

# **R-THEORY: A FURTHER COMMENTARY ON THE SYNTHESIS OF RELATIONAL SCIENCE**

**John J. Kineman, Ph.D.**

Ecosystem Sciences Division, CIRES  
Cooperative Institute for Research in the Environmental Sciences  
University of Colorado , UCB-216  
Boulder, Colorado 80309-0216  
john.kineman@colorado.edu

## **ABSTRACT**

A plain language description of the author's 2010 synthesis of the late Dr. Robert Rosen's relational complexity theory is provided to explain some of the implications of that theory for current and future science. Priority directions for research are also discussed.

## **INTRODUCTION**

In over 300 years of science in the West we have perfected a method of 'seeing' nature as a dynamical system of efficient and material causes (using the terms of natural causality established by Aristotle), constrained by the unchanging parameters (constants and metrics) of a single, universal context that supplies formal cause (which we accordingly attempt to represent in a complete mathematical structure or 'formalism'). This view is generally referred to as the Newtonian, classical, or mechanistic view of nature, and it has dominated science up to the post-modern era. Aristotle's final cause was left out of this view entirely as belonging to the realm of the mystical, and (before we accepted duality in physics) formal cause was thought to be fully describable as one closed system of logic applying to the entire universe.

In Rosen's collective works, he showed clearly that this mechanistic view of science is associated with a category of general mathematics that allows, and restricts us to, creating simple approximations to nature's complex behaviors. In his work, Rosen explored the implications of formal and final cause, which seem to be critically involved in establishing, and thus defining, complex systems and especially in characterizing living systems. And yet formal and final causes have not been well understood within the scientific community. In fact, it can be said that we have not had a useful theory of these causes in the sciences to date. To a very large extent, Rosen's methodical developments were aimed at developing a theory that would account for the effects of formal and final causes in our scientific images of nature, and thereby provide a more rigorous foundation for complexity science. Exploring these implications, as attempted in summary form here, may provide a more integrating view of Rosen's relational theory and hopefully serve as a guide to not only its critical value in science, but to future directions for its development.

## R-Theory

There is no suggestion in Rosen's work that the approach of Western science has been generally wrong; only that it is limited, lacking consideration of important aspects needed to represent the case of life. He described a "simple" system as one that can have a complete model; a criterion that characterizes non-complex, computable, dynamical or mechanistic systems. Simple systems involve efficient and material causes under the presumption that they exist within a single formalism; that is, implicitly, within a completely describable system of formal cause in nature. Rosen described such assumptions as "too impoverished" mathematically to allow modeling complexity or life, and yet "...still the only thing we know how to work with". The aim of much of Rosen's work was to provide tools to allow us to work with more.

We can infer from the sum of Rosen's work that the inadequacy of the dynamical view is rooted in its simplification of formal and final causes; its attempt to overlook or reduce them to efficient and material laws that might be made complete in themselves. In contrast, Rosen's relational theory suggests that it is possible to expand science by re-including the contextual causes that mechanism left out. If we do so, we see nature itself establishing and realizing its own formal paradigms. In other words, systems can establish the context for other systems and therefore formal cause can vary, ensuring that no single descriptive formalism can be complete.

Rosen brought us from the limitations of the dynamical system description to the edge of complexity, which he saw as existing mathematically in the infinite limit beyond what any combination of mechanistic system descriptions is capable of representing. The mechanistic approach has been a powerful method for gaining knowledge about certain aspects of our natural world and for supporting the development of technology precisely because it selects phenomena that have a simple explanation. It presumes that events have a single past configuration and a single future one, such that the future configuration of a system can be predicted completely on the basis of past events and the fixed laws, or as it was modified, fixed probabilistic laws of a universal context. Any finite combination of such system descriptions may give approximations or simulations of events, but the cost of assuming either deterministic or probabilistic simplicity is to be unable to represent the full range of entailment possibilities, particularly the aspect of a system that we refer to as wholeness.

We can see that cost in terms of the presumed separation between an 'observer' of nature – a scientist, perhaps – and what an observer can observe. In effect, that epistemological separation is what establishes the mechanistic view, because it uses a natural system – ourselves – to describe nature as a set of external events, which then appear to belong to a universe that has been separated from the context in which we perceive it. The more we formalize that view, the more nature appears to be separated from all information contexts, because, ultimately, ours is natural. In other words, what we observe is what can be seen, not what sees. If we do not then reason, from ample evidence, that nature 'sees' by modeling itself, we will not include that aspect of nature in our scientific models. By 'see' or 'perceive' is meant an information relation that is fundamentally different from the kinds of interactions we can observe of material objects; one that is, in contrast,

## R-Theory

contextual. Indeed the mechanistic interactions describe an important aspect of natural process, but there is more to nature (and implicitly science) than can be seen from a single perspective; there is also the context and the relation between the two. It has not been immediately obvious, of course, how to describe the larger view; what analytical method can be used to describe relations without either simplifying them to mechanisms, or making them seem mysterious. Rosen's work addressed that middle ground that has eluded us for centuries. These causes then appear in a study from apparently mysterious causes

Translation between externalized events and internalized representations (notably ours) is the essence of science and scientific philosophy; that is, how we will relate "the only thing we know how to work with" (perceptions of an outer world) to inferences that necessarily exist in an internalized information context. Rosen claimed that the translation that is appropriate for mechanisms is not appropriate for complex systems. When analyzing a complex system the assumption that there are no natural information contexts other than our own can no longer be maintained, because that assumption is too highly selective of what we can thus describe or model. Systems that are viewed in the absence of their own internal information relations are seen as acting only through their pre-determined events; for what exists before an event and between events is the essence of information and formal cause. These causes then seem to appear from a mysterious source, to be set aside from knowledge as error or uncertainty.

What seems confusing to us is that some systems retain self-determining relations and some do not. In the latter case, they are what gives nature its persistent forms, and what mechanistic science was focused on. The descriptive simplicity of that view has been extremely useful with regard to predictable aspects of nature and with regard to machine technology. Machines are designed to separate otherwise complex, generative models from their realizations; to, in effect, place operation of the machine in a different system than its production, so that the operation will reflect the original design without altering it beyond certain limits. In complex systems, the context of production is co-mingled with the context of operation, such that a change in one will result in a change in the other. In a living system that principle results in adaptation and evolution. However, when we selectively observe mechanical systems in nature, we then see nature only as a pre-designed artifact, exactly as we chose to see it. The process of realization of models, which is the natural process of definition, is therefore of primary interest in Rosen's theories, but so is the more implicit process of contextualization.

