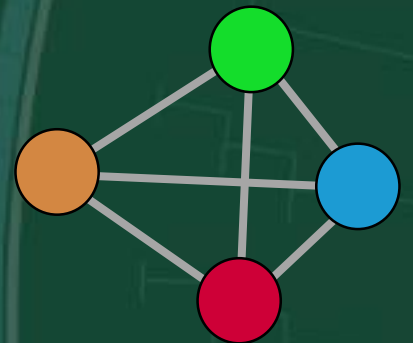
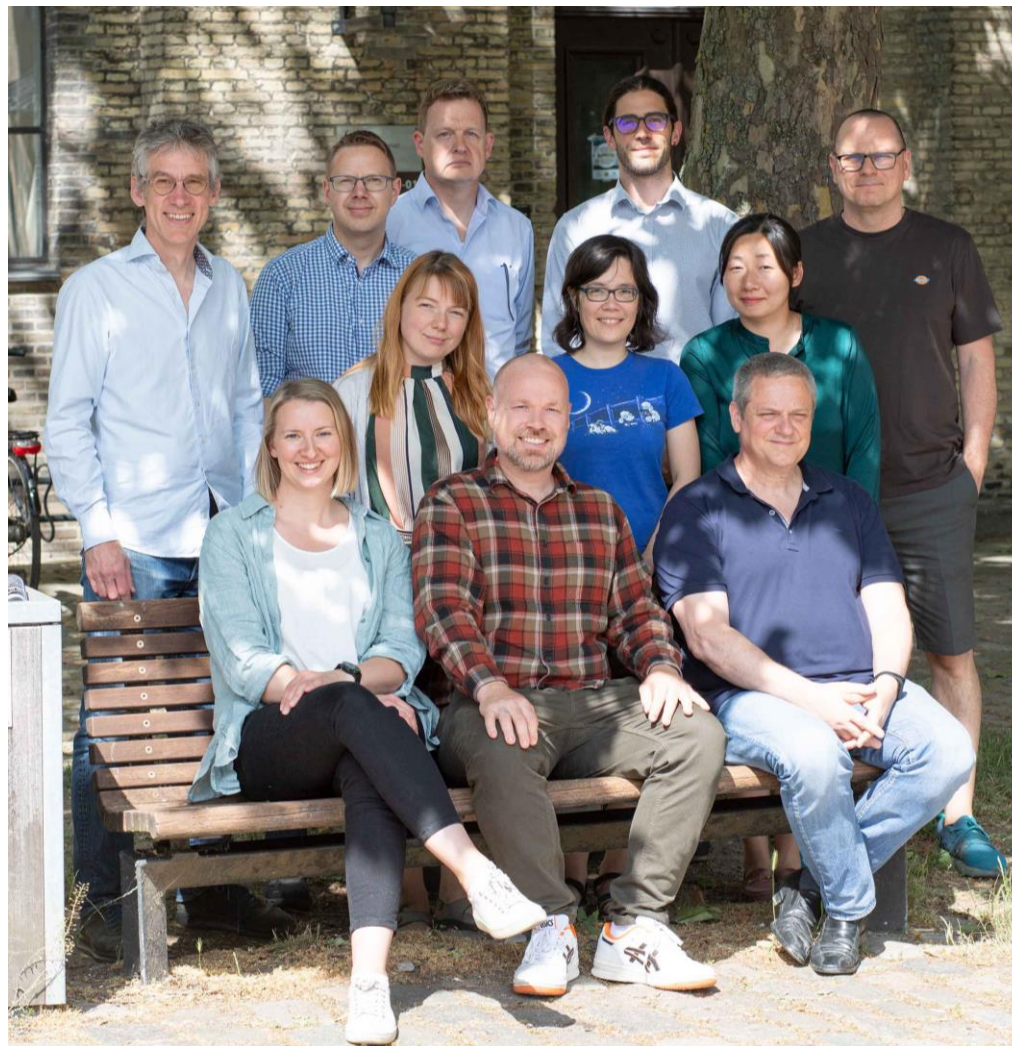
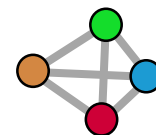


# Social network analysis

Hector Marina



# Cow Social Interaction: Disease Transmission





## Social interactions



Essential feature of  
cattle behavior

Meaningful social  
relationships

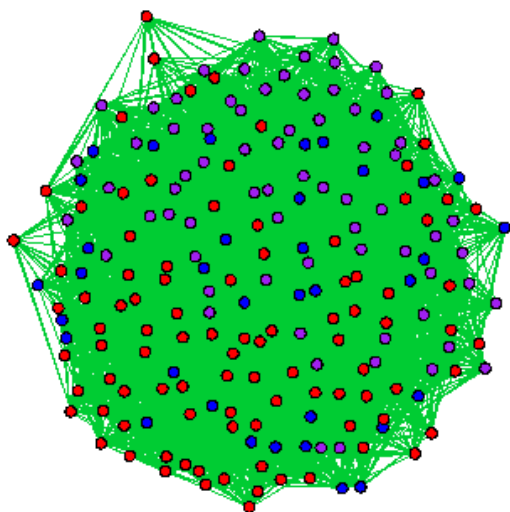
## Ultra-Wide Band technology



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



# Social networks



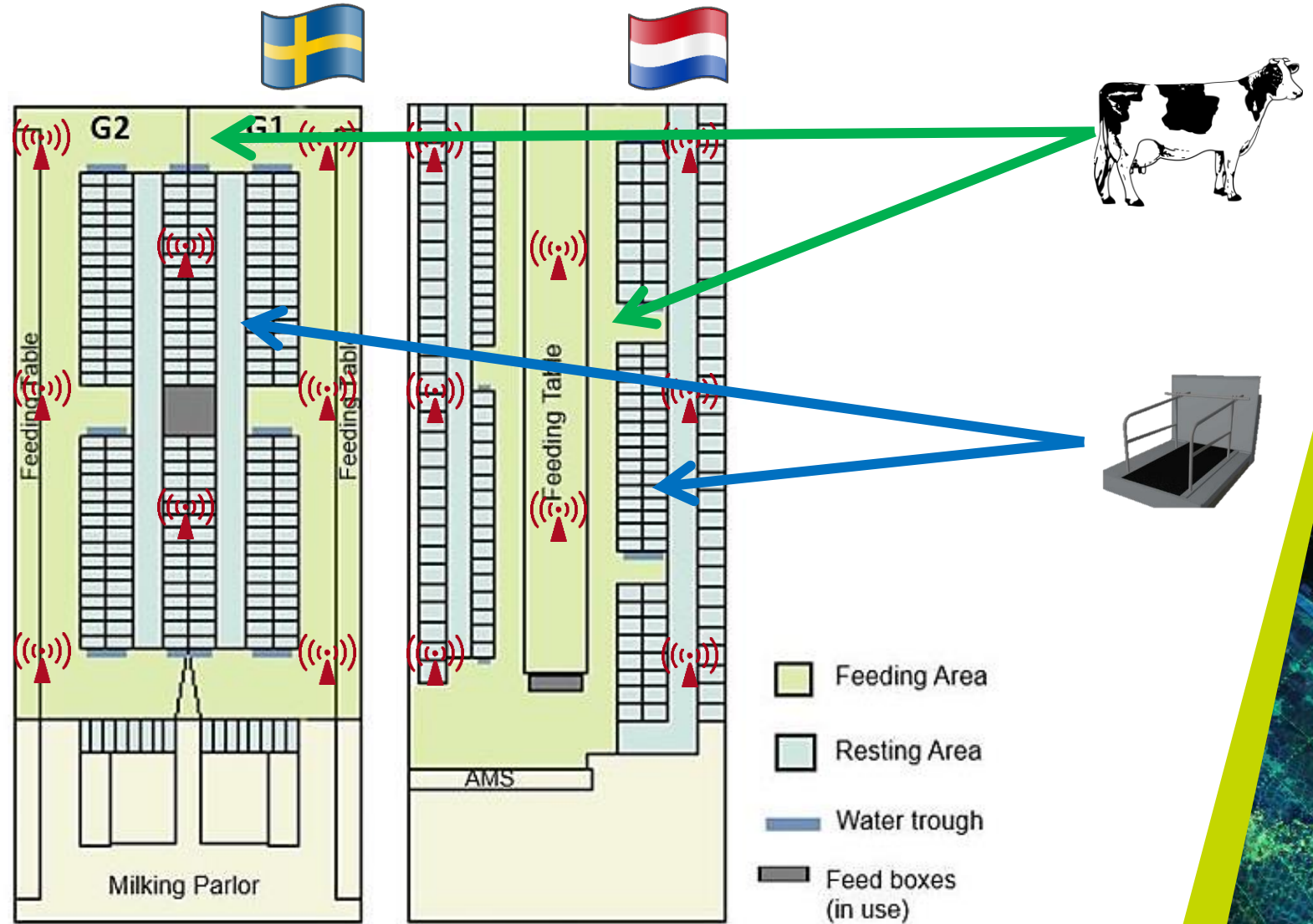
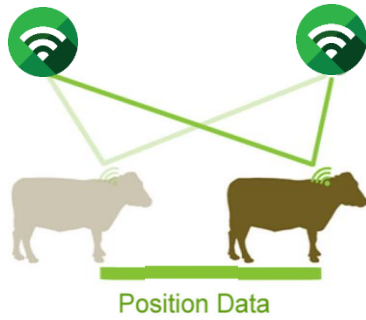
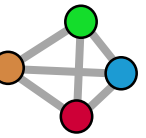
- Dynamics

