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Life of faith, life of science

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I am a practicing scientist and a practicing Christian—occupations that are antithetical in the minds of many. In common caricature, the practice of science is portrayed as rigorous, objective, comprehensive and intellectual in contrast to religious practice which is frequently perceived as superstitious, parochial, and weak-minded. While I certainly encounter tension at times between my life in science and my life in faith, my overwhelming belief is that both science and faith contribute critically to a meaningful, fully-experienced human life. Giving up either would result in a regrettable loss of understanding, depth of experience, and simple joy in my life. I am convinced, then, that much of the perceived incompatibility between science and religion is specious, although real tensions do exist. My purpose in this paper is to lay out the central issues from my point of view—both the real and the false sources of tension between science and religious faith as I have experienced them.

Religion and the *findings* of science

Perhaps the major specious source of conflict between science and religion is the perception that the discoveries of modern science have rendered traditional religious belief untenable. I would argue that just the opposite is true—that the major discoveries of modern science are remarkably compatible with the central religious insights of the monotheistic traditions. The creation stories in Genesis, for example, assert that God created the universe, that the emergence of mankind in God’s image was an intentional result of the creative act, that a nurturing relationship with God is the ultimate aim and reward of our existence, and that we humans have a terrible freedom to enter into or reject this relationship as we see fit.

Although the creation stories are presented in poetic, mythical images, their central religious insights are not in conflict with any specific finding of modern cosmology, physics or biology. The assertion of a central creative act, for example, resonates nicely with the Big Bang, the prevailing scientific theory of the origin of our universe. According to this theory, for which there is considerable empirical evidence, our universe—and space and time themselves—began

in a primordial explosion of energy which occurred at a precise moment. Remarkably, cosmologists can plot the initial sequence of events associated with the Big Bang on a second by second basis, yet there appear to be impenetrable barriers to understanding what, if anything, existed “before” the Big Bang. In other words, our universe had a definable beginning roughly 15 billion years ago, and a dense curtain of mystery veils anything prior to this moment of origin. This basic picture, which is the result of dazzling theoretical insights and empirical measurements of modern astrophysics, would not be at all alien to the writers of Genesis. Robert Jastrow, prominent astronomer and former head of NASA’s Goddard Institute for Space Studies, cogently summarized this ironic turn of events in his short book, *God and the Astronomers*:

For the scientist who has lived by his faith in the power of reason, the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries.¹

In terms of universal origins, then, one could scarcely imagine a scientific theory more compatible with the core beliefs of the biblical writers.

Similarly, an increasing cadre of scientists is recognizing that the laws and constants that comprise the fundamental physical reality of our universe are improbably hospitable to the emergence of life. These critical constants determine among other things the rate of expansion of the universe, the strength of interactions of subatomic particles within the nucleus, and the unique chemical bonding properties of carbon, oxygen, nitrogen and hydrogen—the fundamental atomic constituents of organic life. If any of these physical constants had been different by an infinitesimally small amount, the emergence of life in our universe would have been impossible. From such scientific observations has emerged the notion of an “anthropic principle,” which asserts that the fundamental nature of our physical universe is peculiarly well suited to the emergence of intelligent life^{2,3}. As Stephen Hawking put it:

Nevertheless, it seems clear that there are relatively few ranges of values for the numbers that would allow the development of any form of intelligent life. Most sets of values would give rise to universes that, although they might be very beautiful, would contain no one able to wonder at that beauty.⁴

Of course, these intriguing observations do not *prove* anything one way or the other, religiously speaking. The fact that our universe is improbably hospitable to intelligent life might be sheer coincidence, or there might exist some explanation that we cannot comprehend at this point in time. Nevertheless, many thoughtful observers find these scientific observations to be religiously provocative. Hawking again:

¹ Robert Jastrow, *God and the Astronomers* (W.W. Norton: New York, 1978), p. 116.

² B.J. Carr and M.J. Rees, “The anthropic principle and the structure of the physical world” *Nature* 278:605-612, 1979.

³ J.D. Barrow and F.J. Tipler, *The Anthropic Cosmological Principle* (Oxford University Press: New York, 1986)

⁴ S.W. Hawking, *A Brief History of Time* (Bantam Books: Toronto, 1988), p. 125.

The odds against a universe like ours emerging out of something like the Big Bang are enormous. I think there clearly are religious implications.⁵

Again, my central point is simply that the findings of modern science are quite compatible with a traditional religious viewpoint. The writers of Genesis, given sufficient time to catch up scientifically (!), would find the contemporary picture congenial to their central religious insights.

The scientific discovery that has proven most contentious in certain religious and scientific circles during the past century has been Darwin's theory of evolution by natural selection. At first glance, the central Darwinian vision of the gradual and unpredictable evolution of life (through the interaction of random biological variation and selective environmental pressure) appears to be at odds with the biblical assertion that God created human life intentionally in his image. How can a process that depends on chance and is fundamentally unpredictable be an intentional, creative act of God?

