SACRED INDWELLING AND THE ELECTROMAGNETIC UNDERCURRENT IN NATURE: A PHYSICIST'S PERSPECTIVE

by Lawrence W. Fagg

Abstract. Wolfhart Pannenberg has related the concept of the physical field to the idea of God's divine cosmic field in all of creation. In this article I proffer a physicist's viewpoint by treating the subject from a more specific and focused perspective. In particular, I describe how electromagnetic interactions underlie the operation of all earthly nature, including human beings and their brains. I argue that this ubiquity constitutes a compelling physical analogy for the ubiquity of God's indwelling. The discussion includes the role of electromagnetism in quantum theory, concepts of time, and the evolution of life. I suggest the value of such analogical thought as an area of study to be exploited in the development of a theology of nature as well as a significant datum in the pursuit of a tenable natural theology. This article is intended to clarify, refine, and considerably expand upon an earlier article published in *Zygon* (Fagg 1996). Included also are discussions on the role of electromagnetism in our sense of evil and eternity.

Keywords: analogy; electromagnetism; evil; eternity; evolution; field theory; James Clerk Maxwell; natural theology; Wolfhart Pannenberg; quantum theory; theology of nature; time.

When James Clerk Maxwell was developing his theory of electromagnetism designed to unite the forces of electricity and magnetism, he initially struggled for a formulation based essentially on mechanical concepts. For example, when considering a medium for transmitting the electromagnetic force, he entertained the idea of using the then-current theory of molecular vortices and envisioned a space filled with quasi-mechanical

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[*Zygon*, vol. 37, no. 2 (June 2002).]
 ISSN 0591-2385

molecular wheels and gears. Finally, effecting a dramatic break with the Newtonian mechanistic thought dominant at the time, Maxwell introduced the concept of field, which was a logical extension of Michael Faraday's idea of "lines of force." The pattern of iron filings on a piece of paper placed above a magnet clearly suggests such a concept.

Einstein readily adapted Maxwell's legacy, extending the field concept to gravity and the curvature of spacetime. Following the development of quantum electrodynamics shortly after World War II, the field concept was then successfully applied to the strong and weak nuclear forces with the formulation of what today is known as quantum field theory. As is well known, however, a workable quantum field theory of gravity has yet to be formulated.

Wolfhart Pannenberg has suggested that "theologians should . . . consider it obvious to relate the field of modern physics to the Christian doctrine of the dynamic presence of the divine Spirit in all of creation." He goes on to speak of the "field structure of the cosmic activity of the divine Spirit" and suggests that "one could consider identifying the subject matter intended in the conception of angels with the emergence of relatively independent parts of the cosmic field" (Pannenberg 1988; 1994, 104–5).

Although some criticisms have been leveled against these suggestions (Polkinghorne 1998, 81–82; 2000, 161–65; Worthing 1996, 120–24), I nevertheless support the idea that physical field theory might in some way be useful in theology by serving as a meaningful analogy for God's cosmic presence. So in contrast to Pannenberg's approaching the subject from the perspective of a theologian, I present here a physicist's perspective by pursuing a much more specific and focused approach.

Accordingly, in the first section I describe how each of the four forces of nature and its field, depending on its particular physical characteristics, might be seen as an analogue for divine immanence. In the following section I explain how it is especially the electromagnetic force that most clearly qualifies as such an analogue by describing how inherent and pervasive electromagnetic phenomena are in all of earthly nature, including humans. I show in the third section the relevance that electromagnetic interactions have to four particular areas of special interest to the science-religion community: the quantum theory of measurement, the irreversible nature of time, the evolution of life, and eternity. In the fourth section I treat selected examples of how light, electromagnetic radiation, and the nonvisible properties of electromagnetism figure in the religious and spiritual life of people throughout the world. This is prefatory to showing in the last section how electromagnetic phenomena on earth can be considered a compelling physical analogue to God's, or a divinity's, indwelling. I propose that this physical analogy be exploited for theological study, particularly in the pursuit of a more enriched theology of nature as well as providing a valuable datum in the search for a credible natural theology.

Also included are comments on the relevance of electomagnetic phenomena to concepts of natural evil.

The Forces of Nature as Analogues of Sacred Immanence

It can be argued that each of the four forces of nature by virtue of its ubiquity throughout the universe as well as its breadth and intensity of activity can in varying degrees lay some claim to being an analogue for divine immanence. I suggest that the four forces can constitute a kind of nested hierarchy ordered according to the degree of our awareness of their presence and of their diversity of activity in all of nature (Fagg 2000, 21–23). Accordingly, I discuss each of the forces in order of increasing human sensibility to its potential as an analogy or metaphor for sacred indwelling.

I begin with the weak force. Although it plays a vital role in radioactivity, thermonuclear reactions on the sun and other stars, and many other elementary particle phenomena, its impact on our sensations and awareness is quite distant. It is true that what is called the electroweak theory unifying the weak and the electromagnetic forces received strong experimental verification in the early 1980s. It successfully describes the weak and electromagnetic forces from about one-billionth of a second after the Big Bang, when they were truly one in terms of their interactions, effects, and behavior, to today, when the two act quite differently.

