

Joseph E. Brenner

PROCESS IN REALITY: A LOGICAL OFFERING

Abstract. The conjunction of process and reality is familiar from the original theory of A. N. Whitehead and the subsequent development of process philosophy and metaphysics by Nicholas Rescher. Classical logic, however, is either ignored or stated to be inappropriate to a discussion of process. In this paper, I will show that the value of a process view of reality can be enhanced by reference to a new, transconsistent logic of reality that is grounded in the physical properties of energy in its various forms. These properties justify a principle of dynamic antagonism or opposition that explicates the phenomena of change at all levels of reality. It can be, accordingly, a preferred logic for understanding the dynamics of real processes.

Keywords: actualization, contradiction, energy, implication, included middle, logic, potentialization, process, reality

1. Introduction and Motivation

The notion of process has become fundamental for much current work in philosophy and science. In the last quarter-century, Nicholas Rescher has made a cogent case for a process view of nature and knowledge [Res96]. Tracing the development of views of process from Peirce and Bergson to Whitehead, Rescher sees process metaphysics as a conception of physical existence — reality — as being at the bottom processual. This term implies that processes rather than things or substances best represent the phenomena of the natural world.

Johanna Seibt has developed a non-Whiteheadian process-ontological framework that has applications to current developments in science, especially in the area of quantum mechanics [Sei02, Sei04]. Roberto Poli has

also shown that processual pictures of basic ontological entities are more useful than state-transition ones [Pol04]. From the standpoint of physical science and metaphysics, however, several fundamental aspects of process theory lack rigorous definition, detracting from its utility. In particular, additional grounding would seem necessary for the essential concepts of the causal origins and dynamics of process.

The purpose of this paper is, therefore, to suggest a way of strengthening the validity and relevance of process philosophy and metaphysics. I will do this by relating the process philosophy of, primarily, Rescher and Whitehead to a dynamic “logic of reality” (LOR) that is based on the philosophical logic of Stéphane Lupasco [Lup51]. This system extends *metaphysical* statements about a principle of opposition inherent in energy to *logical* statements about the operation of this principle throughout the various levels of reality, applied to microphysical, macrophysical, biological and ultimately mental, linguistic and social phenomena. If successful, this effort would be in line with Rescher’s stated mission for process philosophy “of enabling us to characterize, describe, clarify and explain the most general features of the real.”

By proposing such a logic “in the service of process”, I will be filling a philosophical gap. There is little in the work of Whitehead and Rescher about logic *per se*. My simple explanation is that the logics available to them, including the most recent extensions of classical logic and paraconsistent logics, failed to capture the essential nature of process-in-reality, and hence were, correctly, ignored. As Rescher said, the logic of object and predicate does not prevail in nature. My concept of a logic of and in reality represents an extension of logic outside its established domain of propositions and mathematics, to real phenomena. It will provide a new basis for explication of how and why processes effect change.

2. Defining Process

Process is one of those terms that are commonly used without sufficient attention to its implications. Processes can be defined simplistically as phenomena involving orderly change, a series of actions or operations taken to reach an end. However, if processes constitute the world of experience — from nature to social reality to perception and cognition itself — they should not be represented in a reductive fashion — in terms of their results, input-output pairs, or by computational or discontinuous, step-wise interpretations involving static identities, in which the underlying dynamics has

been occulted. In my view there are two, related analytical jobs to be done. One is to give processes their proper conceptual role in theoretical descriptions of nature *via* a proper ontological classification of types of dynamic entities. The relationship between the ontological and metaphysical aspects of my logic of reality is complicated by the existence of two major kinds of process ontology, as categories of reality and as categories of *sentences* about reality. However, I will show that the principles of LOR are relevant to both. Here, it should be clear, that as in any ontological category, the processes under discussion are theoretical entities and the dynamics involved are non-developmental.

The second task is to describe those dynamisms or dynamics in terms, which are as general as possible, of some fundamental properties of whatever it is that causes the change.

Rescher defines a process as a “coordinated group of changes in the complexions of reality, an organized family of occurrences that are systematically linked to one another either causally or functionally. He then goes on to say (emphasis mine) “*It (a process) is emphatically not necessarily a change in or of an individual thing, but can simply relate to some aspect of the general ‘condition of things.’*” In other words, process metaphysics argues that the entities we categorize as “things” in the ordinary sense are better understood as instantiations of certain sorts of processes or process-complexes.

To answer the question of how such a thing-as-process can preserve its identity over time — be a particular individual and yet change, Rescher proposes the factor of internal complexity. A process does not change as such, but it can incorporate change through “its unifying amalgamation of stages or phases (which may themselves be processes).” The identity of a process is constituted through a sequential pattern of action. Pursuing this line further, Rescher claims that type homogeneity between cause and effect is not required: existential facts and substantial things can be grounded in non-existential ones and non-substantive circumstances or principles respectively. “Explanations can then be made in terms of processes rooted in the operation of fields or forces that pervade nature at large and in their turn engender the particularized powers and potentialities of identifiable things.”

Rescher looks to the entities of quantum physics for confirmation of this approach. At this level, there appear to be only patterns of process that exhibit stabilities. In line with recent developments in relational quantum mechanics, entities at this level exist only by virtue of their reciprocal interactions. To explain the emergence of higher levels of reality, Rescher suggests that cosmic evolution itself exhibits the emergence of more and more com-

plex and elaborate forms of order, the development of ever more complex concatenations of processes, for which he uses the expression “creative spontaneity”. Rescher thus ultimately relates the processual structure of reality to energy, which is the view I will defend in this paper. Complex processes will be the consequence of the interactions of processes and processes of processes and so on, involving the same kinds of relations as exist within energy itself.

The difficulty is that the definition of process as energy as given above suffers from the same kind of ontological problem as the dualism of thing and activity of substance metaphysics, in which a paradox arises because one cannot characterize a substance without reference to process. In Rescher’s conception, there is a monism of activities of “different and differently organized sorts”, but then what is missing is a notion *why* of they behave the way they do, how they can differ among themselves and, above all, whether the concept of creative spontaneity in nature is adequately fundamental.

In this paper, I propose that a principle of dynamic opposition, inherent in energy, provides the necessary additional factor for an alternate approach to these two major problems and explicates and supports the conceptual structure of a process view of reality.

3. Reality and Realism

The approach presented in this paper will be a realist one. For this discussion of process, we need working concepts of reality and realism that accept the objective independent existence of common-sense physical entities.

One can say that *reality* is defined as what is, or what constitutes, our experiences, representations, theories, logics, images and so on. An independent *real* exists, despite our inability to define it precisely (the veiled real, in the image of D’Espagnat [Des79]), or to give it a meaning that is independent of our intuition. The real is what *is*, but what absolutely resists our attempts to represent it or to see it clearly. On the other hand, the real offers us the possibility, so to speak, of understanding it *via* a concept of levels of reality and the structure of phenomenal reality that we can perceive (non-veiled reality). As stated by Rescher, citing Peirce, “Given that human intelligence is a resource developed over time by creatures that are themselves an evolved part of nature, our capacity to understand the world should not be seen as all that surprising.” The most useful approach may be to maintain a description of reality as being both veiled *and* not veiled.

The idea that reality is divided into levels that are more or less distinct and involve different degrees of complexity has been proposed, in various forms, since antiquity, but it has received more rigorous attention since the advent of quantum mechanics. While there always can and will be arguments about the number of levels and their detailed structure, the approach in this paper suggests ontological and physical pictures that postulate the emergence and existence of levels, which follow different detailed laws, as a natural consequence of the fundamental antagonistic properties of energy [Nic85]. These properties will now be discussed at some length.

4. Logic of Reality — Logic of Energy

In discussing the fundamental aspects of process metaphysics, Rescher quotes Sheldon as saying: "The real phenomena we confront are one and all products of a creative opposition of polar opposites." My approach to a logic of reality can be considered as an attempt to give physical and metaphysical meaning to this statement: understanding the source of the opposition; eliminating the not-so-hidden assumption of total separation between "products" and what produces them; eliminating the pseudo-requirement of absolute polarity of opposites; giving dynamic value to the word "confront", etc. The logical system that I have designated as a logic of reality is thus based on the following considerations, abstracted from a more complete discussion elsewhere [Bre??].

4.1. Reality as Energy

Reality consists of energy in various forms and aspects. Elementary particles exist that can be more or less well characterized; flows of such particles can take place, as in an electric current or the photons of a light beam; and particles and macroscopic objects composed of them generate fields, electrical, gravitational, magnetic and nuclear that exert forces on these entities. Information has been shown to be equivalent to energy, and even the vacuum carries energy, albeit in a way that is still not well understood. Without going into the attempts made to develop a unified theory of physics that explains these phenomena, I will construct a logic of reality as energy based on what I will show are its dialectical characteristics, that is, that it instantiates a number of fundamental dualities. My intent is that this logic will provide a picture of reality "in action" that will approach it somewhat more closely than the classical and neo-classical logics that purport to model some of its aspects.

The basic *physical* characteristics of energy — the laws of thermodynamics, the equivalence of matter and energy and the concept of information as a form of energy are by now well accepted. Further, the existence of dualities of energy, in electricity, magnetism and nuclear physics are well known: positive and negative charge; two magnetic poles; two types of quarks at different energy levels.

