How The Swiss Cheese Model Can Help Us Beat COVID-19

By Nicholas Christakis
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In hopeful news this week, Pfizer and its partner, BioNTech, released interim results from an ongoing trial of their candidate coronavirus vaccine. The study involved 43,538 volunteers who were randomly assigned either the vaccine or a placebo. The rates of infection were small for both groups, but those who got the placebo were substantially more likely to get Covid-19 (85 or more cases) than those who got the treatment (just 9 cases or fewer). This is a terrific development, but it should be noted that even among those who got the vaccine, the infection rate was not zero. It's important to understand that a vaccine, on its own, won't be enough to rapidly extinguish a pandemic as pernicious as Covid-19. The pandemic cannot be stopped through just one intervention, because even vaccines are imperfect. Once introduced into the human population, viruses continue to circulate among us for a long time. Furthermore, it's likely to be as long as a year before a Covid-19 vaccine is in widespread use, given inevitable difficulties with manufacturing, distribution and public acceptance.

Controlling Covid-19 will take a good deal more than a vaccine. For at least another year, the U.S. will have to rely on a multipronged approach, one that goes beyond simplistic bromides and all-or-nothing responses. Individuals, workplaces and governments will need to consider a diverse and sometimes disruptive range of interventions. It helps to think of these in terms of layers of defense, with each layer providing a barrier that isn't fully impervious, like slices of Swiss cheese in a stack.

In fact, the "Swiss cheese model" is a classic way to conceptualize dealing with a hazard that involves a mixture of human, technological and natural elements. The British psychologist James Reason introduced the model more than three decades ago to discuss failures in complex systems such as nuclear power, commercial aviation and medical care. As Prof. Reason argued, "In an ideal world each defensive layer would be intact. In reality, however, they are more like slices of Swiss cheese,

having many holes.… The presence of holes in any one 'slice' does not normally cause a bad outcome. Usually, this can happen only when the holes in many layers…line up…bringing hazards into damaging contact with victims."

This is also an invaluable way to think about the response to Covid-19. Last month, a graphic illustrating the model, sketched by the Australian virologist Ian MacKay, became an online sensation among Covid-19 watchers. It showed particles of the SARS-CoV-2 virus passing through layers of Swiss cheese, shrinking in numbers as they negotiated the holes and finally being stopped at the end.

The main non-pharmaceutical tools available to us in responding to a deadly circulating virus come in two broad categories. At the individual level, the interventions include washing hands, wearing masks and self-isolation. By definition, these actions involve a certain amount of personal agency. Though some Americans have been punished in recent months for flouting such rules, individuals usually have some control over how much they implement them and in what settings.

But there is only so much that individuals acting on their own can achieve, no matter how much they wash their hands, wear masks and maintain physical distance. Collective interventions are also needed to stem the spread of a deadly infectious disease. Such actions are usually coordinated and mandated by governments. They involve and affect everyone, though they may not be to everyone's liking.

These policies include disinfecting public spaces, closing borders, restricting movements, shutting schools, banning gatherings, closing businesses, instituting testing and contact tracing, quarantine of exposed individuals and issuing "stay at home" orders. Because these sorts of interventions often impose very real hardships on citizens who remain (or at least appear) uninfected, they can provoke resentment and even resistance.

Another way to think about these various interventions, individual and collective, is with respect to how they operate as barriers to the spread of the disease. Some— like wearing a mask, hand-washing, sanitizing public places or deploying Plexiglas barriers—achieve their effect by reducing transmission of the pathogen. Others—

like self-isolation, quarantine and school closures—work by modifying the pattern of human interactions to deprive the pathogen of opportunities to spread. They reduce social contact.

These various approaches—whether individual or collective, whether aimed at reducing transmission or contact—are not mutually exclusive. In fact, they often have complementary strengths and weaknesses. And they work best in combination, like using both chemotherapy and radiation to treat cancer or combining exercise and diet to prevent heart disease.

Each layer of defense can reduce the impact of the virus. We know that, after stacking two slices of "Swiss cheese," it might still be possible to look through the two pieces through a hole that happens to line up across the two slices. But after stacking, say, four slices, the random holes are much less likely to align.

Of course, some layers—such as testing, masking and a good vaccine—are more effective than others, such as sanitizing surfaces. These are the Swiss cheese slices with fewer or smaller holes. But no single intervention is enough. Even after a vaccine is widely available, other interventions will still be needed, at least for a while.

Unfortunately, in the early days of the coronavirus epidemic, the rollout of masking, one of our strongest layers of defense, was muddled. Masks alone can have a large effect on respiratory pandemics. A mask with just 50% efficacy in reducing droplet transmission worn by just 50% of people can reduce the infectiousness of the virus from 2.4 new cases per old case to about 1.35, which is roughly the level of seasonal influenza. This means that, in a no-mask scenario, if there were 100 cases of such an infection at the beginning of the month, there would be 31,280 cases at the end of the month; in a mask scenario, there would be only 584. Such an enormous reduction would allow medical personnel to take better care of the smaller number of patients and allow policy makers to deploy other measures more effectively.

