Breakthrough: Connecting The Drops

LYDIA BOUROUIBA: When I'm in nature, I see mathematics. The sun, the sky being blue, I see the clouds forming that contain all these droplets. Everybody's trying to capture the essence of what governs the world around us. And the best way to capture that, instead of having words, is an equation. An equation, a mathematical equation, is truly a universal language that transcends fields, transcends ideas, but also transcends cultures and countries.

Bacteria, viruses spores, are transported in droplets. Knowing basically where it goes is the crux of this whole problem, to understand better how disease is spread. If you look at disease transmission, it's based on humans reporting. And so, the data is not the best data, but in fact, the best way to say anything is to measure it directly. My name is Lydia Bourouiba and I am a professor at MIT, Massachusetts Institute of Technology. And I do research in Fundamental Fluid Dynamics to answer questions in disease transmission. We're trying to understand very fundamental, neglected questions that are important to control the spread of disease. But yet approaching them in a unique way through mathematics.

Growing up in Algeria, we would go camping. Beaches are quite wild. And I would watch the waves breaking for hours and look actually had the trails of descent. Why is it doing this sound and why do we have these patterns? Growing up, what I realized was that mathematics and science was really, truly universal. And that if you go into a direction early on then you could really go anywhere after. At the PHD level, I wanted to find a way that I could give back and leverage all this knowledge and all this education to help the world. My grandmother died of tuberculosis. And some other members of the family died of tuberculosis, which is also transported in droplets. And it just hit me that epidemiology and infectious disease was an area that really I felt very strongly about. We've sent people to the moon, but then we have people that don't have clean water to drink and are affected by diseases that should be eradicated by now.

Droplets are really at the hearts of this whole problem of transmission. Sneezes, coughs, respiratory events, are probably the place, the physical aspect that we should be looking at. To record a sneeze, so sneeze, cough, or any these violent expiration events, there's a few key things that need to be put in place: the lighting, the intensity, the orientations, the angles. At the beginning, it's a bit awkward. For sneezing, we tried light sensitivity, dust, pepper, but it turns out that tickling the nose was the most universal way of getting the human subjects to sneeze. When you zoom in and you look at various parts of the clouds look like snowflakes, and it's really beautiful. Taking an image that you can analyze, precisely, to extract clean enough data at high enough precision is very difficult. And image analysis becomes a critical tool. And now we can actually extract features very precisely, in terms of droplet with sizes, speeds, but also what actually is happening to the whole fluid. The research showed the droplets are heavy and they're going to fall very quickly, but most of them, in fact, are trapped and they're swirling around, moving. You have this momentum that dominates the earlier stage, but then this cloud has buoyancy because it is hot and moist. So if you think about hot air, it's buoyant, meaning that it's basically lighter in comparison to cold air and therefore, it's going to go up. And lighter fluid goes up and heavier fluid goes down. And eventually when the cloud slowed down sufficiently, you see the cloud with some angle moving upward. That's very important because most modern rooms ventilation systems are upward so where the cloud is sucked out to be recirculated.

This problem of transmission, we find it also between plants. There was correlation between rainfalls and when the spots of infection appear in the leaves a few weeks later. You have rain falls or irrigation on contaminated plants through the droplets that are created. Nobody actually put a camera there to actually see what happens. We basically constructed a very detailed drop tower where we had the leaf being the centerpiece and then have basically drops falling on it. We thought we would see bouncing, we never saw that. You see the contaminated drug, it relying completely on the motion of the leaf itself to create droplets of different signatures, of sizes, and distances. Therefore, the overall range of contamination around this species is this and around that species is this.

I wanted to understand if there is a true potential for droplet creation in hospitals. There are all sorts of diseases that you could get from the hospital, like Clostridium Difficile. A lot more people now are dying from it. Instead of the sneezers, we just had this basically toilet flush. It was kind of an awkward set up. We used high pressure toilet that was used in hospitals and also high speed cameras for this problem. There are studies that reported that sprays are coming out from flushing, but during visualization of this to quantify exactly where it's coming from, what type of droplet size distribution, how far distance they're going, it's quite shocking. When you think of the impact potentially for contamination and transmission, it's quite disturbing. But there is a lot of simple questions to be asked about is this design of the hospitals optimized to minimize basic transmission between patients. Now we can actually start revisiting our ventilation systems and also the way that wards are designed in times of emergency when you have to put something together very quickly because you on the front line. Ultimately, pathogens are transported in droplets. All the work that we're doing in the lab relates one way or another to how the droplets are created, whether it's from sneezing or splashes on plants or et cetera.

When I'm in nature, I see fluid dynamics and mathematics with it all the time. Science and mathematics and physics crosses all the boundaries. You find it to describe any laws of nature, and we find it also in other fields like sociology, economics. We can start seeing that all humans are connected, not only through universal feelings, but through very rational ways of understanding the world around us because mathematics is everywhere.

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