

WHO YOU KNOW: NETWORK MODELS OF DISEASE

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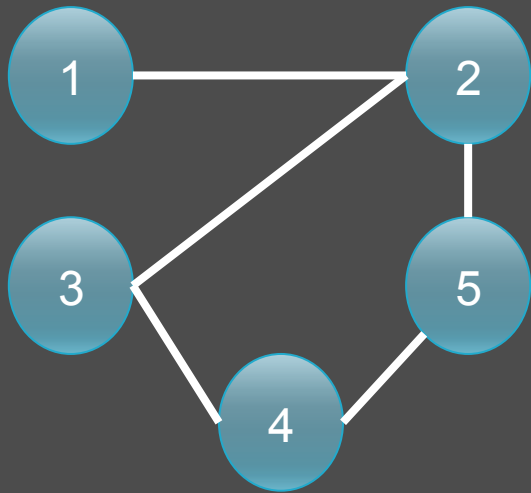
SIR Recap

- ⦿ Population divided into compartments
- ⦿ Population **mixes randomly**
- ⦿ Relaxing that assumption and modeling connections in the population explicitly gives us network models

Networks as a Concept

- ⦿ What is a “network”
 - Way of representing relationships
 - You have *nodes* (people, places, etc.)
 - You have connections between those nodes called *edges*
- ⦿ Can be represented many ways
 - Common ones are a diagram, an edge list and an “adjacency matrix”
- ⦿ Layout may be called “topology”

Network Representations



Diagram

1	2
2	3
2	5
3	4
4	5

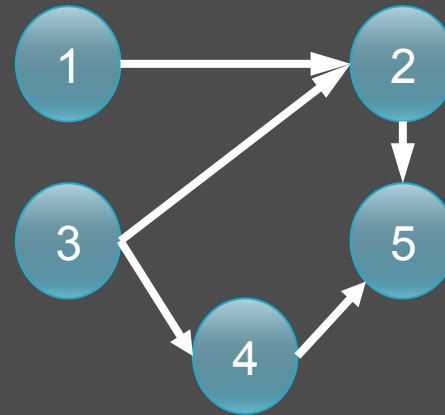
Edge List

$$\begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \end{pmatrix}$$

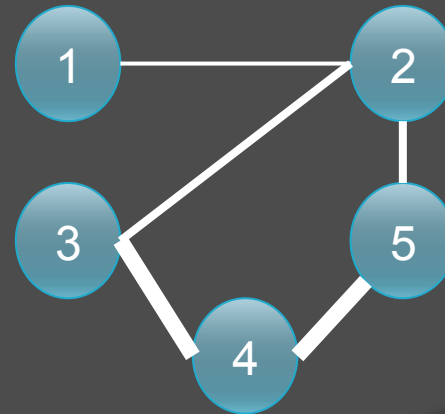
Adjacency Matrix

Complications of Networks

- Directed Networks:



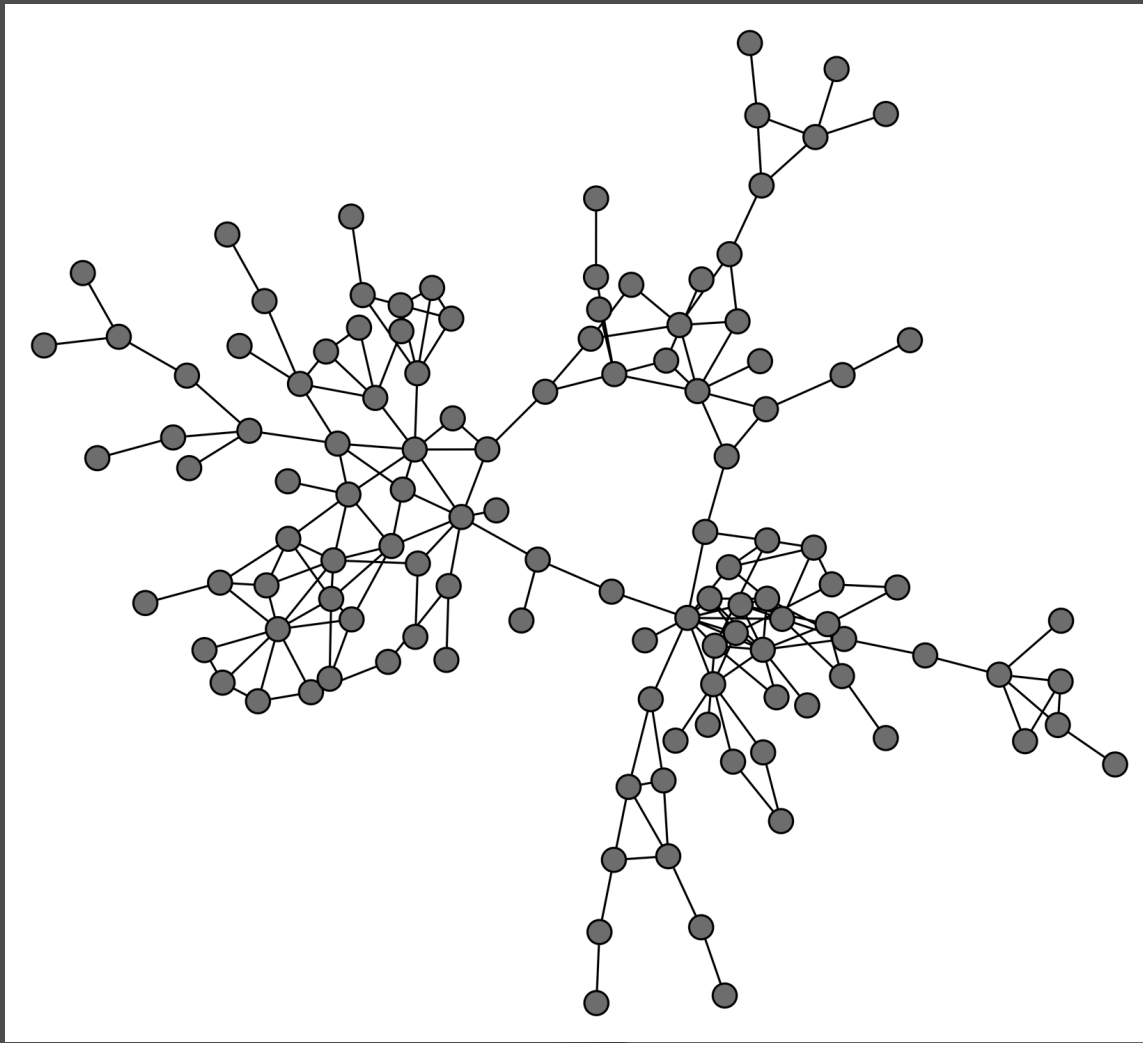
- Weighted Networks:



