A PENTECOSTAL PERSPECTIVE ON ENTROPY, EMERGENT SYSTEMS, AND ESCHATOLOGY

by David Bradnick

Abstract. Many contemporary theologies have given considerable attention to the inbreaking work of God whereby the Spirit imbues creation with life and vitality, but in the process the seriousness of the destructive forces that plague the world has been overlooked. This oversight not only has significant theological consequences, but it also generates a tension with scientific postulates about physical reality. Paradoxically, increasing complexity, including emergent life systems, arise in spite of the overarching conditions. I posit from a theological perspective that the Spirit acts within the world to generate pockets of organization out of disorder. The Spirit not only was present and active at initial creation but also continues to act within the cosmos, sustaining the natural order and giving rise to innovative acts of creation. The world, which groans for and anticipates transformation, experiences local decreases in entropy as proleptic events of God's inbreaking kingdom. This theological hypothesis provides the framework for considering an eschatological response to the world's decay.

Keywords: emergence; entropy; eschatology; pentecostal theology; pneumatology

Tension between science and classical pentecostal theology is perhaps no more evident than when it comes to issues regarding the ultimate fate of the universe and eschatology. Scientific theories about the final destiny of the cosmos are primarily divided into two major camps. One, known as The Big Freeze or The Big Rip, postulates that the universe will continue its rapid rate of expansion, precipitated from the Big Bang and accelerated due to dark energy, eventually ripping apart the entire fabric of space-time

David Bradnick is an adjunct instructor at Duquesne University and Harrisburg Area Community College, 2010 Pennsylvania Ave., York, PA 17404, and a Ph.D. student at Regent University School of Divinity; e-mail davibr3@regent.edu.

[*Zygon*, vol. 43, no. 4 (December 2008)]

© 2008 by the Joint Publication Board of Zygon. ISSN 0591-2385

until virtual nothingness exists. An alternative view, The Big Crunch, predicts that this cosmic expansion eventually will be overtaken by gravitational forces, setting the motion of the universe in reverse, with all things compacting again into a time-space singularity.[1] Regardless of what theory one maintains, the future of the cosmos appears to be on an unalterable course toward nonexistence.

In contrast, pentecostal theology is founded upon an eschatological hope that God will miraculously intervene in the world and transform all of creation to a pristine state under divine governance. Donald Dayton in his book *Theological Roots of Pentecostalism* asserts that the pentecostal movement developed out of a complex process whereby a variety of theological ideas were accumulated, especially from the Holiness movement, serving as a framework for a collective worldview. Presently known as the fivefold gospel, these pentecostal ideas include Christ as the "coming king," representing the pentecostal emphasis on eschatological hope (Dayton 1987, 173).[2] Based on these observations, the very core of pentecostal thought seems to be in direct opposition to the contemporary scientific consensus, so one may be led to question the viability of pentecostalism in a science-dominated context.

Adding to these theological challenges, the final destiny of the universe seems to be anticipated by entropic principles that pervade natural phenomena. A cursory observation of natural processes shows a trend in which the powerful forces of decay, corrosion, and decomposition seemingly suppress creativity and vitality. New life in the animal kingdom inevitably is followed by sickness and death; plants experience fruit-bearing seasons of productivity only to wither away into barrenness and death; the natural forces of wind and water cause erosion of grandiose mountains resulting in the eventual loss of their stature and awesomeness; and systems inevitably cease to function once they have exhausted all of the energy available to them. In general, science categorizes these phenomena under the principle of entropy, in which systems generally tend to move toward greater degrees of disorganization and ineffectiveness. How can pentecostal theology account for this putrefaction and disintegration given its eschatological sensibilities?

Paradoxically, increasing complexity, including biological systems and human consciousness, arose in spite of the overarching entropic conditions. Although systems are inclined toward atrophy and increased disorder, this is not an uncontested process; structures do increase in complexity and organization. The cause of these anomalies is generally attributed to manifestations of rare statistical probabilities or entropic fluctuations across systems in which the overall entropy of the universe continues to increase.

I would like to propose a theological interpretation of negentropy (negative entropy) that can complement these scientific accounts even while also locating the pentecostal eschatological hope on a firmer platform visà-vis the sciences. Where science ascribes increasing order to naturalistic causes, I suggest that the Spirit of God acts within the world to generate pockets of organization and that these local entropic decreases can be seen as proleptic (eschatological) events of God's inbreaking kingdom. Such a pneumatological approach to entropy may advance contemporary discussions on the theology of nature even as it contributes to the nascent but burgeoning pentecostal theological engagement with science.

I proceed in the following manner. First, I present an overview of entropic theory across a number of scientific disciplines, in order to provide a basic understanding of entropy. Next, I summarize the presuppositions of emergence theory and its explanation for the rise of complexity within the cosmos. Finally, I develop a theological approach to entropy and emergence featuring pentecostal perspectives, specifically its hermeneutical methodology, pneumatological theology, and eschatological emphasis.

DECAY, DISORDER, AND DECOMPOSITION: AN OVERVIEW OF ENTROPY

Entropy is a challenging concept to grasp, not only because of its abstract nature and mathematical derivation but also because of the various meanings applied to this term. Entropy is used variously in the sciences of thermodynamics, statistical mechanics, biology,[3] and information theory,[4] and there is debate within scientific circles regarding the broad application of this term. Some theorists maintain an underlying universal principle of entropy that can be applied to any system, while others see it as merely an analogous term with no ontological connectedness (Prigogine 1997, 24).[5] In other words, entropy may be a shared term across fields of study, but its different applications may have very different implications. For this reason a brief survey of the concept of entropy is in order.

