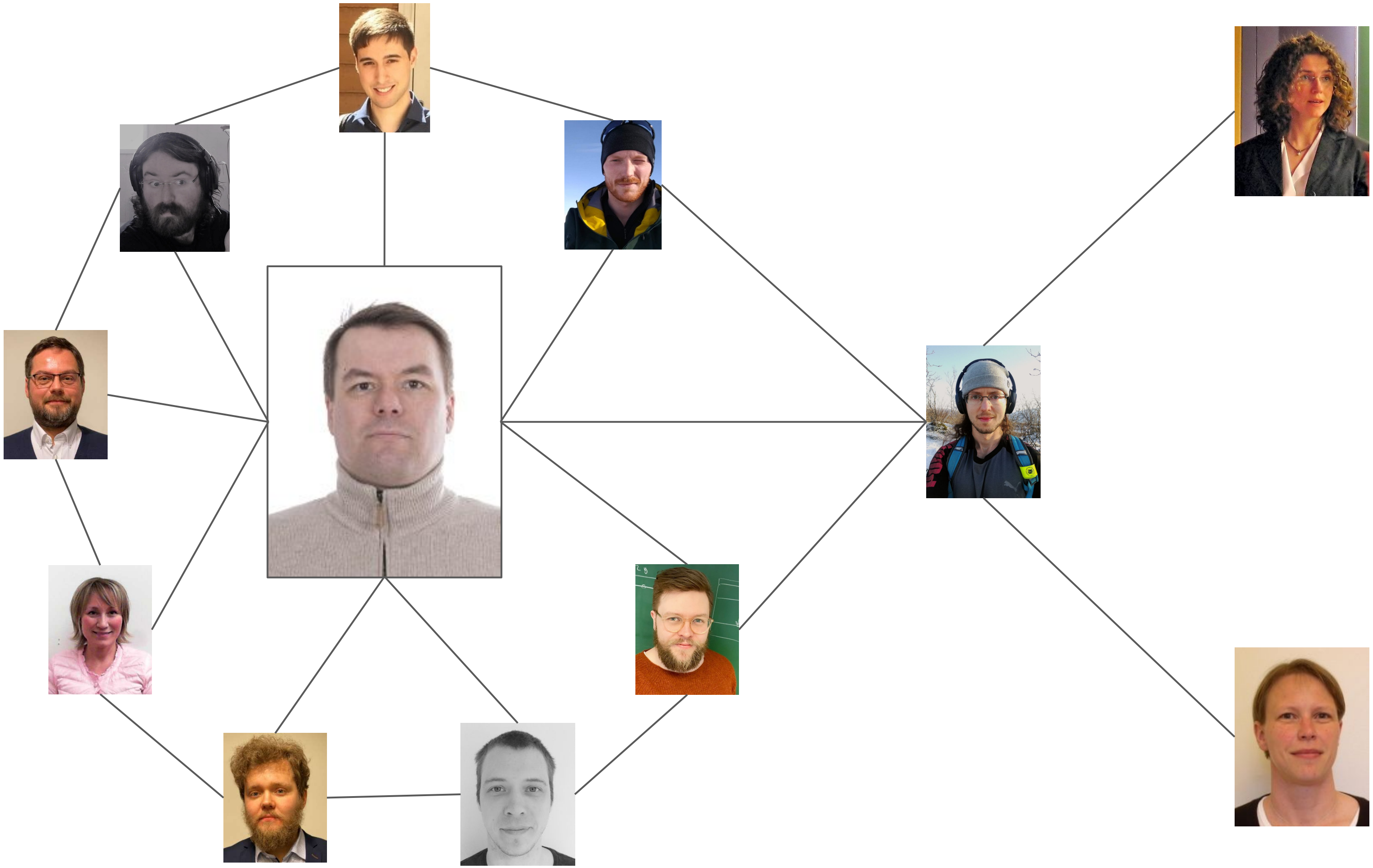
# SOCIAL NETWORK ANALYSIS

(Social Distancing Edition)

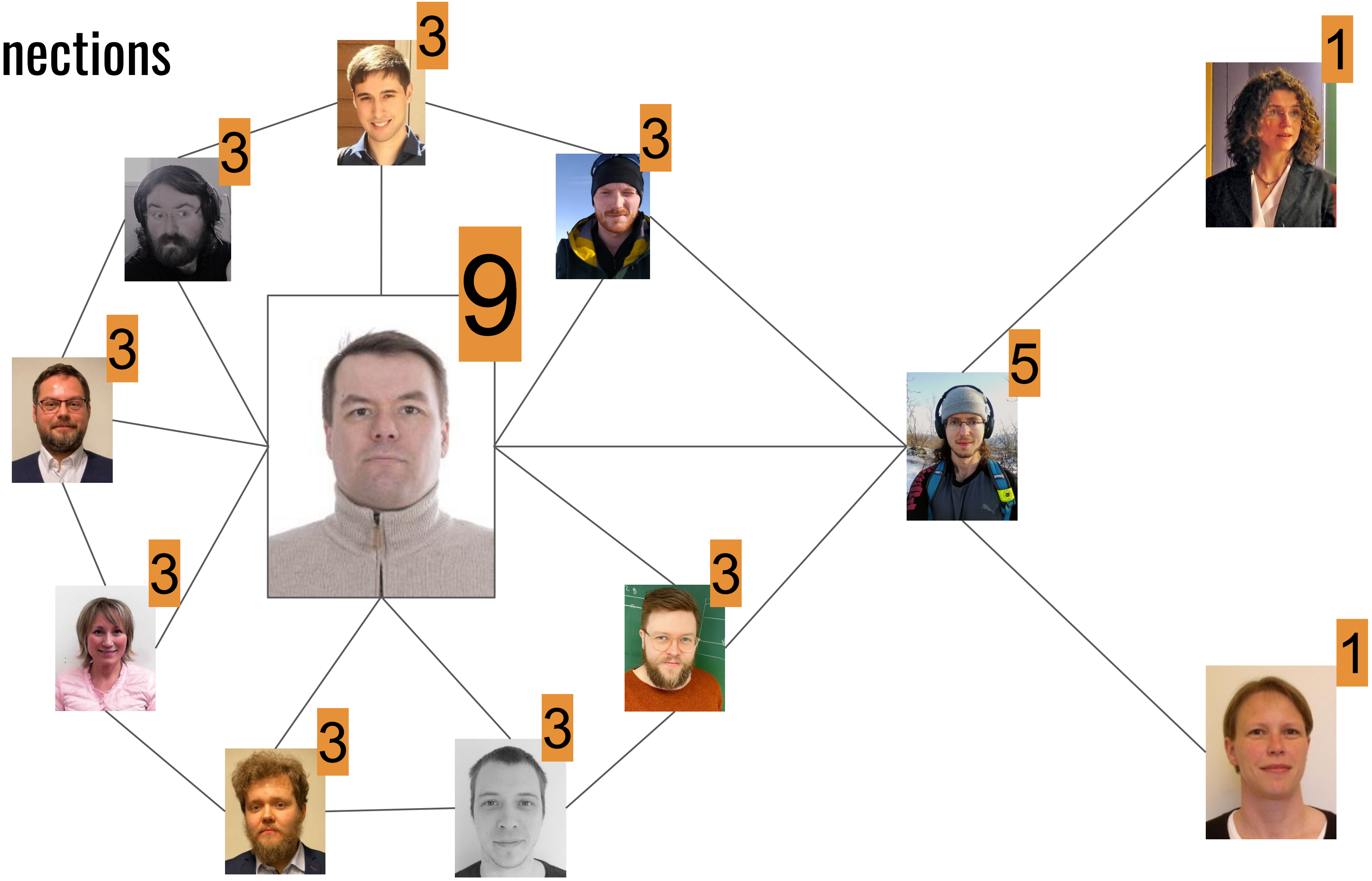
Rafael Nozal Cañadas

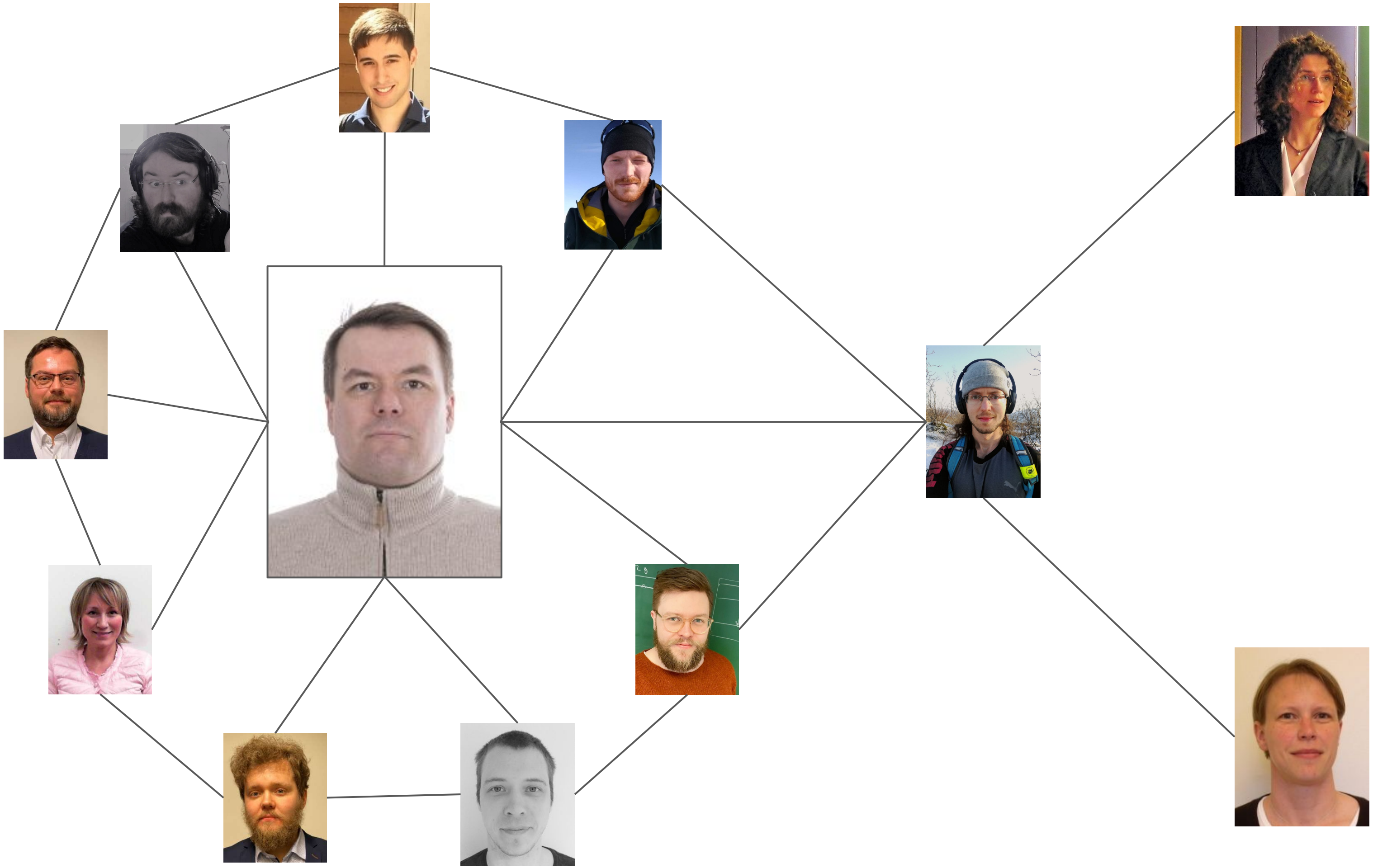
HDL Seminar 2020.03.23

Who do you think is the MOST IMPORTANT person in this network?

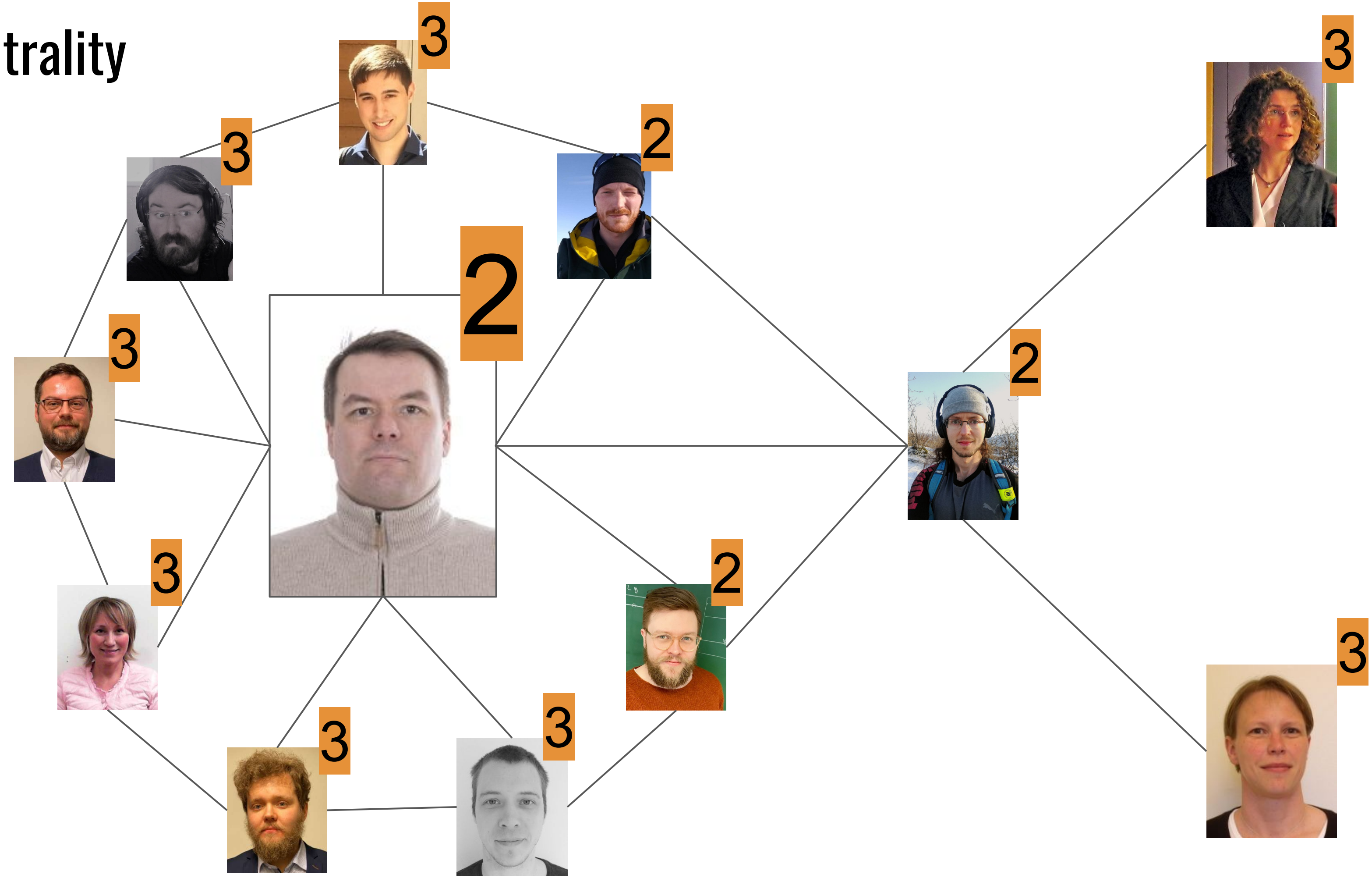


# By connections

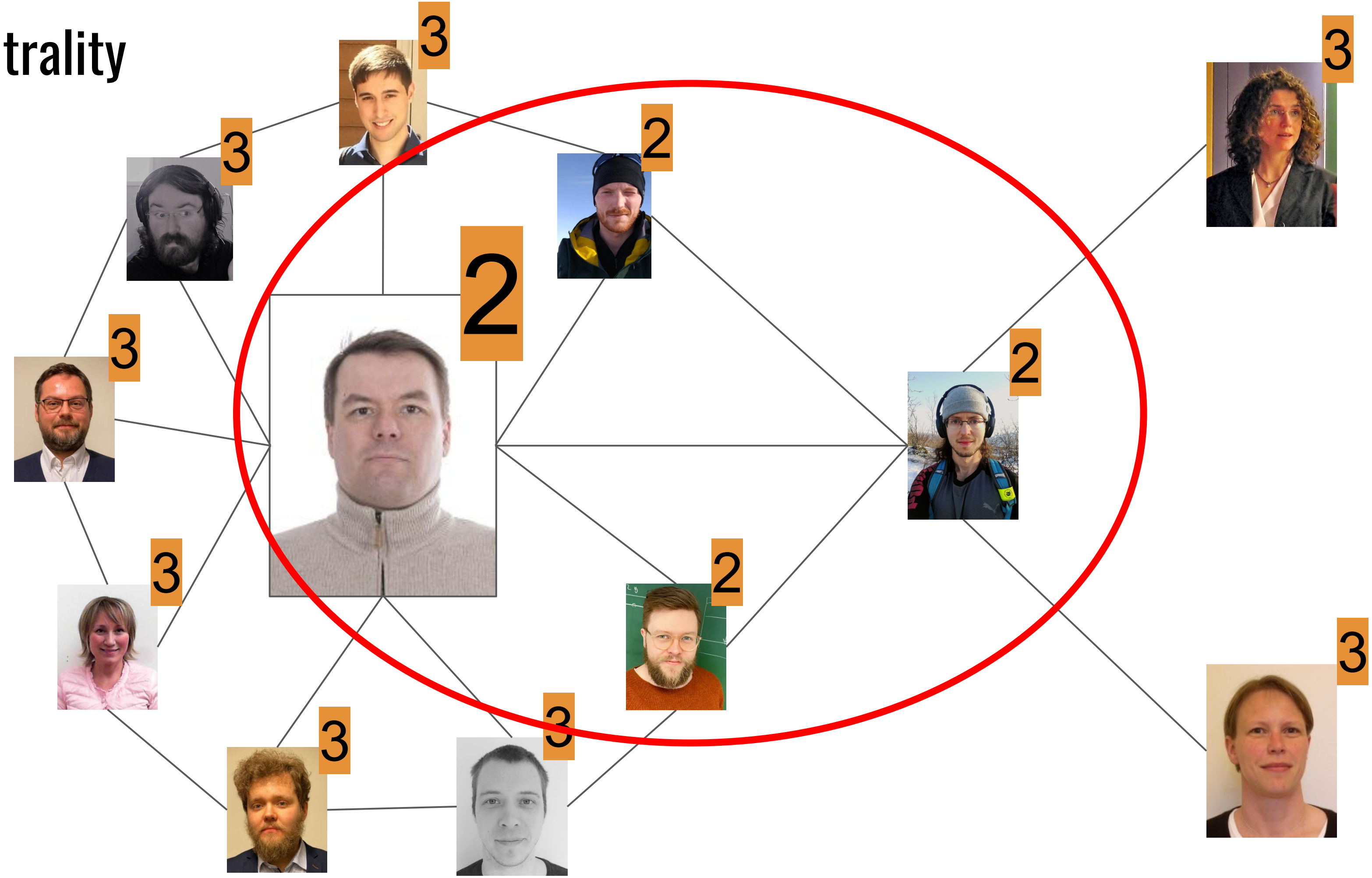


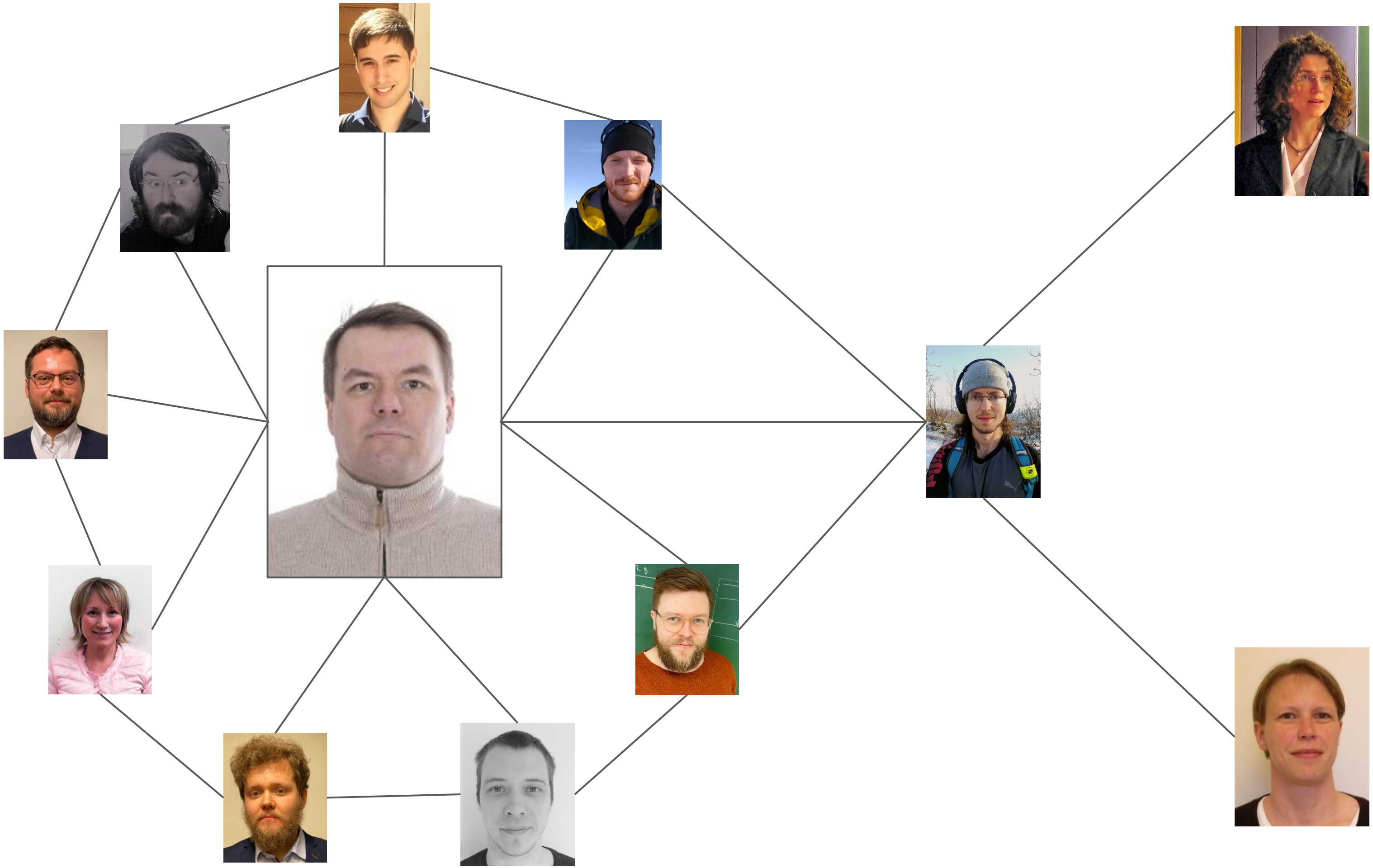


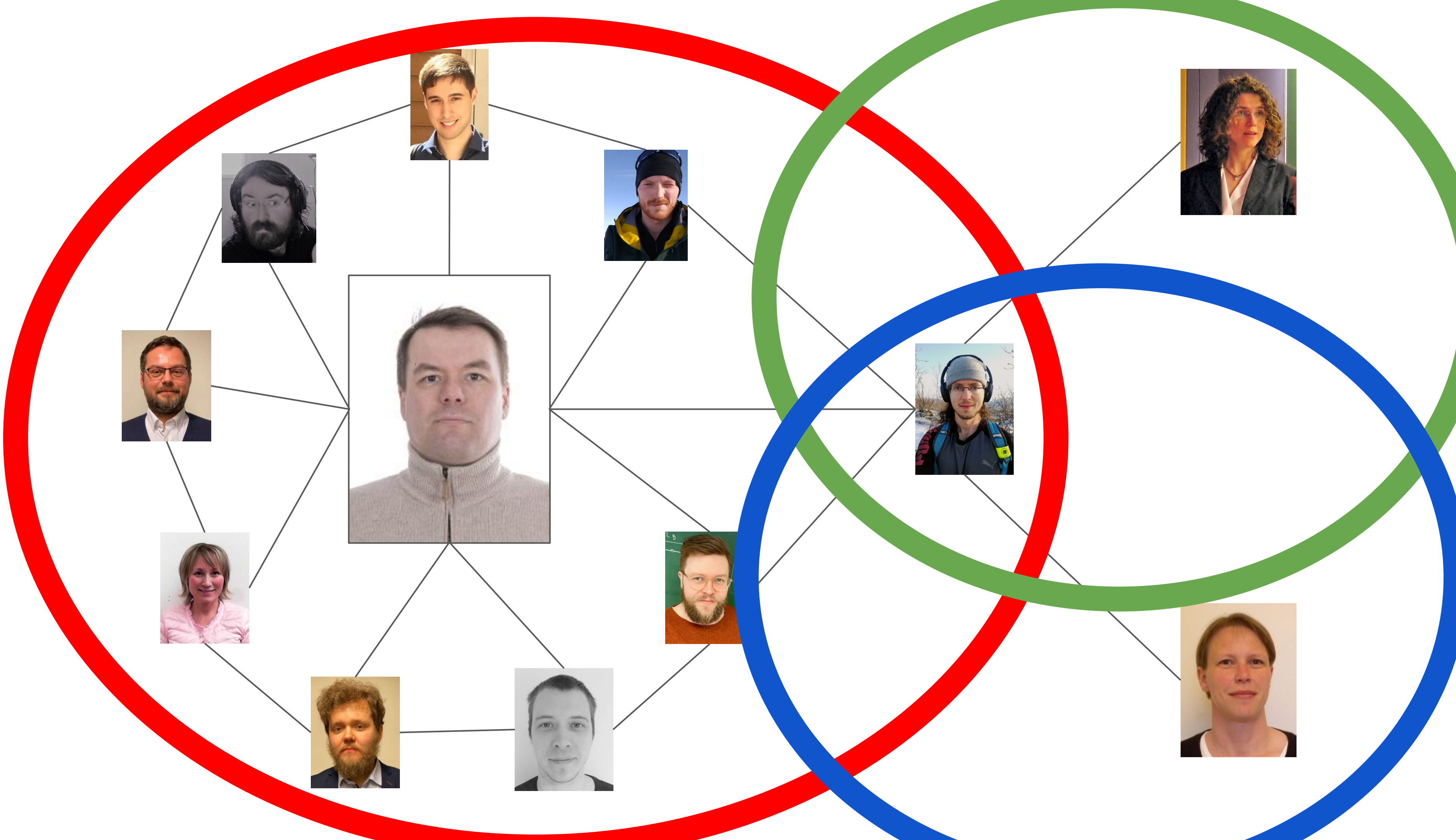
# By centrality



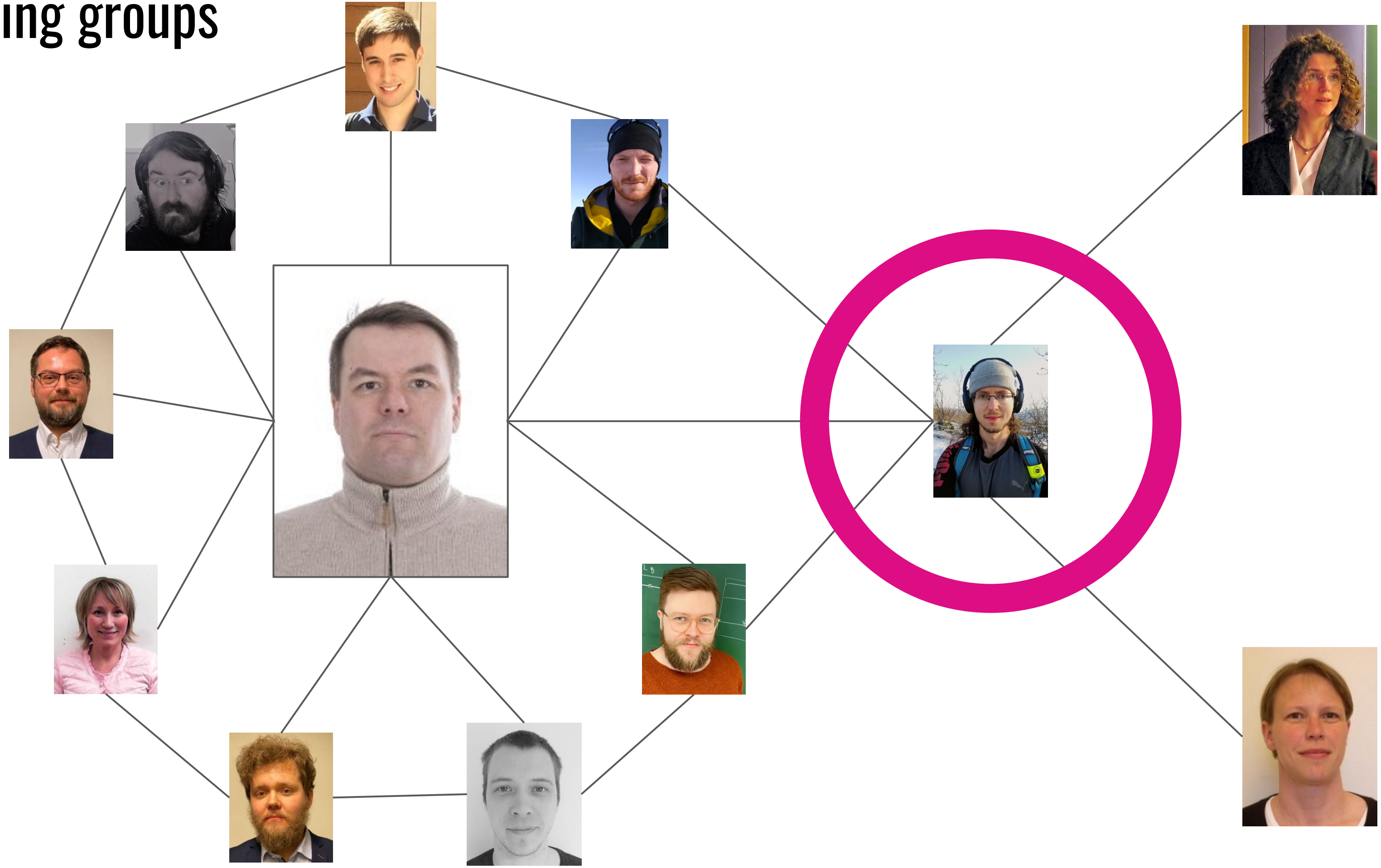
# By centrality

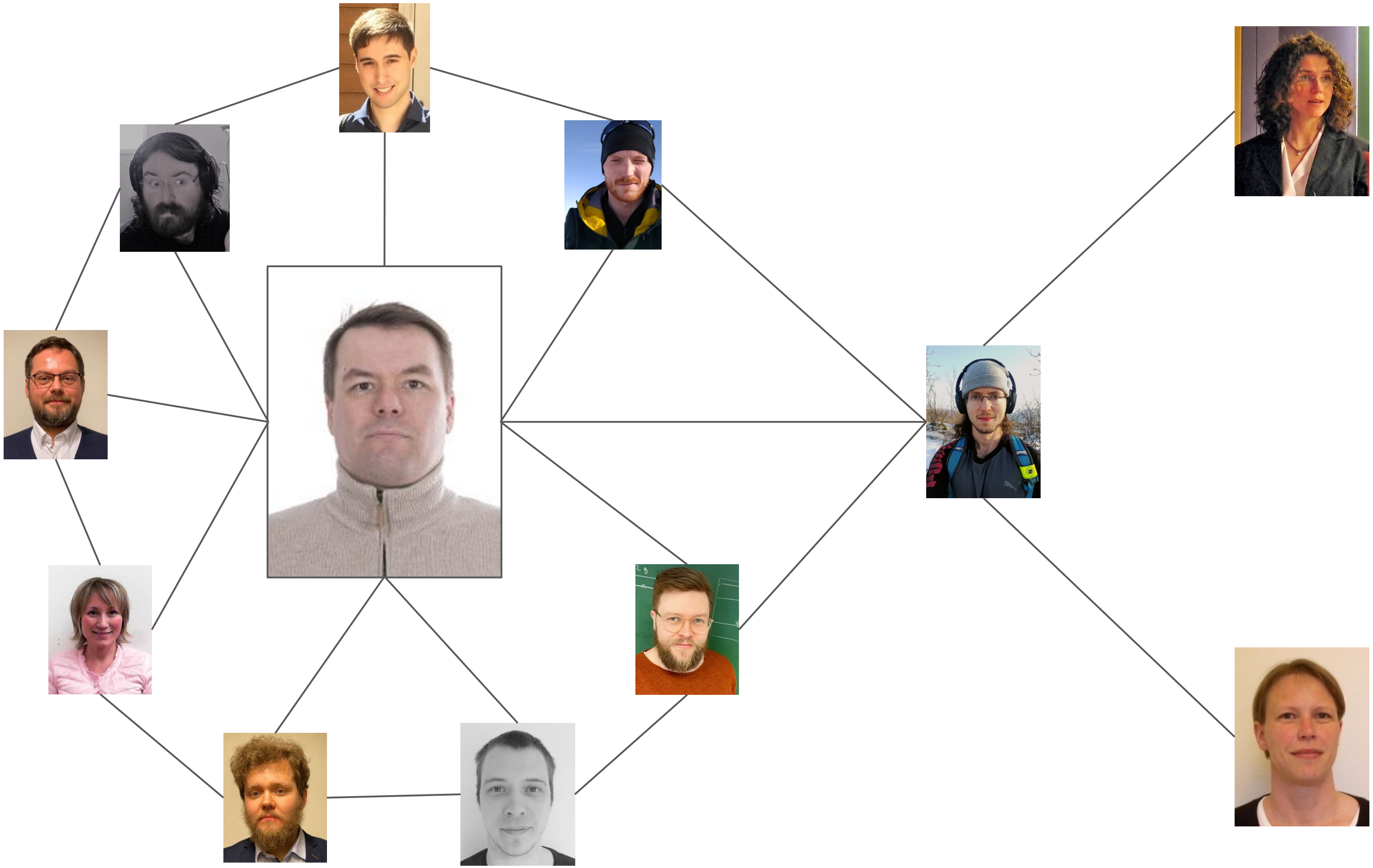


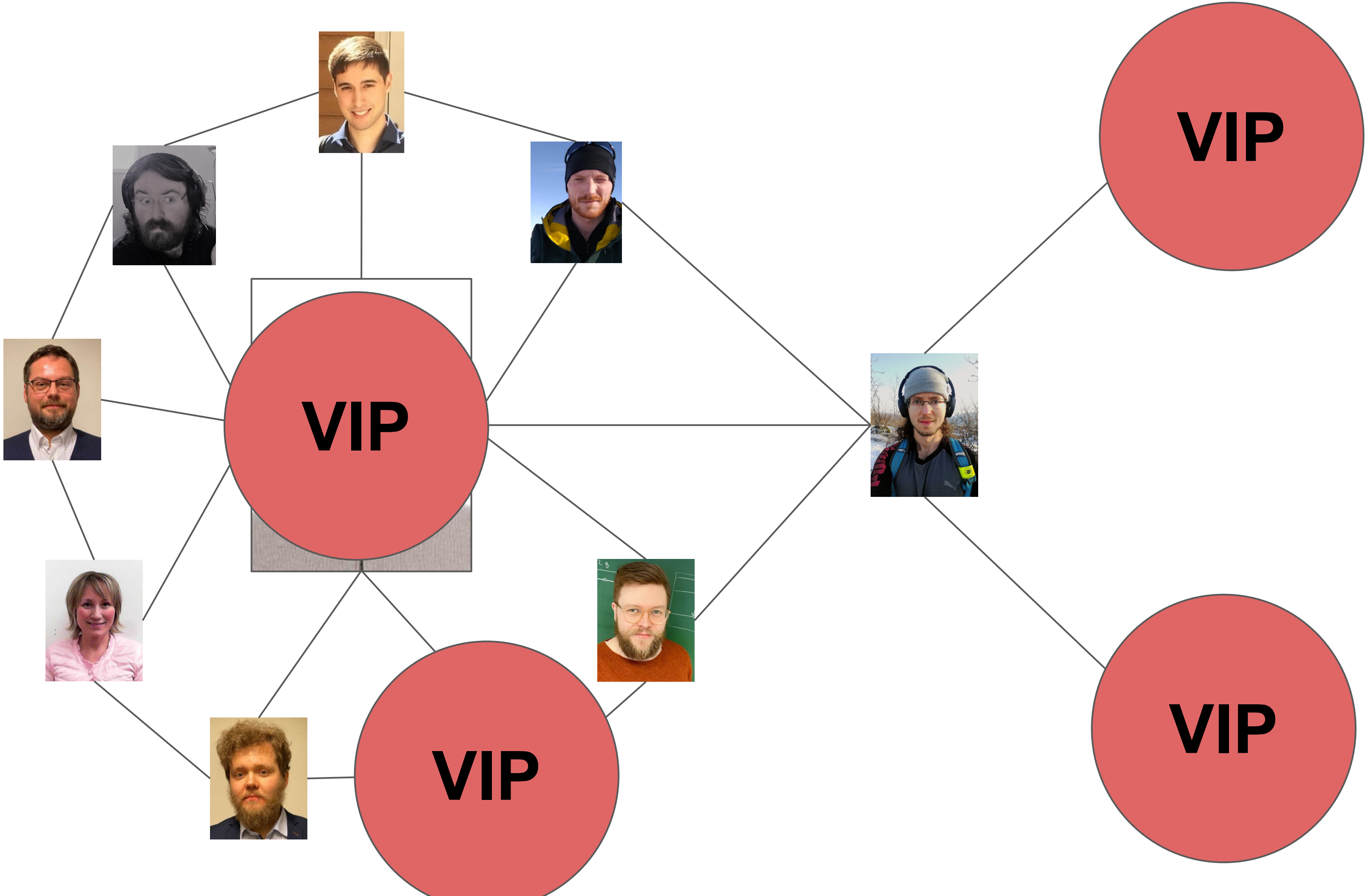




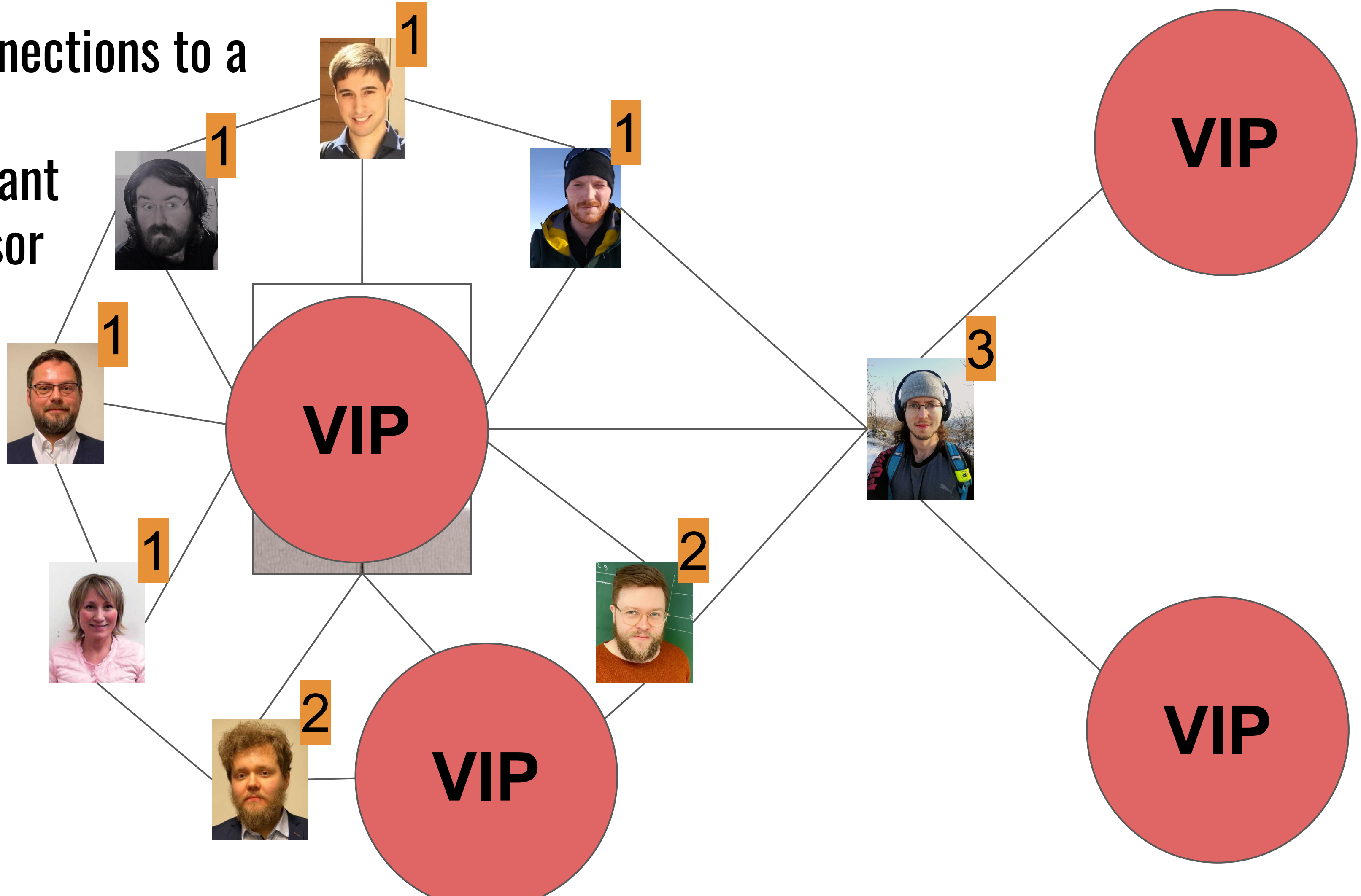
# By joining groups



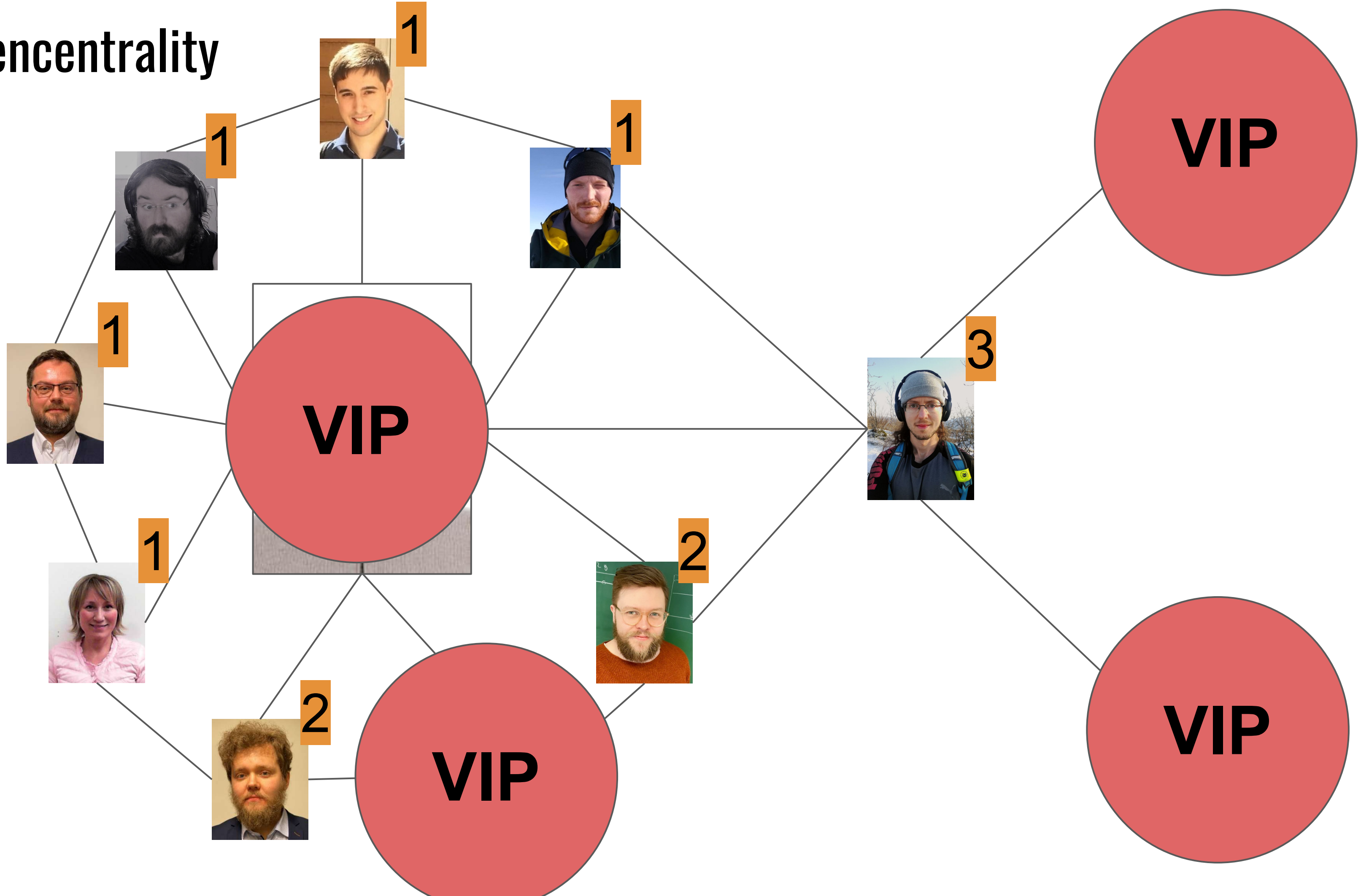



VIP
VIP
VIP
VIP

By connections to a Very Important Proffesor



# By Eigencentrality

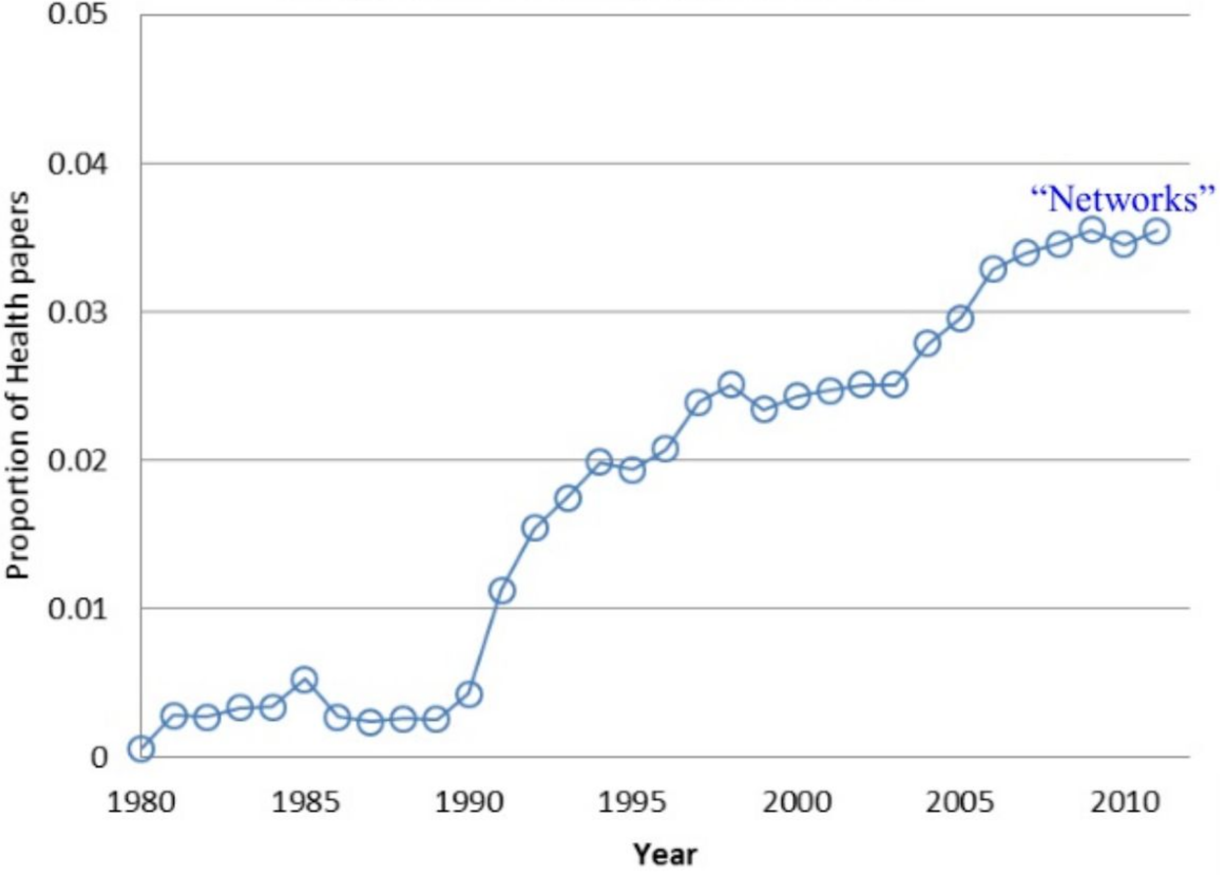


1. Networks in Health
2. Basic concepts
3. Visualization
4. Autocorrelation

# CHAPTER 1:
# Networks in Health

# Papers on Networks and Health

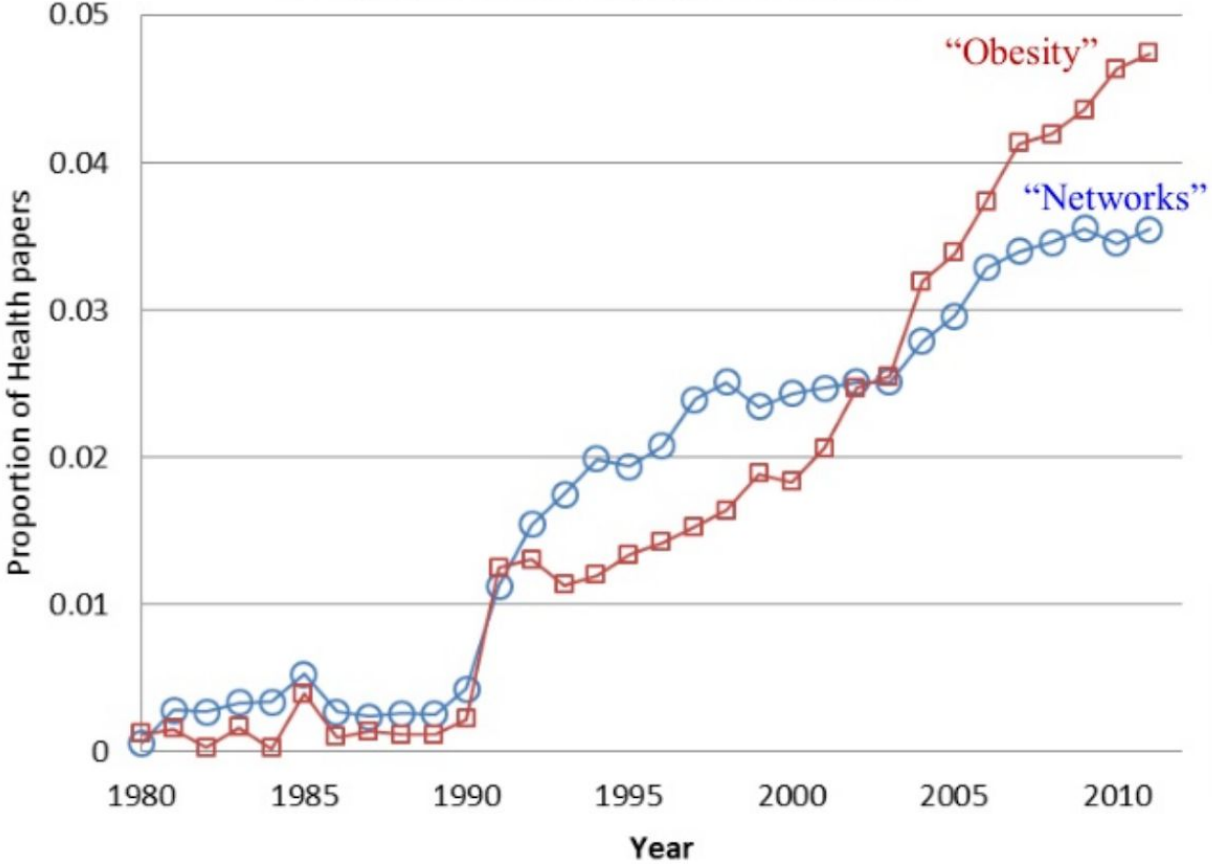
as a proportion of all papers on health




Moody, J., and J. Coleman. "Clustering and Cohesion in Networks: Concepts and Measures." In International Encyclopedia of Social and Behavioral Sciences, edited by J. D. Wright, 3:906–12. Oxford: Elsevier, 2015.

# Papers on Networks and Health

as a proportion of all papers on health




Moody, J., and J. Coleman. “Clustering and Cohesion in Networks: Concepts and Measures.” In International Encyclopedia of Social and Behavioral Sciences, edited by J. D. Wright, 3:906–12. Oxford: Elsevier, 2015.

