

Evolution and the Second Law of Thermodynamics

Granville Sewell
Mathematics Dept.
University of Texas El Paso
El Paso, Texas 79968

Abstract

This is a follow-up to my Fall 2000 article in *The Mathematical Intelligencer*, entitled "A Mathematician's View of Evolution", and my published response to critics, "Can ANYTHING Happen in an Open System?". In these papers, and in the current one, I argue that the underlying principle behind the second law of thermodynamics is that natural forces do not do macroscopically describable things which are extremely improbable from the microscopic point of view, and that this principle seems to have been violated by the development of intelligent life on Earth.

Imagine the construction of a gigantic computer model which starts with the initial conditions on Earth 4 billion years ago and tries to simulate the effects that the four known forces of physics (the gravitational, electromagnetic, and strong and weak nuclear forces) would have on every particle on our planet. If we ran such a simulation out to the present day, would it predict that the basic forces of Nature would reorganize the basic particles of Nature into libraries full of encyclopedias, science texts and novels, or computers connected to laser printers, CRTs and keyboards?

In a Fall 2000 opinion piece in the *Mathematical Intelligencer* [1] I made the assertion that the underlying principle behind the second law of thermodynamics is that natural forces do not do extremely improbable things, and pointed out that this principle seems to have been violated on Earth, because it seems extremely improbable that atoms would rearrange themselves into encyclopedias and computers, even if the Earth does receive energy from the Sun. The argument from the second law of thermodynamics seems pretty compelling to the layman, but it has never seemed to impress many scientists, and my arguments did not seem to impress the mathematicians who wrote in to criticize my essay. Jason Rosenhouse, in his published reply [2], repeated the standard argument that the second law of thermodynamics "only applies to closed systems, which the Earth is not".

One of the predictions of the second law is that in a closed system, thermal entropy—which measures randomness in the distribution of heat—can only increase, as heat energy becomes more randomly distributed (more uniformly distributed). If "thermal order" is defined to be the opposite (negative) of thermal entropy, then we can say that the thermal order can only decrease in a closed system. We can define another "entropy" and another "order" to measure randomness in the distribution of any other diffusing substance, for example, we can talk about the "carbon order" in a solid, and the second law similarly predicts that the carbon order can only decrease in a closed system. More generally, the second law predicts that, in a closed system where only natural

forces are at work, every type of order is unstable and will eventually decrease, as everything tends toward more probable (more random) states—not only will carbon and temperature distributions become more random, but the performance of all electronic devices will deteriorate, not improve. Natural forces, such as corrosion, erosion, fire and explosions, do not create order, they destroy it. The second law is all about probability: the reason natural forces may turn computers into scrap metal, but not vice-versa, is probability.

Let us now imagine a two-room house, which is completely closed off from the rest of the world, and not even heat can enter or leave. The thermal order in the house as a whole must decrease with time, but if the door between the two rooms is open, the thermal order in one room may actually increase, provided the decrease in the other is even greater, so that the total thermal order in the house still decreases. This is the foundation of the evolutionist's argument: order can increase (entropy can decrease) here on Earth, since the Earth is not a closed system, as long as there is a compensating decrease outside the Earth. S. Angrist and L. Helper [3], for example, write, "In a certain sense the development of civilization may appear contradictory to the second law... Even though society can effect local reductions in entropy, the general and universal trend of entropy increase easily swamps the anomalous but important efforts of civilized man. Each localized, man-made or machine-made entropy decrease is accompanied by a greater increase in entropy of the surroundings, thereby maintaining the required increase in total entropy."

According to this logic, then, the second law does not prevent scrap metal from reorganizing itself into a computer in one room, as long as two computers in the next room are rusting into scrap metal—and the door is open. Actually, the argument is even more illogical than that, it is essentially that scrap metal can reorganize itself into computers as long as there is a compensating decrease in thermal order in the other room. The spectacular increase in order seen here on Earth does not violate the second law because order is decreasing throughout the rest of this vast universe, so the total order in the universe is surely still decreasing.