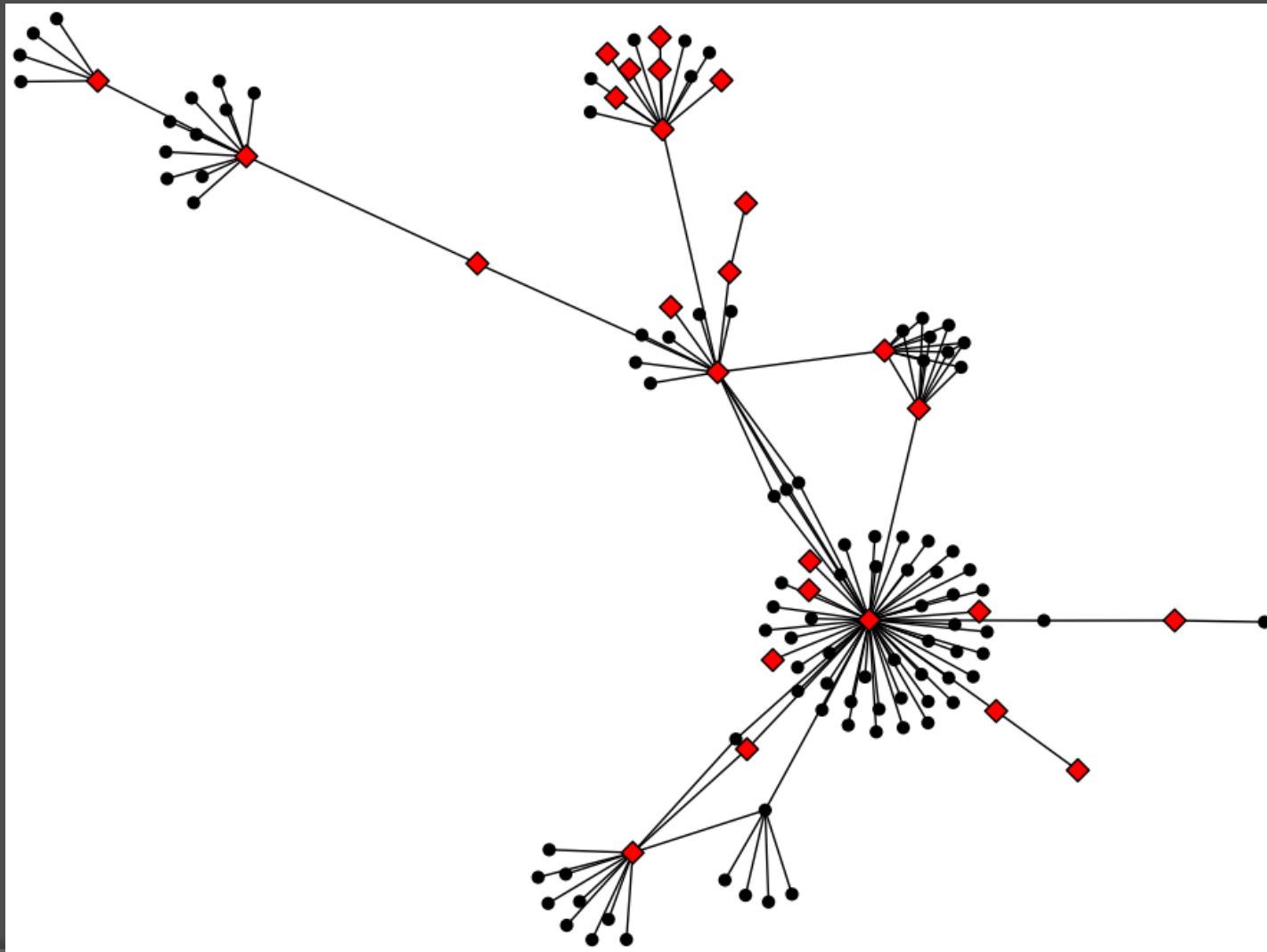
Many Networks, Many Questions

- ◎ Network analysis is interested in study of the shape and structure of networks
 - Questions about the shape and structure of networks – how are nodes connected, do they form patterns, etc.
 - Simulating a process (like an epidemic) on a network is one small part of that
- ◎ Vibrant research field beyond the scope of this presentation – sociology, physics and math all have their own take

