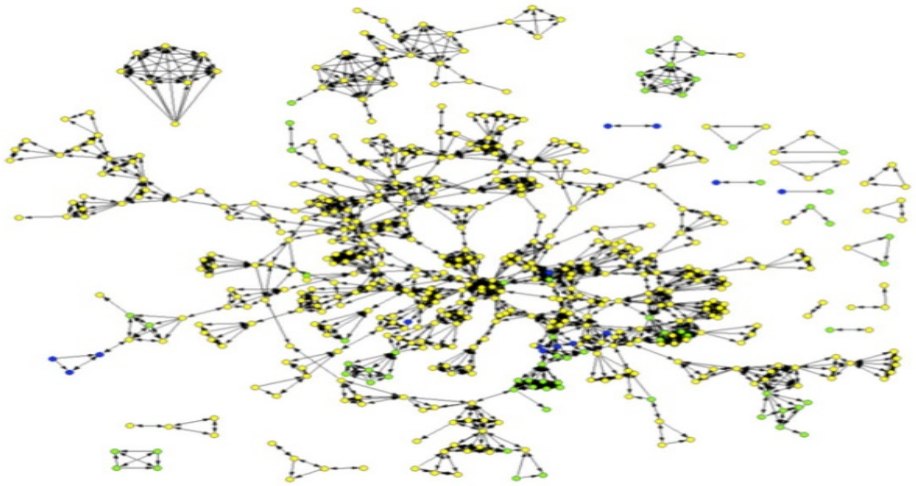
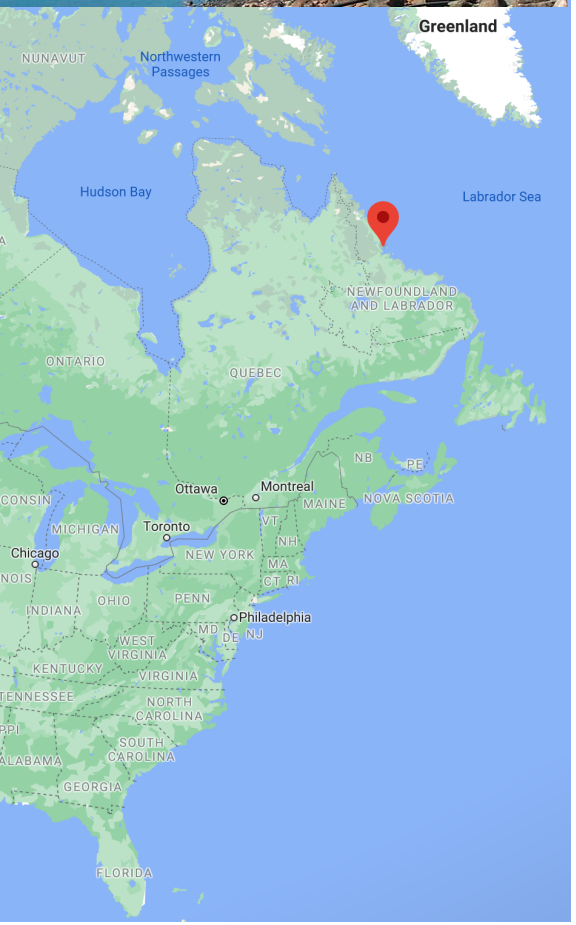
Applications of Social Network Analysis and Simulation to Public Health



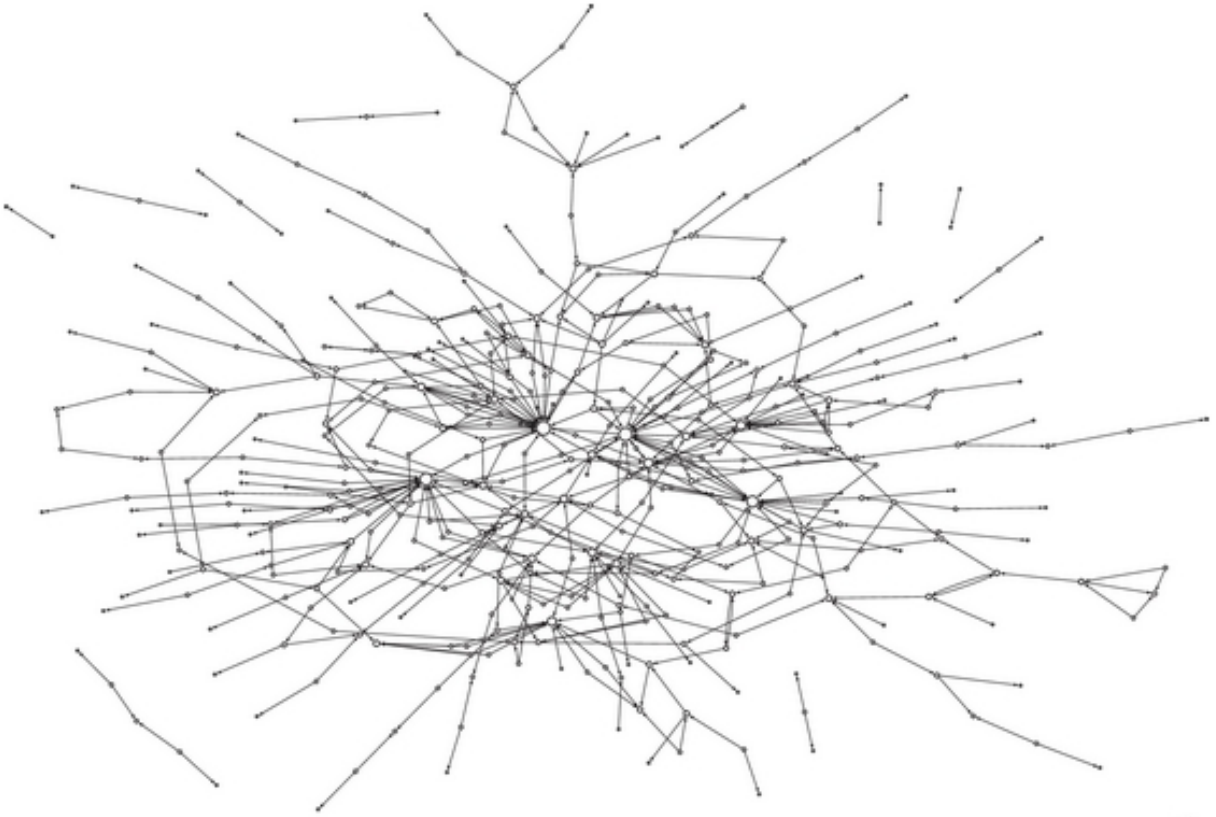
Bilal Khan
Departments of Computer Science & Sociology

University of Nebraska Lincoln



Nain, Labrador

Other 7 network layers: Store-Bought Food, Traditional Knowledge, Domestic Violence, Alcohol Co-Use, Youth Support, Housing, and Jobs

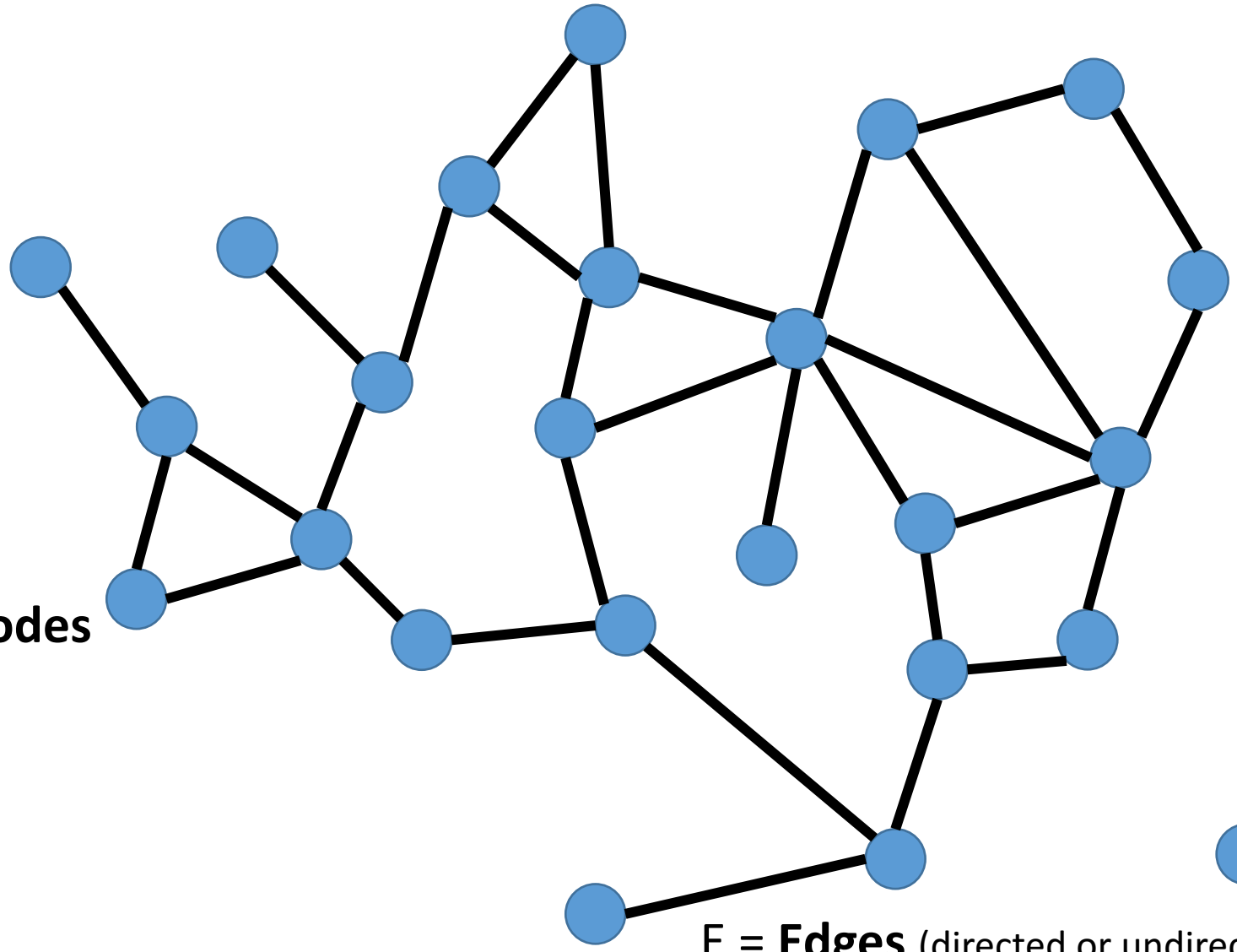


Country Food Sharing
N=330

Pajek

NSF ARC-0908155
2009-2012

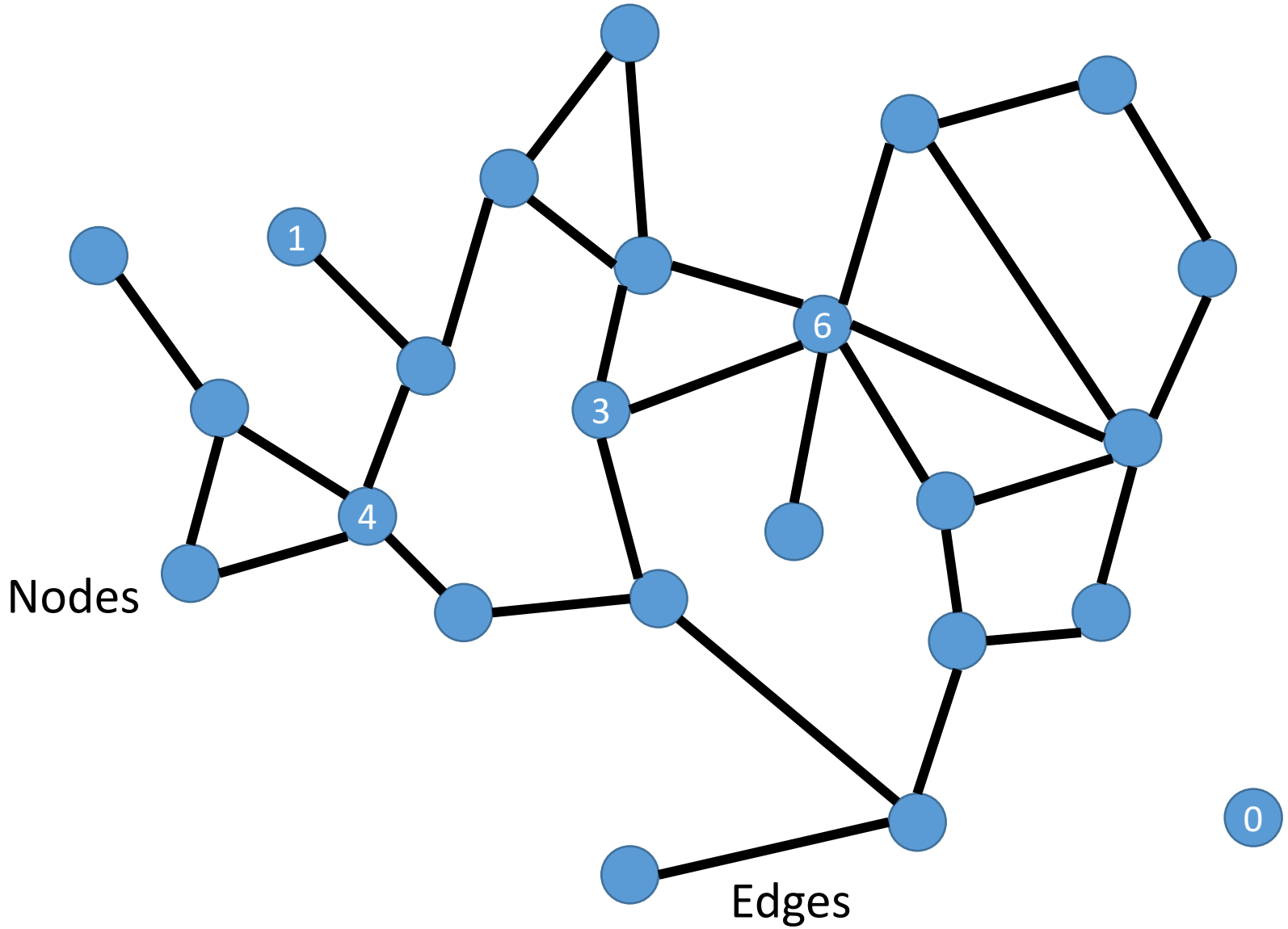
Graph G=(V,E)



