Social and Economic Network Science

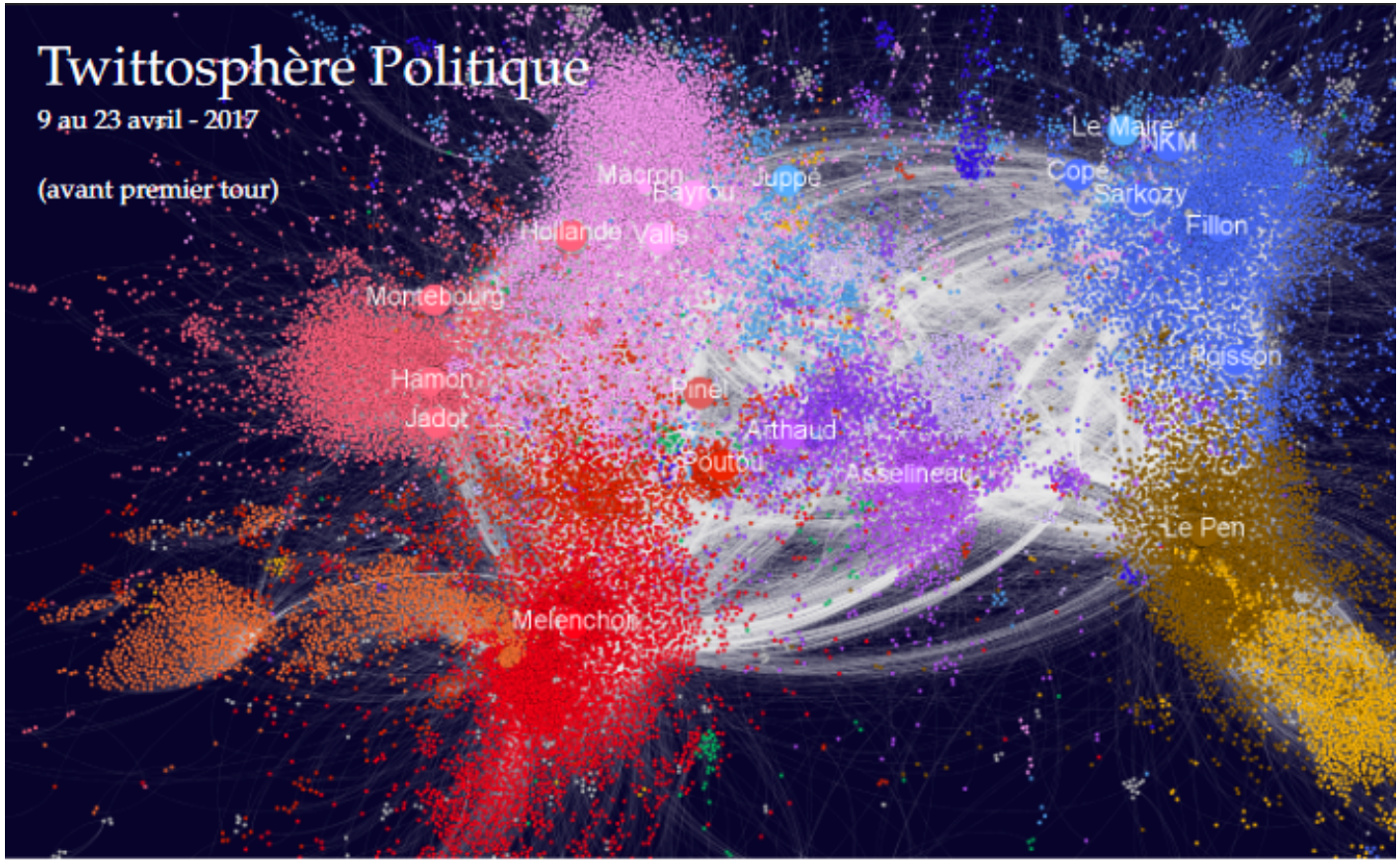
Paola Tubaro and Floriana Gargiulo

ENSAE

7 February 2024

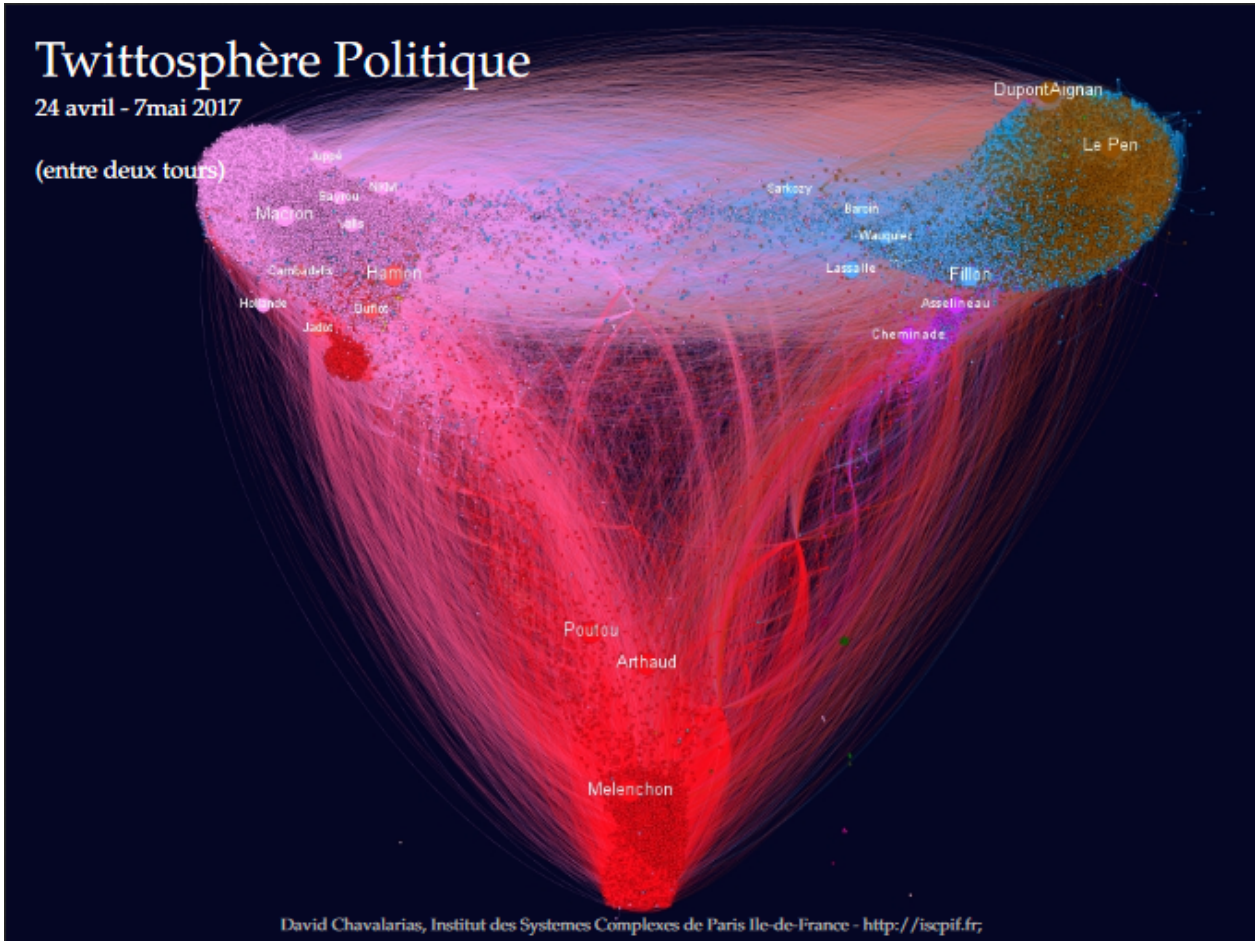
Outline for today

Networks in common parlance



Source: D. Chavalarias, Politoscope, 2017

Networks in common parlance