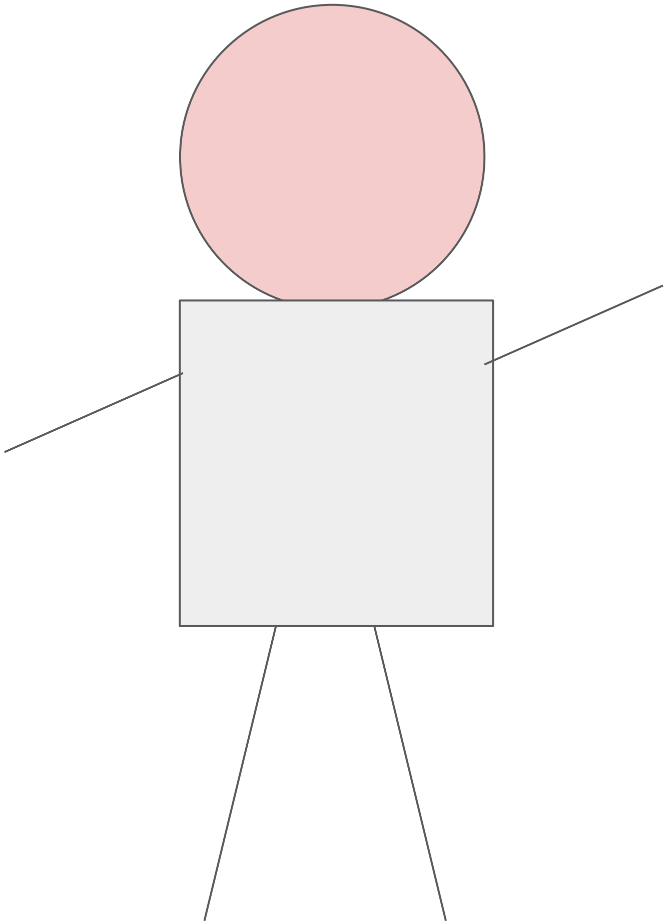
**EXHIBIT 1**

**Relative Contributions of Health Determinants to Health Outcomes**

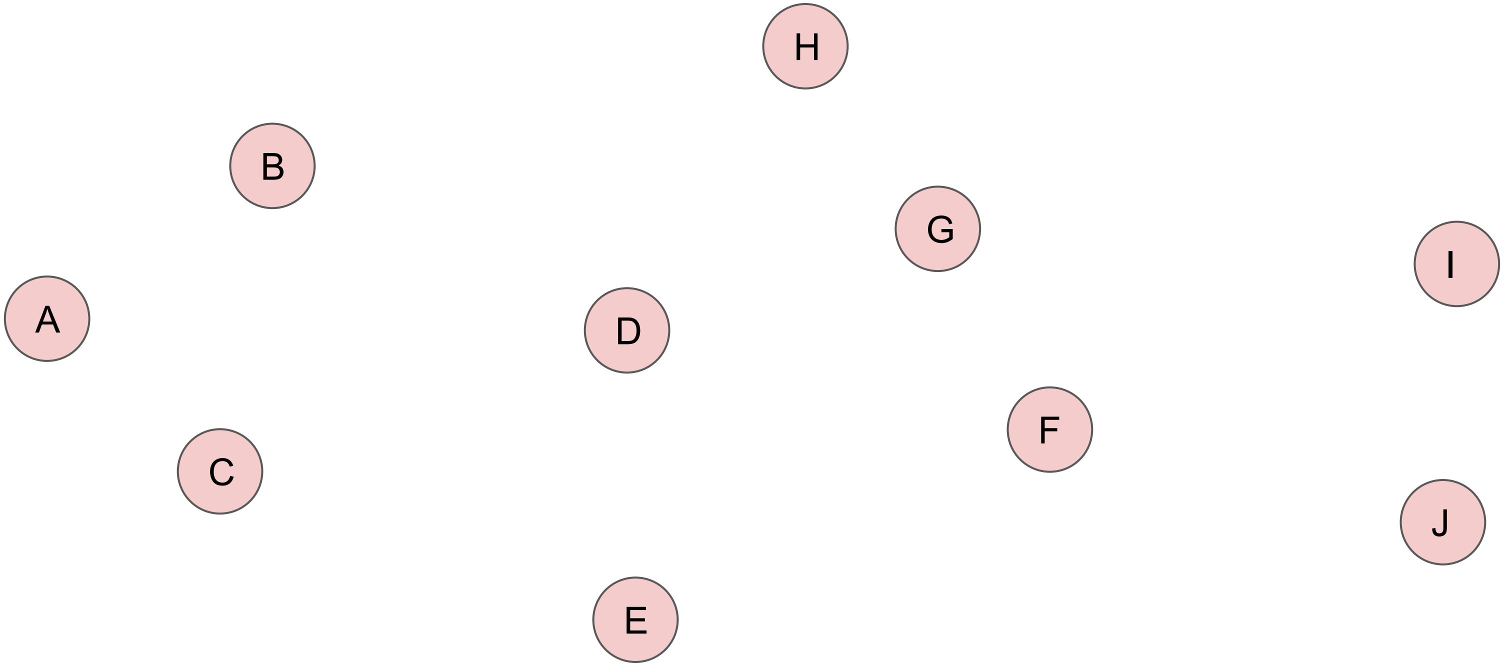
| | | Determinants of health | | | | | |
|---|---|---|---|---|---|---|---|
| **Source** | **Metric** | **Behaviors** | **Social circumstances** | **Environment** | **Genetics** | **Medical care** | **Stress** |
| DHHS, Public Health Service, "Ten Leading Causes of Death in the United States," Atlanta (GA): Bureau of State Services, July 1980[a] | Percentage of total deaths in 1977 (US) | 50% | — | 20% | 20% | 10% | — |
| J. M. McGinnis and W. H. Foege, "Actual Causes of Death in the United States," *JAMA* 270, no. 18 (1993):2207–12 | Percentage of total deaths in 1990 (US) | Tobacco: 19%<br>Diet/activity patterns: 14%<br>Alcohol: 5%<br>**Total = 38%** | — | Microbial agents: 4%<br>Toxic agents: 3% | — | — | — |
| P. Lantz et al., "Socioeconomic Factors, Health Behaviors, and Mortality: Results from a Nationally Representative Prospective Study of US Adults," *JAMA* 279, no. 21 (1998):1703–8 | Mortality hazard rate ratio (HRR) attributable to income (controlling for sociodemographic variables and 4 health behaviors) | Controlled for:<br>Cigarette smoking<br>Alcohol drinking<br>Sedentary lifestyle<br>Relative body weight | Mortality HRR for middle-income group: 2.14<br>Mortality HRR for low-income group: 2.77 | — | — | — | — |
| J.M. McGinnis et al., "The Case for More Active Policy Attention to Health Promotion," *Health Affairs* 21, no. 2 (2002):78–93 | Percentage of "early deaths" (undefined) | 40% | 15% | 5% | 30% | 10% | — |
| A. Mokdad et al., "Actual Causes of Death in the United States, 2000," *JAMA* 291, no. 10 (2004):1238–45 | Percentage of total deaths in 2000 (US) | Tobacco: 18%<br>Poor diet/physical inactivity: 17%<br>Alcohol: 3.5%<br>**Total = 39%** | — | Microbial agents: 3.1%<br>Toxic agents: 2.3% | — | — | — |
| G. Danaei et al., "The Preventable Causes of Death in the United States: Comparative Risk Assessment of Dietary, Lifestyle, and Metabolic Risk Factors," *PLoS Medicine* 6, no. 4 (2009):e1000058[b] | Percentage of total death (US) (various years, depending on variable) | Tobacco: 19%<br>Overweight/obesity: 9%<br>Physical inactivity: 8%<br>**Total = 36%** | — | — | — | — | — |
| World Health Organization, Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks, Geneva: WHO, 2009[c] | Percentage of total deaths in 2004, in high-income countries | Diet and physical inactivity (high blood pressure, high blood glucose, physical inactivity, overweight and obesity, high cholesterol, low fruit and vegetable intake): 25%<br>Alcohol and drug use: 2%<br>Tobacco use: 18%<br>**Total = 45%** | — | 3% (urban outdoor air pollution, unsafe water/sanitation, and lead exposure) | — | — | — |
| B. Booske et al., "Different Perspectives for Assigning Weights to Determinants of Health," County Health Rankings Working Paper. Madison (WI): University of Wisconsin Population Health Institute, 2010[d] | Estimates derived to assign weights to determinants for County Health Rankings, drawing on a number of different perspectives | 30% | 40% | 10% | — | 20% | — |
| S. Stringhini et al., "Association of Socioeconomic Position with Health Behaviors and Mortality," *JAMA* 303, no. 12 (2010):1159–66 | SES differences (gradient) in all-cause mortality, 1985–2009 (civil service population in London, England) | Health behaviors (smoking, diet, alcohol consumption, and physical activity):<br>42% (when assessed at baseline)<br>72% (assessed 4 times over 24 years of follow-up) | — | — | — | — | — |
| P. Thoits, "Stress and Health: Major Findings and Policy Implications," *Journal of Health and Social Behavior* 51 Suppl (2010): S41–53[e] | Percentage of the variance in psychological distress and depressive symptoms | — | — | — | — | — | 25–40% |

## "Health Policy Brief: The Relative Contribution of Multiple Determinants to Health Outcomes," Health Affairs, August 21, 2014

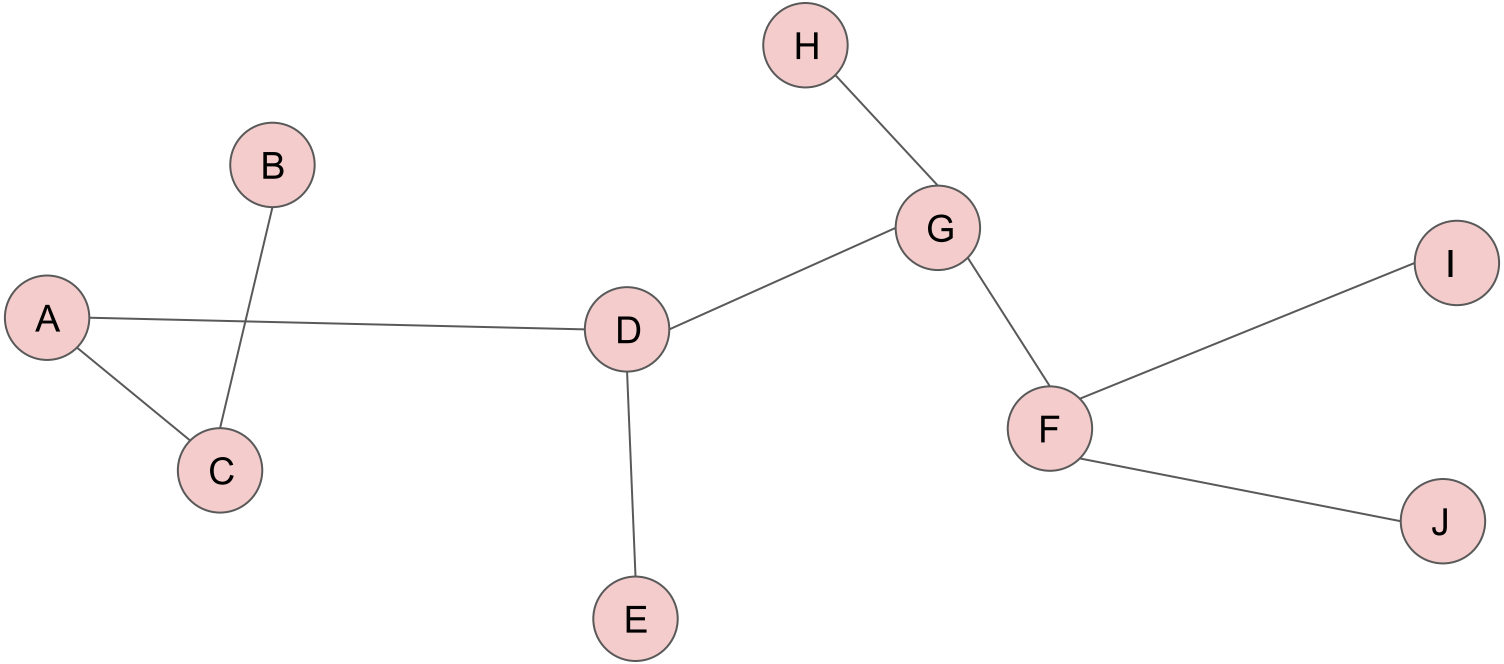
# CHAPTER 2:
# Basic Concepts



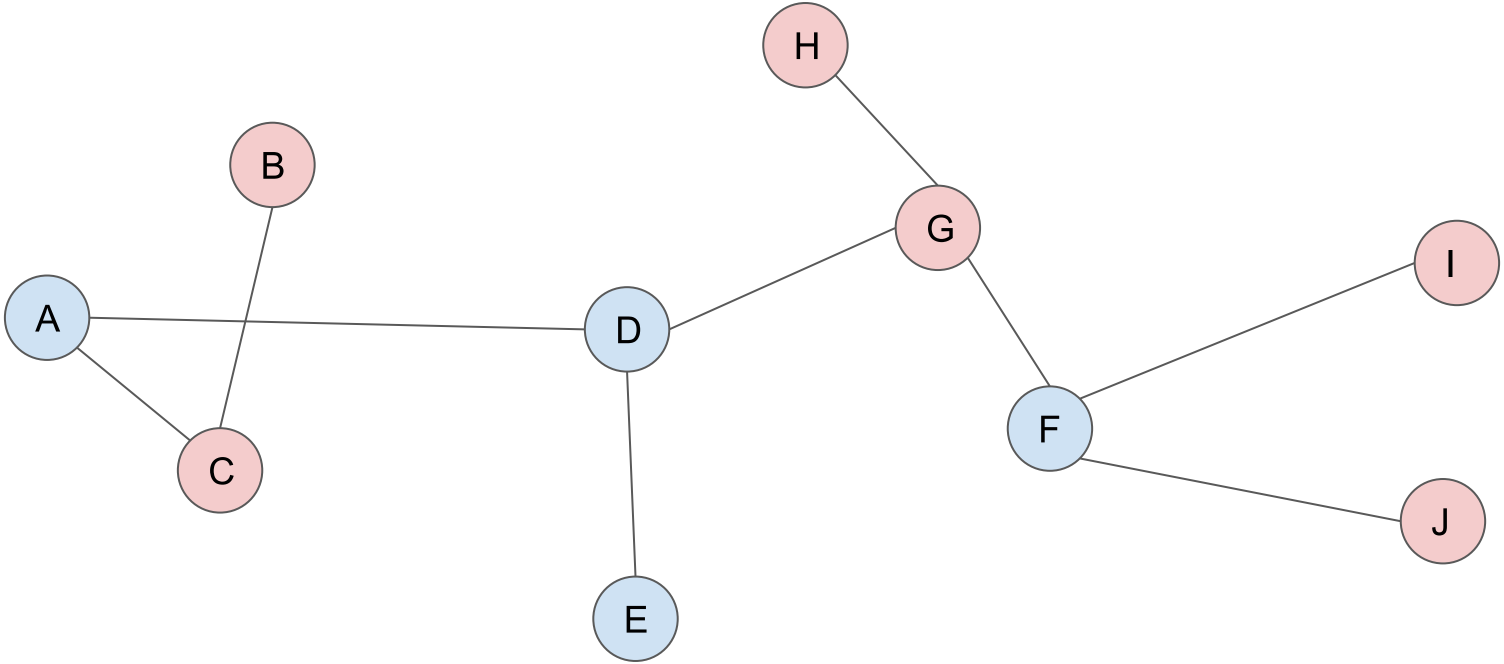
# Nodes



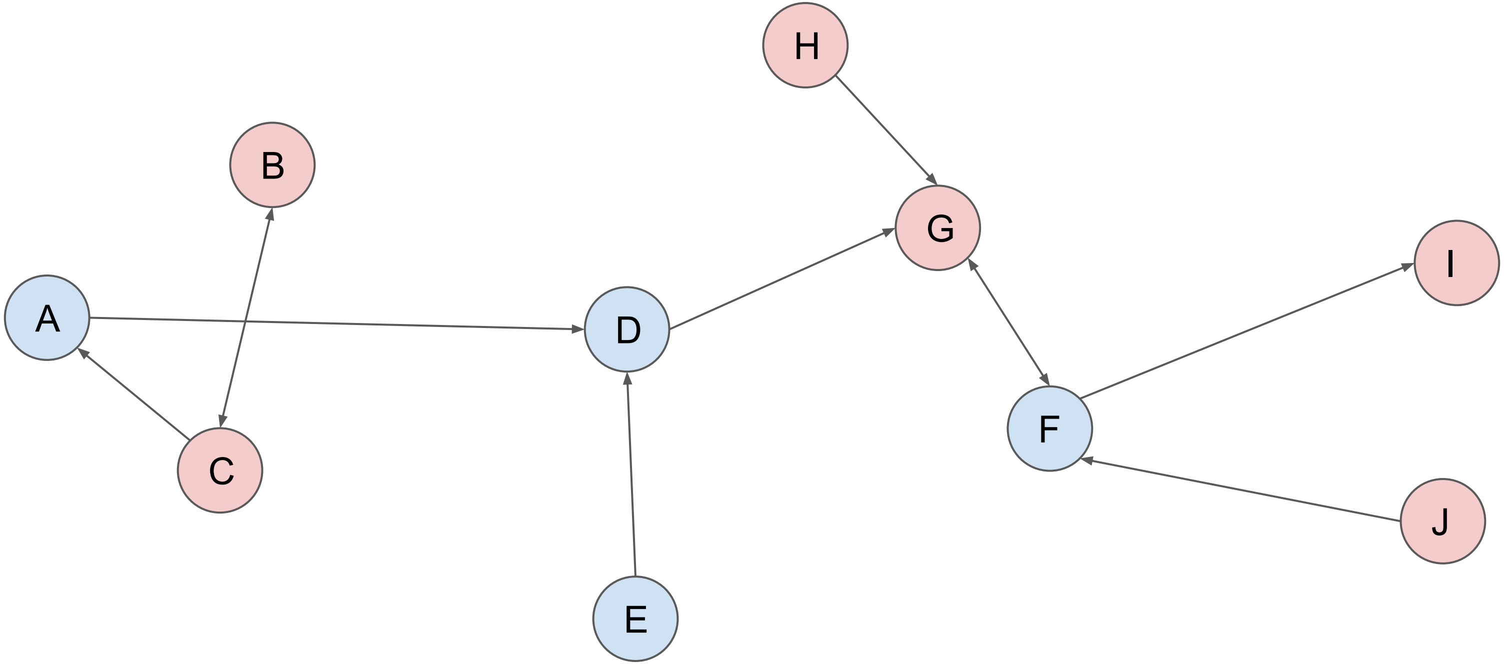
# Edges

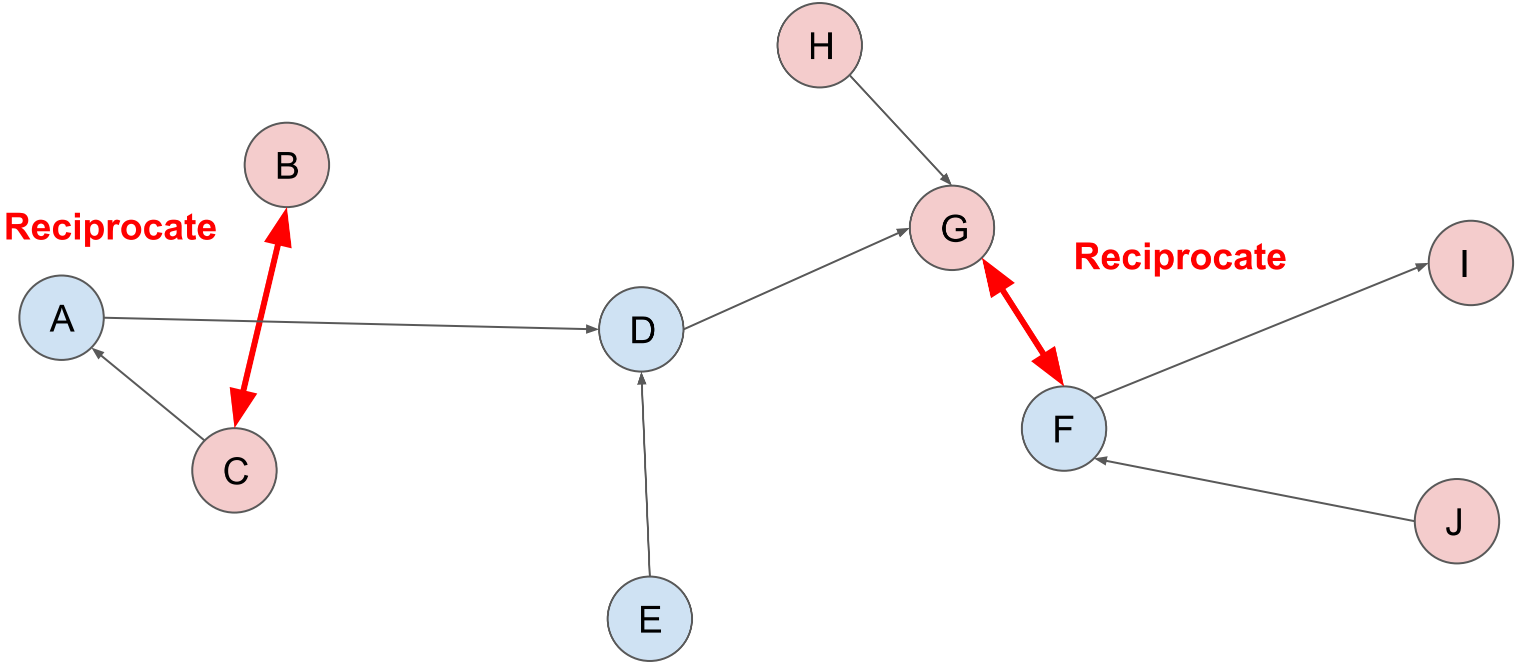


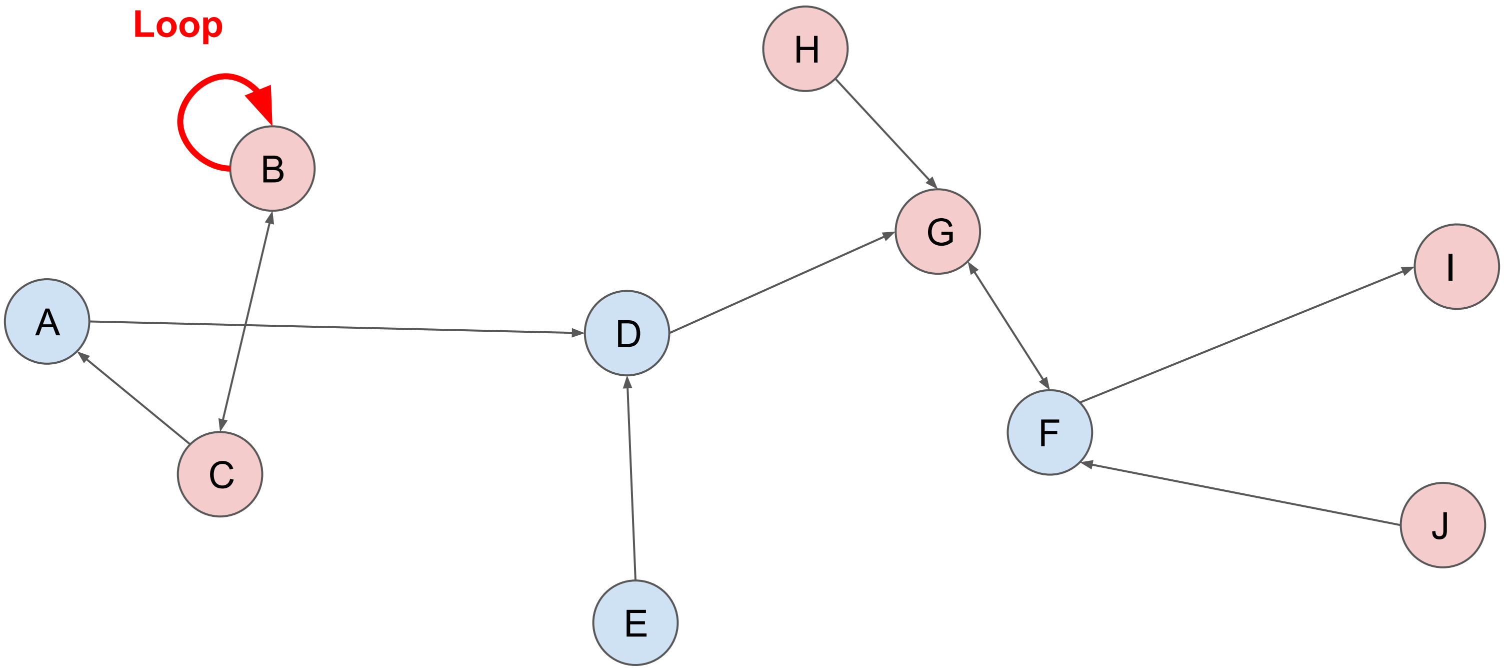
# Attributes



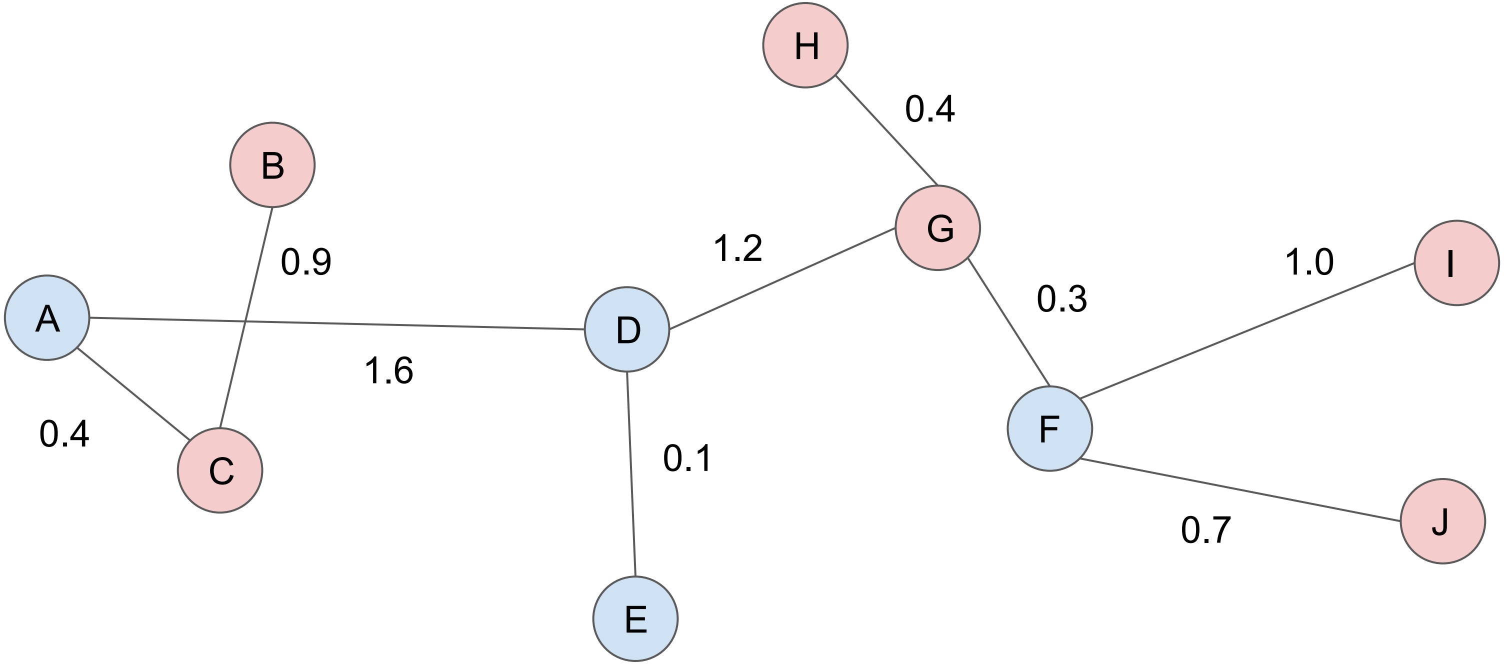
# Directed or Unidirected



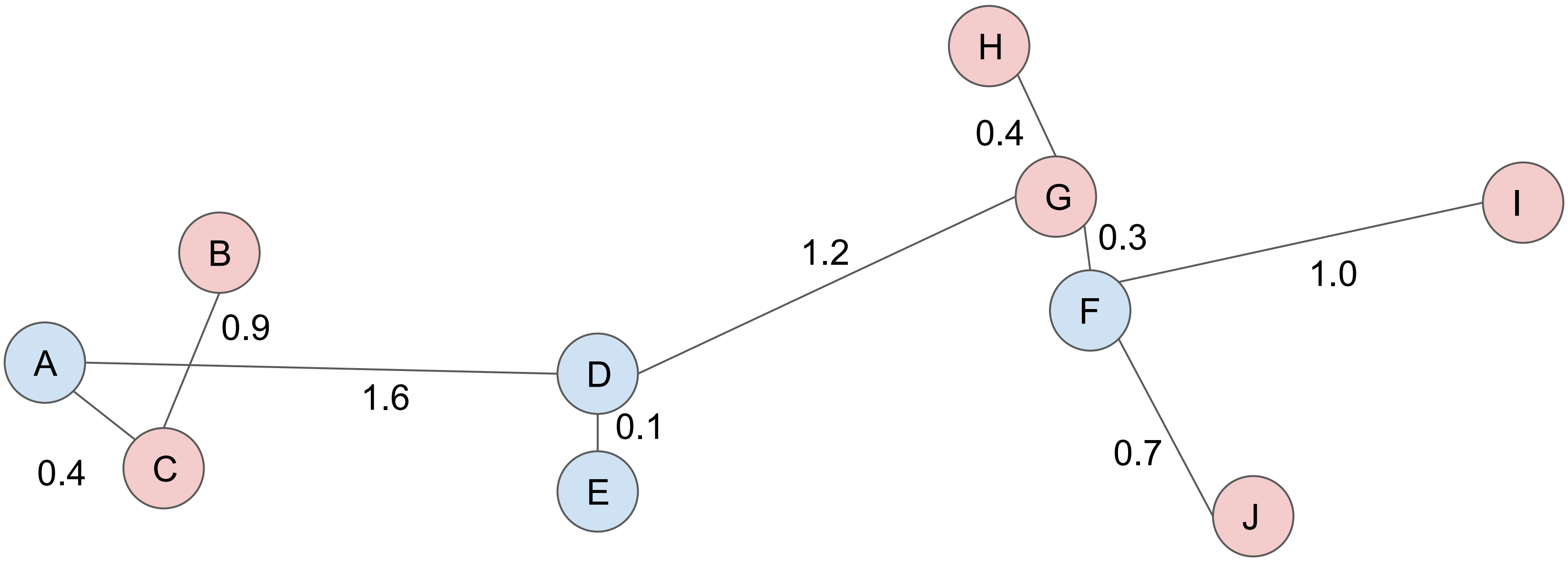

H
B
Reciprocate
G
Reciprocate
I
A
D
F
C
J
E


Loop
A
B
C
D
E
F
G
H
I
J

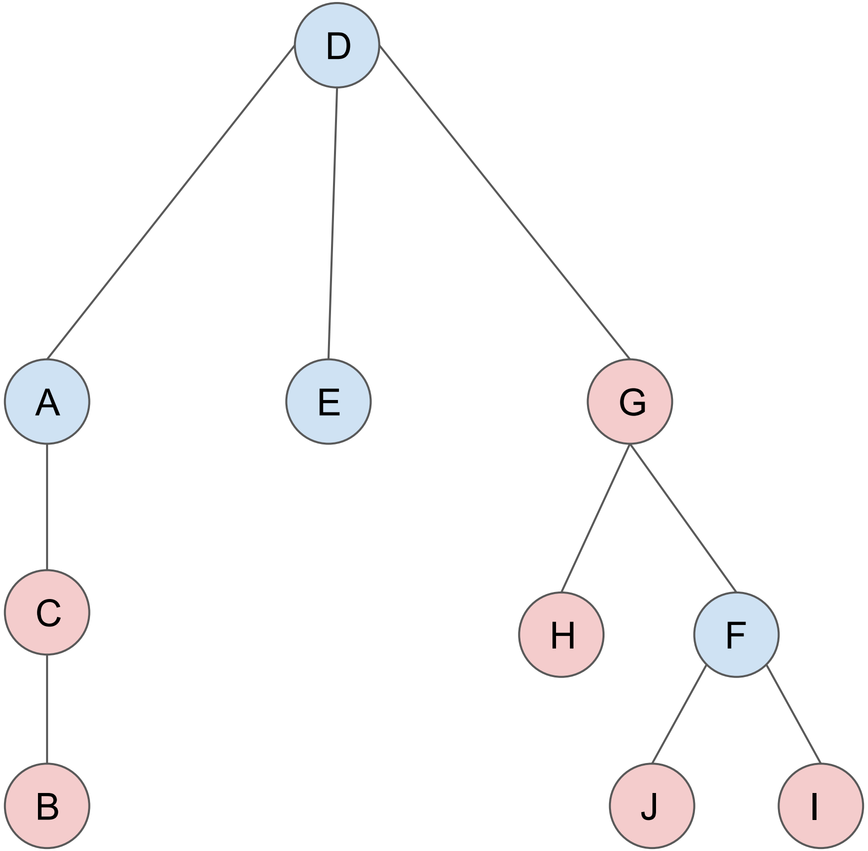
# Binary “0/1” edges or more meaningfull values



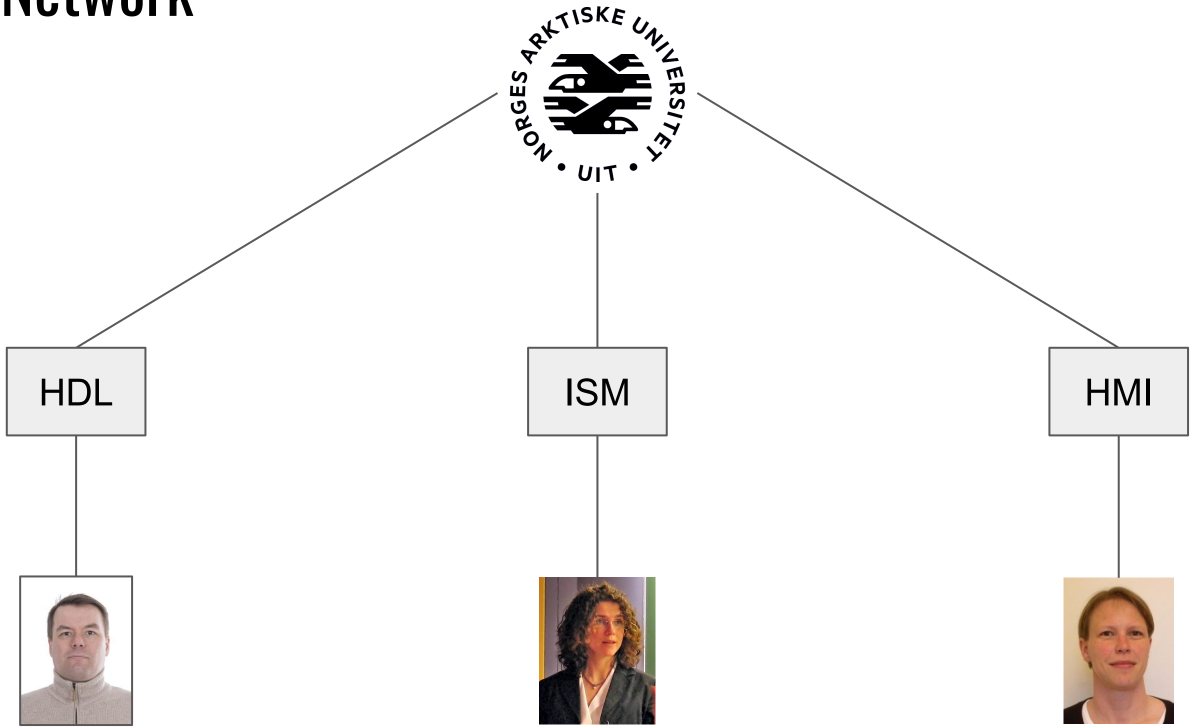
# Spring layout



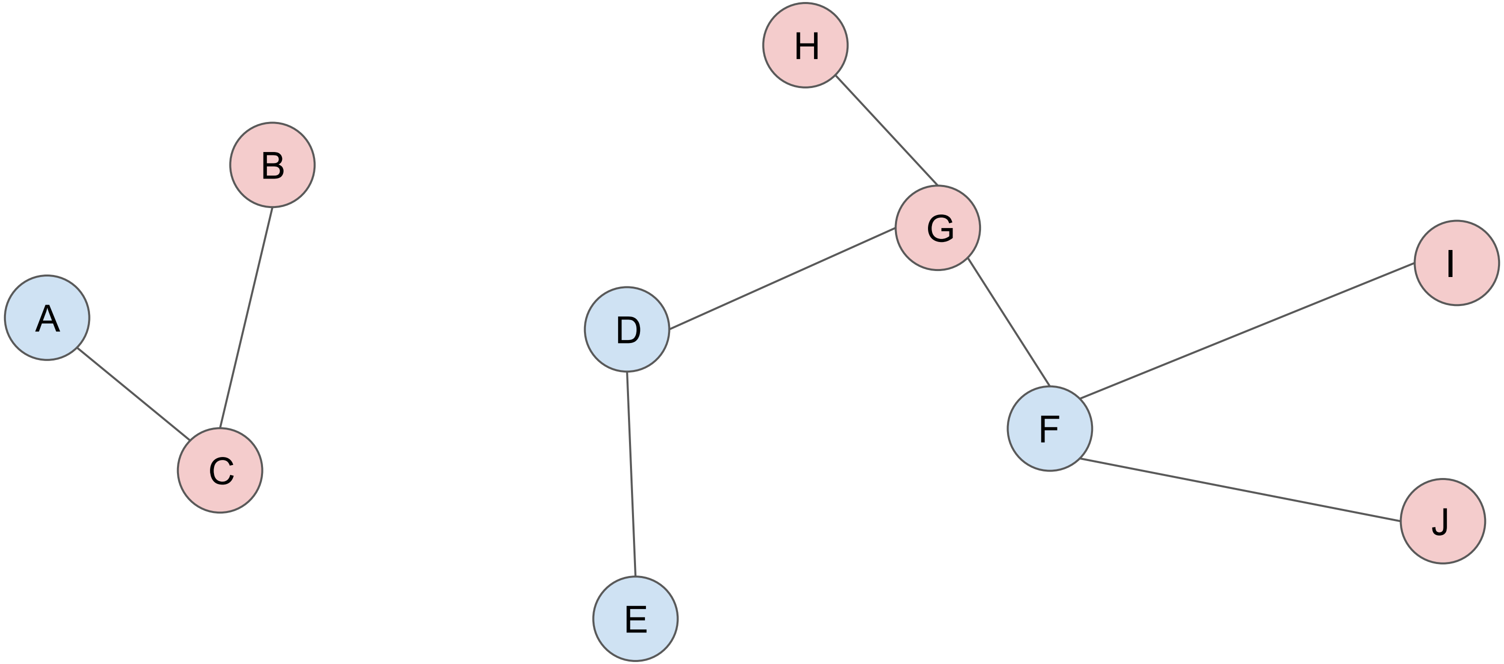
# Hiearchachy layout



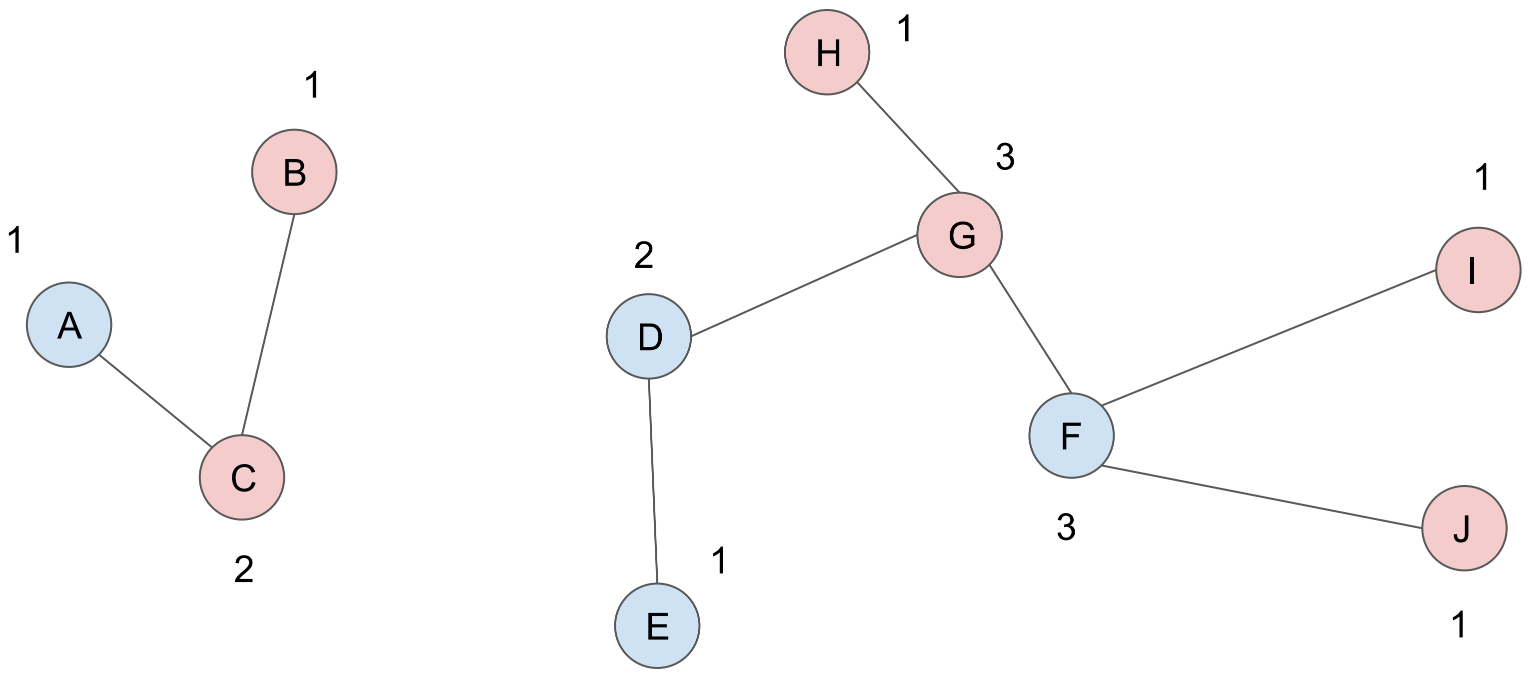
# Multimodal Network



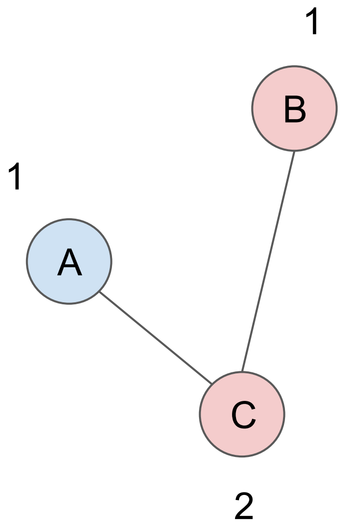
# Components

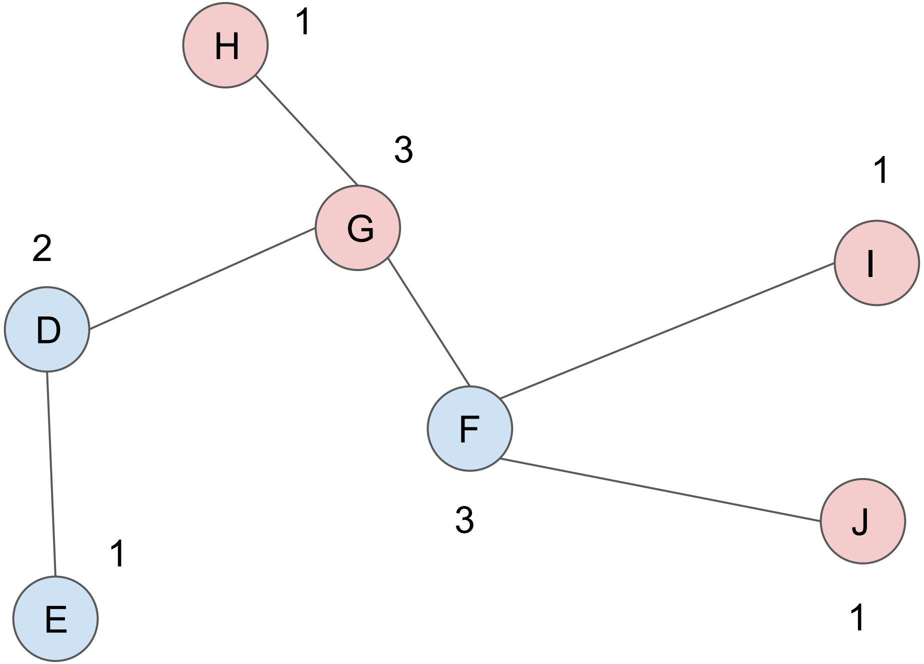


# Degree



# Connectivity



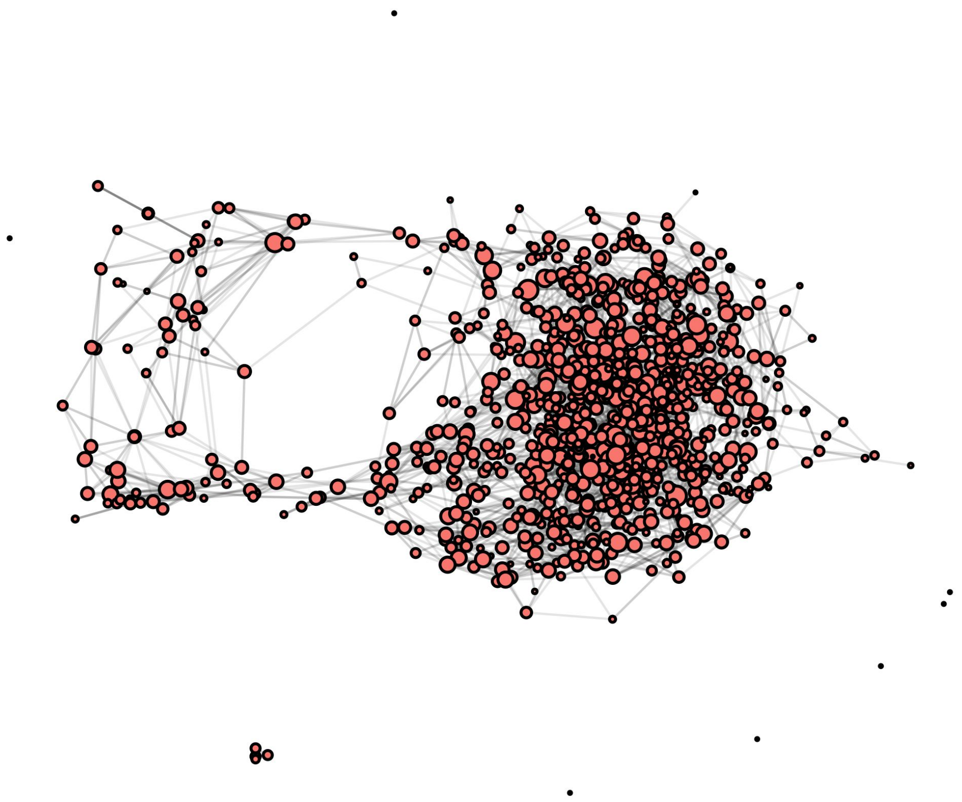

Average: 1.3

Average: 1.71

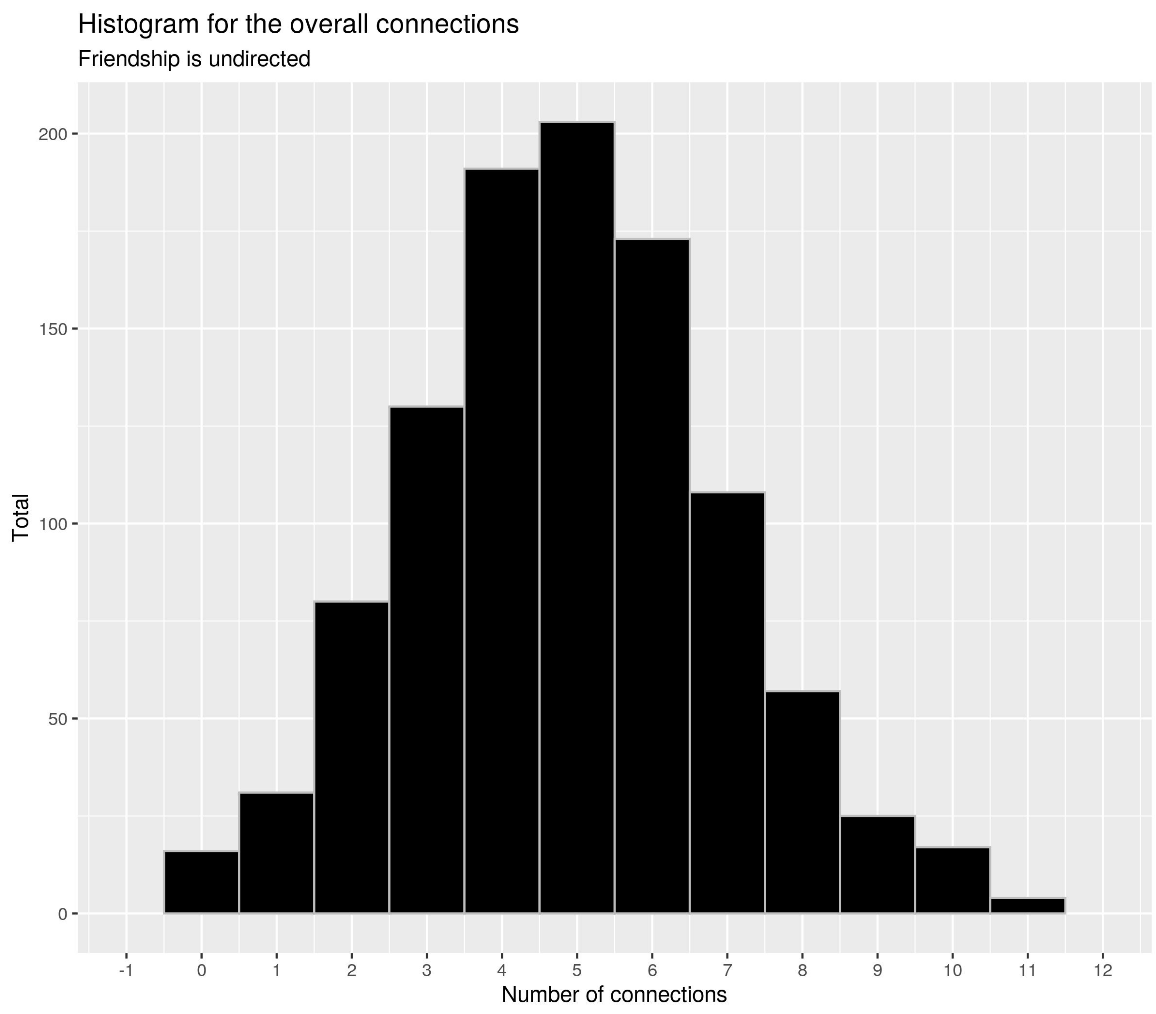
# Connectivity

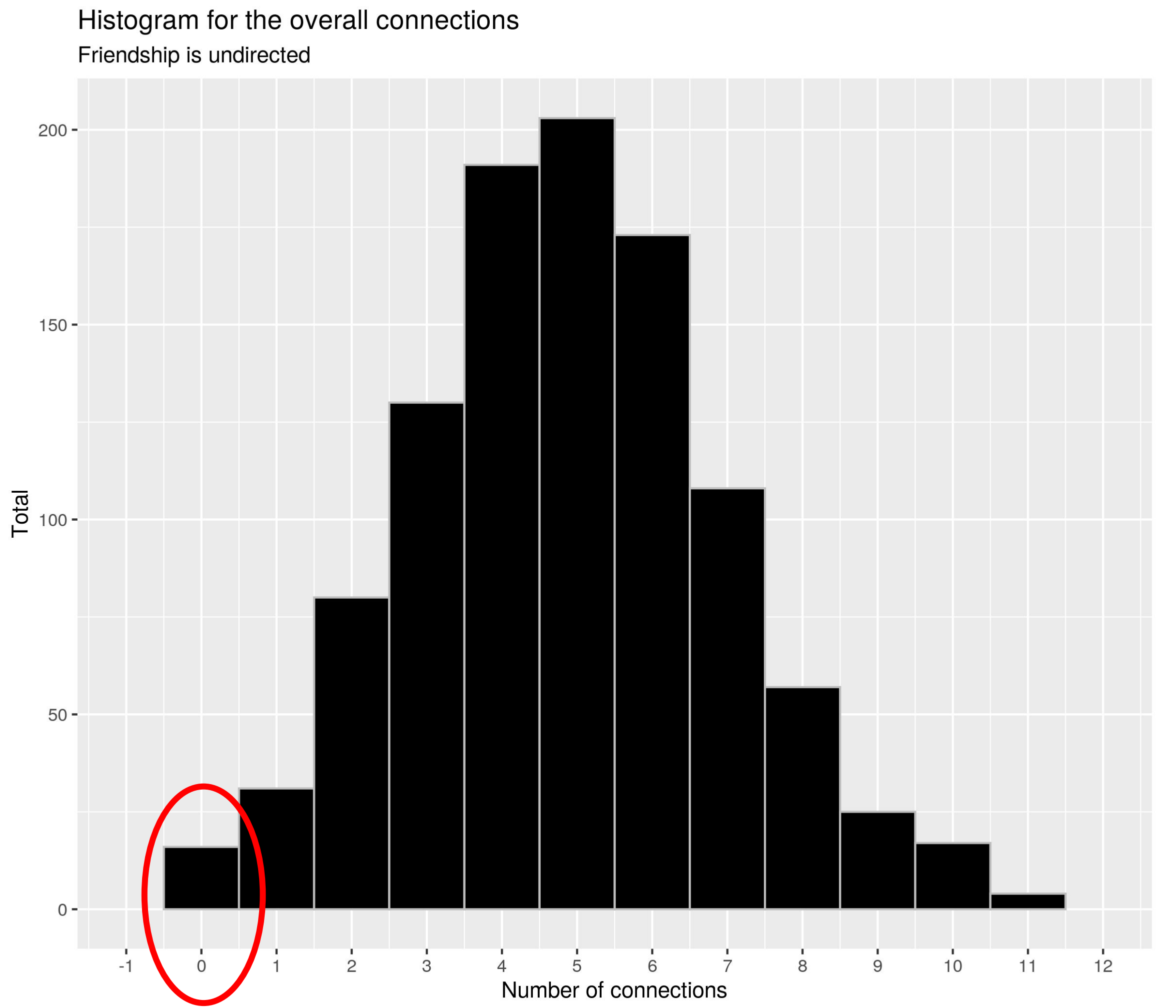
Overall Frienship with all relationships

