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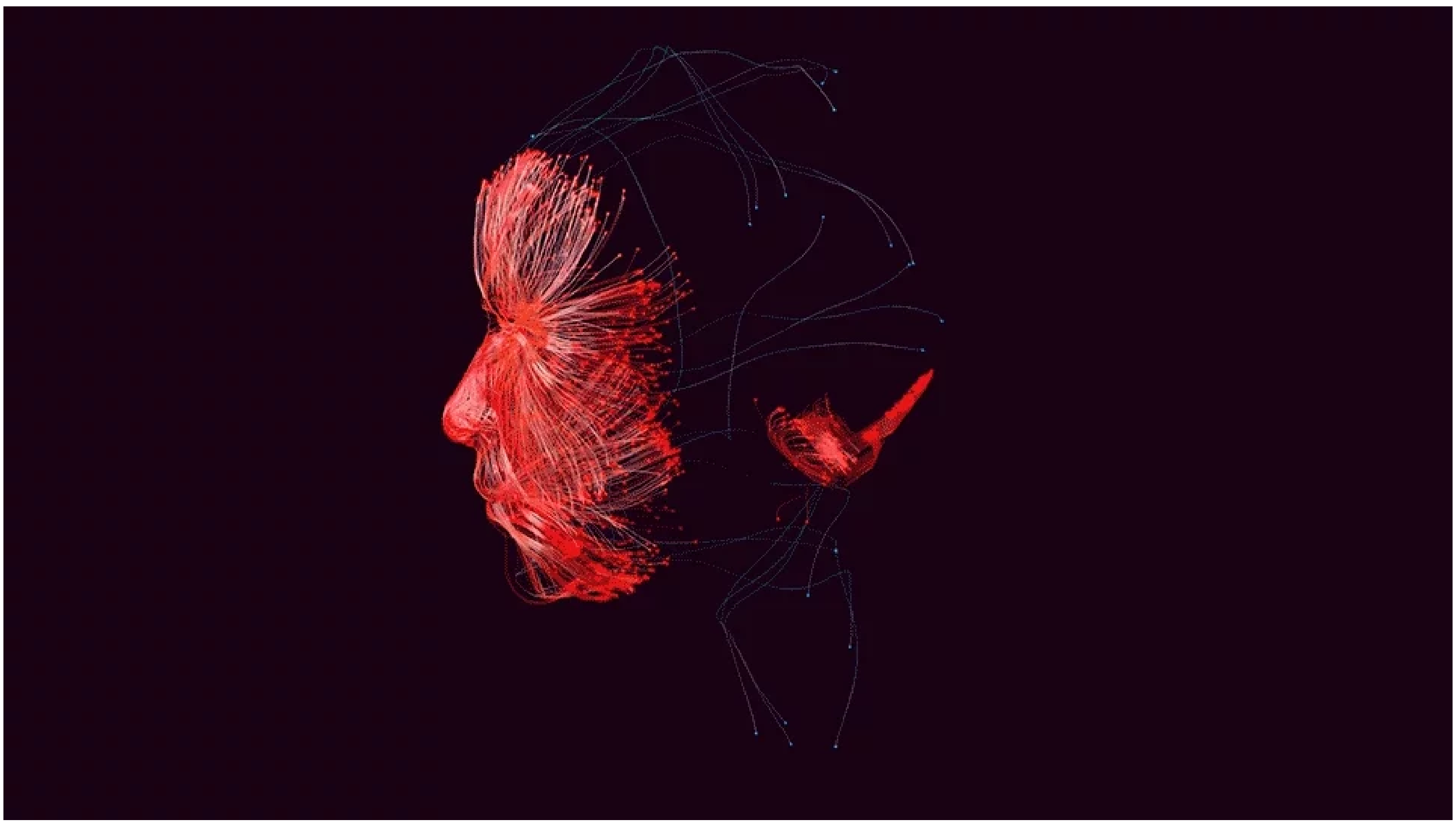
HEALTH

The Plan to Stop Every Respiratory Virus at Once

The benefits of ventilation reach far beyond the coronavirus. What if we stop taking colds and flus for granted, too?

By Sarah Zhang



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When London vanquished cholera in the 19th century, it took not a vaccine, or a drug, but a sewage system. The city's drinking water was intermingling with human waste, spreading bacteria in one deadly outbreak after another. A new comprehensive network of sewers separated the two. London never experienced a major cholera outbreak after 1866. All that was needed was 318 million bricks, 23 million cubic feet of concrete, and a major reengineering of the urban landscape.

The 19th and early 20th century saw a number of ambitious public-health efforts like this. The United States eliminated yellow fever and malaria, for example, with a combination of pesticides, wide-scale landscape management, and window screens that kept mosquitoes at bay. One by one, the diseases that people accepted as inevitable facts in life—dysentery, typhoid, typhus, to name a few more—became unacceptable in the developing world. But after all this success, after all we've done to prevent the spread of disease through water and insects, we seem to have overlooked something. We overlooked air.

