IN THE BEGINNING

and Other Essays on

Intelligent Design (2nd Edition)

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Description

In this revised and expanded collection of essays on origins, mathematician Granville Sewell looks at the big bang, the fine-tuning of the laws of physics, and (especially) the evolution of life. Sewell explains why evolution is a fundamentally different and much more difficult problem than others solved by science, and why increasing numbers of scientists are now recognizing what has long been obvious to the layman, that there is no explanation possible without design. This book summarizes many of the traditional arguments for intelligent design, but presents some powerful new arguments as well.

Granville Sewell is Professor of Mathematics at the University of Texas at El Paso. He has written four books on numerical analysis, and is the author of a widely-used finite element computer program.

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Preface

This book is a collection of short articles on intelligent design and related topics. Some of these articles have been previously published.

A summary of the essays follows.

1. *What is Intelligent Design?* This short essay gives an overview of the main issues in the Darwin-ID debate, and defines intelligent design (ID) by stating what you need to believe to **not** believe in ID. It was published in the on-line edition of *Human Events* on December 16, 2013.

2. *A Mathematician's View of Evolution.* This essay was published in *The Mathematical Intelligencer* in 2000. In discussing Michael Behe's "irreducible complexity" arguments, I drew an analogy between the development of life, as it appears in the fossil record ("most taxa appear abruptly.... Gaps among known orders, classes and phyla are systematic and almost always large"), and the 20-year "evolution" of my partial differential equation solving software. This software also evolved through the release of many new versions, each with obvious similarities to previous versions, but also with large gaps where ma-

jor new features appeared and smaller gaps where minor new features appeared. Major, complex, evolutionary advances, involving new features, require the addition of many interrelated and interdependent pieces. Like major improvements to computer programs, they are not reducible to chains of tiny improvements.

3. *How the Scientific Consensus is Maintained.* This is an article published on Discovery Institute's blog "Evolution News and Views" (www.evolutionnews.org) September 3, 2013 recounting the history of my 2011 *Applied Mathematics Letters* article, part of an all-too-familiar pattern of Darwinists' attempts to suppress opposing viewpoints.

4. *Entropy and Evolution.* This includes an article which was published June 22, 2013 in the journal *BIO-Complexity*, and one section from my contribution to *Biological Information: New Perspectives.*

   If we watched a video of a tornado running backward, turning rubble into houses and cars, would we argue that this did not violate the more general formulations of the second law, because tornados derive their energy from the sun, and the increase in entropy (disorder) on the sun is far greater than the decrease seen on the video? And yet every general physics textbook which mentions evolution and the second law argues that the spontaneous rearrangement of atoms on our once-barren planet into high-speed computers, libraries full of science texts and novels, cars and trucks and airplanes, did not violate the second law because the Earth is an open system—it receives energy from the sun—and the spectacular decrease in entropy seen on Earth is compensated by increases outside our open system. These papers challenge this compensation idea by showing that the very equations of entropy change upon which this idea is based actually support, on closer examination, the common sense conclusion that "if an increase in order is extremely improbable when a system is isolated, it is still extremely improbable when the system is open, unless something is entering which makes it *not* extremely improbable." The fact that entropy can decrease in an open system does not mean that tornados can turn rubble into houses and cars, and it does not mean that computers can appear on a barren planet as long as the planet receives solar energy; something must be entering from outside which makes the appearance of computers *not* extremely improbable, for example: computers.

5. *Why Evolution is Different.* The first section explains why evolution is a fundamentally different and much more difficult problem than others solved by science, and requires a fundamentally different type of explanation. Sections 5.2 and 5.3 present the second law argument, and the argument from irreducible complexity, in a form that can be appreciated by more general audiences. The last section looks at the biggest problem of all for Darwinism, human consciousness.

6. *In the Beginning.* This essay presents some of the evidence for the astonishing but now widely-accepted idea that the universe had a beginning, in a "big bang" about 15 billion years ago. Since there were no natural causes before Nature came into existence, all theories on origins now involve speculation as to

the nature of the supernatural forces—intelligent or unintelligent—that brought our universe into existence.

7. *Design in the Laws of Nature.* This essay discusses some of the fortunate but improbable features of our universe which were required for the development of life. The "fine-tuning" of the fundamental constants of physics, and of the initial conditions of our universe, is based on widely-accepted and published scientific research, and has forced atheists to hypothesize the existence of many universes, with different constants and conditions, to avoid the obvious explanation of design. But not only are the basic constants of physics fine-tuned, so is the fundamental equation itself which underlies all of chemistry, the Schrödinger equation.

8. *The Supernatural Element in Nature.* This essay looks at the history and philosophical consequences of quantum mechanics, which has blurred the distinction between what is natural and what is supernatural. When we try to reduce all of reality to matter in motion, we find quite a surprise: there at the bottom, controlling the motion of matter, is the remarkable Schrödinger equation of quantum mechanics, which tells us that science is an entertaining and useful tool to help us understand our world, but it does not have all the answers, and never will.

9. *The Scientific Theory of Intelligent Design.* This essay looks at some of the issues raised in the debate as to whether or not intelligent design is really "science."

E. *Epilogue: Is God Really Good?* This essay looks at one of the most powerful theological arguments *against* ID, the “problem of pain.” While it may seem out of place in an otherwise scientific book, it is not an unrelated foray into theology, but is relevant to the rest of the book.

About the Author

Granville Sewell is Professor of Mathematics at the University of Texas at El Paso (UTEP). He completed his PhD in Mathematics at Purdue University, and has subsequently been employed by (in chronological order) Universidad Simon Bolivar (Caracas), Oak Ridge National Laboratory, Purdue University, IMSL Inc. (Houston), UTEP, The University of Texas Center for High Performance Computing (Austin), and Texas A&M University, and is currently back at UTEP. He spent one semester (Fall 1999) teaching at Universidad Nacional de Tucuman in Argentina, on a Fulbright grant, and returned to Universidad Simon Bolivar to teach summer courses in 2005 and 2008. Dr. Sewell has written four books on numerical analysis [Sewell 1985, 2014, 2015 and 2018], and is the author of a widely-used finite element computer program (www.pde2d.com).

1

What is Intelligent Design?

The following article appeared in the on-line version of **Human Events** *(www.humanevents.com) on December 16, 2013, with original title "Intelligent Design Theories Gaining Steam in Scientific Circles." It also appeared December 15 in the* **El Paso Times**.

The debut at #7 on the *New York Times* best seller list of Stephen Meyer's new book *Darwin's Doubt* [Meyer 2013] is evidence that the scientific theory of intelligent design (ID) continues to gain momentum. Since critics often misrepresent ID, and paint ID advocates as a fanatical fringe group, it is important to understand what intelligent design is, and what it is not.

Until Charles Darwin, almost everyone everywhere believed in some form of intelligent design (the majority still do): not just Christians, Jews and Muslims, but almost every tribesman in every remote corner of the world drew the obvious conclusion from observing animals and plants that there must have been a mind behind the creation of living things. Darwin thought he could explain all of this apparent design through natural selection of random variations. In spite of the fact that there is no direct evidence that natural selection can explain anything other than very minor adaptations, his theory has gained widespread popularity in the scientific world, simply because no one can come up with a more plausible theory to explain evolution, *other than* intelligent design, which is dismissed by most scientists as "unscientific."

But, in recent years, as scientific research has continually revealed the astonishing dimensions of the complexity of life, especially at the microscopic level, support for Darwin's implausible theory has continued to weaken, and since the publication in 1996 of *Darwin's Black Box* [Behe 1996] by Lehigh University biochemist Michael Behe, a growing minority of scientists have concluded, with Behe, that there is no possible explanation for the complexity of life other than intelligent design.

But what exactly, do these "ID scientists" believe? There is no general agreement among advocates of intelligent design as to exactly where, when or how design was manifested in the history of life. Most, but not quite all, accept the standard timeline for the beginning of the universe, of life, and of the major animal groups. (Meyer's book focuses on the sudden appearance of most of the animal phyla in the "Cambrian explosion," some 500 million years ago.) Many, including Michael Behe, accept common descent. Probably all reject natural selection as an adequate explanation for the complexity of life, but so do many other scientists who are not ID proponents. So what exactly do you have to believe to be an ID proponent?

Perhaps the best way to answer this question is to state clearly what you have to believe to *not* believe in intelligent design. Peter Urone, in his 2001 physics text *College Physics* [Urone 2001] writes, "One of the most remarkable simplifications in physics is that only four distinct forces account for all known phenomena." The prevailing view in science today is that physics explains all of chemistry, chemistry explains all of biology, and biology completely explains the human mind; thus physics alone explains the human mind and all it does. This is what you have to believe to not believe in intelligent design, that the origin and evolution of life, and the evolution of human consciousness and intelligence, are due *entirely* to a few unintelligent forces of physics. Thus you must believe that a few unintelligent forces of physics alone could have rearranged the fundamental particles of physics into computers and science texts and jet airplanes.

Contrary to popular belief, to be an ID proponent you do not have to believe that all species were created simultaneously a few thousand years ago, or that humans are unrelated to earlier primates, or that natural selection cannot cause bacteria to develop a resistance to antibiotics. If you believe that a few fundamental, unintelligent forces of physics alone could have rearranged the basic particles of physics into Apple iPhones, you are probably not an ID proponent, even if you believe in God. But if you believe there must have been more than unintelligent forces at work somewhere, somehow, in the whole process: congratulations, you are one of us after all!

2

A Mathematician's View of Evolution

The following article appeared in **The Mathematical Intelligencer** [Sewell 2000].

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2.1 *Darwin's Black Box*

In 1996, Lehigh University biochemist Michael Behe published a book entitled *Darwin's Black Box* [Behe 1996], whose central theme is that every living cell is loaded with features and biochemical processes which are "irreducibly complex"—that is, they require the existence of numerous complex components, each essential for function. Thus, these features and processes cannot be explained by gradual Darwinian improvements, because until all the components are in place, these assemblages are completely useless, and thus provide no selective advantage. Behe spends over 100 pages describing some of these irreducibly complex biochemical systems in detail, then summarizes the results of an exhaustive search of the biochemical literature for Darwinian explanations. He concludes that while biochemistry texts often pay lip-service to the idea that natural selection of random mutations can explain everything in the cell, such claims are pure "bluster," because "there is no publication in the scientific literature that describes how molecular evolution of any real, complex, biochemical system either did occur or even might have occurred."

When Dr. Behe was at the University of Texas El Paso in May of 1997 to give an invited talk, I told him that I thought he would find more support for his ideas in mathematics, physics and computer science departments than in his own field. I know a good many mathematicians, physicists and computer scientists who, like me, are appalled that Darwin's explanation for the development of life is so widely accepted in the life sciences. Few of them ever speak out or write on this issue, however—perhaps because they feel the question is simply out of their domain. However, I believe there are two central arguments against Darwinism, and both seem to be most readily appreciated by those in the more mathematical sciences.

2.2 Irreducible Complexity

The cornerstone of Darwinism is the idea that major (complex) improvements can be built up through many minor improvements; that the new organs and new systems of organs which gave rise to new orders, classes and phyla developed gradually, through many very minor improvements. We should first note that the fossil record does not support this idea, for example, Harvard paleontologist George Gaylord Simpson [Simpson 1960] writes:

> It is a feature of the known fossil record that most taxa appear abruptly. They are not, as a rule, led up to by a sequence of almost imperceptibly changing forerunners such as Darwin believed should be usual in evolution.... This phenomenon becomes more universal and more intense as the hierarchy of categories is ascended. Gaps among known species are sporadic and often small. Gaps among known orders, classes and phyla are systematic and almost always large. These peculiarities of the record pose one of the most important theoretical problems in the whole history of life: Is the sudden appearance of higher categories a phenomenon of evolution or of the record only, due to sampling bias and other inadequacies?

An April, 1982, *Life* magazine article (excerpted from Francis Hitching's book, *The Neck of the Giraffe: Where Darwin Went Wrong*) contains the following report:

> When you look for links between major groups of animals, they simply aren't there.... 'Instead of finding the gradual unfolding of life,' writes David M. Raup, a curator of Chicago's Field Museum of Natural History, 'what geologists of Darwin's time and geologists of the present day actually find is a highly uneven or jerky record; that is, species appear in the fossil sequence very suddenly, show little or no change during their existence, then abruptly disappear.' These are not negligible gaps. They are peri-

> ods, in all the major evolutionary transitions, when immense physiological changes had to take place.

Even among biologists, the idea that new organs, and thus higher categories, could develop gradually through tiny improvements has often been challenged. How could the "survival of the fittest" guide the development of new organs through their initial useless stages, during which they obviously present no selective advantage? (This is often referred to as the "problem of novelties.") Or guide the development of entire new systems, such as nervous, circulatory, digestive, respiratory and reproductive systems, which would require the simultaneous development of several new interdependent organs, none of which is useful, or provides any selective advantage, by itself? French biologist Jean Rostand, for example, wrote [Rostand 1956]:

> It does not seem strictly impossible that mutations should have introduced into the animal kingdom the differences which exist between one species and the next... hence it is very tempting to lay also at their door the differences between classes, families and orders, and, in short, the whole of evolution. But it is obvious that such an extrapolation involves the gratuitous attribution to the mutations of the past of a magnitude and power of innovation much greater than is shown by those of today.

Behe's book is primarily a challenge to this cornerstone of Darwinism at the microscopic level. Although we may not be familiar with the complex biochemical systems discussed in this book, I believe mathematicians are well qualified to appreciate the general ideas involved.

And although an analogy is only an analogy, perhaps the best way to understand Behe's argument is by comparing the development of the genetic code of life with the development of a computer program. Suppose an engineer attempts to design a structural analysis computer program, writing it in a machine language that is totally unknown to him. He simply types out random characters at his keyboard, and periodically runs tests on the program to recognize and select out chance improvements when they occur. The improvements are permanently incorporated into the program while the other changes are discarded. If our engineer continues this process of random changes and testing for a long enough time, could he eventually develop a sophisticated structural analysis program? (Of course, when intelligent humans decide what constitutes an "improvement," this is really artificial selection, so the analogy is far too generous.)

If a billion engineers were to type at the rate of one random character per second, there is virtually no chance that any one of them would, given the 4.5 billion year age of the Earth to work on it, accidentally duplicate a given 20-character improvement. Thus our engineer cannot count on making any major improvements through chance alone. But could he not perhaps make progress through the accumulation of very small improvements? The Darwinist would presumably say, yes, but to anyone who has had minimal programming experience this idea is equally implausible. Major improvements to a computer program often require the addition or modification of hundreds of interdependent lines, no one of which makes any sense, or results in any improvement, when added by itself. Even the smallest improvements usually require adding several new lines. It is conceivable that a programmer unable to look ahead more than 5 or 6 characters at a time might be able to make some very slight improvements to a computer program, but it is inconceivable that he could design anything sophisticated without the ability to plan far ahead and to guide his changes toward that plan.

If archeologists of some future society were to unearth the many versions of my PDE solver, PDE2D, which I have produced over the last 20 years, they would certainly note a steady increase in complexity over time, and they would see many obvious similarities between each new version and the previous one. In the beginning it was only able to solve a single linear, steady-state, 2D equation in a polygonal region. Since then, PDE2D has developed many new abilities: it now solves nonlinear problems, time-dependent and eigenvalue problems, systems of simultaneous equations, and it now handles general curved 2D regions. Over the years, many new types of graphical output capabilities have evolved, and in 1991 it developed an interactive preprocessor, and more recently PDE2D has adapted to 3D and 1D problems. An archeologist attempting to explain the evolution of this computer program in terms of many tiny improvements might be puzzled to find that each of these major advances (new classes or phyla??) appeared suddenly in new versions; for example, the ability to solve 3D problems first appeared in version 4.0. Less major improvements (new families or orders??) appeared suddenly in new subversions, for example, the ability to solve 3D problems with periodic boundary conditions first appeared in version 5.6. In fact, the record of PDE2D's development would be similar to the fossil record, with large gaps where major new features appeared, and smaller gaps where minor ones appeared. That is because the multitude of intermediate programs between versions or subversions which the archeologist might expect to find never existed, because—for example—none of the changes I made for edition 4.0 made any sense, or provided PDE2D any advantage whatever in solving 3D problems (or anything else) until hundreds of lines had been added.

Whether at the microscopic or macroscopic level, major, complex, evolutionary advances, involving new features (as opposed to minor, quantitative changes such as an increase in the length of the giraffe's neck,[1] or the darkening of the wings of a moth, which clearly could occur gradually) also involve the addition of many interrelated and interdependent pieces. These complex advances, like those made to computer programs, are not always "irreducibly complex"— sometimes there are intermediate useful stages. But just as major improvements to a computer program cannot be made 5 or 6 characters at a time, certainly no major evolutionary advance is reducible to a chain of tiny improvements, each small enough to be bridged by a single random mutation.

2.3 The Second Law of Thermodynamics

The other point is very simple, but also seems to be appreciated only by more mathematically-oriented people. It is that to attribute the development of life on Earth to natural selection is to assign to it—and to it alone, of all known natural "forces"—the ability to violate the sec-

[1] Ironically, W. E. Lönnig's article "The Evolution of the Long-Necked Giraffe," (www.weloennig.de/Giraffe.pdf) has since convinced me that even this is far beyond the ability of natural selection to explain.

ond law of thermodynamics and to cause order to arise from disorder. It is often argued that since the Earth is not a closed system—it receives energy from the Sun, for example—the second law is not applicable in this case. It is true that order can increase locally, if the local increase is compensated by a decrease elsewhere, i.e., an open system can be taken to a less probable state by importing order from outside. For example, we could transport a truckload of encyclopedias and computers to the moon, thereby increasing the order on the moon, without violating the second law. But the second law of thermodynamics—at least the underlying principle behind this law—simply says that natural forces do not cause extremely improbable things to happen,[2] and it is absurd to argue that because the Earth receives energy from the Sun, this principle was not violated here when the original rearrangement of atoms into encyclopedias and computers occurred.

The biologist studies the details of natural history, and when he looks at the similarities between two species of butterflies, he is understandably reluctant to attribute the small differences to the supernatural. But the mathematician or physicist is likely to take the broader view. I imagine visiting the Earth when it was young and returning now to find highways with automobiles on them, airports with jet airplanes, and tall buildings full of complicated equipment, such as televisions, telephones and computers. Then I 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

[2]An unfortunate choice of words; I should have said, 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.

effects that the four known forces of physics (the gravitational, electromagnetic and strong and weak nuclear forces) would have on every atom and every subatomic particle on our planet (perhaps using random number generators to model quantum uncertainties!). 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, nuclear power plants, aircraft carriers with supersonic jets parked on deck, and computers connected to laser printers, CRTs and keyboards? If we graphically displayed the positions of the atoms at the end of the simulation, would we find that cars and trucks had formed, or that supercomputers had arisen? Certainly we would not, and I do not believe that adding sunlight to the model would help much. Clearly something extremely improbable has happened here on our planet, with the origin and development of life, and especially with the development of human consciousness and creativity.

3

How the Scientific Consensus is Maintained

The following appeared at **Evolution News and Views**, *www.evolutionnews.org, September 3, 2013.*

3.1 How the Consensus is Maintained

This is a story about how the scientific consensus is often maintained on controversial issues, even when it is bad science—and how it can be challenged.

Anyone who has ever argued that the spectacular increase in order seen on Earth seems to violate the second law of thermodynamics—at least the more general formulations of this law—is familiar with the standard reply: although entropy (disorder) cannot decrease in an isolated system, the Earth is an open system, and entropy can decrease in an open system as long as the decrease is compensated by increases outside the open system. Isaac Asimov, for example, in a 1970 Smithsonian Magazine article [Asimov 1970], expresses the argument as follows:

> Remove the sun, and the human brain would not have developed.... And in the billions of years that it took for the human brain to develop, the increase in entropy that took place in the sun was far greater; far, far greater than the decrease that is represented by the evolution required to develop the human brain.

Most people, when they hear this "compensation" argument, realize there is something terribly wrong with the logic. If we watched a video of a tornado running backward, turning rubble into houses and cars, would we argue that this did not violate the second law, because tornados derive their energy from the sun, and the increase in entropy on the sun is far greater than the decrease seen on the video? And yet Asimov, Richard Dawkins, and every general physics textbook which mentions evolution and the second law argue that the spontaneous rearrangement of atoms on our once-barren planet into high-speed computers, libraries full of science texts and novels, cars and trucks and airplanes, did not violate the second law because the spectacular decrease in entropy seen on Earth is compensated by increases outside our open system. How is the scientific consensus on this issue maintained? How has such an argument remained almost unchallenged in the scientific community for so many years?

My 2005 John Wiley book, *The Numerical Solution of Ordinary and Partial Differential Equations,* [Sewell 2005] included an Appendix "Can ANYTHING Happen in an Open System?" which challenged this compensation idea. In this Appendix I showed that, in an open system, the "X-entropy" associated with any diffusing component X (if X=heat, X-entropy is just thermal entropy) cannot decrease faster than it is exported through the boundary, or, stated another way, the X-order in an open system cannot increase faster than it is imported. Thus the very equations of entropy change upon which the illogical compensation idea is based actually support, on closer examination, the common sense conclusion that "if an increase in order is extremely improbable when a system is isolated, it is still extremely improbable when the system is open, unless something is entering which makes it *not* extremely improbable." When thermal entropy decreases in an open system, there is not anything macroscopically describable happening which is extremely improbable from the microscopic point of view, something is just entering the open system which makes the decrease not extremely improbable. The fact that entropy can decrease in an open system does not mean that tornados can turn rubble into houses and cars, and it does not mean that computers can appear on a barren planet as long as the planet receives solar energy; something must be entering which makes the appearance of computers not extremely improbable, for example: computers.

In the Fall of 2010, I was invited to give a talk based on the ideas in this Appendix, at a 2011 Cornell University symposium entitled *Biological Information: New Perspectives.* After preparing my paper for this symposium, I decided to submit it to a mathematics journal, *Applied Mathematics Letters.* I warned the editor in a December 2010 e-mail that it would be controversial, particularly because I am known to be an intelligent design (ID) supporter, and have written a book on ID [Sewell

2010]. However, I noted that the article does not discuss ID; in fact, it does not even conclude that the second law has definitely been violated by what has happened on Earth, it only criticizes the compensation argument that Asimov, Dawkins and many, many others have used.

