GENEVA GRADUATE INSTITUTE

INSTITUT DE HAUTES ÉTUDES INTERNATIONALES ET DU DÉVELOPPEMENT
GRADUATE INSTITUTE OF INTERNATIONAL AND DEVELOPMENT STUDIES

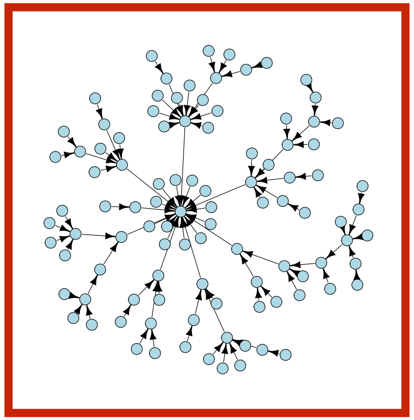
Topology

Introduction to Social Networks

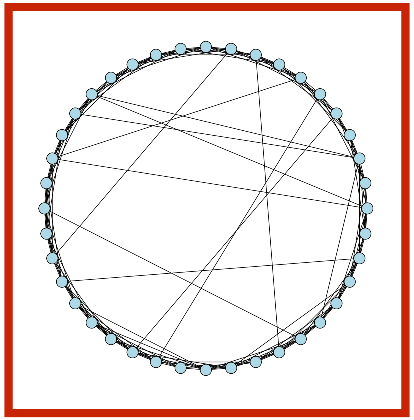
James Hollway

Topology

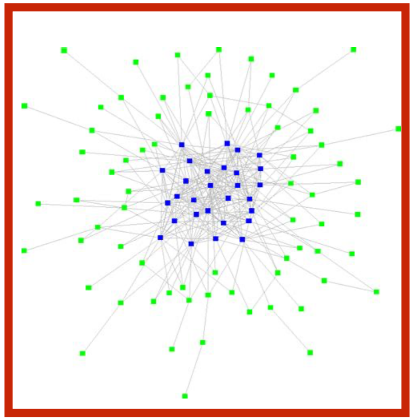
Scale-Free



Small-World



Core-Periphery

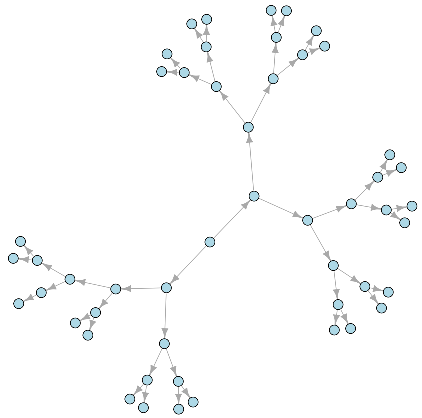


Stylised
Networks

What are stylised network models?

- Ideal type networks
  - Constructed according to 1-2 simple rules
  - Exaggerate structural features commonly found in networks
    - Centrality
    - Cohesion
    - Randomness

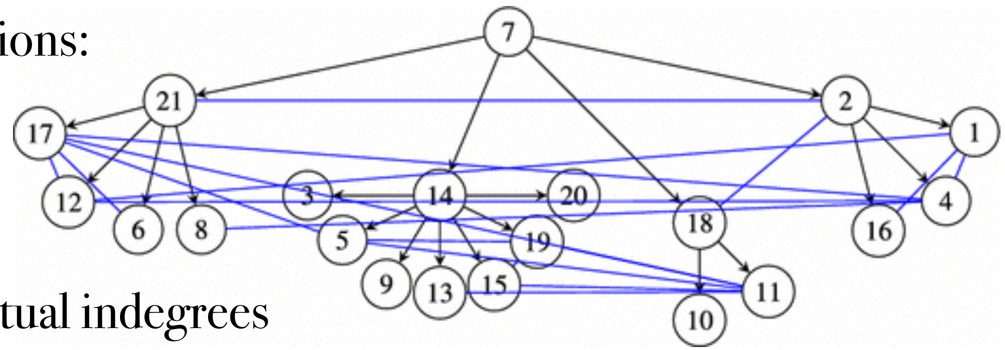
1. Regular Tree



- Rationale:
  - Some networks tend to be centralised, i.e. some nodes have better reach than others and/or network is asymmetric
  - Often the case in asymmetric, functional, or hierarchically organised settings
- Generated by creating a network of *branching* nodes with parameters:
  - Number of branches per node (here 2)
  - Network distance (generations) or dimensions (here n=50)
- Uses: some use in organizational and biological networks

