Supplemental Material for Chapter 6, "Creationist School"

Thermodynamics and Evolution

Version 1.0

Here we present the technical details of the relationship between thermodynamics and evolution. This subject is one of the most confused in the evolution debate on two counts: (1) thermodynamics is often poorly understood by the disputants, and (2) the terminology employed can have multiple meanings and thus lead to fallacious reasoning. For this reason, extreme care must be taken with any argument which attempts to draw a conclusion about evolution based on the laws of thermodynamics.

Before entering into the contentious world of thermodynamics and evolution, let us recall that thermodynamics deals with two measurable quantities: energy and entropy.[*] Energy must always be conserved (First Law), and total entropy must never decrease (Second Law). Now, we must first decide what question we would like to ask thermodynamics to answer for us, or rather, what question it is *capable* of answering for us. In brief, thermodynamics is capable of telling us what *can* happen, but not what *will* happen. Anything *can* happen which results in (1) zero or a positive net change in the entropy of the universe and (2) conserves energy; anything which results in a net negative entropy change, or anything which fails to conserve energy, is forbidden. Whether something permitted *will* happen requires domain knowledge outside of the scope of thermodynamics. For example, it is *possible*, according to the laws of thermodynamics, to build a device known as a Carnot engine, which converts heat to work in the most efficient manner; but no one has ever done so, and is unlikely to do so in the future, because of the limitations of physical materials—not because of thermodynamics. On the other hand, it is *forbidden* to build a machine which extracts heat from a low-temperature source, converts it partially to work, and expels the excess heat to a high-temperature source. Were such a machine possible, useful energy could be extracted from the heat of the oceans, eliminating most need for oil and natural gas, thus undermining OPEC and drastically changing geopolitics! The confusion of these two issues—*can* and *will*—is at the root of the endless disputes about thermodynamics and evolution.

This point is so important that it bears repeating: *the laws of thermodynamics by themselves only circumscribe the possible; they do not tell us whether something which is possible will actually happen*. The only conclusion that thermodynamics can be used to establish is the impossibility of certain events or processes. *Even if an event or series of events or process is not strictly forbidden by the laws of thermodynamics, there is no inference, no guarantee, that it has any reasonable chance of actually occurring, or of occurring at any given speed, or indeed of occurring at all.* For that, specific knowledge

[*] Roughly speaking, entropy is a measure of the disorder of a system. For a brief review of the relevant science, consult any physics textbook.

of materials, processes, and equipment is necessary, together with knowledge of additional scientific laws.

This seems simple enough, but, unfortunately, we are dealing with a subject on which there is great confusion, on all sides of the evolution debate. Right out of the starting gate, principal speakers for Creationism manifest this confusion:

> One very fundamental law of science is the principle of cause and effect: no effect can be greater than its cause. It should be intuitively obvious to everyone that our very complex universe of stars and planets, and animals and people, must have been caused by a great First Cause capable of producing stars and planets and people.[1]

The principle of cause and effect is here misstated. The principle of cause and effect is: "every effect has a cause."[*] The proposition offered, "no effect can be greater than its cause", is an inference, not a deduction from the principle of cause and effect. Neither is a "fundamental law of science" at all, but a metaphysical (philosophical) principle going back to Aristotle and coming down to us through the Scholastics and later philosophers including Descartes and Leibniz. The truth of both propositions has been a matter of dispute since the time of David Hume and Immanuel Kant, and so, whether one accepts causality or not, it is too contentious for use as the basis of arguments either for or against evolution. In addition, application of causality to evolution (and other subjects) is extremely problematic, since evolutionary processes involve multiple causes, and it is difficult to ascertain whether any given cause resulted in an effect which was "greater" than itself, or even what this would mean. For example, energy from the sun causes photosynthesis; can we say that the adenosine triphosphate (ATP) created in photosynthesis is "greater" or "lesser" than the impinging sunlight on a leaf? Moreover, few scientists accept the idea that science must subordinate itself to philosophical principles; and fewer still can agree on any such principles. And finally, even if one accepts the principle of cause and effect at face value, the Creationists' position is not improved because one could then argue that God, as the First Cause, was great enough to account for the order resulting from His creation, one which unfolded through evolution.[†] So we may dismiss this line of argument as useless for the purpose.

Another source of confusion is the very terminology employed. Words such as "order" and "disorder" are often used to describe the import of the Second Law, which is supposed to only allow "order" to decrease and "disorder" to increase. But "order" and "disorder" are terms too imprecise for the scientific purposes of thermodynamics, unless they are very carefully defined; their connotative meaning, in particular, is quite misleading because of its application to situations in daily life. Entropy (*S*) is a physically measurable property, definable in three ways corresponding to three contexts:

1. A measure of the availability of energy to do work. (Most common in macroscopic applications such as chemical reactions.

