Pandemic I:
The First Modern Pandemic

BILL GATES

The coronavirus pandemic pits all of humanity against the virus. The damage to health, wealth, and well-being has already been enormous. This is like a world war, except in this case, we're all on the same side. Everyone can work together to learn about the disease and develop tools to fight it. I see global innovation as the key to limiting the damage. This includes innovations in testing, treatments, vaccines, and policies to limit the spread while minimizing the damage to economies and well-being.

This memo shares my view of the situation and how we can accelerate these innovations. The situation changes every day, there is a lot of information available—much of it contradictory—and it can be hard to make sense of all the proposals and ideas you may hear about. It can also sound like we have all the scientific advances needed to reopen the economy, but in fact we do not. Although some of what's below gets fairly technical, I hope it helps people make sense of what is happening, understand the innovations we still need, and make informed decisions about dealing with the pandemic.

Exponential growth and decline

In the first phase of the pandemic, we saw an exponential spread in a number of countries, starting with China and then throughout Asia, Europe, and the United States. The number of infections was doubling many times every month. If people's behavior had not changed, then most of the population would have been infected. By changing behavior, many countries have gotten the infection rate to plateau and start to come down.

Exponential growth is not intuitive. If you say that 2 percent of the population is infected and this will double every eight days, most people won't immediately figure out that in 40 days, the majority of the population will be infected. The big benefit of the behavior change is to reduce the infection rate dramatically so that, instead of doubling every eight days, it goes down every eight days.

We use something called the reproduction rate, or R0 (pronounced "are-nought"), to calculate how many new infections are caused by an earlier infection. R0 is hard to measure, but we know it's below 1.0 wherever the number of cases is going down and above 1.0 wherever the number of cases is going up. And what may appear to be a small difference in R0 can lead to very large changes.

If every infection goes from causing 2.0 cases to only causing 0.7 infections, then after 40 days you have one-sixth as many infections instead of 32 times as many. That's 192 times fewer cases. Here's another way to think about it: If you started with 100 infections in a community, after 40 days you would end up with 17 infections at the lower R0 and 3,200 at the higher one. Experts are debating now just how long to keep R0 very low to drive down the number of cases before opening up begins.

Exponential decline is even less intuitive. A lot of people will be stunned that in many places we will go from hospitals being overloaded in April to having lots of empty beds in July. The whiplash will be confusing, but it is inevitable from the exponential nature of infection.

As we get into the summer, some locations that maintain behavior change will experience exponential decline. However, as behavior goes back to normal, some locations will stutter along with persistent clusters of infections and some will go back into exponential growth. The picture will be more complex than it is today, with a lot of heterogeneity.

Have we overreacted?

It is reasonable for people to ask whether the behavior change was necessary. Overwhelmingly, the answer is yes. There might be a few areas where the number of cases would never have gotten large numbers of infections and deaths, but there was no way to know in advance which areas those would be. The change allowed us to avoid many millions of deaths and extreme overload of the hospitals, which would also have increased deaths from other causes.

The economic cost that has been paid to reduce the infection rate is unprecedented. The drop in employment is faster than anything we have ever experienced. Entire sectors of the economy are shut down. It is important to realize that this is not just the result of government policies restricting activities. When people hear that an infectious disease is spreading widely, they change their behavior. There was never a choice to have the strong economy of 2019 in 2020.

Most people would have chosen not to go to work or restaurants or take trips, to avoid getting infected or infecting older people in their household. The government requirements made sure that enough people changed their behavior to get the reproduction rate below 1.0, which is necessary to then have the opportunity to resume some activities.

The wealthier countries are seeing reduced infections and starting to think about how to open up. Even as a government relaxes restrictions on behavior, not everyone will immediately resume the activities that are allowed. It will take a lot of good communication so that people understand what the risks are and feel comfortable going back to work or school. This will be a gradual process, with some people immediately doing everything that is allowed and others taking it more slowly. Some employers will take a number of months before they require workers to come back. Some people will want the restrictions lifted more rapidly and may choose to break the rules, which will put everyone at risk. Leaders should encourage compliance.

Differences among countries

The pandemic has not affected all countries equally. China was where the first infection took place. They were able to use stringent isolation and extensive testing to stop most of the spread. The wealthier countries, which have more people coming in from all over the world, were the next to be affected. The countries that reacted quickly to do lots of testing and isolation avoided large-scale infection. The benefits of early action also meant that these countries didn't have to shut down their economies as much as others.