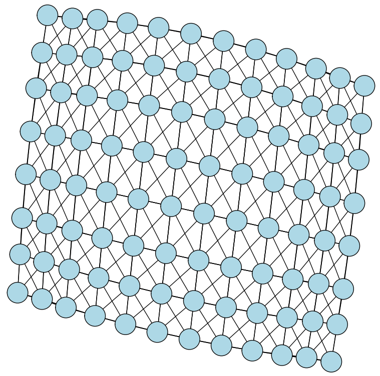
Graph theoretic dimensions (GTD) of hierarchy

- Hierarchy common in networks/ life (Simon 1981), but while intuitive, difficult to be precise
- Krackhart (1994) provided an elegant definition of ideal typical hierarchy as an out-tree graph, where all nodes connected and all but one (the 'boss') has an in-degree of one.
- Four individually necessary and jointly sufficient conditions:
  - Connectedness: proportion of dyads reachable
  - Hierarchy: inverse of reciprocity
  - Efficiency: sum of minimum indegrees over sum of actual indegrees
  - (Least) upper bound: a node that can reach a pair of other nodes (lub is an upper bound that is included on at least one directed path from every other upper bound to each of x and y)



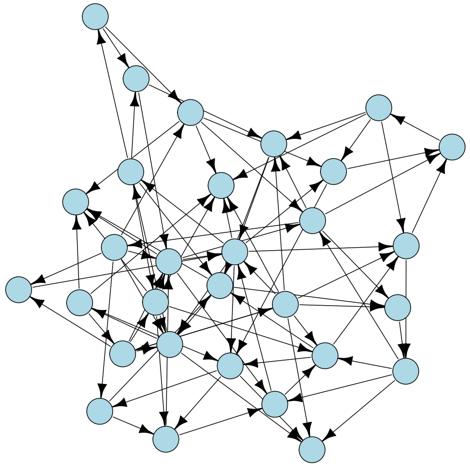
Krackhardt 1994, Everett and Krackhardt 2012

2. Regular Lattice



- Rationale:
  - Some networks tend to be clustered, i.e. high probability that one's interaction partners also interact
  - Often the case where geographic or social space important
- Generated by arranging nodes on a lattice with parameters:
  - Can vary by number of dimensions (here 2)
  - And neighbourhood/interaction distance (here 1+diagonal)
- Uses: commonly used in ABM to show how spatial or network clustering can allow or limit diffusion or make pockets of behaviour stable (more next week)

3. Random network



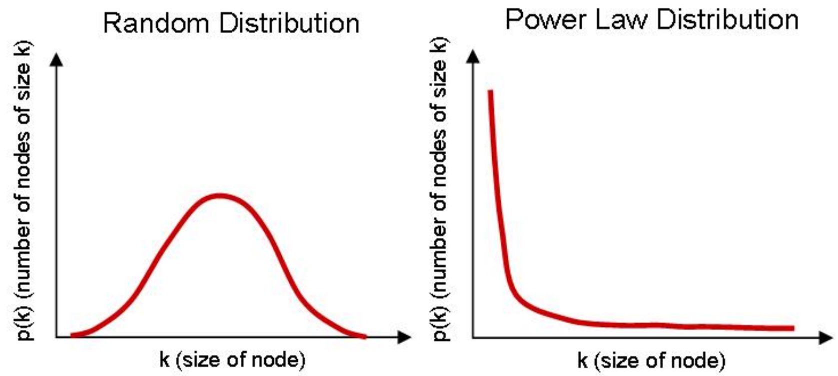
- Also known as a *Bernoulli* network (after Swiss mathematician Jacob Bernoulli, brother to Johann, Euler's advisor) or an *Erdös-Renyi* (1959; see also Rapaport 1953) network
- Rationale:
  - The opposite of a structured network is a random network, i.e. where each tie has an equal probability of existing
  - Rarely the case that an empirical network is truly random, but used as below
- Generated by creating edges at random on a network with parameters:
  - Nodes (here 30)
  - Density
- Uses: often used as a simple baseline to ascertain whether a certain substructure observed more often than expected by chance

