Why your friends have more friends than you do?

Friendship paradox in complex networks

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Definition

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The mean number of friends of friends is always greater than mean number of friends of individuals, for any given social network.

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...stands in contradiction to what most people believe

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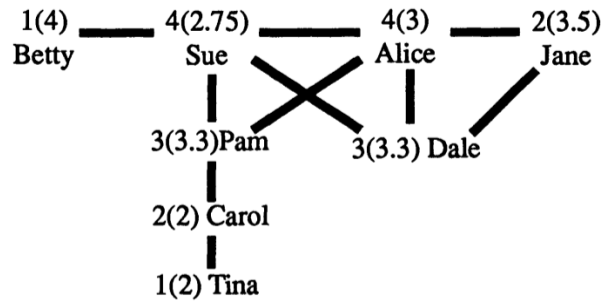
Real world example (Marketville High School)



The number beside each name is her number of friends. The number in parentheses beside each name is the mean number of friends of her friends.

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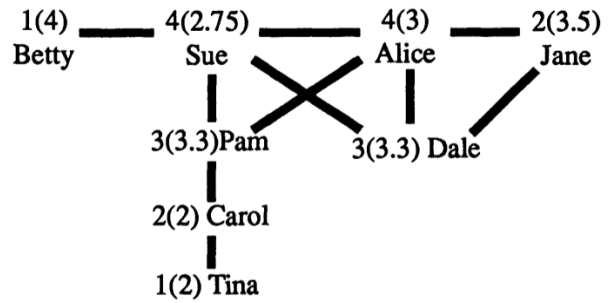

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A SUMMARY OF THE NUMBERS OF FRIENDS AND THE MEAN NUMBERS OF FRIENDS OF FRIENDS FOR EACH OF THE GIRLS IN FIGURE 1

	Number of Friends (x_i)	Total Number of Friends of Her Friends (Σx_j)	Mean Number of Friends of Her Friends ($\Sigma x_j/x_i$)
Betty	1	4	4
Sue	4	11	2.75
Alice	4	12	3
Jane	2	7	3.5
Pam	3	10	3.3
Dale	3	10	3.3
Carol	2	4	2
Tina	1	2	2
Total	20	60	23.92
Mean	2.5*	3†	2.99*

- Paradox “holds” for the network
- Paradox “holds” for 5 out of 8 individuals

- 80:25:41 ratio for entire network (146 girls)