The article[1] was peer reviewed and accepted, and scheduled for publication in March 2011. But only a few days before it was to be published, a New Jersey Darwinist blogger heard that AML was going to publish it, and wrote the AML editor "I am appalled to see a preprint, apparently from AML, of the often repeated and often refuted nonsense of Granville Sewell..." The only evidence he offered that my writings were "often refuted nonsense" was a link to a 2008 *American Journal of Physics* article by Daniel Styer [Styer 2008], which does not mention me or my writings, and which we will discuss later.

The editor replied immediately "Thank you very much for alerting us to the impropriety of publishing Granville Sewell's 'A Second Look at the Second Law,'" and promised to withdraw the article. The blogger spread the good news around the Internet, and in fact that is how I first heard that the article was being withdrawn; I did not receive any communication from the editor until several days later, when he finally wrote me, telling me he was withdrawing it because "our editors simply found that it does not consist of the kind of content we are interested in publishing."

Since the publisher's public guidelines state that withdrawing an article after it has been accepted is only to be done in extreme cases, for example, when serious errors or plagiarism are discovered, I was afraid people would think that the journal had followed its own guidelines

[1] www.math.utep.edu/Faculty/sewell/AML_3497.pdf

and would assume the paper was seriously flawed, or I had committed some sort of ethical crime. So I found a lawyer who persuaded AML to publish an apology in the journal, and in fact the publisher also paid $10,000 in legal fees, thereby acknowledging that the editor had failed to follow the publisher's policies in this case.[2] The published apology [AML Editor 2011] states that the article was withdrawn "not because of any errors or technical problems found by the reviewers or editors, but because the Editor-in-Chief subsequently concluded that the content was more philosophical than mathematical."

Since AML still refused to publish my accepted article, I went ahead and presented it at the May 2011 Cornell symposium, as originally planned, and submitted a revised version for inclusion in the proceedings. Nearly a year later, in March 2012, the proceedings had been peer-reviewed and typeset, and the book was ready to be printed, in accordance with a signed publication agreement with Springer Verlag. The professor who reviewed my submission wrote "This is a first class piece of work... When Elsevier/*Applied Mathematics Letters* pulled this paper from their articles in press, they foolishly lost a great contribution which will be referred to for a great while to come."

But once again, ever-vigilant Darwinists discovered that Springer was about to publish these proceedings, and pressured the publisher into delaying and, in the end, canceling publication.[3] The critics admitted not knowing anything about the contents of the proceedings, they just noticed that the editors were known intelligent design supporters, and, based on this alone, brought pressure

[2]See story, "Journal Apologizes...," at www.evolutionnews.org, June 7, 2011

[3]See story, "On the Origin of the Controversy...," August 19, 2013, at www.evolutionnews.org

on Springer to withdraw the book. In fact, although the editors and most (but not all) of the participants were ID friendly, intelligent design was only rarely mentioned in the talks, though most of them were critical of Darwinism's ability to explain the development of biological information.

Although this time the protests were not directed specifically at my writings (the protesters didn't know what was in the book, remember), for a second time, my article had been peer-reviewed, accepted and close to publication, when people who had no reason to be involved in the editorial process succeeded, at least temporarily, in suppressing it.

Meanwhile, in March 2012, another mathematics journal, *The Mathematical Intelligencer*, published an article by Bob Lloyd [Lloyd 2012], criticizing my writings on this topic, primarily the AML article. The AML article had by now become so widely read that this journal apparently felt it needed to be rebutted, even though it had never been published.

Naturally, I prepared a response to the *Mathematical Intelligencer* piece, and submitted it as a letter to the editor, which, I was told, are normally published "as received," if they are published. My letter was nevertheless sent to a referee, and rejected.[4]

Here I will only look at the last point in my response. In his concluding sentence, Lloyd writes

> The qualitative point associated with the solar input to Earth, which was dismissed so casually in the abstract of the AML paper, and the quantitative formulations of this by Styer and

[4] See story, "Double Censorship...," at www.evolutionnews.org, April 25, 2012

> Bunn, stand, and are unchallenged by Sewell's work.

The Styer paper he mentions is, remember, the only evidence cited by the New Jersey blogger to support his claim, in his letter to the AML editor, that my writings are "often refuted nonsense." In my response I wrote:

> The *American Journal of Physics* papers by Styer [Styer 2008] and Bunn [Bunn 2009] illustrate beautifully the type of logic my writings are criticizing, so let's look at these papers.
>
> Styer estimated the rate of decrease in entropy associated with biological evolution as less than 302 Joules/degree Kelvin/second, noted that this rate is very small, and concluded "Presumably the entropy of the Earth's biosphere is indeed decreasing by a tiny amount due to evolution and the entropy of the cosmic microwave background is increasing by an even greater amount to compensate for that decrease." To arrive at this estimate, Styer assumed that "each individual organism is 1000 times more improbable than the corresponding individual was 100 years ago" (a "very generous" assumption), used the Boltzmann formula to calculate that a 1000-fold decrease in probability corresponds to an entropy decrease of $k_B * log(1000)$, multiplied this by a generous overestimate for the number of organisms on Earth, and divided by the number of seconds in a century.
>
> Bunn [Bunn 2009] later concluded that Styer's factor of 1000 was not really generous, that in fact organisms should be considered to be, on average, about 10^{25} times more improbable

> each century, but shows that, still, "the second law of thermodynamics is safe."
>
> Since about five million centuries have passed since the beginning of the Cambrian era, if organisms are, on average, 1000 times more improbable every century, that would mean that today's organisms are, on average, about $10^{15000000}$ times more improbable ($10^{125000000}$ times, if we use Bunn's estimate) than those at the beginning of the Cambrian. But, Styer argues, there is no conflict with the second law because the Earth is an open system, so any extremely improbable events here can be compensated by events elsewhere in the universe.

I concluded,

> If you want to show that the spontaneous rearrangement of atoms into machines capable of mathematical computation and interplanetary travel does not violate the fundamental natural principle behind the second law, you cannot simply say, as Styer and Bunn and so many others do, sure, evolution is astronomically improbable, but the Earth is an open system, so there is no problem as long as something (anything, apparently) is happening outside the Earth which, if reversed, would be even more improbable. *You have to argue that what has happened on Earth is not really astronomically improbable*, given what has entered (and exited) our open system. Why is such a simple and obvious point so controversial?

Regarding my last point, *The Mathematical Intelligencer* referee wrote "Even if Sewell's criticisms of the

Styer and Bunn papers are cogent, that has almost no relevance to Lloyd's central arguments." Well, Lloyd did defend them in his closing sentence, and Styer and Bunn have just attempted to quantify the argument that Asimov, Dawkins and Lloyd have made. But perhaps I should have addressed my criticisms of these papers to the journal that published them.

Actually, I had already tried some months earlier to publish an article criticizing the Styer and Bunn papers in the *American Journal of Physics.* I received the following rejection from the AJP editor within 2 or 3 hours of submitting my article: "Because it is well established in the physics community that there is no conflict between the second law of thermodynamics and evolution, we can consider manuscripts which help students understand why..." Again, my conclusion was *only* that the compensation argument used by Styer and Bunn has no logical merit, but apparently the editor felt that evolution could not be defended without it, an opinion which appears to be shared by the *Mathematical Intelligencer* referee, who claimed that by criticizing the compensation argument I was "arguing that a major branch of science must be discarded as conflicting with the second law."

In January 2013 I made one more attempt to respond to Bob Lloyd's piece in *The Mathematical Intelligencer.* This time my proposed *Viewpoint* article was rejected by a different editor, with the comment "Though the *Mathematical Intelligencer's* scope is broad, your discussion of the second law is better suited for a physics journal." In other words, the journal's scope is broad enough to include an attack on your unpublished article, but not broad enough to include any response to this attack.

3.2 How the Consensus can be Challenged

But, alas, it seems that, today, silencing dissent is not *nearly* as easy as it used to be. The Cornell proceedings have now been published by another publisher, *World Scientific Publishing Co.* [Marks 2013]; my contribution is on pages 168-178. Notice particularly the little story in "The Common Sense Law of Physics" which shows in a humorous way how silly the compensation argument really is.

And the journal *BIO-Complexity* has just published my new article "Entropy and Evolution"[5] which I believe contains the strongest and clearest presentation of my viewpoint to date. The first thought that will occur to many people who read it will be, how could this illogical compensation argument have gone unchallenged for so long in the scientific literature? Well, now you know how.

[5]Reproduced in Chapter 4. Update: since this chapter was written, I have also published "On 'Compensating' Entropy Decreases" in *Physics Essays* [Sewell 2017]

4

Entropy and Evolution

Sections 4.1-4 were published in **BIO-Complexity** *[Sewell 2013] June 22, 2013, with title "Entropy and Evolution." The last section, containing some relevant mathematics, is Section 2 of my contribution, "Entropy, Evolution and Open Systems," to* **Biological Information: New Perspectives** *[Marks 2013], the proceedings of a 2011 Cornell University symposium.*

4.1 Introduction

There is a long-standing debate over the apparent tension between the second law of thermodynamics, which restricts the circumstances under which order can increase spontaneously, and the origin and evolution of life, a process that seems to have involved a considerable increase in order. In very simple terms, the argument against spontaneous evolution is that the highly special arrangements of matter that constitute living things seem inexplicable as products of spontaneous processes, in view of the fact that, according to the second law, such processes always result in a loss of order.

Isaac Asimov, for example, recognizes the apparent problem:

> You can argue, of course, that the phenomenon of life may be an exception [to the second law]. Life on earth has steadily grown more complex, more versatile, more elaborate, more orderly, over the billions of years of the planet's existence. From no life at all, living molecules were developed, then living cells, then living conglomerates of cells, worms, vertebrates, mammals, finally Man. And in Man is a three-pound brain which, as far as we know, is the most complex and orderly arrangement of matter in the universe. How could the human brain develop out of the primeval slime? How could that vast increase in order (and therefore that vast decrease in entropy) have taken place? [Asimov 1970]

The popular response to this argument makes use of the fact that the common statements of the second law refer to systems that are isolated (i.e., not interacting in any way with anything outside the system). Consider, for example, three common statements of the second law from the textbook *Classical and Modern Physics* [Ford 1973:p. 618]:

1. In an isolated system, thermal entropy cannot decrease.
2. In an isolated system, the direction of spontaneous change is from order to disorder.
3. In an isolated system, the direction of spontaneous

> change is from an arrangement of lesser probability to an arrangement of greater probability.

Statement 1 clearly has little relevance for evolution, and even the more general statements 2 and 3 also refer to isolated systems, so when the second law is described in these terms, one might be tempted to think that it has no bearing on open systems. And since the Earth is clearly an open system, receiving energy from the sun, that line of reasoning seems to provide a convenient response to the argument against spontaneous evolution.

Specifically, the defense of spontaneous evolution takes the form of what I refer to as the compensation argument, which posits that even spectacular reductions in local entropy (increases in order) are consistent with the second law if there are compensating entropy increases (decreases in order) elsewhere. (Although it has a more specific meaning in statement 1 above, "entropy" is most often used simply as a synonym for disorder). For example, Peter Urone makes a statement in *College Physics* [Urone 2001], which is repeated in some form in many other general physics texts:

> Some people misuse the second law of thermodynamics, stated in terms of entropy, to say that the existence and evolution of life violate the law and thus require divine intervention.... It is true that the evolution of life from inert matter to its present forms represents a large decrease in entropy for living systems. But it is *always* possible for the entropy of one part of the universe to decrease, provided the total change in entropy of the universe increases.

Asimov uses this compensation argument in his above-quoted *Smithsonian* article:

> Remove the sun, and the human brain would not have developed.... And in the billions of years that it took for the human brain to develop, the increase in entropy that took place in the sun was far greater; far, far greater than the decrease that is represented by the evolution required to develop the human brain. [Asimov 1970]

Richard Dawkins [Dawkins 2009] writes:

> When creationists say, as they frequently do, that the theory of evolution contradicts the Second Law of Thermodynamics, they are telling us no more than that they don't understand the Second Law...There is no contradiction, because of the sun!

Much of the confusion in applying the second law to evolution, and to other situations where entropy is difficult to define and quantify, comes from the idea that "entropy" is a single quantity which measures (in units of thermal entropy) disorder of all types. The *American Journal of Physics* papers by Daniel Styer [Styer 2008] and Emory Bunn [Bunn 2009] illustrate the confusion that results from thinking of entropy as a single quantity when applying the second law to evolution, so let's look at these papers.

Styer estimated the rate of decrease in entropy associated with biological evolution as less than 302 Joules/degree Kelvin/second, noted that this rate is very small, and concluded, "Presumably the entropy of the Earth's biosphere is indeed decreasing by a tiny amount due to evolution and the entropy of the cosmic microwave background is increasing by an even greater amount to compensate for that decrease." [Styer 2008]. To arrive at this estimate, Styer assumed that "each individual organism is 1000 times more improbable than the corresponding individual was 100 years ago," which, according to Styer, is a "very generous" assumption. He then used the Boltzmann formula to calculate that a 1000-fold decrease in probability corresponds to an entropy decrease of $k_B log(1000)$, multiplied this by a generous overestimate for the number of organisms on Earth, and divided by the number of seconds in a century.

Bunn [Bunn 2009] later concluded that Styer's factor of 1000 was not really generous, that in fact organisms should be considered to be, on average, about 10^{25} times more improbable each century, but went on to show that, still, "the second law of thermodynamics is safe."

In full agreement with this, Bob Lloyd wrote in his *Mathematical Intelligencer* Viewpoint article [Lloyd 2012]:

> [A]lthough there is a local decrease in entropy associated with the appearance and evolution of life on Earth, this is very small in comparison with the very large entropy increase associated with the solar input to Earth. This qualitative idea has received quantitative backing from the calculations of Styer, and particularly as modified by Bunn, which show that the solar contribution is many orders of magnitude larger than any possible decrease associated with evolution.

But not everyone finds this line of argument convincing. Andy McIntosh offers this critique of the Styer [Styer 2008] and Bunn [Bunn 2009] papers in a recent article [McIntosh 2009]:

> Both Styer and Bunn calculate by slightly different routes a statistical upper bound on the

> total entropy reduction necessary to "achieve" life on earth. This is then compared to the total entropy received by the Earth for a given period of time. However, all these authors are making the same assumption—viz. that all one needs is sufficient energy flow into a [non-isolated] system and this will be the means of increasing the probability of life developing in complexity and new machinery evolving. But as stated earlier this begs the question of *how* a local system can possibly reduce the entropy without existing machinery to do this.

Indeed, the compensation argument is predicated on the idea that there is no content to the second law *apart* from a prohibition of net entropy decreases in isolated systems, and moreover that the universal currency for entropy is *thermal* entropy. According to Styer, the Boltzmann formula, which relates the thermal entropy of an ideal gas state to the number of possible microstates, and thus to the probability of the state, can be used to compute the change in thermal entropy associated with any change in probability: not just the probability of an ideal gas state, but the probability of *anything*. This seems very much like finding a Texas State Lottery sheet that lists the probabilities of winning each monetary award and concluding that we now know how to convert the probability of *anything* into its dollar equivalent.

Extending my earlier arguments in [Sewell 2001] and [Sewell 2005:Appendix D], I argue here that there is actually more content to the second law of thermodynamics than proponents of the compensation argument are acknowledging, and that a fuller understanding of this law does indeed challenge the idea of spontaneous evolution.

4.2 Four Test Scenarios

In order to clarify the connection between entropy, order and plausibility, let us consider four scenarios.

A. In an isolated steel object, the temperature distribution is initially non-uniform, and becomes more uniform with time, until the temperature is constant throughout. **Then**, the temperature distribution starts to become non-uniform again.

B. In an isolated steel object, the chromium distribution is initially non-uniform, and becomes more uniform with time, until the chromium concentration is constant throughout. **Then**, the chromium distribution starts to become non-uniform again. (In this scenario, you can replace chromium by anything else that diffuses, of course, and we are assuming nothing is going on but diffusion.)

C. A tornado hits a town, turning houses and cars into rubble. **Then**, another tornado hits, and turns the rubble back into houses and cars.

D. The atoms on a barren planet spontaneously rearrange themselves, with the help of solar energy and under the direction of four unintelligent forces of physics alone, into humans, cars, high-speed computers, libraries full of science texts and encyclopedias, TV sets, airplanes and spaceships. **Then**, the sun explodes into a supernova, and, with the help of solar energy, all of these things turn back into dust.

In scenarios A and B, everyone agrees that the second law is being obeyed during the first stage, and violated during the last stage. In the case of scenario A, "thermal entropy" can be defined in a precise, quantitative, manner, and it can be shown that thermal entropy is increasing during the first stage, and decreasing during the last stage. In scenario B, the "chromium entropy" can be defined in a similar and equally precise manner, and the same equations that are used to show that thermal entropy cannot decrease in an isolated system can be used to show that chromium entropy cannot decrease in an isolated system (see for example, [Sewell 2005:Appendix D]). But note that now "entropy" measures disorder in the chromium distribution, not the temperature distribution, and "entropy" does not even have the same units in the two scenarios. Thus we see that there are different kinds of entropy, even where entropy can be precisely, quantitatively defined.[1]

Scenarios A and B are both straightforward applications of statement 1 of the second law, as given in the Introduction, except that what is diffusing in scenario B is not heat. Statement 1 is one of the first formulations of the second law, and only later was it realized that the reason heat (or chromium, or anything else that diffuses) distributes itself more and more uniformly in an isolated system (causing the associated entropy to increase) is that uniformness is a more probable state in these simple scenarios. So statement 1 is essentially just one application of the later, more general, statements 2 and 3.

In the last two scenarios, entropy is difficult to define and measure, with the result that there is much more controversy and confusion in applying the second law. In

[1] "There are many thermodynamic entropies, corresponding to different degrees of experimental discrimination and different choices of parameters. For example, there will be an increase of entropy by mixing samples of ^{16}O and ^{18}O only if isotopes are experimentally distinguished." R. Carnap, *Two Essays on Entropy* [Carnap 1977].

scenario C, despite the difficulty in defining an associated entropy in a precise manner (and the entropy here has very little to do with either the temperature or the chromium distribution), most scientists would agree that the first tornado, which turns houses and cars into rubble, increases the "entropy" of the town, and what is does is consistent with the second law, while the second tornado, which turns rubble into houses and cars, decreases the entropy, and violates the second law, at least the more general statements 2 and 3. Although most general physics textbooks give examples of entropy increases that are difficult to quantify, such as wine glasses breaking or books burning, because it is more difficult to define an associated entropy precisely in scenario C, some scientists are reluctant to apply the second law to things like tornados. But although sometimes it is difficult to say what the second law predicts, sometimes it is easy, even if what is happening is difficult to quantify. If we saw a video of a tornado turning rubble into houses and cars, the difficulty in defining and measuring entropy would not prevent us from immediately realizing that the video must being running backward, because what we were seeing was completely implausible.

In scenario D, it is again very difficult to define an associated entropy precisely, but again most general physics texts that discuss the matter agree that entropy is decreasing during the first stage, when atoms are spontaneously rearranging themselves into computers and books and airplanes, but would increase during the second stage, when computers and books and airplanes are being turned back into dust. The common sense conclusion would be that the second law is being violated during the first stage of this scenario, and obeyed during the second stage.

However, as noted, every general physics textbook that discusses evolution and the second law employs the compensation argument as a refutation of this common sense conclusion.

Notice that the compensation argument could just as well be applied to scenario C by saying that since tornados receive their energy from the sun, and the Earth is an open system, tornados turning rubble into houses and cars would not violate the second law. In fact, the compensation argument does not even require an open system: one could argue that the second law is not violated during the second stage of scenario B either, as long as the decrease in chromium entropy is compensated by an increase in some other form of entropy in the isolated steel object. In other words, the compensation argument can be used to justify scenarios that all scientists would recognize to be entropically implausible, and this means that it does a poor job of representing the actual content of the second law.

To see how flawed the compensation argument is, let's extend Styer's calculations (see Introduction) to the second tornado of scenario C. Let us "generously" estimate that a house is $10^{1,000,000,000}$ times more improbable than the corresponding pile of rubble, and use the Boltzmann formula to calculate that the decrease in entropy resulting from the construction of one house is about $k_B * log(10^{1,000,000,000}) = 1.38 * 10^{-23} 10^9 log(10) = 3.2 * 10^{-14}$ Joules/degree Kelvin. If we make the generous assumption that 10,000 houses were turned into rubble by the first tornado, and back into houses by the second tornado, and that the second tornado took about 5 minutes to make its improvements, we calculate that this tornado caused the entropy of the universe to decrease at the rate of about $3.2 * 10^{-14} 10,000/300 = 10^{-12}$ Joules /degree Kelvin /second, about 14 orders of magnitude less than the rate of decrease due to evolution, and about 26 orders of magnitude less than the "Earth's entropy throughput" rate given in Styer's Table 1. So by the logic of the compensation argument, the second law is safe even in scenario C, despite its obvious implausibility. It is not clear why entropy decreases associated with the construction of houses or cars should be measured in Joules/degree Kelvin (chromium entropy isn't), or how these entropy decreases could be compensated by thermal entropy increases in the cosmic microwave background, and of course our probability estimates are just wild guesses,[2] but we could raise all of the same objections to Styer's application of the Boltzmann formula to evolution.

Since about five million centuries have passed since the beginning of the Cambrian era, if organisms are, on average, 1000 times more improbable every century, that would mean that today's organisms are, on average, about $10^{15,000,000}$ times more improbable ($10^{125,000,000}$ times, if we use Bunn's estimate) than those at the beginning of the Cambrian. But, according to Styer, there is no conflict with the second law because the Earth is an open system, and entropy increases outside the Earth compensate the entropy decrease due to evolution. In other words, using Styer's understanding of entropy, the fact that evolution is astronomically improbable is not a problem as long as something (*anything*, apparently) is happening elsewhere which, if reversed, would be even more improbable.

