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Discussion

Committee I, Session IV: Entropy

I

The concept of entropy is problematic. Originating in physics, in particular in the field of thermodynamics, it has been extended to other fields. Since the theme of Committee I is "Unifying Principles of Science," is is logical that the concept of entropy be investigated as such a principle. The three papers presented in this Committee offer a wide range of views, with Professor Leopoldo S. Garcia-Colin at one extreme end and Dr. M. Takatsuji at the other. As I intend to show in my comments they are in fundamental disagreement. Meanwhile, let me begin by discussing Professor Michael Higatsberger's informative and less controversial contribution.

II

Professor Michael Higatsberger has presented a brilliant paper, replete with elegant mathematical formulae, on the genesis of the concept of entropy and its extension beyond thermodynamics to biology (living systems), to quantum physics, to cosmology (astrophysics), to information theory. He lucidly explicates the concept of entropy by showing its relation to the fundamental principle of mechanics known as "the principle of the conservation of energy," according to which the sum of kinetic energy and potential energy remains constant. The laws of thermodynamics rest on this principle. The first establishes that mechnical energy can be fully converted into thermal energy; the second, that "heat cannot by itself go from a cooler to a hotter body," but the reverse, suggesting that an irreversible process of cooling or loss of heat prevails in isolated physical systems. "Entropy" may be taken to mean literally the ongoing process of heat loss -- the transformation of energy into less usuable forms. It is the second law of thermodynamics, then, which is the locus classicus of the concept of entropy. As Professor Higatsberger expresses this law: "The entropy of an isolated system cannot decrease but must increase in irreversible processes; in reversible processes the entropy can utmostly be constant."[1]

Professor Higatsberger marshalls the experimental facts for the concept of entropy in thermodynamics. He also illuminates the concept of entropy by means of a startling analogy.[2] Imagine the physical system comparable to an industrial corporation. Then the measure of energy is like the book keeper with the balance sheet that records the cash flow -- how much money (energy) is coming in and how much is going out, whereas the measure of entropy is akin to the manager of the industry whose job it is to direct production. The analogy is startling, and perplexing, because it imbues entropy with positive worth exclusively, whereas some interpretations of it, such as the dread of "heat death" on a cosmic scale, (which, indeed, Professor Higatsberger discusses in the section of his paper on cosmology),[3] suggest that the proper analogue for entropy consists in the fact that the money going out will ultimately exceed the money coming in, so that the industrial corporation is doomed to bankruptcy.

As Professor Higatsberger demonstrates, entropy increases in closed physical systems which by definition cannot interact with external systems that may restore its heat. Living systems are cited as systems which require a fixed range of temperatures, so that entropy has been indispensable in providing the conditions of life, and making possible evolution, which, when generalized into a cosmic principle, portends a direction within the universe opposite to the prospect of heat death that entropy has aroused. Professor Higatsberger touches on this speculative topic when, in his consideration of entropy in living systems, he remarks: "If energy is not supplied anymore from the outside, thermodynamic processes in a living system lead to an entropy increase."[4] He cites Schrödinger's definition of life as that property in matter manifesting its doing something in a material exchange with its surroundings, and he draws upon Teilhard de Chardin's insight that life is a challenge to entropy. But if every living being is itself a physical system exclusively, if the realm of all living beings -- life in general -- is a physical system exclusively, and if the physical universe in which it dwells is a physical system exclusively, then, assuming the universal and necessary application of the second law of thermodynamics, life will inevitably lose the challenge and perish.

Professor Higatsberger's explorations of entropy in quantum physics and astrophysics titillate the speculative imagination, and he invites us to reflect on such cosmological applications of the concept of entropy as the spectre of "entropy death," of possible other worlds, of an oscillating cosmos. But he refrains from pursuing these speculative theories. Rather he turns to what he esteems to be a fruitful scientific application of entropy in information theory. However, information, like life, is a challenge to entropy. And like life, it, too, may not escape the universal and necessary domination of entropy which culminates in ruin.