I would argue first that dependence of a process on random events does not speak to the matter of intentional creation one way or the other. The use of random events is sufficiently important in modern scientific investigation that the design of computer algorithms for generating random numbers has become a high art. Random, or probabilistic, events are intentionally harnessed for scientific purposes in innumerable contexts, including the rapidly emerging field of quantum computing. There is no deep contradiction between the evolutionary mechanism of chance mutation and the religious notion that God intentionally created human life.

Secondly, we must be clear concerning what, exactly, is "unpredictable" about evolution. What biologists generally mean by this is that evolution is, in the words of Stephen Jay Gould, highly "contingent." A specific random mutation in one species in a particular environmental context can have a major impact on survival and thus on the future development of entire ecosystems in the future. The identical random mutation occurring in another species or in the same species in a different environmental context, however, may have little or no impact on survival and the ensuing configuration of species in the environment. The potential interactions between chance mutation, environmental pressure and individual survival are so numerous and complex as to constitute a system whose future states are impossible to predict. Gould argues that contingent events exert such an enormous effect in evolution that if we were able to rewind the history of the earth to a point, say three billion years ago, and let history unwind all over again, it is grossly unlikely that a creature exactly like *homo sapiens* would emerge—a predator with frontally directed eyes, bilaterally symmetric body plan, and a central nervous system organized on the current mammalian configuration.⁶

Two aspects of Gould's argument deserve comment. First, the scientific evidence itself provides grounds for doubting the argument. The counterargument has been made particularly forcefully by the Cambridge paleontologist Simon Conway Morris who changed his original views, which were similar to Gould's, after life-long study of the fossil record of the Cambrian explosion.⁷ Succinctly, Morris is far more impressed by the "convergence" that occurs within evolutionary history than by "contingency." Morris argues that certain body plans and adaptive

⁵ J. Boslough, *Stephen Hawking's Universe* (William Morrow: New York, 1985), p. 121.

⁶ S.J. Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (Norton: New York, 1989)

⁷ S.C. Morris, *The Crucible of Creation: The Burgess Shale and the Rise of Animals*. (Oxford University Press: Oxford)

features (particular points in the entire space of possible animal morphologies) recur independently in evolution with sufficient frequency that they must be regarded as uniquely adaptive to life on this planet. For example, Morris cites the fact that dolphins, which have evolved from dog-like mammals, are shaped similarly to fish because there is an optimal shape and strategy for moving through water.⁸ Thus, Morris argues, if the tape of evolution were to be rewound and allowed to play out again, it is likely that these evolutionary “solutions” to the challenge of living on earth, or very similar ones, would emerge once again.

Since the critical experiment that could resolve this issue is impossible to perform, we may never know the actual answer. From a religious point of view, however, arguments about physical morphology are not critical. The important question is what it means to be created in the “image of God.” Is God a visually directed predator with a bilaterally symmetric body plan and a mammalian central nervous system? I doubt it. Rather, the religious insight of Genesis is directed toward the emergence of a creature with intelligence, with sensitivity to right and wrong, and with the freedom to choose between them. Would such a creature likely re-emerge if the earth’s history were rewound by three billion years, even if its physical appearance were extremely different from *homo sapiens*? I, along with Conway Morris, think that the answer is yes. My view on this matter might be chalked up to religiously motivated wishful thinking, but ironically, I claim as my ally the noted evolutionary theorist Richard Dawkins, certainly no friend to religion. In his book, *The Blind Watchmaker*, Dawkins states:

My personal feeling is that once cumulative selection has got itself properly started, we need to postulate only a relatively small amount of luck in the subsequent evolution of life and intelligence. Cumulative selection, once it has begun, seems to me powerful enough to make the evolution of intelligence probable, if not inevitable.⁹

These are strong words, but my gut feeling is that Morris and Dawkins, who appear to be in essential agreement on this point, are correct. The selective advantages of advanced intelligence are so vast that its emergence in this particular universe, which itself appears uniquely hospitable to life, may indeed have been inevitable once the evolutionary process was started. In this sense, then, the emergence of intelligent, morally responsive life can reasonably be thought to have been an integral feature of our universe from its inception. Certainly no scientific findings argue compellingly against this point of view.

As Kenneth Miller has eloquently argued in his recent book,¹⁰ evolution, properly understood, is no enemy of religion. Despite the continued objections of a vocal minority, most Christians do not see evolution as major point of dispute between science and religion. As Richard Dawkins has observed, the emergence of the theory of evolution in the 19th century “made it possible to be an intellectually fulfilled atheist”¹¹. It had relatively little effect, I think, on the possibility of being an intellectually fulfilled theist.

⁸ See the fascinating exchange between Morris and Gould, “Showdown on the Burgess Shale”, available at www.stephenjygoald.org/library/naturalhistory_cambrian.html.

⁹ R. Dawkins, *The Blind Watchmaker* (W.W. Norton: New York, 1987), p. 146 (page number is from the 1987 paperback edition.)

¹⁰ K.R. Miller, *Finding Darwin's God* (HarperCollins: New York, 1999). Miller's excellent book provides a detailed critique of the uses and abuses of the theory of evolution by conservative Christian creationists on the one hand, and a scientific establishment that largely adheres to an ideology of reductive materialism on the other.