- stERGM

Separable Temporal

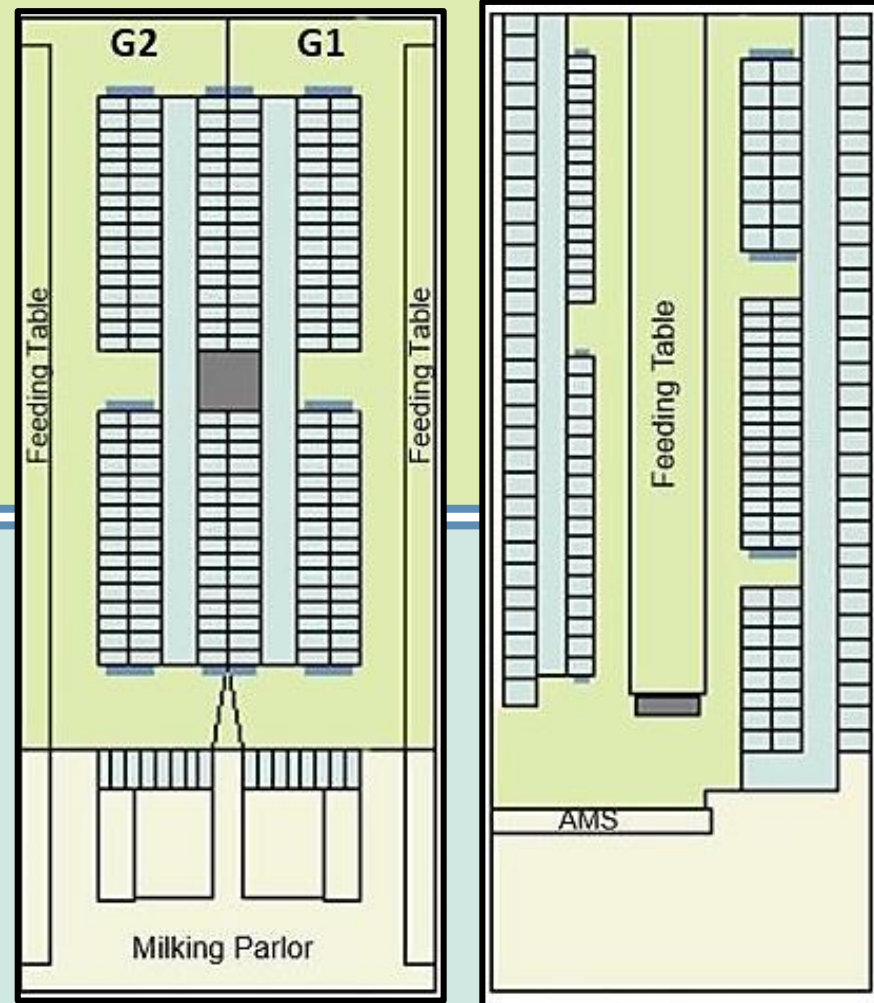
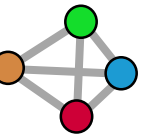


# Spatial interactions

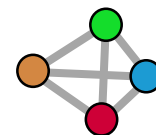





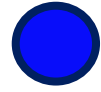
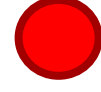


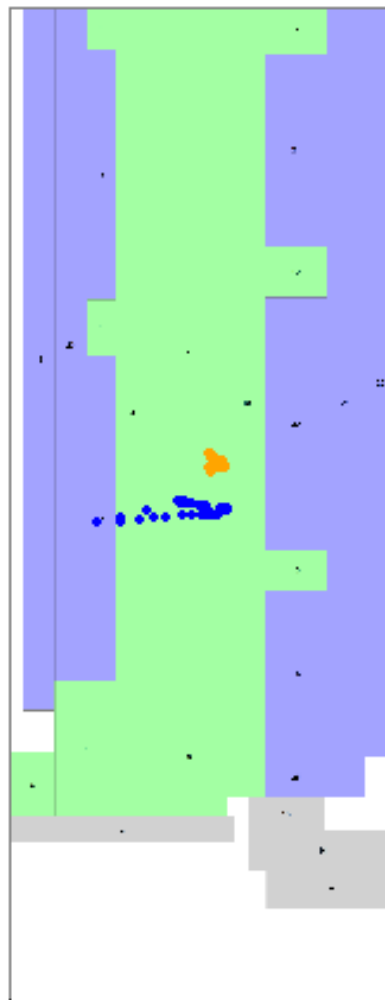
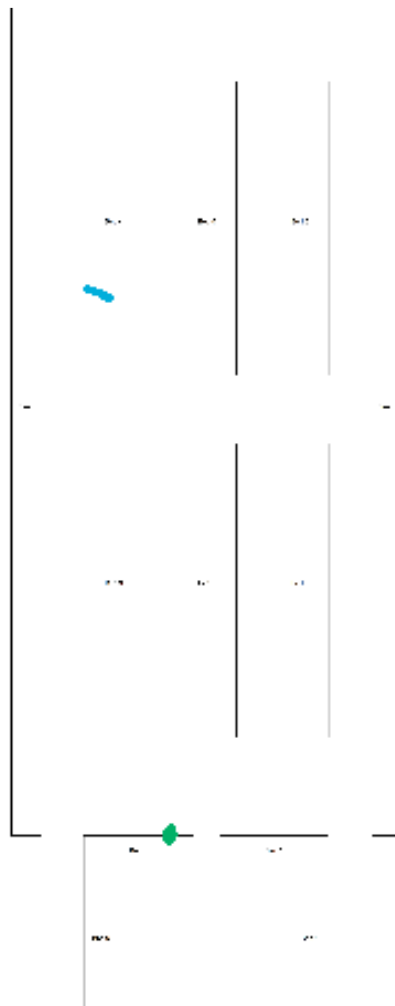
# Spatial interactions