III

Professor Leopoldo S. Garcia-Colin acknowledges the contribution of Professor Higatsberger to the expositon of the genesis of the concept of entropy, but he rules against speculative extropolation of entropy beyond its precise application in equilibrium and nonequilibrium physical systems. As he declares in his opening paragraph: "The main point which lies in the heart of this subject is strictly related to a set of experiments that one may perform on a given macroscopic system and it may only be defined provided one clearly specifies which are the thermodynamic parameters defining the state of the system."[5] He adds: "To speak about this function [entropy] in systems which are far away from equilibrium states, or to say that entropy is the supreme law of nature, that it plays an important role in the evolution towards complexity, and so on, without ever stopping to define it in terms of the set of variables specifying the state of the system we are dealing with, is meaningless."[6]

In consonance with his adherence to a strict and exact conception of entropy, Professor Garcia-Colin first reviews concisely the concept of entropy as it is used in equilibrium thermodynamics, then examines penetratingly, "the question of using the Boltzmann entropy and the famous H-theorem as the kinetic theoretical justification for the equilibrium theory and the second law of thermodynamics."[7] Professor Garcia-Colin insists that the two statements representing the concept of entropy differ in fundamental meanings, and, moreover, that it is scientifically improper, given present limitations, to employ the concept of entropy beyond the local equilibrium state. In this regard he presses his investigation further and deeper to reveal that "attempts to extend the concept of entropy to nonequilibrium states using the basic laws of classical statistical mechanics" are unsuccessful.[8] Professor Garcia-Colin's paper is an elegantly formulated essay distinguished for its conceptual clarity, coherence, and economy.

Nevertheless, Professor Garcia-Colin's results must perforce be dismaying to those who would employ the concept of entropy for wider theoretical endeavors of speculative import. Restricting entropy as "a well-defined and experimentally derivable quantity" to physical systems which are in equilibrium, he repudiates its extension to nonequilibrium states beyond local equilibrium because, as he contends, "We are unable to compute the values of this function from first principles, nor are we able to compare them with experimental results."[9] Professor Garcia-Colin concludes:

> In spite of these stringent restrictions on the use of entropy as a physically measurable quantity, its interpretation in terms of order or disorder has been in the author's opinion boldly extrapolated in the field of nonequilibrium thermal physics as well as in other areas not only of physics but other sciences. This is the case of fields such as cosmology, sociology, economy, ecology, etc., where statements about the variable entropy as playing often a dominant role in describing the characteristics of some relevant phenomena are, if not wrong, completely misleading. . .There is no such thing as a universal law of entropy, as it is often claimed, beyond the realm of equilibrium dynamics, at least for the entropy as we understand it presently.[10]

IV

In contrast with the narrow employment of the concept of entropy by Professor Garcia-Colin, Dr. M. Takatsuji notes that entropy has been used in a wide variety of fields other than thermodynamics, including, in addition to information theory, biology, economics, and anthropology. While he is aware that critical objections have been raised against the use and misuse of entropy, the nevertheless, in opposition to Professor Garcia-Colin's thesis, finds these efforts to extend the application of the concept meaningful. As he affirms: "If it is possible that the word 'entropy' contributes to the creation of a new concept of the world, it should be effectively used outside the natural sciences. It is not until the word is widely applied in various fields and a unifying concept is found that 'unity of the sciences' may be accomplished."[11]

Dr. Takatsuji's investigation of the concept of entropy in information theory, in accord with Professor Higatsberger's remarks on the same topic, reveals how, perhaps coincidentally, Boltzmann's statistical analogue of entropy, in its mathematical formulation, was adopted by Shannon. Within the context of information theory, moreover, meaning yields it's place to the statistical character of a whole range of possible messages. Hence, for example, Professor Garcia-Colin's very narrow construal of entropistic applications is one possible message, and there is a wider freedom of choice in constructing other possible messages on the topic. Nevertheless, as Boltzmann's statistical analogue of entropy provides a measure of the amount of disorder in a physical system and suggests that this disorder inevitably increases, then information, instead of confirming the necessity and universality of entropy, seems actually to display negative entropy.