Size based on number of undirected relationships



Average: 4.9


Histogram for the overall connections
Friendship is undirected
Total
200
150
100
50
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Number of connections


Histogram for the overall connections
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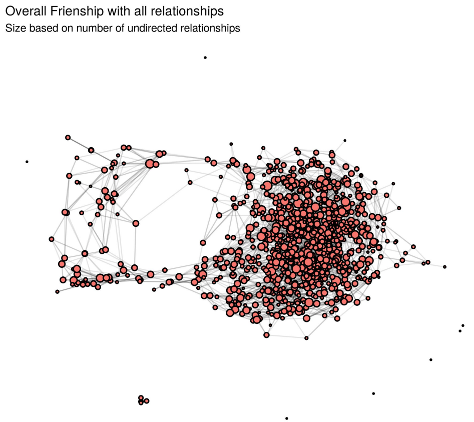
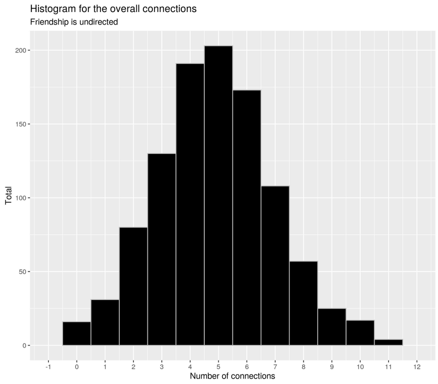
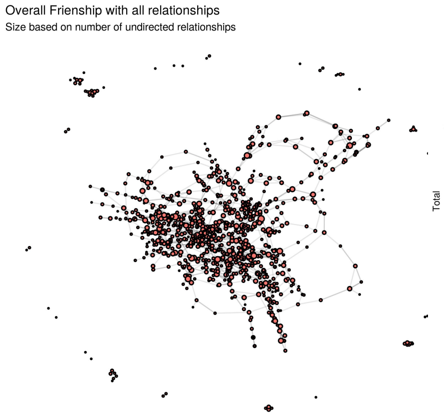
150
100
50
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Number of connections

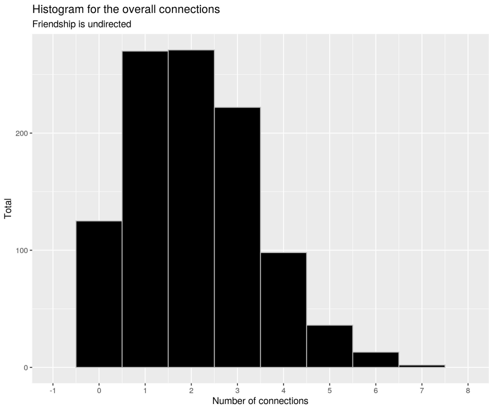
# Average: 4.9



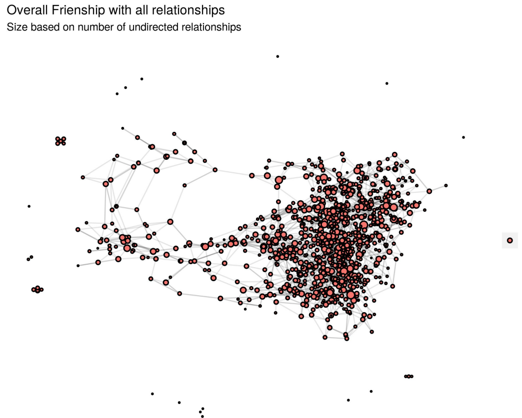



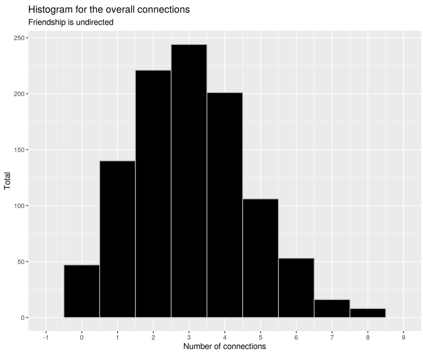

# Average: 2.07



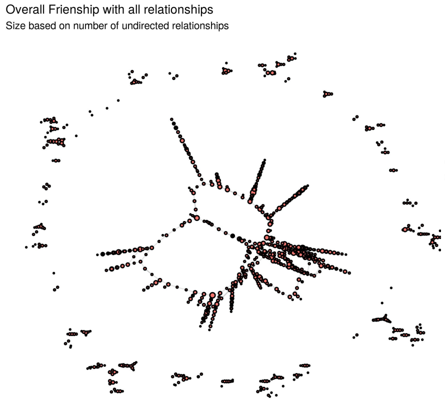



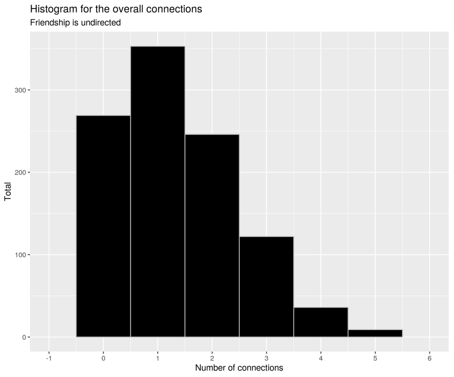

# Average: 3.0



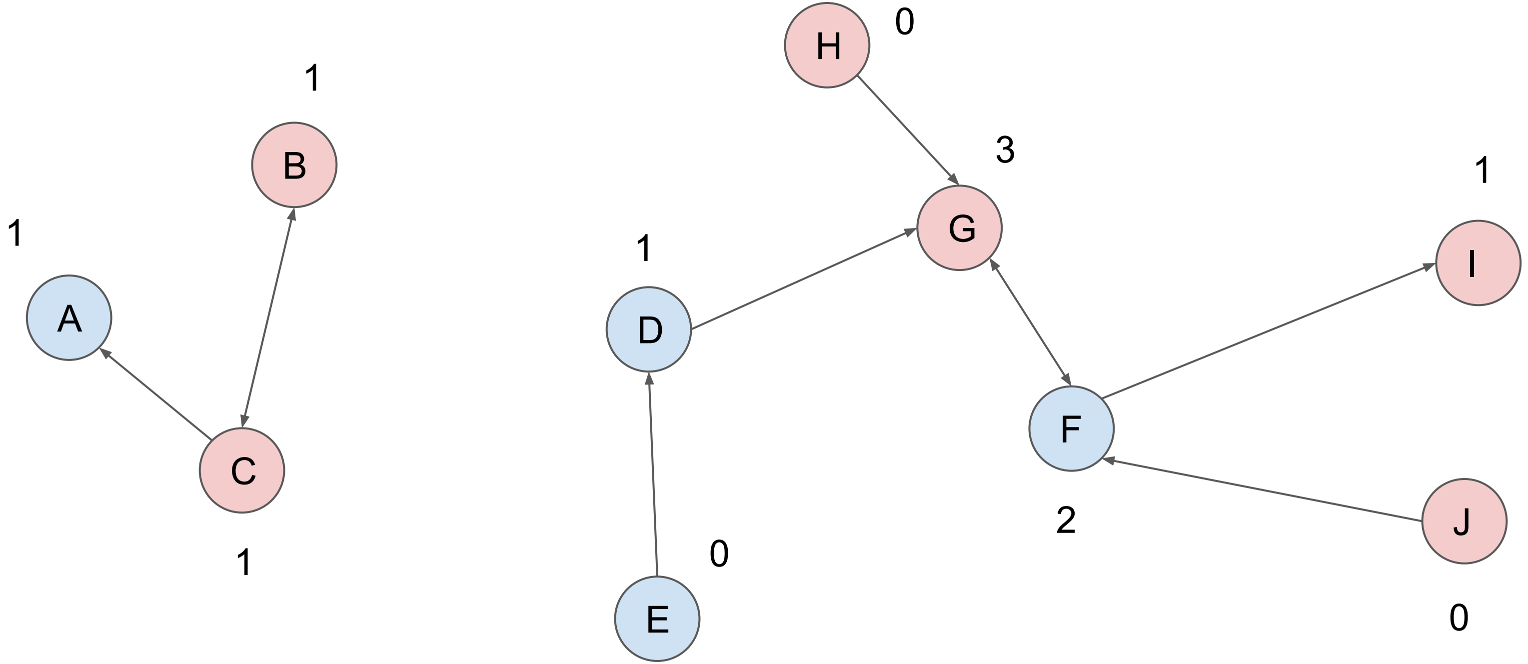




# Average: 1.36

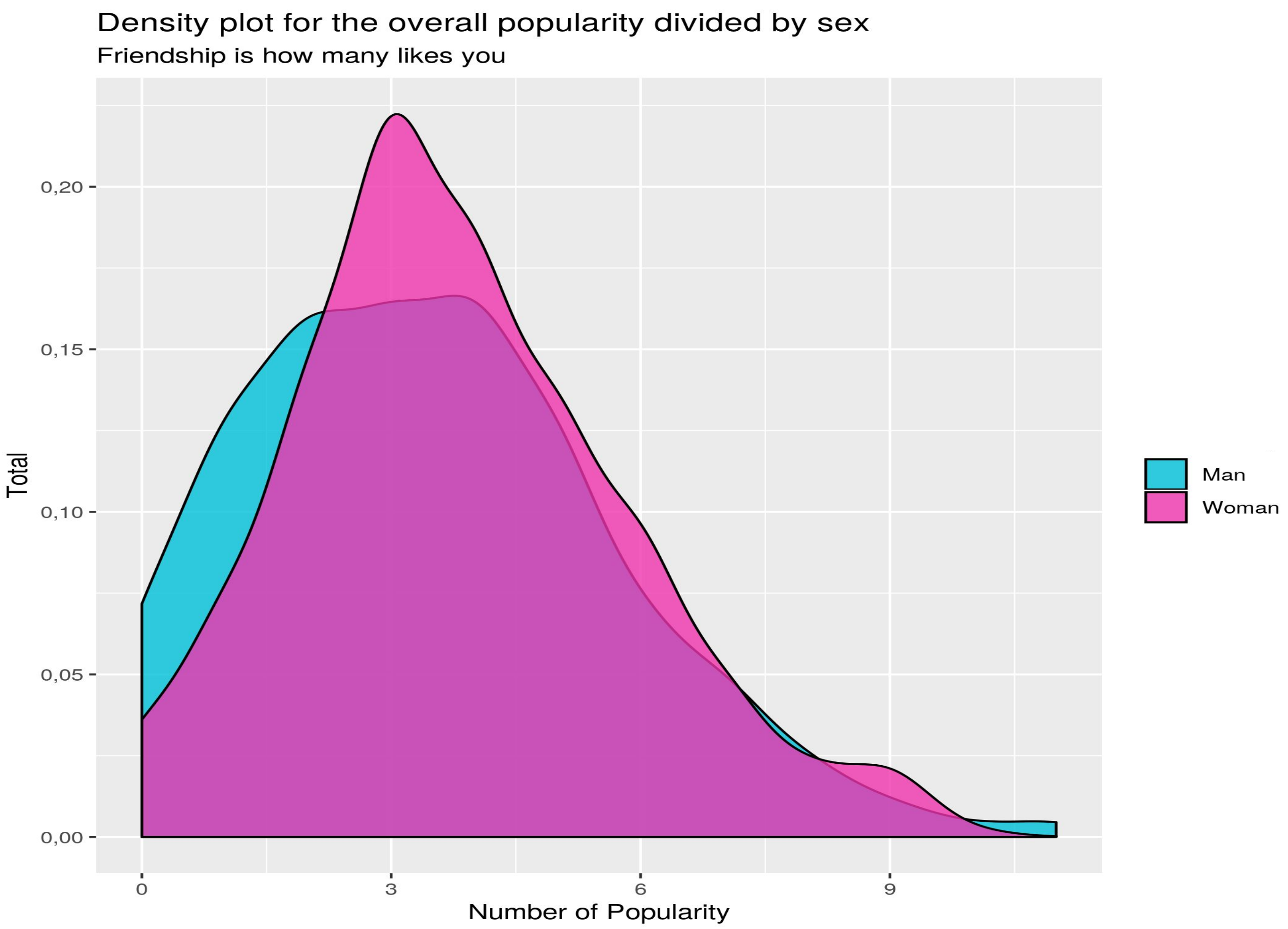


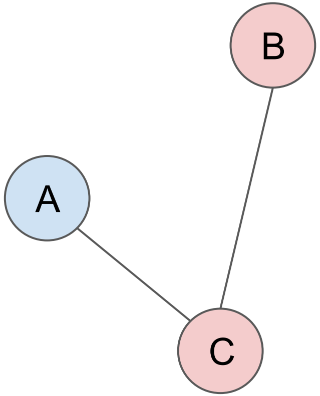
# In/Out Degree

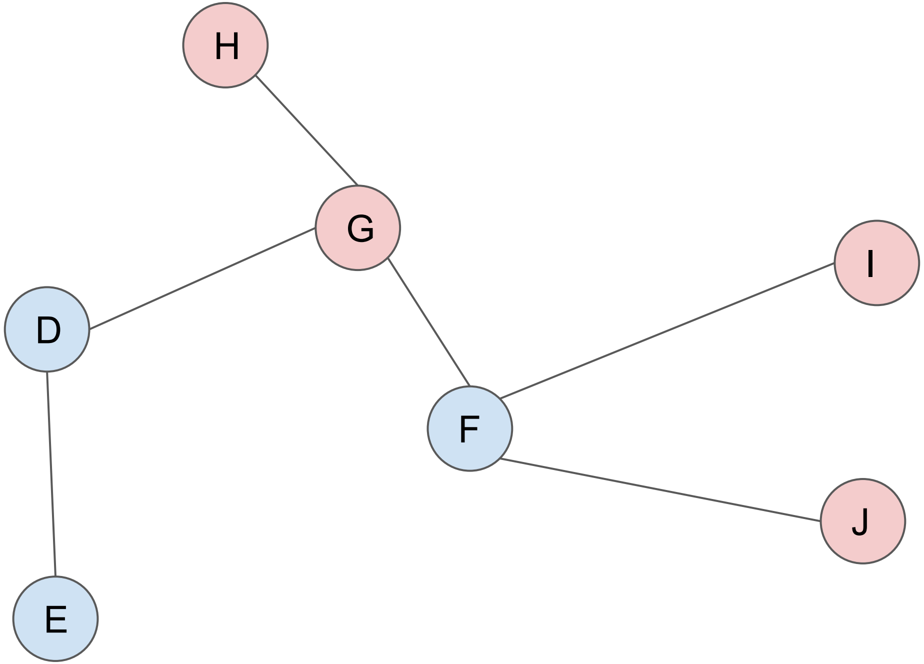


# In/Out Degree



# Density
# (connections/total possible)

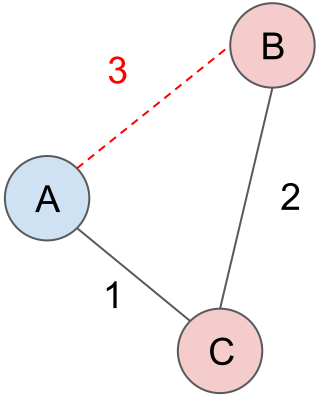


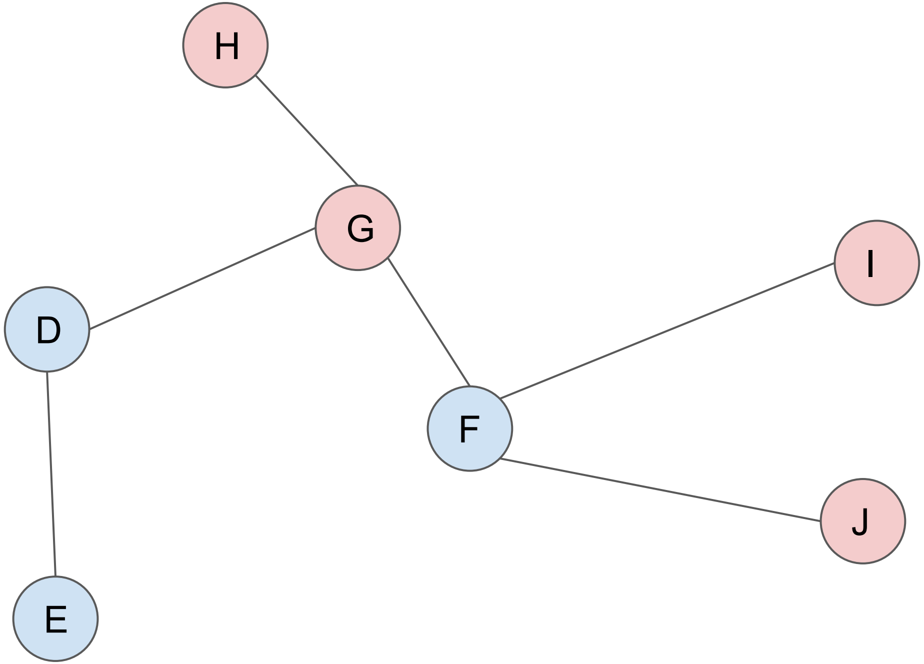

Density: 2 / 3 = 0.66

Density:  6 / 21 = 0.29

# Density
# (connections/total possible)

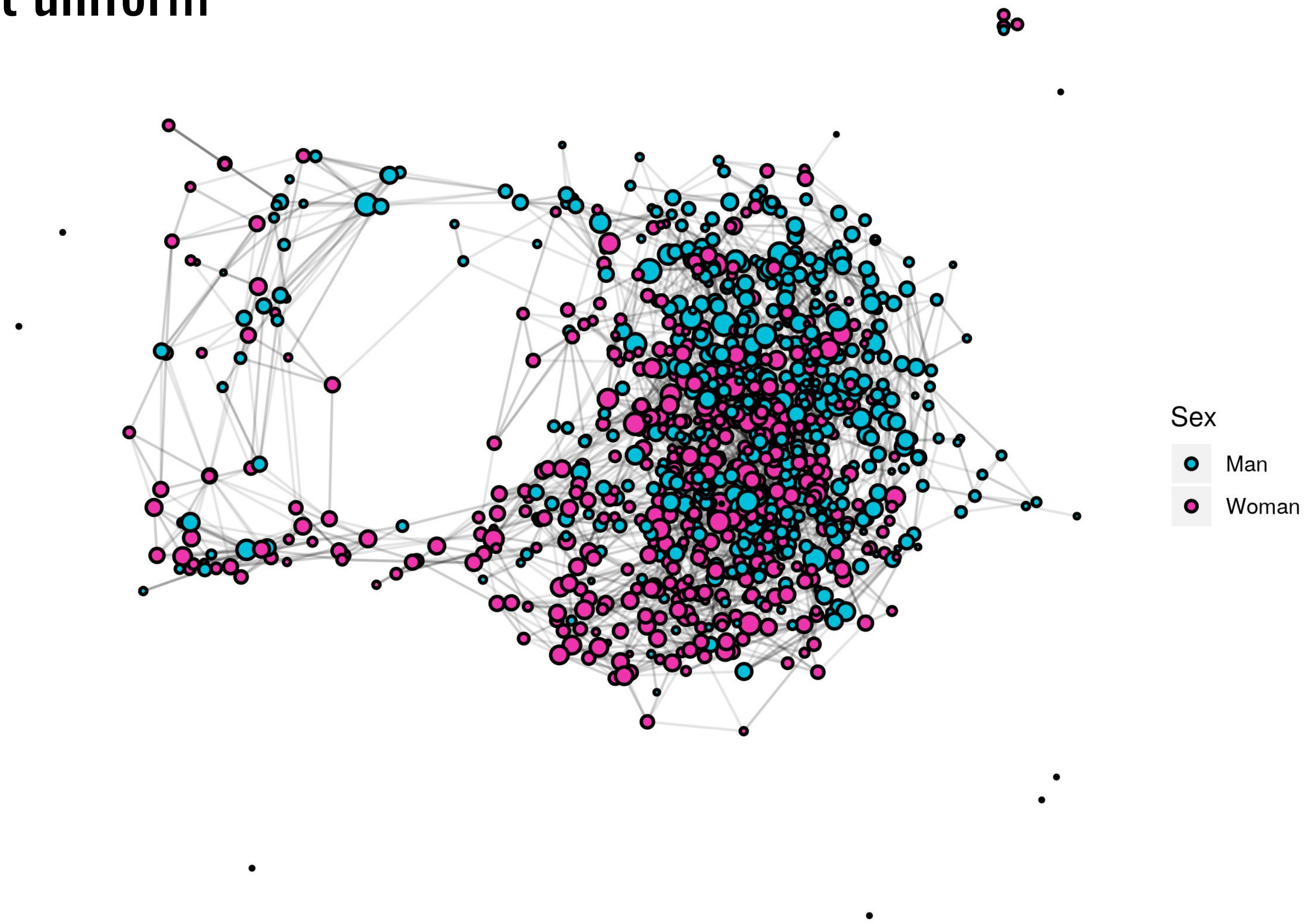



Density: 2 / 3 = 0.66

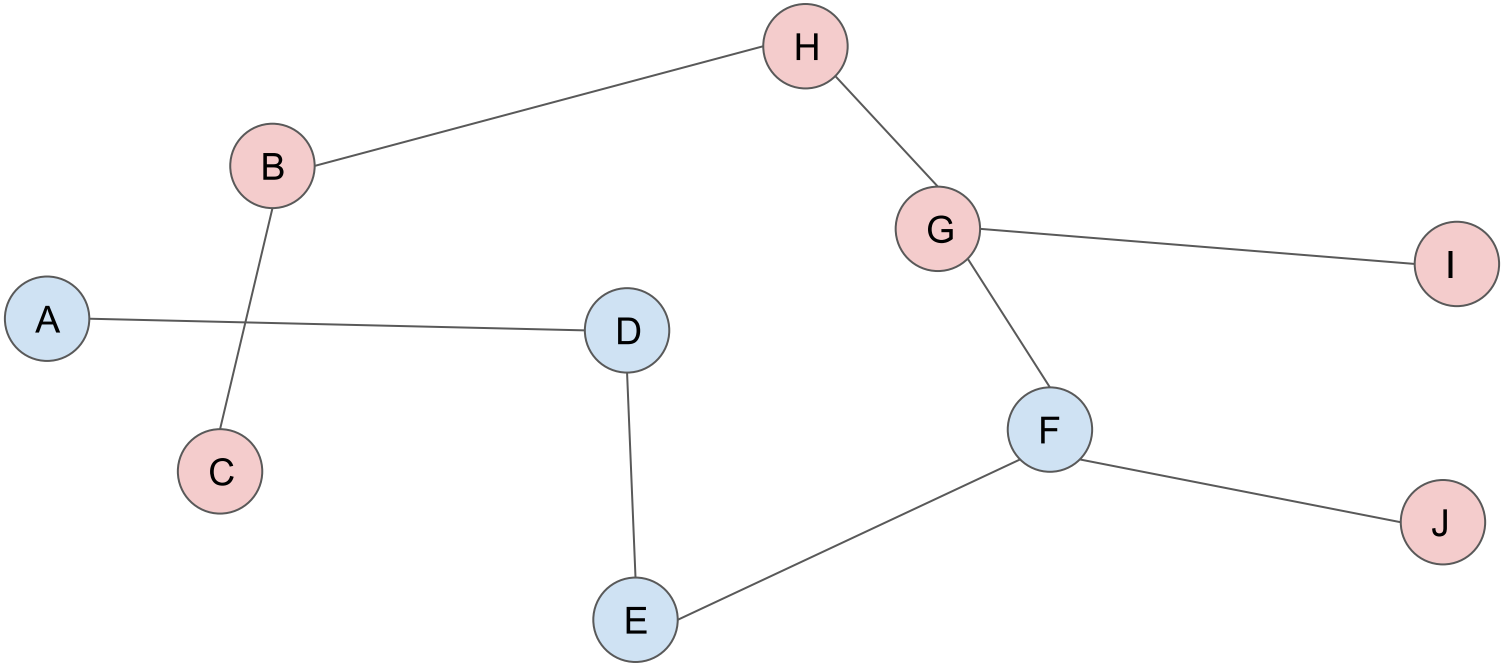



Density:  6 / 21 = 0.29

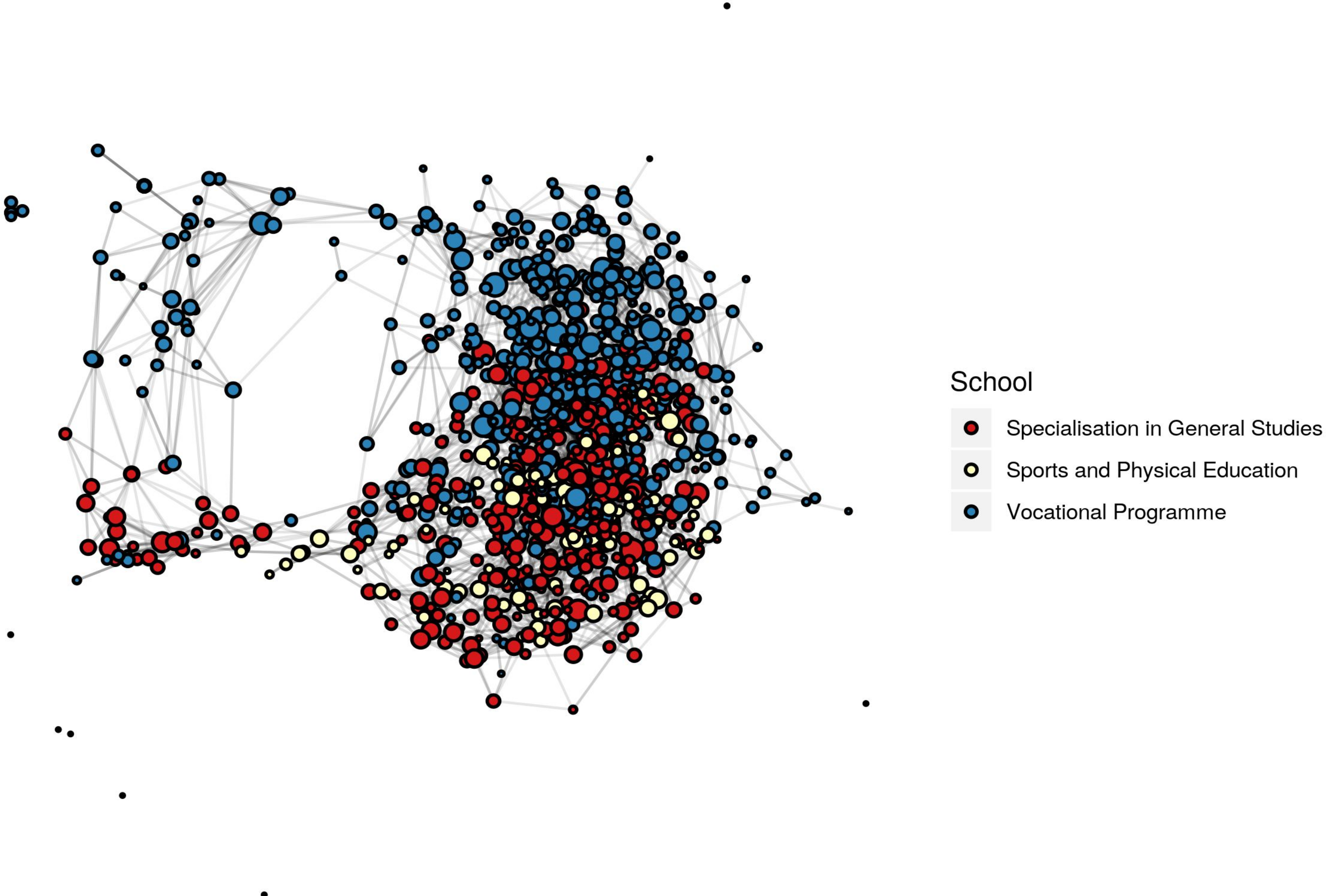
# Density is not uniform



# Homophily



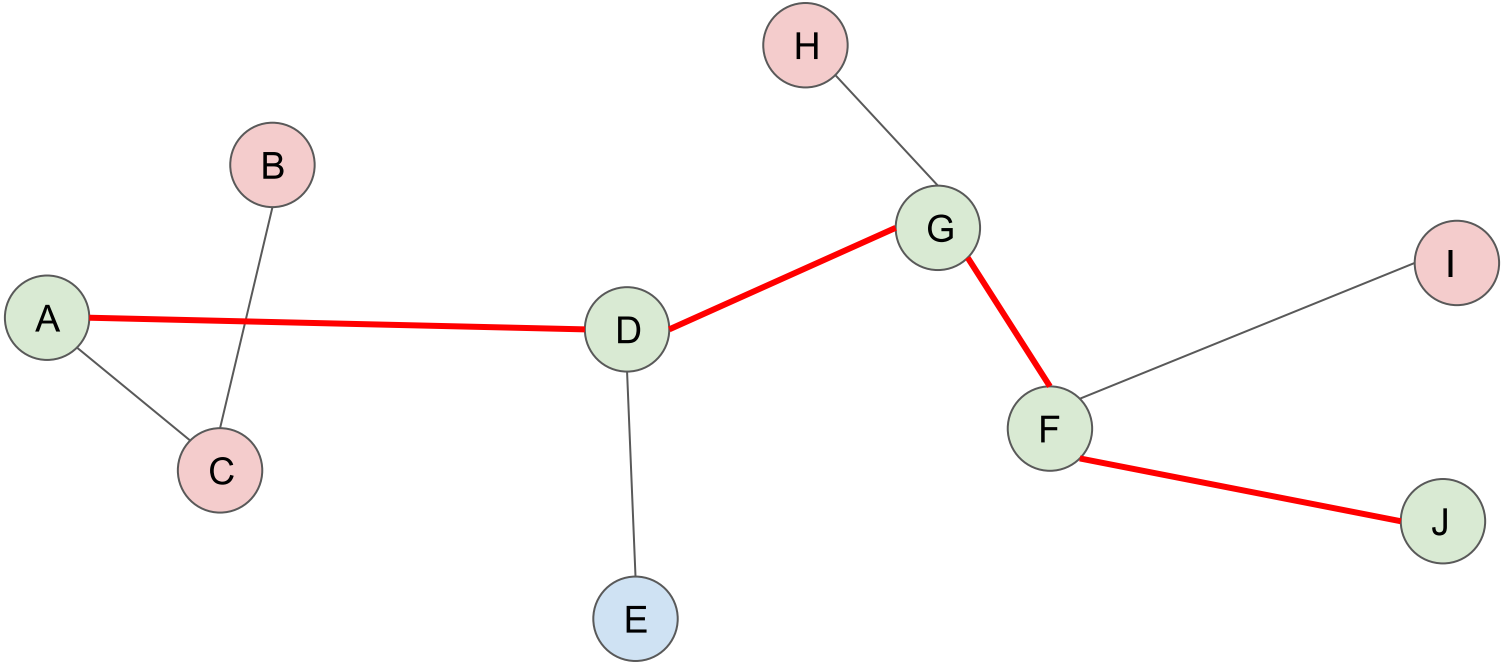
```
homophily(overallGraph,"Sex")

[1] 0,8404566
```


School
Specialisation in General Studies
Sports and Physical Education
Vocational Programme

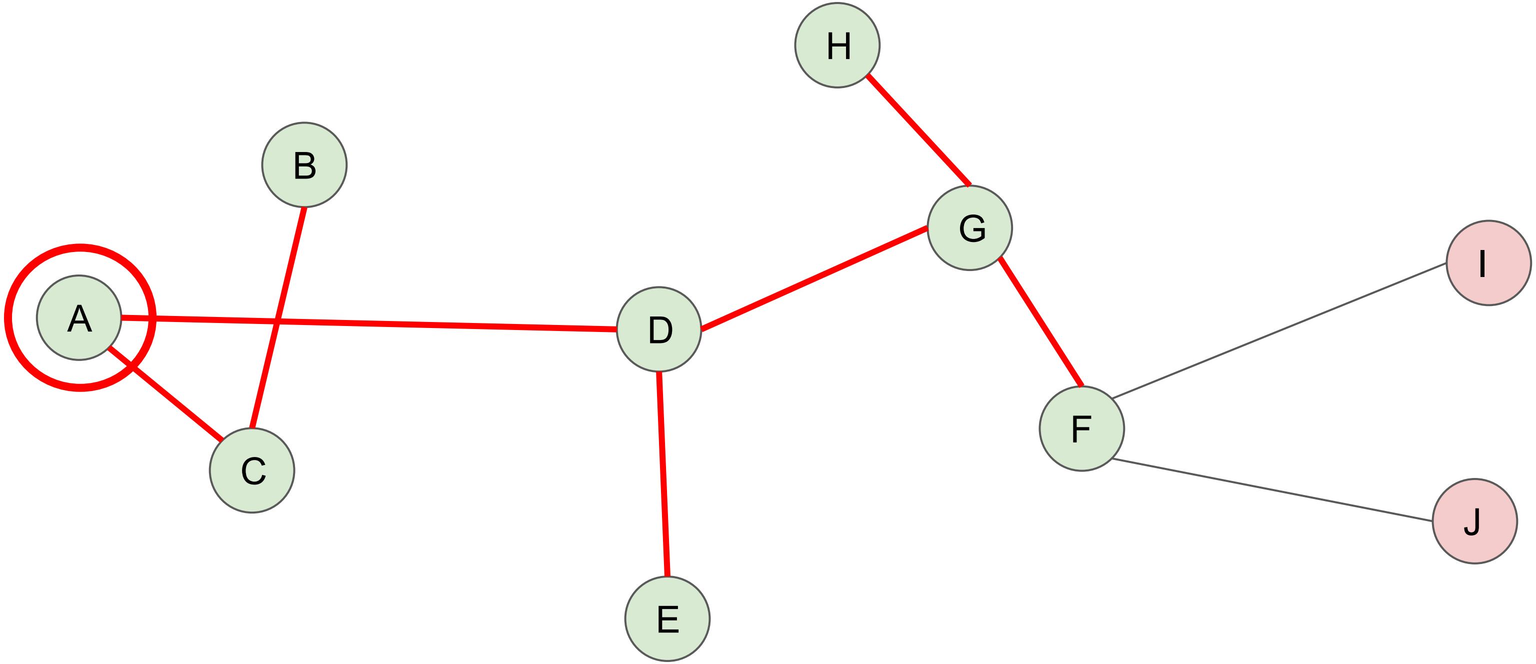
```
homophily(overallGraph,"Sex")

[1] 0,8404566

homophily(overallGraph,"School")

[1] 0,8789488
```

```
homophily(overallGraph,"Sex", “Woman”)

[1] 0,7289129

homophily(overallGraph,"Sex", “Man”)

[1] 0,7205951
```

# Path

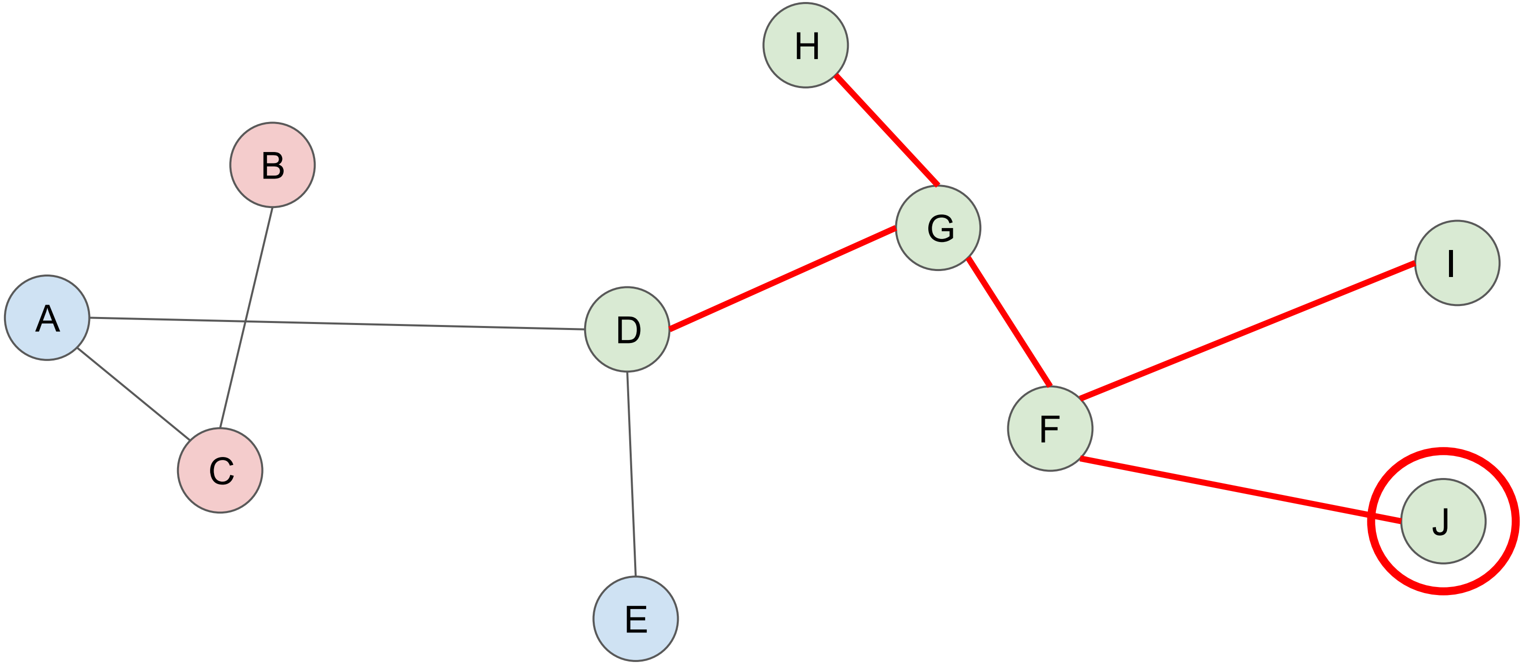


# Coverage

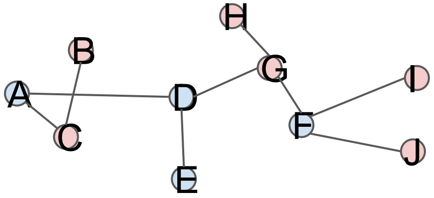



After 3 steps, we cover 8 of 10 nodes from A

# Coverage

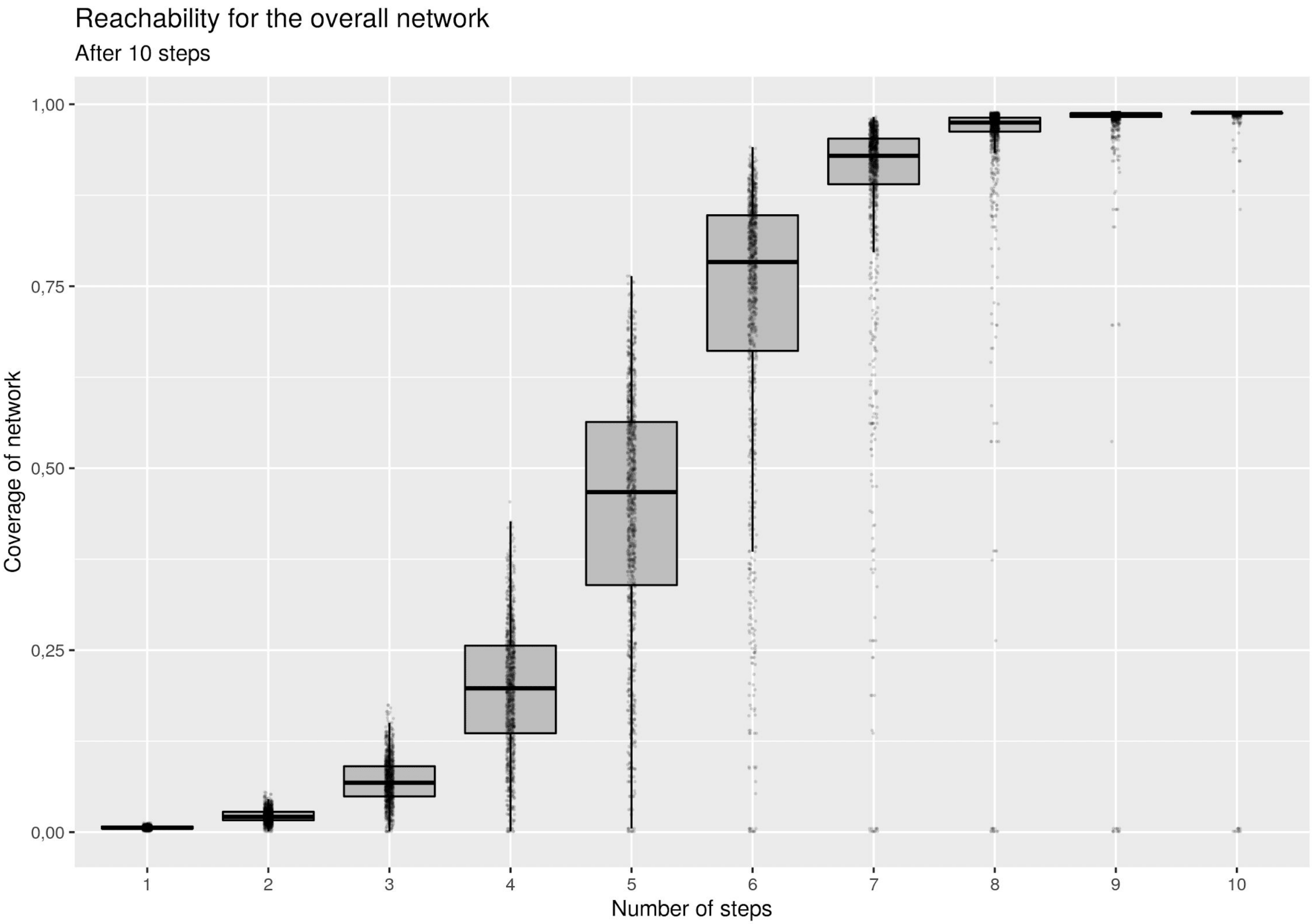



After 3 steps, we cover 6 of 10 nodes from J

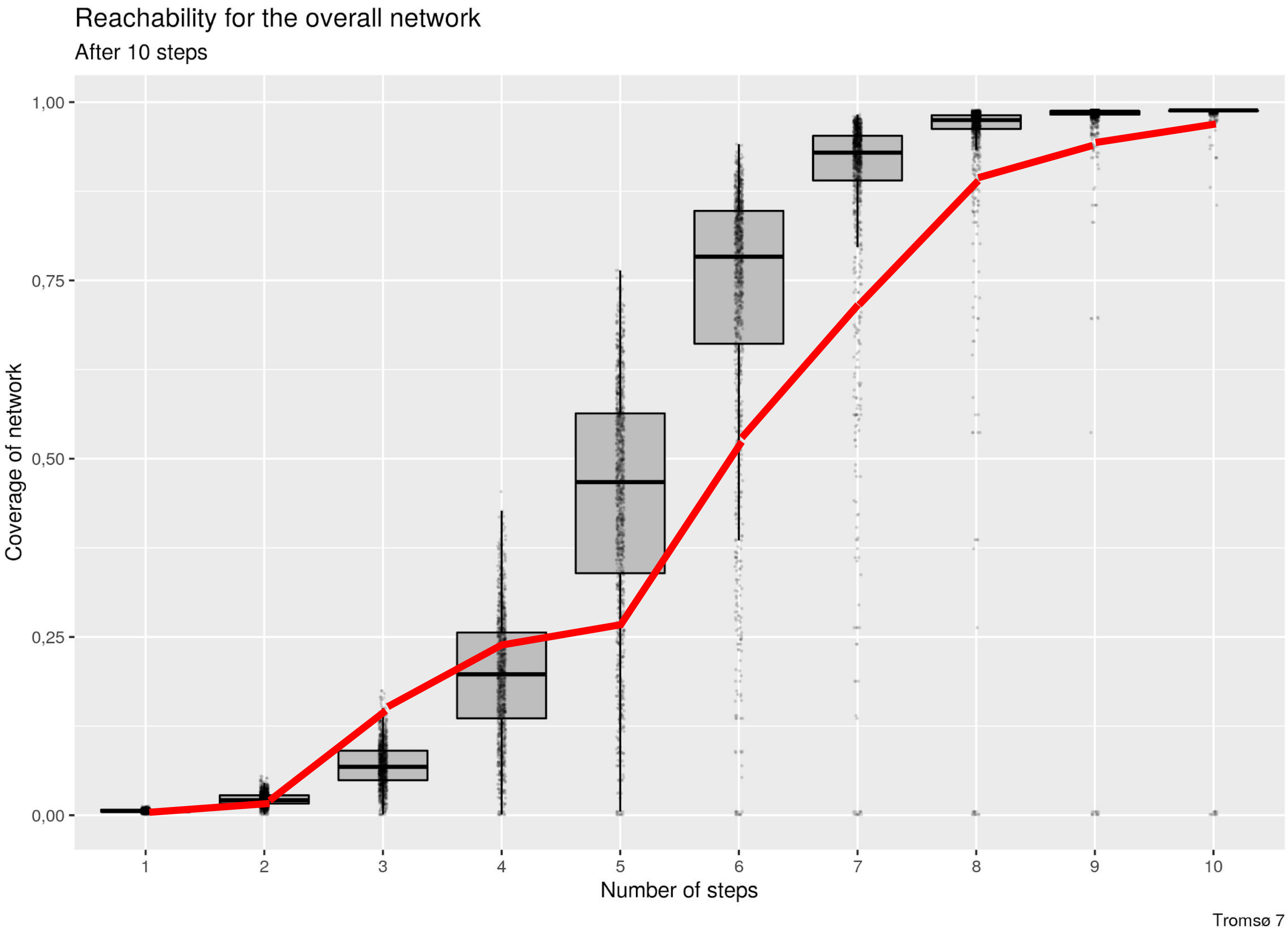



| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0 | | | | | | | | | |
| B | 2 | 0 | | | | | | | | |
| C | 1 | 1 | 0 | | | | | | | |
| D | 1 | 3 | 2 | 0 | | | | | | |
| E | 2 | 4 | 3 | 1 | 0 | | | | | |
| F | 3 | 5 | 4 | 2 | 3 | 0 | | | | |
| G | 2 | 4 | 3 | 1 | 2 | 1 | 0 | | | |
| H | 3 | 5 | 4 | 2 | 3 | 2 | 1 | 0 | | |
| I | 4 | 6 | 5 | 3 | 4 | 1 | 2 | 3 | 0 | |
| J | 4 | 6 | 5 | 3 | 4 | 1 | 2 | 3 | 2 | 0 |

# Reachability



# Reachability



Simulation:

- Everybody has the same chance of spread to someone else. ($p = 0.3$)

- Nobody dies. (constant survival curve)

- Nobody gains inmunity.

- Nobody get cured.

- Virus is not recurrent. (herpes)

- Virus is not biphasic. (tick-borne encephalitis)

- No random jumps in the network. (contact, no airbone)

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- Virus is not biphasic. (tick-borne encephalitis)
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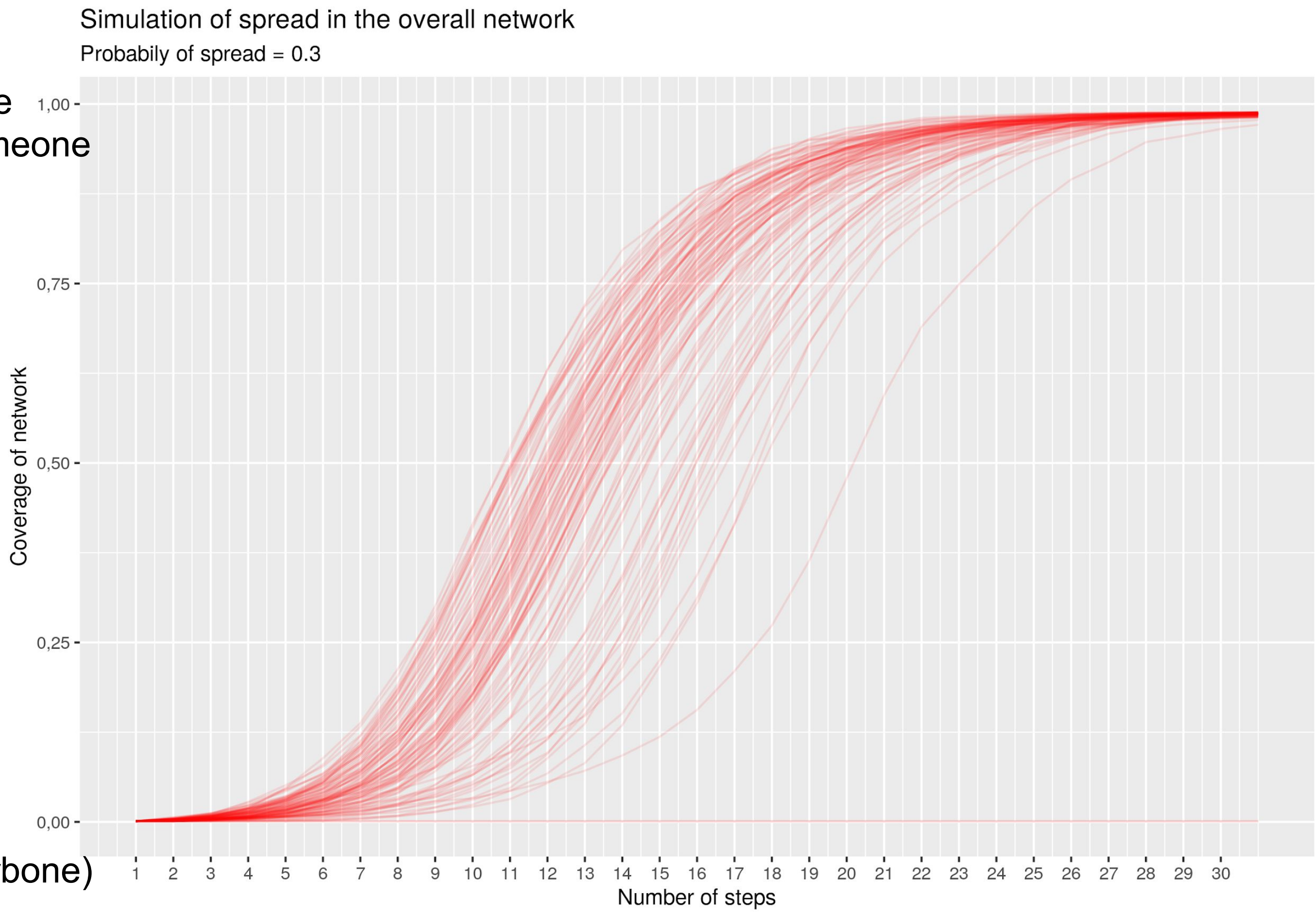


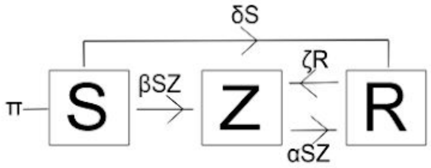



Figure 1: The basic model

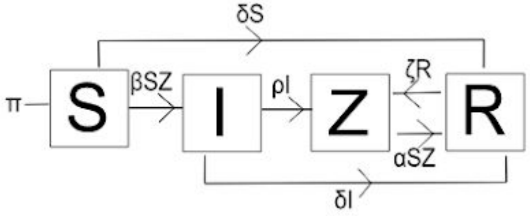



Figure 4: The SIZR model: the basic model with latent infection

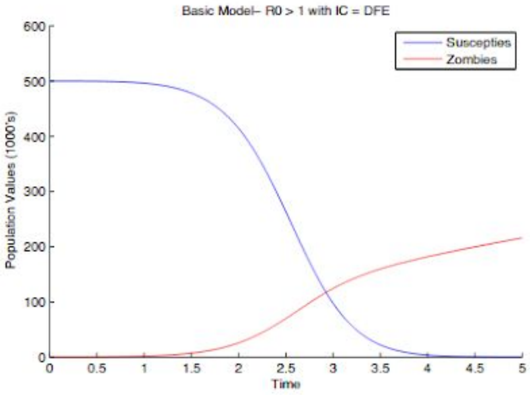



Figure 3: Basic model outbreak scenario. Susceptibles are quickly eradicated and zombies take over, infecting everyone.

