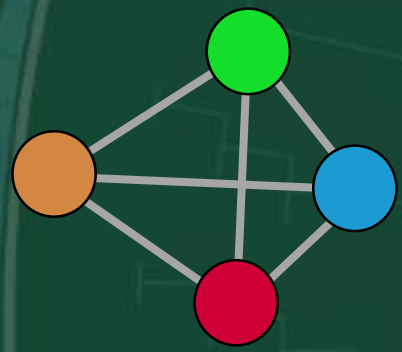
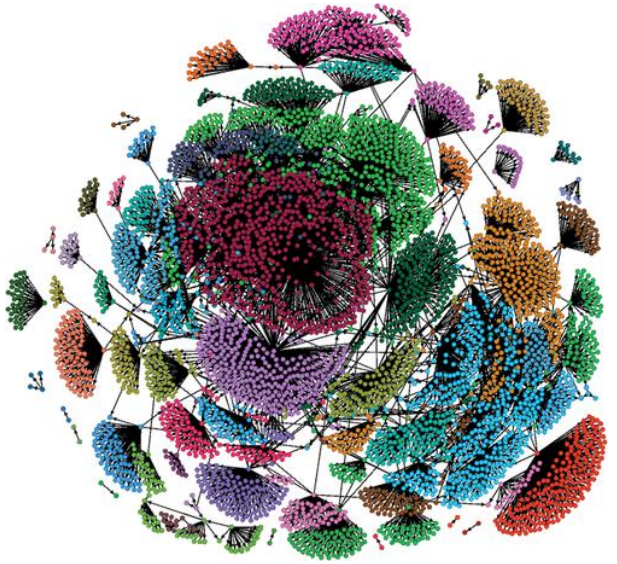
Social network analysis

Hector Marina



Social Networks

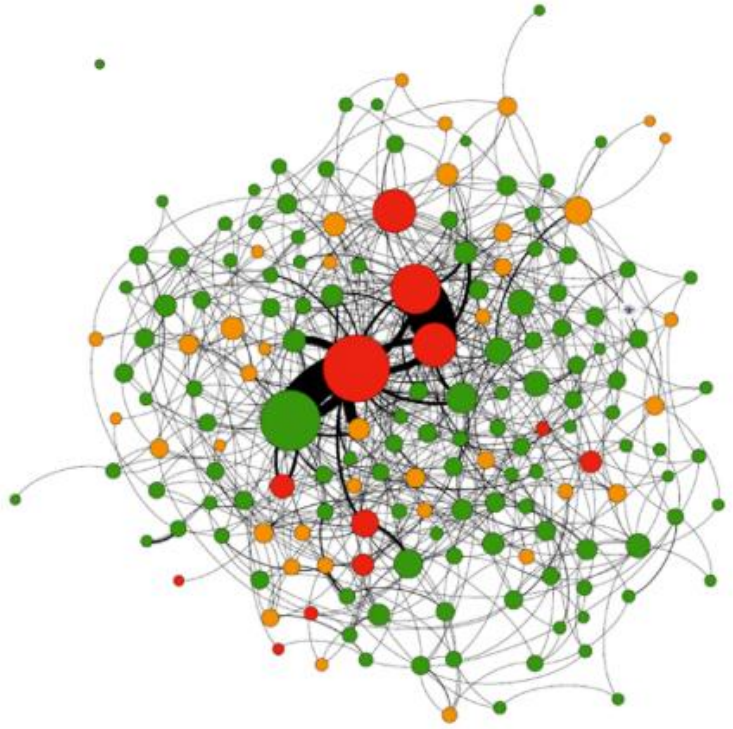
- A **social network** can be constructed from **relational data** and can be defined as a set of social **entities**, such as people, groups, and organizations, with some relationships or interactions between them. These networks are usually modelled by graphs, where vertices represent the social entities and edges represent the **relationships** established between them



(Tabassum et al., 2018)

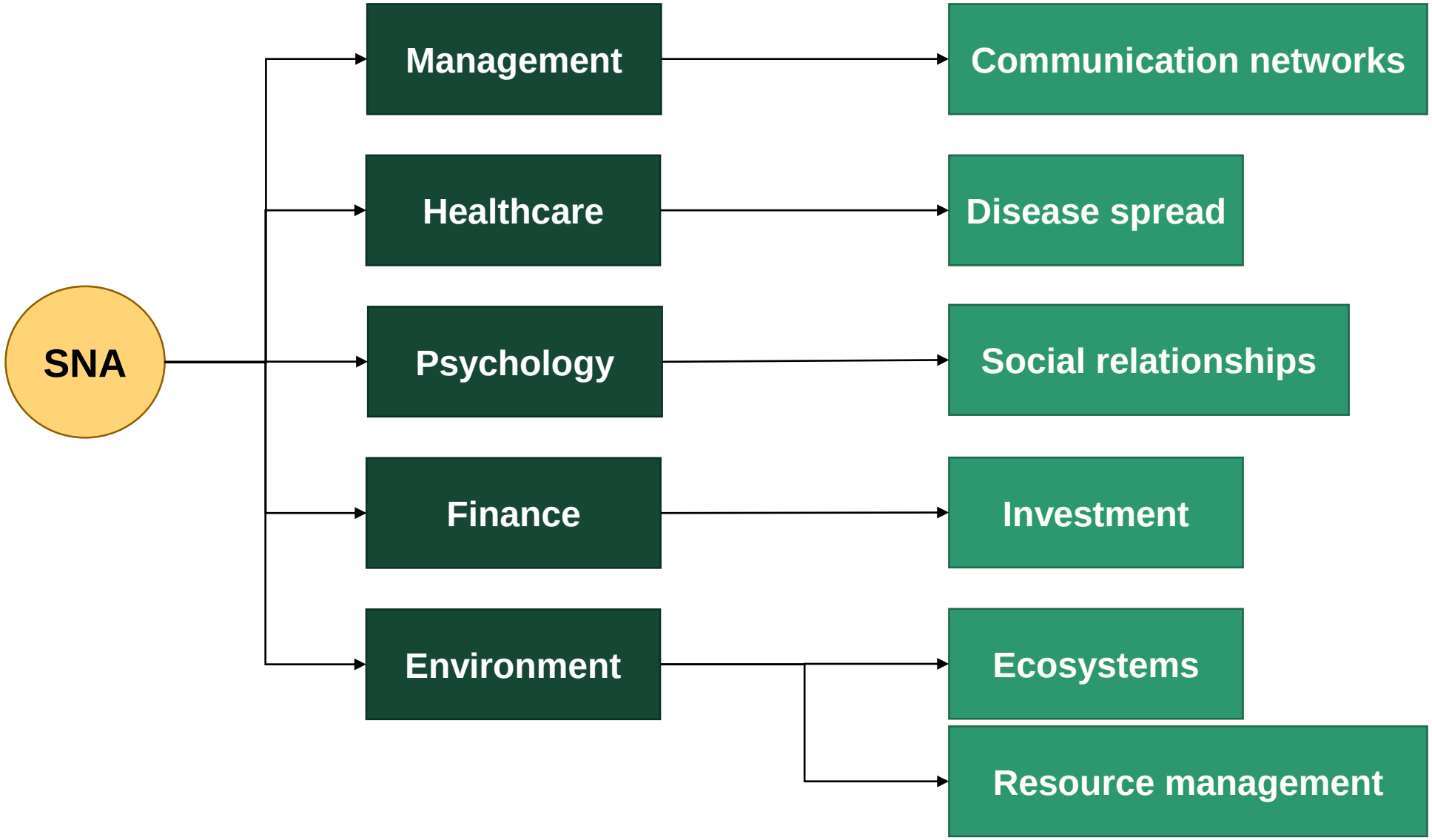
What is SNA?

- **Social network analysis** studies structures of relationships linking individuals and interdependencies in behaviour or attitudes related to configurations of social relations

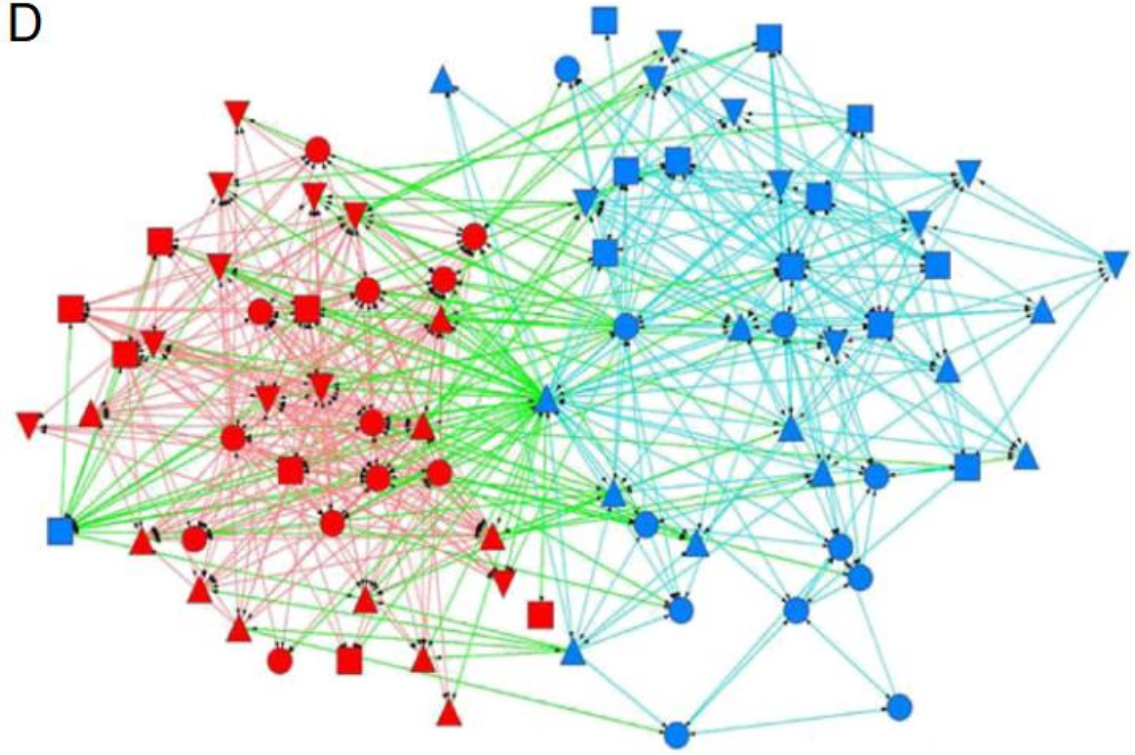


(de Freslon et al., 2019)

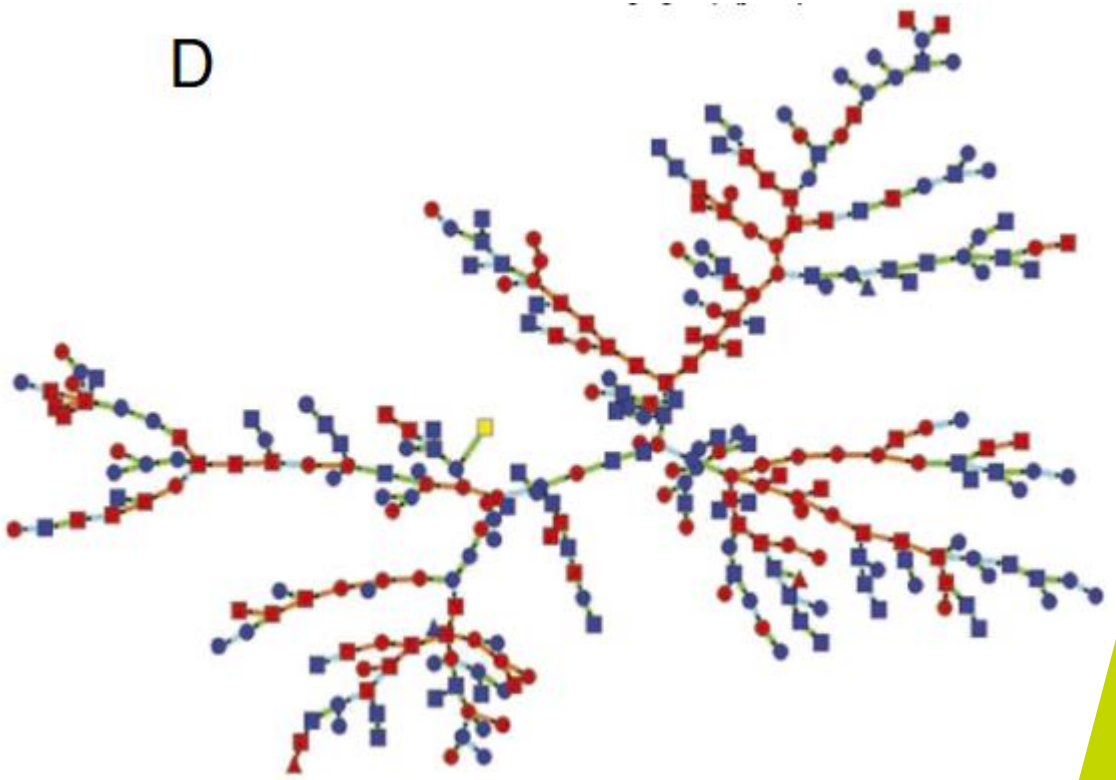
SNA applications



What is SNA?



