Edited by Timothy M. Mosteller
and Gayne John Anacker

Contemporary Perspectives *on* C.S. LEWIS' *The* ABOLITION *of* MAN

History, Philosophy, Education, and Science

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Science in *The Abolition of Man*: "Can Science Rescue Itself?"

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Introduction

In the midst of the darkness of the Second World War in 1943, three significant events took place. In February of 1943, the physicist Erwin Schrödinger delivered a series of lectures at Trinity College, Dublin, about how life can be explained by the laws of physics and chemistry; this was published in 1944 as the book *What is Life?*, and was inspirational to Watson[1] and Crick a decade later in their work on the structure of DNA. In June of 1943, construction began of the first electronic general-purpose computer (ENIAC—Electronic Numerical Integrator And Computer). These two events set the stage for my area of research and my discussion in this chapter. The third event was another lecture series given in February of 1942—three Riddell Memorial Lectures given by C.S. Lewis at Durham College, and published in book form as *The Abolition of Man* (Lewis, 1973).

I first read *The Abolition of Man* in 1974, along with *That Hideous Strength* (Lewis, 1968). I was fourteen years old, growing up in Springdale, Arkansas. Through these and other works, C.S. Lewis changed my life. Under the influence of Lewis and Mr. Merrifield, my high school chemistry teacher, I graduated high school deciding that I wanted to get my PhD in chemistry, which I eventually did. Although I did not fully understand everything Lewis had to teach me as a young man, after many years, I realized that Lewis believed that it was possible to be a Christian and also a scientist, without having to choose between the two. Lewis taught me that science was worth pursuing, but he also showed me the dangers in using science to debunk values.

Three questions

Because of my fondness for Lewis' books, I happily accepted an invitation to contribute to this book regarding Lewis' view of science in *The Abolition of Man*. I have been tasked with three questions in this chapter: (1) How does Lewis view science? (2) What does Lewis mean by seeking a new "regenerate science"? (3) How can science provide a cure for or prevent Man's abolition? I have thought about this for many months now, and the approach I have decided to take is to first give a background, discussing science and how things have changed since 1943, along with some stories from my own personal experiences as a scientist, and then use this context for a discussion of C.S. Lewis' view of science.

Background

A brief history of molecular biology, materialism, and "science vs. religion"

Although I am neither a "C.S. Lewis scholar" nor "official expert" on the topic of science and religion, since I was about twelve years old, I started collecting books about science and religion. To this day, I still like to read about the history of science, and I now have several bookcases, with more than a thousand books, about the history of science, religion and science, and a large collection of books on biology, heredity, DNA, and genomics.

In broad terms, biology has become "molecular," starting with Watson and Crick in the 1950s. Erwin Schrödinger first proposed that hereditary information might be digital, or an "aperiodic crystal." He used the analogy of Morse code—a series of dots and dashes could encode many different messages. Inspired by this, Watson and Crick proposed that different DNA sequences could encode many different organisms. We still have not fully figured out all of the details, but we now know that biological information is "digital" in the sense that much of what we inherit in terms of physical traits is due to the sequence of DNA that came from our parents. I will talk more about biological information later, but want to set the context of a larger picture.

One could argue that a physical chemical explanation for life is an extension of the materialistic view dating back more than 300 years. Robert Boyle, "the father of chemistry," managed to distinguish chemistry from alchemy, and published *The Skeptical Chemist* in 1661. My background is that of a chemist, and so Boyle is one of my heroes—there's a plaque on a wall in Oxford commemorating the place where Boyle and Robert Hooke did famous experiments. One could argue that chemistry really is a purely mechanical, materialistic view of the world, which permeates our modern society. Thomas Hobbes (also from Oxford University) and others quickly saw a physical explanation for the universe as a basis for materialism, with no need for a belief in God. But Boyle was certainly not a "materialist"—nor from my perspective can any Christian be a pure materialist: how can you believe in Christ or anything outside of nature if nature is all that exists? Boyle strongly disagreed with the materialism of Hobbes, which appeared no different than atheism; Boyle set aside some money to establish a series of lectures after his death, on the relationship between Christianity and our contemporary understanding of the natural world. The first of the "Boyle lectures" was given in 1692 as *A Confutation of Atheism* (Bentley, 1692), and the series has continued off and on for more than three centuries—the lectures are currently being held at Gresham College,[2] Oxford. A recent Boyle lecture, *The Mathematics of Evolutionary Biology—Implications for Ethics, Teleology, and Natural Theology*, was delivered by Sarah Coakley (2016). Like the Boyle lecture series, the controversy between science and religion has also continued within Oxford University since the time of Boyle and Hobbes, through C.S. Lewis and Julian Huxley, down to Alister McGrath[3] and Richard Dawkins.