This turned out to have devastating consequences for the beginning of the coronavirus pandemic. The original dogma, you might remember, was that the novel coronavirus spread like the flu, through droplets that quickly fell out of the air. We didn't need ventilation or masks; we needed to wash our hands and disinfect everything we touched. But a year and half of evidence has made clear that the tiny virus-laden particles indeed linger in the air of poorly ventilated areas. It explains why outdoors is safer than in, why a single infected person can super-spread to dozens of others without directly speaking to or touching them. If we are to live with this coronavirus forever—as seems very likely—some scientists are now pushing to reimagine building ventilation and clean up indoor air. We don't drink contaminated water. Why do we tolerate breathing contaminated air?

It's not just about COVID-19. The scientists who recognized the threat of airborne coronavirus early did so because they spent years studying evidence that—contrary to conventional wisdom—common respiratory illnesses such as the flu and colds can also spread through the air. We've long accepted colds and flus as inevitable facts of life, but are they? Why not redesign the airflow in our buildings to prevent them, too? What's more, says Raymond Tellier, a microbiologist at McGill University, SARS-CoV-2 is unlikely to be the last airborne pandemic. The same measures that protect us from common viruses might also protect us from the next unknown pathogen.

To understand why pathogens can spread through the air, it helps to understand just how much of it we breathe. "About eight to 10 liters a minute," says Catherine Noakes, who studies indoor air quality at the University of Leeds, in England. Think four or five big soda bottles per minute, multiply that by the number of people in a room, and you can see how we are constantly breathing in one another's lung secretions.

The particles emitted when people cough, talk, or breathe come in a range of sizes. We've all been unwittingly sprayed by large droplets of saliva from the mouth of an overenthusiastic talker. But smaller particles called aerosols can also form when the vocal cords vibrate to air rushing out from the lungs. And the smallest aerosols come from deep inside the lungs. The process of breathing, says Lidia Morawska, an aerosol scientist at Queensland University of Technology, in Australia, is essentially a process of forcing air through the lungs' moist passages. She compares it to spraying a nebulizer or perfume bottle, in which liquid—lung secretions, in this case—becomes suspended in exhaled air.

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Even before SARS-CoV-2, studies of respiratory viruses like the flu and RSV have noted the potential for spread through fine aerosols. The tiny liquid particles seem to

amount of influenza virus is needed to infect people when inhaled as aerosols rather than sprayed up the nose as droplets. Real-world evidence stretching back decades also has suggested that influenza could spread through the air. In 1977, a single ill passenger transmitted the flu to 72 percent of the people on an Alaska Airlines flight. The plane had been grounded for three hours for repairs and the air-recirculation system had been turned off, so everyone was forced to breathe the same air.

In official public-health guidance, however, the possibility of flu-laden aerosols still barely gets a mention. The CDC and World Health Organization guidelines focus on large droplets that supposedly do not travel beyond six feet or one meter, respectively. (Never mind that scientists who actually study aerosols knew this six-foot rule violated the laws of physics.) The coronavirus should get us to take the airborne spread of flu and colds more seriously too, says Jonathan Samet, a pulmonary physician and epidemiologist at the Colorado School of Public Health. At the very least, it should spur research to establish the relative importance of different routes of transmission. "We had done such limited research before on airborne transmission of common infections," Samet told me. This just wasn't seen as a major problem until now.

At the University of Maryland, Donald Milton—one of the few longtime airborne-transmission researchers—is about to embark on a multiyear, controlled trial aimed at understanding influenza. Flu patients and healthy participants will share a room in this study. And they will take different precautions, such as hand-washing plus face shields or having good ventilation, which would presumably stop either droplet or aerosol transmission. The trial is meant to prove which intervention works the best, and thus which transmission route is dominant. When Milton had managed to get funding for a different aerosol study in the 2000s, he said a public-health official told him, "We're funding you to put the nail in the coffin of the idea that aerosols are important." Now, Milton says, "We'll find out which direction the nail is being driven here."

A virus that lingers in the air is an uncomfortable and inconvenient revelation. Scientists who had pushed the WHO to recognize airborne transmission of COVID-19 last year told me they were baffled by the resistance they encountered, but they could see why their ideas were unwelcome. In those early days when masks were scarce, admitting that a virus was airborne meant admitting that our antivirus measures were not very effective. "We want to feel we're in control. If something is transmitted through your contaminated hands touching your face, you control that," Noakes said. "But if something's transmitted through breathing the same air, that is very, very hard for an individual to manage."