The ability to do testing well explains a lot of the variation. It is impossible to defeat an enemy we cannot see. So testing is critical to getting the disease under control and beginning to reopen the economy.

So far, developing countries like India and Nigeria account for a small portion of the reported global infections. One of the priorities for our foundation has been to help ramp up the testing in these countries so they know their situation. With luck, some factors that we don't understand yet, like how weather might affect the virus's spread, will prevent large-scale infection in these countries.

However, our assumption should be that the disease dynamics are the same as in other countries. Even though their populations are disproportionately young—which would tend to mean fewer deaths from COVID—this advantage is almost certainly offset by the fact that many low-income people's immune systems are weakened by conditions like malnutrition or HIV. And the less developed a country's economy is, the harder it is to make the behavior changes that reduce the virus's reproduction rate. If you live in an urban slum and do informal work to earn enough to feed your family every day, you won't find it easy to avoid contact with other people. Also, the health systems in these countries have far less capacity, so even providing oxygen treatment to everyone who needs it will be difficult.

Tragically, it is possible that the total deaths in developing countries will be far higher than in developed countries.

What we need to learn

Our knowledge of the disease will help us with tools and policies. There are a number of key things we still don't understand. A number of studies are being done to answer these questions, including one in Seattle done with the University of Washington. The global collaboration on these issues is impressive, and we should know a lot more by the summer.

- **IS THE DISEASE SEASONAL OR WEATHER DEPENDENT?**
  Almost all respiratory viruses (a group that includes COVID) are seasonal. This would mean there are fewer infections in the summer, which might lull us into complacency when the fall comes. This is a matter of degree. Because we see coronavirus spreading in Australia and other places in the Southern hemisphere, where the seasons are the opposite of ours, we already know the virus is not as seasonal as influenza is.

- **HOW MANY PEOPLE WHO NEVER GET SYMPTOMS HAVE ENOUGH OF THE VIRUS TO INFECT OTHERS? WHAT ABOUT PEOPLE WHO ARE RECOVERED AND HAVE SOME RESIDUAL VIRUS—HOW INFECTIOUS ARE THEY?**
  Computer models show that if there are a lot of people who are asymptomatic but infectious, it is much harder to open up without a resurgence in cases. There is a lot of disagreement about how much infection comes from these sources, but we do know that many people with the virus don't report symptoms, and some portion of those might end up transmitting it.

- **WHY DO YOUNG PEOPLE HAVE A LOWER RISK OF BECOMING SERIOUSLY ILL WHEN THEY GET INFECTED?**
  Understanding the dynamics here will help us weigh the risks of opening schools. It is a complicated subject because even if young people don't get sick as often, they might still spread the disease to others.

- **WHAT SYMPTOMS INDICATE YOU SHOULD GET TESTED?**
  Some countries are taking the temperature of lots of people as an initial screening tool. If doing this helps us find more potential cases, we could use it at airports and large gatherings. We need to target the tests we have at the people at greatest risk since we don't have enough tests for everyone.
- **WHICH ACTIVITIES CAUSE THE MOST RISK OF INFECTION?**
  People ask me questions about avoiding prepared food or door knobs or public toilets so they can minimize their risk. I wish I knew what to tell them. Judgments will have to be made about different kinds of gatherings like classes or church going and whether some kind of spacing should be required. In places without good sanitation, there may be spread from fecal contamination since people who are infected shed the virus.
- **WHO IS MOST SUSCEPTIBLE TO THE DISEASE?**
  We know that older people are at much greater risk of both severe illness and death. Understanding how gender, race, and comorbidities affect this is a work in progress.

The Gates Foundation's role

In normal times, the Gates Foundation puts more than half of its resources into reducing deaths from infectious diseases. These diseases are the reason why a child in a poor country is 20 times more likely to die before the age of five than one in a rich country. We invest in inventing new treatments and vaccines for these diseases and making sure they get delivered to everyone who needs them. The diseases include HIV, malaria, tuberculosis, polio, and pneumonia. Whenever there is an epidemic like Ebola, SARS, or Zika we work with governments and the private sector to help model the risks and to help galvanize resources to create new tools to stop the epidemic. It was because of these experiences that I spoke out about the world not being ready for a respiratory epidemic in my 2015 TED talk. Although not enough was done, a few steps were taken to prepare, including the creation of the Coalition for Epidemic Preparedness Innovation, which I will discuss below, in the vaccine section.