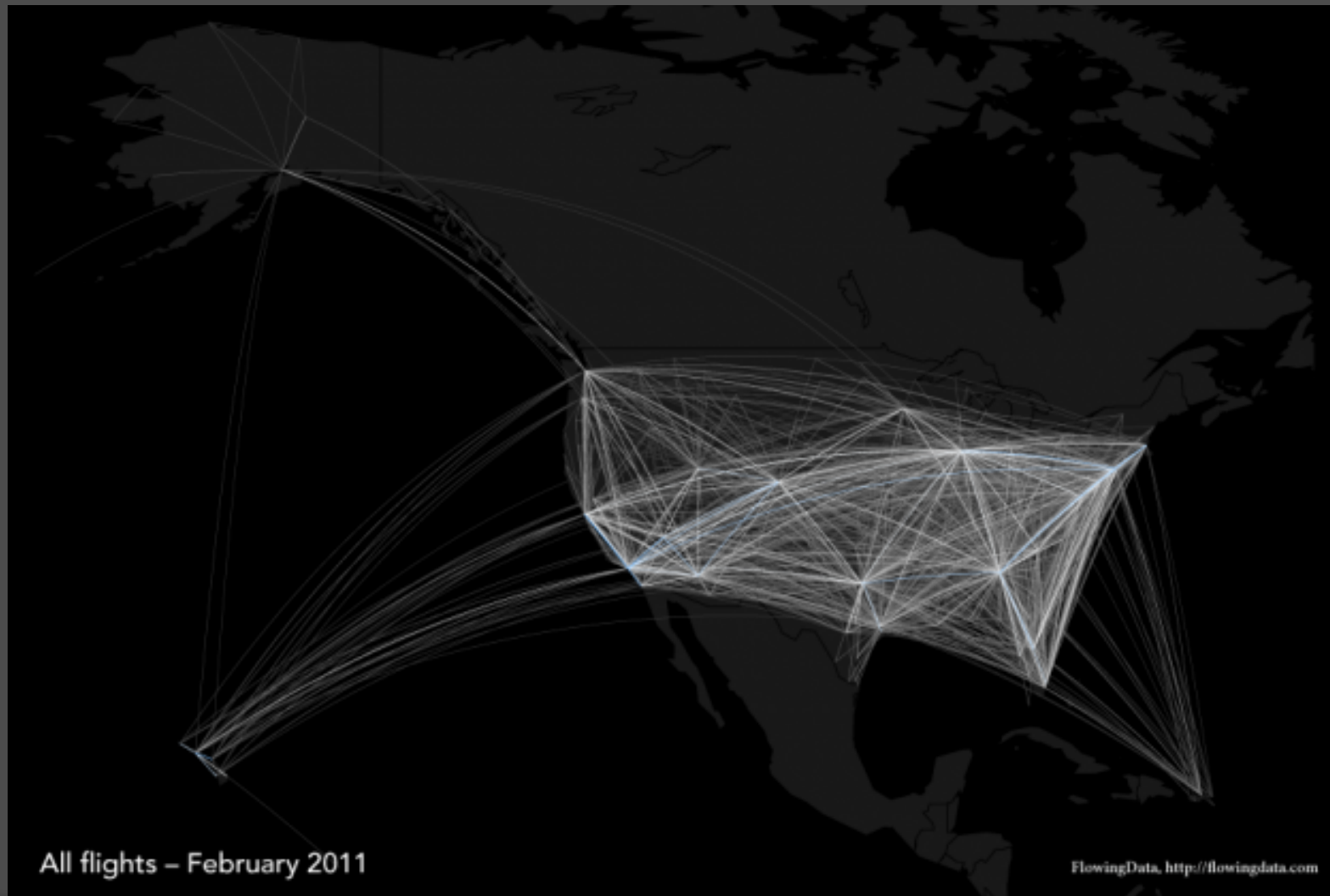
Social Networks



Sexual Networks

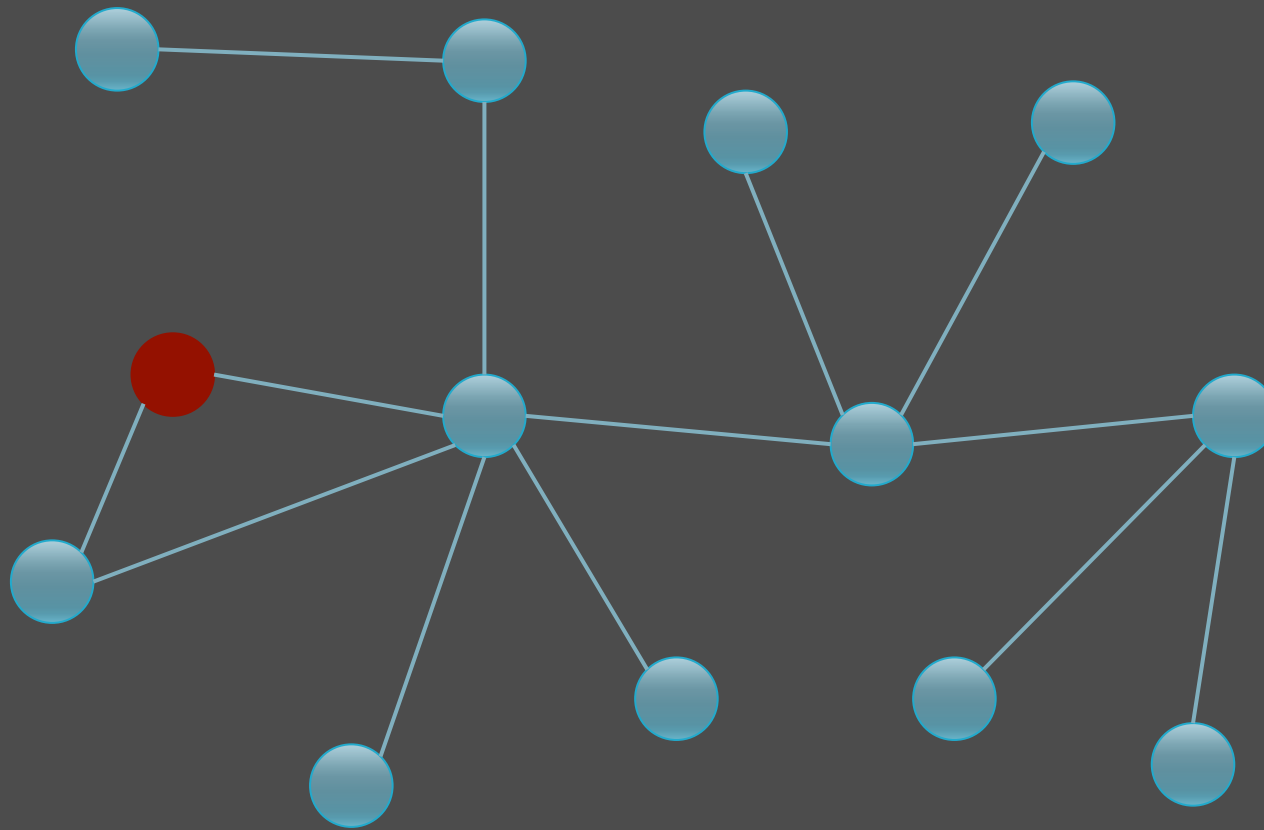


Geographic/Infrastructure Networks



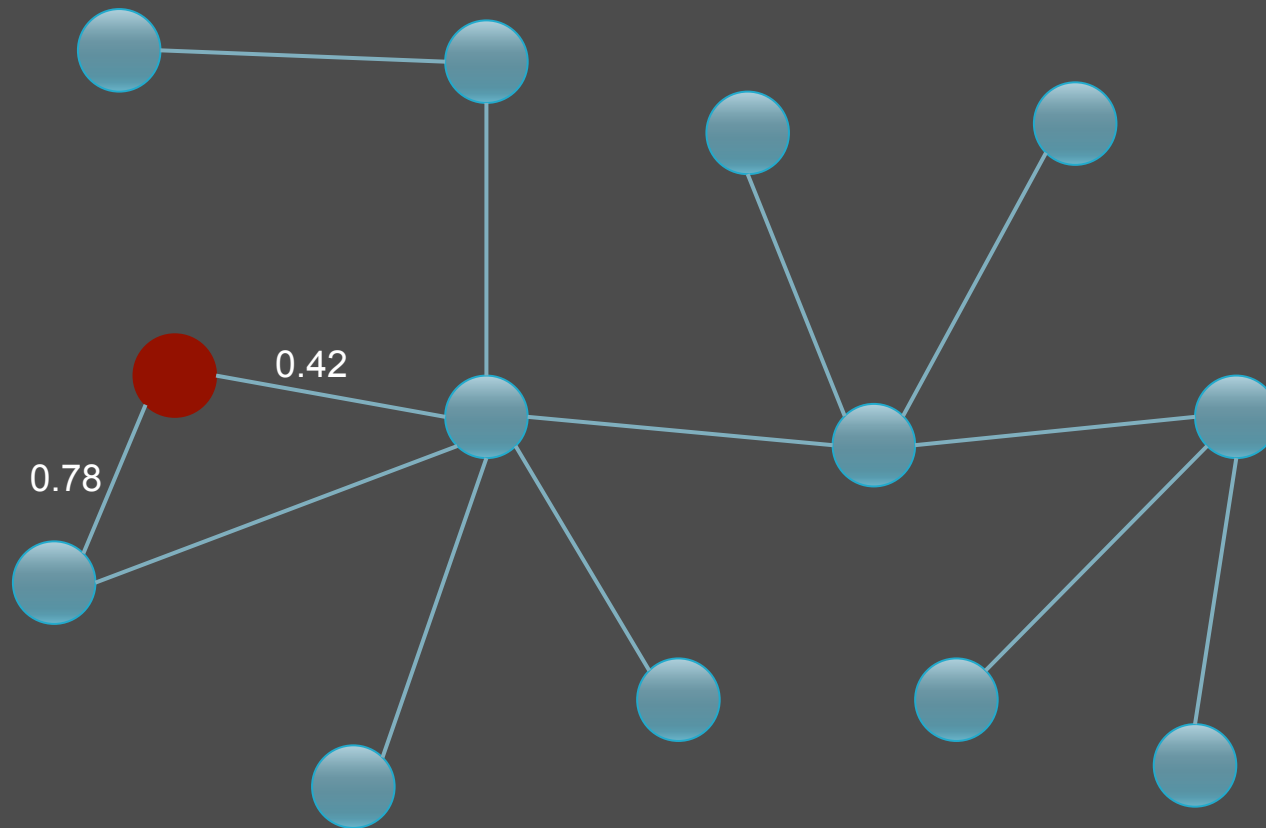
