# The Role of Contact Tracing in the Control of Microbial Epidemics, Including COVID-19

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June 18, 2020

## Rationale

The United States has fared relatively poorly during the current COVID-19 pandemic, in part because, unlike some others, this country failed to institute rapid and far-reaching methods to identify infected persons and their contacts and then quarantine them in early stages of the pandemic. In this report, we describe ways in which testing, contact-tracing, and isolation methods might be improved to reduce morbidity and mortality rates in later phases of the COVID-19 pandemic and in future epidemics.

## Background

SARS-CoV-2 is a novel coronavirus that causes coronavirus disease 2019 (COVID-19). Like other coronaviruses, SARS-CoV-2 is primarily transmitted directly from one infected human being to another, when viral particles from the infected person enter the body of the other person, most commonly through the respiratory tract.

The only definitive way to know whether people are infected by SARS-CoV-2 is to test them for the presence of virus particles, most commonly done using sensitive molecular tests for viral RNA[1]. Once an infected person is identified, it is important to determine the source of that infection and to identify the other people to whom the source and the newly identified infected person might have transmitted the virus (i.e., their *contacts*). By sequencing the viral genomes of the source and the infected person, much can be learned about the rate of virus evolution by following sequential changes (usually nucleotide substitutions) in the genome in relation to established contacts; and by identifying the contacts of an infected person, the spread of the virus can be reduced.

To identify people who have been exposed to an infected person, it is necessary to construct the set of individuals with whom any infected person has recently interacted, a process called *contact-tracing*. When any person on the list of contacts is found to test positive for viral RNA, that person's contacts should be identified and tested in turn. Contact tracing has a proven track record in enabling government health officials to contain and shut down the spread of infectious disease. For example, it played a key role in containing the 2003 SARS-CoV-1 coronavirus outbreak.[2]

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[1] A commonly used virology diagnostic test is RT-PCR (reverse transcription-polymerase chain reaction). This topic is elaborated in our forthcoming report on testing and immune response.

[2] Riley, S., Fraser, C., Donnelly, C. A. et al., Transmission dynamics of the etiological agent of SARS in Hong Kong: impact of public health interventions. *Science* **300**, 1961-1966 (2003); S. Knobler, A. Mahmoud, S. Lemon et

**What makes the use of diagnostic testing and contact tracing difficult?**

There are many challenges, both scientific and logistic, in using contact-tracing to combat COVID-19 and other infectious diseases. In a fast-moving epidemic, an important purpose of identifying newly infected individuals quickly is to keep them from infecting other people. Other purposes are to monitor the individual and to treat symptoms such as respiratory distress, which may be life-threatening; to reduce the severity of that person's infection, if methods exist to do that; and to develop an understanding of the collective (population-level) properties of the virus. The newly infected individuals are identified by testing for the presence of the causative agent – in this instance, SARS-CoV-2. Isolating (and, if needed, treating) a person who tests positive is then appropriate.

It is desirable to identify and test contacts immediately, before second-order exposures occur. The task is complicated, however, because:

- **It is difficult to identify the set of possibly infected contacts quickly.** As discussed subsequently, contact tracing can be done either by human interviewers, by use of digital tools such as smartphones, or by some combination of the two. A person who is interviewed may either deliberately or inadvertently fail to disclose some contacts. Some people may refuse to be interviewed. In addition, interviews take time and human labor, which will slow the process. A smartphone (a proxy for a person) can detect proximate smartphones, but not proximate people who are not carrying phones.

- **Some personal interactions are more likely than others to transmit virus.** In general, many viral particles are required to initiate an infection. The number of particles transmitted from an infected person to a contact is affected by how long the people are in contact, how close they are to one another, and how forceful is the emission of particles from the infected person. If low-duration, large-distance contacts can be identified, they can be given lower priority for testing, freeing up resources.

- **It is difficult to use diagnostic tests to identify quickly the subset of contacts who are infected.** Even if a sample for testing is moved quickly to a test site or if the test is performed where the sample is taken, the testing process inherently takes time. More time will be lost if there are delays in transporting a sample to a laboratory or in reporting the results. If the person is tested too soon after exposure to an infected person, moreover, the test may be negative because the virus has not yet completed enough rounds of replication to produce amounts of virus detectable in the tested sample. In other words, detection of the agent in a newly infected person will be influenced by virus latency (the time required for a virus to enter a cell and produce progeny particles), by the number of rounds of virus replication (in which viruses from initially infected cells infect other cells to increase virus titers exponentially) to produce enough virus particles for a positive test, and by the sensitivity of the test (which is measured by the number of virus particles required to produce a positive result). Test sensitivity may be affected by the number of rounds of virus replication – viruses from the first infected cell then infecting other cells and increasing virus titers

