ROBERT ROSEN'S ANTICIPATORY SYSTEMS THEORY: THE ART AND SCIENCE OF THINKING AHEAD

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Science, at its best, is supposed to be a set of tools, constructed by humanity for use in improving our quality of life, our chances for survival, and the survival and welfare of our progeny. In all of those pursuits, sustainability really is not optional; it is *required*. Sustainability must be the cornerstone for any kind of planning for future outcomes that we want to use our science to achieve. To do other than that is both irresponsible and foolish.

However, even when our intentions are planted firmly on the tenets of sustainability, we still need to be able to trust the tools we intend to use to do the jobs we are asking of them. Chief among those jobs is scientific modeling and prediction. Any proposed therapy we want to consider implementing in local or global ecosystems, for example, will need to be tested in models first—before we decide to risk implementing such a therapy in the natural world. We need to know that the models used are actually capable of accurately predicting *what would happen* in ecosystems, in social systems, physiologies, psychologies, etc. All of these systems involve living organisms and/or interactions between living organisms in critically important ways.

Currently, our science is based on a presumption, buried deep in the foundational theory upon which all science rests, that all systems in the universe are "just like machines" and, therefore, can have only the behavior potentials that machines have. All machines are purely reactive in their behavior potentials: In such a world, causality flows from past through present towards future—just as time is also presumed to do—in a linear, unidirectional fashion. In that scenario, there is no way for the future to act, in any causal way, on the present. But, that is clearly not how life works (The fact that this paper is being written now, months before the conference it is to be presented at, offers one proof of that.)

If life is not "purely reactive", what does that mean for science? Do we hold on to our scientific presumptions about the universe and conclude that aspects such as life and the human mind must therefore be *supernatural* in origin and potential? Or do we turn around and take a hard look at our tools, instead. What happens if we discard the notion of "The Machine" as an appropriate model for all systems in the universe? The reactive paradigm of science need not be discarded: It will remain just as applicable to certain types of systems as it ever was— *BUT*—we are no longer limited to only that. We are then free to expand our scientific capacity in order to study relations between interacting "things", study the impact of changes in such relations on causal outcomes, and to develop some new tools that will be capable of helping us truly learn about the anticipatory nature of living systems. This will allow us to build far better models of them, as individual organisms or as populations within environments, which CAN accurately represent their true capabilities in interactions of myriad types in the natural world.

Only then will we really have a hope of being able to trust in the predictions our tools offer us as we try to decide how to proceed. In short: *We need to think ahead*, individually and collectively—more so now than ever before in human history. The margin for error is growing thinner as our population increases. The old dictum from carpentry applies: Measure twice, cut once. Just as importantly, we will need the right tools for the job. It is a salient truth that the issue of "sustainability" is not a reactive concept; it is an *anticipatory* one.

PRELIMINARIES

Taking an objective inventory of our tools: There are serious implications for science which come out of Robert Rosen's discovery, in the early 1970's, that all living organisms are examples of naturally occurring "anticipatory systems". Human minds are clearly capable of anticipation and yet our own scientific models tell us that it is impossible in this universe. That impossibility, however, is based on an artificial constraint that lies at the foundations of science, itself; the Machine Metaphor of Rene Descartes. This is an incorrectly encoded model of reality. The mischief that the machine metaphor has caused in the development of science really cannot be understated. It is the single biggest impediment to our own survival as a species because it makes our scientific tools (i.e., Reductionism) unreliable when applied to biological systems.

The development of Anticipatory Systems Theory therefore represents a seminal work at the frontiers of biological science which actually belongs at the foundations of Science, itself. Living organisms are natural (i.e., not human-constructed) systems and exist in the same universe as atoms, which are also natural systems. *If living organisms are capable of behaviors that atoms are not, then living organisms have the capacity to teach science something about the <u>nature</u> of atoms—and of the universe, at large—that atoms do not have the capacity to teach science about the nature of living organisms.* Consequently, a science based entirely on the practice of breaking everything down into its constituent parts/particles for study (which is what we currently have) is going to be inadequate, because when you break a living organism down into atoms, and study those, you will not be able to understand why it was alive as an intact organism. There's clearly something more involved; something else here along with the material particles.

This situation—in and of itself—is telling us something fundamental about the potentials of our universe. It is telling us that we can learn about these potentials from a study of the dichotomy embodied in the truth that living organisms are capable of behaviors that atoms are not, despite the fact that organisms are made up of atoms. There are very good reasons for wanting to understand why this is possible. One reason is that we are living organisms. Another is that we depend entirely on other living organisms, directly and indirectly, for our own survival and sustainability.