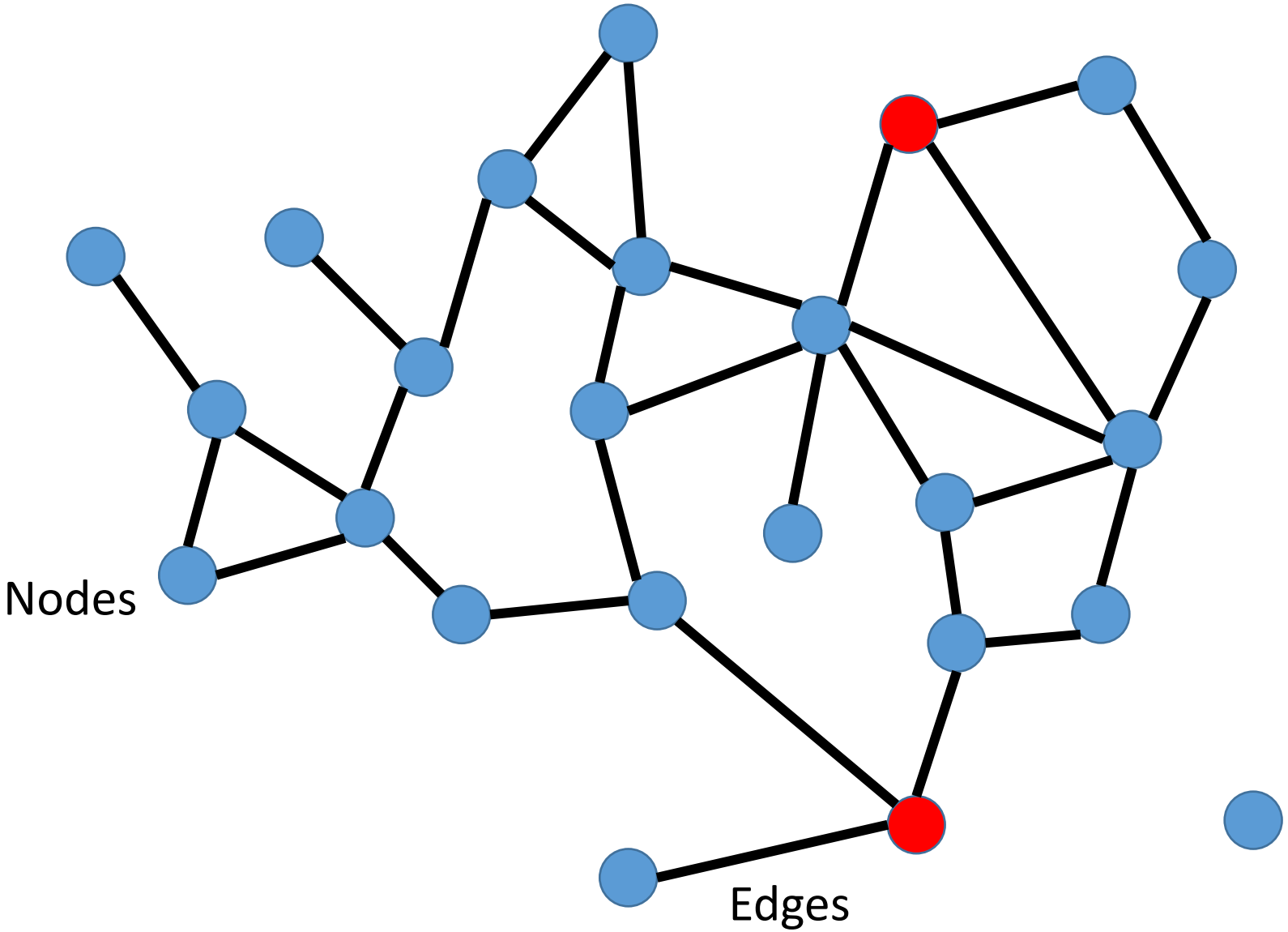
V = **Nodes**

E = **Edges** (directed or undirected)

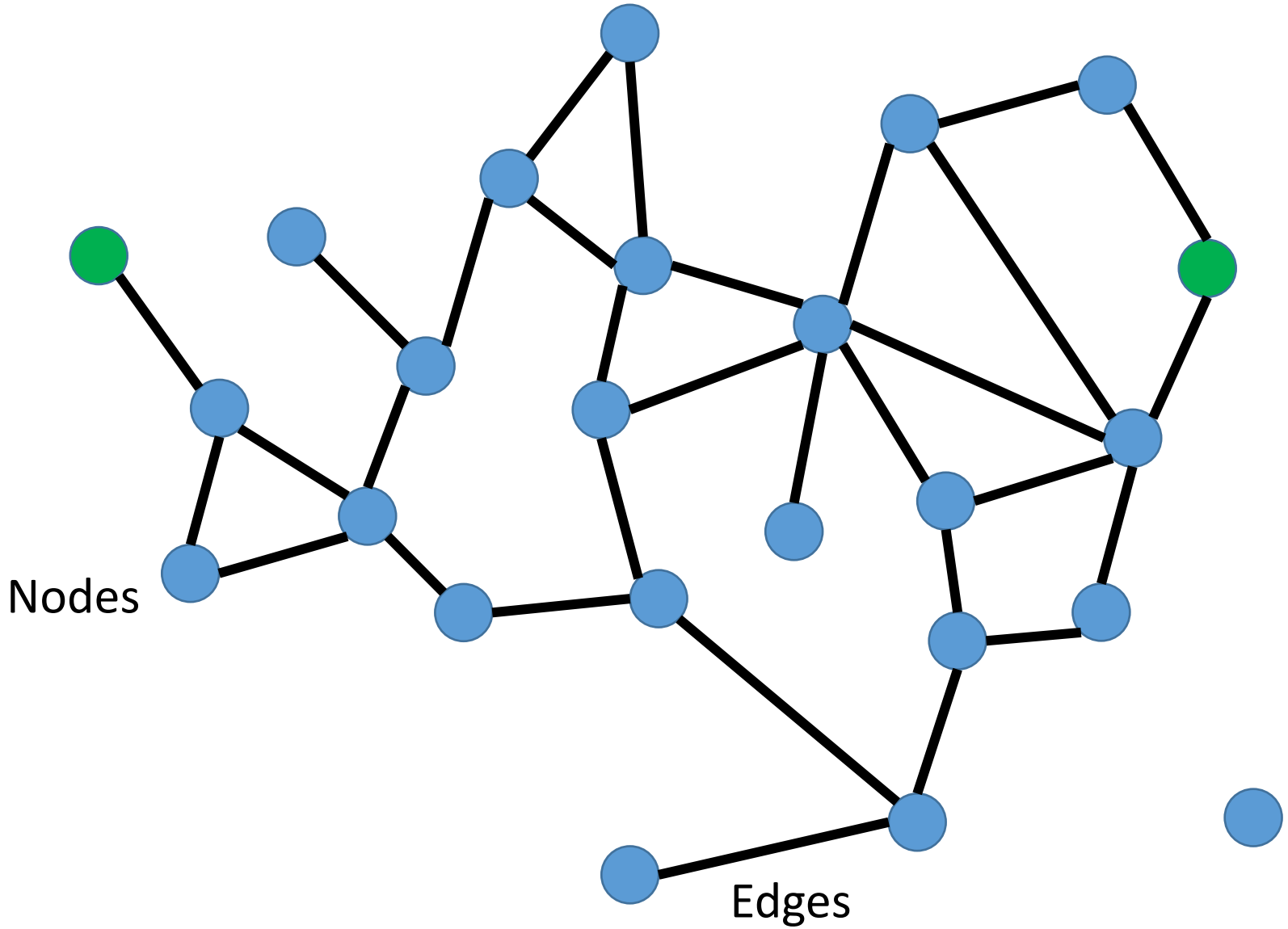
Degree of a node = number of relationships it has

