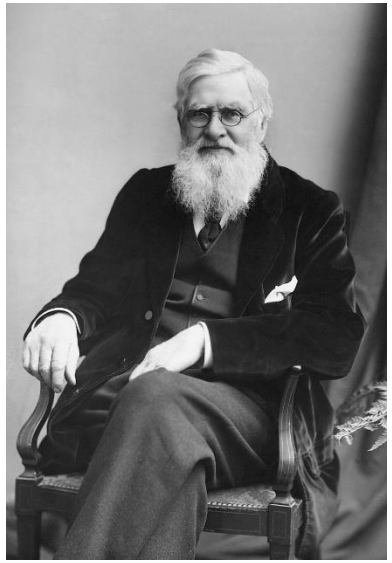
“ It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner (…) “

(Darwin 1859)

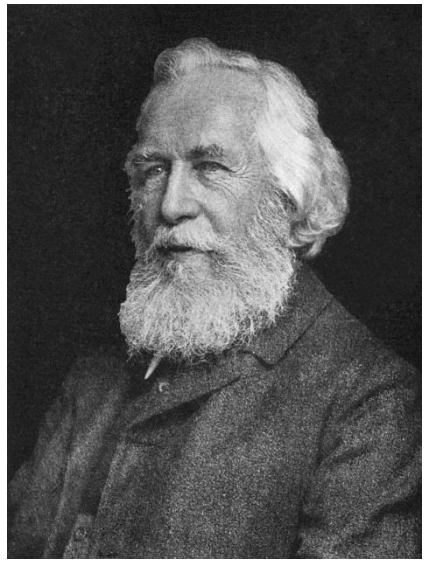
How to study biotic interactions at the community level?



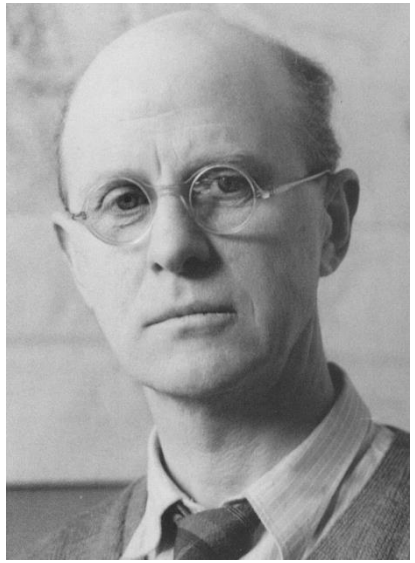
A. von Humboldt
1769-1859



Alfred R. Wallace
1823-1913



Ernst Haeckel
1834-1919



Charles Elton
1900-1991

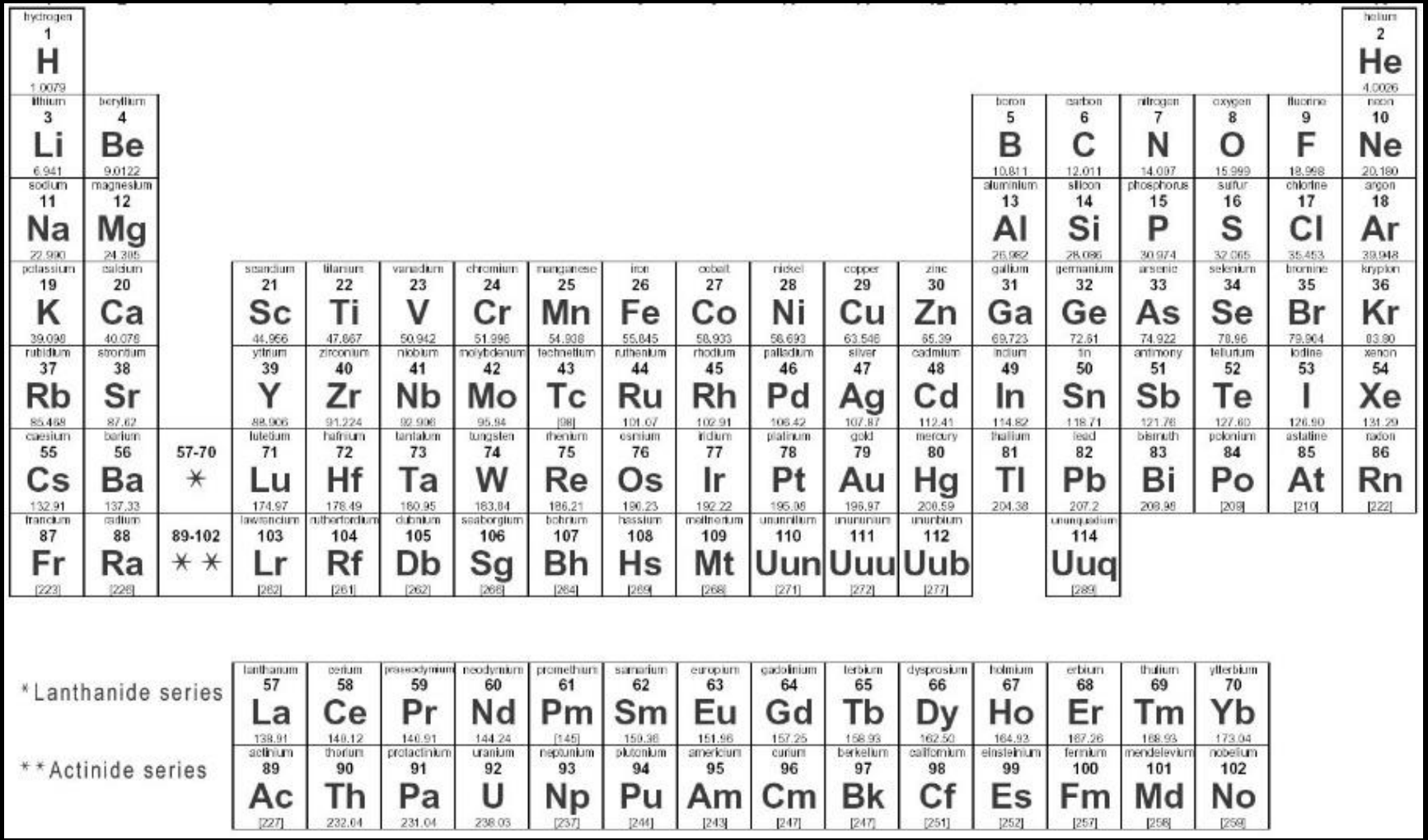
How to compare communities?