Entropy was first introduced by Rudolf Clausius as a result of his research on thermodynamics beginning in the 1850s. He mathematically defined entropy in terms of heat loss within a closed system (Clausius 1879, 195–97).[6] This understanding, coupled with the second law of thermodynamics, led to the mathematical consequence, the Clausius Inequality, establishing that entropy must increase or at the very least remain at zero for any spontaneous process occurring within an isolated system (Clausius 1879, 213).[7] "The second law [of thermodynamics] then implies the existence of a function S, the entropy, which increases monotonically until it reaches its maximum value at the state of thermodynamic equilibrium" (Prigogine 1980, 5).[8]

This monumental conclusion expressed that thermodynamic systems can develop only in a certain fashion because of the parameters established by entropy. Consequently, these systems characteristically tend to move toward equilibrium and strive for maximum entropic value (Fast 1962, 6).

Therefore, in thermodynamics entropy is fundamentally associated with limitations on the amount of free energy within a system.[9]

According to A. H. Wilson, "The increasing property of entropy is therefore equivalent to saying that energy is always being degraded into forms which are more and more difficult to utilize for the production of work" (1960, 27). Where energy is initially easily harnessed, it undergoes a process of dissipation, thus adhering to the Clausius Inequality. The available energy within the system decreases, explaining heat loss within internal combustion engines, the impossibility of developing a perpetual-motion apparatus, and other phenomena that result in mechanical exhaustion. Within the framework of thermodynamics entropy emerged on the scientific front, acquiring its initial meaning and application but also setting the stage for future advancement and utilization.

In the 1870s Ludwig Boltzmann, building upon Clausius' work, developed an entropic equation for molecular configurations by combining classical mechanics with the theory of probability (Kockelmans 1999, 243). Boltzmann set out to formulate a microscopic expression of thermodynamics and experimented with ideal gases because of the tendency of gaseous particles to move in straight lines and the relatively limited interaction that occurs between these particles (Helrich 1999, 505). He observed that molecular collisions within these ideal gases eventually led a system to equilibrium. In thermodynamics entropy is related to the tendency of free energy within a closed system to decline, but in statistical mechanics entropy involves the pressure of the system, specifically the development toward an equivalent distribution in the collision rate of molecular particles. Essentially, Boltzmann identified entropy in terms of a measurement of the total number of macrostates in relationship to actual molecular configurations.[10] "The statistical entropy of a physical system is directly related to the macrostate and thus to the configurational complexity of the system. The area of possible configurations is directly related to the number of available microstates" (Brooks and Wiley 1988, 36). In other words, entropy for Boltzmann is the probability of particle collisions and, as a result, an increase in disorder due to the total number of possible arrangements within a system.

Whereas for Clausius entropy was fundamentally linked to a scientific law, the second law of thermodynamics, Boltzmann employed entropy as a function of probability. Specifically, the maximum number of disordered states within a system substantially outnumbers the ordered potentials, so it is far more likely that a system will move toward a higher state of entropy. Therefore, an increase in entropy denotes a statistical "law of increasing disorder" (Prigogine 1980, 9). According to this understanding of entropy, systems do not always move toward disorder, but this likelihood far outweighs the chances of a system obtaining greater degrees of organization.

Although predictive accuracy increased in physics as the result of Boltzmann's work, the universal application of his definition of entropy underwent heavy criticism (see Prigogine 1980, 156–67). First, the properties of an ideal gas are not collectively shared by all substances, and consequently his observations are not universally transposable and apply only to certain initial conditions. Second, no practical method exists to measure the location and trajectory of every molecule within a system, so Boltzmann's equation is not an exact dynamical approach and merely represents the probability of each possibility within a system. Third, his method does not provide a precise understanding of the microstates within a process, leaving room for discrepancies between macroscopic and microscopic entropy. Carl Helrich writes, "Claims that the second law is a statement regarding disorder in a system are based on Boltzmann's interpretation and are limited to gas systems at or near equilibrium. . . . No understanding of entropy can be formulated in terms of individual molecular states" (1999, 512). Accordingly, Boltzmann's calculations are subject to reversibility, meaning that they do not distinguish whether the systems are moving toward states of order or disorder. Both states of organization are measured as statistical probabilities and do not fall in line with the laws of thermodynamics, so Boltzmann's equation can provide only a "microscopic analogue of entropy" in relation to thermodynamics (Prigogine 1997, 20).[11]

However, the analogous relationship between these two understandings of entropy was not a dead end for scientific investigation. Boltzmann's work expanded the application of entropy beyond thermodynamics and allowed others to build upon his discoveries.

Among those who advanced Boltzmann's efforts was Josiah Willard Gibbs in his notion of ensembles. An ensemble is "a collection of systems having the same macroscopic (thermodynamic) properties" and "consists of those systems which cannot be distinguished from one another by any measurement" (Helrich 1999, 507). Whereas for Boltzmann entropy is based on probabilities of atomic or molecular configurations within a single system, Gibbs expresses entropy in terms of statistical probabilities for groups of identical systems.[12] Boltzmann's microscopic approach to entropy cannot resolve one's ignorance regarding the state of individual atomic particles or molecular structures, but Gibbs's macroscopic concept compensates by calculating an average over all the systems within the ensemble (Gibbs [1902] 1960, 206–7). Therefore, Gibbs's equation provides a more accurate understanding of how systems will likely develop toward increased entropy.[13]

Still, even for the Gibbsian formulation, entropy is defined in terms of a statistical function, and this understanding has become the most common application of entropy across academic disciplines. A. M. Andersen addresses this trend: "Statistical mechanics considers the behavior of large numbers of particles and has developed another view of entropy, completely independent of thermodynamics. . . . [Here] entropy is shown to be related to the probability of events occurring within a framework of possible events. . . . This has led to the use (and misuse) of the concept in almost every conceivable subject" (1996, 81). For this reason it is important to determine how an author employs the term, especially because it may inappropriately become convoluted with the laws of thermodynamics. When speaking about entropy in relation to statistical mechanics one must differentiate its meaning from its thermodynamic application and recognize their analogous relationship.[14] This is not to say that entropy in terms of disorderly states is not a scientific phenomenon; Boltzmann and Gibbs have demonstrated that it is. But the explanatory value of statistical equations of entropy far outweigh their limitations—hence their widespread application.[15]

Against this backdrop, I employ entropy as it functions in statistical mechanics—namely, to refer to the tendency for increasing disorder within a system.[16] This allows for a broader application of entropic phenomena. Thus entropy is not limited to one technical field, like thermodynamics, but can be applied to practically any system, including the universe as a whole.[17] Certainly this does not exclude thermodynamics, but it expands the possible types of systems addressed. When speaking about the nature of the universe, thermodynamic processes are only a fraction of the types of systems contained therein, and entropy in statistical mechanics provides a means of speaking about general disorder in the cosmos.