¹¹ R. Dawkins, *The Blind Watchmaker*, p. 6.

To summarize, the actual findings of modern science are notably congenial to traditional religious belief: a universe with a well defined beginning that is against all odds favorable to the emergence of life, and an evolutionary process that may well have favored the emergence of intelligent, morally sensitive beings. While these observations and reflections *prove* nothing religiously speaking, they are open to everything. No scientific result makes it unreasonable to believe that the universe is our home in a profoundly meaningful sense of the word, and that in some real way our existence was anticipated from the beginning of it all.¹²

Religion and the *assumptions* of science

In contrast to the findings of science, the assumptions of science can cause genuine tension between science and religion. The core assumption underlying natural science is that the universe is orderly and that physical events occur according to immutable laws that can be discovered and described by humans. The famous “method” born of this foundational assumption typically involves repetitive testing of specific measurable phenomena, tweaking the conditions this way and that in each repetition, in order to gain insight into the physical mechanisms that mediate each phenomenon. When science operates at its best, the knowledge derived from the artful combination of theory and experiment is genuinely universal. The basic observations and the theory that ties them together are accessible to, and can be confirmed by any scientist anywhere in the world given the proper equipment and technical expertise. The scientific enterprise has been extraordinarily successful at understanding and gaining control over the physical world, as the history of the past four centuries amply demonstrates. By any account, natural science—both the process and the body of results—is one of the most brilliant achievements in the history of our species.

From a religious point of view, both the core assumption of natural science and the resulting method are fine as far as they go. Conflict arises when the additional assumption is introduced that the scientific process is the *only* reliable way to acquire truth that is meaningful and universal. This radically materialist proposition is, of course, fundamentally incompatible with most traditional forms of religious belief and practice. At one fell swoop, it dismisses the existence of God, the possibility of divine revelation to humanity, any notion of universal grounding for right action (ethics), or any possibility that humanity can participate in a reality that transcends itself—none of which is testable by scientific method or required for understanding the mechanics of nature.

It is essential to realize that this radical materialist assumption, which is the critical factor in so many clashes between science and religion, is extrascientific. It is not a *finding* of science (try to locate a scientific study that proves the assumption!), nor is it *logically necessary* to the scientific process (many excellent scientists do not share the assumption). Rather, it is an ideological position that individual academics frequently choose to adopt for their own reasons. This in itself is fair enough. Everyone, after all, must view the world through interpretive lenses that conform to their own experience, reflection and conscience. Danger arises, however, when the radical form of the materialist assumption is packaged for public consumption, either implicitly or explicitly, as part and parcel of science itself. This is certainly not good science,

¹² In making this statement, I do not wish to be gratuitously anthropocentric. To say that the universe is “our home” is not to exclude that it may be “home” in a similarly sacred sense to other intelligent beings elsewhere in the universe, or perhaps to nonhuman animals on earth.

and I doubt that it is good philosophy either. Yet this uncritical and sometimes unconscious marriage of science with materialist ideology pervades the scientific community and appears frequently in the classroom teaching and in the public commentary of many scientists. To cite a few prominent examples:

William Provine, biologist and historian of science:

Modern science directly implies that there are no inherent moral or ethical laws, no absolute guiding principles for human society...There is no way that the evolutionary process as currently conceived can produce a being that is truly free to make moral choices.¹³

Richard Dawkins, evolutionary biologist:

In a universe of physical forces and genetic replication, some people are going to get hurt, other people are going to get lucky, and you won't find any rhyme or reason in it, nor any justice. The universe that we observe has precisely the properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind, pitiless indifference.¹⁴

Stephen Weinberg, astronomer and physicist:

The more the universe seems comprehensible, the more it also seems pointless.¹⁵

And in a passage remarkable for its hostility to religion¹⁶, even in the context of contemporary "scientific" writing, Richard Lewontin, geneticist, states that the primary goal of scientists in communicating with the public is:

...to get them to reject irrational and supernatural explanations of the world, the demons that exist only in their imaginations, and to accept a social and intellectual apparatus, *Science*, as the only begetter of truth...We take the side of science...because we have a prior commitment, a commitment to

¹³ W. Provine. "Evolution and the foundation of ethics" *MBL Science* 3:25-29, 1988.

¹⁴ R. Dawkins. *River Out of Eden*. (HarperCollins: New York, 1975), pp. 132-133.

¹⁵ S. Weinberg. *The First Three Minutes* (Basic Books: New York, 1977), p. 144 (page number is from the Bantam paperback edition, 1979.)