The importance of stories

Sometimes telling a story can bring home important points through allegory, like the parables that Jesus told. But just as Merlin the magician in Lewis' fiction book is not referring to a "real" person, so some of the stories in the Bible are meant to bring home a point, and not always describe literal, scientific facts. I bring this up here because in our modern society, people often too easily confuse a story or model with reality—I see this often with new PhD students who are learning to speak the language of science and to grapple with scientific models. Science is about making abstractions to model reality—we strive to lesson our ignorance, to learn from our mistakes, and to construct ever better models. But in the end, these are allegories, and the models should not be confused with reality itself.

I see few references to science when I read through *The Abolition of Man*; the book's subtitle[4] implies that the theme of his three lectures (chapters in the book) is mainly reflections on teaching English to young students. However, Lewis says in the preface to *That Hideous Strength* that his point is to tell a "tall story" to flesh out points made in the *The Abolition of Man*.[5] *That Hideous Strength* was written in the same year as *The Abolition of Man*, although the former is a hefty tome of more than 500 pages, and contains much discussion about science and also the "social sciences." I will spend some time looking at *That Hideous Strength* for additional hints about C.S. Lewis' view on science.

How does Lewis view science?

How did Lewis view science, given his commitment to the "doctrine of objective value"? Although little can be found about his views of science in *The Abolition of Man*, it is pretty clear that Lewis believed in an objective reality, apart from our perception of it—for example, electricity and magnetism existed, even before humans observed it. I think Lewis' view of science was along the lines of Plato's allegory of the cave—we see crude images of reality, and from that must build models for what we think to be "real." I also think that Lewis viewed science as being driven by what we do NOT know,[6] and by trying to figure out the best approximation to use for our models—that hopefully would get closer to this "objective reality," but in the end will always only be a model.[7]

Science is modeling an objective, real physical world. Lewis was very supportive of the "hard sciences," like physics and chemistry, although he was skeptical of the "soft sciences," such as sociology. For example, in *That Hideous*

Strength, the "scientific" discipline of the main character (Mark) is sociology. At one point, a chemist named Hingest says to Mark: "There *are* no sciences like Sociology. And if I found chemistry beginning to fit in with a secret police run by a middle-aged virago who doesn't wear corsets, and a scheme for taking away his farm and his shop and his children from every Englishman, I'd let chemistry go to the devil and take up gardening again" (Lewis, 1968, p. 85). It seems that Hingest is being used as a spokesman for the views of Lewis, and that "true science" is about trying to build ever-better models and approximations of an objective reality, and that the "social planners" are not scientists, but rather using science and technology to achieve their own agenda.

I suspect that Lewis often had lunch with a chemist at Magdalen College, which might have been an inspiration for the Hingest character in *That Hideous Strength*. It is likely that faculty often interacted with one another; Magdalen College is quite small—less than 400 students and a small number of faculty. I remember being impressed when I tutored students at Magdalen, and learned that there was a policy of having at least one tutor for every student. Because of the small intimate environment, it seems to me that Lewis probably had regular discussions with science fellows at Magdalen College, and that he had a fairly good understanding of the scientific method.

Science vs. technology

This is probably a kind of technical point, but on the surface, one might have the impression that Lewis has confused science with technology, or at any rate lumped them together. However, I can understand the larger point Lewis was making. Basic research in science is for knowledge, in understanding how things work. Technology is the useful application of this knowledge—for example, in building bridges, or better products. I'm sure that Lewis was well aware of the contrast between the science started with the Greeks, and the technology used by the Romans, who had little interest in science (Russo, 2004). Lewis makes the point in some of his books that many people think that the ancients were kind of dumb, and that with the progression of time, we are much smarter. It is true that with the accumulation of scientific knowledge, there are more facts available to us, but in many ways people today are the same, in terms of capabilities in learning and in basic human behavior, as they were two thousand years ago. Lewis clearly knows a lot about ancient history, because of his extensive classical education and his expertise in Medieval and Renaissance Literature. I was surprised to read a quote from C.S. Lewis in a book on "Myths about Science" that was just recently published; I wonder if Lewis would be bothered by others using him to "debunk a scientific myth."[8]

I am impressed by C.S. Lewis' comments on the use of power in science and technology in *The Abolition of Man*:

> Man's conquest of Nature, if the dreams of some scientific planners are realized, means the rule of a few hundreds of men over billions upon billions of men. There neither is nor can be any simple increase of power on Man's side. Each new power won by man is a power *over* man as well. Each advance leaves him weaker as well as stronger.
>
> Lewis, 1973, p. 58

I agree. Where does this leave us? On the one hand, yes, I think science is great—I love the technology and being able to have iPhones and check my email all the time. But sometimes it is nice simply to get away, and "Be Still, and Know that I am God." This can be difficult to do in a society where we constantly have a screen in our face, interacting with us, demanding our constant attention. I often talk about the explosion of information in my lectures. I tell my students "what information consumes is obvious"—it consumes our attention. Hence a wealth of information means a deficit of attention. We simply get overwhelmed, and sometimes miss the obvious. But there is something else going on here—think of the enormous power that the makers of iPhones have over millions (billions?) of users. Consider the ever-growing power of social media in our lives. Science feeds technology, and it is the application of technology that can vastly empower the few "scientific planners."