Source: D. Chavalarias, Politoscope, 2017

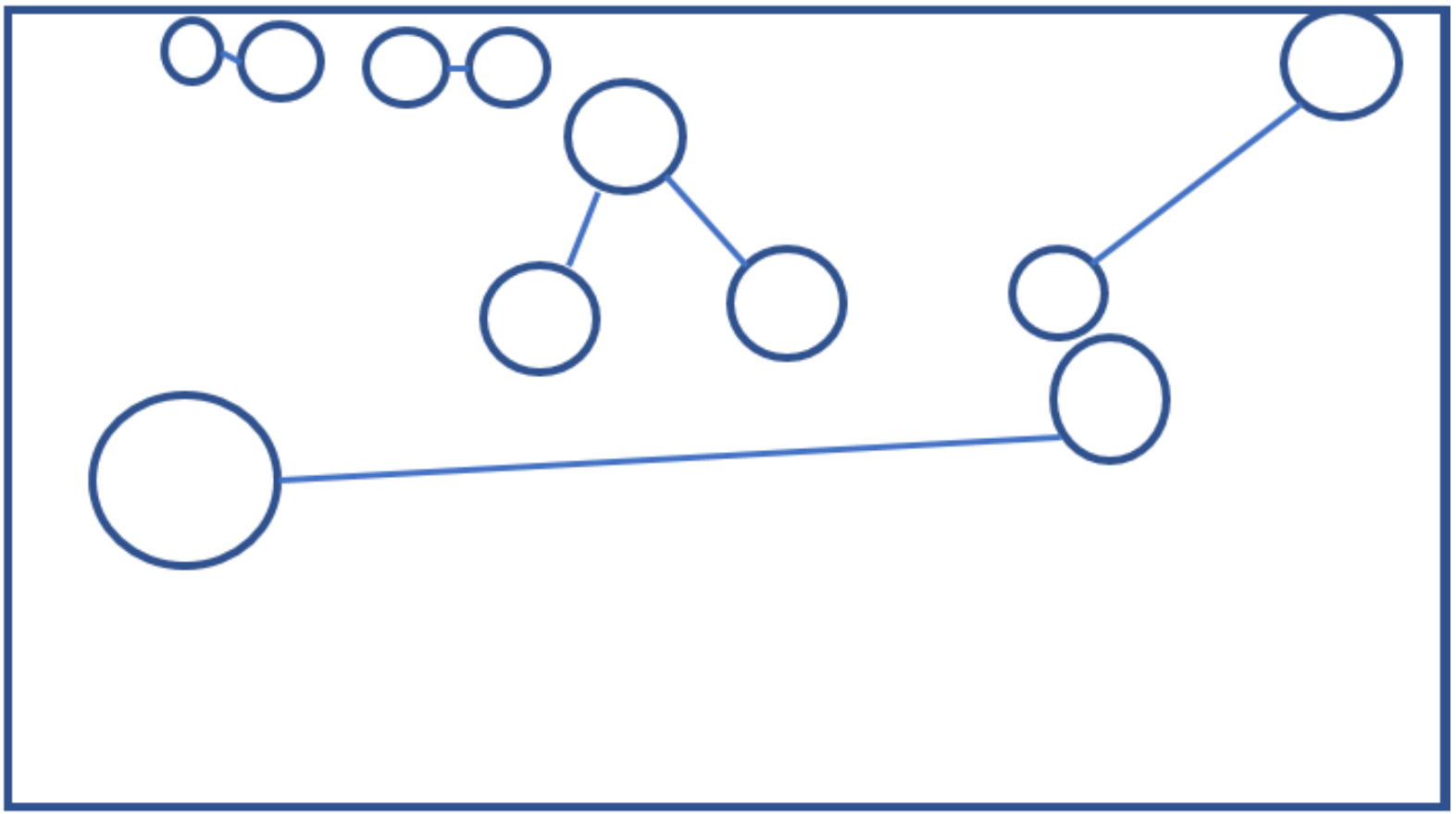
Networks according to researchers

Networks according to researchers

Networks according to researchers

Networks according to researchers

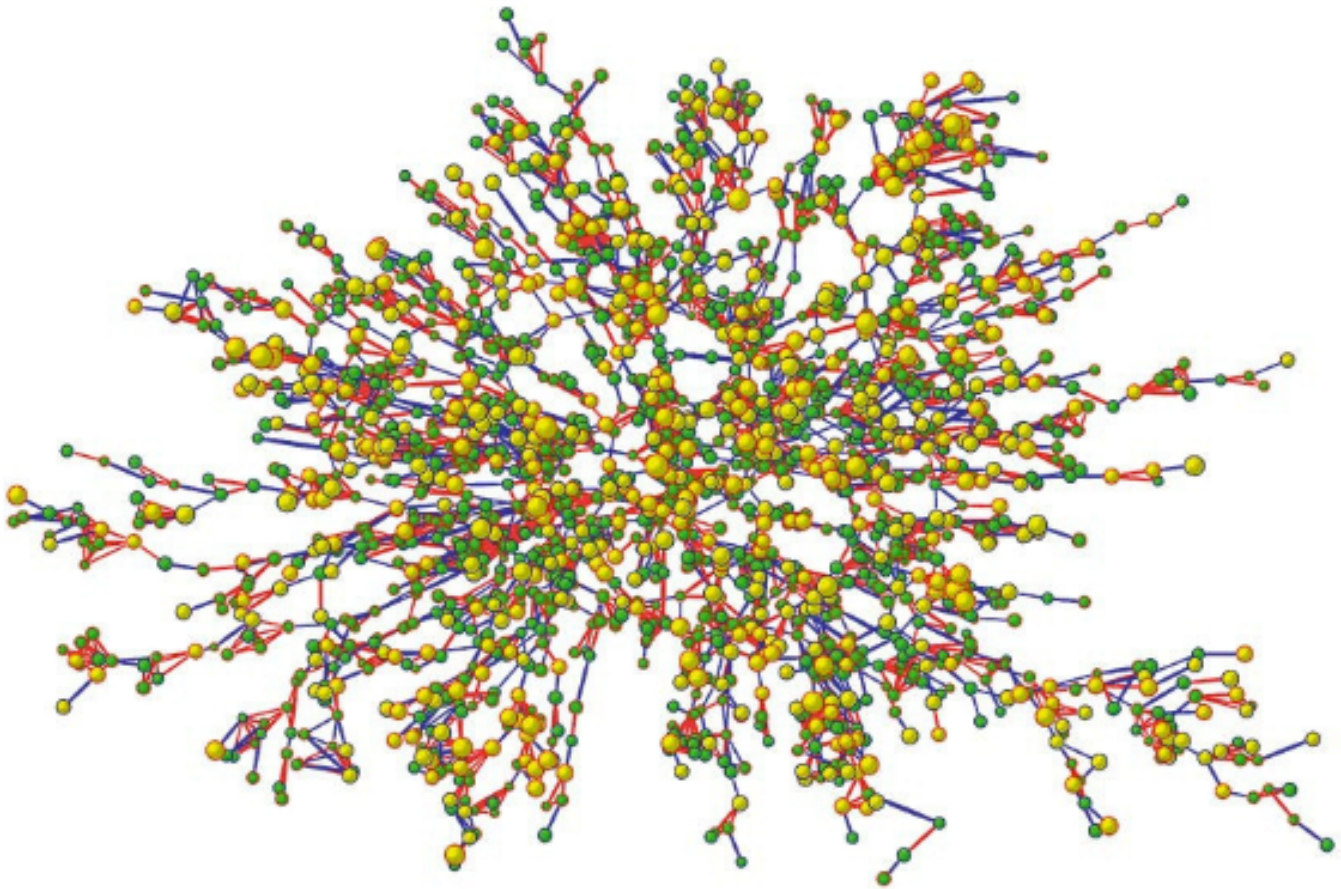
Networks according to researchers



What are social and economic networks?