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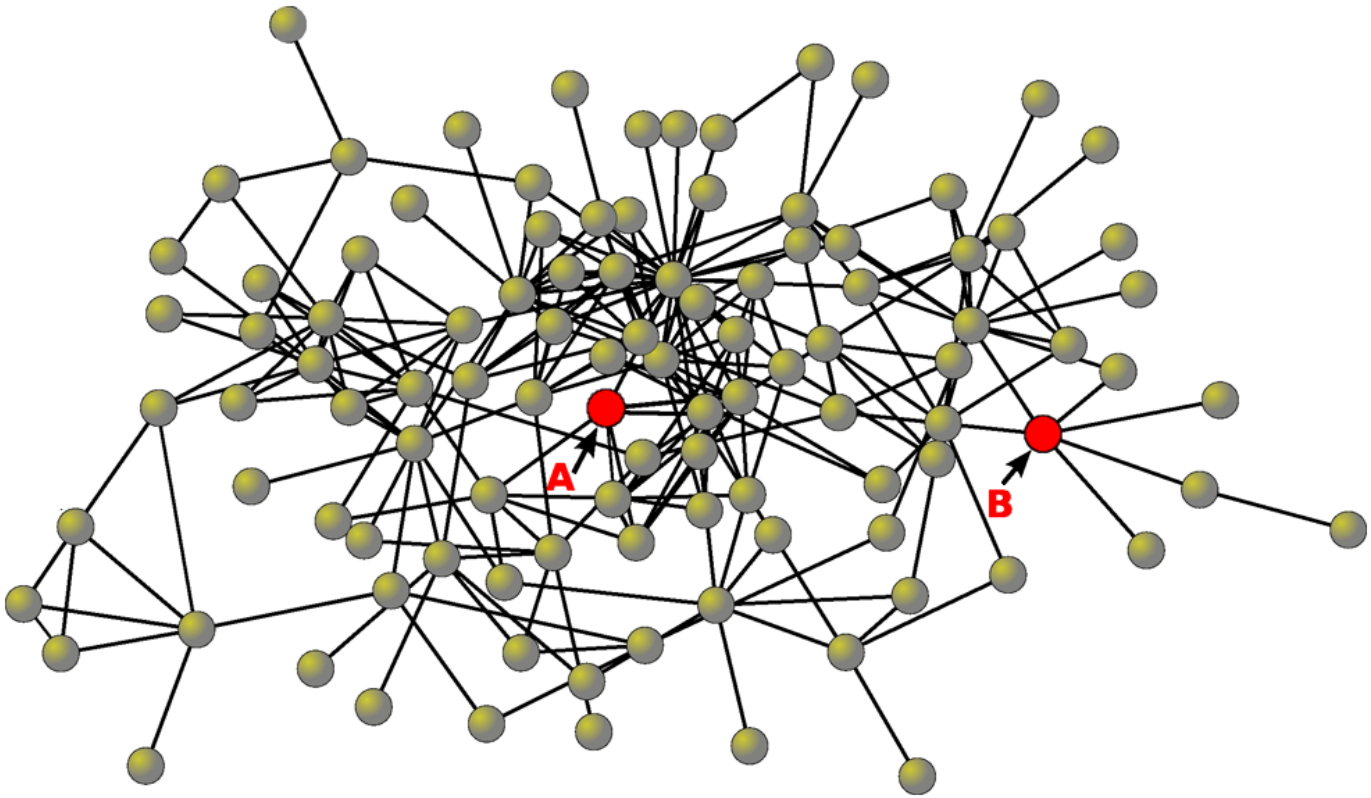
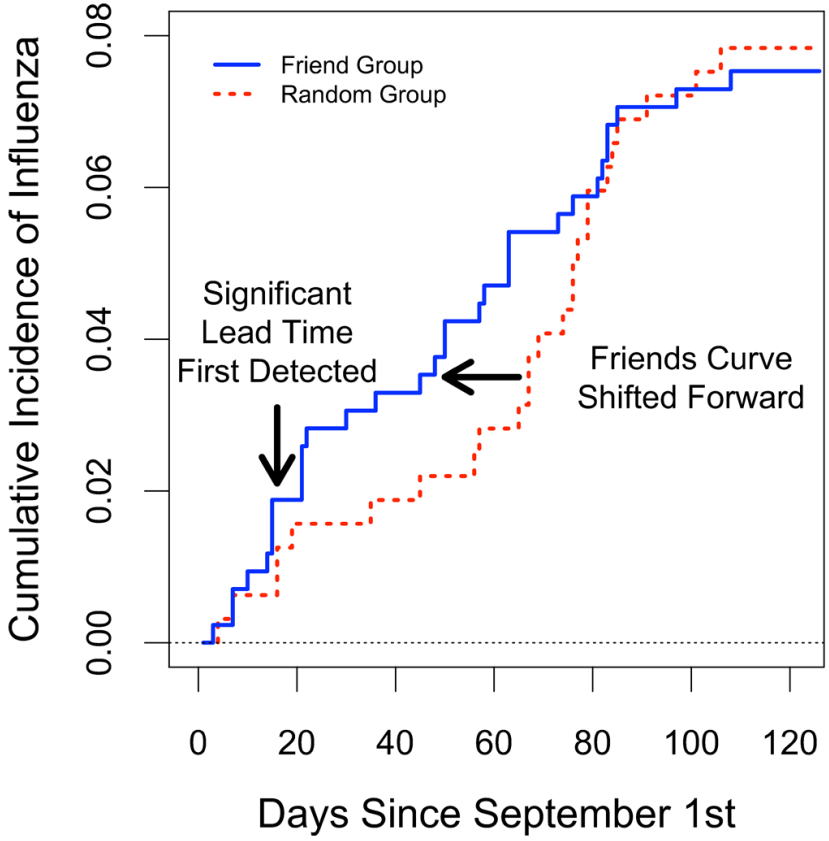
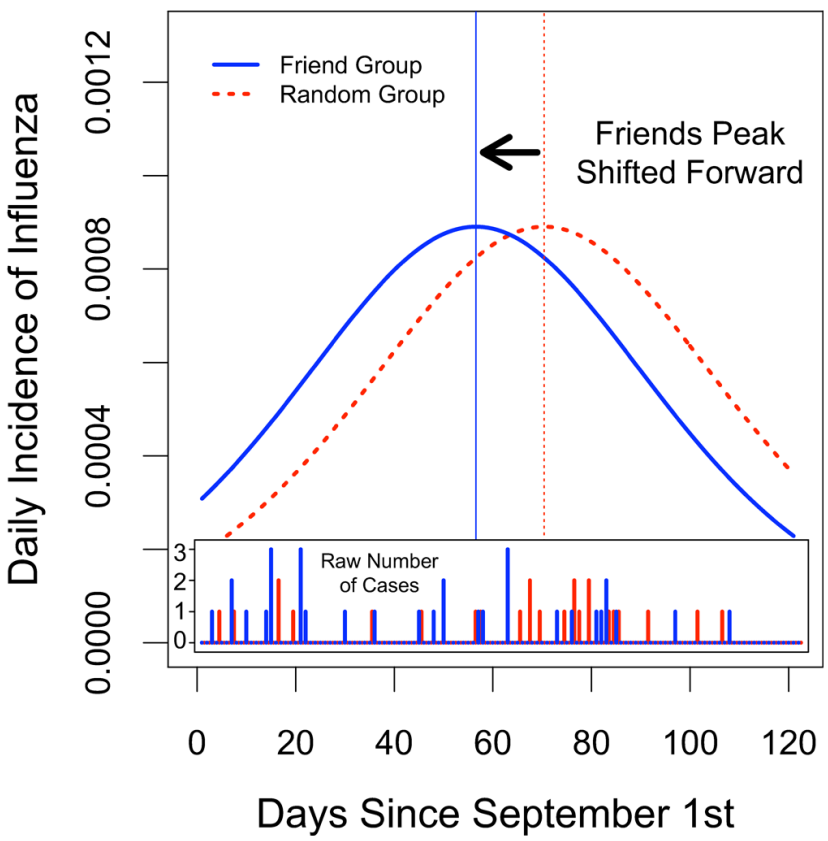
- Facebook (721m users, 69b links)
  - six degrees of separation confirmed
- Twitter (5.8m users, 194m links)
  - friendship paradox holds for >98% users
  - everyone you follow or who follows you has more friends and followers than you
  - *virality paradox*
  - *activity paradox*