The Matthew Effect

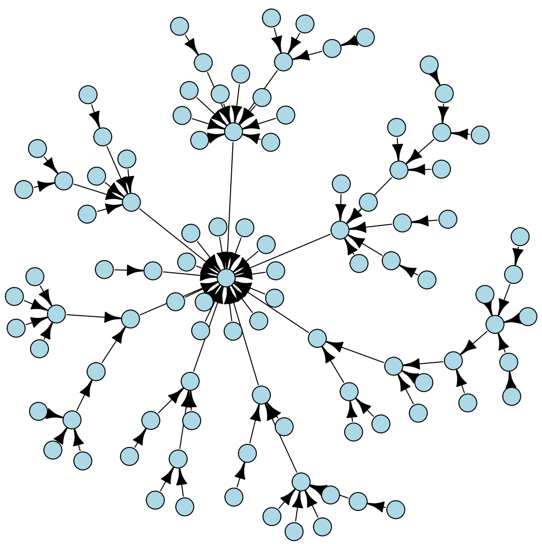
- In 1968, Robert Merton published an article called "The Matthew Effect in Science"
  - "For unto every one that hath shall be given, and he shall have abundance; but from him that hath not shall be taken even that which he hath" Matthew 25:29
- In this article, he discussed how academic fame leads to more fame – in terms of prizes, citations, and attribution of merit (cumulative advantage or preferential attachment)
- In citation networks this mechanism in its purest form can lead to so-called scale-free networks

Merton 1968

4. Scale Free



- Rationale:
  - Some networks have a strong *degree dispersion*
  - Often the case where *positive feedback mechanisms* prevalent (e.g. internet, twitter, academic papers)
- Generated by iterative creation of a network where each new node ties to existing nodes with probability proportional to their degree
  - Degree distribution of this generative process follows a power law
- Uses: some scholars claim power laws are common feature of many networks



De Solla Price 1965; Barabási and Albert 1999

The Milgram Experiment

- In the 60s, Stanley Milgram did an experiment where he invited (through advertisement) people to send a letter to a person unknown to them through intermediaries
- He found that everybody was connected to everyone else through 6 steps
  - He thought this was evidence we lived in a "small world"
- What was wrong with his experiment?

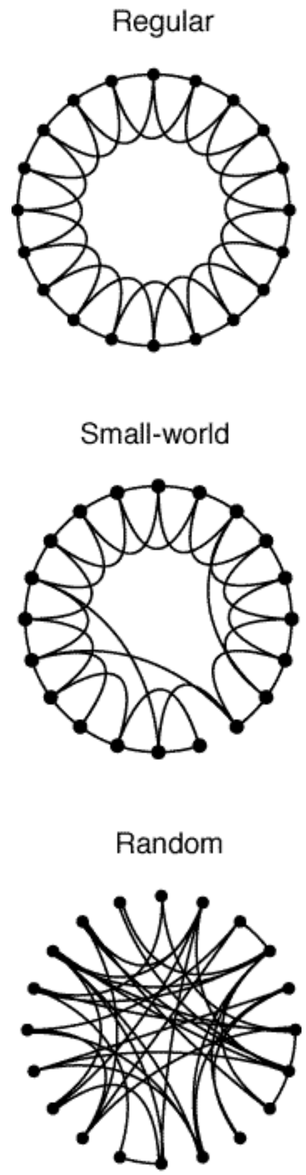
What is wrong with Milgram's (small) world?

