...In this representation, the economic process neither induces any qualitative change nor is affected by the qualitative change of the environment into which it is anchored. It is an isolated, self-contained and ahistorical process—a circular flow between production and consumption with no outlets and no inlets, as the elementary textbooks depict it. Economists do speak occasionally of natural resources. Yet the fact remains that, search as one may, in none of the numerous economic models in existence is there a variable standing for nature's perennial contribution. The contact some of these models have with the natural environment is confined to Ricardian land, which is expressly defined as a factor immune to any qualitative change. We could very well refer to it simply as "space." But let no one be mistaken about the extent of the mechanistic sin: Karl Marx's diagrams of economic reproduction do not include even this colorless coordinate. So, if we may use a topical slogan for a trenchant description of the situation, both main streams of economic thought view the economic process as a "no deposit, no return" affair in relation to nature.

The intriguing ease with which Neoclassical economists left natural resources out of their own representation of the economic process may not be unrelated to Marx's dogma that everything nature offers us is gratis. A more plausible explanation of this ease and especially of the absence of any noticeable attempt at challenging the omission is that the "no deposit, no return" analogue befits the businessman's view of economic life. For if one looks only at money, all he can see is that money just passes from one hand to another: except by a regrettable accident, it never gets out of the economic process. Perhaps the absence of any difficulty in securing raw materials by those countries where modern economics grew and flourished was yet another reason for economists to remain blind to this crucial economic factor. Not even the wars the same nations fought for the control of the world's natural resources awoke economists from their slumber.

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Revolution is a fairly recurrent state in physics. The revolution that interests us here began with the physicists' acknowledging the elementary fact that heat always moves by itself in one direction only, from the hotter to the colder body. This led to the recognition that there are phenomena which cannot be reduced to locomotion and hence explained by mechanics. A new branch of physics, thermodynamics, then came into being and a new law, the Entropy Law, took its place alongside—rather opposite to—the laws of Newtonian mechanics.

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It goes without saying that to undertake a project of this nature requires venturing into territories other than one's own, into fields in which one is not qualified to speak. The most one can do in this situation is to build on the writings of the consecrated authorities in every alien field and, for the reader's sake, to suppress no reference to any source (notwithstanding the current literary wisdom to minimize the number of footnotes or even to do away with them altogether).

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…It concerns one of man's weaknesses, namely, our reluctance to recognize our limitations in relation to space, to time, and to matter and energy. It is because of this weakness that, even though no one would go so far as to maintain that it is possible to heat the boiler with some ashes, the idea that we may defeat the Entropy Law by bootlegging low entropy with the aid of some ingenious device has its periodical fits of fashion. Alternatively, man is prone to believe that there must exist some form of energy with a self-perpetuating power.

It must be admitted, though, that the layman is misled into believing in entropy bootlegging by what physicists preach through the new science known as statistical mechanics but more adequately described as statistical thermodynamics. The very existence of this discipline is a reflection of the fact that, in spite of all evidence, man's mind still clings with the tenacity of blind despair to the idea of an actuality consisting of locomotion and nothing else.

(page 6 – 7) *Electric vehicles seem to be the current incarnation of this.*

It is by such a complicated metamorphosis, of which not all users of the term "entropy " may be aware, that we have come to speak of the *amount of information* of almost any statistical data. And we march on, without even noticing that this terminological mess compels us to say, for instance, that for a country in which income is more equally distributed the statistics of income distribution contains a greater amount of information !

The code of Humpty Dumpty—which allows one to use a word with any meaning one wishes—is much too often invoked as a supreme authority on terminological prerogative. But nobody seems to have protested that ordinarily the only consequence of this prerogative is confusion. An advertising tendency may have been the father to denoting the numerical value of expressions such as (1) or (4) by "amount of information." Be this as it may, this terminological choice is probably the most unfortunate in the history of science.