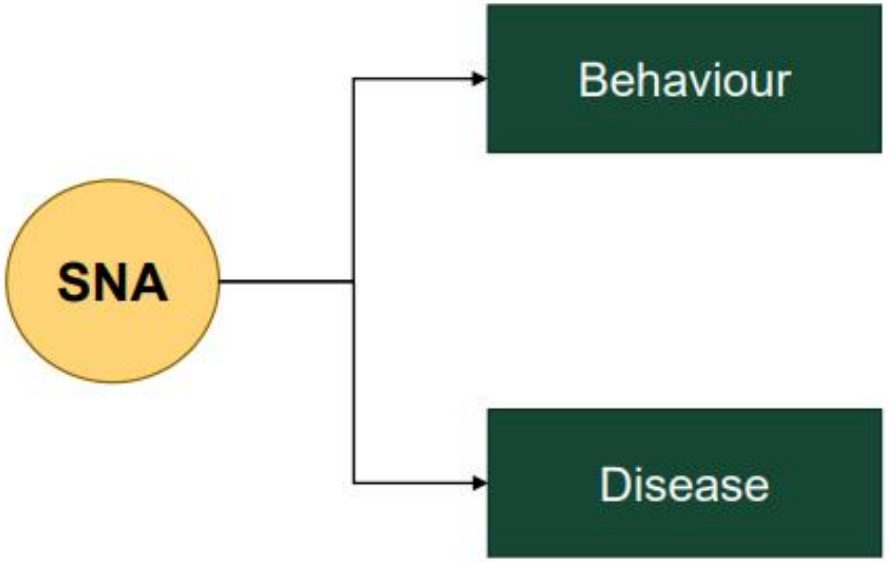
Social networking among fourth graders



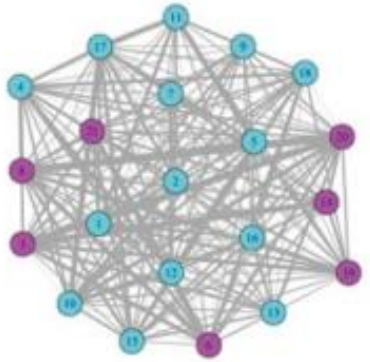
Reconstructed transmission tree

(Cauchemez et al., 2010)

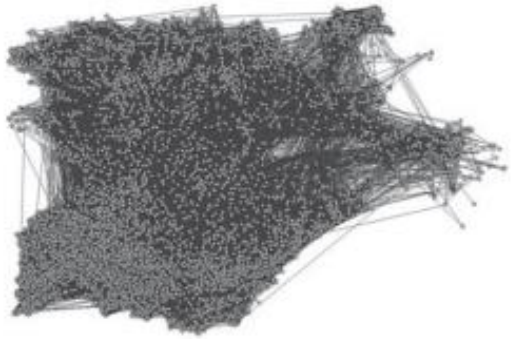
SNA applications in animals



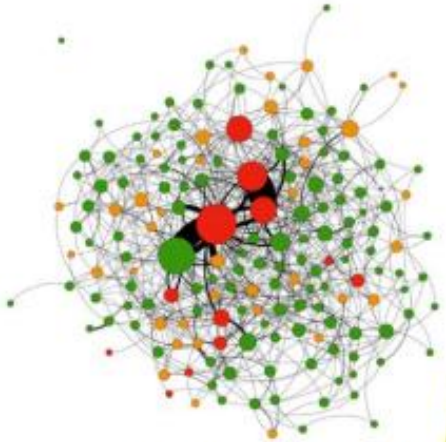
(Rocha et al., 2020)



(Chen et al., 2015)

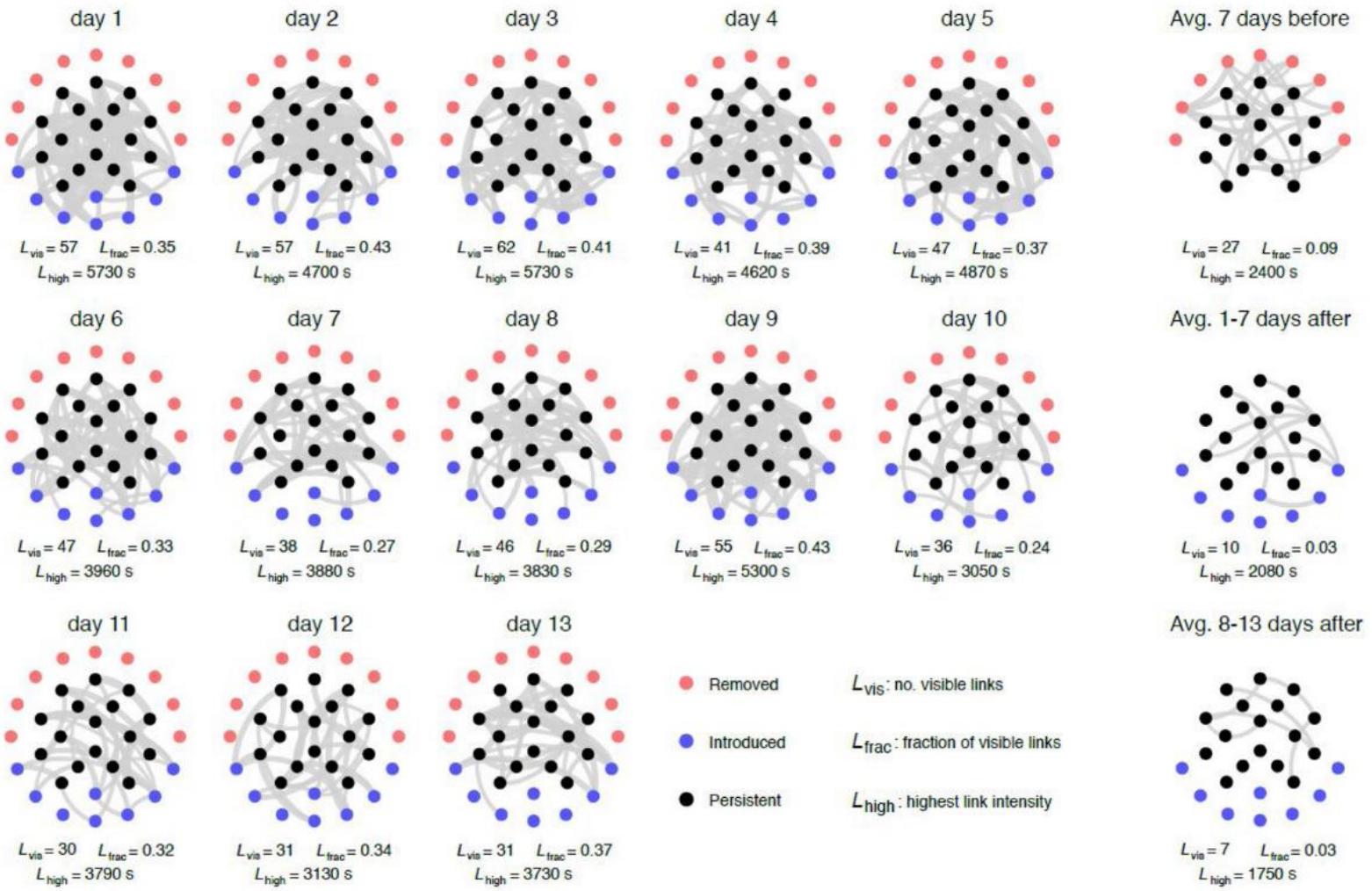


(Martínez-López et al., 2009)



(Freslon et al., 2019)

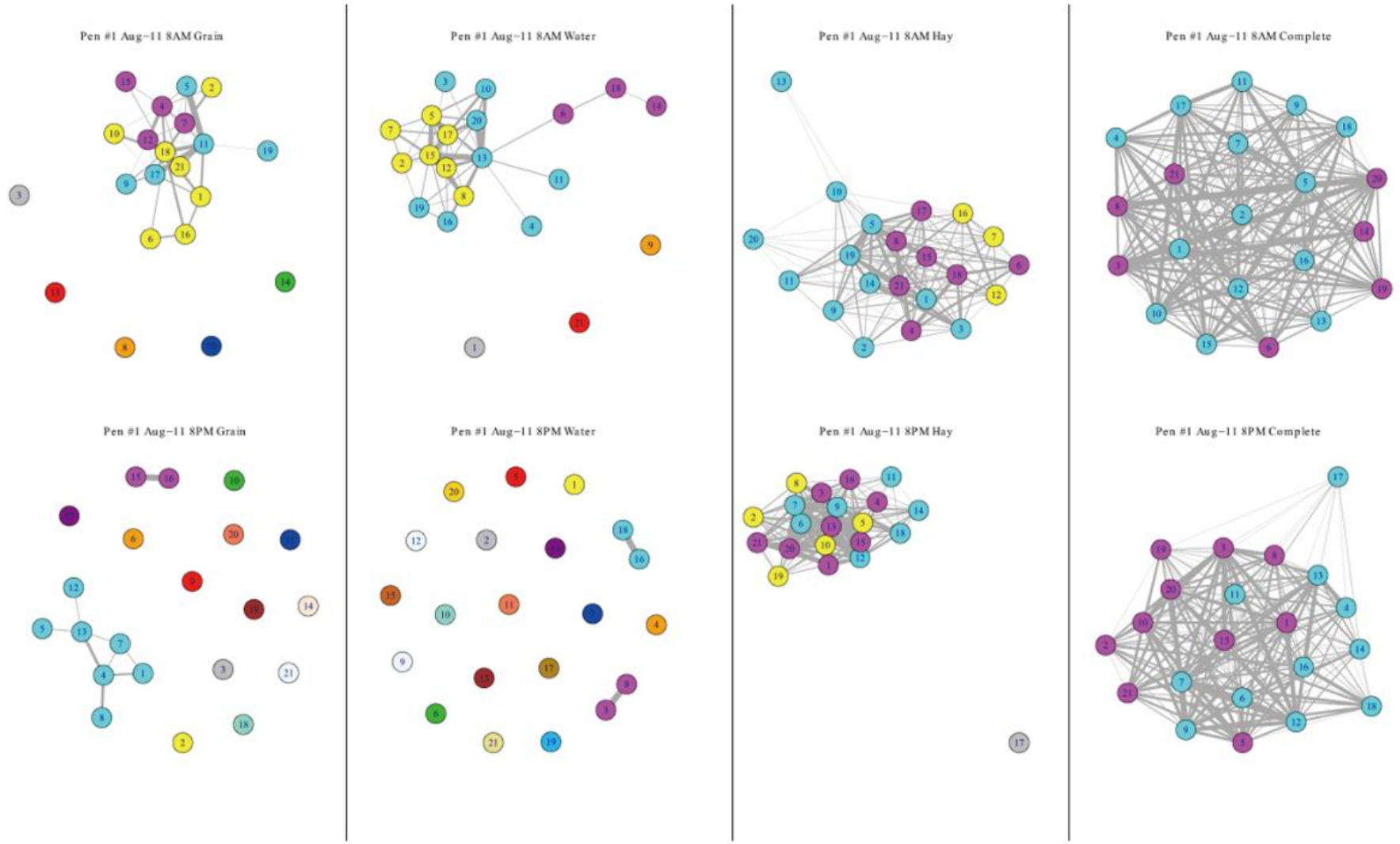
SNA applications in animals



Suggested that each cow has its **own sociality** independent of the group and tend to establish relations with **specific partners** when the population is fixed

(Rocha et al., 2020)

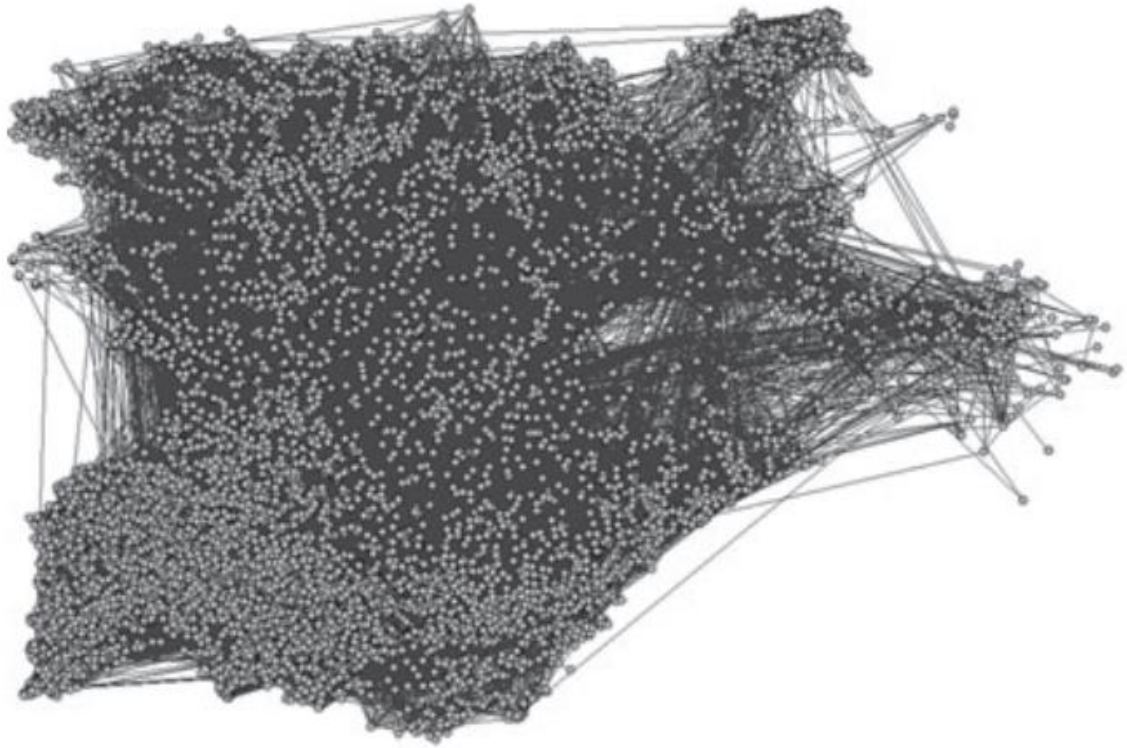
SNA applications in animals



From left to right: networks around grain, hay, water, and complete network in the pen

