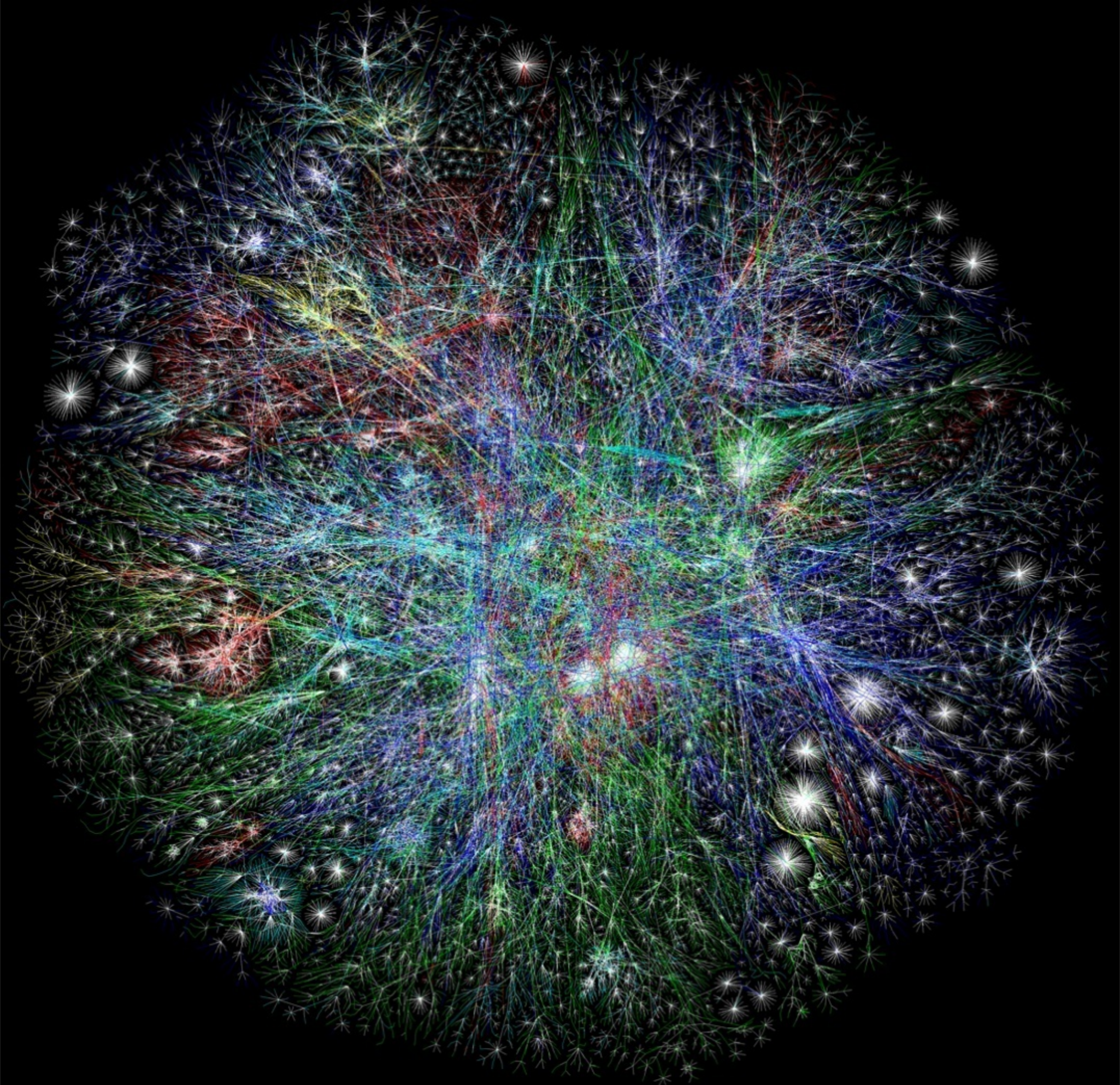


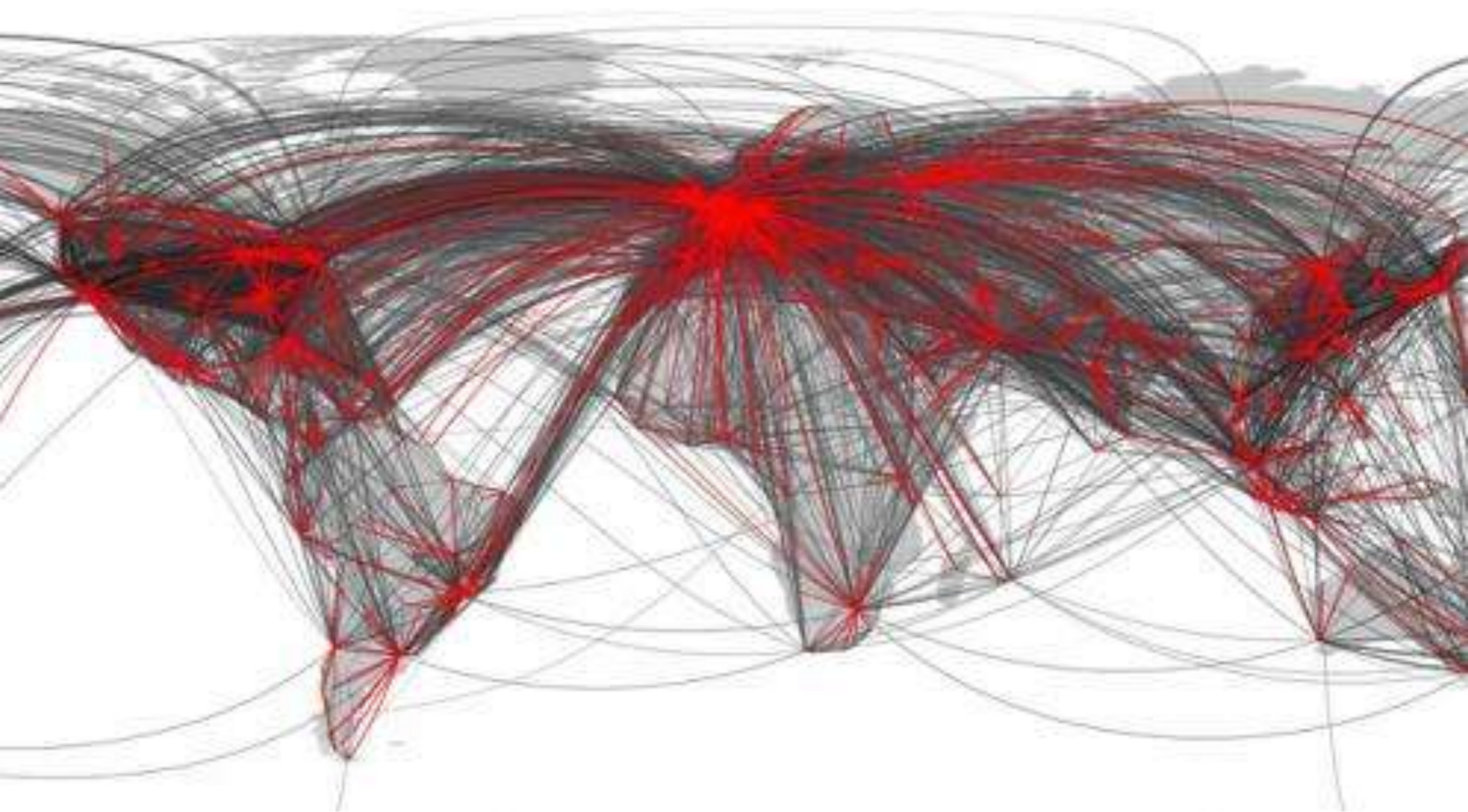


# Lecture 15

Networks: Small Worlds

Geog 490/590  
Spatial Modeling  
Spring 2015





## ARTICLE

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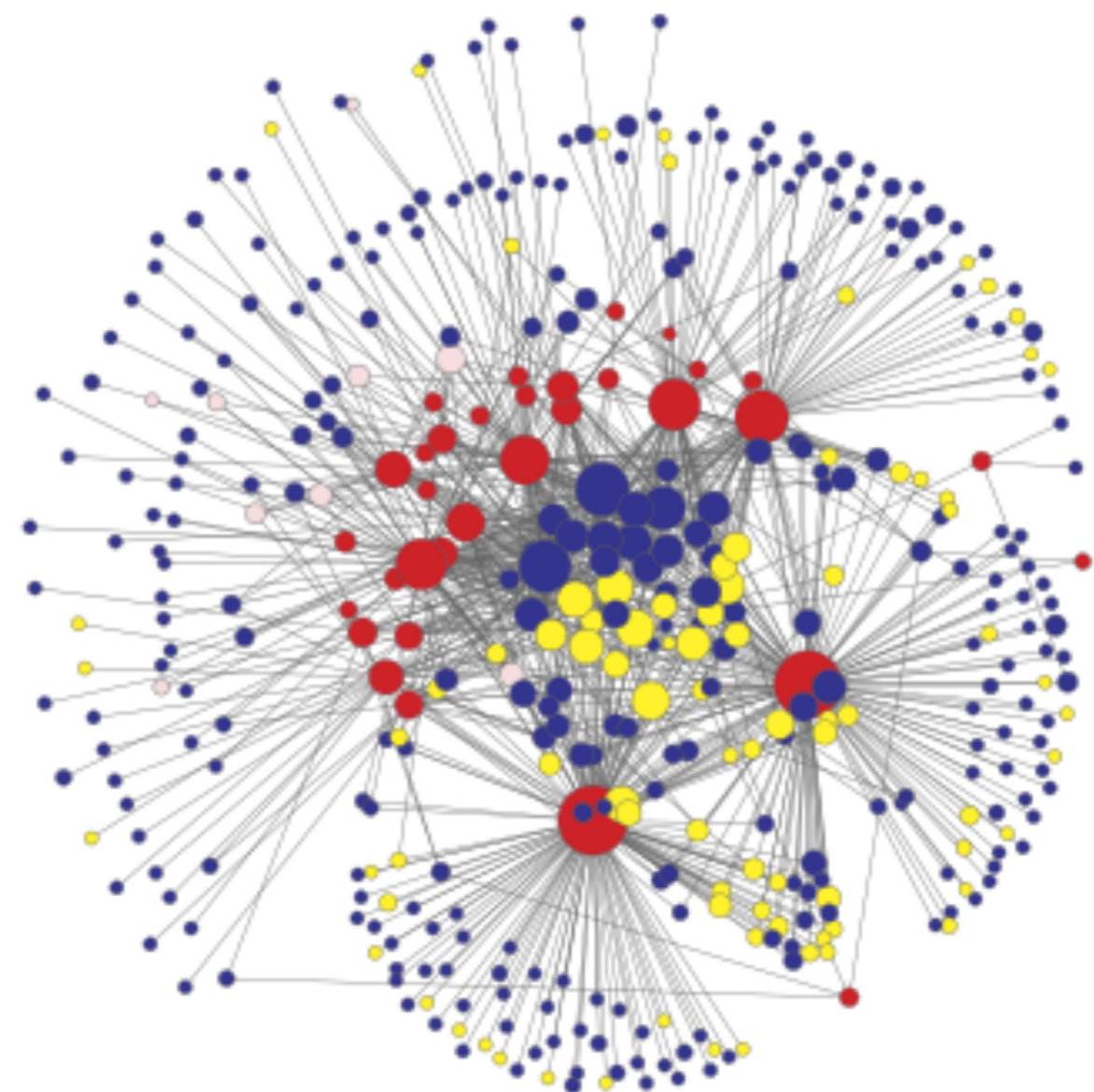
DOI: 10.1038/ncomms6273

OPEN

# Assembly of complex plant-fungus networks

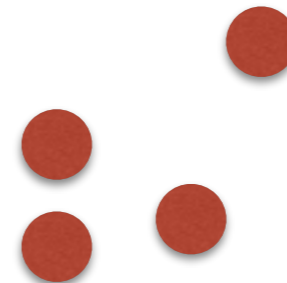
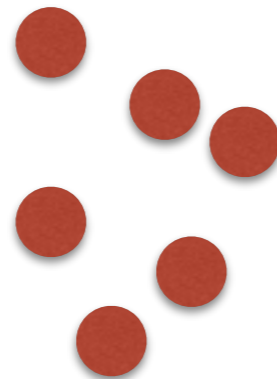
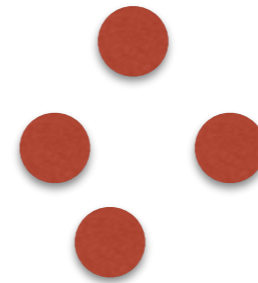
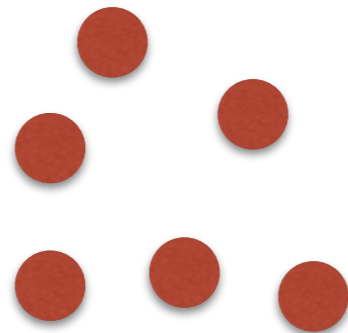
Hirokazu Toju<sup>1</sup>, Paulo R. Guimarães<sup>2</sup>, Jens M. Olesen<sup>3</sup> & John N. Thompson<sup>4</sup>

Species in ecological communities build complex webs of interaction. Although revealing the architecture of these networks is fundamental to understanding ecological and evolutionary dynamics in nature, it has been difficult to characterize the structure of most species-rich ecological systems. By overcoming this limitation through next-generation sequencing technology, we herein uncover the network architecture of below-ground plant-fungus symbioses, which are ubiquitous to terrestrial ecosystems. The examined symbiotic network of a temperate forest in Japan includes 33 plant species and 387 functionally and phylogenetically diverse fungal taxa, and the overall network architecture differs fundamentally from that of other ecological networks. In contrast to results for other ecological networks

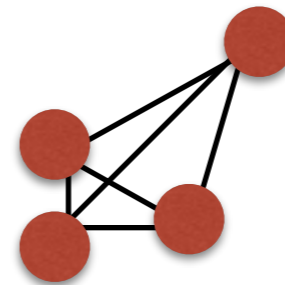
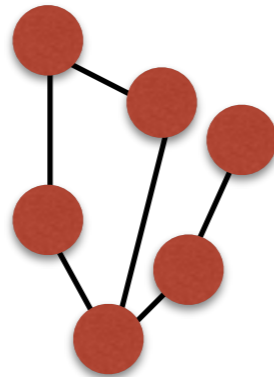
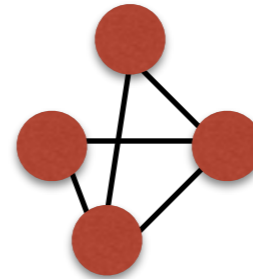
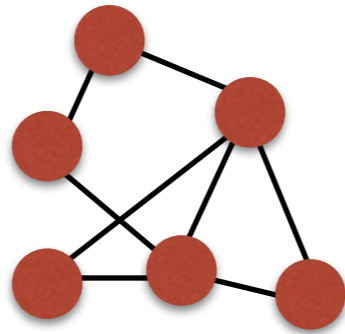


**Figure 1 | Architecture of the below-ground plant-fungus network in a temperate forest in Japan.** In the bipartite network, plant species (red) interact with ectomycorrhizal (yellow) and arbuscular mycorrhizal (pink) fungal OTUs as well as OTUs with unknown ecological functions (blue). The size of nodes represents the relative abundance of plant species or fungal OTUs in the data set<sup>12</sup>.

