

Entropy and the Laws of Information

Dick E. Hammond

Dick E. Hammond is an associate professor of human development and science education at Southwest Texas State Univ., San Marcos, TX 78666. He holds an A.B. in Psychology, an M.A.T. in General Science and an M.S. in Science Education from Indiana Univ. He earned his doctorate in education at the Univ. of Arkansas. Hammond has authored several publications, including the recent book *The Human System: From Entropy To Ethics* (Ginn, 1985) and an article in *The Science Teacher* entitled "Racing Through Space." He also writes for the American College Testing Services. Current chair of the Southwest Texas State Phi Delta Kappa chapter, Hammond also chairs the science education division in the Texas Academy of Science. In 1985, he was honored with the Distinguished Service Award by the Science Teachers Association of Texas.

The second law of thermodynamics is indeed an order-degrading principle *in itself and without constraint*; but when we place it under the control of the higher laws of information theory, it becomes directly responsible for the production of order of a very important type. This is why life has arisen (Gatlin 1972).

The Laws of Thermodynamics

Every student in the United States is exposed to the two laws of thermodynamics. Clausius set down the very terse versions of the energy laws in the 1850s:

1. The energy of the universe is constant.
2. The entropy of the universe tends to a maximum (Kubat 1975).

Today, with more accumulated knowledge, teachers and textbooks use broader definitions:

1. Energy-matter cannot be created or destroyed, but can only be transformed one into the other and moved about from place to place in the universe.
2. Energy-matter will tend to maximum randomness in any isolated or closed system.

There are, of course, many other ways these two laws can be, and are, expressed. But, whatever the expressions, the basic concepts remain the same:

1. Humans have found no way to get energy-matter from nothingness, and no way to annihilate it.
2. All systems tend to go to disorder eventually, even the most complicated, living, open systems which maintain and repair themselves by taking in and expelling energy and matter as long as they live.

What gives living systems, especially humans, this measure of success in spite of the entropy law? That is what information theorists ask themselves. And that is why information theory is coming to play such an important role in understanding life's place in natural phenomena.

Optimal mastery of the physical laws notwithstanding, life would have been stymied in its growth at an early stage if not for the development of complicated systems of information, control, and data processing (Tributsch 1982).

The Laws of Information

What is being discovered are a new set of laws which necessarily evolved for life to cope with the laws of thermodynamics. Analyzing both sets of laws helps students better understand life's evolution.

The First Law of Information: INFORMATION, GENETIC OR LEARNED, EXISTS IN THE ARRANGEMENT OF MATTER.

The arrangement of matter yields us information and determines our form and function, as it does for any other living system. What makes humans so different from other life forms is their ability to arrange matter outside themselves, and to recognize it as representing something which it is not. Pictures, films, records, photos, models, graphs, charts, maps, words, numbers, etc. are an infinite variety of symbols to represent the rest of nature. A painting of three trees is not three trees. The words "three trees" are not three trees. And the number "3 trees" is not three trees. Rather, they are all ways for us to communicate with each other about trees. They are ways of symbolizing and classifying nature, so that nature becomes manageable to the human brain.

Since there are an infinite number of forms and functions, properties and relationships in nature, humans assemble into groups and categories those representations which will be the most beneficial to each oncoming generation. We start with each child's immediate self and environment. This is what each language, each culture and each family does for their new generations. It is necessary for survival that, within each language, nature becomes classified and manageable for communication and for the higher

education of each new human.

Education is responsible for human beings acquiring higher and more complex communication skills. But the infinite number of symbols cannot simply be dumped randomly into the brains of children. Education also has the task of organizing what goes into the brain for the better building of communication skills. This is the difference between instilling confusion and understanding. Educators must help each student understand the symbols which stand for other natural phenomena. This is how the tree of knowledge, awareness and logical reasoning grow best inside the human brain. And it is because the roots of knowledge are in the arrangement of matter, the residence of information.

The Second Law of Information: INFORMATION, GENETIC OR LEARNED, REGULATES TIME, ORGANIZES MATTER, AND CONTROLS ENERGY FLOW.

If energy is to be stored rather than scattered; if energy flow is to be slowed down or speeded up; or if energy is to have its direction of flow channeled, then the organization of matter by humans is imperative.

The plants discovered this simple fact long before any humans were around to become aware of it. Oh, that the human system could trap the scattering energy from the sun and store it so easily! However, like the other animals, we cannot eat direct solar energy. For our own bodily growing and going, we are completely dependent on the entropy decrease taking place inside the plants.

Like the work of the chlorophyll in the plants, the information in the genes of all living systems builds the systems (arranges the matter) in order to control energy storage and flow. There is no other way to existence for life. Fortunately, we do not have to think about building our circulatory systems, or any other of our subsystems which make us whole. What a task that would be!

As humans become more energy wise, we are seeing the necessity for education to place more and more knowledge about energy into the curriculum. Humans have now also come to realize that the information entering the brain (via energy transmission) has enormous control over how each person uses his energy in behaving. In fact, any considerations about human behavior are considerations about how the human system uses energy.

The Third Law of Information: INFORMATION, GENETIC OR LEARNED, IS INVERSELY RELATED TO ENTROPY.

