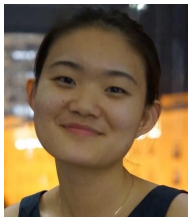
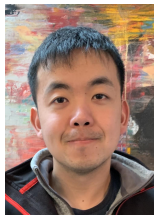
Data Science for All
COVID Modeling Presentation

J. Massey Cashore, Alyf Janmohamed, Jiayue Wan, Yujia Zhang
Cornell University

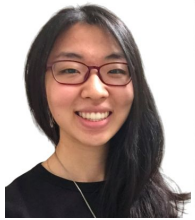

J. Massey Cashore


Ning Duan


Alyf Janmohamed


Brian Liu


Jiayue Wan


Yujia Zhang


Peter Frazier


Shane Henderson


David Shmoys

The COVID Modeling Team

- Originated in early days of the pandemic.
- Original question: can **group-testing** enable nation-wide **asymptomatic screening**?
- Eventually question became more focused: can asymptomatic screening be leveraged to safely **reopen Cornell** in the fall?

The New York Times

OPINION

College Campuses Must Reopen in the Fall. Here's How We Do It.

It won't be easy, but there's a path to get students back on track. Higher education will crumble without it.

April 26, 2020

The New York Times

OPINION

Expecting Students to Play It Safe if Colleges Reopen Is a Fantasy

Safety plans border on delusional and could lead to outbreaks of Covid-19 among students, faculty and staff.

June 15, 2020

Feasibility of COVID-19 Screening for the U.S. Population with Group Testing

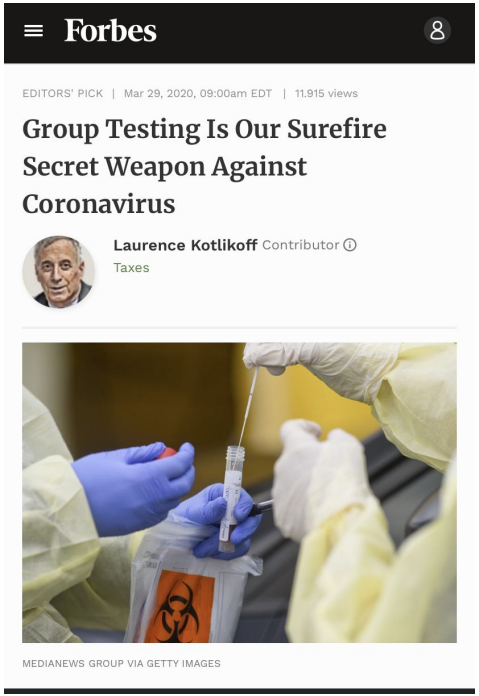
Prof. Peter Frazier, Massey Cashore, and Yujia Zhang, Cornell University, 24 April 2020

Based on a longer whitepaper with the same title

COVID-19 Mathematical Modeling for Cornell's Fall Semester

PhD Students: J. Massey Cashore, Ning Duan, Alyf Janmohamed, Jiayue Wan, Yujia Zhang
Faculty: Shane Henderson, David Shmoys, Peter Frazier*

June 15, 2020



Forbes

EDITORS' PICK | Mar 29, 2020, 09:00am EDT | 11,915 views

Group Testing Is Our Surefire Secret Weapon Against Coronavirus

Laurence Kotlikoff Contributor
Taxes

MEDIANEWS GROUP VIA GETTY IMAGES

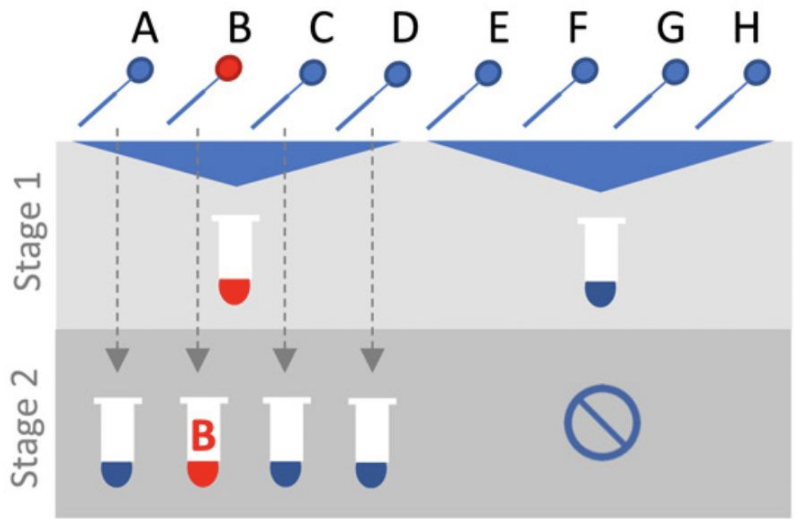
Key Idea: Do frequent asymptomatic screening

- Test all members of a community for the virus on a regular schedule, regardless of whether they show symptoms.

- This allows more social contact within the community compared to a full lockdown -- in the context of Cornell, lets us safely reopen campus.

- Requires massive test capacity. This is enabled via **group testing**.

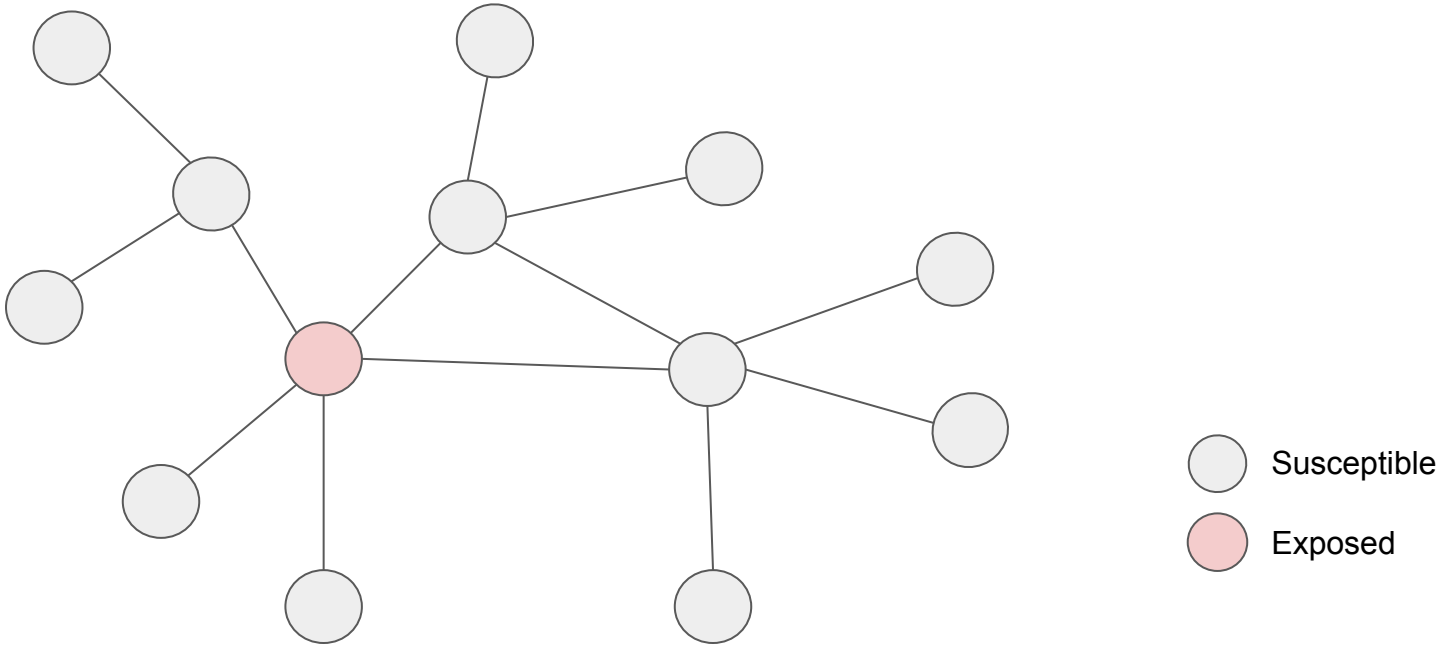
What is Group Testing



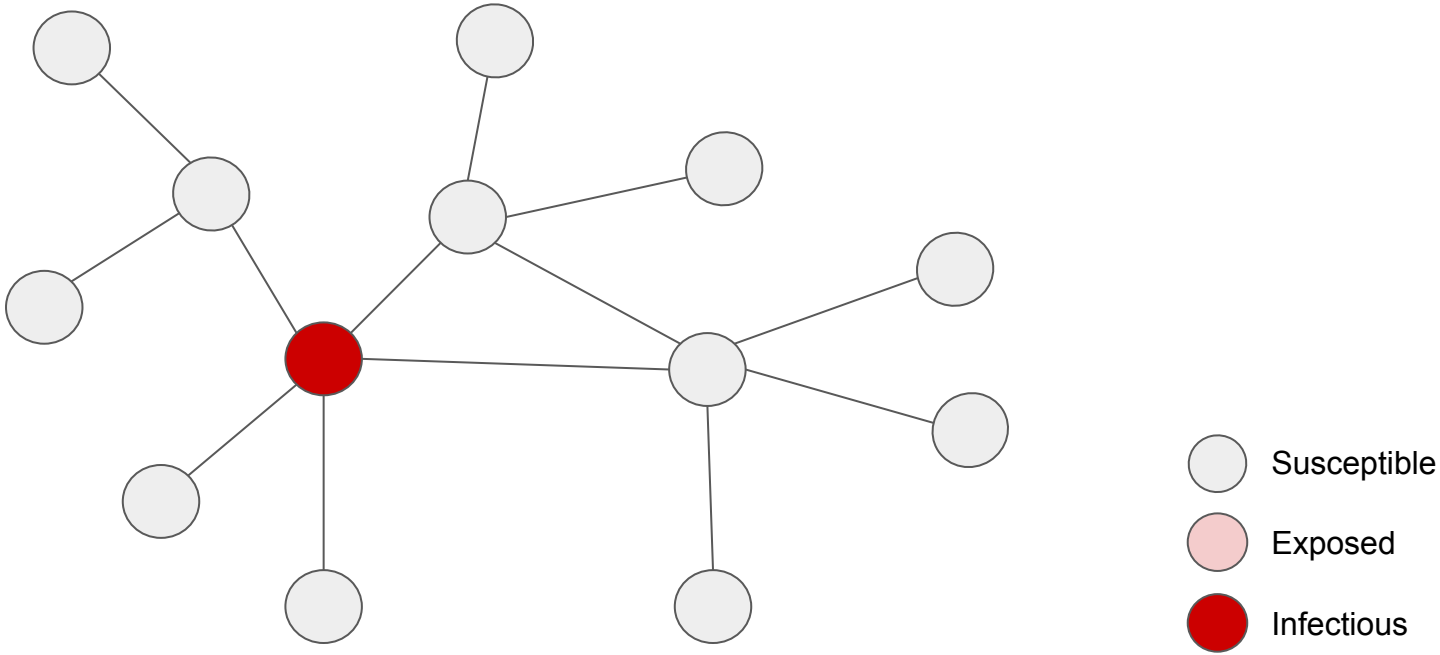
Cleary, Brian, et al. "Using viral load and epidemic dynamics to optimize pooled testing in resource-constrained settings." *Science translational medicine* 13.589 (2021).