The point here is that the weak aspect of the electroweak force cannot do any of the wondrous things attributed to the electromagnetic force in our present world. Even though the weak force is vitally active in stars throughout the cosmos and in radioactive trace elements impregnating the air, water, and earth of our planet, it must be placed at the base of the analogical hierarchy because, compared to the other three forces, its effects are so relatively inaccessible to our senses.

Next in order is the strong nuclear force. It keeps quarks together three at a time to form protons and neutrons, which in turn are held together by this force in the nucleus at the center of an atom. The nucleus of the biologically crucial carbon atom, for example, contains 99.97 percent of the atom's mass. Thus, it is this force primarily that endows us, all of earthly nature, and all heavenly bodies with mass. It makes possible our sense of embodiment and tangibility, our realization that there is something instead of nothing. With these properties prevailing throughout the universe, the nuclear force can be considered as a analogic signature of God's immanence at a more apparent level than that of the weak force.

Even more apparent to our sensibilities, however, is the gravitational force, which, with essentially infinite range, acts on every mass in the universe, however infinitesimal. It is the ultimate arbiter in the competition with the other forces over the life and fate of stars and galaxies. It regulates

the motion of galaxies and galactic clusters and plays a pivotal role in the fate of the universe and its expansion. It keeps the moon in orbit around the earth, the earth around the sun, and the sun around the galactic center. Closer to home, gravity holds us, all of nature, and the atmosphere to the earth, and its pull influences the function of our bodies and that of all living creatures. With its universal pervasiveness and its action from the most subtle to the most powerful and awesome, gravity is certainly a cogent candidate as a physical analogy for God's inhering omnipresence.

Nevertheless, none of the three forces thus far discussed can match the diversity, comprehensive breadth, and exquisite sensitivity of the electromagnetic interaction as such an analogy. Let us see why this is so.

The Pervasiveness of Electromagnetic Phenomena

In recent years much has been made of attempts to unify some or all of the four forces into one theory, often called a theory of everything. But the first major unification of this kind was accomplished by James Clerk Maxwell in 1864. With a set of equations of elegant simplicity and symmetry he was able to give a unified description of the electric and magnetic forces. Maxwell thus showed that electricity and magnetism were simply aspects of one force, electromagnetism.

One of the most important results of Maxwell's work was that the electromagnetic radiation predicted by the theory turned out to propagate at a speed about equal to the speed of light as experimentally measured at the time. It was soon realized that the whole spectrum of radiations, from radio waves to X rays and gamma rays, were all electromagnetic radiations moving at the speed of light, so that the word *light* has now become a common generic label for all electromagnetic radiations, especially among physicists.

Just how intimately light can be understood as part of electromagnetism and how universal it is in a general sense was revealed in the next major refinement of electromagnetic theory. This came soon after World War II, when Richard Feynman, Julian Schwinger, Shinichiro Tomonaga, and Freeman Dyson completed the formulation of quantum electrodynamics (QED). Their theory reconciled Maxwell's theory for electromagnetic phenomena with the universally applicable basic theories of quantum and relativity. QED, although applicable only to electromagnetic phenomena, is the most accurate theory in all of physics, predicting numbers that agree with experiment to better than one part in 10 billion.

QED showed that the electromagnetic force between electrically charged particles is carried by unobservable photons. These photons are called virtual photons, in contrast to the real photons of visible light. The virtual label may seem to imply that virtual photons do not exist, but this is not so. Though they cannot be directly observed, their existence is certified by

the fact that without including them, QED calculations could not yield results that are in such accurate agreement with experiments.

In part because of the accuracy of QED, but also because of the wide technological application of electromagnetic theory, the electromagnetic force is known far better than the other three forces. Its effect and presence in all aspects of our life and relation to the world is ubiquitous.

Electrons are constrained to orbit around the nucleus of an atom by the electromagnetic force by means of its virtual photons. The electromagnetic force is the same interactive "glue" that keeps atoms together in a molecule, so that all of chemistry and biology at root operates by means of electromagnetism. It is this interaction that makes it possible for bacteria, the smallest living cells, to exhibit purposeful mobility, coherent collective action, and remarkable sophistication in their growth and survival. At the other end of the biological ladder, we ourselves and all our organs function by means of this mechanism. This is so from the interactions of blood cells to the activity of neurons in the brain, so that our most intimate interaction with matter is by means of the electromagnetic interaction.

The same interaction that governs the incessant interplay of the molecules in air and water collectively unites their motion to give us sound and ocean surf. Although it is gravity that keeps us, all earthly objects, and the atmosphere attached to the earth, it is the electromagnetic force binding the atoms and molecules tightly together that makes possible the vibrant stasis in solid objects. This force (along with certain quantum effects) is what keeps the table lamp from falling through the table and the table from falling through the floor.