For the above reasons, Rosen found it necessary to "retreat" to a broader mathematical and conceptual foundation; to relax the restrictions that define mechanistic or dynamical systems and thereby to develop a more general mathematics for complex systems in which "the entire epistemology of our approach to natural systems is radically altered." To understand Rosen's approach and its departure from the definitions that restrict us to dynamical systems theory, we must first understand, from his own characterization, that the "ingredients" of his approach are "the basic notions of information" (Rosen, 1985). And although Rosen himself did not complete this theory development, he showed how to put the ingredients together.

## R-Theory

### R-THEORY

There were two avenues of development in Rosen's work that were evident since his book, *Anticipatory Systems*. One avenue was associated with the mapping of causality using category theory, the more general foundation that he referred to in mathematics; and the other avenue was associated with modeling relations, which are explicitly formed of information relations between a model and a natural system that it models. It is the combination of these two tracks that gives us a complete view of relational theory (Kineman, 2010, 2011). Rosen focused primarily on laying the mathematical and epistemological foundation, leaving the full synthesis for others to pursue. Indeed there were hints in his writings that he did not believe we were yet ready as a society to accept that synthesis without considerable re-thinking. As we explore the full implications of what might now be called R-theory, its revolutionary character begins to emerge.

We might understand R-theory best by considering the idea of insides and outsides of systems; that every system or event viewed externally (the basis of the mechanical/dynamical view), must also exist on the inside of another system that constitutes a context. The relationship between externally realized (interactive) properties and internalized or contextualized conditions then establishes the relational view. Its greater generality of that view with respect to the mechanistic view is obvious when we realize that mechanism assumes one and only one causally conditioning interior, or context, shared by all systems; whereas relational theory assumes that every system has both aspects with respect to other systems and therefore contextual definitions (which will be identified as natural models) may be as numerous and varied as natural systems. The question of simplicity is then one of the extent to which contextual specifications agree. The view from a single context reveals nature as a collection of parts with exclusively defined properties, locations, and dynamic changes in that context. The view of the inside of any contextual system reveals it as a set of constituent properties where natural information about intersecting conditions acts like ecological niche models, conditioning and attracting the potential existence of parts (i.e., events and phenomena that consequently come to occupy that set of conditions in the environment). In the total view there cannot be externality without internality, and nature can thus be described by the exchange of information between realized and contextualized domains. Science itself is but one such information context, and even science specifies and changes the outer world as it is put into practical application.

By attempting to formalize science on the basis of observational realities alone, mechanistic science was attempting to standardize on one formal cause context with a set of fixed definitions, parameters, and metrics for efficient laws. The crisis of post-modern science was precisely the result of discovering formal cause variation – that contexts matter. Goedel's incompleteness proof for number theory was also a demonstration that the effect of context, formal cause, cannot be universally reduced to one common system. Instead there are known variations in the parameters of a dynamical system under conditions that isolate events from general interactions. For example, the smooth relativistic change in the Lorentz scaling of space-time (the 'shape' of space) is a continuous variation in the formal metrics of space-time that corresponds with the degree

## R-Theory

of isolation between events separated by speed of light communication. The discontinuous differences in quantum reality occur explicitly when phenomena are isolated from general interactions such that observer interactions are more defining. Wave-particle duality also suggests different contextual constraints on the distribution and interaction of events. However, living systems establish formal cause differences with much greater facility as a consequence of how they are organized, extending and maintaining their functions via self-produced, internalized models that open the system to adaptation and evolution. In relational theory the fundamental causes of complexity are the same for all systems, regardless of scale. That similarity between physical and biological worlds, however, is not what was hoped for by classical scientists; it is not the explanation of biology from the assembly of explicit dynamical behaviors, from the 'bottom-up'; but instead it is the explanation of physical systems from reduction of their natural complexity. That complexity also forms the basis for living systems, which are actually better examples of it because instead of reducing complexity, they employ and enhance it. It is just for this reason that Rosen often wrote that biology has something to teach physics.

The epistemological separation of an observing context from nature-as-observed in external events creates a paradox in which we represent nature as something that itself can have no natural representations. That, in the clearest terms, is what makes the mechanistic view non-complex. By removing information and its causalities from our concept of nature we indeed obtain a view of nature as an independent object of description. But, as a consequence, our own experiences with information cannot then be considered natural and what living systems do best, modeling, cannot be studied as a natural phenomenon. As a consequence science has been struggling, as it matures, to recapture the fullness of nature in some form that will not destroy the predictive and technological advantages of knowing simple mechanisms. It is likely for that reason that Rosen discussed the mechanistic/dynamical system view in depth as a prelude to introducing the differences that characterize complex systems. It was perhaps in hopes of forming a bridge between the two worlds. Even so, he concluded that there is no syntactic way to cross that bridge; that is, from the dynamical side. It must be crossed from the general, contextual (semantic) side, from a new science of complex and anticipatory systems to the science of simple systems. Complexity, while perhaps approached in the ultimate limit of infinite mechanisms, is not reachable by any finite addition of them. In contrast, however, the finite world of mechanisms is reachable by a reduction of the complex.

These epistemological and methodological issues become most critical in considering the problem of anticipation, with which Rosen dealt directly in this book. The entire discussion of dynamical systems, and how to exceed them to understand complexity, underlies the consideration of anticipation. Given the very large sociological gap associated with just the introduction of relational complexity to science, the discussion of anticipation seems almost out of reach. But if we accept Rosen's foundational arguments about complexity, we can then begin the discussion of biology, which is characterized by anticipation. In other words, we must first understand that complex systems are not special in any sense; they are the general case of any system for which we consider

## R-Theory

context dependency. It is then possible to understand the truly special nature of dynamical systems or mechanisms, and it is also possible to understand what is unique about life forms, primarily the special nature of organisms as metabolism-repair (M-R) systems that form a closed loop of causation and thus establish a system identity. Unraveling the layers of misunderstanding about what is special and what is general in nature is thus crucial to understanding Rosen and R-theory. Complexity is general; mechanism and life are special and quite opposite ways of organizing otherwise complex relations.

If mechanistic science was originally meant to be a picture of reality, it was taken that way only naively, with the intention that it might represent an incremental process of gaining knowledge that might not have a limit. Rosen's philosophical arguments are clear on this point; that indeed an infinite series of mechanistic models is implied by any complex system, but unfortunately it is not an infinite increase in knowledge even if all those mechanisms could be specified and combined. It is instead like Zeno's paradox, where the goal is approached by an infinite series of half-measures that assure it cannot be reached at all. The half measure, in this case, is half of Aristotle's four-part causality. In fact, the problem is worse than Zeno's paradox, because as we make incremental additions of efficient and material entailments to approximate complex phenomena, the approximations can reach an absolute limit to their accuracy beyond which further additions will not decrease the error. This is because a complex system does not represent just one end-point. Once uncertainty is encountered in the addition of mechanistic models, it cannot be removed by any similar additions: the other half of causality that takes place via context must be added. Context refers to the formal causes (which may be seen as attractors), by which the parameters of a dynamic system and their events are established; and necessarily the final causes defined by exemplars, by which a contextual model is established. This last step, the closure with final cause, was not directly described in Rosen's work (nor by Aristotle), but remains as a logical and profound conclusion of relational theory that Rosen left for his students and colleagues to infer from the many hints he gave. Why he did not attempt a full synthesis himself may have more to do with his perceived timing with the states of cultural evolution (in other words he thought we weren't ready). We find in Rosen's writings, however, very clear descriptions of the problem of causal closure, and a pathway toward its resolution for those who wish to follow it.