Species + Interactions

<u>Interactions</u> are the cement of biodiversity

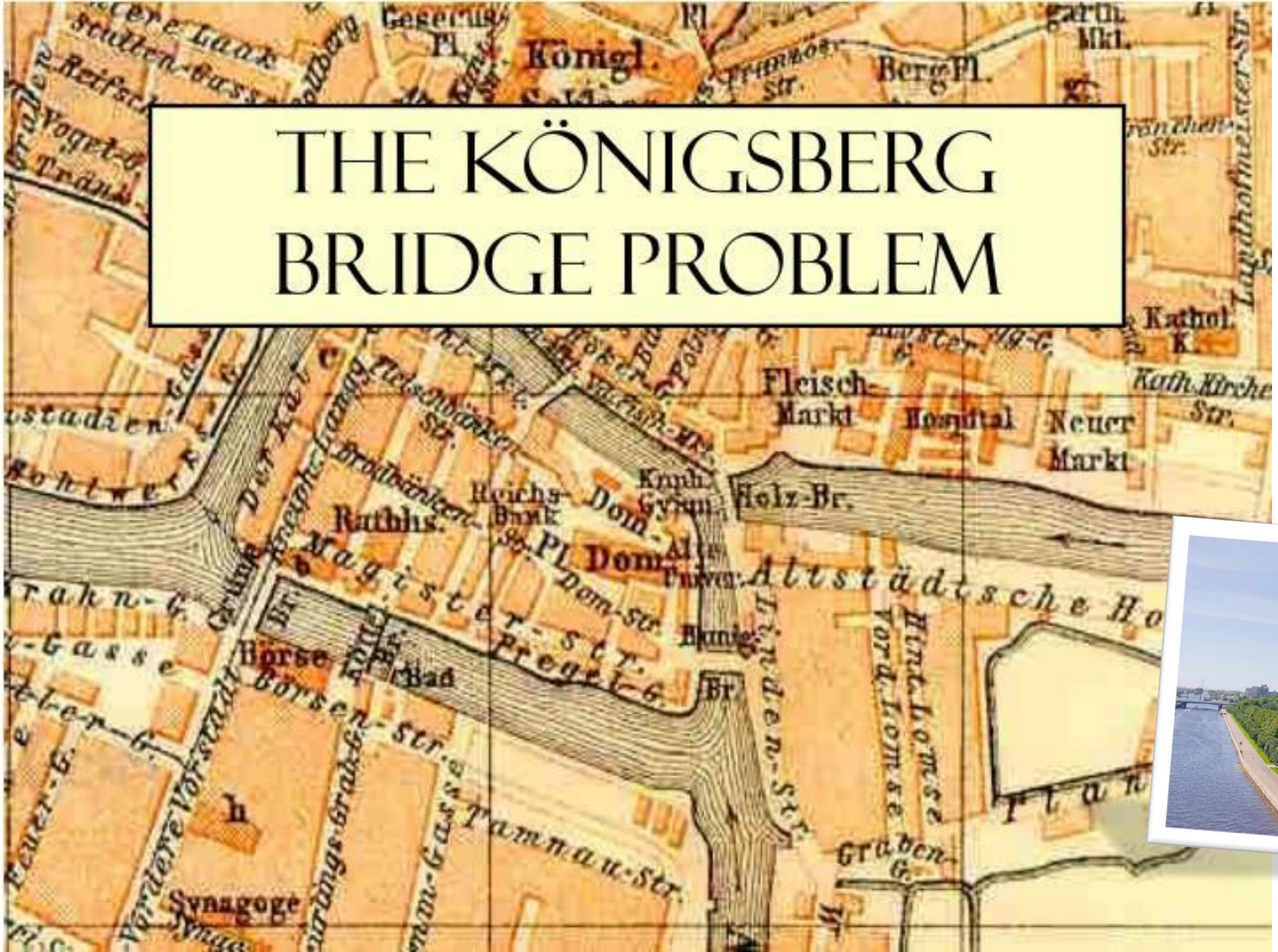
Pollination

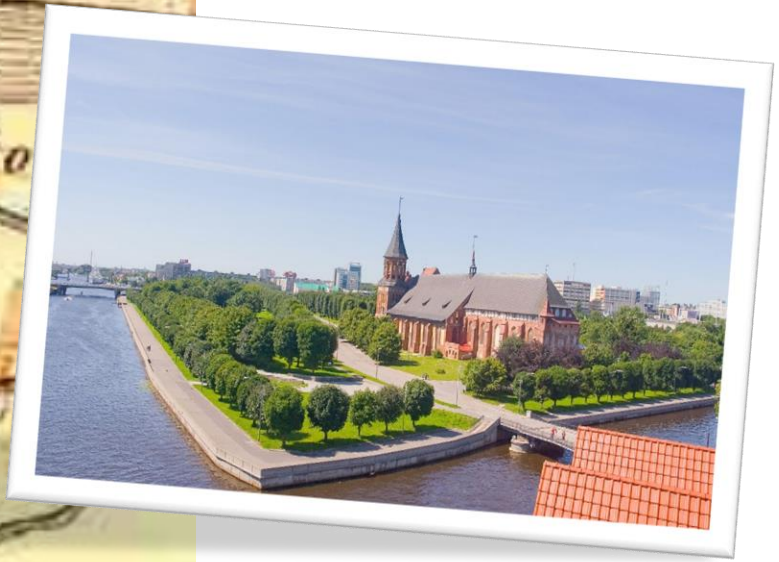
119 elements



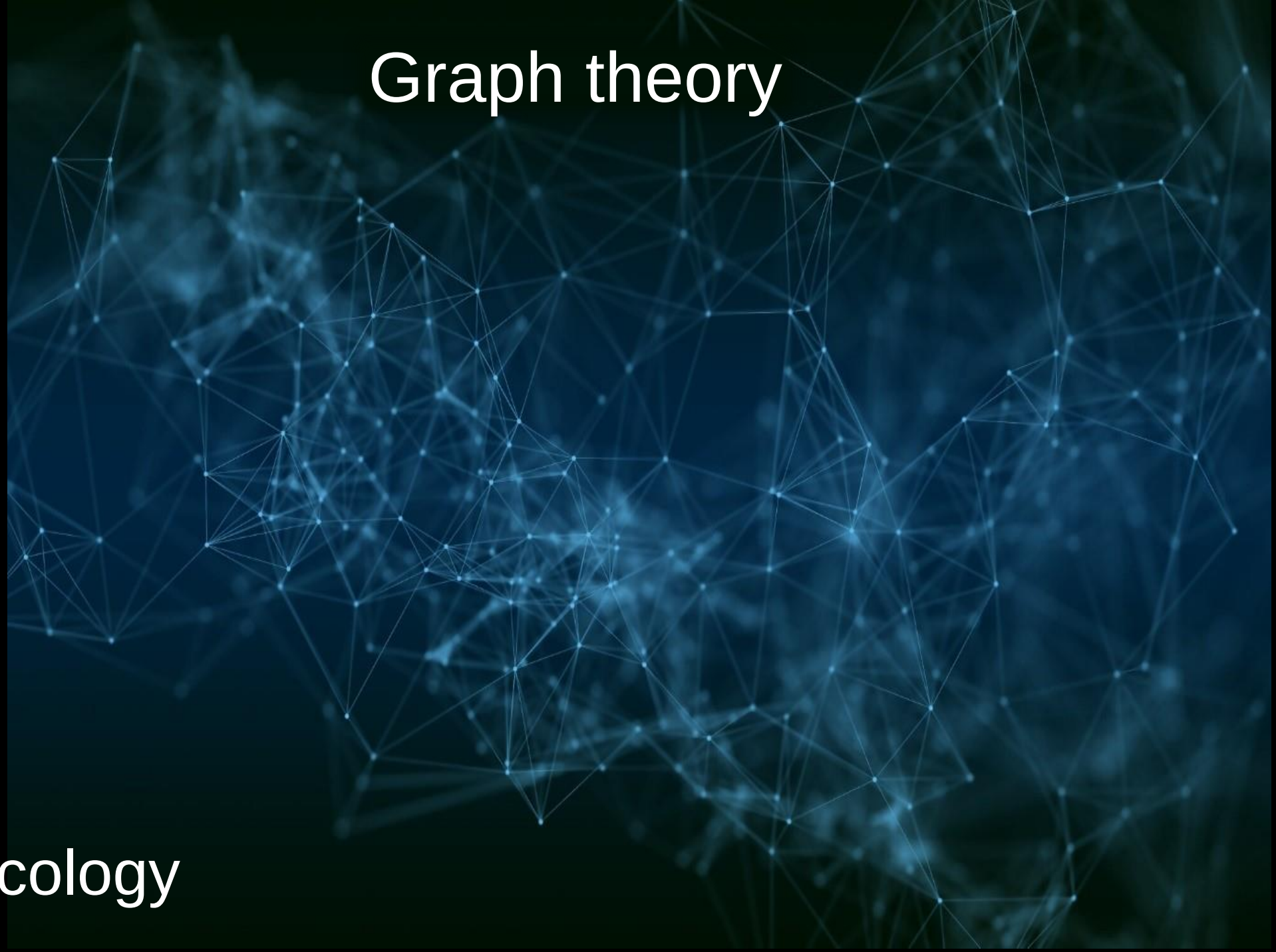
Leonhard Euler, 1736

THE KÖNIGSBERG BRIDGE PROBLEM



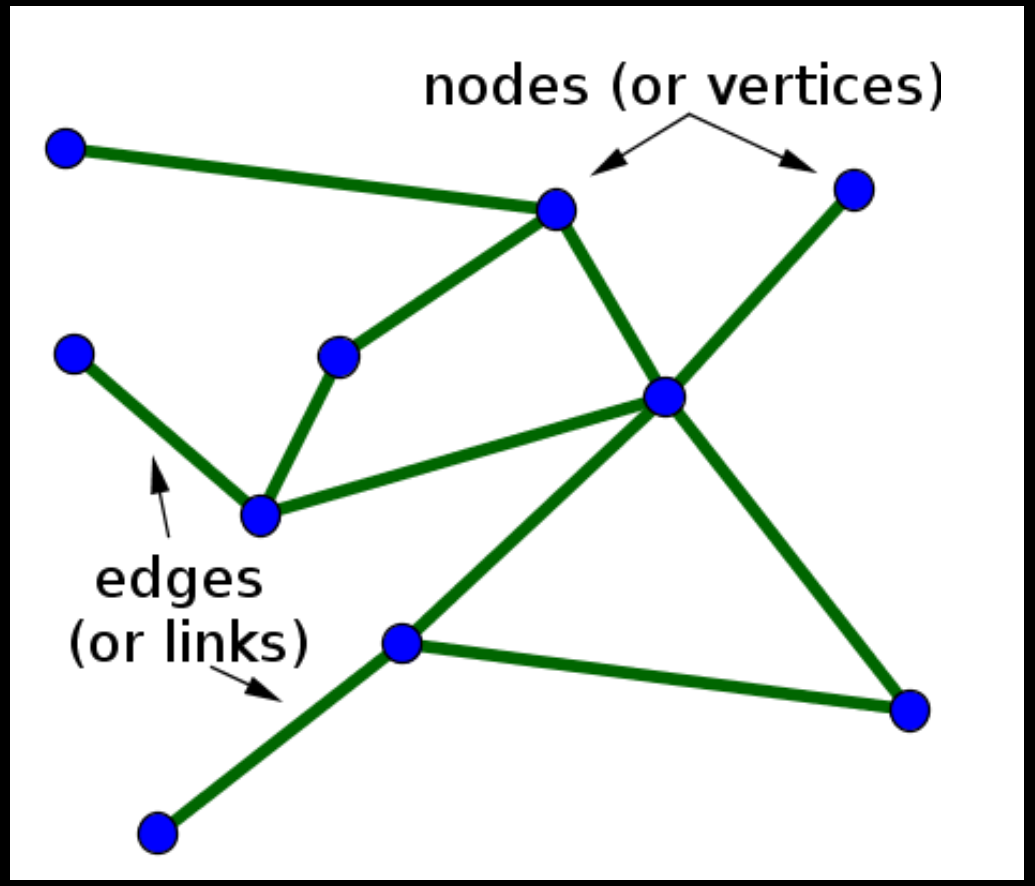


Graph theory



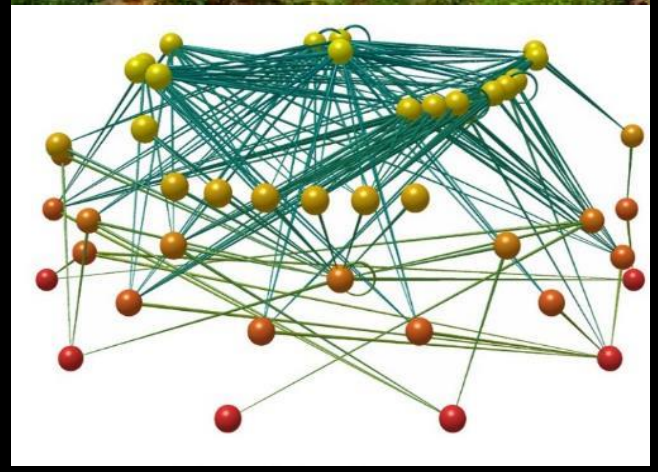
Internet
Social networks
Information
Epidemics
Sports
Transport
Energy
Community Ecology