Whether we are examining the microscopic realm of elementary particles with gigantic particle accelerators or probing the heavens with huge telescopes, the knowledge we gain is mediated by the electromagnetic interaction and its radiation. So virtually all experimental studies of the other three forces, whether in the microscopic or the cosmologic realm, are conducted through an electromagnetic "sensor." This, of course, includes computers and complex electronic instruments that store and analyze the data and make calculations based on the data.

One of the most cogent manifestations of electromagnetism's universality is the role that its radiation (light) and its speed play in our understanding of the structure of spacetime and the nature of the cosmos. Although the 300 million meter/second speed of light is extremely fast, it is not infinite. Light's finite and measurable speed sets the pace at which we learn about the behavior of the cosmos. Some of the farthest galaxies are estimated to be some 13 billion light years away. (A light year is the distance traveled by light in one year.) This means that the light arriving at the astronomers' telescopes now allows them to see the galaxies as they were 13 billion years ago. The farther away a galaxy is, the farther back in

time is our observation. The history of the physical universe is spread out before our eyes, and it is electromagnetic radiation that tells the story.

Perhaps the most relevant property of the electromagnetic interaction in our life in this world, however, is a host of subtle electromagnetic quantum events of very low energy that activate the life of humans and their consciousness. The extreme subtlety of the events is quantified in experiments in microbiology by Ross Adey and his colleagues (Adey 1993) that show that voltage gradients as low as one ten-millionth of a volt per centimeter and frequencies between zero and 100 cycles per second are involved in the interaction between cells in living creatures. He also tells us that all plant and animal life is bathed in, and interacts with, a sea of such very low-frequency radiation that envelops the earth. This is independent of the radiation superimposed by technology.

In fact most of the space occupied by earthly objects is impregnated with an astronomical number of electromagnetic phenomena in a constant flurry of activity. All things that appear to be solid or liquid or to have substance consist principally of this vibrant space. Consider again the carbon atom; while some 99.97 percent of its mass is concentrated in the nucleus at its center, the nucleus occupies roughly one-trillionth of the volume of the atom as a whole. The remainder of the volume is occupied by six electrons (of very low mass) and trillions of unobservable photons transmitting the electromagnetic force that keeps them in their orbits.

Additionally, all of space is alive with the unobservable, evanescent appearance and disappearance of a host of particle pairs, mostly electron-positron pairs. (A positron is an electron with a positive electric charge.) Although the particle pairs are not detectable, if they are not included in quantum electrodynamic calculations, physicists do not obtain results in agreement with experiments, just as is the case with the force-transmitting virtual photons. Hence, we and all apparently material earthly objects are a part of a vast ocean of essentially nonmaterial space energized by an innumerable multitude of virtual electrodynamic phenomena.

With this abbreviated outline of the encompassing scope of electromagnetic phenomena in us and all of nature, it should be evident that the electromagnetic force crowns the hierarchy of physical analogies for divine immanence. Although the other three forces—weak, nuclear, and gravitational, in order—gain successively greater access to our awareness, as a group they still provide a relatively passive, inanimate background to the dynamic, vivifying action of the electromagnetic force. In other words, the other three forces in concert can be regarded as providing a cosmic expanse of "fertile soil" with the potential to nurture the growth and flowering of life and consciousness made possible through the medium of electromagnetism, which is therefore by far the most evident physical analogue for God's immanence in earthly nature (Fagg 1999). This ubiquitous dominance of electromagnetic phenomena in our world includes the fact that

they are involved at a fundamental level in four specific areas of scientific study that have attracted the attention of theologians engaged in the science-theology dialogue.

Electromagnetism in Quantum Measurement, Time, Evolution, and Eternity

Quantum measurement, time, evolution, and eternity continue to be energetically studied in present-day science and, concurrently, have been of primal interest to theologians of nature as well as natural theologians. The rich potential for theological investigation that they offer is attested to by the plethora of current literature dealing with their various aspects. Moreover, the hermeneutic value to theology that can be derived from a continued thorough examination of these areas is far from having been fully exploited. But of relevance here is the fact that electromagnetic phenomena are a basic underlying factor in each case. Let us see how this is so.

Quantum Measurement. For the purposes of background it would be inappropriate in this paper to present a full, lay-oriented description of the quantum theory.[1] It is sufficient here to introduce the discussion with a few distilled remarks.

Quantum theory was developed in order to deal with the fact that there is a fundamental limitation on how precisely measurements can be made on the particles of the microscopic world—molecules, atoms, protons, electrons, photons, and so forth. An often-presented example of this is that it is impossible with ultimate accuracy to determine simultaneously the position and the momentum (or velocity) of such a particle. This is an objective fact of nature and has nothing directly to do with the precision of the measuring instruments.