(Chen et al., 2015)

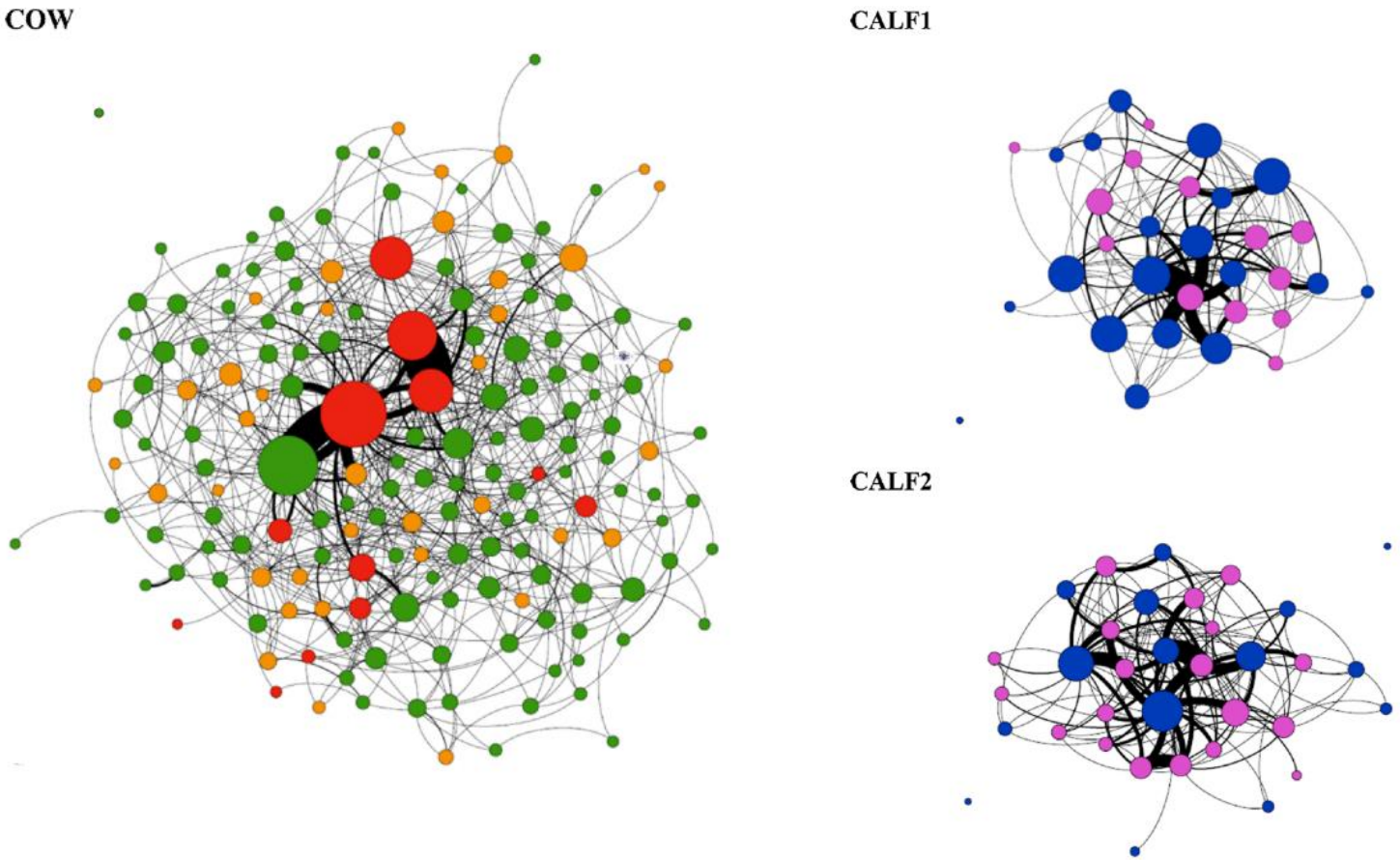
SNA applications in animals



Network of cattle movements in the Spanish region of CyL in 2005.
SNA offers important benefits for the assessment of epidemiological conditions, factors and forces associated with **risk for animal disease spread**

(Martínez-López et al., 2009)

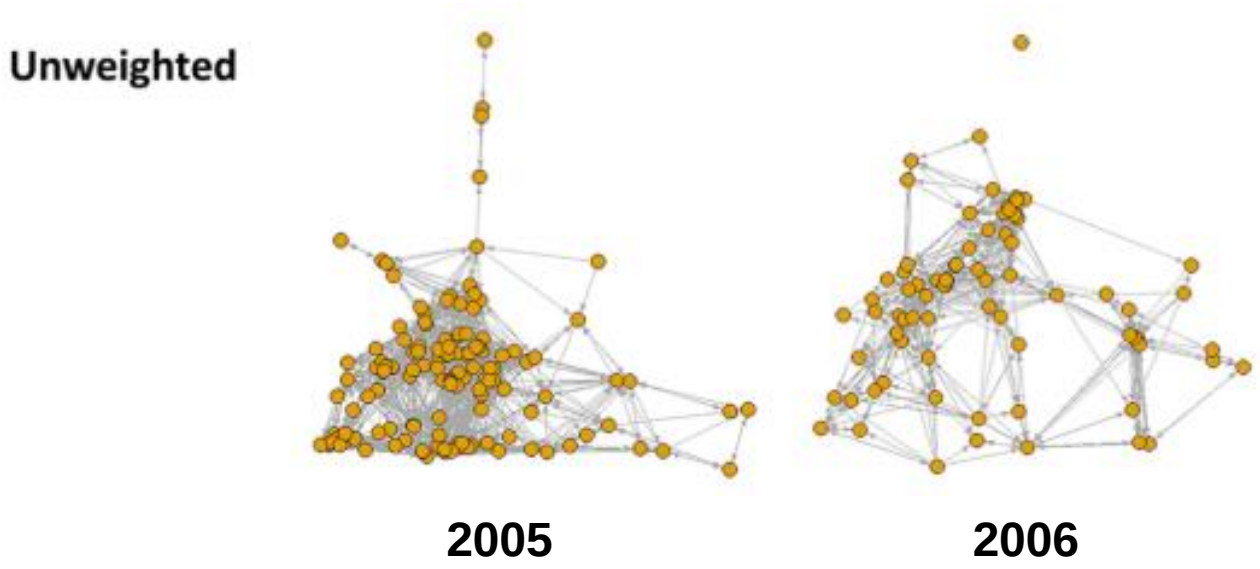
SNA applications in animals



Focused on three contact behaviours that may lead to transmission of pathogenic *Leptospira* spp.: **sniffing, licking and rubbing the face** on the genital area of another animal

(de Freslon et al., 2019)

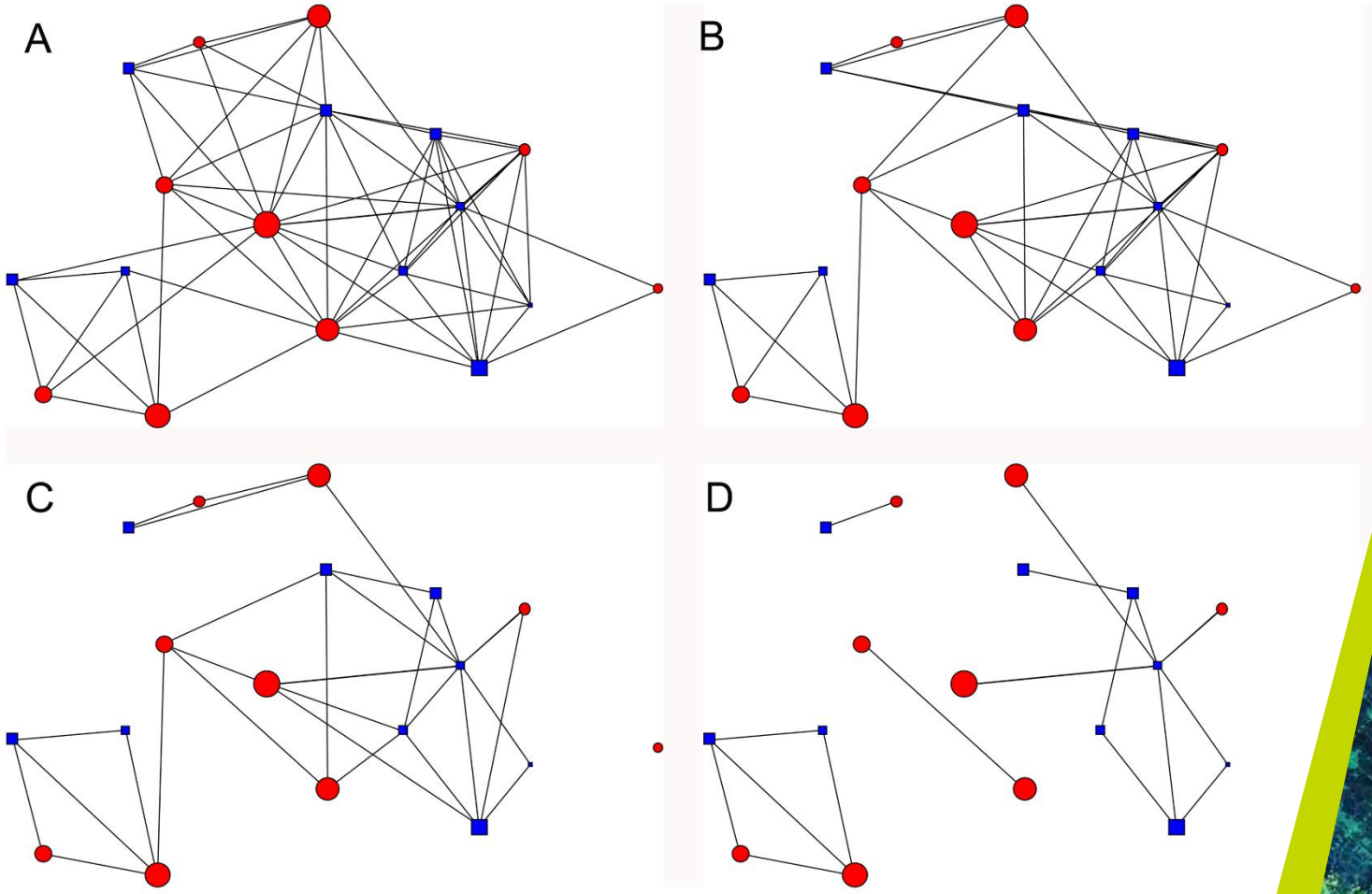
Studies based on infection data



Studies that estimate the role of **scrape-related contact** relative to other types of indirect contact or direct contact will be important for **understanding the potential impacts on chronic wasting disease (CWD)** transmission dynamics.

(Egan et al., 2023)

Studies based on infection data



These findings demonstrate that **raccoon populations are much more tightly connected** than would have been predicted based on previous studies, but also point out that additional research is needed to calculate more precise transmission probabilities by infected individuals (Rabies, canine distemper, parvovirus, leptospirosis, etc.).

