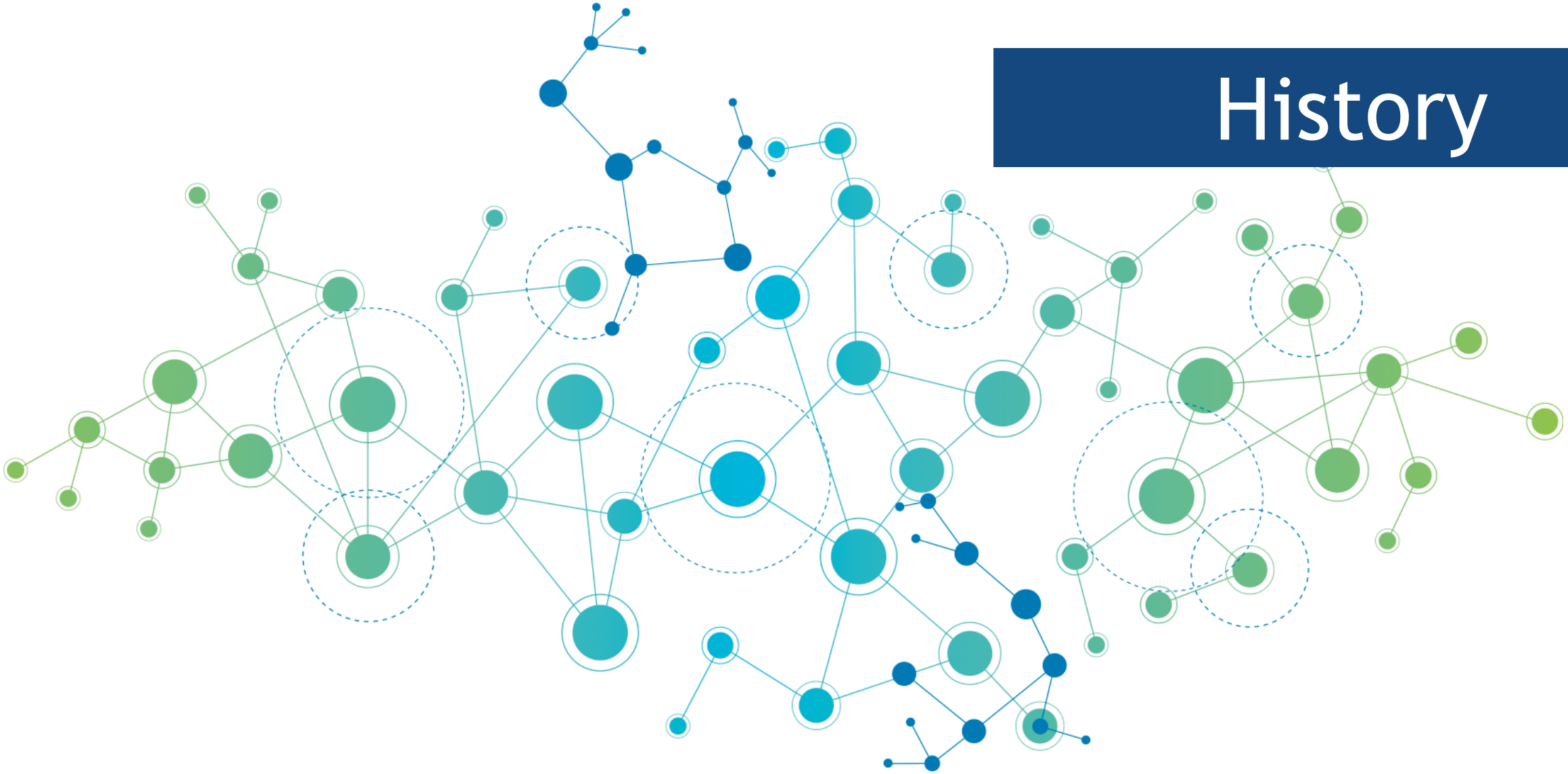
History



Overview

- History of network analysis
  - Roots in multiple disciplines
- Network analysis in public health and the social sciences
- Network analysis as:
  - Method
  - Theory
  - Paradigm
  - Discipline

History of Network Analysis

Role of mathematics, psychology, sociology, anthropology, computer science, physics, political science, public health, and Hollywood

Graph theory

- Study of graphs, mathematical structures used to model pairwise relations between objects from a certain collection.
  - More formally a graph is a collection of *vertices* and a collection of *edges* that connect pairs of vertices.
- Euler & Leibniz laid foundations of graph theory
  - Rich foundation – led to topology, data structures such as trees, mapping problems, and network analysis