Is C.S. Lewis attacking science?

"Nothing I can say will prevent some people from describing this lecture as an attack on science. I deny the charge, of course . . ." (Lewis, 1973, p. 65). Lewis states the foregoing after he says,

> It might be going too far to say that the modern scientific movement was tainted from its birth: but I think it would be true to say that it was born in an unhealthy neighbourhood and at an inauspicious hour. Its triumphs have been too rapid and purchased at too high a price: reconsideration, and something like repentance, may be required.
>
> p. 66

Wow, I'm sure this would offend many modern scientists! But to be honest, I can see where Lewis is coming from here. I think many in our modern society have this kind of blind faith in science (and the Enlightenment). And somewhat ironically, science is now saying that we are not as rational as was assumed in early modern science, several hundred years ago.

Much recent scientific research indicates that we're not nearly the clear thinkers as the Enlightenment assumed—we often get things wrong, make bad decisions, and in general mess things up.[9] From my perspective, realizing this prompts me to be a lot more forgiving and tolerant of others who make mistakes (like me—we all have sinned), but I am sometimes amazed at how intolerant it seems our society has become. We have all seen how a person can make a bad post or link on Facebook or Twitter, and they're haunted for the rest of their lives. I find frightening the machine-learned racism that came out of the "chatbot" Tay, designed for human engagement as part of an artificial intelligence (AI) project (Victor, 2016). At least some people were surprised at how quickly Tay picked up from others and "learned" some pretty depraved ideas. I think Lewis would not be surprised. The problem was not in the actual AI software, but rather what was being used as a training set. This is part of the education of young schoolchildren that Lewis was worried about. Based on *The Abolition of Man*, one could argue that Tay the "chatbot" should first have been given historical stories as a training set—epics and sagas handed down through the ages, coming from the Greeks, Hindus, Norse, Chinese, etc., and from this then been allowed to extract the "*Tao*." Of course, such a trained "moral chatbot" probably would not be very popular amongst youngsters in the "twitterverse." But who knows—some children crave a sense of right and wrong, and are in the process of learning moral values. My point is that the *Tao* exists, but is not easily found in the unrestrained social interactions of young people. Morality is not something that spontaneously appears, but must be learned through positive examples.

I think that in a sense, science has "rediscovered" the total depravity of humans, and at the same time the value in stored wisdom (also known as "religion"). Historically, science was very precise, clockwork, and certain. Now, within the past hundred years or so, modern science has been transformed to being uncertain.[10] But at the same time it has become "less certain," it has become more dominant in society, and now most people assume that science can be the judge of all truth—that is, one can somehow use science to obtain moral values, to provide purpose and meaning in life. Through technology (an application of science), we have now become overwhelmed with "too much information," distracted by what is new and shiny, and seem to have no time for focusing on what is really important. Many of the younger people cannot imagine a time when instantaneous communication and entertainment was not ubiquitous. There have been dramatic changes over the past hundred years.

I remember being surprised when we were looking for a church, after having moved to Oxford, England. A friend of ours from Magdalen College had suggested St. Clements church, and when we asked around for directions, several people told us that it had moved to a "new location." Having moved from Houston, Texas, the "new" church looked quite old. We later learned that the church been built in 1828, but the original parish dated back a thousand years, founded in the year 1004, and got its name from the first recorded rector (Richard de St Clemente) in 1232. "New College" in Oxford was founded in 1379, and the "New Inn Hall" dates to the fourteenth century. Thus, the word "new" had a different meaning at Oxford than in other parts of the world.

In light of this, I remember realizing one day that the science buildings on South Parks Road in Oxford were not really that old (compared to the history of science). Even the "older" buildings were only about a hundred years old, which were "young" compared to many of the other buildings in Oxford. As I began to think about this some, I realized that early on, science was only a relatively minor part of most of the colleges. There is a small "Boyle-Hooke" plaque on High Street, commemorating experiments that Boyle did at University College. But at the time, there was only a few rooms used for science. It is only in the past hundred years or so that science has become a dominant presence at universities. This brings me to some more "stories" that are a bit of a tangent, but provide some necessary background for some points I want to make at the end of this chapter. I want to give a brief overview of how biology has changed since the time of Lewis' writing in 1943, followed by a discussion of how "big data is meeting biology," and then finally come back around to a slightly modified version of the question of "Is C.S. Lewis attacking science?"

What is new in biology since 1943?

