# An assessment of the theory of evolution from a thermal physics perspective

Greg and Ann Hampton
December 4, 2010

The development of thermal physics was driven by a need to understand the emerging heat engines of the Industrial Revolution. Problems that were too difficult to solve by considering the mechanics of individual particles were simplified by defining and understanding macroscopic thermodynamic properties such as temperature, energy, and entropy. The most basic fundamentals of this science may be applied to help understand the proper place of evolutionary theory in the known, observable universe.

## Elementary thermal physics background

Thermal physics helps us to understand certain general features of complex entities without having to understand every detail of every interacting part. This knowledge comes at a price, however, since thermal physics is primarily a statistical discipline and the mathematics of statistics can be difficult, at times. Fortunately, there are some basic thermodynamic relationships that may be grasped with minimal effort. Important among these is the quantity, entropy. Entropy is vital to our understanding of complex systems, and allows us make general assessments that would be very difficult otherwise. Although it is often said that entropy is a hard concept to grasp, we will show here that this is not always the case. In addition, there is much to be gained by a basic understanding [1].

Consider the mathematical definition of entropy,

(1) $S = k \cdot \ln(\Omega)$

The computation of entropy, S, requires few parts to the equation. In fact, it depends on only one variable: $\Omega$, the number of states available to a system. The 'k' is Boltzman's constant. The term system refers to a grouping of elements that compose an entity. The entity could be whatever we choose. For example, the elements that compose the entity could be as fundamental as chemical elements. If the entity were a block wall, the elements might be the blocks that compose it. The term 'states' refers to the properties of the elements. A state could be anything we choose to define the element. It could be temperature, or pressure, or location, or color. Once it is decided what properties define a particular entity and how many combinations of these properties are allowable under our definition of what the entity is, then the entropy of that entity may be established. Entropy calculations fit easily into the realm of quantum mechanics where states of matter are already considered quantized, that is, counted by whole numbers. This is not a requirement for general calculations, however. The broader trends of thermodynamics will work within any consistent framework.

Although Equation (1) is not a linear relationship, entropy will rise and fall with the number of states in which an entity may be found and still be considered to be that entity. For example, if an ice cube is our entity and temperature is a state, then $T > 0$ degC is not allowable while $T < 0$ degC is allowable. Temperature may be arbitrarily quantized by 1.0 degree increments or 0.1 degree increments, as long as we use the same definitions in comparing entropy.

We may compare values of entropy between a final state of an entity and an initial state as follows:

(2) $\Delta S = Sf - Si = k \cdot \ln(\Omega f) - k \cdot \ln(\Omega i)$,

and making use of a familiar property of logarithms,

(3) $\Delta S = k \cdot \ln(\Omega f / \Omega i)$.

Equation (3) has a great deal of utility. The calculation of an absolute quantity for entropy is not always useful by itself and may be clouded by ambiguous definitions for $\Omega$, therefore, it is change in entropy that most often provides practical utility toward problem solving in thermodynamics and related fields. For example, the relationship between the flow of energy into or out of a system and the resulting change in entropy of the same system defines absolute temperature as $T = \Delta E/\Delta S$. This is one of the fundamental relationships of thermodynamics, an understanding of which is critical to the design and development of internal combustion engines, air conditioners, and all other devices employing heat exchangers. Further implications of the definition of temperature as it relates to changes in energy and entropy are discussed in the next section.

Aside from the practical aspects of the thermodynamic understanding of entropy, the statistical definition of entropy in Equation (3) may be generally applied to any situation where accessible states may be counted. As such, it has another very important property. Notice that changes in entropy depend only on the ratio of initial to final allowable states. Consider the case where $\Omega i > \Omega f$. If $\Omega f$ is a subset of $\Omega i$, then the ratio represents the probability that the final state will transition from the initial state. Since the likelihood is less than 1, $\Delta S$ will be negative. Entropy will decrease. Therefore when entropy decreases, the final state is less probable than the initial state. This is a general principle and holds universally. It is the basis for the Second Law of Thermodynamics. Notice that there are no variables representing time or stepwise processes. The mechanism for proceeding from the initial state to the final state is unimportant as long as we properly account for the variable, $\Omega$, along the way.

Now consider the case where $\Omega i >> \Omega f$. The likelihood of this event plummets toward impossibility, marked by a change in entropy that is large and negative. Again, there is no $\Delta t$ in our equation (t, for time) to represent a stepwise process.

In keeping with our statistical definition, it might be preferable to consider entropy as a measure of frailty. The lowest possible value for absolute entropy is zero, occurring when an entity has only one state available to it. If an entity has a small number of states available, it may change between these states and still be identified as that entity. If, however, only one state is available, any change eliminates the entity as it is defined. As entropy decreases, the likelihood that a redefining change will occur increases. The relationship between a numerical value for entropy and the more subjective property 'order' may be thought of in these terms. A higher ordered state is properly equated with a more fragile state.

**Open and Closed Systems, Conservation Laws, and Natural Processes**

If entropy is a measure of order and there is a low probability of spontaneous transition from a disordered system to an ordered system, how do ordered systems exist in the universe? How is it that ordered entities such as stars in the sky and crystals in the earth exist, for example?