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al. Eds, *Learning from SARS: Preparing for the Next Disease Outbreak* (Washington: National Academies Press, 2004).

exponentially – required to produce enough virus particles to produce a positive test. Inadequate numbers of particles in the upper respiratory tract to allow detection or inadequate swabbing of the mucosa are the likely explanations for the relatively high false negative results (up to 30%) and for the recommendation that at least two tests are needed to make a negative test reasonably reliable. (False positive test results are rare and generally attributed to lab contamination or faulty procedures of other kinds.)

- **The appearance of symptoms is not an adequate substitute for a test that unambiguously identifies a person who can transmit the infectious agent**. There is generally a 2- to 6- day period between exposure to SARS-CoV-2 and the appearance of symptoms[3]. During that time, a *pre-symptomatic* person may be shedding virus and infecting others[4]. Diagnostic tests for virus are generally positive during that time and will identify an infected contact much sooner than the appearance of symptoms. In addition, some symptoms that suggest COVID-19 instead may be caused by other diseases.

**What if there isn't enough diagnostic testing and contact tracing?**

Diagnostic tests are important not only for use in contact tracing, but also for protecting vulnerable populations – people in high-contact living or working environments such as health facilities, manufacturing facilities, dormitories, prisons, densely-populated cities, and so forth; and people whose age or health condition heighten the risk that infection would be severe and life-threatening. Yet SARS-CoV-2 tests have been a seriously limited resource in the U.S. (and in some other countries), because of the failure to develop new tests or to provide reliable test kits for existing tests based on RT-PCR at the onset of the SARS-CoV-2 pandemic and to ramp up production and distribution of testing capabilities rapidly[5].

In practice, even when tests are widely available, priorities must be set for testing. In the current pandemic, in which tests have been in short supply or inadequately distributed or inadequately funded, priority has been given to individuals who have symptoms characteristic of COVID-19 that may require hospitalization or to people who are known to have had extensive exposure through home or work to a person known to be infected with SARS-CoV-2. When tests are unavailable, contact tracing is based on the presence of symptoms as a proxy for a positive result of a test for the virus. Contacts can be quarantined and watched, but inhibiting their exposure to others may come too late.

Knowledge of the actual or likely exposure to the virus is retrospective; it is only after an individual tests positive or has symptoms that the contacts are known to have been exposed. By

[3] Symptoms may appear later in some infected individuals, or not at all in *asymptomatic* infected people. For that reason, possibly infected people are usually quarantined for 14 days.

[4] He, X., Lau, E.H.Y., Wu, P. *et al.* Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med* **26,** 672–675 (2020). https://doi.org/10.1038/s41591-020-0869-5

5 Hannah Kuchler, *Coronavirus testing shortages: what's the problem?*, Financial Times, March 18, 2020, https://www.ft.com/content/86efe246-692e-11ea-800d-da70cff6e4d3; Michael Biesecker, Mike Stobbe, and Matthew Perrone, *Testing blunders crippled US response as coronavirus spread*, Associated Press, March 23, 2020, https://apnews.com/c335958b1f8f6a37b19b421bc7759722

then they may already be infected. If testing and contact tracing have not been done effectively at the start of an outbreak, when the number of cases is very small, the number of people who have been in contact with infected individuals becomes very large, and contagion cannot be controlled. That large collective risk is often addressed by quarantining all contacts, whether or not they have tested positive or exhibited symptoms. In the extreme, that leads to the recent lockdown policies, in which everyone is, in effect, quarantined and businesses are closed. If tests are available, widespread testing of asymptomatic socially active people can reduce the burden on contact tracing. Social distancing and the wearing of protective masks are seen by some as a less onerous compensation than quarantine for a lack of testing and contact tracing. By reducing contact proximity and particle transmission, the likelihood of contagion is reduced.

Lockdown and social distancing have negative as well as positive consequences. Those protective policies to fight COVID-19 have led to economic downturn, job loss, educational disruption, social isolation, food insecurity, and societal discontent. Once transmission rates have decreased sufficiently, rapid testing and contact tracing become important tools to relax lockdowns in favor of selective isolation and quarantine.