¹⁶ Persons unfamiliar with academic sensibilities should understand that there *are* legitimate historical reasons for the knee-jerk hostility of many academics to the influence of organized religious institutions. For long stretches of the modern period, academic inquiry was held in thrall to ecclesiastical authority. The freedom to inquire, to think and argue freely, to teach to the best of one's lights, were often suppressed by church authorities who were ever vigilant to detect conflicts with current dogma. The dismal history of the church's dealings with Copernicus and Galileo are only two of the most egregious examples. I feel sure that some religious authorities would do the same today if it were within their power, and academics tend to be very sensitive about this for obvious reasons. This history does not excuse the tendency within contemporary academia to treat Christianity with singular contempt, but that is a topic for another day (see G.M.Marsden, *The Soul of the American University: From Protestant Establishment to Established Disbelief*. Oxford University Press: New York, 1994).

materialism...Moreover, that materialism is absolute, for we cannot allow a Divine Foot in the door.¹⁷

Each of these views, presented as science or the logical consequence of science, in fact depends for its credibility upon the radical materialist assumption. Given the prevailing ideological climate within large swaths of academia, this point cannot be repeated too often: the passages quoted above are permeated with ideology that is extrascientific. If one is skeptical of the radical materialist assumption—that the scientific process is the *only* reliable way to acquire meaningful and universal truth—each of the quotations loses much of its logical force.

This ideologically loaded interpretation of science incorporates a nontrivial amount of circularity in its reasoning. If we assume from the beginning that reality consists exclusively of what can be demonstrated by the scientific method, then of course we will conclude that “science” directly implies a universe in which any other source of knowledge or value is without a compelling foundation. That such circularity continues to permeate public scientific discussion borders on intellectual irresponsibility in my opinion. Let me be very clear about one thing: I am *not* saying that it is inappropriate to have and argue a strong point of view (as I am doing in this paper). I *am* saying that it is intellectually irresponsible to present a particular point of view as a result or direct implication of science when it is in fact no such thing.

In general, science is simply mute before the ultimate questions of meaning, purpose and value. Any being, event or insight that lies outside the realm of cause-and-effect mechanism is not approachable by natural science. This is not a logical declaration about the limits of reality, it is a declaration of the limits of natural science as a system of knowing. As I argue in the next section, our judgments on matters of meaning, purpose and value almost always come from sources other than science and are formed in ways that of necessity depart radically from the scientific method.

A different part of the brain?

I recently made an important career decision largely on the basis of my wife’s employment opportunities as a Protestant minister. As a result, many of my professional colleagues around the country discovered for the first time that I am a Christian, which led subsequently to many interesting conversations (!). For example, I recently shared an airport taxi with a prominent neuroscience colleague, whom I also consider a casual friend, following a scientific conference that we both attended. We respect each other’s science, we have talked casually on previous occasions about science and family life, but we have never been closely involved in any way. It is one of those relationships in which one senses the potential for real friendship if the vagaries of time and space were to allow more interaction.

In a progression that has become familiar in recent months, the conversation proceeded from my recent career decision to my wife’s “interesting” professional occupation to my own religious involvement. During the conversation it became clear that my religious beliefs contrasted greatly with my colleague’s pronounced skepticism in religious matters. This conversation, like many others I have had, was both personally warm and thought provoking.

¹⁷ R. Lewontin, Review of “The Demon Haunted World: Science as a Candle in the Dark” by Carl Sagan. *New York Review of Books*, (January 9, 1997). I first became aware of Lewontin’s review through the extensive quotes in K.R. Miller’s *Finding Darwin’s God*, cited above.

We were genuinely interested in each other's stories, and the conversation was rewardingly unperturbed by any hostility or condescension. Near the end of the conversation, however, my colleague peered intently at me with a very puzzled expression on his face and said about my religious commitment: "I just don't see how you get there; you must use a different part of your brain when you do that."¹⁸

This remark deserves careful consideration because its essence is expressed repeatedly in conversations that I have with academic colleagues. It is the same question posed by a postdoctoral fellow in my laboratory following a rare discussion of religious matters over lunch: "But Bill, this way of thinking is so different from your *normal* way." Both my colleague and my postdoc, of course, were contrasting the modes of thought and belief that underlie my religious commitments to the modes that prevail in my science. In science I am relentlessly critical, demanding high standards of evidence before accepting any scientific "result" into the canon of what I believe to be true about the world. Both my colleague and my postdoc were struck by the apparent inconsistency in my adoption of religious beliefs without similarly rigorous standards of proof.

My reply is that yes, the modes of thought can be quite different in the two domains. This is one of the genuine points of tension between science and religion. Importantly, however, the mode that predominates in religious life is the *normal* mode of evaluation and decision-making in the overall context of human experience. The scientific mode, in contrast, is quite peculiar: it is applicable to a rather narrow range of experience and is generally practiced by a rather small community of professionals. My central argument here is almost obvious, but I find that it needs to be aired repeatedly in the professional circles in which I move: *the most important questions in life are not susceptible to solution by the scientific method*. In fact, I tend to believe that the importance of a question is inversely proportional to the certainty with which it can be answered. How, for example, does one design an experiment to answer the question: is it better to live or to die? This certainly qualifies as an important question and will have been (or is) a live issue for some who read this paper. Or what laboratory procedures can one perform to address the question: "Should I uproot my family, all of whom are deeply enmeshed in their own social networks, in pursuit of a new professional opportunity elsewhere in the country?" Most would agree that this is an important question—of much more intense concern to most people than the value of the universal gravitational constant.

