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GE2234 Social Networks

for Media, Business and Technological Applications

Lecture Note 7: Small-World Phenomenon

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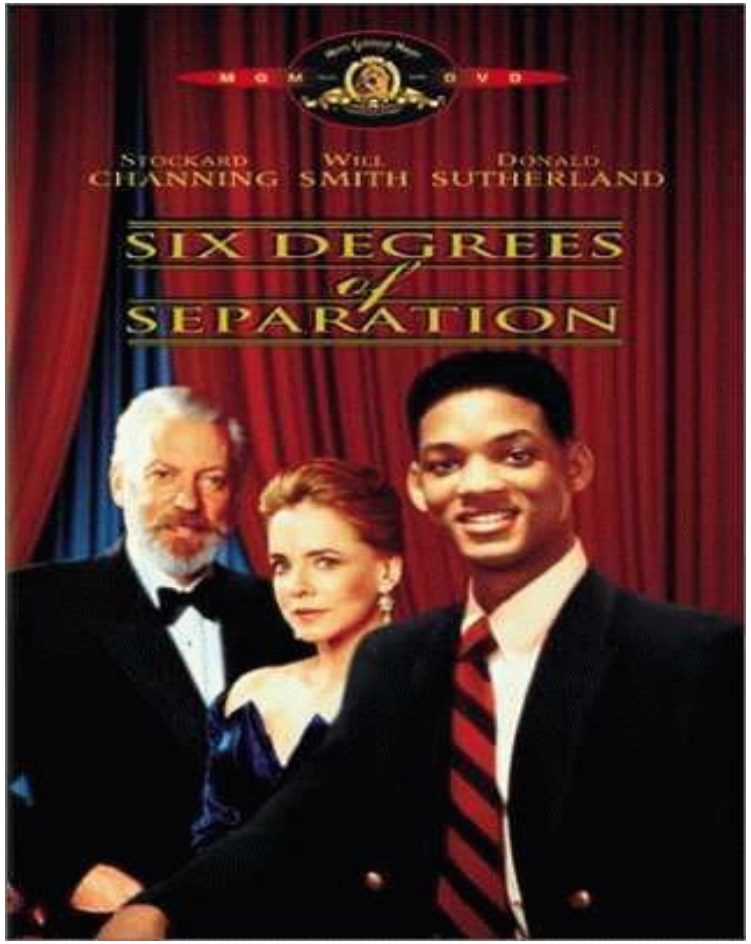
Small World Phenomenon

Small World Phenomenon

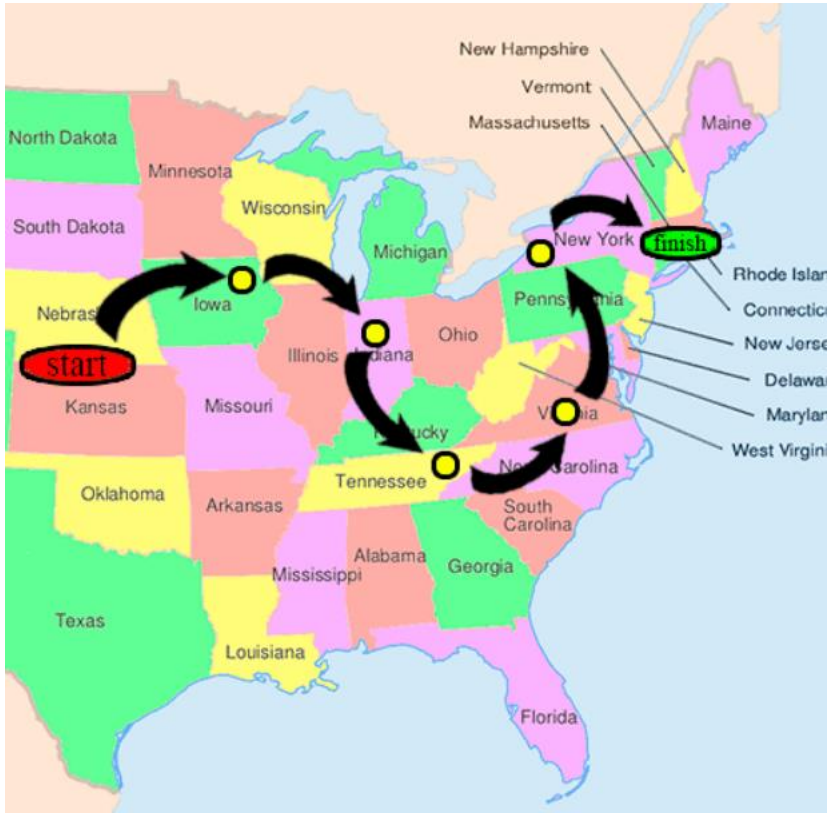
“Everybody on this planet is separated by only six other people. Six degrees of separation between us and everyone else on this planet. The President of the United States, a gondolier in Venice, just fill in the names.”

----Six degrees of separation



Milgram's experiment (1960s)

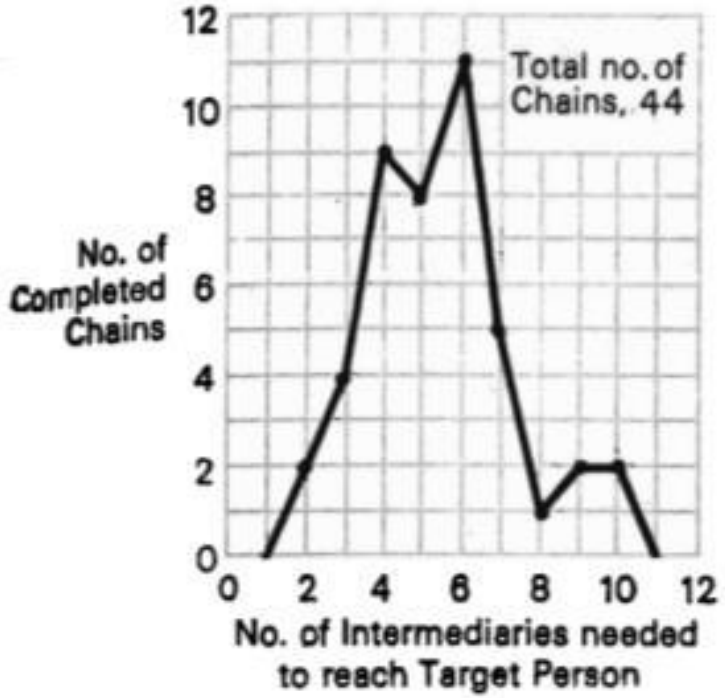
- Choose a random person in Nebraska, e.g. Bob;
- Ask Bob to deliver a letter to a random person in Massachusetts;
- Tell Bob target's name, location, and occupation
- Instruct Bob to only send letter to a single acquaintance he knows on a first-name basis, with the goal of reaching the target as rapidly as possible



Milgram's experiment

- Initial success rate was very low (5%). The follow-up experiments made some modifications of the original experiment.
- The outcome of the experiment led to the term: six degrees of separation

- Over many trials, the **average number** of intermediate steps in a successful chain was found to lie between 5 and 6.



