8 EMERGENCE, LIVING SYSTEMS AND CLOSURE

Abstract The final chapter uses the fundamental axiom of an emergent included middle and the LIR two-level framework as a basis for a discussion of emergence in biology. The principles of LIR permit the formulation of a physics and chemistry of living systems that includes a locus for the potentialities necessary for emergence. A categorial interpretation of the related issues of closure and downward causation is developed, using the LIR notions of time, simultaneity and succession outlined in Chapter 7. LIR is presented as a logical system that can compensate for the inability of standard logics to address general issues in biological science. The application of LIR to the major problems of the origin of life and evolution and natural selection is suggested, and the essential role of the Pauli Exclusion Principle as the physical basis for the emergence of diversity and living systems emphasized. The chapter closes with a comparison of LIR and several current semiotic, thermodynamic and contextual views.

8.1 INTRODUCTION

8.1.1 Emergence

As an introduction to the applications of LIR and NEO to theories of emergence and living systems in the final chapter of this book, let me first restate a hierarchy of levels of reality in a way that will facilitate talking about the connection between them:

- Inanimate Systems
- Living = Perceiving Systems
- Conscious Systems
- Knowing Systems

For all systems, *change* can be defined as involving a new state or position of the same entity, and *emergence* as involving the formation of a new entity. Both display the classical logical problem of the point at which an entity moves or passes from one state to another, or a new entity appears, but, as I will show, the relations defined by LIR largely avoid this problem. Further, juxtaposing the four terms of non-life, life, consciousness and knowledge is not intended to mean that one group of systems is the *cause* of the next. Rather, the former state the conditions of existence of the latter.

I have implied that the concept of emergence applies throughout reality: even evanescent virtual particles can be considered to 'emerge' from the quantum vacuum. However, the question of emergence is most relevant to explanations of phenomena at higher, more complex levels of reality. All sciences receive some new interpretations of their domains in LIR, but I begin here with a discussion of emergence in relation to life, since without life there is neither consciousness nor knowledge! Discussion of these latter topics, as previously noted, will be deferred to another occasion.

There are (at least) three conflicting views of what constitutes emergence that are relevant to my current development:

1. Emergence does not exist at all.
LIR: This view is based on a limited, classical picture of ontology.

2. Emergence is an *empty* concept: to say that a phenomenon is emergent is nothing more than a description of the processes involved.
LIR: This view does focus on what is happening without the reification of a term, but it is too reductionist.

3. Emergence can be associated with several other terms, such as biosemiosis, all of which are equivalent.
LIR: Emergence can be given a general interpretation that suggests useful distinctions with the other terms, and the intuitions of this approach receive needed further grounding and explanation using the principles of LIR.

It is curious and perhaps significant that the form of this debate is very similar to that about laws of nature outlined in Chapter 6.

In this chapter, I will refer to a number of examples from the recent literature. It is clear that my selection cannot be exhaustive, but it is in addition open to (at least) two additional, different forms of objection: the PDO does not apply to a specific subject, or its effect is negligible or trivial. In this case, I may consider revising my thesis with respect to that subject, and agree, on reflection, to reassign it to the category of separable entities. I am, of course, most interested in the applications in which I believe that Non-Separability applies. The form of objection that is relevant here is that my core thesis does not apply at all, either to theory or experiment. The objection has been made, for example, that it is incorrect to speak of logic of any kind in relation to experimental science outside, perhaps, the domain of quantum entities, or that there is no functional connection between a scientific theory and the data of that theory, between metaphysics and physics. My counter-strategy will be to show, as I have in regard to these issues earlier, that theories of biological systems (cf. Appendix 2) that do not take contradiction in the LIR sense into account lead to an impasse, if in fact, from their models, the most problematic aspects of the phenomena in question are not completely excluded. I will also include references in which intuitions are expressed of the need for something like my logic, or in which it is found in 'embryonic' form in the concept of an adequate bridging principle or theory.

8.1.2 Opposition in the Physics and Chemistry of Living Systems

The problems of trying to explain the existence of any change, but particularly of the emergence of biological systems in terms of physics and chemistry, were and are still due to the retention of classical notions of cause, time and matter-energy solely in terms of actualities. This is particularly important in regard to living systems, as I will now show.

I have discussed earlier how the Pauli Exclusion Principle for electrons establishes a basis for heterogeneity, in real as well as epistemological opposition to the 2nd Law of Thermodynamics, which is a basis for homogeneity. This principle of heterogeneity, or tendency toward heterogeneity, is what is considered, in the logic of/in reality, the basis for the existence of increasingly complex macrophysical systems, leading ultimately to those designated as living systems at a biological level of reality. The processes leading, in some as yet undefined way, to entities and their constituents at the biological level – the genome, gametes, other cells, organs, and living individuals – all involve the emergence of new forms, which I have tentatively identified as T-states, included middle elements at another level of reality or complexity. Their origin in turn is in properties of molecular and chemical substrates (under-levels) and processes that are less complex, and I have postulated that all processes, at all levels, are characterized by more or less easily identifiable aspects of dynamic opposition, instantiated in those properties. An overly simplistic model of natural selection as a consequence of the 'pressure' of the environment on the evolution of a species is an example of such opposition.

This postulate of the real, logical and dynamic opposition at the heart of energy, and consequently of its embodiment in matter and information at all more complex levels of reality, requires that it applies to fundamental particles, protons and electrons, atoms and inorganic and organic molecules and ultimately the living organisms that are constituted by them. Everything that involves this principle is a system, a process of systems of systems, etc.; therefore, everything is a system, capable of interacting with other systems in a manner that one can call antagonist. In chemistry the calcium ion, Ca^{++} is a biologically 'active' system as are the toxic thallium ion, Tl^{+} and the carbon atom with its capacity (potential) for four covalent bonds to other atoms that make possible complex molecules, an amino acid, a polypeptide, a hormone, a gene, an egg and a human being. The proposed consequence of LIR for biology and philosophy is that its principles are universal in the sense of applying to chemical elements, inorganic and organic materials, macromolecules, their dynamics, the memory they embody *via* their folding and to all other constraints that enable self-replication of living systems.

Some early proponents of emergence believed that primitive features of matter could exert a primitive form of causality, involving fundamental 'configurational forces'. This, in other terms, is the LIR thesis: the 'features' of phenomena, starting with energy, can be described as involving 'configurational forces', in which significant energy is encoded in potential form. It is in configuration space that the actual and potential states of electrons are present, and it is both these categorial features that are the carriers of the upward causation necessary for emergence. To take the example of the calcium ion, again, the combination of its size and net positive charge results in different potentialities for interactions with, say, water molecules than that of a lithium ion, Li^{+} , and their biological activity, partly as a consequence of this, is quite different, for example, at the psycho-physical level.

I note, not entirely in passing, that the reduction of chemistry to physics is no longer an issue. Every physical entity is a system, unsaturated in its potential for further interactions, the more complex chemical systems that emerge from those interactions will retain part of that unsaturation as higher-level causal properties that I designate as the residual potentialities of the system. These consist, again, in the ability to lose an electron 'completely', to form an ionic bond, say sodium to sodium chloride; to share electrons in a covalent bond, as in the unsaturated ethylene molecule; or to form electrostatic bonds such as those between water molecules and sodium chloride ions. The greater stability of the hydrated ions is the thermodynamic basis for the solubility of salt in water.

While the details of the initial production of biological macromolecules at the origin of life, as discussed below, remain unknown, the concept of opposition or antagonism provides a further entry point for analysis of these processes.

8.2 THE LIR APPROACH TO EMERGENCE

8.2.1 The Category of Emergence

In Chapter 4, I proposed a category of T-states that are the consequence of the operation of the principles of dynamic opposition and of levels of reality. Since the T-state resolves the contradiction between two antagonistic terms at another, 'higher' level of reality, it seemed reasonable to suggest that the T-state emerges from them. Accordingly, one could consider the logic of/in reality as a 'logic of emergence'. However, I need to establish the difference between processes, T-states and emergence. I propose a category of Emergent Processes as a sub-category of Process, and Emergence as the formal category corresponding to it. Emergence focuses on the process *qua* process, or rather, as is usually the case, the transfinite series of processes of processes, while the T-state is the (temporary) end-point of this ortho-dialectic series tending toward contradiction, viewed as an (id)entity.

In one anti-emergentist position (see below), emergence is reduced to a merely epistemic notion, that is, describing formal relations between *statements* about some set of properties of processes, not the inherent properties or processes themselves. As we have seen, however, the relations involved in and between processes are grounded in the inherent properties of energy, and statements about the consequences for higher levels of reality do not have an *a priori* character. Accordingly, the first concept I introduce at this point is the following:

Thesis 8.1: Emergence is a physical and a metaphysical category.

LIR provides a framework for analyzing the organizational properties of biochemical networks, ones not manifested at the level of the parts, but which result from the antagonistic interactions between the parts. Organization can be explained in terms of component properties, which depend on both the properties of the parts and on the state of the system. These have the part-whole structure suggested earlier, namely, the whole is present in the parts as potentialities, and *vice versa.* Emergence is the consequence of the overall two-level structure of interactions, horizontal and vertical (Boogerd et al. 2005).

To see what can be achieved through this concept, I will look first look first at the development of the concept of emergence and then see how the LIR principles can be applied to the three competing views outlined above. I will then discuss the related issue of closure and specific problems pertaining to the understanding of life and evolution.

8.2.2 Emergence and Dualism Under Attack

The concept of emergence is central to current theories of evolution and other developmental biological processes. It corresponds to our intuitive notions of life and growth, creativity and new human relationships. However, for much of the last one hundred fifty years or so, emergence has lacked a sound metaphysical basis and has been and still is open to attack by 'anti-emergentists'. Most of the positions taken against emergence can now be discarded as reductionist-materialist or neo-vitalist. What is 'wrong' with taking such positions is not only that they do not capture the essential processes in reality, or favor one side or the other in the debate. It is, as in the debate between realists and anti-realists, positions are taken exclusively and absolutely.

Kim (1999) has made a serious challenge to the reality of emergence. Let us assume that emergentism implies the existence of fundamentally novel properties, all of whose elements are physical, including some macrofeatures that cannot be explained or deduced as the consequence of, or in terms of complex microfeatures. Kim's challenge, in one form, is that emergentists are faced with the following dilemma: as physicalists, they are either committed to reductionism or materialism, or, if they avoid reductionism, they are committed to a dualism that cannot be distinguished in a principled manner from a vitalism of some kind, outside the laws of physics. Kim has shown, in addition, that emergence requires reflexive downward causation, a new, emergent phenomenon acting on its own constituents. As discussed by Symons (2002), Kim argues that this implies a kind of circular self-causation that is absurd. I will return to the problem of downward causation later in this chapter.

My claim is that the fundamental PDO and its related categorial features can carry the philosophical weight required for an approach to the resolution of dilemmas such as the one proposed by Kim. Very specifically, *I propose LIR as a dualism without vitalism, with the potentialities of fundamental particles governed by the laws of physics.* The consequence is equally important for the first challenge. The second challenge fails, but *LIR avoids reductionist materialism by providing a mechanism for most, if not all, of the critical non-physical and subjective aspects of life (including consciousness and mind).*

In what I consider a further attack on the irreducibility of emergence, to explain biological processes, Wilson (2000) believed that "powerful principles of complexity" would lead to algorithms conserved across many levels of organization. From these algorithms, "self-assembled, sustainable, and constantly changing yet perfectly producing organisms" will somehow be possible. "In other words, they will be living organisms." This will be true, however, only if "general organizing principles exist that allow a living organism to be reconstituted in full without recourse to brute force simulation of all its molecules and atoms." If the same principles apply to mind, behavior and ecosystems, is there a body of mathematics that will "serve as a natural language for biology, parallel to the one that works so well for physics", and show how the principles could be used in the desired models, assuming they could be found? If the essential elements of life could be captured by an algorithm, this would mean, in Lupasco's critique of similar positions (Lupasco 1973b), that "every differentiation not only flows normally from physical, identifying extensities, but they are only epi-phenomena.…

From the point of view of LIR, the Wilson approach, and others like it, amount to simply the reappearance of mechanism in modern dress. By conflating the problem of inter-and trans-disciplinary aspects of the sciences (biology, mathematics, computer science, etc.) with the concept that algorithms can capture the essential 'mechanisms' of life, all the diversities of the phenomena of life are exposed to a reductionist interpretation. The disparate elements of a living entity are no more than means toward ends that transcend and condition them, to which no autonomous power should be ascribed, which might in turn require recourse to some form of constitutive existential antagonism. LIR seeks to correct this view by eliminating the type difference between a living entity and *all* the aspects of its elements. To avoid misunderstanding, I repeat that I am not saying that a calcium ion is alive, but that it is its potentialities that contribute to its function in living systems.

8.2.3 A Peircean Perspective

In his discussion of causal processes, semiosis and consciousness Emmeche claims the advantage for contemporary biosemiotics, the application of concepts of signs to living systems, is that "it does not force on us a dualist metaphysics that separates phenomena into two distinct worlds or realms which are afterwards difficult to reconnect again". Emmeche considers that Peirce's system was an ideal combination of semiotic monism, conjoined (how?) with an ontological category theory. Peirce based his theory on the categories of Firstness (possibility), Secondness (existence) and Thirdness (reality), without the requirement for radically different ontological domains. The 'First' is a 'Sign' or 'Representamen' which is in a genuine triadic relation to a 'Second', called its 'Object' so as to be capable of determining a 'Third', its 'Interpretant' to assume the same triadic relation to its Object in which it stands itself to the same Object'. The term 'Sign' was used by Peirce to designate the irreducible relation between the three terms, irreducible in the sense that it is not decomposable into any simpler relation, such as some form of part-whole relation.

As might be guessed from my comments on dualism above, I do not fully accept this theory, which I consider insufficiently dynamic, despite the common interpretation that the relation is dynamic because it leads to 'chains of triads'. I think this because there is no energy that can be assigned to the triadic relation that would give it a basis in reality (physics). The Peircean framework, from my standpoint, is an outstanding heuristic device for keeping track of the entities involved in biological processes (Queiroz et al. 2005), but its use should not make one forget the real properties of the system.