In sum, entropy generically describes how systems are more likely to move toward greater disorder. This explains why systems tend to wear out, corrode, and decrease in functionality. Entropy supplies the universe with an arrow of time, providing parameters in which processes typically operate. This feature of finite existence tends to limit the overall number of potentialities within the cosmos. Theoretically, the world may be free to develop on the microlevel, because quantum indeterminacy allows for myriad possibilities; on the macrolevel, however, the cosmos appears to be bound to the parameters established by entropy, explaining why life deteriorates, systems move toward disorganization, and nature decays.

VITALITY, ORDER, AND COMPLEXITY: AN EXAMINATION OF EMERGENCE THEORY

Despite the entropic arrow of time, pockets of complexity have managed to arise within nature. The history of the cosmos reveals a progressive emergence that began billions of years ago with the first building blocks of material and consequently the construction of hydrogen and helium atoms. Eventually, celestial objects, including stars and planets, were molded; single-celled organisms appeared on Earth; and complex life forms began to take shape. The arrival of consciousness within human beings marks the most intricate product of cosmic and biological evolution to date, but accounting for the development and evolution of the cosmos becomes problematic for science. Stuart Kauffman writes:

> It is not obvious, in fact, that the universe should be complex. One can imagine universes governed by general relativity that burst briefly into big bang being, then recollapse in a rapid big crunch within parts of a second or a century. Alternatively, one can imagine universes governed by general relativity that burst into big bang being and expanded forever with no further complexity than hydrogen and helium and smaller particles in an open and ever-expanding dark, cold vastness. . . . Why the universe is complex rather than simple is in fact, beginning to emerge as a legitimate question. (2000, 245)

Against probabilistic odds, complexity has refused to obey entropic limitations, generating a series of perceptible irregularities, and this complexification presents a paradox for scientific investigation.

Currently, science is working to develop satisfactory explanations of complexity. “This coming into existence of self-constructing ecosystems must, somehow, be physics. Thus, it is important that we have no theories for these issues in current physics. The stark fact that a biosphere builds up this astounding complexity and diversity suggests that our current physics is missing something fundamental” (Kauffman 2000, 82–83).[18] However, in the absence of scientific laws scholars have developed emergence theory in an attempt to express evolutionary and complexification features in philosophical terms. Theologian and philosopher Philip Clayton writes, “*emergence* is the philosophical position—more accurately, the philosophical elaboration of a series of scientific results—that best expresses the philosophical import of evolutionary theory” (2006, 1–2). More specifically, “Emergence is the view that new and unpredictable phenomena are naturally produced by interactions in nature; that these new structures, organisms, and ideas are not reducible to the subsystem on which they depend; and that the newly evolved realities in turn exercise a causal influence on the parts out of which they arose” (2006, vi). Clayton relies heavily upon Timothy O’Connor (1994, 97–98), who provides the following four criteria for determining the presence of emergent properties (P) resident within objects (O):

1. P supervenes on properties of the parts of O.
2. P is not had by any of the object’s parts.
3. P is distinct from any structural property of O.
4. P has direct (“downward”) determinative influence on the pattern of behavior involving O’s parts.

Essentially, the properties of systems often are greater than the sum of their parts; hence new ontological levels are generated as systems interact with their various constituents.

Many scholars are drawn to emergence because it provides a mediate position between the extremes of substance dualism and reductionist physicalism. Substance (or property) dualism, stemming from the philosophy of René Descartes, speculates that reality is composed of two primary substances. In the Cartesian system these are the *res cogitans* and *res extensa*, the thinking substance and the extended substance, but other forms of substance dualism include soul/body or spirit/body distinctions. It is posited that these two substances exist in a state of ontological differentiation in which they display a "distinct family of properties" (Kim 1993, 336). "The mind and the body are . . . mutually irreducible and logically distinct as subjects of predication: what can be predicated of the one cannot be predicated of the other" (Alanen 2003, 45). In other words, there are certain characteristics that are unique to mental substances, and physical substances display a completely different set of properties. Consequently, many dualists radicalize Descartes' thought and propose that a substance exterior to the physical realm is responsible for generating complexity within the cosmos. The physical substance is acted upon in such a way that it is drawn to move beyond the scope of its intrinsic properties and develop in ways that are outside the nature of the physical realm.

Emergence theorists and physical reductionists reject substance dualism because they claim that there is no satisfactory account to explain how causation would occur across the boundaries of opposing substances. Jaegwon Kim writes, "If you pick any physical event and trace out its causal ancestry or posterity, that will never take you outside the physical domain. That is, no causal chain will ever cross the boundary between the physical and the nonphysical. The interactionist dualism of Descartes is in clear contravention of this principle" (1998, 40). Elsewhere Kim notes, "Cartesianism implies that no scientific theory could hope to achieve coverage unless it encompassed both the physical and mental realms—unless, that is, we had a unified theory of both mental and physical phenomena" (1993, 337). For emergentists and physical reductionists, substance dualism cannot provide a satisfactory explanation that would bridge the gap between opposing substances, so the very notion of a dualistic ontology must be rejected at its very core. An alternative means to comprehend the ontological character of reality must be sought.