The same manifestation of negative entropy (negentropy) occurs in living systems, as Dr. Higatsberger, following Schrödinger, has suggested. Yet Dr. Takatsuji disagrees with the conventional position that life challenges and, perhaps for a while, defeats entropy. As Dr. Takatsuji says, "It is not necessary to think that living creatures take 'negentropy' as Schrödinger did. They are emitting a large amount of positive entropy in such forms as excretion, perspiration and febrility."[12]

Dr. Takatsuji's most provocative application of entropy is in economics. Here Dr. Takatsuji, while alluding to the Club of Rome's celebrated prophecy that economic growth is limited, goes a step further; he adopts Georgescu-Roegen's declaration that economic growth is myth and cites it as an exemplification of the use of the concept of entropy. "Soon," he asserts, "an 'entropy nation' where costs for gaining a definite amount of resources are equivalent to costs for consuming resources will emerge."[13] However, in such a no growth situation, an economy in equilibrium could in principle exist, providing all participants with a fair share of its production.

Dr. Takatsuji also describes features of Eastern thought and anthropology, especially cultural semiology and Balinese culture, which seem to reflect entropistic characteristics. In these parts of his paper, however, two different sorts of considerations emerge: 1) that in Eastern thought and Balinese culture and cosmology efforts have been made to offset entropy without any conscious awareness of the concept or principle involved, and 2) that in anthropology the concept of entropy has been fruitfully applied (although Professor Garcia-Colin would, no doubt, dismiss this application as meaningless).

In sum, Dr. Takatsuji has courageously dared to speculate about the extention of entropy beyond thermodynamics to other fields, particularly as these affect humans within economic, social, political and cultural institutions. What he sometimes shows, however, is not so much the universality and necessity of entropy as the bulwarks life, man, and culture have raised against it.

V

The range of views expressed in the three papers that have been presented in this section of Committee I raise general questions for the participants. I wish to conclude my comments by formulating three major general questions:

1. How can we ascertain the "meaningful" extension of a concept beyond the field in which it has originated? If Professor Garcia-Colin is correct , it is cognitively unjustifiable to extend the concept of "entropy" beyond thermodynamics, but Professor Higatsberger's records, without criticism, such extensions and Dr. Takatsuji applauds some of these applications. This question has significance beyond the

extensions of the concept of entropy, because a narrow answer to the question may foreclose the discovery of any unifying principles in science, except perhaps methodological principles.

2. How can entropy be used as a unifying principle of science with universal and necessary cosmic reach? This question is raised not only in the light of Professor Garcia-Colin's strictures, but also in light of Professor Higatsberger's and Dr. Takasuji's references to negentropy in open systems such as information, life, and culture. Negentropy, it seems to me, invalidates the claim that entropy exhibits universal and necessary cosmic reach.

3. If, indeed, the answer to question 2 asserts or implies that entropy holds sway over the whole universe and everything in it, what implications does this portend for the theme of the conference, "Absolute Values and the New Cultural Revolution"? For if entropy, whether as the inevitable transformation of energy into unusable forms until the cosmos dies out or as the incessant statistical increase of disorder until chaos prevails, dominates, then at best "the new cultural revolution" is a fleeting episode in the adventure of man, and the "absolute values" he cherishes are mere baubles he gathers along the way of his doomed journey into nothingness.

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Notes

[1]Michael J. Higatsberger, "The Genesis of the Concept of Entropy," p. 2.

[2]Ibid., p. 5.

[3] Ibid., p. 22.

[4]Ibid., p. 14.

[5]Leopoldo S. Garcia-Colin, "Entropy in Equilibrium and Nonequilibrium Systems," p. 1.

[6]Ibid., p. 4.

[7]Loc. cit.

[8]Ibid., p. 5.

[9]Ibid., p. 30.

[10]Ibid., pp. 30-31.

[11]M. Takatsuji, "Entropy as a Unifying Concept," p. 1.

[12]Ibid., p. 5.

[13]Ibid., p. 6.