Euler's *Seven Bridges of Königsberg*

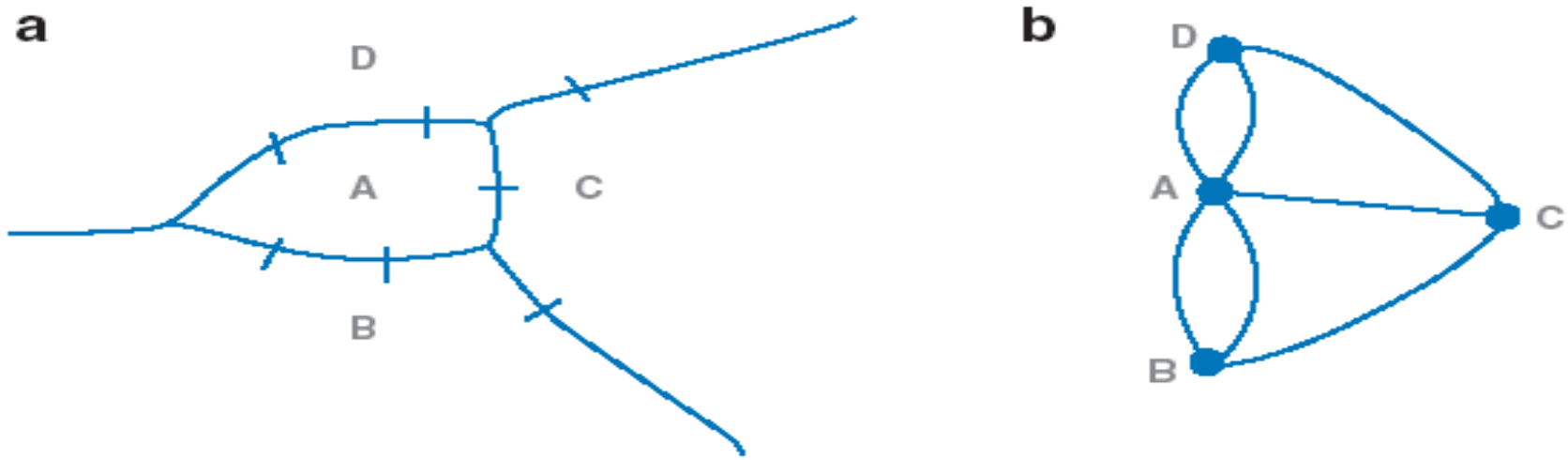
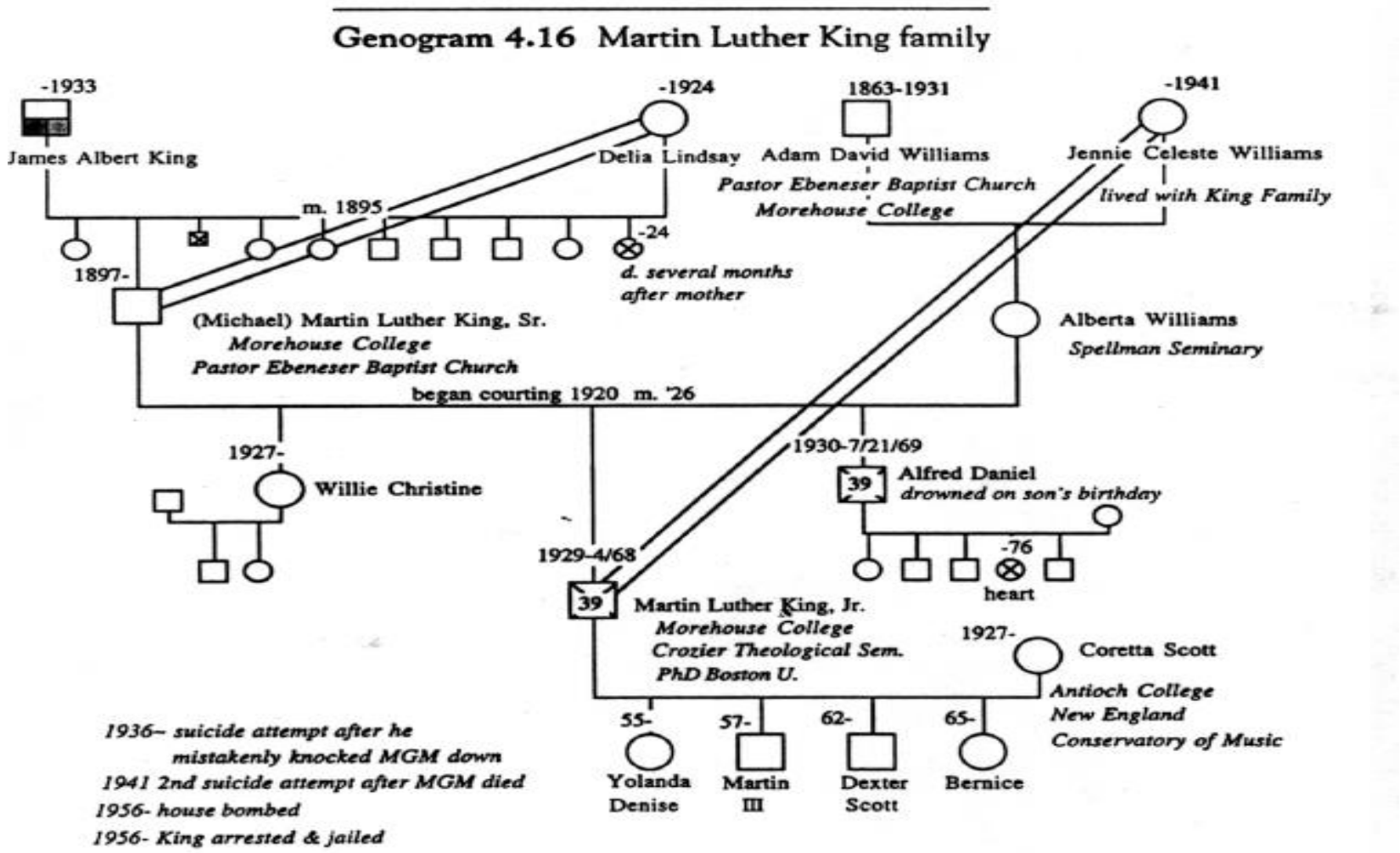


Figure 2

A simplified map of the Königsberg bridges (*a*) and the corresponding graph used by Euler to examine the Königsberg bridge problem (*b*). This graphic was adapted from **http://www.amt.canberra.edu.au/euler.html**.