(Hirsch et al., 2013)

SNA applications

Behav Ecol Sociobiol (2009) 63:989–997
DOI 10.1007/s00265-009-0742-5

REVIEW

Potential banana skins in animal social network analysis

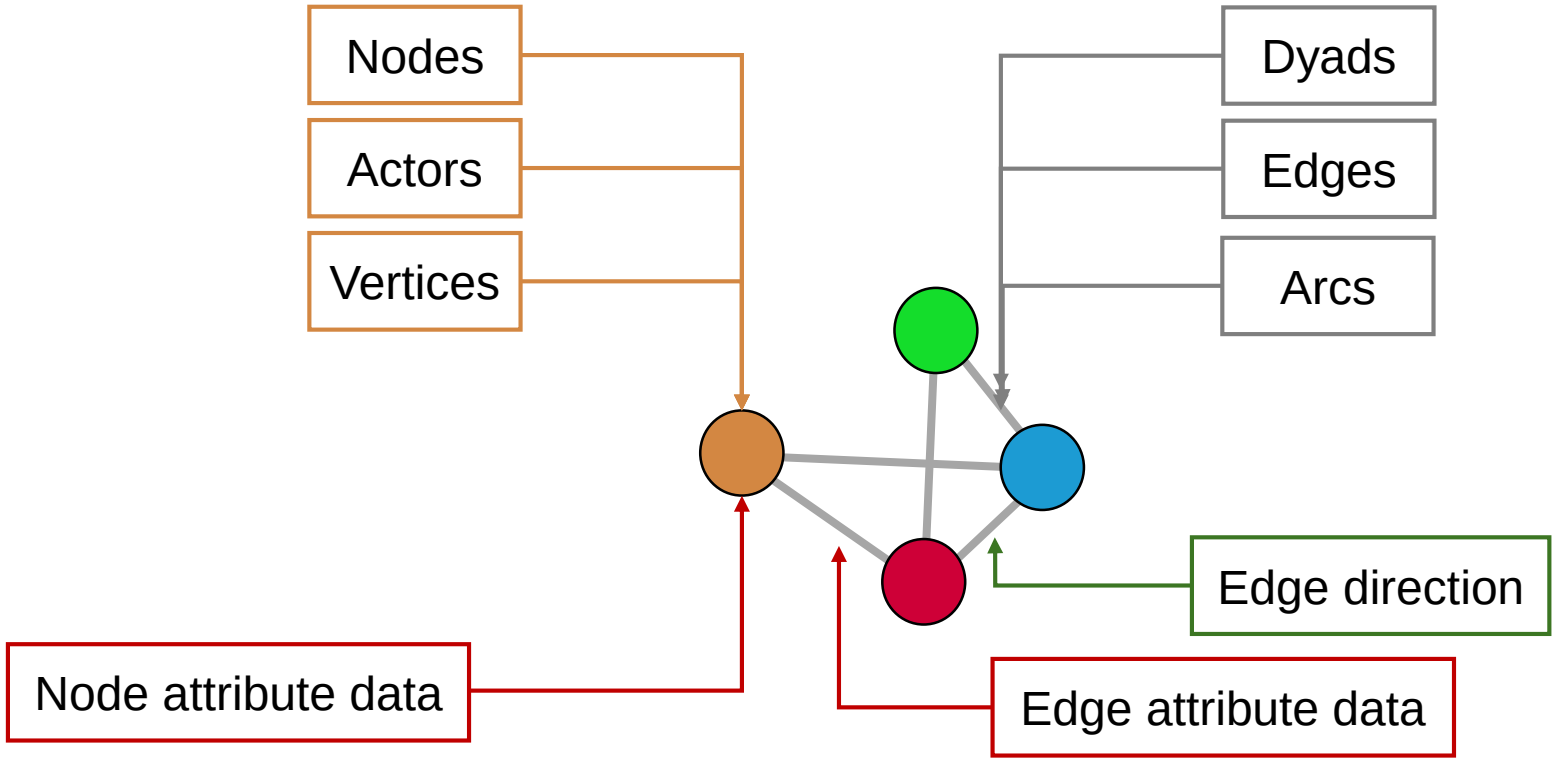
Richard James · Darren P. Croft · Jens Krause

- Observation errors
- Choice of statistical tests
- Is our interpretation appropriate?

(James et al., 2009)

What is a network?

Part of the networks

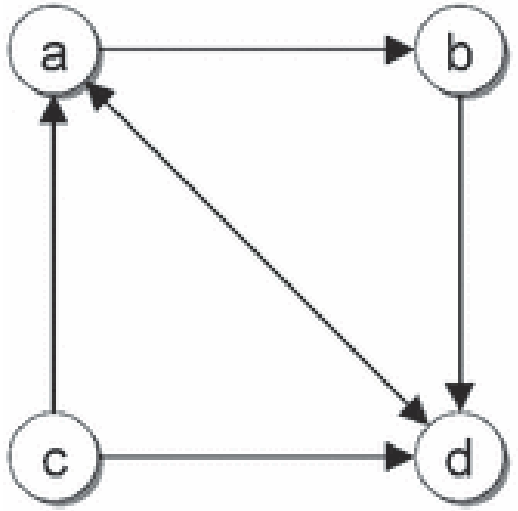


Ways to represent networks

Adjacency matrix

	a	b	c	d
a	0	1	0	1
b	0	0	0	1
c	1	0	0	1
d	1	0	0	0

Graph



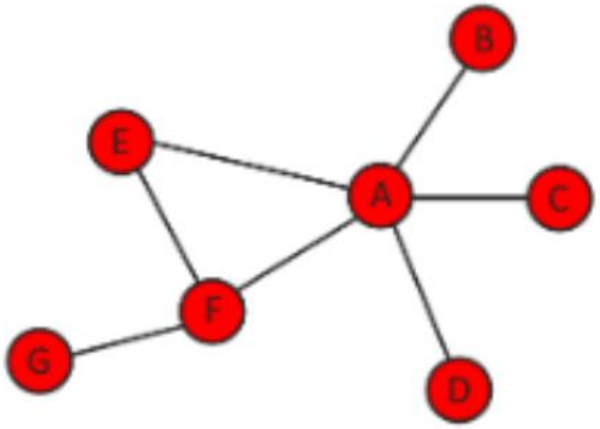
Notation

$$G = \{(a, b), (a, d), (b, d), (c, a), (c, d), (d, a)\}$$

(Martínez-López et al., 2009)

Ways to represent networks

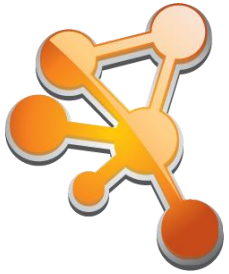
A	B
A	C
A	D
A	E
A	F
E	F
F	G



	A	B	C	D	E	F	G
A	0	1	1	1	1	1	0
B	1	0	0	0	0	0	0
C	1	0	0	0	0	0	0
D	1	0	0	0	0	0	0
E	1	0	0	0	0	1	0
F	1	0	0	0	1	0	1
G	0	0	0	0	0	1	0

Software

Network analysis software



Cytoscape

sna igraph network

networkX igraph

Session: New Session

File Edit View Select Layout Apps Tools Help

Enter search term...

Network

Enter search terms for NDEx...

Drag network files here

Welcome to Cytoscape

Recent Sessions

Cytoscape_Edge_table...

Sample Sessions

Affinity Purification

Import & Save

Ivacaftor Coauthor

Styles Demo

TCGA Colorectal Cancer

Yeast Gene Interactions

Yeast Perturbation

Tutorials News

Node Table

Drag table files here

Command Line

Node Table Edge Table Network Table

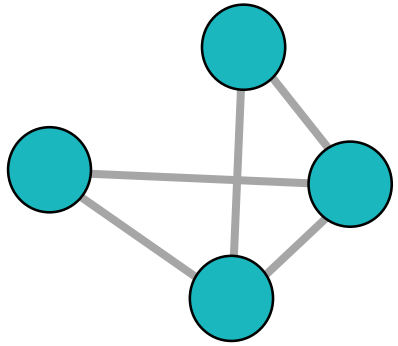
Style Filter Annotation Layout Tools

Descriptive properties of networks

Ways to analyze the information

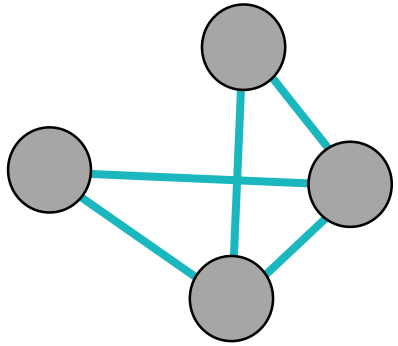
individual- level models

focuses on an **individual-level outcome, network data are used to define explanatory variables**



relational-level models

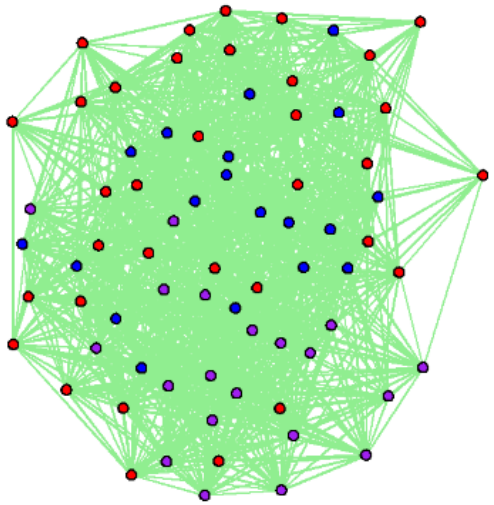
focuses on an **dyad-level,** analyse the **relationship** rather than a characteristic of particular individuals



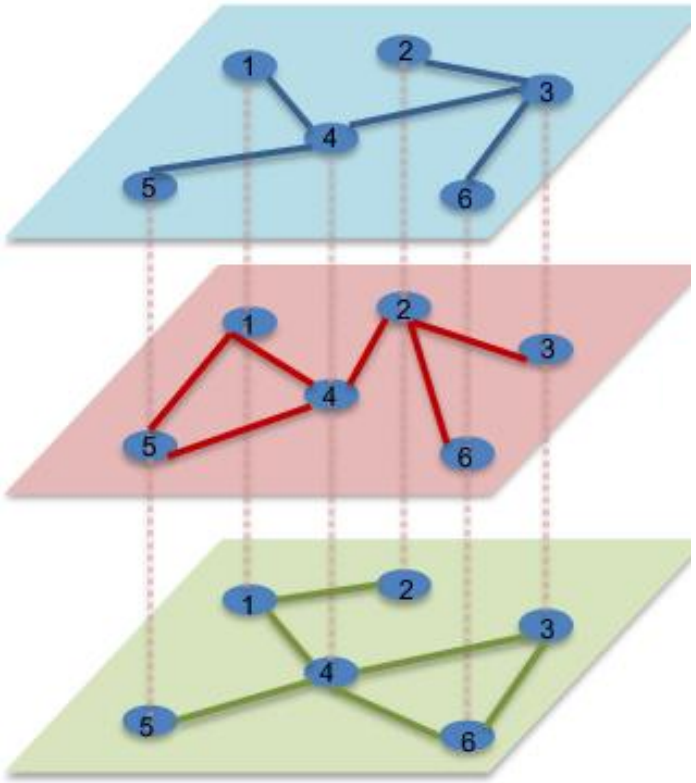
(O´Malley et al., 2008)