This basic restriction on accuracy was quantified in the famous *uncertainty principle* formulated by Werner Heisenberg. He (with Max Born and Pascual Jordan) and Erwin Schrödinger developed separate but equivalent mathematical formalisms of quantum mechanics that were consistent with the uncertainty principle. Schrödinger's formulation was known as wave mechanics and that of Heisenberg and his colleagues matrix mechanics.

In terms of Schrödinger's wave viewpoint, which is more descriptively amenable, knowledge of, for example, the position of a particle is given by what is called a wave function. The amplitude or magnitude of this function is directly related to the probability that the particle is at a given position. Specifically this probability is equal to the square of the absolute value (or modulus) of the wave function. When a quantum system described by a wave function is subjected to a measurement, the function "collapses," or reduces to a specific value for the measurement. Among all of the possible values for which a probability has been calculated, one is chosen.

The essential point to be emphasized here is that, to the best of my knowledge, there is no quantum measurement that does not use some electromagnetic interaction to accomplish the observation. Therefore, although it has been noted earlier that QED theory reconciles Maxwell's classical theory with quantum and relativity theory, the purview of QED in the quantum world extends well beyond the realm of electromagnetism and involves measurements of the other three forces.

For example, in the radioactive decay of a nucleus, which involves the weak force, the detection of the emitted particle, for example, an electron, is accomplished by a scintillation counter. On entering some scintillating material, light produced along the electron's trajectory impinges on a photosensitive surface. Electrons emitted from this surface by the photoelectric effect are then electrically focused onto a succession of electron-emitting surfaces that multiply the event so that it can be detected as an electric pulse by the associated electronics. Generally similar techniques, but on a much larger scale, are used in the detection of particles acted on by the nuclear force in interactions produced by high-energy particle accelerators.

According to current theory, the quantum of the gravitational force is the graviton, which thus far has not been detected. It is hoped that it can be observed within a year or so by a synchronized system with detection equipment at two widely separated locations in the United States known as the Laser Interferometer Gravitational-Wave Observatory (LIGO). But it is electromagnetic radiation that is utilized in the observation process.

Thus, not only do we learn about the heavens by means of a vast range of electromagnetic phenomena, we also learn about the quantum world. Through God's providence we have been given an enormously versatile and exquisitely sensitive "looking glass" to observe both the inner and outer cosmos.

A number of those involved in the development of natural theology have devoted considerable speculative thought to the question of divine action and of how to determine the "causal joint" linking the divine with the living world. Some have studied whether answers can be found in the veil of indeterminacy characterizing quantum measurements. For example, there are those who hold that there is a case for divine action in quantum events (e.g., Russell 1997; Murphy 1995; Ward 1990).

Nicholas Saunders, however, after reviewing the thought of such scholars and considering in detail the measurement process in quantum mechanics, concludes that "quantum mechanics is not easily reconciled with the doctrine of divine action" (Saunders 2000, 517). Carl Helrich suggests that instead of seeking divine action at the quantum indeterminacy level we should look at a higher level "at which we become the system being studied and at the same instant are the measuring instrument" (Helrich 2000, 502). Arthur Peacocke has looked at dissipative, far-from-equilibrium systems (Peacocke 1990, 51–55), and John Polkinghorne at chaotic

systems proceeding toward their strange attractors (Polkinghorne 1998, 61), for hints of divine agency.

Nevertheless, it is by electrodynamic means that the measurement of the quantum processes discussed by Russell, Murphy, Ward, Saunders, and Helrich is accomplished. Moreover, the trigger for a dissipative system to develop in a particular way and the infinitesimal nudge for the chaotic system to follow its divergent course are both effected by quantum electrodynamic events.

In a general sense I agree with an aspect of Helrich's thought. A measuring device is essentially no different from any other macroscopic aggregate that occupies the immediate vicinity of the wave function to be subjected to measurement. Unbeknownst to us, wave functions are collapsing all the time by the measuring process of some such aggregate, each yielding a specific result out of all the possible ones of varying probability as predicted by its wave function (Fagg 1995, 174).

In sum, although I do not wish to propose any views concerning a specific path of divine action by means of a causal joint, I do claim that if that action should occur by any of the means discussed above, electrodynamic events at the quantum level may be considered the physical agents utilized in effecting the causal joint.

The study and discussion of the quantum-measurement problem will probably continue indefinitely. But for now it still seems true that the wave function, a prediction of the future, is collapsed by a measurement in the present to then become a record enriching the past (Fagg 2001), which observation introduces the subject of the irreversible nature of time and electromagnetism's relevance to time.

Time. In the past few decades a number of scholars and writers have cited primarily three natural phenomena by which the passage of time is gauged and which they call "arrows of time." The three are (1) the cosmological gauge based on the expansion of the universe; (2) the thermodynamic gauge based on the average tendency in nature to progress irreversibly to greater states of disorder, the measure of which is a physical quantity called *entropy*; and (3) the psychobiological gauge based on the growth of information and organization characterizing life and the human species, which I relate to evolution, treated in the following subsection.