The Kevin Bacon Game

- Kevin Bacon has been in 56 movies so far
- In January 1994, Bacon's movie *The Air Up There* was airing on TV and he mention that "he had worked with everybody in Hollywood or someone who's worked with them."
- News headed: "**Kevin Bacon is the Center of the Universe**"
- Then, three men were invited to appear on CNN TV Show *Stewart Show* with Bacon; they tried to connect Bacon to any randomly picked actor or actress in the Hollywood
  - Anybody who has acted in a film with Bacon has a bacon number of 1; anybody who does not have a bacon number 1 but has worked with somebody who does, they have bacon number 2, and so on

Kevin Bacon's Six Degrees Secret

- Result: Every actor in the Hollywood could be connected to Kevin Bacon, with typically 2 to 3 connections
- Given that there are about 225,000 such people, this is remarkable.

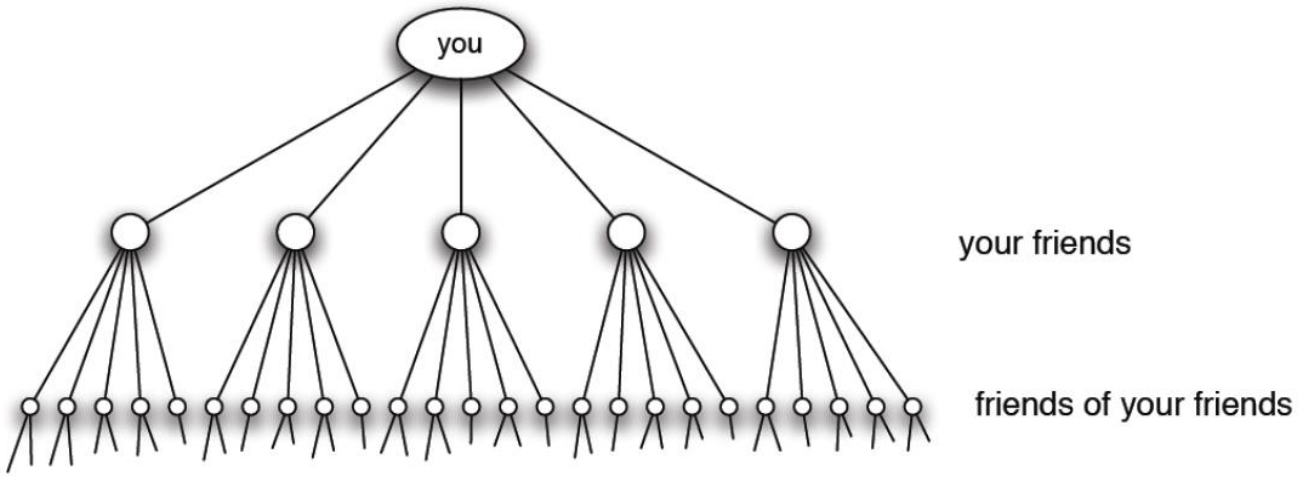
How good a center is Kevin Bacon ?

Kevin Bacon Number	# of People
0	1
1	3303
2	381495
3	1383150
4	356429
5	30815
6	3640
7	584
8	116
9	26
10	1

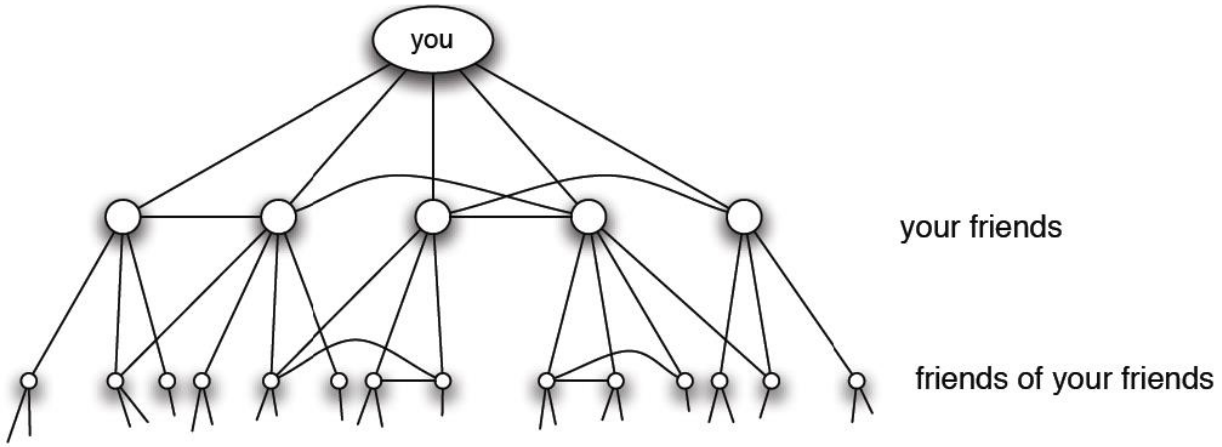
Total number of linkable actors: 2159560
Weighted total of linkable actors: 6522634
Average Kevin Bacon number: 3.020

Two Striking Facts

- Short paths are there in abundance – Watts & Strogatz (1998, *Nature*)
- People, acting without any sort of global “map” of the network, are effective at collectively finding those short paths – Kleinberg (2000, Nature)



- Exponential Growth of Network Size

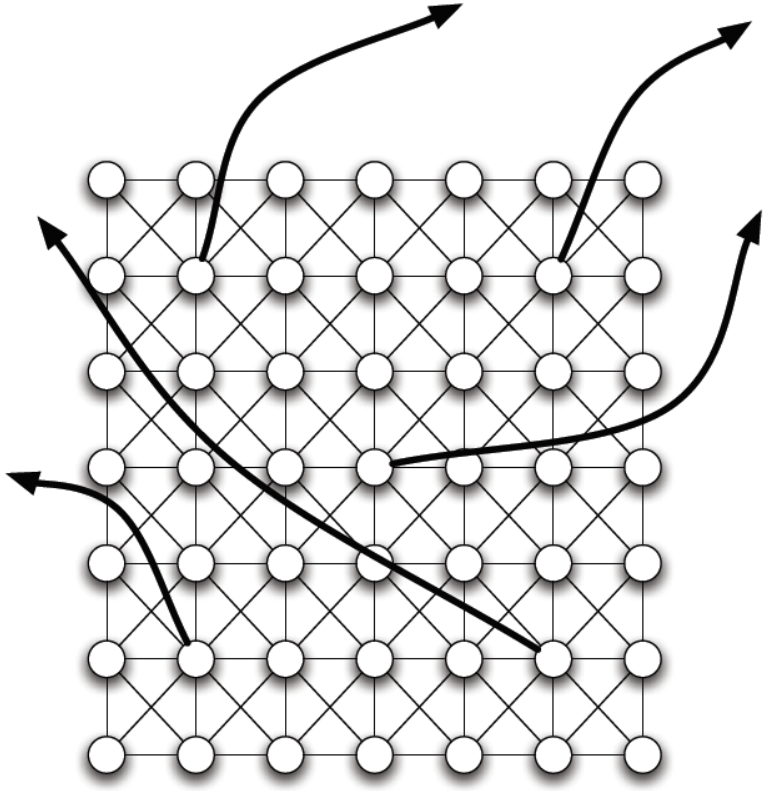


- However…
- Triadic closure will reduce the growth rate
- Locally, our friendship networks are highly clustered
- Globally, we can reach each other along very short paths

Formal Account of Small-World Network (Watts & Strogatz, 1998, *Science*)