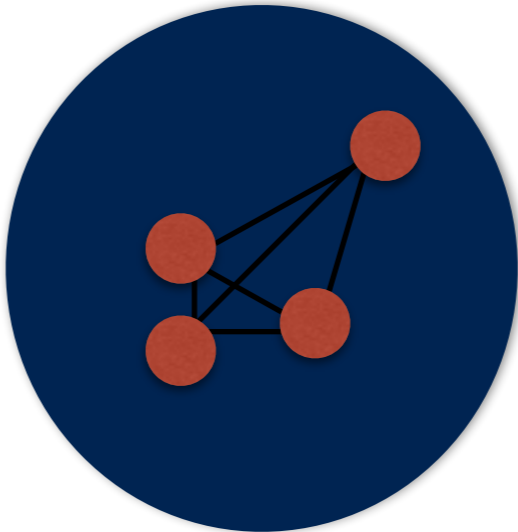
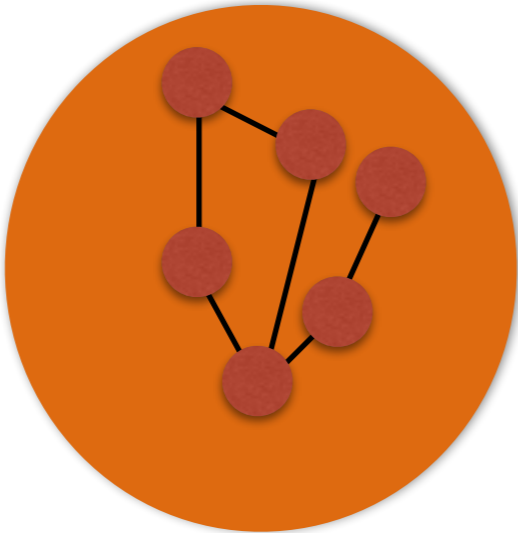
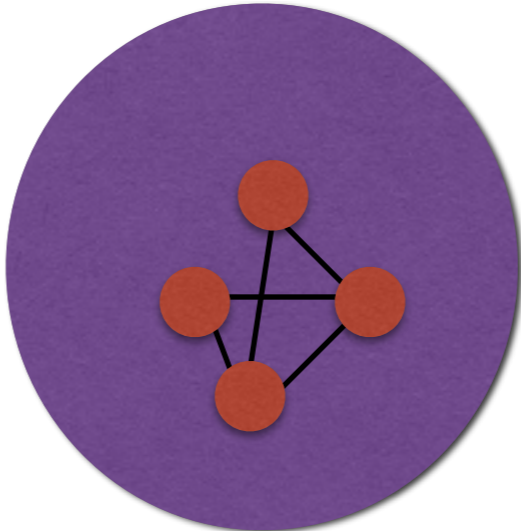
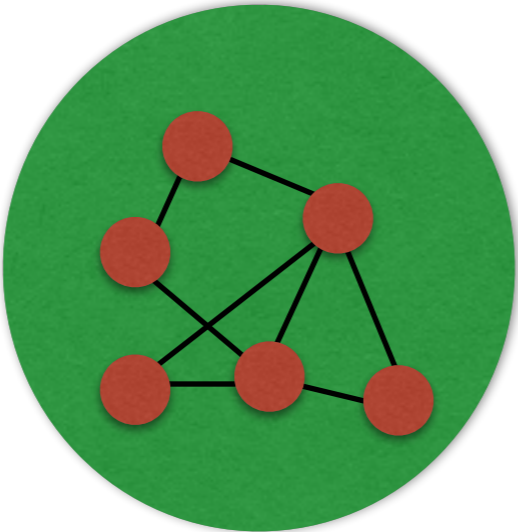
# Individuals (nodes)



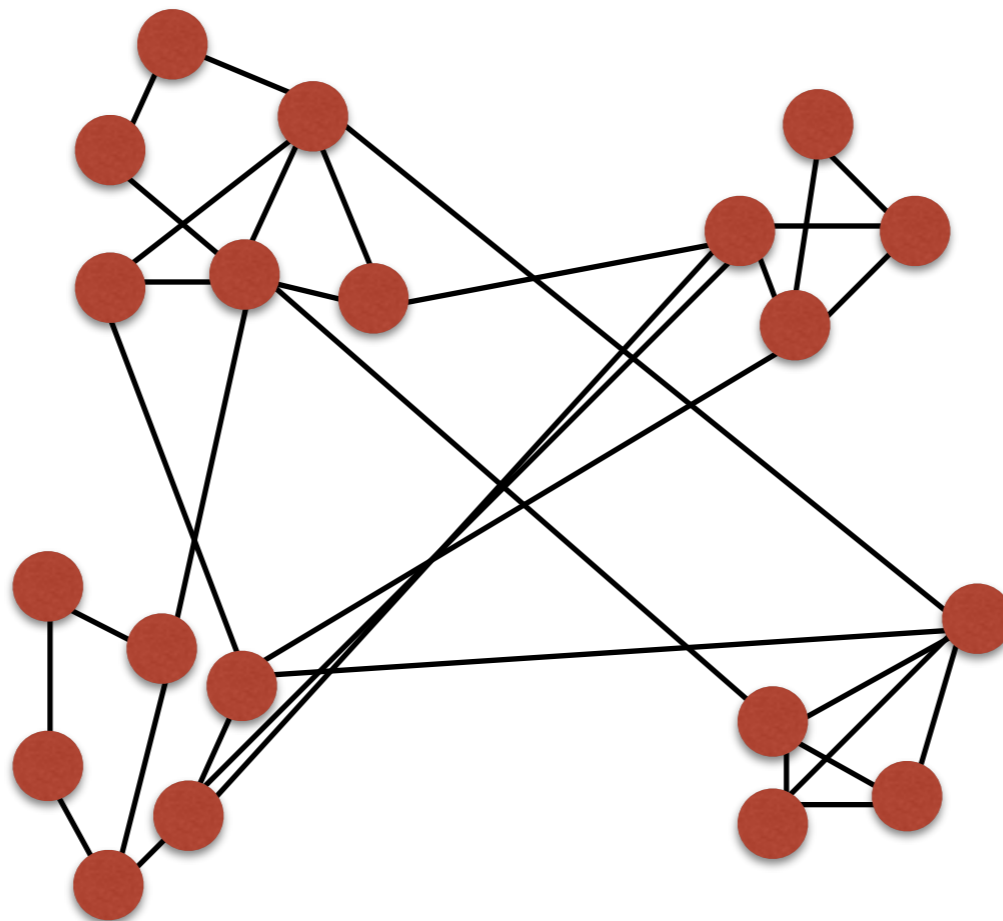
# Relationships (links)