Let me first discuss the thermodynamic gauge, which associates the irreversible increase in entropy with the time asymmetry observed in the macroscopic world of everyday experience. This asymmetry is in direct contrast to the time symmetry or reversibility that characterizes almost all of the interactions in the microscopic world of quantum physics, except for the decay of two subatomic particles known as the neutral K meson and the neutral B meson. That is, except for the behavior of these two particles,

the equations of physics are applicable to the motion of a system proceeding in one way as well as the reverse.

In any case, this almost-universal symmetry at the microscopic level brings us to the central question first addressed by Ludwig Boltzmann more than a century ago and still controversial today: How is it that almost all of the individual events in the microscopic realm are amenable to a time-symmetric description, yet these events somehow aggregate to yield a macroscopic world characterized by time asymmetry? For example, a drop of ink deposited in a glass of water spreads uniformly throughout the glass and never reassembles into the drop again. Boltzmann showed that the progression to greater disorder or entropy occurred because statistically the number of disordered states is always more than the number of ordered states. He therefore provided a statistical mechanical basis for the concept of entropy and for the Second Law of Thermodynamics.

In the last two decades the question has received the attention of Ilya Prigogine (Prigogine 1980). Among his more recent conclusions, perhaps the most controversial is that microscopic phenomena are time irreversible, a view also held by Willard Fadner at Colorado State University (Fadner 1992) and Sun-Tak Hwang at the University of Iowa (Hwang 1972). All of these men use quantum mechanics in their formulations intended to show the microscopic irreversibility of time. It would be out of order here to present details of their respective derivations.

I do wish to point out that there are fundamental and underlying physical events that are effectively responsible for microscopic irreversibility and can be associated with the thermodynamic gauge. Again, in large part this is based on the realization that most of nature on this earth operates by means of electromagnetic interactions. A large proportion of these interactions consist of transitions between atomic and molecular energy levels, which involve the emission or absorption of electromagnetic radiation. These radiative energy exchanges proceed constantly all around us and underlie all of earthly nature.

In addition to atomic and molecular radiative transitions, there are electromagnetic interactions that are essentially collisional in nature and also involve the emission of electromagnetic radiation. This radiation is emitted any time an electrically charged particle is accelerated. Acceleration is the rate of change of velocity. Because velocity involves both speed and direction, any time a charged particle undergoes a change in direction, as is the case in a collision, such electromagnetic radiation is emitted.

Such radiation is also emitted in collisions between neutral atoms and molecules, because during the collision there is a mutual distortion of the electron orbits, which produces a corresponding distortion of the electric-charge distribution of the molecules. These distortions in turn induce electromagnetic radiation known in physics as polarizational bremsstrahlung (Amusia 1988).

The point here is that this radiation, as well as that involved in radiation exchanges among atomic and molecular energy levels, is ultimately and irreversibly lost in the medium, even though in principle according to electromagnetic theory any given one of these quantum electrodynamic interactions is reversible.

John Wheeler and Richard Feynman (1945) showed how the reversibility characterizing classical electromagnetic theory could be reconciled with the irreversibility observed in the emission of light from a source, for example, a candle, where, except for a fluke reflection, the light never returns to the candle wick. The quantum version of this theory, however, has never been successfully formulated. Furthermore, there is some question concerning one of Wheeler and Feynman's assumptions, and experimental tests of their theory cannot confirm it. In any case, for all practical purposes the flurry of electromagnetic interactions and their associated radiations are irreversible and constitute an underlying mechanism driving the thermodynamic gauge of time.

Thus the gaseous particles that Boltzmann dealt with interacted electromagnetically, as do all of the ingredients in the chemical reactions that Prigogine studies. Accordingly, I suggest that addressing the problem of macroscopic time irreversibility from an electromagnetic viewpoint might be a fruitful approach and might also be of use to Prigogine and others in their efforts to show microscopic irreversibility.

Evolution. Let me now discuss the electromagnetic basis for the psychobiologic gauge of time, which is essentially involved in the process of evolution. In the science-religion dialogue in recent years there has been intense interest in the evolution of life and its relevance to divine purpose and action. In virtually all of this dialogue the sciences referred to have understandably been the biological sciences—biology, neurophysiology, zoology, physical anthropology, and so forth. However, to the best of my knowledge there has been little consideration of the underlying physics involved in evolutionary processes.

I suggest that the landscape for this dialectic study could be significantly broadened and enriched by serious consideration of the physical phenomena that have been involved in the evolution of life. In particular, we may ponder what it might mean that, of the four physical forces of nature, it is again the electromagnetic force that underlies and activates all of the phenomena studied by the biological disciplines.