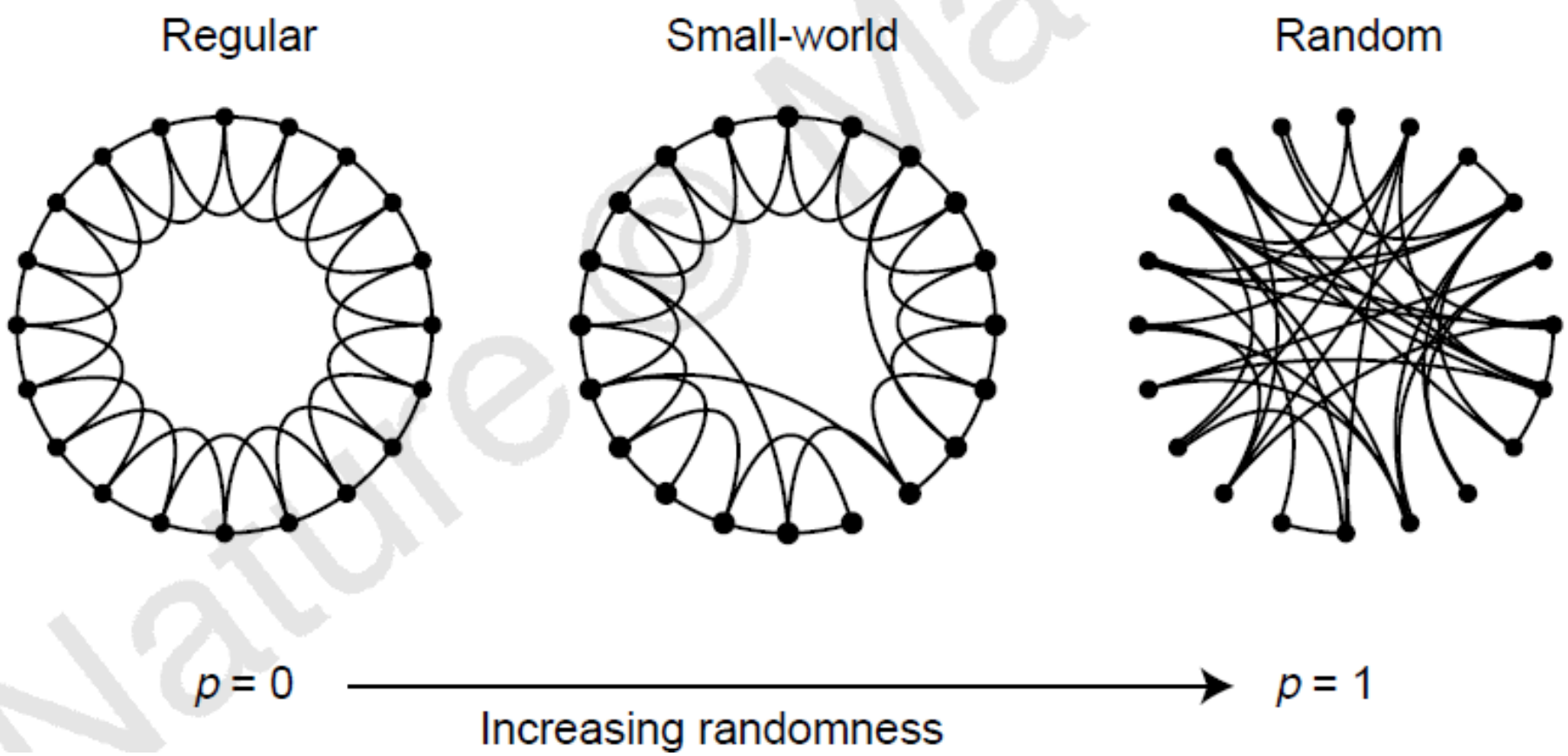
- Two network characteristics for small world
  - Homophily (Triadic Closure)
  - Weak Ties (the links to acquaintances that connect us to parts of the network that would otherwise be far away) -> Widely branching structure that can reach many nodes in a few steps

- Combination of homophily and weak ties will lead to the formation of small-world phenomenon which is characterized by:
  - large clustering coefficients
  - short node-to-node distance

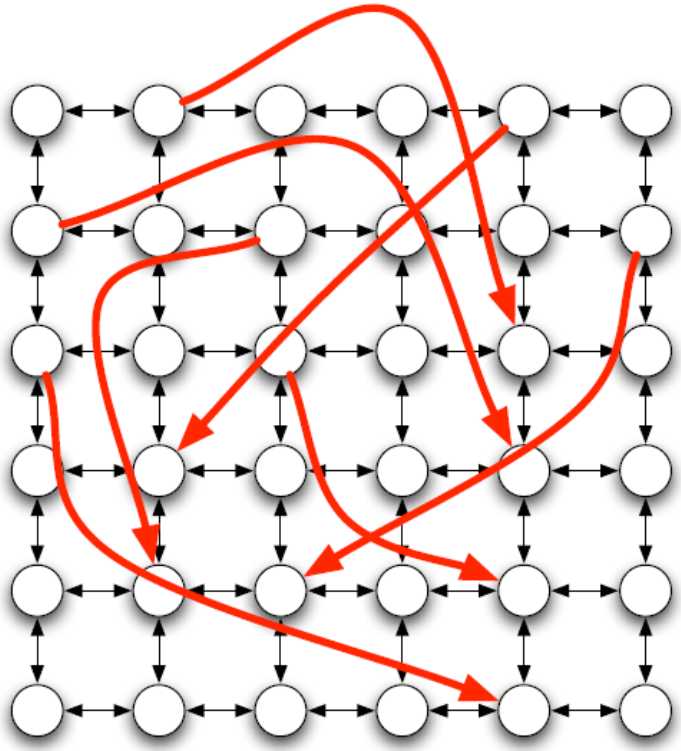


Watts-Strogatz Model (1998, Nature)

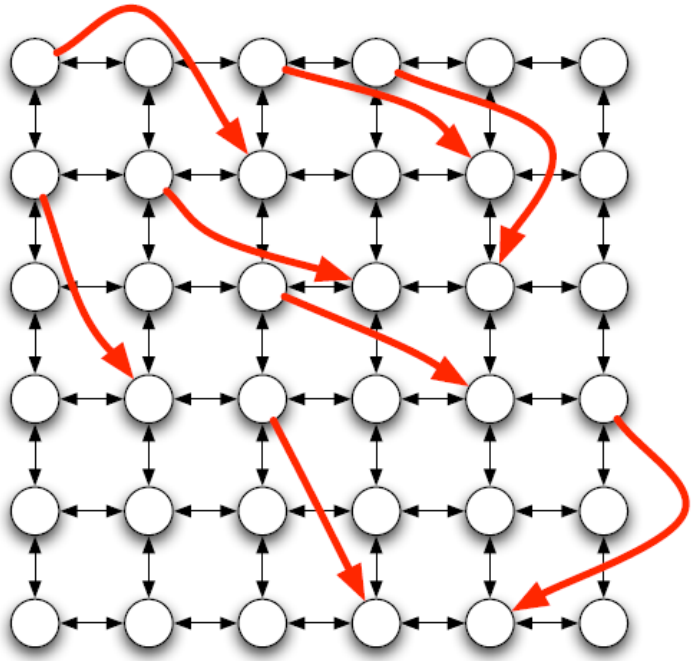
The crux of Watts-Strogatz model: introducing a tiny amount of randomness –in the form of weak ties –is enough to make the world "small," with short paths between every pair of nodes



- even if we posit that the social network contains short paths, why should it been effective for people collectively finding those short paths ?
- “the structure of the **long-range connections** forms a type of gradient that allows individuals to guide a message efficiently towards a target. .” ----Kleinberg, 2000, Nature