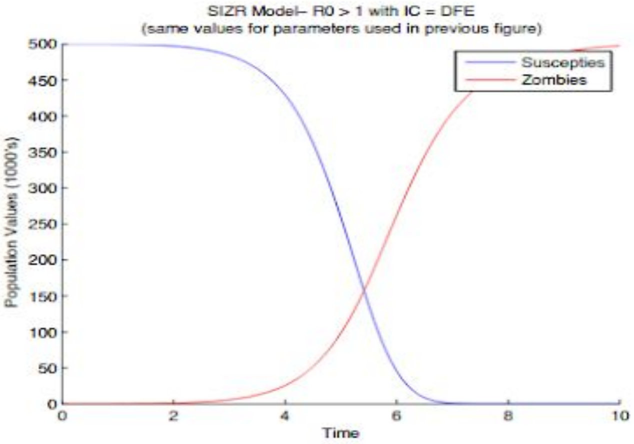
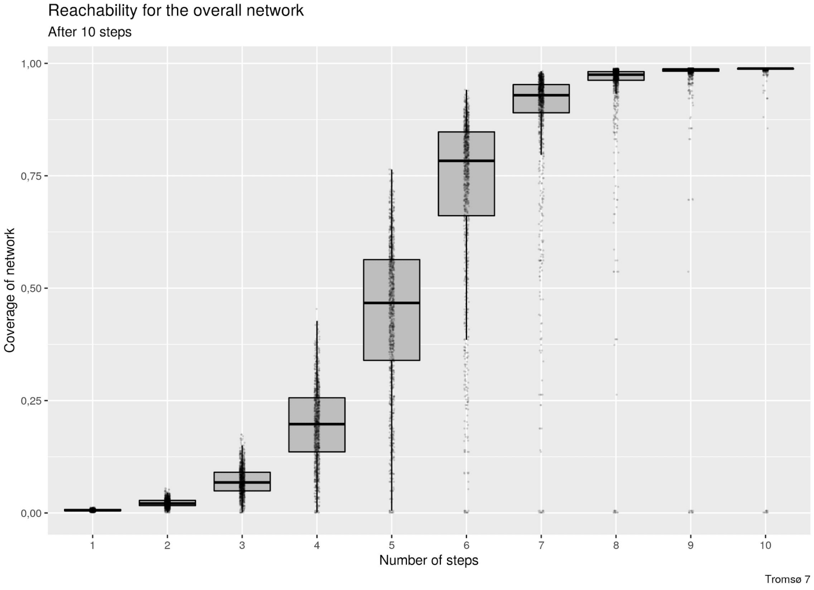



Figure 5: An outbreak with latent infection.

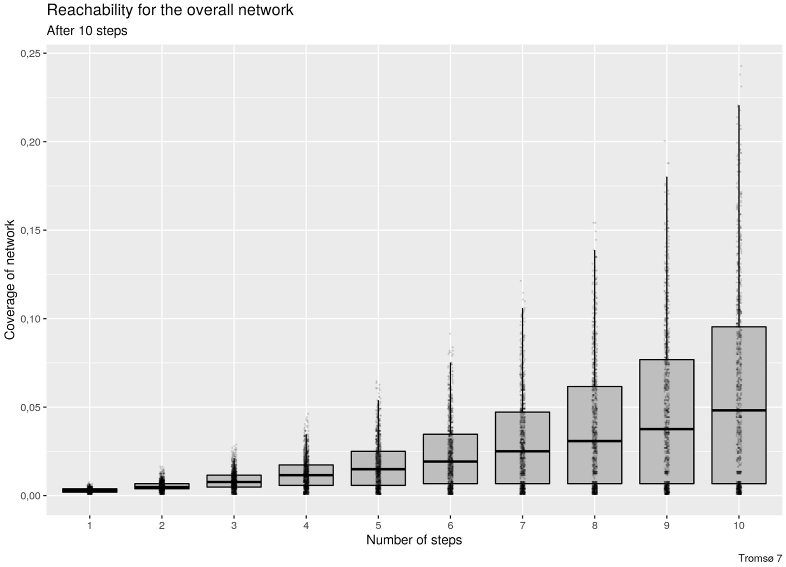
**When zombies attack!: Mathematical modelling of an outbreak of zombie infection**

**Philip Munz, Ioan Hudea, Joe Imad, Robert J. Smith**

Connectivity
Average: 4.9



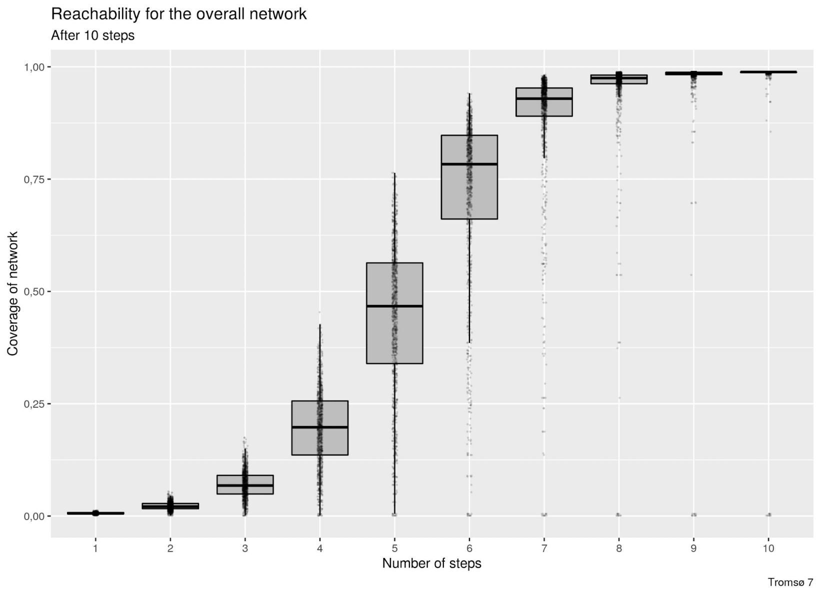

Connectivity
Average: 1.36




Step 5 = 50% Coverage

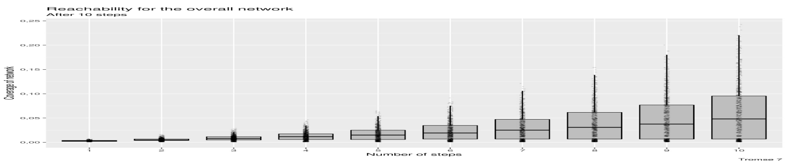
Step 5 = 3% Coverage

Connectivity
Average: 4.9



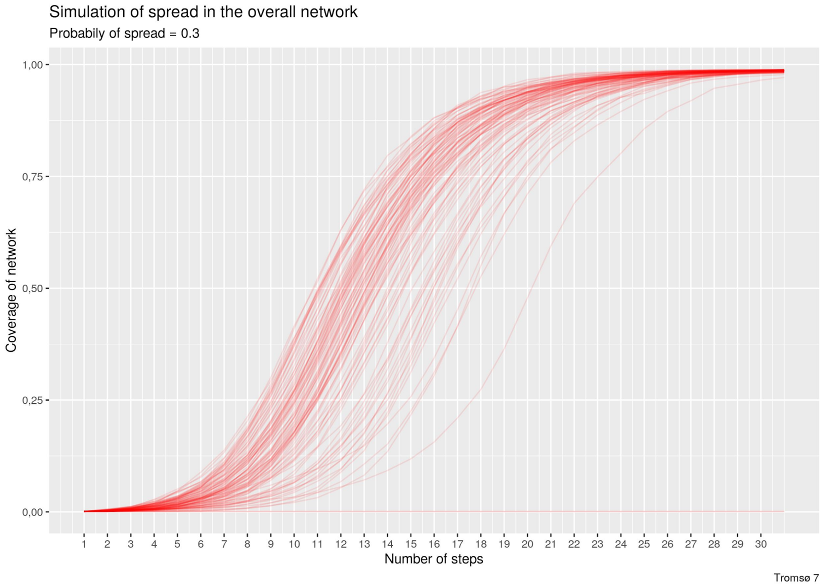

Step 5 = 50% Coverage

Connectivity
Average: 1.36



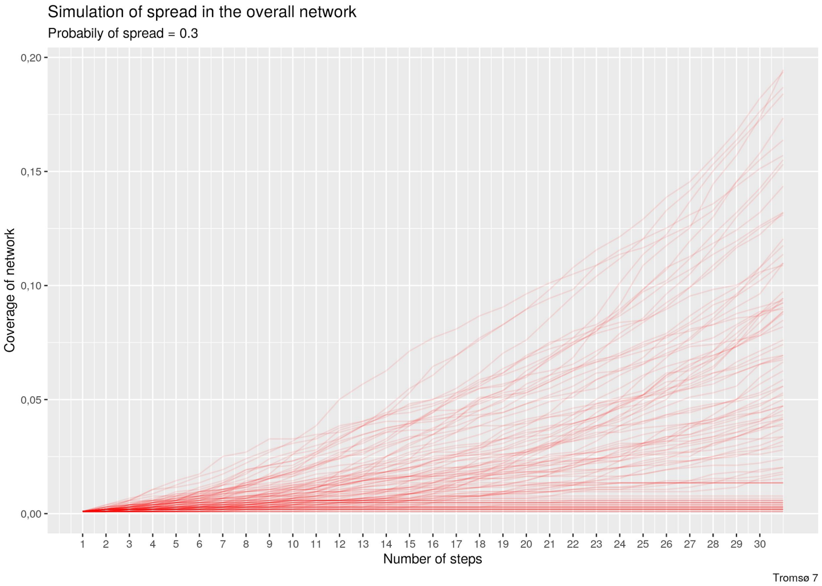

Step 5 = 3% Coverage

## Connectivity Average: 4.9



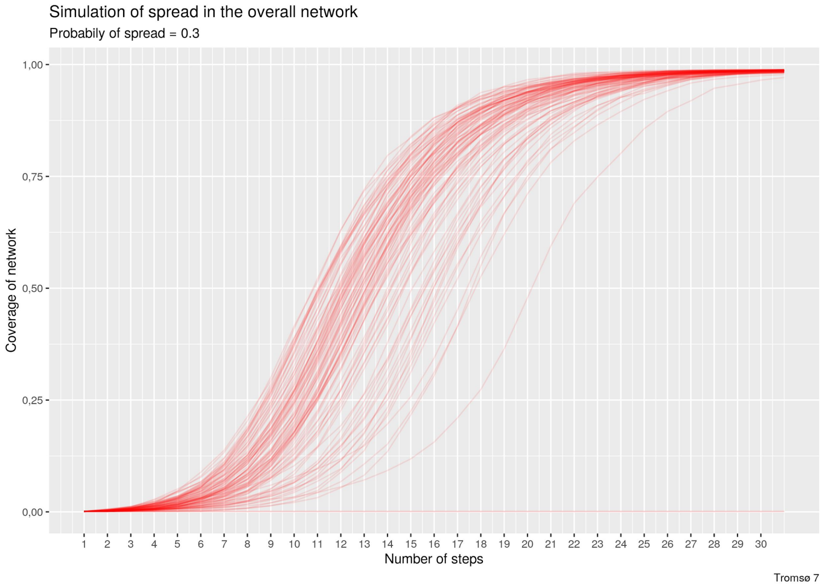

Step 25 = almost 100% coverage in all cases

## Connectivity Average: 1.36



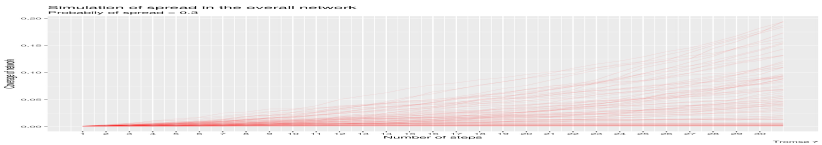

Step 25 = about 5% coverage of median cases

Connectivity
Average: 4.9

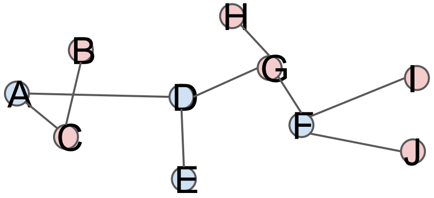



Step 25 = almost 100% coverage in all cases

Connectivity
Average: 1.36

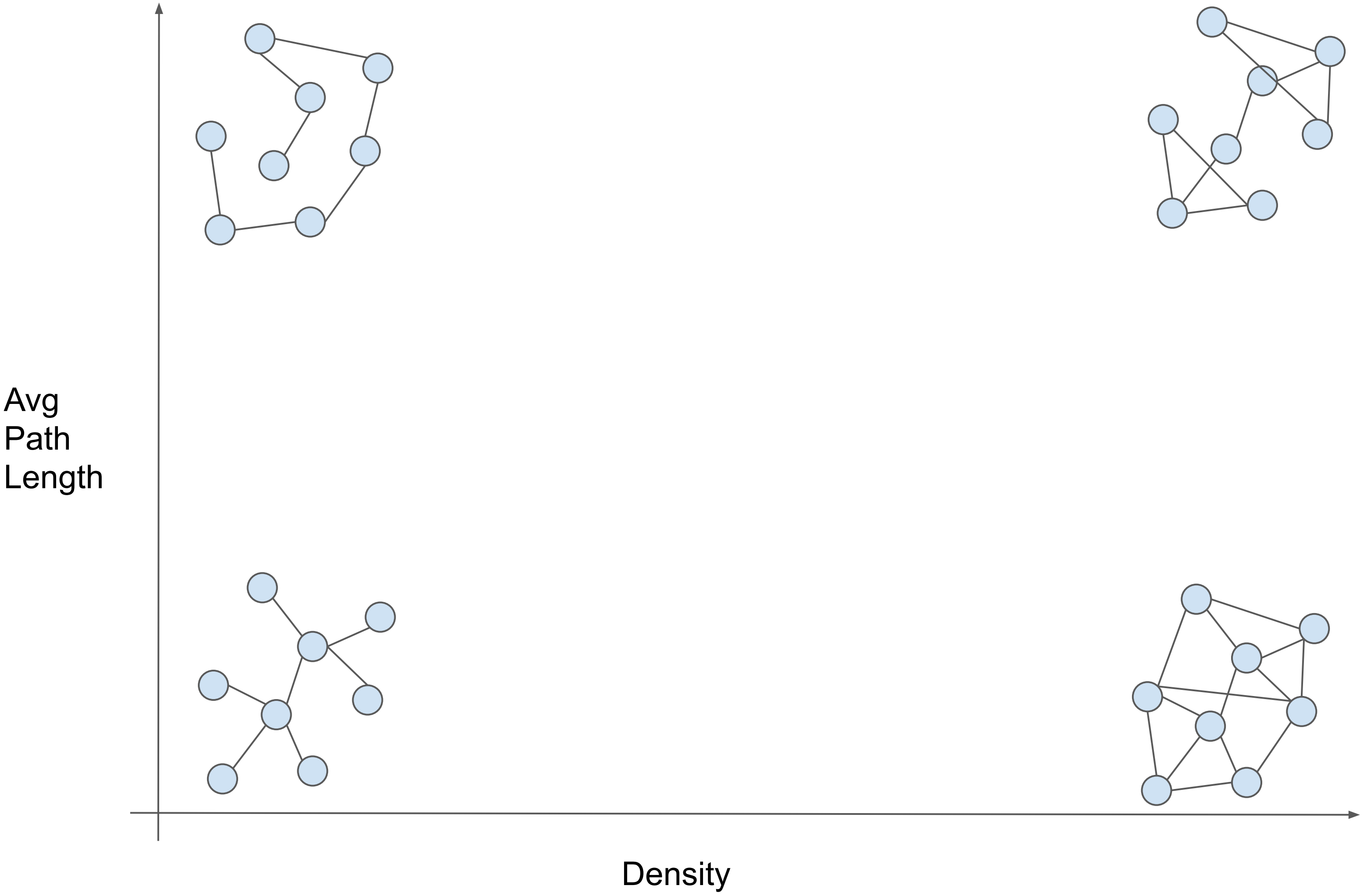



Step 25 = about 5% coverage of median cases

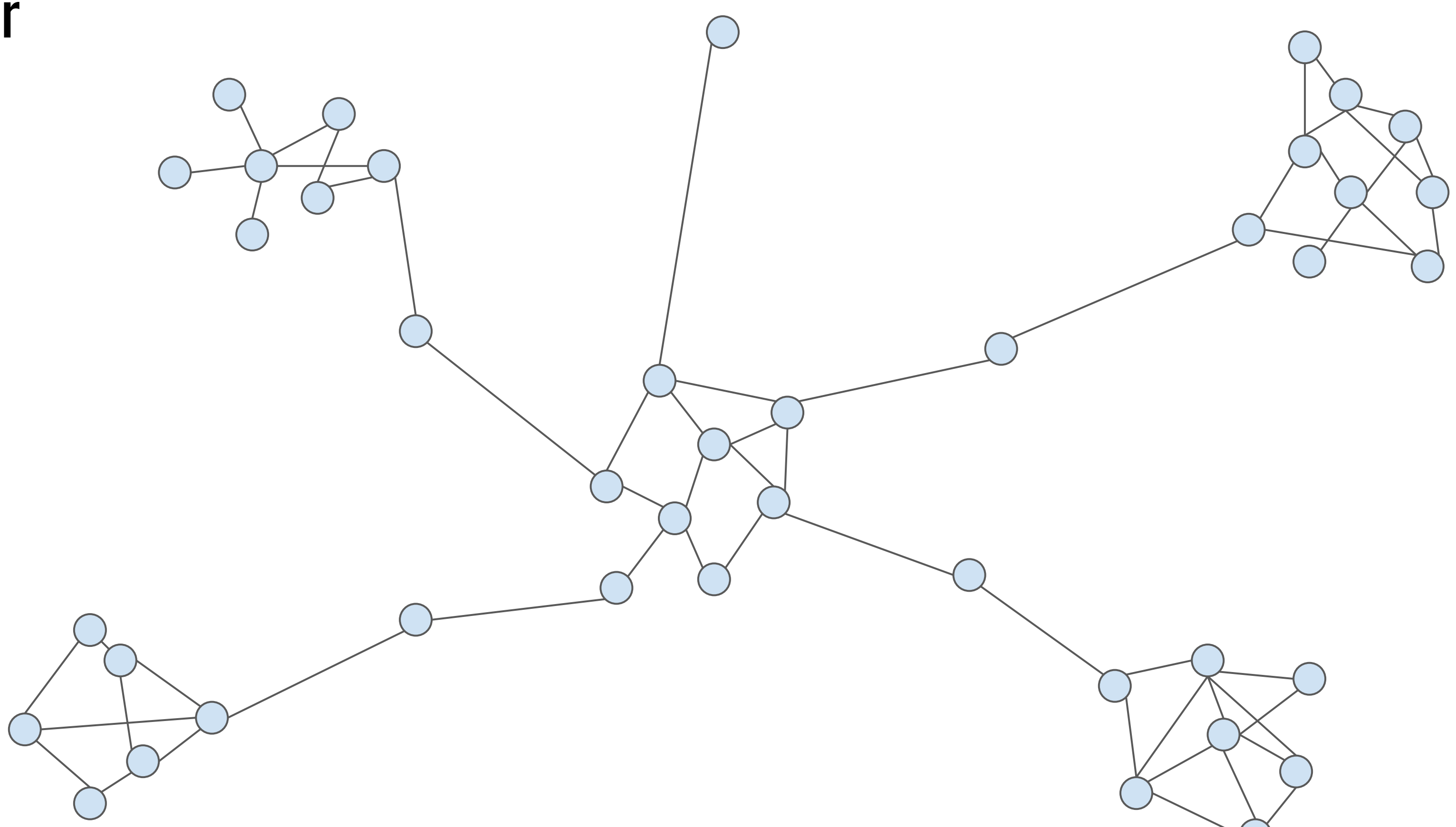



Average Path Length: 2.48

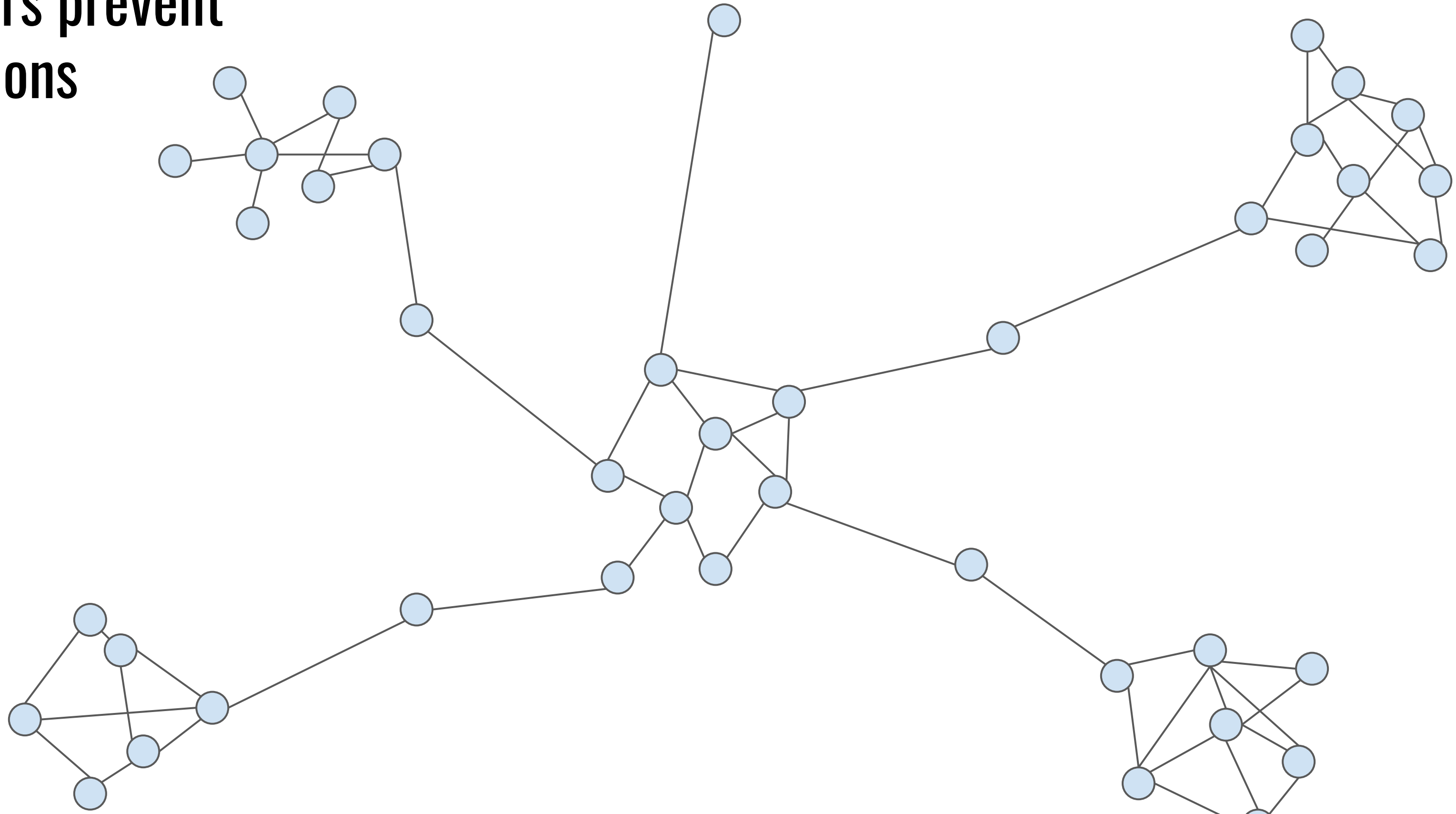
| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0 | | | | | | | | | |
| B | 2 | 0 | | | | | | | | |
| C | 1 | 1 | 0 | | | | | | | |
| D | 1 | 3 | 2 | 0 | | | | | | |
| E | 2 | 4 | 3 | 1 | 0 | | | | | |
| F | 3 | 5 | 4 | 2 | 3 | 0 | | | | |
| G | 2 | 4 | 3 | 1 | 2 | 1 | 0 | | | |
| H | 3 | 5 | 4 | 2 | 3 | 2 | 1 | 0 | | |
| I | 4 | 6 | 5 | 3 | 4 | 1 | 2 | 3 | 0 | |
| J | 4 | 6 | 5 | 3 | 4 | 1 | 2 | 3 | 2 | 0 |