- Selection bias: "starters" were recruited through an advertisement searching for well-connected people
- Non-response bias: if one assumes an attrition rate, longer chains will be underrepresented
- Greedy algorithm: people can only make local decisions and cannot omnisciently recognise the shortest global path
- But, Watts and Strogatz (1998) showed this using computer simulations and rise of relational rewiring has brought "6 degrees of separation" into popular culture

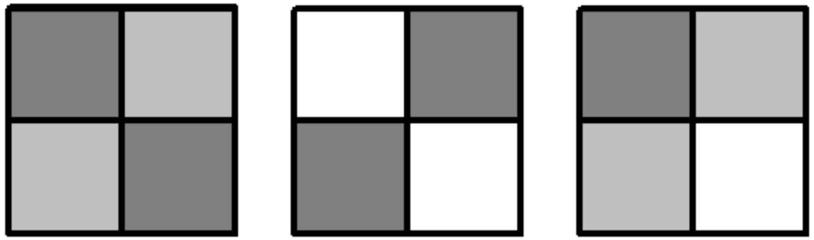
See also Connor and Simberloff 1979

5. Small World

- Rationale
  - Some networks tend to be clustered by interconnected by just a few spanning ties
  - Often the case across a surprising range of settings
- Generated by creating a (ring) lattice and then rewiring a few ties at random with parameters:
  - Lattice dimensions and distance
  - Probability of a tie being rewired
- Uses: commonly used to show “it’s a small world after all” and to model diffusion

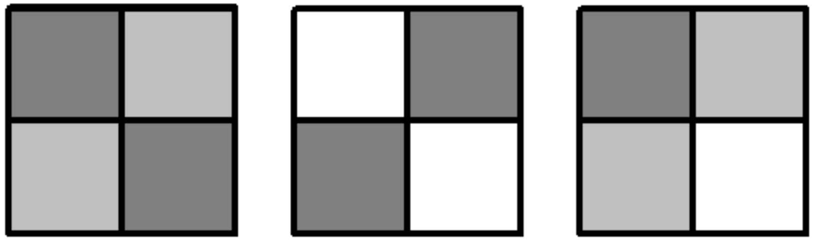


Choose the odd one out



Van Lidth de Jeude et al (2018); see also Prell et al. (2023)

Pick the odd one out

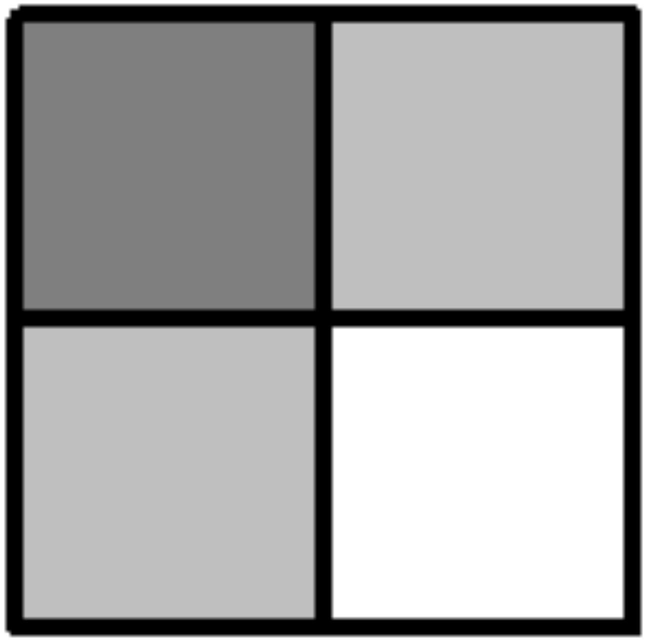


- The idea that at a *meso*-level there are more centralised networks with a *group* of central/core nodes and then others around them is a potentially theoretically relevant observation for many networks
  - e.g. world systems theory (Wallerstein 1974; 2004; Snyder and Kick 1979)

- Various methods for extracting core-periphery structures: statistical inference, spectral decomposition, diffusion mapping, motif counting, geodesic tracing, model averaging

Van Lidth de Jeude et al (2018); see also Prell et al. (2023)