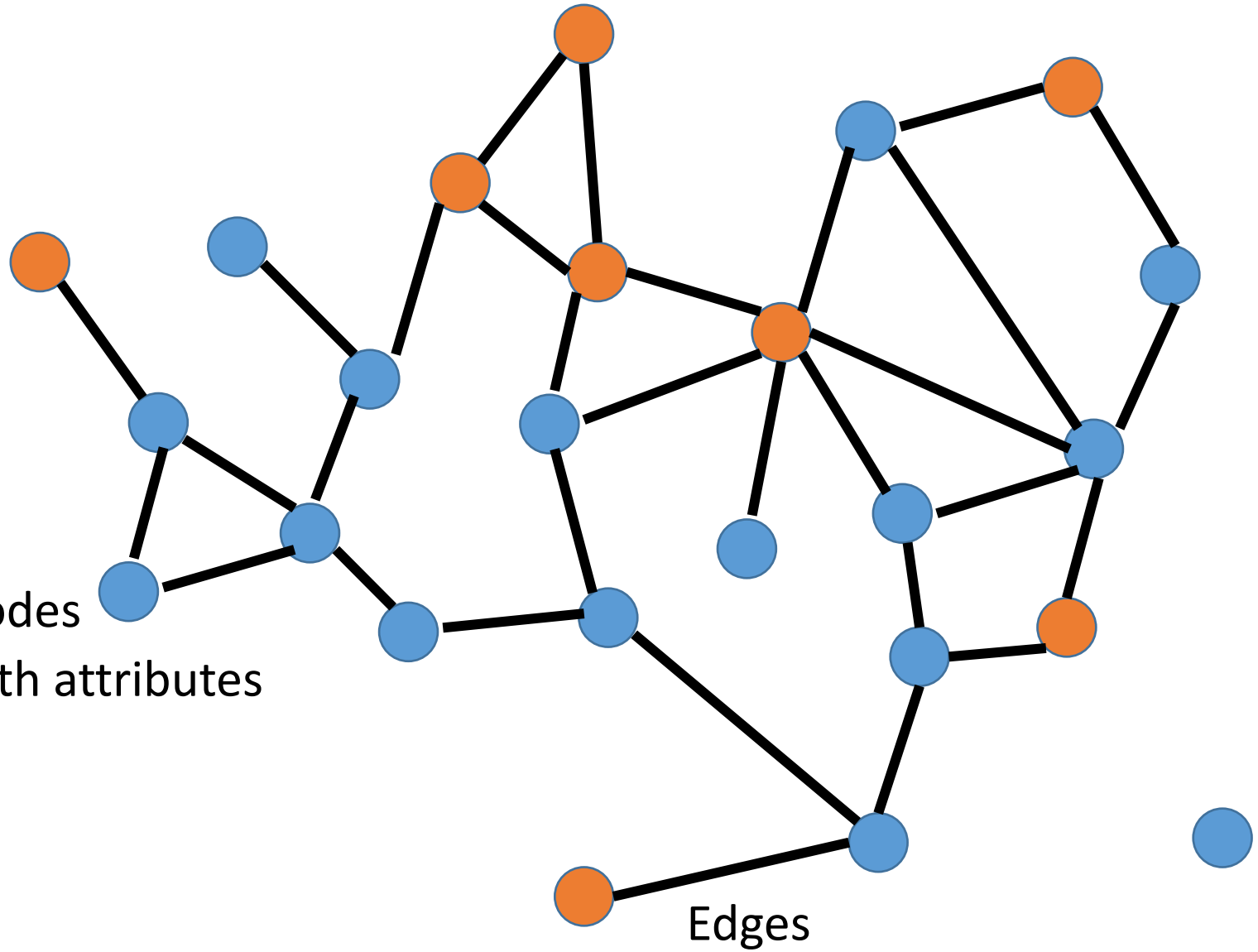


Geodesic between 2 nodes = a shortest path connecting them



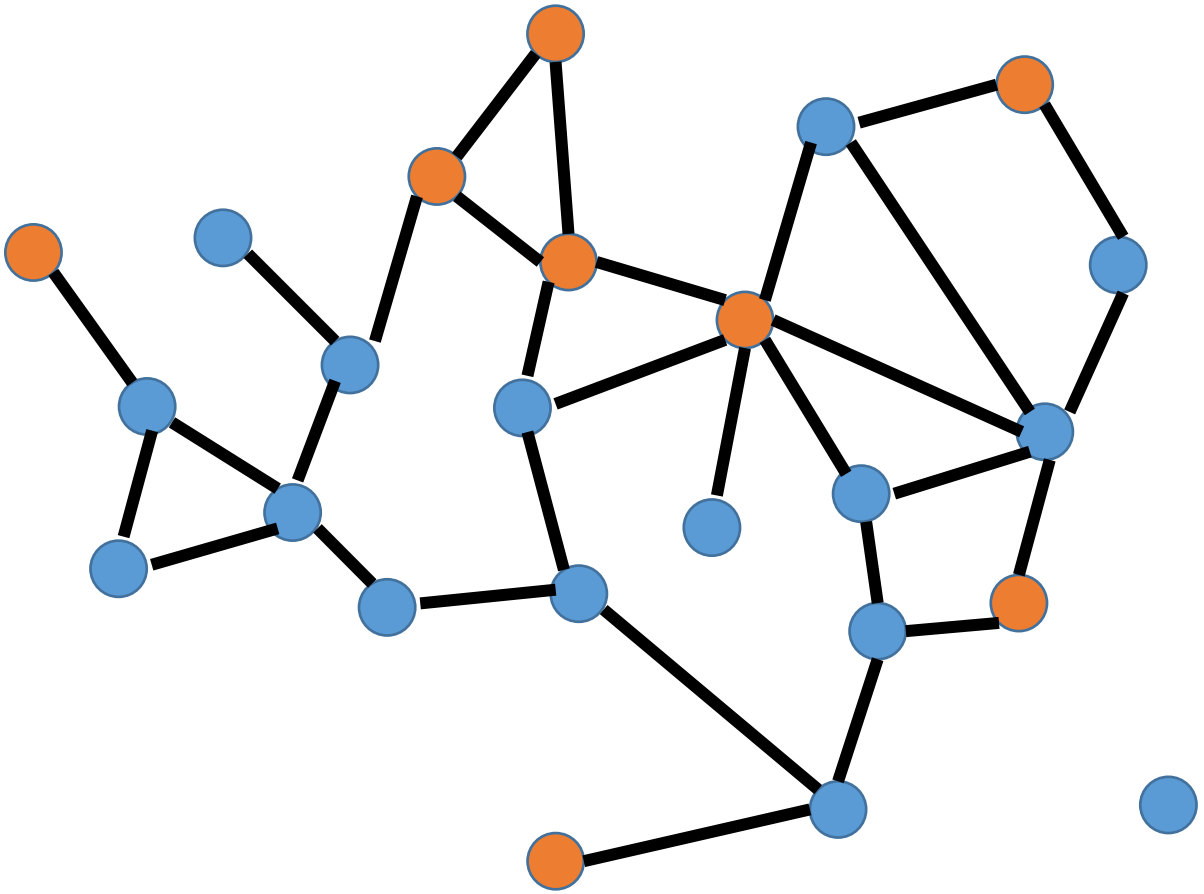
Diameter of a **component** = length of the longest geodesic



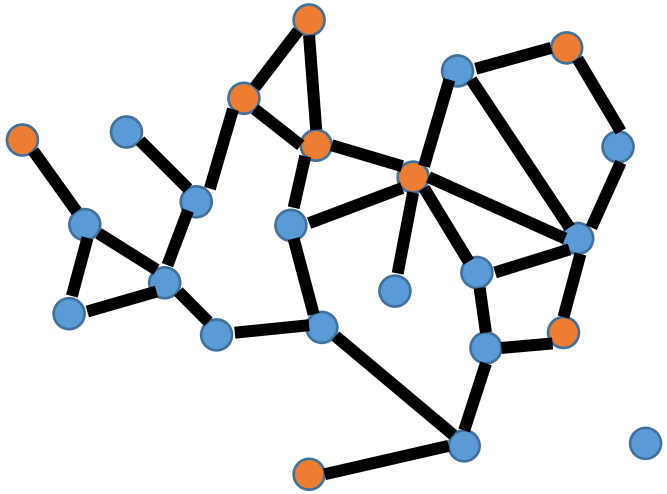


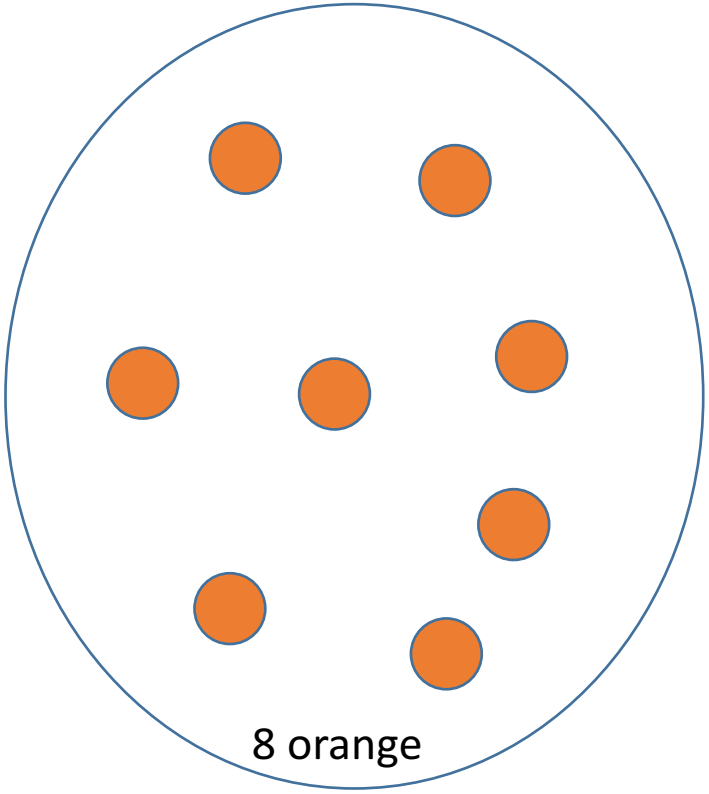
Is the network blind to the attribute?

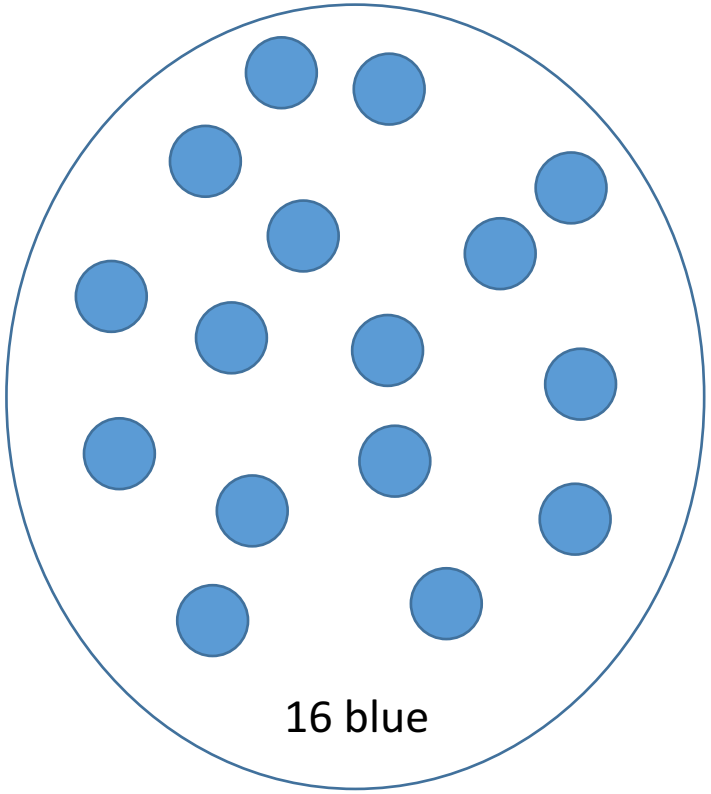
1) How many orange nodes?
2) How many blue nodes?
3) How many relationships do the orange nodes have (with anyone)?
   i.e. *What is the sum of the degrees of the orange nodes?*
4) How many of the relationships in (3) are with other orange nodes?



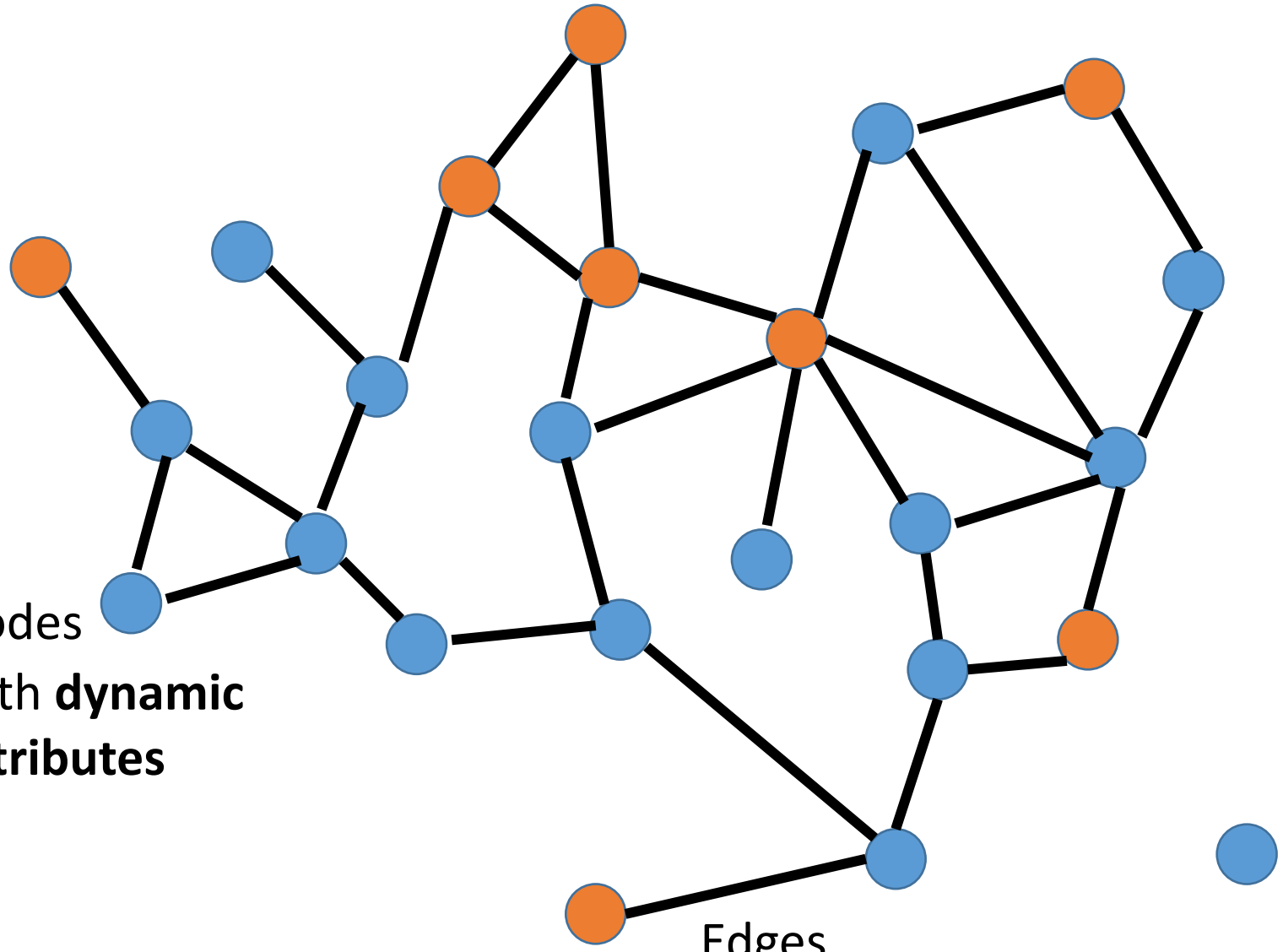
Homophily is the concept that people with similar personal or social traits will tend to have relationships with each other compared to having relationships with those unlike themselves.



