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 microphysical events are determined, insofar as they are determined, by prior microphysical 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 acceptable 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*.

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 physicalist 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-

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

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 prevalence 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 below), *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.

8.3.4 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 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 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.

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[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**.

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.

[4] Or cause them to reject scientific realism.

[5] Cf. Chapter 7.

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 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 (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 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 metaphysical 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

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

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 (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.

8.3.5 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

[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.

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 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.