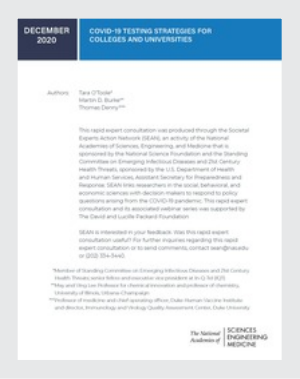

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National Academies of Sciences, Engineering, and Medicine

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COVID-19 TESTING STRATEGIES FOR COLLEGES AND UNIVERSITIES

Authors: Tara O'Toole*
Martin D. Burke**
Thomas Denny***

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SEAN is interested in your feedback. Was this rapid expert consultation useful? For further inquiries regarding this rapid expert consultation or to send comments, contact sean@nas.edu or (202) 334-3440.

*Member of Standing Committee on Emerging Infectious Diseases and 21st Century Health Threats; senior fellow and executive vice president at In-Q-Tel (IQT)
**May and Ving Lee Professor for chemical innovation and professor of chemistry, University of Illinois, Urbana–Champaign
***Professor of medicine and chief operating officer, Duke Human Vaccine Institute and director, Immunology and Virology Quality Assessment Center, Duke University

The National Academies of SCIENCES ENGINEERING MEDICINE

EXECUTIVE SUMMARY

This rapid expert consultation summarizes what is known to be effective with respect to testing strategies for college and university campus reopening, including the types of diagnostic testing employed, testing frequency and targets, metrics typically reported, responses to positive tests, and efforts to ensure compliance. Experience from the fall 2020 semester suggests that fast, frequent testing can help mitigate the spread of COVID-19 in a large and diverse university community, but it must also be emphasized that testing is only one component of a coherent mitigation strategy. A comprehensive approach requires the application of epidemiology and science; rapid isolation of positive individuals and quarantine of those with potential exposures; contact tracing; environmental management; mask wearing; physical distancing; and engagement with the community, particularly local public health officials.

Decision making related to testing strategies occurs in context, and choices are made on the basis of many intersecting factors that affect the educational needs of students and the health and economic needs of students, faculty, staff, and the surrounding community. Decision makers must apply the best available, but often incomplete, knowledge to navigate trade-offs and uncertainties in ways that apply and intersect with the core purpose or mission of their institution. Key contextual considerations include the following:

- The testing environment is highly dynamic, with new test types and formats emerging rapidly.
- Testing will continue to be necessary even after a vaccine is available.
- Colleges and universities are not uniform entities.
- Colleges and universities need to balance fulfilling their missions with the safety of everyone on campus.
- Colleges and universities are embedded in communities.

Lessons learned about COVID-19 testing strategies that can be applied in planning for campus reopenings during the spring 2021 semester and beyond are summarized in Box 1.

BOX 1

LESSONS LEARNED ABOUT COVID-19 TESTING STRATEGIES

1. Testing as one component of a mitigation strategy based on a comprehensive, coherent plan with redundancies.
2. Strategies chosen to match the needs and circumstances of the particular institution.
3. Engaged leadership at the highest levels, interdisciplinary teams, and coordination across groups.
4. Collaboration with local public health authorities and engagement with partners.
5. Routine collection and daily analysis of data to guide decision making, including dynamic prioritization of populations and testing frequency.
6. Quick response to a positive test—communicating results and supporting isolation of positive individuals and quarantine of close contacts—to prevent further transmission of the virus.
7. Adaptability and flexibility to implement different mitigation strategies as circumstances change.
8. Adoption of an information technology infrastructure that respects data transparency and privacy while rapidly providing accurate information.
9. Communication as an essential piece of the testing strategy.
10. Engagement with university and community constituencies, including students, in the development and implementation of the strategy and fostering of a culture of shared responsibility.

INTRODUCTION

The David and Lucile Packard Foundation asked the National Academies of Sciences, Engineering, and Medicine to produce a rapid expert consultation describing the various COVID-19 pre-arrival, arrival, and post-arrival testing strategies that colleges and universities are employing; the range of testing capabilities they possess; the testing types and frequency; the metrics routinely tracked; and who is tested.[1] This document summarizes what is known at this time to be effective with respect to COVID-19 testing on campuses from both available research and university experience and underscores lessons learned for planning for campus reopenings during the spring 2021 semester and beyond.

[1]The complete statement of task is as follows: The National Academies of Sciences, Engineering, and Medicine will produce a rapid expert consultation that will highlight the various COVID-19 pre-arrival, arrival, and post-arrival testing strategies that colleges and universities are employing, as well as the range of testing capabilities they possess. It will discuss testing type, frequency, metrics routinely tracked, and who is tested. The document will summarize what is known at this time to be effective from both available research and university experience, and underscore any lessons that higher education could use as it makes plans for the spring 2021 semester and beyond. The rapid expert consultation will be reviewed in accordance with institutional guidelines.

To better understand the university experience, the National Academies' Societal Experts Action Network and Standing Committee on Emerging Infectious Diseases and 21st Century Health Threats hosted four public information-gathering webinars on October 28–29, 2020.[2] This rapid expert consultation draws heavily on the experiences shared in the course of those discussions; the appendix provides brief summaries of the case examples presented at each session. Although not representative, these case examples highlight a mix of public and private colleges and universities that vary in size, geographic location, profile of students served, and funding/revenues, as well as reopening status. They were identified through outreach by the Board on Higher Education and the Workforce and the Board on Science Education at the National Academies, as well as the American Association of Universities, the Rockefeller Foundation, and Testing for America, among other stakeholders. Colleges and universities unable to participate in the webinars provided descriptions of their testing programs through an online questionnaire.

This rapid expert consultation focuses specifically on asymptomatic surveillance testing. However, it must be emphasized that testing is not effective in isolation and is only one aspect of a coherent COVID-19 response on campuses. It is essential to formulate a comprehensive response that integrates strategies for enacting other prevention and mitigation efforts, such as contact tracing, isolation of those infected, and quarantine of individuals exposed to the virus; digital symptom checks; use of personal protective equipment; exposure notification; wastewater and other group surveillance techniques; and adoption of protective behaviors. Colleges and universities also have addressed such environmental issues as the configuration of residence halls and classrooms; increasing telework and online and hybrid learning; the need to step up cleaning and maintenance efforts; and other environmental concerns, such as heating, ventilation, and air conditioning (HVAC) systems.

Many of the colleges and universities consulted in the development of this rapid expert consultation noted specifically the importance of protective behaviors, such as mask wearing, frequent handwashing, and physical distancing, for mitigating the spread of the virus on their campuses. A separate rapid expert consultation presents developmentally appropriate adaptations of general strategies for promoting the adoption of COVID-19 protective behaviors among college students.[3] A number of organizations, including the American College Health Association,[4] have issued guidance for reopening colleges and universities with consideration of many of these strategies.

TESTING IN CONTEXT

Testing and the associated decision-making process occur in the context of many intersecting factors that affect the educational needs of students and the health and economic needs of students, faculty, and staff, as well as the surrounding community. These decisions require applying the best available, often incomplete, knowledge to navigate trade-offs and uncertainties that apply to the missions of these institutions. Representatives from colleges and universities shared the following insights that bear on these decisions:

[2]Archived agendas, presentations, and videos of the four information-gathering webinars are available at www.nationalacademies.org/SEAN.

[3]See: https://www.nap.edu/catalog/26004.

[4]See:https://www.acha.org/documents/resources/guidelines/ACHA_Considerations_for_Reopening_IHEs_in_the_COVID-19_Era_May2020.pdf.