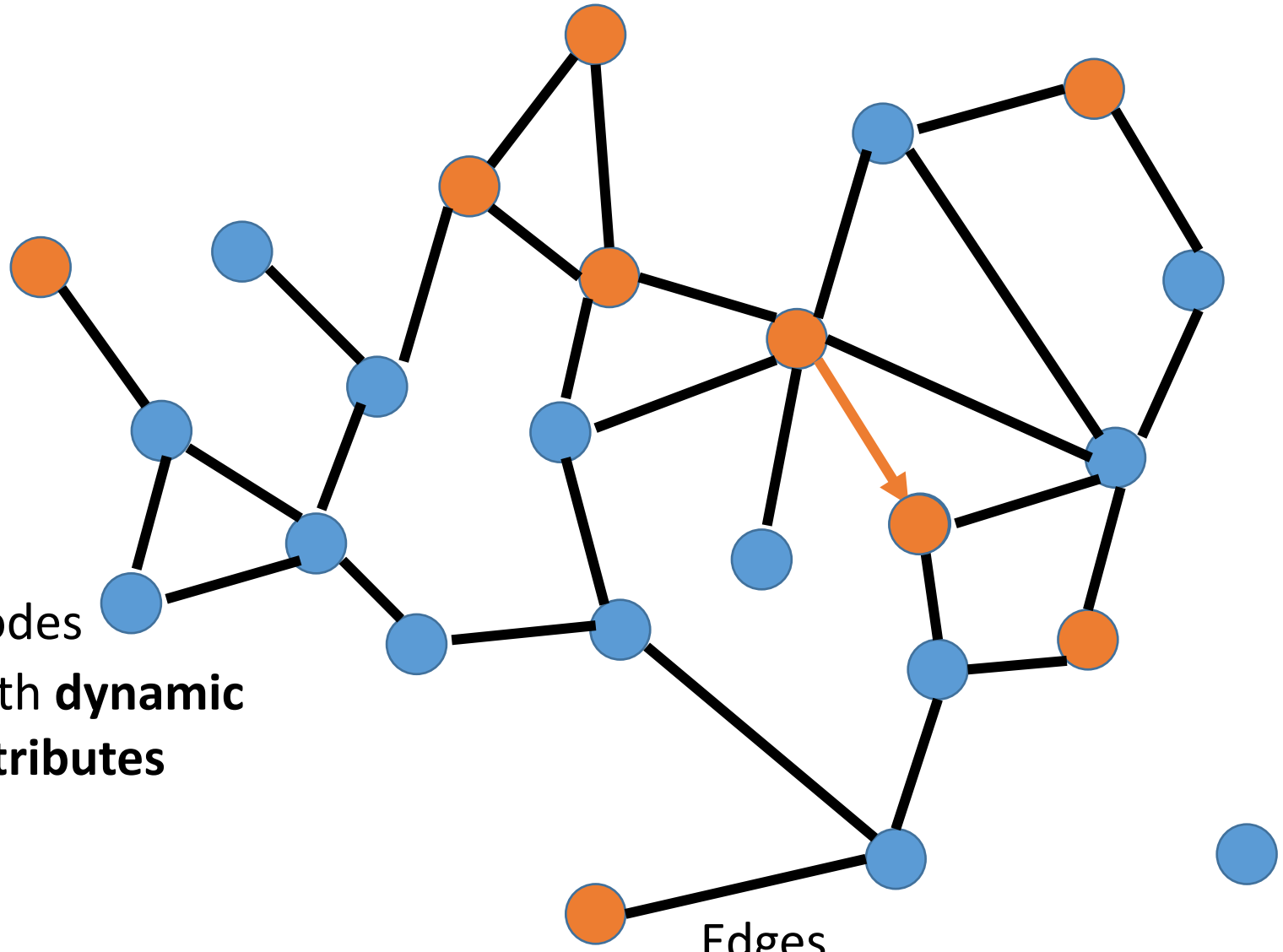




21 relationships total
8 to other orange nodes

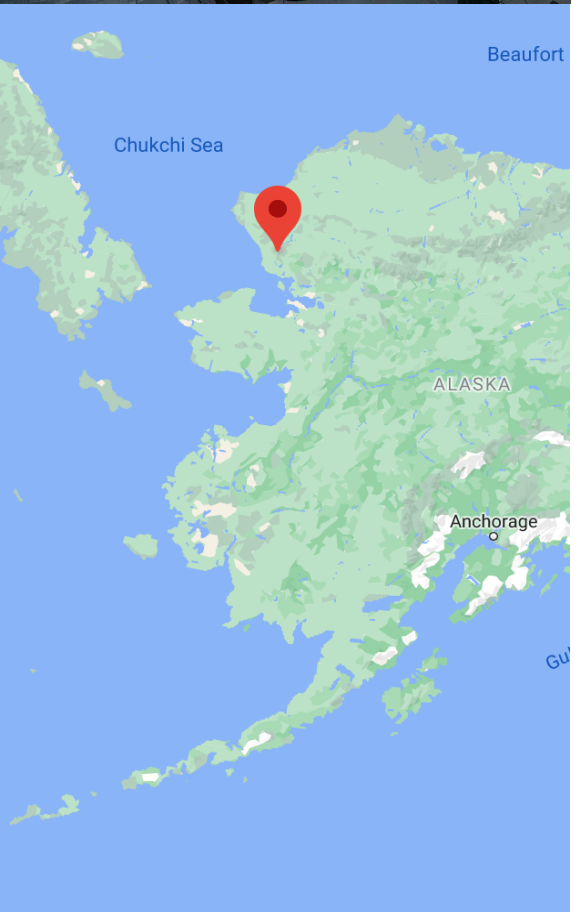

Nodes
with **dynamic attributes**
Edges

Transmission



Degree, geodesics, diameter

Noatak & Kiana, Alaska



Pilot project with overall objectives including increasing intra-community interaction and collaboration to prevent youth suicide

428 people,
- 94% Native American / Alaska Native
- 4% White

100 households
- Average household size was 4.28
- Average family size was 4.51

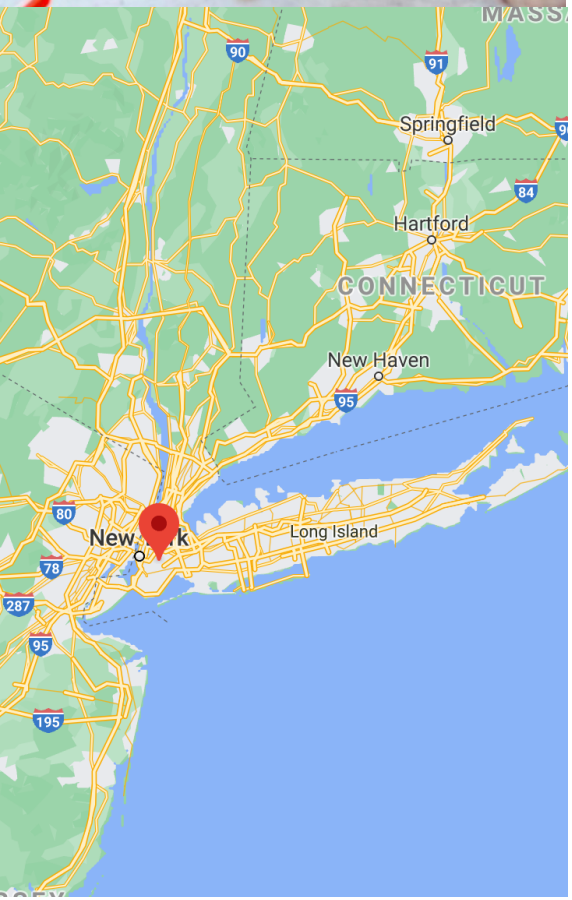
PI Lisa Wexler

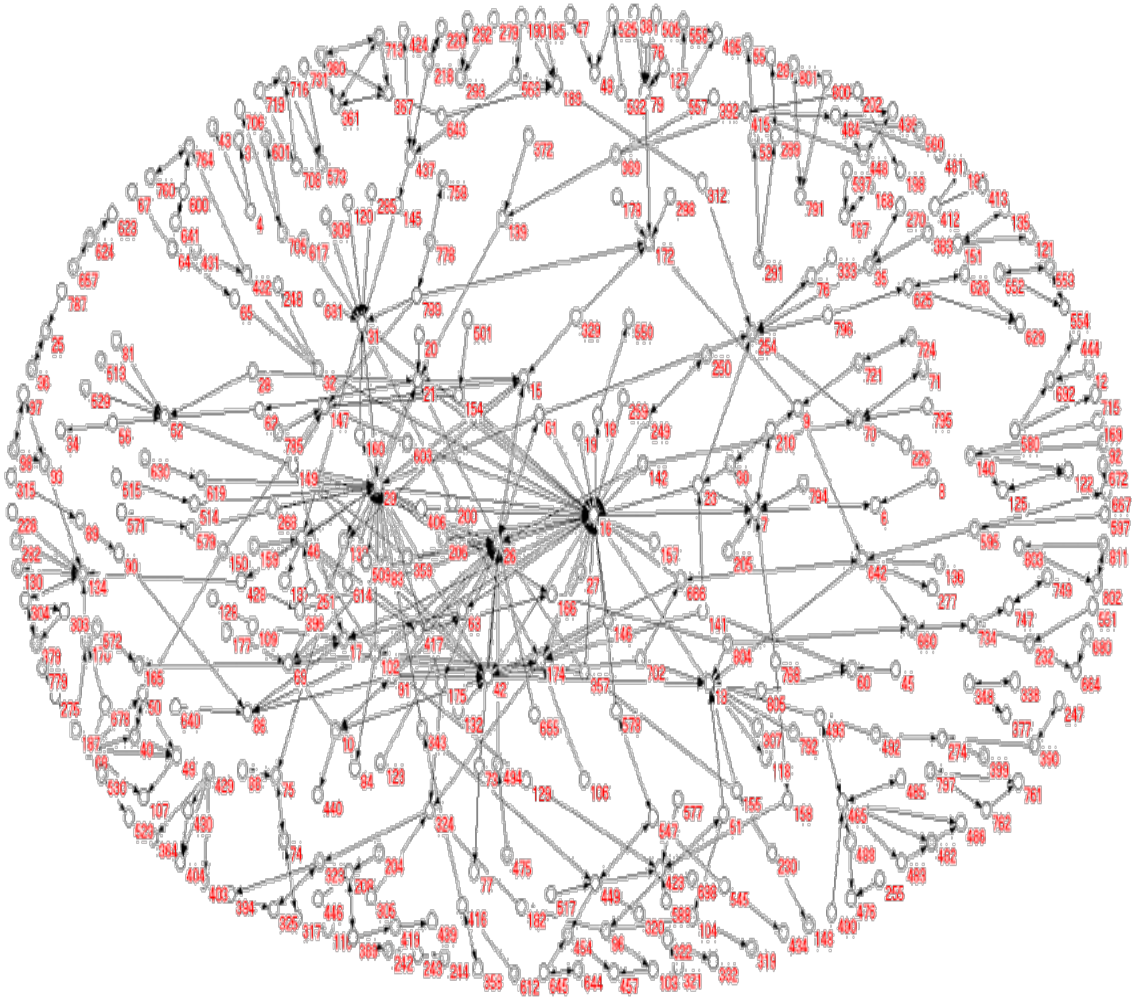
Center for Alaska Native Health Research

P.C. CARES
PROMOTING COMMUNITY CONVERSATIONS ABOUT RESEARCH TO END SUICIDE

NIH R34MH096884
2015-2018

Bushwick, Brooklyn





DA06723 (Ric Curtis PI)
1991-1993

Rural Puerto Rico

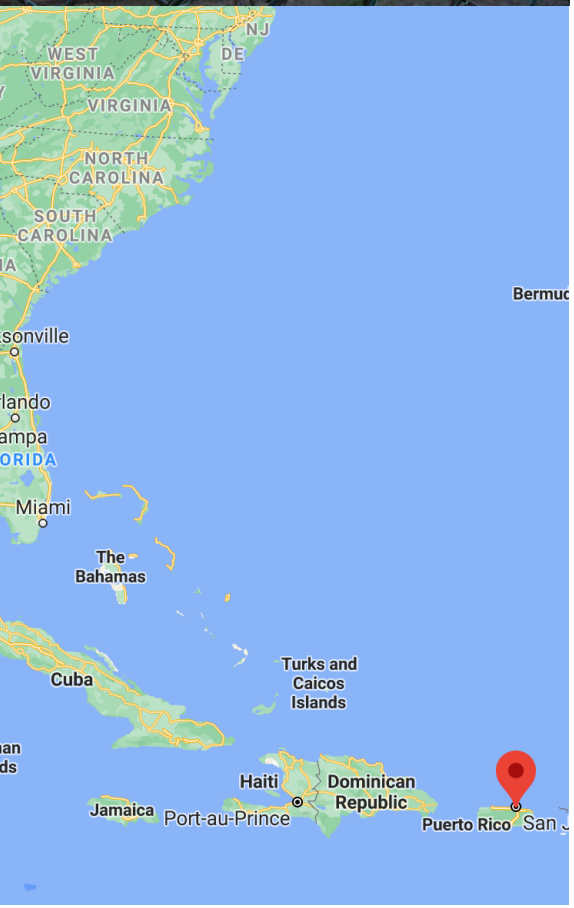
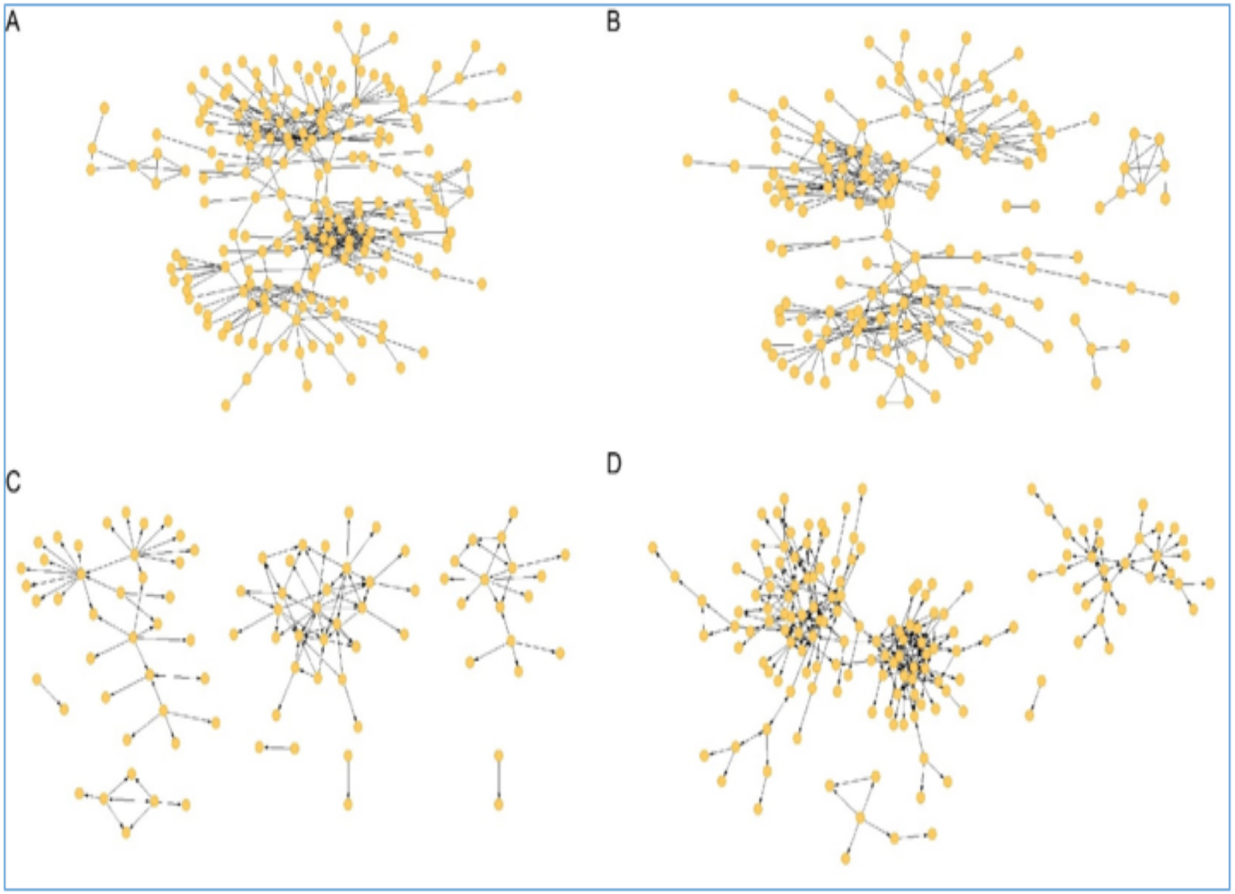


Figure 1: Injection risk network of rural Puerto Rico. (A): Co-use in the last 30 days; (B) Share injection equipment >50% of the time; (C) Used a needle after in the last 30 days; (D) Do not know co-injectors HIV status.



