ENTROPY AND EVIL

by Robert John Russell

Abstract. This paper explores a possible relationship between entropy and evil in terms of metaphor. After presenting the various meanings of entropy in classical thermodynamics and statical mechanics, and the Augustinian and Irenaean theodicies, several similarities and dissimilarities between entropy and evil are described. Underlying the concepts of evil and entropy is the assumption that time has a direction. After examining the scientific basis for this assumption, it is hypothesized that, if evil is real in nature, entropy is what one would expect to find at the level of physical processes, and conversely that, if entropy is coupled to a physical arrow of time, one could expect to find dissipative yet catalytic processes in history and religious experience.

The power of evil is tragically self-evident. The significance of the second law of thermodynamics extends throughout science. Is there any substantive relationship between entropy and evil? Before responding to this question, one must first acknowledge the methodological problems introduced by the very nature of a field as inhomogeneous as religion and science.

Faced with similar procedural questions, others have compared scientific and religious theories in terms of a hierarchy of levels of theories (Schilling 1973; Peacocke 1979), a relationship of consonance of concepts (McMullin 1981), a sharing of metaphors and models (Barbour 1971, 1974; McFague 1982), or a formal correspondence as communities characterized by paradigms and research programs (Barbour 1971, 1974; Kung 1982; Murphy 1983). In this essay, I have

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chosen to frame the discussion in terms of *metaphor*, defined as an analogy between the normal context in which a word obtains its meaning and a novel context in which some new aspects of the concept are emphasized. As Paul Ricoeur and others stress, metaphors are more than mere similes, since they include a negative as well as a positive analogy: both an "is" and an "is not." According to Ian Barbour, a metaphor is extendable to other new contexts, beckoning us with a "suggestive invitation to the discovery of further similarities" (Barbour 1974, 14). I would add that metaphors ought to draw on concepts which have some independent justification in each field and should produce some new insight about the novel context in which they operate.

With this notion of metaphor as my working methodological assumption, this essay will be something of an initial survey, a reconnaissance project looking for general areas for future inquiry. I will begin with an overview of the physics of entropy, restricted primarily to classical thermodynamics, and the theological interpretation of evil as found within representative periods of the Christian tradition. Then I will explore similarities and dissimilarities in the proposed metaphorical relationship between evil and entropy.

Two Conflicting Cosmologies in Physics

Dynamics versus thermodynamics. Seventeenth-century Newtonian dynamics viewed the material world in terms of absolute space, absolute time, strict causality, and temporal reversibility. All material processes were reduced to matter-in-motion through strictly reversible mechanical and gravitational interactions. Whether one considers a ball rolling along a plane, a planet revolving elliptically about the sun, a swinging pendulum, or a spinning top, these processes are such that they could occur "backwards" without violating the laws of dynamics. More accurately, one should say that the laws of dynamics cannot provide any parameter by which to distinguish physically allowable states of affairs from those in which cause and effect are reversed. Alternatively, the form of the dynamic equations is preserved if for time t one substitutes $-t$. Past and future are reciprocally deterministic. Many philosophers have objected to the implications of dynamics concerning the reality of the passage of time and the actuality of the future, but Newtonian physics has remained a formidable opponent to an opposing scientific treatment of time.

Nevertheless, the nineteenth century was an age in which *time's direction* took on a fresh meaning via classical thermodynamics. Although space and time remained absolute in the strict sense, temporal irreversibility became the central characteristic of the physical processes studied. Examples of such irreversible processes include the

diffusion of an aroma from the kitchen throughout the house, a dark ink staining a clear liquid, mixing paint in a pail, ice melting in the sun, a roaring waterfall giving off clouds of spray and mist, ice cracking, mechanical gears heating, hot air rising. Such a world is marked by a radical, undeniable difference between past and future, by a statistical quality to its predictions, and by arbitrariness and contingency. A system is characterized by more than its present state; the path taken also counts, the process is part of the product. How fast ice forms contributes to its structure and fractures; the loudness of a waterfall depends on how steep the drop, not just the height from top to bottom. This world is one where nature is inherently historical, where matter at even the inanimate level displays an indelible sense of evolution. In this world the future state cannot be predicted in detail from the present, even with the governing equations. The character of the present is dependent on the path from the past: although "all roads lead to Rome," the actual journey influences the quality of arrival. It is a world in fluctuation, filled with novelty.

Yet it is a world of dissipation, decay, and destruction. In this world time has an arrow and a claw, and the talons of time lacerate lived experience with a breaking of symmetry, a fracturing of structure, a loss of an irretrievable past, and a staining of the present with the marks of its birth through successive passage and epiphanies.

In Isaac Newton's world the future is always a version of the past; such a world seems irreconcilable with our experience of time's arrow and the inactuality of the future. In thermodynamics, as time passes the world changes irreversibly; nothing can be done to ever quite recover the way things were, and nothing can be done to condition entirely the way things will be next.