# Spatial contacts



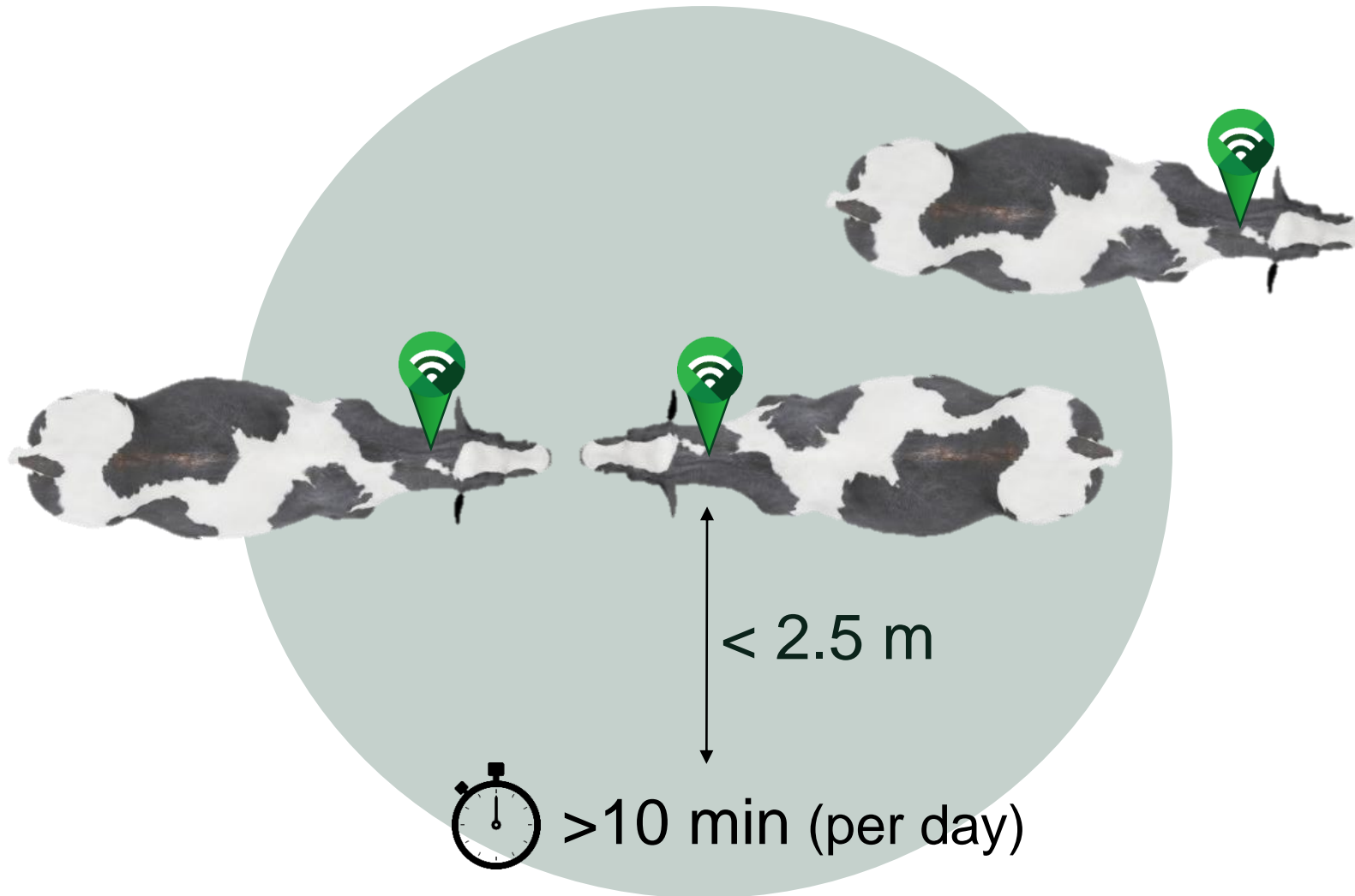
-  Cow: 1
-  Cow: 2
-  Cow: 3
-  Cow: 4
-  Spatial interaction



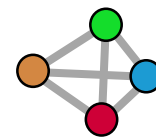


# Spatial contacts

What was consider as social contact?

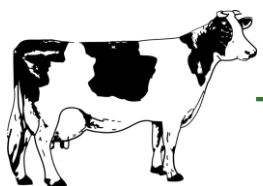


# Spatial contacts



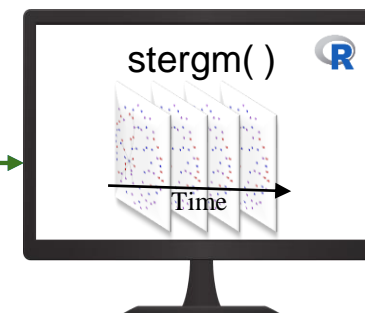
14 consecutive days:

- 2020-10-16
- 2020-10-29

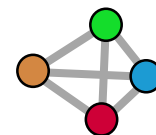


Information available:

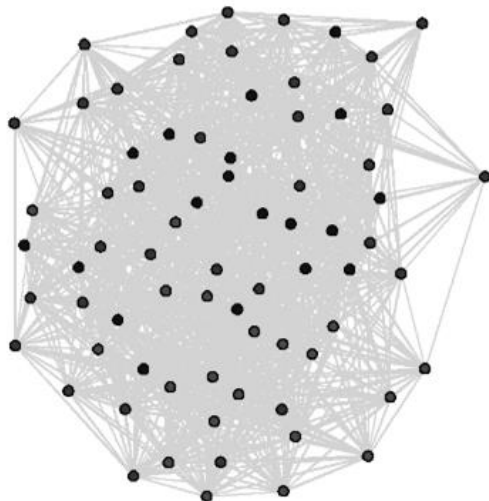
- Parity
- Lactation stage
- Claw health
- Breed
- Early life experience
- Dried off experience
- Pedigree