So I wrote a reply, "Can ANYTHING Happen in an Open System?" [4] to my critics which was published in the Fall 2001 issue of *The Mathematical Intelligencer*. In that reply, I first showed that the second law does not simply require that any increase in thermal order in an open system be compensated for by a decrease outside the system, it requires that the increase in thermal order be no greater than the thermal order **entering** the open system. I showed that the same is true of carbon (or any other diffusing substance): the increase in carbon order in an open system cannot be greater than the carbon order entering the system. In these simple examples, I assumed nothing but heat conduction or diffusion was going on, but for more general situations I offered the tautology that "if an increase in order is extremely improbable when a system is closed, it is still extremely improbable when the system is open, unless something is entering which makes the increase **not** extremely improbable." The fact that order is disappearing in the next room does not make it any easier for computers to appear in our room—unless this order is disappearing **into** our room, and

then only if it is a type of order that makes the appearance of computers not extremely improbable, for example, computers. Importing thermal order will make the temperature distribution less random, and importing carbon order will make the carbon distribution less random, but neither makes the formation of computers more probable.

As I wrote in [4], "order can increase in an open system, not because the laws of probability are suspended when the door is open, but simply because order may walk in through the door...If we found evidence that DNA, auto parts, computer chips, and books entered through the Earth's atmosphere at some time in the past, then perhaps the appearance of humans, cars, computers, and encyclopedias on a previously barren planet could be explained without postulating a violation of the second law here (it would have been violated somewhere else!). But if all we see entering is radiation and meteorite fragments, it seems clear that what is entering through the boundary cannot explain the increase in order observed here." What happens in an open system depends on the initial and boundary conditions; what happens in a closed system depends only on the initial conditions.

If one is willing to argue that it only **seems** extremely improbable, but really isn't, that atoms would reorganize themselves into spaceships and computers and the Internet, one can certainly argue that the second law has not been violated here, and nothing I have said can counter that. However, as of this writing I have not heard from anyone who is willing to argue that, all critics have tried to avoid the question of probability in one way or another. For example, several have attacked my comments on the second law from the opposite direction, and argued that everything Nature does can be considered extremely improbable—the exact arrangement of atoms at any time at any place is extremely unlikely to be repeated, argued one e-mail. Tom Davis, in his published reply [5], made an analogy with coin flipping and argued that any particular sequence of heads and tails is extremely improbable, so something extremely improbable happens every time we flip a long series of coins. If a coin were flipped 1000 times, he would apparently be no more surprised by a string of all heads than by any other sequence, because any string is as improbable as another. Davis concedes that it is extremely unlikely that humans and computers would arise again if history were repeated, "but something would".

According to the old argument, the second law does not prevent atoms from reorganizing themselves into spaceships and computers here because the Earth is an open system. According to the new argument, this is not prohibited even in a closed system.

Obviously, I should have been more careful with my wording in the first article: I should have said that the underlying principle behind the second law is that natural forces do not do **macroscopically** describable things which are extremely improbable from the **microscopic** point of view. Carbon distributes itself more and more uniformly in a closed solid because there are many more arrangements of carbon atoms which produce nearly uniform distributions than produce highly nonuniform distributions. Natural forces may turn a spaceship into a pile of rubble, but not vice-versa—not because the exact arrangement of

atoms in a given spaceship is more improbable than the exact arrangement of atoms in a given pile of rubble, but because (whether the Earth receives energy from the Sun or not) there are very few arrangements of atoms which would be able to fly to the moon and return safely, and very many which could not. TV sets represent order because very few arrangements of atoms allow one to see and hear what is happening on the opposite side of the Earth.