Kinship & genealogy – Genogram example



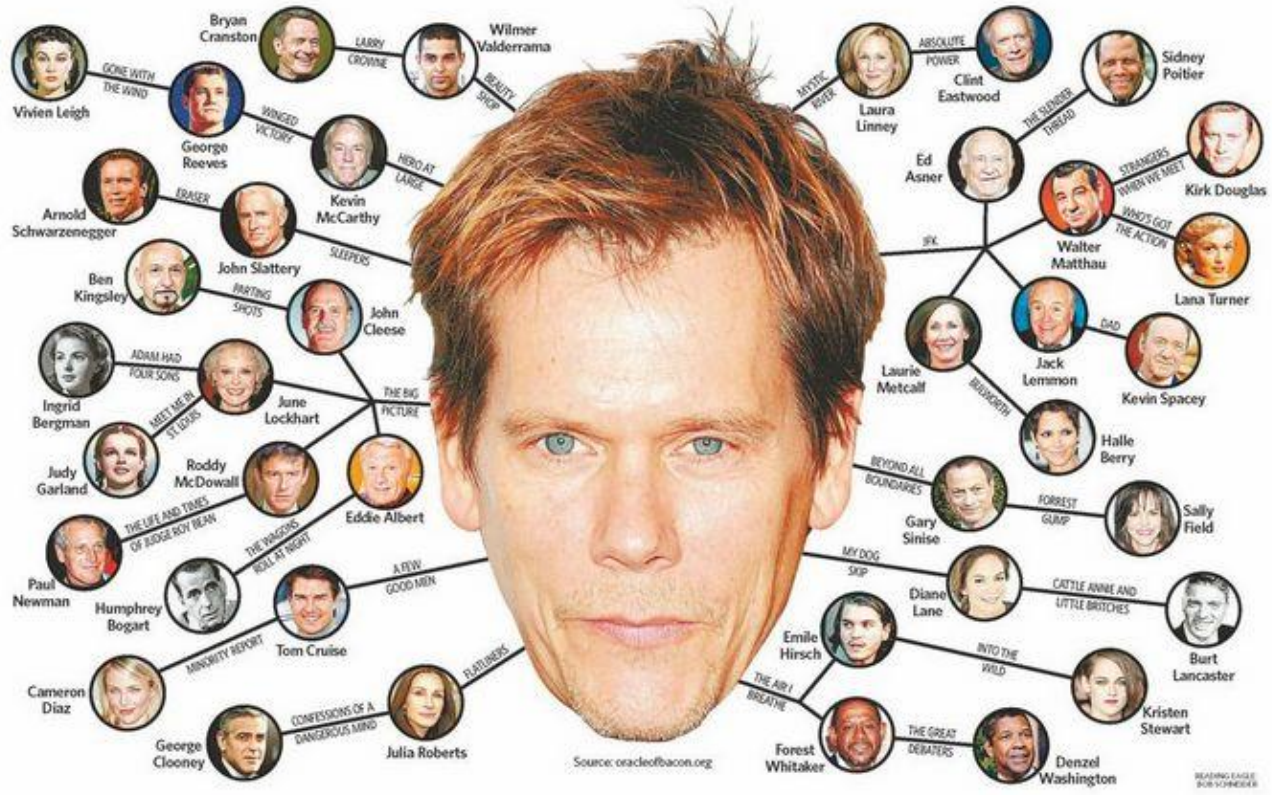
Six Degrees

- Frigyes Karinthy
  - In short story (*Chains*, 1929) a character asserted that he could link anyone in the world to himself through at most five acquaintances.
  - First mention of the concept of six degrees of separation
- Has entered popular culture
  - John Guare's play of the same name
  - Kevin Bacon
  - Erdős number (http://www.oakland.edu/enp/)

Six Degrees of Kevin Bacon

- Is Kevin Bacon the best B-actor of all time; or
- Does he represent a fundamental property o human social systems?

- https://oracleofbacon



Sociometry

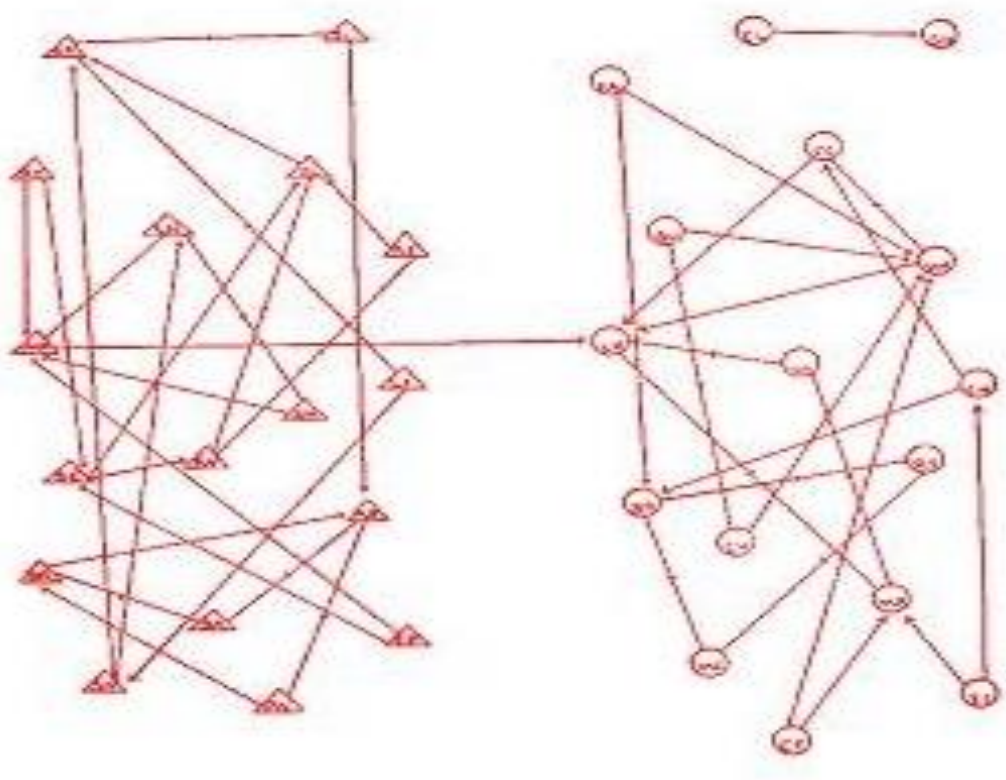
- Jacob Moreno, 1934, psychiatrist by training
  - Interested in investigating how psychological well-being was related to the structural features of what he termed 'social configurations'
- Invented a new way of representing relationships on paper, called a *sociogram*
- Founded the journal *Sociometry*

Example of Moreno sociogram

EMOTIONS MAPPED BY NEW GEOGRAPHY

Charts Seek to Portray the Psychological Currents of Human Relationships.

