Becoming, Being And Passing: Our Myth From Science (the Second Law and Natural Selection)

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ABSTRACT

Our myth from science has three prongs -- to provide answers to: (1a), why is there anything at all? (1b), Why are there so many kinds of systems?; (2), Why do systems not last once they exist?, and (3), Why are systems just the way they are and not otherwise? The answers to (1) come from cosmology and physics (thermodynamics), the answer to (2) comes from a materialist interpretation of information theory, while the answer to (3) comes from evolutionary biology. These answers are: (1a) because the universal expansion following the Big Bang has been accelerating so fast that the universe could not remain in equilibrium. Matter and gravitation are aspects (and signs) of disequilibrium. Matter is embodied energy, a condensed form of energy signaling extreme thermodynamic disequilibrium; (1b) because the universe uses material configurations to dissipate energy gradients; the more different configurations, and systems, there are, the more different kinds of gradients can be dissipated in the interest of equilibration. (2) because information accumulates in all dynamic material systems, leading ultimately to information overload, leading in turn to instability. (3) because only configurations that conform to others, or relate mutually, are stable enough to persist in the face of the overwhelming tendency of things to fall apart via (1b).

INTRODUCTION

All societies and cultures have creation myths, often entailing morality. Myths are stories that are believed, so that, for example, if a biologist believes that natural selection has produced all apparent adaptations, then natural selection is here functioning as a myth, rather than as a scientific hypothesis requiring testing. In our time mythologies must, to be believable by educated persons, reflect scientific knowledge (Salthe, 1990, 1992). It is the renewed task of the philosophy of nature to provide such a myth (Salthe, 2001; see also www.nbi.dk/~natphil/salthe/ -- natural philosophy has the task of making scientific knowledge into an intelligible system).

Since our naturalized myth prominently features physical forces, one can anticipate that some will deprecate this project as reductionist. This charge can be answered by using what I call the specification hierarchy (Salthe, 1991, 1993,a, 2000, a). I refer here to the fact of intensional complexity (Salthe, 1993) -- the view of complexity founded on the fact that most material objects can be understood from more than one viewpoint (Rosen, 1985). So, we could examine an organism from a purely physical standpoint, focusing on diffusion and other thermodynamics-related phenomena. Or we could instead focus upon particular material facts, like metabolism, or we could seek instead real biological facts about, say, cell division. These viewpoints can be taken together under the concept of integrative levels (Salthe, 1988, 1991, 1993,a), and could be displayed as the following specification hierarchy: {physical level {material level {biological level }}} (see also Salthe, 2000; the brackets here represent classes, as in set theory.)

Material phenomena are more generally present in the world than are biological ones, and form the basis out of which biology emerges (and emerged). At the same time biology regulates, harnesses or controls -- integrates -- material processes in its locale. For example, diffusion is regulated, and harnessed, by the circulatory system. If we choose to see only physical phenomena in an organism in this context, it should be clear that no reductionism is intended. We would consciously be taking a very partial view, presumably for some good reason. One good reason would be to contribute to the construction of a unity of the sciences (Neurath et al, 1938-1969; see also Agazzi and Faye, 2001), a project concordant with the aims of natural philosophy. Its major principle in the present context is that a more generally applicable explanation of a phenomenon is preferable to one that is less able to be generalized because such an explanation facilitates comparative studies in the interests of a unified view of nature (see Brooks and Wiley, 1988, for a particular example).

Consider that, in general, energy gradients are unstable, and are susceptible to being dissipated as fast as may be. For example, a concentration of immature protein embodies a double gradient, including the relatively high Gibbs free energy of the not yet folded proteins. At a later time, the concentration gradient will have fallen and the now-native proteins will have developed further into a lower free energy state. In the present view, the general process of gradient reduction is reflected at a higher integrative level when, say, a steep social gradient (in, say, prestige or power) tends to invite revolution. This is here taken to be a more highly specified example of the same principle, and not a mere analogy. Yet it does not explain everything we need to know about a social gradient, including the history of its generation.

Questions of interest to all mythologies are: Where are we? What are we? Why are we here? What are we to do? Natural philosophy is geared to answering 'why' questions, which generally entail 'what' questions (leaving related 'how' questions to science). So, where are we? We are in the expanding universe following the Big Bang. Why are we here? Because the universe requires our services to aid in its project of thermodynamic equilibration. What are we? In this context, dissipative structures (Prigogine, 1980). What are we to do? The answer to this question is not so directly grasped, and requires consideration of various alternatives in a complex setting. This question will be taken up at the end of this paper.

WHY IS THERE ANYTHING AT ALL?

Where Are We?