Network Spread of Disease

A Simple Network Model



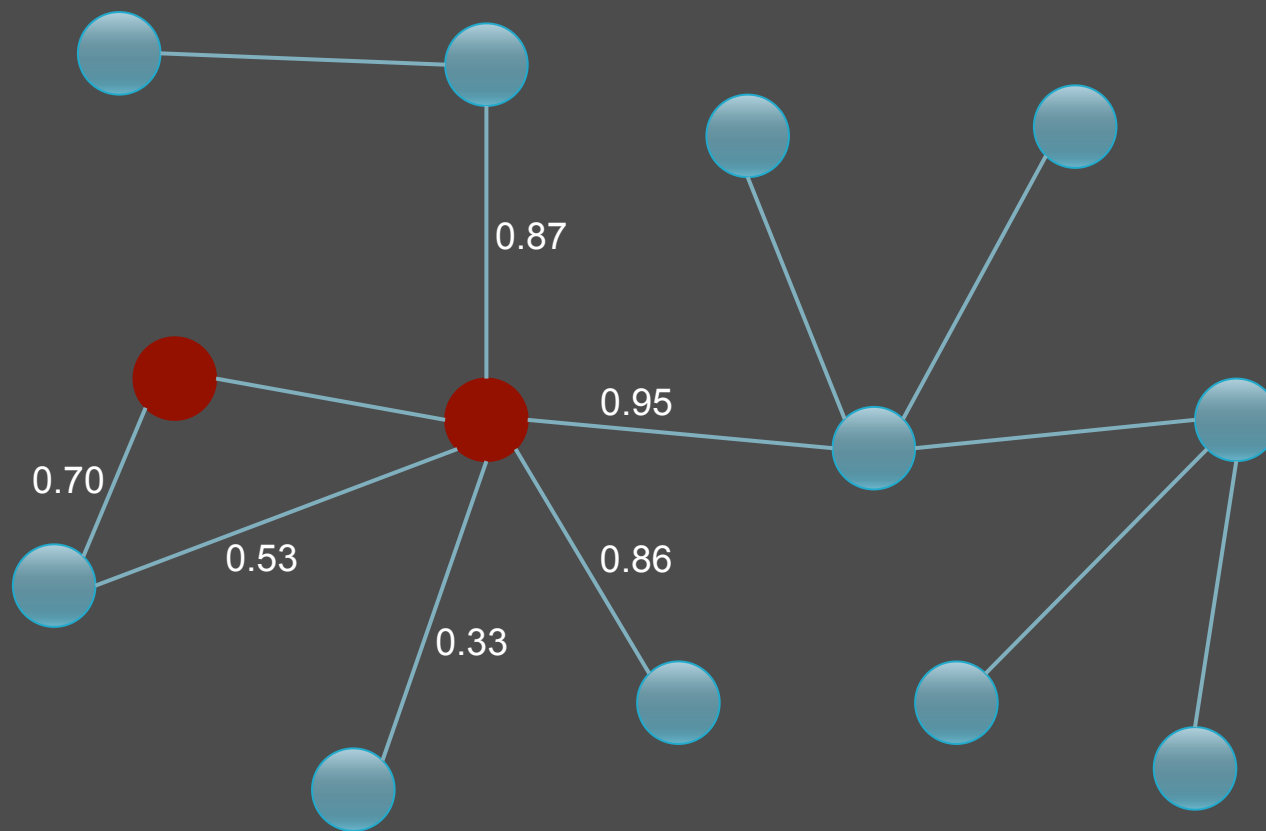
Start with one infected individual

T=1

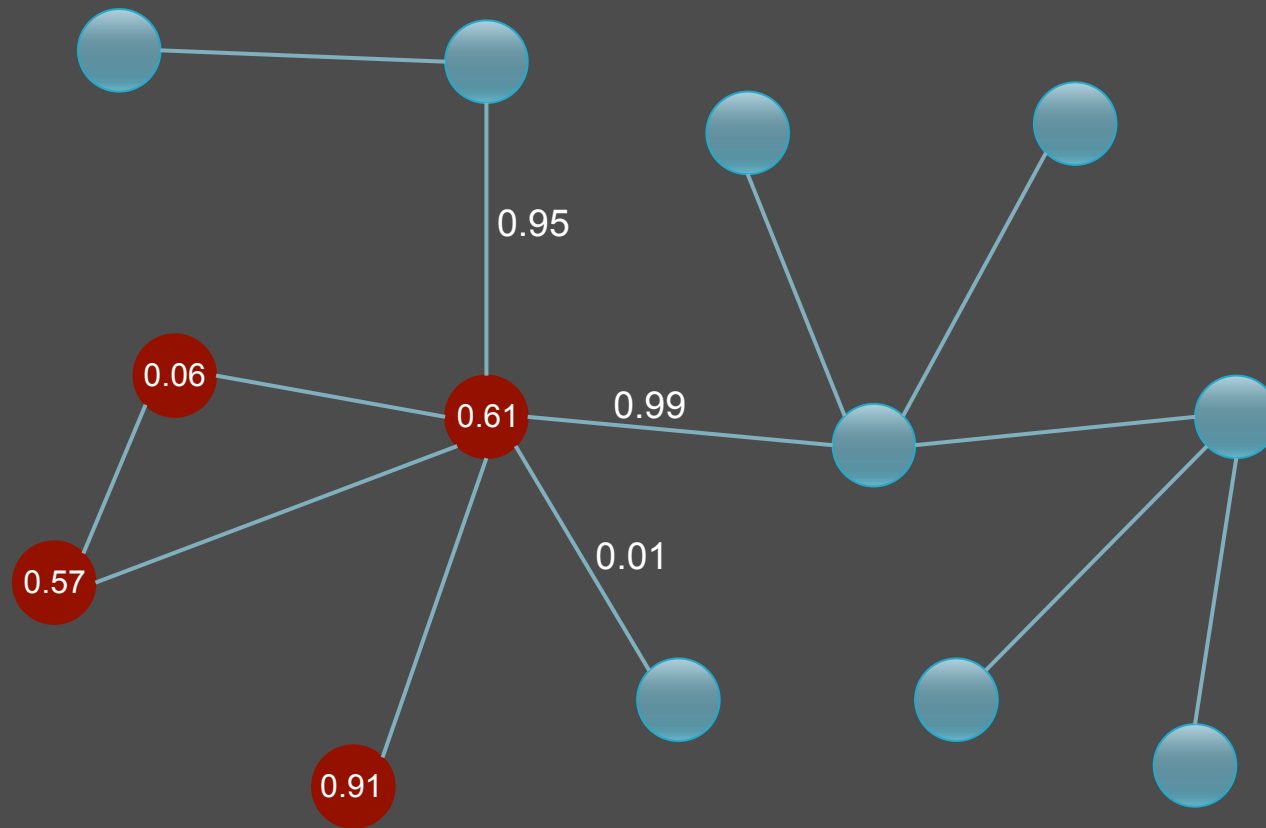