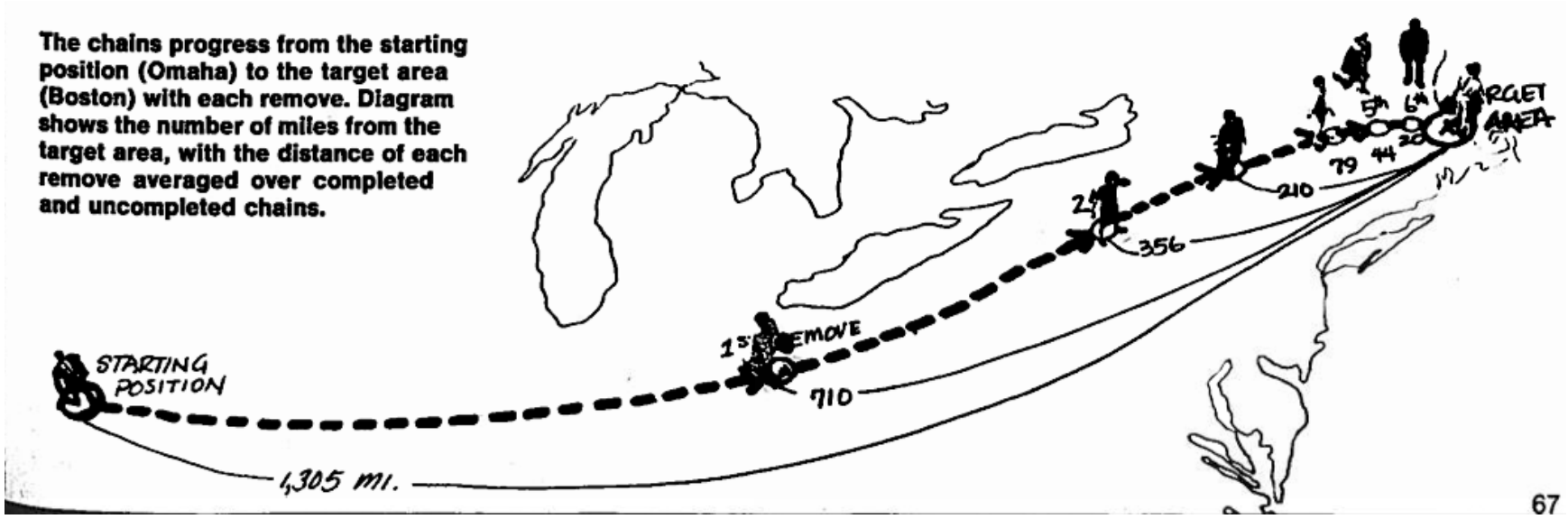
(a) *A small clustering exponent*



(b) *A large clustering exponent*

Effective of searching the short paths

- use long-range weak ties in a fairly structured, methodical way, constantly reducing the distance to the target.



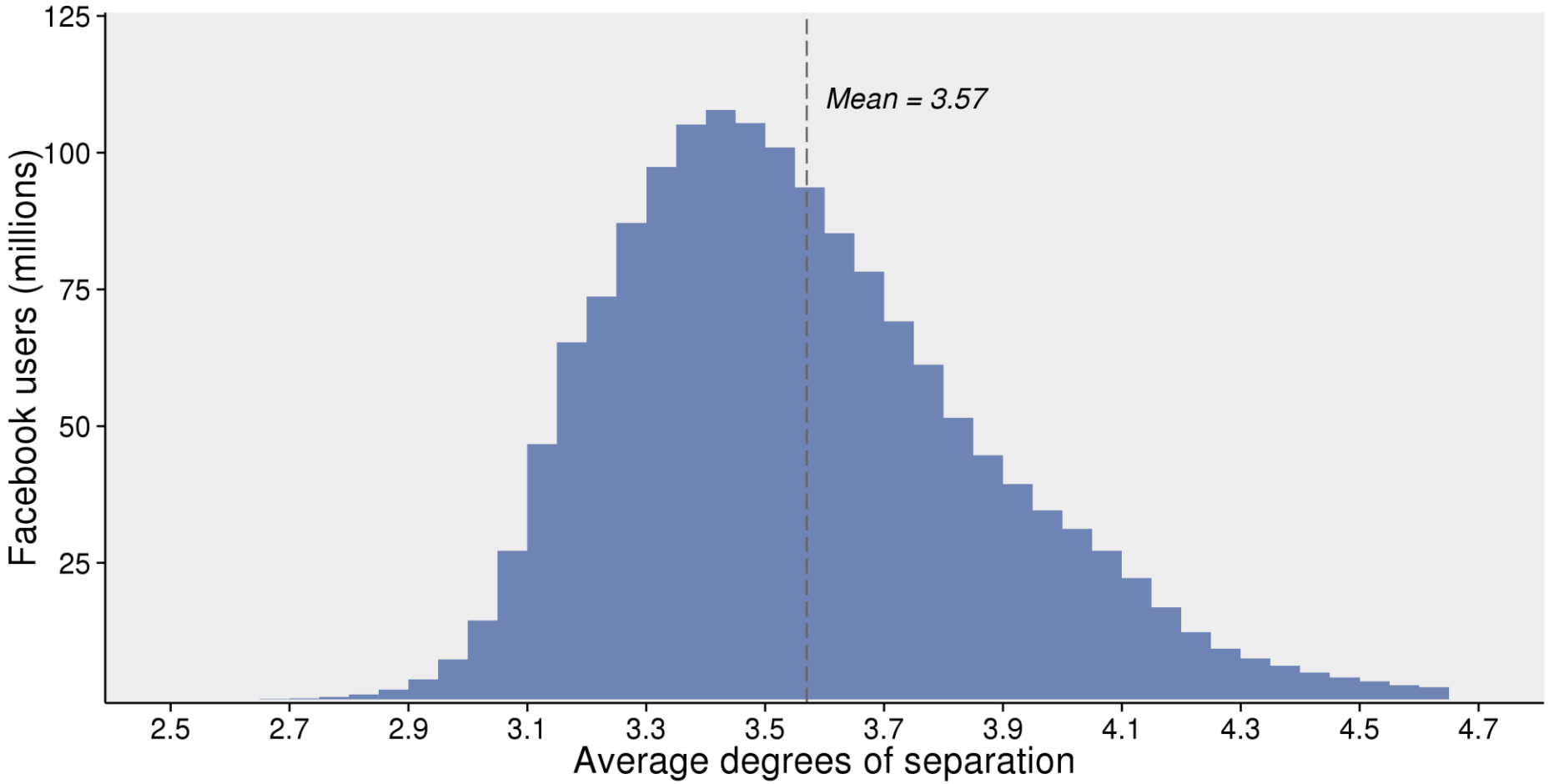
Is Internet making us better connected?

3.5 degrees of separation on FB

- Each person in the world (at least among the 1.59 billion people active on Facebook) is connected to every other person by an average of three and a half other people.