Among possible answers to this question, that most germane to this study is given by the Big Bang theory of the origin of the universe. According to Frautschi (1982), Landsberg (1984) and Layzer (1976; 1990), the expansion of the universe has been accelerating so fast that the system went out of global energy equilibrium rapidly, and has had a tendency toward equilibration -- known as the Second Law of thermodynamics -- ever since. As its expansion accelerated, the universal system cooled and physical particles emerged, which then gave rise to matter, which in turn coalesced into mass, which continually aggregated as collisions brought about by a random search for mattergy equilibrium evoked gravitation. The fact of gravitation, however we model it, is the pre-eminent sign of energy being radically delayed in its equilibration. Its strength reflects the rate of universal expansion (in reverse, as it were). Matter as embodied energy, mass, and gravitation, are all signs of radical disequilibrium in the universe. In this scenario the system has been getting further and further away from an equilibrium distribution of energy and particles as the universal expansion continues to accelerate (Watson, 2002), thereby increasing the drive toward equilibration at the same time, making the Second Law an ever more powerful attractor in the material world as the universe continues to expand.

Given the brute fact of masses of matter stuck in agglomerations nowhere near equilibrium, what might the Universal System do to facilitate equilibration? Following Schneider and Kay (1994), we can surmise that the massive frictional world finds a way to increase entropy production by linking it to convective energy flows facilitated by organized forms abutting energy gradients, which they can rapidly dissipate in a more orderly manner than through friction, conduction and diffusion (see also Swenson, 1997). This is the general explanation for the existence of abiotic dissipative structures like hurricanes and eddies; increasing the steepness of energy gradients at some point spontaneously triggers the organization of material systems there that will dissipate these same gradients as rapidly as possible. From this point of view, living systems are a continuation of this project of reducing energy gradients. The evolution of animals is especially easily interpreted in this way: detrivores acquired movement to burrow into gradients; then they acquired mouths and claws to hurry the disintegration; then predators, as well as herbivores, evolved to hurry the production of detritus; then some of these became homeothermic so that gradients might continue to be dissipated even in the absence of overt activity; then some of these invested in large nervous systems, which consume large amounts of energy continuously (Chaisson, 2001). This general scenario provides the basic 'meaning' of ecological systems, whose developmental (successional) phenomenology shows a tendency to maximize energy throughput (Lotka, 1922; Odum and Pinkerton, 1955; Vernadsky, 1944) by way of configurations and processes at many scalar levels. The punch line -- form results from, and further mediates, convective energy flows, which more effectively degrade energy gradients than would slower frictional processes.

So, we are in a world that, in effect, does not want to be! A world of massive objects that destroy and replace each other incessantly (a situation nicely represented by, for example, the Hindu Shiva principle). We will find that we ourselves are just such objects.

What Are We?

In the present perspective, we are dissipative structures (Prigogine, 1980). That is to say, we are dynamic material systems deriving energy from embodied energy gradients, and dissipating it, via work, into form and activity. The faster any work is accomplished, the less of the dissipated available energy drives that work (is used as exergy), and is lost instead as kinds of energy contaminated by entropy (Carnot, 1824; Clausius, 1851). Entropy is generalizable as disorder (Boltzmann, 1886). Available energy is a gradient that, from the point of view of a given kind of consumer, has an orderly arrangement with respect to that consumer's configuration, so that when the two come together, some of the energy in the gradient can be assimilated by the consumer and used for work. Any energy, gradient or not, that has not got an appropriate arrangement allowing its use for work is entropic, or, as Boltzmann would have put it, disorderly, from a particular consumer's point of view. From the viewpoints of all material systems the most entropic form of energy that we know is heat, which is so disordered that it is capable spontaneously (that is, unfocused) of driving nothing more than Brownian motion. It should be noted here that forefront physical disciplines like quantum mechanics, astrophysics and string theory may find roles for heat energy, as well as forms of energy even more disordered (whatever that could mean), but we are concerned in our myth at present only with the material world, wherein we live.

Future understandings may alter our scientifically informed myth -- which may be its most salient difference from ancient myths.

Dissipative structures grow, either in size or throughputs, or both, up to a point, after which they decline (Salthe, 1993,a; Ulanowicz, 1997). They grow for the same general reason that wave fronts spread and diffusion occurs -- because the universe is way out of equilibrium and getting even moreso all the time. Diffusion and wave front spreading serve the Second Law of thermodynamics by moving local situations toward equilibrium. Dissipative structures do the same, by degrading energy gradients, during growth and repair, as well as in their activities, in such a way as to produce entropy to an extent correlated with the rate at which they dissipate the gradients. That is, the faster a gradient is reduced, the less of its embodied energy can serve as exergy in the interests of its consumers, and the more of it will head toward the sink as, or further in the direction of, heat (Carnot, 1824; Clausius, 1851). This tactic works for the universe, which can tolerate the buildup of energy consumers because as much of an energy gradient tends to be paid as tribute to the Second Law as can become reembodied in its consumers. Quoting Odum (1983, p.116): "According to Lotka's maximum power principle, systems tend to develop designs that maximize power [energy throughput] and thus may be expected to develop loadings [work loads] less than the most efficient. At maximum power half of the input energy must be dispersed with a corresponding entropy increase."