In broad terms, looking back over the years, I can see three stages or movements within biology, since the 1940s: first there was molecular biology,[11] which tended to be very reductionist—taking apart things and seeing how they work, and coming up with molecular explanations for biological events. More recently, there has been a trend towards systems biology,[12] which tries to put things back together and model whole "systems" in biology. This is easier said than done, of course, and much of systems biology currently still tends to be from a reductionist point of view. Finally, the most recent trend is a kind of evolution of genetic engineering—now it is becoming possible to design and synthesize new life forms—called synthetic biology, where scientists design and construct living organisms.[13] The idea is that if a person can make it, then they understand it. This can lead to applications that C.S. Lewis imagines might be possible in his writings, such as in *The Abolition of Man*. But to understand this last and most recent trend, I want to first go through the other two.

1. Reductionism—molecular biology—1943–present

My background is as an experimentalist—I was trained as a molecular biologist / biochemist. During my studies in college and graduate school, I became obsessed with DNA and the history of the discovery of genetic material—the "physical basis for life" that Schrödinger was talking about in 1943. "Molecular biology" has at its heart a fairly simple idea, worked out in the 1960s, that DNA encodes genes that are transcribed as messenger RNA (mRNA), and that the mRNA gets translated to proteins. (Or, "DNA makes RNA makes proteins.") This is something that is very basic and is one of the first things taught in introductory biology courses. There are a lot of details here, but the bottom line is that we now understand an amazing amount of the molecular basis for how life works, and this can be reduced to (bio)chemistry and physics. Molecular biology is considered "reductionistic" because the purpose is to decompose or "reduce" all complex biology in the cell down to a set of more tractable chemical reactions. One of the classical questions is "what is the function of this gene?" A simple question, but often we don't know the function, and infer what it does, based on experiments. Imagine a simple genome with 500 genes. One could knock out each gene individually, and then see what happens to the cells.[14] If the cells cannot grow, the gene is said to be "essential" for function. Sometimes biologists get lucky, and find that if a gene is deleted or de-activated, they can observe a particular function.

2. Reconstruction—"systems biology"—1990s–present

More than twenty years ago, when I was a post-doctoral fellow at Oxford University, I was given the first sequence of a bacterial genome, before it was published. I became very interested in this, and a few years later, in 1998, started my own small research group comparing bacterial genomes, at the Center for Biological Sequence Analysis (CBS), in Denmark.[15] At the time, there were only eight bacterial genomes published, and sequencing cost several hundred thousand dollars, and could take a year or longer to complete. Now, sequencing a bacterial genome costs a few dollars, and can be done in a few minutes; we have a collection of more than 70,000 different bacterial genomes, and soon will have more than a hundred thousand. There are a couple of million viral sequences available. The point is, "big data" has come to biology. Many biologists have not fully realized this, and most people in the field are still using methods developed nearly three decades ago.[16] These methods were "cutting edge" at the time, but today the sequence databases have grown more than a quadrillion times larger and the methods still use more or less the same approach.[17] Further, as we've been sequencing more diverse organisms, some of the initial assumptions were found to be not true.

There are two types of problems—at least! First, the "real world" (objective reality, if you will) is much more complicated than assumed; it is now obvious that sequence diversity is far greater than most people thought. Second, what we measure is not as accurate as most people believe; when we observe biological systems, there is a lot of noise—again, much more noise than had been assumed. Mistakes are made, and current technology is simply not adequate to answer basic questions about genome sequence variation, because the read lengths are quite short (a few hundred base pairs), and many genomes have repeats which make mapping those reads back unambiguously impossible. Further, in the biological world, sometimes genes get expressed at the wrong time, or in the wrong way. In short, biology is messier and sloppier than we would like to think. At the molecular level, much of life is driven by "randomness."[18] I think many people have difficulty understanding randomness, and part of this comes from our culture—inherited from the Greeks, who saw randomness as bad, and order as good. But in our world that we inhabit, there is an element of unpredictability, and apparently random events happen, beyond our control.[19] In physics, a table appears to be solid and obeys the predictable laws of Newtonian physics, but when one zooms in to the atomic level, it becomes more probabilistic and less deterministic. In quantum mechanics, strange things happen at the molecular level—or at least strange to us. Molecular biology (as the name implies) is all about modeling events at the molecular level, where things are far more sloppy and messy and not as easy to predict. We can get an average idea of what is going on, but it is important to remember that much of the individuality of organisms has its origins down at the molecular level.

In this context, it is important to think about the general view of science in society, and compare this with "What is Lewis' view on science?" Sometimes I smile when I think about how upset people get when they think someone is criticizing science, and how it works. Of course, there are plenty of "science deniers" out there. But on the other hand, there are also many who think that science can do no wrong. Without being spoken, the underlying assumption in many people's minds is that scientists are very rational people, dealing with pristine, clean data, and a set of rigorous protocols, that will allow for the "truth" to be precisely determined. However, what I see is much muddled thinking, very messy data, and people bumbling around in the dark. In one of his books, Lewis quotes Aristotle: "Those who wish to succeed must ask the right preliminary questions" (Lewis, 1978, p. 1). I was reminded of this the other day, sitting at a meeting where the main person in charge of the project clearly did not know where he was going, or what he wanted to do. His manager asked what he was expecting to publish, and he had no idea, really. Sadly, I see many experimentalists design "fishing expedition" projects where they "hope to find something," without really having thought carefully about what it is they expect to see. Sometimes we have ideas, test them, and get lucky and get a clearer picture of what is going on, and build better models; in general, there is a kind of "consensus" of scientific theory. But as I've said before, what I think drives science is more trying to solve what we do not know, pushing the boundaries. But of course, in order to do this, we must have a clear grasp of what it is that we do know.