Center and periphery nodes

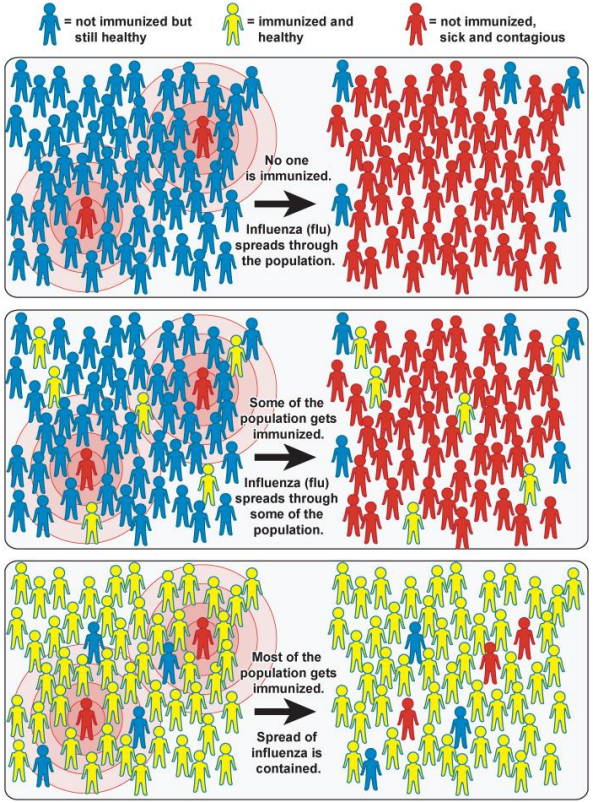


How to predict the epidemic? (H1N1 flu at Harvard; n = 1300)