Mathematical objects defined by groups of **nodes** and **links**

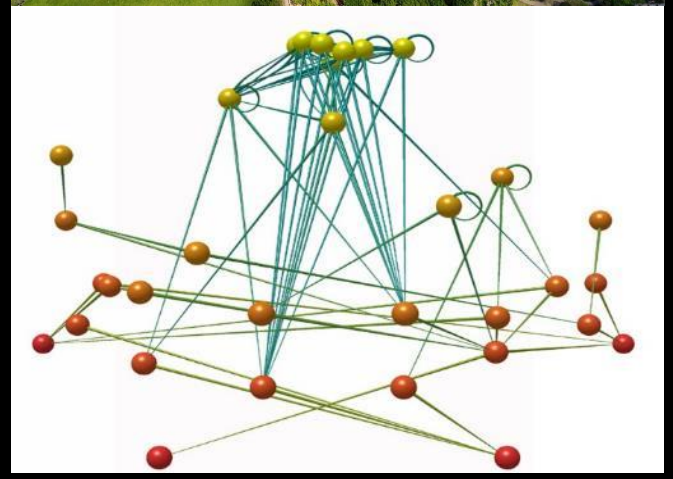


Graph (*português: grafo*)

Community A



Community B



Connectance 26% 9%

H. sapiens

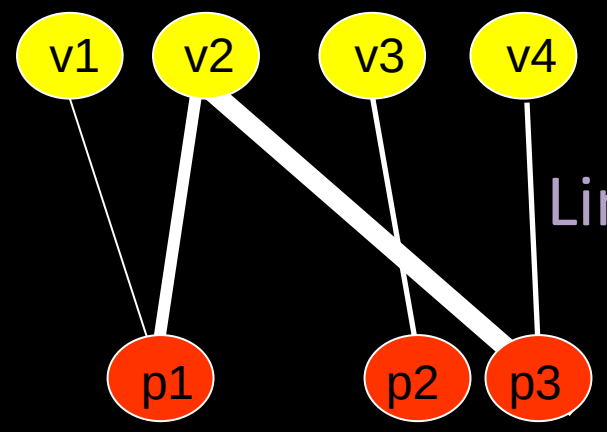
H. erectus

Height: 1.5m 1.7m

How to do a network…

Network

Node



Link (x interaction frequency or weight)

"Trophic" level

Matrix

	Visitor sp.1	Visitor sp.2	Visitor sp.3	Visitor sp.4
Plant sp.1	1	3		
Plant sp.2			2	
Plantsp.3		6		1