I keep telling my students that it really helps to have a clue! With way too much data consuming our attention, we easily get distracted from what is important, and can wind up chasing what is new and shiny, rather than addressing fundamental questions that can test our models—we make predictions, with a clear idea in mind—if I understand this, then I should see this outcome. I think it is important to have a clear model to test. This is different from merely looking at correlations and hoping something might jump out. The latter is useful in biology, but from my perspective, can be dangerous. As just one of many examples, there is a very strong correlation between eating raw tomatoes and being Jewish.[20] But correlation is not the same as causation.

One of my colleagues made the comment that the difference between him and me was that I have a deep knowledge of one area (genomics), and he has knowledge of many different areas. This was really not meant as a compliment,[21] but I think he's right—it is true that I do know an awful lot about one particular area—and I want to take advantage of my "deep knowledge" of genomics to explore the implications of Lewis' view of science.

The "post-genomics" era

In 1995, the first two bacterial genomes were sequenced, with about 1700 proteins encoded by one, and roughly 500 proteins encoded by the second. Comparison of these two genomes yielded about 250 proteins common to the two of them. This was heralded as the set of essential proteins, for all of life. Five years later, in 2000, the number of genomes had increased tenfold (to twenty), and now the set of conserved proteins found in all twenty had dropped to 80 proteins. In 2006, a study of almost 200 genomes found that only 31 proteins were conserved, and a few years later, in 2010, my group found[22] that the number dropped to zero proteins conserved (!) when we looked at a thousand genomes. This simply does not make sense—because obviously one needs the same basic functions across all of life.

Because of this, we started examining the conservation of functional domains, which is a bit of an abstraction, compared to the traditional approach of looking at conservation of the full-length proteins. Early results indicated a set of about a hundred domains conserved across a thousand bacterial genomes, and a few of these domains were of unknown function (DUFs—Domains of Unknown Function). This is kind of fun—there are some functional domains, we haven't a clue what they do, and yet they are found in nearly every single bacterial genome that has been sequenced! At the time of writing, we have examined more than 70,000 bacterial genomes, with a much larger set of more than 15,000 known function domains. We find about 500 functional domains conserved across all bacteria, including a couple of DUFs. These contain all of the basic functions for life—many (~400) for metabolism (to "eat"), with the remainder including all the necessary functions for reproduction (DNA, RNA, and protein synthesis). There appears to be redundancy—that is, in a pinch, some of the domains can substitute for each other, although not as efficiently. But this adds robustness, allowing for bacteria to survive insults from the environment. There is also good experimental evidence from gene knockout studies of about 500 "essential functions" in bacterial genomes, regardless of size, from relatively small genomes encoding less than a thousand proteins, to much larger genomes encoding more than 10,000 proteins. This also provides the basis for designing genomes to use with "synthetic biology"—more on that later in the chapter.

By focusing on an abstraction of proteins (functional domains), this allows us to do very fast searches—for example, we can look for specific functions across a thousand *E. coli* genomes in less than half a second,[23] compared to several weeks using the older full-length alignment approaches. We are working with the computer science group at ORNL to further improve our speed, likely more than a million times faster than traditional methods. Even with this significant increase in speed, it will still take careful planning and critical thinking in order to keep up with the avalanche of new data being generated.

This is a long story, and kind of technical, but there is an important point here: we are viewing the "function" of a protein as an abstraction—by looking for known conserved functional domains, or short amino acid sequence motifs. This greatly speeds things up, but because it is an abstraction, this is an approximation—it gives us a general idea, but when we start looking at the specific details, things get complicated. From my perspective, I really do not think that we can completely understand all of the details of how life works, but we can certainly build some very good models that are predictive of most details. And for most questions asked, these models are "good enough." But we do not yet have complete, robust, definitive models for how life works. This does not mean that we will never get there, just that the problems are complex, and there is a lot we still do not understand. This brings me (finally!) to synthetic biology, where people are trying to literally create new forms of life.

Synthetic biology—2000–present

If you can make it from scratch, then you understand it—this is the idea behind synthetic biology, where one can design and construct novel organisms from a standardized list of parts,[24] and university students can participate in the iGEM (International Genetically Engineered Machine) competition.[25] I have been invited to give talks at meetings on synthetic biology, even though I think this area is not really my area of expertise. In a sense, synthetic biology is partly about engineering organisms, and often people want me to talk about minimal bacterial genomes, that can be used as a "chassis" or starting material for use in synthetic biology. Just last week, I was interviewed by a journalist researching an article on synthetic biology,[26] and this week I've been asked to review another article on synthetic biology and have been invited to write a book chapter on "redefining life."[27] One of my PhD students is currently taking a course on synthetic biology, and is currently working on a list of genes for optimal design for a "streamlined," robust small genome that can be used for synthetic biology. I like the "streamlined" approach, rather than "minimal," because we want something that can grow quickly enough to do experiments, and robust enough to be able to survive and be productive.

