[University of Dayton Review](https://ecommons.udayton.edu/udr?utm_source=ecommons.udayton.edu%2Fudr%2Fvol8%2Fiss3%2F10&utm_medium=PDF&utm_campaign=PDFCoverPages)

Volume 8
Number 3 *Winter*

Article 10

December 1971

Thermodynamics and Life

Frank L. Lambert
Occidental College

Follow this and additional works at: https://ecommons.udayton.edu/udr

Recommended Citation

Lambert, Frank L. (1971) "Thermodynamics and Life," *University of Dayton Review*: Vol. 8: No. 3, Article 10.
Available at: https://ecommons.udayton.edu/udr/vol8/iss3/10

This Article is brought to you for free and open access by eCommons. It has been accepted for inclusion in University of Dayton Review by an authorized editor of eCommons. For more information, please contact mschlangen1@udayton.edu, ecommons@udayton.edu.

Thermodynamics and Life

Frank L. Lambert

Many capable people have made many foolish statements when they tried to apply principles from physical science to the complexities of human goals and behavior. So, in sharing with you some views of a possible relation of thermodynamics with human life, I want to underscore a caution before we begin: The model which I develop has no special aura or built-in "truth" just because it uses words and concepts from chemistry or physics. A model in science or elsewhere is valid only if it is viable, only if it predicts or correlates better than previous hypotheses. And the best model leads to some kind of a crucial test of its validity so that it can be disproved and discarded, or modified, or accepted and applied.

That has been the weakness of even modern discussions of the human situation in scientific terms; the models are non-verifiable and no more useful than ancient constructs involving words such as will and freedom and spirit. At the very least I trust that my development of some basic principles from chemistry will be stimulating. Much more, I hope that some of you might find the discussion worth challenging and modifying to build a better, more operational model.

Basic Statistical Thermodynamics. The Two Tendencies.

Why do things happen? Why does a mountain stream run downhill, and shiny iron nails rust, and tools wear out? Why shouldn't a wrecked car heal itself and become usable again? These questions are worth more than a moment of amused thought, unless you are an auto repair man—in which case the last one would be downright terrifying.

But countless human experience and large body of laboratory evidence from chemical reactions indicates the invariable behavior of inanimate matter. It tends to run downhill—literally and figuratively. It tends to become disorderly. A thermodynamicist would describe it somewhat more pedantically, but more precisely, by saying that there are really two irreducible properties of matter that describe the behavior of any system containing matter and energy. First, matter spontaneously tends to occupy the lowest energy level available to it. Secondly, if energy is constant, matter spontaneously tends to occupy any one of all of the possible quantum states with equal probability.

The first property is ordering and confining in the sense that it tends to restrict matter and energy to the lowest energy level. In contrast and in opposition to this, the second property is dispersive and disordering in that it is associated with randomness: a system may be found in any one of many possible equal-energy states at any given moment instead of being uniquely located in some single state.

In homely terms there is a never ending tug of war between these two inherent

trends. In extreme cases each trend appears to dominate. The tug of the other is weak. For instance, at high temperatures there is a lot of energy, and matter can be totally random in its location and its motion from place to place. Think of how droplets of water skitter around on a hot frying pan. Do you think that the molecules of steam that they change into are moving any less violently or in a more orderly pattern? Disorder usually predominates over the ordering trend in high energy situations. On the other hand, at very low temperatures—forty below zero, 450 below zero Fahrenheit—those same little water droplets change to ice and snowflakes, elegantly ordered crystals. At low temperatures, where there are only low energy levels available, the restricting and confining tendency predominates. And unchanging rigid patterns are what we see rather than disorder.

Now these clear extreme cases should not lead us away from the less obvious situation in all inanimate systems of objects and energy, namely, they inevitably move toward a dynamic *stable* balance—an equilibrium—of the downhill (ordering) tendency and the randomizing (disordering) tendency. Only in this non-anthropomorphic sense of movement toward an ultimate equilibrium of the two opposing tendencies does inanimate matter have a "goal."

Thermodynamics and Living Systems

Stable, Unstable, and Metastable Equilibria

Unlike inanimate systems which must move toward unchanging stable equilibrium points, all mature living organisms maintain themselves in complexly ordered biological (and psychological and social) patterns at high energy levels in metastable equilibrium.

A mechanical analogy using a frictionless ball and equally smooth hills and valleys can clarify the contrast between a stable, an unstable, and a metastable equilibrium.

A stable equilibrium would be represented by Figure 1 in which the ball does not have much energy but ceaselessly rolls back and forth across the bottom of the valley and part way up the side of the hills. This would be a moderate-energy system with some order, some restriction, but still a good many different possibilities

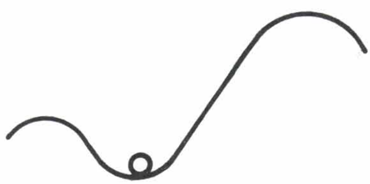

Figure 1. Stable equilibrium.

for the position of the ball. If now some energy is removed from the ball to an outside reservoir, the ball would rest in only one position at the valley bottom, a very low-energy, very stable situation.