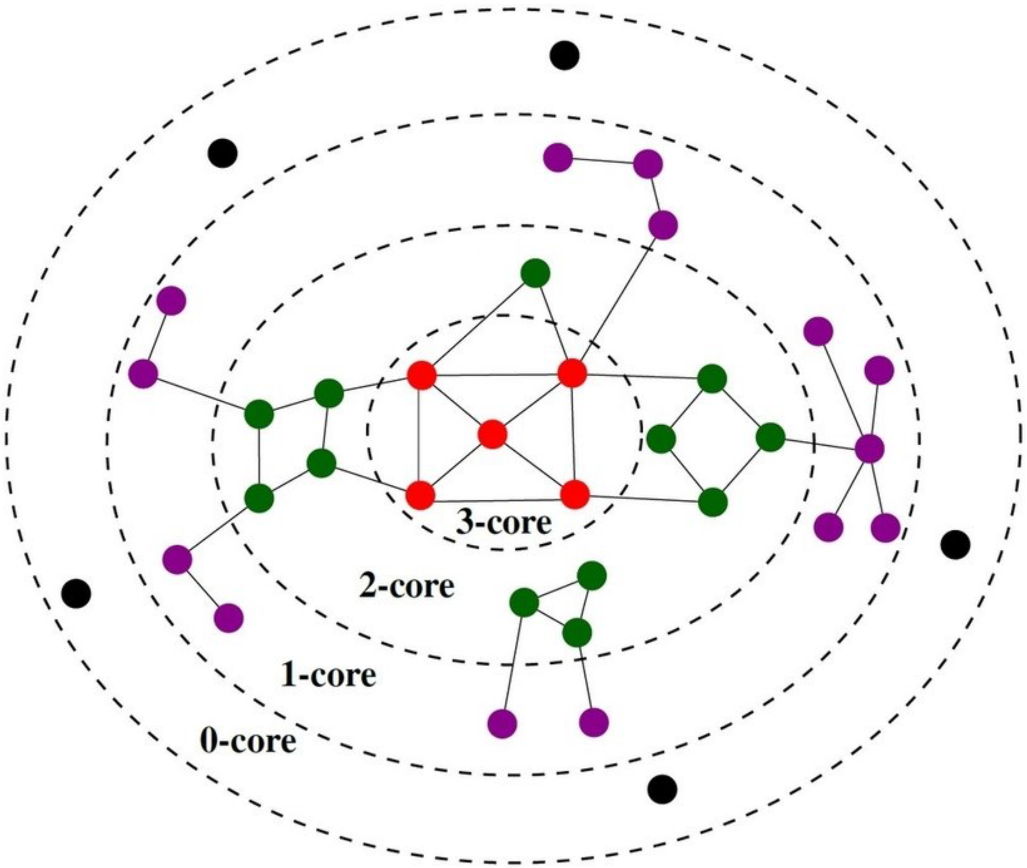
Classic ‘hub-and-spoke’ two-block model



- A fundamental network pattern: dense “core” of tightly connected nodes, connected less densely to peripheral nodes, which are themselves sparsely connected
  - Two groups: “core nodes are adjacent to other core nodes, core nodes are adjacent to some periphery nodes, and periphery nodes do not connect with other periphery nodes”
  - A central hub and a periphery that radiates out from that hub, gets at *core-as-density*