- ***The testing environment is highly dynamic, with new test types and formats emerging rapidly.*** More than 200 COVID-19 reverse transcription polymerase chain reaction (RT-PCR) diagnostic tests have been approved under the Food and Drug Administration's (FDA's) emergency use authorization, and the U.S. Department of Health and Human Services' (HHS's) Rapid Acceleration of Diagnostics (RADx) Program has awarded approximately $476 million to support the development and manufacture of lab-based and point-of-care COVID-19 diagnostics. Rapid-readout point-of-care tests detect antigen (protein surrounding the RNA of the virus) and are generally cheaper than PCR tests, provide rapid (minutes to an hour) results, and are easier to administer. However, these antigen tests are also generally less sensitive than PCR. Most colleges and universities are currently relying on PCR testing, although many have plans to add or transition to antigen testing for surveillance purposes, even though current recommended use of antigen testing is for symptomatic individuals, and data to guide its use for asymptomatic individuals are limited.[5]
- ***Testing will continue to be necessary even after a vaccine is available.*** When a vaccine arrives, it will take time to be distributed, and relatively young, healthy college/university students will not be a high-priority population for initial immunization. Moreover, some students, faculty, and staff may be unable to be vaccinated because of certain preexisting conditions.
- ***Colleges and universities are not uniform entities.*** Colleges and universities vary enormously in their size, in their complexity, in the profiles of their students, and in the scope of their function. Relevant to testing requirements, variation occurs across a number of domains, such as whether a medical school or laboratory capacity exists on campus; whether the university has its own housing for students; the design of campus dining facilities and operations; the scale of campus life and social activities; and the resources for remote and in-person teaching, as well as the suitability of program offerings (e.g., laboratory or clinical classes and technical courses, such as auto mechanics) for remote learning. These variations across the full spectrum of colleges and universities are important elements that affect decision making in any single institution.
- ***Colleges and universities need to balance fulfilling their missions with the safety of everyone on campus.*** In an educational institution with responsibilities for teaching, for research, and for service, testing fits in the context of both the COVID-19 response and the ways in which colleges and universities go about meeting the needs of students, fulfilling the functions of the institution, generating revenue, and providing a safe workplace for faculty and other staff.
- ***Colleges and universities are embedded in communities.*** Local and state policies regarding COVID-19 mitigation (e.g., opening/closing of bars and restaurants, restrictions on gatherings over a certain size, requirements to wear face masks indoors) influence the environments and experiences in which the campus community can engage. The status of the outbreak in the community also provides important

[5]National Academies of Sciences, Engineering, and Medicine. (2020). *Rapid Expert Consultations on Critical Issues in Diagnostic Testing for the COVID-19 Pandemic (November 9, 2020).* Washington, DC: The National Academies Press. Available: https://www.nap.edu/catalog/25984/rapid-expert-consultation-on-critical-issues-in-diagnostic-testing-for-the-covid-19-pandemic-november-9-2020.

context, as decision makers are mindful of the risk of transmission among students; among students, faculty, and staff; and between students and the surrounding community.

LESSONS LEARNED ABOUT TESTING STRATEGIES TO SUPPORT PLANNING FOR CAMPUS REOPENINGS DURING THE SPRING 2021 SEMESTER AND BEYOND

1. **Testing as one component of a mitigation strategy based on a comprehensive, coherent plan with redundancies.** Additional mitigation efforts, such as contact tracing, isolation of individuals with positive tests and quarantine of those possibly exposed to the virus, environmental management, use of personal protective equipment where appropriate, exposure notification, wastewater and other group surveillance methods, health communication, and messaging to promote adoption of protective behaviors need to be considered as part of a comprehensive response.
2. **Strategies chosen to match the needs and circumstances of the particular institution.** Colloquially, one size does not fit all. Programs need to be tailored to different schools and different situations. For example, whether a college or university is a commuter versus a noncommuter school or urban versus rural, the degree to which programming is remote or in person, the design of residence halls and dining facilities, and the prevalence and rate of transmission COVID-19 in that particular area will all inform how testing programs can be optimally designed.
3. **Engaged leadership at the highest levels, interdisciplinary teams, and coordination across groups.** Many universities reported holding consistent, frequent virtual meetings to share best practices and inform planning both internally and among the universities. Systematic outreach and coordination across all levels of the institution (e.g., from president's office, to campus facilities, to medical school), along with accountability at all levels for their part of the COVID plan, are also important components.
4. **Collaboration with local public health authorities and engagement with partners.** Collaboration and partnership can allow for leveraging of resources and sharing of best practices as resources ebb and flow and as feedback from the university community prompts changes toward more acceptable and sustainable strategies. Universities and local public officials can also work collaboratively to identify times when aggressive action, such as shelter-in-place orders for the campus community, may be required.
5. **Routine collection and daily analysis of data to guide decision making, including dynamic prioritization of populations and testing frequency.** Having a set of predetermined metrics with specific guidelines that inform decision making, particularly around the types of classes offered and the sizes and types of social activities allowed, enable more transparent and responsive decision making. Surveys and focus groups involving the campus community can inform understanding of the testing experience, compliance with mitigation behaviors, and challenges and barriers to participation, among other questions. Uncertainty surrounding the pandemic necessitates consistent information gathering to inform decision making. Ideally, routine testing is supplemented by in-depth responsive testing when outbreaks are identified in defined populations, such as on-campus residents, those involved in the

performing arts, members of athletics teams, or the Greek system. This strategy allows for rapid isolation and has the potential to minimize transmission.

6. **Quick response to a positive test—communicating results and supporting isolation of positive individuals and quarantine of close contacts—to prevent further transmission of the virus.** Speed is critical in response to a positive test, and offering care and assistance to those who test positive in getting safely isolated within hours, not days, as well as ensuring that possible close contacts are tested 3 to 5 days after exposure, has been shown to be effective in reducing transmission. Dedicated teams tasked with responding to a positive test may facilitate this rapid response.
7. **Adaptability and flexibility to implement different mitigation strategies as circumstances change.** Strategies will need to adapt as new technology and new information become available and as the nature and scope of outbreaks both on campus and in the community change. Tracking and analyzing such metrics as transmission location, transmission method, and transmission type are key steps in adapting mitigation strategies as needed.
8. **Adoption of an information technology (IT) infrastructure that respects data transparency and privacy while rapidly providing accurate information.** A convenient and consistent user interface for test registration, check-in, and delivery of results (both to individuals and to the university community in the aggregate) is important. Establishing an efficient data system sufficient to inform timely decision making may require significant changes to existing IT systems. This appears to be especially true for large universities conducting thousands of tests per day. Trust also is built between the university and the local community by ensuring that reporting of results from on-campus testing is following legal protocols.
9. **Communication as an essential piece of the testing strategy.** Public-facing dashboards and forums for sharing information, such as weekly town hall discussions, are examples of ways to share information with students, faculty, staff, and the public. Many colleges and universities routinely report publicly their test positivity rates, case numbers, number of tests completed, and capacity of isolation and quarantine facilities.
10. **Engagement with university and community constituencies, including students, in the development and implementation of the strategy and fostering of a culture of shared responsibility.** Participation in COVID-19 response activities may provide opportunities for experiential learning or internships. Building shared responsibility is critical in terms of the entire campus community's practice of protective behaviors in conjunction with the testing strategy.

CONSIDERATIONS FOR CHOOSING COMPONENTS OF A TESTING STRATEGY

This section describes components of the various COVID-19 testing strategies currently employed on some college and university campuses, including the type of diagnostic testing employed, the frequency and targets of testing, response to positive tests, and efforts to ensure compliance with testing requirements. Reporting metrics to students, faculty, staff, and the public is also an important component, and examples of data dashboards and the metrics included are described in Box 2. For each component, key considerations for decision making are highlighted. While colleges and universities vary in their implementation of testing strategies and emphasis

across these key considerations, their experience suggests that any surveillance testing system needs to be clearly planned, transparent, comprehensive, data-driven, agile, and timely.

Type of Diagnostic Testing

A variety of molecular, antigen, and antibody tests have been developed for the SARS-CoV-2 virus and authorized by the Food and Drug Administration (FDA) on an emergency use basis. These tests vary in their sensitivity and specificity, reliability, availability, cost, and time to completion. Some tests can be performed and deliver results at the point of care, while others require samples to be sent to a Certified Laboratory Improvement Amendments (CLIA)–approved laboratory.[5] A recent rapid expert consultation produced by the National Academies' Standing Committee on Emerging Infectious Diseases and 21st Century Health Threats reviews critical issues in diagnostic testing for the COVID-19 pandemic. Its findings include the following. First, "the majority of diagnostic testing for SARS-CoV-2 is carried out using centralized RT-PCR-based tests that may not scale to the throughput, turnaround time, and cost-effectiveness needed for infection containment in the community." Second, "there are a number of point-of-care diagnostic tests based on innovative technologies that are in various stages of development and may complement the existing RT-PCR diagnostics system." Third, "pooled testing and wastewater surveillance are two strategies that can provide advantages beyond individual diagnostic testing methods." Fourth, "diagnostic tests based on next-generation sequencing may offer a centralized testing system that can speed throughput and turnaround time for certain use cases."[6] A summary of performance trade-offs in screening tests is included in Box 3.

