▶ **Davies replies:** I greatly appreciate this helpful feedback on my article "Does new physics lurk inside living matter?" Julian Ting raises a question about quantum tunneling through organic molecules. Single-molecule conductance experiments are now established technology and are being developed for DNA sequencing. Ting is correct that the geometrical configuration of the molecule can be extremely important, especially in the case of folded versus unfolded peptides.

However, although individual organic molecules may be insulators or conductors, I am unaware of any simple relationship between single-molecule conductance values and bulk conductance values. The full details of the claimed "quantum criticality" of key biological models may be found in the paper by Gábor Vattay and coauthors,[1] which I cited in my article. I discuss other examples of quantum tunneling in organic molecules in my book *The Demon in the Machine: How Hidden Webs of Information Are Solving the Mystery of Life* (2019). The discussion there includes the important work of my Arizona State University colleague Stuart Lindsay on tunneling through nucleotides and peptides.

Edwin Kerr touches on what I regard as one of the deepest outstanding challenges in explaining life's origin: the emergence of encrypted-information processing—what biologists call translation (from the 4-letter DNA alphabet to the 20-letter amino-acid alphabet). All known terrestrial life uses a common code, an encryption–decryption system. There is no agreement about how the specific coding assignments, or indeed *any* coding assignments, first evolved. How did such "software" come out of chemistry—that is, "hardware"? As Kerr surmises, I do indeed think that this transition is where new physics may lie. I should clarify, however, that the accumulation of information in living matter is entirely consistent with the second law of thermodynamics: Living organisms are open systems, and they export entropy into their surroundings to pay for the information gained.

Finally, I am grateful to Akira Hasegawa for emphasizing the astonishing thermodynamic efficiency of the human brain, which deploys legions of Maxwell-demon-like molecules to operate gated ion channels that enable information to propagate between neurons with relatively little waste heat.

Reference

1. G. Vattay et al., *J. Phys.: Conf. Ser.* **626**, 012023 (2015).

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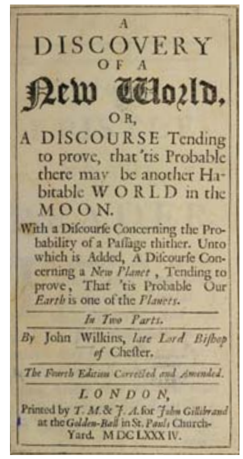
Journey to where outer space begins

Jonathan McDowell's Quick Study "Where does outer space begin?" (Physics Today, October 2020, page 70) gives an excellent outline of the rationale for adopting a definition based on the balance between gravity and aerodynamic force and justifying an 80 km altitude as a boundary between aeronautical and astronautical domains. It also notes the physiologically derived Armstrong limit of 19 km, where blood begins to boil.


A
DISCOVERY
OF A
New World,
OR,
A DISCOURSE Tending to prove, that 'tis Probable there may be another Habitable WORLD in the MOON.
With a Discourse Concerning the Probability of a Passage thither. Unto which is Added, A Discourse Concerning a New Planet, Tending to prove, That 'tis Probable Our Earth is one of the Planets.
In Two Parts.
By John Wilkins, late Lord Bishop of Chester.
The Fourth Edition Corrected and Amended.
LONDON,
Printed by T. M. & J. A. for John Gillibrand at the Golden-Ball in St. Paul's Church-Yard. MDCLXXXIV.

TITLE PAGE from *A Discovery of a New World, or A Discourse Tending to Prove, that 'Tis Probable There May Be Another Habitable World in the Moon . . .*, 4th ed., by John Wilkins, 1684. (Public Domain Mark 1.0.)

As I recount in reference 1, in 1684 John Wilkins, an English clergyman and cofounder of the Royal Society, imagined that the Moon might be inhabited.[2] Although Wilkins recognized that the upper air was cold and thin and that there would be no inns en route to offer victuals and shelter, he affirmed that it might be "possible to make a Flying Chariot. In which a Man may sit, and give such a Motion unto it, as shall convey him through the Air. And this perhaps might be made large enough to carry divers Men at the same time" (page 184). He went on to make the remarkable prediction "That supposing a Man could Fly, or by any other means, raise himself Twenty miles upwards, or thereabouts, it were possible for him to come unto the Moon" (page 162).

Three centuries later those two benchmarks were met, only a few years apart. No human reached an altitude of 32 km (20 miles) until the Bell X-2 rocket plane hit 38.5 km in 1956, just 13 years before *Apollo 11* took men to the Moon. And although ballooning began long before heavier-than-air aviation, the 32 km threshold was not breached until the Stratolab High V balloon did so in 1961, shortly after Joseph Kittinger Jr's famous parachute jump of 31 km from the US Air Force's Excelsior III balloon in August 1960.

In space exploration, as in so many other long journeys, the first 20 miles are the hardest.

References

1. R. D. Lorenz, *Exploring Planetary Climate: A History of Scientific Discovery on Earth, Mars, Venus and Titan*, Cambridge U. Press (2019).
2. J. Wilkins, *A Discovery of a New World, or A Discourse Tending to Prove, that 'Tis Probable There May Be Another Habitable World in the Moon . . .*, 4th ed. (1684), book 1.

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Correction

January 2021, page 23—Manitoba, Canada, was mistakenly listed as relying mainly on fossil fuels. Most of the province's energy is hydroelectric. PT