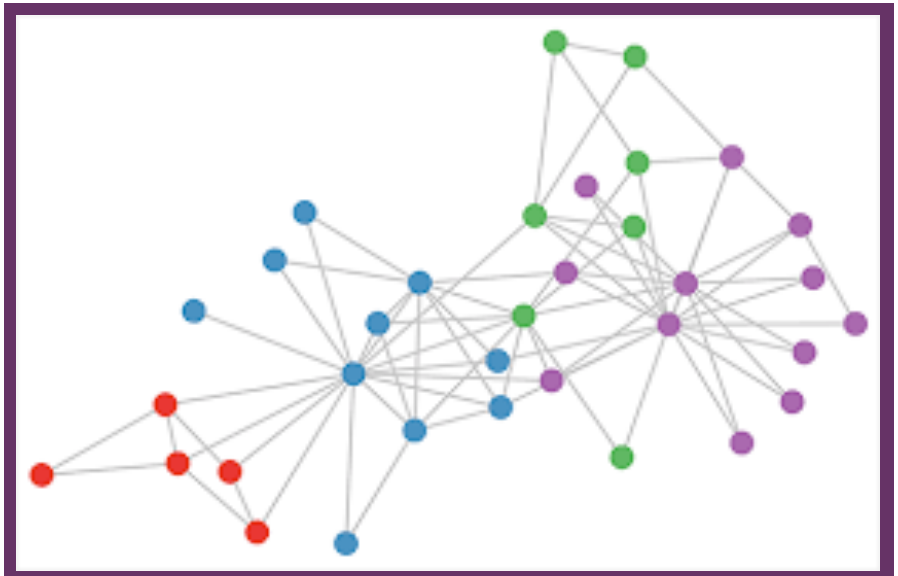


Network analysis in epidemiology/ecology

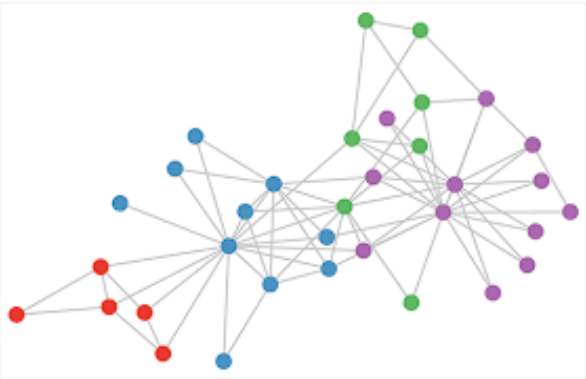
Created by Fidisoa Rasambainarivo
Presented by Andres Garchitorena

Outline

- What is a network? Why use Network?
- How can networks be used to study disease transmission?
  - What can network analysis tell us?
    - Basic concepts
  - Further analysis from a network
    - MRQAP
- Building a network in R: Interactions between researchers at Valbio

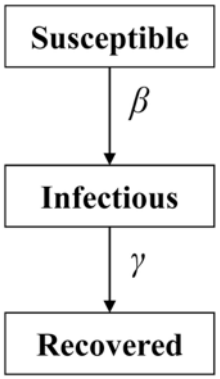
Why use a network in epidemiological studies?

- In epidemiology we want to understand:
  - Dynamics in the spreading of a disease
    - How do contagions spread in populations?
    - Will a disease become an epidemic?
    - Who to vaccinate?
    - …



Why use a network in epidemiological studies?

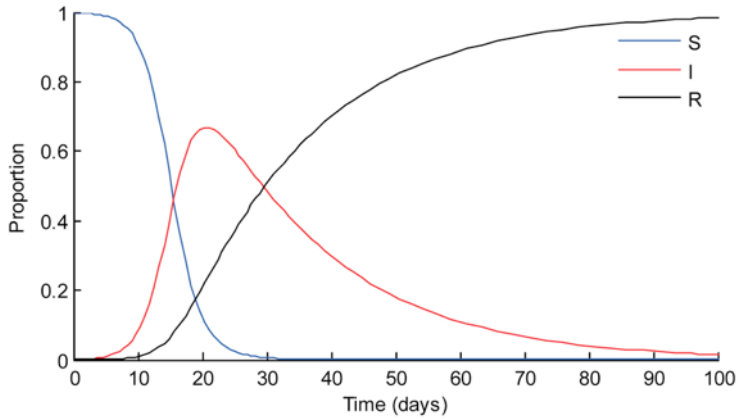
- Classic epidemiological models



$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$



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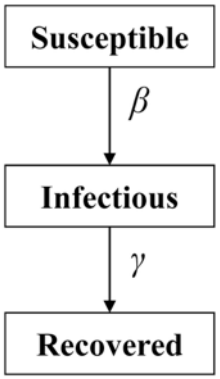