Phenomenology, epistemology and logic are directed towards an understanding of other fundamental philosophical dualities including reality and appearance, knower and known, and being and becoming. The development of these dualities culminates in increasingly elaborate conceptions of reality, knowledge, human consciousness and higher-level mental phenomena, creative activity, art and social behavior. The lines of argument pursued here will overlap to a substantial extent and finally converge, because all phenomena in this view, including theories, are different instantiations of the energy common to all of them.

However, for my discussion, six dual but *metaphysical* aspects of energy must also be taken into account, and the most fundamental of these are intensity and extensity.

4.2. The Dialectical Aspects of Energy

- Intensity and Extensity

The German electrochemist Ostwald (1853-1932); Nobel Prize, 1909) looked in detail at the extensive and intensive properties of various forms of energy. The “measures” of intensive energies are vectors or tensors, whereas extensity always implies a certain measurement in terms of a number of identical, scalar units. For example, volume, mass and electric charge are extensive; temperature and gravitational and electric potential are intensive. Ostwald pointed out that an intensity and an extensity could be both actual and potential, *but not at the same time*. He thus provided the philosophical basis for both the alternation of actuality and potentiality (see below) and the relation in energy itself of intensity and extensity.

- Homogeneity and Heterogeneity

The second most fundamental aspect of energy is expressed by the dialectic between its entropic and negentropic properties. Energy moves from diverse, heterogeneous high-level forms toward a single, homogeneous low-level form (heat), governed by the 2nd Law of Thermodynamics. Let us designate such a tendency toward a single undifferentiated state of affairs as

exemplifying identity or, simply, identifying or “homogenizing”. At the same time, energy, as apparently indistinguishable electrons, shows a property of diversity, governed by the Pauli Principle of Exclusion. Electrons are located in shells around the nucleus of an atom, but two electrons in the same shell cannot have the same spin. Build-up of a multiplicity of shells is possible, for atoms heavier than hydrogen, in which the electrons will all have different capacities for reacting with other atoms to form different molecules enabling the existence of, ultimately, life and human beings.

Energy and accordingly all existence thus also show a tendency toward or instantiate an opposing process of heterogeneity, or non-identity or diversity, a “heterogenizing” process. Combining this idea with the one in the previous paragraph, I suggest that homogeneity, exteriority and objectivity characterize the process of extensity, and heterogeneity, interiority and subjectivity that of intensity, time intervening in the second due to the necessary aspect of succession in change, but not in the first.

- Actuality and Potentiality. The Fundamental Principle

The concept of a pendulum is familiar: energy goes from potential when the pendulum is at rest at the top of its arc to actual, kinetic when it moves most rapidly at the bottom. Now, the concept of potentiality is central to my thesis. While the term is applied routinely in many scientific fields — oxidation/reduction potential in chemistry; activation potential in neurophysiology — the absence of a general framework has made it difficult to understand its origin as well as the modalities of its operation at specific levels of reality.

The first point is that for energy to manifest itself with regard to an observer, it must go from a certain state of potentiality to a certain state of actualization. If everything were completely actualized or realized, for any reason, everything would be definitively static; no event or change could take place. However, for any energy to be in that state of potentiality, something, some brake or obstacle, which in an energetic universe can only be another quantity of energy, must be what maintains the former energy as such, through the latter’s own actualization. And this latter potentializes itself or is potentialized, in its turn, to enable the former to become actual. The movement from one state predominating to the other takes place within the global energy gradient of the universe present since the Big Bang or its equivalent. In other words, since, according to the 2nd Law of Thermodynamics, some energy is degraded to heat in all real processes, one never comes back exactly to the same actualized state. Circularity is avoided.

Also, the origins of all the processes of change discussed in this theory are statistical and probabilistic, without the need for any other causal principle.

The juxtaposition of the terms energy, actuality and potentiality goes back to Aristotle. The condition of an entity whose essence is fully realized is an entelechy, a condition of actuality as distinguished from potentiality. However, nothing like the concept of a dynamic reciprocity of actualization and potentialization has been ascribed to Aristotle or to anyone else before Lupasco.

I describe again the principle of antagonism in energy as follows: whatever it is that prevents a quantity of energy A from moving in one direction or another can only be an opposing quantity of energy, which I will now call non-A or anti-A, such that the actualization of non-A implies the potentialization of A, and *vice versa*. For a chemical reaction to take place, for example, a certain quantity of energy must pass from a state of potential in a reactant to a state of reality. At some point, for all phenomena, there will be a point of equilibrium between the two tendencies, “on the way from one to the other”. This is a point of maximum opposition or contradiction at which both elements are actualized and potentialized to the same degree (each is semi-actualized *and* semi-potentialized), which can be considered as a third element existing simultaneously with the other two (T-state, from *tiers inclus* or included “third” element). In the simple example of the chemical reaction, it can be thought of as similar to the transition state. The significance of the T-state for more complex processes will become apparent later.

An objection can be made against antagonism as a principle: even if there are two factors or aspects present in energy, their relation is not one of interactive opposition. Consequently, antagonism and its equivalents are not general properties of phenomena. Following Lupasco, I suggest that energy is not a substance having an existence independent of its forms and transformations. Energy is not one thing and the energetic factors of extensity and intensity another, but energy exemplifies or instantiates the two opposing dynamisms. Energy is extension in the sense of unity and indestructibility and intension in the sense of being observable only through *changes* in level. Similarly, the notion of relation requires that of interaction and a concomitant contradictory duality implied by the “otherness” of the elements related.

As an interim conclusion, I can say that every phenomenon is characterized both by coefficients of identity and diversity on the one hand *and* of actuality, potentiality and T-state on the other. Further, in my concep-

tion, a relation is not only one of inherence or identification, but also of exclusion, non-linkage, or rupture, governed by the same logical principles. Relations can involve other dualities or contradictory orders of things, variant and invariant, real and apparent, internal and external. The smallest unit of energy, the Planck energy, instantiates duality in having aspects that are both continuous (frequency) and discontinuous (the Planck constant). The photon has aspects of both a particle (discontinuity) and wave (discontinuity). According to the Heisenberg uncertainty principle, the energy (momentum) and position of a particle are both localized and non-localized in the sense that to the extent that one is actualized more precisely by some measurement, the value of the other becomes more imprecise. The essential concept here is that energy is inherently dual, and the implication is that the duality will be present in all the manifestations of energy, although it will not necessarily be always the *same* duality.

The term “dynamism”, used to designate intensity and extensity means that they are not only processes or mechanisms of the operation of energy and are responsible for its development and motion, but also theoretical constructs, that describe the universe in terms of energy. The definition of intensity and extensity provided above, by this hypothesis, converges to that of dynamics, since they are, at the same time, themselves forces that *together, in an antagonistic or contradictorial relation (conjunction)*, produce motion, activity and change.

If this is accepted, then what are the definitions and characteristics of actuality and potentiality and homogeneity and heterogeneity? These would appear to be intensive properties of real elements or entities to which could be assigned complex values as observables. At the same time, however, I have described change as involving actualization and potentialization, and the operation of homogenizing or heterogenizing forces, which as dynamisms would appear to have the character of processes. One now has the problem of the relation between actuality and actualization (or actualizing, homogenizing and so on). My preferred answer to this point is itself an illustration of the logic of reality: the two terms, the noun and verb forms, cannot be considered as totally separate and independent and one is not more basic than the other. There is always some degree of process to actuality and of property to actualization (and to potentiality and potentialization). One should be able to “feel” an actuality-in-its-repressing of something antagonistic to it that would, if it could, cause it to change, rust, degrade, or disappear, on an appropriate time scale that is defined for each case. An example from the political sphere, in 2005, is that of a potential Palestinian State.

The application of the fundamental principle to the problem of the nature of space and time results in a major change of perspective relative to clock-time and map-space. Space and time are contradictorily related, as are simultaneity and succession (cf. Section 7). Entities (processes) in which, for example, primarily extensity, which is spatial, involving identities, would be instantiated (actualized) would at the same time see their temporality potentialized. This is perhaps a way of looking at crises that deserves further exploration.

4.3. The Fundamental Postulate

The fundamental postulate of my approach is that the dialectical characteristics of energy discussed above — actual and potential, continuous and discontinuous; entropic and negentropic, identifying or homogenizing and diversifying or heterogenizing — can be formalized as a structural logical principle of dynamic opposition, an antagonistic duality inherent in the nature of energy and accordingly applicable to all phenomena, physical and mental, including information, propositions and judgments.

I quote here a key passage from Lupasco's *Le principe d'antagonisme et la logique de l'énergie* [Lup51]:

“Energy must possess a logic that is not a classic logic nor any other based on a principle of pure non-contradiction, since energy implies a contradictory duality in its own nature, structure and function. The contradictory logic of energy is a real logic, that is, a science of logical facts and operations, and not a psychology, phenomenology or epistemology.”

Contradictions or dynamic oppositions thus exist in things being continuous and discontinuous, unified and diversified, wave and particle, at the same time. The principles of Section 4.2 have been incorporated in the axioms of this logic, listed in Section 4.4, so that they reflect the reality of dynamic opposition.