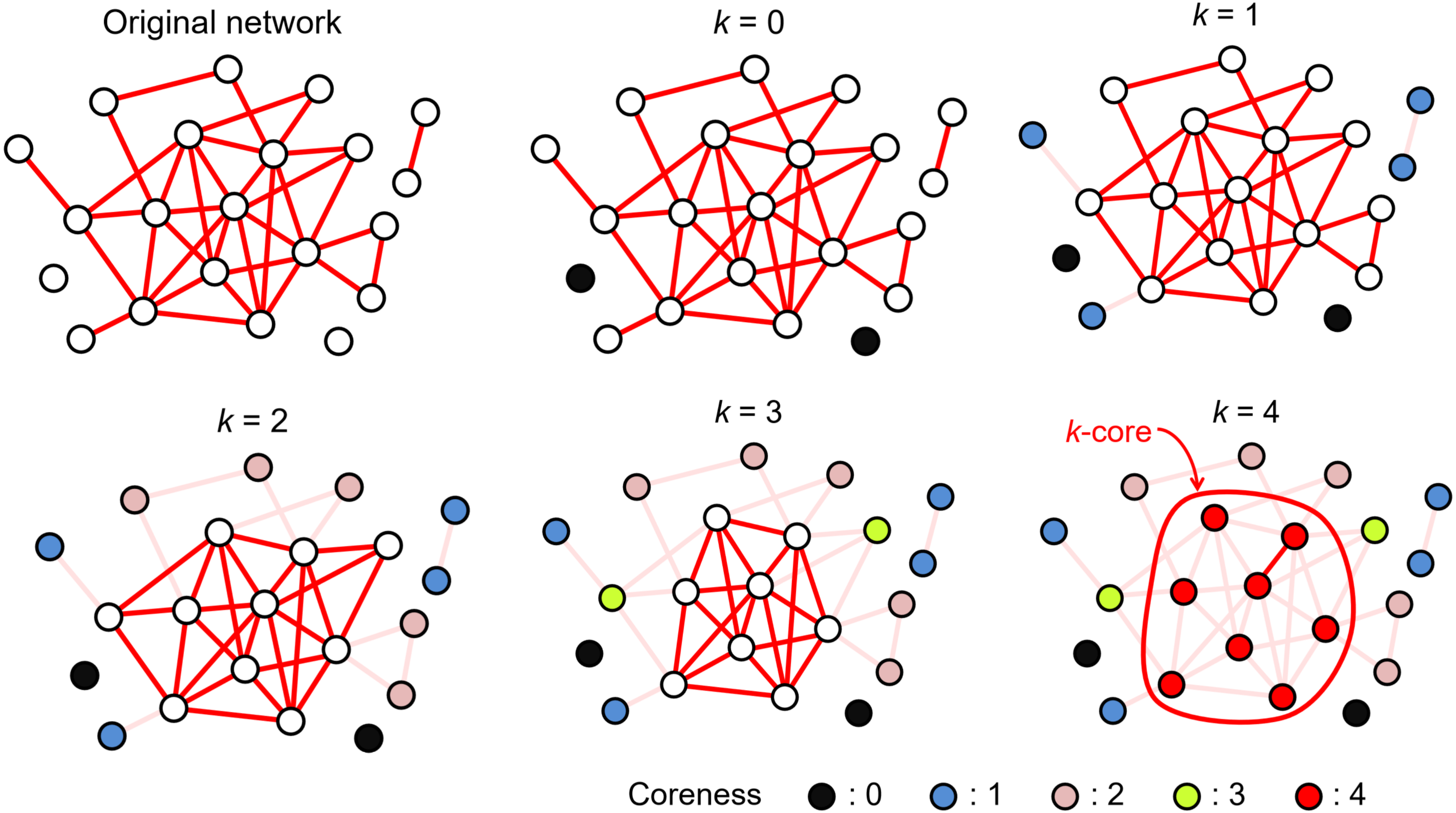
Borgatti and Everett 1999; see also Zhang et al 2015, Kojaku and Masuda 2017, Rombach, Porter et al. 2014

Alternative: layered coreness



- Alternatively, some instead look at *k*-cores
  - The largest subset of nodes in the network such that every node has at least *k* connections to other nodes in the *k*-core but not the (*k*+1)-core
  - Periphery described as "shells", "onion layers", "leaves", and core "epicenter", "corona", or "nucleas"
  - Advantages that it is scalable and gets at *core-as-nesting*

