Data Science for All
COVID Modeling Presentation

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

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
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

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

Diagram showing network of individuals with the following statuses:

- Susceptible
- Exposed
- Infectious
- Symptomatic
Index case calls doctor, is tested, then isolated by health department
Contacts are traced and quarantined, but two are missed
The infections we miss can keep spreading
The infections we miss can keep spreading

Infectious & detectable

Susceptible

Exposed

Symptomatic

Quarantine / Isolation
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

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>
<thead>
<tr>
<th>Parameter Name</th>
<th>Nominal</th>
<th>Optimistic</th>
<th>Pessimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in E</td>
<td>Poisson(2)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Time in D</td>
<td>Poisson(2.5)</td>
<td>Poisson(3)</td>
<td>Poisson(3.5)</td>
</tr>
<tr>
<td>Time in ID (with and w/o symptoms)</td>
<td>Poisson(10)</td>
<td>Poisson(12)</td>
<td>Poisson(14)</td>
</tr>
<tr>
<td>Contacts per day (for each free person)</td>
<td>8.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P(indirect transmission</td>
<td>susceptible-infectious contact)</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td>Total population</td>
<td>34310</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student-origin prevalence</td>
<td>0.5%</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>T/H PCA outside prevalence</td>
<td>0.1%</td>
<td>0.278%</td>
<td>1.25%</td>
</tr>
<tr>
<td>Incidence at beginning of compartmental simulation</td>
<td>0.05%</td>
<td>0.09%</td>
<td>0.175%</td>
</tr>
<tr>
<td>Asymptomatic rate</td>
<td>27.3%</td>
<td>47.8%</td>
<td>68.3%</td>
</tr>
<tr>
<td>P(self-report each day</td>
<td>no symptoms)</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>P(self-report each day</td>
<td>symptoms)</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>New quarantines + isolations per contact trace</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implied new isolations per self-report contact trace</td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection rate per screening positive / isolations per self-report</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m of contacts identified and traced</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact tracing delay</td>
<td>1 day</td>
<td>1 day</td>
<td>2 days</td>
</tr>
<tr>
<td>Testing false positive rate</td>
<td>0.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing false negative rate</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P(an isolated individual recovers each day)</td>
<td>0.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P(a quarantined individual is released each day)</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-severity matrix</td>
<td>(Table 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implied $R_0$ w/o intervention</td>
<td>2</td>
<td>2.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Simulated time length</td>
<td>16 weeks (112 days)</td>
<td>(Table 10)</td>
<td></td>
</tr>
</tbody>
</table>

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

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

Cornell Infections, sampling parameters from the prior.
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