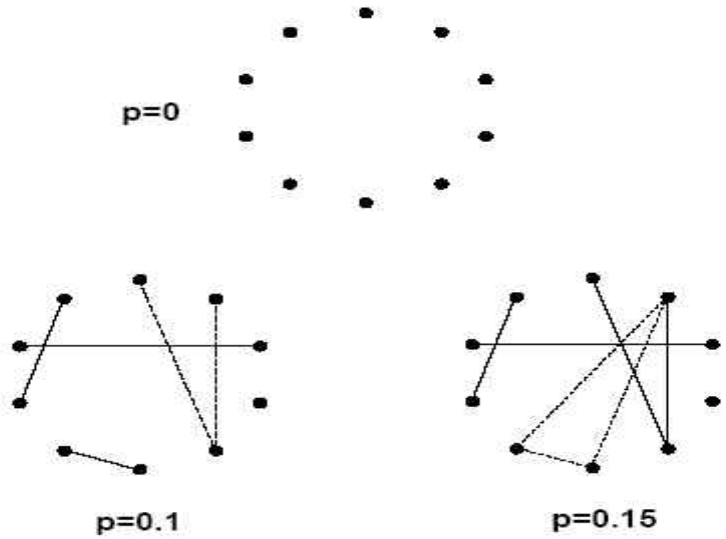
New York Times
April 3, 1933

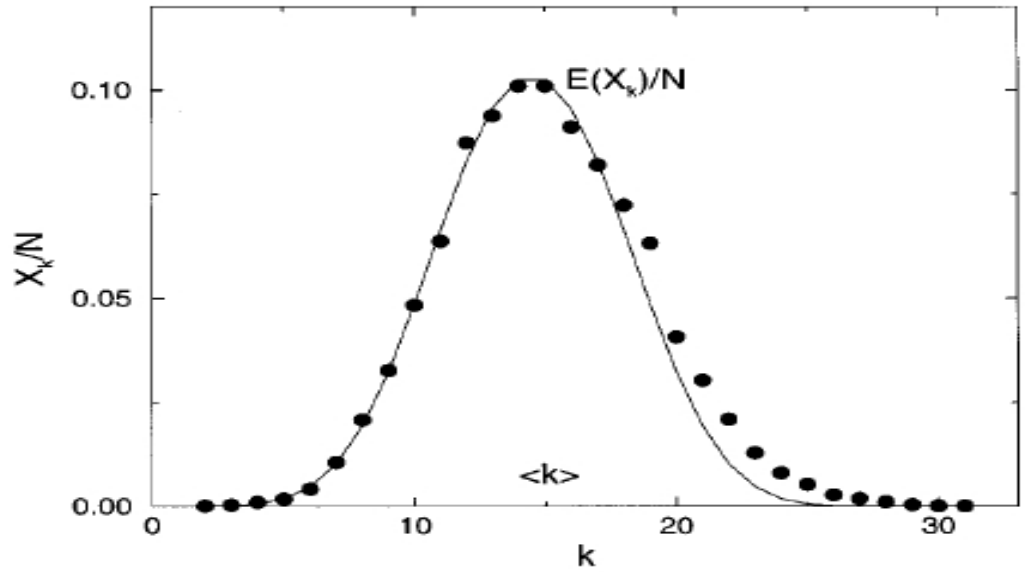


Math 1 – Random graphs

- Erdős-Renyi random graphs
- Random graph – take a set of nodes (vertices), and randomly connect pairs of vertices with ties (edges)
  - Important finding – only a small percentage of pairs need to be randomly connected before the entire graph is connected, and this percentage goes down as the network gets larger
  - E.g., for the Earth's population, people only need to have around 24 connections to have the entire planet included in one social network