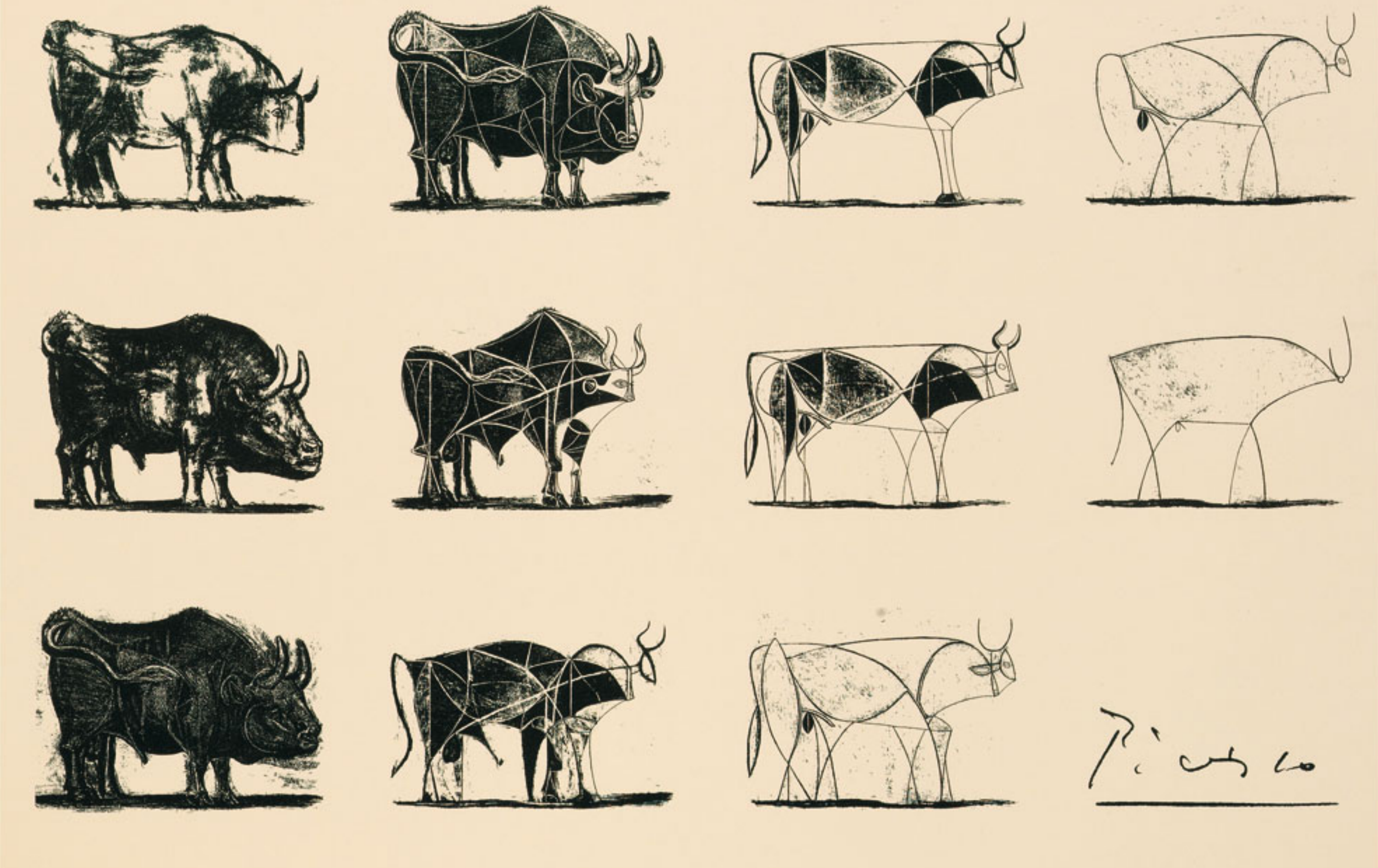
Gallagher, Young and Welles 2021


Original network
k = 0
k = 1
k = 2
k = 3
k = 4
k-core
Coreness : 0 : 1 : 2 : 3 : 4


INDOCTRINATION
CENTER
AHEAD

Stylised network models

provide ideal typical patterns of interaction



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provide ideal typical patterns of interaction