Classical logics, in which one tries to eliminate or avoid contradiction, are not adequate to describe real systems, all of which are derived from energy. Current paraconsistent logics, which permit true contradictions, but retain idealized, abstract concepts of truth and falsity as discussed further below, fail to give an adequate picture of the emergence of complex, real-world phenomena. These points apply to all phenomena: ideas, theories, propositions, as well as physical systems. Further, contradictions, in this physical sense of real opposing characteristics or properties can never disappear completely, since this would imply, ultimately, going below the standard quantum limit,

defined by the Planck quantum of action. All phenomena thus continually but non-reflexively (that is, without “perfect” circularity) alternate between degrees of actualization and of potentialization of themselves and their contradictions. In Lupasco’s words:

“To every phenomenon or element or logical event whatsoever, and accordingly to the judgment which thinks of it, the proposition which expresses it, to the sign which symbolizes it: e , for example, must always be associated, structurally and functionally, a logical anti-phenomenon, or anti-element or anti-event and therefore a contradictory judgment, proposition or sign $\text{non-}e$ in such a fashion that e or $\text{non-}e$ can only be but potentialized by the actualization of $\text{non-}e$ or e , but not disappear such that $\text{non-}e$ or e could be self-sufficient in an independent and therefore rigorous non-contradiction — as in all logic, classical or otherwise, that is based on an absoluteness of the principle of non-contradiction.”

The logic of reality is consistent with a view of a phenomenon as instantiating both appearance, the original meaning of the word, and an underlying reality. An appearance is something relational, what something is for something else. It is a being *for itself* by opposition to a being *in itself* independently of its apprehension by another entity, as in the conceptions of Varela and Sartre. However, these authors do not suggest any interaction between the two terms, which in my view is critical and is the central feature of the logic of reality described in this paper.

4.4. The Axioms of LOR. The Included Middle

The three fundamental axioms of classical logic are the axioms of identity, of non-contradiction, and of the excluded middle, written as applying to propositions:

1. Identity: A is A .
2. Non-Contradiction: A is not $\text{non-}A$ (not (A and $\text{non-}A$)).
3. Excluded Middle: there exists no third term T that is at the same time. A and $\text{non-}A$

The separation of terms that this classical logic requires shows up in, for example, definitions of universals and particulars and in an absolute difference between internal and external processes. This logic, in various forms, thus underlies arguments in all areas of philosophy, such as the discussion of whether geometry or dynamics is more fundamental in the universe, or

whether reductionism or holism, or their connection by recursive structures, as in the concept of Hofstadter of “tangled loops”, better describes the world.

The logic of reality, as we have seen, is an extension of logic to real-world phenomena that does not avoid but resolves such dichotomies. It is based on the inherent, foundational dualism of intensity and extensity of energy, which translates into a principle of dynamic opposition or contradiction (counter-action) not only in basic physics, but also throughout nature. It requires rewriting these three axioms (laws) of classical logic to apply to real-world elements, rather than terms, representing complex values of matter or energy, also as information and processes, as follows:

1. Non-identity: There is no A at a given time that is identical to A at another time.
2. Conditional Contradiction: A and non-A both exist at the same time, but only in the sense that when A is actual (but never to the extent of 100%), non-A is potential (but never to the extent of 100%), reciprocally and alternatively.
3. Included Middle: An included or additional third state T emerges from the point of maximum contradiction at which A and non-A are equally actualized and potentialized, but at a higher level of reality, at which the contradiction is resolved [Nic85].

Hegel had incorporated contradiction in logic and rejected the idea of classical “formal” logic that claimed to be a study of the form of thought in abstraction from content. This is similar to the LOR view, also in the sense that thoughts and concepts reflect the universe in some way, but the dynamics involved are very different. Hegel proposed three axioms to describe reality that differ from those of LOR above: A is A; A is non-A; non-A is A after all, or else they are all together [Tay75]. They imply a primarily diachronic sequence of A, non-A and A as thesis, anti-thesis and synthesis, whereas in LOR there is a synchronic and diachronic existence of A, non-A and the T-state as an included third term. Hegel did not address the question of what drives the change from thesis to antithesis to synthesis, that is, how any term cannot “stand on its own” but “goes over” into its opposite. Hegel thought that antinomic arguments could drive *thinking* from one ontological category to the next, but he did not show how this could take place in reality. Russell demonstrated that Hegel’s logic could be deconstructed because it still presupposed traditional Aristotelian logic, but not for this specific reason.

To my knowledge, the theory developed here is the only one in which all three axioms of classical logic are modified at once and extended to reality. My restatement confirms that at a single level of reality, the axioms of non-contradiction and *excluded* middle are essentially identical. To put it another way, standard logics, (classical or non-classical) consist of axioms or a set of rules of inference for determining the truth of propositions and linguistic formulations of beliefs, etc. My logic consists of axioms and or rules for determining the dynamic state of the contradictory elements involved in a phenomenon. In what follows, the term “contradictorically related” means that two elements or processes are to be looked at as dynamic antagonists in the sense of Axiom 2, that is, when one is (predominantly) actualized the other is (predominantly) potentialized, reciprocally and alternately. Existence requires the “built-in” fundamental opposition of which this is a consequence.

Modal logics are methods for formally accounting for the intuitions which accompany the large part of human thought devoted to non-actual situations, represented by the expressions “it is necessary that” and “it is possible that” and the development and revision of beliefs. Modal operators apply to all standard types of logic. These formal operators cannot be used in LOR without modification, but the basic modal concepts of necessity and possibility do apply, and a dynamic interpretation can be provided for them. By relating knowledge and intuition contradictorically, LOR can also address for a broad range of other kinds of intuition related to real-world situations, such as the intuition ascribed predominantly to women.

4.5. Truth Value Replacements

Restating the axioms in the notation developed by Lupasco,

- (1) $(e_A \supset \bar{e}_p) \supset \bar{C}_A \supset C_p$
- (2) $(\bar{e}_A \supset e_p) \supset \bar{C}_A \supset C_p$
- (3) $(\bar{e}_T \supset e_T) \supset \bar{C}_p \supset C_A$

which reads, **e** actual implies **non-e** potential implies **non-contradiction** actual; similarly, **non-e** actual implies **e** potential also implies **non-contradiction** actual; and **e-Tstate** implies **non-e-Tstate** implies **contradiction** actual.

In this formalism, the reciprocally determined “reality” values of the degree of actualization A, potentialization P and T-state T replace the truth values in standard truth tables, permitting a non-truth functional semantics.

\underline{e}	\overline{e}	\underline{e}	\overline{e}
True	False	A	P
False	True	T	T
		P	A

\underline{e}	\overline{e}	\overline{C}	\underline{C}
A	P	A	P
T	T	P	A
P	A	A	P

The third table is simply a restatement of the previous paragraph, but the concept of truth to which these considerations lead is far-reaching. “Truth” becomes the reality of non-contradiction and contradiction, and leads to a non-truth functional semantics for LOR.

Opposing aspects of phenomena generally considered independent can be understood as being in the dynamic relationship suggested, namely, as one is actualized, the other is potentialized. As noted above, this critical concept does not appear in any theory since and including Aristotle’s own view of potentiality and actuality. My logic is most closely related to some quantum logics that discuss quantum objects as “superpositions” of two other, limiting states. Problems due to the assumption of an absolute independence or separation between terms (e.g., local/global, part/whole, set/member of set, knower/known, rational/irrational, etc.) can be approached from this standpoint. It provides a realistic explication of intuitions such as “things in nature are neither absolutely the same nor absolutely different”; every analogy carries disanalogies with it or Piaget’s “reciprocity” between subject and object. A work of art can be seen as a T-state emerging from the contradiction between the rational and irrational drives or tendencies in an artist’s personality.

4.6. LOR is a Logic

Logic began, in antiquity, as a theory of reasoning about nature, or reality. However, relatively early, logic became separated from ontology and metaphysics and became simply a tool for determining the truth or falsity of propositions. Deductive reasoning *per se* was disconnected both from processes of scientific inference and, in its prior and still current linguistic form, from common experience. Classical logic, defined above, was and is so successful in practice in describing a wide variety of simple phenomena that it has come to be considered as an *a priori*, corresponding in some way to the laws of thought and reason.

I took the position above that the logic of reality I propose was a valid extension of logic, and that only tradition supports the standard definition limiting the content and structure of logic to aspects of language and mathematics, following linguistic and mathematical “turns”. In my view, the logic of reality is also a logic *in* reality, that is, it really is a logic. It has some, although not all, of the structural characteristics generally ascribed to a logic of propositions, e.g., the axioms above, a syntax and a semantics. The semantics is, obviously, not truth-functional, given the change noted in the concept of truth. But the major aspect of this semantics, the *sense* of truth that the semantics gives is the dynamic state of the event, phenomenon, judgment, etc, where the event is “on the way”, more or less, as the case may be, between its actualization and the potentialization of its contradiction.

Béziau has suggested [Béz04] that although the use of the term “formal” is neither necessary nor desirable in conjunction with logic, any specific logic should be characterized by the following rigorous meta-logical features, among others: a proper grounding at an abstract level; an understanding of its intensionality and extensionality; and an appropriate relation to mathematics. Béziau believes that mathematical logic is the logic of human reasoning, and hence what is needed for philosophical discussions about logic are clear definitions of its central features. These should involve *mathematical abstract conceptualisation* rather than symbolic formalization.

At this time, it is not clear whether a mathematization of LOR is possible or whether *any* of the many approaches that have been developed for propositional or multi-valued logics could be applied. The Logics of Formal Inconsistency of Carnielli, which include methods for explication of epistemic paradoxes and conflicting scenarios *via* an operator developed to handle inconsistency, can codify any classical or paraconsistent reasoning [Car05]. Although such systems cannot handle the logic of reality, there is no reason why another type of formalization might not be possible [Car05a].