If there is not some structure to matter, some organizational arrangement in matter, then there can be no energy control. In other words, without the orga-

nization of matter (which is the same as high information and low entropy) the energy laws tell us that energy rapidly disperses to an unusable state. Energy scatters from an area of high concentration to one of low concentration. We see this one directional flow from a burning candle, from a sound source, from any mechanical device, from an electrical system, and fortunately for us, from the sun. If that tendency to flow toward equilibrium is to be reversed, then additional time, energy and matter must be used from outside the system. In addition, know-how, which comes from information and reasoning, must be applied.

Human engineering performs this feat quite well, as can be observed in the example of the refrigerator-freezer. Just plug in the electric cord of the refrigerator and the heat energy inside is moved to the outside. Inside, the entropy will decrease. A tray of cold or frozen water molecules has more order, less entropy, than the same hot water with molecules rapidly evaporating. But outside the refrigerator, all the energy leaves as heat, and some unwanted sound, going out into the space around the earth. The energy is lost from further human usage, except for warming the kitchen a bit along the way.

The point is that humans have learned how to reduce entropy locally. The know-how comes from the human brain. We see that even a simple closed system like a heat pump can have its internal entropy reduced. But, as we are all aware, the refrigerator, like any other functioning device built by humans, will eventually wear out and deteriorate.

This is precisely what all living systems have had to contend with. They have had to control the flow of energy to exist, because they have had to reduce entropy to exist. But unlike the education needed to develop the engineer, the genes evolved the same know-how billions of years ago, with an added dimension not yet simulated by human engineering. Since any individual functioning system will eventually wear out, something more is needed for prolonged survival. The genetic solution was, and still is, to assimilate usable elements into living systems, along with energy. This process has led to an infinite variety of open systems. Therefore, unlike the closed systems built by engineers, the living, open systems are able to make internal repairs.

But there is still another aspect of the living, open system which is just as important as internal maintenance, and perhaps even more so. The information in the genes must be reproduced for each cell in a living organism, and it must also be passed along from one generation to the next or else the whole process of reducing entropy would cease. This leads to the possibilities for constantly changing evolution built into each one of us, into each species and, indeed, into all of life on earth.

Because the organizational arrangement of matter (information) is the key to prolonged survival, it is not surprising that the brain has evolved to such prominence in living systems. But the brain evolved enormous flexibility, unlike the fixed genetic information each one of us inherits at conception. Throughout nature there are infinite possibilities for the arrangement of matter. If the human brain were to cope with all the possibilities, the best survival tactic would be to have as few restrictions as possible on what information the brain could accept.

We see the flexibility of the brain when we conceptually survey all the past and present human cultures. Think of the number of different languages. Because the brain is so flexible, an infinite number of written and spoken words are possible. They represent the infinite variety of forms and functions in the rest of nature. This accounts for the many different types of beliefs, customs and traditions expressed in human cultures. The human brain, like the genes, is geared for adaptation and change . . . but can work at it more rapidly than the genes . . . a tested way to survival.

The genes have been wending their way through the branches of biological evolution for billions of years. The genes found a way to utilize energy and matter for prolonged survival. Now the human brain is becoming aware that it too must work with the same natural phenomena, if the human system is to be successful in continuing to inhabit this planet.

The Fourth Law of Information: INFORMATION, GENETIC OR LEARNED, IS CREATED AND DESTROYED.

When a library is burned down, or when a tapestry is eaten up by moths, or when a child's quilt is dissolved in acid, the energy and matter of which the items are made are not destroyed. There is no way to create or destroy energy-matter. But the buildings, the books, the symbols, the pictures, the numbers and the child's quilt can be destroyed. They can be sent to high entropy fast, and that is not often to our liking.

The organized matter is what makes the world around us manageable and meaningful. When this organized matter and concentrated energy (information and locally reduced entropy) are lost from our further usage, we do not weep because the energy and matter have been dissipated and dispersed. Of the billions of people who have existed, most of them have not understood that energy-matter cannot be created or destroyed. But still, humans have had to make organized matter and organizing matter very valuable to them. It should remain so, and is one of the most basic values educators can pass along to their students. Why?

1. Because of evolution and communications, as

we have seen.

2. Because the cost of replacing organized matter can be very great in terms of more money, time, knowledge, matter and energy required.
3. Because the immediate loss of organized matter can threaten the very existence of the loser.

Deterioration, decay, destruction and death all remind us how fragile existence is. Better to punish the destroyer and praise the creator!

References

- Blum, H.F. (1968). *Time's arrow and evolution*. Princeton: Princeton University Press.
- Campbell, J. (1982). *Grammatical man: Information, entropy, language and life*. New York: Simon and Schuster.
- Gatlin, L. (1972). *Information theory and the living system*. New York: Columbia University Press.
- Jastrow, R. (1981). *The enchanted loom: Mind in the universe*. New York: Simon and Schuster.
- Kubat, L. & Zeman, J. (Eds.). (1975). *Entropy and information in science and philosophy*. New York: Elsevier Scientific Publishing Company.
- Lehninger, A.L. (1973). *Bioenergetics*. Menlo Park: W.A. Benjamin, Inc.
- Tributsch, H. (1982). *How life learned to live*. Cambridge: The MIT Press.

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