These kinds of questions, which we all face constantly, simply do not admit of scientific solutions. We cannot make one choice and see how the experiment comes out, then rewind the tape and make the other choice to determine the outcome in the alternative scenario. Rather, we have a one-time shot at our most important decisions. We are forced to rely on intuition, on past experience, on the advice of friends, on precarious projections into the future, and in the end, on our gut feelings about what is likely to prove "right" in a given situation. Anyone who has been a parent, particularly a parent of teenagers, knows that excruciating decisions must be made on the basis of distressingly little "hard" data about likely outcomes!

Simply put, this is the human condition. It is *life*, and our most consequential decisions in life have little or nothing to do with science. This does not mean that we cannot bring rational analysis to bear on the issues. Thoughtful people reflect carefully about important decisions and try to take into account as much evidence as is reasonably available at all times. Nevertheless,

¹⁸In talking about a "different part of the brain", my colleague was making a serious point in whimsical neuroscience-speak. He was not actually proposing a theory that specialized brain circuits are responsible for religious belief and behavior, although this is a possibility that some neuroscientists take seriously.

rational analysis rarely compels a particular choice and certainly does not guarantee an end result.

At the risk of belaboring the obvious, it is worth considering a particular decision that people commonly confront: the decision to marry a specific person. Difficult and highly consequential judgments must be made. Do I love this person in a deeply authentic, sacrificial way that can sustain a lifetime relationship? Or is my desire to marry based on less worthy forms of self-interest, whether related to money, status, infatuation, sex or certain notions of compatibility? Does this person, in turn, love me genuinely? Do we have what it takes to weather the storms that life will inevitably bring our way?

Certainly experience in the relationship counts for a lot in making such judgments. Knowledge of the values provided by the potential spouse's family of origin can yield significant insight. The advice of friends and mentors carries weight. Yet all of these sources of information can be flawed and deeply misleading. In the end, a considerable amount of faith is involved in the commitment to marry. The commitment carries substantial risk, as anyone who has been through a divorce (and many who have not) can attest. But it also offers the opportunity for the most rewarding of human relationships, as many can also testify. If one waits for compelling evidence (in the scientific sense) before marrying, one will never marry. One might say with my colleague that this sort of decision-making occurs in a "different part of the brain" than scientific decision-making, yet it is common to all of us, including my colleague and my postdoc.

I believe that the religious quest involves exactly the same mode of thought (i.e. "part of the brain") that is involved in the marriage example above. Reduced to its most basic level, the religious quest hinges on a gut-level judgment about what sort of universe we really inhabit. Do we accept the "pointless" and "indifferent" universe of Weinberg and Dawkins, or can we perceive with Tielhard de Chardin that, "there is something afoot in the universe, something that looks a lot like gestation and birth"? Can we observe with Paul Tillich that, "here and there in the world and now and then in ourselves is a New Creation"? Our actions, our hopes and our aspirations hang critically on the answer to this single question. Sources of evidence are available to guide my judgments: my own primary experience in relationship with God (worship, prayer, and at least something like halting obedience), my experience in my religious community, the testimony of scriptural writers and other authentic seekers through the ages, and the critical reflections of fellow pilgrims who I meet along the journey. Nevertheless, the evidence in the end is not compelling in a scientific sense. As in marriage, faith accompanied by commitment must play a foundational role in the religious quest; considerable risk is involved and the stakes are high. I might make a complete fool of myself, or I might, as crazy as it sometimes seems, come into contact with the central reality of our universe, which I believe is more wonderful than we usually dare dream.

This tension between scientific and religious judgment was captured pungently in a brief conversation I once had with a faculty colleague at Stanford. At the center of Stanford's beautiful old quads lies Memorial Church, a romanesque masterpiece dearly loved by many members of the Stanford community. My faculty colleague felt differently, however, and once exclaimed to me only half in jest, "That church pisses me off; I think we should bomb the thing!" When I asked why he felt that way he replied, "It is a monument to irrationality; it doesn't belong on a university campus." As it happens, I lived at the time in a home on the Stanford campus, and my reply to my colleague was: "By far the most irrational thing I have ever done

was to marry and have children. If we are going to bomb campus monuments to irrationality, we had better start with my home!”

The tendency of some scientists (perhaps academics in general?) to quarantine religion into a uniquely irrational category of human behavior seems to me profoundly mistaken. It fails to grapple honestly with the complexity of the human condition and with the highly varied forms of thought and judgment that are required of us all as we navigate our ways through life.

Human freedom

A central tenet of Christianity and most other religions is that human beings have a meaningful degree of freedom to make moral choices. We can make loving, divinely inspired choices in how we interact with others, or we can act in ways that are utilitarian, exploitative, or at worst overtly hateful. The issue of human freedom is an increasingly vexing point of tension between religious and scientific world views. What are we to make of human freedom when, from a scientific point of view, all forms of behavior are increasingly seen as the causal products of cellular interactions within the central nervous system, which themselves are substantially influenced by the toss of genetic dice that occurred when each of us was conceived? To frame the issue in an everyday context, can I really choose to have fish or chicken for dinner this evening, or do events already in motion reduce me to a predetermined course of action? More disturbing yet, if our sense of choice is illusory, can anyone reasonably be held responsible for his or her actions?