Contrarily, reductionist physicalists theorize that reality is composed of a single universal substance, and systems are typically explained in terms of upward causation, stemming from the subatomic level. Proponents of this view hypothesize that all things within the universe are composed of one fundamental particle manifest in countless configurations, and its discovery will provide science with the key to unlocking the mysteries of the cosmos. Moreover, all naturalistic phenomena can be ascribed to the functions of this basic building block of the universe, providing a grand unified theory. Here proponents move to a position that is diametrically opposed to substance dualism, but emergentists suppose that this may be overly optimistic in an attempt to correct dualistic shortcomings.

Emergentists would say that the manifestation of unique phenomena cannot be reduced to mere physics, but the very essence of reality consists of various ontological stages in which new characteristics emerge. These are not simply epistemological gaps within our scientific knowledge but are inherent features of how reality unfolds. Physics alone cannot account for the appearance of new properties or ontological levels within the cosmos, and emergentists point to phenomena like consciousness in order to substantiate their claims. Clayton, for example, proposes,

> In one sense [consciousness] is merely another in a very long series of steps that have characterized the evolutionary process. . . . But consciousness is not utterly unique; conscious phenomena also manifest important analogies to emergent realities at much earlier points in evolutionary history. In so far as it recognizes that consciousness is in one sense "just another emergent level", emergence theory is not dualism in disguise. (2006, vi)

In opposition to substance dualism, emergent levels are still "continuous" with preceding stages of development, yet they generate radically new properties (Clayton 2000, 645). The unfolding of the universe is a process in which present stages are dependent upon previous phases, but in response to physical reductionism they cannot be reduced to a single set of foundational laws. In other words, the totality of the system can precipitate top-down influences in which the whole of a system can affect its various components (Kauffman 2000, 129). Therefore, emergence theory does not ascribe primacy to either top-down or bottom-up causality, but both of these aspects must be recognized as fundamental to the ontological character of reality. Neither bottom-up causation nor substance differentiation alone can account for the nature of how systems develop and evolve.

If emergentists are correct in their assessments, this provides an important insight pertaining to entropic phenomena, because entropic calculations cannot account for the presence of emergence and complexity within the universe. As noted earlier, entropy is primarily a statistical equation that necessitates prestating all possible configurations of a system and calculating the probable outcome of each state, but emergence theory challenges the feasibility of using this method in predicting the future condition of the universe. However, according to Kauffman (2000, 143), the "adjacent possible," or all the potential directions that a system can take at any given time, is impossible to determine in advance. Some outcomes cannot be predicted a priori, thus making entropic calculations impotent in anticipating the emergence of new properties. "So the biosphere, it seems, in its persistent evolution, is doing something literally incalculable, nonalgorithmic, and outside our capacity to predict, not due to quantum uncertainty alone, nor deterministic chaos alone, but for a different, equally, or more profound reason: Emergence and persistent creativity in the physical universe is real" (Kauffman 2000, x). He adds, "I will argue that the very diversity and complexity of a biosphere begets its further diversification and complexification. I strongly suspect that the same is true of the universe as a whole. The universe's very diversity and complexity begets its further diversification and complexification" (2000, 82–83). Using the unpredictable outcomes of algorithms as suggestive evidence, Kauffman demonstrates the inability to make accurate predictions based on current understandings of systems and the laws by which they operate. This in turn is used as evidence supporting the veracity of emergent properties.[19]

According to Kauffman, the challenge of obtaining foreknowledge of emergent phenomena presents an epistemological gap for predicting evolution and complexity (2000, 134). This fissure results from incomplete knowledge of the regulations governing the universe, and consequently he suggests that there may be undiscovered scientific laws that direct the emergence of complexity. Although he admits that no one is sure about how emergence occurs, Kauffman suspects there may be a fourth law of thermodynamics.[20] "[It] seems reasonable to expect such laws and honorable to begin, even now, to seek them. At worst we will be wrong. Rather more stunningly, we may be right" (2000, 159). Kauffman represents those within the scientific community who subscribe to emergence, but ultimately he speculates that this theory will be vindicated through scientific laws that govern such phenomena.

We confront two problems here. First, as Kauffman points out, there is no scientific account for the emergence of complexity, so at this point any explanation is largely conjecture. Second, although emergence theory presents a feasible explanation, as Clayton says, it is a philosophical interpretation based on scientific observations; therefore it also does not fully present why or how these trends occur within the universe. Although Kauffman predicts the presence of scientific principles at work, he does maintain a fallibilistic attitude—recognizing that he could be wrong. Such caution invites perspectives from other disciplines that may provide key insights for understanding the evolutionary history of the natural world. This, in turn, may open the door to theological reflection. Considering what Kauffman says about the possible payoffs of exploring pioneering options, a theological look at entropy and emergence should—at the very least—be entertained.

THE PROLEPTIC WORK OF THE SPIRIT: A PENTECOSTAL APPROACH TO EMERGENCE AND ENTROPY

Even if Kauffman's prediction regarding a fourth law of thermodynamics is accurate, there is no guarantee that it could fully explain the development and evolution of the biosphere and the universe. It is quite possible that predictive ignorance stemming from the inability to prestate the initial boundaries of a system is not merely an epistemological gap but reflects an ontological characteristic of the universe. If this is the case, the universe not only operates on conditions of quantum uncertainty, but it also includes a level of macro-uncertainty. Further, the lack of an explanatory framework for the complexification of the cosmos may not simply be an epistemological gap in scientific knowledge; it may point to something of spiritual significance, and theology may be able to play an important role in understanding the dynamics at work in entropy and emergence. I contend that pentecostal theology may provide a unique perspective that can balance the tension between entropy and emergent systems because of its application of an experiential hermeneutic, pneumatological emphasis, and eschatological focus. In what follows I briefly examine these ideas.