- Any structure of relationships / interactions / inter-dependencies is a network
- Digital technologies may facilitate relationships / interactions / inter-dependencies, but are not necessary
- Social (and other) sciences have studied networks well before the internet
- Our goal: understanding these structures, their dynamics, and their linkages to behaviours
  - Formal models and substantive expertise are complementary

Example 1: Diffusion of obesity



Christakis & Fowler (2007)

Network contagion

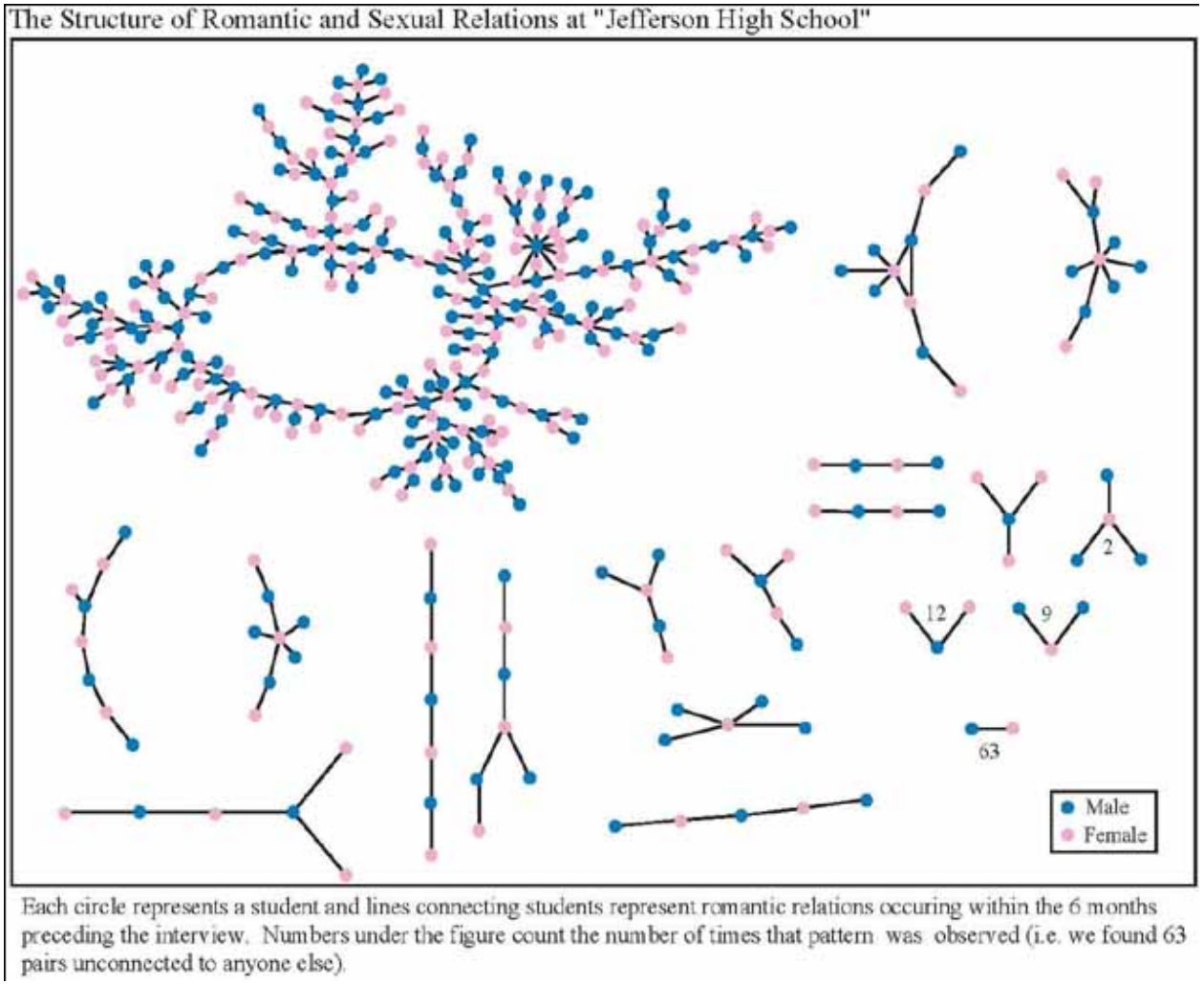
- Data: a social network of 12067 people surveyed between 1971 and 2003
- Results:
  - Cliques of obese people at every point in time
  - The chances of becoming obese increase if a friend, sibling or spouse becomes obese
  - Stronger effect between same-gender people
  - Control for geographic location and other behaviours (smoking, drinking etc.)

Network 'medicine'?

Barabasi (same issue of *NEJM*, 2007):

> *Networks [. . .] may have just as strong an impact on the development of obesity as the otherwise strong genetic effects. [. . .] Network effects increasingly affect all aspects of biologic and medical research*

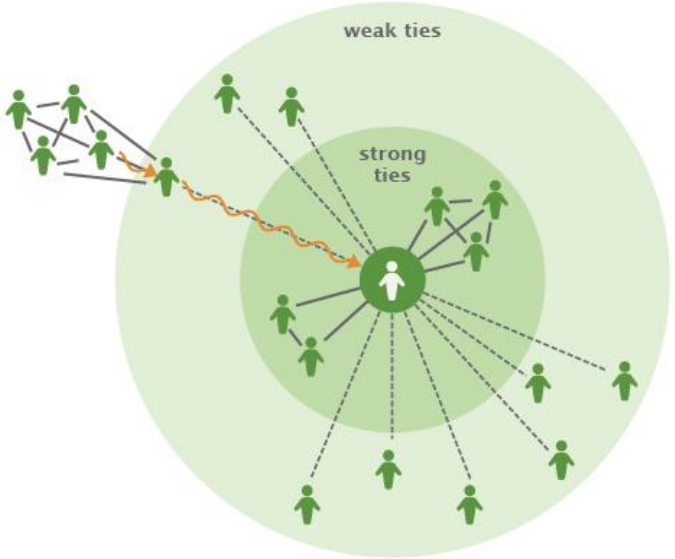
Example 2: Discovering exposure to risk



Romantic and sexual relationships between students in a US high school (Bearman et al., 2004)

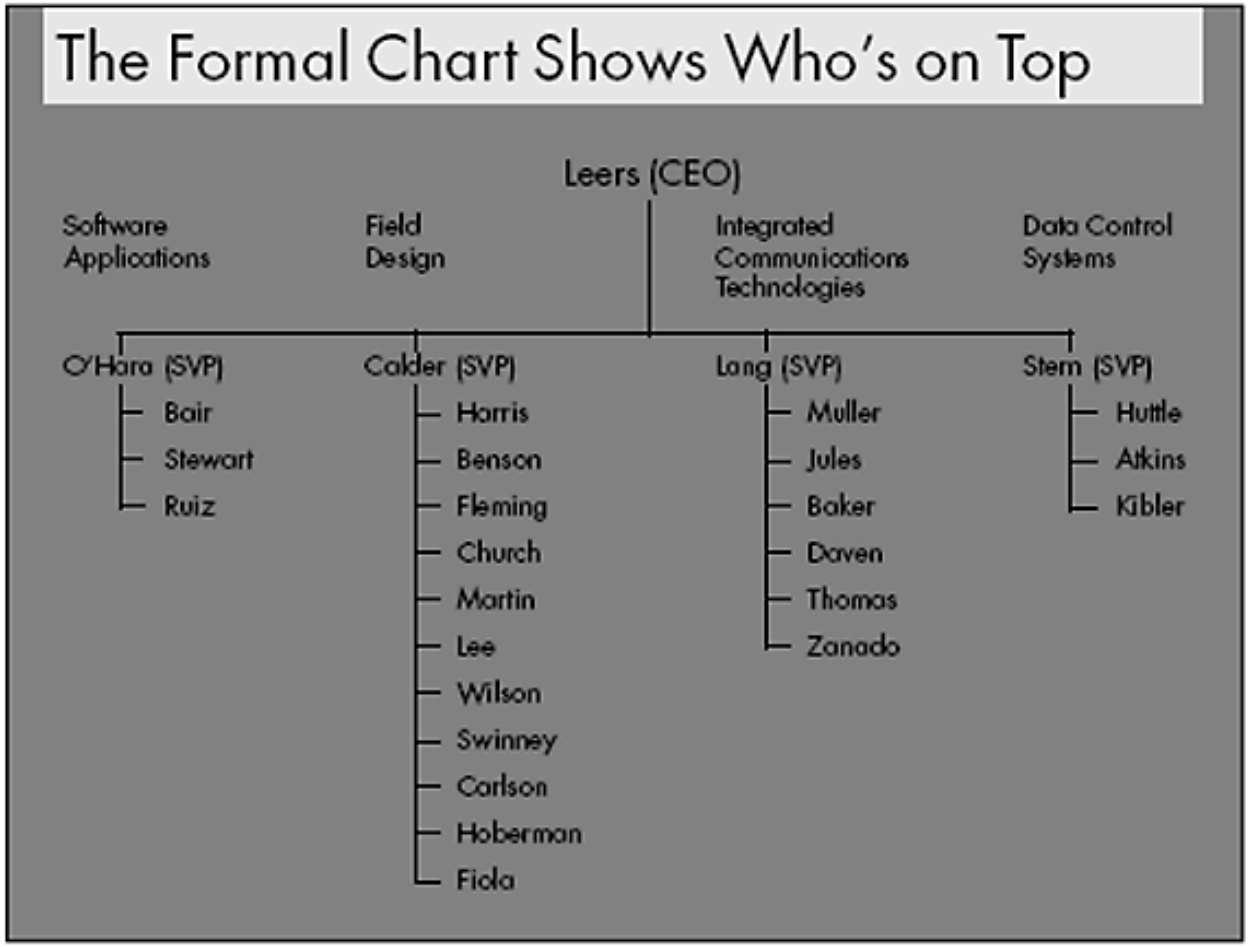
Example 3: finding a job through contacts