Despite his deep and anticipatory intuitions, Peirce made no ontological commitment regarding his concepts. He wrote specifically that his ‘phaneroscopy’ (phenomenology) had nothing at all to do with the question of how far the ‘phanerons’ it studied correspond to any realities. It abstains from all speculation as to any relations between its categories and physiological facts, cerebral or other. It does not undertake, but sedulously avoids, hypothetical explanations of any sort. Peirce also said that the one intelligible theory of the universe is that of objecttive idealism. In a general way, as a Kantian, it would appear that Peirce was uncomfortable with contradiction, and rejected even Hegel‘s more dialectic categories and their associated or implied dynamics. He considered a principle of continuity as “a supreme guide in framing philosophical hypotheses”, relegating heterogeneity and discontinuity to second-class status. ‘Sportings’ and pure chance are the sources of evolution and change in Peirce’s cosmogony. These positions should not be taken too seriously. Peirce was anxious to avoid being tagged as a naïve realist or nominalist. My point here is not to deconstruct Peirce but to provide a working alternative to ‘naïve’ realism and classical dualism, and I have suggested LIR as a variety of conditional dualism as such an alternative.

8.2.3.1 Virtual Logic and Organic Logic

There are two additional systems of logic that are worth mentioning, as they derive from this Peircean view of the structure of reality: the virtual logic of Kauffman and the organic or dichotomistic logic of McCrone (2007).

According to Kauffman (1997), virtual logic is “that which energizes reason” without being a (standard) logic nor the actual subject matter of the discipline in which it may be embedded. … “it is a pivot that allows us to move from one world of ideas to another.” The emphasis here is on virtuality, a wholeness with unlimited potential for becoming, with dynamic aspects capable of all possible changes. Peirce is quoted to the effect that semiosis is virtual, including appearance (in the sense of formation) of connections between things, events, phenomena and processes seen *a priori* as signs not interacting with each other. Kauffman then says that semiosis can be a methodology for exploring nature in the sense of looking for patterns “emerging out of the tangled web of interdependent relationships”.

McCrone’s statement that logic is about the way things do and *must* happen is in principle congenial to LIR. Organic logic is a model of reality composed of a combination of monadic (Peirce’s Firstness), dyadic (Secondness) and triadic (Thirdness) elements. Processes start with vagueness, a state of pure (sic) potential, poised equally between existence and non-existence. Vagueness is the ground from which come Dichotomies, the driving forces that result from, and/or are cause of the splitting of the ground. Hierarchies, which themselves have a triadic structure, instantiate the result or the destination of Dichotomies, a triadic state of balance marking the presumably temporary outcome of the process.

It is relatively easy to translate these more philosophical than logical languages into LIR terms, since some of the underlying intuitions are similar. LIR provides a more physical and metaphysical understanding of the movement from actual to potential, as well as potential to actual, based on the dualistic structure of energy itself, without recourse to the idea of a pure or unlimited potential.

In another paper, Kauffman (2002) shows that virtual logic can be interpreted as a new logic without a law of the excluded middle. It is then capable of handling or systematizing a wide variety of problems related to imaginary values in (Boolean) mathematics and the geometrical constructions of both Peirce and Spencer-Brown ("Logic could be an encoded form of geometry.") In my view, the Kauffman discourse takes place in the domain of classical logic, in which there is no basis for giving meaning to the otherwise correct statement that the system and its observer are neither separate nor coincident. In another passage however, dealing with time series and recursion, a source is given of time series "partaking of chaos and yet resembling the patterns of biological time. Incredible worlds come into being beyond the dichotomy of True and False." The domain beyond this dichotomy is, of course, the one described in this book, and my choice of an 'incredible' world is none other than our own!

8.3 EMERGENCE IN PERSPECTIVE

It a relatively simple matter to observe the two forms of psychological process that drive people toward one or the other monism of identity or diversity as the basis of their preferred theories of reality, existence and thought. This tendency is nowhere more clearly illustrated than in the debate in science, still in progress, between mechanistic and non-mechanistic views of the origin, emergent development and functioning of living systems. Mechanistic explanations have had relative success against standard dualist or vitalist ones, but even in current theories of evolution and emergence, classical notions of part and whole, synchronicity and diachronicity and predictability and unpredictability make it difficult to devise principled counters to reductionist concepts of evolution and skeptical positions against metaphysical emergence. Systems concepts, which provide a first line of argument for it, generally also require some further grounding in physics. Finally, with the return of vitalism to education and politics in some countries, the importance of establishing a theory of evolution on a basis sounder than neo-Darwinism, unfortunately, now goes far beyond the realm of civilized scientific and philosophical debate.

The history of emergentist ideas begins with the arguments between mechanists and vitalists in the late 19th and early 20th centuries. British emergentists tried to develop a compromise position, avoiding vital substances but retaining some sense of irreducibly vital qualities (O'Connor and Wong 2002). Mill, an early exponent of emergentism, tried to distinguish between modes of conjoint action of causes leading to: (1) a total effect equivalent to the sum of the causes acting alone – homeopathy; and (2) an effect which is in no sense the sum of the effects of the individual causes, as in a chemical reaction – heteropathy. The laws and effects corresponding to the latter were called ‘emergent’. Hierarchical levels were seen within levels of heteropathy that could be governed by homeopathic laws in what appears to be a primitive model of levels of reality or strata. Mill’s account of emergence involves causal laws and interactions and is both dynamical and diachronic.

Broad developed a synchronic, non-causal, co-variational account of the relationship of emergent features to the conditions that give rise to them. Broad was interested not only in resolving the debate between mechanists and vitalists, but also in answering the question of whether biology and chemistry were reducible to physics. Broad suggested that two possible positions could be taken, one mechanist and the other emergentist. The former, in LIR terminology, is one of pure identity and homogeniety, one and only one kind of material, one uniform law of composition, one science, and so on. To anticipate, I can already note, however, that although the mechanist position will be seen to be untenable, *part* of it must be incorporated within the framework of an adequately antagonist theory of emergence. There *is* only one “kind of material”, and it is energy in different forms, the consequences of its inherent dynamic opposition, and the homogenizing tendencies in macroscopic matter are present in all phenomena.

Emergentists were physical monists too, but they recognized

> aggregates of matter of various orders, a stratification of different kinds of substances with different kinds belonging to different orders or levels. Each level is characterized by certain fundamental, irreducible properties that emerge from lower-level properties. Correspondingly, there are two types of laws: (1) ‘intraordinal’ laws, which relate events within an order … and (2) ‘trans-ordinal’ laws that characterize the emergence of higher-level properties from lower-level ones and identify them.

To recall the LIR picture, the phenomena of different levels of reality and complexity are, similarly, characterized by different, if isomorphic, laws, but the emergence at a T-state is governed by Axiom **LIR3** of the Included Middle. The unpredictability that was associated with Broad’s emergentism does not present a major problem, given the contradictorial view of determinism and indeterminism. This unpredictability is not constitutive of emergence, but rather a consequence of the metaphysical irreducibility of emergent properties.

Broad’s ontological description of emergence is, accordingly, generally compatible with the LIR view: in both, emergent laws are not totally irreducible to laws characterizing properties at lower levels of complexity (or reality), otherwise there would be no basis for the discontinuity between levels. Both concur that since emergent features have not only same-level effects, but also effects in (or on) lower levels; they accordingly accommodate the concept of downward causation. At this point, I have not made explicit an account of the relationship between the necessary physical conditions and the emergents, apart from the agreed upon, general and lawful character of emergence. Given the requisite structural conditions, does a new level invariably appear? I say yes, the universe is logical and deterministic at least to this extent.

The same criticism can be made of the proposal that emergent properties are not epiphenomenal because they pass a counterfactual test for causal efficiency. To explain the relationship between the mental and the neuro-biological, either each causes the other, or they have similar properties of some undefined kind. These views are close to standard non-reductive physicalism (NRP). Again, the theory presented in this book might at first be considered a form of NRP also, provided one excludes concepts and laws that cannot be derived from fundamental physics. LIR does not require 'natural kind' pictures[1] since it proposes something fundamental in addition, which is close to the Mill and Broad view plus synchrony, or, better, the view of time in which the actual state-of-affairs involves both synchrony and diachrony in the dynamic relationship discussed in Chapter 6.

The work of another influential British emergentist, Samuel Alexander, in its interpretation by Gillett (2006) is of interest in view of its rather extraordinary combination of what are, from an LIR standpoint, both correct and incorrect intuitions about emergence.

As shown by Gillett, Alexander was able to combine three desirable metaphysical positions: (1) Physicalism – all individuals are constituted by, or identical to, microphysical individuals and all properties are realized by, or identical to, microphysical properties; (2) Completeness of Physics – all micro-physical events are determined, insofar as they are determined, by prior micro-physical events and the laws of physics; and (3) Higher Causal Efficacy – there are higher level properties that are causally efficacious. Subject to the redefinition of individuals, properties and cause made earlier, these principles are accept-able in LIR.

The significant contribution of Alexander to a theory of emergence consists in the following statements:

SA1: A new emergent property H is at the same time new and identical to a combination of lower level properties.
SA2: The microphysical realizers are used up to produce something different from and transcending them, but they are not altered or superseded. There is transformation of these parts in building something higher, but the parts remain what they were.
SA3: Microphysical realizers are neither unconditioned nor homogeneous, such that the higher level entity H can have causal powers of its own.
SA4: A new emergent property H is jointly responsible with the lower level properties in determining its causal powers. One of the fundamental realizer properties is such that it has a conditional power whose contribution is partly determined by the higher level property it realizes.
SA5: The determinative influence of H on the lower level property is *non-causal, instantaneous, and does not involve a force, configurational or otherwise and/or the transfer of energy.*

[1] No longer needed in any case since Quine's critique of Natural Kinds (Quine 1969), especially Chapter 3 "Epistemology Naturalized".

The problem is that in order to insure that the realized property *can* influence the course of events leading to its instantiation, one requires some form of downward causation which Gillett shows, in an argument also used by Kim, apparently cannot take place diachronically without paradox, either H or the already transformed emergent property needs to exist prior to the transformation! The solution requires something like the LIR picture of synchrony and diachrony that I presented in Chapter 6 and will review further below in Section 8.6.

Acceptance of SA4 and SA5 together is equivalent to the abandonment of the Completeness of Physics. This position is not acceptable within the physiccalist metaphysics espoused in this book. I do not believe that causal influences propagate among non-physically constituted objects or events nor that non-causal influences propagate among physically constituted objects or events. I accept here the implied critique of Ladyman and Ross, in particular, the need to accept the transfer of information as an energetic one.

For my theory of emergence, I retain the desirable aspects of the Alexander framework (that is SA1–SA3), I eliminate SA5, and I add an additional phrase from Alexander himself:

> SA4-1: "Microphysical realizers are 'peculiar' in "contributing slightly different powers when realizing emergent properties than they do in other conditions."

The higher level property in my view, does not have to have an ontologically *fundamental* force, while exhibiting causal powers. The force consists of the residual potentialities brought to it from the lower levels. I see this as a description, in other words, of what takes place at the T-state, the point of maximum interaction of the low-level realizers. Without this additional principle, Gillett's interpretation does not eliminate the fatal weakness in Alexander's scheme, but rather amplifies it by recourse to non-causal determination.

The approach in this book renders superfetatory the metaphysical relation of fusion one sees from time to time. The idea is that emergent properties result from an essential interaction (i.e. fusion) between their constituent properties, an interaction that is nomologically necessary for the existence of the emergent property. The claim is that fusion is a real physical operation, not a mathematical or logical operation on predicative representations of properties. This is a kind of Hegelian synthesis (based on an underlying identity). LIR provides an alternative for the interaction that is both logical and physical, as I have tried to show, and that is applicable to situations more complex than those equivalent to mixing and changes of physical phase.

Some objections made against ontological emergence appear to be due primarily to a desire to maintain an absolute separation between 'high-level principles' and an underlying microscopic 'Theory of Everything'. Authors taking these views include Prigogine, who suggested that the ‘dissipative structures’ of non-equilibrium thermodynamics involve properties and dynamical principles irreducible to basic physics, and Laughlin and Pines:

> the generic low-energy properties (of the crystalline state) are determined by a higher organizing principle and nothing else.

The *apparent* independence of various confirmed high-level principles, and the practical impossibility of deriving them from fundamental principles in fact supports ontological emergence (against objections to it). I take this statement as a basis for a new postulate on emergence, as follows:

Postulate: “All high-level principles reflect, and can be derived from, the same basic antagonistic properties of energy that constitute the fundamental principles of existence, including those of basic physics. Accordingly, the phenomena of ontological emergence can be described by the former and are explicable in terms of the latter.”

In my discussion, the word phenomena has been used as covering both ‘properties’ (or the event or states consisting in a system’s having a property), *and* systems and objects as such, seen as emergent ‘included middles’ arising from dialetheias, true and real-world contradictorial processes. Some difficulties certainly arise by the conflation of systems and ‘objects’ as they are usually thought of, that is, non-dynamic non-systems. Merricks (2001) does not take a position on what emergence is, nor on the nature of causation, for which we now have a contradictorial picture, but he does, however, assign macroscopic causal powers to it, similarly to Laughlin and Pines. Merricks also talks about relations among his basic microphysical entities, but this relation is obscure.

> The relation of physical substrate to emergent features could be a) one of causal determination or brute fact, or emergent features could necessarily appear (supervenience), or b) at best contingently appear in all systems attaining a requisite level of complexity.

With regard to (a), my view would reject the concept of brute (independent) facts as untenable by the fundamental postulates of the logic of reality and energy. As far as (b) is concerned, the fact of the appearance of emergent features is contingent, but some words in the question need explaining. ‘At best’ seems superfluous, and the word ‘all’ is inoperative. Emergent features have the *potential* for appearing; whether they will or not depends on probabilistic aspects of adjacent systems within the overall a-determinacy of the universe.