Pentecostal hermeneutics is foundationally structured to incorporate an element of the experiential. It does not claim a purely subjective approach to the interpretive process, but it recognizes and invites interpreters to bring their experience to bear in their interpretation of texts and theological constructions.[21] John Christopher Thomas makes the case that a pentecostal hermeneutic is unique because not only is scripture used to illuminate experience, but experience also illuminates scripture (2000, 119–20). Reflecting on historical pentecostal hermeneutics, Kenneth J. Archer writes, "The Pentecostals said yes to both the authority of Scripture and the authority of experience. This put Scripture and lived experience into a creative dialectical tension. Pentecostalism's lived experience was coloring their understanding of Scripture and Scripture was shaping their lived experiences" ([2004] 2006, 63).

With this in mind, I suggest that a pentecostal hermeneutic is partially empirical in nature; therefore, a pentecostal perspective on natural phenomena need not be in opposition to scientific observations. Pentecostal theologian Amos Yong remarks, "The goal of theological interpretation, after all, includes within its orbit not only truth as pragmatic and utilitarian, but also truth as systematic coherence and dyadic correspondence between propositional and doctrinal content with the diverse arenas of knowledge, including the sciences" (2002, 305). In light of these features, pentecostal hermeneutics and theology should embrace scientific data, including phenomena such as entropy and emergent complexity, and use these observations to illuminate scripture and theology. This would allow for dynamic integration between science and theology that does not subordinate one discipline to the other, as both can contribute to a further understanding of reality.

Because a pentecostal hermeneutic allows for a dialectical relationship between theology and science, it is justified not only in engaging scientific perspectives on entropy and emergent systems but also in allowing science to inform theology. A pentecostal hermeneutic that incorporates experiential or empirical disciplines may open up alternative vistas for theology because it can accumulate and integrate a wider range of knowledge. Experience, in this case scientific observations, may illuminate doctrine, thus allowing for theological discourse that embraces a diversity of knowledge and that flourishes in arenas that are new to theological reflection.

Ideally, pentecostal scholarship not only makes room for a wide range of academic fields but also is hopeful in its ability to address and enlighten disciplines traditionally located beyond pentecostal concerns. Specifically, pentecostalism can offer a unique perspective on natural phenomena because of its pneumatological emphasis. Pentecostals typically have stressed the active role of the Spirit within the world, and developments in contemporary pneumatological theology have contributed to the formation of a more robust trinitarian theology. A pneumatologically informed theology of nature offers a fundamentally different approach to naturalistic reductionism and substance dualism, and I suggest that such a stance is compatible with emergence theory. In the midst of a universe bound by entropic parameters, the Spirit of God brings order out of chaos, energizes creation, and gives shape to new physical structures and dynamic forms of life.

Divine processes operate not only to initiate creation but also to sustain it (*creatio continua*). As a result, attention must be given to the interior work of God whereby the Spirit imbues creation with life and vitality. The animation bestowed upon creation comes through the activity of the Spirit, placing inherent value upon the cosmos and emphasizing the immanent dynamics of God who actively engages in ongoing creativity and evolution. This resurgence of pneumatological thought has invigorated discussions in theology of nature in which the Spirit is understood to act in all natural processes, directing them toward new potentialities and fullness of life. Denis Edwards provides a concise example:

> The history of the Spirit . . . is coextensive with the *total* life of the universe. God's Spirit has been breathing life into the processes of the evolving universe from the very first. The laws of nature and the initial conditions of the early universe exist only because of the empowering presence and action of the Creator Spirit. . . . It is this Breath of God who breathes fire into the equations and continues to breathe life into the exuberant, diverse, interrelated community of living things. (2006a, 33)

For Edwards the Spirit instills creation with life, animating existence and budding new activity. The creation of the cosmos, its continuance, and its future unfolding cannot be bifurcated from the movement of the Spirit. They are thoroughly entangled. It is impossible to grasp creation in all its wonder and splendor apart from God's Spirit. Pneumatology provides the lens through which one can interpret the meaning and history of creative processes in the world.

Edwards argues for a noninterventionist notion of divine action that operates within a Thomistic framework of secondary causes. Building upon

Karl Rahner, he posits that God must be embedded in the world through God's "self-communicating presence" (Edwards 2006b, 821).

> But this same transcendent Creator is radically interior to each creature in self-bestowing love. God is the very core of the world's reality, and the world is truly the fate of God. Creation is intrinsically directed toward self-bestowal. It is not simply that God creates something other but that God freely communicates God's own reality to the other. The universe emerges in the process of God's self-bestowal. . . . God enables creatures not only to exist, but also to transcend themselves, to become something new. (2006b, 824–25)

For Edwards the transcendent properties of creation are objectified within the resurrection of Jesus, the central event in history, which has been the interior goal of God's creative activity. Moreover, the Spirit has eternally operated within creation to spawn emergent phenomena that reflect the kenotic nature of God.

Edwards's proposal for divine action that is noninterventionist and eschatological adequately addresses the conflicting issues presented by entropy and emergence. Although some scientists are quick to point out that the appearance of decreased entropy is an illusion and that the overall state of the universe maintains its thrust toward disorder and decay, entropy is fundamentally a probabilistic law, and in some natural processes there may be an increase in order, leading to a decrease in total entropy. The probability may be extremely low, but negentropy cannot be disregarded as a possibility (Greene 2004, 156). Therefore room is left for the Spirit to work within the laws of physics or in accordance with the laws of nature, developing new and dynamic systems. The Spirit may direct entropic fluctuations within and across system boundaries to open up new potentialities within the cosmos, thus freeing pockets of creation from the fatal bonds of a deterministic destiny.

Jürgen Moltmann makes similar claims:

> The Spirit is the principle of creativity on all levels of matter and life. He creates new possibilities, and in these anticipates the new designs and "blueprints" for material and living organisms. In this sense the Spirit is the principle of evolution. . . . All created things are individuations of the community of creation and manifestations of the divine Spirit. (1993, 100–101)

Moltmann upholds the notion that God is not a distant entity that initiated the creative process and is now standing back to watch creation unfold; rather the immanent Spirit is continuously at work to reinvigorate, enliven, and vitalize creation. The Spirit God breathes new impulses into creation in spite of the entropic forces that threaten its demise.