- Granovetter (1973, 1974): importance of relationships to find a job
- Strong ties less effective than weak ties!
- Large, spatially distant social groups depend on weak ties for cohesiveness



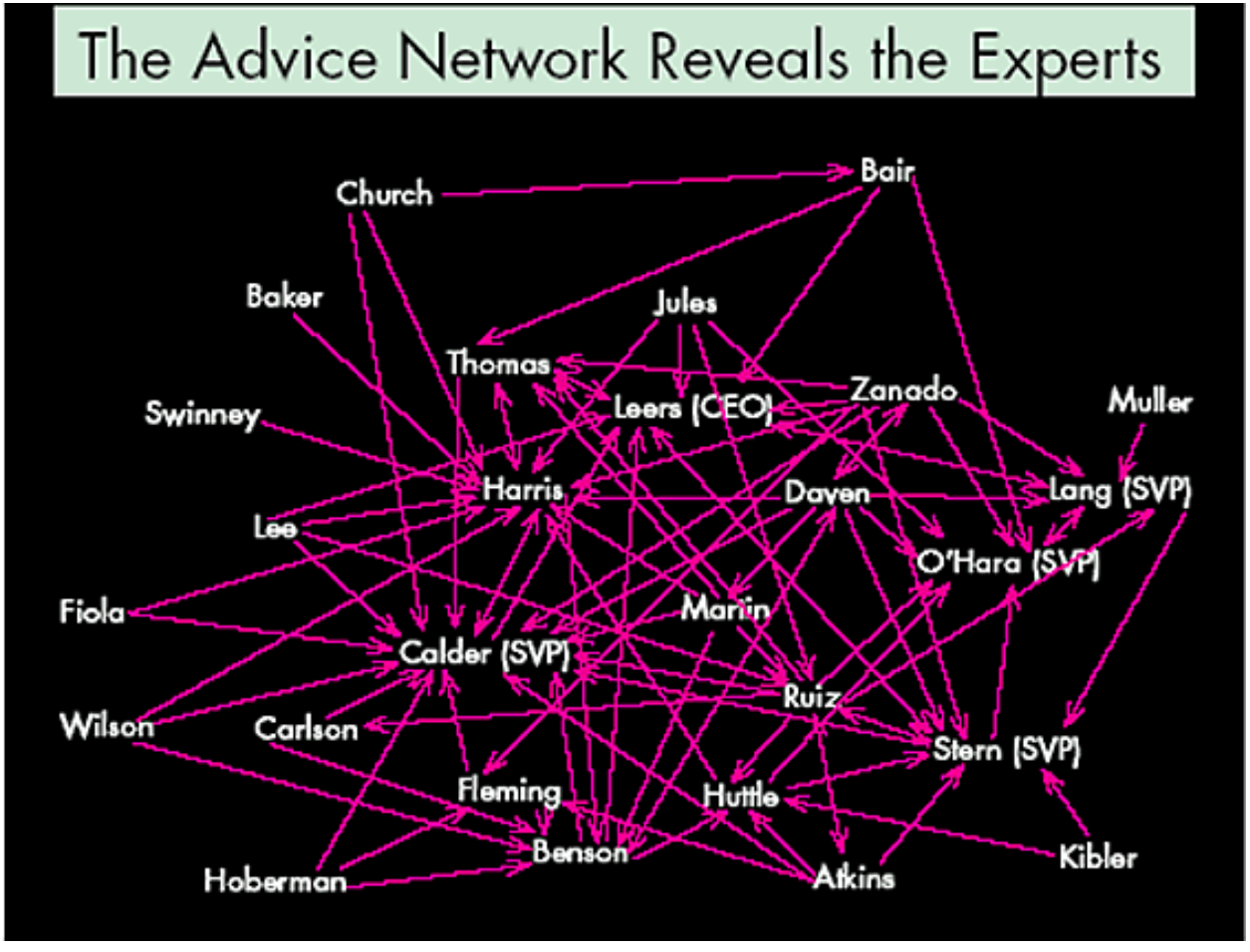
'those to whom we are weakly tied are likely to move in circles different from our own and will thus have access to information different from that which we receive' (Granovetter, 1973, p. 1371)

Example 4: The company behind the chart



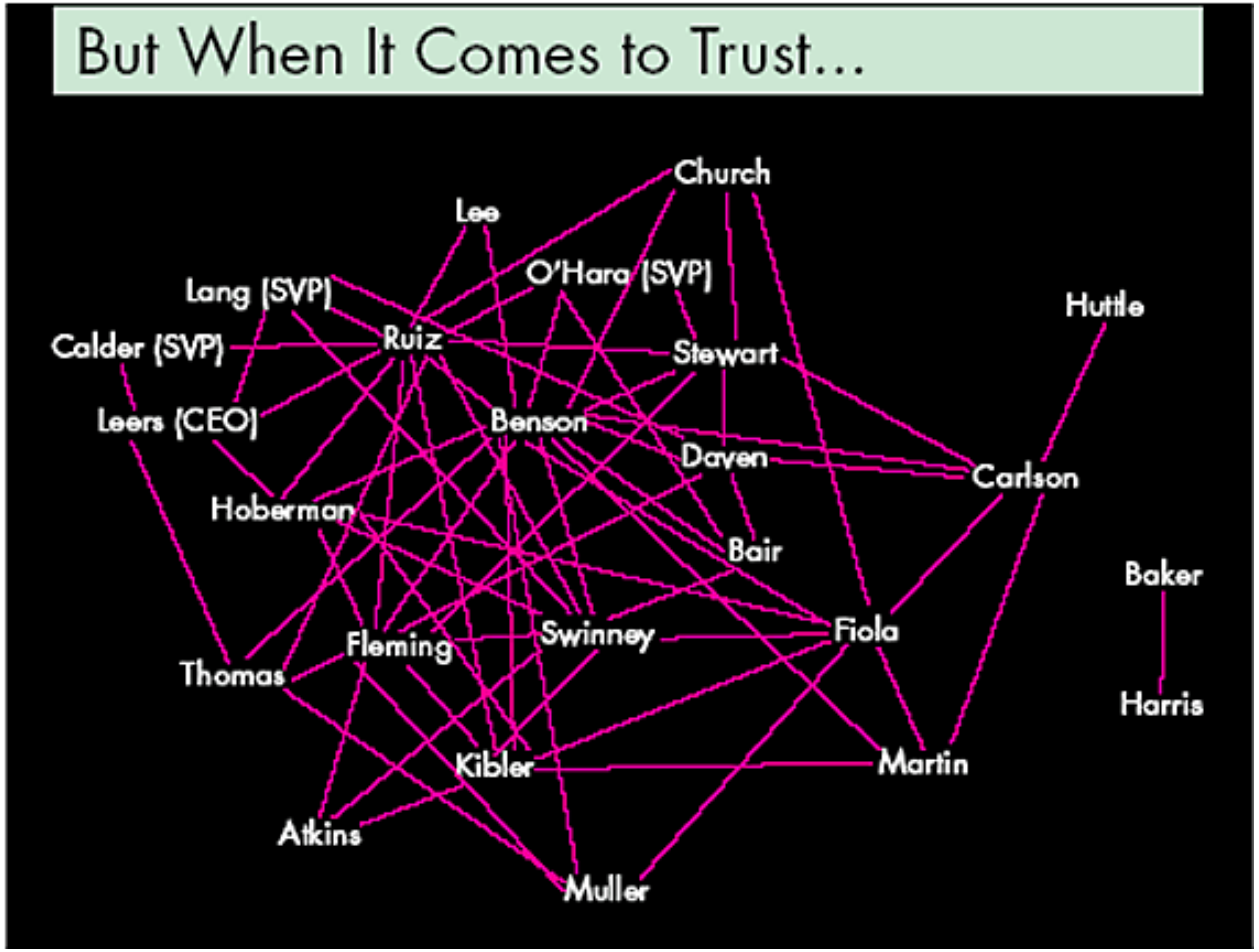
Krackhardt & Hanson (1993)