R01DA037117
2014-2019

Rural Puerto Rico Drug Injector Network

Gender (n=315)	
Male	90.48
Female	9.21
Transgender	0.32
Age (n=315)	40.78
Born in Puerto Rico (n=315)	93.02
Currently homeless (n=315)	21.90
Income (n=311)	
Less than $5000 per year	80.06
More than $5000 per year	19.94
Marital Status (n=315)	
Single	46.98
Married/Cohabiting	22.22
Separated, divorced, widowed	30.80
Education (n=315)	
Less than High school	47.62
Completed High school or GED	33.65
College	18.73

Injection drug use	
Age at first use (n=315)	21.91
Frequency of use (n=315)	
1-3 x/month	5.71
1-6 x/week	9.52
1-3 x/day	45.08
4 or more x/day	39.69
Speedball (Heroin & Cocaine) Use (n=314)	91.08
Drug/Alcohol treatment	
Alcohol treatment (n=314)	10.19
Drug treatment (n=315)	81.27

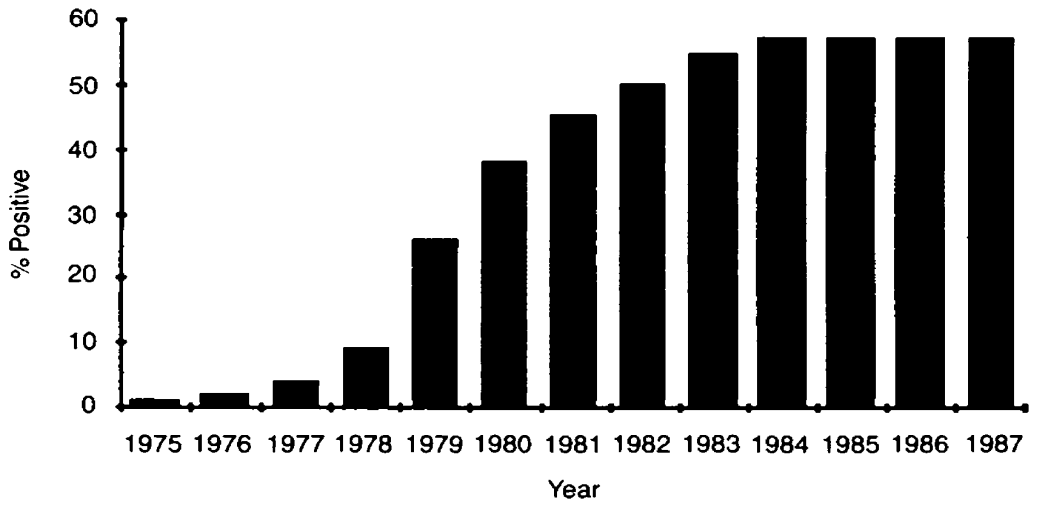
Hepatitis C (n=303)	
Unknown status	22.77
Negative	27.06
Positive	50.17

HIV (n=315)	
Unknown status	13.97
Negative	81.90
Positive	4.13

Subsaturation
Why?

Seroprevalence of Anti–Human Immunodeficiency Virus Type 1 (HIV-1) Among Intravenous Drug Users Who Entered Drug Abuse Treatment in Manhattan, New York City, 1978 Through 1987

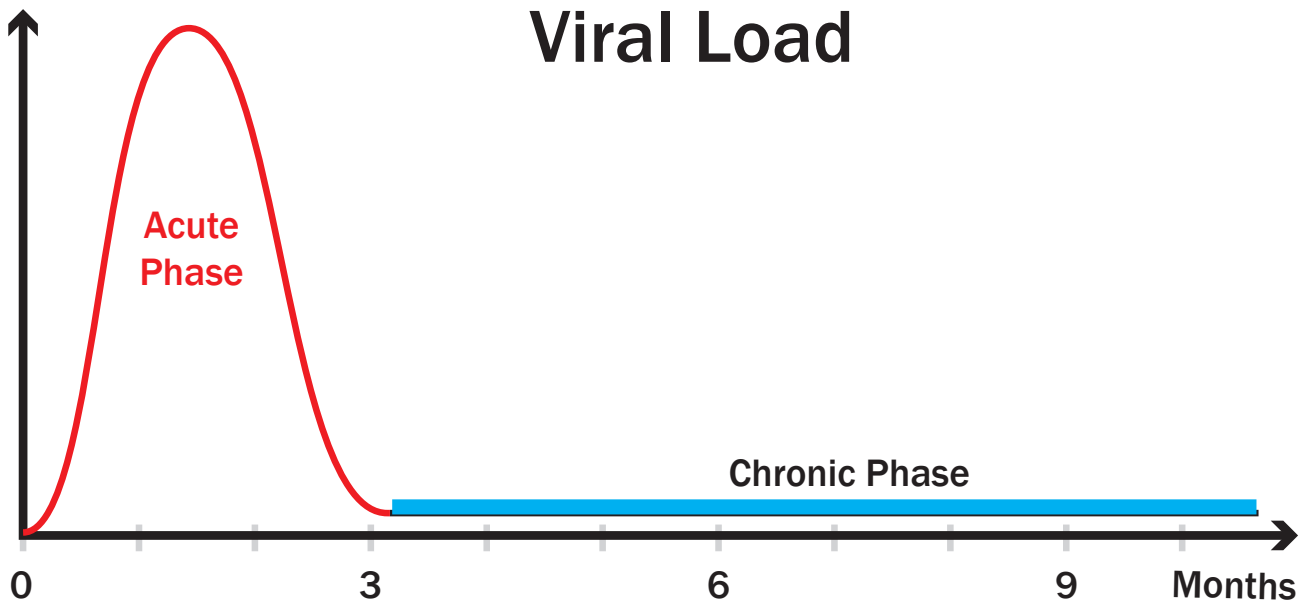
Year Blood Collected	Program Entered	No. (%) Anti–HIV-1 Positive
1978	Detoxification/medical	1/11(9)
1979	Detoxification/medical	13/50(26)
1980	Detoxification/medical	8/21(38)
1981-1983	Detoxification/medical	14/28(50)
1984	Detoxification	75/137(55)
1984	Methadone	38/63(60)
1986	Methadone	36/65(55)
1987	Methadone	169/294(57)



Historical reconstruction of human immunodeficiency virus type 1 seroprevalence among active intravenous drug users in Manhattan, New York City. Reconstruction is based on seroprevalence data for 1978 through 1984 and 1986 through 1987, with acquired immunodeficiency syndrome case data used to estimate seroprevalence for other years. Curve has been smoothed for 1984 through 1987.

Des Jarlais et al JAMA 17 Feb 1989 (vol 261, no 7: 1008-1012.

Modeling Disease Dynamics



- The infectiousness curve of HIV-1 (based on viral load) shows a short latency period followed by a period of peak infectiousness that lasts for 6-12 weeks

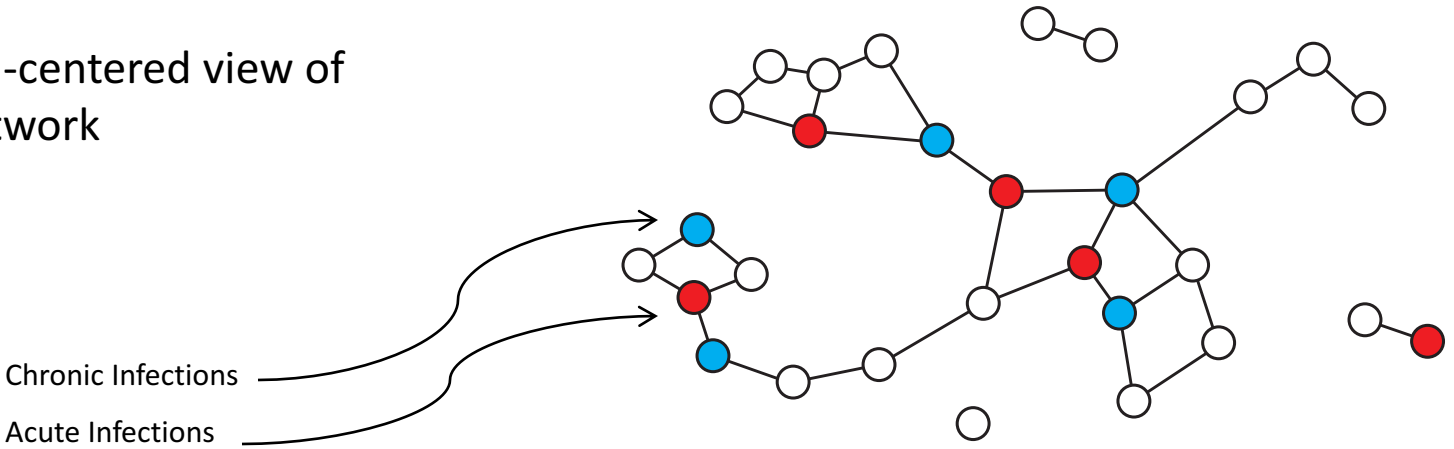
- For purposes of simplicity in the model, this modeled as a three stage process
  - Initial lag of 3 weeks (“Latent”)
  - Peak infectious period (labeled “Acute”) lasting the subsequent 9 weeks
  - A period of low infectiousness (“Chronic”) lasting the remaining duration

Friedman et al (2000) hypothesize a “firewall effect” whereby mature (low infectious) individuals in key network positions prevent new infections from spreading to uninfected portions of the network

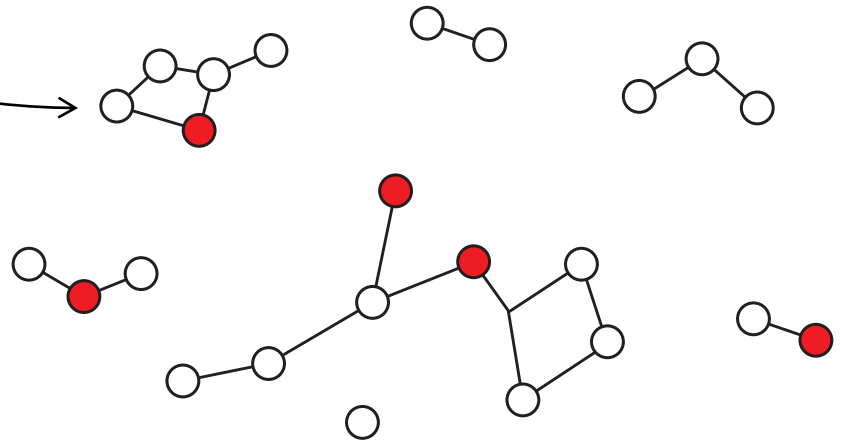
Friedman et al “Network-related Mechanisms May Help Explain Long-term HIV-1 Seroprevalence Levels That Remain High but Do Not Approach Population-Group Saturation”
*American Journal of Epidemiology (*2000) Vol. 152, No. 10: 913-922).