Herd immunity (firewall in the spread of the contagious disease)



- 100% immunised → immunity
- 96% immunised → immunity

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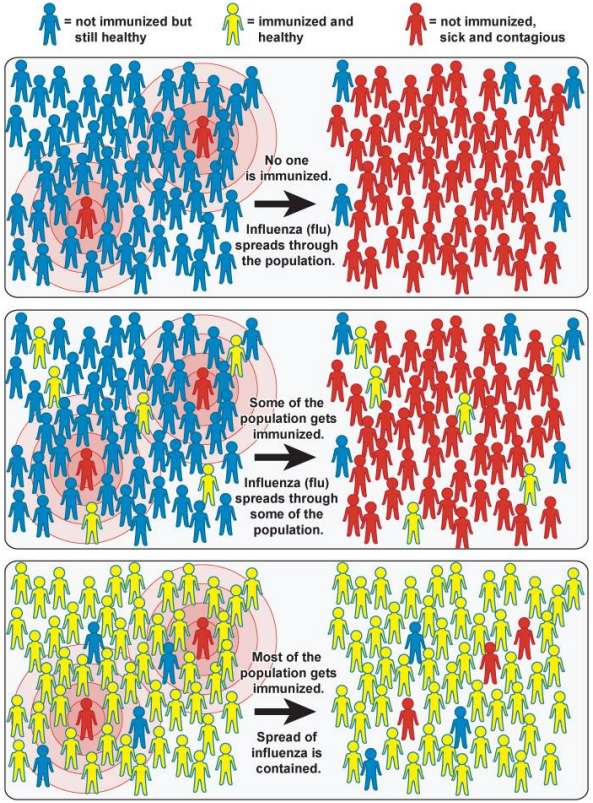

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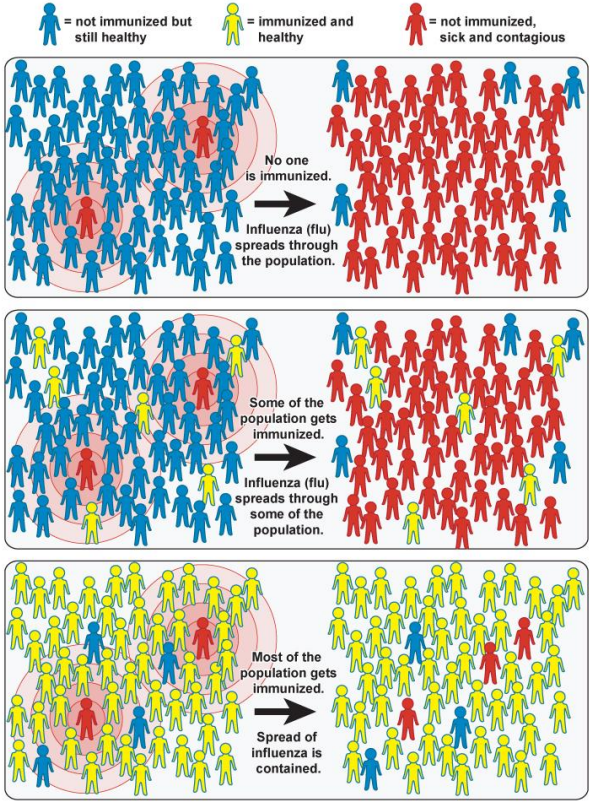