An unstable equilibrium would be shown by Figure 2 wherein the round ball is poised at the smooth top of a hill. This is not a probable resting place; the slightest sideward force on the ball would result in its rolling downhill. This is a high-energy situation with much potential for the ball to move to many positions on the hill-sides. If energy is removed from the ball at any time, it will fall to rest at the bottom of the valley—a lower energy situation than that shown in Figure 2; obviously one of greater order with no potential for variations in the position of the ball.

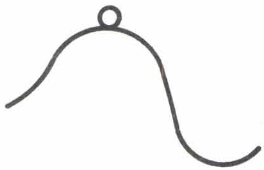

Figure 2.
Unstable equilibrium

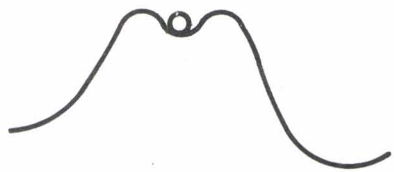

Figure 3.
Metastable equilibrium

A metastable equilibrium would be a system in which the ball is prevented from dropping to a lower level by barriers of adjacent small hills, as in Figure 3. This differs from a stable equilibrium in that there are lower valleys than the ball's present position to which the ball could fall. Thus, a metastable equilibrium is comparable to an unstable equilibrium because a relatively small input of energy (or disruption of the system by "tunneling" through one of the small barrier hills) will allow the ball to drop to a lower energy level. In this sense, the metastable situation is one of tension between randomness and order, between the possibility of the ball moving to any one of a number of different positions on the hillside or the valley if tunneling could occur (a rough parallel to randomness) and the ball's continuing to be confined at a high energy level by the barrier hills (a rough parallel to complex order).

In relatively high energy systems, such as our earth with its sun, inanimate matter is greatly patterned and orderly only when there is little possibility for change. Such a tautology becomes significant when it is contrasted with the behavior of living organisms. Salt or sugar crystals have beautifully symmetrical shapes because of the strong attractive forces which hold their individual particles in regular array. But as a further consequence of these attractive forces, crystals lack the potential to change their rigid structures into radically new patterns or to move spontaneously through space. Conversely, inanimate matter which is capable of change or is freely mobile, such as the darting molecules in a gas or the particles of dust in a storm, shows little pattern. Great molecular "freedom"—either in the sense of a number of different possibilities of position and momentum, or in the sense of being able to change into many other substances spontaneously—this freedom does not coexist with a great deal of order in inanimate systems. Any time that a system is at a relatively high energy level there is much possibility for

change, but then there is little pattern. Living organisms are in startling contrast to this generality: They consist of matter at a relatively high energy level and not only is it composed of remarkably patterned giant and small molecules, but also these molecules are rapidly interacting in processes which themselves are patterns within patterns within patterns. And, unlike inanimate matter, living creatures are not continuously losing energy to their surroundings and dropping to a low-energy, ordered stable equilibrium. They must take in energy to continue living, to maintain themselves at a metastable equilibrium, always at an imminently changeable tension point between the two opposing tendencies of order and randomness. Life in any form is thermodynamically improbable.

I am not claiming that living beings have been quantitatively treated by thermodynamics. They may never be. However, it is now generally agreed that living organisms function qualitatively as metastable, dynamic flow systems such as whirlpools or steady flames. Now, the overwhelmingly greater complexity of a plant or an animal than a flame is obvious. The flame takes in matter and releases altered matter and energy, but it contains relatively few sub-systems. Equally significant, only a slight change in its input or its environment upsets it so much that it goes out. The high-energy metastable equilibrium has been tunneled. The system steadily moves toward a lower energy, more stable equilibrium.

The animate is a metastable flow system with a staggering number of constant, yet dynamic, interdependent biochemical subsystems that make the organism capable of adapting to multifarious changes in its environment. I think that we will find it helpful to define "homeostasis." This term, dynamic homeostasis, has been used to encompass all of the media and mechanisms by which the organism maintains itself within narrow physiological limits despite wide environmental variations. I would like to broaden this usage to emphasize the fact that any environment is unfriendly to you and me in a thermodynamic sense. Even though most people would agree that being naked at the North Pole with a bunch of viruses floating around in some arctic smog would truly be a hostile environment, few other than you and I would immediately see that even if we were in Hawaii under the shade of a Lahaina palm tree eating macadamia nuts, the always present thermodynamic environment is unfriendly. It is only the totality of homeostasis, which is represented by the protective set of hill barriers in Figure 3, that prevents the living creature from being unstable. If we are unstable thermodynamically and therefore cannot continue to process energy in a correlated fashion, we rapidly lose energy to our environment and move down to a more probable thermodynamic level of stability. The chemicals in us, whether in our livers or our brains, are no longer related and relating as they were. When homeostasis goes, death comes.