I will now discuss some general aspects of emergence beginning with physical emergence outside the specifically biological area.

8.3.1 Physical Emergence

Many physical phenomena are described as emergent: tornadoes certainly arise from complex temperature and humidity gradients. Other systems involved in non-linear dynamic interactions can exhibit new behavior relative to the behavior of their substrates. From the LIR standpoint, they are (almost) pure, actualized macrophysical processes with no form of internal representation or semantics. Examples are the dissipative, far-from-equilibrium systems described by Prigogine, other intrinsically simple structures such as the convection cells in heated liquids or certain oscillating chemical systems that have described and discussed *ad nauseam.*

It is thus correct to discuss such systems, which are identities "to all intents and purposes", from an essentially mechanistic standpoint. Batterman considers such phenomena as emergent since they display singularities (critical points) rather than as simply resulting from the underlying causes (Batterman 2002). What is not correct in my view is to take them as models of the fine structure of emergence at other levels of reality. As noted previously, the pre-valence of T-states and emergence is not a smooth function of level of reality, but is at a minimum at the macroscopic level. Individual particles nevertheless retain all their potentialities for entry, under the right conditions, into more complex, emergent configurations.

8.3.2 Normative Emergence

The fundamental metaphysical conception of a split between two kinds of substances, the factual, non-normative world and the mental, normative and largely intensional world goes back to Descartes. In Bickhard's succinct summary, substance metaphysics makes process problematic, emergence impossible and normativity, including representational normativity, inexplicable. I will mention some of the major arguments made (Bickhard 2003) to model causally efficient ontological emergence within a process metaphysics, deconstructing the challenges of both Kim (metaphysical) and Hume (logical). Both of these critiques are fully compatible with the LIR-NEO framework.

As discussed first in Chapter 6, Kim's view is that all higher level phenomena are causally epiphenomenal, and causally efficacious emergence does not occur. This argument depends on the assumption that fundamental particles participate in organization, but do *not* have organization of their own. The consequence is that organization is not a locus of causal power, and the emergence assumption that new causal power can emerge in new organization would contradict the assumption that things that have no organization hold the monopoly of causal power. Bickhard's counter is that particles as such do not exist; 'everything' is quantum fields; such fields are processes; processes are organized; all causal power resides in such organizations; and different organizations can have different causal powers and consequently also novel or emergent causal power.

In LIR, as we have seen, a degree of organization is ascribed to particles as particles, as well as to the quantum field (its self-duality) and hence there is no difficulty in ascribing causal powers to them. Further, in the above argument, the simple possibility of emergence being ubiquitous in new organizations of process is not an explanation of how it occurs. In my theory, the dynamic opposition inherent in the particles provides the necessary causal mechanism.

As Bickhard shows, Hume's argument is that norms cannot be derived from facts, due to the presumed empiricist origin of representational or semantic content. Thus valid derivations do not go beyond whatever is available in the premises with respect to their basic terms and that accordingly nothing fundamentally new can be introduced. This argument is proved to be unsound, and that normative emergence is possible, by reference to the linguistic concept of implicit definition. Contrary to the abbreviated definition to which the above construction is equivalent, the implicit definition says that formal sentences implicitly define the translations of the non-logical terms that yield a consistent interpretation of the overall set of sentences. It is Humean sense data reduction that is the less common of the legitimate forms of definition. Hume's restriction to factual premises reflects the substance-ontological commitment: substances motivate empiricist notions of perception and representation, and substances are themselves not normative.

I would simply note that a theory that gives appropriate energetic process characteristics to perception and representation does not need to have the possibility of normative emergence further demonstrated. The absence of a principle of antagonism in energy leads Bickhard to focus on the locus of his otherwise correct dynamic model of emergent normative function in far-from-equilibrium systems of the Prigogine type. Living systems are indeed far from some ultimate equilibrium, and the operation of their complex cybernetics, close to the dynamic equilibria I have defined, also requires energy such that entropy is maximized locally as well as globally, as suggested by the principle of Maximum Entropy Production (MEP; see Section 8.8), *via* functional input from and interaction with the environment.

My claim is only that the operation of MEP is necessary but not sufficient for emergence, and that as suggested on several occasions in this book, some principle of exclusion between like entities, of which the Pauli Exclusion Principle for electrons is the simplest expression, is also required.

8.3.3 Catastrophe Theory and Emergence

In Chapter 5 I discussed some aspects of the catastrophe theory of Thom and Petitot as a metaphysical theory of morphogenesis. I give credit to Thom and Petitot for giving new vitality to the problem of form in biology and elsewhere. But they went too far; my use of the word 'vitality' here could be considered sarcastic, under the circumstances, if it were not for the fact that Thom considered his method as one of 'geometric vitalism'. I can agree with Thom's criticism of reductionist biology as metaphysical in a negative sense, since it postulates "a reduction of vital phenomena to a pure physical chemistry that has never been experimentally established" (Petitot 1988), whereas vitalism "is based on an impressive ensemble of facts of control and finality that cover the quasi-totality of vital activities (Thom 1972)."

Petitot converted this vitalism of Thom, for which Thom had been (of course) criticized, to something which is far from the naïve idealist vitalism of the early 20th century. It is methodological and geometric, compatible with a local physico-chemical determinism of the substrates and strictly structural.[2]

Petitot thus claimed to have achieved, through catastrophe theory, a reconciliation of the principle of finality (teleology) inherent in vitalism (structuralism) with physical objectivity (mechanism, reductionism). I can claim not to have reconciled them, but suggest that one can show, through application of the PDO, where each fails both to describe its own elements correctly and to include the proper aspects of the other, and that a third possibility for explication exists. LIR eliminates the need for any form of vitalism, and suggests a functional relation between physics, chemistry and biological phenomena, based on the recurrence of energetic antagonism at different levels of organization and reality.

The pure geometrical-topological modeling of reality in catastrophe theory, as I have discussed, fails to capture the dialectical mechanism of process reality – emergence in other terms. I have thus been at pains to show that the categories of the logic of/in reality in my New Energy Ontology (NEO) instantiate a form of conditional dualism, comparable to the Axiom **LR2** of Conditional Contradiction whose principle is that the two elements of a duality are not totally separated and independent but linked by a relation of dynamic opposition.[3] I will now show in more detail how the principles and categories of LIR provide approaches to questions of emergence in phenomena at the biological level.

8.4 EXPLAINING EMERGENCE

To summarize, based on the principles of LIR, emergence as a process is not separable, or different from, its instantiations. It is no more correct to say that emergence 'is' something than that cause or consciousness 'is' something. The only criterion or locus for emergence is the real existence of all entities or processes, that is, all those which consist of energy-in-change. Where emergence does not take place is in or between non-spatio-temporal entities that can be described

[2] Petitot was able to incorporate, in his synthesis, the concept of *entelechy* that Goethe developed as the *a priori* constitutive of the universe of forms, the basis of his speculative idealist vitalism.

[3] Processes that instantiate dynamic opposition can also be the source at the mental level of emergent phenomena as included middle T-states by Axiom **LIR3**.

as following binary logic. I have touched in Chapter 3 on the ontological status of such objects, our mental representations of them, the nature of 'non-existence' *vs.* existence and what it might mean for such objects to exist in 'other worlds'. On the other hand, the degree of emergence in our world at short time scales can be minimal: the billiard ball that is struck and modified in the process is, to all intents and purposes, not a 'new' billiard ball, but it can be so considered, both logically and physically (experimentally). Once this is accepted, emergence can be seen for what it is, a universal metaphysical principle.

I will therefore state, as a result of my analysis to date, the second thesis of the application of LIR to biological emergence:

Thesis 8.2: The logic of/in reality, LIR, and its associated new energy ontology, NEO, provides a doctrine of emergence that is *both* physicalist and dualist, but its dualism follows the category of dynamic opposition and the axiom of Conditional Contradiction, and confirms the physical and metaphysical reality of emergence.

Let us now compare this thesis with the three views mentioned in the first section and see how they can be interpreted using the principles of LIR. As will become clear, I support the second two, but not the first.

8.4.1 Emergence Is a Dogmatic Concept?

The position taken here, for example by Maurel (2005), is a consequence of frustration at the lack of proper explanations for the origin and functioning of living systems. It is expressed by a resistance to emergence, characterized as an 'artifice', in the same category as (standard) logic and reductionism. That life has 'emerged' from non-life is considered as a linguistic device that fails to describe in any way the chain of events necessary for the construction of biological molecules and macromolecules. Thus, emergence is not a valid concept because the underlying theory is not available.

The problem is of course real. There is as yet no agreed upon pathway leading from the simplest amino acid, the probable result of the combination of small molecules produced by electrical discharges in the primitive atmosphere, to simple peptides capable, perhaps with the aid of inorganic catalysts, to the emergence of polypeptides with a capacity for self-replication. There is no detailed way of understanding how "molecules acquire an order that puts them in the right place at the right time" in the organization of a pre-biological entity. For this author, the term of emergence corresponds to a kind of revealed dogma of life, a bit mysterious, not to say mystic, that refers to the sudden appearance of properties *whose foundations are unknown* (emphasis mine).

An additional, metaphysical problem, related to the formulation above by Kim, is the following: if emergent properties depend in fact on the methodology of scientific explanation, how can a scientific explanation not be reductionist and mechanist?

The above view demonstrates the point I wish to make: LIR cannot, in any specific case such as this one, describe how an event of chemical synthesis on a particular surface of slate or clay *x* billion years ago might have been *the* 'real beginning' of life, the obvious identity that is the only thing that will satisfy most people.[4] LIR in a sense seeks to change the climate in which such questions are posed, and to see what other questions might be posed and what the acceptable form of answers to them could be.

One can say, as a start, that the appearance of the small molecules of life, ammonia, formaldehyde and so on required the input of substantial amounts of energy, and potential catalysts such as silicate materials have high surface energies. Since these energies appear to have had real consequences, a reasonable assumption is that such developments in existence are not accidental but deterministic, inherent in the potentialities in nature. A better strategy, which, summarizing rapidly is that of this book, is to look closely at what this inherence involves without postulating new laws of physics, but seeing how existing ones might be interpreted, as in LIR, in a contradictorial manner.

If one accepts that the PDO explains *something*, that potentialities have *some* functional role, and that 'time' is a complex property of matter involving *both* synchronic and diachronic aspects,[5] one is perhaps in a better position to evaluate and support new theories that give substance to the concept of emergence. I will now to do this with reference to some work of the Danish school.

8.4.2 The Emmeche Synthesis

Emmeche (2000) has made a trenchant critique of what I have designated in various parts of this study as attempts to construct theories of life or existence using, implicitly or explicitly, the axioms and concepts of binary logic. In considering the epistemological problems in such general theories about living systems, he sees a number of 'hidden connections' between different areas of human experience, such as folk biology and scientific biology, as well as hidden connections between central concepts of theoretical biology such as function, semiosis, closure and life. These connections are, in my opinion, of the utmost relevance for fresh approaches to these areas.

In this view, there must be some form of a 'hidden prototype fallacy' in most discourses that results in the *reification of their own abstractions* and hides

[4] Or cause them to reject scientific realism.

[5] Cf. Chapter 7.

the fuzzy, basic and problematic semantic references to the particulars of system types, in other words, the real world. The five examples given are

- The theory of autopoiesis, the 'self-production' of systems;
- Non-equilibrium thermodynamics, which takes its examples basically from the macroscopic physical world, or primitive biological entities like slime molds, which he compares, in concordance with my approach, to simple syllogisms;
- Dual mode theories of life, in which the hidden prototype is the genotype-phenotype duality of classical genetics
- Complexity studies, with their heavy computational bias and agenda, leading to
- Artificial life research.

Autopoiesis is the term Maturana and Varela gave to the continual production by a network of the very components that comprise and sustain the network and its processes of production. Despite the extraordinary insights of these thinkers and their followers, I believe their systems approach suffers from the retention of abstract and absolute terms, of which circular causation is an example. Maturana indeed talks about the inseparability of a living system and its niche, and structural coupling is the term used to denote their interdependence. Structural coupling is the conjoint result of thermodynamic or macrophysical openness, which allows (how?) the flow of matter and energy through the organism, and operational closure, which enables autopoësis and homeostasis. The resulting adaptation is an *invariant* relation because the operations of the living system "cohere with – they are not contradicted (sic) or thwarted by – the surrounding medium (Maturana 2003)".

My critique of this approach is not so much that it fails to refer explicitly to some form of dynamic opposition at the level of organisms, although I believe such reference would be desirable. It is that without some such concept of opposition, and the concept of potentiality as well as actuality subsumed by it, the systems described cannot be physico-chemically related to any substrate levels.

In the Maturana system, the result of an interaction between an organism and a stimulus external to the organism is not determined in any way by that stimulus, but only by the aggregate state of the organism itself at a given moment. The effects of molecular interactions ramify and amplify into behavior at the macromolecular level, all the way up to the level of the organism, and the same is true in the other direction. In the LIR view, as I have indicated, it is in the potentialities of the molecules involved that the source of the upward (and downward) causation should be sought.

As alternatives to the above five points, Emmeche proposes the minimum complexity of the endosemiotic biological code as a requirement for maintenance of life. He speculates about the unknown laws of complexity that may be involved and the primitive kinds of metabolisms that cover the continuum no-life – primordial life – life. Obviously, LIR does not provide a description of these unknown laws as such, but as indicated above, its basic postulates can been seen as potential constituents of such unknown laws.

Emmeche's conclusion exemplifies the non-absolute aspects of a vision based on LIR. For a prototype organism, say, a single cell, biosemiosis implies functionality, and functionality is only possible under a closure of operations in the special sense of the category of closure that I will propose below:

> This closure is an emergent phenomenon of a semiotic character, and as a *closure*, it is only partial, imperfect, relatively open. Therefore we can conclude: (1) synthesis is needed; (2) further epistemological clarification of these concepts is needed also; and (3) a null hypothesis – that the four notions of life – biosemiosis, functionality, emergence and closure, express four independent characteristics of life – has been refuted.