Now that the epidemic has hit, we are applying our expertise to finding the best ideas in each area and making sure they move ahead at full speed. There are many efforts going on. More than 100 groups are doing work on treatments and another 100 on vaccines. We are funding a subset of these but tracking all of them closely. It is key to look at each project to see not only its chance of working but also the odds that it can be scaled up to help the entire world.

One urgent activity is to raise money for developing new tools. I think of this as the billions we need to spend so we can save trillions. Every additional month that it takes to get the vaccine is a month when the economy cannot return to normal. However, it isn't clear how countries will come together to coordinate the funding. Some could go directly to the private sector but demand that their citizens get priority. There is a lot of discussion among governments, the World Health Organization, the private sector, and our foundation about how to organize these efforts.

Innovation to beat the enemy

During World War II, an amazing amount of innovation, including radar, reliable torpedoes, and code-breaking, helped end the war faster. This will be the same with the pandemic. I break the innovation into five categories: treatments, vaccines, testing, contact tracing, and policies for opening up. Without some advances in each of these areas, we cannot return to business as usual or stop the virus. Below, I go through each area in some detail.

TREATMENTS

Every week, you will be reading about new treatment ideas that are being tried out, but most of them will fail. Still, I am optimistic that some of these treatments will meaningfully reduce the disease burden. Some will be easier to deliver in rich countries than developing countries, and some will take time to scale. A number of these could be available by the summer or fall.

If in the spring of 2021 people are going to big public events—like a game or concert in a stadium—it will be because we have a miraculous treatment that made people feel confident about going out again. It's hard to know precisely what the threshold is, but I suspect it is something like 95 percent; that is, we need a treatment that is 95 percent effective in order for people to feel safe in big public gatherings. Although it is possible that a combination of treatments will have over 95 percent effectiveness, it's not likely, so we can't count on it. If our best treatments reduce the deaths by less than 95 percent, then we will still need a vaccine before we can go back to normal.

One potential treatment that doesn't fit the normal definition of a drug involves collecting blood from patients who have recovered from COVID, making sure it's free of the coronavirus and other infections, and giving the plasma to people who are sick. The leading companies in this area are working together to get a standard protocol to see if this works. They will have to measure each patient to see how strong their antibodies are. A variant of this approach is to take the plasma and concentrate it into a compound called hyperimmune globulin, which is much easier and faster to give a patient than unconcentrated plasma. The foundation is supporting a consortium of most of the leading companies that work in this area to accelerate the evaluation and, if the procedure works, be ready to scale it up. These companies have developed a Plasma Bot to help recovered COVID patients donate plasma for this effort.

Another type of potential treatment involves identifying the antibodies produced by the human immune system that are most effective against the novel coronavirus. Once those antibodies have been found, they can be manufactured and used as a treatment or as a way to prevent the disease (in which case it is known as passive immunization). This antibody approach also has a good chance of working, although it's unclear how many doses can be made. It depends on how much antibody material is needed per dose; in 2021, manufacturers may be able to make as few as 100,000 treatments or many millions. The lead times for manufacturing are about seven months in the best case. Our grantees are working to compare the different antibodies and make sure the best ones get access to the limited manufacturing capacity.

There is a class of drugs called antivirals, which keep the virus from functioning or reproducing. The drug industry has created amazing antivirals to help people with HIV, although it took decades to build up the large library of very effective triple drug therapies. For the novel coronavirus, the leading drug candidate in this category is Remdesivir from Gilead, which is in trials now. It was created for Ebola. If it proves to have benefits, then the manufacturing will have to be scaled up dramatically.

The foundation recently asked drug companies to provide access to their pipeline of developed antiviral drugs so researchers funded by the Therapeutics Accelerator can run a screen to see which should go into human trials first. The drug companies all responded very quickly, so there is a long list of antivirals being screened.

Another class of drugs works by changing how the human body reacts to the virus. Hydroxychloroquine is in this group. The foundation is funding a trial that will give an indication of whether it works on COVID by the end of May. It appears the benefits will be modest at best. Another type of drug that changes the way a human reacts to a virus is called an immune system modulator. These drugs would be most helpful for late-stage serious disease. All of the companies that work in this area are doing everything they can to help with trials.

VACCINES

Vaccines have saved more lives than any other tool in history. Smallpox, which used to kill millions of people every year, was eradicated with a vaccine. New vaccines have played a key role in reducing childhood deaths from 10 million per year in 2000 to fewer than 5 million per year today.

Short of a miracle treatment, which we can't count on, the only way to return the world to where it was before COVID showed up is a highly effective vaccine that prevents the disease.