Entropy as a measure of available energy. Thermodynamics, the study of energy transformations, originated with the study of the bulk properties of matter such as pressure, volume, and temperature. Newtonian dynamics had already provided a framework for the mechanical interpretation of material processes, centered around the definition of work as the result of forces causing a body to move through a distance. Mechanical energy is the ability to do work: to lift a rock, accelerate an arrow, move the planets in their orbits. Central to mechanics was the law of energy conservation: in all mechanical processes the total energy of a closed system is constant, although it might be changed from potential energy to kinetic energy. Thermodynamics was related consistently to mechanics by treating heat as a form of energy. Energy conservation then included the transformation of mechanical energy into heat. For example, as we rub our hands together on a cold day, friction transforms mechanical energy into heat.

It is useful to define the state of *thermodynamic equilibrium* as one in which the macroscopic properties of the system do not change in time, for example, gas in an insulated bottle or water in a closed container. All parts of such a system and its environment must be at the same temperature, T. If external forces are applied to the system, such as a change in volume or pressure, or if heat is applied, the system will change until a new state of equilibrium is attained. If these forces are sudden and sharp, the system will change wildly and imprecisely, like bursting a balloon or tossing grease on a hot skillet. If gradual forces are applied, changes in the system will proceed slowly, even imperceptibly, like simmering a meal over a slow fire. If a system evolves smoothly from one state of equilibrium to the next, then in principle the process could be reversed, returning the system to its original state without incurring other net effects. For example, a piece of ice could melt so gradually that, if the air temperature began to cool, it might refreeze to nearly its original shape. Reversible processes are also the only ones for which a precise description is possible, since they are limited to states of thermodynamic equilibrium and it is only for such states that the bulk parameters are well defined.

However, in nature such reversibility is an ideal and limiting case of actual processes which often involve abrupt, even catastrophic changes that drive the system far from equilibrium. Like surf breaking on the beach, the cracking of an iceberg, the diffusion of an aroma, the melting of snow, or the fermenting of sugar, they cannot be undone by somehow merely reversing the environmental factors. There will always be some other effect in the total system. Just as the concept of energy served to limit the kinds of processes which are allowable in principle, so the concept of entropy fixes the direction in which actual processes tend to go. Hence, although energy would be conserved whether an aroma diffused out from its source or, somehow, back to it from throughout the environment, entropy would increase in the former but decrease in the latter.

In general, then, entropy and the irreversibility which we expect of most physical processes are fundamentally linked, as expressed by the second law of thermodynamics: The entropy of an isolated system remains constant during a reversible process or increases during an irreversible process; the entropy of a system interacting with its environment can decrease only if the entropy of the system and its environment remains constant or shows a net increase. Hence the second law of thermodynamics tells us that all natural processes take place in such a way as to increase the entropy of the whole, that is, the system plus its environment.

The second law was given various formulations by Rudolph Clausius, Lord Kelvin, and Sadi Carnot. Studying the conversion of

mechanical energy to heat, they found that in each case mechanical energy which would otherwise have been available for useful work was lost to heat. For example, friction drains the usable kinetic energy of a moving cart, turning it into heat. Hence the increase of entropy in irreversible processes was initially understood in terms of the loss of energy available for mechanical work. We say that systems run down, that entropy measures the dissipation of energy, the degrading of the environment, the irreversible conversion of work into heat.

Entropy as a measure of disorder. In the kinetic theory of gases, the bulk properties of gas are related statistically to the random motion of an enormous number N of gas molecules. Precisely because of the extraordinary size of N (typically a million billion billion molecules), statistics apply extremely well, and the molecular ensemble can be characterized by a few variables. For example, pressure is associated with collisions of the gas molecules with the container's walls; temperature is related to the kinetic energy of the molecules. How is entropy, defined macroscopically, that is, as a "state variable," related to the microscopic events underlying bulk phenomena?

Suppose we have a container with two compartments, A and B, separated by a partition, and image that there are two balls in compartment A. Clearly this is a unique state for the system of container and balls. If we remove the partition and shake the container, each ball could be in either A or B, or both in either A or B. The number of possible states of the system has therefore increased fourfold. In addition, note that this process is irreversible: merely by replacing the partition we will not ordinarily find both balls in their original state in compartment A. The second law of thermodynamics tells us that the entropy of this system has increased during this process. Since the number of states of the system has also increased (fourfold), we might try identifying entropy with the number of states of the system. Such an idea was proposed by Ludwig Boltzmann in the late nineteenth century, and it turned out to work with enormous success. It provided a bridge between statistical mechanics and classical thermodynamics by giving analytic precision to the conceptual correlation of macroscopic and microscopic description.

In addition, statistical mechanics suggests a probabilistic interpretation of entropy which accounts for the sense that systems evolve irreversibly in time even though their underlying mechanical interactions are time invariant. We may equate the number of equivalent microscopic states of a system with a measure of the probability that the macroscopic state will occur which corresponds to it. Suppose, for example, that in the previous example there had been ten balls. Al-

though there would still be only one way in which all the balls were in compartment *A*, there would be many ways to arrange the balls and still have, say, five balls in each compartment. Hence we would say that it is much more likely to find five balls in each compartment than all ten balls in compartment *A*. Notice too that, if we started with all the balls in compartment *A* and then shook up the container, as time proceeded, ordinary mechanical, time-reversible processes between the balls (bouncing off each other or the walls of the container) would tend to distribute them evenly between the compartments. It would be a long wait indeed before they would all happen to be back again in compartment *A*! We may legitimately say that the initial state is well ordered and the later states are disordered. Hence entropy can be considered as a measure of the disorder of the system, or as a parameter linked to the probability of finding the system in a particular state. Here an increase in entropy is equivalent to an increase in the disorder of a system, or an increase in the likelihood of finding that state over the previous ones.