[5]"*Genomic tests* detect the presence of portions of the SARS-CoV-2 genome, which is composed of RNA. Because the virus causes a respiratory disease (COVID-19), samples from a patient are typically taken from the respiratory tract. Most tests take nasopharyngeal (NP) swabs as their sample type, but samples from the anterior nares, mid-turbinate, or oropharyngeal areas are also accepted by many tests; these samples are taken by trained professionals in clinical settings or at testing stations. Tests have also been validated to use samples as simple to obtain as saliva or nasal swabs; these samples in some cases can be collected by persons at home, either alone or under supervision through a telehealth provider, and sent to a lab by mail or courier. *Antigen tests* detect another portion of the SARS-CoV-2 virus, the protein coat that surrounds the RNA genome. As such, antigen tests are intended to detect the viral presence in symptomatic individuals. Confirmatory follow-up testing by more sensitive RT-PCR methods is recommended in high-risk or suspected cases that receive a negative antigen test result. Likewise, the CDC currently considers a positive antigen test result in asymptomatic patients with low exposure risk as a presumptive case and recommends a confirmatory test by RT-PCR. Like molecular tests, antigen tests are performed on samples obtained from the respiratory tract, for the same reasons explained above. There are (as of early October 2020) five antigen tests authorized for use in the United States. All are performed with small instruments or devices that can be used at the point of care or in laboratories, and all five take nasal or nasopharyngeal swabs as their input sample." Ibid; see also Carter, L., Garner, L., Smoot, J., Li, Y., Zhou, Q., Saveson, C., Sasso, J., Gregg, A., Soares, D., Beskid, T., Jervey, S., and Liu, C. (2020). Assay techniques and test development for COVID-19 diagnosis. *ACS Central Science*, 6(5), 591-605.

[6]National Academies of Sciences, Engineering, and Medicine. (2020, p. 17-18). *Rapid Expert Consultations on Critical Issues in Diagnostic Testing for the COVID-19 Pandemic (November 9, 2020).* Washington, DC: The National Academies Press. Available: https://www.nap.edu/catalog/25984/rapid-expert-consultation-on-critical-issues-in-diagnostic-testing-for-the-covid-19-pandemic-november-9-2020.

BOX 2
EXAMPLES OF COVID-19 TRACKING DASHBOARDS

Surveillance metrics need to be collected in a routine, systematic, consistent, and timely manner. A number of colleges and universities have public dashboards that provide information to students, faculty, staff, and the public. Some examples are briefly described below.

University of California, San Diego (see: https://returntolearn.ucsd.edu/dashboard/index.html)

- Student daily tests and cases (on and off campus)
- Campus employees daily tests and cases
- 4-day rolling percentage of positive cases among tests by date reported (students, campus employees, San Diego County)
- Total cases last 7 days
- Cumulative cases since fall 2020 instructional term
- Residential undergraduate move-in testing
- Campus density (students living on campus, students living off campus, class sections in person, campus employees, percentage campus employees working on campus, and isolation housing available)
- San Diego County prevalence data

University of Maine (see: https://www.maine.edu/together/#CovidSummary)

- Total tests
- Total positive tests
- Total tests last 14 days
- Total positive tests last 14 days
- Weekly wastewater sampling for the presences of SARS-CoV-2

Tulane University (see: https://tulane.edu/covid-19/dashboard)

- Tests completed
- Cumulative positive tests (students and employees)
- Active cases (students and employees)
- Percent testing positive
- 7-day average percent testing positive (Tulane, New Orleans, Louisiana)
- Isolation and quarantine cases and capacity by facility

Colleges and universities have in place additional important measures for monitoring beyond testing data, such as compliance with face coverings and physical distancing and emergence of secondary cases after close contact. Penn State University, for example, also monitors local hospital capacity.

BOX 3
Performance Trade-offs in Screening Tests

Both nucleic acid and antigen POC [point-of-care] tests have been reported in developmental studies to have specificity comparable to that for standard RT-PCR [reverse transcription polymerase chain reaction] tests, although the true specificity in field use may be lower due to factors such as variations in sample collection, operator skill, or off-label use.* Though they are generally less sensitive than RT-PCR tests, tests that have received EUA so far are designed to diagnose symptomatic individuals, who are likely to have higher viral loads, compensating to some extent for the test's lower sensitivity. Their performance in the field can also be augmented by more frequent testing. For example, recent models have shown that the frequency and result turnaround time may be more important than sensitivity for effective outbreak control when testing is performed as part of community surveillance.** Such tests are also generally cheaper than PCR and provide rapid results (within hours)—performance traits that are favorable for screening applications. Indeed, modeling of four testing strategies found that repeated population-wide screening using a test with modest sensitivity may decrease morbidity and mortality.*** Such widespread and repeated screening of the population necessitates a substantial increase in testing capacity that may be difficult to meet. In the absence of sufficient national capacity, strategies to prioritize testing in different communities may be guided by multiple factors that include the current infection incidence rate. In general, when the prevalence of infection is extremely low in a community, test specificity is important in reducing the proportion of false positives; when the prevalence of infection is higher, better test sensitivity become more important as it avoids false negatives. In communities and subgroups or subpopulations with low infection rates, screening with tests that have inadequate specificity could lead to follow-up testing of large numbers of initial, false positive results and place a heavy burden on the diagnostic system, thus negating the purpose of screening in the first place.

*Dinnes, J. Rapid, point-of-care antigen and molecular-based tests for diagnosis of SARS-CoV-2 infection. *Cochrane Systematic Review* 8:CD013705. https://doi.org/10.1002/14651858.CD013705.
**Paltiel et al. 2020. Assessment of SARS-CoV-2 screening strategies to permit the safe reopening of college campuses in the United States. JAMA Network Open 3(7):e2016818. doi: 10.1001/jamanetworkopen.2020.16818; Larremore et al. 2020. Test sensitivity is secondary to frequency and turnaround time for COVID-19 surveillance. medRxiv. https://doi.org/10.1101/2020.06.22.20136309.
***Neilan et al. 2020. Clinical impact, costs, and cost-effectiveness of expanded SARS-CoV-2 testing in Massachusetts. *Clinical Infectious Diseases.* https://doi.org/10.1093/cid/ciaa1418.

SOURCE: Excerpted from National Academies of Sciences, Engineering, and Medicine. (2020). *Rapid Expert Consultations on Critical Issues in Diagnostic Testing for the COVID-19 Pandemic (November 9, 2020).* Washington, DC: The National Academies Press. Available: https://www.nap.edu/catalog/25984/rapid-expert-consultation-on-critical-issues-in-diagnostic-testing-for-the-covid-19-pandemic-november-9-2020.

As noted earlier, colleges and universities have been relying on RT-PCR[7] testing, and many are planning to add or transition to rapid point-of-care tests.[8] These rapid antigen tests can be useful and are cheaper and more convenient than PCR tests, but they are not a panacea, and false positives may decrease the testing population's faith in testing and willingness to comply unless the testing strategy is clear and well communicated.[9] The institutions that participated in the webinars held to inform the development of this rapid expert consultation highlighted a number of key considerations that have shaped their decision making around the type of test to administer on their campus, including the accuracy of the test; the availability and accessibility of the test (e.g., supply chain considerations); the timeliness of the reporting of results; available laboratory capacity; costs; the prevalence of the virus in the community; and the willingness of students, faculty, and staff to participate in the testing (e.g., more invasive nasopharyngeal swabs versus anterior nasal or saliva testing).

Accuracy of the test. Many of the colleges and universities participating in the webinars noted that the decision about which type of diagnostic test to use was made in late spring/early summer. At that time, rapid antigen testing had a number of shortcomings related to specificity, and sensitivity.[10] According to the recent National Academies rapid expert consultation on

[7]"Overall, RT-PCR is a highly useful indicator of infection early in the infection, when decisions about care of the patient and limiting transmission are most important. RT-PCR and other genomic test technologies such as loop-mediated isothermal amplification (LAMP) and next-generation sequencing (NGS) are highly specific, meaning a positive test is extremely rare in the absence of infection. In theory, genomic tests can return results within hours, although transport of samples, backlog due to high volume, and laboratory logistics can add hours to days before results are reported. Test sensitivity is variable in real-world settings, perhaps related to the vagaries of sample collection or the dynamics of viral load at different stages of the infection." Ibid.

[8]"Two types of rapid read-out, POC tests have been developed. Nucleic acid amplified tests (NAATs) can be carried out at the point-of-service, such as in physicians' offices, clinics, and nursing homes. Abbott's 'ID Now' and Cepheid's 'Xpert Express' tests were among the first POC NAATs to be granted EUA status. Both are instrument-based tests executed on mobile platforms. Tests that use the "clustered regularly interspaced short palindromic repeats" or CRISPR technology are similar to conventional NAATs but use a different detection method that depend on recognition of the viral RNA by a CRISPR enzyme followed by collateral degradation of a signaling RNA sequence, rather than amplification of nucleic acids. The second type of rapid, POC tests are based on detection of viral antigen. Antigen tests provide fast turnaround times, are cheap and are relatively easy to manufacture at scale. Such tests may be useful for detecting asymptomatic individuals who may be carrying and able to transmit the virus. The FDA recently updated their EUA submission template for antigen tests to note that if a test is intended for POC use, the submitter should include data that demonstrates non-laboratory personnel can use it accurately, and if it is intended to be used in asymptomatic individuals, they should include a clinical study in that population comparing it to another assay. The guidance provided through the EUA template is not compulsory for submission but signals the agency's increased attention in point-of-care and asymptomatic test use. Abbott recently received EUA status for 'BinaxNOW,' an antigen-based test that does not require an instrument to read and has been reported by the company to provide results in 15 minutes. The results can be displayed on users' smart phones to enable those who test negative to display a 'temporary encrypted digital health pass.' As discussed below, the information value of a testing strategy builds on the performance of an individual test plus the frequency with which tests can be repeated. For example, the cumulative sensitivity of a sequence of regularly repeated tests can be superior to the performance of an intrinsically more sensitive test done only once." Ibid.