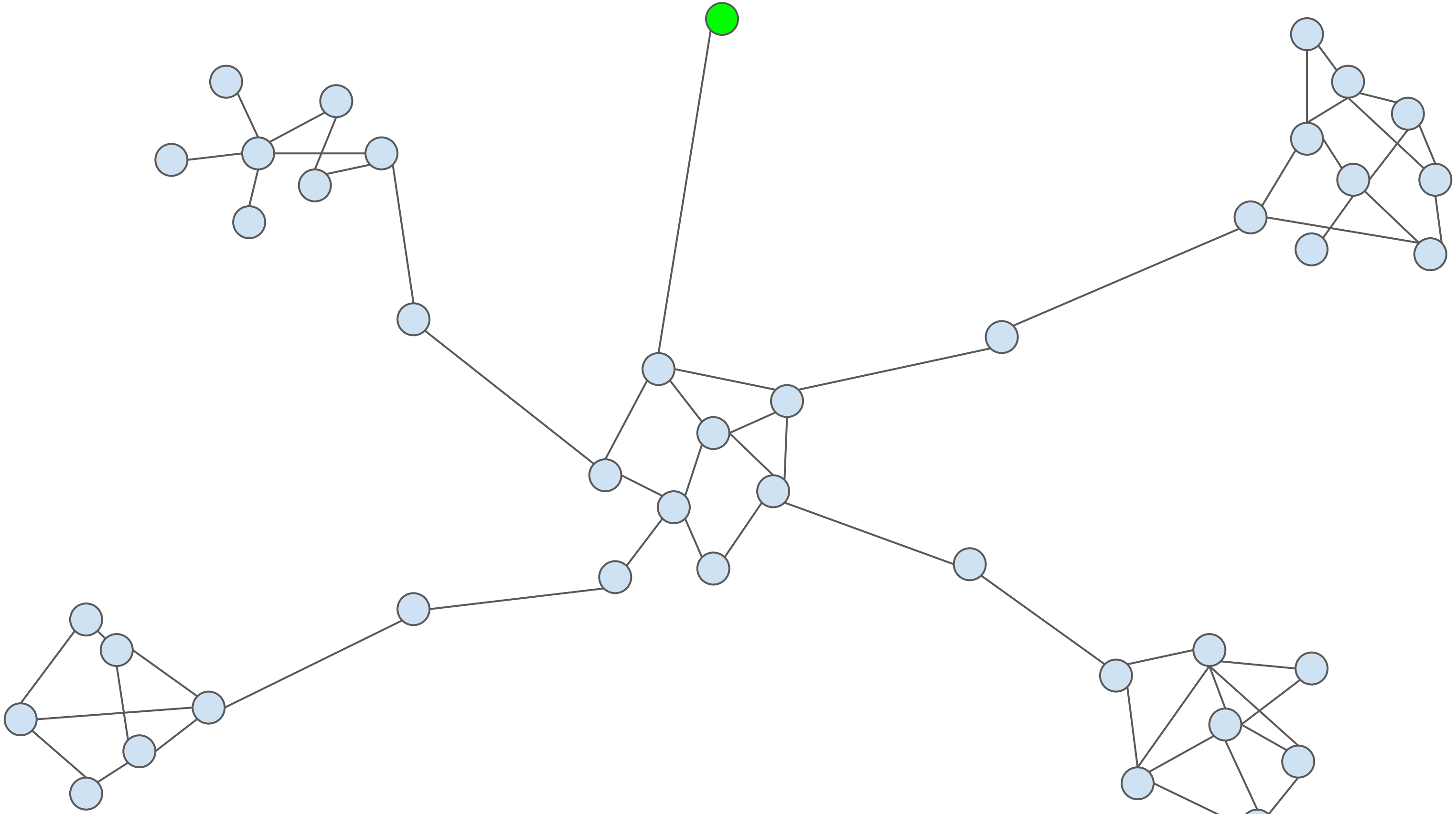

Avg
Path
Length
Density

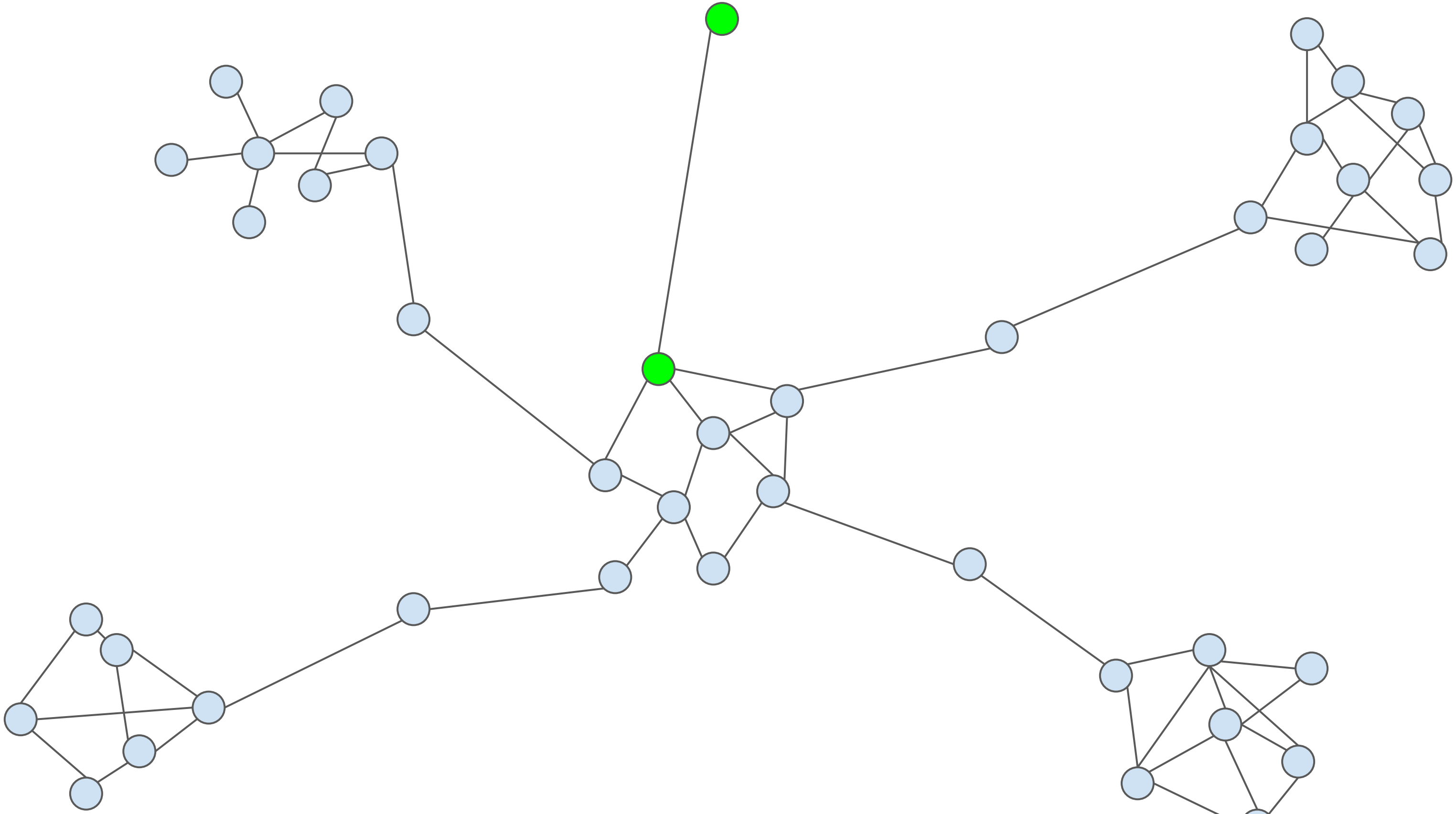
# Cluster

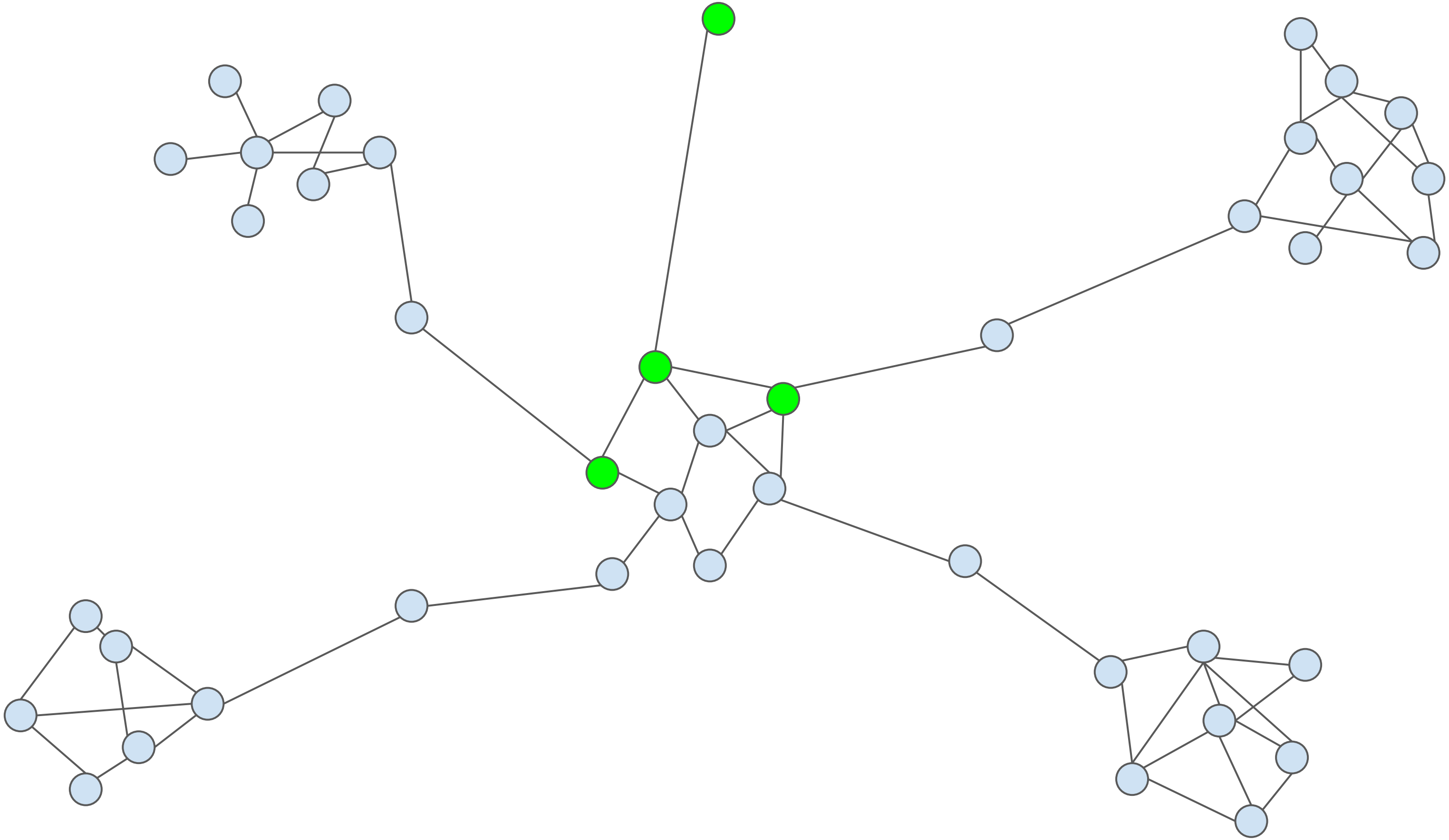


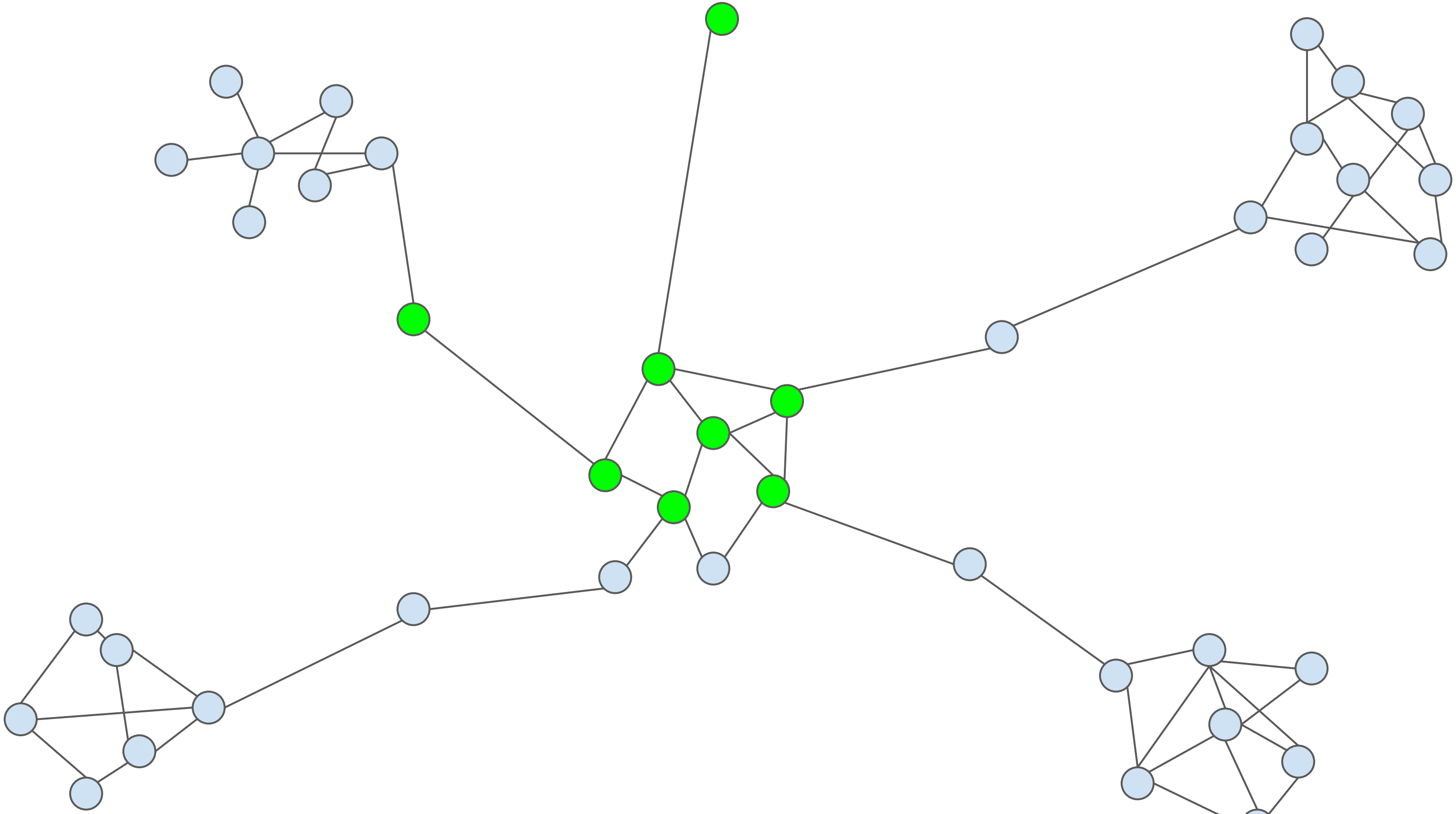
# Clusters prevent infections

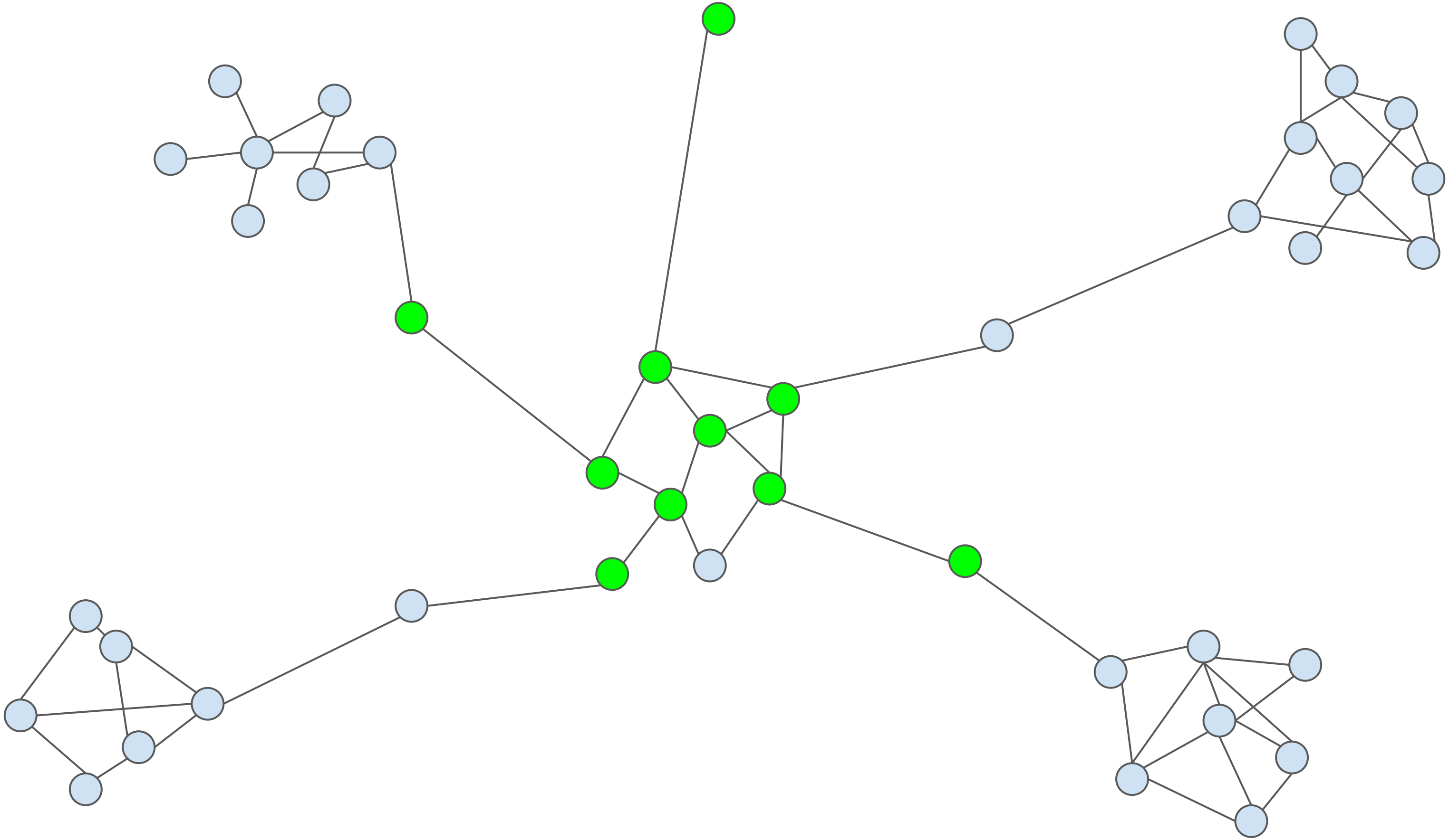


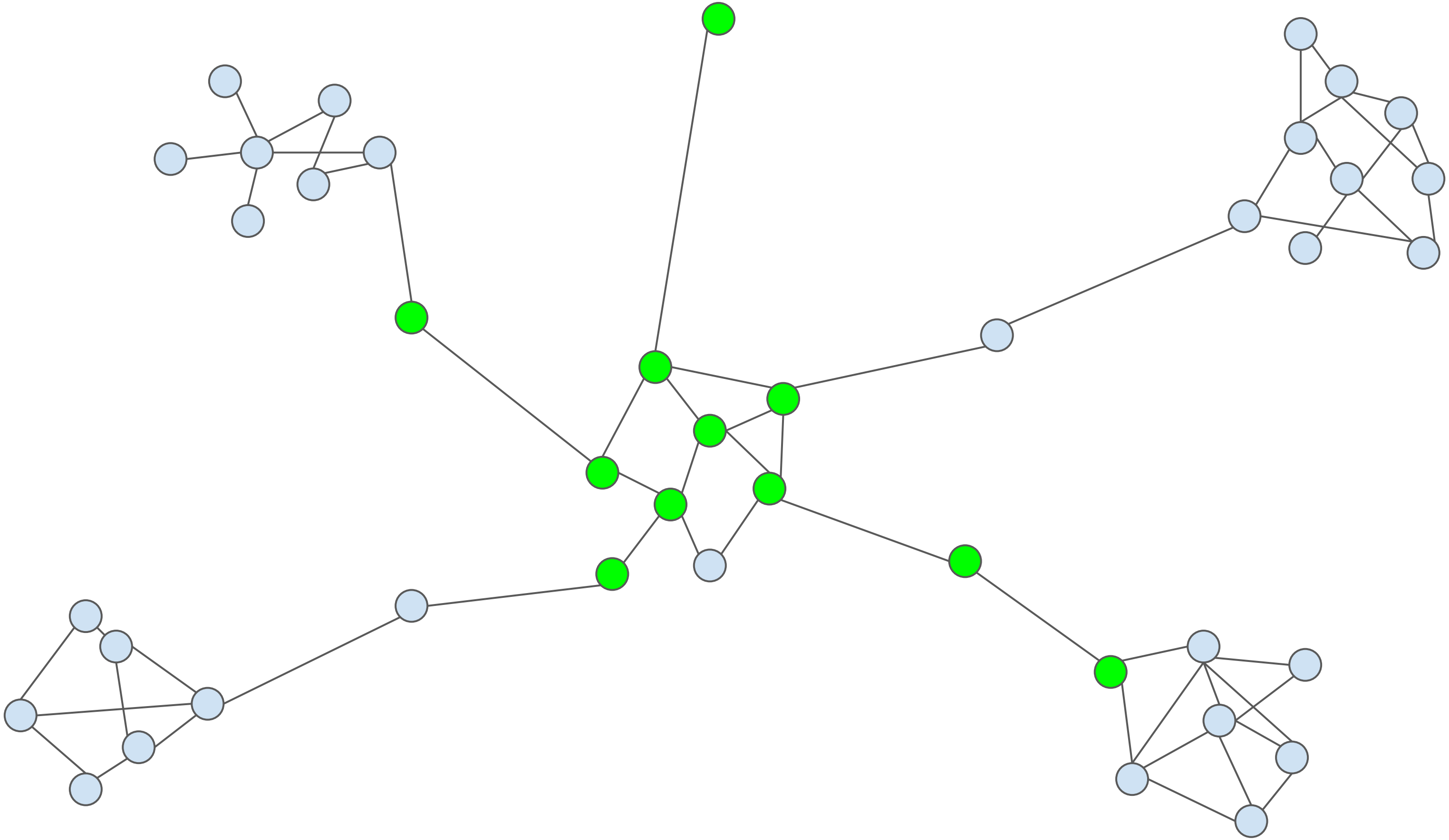


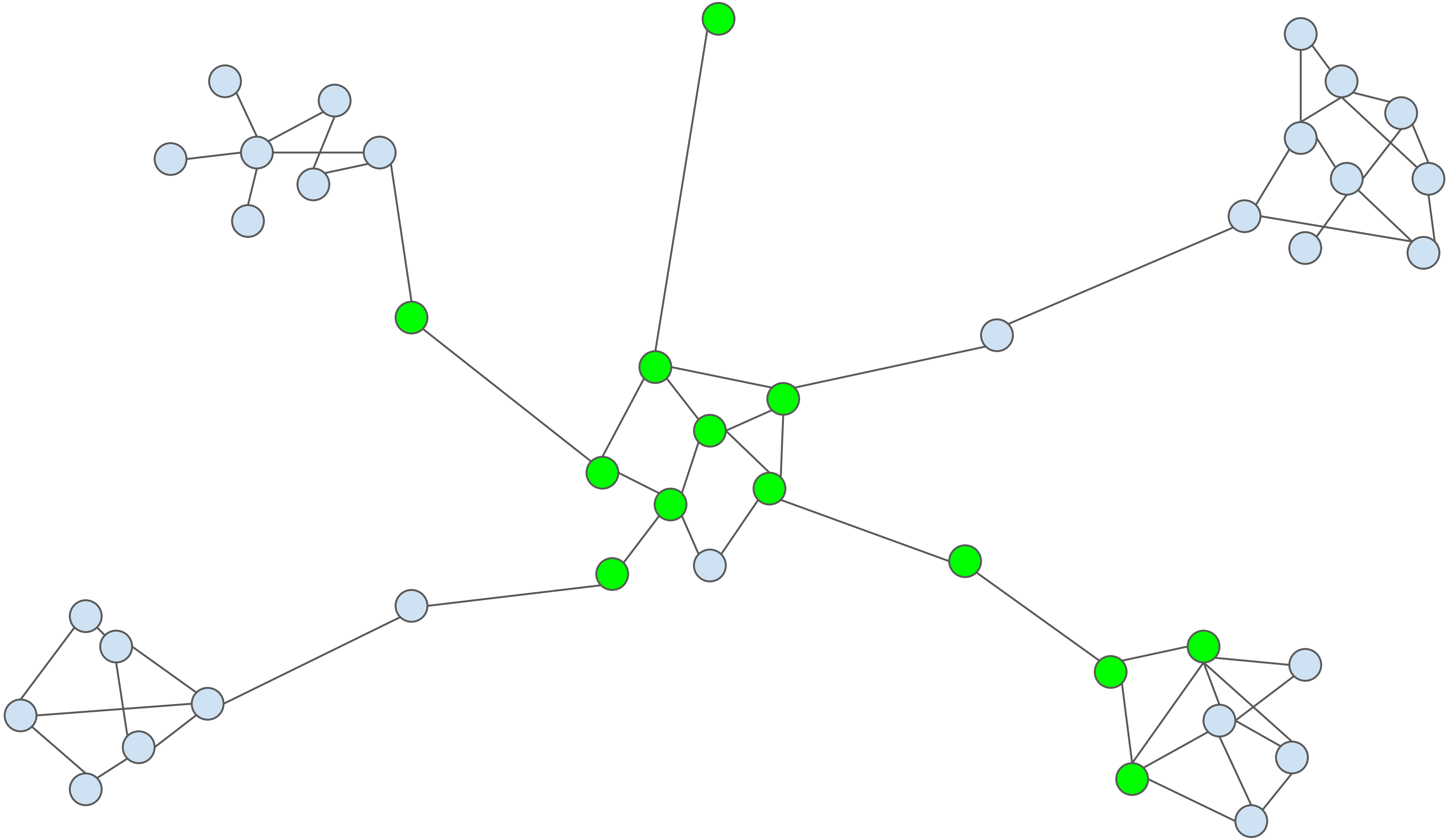


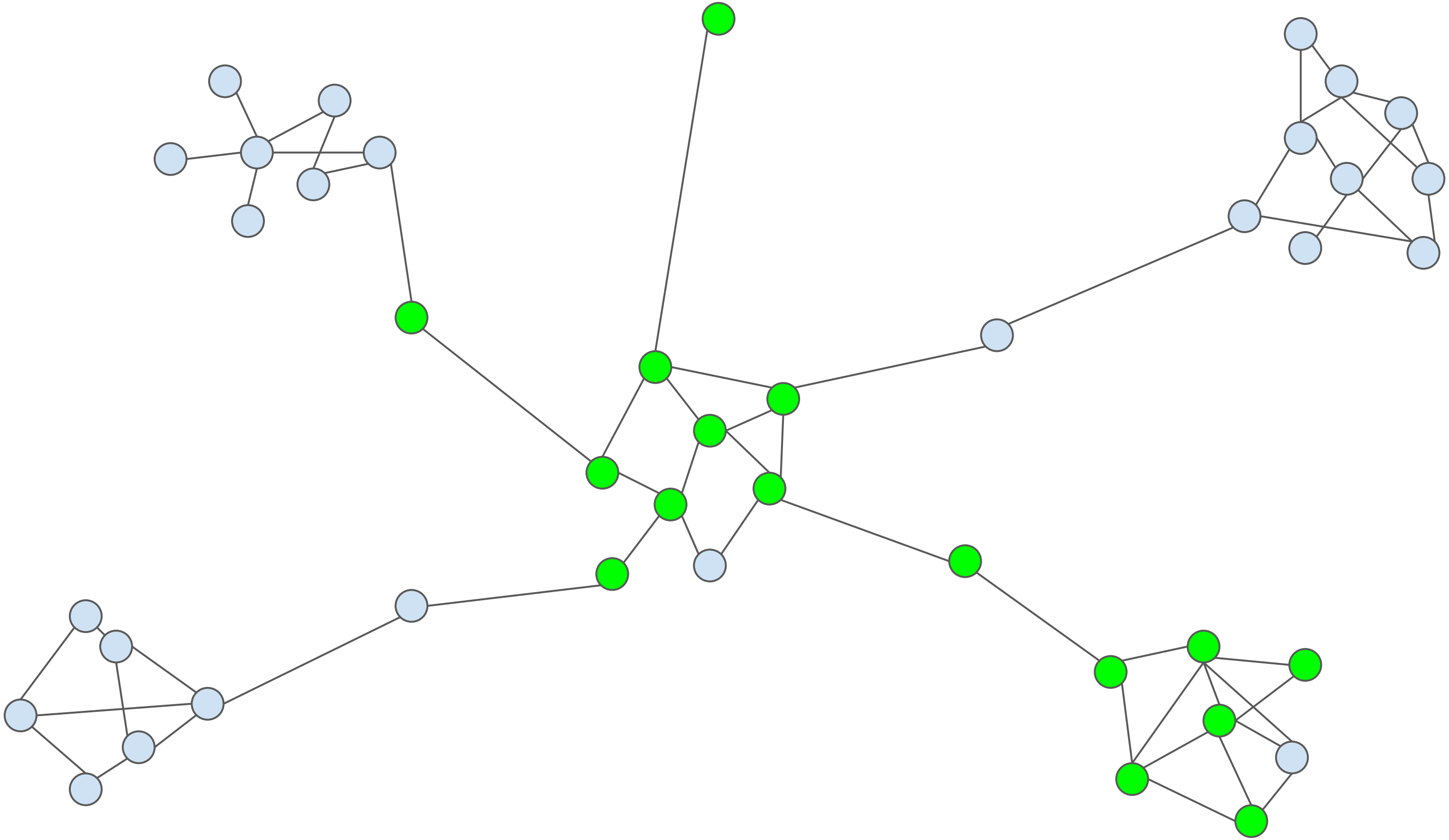


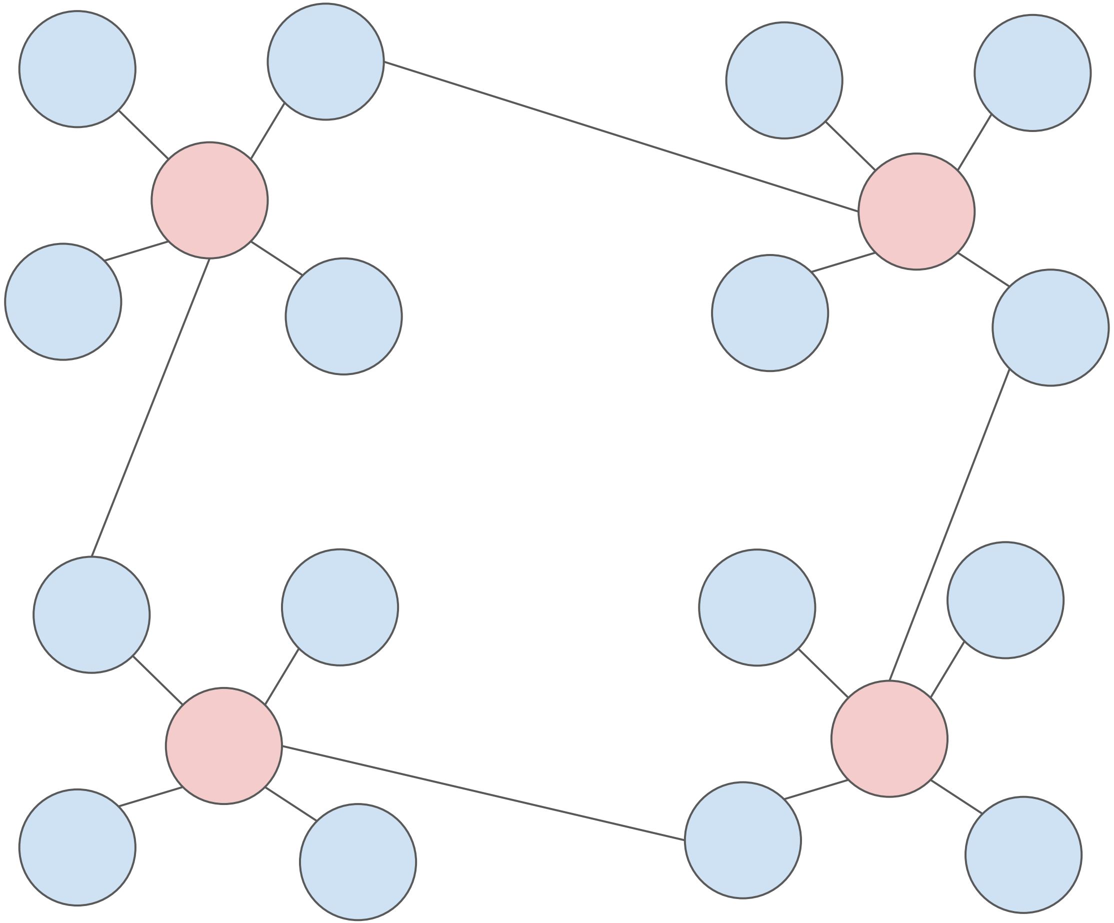






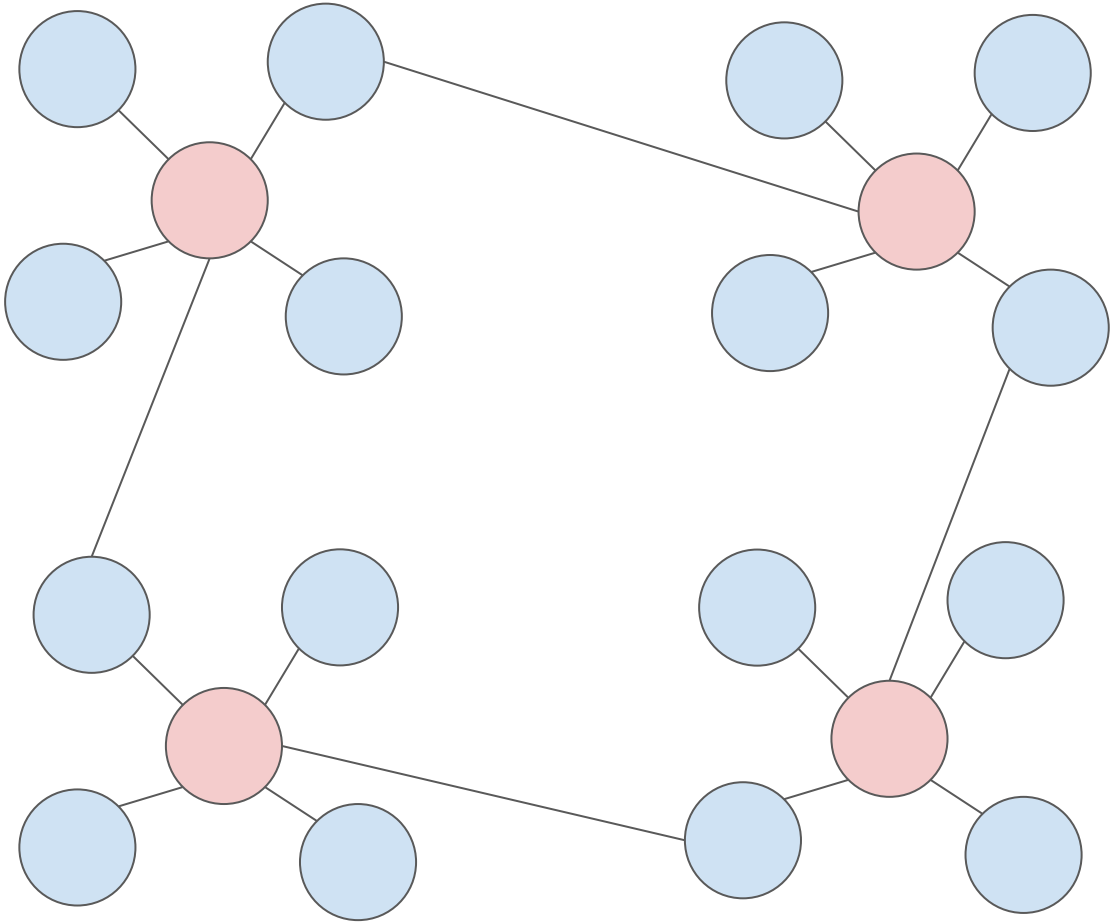




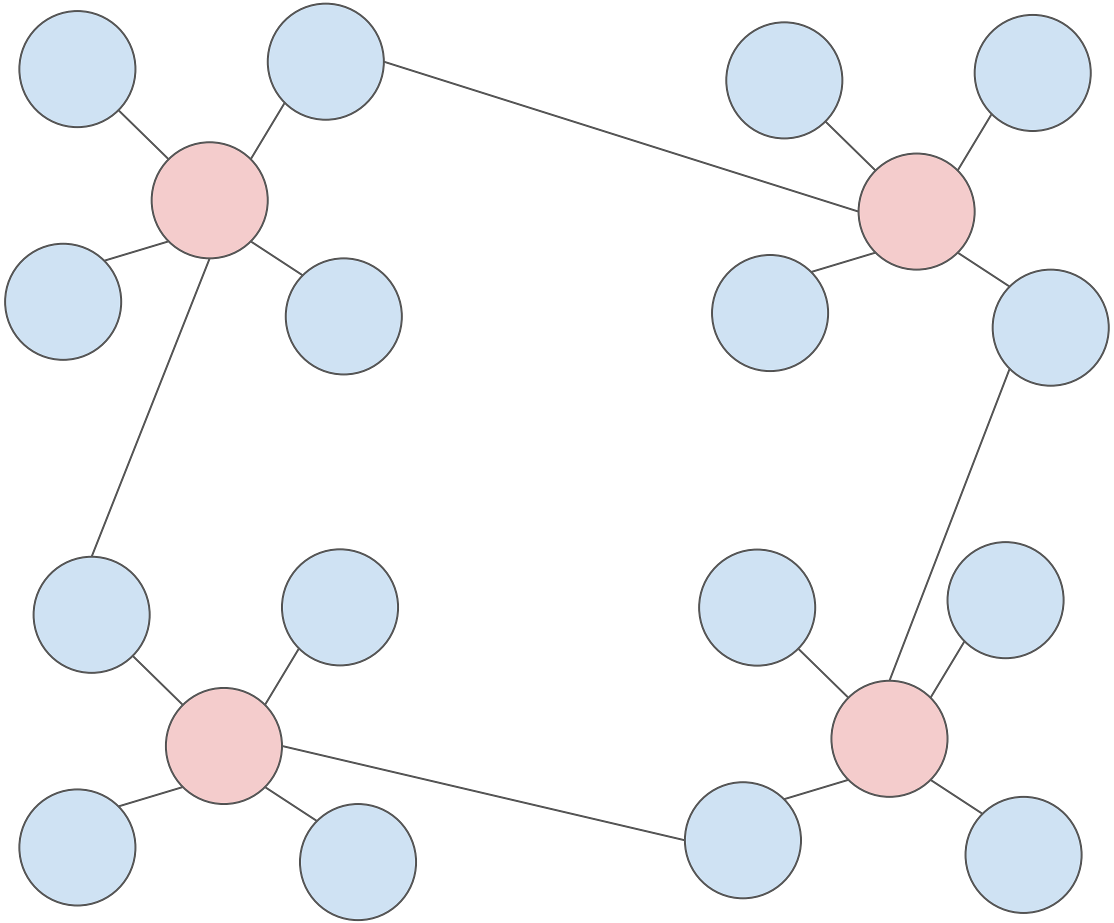


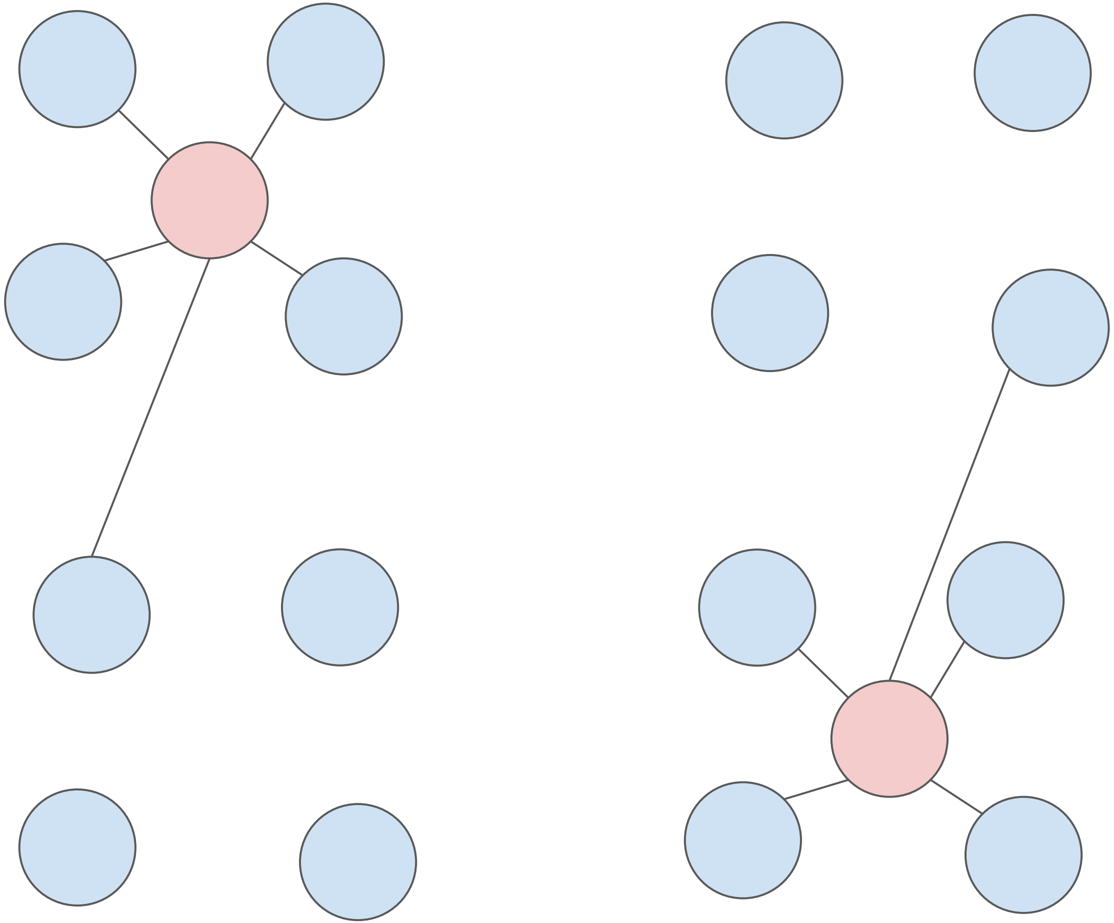
Moody, James, Jimi Adams, and Martina Morris. “Epidemic potential by sexual activity distributions.” Network Science (Cambridge University Press) 5, no. 4 (December 2017): 461–75.

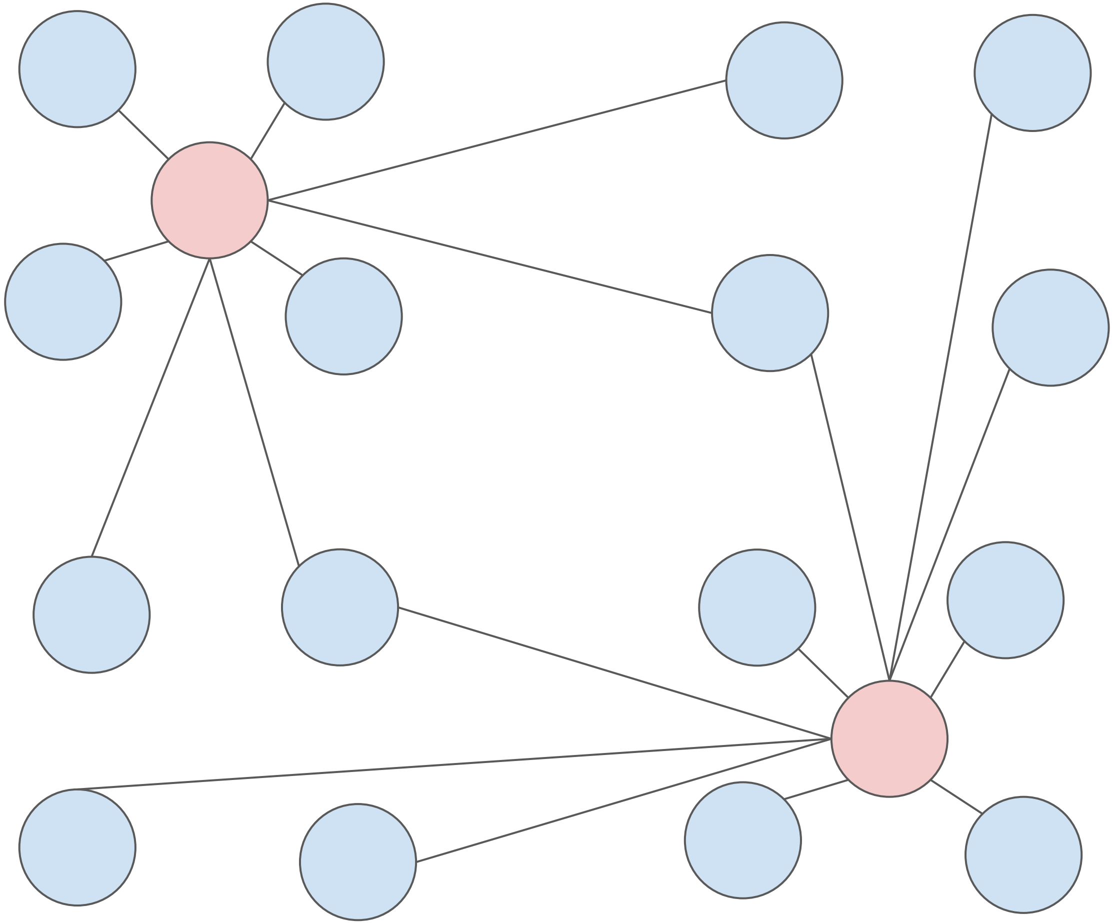
Sex workers in Shanghai
(SIMPLIFIED!!!)

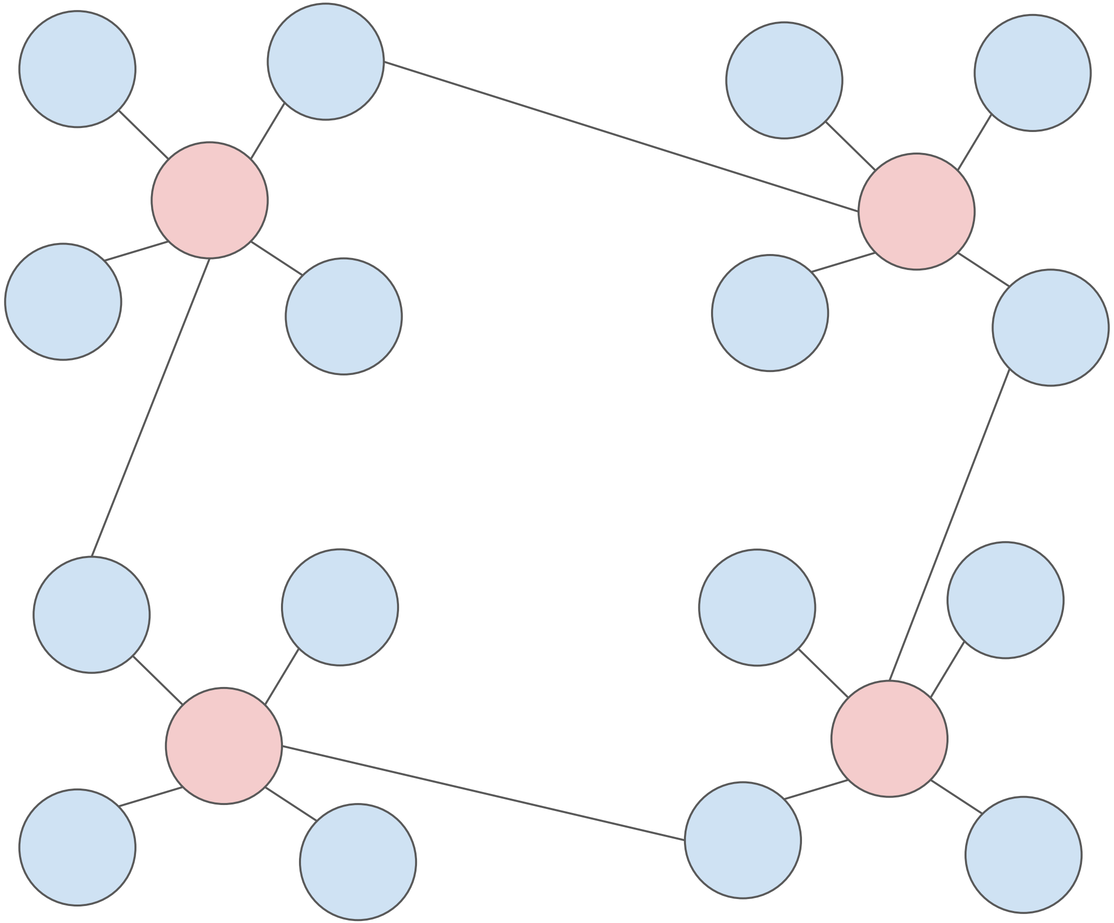


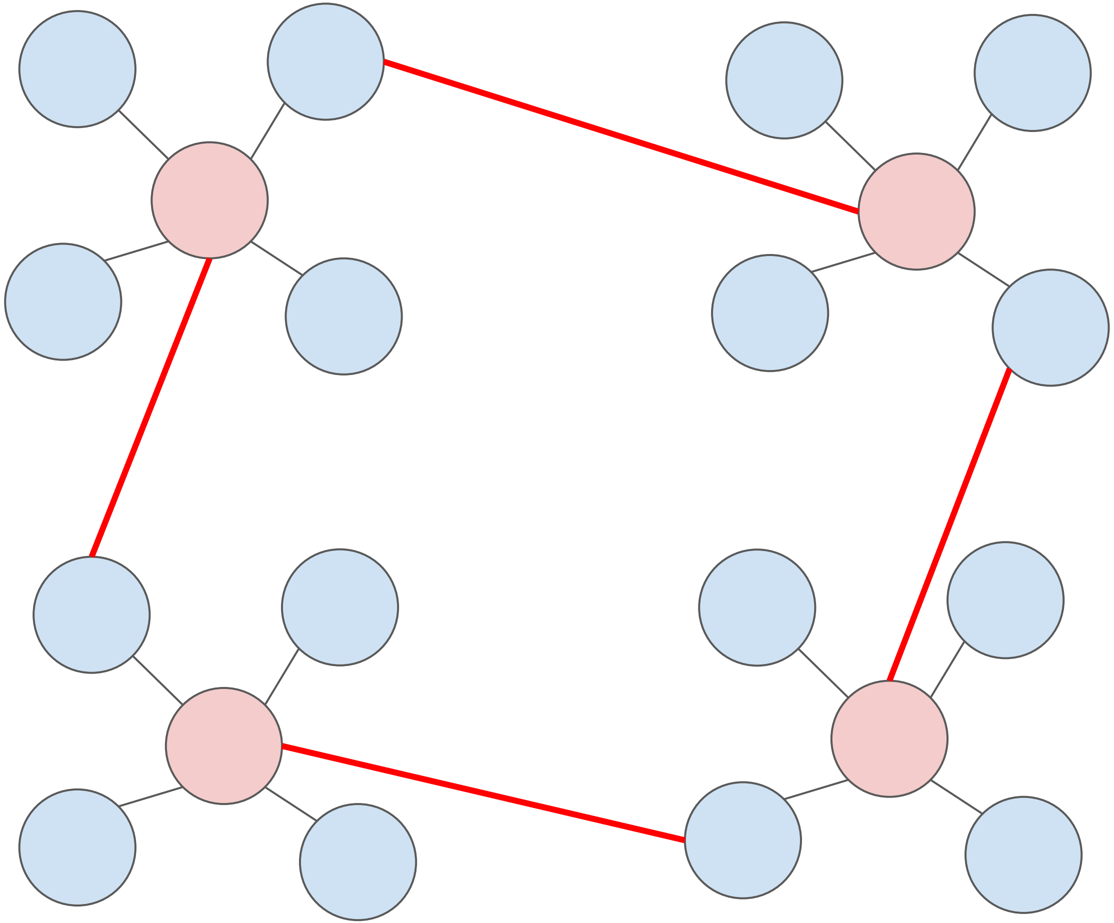
**Moody, James, Jimi Adams, and Martina Morris. "Epidemic potential by sexual activity distributions." Network Science (Cambridge University Press) 5, no. 4 (December 2017): 461–75.**

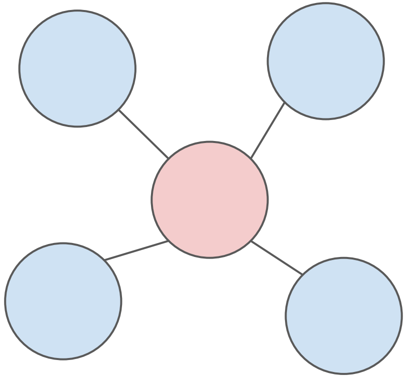
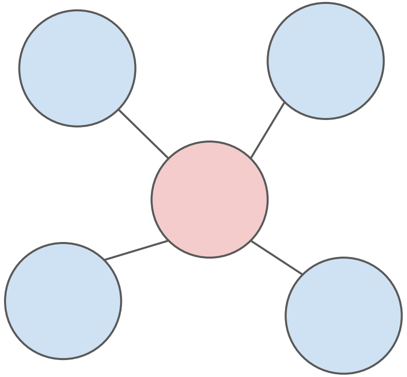
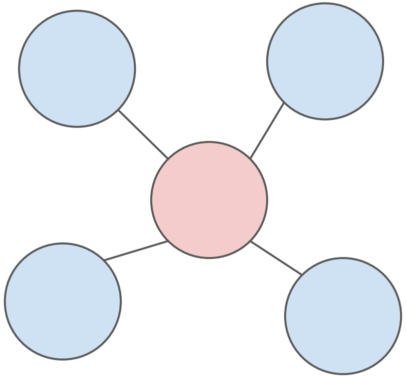
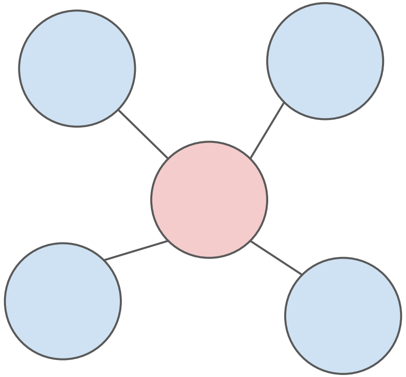


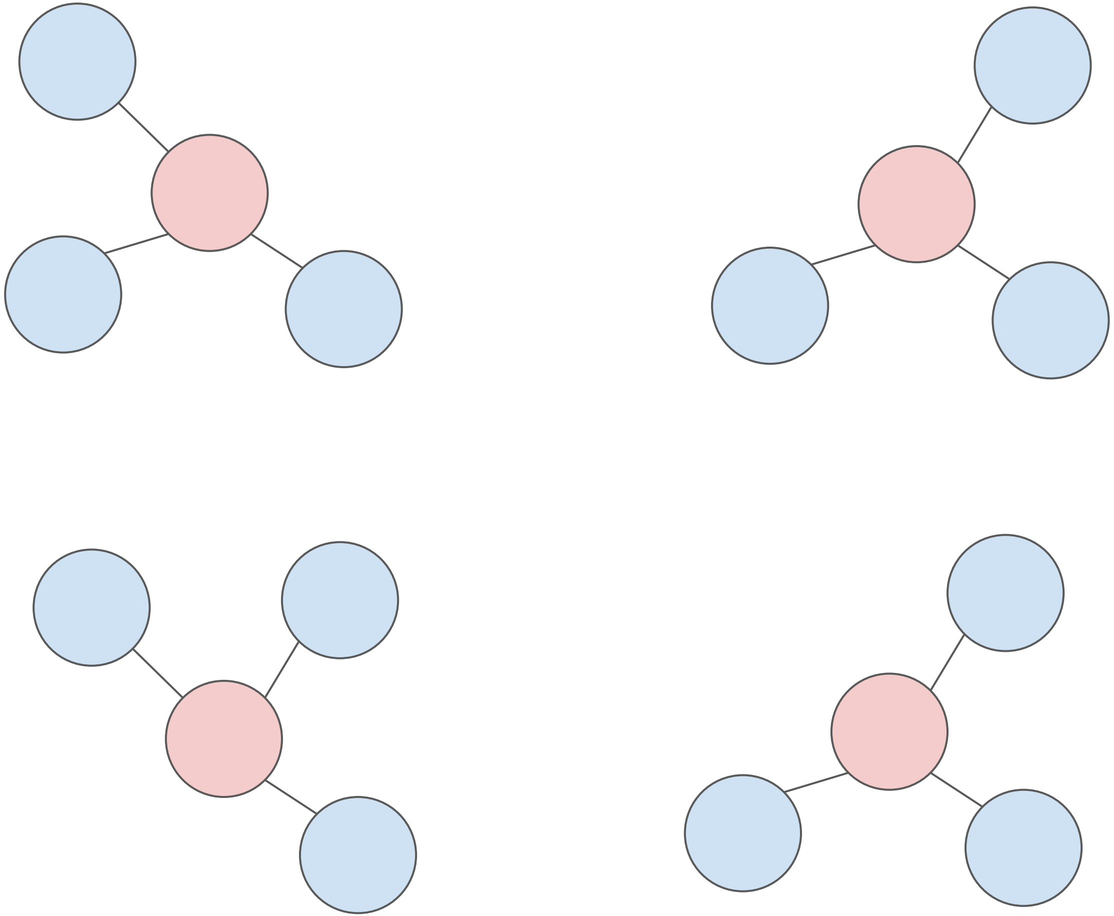




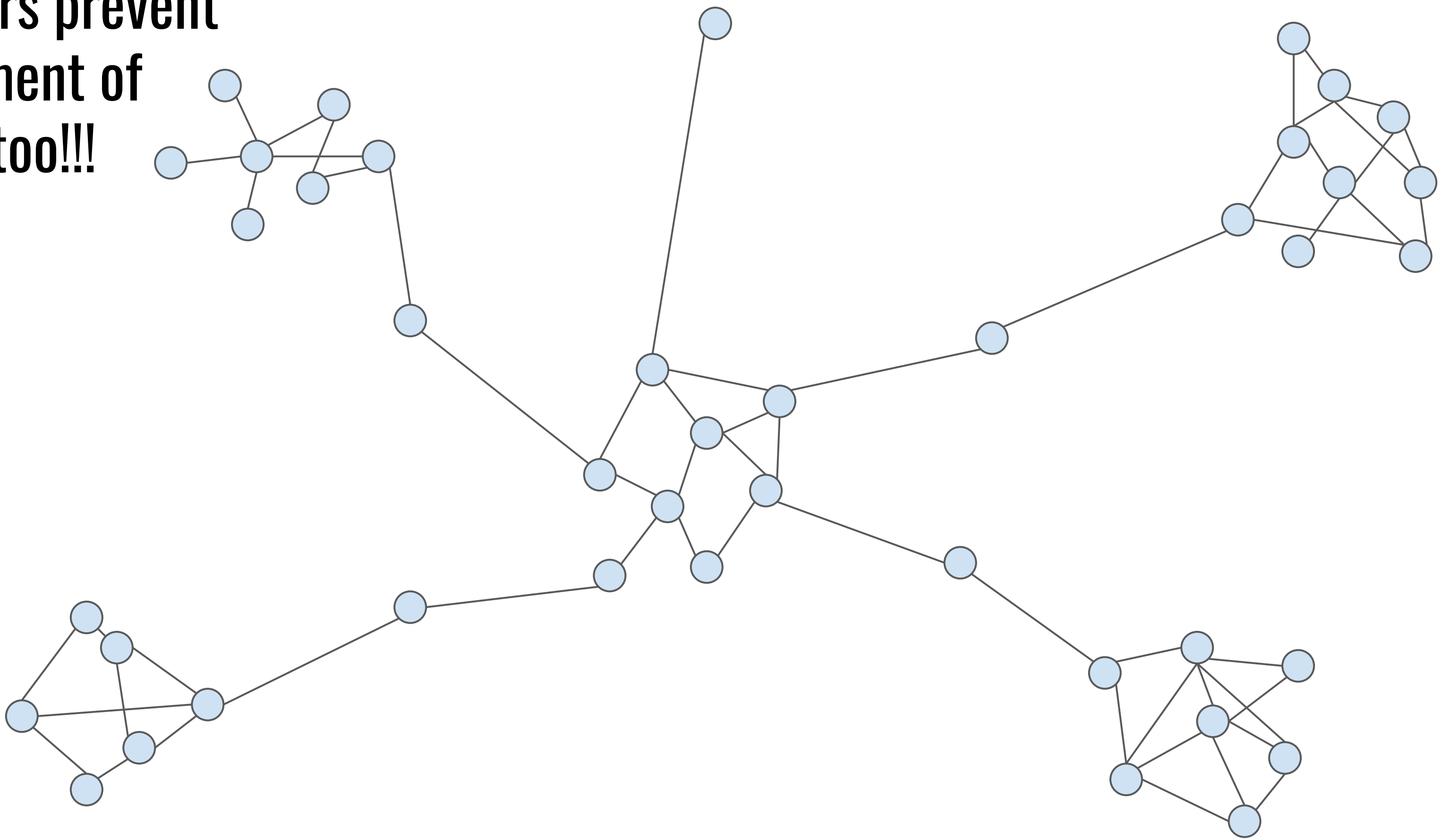


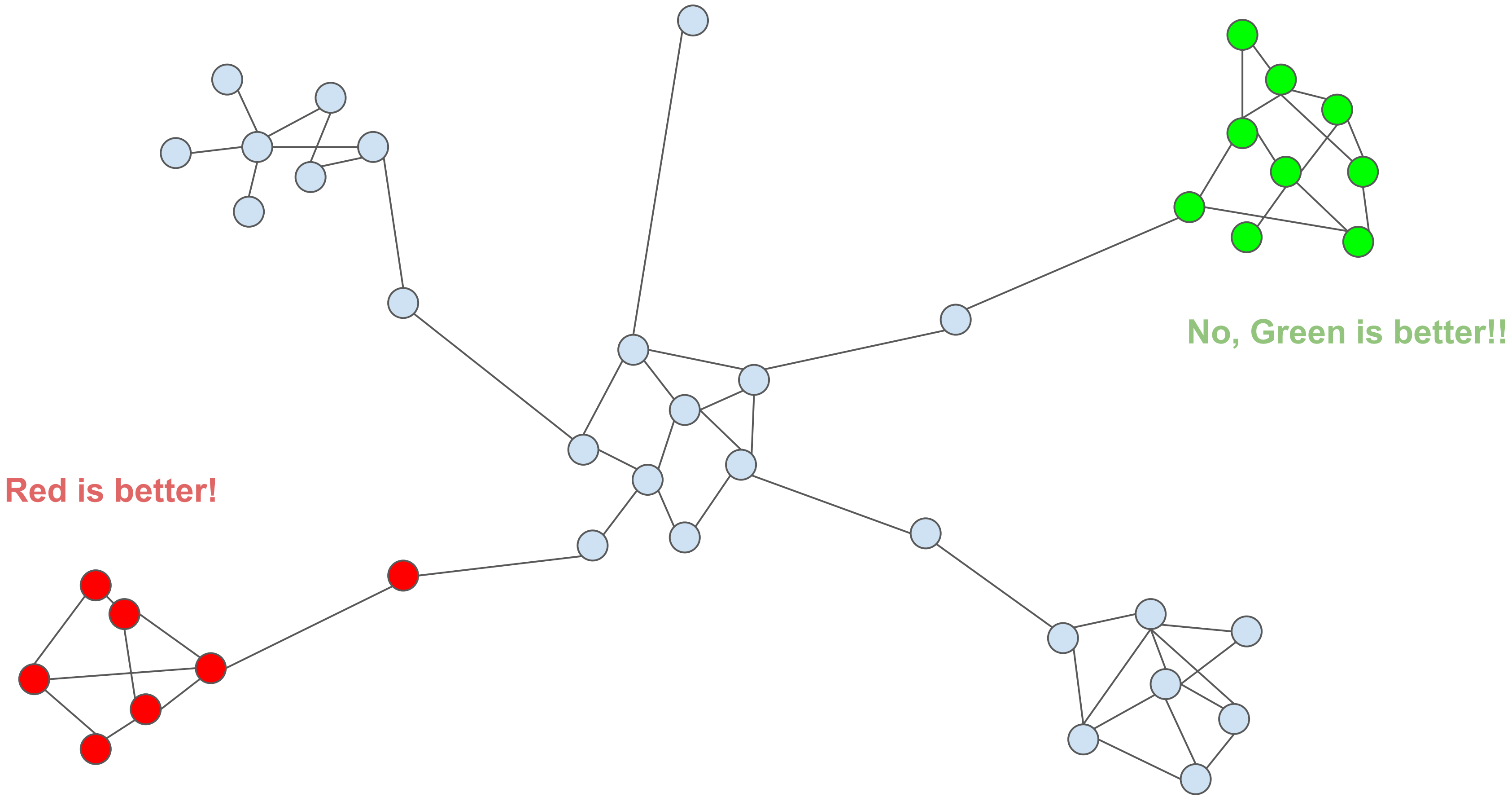




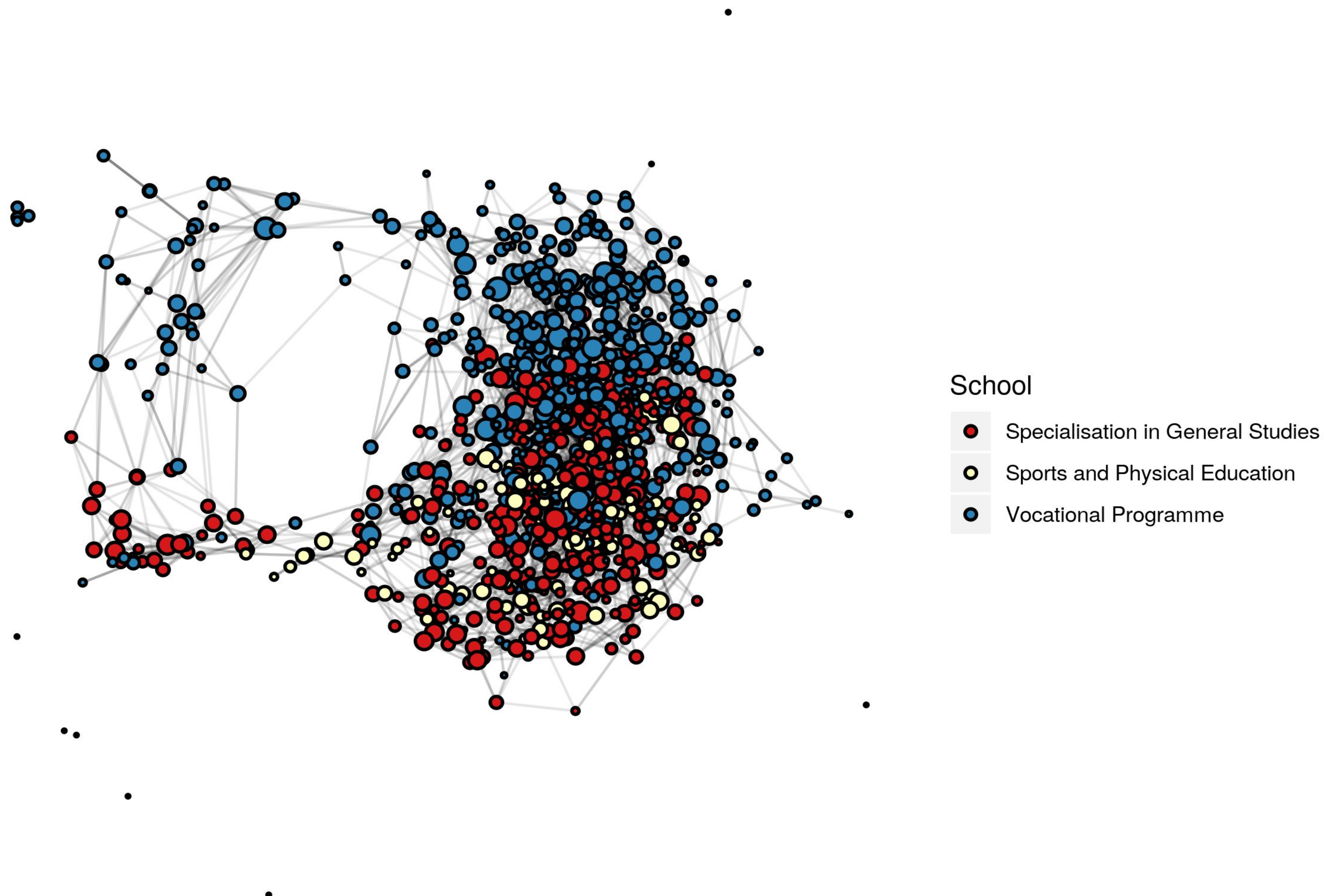
# Clusters prevent Movement of Ideas too!!!

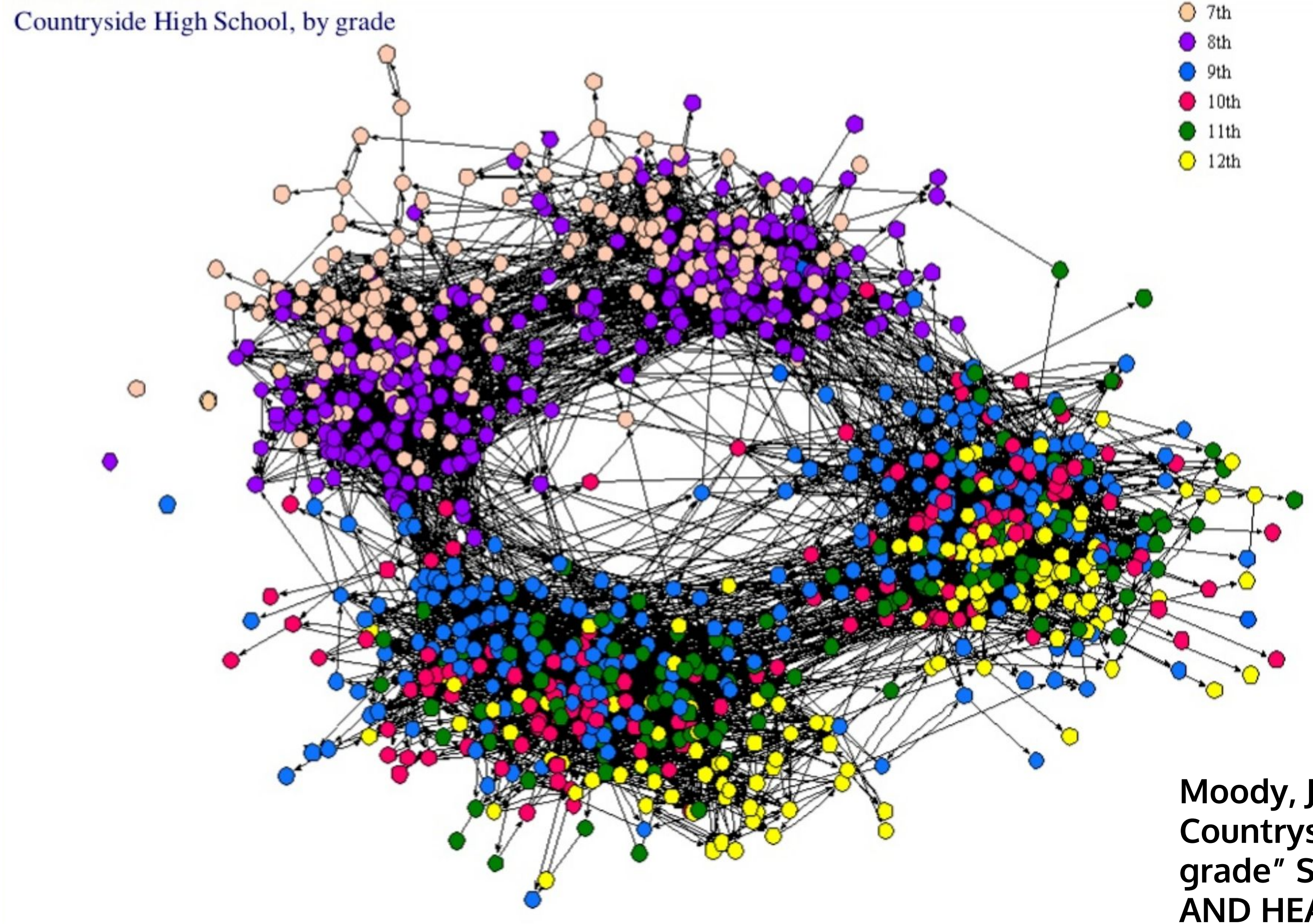




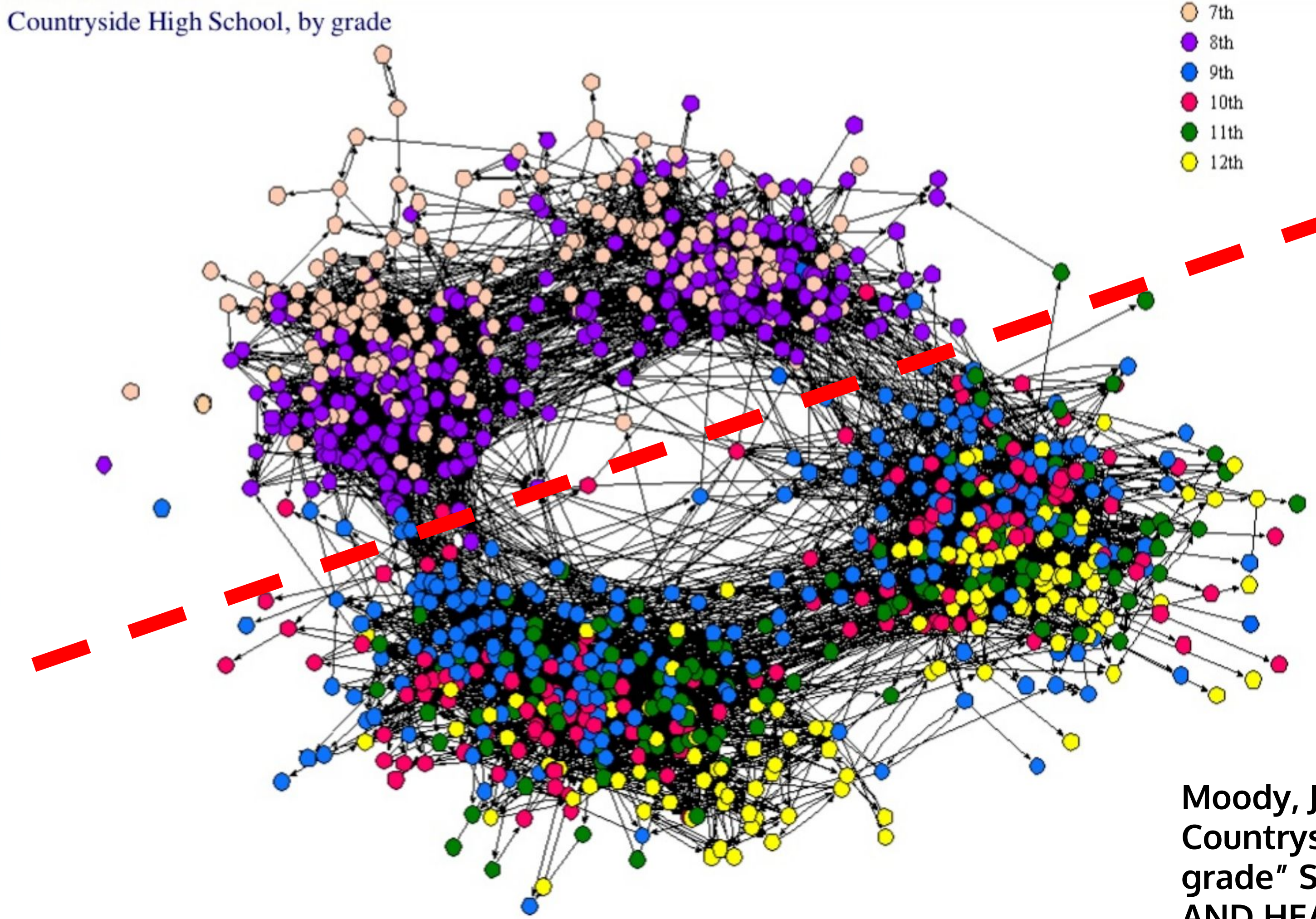
No, Green is better!!
Red is better!