How does the virus spread without asymptomatic screening?

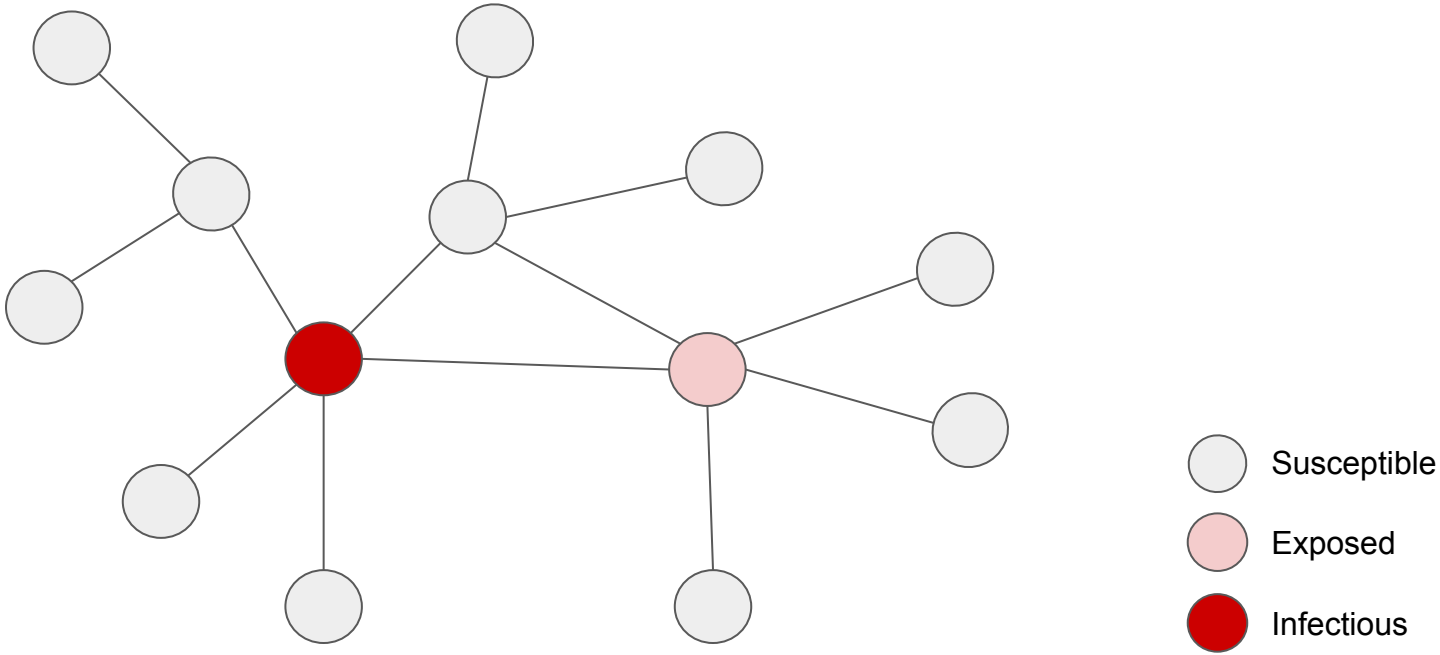
Index case is infected, not yet infectious