[9]Ibid.

[10]Test specificity refers to the ability of a diagnostic test to return a negative result when the disease in question is absent. Test sensitivity refers to the ability of a diagnostic test to return a positive result when the disease in question is present. An error in test specificity produces a false positive result, while an error in test sensitivity produces a false negative result.

diagnostic testing, "Diagnostic tests may be used to screen individuals to allow them to participate in school, sports, work, or other activities. Tests for this purpose of *assurance* must provide rapid results and may be useful if repeated with sufficient frequency, even if each individual assurance test has lower sensitivity and specificity than a more definitive test.…All positive antigen tests should be followed up with a more specific test as needed to ensure an accurate conclusion, and test results should be provided to local public health officials."[12] The University of Arizona, for example, administers rapid antigen testing for asymptomatic individuals whereby results are typically available within 1 hour. Validation studies were conducted in subpopulations during the summer to determine the accuracy of the antigen tests for large-scale roll-out.

Availability and accessibility of the test. According to the earlier rapid expert consultation cited above, "Many essential testing materials (e.g. reagents, nasal swabs, transport media, etc.) are in short supply."[11] To overcome supply chain shortages, Duke University, for instance, chose to use a quantitative viral load assay and QIAGEN platform, which is robotically driven.[12] Because the platform is not supported in clinical laboratories, Duke believed it would be an easier platform with which to ascertain reagents and bypass supply chain challenges with other tests. Accessibility of tests is also of concern. Representatives from the University of Maine system suggested that the use of saliva-based testing provided advantages for their mostly rural, small campuses, making testing more accessible for students/faculty/staff who may commute to campus and may face challenges with attending a testing appointment.

Timeliness of the reporting of results. Compared with RT-PCR tests, which may require that samples be sent to off-site laboratories, antigen tests can report results within 15 minutes.[13] Representatives from Morgan State University reported that concerns about timeliness influenced their decision to begin using rapid antigen testing, noting that some individuals experience anxiety after a test is conducted, and a prolonged period of waiting for results can increase that anxiety. Rapid response testing will be implemented at Morgan State in late November 2020 for athletes, and in the spring semester will be the primary test used, together with selected use of PCR testing for confirmation of any positive result and for any symptomatic person.

Available laboratory capacity. Colleges and universities have used a number of strategies to ensure adequate laboratory capacity for quick turnaround of testing results. Some schools have utilized resources already on campus associated with medical or veterinary schools, while others have partnered with local commercial labs. Many schools in New England, for example, have partnered with the Broad Institute of MIT and Harvard, which provides 108 public and private colleges and universities with regular COVID-19 testing for students, faculty, and staff.[14] The

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[12]National Academies of Sciences, Engineering, and Medicine. (2020). *Rapid Expert Consultations on Critical Issues in Diagnostic Testing for the COVID-19 Pandemic (November 9, 2020).* Washington, DC: The National Academies Press. Available: https://www.nap.edu/catalog/25984/rapid-expert-consultation-on-critical-issues-in-diagnostic-testing-for-the-covid-19-pandemic-november-9-2020.

[11]Ibid; see also Wu, K.J. (2020, July 23). "It's like Groundhog Day:" Coronavirus testing labs again lack key supplies. *New York Times*. Available: https://www.nytimes.com/2020/07/23/health/coronavirus-testing-supply-shortage.html.

[12]See: https://iqa.center.duke.edu/.

[13]Abbott. (2020). *Upping the Ante on COVID-19 Antigen Testing.* Available: https://www.abbott.com/corpnewsroom/product-and-innovation/upping-the-ante-on-COVID-19-antigen-testing.html.

[14]See: https://www.broadinstitute.org/coronavirus/covid-19.

University of New Hampshire, which did not have a medical or veterinary school on campus, chose to build its own CLIA-certified laboratory, going from "zero to CLIA in 100 days." The University of California, San Diego, utilized its health system's CLIA-certified laboratory, and also transformed several research laboratories into pop-up labs for testing.

Costs. The relatively high cost of commercial RT-PCR tests may inhibit their sustained, widespread use across college and university campuses. Pooled testing[15] can be an effective strategy for reducing costs, especially when the prevalence of infection in the test population is low. Researchers at Duke estimate that pooled testing has "yielded an approximate 80 percent savings in testing resources compared with performing surveillance testing on individual samples."[16] And Western Washington chose to implement pool batch testing—10 swabs per pool—making it possible to reduce costs from $130 to $13 per test. Additional costs that may be incurred include facility space and personnel.

Willingness of students, faculty, and staff to participate in the testing. The University of Illinois, for example, conducted outreach to students and determined that there was early concern about the invasiveness of testing done with nasal swabs. Conversely, positive feedback was received regarding willingness to participate in a twice weekly testing regimen if it was conducted using a saliva-based test.

Frequency and Targets of Testing

According to the prior rapid expert consultation, "Diagnostic tests can also be deployed for public health purposes to perform *routine or targeted surveillance of populations*. Especially with a pathogen such as SARS-CoV-2 that frequently results in asymptomatic infection, routinely surveying populations can provide public health officials crucial information to determine the prevalence of infection and changes in infection rates over time."[17] In the college

[15]"Pooled testing is an approach intended to conserve test resources without sacrificing accuracy where infection prevalence is low. One procedure is called split-pool testing and involves 'halving' steps. In this approach, a cohort of samples that tests positive is split into two sub-pools of the same size that are each re-tested. The process is repeated until the positive individual sample(s) is identified. If the sample cohort tests negative, then the test is repeated once on the same cohort to confirm the negative result. This approach may be more accurate and efficient than a frequently cited 'Dorfman Protocol' that specifies follow-up testing of each individual sample after a positive pool test. The appropriateness of pooled testing and the choice of protocol should take into account the test positivity rate in the area, as well as technical feasibility of the responsible laboratory. Split pool testing may be feasible and useful when lab technical talent is available and prevalence of infection is low. Reductions in test sensitivity are a concern with split pool testing. The FDA has noted that they 'have seen highly variable results even on the same platforms in different labs. We believe the science is still evolving […]' FDA guidance recommends a positive predictive value of 85% between pooled and individual tests and the implementation of a plan to monitor local test positivity rates. The RADx program has awarded funds to companies for the purpose of developing pooled testing protocols using next-generation sequencing diagnostics." National Academies of Sciences, Engineering, and Medicine. (2020). *Rapid Expert Consultations on Critical Issues in Diagnostic Testing for the COVID-19 Pandemic (November 9, 2020)*. Washington, DC: The National Academies Press. Available: https://www.nap.edu/catalog/25984/rapid-expert-consultation-on-critical-issues-in-diagnostic-testing-for-the-covid-19-pandemic-november-9-2020.

[16]Denny et al. (2020). Implementation of a pooled surveillance testing program for asymptomatic SARS-CoV-2 infection on a college campus—Duke University, Durham, North Carolina, August–October, 2020. *Morbidity and Mortality Weekly Report,* November 17.

[17]National Academies of Sciences, Engineering, and Medicine. (2020). *Rapid Expert Consultations on Critical Issues in Diagnostic Testing for the COVID-19 Pandemic (November 9, 2020).* Washington, DC: The

and university context, targeted surveillance may involve use of diagnostic tests to screen individuals so they can participate in sports, classes, or other on-campus activities. Tests for this purpose of assurance "must provide rapid results and may be useful if repeated with sufficient frequency."[18]

Testing strategies need to take account of the prevalence of COVID-19 in the surrounding community, the number of off-campus students who frequent the campus, and evolving data and results from the current testing program, among other factors. Recommendations from the Massachusetts Higher Education Testing Group suggest a framework for determining the frequency of asymptomatic surveillance testing needed on campuses: "Individuals more likely to become infected (based on their local environment and interaction frequency) might be tested more frequently than those at lower risk of transmission." The highest-risk category includes students in residential housing; the medium-risk category includes nonresidential individuals who commute to campus and have limited contact with residential students; the low-risk category includes staff who transit to campus and who have little or no contact with students; and the lowest-risk category includes students, faculty, and staff participating in only virtual activities.[19]

Colleges and universities vary with regard to both the frequency with which they test their populations and the populations tested. Morgan State University and the University of Illinois, for example, test residential students twice weekly, while Hampshire College tests students once a week. In addition to having a robust walk-in testing program, the University of Arizona engages in asymptomatic random testing—targeting weekly about 500 to 800 employees and 50 percent of the students who live on campus—with serial surveillance testing (more frequent testing on a routine basis) for active, high-risk groups (e.g., athletes, performing arts students, and those living in campus housing). Similarly, the University of Maine tests a random sample of students (10 percent) every 10 days.