The formalization has been made that consists of diagrams of a series of deductions and implications involving the application of the axioms of LOR to the logical operations themselves [Lup51]. On this basis, I claim that LOR can be considered as a logical framework that models reality perhaps more closely than the other logics mentioned, but to which the usual limitations of any model apply. The fact that LOR is *grounded* in physics may be novel (I think it is), but as a method of making reasoned inferences about reality, including reasoning, LOR is worthy of consideration, at least, as *also* a logic.

4.7. Process Elements

The logic of reality supports a process philosophy that incorporates the above points, specifically, in the replacement of discrete individualities of substance philosophy by interactive relatedness, a term used by Rescher. Thus, there are no *elements* of process, at least, not in the usual sense. Each sub-process is a “moving target” actualizing the properties of the global process to a greater or lesser degree, and *vice versa*. In other words, the elements of a process all have aspects of the process itself, as if they were the “active” members or elements of an “active” set.

Other examples of this contradictorial relation will be given in the discussion of process semantics.

5. Other Logics and Theories of Process

5.1. Advances in Non-Classical Propositional Logic

Paraconsistent logics are among the major developments in logic of the 20th Century. In the last twenty years, paraconsistent logics have been shown to allow reasoning in the presence of contradictions and underlie some essential theories of modern science. In these logics, sentences and inferences of the form A and non-A are considered true, that is, the 2nd classical axiom of non-contradiction is abrogated.

Priest has shown the existence of true contradictions (dialetheias) and developed several paraconsistent logics, a logic in which the inference from A and non-A to any arbitrary conclusion (explosion) is not valid. The logic of reality is based on the contradiction between A and non-A giving rise to a specific resolution (at another level of reality); it could therefore be considered paraconsistent. However, in Priest’s paraconsistent concept of contradiction, the two opposing terms, or true and false, are both actual at the same time. In LOR logic, if A is (predominantly) actualized, non-A is (predominantly) potentialized, and vice versa, alternately, without either ever disappearing completely. To show the difference more clearly, Priest admits that the set of logical truths in his paraconsistent Logic of Paradox is identical to that of classical logic, and all of the more complex varieties of paraconsistent logics add truth operators or relations whose value as descriptions of the real world are open to question. In LOR, standard truth values are replaced by the reality values of actualization, potentialization and T-state. Priest first introduced the term *transconsistent* to describe “the realm

beyond the consistent”. I have used the term to designate my logic, since the significance of contradiction is retained but expanded to include the dynamic opposition of real elements, grounded in physics.

Intuitionist logic was developed by A. Heyting as a basis for the intuitionist mathematics of Brouwer, to which the latter was forced by reasoning about infinite sets. It explicitly denies the *necessity* of the law of the excluded middle, the 3rd axiom of classical logic. Brouwer had rejected the application to mathematics of a classical binary logic of “truth” and “falsehood”, and of the concept of truth as a relationship between language and an extra-linguistic reality. However, there is no indication in Brouwer’s work of a basis (or need) for applying such principles outside mathematics. Brouwer and Heyting did not, apparently, formulate or show the necessity of a law of the *included* middle and the law of non-contradiction is maintained in intuitionist logic.

In addition to the above, a wide range of logics have been developed whose objective was to provide a better picture of change. These include the action logic of von Wright, the dynamic logic of van Benthem and the multi-valued and fuzzy logics derived from the initial three-valued logic of Łukasiewicz. All newer logics, however, with the possible exception of quantum logic, are based on classical or neo-classical notions of truth and/or non-contradiction.

Adaptive logics [Bat04] are formal logics designed to explicate dynamic consequence relations occurring in human reasoning that are not decidable and require a special kind of proof. The strategy adopted in an adaptive logic is to quarantine or otherwise neutralize “abnormalities” — contradictions, inconsistencies and negations of various types when they occur. They are termed ‘inconsistency-adaptive’ logics or corrective logics. They are considered superior to paraconsistent logics, which are considered too weak due to their invalidation of the axiom of non-contradiction. Ampliative adaptive logics are extensions of the adaptive approach aimed specifically at giving a better picture of abduction or abductive reasoning processes, that is, reasoning from observation back to causes.

The basic features of the dynamics of such logics exist at the propositional level, and the relevant relations are intended to apply to sequences of statements or premises that are linked by inference but not by energy. They are literally abstract from a dynamic standpoint. Accordingly, it is not possible, in my opinion, to extend such systems to reasoning or to other real world processes, nor to imply that, because they model reasoning, for example, that they explicate it as a process.

5.2. “Process Logic” and Qualitative Process Theory

In the early 80’s, “Process Logic” was developed as an elementary language for reasoning about the behavior of a program during computation. It was contrasted with a so-called “Propositional Dynamic Logic” which could only reason (sic) about the input-output states of a program. For example, Baeten, Bergstra and Bol [BBB93] report the use of state-transition diagrams to describe their “real time” process logic.

These logics are mentioned here simply as examples of how differently the terms process and dynamic can be used. Even a cursory survey of the Internet reveals the vast number of publications dealing with process logics for handling computational problems of various kinds, program development, control systems, real-world business and organizational problems and so on. These tasks are of great practical and theoretical value in their own right, but the process logics used do not raise fundamental issues about the nature either of logic or process.

Qualitative process theory (QPT), originally proposed by Forbus [For84] has been used to create domain theories ranging from simple models of fluids, motion and materials to computer programs for a wide range of planning, diagnosis, design and learning applications. QPT organizes the domain theories around the notion of physical processes that effect change in objects by causing quantities associated with them to change. Physical processes are explicitly defined in terms of the individuals that give rise to them, the conditions under which they are true, and their direct consequences. These ideas developed into qualitative physics, the branch of artificial intelligence that aims at developing methods for qualitative modeling of physical systems in general, and a basis for reasoning about its evolution.

What seems to me to characterize all of this work is its limitation to relatively simple cases, e.g., common, macroscopic phase changes, in which the limiting states are well defined. I doubt that QP models can be extended to construct realistic domain models that can capture a wide range of phenomena, such as those now studied in Dynamic Systems Theory (Section 9.2).

5.3. Potentiality in Process Logic and Theory

Hector Sabelli [Sab95] is a contemporary representative of the Heraclitean tradition in that he considers opposition or contradiction in nature as fundamental. His process logic postulates a concept of change based on opposition: being *vs.* becoming; a principle of global or universal contradiction — every

existing entity/true statement implies its opposite; and a principle of local non-contradiction: opposites do not coexist at the same time, in the same place and/or in the same regard. As Sabelli points out, evolutionary science requires a process logic that deals with action and change, not stable entities; with actual oppositions, not an abstract separation of opposites. As in my interpretation, logical and natural processes (of sufficient complexity) can generate novelty by emergence. Co-existing opposites interact to create a “third case”, such as the fold catastrophe in catastrophe theory. Catastrophes and other creative bifurcations also involve an increase in dimensionality.

The most significant difference between LOR and this theory is the foundational role that LOR assigns not only to opposition, but also to potentiality, the physical aspect of energy of which opposition and contradiction is the expression. To be sure, opposites can coexist necessarily in various proportions and with an alternative preponderance of one or the other, but in the Sabelli system, only the actualized part of each term has causal properties. For LOR, potentiality is essential to knowledge, memory and other higher mental functions. In my view, evolution cannot take place and complex entities cannot be built up from fundamental particles without, at each level of reality, a distributed, non-localized form of energy as potentiality.

Similarly, an article by Thompson [Tho03] is of interest here in view of the central role it assigns to process theories to compensate for the failure of pure wave or particle philosophies of nature. Following Whitehead, it is only *events* that are the actual entities of the physical world; only *events* need to exist in order to have a physics. Thompson starts from this ontology of actual events, and his dispositional analysis is based roughly on the common-sense intuition that causes or “dispositions” exist. This leads to a new idea of physical substances, that of a distribution of potentialities, “powers” or propensities, that are “reasonable consequences of a theory of processes”, which in turn could provide a foundation for quantum physics. Unfortunately, Thompson simply leaves to physics the task of defining what such terms as “power”, “capability” or “dispositional property” mean, other than saying that they do *not* refer to energy flow per unit time, and how they can interact.

In my view, these and similar difficulties are due to reliance on an abstract neo-classical view of space-time and causality. Actualities can be the “realization” of possibilities or potentialities, but no indication is given of why such actualizations occur. The logic of reality is based on a principle of dynamic opposition operative at the most fundamental physical level as

well as all higher levels of reality. LOR may accordingly provide a better account of process than the above. Like Thompson, I deny that continuants (continuing 'substances') are *fully* actual and determinate. However, the principle of dynamic opposition or contradiction, and a robust notion of potentiality, is required for the "closer relation" that Thompson seeks between substances, events and process.

6. Process and Reality in Whitehead

As an application of the logic of reality to the understanding of process, I will look at the some of the key concepts in the work of A. N. Whitehead. A complete Critique, from the standpoint of the logic of reality, of the Whiteheadian view of process [Whi75], which would require reference to a large portion of his complex system, is obviously outside the scope of this paper. Summarizing outrageously, I can say that LOR explicates and supplements Whitehead's intuitions and makes them applicable to the real world by correcting the latter's Critique of Hume and the empiricists. The purpose of my Critique is not only to show that the principles of LOR can be used as an analytical tool of a rather unique and highly complicated system of thought. It is to support the view that there is something essentially correct about the process approach to reality to which both intuitions and formal reasoning can contribute.