In support of his view of emergence, Emmeche et al. (1997) calls for an ontological, materialist but non-reductionist theory of levels of reality that includes a concept of their origin. In this view, several additional relationships to the LIR theory 'emerge'.

Emmeche shows that the 'emergence' which is described by computational, mathematical and algorithmic (formal) notions fails to capture key aspects of real-world emergence. Citing Cariani, apparent emergent behavior in cellular automata is not intrinsic to the formal system, although it may be the source of ascriptions by the observer. As noted above, simple examples in physics and chemistry of thermodynamic emergence (self-organizing behavior) are not easily related to a theory of biological evolution. This picture is consistent with my view of a general division of the world into domains of applicability of binary and ternary logic. Binary logics are adequate for mathematical or computational cases of emergence, but ternary logic is required for an understanding of biological and psychological emergence. The fact that emergence is also observed in the former, binary domain should not be a source of amazement, given that it is a basic feature of our world, but it is the properties of the latter that explain the former. 'Thermodynamic' macrophysical emergence, without an appropriate source of heterogenization, results only in limited, 'static' entities or processes.

The remodeling of the relation between determinacy and prediction has the consequence that "it is no longer a problem to defend the statement that systems with emergent processes can be deterministic; the concept of emergence does not necessarily entail the presence of indeterminacy, nor of any kind of 'invention' of the process." Emmeche takes the side of Thom in his debate with Prigogine: the latter takes the unpredictable event as his deepest level of explanation. For Thom, science is the embedding of a realized process in the space of virtual (in my terms, potential) processes, supporting an ontological view of science by 'expelling' the various ideas of indeterminacy as being a relevant fact. The application of the PDO to determinacy, indeterminacy and a-determinacy clarifies this view, and supports the position, *contra* Prigogine, that potentiality in the sense of the possibilities existing for a given process is a fundamental necessity. "Emergence is not an omnipresent creative force, but simply the fact that some of these virtual (i.e. potential) processes possess new properties."

Emmeche defines primary ontological levels and proposes a difference between the "first time emergence of a primary level and later repetitions of the creations of entities". Constitution of levels is accomplished by the application of initiating and constraining conditions, whereby the constitution of the primary levels is the emergent process that selects the constraining conditions for subsequent levels. In LIR, as in Emmeche, *potentiality* describes an entity at a given level in relation to the levels above and below it.

The significant difference between the above primary levels and those of LIR is that the quantum level is subsumed under 'physical-chemical'. This occults the clear difference in applicable laws between microscopic and macroscopic physical entities and results in a category error. The thesis of this book provides two hypotheses that are ontologically applicable: (1) that the lowest relevant level is the microphysical one; and (2) that the notion of the alternating, antagonistic relation between actual and potential not only applies to it and all subsequent levels. Any 'next level' does not exist (is not actualized) *synchronically* with the initial level but exists as non-localized potential in it. I make a similar argument in Section 8.6 on downward causation.[6]

It is true that the appearance of biological systems in the whole phase space of the universe is determined by physics, and given some specific changes, the universe *might* have developed in a way leading to different species. The ones we know would have been unrealized and existed as potential only. The existence of parallel evolution, however, suggests a simpler, non-skeptical picture. The existence of some degree of organization at the lowest physico-chemical level implies that the evolutionary response to similar external conditions *may* be similar. This is an alternative argument that does not require the postulation of some prior physical contact between land masses to allow for animal migration. A similar argument can be made for the appearance of pyramids in Egypt and Central America, without the intervention of aliens from outer space. More frighteningly, it is a possible model for the development of terrorist cells in the absence of any 'mastermind'.

8.4.3 Biosemiotics

The further thesis of Emmeche that Peirce's semiotics (theory of signs) can be extended to comparable semiotic processes(Emmeche 2003) at physical and biological levels is a major advance toward a needed theory of emergence. If the current physical universe and its chemical elements is indeed a "particular way of 'coding' the energy of the universe", and biological phenomena are a particular way of 'coding' organic chemistry, and if, as discussed above, the energy is inherently antagonistic, instantiating dynamic opposition, then all these semiotic processes also encode this fundamental antagonism and its ontological

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[6] For an opposing view, see again the work of Salthe, Chapter 6.

predicates. In fact, all of the processes associated with living systems can be captured in an NSC sub-category of Emergent Processes in which the key axiomatic meta-physical concept is that of dynamic opposition.

In this theoretical biology, for example, analog and digital codes are shown to be equally necessary, interdependent forms of activity "arising like twins in the individuation of that logic which we call life (Hoffmeyer 2000)". In general, theoretical biology has always been forced to consider two dynamically related elements and an emergent third element, but the availability of a logical framework facilitates discussion of the processes involved. In fact, I will show that the logic and the ontology I propose provide a way of bridging the *epistemic cut*, the 'cut' between knower and known, and also between life and non-life, in a way congruent to my proposed bridging of the ontological-metaphysical 'cut'.

8.4.4 Quantum Morphogenesis

The concept of quantum morphogenesis, developed by Aerts et al. (2003) suggests a universal treatment of morphogenesis, understood as a temporarily stable change of form of both quantum and non-quantum systems, that does not depend on the details of the interactions that form a concrete ecosystem, organism or society. Systems are described by an abstract state-space, and the following aspects show the relation to LIR:

1. Sets of mutually inconsistent propositions are allowed, thus the law of non-contradiction does not hold absolutely. The situations involve non-Boolean logic and contexts, in which the logical value of the propositions depends on the history of the system.

LIR: The reciprocal relation between the degree of actuality and potentiality of a phenomenon and its contradiction in the principle of antagonism are such 'propositions'.

2. The systems are probabilistic. Morphogenesis is described in terms of probabilities or uncertainties associated with given sets of propositions. The contextual nature of the propositions requires non-classical probability distributions (non-Kolmogorovian).

LIR: LIR logical values are contextual, i.e., also depend on the history of the system (are systems of systems, etc.), and the shifts from actual to potential and inversely are probabilistic.

3. *Feedback* is a crucial element. Changes in the environment and system interact and influence one another.

LIR: All complex systems involve feedback, enabling a parallel with Aerts' construction.[7]

Aerts' key point is the following:

> "What makes our construction essentially different from the models one finds in the literature is the role of non-commutativity of the system of propositions. Non-commutative propositions are related by uncertainty principles and are typical of systems which cannot, without an essential destruction, be separated into independent parts."

I developed this concept in Chapter 1, and suggested the concept of actuality and potentiality as probability-like, as a basis for the more formal axiomatization of LIR. Aerts hoped that his "quantum mechanical model for the cognitive layer of reality could be an inspiration for the development of a *general interactive logic* that could take into account more subtle dynamical and contextual influences than just those of the cognitive person on the truth behavior of cognitive entities." This is what I propose LIR is in principle capable of doing.

8.4.5 Half of the Story

I return for a moment to Bickhard's refutation of Kim's argument against emergence. It states that it is not particles that are fundamental units of physics but quantized fields. These are processes, and processes are inherently organized, since a point process is an incoherent notion. "Processes are distributed in space and time, unlike dimensionless point particles." Fields are formulated in terms of differential equations, and such equations are not definable on discrete point sets.

While, as indicated, I agree with Bickhard's conclusions, his argument makes some classical assumptions, e.g., about the relation between particles and space-time that detract from its usefulness. Cao, whom Bickhard quotes, says that the theory of quantum electrodynamics (QED) within quantum field theory (QFT) has an ontology underlying the mechanism of interaction that is essentially the field rather than the particle. However, as locally quantized fields, they have to a great extent (not completely!) lost their continuity (Cao 1997). Therefore, in LIR terms, quantum fields instantiate both continuity and discontinuity. Further, as discussed in Chapter 4, emergent processes at quantum critical points, unlike simple macrophysical changes of state, have both particle and field aspects.

In either the particle or field descriptions, some principle of organization seems to be involved which grounds emergence at the quantum level, and I have

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[7] The reason is, as discussed in detail in Appendix 2 on Systems Theory, that every feedback loop, natural or artificial, (cybernetics) can be viewed as a dialectics involving dynamic opposition, since every cybernetics involves an alteration, a perturbation by an antithetical contradictory aggression, followed by the return to the (state of) regulation that must prevail for the system to be temporarily stable.

suggested that dynamic opposition is just such a principle. If this is so, LIR and the categories of NEO support a theory of emergence, evolution and life that contains at least one new and generally applicable physical (scientific) principle (or law of nature, see Chapter 6). It could provide the metaphysical justification for an interpretation of the relations between the terms of the dualities that are observed throughout the physical, biological and cognitive worlds. There is no reason to assume, because the quantum processes underlying the universe are not (yet) completely known, in the absence of further experiment, that they are irrelevant to higher level emergent phenomena involving self-organization, and that such self-organization follows totally different rules.

My conclusion is that the PDO is an additional *necessary* condition for life and evolution, but it is not *sufficient*, or rather that we do not know if it is sufficient or not, and if not what categories any additional principle might involve. I claim that there is something 'true' and potentially open and fecund about this ignorance. This is similar, albeit formally so, to the anti-realist position that propositions about reality are either true or false but we cannot tell which.

Nevertheless, I *have* added one more explanatory step between us and the universe, consisting of a model of reality and a set of its categories that capture some essential aspects of living systems. I take seriously, in my development of this 'step down', the apparent confrontation or dynamic opposition between dark matter and negative energy (cf. Section 7.6.4 on the cyclic model of the universe). If one assumes that this opposition may have produced, as an emergent by-product, standard matter-energy, in which opposition is also inherent, it is not unreasonable to follow the PDO to higher levels of organization to see what insights it may provide.

Let us now see how the LIR picture might apply to the closely related concept of closure in biological systems.

8.5 CLOSURE IN LIVING SYSTEMS

8.5.1 Defining Closure

The term closure is usually defined as the establishment of a domain of discourse within a given discipline that is complete and self-sufficient. The concept developed from set theory: the closure of a set and its internal structure provide for adding additional elements. Closure in propositional logic means that the logic contains all the rules and elements necessary for the development of further theorems. The basic idea of closure in general is to separate objects into one class of interest that is included in the domain and the exclusion of other objects or classes. However, also as shown by Aerts, there is a tight formal connection between quantum mechanics and closure (Aerts et al. 2005), and hence a potentially significant relation to the quantum-like aspects of LIR. This section compares the roles of LIR and closure in explaining the emergence, development and evolution of structurally stable systems at chemical, biochemical, biological, psychological and cultural levels.

Closure is defined and used by its proponents in a large variety of ways (Chandler and van de Vijver). In the physical sciences, the concept of closure implies addressing the basic issues of the organization of matter in space and time, in which the assumptions of set theory are seldom applicable. A thermodynamics that is grounded on isolated systems at equilibrium begins as a well-defined closure, but many other scientific theories lack a persuasive logic of closure. In LIR, of course, the logical property of closure is *also* a dynamical property of closure – closure with respect to a dynamic system.

Thus it is the dynamic characteristics of energy in general that can provide the basis for an understanding of closure. For example, I would add to theoretical basis of closure the Pauli Exclusion Principle, giving it importance equal to that of thermodynamics, whether systems are at equilibrium or not. What this means is that no theory of emergence could be closed without reference to the Pauli principle. However, there is nothing in LIR that should be taken as stating or implying that the actual world is not closed under the laws of physics.

There are many issues in accounts of closure, implicit or explicit, which the logic of/in reality could clarify. For example, the idea that living organisms construct their own time from internal molecular-biological dynamics is difficult to reconcile with a standard relativistic but non-contradictorial account of space-time. How time is 'entwined' with space in temporal biological closure can be approached by looking at the dynamic opposition in the dependent relation between living organisms and their lower level dynamics.

8.5.2 The Category of Closure

In view of the above comments, I believe it is useful to consider closure, like emergence, as a formal sub-category of Process.

Thesis 8.3: Closure is a formal sub-category of Process describing a more or less complete set of functional relations between a system and its environment that embody the categorial features of antagonistic duality and fit the Axioms of LIR.

Closure thus is accompanied, as any real process, by its non-separable opposite of Non-Closure. Indeed, people talk freely of autonomous systems being based a *special form of closure* that involves active, functional relations with the environment, hence with what is *outside* the system, a closure that is unclosed. The LIR-NEO categorial view provides a formal way of discussing internal and external closure and their coupling, as Moreno (2000) puts it, "in such a way that they cannot exist without each other." This is simply a less specific statement of the PDO in other terms. (For those who might balk at the expression that closure is in this sense closed *and* not closed, or is 'leaky' as suggested by van de Vijver, I suggest the term *exclosure*, which captures the concept in French behind the cognate *éclosion* – opening or budding).

8.5.3 Opening Up Closure

Continuing the thought in the previous section, let us recall that in the LIR concept of levels of reality, differences in laws and fundamental concepts exist as one goes from contradictions between elements at one level of reality to another, according to the Axiom **LIR3** of the Included Middle. On the other hand, movement between hierarchical levels of organization *within* a level of reality also takes place, and there must be some energetic mechanism that drives this movement as well. In other words, the proper objective of an analysis, applied to studies of hierarchies in complex systems, would be to give meaning to the verbs in such phrases as "*going* up one level in scale" or "an open variation that *is reorganized* at some higher level".

Lemke (2000) offers an hypothesis about the relationship between semiotics and the dynamics of complex self-organizing[8] systems within the biological level of reality. The standard Peircean definition is used of semiosis as a process of meaning making, of construing a material entity or phenomenon as a *sign*, rather than simply interacting with it energetically: "semiotic interpretation differs from simple physical interaction." One could consider information and meaning as energy here, but the *distinguo* is not trivial; meaning is at a higher level of interpretation in the sense of Section 5.2 in its including of 'meaning for'. This is the essential distinction between information considered in the sense of Shannon as simple negentropy and what Logan (2007) has called instructional or biotic information. Standard logic is applicable to the first since it represents only the non-contradictory aspects of diversification. The second requires LIR since it involves emergence and meaning, described below as "topological semiosis".