[2] To say that a house is N times more improbable than the corresponding pile of rubble presumably means there are N times as many "rubble" microstates as "house" microstates, but it is not clear how one could count these microstates.

4.3 Extending the Second Law to Open Systems

Although all current statements of the second law apply only to isolated systems, the principle underlying the second law can actually be stated in a way that applies to open systems. In Appendix D of my 2005 book *The Numerical Solution of Ordinary and Partial Differential Equations* [Sewell 2005], and earlier in [Sewell 2001],[3] and more recently in an *Applied Mathematics Letters* article,[4] I showed that in scenario A, if the object is no longer isolated, then the thermal entropy can decrease, but no faster than it is exported. Stated another way, the thermal order (defined as the negative of thermal entropy) can increase, but no faster than it is imported. And in scenario B, if the object is not isolated, the "chromium order" can increase, but no faster than chromium order is imported. Thus statement 1 of the second law can be generalized to:

1b. In an open system, thermal order (or "X-order," where X is any diffusing component) cannot increase faster than it is imported through the boundary.[5]

Just as statement 1 is one application of the more general statement 2, statement 1b is one application of the following tautology ([Sewell 2001] and [Sewell 2005]),

[3] And also in Section 4.5.

[4] "A Second Look at the Second Law" (www.math.utep.edu/Faculty/-sewell/AML_3497.pdf) was accepted by *Applied Mathematics Letters* in 2011, then withdrawn by the editor at the last minute, "not because of any errors or technical problems found by the reviewers or editors, but because the Editor-in-Chief subsequently concluded that the content was more philosophical than mathematical," according to the apology [AML Editor 2011] that was later published in this journal.

[5] Here, as before, we are assuming nothing is going on but diffusion or heat conduction (diffusion of heat).

which generalizes statement 2 to open systems:

2b. If an increase in order is extremely improbable when a system is isolated, it is still extremely improbable when the system is open, unless something is entering (or leaving), which makes it not extremely improbable.

Applying this tautology to the less quantifiable scenarios C and D, we conclude that the fact that order can increase in an open system does not mean that tornados can turn rubble into houses and cars without violating the second law. And it does not mean that computers can appear on a barren planet as long as the planet receives solar energy. Something must be entering from outside which makes the appearance of computers not extremely improbable, for example, computers.

Bob Lloyd's primary criticism [Lloyd 2012] of my approach was that my "X-entropies" (e.g., "chromium entropy") are not always independent of each other. He showed that in certain experiments in liquids, thermal entropy changes can cause changes in the other X-entropies. Therefore, he concluded, "the separation of total entropy into different entropies...is invalid." He wrote that the idea that my X-entropies are always independent of each other was "central to all of the versions of his argument." Actually, I never claimed that: in scenarios A and B, using the standard models for diffusion and heat conduction, and assuming nothing else is going on, the thermal and chromium entropies are independent, and then statement 1b nicely illustrates the general statement 2b (though I'm not sure a tautology needs illustrating). But even in solids, the different X-entropies can affect each other under more general assumptions. Simple definitions of entropy are only useful in simple contexts. But my basic arguments in [Sewell 2001] and [Sewell 2005] and in my *Applied Mathematics Letters* paper do not depend on any definition of entropy, as seen in the next section.

4.4 The Fundamental Principle Behind the Second Law

Statements 2 and 2b of the second law are more general than statements 1 and 1b, but often difficult to apply, because "order" (or "entropy") can mean different things in different contexts, and it may be very hard to define an associated order or entropy in others. It is especially confusing if you insist on thinking of "entropy" as a single number that measures all types of disorder, as Urone, Asimov, Styer, and Lloyd do above.

Statement 3 is much clearer and easier to apply: "In an isolated system, the direction of spontaneous change is from an arrangement of lesser probability to an arrangement of greater probability." A highly non-uniform arrangement of chromium atoms is a less probable state than a uniform arrangement, so diffusion produces a more uniform chromium distribution. The reason that natural forces can turn a computer into scrap metal in an isolated system, but not vice-versa, is that of all the arrangements that atoms could take, only an extremely small percentage would be able to do mathematical computations. Rust, fire, tornados, crashes and supernovae can destroy airplanes, but not create them, because of all the arrangements atoms could take, only an extremely small percentage would be capable of long-distance air travel. A computer or an airplane obviously represents an arrangement of lesser probability than a pile of scrap metal, even if it is difficult to define an associated entropy to measure the probabilities involved. But the laws of probability do not apply only to isolated systems, so statement 3 can also be generalized to open systems:

3b. Natural (unintelligent) forces do not do macroscopically describable things that are extremely improbable from the microscopic point of view.

In an open system you just have to take into account what is entering (and leaving) the system when deciding what is extremely improbable and what is not. When thermal entropy decreases in an open system, there is not anything macroscopically describable happening that is extremely improbable from the microscopic point of view, rather, something is crossing the boundary that makes the decrease not extremely improbable.

Of course we have to define "extremely improbable" events using a very low probability threshold. If we repeat an experiment 2^k times, and define an event to be "simply describable" (macroscopically describable) if it can be described in m or fewer bits (so that there are 2^m or fewer such events), and "extremely improbable" when it has probability $1/2^n$ or less, then the probability that any extremely improbable, simply describable event will ever occur is less than $2^{k+m}/2^n$. Thus we see that it is possible to define "extremely improbable" events using a threshold probability so low ($n >> k + m$) that we can safely assume that *no* extremely improbable, macroscopically describable event will *ever* occur. If we flip a billion fair coins, any outcome we get can be said to be extremely improbable, but we only have cause for astonishment if something extremely improbable and simply describable happens, such as "all heads" or "every third coin is tails." Note the similarity between (3b) and William Dembski's argument [Dembski 2006] that unintelligent forces do not do things that are "specified" (simply or macroscopically describable) and "complex" (extremely improbable).

This basic principle is the *only* thing the four applications in the second section, and all other applications of the second law, have in common. The second law is all about using probability at the microscopic level to predict macroscopic change. The confusion in applying it to less quantifiable applications such as evolution is the result of trying to base it on something else, such as "entropy cannot decrease," when entropy may be difficult or impossible to define.

This statement of the second law, or at least of the fundamental principle behind the second law, is the one that should be applied to evolution. Those wanting to claim that the basic principle behind the second law is not violated in scenario D need to argue that, under the right conditions, macroscopically describable things such as the spontaneous rearrangement of atoms into machines capable of mathematical computations, or of long-distance air travel, or of receiving pictures and sounds transmitted from the other side of the planet, or of interplanetary space travel, are not really astronomically improbable from the microscopic point of view, thanks to the influx of solar energy, and to natural selection or whatever theory they use to explain the evolution of life and of human intelligence. And those wanting to claim that the second law is not violated in scenario C cannot argue that what the second tornado does is compensated by entropy increases outside the Earth; they likewise must argue that, under the right conditions, tornados turning rubble into houses and cars are not really astronomically improbable, thanks to the influx of solar energy that causes tornados, and to whatever theory they may have to explain constructive tornados.

4.5 The Equations of Entropy Change

This is Section 2 of my contribution to **Biological Information: New Perspectives** *[Marks 2013, p168ff]*

Of course the whole idea of compensation makes no sense logically: an extremely improbable event is not rendered less improbable simply by the occurrence of "compensating" events elsewhere.

To understand where this argument comes from, we need to look at the equations for entropy change, as given in Appendix D of my 2005 John Wiley book [Sewell 2005], and previously in my 2001 *Mathematical Intelligencer* article [Sewell 2001], "Can ANYTHING Happen in an Open System?".

Consider the diffusion (conduction) of heat in a solid, R, with absolute temperature distribution $U(x, y, z, t)$. The first law of thermodynamics (conservation of energy) requires that

$$Q_t = -\nabla \bullet \mathbf{J} \tag{4.1}$$

where Q is the heat energy density ($Q_t = c\rho U_t$) and $\mathbf{J}$ is the heat flux vector. The second law requires that the flux be in a direction in which the temperature is decreasing, i.e.,

$$\mathbf{J} \bullet \nabla \mathbf{U} \leq 0 \tag{4.2}$$

Equation 4.2 simply says that heat flows from hot to cold regions—because the laws of probability favor a more uniform distribution of heat energy.

"Thermal entropy" is a quantity that is used to measure randomness in the distribution of heat. The rate of change of thermal entropy, S, is given by the usual definition as

$$S_t = \iiint\limits_R \frac{Q_t}{U} dV \tag{4.3}$$

Using (4.3) and the first law (4.1), after doing a (multi-dimensional) integration by parts, we get

$$S_t = \iiint\limits_R \frac{-\mathbf{J} \bullet \nabla \mathbf{U}}{U^2} dV - \iint\limits_{\partial R} \frac{\mathbf{J} \bullet \mathbf{n}}{U} dA \tag{4.4}$$

where **n** is the outward unit normal on the boundary ∂R. From the second law (4.2), we see that the volume integral is nonnegative, and so

$$S_t \geq - \iint\limits_{\partial R} \frac{\mathbf{J} \bullet \mathbf{n}}{U} dA \tag{4.5}$$

From (4.5) it follows that $S_t \geq 0$ in an isolated system, where there is no heat flux through the boundary ($\mathbf{J} \bullet \mathbf{n} = 0$). Hence, in an isolated system, the entropy can never decrease. Since thermal entropy measures randomness (disorder) in the distribution of heat, its opposite (negative) can be referred to as "thermal order," and we can say that the thermal order can never increase in an isolated system.

Since thermal entropy is quantifiable, the application of the second law to thermal entropy is commonly used as the model problem on which our thinking about the other, less quantifiable, applications is based. The fact that thermal entropy cannot decrease in an isolated system, but can decrease in a non-isolated system, was used to conclude that, in other applications, any entropy decrease in a non-isolated system is possible as long as it is compensated somehow by entropy increases outside this system, so that the total "entropy" (as though there were only one type) in the universe, or any other isolated system containing this system, still increases.

However, there is really nothing special about "thermal" entropy. Heat conduction is just diffusion of heat, and we can define an "X-entropy" (and an X-order = -X-entropy), to measure the randomness in the distribution of any other substance X that diffuses; for example, we can let $U(x, y, z, t)$ represent the concentration of carbon diffusing in a solid, and use equation (4.3) again to define this entropy ($c\rho = 1$ now, so $Q_t = U_t$), and repeat the analysis leading to equation (4.5), which now says that the "carbon order" cannot increase in an isolated system.[6]

Furthermore, equation (4.5) does not simply say that the X-entropy cannot decrease in an isolated system; it also says that in a non-isolated system, the X-entropy cannot decrease faster than it is exported through the boundary, because the boundary integral there represents the rate at which X-entropy is exported across the boundary. To see this, notice that without the denominator U, the integral in (4.3) represents the rate of change of total X (energy, if X=heat) in the system; with the denominator it represents the rate of change of X-entropy. Without the denominator U, the boundary integral in

[6] "Entropy" sounds much more scientific than "order," but note that in this paper, "order" is simply defined as the opposite of "entropy." Where entropy is quantifiable, such as here, order is equally quantifiable. Physics textbooks also often use the term "entropy" in a less precise sense, to describe the increase in disorder associated with, for example, a plate breaking or a bomb exploding (e.g., [Ford 1973], p 651). In such applications, "order" is equally difficult to quantify!

(4.5) represents the rate at which X (energy, if X=heat) is exported through the boundary; with the denominator therefore it must represent the rate at which X-entropy is exported. Although I am certainly not the first to recognize that the boundary integral has this interpretation (see [Dixon 1975], p.202)[7], this has been noticed by relatively few people, no doubt because usually the special case of isotropic heat conduction or diffusion is assumed, in which case $\mathbf{J} = -K\nabla\mathbf{U}$, and then the numerator in the boundary integral is written as $-K\frac{\partial U}{\partial n}$, and in this form it is not obvious that anything is being imported or exported, only that in an isolated system, the boundary integral is zero. Furthermore, entropy as defined by (4.3) seems to be a rather abstract quantity, and it is hard to visualize what it means to import or export entropy.

Stated in terms of order, equation (4.5) says that the X-order in a non-isolated system cannot increase faster than it is imported through the boundary. According to (4.4), the X-order in a system can decrease in two different ways: it can be converted to disorder (first integral term) or it can be exported through the boundary (boundary integral term). It can increase in only one way: by importation through the boundary.

[7] Dixon has a section "The Entropy Inequality for Open Systems," which contains the inequality, written out in words: "rate of change of entropy inside > rate of entropy flow in - rate of entropy flow out."

5

Why Evolution is Different

Section 5.1 appeared at **Evolution News and Views** *(www.evolutionnews.org) September 2, 2014 (see also the video at www.youtube.com/watch?v=aJua-0FpmnI).*

5.1 Why Evolution is Different

In the current debate between Darwinism and intelligent design, the strongest argument made by Darwinists is this: in every other field of science, naturalism has been spectacularly successful, why should evolutionary biology be so different? Even most scientists who doubt the Darwinist explanation for evolution are confident that science will eventually come up with a more plausible explanation. That's the way science works, if one theory fails, we look for another one; why should evolution be so different? Many people believe that intelligent design advocates just don't understand how science works, and are motivated entirely by religious beliefs.

Well, perhaps the following discussion will help critics of intelligent design to understand why evolution *is* different.

Figure 5-1. Moore before first tornado

Figure 5-2. Moore after first tornado

Here is a set of pictures of a neighborhood in Moore, Oklahoma. The first was taken before the May 20, 2013 tornado hit, and the second was taken right after the tornado.

Fortunately, another tornado hit Moore a few days later, and turned all this rubble back into houses and cars, as seen in the third picture below.

Figure 5-3. Moore after second tornado

If I asked you why you don't believe my story about the second tornado, you might say this tornado seems to violate the more general statements of the second law of thermodynamics, such as "In an isolated system, the direction of spontaneous change is from order to disorder."[1] To this I could reply, Moore is not an isolated system, tornados receive their energy from the sun, so the decrease in entropy in Moore caused by the second tornado is easily compensated by increases outside this open system. Or I might argue that it is too hard to quantify the decrease in entropy caused by the second tornado, or I could say I simply don't accept the more general statements of the second law, the second law of thermodynamics should

[1] See Section 4.1

only be applied to thermodynamics.

Nevertheless, suppose I further said, I have a scientific theory that explains how certain rare types of tornados, under just the right conditions, really can turn rubble into houses and cars. You doubt my theory? You haven't even heard it yet!

Now I have three more pictures for you, and two more stories. The first picture shows a certain Earth-like planet in a certain solar system, as it looked about 4 billion years ago. The second shows a large city at the same location about 10,000 years ago. At its prime, this city had tall buildings full of intelligent beings, computers, TV sets and cell phones inside. It had libraries full of science texts and novels, and jet airplanes taking off and landing at its airport.

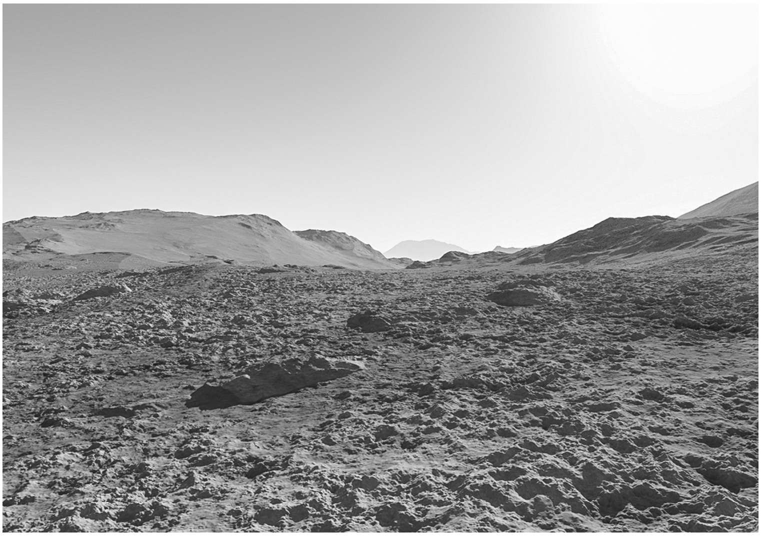

Figure 5-4. Earth-like planet soon after it formed

Figure 5-5. Planet at height of its civilization

Scientists explain how civilization developed on this once-barren planet as follows: about 4 billion years ago a collection of atoms formed by pure chance that was able to duplicate itself, and these complex collections of atoms were able to preserve their complex structures and pass them along to their descendants, generation after generation. Over a long period of time, the accumulation of genetic accidents resulted in more and more elaborate collections of atoms, and eventually something called "intelligence" allowed some of these collections of atoms to design buildings and computers and TV sets, and write encyclopedias and science texts.

Sadly, a few years after the second picture was taken, this planet was hit by a massive solar flare from its sun, and all the intelligent beings died, their bodies decayed, and their cells decomposed into simple organic and inorganic compounds. Most of the buildings collapsed immediately into rubble, those that didn't, crumbled eventually. Most of the computers and TV sets inside were smashed into scrap metal, even those that weren't, gradually turned into piles of rust. Most of the books in the libraries burned up, the rest rotted over time, and you can see see the final result many years later in the third picture below.

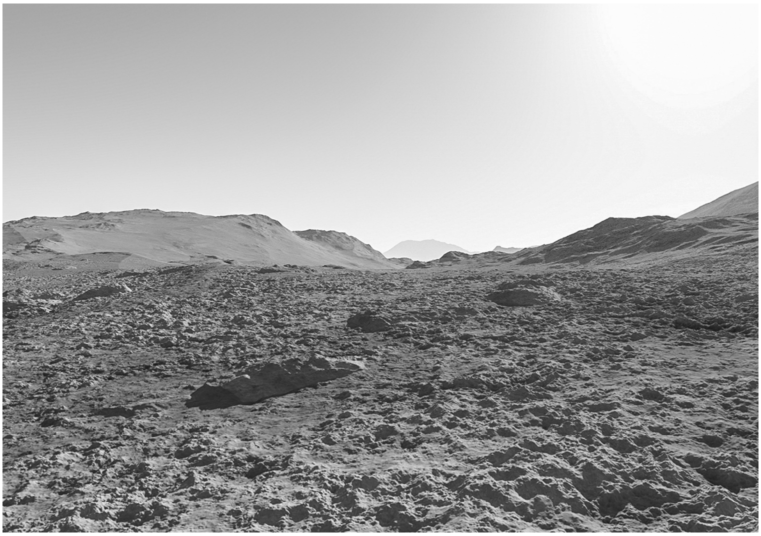

Figure 5-6. Planet today

Now it is the first story that is much more difficult to believe. The development of civilization on this planet, and the tornado that turned rubble into houses and cars, each *seems* to violate the more general statements of the second law, in a spectacular way. Various reasons why the development of civilization does not violate the second law have been given, but all of them can equally well be used to argue that the second tornado did not violate it either. That is, all *except one:* there is a theory as to how civilizations can develop on barren planets which is widely-accepted in the scientific world, while there is no widely-believed theory as to how tornados could turn rubble into houses and cars.

Well, maybe science will eventually come up with a plausible naturalistic explanation for evolution. But my question to those who treat evolution as just another scientific problem is this: do you really still believe that anyone who doubts that science can explain the development of life and of human intelligence in terms of a few unintelligent forces of physics alone simply does not understand how science works? Can you now at least understand why some of us feel that evolution is a fundamentally different and much more difficult problem than others solved by science, and requires a fundamentally different type of explanation?

5.2 A Second Look at the Second Law

Our common sense tells us that both the tornado which turned rubble into houses and cars in the above story, and the development of civilization on the barren planet, run contrary to *some* fundamental natural principle: if not the second law of thermodynamics as currently stated in the textbooks, then at least the basic principle underlying this law. So let's look at this law more carefully.

The first formulations of the second law of thermodynamics were all about heat: a quantity called thermal "entropy" was defined to measure the randomness, or disorder, associated with a temperature distribution, and it was shown that in an isolated system this entropy always increases, or at least never decreases, as heat diffuses and the temperature becomes more and more randomly (more uniformly) distributed. If we define thermal "order" to be the opposite (negative) of thermal entropy, we can say that the thermal order can never increase in an isolated system. However, it was soon realized that other types of order can be defined which also never increase in an isolated system, for example, we can define a "carbon order" associated with the distribution of carbon diffusing in a solid, using the same equations, and through an identical analysis show that this order also continually decreases, in an isolated system. With time, the second law came to be interpreted more and more generally, and today most discussions of the second law in physics textbooks offer examples of entropy increases (or order decreases, since we are defining order to be the opposite of entropy) which have nothing to do with heat conduction or diffusion, such as the shattering of a wine glass or the demolition of a building.

For example, in *Basic Physics* [Ford 1968] Kenneth Ford writes,

> Imagine a motion picture of any scene of ordinary life run backward. You might watch... a pair of mangled automobiles undergoing instantaneous repair as they back apart. Or a dead rabbit rising to scamper backward into the woods as a crushed bullet re-forms and flies backward into a rifle.... Or something as simple as a cup of coffee on a table gradually becoming warmer as it draws heat from its cooler surroundings. All of these backward-in-time views and a myriad more that you can quickly think of are ludicrous and impossible for one reason only—they violate the second law of thermodynamics. In the actual scene of events, entropy is

increasing. In the time reversed view, entropy is decreasing.

It is a well-known prediction of the second law that, in an isolated system, every type of order is unstable and must eventually decrease, as everything tends toward more probable states. Natural forces, such as corrosion, erosion, fire and explosions, do not create order, they destroy it. S. Angrist and L. Hepler, in *Order and Chaos* [Angrist and Hepler 1967], write, "An arsonist working on a big library is merely speeding up the inevitable result demanded by the second law."