It is regrettable that many correct intuitions in Whitehead's process metaphysics and philosophy were obscured or lost in three ways: 1) by his own insistence on their grounding in a theology; 2) the subsequent conflation of his process philosophy with process theology in the "New Thought" movement; 3) the disregard of their dynamic aspects by some of his major followers and critics. Let us proceed simply by listing a few of the principal ideas of Whitehead about process which demonstrate his oscillation between realist and idealist concepts:

The first Category of Explanation is that the actual world is a process, and that the process is the becoming of actual entities, or actual occasions, the first Category of Existence. Two descriptions are required for an actual entity, one which is analytical of its potentiality for 'objectification' in the becoming of other actual entities and another which is analytical of the process which constitutes its own becoming. The *principle of process* is that the being of an actual entity is constituted by its becoming: *how* an actual entity becomes constitutes *what* that actual entity *is*, so that the above two descriptions of an actual entity are not independent. These ideas convey

an idea of a dynamic relationship between phenomena, and if one were to replace actual entities by an “entity” and its opposite, one would be close to my formulation.

The fourth Category of Explanation, while not directly relatable to the concept of potentiality developed in LOR, shows that Whitehead had a feeling for the importance of potentiality as well as actuality:

“the potentiality for being an element in a real concrescence of many entities into one actuality is the one general metaphysical character attaching to all entities, *actual and non-actual* (emphasis mine); and that every item in the universe is involved in each concrescence. In other words, it belongs to the nature of a ‘being’ that it is a potential for every ‘becoming’”

Whitehead says explicitly that actual facts include in their own constitution real potentiality that is not only referent beyond itself, but also requires a notion of space-time that does not involve absolute place and absolute duration. However, potentiality is given a highly abstract role in the ‘ingression’ of eternal objects (see below) into reality, and there is no concept of interaction between potentiality and actuality in his ‘principle of relativity’. Elsewhere, however, he states his third metaphysical principle, that to be ‘something’ is to have the potentiality for acquiring real unity with other entities. Hence to be a real component of an actual entity is to in some way realize this potentiality.

Whitehead previously defined his “philosophy of organism” as an advance on subject-predicate and substance-quality forms of thought which in his view are *not* direct reflections of fact. His system preserves coherence via the discovery that the concrescence, which is equated with process, of any given actual entity involves the other actual entities among its components.

Another idea that implies a principle of contradiction (never explicitly stated) is that an actual entity combines (or instantiates) self-identity with self-diversity because it is actual when it has significance for itself (and others?) and functions in respect to its own determination. He introduces the Category of the Ultimate and ‘eternal objects’ as the other type of fundamental entity, which abstract from the concrescence (process) and are based solely on intuition. If one ignores, for the moment, the question of ‘ingression’, one can identify eternal objects with the domain of non-dynamic mental constructions: “An eternal object realized in respect to its *pure* potentiality is related to determinate logical subjects is termed a ‘propositional

feeling' in the mentality of the actual occasion in question (the mind of the logician)."

Later in the entire, albeit short Chapter in *Process and Reality* that Whitehead devoted to process, after defining the chief task of metaphysics as the elucidation of the meaning of Heraclitus' *panta rhei*, he shows the opposition between a metaphysics of flux or process and one of substance, and its related static logic. As did Lupasco independently, Whitehead points out that Bergson went to an extreme in his 'temporalization' as opposed to the 'spatialization' of the universe. The remainder of Whitehead's discussion, however, demonstrates the problems that result from referring to abstract elements of process that are devoid of internal dynamics.

Whitehead needs two kinds of 'fluencies' to describe the actual world: one is the concrescence or process involved as above in the constitution of an existent (Locke's term for actual entity). In the other, the 'perishing' of the process, on the completion of the particular existent, constitutes that existent as an original element in the constitutions of other particular existents elicited by repetitions of process. This fluency is termed 'transition' and is the vehicle of the 'immortal' past as efficient cause, while concrescence moves toward its final cause. Whitehead defines a 'theory of objectification': particular existents or occasions become original elements for a new creation, a unity of a datum for a creative (new) concrescence. In acquiring this measure of connection, (in an operation of mutually adjusted abstraction), their inherent presuppositions of each other eliminate certain elements in their constitutions, and elicit into relevance other elements. I suggest that the contradictory interaction between events and their opposites corresponds more directly to processes in the actual world, and physical meaning should be assigned to such 'inherent presuppositions'.

Finally, again doing violence, in my view, to a coherent view of reality, Whitehead defines two species of process, macroscopic and microscopic: the former effects the transition from the actual to the merely real and is efficient; the latter effects the growth from the real to the actual and is teleological. Without going into additional detail, let it suffice to say that Whitehead gives no indication of what is driving either of these processes, and when one or the other is functional 'in proceeding from phase to phase' in an immediate actuality.

If there is any recognition of the existence and/or importance of dynamic opposition or contradiction in *Process and Reality*, it is in a belated discussion of ideal, contrasted opposites, especially, God and the World. Process remains unidirectional — disjoined multiplicity, with its diversities in op-

position, moving toward concrescent unity, with its diversities in contrast. However, in each actuality exist physical and conceptual poles, whereby the latter is by its nature unbounded by contradiction, and the former is by its nature exclusive, bounded by contradiction. Whitehead continues by saying that: “opposed elements stand to each other in mutual requirement. In their unity, they inhibit or contrast.” and God and the World stand to each other in this opposed requirement, each the “instrument of novelty for the other”, never reaching static completion. If one can avoid being put off by the direct theological reference, this passage can be read as a strong statement of contradiction as foundational to process metaphysics.

7. On Time and Space

Before proceeding further, it is essential to outline the view of time and space implied by the fundamental principle of dynamic opposition.

Any philosophy of process as motion, development or change in general, in fact any adequate metaphysics, cannot be fitted to the rigidly determined categories of binary logics and semantics. In the case of the classical paradox of motion — Zeno’s arrow paradox — the paradox states that the arrow can be neither at rest nor in motion during the instants of its flight: not at rest since it is moving, and not moving since at any instant things are where they are, i.e., at rest. According to Rescher, the problem is solved by saying that the statement “The arrow is right now, at this very instant, flying” cannot be classed as either true or false. The same paradoxical situation obtains at any juncture of being and becoming, such as the point at which one enters or leaves a room and so on. The reason why I feel that something more than truth-status indeterminacy is needed is that these are *prima facie* not semantic phenomena. This explanation by the concept of truth-status indeterminacy, with its semantic notion of truth, seems to me necessary but not sufficient.

A picture that incorporates more features of the real world is provided by the principle of dynamic opposition of the logic of reality in two ways: 1) the semantic values of truth are replaced, as noted, by the physical values of actualization and potentialization of the phenomenon and its opposite, here, time and space; and 2) time and space have the property of being both static and dynamic, divisible and indivisible into spatial and temporal “instants” at the same time, due to their constitutive existential antagonism, and there can be a continual oscillation between one or the other predominating. In a complex composed by the dissymmetric equilibrium of the antagonistic

factors of time and space, actual movement such as this can be seen as a T-state emerging from the point of maximum antagonism. The dissymmetry, also energetic, is introduced by actualization of the potential energy of the stretched bowstring.

The argument against this view is that I have merely displaced the problem, by invoking a functional, operative antagonism between time and space. This criticism can be answered by a summary of the concepts of time and space in the logic of reality. Although incomplete, I believe it will be sufficient, nevertheless, to show that all systems of philosophy, including those based on special relativity, that maintain concepts of space and time that are *not* antagonistically related are leaving something out, and that something *like* a dynamic view is required.

My basic concept is that the time and space of an energetic phenomenon (event) are related contradictorily, and that objects and events do not exist or take place in space and time, but are the sources of or unroll their own space and time. Classic logic, and views of reality based on it, is non-temporal, since its rigorous non-contradiction, pure identity and relations and implications are totally fixed, incompatible with time and change. In LOR, the actualization or potentialization of a logical event is not a function of time, A_t or P_t but time that is a function of the dynamics of actualization and potentialization, t_A or t_P for the following reason: if an actualization is rigorous and absolute, there is no more time; the process element is fixed and immutable. If the consequent potentialization is, accordingly, infinite, the element disappears along with the temporality. The notion of time enters into the concepts of wear, change and transformation, all of which require modification of identity. Complete actualization or potentialization would be equivalent to an end of time, in the heat death of the universe, for example, the absolute homogenization of energy. Time is only possible due to the existence of contradictory dualities whose energetic antagonism is both the source and necessary condition of partial, non-infinite actualizations and potentializations. Time is thus, like the dynamisms that generate it, neither finite nor infinite but transfinite. Reversing Kant, time is not a condition of phenomena, but conditioned by phenomena, due to its logical structure. The first “object” to unfold both a time and a space would be, of course, the singularity of the Big Bang, or its latest non-absolute cyclic replacement. To repeat, time, like space, results from the development of a process that actualizes itself, the necessary consequence of the dynamic structure of energy and its logic.