Christian Thought Concerning Evil

Although the presence of evil seems unassailable, witnessed by the atrocity of our species to its own kind and to nonhuman nature, no universally accepted definition of evil exists. Each value system or world view defines what it considers to be the good; the thwarting of this good is usually defined to be "moral" or "intrinsic" evil. For a Stoic evil is unreason, for a hedonist it is pain. For a Utilitarian it lies in the denying of the greatest good to the greatest number, while for a theist evil occurs as opposition to the will of God.

Evil can be taken to pertain only to human behavior as discussed in moral theology, or its presence can be extended into the natural dimensions of the world, in earthquakes, plagues, lightning, hurricanes, and the relentless struggle of predator over prey. In the past, natural events in the world were usually taken as morally neutral, neither good nor evil in themselves, but combined with human moral choice they could become occasions of natural or "extrinsic" evil. Yet might there be a more deeply engrained connection between the evils common to our species and the whole of nature? It is certainly part of the program I envision for relating religion and science that we ask just such a question.

Before exploring this further, however, we must recognize that in asserting the reality of evil a critical paradox is forced onto traditional Christian theism. Often called "theodicy" from the Greek words for God (*theos*) and justice (*dikaia*), the theist's fundamental concern is to understand how the reality of evil in the world does not force us to abandon belief in the biblical God. The locus classicus of this issue is to

be found in the threefold paradox attributed to Epicurus: How can one believe in a powerful and good God if evil is real? Alternatively, how can a loving God permit human suffering which through God's power could be avoided?

Christian theology has struggled perenially with this problem, seeking neither to deny the reality of evil (as in monism) nor to assert the ultimacy of evil (as in dualism)—either of which would resolve the Epicurian paradox at the cost of abandoning fundamental biblical faith. In a deep sense, the history of Christian thought from the apostle Paul to the present represents a profound wrestling with this single, central paradox of evil. Moreover, from the Genesis saga of the creation of the world, where God is pictured as brooding over the waters of chaos, to Calvary, where the forces of betrayal and abuse reach a pinnacle of expression in a wooden cross and rusted nails, evil as moral sin and evil as natural decay have seemed intimately joined.

The responses by Christian theologians to the problem of evil have varied strikingly across the centuries, so much so that it would take an extended essay to introduce them with real precision. Still, as John Hick (1966) has suggested, these responses can be grouped in terms of two basic points of view, rooted in the theologies of Augustine and Irenaeus. Here are the two parts of Hick's argument.[1]

Evil as the privation of good. According to Augustine, being as such is good since it reflects the goodness of the divine Creator. However, as it was made from nothing, being is mutable and hence capable of being corrupted. The primary agent of corruption is our free will, the cause of human suffering. In Augustine's view, evil is the corruption of natural form. Having no independent reality or material content, evil is like a brokenness in the nature of things, an abuse of the full being of each created thing, and a self-destructiveness caused by a corrupt free will. Evil is therefore to be found both in the human realm and in nature. In a similar vein, Thomas Aquinas identified evil with a defect which deprives things of their full potential. Although free will is an essential part of the goodness of God's creation, it too is defective, the defect being moral evil.

In Protestant thought, doctrines such as John Calvin's divine predestination and Karl Barth's emphasis on God's sovereignty over evil through the divine "No!" underscore the restrictions laid on the power of evil to work against the will of God. Paul Tillich affirmed the basic goodness of finitude, of freedom, and hence of finite freedom. It is only through the abuse of such freedom that sin, or existential estrangement, arises. Existence is thus a broken form of being, estranged from and contradicting its essential structure, and the human person is

a particularly fragmented and self-contradicting creature. Yet for Tillich, too, such fragmentation is not brought about by an external agent, "but it is the consequence of the structure of estrangement itself," or as he called it, the "structure of destruction" (Tillich 1957, 2:60).

Evil as developmental obstruction. In the theodicy of Irenaeus we find the roots of a second, and earlier, tradition.[2] Irenaeus distinguished between the *image* and the *likeness* of God in humankind. Although it is basic to human nature to express the divine image in the form of moral freedom and responsibility, this is only part of our inheritance from God. Through spiritual growth and struggle we have the possibility of maturing into the full manifestation of our relationship to God and of ultimately taking on a genuine likeness to God. In this view, evil is a stumbling block to our spiritual progress, an obstruction to our development into full spiritual maturity. Clement of Alexandria (died c. 220) wrote that we were "adapted to receive virtue." Although our nature may be disordered, this weakness is only a childlike immaturity which can be overcome by the Spirit. Perfection lies in the future, not in the broken past.