Network dimensions

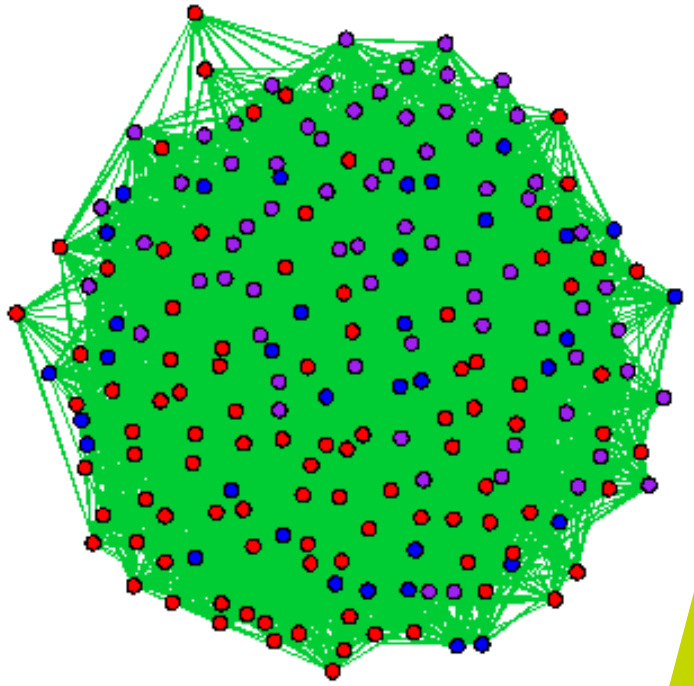
Unidimensional data



Multidimensional data



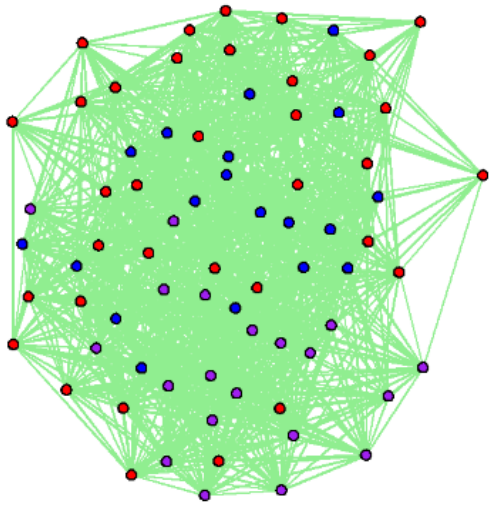
Longitudinal data



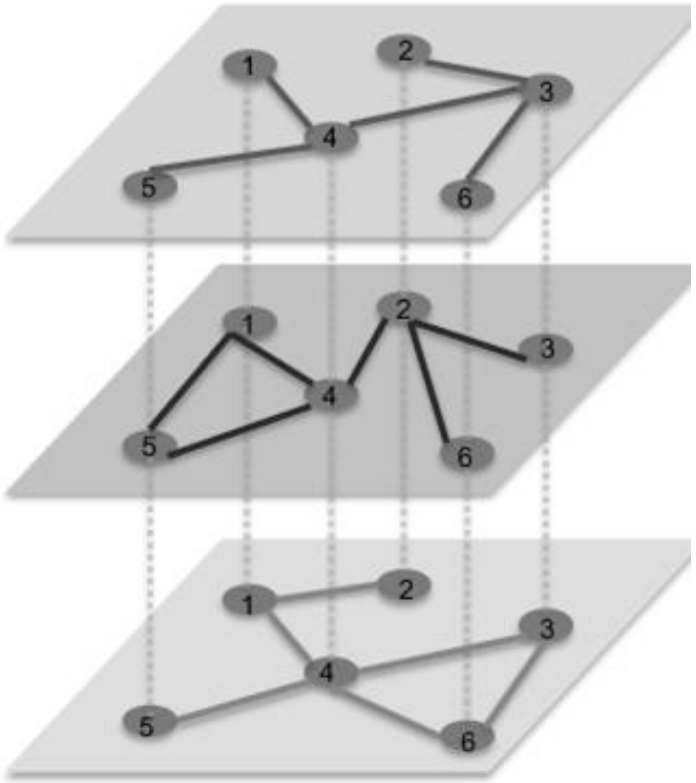
Time

Network dimensions

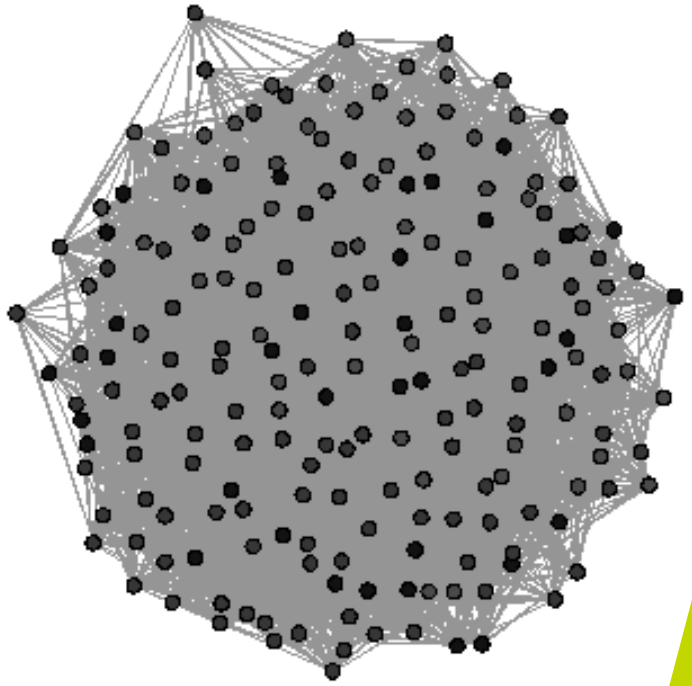
Unidimensional data



Multidimensional data

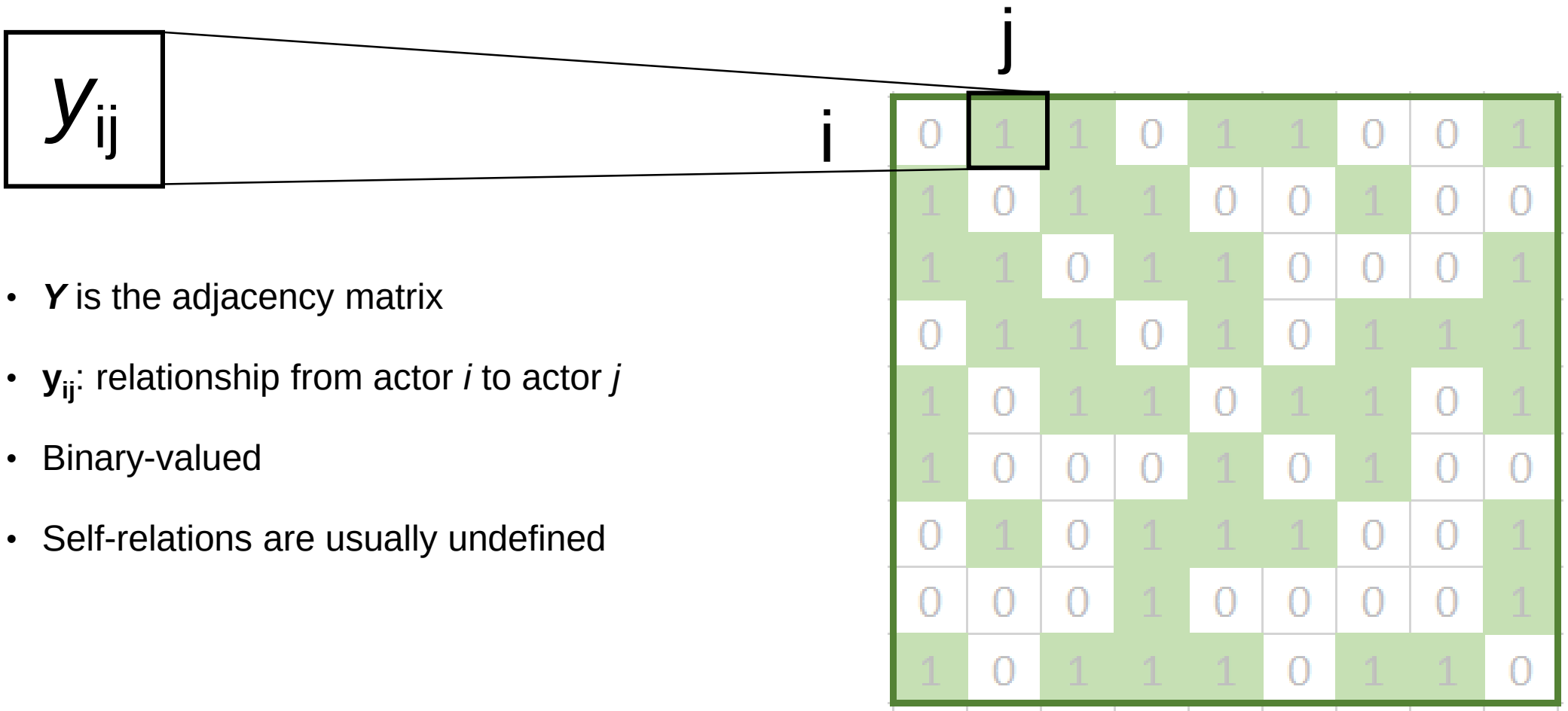


Longitudinal data



Time

Descriptive properties of networks



- ***Y*** is the adjacency matrix
- $\mathbf{y_{ij}}$: relationship from actor *i* to actor *j*
- Binary-valued
- Self-relations are usually undefined

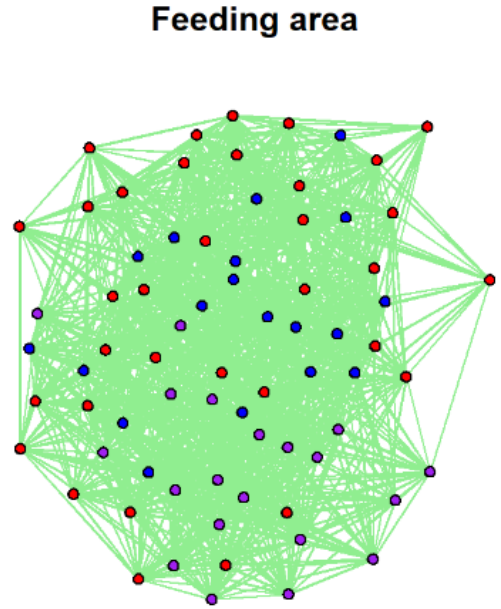
(O´Malley et al., 2008)

Descriptive properties of networks

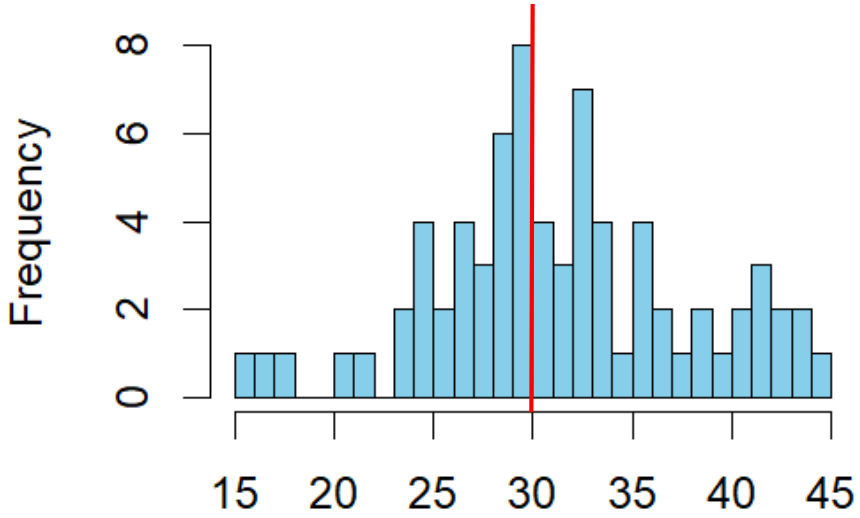
1) Size and density of the network

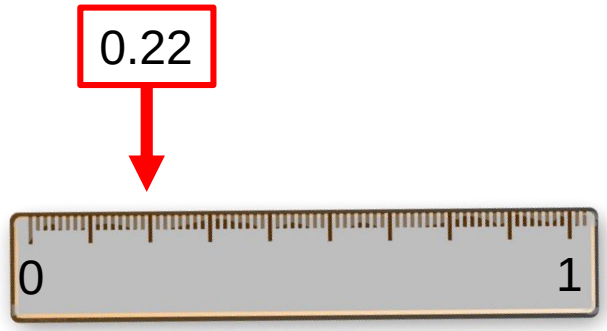
$$L/(N(N-1))$$

$$(L = \sum_{i,j} y_{ij})$$



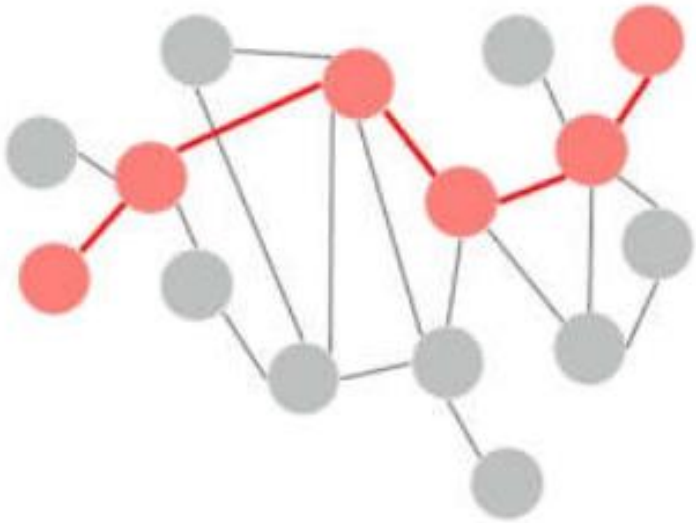
2) Degree and the degree distribution

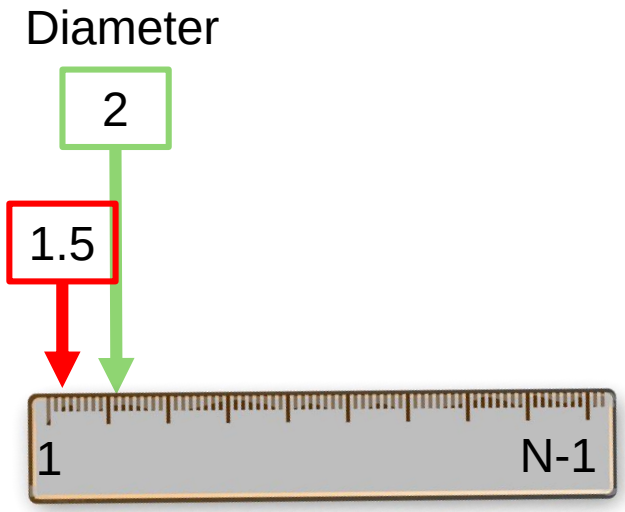




Descriptive properties of networks

3) Geodesic distance:



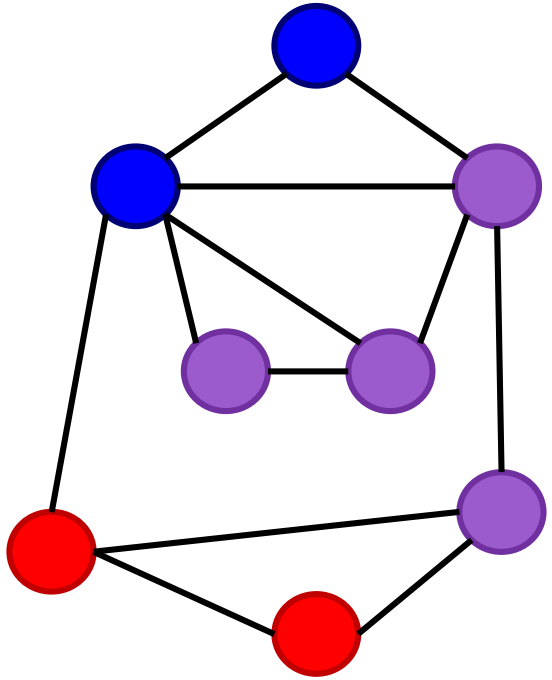


Descriptive properties of networks

4) Centrality parameters:

Degree:

- The simplest is based on an actor's degree
- Reflects an actor's level of network activity or involvement



Descriptive properties of networks

4) Centrality parameters:

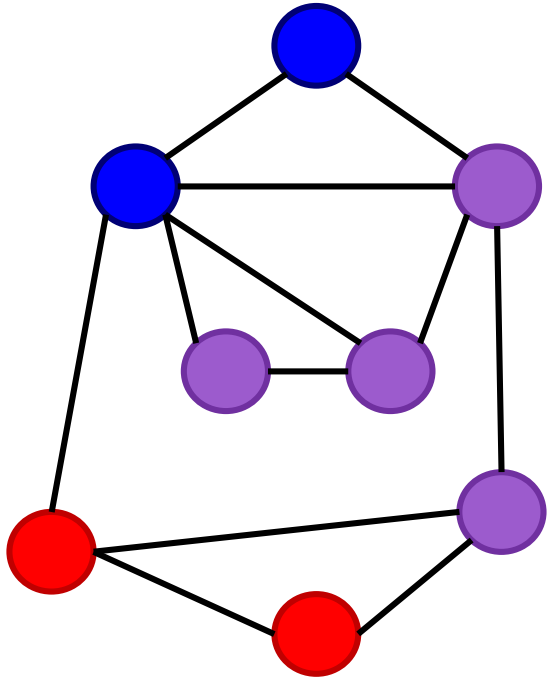
Betweenness:

- Number of times a node acts as a bridge along the shortest path between two other nodes

Shortest path from s->t
that cross through v

$$g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

Shortest path from s->t



Descriptive properties of networks

4) Centrality parameters:

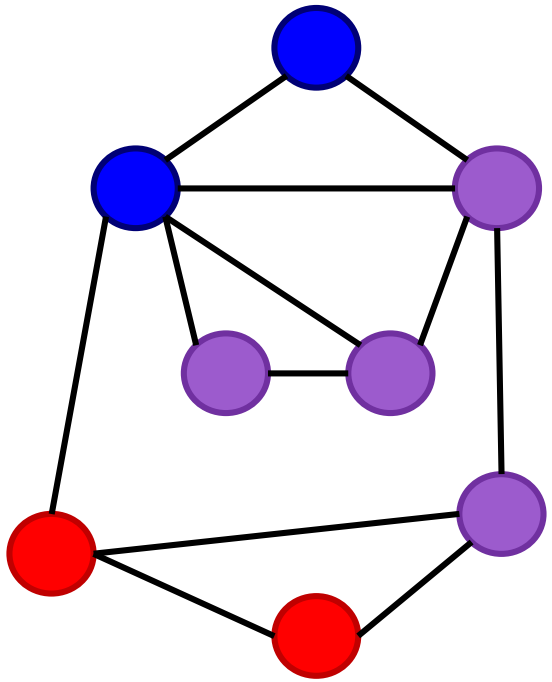
Closeness:

- Sum of the length of the shortest paths between the node and all other nodes in the graph

$$C(v) = \frac{N-1}{\sum_u d(u,v)}.$$

← Number of nodes in the graph

← Distance between vertices u and v

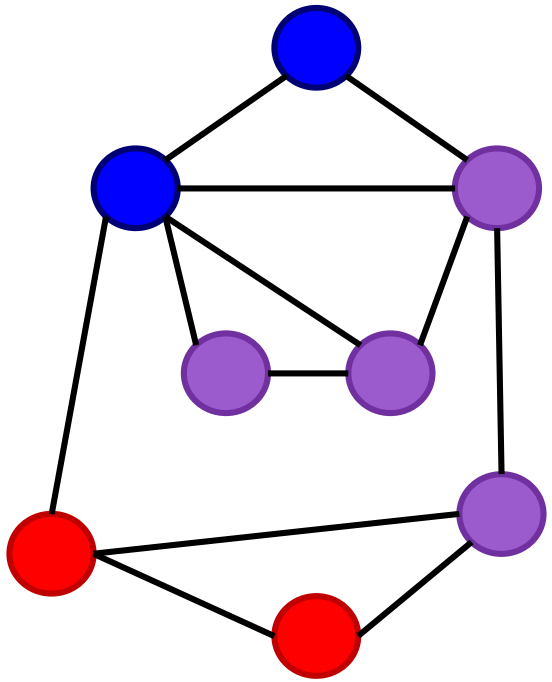


Descriptive properties of networks

4) Centrality parameters:

Eigenvector:

- Principal eigenvector using the adjacency matrix
- Measures a node's importance while giving consideration to the importance of its neighbors

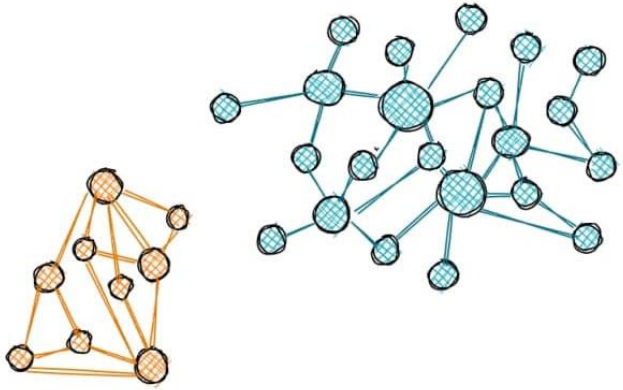


Descriptive properties of networks

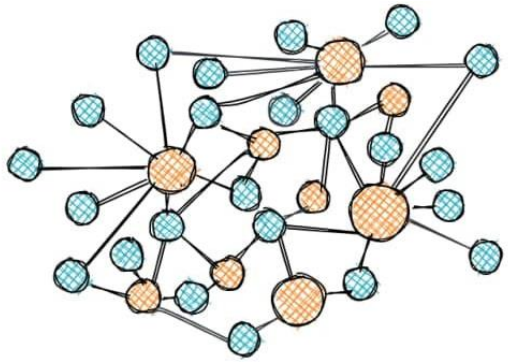
5) Homophily:

- Represents the propensity of individuals to interact with others of similar characteristics

Homophily



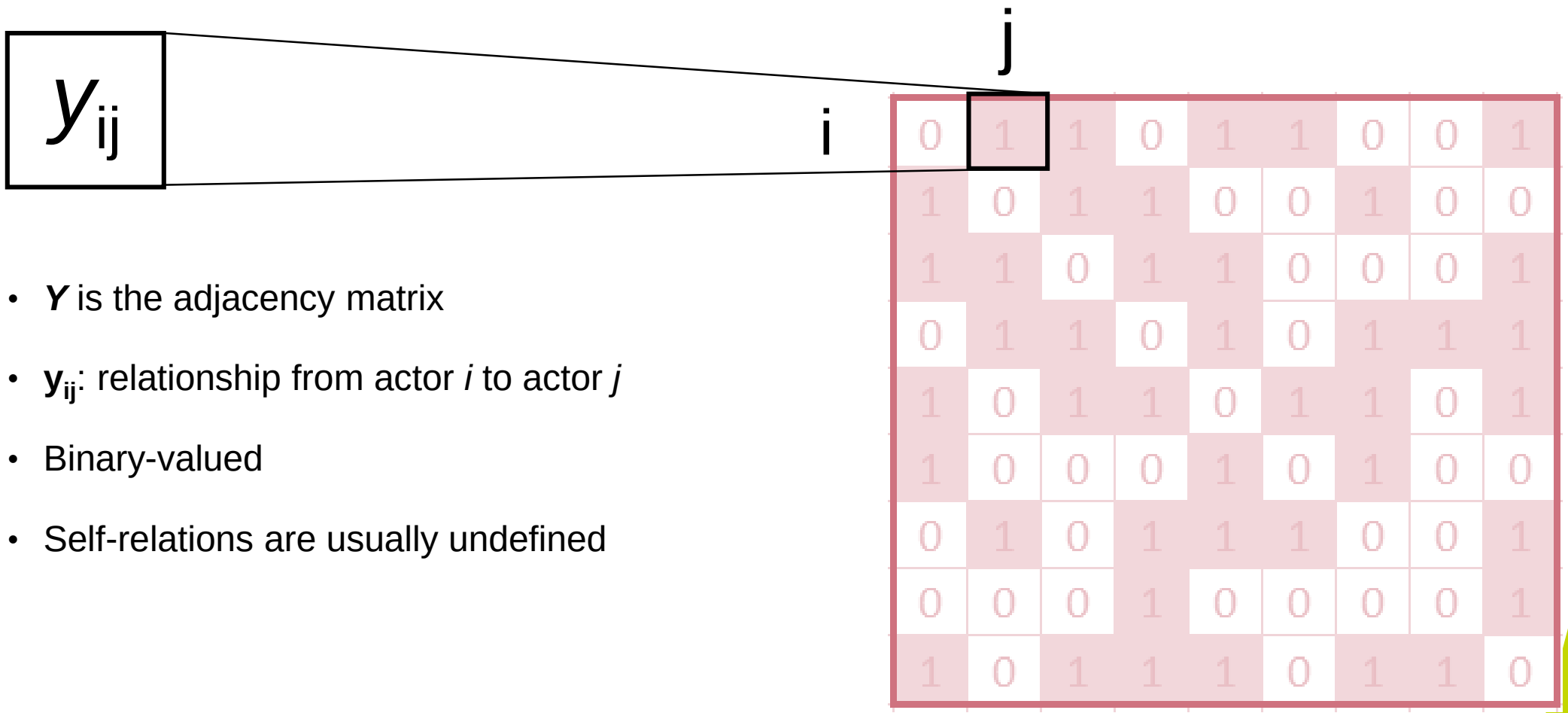
Heterophily



Dyad-level models

Relational or dyad-level models

- Exponential random graph models (ERGMs):



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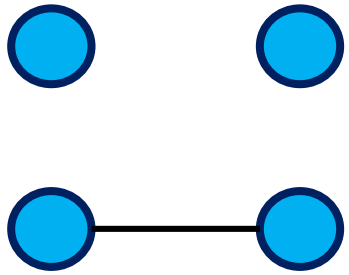
- Binary-valued
- Self-relations are usually undefined

Relational or dyad-level models

- Exponential random graph models (ERGMs):

y_{ij}



Absence

Presence

$$\text{logit}\mathrm{P}(Y_{ij} = 1) = \mu + \beta x_{ij}$$

Intercept

Logistic regression

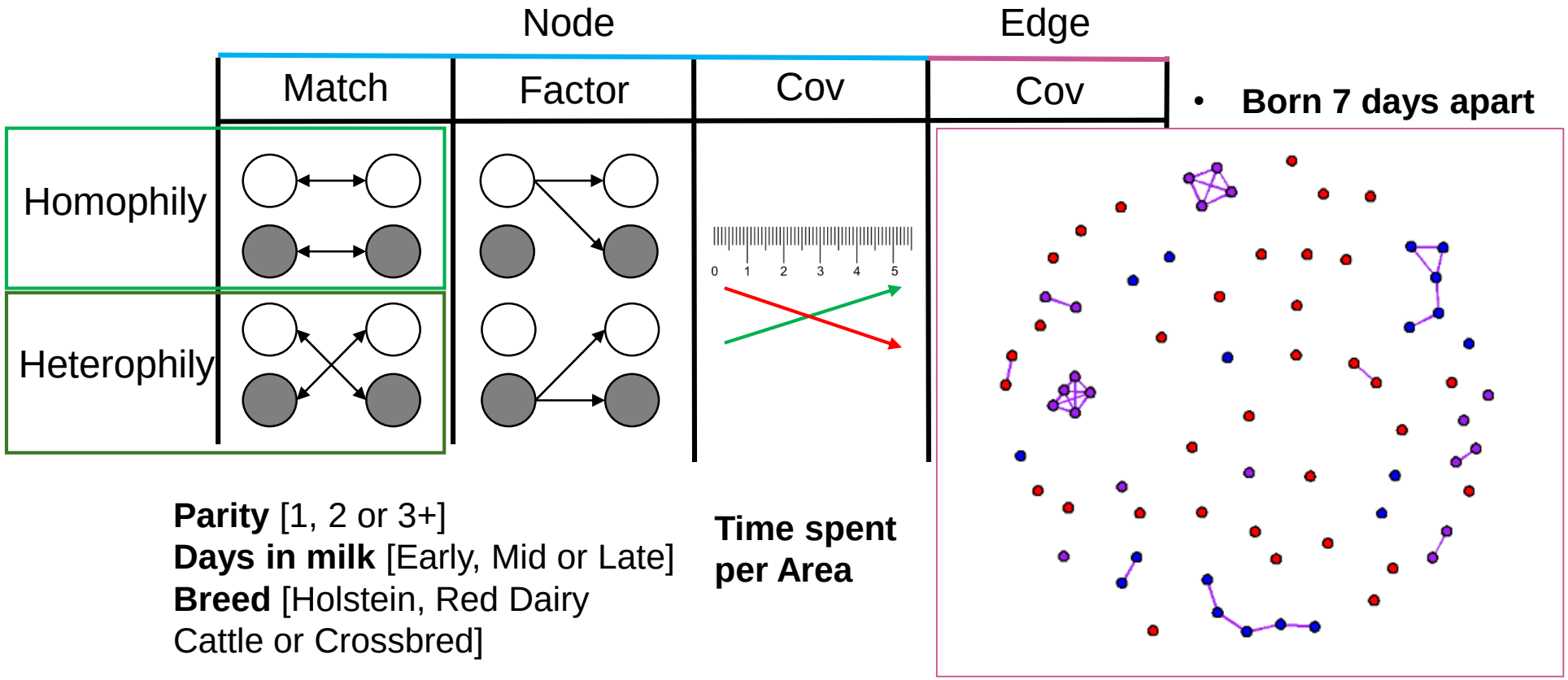
Covariable

Relational or dyad-level models

- Exponential random graph models (ERGMs):

$$\begin{aligned}\text{logit}\mathrm{P}(Y_{ij}=1) = {} & \mu_{edges} + \beta_{breed_k} x_{nt,breed_k} \\ & + \gamma_{breed} x_{nf,bread} + \beta_{claw\,health_l} x_{nf,claw\,health_l} \\ & + \gamma_{\text{claw health}} x_{nm,\text{claw health}} + \beta_{lactation\,stage_p} x_{nf,lactation\,stage_p} \\ & + \gamma_{lactation\,stage} x_{nm,lactation\,stage} + \beta_{\text{parity}_q} x_{nf,\text{parity}_q} \\ & + \gamma_{parity} x_{nm,\text{parity}} + \beta_{pregnancy\,status} x_{nf,pregnancy\,status} \\ & + \gamma_{pregnancy\,status} x_{nm,\text{pregnancy status}} + \gamma_{AGEcont} x_{nm,AGEcont} \\ & + \gamma_{DIMcont} x_{nm,DIMcont} + \beta_{REL} x_{edge,REL} + \beta_{time\,in\,area} x_{time\,in\,area,}\end{aligned}$$

