Appendix 2: Frazier Modeling Report Executive Summary

- Initial modeling results suggest that a combination of contact tracing, asymptomatic surveillance, and low initial prevalence (supported through testing students prior to, and upon, returning to campus) can achieve meaningful control over outbreaks on Cornell's Ithaca campus in the fall semester if asymptomatic surveillance is sufficiently frequent and if we have sufficient quarantine capacity. This would dovetail with a complementary effort at Cornell to reduce transmissions through housing policy, class organization, and regulations on social gatherings.
- We use our model to predict outcomes for a full return of students, faculty and staff in the fall semester over a 16-week time period, with cases imported from returning students and from Tompkins county, counterbalanced by aggressive asymptomatic surveillance where every member of the campus community is tested every 5 days. The course of the epidemic is random, and we directly model that randomness. Accordingly, our model produces a range of potential futures. In the median random potential future, under our nominal set of parameters, 3.6% of the campus population (1254 people) become infected, and 0.047% of the campus population (16 people) require hospitalization. The 90% quantile rises to 4.02% infected and 0.051% requiring hospitalization. Of the 1254 infections in the median outcome, 570 are due to direct outside infections and ensuing additional infections prior to isolation, while 31 (0.09% of the campus population) are infected before arrival to campus but missed in the test-on-return protocol. There are an additional set of people infected before arrival, found through test-on-return, and isolated in Ithaca (22 people) or at home prior to travel (180 people).
- Outside infections from Tompkins County are predicted to be a significant source of cases. Testing every 5 days is sufficient to keep these imported cases from growing into large epidemics, but even low prevalence (e.g., 0.1%) creates a steady stream of imported cases, each of which then creates 2-3 more cases on campus before we catch the cluster. Over the course of a semester, outside infection can dominate returning students as a disease source. Measures that would reduce outside prevalence, especially among those that interact most closely with the Cornell community, are likely to also improve on-campus health outcomes and reduce quarantine needs. This includes using results from on-campus surveillance to identify transmission vectors, reducing transmission of virus from Cornell to the broader community, and expanding access to testing. Measures reducing contact between the Cornell community and those outside would have similar benefits.
- Peak Quarantine Capacity: Our preliminary nominal analysis suggests that the number of people that would need to be quarantined or isolated in the peak period following move-in is 700. This estimate includes members of the Cornell community who could self-isolate, so should be taken as an over-estimate of the needed quarantine capacity. It is highly sensitive to assumptions. Due to the uncertainty this creates, we recommend planning for a peak capacity greater than 700.
- Sustained Quarantine Capacity: Outside infections create a sustained need for quarantine and isolation capacity. While lower than peak capacity requirements, these may be significant, with hundreds of people quarantined or isolated at any given time. Since the greatest sustained source of infection will be interaction with the outside community, the quarantined population is likely to contain a larger fraction of faculty, staff, and students living off campus than the peak load following move-in. Work is ongoing to quantify these needs.
- To provide context, we also model what would happen if we did **not** open Cornell for a residential fall semester and did full virtual instruction instead. Our nominal parameters assume that 9000 students would remain in Ithaca but outside the control of the University in off-campus apartments without asymptomatic surveillance, and that a population of 15000 faculty, staff, and graduate students would remain on campus *with* asymptomatic surveillance. The median number of infections over a 16-week period in the no-reopen scenario is ~7200, which is significantly larger than the ~1200 that occur under the nominal fall-reopen parameters. This is because the loss of asymptomatic screening allows cases to grow significantly in the unmonitored student population. It is also because infections from outside Cornell, a large driver of cases in the residential-campus scenario, continue to drive cases.