Note that, since the slower any work is done, the more efficient is the exergy extraction in its interest, we must ask why natural dissipative structures are not more efficient. Given any gradient, and several consumers abutting it, those that can dissipate it fastest will get most of it. Therefore they will burgeon, while the slowpokes will dwindle. In organisms this competition gets translated into reproductive effort (Tinkle, 1969), in the generation of which, competition gets mediated by natural selection (see below). Natural dissipative structures are therefore in principle the least energy efficient of their kinds that might exist. That is, given that their very existence demonstrates considerable efficiency of energy use commensurate with their complexity (whatever energy goes into work cannot be lost as entropy), dissipative structures in their activities are driven by competition for energy to be quite inefficient and wasteful by using it up as fast as may be possible. So the universal solution to the clot of clumping matter caused by its own extravagant expansion was to destroy clumps by means of other clumps, and this ploy entrained the further evolution of complex forms, all the way to living ones.

This interpretation finds that the Second Law is the final cause of all form (Salthe, 1993,a) because form is capable of initiating orderly convective flows that move energy from gradients toward the sink more effectively than can haphazard conduction, like diffusion (Schneider and Kay, 1991; Swenson, 1989,a, 1991,a). So, form has teleological meaning. The sequence { teleomaty { teleonomy { teleology }}} (otherwise {natural tendency { function {purpose }}}) shows the relations between teleo types (O'Grady and Brooks, 1988). In words, intentional teleology, or purpose, is an example of a kind of functionality, which in turn is a kind of natural tendency along the lines of the Second Law of thermodynamics -- that is to say, function is a subclass of (or a more highly developed, or more precise or refined, example of) variational principles. All these teleo projects are examples of final causality, answering the question: 'why does something occur?'.

Science typically avoids questions in the 'why' form, inquiring instead into how something occurs, involving, in different sciences, one or another of: (a) material cause: an understanding of the situation that gives rise to an occurrence, as in 'the reproduction of cells causes the growth of organisms'; (b) efficient cause: an understanding of what forced, or proximately pushed, the occurrence, as in 'an influx of energy gradient stimulated the reproduction of cells'; and (c) formal cause, an understanding of the natural laws involved and the arrangements harnessing them in any given instance, as in 'the cell divides because under certain conditions some of its organelles contract in a particular way as a result of harnessing some energy from the spontaneous hydrolysis of ATP'. But Natural philosophy is involved explicitly with finality, and in the Continental version informing my thinking (Salthe, 1993,a) has always been, from its beginnings with Schelling and Goethe in the Nineteenth Century.

So, the specification hierarchy of integrative levels shows why we are not being reductionist here. The maximum energy throughput program is instituted at the physical level. But no biological systems could exist under conditions of absolute entropy production maximization, as in combining with oxygen during an explosion. In biology, oxidation is much tamer (and more efficient), going by way of dehydrogenation, which allows a degree of complication of form that an explosion would not. In other words, entropy production in biology was placed under further constraints, the payoff of which was twofold: weaker gradients could be more efficiently dissipated, and the dissipation could be taken further in the direction of heat energy, the kind most easily diffusable toward equilibrium. In terms of serving the Second Law, both rapidity of gradient dissipation and completeness of dissipation to heat are involved, but not often accomplished equally well by a single kind of dissipative system. First Law dissipation into multiple gradients of lesser quality is furthered by the haste entailed by competition for gradient, while Second Law dissipation all the way to heat is furthered by some complication of form. Organisms reflect both services, and are, as it were, optimized between both tasks.

Still further constraints are instituted historically by social systems, which could not exist except by constructing protection from the more intense rates of dissipation that (as larger scale entities) they mediate, as well as protections from the polluting weaker gradients that this hasty energy use produces as wastes. As more integrative levels emerge during evolution, the Second Law becomes, as it were, increasingly impatient, and therefore more powerful as an attractor. I suggest that the emergence of multiple integrative levels serves the purposes of the Second Law even if utilization efficiency thereby increases because higher integrative levels uncover previously inaccessible energy gradients to exploit, as when Western society dug into fossil fuels in a big way. So, in this view systems are seen to exist primarily in order to produce entropy, but also, ultimately, for various other reasons as well, all of these reasons -- not the least of which is to move occult and elusive energy gradients in the direction of heat energy, as in pumping oil -- being consistent with the primary finalism.