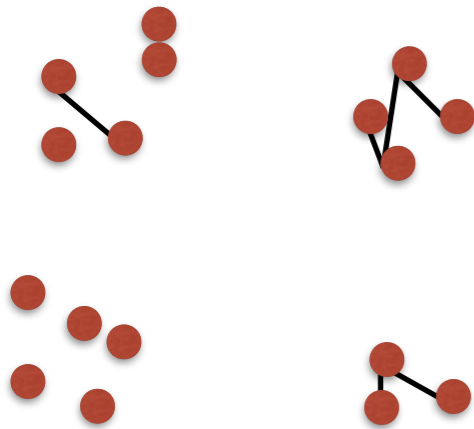
# Network Clusters



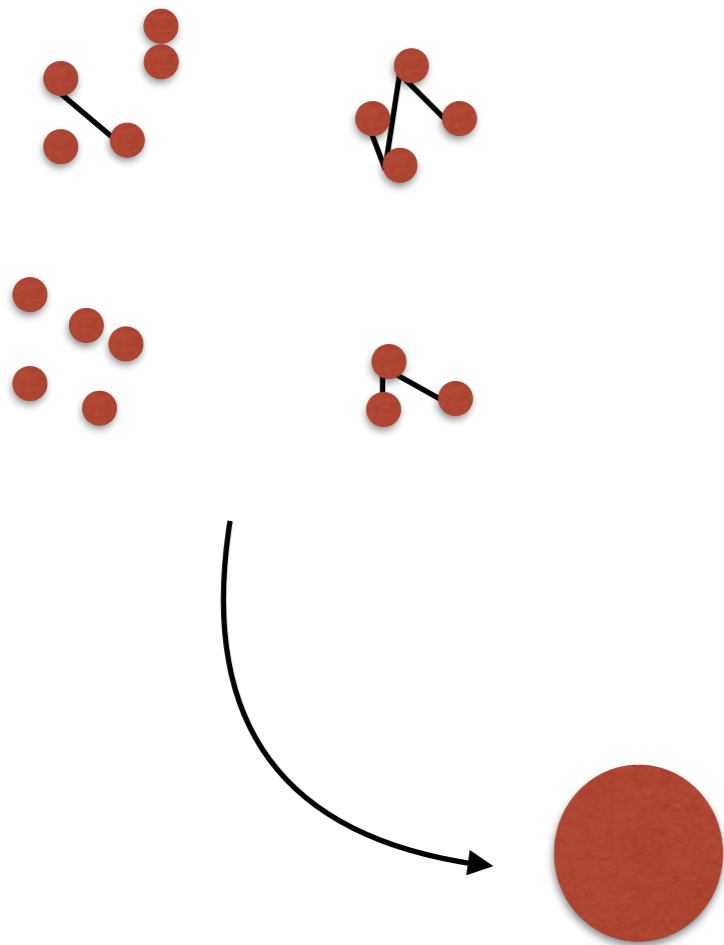
# Connected Network



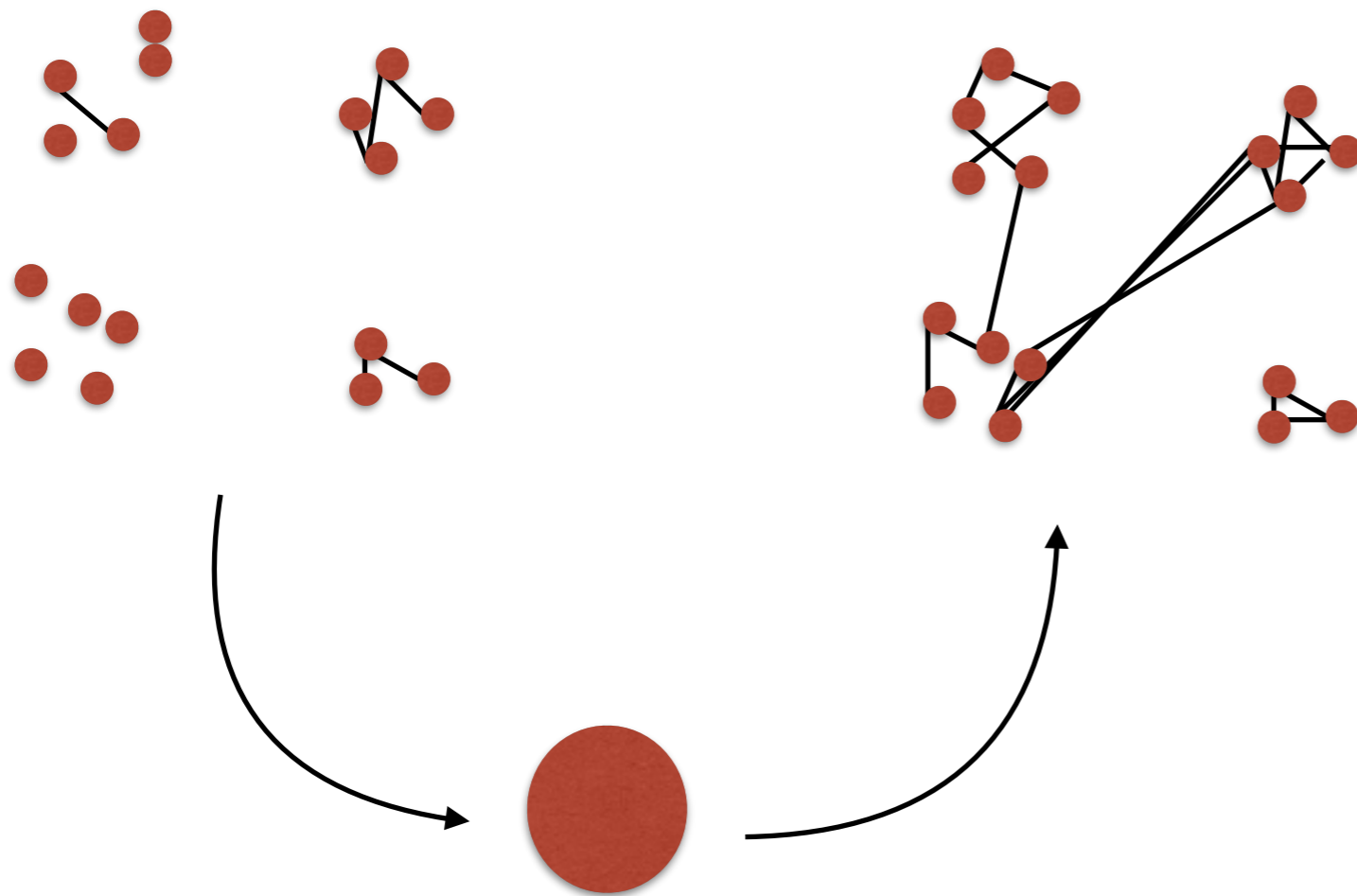
# Social Networks



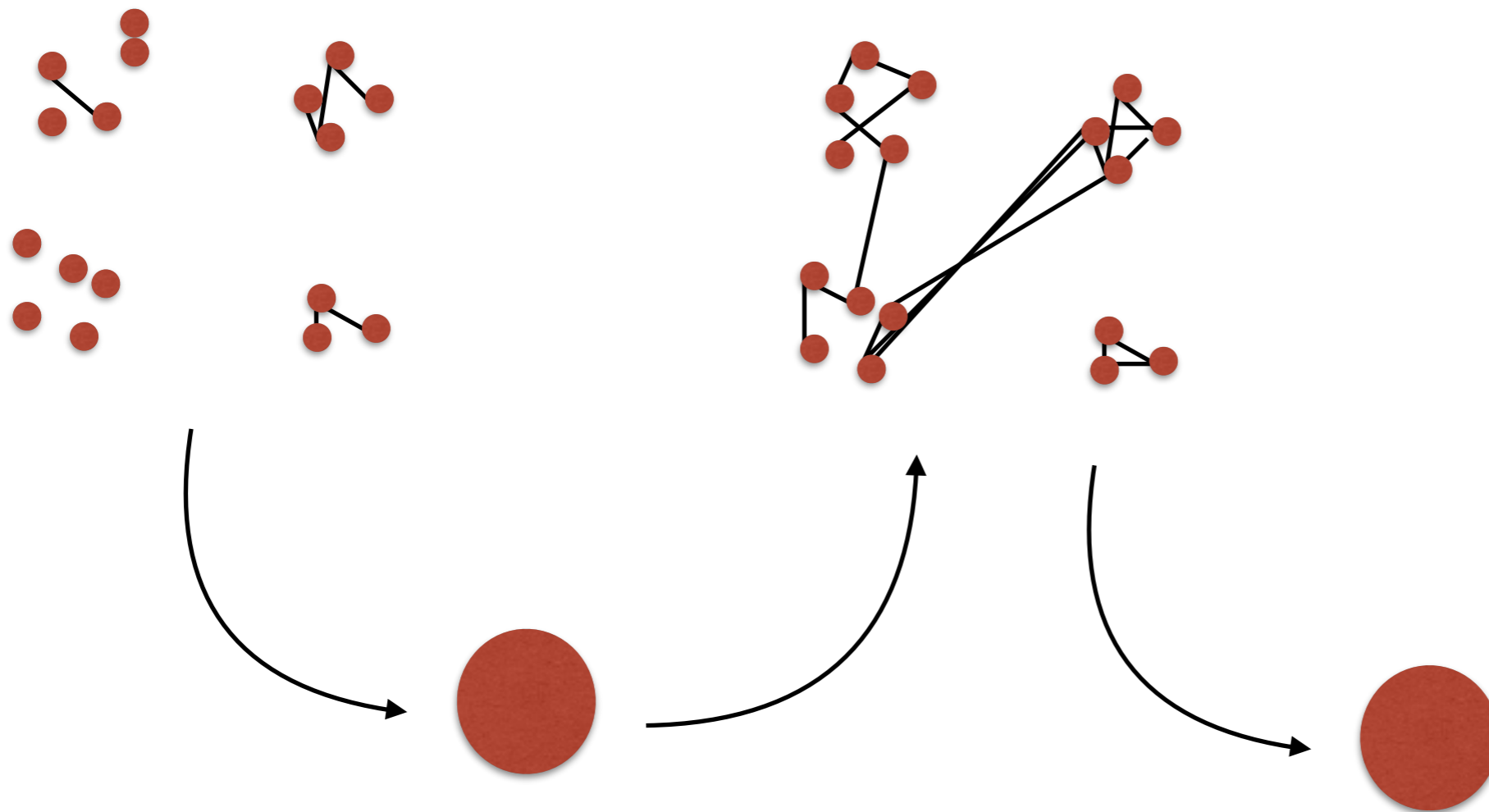
# Social Networks



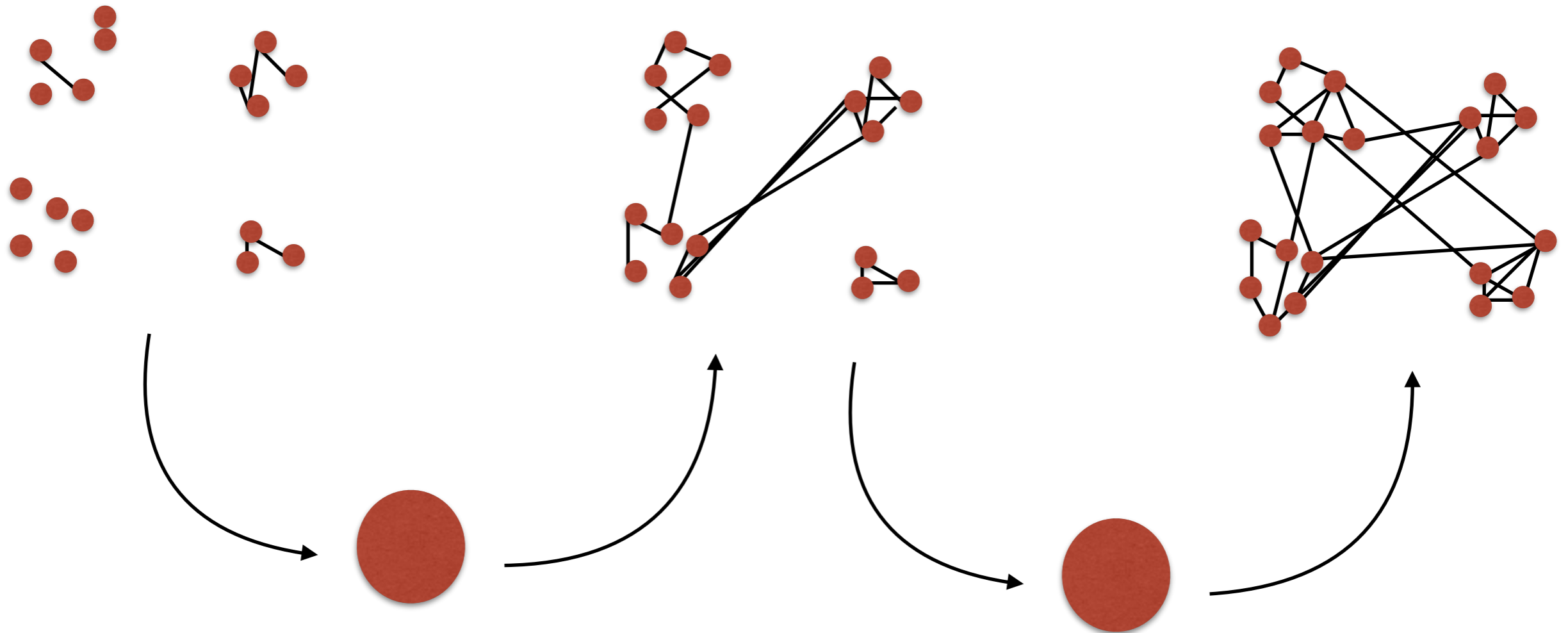
# Social Networks



# Social Networks

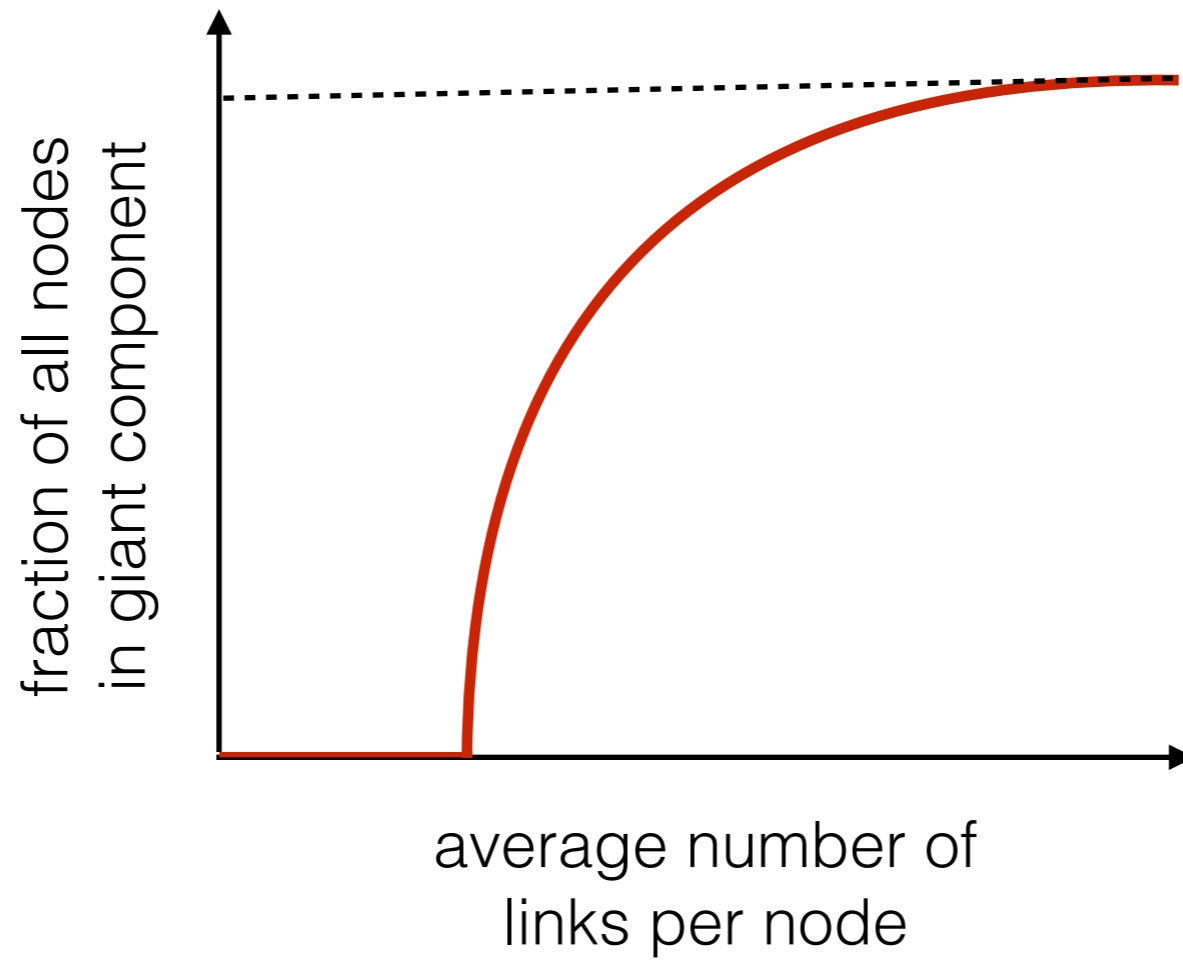


# Social Networks

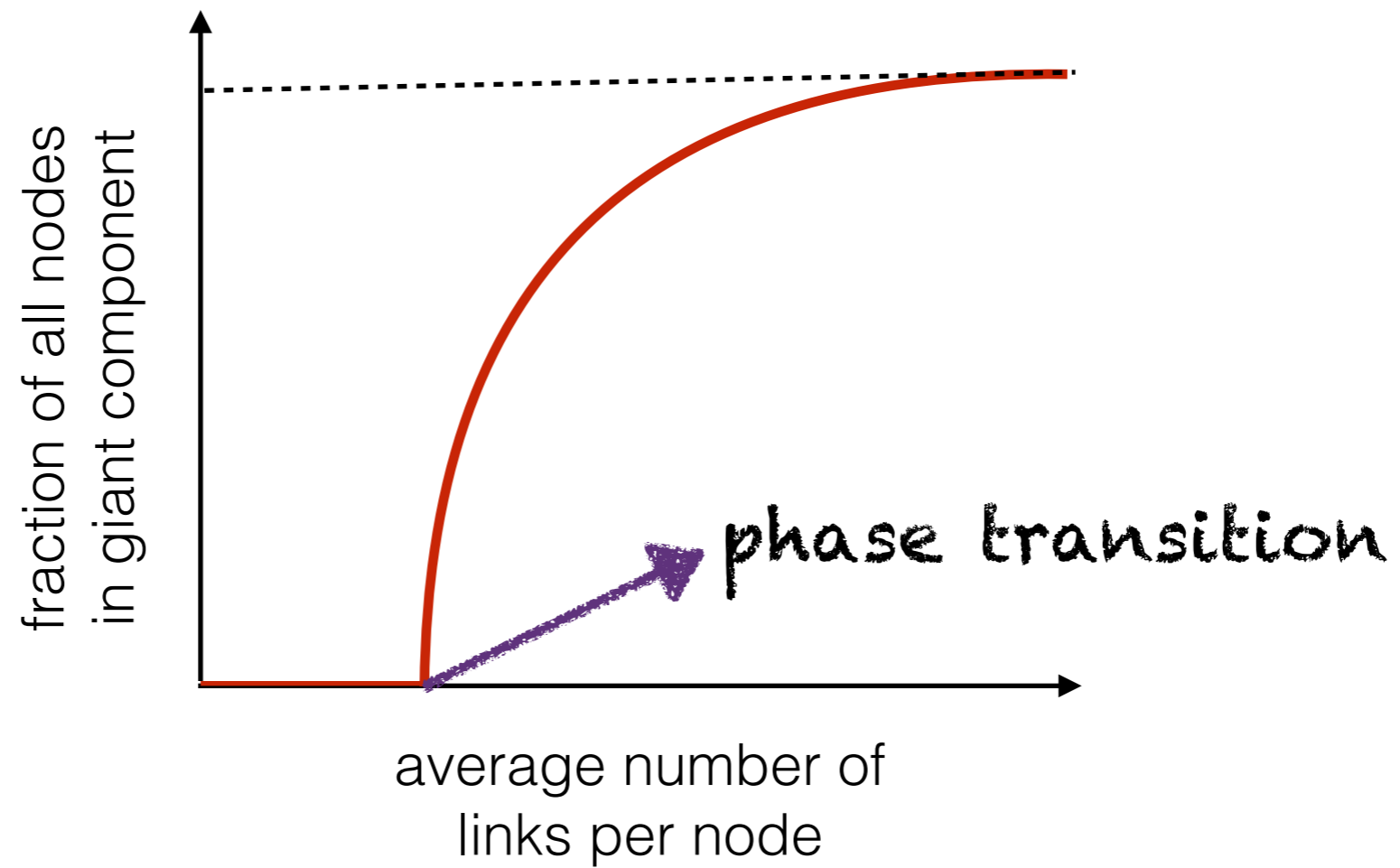


(People) make their own history, but...they do not make it under circumstances chosen by themselves.

