and having any hope of life-producing chemistry would need even stronger, more persistent magnetic fields. Those fields might even be detectable in searches of extrasolar planets.

Reference

1. J. O. Bennett, M. O. Donahue, N. Schneider, M. Voit, *The Cosmic Perspective*, 7th ed., Pearson (2014), p. 535.

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■ **Johnson replies:** Richard Mielbrecht raises an interesting and important topic. The first point to be made in response to his concern is that we do not understand the conditions for life on our own planet, let alone others. Thus many questions remain about the habitability of planets orbiting red dwarfs or any star other than the Sun, given that our planet is the only location in the galaxy where life is known to exist.

The job of planet hunters like me is to identify where Earth analogues exist, having first characterized the host stars and planetary orbits. Then we need to determine whether any have an equilibrium temperature that may allow for the existence of liquid water. That step is merely the first in a long process of assessing the potential habitability of a planet.

Other concerns include assessing whether the planet has plate tectonics; a suitable atmospheric mass and composition; enough but not too much water; and, as Mielbrecht points out, whether it has a strong enough magnetic field to shield it from energetic flares. All those points were outside the scope of my article, which focused on the search for distant worlds. But those topics are certainly worthy of a follow-up article.

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Modeling a cell in an external electric field

Letters written by Bob Eisenberg (PHYSICS TODAY, July 2013, page 10) and John Michael Williams (December 2013, page 9) raise the issue of how to model a cell in an electrostatic field.

Cytoplasm, the gel-like interior of a cell, is a good ionic conductor. When an external electric field is applied, the ions quickly redistribute themselves to produce a field that essentially cancels the applied field inside the cytoplasm. The resulting change in potential difference must then appear almost entirely across the membrane. The time scale for that process is on the order of a microsecond. Consequently, for applied fields with a frequency of less than about 1 MHz, the molecules in the cytoplasm are not directly affected by the external field.

Effects produced inside the cell must then be due to the action of the external field on the cell membrane. Three physical models have been proposed to describe that process: electrodiffusion of cell-surface receptors; opening of voltage-gated channels; and electromechanical torque acting on transmembrane, negatively charged glycoproteins connected to the cytoskeleton. Fields on the order of 100 V/m in the extracellular fluid applied for up to a few seconds have been shown to produce a wide variety of bioeffects. Fields on the order of 1 kV/m applied for about 15 minutes are required for electrodiffusion,[1] and typical applied fields are not strong enough to open voltage-gated channels.[2] In contrast, the electromechanical model avoids these problems and makes specific predictions that are confirmed experimentally.[3] Methods for modeling the fields in complex cellular systems can be found in reference 3.

References

1. R. C. Lee et al., *Biophys. J.* **64**, 44 (1993).
2. F. X. Hart et al., *Bioelectromagnetics* **34**, 85 (2013).
3. F. X. Hart, in *The Physiology of Bioelectricity in Development, Tissue Regeneration, and Cancer*, C. Pullar, ed., CRC Press (2011), chap. 2.

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Letters and commentary are encouraged and should be sent by email to ptletters@aip.org (using your surname as the Subject line), or by standard mail to Letters, PHYSICS TODAY, American Center for Physics, One Physics Ellipse, College Park, MD 20740-3842. Please include your name, work affiliation, mailing address, email address, and daytime phone number on your letter and attachments. You can also contact us online at http://contact.physicstoday.org. We reserve the right to edit submissions.

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