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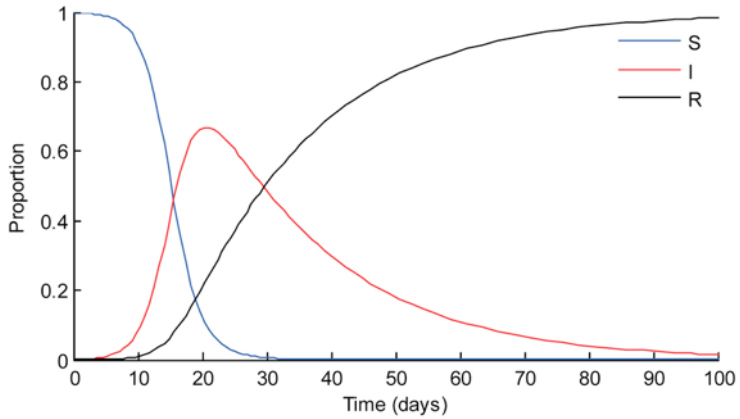
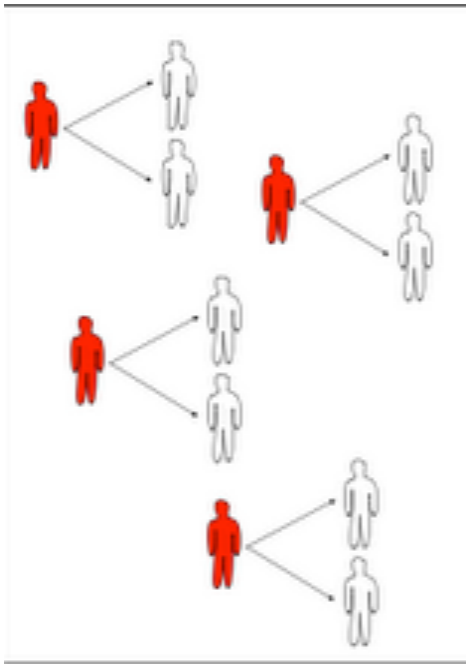


- Calculate R0
- Major assumption:
  - Full mixing



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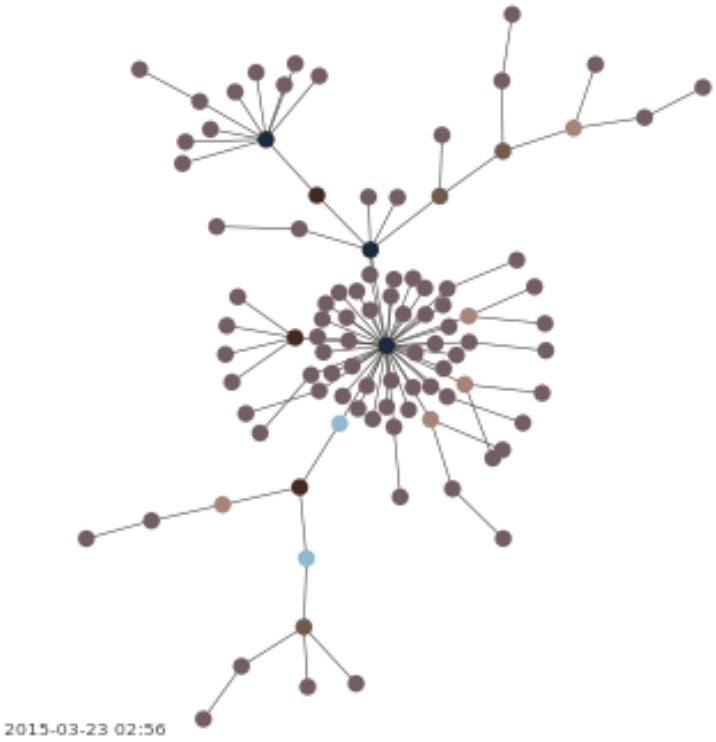
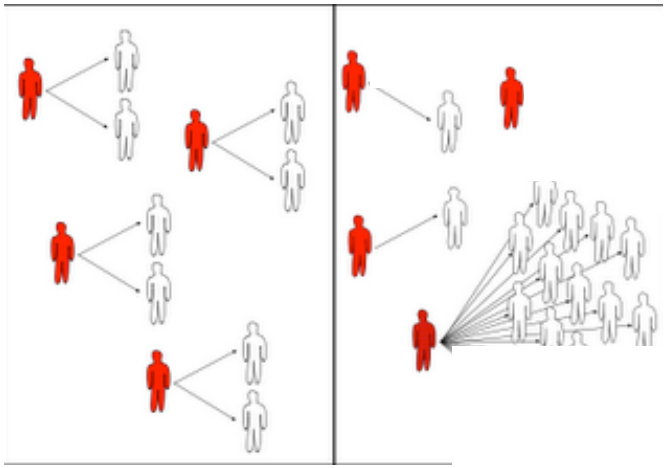