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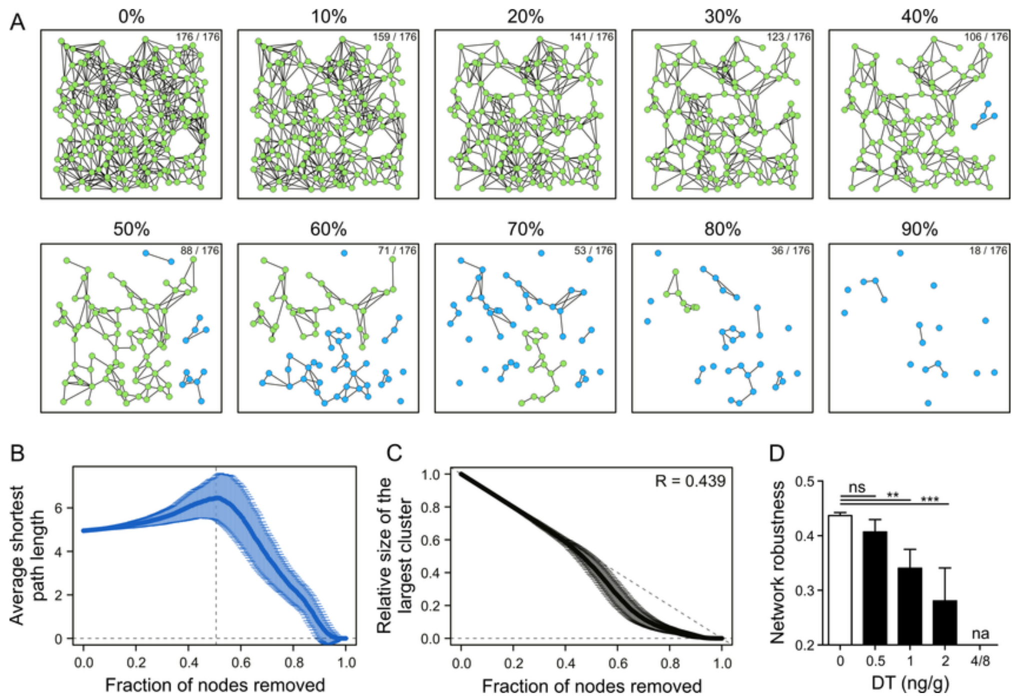
- Good for theory-building and understanding that structure matters

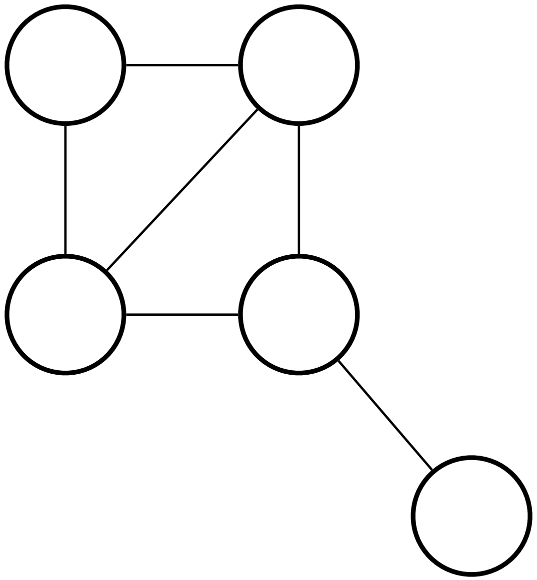
- These mechanisms at best capture only part of the story
- Little use in comparing empirical and stylised networks and claim that a "fit" means the network is explained

Network Robustness



Network percolation theory is a literature that tries to identify how many random or specific nodes can be removed before a network breaks into multiple components

Cohesion and Adhesion



- Cohesion is a count of the number of *nodes* that would need to be dropped for the number of components to increase
    - Cutpoints are the nodes that, if dropped, would result in the number of components to increase
- Adhesion is a count of the number of *ties* that would need to be dropped for the number of components to increase
    - Bridges are the ties that, if dropped, would result in the number of components to increase

Topology

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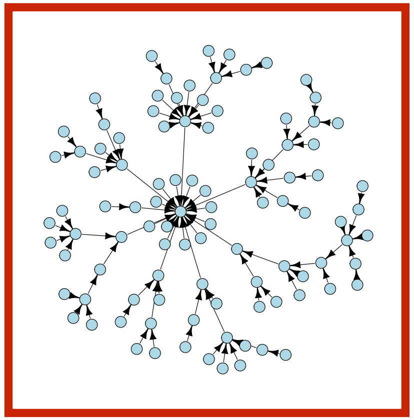

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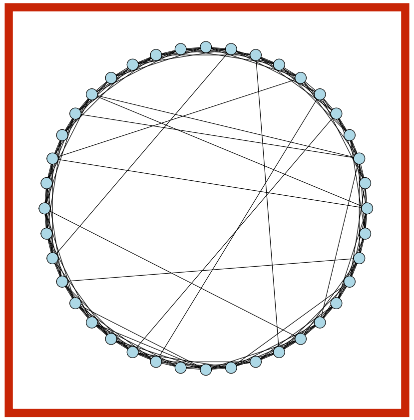

Core-Periphery