Erdos-Renyi random graphs

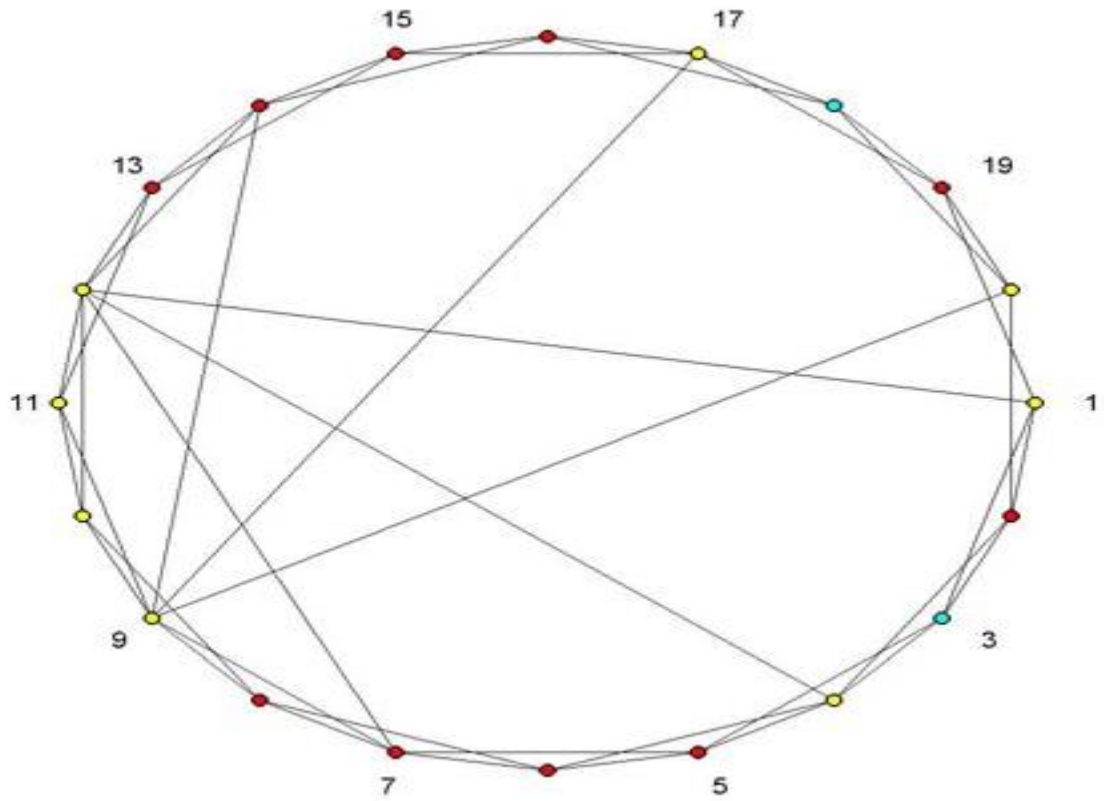


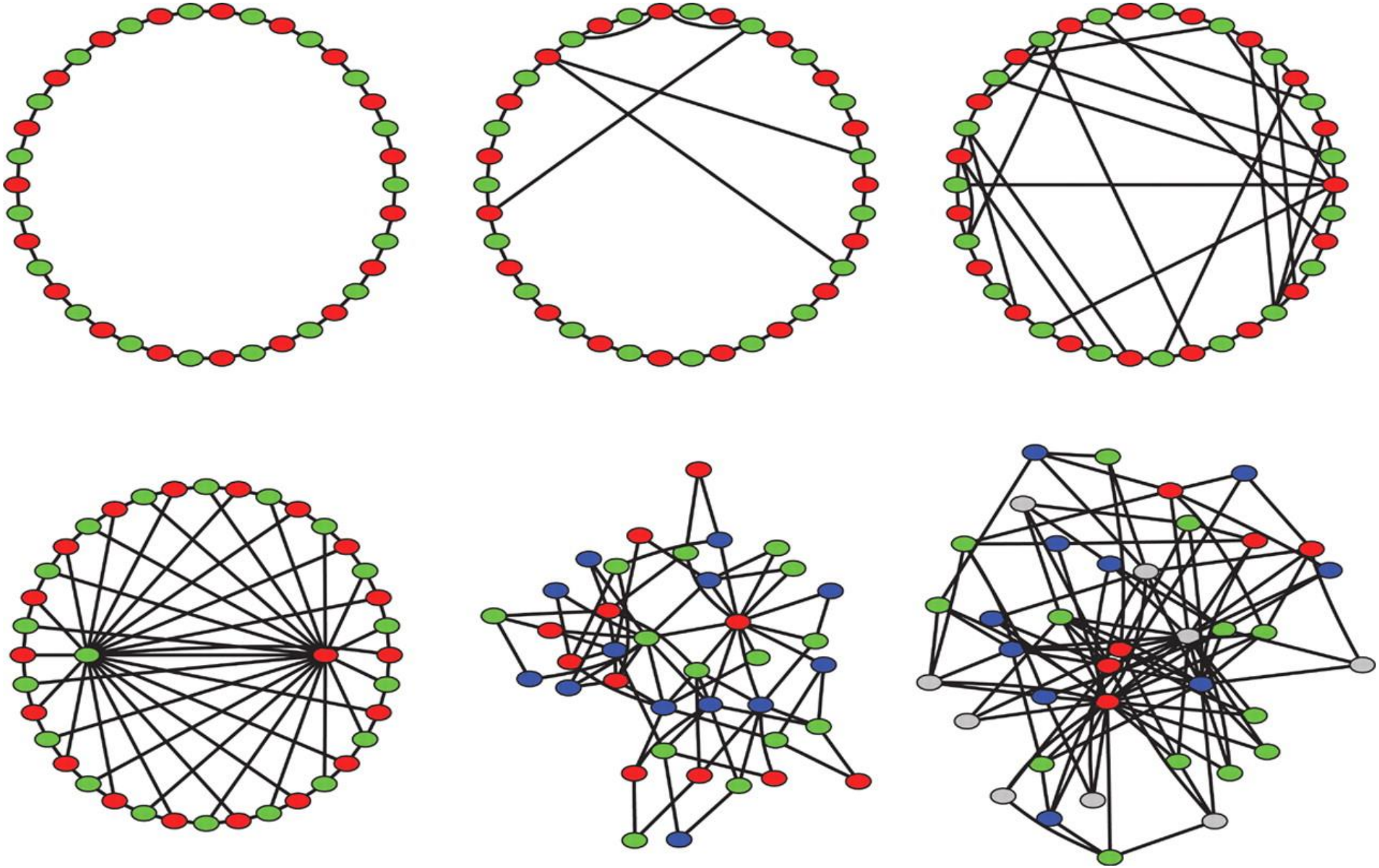


Math 2 – Small-world model

- Watts, Strogatz – mathematicians trying to understand how large, widely distributed networks could show coordinated activity
  - e.g., firing neurons, chirping crickets, clapping crowds
- Discovered that large structured networks suddenly exhibit ‘small-world’ properties when a small number of random ties are added to the structured network