Why use a network in epidemiological studies?

- In reality, heterogeneities…
  - Pareto principle: 20/80

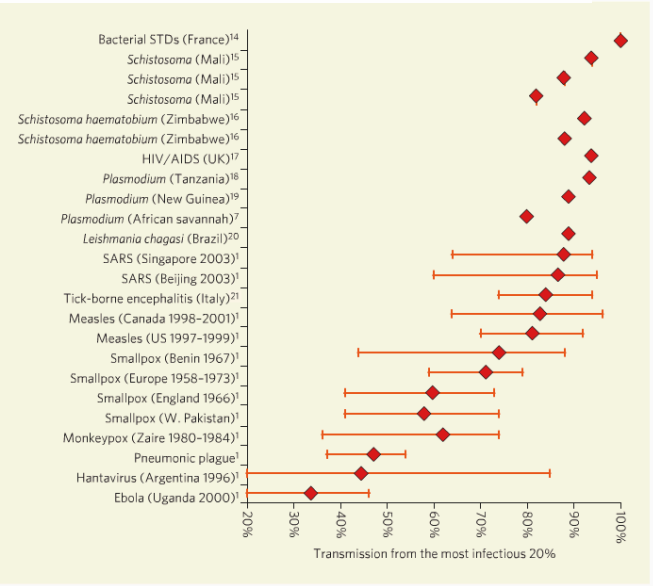


EPIDEMIOLOGY

Dimensions of superspreading

Alison P. Galvani and Robert M. May

Analyses of contact-tracing data on the spread of infectious disease, combined with mathematical models, show that control measures require better knowledge of variability in individual infectiousness.



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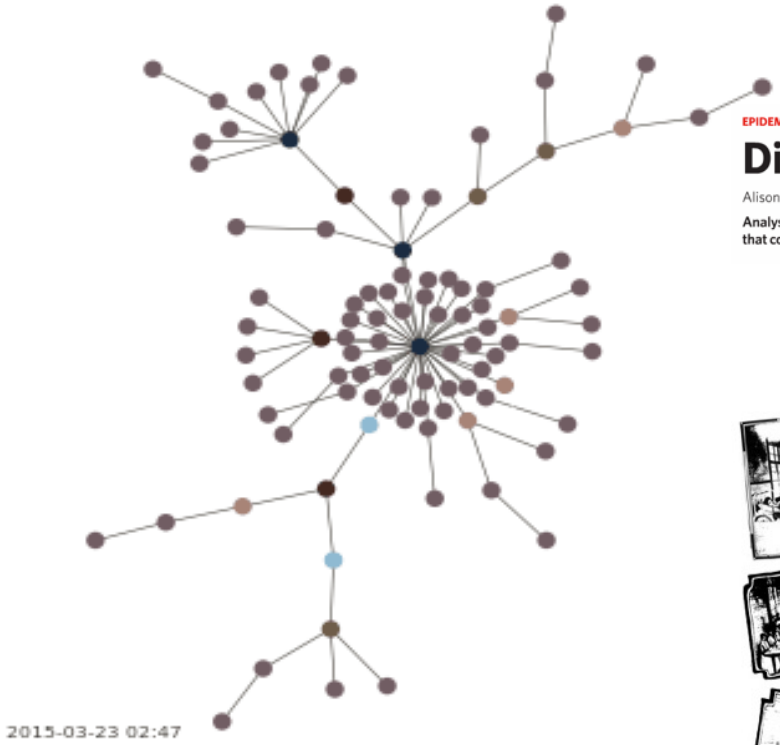