It is in our own best interest, therefore, to build a larger paradigm for our science such that the tools will be able to help us make substantive progress in our understanding of how life works, of what we are as living organisms (and as human beings), and *why* we are this way. The most pressing issues facing humanity in the coming decades involve the interactions of living organisms to some degree. If we want future outcomes to be more positive than our current situation, then we need to understand how to promote beneficial changes in these highly complex, anticipatory interactions-- without provoking unpleasant and/or dangerous side effects. Science currently does not know how to achieve this *except by trial and error*.

THE INGREDIENTS OF LIFE

What are the ingredients of life? Are they the same ingredients that make up any given organism on Earth? If we restrict ourselves to material ingredients, like the recipe for a cake, then it is clear that Earth's organisms are all over the map as far as their material ingredients go. For example, humans have blood based on iron, but octopuses have blood based on copper. The vast majority of organisms don't even have blood. If we break it down even further, say all the way to the atomic level, we will have a list of elements—the same elements that were present here on Earth when we developed, here. But elemental molecules and atoms are not alive. Scientists have been trying for quite some time now to generate life, from scratch, mixing elemental ingredients together in so-called "primordial soup" experiments, but these primordial soup kitchens always fail to produce life. What are we missing? Whatever it is, it must be related to the "something else" that exists *between* the atoms of all intact living organisms: Something which is not material but upon which all matter—indeed the universe, itself, as we know it—depends for existence. The question, then, is *What could that possibly be?* How can we study it if we don't know where or how to look for it?

There is a hint to be found in the situation of allotropes of elements. Allotropes are molecules in which the component atoms are all the same element. The allotropes of carbon are particularly revealing because they represent both the hardest natural material known (diamond) and the softest (graphite)-- and yet they are both pure carbon. They have exactly the same atomic ingredients but that is not apparent from direct experience of these two materials. How is it that they can be so different from one another? Physics, the science that specializes in fundamental atomic behaviors, currently cannot tell us the answer to that question. Nor can Chemistry. Robert Rosen's answer came from outside of both those specialties. It turns out that the same phenomenon is presented, in a massive way, in biology. His answer, however, turns out to be applicable even here, at the level of atoms and allotropes: It is the *organization* of a system that makes the difference.

WHAT IS "ORGANIZATION"?

Organization is an amazing thing: It is able to make something completely different out of the same material ingredients (allotropes) and is also able to make something completely the same out of different material ingredients (organisms). Why is that possible? Frankly, it is still the case that, even today in the 21st Century, nobody knows why. But the fact that it IS possible represents an aspect of reality, and of causality, that clearly needs to be studied, scientifically. What is it about organization that has the power to change the behaviors and potentials of the intact system so dramatically from the sum of the potentials of its constituent parts? It is worth taking a moment to talk about the concept of organization as a systemic term and arrive at a working definition.

The material ingredients of any system are certainly part of its organization, but those ingredients and the material structure of the intact system are only a small part of what the term "organization" means. The way a system is organized subsumes material structure. Structure, then, has the capacity to act as a distinct component, within the overall organization, in its own right. Organization must also necessarily include, as ingredients or components of the system, all the relations between material parts, all interactions (specified according to those relations), all effects of those interactions within the system, relations between the effects, interactions between the effects (as specified according to those additional relations), etc… and all non-material ingredients, like time.

It may seem odd to list *time* as an ingredient but multiple aspects of time (sequence, rate, simultaneity, concurrence, chronology, etc.) are definitely involved in generating the nature of any effects of interaction, as well as flowing through any interaction, itself—and there are multiple interactions within any natural system. The more complex the system is, the more time seems to matter.

So, the term "organization" refers to all these ingredients/components, be they material, non-material, or relational and all the constraints imposed—and new degrees of freedom created—by those ingredients *as organized*: i.e., with time flowing through the system (meaning all interactions are active and ongoing, with all effects of such interactions present and able to interact as well, according to relations which can only exist under these conditions)—and including also the relations with, interactions with, and the effects of environment on the system, through time. This is not intended to be a fully comprehensive or technical definition of organization, but hopefully it gives the reader some idea what the essence of this aspect of "system-hood" means.