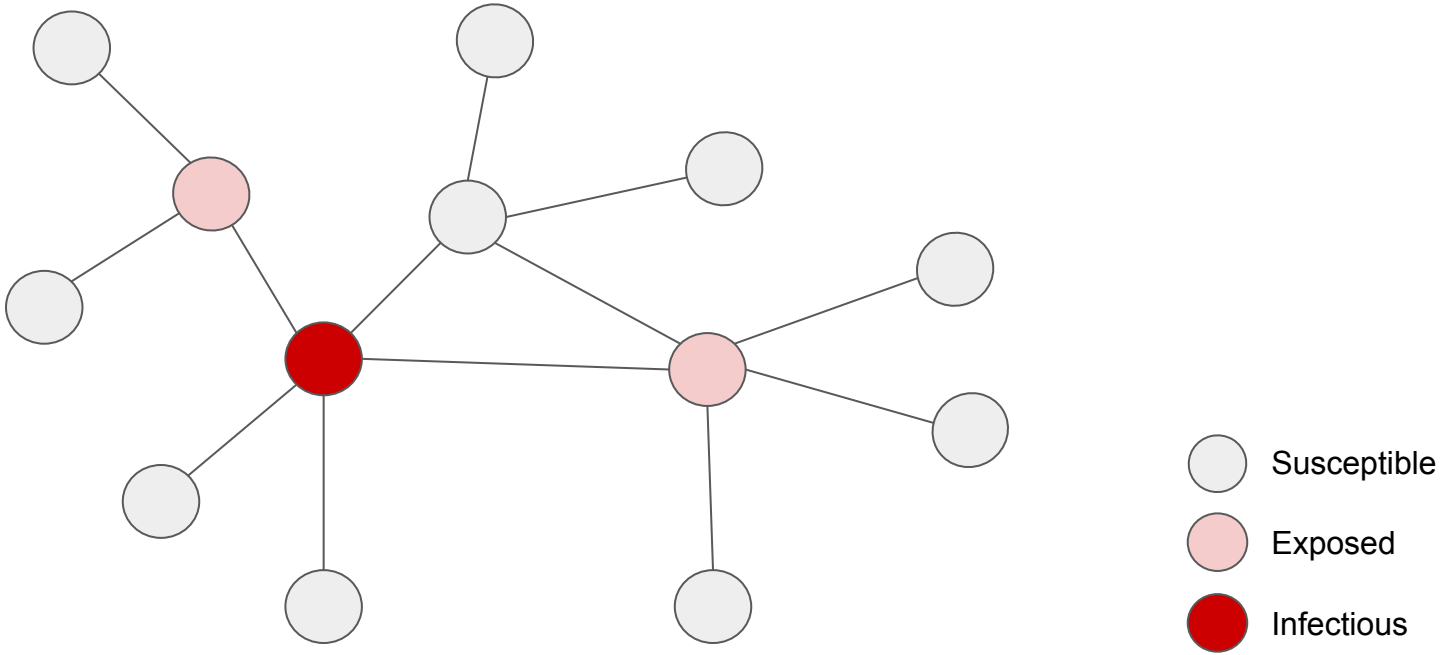
Index case is infectious & asymptomatic



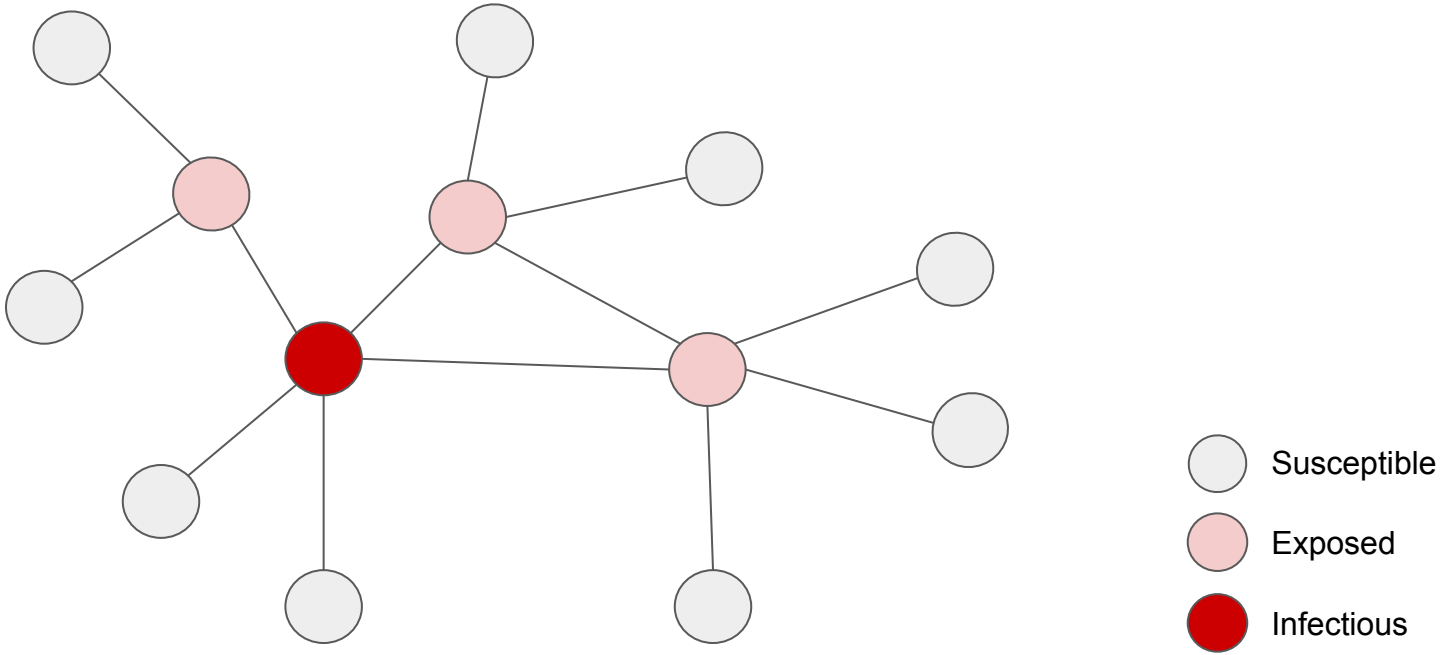
Another person becomes infected



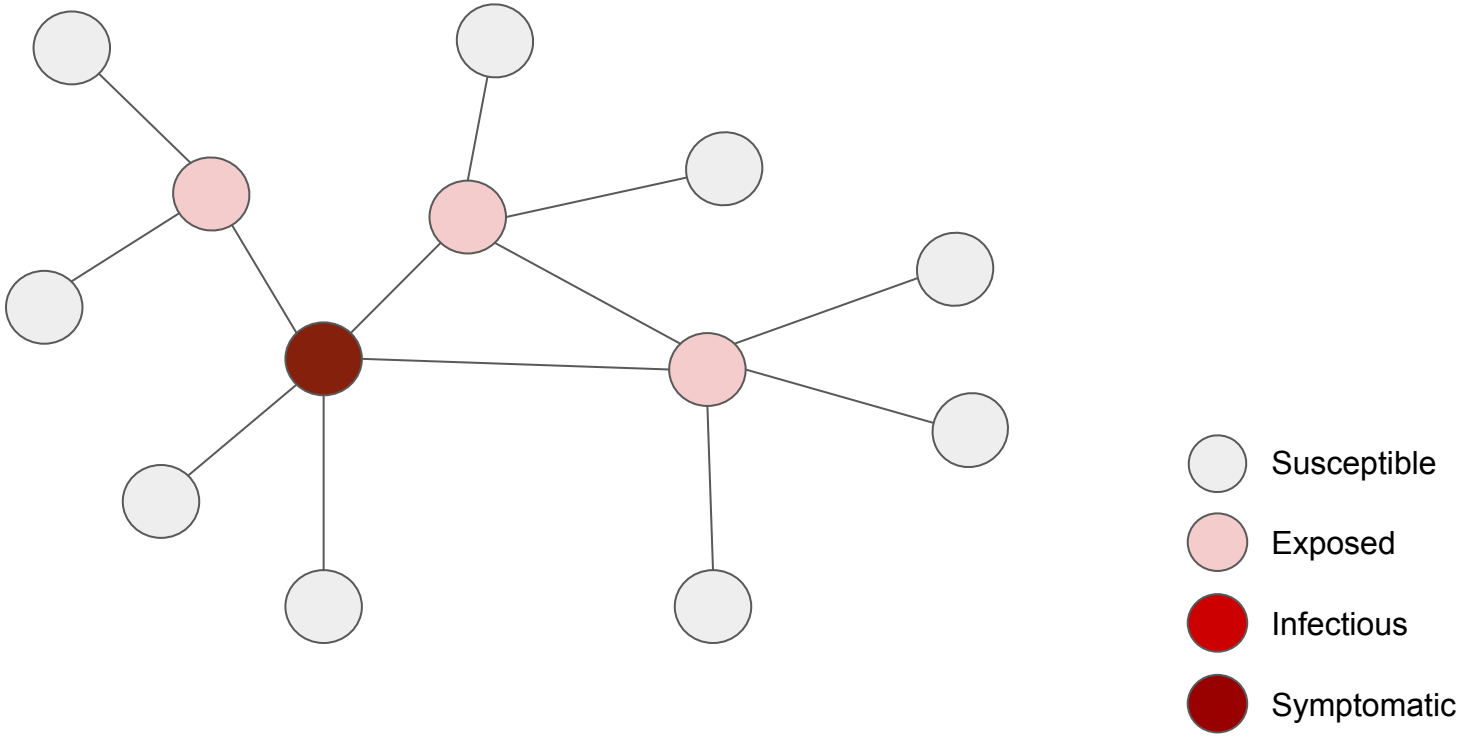
Another person becomes infected



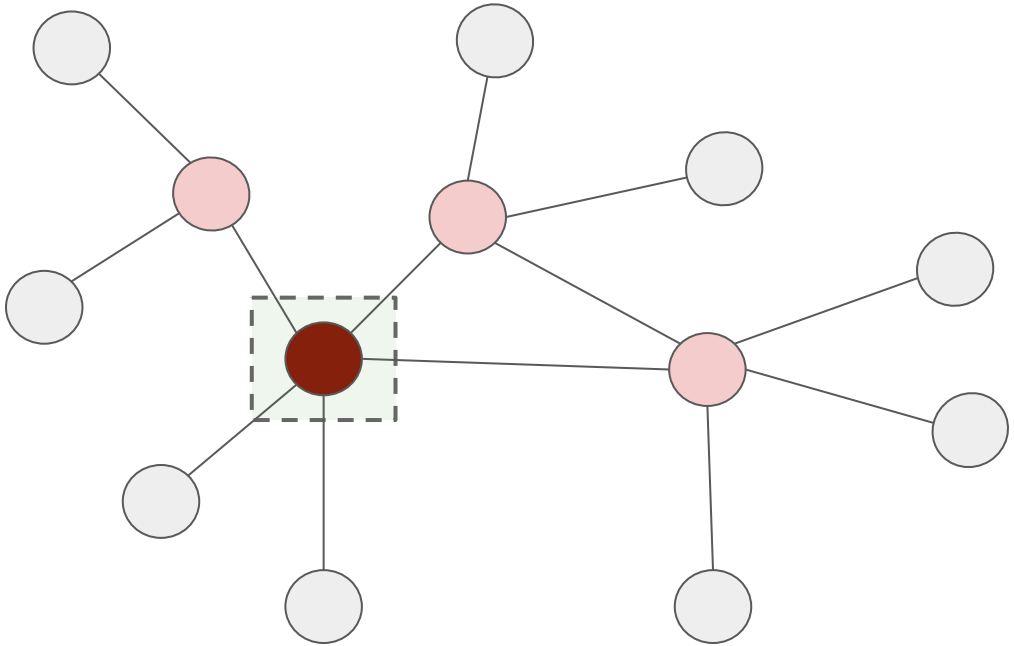
Another person becomes infected



Index case shows symptoms



Index case calls doctor, is tested, then isolated by health department



Susceptible

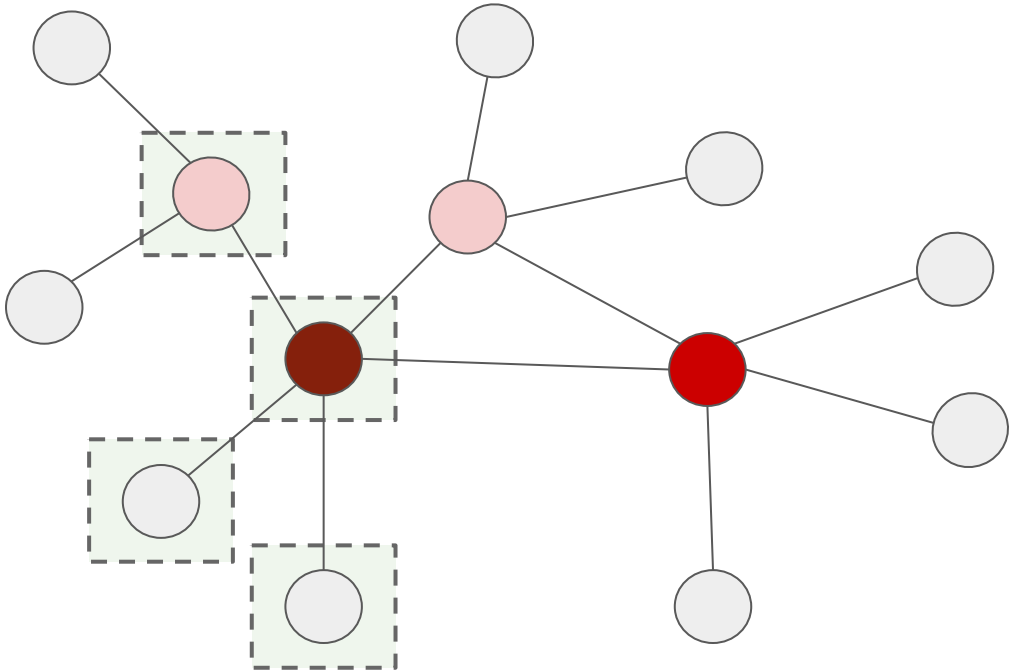