From this one can derive what effectively is a Principle of Alternation and a Principle of Emergence: a new level in the scale hierarchy of dynamic organization emerges if and only if a new level in the hierarchy of semiotic interpretation emerges. The examples of typological alternation or typological semiosis seem essentially equivalent to what I have referred to as alternation between limiting

[8] See Section 6.2.8.2 on self-organization.

cases of opposing terms without internal dynamics. This term is defined as a generalization of digital signaling and as the principle for mathematical and scientific symbol systems, that is, ones that are dynamically inert. Topological semiosis, on the other hand, is a generalization of the notion of analog signaling.[9] In topological semiosis, all the interactions, responses, etc., of the organism involve dynamic opposition, and in any movement to any higher 'level', say, even of complexity, that opposition results in the emergence of a T-state, equivalent to a logical included middle. There is no reason why this T-state cannot be, at its level, a discrete type. Semiotically, each higher level is characterized by its own exhaustive paradigms of types, and *at* levels of organization where only typological difference matters, and *for* levels for which this is true, one speaks of semiotic closure *within* a level. However, if the Principle of Alternation is involved, then *across* semiotic triples of levels there is always somewhere a lack of *topological-semiotic* closure, and it is this source of *potentially* meaningful open variation that is reorganized at some higher level again into a new typological-semiotic closure. This is to me a most interesting example of the dynamic, functional role that can be played by an absence or lack.

8.6 DOWNWARD CAUSATION

8.6.1 The Category of Downward Causation

One way of defining downward causation (Heylighen 1995) is as the converse of the standard reductionist principle, namely, that the behavior of a whole or system is completely determined by the behavior of its parts, elements or sub-systems. In downward causation, "The whole is to some degree constrained by the parts (upward causation), but at the same time the parts are to some degree constrained by the whole." Thus, determinacy is not complete. It is necessary, however, to give an explanation of why parts and wholes have these abilities. According to the principles of LIR is because they share in part one another's properties: the LIR approach is an attempt to resolve the inevitable problems resulting from the classical concepts of space, time and causality as categories with *separable categorial features*, and these include final and effective cause.

I thus construct the material category of processes instantiating downward causation, also as a sub-category of Process – Downward Causation that fits the Axioms of Conditional Contradiction and so on.

[9] Lemke gives a useful table, with the suggestive name of "Trans-organization across modes, of Level *N*-1 topology to level *N* typology, and of Level *N*-1 typology to level *N* topology".

Emmeche (2003) also states that downward causation, like emergence, should be considered as a category of the processes instantiating it. However, I do not agree that it is a formal category of cause that is independent of any time-sequential effective cause. I thus rephrase Emmeche's claim by saying that downward causation from the emergent level to the parts level *is* extended in sequential time *and* is a movement through phase space. This way the use of the word 'movement' does not beg the question (by implying a notion of time), and the picture is not simply a loose metaphorical analogy.

8.6.2 Synchronic Reflexive Downward Causation

Processes of downward causation in emergent biological phenomena are those by which, for example, an organism acts on its own constituents in a way that can be distinguished from the behavior of those constituents. Symons (2002) captures a metaphysical picture of downward causation in his paper on emergence and reflexive downward causation. In this view, emergence provides a necessary conceptual framework for understanding the related notions of causation, explanation and individuation that are required for an explanation of downward causation. He claims that (1) a probabilistic interpretation of causation gives a meaningful sense in which a whole can act on its parts, without becoming something other than itself in the process; and (2) the structural property of the whole, *qua* emergent property exerts a change on the causal power of the parts, but a "funny kind of change", namely, a change in their *potential* (emphasis mine) for behavior in the moment immediately following their entry into the whole.

In the LIR category of Process (change-as-process), the passage, spiral not circular, from actual to potential and back, is indeed to be sought in statistical and probabilistic factors, and the antagonistic picture of wholes and parts eliminate the 'philosophical risk' of things becoming other than themselves since they were not 'all themselves' to start with, but, as dynamic systems, shared properties of the other member of the pair, given the ontological predicates of NEO applied in this case to parts and wholes. The point (2) above, together with the thought experiment on which it is based, shows the power of the concept of potentiality as a cause or mechanism of downward causation.

Symons points to the problem of trying to resolve differences between constitution and identity, between what something is made of and what it is, using functionalist concepts of something 'half-way' between physicalism and classical dualism, equivalent to an instance of the concept of 'both-at-once' that I have criticized as non-explanatory.

As proposed throughout this book, LIR is an argument for the reality of entities and the relations between them. It both accommodates and supports a concept of emergence and supports the objective for it of "providing a way of recasting our basic metaphysical assumptions so as to account for the usefulness of higher-level phenomena." LIR, unlike standard non-reductive materialist views, provide a way of differentiating between the causal power of mental events *qua* mental events and the causal power of the microphysical phenomena that realize, but do not embody them *per se.* What is embodied in both is the PDO, and the function of the microphysical entities is to act as carriers of the conflict between the intensional and extensional properties of energy to the higher levels, where they combine in obviously more and more complex ways. I would again point to the significance of this concept for a potential new philosophy of mind.

The LIR approach can be used to undercut Kim's epistemological criticism of reflexive downward causation that suggests that higher-level phenomena are only artifacts of our representational systems. As noted, I have no difficulty in accepting the physicalists' metaphysical assumptions that non-basic properties supervene on their physical constituents or that the world is causally closed under the laws of physics. Supervenience in this sense requires only the generalized application of the category of Dynamic Opposition, plus the definition I have given of the relation between cause and effect. It seems to me that this goes a long way in the direction of providing emergentists the needed support for legitimizing emergent phenomena as real.

Using LIR, a number of illustrations of downward causation can be given, involving physical, biological or neuro-psychical systems. For example, in the internal dialectics of concepts (Lupasco 1979), the resultant systems (of systems, etc.) involve the interaction of all three of the corresponding contributing dialectics, that is, those of the 'higher level' T-state itself with the 'lower' ones from which it emerged. However, how can the existence of downward causation as an interaction be reconciled with a requirement of the discontinuity of levels of reality, involving a change in the laws applicable at each level?

I suggest that where the principles apply and a T-state emerges from the dynamic opposition of two terms, it can be at another level either of reality or of complexity. The latter can be a hierarchical level within the same level of reality (e.g., socio-political), provided the contradictory elements are in a dynamic relation, and not a classical logical relation, of conjunction or disjunction (Nicolescu 1999), and complex enough to instantiate some form of internal representation. LIR is also a logic of complexity that permits crossing between different domains of knowledge. In higher, ontological levels of reality, the dynamic 'complementarity' of Paul (2002, private communication) can be the organizing principle, rather than contradiction in the sense of counter-action as noted earlier. However, at all levels, those involving complex mental phenomena, in which macrophysical and biological components are (almost) absent, and those in which the latter are predominant, the category of T-states as included middles always enables, and is in fact equivalent to, a downward causal connection between adjacent levels. In this picture, as indicated in the discussion of levels, a change of one significant parameter is sufficient to characterize the difference between level and meta-level.

The major challenge to a theory of emergence, as formulated by Kim, is to resolve the apparent paradox involved in *synchronic* reflexive downward causation. Given the layered picture of the natural world as the most acceptable one, along the lines of my discussion of levels of reality in Chapter 1, within this world, properties can cause instantiations of other properties at the same level, at higher levels or at lower levels. Upward causation and same-level causation have been easy to imagine, even for reductionists, despite their lack of understanding of the contradictory processes that I consider are involved in both, but which yield different results. Upward and downward causation involve T-states; same-level does not, that is, only relations practically without internal dynamics or representation, *qua* the level, are involved, the conditions for applicability of standard logic.

Kim says in effect that higher-level properties can serve as causes in downward causal relations only if they are reducible to lower-level properties. If this is not the case, and downward causation is, also, transitive, it is circular, equivalent to self-causation. Introducing the concept of time, Kim attempts to show that synchronic reflexive downward causation is unacceptably paradoxical "by virtue of the assumption that for an entity to be responsible for an act, *it must have had the power to perform the act prior to performing it*". In a certain deep sense, this statement of Kim's is literally true, but one must not look for this 'power' in some impossibly actualized structure. It is there as *potential*, or perhaps better, in the interaction of the set of potentials of the parts, as implied by point (2) above.

Diachronic reflexive downward causation can be reduced to supervenience by removing the reflexive aspect, free of self-causation and self-reference, but this is an unacceptable weakening of functional emergence. A better approach is to suggest alternatives to the usual concepts of synchrony and diachrony, which amount to binary logic in temporal terms. Something more fundamental and 'exciting' than supervenience *is* involved in the apparently diachronic case, since I feel there are no merely additive consequences of interactions, as if we were dealing with purely standard categorial properties. The causes and effects occur in space-time that is both successive and simultaneous, one or the other aspect being predominantly actualized and the other potentialized, in turn. To restate the basic concepts of antagonism somewhat differently, it is the dynamic opposition between parts and wholes, carried by the structure of the whole, which is the basis for the effect of the structure on its constituents that is distinct from the powers of those same constituents. In the probabilistic, antagonistic system of cause (or cause/effect), one can propose an account of this effect 'taking place' that is both synchronic and diachronic. This is my proposed interpretation of Symons' phrase "the moment immediately following their (the parts') entry into the whole."

Given the principle of dynamic opposition inherent in the logic of energy and of levels of reality, and their consequences for the causal and temporal properties of phenomena, I have shown how emergence seems to follow naturally. We have seen in Chapter 7 how the LIR theory supports a non-reductionist, relational view of quantum mechanics. Downward causation can follow as a corollary to *any* ascriptions of causal relations above the (quantum) level of basic physics. I have tried to demonstrate, in effect, that the *essential contradictory aspect* of those relations is the same for quantum level and for higher level phenomena, and thus that it holds throughout nature. There is, accordingly, nothing objectionable to downward causation being of a reflexive form that is consistent with emergence.

8.7 EVOLUTION AND THE ORIGIN OF LIFE

The processes involved in contemporary living systems at the biological level are more or less completely accessible to direct investigation, and enormous progress has been made in determining critical aspects of structure and function at all levels from biological macromolecules such as proteins and polynucleotides to complete individuals and groups. The use of DNA analysis has made possible new, more accurate models for the migration of primitive man from an initial locus in Africa to the rest of the world.

Systems biology is the name of the new discipline that seeks to convert the masses of new data that have become available into an explanation of how whole organisms function. Relying heavily on mathematics and statistics, new data-intensive techniques and new algorithms, it is an attempt to build models and make predictions about how complete biological systems behave. In the view some of its practitioners (Pennisi 2003), the similarities between evolved circuits and engineering circuits raise the hope that there are deep laws of nature that unite living and designed systems. Others believe that the ‘rules’ of biology will remain elusive.

Despite these developments, many questions over larger scales of time and complexity cannot be directly studied, and remain without satisfactory answers. These are the problems of life in their most general form:

- Origin of Life – the emergence of animate from inanimate matter
- Evolution – the emergence of new species
- Growth – the emergence of new forms in the life of an individual
- Reproduction – the emergence of new individuals

Common to all of these problems is the issue of emergence, how more complex entities, or less complex but still new entities can emerge from lower level substrates. As we have seen, there is substantial debate over what emergence is, and even if it exists as a valid concept, as well as over the related issues of ‘inverse’ emergence – downward causation, and the meaning of closure for living systems.

Death and disappearance, the 'opposite' of these processes, are in a sense intuitively well-understood as the inability of a living system to 'resist' antagonistic, invading forces of various kinds, followed by, ultimately, the return to a lower, macrophysical level of matter-energy. Emergent life processes, on the other hand, have not yet been modeled in the laboratory, despite major research efforts in this direction. Little progress on the origin of life had been made since the simulation by Miller in 1953 of the production of organic molecules in the Earth's atmosphere. Attempts to create precursors to the macromolecules of life by polymerizing them on existing inorganic templates have been partly successful, but require highly artificial conditions (Rasmussen 2004). 'Simple' organisms such as bacteria and viruses can be seen to evolve on short time scales under pressure from anti-bacterial and anti-viral drugs, but there are few explanations as to how such processes, or even normal embyrogenesis, are related functionally to biologically active substances, from hormones to ones as simple as calcium ions.

In my position statements in Chapter 5, I stated that classical logic biases the debate in science in two ways, because (1) the internal structures of theories such as those of theoretical biology follow the rules of classical logic; and (2) the domain of description of these theories is a reality that is conceived of in classical logical terms, that is, it is misrepresented by classical ontologies.

My 'ideal state' would be, therefore, that in biology as in other science, (1) arguments would be presented that would see new concepts and patterns of inference emerging, more or less according to the LIR theory suggested, something like T-states from the 'clash' of opposing alternatives at the theoretical level; and (2) that the domain of description of biological theories should be understood as suggested by my New Energy Ontology (NEO), that is, involving the all its categories and sub-categories.

8.7.1 The Absence of Logic in Biological Science

It is perhaps an understatement to say that logic has not had a major role to play in current biological science. Given the limitations of logic to linguistic and mathematical domains this is not surprising, and I can understand the resistance of biologists to considering that any *logic* could have something explanatory to say about biology. As in the case of other disciplines, however, I claim that it is the underlying presuppositions of classical and neoclassical logics that vitally affect the kinds of interpretations of biological phenomena and theories that are made to explain them. I will show, in support of this claim, that recourse is often made to a dialectics, a duality, the function of whose elements cannot be understood when they are, as in the vast majority of cases, considered as independent of one another. Calling attention to the function of dynamic opposition, as defined in LIR, may not resolve the problem or the dichotomy completely, but the gain in explanatory power may provide guidance for further experiment.