If we toss a billion coins, it is true that any sequence is as improbable as any other, but most of us would still be surprised, and suspect that something other than chance is going on, if the result were "all heads", or even "all tails except for coins $3i^2 + 5$, for $i=1,2,3,\dots$ ". When we produce simply describable results like these, we have done something "macroscopically" describable which is extremely improbable. There are so many simply describable results possible that it is tempting to think that all or most outcomes could be simply described in some way, but in fact, there are only about 2^{3000} different 100-word paragraphs, so the odds are nearly $10^{300000000}$ to 1 that a given result will not be that highly ordered—so our surprise would be quite justified. There may be many different types of order present in a new deck of cards, but every type of order will decrease as the deck is shuffled and re-shuffled, at least if there is a very large number of cards in the deck. In the real world it is sometimes much harder to say what the laws of probability predict than in a coin-flipping experiment (for example, now a regular pattern may not be improbable at all), and thus even harder to define and measure order, but sometimes it is easy. In any case, with 10^{23} molecules in a mole of anything, we can be confident that the laws of probability at the microscopic level will be obeyed (at least on planets without life) as they apply to **all** macroscopic phenomena—this is precisely the assumption behind all applications of the second law. Everything the second law predicts, it predicts with such high probability that it is as reliable as any other law of science—tossing a billion heads in a row is child's play compared to appreciably violating the second law in any application. In fact, since the second law derives its authority from logic alone, and thus cannot be overturned by future discoveries, Sir Arthur Eddington [6] called it the "supreme" law of Nature.

What the Darwinists really want to say, but don't dare say, is "to hell with the second law, we have a scheme that can beat it." They are convinced that natural selection is the one natural force in all the universe that can create order out of disorder, so let's review why it can't. The usual argument against Darwinism, outlined in the first part of [1], is that natural selection cannot guide the development of new organs and new systems of organs through their initial useless stages, during which they provide no selective advantage. Consider, for example, the aquatic bladderwort, described in [7]:

"The aquatic bladderworts are delicate herbs that bear bladder-like traps 5mm or less in diameter. These traps have trigger hairs attached to a valve-like door which normally keeps the trap tightly closed. The sides of the trap are compressed under tension, but when a small form of animal life touches one of the trigger hairs the

valve opens, the bladder suddenly expands, and the animal is sucked into the trap. The door closes at once, and in about 20 minutes the trap is set ready for another victim.”

The development of any major new feature presents similar problems, and according to Lehigh University biochemist Michael Behe, who describes several spectacular examples in detail in "Darwin's Black Box" [8], the world of microbiology is especially loaded with such examples of "irreducible complexity."

Although I cannot imagine any uses for the components of this airtight insect trap before the trap was almost perfect, a good Darwinist will imagine 2 or 3 far-fetched intermediate useful stages, and consider the problem solved. I believe you would need to find thousands of intermediate stages before this example of irreducible complexity has been reduced to steps small enough to be bridged by single random mutations—a lot of things have to happen behind the scenes and at the microscopic level before this trap could catch and digest insects. But I don't know how to prove this. I am furthermore sure that even if you could find a long chain of useful intermediate stages, each would present such a negligible selective advantage that nothing as clever as this insect trap could ever be produced, but I can't prove that either. More importantly, that natural selection seems even slightly plausible depends on the fact that while species are awaiting further improvements, their current complex structure is "locked in", and passed on perfectly through many generations. This is inexplicable—I don't see any reason why all living organisms do not constantly decay into simpler components—as, in fact, they do as soon as they die.

However implausible it may seem to some of us, Darwin's explanation for evolution is difficult to disprove, because some selective advantage can be imagined in almost anything. Difficult to disprove, that is, until you look at the broader picture, then it is easy.

Darwin's defenders constantly point to the similarities between fossil species as conclusive proof that the development of life was guided by natural selection, when, in truth, these similarities do not tell us anything about the causes of the changes, or prove that only natural (unintelligent) forces were at work. In fact, the fossil record does not even support the idea that new organs and new systems of organs arose gradually; new orders, classes and phyla consistently appear suddenly [1]. For example, in November 1980, a New York Times News Service report contained the following:

"Biology's understanding of how evolution works, which has long postulated a gradual process of Darwinian natural selection acting on genetic mutations, is undergoing its broadest and deepest revolution in nearly 50 years. At the heart of the revolution is something that might seem a paradox. Recent discoveries have only strengthened Darwin's epochal conclusion that all forms of life evolved from a common ancestor. Genetic analysis, for example, has shown that every organism is governed by the same genetic code controlling the same biochemical processes. At the same time, however, many

studies suggest that the origin of species was not the way Darwin suggested...Exactly how evolution happened is now a matter of great controversy among biologists. Although the debate has been under way for several years, it reached a crescendo last month, as some 150 scientists specializing in evolutionary studies met for four days in Chicago's Field Museum of Natural History to thrash out a variety of new hypotheses that are challenging older ideas...No clear resolution of the controversies was in sight. This fact has often been exploited by religious fundamentalists who misunderstood it to suggest weakness in the fact of evolution rather than the perceived mechanism. Actually, it reflects significant progress toward a much deeper understanding of the history of life on Earth. At issue during the Chicago meeting was macroevolution, a term that is itself a matter of debate but which generally refers to the evolution of major differences...Darwin knew he was on shaky ground in extending natural selection to account for differences between major groups of organisms. The fossil record of his day showed no gradual transitions between such groups, but he suggested that further fossil discoveries would fill the missing links. "The pattern that we were told to find for the last 120 years does not exist," declared Niles Eldridge, a paleontologist from the American Museum of Natural History in New York. Eldridge reminded the meeting of what many fossil hunters have recognized as they trace the history of a species through successive layers of ancient sediments. Species simply appear at a given point in geologic time, persist largely unchanged for a few million years and then disappear. There are very few examples—some say none—of one species shading gradually into another."

Of course, none of the authors of the very angry letters the journal and I have received are going to be impressed by the above arguments. When these people discover that all of the basic constants of physics, such as the speed of light, the charge and mass of the electron, Planck's constant, etc., had to have almost exactly the values that they do have in order for any conceivable form of life to survive in our universe, they propose the "anthropic principle" [eg, 9] and say that there must be many other universes with the same laws, but random values for the basic constants, and one was bound to get the values right. When you ask them how a mechanical process such as natural selection could cause human consciousness to arise out of inanimate matter, they say "human consciousness—what's that?", and they talk about human evolution as if they were outside observers, and never seem to wonder how they got inside one of the animals they are studying. And now, when you ask how the fundamental forces of Nature could rearrange the basic particles of Nature into libraries full of encyclopedias, science texts and novels, and computers, connected to laser printers, CRTs and keyboards, they say, well, **something** had to happen.

Why are so many people willing to go to such extraordinary lengths to avoid the obvious conclusion, that we are the product of intelligent design, not chance

processes? I think I understand the reasons fairly well. There are the problems with the Bible, and the desire not to be labeled a "fundamentalist". The misery and evil in the world lead many to doubt that there is a mind behind it all. The steady progress of science has made many confident that nothing is beyond the reach of our science, and even those who believe in God often seem convinced that He has an agreement with us not to do anything we won't be able to understand. There are many things about the history of life which give the "appearance" of natural causes—though little to suggest what those causes might be. And one can produce an endless array of publications by studying the similarities between species and the many ways in which species are magnificently "adapted" to their environment. About all you can say in response to all this is that evolution through natural selection or any other natural process is extremely improbable, and you cannot get too many publications out of repeating that. But it is extremely improbable.

The development of intelligent life on Earth may have violated only one law of science, but that was the "supreme" law of Nature, and it has violated that law in a most spectacular way.

References

- 1 Granville Sewell, "A Mathematician's View of Evolution," *The Mathematical Intelligencer* 22 (2000), no 4, 5-7.
- 2 Jason Rosenhouse, "How Anti-Evolutionists Abuse Mathematics," *The Mathematical Intelligencer* 23 (2001), no 4, 3-8.
- 3 S. Angrist and L.Hepler, "Order and Chaos," Basic Books, 1967.
- 4 Granville Sewell, "Can ANYTHING Happen in an Open System?," *The Mathematical Intelligencer* 23 (2001), no 4, 8-10.
- 5 Tom Davis, "The Credibility of Evolution," *The Mathematical Intelligencer* 23 (2001), no 3, 4-5.
- 6 Arthur Eddington, "The Nature of the Physical World," McMillan, 1929.
- 7 R.F.Daubenmire, "Plants and Environment," John Wiley Sons, 1947.
- 8 Michael Behe, "Darwin's Black Box," Free Press, 1996.
- 9 A.J.Leggett, "The Problems of Physics," Oxford University Press, 1987.