- 100% immunised → immunity
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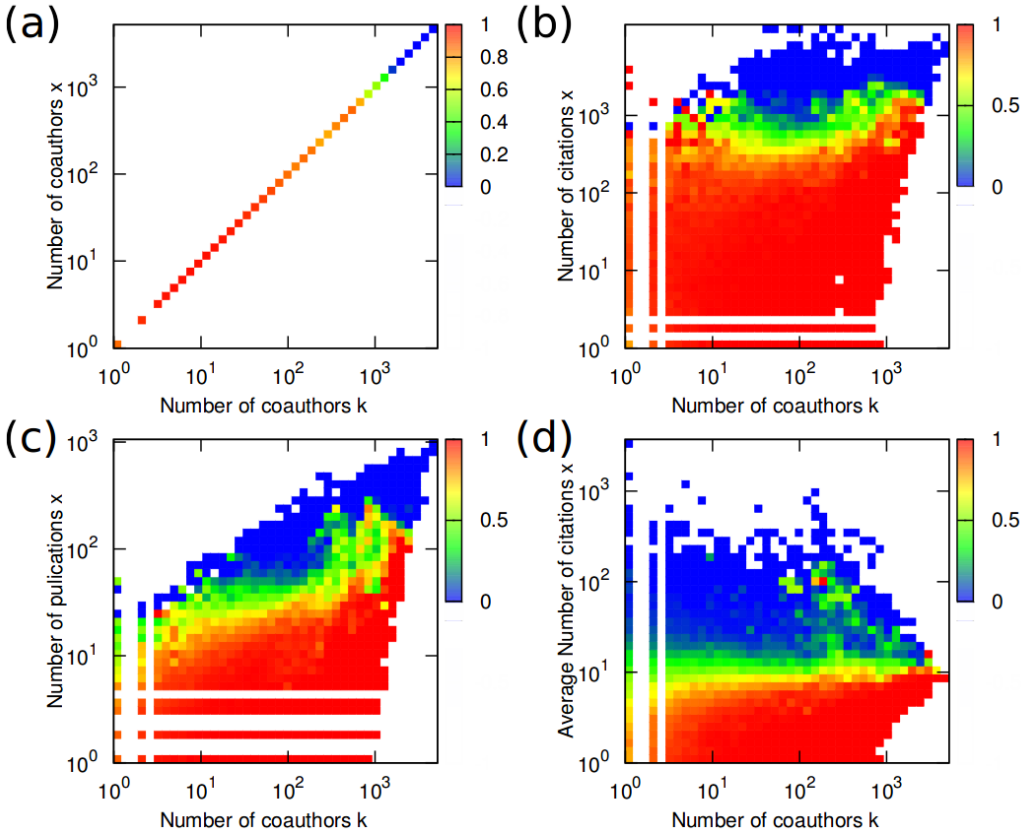
- random 30% → no immunity
- 30% friends → same as 96%

Generalised friendship paradox (GFP)