**How is contact tracing done?**

Contact tracing to control virus contagion has a long history. It is normally carried out by interviewing individuals. That strategy has helped in managing other viral epidemics such as HIV/AIDS, H1N1-influenza, and Ebola. The strategies need to be adapted to the characteristics of the relevant viruses, however, especially to the modes of transmission. Among the advantages of human contact tracing are the ability to reach disadvantaged people and the benefit that social interaction has in helping them deal with the threat or actuality of disease. Among the disadvantages are flawed human memory for identifying the contacts, unwillingness to reveal some contacts, or unwillingness to be interviewed, and the labor-intensive nature of human tracing, which leads to delay. If the virus can spread rapidly, or if contact tracing starts late, the availability of enough human interviewers is a barrier. There is also a potential loss of privacy, since contacts are identified and the information is centrally stored.

During the COVID-19 pandemic, many groups have proposed to use digital information to approximate or supplement human contact-tracing. Digital data that indicate where an individual was at a given time include GPS data from mobile phones, credit card usage, public cameras, and public-transit records. A pool of possible contacts can be determined by identifying people who were in the same place at the same time. This approximation is imprecise – in general, the data might not record the distance between interacting individuals or the duration of the interaction. Consequently, care must be taken in how the data are used.

Another way to obtain contact data is to use BLE (Bluetooth Low Energy) to allow a smart device to record other smart devices (call them “smartphones” for convenience) that are close to it at a particular time. As with the use of GPS, it is phones that are being tracked, not people. Although in the developed world each phone is normally carried by a unique individual, phones are often shared in the developing world, complicating interpretation of the data. Unlike GPS data, which are obtained from cell towers, BLE contact data are stored on each phone, typically in encrypted form, and shared more widely only if they are uploaded to some central service. The data can include the duration of the contact. The uploaded data might, but need not, contain the location of each contact. By its nature, the interaction recorded by the smartphones implies propinquity of the two individuals, but the opportunity for transmission of viruses may have been modulated by virus barriers such as face masks.

Digitally enabled contact tracing together with extensive testing appears to have been used successfully early on to contain COVID-19 in South Korea and, until recently, in Singapore. It is reported that South Korea used low-privacy contact tracing with GPS, security-camera footage, and credit card records. Their Corona app notifies individuals if they come within 100m of an infected person.[6] Singapore deployed an opt-in BLE app (TraceTogether) to track proximity[7]. Users are notified immediately or retrospectively if they were near an infected person. The Israeli Health Ministry has used the HaMagen opt-in app to track proximity, using GPS data maintained by the government security agency[8].

Many additional apps are being developed[9]. Most of them are intended for peer-to-peer notification of possible exposure, and most of them are opt-in. Depending on the app, users can report either COVID-19-like symptoms or the presence of infection determined by a diagnostic test and can upload their proximity data to a shared repository or database (whether or not they have symptoms). The users are identified by unique IDs (sometimes called pseudonyms) – users need not reveal their identities. To protect privacy, the IDs are changed frequently – over time a given user will have multiple IDs, making it difficult to track the user. Users of the app can be notified immediately if they have been exposed to the virus with high likelihood (because of a contact individual who is symptomatic or infected but asymptomatic) and should self-quarantine or take other measures. That notification can direct the person to testing, to a human interviewer, or to some other resource.

There is strong evidence that, from a technical perspective, high-quality apps can be built. The apps need to have two parts. First, there must be a system-level capability to discover and record the phone-to-phone proximity information – a process that depends on how BLE peer-to-peer communication works on a particular phone with a particular operating system. Then there must be user-level capabilities that access those data and use them to notify users about relevant contacts, when they occurred, and for how long. On April 10, 2020 Apple and Google announced a collaborative effort to create needed the system-level capability for each of their operating systems and to provide a common API (application program interface) that user-level apps can use to access the contact data[10].

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[6] *Canada Covid-19 Response: Deep-dive on testing and tracking*, Boston Consulting Group, March 30-2020

[7] An *opt-in* app is one in which the user must take an action to activate the app.

[8] Stuart Winer, *Health Ministry launches phone app to help prevent spread of coronavirus*, The Times of Israel, 23 March 2020, https://www.timesofisrael.com/health-ministry-launches-phone-app-to-help-prevent-spread-of-coronavirus/; Sara Toth Stub, *Israeli Phone Apps Aim to Track Coronavirus, Guard Privacy*, U.S. News and World Report, April 20, 2020, https://www.usnews.com/news/best-countries/articles/2020-04-20/new-tech-apps-in-israel-aim-to-track-coronavirus-guard-privacy

[9] The github summary document Unified research on privacy-preserving contact tracing and exposure notification for COVID-19 , which is updated regularly, listed 64 projects in early April. On June 9, 81 app. developer projects are listed.