Edge list

Plant sp.1	Visitor sp.1	1
Plant sp.1	Visitor sp.2	3
Plant sp.2	Visitor sp.3	2
Plant sp.3	Visitor sp.2	6
Plant sp.3	Visitor sp.4	1

Frugivores

Plants	Sylvia borin	Sylvia atricapila	Sylvia cantillans	Ficedula hipoleuc	Serinus serinus	Erithacus rúcula	Turdus phylomel	Turdus viscivorus	Turdus merula	Parus major	Periparus ater	Degree or Linkage level
Ilex integra			29									1
Oxalis pes-caprae		20							35			2
Tetrapanax papyrifer				2					4			2
Cistus sp.	2								10			2
Salvia elegans	36		14		17			16	147	1	3	7
Rhaphiolepis indica	1				3			17	175			4
Digitalis sp.	2								95			2
Photinia sp.2		2		24	2		9		1			5
Salvia officinalis									2	1		2
Liriodendron tulipifera				1					4	1		3
Philadelphus incanus		764	6	163		138	52	20	301			7
Spiraea albiflora		182				303						2
Deutzia scabra		342				209			28			3
Lonicera sp.1		15		15				1	19			4
	4	6	3	5	3	3	2	4	12	3	1	46

Plants = 14

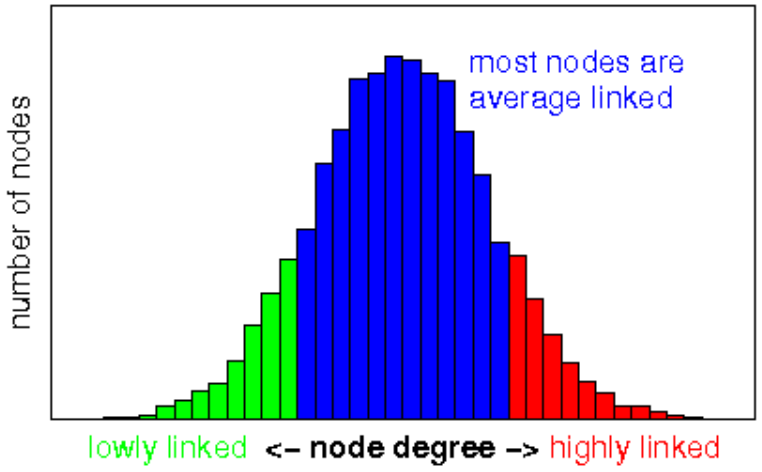
Animals = 11

Links = 46

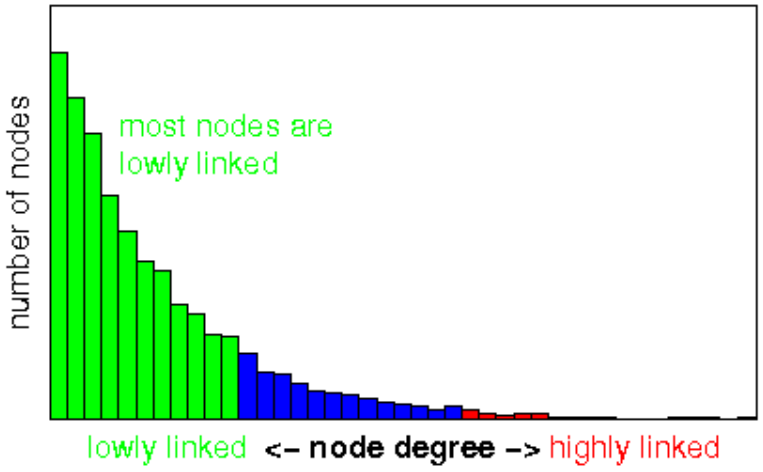
Size =11x14 = 154

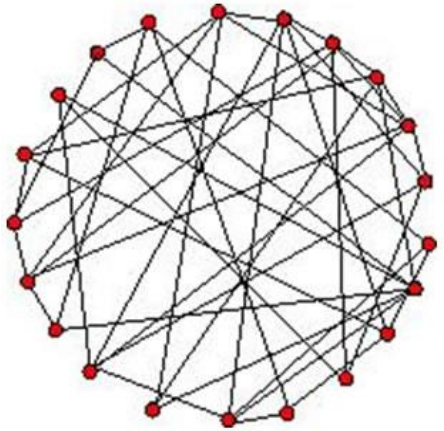
Connectance = Links / Size = 0.29

Random networks

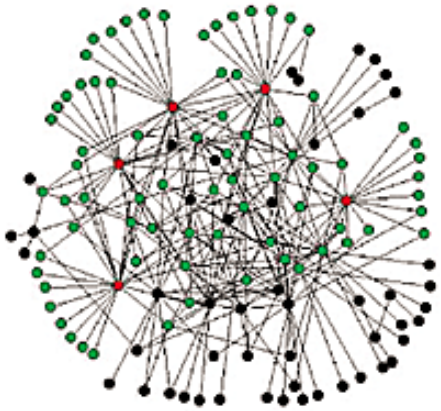


Real networks

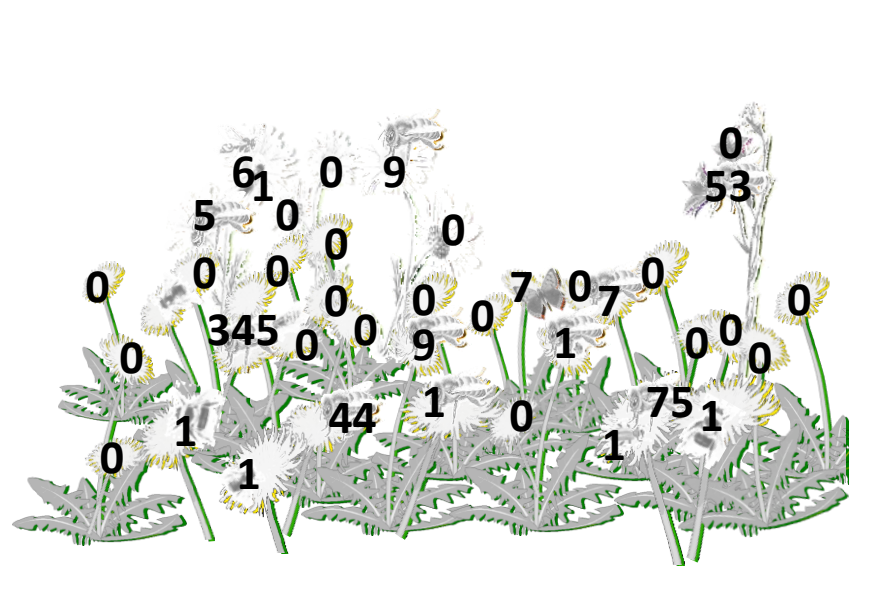




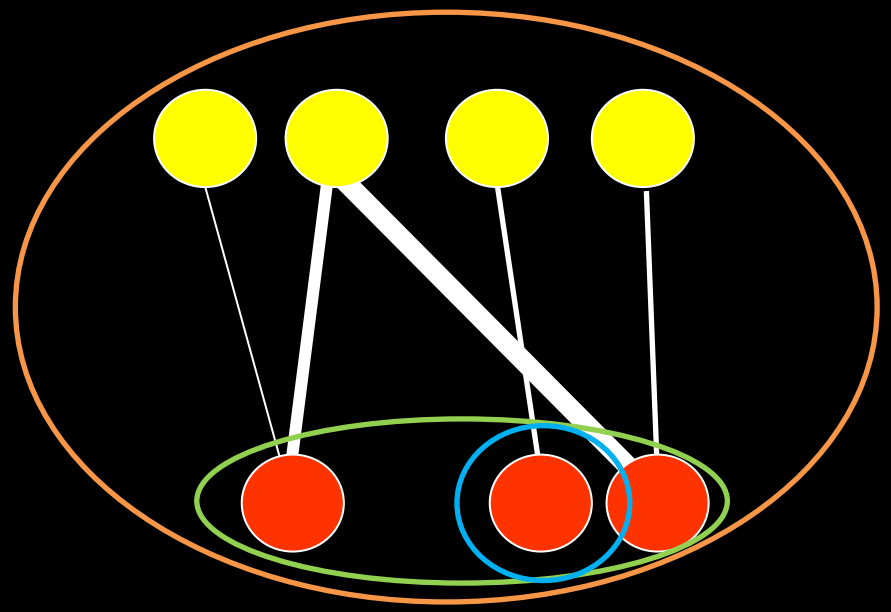
Erdös y **Rényi** , 1959



Barbási y Albert 1999




THE
MATRIX



Network level descriptors

Connectance (realized proportion of all possible links)
Modularity (refers to the existence of subsets of closely interacting species)
Nestedness (extent to which the matrix adheres to a fully nested pattern)

Guild or Group level descriptors

Niche overlap (proportion of shared partners between species)
Robustness (rate of secondary extinctions)

Species level descriptors

Degree = Linkage level (sum of interactions per species)
Strength (sum of dependencies of each species)