The issue of human freedom is a tricky one. Some modern thinkers find refuge from strict determinism in quantum mechanics, which describes events probabilistically rather than deterministically. While quantum mechanics does imply that we live in a fundamentally unpredictable world, I am not yet convinced that it offers substantial insight into human freedom. Quantum mechanics can establish probabilities for the occurrence of specific events, but within the constraints of those probabilities events occur randomly. It is not clear to me that randomness provides an understanding of human freedom that is any more meaningful than that of strict determinism.¹⁹ Our intuitive understanding of human freedom is that we have some meaningful degree of *self-determination*. While we are certainly influenced by random events (in the quantum mechanical sense) and by strictly determined events (in the Newtonian sense), we are at the complete mercy of neither.

Some of my scientific colleagues seem to feel that the notion of human freedom must be tolerated as a practical matter in order to maintain a functioning society, but that human freedom

¹⁹ A deeper argument for the relevance of quantum theory to the notion of human freedom is provided by Henry Stapp (see H.P. Stapp, *Mind, Matter and Quantum Mechanics*, Springer-Verlag, Berlin, 1993). In a nutshell, the argument is that quantum theory, which is our most sophisticated and far-reaching physical theory of the universe, requires the existence of an "observer" to ask questions of nature (i.e. to pose experiments) who lies outside the causal system of physics. Because the observer lies outside the causal system described by the wave equations of quantum mechanics, the observer is free of constraints in a manner that conforms to intuitive ideas of human freedom. I am intrigued by this argument because it appears to be profoundly required by the best available physical theory of the universe, but the biologist in me finds it difficult to swallow. For the biologist, the "observer" asking questions of nature cannot lie outside of nature; she/he is a human being who operates wholly within the natural system of life on earth. The nagging suspicion of the biologist is that quantum theory (or at least some prevailing interpretations thereof) just doesn't have it right yet!

is likely to prove illusory in the final analysis. Brains are extremely complex neurochemical machines, and their behavior will ultimately be understood in the same mechanical terms that any other machine is understood. While notions of human freedom are convenient, and probably even necessary to get along in everyday life, our subjective experience of freedom itself is no more than the result of machine-like activity within specific regions of the central nervous system.²⁰

What this point of view fails to realize, however, is that the sense of human freedom is just as important for scientific understanding as for everyday understanding of the world. Thorough-going determinism becomes entangled in profound logical difficulties in science no less than in everyday life. J.B.S. Haldane put the matter succinctly:

If my mental processes are determined wholly by the motions of the atoms in my brain, I have no reason to suppose that my beliefs are true...and hence I have no reason for supposing my brain to be composed of atoms.²¹

Haldane's point is that the entire enterprise of science depends upon the assumption that scientists have freedom to evaluate evidence rationally and make reasoned judgments about the truthfulness of particular hypotheses and results. If, however, the scientist's rational judgments, and his beliefs about the validity of the scientific method, simply reflect an inevitable outcome of the atomic, molecular and cellular interactions within a particular physical system, how can we take seriously the notion that his or her conclusions about the world bear any relation to objective truth? (Ironically, the ardent determinist becomes an intellectual bedfellow of the ardent deconstructionist.) And if we cannot believe that the scientific approach leads to some approximation of truth, how can we take seriously the scientifically based assertion that mechanical determinism is the correct way to think about the world? The attempt to adopt a thorough-going determinism is like sawing off the limb of a tree upon which one is sitting; the result is intellectual freefall.

Like it or not, then, achieving a meaningful understanding of human freedom is profoundly important for science, for society, and for each individual person. We are all aware that our freedom is quite sharply limited. I am not free, for example, to play the violin like Itzhak Perlman or basketball like Michael Jordan. My freedom is limited by my biology—by the biology of my central nervous system no less than by the biology of muscle and bone. The remarkable studies of “identical twins raised apart”²² emphasize the pervasive influence of our genetic composition on surprisingly varied aspects of behavior from basic temperament to small behavioral tics; we are not free to escape many aspects of our genetic heritage. Nevertheless, our subjective experience, the mores of responsible living within a society of other persons, and the enterprise of science itself all suggest (demand?) that we have a meaningful degree of personal choice and freedom within the constraints of our biology. Understanding how that freedom, or

²⁰ But as Charles Jennings has observed, throw a rock through the living room window of the most reductionistic neurophilosopher and you will probably find out just how quickly the dispassionate notion of behavioral determinism evaporates! (Editorial, *Nature Neuroscience* 1:535-536, 1998)

²¹ J.B.S. Haldane. *Possible Worlds*. (London: Transaction Publishers) p. 209.

²² See, for example: K.S. Kendler, “Twin studies of psychiatric illness: current status and future directions.” *Arch. Gen. Psychiatry* 50:905-915, 1993; G.E. McClearn, B. Johansson, S. Berg, N.L. Pedersen, F. Ahern, S.A. Petrill and R. Plomin. “Substantial Genetic Influence on Cognitive Abilities in Twins 80 or More Years Old.” *Science* 276:1560-1563, 1997.

self-determination, arises from the central nervous system should ultimately be a primary goal of the neuro-behavioral sciences.