About five years ago, I was invited to give a talk in China at a meeting on synthetic biology; I was one of a panel of twelve experts they brought in. The

Chinese want to use synthetic biology in their industry—they have the goal of having 10% of their factories use synthetic biology within the next five years, with the percentage rising in the future. For example, they are interested in designing computers that can fix themselves, and having them self-assemble. The idea is to have a set of chemicals that can be mixed together and, under the right conditions, a computer is formed; this computer could then send back commands to make improved designs—so a computer that can improve itself. Kind of strange! Anyway, this conference was sponsored in part by the Max Planck Society in Germany (most of the scientists attending were from Europe; I came from Denmark, and then there were two other Americans—one from MIT in Boston, the other from Texas). There was a session on "ethics" at the meeting after dinner one evening. There were two talks. The first was by an Austrian group, who showed some clips from Jurassic Park, and said that even though Hollywood thinks scientists are bad, in general scientists can be trusted . . . Then the Chinese head of the Beijing Genomics Institute, the largest sequencing center in the world, gave a talk. He said that China was working toward genetically engineering a "superior race," and that he thought this was a great thing (I heard gasps of "Mein Gott" from the Germans!!!). It was a kind of strange and alarming experience. Many (including the other two Americans) were really upset, one of whom was going to complain to her congressman about it; but I felt like there wasn't much we can do here—we are hugely in debt to China. But it was rather disturbing. So from my perspective, the reason I told this story is to say that, yes, I think that "unregenerate science" can be a big threat to humanity. Having said that, based on past experience and knowing genetics, trying to "genetically engineer a superior race" won't work. But we can really create a big mess trying! I think that this is one possible scenario that Lewis was worried about.

Is C.S. Lewis attacking biology?

I want to come back to a slightly different version of the question "Is C.S. Lewis attacking science," by replacing "science" with "biology" in the question. I have had several friends tell me that they have heard that C.S. Lewis was a "young-earth creationist"—that is, Lewis believed that the world was created less than 10,000 years ago, and that biology has simply got it all wrong here, when it comes to biological evolution. Many years ago I remember being surprised in one of Lewis' essays, where he says that "we must sharply distinguish between Evolution as a biological theorem and popular Evolutionism." Lewis distinguishes Evolutionism as a materialistic philosophy and the basis for atheism for many, from the scientific theory of biological evolution.[28] There has been a recent movement to help biologists and evangelicals talk with each other, and many scientists feel strongly that no, Lewis is not attacking biology. Darrel Falk is a biology professor at Point Loma Nazarene University; he describes how C.S. Lewis influenced him, in his wonderful book, *Coming to Peace with Science: Bridging the Worlds Between Faith and Biology*. The audience of Falk's book is evangelical Christians (mainly in the US) who have been struggling with how to accept the biological sciences. The book has a forward by Francis Collins,[29] and the two of them formed the BioLogos Foundation, which seeks to have a conversation between faith and biology. For the past two years, I have given lectures on introductory genomics at a "Science and Faith" workshop for pastors, held at Gordon College, Massachusetts.

How can science offer a cure for or prevent the abolition?

C.S. Lewis clearly sees potential problems for the misuse of science. But are things really completely hopeless? Is the "abolition of man" inevitable? Lewis imagines a "regenerate science" that could be constructive, redeeming, and beneficial, rather than destructive:

> Is it, then, possible to imagine a new Natural Philosophy, continually conscious that the "natural object" produced by analysis and abstraction is not reality but only a view, and always correcting the abstraction? I hardly know what I am asking for. I hear rumours that Goethe's approach to nature deserves fuller consideration—that even Dr Steiner may have seen something that orthodox researchers have missed. The regenerate science which I have in mind would not do even to minerals and vegetables what modern science threatens to do to man himself.
>
> Lewis, 1973, p. 81

To be honest, I am not sure what Lewis means by "regenerate science" here, but I do know that there is an aspect of science that is driven by a humble search for knowledge and understanding, and that requires monk-like devotion. I can see how that science can be used as a tool—for good as in medical research, as well as for bad things such as designing weapons to kill more people more quickly. I want to make one last digression, one last story, and then come back to the point of "regenerate science."