The logic presented here, in which all is process and energy, dynamically contradictory, is a logic *par excellence* of the *a posteriori*. Therefore, if space is a logical phenomenon, it is *a posteriori*, like time, not a Kantian condition of phenomenal actualizations but conditioned by them. Space requires simultaneity; if events do not succeed one another, the required notion of space cannot develop. The moment two elements exist at once, simultaneously, they imply, simply because they do not coalesce, a space, a location with a distance between them. By the fundamental postulates of the logic of energetic phenomena, the generation of a transfinite series of systems of systems, or processes of processes, necessarily generates the logical space for them.

The link between space and time is described as follows by Lupasco:

“In every actualization, and precisely because there exists an antagonistic actualization relative to a contradictory potentialization and never the possibility of an absolute actualization, a contradictionnal conjunction essentially and irreducibly accompanies the development of the process of actualization and potentialization. In other words, there is always a simultaneity of an element or event that is more or less actualized and of an element or event more or less potentialized.”

This contradictionnal conjunction is present during the unfolding of any actualization in such a way that one can say that the logical temporality that is generated by energy is always tied to a logical spatiality that is generated similarly. This concept is thus based on the logical structure of energy itself rather than on any physico-mathematical hypotheses. There are both spaces and times, which are *proper to* individual phenomena, functions of their actualization.

Thus if phenomena do not unfold in space, but unfold a space, objects are not in space, but space is in objects; objects are not localized, but localize, create localizations. Such a space has the same characteristics as a configuration space in physics, that is, it is a function of the number of its elements and of their degrees of freedom; it is what links the elements, that permits their co-existence in a system and their simultaneity. There is no spatial location outside of what is inside it. Logical space and logical time constitute a space-time proper to each system, a configuration space-time. Thus time cannot be separated from space; only space-time exists, but with the indicated properties.

In this picture, if simultaneity is a contradictory *conjunction* as above, succession is a contradictory *disjunction* or *exclusion*, opposed to the simultaneity or conjunction. The former requires the presence of elements that are both identical and diverse, otherwise the simultaneity would have no meaning and tend to disappear. The latter also involves identity and diversity of elements at the same time, but succession involves an actualization of a series of identities and potentialization of a series of heterogeneities, something like a choice between contradictory elements or events. Succession in time is a dialectical series of choices.

The key conclusion of this discussion is the following: logical space, in the sense of simultaneity or conjunction is opposed to logical time as succession or disjunction. The simultaneity of space is based on succession or time, and *vice versa*. But neither of the contradictory relations being absolute, each will always have an irreducible residue of the other; there will always be some space in time, some time in space.

We now have in hand, I believe, a more rigorous analysis of what Rescher meant when he said that 1) space-time was part of the overall law structure that natures' processes internalize; and 2) space and time are no more and no less than the inherent aspects of the characteristic interrelationship of physical processes.

8. Process Logic and/or Process Semantics

One definition of a logic is a set of statements (syntax) and a relation of semantic consequence showing how those statements are to be used. The function of the semantics is to insure truth preservation as a basis for validity of the set of propositions. If logic reflects only notions of reasoning as simple, stepwise processes of going from A to B, or perhaps to B1 by inclusion of better evidence, one should not be surprised that its structure also reflects at best a stepwise view of change. In other words, there are no dynamic relationships involved in the modelling of the elements of a logic, and such a logic cannot be or support a theory of reasoning or process in reality.

Rescher saw the development of a process semantics, as opposed to logic, as the conceptually most versatile and philosophically most fundamental tool for understanding reality. It is at the basis of his ideas of process philosophy and process metaphysics. What he called the mainstream logical theory of the West, which takes an approach to truth that is committed to its static fixity, was and is unable to meet this challenge (cf. Section 5.2 on process logic). He considered process philosophy rather as something schematic and

idiosyncratic, about doctrinal tendencies rather than positions. It lacks a formal structure, and in this resembles the natural logic of Grize [Gri96], which excludes the formalisms of classical logic as being inappropriate to language.

From his processual perspective, Rescher deconstructed the standard static view of truth, basing his authority in part on Aristotle himself, and proposes a dynamic rather than a substantialist approach to knowledge, and established a proper linking of process, logic, philosophy and metaphysics:

“It is clear that any philosophy in which process in its various guises of origination, motion and change plays a significant role — in short, any adequate metaphysics whatsoever — will face substantial theoretical problems in fitting the comparatively stable and rigidly determinate categories of orthodox logic and semantics to the more fluid and volatile reality that such a metaphysics envisions.”

Rescher saw natural processes as fluid, having an ‘analog’ nature related to the continuities captured (sic) by differential equations and the mathematics of infinitesimals (see discussion of Smooth Infinitesimal Analysis below), unlike the ‘digital’, binary (yes-or-no; on-or-off) character of natural language. Accordingly, he proposed a process semantics that ‘trades’ adjectives for verbs and adverbs and accomplishes “whatever a semantics of individuals can manage to do with properties and relations.” In my view, this is an essential first step in the ‘process’ of moving from the static elements of classical and neo-classical logics toward a logic of dynamic reality. However, the disregard of the existence of non-binary paradoxical aspects of natural language is an indication that this approach may also be incomplete.

Rescher has difficulty in countering the challenge that process theorists have no alternative to propose to the classical and neo-classical quantificational logics based on substance semantics. He did not take into account the paraconsistent logics that can apparently accommodate the needed truth-status indeterminacy, but as we have seen, fall short of being able to model real process. Further, no description has yet been provided either of the sources of change (the ‘ever-changing reality’) or those of (relative) stability. Rescher’s emphasis on the *absolute* character of process-as-change is a form of neo-Bergsonism, literally the dynamic opposite of what he criticizes as Whitehead’s fallacy of misplaced concreteness.

I suggest that to the extent the logic of reality describes change in terms of dynamic opposition, it captures the features of process described by Rescher and can be seen as the preferred logic of, in and for process. The grounding of potentiality it provides the basis for Rescher’s statement

in Section 2 about 'particularized potentialities' and provides for *both* the stability and identity of a process and its change, as contradictorily related and a driving force for process being constituted through a sequence of systems of systems, each of which instantiates the alternance of actualization and potentialization as a pattern of action.

9. The Process Semantics of Roberto Poli

Process semantics, in particular *kinematics*, the study of transitions between states and the logics that apply to them, is a rapidly developing field, driven, as have been many others, by the needs of computer science and related areas [Pol03]. Poli's approach is of direct interest for this discussion because the principle of dynamic opposition involves transitions between actual and potential states; hence, their compatibility with process semantics is of immediate scientific interest as well.

This work on processual interpretations (PI) of process semantics and their comparison with state-transition interpretations (STI) is most suggestive:

“According to the state-transition interpretation, the basic ontological items are states. Processes connect states; they mark the passage from state to state. Thoroughly processual interpretations read the situation the other way around: processes are the basic ontological items. Sometimes, they discern a pause in something that may appear to be static items. *From an ontological viewpoint, some sort of Gestaltic switch takes place between the two interpretations: the one considers to be basic what the other considers to be derived, and vice versa* (emphasis mine).”

The logic of reality has a number of things to offer to this approach:

- It includes a place for and describes exactly the above dynamic contradictory interaction between interpretations, or theories, as such.
- It can accommodate both interpretations applied to the real world, states (or systems of systems) having, of course, a relative stability as the result of series of contradictory processes. It also focuses, as in the PI, on the essential aspect of the processes as compared to the states.
- It provides a mechanism, in terms of energy/information, for causality, for the driving of the passages from state to state that is not simply an ethereal “Gestaltic switch”.

- The vision of science and philosophy is both physically and non-physically oriented, in the sense of the ontological aspects of levels of reality, and provides a logical basis for emergence.

In the different approach of state-transition systems (STS) and process systems (PS), in regard to time, there is a striking convergence with the ideas expressed in LOR. In the state-transition case, time is an ordered, external sequence of the input-output type. “Process systems, by contrast, unfold continuously in time. They *are* time.” This is close to my statement that phenomena do not take place in time, but unfold or unroll their own time. For STS, time is a parameter. In the case of PS, time is instead a constitutive dimension. “Processes are not *in* time; they *are* time; they are intrinsically temporal phenomena.” Poli posits a temporal continuum composed of units which, when one adopts the usual spatial translation of time, possess “some sort of extension”. I suggest that the dynamics of antagonism being the basis of the relation between space and time is a more useful picture. I agree that the world is a dynamic reality, and that material, psychological and social phenomena are, for the most part, dynamic phenomena. Many phenomena are dynamic but do not involve contradictory dynamic interactions. These are often the ones discussed in neo-classical dynamic logics, and they are rather of less complexity and hence of less interest than the ones that do.

In Poli’s discussion of formal and ontological theories, “objects”, “processes” and “stuffs” are suggested as the categories of particulars [Pol03]. In a way, there are connections and dependences between them, for example, objects and processes may refer to each other. Poli concludes that category theory is the natural framework for a theory of process semantics. But he also says that there is a basic difference between the way in which formal theories and ontology consider the furniture of the world, and he includes mathematics and logic in the first group. This is true for all logics of which I am aware, which have essentially been defined as excluding ontology. My theory may have aspects that could enable an association, if not a marriage, with ontology.

9.1. On Causality and Continuity

Rescher [Res02] construed processes “in pretty much the usual way — as a sequentially structured sequence (sic!)” of successive, distinct stages or phases. Discontinuity thus appears to be an essential property of process, and a state-transition interpretation of its semantics would seem appropri-

ate. Elsewhere, however, he stated that it is the mathematical language of differential equations that best represents nature's language of process.

