The Mutual Implication of Physical and Informational Entropies

(February, 2001)

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We can begin with the Carnot/Clausius physical entropy (entropie). It is basically a measure of the lack of efficiency of work done on an environment in which energy gradients are found. That is, we have a system that is organized so that it can do work, and this system abuts an energy gradient, which it can harness with a certain maximum efficiency for that work. The energy in the gradient in question is degraded during the work, having been dispersed by it or transformed into other forms. Other forms of energy are less (or not at all) suitable to do the work the system does, and so, with a finite gradient, the efficiency with which the system can carry out its work diminishes. As well, whatever is left of the original gradient will have been deranged as a result of its utilization, which we can describe as the gradient having been diminished. This too impairs the efficiency with which the available energy in the gradient can be harnessed (as exergy) to produce the work. Our system will have to find, or be presented with, more of the energy in question, available in a suitable gradient, or it will eventually cease doing the work in question. The loss of efficiency of doing its work as a result of the transformation of the energy source while doing that work, plagues each material system, and is signaled by the Second Law of Thermodynamics. This labels the irreversibility of the conversion of usable forms and configurations of energy into unusable ones (or the loss of energy availability) as a result of a diminished efficiency of the transformation of available energy to work, as generated by doing that work.

If our system and the energies are inside a larger isolated system, we could show that the total amount of all energies in the system will not have changed after the work has been done, and this is the First Law of Thermodynamics. What has changed is the suitability of the remaining energies to be harnessed by (or be available to) the system in question to do the work we have been talking about, which has decreased irreversibly. In this setting, it can also be shown that, if the work done is accomplished more and more slowly, its efficiency would increase, until the point where barely any work is done at all in a given time period, when the efficiency of doing it will hardly be impaired at all in the doing, and in this situation the work done can be reversed at no cost as well. But all significant material systems need to do work at rates that make the transformation of energy irreversible -- that is, they must dissipate some of their energy sources in directions unrelated to their needs (like taxes or tributes) because they need to accomplish something just in order to persist .

The degree of inefficiency is called entropie (I use Carnot's original French spelling here to distinguish this particular kind of entropy from the general concept). It is measured indirectly using the amount of energy dissipated during work less the amount that was harnessed successfully to the work. If a process is 30% efficient, the entropie produced during its operation is such that 70% of the available energy in the gradient will have been converted to unusable kinds or configurations of energy because of the production of entropie, which is related to disorganization. If a machine can utilize a particular form of energy with a maximum efficiency of 60%, the entropie of that energy source, for that machine, will start at 40%. If the overall process, as above, is only 30% efficient (because of heat produced by friction, for example), then the entropie relative to that energy source will have increased by 30% to 70% overall. Entropie is not itself a form of energy; it is not useless energy. Instead, it is a measure of inefficiency, which always results in energy becoming useless for a given system, and which is generated to the degree that the work done is accomplished hastily -- as with monkeys eating fruit in treetops getting only some of it into the gut.

While the measure of entropie is the heat energy given off during some process divided by the ambient temperature (its units are ergs/degree), since degrees are a measure of average kinetic energy at the molecular level, entropie is essentially dimensionless. Therefore, it would seem that those physicists who take entropie to be informational in character make a good point. The insight here is that the nature of the material arrangements (their relations) will affect the efficiency of a process. This approach was broached by Boltzmann with his statistical mechanics, which focuses, not so much on macroscopic mechanical arrangements, but on the distribution of microscopic particles.

If left to themselves the molecules of a gas will gradually distribute themselves randomly by way of diffusion. When they have reached their widest dispersion, their macroscopic statistical properties will stop changing, because they will have reached an equilibrium distribution -- the most probable distribution given the constraints -- where any further changes that take place, with some particles replacing others at any given locale, will give rise to no further changes in the macroscopic properties of the ensemble, like density, temperature or volume. In order for heated air to do work, it must be concentrated at a locale. As it spreads out from there, its density and temperature will decrease as its volume increases. An energy gradient can be visualized as energetic particles all concentrated in a particular place. As they spread out from there in the process of seeking an equilibrium distribution, their energy will diminish, having been converted by friction to heat energy, which by definition is not oriented in any particular direction (and so cannot be used to do work). Energy that is available to do work instead has an arrangement favoring its transformation to directed kinetic energy. With hot air, that could involve making it flow through, say, a narrow aperture, allowing only the molecular rush in one direction to be expressed, mobilizing the rest to maintain a temperature gradient by way of constrained random movements in a decreasing volume behind the aperture.