d' specialization (discrimination from random selection of partners)

Network structure descriptors (metrics)

Network-level

connectance
web asymmetry
links per species
number of compartments
compartment diversity
cluster coefficient
nestedness
weighted nestedness
weighted NODF
interaction strength asymmetry
specialisation asymmetry
linkage density
Fisher alpha
interaction evenness
Alatalo interaction evenness
Shannon diversity
H2 network specialisation

Group-level

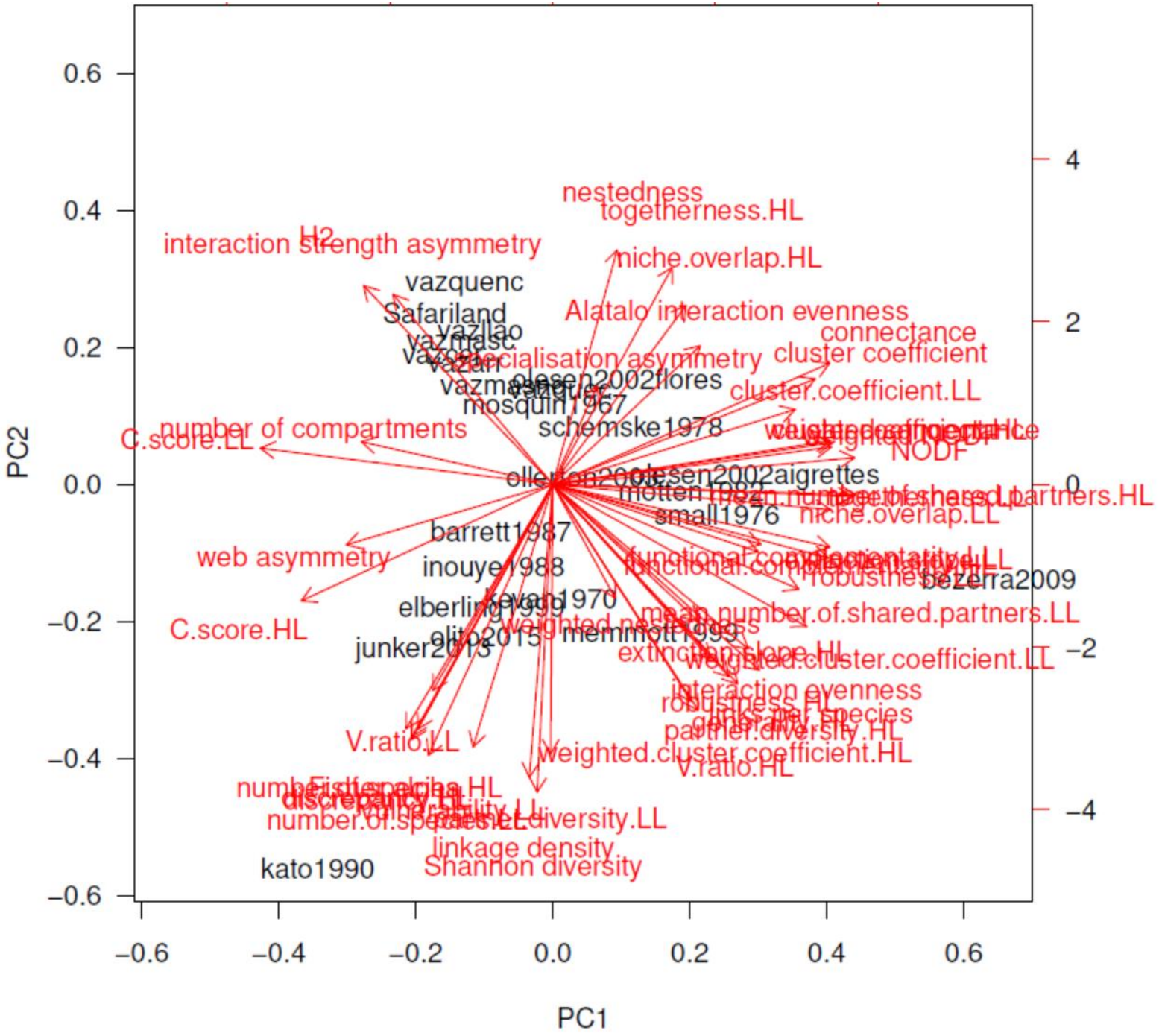
number of species
mean number of links
mean number shared partners
cluster coefficient
weighted cluster coefficient
togetherness
C score
V ratio
discrepancy
degree distribution
extinction slope
Robustness
niche overlap
generality
vulnerability
partner diversity
fd functional diversity

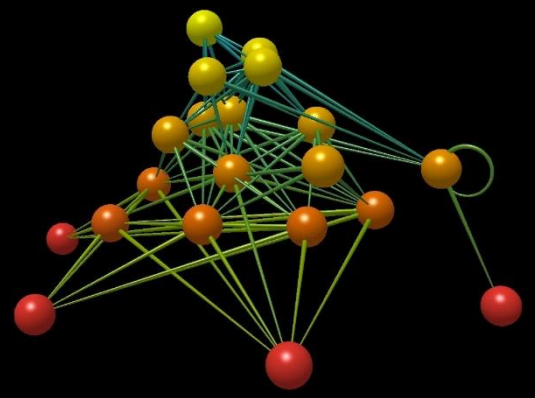
Species-level

degree
normalised degree
species strength
nestedrank
interaction push/pull
Paired Differences Index
resource range
species specificity
pollination service index
node specialisation index
betweenness
closeness
Fisher's alpha
diversity
effective partners
proportional generality
proportional similarity
d' selectivity

Link-level

dependence
endpoint degree


PC1
PC2
nestedness
togetherness.HL
interaction strength asymmetry
H2
niche.overlap.HL
vazquenc
Safariland
Alatalo interaction evenness
connectance
cluster coefficient
specialisation asymmetry
olesen2002flores
cluster.coefficient.LL
mosquin1967
schemske1978
number of compartments
C.score.LL
NODF
olesen2002aigrettes
motten1982
small1976
niche.overlap.LL
barrett1987
web asymmetry
inouye1988
bezerra2009
elberling1999
keyan1970
C.score.HL
junker2013
olito2015
memmott1999
mean.number.of.shared.partners.LL
weighted.cluster.coefficient.LL
interaction evenness
partner.diversity.HL
V.ratio.LL
weighted.cluster.coefficient.HL
V.ratio.HL
discrepancy.LL
linkage density
Shannon diversity
kato1990