Summing this view, then, while we see our own purposes reflected in the work we undertake, the universe is “interested” in the entropy we generate while doing it.

WHY ARE THERE SO MANY KINDS OF THINGS?

Form can catalyze increased rates of energy dissipation from gradients, and different forms can be effective in this regard with different gradients. Asteroids can pulverize planets, microbursts can level trees, while drainage systems wear away rocks, all producing heat and scattered -- unsystematized -- matter. In this scene living systems have their roles as well, as they consume gradients in the immediate interest of promoting the presence of their own kinds. These roles are of smaller scale than those of the coarser abiotic systems from which they emerged, but the finer gradients they consume would be left largely untapped without them. It seems plausible that the agency of massive, powerful abiotic systems was relatively more important earlier in the universal expansion, and that the roles of living systems could increase into the future. With the gross rate of recycling (and heat energy generation) having diminished over time as the universe cooled, living systems seem poised to play out their roles on the asymptote -- without us the universe could be left forever stuck away from equilibrium, with increasingly smaller planetoids scattered unevenly throughout. Here I am making a strongly finalistic assumption on the basis only of the attitude of the erstwhile Continental version of Natural Philosophy.

So, the final cause of the origin of life will have been the pull of gradients to be demolished. Some of these, more accessible at the surface of appropriate planets, would simultaneously have been among the material causes as well (along with prebiotic chemical forms like various liquid crystal membranes). As with any dissipative structures, the laws of nature and of matter would have been the formal causes of the originating processes, while efficient causes would have come from the likes of winds, gravitation and fluid gyres, as well as the coming and going of light. In this perspective the continued evolution of living systems has been a finalistic search for untapped energy gradients, seeking ever more finely tessellated and inaccessible ones. Life began in shallow waters, then moved into both elevated torrents and the abyssal depths, as well as onto land. The ecologies of all of these places were colonized by living systems, who provided ever more diverse forms suited to dissipating ever more elaborate and occult energy gradients. Increasing local biological diversity is a way to maximize the entropy production of a given locale (Salthe, in press, a, b) over and above what might might be accomplished by abiotic agencies alone.

The spontaneous eliciting of form does not exhaust the role of the Second Law in ecology. As shown by Carnot, energy consumption can never be fully efficient, and is less so to the degree that it is hasty. If we observe the feeding of animals (often quite hasty!) we find that heat energy, the most thoroughly degraded form, is not the sole product of gradient consumption. Rather, several other gradients are produced, from various scraps to feces, that can serve as gradients for other life forms. So, by preventing the most effective energy consumers from getting all of it in a gradient, and by doing this to the extent that they <u>are</u> effective, the Second Law spreads energy laterally into other forms of availability (Taborsky, 2000). In both of its roles, the Second Law elicits -- calls for, entrains, affords -- the subdivision of niche space that we refer to as biological diversity, so that entropy may be produced as fast as possible everywhere on the earth's surface.

WHY DO SYSTEMS NOT LAST ONCE THEY EXIST?

The primary fact about natural dissipative structures is that, as long as they survive, they grow in energy throughput (which in many cases entrains increase in size as well), until some point when they begin to get recycled. This growth has been noted in several studies, and even dubbed a Fourth Law of thermodynamics. Odum (1983) notes approvingly that Lotka (1922) suggested that the maximum power principle, more fully elaborated later by Odum himself, be thought of as a Fourth thermodynamic Law. This principle, characteristic of the successional development of ecosystems, has it that development will occur in such a way that the gross energy flow through a system increases, albeit at an ever decreasing rate after immaturity, until the system is perturbed back to an earlier stage. Odum sees this as working by way of stored energies in a system being deployed to maximize its energy throughput, for example, by providing activation energies at crucial points. This is concordant with a Fourth Law suggested by Kauffman (2000), to the effect that dissipative structures continually extend the area of their work surfaces. This would be one way to describe how a system might come to exemplify the Lotka-Odum maximum power principle. The growth of dissipative structures, which results from their increasing energy throughput, can in general be viewed as a way by which they can increase their entropy production, because it would tend to generate further energy consuming surface area, in a positive feedback relation. Increased size would tend as well to provide access to further energy gradients (Swenson, 1989,b). So growth uses energy in such a way that more available energy may be encountered, producing entropy in the process. Furthermore, as growth in viscous systems often leads to instability tending to cause subdivision of the system, new gradients will more likely be encountered by more (daughter) systems.

Jørgensen (1999, 2001) proposed a closely related Fourth Law, to the effect that, given alternative developmental pathways to explore, a system will tend to develop in the direction which results in the greatest amount of stored energy. Here the system is seen to maximize its exergy mobilization potential. This stored energy would be embodied (as the potential energy crucial to Odum's concept) in a system's forms, which would include its work surfaces. So the increased work surface idea links the increasing power idea with the increasing energy storage one, the three ideas thereby revealing aspects of a single coherent concept.