Example 4: The company behind the chart



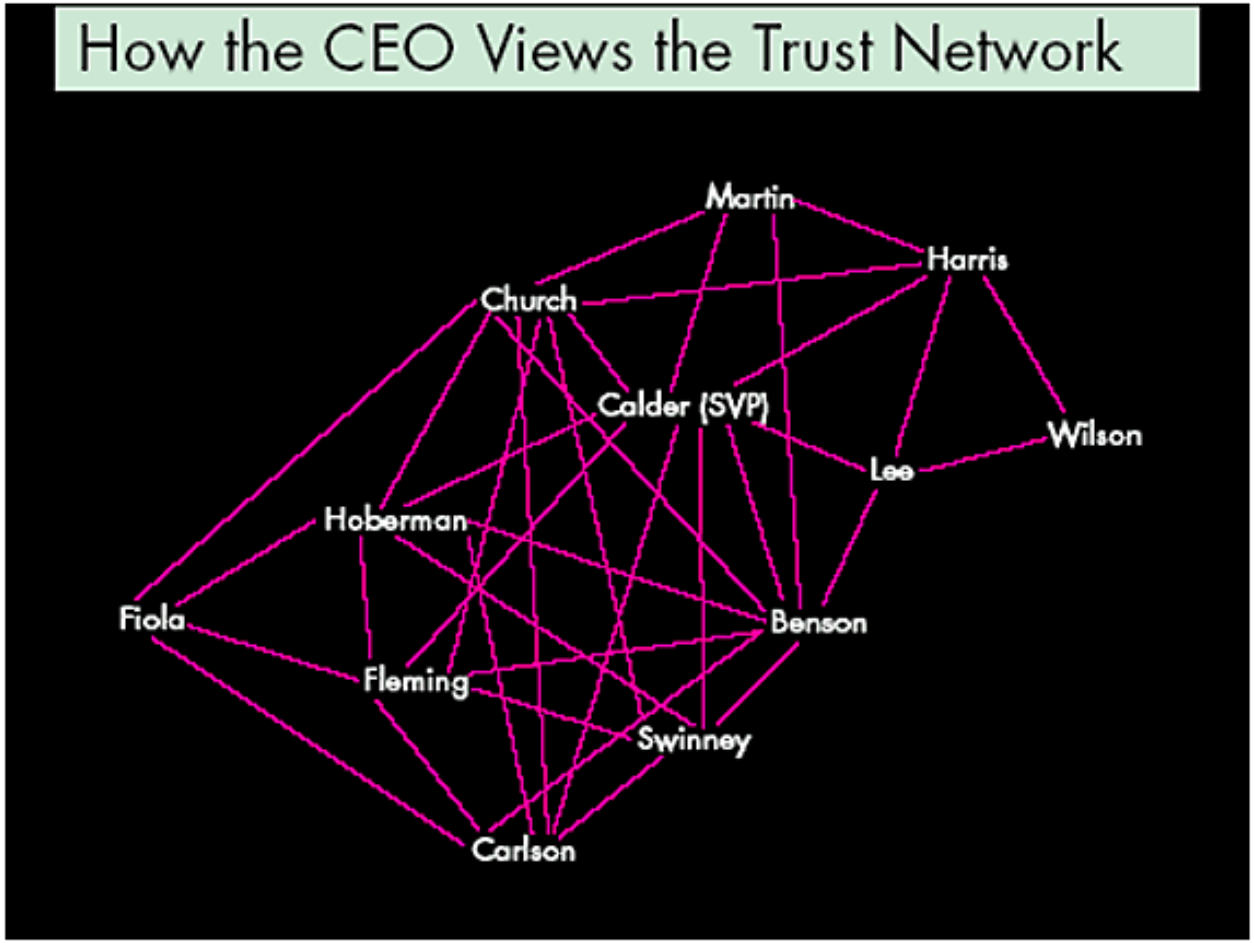
Krackhardt & Hanson (1993)

Example 4: The company behind the chart



Krackhardt & Hanson (1993)

Example 4: The company behind the chart



Krackhardt & Hanson (1993)

Networks reveal the informal organization

- Formal relationships are OK for routine tasks, informal ones address exceptional problems
- Network study serves to 'make invisible work visible'
- Managers do not always see the structure of informal relations very well
- Network approach to address and solve organizational problems

Early intuitions

« **Le monde est fait d'un nombre incalculable de réseaux** qui unissent les choses et les êtres les uns aux autres. Ces réseaux sont formés eux-mêmes de mailles compliquées et relativement indépendantes. Les éléments qu'elles unissent ne sont pas fixes, et la forme même du réseau est soumise au changement : constitué d'une pluralité de petits systèmes doués chacun d'une vie autonome, il se forme, se déforme et se transforme sans cesse. »

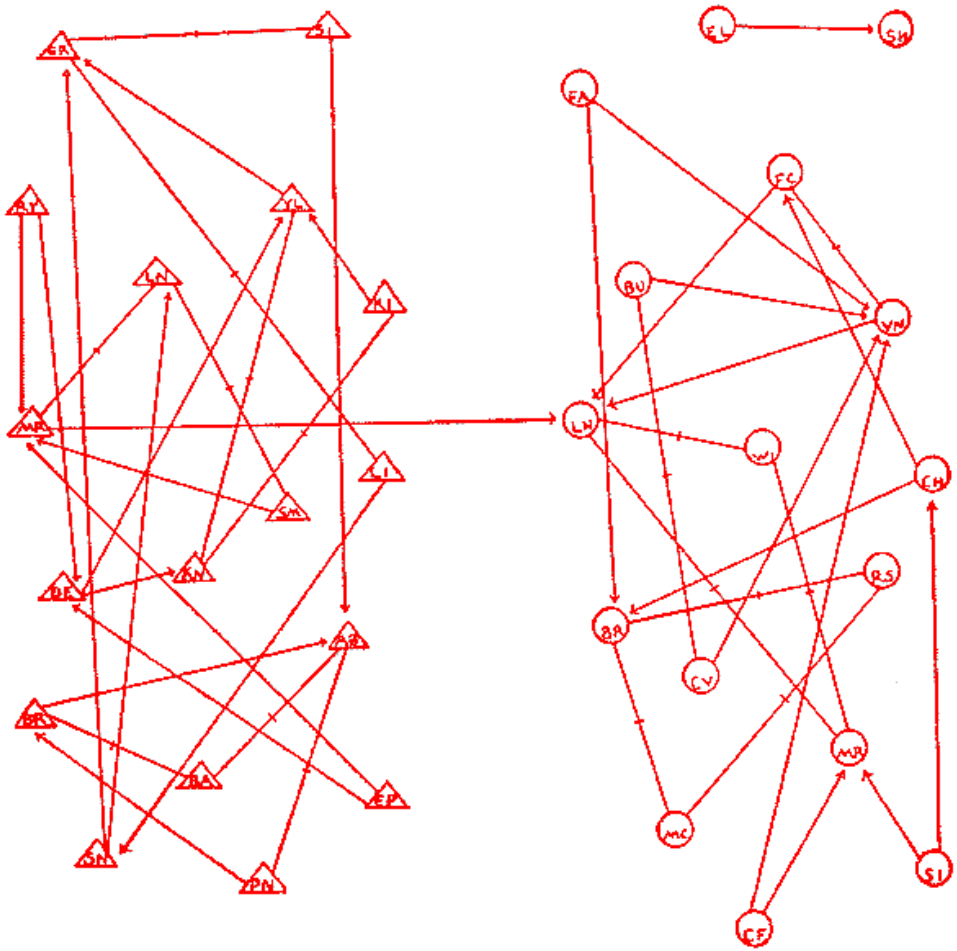
- É. Durkheim, 1913-1914, *Pragmatisme et sociologie. Cours inédit prononcé à La Sorbonne en 1913-1914 et restitué par Armand Cuvillier d'après des notes d'étudiants*, Paris, Jean Vrin, 1955, http://classiques.uqac.ca/classiques/Durkheim_emile/pragmatisme_et_socio/pragmatisme_et_socio.html.