# Communities

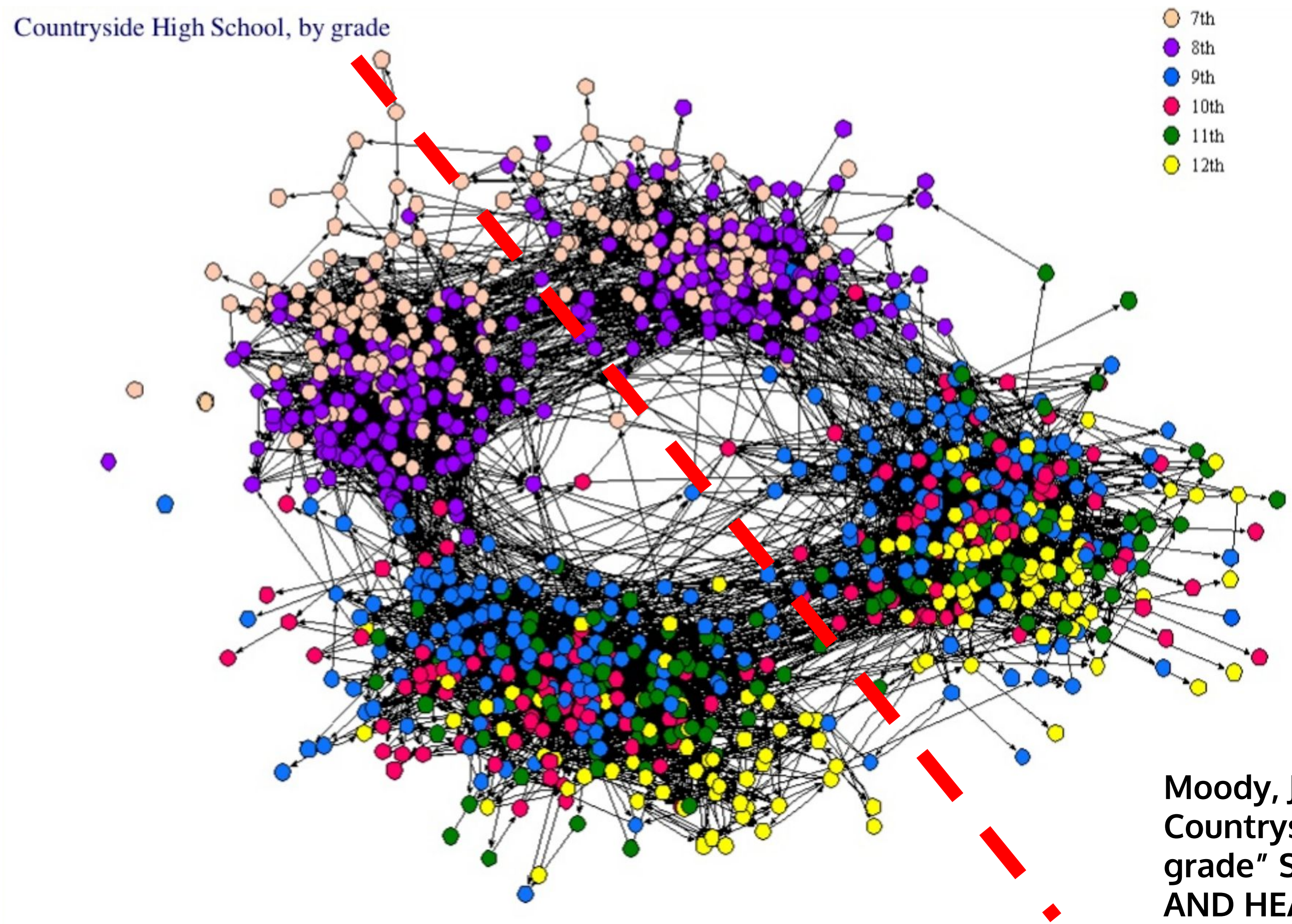




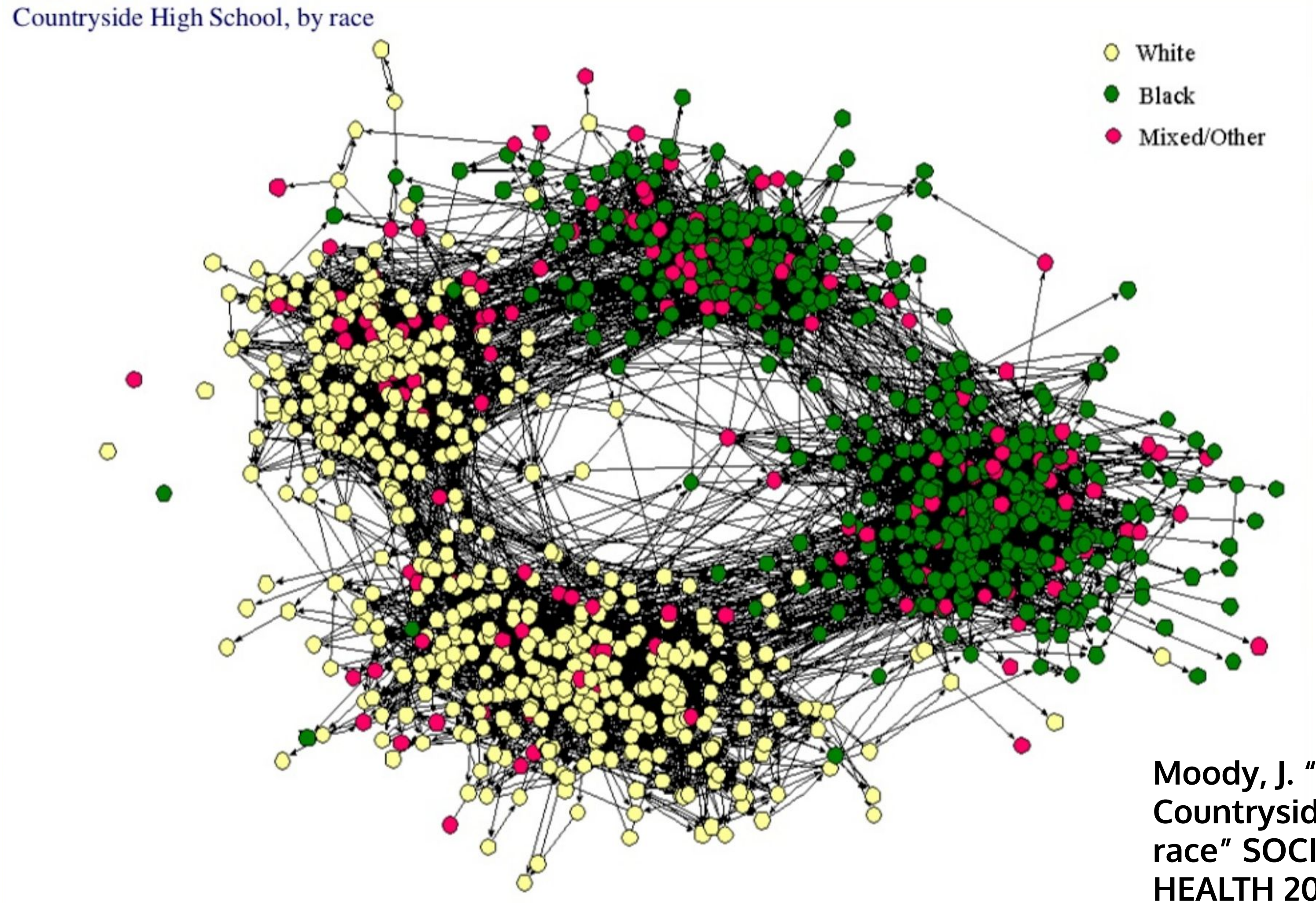

Moody, J. “Introduction Countryside High School, by grade” SOCIAL NETWORKS AND HEALTH 2018 workshop




Moody, J. “Introduction Countryside High School, by grade” SOCIAL NETWORKS AND HEALTH 2018 workshop



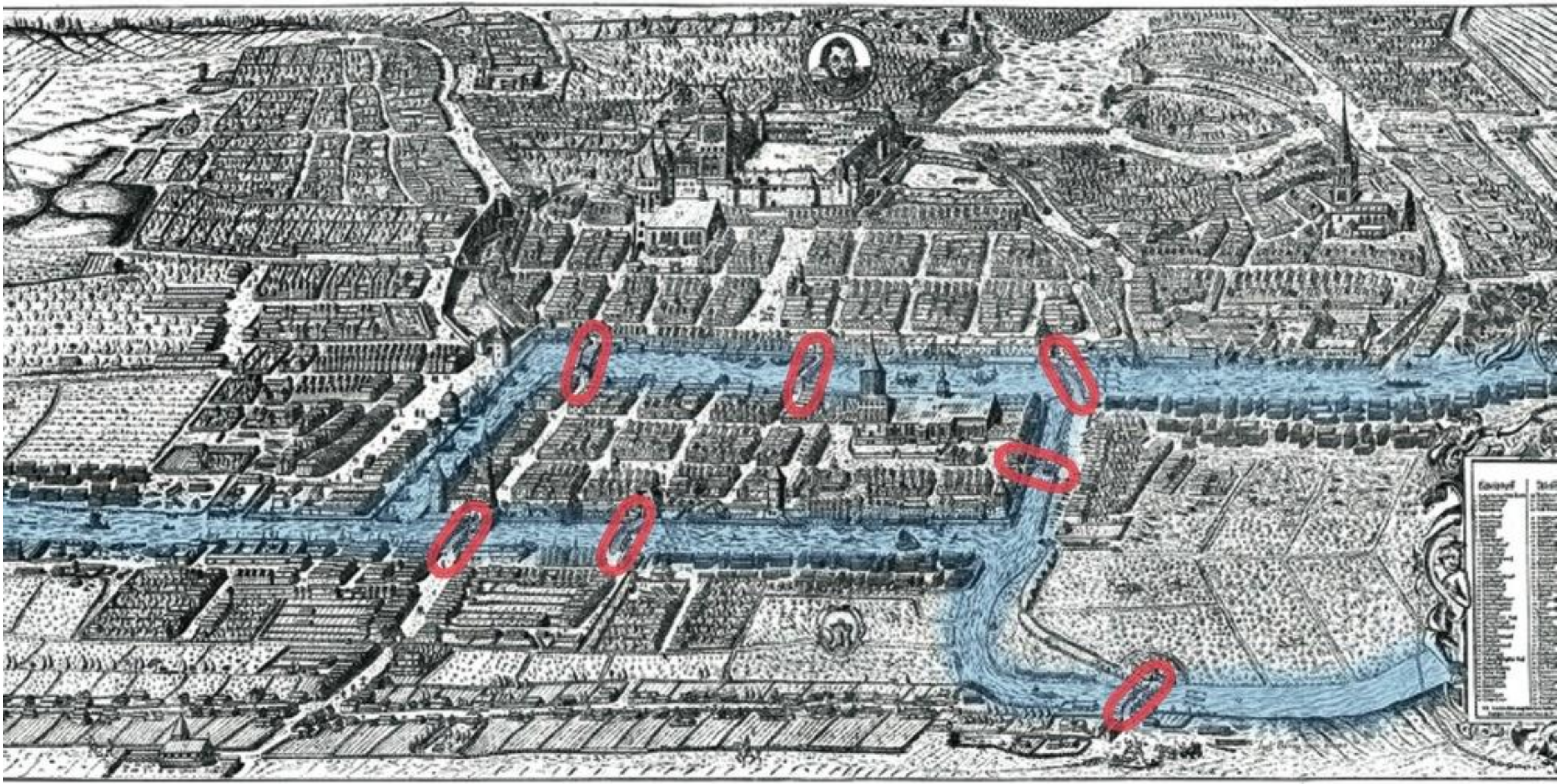

Moody, J. “Introduction Countryside High School, by grade” SOCIAL NETWORKS AND HEALTH 2018 workshop

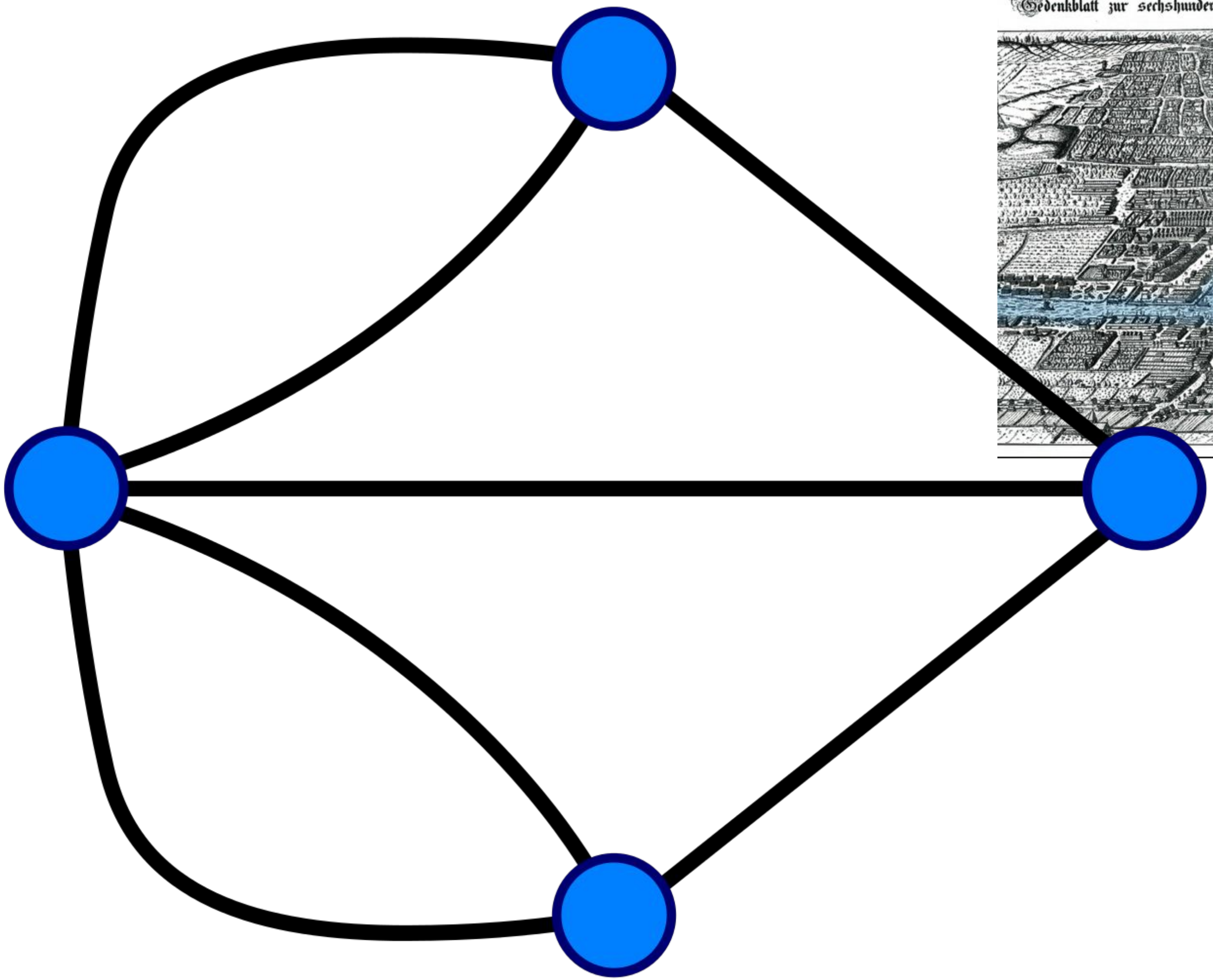


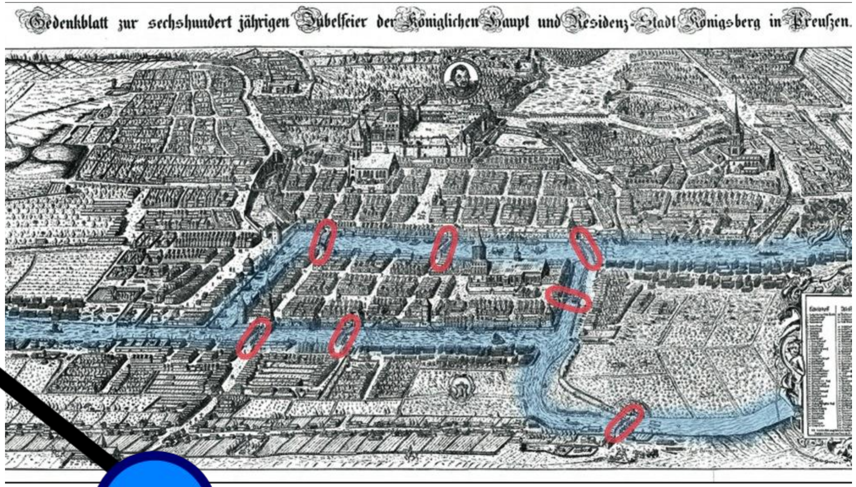

Moody, J. "Introduction Countryside High School, by race" SOCIAL NETWORKS AND HEALTH 2018 workshop

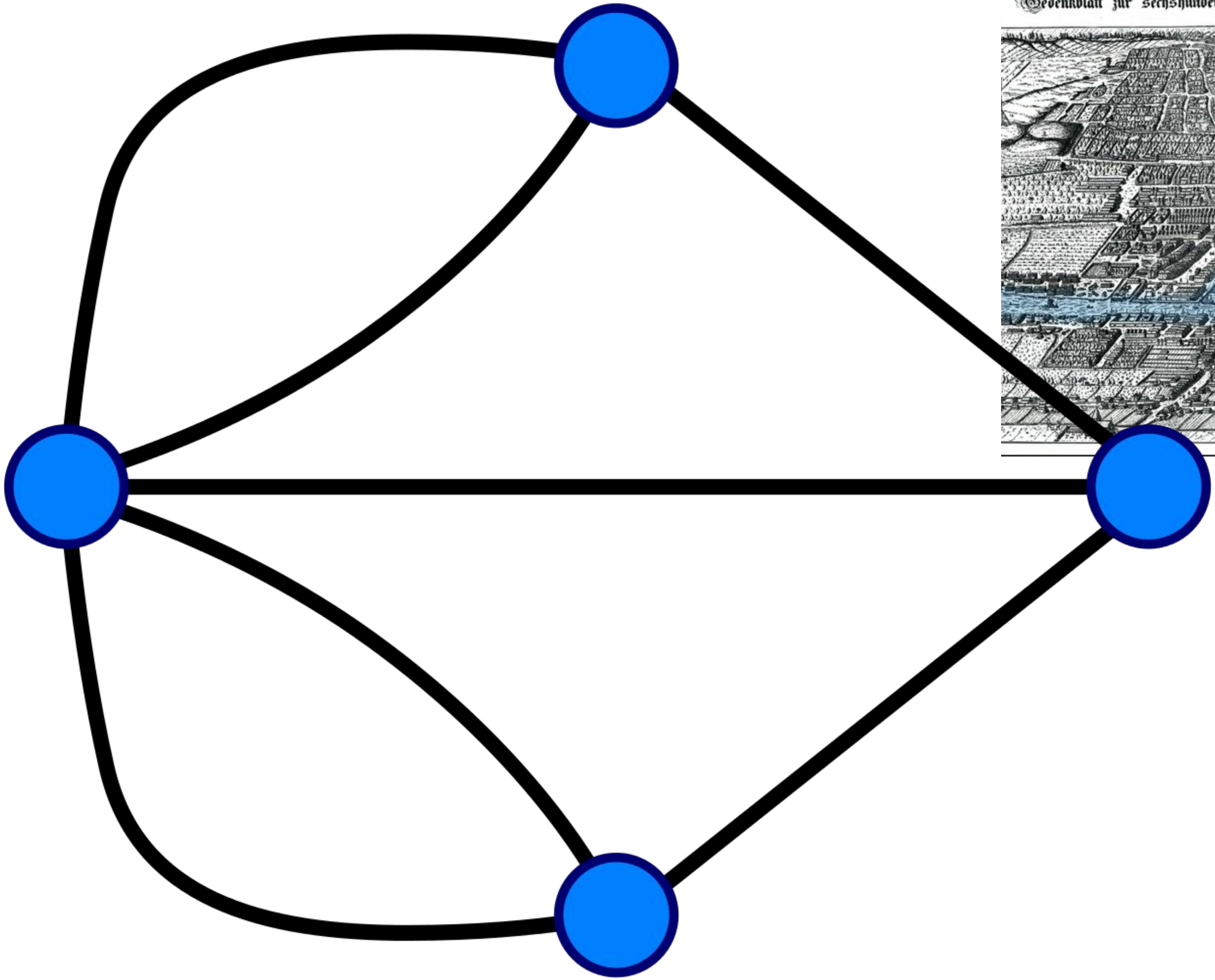
# CHAPTER 3:
# Visualization

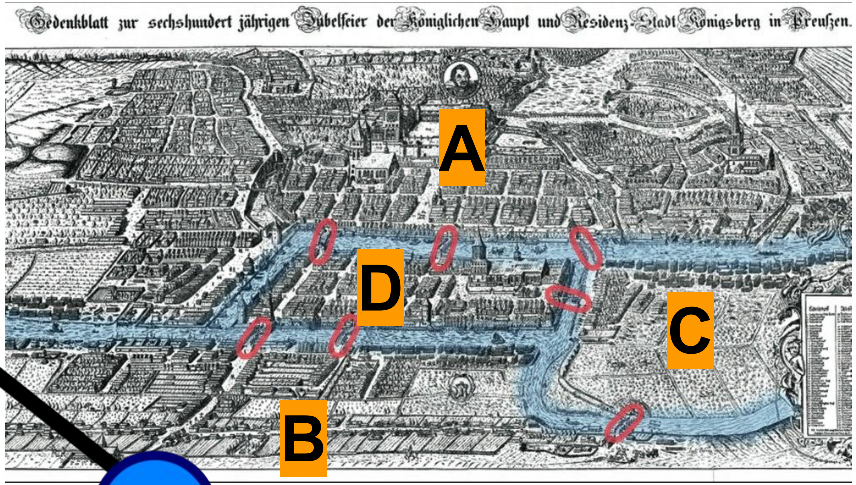
Gedenkblatt zur sechshundert jährigen Jubelfeier der Königlichen Haupt und Residenz-Stadt Königsberg in Preußen.

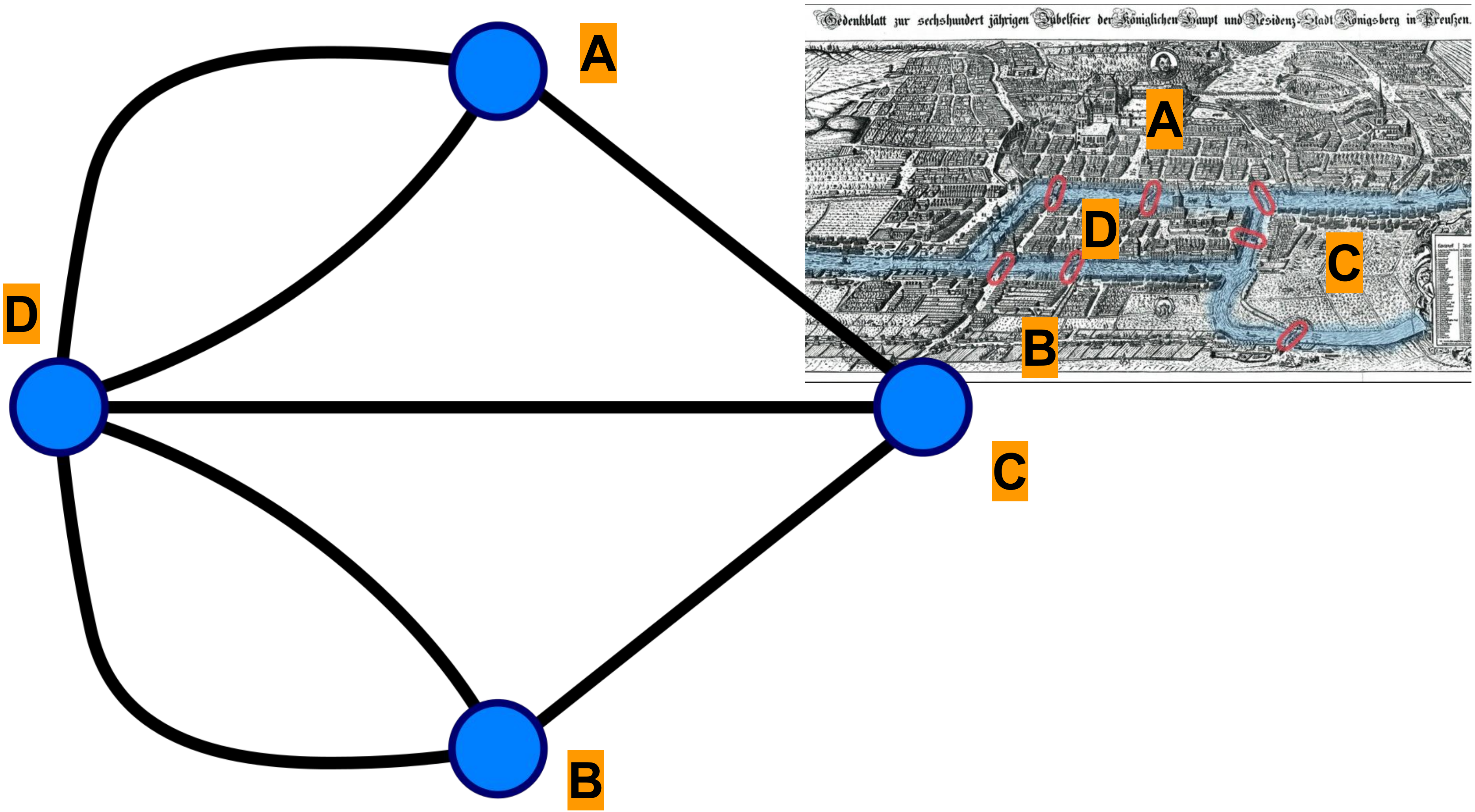




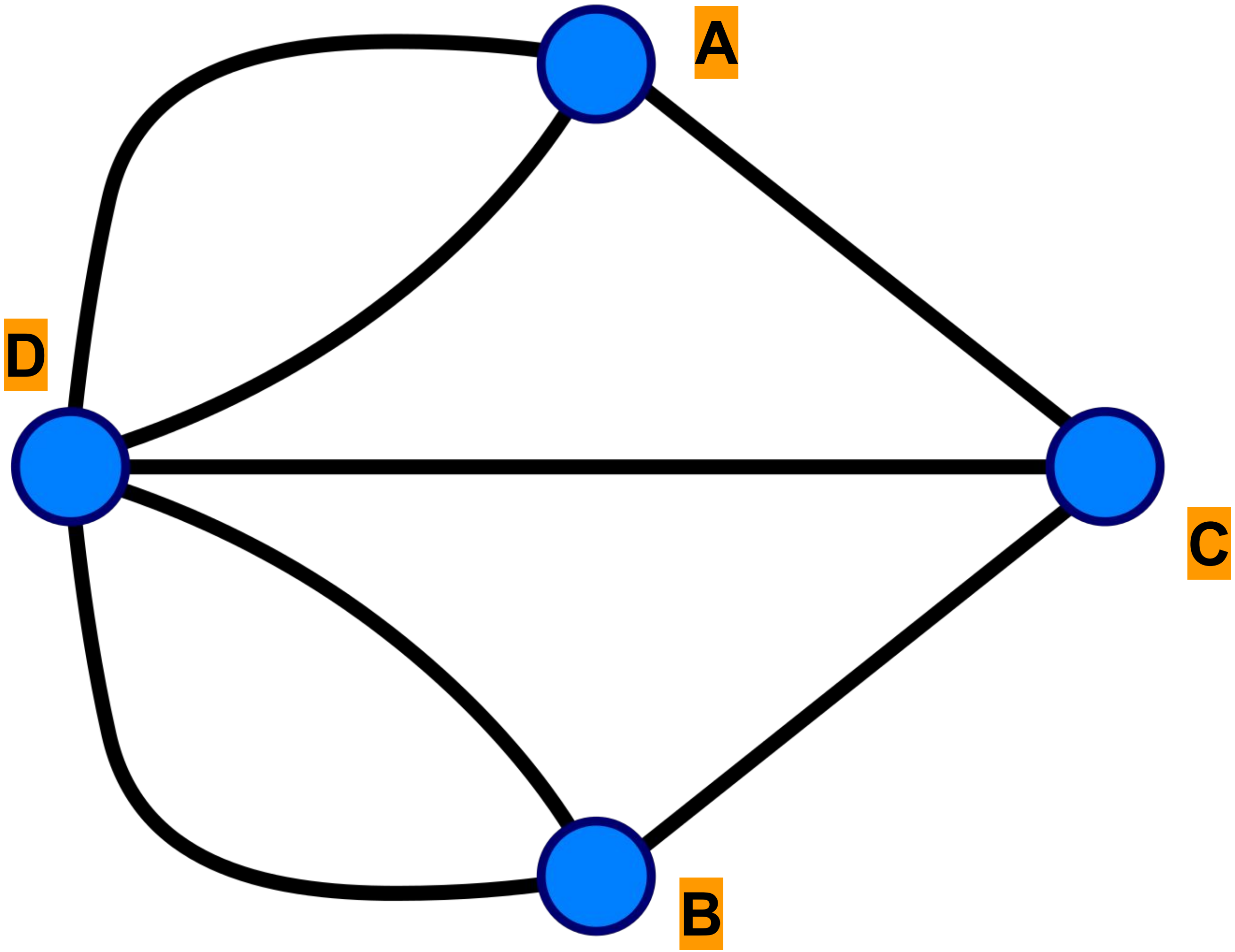

Gedenkblatt zur sechshundert jährigen Jubelfeier der Königlichen Haupt und Residenz-Stadt Königsberg in Preußen.



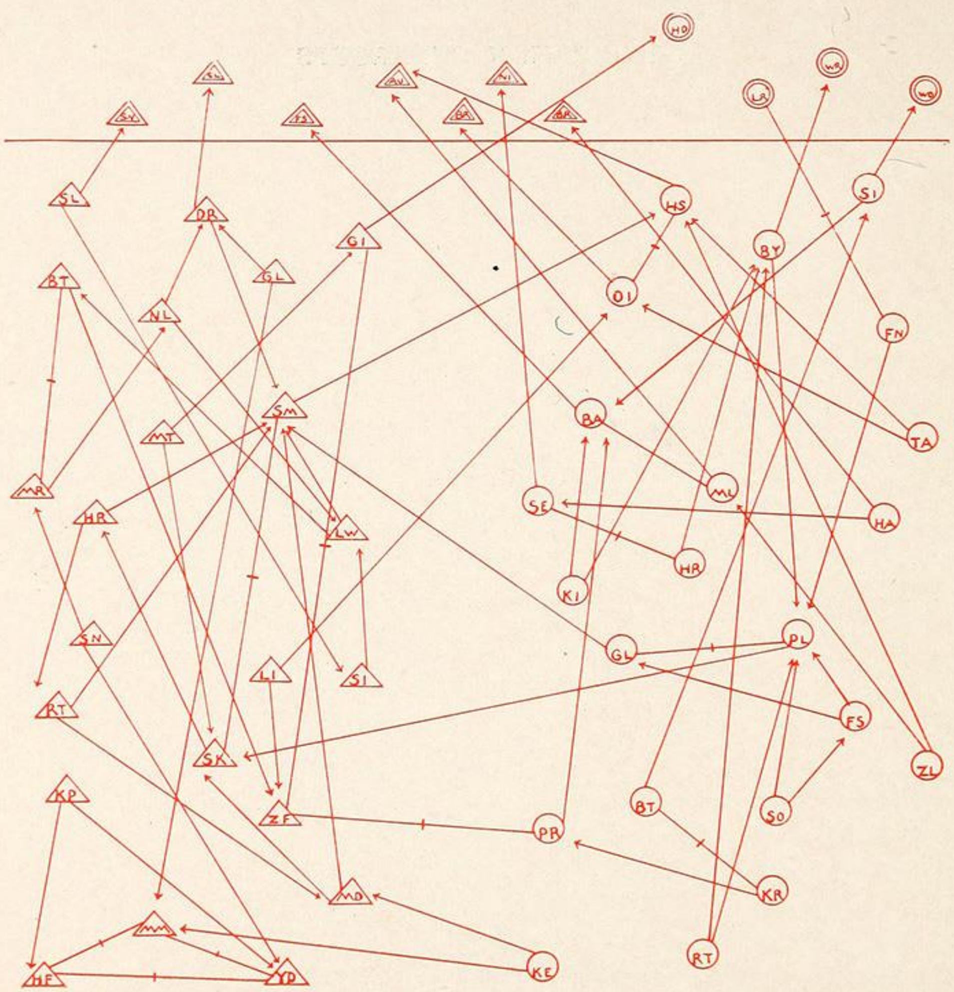

Gedenkblatt zur sechshundert jährigen Jubelfeier der Königlichen Haupt und Residenz-Stadt Königsberg in Preußen.
A
D
C
B



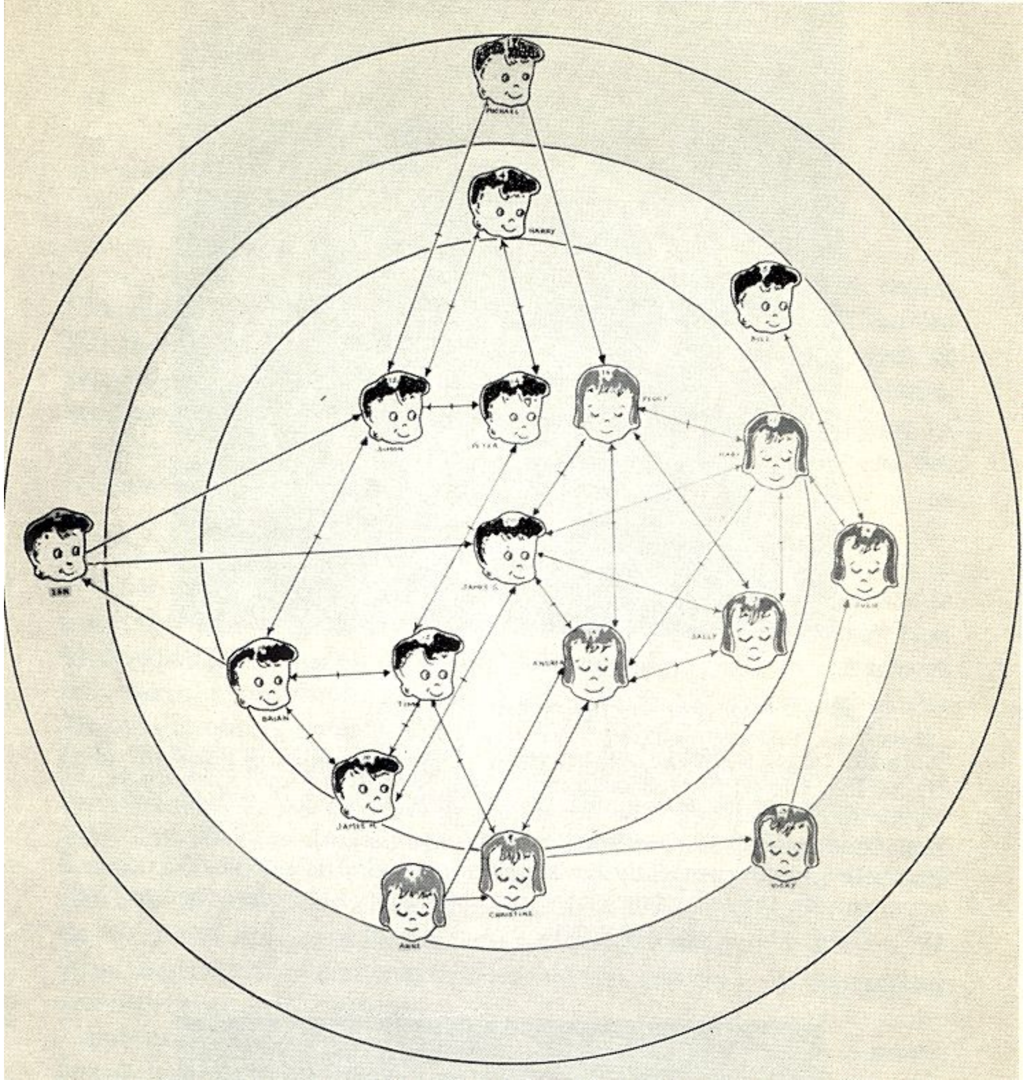
A
D
C
B
Gedenkblatt zur sechshundert jährigen Jubelfeier der Königlichen Haupt und Residenz-Stadt Königsberg in Preußen.
A
D
C
B


A
B
C
D

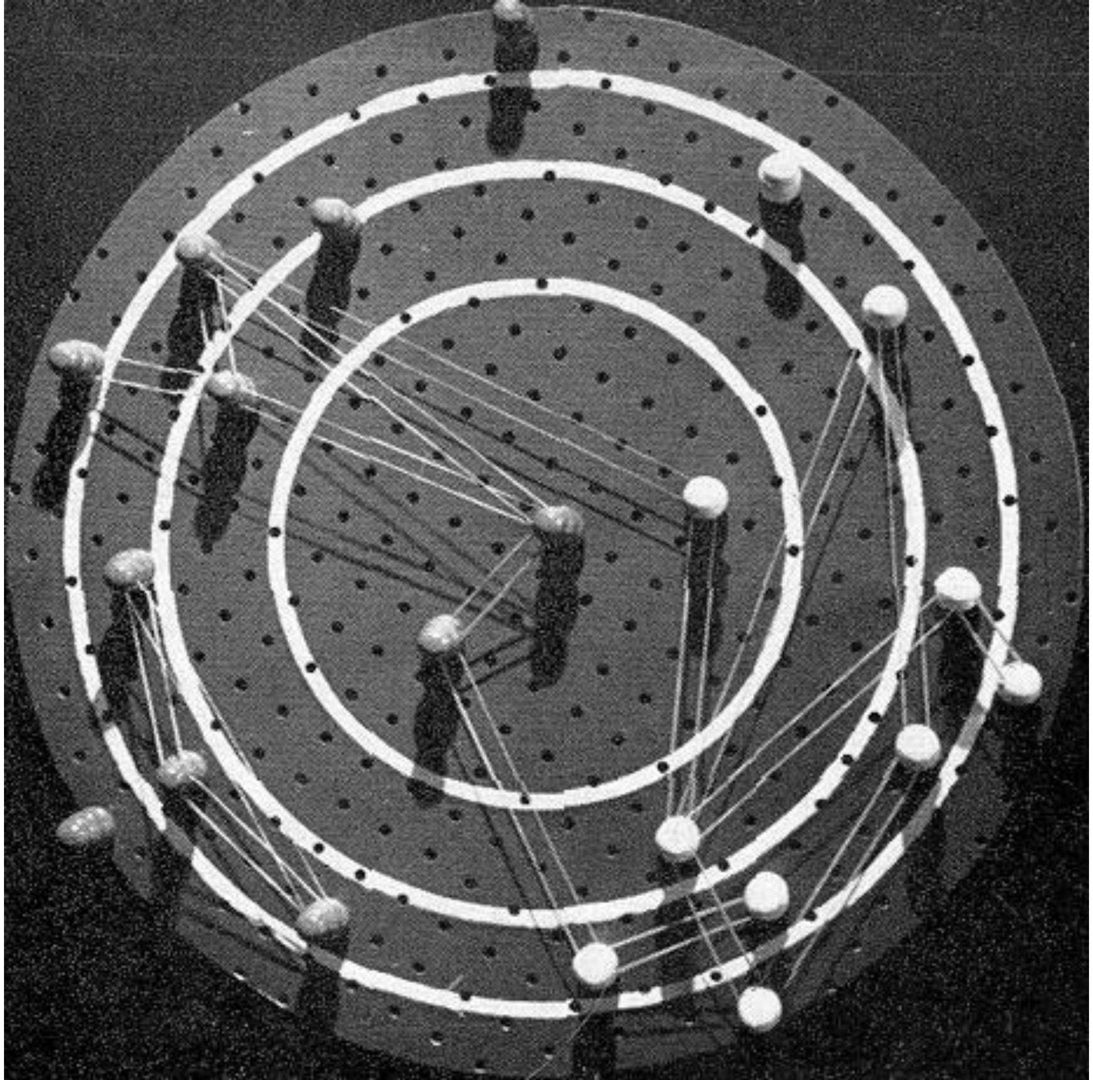
EVOLUTION OF GROUPS



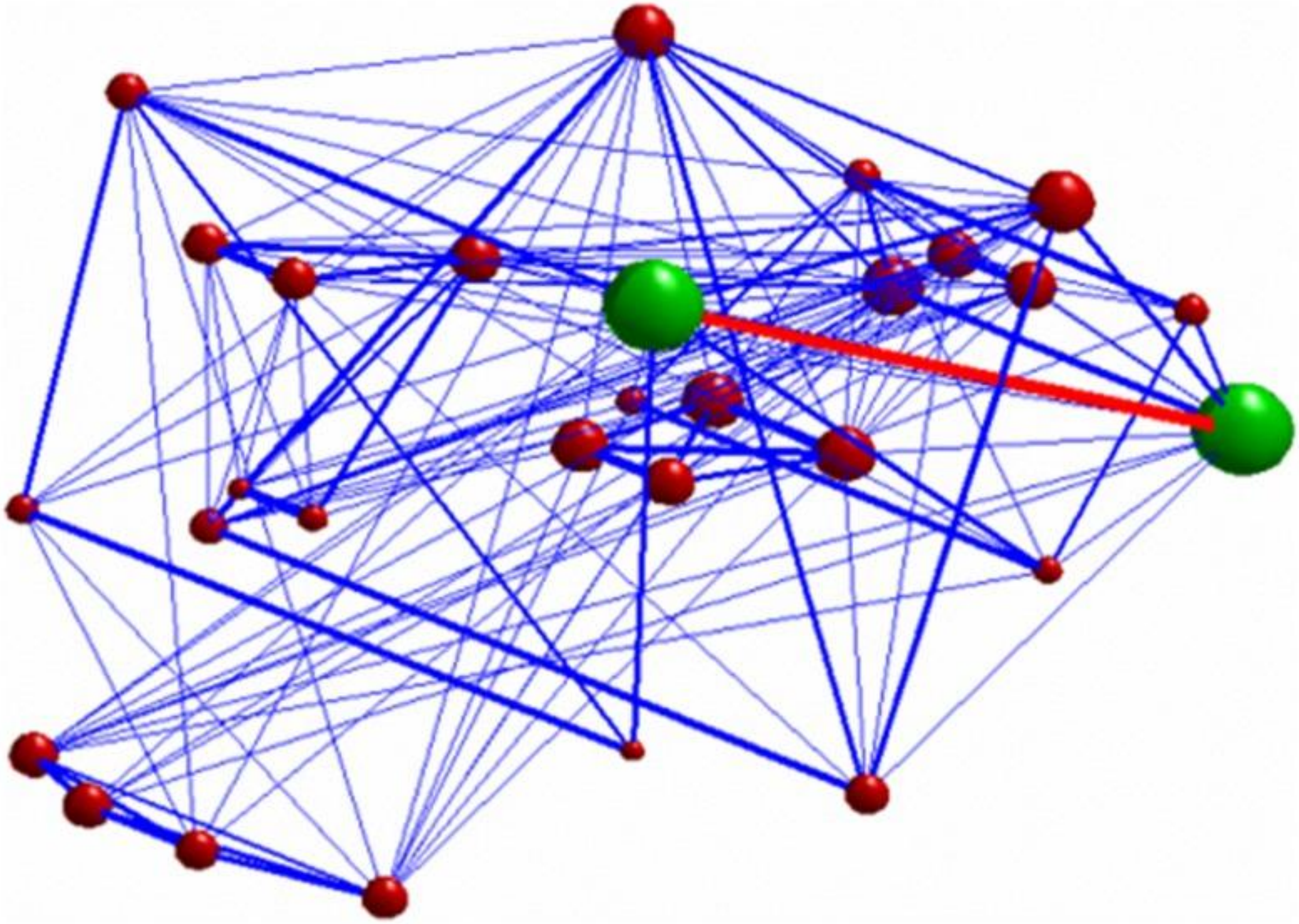

*J.L. Moreno, New York Times, April 13, 1933*



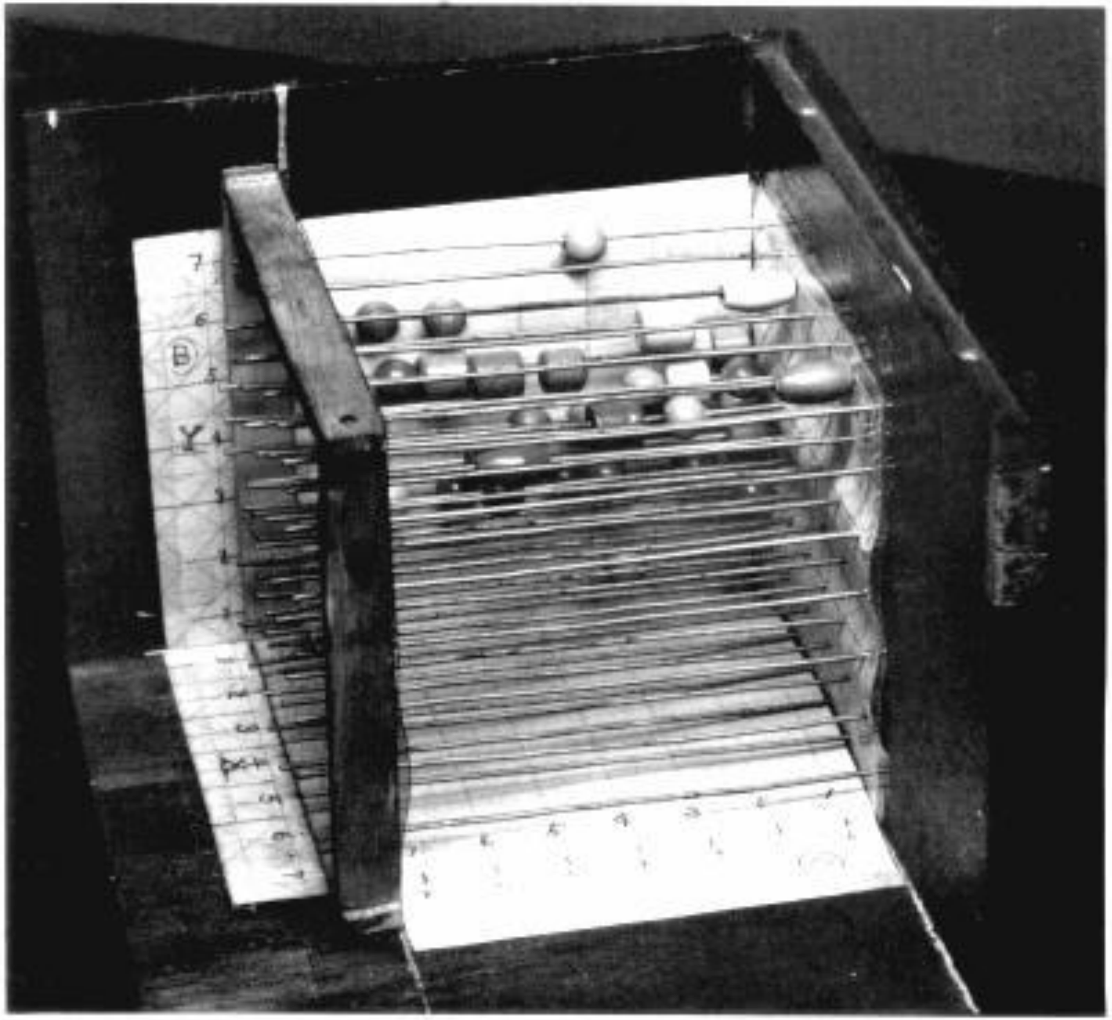
***Grant's Drawing of a Target Sociogram of a First Grade Class (from Northway, 1952).***



*McKenzie's Target Sociogram Board (from Northway, 1952).*



*Network Based Statistical Analysis Detects Changes Induced by Continuous Theta-Burst Stimulation on Brain Activity at Rest (2014)*




*Chapin (1950)*

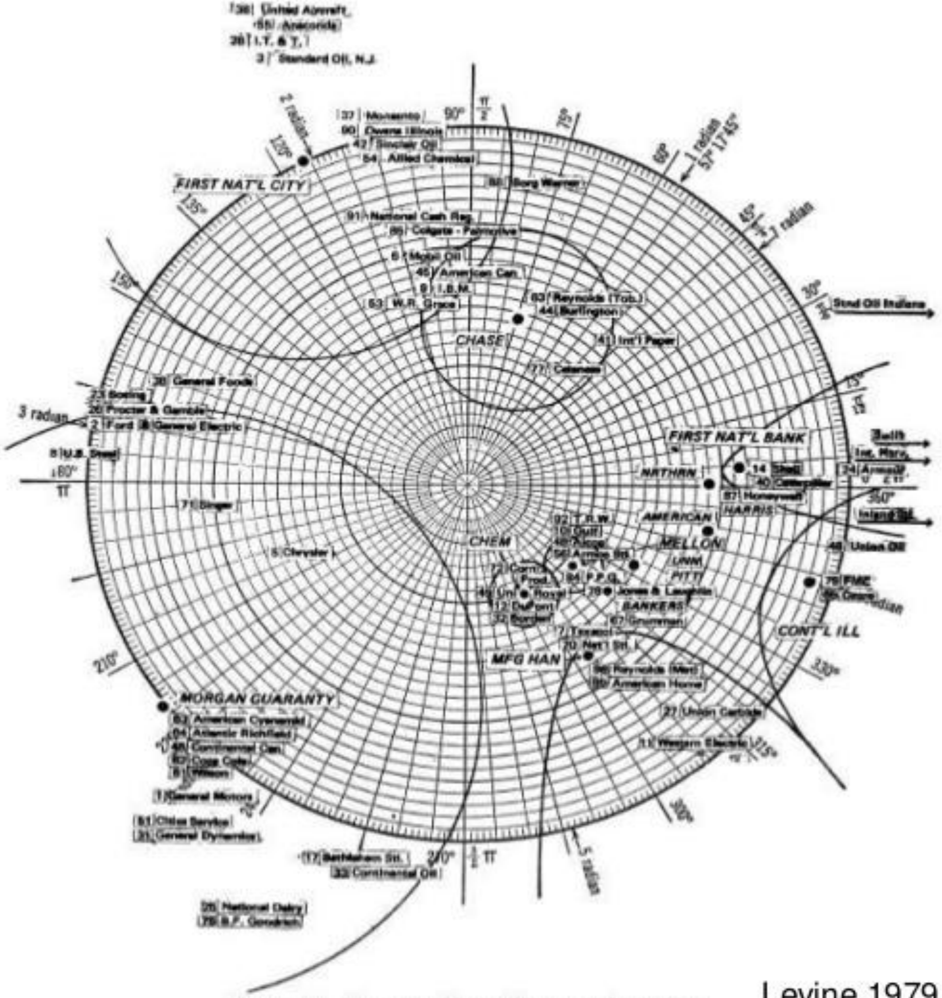
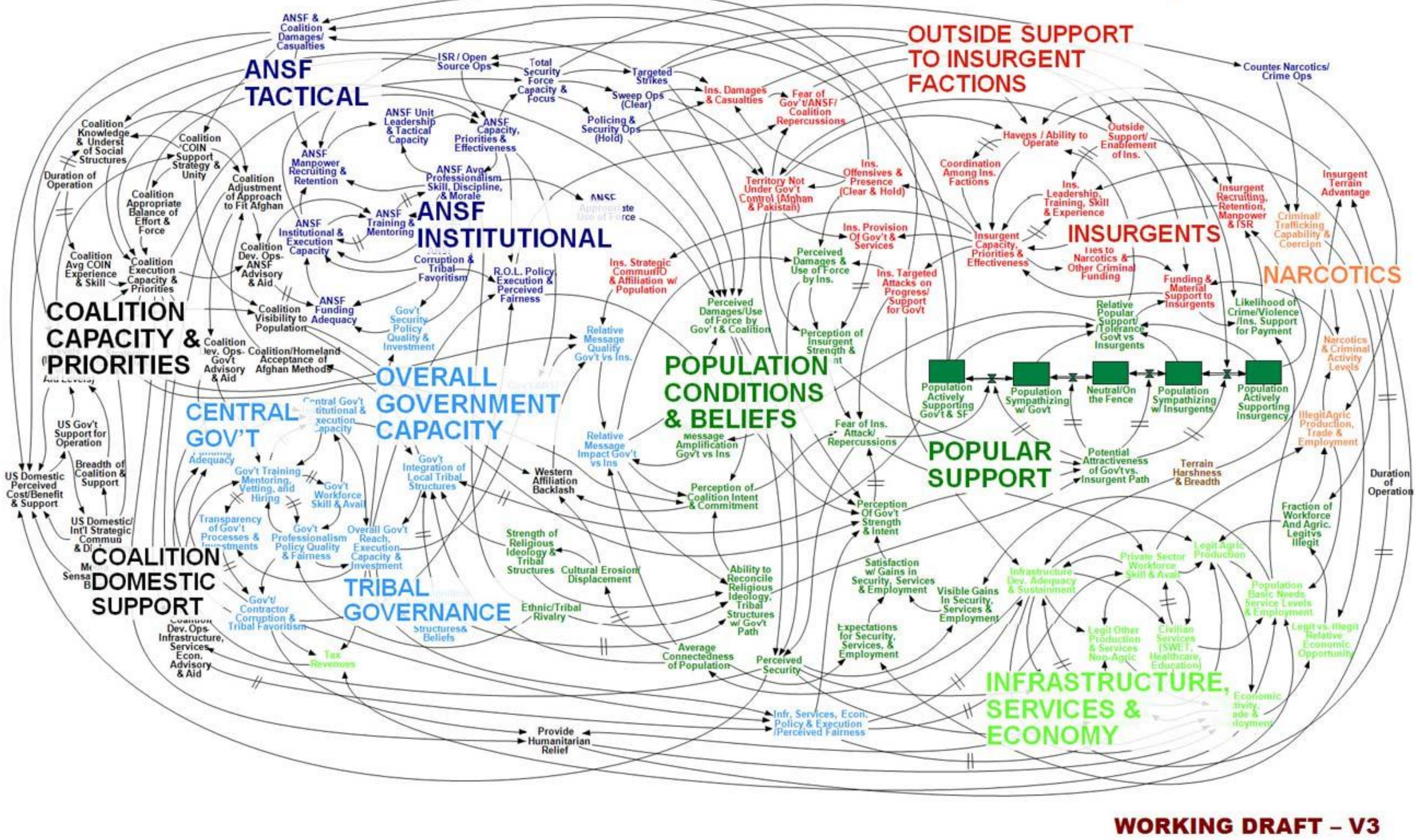



FIGURE 10. GNOMONIC MAP OF SPHERE OF INFLUENCE

Levine 1979

# Afghanistan Stability / COIN Dynamics




*Gen Stanley McChrystal, leader of American and NATO forces in Afghanistan 2009*

- Beautiful and mesmerizing
- Useful scientifically

## Anscombe's Quartet

| Set 1 X | Set 1 Y | Set 2 X | Set 2 Y | Set 3 X | Set 3 Y | Set 4 X | Set 4 Y |
|---|---|---|---|---|---|---|---|
| 10 | 8.04 | 10 | 9.14 | 10 | 7.46 | 8 | 6.58 |
| 8 | 6.95 | 8 | 8.14 | 8 | 6.77 | 8 | 5.76 |
| 13 | 7.58 | 13 | 8.74 | 13 | 12.74 | 8 | 7.71 |
| 9 | 8.81 | 9 | 8.77 | 9 | 7.11 | 8 | 8.84 |
| 11 | 8.33 | 11 | 9.26 | 11 | 7.81 | 8 | 8.47 |
| 14 | 9.96 | 14 | 8.1 | 14 | 8.84 | 8 | 7.04 |
| 6 | 7.24 | 6 | 6.13 | 6 | 6.08 | 8 | 5.25 |
| 4 | 4.26 | 4 | 3.1 | 4 | 5.39 | 19 | 12.5 |
| 12 | 10.84 | 12 | 9.13 | 12 | 8.15 | 8 | 5.56 |
| 7 | 4.82 | 7 | 7.26 | 7 | 6.42 | 8 | 7.91 |
| 5 | 5.68 | 5 | 4.74 | 5 | 5.73 | 8 | 6.89 |

| Property | Value |
|---|---|
| Mean of X in each case: | 9 (exact) |
| Variance of X in each case: | 11 (exact) |
| Mean of Y in each case: | 7.50 |
| Variance of Y in each case: | 4.122 or 4.127 |
| Correlation between X & Y in each case: | 0.816 |
| Linear regression line in each case: | y=3.00 + 0.500x |

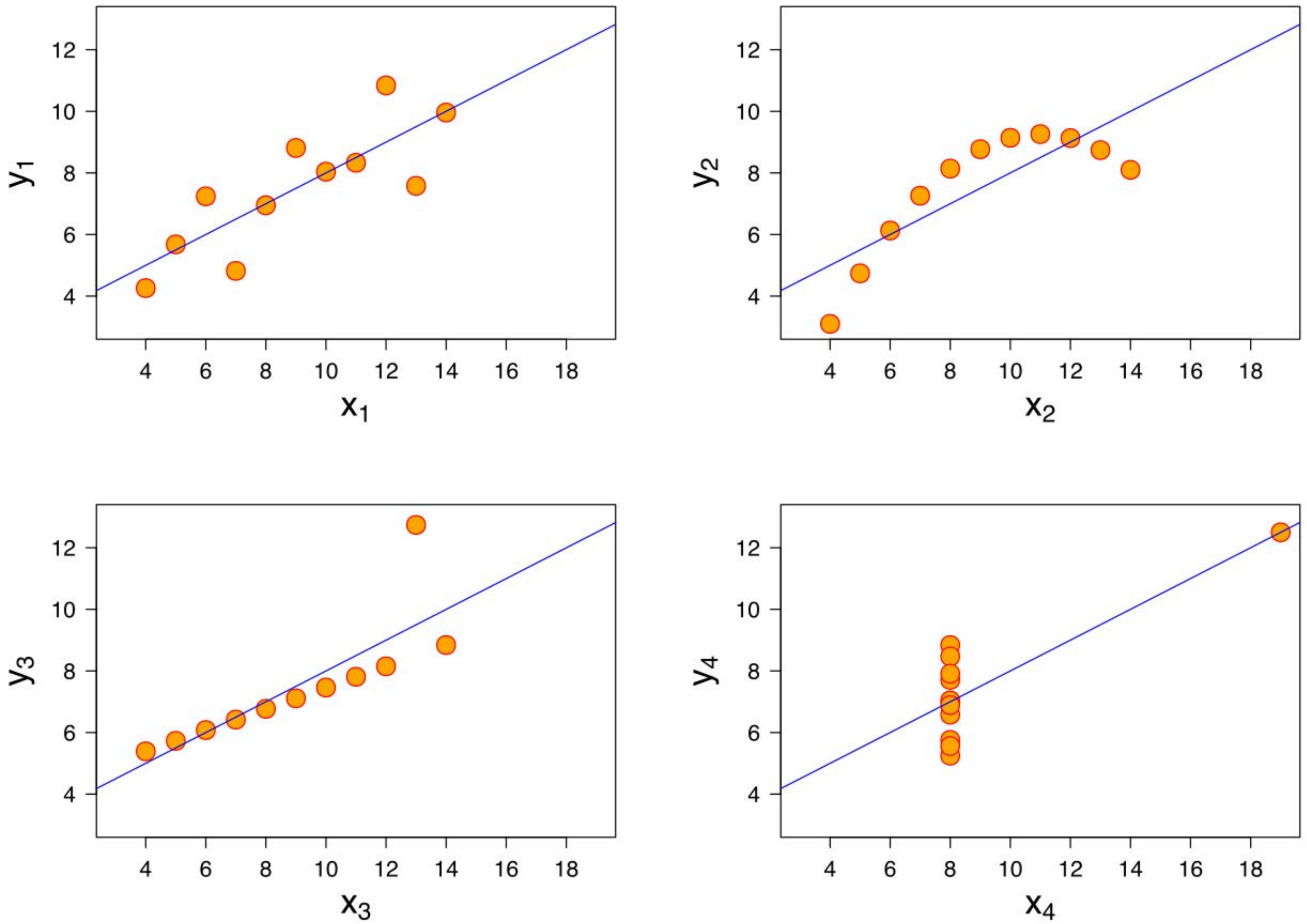
We have all the metric perfectly describe, why even bother???