This Fourth Law of thermodynamics is coherent as well with the major principle of infodynamics, to the effect that dissipative structures continually incorporate new informational constraints, albeit eventually at decreasing rates (Salthe, 1993,a; 2000, b). So, we have a system that, because of its existence only at a given range of scale, cannot keep growing endlessly. Every dissipative structure approaches its finite size at ever decreasing rate. Yet, because material objects are marked by historical encounters, new information continues to be shipped on board, refining and modifying existing informational constraints. The effect of this, in an already definitive, non-growing system, would be to insert new constraints in between already existing ones, with at least two results. First, given that a system is already functioning, it would insert here and there information that could interfere with its internal communications, causing lags and delays in responses to environmental perturbations. This same effect could as well start new directions in a system at variance with its habitual ones, which would tend to dissect it into subdivisions unnecessary to its continuance, a process that must eventually tear it apart -- e.g., a river becomes a swamp with innumerable channels. The second major effect of inserting new information into an already definitive system would be to enhance or further overdetermine those of its habitual behaviors that have already become inertial, thereby diminishing its flexibility of response to perturbations. This effect is pathological in many kinds of senescent systems because of their reduced energy throughput (Aoki, 1991; Zotin, 1972). The result of these combined effects is system rigidity, setting it up for the recycling that has now become its best opportunity to further fulfill its entropy production destiny.

So, systems have only finite destinies because they cannot help incorporating new information as a result of their historical adventures, and this is because matter is a medium that gets marked. That is, with the Universal expansion continuing apace, new information tends to precipitate into the world along with matter and mass. Yet, motivated by the Second Law, the material world allows no particular configuration an indefinite continuation.

WHY ARE SYSTEMS JUST THE WAY THEY ARE?

Objects and systems can persist if they are stable, and/or if types of them can replace their kind before their instances get recycled. Stability only exists in relation to the particular environment of a system, to a system's fittingness with respect to its surroundings. As environments generally antedate the systems in them, as well as being larger in scale, it makes sense to view them as being selective with respect to what may persist within them. A simple thought experiment projects this idea. Suppose we have a gently sloping board with scattered holes of a particular size. We take a handful of marbles of several sizes to the top of the board and release them, as in a pinball machine. Those that happen to have a size matching the holes, and that happen to encounter a hole, will persist on the board -- will be stable there -- while other kinds, as well as unlucky individuals of the same kind, are swept away.

Selection here reflects a differential stability of relationship, encountered by chance.

Consider next the formation of a drainage system. Water pours off a melting glacier, constructs runnels here and there which branch and conflow according to the terrain. Some channels will deepen, others will flow into them and get drained. Gradually a major tributary will emerge according to geological conditions. Channels that allow the greatest rate of flow -- i.e., afford the greatest entropy production -- will take the flow from others. Here we have selection, by conditions, of one configuration out of numerous possible others, according to its consequences (Skinner, 1981) in entropy production (Swenson, 1991,b). Here fittingness is measured in entropy production. Note that this selection operates, not among contending actual major channels -- in the manner of classical natural selection (see below) although on long time scales that might happen too -- but gradually finds a single one on the basis of competition between many incipient ones in earlier stages of development. It is conceivable that there might have been an ultimately even more dissipative major channel developed out of a different earlier stream, but, of course, selection cannot foretell the future. It works every moment only upon choices present at that moment.

In order to see how there can be actual <u>kinds</u> of natural phenomena in the abiotic world, let us consider hurricanes. Atlantic hurricanes are one ‘species’, as compared to Pacific typhoons. These hurricanes, succeeding each other during each season over the years, make up a population (e.g., Tannehill, 1938). The general boomerang shape of their trajectories over the map reveals the shape of the environmental affordances sculpting them. Their boomerang shape is analogous to the forms of organisms, which are also, in part, entrained by their immediate environment. Of course, with organisms their form is even more importantly shaped indirectly by past environments, information that was selected by which being now imposed internally, from genetic arrays. But the shapes of plants, for example, are also to a significant degree still molded directly by environmental forces, as the most primitive biotic systems must also have been.