Big data, artificial intelligence, and *The Abolition of Man*

Although Lewis claimed that science was "born in an unhealthy neighbourhood and at an inauspicious hour," it is interesting to contrast this with the history of "data." In her wonderful book *Big Data, Little Data, No Data—Scholarship in the Networked World* (2015), Christene Borgman points out that the word "data" comes from Latin, and was used in math and theology 500 years ago. "Data" originally meant a set of facts, particularly those taken from scripture. Thus, one could imagine a king wanting to know what to do in a particular situation, and he brings in his counselors, and they present the "data" to him—these are arguments from scripture. It was not until the seventeenth century that the word "data" began to take on the meaning we are more familiar with, but Borgman notes: "Now in its fifth century of use, the term data has yet to acquire a consensus definition." Further, data "are not pure or natural objects with an essence of their own. They exist in a context, taking on meaning from the context and from the perspective of the beholder" (p. 18). In biology, we are drowning in too much sequence data, and in a sense dying of thirst for knowledge of the biological context.

There are several ways to deal with too much data. The first is statistics, which can of course be helpful, and provide a good overview of the data. Visualization is another very important way to deal with too much data, and part of my research over the past twenty years has involved visualization of potential DNA structures along a chromosome, and also comparative genomics, where sometimes we are mapping millions (or more!) of comparisons along the chromosome—all in one figure, mapped along a reference genome.[30] I have a slide I made a few years ago, of a bacterial chromosome, compared to more than a hundred other genomes of the same species. On the slide, I've calculated how long it would take, if one were to look at each comparison, gene-by-gene—there are so many comparisons, at the rate of just looking at one per second, it would take more than two years! And yet, here on a single figure it is possible to get an overview of all the comparisons, and zoom in on the electronic version to examine areas of interest.

The third method is machine learning. I often think that since machines got us into this mess of "too much data"—much of the information that is generated is coming from computers—maybe they can help us learn what is important from the data. There are many different approaches to machine learning, but in general all of these involve trying to "learn" how to classify data—and this is where the training sets and quality of known data becomes really important. One popular method, inspired by biology, is to train artificial neural networks (ANNs); for more than twenty years now, there has been a poster on the wall at CBS of the genetic code, along with the chemical structure of the amino acids. This is from a paper[31] from the center director (Søren Brunak), where an ANN was trained to classify the 61 nucleotide triplets of the genetic code into 20 amino acid categories. The question was, how did the ANN "learn" the genetic code? By watching the choice of weights as the ANN learned to make better predictions, it was possible to dissect information about how the genetic code might have evolved over time. This is kind of technical, but I have been impressed by the thought of gaining useful information from watching how a machine learns things. To learn is to err and err again and less and less and less . . . It is an iterative, training process, and again, one needs to have the right training set.

Artificial intelligence has a surprisingly long history. There are Greek myths about thinking machines. Our brains are designed and optimized for sharing and listening to stories. George Zarkadakis argues[32] that we strive to create artificial intelligence to be more successful—AI will prevent us from making mistakes:

> Artificial Intelligence has the potential to make everyone reach perfection in their personal lives, by always choosing the right partner, profession, job—everything. Hard choices will become less hard. The unquantifiable that defines our moral lives will be quantified, because having the technological means to achieve maximum utility from our decisions will prove too great a

> temptation to ignore. Unchallenged by moral dilemmas, secure in the knowledge that we can do no wrong, we will be in danger of losing the most precious part of our humanity: our humility.
>
> 2015, p. 317

And here is where C.S. Lewis and *The Abolition of Man* come into play again, in my opinion. Many years ago, there was a saying in computer science, "garbage in, garbage out." The real trick is to figure out what is important, in terms of what is used for training. Lewis argues that for grammar school students, the best training set for their "human neural networks" is to give them classical stories—epics, myths, moral stories where the children can learn proper moral behavior; it is not something easy in terms of a short list of things to do—there is a need to train people to be able to decide, in a given context, how to behave properly. It is possible, but not easy, and it takes time. And I am not so sure that AI can really *always* help us make the "right choice" or the "best decisions"—this really depends on a large-scale, quantitative evaluation, and from my perspective a full life explored is difficult to quantitate. But, of course, we can learn to make good choices, and to behave morally and make informed, wise decisions.

Summary

Lewis' view of science is that the physical sciences are attempts to model an objective reality, and that science is merely a tool—it is the potential use of science in social engineering that worries him. Further, it is possible for science to be used in a constructive way to bring a "cure" or a prevention of Man's abolition. The choice is ours, and of course is one that society as a whole will experience. The world seems to be changing ever faster, with increases in technology. But at least for now, we are still using the same basic moral reasoning and capabilities.

I want to end with a few disclaimers. In looking at the outline for this book and also doing a bit of research on books about C.S. Lewis, I realize that there is a large group of people in the US who have dedicated themselves to becoming "C.S. Lewis scholars"—going through everything he's written, and spending their whole lives studying his work. I guess in a way this is no different than historians spending their careers studying Abraham Lincoln. Although I would not consider myself in the same category as these people who have dedicated much of their life to studying his work, as I said at the beginning of this review, C.S. Lewis changed my life, for the better, by giving a solid pointing toward classic thought, literature, and values. Finally, the views presented here are of a single scientist—they are my own, and I've tried to take into account views held by other scientists, but this chapter should not be viewed as any sort of definitive, objective view of "Science in Lewis' Writing." It is one view, and I provide references to many books that I have found useful.