Life's entire evolutionary process, from the assembly of molecules to form, first, bacteria cells, then the host of plant and animal species, and finally human beings, has occurred through the action of electromagnetic phenomena. In each case the breakthrough to a greater level of complexity has been carried out as the result of incessant probing and testing by a multitude of exquisitely sensitive "electrodynamic photon messengers,"

effecting the interaction among molecules and cells. These photons restlessly and unremittingly serve as agents in the experimentation and search for a higher level of ordered complexity or organization. Thus, the construction of a gene, consisting of beautifully symmetric double-helix DNA molecules, which in turn exhibit vastly varying arrangements of nucleotides, has been effected by multitudes of subtle electromagnetic interactions.

Furthermore, it is of direct supplementary relevance that virtually all of modern technology also depends on the electromagnetic force for its operation. This is so from the alignment and synchronization of electromagnetic waves to form a laser beam for eye surgery to the massive motor generators furnishing electric power to our homes. In a real sense this technology, with our constant interaction with it and our dependence on it, can be seen as a vital and intimate adjunct to our continued evolution. Consider, for example, the growing proximate interaction we have with computers, cell phones, and robotics devices. Indeed, our very survival as a species may depend on the technology we develop to combat the increasing number of diseases that are resistant to antibiotics or to launch a rocket that can prod an asteroid out of its earth-destroying trajectory.

The inexhaustible variety in the continuous ranges of the four basic properties of electromagnetic radiation—intensity (or strength), frequency, phase, and polarization—exercises the ingenuity and imagination of scientists, engineers, and inventors and will continue to do so. These properties characterize not only visible or detectable radiation but also the unobservable virtual photons that transmit the electromagnetic force. How these properties can be orchestrated to provide the physical basis for the incredible richness of life and human interaction on this earth is to me an awe-provoking question. For those engaged in the science-religion dialogue, the essential idea to contemplate is that, just as we have used these electromagnetic tools to create almost all of the technology we enjoy today, so did God, with infinitely more dexterity and subtlety, use them to create us.

Reflections on Eternity. Our cognizance of God's living creation and our perception of the irreversible nature of time come to us primarily through our awareness of the transience and ever-changing character of the moment. An especially cogent understanding of how the moments that sequentially make up time's passage possess a profound spiritual quality derives from the thought of Martin Buber. The prototypical example of this thought is found in *I and Thou* (Buber 1958). He speaks of stepping into the living present totally and spontaneously without reservation. Each such here-and-now is unique and sacred and will never be repeated, never quite with the same flavor and nuances, thus constituting an irreversible succession.

It is through this present that we have some access to the notion of eternity. Robert Neville, in *Eternity and Time's Flow*, sees time and eternity

as inseparable and eternity itself as the ontological context in which the past, present, and future are embedded (Neville 1993, 12–14).

Accordingly, I suggest that it is largely because we humans have a present whose duration is longer than that of most other animals, which therefore includes elements of the immediate past and future, that we are able to conceive of the idea of eternity at all. I base this suggestion on the reasonable premise that the duration of a creature's present depends at least in part on its physiological size and thus in turn on the extent and complexity of its neural network. It takes time for all of the electrodynamic sense signals to be assembled and integrated into a present moment. The duration of the present for a bee is less than that for a squirrel, which is less than that for a human. This human present, which according to experimental psychologists can vary from 0.05 of a second to 2 seconds, depending on the experiment, gives us a pencil-like glimpse of the sweep of eternity.

This perception of the relation of the present moment to eternity is congenial with that of Søren Kierkegaard, who saw time's connection with eternity as being through the present, the moment: ". . . the moment is not properly an atom of time but an atom of eternity. It is the first reflection of eternity in time, its first attempt, as it were, at stopping time" (Kierkegaard 1980, 86).

In any case, the ability of our brains to integrate and organize electrodynamic quantum signals from the far reaches of our nervous systems so as to underlie our sense of the eternal moment is still only one among an indefinite number of examples of how universal electromagnetism and its radiation are in our internal and external experience. For no other phenomenon of physical nature so totally and intimately permeates and affects our lives and our world, providing the means by which humans can not only experience a perception of eternity but also sense in nature the presence of the sacred.

The Spirituality of Light and Nature's Indwelling

Electromagnetic radiation, light, has served as a primary medium for the spirituality of men and women since the dawn of human consciousness. It has been an essential component in the creation myths of a variety of different cultures throughout the world. These include not only the biblical creation accounts but also creation myths of the Navaho and Zuni in the southwestern United States, the Polynesians, and the Egyptians, to name a few.

Besides being among the first emergents of the creative act in such cosmologies, light subsequently figures prominently in characterizing the nature of God's posture with respect to humankind. The Bible is replete with the use of light to symbolize God's provident and salvational relation to men and women. It contains many such examples, particularly in Isaiah, the Psalms, and the Gospel of John.

In Sura 57 of the Qur'an, light proceeds ahead of believers and is provided by God so that believers may walk straight. In the Bhagavad Gita, the scriptural jewel of Hinduism, we read: "I behold thee . . . as a mass of light shining everywhere with the radiance of flaming fire and sun" (Deutsch 1968, 11:17).