Drainage systems and hurricanes reveal the basic nature of prebiotic selection. Stability is gained by fitting the greatest possible entropy production into the existing surrounds. The slanting board experiment uncovers a question about the relation of chance to the final outcomes. A marble will find itself in a fitting hole purely contingently. As well, the actual trajectory of a particular hurricane will have been affected by contingent events and configurations in the atmosphere. If a drainage system actually discovers the fastest possible route to the ocean, this could only be by the chance that in each of its earlier stages it it just happened, by chance, to be flowing faster than other contending streams were doing. Particular instances of kinds of events are individuated by fluctuations in the initial and boundary conditions bearing upon them. So the differences between instances are historical in nature, and selection preserves some of these as historical records, which may get projected into the future as evolving traditions. But what about, say, the large scale initial and boundary conditions controlling the appearance of hurricanes in a given region year after year? These must be stable over many decades at least, but it is clear that ultimately they too must have been set by chance fluctuations in the history of the earth. The shapes of events and objects, the forms of systems, are all kinds of historical records. Those that recur represent evolving traditions. Things are the way they are because a series of events and contingencies just happened to happen.

It might be worth noting that this interpretation reflects our current biases. Are fluctuations random or arbitrary? After all, there is no way to tell whether a particular instance of a kind of event happened by caprice, or by choice (Salthe, 1993,b). The answer here would depend on whether or not the resulting ensemble of instances of a kind of event realizes one or another known frequency distribution, like the binomial or lognormal. If it does conform to one of these, we have reason to suppose the instances to have just spun chaotically out of chance configurations. But it is worth noting that populations of instances of types of moves in Master chess games are binomially distributed (Salthe, 1975), even though no one would suggest that any of them were made at random. Each choice was certainly constrained by boundary conditions, but was not fully determined, and certainly was not made accidentally. Well, history is made up of both choices and chance events, and the point here is that historical contingencies of either kind, or both, determine the occurrence of actual events and the resulting configurations of systems. So these configurations all carry information, inasmuch as they might have been different, given the same expenditure of energy in their construction.

The information concept leads us to consider particularly biological dissipative structures, since, as is well known, the DNA in cells is considered to carry information relative to the past environments of ancestral populations. Cellular processes are informed by these arrays such that the resulting configurations resemble closely those of ancestral cells and organisms. The origin of life was the origin of stable internal informational arrays (a process still remaining largely mysterious). So, in addition to the external boundary conditions considered above, living systems also have internal information to regulate their self-organization. Selective effects -- now the natural selection of Darwinians -- in this case distinguish between kinds of individuals (different genotypes) by means of their differential reproduction as much as, and even moreso, than by their differential stability (now viability). In other words, differential reproductive success (the fertility component of fitness -- Thoday, 1953) represents the consequences of concern here that flow from the interaction of genotypes with their environmental conditions. These interactions still, of course, involve a viability component of fitness, which is not conceptually different from the stability criterion in respect of abiotic systems, as discussed above.

The fertility component of fitness is a new effect instituted by biology, and represents an active projection of types into the future. This is something that could be accomplished by abiotic dissipative structures only very indirectly and haphazardly by way of modifying environmental conditions in such a way as to enhance the survival of subsequent similar instances, an effect which still occurs in biology too, but less haphazardly -- for an example, in the dams of beavers or in the conditioning of soils by plants. So, instituting differential fertility was a refinement of prebiotic selection (Depew and Weber, 1995), adding it to differential stability. Stability has been enhanced too by internal information, since worn out protein components can be replaced using internal information, and this affords significantly greater elaboration of form. These elaborations of form importantly allow exploitation of energy gradients not previously tapped by coarser abiotic dissipative agents. Furthermore, the instability of the internal information due to frictional effects, is the ultimate source, by way of resulting mutations, of a diversity of biological types (Brooks and Wiley, 1988), each capable of exploiting a different mix of energy gradients.

Note that with the origin of natural selection there has been added a new dimension to selection -- competition between fully formed instances of different kinds. This is because biological individuals do not reproduce until maturity has been attained. Whatever failures there may have been during earlier stages of development are recorded only during reproduction, by contributing to the differential fertility of the different types in a population. If a genotype had less success than another in converting available energy into its own embodiment, but nevertheless outreproduced the other, its kind would be more represented in the next generation than the more efficient energy assimilator. For this reason the ancient stability / viability component of selection could actually even be nullified -- for example, if resources became unlimited (as in the boom phase of a boom and bust way of life) -- reducing fitness just to its fertility component. This situation (rare in nature) emphasizes the basic competitive nature of natural selection in biological systems. Competition between types is the mediator of natural selection.

What are these types? While all material configurations are historical in nature, types like Atlantic hurricanes result from stable boundary conditions. In biological systems, types result primarily from stable internal generative tendencies, inscribed in genetic information, stabilized by natural selection. These tendencies are inherited ways of fitting in -- inherited traditions -- which occupy biological systems and use them to project themselves into the future (Dawkins, 1976). We call these traditions genotypes, races and species. Each of us is a system deployed by, and representing, our genotypes and species, some of the information from which drives us eagerly to reproductive activity. We could note, for example, that penises and breasts belong, not to us, but to our species, as these form the material links within a species, but do nothing for us, as organisms, personally. To emphasize this point, we should note that reproduction is bad for us. It uses energies that could instead have been used for growth or repair. It throws animals in the way of personal danger, having, for example, to return to nesting sites, making it easier for predators to track them, or having to engage in dangerous battles over access to mates. And we could note as well breast and prostate cancers among people, or venereal diseases. We are indeed successfully entrained by our biological traditions (and, of course, since reproductive activities are notably spirited, by the Second Law as well)!