In this light, the intuitive statement, "a complex system is more than the sum of its parts" makes perfect sense—as does the realization that taking a living organism apart to study it loses nearly all of that "something more—something else" mentioned earlier. Indeed, most of what makes an organism the way it is can only exist while the organization is intact. Consider, for example, the role played by such seemingly incidental aspects as body heat in mammals. Body heat, of a specific temperature with a very narrow range for each species, must be recognized as an essential component of the organization of certain living organisms. The same is true for the electricity pulsing through our bodies, which is somehow also generated by our bodies. Medical science generally does not refer to electricity as a component of our circulatory systems and yet a heart cannot beat without it. There are many other examples of such components of human physiology which can only exist when the systemic organization, including the relations with native environment, remains intact. This reality is even more apparent when we consider the universal living functional capabilities of metabolism and repair.

RELATIONS

A violin and bow can produce intolerable noise or sublime music, depending on how the two interact with each other, and a talented musician will have developed from the former to the latter, by progressively learning how to modulate that interaction. Most of us have learned, through our own direct experience, that the way things interact is critical if a certain outcome is desired. So, it isn't enough to simply put things into interaction without specifying how that interaction should take place.

The way things interact is a *relational* aspect. Relational information is often relegated in science to the category of preconditions, "extraneous details," or "contextual information". In journal articles and research descriptions, such preconditions and contextual details are frequently passed over, as human attention is drawn towards what looks like meatier aspects of scientific experiments. Worse: In the misguided quest for scientific objectivity, matters of context are often discarded as subjective information. However, "scientific objectivity" is a myth. Wherever biological systems are concerned or involved, there is no such thing as complete objectivity. Science is a human construct and human pursuit, therefore it will always involve at least one biological system—the scientist—even when his/her area of science does not pertain to biological systems. This must not be forgotten. Just as the difference between noise and music is a difference caused by a change in the relations between violin and bow—those relations become a part of the causal outcome in the same way that Einstein's observer becomes part of any measurement he/she makes.

Another example: The difference between burnt food and cooked food is a relational one. Two things are interacting—food and heat. If we keep the heat source and the food exactly the same but vary the distance between the two during otherwise identical interactions, the outcomes will be different. If we vary the time relations (how long the interaction continues) but keep everything else identical, the outcomes will again be different. By tweaking the relations, we can find the optimum organization of relations, material ingredients, and time to achieve the desired outcome. But consider what happens if we next vary the material ingredients in some way: If we increase the intensity of the heat, for example, then we won't be able to use the same relations we used before, to cook our food without burning it. Likewise, if we keep the heat the same as it was before, but increase the mass of the food to be cooked, a similar problem arises—the prior relations of distance and time won't be appropriate. However, if we vary the relations according to the changed ingredients/components, we can achieve the exact same desired outcome as before. Perfectly cooked food.

In this way, the organization of systems is capable of generating the same patterns of manifested behavior via systems possessing entirely different material ingredients.

LIFE

How do we recognize life? How is it that we are able to know that some system is a living organism or not, when we observe it? We are, somehow, clearly able to do it—and have even built a whole wing of science to study such systems: Biology. It was once thought that the biological sciences study a class of systems that are very unusual in the vast, *universal* scheme of things. Earth is the only place we've found systems such as ourselves. But the truth is we haven't really had a decent look around the universe, have we. We've only peered at it, from afar, through various lenses, looking for signs of life. What are those signs? And, are our "lenses" appropriate for seeing them?

Currently, science looks for evidence of water on other planets, assuming that water is necessary for life. But, is it? If organization can generate the same manifested behavior patterns via different material ingredients, then why should we presume that water is necessary in any way? The way that living systems have formed on Earth has included the materials that were present here as ingredients. If life develops on other planets, it is logical to hypothesize that those systems will reflect the materials that existed wherever they formed. So, the question remains: How do we recognize life?

I think what we recognize is actually the anticipatory signature, which is a manifested behavior pattern of all life. All living organisms manifest the same pattern and we are able to recognize it and we call it "life". My father, Robert Rosen, in his work distilled the essence of that pattern down to two functional capabilities which, in his view, were the bare minimum necessary and sufficient for life: Metabolism and Repair. This is true, he said, regardless of material ingredients or material form; all living organisms manifest these two capabilities. He created a relational model of organisms based on metabolism and repair, referring to them as "(M,R)-Systems". To reduce any further than this, he warned, would destroy what we seek to understand.

