

Living Through the Scientific Revolution From Droplet to Aerosol Transmission of a Coronavirus

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When SARS-CoV-2 appeared, it was thought to spread (like other coronaviruses) by macroscopic droplets.¹ Studies such as the National Football League (NFL)-Centers for Disease Control and Prevention (CDC) study, however, shifted health care workers' understanding toward a contrary view: aerosol spread.² This was a paradigm shift, and a humbling one. It has relevance beyond infection prevention. Indeed, it has two important messages for physicians. First, since science is continually evolving, our efforts to communicate science to the general public need to place more emphasis on communicating uncertainty. Second, it reiterates the importance of evidence-based medicine (EBM).

At the onset of the pandemic, infectious diseases specialists “knew” that, like other coronaviruses, SARS-CoV-2 spread in macroscopic droplets traveling 1 to 2 meters from a patient who sprays droplets by coughing or sneezing. Aerosol scientists disagreed, and they were right. These scientists argued that SARS-CoV-2 often spreads within a meter or two simply because the concentration of aerosol particles is higher closer to the source. However, these tiny particles sometimes remain suspended for some distance, allowing transmission to occur

at greater distances. Plexiglass barriers, they noted, may shield individuals from spray droplets but also may impair ventilation, which is critical for dispersing aerosol particles.¹ By the end of 2021, this perspective was supported in the medical literature.³ Aerosol transmission was recognized as the predominant mode

constructing systems of cycles and epicycles, they posited explanations involving ventilation patterns and air currents. Consider the superspreader event involving multiple tables in a restaurant.⁶ The source of the outbreak was well over 1 meter away from some contacts. Droplets ordinarily would not travel sev-

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of transmission, and a droplet-based model became untenable.⁴

This paradigm shift was the sort of phenomenon at the heart of Thomas Kuhn's book, *The Structure of Scientific Revolutions*, which popularized the term “paradigm shift.”^{1,5} Kuhn's most striking example was the shift from the Ptolemaic view of the Earth at the center of the universe to the Copernican concept of the sun at the center of the solar system. Ptolemaic astronomers struggled to explain observations of planetary movements, constructing a complex system of cycles and epicycles. For example, they thought that Mercury episodically moved in retrograde. Copernicans, however, had simpler explanations for observations such as the movements of Mercury.

Like the Ptolemaic astronomers, droplet-oriented infectious diseases specialists struggled to explain some observations. Instead of

eral meters across the room; a droplet-based explanation required positing special airflow patterns from the ventilation system. Aerosol transmission, in contrast, can readily explain this event. Consider also the NFL-CDC study. Its protocols required players to wear proximity tracking devices; data showed no transmissions occurring outdoors. Yet the droplet model would predict outdoor transmission given the heavy breathing and close contact inherent in football.² For defenders of the droplet model, the absence of transmission on the field posed a substantial challenge. The aerosol model, however, can point to dilution of viral particles outdoors.⁴ This challenge to the droplet model parallels the challenges faced by the Ptolemaic model.

Taken together, these observations suggest that we have lived through a “scientific revolution” or, as Kuhn would say, a paradigm shift.

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Recognizing this paradigm shift (admittedly one with far less significance than the Copernican revolution) has more than intellectual interest alone. In his book, Kuhn elaborates a conception of science and scientific revolutions that offers two lessons directly relevant to physicians.

First, Kuhn reminds us that scientific concepts evolve, sometimes rapidly. This message warrants emphasis, especially when physicians communicate medical information to the public, some of whom may perceive science as a static collection of facts. Physicians should communicate uncertainty. Indeed, the communications chapter of the CDC's instructions for investigating an epidemic, *The CDC Field Epidemiology Manual*, advises telling the public about what remains unknown.⁷

Second, some concepts from old paradigms may still have practical utility. In identifying which concepts retain usefulness, EBM plays a crucial role. Aspects of old paradigms persist in some settings. For example, we still speak of "sunrise" and "sunset," although the apparent motion of the sun up and down is an illusion created by the Earth's rotation. Even the "flat

Earth" paradigm persists in limited applications: when surveying small land areas, the curvature of the Earth is often not considered. Which infection prevention measures, grounded in the older droplet transmission paradigm, still have value in an era recognizing the importance of aerosols? For example, meningococci were historically thought to spread via droplets, and infection prevention precautions for meningococcal meningitis patients were designed with that in mind. Rooms with ordinary hospital ventilation (rather than airborne isolation rooms with negative air pressure) were considered acceptable. As the aerosol paradigm supplants the droplet paradigm for respiratory infections, should isolation practices for meningococcal meningitis change? Ultimately, evidence will answer that question for those practicing EBM. In some cases, elements of older paradigms retain value even in the peer-reviewed medical literature. Indeed, 500 years after Copernicus, the terms sunrise and sunset are still a part of our vernacular.

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