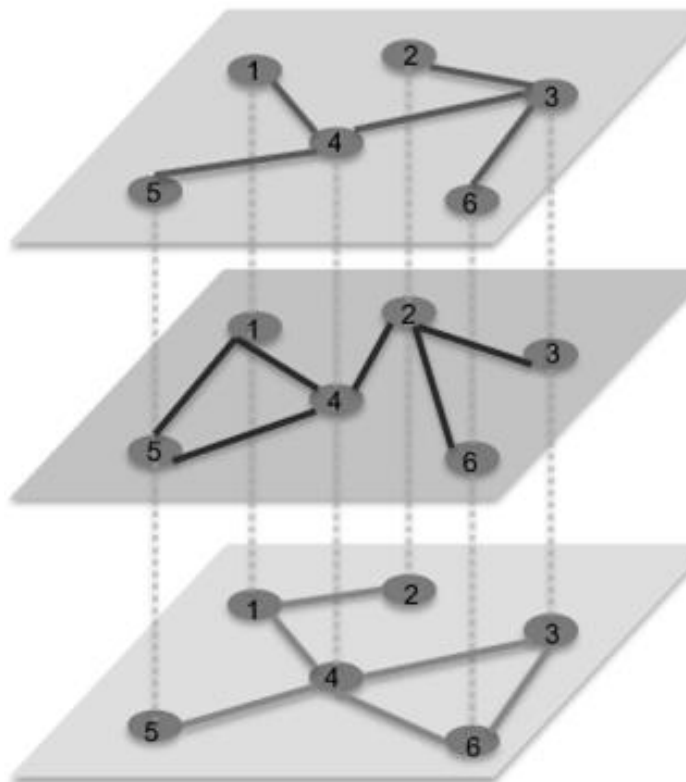
# Network dimensions



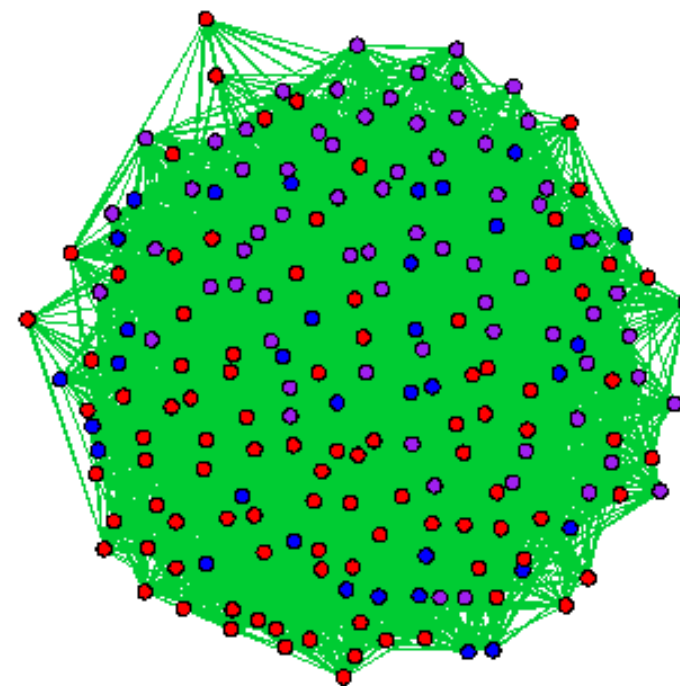
Unidimensional  
data



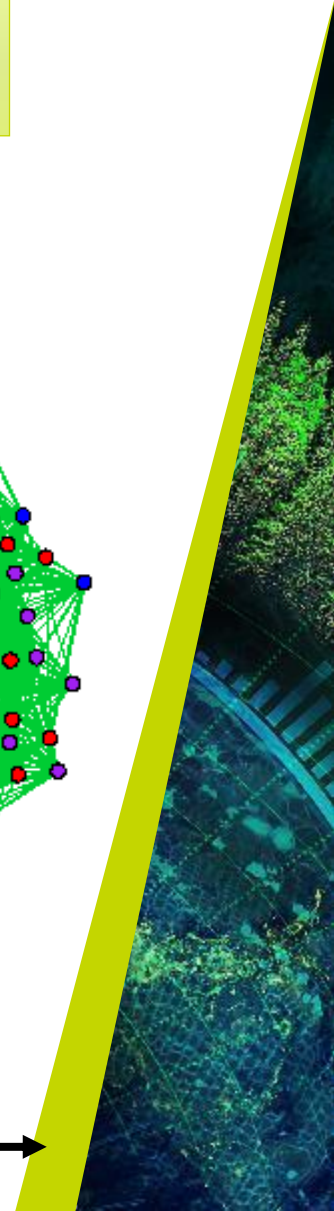
Multidimensional  
data



Longitudinal data

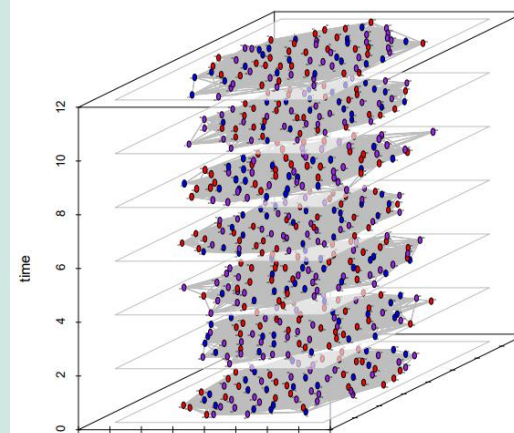
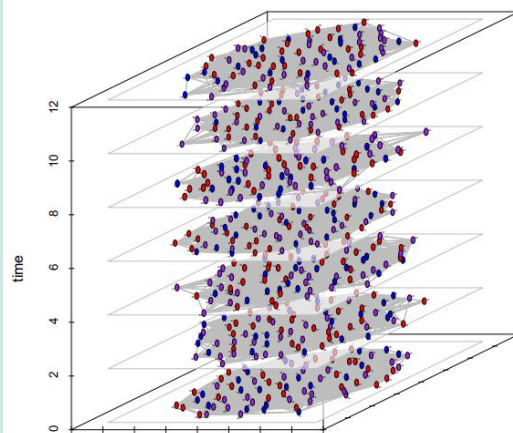
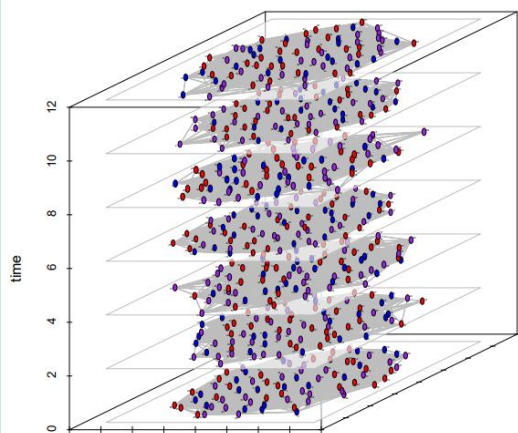
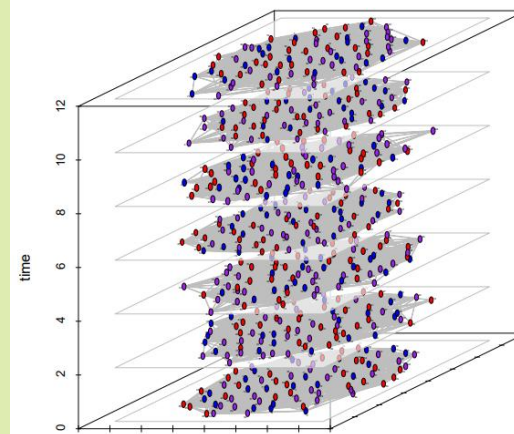
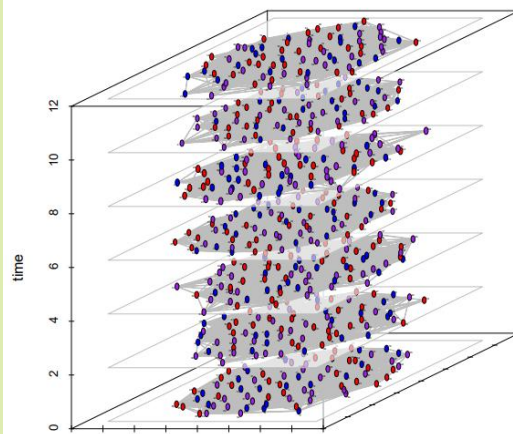
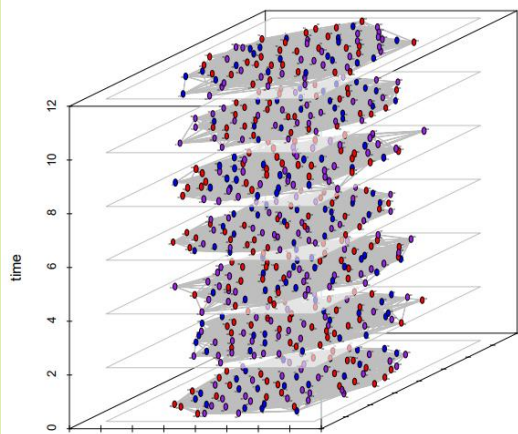
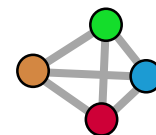


Time

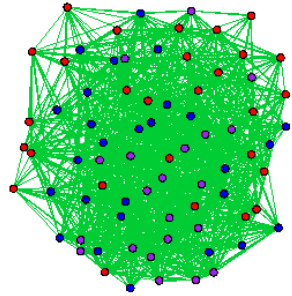
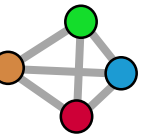




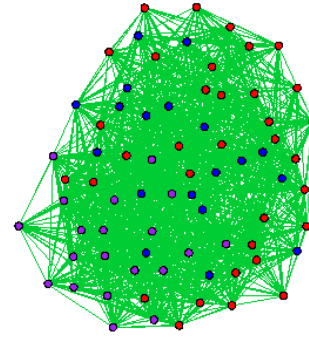
# Spatial interactions



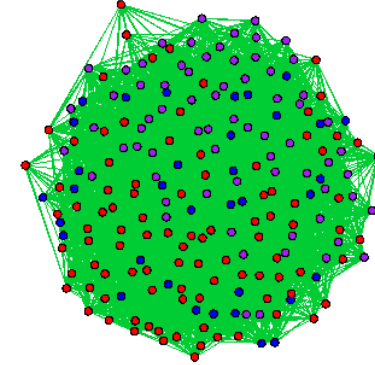
# Spatial interactions



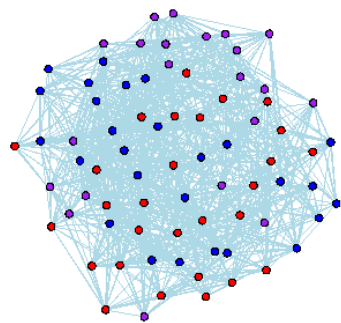
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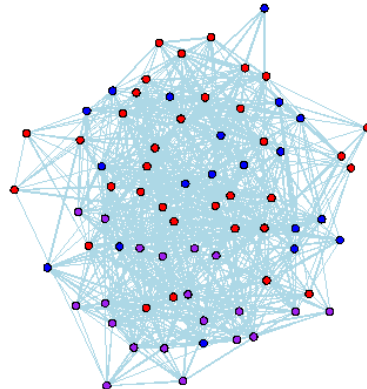
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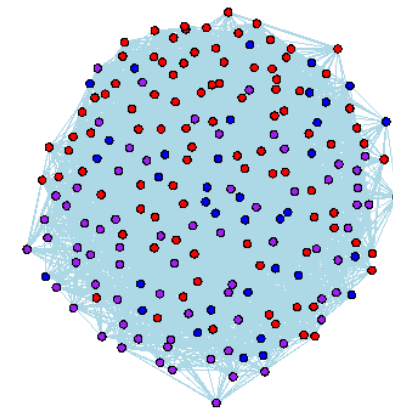
$t=0-1$



$t=0-1$

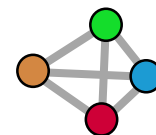


$t=0-1$



$t=0-1$

# Dyad-level models



0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

0	1	X	0	1	0	X	1
1	0	X	1	0	0	1	0
1	X	0	X	1	X	0	0
X	1	X	0	1	0	1	X
X	0	1	1	0	1	1	X
1	0	X	0	1	0	1	X
0	1	0	1	1	1	0	X
X	0	0	X	X	X	X	0
1	0	1	X	1	0	X	1