Webinar participants suggested the following as key considerations in determining the frequency of their testing programs: cost, logistics, campus calendar and arrival and reentry planning, prevalence of the virus in the surrounding community, a desire to increase perceptions of safety on campus, and labor agreements related to faculty/staff testing. Representatives from a number of colleges and universities noted that increased frequency of testing was related to perceptions of safety on campus, and the choice to test once or twice a week was influenced by this concern. Others said they also considered the burden that might be posed by frequent testing. Initial surveys of campus communities at the University of Illinois, for example, revealed concern about the potential disruptive nature of a strategy that required frequent testing and an emphasis on the need to balance testing with the ability to offer premier educational and research experiences.

Regarding logistics, considerations varied among the webinar participants, but one common concern was driven by the choice among self-administered, self-administered and observed, or clinically performed testing. In particular, observed and clinically performed testing require staff and facility capacity to manage testing sites. Other logistical challenges highlighted included the need to manage traffic flow around test facilities, the ability to transport specimens

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National Academies Press. Available: https://www.nap.edu/catalog/25984/rapid-expert-consultation-on-critical-issues-in-diagnostic-testing-for-the-covid-19-pandemic-november-9-2020.

[18]Ibid.

[19]See: https://www.wellesley.edu/sites/default/files/assets/departments/publicaffairs/files/final_report_of_the_ma_higher_education_covid-19_testing_group_1.pdf.

routinely to laboratories, and the availability of facilities and spaces of an appropriate size to allow for physical distancing.

A number of participating college and universities described testing strategies that involved ramped-up testing related to on-campus arrivals at the beginning of the fall quarter/semester, as well as increased testing around fall breaks. For instance, Duke University implemented what it termed "gateway testing." Students returning to campus at the beginning of the semester were asked to self-quarantine for 14 days before arriving at campus. They then were required to present for testing upon arrival, which was followed by the roll-out of surveillance testing about 5 days later. Representatives from the University of Illinois outlined a similar plan for reentry of students to campus in 2021, which includes phased reintroduction by class over a roughly 2-week period. In order to reenter campus, students will be required to have received two negative tests, 4 days apart.

In addition, some colleges and universities adjusted their campus schedules to end in-person classes prior to the Thanksgiving holiday (in contrast to a traditional break for Thanksgiving), with returns to campus scheduled for January 2021. The University of Florida and University of Arizona reported choosing this course and said they will offer testing to students before they leave campus prior to Thanksgiving as a public health measure designed to ensure the safety of families and communities to which the students are returning. Other universities noted considering such community events as Mardi Gras as triggers for consideration of ramping up the frequency of testing on campus.

While one size will not fit all, these experiences of various colleges and universities suggest that routine collection and analysis of data to inform dynamic prioritization of populations to be tested and the needed frequency of that testing can be effective. Allowing for adaptability and flexibility in the testing plan is critical to accommodate evolving circumstances.

Response to a Positive Test

Key to any testing strategy is a plan for and capacity to respond to a positive result. Testing is effective only if the testing strategy includes a way to quickly communicate results, rapidly isolate affected individuals, provide supportive measures and care to those who test positive (including mental health services), conduct contact tracing, and sanitize living or work spaces. Once students have tested positive, it is also important to strongly support, and enforce if necessary, isolation and quarantine. Colleges and universities participating in the webinars highlighted a number of strategies for ensuring quick responses. Shield Team 30, for example, is a program established by the University of Illinois with the goal of making sure that individuals who receive a positive test are isolated within 30 minutes of receiving those results. Similarly, the University of New Hampshire aims to isolate positive cases within 6–8 hours of a sample's arrival at the laboratory. Columbia University conducts its own contact tracing and recommends testing of close contacts 8 days after exposure. Other universities, including the University of California, Riverside, similarly require testing of close contacts of individuals with a positive test result.

It is important to note that some cases of COVID-19 among students and staff are identified through off-campus testing. Partnerships with local public health authorities can help ensure that these cases are identified and those results are provided to the institution so they can assist in on-campus investigations and in better understanding on-campus dynamics among those who are being tested off campus.

In addition, a number of colleges and universities are using or piloting exposure notification technologies. The University of Alabama, one of the first institutions of higher education to implement such technology, uses the GuideSafe Exposure Notification App to alert the campus community of potential close contacts with someone who has had a positive test.[20] A similar pilot program is under way at the University of California, San Diego, which is partnering with the California Department of Public Health and Department of Technology to pilot the use of exposure notification technology through the California COVID Notify system. The university uses a Google Apple Exposure Notification technology with key privacy protections—the application does not use location information or collect, store, or transmit personal information—and its use is voluntary.[21]

Evaluation and monitoring of positive test results was another key theme raised by webinar participants. Several speakers discussed efforts to capture and analyze subsequent transmission patterns and identify any clusters or patterns of transmission. Most noted as an important result of their testing strategy that they were seeing minimal if any classroom transmission, clusters affecting faculty/staff, or transmission to the community.

Compliance

The majority of college students are aged 18–25, a critical period in the lifespan for brain development. Findings from neuroscience and developmental psychology, summarized in the previously cited rapid expert consultation on adaptation of strategies for promoting COVID-19 protective behaviors among college and university students, show that exploration, risk taking, and making mistakes are normal and expected parts of development during this period.[22] Colleges and universities might choose to establish public health ambassadors within the student community who could provide feedback on what is happening among students.

Colleges and universities need to communicate clearly the consequences of noncompliance with testing protocols, and any consequences need to allow for positive growth and development. At the same time, however, it should be recognized that communications focused solely on the consequences of and sanctions for noncompliance are unlikely to be effective at encouraging participation in and compliance with testing regimens. Instead, communications need to focus on acceptable behaviors (e.g., "safely social" activities). Offering incentives may also be a promising strategy. For example, the University of Illinois uses its Safer Illinois application to communicate compliance with the testing regimen. Students receive a "check mark" on their smartphone screen, which can then be shown to gain entry to buildings on campus. Bars and restaurants in the surrounding community are also asking students to show compliance through the app to gain entry, as a way to create safer environments for socialization.

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[20]See: https://news.ua.edu/2020/08/fight-covid-19-with-guidesafe-exposure-notification-app/.

[21]See: https://covid19.ca.gov/notify/.

[22]"College students are primed for exploration, and risk-taking is a normative part of their development. Sensation seeking is normal for adolescents and young adults; it is not inherently dangerous and can be as simple as attending a party with friends. The risk-taking calculus itself also differs during this developmental period, with more weight on the immediate rewards than on the costs of the behavior. Connectivity in key parts of the brain that process rewards and respond to stimuli contributes to the allure of risk-taking for adolescents and young adults." See: https://www.nap.edu/catalog/26004; see also National Academies of Sciences, Engineering, and Medicine. (2019). *The Promise of Adolescence: Realizing Opportunity for All Youth*. Washington, DC: National Academies Press.

Another important consideration when deciding on strategies for increasing compliance with testing is attention to issues of equity and regard for historical patterns of marginalization and distrust in the health care system. Representatives from Morgan State University noted concerns among students about fairness, disproportionate impacts, and distrust of institutions and health interventions resulting from historical patterns of marginalization, especially within Black and Native American communities.

Finally, with respect to requirements for employees and staff, it is critical for legal teams to be engaged throughout this decision-making process to ensure that strategies are compliant with local, state, and federal laws on mandating testing, as well as special considerations for essential staff.

CONCLUSION

Frequent testing of asymptomatic individuals with rapid reporting of test results can help mitigate the spread of COVID-19 in diverse college and university communities. But testing alone is not a silver bullet. Rather, it must be part of a comprehensive approach that includes the application of top-notch epidemiology and science; rapid isolation and quarantine; contact tracing; environmental management; mask wearing; physical distancing; use of personal protective equipment where appropriate; and engagement with the community, particularly local public health officials. At the same time, testing is a critically important component of a comprehensive strategy for preventing the spread of COVID-19 on campus. As one webinar participant remarked, “Testing is like electricity.…You can have college without it, but you really can’t function very well.”

SEAN is interested in your feedback. Was this rapid expert consultation useful? Send comments to sean@nas.edu or (202) 334-3440.

APPENDIX

TESTING STRATEGIES ON COLLEGE AND UNIVERSITY CAMPUSES: CASE EXAMPLES

As described in the introduction to this rapid expert consultation, to better understand the college and university experience, the National Academies' Societal Experts Action Network and Standing Committee on Emerging Infectious Diseases and 21st Century Health Threats hosted four public information-gathering webinars during October 28–29, 2020. The presentations made during the webinars are summarized in this appendix. While most of the college and university testing programs discussed have yet to be formally evaluated, many of the webinar participants remarked that, in their opinion, their ability to remain open for the entirety of the fall 2020 semester was in and of itself a successful outcome of their testing strategies.