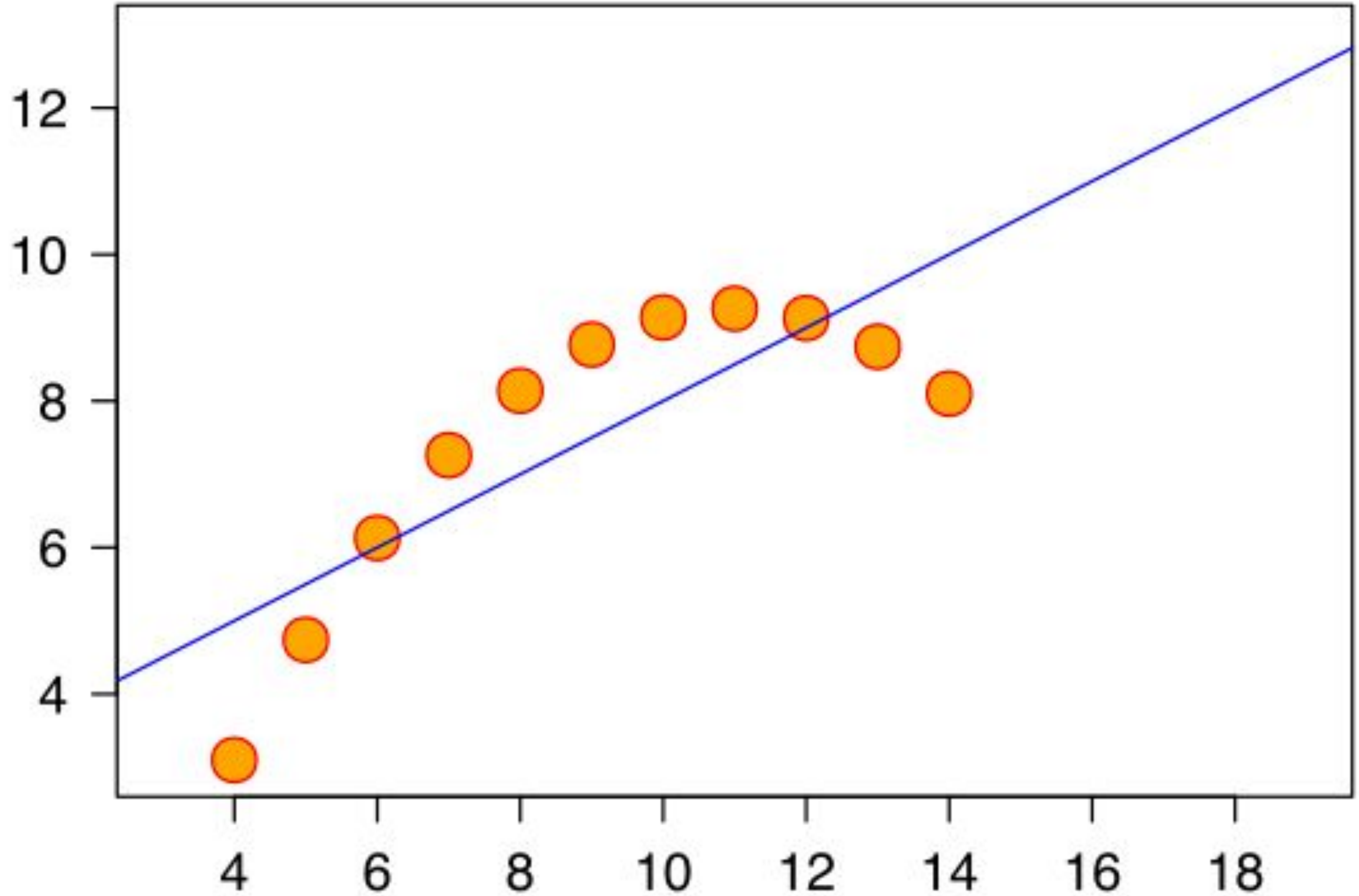
¯_(ツ)_/¯

# Anscombe's Quartet

| Set 1 | | Set 2 | | Set 3 | | Set 4 | |
|---|---|---|---|---|---|---|---|
| X | Y | X | Y | X | Y | X | Y |
| 10 | 8.04 | 10 | 9.14 | 10 | 7.46 | 8 | 6.58 |
| 8 | 6.95 | 8 | 8.14 | 8 | 6.77 | 8 | 5.76 |
| 13 | 7.58 | 13 | 8.74 | 13 | 12.74 | 8 | 7.71 |
| 9 | 8.81 | 9 | 8.77 | 9 | 7.11 | 8 | 8.84 |
| 11 | 8.33 | 11 | 9.26 | 11 | 7.81 | 8 | 8.47 |
| 14 | 9.96 | 14 | 8.1 | 14 | 8.84 | 8 | 7.04 |
| 6 | 7.24 | 6 | 6.13 | 6 | 6.08 | 8 | 5.25 |
| 4 | 4.26 | 4 | 3.1 | 4 | 5.39 | 19 | 12.5 |
| 12 | 10.84 | 12 | 9.13 | 12 | 8.15 | 8 | 5.56 |
| 7 | 4.82 | 7 | 7.26 | 7 | 6.42 | 8 | 7.91 |
| 5 | 5.68 | 5 | 4.74 | 5 | 5.73 | 8 | 6.89 |

| Property | Value |
|---|---|
| Mean of X in each case: | 9 (exact) |
| Variance of X in each case: | 11 (exact) |
| Mean of Y in each case: | 7.50 |
| Variance of Y in each case: | 4.122 or 4.127 |
| Correlation between X & Y in each case: | 0.816 |
| Linear regression line in each case: | y=3.00 + 0.500x |

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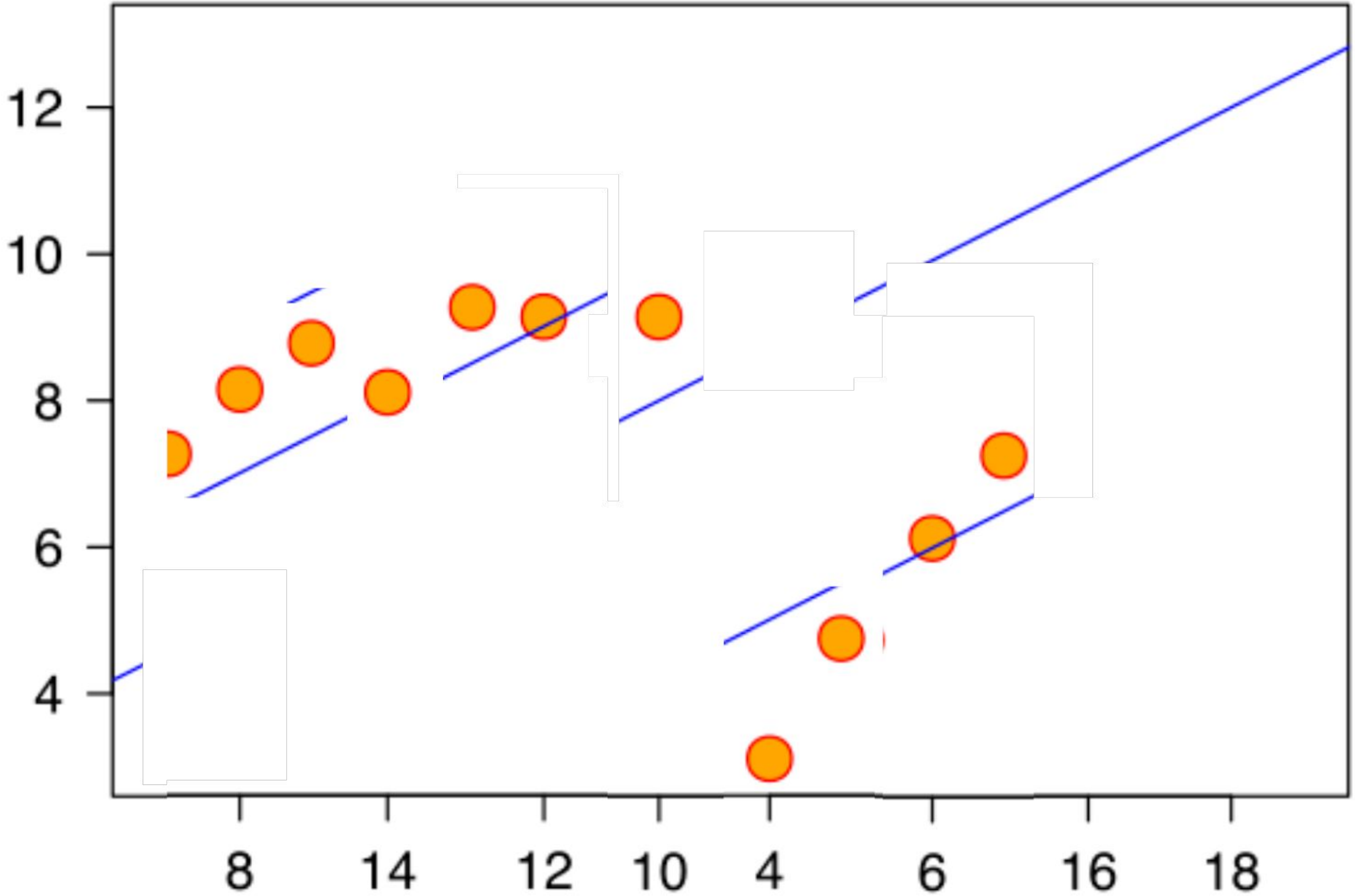
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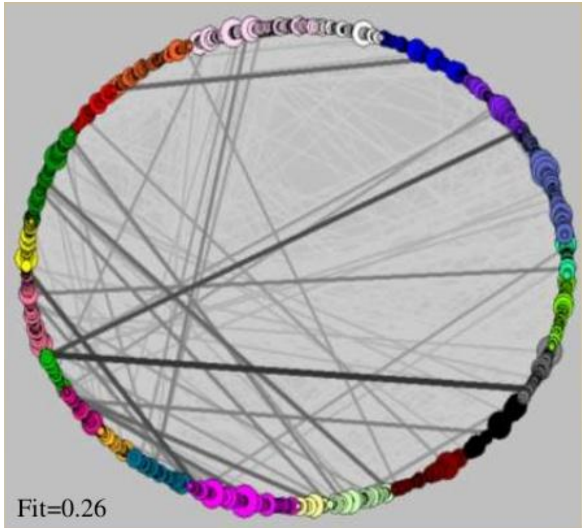
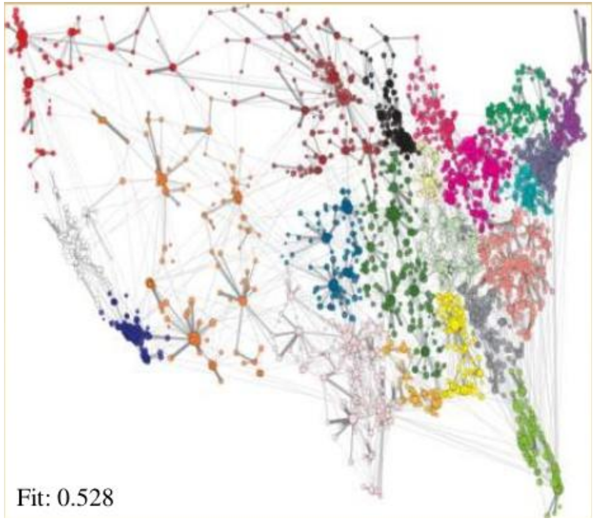
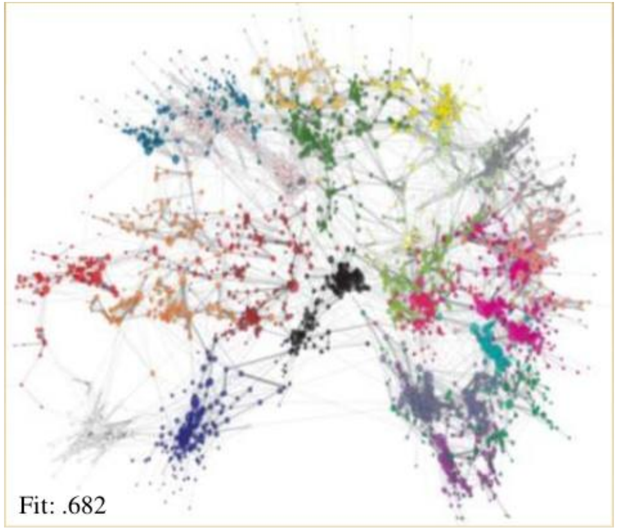


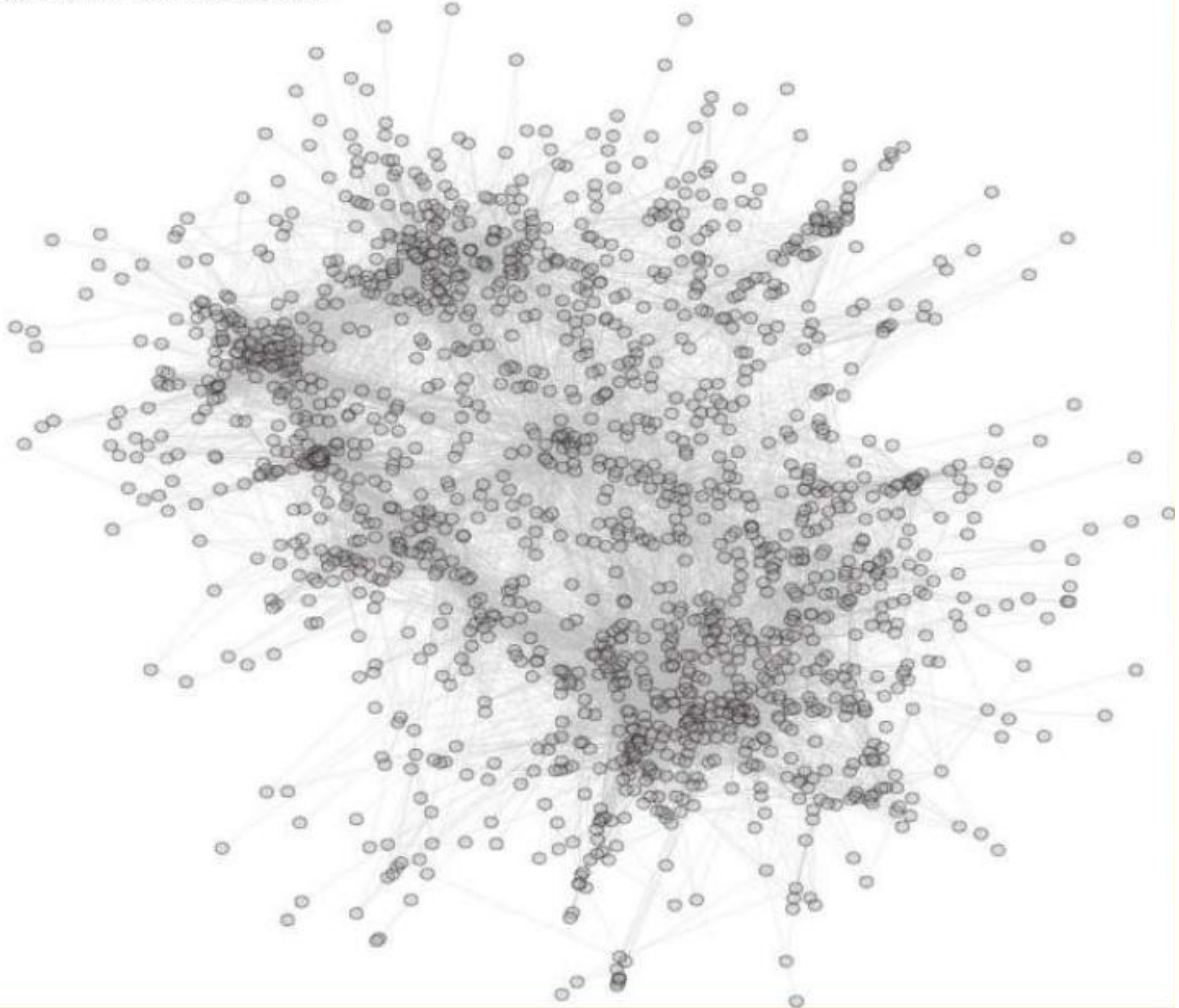

Moody, J. "Hospital network colaboration" SOCIAL NETWORKS AND HEALTH 2018 workshop



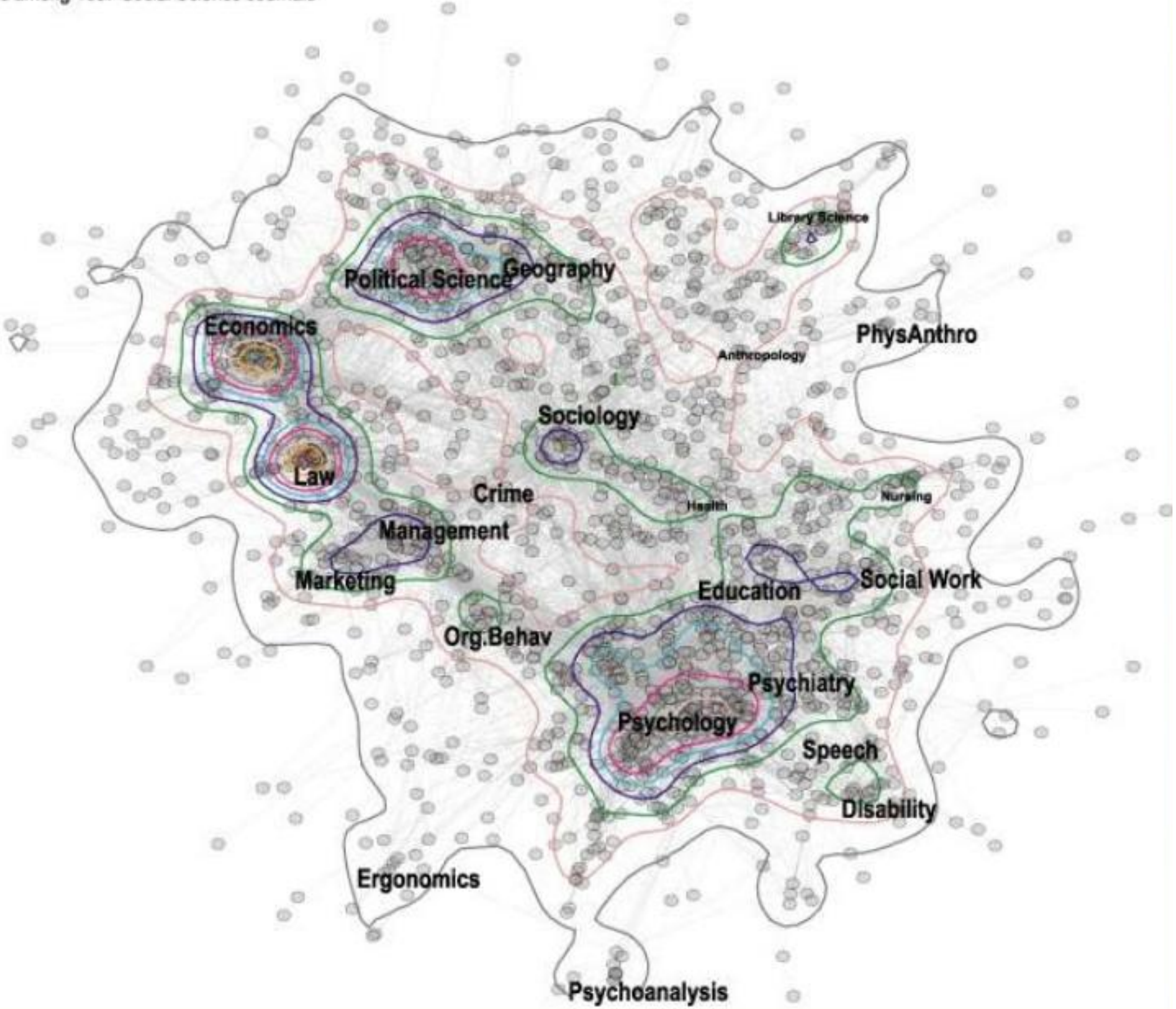
## The Discipline Structure of Social Science Journals

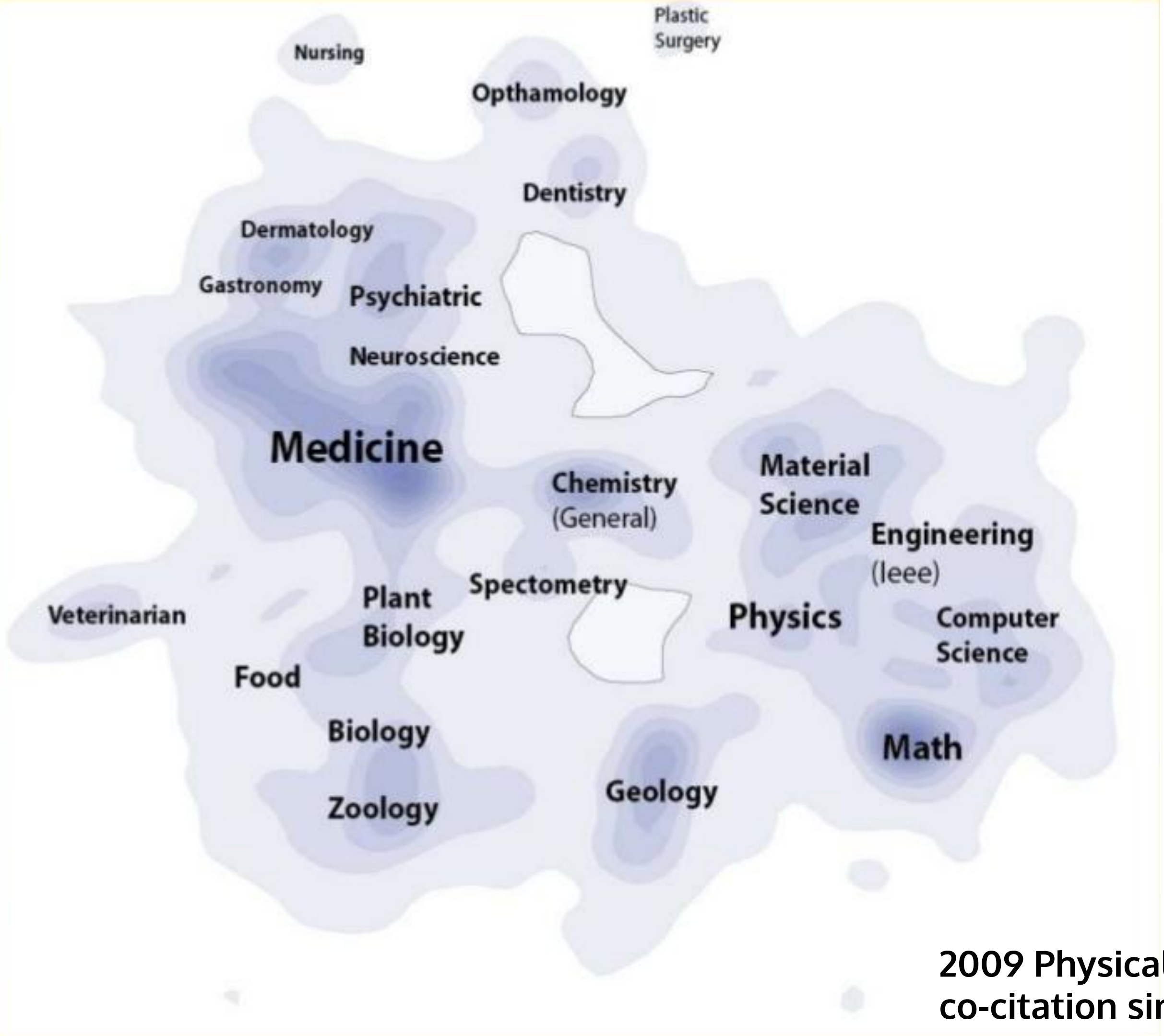
Co-citation ties among 1657 Social Science Journals



# The Discipline Structure of Social Science Journals

Co-citation ties among 1657 Social Science Journals






2009 Physical Science Journal co-citation similarity

# CHAPTER 4:

# Autocorrelation

The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL ARTICLE

# The Spread of Obesity in a Large Social Network over 32 Years

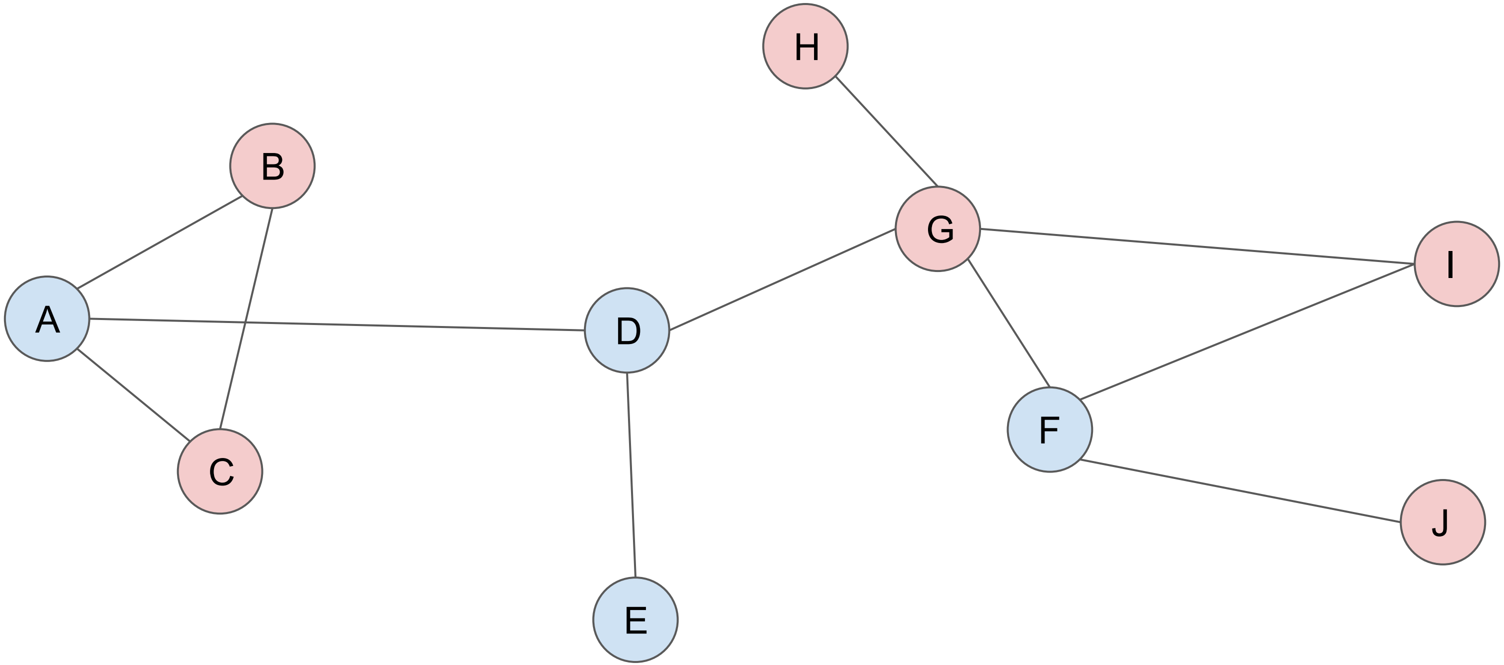
Nicholas A. Christakis, M.D., Ph.D., M.P.H., and James H. Fowler, Ph.D.

The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL ARTICLE

# Your friends make you fat

Nicholas A. Christakis, M.D., Ph.D., M.P.H., and James H. Fowler, Ph.D.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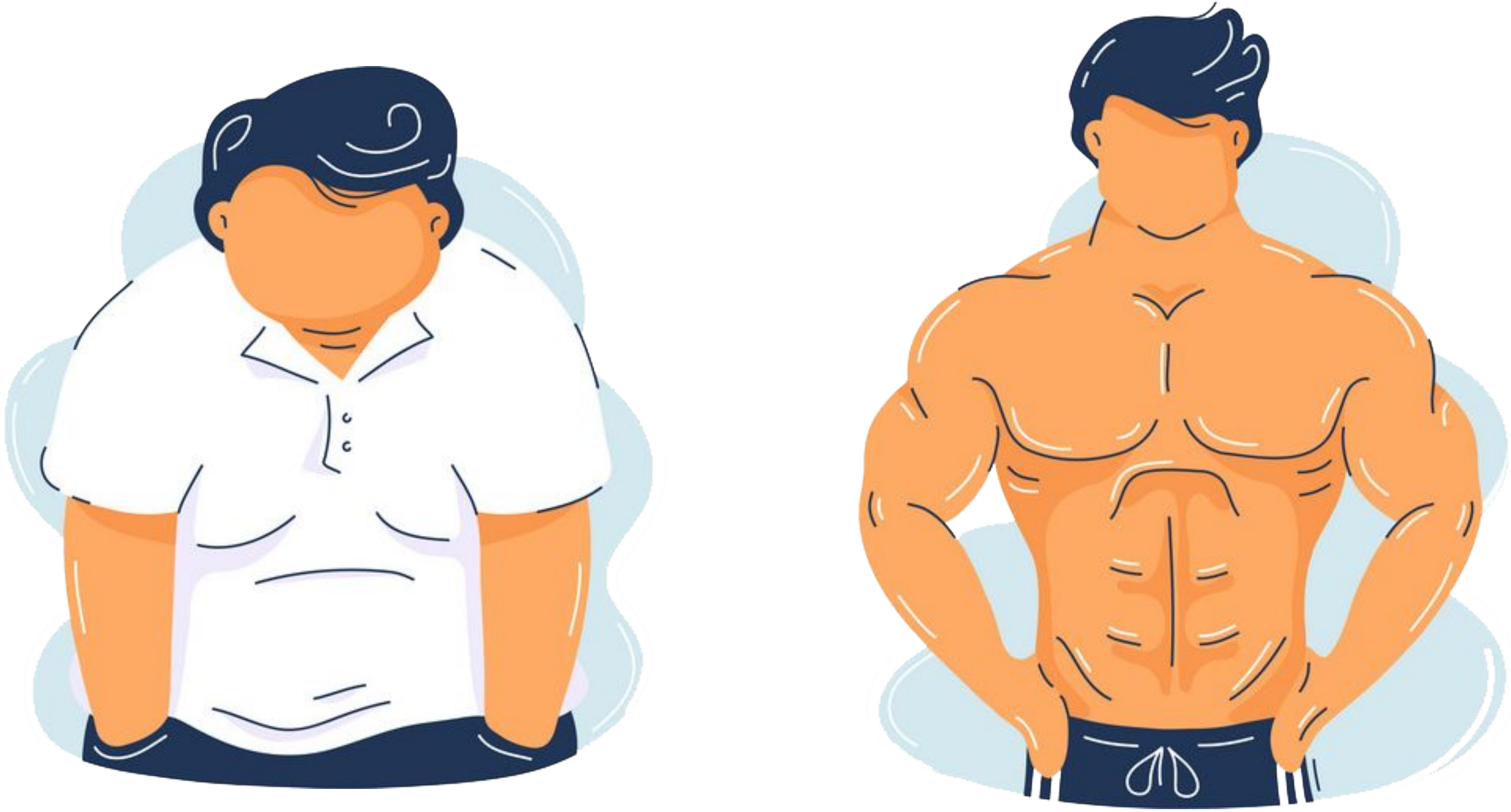
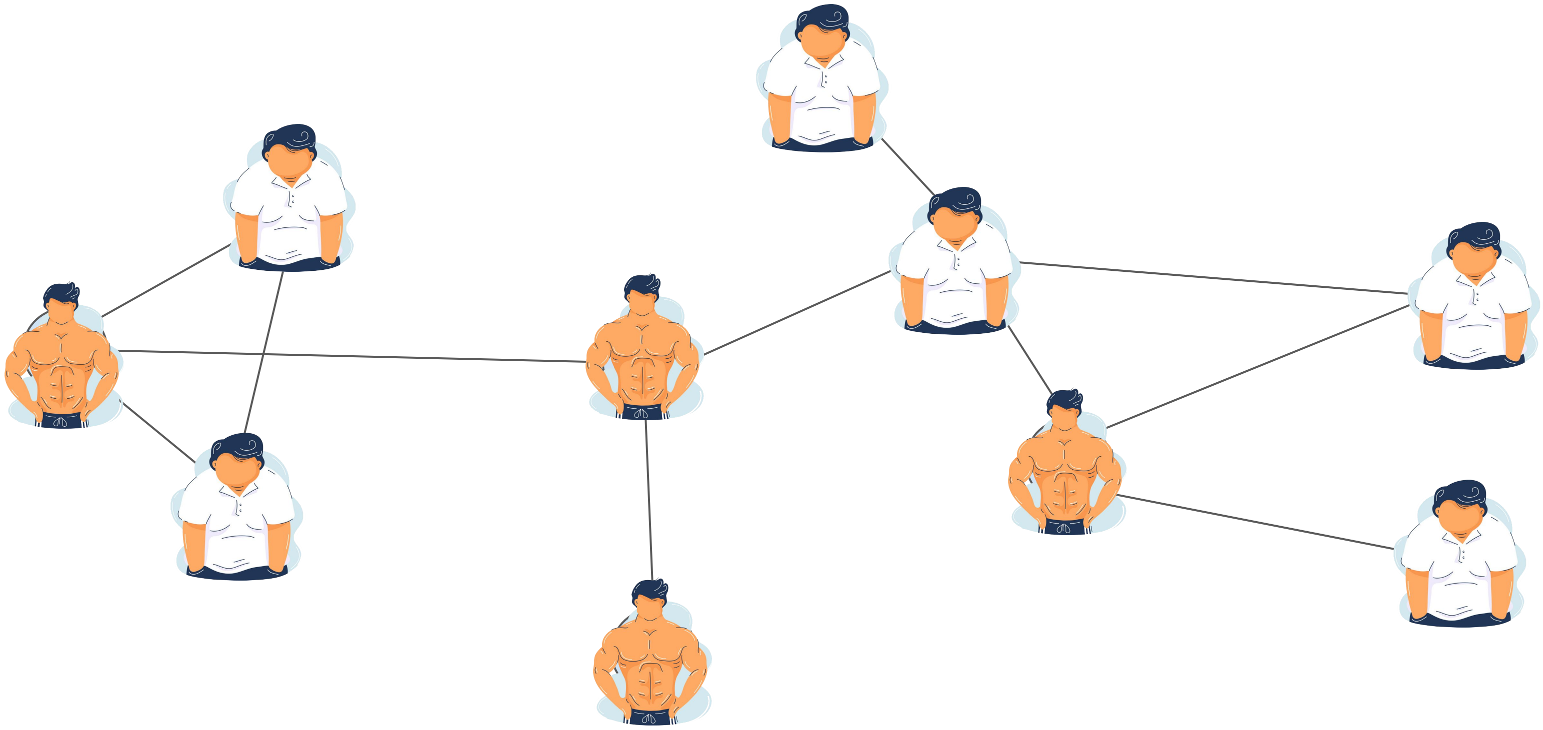
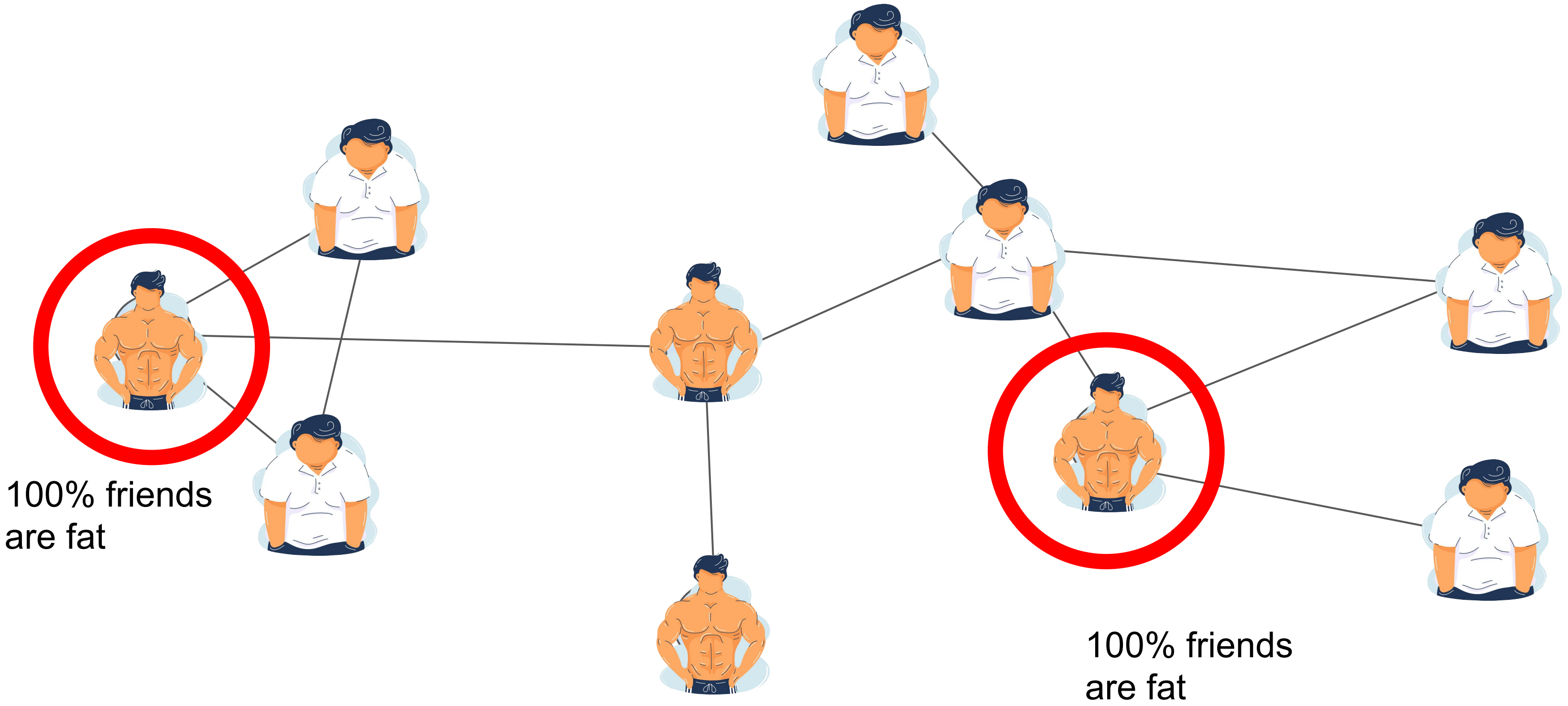
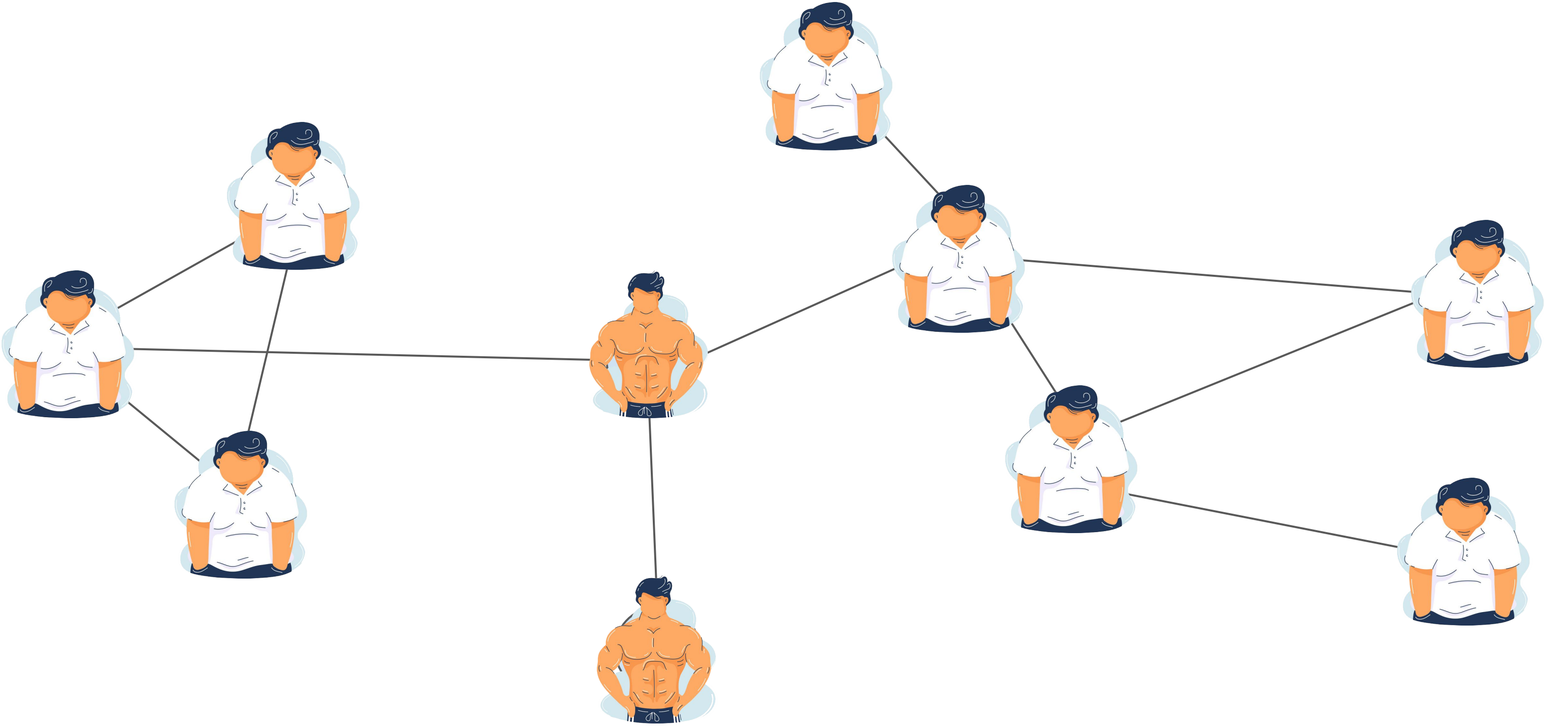
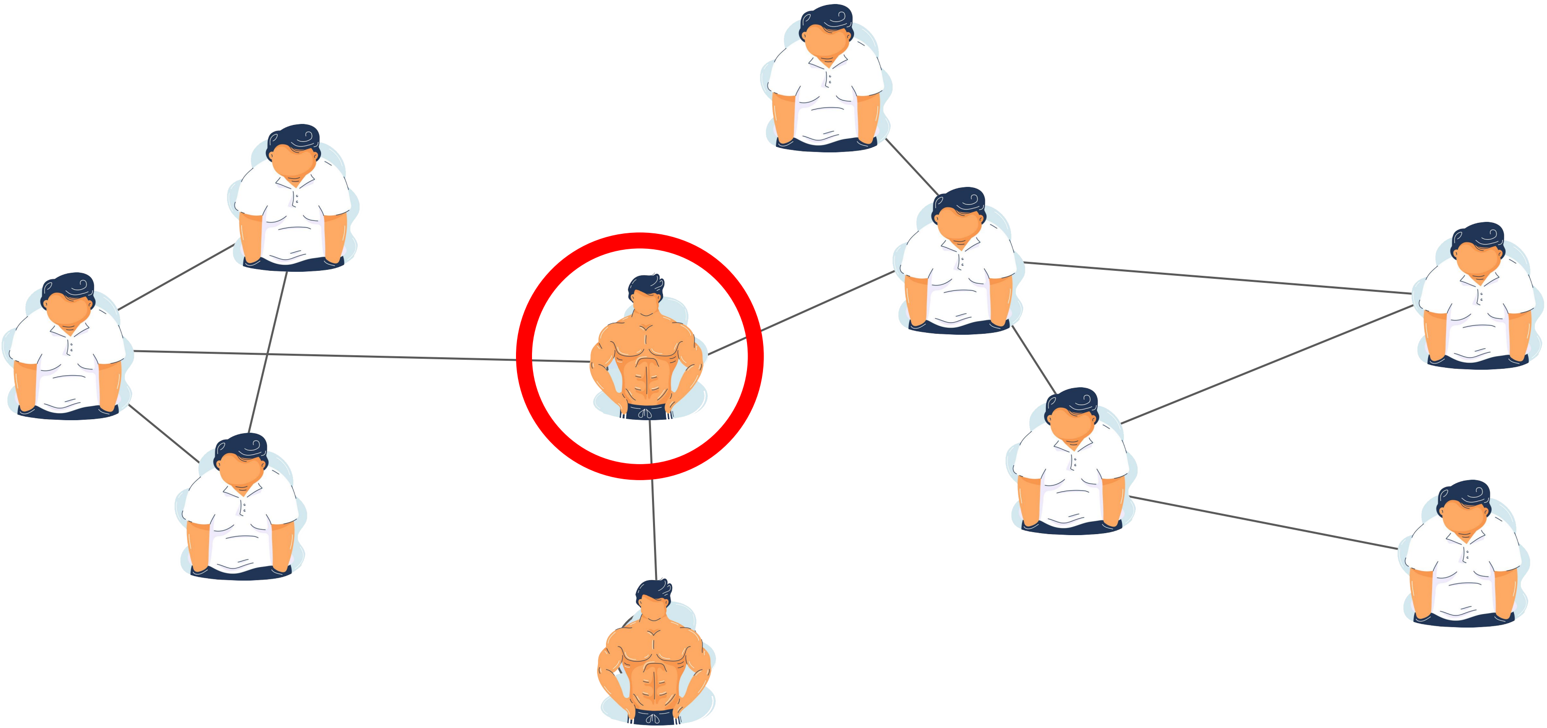
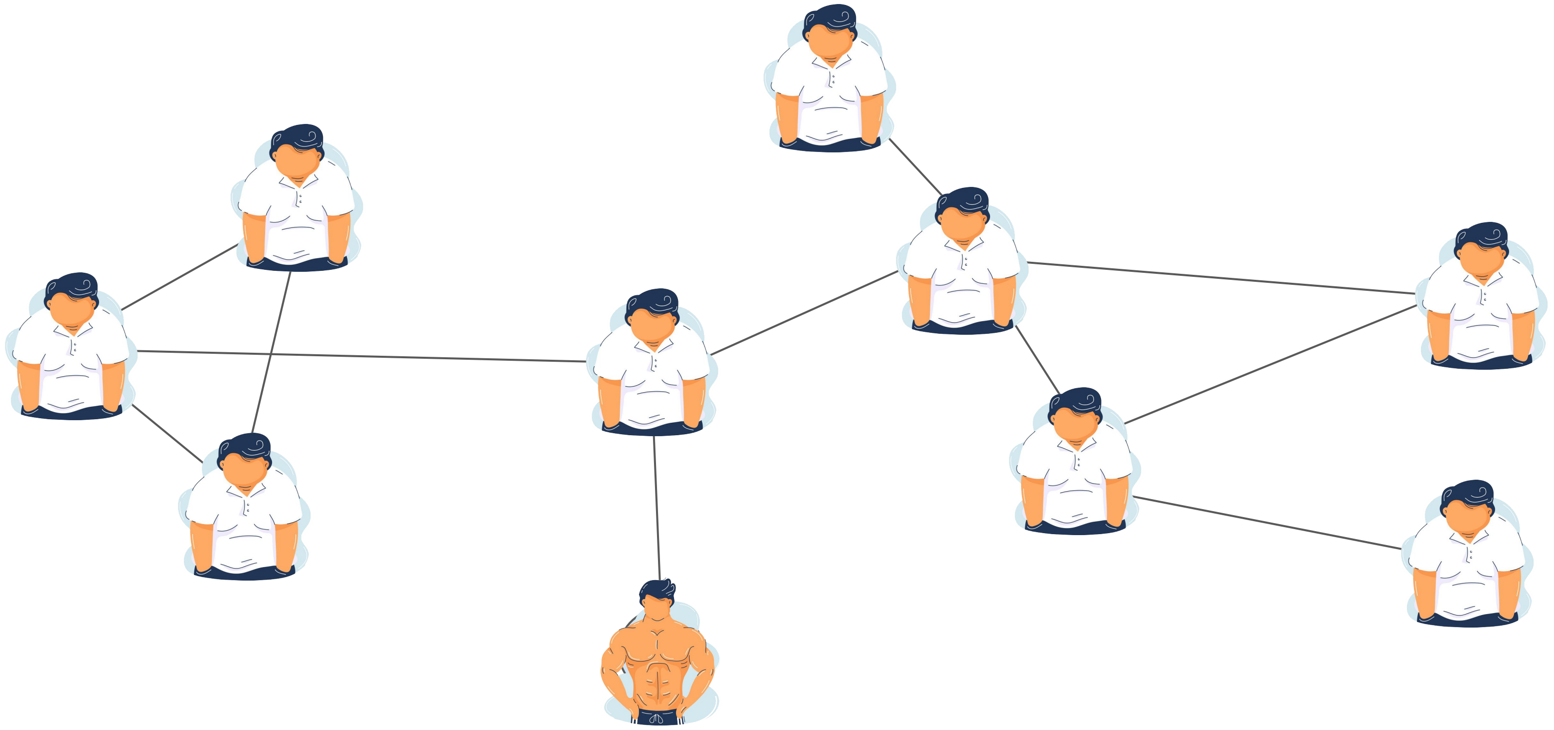