The functional capabilities of metabolism and repair are both generated from within the organization of living systems, which gives us a benchmark; a partial diagnostic, to use in determining whether or not any given system of interest is alive. Another characteristic is that living systems always interact with their environments in accordance with these two essential functional requirements. Guiding the whole endeavor are two fundamentals which also emanate from the organization: 1.) A systemic definition of "self" and; 2.) A systemic definition of optimality, or "health", for self. Everything else that any given organism does will be based on those two, organization-based definitions. Already, though, it becomes clear that living organization is based around what looks like a prediction. At root, it is a built-in prediction of a future.

Organisms, at every level of their being, behave in ways that contradict the accepted scientific understanding of how time works. They consistently initiate behavior in the present according to events which have *not yet occurred*. Living behavior is rife with examples of the future being pulled into present behaviors, as a causal force. Anticipatory Systems Theory proposes a coherent scientific foundation for such behaviors and explains how and why organisms are able to do this. If correct, it requires us to reassess certain fundamental assumptions of science, such as the Arrow-of-Time. Our current mainstream scientific model of the universe, as of 2009, not only cannot explain living behaviors, but actually tells us that such behaviors are not possible.

ANTICIPATION

According to Robert Rosen, an anticipatory system is one which can encode and build models of self and environment for the purposes of system guidance and control, and can utilize those models in order to change behavior in the present according to predicted future events or conditions. At first, it may seem odd conceptualizing certain types of organisms as being capable of encoding information, much less building and utilizing models made from it. Consider, for example, single cellular organisms like bacteria, algae, amoebas… How do they "encode information"?

How they do it is not the issue, really. There are probably multiple (perhaps even infinite) modes for encoding and decoding information in living organization. The fact that organisms must be doing it, however, is the critical issue to talk about. Most people no longer argue with the notion of genetic information as being "encoded information"—and we have a wealth of examples of different organisms which have genetic information as part of their organization. Human beings have it in all of our body cells, but we didn't deliberately put it there. We had no say in it. So, it shouldn't be such a stretch to consider that there can be other types of encoded information as well and that it requires no volition on the part of the organism, whatsoever. Science currently doesn't really have a clue how genetic information gets encoded/decoded in living systems, or how life, never mind DNA/RNA, came into being in the first place. But, knowing that is not necessary in order to learn about how it works. I think that the same is true with regards to "anticipation".

Examples of anticipatory behavior in living organisms are, literally, right in front of us all the time and it has been my experience that, once people begin to recognize it for what it is, they quickly see that it is rampant. In truth, our own human behavior is so much more understandable from this perspective (including human pathologies, neuroses, and psychoses). But, my favorite examples come from organism species which can't "think". When there is no question of any human-type conscious awareness or thought process being involved, then it becomes much clearer what is actually going on. Therefore, the organism species in which I think anticipatory behavior is best revealed are all plants.

Plants are infinitely useful organisms which, as a class, have an innate, symbiotic relationship with us (even poison ivy): They're main metabolic activity (photosynthesis) requires carbon dioxide as a raw material and produces oxygen as a waste product—and our metabolic processes are the exact mirror inverse of that. We balance each other, like Yin and Yang. Most of our technologies and economic systems also rely on plants, directly or indirectly, including the petrochemical-based ones. Oil is the sequestered carbon residue left behind by the photosynthesis of plants from millions of years ago, transformed by natural processes over time. In terms of illustrating anticipatory behavior, plants prove to be particularly helpful, once again. There can be no doubt about what generates their behavior. Plants do not have a brain or a central nervous system. Indeed, they differ from human beings in almost every way we can observe and yet we have no doubt that they are alive. Plants also offer the benefit of the fact that they are familiar to all of us from a lifetime of intimate co-existence and interaction. Even people who never garden and don't like the outdoors have amassed a wealth of knowledge about various plants because we eat them (and/or smoke them, wear them, clean with them, rub them on our skin, etc.) every day.

EXAMPLES

The contrast, on our planet, between the seasonal weather cycles of the mid-northern hemisphere and that of equatorial regions, is quite pronounced. Plants which evolved in equatorial climates cannot handle northern winters, as any gardener will know all too well. Gardeners tend to call such plants "annuals" because they die with the first frost in northern gardens, despite the fact that they may be able to live for decades in their native habitat and climate. The difference, in autumn, between the behavior patterns of plants which evolved in northern climates compared with the behaviors of tropical transplants, illustrates a great deal about anticipation in action. Most native northern plants are preparing, in autumn, for winter dormancy; ceasing photosynthesis, dropping leaves, pulling sap down into roots or increasing "anti-freeze" chemicals in plant tissues, etc. They begin to do this in late summer, long before cold temperatures arrive, and continue through autumn. Tropical plants, in contrast, continue blooming and growing right up until a killing freeze occurs—at which point, they die. Why such a difference?