DELAWARE STATE UNIVERSITY

Delaware State University (DSU) is a historically Black college located in Dover, Delaware. Currently, about 1,582 students, or 53 percent of the student population, live on campus. As part of DSU's reopening plan, all individuals reporting to campus were required to be tested and complete a health and safety agreement. Residential students, as well as staff and faculty, had to be tested before reporting to campus. Students who tested positive were required to isolate at home before returning to campus. In addition, students were required to undergo testing upon their arrival at campus for move-in. To facilitate testing before students moved in, DSU hosted a drive-through testing event during the move-in weekend.

DSU began its testing program in early July by testing a small group of aviation students who had returned to campus. Initially, students, faculty, and employees were tested twice per week using self-administered anterior nasal swabs. Originally, DSU had intended to test once per week, but it ultimately chose to be more aggressive in light of increases in positivity rates at other colleges and universities. As of October 19, the university had shifted to testing faculty and employees once per week, with some exceptions. To test the entire student body twice per week, DSU broke students up into cohorts, with one cohort being tested on Mondays and Thursdays and the other on Tuesdays and Fridays. Testing for America, an independent, nonprofit organization, provided some funding for the testing. To staff the testing sites, DSU created a volunteer pool of students from the Department of Public and Allied Health Sciences, which created experiential learning opportunities for students interested in assisting with the university's COVID response. In addition, DSU has received support from the Delaware Medical Reserve Corps. Test results have usually been returned within 30 to 36 hours, and contact tracing has begun immediately after a positive test result has been received. DSU has set aside a residence hall for isolation and quarantining of students, who receive mail, homework, and food deliveries, as well as mental health checks from counseling staff.

DUKE UNIVERSITY

In advance of reopening for the fall 2020 semester, Duke University in Durham, North Carolina, set up an on-campus program to test students, faculty, and staff.[23] A pooled surveillance testing approach is used to test students. About 40 percent of the university's undergraduate population is currently on campus, and the university has a mix of online and in-person instruction under way.

Upon students' return to campus in August, Duke conducted individual "gateway" tests of all the students to identify positive cases. After the initial testing, the university switched to a surveillance testing program, with mandatory testing for students. Samples are collected from students at 20 different test sites around the campus, where observed self-administered nasal swabs are performed. In addition to these on-campus test sites, the university uses a mobile testing van to reach students living off campus. Samples are then sent to a laboratory, where they are pooled into groups of five. The lab uses robotic devices that have been programmed to perform automated PCR tests. If a pool comes back positive, it is deconvoluted, and the samples are tested individually in a College of American Pathologists (CAP)-CLIA–certified lab. The results are then reported out via the student or employee health system. Through this system, the university has the capacity for about 3,200 tests per day and processes 2,200 to 2,400 tests per day.

According an article by Denny and colleagues, "During August 2–October 11, 2020, Duke completed 68,913 student tests, including entry testing, asymptomatic testing, and symptomatic testing of 11,046 students and student-athletes; 84 yielded positive results for SARS-CoV-2 (excluding confirmatory tests). Combined risk reduction strategies and surveillance testing likely contributed to a prolonged period of low transmission on this college campus, and the large proportion of infections identified (51%) in asymptomatic students identified by extensive pooled testing highlights the importance of combining preventive measures with comprehensive surveillance….Average per-capita infection prevalence among students was estimated to be 0.08 percent (95% CI: 0.00056, 0.00103). By comparison, for October 12–18, the weekly per-capita positive rate for Durham County was 0.10 percent."[24]

HAMPSHIRE COLLEGE (MASSACHUSETTS)

Hampshire College, located in Amherst, Massachusetts, is part of a five-college consortium working together to mitigate the spread COVID-19 on their campuses.[25] Largely because of decreased enrollment, they were able to de-densify dorms and apartments and are providing every student with an individual room this semester. The university uses a two-tier

[23]See: https://coronavirus.duke.edu/.

[24]Denny, T. et al. (2020). Implementation of a pooled surveillance testing program for asymptomatic SARS-CoV-2 infections on a college campus—Duke University, Durham, North Carolina, August-October, 2020. *Morbidity and Mortality Weekly Report,* November 17.

[25]See: https://www.hampshire.edu/news/2020/08/21/covid-19-student-testing-program.

testing program: the first tier is asymptomatic testing of all students and front-facing staff/faculty, while the second is symptomatic and close-contact testing of students.[26]

For asymptomatic testing, Hampshire College uses the services of the Broad Institute in Cambridge, Massachusetts, which offers RT-PCR testing with an 18- to 24-hour turnaround and provides the testing supplies and lab capacity. Asymptomatic test takers self-administer a nasal swab observed by health care providers on campus. The samples are then sent to the Broad Institute, and participants receive their results via email or a smartphone application, which can also be used to schedule a test and remind users to check their symptoms. Every living area and work department was divided into Group A and Group B to help identify where cases were emerging in the event of a spike, with each group being tested once every 2 weeks. University staff, including event staff, were reassigned to help with testing and test procurement. When students arrived on campus, they were tested and required to quarantine for 2 weeks if they were coming from a higher-risk state. Hampshire College is also offering flu shots, required by the state for all students living in student residences, at asymptomatic testing sites. Symptomatic testing (PCR) is available daily at the on-campus Health Center, with same-day turnaround from the University of Massachusetts Amherst laboratory.

For additional student support, Hampshire College also set up a dedicated email address to address any testing-related questions or needs. The college also contracted with the University of Massachusetts Amherst to form a group of 30 dedicated contact tracers. A student life team at the college deals with case management and student follow-up when isolation or quarantine is needed. The college carefully monitors its college and community metrics weekly, including test positivity, number of cases, isolation and quarantine spaces, case management capability, health center capability, hospital capacity, and contact tracing capacity. Looking to the future, Hampshire College plans to carry out increased testing on a weekly basis for the spring 2021 semester.

Representatives from Hampshire College noted having a supportive and engaged college president; exercising clear communications; and having strong relationships with directors of health centers, local public health nurses, and the public health department as key components of their testing strategy.

MORGAN STATE UNIVERSITY

Morgan State University (MSU) reopened using a hybrid model consisting of mostly remote classes but also some in-person classes, which resulted in roughly 500 students on campus.[27] Representatives from the university noted that some students may not have resources in their own homes that would enable them to attend class remotely and therefore need access to the university's resources. Without a medical school, MSU relied on the Public Health Program and Nursing Program in its School of Community Health and Policy to help in addressing COVID-19–related issues and assume the role of clinical partners in the university's testing and monitoring efforts. The School of Community Health and Policy has assumed leadership in coordinating the collective response, while testing has been handled by the University Health Center, which historically has served only students but during the pandemic is responsible for overseeing the testing of both students and employees. The Nursing Program is expected to

[26]See: https://www.hampshire.edu/news/2020/08/26/asymptomatic-testing-program-for-fall-2020.
[27]See: https://www.morgan.edu/coronavirus.

begin assisting with test administration in spring 2021.

Testing is just one component of MSU's holistic approach, which also emphasizes active campus risk communication to encourage mask wearing, physical distancing, and handwashing. Students were required to receive a negative test no more than 14 days before arriving on campus and were then tested again during the move-in process. On-campus students undergo PCR testing twice per week, students taking classes or participating in activities on campus but not living on campus are tested once per week, and staff are tested once per week. Testing is scheduled online, and results are returned within 48 hours. In the case of a positive test, the university medical director is notified, the individual is contacted, and contact tracing is initiated. Positive results are also reported to the Baltimore City Health Department. As a decision point, a 5 percent positivity rate is a trigger for the university to conduct a deeper review of its testing processes and connect with the Baltimore City Health Department to discuss whether a change its operating status is needed.

TULANE UNIVERSITY

Tulane University, located in New Orleans, Louisiana, gave all 14,000 of its students the option of returning for the fall 2020 semester, and all but 1,000 chose to do so. The fact that the majority of Tulane students travel more than 500 miles to get to campus raised concerns for university leadership regarding the effect of the incoming students on New Orleans, where coronavirus cases were surging in August 2020. Thus, Tulane leadership decided to test all students upon their return using nasopharyngeal testing and PCR processing. Two testing centers were initially set up to accommodate students. After the initial testing, which identified 49 positive cases out of 14,000 individuals, the university shifted to a surveillance testing program. The original plan was to test everyone monthly except undergraduates, who would be tested more frequently. However, the initial testing under this plan identified a surge in positive cases, prompting university leadership to switch to more frequent testing. Initially under this revised plan, residential undergraduate students were tested weekly and off-campus undergraduate students monthly. By the second week of testing, however, the frequency of testing for residential undergraduate students had increased to twice weekly, and off-campus undergraduate students were moved to weekly. After a surge in cases occurred between August 19 and October 15 (about a 5% positivity rate), Tulane decided to test all undergraduates twice per week, graduate and professional students once every 2 weeks, and employees once per month, demonstrating data-driven decision making. By late October 2020, the positivity rate on campus had declined to about 0.3 percent on any given day.