How species interact

Community Composition, Structure and Function / Health

Species lists

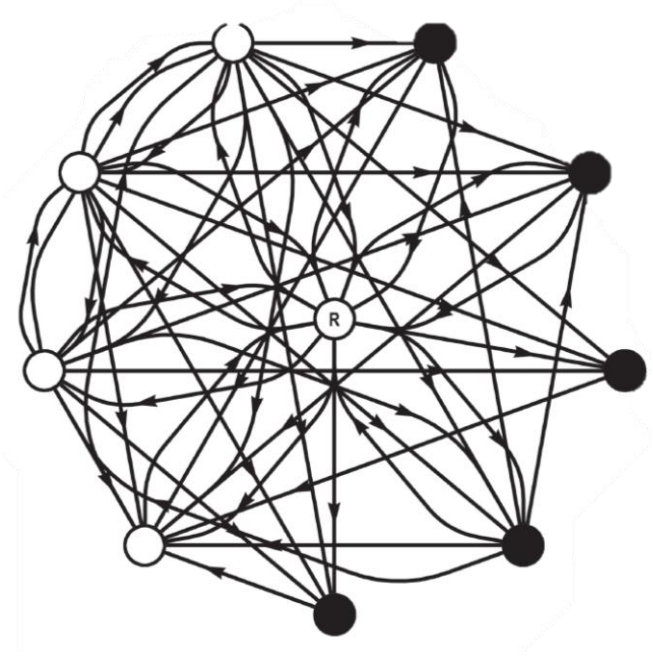
What species do

Pollinate flowers
Disperse seeds
Provide biotic resistance

Types of networks

Unipartite

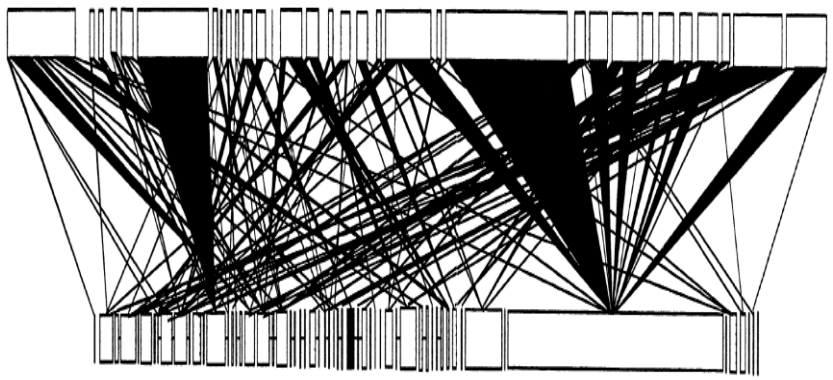
(one-mode)



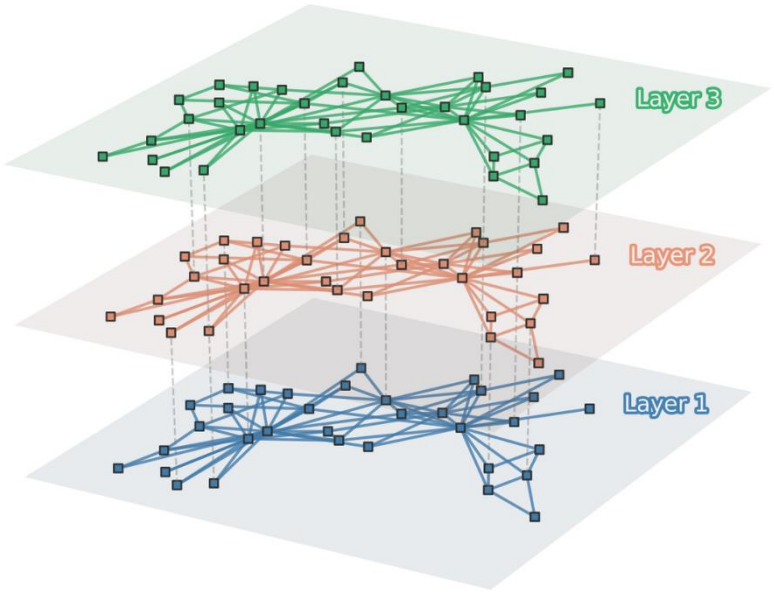
(foodweb)

Bipartite

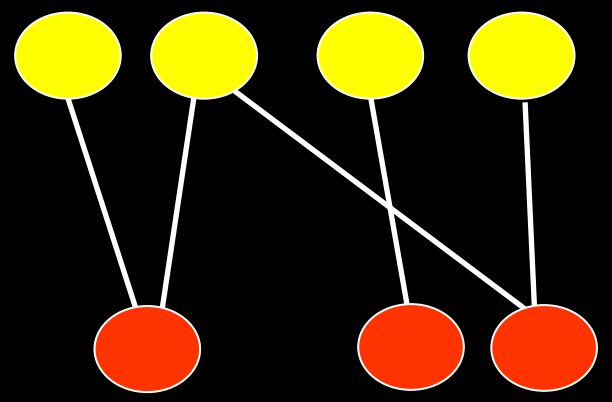
(two-mode)