Unfortunately, the typical development time for a vaccine against a new disease is over five years. This is broken down into: a) making the candidate vaccine; b) testing it in animals; c) safety testing in small numbers of people (this is known as phase 1); d) safety and efficacy testing in medium numbers (phase 2); e) safety and efficacy testing in large numbers (phase 3); and f) final regulatory approval and building manufacturing while registering the vaccine in every country.

Researchers can save time by compressing the clinical safety/efficacy phases while conducting animal tests and building manufacturing capacity in parallel. Even so, no one knows in advance which vaccine approach will work, so a number of them need to be funded so they can advance at full speed. Many of the vaccine approaches will fail because they won't generate a strong enough immune response to provide protection. Scientists will get a sense of this within three months of testing in humans by looking at the antibody generation. Of particular interest is whether the vaccine will protect older people, whose immune systems don't respond as well to vaccines.

The issue of safety is obviously very important. Regulators are very stringent about safety, to avoid side effects and also to protect the reputation of vaccines broadly, since if one has significant problems, people will become more hesitant to take any vaccines. Regulators worldwide will have to work together to decide how large the safety database needs to be to approve a COVID vaccine.

One step that was taken after the foundation and others called for investments in pandemic preparedness in 2015 was the creation of the Coalition for Epidemic Preparedness Innovations (CEPI). Although the resources were quite modest, they have helped advance new approaches to making vaccines that could be used for this pandemic. CEPI added resources to work on an approach called RNA vaccines, which our foundation had been supporting for some time. Three companies are pursuing this approach. The first vaccine to start human trials is an RNA vaccine from Moderna, which started a phase 1 clinical safety evaluation in March.

An RNA vaccine is significantly different from a conventional vaccine. A flu shot, for example, contains bits of the flu virus that your body's immune system learns to attack. This is what gives you immunity. With an RNA vaccine, rather than injecting fragments of the virus, you give the body the genetic code needed to produce lots of copies of these fragments. When the immune system sees the viral fragments, it learns how to attack them. An RNA vaccine essentially turns your body into its own vaccine manufacturing unit.

There are also at least five leading efforts that look promising and that use other approaches to teach the immune system to recognize and attack a viral infection. CEPI and our foundation will be tracking efforts from all over the world to make sure the most promising ones get resources. Once a vaccine is ready, our partner GAVI will make sure it is available even in low-income countries.

A big challenge for vaccine trials is that the time required for the trials depends on finding trial locations where the rate of infection is fairly high. While you are setting up the trial site and getting regulatory approval, the infection rate in that location could go down. And trials have to involve a surprisingly large number of people. For example, suppose the expected rate of infection is 1 percent per year and you want to run a trial where you would expect 50 people to be infected without the vaccine. To get a result in six months, the trial would need 10,000 people in it.

The goal is to pick the one or two best vaccine constructs and vaccinate the entire world—that's 7 billion doses if it is a single-dose vaccine, and 14 billion if it is a two-dose vaccine. The world will be in a rush to get them, so the scale of the manufacturing will be unprecedented and will probably have to involve multiple companies.

I am often asked when large-scale vaccination will start. Like America's top public health officials, I say that it is likely to be 18 months, even though it could be as short as nine months or closer to two years. A key piece will be the length of the phase 3 trial, which is where the full safety and efficacy are determined. When the vaccine is first being manufactured, there will be a question of who should be vaccinated first. Ideally, there would be global agreement about who should get the vaccine first, but given how many competing interests there are, this is unlikely to happen. The governments that provide the funding, the countries where the trials are run, and the places where the pandemic is the worst will all make a case that they should get priority.

TESTING

All of the tests to date for the novel coronavirus involve taking a nasal swab and processing it in a Polymerase Chain Reaction (PCR) machine. Our foundation invested in research showing that having patients do the swab themselves, at the tip of the nose, is as accurate as having a doctor push the swab further down to the back of your

throat. Our grantees are also working to design swabs that are cheap and able to be manufactured at large scale but work as well as ones that are in short supply. This self-swab approach is faster, protects health care workers from the risk of exposure, and should let regulators approve swabbing in virtually any location instead of only at a medical center. The PCR test is quite sensitive—it will generally show whether you have the virus even before you have symptoms or are infecting other people.

There has been a lot of focus on the number of tests being performed in each country. Some, like South Korea, did a great job of ramping up the testing capacity. But the number of tests alone doesn't show whether they are being used effectively. You also have to make sure you are prioritizing the testing on the right people. For example, health care workers should be able to get an immediate indication of whether they are infected so they know whether to keep working. People without symptoms should not be tested until we have enough tests for everyone with symptoms. Additionally, the results from the test should come back in less than 24 hours so you quickly know whether to continue isolating yourself and quarantining the people who live with you. In the United States, it was taking over seven days in some locations to get test results, which reduces their value dramatically. This kind of delay is unacceptable.