If the masks were even more efficient and the use rate even higher, the epidemic could be brought even more to heel. If 70% or more of the population in a typical urban situation used masks that were 70% effective, it could prevent a large-scale outbreak of a moderately contagious respiratory disease such as Covid-19. One analysis of data from 11 European countries found that even lockdowns, which are highly effective, were not perfect; they reduced SARS-CoV-2 transmission by 81%. Another analysis of 13 European countries found that intercity travel restrictions, canceling public events and closing nonessential workplaces had meaningful impacts on the death rates for the virus (closing schools and imposing stay-at-home rules showed smaller effects). An analysis of early stages of the pandemic in China found that detecting and isolating cases was more effective than travel restrictions, but combinations of approaches were optimal. The Swiss cheese model can thus show us a path forward for sensible, science-based policies at the local and national level.

First, it's clear that, in order to stop the spread of the virus and deflect the course of the pandemic, we need to think in terms of deploying enough layers of Swiss cheese. In any setting, it's more important to choose several interventions than any particular one. No matter the specific combination, so long as a certain threshold is achieved, the epidemic can be controlled. Usually, that will mean a combination of actions designed to reduce transmission and to limit contact. But to succeed, a person, family, business or nation must adopt several different measures, not just one or two.

Consider the unfortunate fact that the virus has infected so many people at the White House, including President Trump, his chief of staff, other members of his staff and family, and several U.S. Senators. Why did the White House Covid-19 response fail? The problem is that it relied almost exclusively on a single prevention strategy: testing. But in order to prevent outbreaks, the CDC recommends that workplaces implement multiple procedures, including maintaining at least 6 feet of physical distance, encouraging sick employees to stay home and providing face masks if employees are not already using one.

The Swiss cheese model also helps to explain how and why different countries have succeeded using different approaches. South Korea relied on mask-wearing and testing on a very wide scale; New Zealand closed its borders and did extensive contact tracing; Greece banned gatherings and closed schools. These were the key layers of their defense against the virus, to which they added several others. Places that have not deployed enough layers of defense, like many areas of the U.S. now experiencing skyrocketing caseloads, need to do more if they hope to contain the spread of Covid-19 and avoid more death.

Finally, the Swiss cheese model highlights how we might avoid relying on some of the more disruptive and controversial Covid-fighting measures, such as stay-at-home orders and school closures. If several layers of defense are already in place and holding strong, additional layers might be unnecessary to close gaps.

It's important to recognize that the virus itself often compels many of these measures. In centuries past, during outbreaks of bubonic plague, people engaged in physical distancing without being ordered to do so. Economic collapse and social disarray have been features of epidemics for centuries. As the historian and priest John of Ephesus noted over 1,500 years ago, during the Plague of Justinian: "Buying and selling ceased and the shops with all their worldly riches beyond description and moneylenders' large shops closed. The entire city then came to a standstill as if it had perished."

The early discussion in the U.S. about responding to Covid-19 focused ferociously on just a few interventions, all of which became politicized, such as border closures, masking and lockdowns. But we need to think more nimbly and more adaptively, in part to prepare the way for a vaccine, which itself will not be a panacea.

The country needs a fresh start in how we discuss and solve this crisis. We must realize that we all bear responsibility for implementing multiple interventions and that doing so will actually free us from other, more serious constraints on our social and economic lives.

As for public health officials and political leaders, they need to implement shrewdly chosen policies in a timely way and garner public support for them. Many of the crucial "slices" of Swiss cheese in the fight against Covid-19 are inconvenient, unnatural and costly, so people understandably wish to avoid them if possible, especially when they have not directly experienced the dire effects of the disease, such as the death of a loved one.

In any epidemic, a basic task of leaders is to help people understand what is happening and to model good behavior themselves. Garnering public trust can be seen as its own layer of defense and not just as a way to boost the efficacy of other interventions. This requires honest communication about the rationales for, and limitations of, recommended policies. There are always uncertainties and trade-offs, and the public needs to know about them, too.

Such leadership will be crucial for galvanizing public acceptance of vaccines that will likely be available in the coming year, offering us the most formidable layer of defense yet. In the midst of growing skepticism about vaccines of all kinds, we'll need to see public education campaigns that reach into every corner of American society. The good news is that, not too long ago, the U.S. was the world's beacon in controlling epidemic disease. With effective leadership at every level, starting with President-elect Biden, we can work together to build real defenses against Covid-19, layer by layer.

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