The debate between mechanists and vitalists, presented earlier in this chapter, can be viewed as a logical one in the extended sense of the logic of/in reality. No one espouses vitalist positions today, but the debate reappears in other forms, in the transcendentalism of catastrophe theory and in attempts to explain emergence itself. Descriptions of biological processes in terms of dynamic feedback mechanisms or cybernetics[10] (cf. Section 8.8.2) are now common, but little reference is made to these processes as *logical* consequences of something more fundamental. In general, any logically binary position involves ideal, or idealized or abstract entities, as one prefers. Such positions, like those that base their arguments on some form of spontaneity, are not vitalist ones, but they share the abstract properties or categorial features of absolutism and exclusivity with vitalism.

My extension of logic to reality and its structuring as an ontology permits another way of approaching biology. This approach is in a sense quite novel, but I believe it may useful as a way of insuring that correct insights of conflicting views receive serious recognition. Let me therefore summarize some current views and the problems with them, and suggest initial LIR alternatives.

8.7.2 Natural Selection

Natural selection as the basis for evolution *looks* like a notion that embodies antagonism, but on closer inspection, there is nothing to distinguish it from a purely physico-chemical concept of life. It can be placed together with other reductionist notions of hierarchy, progress and Manichean conflict. Some sort of efficient cause seems to be the only basis proposed for natural selection to operate, whereas I propose a fundamental role for the antagonisms found at the physical and chemical levels of reality and consequently for the phenomena the origin of life and evolution at the biological level as well.

Both Lupasco and Emmeche have castigated the account of evolution in the neo-Darwinian paradigm of natural selection as brutal, cynical, algorithmic and mechanist, adequate at best as a theory for insentient zombies. However, the establishment of the categories of Emergence, Closure and Downward Causation is necessary but not sufficient as an approach to a theory of the origin of life and evolution. Emmeche considered biosemiotics, as noted above, as a promising perspective, but was concerned that its concept of code-duality also might imply a hidden prototype fallacy, the genotype-phenotype duality of classical genetics (Emmeche 2000). He later described biosemiotics as a "corrective theoretical enterprise" that enables investigations of questions to be made that have been dismissed due, in his view and mine, to the materialist and reductionist assumptions of much neo-Darwinism. As Emmeche remarked, "the real challenge is not just to consider life as semiotic processes rather than as organized molecular systems but

[10] In Appendix 2, I provide an overview of developments in cybernetics and systems science from the LIR viewpoint.

to investigate the relation between the molecular and semiotic aspects of life processes".

I consider that LIR and NEO provide another form of 'interactionist' explication in the evolution-developmental debate that does not suffer from the absence of physical grounding as in the research of Kauffman, Maturana and others. Above all, my task is simplified by the fact that naïve dualism should no longer be an issue. Contradictorial or conditional dualism and its related conception of contradictorial cause and effect offer a non-traditional, non-mechanistic metaphysical and methodological approach.

In this section, I will first point to the not-so-hidden prototype fallacies (cf. Section 8.4.2) in one approach to semantic closure and the epistemic cut. Since these considerations are fairly complete, they provide a good testing ground for the principles of the logic of/in reality. I will then indicate my preferred way of looking at the problems of life.

8.7.3 The Epistemic Cut

The concept of an epistemic cut was originally formulated by von Neumann in his demonstration that the function of measurement of some physical variable is irreducible to the dynamics of the measuring device (Pattee 2001). The logic here is related to the necessary separation of the symbolic memory and the dynamic laws required for the self-replication of a biological system. It has been considered as a special case of a general epistemic problem: how to bridge the separation between the observer and observed, the controller and the controlled, the subject and the object.

The first observation I make, from the point of view of LIR, is that such separation, that is, the existence of such a cut, is not an necessary property of all systems, but involves a category of processes in which Separability is instantiated, which is accompanied by another in which the cut is replaced by a relation of interaction that I have called Non-Separability.

An epistemic cut appears in a view of dynamical laws which requires that such laws and the initial conditions of a system are sharply separated, the initial conditions are capable of being measured, and measurement and laws have no reciprocal influence. This intellectual distinction between initial conditions and laws *allegedly* has its origin and embodiment in living organisms. In this concepttion, our perceptions as well as our natural languages support a deterministic, either-or logical syntax and causal semantics that conform to a classical dynamics. This happens to be true. I would say science is *burdened* with this concept of state-determined behavior as a modern form of Laplacean determinism, but it does not validate these considerations as the basis for a theory of biology in particular or reality in general. I have shown that such a view of syntax and dynamics is suspect, since it fails in many areas in addition to quantum mechanics. For example, natural language cannot be described even by categorial extensions of classical logic.

Non-integrable conditions, or constraints, can be proposed for bridging the epistemic cut. One constraint states that, in order to provide configurational space for hereditary processes, there most be more degrees of freedom available for the description of the total system than for following its actual motion. As stated by Pattee, since law-based dynamics are based on energy, in addition to non-integrable memory reading, memory storage requires alternative states of energy. Constraints are formally equivalent to laws, and the evolution of systems depends on both.

The complementarity of dynamic laws and the measurement function is irreducible, based on a demonstration by von Neumann that the contrary would lead to an infinite regress of measurement devices operating on systems of systems plus measuring devices and so on. However, Pattee makes the assumption that epistemic irreducibility does not imply any *ontological dualism* (emphasis mine) and that it arises whenever a distinction must be made between a subject and an object, or in semiotic terms, between a symbol and its referent. But an ontological (read metaphysical) dualism is exactly what results, and the consequences are subject to my version of the Leibnizian analysis (of similarity and difference, etc.). If the terms are different they cannot communicate or interact; if they are the same there is no cut. The only possibility of a bridge is that they are the same *and* different.

The classical view of logical disjunction is that something is totally different from something else. Is the epistemic cut, then, essentially equivalent to classical? I think it is. The terms are only epistemologically and not *functionally* connected. No one would think of 'separating' conjunction and disjunction. However, this does not confer any additional reality to the cut, but demonstrates its limitations.

Without any epistemic cut, it can be argued, any use of the concepts of measurement of initial conditions and symbolic control of structuring would be gratuitous. I disagree, and the category of Subjects and Objects and their included middle – Subject-Objects – offers an alternative approach to a description of the relation between the terms in this picture. To recall my definition, being a subject means primarily instantiating actualization (efficient cause) and being an object potentialization (final cause). One can easily associate potentialization with symbolic control and actualization with measurement, following the approach implied by the categorial features of Subject and Object.

The absence of a non-interactive relation between the two sides of the epistemic cut, as proposed, leads to a dead end. Pattee admits that the cut itself is an epistemic necessity, not an ontological condition. What is going on ontologically at the cut is not analyzed, but is it true that only the subject side of the cut can measure or control? For genes to control protein synthesis, they must rely on previously synthesized macromolecules such as enzymes and RNA. Semantic or semiotic closure is defined as such an additional self-referent condition for being the subject-part of the epistemic cut, a "molecular chicken-egg closure that makes the origin of life problem so difficult."

Pattee then says:

> "The concept of an epistemic cut must first arise at the genotype-phenotype control interface. Imagining such a subject-object distinction before life existed would be entirely gratuitous, and to limit control only to higher organisms would be arbitrary. The origin problem is still a mystery. What is the simplest epistemic event?"

I do not begin the story of life with enzymes. From my point of view, the 'simplest epistemic event' was the emergence of matter-energy, as we now know it, in the universe, or multiverse, etc. All the necessary distinctions were present as potentialities, sometimes referred to in theological contexts, independently of any LIR interpretation, as *haecceities*. Given the prior definition of subject and object by the standards of classical logic, von Neumann's argument that the distinction between them requires a description of the constraints that execute measurement and control processes and that such a description is not reducible to the dynamics being measured or controlled is correct, but it is not complete, in the sense that subject and object also instantiate partial categorial conjunction (cf. Section 4.6).

If we have come to think of symbol systems as being independent of physical laws, in my view this independence is *apparent*. The view that genetic symbol systems have evolved so far from the origin of life and that semiotics does not *appear* to have any necessary relation whatsoever to physical laws is also true, but it occults the fact that the processes involved instantiate the same categories of Dynamic Opposition and Non-Separability. I can thus agree with Pattee on the following points: (1) the illusion of isolation of symbols from matter can arise from the arbitrariness of the apparent epistemic cut; (2) the apparent isolation of symbolic expression from physics seems born of an epistemic necessity, but ontologically *it is still an illusion*; making a clear distinction is not the same as isolation from all relations; (3) one clearly separates the genotype from the phenotype, but one certainly does not think of them as isolated or independent of one another.

Further elaboration of the matter-symbol problem is possible using the two-level framework of Section 5.2. If the illusion of isolation is an epistemic illusion, whose reality is accepted, the paragraph above *must* mean that symbolic expression is *not metaphysically isolated from physics*. Consequently, their relation or interaction is real, and it can be considered to have an appropriate dynamics. The remaining question concerns the use of antagonism or constraints to characterize these dynamics. This can be resolved by a view of symbolic memory constraints as dynamic processes in themselves, co-evolving with the other components of the biological systems.

My purpose in reviewing these ideas was to provide background for my essential claims, namely, that there must be some form of dynamic interaction between the members of the various dualities involved in evolution, and it is the proposed cut itself that is the most serious 'illusion'. If something is not independent of something else, then the dependence relation must be specified, ontologically or otherwise, and my thesis is that LIR and NEO accomplish this.

8.7.4 Semantic Closure: The Matter-Symbol Problem

In the terminology of LIR, the macrophysical phenomena studied by physics display an essentially exclusive tendency toward homogeneity, following the 2nd Law of Thermodynamics. This is equivalent to a sharp categorial distinction between matter and symbol. As implied in Chapter 5, material systems, *in general*, do not contain intrinsic symbolic activities or functions. In extreme physicalist-reductionist positions, symbols are considered epiphenomenal and fated to become superfluous when adequate material descriptions of symbolic behavior are found. Like classical physicalism, functionalism and computationalism make the same distinction between matter and symbol, but they focus only on the symbolic category. Functionalists consider the specific material embodiment of symbolic activity as unimportant. Computationalists are functionalists who interpret all processes in terms of computation, and the matter-symbol relation is ignored. It is, however, possible to see these two sets of approaches as limiting cases, the first of identification and the second of diversification in the sense of an absence, or lack of grounding or meaning. Models of artificial life and artificial intelligence 'float' in an abstract domain, and their relation to an empirical reality seems to me forced.

Organisms, on the other hand, depend on internal symbolic controls, and the process of the origin of life requires, among other things, the existence of some form of symbolic genetic code as a crucial component. For a hereditary process to function, that is, have open-ended evolutionary potential, biological macro-molecules must have specific capacities for acting as templates for exact replication and mechanisms for handling mutations. A specific form of self-reference (Pattee 2000) applies to the relation between the material and symbolic aspects of, in particular, living organisms. Self-reference that has sufficient evolutionary potential is an autonomous closure between the dynamics (physical laws) of the material aspects and the constraints (syntactic rules) of the symbolic aspects of a physical organization. Pattee calls this self-referent relation semantic closure "because only by virtue of the freely selected symbolic aspects of matter do the law-determined physical aspects of matter become functional (i.e. have survival value, goals, significance, meaning, self-awareness, etc.) *Semantic closure* requires complementary models of the material and symbolic aspects of the organism."

The definition of a symbol now becomes crucial: a symbol can be described as a relatively simple material structure, material including the senses of energy and information, which while conforming to laws of physics, has significance or semantic function that is not describable by those laws. Physical laws are supposed to describe only those properties of matter that are independent of observers and individual measurements, in order to be sufficiently universal.

Symbols, however, are selected for their context-dependent contribution to the survival of individual unity or identity in a local environment. The universal aspects of matter that are described by laws have no significance for individuals; they are the material equivalent of logical constants. To insure that physical theory can treat symbols as something more than matter described by laws, a division of experience must be made into things that change and things that do not change. Only the independence of symbolic and material aspects allows the clear fundamental separation of laws and initial conditions. Symbols must be viewed as belonging to a general category of initial conditions, which also includes boundary conditions and constraints.

The difficulty with such a picture of symbolic function in developmental evolution is that it depends on either the assumption of an absolute duality – change and non-change – or a clear hedge: physical laws describe only those properties of matter that are independent of observers and individual measurements *as far as possible.* Laws and measurements are different categories, since individuals, not laws, make measurements, but the problem is not about laws, it is about the relation between the allegedly complementary material and symbolic aspects. From the perspective of the origin of life and evolution, the problem is how material structures following physical laws (or their equivalent) with no function or significance gradually developed into symbolic entities possessing such function and significance. It is also difficult to see, from the epistemic cut position, how life could have evolved. The suggestion of mechanism is made of "a sort of downward causation through the action of natural selection" does not answer the question of how physical constraints could become semiotic controls.

The absence of an answer to this question suggests that there is something wrong with or missing in the argument and LIR provides two possible corrections: (1) as discussed above, the concept of passive complementarity should be replaced by that of Conditional Contradiction and Functional Association. Matter and symbol are dynamically, contradictorially related; and (2) the assumed division of experience is not foundational. The minimum requirements of a theory of evolution and the origin of life are a chemistry that incorporates the PDO; an actual physics of living matter that includes the details of how subject and object interact; and the involvement of that chemistry and physics in the potentiality – memory controlled construction of biologically active macromolecules as suggested above.

8.7.5 Code Duality: Bridging the Epistemic Cut

It should be obvious that the simplistic continuity approach (the *no-*cut position) to evolution tends to exclude essential aspects of evolving living systems. A standard no-cut position is as follows:

> The increasing complexity of evolution is the function of operation of contextual constraints. Parts no longer independent of each other constitute the self-organization of a higher level; as such, contextual constraints are the agents of inter-level, bottom-up causality. Acting top-down they simultaneously create new roles for those parts as they create them.