We may recall here that these traditions, so assiduously committed to their own survival, must accomplish this trick in a world committed to the destruction of all forms. They can survive only by fitting in, by relating effectively to other traditions, and, of course, by paying tribute in entropy -- paid only by degrading energy gradients, most of which represent other traditions, as when lions eat wildebeests. Within a species, genotypes strenuously work to outreproduce other contending ones -- the more strenuously, the more entropy will be produced. Types of slackers, of course, do not succeed in surviving through many generations. Extending this line of thought, cultures survive as well by paying entropy tribute, as by building pyramids and airplanes, and, of course, by then destroying them in wars. One might well be puzzled as to why warfare of one kind or another is so characteristic of human cultures. The answer at the lowest integrative level is that in this way entropy can be extracted from cultural artifacts as they get recycled, making way as well for more entropy-taxed construction. Cycles of this kind get reflected as well in more abstract ways in the likes of business cycles (Soros, 1998) and other kinds of modern potlatches.

This line of thought raises the question as to possible direct connections between the Second Law and natural selection (Depew et al, 1989). We can make the following argument. It is widely supposed that traits of organisms that are relatively more important in increasing their fitness (relative reproductive success) will display less variability than less important traits, as a result of a continued selective culling of individuals in relation to them over the generations. For example, Salthe and Crump (1977) showed that traits of frog hindlimbs (ratios of measurements) considered to be important for jumping were less variable than traits considered by functional morphologists to be less important in this regard. Furthermore, in kinds of frogs that do not jump, these same traits were not significantly less variable than other randomly constructed phenotypic ratios. Selection reduces variance in fitness (Fisher, 1958). I have suggested (Salthe, 1975) that in behavioral and physiological traits (like heartbeat rate), variability will diminish in the direction of peak performance. For example, heartbeat would become increasingly critical, say, when escaping from predators, and so its peak performance would have been especially important in saving those that lived to breed. Peaks of importance should generally tend to coincide with peaks intense activity. Preliminary evidence of several kinds supports this idea. Supposing the idea to be viable, we can tie the Second Law directly into selection, because peaks of intense activity would also tend to be peaks of entropy production, since this must increase with rate of activity. That is, at critical moments in the lives of individuals, they tend to be producing more entropy than during more routine moments. We can provisionally conclude that natural selection tends most intensely to review the performance of functional traits in the context of increased entropy production. Selection, then, tends to support systems that can most effectively produce entropy. In this way, the Second Law constrains the results of natural selection, or, fitness maximization is entrained by entropy production increase. Using the specification hierarchy formalism, we get {entropy production increase { fitness maximization }}. That is, fitness maximization could be said to be a kind of entropy production maximization. Our myth is reinforced by seeing that its two major principles are mutually consistent.

Well, here we are in a world of historical traditions striving to maintain themselves in the face of the Second Law, and striving as hard as they can to serve this law at the same time, as the price of their continuance. The survivors include only those that have worked as hard as they possibly could (even though that might not be sufficient for success). Ours are among these surviving traditions, as we serve the interests of a species, of populations and cultures that have maintained themselves by building and burning, eating and procreating. We serve their interests, note, despite their defiance of the Second Law, whom we also serve. So we are faced with a kind of trade-off. We can strive for our traditions only if we pay at least equal tribute to the Second Law -

- which means that this striving must be striving indeed!

WHAT ARE WE TO DO?

Realizing that we are positioned in such an entropy deficient world, we need to consider what it is meet for us to do. One answer to this, since we are among the current survivors here, is to continue doing just what we have been doing. That is, in the Western orbit, practice the growth economy, recycle mature ecosystems and replace them with urban areas, farms and fisheries, burn up resources as fast as we can, reproduce maximally, and outcompete other contending social systems. Our mythology, not surprisingly, implies the values (as judged by its activities) of the culture that has been constructing it. Another approach would be to note the very few practices <u>not</u> furthering the Second Law or being involved with competition -- quietism, contemplation, meditation -- and eschew them. As well, in narrower focus, we could note laziness, procrastination, overcautiousness, indecision. The latter two suggest that complexity (= variety -> disorder -> perplexity) could be a problem. Undo concern with it at present may be thwarting scientific discovery, which is the basis of our economy. Classical science has proven itself quite effective in supporting technology. If this liaison has betimes produced some disturbing unexpected effects, like radiation and other pollutions, we need to see that these effects too serve the Second Law.