# Random Network



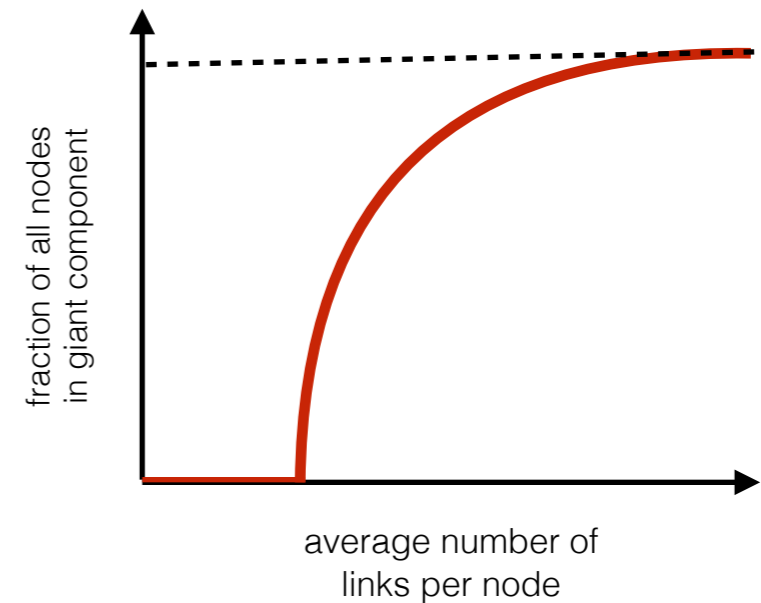
# Random Network



# Limits to the Random Network Approach?

# Limits to the Random Network Approach

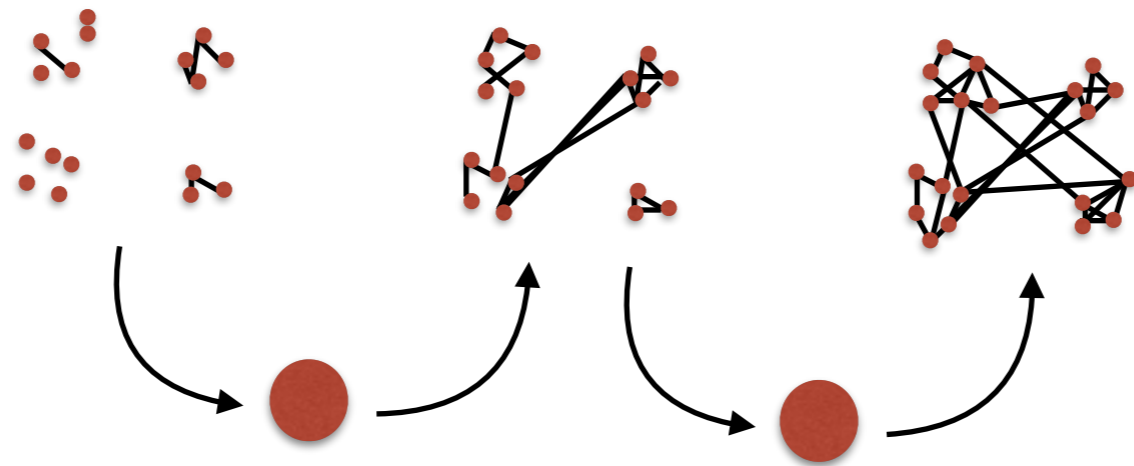
Are your connections random?



# The Delicate Balance of Social Networks

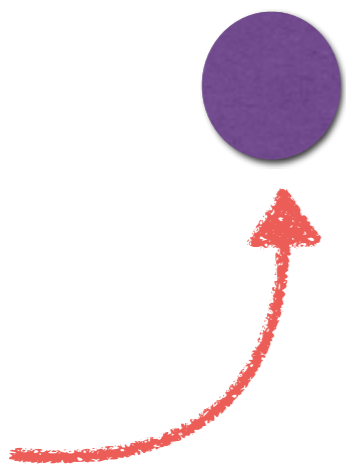
**Structure:** the surrounding constraints in which we operate