The WHO took until July 2020 to acknowledge that the coronavirus could spread through aerosols in the air. Even now, Morawska says, many public-health guidelines are stuck in a pre-airborne world. Where she lives in Australia, people are wearing face masks to walk down the street and then taking them off as soon as they sit down at restaurants, which are operating at full capacity. It's like some kind of medieval ritual, she says, with no regard for how the virus actually spreads. In the restaurants, "there's no ventilation," she adds, which she knows because she's the type of scientist who takes an air-quality meter to the restaurant.

Earlier this year, Morawska and dozens of her colleagues in the fields of building science, public health, and medicine published an editorial in *Science* calling for a "paradigm shift" around indoor air. Yes, vaccines and masks work against the coronavirus, but these scientists wanted to think bigger and more ambitious—beyond what any single person can do to protect themselves. If buildings are allowing respiratory viruses to spread by air, we should be able to redesign buildings to prevent that. We just have to reimagine how air flows through all the places we work, learn, play, and breathe.

The pandemic has already prompted, in some schools and workplaces, ad hoc fixes for indoor air: portable HEPA filters, disinfecting UV lights, and even just open windows. But these quick fixes amount to a "Band-Aid" in poorly designed or functioning buildings, says William Bahnfleth, an architectural engineer at Penn State University who is also a co-author of the *Science* editorial. (Tellier, Noakes, and Milton are authors too; the author list is a real who's who of the field.) Modern buildings have sophisticated ventilation systems to keep their temperatures comfortable and their smells pleasant—why not use these systems to keep indoor air free of viruses too?

Indeed, hospitals and laboratories already have HVAC systems designed to minimize the spread of pathogens. No one I spoke with thought an average school or office building has to be as tightly controlled as a biocontainment facility, but if not, then we need a new and different set of minimum standards. A rule of thumb, Noakes suggested, is at least four to six complete air changes an hour in a room, depending on its size and occupancy. But we also need more detailed studies to understand how specific ventilation levels and strategies will actually reduce disease transmission among people. This research can then guide new indoor air-quality standards from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), which are commonly the basis of local building codes. Changing the building codes, Bahnfleth said, is what will actually get buildings to change their ventilation systems.

The challenge ahead is cost. Piping more outdoor air into a building or adding air filters both require more energy and money to run the HVAC system. (Outdoor air needs to be cooled, heated, humidified, or dehumidified based on the system; adding filters is less energy intensive but it could still require more powerful fans to push the air through.) For decades, engineers have focused on making buildings more energy efficient, and it's "hard to find a lot of professionals who are really pushing indoor air quality," Bahnfleth said. He has been helping set COVID-19 ventilation guidelines as chair of the ASHRAE Epidemic Task Force. The pushback based on energy usage, he said, was immediate. In addition to energy costs, retrofitting existing buildings might require significant modifications. For example, if you add air filters but your fans aren't powerful enough, you're on the hook for replacing the fans too.

The question boils down to: How much disease are we willing to tolerate before we act? When London built its sewage system, its cholera outbreaks were killing thousands of people. What finally spurred Parliament to act was the stench coming off the River Thames during the Great Stink of 1858. At the time, Victorians believed that foul air caused disease, and this was an emergency. (They were wrong about exactly how cholera was spreading from the river—it was through contaminated water—but they had ironically stumbled upon the right solution.)

COVID-19 does not kill as high a proportion of its victims as cholera did in the 19th century. But it has claimed well over 600,000 lives in the U.S. Even a typical flu season kills 12,000 to 61,000 people every year. Are *these* emergencies? If so, what would it take for us, collectively, to treat them as such? The pandemic has made clear that Americans do not agree on how far they are willing to go to suppress the coronavirus. If we can't get people to accept vaccines and wear masks in a pandemic, how do we get the money and the will to rehaul all our ventilation systems? "The costs of that kind of large-scale infrastructure remodeling are astronomical, and the tendency is to look for other kinds of fixes," Nancy Tomes, a historian of medicine at Stony Brook University, said. It's also a problem distributed across millions of buildings, each with its own idiosyncrasies in layout and management. Schools, for example, have struggled to get the funds and make the ventilation upgrades in time for the school year.

In their *Science* editorial, Morawska and her co-authors wrote, "While the scale of the changes required is enormous, this is not beyond the capabilities of our society, as has been shown in relation to food and waterborne disease, which have largely been controlled and monitored." Morawska is optimistic, which perhaps you have to be to embark on this endeavor. The changes might take too long to matter for this current pandemic, but there are other viruses that spread through the air, and there *will be* more pandemics. "My whole drive is to do something for the future," she told me.

How much actually changes "depends on the momentum created now," she said. She pointed out that the vaccines looked like they were going to quickly end the pandemic—but then they didn't, as the Delta variant complicated things. The longer this pandemic drags on, the steeper the cost of taking indoor air for granted.