In nineteenth-century Protestant thought, Friedrich Schleiermacher took up this same insight by stressing that the purpose of God should come about through the human species, in which world-consciousness and God-consciousness can at last coexist and develop together. According to Scheiermacher, human perfection is rooted in human nature since this is where God-consciousness is both possible and actual, as we experience it in moments of pain and ecstacy. Perfection no longer means something found only in the distant past; it is a characteristic that is ever present and evolving toward greater realization. Sin is a preoccupation with the world, and it occurs as an obstruction in the otherwise smooth development of God-consciousness. Though granting that "sin is unnecessary but inevitable," our personal responsibility for sin is in no way diminished (Schleiermacher 1928, par. 68, 3). Moreover, personal and community responsibilities for sin are blended in a suggestive way: "Sin is, in each, the work of all, and in all, the work of each" (Schleiermacher 1928, par. 71, 2).

Pierre Teilhard de Chardin has continued in this tradition, though with occasional reference to an original perfection and the Fall. Teilhard stressed the evolution of Homo sapiens from other primate species, and hence saw evil (both moral and natural) as an inevitable experience in the growth and spiritual maturing of people. We are creatures, he wrotes, "who already exist, but are not yet complete." Thus we move toward a supremely good future, characterized by the emergence of a new global humanity and a final unity in the Omega point (Teilhard de Chardin 1960, 64).[3]

Evil and Entropy: A First Look

Clearly the concepts of evil and entropy present, at face value, several similarities, suggesting for our working metaphor that entropy is a prefiguring of evil on the physical level. After briefly describing three of these similarities in this section, I wish to examine in the following section ways in which the metaphor produces new insights about both evil and entropy. Hopefully these observations will lend some justification for mixing the language of two separate fields of inquiry by showing the heuristic value of the metaphor.

First, throughout the history of theology the dominating instinct has been that God creates order out of disorder, ruling and overruling chaos, building up a world of harmony and a community of covenant. Whether cast in classical or modern metaphysics, God creates all that is through processes aimed at a dynamic peace. Evil is likened to a disorder, a disfunction in an organism, an obstruction to growth or an imperfection in being. Entropy refers to such disorder, measuring the dissipation of a system, the fracturing of a whole. In religious language, sin is universal and it inevitably leads to despair, war, and death. Even though we grow in our relationship with God and each other, evil thwarts us. Similarly, our wasted energy scars our world and pollutes our environment. More generally, we need only to think of the pain and cost of natural disasters like famines, hurricanes, earthquakes, lightning, tornadoes, accidents of all kinds, or of plagues and diseases, to recognize the extent of suffering in this world. All these are rooted in the press of entropy, the relentless disintegration of form, environment, organism; all are an affront to hope and peace.

In a primal sense, entropy gives to time its "talons." Time passes, and in time we do what we should not do while we leave undone those things we should do. In time entropy increases, fires burn low, and night encrouches upon our momentary shining day. Our bodies age and die, and even the universe cools. How can the future be filled with hope in an inexorably dissipating cosmos? Perhaps a very distant future in a recontracting universe would allow some margin of promise, but the characteristic of this present age seems one of remorseless unwinding.

In an Augustinian sense nature is marred by chaos and destruction; in an Irenaean sense the hope for a better future must do battle with the drain of usable energy. It is as though an overall increasing degree of chaos in nature is a global characteristic of the universe—from beginning to end.

Second, both evil and disorder are dependent on being, lacking independent existence. Is it the razor-sharp edge or the steel of the knife that cuts? Is it the vitality or the disorganization of cells reproduc-

ing without bounds that gives cancer its deadly power? In the language of Tillich, evil "has no independent standing in the whole of reality, but . . . it is dependent on the structure of that in and upon which it acts destructively" (Tillich 1957, 2:60).

Like evil, entropy is a function of the processes of nature, not an autonomous entity in nature. As in theodicy, entropy is parasitic to natural processes, not a participant in those processes. Moreover, entropy represents an inevitable limitation on the varieties of processes which could occur according to the laws of physics, and as such it measures the distance of actual processes from their ideal. In Augustinian theodicy evil arises as the mark of brokenness of being, while in Irenaean theodicy the processes of spiritual growth are characterized by regress and diversion, the power of sin.

Third, in thermodynamics entropy represents a function which never decreases in closed systems. In systems contained as subsystems in larger ones it can decrease in the subsystem, but the entropy of the system as a whole must not decrease. Cast in religious language, we would expect to find an inevitable increase in the power of evil in communities that cut themselves off from the needs of the rest of humanity and the challenge of global pluralism, or among those who view the human species as fundamentally separate from the rest of nature. Of course, if we press the metaphor we would expect that any closed community could contain additional internal communities which could evolve toward virtue and blessedness, but at the cost of the inclusive system. In a broader sense, if applied to our planet even with all of its species, we are still isolated, at least culturally, from the rest of the universe. Perhaps only if we venture out into the universe to other worlds will we find temporary release from the inevitability of the second law at the personal and cultural level.