The equipment we need to do so is a basic understanding of causality, more or less as it was divided into four parts by Aristotle, but closed within nature in a way that Aristotle did not perceive. We need also to relate the causes to each other, which Aristotle did only hierarchically and with some ambiguity that has prevented their integration ever since. The full and recursive integration of these causes is how we can define and describe whole systems, which may then be seen as the objective relational units of nature that we can analyze. It was Rosen's conclusion that the answer to understanding complexity and life was to dissolve the divide between objective and subjective domains by objectifying the relations between them. Those relations are natural instances of modeling relations, consisting of a recursive hierarchy of the causes. That unique organization of causes defines wholeness and gives identity to systems, which then interact by sharing or

## R-Theory

substituting causes. The picture of reality that emerges is one that is non-rigorously familiar to ecologists; it is that of a fully interconnected system-dependent reality in which wholes are more than the sum of their parts, precisely because of relations. The view is approached in physics as ‘model-dependent realism’, although current descriptions in physics do not adequately explore the realism.

Perhaps the greatest stumbling block has been that in a true modeling relation, final cause must be part of wholeness, and yet it has been shunned as external to nature. In R-theory it is part of the naturally complex world completing or ‘closing’ the other causes by providing natural exemplars. This re-interpretation of causality thus closes the causality loop by defining final cause as imminent in nature, rather than immanent from a mystical domain, as was the accepted cosmology in Aristotle’s time. Final and formal causes are thus brought within our understanding in terms of creative potentials that establish shape and direction of change in the event world; in other words they provide an explanation for the existence of dynamics and predictability and thus the origin of systems. As with any theory, however, there must remain a mystical edge beyond which the method of description cannot be applied, for no system can include a complete explanation of itself without establishing an infinite regress. The question, however, is where that edge occurs in a given view. Context is unlimited in the relational view, but it is also holarchical, meaning that the most distant causes can be made the center of focus. The hope of finding an ‘exact’ science led us to place finality outside of and prior to nature (and thus to reinforce the uniquely Western view of an unnatural external creator), whereas returning it to nature represents nature as fundamentally complex, and thereby gains us the ability to consider the origin and identity of systems.

As must be expected, anticipation and the formation of anticipatory systems involve final cause. But relational logic leads to the conclusion that final cause is a prerequisite for anticipation not a definition of it: It is part of general complexity and wholeness in all of nature, living or not. Final cause steers (or attracts) the development of a system toward exemplars; but anticipation is a special use of final cause in which exemplars are selected on the basis of system sustainability. That internal selection is thus a factor in determining an evolutionary pathway (as James Mark Baldwin claimed), matching prior exemplars of system sustainability with current models. While final causes themselves may provide end-points of system change, anticipation associates those end points with current meaning in terms of functions that the system will act to preserve. In other words, end-directedness itself might explain why any system moves toward a future condition at all, but anticipation is the selection of exemplars that an internal model predicts will be most viable. Anticipation is thus defined by adaptive final cause.

It seems that Rosen was quite aware that the deep and inescapable implications of relational thinking would be hard for many to accept. Final cause, after all, had been purged from science and labeled nearly as its antithesis. Nevertheless, he seemed also quite aware that the incentives for following his path would increase in future years, because if the limitations that were built into mechanistic science are applied extensively and rigorously enough, they must eventually cause problems of incompleteness. At first the discovery of regularities in nature was the hallmark of modern science, but post-

## **R-Theory**

modern science has been more characterized by the discovery of nature's irregularities, particularly irregularities in the classical descriptions established through the modern era. The implications of uncertainty were thought to be damaging to the very foundation of science. But the classical alternative was actually worse because it clearly implied that either we too are machines, or that the one thing we must take for granted, our own experiential existence, has no explanation at all. It seems bizarrely paradoxical that the way to gain knowledge about the natural world should be to describe it as separate from all knowledge: we have to be suspicious of what kind of knowledge such a program can produce. Quite plainly, it produces descriptive knowledge about outcomes, which is only prescriptive if the system under consideration is already scripted; that is, if it appears fully constrained by a general context. It provides no knowledge about how the scripting takes place; the causal origins of a system.

### **CAUSE VS. PROBABILITY**

Science has been at a cross-roads for over a century now. The post-modern/post-normal era of science has been one characterized by a combination of immiscible theories and hopes for an acceptable synthesis; that is, one that could be demonstrated to be consistent with prior facts, parsimonious in its formulation, general in its terms of reference, universal in its scope, applicable as an analytical method, and capable of improving our knowledge in testable ways. We began searching for a scientific 'theory of everything' but especially we were searching for a theory that could explain how indeterminism in nature could arise at all from a deterministic background. Evidence for self-determination (which Humberto Maturana and Francisco Varela called autopoiesis) in living, conscious and thinking organisms was shrouded in epistemological and other confusion, but the evidence for uncertainty in physics became unavoidable. Evidence at many scales revealed apparently self-generating behavior that we could not comprehend, and that hinted at greater levels of organization. Certainly living systems involve complex organization, but it was a shock to discover that the most fundamental physical systems do too. Most scientists could not accept that a theory of mind, while perhaps providing analogies and metaphors for physics, could affect its equations. Theories of information were limited to the thermodynamic concept of entropy, which itself is limited to the efficient and material world of energetically closed (causally open) systems. Mechanistic thinking, by itself, does not represent levels of organization that are not law-like. And yet we naively thought that all organization in nature would turn out to be governed by fixed efficient laws. We did not understand the nature of the problem, which was that a system cannot describe itself without setting up an infinite regress of exteriors, or 'larger systems' as Rosen called them. Machines are made; they have their origin in another system. Therefore the machine metaphor requires an external maker, a fixed causality that is outside the natural world of that description.

Perhaps for that very reason, scientists and even philosophers have been unwilling to explore very far outside the mechanical box; fearing that science would be in chaos if its laws admitted to any variations at their origin. The discovery of wave-particle duality was thus precisely the crisis everyone had been working to prevent, and mainly as an



## R-Theory

emergency measure they decide to patch the problem with probability theory, thus preserving the use of number theory but allowing for duality in the difference between probability and certainty. However, it was an unsatisfying solution for many because it essentially assigned ontological status to a subjective or at least conditional measure. Neither Einstein nor Schrodinger accepted it as a natural philosophy, arguing that nature is not governed by chance; that there must be a more fundamental set of principles.