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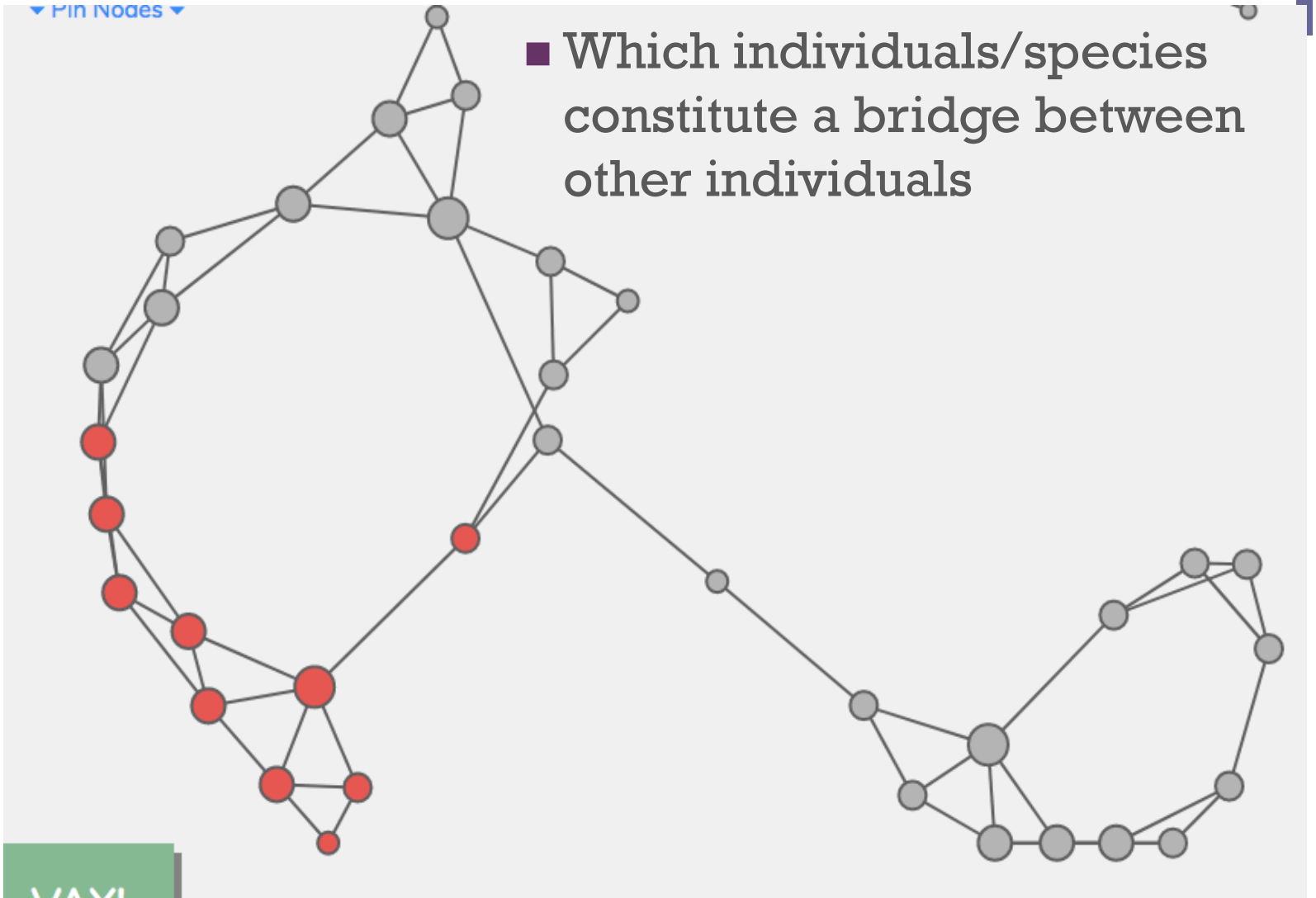