Exposed

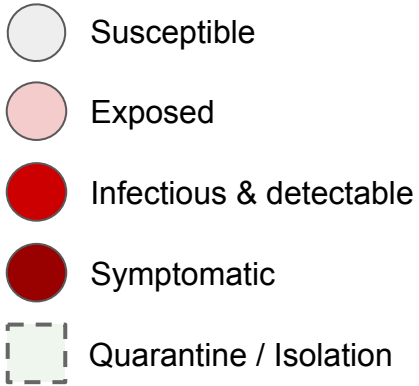
Infectious & detectable

Symptomatic

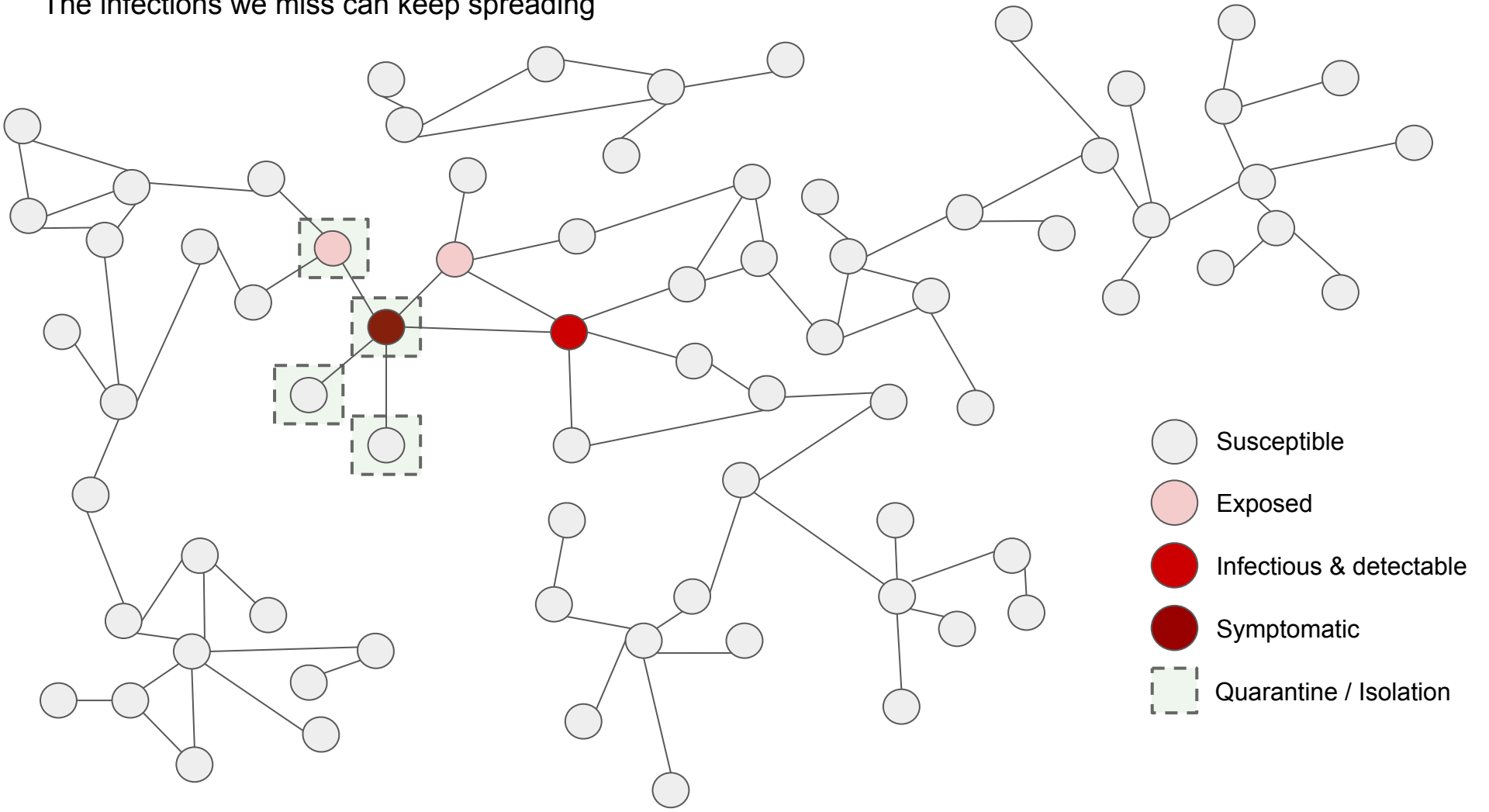
Quarantine / Isolation

Contacts are traced and quarantined, but two are missed





The infections we miss can keep spreading



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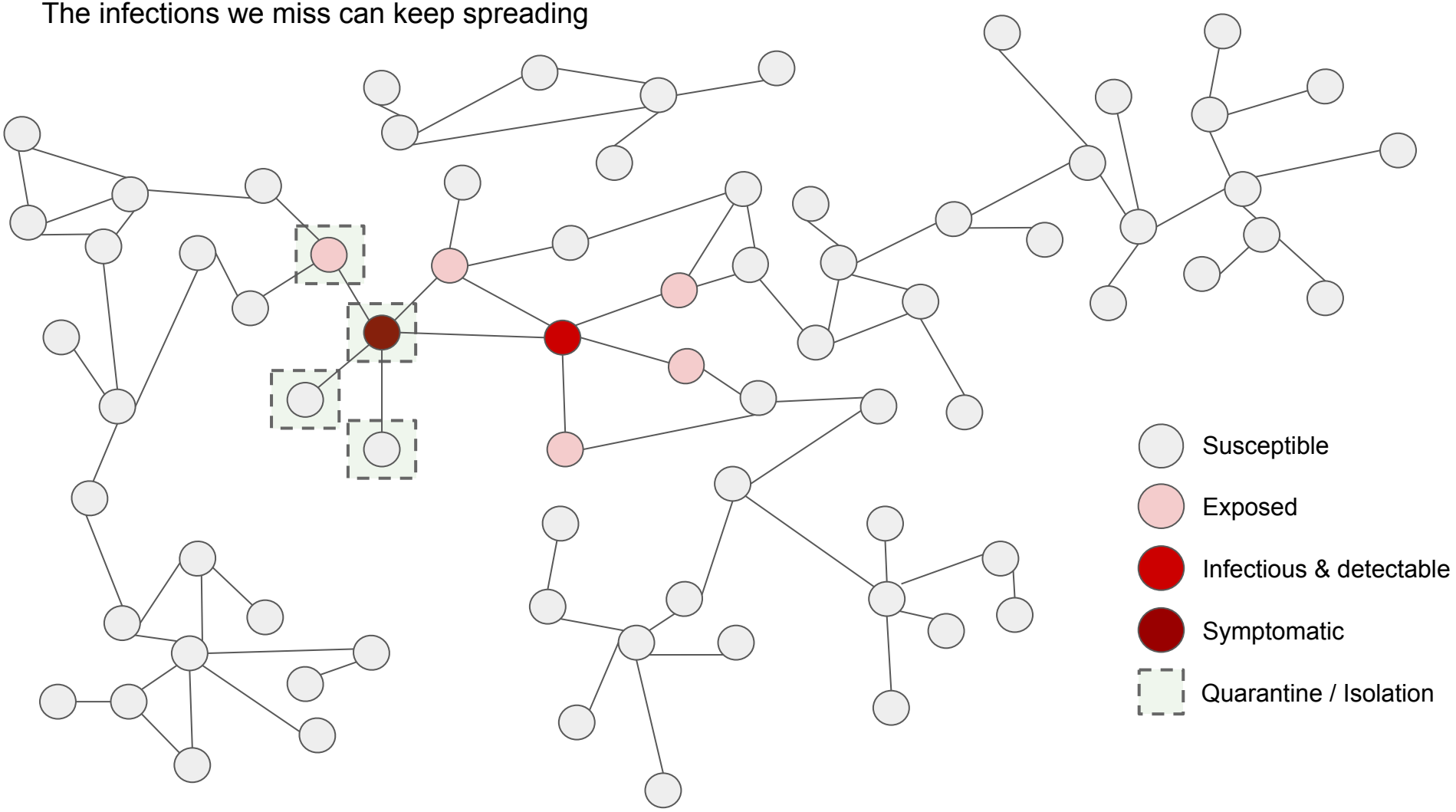
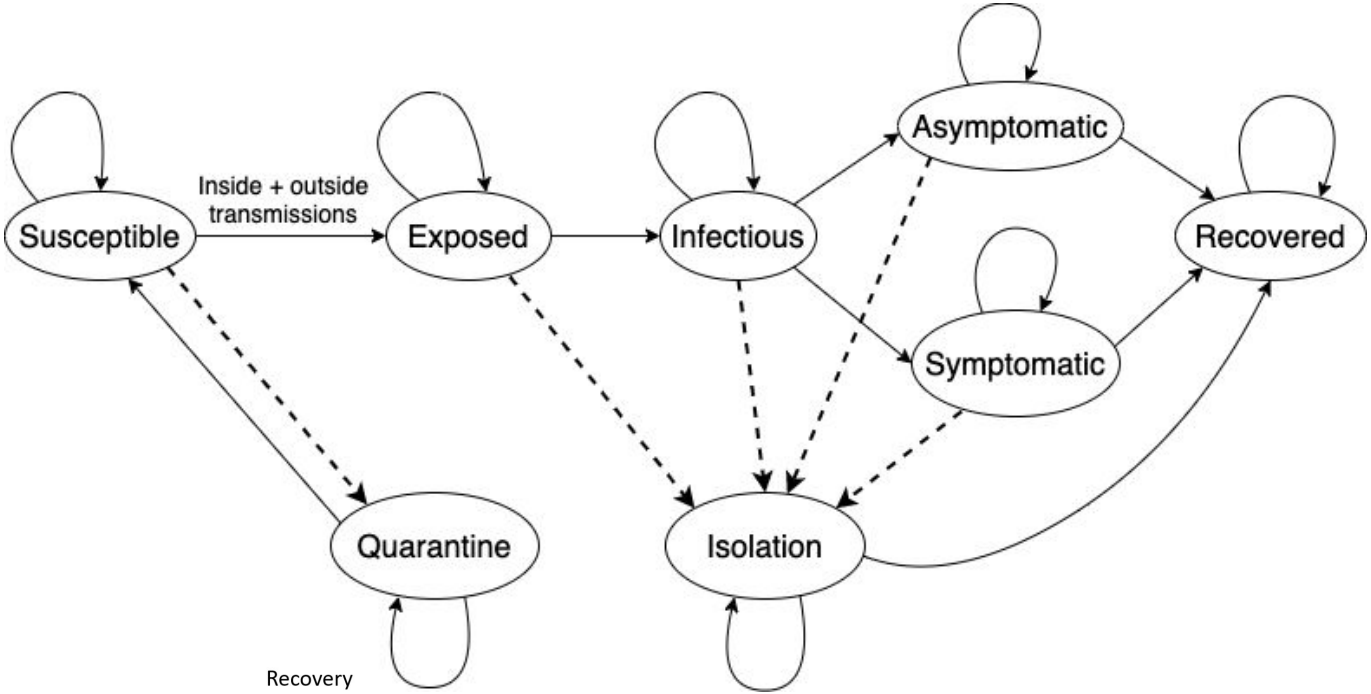
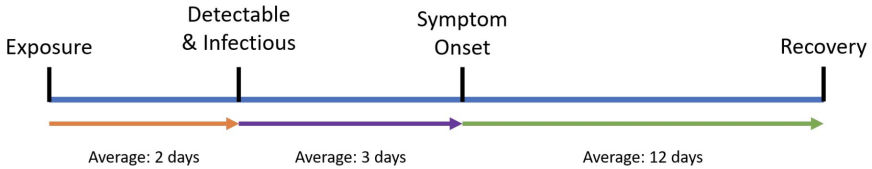