Entropy and Evil: A Closer Look

We have listed some parallels between evil and entropy which suggest as our metaphor that entropy prefigures evil on the physical level. In order to test the fruitfulness of this metaphor and to show how this kind of interaction between science and theology can have more than poetic interest, we must see whether we can use the metaphor to suggest new avenues of thought in both theology and physics. I will briefly discuss three possibilities.

First, along with its functioning power, the *form* of evil is a central aspect in theology. Tillich, for example, discusses the form of evil in terms of the "structure of destruction," suggesting that evil contains within it an order, which, though destructive, embodies a remorselessness and a directionality: "Even destruction has structures. It 'aims' at

chaos, but as long as chaos is not attained, destruction must follow the structures of wholeness; and if chaos is attained, both structure and destruction have vanished" (Tillich 1957, 2:60).

Tillich leaves this metaphor tantalizing before us, without pursuing the details of this structure. Yet the fact that he refers to it is significant in itself. In classical statistical models of entropy one finds the familiar "bell-curve" form (the Gaussian distribution function) as the mathematical structure of chaos. This form acts as an identifying signature of randomness. Thermal equilibrium, the physical paradigm of a system in a state of maximum entropy, is precisely one whose states are governed by a Gaussian distribution function. The mathematical structure of entropy could suggest something about the specific form Tillich's "structure of destruction" might take and, thus, in turn open Tillich's metaphor for evil to further interpretation and extension. The detailed dynamics of systems approaching thermal equilibrium could magnify Tillich's suggestion of the "aim" of chaotic behavior. Finally, if modern thermodynamics is brought into the discussion, new mathematical structures occur which drive our theological inquiry about disorder into areas still to be explored.

Second, the cost of life in terms of entropy extends our metaphor into the context of biology. How can living organisms survive given the inexorable dissipation and disordering of a closed system? Clearly, as pointed out by Erwin Schroedinger (1956) and others, biological organisms are open systems, exchanging energy and matter with their environment. Hence living things develop themselves as local centers of order by causing greater disorder in their environment, and hence a net increase in disorder of the organism plus environment. Life flourishes in spite of the overall increase of entropy—but at a cost to the environment and, ultimately, to itself. In this sense the coupling of individual life to the ecological whole presses home with new significance Schleiermacher's characterization of sin as "in each the work of all and in all the work of each."

Third, continuing to explore the cost of living systems in terms of entropy we come upon another instance of the dark side of existence. This forboding dimension of life seems to me to be underestimated in religion, where life is generally of supreme value as a gift of, even a form of, the living God. In this century, the work of Henri Bergson, Samuel Alexander, Teilhard de Chardin, Jurgen Moltmann, Peacocke, Barbour, Charles Birch and John Cobb, and numerous others underscores the theological significance of evolution. Although they express quite different interpretations of the relationship between God and the world, the writings of these men have in common an underemphasis on the *cost* of life and evolution. Yet it is here that entropy and evil seem to conspire on a grand scale.

In a recent book, Jeremy Rifkin writes:

> We are so used to thinking of biological evolution in terms of progress. Now we find that each higher species in the evolutionary chain transforms greater amounts of energy from a usable to an unusable state. In the process of evolution, each succeeding species is more complex and thus better equipped as a transformer of avilable energy. What is really difficult to accept, however, is the realization that the higher the species in the chain, the greater the energy flow-through and the greater the disorder created in the overall environment. The Entropy Law says that evolution dissipates the overall available energy for life on this planet. Our concept of evolution is the exact opposite. We believe that evolution somehow magically creates greater overall value and order on earth (Rifkin 1981, 55).

The Irenaean view of evil as a hindrance to growth returns now to signify the role of entropy in evolution and civilization, while the Augustinian insight underscores the brokenness of existence as our modes of interdependence—food, clothing, warmth, work—cost more than they yield. What could be a more appropriate interpretation of the communal cost and responsibility of sin, and the power of sin to grow and extract as its wages, death? Not only individual life, but evolution itself, is like a plague devouring the order of the world; and humankind through its complicated civilization is the most insatiable consumer of all. I would extend Rifkin's comment to a cosmic scale. Stars radiate light energy at a vast cost in entropy. Stars produce heavy elements via nucleosynthesis, then explode to fertilize the interstellar regions with these life-giving elements—all the while entropy counts the cost. Even the universe in its global expansion seems to grow at the expense of greater entropy.[4]

In a striking passage in his Pulitzer prize-winning book, *The Denial of Death*, Ernest Becker forces the point Rifkin and others are making about life:

> What are we to make of a creation in which the routine activity is for organisms to be tearing others apart with teeth of all types—biting, grinding flesh, plant stalks, bones between molars, pushing the pulp greedily down the gullet with delight, incorporating its essence into one's own organization, and then excreting with foul stench and gasses the residue. Everyone reaching out to incorporate others who are edible to him.... Creation is a nightmare spectacular taking place on a planet that has been soaked for hundreds of millions of years in the blood of all its creatures.... Science and religion merge in a critique of the deadening of perception of this kind of truth, and science betrays us when it is willing to absorb lived truth all into itself (Becker 1973, 282-83).

All of Becker's examples hinge on the relentless and universal second law. Life is suddenly dethroned from its pedestal of value. How would theology respond to this massive gestalt switch?

