EVOLUTIONARY INDICES

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1. Introduction

As *Homo sapiens* we have always believed that we are higher organisms. After all, we are more complex, more differentiated, more highly ordered than lower organisms. As thermodynamicists we recognize these words and realize that the concept of entropy must somehow enter into the explanation of this.

We have always had the vague notion that as higher organisms have evolved, their entropy has in some way declined because of this higher degree of organization. For example, Schröedinger made his famous comment that the living organism "feeds on negative entropy." We reason that this decreasing entropy of evolving life, if it exists, does not in any way, violate the second law of thermodynamics which states that the entropy of an isolated system never decreases. The living system is not isolated and the reduction in entropy has been compensated for by a correspondingly greater increase in the entropy of the surroundings. It does not violate the letter of the second law, and yet something about it seems to make us uneasy. Why should the evolution of the living system constantly drive in the direction of increasing organization while all about us we observe the operation of the entropy maximum principle, which is a disorganizing principle? I know of no other system except the living system which does this.

First of all, can we establish that the entropy has, in fact, declined in higher organisms? No one has ever proved this quantitatively. In fact, one can argue that it is impossible to establish this thesis by classical means because of the uncertainty principle in its broadest sense. In particular, if we were to make the precise and extensive measurements necessary to determine accurately the entropy difference between a higher and a lower organism, these measurements would disturb the living systems so much that they would kill them. So, it is impossible by classical means to even establish this proposition in which almost all of us seem to believe.

When concepts break down like this they are of little use to us. I think that our classical notions of entropy are totally inadequate in dealing with the living system. This does not mean that there is anything mysterious, supernatural, or vitalistic about the living system. It simply means that our classical notions of entropy are inadequate, just as the laws of Newtonian mechanics were inadequate in dealing with the interior of the atom.

I shall extend the entropy concept primarily through the apparatus of information theory, but I shall extend this also. Shannon [10] gave the most general