Despite its apparent Peircean pan-semiotic flavor, there is no physical meaning in these contextual constraints. I suggest that higher level contextual constraints were provided by the basic dynamic antagonisms in energy and were operative at an early pre-biotic stage, and that most of the subsequent expansion of biological space took place guided by these constraints, at both the 'high' level of the universe and the 'low' one of the photon. Auto-catalytic cycles, tornadoes or other such entities are real, but that there is an important sense in which they are logically different from living entities, namely, they do not interpret their environments.

As I remarked, I believe any absolute distinction between a dynamic and linguistic mode is incorrect given the dynamic origins of language. The dynamic mode in living systems is always a semiotic mode both index-coded (digital) and analog-coded (symbolic), and distinguishes between digital and analog contextual constraints. Such a distinction, based on a fundamental duality of life, is needed to account for the evolutionary origin of any apparent epistemic cut.

Through the introduction of the concept of tacit cellular knowledge, Hoffmeyer (2000) provides the equivalent for an alternative antagonistic mechanism for the evolution and higher development of living systems that embodies some of the key concepts of LIR. The tacit knowledge aspect of cellular (or organismic) activity, the recognition capabilities of macromolecules, Hoffmeyer argues, is "the strangely overlooked key to biosemiosis." As I suggest below in the systems model of evolution, 'genocentrism' is only one aspect of a general cultural bias towards what can be called 'digitalism', the *preferential allocation of realness to digital aspects of the world, numbers and sequences.* Digital aspects refer to everything I mean by the paradigm of identity and its binary.

The idea that the developmental control value of "activator, repressor or hormonal" molecules is not an inherent chemical property, but only a complex *relation* established by a collective hierarchical organization requiring the whole organism is incomplete. It is *also* in part an inherent *potentiality*, a meaningful semiosis or sign. Pattee did not assign a semiotic nature to this hierarchical organization, which he saw as "safely belonging to the world of dynamics." The concept of code-duality as outlined here claims that the dynamic mode is basically a semiotic mode. What is essential is the "interdependence of the analog and the digital as two equally necessary forms of referential activity arising like twins in the individuation of that logic we call life." Digital codes provide stable access to the temporal world, and analog codes provide the basis for interaction with the world, other-reference and preference. "To claim that only the digital twin is semiotic, whereas the analog twin remains in the sphere of classical dynamics, is to block the only possibility for ever transcending the epistemic cut." It may be a source of sardonic amusement that classical dynamics comes to occupy here, in a classical, binary mode of reasoning, the 'despised' role of the source of diversity!

In the LIR view, it is the inherent potentialized chemical properties in molecules that correspond to 'tacit knowledge', as well as the relations. They are arbitrary, in a sense, but they are tied back to the antagonistic categorial processes that pervade existence. From this standpoint, *even* digital codes have some residual potential semiotic character, and one would be ill advised to make the separation too absolute. The 'interdependence' of analog and digital, is an example of contradictional dynamic opposition, one aspect being temporarily and alternatively actualized at the expense of the other, with the emergent organism playing the role of an included middle.

The pattern of processes out of which life arose may have reflected the same general logic. The first process is an 'interiorization', in which membranes build up an asymmetry between their excluded interiors and exteriors. Pre-biotic membranes 'chose to prefer' their insides from their outsides, or one might perhaps see this as a sort of colonization of the interior space.

Hoffmeyer coined the term *selfication* to describe a particularly human kind of natural individuation as "a necessary theoretical resource not reducible to thermodynamics nor to an emergent hierarchy of contextual constraints."

> … Thus, persistent architectures appeared as entities engaged in the trick of conjuring up a *virtual reality* at their insides for the purpose of coping effectively with their outsides. … The general principle described here might be called *semiotic closure*, a closure that locks analog (indexical) and digital (symbolic) codings into a shared selfication context.

I see the selfication context as a T-state emerging from the interaction of analog and digital processes. The potentialities postulated by LIR can be considered an alternative term for a physical virtual reality that is a necessary stage in the emergence of life.

8.7.6 A Systems Picture

The concepts of LIR and the categories of NEO explicate the systemic-historic perspective on developmental and evolutionary biology. Its chief tenet is that an epigenetic structural drift that is not solely genetically determined constitutes the ontogeny of an organism. Biological epigenesis implies that although the development of the phenotype is made possible by an initial structure including, but not limited to, the genome, it is not determined by it (Cecchi 2004).

The genotype-phenotype relation (phenotype as cell or complete organism) contributes to the expression of new structural features, but only by participating in a process that takes place in a structural context that is distinct and operationally complementary to the genotype. The LIR picture is very similar, but provides in addition a description of the lower level, contradictorial processes that combine or couple to result in this complementarity.

In the gene-centered view, genes establish and determine the direction that the structural change of the whole undergoes, independent of the prior dynamics of the whole. The systems-historical view stresses the reciprocal relationship between the whole and the parts and the organism/environment relationship for ontogenetic changes during development of the phenotype *as well as* changes in the genotype or in any other component in the evolving lineage. The phenotype is the result of development understood as the ontogenic history of the individual.

In other words, an organism is a unique organized whole of mutually correspondent parts that exist only in realizing a particular mode of relationship with their environment, neither as the consequence of design ('intelligent design'), acting an Aristotelian final cause, nor as the result of an internal component, the gene, as an efficient cause, acting as a plan or program of construction.

Cells as biomolecular systems must have the capacity for continuous structural change and be at the same time discrete, as noted above, with a self-generated boundary as a condition of existence. Biological macromolecules are ontologically related to cells in the same way that organs are related to organisms. They do not exist nor can they be formed in nature outside their structural context or a laboratory environment. In the latter case, it is the cellular structural context that it is proving even more difficult to duplicate. Both biomolecules and the cells that they compose are assumed to have arisen together in a historical process of origin and evolution of cells as multi-structural totalities.

The problem with this historical process view is that it is considered, by its proponents as a *spontaneous* one, and this is enough to render it suspect, at least to me, without further discussion. As I have suggested in other cases in which recourse to spontaneity is made at the lowest explanatory level, the only possibility available is to look at a lower level of physical and chemical entities as also instantiating, not the full set of actualized symbols that would lead, ulti-mately, to pan-psychism, but contradictorially adequate potentialities that insure the emergence of the next level of entities such as those in this picture.

Johnson (2000) supports my critique of this systems picture in his view of a functional role of the categorial feature of diversity, specifically, in self-organizing ecosystems and their natural selection. Although a concept of diversity has always been part of the lexicon of ecologists and social scientists, any formal or quantitative understanding of diversity, like that of complexity, has been limited. "The difficulty is that diversity is only meaningful in heterogeneous constituent systems and available analytical tools for evaluating diversity have been lacking." Although some detailed concepts of non-local diversity exist, there appears to be no satisfactory explanation for both local and global diversity in the simple application of natural selection. Johnson suggests a multi-level perspective that says that natural selection is responsible for improvement in the performance of the individual, but as an interdependent, multiple-level system develops, the need for selection is reduced, as non-competitive processes for global performance start to function.

My preferred answer to question of the *origin* of processes of global system functionality during evolution is that the global system itself contains the relevant structural aspects, and individual organisms form and exist within it, but that there are also mechanisms for the global co-evolution of the traits necessary to propagate the global system. Both the ecosystem and the individuals themselves contain, as potentialities, some of the relevant structures necessary for such co-evolution. This view is consistent with the idea that natural selection has a major function role in the potential production of new *combinations* of phenotypic character traits, but that the effects of mutations of the genome are constrained by the interactions with the environment of the organism's existing systems resulting from the non-mutated genes already present.

8.7.7 Evolution as Context-Driven Actualization of Potential

In this further example of the LIR approach to an explanation of the emergence of life from non-life and evolution, I will look at the implications of the LIR principle of the two opposing properties of matter, toward identity or homogeneity and toward diversity or heterogeneity, with both always actual and potential to differing extents in relation to a model of evolution proposed by Aerts.

As I mentioned in Chapter 1, Aerts has also applied his concepts, in particular that of context-driven actualization of potential (CAP) to a theory of evolution (Gabora and Aerts 2005). The basic idea is that all entities evolve through a reiterated process of interaction with a context. As before, the interaction between context and entity leads to indeterminism that defines a non-Kolmogorovian distribution of probabilities that is different in this case from the classical distribution of chance described by a Darwinian theory of evolution based on natural selection alone. The Darwinian view is seen as materialist, selection for "forms of concrete and actual matter" – materially actualized states.

In this more general theory of evolution, potentiality states, defined with respect to a given context (superposition states in standard quantum mechanics) co-exist with actuality as the basis for context-entity interaction, making possible in turn different pathways for evolution that do not exist in the classical sense. The general evolution process is broadly construed as the incremental change that results from recursive CAP. Aerts believes that this theory of evolution provides explanations for the non-code-dependent processes of real evolution, including other non-Darwinian, that is, non-selective processes such as autopoësis, emergence and symbiosis, noting that the concept of natural selection offers little in the way of explanation for why biological forms and phenotypes arise in the first place. A model of an evolutionary process may consist of both deterministic segments, where the entity changes state in a way that predictably follows given its previous states and/or the context to which it is exposed and/or non-deterministic segments where this is not the case.

The ‘pure’ randomness or indeterminacy that is a necessary condition for Darwinian natural selection is incorrect, but it is so not because it does not exist, but because it is not absolute. As we have seen, in LIR, potentiality and actuality do not just ‘co-exist’, they mutually determine one another, and potentiality is not a superposition of states, but a property of matter that, with actuality, can define another state as an included middle. Finally, potentializations, as energetic phenol-mena, should not be considered as non-material, simply because non-actual.

Aerts is correct to call attention to CAP as describing evolution in other domains, for example creativity and culture, as requiring a non-classical formalism given the possibility for inheritance of acquired characteristics. I will not suggest specific criticisms or alternatives here. What I wish to point out is that CAP, like the theories of Pattee and other discussed above, also fails to explain “why biological forms and phenotypes arise in the first place”, as well as at the other two critical junctures in the story of life.

1. Assuming that prior to self-replication, there was random formation of biopolymers on some template, possibly inorganic, and some of these catalyzed the formation of others in an auto-catalytically closed set, some residual potentialities must have been involved derived from lower levels to result in the high free-energy surface or structure that catalysis requires. If there is a further requirement that some polymers adhere to one another, to form a proto-cellular structure, it is again otiose to say that they must have done so spontaneously. Further dialectical interaction with the context, including some internalization of elements of the environment, also requires that relevant potentialities be available for that process.

2. The transition from uncoded, self-organized replication to replication *per* the instructions given by genetic code is indeed significant, especially in placing restrictions on passing on acquired characteristics to the next generation. But what on earth results in the “advent of explicit self-assembly instructions”? Certainly something more than random processes are involved, but attempts to make DNA only from small molecules in the laboratory under biological conditions have failed. The only thing I can suggest is that further transformation of high-energy bonds of precursors of DNA and RNA into the additional necessary complexity occurred because such complexity was present as potentialities. A better understanding of the interaction between the precursors and their proto-cell environment seems necessary to define what these were.

3. The same problem exists for the “advent of sexual reproduction”, although here the terminology becomes almost familiar: a mate is needed (as context) to actualize an organism’s *potential* for offspring. The question remains open as to what might have been at the basis of the transition to this form of living system.

8.7.7.1 Exclusion-Driven Potentialities

As I discussed above, the picture of the origin of life and evolution that emerges from the fundamental postulate is one of the creation of entities of increasing complexity under the influence of *two* causal energetic processes: one the familiar dynamism of homogenization described by the 2nd Law of Thermodynamics, and the other, much less familiar, of a 'drive' toward locally increased heterogeneity of the same matter-energy. This drive expresses the Pauli Exclusion Principle in more and more complicated ways, and I could use the term for this process "exclusion-driven", to emphasize its fundamental importance relative to context.

The predominant actualization of a trend toward entities with increasing levels of heterogeneity is made possible by an input of energy in various free or bound forms – heat, radiation, high-energy chemical bonds, unequal electric charge distribution, and so on to atoms, other chemical or electrostatic bonds, sterically hindered structures, secondary and tertiary biopolymer structures, cells and organs. Part of this energy will always be degraded to lower levels or less differentiated forms, but not all. Some of it will bring the potentialized aspect of the entity to a state of equal or greater energy to that which was opposing its actualization resulting in the possibility of emergence of a new form as a T-state. In this, homogeneous and heterogeneous structures, and homogenizing and heterogenizing functions are all present in new configurations, but ones in which the latter predominate.

LIR states that the potentialities that are necessary and sufficient, over time, to effect the transitions mentioned above and at the beginning of this chapter consist of the re-expressions of the fundamental heterogeneity of the existence of electrons in two spin states, a heterogeneity that includes the potential for further actualizations. At any level, an entity expresses homogeneity and heterogeneity, stability and functional potentiality for effecting change to the next level.

Some readers may conclude that a form of teleology has crept back into my argument: given the existence, say, of amino acids embodying asymmetry (optical isomers), proteins were inevitable and all the rest follows. I do not consider this a serious objection to the overall theory. There is no more teleology in the usual idealist sense in this view than in the statement that if two electrons of the same spin cannot be in the same sub-shell around a nucleus, a definite number of such levels are possible and, with an input of energy, an electron can be added or removed, or jump to a higher energy level, providing the basis for chemistry, biology and life. No further external *structuring* influence is required, as in other self-structuring or – organizing processes (see Section 4.8.1 and below). Life is the embodiment of the PDO in the category of Non-Separability of self and other. I will close this chapter with a few further final remarks on biological theory.

8.8 THE THERMODYNAMIC AND CYBERNETIC STANDPOINTS

The purpose of this final section is to use the LIR categorial antagonistic principles of actuality and potentiality, and identification (homogenization) and diversification (heterogenization) to refine the usual picture of the functioning and auto-regulation of living systems, that is, of goal-directed organisms whose first goal is survival, as a minimum requirement for reproduction.

In Appendix 2, I provide a discussion of an LIR theory of systems that is in fact another statement, in general terms, of the logical necessity of the PDO and its axiomatic consequences. I also show the relation of my theory to the General Systems Theory of von Bertalanffy and some recent developments of it.

