Where physics meets biology: More information

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In his article "Does new physics lurk inside living matter?" (PHYSICS TODAY, August 2020, page 34), Paul Davies mentions many interesting phenomena in biology, including epigenetic influence in two-headed worms. I agree that such information might be important to both physics and biology.[1]

As I finished reading, I realized the article is advocating quantum biology. Davies cites a claim made by researchers in 2015 "that many biologically important molecules, such as sucrose and vitamin D3, have unique electron-conductance properties associated with the critical transition point between an insulator and a disordered metal conductor."

What I do not know is this: How could bulk material properties such as electron conductance be defined at the molecular level? In my opinion, geometry will be more important than material properties at that level.

Reference

1. J. J.-L. Ting, *J. Appl. Phys.* **125**, 144702 (2019).

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Paul Davies (PHYSICS TODAY, August 2020, page 34) states, "The synthesis of [Claude] Shannon's information theory and thermodynamics led to the identification of information as negative entropy." The second law of thermodynamics states that the overall result of any real physical process leads to an increase of entropy, or in an ideal process, the overall entropy remains constant, but there is no process that leads to an overall decrease of entropy. If information is negative entropy, then any real process destroys some information somewhere, or an ideal process preserves the overall information, but no process can increase the overall information in the universe.

DNA stores information, and living systems utilize it. How, then, did life begin from lifeless chemicals? Is the answer to that question the "new physics" that is required to reconcile physics and biology?

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The article by Paul Davies (PHYSICS TODAY, August 2020, page 34) addresses the importance of information theory in biological systems. As pointed out by Erwin Schrödinger, biological systems gain negative entropy from food and have tremendously less entropy than physical or thermodynamical systems.

Let me quantify that statement. Claude Shannon showed that the entropy in information theory is related to a thermodynamical system through $-k_B N \ln p$, where k_B is the Boltzmann constant, p is the probability of a given state, and N is the state's number of degrees of freedom.[1] The fact that a biological system has huge negative entropy can be explained simply by considering N.

If a DNA molecule acts as one unit of a degree of freedom, as it should, the entropy of a human body is about 12 orders of magnitude smaller than that of a system having free molecules in equilibrium at the same temperature, since the molecular weight of a DNA molecule is approximately a trillion times that of, say, a water molecule. That is, human cells are better ordered by a huge factor (10^{12}) than is a system in thermodynamic equilibrium.

That factor allows the human system to work with a thermal efficiency much higher than a supercomputer's. In a chess game between a person and a supercomputer, for example, the energy efficiencies differ by about six orders of magnitude. A human brain weighs about one-millionth of what a supercomputer does; thus the efficiency per unit weight of a human brain can be 1 trillion times greater, in agreement with the amount of negative entropy of the human cell system.

Since the molecular weight of human DNA is not much different from that in other living cells, a similar argument applies to most living systems. Most other animals do not play chess, but the amount of information processed in their visual and other sensory systems can be similar in magnitude to the human brain's processing capacity. Furthermore, I would say that life is a process of maintaining the system's huge negative entropy through cell division (reconstruction of a cell) and autophagy, while disease and death arise in the gradual and sudden increase of internal entropy or loss of negative entropy.

Reference

1. See, for example, L. Brillouin, *Science and Information Theory*, Academic Press (1962).

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