Relational or dyad-level models

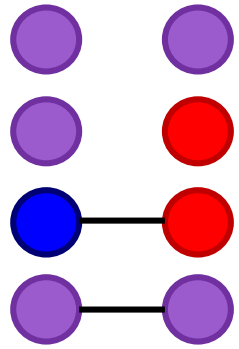


Parity [1, 2 or 3+]
Days in milk [Early, Mid or Late]
Breed [Holstein, Red Dairy Cattle or Crossbred]

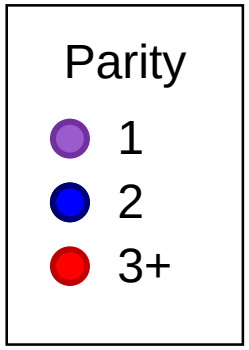
Time spent per Area

Relational or dyad-level models

- Exponential random graph models (ERGMs):



	Parity		TimeInArea	AGEnet
	Match	Factor	Cov	Cov
$Y_{ij} = 0$	1	0 0	0.22+0.43	1
$Y_{ik} = 0$	0	0 1	0.22+0.33	0
$Y_{jk} = 1$	0	1 1	0.56+0.33	0
$Y_{im} = 1$	1	0 0	0.22+0.13	0



Spatial interactions

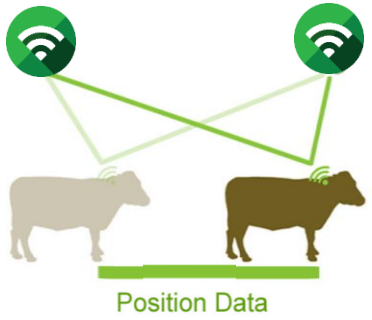
Social interactions

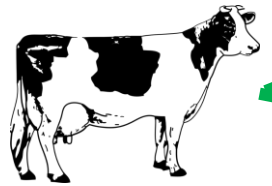
Ultra-Wide Band technology

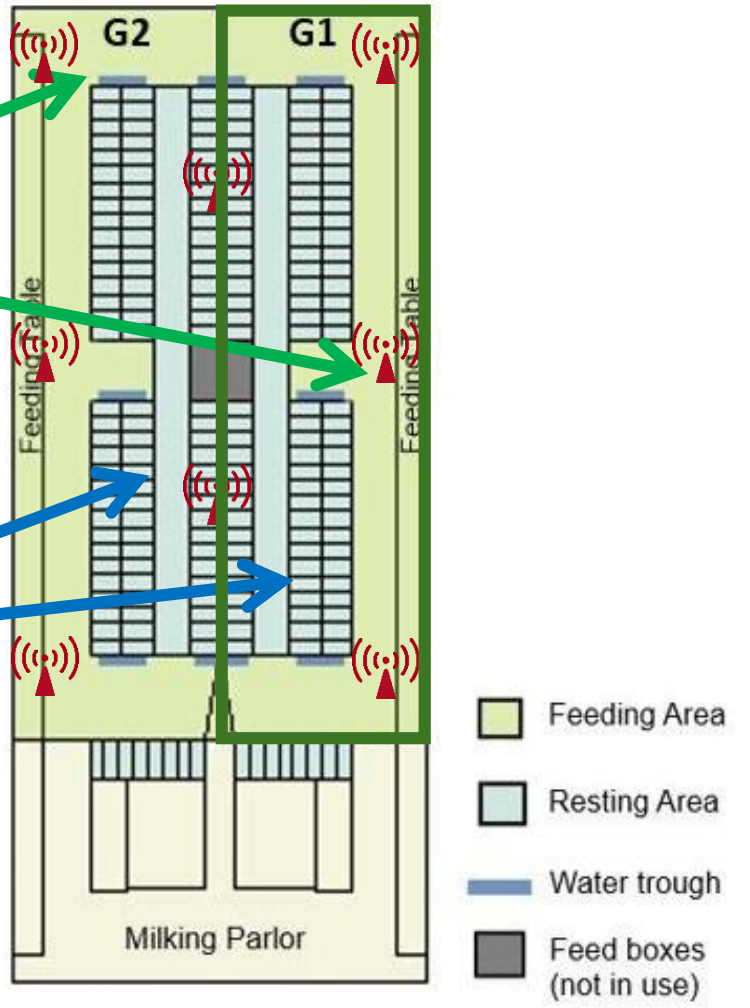
- Collecting positions of all cows every second
- Spatial interactions
- Real time information

Spatial interactions

Real-time Location System

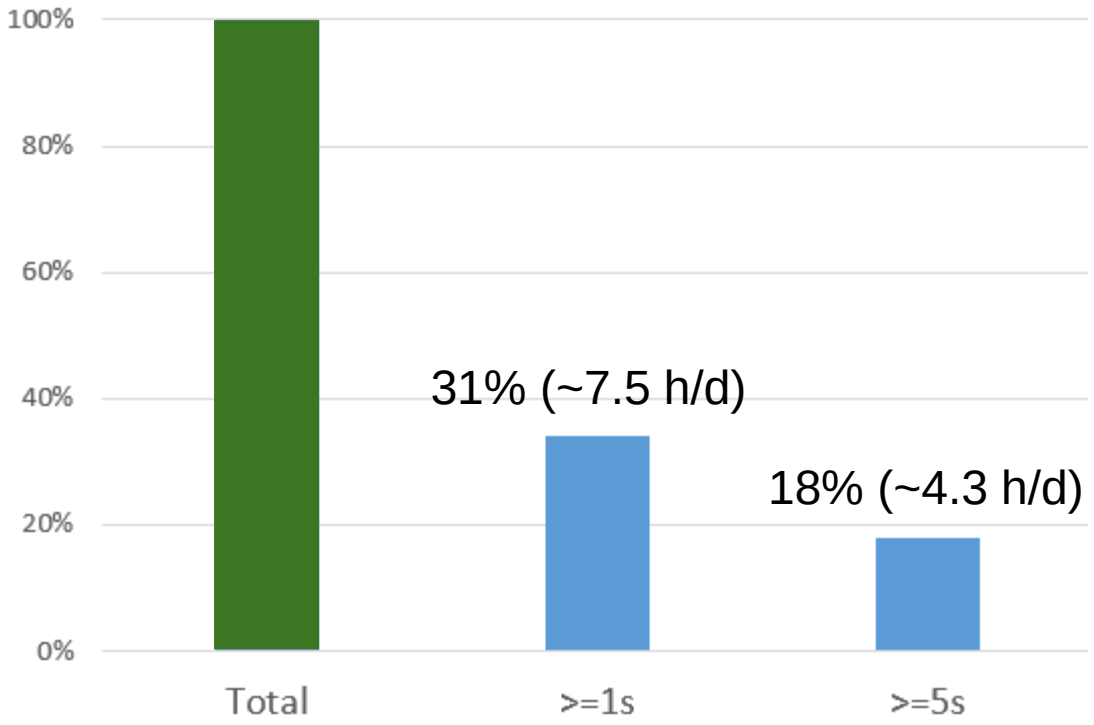




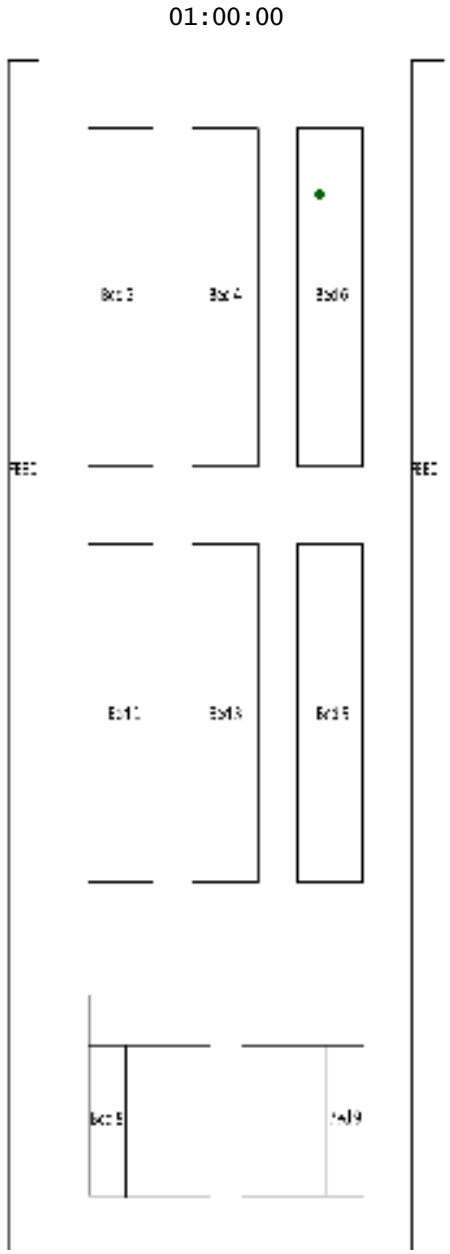


(Hansson et al., 2023)

Interpolation

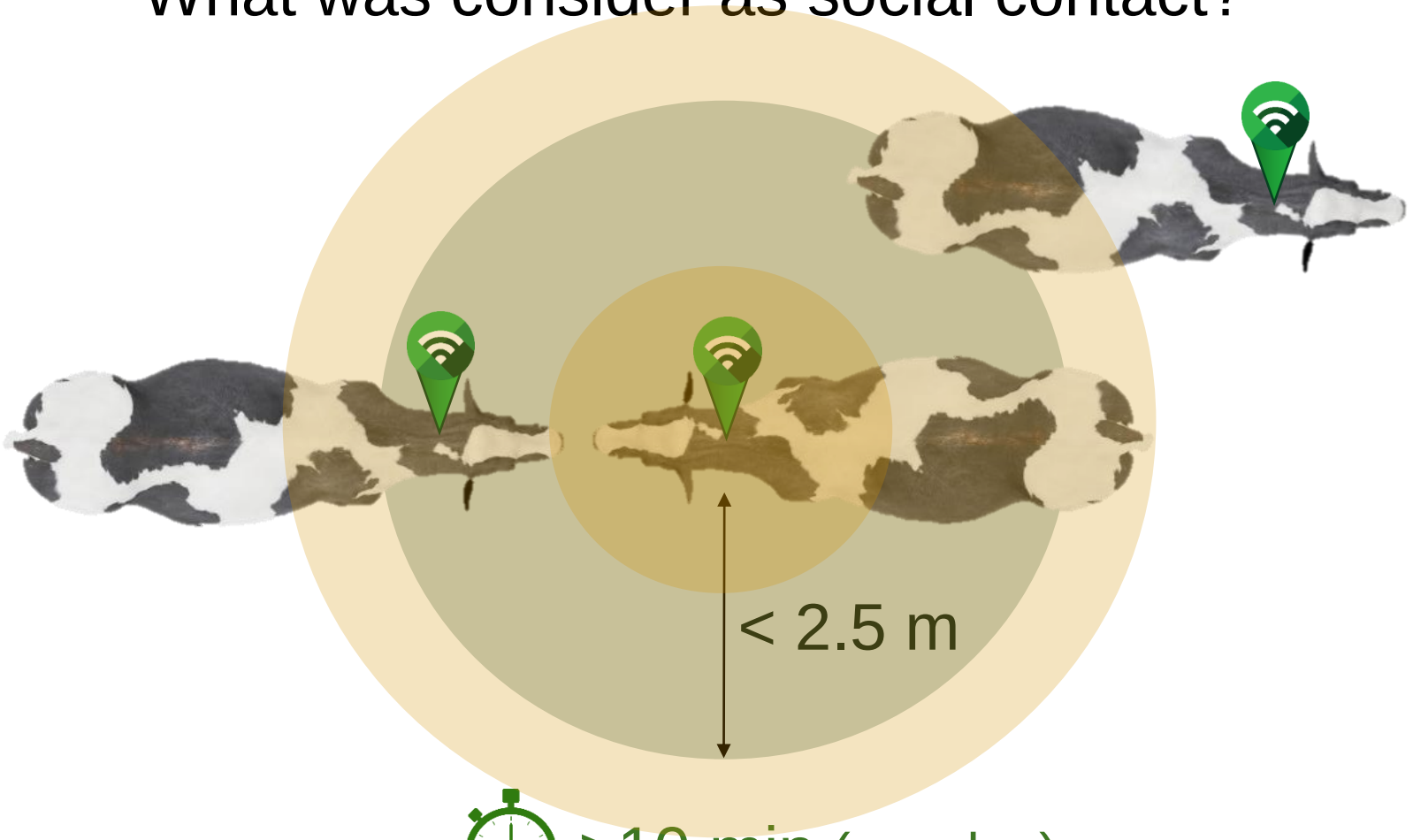


(Ren et al., 2021)



Spatial interactions

What was consider as social contact?