[10] A high-level infographic is at https://blog.google/documents/57/Overview_of_COVID-19_Contact_Tracing_Using_BLE.pdf. Preliminary technical specifications have also been posted https://www.apple.com/covid19/contacttracing/

**Why digitally enabled tracing is needed**

A research team from the University of Oxford recently developed a model of infectiousness and transmission using existing data from China and Singapore on SARS-CoV-2 and its spread[11]. The authors determined that between a third and half of all transmissions come from infected people in a pre-symptomatic phase, before symptoms of COVID-19 appear, probably because the individuals remain active and are unaware of their infection[12]. To control further spread of the disease, time is of the essence. The longer an infected person is in contact with others, the more people that person can infect.

The model presented in the paper uses two key parameters – the proportion of cases (symptomatic people) who are isolated or otherwise prevented from infecting others and the proportion of contacts that are identified and quarantined – and considers the elapsed time between case identification and contact determination[13]. The authors show that even if all cases are isolated and all contacts are found and quarantined, whether symptomatic or not, human contact tracing alone is not fast enough to control the spread of SARS-CoV-2[14] (although it was for some other pandemics in which pre-symptomatic people did not shed virus particles). With a smartphone app, however, contact identification and notification is almost instantaneous. In that case, if enough symptomatic individuals are identified and isolated and enough of their contacts are quarantined quickly, the epidemic could be controlled. The authors observe that their model does not incorporate indirect tracing (tracing the contacts of all exposed contacts even before it was known whether they were infected), which might make the technique even more effective, since contacts of contacts would be expected to quarantine even before they were symptomatic or had been tested.

The extent of isolation and quarantine needed to control an infectious disease depends, in part, on the efficiency of transmission of the virus – how many individuals, on average, one infected person infects if nobody has immunity. As part of a long discussion of testing and contact tracing that builds on the work of the Oxford team[15], Tomas Pueyo argues that in order to use testing and tracing, together with isolation and quarantine, in place of lockdowns, 70-90% of a symptomatic individual's contacts must be traced (depending on the degree of contagion) and then tested or quarantined. His analysis shows that for COVID-19, that level of tracing cannot be achieved without digital contact tracing. Moreover, for digital contact tracing to achieve those percentages:

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[11] L. Ferretti *et al*., *Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing, Science* 10.1126/science.abb6936 (2020). https://science.sciencemag.org/content/368/6491/eabb6936

[12] That result is confirmed by another recent study: M. M. Arons, K. M. Hatfield, et. al, *Presymptomatic SARS-CoV-2 Infections and Transmission in a Skilled Nursing Facility*, New England Journal of Medicine, April 24, 2020, https://doi.org/10.1056/NEJMoa2008457;

[13] The model uses the appearance of symptoms rather than the result of a diagnostic test.

[14] Finding and quarantining the contacts is assumed to take 3 days on average. Even if it takes 2 days, the success rates for identifying and isolating cases, and for identifying and quarantining their contacts would each have to be well above 80%.

[15] Tomas Pueyo, *Coronavirus: How to Do Testing and Contact Tracing Part 3 of Coronavirus: Learning How to Dance*, medium.com, April 28, 2020, https://medium.com/@tomaspueyo/coronavirus-how-to-do-testing-and-contact-tracing-bde85b64072e

- the system-level, proximity-gathering app must be installed and enabled on virtually all smartphones – which can be done via the operating system;
- the app that accesses and can upload those data must be installed and enabled on the phone by default. Studies show that if the user must opt-out, *i.e.* the app is active unless the user disables it, the app almost always remains enabled, whereas if the user must opt-in, inertia will lower use of an app substantially; and
- if the user is infected, the contact data are uploaded to human investigators.

**Will a digital-tracing implementation provide enough tracing?**

Will there be sufficient adoption of digital contact-tracing apps to stem transmission in the absence of lockdowns? The evidence thus far is inconclusive. According to the Pew Research Center, as of February 2019, 96% of Americans owned a cellphone, and 86% owned smartphones[16], so cellphone availability is not a barrier to adoption. It is widely asserted, however, that digital contact tracing will carry risks to privacy[17]. But that need not be the case.