Note that, left to themselves molecular particles will just diffuse to an equilibrium distribution, and then jiggle around to no further macroscopic effect. Furthermore, in order for there to be energy gradients, work must have been done to concentrate the particles. Boltzmann defined entropie -- his S -- as related to the degree of undirectedness of molecular motion. So, the most probable distribution of particles -- the fully random one, when they move as likely in one direction as another -- has maximum S. Any more asymmetric distribution will have some possibility of being made available to do work, or to become exergy. And so any situation that is not at equilibrium will have a tendency to increase its S, and this tendency can be harnessed in principle to do some work on the way. So, when an energy gradient is used to do work, the end result is a scattering of the energies into different forms, including heat energy. We might note here that once again entropy is a question of the arrangement of a setup, but something else has been added.

If we look into the actual distribution of individual particles, we will find that at equilibrium there are very many configurations (Boltzmann's complexions) that would express the same macroscopic properties, like temperature. One could say that the situation is very disorderly microscopically. If we look instead at an energy gradient, there would be many fewer molecular configurations that are compatible with the macroscopic properties characteristic of that situation. An energy gradient is more orderly in that one could (in principle) better predict its microscopic configuration at any given moment than if its components were at equilibrium. S is defined as the number of microscopic states that are compatible with a given macroscopic condition. So, S is proportional to the variety of microscopic states compatible with a given macroscopic situation. This is maximized at equilibrium.

Taking stock here, we can note that entropie is informational in that it involves configurations that affect the efficiency of the conversion of energy gradient to work. Gradients are orderly, and must be in order to be harnessed to work. S too is informational, involving the configurations of microscopic particles. In each case, entropie or S, the entropy is a matter of missing information. In the first case it is information about macroscopic material configurations, which, when lacking, allows a disorderly (less efficient) dispersion of energy gradient. In the second case this missing information is that which might have prevented the unconstrained diffusion of energetic particles. But in this case missing information is also found as a result of microscopic dispersion itself, because of which it would take considerably more information (called microinformation by Layzer) to locate any given particle, or to predict any given microstate, than would be the case if the particles were constrained into some more orderly configuration.

In Boltzmann the missing information relates indirectly to missing barriers to diffusion and directly to the uncertainty of configuration of the microscopic particles. With entropie the missing information relates to missing barriers to undirected dispersion of gradient, and also to information affecting the rate of gradient utilization. In both cases, if all information is missing the entropy will be maximized as the energetic particles just diffuse away.

A major difference between entropie and S appears in the fact that entropie production will be increased by rapid gradient utilization. This appears not to be modeled by Boltzmann, although the resulting scattering of gradient particles would be. In other words, Boltzmann did not model one of the causes of entropie with his S, which models only, one might say, the more basic cause of spontaneous diffusion -- a law of matter. With Boltzmann we discover that a necessary increase in entropy, if it changes, can be taken to be a major factor in the material world, but we lose sight of one aspect of it. It is my opinion, however, that we have gained something equally valuable -- the ability to generalize entropy up to macroscopic systems in another very important way, that involving the concept of information.

The concept of information used in infodynamics is as follows. The growth of material systems involves the generation of informational constraints, which can be taken as degrees of freedom, or as new symmetries. If these symmetries are broken, or the degrees of freedom they provide are reduced or fixed, then information neat is generated. This connects with the negentropy principle of information (NPI) as follows: a system having multiple fixed, or (as in behavior) sequentially revisable, degrees of freedom can exist in many different variant forms, generated by permutations. The deployment of a collection of these variant forms in irregular patterns generates uncertainty as to the meaning of these variables for any system needing to relate to their configuration. This uncertainty implicates, once again, missing information, which here can be seen to project information carrying capacity upon the locus of the variables.

The missing information in the Boltzmann case is microinformation, which many thinkers do not believe functions as genuine information. In order to see that it does, it is necessary to think in terms of isomorphies across scale. Microinformation would be actual information only for microobservers, or systems of interpretance functioning at the microscopic level. In order to think about these, it is necessary to be able to generalize the notion of interpretation -- as has been done, for example, in biosemiotics, to the cell, taken as interpreting its DNA messages. Once one has generalized this far, it is in my opinion impossible to prevent further generalization to any coherent system that is affected by its surroundings -- macro- or microscopic.