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

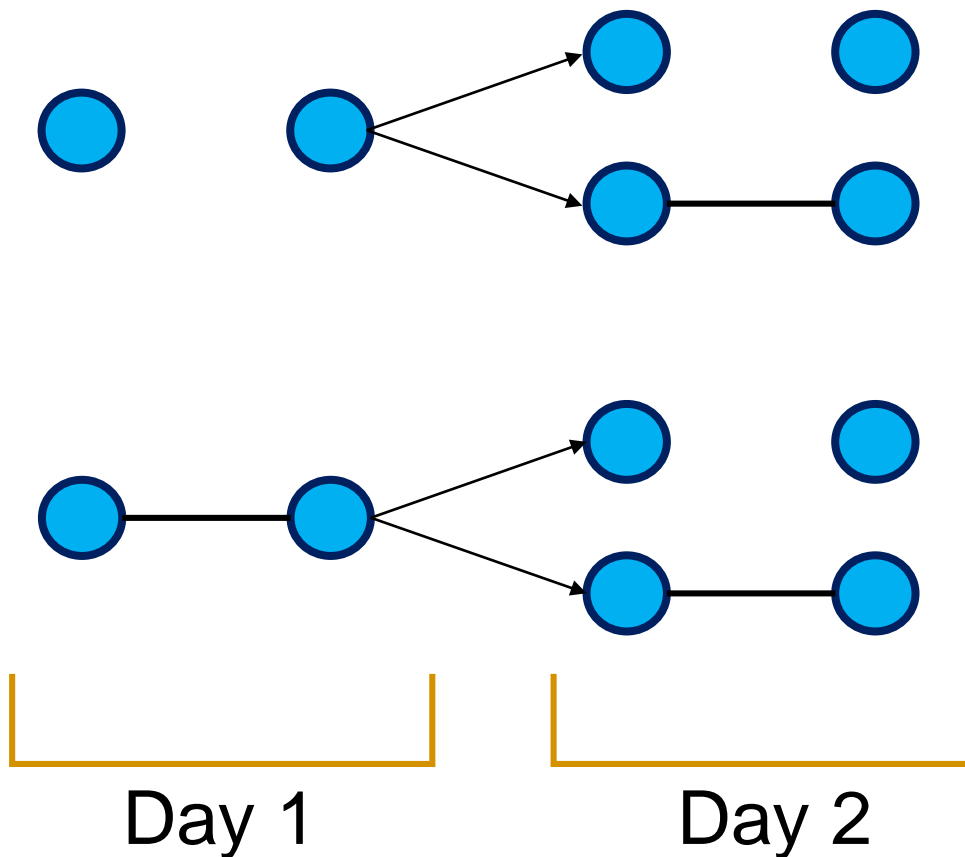
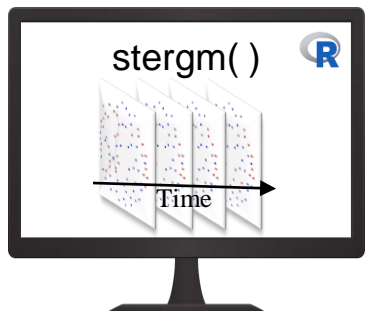
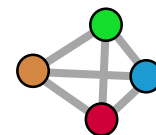
0	1	1	X	X	1	0	X	1
1	0	X	1	0	0	1	0	0
1	X	0	X	1	X	0	0	1
X	1	X	0	1	0	1	X	X
X	0	1	1	0	1	1	X	1
1	0	X	0	1	0	1	X	0
0	1	0	1	1	1	0	X	X
X	0	0	X	X	X	X	0	1
1	0	1	X	1	0	X	1	0

Day 1

Day 2



# Dyad-level models



Absence









Formation

Dissolution




Persistence

# Dyad-level models

- Exponential random graph models (ERGMs):

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

Parity

-  1
-  2
-  3+

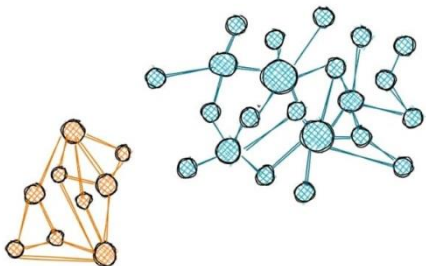
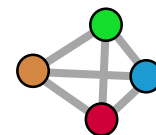
# Dyad-level models



- Separable temporal exponential random graph models (stERGMs):

$(Y_{ij,t+1} = 1 Y_{ij,t} = y_{ij,t})$					Parity		TimeInArea	AGEnet		
					Match	Factor		Cov	Cov	
	0	1	0	0	0.22+0.43	1	Formation			
	1	0	0	1	0.22+0.33	0				
	0	0	1	1	0.56+0.33	0	Persistence			
	1	1	0	0	0.22+0.13	0				

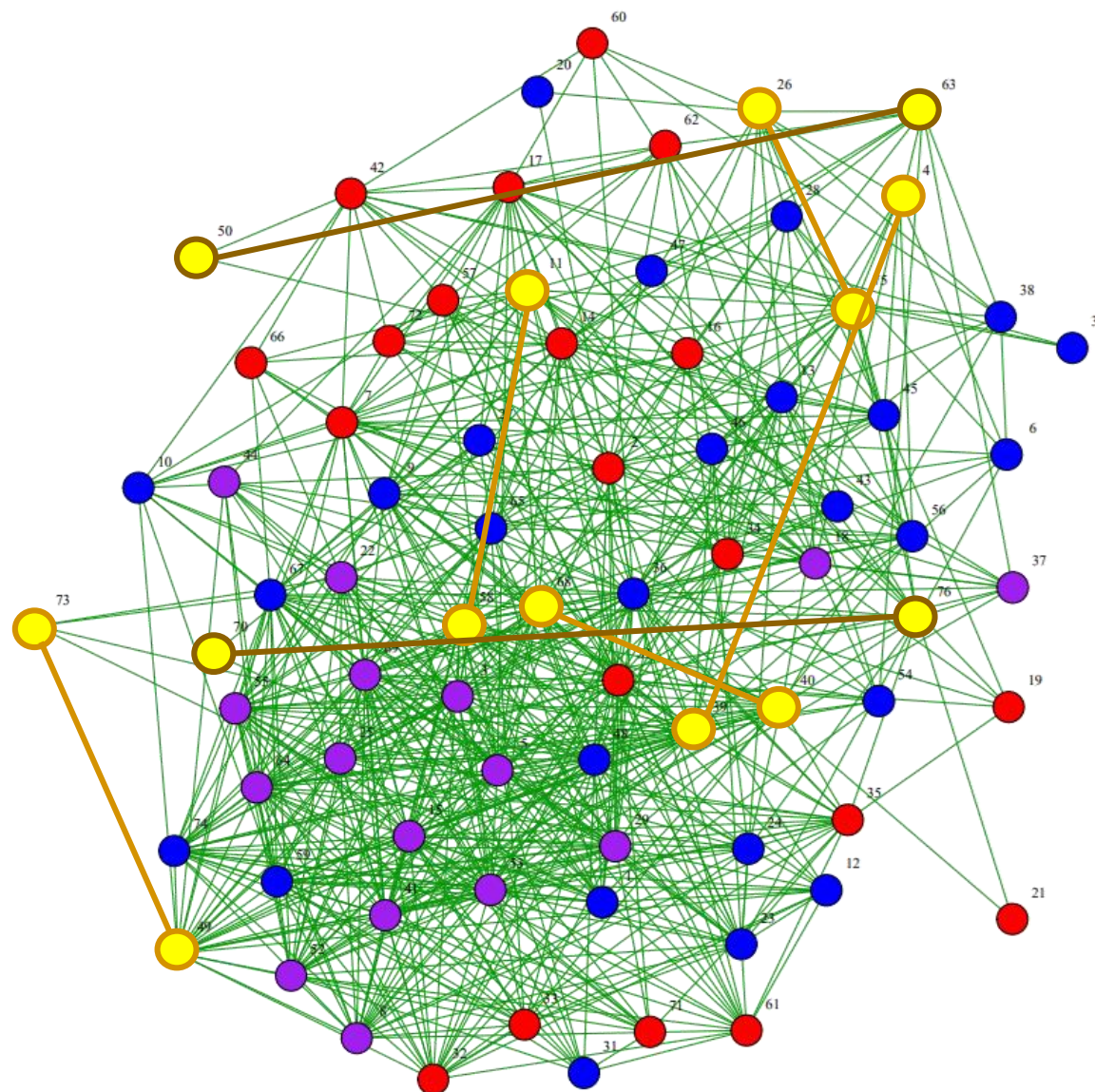
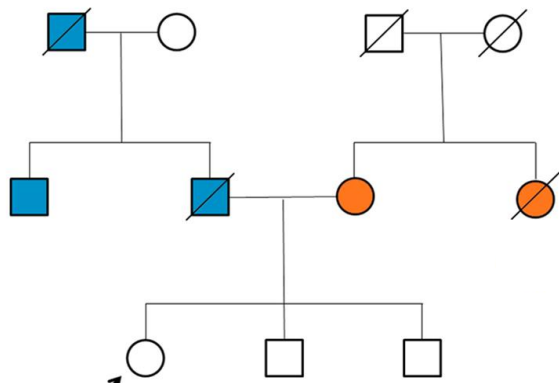
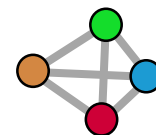