Spreads along edges to other nodes at a probability p
 $p = 0.65$

T=2

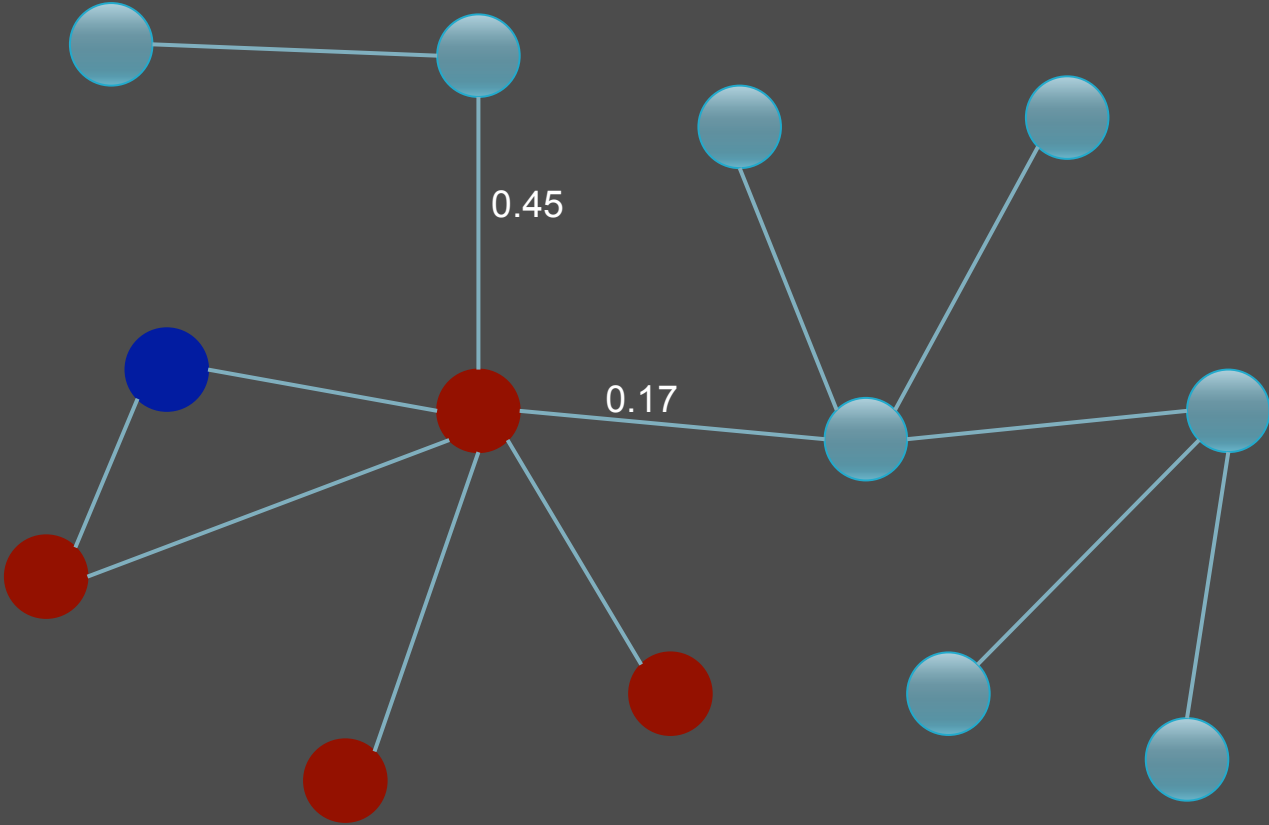


T=3

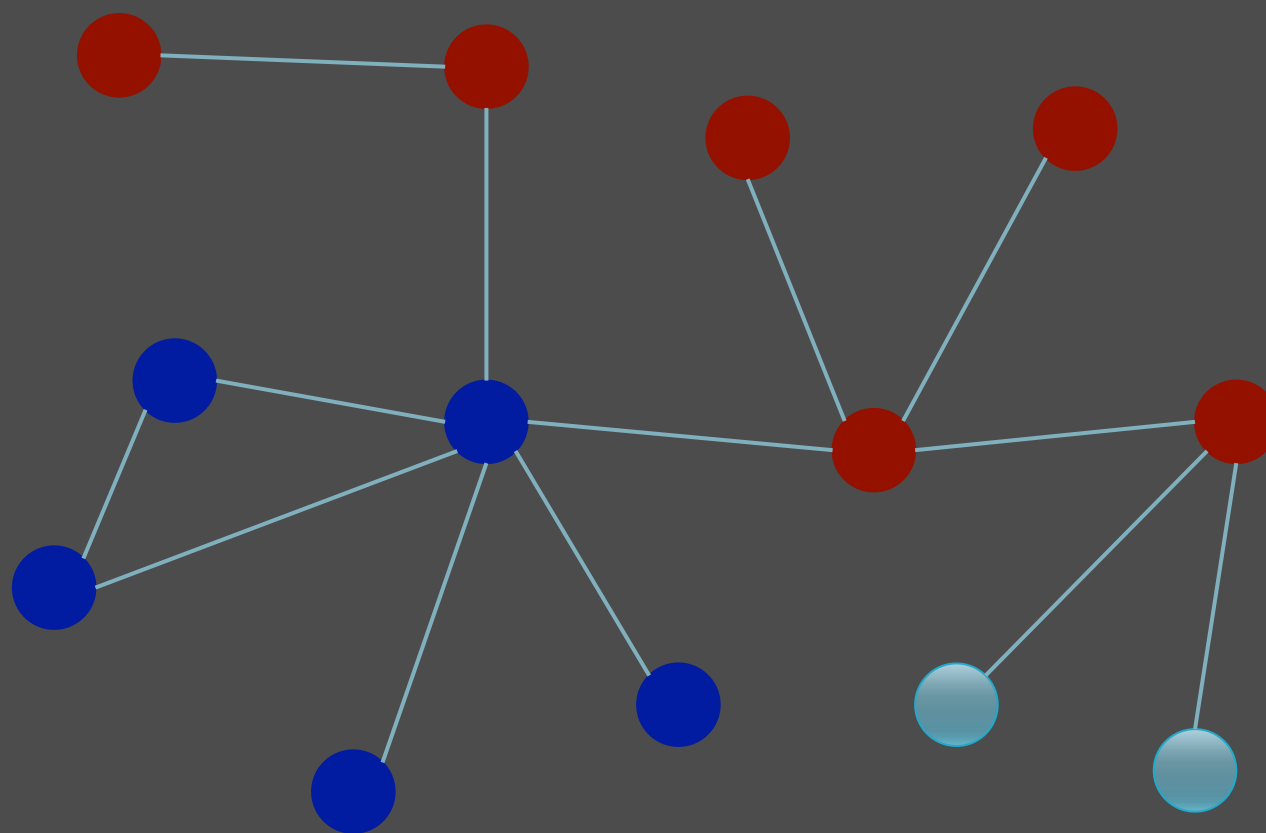


Infected nodes die with probability g
 $g=0.10$

T=4