These relations have been formalized in the Shannon information capacity (H) concept, which is formally isomorphic with Boltzmann's S. The latter is more highly specified than H in requiring more variables to scale it to a particular kind of material system. That is: {H { S }} -- S is a kind of H, or, molecular disorder is a kind of uncertainty for a particular kind of observer. So, H and S are metaphors (in Rosen's sense) of each other, with H having meaning for potentially more kinds of observers than does S.

Many natural scientists object to this particular metaphorizing because it does not appear to be useful in dealing pragmatically with the world. Here we are more concerned with the intelligibility of our picture of the world than with trying to harness it to our interests.

In order to weld a tighter bond between H and S we need now to deal with the fact that S is a necessarily increasing variable in an isolated system. Is H necessarily increasing? Or rather, when is H necessarily increasing? Cosmologists and some biologists have noted that H necessarily increases in expanding or growing systems. It is my contention that most if not all material dissipative structures expand or grow. I have also tried to show that when observed from inside a system, the amount of uncertainty that system has to deal with necessarily tends to increase if it attempts to acquire information about its environment, provided that the latter is at all complicated and closes upon itself in any way. This is so because the search, being a material activity, will impact the world in unknown ways, the results of which will propagate outward, eventually to return to the system as new uncertainty. The more a system learns, the more it will have to learn (perhaps, it may be, in diminishing amounts). These strictures on H being a necessarily increasing value seem to map pretty well to the material world, which is both expanding and observed (by us) from within.

Now, entropie increases faster the more effort is applied over a given time period because the efficiency of that effort will decline as the effort increases. Entropie is a kind of negefficiency, or negative specificity. How might that relate to information being a kind of negentropy? Well, of course, energy use efficiency relates to just how particular informational constraints in a given locale are reduced, and how, as variables in equations of state, they relate to each other. But to get at effort we need to map H to, in my opinion, the rapidity of interpretation. We would like to say that the efficiency of interpretation decreases as the rapidity of its formation increases. That is to say, singularity of interpretation should be hampered by an increase in possible interpretations as the speed of interpretation increases. Efficiency here is mapped to accuracy. As an energetic system is more efficient, it more accurately applies available energy to its work. It seems plausible that snap judgments are less likely to be "correct" than more leisurely considered ones (leaving aside intuition, which is not a valid category in information theory anyway). As effort increases, more available energy is utilized per unit time, AND proportionally more of it is dispersed in directions unrelated to the work at hand, showing that negefficiency has increased. As the speed of {reading} increases, more possible directions of interpretation might be spun off than are useful in understanding -- the number of complexions of interpretation increases, perhaps in an exponential way. And, of course, this relates to the scale of {reading}. A rapid computer can assimilate information properly presented to it faster than we could, but it seems plausible that even its accuracy should eventually break down with further increases in required speed. Just as entropie involves both the given arrangements of material configurations AND the speed of energy utilization, so H involves both the equivocation generated by the source and the noise accrued in the process of interpretation, which should increase with haste.

I conclude that, as entropie is negefficiency, so H is a bonafide entropy. Like S, it must increase if it changes in the material world; like entropie, it signals stuff oriented away from what is needed by the activities of the system needing it -- but for H this is information instead of energy.

So, I will conclude that, in general, entropy (including entropie, S and H) is a deficiency in what is needed (available energy or information -- or whatever) which is generated by the activities requiring it, to the degree that these activities are not well configured for the purpose, or are strenuous or hasty (therefore clumsy). Since activities would likely be strenuous in a situation not designed for them, the lack of perfect context seems basic. However, entropy will necessarily be generated by any system that is expanding -- or, one might say, just falling apart, as in diffusion. Here too, since the expanding system cannot remain perfectly contextualized by an environment not expanding in synchrony with it, the lack of designed context seems crucial. I have suggested that entropy is the preeminent sign of the material world, where every activity -- work, interpretation and even decay -- is taxed to the degree that it progresses rapidly in an imperfect setting. It is the progressive tax of the material world, which is never quite appropriately contextual, and therefore always requires effort in energy consumption.

From the point of view of any consumer of energy, entropy is a liability, a tax, but from the point of view of the global system, where, via the First Law of Thermodynamics, we see that various kinds of energy get transformed into each other, entropy could be seen as the mediator of a plenitude of energy utilizations, as it prohibits total consumption by the greediest consumers. So it allows energy to be deployed in the greatest number of pathways, and so favors the greatest number of energetic links. In this role it feeds energies in the direction away from locales of maximum entropy production and in the direction of minimum entropy production locales. That is to say, it directs energies toward relatively senescent systems.

I thank John Collier, Sungchul Ji and Edwina Taborsky for interesting comments.