Emergence does not need to be limited to the philosophical and scientific realms but, when coupled with pneumatological insights, can provide us with new ways of speaking about God's interaction with creation. The theologies of Edwards and Moltmann in particular offer a pneumatological perspective that makes room for emergence while responding to the threat of entropy. A number of pentecostal theologians have identified with significant aspects of Edwards's and Moltmann's theologies, and consequently pentecostals would be at home adopting this approach and furthering its implications.[22]

This leads, finally, to the claim that pentecostal theology allows for a unique perspective on the paradoxical nature of entropy and emergence because of the emphasis placed on eschatology. Emergence and entropy have significance for the future of the cosmos, and a pentecostal eschatological perspective may provide unique theological insights that can speak to these discussions. Pneumatological actions of emergence are not isolated events but have a rippling effect, metaphorically speaking, across the cosmic lake. The past is always active within the present, and the future is always conditionally present in the here and now. For pentecostal theology eschatology is always on the forefront of the constructive process whereby "that which is not yet" breaks into the present. Moltmann appropriately draws attention to the Spirit's eschatological action when he writes, "If the cosmic Spirit is the Spirit of God, the universe cannot be viewed as a closed system. It has to be understood as a system that is open—open for God and for his future" (1993, 103). Emergence, theologically speaking, is not only a present naturalistic occurrence but also an eschatological signpost pointing back to preceding divine action and forward to further divine action within the cosmos.

Yong addresses the issue of eschatological divine action in terms of Special Divine Action (SDA):

> Divine action "works" unlike material or efficient causes proceeding from the past toward the present, but proleptically or teleologically (to use Aristotelian terms) from the future. . . . The pneumatological logic I am advocating, however, would recognize SDA as charismatic actions of the Spirit that are proleptic anticipations of the world to come. Each case of SDA, more or less miraculous, would be signs of the new age that will be freed from the bondage of suffering and decay characteristic of a world under the effects of sin. (Yong forthcoming)[23]

Yong's case is enhanced even more when viewed in light of entropy and emergent systems. In this framework, not only can SDA can be viewed as proleptic eschatological events, but I propose that the phenomenon of emergence now also becomes a pointer to God's redeeming activity. The Spirit relentlessly operates within the world to generate pockets of organization out of disorder, not only begetting initial creation but also continuing to act within the cosmos, sustaining the natural order and giving rise to innovative and dynamical formation. The Eschaton becomes a transhistorical and transspatial cosmic event in which all of creation participates. The Spirit pervades creation, overcoming entropic constraints to infuse and increase the kingdom of God within the present. The world that groans for and anticipates rejuvenation (Romans 8:22) experiences local decreases in entropy as proleptic events of God's transformative actions and glimpses

God's eschatological response to the world's decay. This embraces and reinforces the pentecostal hope in a God who actively transforms the world.

Pentecostal theology may provide a perspective that furthers theology's engagement with the sciences, specifically concerning entropy and emergence. First, pentecostalism's experientially based hermeneutic provides a gateway for reciprocal interaction with the sciences whereby scientific insights are welcome to illuminate theological construction. Second, pentecostal emphases on pneumatology provide a valuable springboard from which we can talk about divine action within the world without violating firmly established scientific laws. Third, foundational aspects of pentecostal theology, such as eschatology, provide a new theological lens through which natural phenomena can be interpreted. Therefore, considering the current conversation regarding entropy and emergence, pentecostalism may be primed to offer dynamic insights that can advance—or at least perpetuate—dialogue between theology and science.

NOTES

A version of this essay was presented at the annual meeting of the Society for Pentecostal Studies (SPS) jointly held with the Wesleyan Theological Society at Duke University Divinity School, 13–15 March 2008.

1. These models are oversimplified and are not the only theories regarding the future state of the universe. The oscillatory model, or The Big Bounce, conflates these two theories, postulating that the universe is in a perpetual state of expansion and implosion (see Ellis, Murugan, and Tsagas 2004; Wang et al. 2004; Tolman 1987, 361–419; Câmara et al. 2007; Reddy, Rao, and Rao 2006; Debnath and Paul 2006; Xu, Liuy, and Zhang 2006; Khadekar and Patki 2005).

2. The other four aspects that define pentecostal thought as identified by Dayton are Christ as savior, sanctifier, baptizer with the Holy Spirit, and healer. While entropy and emergence may be approached from all of these theological aspects, I focus my attention on eschatology.

3. Theoretical work in the natural sciences also has used entropic principles in order to explain the behavior of biological systems, especially evolutionary characteristics. Although organisms are considered open systems because of the reciprocal energy exchange with the environment, they are closed systems in terms of information exchange encoded within the genetic material; therefore, this school of thought follows some of the same principles associated with information theory (Brooks and Wiley 1988, 35). According to Daniel Brooks and E. O. Wiley, "Instructional information is subject to the constraints of the second law in a manner similar to the way in which energy flow is subject to constraints. . . . Copy mistakes are . . . purely entropic phenomena in the flow of information since they represent a randomization process relative to the previous state of the system" (1988, 34). In statistical mechanics systems tend to move toward a greater degree of disorganization, and in a similar manner biological information develops increased complexity through genetic variations and copy mutations. Brooks and Wiley propose that this increase in entropy, or evolution, has led to greater complexity and the explosion in the number of species currently found on Earth. In this discipline entropy leads to greater complexity and reorganization in the genetic material or microstates which may enhance the overall condition of the macrosystem.

4. I do not provide here an overview of entropy in information theory. However, it should be noted that Ludwig Boltzmann's approach is significantly related to a condition of ignorance regarding the microstates of the system, and as a result it has found many applications in the realm of information theory (see Machta 1999).

5. Ilya Prigogine rejects an ontological relationship of entropy and information ignorance. For him entropy is related to irreversibility, and consequently it is not an epistemological gap in knowledge; rather it is an ontological characteristic of the forward direction of time within the

universe. In this section he is specifically addressing an assertion made by Murray Gell-Mann (1994, 219–20).