Why asymptomatic screening is more effective than contact tracing alone

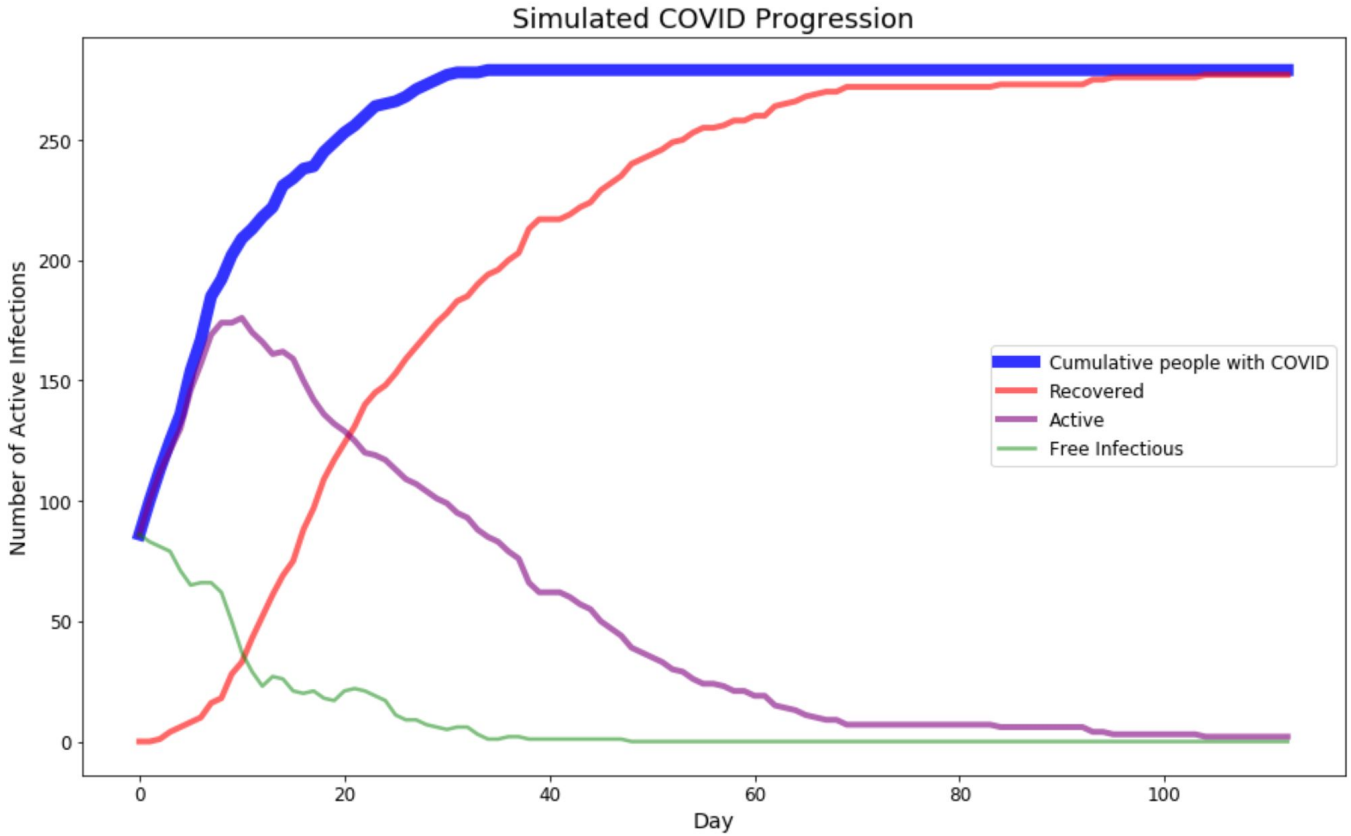
1. Asymptomatic screening tests carriers who might be missed by contact tracing
2. Carriers are most infectious **before** becoming symptomatic
3. Many carriers (~50%) **never** become symptomatic, especially among young people

Summer 2020: what is our model and how do we quantify uncertainty?





Simulated trajectory



Parameter uncertainty

Table 4: Parameters for age-stratified infection probability and severity level distribution. Sources: (28; 7; 13; 4; 25).

	Age grp 1 (0-17)	Age grp 2 (18-44)	Age grp 3 (45-64)	Age grp 4 (65-74)	Age grp 5 (75+)
P(infection | age)	1.8%	2.2%	2.9%	4.2%	4.2%
P(sev 1 | infected,age)	17.0%	52.0%	31.0%	13.0%	13.0%
P(sev 2 | infected,age)	81.6%	47.2%	65.9%	80.6%	80.6%
P(sev 3 | infected,age)	1.1%	0.6%	2.2%	4.7%	4.7%
P(sev 4 | infected,age)	0.3%	0.2%	0.9%	1.7%	1.7%

Table 6: Parameters for age distribution on campus for Fall reopen.

	Age group 1 (0-17)	Age group 2 (18-44)	Age group 3 (45-64)	Age group 4 (65-74)	Age group 5 (75+)
P(age) for Fall reopen	0%	85.81%	13.17%	0.88%	0.14%

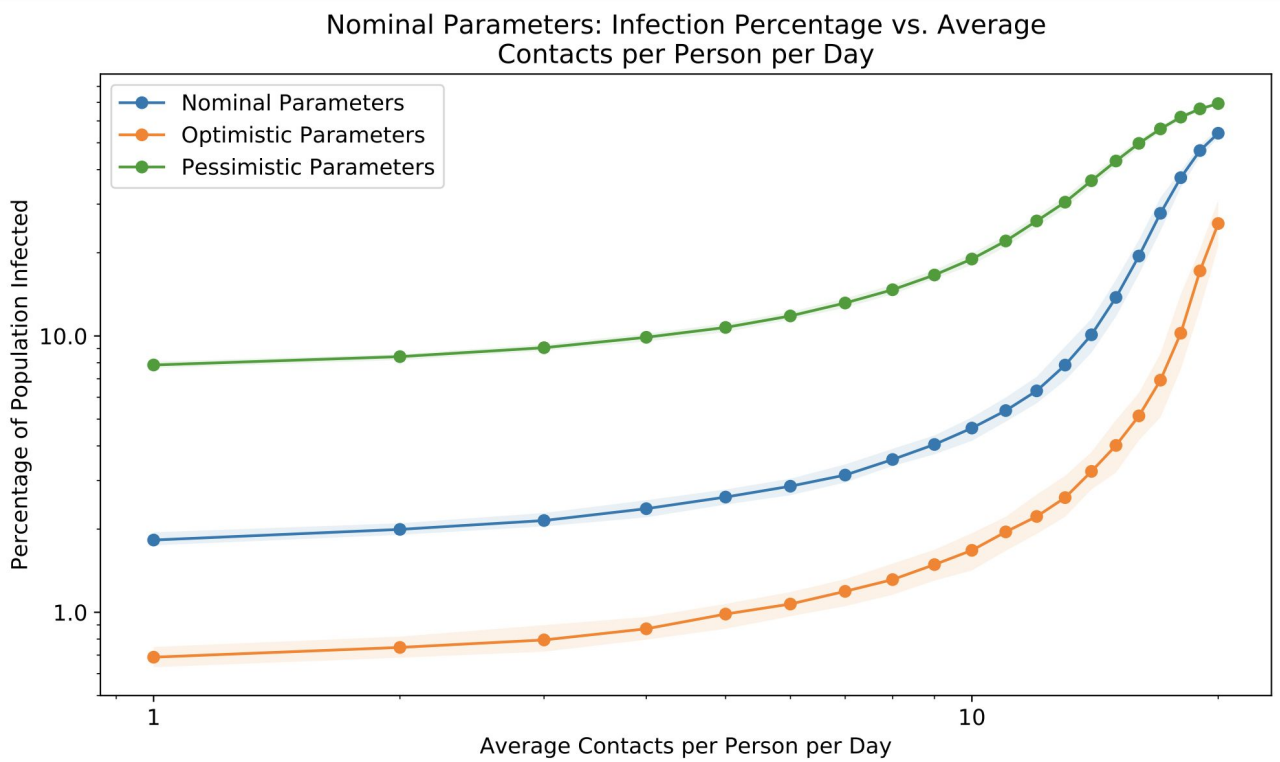
2.8 Parameter Values for Fall Reopen

In addition to the nominal parameters, we consider an optimistic and a pessimistic setting. Table 12 is a comprehensive summary of the parameters we use for all settings.

Table 12: Parameters for optimistic, nominal, and pessimistic settings.