(page 8 – 9) *Always wondered about this usage myself!*

Be this as it may, the fact is that the material basis of life is an entropic process. As Erwin Schrodinger crystallized this idea, any life-bearing structure maintains itself in a quasi-steady state by sucking low entropy from the environment and transforming it into higher entropy. Some writers—the French philosopher Henri Bergson, in particular—even contended that life actually opposes the trend of qualitative degradation to which inert matter is subject. Think of the nucleus of some primeval strain of amoeba which may still be around in its original pattern. No inert structure of as many molecules can boast the same tour de force— to resist the disrupting work of the Entropy Law for perhaps as long as two billion years.

(page 10 - 11) *Referring to his "What is Life" lecture in 1943, no doubt.*

…A living being can evade the entropic degradation of its own structure only. It cannot prevent the increase of the entropy of the whole system, consisting of its structure and its environment. On the contrary, from all we can tell now, the presence of life causes the entropy of a system to increase faster than it otherwise would.

(page 11) *Interesting set of debates between Lynn Margulis and Richard Dawkins (after the selfish gene book), where she adamantly opposed DNA and natural selection as the only driver of evolution.*

But aggressive scholarship will never run out of new plans for the "betterment of mankind." Since the difficulties of making an *old* society behave as we want it can no longer be concealed, why not produce a *new* society according to our own "rational" plans ? Some molecular biologists even assure us that our ability to produce "Einsteins from cuttings" is around the corner. But they close their eyes to many elementary obstacles, among which are the supercosmic dimensions of some aspects of the problem and the novelty by combination. Most interesting of all, they do not even seem to suspect that a society made only of geniuses, nay, of people fit only for an intellectual occupation, could not live even for one day. On the other hand, if the man-made society includes also a "productive" class, the inevitable social conflict between the two classes will stop that society from being "rational" (unless the same biological wizards can remodel the human species after the genetic pattern of the social insects).

(page 16) *Like seeing this, social engineering without understanding basic principles, pretty common.*

Instead of looking for a thermodynamic homology in the usual mathematical systems of economics, we may now try to represent the economic process by a new system of equations patterned after that of thermodynamics. In principle, we can indeed write the equations of any given production or consumption process (if not in all technical details at least in a global form).

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Nor does the intimate connection between the Entropy Law and the economic process aid us in managing a *given* economy better. What it does is, in my opinion, much more important. By improving and broadening our understanding of the economic process, it may teach to anyone willing to listen what aims are better for the economy of mankind.

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The Entropy Law does not help an economist to say what precisely will happen tomorrow, next year, or a few years hence. Like the aging of an organism, the working of the Entropy Law through the economic process is relatively slow but it never ceases. So, its effect makes itself visible only by accumulation over long periods. Thousands of years of sheep grazing elapsed before the exhaustion of the soil in the steppes of Eurasia led to the Great Migration. The Entropy Law enables us to perceive that a development of the same nature and of far greater consequences is running its full course now. Because of the pressure of population on agricultural land the area of which cannot be appreciably increased, man can no longer share the, agricultural low entropy with his traditional companions of work, the beasts of burden. This fact is the most important reason why mechanization of agriculture must spread into one corner of the world after another, at least for a long time to come.

The Entropy Law also brings to the fore some fundamental yet ignored aspects of the two problems that now preoccupy the governed, the governments, and practically every scientist: pollution and the continuous increase of population.

(page 19) *entropy will produce pollution, no matter how it's done.*

The most extremist views of the literary group of Vanderbilt Fugitives, many of whom decried the effects of modern technology on the pastoral life of the countryside, would simply pale in comparison with those professed now by some members of the rising class of pollution experts. Other members seem to think that, on the contrary, mankind can simply get rid of pollution without any cost in low entropy provided we use only pollutionless industrial techniques—an idea that betrays the belief in the possibility of bootlegging entropy of which I spoke earlier. The problem of pollution is one of very, very long run and intimately connected with the way mankind is going to make use of the low entropy within its reach. It is this last problem that is the true problem of population.