6. Clausius defined entropy (S) as the quotient of a transfer in heat (Q) divided by the temperature (T) of a controlled mass ($\delta S = \delta Q/T$).

7. The Clausius Inequality is represented by the mathematical equation $\delta Q/T \leq 0$. By definition a closed system may exchange energy, but not matter, beyond the borders of the system, whereas open system may exchange energy and matter. The mathematical representation for entropy in open systems is $\delta S = \delta_e S + \delta_i S$, $\delta_i S$ 0 where $\delta_e S$ represents the transfer of entropy across system boundaries and $\delta_i S$ expresses the change of entropy within a system (Prigogine 1980, 78).

8. Some attribute the "intellectual ancestry of the Second Law" to Sadi Carnot (Langton 2002, 450).

9. Basing his statement on Herbert B. Callen (1960), A. M. Andersen writes, "Entropy is a smoothly varying function of the other state variables and is an increasing function of the internal energy U" (Andersen 1996, 49).

10. The components of Boltzmann's relation ($S = k \log P$) consist of the Boltzmann constant (k) and a logarithm of the probability of molecular arrangements within a system (P). The Boltzmann constant is the ratio of the universal gas constant (R) to the Avogradro number (N_A). $k = 1.38066 X 10^{-23}$ J/K.

11. Attempting to correct Boltzmann's shortcomings, Josiah Willard Gibbs turned toward the use of ensembles, a collection of systems having the same macroscopic properties, whereby the experimental subjects cannot be distinguished from one another by any measurement of temperature, pressure, or number of molecules. This strategy of "population dynamics" provides a two-pronged advantage, allowing for the study of systems where initial conditions are known or where there may be multiple initial conditions possible (Prigogine 1980, 26).

12. Identical systems (an ensemble) are those that cannot be distinguished from one another on the basis of measurements of temperature, pressure, and number of particles.

13. $S_G(\rho) = -k \, f \rho \, (X) \, [\log(\rho(X)]) \, \delta X$. Defined for a microstate *X* of a macroscopic system (Lebowitz 1993, 32).

14. See note 16. Prigogine also has asserted an analogous rather than ontological relationship between entropy in thermodynamics and information theory.

15. Enhancing Boltzmann's approach, Gibbs also used statistical function to develop conclusions about systems, but instead of focusing on the molecules he examined the systems themselves, determining the average over all the systems to develop a probabilistic function. Gibbs's work greatly enhanced the ability to make more accurate predictions for a wider variety of systems (Helrich 1999, 506–7).

16. "Boltzmann was first to provide the statistical definition of entropy, linking the concept of entropy with the molecular disorder or chaos. Boltzmann entropy is the key to the foundation of statistical mechanics and is, in fact, the basis of all statistical concepts of entropy" (Chakrabarti and Chakrabarty 2006, 1471).

17. Despite its interdisciplinary application, entropy must always be spoken of in terms of systems (Helrich 2007, 108).

18. Kauffman adds, "A biosphere, or an econosphere, self-consistently co-constructs itself according to principles we do not yet fathom" (2000, 20). "While we have, it seems, adequate concepts of matter, energy, entropy, and information, we lack a coherent concept of organization, its emergence, and self-constructing propagation and self-elaboration" (2000, 104).

19. Kauffman references the work of Walter Fontana, whom he deems to be the inventor of "algorithmic chemistry," which uses a computer language known as "lisp" which employs lisp expressions that can operate on one another, thus generating new lisp expressions (Kauffman 2000, 121). See also Hofaker et al. 1994, 167–88.

20. Chapter 8 of *Investigations*, "Candidate Laws for the Coconstruction of a Biosphere," explores four assertions that may help explain how a biosphere is constructed.

21. I should note that there is no universal agreement on what constitutes a pentecostal hermeneutic. In fact, there is ongoing debate within pentecostal circles regarding whether a pentecostal hermeneutic is even necessary.

22. In fact, Moltmann was keynote speaker at the joint meeting of the Society for Pentecostal Studies and the Wesleyan Theological Society at Duke University, Durham, N.C., 13–15 March 2008.

23. Yong's essay was originally presented at the Science and Spirit Research Colloquium, Regent University, Virginia Beach, Virginia, 11 June 2007. George Murphy makes a similar claim (1991, 359–72), although he does not approach the issue from a pneumatological perspective.

REFERENCES

Alanen, Lilli. 2003. *Descartes' Concept of Mind.* Cambridge and London: Harvard Univ. Press.

Althouse, Peter. 2003. *Spirit of the Last Days: Pentecostal Eschatology in Conversation with Jürgen Moltmann*. Journal of Pentecostal Theology Supplemental Series 25. London and New York: T&T Clark International.

Andersen, A. M. 1996. *Thermodynamics of Natural Systems*. New York: John Wiley.

Archer, Kenneth J. [2004] 2006. *A Pentecostal Hermeneutic for the Twenty-First Century: Spirit, Scripture and Community*. Journal of Pentecostal Theology Supplemental Series 28. London and New York: T&T Clark International.

Brooks, Daniel R., and E. O. Wiley. 1988. *Evolution as Entropy: Toward a Unified Theory of Biology*. 2d ed. Chicago: Univ. of Chicago Press.

Callen, Herbert B. 1960. *Thermodynamics: An Introduction to the Physical Theories of Equilibrium Thermostatics and Irreversible Thermodynamics*. New York: Wiley.

Câmara, C. S., R. B. Nascimento, J. C. Carvalho, and M. R. De Garcia Maia. 2007. "Solutions of Cosmological Models with Varying Speed of Light." *International Journal of Modern Physics D* 16 (2–3): 433–37.

Chakrabarti, C. G., and I. Chakrabarty. 2006. "Boltzmann–Shannon Entropy: Generalization and Application." *Modern Physics Letters B* 20 (23): 1471–79.