Formalizing the FW hypothesis

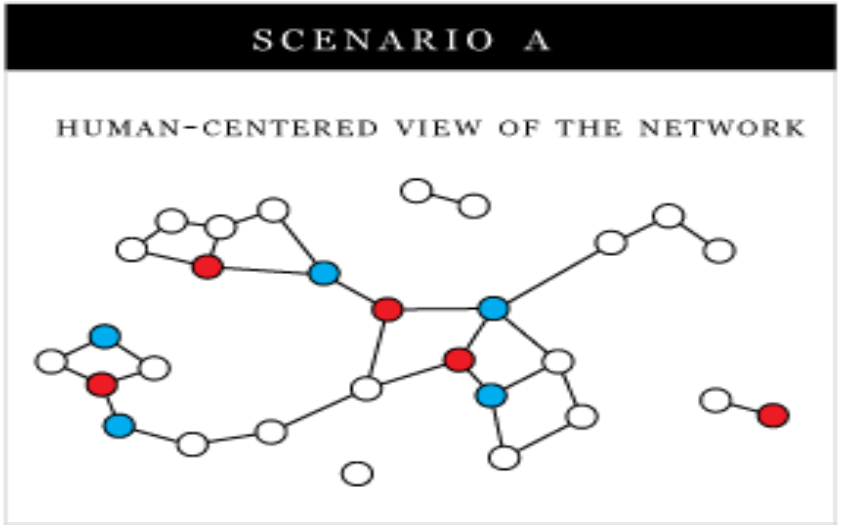
Human-centered view of the network

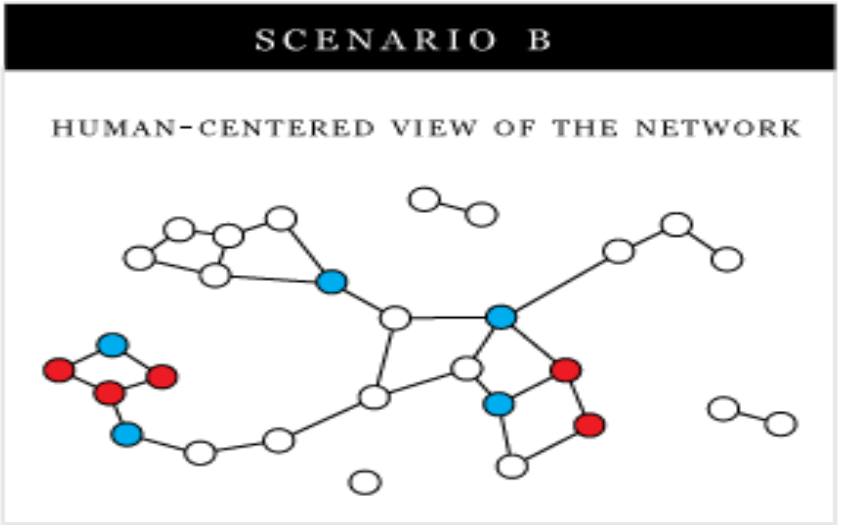


Virus-centered view of the network (chronic nodes removed)



Example

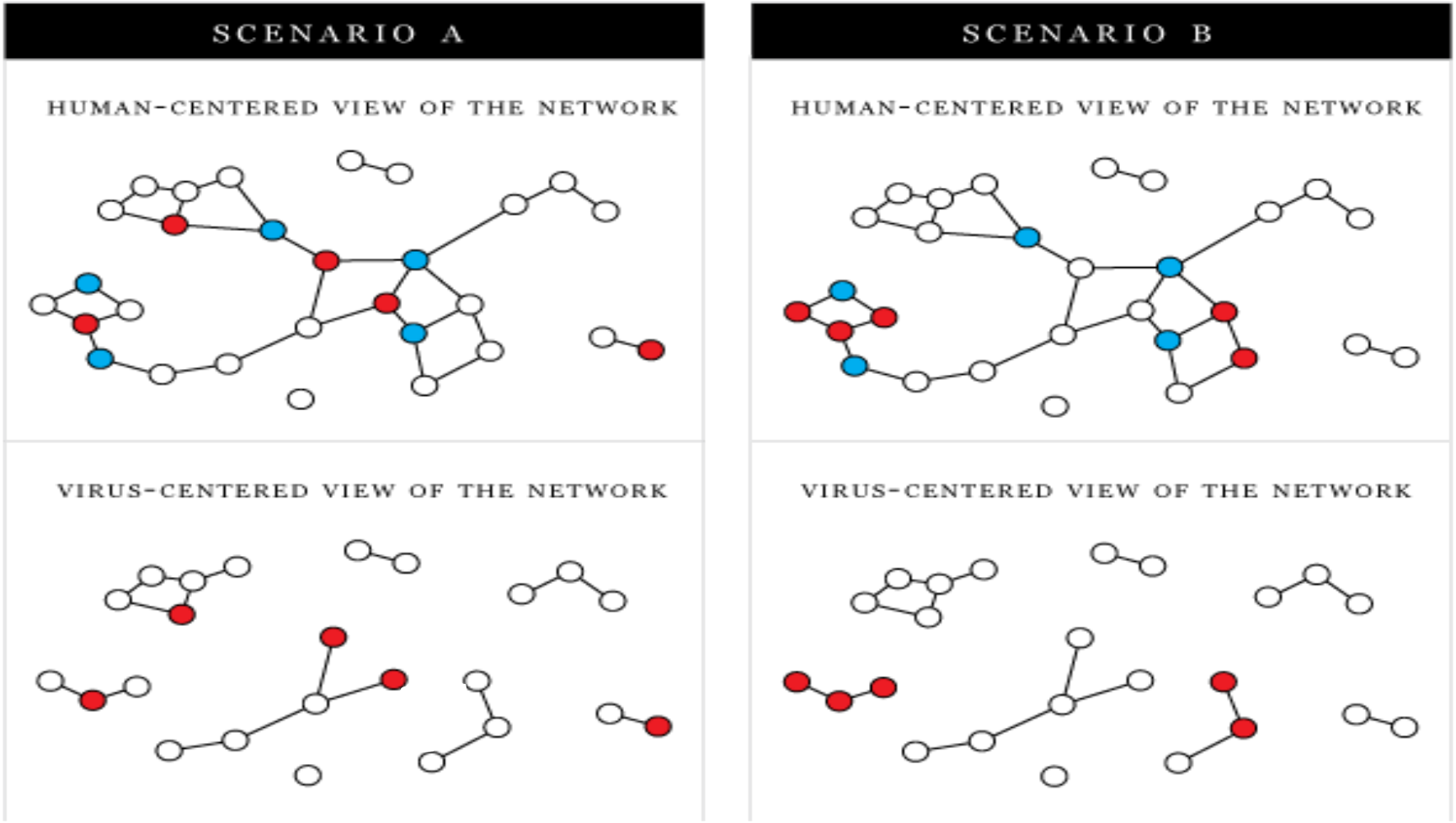




For each scenario (A and B)

5) How many people are there in the network?
6) How many are chronic HIV+?
7) How many are acute HIV+?

Example



For each scenario (A and B)

8) How many components are there?

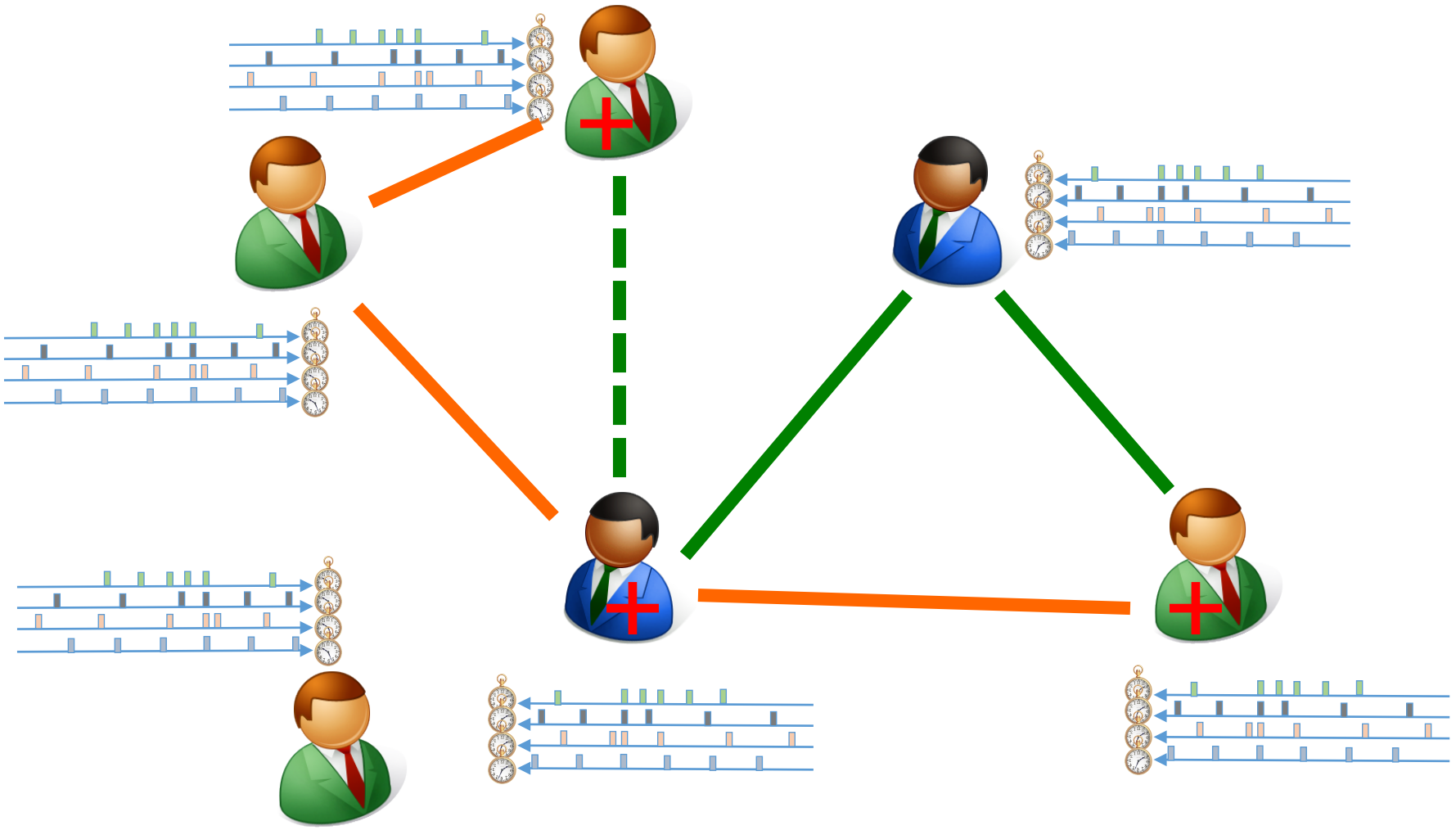
9) How many components have an acute infection in them?

The firewall (FW) measure

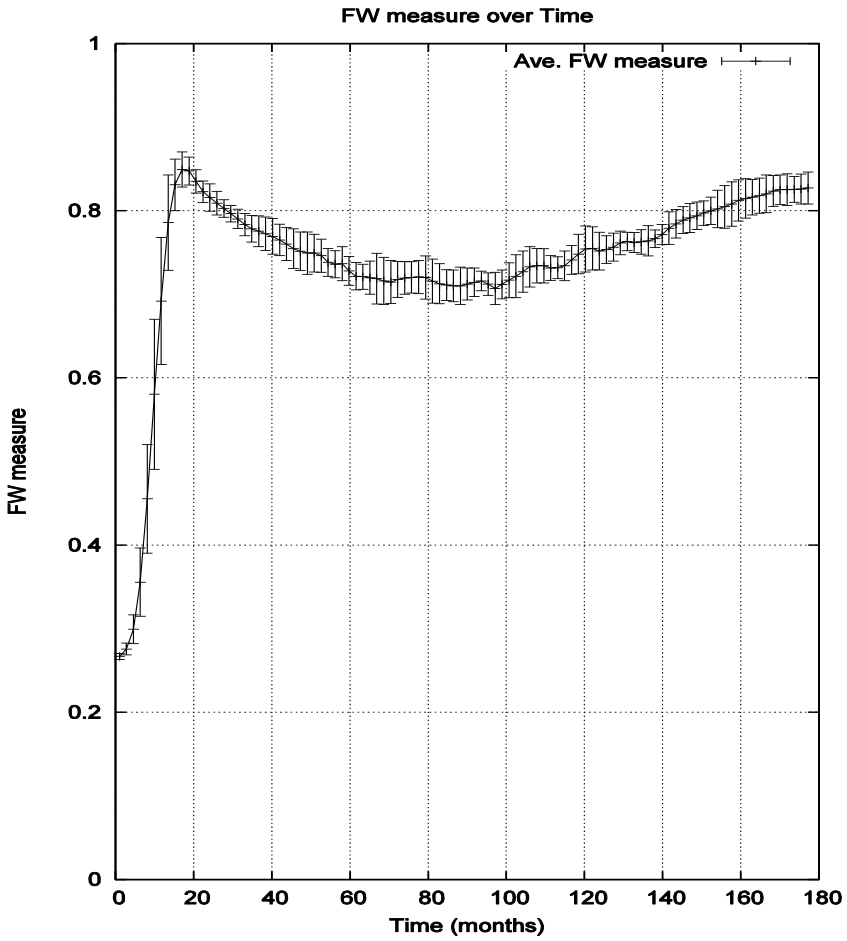
FW(t) := the proportion of uninfected nodes which exist in a network component *(after the deletion of chronic infections)* having no acute infections.

$FW(t) \approx 1$ there is a firewall effect
$FW(t) \approx 0$ there is no firewall effect.