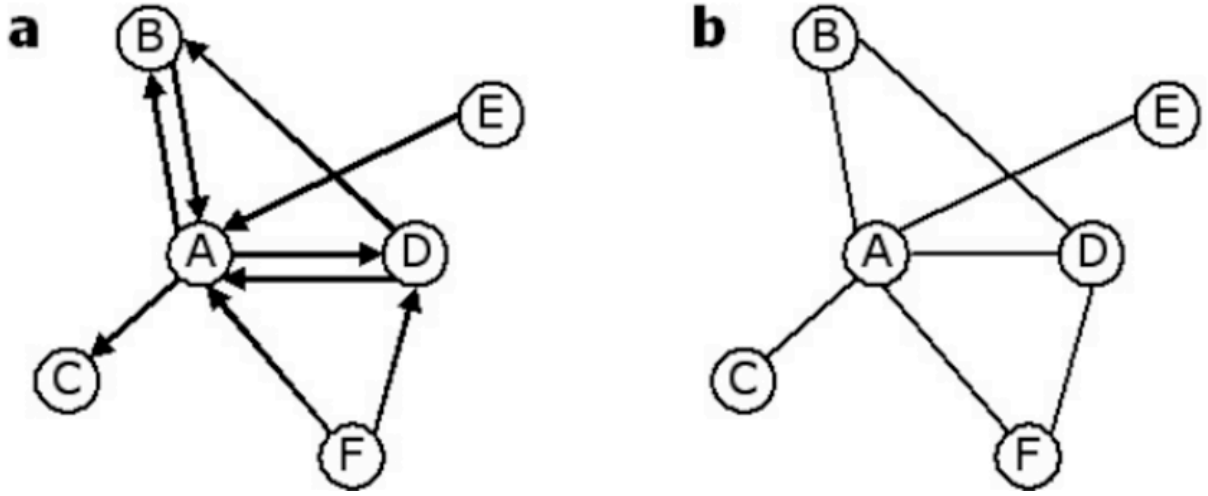
What is a network

- A (social) network: social structure made up of actors that are **interacting**
- Each actor (individual/village) is called a **vertex** (plural: vertices)

- Ties or link between two (dyad) vertices is called an **edge** and may represent sharing information, photographs, resources, space, pathogen… whatever…