Notes

1 The first chapter in *The Molecular Biology of the Gene* (Watson, 1965) is entitled "Cells obey the laws of physics and chemistry;" the first chapter in my textbook on comparative genomics is "Sequences as biological information: Cells obey the laws of chemistry and physics" (Ussery, 2008a).

2 See Boyle Lectures (2016).

3 McGrath has published extensively, including a number of books about C.S. Lewis.

4 "Reflections on education with special reference to the teaching of English in the upper forms of schools."

5 "This is a 'tall story' about devilry, though it has behind it a serious 'point' which I have tried to make in my Abolition of Man;" from the preface of *That Hideous Strength* (Lewis, 1968, preface).

6 See, for example, Firestein (2012).

7 I recommend Alister McGrath's *The Open Secret: A New Vision for Natural Theology* (2008) for an extensive discussion of this.

8 See Michael Keas's "That the Copernican revolution demoted the status of the Earth," in *Newton's Apple, and Other Myths about Science* (2015), which appears in the section entitled "Medieval and Early Modern Science." Keas states, "The British literary scholar C.S. Lewis summarized the medieval vision of the human place in the cosmos to be anthropoperipheral" (p. 24).

9 For example, have a look at *Thinking, Fast and Slow* by Daniel Kahneman (2013), or for something shorter and more fun, *What Makes Your Brain Happy and Why You Should Do the Opposite* (Disalvo, 2011).

10 See, for example, *From Certainty to Uncertainty: The Story of Science and Ideas in the Twentieth Century* (Peat, 2002).

11 See Judson (1979).
12 See Capra (2014). For a more popular overview, see Noble (2008).
13 See Church (2014).
14 See Lazebnik (2002) on the reductionist approach to molecular biology.
15 www.cbs.dtu.dk
16 BLAST, or "Basic Local Alignment Search Tool," developed by Stephen Altschul and colleagues in 1990 (Altschul *et al.*, 1990), is still used by many people to align sequences—it is an extension of methods developed by David Lipman and William Pearson in 1985 (Lipman and Pearson, 1985). Many of my students were not alive when these papers were published!
17 Some of my friends are really impressed with a new method called "Diamond," published in 2015, which can be either faster than the (30-year-old) BLAST method, or as accurate (but not both!).
18 See, for example, *Life's Rachet—How Molecular Machines Extract Order from Chaos* (Hoffmann, 2012). From the introduction: "This book is a vindication for randomness, a much maligned force. Without randomness, there would be no universe, no life, no humans, and no thought" (p. 7).
19 I discuss this further in Ussery (2008b).
20 See Aschwanden (2016). http://fivethirtyeight.com/features/you-cant-trust-what-you-read-about-nutrition/
21 I am utterly dependent on others, and I know that I cannot possibly master every subject, so I try to surround myself with experts that I can trust and who then work together with me as a team. I am often humbled by the amazing productivity and intelligence and creativeness of the people I work with. I find it easy to follow Jim Watson's advice to "never be the smartest person in the room"!
22 See Lagesen *et al.* (2010).
23 See Cook and Ussery (2013).
24 See Knight (2003) on "BioBricks" and "Cello."
25 See http://igem.org/Main_Page. CBS has had student teams participating in iGEM since 2009.
26 See Singer (2016).
27 The email is from a friend of mine, who is a "lecturer in synthetic biology" at University College, London. Here is the full quote: "In particular, I wondered if you would be interested in contributing a review covering the scientific impact of synthetic biology, particularly covering redefining life/species/GMOs."
28 Here is the full C.S. Lewis quote on "biological evolution vs. Evolutionism":

> The central idea of the Myth is what its believers would call "Evolution" or "Development" or "Emergence", just as the central idea in the myth of Adonis is

> Death and Re-birth. I do not mean that the doctrine of Evolution as held by practicing biologists is a Myth. It may be shown, by later biologists, to be a less satisfactory hypothesis than was hoped for fifty years ago. But that does not amount to being a Myth. It is a genuine scientific hypothesis. But we must sharply distinguish between Evolution as a biological theorem and popular Evolutionism or Developmentalism which is certainly a Myth. Before proceeding to describe it and (which is my chief business) to pronounce its eulogy, I had better make clear its mythical character.
>
> Lewis, 1967, p. 93

29 He is also a C.S. Lewis fan, and the director of the National Institutes of Health.

30 See, for example, figure 5 in Vesth *et al.* (2010), "On the origins of a *Vibrio* species." There are some genomic islands containing sets of genes found only in *V. cholera*, and missing in other *Vibrio* species; these genes encode chitinase, or the ability to live on fish gills, providing a unique habitat.

31 See Tolstrup *et al.* (1994).

32 See Zarkadakis (2015).

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