The second law is all about probability, it uses probability at the microscopic level to predict macroscopic change: the reason carbon distributes itself more and more uniformly in an insulated solid is, that is what the laws of probability predict when diffusion alone is operative. The reason natural forces may turn a spaceship, or a TV set, or a computer into a pile of rubble but not vice-versa is also probability: of all the possible arrangements atoms could take, only a very small percentage could fly to the moon and back, or receive pictures and sound from the other side of the Earth, or add, subtract, multiply and divide real numbers with high accuracy. The second law is the reason that automobiles will degenerate into scrap metal over time (or quickly, as in Ford's movie) and, in the absence of intelligence, the reverse process will not occur; and it is the reason that Ford's rabbit and other animals, when they die, decay into simple organic and inorganic compounds, and, in the absence of intelligence, the reverse process will not occur.

In a 2000 *Mathematical Intelligencer* article,[2] I asserted that the idea that the four fundamental forces of

[2] Section 2.3

physics alone could rearrange the fundamental particles of Nature into spaceships, nuclear power plants, and computers, connected to laser printers, CRTs, keyboards and the Internet, appears to violate the second law of thermodynamics in a spectacular way.

Anyone who has made such an argument is familiar with the standard reply: the Earth is an open system, it receives energy from the sun, and order can increase in an open system, as long as it is "compensated" somehow by a comparable or greater decrease outside the system. Peter Urone, for example, in *College Physics* [Urone 2001] writes, "Some people misuse the second law of thermodynamics, stated in terms of entropy, to say that the existence and evolution of life violate the law and thus require divine intervention.... It is true that the evolution of life from inert matter to its present forms represents a large decrease in entropy for living systems. But it is *always* possible for the entropy of one part of the universe to decrease, provided the total change in entropy of the universe increases."

According to this reasoning, 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. (Or the thermal order in the next room is decreasing—though I'm not sure what the conversion rate is between computers and thermal order!) This strange argument of compensation makes no sense logically: an extremely improbable event is not rendered less improbable simply by the occurrence of "compensating" events outside the open system. To understand where this argument of compensation comes from, one needs to understand that of the example applications mentioned in the Ford text above, the coffee cup example is special: the application to heat conduction is special not only because it was the first application, but because it is quantifiable. It is commonly used as the "model" problem on which our thinking about the other, less quantifiable, applications is based. The fact that thermal order cannot increase in an isolated system, but can increase in an open system, was used to conclude that, in other applications, anything can happen in an open system as long as it is compensated by order decreases outside this system, so that the total "order" in the universe (or any isolated system containing the open system) still decreases.

In Appendix D of *The Numerical Solution of Ordinary and Partial Differential Equations* [Sewell 2005] (see also Section 4.5), I took a closer look at the equations for entropy change, which apply not only to thermal entropy but also to the entropy associated with anything else that diffuses, and showed that they do not simply say that order cannot increase in an isolated system, they also say that in an open system, order cannot increase faster than it is imported through the boundary. According to these equations, the thermal order in an open system can decrease in two different ways—it can be converted to disorder, or it can be exported through the boundary. It can increase in only one way: by importation through the boundary. Similarly, the increase in "carbon order" in an open system cannot be greater than the carbon order imported through the boundary, and the increase in "chromium order" cannot be greater than the chromium order imported through the boundary, and so on.

The "compensation" argument was produced by people who generalized the model equation for isolated systems, but forgot to generalize the equation for open systems. Both equations are only valid for our simple models, where it is assumed that only heat conduction or diffusion is going on; naturally in more complex situations, the laws of probability do not make such simple predictions. Nevertheless, in [Sewell 2001] I generalized the equation for open systems to the following tautology, which is valid in all situations: *"If an increase in order is extremely improbable when a system is isolated, it is still extremely improbable when the system is open, unless something is entering which makes it* 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 into an open system 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.

What happens in an isolated system depends on the initial conditions; what happens in an open system depends on the boundary conditions as well. As I wrote in "Can ANYTHING Happen in an Open System?" [Sewell 2001] "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....

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."

5.3 Darwin's Order Source

The evolutionist, therefore, cannot avoid the question of probability by saying that anything can happen in an open system, he is finally forced to argue that it only seems astronomically improbable, but really isn't, that, under the right conditions, atoms would spontaneously rearrange themselves into spaceships and computers and the Internet.

Darwinists believe they have already discovered the source of all this order, so let us look more closely at their theory. Where is the evidence that natural selection—alone among all natural forces—can create spectacular amounts of order out of disorder, and even design human brains, with human consciousness? In his book, *The Edge of Evolution* [Behe 2007], Lehigh University biochemist Michael Behe looks in considerable detail at the struggle for survival between humans and the malaria parasite where, in the last 100 years, the evolution of far more organisms can be studied than were involved in the entire natural history of mammals. He finds that natural selection can be credited with some very minor change, but "Far and away the most extensive relevant data we have on the subject of evolution's effects on competing organisms is that accumulated on interactions between humans and our parasites. As with the example of malaria, the data show trench warfare, with acts of desperate destruction, not arms races, with mutual improvements. The thrust and parry of human-malaria evolution did not build anything—it only destroyed things." Behe also looks at Richard Lenski's 20-year *E.coli* experiment, which a June 9, 2008 *New Scientist* article claims represents "the first time evolution has been caught in the act," and concludes that "nothing fundamentally new has been produced." Behe claims that the minor changes observed in this experiment are all due to "breaking some genes and turning others off."[3] Once in a while, breaking things can confer a selective advantage. Thus it seems that perhaps natural selection is like every other unintelligent cause in the universe after all, and tends to create disorder out of order, and not vice-versa.

In any case, the *New Scientist* article contains a remarkable admission, that natural selection has never before (and not even now according to Behe) been actually observed to produce any significant advance! To claim that the mechanism which produces such minor changes in bacteria and parasite populations is capable of producing human brains is an incredible extrapolation, yet this claim is routinely presented as being as well-established as gravity. In *any* other field, a scientist making such an extrapolation with such confidence would be the laughingstock of his peers.

The traditional argument against Darwinism is that natural selection cannot guide the development of new organs and new systems of organs—i.e., the development of new orders, classes and phyla—through their initial useless stages, during which they provide no selective advantage. Natural selection may be able to darken the

[3]Update: In his new book "Darwin Devolves," [Behe 2019] Behe writes, "Darwinian evolution proceeds mainly by damaging or breaking genes, which, counterintuitively, sometimes helps survival. In other words, the mechanism is powerfully *de*volutionary. It promotes the rapid loss of genetic information."

wings of a moth (even this is disputed), but that does not mean it can design anything complex.

Consider, for example, the aquatic bladderwort, described in *Plants and Environment* [Daubenmire 1947]:

> 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.

In a *Nature Encyclopedia of Life Sciences* [Lönnig and Becker 2004] article on carnivorous plants, authors Wolf-Ekkehard Lönnig and Heinz-Albert Becker acknowledge that "it appears to be hard to even imagine a clearcut selective advantage for all the thousands of postulated intermediate steps in a gradual scenario...for the origin of the complex carnivorous plant structures examined above."

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* [Behe 1996], the world of microbiology is especially loaded with such examples of "irreducible complexity."

It seems that until the trigger hair, the door, and the pressurized chamber were all in place, and the ability to digest small animals, and to reset the trap to be able to catch more than one animal, had been developed, none of the individual components of this carnivorous trap would have been of any use. What is the selective advantage of an incomplete vacuum chamber? To the casual observer, it might seem that none of the components of this trap would have been of any use whatever until the trap was almost perfect, but of course a good Darwinist will imagine two or three 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 animals. But I don't know how to prove this. I am further sure that even if you could imagine a long chain of useful intermediate stages, each would present such a negligible selective advantage that nothing as clever as this carnivorous trap could ever be produced, but I can't prove that either.

Finally, that natural selection seems even remotely plausible depends on the fact that while species are awaiting further improvements, their current complex structure is "locked in," and passed on almost perfectly through many generations (in fact, errors are constantly corrected and damage is constantly repaired). This phenomenon is observed, but 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.[4]

[4]Some Darwinists use computer programs, written by intelligent humans, which contain strings that simulate information in the DNA, and they run these programs on computers designed and maintained by intelligent humans. They introduce random errors into the strings, test the new strings for "fitness" in some way and discard the less fit strings, and claim the very modest progress observed simulates evolution. If they want to see what unintelligent forces alone can accomplish, however, they should introduce random errors not only

Although with all our technology we are still not close to designing any self-replicating machine, that is still pure science fiction (so how could we believe that such a machine could arise through a pure chance configurations of atoms!), imagine that it were possible to construct, say, a fleet of cars that contained completely automated car-building factories inside, with the ability to construct new cars—and not just normal new cars, but new cars containing automated car-building factories inside them. If we left these cars alone and let them reproduce themselves for many generations, is there *any* chance we would eventually see major advances arise through natural selection of the resulting duplication errors? Of course not, the whole process would grind to a halt after a few generations without intelligent humans there to fix the mechanical problems that would inevitably arise, long before we saw duplication errors that held any promise for advance.

When you look at the individual steps in the development of life, Darwin's explanation is difficult to disprove, because some selective advantage can be imagined for almost anything. Like many other schemes designed to violate the second law, it is only when you step back and look at the net result that it becomes obvious it won't work.

The wonderful video *Metamorphosis*[5] provides us with another example of irreducible complexity: the metamorphosis of a caterpillar into a butterfly. The process of transforming a caterpillar into a butterfly is surely

into the strings, but throughout the entire program, the compiler and operating system it uses, and the computer hardware. If you are trying to simulate how the accumulation of molecular accidents could produce complex organisms, why assume that only the DNA molecules are vulnerable to random damage? (This analogy was suggested by Gil Dodgen.)

[5] www.metamorphosisthefilm.com

far more complex than anything ever accomplished by man. The information needed to control this process, stored somewhere in the caterpillar's cells, must be far greater than that stored in any man-made computer program. And explaining how this enormous program arose through many tiny improvements is even more challenging here, because now the intermediate stages are not just useless, they are fatal. Metamorphosis involves the destruction of the caterpillar: the butterfly, with an almost completely new body plan, is constructed from dissolved and recycled tissues and cells of the caterpillar. Now we are not talking about climbing Dawkins' "Mount Improbable" by taking many tiny steps, we are talking about building a bridge across an enormous chasm, between caterpillar and butterfly. Until construction of this extremely long and complicated bridge is almost complete, it is a bridge to nowhere. Until a butterfly emerges, the chrysalis only serves as a casket for the caterpillar. Now we do not have to simply imagine uses for not-quite-watertight vacuum chamber traps, we have to imagine a selective advantage for committing suicide, and that is an even more difficult challenge![6]

[6]See *Metamorphosis* (www.discoveryinstitutepress.com/metamorphosis), Section 4, for Paul Nelson and Ann Gauger's criticism of attempted Darwinian explanations.

Figure 5-7. Metamorphosis produces a butterfly

A November 2004 *National Geographic* article proclaims that the evidence is "overwhelming" that Darwin was right about evolution. Since there is no proof that natural selection has ever done anything more spectacular than cause bacteria to develop drug-resistant strains, where is the overwhelming evidence that justifies assigning to it an ability we do not attribute to any other natural force in the universe: the ability to create order out of disorder?

Three types of evidence are cited: first, the fact that species are so well suited to their environments is offered as evidence that they have "adapted" to them. Of course, if they were not well-adapted, they would be extinct, and that would be offered as even stronger evidence against design. Second, they point to minor changes due to artificial selection, where intelligent humans select features already present in the gene pool, as evidence of what can be accomplished when natural forces select among genetic accidents. But, as always, the main evidence offered is the "evolutionary tree" of similarities connecting all species, fossil and living. These similarities were of course noticed long before Darwin (many animals have four legs, one head, two eyes and a tail!); all modern science has done is to show that the similarities go much deeper than those noticed by ancient man.

To our modern minds, these similarities may suggest natural causes: the argument is basically, "this doesn't look like the way God would have created things," an argument used frequently by Darwin in *Origin of Species.* But if the history of life does not give the appearance of creation by magic wand, it does look very much like the way we humans create things, through testing and improvements.

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 ("most taxa appear abruptly....Gaps among known orders, classes and phyla are systematic and almost always large" [Simpson 1960]; see Section 2.2). We see this same pattern, of large gaps where major new features appear, in the history of human technology. For example, if some future paleontologist were to unearth two species of Volkswagens, he might find it plausible that one evolved gradually from the other. He might find the lack of gradual transitions between automobile families more problematic, for example, in the transition from mechanical to hydraulic brake systems, or from manual to automatic transmissions, or from steam engines to internal combustion engines; though if he thought about what gradual transitions would look like, he would understand why they didn't exist: there is no way to transition gradually from a steam engine to an internal combustion engine, for example, without the development of new, but not yet useful, features. He would be even more puzzled by the huge differences between the bicycle and motor vehicle phyla, or between the boat and airplane phyla. But heaven help us if he uncovers motorcycles and Hovercraft, the discovery of these "missing links" would be hailed in all our newspapers as final proof that all forms of transportation arose gradually from a common ancestor, without design.

The similarities between the history of life and the history of technology go even deeper. Although the similarities between species in the same branch of the evolutionary "tree" may suggest common descent, similarities (even genetic similarities) also frequently arise independently in distant branches, where they cannot be explained by common descent. For example, in their abovecited *Nature Encyclopedia of Life Sciences* article [Lönnig and Becker 2004] on Carnivorous Plants, Wolf-Ekkehard Lönnig and Heinz-Albert Becker note that "carnivory in plants must have arisen several times independently of each other... the pitchers might have arisen seven times separately, adhesive traps at least four times, snap traps two times and suction traps possibly also two times.... The independent origin of complex synorganized structures, which are often anatomically and physiologically very similar to each other, appears to be intrinsically unlikely to many authors so that they have tried to avoid the hypothesis of convergence as far as possible." "Convergence" suggests common design rather than common descent: the probability of similar designs arising independently through random processes is very small, but a designer could, of course, take a good design and apply it several times in different places, to unrelated species.

Convergence is a phenomenon often seen in the development of human technology, for example, Ford automobiles and Boeing jets may simultaneously evolve similar new GPS systems.

So if the history of life looks like the way humans, the only other known intelligent beings in the universe, design things—through careful planning, testing and improvements—why is that an argument *against* design?

5.4 A *New York Times* Article

Since I am well aware that logic and evidence are powerless against the popular perception, nurtured by prestigious journals such as *National Geographic* and *Nature*, that no serious scientists harbor any doubts about Darwinism, I want to offer here a portion of a November 5, 1980 *New York Times News Service* report:[7]

> 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

[7] See the rest of this article at www.evolutionnews.org, February 24, 2014

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. The meeting, which was closed to all but a few observers, included nearly all the leading evolutionists in paleontology, population genetics, taxonomy and related fields. 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, such as those separating species or larger classifications.... Darwin suggested that such major products of evolution were the results of very long periods of gradual natural selection, the mechanism that is widely accepted today as accounting for minor adaptations.... Darwin, however, 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.

The inability of natural selection to explain the major steps of evolution is not a big deal, according to this writer and many others. If Darwinism cannot explain macroevolutionary changes, such as the development of carnivorous plant traps or metamorphosis, we just have to wait for science to come up with alternative theories, there is no need to resort to intelligent design, which is not scientific.

Well, we can define science to exclude intelligent design and wait as long as we want, but intelligence will still be the only thing in the universe that can look ahead to see a desired function and keep adding useless lines of computer code until the code can perform that function, and it will still be the only thing that can guide the development—gradual or not so gradual—of new organs through their initial useless stages. And it will still be the only thing that can imagine a butterfly as the final product and develop a gigantic code for metamorphosis, though intermediate stages that would produce nothing but the destruction of the caterpillar.

5.5 Human Consciousness

For the layman, it is the last step in evolution that is the most difficult to explain. You may be able to convince him that natural selection can explain the appearance of complicated robots, who walk the Earth and write books and build computers, but you will have a harder time convincing him that a mechanical process such as natural selection could cause those robots to become conscious. Human consciousness is in fact the biggest problem of all for Darwinism, but it is hard to say anything "scientific" about consciousness, since we don't really know what it is, so it is also perhaps the least discussed.

Nevertheless, one way to appreciate the problem it poses for Darwinism or any other mechanical theory of evolution is to ask the question: is it possible that computers will someday experience consciousness? If you believe that a mechanical process such as natural selection could have produced consciousness once, it seems you *can't* say it could never happen again, and it might happen faster now, with intelligent designers helping this time. In fact, most Darwinists probably do believe it could and will happen—not because they have a higher opinion of computers than I do: everyone knows that in their most impressive displays of "intelligence," computers are just doing *exactly* what they are told to do, nothing more or less. They believe it will happen because they have a lower opinion of humans: they simply dumb down the definition of consciousness, and say that if a computer can pass a "Turing test," and fool a human at the keyboard in the next room into thinking he is chatting with another human, then the computer has to be considered to be intelligent, and conscious. With the right software, my laptop may already be able to pass a Turing test, and convince me that I am Instant Messaging another human. If I type in "My cat died last week" and the computer responds "I am saddened by the death of your cat," I'm pretty gullible, that might convince me that I'm talking to another human. But if I look at the software, I might find something like this:

```
if (verb == 'died')
  fprintf(1,'I am saddened by the death of your %s',noun)
end
```

I'm pretty sure there is more to human consciousness than this, and even if my laptop answers all my questions intelligently, I will still doubt there is "someone" inside my Intel processor who experiences the same consciousness that I do, and who is really saddened by the death of my cat, though I admit I can't prove that there isn't.

I really don't know how to argue "scientifically" with people who believe computers could be conscious. About all I can say is: what about typewriters? Typewriters also do exactly what they are told to do, and have produced some magnificent works of literature. Do you believe that typewriters can also be conscious?

And if you *don't* believe that intelligent engineers could ever cause machines to attain consciousness, how can you believe that random mutations could accomplish this?

6

In the Beginning

6.1 The Expanding Universe

Using the Doppler shift to measure the speeds of distant stars, astronomer Edwin Hubble discovered in 1929 that all but a few of the closest galaxies are moving away from us, and that the speed at which each is moving away is approximately proportional to its distance from us. The proportionality constant is called the Hubble constant, so that the speed with which a galaxy recedes from us is approximately given by H times its current distance from us. Current estimates of the Hubble constant are in the neighborhood of H=$7 * 10^{-11}$/year. In other words, a galaxy which is currently R miles away from us is now receding from us at the rate of about H*R miles/year. At this rate, every 1/H years it recedes H*R*(1/H) = R miles, and so if we assume that it has always been receding from us at this same velocity, it is easy to see that 1/H years ago it must have been 0 miles from us! Since the same thing can be said for any distant galaxy, we calculate that all the galaxies would have been very closely clustered together some $1/H \approx 15$ billion years ago, when the current expansion must have begun. Actually, the gravitational attraction between stars and galaxies must be gradually slowing down this expansion, so that the expansion rate in the past must have been even higher. This means that 15 billion years is an upper limit to the time which has passed since the beginning of the expansion of the universe. In fact, if the only significant force between astronomical bodies, the force of gravity, works against expansion, what force sent the galaxies hurdling away from each other through space 15 billion years ago? It must have required quite an explosion, quite a "big bang," to overcome the force of gravity and send all this cosmic debris flying out through space.

In order to use the apparent expansion of the universe to interpret either the past or the future, we must make some assumptions. The basic assumption of cosmology is the "cosmological principle," which states that the universe appears essentially the same (i.e., modulo minor local variations) to observers at any point in it. This means that matter must be distributed more or less evenly throughout the universe, so that we may treat the matter in it as if it were a gas of more or less constant density. Of course there are local variations: an observer in the middle of the Milky Way galaxy will see a lot more stars in his sky than an observer halfway between galaxies, but we are talking about the larger view, where galaxies can be considered the "molecules" of the gas!

Notice that the cosmological principle also implies that the universe cannot have boundaries, because then it would appear different to an observer near the edge than to one far from the boundary (a boundary would be rather problematic in any case!). Surprisingly, this does not necessarily mean that the universe has to be infinite in volume, with an infinite quantity of matter distributed throughout. According to Einstein's general theory of relativity, the universe could be "finite but unbounded." A "finite but unbounded" universe is a concept which can only be grasped intuitively by saying that the universe would appear to us like the surface of a sphere would appear to a creature who can only imagine two dimensions. The surface of a sphere has a finite area but it has no boundaries, and it looks the same to all its two dimensional inhabitants, wherever they live on it. Our universe is three dimensional but, according to Einstein, we can think of it as being embedded in a higher dimensional space.

According to the general theory of relativity, space is warped, or curved, in the vicinity of matter, and if the density of matter (which we are still assuming to be approximately the same throughout the universe) is greater than some critical density, the curvature of space will be large enough to ensure that the universe is closed, comparable to the surface of a sphere. If the density is less than this critical density, we can compare our universe to a curved but open surface in 3D space, such as a hyperbolic paraboloid (Figure 6-1).

Is the cosmological principle justified by the evidence? Although the part of the universe that we can see does appear extremely homogeneous, the justification for the cosmological principle is really as much philosophical as observational, since we can presumably see only a small portion of the whole universe. However, it is hard to see how we could assume anything else—if the cosmological assumption is not valid, there is not much hope for modeling the expansion of the universe.

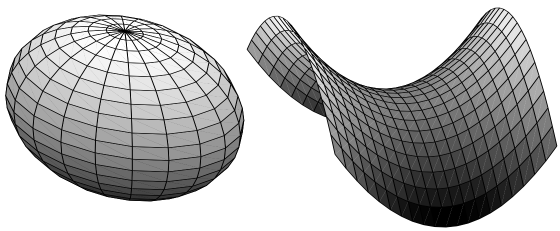

Figure 6-1. Closed and Open 2D Universes

Now we are ready to talk about the future of the universe. Will the universe continue to expand forever, or will the attractive force of gravity slow the expansion rate to zero, then cause the universe to begin contracting? To answer this question would seem to require the more modern ideas about gravity given by Einstein's general theory of relativity (which are far beyond the scope of this book), but in fact it is possible to pose this question in a mathematically correct way using the classical (Newtonian) theory of gravity. This is done in Section 6.5.