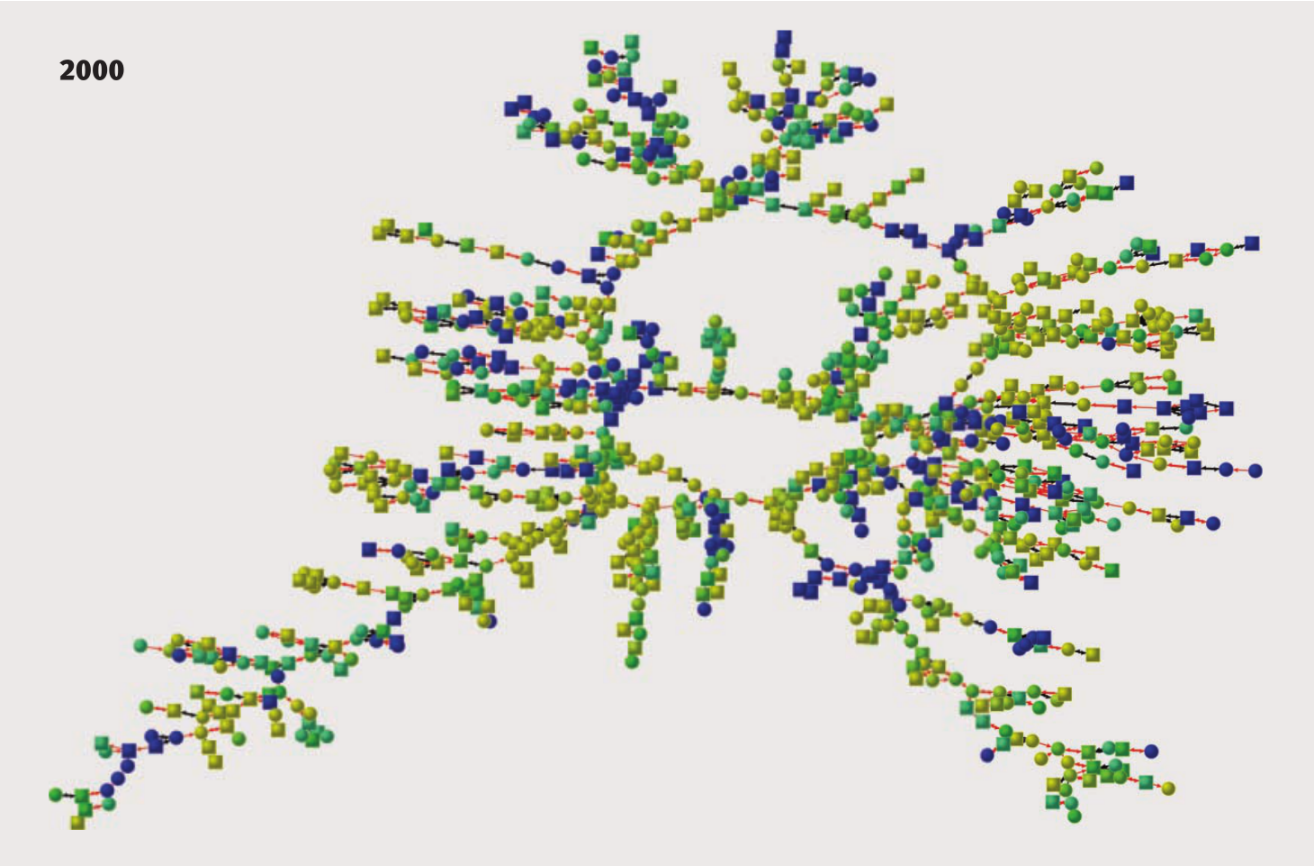
Friendship paradox which is applied to other individual characteristics

paradox holding probability *h* *(k, x)*

from Physical Review coauthorship
(242k authors, 463k papers)



Happiness clusters

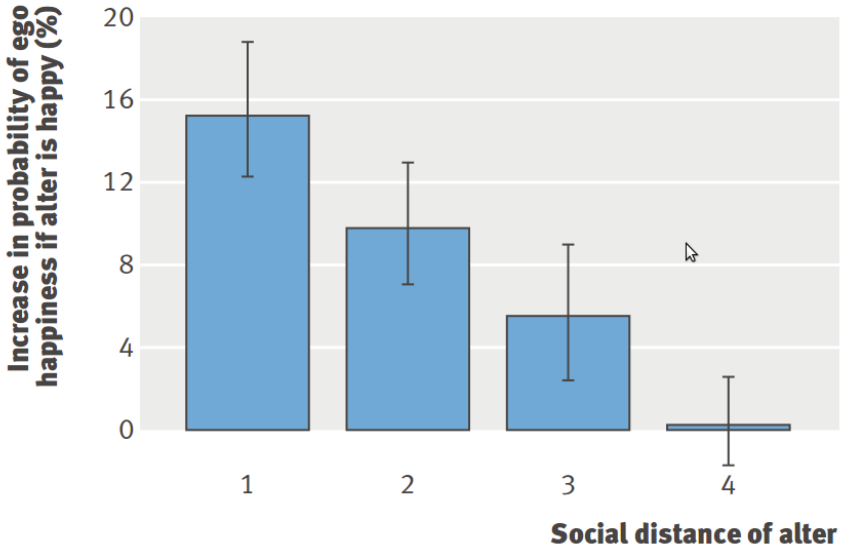


(Framingham Heart Study)

Happiness spreads across a diverse array of social ties.