Probability is based on counting how often something occurs under given conditions and then expecting it to be that way in the aggregate under the same conditions. It abandons the idea of predicting individual events and instead defines limits to knowledge (i.e., ignorance) of such specifics. It was not meant to be about natural causality but about empirically determined regularities in collective data, the specific causes of which may be unknown (or unknowable). A contextual domain of possibilities can indeed be described by a set of empirical probabilities referencing it to past exemplars (say, actual distributions or logical possibilities, as in the flipping of a coin). However, even a probability model depends on how conditions are evaluated; in other words it ultimately assumes some necessary relation that links conditions with events. There is always an implicit or explicit underlying model of how supposedly random events should distribute, and an implicit assumption that there are fixed laws of probability and randomness. In effect, then, using a probability model shifts the original assumption that we can have an exact model for predicting events, to the assumption that we can have an exact model for predicting the random distribution of events (the probability density function), which is an expression of formal causation. In the case of quantum mechanics, the underlying quantum wave function, path integrals, or QED heuristics, implicitly act as models of nature, no matter how much one might insist that they are just a way of describing results (the presumption of M-theory). Unavoidably, formal cause, one step prior to efficient cause, brings us that much closer to dreaded final cause, and for that reason it has been difficult to discuss it as a ubiquitous aspect of nature.

For example, quantum probability waves are implicitly a propagation of natural model-based information about nature, essentially representing formal cause as a necessary consideration in our picture of the physical world. The success of this theory confirms the need to include the idea of natural contextual entailments in science; in other words, to consider contextual system dependency, which is formal cause. To the degree that the underlying probability models (quantum wave functions) were thought to have a natural referent of some kind, the use of probability theory in physics was a step toward relational thinking. Both theories are based on information relations associating events with conditional models and both specify potential existences, thus softening the connection between prior conditions and expected results by predicting only the tendency, frequency, or suitability of occurrence of events. But most theorists attempt to explain these probabilities in terms of fixed background potentials without considering the cause of those potentials themselves.

Nevertheless, taking this first step and introducing uncertainty between the model and observations, as has been done in post-modern science, covers a multitude of sins. Not only does it change the idea of Natural Law to a tendency (a potential occurrence) instead

## R-Theory

of a necessity, it also covers the problems of lack of knowledge or just plain measurement error. With exact science in question, probability theory has invaded nearly every branch of science; but because it conflates natural indeterminism and measurement error it is often easiest not to make the distinction, which would require going to deep theoretical foundations. The result has been that the concept of causality itself (which was defined to mean something deterministic) has fallen out of favor. Rosen, like Einstein, was seeking to find a deeper causal basis for nature, but as it became increasingly unpopular to speak of causality, Rosen was accused of “answering questions nobody wants to ask.” The final cause origin of models that necessarily underlie probabilities should be explored with the same realist implications that led us to accept formal cause; in other words to ask what the cause of formal cause might be. But unfortunately, reluctant acceptance of formal cause in physics did not mean a further exploration of final cause but rather a multitude of attempts to repair our rule-based notion of formal with yet another theoretically complete formalism with finite, calculable dimensions.

Consequently, there is a major difference between relational theory and the general use of probability theory in science where we may ask neither the specific causes of individual events, nor, in many cases, the cause of the probabilities. It has become sufficient to quantify a potential and treat that as a fact, even though science does not have to halt there. Since it was acceptable, with minor exceptions, to arrogate final and formal causes to human cognition alone, probability theory was designed for just that descriptive philosophy. Its implicit adoption as a quasi-reality in quantum mechanics was thus unexpected and shocking; but it spoke of a greater reality, not a dark secret to hide. Without a theory of how the probabilities originate, there is no way to distinguish uncertainty in nature from uncertainty in human perception, and today a great deal is being made of that fact to suggest that there may be no difference at all, and no benefit in making the distinction. But that hides the discovery that nature is relational and even returns us to some very extreme forms of anthropocentrism. Even if the cause of uncertainty in human perception is the same as its cause elsewhere in nature, which is a logical assumption, we still perceive ourselves as a different system and the entire knowledge enterprise is rooted in that difference. But we have only taken the first step toward complexity, consideration of formal cause; and that step necessarily conflates the two uncertainties.

The next step is to describe final cause to explain the natural origin of uncertainty and thus the root cause of probabilities; that is, to consider probabilities as generated rather than pre-existing potentials. Relational theory, when fully developed, gives a causal theory once again, explaining how mechanisms are produced from a larger relational system, and how a fundamentally complex system can increase its organization to produce living systems. As such it necessarily accords model-based behavior to all of nature, and it thus allows us to explore organizational differences that account for the different kinds of natural systems we observe. Once this view is worked out sufficiently, we will regain all that was lost, because the more deterministic modeling exercises remain, where they are accurate, as system-specific reductions of the complex; while living systems represent an enhanced organization that introduces anticipation and adaptation. But to arrive there we must assume not that there are fixed underlying

## R-Theory

potentials for anything, but that the underlying distribution model for potential occurrence of an event is determined by exemplars (final cause) within, not prior to or outside of nature.

Probability theory was adopted widely for its ability to analyze knowledge, and its realist interpretations, where unavoidable, were safely confined to special areas of sub-atomic physics and thermodynamics. To a great extent the rest of science was insulated from its potentially meaningful implication of contextual causality. Ecology, for example, has struggled without a central theory since its beginning and, aside from very limited dynamical models; it consists mainly of statistical interpretations of data to determine emergent patterns and dynamic sub-processes of an otherwise mysteriously complex system. And yet, of all the sciences, ecology is probably the most quintessentially relational. It is potentially broader in its causal foundation than quantum physics. Quantum mechanics, for example, is a more restricted version of relational theory because it has yet to fully extend the concept of the observer (and thus contextual causes) to all systems, and thus to incorporate the idea of natural exemplars into causality.

While it may seem theory-neutral to view the natural world through a probability filter it is not, because in the absence of attributing the cause of underlying potentials to natural conditions, one merely succeeds in substituting the observer's assumptions about the distribution of probabilities. When restricted philosophically to a theory of knowledge, a probability model is about the process of observing, and indeed, some robust patterns emerge. However, it may well be that the theory works in the quantum world because systems that are capable of exhibiting events are also capable of behaving like observers; and we must consider that natural systems are observers. In relational theory systems have dual aspects as material systems and contextual models (of self and other systems). We may indeed be limited in our ability to distinguish incomplete knowledge from natural indeterminism, but with a realist interpretation of contextual causes, analysis can be aimed at experiments to make that distinction. The instrumentalist view of model-dependent phenomena (which is currently popular) erects a barrier to knowledge by assuming that knowledge itself cannot be part of nature; that an arrogated and undefined entity called 'we' constitutes observers and all else does not.