The threat to privacy comes not from the pseudonymic contact data stored on one's own phone, but from what happens to the data after the contacts are uploaded to a shared database[18]. To mitigate the privacy threat, user-level apps need to be developed that have the following properties:

- Contact data that are uploaded and stored contain neither location data nor non-pseudonymic identifying information[19].
- Contact data are used only for the intended purpose – namely, to notify users about contact with a symptomatic or infected person, and to tell them what to do about it.
- Uploaded contact data are deleted when contact risk has subsided – after 30 days at most.
- Uploaded contact data are held by a trusted source – a public-health organization rather than a commercial entity.
- Contact-tracing software installed on a phone is automatically removed when the need for it has passed.

Apart from de-identified data, those same properties (encryption, restricted use, data deletion, and trusted database ownership and access) are all necessary for privacy protection in human contact tracing.

On April 23, Apple/Google renamed the service they plan to provide from "contact-tracing" to "exposure notification", signaling that they did not intend to provide the user-level apps. The

[16] Pew Research Center Mobile Fact Sheet, June 12, 2019, https://www.pewresearch.org/internet/fact-sheet/mobile/
[17] Daniel Gillmor, *Principles for Technology-Assisted Contact-Tracing*, ACLU, April 16, 2020, https://www.aclu.org/report/aclu-white-paper-principles-technology-assisted-contact-tracing
[18] *Big Data and Privacy: A Technological Perspective*, Report to the President, President's Council of Advisors on Science and Technology, May 2014, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_big_data_and_privacy_-_may_2014.pdf
[19] Location information is available from GPS records, but might not be easily linked to contacts. Some people regard tracking where they have been as a breach of personal privacy.

companies posted a Frequently Asked Questions (FAQ) explanation of the technology they will provide[20]. According to the document, their system will have the following properties:

- The system uses unique IDs; they are changed every 10-20 minutes.
- The system does not collect location data and does not share identities with other users, Apple, or Google
- "Access to the technology is granted only to public-health authorities. Their apps must meet specific criteria around privacy, security, and data control."
- "Google and Apple will disable the exposure notification system on a regional basis when it is no longer needed."

The way notification will work is that the user can choose to report a positive diagnosis of COVID-19 to their public-health app, in effect, uploading "their most recent" pseudonyms to the positive diagnosis database maintained by the public-health authority. Those pseudonyms will be downloaded to all phones running the public-health app and compared with the contact IDs stored on the phone. If there's a match, "the system will share the day the contact occurred, how long it lasted, and the Bluetooth signal strength of that contact." The signal strength is a measure of distance.

Unfortunately, the Exposure Notification addendum to the Apple Developer Program License Agreement greatly weakens the usefulness of the system-level app[21]. Section 3.4 states "You agree that neither You nor your Contact Tracing App will derive, collect, use, or store any Rolling Proximity Identifiers." In other words, the user-level app cannot upload contact pseudonyms to a public-health authority; it can only send messages to the contacts themselves. The policy satisfies the five privacy requirements given above not by requiring protection of uploaded data, but by prohibiting the collection of data altogether. Public-health authorities must rely on contacts to reach out to the authorities, rather than the authorities being able to reach out to contacts, as they do in human contact tracing.

Furthermore, the Apple/Google rules do not satisfy the criteria for contact tracing described by Tomas Pueyo. Apple/Google rules require that the user opt-in to the system-level contact collection running on their phone. We see no reason why that enhances privacy. Also the user must explicitly download the public health app. If no data can be uploaded to public health authorities without user consent at the time of upload, we see no reason why the phone cannot be "ready to go" by having the app already installed[22]. We have not been able to determine whether the Apple/Google public-health app can send messages to contacts (for example, reminding them to call, inviting them to be tested, or asking them to self-quarantine). If enough contacts would identify themselves to public-health officials in response to requests from the infected individuals, then the fact that the app does not identify contacts would not inhibit effective contact tracing.

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[20] Apple/Google Exposure Notification Frequently Asked Questions, v1.1, May 2020, https://covid19-static.cdn-apple.com/applications/covid19/current/static/contact-tracing/pdf/ExposureNotification-FAQv1.1.pdf

[21] Exposure Notification APIs Addendum (to the Apple Developer Program License Agreement), May 4, 2020. https://developer.apple.com/contact/request/download/Exposure_Notification_Addendum.pdf

[22] Apple installs many apps on your phone automatically as opt-out, even some regarded as intrusive by many users. Siri is an example.

**Will contact tracing reach enough contacts?**

Pueyo's analysis and recent reports from Johns Hopkins University[23] and Harvard's Safra Center[24] make clear that public-health authorities need to combine digital contact tracing with human contact tracing, to provide a more robust way to identify, test, and/or quarantine individuals likely already to be infected or become so. Individuals identified digitally should have the same opportunities for testing, guidance, and treatment as those identified by human tracing.