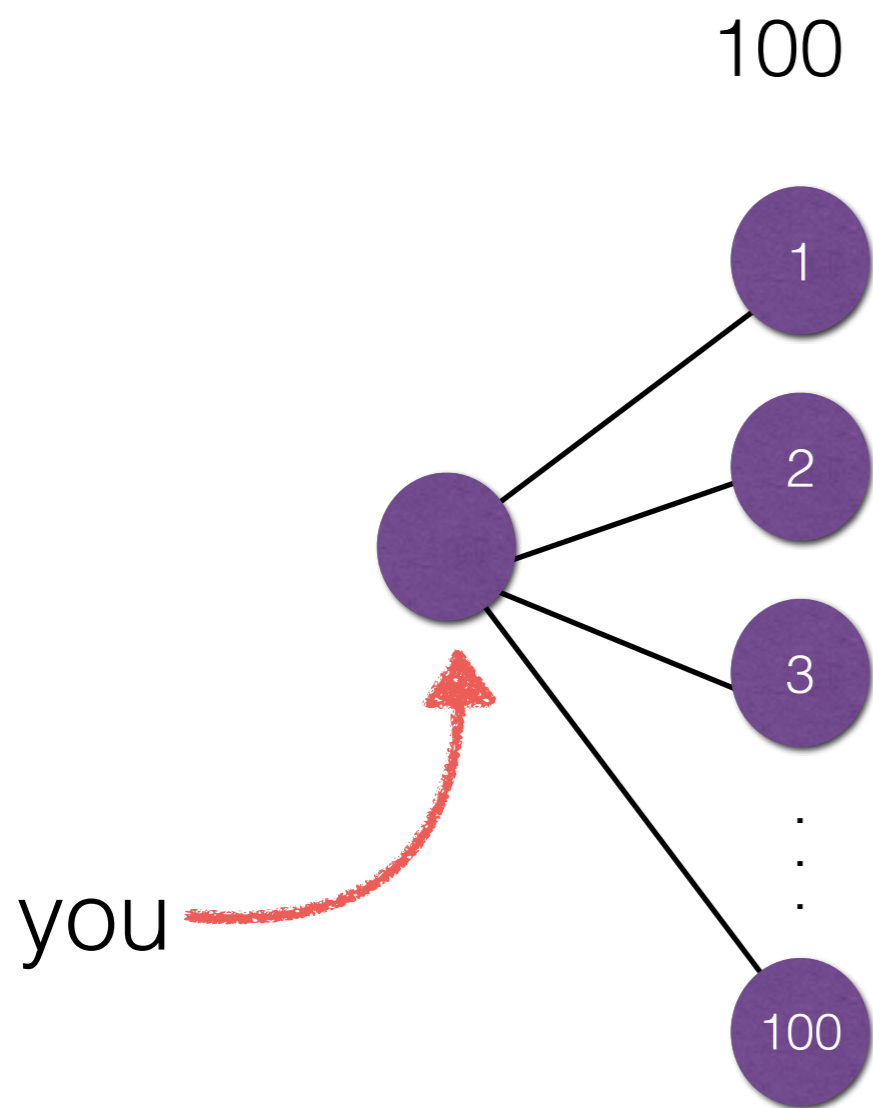
**Agency:** individual preferences

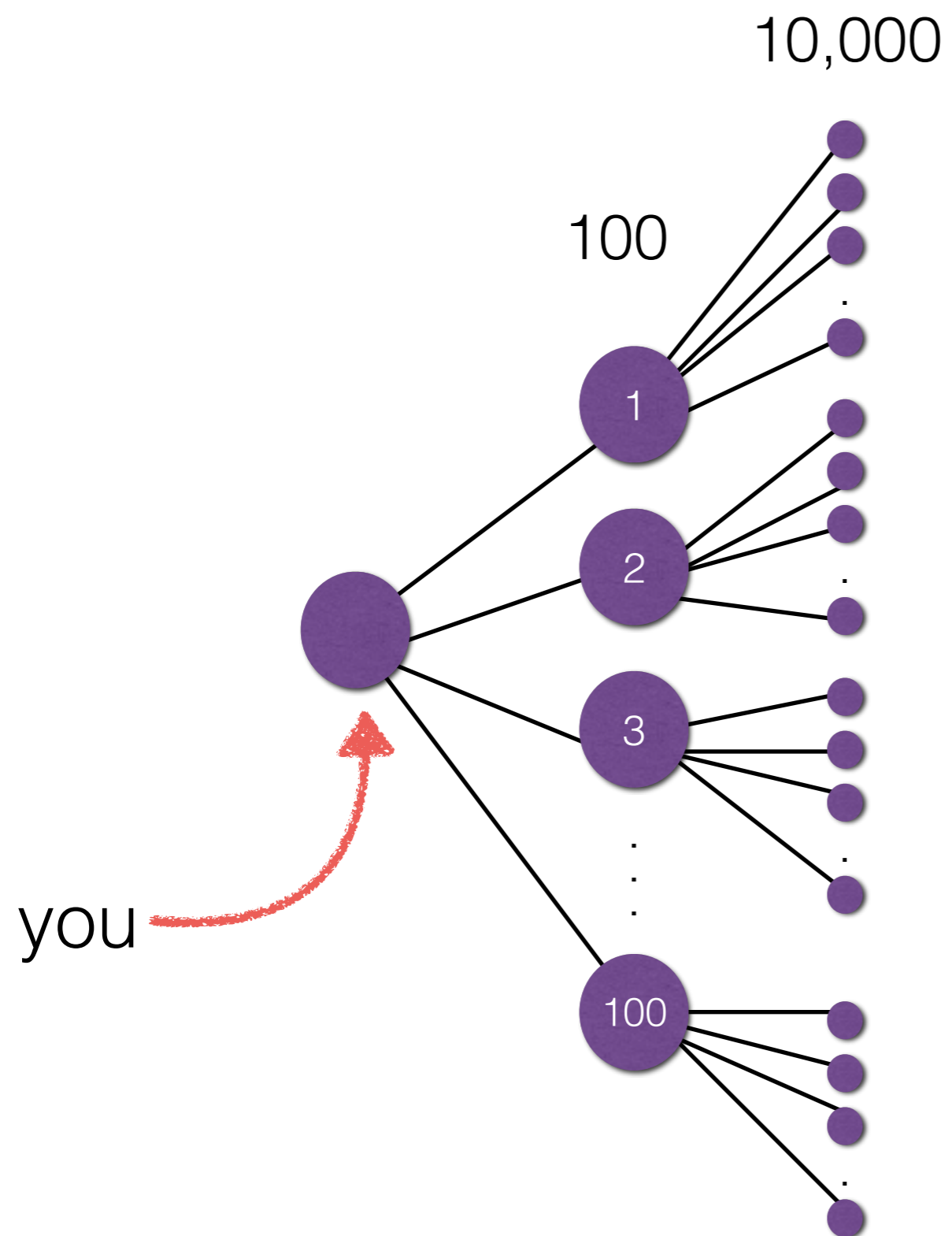


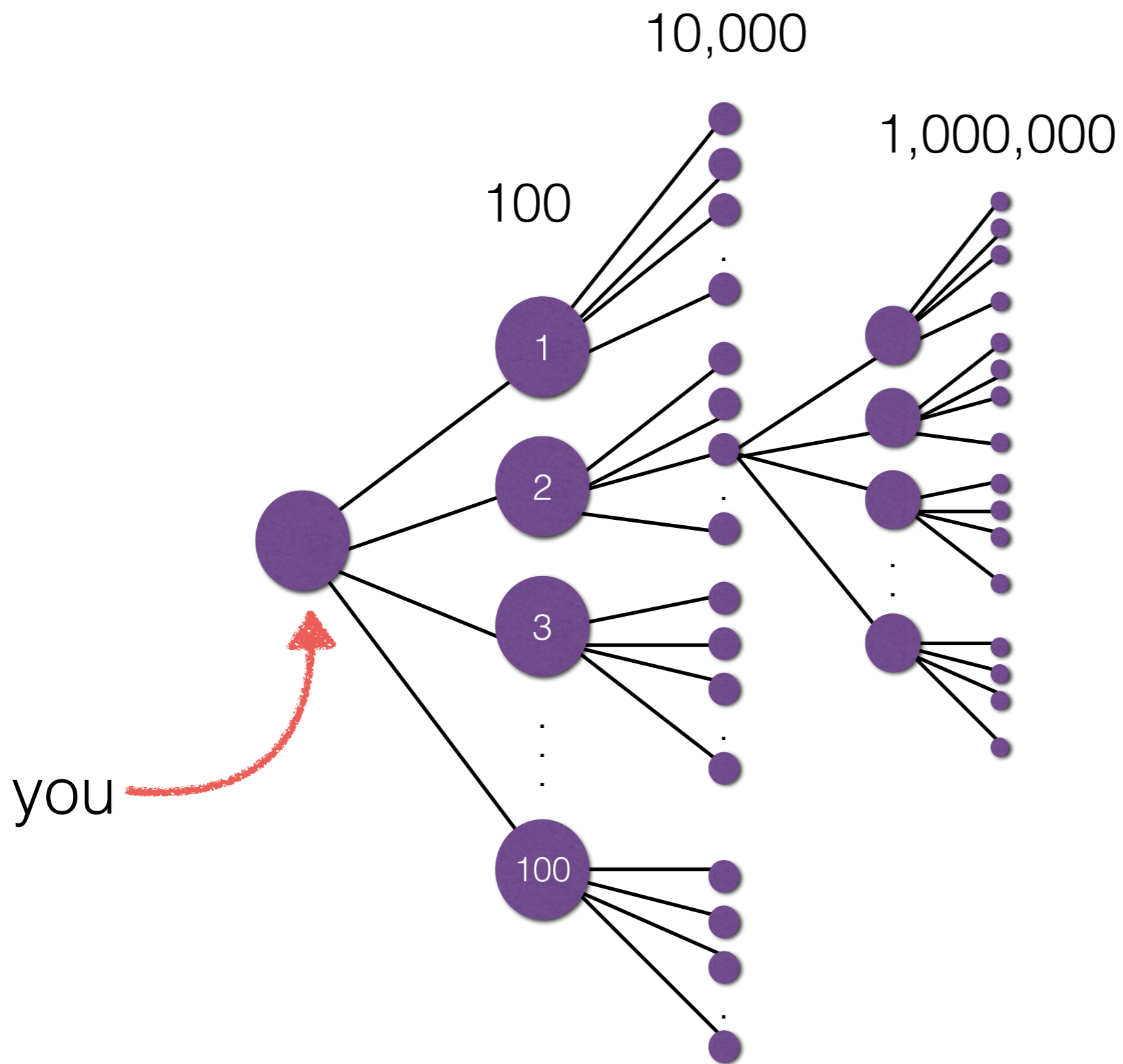
Its a small world

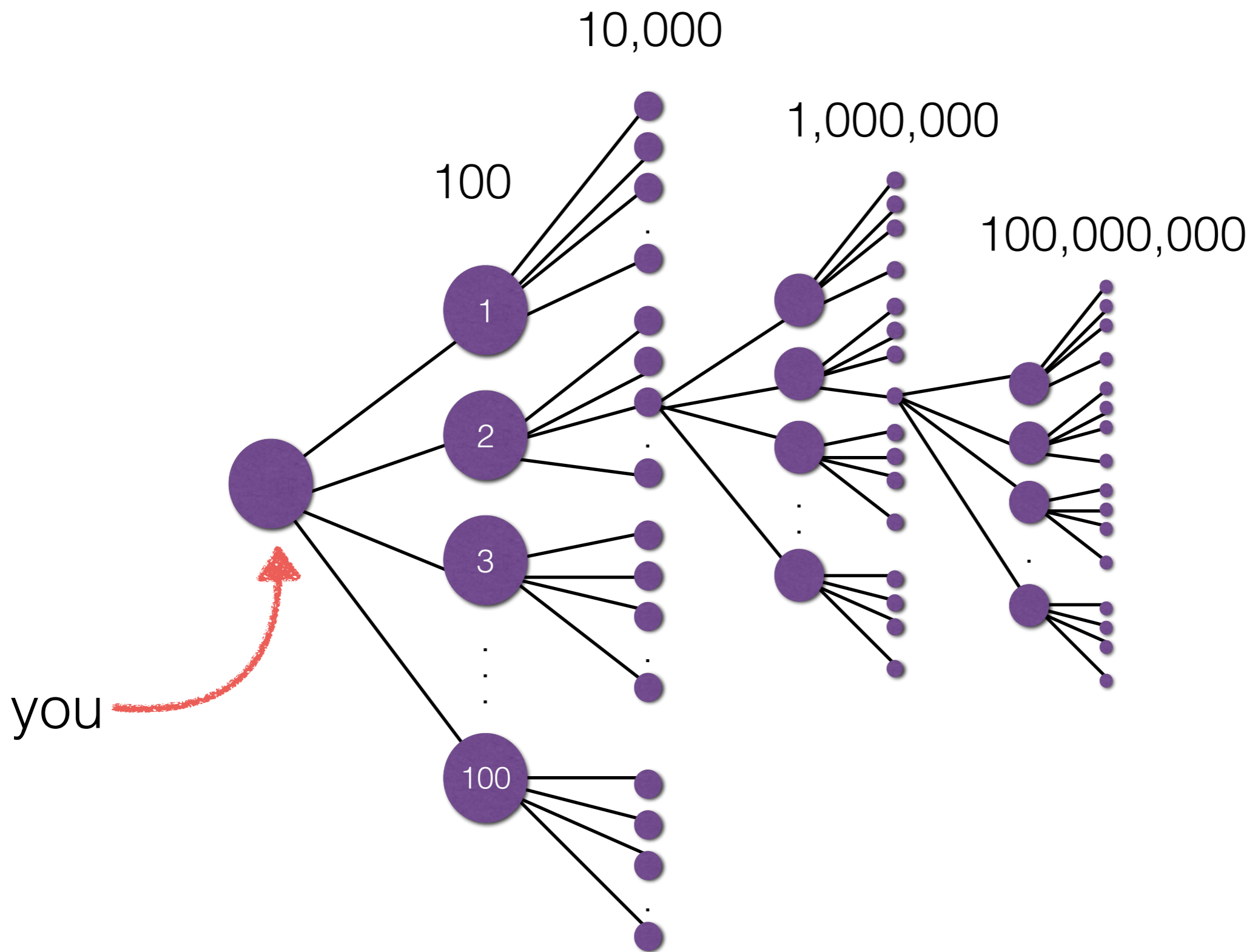
you

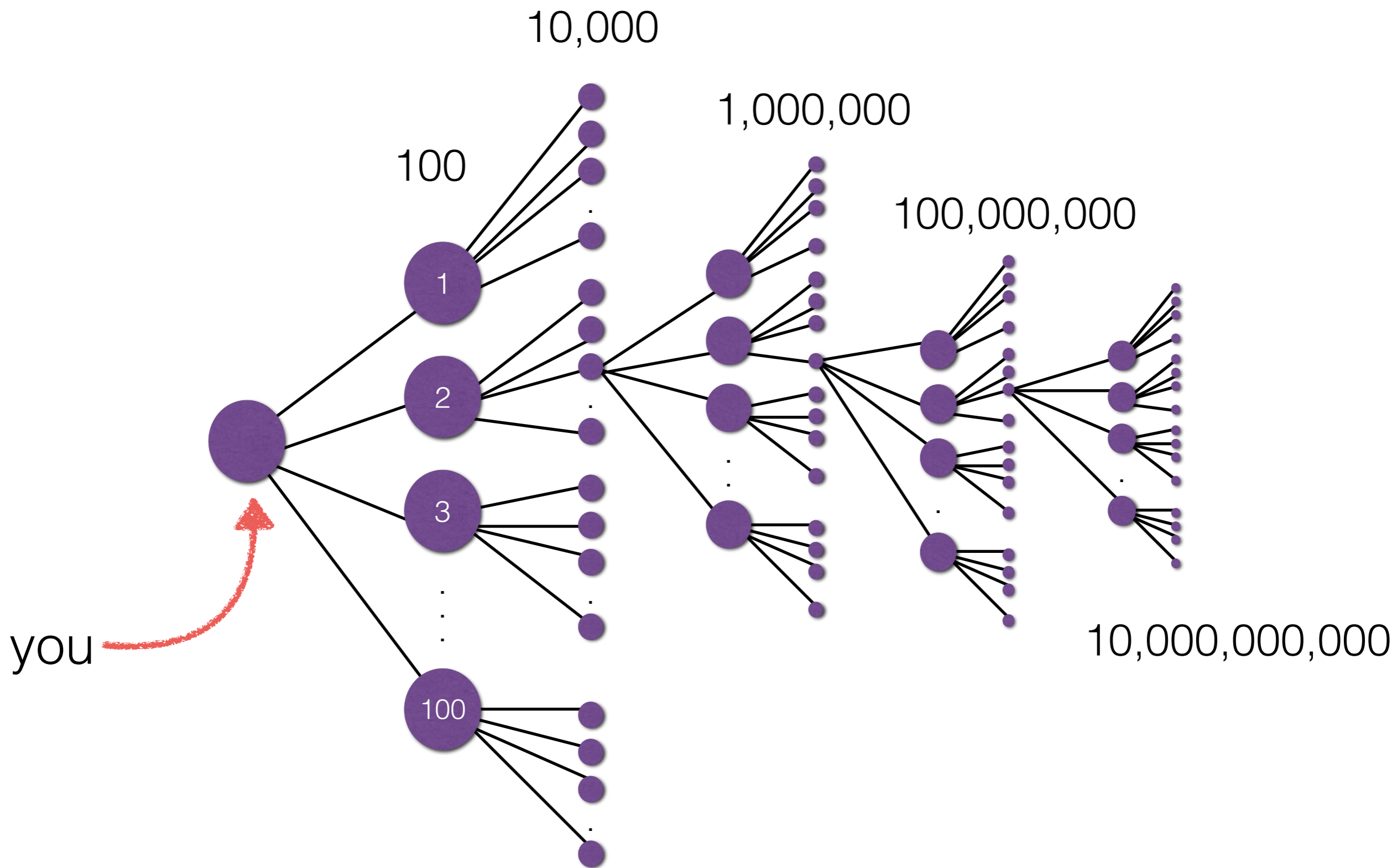








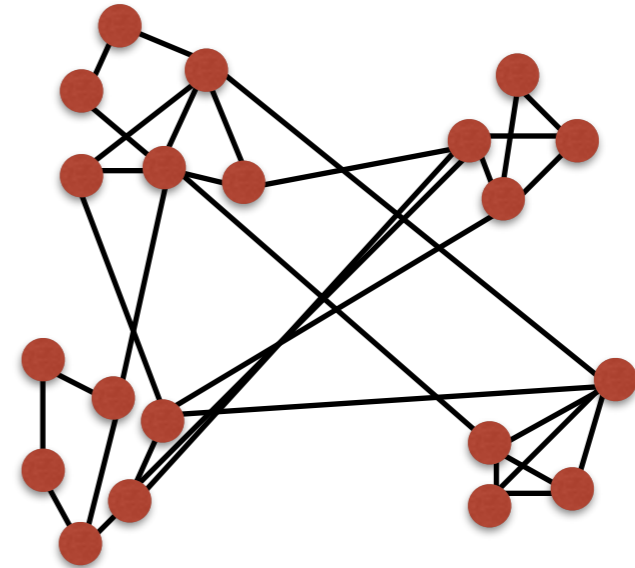
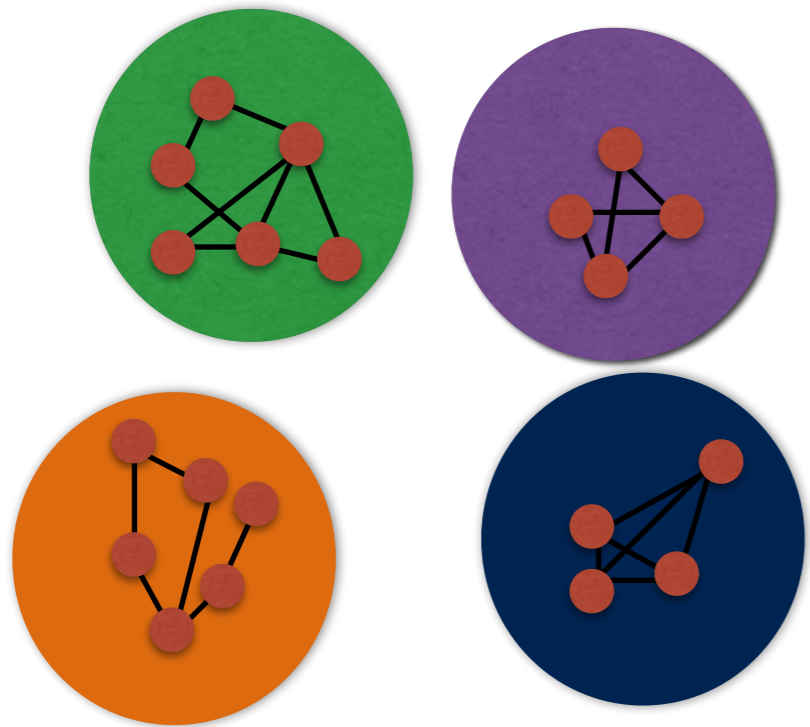




# Small World Networks

1. Consist of many, small overlapping groups
2. Dynamic
3. Not all relationships (links) are have an equal probability of occurring
4. Actors connect based on individual preference

# Clusters vs Connected



# Connection Preference

$a$  (alpha) = preference for connection

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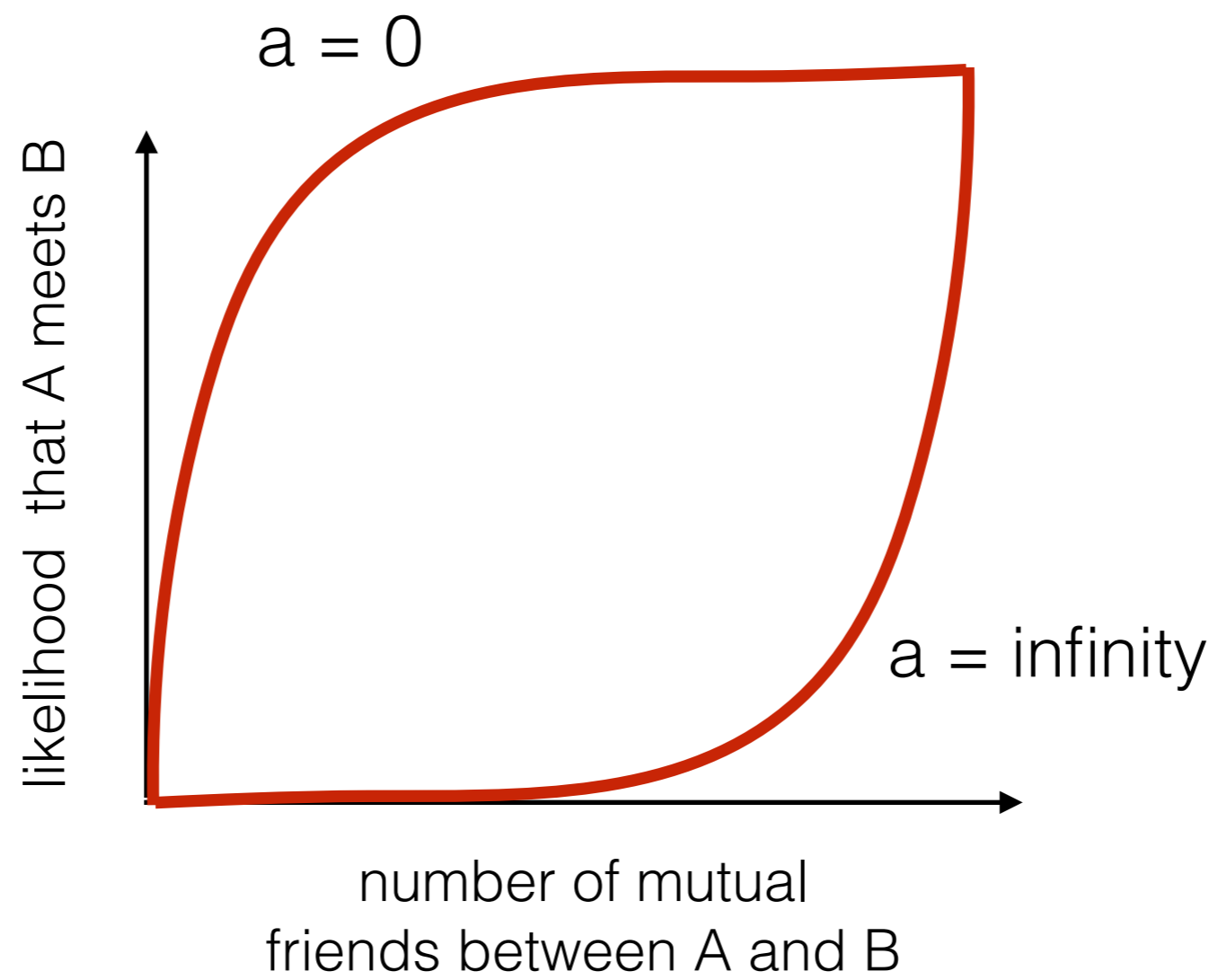
low  $a$  = preference to connect  
to friends of your friends