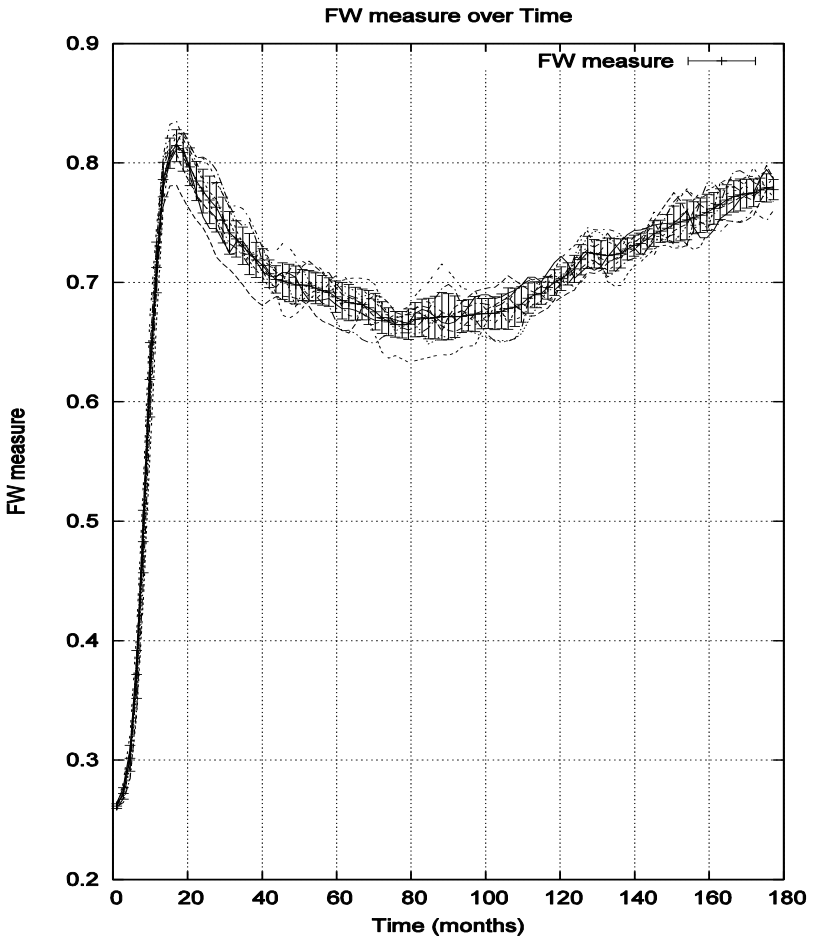
Agent-based simulation



FW Measure (Simulated)

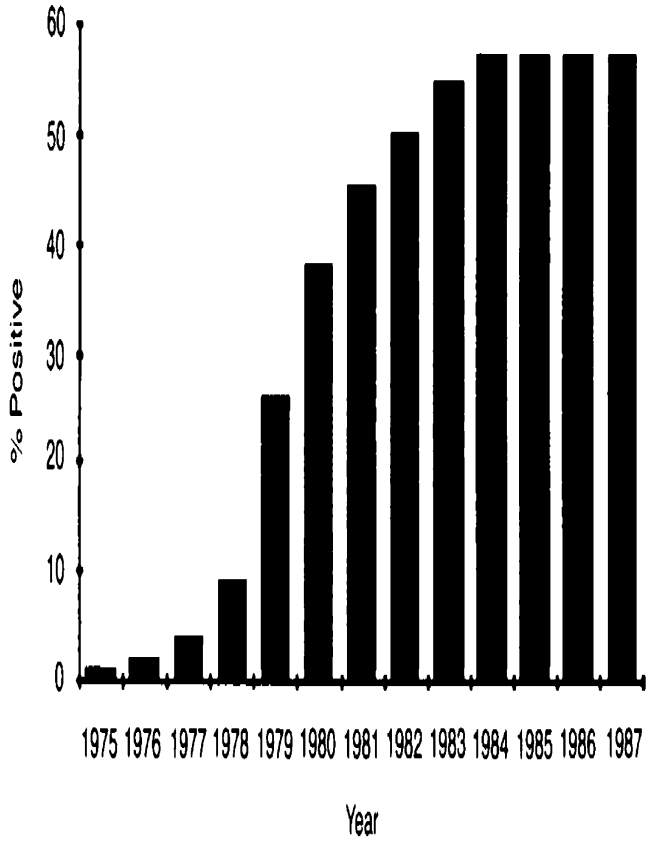


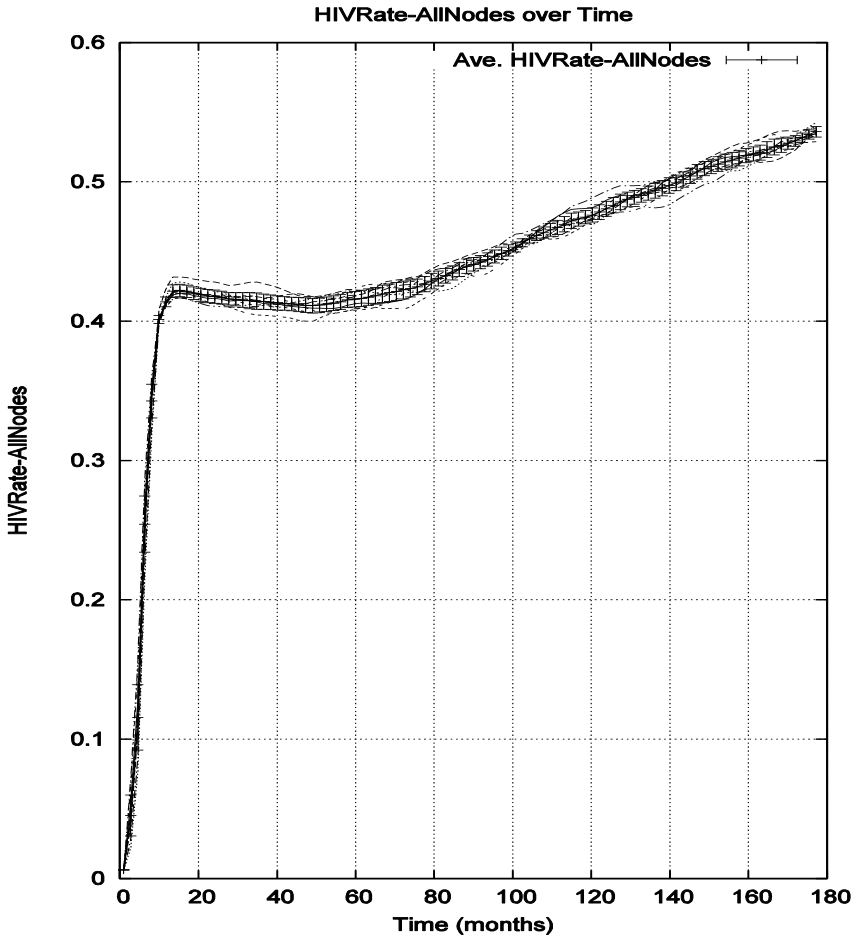
10 trials, 10,000 node graphs



10 trials, 25,000 node graphs

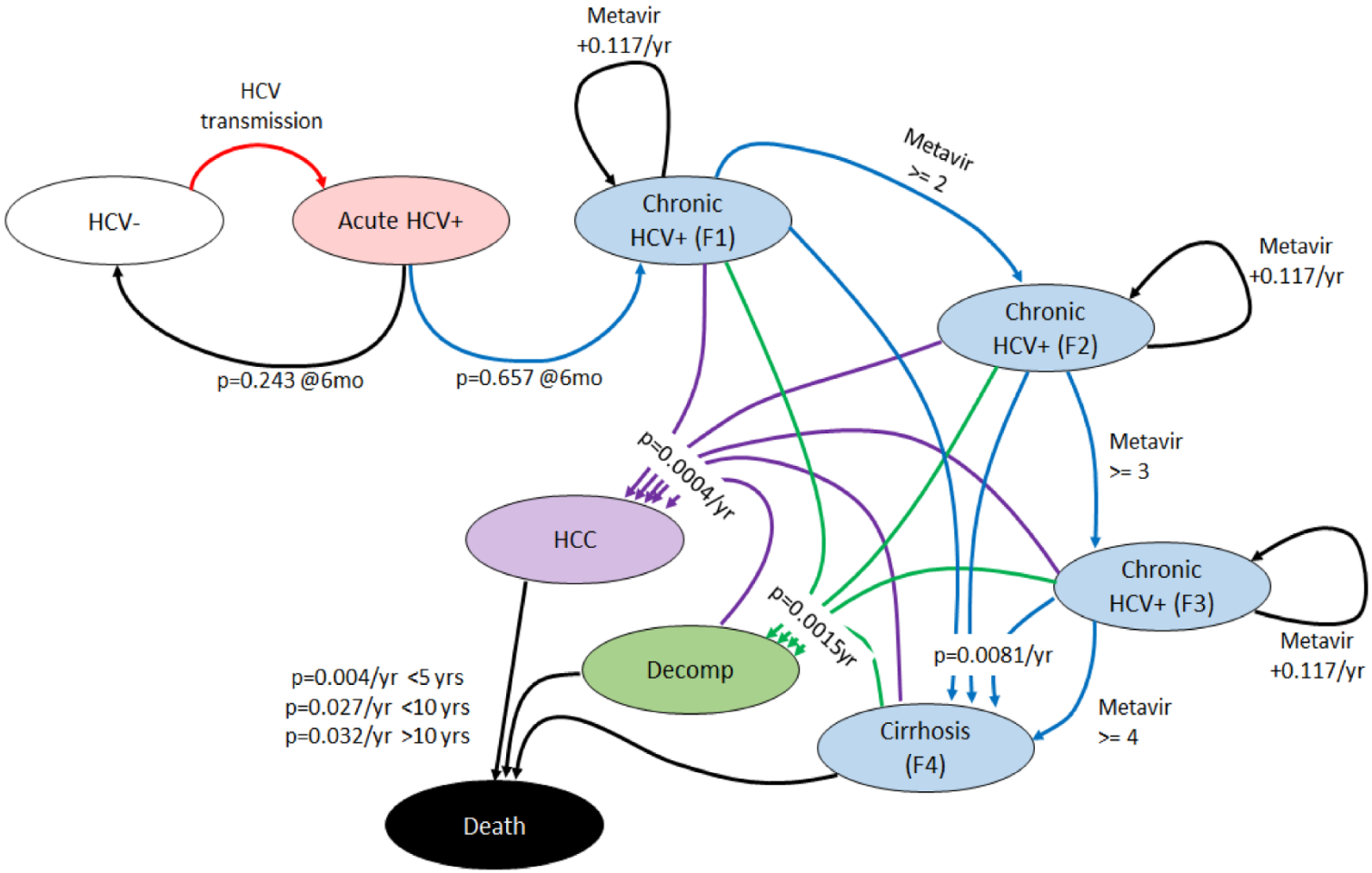
HIV Prevalence (Simulated)





10 trials, 25,000 node graphs

Compared to HIV, Hepatitis C is complicated



DAA
Direct-acting Antivirals

Each year:

- Fixed percentage of chronically infected HCV chosen at random
  1. Shielded from risk events
  2. Undergo treatment
     - 90% adhere for full 168 days
       - Those who complete, are cured with 95% chance

Smit C, van den Berg C, Geskus R, Berkhout B, Coutinho R, Prins M. Risk of hepatitis-related mortality increased among hepatitis C virus/HIV-coinfected drug users compared with drug users infected only with hepatitis C virus: a 20-year prospective study. JAIDS Journal of Acquired Immune Deficiency Syndromes. 2008;47(2):221–225.

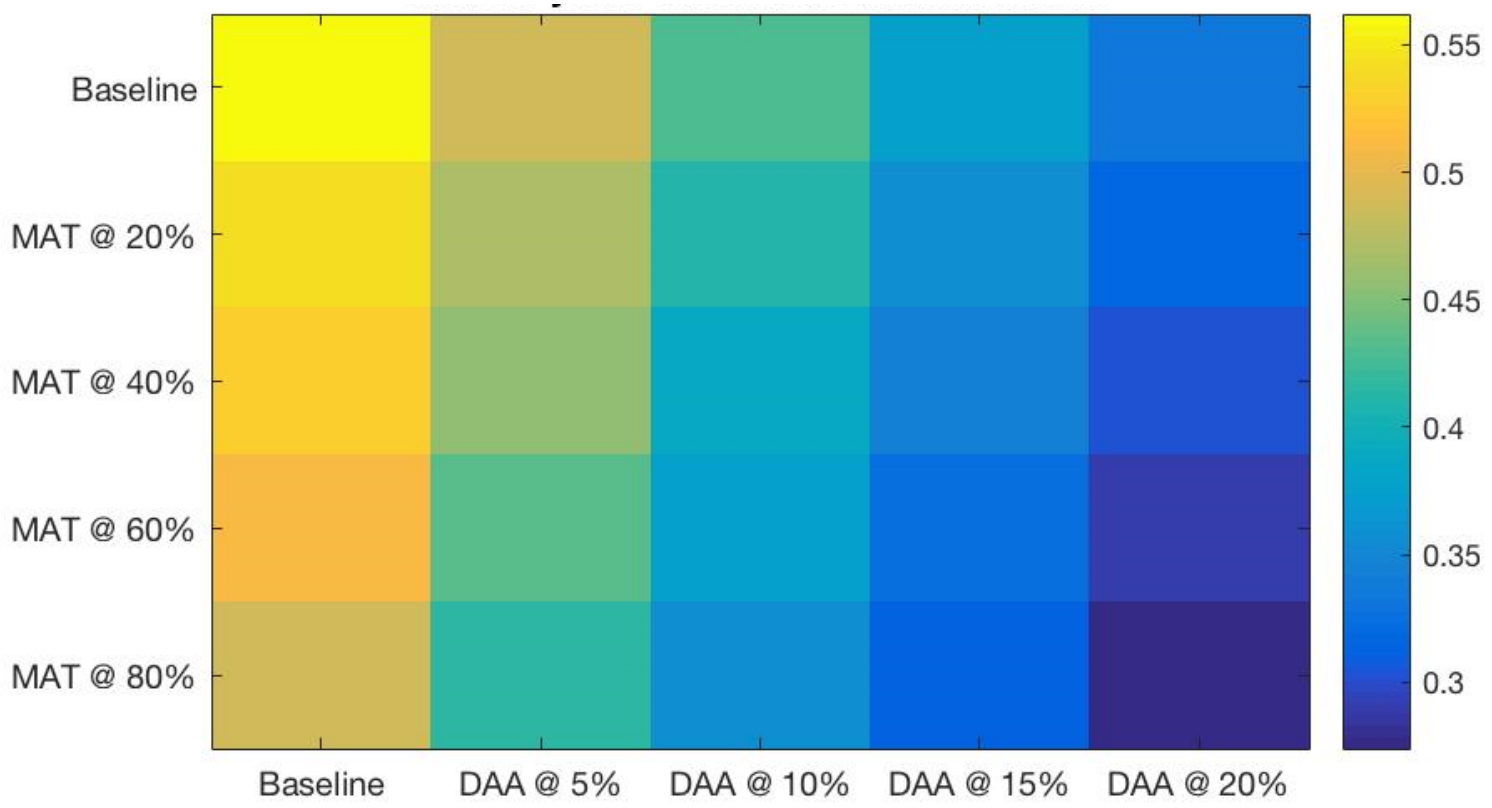
SA/MAT
Syringe Access+ Medically Assisted Treatment (e.g. opioid substitution)

Each year:

- Fixed percentage of chronically infected HCV chosen at random
  1. Engaged for 3 months
  2. During engagement period, frequency of risk events by 80%
  3. After engagement period, return to pre-intervention risk rate

Turner KM, Hutchinson S, Vickerman P, Hope V, Craine N, Palmateer N, et al. The impact of needle and syringe provision and opiate substitution therapy on the incidence of hepatitis C virus in injecting drug users: pooling of UK evidence. Addiction. 2011;106(11):1978–1988.