One place to begin would be with Teilhard de Chardin in whose writings the power of God is interpreted as working throughout nature in terms of the "within" of things.[5] Entropy now seems to me to emerge

as a forboding symbol connected with this within. For Teilhard, radial energy works to center, structure, and develop the within of things from the atom to the human, bringing matter to life and mind and finally to Christ as Omega. I would propose that we add a new metaphor to that of Teilhard's, namely of a "radial entropy" which measures the consuming of our center, the dissipation of our structure, and the paying of wages to the insatiable foe. Entropy in this metaphor is the natural basis for evil, the prerequisite for personal sin—even as physical indeterminacy is, arguably, the prerequisite for human freedom. It is the enemy within, the sword hidden in the wings of the angel, turning us constantly back from a lost paradise to the world of war and ashes.

Dissimilarities in the Metaphor: The Value of Entropy

The essential tension of a creative metaphor arises from the dual affirmation of similarity and dissimilarity. Having looked for some correspondence between evil and entropy, we now begin with several reasons which suggest that entropy is instead a component of growth and change, providing the basis by which the development of new orderliness occurs, and that it is a part of the *goodness* of creation.

First of all, many of life's most valuable moments—those of genuine excitement, awe, a quickening sense of numinous mystery, the rustlings of the divine presence in one's deepest self-understanding—come during moments of radical change in life situation. One's first walking step, first encounter with the Thou of another, the birth of one's children, death of a relative or friend, moments of great personal fear, the prospect of one's own death—these bring the depth of being into the course of living. Such sudden changes, such breakthroughs, take us far from "equilibrium" into a strange land of discovery and danger.

In thermodynamics, it is precisely these sudden changes in the macroscopic state where entropy grows rapidly. Although reversible processes evolve with a minimal increase in entropy, dramatic, irreversible processes are characterized by large increases in entropy. Is entropy, or something like it in the personal and spiritual realm, intimately coupled to the cataclysms in our life? Many of these are religious rites of passage, marked by sacraments and considered as sacred times in which eternity enters into the ordinary present with a transformative and salvific power. We cannot describe those personal moments of sudden growth or insight very well, except to say that they really are not like the periods of gradual, smooth living. Interestingly, in thermodynamics as well it happens that we cannot describe in tight analytic formulas the changes in state of a system during rapid alteration. An important research area of physics is actively investigating such "critical phenomena," searching for new mathematical methods for analyzing

the anomalies and singularities associated with sudden gross changes in the state of the system.

Seen in this light, the unresolvability and paradoxical nature of evil itself takes on new, *positive* significance; like the ambiguity inherent in descriptions of catastrophic physical change, life crises too seem to transcend the limits of tight linguistic formulas or verbal accounts. A divine mystery lurks in the cauldron of our wrestling with the deepest moral ambiguities of conscience, and the very inexpressibility of such experiences testifies to their genuinely religious dimension, laced with the mysterious divine/human encounter. Perhaps there is a theological parameter, like entropy in physics, which is associated with the intrusions of the spirit in such deep moments where revelation, self-knowledge, and choice drive religious "state variables" such as confession, silence, and worship.

Second, although life and evolution cost the environment in increased entropy, the value of life and indirectly the value of entropy as a necessary component to life cannot easily be dismissed. In C. E. Raven's 1951 Gifford Lectures, the biological reality of "new life through death of the old" was stressed as "the sublime law of sacrifice" (Raven 1953, 15; Raven attributes this remark to J. H. Fabre). Through processes of physical evolution, the basis is ultimately laid for the evolution of planets, some of which develop atmospheres and oceans and revolve at reasonable distances around moderate suns. In some of these cataclysmic processes release enough energy to produce macromolecules and an organic soup, the womb of life. And in the case of at least one gentle green world the species which evolved includes humankind. As Peacocke points out, "Death, pain, and the risk of suffering are intimately connected with the possibilities of new life, in general, and of the emergence of conscious, and especially human, life, in particular. . . . It seems hard to avoid the paradox that 'natural evil' is a necessary prerequisite for the emergence of free, self-conscious beings" (Peacocke 1979, 166).

Although life inevitably involves disease and death, the New Testament vision is one of ultimate triumph: the apostle Paul wrote, "We know that the whole creation has been groaning in travail together until now." "The creation itself will be set free from its bondage to decay and obtain the glorious liberty of the children of God" (Rom. 8:22,21). Are we somehow to be freed from the tyranny of entropy, and is the universe to shine forever as the resplendent creature of God—a *new* heaven and earth?

Moreover, in the miracles of Jesus, filled with the promise of new creation and spiritual life, we hear of processes whose entropy, if one can speak of their physical dimension as surely an incarnational faith would wish to, must surely diminish radically. Through themes of life

and light, life abundant, loaves and fishes, water and wine, and life everlasting, a new order of nature is described; in such metaphors of God's continued creation, the power of new normative being seems to break the back of dissipative, destructive entropy.

