OUT OF THE MOUTHS OF BABES

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My favorite explanation is one that I sought as a boy. Why is the sky blue? It's a question every toddler asks, but it's also one that most great scientists since the time of Aristotle, including Leonardo da Vinci, Isaac Newton, Johannes Kepler, René Descartes, Leonhard Euler, and even Albert Einstein, have asked.

One of the things I like most about this explanation—beyond the artless simplicity of the question itself—is how many centuries of effort it took to arrive at and how many branches of science it involves.

Unlike other everyday phenomena, such as the rising and setting sun, the color of the sky did not elicit much myth-making, even by the Greeks or the Chinese. There were few nonscientific explanations for its color. It took a while for the azure sky to be problematized, but, when it was, it kept our (scientific) attention. How could the atmosphere be colored, when the air we breathe is not?

Aristotle is the first, as far as we know, to ask why the sky is blue. His answer, in the treatise *On Colors*, is that the air close at hand is clear and the deep air of the sky is blue in the same way that a thin layer of water is clear but a deep well of water looks black. This idea was still being echoed in the 13th century, by Roger Bacon. Kepler, too, reinvented a similar explanation, arguing that the air merely looks colorless because the tint of its color is so faint when in a thin layer. But none of them offered an explanation for the *blueness* of the atmosphere.

In the *Codex Leicester*, Leonardo da Vinci, writing in the early 16th century, noted, "I say that the blue which is seen in the atmosphere is not its own color, but is caused by the heated moisture having evaporated into the most minute, imperceptible particles, which beams of the solar rays attract and cause to seem luminous against the deep, intense darkness of the region of fire that forms a covering above them." Alas, Leonardo does not actually say why these particles should be blue either.

Newton contributed, both by asking why the sky was blue and by demonstrating, through his pathbreaking experiments with refraction, that white light could be decomposed into its constituent colors.

Many now-forgotten and many still-remembered scientists since Newton joined in. What might refract more blue light toward our eyes? In 1760, the mathematician Leonhard Euler speculated that the wave theory of light might help to explain why the sky is blue. The 19th century saw a flurry of experiments and observations of all sorts, from expeditions to mountaintops for observation to elaborate efforts to re-create the blue sky in a bottle—as chronicled in Peter Pesic's wonderful book, *Sky in a Bottle*. Countless careful observations of blueness at different locations, altitudes, and times were made, including with bespoke devices known as cyanometers. Horace-Bénédict de Saussure invented the first cyanometer in 1789. His version had fifty-three sections with varying shades of blue arranged in a circle. Saussure reasoned that something suspended in the air must be responsible for the blue color.

Indeed, for a very long time it had been suspected that something in the air modified the light and made it appear blue. Eventually it was realized that it was *the air itself* that did this—that the gaseous molecules that compose the air are essential to making it appear blue. And so the blueness of the sky is connected to the discovery of the physical reality of atoms. The color of the sky is

deeply connected to atomic theory, and even to Avogadro's number. This in turn attracted Einstein's attention in the period from 1905 to 1910.

So, the sky is blue because the incident light interacts with the gas molecules in the air in such a fashion that more of the light in the blue part of the spectrum is scattered, reaching our eyes on the surface of the planet. All the frequencies of the incident light can be scattered this way, but the high-frequency (short wavelength) blue is scattered more than the lower frequencies in a process known as Rayleigh scattering, described in the 1870s. John William Strutt, Lord Rayleigh, who received the Nobel Prize in physics in 1904 for the discovery of argon, demonstrated that when the wavelength of the light is on the same order as the size of the gas molecules, the intensity of scattered light varies inversely with the fourth power of its wavelength. Shorter wavelengths like blue (and violet) are scattered more than longer ones. It's as if all the molecules in the air preferentially glowed blue, which is what we then see everywhere around us.

Yet the sky should appear violet, since violet light is scattered even more than blue light. The sky does not appear violet to us because of the final, biological part of the puzzle, which is the way our eyes are designed: They are more sensitive to blue than violet light.

The explanation for why the sky is blue involves much of the natural sciences: the colors in the visual spectrum, the wave nature of light, the angle at which sunlight hits the atmosphere, the mathematics of scattering, the size of nitrogen and oxygen molecules, and even the way human eyes perceive color. It's most of science, in a question a young child can ask.