[*] There are, in fact, many versions of the principle of cause and effect, or of causality, as it is usually termed. This is a very simple, straightforward statement of it.

[†] This subject is beyond the scope of the present book, but will be addressed in a companion volume.

2. A measure of the order of a system as reflected in the number of states in which the system can exist, (more states corresponds to more disorder).[2] (Most common in solid state and low and high temperature physics).
3. A measure of the information content of a message as reflected in the symbols used to encode it, information entropy,[3] The more information, the less disorder.

The Second Law tells us that net entropy must remain the same or increase; any discussion of the subject must return to this simple statement.

Areas of applicability of thermodynamics

There are basically three areas where the laws of thermodynamics intersect the theory of evolution, that is, three areas where, potentially, the laws of thermodynamics could forbid an event, mechanism, or process crucial to evolution:

1. Abiogenesis or spontaneous origin of life (the first living cell) from non-living matter.
2. Emergence of order on the earth (decrease of entropy) resulting from evolutionary processes which have been occurring for about 4 billion years
3. Ongoing life processes in cells and organisms, such as cellular growth and metabolism

Our discussion indicates that there are two separate questions which apply to each of the foregoing three areas:

(a) Is this process (or event or series) *permitted* by the laws of thermodynamics?
    (i) Closed system (universe as a whole)
    (ii) Open system (subset of universe)
(b) If permitted, what is the *likelihood* that this process (or event or series) can actually occur?

Of course, if the answer to (a) is negative, then obviously the answer to (b) is zero. But even if the answer to (a) is affirmative, the answer to (b) may still be zero for all practical purposes. So arguments from thermodynamics will not necessarily decide between NDT and Creationism, in the sense that even if Creationists lose (a), evolutionists have not won (b).

Returning to the areas of interest listed above, note that item (1), abiogenesis, is outside the scope of this book, as it deals with events which must occur *before* evolution can begin.[*] Item (2) is the focus of most Creationist arguments that attempt to discredit evolution based on thermodynamics. Item (3) is a serious problem, one which is still poorly understood, but not necessarily fatal to or even important to the question of whether evolution is possible. Let us, then, focus on Item (2).

The basic line of argument followed by the Creationists is that evolution is impossible because it violates the Second Law of Thermodynamics, that is, they wish to

[*] Most Creationist arguments that utilize thermodynamics center on the question of abiogenesis. As we noted in the Introduction, abiogenesis is not, strictly speaking, part of evolution but rather something which must happen before evolution can get underway.

argue (a) above as negative. This is because, in their view, evolution of successively higher and more complex forms of life represents a net *increase* of order and thus a net *decrease* of entropy, and such spontaneous transformations are forbidden by that law. As they view the matter, the Second Law says that order can only decrease spontaneously, not increase. Thus, no such thing as evolution could occur regardless of mechanisms proposed or other evidence adduced.

(i) Closed systems: the universe as a whole

So does thermodynamics say that 'order' can never arise out of 'disorder', i.e., can organization and structure *never* increase? Some Creationist literature appears to claim this, especially with the universe as a whole:

> …the law of increasing entropy is a universal law of *decreasing* complexity, whereas evolution is supposed to be a universal law of *increasing* complexity. Creationists have been pointing out this serious contradiction for years…[4]

Other authors echo this claim.[5],[6]: Noted Creationist Duane Gish restates the issue more specifically as follows:

> Unquestionably, the second law applies to an isolated system, one into which no energy is entering from the outside. The second law says that the order and complexity of such a system can *never* increase, but that the disorderliness or randomness of such a system (its entropy) will steadily increase with time. Yet evolutionists believe the universe is an isolated system that transformed itself from an initial chaotic state (following the Big Bang) to its present highly complex state. This is directly contradictory to the second law.[7]

The problem with this line of argument is that it utilizes order in far too loose a fashion. Remember, the Second Law deals with the physically measurable property of *entropy*, defined as above, not with order in our usual sense. The state following the Big Bang may have been "chaotic" or "disorderly" in a sense to an observer of it; but from a thermodynamic standpoint, that state was one very rich in available energy and correspondingly had a relatively *low* entropy—the things which alone determine the possible future evolution of it.[8] Clearly, *the net entropy of the universe has increased* since the Big Bang—Gish is quite correct on that point; but it is not one disputed by evolutionists. Everyone agrees that the entropy of the universe as a whole has always increased and continues to do so. But this does not mean that *locally* there could not have been decreases in entropy. This is possible because the net entropy of the universe is increasing, i.e., local *decreases* in entropy may occur because they can be "paid for" by *increases* elsewhere. Thermodynamics stops there; *it does not tell us whether this actually occurred—that is outside of its scope*. If one wishes to toss information theory into the mix, the results will be unchanged, due to the extremely low entropy "cost" of information and organization.[9] The Creationist argument would go through only if one could show that the entropy of all structures of the universe was less than that at the time of the Big Bang. No one believes this to be the case.