People who are surrounded by many happy people and those who are central in the network are more likely to become happy in the future.

Three degrees of separation

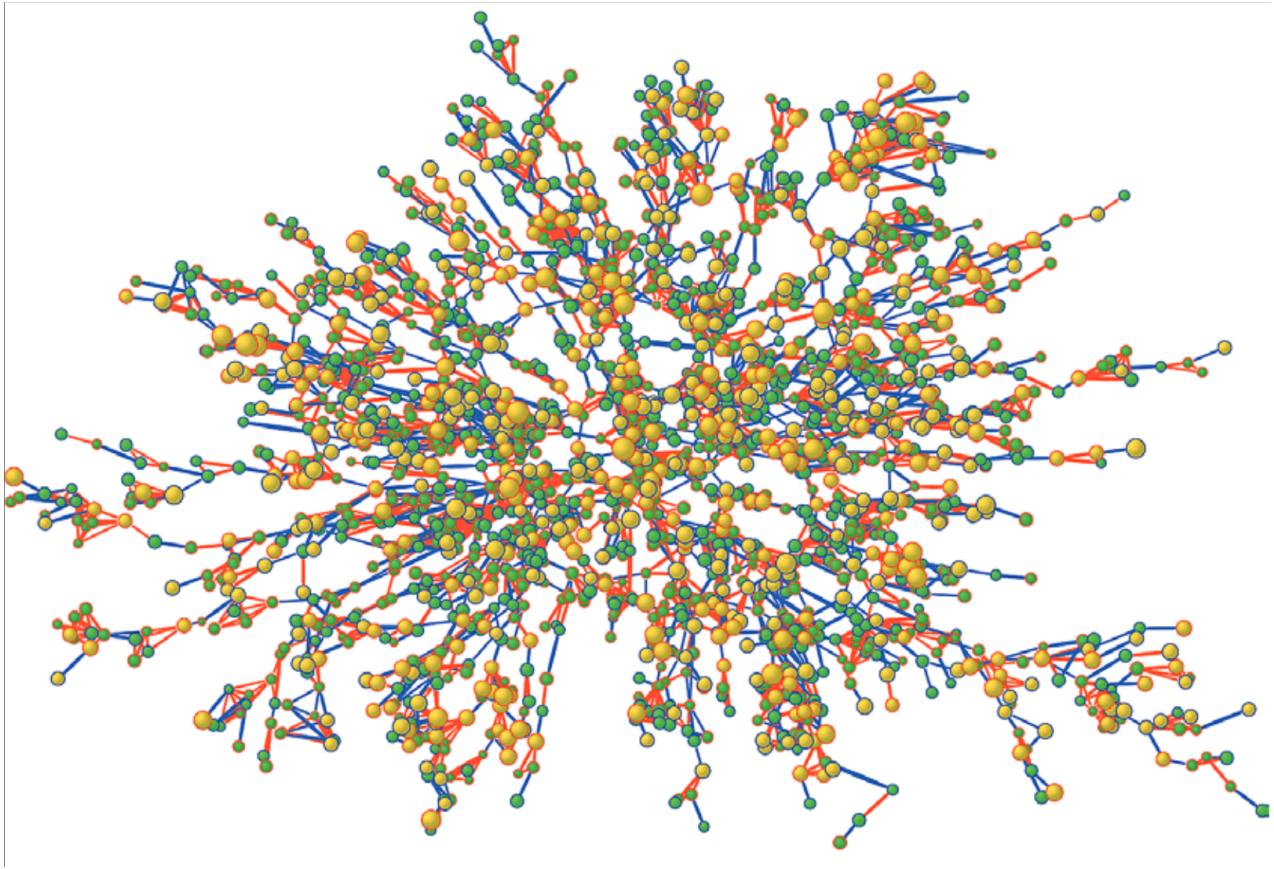


A friend [who lives within a mile] and who becomes happy increases the probability that a person is happy by 25%

Also:

- coresident spouse (8%)
- siblings [1 mile] (14%)
- next door neighbours (34%)

Obesity clusters



(Framingham Heart Study)

Clinically obese person has BMI ≥30

People who are surrounded by many obese people and those who are central in the network are more likely to become obese.