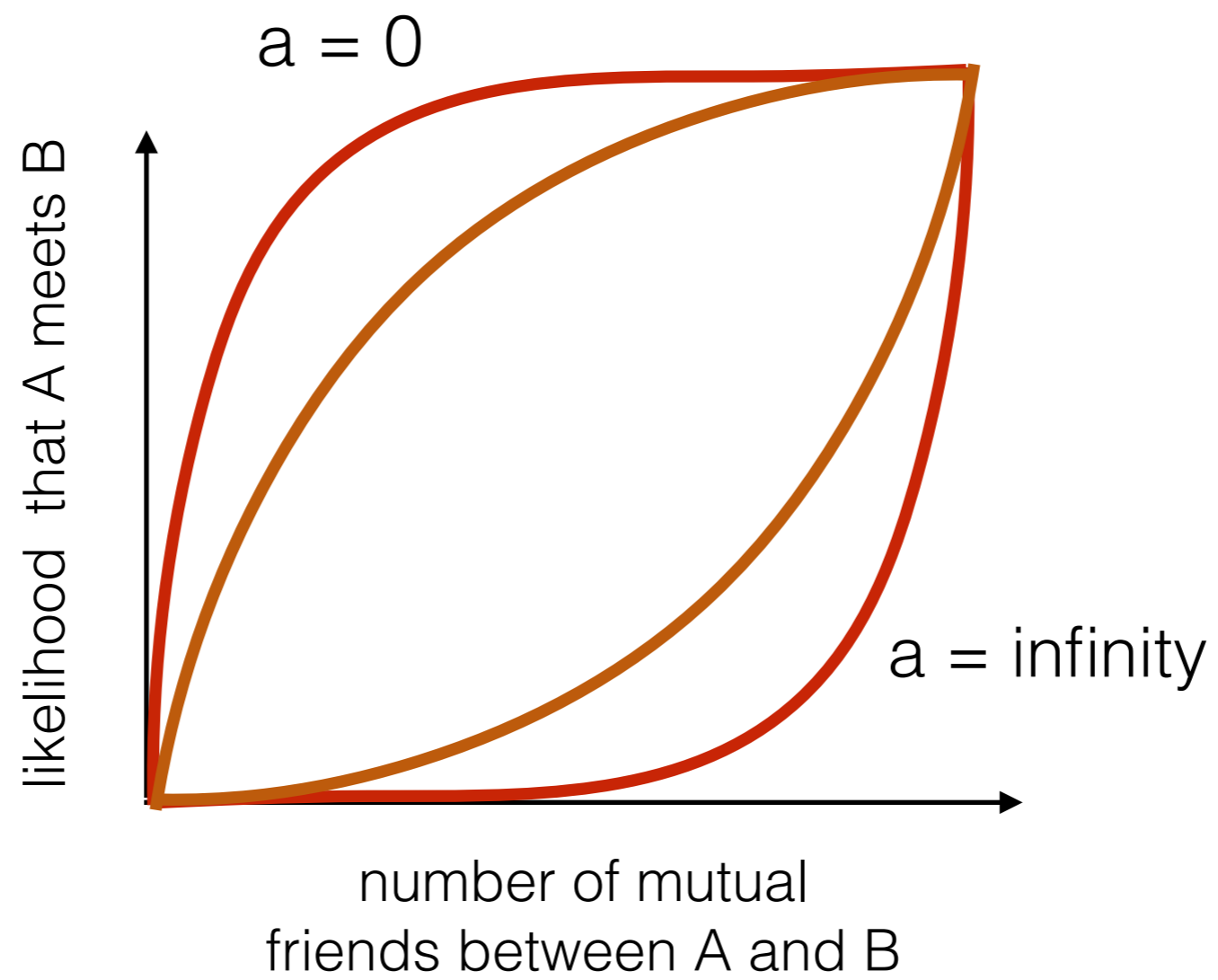
# Connection Preference

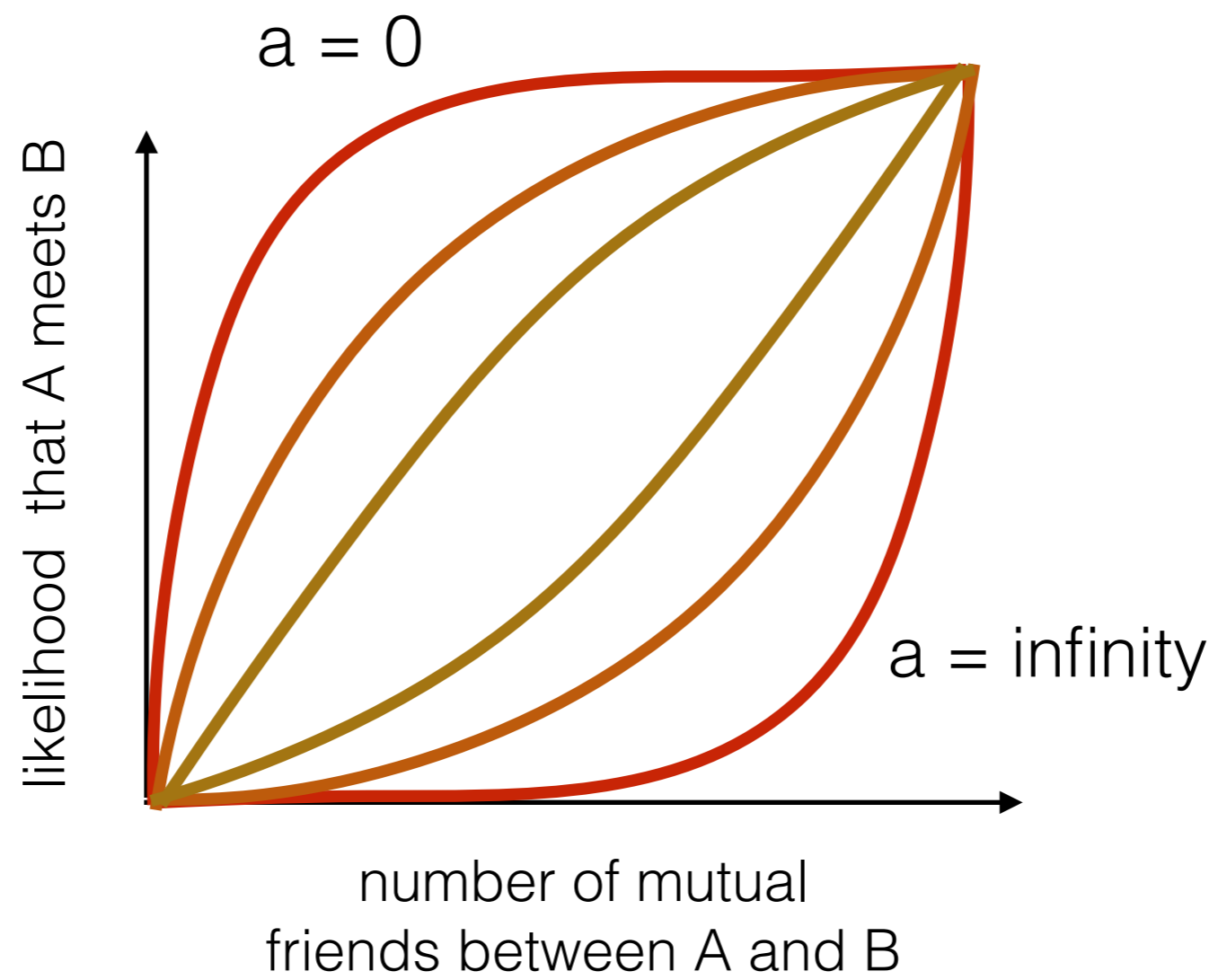
$a$  (alpha) = preference for connection

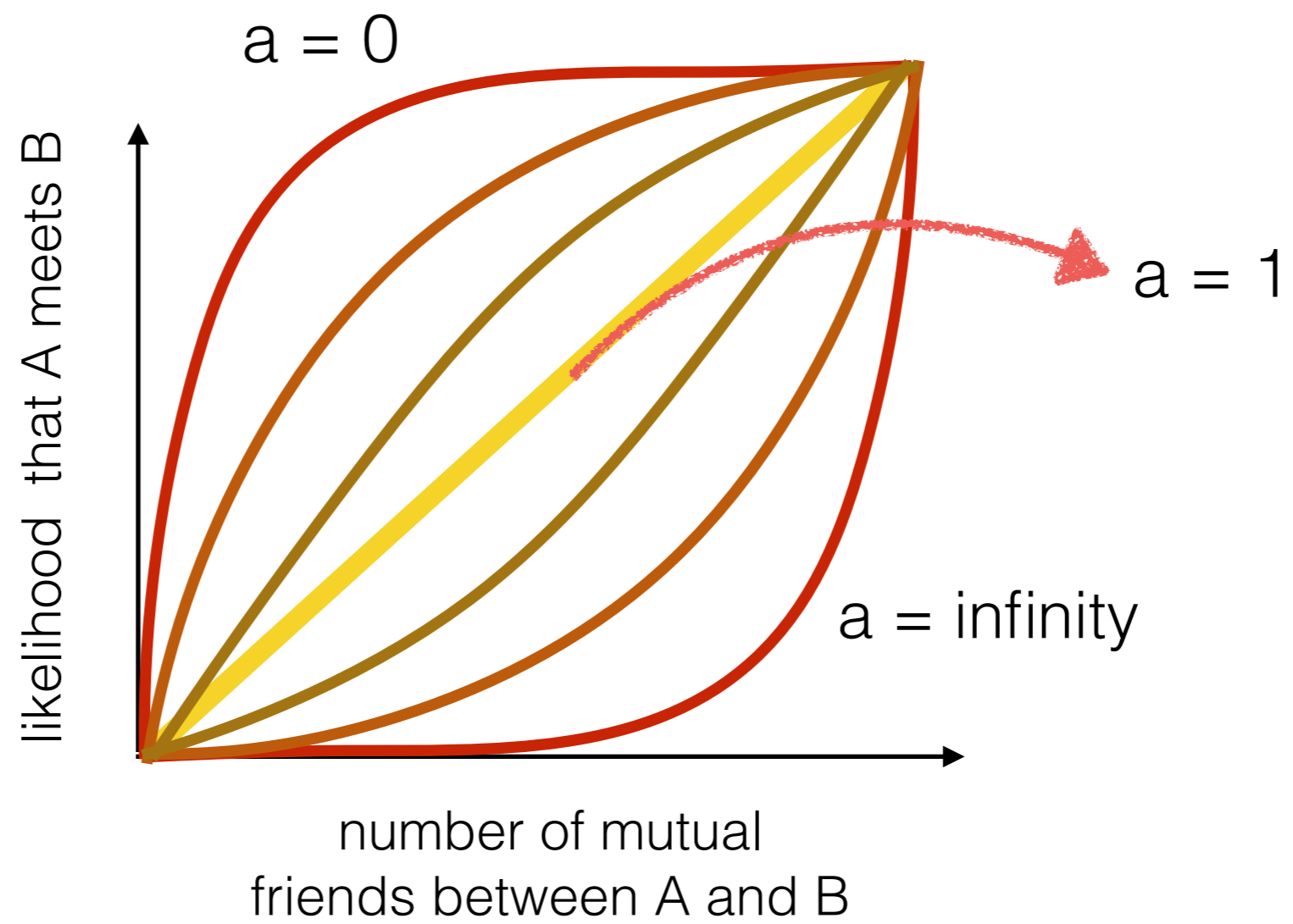
low  $a$  = preference to connect  
to friends of your friends

high  $a$  = preference to connect  
to someone other than a friend  
of your friends









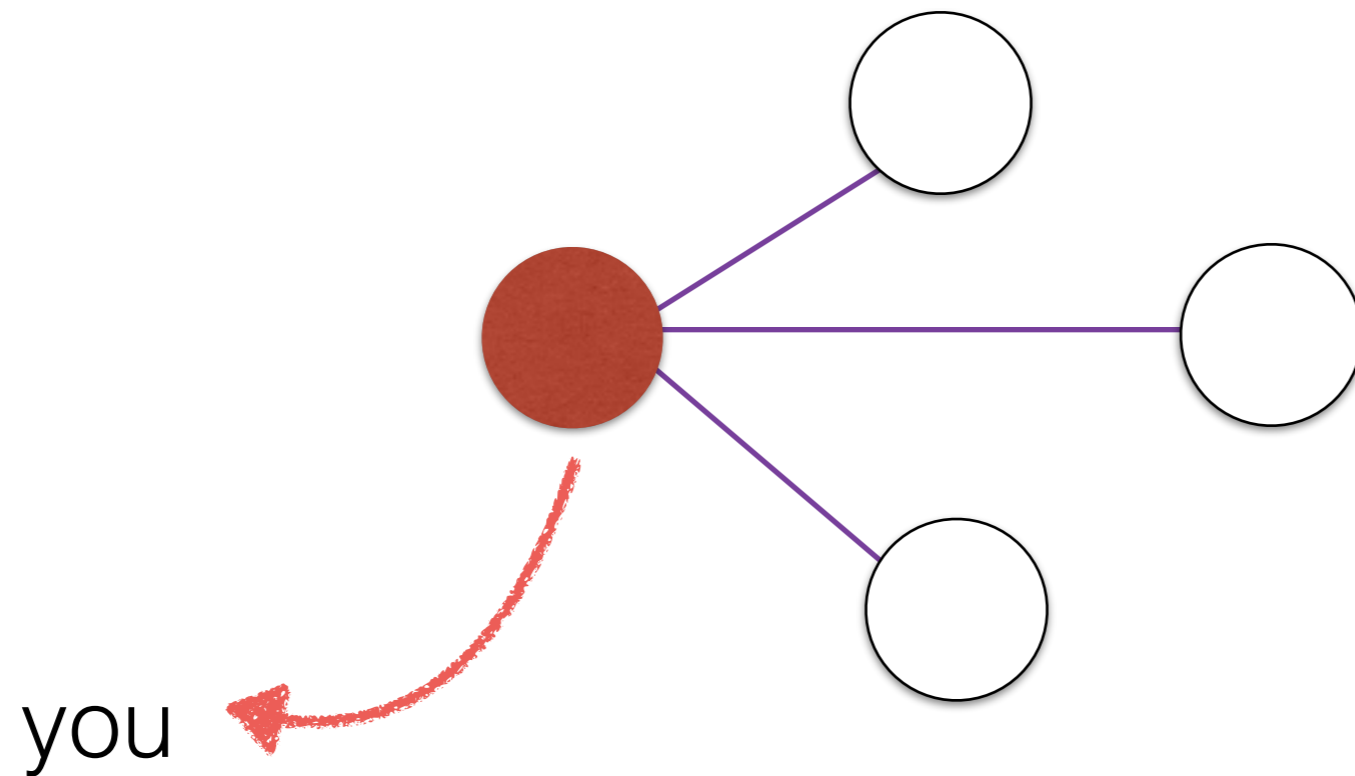
# Path Length

average number of steps along the shortest paths  
for all possible pairs of network nodes