Human contact tracing and digital contact tracing have complementary strengths and weaknesses[25]. Both methods provide incomplete contact information: human interviewees may have faulty recollection of their contacts and may deliberately hide information they regard as confidential; digital methods depend on users carrying mobile phones equipped with proximity tracing and apps. Human interviews necessarily reveal identity; digital tools may conceal it. Both methods carry privacy risks, with or without privacy-protecting policies. Human methods are labor-intensive and may not scale to large numbers of new cases per day. Digital methods can identify contacts who are strangers, such as proximate protesters in the demonstrations following the death of George Floyd. But digital methods will not reach individuals who do not use smartphones.

Several states and large cities have initiated contact-tracing programs, largely to relax lockdown rules. In early April 2020 the state of Massachusetts launched the Massachusetts COVID-19 Community Tracing Collaborative (CTC), a collaboration between three state groups and Partners in Health, a nonprofit health organization with a strong track-record in human contact tracing[26]. They will hire nearly 1000 contact tracers, drawing from a pool made possible by the large biomedical workforce in Massachusetts and the availability of people sidelined by social distancing requirements.

On May 7, 2020 National Public Radio summarized many of the other programs under way[27]. More programs continue to be added. Estimates of the number of human contact tracers are based on percentage of population, but it is the number per new active cases that is the more salient measure. So far, these programs have not incorporated digital tracing, some because the appropriate apps and infrastructure are not yet available, and some because it is an unfamiliar change to previous practice.

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[23] Crystal Watson, Anita Cicero, et. Al, *A National Plan to Enable Comprehensive COVID-19 Case Finding and contact Tracing in the U.S,*. Johns Hopkins Bloomberg School of Public Health, Center for Health Security, April 10, 2020, https://www.centerforhealthsecurity.org/our-work/pubs_archive/pubs-pdfs/2020/200410-national-plan-to-contact-tracing.pdf

[24] *Roadmap to Pandemic Resilience: Massive Scale Testing, Tracing, and Supported Isolation (TTSI) as the Path to Pandemic Resilience for a Free Society***,** Edmond J. Safra Center for Ethics, Harvard University, April 20, 2020, https://ethics.harvard.edu/files/center-for-ethics/files/roadmaptopandemicresilience_updated_4.20.20_1.pdf

[25] A recent Economist article presents a useful discussion. https://www.economist.com/science-and-technology/2020/04/15/app-based-contact-tracing-may-help-end-coronavirus-lockdowns

[26] https://www.mass.gov/info-details/learn-about-the-community-tracing-collaborative

[27] *States Nearly Doubled Plans For Contact Tracers Since NPR Surveyed Them 10 Days Ago*, NPR, May 7, 2020, https://www.npr.org/sections/health-shots/2020/04/28/846736937/we-asked-all-50-states-about-their-contact-tracing-capacity-heres-what-we-learne

Human contact tracers have also expressed concern that for privacy reasons the digital methods do not include location data[28]. Location data are useful for identifying hotspots (sites at which considerable transmission occurs) and for understanding the nature of disease transmission. Another way to identify hotspots is to post smartphone-like devices in densely occupied places[29]. Those devices, which need to support only proximity-gathering, not telephony, would record all contacts. If one or more of the contacts are determined to be infected, and there were many other simultaneous contacts, the location is a hotspot. Of course, to use such devices, public-health apps would need to be able to check whether the pseudonyms of an infected person are place-based contacts, to determine the number of proximate contacts at that location, and to notify the proximate contacts that they had been in a location with infected people.

Contact-tracing policies must also distinguish between data about infected individuals and data about contacts who do not become infected (as determined by negative tests or the passage of time). Data about infected persons must be privacy-protected as long as they are retained; data about individuals not infected by a particular contact should be discarded.

Contact tracing shows great promise for reducing the need for lockdowns and for enabling the economy to restart. The widespread availability of tests to detect the pathogenic agent, in this case SARS-CoV-2 is an important factor in the effectiveness of contact-tracing. Testing is important not only to confirm that a user with COVID-19-like symptoms has the virus, but also to identify pre-symptomatic carriers in light of their proximity to COVID-19 victims. Had a test been available and administered when an early unexplained death occurred in California on February 2, 2020, or shortly thereafter, many fewer people might have been infected and fewer would have died[30].