6.2 The Big Bang

In Section 6.5, an equation for $r(t)$, the normalized size of the universe (normalized so that $r = 1$ today) is derived and it is shown that there is a critical value ρ_c of the density of matter in the universe such that if the current density ρ_0 is larger than this value, the gravitational attraction between galaxies will be strong enough to eventually stop the expansion of the universe and cause it to contract; otherwise it will continue expanding forever. It turns out that ρ_c is also exactly the critical density which will "close" space. In other words, if the current density is larger than ρ_c not only can we conclude that the expansion of the universe will eventually halt, but also that the universe is finite but unbounded (closed). Thus a closed universe will eventually contract, while an open universe will continue expanding forever.

Is ρ_0 larger than the critical value? The best current estimates say no, so that the universe is infinite in size, and will continue expanding forever. But it is very difficult to estimate the density of matter in the universe, and the current estimates of ρ_0 are close enough to ρ_c to leave considerable doubt as to the size and future of the universe. I believe the universe is finite, because, in my opinion, "infinity" is an abstract concept which exists only in pure mathematics, I don't believe there could really be an infinite amount of anything. But I could be wrong, since it is a surprising universe we live in.

If we give a rock an initial upward velocity which equals or exceeds the Earth's escape velocity, it will continue upward forever and never return to Earth. If we give it an upward velocity less than this escape velocity, the attraction of the Earth's gravity will cause the rock to slow down and finally stop and begin falling back down. But in any case, if we see a rock flying upward through the air, even if we are unable to calculate whether its future holds a return to Earth or an eternal flight through outer space, we can confidently deduce its past.

In a similar manner, whatever the future of the universe may be, it is clear that at some time in the past $r(t)$ was very small, and the matter in the universe was very tightly packed. If we solve the equation (6.2), derived in

Section 6.5, for $r(t)$ we find that, no matter what value we assign to ρ_0, at a particular negative (past) value of t, the normalized size of the universe was $r = 0$, and the velocity of expansion was $r' = \infty$. The value of t for which $r = 0$ depends on our estimate of ρ_0, but we have already seen that it cannot have been more than 15 billion years ago. For example, if $\rho_0 = \rho_c$, then it is shown in Section 6.5 that the big bang must have occurred about 10 billion years ago. That $r' = \infty$ when $r = 0$ can be seen directly from (6.2), and it reflects the fact that the gravitational attraction between bodies becomes infinite as their separation approaches zero, and so an infinitely large initial velocity would be required to overcome the infinitely strong attraction of gravity associated with the state $r = 0$. This is suggestive of a very "big bang"!

The justification from Newtonian gravitational theory for the equations derived in Section 6.5 would seem to break down when r is close to 0, because other forces are no longer negligible then, but the real justification for these equations is not Newtonian physics but the general theory of relativity. A model of the universe which is based on the general theory of relativity still predicts a singularity, with $r = 0$ and $r' = \infty$ in the finite past. The currently accepted model, called the "standard model," still says that the universe arose from nothing with a "big bang."

For a while scientists were divided between the big bang theory and the "steady state" theory of the universe. The steady state theory holds that the average density of the universe is maintained at a constant level as the universe expands, by the creation (somehow) of new matter. However, there are several theoretical and experimental reasons why the steady state model has now been rejected in favor of the big bang theory. In particular, the 1965 discovery by a pair of radio astronomers of a background of microwave radiation permeating the universe was spectacular confirmation of one of the predictions of the big bang model. Proponents of the big bang theory had calculated that at a time shortly after its beginning, when the temperature of the universe was about $3,000^o$ Kelvin, the universe must have been filled with high energy, that is, short wavelength, photons. They calculated that the entire universe at that point would function as a "blackbody," and that the photon wavelengths would be distributed in the manner characteristic of blackbody spectra. As the universe expanded, this radiation cooled and by now, they calculated, it should have an equivalent temperature of about 3^o Kelvin. With the drop in temperature, the photon wavelength distribution would shift and would now have a peak in the microwave range.

It was this 3^oK remnant microwave radiation, emanating not from any particular astronomical object but from the entire sky, that Bell Telephone Laboratory radio astronomers Arno Penzias and Robert Wilson discovered in 1965. Not only was the peak close to the expected value, but the form of the observed wavelength distribution curve conformed closely to the predicted shape. Robert Jastrow, founder and director of NASA's Goddard Institute for Space Studies, and professor at Columbia University, describes the discovery of the background microwave radiation in layman's language [Jastrow 1978]:

> The two physicists were puzzled by their discovery. They were not thinking about the origin of the universe, and they did not realize that they had stumbled upon the answer to one of the cosmic mysteries. Scientists who be-

> lieved in the theory of the big bang had long asserted that the universe must have resembled a white-hot fireball in the first moments after the big bang occurred. Gradually, as the universe expanded and cooled, the fireball would have become less brilliant, but its radiation would never have disappeared entirely. It was the diffuse glow of this ancient radiation, dating back to the birth of the universe, that Penzias and Wilson apparently discovered.
>
> No explanation other than the big bang has been found for the fireball radiation. The clincher, which has convinced almost the last doubting Thomas, is that the radiation discovered by Penzias and Wilson has exactly the pattern of wavelengths expected for the light and heat produced in a great explosion. Supporters of the steady state theory have tried desperately to find an alternative explanation, but they have failed. At the present time, the big bang theory has no competitors.

We suggested earlier that our 3D universe, if finite, may appear to us like the surface of a sphere would appear to a 2D creature who cannot even comprehend the concept of a third dimension. The inflation of a sphere or balloon is perhaps a better analogy than an explosion to illustrate the expanding universe. If air is pumped into a balloon, it will expand in such a way that every point in this 2D universe (the balloon surface) recedes from every other point. This analogy also helps us understand how the attraction of gravity could cause the expansion to slow, or to reverse itself, even though the pull of gravity on any star is the same in every direction.

The word "explosion" implies that a volume of empty space is already there, and an explosion at one point in that volume sends debris flying out in all directions through the already-existing space. But our expanding universe is more like the surface of a sphere whose radius has expanded from $r = 0$ to its current size. There was no universe, not even an empty one, before the big bang, and it is the entire universe—empty space and all—which is expanding. $r = 0$ does not mean a very small, dense, universe, it means nothing existed: not only no matter or energy, but no space or time either!

6.3 The Finite Age of the Universe

Although the discovery of the background microwave radiation permeating the universe is one reason that the big bang theory is the "standard" model today, there are other reasons to believe the universe had a beginning, and most are consistent with the time frame of 15 billion years estimated from the expansion rate of the universe. The ages of various celestial objects can been estimated, and all are found to be less than 15 billion years old. For example, radioactive dating techniques can be used to compute the age of a meteorite; the fraction of a radioactive isotope remaining tells us how many half-lives have passed since the isotope was created.

The fraction of the matter in the universe represented by hydrogen is continually decreasing, as hydrogen atoms in the stars fuse to make helium and other heavier elements. If the universe were infinitely old, all the hydrogen would presumably have been consumed long ago.

A similar argument is based on the second law of thermodynamics, which states that the "entropy" (disorder) in the universe continually increases. Every time hot and cold substances exchange heat, or two gases mix, or mechanical energy is converted by friction into heat energy, the entropy of the universe increases irreversibly—the universe "winds down" a little. But, again, if the universe were infinitely old, the continual increase in randomness predicted by the second law of thermodynamics would ensure that all that would have been left by now would be a homogeneous, "wound down" universe.

Russian astrophysicists Y.B. Zel'Dovich and I.D. Novikov [Zel'Dovich and Novikov 1983] argue that even if we conjecture that the universe goes through cycles of expansion and contraction (and they see no evidence of any repulsive force which could turn contraction back into expansion) the second law of thermodynamics still guarantees that the age of the universe is finite. They write: "It follows from this that the universe has lived through only a finite number of cycles in the past and has a finite time of existence because in each cycle the entropy increases by a finite amount. For an infinite number of cycles, therefore, the specific entropy would be infinite;[1] but this is not the case."

It is conceivable, though it seems extremely unlikely, that evidence will someday be uncovered which forces us back to a steady-state or oscillating universe theory. But it is inconceivable that natural processes will be discovered which can reverse the normal flow of entropy, and cause disorder to reorganize itself into order. Thus Nature's irreversible tendency toward disorder will not allow us to avoid the problem of a true beginning of time, of a "moment with no moment preceding it" (as Arthur Eddington put it).

[1] The authors should have said, "maximal."

6.4 Philosophical Implications

In the introduction to his book *The First Three Minutes* [Weinberg 1977] Steven Weinberg wrote:

> How then did we come to the 'standard model'? And how has it supplanted other theories, like the steady state model? It is a tribute to the essential objectivity of modern astrophysics that this consensus has been brought about, not by shifts in philosophical preference or by the influence of astrophysical mandarins, but by the pressure of empirical data.

To say that rejection of the steady state model in favor of the big bang theory was not due to shifts in philosophical preference is an understatement, because many scientists would agree with Weinberg that the steady state model is "philosophically far more attractive." Einstein introduced an arbitrary additional term into his equations of general relativity in an attempt (which he later regretted) to avoid the expanding universe solution. Robert Jastrow [Jastrow 1978] writes that:

> Some prominent scientists began to feel the same irritation over the expanding universe that Einstein had expressed earlier. Eddington wrote in 1931, 'I have no ax to grind in this discussion, but the notion of a beginning is repugnant to me. The expanding universe is preposterous... incredible, it leaves me cold.'

Carl von Weizsäcker [von Weizsäcker 1964] recounts the reaction of German chemist Walther Nernst to the discovery that time had a beginning:

> He said, the view that there might be an age of

> the universe was not science. At first I did not understand him. He explained that the infinite duration of time was a basic element of all scientific thought, and to deny this would mean to betray the very foundations of science. I was quite surprised by this idea and I ventured the objection that it was scientific to form hypotheses according to the hints given by experience, and that the idea of an age of the universe was such a hypothesis. He retorted that we could not form a scientific hypothesis which contradicted the very foundations of science. He was just angry, and thus the discussion, which was continued in his private library, could not lead to any result. What impressed me about Nernst was not his arguments; what impressed me was his anger. Why was he angry?

The reason that many scientists were reluctant to accept the big bang is obvious: it points out the incompleteness of science. If the goal of science is, as Joseph Le Conte [Le Conte 1888] put it, to explain how "each state or condition grew naturally out of the immediately preceding," then this pursuit meets a dead end in the big bang, for the chain of causality must end with the beginning of time. The implications of the discovery that the entire universe—matter, energy, space and time—had a true beginning are enormous, and do not yet seem to have sunk in to our scientific consciousness; many scientists still gloss over the big bang as if it were just another explosion. Many scientists still tend to think of religions as systems of beliefs which have no root in science, and of atheism as the absence of any such unprovable beliefs.

The truth is that now all theories of origins, theistic or atheistic, involve speculation as to the nature of the supernatural force which created our universe out of nothingness, because there were no "natural" causes before Nature came into existence. The question is only, was it an intelligent or an unintelligent supernatural force that created time, space, matter and energy out of nothingness?

Some religious people do not like the big bang theory because they believe it is an attempt to explain scientifically how our universe came into existence. But while the big bang theory attempts to explain what happened from the very early stages onward, it does not attempt to explain how or why our universe came into being from nothingness—how could any scientific theory ever do that? It only states that, according to the evidence, that is exactly what happened.

British physicist Edmund Wittaker [quoted in Jastrow 1978] stated what other scientists had to be thinking: "What came before the beginning? There is no ground for supposing that matter and energy existed before and were suddenly galvanized into action. For what could distinguish that moment from all other moments in eternity? It is simpler to postulate creation *ex nihilio*—Divine will constituting Nature from nothingness."

6.5 A Model for the Expanding Universe

If I dig a hole to the center of the Earth and excavate a small chamber there, I will be able to float about weightlessly in my chamber, because the gravitational attraction of the Earth on my body is equally strong in all directions. What if I only tunnel halfway to the center?

As you might expect, I will weigh less than I did on the surface, but I will not be completely weightless; there is still a net force toward the center of the Earth. It can be shown by summing up the gravitational forces exerted on my body by all the molecules in the Earth (thanks to integral calculus, this is not as difficult as it sounds), that the net force exerted by that portion of the Earth which is closer to the surface than I am is zero, so that only the portion closer to the center than I contributes to my weight. If I could hollow out the inner core of the Earth, the entire hollow core would be a giant weightless chamber and I could float about in it, because at any point within the hollow core the tug of gravity would be the same in every direction. Thus the Earth's gravitational attraction on my body can be calculated by throwing away the outer shell and pretending that I am standing on the surface of a smaller planet, half the diameter of the Earth.

Now let us replace the Earth in our story by the entire universe, and let us take our planet to be the center of the universe. (Copernicus showed us that the Earth is not the center of the universe, but the cosmological principle and the theory of relativity tell us that it is as good a center as any!) Then consider a certain galaxy (A) whose distance from the Earth is given as a function of time by $R(t)$, and let us calculate the "weight" of that galaxy—that is, the gravitational force with which the rest of the matter in the universe pulls it toward the center (us). By the same reasoning as used above, we conclude that we can ignore all matter further away from the center than A, and calculate the force pulling A toward the center as the force of gravity between A and a sphere of matter whose center is the Earth and whose radius is R. According to Newtonian gravitational theory, this force is $GMm/R(t)^2$, where G is the universal gravitation constant, m is the mass of A, and M is the mass of the above described sphere, on whose surface A rests. M is just the density $\rho(t)$ times the volume of this sphere, $\frac{4}{3}\pi R(t)^3$. As the universe expands or contracts, this sphere will expand or contract proportionally, so the quantity of matter in the sphere will remain constant. Then we may use the current ($t = 0$) values for $\rho(t)$ and $R(t)$, and write M = $\frac{4}{3}\pi\rho_0 R_0^3$.

This gives, for the gravitational force on A:

$$GMm/R(t)^2 = \frac{4}{3}\pi\rho_0 R_0^3 Gm/R(t)^2$$

By Newton's second law, then, the acceleration (R'') of A is equal to this force divided by the mass (m) of A:

$$R''(t) = -\frac{4}{3}\pi\rho_0 R_0^3 G/R(t)^2$$

where the negative sign is used because the acceleration is negative, that is, gravity decelerates (slows down) the expansion.

The initial conditions for this differential equation are obtained by noting that at $t = 0$ (now) we have $R(0) = R_0$ and $R'(0) = HR_0$, since the rate at which any galaxy is receding from us is supposed to be approximately H (the current Hubble constant) times its distance from us.

If $r(t)$ is defined to be $R(t)/R_0$, r can be interpreted as the size of the universe normalized to make the current size equal to 1. Then the differential equation and initial conditions simplify to:

$$\begin{aligned} r'' &= -\frac{4}{3}\pi G\rho_0/r^2 \qquad (6.1) \\ r(0) &= 1 \\ r'(0) &= H \end{aligned}$$

Now there is an objection which the reader may raise to the way in which (6.1) was derived. It may be argued that there is no net gravitational force on either the Earth or A, because in either case the pull of the rest of the matter in the universe is equally strong in all directions—either can be considered the center of the universe. The answer is that the ultimate justification for (6.1) comes from the general theory of relativity. However, if we look at any sphere of small (cosmologically speaking!) radius, the general theory of relativity allows us to ignore the gravitational effects of material outside that sphere, and to use Newtonian gravitational theory inside the sphere. And we will get equation (6.1) using classical ideas if we take the universe to be a sphere of arbitrary radius, with center at any particular point—Earth, galaxy A, or a neutral third party.

Using techniques found in any elementary differential equations text we find that (6.1) implies:

$$r' = \sqrt{(8\pi/3)G\rho_0/r + C} \qquad (6.2)$$

where C is found, by applying the initial conditions, to be

$$C = H^2 - \frac{8}{3}\pi G\rho_0$$

Now if C is positive, that is, if $\rho_0 < 3H^2/(8\pi G) \equiv \rho_c$, then it is clear from (6.2) that the universe will continue expanding forever, since r' will always be positive. On the other hand, if $\rho_0 > \rho_c$, C will be negative and there will be a value of r which will make $r' = 0$, so that when the normalized size of the universe reaches that value of r, it will stop expanding and begin to contract. This contraction would presumably continue until the universe ends in a "big squeeze."

The differential equation (6.2) can be further solved for $r(t)$ using standard differential equations techniques, but the resulting solution is rather complicated to write out. However, for the case $\rho_0 = \rho_c$, which is thought to be reasonably close to correct, C=0, and (6.2) reduces to $r' = \frac{H}{\sqrt{r}}$ which can be easily solved (remembering that $r(0) = 1$) to give $r(t) = (\frac{3}{2}Ht + 1)^{2/3}$. In this case, we can see that $r = 0$ and $r' = \infty$ when $t = -\frac{2}{3}H^{-1}$, which places the big bang about 10 billion years ago. For other values of ρ_0, the solution is more complicated, but still predicts that $r = 0$ in the finite past, less than $H^{-1} \approx 15$ billion years ago. Some estimates of ρ_0 are around $0.01\rho_c$; that would make the age of the universe about $0.98H^{-1}$.

7

Design in the Laws of Nature

7.1 The 'Fine-Tuning' of the Laws of Physics

The development of models of the early universe involves primarily theoretical calculations, intended to reconstruct what must have happened in the aftermath of the big bang. These computations, and many others made by physicists, show that we are the beneficiaries of some very lucky coincidences. In an interview published in [Varghese 1984], Columbia University astronomer Robert Jastrow discusses what he calls "the most theistic result ever to come out of science:"

> According to the picture of the evolution of the universe developed by the astronomer and his fellow scientists, the smallest change in any of the circumstances of the natural world, such as the relative strengths of the forces of Nature, or the properties of the elementary particles, would have led to a universe in which there

> could be no life and no man.

As an example, Jastrow cites the forces binding the nuclei of atoms together. If the nuclear force were increased in strength by a small amount, he says, this attraction would have been sufficient to cause all hydrogen nuclei (protons) to fuse together into helium during the early stages of the universe, and there would be no hydrogen left to fuel the stars. On the other hand, if the nuclear force were slightly decreased in strength, the attraction would have been insufficient to drive the nuclear fusion reactions which created elements heavier than helium (such as carbon and oxygen), and it is impossible to imagine how any complex life forms could be constructed out of hydrogen and helium alone.

Jastrow continues:

> It is possible to make the same argument about changes in the strengths of the electromagnetic force, the force of gravity, or any other constants of the material universe, and so come to the conclusion that in a slightly changed universe there could be no life, and no man. Thus according to the physicist and the astronomer, it appears that the universe was constructed within very narrow limits, in such a way that man could dwell in it. This result is called the anthropic principle.
>
> Some scientists suggest, in an effort to avoid a theistic or teleological implication in their findings, that there must be an infinite number of universes, representing all possible combinations of basic forces and conditions, and that our universe is one of an infinitely small fraction, in this great plenitude of universes, in

> which life exists.

Now the Darwinist might argue that a different universe, which might be hostile to life as we know it, would only have resulted in life forms which are adapted to different conditions. However, we are not talking about conditions which are hostile to life as we know it on Earth, but rather conditions so hostile that any imaginable form of life would be impossible. In *The Problems of Physics*, A.J. Leggett [Leggett 1987] lists several ways in which the development of life depends sensitively on the values of the universal constants, and says,

> The list could be multiplied endlessly, and it is easy to draw the conclusion that for any kind of conscious beings to exist at all, the basic constants of Nature have to be exactly what they are, or at least extremely close to it. The anthropic principle then turns this statement around and says, in effect, that the reason the fundamental constants have the values they do is because otherwise we would not be here to wonder about them.

Physicist Steven Hawking discusses some of these fundamental constants of Nature and says [Hawking 1988], "The remarkable fact is that the values of these numbers seem to have been very finely adjusted to make possible the development of life."

In *Cosmology*, Edward Harrison [Harrison 1981] mentions some other bad things which would happen if certain constants were tampered with:

> We first notice that alterations in the known values of c [speed of light], h [Planck's constant], and e [electronic charge] cause huge changes

> in the structure of atoms and atomic nuclei. Even when the changes are only slight, most atomic nuclei are unstable and cannot exist.... We also find that slight changes in the values of c, G [gravitational constant], h, e, and the masses of subatomic particles cause huge changes in the structure and evolution of stars. The majority of universes will actually not contain any stars at all, and in the few that do, the stars either are nonluminous or are so luminous that their lifetimes are too short for biological evolution.... Our universe is therefore finely tuned, and we would not exist if the constants of Nature had different values.

But we have to ask ourselves not only, why do the gravitational, nuclear and electromagnetic forces have the strengths that they have, and why do electrons, protons and neutrons have the masses and charges they do, but why are there particles at all, and why are there forces between them? We need to wonder not only why the speed of light is 299,792 km/sec, but why are there photons?

And we should not only wonder why Planck's constant, which appears in the Schrödinger equation, has such a lucky value, but why are the motions of all particles governed by this partial differential equation?[1] One of the most surprising things about our universe is the

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[1] In an N-particle system whose potential energy is given by V, the probability (per unit volume) of finding particle 1 at (x_1, y_1, z_1), particle 2 at (x_2, y_2, z_2), etc, at time t, is $|u(t, x_1, y_1, z_1, ..., x_N, y_N, z_N)|^2$, where u is the solution to the Schrödinger equation

$-i\hbar \frac{\partial u}{\partial t} = \sum_{k=1}^{N} \frac{\hbar^2}{2m_k}[\frac{\partial^2 u}{\partial x_k^2} + \frac{\partial^2 u}{\partial y_k^2} + \frac{\partial^2 u}{\partial z_k^2}] - V(t, x_1, y_1, z_1, ..., x_N, y_N, z_N)u$

where $\hbar$ is Planck's constant, m_k is the mass of particle k and i is the complex number $\sqrt{-1}$.

beautiful way in which mathematical equations can be used to elegantly model physical processes. In the case of macroscopic processes, such as diffusion or fluid flow, we can derive the equations from more basic processes, so that in these cases we feel we "understand" why the mathematics fits the physics. But when we get down to the most fundamental particles and forces, we find they *still* obey an elegant mathematical equation, and we have absolutely no idea why—they just do. There is no conceivable reason why the effect that the fundamental forces have on the fundamental particles should be given by the (complex-valued!!) solution to a wave or eigenvalue partial differential equation, except that it results in elements and chemical compounds with extremely rich and useful chemical properties, and gives partial differential equation software developers like me some very interesting applications to solve. If the elementary particles interacted by bouncing off each other like tiny balls obeying classical Newtonian laws, chemistry would be dead. In *Partial Differential Equations* [Strauss 2008], Walter Strauss writes,

> Schrödinger's equation is most easily regarded simply as an axiom that leads to the correct physical conclusions, rather than as an equation that can be derived from simpler principles.... In principle, elaborations of it explain the structure of all atoms and molecules and so all of chemistry!