- https://research.fb.com/blog/2016/02/three-and-a-half-degrees-of-separation/

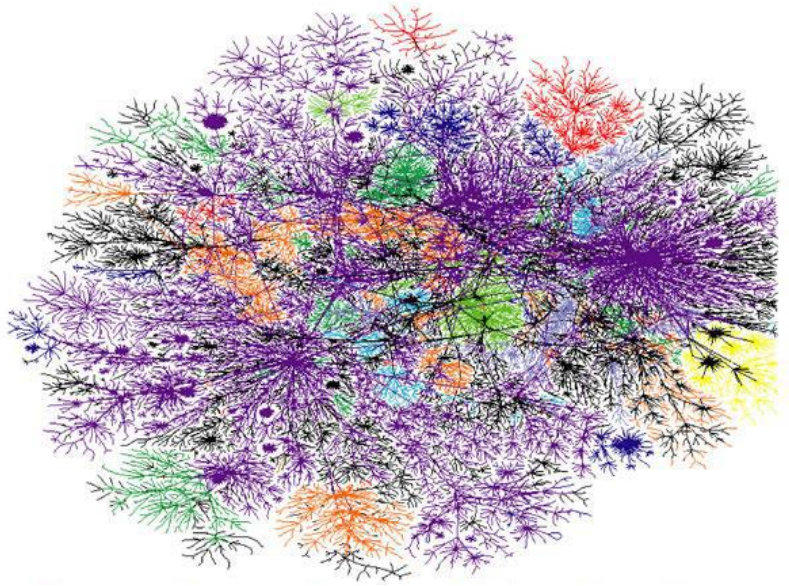
3.5 degrees of separation on FB

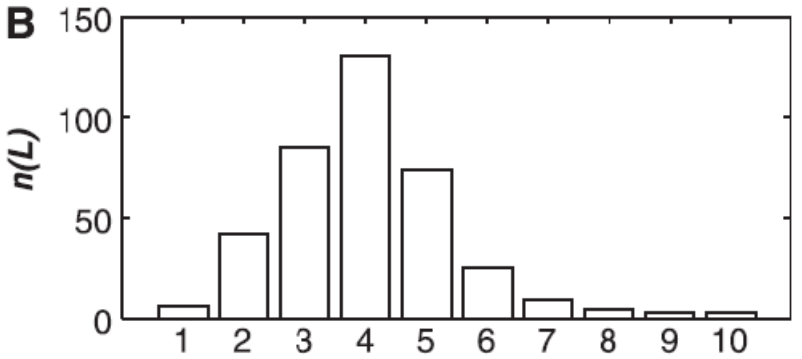


https://research.facebook.com/blog/three-and-a-half-degrees-of-separation/

Milgram's Experiment Repeated (Dodds et al., 2003, *Science*)

- In the study, more than 60,000 e-mail users attempted to reach one of 18 target persons in 13 countries by forwarding messages to acquaintances
- 24,163 message chains
- 384 reached their targets average path length 4.0

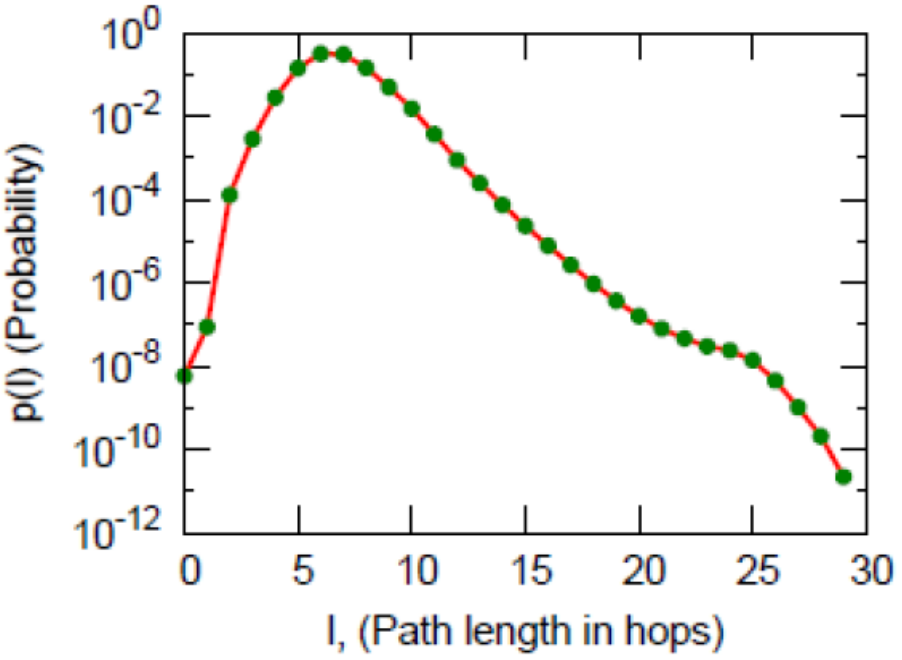




The number of chains that are completed in *L* steps

Milgram's Experiment Repeated (Leskovec & Horvitz, 2008, WWW)

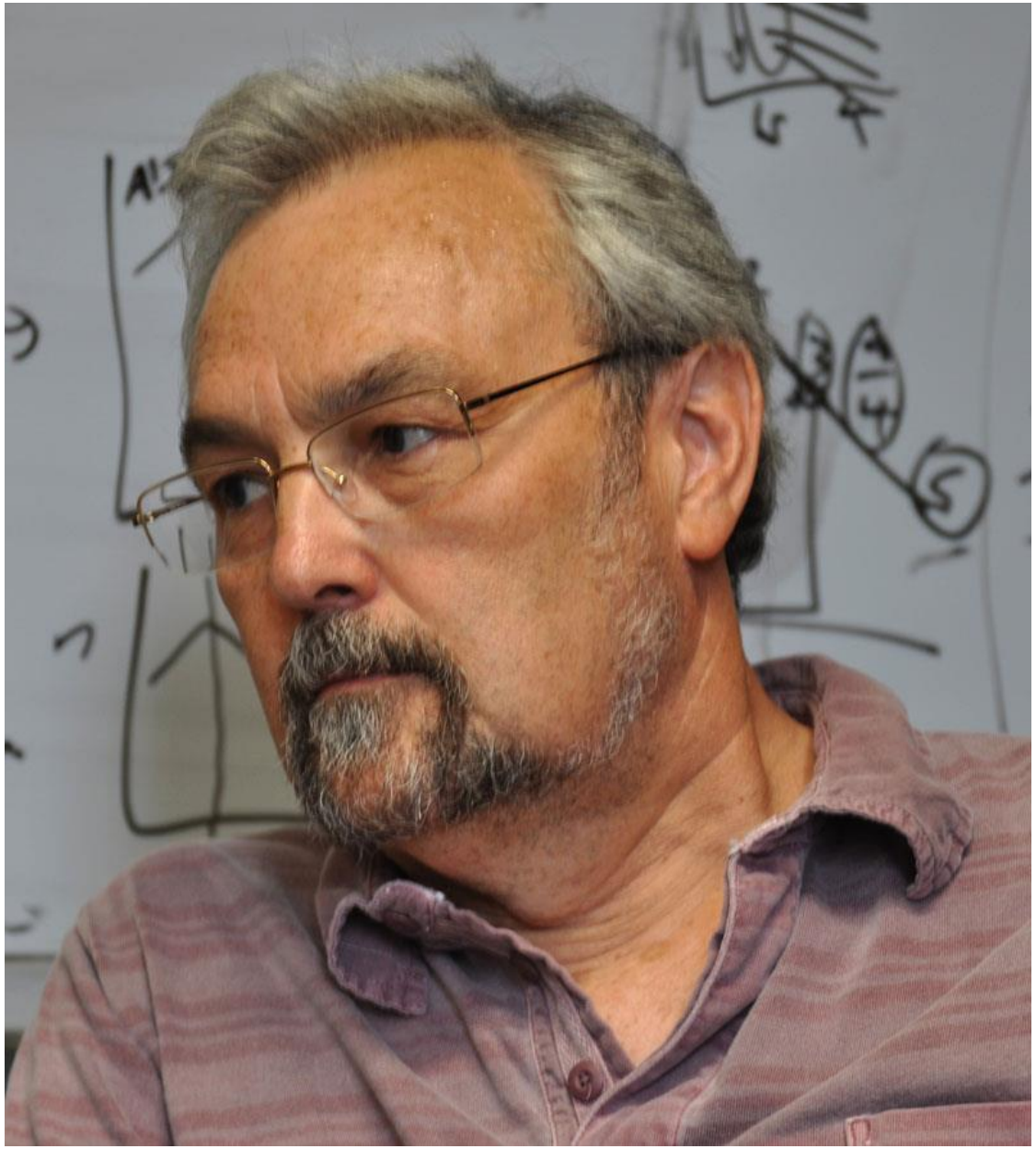
- 240 million active user accounts on Microsoft Instant Messenger
- Edge between two users if they engaged in a two-way conversation at any point during a month-long observation period
- Average distances within this communication network were very small (average distance of 6.6)



Is social media breaking the limit on the size of our social groups?