Analytically, translating prior exemplary occurrence (distributions of events sampled statistically and interpreted probabilistically) into a contextual potential, involves the modeling relation as a meta-model for nature's own way of establishing attractive potentials from prior exemplars. Theoretically, this step is the essence of ecological niche modeling, if that exercise is taken primarily to be about modeling adaptation (and not merely about statistical correlations). The fields of landscape and geographical ecology, for example, are currently experiencing a rapid rise of interest in niche modeling, but most of the work still focuses on making strictly statistical predictions of occurrence. In a bizarre reversal of epistemology that commits two sins. First, it bases the modeler's choice of factors on mere correlations instead of experimental science to infer adaptation; and second, it ignores the domain of traditional science, where ecological dynamics are responsible for realizing the niche. The reason for this discontinuity in ecology and other living system sciences is, again, the taboo against taking formal and final causes

## **R-Theory**

seriously. In other words, the result of the false assumption made by most physicists, that nature does not establish system-dependent formal and final causes, is that other sciences that have deferred to physics are crippled in their ability to consider the full causality of the living system.

To summarize: Analysis of complexity requires consideration of both realized and contextual domains; i.e., all four of Aristotle's causes reinterpreted as a recursive holarchy within nature. A current synthesis of that view is now available (Kineman, 2010, 2011), suggesting that science must now consider two kinds of models: one describing system-dependent (contextual) potentials and the other describing dynamics of system realization. The two kinds of models cannot be merged or reduced except when modeling a mechanism; and otherwise they must be coupled in a modeling relation.

### **CONTEXT: THE FINAL AND FORMAL CAUSES**

Formal cause is the implicit system dependency of nature's laws, which makes it fundamentally complex, impredicative, and non-computable. It is the formative potential of a contextual model that may have multiple realizations. The externally attributed properties of a system are events. They occur on the causal 'inside' of another system, which is their context. There cannot be an event without a context for the event, and yet the context is not itself a local object; it is the organization of events that conditions and attributes the existence of additional events. For example the metrics of space-time constitute formal cause for the organization of the event world, attributing events with local coordinates and the 'shape' of that coordinate system. The grand assumption of classical science was that all system contexts have the same effect on the organization of internal events; that there exists one and only one formal cause. We can no longer maintain that assumption, but if we admit formal cause variation into the epistemology of science, the question of what causes differences in formal cause can then be answered as final cause: the effect of exemplars from prior realization, thus implying self-reference and self-similarity.

Neither Aristotle nor his followers had a natural answer for where final cause originates. As a result final cause has not been dealt with in science, and formal cause variations had to be treated as exceptions at the 'edge' of reality, with mysterious origins. Unfortunately that placed living systems at the same edge, hardly where they belong in a world that needs answers about how to manage them. The consequence of these decisions about the organization of science has been that it could advance society considerably in abilities to make efficient changes and to employ efficient processes for specific ends, but not at all ability to comprehend broader systemic effects and relations, or the origins of various kinds of systems.

Duality is our great clue in this mystery of the causes. At its root it involves the relation between foregrounds and backgrounds or outsides and insides of a system. It is the relation between what is singled out (abstracted) from nature and the context in which it is perceived or interacted with. For example, we observe discrete events of the

## **R-Theory**

mechanistic world in a space-time context that is defined on the principle that two things cannot occupy the same space at the same time and one event cannot be in two different locations. Only if the rules of space-time itself are altered can there be an exception. However, such exceptions have occurred under controlled laboratory conditions that in effect alter the formal cause system of space-time. In other words, space-time itself must now be considered relative and produced; not a fixed prior reference system. With that modification, the strangeness of uncertainty becomes understandable as the effect of different space-time 'selections' or alterations.

Aristotle's view of final cause did not allow for its inclusion in natural science because he and many others saw the ultimate cause of everything as the act of an external creator. That concept is retained in mechanistic science in terms of the big-bang origin of the universe; where it can be kept historical: one act of creation after which everything is presumed to operate mechanically (except that it doesn't). In Aristotle's view nature is produced from an undivided whole that is an immanent cause of the world (final cause), after which its operation is governed by the descending hierarchy of formal, efficient, and material causes. Philosophers and scientists who followed Aristotle realized the problem this hierarchy posed for science: external intervention with implicit purpose toward unknowable ends. Mechanistic science was thus a grand compromise, resolving that external cause as an historical event. But consequently it cannot deal with the origins of any system, let alone itself; only the conservative reconfiguration of one system that unexplainably originated from nothingness 14 billion years ago.

Mechanistic science, thus steeped in as much theology as any other view, nevertheless left us with some ability to understand and even control the temporal world. Perhaps not too surprisingly, then, we retained Aristotle's hierarchy culturally but distinguished half for science and half for the humanities, arts and 'soft' sciences. To the early Western philosophers of science dealing with the politics of the time there could be no other solution than to divide the causal levels in this way, with obvious advantages for establishing a new discipline and, in some cases, saving people's lives.

## **CAUSAL CLOSURE**

We can read amid the detailed mathematical treatment in Rosen's primary work, that his proposed solution to the scientific and epistemological questions of complexity, final cause, and life was causal closure, which ultimately leads us to the implications described above. In other words, if Aristotle's four causes are a hierarchy, as Aristotle said, they must constitute a closed hierarchy within nature in order to avoid the problem of external origin. If that is the case, it is then possible to describe systems that are causally closed with each other and thus complex. Rosen presented this idea as efficient closure between natural systems that therefore produce each other. He used familiar mechanistic terms but nevertheless challenged the limitations that mechanism places on our concept of the natural world, limitations that would preclude such causal loops. Efficient causes are processes by which a current system configuration is produced. From the view of purely efficient/material (mechanistic) cause, a single future system is produced from a single

## R-Theory

prior one, on back to original creation and external context for the universe. But, if different systems of efficient cause can produce each other, system origins can then be entailed from within nature. Rosen suggested that is exactly what characterizes complexity and thus allows for life.

In mechanism, laws govern the dynamics of material objects, but material objects do not govern the creation of efficient laws. Thus mechanism allows for only one form of end-directedness: It is a one-way descent from immanent (supreme) causation toward material death (entropic 'heat death') from which nothing recovers. But if this is only half of causality, what happens in the other half that was left out of the mechanistic picture? If Aristotle's hierarchy is a circular hierarchy, then the contextual side that includes final and formal cause is an ascendant causality, generating new functions from prior structures. As Rosen wrote (citing Erwin Schroedinger), it is the case of an 'inertial object' (a material result) acting as a 'gravitational object' (a cause of dynamics). Clearly the explanations for life cannot exist only on the descendent side of these causes, but by treating causality as a closed loop it is possible to bring the ascendant, contextual causes into natural science. Rosen is thus clear that there is nothing mystical about relational theory, although from its implications we can certainly speculate differently than before about the mystical, which relational theory places within nature, as an intrinsic property, rather than without.