Goal and Purpose in Humans

Let us look for a moment at goal or purpose in humans. Physiologically, as a zoologist neatly summarized the whole picture, an individual organism's goal is to live. That surely is simple, even though the hugely complex biochemical pro-

cesses which serve this homeostatic goal are not. Psychologically man's purposes may vary widely but one common goal seems to be a dynamic homeostasis on the mental level: a maintenance of already acquired patterns of individual and social belief and action which usually involves the individual's accepting more easily any new input which conforms to the already preferred mental patterns. Of course, if the person is truly uncreative, his metastable mental state drifts with age toward more and more stable equilibria. Such lower energy levels in the brain would literally correspond to lower processing rates for input information, but even more probably would involve rejection of much new input and incorporation of new data incorrectly by forcing it into inappropriate established mental patterns. These are homeostatic mechanisms.

By contrast, in the truly creative person—and at times in everyone—psychological purpose is shown by an active search for new information and experience. This is analogous to energy flowing into an inanimate system. And randomness predominates in a high-energy closed system. The analogy is at least qualitatively successful because it would predict that an extreme influx of novel information and ideas to the individual would lead to a shattering of old patterns and possible mental chaos. Experimentally, such a result is as old as Freud and as new as *Future Shock*. How does the "balanced" creative individual cope with a torrent of disparate input? What counters randomness in an inanimate system? Two analogous processes in the brain may be by developing storage registers for ambiguous information (that which does not fit with established mental constructs), and by devising more complex networks of concepts so old patterns are abandoned for new arrangements which fit the data better. These strategies are homeostatic. They allow achievement of new levels of metastable equilibria without chaos.

But wait a moment. It is not too difficult to accept the possibility that thermodynamics may be involved in man's physiology and his physiological goal. After all, biochemistry in a human or a test tube involves chemicals and chemical systems. And thermodynamics certainly applies to chemical systems. But to make the facile jump of talking about mental processes in terms of energy may sound terrifyingly like Reich's "orgone energy" or "psychic energy" or "dianetic scientology." I hasten to assure you that I do not believe in any of these. My only basis for suggesting that considerations from thermodynamics may be pertinent to mental processes is the increasingly strong evidence that biochemistry is involved in *all* mental activity. For just a few examples: The irreversible damage that the brain suffers when its tissues are deprived of oxygen for any extended time, the change toward emotional euphoria and incapacity to process information when its oxygen supply is reduced (as at high altitudes), the startling visions and trans-relationships which one experiences via the brain when minute quantities of chemicals such as LSD are introduced, the dramatically successful treatment of manic-depressive states by the use of simple lithium chloride (common table salt's chemical brother), the dependence of long term memory on protein synthesis—these are but bits of the rapidly mounting evidence that the brain and

the mind and the emotions are based upon chemicals systems. A revealing simple indication of possible chemical dependence of our thought processes is given to each of us when we have a fever of just a few degrees. Have you ever tried to avoid random and erratic mental jumps when you were running a temperature of 101°? About two degrees Fahrenheit—a tiny quantity in terms of our weather or our coffee temperature—but this is enough to seriously addle our thoughts disastrously, be they trivial or philosophical, or spiritual. Yet, to a chemist, this kind of temperature effect is characteristic of any chemical process with a low activation energy. The brain is certainly no exception to our dependence on biochemistry.

The Search for Immortality as Psychological Homeostasis

As briefly developed here, I believe that in the less creative individual, simple maintenance of the *status quo,* both physiologically and psychologically, is hemeostatically controlled. The homeostatic processes in physiology are of course, biochemical. It seems an obvious hypothesis that the bases for psychological homeostasis will be found to be some sort of stock biochemical programming. Both kinds of barriers to movement away from a metastable equilibrium could have been selected for by an evolutionary mechanism.

In the creative individual there is an additional, psychological factor overlying the fundamental *basso continuo* of maintenance of the *status quo*. The capacity for curiosity, for playing, for seeking the new is a common attribute of modern primates. It is not difficult to accept the postulate that these traits of curiosity, coupled with cerebral processing to integrate the new input, were selected for in the early humanoids. Those individuals with a slight excess over the low "normal" capacity for trying the new food, or seeking the new living space after an epidemic, the better water supply, would have an advantage over their fellows in surviving radical changes in their environment. Such a mental-physical search for the novel would have had no evolutionary advantage after the age of maximal breeding and, therefore, would probably follow a declining distribution in the population past twenty-five. But, at any age, the creative person possesses not only the potential for search for the new, but homeostatic mental barriers to the randomization that the new input always threatens.

Death, to either extreme type of hominid, is the end of energy processing and of homeostasis. To put it banally, it does not fit the goals of man—and, as the ultimate threat to psychological homeostasis, it cannot be allowed to occur. The human organism has evolved to overcome obstacles to its continued existence, physiological and psychological. Immortality in its various forms is a concept which offers a way around the obstacle of death.

Certainly, regardless of its operational reality in other ways, immortality can act as a homeostatic mental construct by preventing the psychoses which the fear of death might otherwise cause. But this is a relatively trivial aspect of the idea of immortality. I trust that others today will develop the insights which their disciplines bring to a modern understanding of the concept of immortality.

Occidental College