Are we to assume that in all these other universes there are still nuclear and electromagnetic forces, electrons, protons and neutrons, and the behavior of the particles is still governed by the Schrödinger partial differential equation; but the forces, masses and charges, and Planck's constant have different values, generated by some cosmic random number generator? Or perhaps the behavior of particles is governed by random types of partial differential equations in different universes, but there are still many universes in which Schrödinger's equation holds, with random values for Planck's constant? No doubt there were some universes which couldn't produce life because their fundamental equation of chemistry looked just like the Schrödinger equation, but with first derivatives in space where there should be second derivatives, or a second derivative in time where there should be a first derivative, or the complex number i was missing, or the linear Vu term was replaced by a nonlinear term Vu^n, where n is not equal to one.[2] The fundamental equation of chemistry appears to itself be fine-tuned.

Scientists modeling the big bang have discovered that a universe capable of supporting life requires not only finely-tuned laws, but also initial conditions which are astronomically improbable. Paul Davies, in *Other Worlds* [Davies 1980], appeals to the anthropic principle no fewer than 10 times to explain benevolent features of our universe. Citing the calculations of various physicists and astronomers, he notes that fine-tuning of various laws is required (e.g., the strengths of the strong and weak nuclear forces must be just right), but also shows that, for example, if the matter in the early universe were distributed a tiny bit more—or less—uniformly, or if the material density were a tiny bit higher—or lower, then the resulting universe would have been very hostile to-

[2] Any of the changes listed—and others not listed—would fundamentally alter the nature of the solutions, and chemistry as we know it would not exist. For example, without the -i, this is essentially a heat equation! In fact, for the real Schrödinger equation, the integral of $|u|^2$ is constant with time; any of the changes suggested would destroy this property, and then solutions could not even represent probability distributions.

ward the conception and development of any form of life. Davies estimates the odds against one of these coincidences to be $10^{1000000000000000000000000000000}$ to 1. And he adds that "there are probably many more features of the world that are vital to the existence of life and which contribute to the general impression of the improbability of the observed world."

Although Davies recognizes that some may see design in the fortuitous features of our universe, he attempts to defend the multiple universes theory. "If we believe that there are countless other universes, either in space or time, or in superspace, there is no longer anything astounding about the enormous degree of cosmic organization that we observe. We have selected it by our very existence. The world is just an accident that was bound to happen sooner or later," he says. Davies compares the anthropic principle's explanation of why the laws, particles and forces of physics are so friendly toward life to the traditional scientific explanation of why conditions on Earth are so ideally suited for life: "The many universes theory does provide an explanation for why many things around us are the way they are. Just as we can explain why we are living on a planet near a stable star by pointing out that only in such locations can life form, so we can perhaps explain many of the more general features of the universe by this anthropic selection process."

As Michael Behe points out in *The Edge of Evolution* [Behe 2007], however, anthropic selection only claims to explain why we live in a universe which can support life, it does not explain why we live in such a "lush" universe, where the fundamental laws of physics not only make life possible, they make it interesting. For example, some of the heavier chemical elements (for example, copper or uranium), which are probably not vital for life itself, have played a critical role in the progress of science and technology, and the existence and useful chemical properties of these elements can also be traced to the fine tuning of our physical laws.

A related argument is now being made regarding the "privileged" position of our planet. It is well-documented that the conditions on Earth are very fine-tuned for the development of life: our planet is the right size, with the right kind of atmosphere, it circles the right kind of star, it is the right distance from this star, to name only the most obvious. Of course, there are many stars, so it has always been argued that there were bound to be some planets in this huge universe with the conditions needed for life. (In fact, there is now some doubt about this, as research continually increases the known list of privileges enjoyed by our planet [Ward and Brownlee 2003].) But now some scientists, such as astronomer Guillermo Gonzalez [Gonzalez and Richards 2004], argue that our planet enjoys other "privileges" which are rare in the universe, which have nothing to do with survival, but seem to give us an ideal platform from which to *view* the universe.

According to the picture drawn by the popular media, primitive man attributed many phenomena in Nature to design, but science has progressively removed the need for the design hypothesis from these phenomena one by one, and now a group of religious fanatics is trying to make a last stand in biological origins, where things are most difficult to explain. The true picture is very different; in fact, we are discovering that primitive man was *not* wrong in attributing many natural phenomena to design, the design just dates back much farther than he imagined, to the origin of the universe. And of course all of the arguments in this chapter take for granted that once the right conditions to support life are present, life can spontaneously develop, an assumption for which there is absolutely no supporting evidence. As Richard Dawkins famously admitted in the movie *Expelled*,[3] no one really has any idea how life could have originated.

It is difficult to argue with those who appeal to "anthropic selection" to explain improbable circumstances; about all you can say is that there is a simpler explanation. But other universes are by definition beyond observation, so that the anthropic principle is untestable, and therefore unscientific. It is interesting to see how those who for many years have criticized the creationists for inventing an agent external to our universe to account for the appearance of man are now reduced to inventing other universes to explain our existence.

Fred Heeren [Heeren 1995] illustrates the silliness of the idea that, given enough universes, everything will eventually happen. If there are enough universes, he says, one of them would be just like ours except that in that one Elvis Presley kicked his drug habit, got involved in Tennessee politics, and became president of the United States. It seems much simpler to believe that our universe appears to be cleverly designed because it *is* cleverly designed.

7.2 Design in Mathematics

When we think of design, we normally think of biology, or perhaps physics, but usually not mathematics. How can we see design in something that could not be any different than it is? I don't know if mathematics

[3] www.expelledthemovie.com

could have been different than it is, but as a mathematician, I still see design in mathematics, and plenty of it. The non-mathematician, who may think of mathematics as consisting only of arithmetic and perhaps algebra and geometry, could never imagine the richness that is there, waiting to be discovered, in the many fields and subfields of mathematics. How could he imagine that there are enough interesting and challenging problems to keep thousands of mathematicians busy and entertained throughout their lifetimes? Number theory is the study of the positive integers: 1,2,3,4,.... One might think that at least in this field of mathematics the number of interesting problems would be soon exhausted, and that all of the most important problems would be quickly solved; but one would be quite wrong on both counts. Many simple-sounding problems in number theory remain unsolved to this day, for example, are there an infinite number of "twin primes"—primes which differ by 2, such as 881 and 883?

To illustrate the richness that can be hidden in a simple-looking mathematical definition or equation, I offer the following example. Consider the iteration:

$$x_{n+1} = ax_n(1 - x_n)$$

If a is between 1 and 3, you can start anywhere in the interval $0 < x_0 < 1$ and you will converge eventually to a specific fixed point, $x = \frac{a-1}{a}$. If a is between 3 and 3.4495, you can start almost anywhere (anywhere except exactly at the fixed point $x = \frac{a-1}{a}$, which no longer attracts nearby iterates) in the interval $(0, 1)$ and you will end up oscillating back and forth between two specific points, that is, you will converge to an "orbit" of period

2. If you increase a a little more, you can start almost anywhere (anywhere except at the fixed point or one of the points of the period 2 orbit, which is also no longer "attractive") and you will converge to an orbit of period 4, a little more and the attractive orbits have higher and higher periods. Finally, if a is increased to 4, you have the following strange situation. There are now orbits of every possible period, but none of them are attractive, so if your x_0 avoids all of these orbits, you will wander around in a random-looking, "chaotic," fashion forever, never converging to any fixed point or any periodic orbit. Since there are an infinite number of periodic orbits, one might think that if you pick x_0 at random your chances of missing all of them would be pretty low. But in fact, your chances are 100%—you are virtually certain to miss them all, and jump around in a chaotic manner forever. All of this information can be gleaned from analyzing this simple equation, called the logistic equation.

Biologists find that as they look deeper and deeper into the cell, things do not become simpler, they become more complex, and more interesting. Scientists in other fields have also found that the deeper they dig, the more interesting things become, and I see no sign that any subfield of mathematics is beginning to run dry either, all indications are that there are as many entertaining problems in each of them as there are mathematicians to study them. Furthermore, the connection between mathematics and the sciences is truly astounding, and points to a common designer. Who could have imagined, for example, that a field of "pure" mathematics such as algebraic group theory would be important to quantum physics? Similar mathematical equations show up in the most diverse applications. To cite an example in my own area of expertise: partial differential equations find applications in almost every conceivable field of science and engineering, as can be appreciated by looking at the list of over 250 publications (in over 100 *different* journals, at www.pde2d.com) in which my partial differential equation-solving software has been used to simulate physical phenomena.

British physicist Sir James Jeans said "From the intrinsic evidence of his creation, the Great Architect of the Universe begins to appear as a pure mathematician." I don't know how mathematics could have been different than it is, but I nevertheless insist: mathematics is also designed.

7.3 The Stability of Planetary Orbits

Here is a simple example to illustrate "fine-tuning" in the laws of physics.

In our universe, the force of gravity between two bodies of masses M and m, at a distance r apart, is given by $F = -GMm/r^2$, where G is the gravitational constant. We have already mentioned that if we play with the constant G and make it a bit larger or smaller, terrible things would happen that make it impossible for our universe to support life, but it requires some advanced physics to show this. However, it requires only a little physics, and a little calculus, to see what would happen if we play with the r^2 term in the denominator, so let's do this. The results are not nearly as striking, but this is one of the few examples of fine-tuning that can be understood without any advanced physics.

So let us replace our inverse square law of gravity by $F = -GMm/r^n$, where n may be an integer other than

2, and let us look at the orbit of the Earth around the sun. If the position of our sun, of mass M, is taken to be fixed at the origin, and the position of Earth, of mass m, is given by $(x(t), y(t), z(t))$, Newton's second law says

$$m(x'', y'', z'') = -\frac{GMm}{r^n}(\frac{x}{r}, \frac{y}{r}, \frac{z}{r})$$

that is, the mass of the Earth times its acceleration vector is equal to the force of gravity on the Earth, which is a vector of magnitude GMm/r^n in the direction of the unit vector $-(\frac{x}{r}, \frac{y}{r}, \frac{z}{r})$, ie, toward the sun.

Since orbits will remain in the plane they start in, and we can take the z axis to be normal to this plane, we can express the Earth's position using polar coordinates as $x(t) = r\ cos(\theta), y(t) = r\ sin(\theta), z(t) = 0$. Now, after a bit of work, the above differential equations can be written in polar coordinates as:

$$\begin{aligned} r'' - r(\theta')^2 &= -GM/r^n \\ 2r'\theta' + r\theta'' &= 0 \end{aligned}$$

The second equation, after multiplying through by r, is equivalent to $(r^2\theta')' = 0$, which means $r^2\theta' = c$, a constant. Substituting $\theta' = c/r^2$ into the first equation, we get a differential equation for $r(t)$:

$$r'' = c^2/r^3 - GM/r^n \tag{7.1}$$

From equation (7.1) we can see why orbits can be stable in an inverse-square force field: if $n = 2$, then when r gets too small, the positive term (due to the centrifugal force) dominates, and the radial acceleration is positive, which tends to increase r. When r gets too large, the negative term (due to gravity) dominates, and the radial acceleration is back toward the sun. But what if we increase n, to 3? Now, $r'' = (c^2 - GM)/r^3$ and if $c^2 - GM$ is positive the acceleration will always be positive, and the Earth would spiral away out of the solar system; if $c^2 - GM$ is negative, the Earth would spiral into the sun. Neither outcome would be very healthy for life on Earth! If n is even larger than 3, the negative term in (7.1) dominates when r is small, and the positive term dominates when r is large, so that all orbits of all planets are again unstable.

Now one could argue that it is only natural that in our three-dimensional universe, the force of gravity would obey an inverse-square law (though the nuclear forces do not). In an N-dimensional universe, the energy from a source (e.g., the sun) is spread out, at a distance r, over an "area" of size proportional to r^{N-1}, so its intensity is proportional to $1/r^{N-1}$. Thus it might seem reasonable that the effect of the sun's gravity would also die out at this rate as we move away from it. But if we accept this argument, we can say we are lucky we live in a three-dimensional universe, because if N were 4 or more, gravity would obey an inverse cube (or worse) law, and since orbits would still be planar (a planet would remain in the 2D subspace spanned by its initial position and velocity vectors), the above polar coordinate analysis is still valid and shows that all orbits would be unstable in universes of more than three dimensions. And who wants to live in a 1D or 2D universe, where all we could see would be points or lines!

8

The Supernatural Element in Nature

8.1 Axioms and Evidence

In his 1888 book *Evolution* [Le Conte 1888] Joseph Le Conte, professor of Geology and Natural History at the University of California, and (later) president of the Geological Society of America, writes:

> Intermediate links may be wanting now, but they must, of course, have existed once—i.e., in previous geological times, and therefore ought to be found fossil. In distribution in space or geographically, organic kinds may be marked off by hard-and-fast lines but, if their derivative origin be true, in their distribution in time or geologically, there ought to be many examples of insensible shadings between them. In fact, if we only had all the extinct forms, the organic kingdom, taken as a whole and throughout all time, ought to consist not of species at

> all, but simply of individual forms, shading insensibly into each other.... But this is not the fact. On the contrary, the law of distribution in time is apparently similar in this respect to the law of distribution in space, already given. As in the case of contiguous geographical faunas, the change is apparently by substitution of one species for another, and not by transmutation of one species into another. So also in successive geological faunas, the change seems rather by substitution than by transmutation. In both cases species seem to come in suddenly, with all their specific characters perfect, remain substantially unchanged as long as they last, and then die out and are replaced by others. Certainly this looks much like immutability of specific forms, and supernaturalism of specific origin.... The reason for this, given by Darwin and other evolutionists, is the extremely fragmentary character of the geological record.... While it is true that there are many and wide gaps in the record... yet there are some cases where the record is not only continuous for hundreds of feet in thickness, but the abundance of life was very great, and the conditions necessary for preservation exceptionally good... and yet, although the species change greatly, and perhaps many times, in passing from the lowest to the highest strata, we do not usually, it must be acknowledged, find the gradual transitions we would naturally expect if the changes were effected by gradual transformations.

Le Conte also acknowledges that natural selection cannot explain the appearance of new, irreducibly complex, features (called "novelties" in his day):

> ... neither can it [natural selection] explain the first steps of advance toward usefulness. An organ must be already useful before natural selection can take hold of it to improve on it.

After acknowledging that the only direct evidence, the fossil record, does not support the idea of gradual change, and that the only theory ever taken seriously as to the causes of these changes can explain everything except anything new, Le Conte nevertheless concludes:

> We are confident that evolution is absolutely certain—not evolution as a special theory—Lamarckian, Darwinian, Spencerian... but evolution as a law of derivation of forms from previous forms. In this sense it is not only certain, it is *axiomatic*.... The origins of new phenomena are often obscure, even inexplicable, but we never think to doubt that they have a natural cause; for so to doubt is to doubt the validity of reason, and the rational constitution of Nature.

And so in 1888 Le Conte acknowledges what will become clear to anyone who follows the modern debate between Darwinism and intelligent design: evolution is an axiom, and axioms do not need supporting evidence.

Le Conte illustrates the optimism which prevailed in science in the late 19th century. Science had made such progress explaining previously mysterious phenomena that there was no reason to believe, it was felt, that any of the secrets of Nature, even the secrets of life itself, would long endure the assault of scientific investigation. In Le Conte's day, nearly all scientists held the view that everything that happens in our world is completely determined by the laws of Nature, that the only limits to our ability to understand what has happened, and predict what will happen in the future, are practical limits on the extent of our knowledge.

Le Conte's axiom that science can explain everything continued as a fundamental pillar of philosophy throughout the 20th century. Olan Hyndman, in *The Origin of Life and the Evolution of Living Things*, [Hyndman 1952], calls Darwinism "the most irrational and illogical explanation of natural phenomena extant." Yet he says "I have one strong faith, that scientific phenomena are invariable... any exception is as unthinkable as to maintain that thunderbolts are tossed at us by a man-like god named Zeus," and so he goes on to develop an alternative—and even more implausible—theory (Lamarckian, basically) of the causes of evolution. Jean Rostand [Rostand 1956], quoted in Section 2.2, says "However obscure the causes of evolution appear to me to be, I do not doubt for a moment that they are entirely natural." Hans Gaffron [Gaffron 1960], in a paper presented at the 1959 University of Chicago Centennial Congress *Evolution after Darwin*, presents a theory on the origin of life, but admits, "no shred of evidence, no single fact whatever, forces us to believe in it. What exists is only the scientists' wish not to admit a discontinuity in Nature and not to assume a creative act forever beyond comprehension."

A November 10, 2008 article in *News at Princeton* (www.princeton.edu/main/news/archive) entitled "Evolution's New Wrinkle: Proteins with Cruise Control Provide New Perspective," reports on research by four Princeton scientists, published in a *Physical Review Letters* article:

> The experiments, conducted in Princeton's Frick

> Laboratory, focused on a complex of proteins located in the mitochondria, the powerhouses of the cell.... Chakrabarti and Rabitz analyzed these observations of the proteins' behavior from a mathematical standpoint, concluding that it would be statistically impossible for this self-correcting behavior to be random, and demonstrating that the observed result is precisely that predicted by the equations of control theory.... The authors sought to identify the underlying cause for this self-correcting behavior in the observed protein chains. Standard evolutionary theory offered no clues.... Chakrabarti said, 'Control theory offers a direct explanation for an otherwise perplexing observation and indicates that evolution is operating according to principles that every engineer knows.' The scientists do not know how the cellular machinery guiding this process may have originated, but they emphatically said it does not buttress the case for intelligent design.

No explanation whatever is offered for why the authors reject the conclusion to which their experiments and observations seem to point. None is needed, because everyone understands the reason: Le Conte's axiom.

8.2 The Advent of Quantum Mechanics

Surprisingly, less than 40 years after his book appeared, Le Conte's axiom was shattered by the discoveries of quantum mechanics, which introduced, quite literally, a "supernatural" element into science.

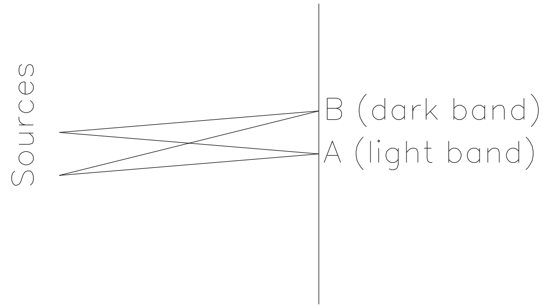

Figure 8-1. Wave Diffraction

To understand the background for the discoveries of quantum mechanics, let us start with a classic diffraction experiment. Suppose two wave sources in phase and of the same wavelength, λ, are placed a small distance apart as shown in Figure 8-1. We can imagine these to be sound waves, for example. At a point on a wall, A, chosen to be equally distant from each source, the waves from the two sources will arrive in phase, and reinforce each other. However, at a point B, chosen to be exactly $\lambda/2$ further from one source than the other, the waves will arrive one half cycle out of phase, and cancel each other at all times. We will also observe this cancellation at the points whose distances from the two sources differ by 1.5, 2.5, 3.5,... wavelengths, and so as we move up the wall we will encounter alternating points of reinforcement and cancellation. Experiments with light diffraction had been carried out, in which light from a distant source, of a single wavelength, is passed through two narrow slits on a plate perpendicular to the direction to the source. Since the two slits are equally distant from the source, the light should hit the two slits in phase, and the two slits can thus be considered to be separate light sources in phase with each other. Where the light from these two "sources" hits a wall, a diffraction pattern with alternating light and dark bands will be observed. If one slit is covered up, the dark bands go away!

It is easy to see why, at the beginning of the 20th century, it was unanimously agreed that light must consist of waves. If light consists of particles, it is hard to see how light from one source could cancel the light from another source!

Some new experiments, however, seemed to be inconsistent with the wave theory of light. In the photoelectric effect, for example, it was observed that when a metal plate was illuminated, the energy delivered by the light caused some electrons to be stripped from their host atoms and ejected from the plate. Since an electron must reach a certain threshold energy level before it can escape the metal, experimenters were surprised to find that even when light of extremely low intensity was aimed at the plate, a few electrons were immediately able to absorb enough energy to be ejected. If light were propagated through waves we would expect the light energy to be spread more evenly over the metal, and at very low intensities we would expect to have to wait a while before *any* electron could absorb enough energy to escape. When the intensity of the light was increased, another unexpected result was observed. The number of electrons emitted increased with the intensity, but the energies of the individual emitted electrons were unchanged. The ejected electrons, it seemed, had received a packet, or "quantum," of energy whose magnitude was independent of the light intensity; increasing the intensity seemed only to increase the number of such packets available.

A particle theory of light would explain these results: even at very low light intensities, a few electrons (those hit by the light “particles”) would be immediately ejected, and increasing the intensity (the number of light particles bombarding the metal) would cause more electrons to be knocked out, but the energy of an individual ejected electron would depend only on the energy of the light particle which struck it, not on the number of light particles. Further experimentation showed that while the energy of an individual ejected electron did not vary with the intensity of the light, it did change with color, increasing as the wavelength of the light was decreased.

For a while, light had to be considered to have a dual nature, since some experiments (such as diffraction) could only be explained using the wave theory, while others (such as the photoelectric effect) could only be explained using the particle theory. The spectroscope, a tool used by astronomers, separates out the different wavelengths of light by bending them through different angles. It was designed using the wave theory of light and it should not work, according to the particle theory. The Geiger counter, on the other hand, is designed to count individual “particles” of electromagnetic radiation, and light is electromagnetic radiation.