Causal closure means that there is an inverse causality (referred to here as context) that entropically runs opposite to the apparent end of mechanism. This result is indicated by the fact that a system of efficient closures is a paradox in the mechanistic view; it should not exist and yet it describes the behavior of complex systems, which obviously do exist. That paradox is only resolved by incorporating contextual causation, thus relating both sides of the causal hierarchy, both contextual and phenomenal realities, into a larger view.

To describe life itself mathematically Rosen adopted the more general formalism of category theory, which broadens the mathematics of natural description by generalizing objects as sets and their morphisms. The entailment diagram that he presented shows a solid headed arrow (an efficient cause) implicating a hollow-headed arrow (a material cause) characterizes this analysis. That mapping is a basic picture of mechanistic cause, except that in category theory the result of a material map itself can become a morphism; that is, the result of one process can be the cause of another, thus removing the requirement that laws cannot be system dependent. When that is allowed, a natural inverse contextual category is implied that accounts for the generation of new systems and new functions from existing nature; and there is a corresponding increase in the number of unrealized possibilities in nature. By definition, that is a decrease in entropy. While from the limited perspective of the mechanistic view any reversal of the 2<sup>nd</sup> law of thermodynamics must be a local reversal, this larger view suggests that such reversal is a natural consequence of contextual entailment at any level; that is, any system that is closed in all four causes and thus whole.

## **R-Theory**

In this view, complexity is natural and the theoretical problem facing relational science is then to explain mechanism and the apparent existence of a self-consistent classical world. As it turns out, that is easy: Classical mechanism is a fully reduced modeling relation; it is the limit to which a complex system can be constrained by interactions forming a general context. With these new terms of reference we can say that natural functions (which can be associated with nature's laws) change states of a system (which describe its physical structure), and it is also true, as allowed in category theory, that natural structures change functions. With that freedom added back into our thinking, it is then possible to develop descriptions of a natural system that include the apparent intervention into mechanistic formalism mentioned earlier, which quite reasonably comes from causal loops between relatively isolated systems. Thus justifying this expansion of science: If closed hierarchical loops of causation cannot exist in a mechanistic domain of mathematics (Louie, 2010) or as attributed to nature, then we must define a broader domain of science and nature where they can exist.

### **MODELING RELATIONS**

The critical role of modeling relations was revealed at an early stage in Rosen's work. Even at that stage, however, he gave strong hints that modeling relations might be taken as a fundamental reality; as a true picture of science but also, by implication, of how natural systems relate to each other through natural models. He also wrote that they are not exclusively about biology, that "the concept of a model is not something exotic or unusual, but rather of the broadest currency imaginable in all disciplines" (Rosen, 1985). A modeling relation is an information relation between a model, which we might see more generally as the contextual aspect of a system, and the realized aspect of a different system (or the same system as an identity relation) that is abstracted and modeled within that context. The modeling relation allows neither complete agreement nor complete disagreement between the two (there is always similarity and error, or a "discrepancy" in the relation), and therefore it establishes a principle whereby nature can communicate with images of itself. It is also an explicit representation of the mind-body problem, thus implying information in nature, as, for example, Gregory Bateson also claimed. Modeling relations, as Rosen described them, turn out to be the critical idea in forming an analytical and theoretical synthesis for relational science. However, these broader and more controversial implications were not highlighted in Rosen's mathematical underpinning in which he left the conclusions to be drawn.

Rosen applied the concept of a relation between nature and models of nature as a central element of his arguments about complexity and anticipation. There were two levels of that application. First there was a description of science itself as a program to understand nature by representing it in surrogate (or analogous) systems with similar entailments. In such an exercise scientists attempt to get a model of the system's entailments to commute with nature, or at least to get a simulation to commute with certain behaviors. The important question for science, then, is to what degree can one system represent another system? In distinguishing approaches in science that involve more complex relational thinking from those that reduce nature to mechanisms, Rosen made the bold assertion that

## R-Theory

scientific models should themselves be entailed, that is organized, in the same way that we believe nature is organized. Implicitly that means considering all possible causes. When science does not do that, for example when it focuses only on efficient and material causes (mechanisms), it is actually not applying a model at all in Rosen's terms, but a simulation. Most of current science is thus based on simulation. However, the importance of this observation goes beyond mere labeling. By this criterion, a true model must then be a natural system; only then can it be said to be fully entailed like nature. Without delving into the philosophical arguments surrounding this issue, which are extensive, we can understand the depth of Rosen's theory best in this concept of a model. If a modeling relation involves all the known causes then nature must be describable in terms of modeling relations. A system of analysis must therefore exist in which nature is seen to comprise nothing but modeling relations.

Unfortunately, in all of Rosen's work, a complete synthesis of the ideas of modeling relations and the ideas of relational causality in terms of category theory mappings was not presented. In effect he presented two views of complexity, one of the mechanistic paradox in which closed loops of efficient causation cannot technically exist in current thinking; and the other of the implicit incompleteness of all descriptions when considered from the perspective of modeling relations. Rosen thus reasoned quite legitimately from Godel's incompleteness to the logical incompleteness of any system of description in which 'realized' components of nature are the exclusive elements of analysis. His view was perhaps most clearly stated in his book "Life Itself", in which he wrote that instead of objectifying the efficient and material aspects of a system, the aim of a science of complex systems should be to "objectify the modeling relation itself" (Rosen, 1991).

Modeling relations are both information decodings from contextual models into realized behavior, and information encodings from realized behavior into contextual models. As such they define the concept of wholeness and whole systems in the ideal sense, as closed hierarchies (holarchies) of all four causes. Again, we have to read somewhat between the lines in Rosen's writings (or actually to put the lines of reasoning together) to arrive at the conclusion that the implied existence is a complex reality constituted of modeling relations. That result corrects the blunder in Western science (albeit perhaps a willing one, as mentioned earlier), of imagining that final causation comes from outside of nature. It changes our idea of nature from a causally open and materially closed reality, to the other way around.

Most significantly a causally closed system allows us to define system identity, wholeness, and relatedness; placing causation in the framework of a modeling relation and merging the two theory tracks. The realized domain is one of exclusive system properties as traditionally analyzed. Its exclusivity is what allows measurement and concepts of natural interaction. But in the contextual domain, system potentials are non-exclusive, overlapping as in Venn diagrams, with three possible results. The non-intersection defines unrelated identities of different systems; the union identifies a larger system in which both systems are implied; and the intersection defines a new system specified by the mutual constraints of the original system models. The contextual intersection thus indicates a new system in the realized world, with emergent properties.