A compelling answer to this question does not appear to be close at hand, but I suspect that success will ultimately lie in a deeper understanding of emergent behavior within complex systems. This is a somewhat slippery concept and has been used in different ways by different authors. By “emergence”, I mean that complex assemblies of simpler components can generate behaviors that are not predictable from knowledge of the components alone and are governed by logic and rules that are independent of, although constrained by, those that govern the components. Many authors have cited examples of emergent behavior, a favorite example being the unicellular organism. The existence of unicellular organisms permits an enormous number of new phenomena that could not be predicted from knowledge of macromolecules alone and that operate on principles that go well beyond those that govern macromolecules: cellular motility, foraging for resources, competition with other organisms, and adaptation to environmental pressure by means of mutation, to name but a few. Each of these phenomena must be identified and described in-and-of-themselves, and their internal logical rules worked out, before rigorous links can be made to lower level mechanisms.

It is critical to be very clear on one point: the concept of “emergence” does not imply magic or mysticism.²³ As far as we know, nothing about the life of unicellular organisms violates the laws of physics or the chemical laws that govern the behavior of macromolecules. The cell cannot behave in any way that is not permitted by the lower levels of organization of its constituent parts; the behavior of the cell is thus *constrained* but not *determined* by the lower levels.

Obviously, the crucial distinction here is between the words “constrained” and “determined.” This distinction comes into clearest relief for me when considering the operation of the computer program that is running right now on my laptop computer. If I want to understand how Microsoft Word operates, I can tackle the problem at the mechanistic level of transistors, resistors, capacitors and power supplies, or I can tackle the problem at the level of the software—the logical instructions that lie at the heart of the process of computing. It seems clear to me that the most incisive understanding of Microsoft Word lies at the higher level of organization of the software. One wants to understand the logical relationships that comprise computation: for-loops, if-statements, and the like. The logic of the computation exists

²³ My discussion here will search for an understanding of human freedom that does not postulate brain events that violate known physical principles. More than anything else, this reflects my biological intuition that the human brain, as a product of the natural evolution of the universe in general and life on earth in particular, will generally operate in a manner consistent with (i.e. constrained by) known physical laws. As a theist, however, I do believe in the existence of a nonphysical being (God) who created and sustains our orderly physical universe. As a Christian, I believe that very special events, probably involving exceptions to known physical law, occurred in the life of Jesus. Nevertheless, my working assumption is that the normal functioning of the human brain does not involve such events and that a proper understanding of human freedom must be sought within the overall picture of nature that conforms to known physical law. Although it is certainly conceivable, and perhaps likely, that that some aspects of human and animal consciousness will never be satisfactorily understood from the point of view of the reductive sciences (see, for example, T. Nagel, “What is it like to be a bat” *Philosophical Review* 83:435-450, 1974), one doesn't want to throw in the towel until absolutely forced. If Copernicus and Galileo, for example, had shrugged their shoulders and accepted contemporary theological explanations of celestial motion, progress in understanding our solar system would have been severely stunted. As many writers have pointed out, eager acceptance of extra-physical accounts for a particular phenomenon is “giving up” from a scientific point of view, and it is far too early in the history of neuro-behavioral science to entertain the thought of giving up.

independently of the physical system of electronics that make up the computer (the software can be transferred to another computer) and operates according to its own rules that cannot be predicted from knowledge of the hardware alone. Again, nothing magical or mystical is occurring here. The software is constrained by the hardware; the software cannot abrogate the laws of physics nor the principles that govern the behavior of electronic circuits. Nevertheless, the behavior of the computer as I type this manuscript is *determined* at a higher level of organization—the software—not by the laws of physics or the principles of electronic circuitry.

Although this computer example emphasizes the critical distinction between “constraint” and “determination”, it is *not* an example of emergence because the software did not evolve from a natural process of self-assembly but was designed by human programmers. A better example of emergence in the computing world lies in the relatively new field of neural networks. In a neural net, multiple layers of “neuron-like” computing units are linked to each other in a hierarchical manner such that the behavior of units in each lower layer influences units in the next highest layer. The influence of any given lower level unit upon units in the next higher level is governed by a set of “weights” that determines the effectiveness of the link between each pair of units. In the initial state of the network, the weights governing the many links are chosen randomly. An input is then provided to the lowest level of the network, and an output emerges at the highest level. A “teacher” (a software entity) recognizes whether the actual output is similar to the desired output (the correct answer) and adjusts all of the weights of the links between computing units accordingly. After many iterations of the input-output-adjustment cycle, the network “learns” to produce the correct output for a given input.