Recall that absolute temperature may be defined as, $T = \Delta E/\Delta S$. For small, incremental changes in energy and entropy,

(4) $\Delta S = \Delta E / T$.

Consider first small changes in energy, $\Delta E$. Perhaps the most verified law in all of physics is the conservation of energy. Simply stated, energy may not increase or decrease in a closed system. A closed system does not permit energy flow either in or out of the region occupied by the system, while an open system is not insulated. We may conclude, therefore, that although energy may be converted to various forms, it is neither created nor destroyed. The total level of energy remains constant with time in a closed system. Equation (4) may be applied to open systems which exchange small amounts of energy with their surroundings at a constant temperature. Equation (3) may be applied generally.

There is no corresponding conservation law for entropy. In a closed system, entropy may increase or decrease, but the likely tendency is to increase, particularly in systems with large numbers of particles. In an open system, entropy will typically increase as energy is added to the system and decrease as energy is removed. These are statistical tendencies. The opposite is always possible, but the chances diminish rapidly for large systems, like those composed of large numbers of atoms. For example, we would be alarmed to see ice cubes spontaneously form on the kitchen table, but when they appear in the freezer, we are not so surprised. If a decreasing entropy situation is to be feasible, energy must be directed outward and cooling must occur. Randomly adding energy, either mechanical energy, heat, or both in combination, forces systems into less ordered states (Figure 1). The opposite is true in general for crystal formation where energy is lost through thermal or chemical means. In such a situation Equation 4 holds true for small changes at a constant temperature. In short, the laws of thermodynamics are not violated when large-scale systems become more ordered, provided enough energy is removed from the system. In this manner, they fit both the constraints of thermodynamics and statistical physics. Those tendencies or processes are natural, that is, they match our experience whenever the less probable situation is followed by the more probable situation. Decay happens. Leaves fall out of trees rather than leaping from the ground and affixing themselves to branches. Stars become progressively more ordered, but we expect them to shed prodigious amounts of energy in the process.

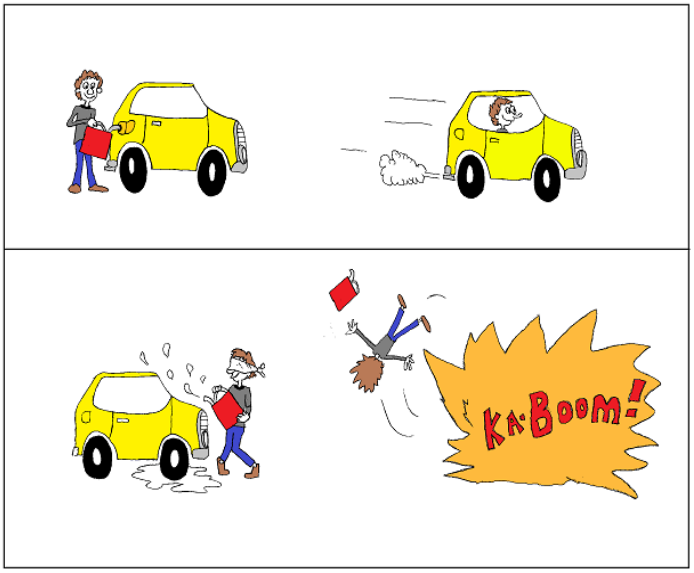


Figure 1. A system is likely to gain entropy when energy is added randomly. Every form of order must be accounted for in the total entropy budget. Therefore, it is insufficient and typically inaccurate to say that adding energy provides a means for decreasing entropy.

**Evolution and Extreme Examples of Entropy Change**

Significant discoveries in microbiology are coming so quickly in modern times that it becomes difficult to digest them all. For example, it was recently reported that researchers at the Stanford University School of Medicine had applied for patents on new brain scanning techniques [2]. The new methods are allowing never-before-seen images of the neural networks within the brain, and as is so often the case with modern biology, the former, overly simplistic understanding is now being replaced by a new appreciation:

"*One synapse, by itself, is more like a microprocessor--with both memory-storage and information-processing elements--than a mere on/off switch. In fact, one synapse may contain on the order of 1,000 molecular-scale switches. A single human brain has more switches than all the computers and routers and Internet connections on Earth*." [3]

The article continued to place new observations in perspective:

"*A typical, healthy [human brain] houses some 200 billion nerve cells, which are connected to one another via hundreds of trillions of synapses. Each synapse functions like a microprocessor, and tens of thousands of them can connect a single neuron to other nerve cells. In the cerebral cortex alone, there are roughly 125 trillion synapses, which is about how many stars fill 1,500 Milky Way galaxies*." [4]

Using these given observations, we may draw some unavoidable and important conclusions regarding the theory of evolution. Evolution teaches that,

"*Hydrogen is a light and odorless gas which, given enough time, turns into people*." [5]

If, in fact, we derive our existence from such conditions, we may readily make an assessment of the change in entropy that must take place in order to accommodate such an event. In our initial state, we are presumably a random cloud of gas. As such systems go, the number of states available to us, that is, assuming that we are defining ourselves as gas, is proportional to the volume of space in which we exist, raised to the power of the number of hydrogen atoms that compose us [6]. Regardless of the energy levels or quantum states of our atoms, this situation represents an extremely high level of entropy. In fact, no matter how the accessible states are defined, there are few situations in the universe that could produce higher levels of entropy for any similar grouping of atoms that could exist within gravitational reach of one another [7]. That would be our initial state, one of much disorder.