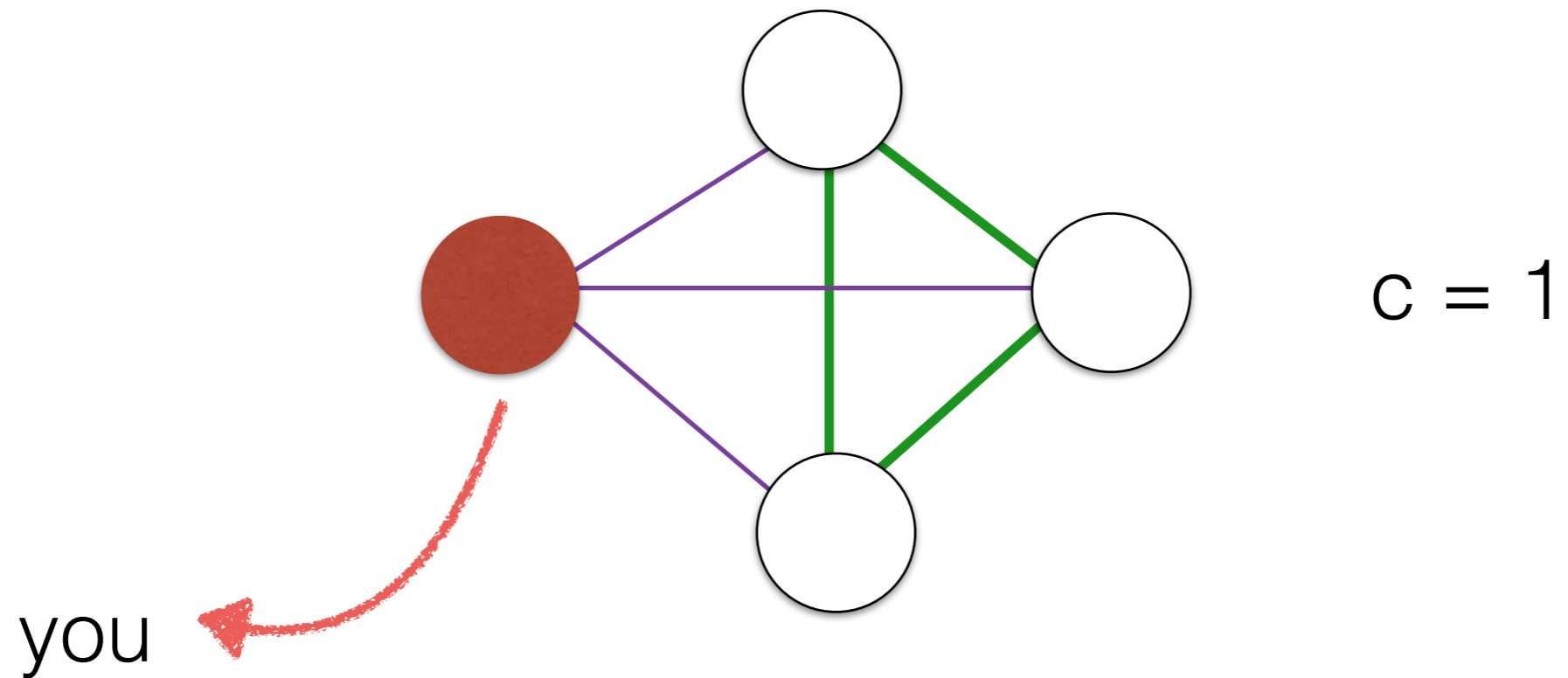
# Clustering Coefficient

a measure of the degree to which a single node cluster together (are your friends friends?)