Parameter Name	Optimistic	Nominal	Pessimistic
Time in E		Poisson(2)	
Time in D		0	
Time in ID	Poisson(2.5)	Poisson(3)	Poisson(3.5)
Time in Sy (with and w/o symptoms)	Poisson(10)	Poisson(12)	Poisson(14)
Contacts per day (for each free person)		8.3	
P(infection transmission | susceptible-infectious contact)		2.6%	
Total population		34310	
Student-origin prevalence	0.5%	2%	4%
Ithaca outside prevalence	0.1%	0.278%	1.25%
lence at beginning of compartmental simulation	0.05%	0.09%	0.175%
Asymptomatic rate	27.3%	47.8%	68.3%
P(self-report each day | no symptoms)		0%	
P(self-report each day | symptoms)		18%	
New quarantines+isolations per contact trace		7	
(Implied) new isolations per self-report contact trace		0.92	
lations per screening positive) / (isolations per self-report)		0.5	
n of contacts identified and traced		0.5	
Contact tracing delay	1 day	1 day	2 days
Testing false positive rate		0.1%	
Testing false negative rate		10%	
P(an isolated individual recovers each day)		0.05	
P(a quarantined individual is released each day)		0.3	
Age-severity matrix		(Table 5)	
Implied R_0 w/o intervention	2	2.5	3.2
Simulated time length		16 weeks (112 days)	
Parameters for the Excel model		(Table 10)	

Parameters significantly impact simulation outcome



Summer 2020: how do we make principled decisions in light of this uncertainty?

We will focus on 2 key questions:

1. Should we reopen
2. How frequently should we test?

Question 1: Should we reopen?

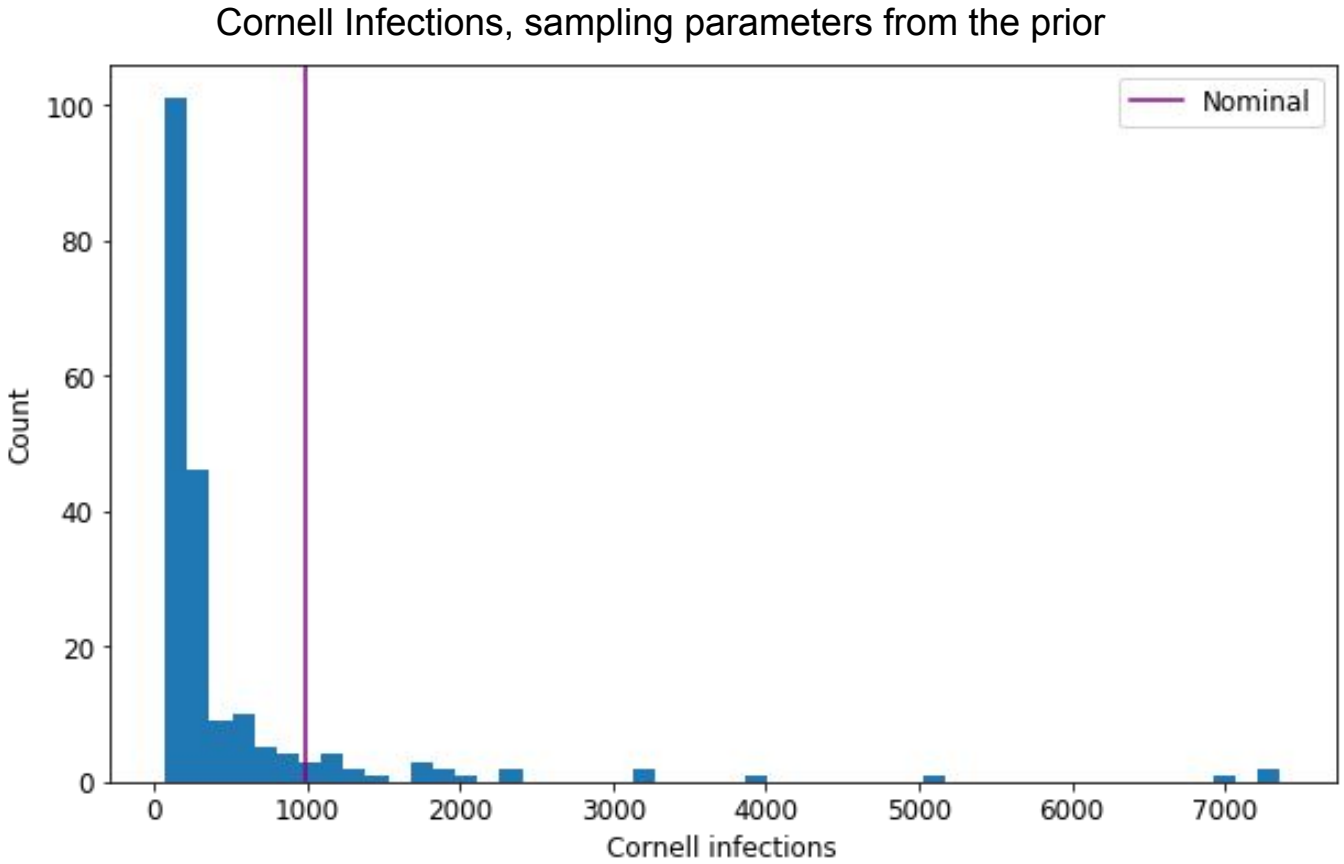
Key tradeoff: If we reopen,

- More students return to Ithaca
- Better ability to enforce compliance with social distancing, mask wearing, surveillance testing

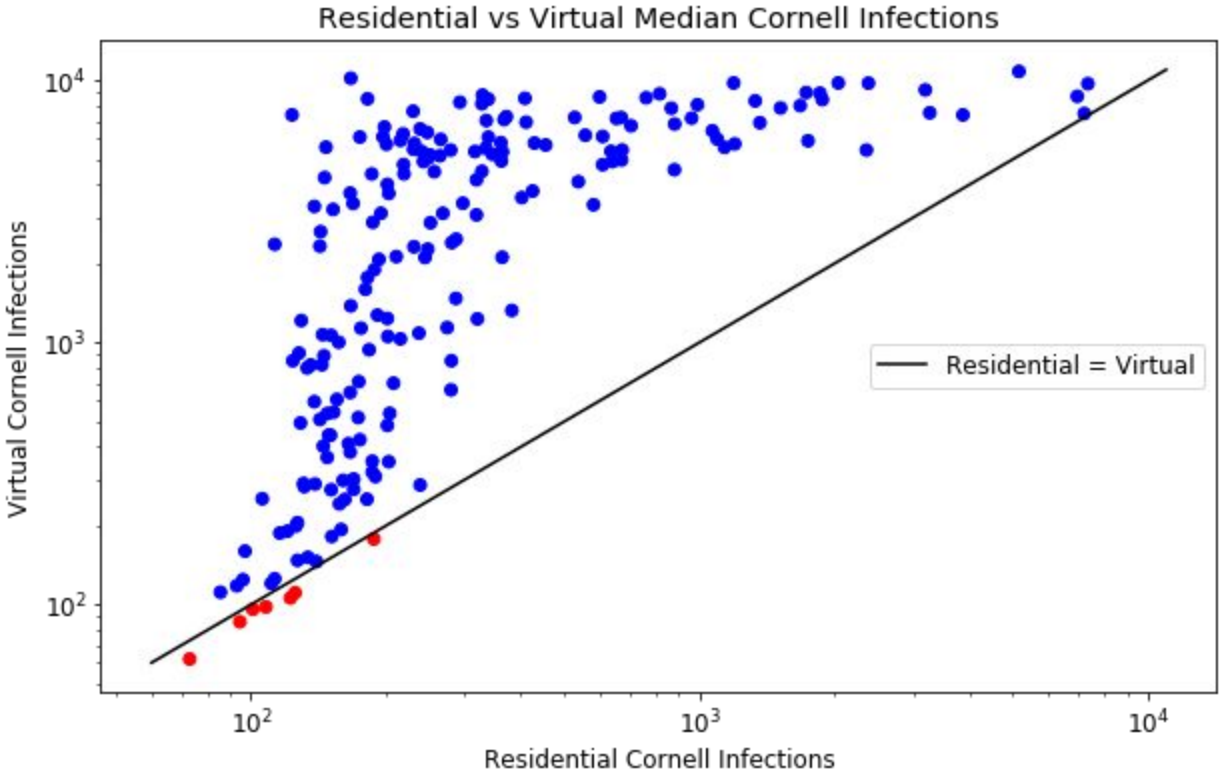
Metrics:

- Infections and Hospitalizations in the Cornell and Greater Ithaca communities

Parameter uncertainty created a chance things would go badly

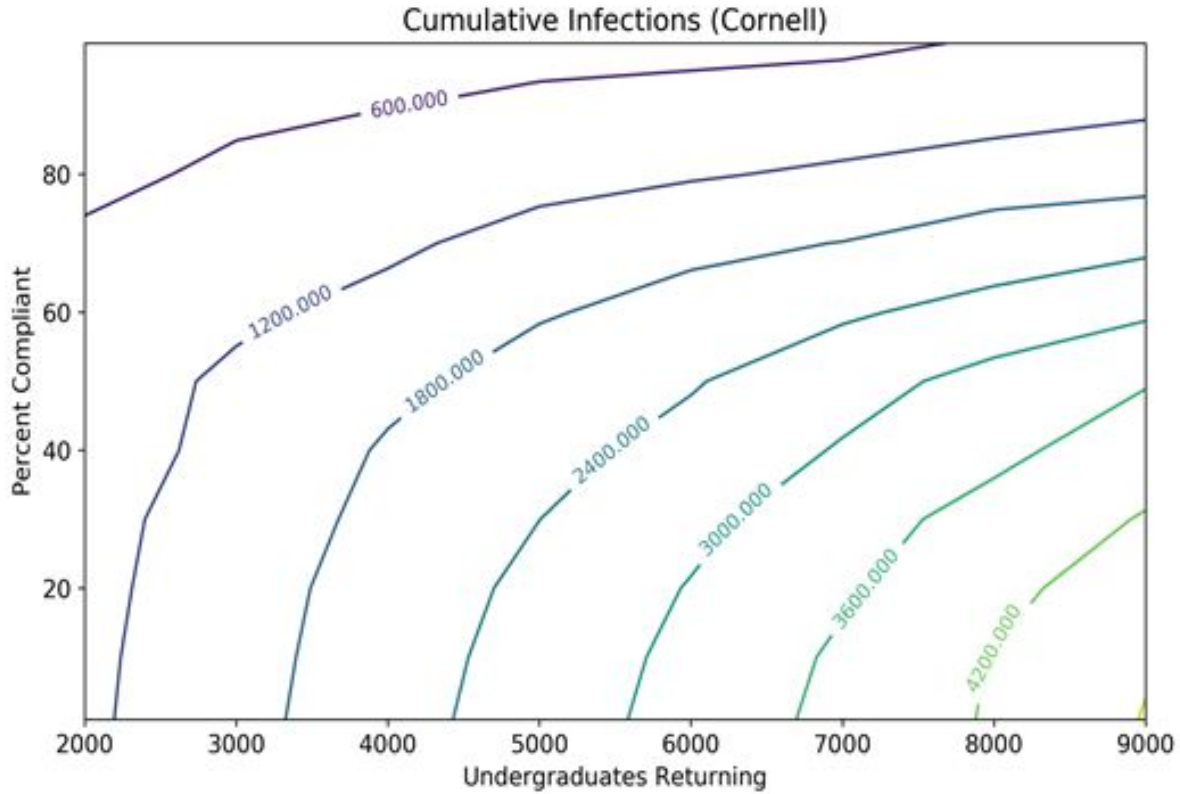


But, under plausible pessimistic parameter configs, shutting down would have been worse



- Based on surveys & leases signed with landlords, several thousand undergraduates seemed likely to return to Ithaca, even with virtual instruction only
- Asymptomatic screening would have been be hard to mandate and enforce for these students
- For parameters with uncontrolled spread under residential instruction, there is also uncontrolled spread under virtual instruction

Even with few undergraduates returning in a virtual scenario, a decrease in test compliance can create many infections



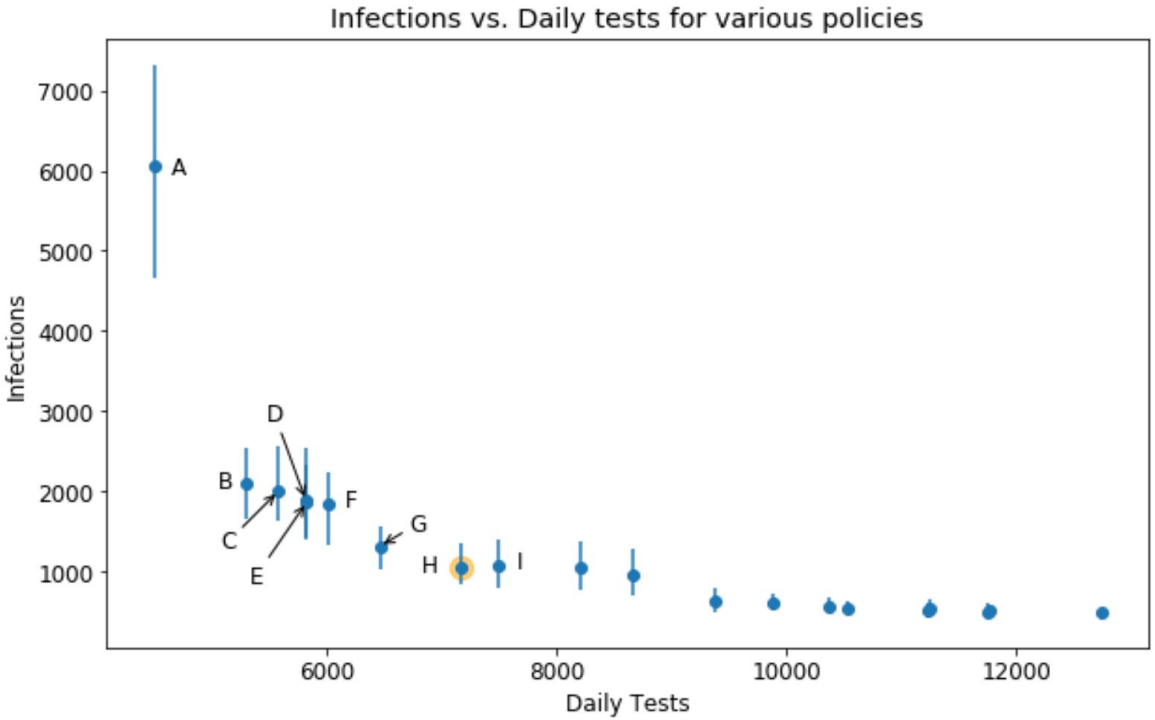
Question 2: How frequently should we test people?

Key tradeoff: Testing is expensive and we have a finite capacity. What is the best way to allocate this scarce resource?

Metrics: Want to have an ‘efficient’ allocation that we can actually implement

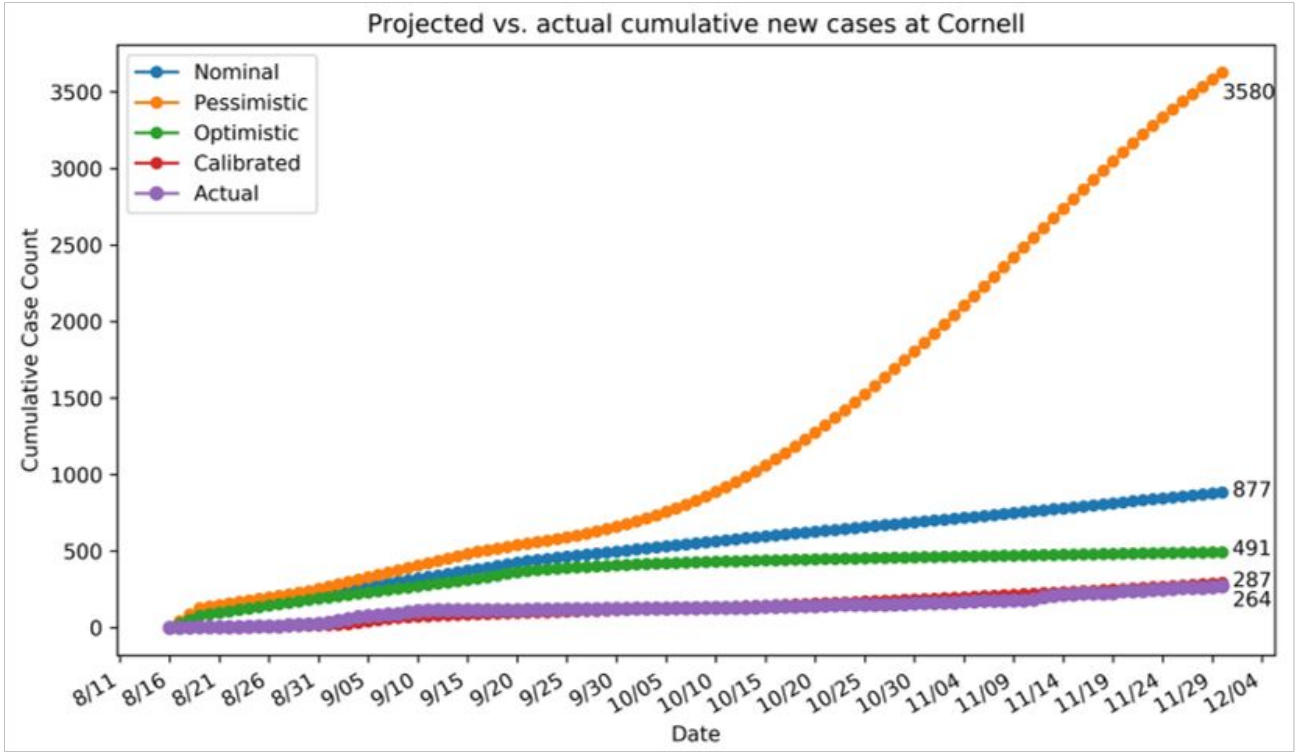
Idea: Let’s use our model to evaluate many potential policies