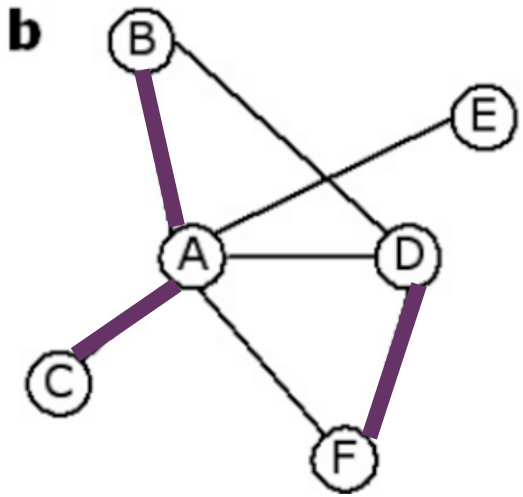
Network: basic terms and concepts

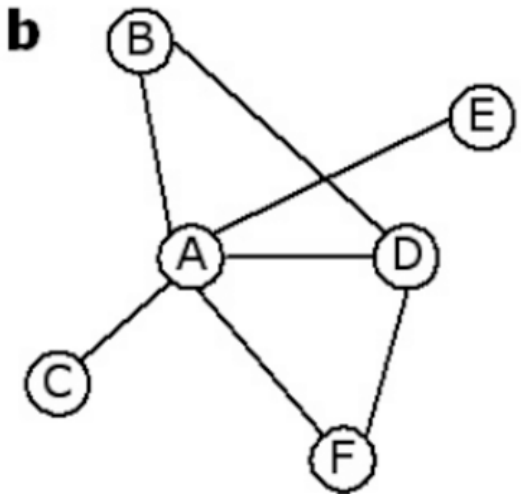
- Directed, undirected,



Network: basic terms and concepts

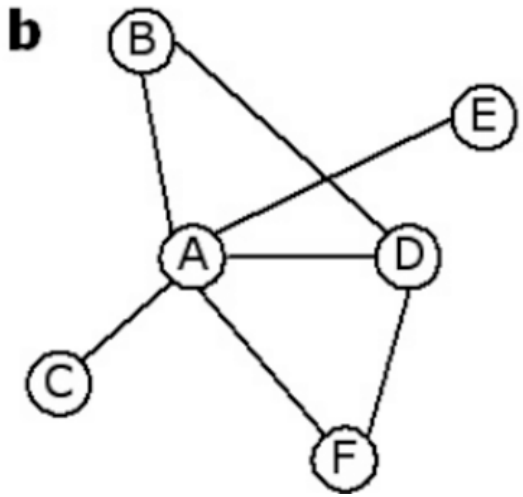
- Weighted, unweighted

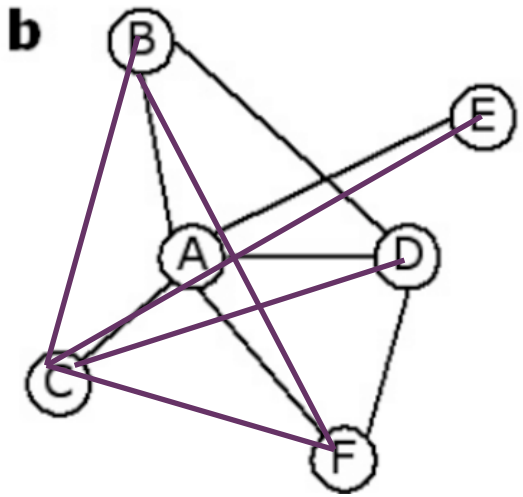




Network: basic metrics

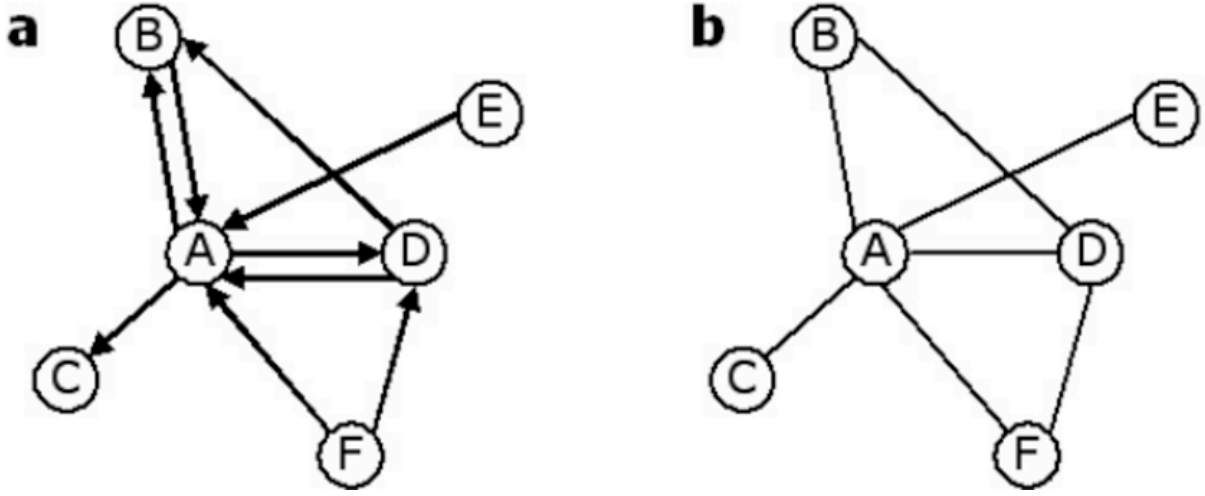
- Network density





Network: basic metrics

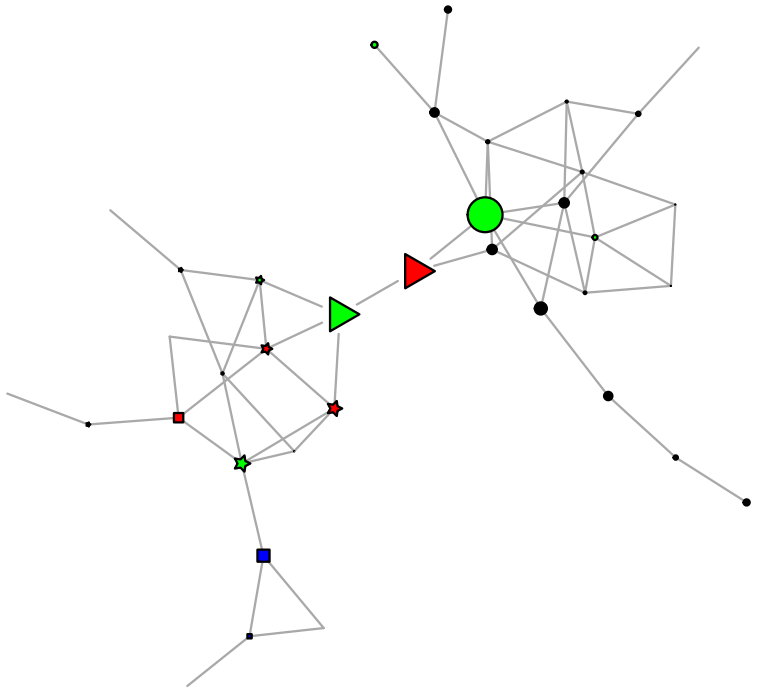
- Degree (k)



Individual	Degree
A	5
B	2
C	1
D	3
E	1
F	2

Network: basic metrics

- Betweenness
  - Number of shortest paths that go through a node



$$C_B(p_i) = \sum_{j=i}^{N} \sum_{k=1}^{j-1} \frac{g_{jk}(p_i)}{g_{jk}}$$

To analyze and compare multiple networks…

- For example, are two individuals of the same group more likely to share another characteristic?
-

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- A very simple approach to find out would be to use GLM/GLMM (or, if the data were binary, to use logistic regression—or if the data were a count, to use a negative binomial, etc.)
  - E.g: If two individuals both have or both do not have a disease, we note it 1, then measure geographic distance two individuals and we could run GLM…

To analyze and compare multiple networks…

- For example, are two individuals of the same group more likely to share another characteristic?

- A very simple approach to analyze would be to use GLM/GLMM (or, if the data were binary, to use logistic regression—or if the data were a count, to use a negative binomial, etc.)

- But there is a problem…

To analyze and compare multiple networks…

- Network inherently examines relationship:

To analyze and compare multiple networks…

