PROBLEM
Infectious diseases such as measles and pertussis once thought eradicated in the United States are reemerging as new challenges, at the same time as new infectious diseases and antibiotic-resistant strains of more common pathogens are emerging. Global airline travel and newly recognized but poorly understood disease transmission processes in hospitals are allowing such pathogens to spread quickly and widely among people who don't have direct contact. Unfortunately, traditional epidemiological tools don't provide a clear understanding of the contact dynamics shaping the pattern of disease transmission between hosts. Exactly how do pathogens ejected by a violent sneeze or cough reach people in different areas of a building or vehicle who may not be in direct contact?

APPROACH
Professor Lydia Bourouiba uses a combination of experiments and mathematical modeling to elucidate the physical mechanisms that shape disease transmission from host to host. In the case of human respiratory diseases, she's addressing the fluid dynamics of sneezes and coughs to examine their role in shaping airborne pathogen contamination. She designed a visualization experiment that employs high-speed videography to capture and track the flow of violent expiration droplets ranging from a single micron to a few thousand microns in diameter. The videos captured the entire violent expiration cloud of a sneeze and the trajectory of individual droplets. Using mathematical modeling, she described the dynamic regime and spatiotemporal evolution of the multiphase cloud and set out to determine if the cloud dynamics is important in shaping the fate of the pathogen-bearing droplets.

Bourouiba tested the predictions of her theoretical models against data gathered from analog experiments in which a buoyant, dyed, freshwater fluid containing beads is ejected into a quiescent tank of saltwater. The injection generates a buoyant multiphase turbulent puff that is initially driven by the momentum of the injection, much as the clouds generated by sneezes. With these experiments, Bourouiba and visiting undergraduate student Eline Dehandschoewercker were able to capture the overall range and distribution of particle deposition.

FINDINGS
The dynamics of the multiphase turbulent buoyant clouds created by a sneeze play a key role in extending the range of pathogen-laden droplets. While large droplets follow their own trajectory, usually dropping to the floor close to the sneezer, smaller droplets remain suspended in the cloud sometimes indefinitely. The results of this study showed that a violent expiration cloud can extend the range of a 30-micron droplet by at least a factor of 200, allowing droplets to flow upwards 4 to 6 meters to ceiling height, where they can enter the air ventilation system.

IMPACT
This study highlights the importance of multiphase turbulent cloud dynamics in extending the reach of respiratory pathogens, especially those contained in the smallest droplets ejected by sneezes and coughs. It also shows that the current public health estimations of contamination ranges — which ignore the cloud dynamics — are dramatically underestimated. Setting up a physically rooted framework for disease transmission is an important step in understanding the patterns of transmission that allow infectious disease to spread quickly and often globally. This work could lead to the reformulation of the epidemiological models of disease transmission currently used to assess mitigation strategies and risks. It also could lead to new concrete public health solutions to curtail disease transmission, including changes to the design of air ventilation systems and other aspects of shared indoor spaces such as in airplanes and in hospitals, schools and other buildings.

MORE
A paper on this work by Lydia Bourouiba, Professor John Bush of the Department of Mathematics, and Eline Dehandschoewercker, who is now a doctoral student at ESPCI Paris Tech, appeared online March 24 in the Journal of Fluid Mechanics.