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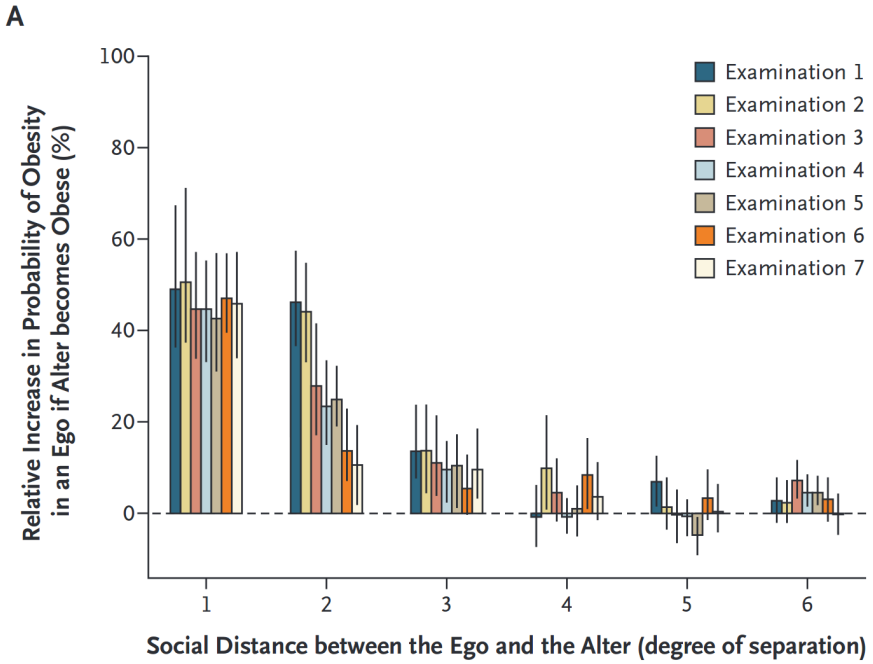

A friend who becomes obese increases the probability that a person becomes obese by 57% (in the same time interval)

Also:

- spouse (37%)
- siblings (40%)
- next door neighbours (no effect)

Degrees of influence

- Information
- Happiness
- Obesity
- Wealth
- Extraversion
- Smoking
- Drinking
- Drug use
- Loneliness
- Depression
- Altruism
- Sleep
- Vaccination
- Purchases
- Ideas

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- Friends are more popular and central in the network
- Different things spread in networks in different ways

  …but your friends are more likely to receive it
- Networks magnify whatever they are seeded with

References

1. Feld, Scott L. (1991), "Why your friends have more friends than you do", American Journal of Sociology 96 (6): 1464–1477
2. Zuckerman, Ezra W.; Jost, John T. (2001), "What makes you think you’re so popular? Self evaluation maintenance and the subjective side of the “friendship paradox"", Social Psychology Quarterly 64 (3): 207–223
3. Eom, Young-Ho; Jo, Hang-Hyun (01/2014). "Generalized friendship paradox in complex networks". eprint arXiv. Retrieved 17 January 2014
4. Christakis, Nicholas A.; Fowler, James H. (2010), "Social Network Sensors for Early Detection of Contagious Outbreaks", PLoS ONE 5(9): e12948
5. Fowler, James H.; Christakis, Nicholas A. (2008), "Dynamic spread of happiness in a large social network: longitudinal analysis over 20 years in the Framingham Heart Study", BMJ 2008; 337:a2338
6. Christakis, Nicholas A.; Fowler, James H. (2007), "The Spread of Obesity in a Large Social Network over 32 Years", N Engl J Med 2007; 357:370-379