There are two types of PCR machines: high-volume batch processing machines and low-volume machines. Both have a role to play. The high-volume machines provide most of the capacity. The low volume machines are better when getting a result in less than an hour is beneficial. Everyone who makes these machines, and some new entrants, are making as many machines as they can. Adding this capacity and making full use of the machines that are already available will increase the testing capacity. The foundation is talking to the manufacturers about different ways to run the big machines that could make them more than twice as productive.

Another type of test being developed is called a Rapid Diagnostic Test (RDT). This would be like an in-home pregnancy test. You would swab your nose the same way as for the PCR test, but instead of sending it into a processing center, you would put it in a liquid container and then pour that liquid onto a strip of paper that would change color if it detects the virus. This form of test may be available in a few months. Even though it won't be as sensitive as a PCR test, for someone who has symptoms it should be quite accurate. You would still need to report your test result to your government since they need visibility into the disease trends.

A lot of people talk about the serology test, where you give blood and it detects whether you have antibodies against the virus. If you do, it means you have been exposed. These tests only show positive results late in your disease, so they do not help you decide whether to quarantine. Also, all the tests done so far have problems with false positives. Until we understand what level of antibodies is protective and have a test with almost no false positives, it is a mistake to tell people not to worry about their exposure to infection based on the serology tests that are available today. In the meantime, serology tests will be used to see who can donate blood and to understand the disease dynamics.

A lot of countries did a good job focusing the PCR capacity on the priority patients. Most countries had their government play a central role in this process. In the United States, there is no system for making sure the testing is allocated rationally. Some states have stepped in, but even in the best states, the access isn't fully controlled.

Testing becomes extremely important as a country considers opening up. You want to have so much testing going on that you see hot spots and are able to intervene by changing policy before the numbers get large. You don't want to wait until the hospitals start to fill up and the number of deaths goes up.

Basically, there are two critical cases: anyone who is symptomatic, and anyone who has been in contact with someone who tested positive. Ideally both groups would be sent a test they can do at home without going into a medical center. Tests would still be available in medical centers, but the simplest is to have the majority done at home. To make this work, a government would have to have a website that you go to and enter your circumstances, including your symptoms. You would get a priority ranking, and all of the test providers would be required to make sure they are providing quick results to the highest priority levels. Depending on how accurately symptoms predict infections, how many people test positive, and how many contacts a person typically has, you can figure out how much capacity is needed to handle these critical cases. For now, most countries will use all of their testing capacity for these cases.

There will be a temptation for companies to buy testing machines for their employees or customers. A hotel or cruise ship operator would like to be able to test everyone even if they don't have symptoms. They will want to get PCR machines that give quick results or the rapid diagnostic test. These companies will be able to bid very high prices—well above what the public health system would bid—so governments will have to determine when there is enough capacity to allow this.

One assumption is that people who need to get tested will isolate themselves and quarantine those in their household. Some governments police this carefully, whereas others simply assume people will follow the recommendation. Another issue is whether a government provides a place for someone to isolate themselves if they can't do it at their home. This is particularly important if you have older people in close quarters at your house.

CONTACT TRACING

I mentioned in the testing section that one of the key priorities for testing is anyone who has been in close contact with someone who has tested positive. If you can get a list of these people quickly and make sure they are prioritized for a test like the PCR test (which is sensitive enough to detect a recent infection), then these people can isolate themselves before they infect other people. This is the ideal way of stopping the spread of the virus.

Some countries, including China and South Korea, required patients to turn over information about where they have been in the last 14 days by looking at GPS information on their phone or their spending records. It is unlikely that Western countries will require this. There are applications you can download that will help you remember where you have been; if you ever test positive, then you can voluntarily review the history or choose to share it with whoever interviews you about your contacts.

A number of digital approaches are being proposed where phones detect what other phones are near them. (It would involve using Bluetooth plus sending a sound out that humans can't hear but that verifies that the two

phones are reasonably close to each other.) The idea is that if someone tests positive then their phone can send a message to the other phones and their owners can get tested. If most people voluntarily installed this kind of application, it would probably help some. One limitation is that you don't necessarily have to be in the same place at the same time to infect someone—you can leave the virus behind on a surface. This system would miss this kind of transmission.