Why do we have language?

- Because it made hunting easier
- Because it made knowledge transfer easier
- Because it made us able to attract potential mates
- …



http://www.cabdyn.ox.ac.uk/complexity_images/profile_photos/R_Dunbar_web.jpg

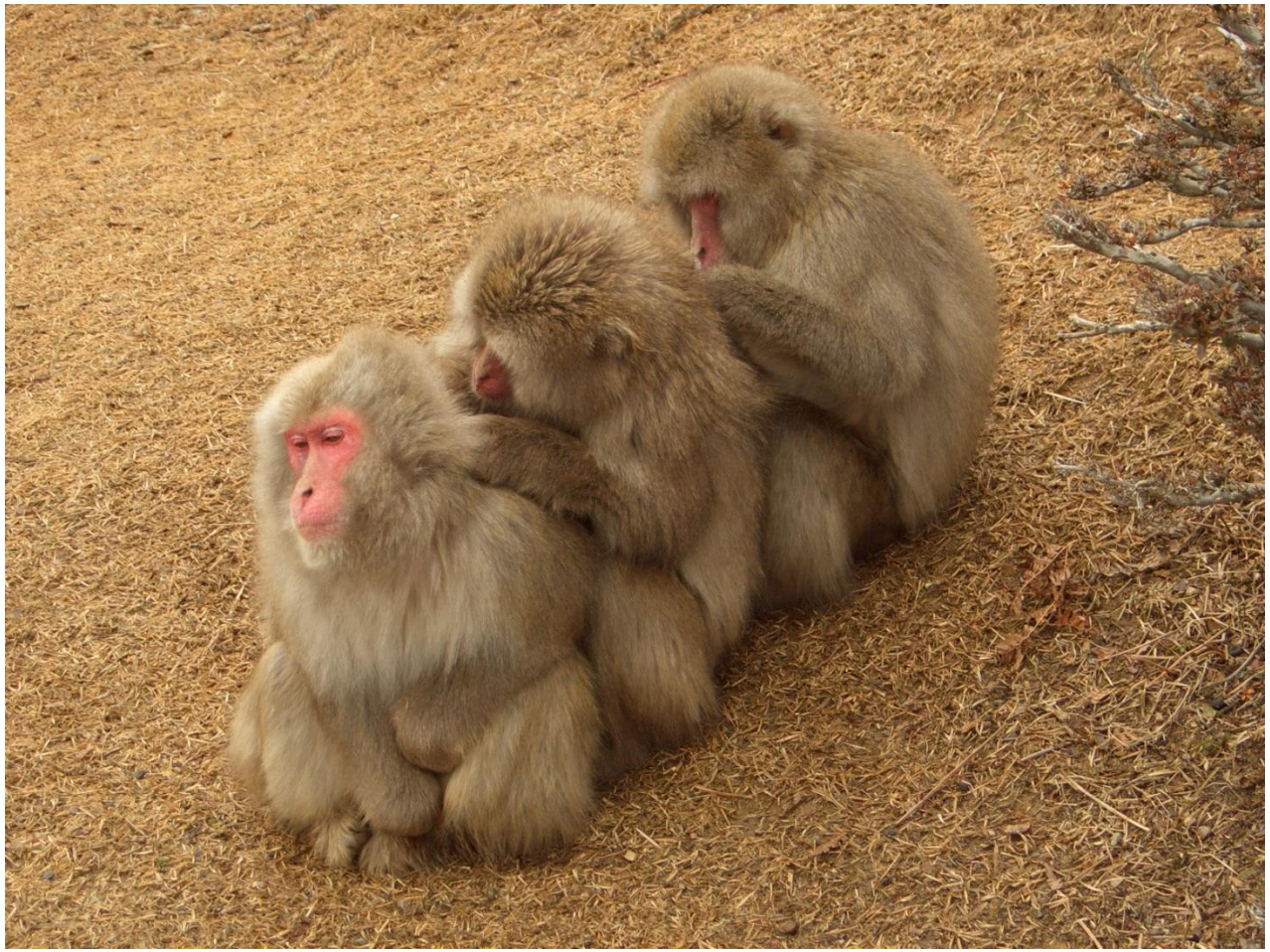
Evolutionary perspective

“Because it made us able to gossip”

- Robin Dunbar

Utility of Grooming

- To reconfirm the boundary of ingroup
  - Who can be trusted?
  - Who reciprocates my favor?
  - Who are the free riders?
- Grooming is physically constrained
  - Time, geographical area, energy, etc.
  - Human being invented languages to gossip as a substitute of grooming (social brain hypothesis)