Example – small world network

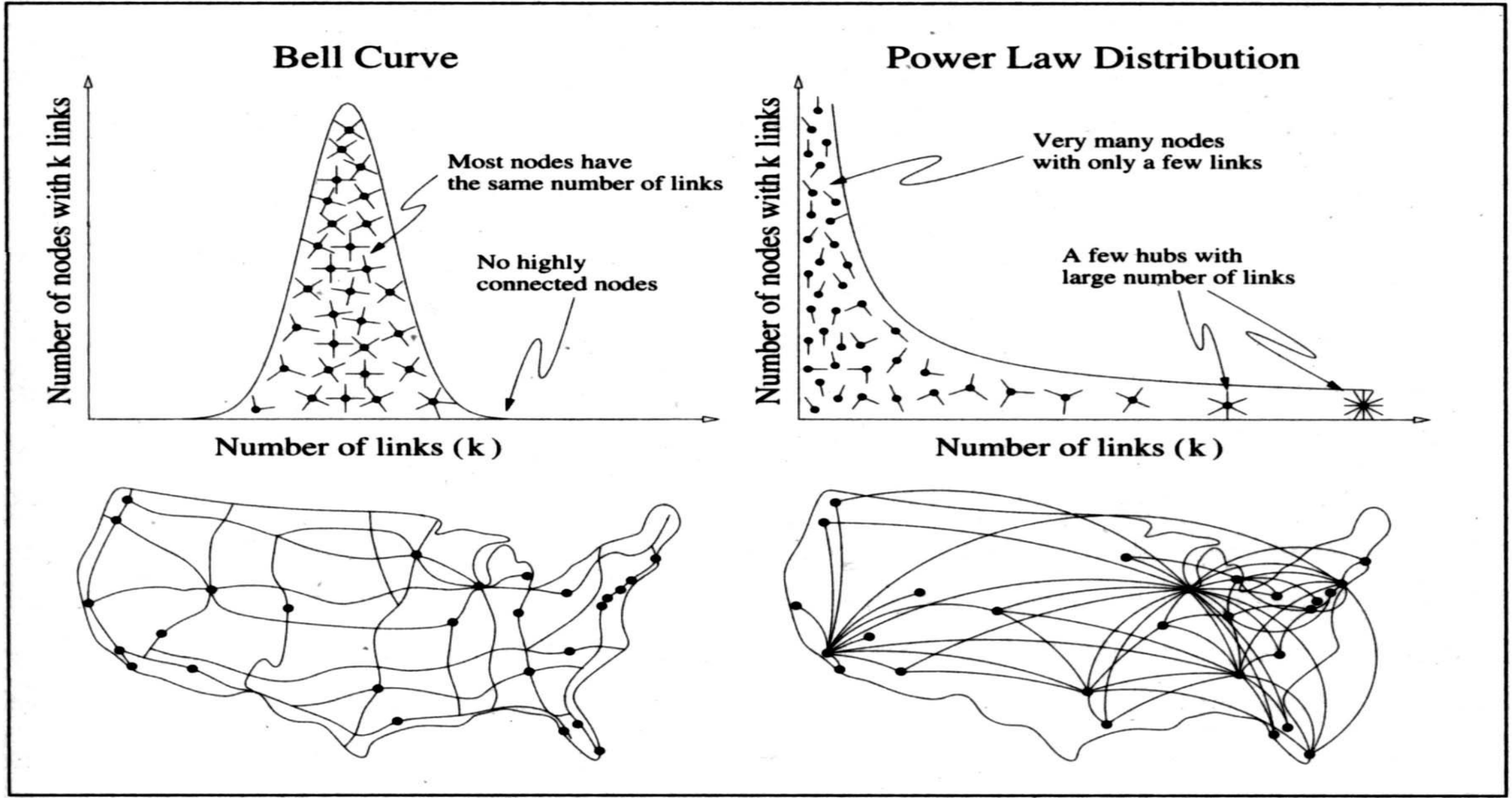




http://www.cis.upenn.edu/~mkearns/teaching/NetworkedLife/

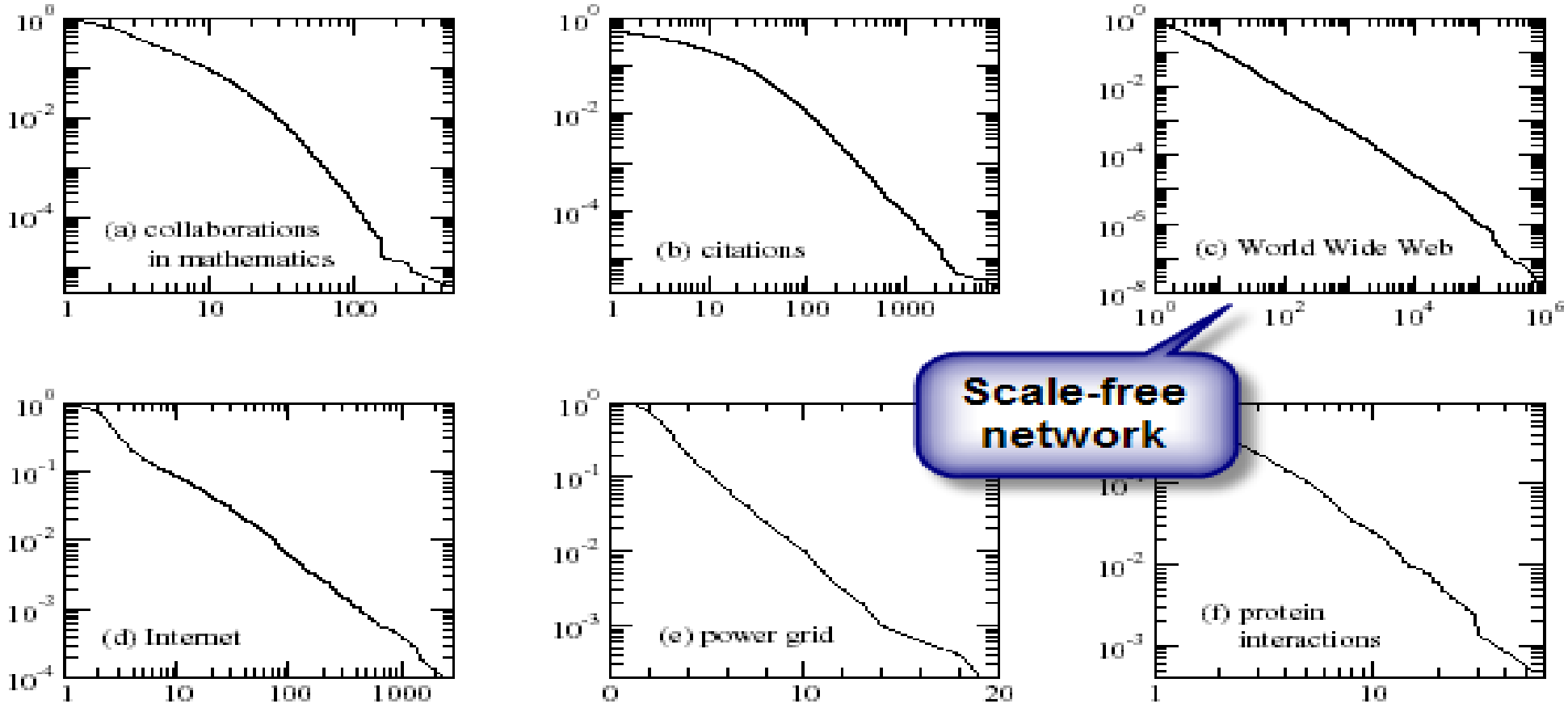
Math 3 – Scale-free networks

- Distribution of node degree follows a power law (scale free)
- Current understanding is that many networks grow according to a process of cumulative advantage (‘rich get richer’), this leads to the distinctive power law relationship



Reprinted from Linked: The New Science of Networks by Albert-Laszlo Barabasi

Degree distributions for some real networks



From Newman (2003)

Sex is scale-free

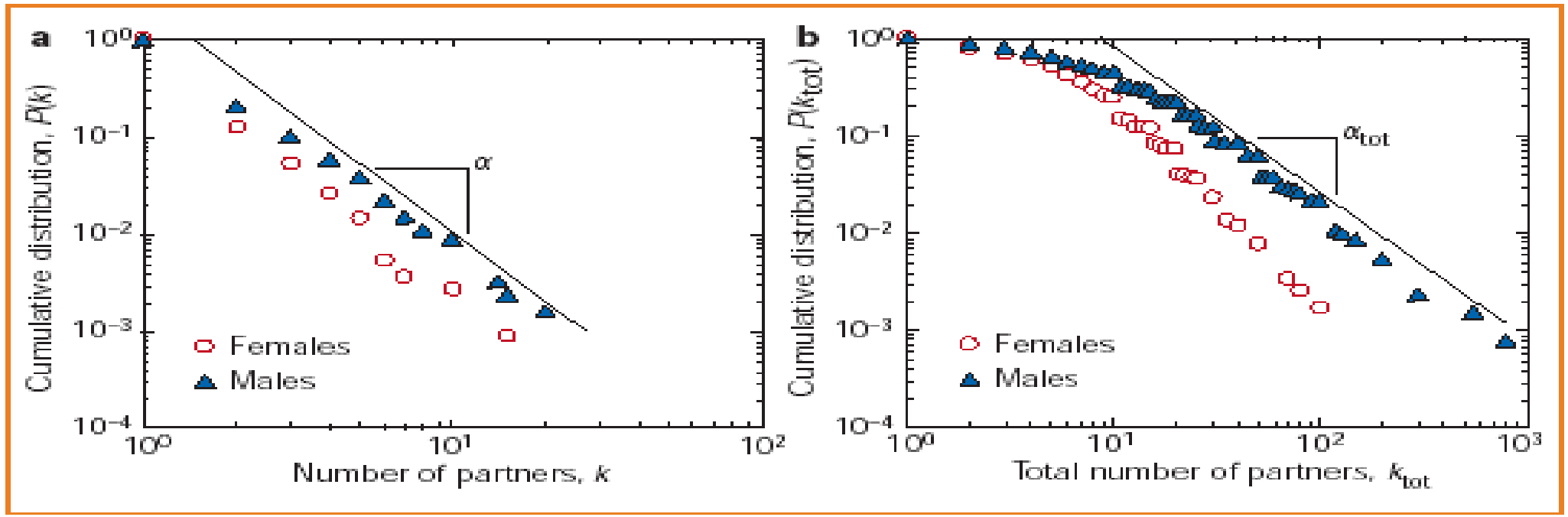
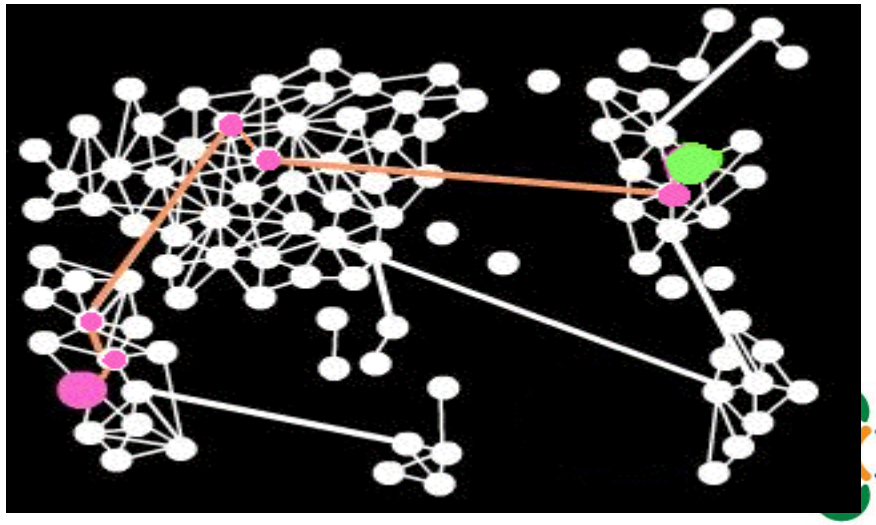


Figure 2 Scale-free distribution of the number of sexual partners for females and males. a, Distribution of number of partners, k, in the previous 12 months. Note the larger average number of partners for male respondents: this difference may be due to 'measurement bias' — social expectations may lead males to inflate their reported number of sexual partners. Note that the distributions are both linear, indicating scale-free power-law behaviour. Moreover, the two curves are roughly parallel, indicating similar scaling exponents. For females, $\alpha = 2.54 \pm 0.2$ in the range $k > 4$, and for males, $\alpha = 2.31 \pm 0.2$ in the range $k > 5$. b, Distribution of the total number of partners k_{tot} over respondents' entire lifetimes. For females, $\alpha_{tot} = 2.1 \pm 0.3$ in the range $k_{tot} > 20$, and for males, $\alpha_{tot} = 1.6 \pm 0.3$ in the range $20 < k_{tot} < 400$. Estimates for females and males agree within statistical uncertainty.