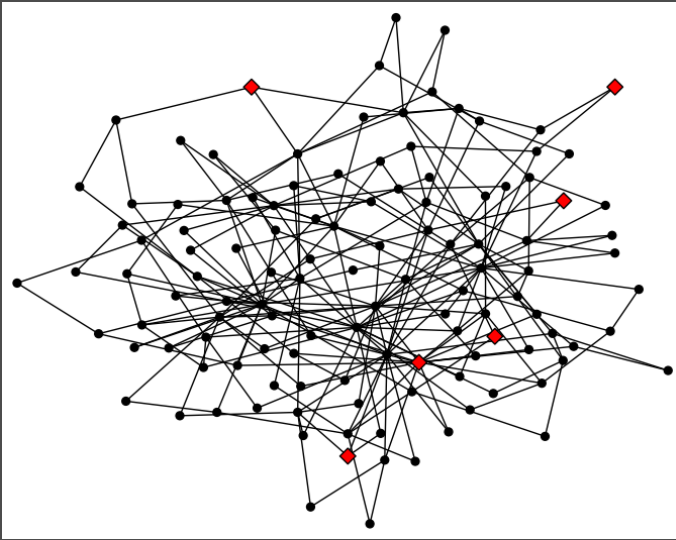
And so on...until



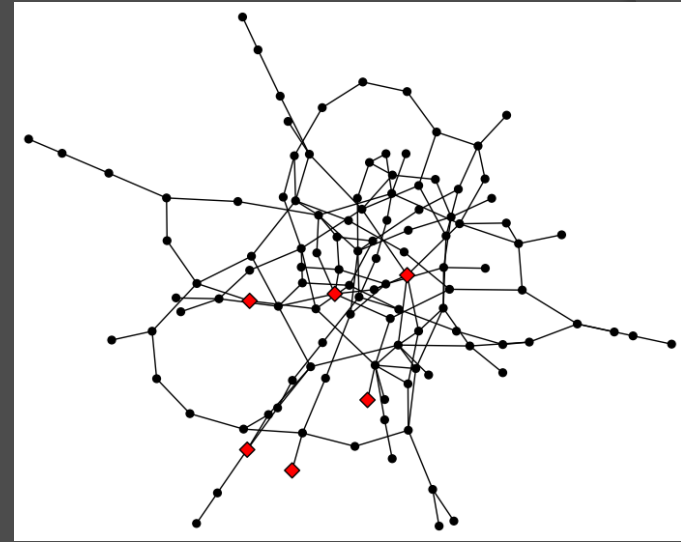
Differences Between Compartmental and Network Models

- ⦿ Results of the two will often not agree
- ⦿ This can be the result of:
 - Random chance
 - Stochastic extinction
 - Network structure
 - Contact pattern – note that each node has fewer interactions than they would have in a compartmental model