https://en.wikipedia.org/wiki/Japanese_macaque

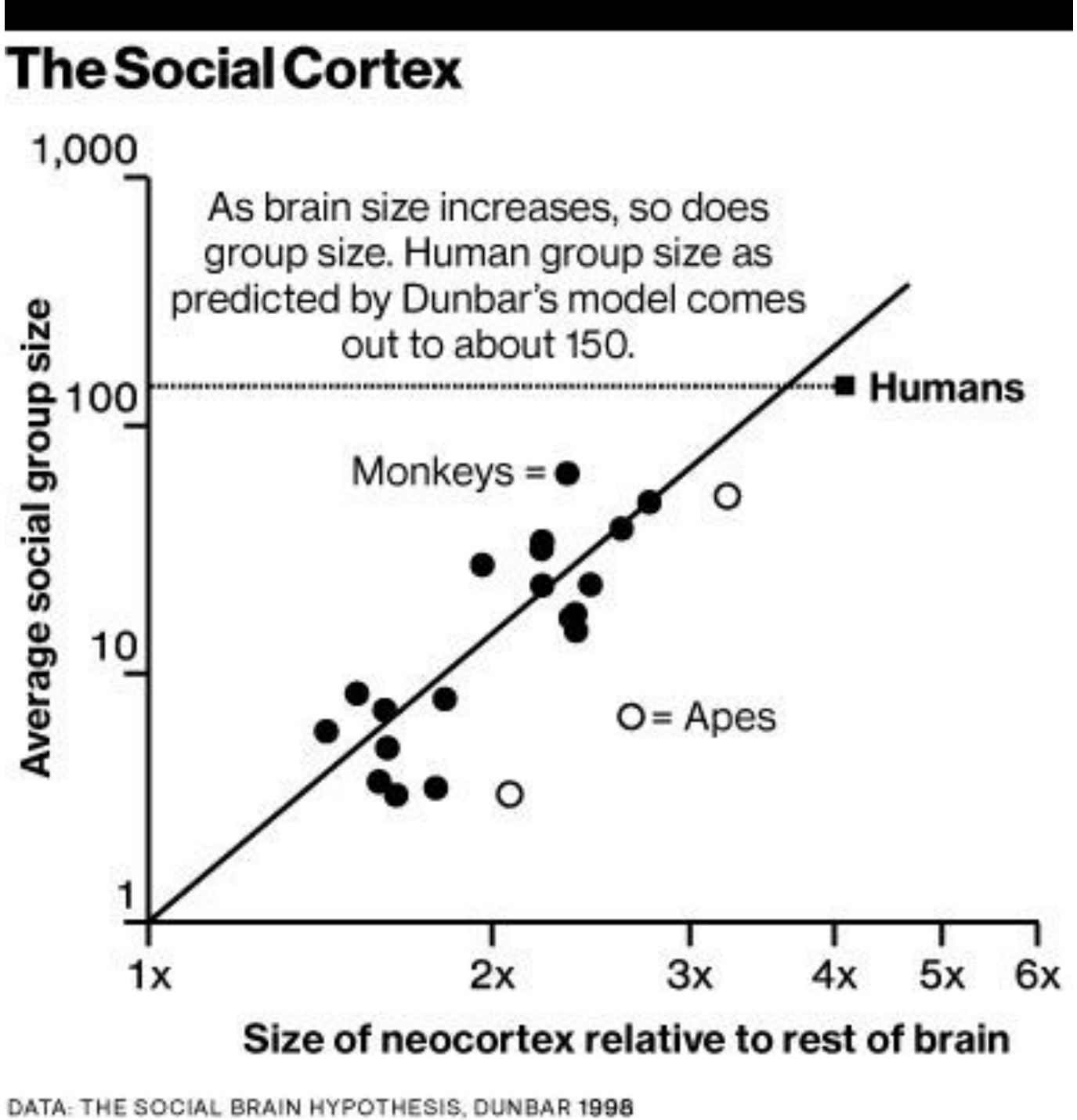
Natural selection

- Those who gossip with a language can
  - know who's trustworthy
  - know who reciprocate your favor
  - avoid untrustworthy people
  - without physical constraints

- More food, more safety, more mating partners, etc.
- More babies!

However,
we cannot gossip about unlimited number of friends

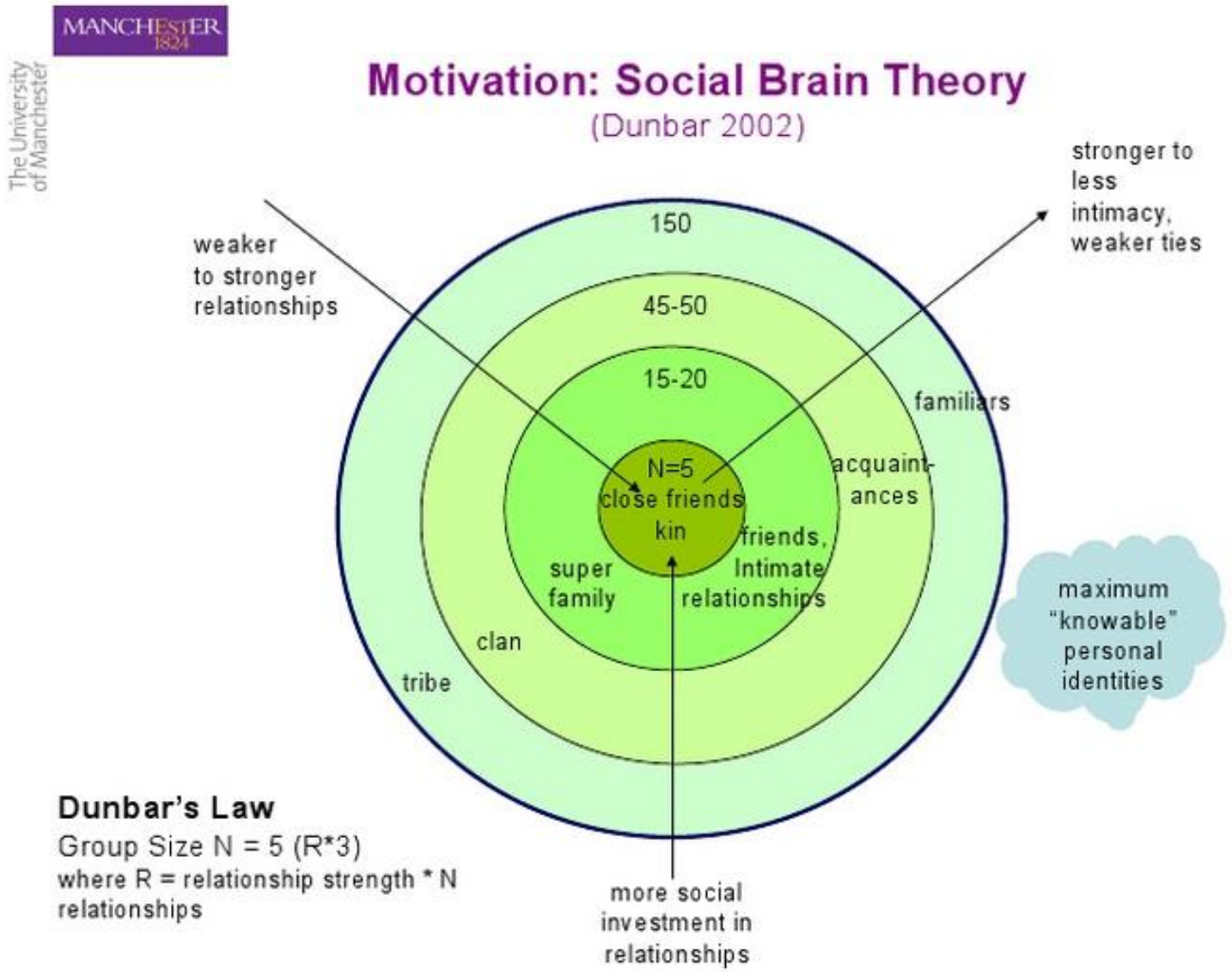
Social Brain Hypothesis



Real Friends (Offline)

- Dunbar's number = 148
  - "this limit is a direct function of relative neocortex size, and that this in turn limits group size ... the limit imposed by neocortical processing capacity is simply on the number of individuals with whom a stable inter-personal relationship can be maintained."