# Dyad-level models



Homophily				
	Formation	Persistence	Formation	Persistence
Parity	(+) ***	(+) ***	(+) ***	(+) ***
Early life	(+) **	(+) *	-	-
Pedigree	(+) **	(+)	-	-

# Network dimensions

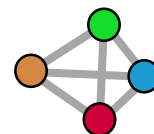





Parity

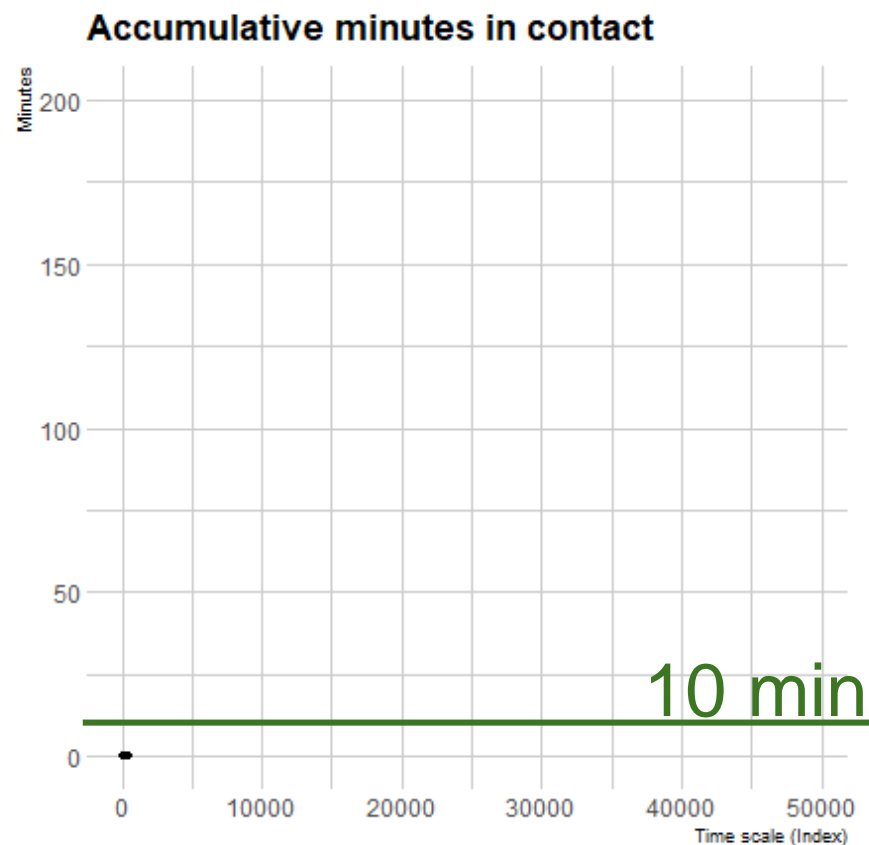
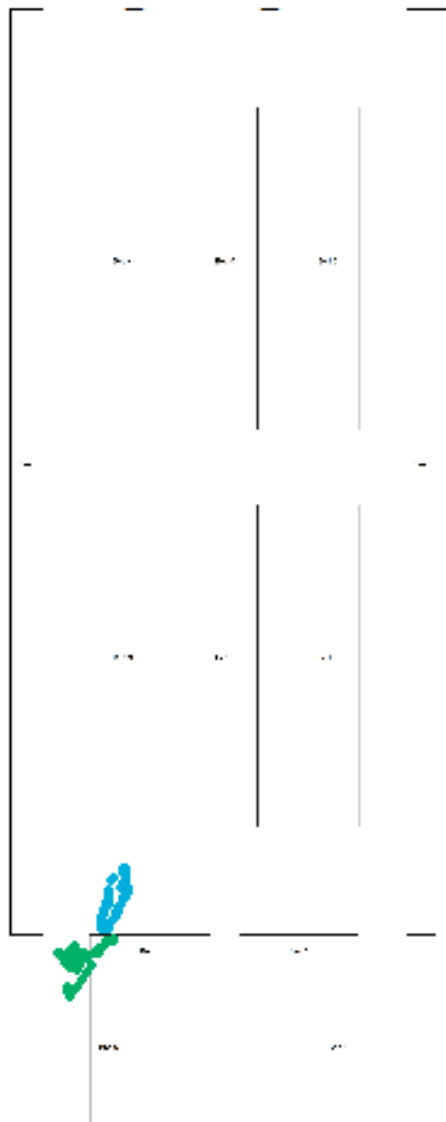
- 1
- 2
- 3+



# Network dimensions

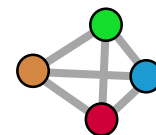


-  Mother
-  Daughter
-  Spatial contact



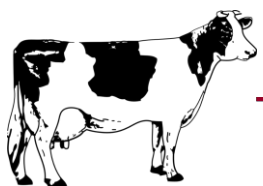


# Endogenous parameters



14 consecutive days:

- 2020-10-16
- 2020-10-29

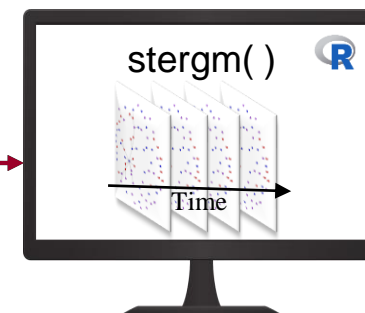


Information available:

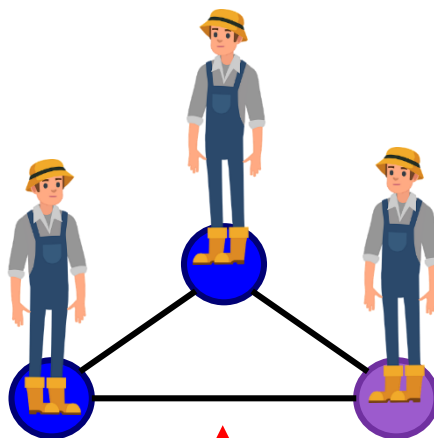
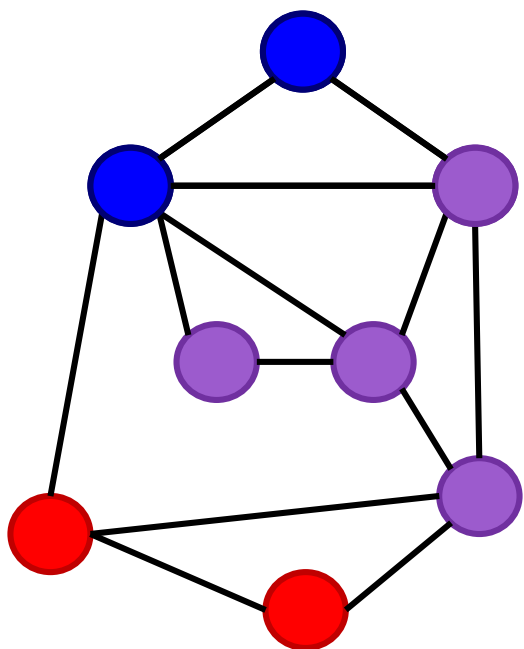
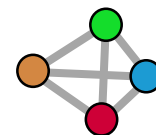
- Parity
- Lactation stage
- Claw health
- Breed
- Early life experience
- Dried off experience
- Pedigree