Dowe [Dow97] suggests that despite their differences, most philosophers from Russell onwards associate *continuity* with *bona fide* causal processes, those that instantiate energy in some form (conserved quantity). This provides a criterion for distinguishing causal processes from processes defined as non-causal (pseudo) that may exhibit discontinuity. It is possible to construct thought-objects that possess energy yet are discontinuous. The argument I make is made that such objects are non-causal because they do not transmit energy, e.g., as information, and that both possession and transmission of energy are required for a process to be causal.

The initial conclusions to draw from this debate are that:

- a) the majority of real-world causal processes appear to be, also, continuous. For such processes, a processual interpretation, in which the basic ontological term is not the passage from state to state, is necessary;
- b) special cases can also exist of discontinuous causal processes. In this case, a state-transition interpretation may be appropriate;
- c) an interpretation that incorporates both continuity and discontinuity may be the closest to complex reality.

If the properties of continuity and discontinuity are inherent in energy and consequently in processes at the same time, it is not unexpected that processes may instantiate discontinuity at some point. Cause and effect are also energetic processes viewed from another standpoint. The domain of non-causal objects, neither possessing nor transmitting energy, is that of abstractions governed by the axioms of classical or non-classical binary logic. Cause and effect are contradictorily related in LOR, which enables an alternative to the impact paradigm of causation: phenomena are their own causes and effects, or cause/effects. Further discussion of causality is outside the scope of this paper, but we will look briefly closely at the question of continuity and discontinuity as discussed in dynamic systems theory.

9.2. Dynamic Systems Theory and Smooth Infinitesimal Analysis

The discussion of process metaphysics comes to a head, so to speak, as one goes from a consideration of physical processes to mental ones. Dynamic systems theory (DST) claims, as I do, that the same basic laws that govern physical systems also govern the laws of cognitive (or cognizing) systems.

Therefore, cognitive systems can be described by the mathematics of physics, especially, of non-linear dynamics rather than by the computational symbolic systems approach, which uses the rules of (classical and neo-classical) logic and syntax. Thus proponents of DST believe that differential equations are the most appropriate tool for modeling human behavior, a process *par excellence*.

According to the theory in this paper, however, this position only displaces the philosophical and metaphysical problem. The usual notion of infinitesimal calculus is that it captures the simultaneously continuous and discrete nature of changing phenomena. We recall Rescher's statement that differential calculus was the "language" of nature. Change at an instant is what calculus presents in formal terms. Exactly. But this begs the question of whether reality is composed of "instants" in the sense used in the theory. If it is not, then calculus, like classical logic, is *not* capturing the essential property of process-in-reality. My position is supported by the following discussion of the Smooth Infinitesimal Analysis of (SIA) of Bell [Bel98], which provides the conceptual background for development of a non-speculative mathematically based theory of *tendency* and *potentiality*. SIA, in Bell's theory, changes the concept of infinitesimals to entities that "have location and direction without magnitude, intermediate in nature between a point and a Euclidean straight line." These "linelets" are too small to have either the possibilities or trajectories of "actual" classical objects, but instead, potentiality and tendency, "the latter being considered the micro-degree of the former." Potentiality and tendency can be ascribed to linelets (and to timelets, the corresponding infinitesimals of time in SIA). However, the fact that the infinitesimals of SIA (and its precursors) prove to be useful heuristic devices is not *en soi* a proof of their existence; the real world is not smooth.

From the way a continuum is defined by Bell, or in catastrophe theory of which Dynamic Systems Theory is a current version, several things follow, *viz.*, their consistency and the failure of the law of the excluded middle (LEM). The formulation used by Bell for LEM is that every statement is either definitely true or definitely false cannot be generally affirmed within smooth worlds. A "faithful" account of the *truly* (emphasis mine) continuous will involve jettisoning LEM, that is, intuitionist logic applies.

In my theory, LEM fails in reality, in the sense of my Axiom 3 above. However, this failure does not imply that the real world is a true continuum; discontinuities, including the "flip" from actual to potential, are also present and require explication. This, like Peirce's proposal that immediate consciousness involves a non-punctiform, extended infinitesimal of time can

be explained by a contradictorial view of simultaneity and succession, and space-time that is deployed by objects, rather than being a locus of them.

Bell states that non-zero infinitesimals exist only in a “potential” sense, and this potential existence suffices for the development of infinitesimal analysis in smooth worlds. Also, that the law of non-contradiction (2nd Axiom) continues to be upheld without modification.

From the point of view of LOR, in such worlds, there is no transfer of energy in any form. In the real world, for change to occur, one needs both actuality *and* potentiality, and this distinguishes them from smooth worlds. Further, Bell shows correctly that one cannot single out an actual non-zero infinitesimal, “for such an entity would possess the property of being both distinguishable and indistinguishable from 0, which is clearly impossible”.

There are additional points in Bell’s SIA, however, that are *prima facie* contradictions in terms, despite the (inconsistent!) fact that they are intended to guarantee consistency! For example, infinitesimals are alleged to be intrinsically varying quantities, as a consequence of their being in a “nascent, or evanescent state”, and this varying takes place over a definite domain, with a definite co-domain in which it takes values.

This contradicts the assumptions of a *smooth* world, since discontinuities have been reintroduced in the form of definite domains and as change in the form of a needed reversal between nascent and evanescent (virtual particles appear from and disappear to the vacuum discontinuously). The principal applications in calculus, geometry and physics are only possible because they have been restricted to areas in which classical or consistent intuitionist logics hold. Bell quotes Weyl to the effect that “we are employing the principle of gaining knowledge of the external world from the behavior of *its* (emphasis mine) infinitesimal parts.” The error I feel that Weyl made is in the ‘its’. Nothing has yet been adduced to prove that Bell’s infinitesimals and those of the external world, (if such exist), are the same.

I conclude that Bell’s SIA, and in fact any differential calculus, as a theory of abstractions, is unsuitable for a process ontology that purports to deal with the world of real change. A theory of infinitesimal geometric objects, designed to provide an intrinsic formulation of the concept of differentiability, is perhaps not more than that. The real world is not differentiable. To conclude that geometry is in some deep sense more fundamental than dynamics, energy in the standard view, is to neglect the real contradictorial relation between statism and dynamism, neither being more fundamental than the other. The infinitesimal units of calculus are, from my point of view, pure *intensity*, and thus cannot and do not exist, any more than can

any idealized, abstract constructs. Despite their interesting properties, to assign them any role in modeling real phenomena, with the exception of description of pure physical processes totally dominated by the 2nd Law of Thermodynamics, seems to me abusive. Applications to systems such as computer science, artificial intelligence and data processing are included in this group, but all of these require no more than a binary logic, sufficient when there is no exchange of energy *qua* the elements or terms of analysis.

Computational and dynamic systems theories can be seen as illuminating complementary aspects of cognitive and other processes, but the on-going debates on how they should be applied is an indication of the need for a theory, like LOR, that can include the real properties of energy itself.

10. The Free Process Theory (FPT) of Johanna Seibt

The Free Process Theory (FPT) of Johanna Seibt [Sei03], referred to in the Introduction, makes a strong case for a central role for process in ontology. FPT is a process-ontological framework that avoids substance-ontological and logical presuppositions that have hobbled analysis of dynamic categories. FPT, as developed over the last 10-15 years, is of interest as a non-Whiteheadian framework that supports my view of the limitations of the Whiteheadian concept of process, namely, its reliance on idealized, abstract objects of reality. Free processes are defined as general individuals that are both dynamic and concrete and constitute a new ontological category. They are not changes in things or even dynamic modifications of a medium but ways of going-on, activities considered in qualitative regards. They are similar to the LOR concept of 'tendencies', phenomena in movement from actuality and potentiality (and *vice versa*), incorporating the notions of dynamism *and* its inhibition, the stopping of the dynamism or process. The FPT strategy can account for individuality in terms of dynamic qualities that fully capture our 'core intuitions' about the uniqueness of individual entities. In the logic of reality the concepts of an individual (or a set of individuals) are the limiting end-points, approached asymptotically but never totally reached, of a transfinite sequence of energetic steps or systems of systems, each of which is a real, bound process in the sense of relation to lower level processes. The qualities instantiated (predominantly actualized) are the opposing contradictory (or counter-acting) energetic terms applicable at the level of reality given.

I would, however, modify Seibt's concept that processes may superpose spatio-temporally with or without creating or suppressing functional features

of the ingredients. This point is relevant to the study of emergence and other dynamic phenomena *via* an appropriate process ontology. The formulation is applicable to theoretical entities, but it appears to separate processes and the functional features of real ingredients, subject to the space-time considerations discussed. Processes *are or deploy* their own spatio-temporality, and do not take place in an external Einsteinian space-time. Any real (non-binary) process element (ingredient), in my view, is *continuously* suppressing its contradictorial antagonist or being suppressed by it, “prior” to entering into another such relation with another process. The process *is* the functional features. The emergent phenomenon, as discussed above, is ‘created’ when the two process elements, the ‘stuffs in time’ are both actualized and potentialized to the same extent.