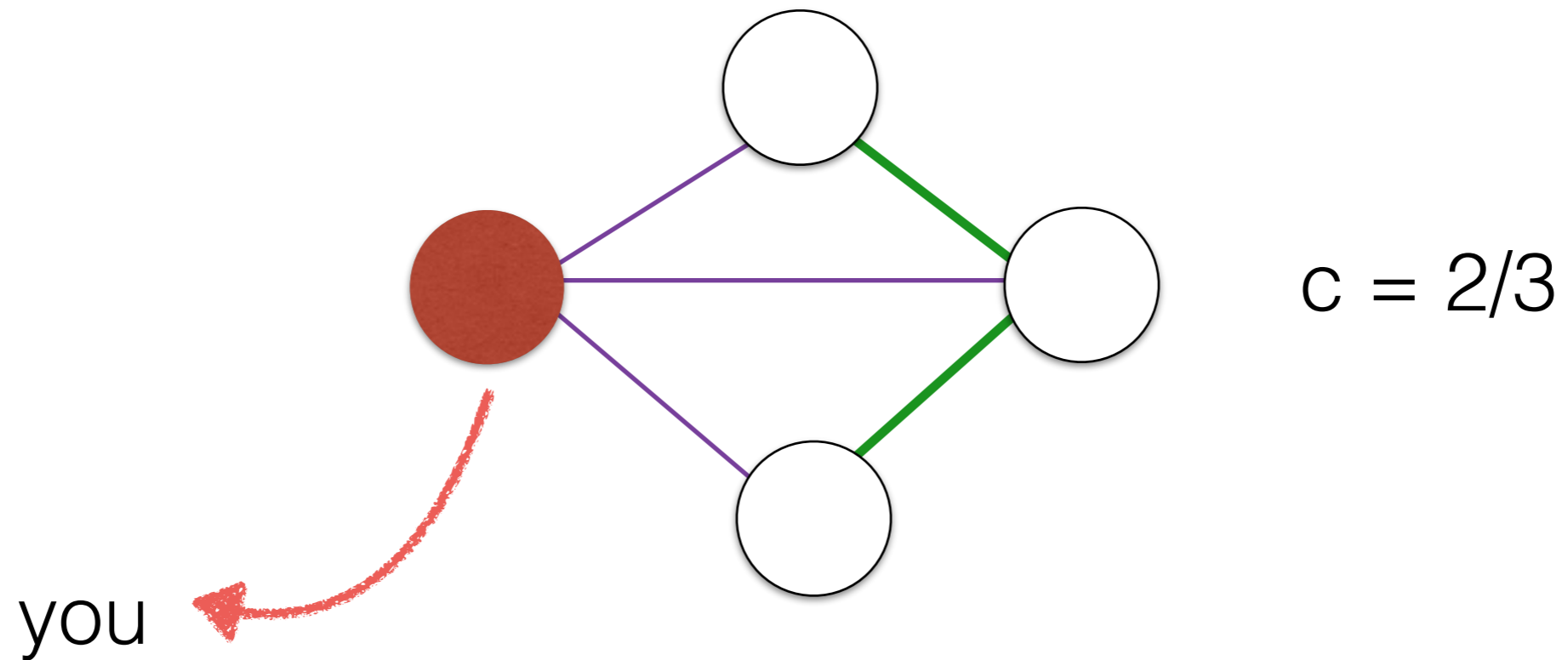
# Clustering Coefficient



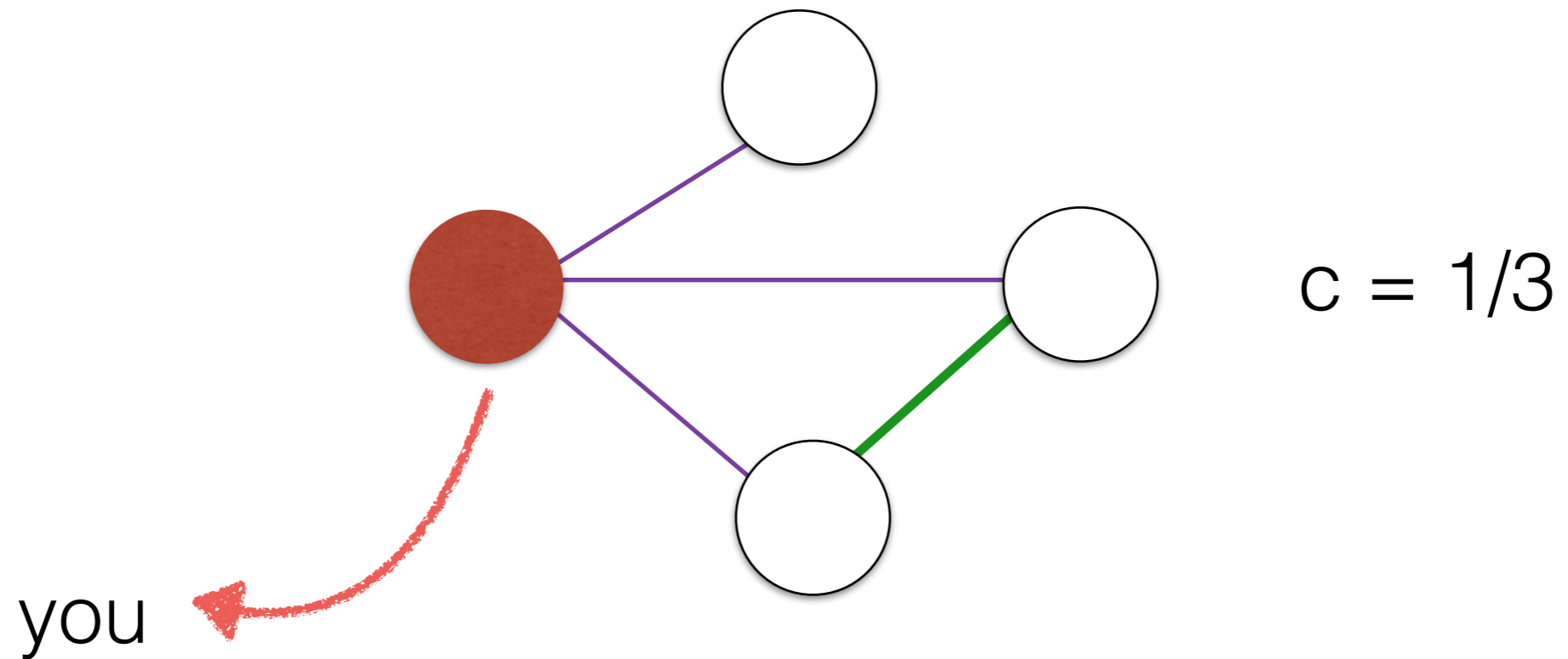
# Clustering Coefficient



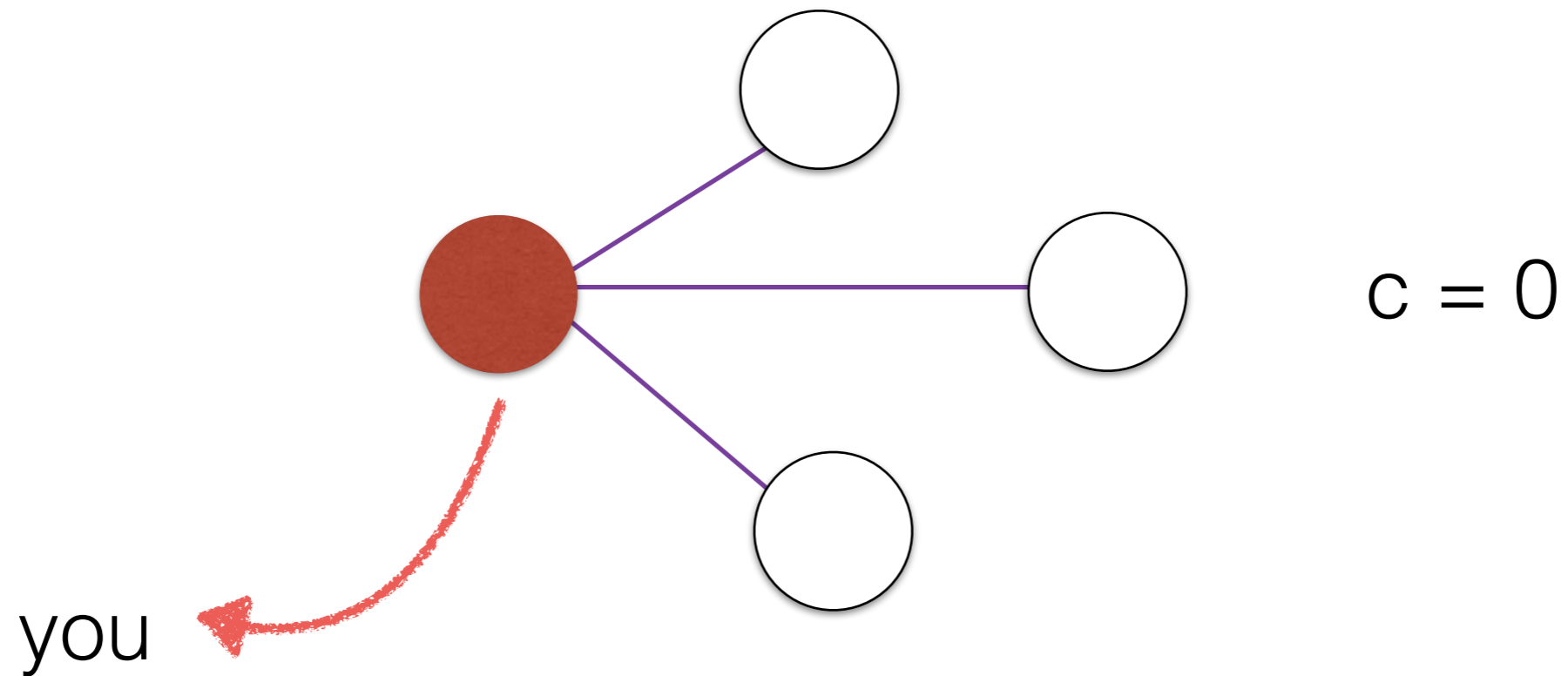
# Clustering Coefficient

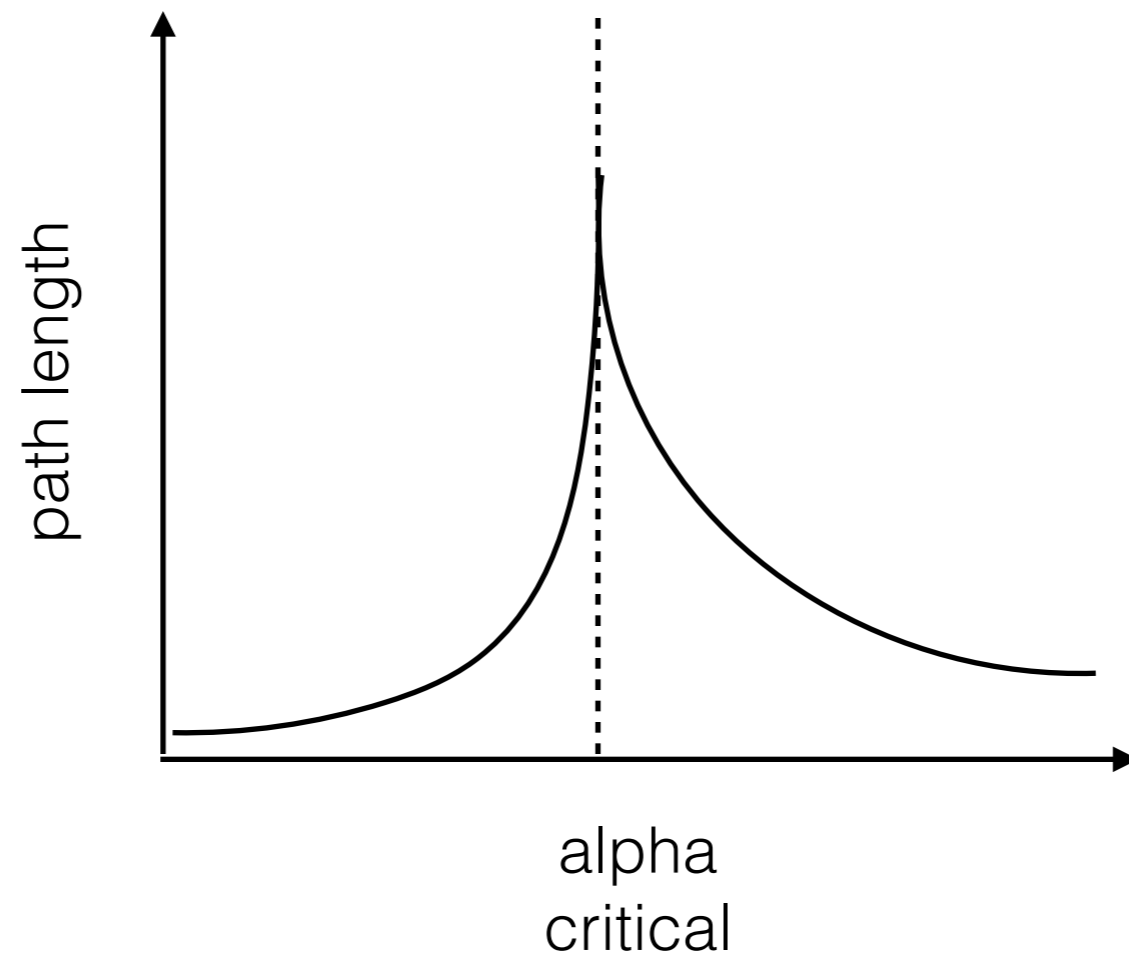


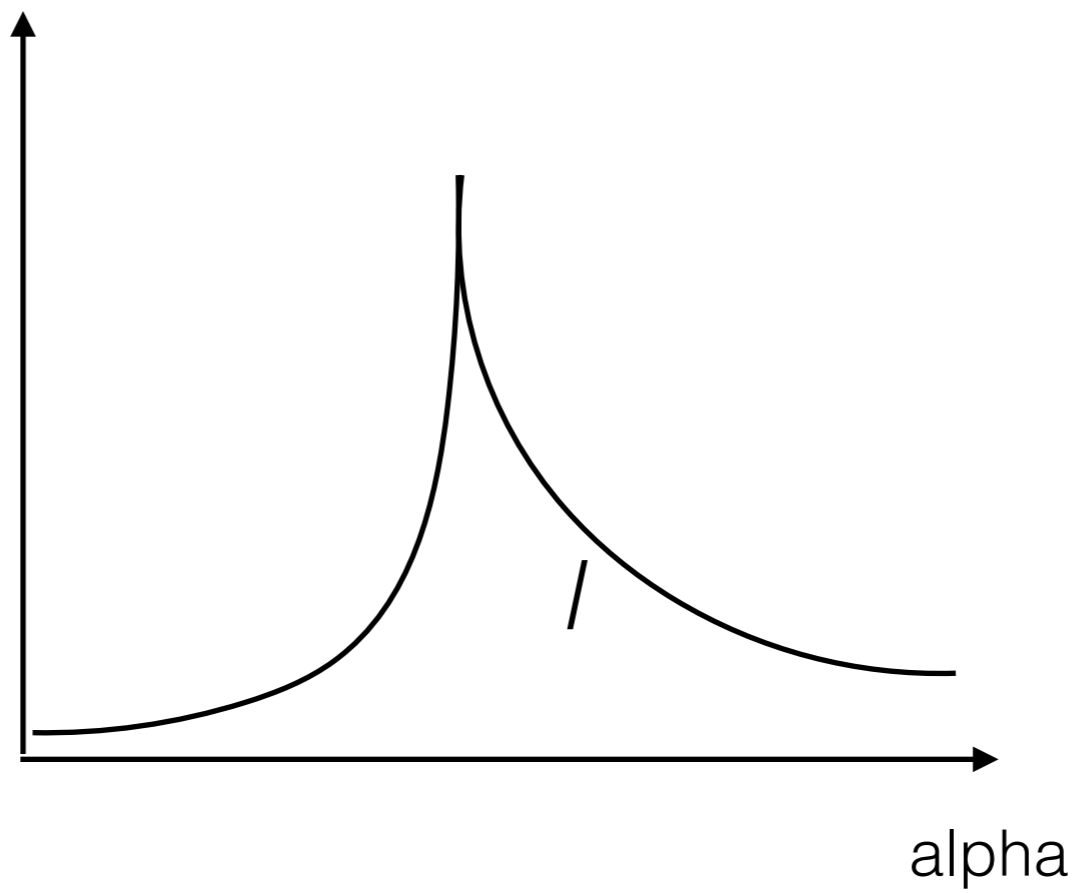
# Clustering Coefficient

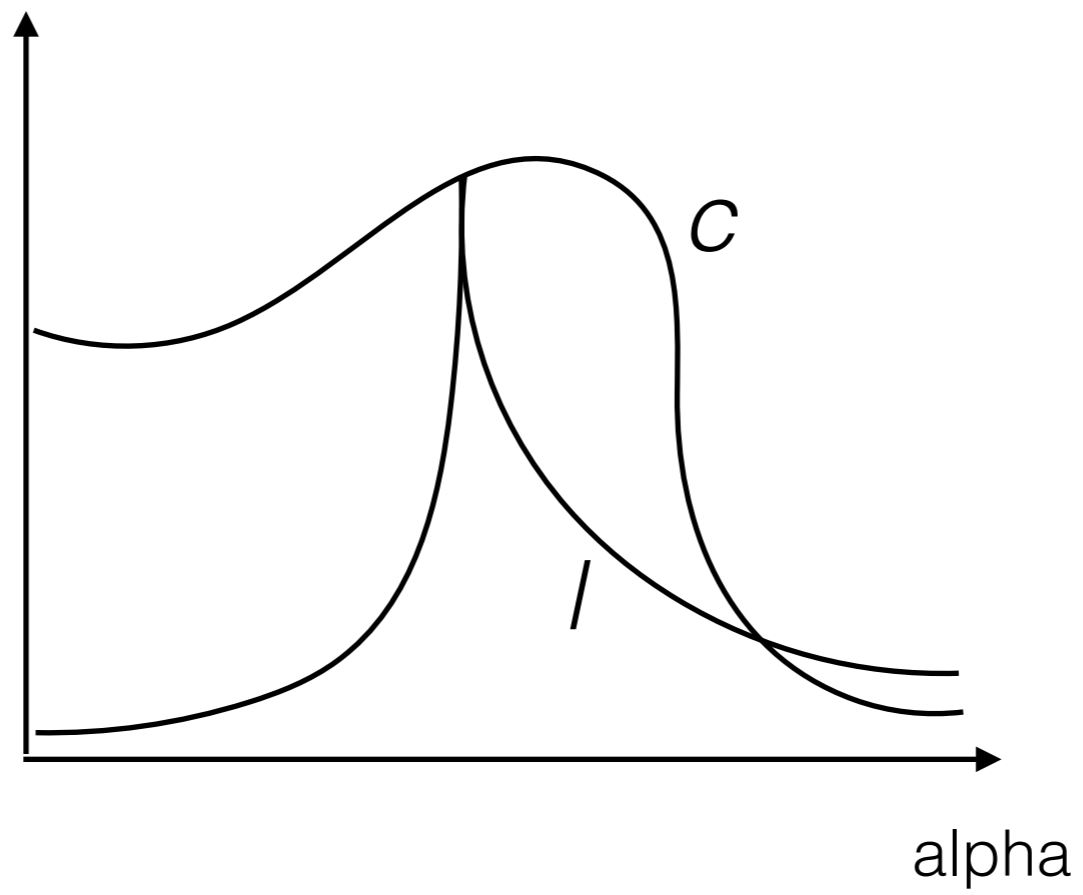


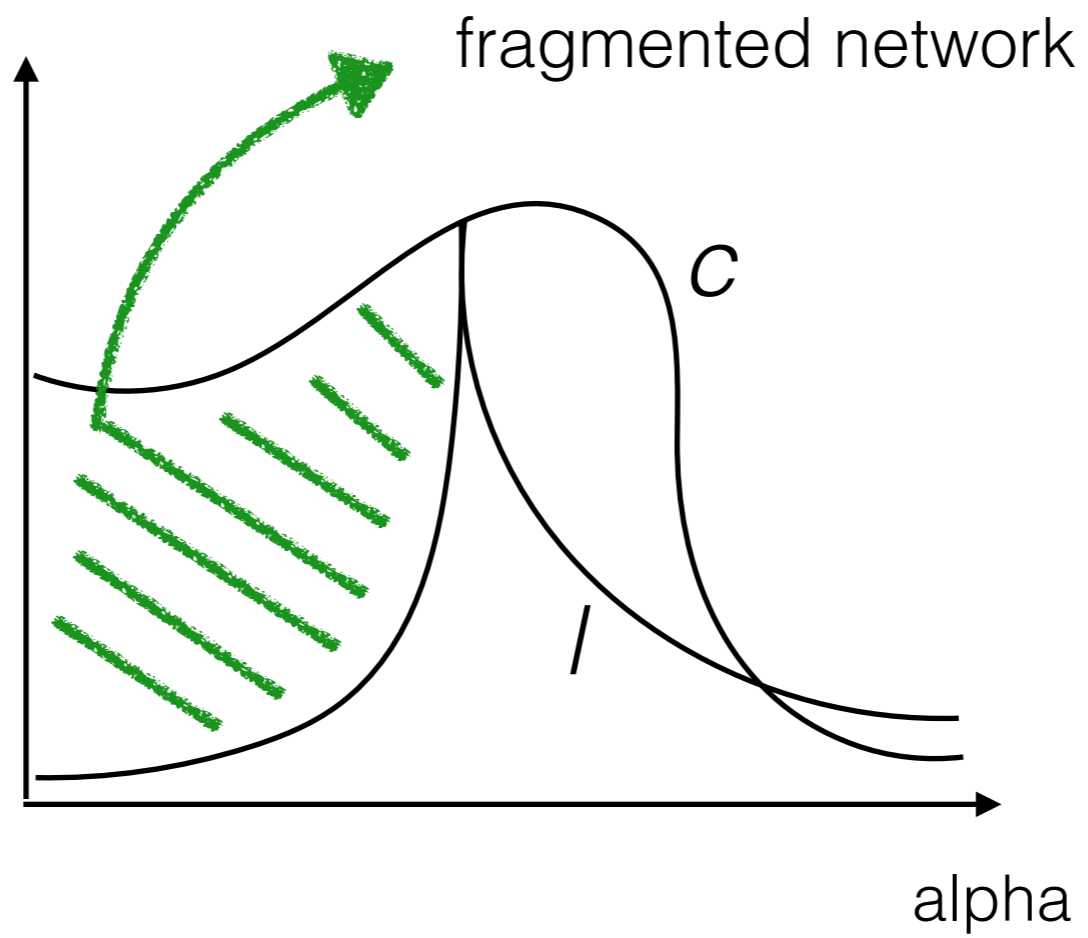
# Clustering Coefficient

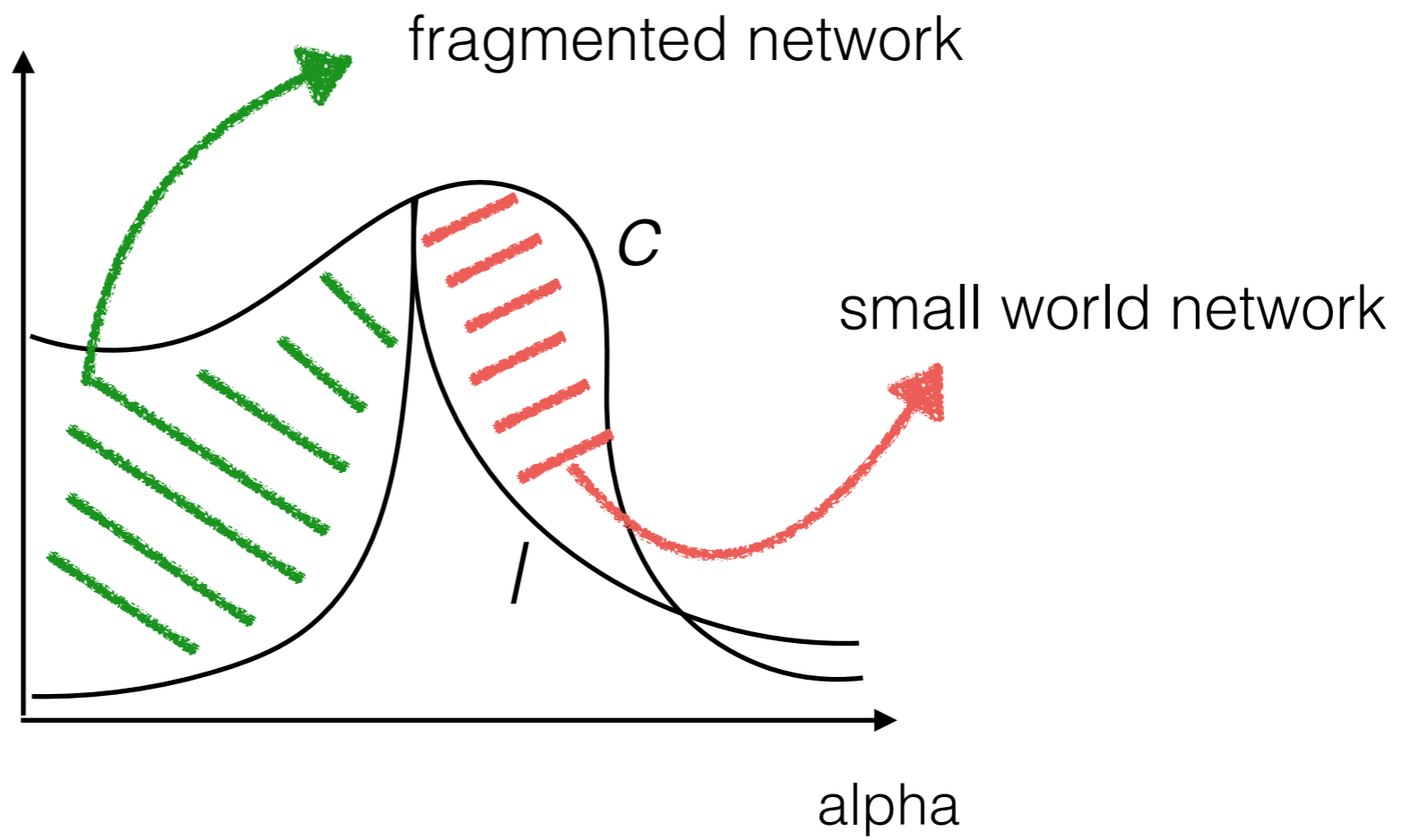












# The Take Away

1. Networks can either be clustered or connected; they cannot be both.
2. The critical value of alpha represents a *phase transition* from a clustered to a connected (small world) network.
3. Once a network passes through the phase transition, it becomes amenable (or susceptible) to the spread of some entity throughout the network.

# Team Assembly Model