From a human group to a network

> Each person is, as it were, in touch with a number of other people, some of whom are directly in touch with each other and some of whom are not. Similarly each person has a number of friends, and these friends have their own friends; some of any one person's friends know each other, others do not. I find it convenient to talk of a social field of this kind as a *network*. The image I have is of a set of points some of which are joined by lines. The points of the image are people, or sometimes groups, and the lines indicate which people interact with each other. We can of course think of the whole of social life as generating a network of this kind.

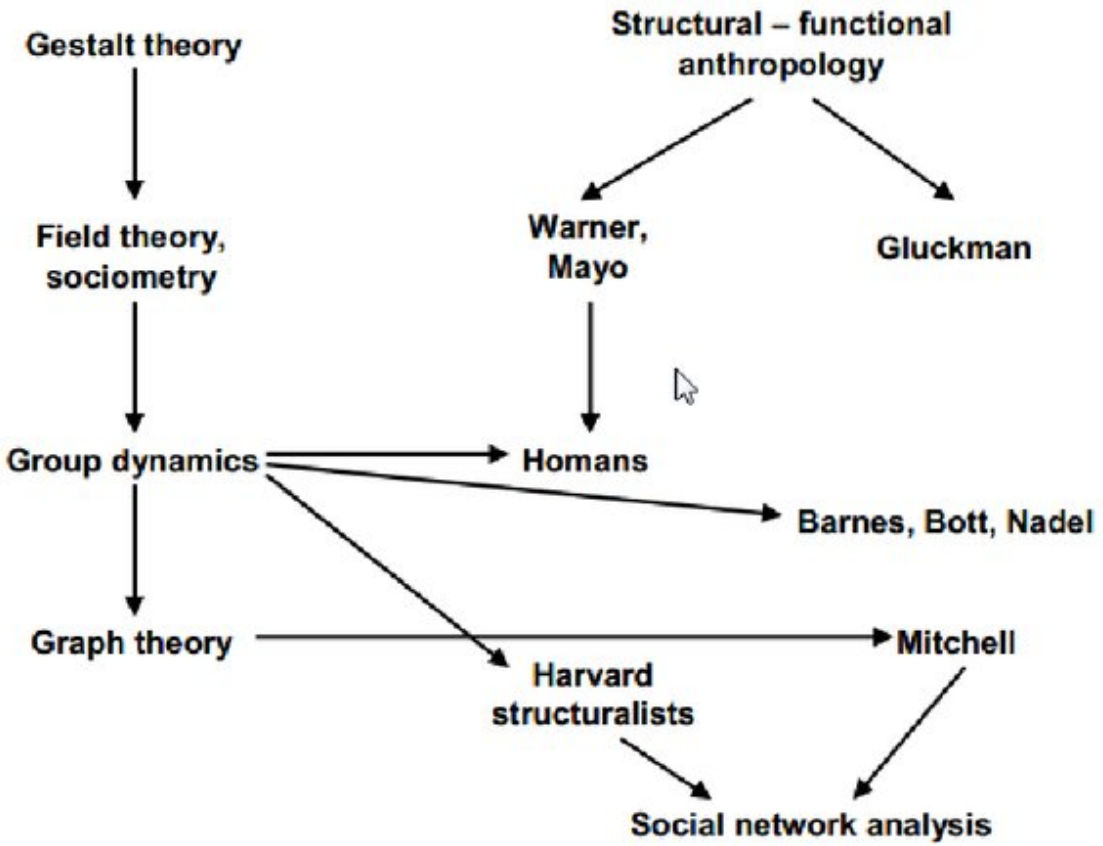
Barnes (1954, p. 237)

Early point-and-line representations



Friendship network in a school (Moreno, 1934). Triangle = boy, circle = girl.

Genealogy



Scott (2012)

Two main perspectives

- Small-networks tradition (SNA)
  - Roots in social science
  - Rich but small-sized data
- Large-networks approach (NS)
  - Roots in physics, computer science
  - Large but 'poor' data

$\Rightarrow$ Different techniques

This course

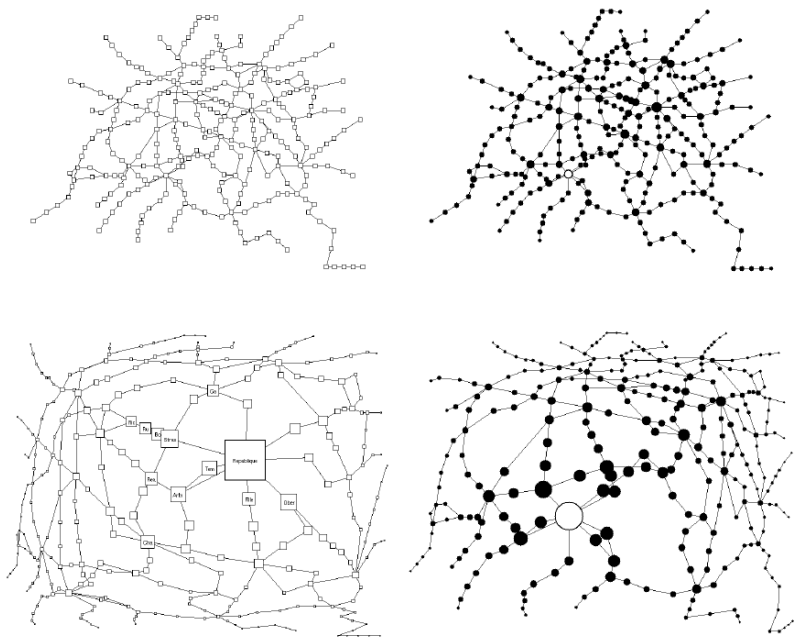
- Reconciling the two traditions
- Be aware of the richness and opportunities, but also of the limitations, of each of them
- Recognize which techniques fit best with whch datasets
- Be prepared to address the challenges of the future — more and more rich and large datasets

Social network economics

- Economists noticed social networks relatively late, but the field is growing fast
- Game-theoretic approaches (relational strategies)
- New data and applications (social media...) attract attention
- Today, a network dimension is considered in a number of fields (development economics, international trade, digital economy, labour markets)
- JEL code: D85