Anticipatory Systems Theory postulates that all organisms have encoded information pertaining to self and environment, through time, as part of their organization. The behaviors generated by these encodings—acting as a set of predictive models—is visible in behaviors we refer to as purely "instinctive". Instinctive behaviors can be extremely detailed and intricate, so much so that it sometimes astounds us human beings. We tend to believe that we rely far more on what we call "learned behaviors" than on instinctive ones. Whether this is true or not can be debated. However, learned behaviors are also encoded. They are just encoded differently than instinctive ones are. So, while it sounds strange to say that a maple tree instinctively "knows" what season is currently underway and also that winter follows autumn, that is essentially the case. Its internal models predict next phase from current phase. The trigger for dormancy, in Sugar Maple trees for example, is decreasing day-length.

In contrast, the tropical plant "knows" nothing about winter because it's encoded information doesn't include anything about the weather cycles at northern latitudes. Decreasing day-length is an anomaly, as far as its models are concerned. Each plant only has information from its native habitat encoded. Hence, the tropical plant cannot anticipate winter, it can merely *react* to winter once the season arrives—and the plant does so *by dying*. Clearly, the ability to encode and predict, accurately, offers a boon for survival over reaction. Hence, the concept of "fitness" comes in and can act to shape anticipation. Because of this, anticipation also becomes one of the primary drivers in the processes of evolution and adaptation as well as a product of it.

Human beings manipulate plants via their encoded models, for our own benefit or to suit our own ends, all the time. Whole industries have been built on this, in fact. How do we ensure that there will be a huge stock of Poinsettias in bloom right in time for the Christmas season or Easter Lilies in bloom in time for the Easter season? We mimic the behavior of their native environments—as it would be at the time just prior to their natural bloom cycle—which triggers them to change behavior just as it does when they were actually IN their native environment *at that time*. In other words, we trick them. But, they don't have a brain. So, what are we tricking? We are tricking their somatic models (which are the evolutionary precursors to the human brain).

In many cases we have even figured out exactly what a particular plant species' environmental triggers are for a specific desired behavior in the plants. In that case, we can just use those triggers rather than going to the trouble and expense of reproducing all aspects of their native habitat's behavior at the target phase. Sometimes, all we need to know is how long of a "cold phase" various seeds require before they will be able to germinate or that certain bulbs require in order to set blooms for the next growing season. A timed stint in the fridge will do. This kind of information is even useful for such things as growing hydroponic tomatoes inside glass houses during the long northern winters; with artificial lighting augmenting the shorter days so that the plants perceive they are at the "right" time to bloom and set fruit.

Requirements or constraints such as these are built-in to all organisms. The fact that we can trigger these kinds of error behaviors in plants, reliably, according to each species evolutionary habitat, reflects the presence of information pertaining to multiple aspects of the native environment within the organization of these organisms. What we're really doing is manipulating them according to the predictions of their encoded models. Yet, most botanists and horticulturists know nothing about Anticipatory Systems Theory. How much faster, and further, could plant science progress if it was properly guided, rather than relying entirely on trial and error? A great number of products in the pharmaceutical industry are, either directly or indirectly, extracts from plants.

SOME NON-PLANT EXAMPLES

Monarch butterflies are triggered by seasonal changes, as well. Each autumn, in North America, they migrate south for the winter. In fact, the monarchs that hatch in my neighborhood have to travel all the way from western New York State to a patch of forest in the mountains of central Mexico for the winter months, and then all the way back north again for the following spring! They manage this epic annual journey of 2,500 miles—each way—using *only* instinctive information. How do they know where to go, much less how to get there? It isn't learned behavior (even though they do have a rudimentary brain). It is clear from their life cycle that no parental teaching is involved: They are on their own as soon as the eggs are laid. They don't have GPS. They don't consult maps. They don't have the option of pulling into gas stations to ask for directions. The amazing truth is that they simply are born "knowing". But their knowledge is the same instinctive kind as evidenced by the behavior of plants. It derives from a set of somatic encodings which correspond to their evolutionary habitats over time and which, collectively, are able to predict for them the next behavior of that environment according to the current behavior of it. Everything they do, then, must be considered in terms of their encodings and the interpretations generated by them.