From Liljeros, et al. (2001). The web of human sexual contacts. *Nature, 411,* 907-908.

Milgram – Test of *Six Degrees*

- Stanley Milgram performed first formal study of the *Six Degrees* idea
  - Asked strangers to try to send a letter to a particular person in Boston
  - "If you do not know the target person on a personal basis, do not try to contact him directly. Instead, mail this folder to a personal acquaintance who is more likely than you to know the target person."
  - Found that most letters arrived taking around six steps (median 5.5).
  - Results have been critiqued, but replicated.



Net picture from Logan Scott

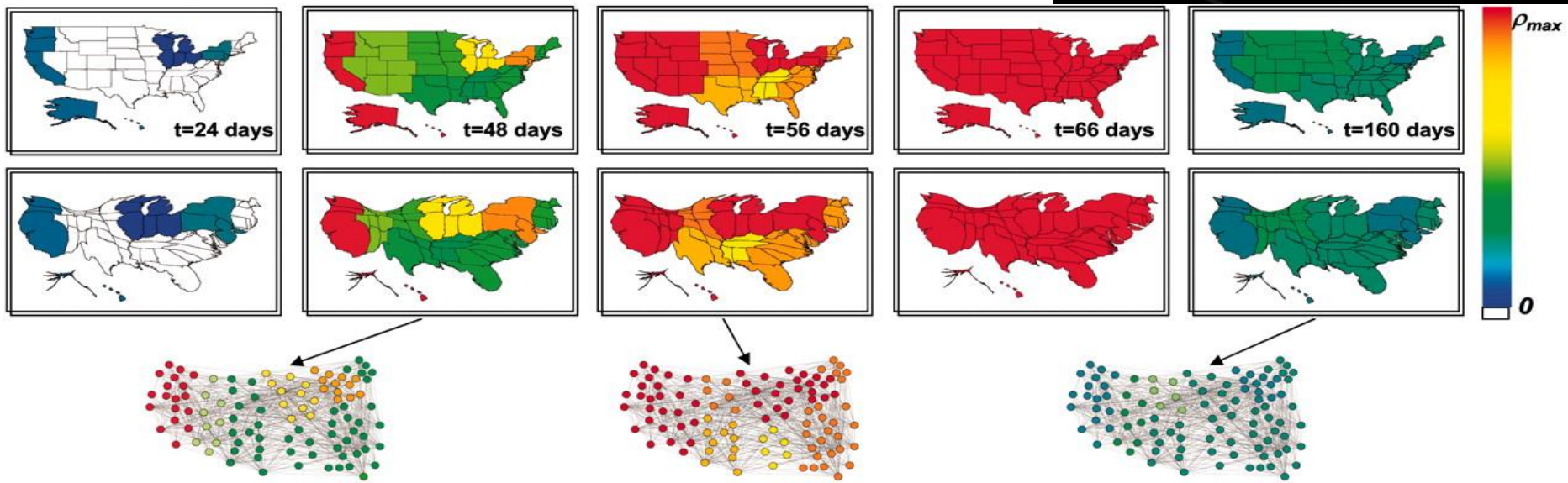
Granovetter – *Strength of weak ties*

- Are you more likely to find a job by asking a close personal friend, or by asking a casual acquaintance?
  - Mark Granovetter discovered that connections with acquaintances or distant contacts were more important for finding a job. Strong connections between close friends and colleagues are less likely to lead to new information.
  - *Strength of Weak Ties* one of the most cited articles in sociology

Modern history

- Computer methods: algorithms, software, visualization, large-scale databases
- Physics rediscovers network analysis
- Interest in very large networks
- Integration of network analysis into statistical theory

Geographical representation of the disease evolution in the United States for an epidemics starting in Hong Kong based on a SIR dynamics within each city.



Vittoria Colizza et al. PNAS 2006;103:2015-2020

Tipping point

- Paradigm shift, networks enters into mainstream consciousness
- Kevin Bacon, Six Degrees
- Role of the Internet
  - Amazon
  - MySpace, Facebook, Instagram
- Networks seen as way to understand (and change) terrorism, global warming, integrated circuit design, etc.

Ways to view network analysis

Social network analysis can be viewed as a methodology, and set of theories, a paradigm, and as a discipline

Theories of networks

- Development of theories explaining network formation, network structure, effects of networks on individuals, etc.
- Example, social science theories of communication networks (Monge & Contractor, 2003)
  - Self-interest & collective action
  - Contagion
  - Cognitive
  - Exchange, dependency
  - Homophily, proximity
  - Social support
  - Evolutionary

Ways to view network theory

- Connected to, but distinct from many social science theories
  - See http://lrs.ed.uiuc.edu/tse-portal/analysis/social-network-analysis/#network%20theories
- Networks as predictors, networks as outcomes, co-evolution of network structure and (health) behavior
- Simple example from Contractor
  - It is *who* you know…
  - It is what who you know *knows*…
  - It is what you *think* who you know knows…

Network analysis as a paradigm

- Paradigm in the Kuhnian sense
- Paradigmatic lenses for network analysis
  - Reductionism vs. holism
  - Individual (survey) approach vs. social groups, contexts
  - Linear science vs. systems science

SNA as a discipline

- Characteristics of field (Freeman, 2004)
  - Social network analysis is motivated by a structural intuition based on ties linking social actors
  - It is grounded in systematic empirical data
  - It draws heavily on graphic imagery
  - It relies on the use of mathematical and/or computational models
- Distinctive theories and methods

Professional organizations & outlets

- Professional organization
  - International Network of Social Network Analysis
  - http://www.insna.org
- Scientific outlets
  - *Social Networks*
  - *Connections*
  - Sunbelt International Social Network Conference