Effectiveness also depends on sufficient identification and access to contacts. Social distancing and the wearing of face masks can reduce the number of contacts of an infected person. But it is known that some people are unable to distance themselves because of home or work situations, and some are unwilling to distance themselves or to wear masks. In light of the current distrust of telephone solicitations from strangers and the lack of trust in public institutions, it is not known whether enough contacts will cooperate with public-health workers and whether enough digitally identified contacts will reach out to public health workers. An effective public-communications strategy in partnership and dialogue with local and professional communities will be necessary to achieve sufficient participation. The experience from the Massachusetts CTC project suggests that providing resources to those who are infected or need to quarantine is essential as well.[31]

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[28] National Public Radio, *Apple, Google Coronavirus Tool Won't Track Your Location. That Worries Some States*, May 13, 2020, https://www.npr.org/2020/05/13/855064165/apple-google-coronavirus-tech-wont-track-your-location-that-worries-some-states

[29] David Culler, Prabal Dutta, Gabe Fierro, Joseph E. Gonzalez, Nathan Pemberton, Johann Schleier-Smith, K. Shankari . Alvin Wan, and Thomas Zachariah, *CoVista: A Unified View on Privacy Sensitive Mobile Contact Tracing Effort*, May 27, 2020, arXiv.org, http://arxiv.org/abs/2005.13164

[30] https://www.nytimes.com/2020/04/22/us/santa-clara-county-coronavirus-death.html

[31] Benjamin Wallace-Wells, *Can Coronavirus Contact Tracing Survive Reopening?*, The New Yorker, June 12, 2020, https://www.newyorker.com/news/us-journal/can-coronavirus-contact-tracing-survive-reopening

**Recommendations:**

Recommendation 1. Establish a unit for testing and contact tracing at the Department of Health and Human Services (HHS).

Testing, contact tracing, and the use of technology are essential in slowing the spread of SARS-CoV-2 and reducing the need for lockdowns. The United States has been unprepared to use these tools to their full effect in the present pandemic. In its next relief legislation, Congress should establish and fund a permanent organization, managed and overseen by HHS, to develop and maintain these aspects of pandemic preparedness[32]. Among the organization's responsibilities would be

a. through CDC, to coordinate and serve as a clearing house for the development of digital contact tracing tools by state and regional public health organizations, and to facilitate public-private partnerships aimed at ensuring that the tools best meet the needs of public health. The first generation of these tools should be in use in some states and cities by September 1, 2020.
b. in collaboration with the Office of Management and Budget (OMB) to determine the amount of funding needed to carry out combined human/digital contact tracing and immediate testing of people exposed to the virus at the levels recommended by the National Security Council (NSC)[33].
c. in collaboration with the National Institute of Standards and Technology(NIST), the National Institutes of Health(NIH), the Agency for Healthcare Research and Quality(AHRQ), the Biomedical Advanced Research and Development Authority (BARDA), and the relevant professional societies, to analyze and document experiences and best practices in testing, contact tracing, and quarantining that have been used by Federal, state and local entities to reduce COVID-19 transmission. These studies would inform plans and practices for the COVID-19 pandemic and for future pandemics.

Recommendation 2. Funding for contact tracing and diagnostic tests.

Congress should continue to increase the funding for widespread COVID-19 testing and contact tracing. The relief package, Paycheck Protection Program and Health Care Enhancement Act (COVID 3.5) signed into law April 24 provides $25 billion in total, but only $11 billion for states and localities for testing and tracing, together with $1 billion for Centers for Disease Control(CDC) surveillance measures and $1 billion for BARDA; and a mandate that the Trump administration establish a national strategy to help states

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[32] The organization could be part of a broader Federal Office of Pandemic Preparedness if such an office is established.

[33] In 2016 the NSC issued the Playbook for Early Response to High Consequence Emerging Infectious Disease Threats and Biological Incidents, https://assets.documentcloud.org/documents/6819703/WH-Pandemic-Playbook.pdf, a guide to decision making.

and localities, which are required to outline their own plans for testing[34] [35]. That is only a first step. The Health and Economic Recovery Omnibus Emergency Solution (HEROES) Act passed by the House on May 15, 2020 proposes $75 billion in its COVID-19 National Testing and Contact Tracing Initiative, but that bill has not passed the Senate[36]. Congress should appropriate funding at the level specified by the HEROES Act in the next few months. If the analysis resulting from Recommendation 1(b), determines that more funding is needed, the additional funding should be appropriated as well.