- Our analysis of virtual instruction assumes that (1) virtual instruction allows asymptomatic screening only for those faculty, staff and graduate students who are assumed to continue to work/study on campus, with students living locally but taking classes remotely not included; (2) social distancing interventions are effective enough for virtual instruction students in Ithaca that contacts and transmission are comparable to residential instruction; and (3) gateway testing can be implemented for those returning to Ithaca for virtual instruction. Also note (4) our nominal scenario for residential instruction assumes full compliance with testing, quarantine and isolation. Assumptions (2) and (3) are likely overly optimistic for virtual instruction while assumption (4) may be overly optimistic for residential instruction. Other assumptions would create different predictions. Work continues to understand sensitivity to parameter choice, but early results suggest the conclusion that residential instruction has better health outcomes than virtual instruction is robust to assumptions.
- In all of our modeling results, modifying modeling parameters by only a modest amount from nominal values can result in substantially different numbers of infections and hospitalizations. Some parameter combinations, that we consider to be not implausible, can yield extremely serious consequences if interventions do not adjust to meet the challenge. Such outcomes point to the need to design a robust early-warning system. Regular asymptomatic testing as evaluated here can supply this early warning.
- Moreover, such scenarios suggest that the best course of action may be one that can *adapt* to facts on the ground, e.g., by adjusting asymptomatic screening frequency based on observed prevalence, or by beginning with stronger protections for vulnerable populations that can be relaxed if the risk level permits.
- In addition to uncertainty about parameters, our model cannot fully capture the intricacies of the real world. For example, it is difficult to accurately capture the interactions between the Cornell and non-Cornell communities.
- We developed a second model of outside infections that would appear equally reasonable to the one we present here, but whose number of outside infections imported is a factor of 3 smaller when passed the same raw parameters. A full list of model limitations is given in the report.
- Under a range of plausible parameter settings, regular asymptomatic testing is essential to keeping the epidemic under control; without it we see a significant increase in infections and hospitalizations. We envision that this asymptomatic testing would be enabled by the capacity at Cornell's Animal Health Diagnostic Center, with costs controlled through group testing. Work continues with collaborators in the College of Veterinary Medicine to validate group testing protocols and obtain regulatory approval. While substantial cost savings may be possible with large pool sizes (20 or more), we focus our analysis on a more conservative method using pools of size 5 in which we are more confident that a false negative rate of 10%, which is comparable to that of individual testing, can be achieved. (This false negative rate does not include a post-exposure low viral load period during which we assume PCR cannot detect infection).
- A small number of cases originating from Cornell students or employees could multiply in the broader community given that aggressive asymptomatic screening is not available to the general public, especially as social distancing measures are lifted. The cases thus created could then return to re-infect the Cornell community. This proliferation of cases in the broader community is not captured by our model.
- Modeling suggests other opportunities for reducing infections and hospitalizations: increasing the number of infectious cases identified with each contact trace by encouraging students to take phone calls from health department contact tracers; controlling the number of contacts per day and transmission probability per contact through housing policy, classroom design, and regulations on social gatherings; leveraging on-campus surveillance to alert Tompkins County to vectors infecting individuals on campus (e.g., Ithaca City Schools, a business in Collegetown); and perhaps even expanding test access beyond the Cornell community to help reduce prevalence in Ithaca and thus reduce outside infections.
- There are also unmodeled opportunities to reduce infection. Of interest is directed asymptomatic surveillance, e.g., follow-up testing on a dorm floor if a resident living on that floor is identified as positive. Such interventions are likely to reduce the required frequency of undirected asymptomatic surveillance. Also, we hypothesize that testing everyone

on a deterministic schedule (each person is tested once every 5 days) will outperform testing randomly, though our model assumes random testing to simplify computation.

- Toward the goal of quantifying uncertainty, we are continuing efforts to estimate parameters, provide ranges of plausible parameter values against which we should plan, and investigate the impact of modeling assumptions. This effort is supported by a literature review being conducted by the Cornell library and a set of reviews provided by experts both within and outside Cornell on a previous version of this report.
- In parallel, we are using the model to investigate the impact of having vulnerable individuals stay away from campus and modifications to student housing. We are also adding the capability to differentiate student from faculty/staff populations.