Open systems: subsets of the universe

Now, there is no dispute about the fact that no fully closed system exists except the whole universe. That leaves the Creationists with (a)(ii), the local option. Before

addressing their arguments, let us note that thermodynamic reasoning for any practical case proceeds by *drawing a boundary* around some system of interest, such as an engine, and then calculating the energy and entropy changes, both internal and external to the boundary. The sum of all the changes must, of course, satisfy the First and Second Laws. But within the boundary, it is possible for entropy to decrease—i.e., for order to increase. This happens, for instance, in the case of a refrigerator or an air-conditioned house, within both of which the entropy decreases. Of course, this is paid for by an even greater increase in entropy elsewhere. So the net result is an increase in entropy. Creationists agree that this is possible, that is, "…local order can increase in an open system if certain conditions are met."[10] Typically a system capable of locally lowering entropy requires an energy source, and a mechanism which allows heat (Q) to be pumped out of the refrigerator or house, thus decreasing its entropy ($\Delta Q/T$). This energy source is usually electricity, which in turn has been generated by a coal-fired or hydroelectric power plant, both of which make use of stored energy ultimately from the sun. The energy source could also be solar energy directly from photovoltaic cells. But in any case, there is no violation of the laws of thermodynamics: the entropy *decrease* in one region (inside the boundary) is more than compensated for by an *increase* in entropy elsewhere, either in the coal, the rivers responsible for the power plant, or the sun itself as it burns its fuel. As before, we must emphasize that *thermodynamics is restricted to saying whether this is possible, not whether it will actually happen.* And indeed, as the Creationists frequently point out, raw energy by itself will not decrease entropy; the energy must be properly directed:

> It should be self-evident that the mere existence of an open system of some kind, with access to the sun's energy, *does not of itself generate growth*. The sun's energy may bathe the site of an automobile junkyard for a million years, but it will never cause the rusted, broken parts to grow together again into a functioning automobile.[11]

And Gish argues that it could not account for the origin of life because "...raw, uncontrolled energy is destructive, not constructive."[12] Of course, this is correct: the sun's energy does not generate growth; it only establishes the thermodynamic conditions which make growth *possible*. This quotation reveals the confusion alluded to earlier, between the role of thermodynamics as stating whether some event or process is *possible*, and the role of specific domain knowledge, which will determine if it is *probable*. Most energy will act to increase entropy. But that is not the point in dispute in the evolution controversy. The question is not whether energy can increase or decrease entropy—clearly it can do both, under the proper circumstances. Rather, the question thermodynamics can answer is whether the available energy received by the earth since the Cambrian period was *sufficient to permit* the creation of the order that is represented by life on earth and its history, *with respect to the entropy changes involved* It *cannot* answer the question of whether this occurred by the naturalistic processes assumed by evolution, or its probability of occurrence.

To see another example of the confusion on this point, consider the view of Duane Gish, associate director of the Institute for Creation Research:

> …no scientist has ever detected any tendency of matter to transform itself from a disordered state to a complex, ordered state. There is no natural law in science

> that describes such a property of matter. There is, however, a natural law that describes exactly the opposite tendency known as the second law of thermodynamics.[13]

Once again, this is asking thermodynamics to do what it cannot do. Whether matter can spontaneously transform itself into an ordered state is an important issue for physical chemistry, but it goes far beyond the scope of thermodynamics, which says that such a process need only satisfy the appropriate entropy and energy accounting rules. If the sum of the entropies of the "complex ordered state" and the surrounding environment is higher than that of the starting components, the Second Law is satisfied. That says nothing about whether the transformation can indeed come about spontaneously. In the case of such things as viral capsid assembly it appears that it does happen spontaneously, but this need not always be the case. Late Creationist Sean O'Reilly recognized the distinction. He lists four criteria that Creationists generally claim are necessary for a system to be one in which order can increase:[14]

1. It must be an open system.
2. There must be sufficient available energy.
3. There must be a directing program.
4. There must be a conversion mechanism, to convert the available energy into the specific work needed.