Neural networks can perform remarkable feats that are extremely difficult to accomplish by traditional computing methods which employ mathematically precise algorithms specified by a programmer. Some of the most impressive examples lie in the arena of voice and character recognition and in the arena of robotics. Yet a remarkable intellectual quandary is often encountered in the neural network field: a network can be trained to solve a fiendishly difficult problem, and in the end, the human operator who designed the network and orchestrated the training procedure may have little or no insight into *how* the problem has actually been solved! The scientist can show us the final pattern of weights between the individual computing units that somehow embodies the solution, but we frequently remain embarrassingly ignorant concerning the algorithmic principle(s) the network has “discovered” in solving the problem. A close colleague of mine at Stanford refers derisively to these networks as “know-nothing networks” because at the end of the exercise, the scientist still may not *understand* the solution that has been achieved.

This example comes closer to the meaning of emergence. We *do* understand the physical principles by which the neural network operates. We know all about the electronic components of the computer, the software that specifies the neural network model, the learning procedure that enables the network to “solve” a problem, and the connection weights that comprise the final state of the network. Yet a higher level of organization emerges within the network during the “learning” process that goes beyond connection weights. We *must* understand this higher level of organization, which involves formal computational logic, to be intellectually satisfied with the result. This higher level of organization has its own rules and logical integrity that must be grasped in-and-of-themselves. Although the higher level behavior of the network is certainly constrained by the lower level hardware and software (there is no magic involved), analysis of the lower levels alone does not produce insight that comprises *understanding*. One might even argue that the network, by virtue of its learning rules and its ability to interact with its

environment, is "free" in some sense to discover solutions to problems and to make judgments about its environment independently of guidance from the human programmer!

I do not wish to push the neural net analogy too far in the context of a discussion of human freedom. Certainly one may still consider the interaction of the neural net with its environment to be a quasi-deterministic system at a larger scale. Nevertheless, the central point remains: an entity that is capable of interacting with its environment and *learning* as a result of the interaction, can enter into novel realms of operation—or existence—that transcend (are not encompassed or determined by) the lower levels that define its constituent parts.

The human brain, of course, is infinitely more complex than our most sophisticated network models, and it seems inevitable that the emergent (or transcendent?) properties of the human brain will be substantially more sophisticated and surprising than those of neural networks. Although my examples of emergence are at best heuristic in the current context, my hunch is that this is the general arena in which a deeper understanding of human freedom will ultimately develop. I am not optimistic about being around to witness this "new emergence" personally. Genuine progress toward this level of understanding of the human person, as well as its implication for the spiritual quest, will be measured in decades or perhaps centuries, not in years. If we still have difficulty identifying the higher order principles "discovered" by artificial neural networks, how much more challenging will it be to discern those "discovered" by the unfathomably complex networks within the brain? In the meantime, however, I continue to believe steadfastly in the reality of human freedom, and in the integrity and responsibility this freedom bestows upon each person, upon society, and upon science itself.

Concluding remarks

My purpose here has been to examine the interaction of science and religion, primarily as I have experienced them in my own life. To summarize briefly, I perceive no serious conflict between the specific findings of natural science and the religious insights of the major monotheistic traditions; I generally find them remarkably consonant. I like many others, however, perceive fundamental conflict between religion and radically materialist philosophy, sometimes labeled "scientism," that is frequently shopped in the marketplace of ideas as a direct result or implication of science. It is no such thing, and marketing it as such is intellectually disingenuous. This philosophy depends critically on extrascientific assumptions—assumptions that must be justified like any others in terms of their ability to "make sense" of the raw data of life. As I have argued elsewhere, the Christian faith rings far truer to my own experience than any lack-of-faith that I have encountered.²⁴

I have also explored an aspect of the science/religion relationship that I encounter with surprising frequency in academic circles: the tendency of scientists, at least, to perceive religious faith as a uniquely irrational aspect of human life and therefore highly suspect *a priori*. In contrast, my experience suggests that all of the most important decisions in our lives incorporate aspects of the "irrationality" that my colleagues so consistently decry in religion. When examined carefully, the blend of analysis, faith and commitment that characterizes religious life is not peculiar at all; rather, it is science that is uniquely peculiar in restricting its subject matter

²⁴ W.T. Newsome, "Science and Faith: A Personal View", in *The Ellul Forum* (January, 2000, Issue #24), pp. 2-8.

and its way of knowing as much as possible to a slice of reality that is most amenable to mechanistic analysis.

Finally, I have suggested that understanding human freedom is perhaps the most important and most difficult long-term challenge facing the neuro-behavioral sciences. Although our freedom is certainly restricted (more so than most of us would like to admit), a real human capacity for self-determination is an irreplaceable foundation for taking seriously the notions of scientific truth, religious truth, and individual moral responsibility. I, at least, do not yet have anything approaching a clear grasp of how the capacity for self-determination might arise from the human brain, although I am thoroughly convinced that it does. As indicated above, I suspect that the answer ultimately will lie in the concept of emergence within complex systems. Emergent behaviors of even simple learning systems are often surprising and deeply perplexing, yet they can "get in touch with" realities whose deeper foundations we struggle to discern long after we accept the validity of the behavior. Thus "emergence" becomes a pivotal concept for interpreting the reality of human life in all its complexity, from scientific endeavor to personal morality to religious understanding. Although emergence is a notoriously difficult phenomenon to study rigorously, few areas of study are likely to prove as intellectually and practically consequential in the long run.