The entropy of our final state must take into account the uniqueness of highly complex biological systems. Large numbers of particles are involved, but the number of available states is greatly reduced by complex and far-reaching interactions. For example, should a very small change occur in one of any number of critical regions in the brain (e.g., a change in the shape of dopamine receptors in the synapses), it would immediately cease to function. The high level of order demands a lessened robustness. In addition, every part of the human body is interconnected with every other part, and all of this is contained within the small volume of the human frame. This is our final state of entropy. In the known universe, there is not another uniquely defined entity composed of such a large number of particles interacting in such complex ways in such a small volume [8].

The change in entropy may be derived from Equation (3). Here no appeal may be made to thermodynamic limitations of open or closed systems, that is, no amount of energy flow will save the situation from the obvious conclusion because the temperature of the final state is higher than the initial state. Invoking an external mechanism that forces order upon us fails as well, since natural processes require that the driving mechanism must originate from the same, initial cloud of gas. Appeals to time or gradual stepwise processes also fail because neither time nor gradual processes are required to appropriately define the initial or final available states. The situation is analogous to traveling between two hills on a frictionless sled. It wouldn't do to start a downward slide from an initial hill that was shorter than the final hill if one expected to ever reach the top of the final hill. In our frictionless analogy, the only important fact is whether the first hill is higher or lower than the second hill. The path between them is not important (Figure 2).

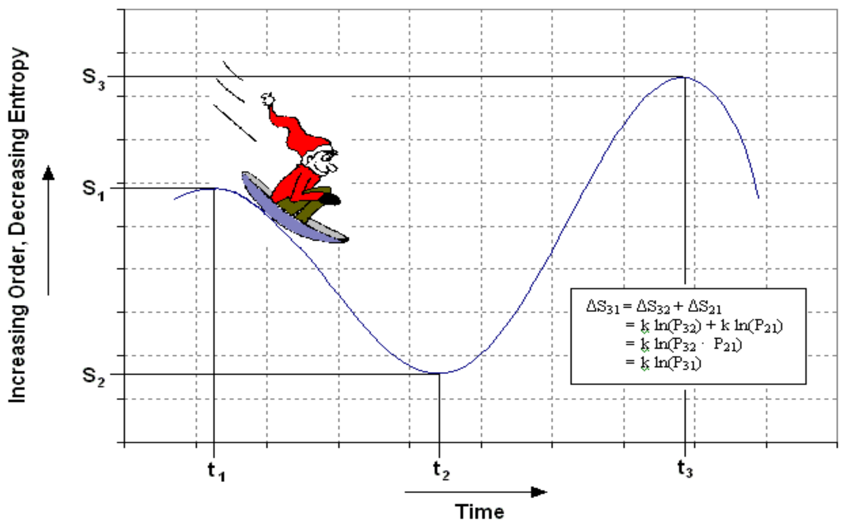


Figure 2. The sled analogy: Calculating change in statistical entropy depends on the difference between final and initial states. It is independent of the path between the two.

Our conclusion is simple. The change in entropy required by the theory of evolution is the greatest in the observable universe. The undeniable conclusion drawn from this scientific observation is equally clear. Modern physicists, especially those well known to the popular media have presented an opposing view, but as demonstrated here, facts are immune to popular opinion. The only fact of evolution we may count on is this: that humankind derives its existence through undirected processes from a cloud of hydrogen gas is the most improbable occurrence in the known universe. Therefore, regarding the theory of evolution, nothing could be further from the Truth.

## References

1. For a concise commentary on the significance of entropy see Van Wylen, G.J. and Sonntag, R.E., Fundamentals of Classical Thermodynamics, John Wiley & Sons, New York, 1973, pp. 247-248. Note especially the closing paragraph.

2. Moore, E.A., Human brain has more switches than all computers on Earth, Cnet News, Nov 2010. <news.cnet.com/8301-27083_3-20023112-247.html#ixzz16KZAvwkq>

3. Moore, quote from Stephen Smith, senior author of the study.

4. Moore.

5. Wiley Jr., John P., Smithsonian Magazine, 26 (9): 26,1995. John P. Wiley Jr, quoting Edward R. Harrison. An earlier version of this quote has been attributed to creationist astronomer George Mulfinger: < www.icr.org/article/beginning-hydrogen>.

6. Reif, F., Fundamentals of statistical and thermal physics, McGraw-Hill, New York, 1965, pp. 61-66.

7. For a summary of universal entropy calculations, both observable and speculative see Egan, C.A., and Lineweaver, C.H., A Larger Estimate of the Entropy of the Universe, Astrophysical Journal 710 (2): 1825-1834, 2010.

8. Asimov, I., In the Game of Energy and Thermodynamics You Can't Even Break Even, Smithsonian, August 1970, p. 10.