In many of the spiritual paths traveled by Christian mystics, light has been a major feature in the visions they have experienced. Saint Theresa of Avila speaks of "a light which knows no night" and Mechthild of Magdeburg of "the flowing light of the Godhead" (Underhill 1961, 249). Jesus, Christian saints, and the Buddha are pictured with haloes of light surrounding their heads. Paul's conversion on the road to Damascus was accompanied by a blinding light. Many of those who have had near-death experiences report finding themselves at the final stage of the episode in the presence of a "being of light" that exudes unquestioned warmth and love and requires an unequivocally honest response.

The quiet, calm glow of a small candle has been a spiritual symbol for men and women for millennia. Such use of candles to symbolize the spirituality expressed in rituals is found in religions throughout the world.

Furthermore, the reference to light as a symbol or metaphor is common in the writings of theologians and religious scholars worldwide. They see in the spiritually directed use of light a clear distinction between the worldly light that God created and the Uncreated Light that characterizes God.

Complementing the role that light plays is that played by the nonvisible properties of electromagnetism. Again, it is the electromagnetic interaction that activates all of the biological and chemical operations that give life to earthly nature. It is this life, this muted dynamism, that those with a reverence for nature see as having a spiritual, indwelling aspect. Literature worldwide abounds with rich descriptions of the unqualified spiritual sense of a divine presence in surrounding nature. This sense has been cogently expressed by such Christian mystics as William Blake, Jacob Boehme, Saint Rose of Lima, and Saint Francis of Assisi, as well as the Muslim Jalal Ad-din Rumi. In the East the vibrant presence that inheres in nature especially characterizes the Taoist, Shinto, and some Buddhist traditions. For example, in Taoism the Tao is the mysterious quiet that pervades the natural world.

In the twentieth century there were religious thinkers whose philosophic approach to the phenomena of the natural world implied a spiritual indwelling and the influence of God. Leading among these were Alfred North Whitehead and Pierre Teilhard de Chardin. Whitehead saw the natural world as proceeding by means of irreducible events or elements of experience called "actual occasions," which can be influenced, but not determined, by God. Teilhard spoke of the "within of things" characterizing all of nature.

Analogy and Theology

The immanence in nature expressed by all of these sources, however, finds its most proximate physical undergirding in the electromagnetic interaction and its corresponding field. This is essentially the reason why I see this interaction and its field as a meaningful physical analogue to God's immanence.

In attempts to describe the nature of God as Creator, metaphorical analogies have been used for centuries. God has been called a watchmaker who wound up the universe and started it ticking; a playwright, with us the inept actors; a painter who, with a splash of the brush, produced nature's florid display.

Of course, an analogy is only an analogy; it is not the real thing being analogized. And in the case of using part or all of finite creation as an analogy to some aspect of God, it is very far from the real thing (Oakes 1997, 27). Nevertheless, analogy is one powerful means to help us understand something about God. Analogy helps connect us to God. Analogy helps us place ourselves in a realistic perspective with respect to God, because we are not only separate and different from God but also linked to God as derivative creatures bearing some signs of the Creator (Oakes 1997, 26).

One primal way that we are able to feel linked to God is by our awareness of God's being in us and nature, that is, of God's immanence. But again, wherever that immanence can be perceived on this earth, it is electromagnetism that provides its physical grounding. Although it is true that by definition any analogy involves both similarities and differences and is therefore an incomplete comparison, especially in reference to God, I reason that one of the most complete of the incompletes is the electromagnetic field, specifically with respect to God's immanence.

This hypothesis is based essentially on *how* this interaction can be seen to be analogous to divine immanence. First, both God and electromagnetic interaction share in the property of ubiquity; both are all-pervasive in our world. Second, they have analogous ranges of intensity, from the most subtle and sensitive natural phenomena and human experiences to the most powerful and awesome. Third, they are analogous because light is so often used as an analogy, symbol, or metaphor for God's presence. But light is electromagnetic radiation. Just as God's light is far beyond what we can see, so analogously the electromagnetic spectrum extends far beyond what is visible to us. Fourth, just as there is beauty in a spiritual experience or insight, so also there is beauty in physical nature and the elegance and symmetry of the electromagnetic equations that describe that nature.[2]

I emphasize, however, that God is not light or electromagnetism, and electromagnetism is not divine immanence. But it is the primal physical mechanism serving as an analogue to help us have access to that immanence.

I believe it awaits appreciation as such by any theology that seeks to understand God's or any deity's relation to us and the natural world.

This is particularly true of a theology of nature, which is the study of the theological implications of our modern scientific knowledge of nature from the standpoint of time-honored revelatory theology. What I have said here for the most part assumes the existence of a revealed God and therefore is in the context of a theology of nature.

I also suggest, however, that the ubiquity of electromagnetism in our world serves as a compelling pointer to the possibility of an ubiquitous, immanent God and thus constitutes an encompassing, fundamental datum useful in formulating a natural theology.