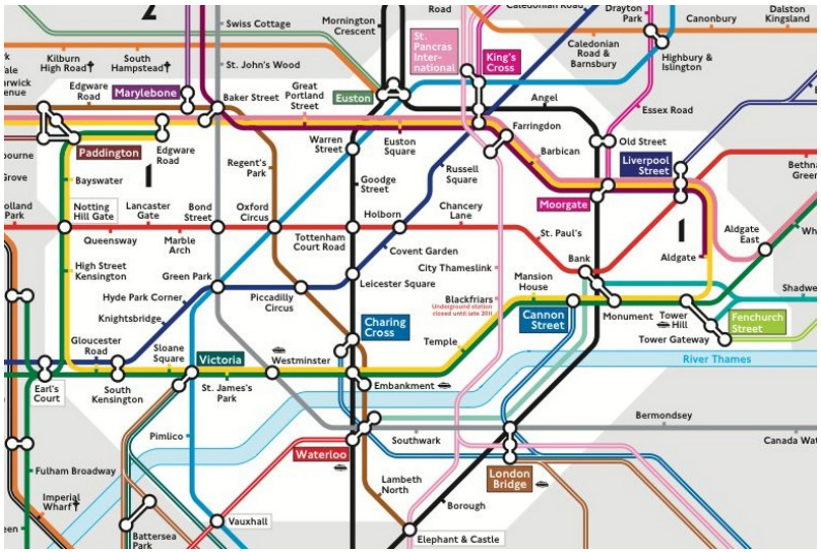
Bases of graph theory

- Social networks are systems of relationships
- Based on mathematical graph theory
- An abstract tool, used in a variety of domains



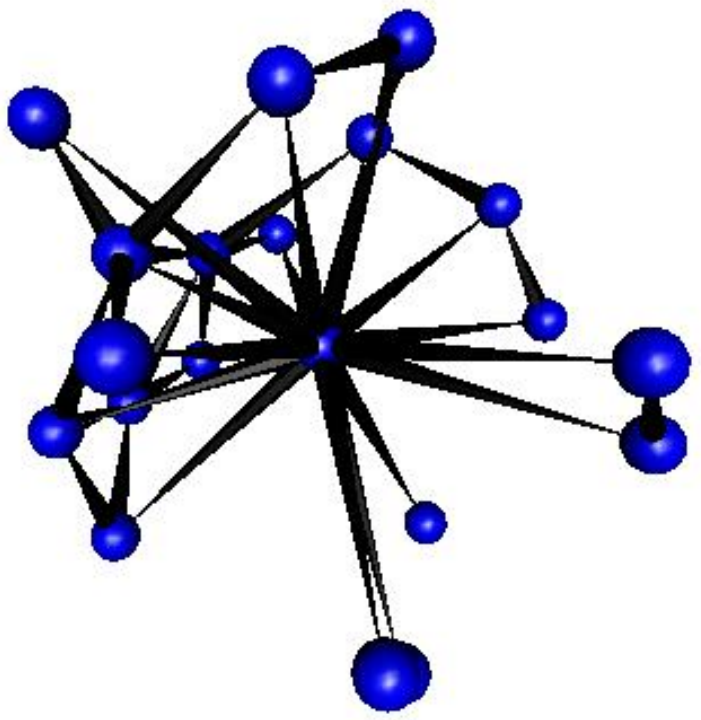
Bases of graph theory

- Social networks are systems of relationships
- Based on mathematical graph theory
- An abstract tool, used in a variety of domains



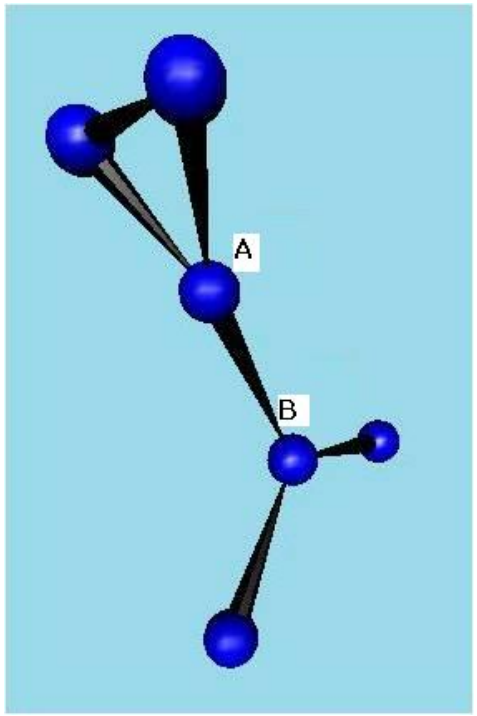
Graph, node, link

- Graph = A set of units (vertices, nodes) connected by one or more links (edges, ties)
- Node: depending on context, it can be a person, group/organization, object
- Link: relationship, interaction or shared attribute (friendship, advice, exchange...)



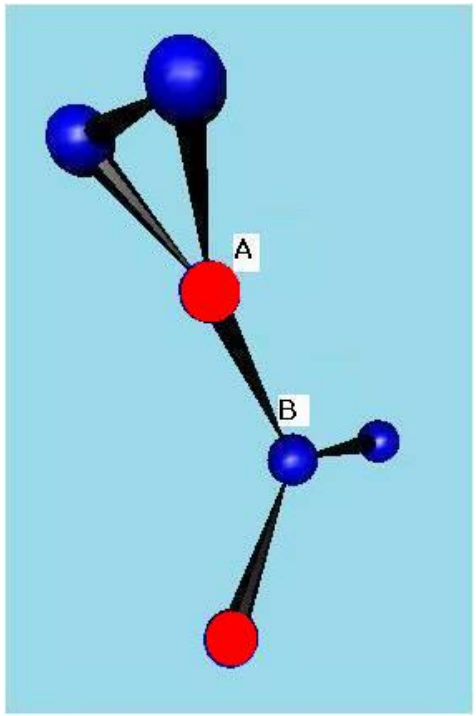
Visualizing networks

- Vertices (A, B): units
- Edges (e.g. between A and B): relationships
- Graph visualizes the structure of relations of a given set of units
- Graphical conventions (colour, size, shape) to represent attributes



Visualizing networks

- Vertices (A, B): units
- Edges (e.g. between A and B): relationships
- Graph visualizes the structure of relations of a given set of units
- Graphical conventions (colour, size, shape) to represent attributes



Terminology

- 'Network' and 'Graph' often used as synonyms
- Differences between disciplines

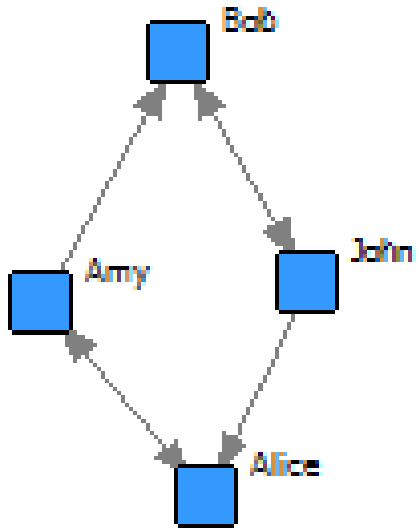
points	lines	
vertices	edges, arcs	math
nodes	links	computer science
sites	bonds	physics
actors	ties, relations	sociology

Source: L. Adamic, Social Networks MOOC - Week 1, 2008.