Just as I am doing for contradiction in logic, Seibt has showed how characteristic Aristotelian presuppositions have constrained ontology to a substance paradigm. From her framework, Seibt sees a trend in ontological theories that leads from traditional substance-ontological schemes operating with concrete, particular, static and ‘causally separate’ entities (including abstract and general entities) to schemes whose basic entities are concrete but non-particular, dynamic and ‘causally interlaced’ or ‘overlapping’. I give a basis for moving from the first group of entities to the second and suggest a physical meaning to ‘interlaced or overlapping’ that founds this approach for reality, that is, metaphysically, and perhaps for ontology. My strategy thus assists process-ontological inquiry by providing a “generic or category-neutral characterization of the domain of a conceptual framework which facilitates conceiving the domain items as items with variable categorical form”. By replacing the separation of internal and external with their contradictorial interaction, it supports the view that, in a more representationally adequate process-based ontology, one can make framework-dependent claims with external, i.e., positive-ontological, significance.

An ontological descriptive framework can thus be seen as a necessary, essential stage in the hierarchy of ontological representations. It remains a methodology for the organization and construction of a typology and categorization of processes, without direct implications for the physics and metaphysics of the processes as such. A bridge is suggested, however, by Seibt’s reference to Sellars’ use of the word ontology as describing a metaphysical categorical investigation of the reality or adequacy of a conceptual structure, with inevitable consequences for the ultimate sorts of beings in reality. I can even hazard a relation with this analytical ontology: when Seibt says: “Our *judgments* about the numerical, qualitative and trans-temporal identity of

things and persons can best be captured if we treat them as *statements* about types of dynamics or free processes”, I can emphasize the theoretical parallel with LOR by saying: “The numerical, qualitative and trans-temporal identity (and diversity) of things and persons can best be captured if we treat them as types of dynamics or processes.”

Like any ontological category, the free processes discussed above are theoretical entities with only axiomatic characterization. No causal interactions obtain between free processes, but their formal combinations to a certain extent mimic the emergence, complexity and interference displayed by real processes. In fact, just as substance-based ontologies “import” presuppositions of classical logic, free process theory includes the theoretical skeleton of dynamic elements of reality as described by the logic I propose. For example, allowance is made in the overlap of two entities for the existence of wholes whose parts cannot be completely disentangled. This corresponds to the dynamic relation I have proposed at the heart of real process.

11. Conclusion

It is now perhaps clearer what the title of this paper, "Process in Reality" (PIR) is intended to imply. It is both 1) that *reality* is a complex of the processes that are embedded in it, which operate according to a logical principle of change, the logic of reality; and 2) what *process* really *is*, namely, how it embodies this real physical-metaphysical but also logical principle. The analysis of process in this paper is based, accordingly, on an extension of logic to real world phenomena that will have been unfamiliar to most readers. However, even the small number of examples given of the theory and philosophy of process is sufficient to illustrate the need to distinguish between two domains of reality. In one domain, change is modeled by selection between specific alternatives and/or stepwise addition of others (with consequent possible selection between these and previous ones). In this category should be placed, for example, the process logics mentioned in Section 5.2.

In the other domain, a dynamic process of creative interaction or opposition obtains that results in the emergence of new, more complex entities. The currently most appropriate logics applicable to the first, ampliative adaptive logics and paraconsistent logics, provide an effective reductive structure for analyzing the domain. The transconsistent logical system, which is applicable to the second domain, represents a further bridge or intermediate explanatory structure between these logics and reality. However, its use as

a methodology requires a shift from focus on the axioms and formalism of classical and neo-classical propositional or mathematical logic as the criteria of a valid logical system.

I have argued that what is missing is, in fact, a framework that permits the incorporation of the foundational dynamic opposition that is inherent in energy and hence not only in basic physics, but in causal relations throughout nature. Such a framework may be necessary, but I am by no means suggesting that it is sufficient for a theory of process. In addition, one needs to have laws of self-organization, complexity and order such as those sought by Stuart Kauffman [Kau95]. I suggest, however that at the heart of such laws, a form of dynamic opposition may also be identified.

In the ternary, transconsistent logic of reality, the logic of the included middle, valid arguments and interpretations of nature do not require the absolute mutual exclusion of contradictory elements. Advantage can be taken of their dynamic interaction and alternating physical actuality or non-physical relevance. I suggest that this offers a new and promising approach to the philosophy and metaphysics of process.

References

- [BBB93] Baeten, J., J. Bergstra, and R. Bol, “A Real Time Process Logic”, *Progr. Report P9309, UvA 1993, report CSN 93/15, EUT 1993*.
- [Bat04] Batens, D., et al., *Adaptive Logics Home Page*, <http://logica.rug.ac.be/adlog/al.html> 2004.
- [Bel98] Bell, J., *A Primer of Infinitesimal Calculus*, Cambridge University Press, Cambridge, U.K, 1998.
- [Bre??] Brenner, J.E., *Logic in Reality*, MSS for publication.
- [Car05] Carnielli, W., “Logics of Formal Inconsistency”, *CLE e-Prints*, Vol. 5 (1), 2005.
- [Car05a] Carnielli, W., private communication, 2005.
- [Cla98] Clark, A., “Color Perception (in 3000 Words)”. In: W. Bechtel and G. Graham, (eds.), *A Companion to Cognitive Science*, Blackwells, 1998. <http://www.ucc.uconn.edu/~wwwphil/ccompan.html>
- [Dav94] Davis, E., “Axiomatizing Qualitative Process Theory”, 1994. http://csdo.cs.cs.nyu.edu/Dienst/Repository/2.0/Body/ncstrl.nyu_cs%2FTR1991-590/postscript

- [Des79] D'Espagnat, B., *A la recherche du réel*, Gauthier-Villars, Paris, 1979, p. 79.
- [Dow97] Dowe, P., "Causal Processes", *The Stanford Encyclopedia of Philosophy (Fall 1997 Edition)*, Edward N. Zalta, (ed.), URL = <http://plato.stanford.edu/archives/fall1997/entries/causation-process>
- [Gri96] Grize, J.-B., *Logique naturelle et communication*, Presses Universitaires de France, Paris, 1996.
- [For84] Forbus, K., "Qualitative Process Theory", *Artificial Intelligence* 24: 85–168, 1984.
- [Kau95] Kauffman, S., *At Home in the Universe*, Oxford University Press, New York/Oxford, 1995.
- [Lup51] Lupasco, S., *Le principe d'antagonisme et la logique de l'énergie*, 1951. Re-edited Editions du Rocher, Paris, 1987.
- [Nic85] Nicolescu, B., *Nous, la particule et le monde*, 1985. Re-edited Editions du Rocher, Paris, 2002.
- [Pol03] Poli, R., "Descriptive, Formal and Formalized Ontologies". In: D. Fisette, (ed.), *Husserl's Logical Investigations Reconsidered*, Kluwer, Dordrecht, 2003, pp. 193-210.
- [Pol04] Poli, R., "Process Semantics". In: M. Weber, (ed.), *After Whitehead: Rescher on Process Metaphysics*, Ontos Verlag, 2004, pp. 267-288.
- [Pri00] Priest, G., "Paraconsistent Logic". In: *Handbook of Philosophical Logic*, D. Gabbay and F. Guenther, (eds.), 2nd ed. Kluwer, Dordrecht, 2000, p. 259.
- [Res96] Rescher, N., *Process Metaphysics. An Introduction to Process Philosophy*, State University of New York Press, Albany, 1996.
- [Res02] Rescher, N., "Process Philosophy", *The Stanford Encyclopedia of Philosophy (Summer 2002 Edition)*, Edward N. Zalta, (ed.), URL = <http://plato.stanford.edu/archives/sum2002/entries/process-philosophy>
- [Sab95] Sabelli, H., "Non-linear Dynamics as a Dialectic Logic", *Proc. International Systems Society*, pp. 101–112, 1995; cf. <http://creativebios.com>
- [Sal91] Saloma, J., "The Theory of Process 1; Search for a Paradigm. The Theory of Process 2; Major Themes in *The Reflexive Universe*", 1991 <http://arthuryoung.com/the1exc.html>; <http://arthuryoung.com/the2exc.html>
- [Sei00] Seibt, J., "Pure Processes and Projective Metaphysics", *Philosophical Studies* 101 (2000), 253–289.

- [Sei03] Seibt, J., “Free Process Theory: Towards a Typology of Occurrences”. In: J. Seibt, (ed.), *Process Theories: Cross-disciplinary Studies in Dynamic Categories*, Kluwer Academic Publishers, Dordrecht, 2003, pp. 23–55.
- [Sei04] Seibt, J., “Going on and Coming About — Applications of Process Ontology”, *Non-Reductive Theories of Process — A Study in Applied Ontology*, Post-Doctoral Research Project, 2004. <http://www.hum.au.dk/filosofi/process/Post-doc-page.htm>
- [Smi99] Smith, D. W., “Intentionality Naturalized?”. In: J. Petitot et al., (eds.), *Naturalizing Phenomenology*, Stanford University Press, Stanford, 1999.
- [Tay75] Taylor, C., *Hegel*, Cambridge: Cambridge University Press, 1975, p. 314.
- [Tho03] Thompson, I., “Process Theory and the Concept of Substance”, 2003. <http://www.generativescience.org/ph-papers/subst5c.html>
- [Whi78] Whitehead, A. N., *Process and Reality; Corrected Edition*, THE FREE PRESS, New York, 1998.

JOSEPH E. BRENNER

International Center for Transdisciplinary Research and Studies, Paris
(CIRET),

<http://perso.club-internet.fr/nicol/ciret>

P.O. Box 235, CH-1865 Les Diablerets, Switzerland

Phone: +4124 492 21 18

FAX: +4124 492 13 81

jebrenner@compuserve.com