Thermodynamics can tell us if (2) is met, and if (4) violates the First or Second Law. But it cannot tell us if (3) is satisfied, nor if (4) will actually do the work needed. Thermodynamics, then, cannot play the role assigned to it by the Creationists, namely, that of spoiler of evolution—not because the question of spontaneous increase of order is not important, but because the processes envisioned do not contravene the law of decreasing entropy. DNA (or its predecessors) provides the directing program and the cell or organism has internal mechanisms to do energy conversion. The rare favorable random mutations assumed to be the driving force behind evolution simply represent improvements to the directing program, and no violation of the laws of thermodynamics are involved—they are paid for by abundant free energy ultimately coming from the sun. Whether such mutations can actually arise and propagate through a population is, of course, at the heart of the evolution controversy, but far outside of the scope of thermodynamics.

Some Creationists have sought to go farther, however, and argue that such local decreases in entropy *cannot* be invoked to explain how evolution occurred because there was in fact no local decrease. We quote the following argument at length:

> What the evolutionist is demanding is to have an entropy sink in a system. No part of any thermodynamic system, living or inanimate has ever been shown to act as an entropy sink. Essentially the claim is this:
>
> $$dS_I \geq 0 \qquad \text{(D-1)}$$
>
> I—An entropy increase in most of the universe. However,
>
> $$dS_{II} \leq 0 \qquad \text{(D-2)}$$

II—An entropy decrease in the part of the universe where evolution has occurred. This would be justified as long as

$$dS_T = dS_I + dS_{II} \geq 0 \qquad \text{(D-3)}$$

where dS_T is the total entropy change in the system and $dS_I > dS_{II}$. However, *since evolution is an irreversible process,* and $dS > 0$ for irreversible processes, then $dS_T = dS_I + dS_{II} \geq 0$, but

$$dS_I \geq 0 \text{ and } dS_{II} \geq 0 \qquad \text{(D-4)}$$

since irreversible processes are occurring in both I and II and the first situation (equation D-2) cannot be true.[15] [italics added]

Whoa!! This is another case of an argument which fails because a word changes meaning in the middle of it. The problem has to do with the italicized phrase. In the original, it is footnoted to an article by Julian Huxley entitled "Evolution and Genetics". It is clear that Huxley is referring to evolution in general layman's terms as an "irreversible process", that is, organisms do not normally revert to earlier forms because changing environmental conditions would not favor such a move.* He is not referring to thermodynamic processes. In the next phrase, however, the term "irreversible process" is used in the strict thermodynamic sense, namely one in which entropy increases. The first meaning, clearly, does not imply the second, as they are addressing entirely different questions. And in fact, if one looks at the presumed mechanism of evolution, as a random point mutation in DNA, say substitution of an adenine molecule for cytosine, by definition (3) above the entropy of the DNA has not changed at all because the number of possible states of the DNA is still the same, and only a single one of them has been chosen. This implies, of course, that the entropy change of the point mutation is zero—so there is no irreversible process and no violation of the Second Law.

Overall, then, the Creationists have failed to show any contradiction of evolution with the laws of thermodynamics. Of course, it does not follow that evolution is therefore confirmed, only that it is not forbidden.

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[1] Henry M. Morris, John D. Morris, *The Modern Creation Trilogy*, Green Forest, AR: Master Books, 1996, Vol. 2, p. 125.
[2] Feynman, Richard, *Statistical Mechanics*, Reading, MA: Perseus Books, 1998, p. 6-7.
[3] Gallager, Robert, *Information Theory and Reliable Communication*, New York: Wiley, 1968, p. 20.
[4] Henry M. Morris, John D. Morris, *The Modern Creation Trilogy*, Green Forest, AR: Master Books, 1996, Vol. 2, p. 137.
[5] O'Reilly, *op. cit.*, p. 56
[6] Henry M. Morris, John D. Morris, *The Modern Creation Trilogy*, Green Forest, AR: Master Books, 1996, Vol. 2, p. 135.
[7] *Ibid.*
[8] Barrow and Silk, *op. cit.*
[9] L. Brillouin, *Science and Information Theory*, Second Edition, New York: Academic Press, 1962; T. Fowler, "Brillouin and the Concept of Information", *Int J. General Systems*, Vol. 9 (1983), p. 143-155.

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* This can, however, occur.

[10] Morris, Henry M., *The Scientific Case Against Evolution*, Santee, CA: Institute for Creation Research, 2001, p. 18.
[11] Henry M. Morris, John D. Morris, *The Modern Creation Trilogy*, Green Forest, AR: Master Books, 1996, Vol. 2, p. 139.
[12] Gish, *op. cit.*, p. 30.
[13] *Ibid*., p. 29-30.
[14] *Ibid*., p. 57.
[15] Williams, Emmitt L., "Resistance of Living Organisms to the Second Law of Thermodynamics", Chapter 5 in *Thermodyanmics and the Development of Order*, ed. by Emmett L. Williams, Kansas City: Creation Research Society, 1981, p. 100.