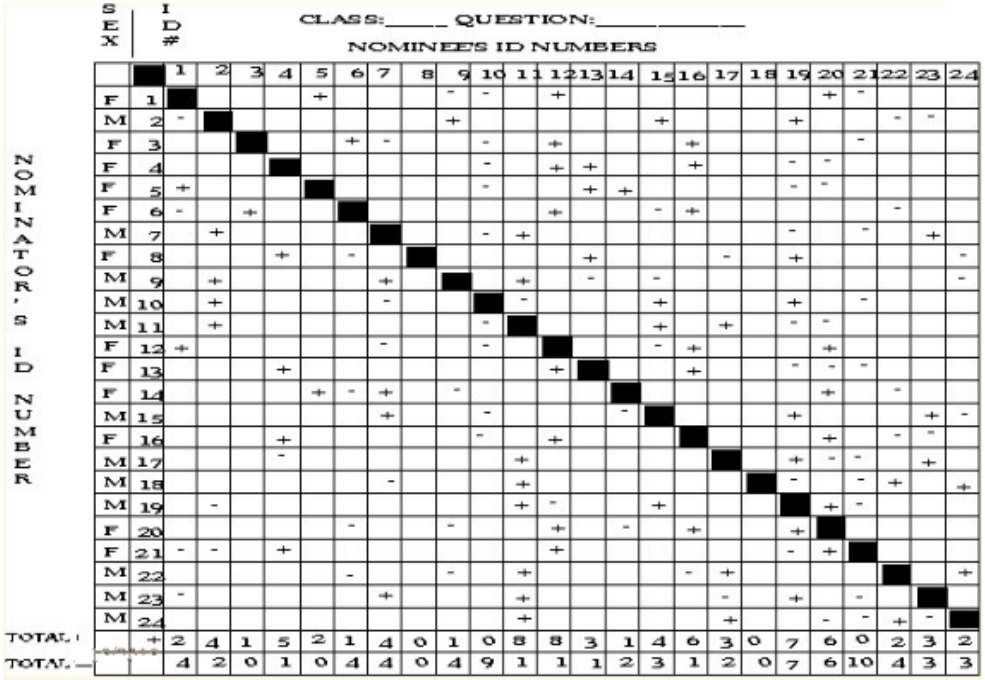
Graphs and matrices

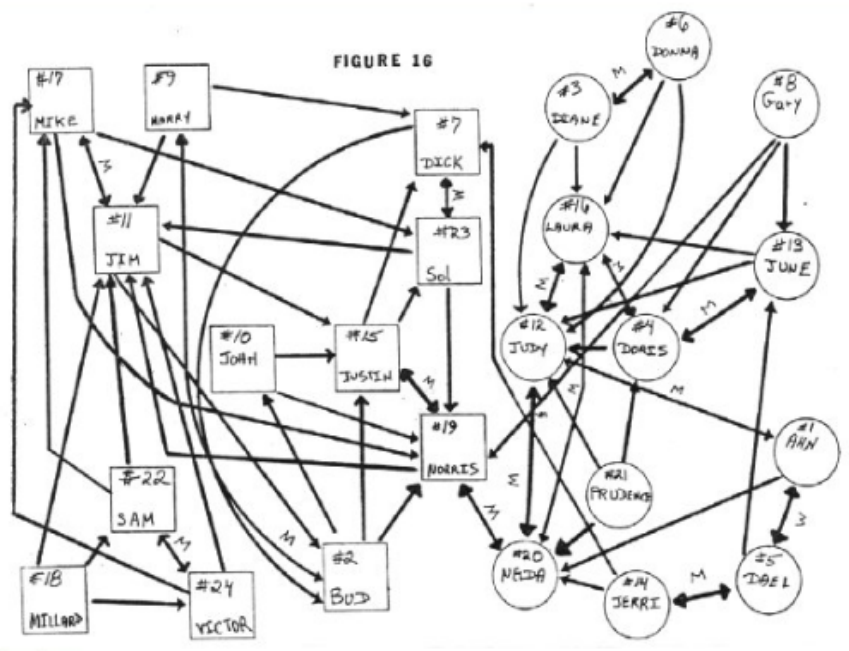
- 'Sociomatrix' and 'sociogram'
- Network data often stored as (adjacency) matrices
- Graph and matrix are equivalent representations

	Amy	Bob	Alice	John
Amy		1	1	0
Bob	0		0	1
Alice	1	0		0
John	0	1	1	



Matrices and sociograms in J.L. Moreno





Data storage: square matrix

Network data can be stored in a square matrix $n \times n$ with all nodes in rows and columns.
Cell (i, j) is 1 if nodes i and j are connected, 0 otherwise.
Diagonal is meaningless.

	Julie	**Marie**	**Lucas**	**Sarah**	**Alain**	**Thomas**
Julie		1	1	0	0	0
Marie	1		0	1	0	0
Lucas	1	0		0	1	0
Sarah	0	1	0		1	0
Alain	0	0	1	1		1
Thomas	0	0	0	0	1	

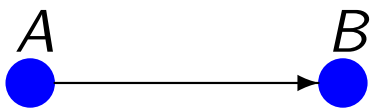
Alternative format: *Edge list*

The edge list stores every pair of connected nodes in a row

Node1	***Node2***
Julie	Marie
Julie	Lucas
Marie	Sarah
Lucas	Alain
Alain	Thomas
Alain	Sarah

Edges I

Directed:

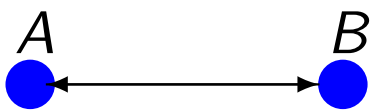


- Edge from vertex A to vertex B, but not necessarily from B to A
- Examples: advice, lending money
- Graphically: arrow
- Reciprocated tie: A to B and B to A
- Double arrow

Edges I

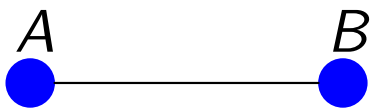
Directed:

- Edge from vertex A to vertex B, but not necessarily from B to A
- Examples: advice, lending money
- Graphically: arrow
- Reciprocated tie: A to B and B to A
- Double arrow



Edges II

Undirected:



- Ties are mutual by definition
- Example: being colleagues or siblings
- Graphically: line

Undirected ties: matrix is symmetric

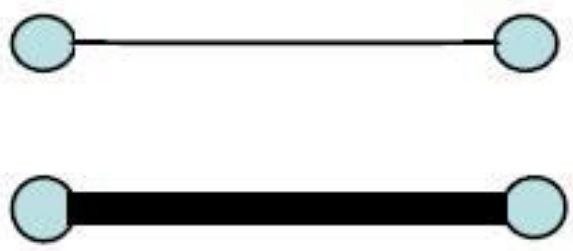
	Julie	**Marie**	**Lucas**	**Sarah**	**Alain**	**Thomas**
Julie		1	1	0	0	0
Marie	1		0	1	0	0
Lucas	1	0		0	1	0
Sarah	0	1	0		1	0
Alain	0	0	1	1		1
Thomas	0	0	0	0	1	

Directed ties: matrix is not symmetric

	Julie	**Marie**	**Lucas**	**Sarah**	**Alain**	**Thomas**
Julie		1	1	0	0	0
Marie	0		0	1	0	0
Lucas	0	0		0	1	0
Sarah	0	0	0		0	0
Alain	0	0	0	1		1
Thomas	0	0	0	0	0	

Binary vs valued ties

- Binary values indicate presence or absence of ties
- One can also measure tie strength, with a suitable definition of 'strength':
  - Emotional proximity
  - Frequency of contact
  - Duration of relationship
- Graphically: thickness of the line (arrow) represents tie strength



Store valued ties in an edge list

Node1	***Node2***	**Strength**
Julie	Marie	5
Julie	Lucas	2
Marie	Sarah	3
Lucas	Alain	1
Alain	Thomas	2
Alain	Sarah	2

Store valued ties in a matrix

	Julie	**Marie**	**Lucas**	**Sarah**	**Alain**	**Thomas**
Julie		5	2	0	0	0
Marie	0		0	3	0	0
Lucas	0	0		0	1	0
Sarah	0	0	0		0	0
Alain	0	0	0	2		2
Thomas	0	0	0	0	0	

Exploring graph properties: degree

- Formally, the number of edges incident to a vertex
- If the graph is undirected:
  $D(i) = \sum_{j=1}^{n} x_{ij} = \sum_{j=1}^{n} x_{ji}$
- If the graph is directed, one distinguishes:
  - Indegree: $D_{In}(i) = \sum_{j=1}^{n} x_{ji}$
  - Outdegree: $D_{Out}(i) = \sum_{j=1}^{n} x_{ij}$
  - Degree $= D(i) = D_{In}(i) + D_{Out}(i)$

References I

Barnes, J. (1954). Class and committees in a Norwegian island parish. *Human Relations*, 7(1), 39–58.

Bearman, P., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. *American Journal of Sociology*, 110(1), 44–91.

Christakis, N. & Fowler, J. (2007). The spread of obesity in a large social network over 32 years. *NEJM*, 357, 370–379.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology*, 78(6), 1360–1380.

Granovetter, M. (1974). *Getting a Job. A Study of Contacts and Careers*. The University of Chicago Press.

References II

Krackhardt, D. & Hanson, J. (1993). Informal networks: The company behind the chart. *Harvard Business Review*, 4, 104–111.

Moreno, J. (1953 (Orig. 1934)). *Who shall survive?: A new approach to the problem of human interrelations*. Nervous and Mental Disease Publishing Co.

Scott, J. (2012). *Social Network Analysis, Third Edition*. Sage.

Thank you!

Paola Tubaro, paola.tubaro@ensae.fr