At the start of the university's testing program, Tulane's labs could process about 800 tests per day; today they can process 2,500–3,000 tests per day using a pooled sampling method. Although the university already had a CLIA-certified pathology lab, it increased the lab's capacity to accommodate the increase in tests. The School of Medicine created a small laboratory to process samples, and information management systems were developed to handle the results. After initially using the CDC's PCR test, Tulane switched to the ThermoFischer PCR test and automated as many lab processes as possible. Tulane has considered using saliva testing in addition to nasal swabs, but nasal swabs offer a relative advantage in sample collection and processing. This example illustrates the complexity of determining what tests to use and how to establish effective and cost-efficient lab practices when universities are conducting their own testing.

UNITED TRIBES TECHNICAL COLLEGE

The United Tribes Technical College (UTTC) is a tribal college serving students from 75 federally recognized tribes in Bismarck, North Dakota. While the vast majority of students are currently attending classes in a synchronous learning format, a small number of students in technical programs attend classes on campus.

Testing at UTTC is paid for by the Indian Health Service. However, UTTC faced a number of challenges with implementing a testing strategy at its largely commuter school, including concerns about the risk of inviting potentially symptomatic individuals to the campus for testing. Logistics were also a concern. For example, the main entrance to the college is via a busy highway, which presented challenges for safely organizing an outdoor testing event with appropriate traffic control. To address safety concerns, the college encouraged people to wait in their cars and created lanes for that purpose.

UTTC has held testing events and made efforts to communicate them broadly to students, employees, and the local community. Moreover, to assist during the testing events, the college partnered with the North Dakota National Guard, which has experience conducting testing and access to adequate personal protective equipment to handle the sample collection process. While the testing events themselves have gone smoothly, the college did experience delays in receiving test results because of a lack of capacity at the state laboratory. Accordingly, UTTC is exploring alternative tests or processes that would not rely on the state lab.

UNIVERSITY OF ARIZONA

To reopen its campus this fall, the University of Arizona implemented its Test, Trace, Treat program.[28] The testing strategy uses a combination of three types of tests: two types of diagnostic testing (antigen and PCR) and a locally developed antibody test. Antigen tests make up the bulk of the testing, with PCR testing used as needed for secondary verification. The university's testing strategy was designed by a team of thought leaders under the authority of the campus president. In-parallel working groups were established to focus on technology, testing, tracing, isolation, and implementation. The resulting Test All Test Smart program includes voluntary testing, mandatory testing for students living in residence halls, wastewater monitoring, and mitigation strategies for areas of outbreak. Mitigation measures include dorm oversampling, or testing an entire dorm or dorm floor. Another major element of the testing strategy is the implementation of asymptomatic random sampling after initial move-in testing for all students living on campus. The random sampling included approximately 500–800 asymptomatic employees who had been on campus at least once in the prior week, who were randomly selected for PCR testing, and approximately 50 percent of the on-campus students, who were selected for antigen testing per week.

Having a set of metrics, such as prevalence, allows for agile decision making around reentry, as well as mitigation strategies when outbreaks and hotspots are identified. Mitigation strategies include testing of those at high risk of exposure, deep cleaning of areas after infection(s) are identified, and reiteration of safe behaviors to high-exposure groups. Additionally, certain populations, including athletes, performing arts students, dancers, and

[28]See: https://covid19.arizona.edu/test-trace-treat.

ROTC students, undergo more frequent testing because of their high(er) risk from essential in-person activities. This testing consists of four stages:

- Stage 1: PCR/antibody testing upon entry, followed by a period of quarantine and education regarding mitigation strategies
- Stage 2: weekly surveillance
- Stage 3: tiered testing based on risk
  - Dancers: daily antigen testing
  - Higher-risk sports: tested twice per week
  - Lower-risk sports: tested once per week
- Stage 4:
  - High risk: weekly PCR tests/daily antigen tests
  - Antibody tests offered weekly, biweekly, every 3 weeks, or monthly
  - No testing for 90 days with PCR or antigens after an active infection

Because the institutional review board (IRB)–approved statewide antibody research study was expanded to include all University of Arizona students and employees, antibody testing has been expanded to provide more opportunities to undergo an antibody test on the main campus in addition to locations around the state. Individuals who test positive for antibodies are excused from mandatory testing for 90 days.

Representatives from the University of Arizona also noted the importance of its transparent and accessible electronic platform to its testing program. Created by a team of computer and data scientists, this open-source platform was established as a convenient and effective way to facilitate the testing process. The platform generates a unique QR code for each student and employee to help him or her find and register for COVID-19 testing based on the population within which he or she falls. Testing sites were set up around the campus, with flexibility to open more during high-volume periods or have others close during low-volume periods. Looking forward, the university hopes to have indoor kiosks available as well. It also created a University of Arizona Test Results Portal Data Dashboard to provide transparent information about COVID-19 cases to the campus and the surrounding community to help individuals make better decisions on where and whether to go. In addition, the university worked collaboratively with external partner Covid Watch to develop a specific mobile application using the GAEN technology and is the first campus to fully launch a GAEN app, at its main campus in Tucson. The app is fully integrated into all on-campus testing and allows students to upload codes when they test positive so they can anonymously notify all others with whom they have been in contact during the infectious period. The university also has benefited greatly from its partnership with the local Pima County Health Department, which helped manage testing for the off-campus student population.

UNIVERSITY OF CALIFORNIA, SAN DIEGO

The testing program of the University of California, San Diego (UCSD), called Return to Learn, involves testing 1,500–2,000 individuals per day.[29] This year roughly 10,000 students live on campus, and about 12 percent of classes are offered in person. After piloting an asymptomatic

[29]See: https://returntolearn.ucsd.edu/.

testing program in May 2020, UCSD launched its testing program by testing all students upon their arrival to campus for the fall 2020 semester. After an initial test, on-campus students are required to be tested once every 14 days, and off-campus students and faculty and staff are encouraged, but not required, to be tested once every 2 weeks. Testing is available free of charge for students, faculty, and staff at campus health facilities, off-campus health system facilities, and on-campus pop-up sites. In addition to the regular asymptomatic testing, symptomatic testing is available to students and staff who need it.

Samples are processed in a CLIA-certified lab, which is part of the UCSD health system, and in several pop-up labs run by researchers throughout the university. The test results are then integrated into students' electronic health record and returned within 14 hours, on average. When a positive test result is identified, students are isolated, contact tracing begins, and close contacts are quarantined and monitored for symptoms.

As of October 28, 2020, positivity rates on campus for employees and students were roughly 0.2 percent and 0.3 percent, respectively, compared with a positivity rate in the surrounding county of roughly 3 percent.

UNVERSITY OF FLORIDA

The University of Florida has implemented a testing program called Screen, Test, and Protect,[30] supported by scientific oversight from a group of infectious disease and epidemiology experts from the Emerging Pathogens Institute and the Science Advisory Team within the university's College of Medicine and College of Public Health, respectively. Together, these experts oversee testing strategies, other potential areas of mitigation, and overall testing program needs. While the campus is operating approximately 70 percent online, the remaining 30 percent of classes necessitate a strong testing protocol. Testing is available for anyone in the campus community, and the university monitors three key indicators: test positivity, case numbers, and capacity for isolation and quarantine for those on campus. The targeted testing program focuses on three main groups:

1. contacts (identified by disease investigators or contact tracers as those with whom an infected person spent more than 15 minutes within 6 feet);
2. expanded contacts (those living in congregate settings, such as dorms or Greek housing) and those with mild symptoms; and
3. self-selected individuals (anyone who wants to be tested).

Representatives from the university also noted the use of electronic platforms as a key component of their testing program. Individuals receive a unique QR code; they can then complete a questionnaire about their symptoms, schedule next-day or even same-day testing, and initiate isolation or quarantine depending on the test result. The University of Florida offers both drive-thru and walk-up testing sites on campus. As it has transitioned from nasopharyngeal swabs to saliva testing and direct processing (along with PCR testing), more walk-up sites have become available. The university's lab services were kept in house within the on-campus Medical Center, which made it possible to scale up depending on need and avoid national supply chain issues. As of this writing, 15,000 PCR tests can be administered per week without pooling.

[30]See: https://coronavirus.ufhealth.org/screen-test-protect-2/.

The university is planning to provide tests before students leave for Thanksgiving and upon their return in January, with an emphasis on high-risk groups, such as those in residential housing, Greek life, and ROTC.