## R-Theory

Context is therefore the domain where emergence of new systems takes place: It comprises the natural conditions that act as models with respect to realized systems. A more specific model thus originates a new system that may introduce a host of new functional relations in nature. Clearly, then, excluding that domain from science excludes all consideration of origins and any causes that can be called creative. However, how tightly (mechanistically) constrained, or ascendantly organized a system is, depends on the relative isolation of its internal relations from general interactions with the environment that would bring its models into a more strictly reactive correspondence with the general causality.

### M-R SYSTEMS AND ANTICIPATION

If modeling relations are not unique to living systems but ubiquitous in nature, and closure is also natural, then something additional is required to characterize biology. We find that additional criterion in the M-R system of internalized entailments which characterize cells and organisms. In other words, this special arrangement of internalized models that establish each other (are closed to efficient cause) seems to distinguish life forms from all other kinds of systems. As M-R systems were examined more deeply in later and related work, Rosen showed that they represent an efficient closure of three functions necessary for life; metabolism, repair and replication, which emerge from four natural components. This unique organization of internal components and their functions can be shown to have its own modeling relations with the outer environment representing behavior and selection, thus forming an identity and ensuring that an M-R system is adaptive and evolutionary. Rosen identified M-R systems with anticipatory systems as a unique category of systems that generate their own internal predictive models (the most commonly referenced diagram of the M-R system was presented later, in *Life Itself*).

Describing nature in terms of modeling relations means that no system is truly separate from everything else, and that no two systems are exactly alike; it is a world view of qualified separation and qualified connection that, therefore, is complex and relational. But it was also clear that mere possession of an internal model is an insufficient criterion for defining life. The mere existence of models is identified with fundamental complexity in nature, whereas it is the autonomous production and use of an “internal predictive model” that is identified with living systems, and the main criterion that addresses Rosen’s primary question, “What is life?”

Rosen defined an anticipatory system as one that changes its behavior according to an internally produced model of the future "for a desired result" (Rosen, 1985). The last part of this criterion is important but often overlooked because in science it is not considered appropriate to attribute intention to natural systems. However, merely responding to a model of the future means nothing if it is not an adaptive response. We can translate the term “desired” into natural terms by associating it with formal cause and thus distinguishing anticipation from pre-adaptation. We can then say that living systems are distinguished from non-living systems by their ability, through adaptation and evolution, to employ and enhance complex system models in a unique way (via the M-R system)

## R-Theory

that prolongs system functions, often by quite sophisticated means. Thus the living system anticipates an internally predicted future in the sense that adaptation to predicted conditions prolongs existence; whereas merely responding to a future prediction, perhaps randomly, can at most result in pre-adaptation.

Anticipation thus involves selective response to possible futures represented in the present. The very neatly predictable mechanistic world, where ‘the future’ is imagined as the one and only possible outcome of the past, cannot be preserved if there are systems that anticipate, for anticipation involves symbolizing multiple unrealized possibilities and selecting from those choices. Impredicativity, as part of a temporal sequence, means that the future states of a system are not uniquely predicated on its past, as would be required of a mechanism; and therefore they are not uniquely predicated on general laws that dictate temporal change. Systems that are capable of symbolizing and responding to multiple possible futures, that is, systems driven by internal models, are thus capable of selecting or being selected by alternative futures through their present and subsequent behavior. Furthermore, these effects are cumulative across all systems, thus conflating prediction of the future with collectively creating it. Once present behavior is predicated on a symbolized outcome, we are in a domain of causal feedback in which the present is, in some part, governed by conditions that will, at least in part, become the future.

It may be worth noting that even stronger ideas of ‘retrocausation’ may also be treated in a relational framework. For example, modeling relations can represent multiple historical pathways that might equivalently arrive at the present. In other words, the formal representation of the past may be determined by present models, and in a complex world multiple non-contradictory models may provide alternative histories. Furthermore, if we consider potential futures and plausible pasts modeled in the present to thus ‘exist’ in the sense of a model, we might go one step farther, as some physicists do, and suggest that such multiple realities are in a sense actual. Instead of imagining that present models are the result of history, we can imagine they are merely selecting which alternatives will be experienced by the ‘observer.’ The application of R-theory to explain temporal sequences (normal dynamics), for example, requires that events be sequentially realized from a context and that they are in that sense discontinuous. That discontinuity allows multiple sequences (multiple histories) to be collectively true for their associated set of events where no specific measurements are in contradiction.

We thus enter a reality that is best described as a relationship between that which exists in the present as a measurable set of conditions, and that which cannot be said to exist as such, but is nevertheless causal. It is a modeling relation between existence in a locally defined and attributed domain -- the world of realized, measurable systems, and existence in a non-locally distributed context where models are formed and can combine to originate new systems. In this sense both domains exist. In the domain of local existence, which is defined by space-time coordinates, we measure what has already happened; whereas in the contextual domain of non-local potentials, models define what might happen as nature’s possibilities. As each of these domains is formed from the other, the two are mutually attractive, resulting in complexity and even directional change. On the other hand, to the extent that the system being considered is not causally closed, that it is

## R-Theory

interactive, its interactions will establish a common context that we can recognize as the realized world and that can be successfully described with mechanistic models. It is thus the case in this view that both the living and the material world are emergent from the complex.

### ORGANIZATION, ENTROPY, AND TIME

In R-theory, whether a system is complex, simple, or living depends on how its modeling relations are organized. When a system contains macroscopically complex components like living cells, neurons, organisms, species, etc., its complexity and uncertainty relations are the same in principle as those of a sub-atomic system that has microscopically complex components. Complexity is not a function of scale, it is associated with causal isolation of components of a system, which living systems excel at establishing.

In the cases of living systems, the closed M-R entailment of realized efficient causes has multiple contextual organization possibilities. For example, there are implicitly three kinds of living systems indicated, that differ in their contextual organization and as a consequence have different behavioral characteristics (Kineman, 2010, 2011). These organizational possibilities are the result of how the inverse entailments are organized on the contextual side of the system's causality; that is, its final and formal causes, conferring different life strategies to the three types. The generation of different organizational possibilities from contextual differences alone allows novel behaviors and thus new systems to emerge.