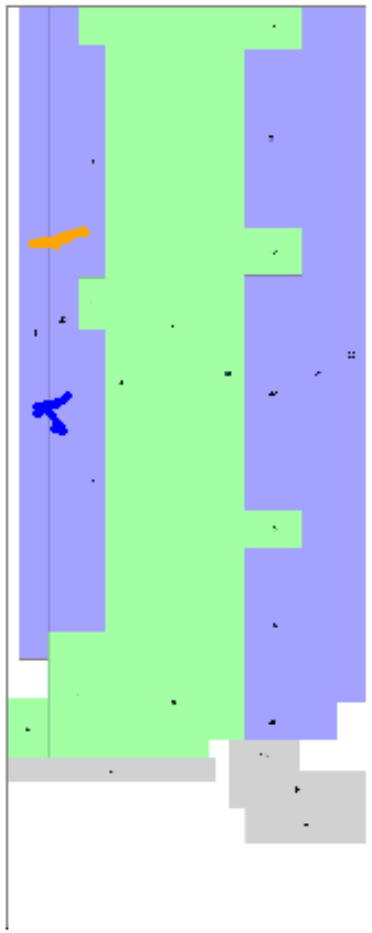
>10 min (per day)
>20 min (per day)
>30 min (per day)

Spatial interactions

Cow: 1

Cow: 2

Spatial contact

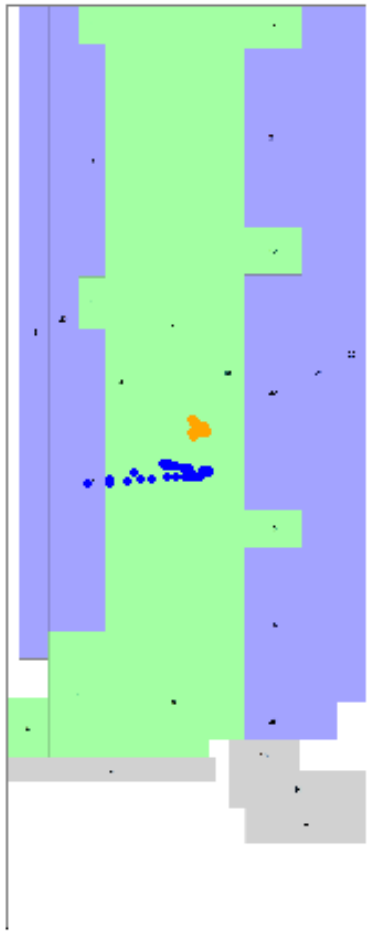


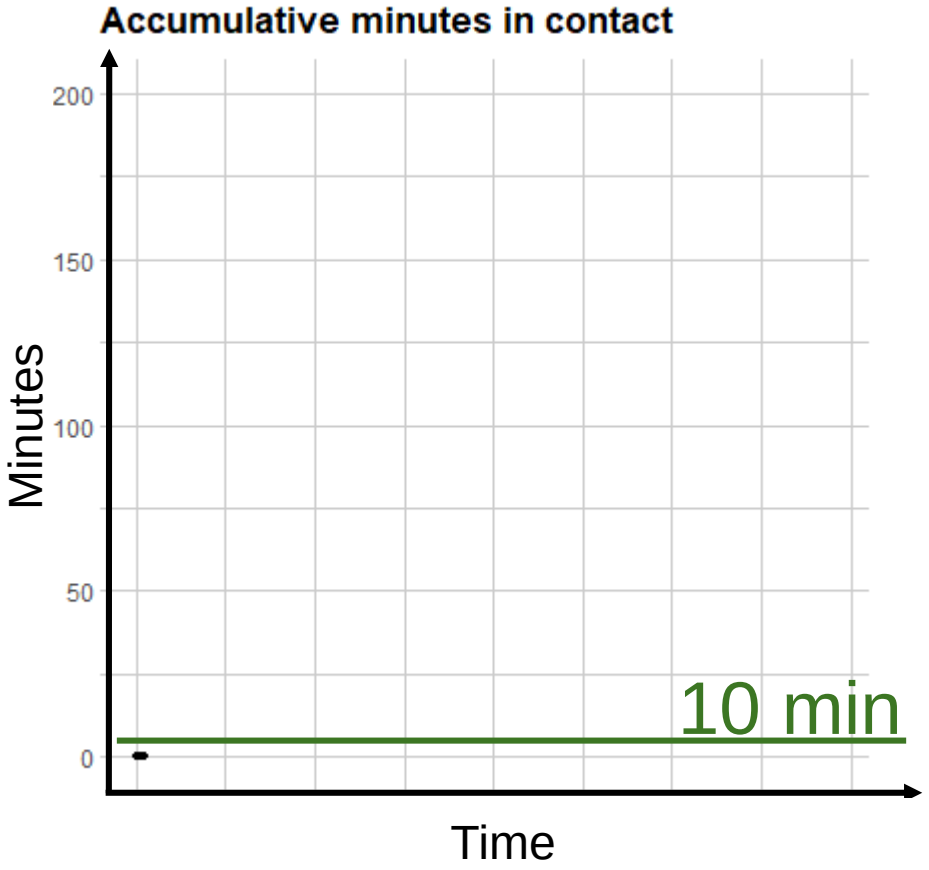
Spatial interactions

Cow: 1

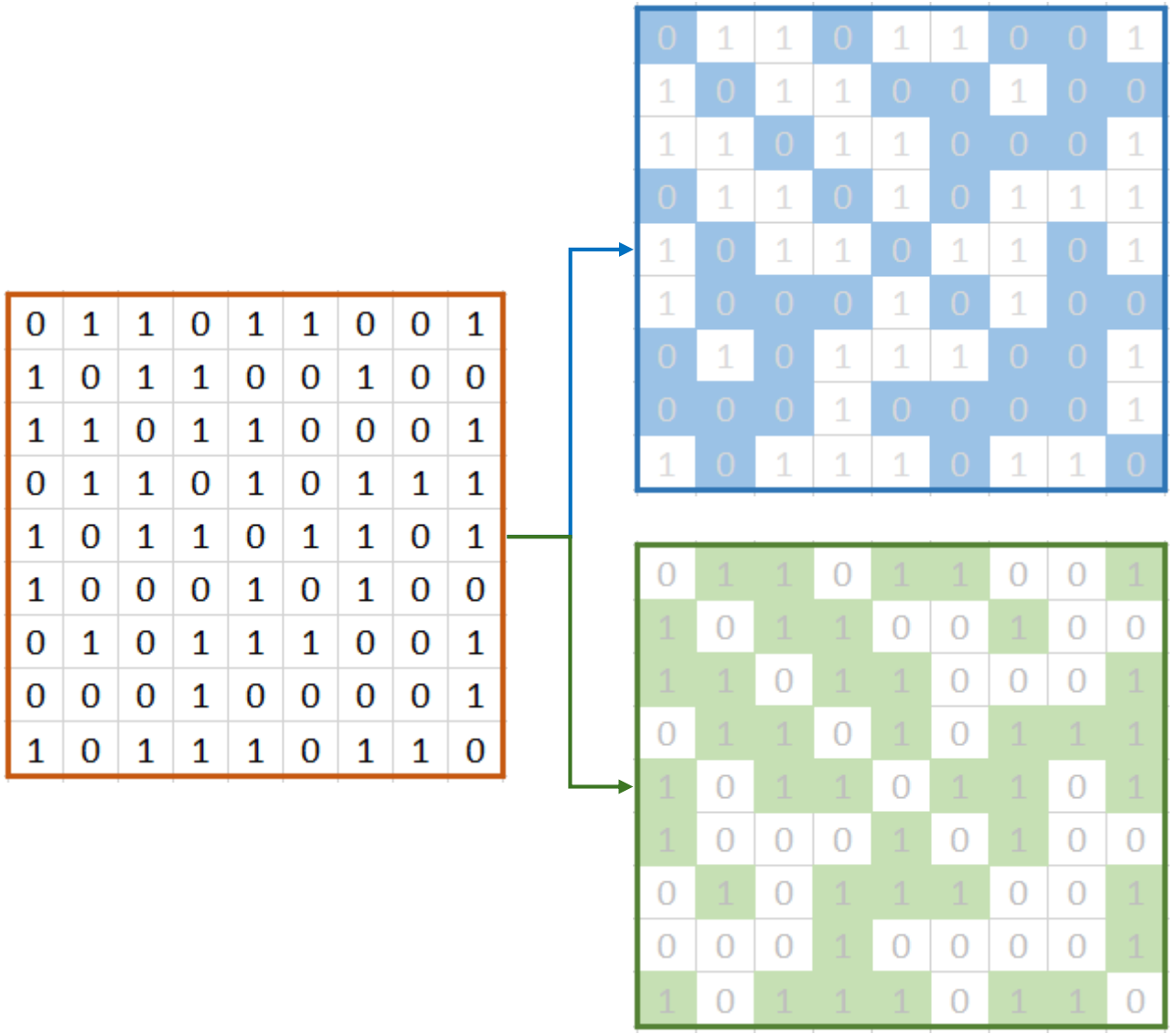
Cow: 2

Spatial contact

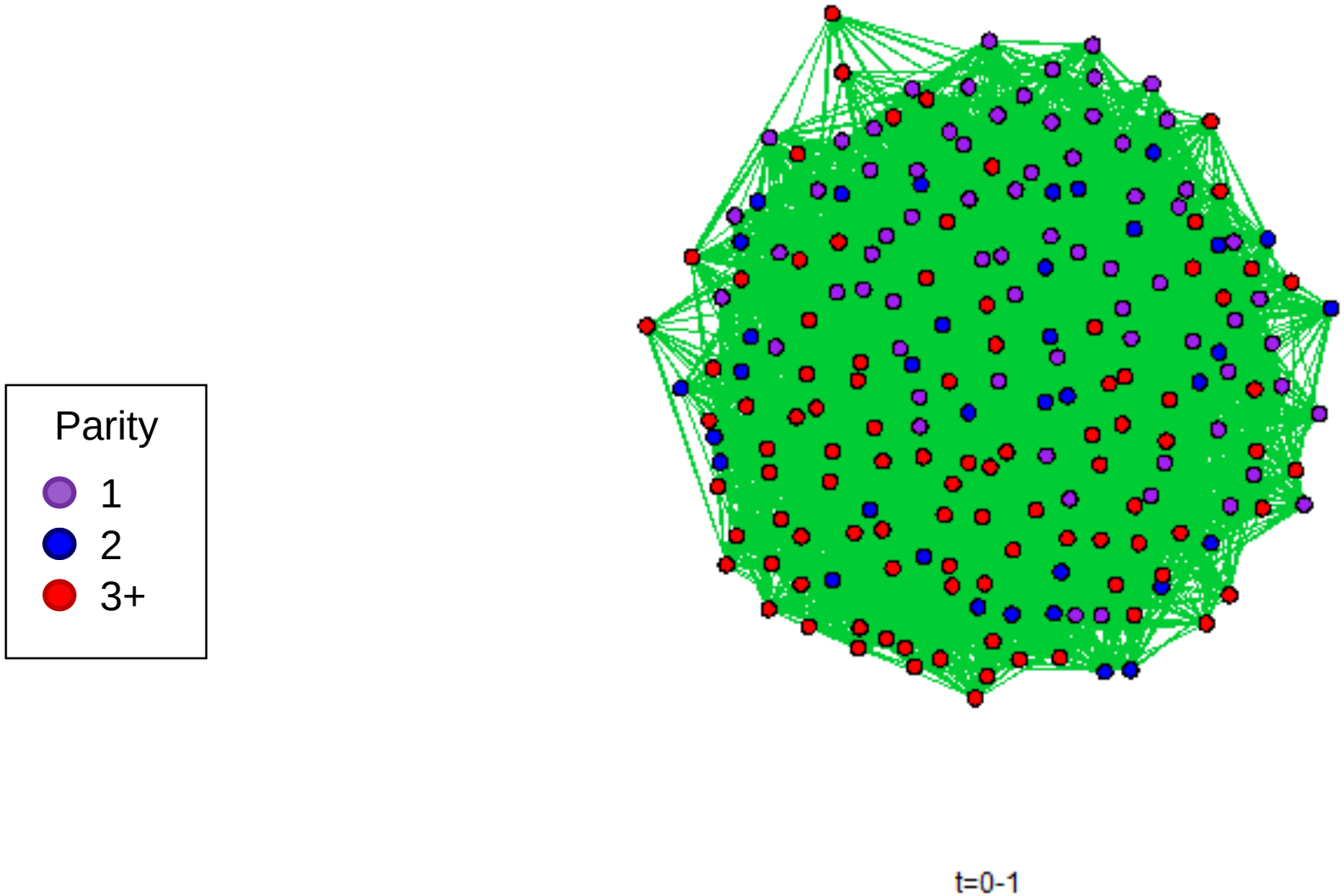




Spatial interactions



Spatial interactions




hands
on

Recommended literature

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9. S. Cauchemez, A. Bhattarai, T.L. Marchbanks, R.P. Fagan, S. Ostroff, N.M. Ferguson, D. Swerdlow, & the Pennsylvania H1N1 working group, S.V. Sodha, M.E. Moll, F.J. Angulo, R. Palekar, W.R. Archer, & L. Finelli, Role of social networks in shaping disease transmission during a community outbreak of 2009 H1N1 pandemic influenza, Proc. Natl. Acad. Sci. U.S.A. 108 (7) 2825-2830, https://doi.org/10.1073/pnas.1008895108 (2011).
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11. Hirsch BT, Prange S, Hauver SA, Gehrt SD (2013) Raccoon Social Networks and the Potential for Disease Transmission. PLoS ONE 8(10): e75830. https://doi.org/10.1371/journal.pone.0075830

6th PLE workshop / seminar

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