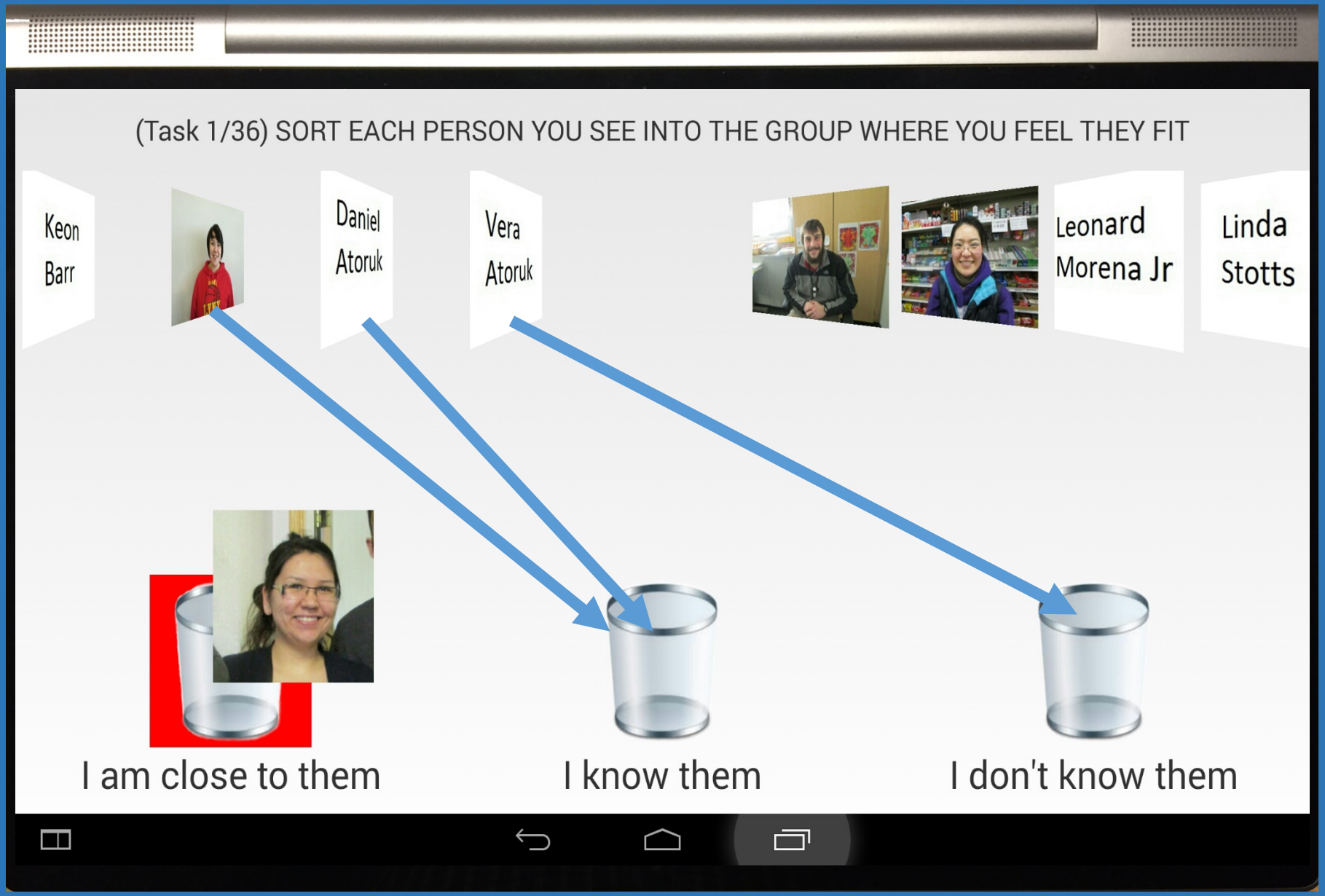
HCV prevalence under combination strategies



HCV prevalence rate (at 15 years (post 5 year burn-in)

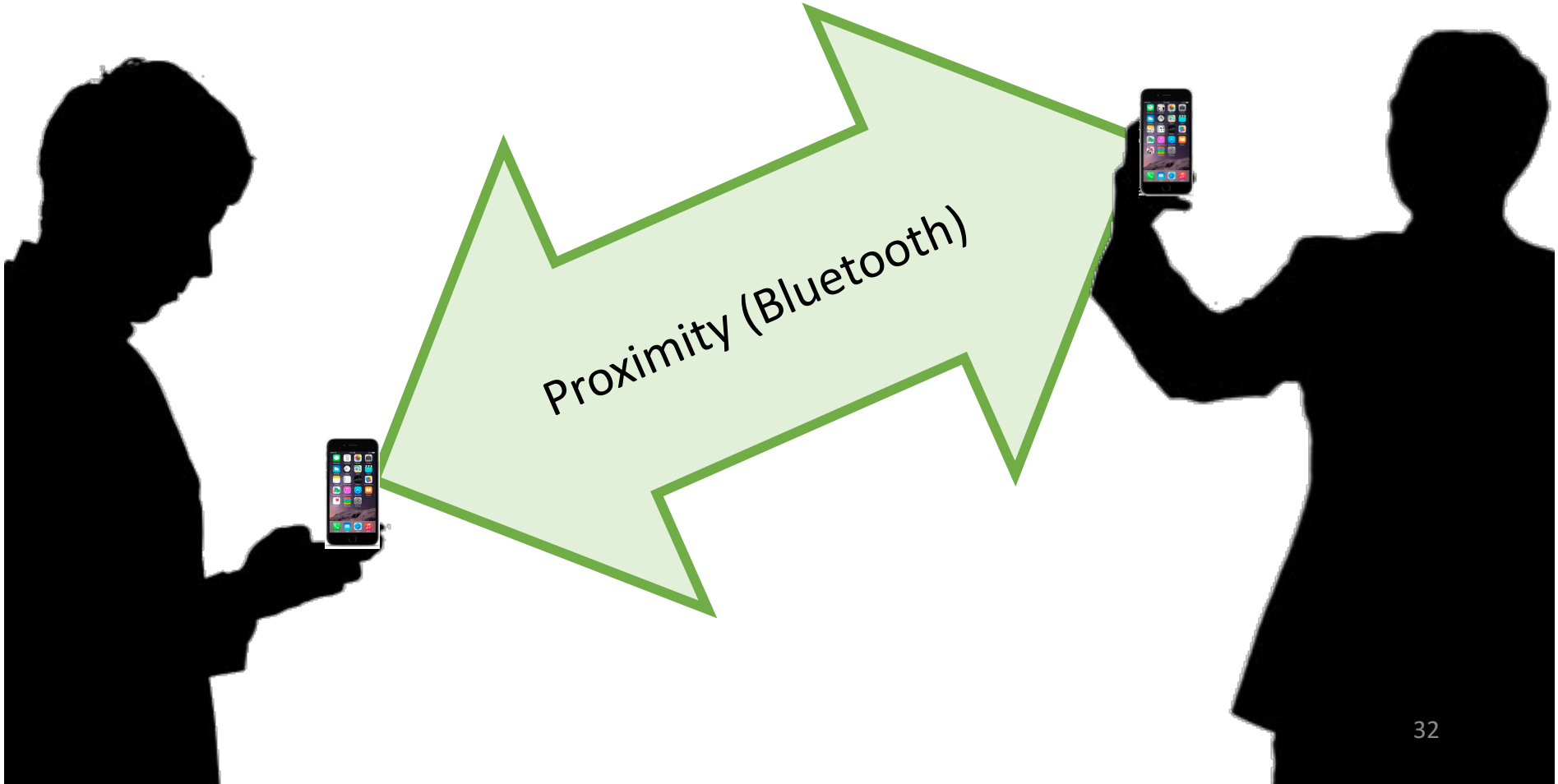
Key Takeaways

- Getting data on the network is hard work
- The structure of the network matters when it comes to disease transmission
  - It is important to view the network from the perspective of the virus
- Simulation based on real-world data can help in evaluating different options for public health policy

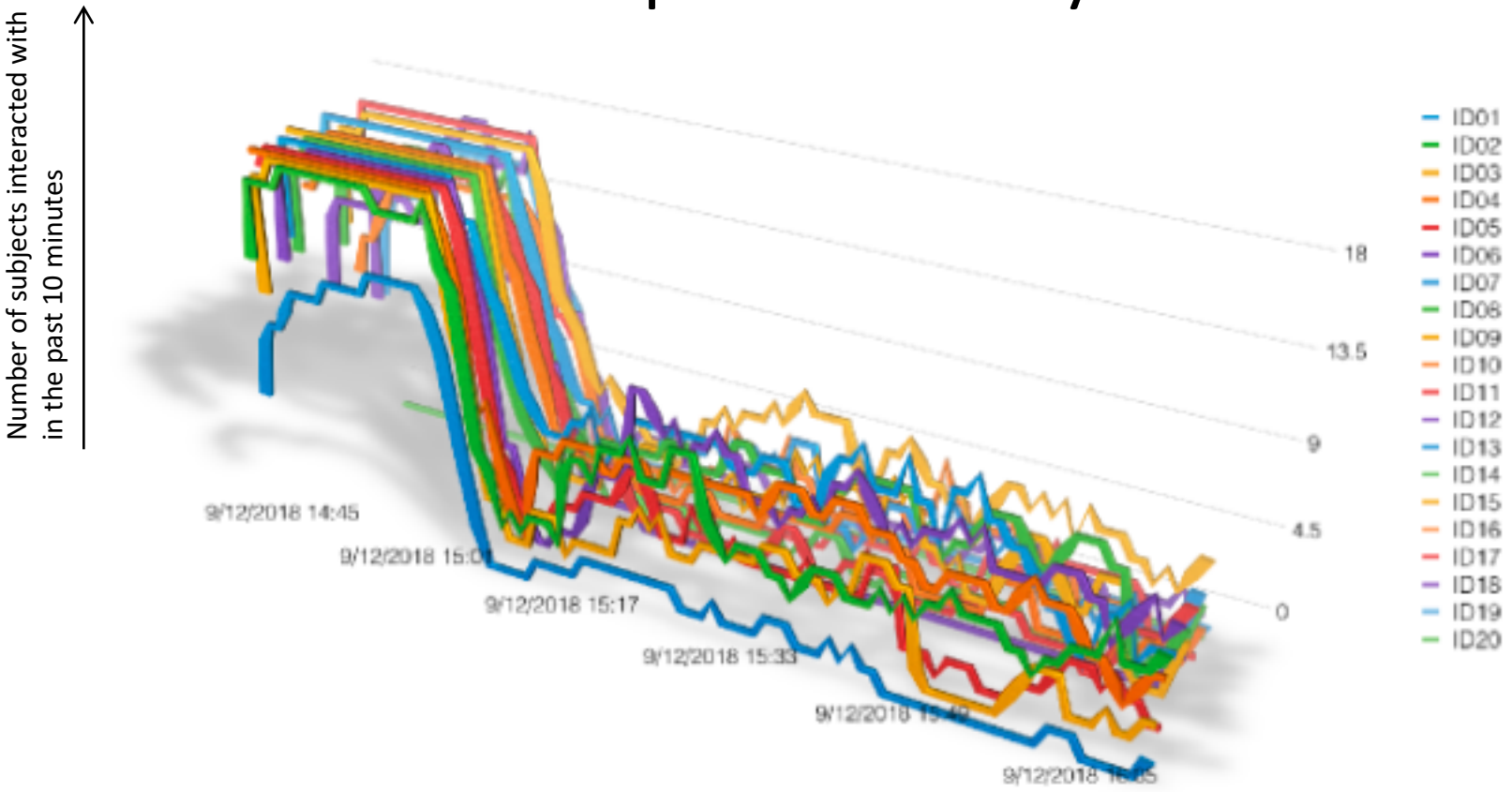


SNAPT: Rapid social network mapping

ODIN: Passive network data collection



A pilot study



N=20 students

Weekly multiple choice questions covering 8 topics, written by the instructor.