In the early 1920’s, the two opposing views of light were reconciled by the following theory: Light consists of particles (photons), but there is a wave associated with each photon, whose intensity at a given point gives the *probability* of finding a photon at that point. In other words, light consists of particles whose motions are guided by probability waves.

In 1924 French physicist Louis de Broglie further suggested that this dual wave/particle nature was characteristic not only of electromagnetic waves, such as light, but of all “particles.” He concluded that any particle of momentum p is guided by a probability wave of wavelength $\lambda = h/p$, where h is called Planck's constant. This would explain why, in the photoelectric experiment, the electrons knocked out by the lower wavelength light came off with a higher energy: the lower wavelength photons have a greater momentum. Spectacular confirmation of de Broglie's conclusion came in 1927, when electron diffraction was first observed, by Davisson and Germer at Bell Telephone Laboratories. The electron's particle nature was undisputed: we find 1,2,3... electrons in an atom; we never find the electronic charge or mass in other than integral multiples. Yet electrons were observed to diffract—a phenomenon unique to wave motion, involving cancellation—when passed through a metal crystal. Because electrons typically pack a much greater momentum than photons, and thus their associated wavelengths are much smaller, the electron diffraction pattern is only observable when the spacing between slits is very small. That is why electron diffraction was first observed using the tiny spaces between atoms in a metal crystal as "slits." Other atomic particles such as neutrons have since been made to exhibit the diffraction characteristic of waves as well.

The governing equation of the new quantum physics is the Schrödinger equation, which can be used to calculate the "probability distribution" of particles. For example, Figure 8-2 [taken from Fitzgerald and Sewell 2000] shows the probability distribution associated with the second lowest energy level, for an electron in the vicinity of two protons, as calculated by my partial differential equation solver, PDE2D (www.pde2d.com). Note that there is no attempt to say exactly where the electron is at any given time (until it is directly observed), we can only say where it "probably" is.

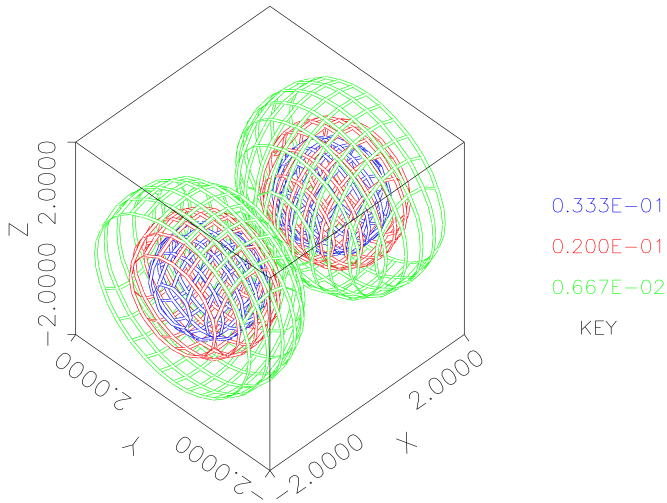

Figure 8-2. Electron Probability Density Near Two Protons
(levels coded by color)

To fully appreciate why science was forced, to the dismay of many, to drag "probability" into the picture, let us go back and repeat the two-slit diffraction problem of Figure 8-1, only this time let us imagine a beam of electrons rather than a beam of light, and let us replace the wall with a photographic plate. (We need to also imagine that the spacing between slits is extremely small, since these are electrons.)

Let us set the intensity of the electron beam at such a low level that we can assume that only one electron at a time passes through the diffraction apparatus. Each electron which is not stopped by the first plate will pass through one of the two slits and hit the photographic plate at a particular point, marking its impact with a dark spot. After these dark spots begin to accumulate, however, we begin to observe the familiar wave diffraction pattern of alternating light and dark bands on the film. The individual electrons impact the film at specific spots, yet the collection of impact marks conforms to the diffraction pattern expected for a wave whose wavelength is given by the de Broglie formula. In other words, a particular electron may hit the film almost anywhere, but when a large number of electrons pass through the slits, the result is highly predictable.

Suppose we repeat the experiment, only this time instead of leaving both slits open long enough for N electrons to pass through, we block the top slit and leave the bottom slit open until N/2 electrons have passed through it; then we block the bottom slit and let another N/2 electrons pass through the top slit. Surely the results will be the same as in the first experiment. How could it possibly matter whether we allow the electrons to alternate randomly between slits, or force the first batch of electrons to pass through the bottom slit and the second batch to pass through the top slit? But it does matter: in the first experiment we would get a diffraction pattern, while in the second we would get only a more or less uniformly exposed film. Incredibly, the behavior of an electron passing through one slit seems to be affected by whether or not it *could have* passed through the other! We can explain these results only if, when both slits are open, we think of each individual electron as a probability wave, passing through both slits—and yet each electron strikes the film as a particle! In other words, until it is actually observed, we must think of the position of the electron as *inherently* ill-defined, specified only by a probability density function; when it is finally observed (when it hits the film) it has a very definite position.

8.3 Philosophical Implications

The introduction of "probability" into physics has enormous philosophical implications. For the first time, science had to face the fact that no matter how well we prepare for any experiment, no matter how much data we accumulate, we cannot predict with certainty the outcome of the experiment. British astronomer Sir Authur Eddington, in his classic work *The Nature of the Physical World* [Eddington 1929], says that according to quantum theory, "the future is a combination of the causal influences of the past together with unpredictable elements—unpredictable not merely because it is impracticable to obtain the data of prediction, but because no data connected causally with our experience exist."

Einstein objected to quantum mechanics with its introduction of chance and the "uncertainty principle" into science, saying "God does not play dice," but the quantum theory has been so successful in explaining scientific phenomena that it is now universally accepted.

If there are a billion electrons in an electron beam, we can predict with high accuracy and high confidence the pattern they will make as they hit the target, but if we look at a particular electron in the beam we can predict where it will hit with much less accuracy. If we have a billion atoms of a radioactive substance whose half-life is 10 years, we can be very confident that almost exactly a half billion will decay within 10 years, but if we try to predict when a particular atom will decay, all we can do is guess. And it doesn't matter how much we learn about that particular electron or radioactive atom, or its neighbors, we will never be able to predict with certainty what the electron or atom will do. For it is not the practical constraints of our experiment, but the theory itself, that limits our predictive powers.

One of the philosophical implications of the "uncertainty principle" introduced by quantum mechanics is that the idea—so contrary already to our intuition—that all human actions are strictly determined (in a complicated way) by external influences, is shown once and for all to be wrong. For even the individual particles which make up the brain have a "free will" of their own; even their behavior is not strictly predictable. Eddington says [Eddington 1929], "It is meaningless to say that the behavior of a conscious brain is precisely the same as that of a mechanical brain, if the behavior of a mechanical brain is left undetermined." Further, he states that with the advent of quantum mechanics, "science thereby withdraws its moral opposition to freewill."

It could be added that science must also withdraw its moral opposition to religion, for if we define the "supernatural" to be that which is forever beyond the ability of science to predict or explain, then there is, quite literally, a "supernatural" element to all "natural" phenomena. Eddington says that quantum mechanics "leaves us with no clear distinction between the natural and the supernatural."

When we say that the result of a coin toss, for example, is determined by "chance," we really mean that it is determined by factors too complicated to predict in practice, but we assume that if we knew the initial conditions and forces with sufficient accuracy we could predict whether it would land heads or tails. But with quantum mechanics, when we talk about “chance,” we mean something very different, we do not mean a factor too complicated to predict in practice, but rather a factor which is *inherently* impossible to predict. Although science can still be used to predict macroscopic phenomena with probabilities approaching certainty, it can predict microscopic phenomena with less confidence.

We have already seen in Chapter 6 that the discovery of the big bang means that atheists can no longer complain that those who believe that “in the beginning God created the heavens and the Earth” are profaning science with supernatural speculation. Since there were no natural causes before Nature came into existence suddenly a few billion years ago, they are now just as guilty; now everyone must speculate about the supernatural forces which created our universe, the debate is now only about whether those forces were intelligent or unintelligent. Now the same can be said about the origin of life, or the origin of species: the atheist can no longer criticize proponents of intelligent design for staining the purity of science by trying to introduce supernatural causes into the picture (this criticism is still used, of course, and quite liberally, but it is no longer logically valid). Now it must be accepted by everyone—everyone who is aware of quantum mechanics, at least—that there is a supernatural component to all natural phenomena, the question is again only whether this supernatural component is intelligent or unintelligent. And while it is difficult to see any clear and compelling evidence of intelligent design in many “natural” phenomena, when we look at the origin and development of life, the evidence is overwhelming. Even if we accept the Darwinist's claim—wholly unsupported by the evidence—that species developed very gradually, the question is still there: was the supernatural element involved intelligent or truly "random," as Darwin believed?

In summary, those who claim that science has eliminated the supernatural from Nature have a view of science that has been out of date for 90 years. When we try to reduce all of reality to matter in motion, we find quite a surprise: there at the bottom, controlling the motion of matter, is the remarkable Schrödinger equation of quantum mechanics, which tells us that science is an entertaining and useful tool to help us understand our world, but it does not have all the answers, and *never will.*

9

The Scientific Theory of Intelligent Design

9.1 'You Have Lost Your Mind'

In a December 21, 2005 on-line *American Spectator* article, Jay Homnick wrote:

> It is not enough to say that design is a more likely scenario to explain a world full of well-designed things. Once you allow the intellect to consider that an elaborate organism with trillions of microscopic interactive components can be an accident... you have essentially 'lost your mind.'

Before Darwin, nearly everyone, in every corner of the world, believed in some type of "intelligent design" (the majority still do), for good reasons. Since the publication of *Origin of Species*, science has discovered that living things are far more complex and clever than Darwin could have ever imagined, and Darwin's explanation for this complexity has become less and less plausible, so the reasons for believing in intelligent design have only *increased* in the last 150 years. Even atheist Richard Dawkins wrote [Dawkins 1996] that “biology is the study of complicated things that give the *appearance* of having been designed.” So how did it happen that a majority of our intellectuals lost their minds?

I think I can explain. When one becomes a scientist, one learns that science can now explain so many previously inexplicable phenomena that one comes to believe that nothing can escape the explanatory power of our science. When one becomes a biologist, or a paleontologist, one discovers many things about the origin of species, such as the long periods involved and the evidence for common descent, that give the impression of natural causes. When one studies history, one may become overwhelmed by the misery and confusion of the human condition, and wonder, why is it so hard to see evidence of the hand of God in human history?

But notably absent from any list of reasons why intellectuals reject intelligent design is any direct scientific evidence that natural selection of random mutations or any other unintelligent process can actually do intelligent things, like design plants or animals. The argument “we have found natural explanations for many other previously unexplained phenomena” is powerful, but not definitive: there are numerous examples in the history of science of ideas that worked well for a long time, then quit working when applied in new situations. The arguments “this just looks like natural causes” and “why is the world God created sometimes so cruel?” are also persuasive—there *are* many things in the history of life that leave a strong impression of natural causes, and I certainly do understand why the pain and evil that exist in this world cause many to doubt that it is designed (see the Epilogue)—but these arguments are obviously also not conclusive.

Darwinists have discovered that they can simply line up a series of similar fossils in a museum and count on this as being mistaken as conclusive evidence for "natural" causes. A series of fossils is not a scientific argument against design, it is a theological argument against design; it does not tell us *anything* about the causes of the changes. The argument is basically, "this doesn't look like the way God would have created things," an argument frequently used by Darwin in *Origin of Species*, even though it does look a lot like the way we create things (see Sections 2.2 and 5.3). Somehow we got the idea that while humans, the only other known intelligent designers in the universe, have to create through careful planning, testing and improvements, God doesn't need to get involved in the details, so He should be able to create anything from scratch, using a magic wand. But no matter how intelligent a designer is, he still has to get involved in the details, that's what design is!

However strong may be the philosophical, psychological and religious reasons why many of our greatest minds reject it, the argument for intelligent design is still crystal clear to the unindoctrinated: unintelligent forces cannot design eyes, ears, hearts and brains.[1] This argument *is* definitive, and from a purely logical point of view, much

[1] The second law argument used in Chapters 3-5 is one way to state in more "scientific" terms what is already obvious to the layman, that unintelligent forces cannot do intelligent things. Another popular way to state this: only intelligence can create information. Molecular biologist Jonathan Wells [Wells 2006] says "The secret of life is not the physical DNA molecule, but the information it carries." Stephen Meyer [Meyer 2009] says, "information typically degrades over time unless intelligent agents generate (or regenerate) it.... Common experience confirms this general trend—and so do prebiotic simulation experiments and origin-of-life research."

more powerful than all the others, which are just diversions from the real issue. No matter how many other mysteries of Nature may yield to scientific investigation, and no matter how much evidence for common descent we may find, Jay Homnick is still right. Once you allow yourself to seriously consider the possibility that the human body and the human brain could be entirely the products of unintelligent forces, you have lost your mind.

9.2 Theistic Evolution

Nevertheless, Le Conte's axiom (Section 8.1) that everything must have a natural explanation has become the foundation of all of modern thought—and indeed it has proven to be a very useful and productive axiom. Even many people who believe in God accept Le Conte's axiom (for example: Le Conte!). "Theistic evolutionists" argue that God created the universe and its laws, and that these laws are sufficient to explain everything we see today. Science has proven so far to be such a powerful tool that these people are convinced that God has an agreement with us never to do anything that we cannot understand using this tool.

I have no philosophical or theological problem with such a view: the laws God created are very cleverly designed, and they alone may be sufficient to explain all of chemistry, geology, astronomy and atmospheric science, for example, so it is not surprising that many would insist that it must be possible to explain all of biology using these laws as well. The problem I have with this view is logical: the known laws of physics are indeed very cleverly designed, and may explain everything that has happened on *other* planets, but they are obviously *not* clever enough to explain all of biology. The atheistic evolutionist has decided *a priori* that there can be no design in Nature; the theistic evolutionist has decided *a priori* that there can be design only in the original laws of Nature. ID proponents argue that we should look at the evidence before deciding where there is design.

I wrote a short humorous post for "Evolution News and Views" (www.evolutionnews.org) September 23, 2013, entitled "Theistic Evolution Explained:"

> Three geologists stand at the foot of Mt. Rushmore. The first geologist says, "This mountain depicts perfectly the faces of four U.S. Presidents, it must be the work of a master sculptor." The second says, "You are a geologist, you should know that all mountains were created by natural forces, such as volcanos and plate movements, the details were then sculpted by erosion from water and wind. How could you possibly think this was the work of an intelligent sculptor? Only a person completely ignorant of geophysics could think those faces were designed."
>
> The third geologist says to himself, "I don't want to be seen as ignorant, but the faces in this mountain sure do look like they were designed." So he thinks a moment and says to the second geologist, "Of course you are right, these faces were sculpted by natural forces such as erosion. Only an ignorant person would think they were designed." Then he turns to the first and says, "But what a magnificent result, there obviously must have been a master sculptor standing by and watching."

Actually, I suspect many people we might call theistic evolutionists really believe that the "master sculptor" was secretly doing more than standing by and watching. In other words, they really believe in intelligent design and don't realize it—or don't want to admit it.

Figure 9-1. Mt. Rushmore

9.3 Is Intelligent Design Science?

I have been writing on this topic for more than 35 years now, and some of the ideas in this book first appeared in self-published booklets in the 1980s, and in a "Postscript" of a 1985 Springer Verlag book [Sewell 1985], because in those days it was even harder to publish anything critical of evolution in the scientific journals. Then, the only other people questioning Darwin's explanation for the development of life were the so-called "creationists," who were right on the main issue, but who had a much broader agenda, they were trying to make the case for a literal interpretation of Genesis, and debates over evolution often became debates over the historical accuracy of the Biblical account of Noah and the flood. The modern resurgence of "intelligent design," which perhaps began with the 1996 publication of Michael Behe's landmark work, *Darwin's Black Box* [Behe 1996] and which is led by the Discovery Institute's Center for Science and Culture (CSC) (www.discovery.org/id), is quite different from yesterday's creationist movement. ID supporters claim, correctly, that one can deduce the existence of an intelligent designer from the evidence all around us, particularly in biology, but do not attempt to go any further than that, because that is as far as the scientific evidence alone can take us. In fact, many ID proponents will not even identify this designer with God, because, they say, the scientific evidence does not tell us anything about the designer. For all we know, for example, he could have been a "more evolved" visitor from another planet, as Richard Dawkins speculated in the movie *Expelled.* This is true; however, the fine tuning of the laws of physics (Section 7.1) obviously cannot be credited to Dawkins' alien, and it seems reasonable to assume it was the same designer, and the designer of the laws of Nature is "God" by definition—by my definition, at least. Naturally, the scientific evidence does not tell us if this is the God of the Bible, or of the Koran, or an "unknown" God.

Many critics of ID today still try to label ID as "creationism," because it was so much easier to discredit the old creationists—all you had to do was produce evidence for an old Earth, or for common descent, then you didn't have to deal with their main point. Others avoid the real issue by simply dismissing ID as "not science." The attitude of the majority of scientists today still seems to be that ID must be discarded *a priori*, before even evaluating the supporting evidence, because ID is not science. We recall from Chapter 6 that the idea that time could have a beginning was also rejected *a priori* by many scientists—Walther Nernst said it "contradicted the very foundations of science." The big bang theory nevertheless eventually won acceptance due to the "pressure of empirical data."

Biologist Wolf-Ekkehard Lönnig of the Max Planck Institute for Breeding Research in Cologne, who studied mutations for over 30 years, has written a detailed, thoroughly researched, article (www.weloennig.de/Giraffe.pdf) "The Evolution of the Long-Necked Giraffe" which shows that nearly everything about the popular Darwinian story of how the giraffe got its long neck (including the idea that it happened gradually) is either false or unsubstantiated, and concludes, in Part II:

> ... the scientific data that are available to date on the question of the origin of the giraffe make a gradual development through mutation and selection so extremely improbable that in any other area of life such improbability would force us to look for a feasible alternative. Yet biologists committed to a materialistic world view will simply not consider an alternative. For them, even the most stringent objections against the synthetic evolutionary theory are nothing but open problems that will be solved entirely within the boundaries of their theory. This is still true even when the trend is clearly running against them, that is, when the problems

> for the theory become greater and greater with new scientific data. This essential unfalsifiability, by the way, places today's evolutionary theory outside of science....

To illustrate how "unfalsifiable" evolutionary theory is, consider the reaction of evolutionary biologists to the "front-loading" being discovered by modern science in the genes of primitive animals, as reported in this August 22, 2008 *Science* article [Pennisi 2008]:

> Trichoplax adhaerens barely qualifies as an animal. About 1 mm long and covered with cilia, this flat marine organism lacks a stomach, muscles, nerves, and gonads, even a head... yet this animal's genome looks surprisingly like ours, says Daniel Rokhsar, an evolutionary biologist at the University of California, Berkeley. Its 98 million DNA base pairs include many of the genes responsible for guiding the development of other animals' complex shapes and organs, he and his colleagues report in the 21 August issue of *Nature*.... Adds Casey Dunn, an evolutionary biologist at Brown University, 'It is now completely clear that genomic complexity was present very early on' in animal evolution.... 'Many genes viewed as having particular functions in bilaterians or mammals turn out to have a much deeper evolutionary history than expected, raising questions about why they evolved,' says Douglas Erwin, an evolutionary biologist at the Smithsonian National Museum of Natural History in Washington.

Front-loading is completely fatal to Darwinism: there is no possible selective advantage for the possession of genes for traits which would not evolve until millions of years later! Yet for today's evolutionary biologists, such discoveries only "raise questions about why they evolved." They seem completely incapable of drawing the obvious conclusion, that processes incapable of planning ahead—incapable of *design*—could not possibly cause genes to appear long before the traits they support exist.[2]

I was a visiting assistant professor at Purdue University in 1978-79, when I replied to a letter in the Purdue student newspaper (the *Exponent*) which compared those who doubt Darwin to "flat earthers." My response anticipates today's debate over whether intelligent design is science or not:

> Last year I surveyed the literature on evolution in the biology library of Oak Ridge National Laboratory and found Olan Hyndman's *The Origin of Life and the Evolution of Living Things* in which he calls the neo-Darwinian theory of random mutation and natural selection 'the most irrational and illogical explanation of natural phenomenon extant' and proposes an alternative theory; Rene Dubos' *The Torch of Life* in which he says '[The neo-Darwinian theory's] real strength is that however implausible it may appear to its opponents they do not have a more plausible one to offer in its place'; and Jean Rostand's[3] *A Biologist's View* in which he says that the variations which made up evolution must have been 'creative and not ran-

[2] But programmers can and occasionally do include code which is not used by the current version of their program, in anticipation of a need for it in some future version.

[3] Rostand was "one of the leading European biologists," according to the book cover, and the author of more than thirty scientific books.

> dom.' Rostand, who elsewhere has called the neo-Darwinian theory a 'fairy tale for adults,' attributes this creativeness to the genes themselves, and says 'quite a number of biologists do, in fact, fall back on these hypothetical variations to explain the major steps of evolution.' I was not, however, able to find any books which suggested that this creativeness originated outside the chromosomes—these are restricted to theological libraries, because they deal with religion and not science, and their authors are compared to flat earthers in *Exponent* letters.

It is argued that ID is not science because its proponents are not sure, and cannot agree among themselves, exactly when, where or how design came into play in evolution—was design involved in the creation of every new species or, for example, front-loaded into the genes of the new animal phyla which appeared suddenly during the Cambrian explosion 500 million years ago (see [Meyer 2013])? Were new species "special creations," or actual descendents of previous species, the products of "creative" mutations?[4] These are legitimate objections, and certainly ID is a science in its infancy, but by looking at the larger view, we can be sure there was design involved in the history of life, even if we do not yet know when, where or how. It is possible that we will never know. But even if we concede that ID is not science, and thus should not be taught in the science classroom,[5] that does not justify teaching bad science as established

[4] "Most mutations that built the great structures of life must have been nonrandom," concludes Michael Behe [Behe 2007].