Time's Arrow: The Hidden Assumption Behind Both Entropy and Evil

Entropy in thermodynamics is linked with irreversible processes and hence with the direction of time in nature. In religion, the direction of the passage of time is an underlying, though normally tacit, assumption without which most personal experience and community history would be meaningless. We watch our children grow; we sorrow over lost friends and broken promises; we mourn the death of our loved ones; we can be tormented by the anticipation of suffering; we struggle for a better future; we believe in the promise of divine redemption; in short, we *know* the passage of time. Yet is the "arrow of time" a thoroughly established fact in all of physics? If not, would our human experience of its talons be, ultimately, an illusion? For me, victory can only be true, and defeat only bearable, if time will not one day erase the stages of my living. The reality of history, the values of our action, the power of evil, and the unending increase of entropy—all are based on an assumption lying prior to the level at which we have been exploring a working metaphor between entropy and evil.

So now we must move to that deeper level. Recall that in Newtonian dynamics, the arrow of time is an illusion, although it is very real in thermodynamics. We are back at the conflict between the world views of classical physics: Newtonian, dynamic reversibility, and thermodynamic irreversibility (characterized by entropy). Our metaphors relating entropy and evil have tacitly assumed that entropy, or more generally thermodynamics, is an autonomous, irreducible description of the world. In physics, however, this is not generally accepted. Most adopt the view that thermodynamics can be reduced to dynamics by appeal to statistics: that irreversibility is a result of initial, unusual conditions, not a fundamental fact based intrinsically in nature. For example, imagine continuously shuffling a deck of cards. The deck may momentarily start out ordered, but it gets quickly disordered. Still after a long time it will once again momentarily be ordered, then again disordered for another long time, till it is again momentarily ordered, and so on. Since the period of time between ordered states is so large, if we start from one such state, we never in practice get to the next one. Hence, although we would normally expect that only disorder could follow order, it is inevitable that ordered states appear during extended random sequences.

By reducing thermodynamics to statistical mechanics, physics reduces entropy and time's arrow to the characteristics of a small sample in a much larger ensemble with long-range periodicity over reversible fluctuations. This reduction leaves us with a cosmos which is too symmetric, too perfect, too absolute for evil—or redemption—to be real. T. S. Eliot captures a sense of this problem in his first lines from "Burnt Norton" (1952, 117):

> Time present and time past
> Are both perhaps present in time future,
> And time future contained in time past.
> If all time is eternally present
> All time is unredeemable.

Is there a way out? Although differing in other respects, the reality of time and duration and the difference between past and future are of central concern for philosophers such as Bergson, Alfred North Whitehead, and Milic Capek, for physicists including J. A. Wheeler, Freeman Dyson, and David Bohm, and for theologians like Moltmann, Langdon Gilkey, Wolfhart Pannenberg, Tillich, and Karl Rahner. Certainly then one would hope that in making scientific sense we can avoid talking nonsense theologically. Alpha and omega are simply not interchangeable theological symbols; a scientific cosmology which is based on the reversibility of time might thereby indicate its own transitory, limited value.

Should this theological criticism of time in physics be resolved by physics? This introduces a much broader question, whether one must not, for methodological, epistemological, and practical reasons, finally divorce theology from science, since to do otherwise could lead to some sort of perpetual conceptual contingency. But in this paper we are concerned with bridge-building, and the flow of traffic—in both directions—is the purpose and warrant for a bridge. So again I turn to physics asking whether there is new light on this question at the scientific level. If thermodynamics is locked in desperate conflict with dynamics (a battle which in most physicists' opinion has been won in principle by dynamics, though skirmishes continue), perhaps modern physics can rescue the arrow of time.

Unfortunately, this does not seem likely—with one exception. Both special relativity, general relativity, and quantum mechanics are consistent with temporal reversibility at the formal level;[6] the direction of processes, including the expansion of the universe itself, is accounted for by appeal to special initial conditions. (In the cosmological case, for example, these conditions are called the "big bang" or "moment of creation" [see, e.g., Trefil 1983; McMullin 1981].) One can appeal to the arena of the weak interaction in which certain radioactive decay pro-

cesses are not time symmetric.[7] However, this effect is extremely small; the vast majority of elementary particle interactions are symmetric in time. In my opinion, trying to explain the arrow of time in this way is a bit like expecting the tail to wag the dog.

Recently, however, a new perspective on the ultimacy of temporal irreversibility is being developed, and surprisingly it comes from the area of modern thermodynamics! Normally dissipative systems evolve from states of order to disorder. Now the research of Ilya Prigogine (1980) and others suggests that, as one drives a system far from thermodynamic equilibrium, new forms of extraordinary order appear. Moreover, they claim that thermodynamics cannot be resolved into statistical dynamics merely by appeal to special initial conditions. In ordinary thermodynamics, different complex states evolve into similar final states (everything consumed by fire turns to ash). Prigogine has studied the detailed evolution of new classes of physical systems far from the kind of physics normally explored. Using bifurcation theory, he now argues that in many cases two initially similar systems will eventually evolve into final states which differ drastically from each other. Cells, compartments, groups, vortices, inhomogeneities, clusters, lattices—these highly ordered spatial structures evolve in time through processes which seem to defy the law of entropy. Hence Prigogine suggests that temporal irreversibility is fundamental in nature, and that entropy plays a catalytic role during processes of unusual complexification.