(page 20) *electric vehicles, again!*

If we abstract from other causes that may knell the death bell of the human species, it is clear that natural resources represent the limitative factor as concerns the life span of that species. Man's existence is now irrevocably tied to the use of exosomatic instruments and hence to the use of natural resources just as it is tied to the use of his lungs and of air in breathing, for example. We need no elaborated argument to see that the maximum of life quantity requires the minimum rate of natural resources depletion. By using these resources too quickly, man throws away that part of solar energy that will still be reaching the earth for a long time after he has departed.

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The realization of these truths will not make man willing to become less impatient and less prone to hollow wants. Only the direst necessity can constrain him to behave differently. But the truth may make us foresee and understand the possibility that mankind may find itself again in the situation in which it will find it advantageous to use beasts of burden because they work on solar energy instead of the earth's resources.

(page 21) *It could be a much reduced population will use mules and oxen again.*

What follows is an extract from my old thermodynamics textbook, at least acknowledging there is something to consider with entropy rather than just steam turbine design. Also appreciate the comment on the "strangeness" of entropy to most people, but then the "false familiarity" the same people have with energy. In actuality they both are abstract concepts that lend themselves to mathematical treatment.

7.17 SOME GENERAL COMMENTS REGARDING ENTROPY

It is quite possible at this point that a student may have a good grasp of the material that has been covered, and yet may have only a vague understanding of the significance of entropy. In fact, the question "What is entropy?" is frequently raised by students with the implication that no one really knows! This section has been included in an attempt to give insight into the qualitative and philosophical aspects of the concept of entropy, and to illustrate the broad application of entropy to many different disciplines.

First, we recall that the concept of energy rises from the first law of thermodynamics and the concept of entropy from the second law of thermodynamics. Actually it is just as difficult to answer the question "What is energy?" as it is to answer the question "What is entropy?" However, since we regularly use the term energy and are able to relate this term to phenomena that we observe every day, the word energy has a definite meaning to us and thus serves as an effective vehicle for thought and communication. The word entropy could serve in the same capacity. If, when we observed a highly irreversible process (such as cooling coffee by placing an ice cube in it), we said, "That surely increases the entropy," we would soon be as familiar with the word *entropy* as we are with the word *energy*. In many cases when we speak about a higher efficiency we are actually speaking about accomplishing a given objective with a smaller total increase in entropy.

A second point to be made regarding entropy is that in statistical thermodynamics, the property entropy is defined in terms of probability. Although this topic will not be examined in detail in this text, a few brief remarks regarding entropy and probability may prove helpful. From this point of view the net increase in entropy that occurs during an irreversible process can be associated with a change of state from a less probable state to a more probable state. For instance, to use a previous example, one is more likely to find gas on both sides of the ruptured membrane of Fig. 6.11 than to find a gas on one side and a vacuum on the other. Thus, when the membrane ruptures, the direction of the process is from a less probable state to a more probable state and associated with this process is an increase in entropy. Similarly, the more probable state is that a cup of coffee will be at the same temperature as its surroundings than at a higher (or lower) temperature. Therefore, as the coffee cools as the result of a transferring of heat to the surroundings, there is a change from a less probable to a more probable state, and associated with this is an increase in entropy.

The final point to be made is that the second law of thermodynamics and the principle of the increase of entropy have philosophical implications. Does the second law of thermodynamics apply to the universe as a whole? Are there processes unknown to us that occur somewhere in the universe, such as "continual creation," that have a decrease in entropy associated with them, and thus offset the continual increase in entropy that is associated with the natural processes that are known to us? If the second law is valid for the universe (we of course do not know if the universe can be considered as an isolated system), how did it get in the state of low entropy? On the other end of the scale, if all processes known to us have an increase in entropy associated with them, what is the future of the natural world as we know it?

Quite obviously it is impossible to give conclusive answers to these questions on the basis of the second law of thermodynamics alone. However, we see the second law of thermodynamics as a description of the prior and continuing work of a creator, who also holds the answer to our future destiny and that of the universe.