But regardless of which theology is being considered, I believe that I am proposing a refreshing approach. Instead of dealing in the broad generalities that perforce characterize much of the science-religion dialogue, I am discussing a specific part of nature and associating it with a specific attribute of God, divine immanence. On the other hand, because electromagnetic phenomena underlie so much of the nature that is examined in this dialogue, it provides a unifying and cohesive influence in the pursuit of either a theology of nature or a natural theology.

There is one theological issue that I believe can be informed by thoughtful reflection on electromagnetism's ubiquity. While it is true that electromagnetism provides the physical underpinning for all of the diversity and fecundity we see in earthly nature, it is equally true that it is the underlying physical basis for the dangerous aspects of nature. Electromagnetism is completely neutral on this issue. Thus, sharks, tornadoes, earthquakes, poison ivy, and the AIDS virus all at root are also energized by electrodynamic interactions. The beautiful and the dangerous live side by side and at times even coalesce: the rings of the poisonous coral snake are quite strikingly colorful; the graceful undulations of a swimming shark are equally impressive; the uniform symmetry of a tornado likewise reveals its own awesome beauty.

If there is a creating God, the fact that this creature, this electromagnetism, was made to physically underlie both the beautiful and benign and the ugly and dangerous colors my view of what constitutes evil. In particular, I believe that electromagnetism's neutrality with respect to the "good" and "bad" things in nature may suggest a qualification and refinement of what has been called natural evil (as opposed to moral evil). Perhaps, for example, at the very least the inanimate creations of this earth, such as tornadoes, earthquakes, and hurricanes, although extremely dangerous, might be considered for exclusion from the realm of natural evil. This, of course, depends on whether the discussion of evil includes anything that causes suffering, or whether suffering is accepted as part of living, and the discussion is then restricted to a deliberate, directed malintent toward a living creature or group of creatures. In any case, electromagnetism's neu-

trality with respect to the "good" and "bad" features of nature might be looked on as a manifestation of natural creation's God-given freedom.

Nevertheless, despite the problem of evil, aesthetics is an important aspect of theology, and it seems that theologians these days rarely consider the beauty of some of the concepts they are pondering. On the other hand, many theoretical physicists throughout their careers have told how they have been guided by the criteria of beauty and simplicity in their work. The physical laws they have formulated find much of their beauty in the symmetries that are exhibited. This underlying symmetry at the quantum level becomes ultimately reflected, for example, in the beautiful symmetry of a maple leaf, the hexagonal symmetry of snowflakes, and the symmetry of the human body.

So, fundamental symmetries characterize the electromagnetic interactions in all of space that help in arranging matter to yield the awesome spectacle seen in the material world. But this world is far less material than it appears. The living creatures of the world, including humans, are carbon-based. As discussed earlier, the nucleus at the center of the carbon atom occupies only one-trillionth of the atom's volume. The rest of the volume is occupied by six electrons (of very low mass) and trillions of virtual photons transmitting the electromagnetic force that keeps the electrons in their orbits.

Thus, a vast array of electrodynamic phenomena fills most of the world's space, so that we ourselves are in a very real sense immersed in an ocean of electromagnetic events; indeed we are part of the ocean. This helps me see electromagnetism as constituting the farthest frontier of the physical realm, probing with its sensitive tendrils into the unknown gap between that realm and the realm of the conscious and spiritual. It therefore plays a unique role in our search for a fuller cohesion of the whole continuum of existence from the material to the spiritual.

Notes

Portions of this paper were presented at the 1995 conference of the Institute on Religion in an Age of Science, Star Island, N.H.; the 1998 "Cosmos & Creation" Conference, Loyola College, Baltimore, Md.; as the 2000 Kirschner Berz Lecture, George Washington University, Washington, D.C.; and at the 2001 "Religion and Science Dialogue with Wolfhart Pannenberg" conference, under the auspices of the CTNS Science and Religion Course Program, Chicago, Ill.

1. For a nonmathematical description of quantum measurement theory that is lucid and informative, see Carl Helrich's recent *Zygon* article (Helrich 2000).

2. In the context of Whitehead's religious philosophy involving his concept of actual occasions, however, I suggest that a stronger claim may be made: that the electromagnetic interaction (EMI) is a viable physical correlate to God's immanence. That is, more than simply a paralleling analogue, the EMI plays some interactive role in the relation between God and actual occasions.

For Whitehead, God uses and needs actual occasions "as an intermediate step towards the fulfillment of his own being" (Whitehead 1978, 105). It is his conception of God being interactive with actual occasions and consequently in this sense also being processive that I suggest that the electromagnetic interaction may be the correlate for God's immanence. Given that this interaction is the "workhorse" that provides the underlying physical operations that help bring

about the fruition of an actual occasion, it also plays some role as the physical conveyer of the interaction between God and the actual occasion, an interaction that influences both the occasion and God. Electromagnetism provides the physical component of this reciprocal interaction, and in this sense it may be said to be a physical correlate for the immanence of God.

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