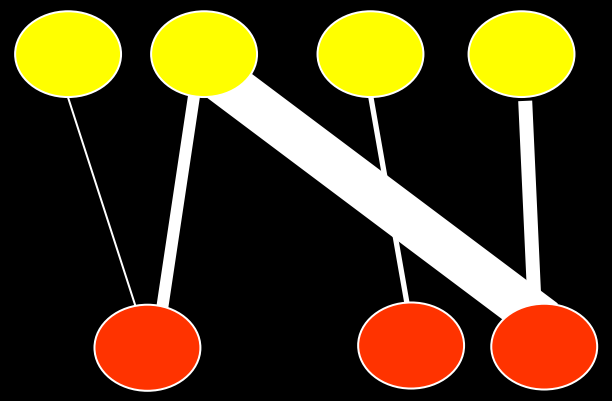
multilayer



Qualitative – Quantitative

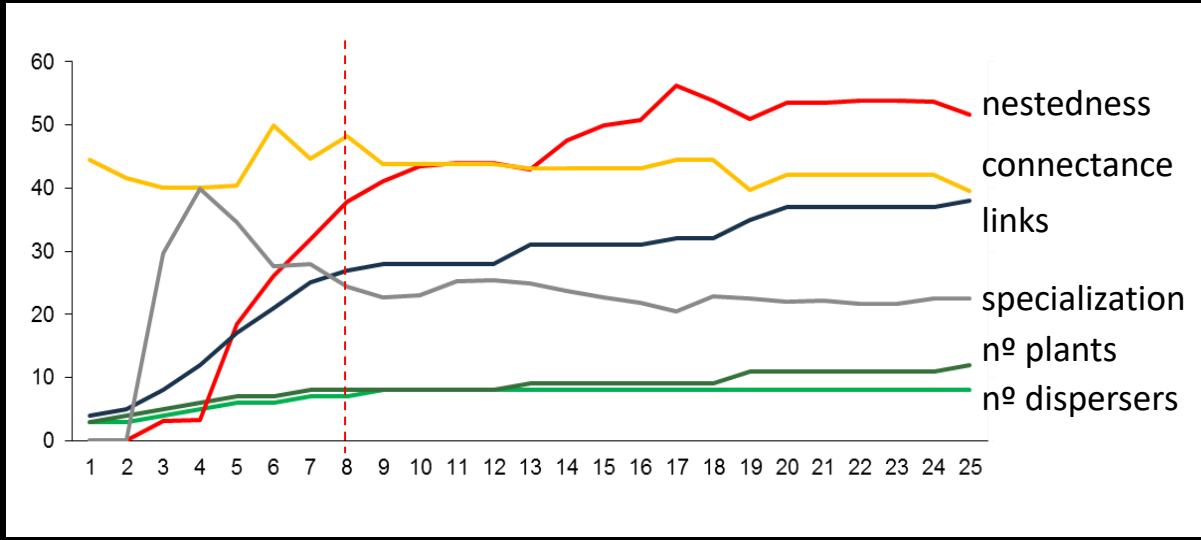


	Insect1	Insect2	insect3	Insect4
Plant1	1	1	0	0
Plant2	0	0	1	0
Plant3	0	1	0	1



	Insect1	Insect2	insect3	Insect4
Plant1	1	3	0	0
Plant2	0	0	2	0
Plant3	0	6	0	1

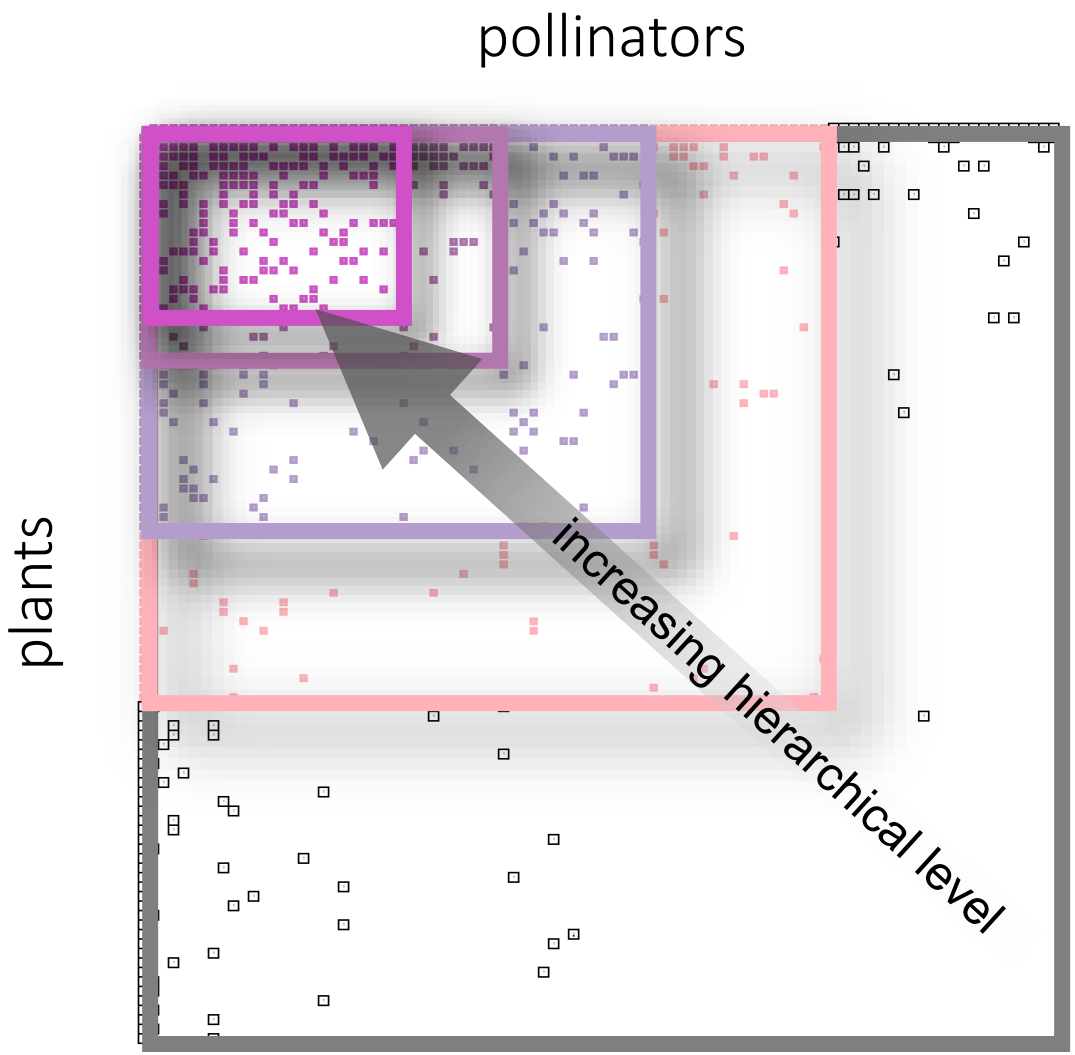
Sampling completeness (quality)

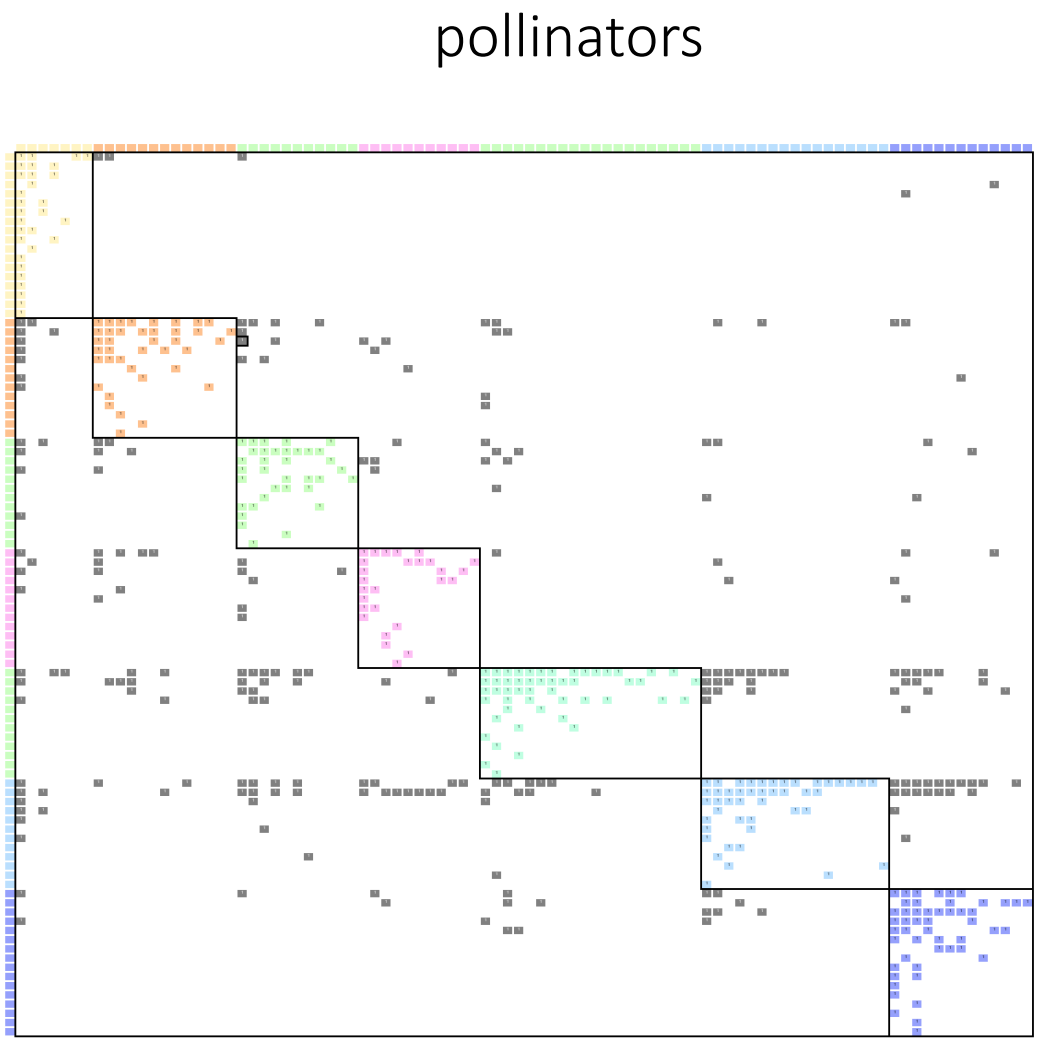


All networks have three types of boundaries:

- Spatial
- Temporal
- **Functional**

What is a community?





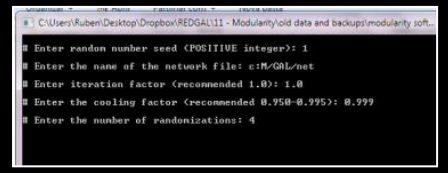
to explore more on networks

Package bipartite for R: http://cran.r-project.org

Gephy: https://gephi.org

Pajek: http://pajek.imfm.si/doku.php

NodeXL: http://nodexl.codeplex.com



Netcarto: http://etseq.urv.cat/seeslab/downloads/network-cartography-netcarto

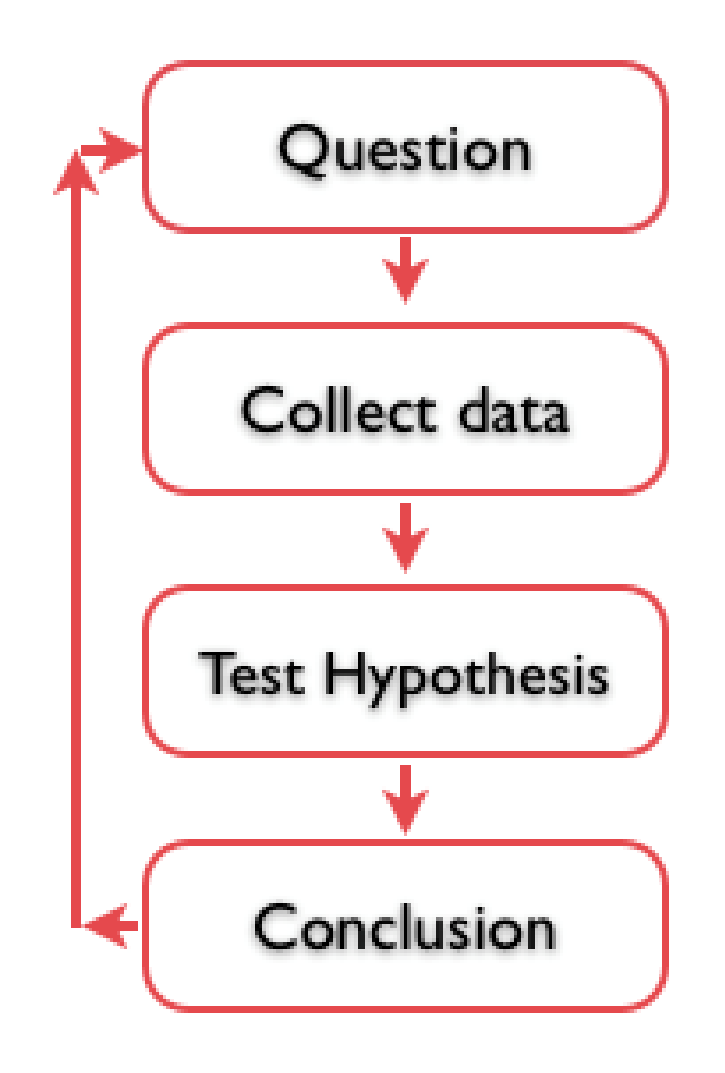
NodeGoat: http://nodegoat.net

Cytoscape: http://www.cytoscape.org

Mapequation: http://www.mapequation.org

Network3D: http://www.foodwebs.org

A technique is only useful if it can help answering questions



- You have a an **idea** you want to explore → **hypothesis**
- Collect **data**

- Create matrices ← Sampling biotic interactions
- Draw network
- Calculate the relevant descriptors

new hypothesis

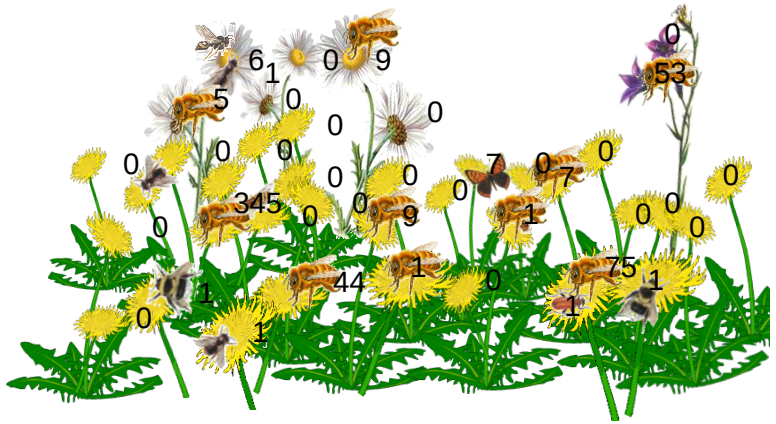
- Statistical **analyses**

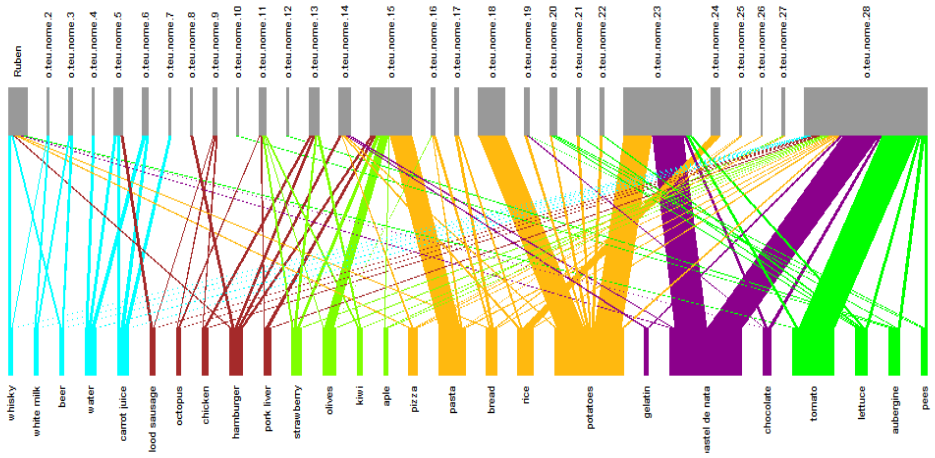
  (test hypothesis)

- **One network:**
  - Compare species roles
  - Compare network with other studies
  - Compare network with null models
- **Many networks:**
  - All of the above
  - Compare community structure along environmental gradients

Conclusion

Hands on bipartite





https://goo.gl/ugkWML