[5] The Discovery Institute CSC opposes any effort to *require* the teaching of ID in science classes, it only promotes teaching the "strengths and weakness" of neo-Darwinian evolutionary theory, see www.discovery.org/a/3164

fact. Why can't we simply tell students the truth, that we know nothing about the origin of life, and hardly anything about the causes of evolution? Why can't students be told that we know virtually nothing about the origin of species (or at least of orders, classes and phyla), and allowed to draw their own conclusions as to whether the forces that created eyes, ears, hearts and brains were intelligent or unintelligent? Of course, if students are told that the causes of evolution are unknown, or even controversial, most will revert back to the default, common sense, explanation, design. This explains why Darwinists feel the need for the constant intimidation of opponents and suppression of opposing viewpoints that we see today in academia, and why they insist on telling students there is no controversy over causes among scientists, when there obviously is.

Science has been so successful in explaining natural phenomena that the modern scientist is convinced that it can explain everything, and anything that challenges this assumption is simply ignored. It doesn't matter that there were no natural causes before Nature came into existence, so he cannot hope to ever explain the sudden creation of time, space, matter and energy and our universe in the big bang. It doesn't matter that quantum mechanics is based on a "principle of indeterminacy," that tells us that every "natural" phenomenon has a component that is forever beyond the ability of science to explain or predict, he still insists nothing is beyond the reach of his science. When he discovers 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, he proposes the "anthropic principle" and says 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 him how a mechanical process such as natural selection could cause human consciousness to arise out of inanimate matter, he doesn't understand what the problem is, and he talks about human evolution as if he were an outside observer, and never seems to wonder how he got inside one of the animals he is studying. And when you ask how the four fundamental forces of Nature alone could rearrange the basic particles of Nature into libraries full of encyclopedias, science texts and novels, and computers, connected to laser printers, LCDs and keyboards and the Internet, he says, well, order can increase in an open system.

9.4 A Theological Supplement

It is widely believed that Darwinism is based on good science, and that those who oppose it simply do not like its philosophical and religious implications. The truth is exactly the opposite. In a June 15, 2012 post at www.evolutionnews.org, Max Planck Institute biologist W.E. Lönnig said "Normally the better your arguments are, the more people open their minds to your theory, but with ID, the better your arguments are, the more they close their minds, and the angrier they become. This is science upside down." The case for Darwinism is weaker every day, and yet Darwinist rhetoric only becomes stronger and angrier; clearly this theory draws its power not so much from scientific evidence as from philosophical and religious convictions. If you really examine the reasons scientists support Darwinism, I believe you will find in most cases that they are philosophical and theological. For example, Darwin wrote [Barlow 1958], "I can indeed hardly see how anyone ought to wish Christianity to be true; for if so the plain language of the text seems to show that the men who do not believe, and this would include my father, brother and almost all my best friends, will be everlastingly punished." Darwin is apparently referring to passages like John 3:18, "He who does not believe is condemned," which are sometimes interpreted to mean that all non-Christians are "condemned." If I thought the Christian God were that unfair, I would share Darwin's view of Christianity, and I might also prefer to believe we were accidents of Nature. But that John did not mean this as a condemnation of all non-Christians is clear from the following verse: "... and this is the condemnation, that light has come into the world, and men preferred the darkness, because their deeds were evil."

Because it has become obvious to me through the years that support for Darwinism in the scientific world is primarily based not on good science but on the philosophical and theological problems scientists have with what they see as the alternative, I have attempted to deal with some of these difficult problems in a theological supplement entitled "Christianity for Doubters" [Sewell 2016]:

www.math.utep.edu/Faculty/sewell/articles/doubt.html

Including all of these theological chapters in a book on intelligent design would not be appropriate, as it would only encourage those who claim that ID proponents do not understand the difference between science and religion. Most of us do understand the difference, we are just interested in both, and so are our critics.

I am nevertheless including one of these chapters here, as an "Epilogue" to set it off from the scientific chapters, because it deals with what I believe is by far the most powerful of all the philosophical and theological objections to ID, the problem of pain.

Epilogue: Is God Really Good?

This is the last chapter of "Christianity for Doubters" [Sewell 2016], discussed in Section 9.4.

E.1 Is God Really Good?

Why do bad things happen to good people? This is the question which Rabbi Harold Kushner, in his highly-acclaimed 1981 book [Kushner 1981] called "the only question which really matters" to his congregation. It is a question which has been asked by philosophers and ordinary human beings throughout the ages; if not the most-asked question, certainly the most passionately-asked. It was certainly the first question that occurred to me in 1987 when I was told that my beloved wife Melissa, 34 years old and the mother of our two small children (Chris and Kevin), had cancer of the nose and sinuses, and in 1990 when we discovered that the cancer had recurred. The suffering she bravely endured during those years was beyond description, from the aggressive chemotherapy treatments, each of which required hospitalization for severe nausea and other side effects, from the radiation therapy, and from three major surgeries. Before the last surgery, during which they would remove her left eye and half of her teeth, she said, well, many people would be happy to have one eye. The cancer recurred two months after this surgery and I was terribly depressed for many years after her death. Since I am a pretty logical person, it never occurred to me to ask "does God really exist?" but I certainly wondered, "is God really good?"

Figure E-1. Melissa Wehmann Sewell (1953-1991) with Chris

I think most people who claim not to believe in God, say this not because of any shortage of evidence for design in Nature, but because it is sometimes so hard to see evidence that God cares about us, and they prefer not to believe in God at all, than to believe in a God who doesn't care.

Of course, Christians point to the life and death of Jesus as the ultimate proof that God does care about us, because He came to live and suffer with us. Jesus asked the same question we have all asked at some time in our lives: "My God, my God, why have you forsaken me?" But while it is comforting to think that, despite all evidence to the contrary, God really does care about us, that still does not explain why the world God made is sometimes so cruel.

A wonderful little article in *UpReach* [Nov-Dec 1984] by Batsell Barrett Baxter, entitled "Is God Really Good?" contains some insights into the "problem of pain," as C. S. Lewis calls it [Lewis 1962], which I have found very useful. I will follow Baxter's outline in presenting my own thoughts on this question, and I would like to begin with his conclusion: "As I have faced the tragedy of evil in our world and have tried to analyze its origin, I have come to the conclusion that it was an inevitable accompaniment of our greatest blessings and benefits." In his outline, Baxter lists some examples of blessings which have, as inevitable consequences, unhappy side effects. None of these points is likely to make suffering in its severest forms any easier to accept, and we may be left wondering whether these blessings are really worth the high cost. But I believe they do at least point us in the right direction.

E.2 The Regularity of Natural Law

The laws of Nature which God has made work together to create a magnificent world of mountains and rivers, jungles and waterfalls, oceans and forests, animals and plants. The basic laws of physics are cleverly designed to create conditions on Earth suitable for human life and human development. Gravity prevents us and our belongings from floating off into space; water makes our crops grow; the fact that certain materials are combustible makes it possible to cook our food and stay warm in winter. Yet gravity, water and fire are responsible for many tragedies, such as airplane crashes, drownings and chemical plant explosions. Tragedies such as floods and automobile accidents are the results of laws of physics which, viewed as a whole, are magnificently designed and normally work for our benefit. Nearly everything in Nature which is harmful to man has also a benevolent side, or is the result of a good thing gone bad. Even pain and fear themselves sometimes have useful purposes: pain may warn us that something in our body needs attention, and without fear, we would all die young doing foolish and dangerous things, or kill ourselves the first time life disappoints us.

Figure E-2. "...a magnificent world of mountains and rivers, jungles and waterfalls..."

But why won't God protect us from the bad side effects of Nature? Why doesn't He overrule the laws of Nature when they work against us? Why is He so "silent" during our most difficult and heart-breaking moments? First of all, if we assume He has complete control over Nature, we are assuming much more than we have a right to assume. It does not necessarily follow that, because something is designed, it can never break down. We design cars, and yet they don't always function as designed. When our car breaks down, we don't conclude that the designer planned for it to break down, nor do we conclude that it had no designer; when the human body breaks down, we should not jump to the conclusion that God planned the illness, nor should we conclude that the body had no designer.

That we were designed by a fantastically intelligent super intellect is a conclusion which is easily drawn from the evidence all around us. To jump from this to the conclusion that this creator can control *everything* is quite a leap. In fact, I find it easy to draw the opposite conclusion from the evidence, that this creator *cannot*, or at least does not, control everything. Nearly everyone seems to assume that if you attribute anything to God, you have to attribute everything to God. And even if we assume He has complete control over Nature it is hard to see how He could satisfy everyone. Your crops are dry so you pray for rain—but I am planning a picnic. It seems more fair to let Nature take its course and hope we learn to adapt. Controlling the motions of all the atoms in the world so that nothing terrible ever happens to us, so that we always get what we most need, is probably not as easy as it sounds!

In any case, what would life be like if the laws of Nature were not reliable? What if God could and did stand by to intervene on our behalf every time we needed Him? We would then be spared all of life's disappointments and failures, and life would certainly be less dangerous, but let us think about what life would be like in a world where nothing could ever go wrong.

I enjoy climbing mountains—small ones. I recently climbed an 8,700 foot peak in the Guadalupe Mountains National Park and was hot and exhausted, but elated, when I finished the climb. Later I heard a rumor that the Park Service was considering building a cable car line to the top, and I was horrified. Why was I horrified—that would make it much easier for me to reach the peak? Because, of course, the pleasure I derived from climbing that peak did not come simply from reaching the top—it came from knowing that I had faced a challenge and overcome it. Since riding in a cable car requires no effort, it is impossible to fail to reach the top, and thus taking a cable car to the peak brings no sense of accomplishment. Even if I went up the hard way again, just knowing that I could have ridden the cable car would cheapen my accomplishment.

When we think about it, we see in other situations that achieving a goal brings satisfaction only if effort is required, and only if the danger of failure is real. And if the danger of failure is real, sometimes we will fail.

When we prepare for an athletic contest, we know what the rules are and we plan our strategy accordingly. We work hard, physically and mentally, to get ready for the game. If we win, we are happy knowing that we played fairly, followed the rules, and achieved our goal. Of course we may lose, but what satisfaction would we derive from winning a game whose rules are constantly being modified to make sure we win? It is impossible to experience the thrill of victory without risking the agony of defeat. How many fans would attend a football game whose participants are just actors, acting out a script which calls for the home team to win? We would all rather go to a real game and risk defeat.

Life is a real game, not a rigged one. We know what the rules are, and we plan accordingly. We know that the laws of Nature and of life do not bend at our every wish, and it is precisely this knowledge which makes our achievements meaningful. If the rules of Nature were constantly modified to make sure we achieved our goals—whether they involve proving Fermat's Last Theorem, getting a book published, finding a cure for Alzheimer's disease, earning a college degree, or making a small business work—we would derive no satisfaction from reaching those goals. If the rules were even occasionally bent, we would soon realize that the game was rigged, and just knowing that the rules were flexible would cheapen all our accomplishments. Perhaps I should say, "if we were aware that the rules were being bent," because I do believe that God has at times intervened in human and natural history, and I would like to believe He still does so on occasions, but *in our experience,* at least, the rules are inflexible.

If great works of art, music, literature, or science could be realized without great effort, and if success in such endeavors were guaranteed, the works of Michelangelo, Mozart, Shakespeare and Newton would not earn much admiration. If it were possible to realize great engineering projects without careful study, clever planning and hard work, or without running any risk of failure, mankind would feel no satisfaction in having built the Panama

Canal or having sent a man to the moon. And if the dangers Columbus faced in sailing into uncharted waters were not real, we would not honor him as a brave explorer. Scientific and technological progress are only made through great effort and careful study, and not every scientist or inventor is fortunate enough to leave his mark, but anyone who thinks God would be doing us a favor by dropping a book from the sky with all the answers in it does not understand human nature very well—that would take all the fun out of discovery. If the laws of Nature were more easily circumvented, life would certainly be less frustrating and less dangerous, but also less challenging and less interesting.

Many of the tragedies, failures and disappointments which afflict mankind are inevitable consequences of laws of Nature and of life which, viewed as a whole, are magnificently designed and normally work for our benefit. And it is because we know these laws are reliable, and do not bend to satisfy our needs, that our greatest achievements have meaning.

E.3 The Freedom of Man's Will

I believe, however, that the unhappiness in this world attributable to "acts of God" (more properly called "acts of Nature") is small compared to the unhappiness which we inflict on each other. Reform the human spirit and you have solved the problems of drug addiction, drunk driving, war, broken marriages, child abuse, neglect of the elderly, crime, corruption and racial hatred. I suspect that many (not all, of course) of the problems which we generally blame on circumstances beyond our control are really caused by, or aggravated by, man—or at least could be prevented if we spent as much time trying to solve the world's problems as we spend in hedonistic pursuits.

God has given us, on this Earth, the tools and resources necessary to construct, not a paradise, but something not too far from it. I am convinced that the majority of the things which make us most unhappy are the direct or indirect result of the sins and errors of people. Often, unfortunately, it is not the guilty person who suffers.

But our evil actions are also the inevitable result of one of our highest blessings—our free will. C. S. Lewis, in *Mere Christianity* [Lewis 1943], says,

> Free will, though it makes evil possible, is also the only thing that makes possible any love or goodness or joy worth having.... Someone once asked me, 'Why did God make a creature of such rotten stuff that it went wrong?' The better stuff a creature is made of—the cleverer and stronger and freer it is—then the better it will be if it goes right, but also the worse it will be if it goes wrong.

Why do a husband and wife decide to have a child? A toy doll requires much less work, and does not throw a temper tantrum every time you make him take a bath or go to bed. A stuffed animal would be much less likely to mark on the walls with a crayon, or gripe about a meal which took hours to prepare. But most parents feel that the bad experiences in raising a real child are a price worth paying for the rewards—the hand-made valentine he brings home from school, and the "I love you" she whispers as she gives her mother and father a good night kiss. They recognize that the same free will which makes a child more difficult to take care of than a stuffed animal also makes him more interesting. This must be the way our Creator feels about us. The freedom which God has given to us results, as an inevitable consequence, in many headaches for Him and for ourselves, but it is precisely this freedom which makes us more interesting than the other animals. God must feel that the headaches are a price worth paying: He has not taken back our free will, despite all the evil we have done. Why are there concentration camps in the world that God created? How could the Christian church sponsor the Crusades and the Inquisition? These terribly hard questions have a simple answer: because God gave us all a free will.

Jesus told a parable about "wheat and tares," which seems to teach that the weeds of sin and sorrow cannot be eliminated from the Earth without destroying the soil of human freedom from which the wheat of joy and goodness also springs. It is impossible to rid the world of the sorrow caused by pride, selfishness and hatred without eliminating the free will which is also the source of all the unselfishness and love that there is in the world. Thought itself is an expression of our free will, and to say that God ought to prevent us from doing evil is to request that our ability to think be withdrawn. If we ask God to take back the free will which He has given us, we might as well ask Him to turn us into rocks.

If we base our view of mankind on what we see on the television news, we may feel that good and evil are greatly out of balance today; that there is much more pain than joy in the world, and much more evil than goodness. It is true that the amount of pain which exists in our world is overwhelming, but so is the amount of happiness. And if we look more closely at the lives of those around us, we will see that the soil of human freedom still produces wheat as well as weeds. The dark night of Nazi Germany gave birth to the heroism of Dietrich Bonhoeffer, Corrie ten Boom and many others. The well-known play "The Effect of Gamma Rays on Man-in-the-Moon Marigolds" is about two sisters raised by a bitter mother who suffocates ambition and discourages education. One sister ends up following the path to destruction taken by her mother; the other refuses to be trapped by her environment, and rises above it. It may seem at times that our world is choking on the weeds of pain and evil, but if we look closely we will see that wheat is still growing here.

Again we conclude that evil and unhappiness are the inevitable by-products of one of our most priceless blessings: our human free will.

E.4 The Interdependence of Human Lives

Since it is our human free will which makes our relationships with others meaningful, his third point is closely related to the second, but Baxter nevertheless considers this point to be important enough to merit separate consideration.

Much of an individual's suffering is the direct or indirect result of the actions or misfortunes of others. Much of our deepest pain is the result of loneliness caused by the loss of the love or the life of a loved one, or of the strain of a bad relationship. How much suffering could be avoided if only we were "islands, apart to ourselves." Then at least we would suffer only for our own actions, and feel only our own misfortunes. The interdependence of human life is certainly the cause of much unhappiness.

Yet here again, this sorrow is the inevitable result of one of our greatest blessings. The pain which comes from separation is in proportion to the joy which the relationship provided. Friction between friends is a source of grief, but friendship is the source of much joy. Bad marriages and strained parent-child relationships are responsible for much of the unhappiness in the modern world, but none of the other joys of life compare to those which can be experienced in a happy home. Although real love is terribly hard to find, anyone who has experienced it—as I did for a few short years—will agree that the male-female relationship is truly a masterpiece of design, when it works as it was intended to work.

As Baxter writes, "I am convinced that our greatest blessings come from the love which we give to others and the love which we receive from others. Without this interconnectedness, life would be barren and largely meaningless. The avoidance of all contact with other human beings might save us some suffering, but it would cost us the greatest joys and pleasures of life."

E.5 The Value of Imperfect Conditions

We have thus far looked at suffering as a by-product of our blessings and not a blessing in itself. And certainly it is difficult to see anything good in suffering in its severest forms.

Nevertheless, we cannot help but notice that some suffering is necessary to enable us to experience life in its fullest, and to bring us to a closer relationship with God. Often it is through suffering that we experience the love of God, and discover the love of family and friends, in deepest measure. The man who has never experienced any setbacks or disappointments invariably is a shallow person, while one who has suffered is usually better able to empathize with others. Some of the closest and most beautiful relationships occur between people who have suffered similar sorrows.

It has been argued that most of the great works of literature, art and music were the products of suffering. One whose life has led him to expect continued comfort and ease is not likely to make the sacrifices necessary to produce anything of great and lasting value.

Of course, beyond a certain point pain and suffering lose their positive value. Even so, the human spirit is amazing for its resilience, and many people have found cause to thank God even in seemingly unbearable situations. While serving time in a Nazi concentration camp for giving sanctuary to Jews, Betsie ten Boom [ten Boom 1971] told her sister, "We must tell people what we have learned here. We must tell them that there is no pit so deep that God is not deeper still. They will listen to us, Corrie, because we have been here."

In a letter to our children composed after she realized she had lost her battle with cancer, Melissa wrote:

> While I no longer feel physically normal...in an odd sort of way, I feel even more human. I have seen and felt more suffering by myself and others around me in the last few years than I probably ever would have. I have seen children still in strollers hooked up to IV chemotherapy and young children, my own children's ages, with monstrous tumors bulging from their necks. In the face of this unjust tragedy, they still had a sweet innocent smile on their faces. I have talked with young women and men my own age who are struggling with the reality of leaving

> their young children and spouses long before their responsibilities of parenthood are completed.
>
> I have also discovered a deepness in relationships with others that I probably never would have otherwise cultivated.... I have seen the compassion and love of others towards me. I have witnessed how good and true and caring the human spirit can be. I have learned much about love from others during these times.

We might add that not only the person who suffers, but also those who minister to his needs, are provided with opportunities for growth and development.

C. S. Lewis concludes his essay on *The Problem of Pain* [Lewis 1962] by saying "Pain provides an opportunity for heroism; the opportunity is seized with surprising frequency." As Baxter put it: "The problems, imperfections and challenges which our world contains give us opportunities for growth and development which would otherwise be impossible."

E.6 Conclusions

In *Brave New World* [Huxley 1932], Aldous Huxley paints a picture of a futuristic Utopian society which has succeeded, through totalitarian controls on human behavior and drugs designed to stimulate pleasant emotions and to repress undesirable ones, in banishing all traces of pain and unpleasantness. There remains one "savage" who has not adapted to the new civilization, however, and his refusal to take his pills results in the following interchange between "Savage" and his "civilized" interrogators:

“We prefer to do things comfortably,” said the Controller.

“But I don’t want comfort, I want God, I want poetry, I want real danger, I want freedom, I want goodness, I want sin.”

“In fact,” said Mustophe Mond, “you’re claiming the right to be unhappy.”

“Alright then,” said the Savage defiantly, “I’m claiming the right to be unhappy.”

If God designed this world as a tourist resort where man could rest in comfort and ease, it is certainly a dismal failure. But I believe, with Savage, that man was created for greater things. That is why, I believe, this world presents us with such an inexhaustible array of puzzles in mathematics, physics, astronomy, biology and philosophy to challenge and entertain us, and provides us with so many opportunities for creativity and achievement in music, literature, art, athletics, business, technology and other pursuits; and why there are always new worlds to discover, from the mountains and jungles of South America and the flora and fauna of Africa, to the era of dinosaurs and the surface of Mars, and the astonishing world of microbiology.

Why does God remain backstage, hidden from view, working behind the scenes while we act out our parts in the human drama? This question has lurked just below the surface throughout much of this book, and now perhaps we finally have an answer. If He were to walk out onto the stage, and take on a more direct and visible role, I suppose He could clean up our act, and rid the world of pain and evil—and doubt. But our human drama would be turned into a divine puppet show, and it would cost us some of our greatest blessings: the regularity of natural law which makes our achievements meaningful; the free will which makes us more interesting than robots; the love which we can receive from and give to others; and even the opportunity to grow and develop through suffering. I must confess that I still often wonder if the blessings are worth the terrible price, but God has chosen to create a world where both good and evil can flourish, rather than one where neither can exist. He has chosen to create a world of greatness and infamy, of love and hatred, and of joy and pain, rather than one of mindless robots or unfeeling puppets.

Batsell Barrett Baxter, who was dying of cancer as he wrote these words, concludes: "When one sees all of life and understands the reasons behind life's suffering, I believe he will agree with the judgment which God Himself declared in the Genesis story of creation: 'And God saw everything that He had made, and behold it was *very* good.'"

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