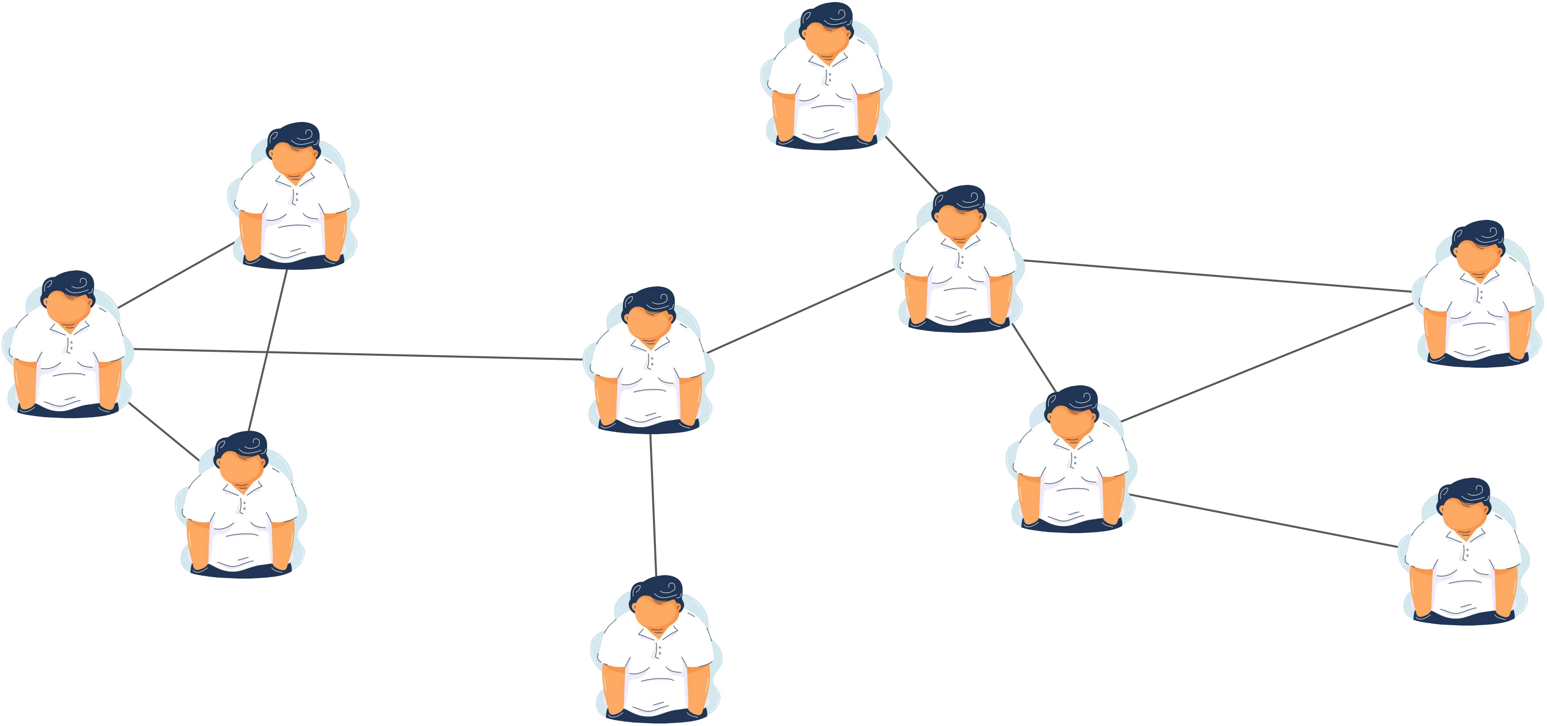


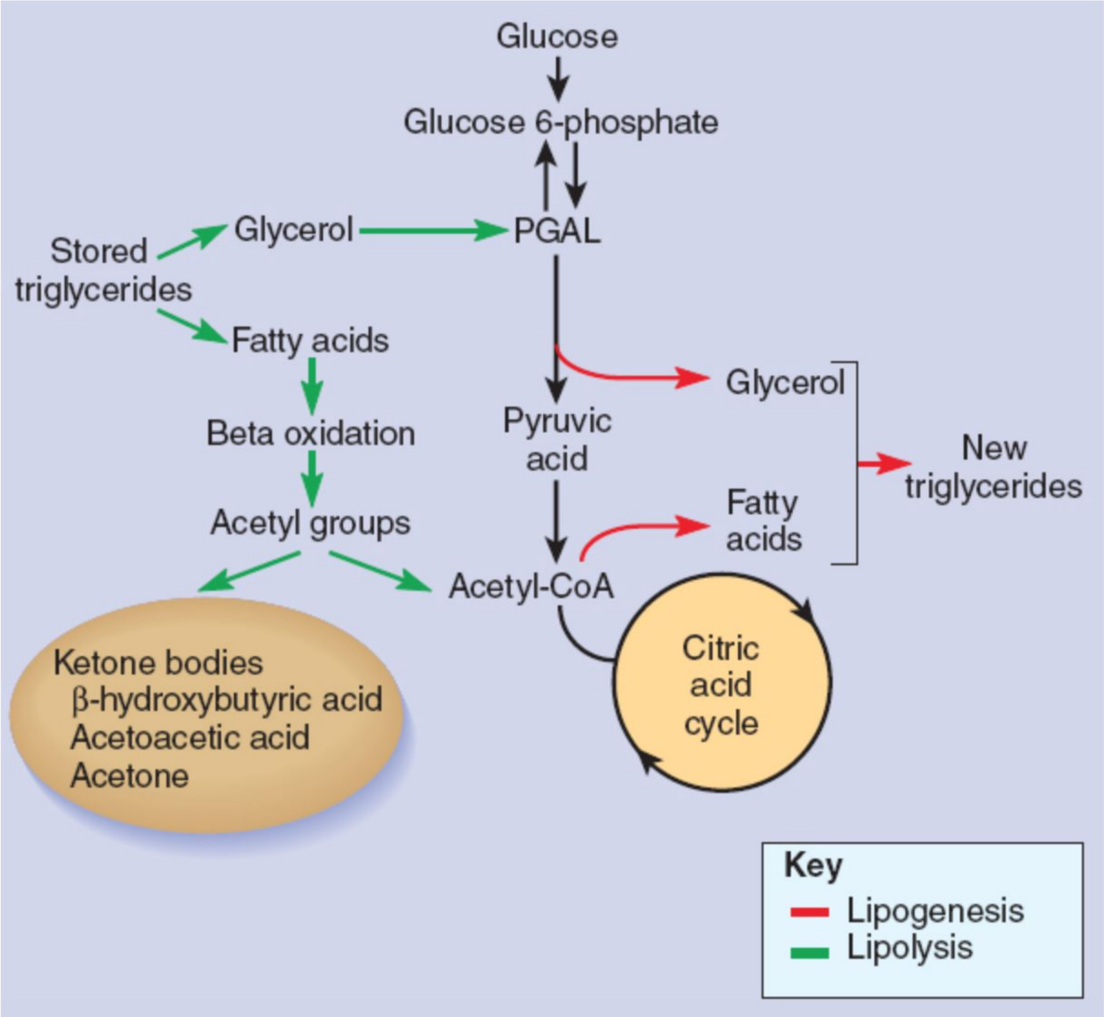

100% friends are fat
100% friends are fat

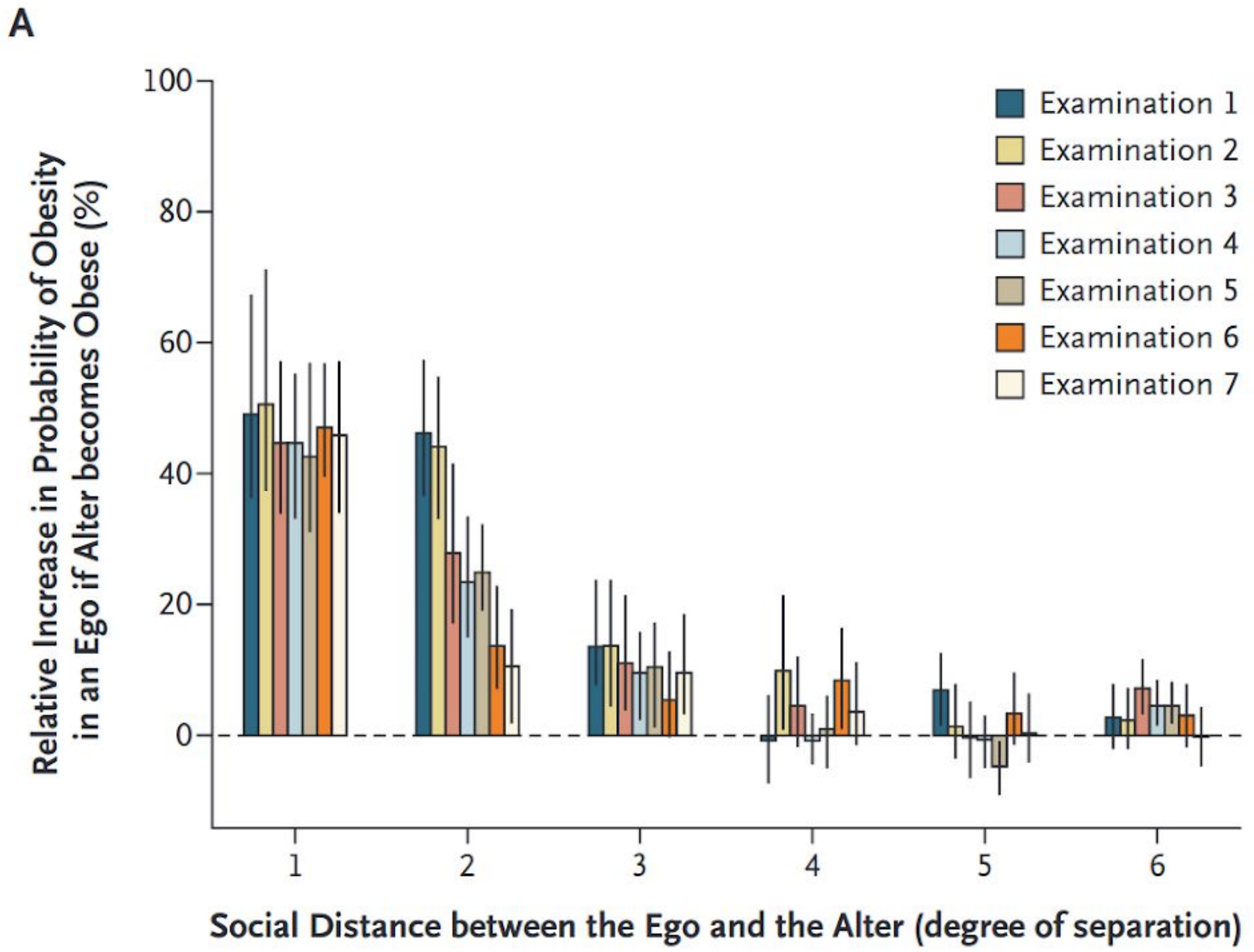


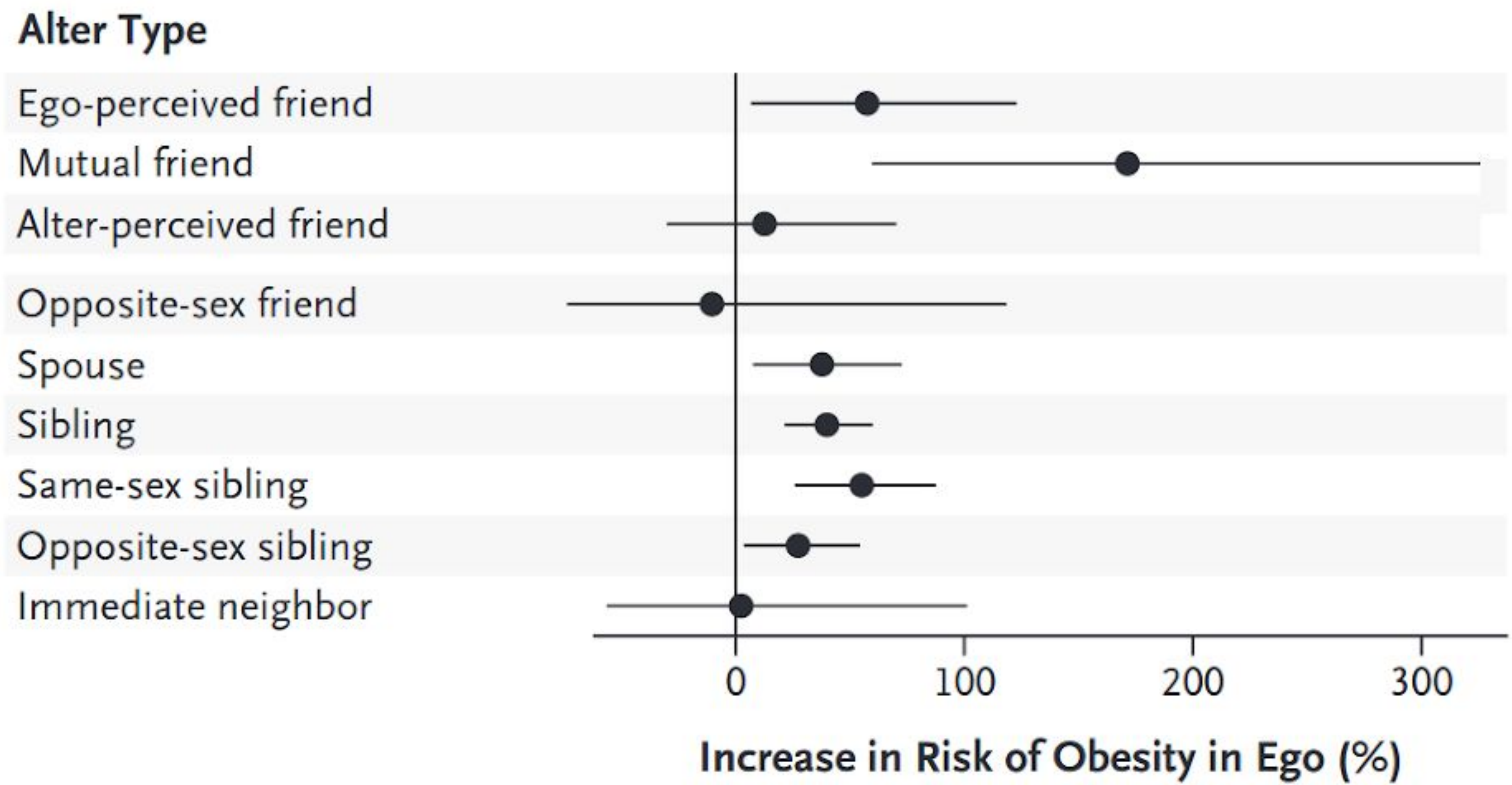


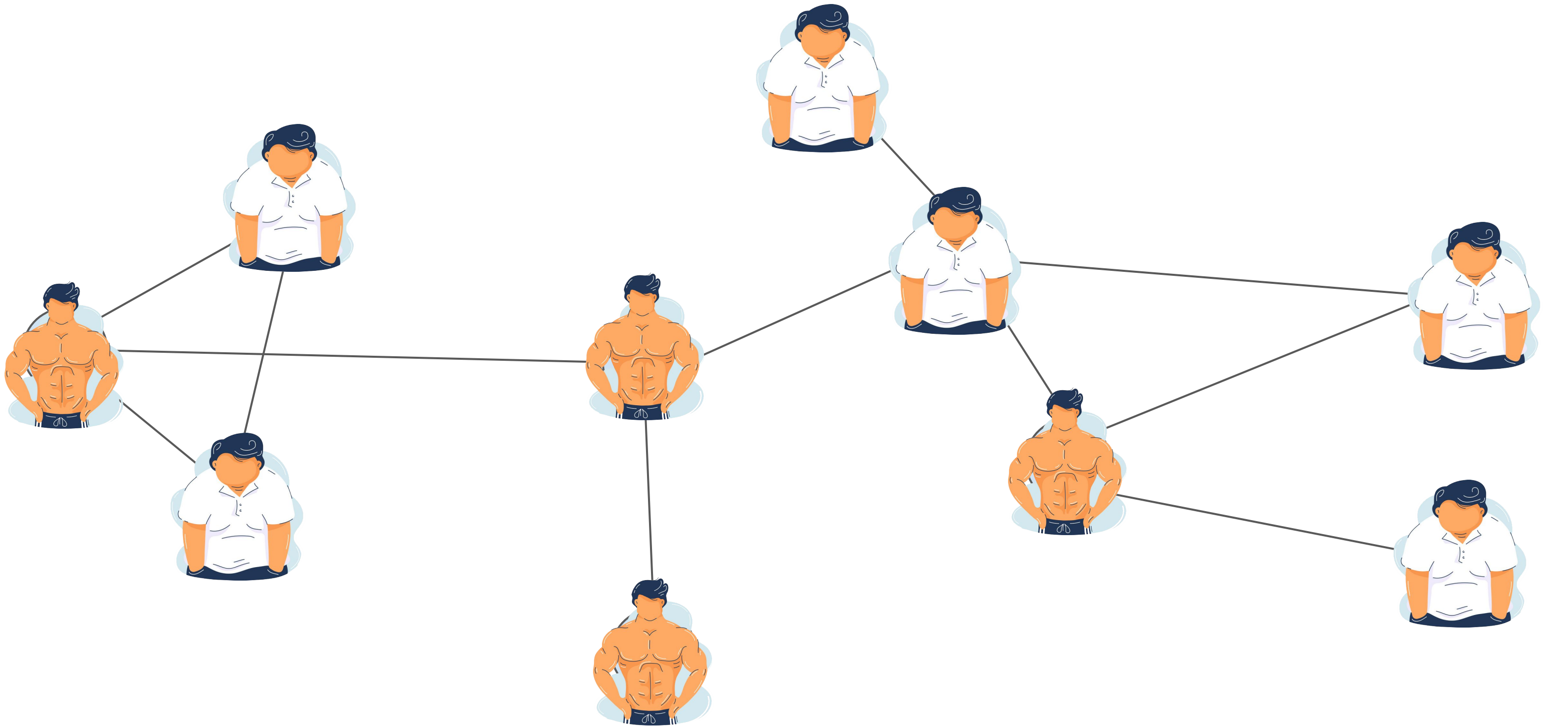


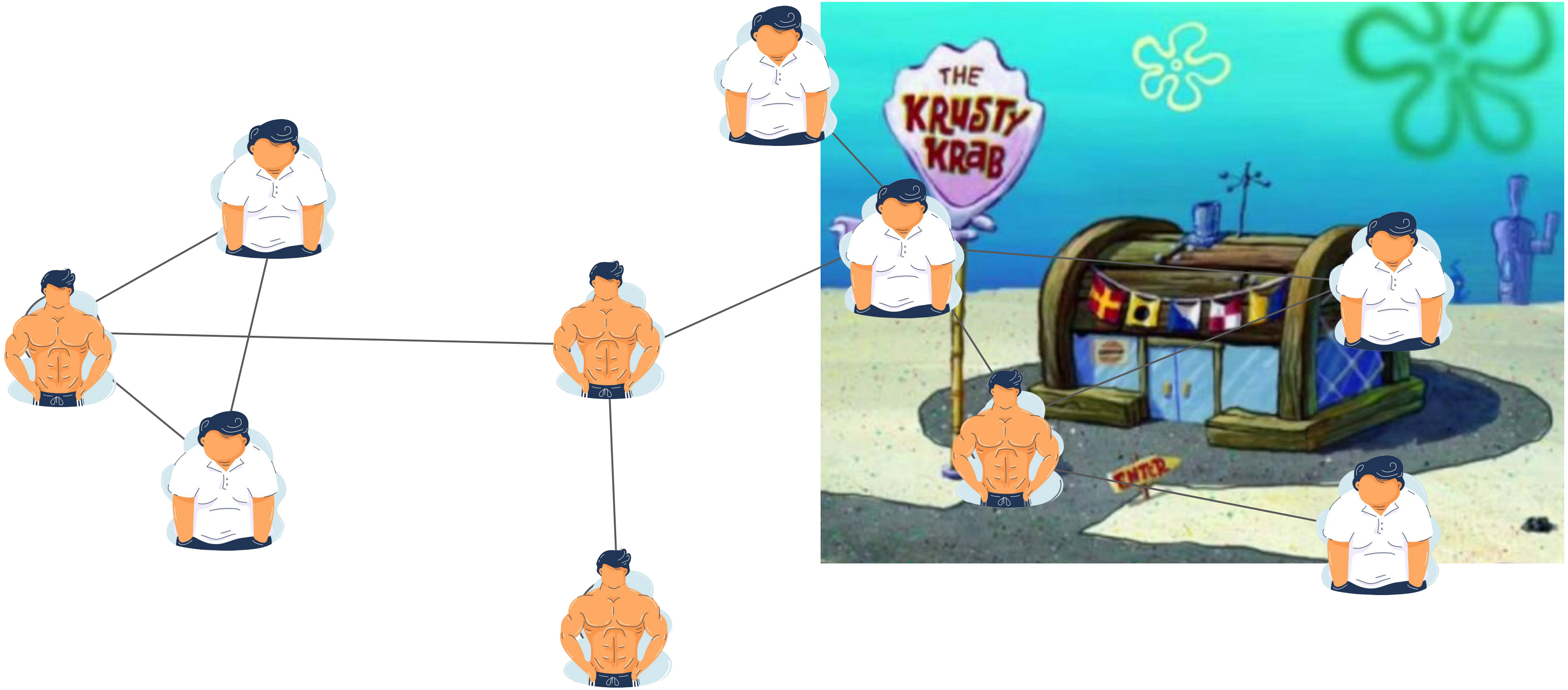


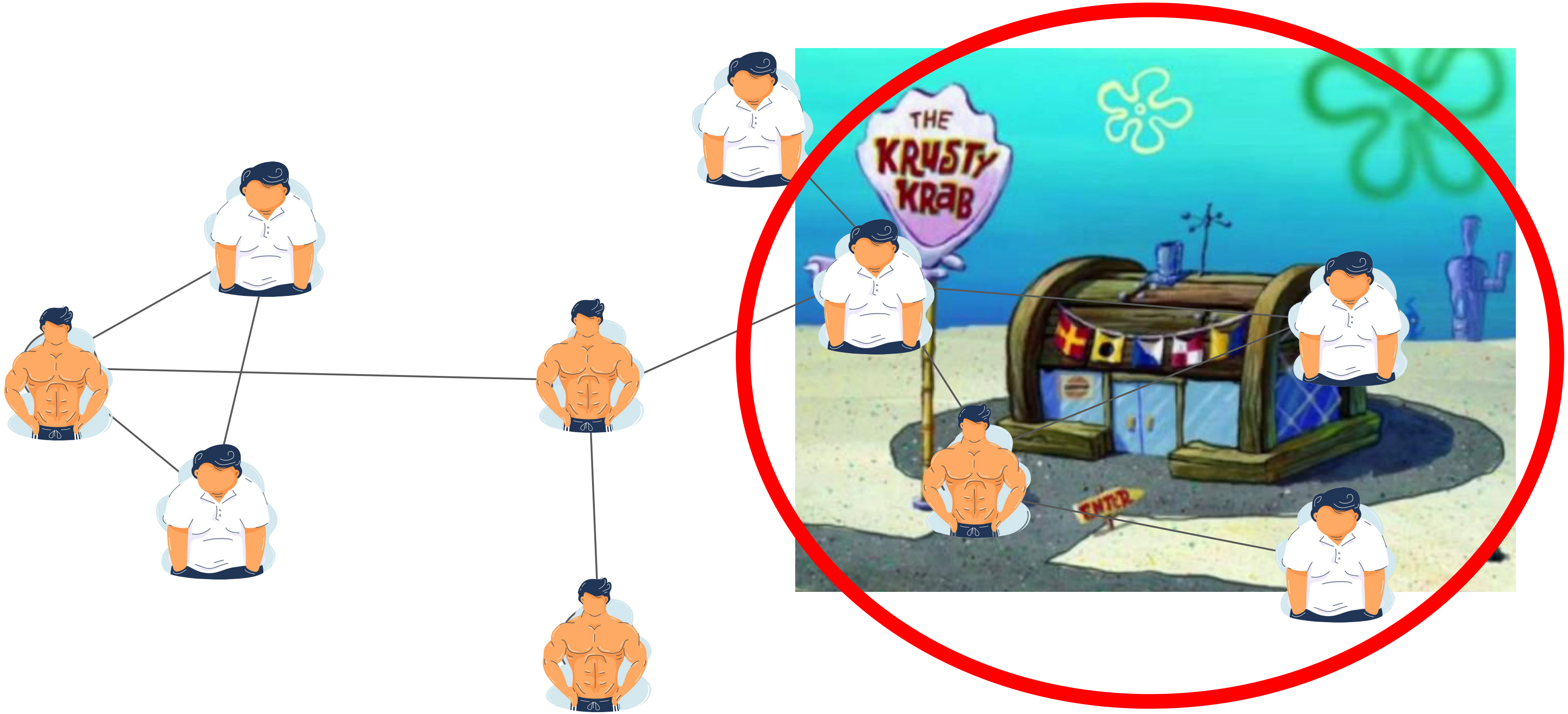

Glucose
Glucose 6-phosphate
Stored triglycerides
Glycerol
PGAL
Fatty acids
Beta oxidation
Acetyl groups
Pyruvic acid
Glycerol
Fatty acids
New triglycerides
Acetyl-CoA
Ketone bodies
β-hydroxybutyric acid
Acetoacetic acid
Acetone
Citric acid cycle
Key
Lipogenesis
Lipolysis


A
Examination 1
Examination 2
Examination 3
Examination 4
Examination 5
Examination 6
Examination 7
Relative Increase in Probability of Obesity in an Ego if Alter becomes Obese (%)
100
80
60
40
20
0
1
2
3
4
5
6
Social Distance between the Ego and the Alter (degree of separation)

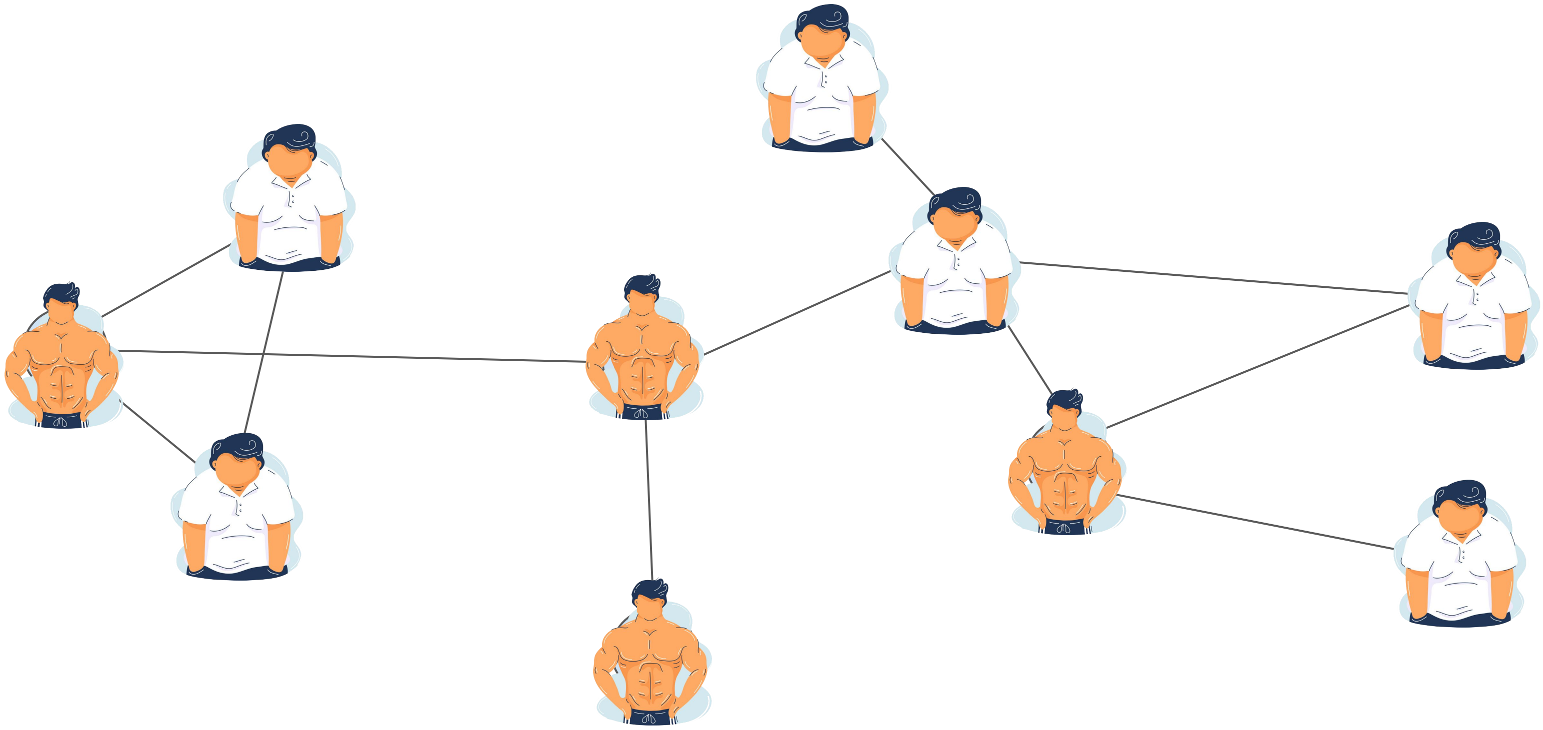

Alter Type
Ego-perceived friend
Mutual friend
Alter-perceived friend
Opposite-sex friend
Spouse
Sibling
Same-sex sibling
Opposite-sex sibling
Immediate neighbor
0
100
200
300
Increase in Risk of Obesity in Ego (%)

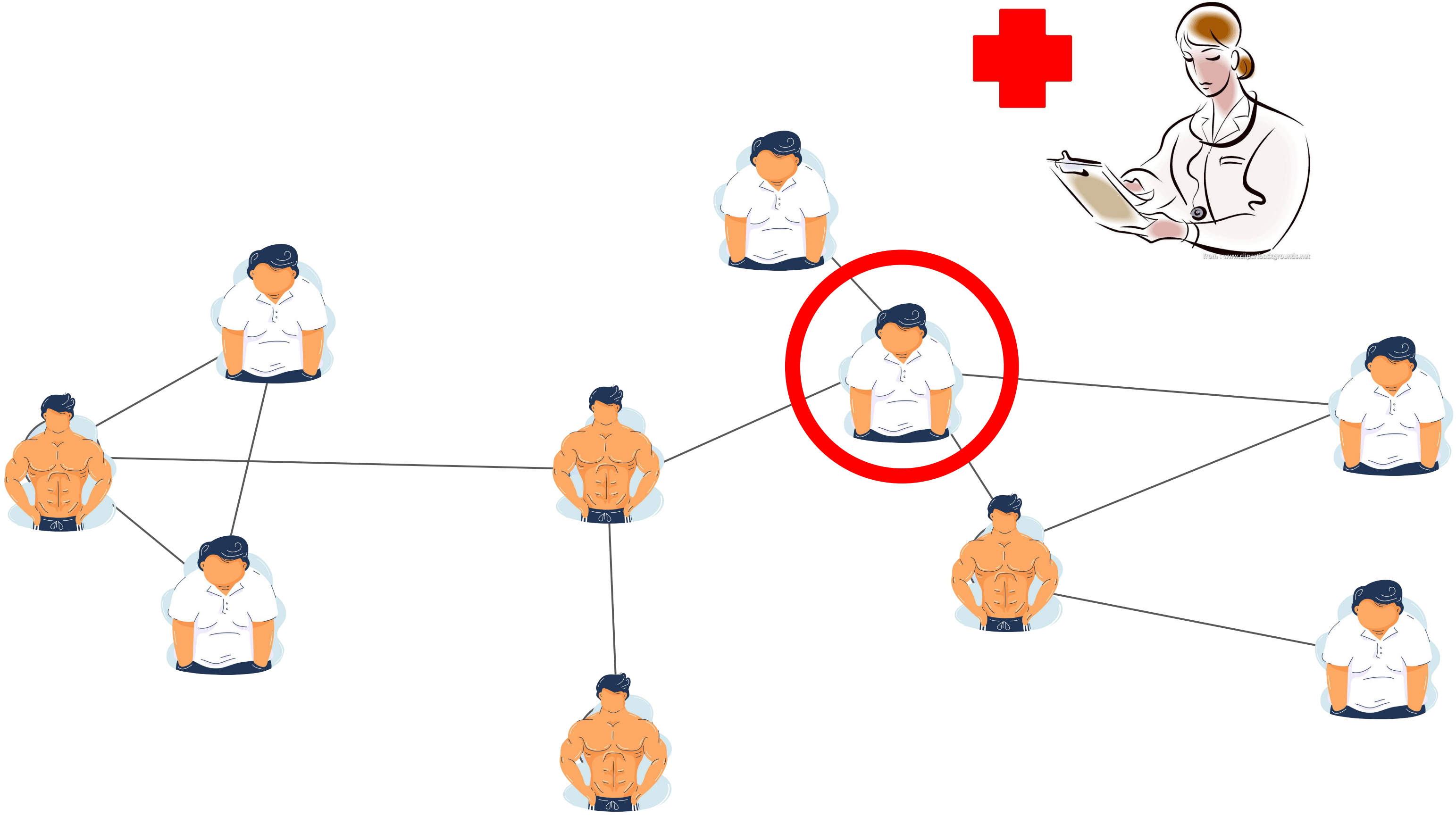


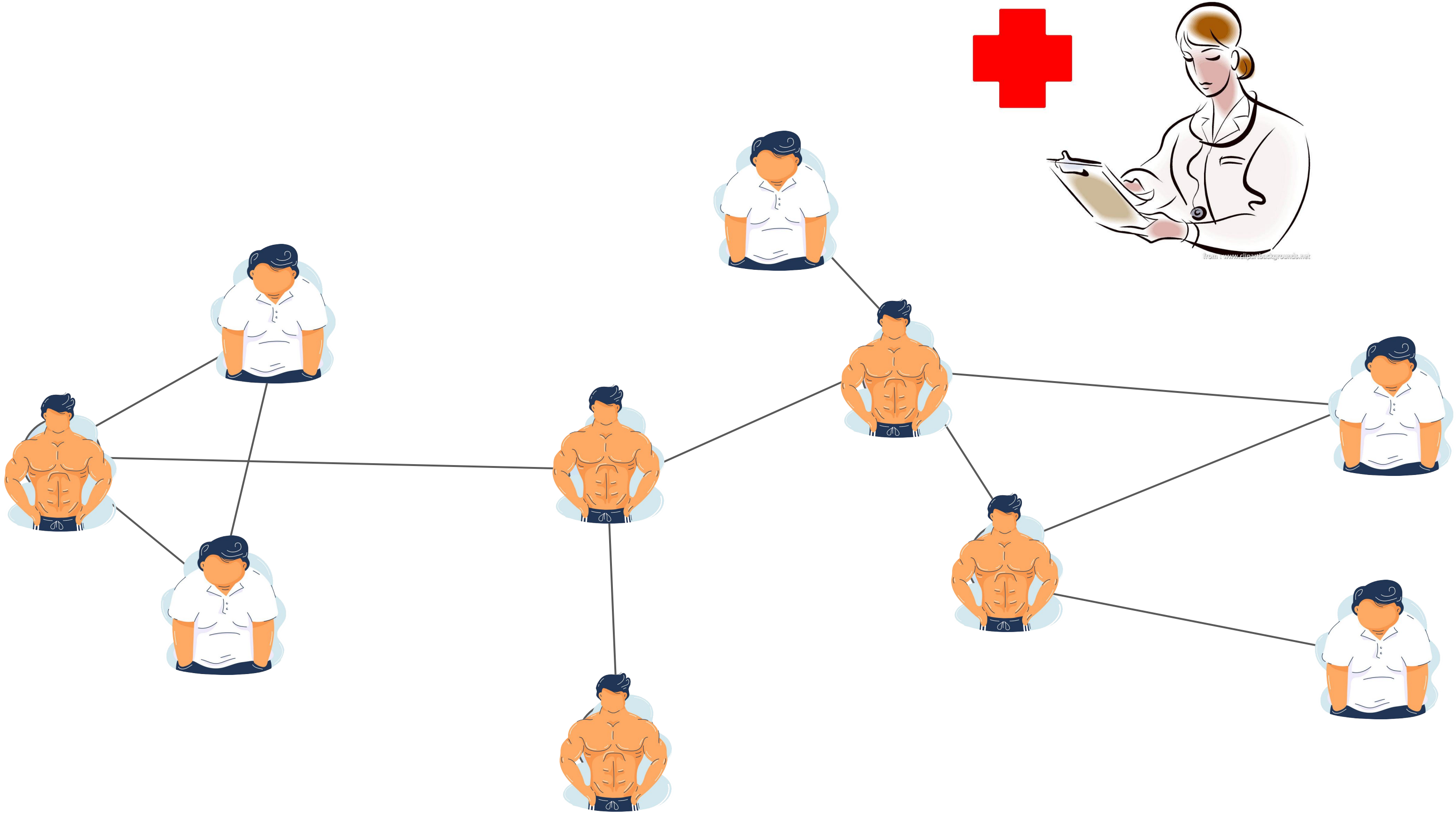

THE
KRUSTY
KRAB
ENTER

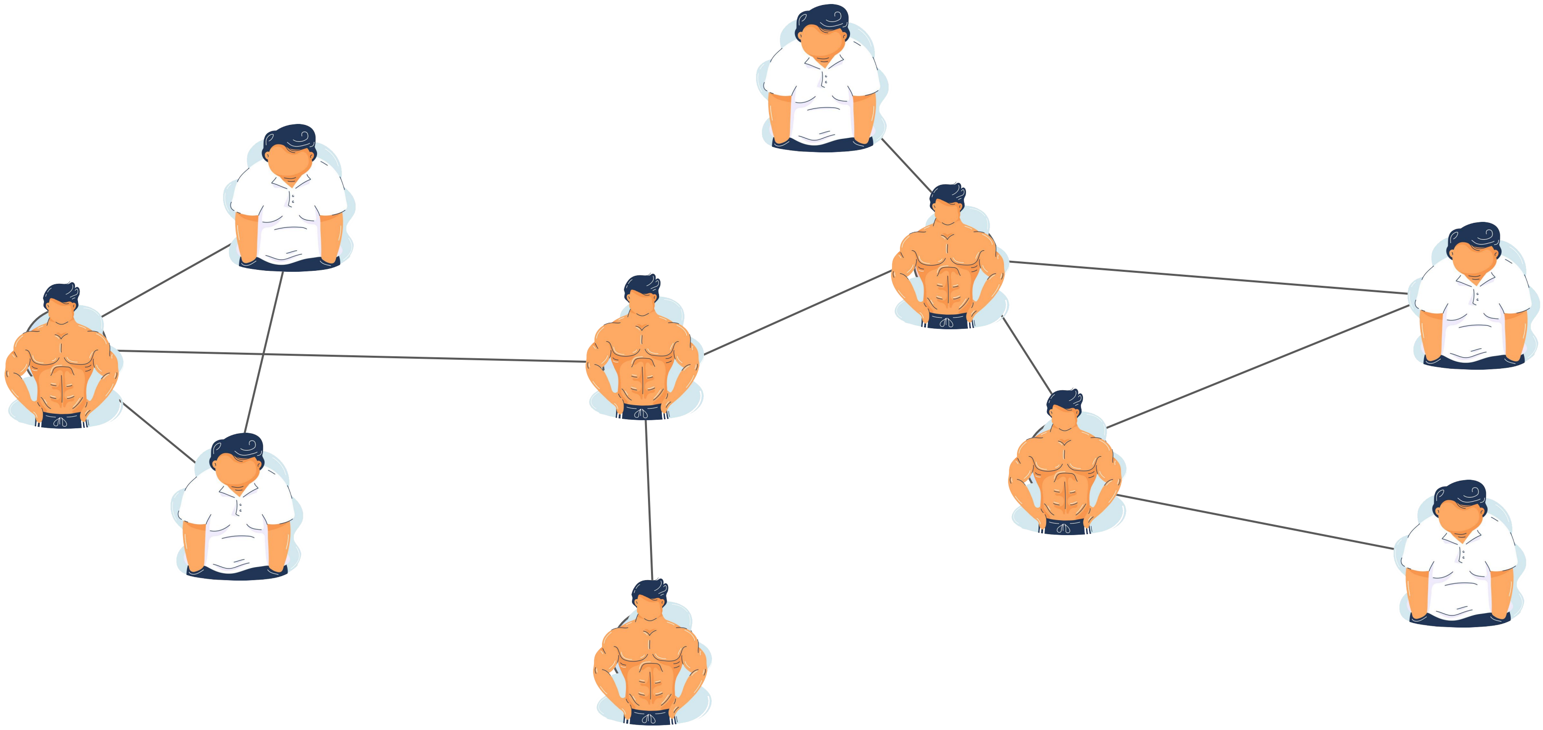

THE
KRUSTY
KRAB

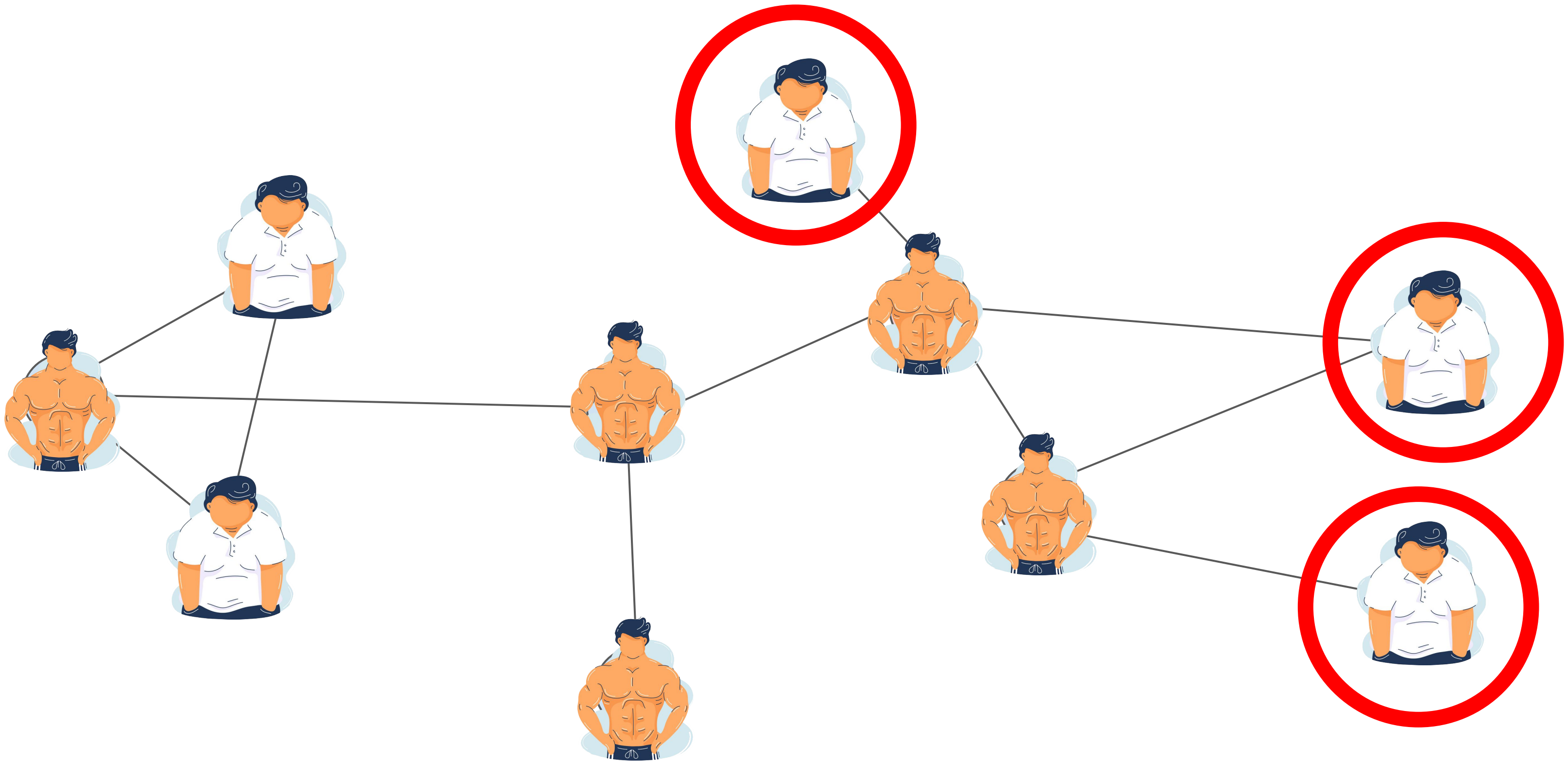
# Spillover effect

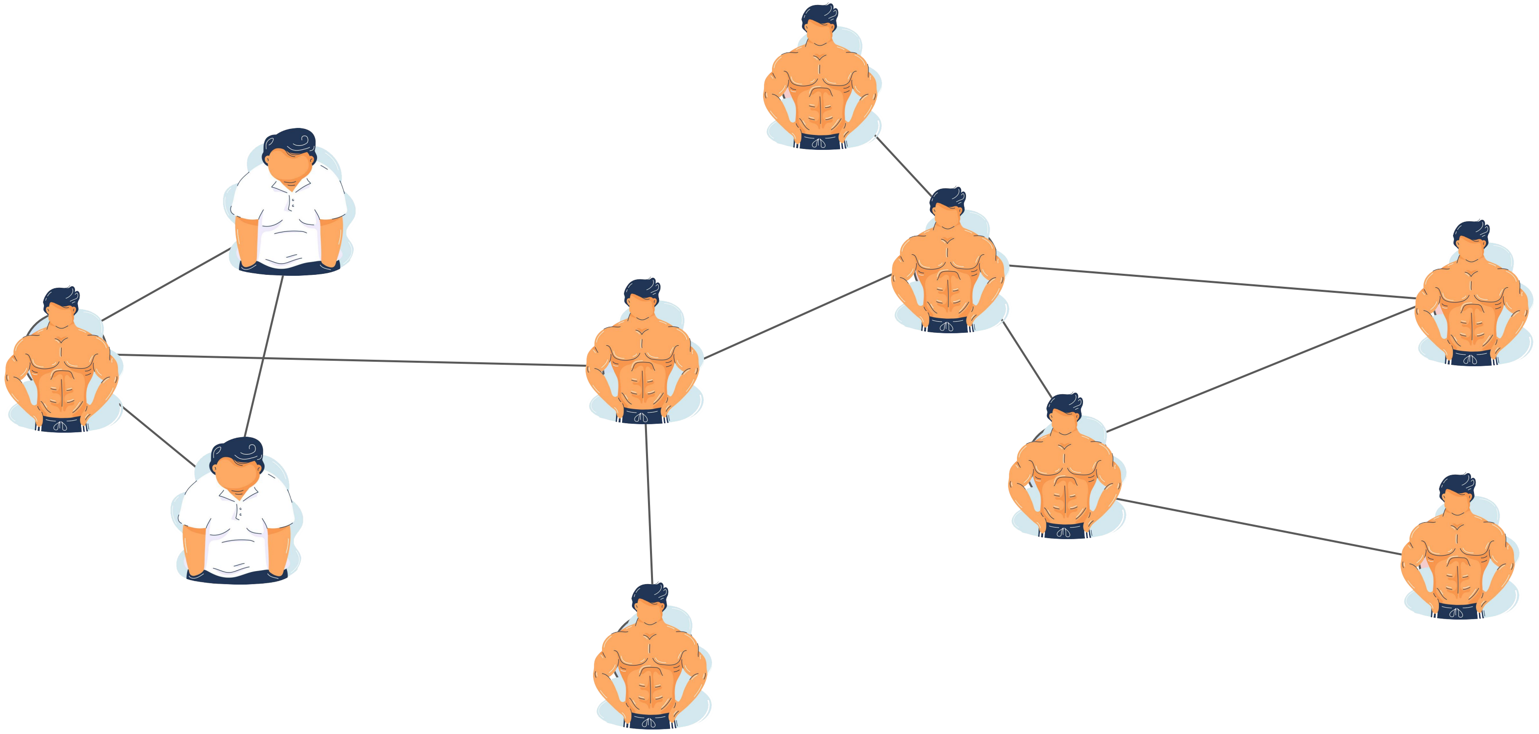












- Through social interaction, people change each other believe/behaviour.

- **By similarity:** A wants to be like B
(ie: gain social acceptance, everybody is buying toilet paper, so I should do the same!)

- **By distiction:** A want to distance from B
(ie: gain social status, I want a better body so I get the ladies instead of somebody else)

$$Y^{(1)} = X\beta$$

$$Y^{(1)} = X\beta$$

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
$X$ = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

The kind of person you are

Your initial believes

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
$X$ = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

$$Y^{(1)} = X\beta$$

Your initial believes

The kind of person you are

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
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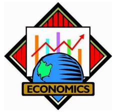
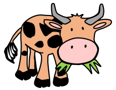
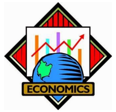
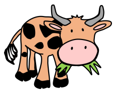
| |  |  |  |  |
|---|---|---|---|---|
|  | 0.4 | 0.6 | 0.8 | 0.7 |
|  | 0.7 | 1.1 | 1.0 | 0.6 |
|  | 0.9 | 1.1 | 0.9 | 0.6 |

=

| |  |  |  |
|---|---|---|---|
|  | 0.7 | 0.5 | 0.2 |
|  | 0.3 | 0.8 | 0.6 |
|  | 0.3 | 0.5 | 0.9 |

| |  |  |  |  |
|---|---|---|---|---|
|  | 0.1 | 0.1 | 0.5 | 0.8 |
|  | 0.4 | 0.8 | 0.7 | 0.2 |
|  | 0.7 | 0.7 | 0.4 | 0.3 |

The kind of person you are

Your initial believes

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors

$X$ = N x K matrix of K exogenous variables that affect Y

$\beta$ = K x M matrix of coefficients relating X to Y

Your initial believes

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
X = N x K matrix of K exogenous variables that affect Y
β = K x M matrix of coefficients relating X to Y

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

Your initial believes

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
$X$ = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

$Y^{(t)}$ = N x M matrix of current opinions on M issues for N actors
$W$ = N x N matrix of interpersonal influences
$\alpha$ = a weight of the strenght of endogenous interpersonal influences

Your initial believes

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

```
Y(1) = N x M matrix of initial opinions on M issues for N actors
X    = N x K matrix of K exogenous variables that affect Y
β    = K x M matrix of coefficients relating X to Y
```

Your initial believes

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

```
Y(t) = N x M matrix of current opinions on M issues for N actors
W    = N x N matrix of interpersonal influences
α    = a weight of the strenght of endogenous interpersonal
       influences
```

The kind of person you are

Your initial believes

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
X = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

Your initial believes

$$Y^{(t)} = \boxed{\alpha W Y^{(t-1)}} + \boxed{(1 - \alpha) Y^{(1)}}$$

The opinions of others

Your opinions

$Y^{(t)}$ = N x M matrix of current opinions on M issues for N actors
W = N x N matrix of interpersonal influences
$\alpha$ = a weight of the strenght of endogenous interpersonal influences

Your initial believes

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
X = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

How sturborn you are

Your initial believes

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

$Y^{(t)}$ = N x M matrix of current opinions on M issues for N actors
W = N x N matrix of interpersonal influences
$\alpha$ = a weight of the strenght of endogenous interpersonal influences

Your initial believes

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$ = N x M matrix of initial opinions on M issues for N actors
X = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

How sturborn you are

Your initial believes

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

How much do you value the opinion of each friend

$Y^{(t)}$ = N x M matrix of current opinions on M issues for N actors
W = N x N matrix of interpersonal influences
$\alpha$ = a weight of the strenght of endogenous interpersonal influences

$$0 \leq w_{ij} \leq 1$$

$$\sum W_{ij} = 1$$

$$0 \le w_{ij} \le 1$$

You are doing the complete opposite of what I'm telling you to do

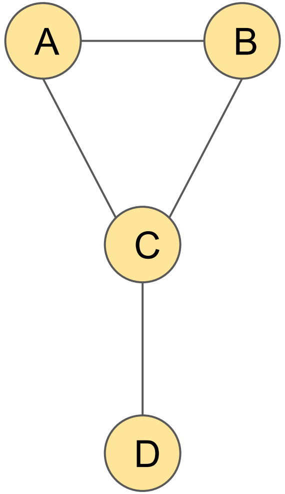
$$\sum W_{ij} = 1$$

$$0 \le w_{ij} \le 1$$

You are doing the complete opposite of what I'm telling you to do

I told you something that scared the hell out of you, and believe it now more than you ever did before!

$$\Sigma W_{ij} = 1$$




| | A | B | C | D |
|---|---|---|---|---|
| A | 1 | 1 | 1 | 0 |
| B | 1 | 1 | 1 | 0 |
| C | 1 | 1 | 1 | 1 |
| D | 0 | 0 | 1 | 1 |

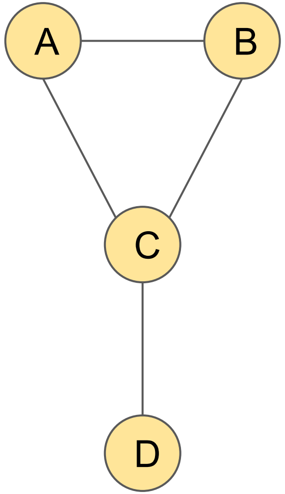
Even distributed weight

| | A | B | C | D |
|---|---|---|---|---|
| A | 3 | 1 | 1 | 0 |
| B | 1 | 3 | 1 | 0 |
| C | 1 | 1 | 3 | 1 |
| D | 0 | 0 | 1 | 3 |

My opinion counts triple that anyone else

| | A | B | C | D |
|---|---|---|---|---|
| A | 2 | 1 | 1 | 0 |
| B | 1 | 2 | 1 | 0 |
| C | 1 | 1 | 3 | 1 |
| D | 0 | 0 | 1 | 1 |

My opinion as much as I can influence other people




| | A | B | C | D |
|---|---|---|---|---|
| A | 1 | 1 | 1 | 0 |
| B | 1 | 1 | 1 | 0 |
| C | 1 | 1 | 1 | 1 |
| D | 0 | 0 | 1 | 1 |

| | A | B | C | D |
|---|---|---|---|---|
| A | .083 | .083 | .083 | 0 |
| B | .083 | .083 | .083 | 0 |
| C | .083 | .083 | .083 | .083 |
| D | 0 | 0 | .083 | .083 |

| | A | B | C | D |
|---|---|---|---|---|
| A | 3 | 1 | 1 | 0 |
| B | 1 | 3 | 1 | 0 |
| C | 1 | 1 | 3 | 1 |
| D | 0 | 0 | 1 | 3 |

| | A | B | C | D |
|---|---|---|---|---|
| A | .15 | .05 | .05 | 0 |
| B | .05 | .15 | .05 | 0 |
| C | .05 | .05 | .15 | .05 |
| D | 0 | 0 | .05 | .15 |

| | A | B | C | D |
|---|---|---|---|---|
| A | 2 | 1 | 1 | 0 |
| B | 1 | 2 | 1 | 0 |
| C | 1 | 1 | 3 | 1 |
| D | 0 | 0 | 1 | 1 |

| | A | B | C | D |
|---|---|---|---|---|
| A | 0.12 | 0.06 | 0.06 | 0 |
| B | 0.06 | 0.12 | 0.06 | 0 |
| C | 0.06 | 0.06 | 0.18 | 0.06 |
| D | 0 | 0 | 0.06 | 0.06 |

$Y^{(\infty)}$ = N x M matrix of converging opinions on M issues for N actors
X = N x K matrix of K exogenous variables that affect Y
$\beta$ = K x M matrix of coefficients relating X to Y

$$Y^{(\infty)} = \alpha W Y^{(\infty-1)} + X\beta - \varepsilon$$

random variable of error term is based on the assumption of being independently and identically distributed (*i.i.d.*) with mean zero and equal variances, $\sigma^2$

$Y^{(t)}$ = N x M matrix of current opinions on M issues for N actors
W = N x N matrix of interpersonal influences
$\alpha$ = a weight of the strenght of endogenous interpersonal influences

$$Y^{(\infty)} = \alpha W Y^{(\infty-1)} + X\beta - \varepsilon$$

How sturborn you are

$$Y^{(\infty)} = \alpha WY^{(\infty-1)} + X\beta - \varepsilon$$

Solveig Engebretsen*, Arnoldo Frigessi, Kenth Engø-Monsen, Anne-Sofie Furberg, Audun Stubhaug, Birgitte Freiesleben de Blasio and Christopher Sivert Nielsen

# The peer effect on pain tolerance

https://doi.org/10.1515/sjpain-2018-0060
Received March 23, 2018; revised April 4, 2018; accepted April 4, 2018; previously published online May 19, 2018

Solveig Engebretsen*, Arnoldo Frigessi, Kenth Engø-Monsen, Anne-Sofie Furberg, Audun Stubhaug, Birgitte Freiesleben de Blasio and Christopher Sivert Nielsen

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$$\boldsymbol{Y} = \rho \boldsymbol{W}_{\mathrm{N}} \boldsymbol{Y} + \boldsymbol{X}\boldsymbol{\beta} + \epsilon,$$

where $\boldsymbol{Y}$ is the vector of pain tolerance for all the individuals, $\rho$ is the autocorrelation between an individual's pain tolerance and the friends' pain tolerance, $\boldsymbol{W}_{\mathrm{N}}$ is the adjacency matrix, normalised by the number of friends for each individual (so that the rows sum to one), $\boldsymbol{X}$ is a matrix with other explanatory variables, $\boldsymbol{\beta}$ is the corresponding vector of coefficients and $\epsilon$ is a vector of random normal noise with mean 0 and variance $\sigma^2$. The autocorrelation

Solveig Engebretsen*, Arnoldo Frigessi, Kenth Engø-Monsen, Anne-Sofie Furberg, Audun Stubhaug, Birgitte Freiesleben de Blasio and Christopher Sivert Nielsen

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$$Y = \rho W_N Y + X\beta + \epsilon,$$

where $\boldsymbol{Y}$ is the vector of pain tolerance for all the individuals, $\rho$ is the autocorrelation between an individual's pain tolerance and the friends' pain tolerance, $\boldsymbol{W}_N$ is the adjacency matrix, normalised by the number of friends for each individual (so that the rows sum to one), $\boldsymbol{X}$ is a matrix with other explanatory variables, $\boldsymbol{\beta}$ is the corresponding vector of coefficients and $\epsilon$ is a vector of random normal noise with mean 0 and variance $\sigma^2$. The autocorrelation

**Table 2:** Fitted network autocorrelation model.

| | $\rho$ | Intercept |
|---|---:|---:|
| Estimate | 0.44 | 55.45 |
| Std. dev | 0.062 | 6.19 |
| *p*-Value | $1.40 \cdot 10^{-12}$ | $<2.0 \cdot 10^{-16}$ |

Estimated coefficients in the network autocorrelation model using data from the Tromsø Study: Fit Futures I, standard deviation (Std. dev) and *p*-values.

autocorrelation coefficient $\rho$ is highly significant. The estimated size of the effect is that an increase in the average pain tolerance of friends by 1 s increases the expected pain tolerance of the individual by 0.44 s.

A. On-growing reseach field

B. Easy to understand

C. Many different models

D. Visualization is important

# THE END

# Thank you for (not) comming!

*...questions?*