Internal network structure

- Triangles

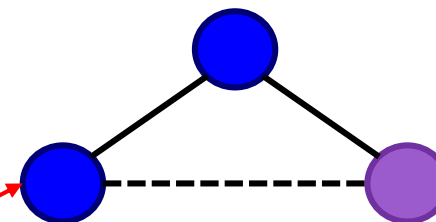


# Triangles

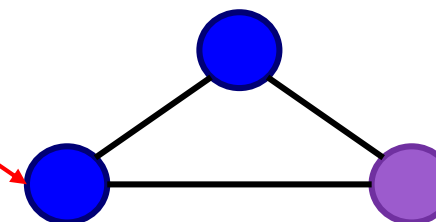


Likelihood

Formation

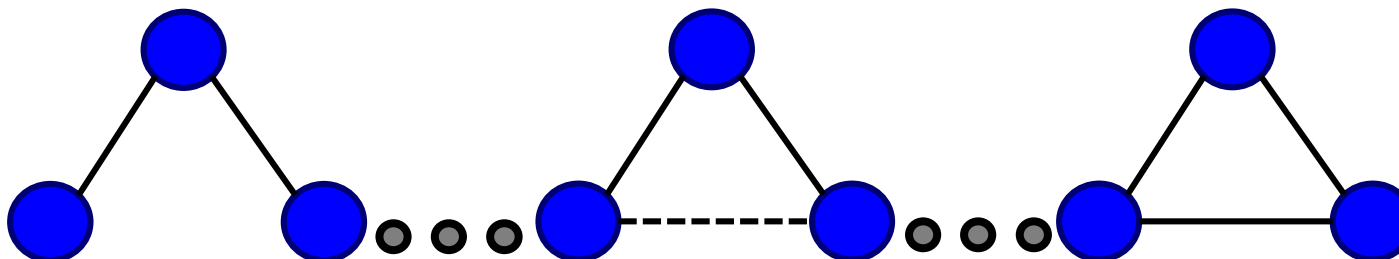


Persistence

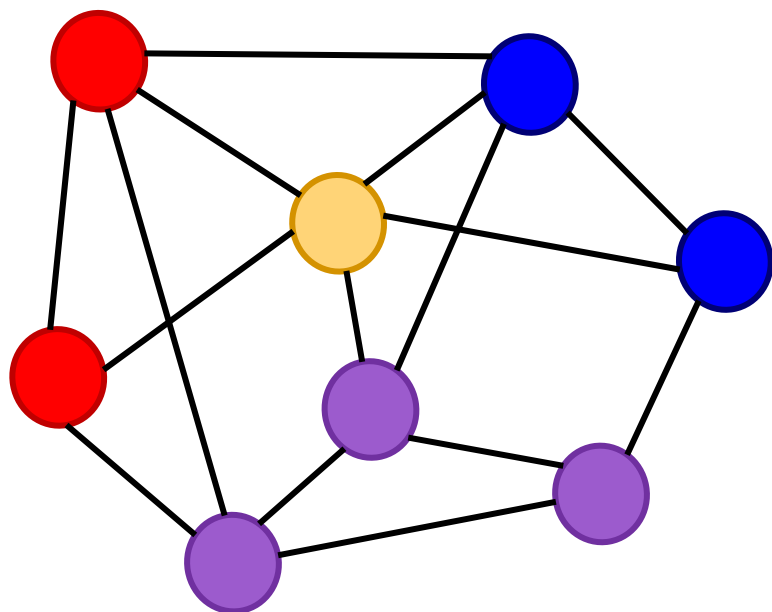
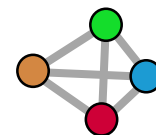




	Formation	Persistence
<b>Triangles</b>	(+) ***	(+) ***
Parity	(+) ***	(+) ***
Early life	(+) ***	(+) *
Pedigree	(+) ***	n.s.



# Topological parameters

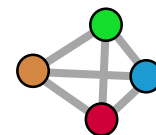




- TP describe the structural properties and characteristics of the networks
- Quantify the influence of the nodes in the networks
- TP's repeatability indicate how constant is the social role of the animals over time



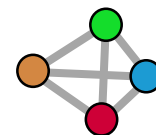




# Topological parameters



r <sup>2</sup>				
	Feeding area	Resting area	Feeding area	Resting area
Degree	0.26-0.31	0.25-0.33	0.14	0.33
Betweenness	0.21-0.24	0.37-0.39	0.20	0.23
Closeness	0.23-0.24	0.38-0.40	0.12	0.32
Eigenvector	0.33-0.34	0.41-0.42	0.12	0.38

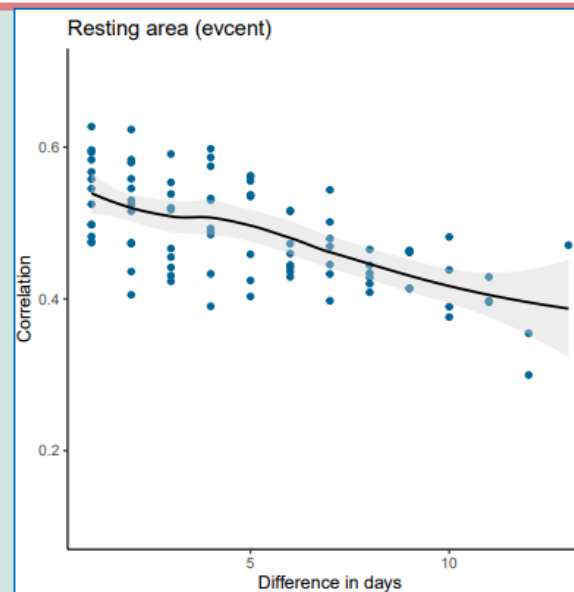
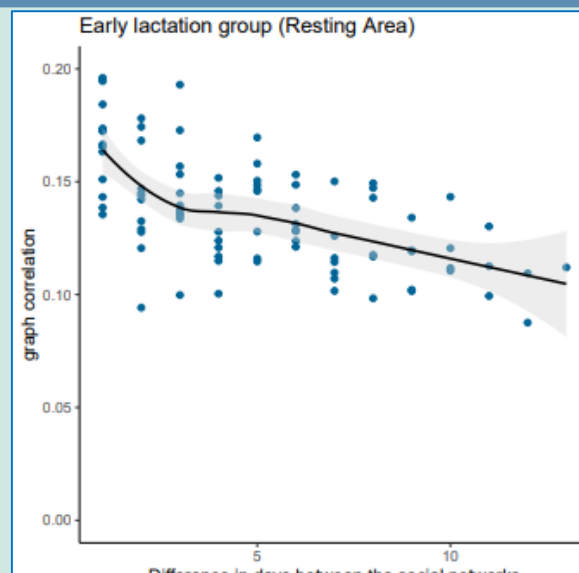
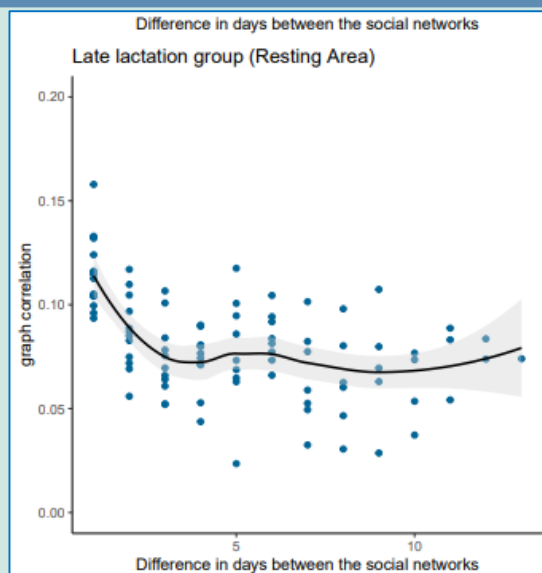
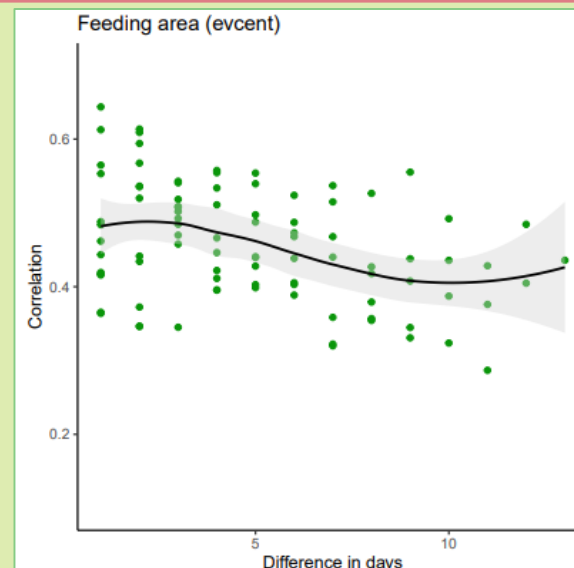
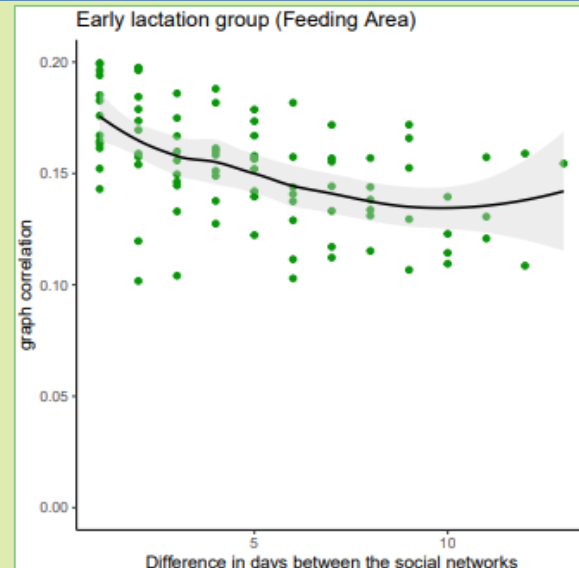
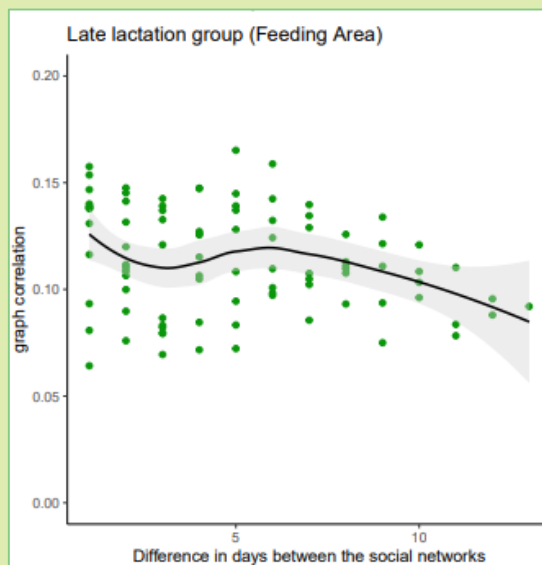
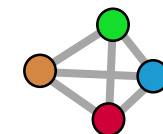
# Topological parameters