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To analyze and compare multiple networks…

- Network inherently examines relationship: Violating assumptions of independence.

- Many statistical social network models
  MRQAP (Multiple Regression Quadratic Assignment Procedure)
  ERG (Exponential-family random graph)

MRQAP (Quadratic Assignment Procedure)

- Multiple Regression Quadratic Assignment Procedure
  - Basically logistic regression analysis applied to matrix data.
  - Is your response variable linked to explanatory variable 1 while controlling for all other variables?

Working example:

- Cases of unknown pathogen are threatening the Great Republic of E2M2
  (cases detected in a nearby community).
  Public health officials launch a research project to evaluate the risks of spread of the disease in the community and help mitigate the risks.

- Specifically:
  - Dr Anonymous would like to know if there is a group of individuals in this community that have more (or less) interactions with other individuals?
  - Because of the apparent social structure in the community, Dr Anonymous is interested in knowing, are individuals of the same sex, individuals from the institution (“students”, “mentors”, “instructors”) or individuals with same sex more likely to interact with each other?

- 79 E2M2 citizens record whether they spent time with another individual of the Republic in the previous 3 days.

Now that we are Epi Network Experts, let's play a game!

- A volunteer?
- You are the representative of the ministry of health of the Democratic republic of E2M2.
- You are tasked to prepare for an outbreak by vaccinating individuals.

- Let's save lives!

Thank you!