Recommendation 3. Funding for research related to contact tracing.

Congress should fund the government research enterprise – including the National Science Foundation(NSF), NIH, BARDA, and the Defense Advanced Research Projects Agency(DARPA) – on an ongoing basis to advance the use of science and technology to control and reduce the spread of infectious disease. As examples, in the near term, that research should develop efficient screening mechanisms in public places for pre-symptomatic people (since temperature screening only detects individuals with symptoms of the virus), continue to develop effective and efficient diagnostic and serological tests, estimate the effectiveness of early aggressive testing and contact tracing in reducing or eliminating the need for lockdowns, and explore the causes of disease spread both to newly infected individuals and within the human body.

In the longer term, that research should address not only new approaches, but also efficacy of methods in use and human factors that govern the success or failure of contact tracing and related methods. It should also address security and privacy considerations and their interplay with policy directives in times of emergency.

The organization established in Recommendation 2 should coordinate this research program. The Secretary of HHS should provide an annual report to Congress on the needs determined by that program and the progress in finding solutions to those needs.

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[34] https://www.nytimes.com/2020/04/21/us/politics/congress-business-relief-ppp.html

[35] The report, *COVID-19 Strategic Testing Plan***,** was released to Congress on May 24, 2020, https://skillednursingnews.com/wp-content/uploads/sites/4/2020/05/COVID-National-Diagnostics-Strategy-05-24-2020-v-FINAL.pdf

[36] The $75 billion in the bill is for coordinated testing, contact tracing, surveillance, containment, and mitigation. The bill contains no explanation of how that amount is calculated. It includes both diagnostic and serological tests, and social services for infected individuals and underserved populations. There is no mention of digital contact tracing tools. The funding goes through FY21 and beyond.

The cost of diagnostic testing and contact tracing depends, in part, on the number of new cases, so we can only estimate the actual cost through the end of 2020. At the Medicare rate of $51/test, 3 million tests per week for 26 weeks will cost roughly $40 billion. Current prices are often more than the Medicare rate; future prices might drop if the actual cost of the tests drop. Roughly 300,000 contact tracers (number estimated by former CDC Director Tom Frieden) at $70,000 per tracer (estimate by CDC Director Robert Redfield) would cost roughly $21 billion. There would be additional costs to deploy digital contact tracing and serology testing. More funding will be needed beyond 2020.

## Conclusion

It is not too late to strengthen the Nation's attack on the COVID-19 pandemic and its preparedness for future pandemics. Better testing, contact tracing, and methods for controlling the spread of this and other infectious diseases are essential.

## The Ad Hoc Group

The authors are a subset of the members of President Obama's Council of Advisors on Science and Technology (OPCAST) who were involved in producing the six reports dealing with issues related to viral pandemics that his PCAST delivered between 2009 and 2016. In alphabetical order, they are:


Christine Cassel, University of California, San Francisco
Christopher Chyba, Princeton University
Susan L. Graham, University of California, Berkeley
John P. Holdren, Harvard University (OPCAST Co-Chair)
Eric S. Lander, Broad Institute of MIT and Harvard (OPCAST Co-Chair)
Ed Penhoet, University of California, Berkeley
William Press, University of Texas, Austin (OPCAST Vice Chair)
Maxine Savitz, National Academy of Engineering (OPCAST Vice Chair)
Harold Varmus, Weill Cornell Medicine (OPCAST Co-Chair)


The six indicated reports by the Obama PCAST are:

**U.S. Preparations for 2009-H1N1 Influenza**, 88 pp, August 2009
https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-h1n1-report-final2.pdf

**Reengineering the Influenza Vaccine Production Enterprise to Meet the Challenges of Pandemic Influenza**, 87 pp, August 2010
https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST-Influenza-Vaccinology-Report.pdf

**Realizing the Full Potential of Health Information Technology to Improve Healthcare for Americans: The Path Forward**, 108 pp, December 2010
https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-health-it-report.pdf

**Propelling Innovation in Drug Discovery, Development, and Evaluation**, 110 pp, September 2012
https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-fda-final.pdf

**Better Health Care and Lower Costs: Accelerating Improvement through Systems Engineering**, 66 pp, May 2014
https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_biodefense_letter_report_final.pdf

**Preparing for Biological Threats**, 18 pp, November 2016
https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_biodefense_letter_report_final.pdf

In the coming weeks and months, the Ad Hoc Group will be issuing additional reports on other aspects of responding to COVID19 and future pandemics, drawing on these earlier studies and subsequent research and experience.