Screening should be targeted

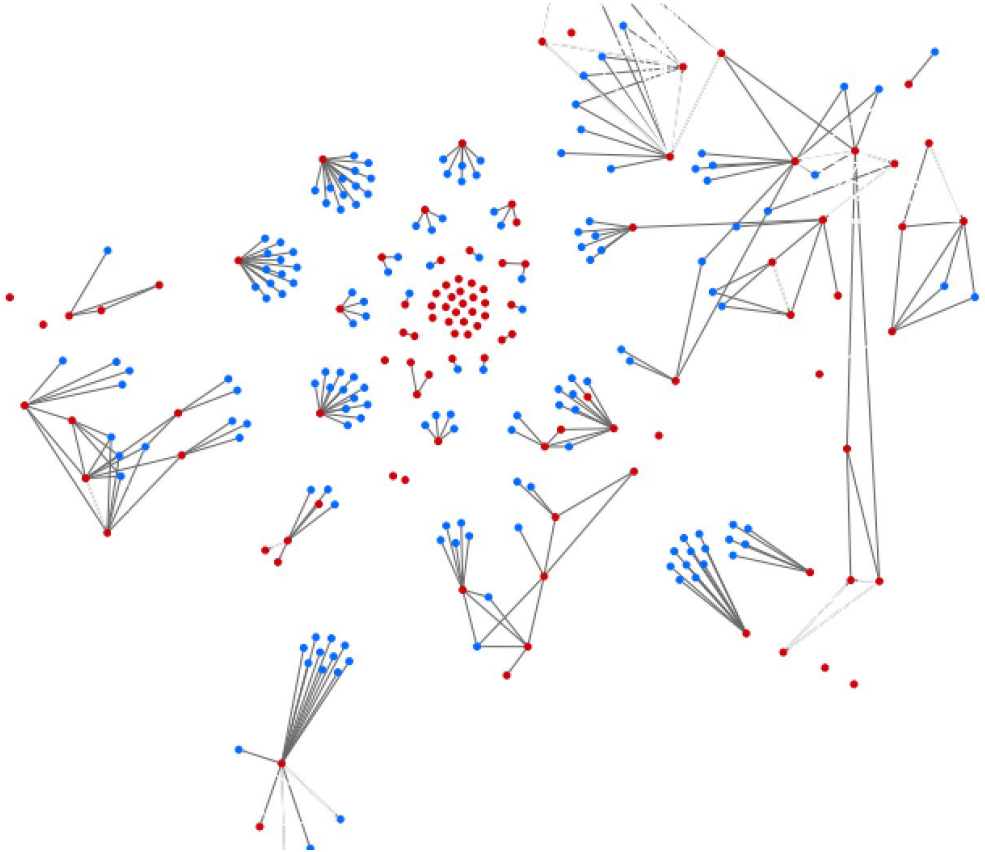


- Each point corresponds to a test policy (every group has a test frequency e.g. 2x / week)
- We enumerate options & use model to estimate number of infections and variance

Fall 2020: What did we do once we had data?



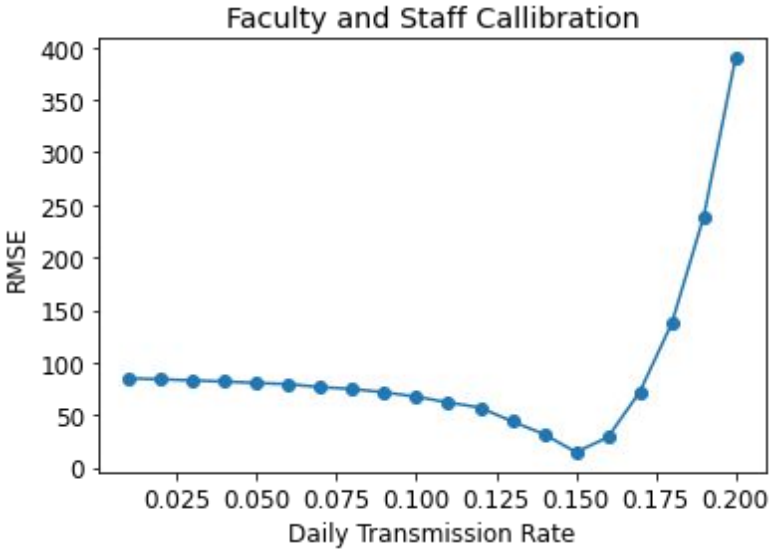
Contact tracing helps us understand the transmission network

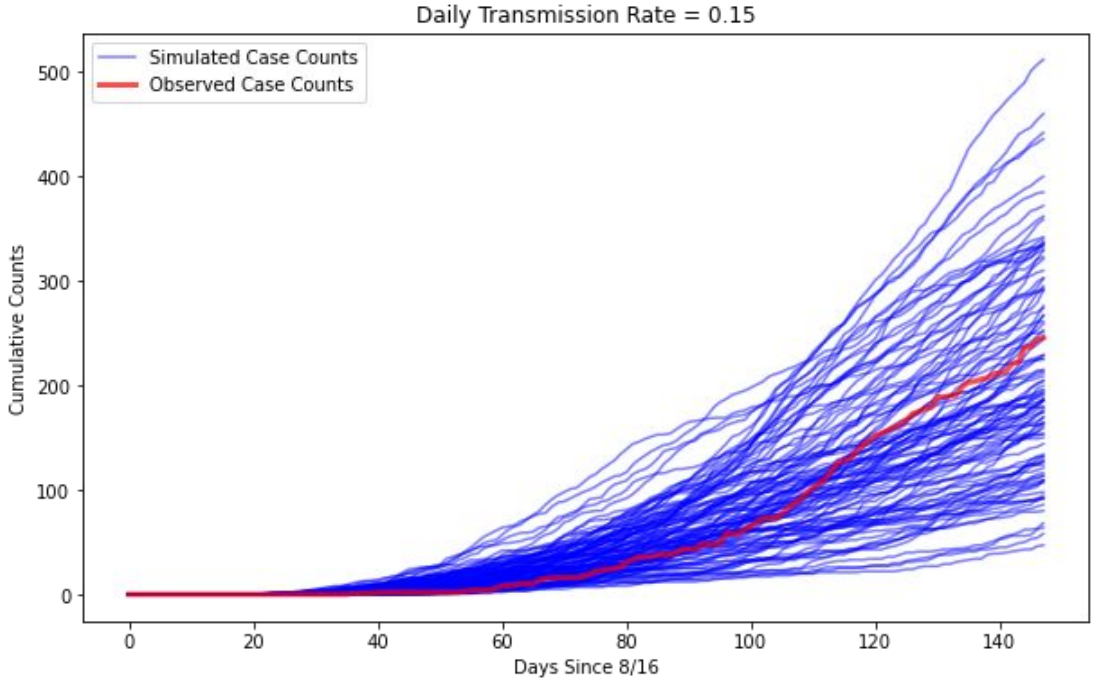


Parameters estimated directly from data

- Rate of infections imported from outside Ithaca
- Contact tracing effectiveness
- Test compliance
- ...

Calibration - by analogy with linear regression





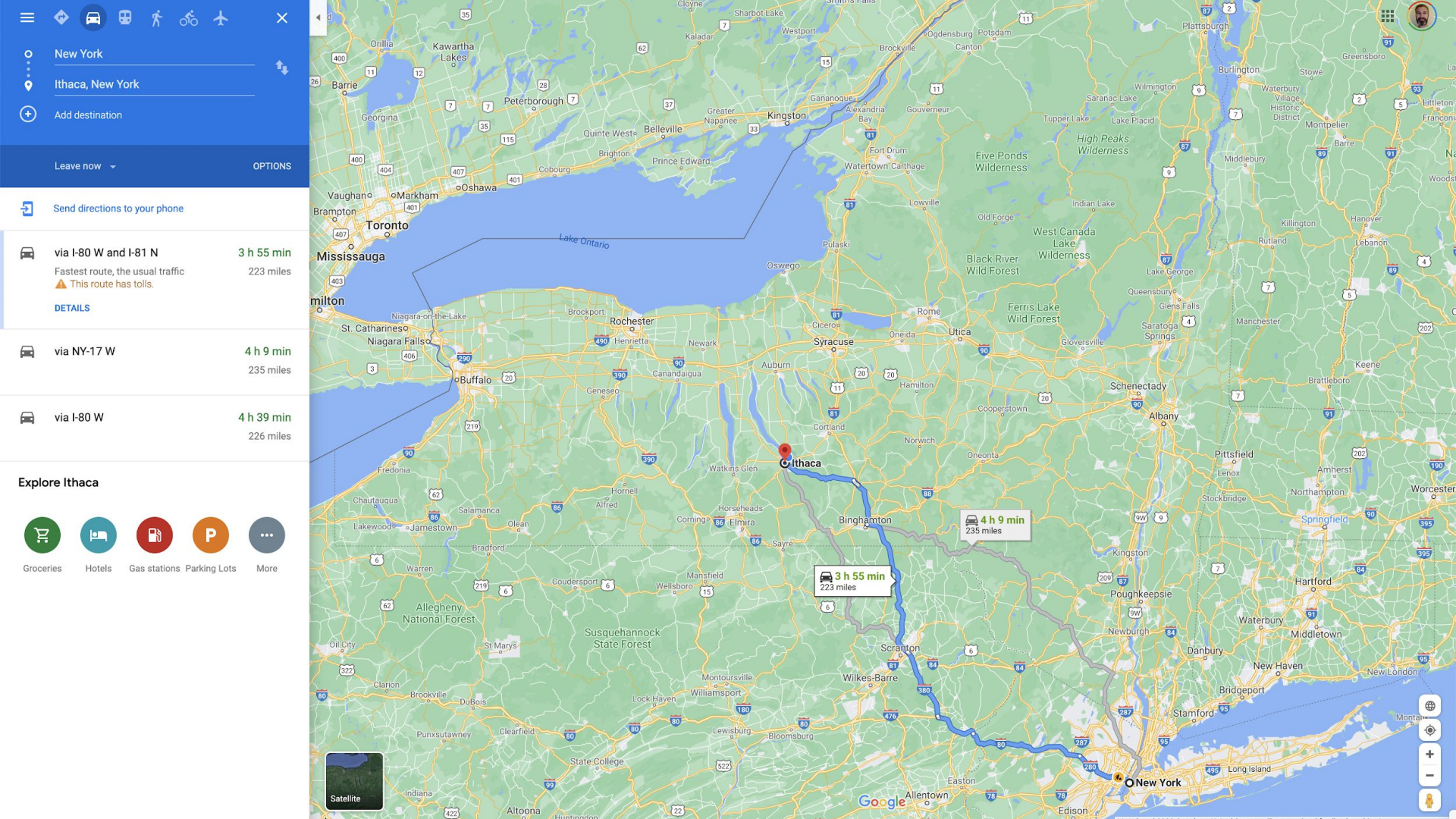
High-level takeaways

- Prediction accuracy is not always the goal. Instead: make a good decision.
- Modeling & uncertainty quantification provide a principled approach to making complex decisions.

What made it all possible

Thank you to

- University leadership
- Animal Health Diagnostic Lab, staff at Cornell Health, volunteers at testing centers
- All students
- Ithaca for being in the middle of nowhere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