Clausius, Rudolf. 1879. *The Mechanical Theory of Heat.* Trans. Walter R. Browne. London: Macmillan.

Clayton, Philip. 2000. "Neuroscience, the Person, and God: An Emergentist Account." *Zygon: Journal of Religion and Science* 35:613–52.

———. 2006. *Mind and Emergence: From Quantum to Consciousness*. Oxford and New York: Oxford Univ. Press.

Dayton, Donald W. 1987. *Theological Roots of Pentecostalism*. Metuchen, N.J.: Scarecrow.

Debnath, P. S., and B. C. Paul. 2006. "Cosmological Models with Variable Gravitational and Cosmological Constants in R^2 Gravity." *International Journal of Modern Physics D* 15 (2): 189–98.

Edwards, Denis. 2006a. *Breath of Life: A Theology of the Creator Spirit*. Maryknoll, N.Y.: Orbis Books.

———. 2006b. "Resurrection and the Costs of Evolution: A Dialogue with Rahner on Noninterventionalist Theology." *Theological Studies* 67 (December): 816–33.

Ellis, George F. R., Jeff Murugan, and Christos G. Tsagas. 2004. "The Emergent Universe: An Explicit Construction." *Classical and Quantum Gravity* 21:233–49.

Fast, F. D. 1962. *Entropy: The Significance of the Concept of Entropy and Its Applications in Science and Technology*. New York: McGraw-Hill.

Gell-Mann, Murray. 1994. *The Quark and the Jaguar: Adventures in the Simple and the Complex.* New York: W. H. Freeman.

Gibbs, J. Willard. [1902] 1960. *Elementary Principles in Statistical Mechanics Developed with Special Reference to the Rational Foundation of Thermodynamics*. New York: Dover.

Greene, Brian. 2004. *The Fabric of the Cosmos: Space, Time, and the Texture of Reality.* New York: A. A. Knopf.

Helrich, Carl S. 1999. "Thermodynamics: What One Needs to Know." *Zygon: Journal of Religion and Science* 34:501–14.

———. 2007. "Is There a Basis for Teleology in Physics?" *Zygon: Journal of Religion and Science* 42:97–110.

Hofaker, Ivo L., Walter Fontana, Peter F. Stadler, L. Sebastian Bonhoeffer, Manfred Tacker, and Peter Schuster. 1994. "Fast Folding and Comparison of RNA Secondary Structures." *Monatshefte für Chemie (Chemical Monthly)* 125:167–88.

Kauffman, Stuart A. 2000. *Investigations*. Oxford: Oxford Univ. Press.

Kim, Jaegwon. 1993. *Supervenience and Mind: Selected Philosophical Essays*. New York: Cambridge Univ. Press.

———. 1998. *Mind in a Physical World: An Essay on the Mind-Body Problem and Mental Causation*. Cambridge: MIT Press.

Khadekar, G. S., and Vrishali Patki. 2005. "String Dust Cosmological Model in Higher-Dimensional Space Time." *International Journal of Modern Physics D* 14 (9): 1621–34.

Kockelmans, Joseph J. 1999. "Ludwig Boltzmann: Introduction." In *Philosophy of Science: The Historical Background*, ed. Joseph J. Kockelmans, 243–45. New Brunswick and London: Transaction Publishers.

Langton, Stacy G. 2002. "What Did Carnot Say about the Second Law?" *AIP Conference Proceedings* 643 (1): 448–51.

Lebowitz, Joel L. 1993. "Boltzmann's Entropy and Time's Arrow." *Physics Today* 46 (September): 32–38.

Machta, J. 1999. "Entropy, Information, and Computation." *American Journal of Physics* 67 (December): 1074–77.

Moltmann, Jürgen. 1993. *God in Creation: A New Theology of Creation and the Spirit of God.* Minneapolis: Fortress.

Murphy, George L. 1991. "Time, Thermodynamics, and Theology." *Zygon: Journal of Religion and Science* 26:359–72.

O'Connor, Timothy. 1994. "Emergent Properties." *American Philosophical Quarterly* 31 (April): 91–104.

Prigogine, Ilya. 1980. *From Being to Becoming: Time and Complexity in the Physical Sciences.* San Francisco: W. H. Freeman.

———. 1997. *The End of Certainty: Time, Chaos, and the New Laws of Nature*. New York: Free Press.

Reddy, D. R. K., M. V. Subba Rao, and G. Koteswara Rao. 2006. "A Cosmological Model with Negative Constant Deceleration Parameter in a Scalar-Tensor Theory." *Astrophysics and Space Science* 306:171–74.

Thomas, John Christopher. 2000. "Reading the Bible from within Our Traditions: A Pentecostal Hermeneutic as Test Case." In *Between Two Horizons: Spanning New Testament Studies and Systematic Theology*, ed. Joel Green and Max Turner, 108–22. Grand Rapids, Mich.: Eerdmans.

Tolman, Richard C. 1987. *Relativity, Thermodynamics, and Cosmology*. New York: Dover.

Wang, Yun, Jan Michael Kratochvil, Andrei Linde, and Marina Shmakova. 2004. "Current Observational Constraints on Cosmic Doomsday." *Journal of Cosmology and Astroparticle Physics* 12 (December): 006.

Wilson, A. H. 1960. *Thermodynamics and Statistical Mechanics.* Cambridge: Cambridge Univ. Press.

Xu, Li Xin, Hong Ya Liuy, and Cheng Wu Zhang. 2006. "Reconstruction of 5D Cosmological Models from the Equation of State of Dark Energy." *International Journal of Modern Physics* 15 (2): 215–24.

Yong, Amos. 2002. *Spirit-Word-Community: Theological Hermeneutics in Trinitarian Perspective*. Eugene, Ore.: Wipf & Stock.

———. Forthcoming. "The Spirit at Work in the World: A Pentecostal-Charismatic Perspective on the Divine Action Project." *Theology & Science*.