Human beings have somatic encodings too. In fact, we have all the somatic predictive models that living organisms, as an organizational class of systems, are both guided and constrained by. But, we also have an additional set of options due to the evolutionary development of intelligence. I believe the emergence of conscious awareness, or "mind", is an evolutionary extension of the anticipatory capacities of life, itself, but in humans it has progressed to the point that it represents a *second* anticipatory system in its own right which is co-evolving with, and surpassing, the original (somatic) one.

THE DANGERS OF ANTICIPATION

Our species represents a relatively new evolutionary development whereby we have what I consider to be two distinct sources of predictive models—two anticipatory systems within a single organism. What intelligence allows an organism to do is encode new models (learning) and adapt to environmental changes "on the fly"—in real time—rather than having to wait for evolutionary processes to generate those adaptations in the flesh. The somatic encodings we have are the same category of encodings that all living organisms must necessarily possess, but the human mind represents another, which can (and often does) conflict with the first. Indeed, a great deal of human pathology is likely caused by the battles for supremacy between our two evolutionary steering wheels.

This illustrates something about the dark side of anticipation. Because our bodies have multiple aspects of our evolutionary environments encoded into them, we now must maintain certain aspects of those prior environmental conditions or else we run into dysfunction. Why dysfunction? Because the models don't stop interpreting current behavior of environment according to encoded information. If the behavior set of our actual environment changes too far beyond what our somatic models were encoded *from*, the interpretations of current behaviors of environment are bound to be erroneous and the predictions will be, also. Yet, they can still trigger changes in our physiology!

The need for sleep is generated by encodings about the diurnal behavior of our environment, incorporated into our organization. The pattern of night and day, through the seasons, is a rhythmic, repeating cycle of time, *over* time, which we evolved with from the beginnings of life on this planet. If we, for whatever reason, avoid sleep for long enough, the body will eventually take over and force the issue, just as intentionally holding one's breath for long enough will result in loss of consciousness and the function of breathing will begin again, under the influence of our somatic requirements. If we use drugs and/or technologies to avoid giving in to our somatically mandated requirements for sleep, then past a certain point the body and mind actually begin to unravel. Dysfunction ensues.

The point, however, is that human beings actually CAN (and do) extend our will over the instinctive drives generated by our body/brain in this way, even to the detriment of our own health. But there is an up-side: By the same token, we are also able to control primal drives, such as tribalism, aggression, and unbridled sexuality, that have proven to be counter-productive in the modern world and we can also use our intellect to build new models for peaceful social interaction. As a species, we are characterized as much by our capacity for altruism as we are for the natural opportunism of life in general. It stands to reason that we have a better chance of overcoming our baser urges if we understand the anticipatory nature of their production. Our survival, as a species, will likely depend in some critical way on our ability to realize that the vision of ourselves as somehow separate from the natural world is a false one. We are related to all living organisms in fundamental ways and it is in our own best interest to consider the welfare of the biosphere in everything we do or plan to do—locally *and* globally.

LIFE, KNOWLEDGE, AND WISDOM

As organisms, human beings have vestiges of our earliest evolutionary environment, the sea, encoded into us. That our blood is exactly the same salinity as the oceanic environment we came out of is, in my view, a significant fact. We have even more of our later evolutionary environments encoded, as well, which may be observed in the body. We have lungs for interacting with atmosphere instead of water, and the nature of our skin is no longer appropriate for life in an aquatic environment, both of which illustrate environmental relations as influences on morphology. In this same way, it is possible to determine that whales were once land animals which then returned to the sea. Their bodies are in the process of changing back in interesting ways; they still have lungs, but their nostrils have migrated to the top of their head, for example.

There are many more somatic encodings in all organisms which are not so readily visible, but are equally tied to relations with environment and their effects—particularly when dysfunction sets in—can be devastating. Our dietary requirements represent a clear set of examples. If we stray too far from our evolutionary encodings—too much processed carbohydrates, for example—we develop all sorts of health issues, some of which are ultimately lethal. But there are some somatic encodings which are subtler, still. I discovered one of them fairly recently and it astonished me: The aforementioned requirement for sleep is not the only encoded reference within our physiology pertaining to the diurnal behavior of our native habitat: we also have a daily requirement for DARKNESS.

