

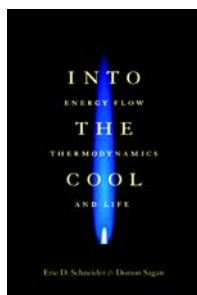
Roger Penrose, Michael Penston, Martin Rees, Peter Scheuer, and Virginia Trimble, along with a new generation of radio observers and a stream of young visitors from around the world. Yet Hoyle, who must have been aware of what they were discovering and its enduring importance, became almost totally disengaged from them and their research. It would be interesting to learn the group's attitude toward Hoyle then and today.

Was Hoyle a genius, and was his life a triumph or a tragedy? Maybe, in the words of the English writer and politician, Edward Bulwer-Lytton, "genius is master of man. Genius does what it must, and talent does what it can." Mitton's balanced and entertaining biography convinces me to agree with the Wester Ross landlord and provides a clear account of how much of the astrophysics and cosmology that we now take for granted came to be understood.

Into the Cool: Energy Flow, Thermodynamics, and Life

Eric D. Schneider and
Dorion Sagan
U. Chicago Press, Chicago, 2005.
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In a universe obedient to the second law of thermodynamics, how is it that life was able to arise, replicate itself faithfully, and ultimately produce organisms of ever greater complexity?



That paradox, discussed by Erwin Schrödinger in his 1943 lecture series "What is Life? The Physical Aspect of the Living Cell," appears in the first chapter of *Into the Cool: Energy Flow, Thermodynamics, and Life* by Eric D.

Schneider and Dorion Sagan. From that starting point the authors launch into a well-researched and often fascinating discussion that covers an impressive range of subjects, including Maxwell's demon (the gnome in James Clerk Maxwell's thought experiment), weather patterns, natural selection, the maturity of ecosystems, and the purposefulness of life.

The disparate topics are linked by the book's central thesis—that complex structures arise spontaneously to eliminate or reduce thermodynamic

gradients because "nature abhors a gradient." For instance, chapter 10 describes hurricane formation. What begins as a modest low-pressure system over the ocean, with vertical air currents, is amplified by positive feedback into a monster storm. Although potentially devastating, a hurricane serves a basic thermodynamic purpose: The massive movement of moist air to higher altitudes where condensation occurs greatly accelerates the transfer of heat from the warm waters of the ocean to the cool reaches of the atmosphere. In that way, the storm acts to reduce a temperature gradient and thus increases the entropy of its surroundings. A hurricane provides just one example in which a complex structure arises to counteract a thermodynamic gradient. Other instances discussed in the book include the hexagonal patterns of Bénard convection and counter-rotating Taylor vortices.

With such examples under their belts, Schneider, formerly a senior scientist at the National Oceanic and Atmospheric Administration and director of the National Marine Water Quality Laboratory of the US Environmental Protection Agency, and Sagan, an accomplished science writer, move on to "the scientific meat" in the book's third section, "The Living." They argue that life itself, far from conflicting with the second law of thermodynamics, is the quintessential example of complexity reducing a gradient, specifically "the immense gradient between a 5,800 K sun and the 2.7 K temperature of outer space." Toward the end of chapter 15, on plants, the authors note that some two-thirds of the radiation impinging on a tree is ultimately spent pumping water into the surrounding air (evapotranspiration) and conclude, unpoetically, that "a tree is best understood as a giant degrader of [solar] energy."

It is well known, of course, that most organisms feed directly or indirectly off the stream of energy that arrives as photons from the Sun. Only by cycling energy and matter through its metabolic network is an organism able to stave off the decay toward thermal equilibrium—that is, death. Schneider and Sagan, however, contend that a "thermodynamic imperative" to efficiently reduce gradients provides the key to understanding such processes as the evolution of species ("Genetics . . . is not enough," they write) and the development of ecosystems. At times the authors give the second law of thermodynamics a Darwinian status, as in chapter 17, where one reads that it "selects" . . .

those systems best able to reduce gradients under given constraints." In the book's final chapter, Schneider and Sagan suggest that tapping into thermal gradients is not just a necessary condition for life but ultimately the explanation of life's purposeful behavior. These ideas are neat, but does the evidence really support them? Although it is true that life, to persist in its state of low entropy, must continually degrade the free energy of its surroundings, it is not clear that a dictate to do so with maximum efficiency is really what drives the biosphere's evolving complexity.

Physicists might also quibble with the authors' promotion of the slogan "nature abhors a gradient" as a kind of distillation of the second law. "The world changes when you view it through the lens of irreversible gradient reduction, rather than mere entropy increases and decreases," they write. The authors envisage "a thermodynamics in which the spontaneous degradation of gradients is paramount." Even if we leave aside gravity, which the authors acknowledge does not quite fit their paradigm, it should be clear that nature does not always abhor a gradient. Entropy is ultimately a more useful concept than gradient reduction for explaining why an oil droplet placed in water does not diffuse while an ink droplet does.

Into the Cool shows that there is much more to thermodynamics than Carnot cycles and phase diagrams. The book delivers an engaging, non-technical introduction to a variety of topics, with some interesting speculations along the way, and an excellent bibliography for those interested in learning more. Although I have not been converted to Schneider and Sagan's point of view, the book left me thinking long after I had closed its pages.

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The Grand Contraption: The World as Myth, Number and Chance

David Park
Princeton U. Press, Princeton, NJ,
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Early conceptions of the universe were vitalistic, mythological, and teleological: Nature was filled with spirits, gods, demons, and purposes. However, starting in about 1600 AD, the universe was understood to have