In any case, the only completely forbidden activity in the present context is perpetual motion, or, mapped into looser social terms, something for nothing. But care needs to be used in applying this dictum. Babies get something -- but not, even though seemingly, for nothing. Among humans they have the highest intrinsic rates of metabolic entropy production. Therefore sustenance given to them is well spent, which it would not be, for example, if given to the elderly, whose entropy production is well known to be relatively low and declining (Aoki, 1991, Zotin, 1972). And, of course, in the competitive aspect of things, babies represent the currency with which one population might eventually outcompete another.

But no moralist worthy of the name ever endorses the current practices and attitudes of his/her society. We might first notice the dangers in fully embracing the Second Law as our fate and god. It could mean that we should take the quickest route to maximizing our entropy production <u>now</u>. For us this might be all out global nuclear warfare. However, I think this might be short sighted. It would leave vast stores of energy gradients -- like all that oil -- still untapped, perhaps never to be tapped until the sun burns out. It also fails to notice that there might be better ways (from our own selfish point of view as organisms) to maximize entropy production, as in huge construction projects like the Three Gorges Dam. As well, we cannot help but note that this dam, when finished and protecting China from disastrous floods, as well as doling out energy in a(n all too) temperate manner, will have become a metastable configuration now bottling up great amounts of potential entropy production, which could be realized only by its collapse. We would need in the first instance comparative studies on the entropy production, or, more directly, the gradient dissipation power, of various courses of action -- something probably doable even now.

It might help as well to examine more closely what our own selfish motivations might be. As relatively long-lived organisms, and especially as sentient ones with language-constructed historical selves, we do not wish to burn up too fast, and, indeed, a leisurely old age surrounded by sentimental objects is still appealing. As carriers of various traditions, we find existence fulfilling and, most often, continuance a value. In the present context, this memorializing is nothing less than a sign of original sin, a cleaving to the trespass of material being -- especially extended material being -- filling portions of a space that beckons instead (and as a result) for equilibrium. We exist because an explosion was so violent that it resulted in some local assembly rather than total global dispersal -- something repeated in smaller scale when imploding stars forge heavy chemical elements.

So, to be sure, something must blow up, but need it be us? We could sacrifice other entities, mostly in less violent explosions, and even in slow dehydrogenations, as payment for our own continued, guilty, existence. This is, of course, more or less what we are doing now.

Taking stock: Our dilemma is to either build or burn. We think that we choose to build (even while burning ferociously!) In any case, building involves burning up gradients, and leads ultimately, as well, to senescent forms that will need to be burned up in turn. Of course, we will cleave to our traditions in any case. For this reason, their origins need to be constructed carefully. Here again we face the dilemma of whether they are intrinsically valuable because they are products of choice, or basically meaningless because they are the products of chance. Just as we cannot cleanly decide materially between building and burning, so we cannot here choose logically between choice and chance. Species, races and genotypes have all been constructed by Darwinians as products of chance (mutation -> selection, as well as random genetic drift and accidental isolation of populations), but sociocultures have implicitly been taken to be the products of choices.

My tentative suggestion is as follows: note again that there is, in highly evolved, complicated systems, a stage in between immaturity and senescence -- the mature stage. This stage (unknown in abiotic systems like tornadoes) uses significant energy flows and considerable embodied information to maintain itself, for a while. My suggestion is, simply, to try to preserve this stage of our socioculture as long as possible. We need to oppose the capitalist notion of grow or die -- even though this would be acting in direct opposition to the Second Law of thermodynamics. Here I join Thomas Henry Huxley (1898), who took a similar stance against the ethical implications of Darwinian evolutionism, which he acknowledged as being plausible. The mature stage is a product of informational arrays. The senescent stage is a product of too much information (Salthe, 1993,a). We need to resist getting information bound, and we need to resist hooking our system up to the most powerful possible energy gradients (thereby rejuvenating it). We need, in short, moderation in all things. We need to preserve, not conquer; we need to contemplate as much as to act. We need to judiciously discard as much information as we acquire, or we need to condense older information. We need to abjure both evolution (into senescence) and revolution (into rejuvenation). We need an Age of Reclamation, a pulling together of what the peoples of the world have produced, focusing it into a moderate, non-growing civilization. We are almost at the point where this might be possible, as the Western

World has almost eliminated possible organized opposition to its hegemony. If there were any other system as powerful, that system would consume the Western World if the latter went in for moderation, but there does not seem to be such and entity of equal magnitude. And so we will soon have a window of opportunity to conserve our traditions in a long drawn out maturity. We need neither a bang nor whimper, but to seek a continuing golden age.

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