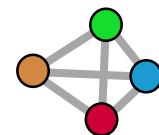


h <sup>2</sup>				
	Feeding area	Resting area		
Degree	0.07-0.11	0.08-0.16		
Betweenness	0.09-0.09	0.09-0.15		
Closeness	0.08-0.11	0.09-0.17		
Eigenvector	0.10-0.14	0.07-0.20		



# Network evolution



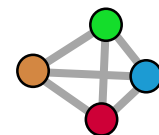


Understanding the dynamics of social networks could contribute to:

- The stability of the social structure of dairy cattle
- Identifying social abnormal behaviour
- The design of prevention protocols for transmissible diseases





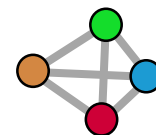


Understanding the dynamics of social networks could contribute to:

- The stability of the social structure of dairy cattle
- **Identifying social abnormal behaviour**
- The design of prevention protocols for transmissible diseases



# Predict social behaviour

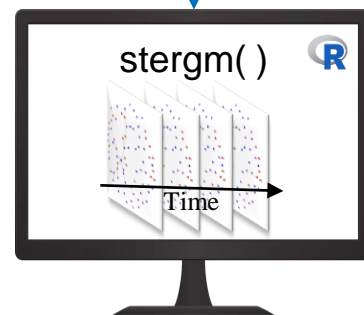


Prev. Adj. Mat.

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

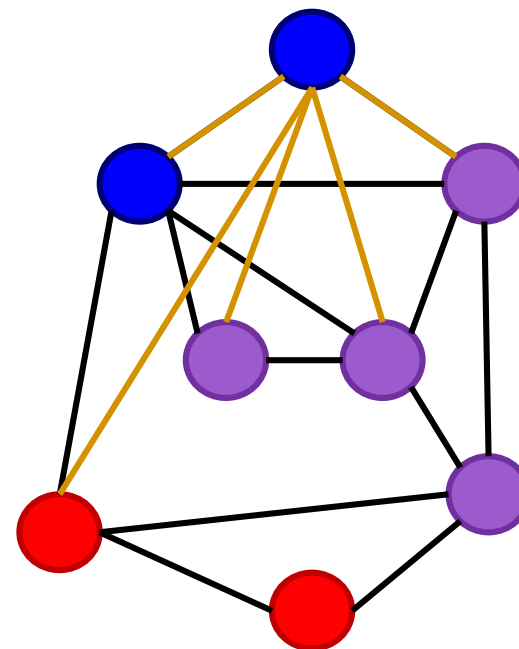
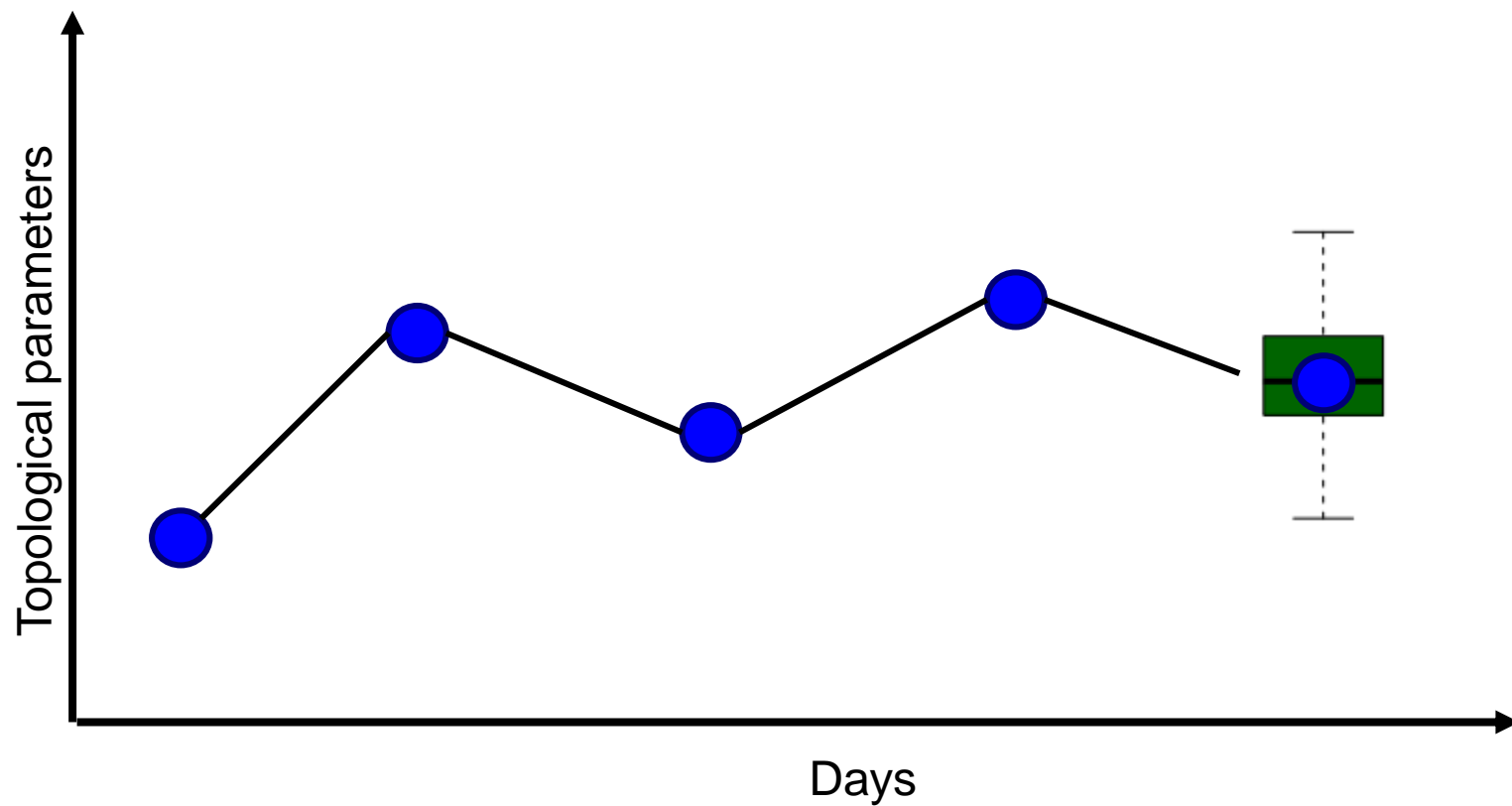
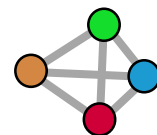
0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0

0	1	1	0	1	1	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	1	1	0	0	0	1
0	1	1	0	1	0	1	1	1
1	0	1	1	0	1	1	0	1
1	0	0	0	1	0	1	0	0
0	1	0	1	1	1	0	0	1
0	0	0	1	0	0	0	0	1
1	0	1	1	1	0	1	1	0



0	0.1	0.7	0.3	0	0.8	0.7	0.3	0.3
0.1	0	0.5	0.9	0.6	0.1	0.9	0	0.9
0.7	0.5	0	0.2	0	0.8	0.5	0.7	0.2
0.3	0.9	0.2	0	0.6	0.5	0.1	0.3	0.3
0	0.6	0	0.6	0	0.3	0.8	0.9	0.6
0.8	0.1	0.8	0.5	0.3	0	0.2	0	0.4
0.7	0.9	0.5	0.1	0.8	0.2	0	0.5	0.4
0.3	0	0.7	0.3	0.9	0	0.5	0	0.6
0.3	0.9	0.2	0.3	0.6	0.4	0.4	0.6	0

# Predict social behaviour







SCIENCE AND  
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**LIFE**

Publications



Code available