Here, I will mention some examples in chemistry and biology that illustrate the operation of these principles and relate them to current views in biological theory.

- Reduction and Oxidation

Oxidation and reduction are clearly contradictorial in the LIR logical sense since one always implies the other. One in fact always speaks of reduction-oxidation (redox) systems. The quantity of energy-as-potential can even be readily measured *in vitro* in this case: it corresponds to the standard oxidation or reduction potential. Oxidation-reduction processes *in vivo* are characterized in addition by their tendencies to lead to homogeneity or heterogeneity. In any case, the key point is to not to look at single values and to represent phenomena, not in terms of substances or elements but as processes, events and energetic actions. Photosynthesis amounts to the reduction of carbon dioxide to carbohydrates, complex, biological polymers by solar photons. It is a biological process that illustrates a process inverse to the degradation of energy according to the 2nd Law of Thermodynamics, since in it photons are 'up-graded' to the electrons that effectuate the reduction.

- Enzyme-Substrate Reactions

Most processes catalyzed by enzymes involve two or more steps. Rather than a system acquiring energy from a high-energy bond *here* and using it *there* to produce the desired new structure, one can talk in terms of the actualization of the bond's energy and the potentialization of the energy of heterogenization of the new biological systems, followed by a second step of its actualization by another enzyme. The enzyme inherits *its* catalytic properties from the gene coding for it due to the antagonistic physical and biological systems incorporated in the gene, homogenizing and heterogenizing, structuring and operational. Enzymes and other catalysts act at the critical point of stability and instability of molecular systems (threshold phenomena), such that only a weak, statistical "flick" is necessary to effectuate the reaction.

Additional antagonistic dualisms are the operation of activators and inhibitors of enzymes and of hormones operating antagonistically in pairs – androgens and estrogens for example.

- Nerve Cell Polarization, Depolarization and Re-polarization

Before excitation by internal or external stimuli, a nerve cell system is in a state of *potentiality*, maintained by the antagonistic actualization of the polarization or electrostatic equilibrium – equilibrating antagonism (Lupasco 1986). Excitation results in a new actualization, potentializing the ionic equilibrium, equivalent to a heterogeneity of sensations; the next step is an inhibition, a re-equilibration (re-polarization) of the excited nerve cells.

Obviously, for these processes to occur, input of energy is required, according to the principles of thermodynamics, but these are at the same time clear examples of cybernetic systems instantiating *feedback.* The principle of dynamic opposition applies to and explicates the operation of feedback, as I discuss in Section 8.8.2.

8.8.1 Thermodynamics and Complexity

I referred to the thermodynamic view of Salthe and others in connection with causality in Chapter 6. It is interesting that the situation has not evolved (sic), at least, to any new consensus, since Lupasco first stated in 1960 that relative to the macrophysical world, some biologists thought that life could be fully explained by the 2nd Law of Thermodynamics; living systems simply accelerated the entropic becoming of the universe (Salthe says that evolution of more and more complex living systems, which dissipate energy more rapidly than inorganic processes, "is the Universe's devious route to its own negation.").

The attraction of such theories is that they provide fairly complete descriptions of living systems in terms of the emergence of levels or hierarchies of complexity, a vast and complex field in itself that I have not made a major focus of this book. It is based on the fairly obvious notion that individual living systems function globally far from thermodynamic equilibrium, degrading large quantities of energy (generating entropy) from which, at different scales, enough is extracted to support the chemical and biological processes of life. More complex dissipative structures are said to evolve in order to accomplish this more and more efficiently. There is then no 'difference' between the way human beings and hurricanes, for example, exist, from a thermodynamic standpoint, and no additional *fundamental* principle is needed to account for the emergence and functioning of new forms of life, biological structure and mind. The applicable picture of causality is one of classical finality and efficient cause.

The thermodynamic view requires several supporting theories, including an irreversible Big Bang cosmology, with its inexplicable singularity, and exclusive application of the 2nd Law of Thermodynamics in the currently known universe of light energy and matter. The existence of immanent levels of reality or complexity in real entities is hinted at, but not ascribed foundational importance, which might imply interactive antagonism with other factors as causally significant. Further, it is known that in mental processes, large quantities of energy are degraded. Mental systems in the LIR view are highly contradictory, that is, not far from the point of a dynamic equilibrium between opposing elements that can be called variously drives, concepts, beliefs, and so on. LIR proposes: (1) the Pauli Exclusion Principle as an organizing principle, at the level of electrons; (2) an isomorphic principle of exclusion at the level of organisms, self and non-self; and, perhaps, and (3) an equivalent one at the mental level of human individuality. To ground the phenomena of emergence, evolution and cybernetic processes at the lowest level, many thermodynamic views have no recourse other than spontaneity. This is for me the ineluctable area of conflict between LIR and such theories, but perhaps from *this* conflict new insights may emerge.

8.8.2 Cybernetics and Information

The standard view of cybernetics is a science that studies the abstract principles of organization and functioning in and of complex systems. It focuses on how systems use information and control internal and external processes to steer towards and maintain their goals, while counteracting various disturbances or aggressions that are perturbing or could perturb them. Both so-called first-order and second-order cybernetics assume the influence of an observer, although the latter does so more explicitly (Heylighen 2001).

Cybernetics is composed of a certain number of laws and principles, of which the following are most relevant to this analysis:

- Variety, Constraint and Entropy

Variety refers to the number of states that a system can exhibit. If this number is smaller than that potentially available, the system is said to be constrained. A Constraint is the difference between these and as it reduces uncertainty about the system, it is a kind of information. Variety and constraint can also be expressed in terms of probabilities, where variety is equi-valent to entropy. Entropy is maximum when all states are equally probable, in which case entropy reduces to variety. As in LIR, the probabilities need not sum to zero or 1.

- Asymmetric Transition

Variety and hence the statistical entropy diminishes as the system goes toward what is for it a more stable or dynamic equilibrium as it is going from a larger number of states to a smaller one. Negentropy increases but energy is required to achieve this self-organization. In dissipative structures, the stability is dynamic, in the sense that what is maintained is not a static state but a process.

- The Law of Requisite Variety

During regulatory or control processes involving feedback, in the face of perturbations with a variety of possibilities for action, the regulative mechanisms must be able to produce at least as many types of counteractions as there are disturbances. The regulator should thus have a maximum *potential* of internal variety or diversity.

- Control Loops

There is a tendency in standard views of the perturbation relation between an entity and its environment to focus attention on the former as agent and the latter as patient. Cybernetics correctly views control loops as symmetric: the environment can be the system and the perturbation the goal. I look rather at the scheme as one of two interacting systems in the original sense of LIR, a process and its contradictorial conjugate. If the goals are incompatible, this is a model of conflict or competition, and there is the possibility of emergence of a new goal. If they are compatible, the interaction can result in simple compromise or cooperation.

In the LIR probabilistic view, which is largely consistent with the above, every cybernetics, natural or artificial, is a dialectics, since each one involves an alteration, a perturbation by an antithetical contradictory process, followed by the return to the (state of) regulation that must prevail for the system to be "stable". In other words, a cybernetics alternately actualizes certain phenomena and potentializes the antagonistic, contradictory phenomena in consequence. It is an "oriented dialectical systematization of energetic events, inherent in the nature of energy" (Lupasco 1987b).

I have used the term 'feedback' on previous occasions in this book as a natural property of the complex dynamic systems to which the logic of and in reality applies. Any cybernetic system (Lupasco 1979) has the capacity for *feedback*, for counter-action using the term mentioned in Chapter 2. Also, any normally functioning, unperturbed system has a potentiality for being perturbed, for malfunctioning. As "Murphy's Law" in Anglo-American popular culture states: "Anything that can go wrong, will." A perturbation is the information that potentializes the normal (probabilistic) functioning of the system and provokes the subsequent and consequent actualization of the control mechanism that re-equilibrates or regulates it.

The cybernetics of physical systems is characterized by a return to an identity, a constant value, invariance, or homogeneity; biological cybernetics results in a further variance, a heterogeneity. This tendency by negative feedback toward a homo- or heterogeneity is equivalent to a return to a progressive non-contradiction in the two cases. In the dialectics of quantum or psychic phenomena, there is a third dialectic cybernetics, in which feedback leads to the semi-actualization and semi-potentialization of the two terms in the T-state of the included middle.

Kauffman and his colleagues propose a new reading of information that unites matter, energy and information (Kauffman et al. 2006). They show that neither the Shannon definition of information as a scalar quantity of bits, devoid of meaning, nor Kolmogorovian information which refers to standard probability distributions of non-interactive systems is applicable in biology. Information should be designated as 'instructional' or 'biotic' in the sense that it carries meaning and consists of constraints or their physical equivalents – boundary conditions that also partially cause events, where the coming into existence of the constraint is itself part of the propagating organization of the entity. "Constraints are information and information is constraints." This recursive aspect is characteristic of Markov chains, the non-Kolmogorovian probability behavior of two mutually dependent entities to which LIR applies.

LIR brings the 'missing ingredient' of dynamic opposition or antagonism that reinforces this picture of information for the evolution of living systems. It provides a cybernetic explanation of how a constraint in its physical manifestation can be causally effective.

Any theory of biological development or becoming must capture the duality of biological systems, that is, the composition of living systems by non-living substrates. This can be presented as the existence, concomitantly and contradictorially, as the presence of a cybernetics of macroscopic matter and one of biological matter. In the absence of a logic that defined their existence, there has been little justification for such a distinction. One can then look at the unique relation between these two cybernetics and the quantity of information present, as follows: in physical systems, with the increase in positive entropy, that is, homogenization, the quantity of variety or information decreases in direct proportion. Biological phenomena, from this standpoint, are highly improbable, and their information content should also increase in direct proportion to the negentropy generated.

From the standpoint of the living system itself, in its dissymmetrical equilibrium with inorganic matter, the production of negentropy has a *higher* probability, and the amount of information should *decrease* in proportion. Improbable and hence information-rich 'homogenizing' perturbations provide the information that initiates the control loop, permitting the information-poor system to maintain its heterogeneity (repair itself, etc.).

Information can thus vary directly or inversely to the quantity of negative or positive entropy being produced, according to the relative probabilities of homogenization or heterogenization. At the microphysical and cognitive levels, entropy and negentropy result in increased quantities of information, since the probability of any dominant development of either homogenization or heterogenization decreases or is blocked (but their contradictorial coexistence has a high probability). This is another way of describing the decrease in indeterminacy with increased contradiction that is a corollary of the PDO.

It is at this point that the thermodynamic view and the LIR/Cybernetics view intersect. The evolution of cosmological and simple physical structures – far from equilibrium dissipative systems (FFEDS) – requires an extensive degradation of energy and ‘production’ of entropy. A principle has been defined for such systems (Lineweaver 2005), the Maximum Entropy Production principle (MEP) that states that structures that destroy energy gradients for their growth or maintenance will arrange matters such that a maximum amount of entropy is produced. However, the principle is limited to *reproducible* systems and Lineweaver questions whether MEP applies to biological systems, given their *non-reproducible aspects.* “Whether biogenesis is reproducible is unclear and without this MEP may not be applicable to biotic activity.” That it may not would be consistent with the above analysis from the principles of LIR. This discussion also suggests that some principle, such as functional exclusion of the Pauli type, is needed in addition to the 2nd Law that grounds non-reproducible aspects of biological phenomena. My thesis is, again, that the two, together with the general principle of dynamic opposition, ground *both* the two characteristic life processes of monotonic proliferation and morphoneogenesis, some of which will occur *near* equilibrium.

8.8.3 Teleonomy

As noted above, a form of non-theological teleology has reappeared in the thermodynamic view of biology that assigns some thermodynamic purpose to the operation of the 2nd Law as a means of explaining life and evolution. Monod (1970) introduced *teleonomy* as one of the three fundamental properties of biological objects, together with autonomic morphogenesis and reproductive invariance. Teleonomy was defined as the *apparent* purpose or possession of a project in the organization of a living system. However, Monod fell back on pure chance as the basis for change and a spontaneous process of “matching” for the functioning of DNA (see Section 5.5.1.2 on Spontaneity). Subsequently, despite these and other weaknesses of explanation, teleonomy became quite popular as a theoretical basis for discussions of mental and other phenomena by Edelman and others.

LIR offers the possibility of retaining some of the descriptive elements of teleonomy by proposing a foundation for the reality of which teleonomy is the appearance. I recall that reality and appearance are both real, as are the dynamics of their alternating actualization and potentialization. An alternative picture of chance and necessity, determinism and indeterminism was suggested in Chapter 6. As indicated previously in this chapter, the origin of life and evolution are only possible because of the inherent, residual potentialities in the molecules built up in turn from lower physical levels, which coexist with the actualities.[11]

A proponent of teleonomy may object at this point that I have made the inherent potentialities and antagonisms of whatever might have been the first quantum entity or process in the universe responsible for all subsequent development, and such an entity is no more probable than some fully organized one. The only possible response at this time is that if the entire universe instantiates a contradictorial dynamics, as suggested by the cyclic model of Steinhardt (Chapter 7), and that dynamics is available for any subsequent organization of normal matter-energy. (I have admitted that the question of a first cycle or first entity is unanswered, but it may be badly posed). The creationist argument[12] for the appearance of life and its complexity, as well as the teleonomic one, accordingly, fails. The existence of the universe, that there is something rather than nothing, was discussed from a logical-metaphysical perspective in Chapter 3, and the subsequent analysis has been an attempt to restate its most fundamental characteristics. The question of *why* the universe exists, and the meaning of this question, if any, is beyond the scope of this book.

In the last pages of this book that constitute its conclusion, I will point to some additional areas to which the principles of LIR may apply.

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[11] Monod did see the origin of processes of morphogenesis at the microscopic level of the chemical structure of DNA, not preformed as such, but offered no explanation of a) why this should be and b) what might be the role of the atoms constituting the molecule.

[12] Creationism alleges that the rationally unexplainable emergence of a viable cell, cellular structure or individual, necessitates a deity.

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