Dunbar's Law

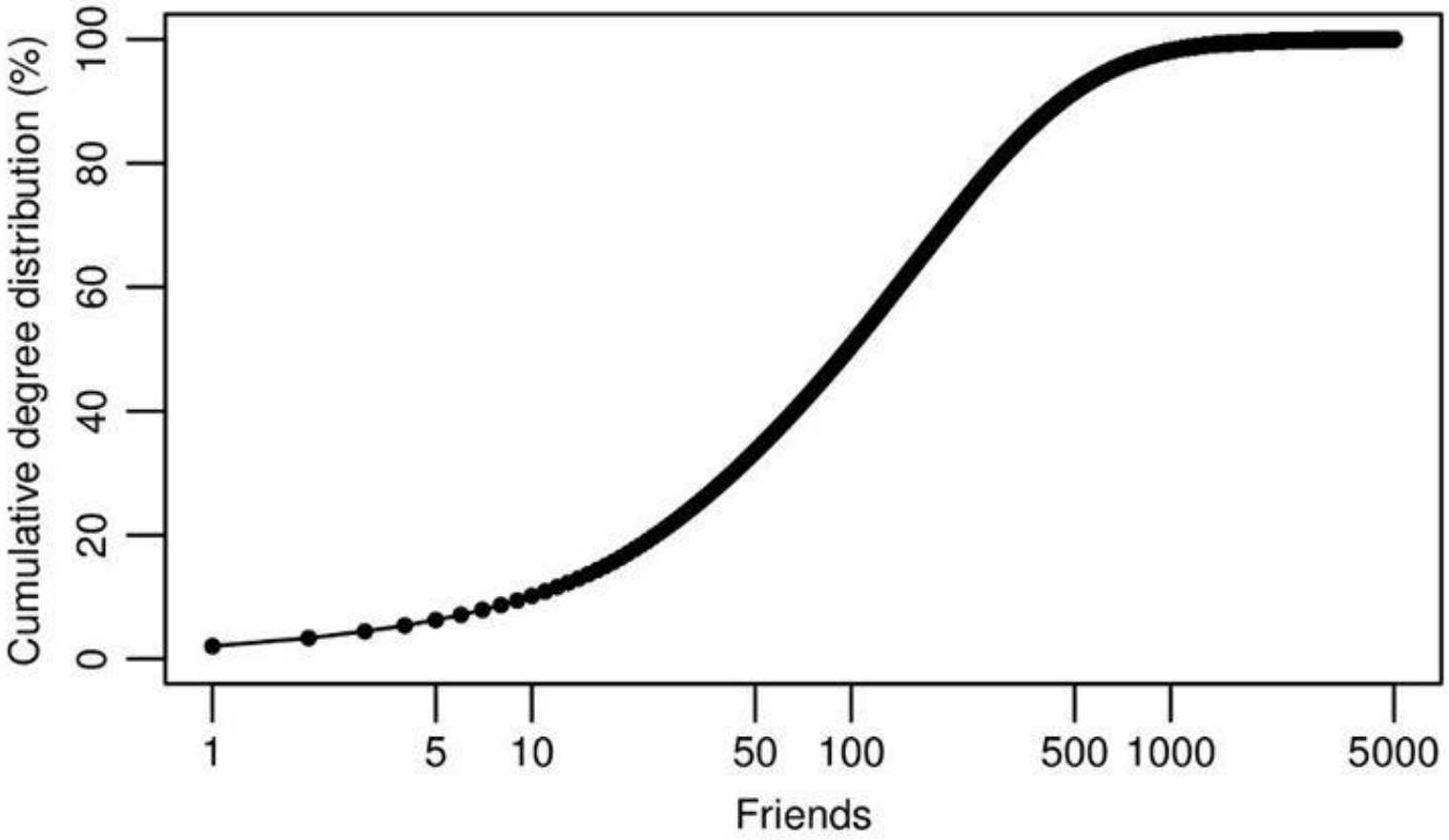


http://anarchism.pageabode.com/andrewnflood/anarchist-organising-dunbars-number

Dunbar’s number

- 150 as the estimated size of a Neolithic farming village
- 150 as the splitting point of Hutterite settlements
- 200 as the upper bound on the number of academics in a discipline’s sub-specialization
- 150 as the basic unit size of professional armies in Roman antiquity and in modern times since the 16th century
- 150 as the notions of appropriate company size

of “friends” on Facebook

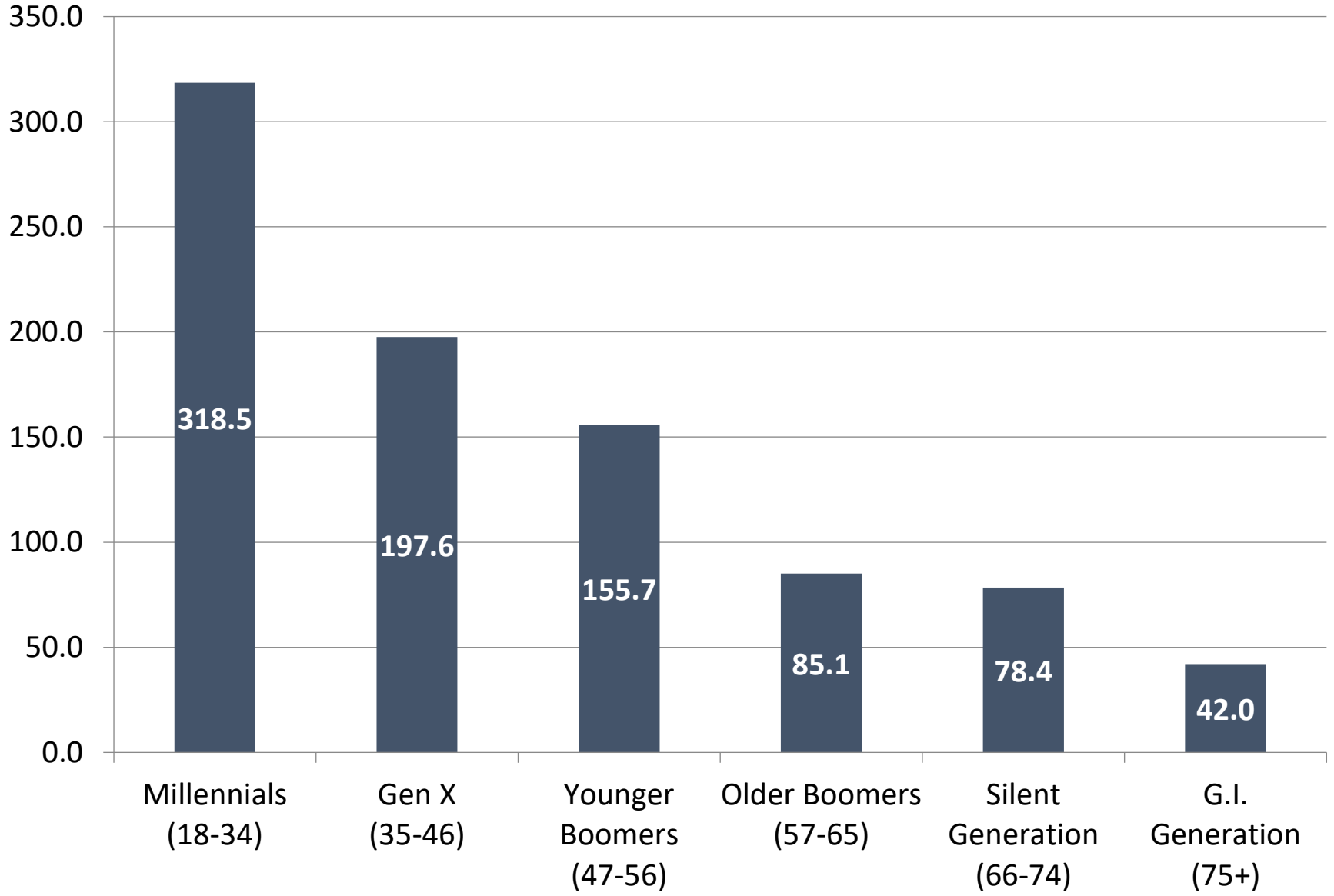


721 million active Facebook users (more than 10% of the global population), with 69 billion friendships among them as of 2011.

Mean = 190, Median = 100

https://www.facebook.com/notes/facebook-data-science/anatomy-of-facebook/10150388519243859/

Mean size of Facebook friends network



Source: Pew Research Center's Internet & American Life Project, October 20-November 28, 2010 Social Networking survey.

Connected, but alone?

- Sherry Turkle: Connected, but alone?