The university also has a clear plan in place in the event that a student on campus tests positive for COVID-19. It receives that student's electronic health record from the university's health center in its data system. Next, the student receives a Health Insurance Portability and Accountability Act (HIPAA)-secured email reporting his or her positive status at the same time that the staff team is notified. The daily case count is updated, and the individual receives a call to initiate contact tracing. The student is then withheld from campus, and his or her status is available on the student dashboard and sent automatically to that student's professors. The university also has a strong partnership with the local public health department, and using cross-matching, can identify cases that were not tested through the on-campus system.
The use of interoperable IT systems has essentially allowed the university to create a self-sustained public health surveillance unit.

In addition to testing, the University of Florida implements other, complementary mitigation measures, such as wastewater monitoring, cluster evaluations, mapping of cases to campus locations and classes, and transmission of weekly questionnaires to support targeted testing.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Under its overall initiative entitled Shield, the University of Illinois at Urbana-Champaign employs a testing strategy called the Target, Test, and Tell Initiative.[31] This strategy targets all members of the campus (~50,000 people), who were all initially tested twice per week. After the first few weeks, the program transitioned to testing faculty, staff, and graduate students once per week after case numbers in those groups were found to be low and continued to test all undergraduates at least twice per week. Undergraduates identified to be highest risk based on their living situations are tested three times per week. High need forced the development of a novel saliva-based test that goes directly to PCR.[32] This transition, designed by a team that included students and postdocs, helped better meet demand and ensure that the testing would be both fast and scalable. This test also creates a safer environment for those working in the lab, because the method involves deactivating the contents of the test tubes before opening them. This feature also serves to make the testing more scalable.

When students return for the spring semester in January 2021, the university plans to adopt a phased reentry for undergraduates based on year (freshman–senior) over a 2-week period. Students will be required to have two negative tests 4 days apart to be granted reentry. Additionally, the campus has established testing sites across campus where students can walk up, scan their student card to generate a unique barcode for their test tube, and self-administer a saliva test—all while being physically distant. A golf cart then transports the samples to the lab every hour. The university uses the campus's veterinary lab, which was converted to a COVID-19 testing facility, with results being returned within 3–9 hours.

The university developed an app called Safer Illinois that provides test results and

[31]See: https://covid19.illinois.edu/on-campus/return-to-on-site-operations-committees/shield-target-test-tell-committee/.

[32]See: https://www.biorxiv.org/content/10.1101/2020.06.18.159434v1.full.pdf.

exposure notifications directly to users' phones. The phone of an individual who has up-to-date testing and tests negative flashes a check mark that allows entry to the buildings on campus. The phone of an individual who either does not have up-to-date testing or tests positive flashes an "X," and access to buildings on campus, as well as places in the nearby community, is denied. Shield Team 30, which aims to get people safely isolated within 30 minutes of receiving a positive result, is also a key component of the university's testing program.

Representatives from the university identified several lessons learned or key ideas from its testing program. First, as noted throughout this rapid expert consultation, testing is not a silver bullet, but just one critical component of a comprehensive, multimodal approach that includes physical distancing, mask wearing, contact tracing, and rapid isolation, among other measures. The university also has learned that partnering with the local public health department is crucial; that fast and frequent testing can help mitigate the spread of the virus; that asymptomatic testing is important; that it is essential to partner with undergraduates to facilitate safe ways to socialize; and that thus far, it has found no evidence of the spread of COVID-19 via classroom interactions.

UNIVERSITY OF MAINE

The University of Maine System (UMS) encompasses seven campuses across the state, including the flagship University of Maine, Orono. About 45 percent of students returned to in-person classes during the fall 2020 semester. UMS's testing plan involves several phases. The first included baseline testing of all students returning to campus from outside the state, residential students, and students in high-risk groups upon their return to campus. After the initial baseline testing, all students were retested within 7–10 days to identify any who may have developed COVID-19 during their travel back to campus. The third phase, which is currently under way, involves testing 10 percent of students and faculty/staff every 10 days, in conjunction with statistical analysis and wastewater monitoring.

The testing is conducted through a partnership with Convenient MD, a New England urgent care franchise, and Jackson Laboratory, a CLIA-certified lab in Connecticut. Convenient MD conducts the tests, which are anterior nasal swabs, and the samples are couriered to Jackson Laboratory. In addition to the nasal swabs, UMS uses saliva-based testing for students on its smaller and more rural campuses. The saliva tests provide greater flexibility for smaller campuses and commuter students, who may not be able to schedule a testing appointment.

When a positive case is identified through the surveillance testing program or through symptomatic testing, the individual is rapidly isolated, and his or her close contacts are identified through contact tracing. Those close contacts are then quarantined for 14 days. Positive and exposed individuals are isolated or quarantined, respectively, in spaces within dormitories designated for that purpose.

UNIVERSITY OF NEW HAMPSHIRE

The University of New Hampshire (UNH) decided early on to bring students back to campus for fall 2020.[33] To this end, it was necessary to create a safe environment for students and faculty, but low availability of testing and slow return of results when testing was available

[33]See: https://www.unh.edu/coronavirus/covid-testing.

were key concerns in planning a testing program. UNH therefore decided to build its own lab, a decision made more difficult by the fact that the campus did not have its own medical school, veterinary school, or other labs. But in just 100 days, the university both built and achieved CLIA certification for its COVID-19 lab.

To reopen successfully, UNH set a goal of testing its students twice per week and its faculty and staff once per week—a goal it has achieved, resulting in approximately 25,000 tests per week. Using RT-PCR nasal swabs, the university has established self-testing kits whereby students swab themselves and deposit their swabs at one of 10 drop-off locations around the campus. Samples are picked up every hour, 6 days per week, from 8 AM to 6 PM. Tests are then pooled using 4-to-1 pooling. If all four tests are negative, the report is issued as "compliant." If one or more of the four tests indicates a potential case(s) of COVID-19, the four samples are separated and tested individually, and the individual(s) with positive tests are then contacted to have a CLIA-certified administered swab for confirmation. This process ensures that separation of the pooled tests that include a positive case(s) happens 6–8 hours after their arrival at the lab, with the individual confirmation test(s) occurring just a few hours after that.

Self-testing kits are distributed on a monthly basis because of supply chain issues. UNH also uses wastewater surveillance testing and hopes to use loop-mediated isothermal amplification (LAMP) and/or genomic testing in the future. As a result of the university's testing strategy, classes this fall are taking place mostly in person, but online courses continue to remain available. The university ordered enough supplies early on to last an entire semester, and it credits some of the success of its testing program to this foresight.

Additionally, UNH, like many other universities, created a multidisciplinary and cross-functional team that meets twice a week to discuss testing, contact tracing, and future planning. The university uses trained contact tracers who work in partnership with its health and wellness center. It is also transparent about its data sharing and reports out statistics to both students and the public. The metrics shared include active cases among students, faculty, staff, and contractors; isolation and quarantine; the number of positive daily tests; and the average number of tests per day. These metrics help determine both the positivity rate and prevalence.

WESTERN WASHINGTON UNIVERSITY

Western Washington University (WWU) is a public university in northwest Washington State serving 16,000 students, 96 percent of whom are undergraduates and 30 percent of whom are first-generation college students. WWU elected to use a hybrid model for the fall 2020 quarter, with 90 percent of students attending classes remotely and 10 percent—or 3,000 students—attending in person or in a combination of in-person and remote classes. About 1,000 students currently live on campus.

Since the university does not have a virology lab, a school of medicine/public health, or a department of epidemiology, it had to outsource its COVID testing. The university initially planned an asymptomatic surveillance program with PCR testing for all students, but that strategy proved to be cost-prohibitive. Instead, WWU developed a pooled batch PCR testing surveillance model, which reduced testing costs from $130 to $13 per test. In this testing model, 10 individual nasal swabs are collected by a nurse and placed in a single conical. The conical is then sent to the local commercial lab, which provides results within 24–48 hours. If any tests in a batch come back positive, individuals in that batch are retested individually with diagnostic PCR tests to confirm the positive case(s). Upon identification of a positive test, the university works

closely with the local health department, university housing, and other campus partners to isolate that student and conduct contact tracing.

In addition to addressing cost concerns, the university had to address the concerns of students who were unable to access testing in their home communities. Initially, WWU had planned to require students to get tested before returning in the fall, but it found that many students were unable to access timely testing for this purpose. In response, the university opened its testing facility early to accommodate students who would be returning to campus.

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Project Staff:
LISA BROWN, *Senior Program Officer*
AUTUMN DOWNEY, *Senior Program Officer*
CAROLYN SHORE, *Senior Program Officer*
SCOTT WOLLEK, *Senior Program Officer*
AURELIA ATTAL-JUNCQUA, *Associate Program Officer*
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