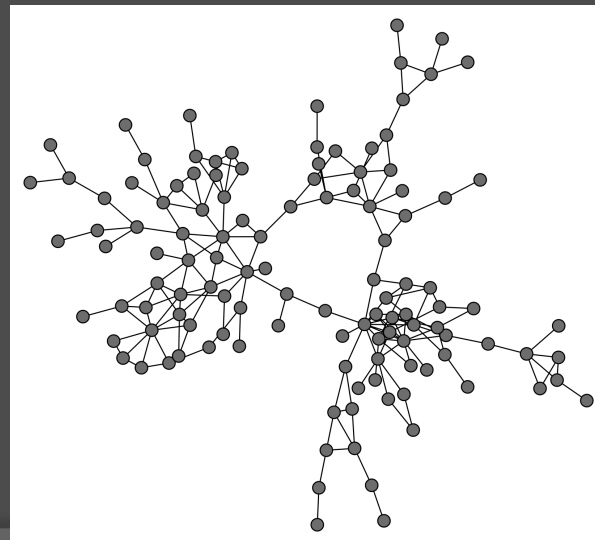
Different Network Structures



Scale-Free

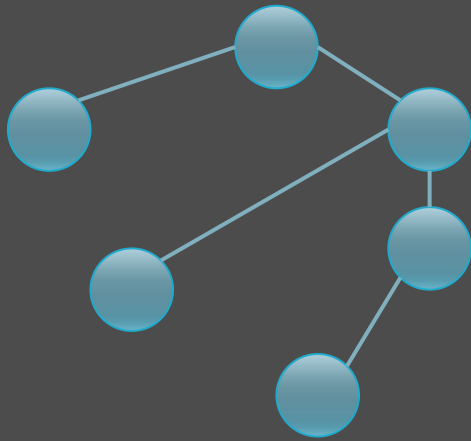


Random

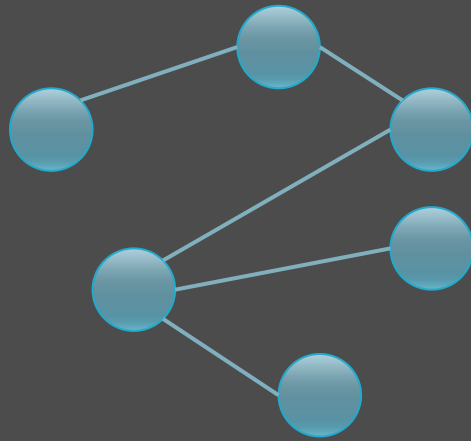


Empirical

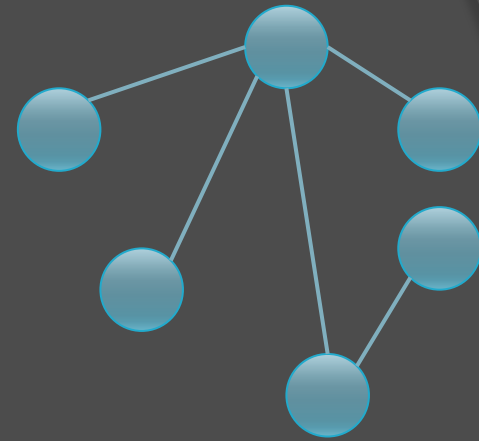
Dynamic Networks



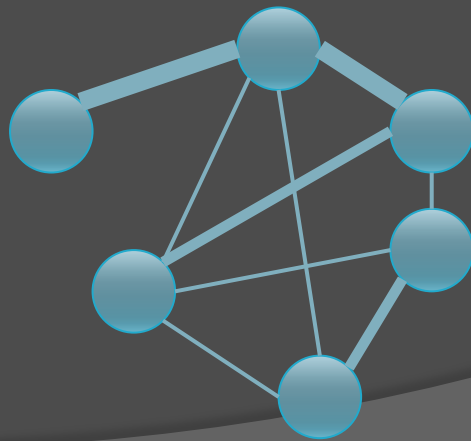
Day 1



Day 2

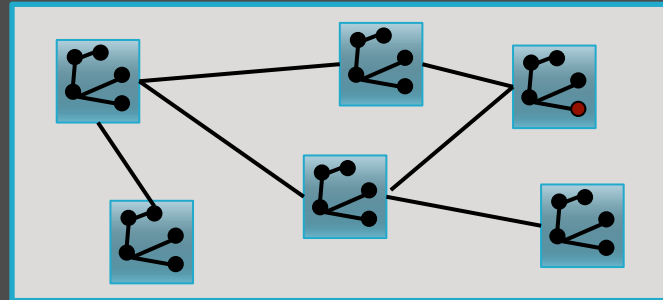


Day 3

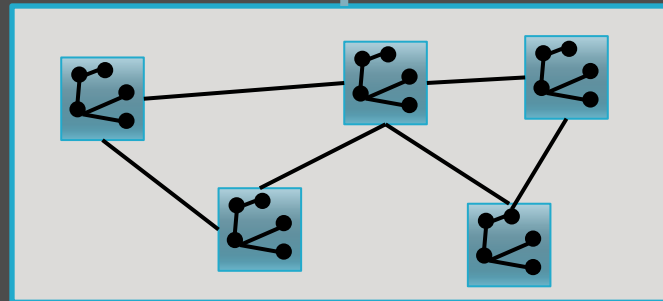


Weighted Union

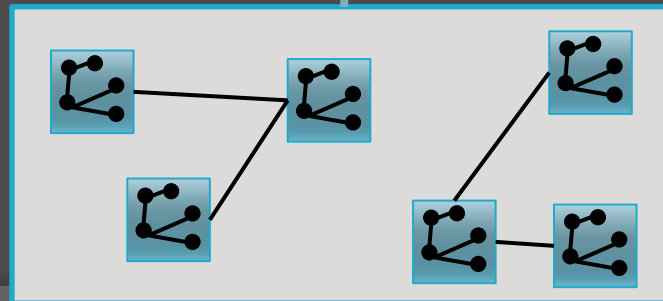
Complex Networks



Baltimore



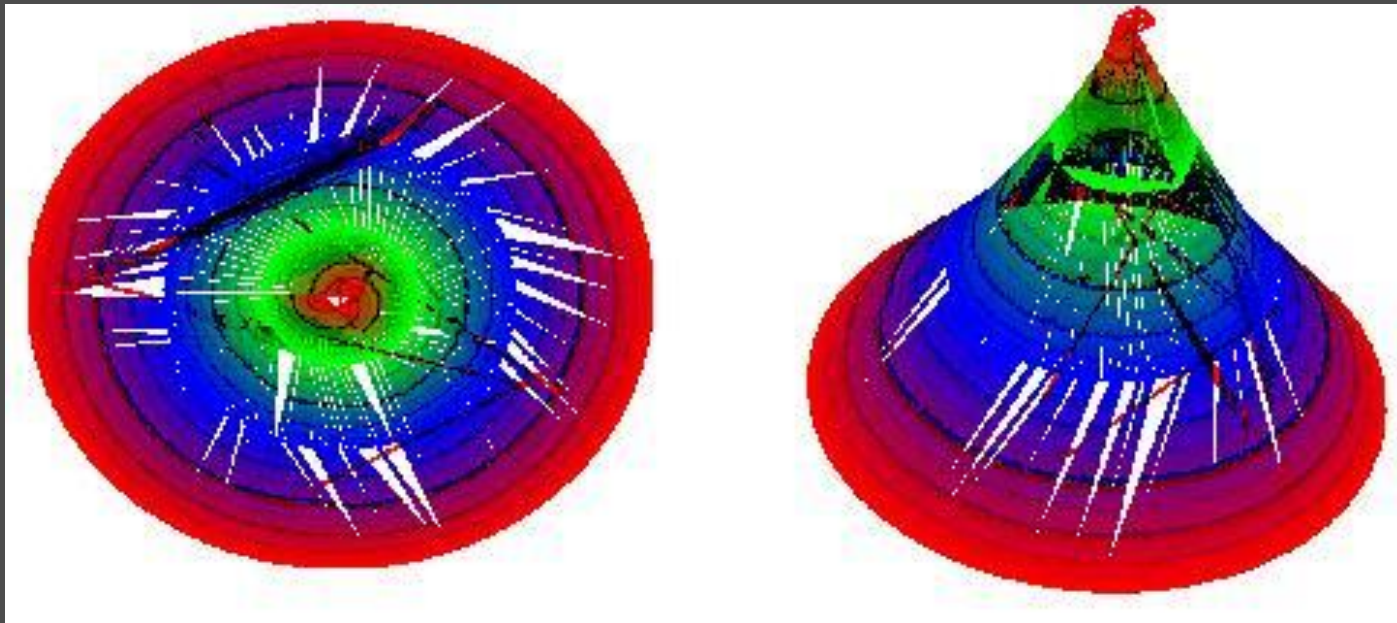
Washington DC



Richmond

Complex Networks

- These can get *staggeringly* complex



<http://ndssl.vbi.vt.edu/episims.php>

Parting Thoughts

- ◎ Many things can be thought of as networks but that doesn't make it useful to do so
 - Is your disease driven by a network process?
- ◎ Many things that aren't usually thought of networks might be
- ◎ Combination of randomness and network topology makes study design hard – need to control one, or have massive numbers of simulations