It turns out that human beings have light sensors in the eyes that have nothing to do with vision. Those sensory cells are not hooked up to the visual cortex of the brain but, rather, to the pineal gland. The pineal gland is the primary source of the hormone melatonin, which has long been considered a regulator of biorhythms. It was while researching time signatures in organisms that I came across the information that melatonin has many other functions within our physiologies, as well, including regulation of multiple hormone cycles and immune system functions. In fact, one of the most critical roles of melatonin within the human immune system is an oncostatic one: a protective capacity against cancerous changes in body cells, via several different modes of action.

Artificial light at night, therefore, represents a significant threat to human health because melatonin is only secreted during dark-phase time. Any light hitting the inside of the eye, at any time during the night, can actually shut down melatonin production for the rest of the night. It is pretty clear that our bodies are interpreting the situation thusly: *If light, then morning.* Under these circumstances, the rising number of cancer diagnoses in developed countries, and particularly among night-shift workers, is no surprise. The truth is that artificial light, in and of itself, is not toxic to us at all. The *time relation* is actually the source of toxicity, and this can only be fully explained from the perspective of Anticipatory Systems Theory. Hence the field of Medicine would be one of the first beneficiaries of the recommended expansion at the foundations of science.

EVOLUTION AND SUSTAINABILITY

The strongest drive in all living organisms is to survive—according to what our encodings define as "self" (be it individual life, reproduction and/or offspring, some collective like "the family", "the pack", "the hive", etc., or the intellectual self). However, human beings have evolved the capacity to use the mind to override even the somatic encoding for survival and commit suicide if we so choose. That may seem an odd way to enhance our survival, as a species, but so far this evolutionary experiment into increasing intelligence-as-dual-anticipation has worked spectacularly well. Human beings are currently so overpopulated (and increasing) that we are in danger of overwhelming the resources of our environment to support us in many localities, and may be progressing to environmental systemic failure on a global scale, as well. Unless we change how we are interacting with our environments (locally AND globally) in fundamental ways, we are currently still progressing along a path that is not sustainable.

There has been a great deal of argument among the scientific community and in the mass media over whether "Global Warming" is a false prediction or not. It may be. What there is no argument over, however, is that human activity over the last few centuries has measurably altered the composition of Earth's atmosphere. There is plenty of argument over what that *means*, but there is also general agreement that this change has occurred within a time-frame that is unnaturally short. Natural processes, such as the rise of plant life on primitive Earth, can (and did) change the composition of the atmosphere, too—but those changes occurred over eons of time, allowing for the relatively slower process of evolutionary adaptation to take place.

The only other times in Earth's history that this kind of rapid global change has occurred was due to catastrophic terrestrial geological events or asteroid collisions. Those rapid bisopheric changes, according to the fossil record, induced mass extinctions of species across the planet. Anticipatory Systems Theory offers new insights into how this phenomenon characteristically happens, and also sounds the alarms—telling us why and how *rapid* change in ecosystems is *always dangerous*.

In a relational, interconnected web of life, like the biosphere, there is no way that changes in atmospheric composition will not also generate myriad changes in other, related aspects of the web, which will then propagate further, in a cascade of rapid change. In this way, whatever damage is caused initially can magnify and travel much further, affecting species that otherwise would be undamaged by the changes in atmospheric composition, alone. This truth is rarely included in any cost analysis conducted by economists, to their—and our—detriment. To be fair, though, science currently does not offer economists the tools nor the reasons for studying the impact of changes in relations between things.

The good news is that the human capacity for learning and model building gives us an edge—and it is an edge we can extend to the benefit of the biosphere, as well. We have a real shot at imagining and implementing changes in our own ways of doing things such that our path, as a species, becomes one of sustainability and the related global systems of atmospheric composition, water vapor, and temperature can all restabilize before extreme oscillations set in.

That's my hope and my reason for continuing my father's work. I have children who are going to inherit this world along, perhaps, with yours. I think they're going to need tools they can truly rely on.

Endnotes:

Robert Rosen's book, Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations, was written in the mid-1970's and originally published in 1985. It has been out of print for a number of years but an expanded Second Edition is currently being finalized for publication and will hopefully be out by the end of 2009. Copies of the original text are being made available on disk to conference attendees and ISSS members for a discounted fee, during the conference. Come see me if interested.