If Prigogine is correct, the direction of time will find an irreducible foundation in modern thermodynamics, and the role of time in theological concepts like evil and history may be strengthened. Perhaps, then, the relationship between concepts of entropy and evil will be one of "consonance," as Ernan McMullin suggests in a similar vein regarding the problem of the origin of the universe and the Christian belief in divine creation.[8] I will venture to formalize this relationship in terms of the following working hypothesis: Although the characteristics of entropy and evil do not give direct support to one another, if evil is real in nature, entropy is what one would expect to find at the level of physical processes. Conversely, if a real arrow of time is coupled to entropy in physical processes, one would expect to find dissipative, disruptive, yet subtly catalytic processes in history and religious experience.

Conclusion

We have explored a metaphorical relationship between entropy and evil, which has led to a discussion of time's arrow. The Augustinian interpretation of evil seems more akin to the negative sense of

entropy—as a measure of increasing disorder, disfunction, decay, destruction, and dissipation. Entropy is involved in the fragmenting of creation, even in those processes which form new creation. The cost of industrialization in the pollution of the environment mirrors in a sociological context the staggering cost of biological evolution, borne by lower species in the food chain and finally by the cosmos itself which, while slowly dying, gives birth to its young. We eat, we grow, we explore, we destroy, we hope, we love, we die—some things increase beauty and compassion, others bring ruin and anguish; yet all in toto increase the heat death of the whole. The disorder of the physical world, the cost of life and living, the inevitability of further disorder—these all reflect the dominion of sin as stressed by Augustinian theology.

The Irenaean interpretation may be closer to the dynamic sense of entropy as a characteristic of violent change leading, perhaps, to greater harmony, deeper insight, and broader structure. The Irenaean stress on the future, on development of the spirit, on growth toward full relationship with God clearly gives greater weight to time over the more static, structural Augustinian analysis. Moreover, "order out of chaos" is deeply consonant with the Irenaean theodicy: we grow spiritually from image to full likeness of the divine. This surprising feature of Irenaean theodicy suggests a striking parallel with the recent discoveries by Prigogine concerning temporal irreversibility and the development of novel structures in systems far from thermal equilibrium.

In sum, entropy seems a surprisingly pliable concept. It is related to processes of despair, decay, degeneration, and to the perfecting of creation as the signature of God's continuing creative participation in the evolving universe. The dynamic concept of entropy, rooted in the flow of time and characterizing processes throughout nature, embraces both the Augustinian and the Irenaean theologies and suggests a new conception of order evolving out of disorder.

Of course this level of inquiry is more of a first look, the suggesting of metaphors as signposts for further thought. There are numerous complexities in both the theological and scientific dimensions which have been barely touched on. For example, one would want to develop the traditional theological issues involved in much greater detail. The discussion ought to be expanded to include several broad areas of current theology, including Ricoeur's analysis of symbolism and evil; the theology of Moltmann, Pannenberg, Peacocke, and Teilhard; and Whiteheadian, feminist and liberation perspectives. In modern physics there are a variety of new aspects to be investigated for their relevancy to the theme of this paper, including quantum statistics, thermal fluctuations, strange attractors, and Prigogine's continuing research in

nonequilibrium thermodynamics. Also, since a metaphor is far from an identity statement, the dissimilarities in the metaphorical relationship between evil and entropy deserve fuller discussion. Still, with this first look, a form of consonance between the theology of evil and the physics of entropy seems to have been found. We shall see whether the consonance turns to a symphony.[9]

NOTES

1. Hick (1966) includes a provocative evaluation of recent trends in theodicy and their positive relationship to Christian eschatology.
2. For references to Irenaeus and Clement, see the Ante-Nicene Library.
3. It would be interesting to analyze both the conflicting views in physics (thermodynamics versus dynamics) and the conflicting views in theology (Augustinian versus Irenaean theodicy) in terms of Imre Lakatos's methodology of scientific research programs (Lakatos 1978).
4. Whether entropy can be applied to an open cosmology is a controversial point which will not be explored in detail here.
5. Since writing this paper I have learned of a very thoughtful development of similar themes related to Teilhard by Juan Luis Segundo (1974).
6. Eugene Wigner and others have suggested that the measurement problem in quantum mechanics necessarily involves consciousness as an actualizing agent in nature. This could provide a means of introducing time's arrow within physical processes. There are several arguments against such an approach, however, and it has not been widely adopted.
7. This result is linked with parity violations and PCT conservation. For a readable account, see John C. Polkinghorne (1979).
8. In a recent article McMullin argues that the Big Bang does not support the Christian docrtine of creation, nor does the Christian doctrine of creation support the Big Bang. "What one *could* readily say, however, is that if the universe began in time through the act of a Creator, from our vantage point it would look something like the Big Bang that cosmologists are now talking about" (1981, 39). It will be interesting to see whether McMullin's position can be sustained by a careful investigation of alternative physical cosmologies and their implications for present observational astronomy.
9. One way to orchestrate such a piece would be to use Lakatos's methodology (1978) applied to the nested sets of competing theological and scientific research programs.

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