

Uncovering a pandemic's 'perfect storm'

Renowned infectious disease expert studies factors that fuel — and can stop — global outbreaks

By Dolores Tropiano, ASU News
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In 2020, the COVID-19 pandemic shut down the world and claimed more than 3 million lives, creating reverberations that we still feel today.

It was a catastrophic event that researchers like [Nina Fefferman](#) are working to ensure we never have to live through again.

Fefferman, one of the world's leading experts on infectious disease modeling, joined the faculty at Arizona State University last fall and brought her research group, the [Analysis and Prediction of Pandemic Expansion](#), or APPEX, Center with her. She has been awarded \$18 million from the National Science Foundation to study the complex circumstances that lead to pandemics, with a focus on identifying the “perfect storm” of factors that drive disease-spreading viruses.

Fefferman, the new director of the [School of Mathematical and Natural Sciences](#), does this by examining the expansion of a pandemic through the eyes of a mathematical modeler.

Mathematical modeling is the art of translating a real-world problem into the language of math. Fefferman takes all of the complexities of factors and attempts to distill them into a fundamental logic to make predictions about pandemics.

Here, she explains more about the center and her work, and why she compares mathematical modeling to storytelling.

Note: Answers have been edited for length and/or clarity.

Question: Can you begin by explaining what mathematical modeling is and why you liken it to storytelling?

Answer: A good storyteller not only describes to an audience what is happening but does it in a way that highlights some elements over others to shape the listener's experience. One writer may describe a conversation between two people by first telling us about the light and scent of the room

where they are standing. Another writer may describe the physical movements of the people; did they stand close together, did they whisper or shout? As an audience, our understanding of the conversation is framed by these details and we may take different lessons from the different tellings.

Mathematical modelers make choices to pay attention to specific elements, leaving others out to clearly understand particular aspects and dynamics. We learn different things from different models — even of the same system — gradually working towards a full understanding of the real world by these gradual, layered, simplified mathematical stories.

Mathematical modeling is the art and science of turning real-world problems into logical descriptions. It boils down the complexity of the problem to its fundamentals in a way that we can then analyze, simulate and stress-test to increase our understanding and ability to address the problem.

Q: Math might not be the first field people associate with disease prevention. How can it help track and curb the spread of infectious diseases?

A: The basic logic of infectious diseases is that a healthy person catches an infection from a sick person. While there are different types of exposure — for example, eating or breathing — the basic logic is the same. We can use math to analyze this logical structure to understand some really useful, real-world facts more easily than we could if we had to infer the same rules from measurements.

For example, if we know an average number of new infections that a single sick person is likely to cause, we can very accurately predict how many people will be infected at the peak of a new outbreak in a population that has never been exposed to that disease before.

This gives us advanced warning about how many hospital beds, medical staff and doses of medicine we need to prepare. Without models, we would have to hope that the new outbreak behaved like others in the past, which isn't always true, or make much shorter-term predictions with much less lead time.

More importantly, we can then go beyond prediction to interventions that change how many people get sick.

Q: You earned your undergraduate degree in math from Princeton University and received advanced degrees from Rutgers and Tufts Universities. What drew you to ASU?

A: My undergraduate degree was in math, my master's degree was also in math and my doctoral work was in biology. I absolutely used math in my doctoral work, but my degree was still in biology, not mathematical biology. Since then, I've spent my time in more and more integrated institutions.

ASU is a truly unique institution, leading the way in breaking down traditional boundaries and fostering the kind of creativity and collaboration that allows researchers to really make a difference in understanding and impacting the real world. It's even obvious from the name.

I went from being appointed separately as a professor in an evolution and ecology department and a math department at my last institution to coming here to join the School of Mathematical and Natural Sciences where the "and" signifies true synergy. I'm so excited to be here.

Q: What is the mission of the APPEX Center and what is the plan for reaching the center's goals?

A: I would feel silly if I didn't quote our mission statement here directly. It boils down to a mission to bring people together from all areas of experience and expertise to try to improve how we prevent infectious disease outbreaks from harming the health of all living things. We focus on what actions and policies people can do to influence risks from infectious diseases and use mathematical modeling as both our common language and tool kit for analyzing scenarios and exploring potential solutions. We produce basic scientific insights, practical applied solutions and world-class training for the rising generation of pandemic scientists and health practitioners.

The plan for reaching our goals relies on how we form our teams — inviting anyone from fifth graders to CEOs, from professors to policymakers, and from next door to across the planet to help us imagine how we should be tackling infectious disease health challenges — we call these our “seed ideas.” Then we help self-organizing teams to coalesce around some of those seed ideas and make concrete progress toward addressing them.

Q: You've described math as a kind of puzzle — one that reveals hidden patterns and brings order to complexity. How will that perspective impact or shape your work at APPEX?

A: One of the most beautiful things about research in mathematics is that it boils down any problem into its fundamental logic. Even though it's a silly example, if you had to ask in math, “Do you have more apples or watermelons?”, math instantly forces you to make a better question: “Do you want to know whether you have more individual fruits of one kind? Or instead, did you want to know which of the two has a greater total volume?” A watermelon is much bigger than an apple, maybe you need to know how many you could sell (numbers), but maybe you want to feed more people (volume). Even in this silly example, it's wonderful how having to say things really precisely in the language of math forces you to see the problem more clearly.

At APPEX, we use mathematical modeling as a way to ask everyone involved in tackling a problem in pandemic science, “Why did you want to know that? What did you really need to know?” — to make sure that all the different experts are understanding their own questions as clearly as possible, communicating them well to each other and putting the pieces of the puzzle together correctly. That's what the APPEX math modeling community does within our broader pandemic science mission.

Q: Your work will not be focused exclusively on pandemics. How will your research at ASU go beyond a singular pandemic-focused study or science? For example, cold and flu season — can your work be applicable to the spreading of these illnesses?

A: This is a great question! A core belief of APPEX is that most of the challenges in infectious disease research that we tackle to try to keep us all healthy and happy boil down to the combined influence of many smaller factors. We control some of them but others are beyond our control. We are working to understand how different types of small factors interact, which are under our control, and when we can interrupt those combined effects to improve health and happiness.

The same processes and insights we are using to try to predict and prevent the next 1918 flu pandemic are the same ones we are using to understand regular seasonal flu, colds and lots of other diseases. And while we are absolutely trying to save people from dying in severe pandemics, we'll also be really happy if we can reduce the number of colds that an average kid catches in

elementary school each year.

Q: Looking back, how could your modeling methods have helped constrain COVID-19 in the past, and how do you hope it helps curtail the spread of infectious diseases in the future?

A: A lot of what we all saw as experts in pandemic science at the start of the COVID-19 pandemic was that the failures did not come from the basic science, they came from the communication and coordination — and a lot of that was still the fault of the way we traditionally do science. We don't worry about that full set of factors that combine to create risk and we hand off the coordination among fields, among people and among communities to be someone else's problem. APPEX was designed to help address that — to focus on co-creation, on serving the needs of our whole community because our whole community is part of creating the solution, and on using our math modeling skills to help enable and facilitate that shared process of discovery and invention.

We hope that this means we won't just discover new science to understand why some diseases are more likely to cause outbreaks than others, but that, when we do improve that understanding, we'll also have improved how well we can turn that knowledge into action together.

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Main image



Nina Fefferman, one of the world's leading experts on infectious disease modeling, studies the complex circumstances that lead to pandemics, with a focus on identifying the "perfect storm" of factors that drive disease-spreading viruses. Photo by Charlie Leight/ASU News