In the above manner, true relational complexity also alters the standard model of entropy. Rosen pointed out, for example, that the 2<sup>nd</sup> law of thermodynamics applies to materially and energetically closed systems (of which there are none in nature). When systems are partially open (therefore open both energetically and causally) such that they are both interactive and partly autonomous complex identities, they will then exhibit entropy increase and entropy decrease in their simple and complex aspects, respectively. Entropy was invented as a classical measure of total system order, which can be related to 'organization' in the following way. If entropy is increased or decreased it is understood to indicate a corresponding decrease or increase of order, respectively. That change in entropy (and degree of order) is also associated with changes in the flow of energy through the system. However, as a result of complexity, there may be alternative patterns of organization that decrease entropy as distinguished from the increase in entropy resulting from metabolic processes.

Our choice of world views has much to do with how we view change through time. We see, through Rosen's work, that the mechanical view in science is one in which we assume, incorrectly, that we can learn all possible behaviors from those that have already occurred, and that what will occur in the future is a predictable reconfiguration of the past. It is a view devoid of anything truly creative, anything truly new or alive, and it corresponds with the basic physical (and Western theological) assumption that creation

## **R-Theory**

occurred at one unapproachable point in projected history (and thus by an external agent), after which the universe has run automatically, using up its energy and increasing its entropy toward eventual heat death. However, that implicit end only exists in a rather limited cosmology.

The goal of traditional Western science has been to figure out the mechanism(s) of presumed automation. On the other hand, the relational view suggests that existence as we measure it is a realization of models that establish events and also the parameters of space and time that will be interpolated between those events. It suggests that the event world is discrete and contextually relative, not continuous and uniquely defined; and that a temporal sequence of events is not really a change but a re-creation of the event at different times and locations. In other words the event world is quantized by its events and organized by its formal models. If this is the more correct view, it opens many possibilities for investigation of currently anomalous phenomena that seem to violate not only the laws of thermodynamically closed systems, but those of space and time. But the true value of relational theory is not necessarily to present a new cosmology or to challenge proven modes of understanding. It is to introduce a broader theoretical framework where these and other questions can be asked.

## **CONCLUSION**

A comprehensive re-structuring of the foundations of science, primarily its epistemological assumptions, is needed to expand science so that it can address complex phenomena that are pressing upon us at an astonishing rate, with equally astonishing failures in our understanding of them – phenomena that call into question the nature of existence and the future of humanity. Nothing can be more important in science today than to develop these new theoretical lines. Indeed, we must explore different futures than the machine metaphor alone can imply.

The basic complex relation is between two aspects of an otherwise unified whole. These aspects are: (1) the realized (actual) aspect that can be locally observed, and (2) the contextualized (potential) aspect that can only be inferred as a non-local potential. These complementary aspects never exist separately but they act differently and have different causal properties that we can know. Contextual and realized complements of nature are never ‘fractioned’ in a relational analysis as they are in a mechanistic analysis, as neither side is discarded. The knowable aspects of this relation – the terms of reference for scientific models – are ‘structure’ (measured state and change) and ‘function’ (inferred potential, or ‘law’), more or less as understood previously, but adding their contextual aspects. Whereas the fundamental modeling relation represents our ontological view of nature (the “man behind the curtain”); structure and function are the epistemological units that can constitute an empirical study and analysis.

Relational theory remains completely inside the domain of scientific epistemology by the fact of relating fully natural domains distinguished only by their contextual relation as insides and outsides of related systems. The boundary between living and non-living

## **R-Theory**

systems, in this theory, involves a categorical difference in how systems are entailed (the M-R system vs. complex modeling relations or mechanisms not organized as self-producing units). Systems entailed as one interactive system produce a classical world; whereas systems entailed with causally isolated components, separated from their environment by internal entailments, are complex. Because events in the realized domain are distributed and separated by space and time coordinates, and the conditions for their viability and identity (their models) are separately realized, all systems are out of equilibrium with their potential existence, which drives them dynamically and attractively. We need only the complexity-reducing interaction of modeling relations to describe the non-complex domain, both its indeterminate nature and its collective classical nature. But to describe the biological domain we arrive at a special self-entailment that internalizes and isolates the cause of modeling relations themselves, thus establishing ecological and evolutionary M-R systems. Living systems, owing to their closed causal entailments, are capable of constructing sophisticated internal models that are necessarily involved in anticipation, adaptation and evolution.

Rosen's method of inferring the greater reality by combining paradoxical results from two theory tracks was precisely the method describe by Einstein in his layman's explanation of how he discovered relativity theory: by combining two paradoxical conclusions of Newtonian physics. He wrote: "...by systematically holding fast to both these laws, a logically rigid theory could be arrived at" (Einstein, 1924). Rosen's theory of relational complexity, applying the same method of synthesis by holding fast to complex entailments between phenomena and information relations between entailments, also results in a logically rigid theory that should change science and our perception of the natural world. Rosen may well be considered the Einstein of biology, having provided what may be an even more comprehensive world-view than Einstein provided in physics.

While this discussion may seem to reach far beyond the careful mathematical presentations that Rosen made, his theory does not stand alone and without implications for the broader philosophy of science. One must see his work as a very methodical series of steps in a carefully constructed theory of life that he assembled over the course of his lifetime. This commentary drew from the depths of that work as a whole and the author's own formal synthesis. Rosen's original work seems to remain relatively flawless and the necessity of advancing the theory along those lines should be strongly emphasized. The logical consistency and profound implications of that work have survived extremely well the test of professional critique, and it is now time to seriously explore the full extent of its applicability.

### **Acknowledgement**

I wish to express my deep appreciation for the close collaboration I have had for most of a decade with Judith Rosen, daughter of the late Dr. Robert Rosen. Robbed of the opportunity to study Rosen's theories directly with him, as a result of his untimely death in 1988, I have instead had the fortune to team with perhaps his closest confidante on the intended 'everyday' meaning of relational science. Through this connection I feel that I

## **R-Theory**

may yet gain some claim of membership in the Rosen/Rashevsky School of relational biology, despite the diversity of views and interpretations in that rarefied club even while Rosen was alive.

### **REFERENCES**

- Einstein A. 1924. *Relativity: The Special and the General Theory*. New York, NY: Henry Holt and Company.
- Kineman, J.J. 2010. *Relational Science: A Synthesis*. In: Allen, J. and Wilby, J. (eds.) *Proceedings of the 54th Meeting of the International Society for the Systems Sciences*, Waterloo: ISSS.
- Kineman, J.J. 2011 (in press). *Relational Science: A Synthesis*. DOI: 10.1007/s10516-011-9154-z. *Axiomathes*. Pre-print available online at: [Http://www.springerlink.com/content/4n5705051262323h/fulltext.html](http://www.springerlink.com/content/4n5705051262323h/fulltext.html)
- Rosen, R. 1985. *Anticipatory systems: philosophical, mathematical, and methodological foundations*. Pergamon Press, New York.
- Rosen, R. 1991. *Life itself: A comprehensive inquiry into the nature, origin, and fabrication of life*. Complexity in ecological systems series. Columbia University Press, New York.