I think most countries will use the approach that Germany is using, which requires interviewing everyone who tests positive and using a database to make sure there is follow-up with all the contacts. The pattern of infections is studied to see where the risk is highest and policy might need to change.

In Germany, if someone is tested and confirmed positive, the doctor is legally required to inform the local government health office. The doctor must provide all personal data—name, address, phone number—so that the health office can contact the person and ensure they isolate themselves.

Then the local health office begins the process of contact tracing. They interview the infected person, find out how to contact all the people he or she has met in the past couple of weeks, and contact those people to ask them to self-isolate and get a test.

This approach relies on the infected person to report their contacts accurately, and also depends on the ability of the health authorities to follow up with everyone. The normal health service staff can't possibly do all this work even if the case numbers are fairly low. Every health system will have to figure out how to staff up so that this work is done in a timely fashion. Everyone who does the work would have to be properly trained and required to keep all the information private. Researchers would be asked to study the database to find patterns of infection, again with privacy safeguards in place.

OPENING UP

Most developed countries will be moving into the second phase of the epidemic in the next two months. In one sense, it is easy to describe this next phase. It is semi-normal. People can go out, but not as often, and not to crowded places. Picture restaurants that only seat people at every other table, and airplanes where every middle seat is empty. Schools are open, but you can't fill a stadium with 70,000 people. People are working some and spending some of their earnings, but not as much as they were before the pandemic. In short, times are abnormal but not as abnormal as during the first phase.

The rules about what is allowed should change gradually so that we can see if the contact level is starting to increase the number of infections. Countries will be able to learn from other countries that have strong testing systems in place to inform them when problems come up.

One example of gradual reopening is Microsoft China, which has roughly 6,200 employees. So far about half are now coming in to work. They are continuing to provide support to employees who want to work at home. They insist people with symptoms stay home. They require masks and provide hand sanitizer and do more intensive

cleaning. Even at work, they apply distancing rules and only allow travel for exceptional reasons. China has been conservative about opening up and has so far avoided any significant rebound.

The basic principle should be to allow activities that have a large benefit to the economy or human welfare but pose a small risk of infection. But as you dig into the details and look across the economy, the picture quickly gets complicated. It is not as simple as saying "you can do X, but not Y." The modern economy is far too complex and interconnected for that.

For example, restaurants can keep diners six feet apart, but will they have a working supply chain for their ingredients? Will they be profitable with this reduced capacity? The manufacturing industry will need to change factories to keep workers farther apart. Most factories will be able to adapt to new rules without a large productivity loss. But how do the people employed in these restaurants and factories get to work? Are they taking a bus or train? What about the suppliers who provide and ship parts to the factory? And when should companies start insisting their employees show up at work?

There are no easy answers to these questions. Ultimately, leaders at the national, state, and local levels will need to make trade-offs based on the risks and benefits of opening various parts of the economy. In the United States it will be tricky if one state opens up too fast and starts to see lots of infections. Should other states try to stop people moving across state boundaries?

Schools offer a big benefit and should be a priority. Large sporting and entertainment events probably will not make the cut for a long time; the economic benefit of the live audience doesn't measure up to the risk of spreading the infection. Other activities fall into a gray area, such as church services or a high school soccer game with a few dozen people on the sidelines.

There is one other factor that is hard to account for: human nature. Some people will be naturally reluctant to go out even once the government says it is okay. Others will take the opposite view—they will assume that the government is being overly cautious and start bucking the rules. Leaders will need to think carefully about how to strike the right balance here.

Conclusion

Melinda and I grew up learning that World War II was the defining moment of our parents' generation. In a similar way, the COVID pandemic—the first modern pandemic—will define this era. No one who lives through Pandemic I will ever forget it. And it is impossible to overstate the pain that people are feeling now and will continue to feel for years to come.

The heavy cost of the pandemic for lower-paid and poor people is a special concern for Melinda and me. The disease is disproportionately hurting poorer communities and racial minorities. Likewise, the economic impact of

the shutdown is hitting low-income, minority workers the hardest. Policymakers will need to make sure that, as the country opens up, the recovery doesn't make inequality even worse than it already is.

At the same time, we are impressed with how the world is coming together to fight this fight. Every day, we talk to scientists at universities and small companies, CEOs of pharmaceutical companies, or heads of government to make sure that the new tools I've discussed become available as soon as possible. And there are so many heroes to admire right now, including the health workers on the front line. When the world eventually declares Pandemic I over, we will have all of them to thank for it.