CONGRESS PAPER FINAL
Logic and the Pillars of Transdisciplinarity

Table of Contents

Introduction

As a high-school student in New York City, I came in contact with the book on symbolic logic by Charles Dodgson, better known as Lewis Carroll, the author of *Alice in Wonderland*. However, I soon became bored by the often amusing but only superficially brilliant syllogisms and conclusions that in fact led nowhere. This logic had nothing to do with reality.

A few years ago, when I began a first study of transdisciplinarity in collaboration with Professor Basarab Nicolescu, I became aware of the central role played by the logic of the included middle. This logical system was developed by Stéphane Lupasco over the period 1935-1988 and extended by Nicolescu by the principle of levels of reality. I also became aware of the degree to which the science and philosophy of today still refer, implicitly or explicitly, as their foundation, to the classical binary logic of Aristotle, and of Dodgson, despite its continued limitation to formal linguistic and mathematical domains. Most of my relationships with other logicians, philosophers and scientists, in which I try to discuss the Lupasco-Nicolescu approach, are difficult as a consequence. Such people, given their education, training or perhaps, unfortunately, conditioning, do not have the facility of accepting the radical change in perspective that the logic of the included middle implies. They demonstrate a strong resistance to it and to its implications for the totality of human life, individual and social. A well-known professor, an authority in quantum physics, told me in private that he believed that a principle of contradiction, similar to that in the Lupasco logic, was necessary for an adequate description of quantum states. However, he avoided discussion of it in his papers for fear of their rejection by referees.

As a physical scientist by training, and in accord with Basarab Nicolescu, I have focused my study on ways of making the Lupasco logic both accessible and acceptable to workers in the above fields on *their* terms, with reference to *their* work. This has been and is an extremely difficult undertaking. Only a small fraction of the people with whom I come into contact evince a minimum interest in a dialogue. Nevertheless, one must not neglect the humanistic implications of transdisciplinary knowledge and attempt to provide a rigorous but accessible foundation for it, while maintaining respect for the ideas of people who do not agree. It is, however, very rewarding to find, from time to time, a few people at the summit of their respective disciplines, who perceive the value of the Lupasco-Nicolescu approach and provide, accordingly, a transdisciplinary justification of it. Access to the concepts of logic is also necessary in the field of transdisciplinary education, as my friends who do this wonderful work in Brazil tell me. In discussions such as this Congress, it is thus very agreeable to me to be able to look with you at the principles involved in the Lupasco-Nicolescu logic, which is the most specific of the principles or pillars of transdisciplinarity.

1. The Pillars of Transdisciplinarity

At the beginning of his *Manifesto*,[1] Basarab Nicolescu describes transdisciplinarity as a new philosophical movement. Transdisciplinarity is not a new discipline, but rather possesses a number of characteristics, and can accomplish a number of things, of which the following are a brief and highly personal selection:

- Transdisciplinarity is a **process** that offers a new vision of nature and reality.
- Transdisciplinarity provides a **platform** for expressing and reinforcing the hopes and aspirations of mankind.
- As a **logic** of human experience and human intelligence, transdisciplinarity provides a new **approach** to age-old problems and paradoxes of human thought, science and philosophy.
- Transdisciplinarity is a **method** for thinking about the relations and implications between human actions and events and about how to include emotional, artistic and philosophical elements in discussion of solutions to practical problems.

As proposed by Nicolescu and noted already at this Congress, transdisciplinarity can be described as being supported by three major "pillars": complexity, levels of reality and the logic of the included middle. Further, the general methodology of transdisciplinarity is based on these three pillars, as they have emerged from the study of modern science, especially, of quantum physics, but also of molecular biology and cosmology. My paper will in fact be an example of the practice of transdisciplinarity involving the implementation of this methodology in a specific situation, one in which the subject and object of the inquiry are the principles or pillars themselves.

In particular, I will look at what it means to provide support to transdisciplinarity. What it is in transdisciplinarity that is being supported should however be clear: it is its validity as a rigorous system of thought that is relevant to today's world.

Predrag Cicovacki[2] has proposed redefining them as a transdisciplinary epistemology, ontology and logic respectively. I take a somewhat different approach, in that I will look more closely at the relations between these principles as it affects their relation to critical issues in science, philosophy and logic itself. The purpose, again, is to facilitate a dialogue with but also between specialists in the individual disciplines.

To begin with, an important distinction needs to be made regarding the pillars: they are, and should be considered, as different kinds of things, albeit closely related ones:

- Complexity is a *property* which is exemplified or attached in some way to its instances, the things or systems that are complex;
- Levels of reality is a *categorical concept*;
- The logic of the included middle is a *discipline* as such.

These subjects are all currently studied within many philosophical disciplines, of which the most important can be defined as follows[3]:

- Ontology is the study of being – what is
- Epistemology is the study of knowledge – how we know
- Logic is the study of valid reasoning – how to reason
- Ethics is the study of right and wrong – how we should act
- Phenomenology is the study of our experience – how we experience

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[1] Nicolescu, Basarab, *La transdisciplinarité. Manifeste.* Paris: Éditions du Rocher, 1996, re-edited as *Manifesto of Transdisciplinarity.* Albany: State University of New York Press, 2001 (hereinafter *Manifesto*); p. 63

[2] Cicovacki, Predrag, "Critical Reflection On The Three Pillars Of Transdisciplinarity",

[3] Smith, David Woodruff, "Phenomenology", *The Stanford Encyclopedia of Philosophy (Winter 2003 Edition)*, Edward N. Zalta (ed.), URL = http://plato.stanford.edu/archives/win2003/entries/phenomenology/

Metaphysics includes all of the above, as well as science, as it is concerned with the fundamental structure of reality as a whole. Metaphysics is a universal discipline, in which everything, including the status and validity of metaphysics itself, is a proper subject of study[4]. One of the interesting consequences of the Lupasco view of reality is that it points toward a convergence of metaphysics and physics.

Complexity is studied from many different standpoints, all involving more than one discipline. A Conference will take place shortly in Liverpool, England that refers explicitly to the many different aspects of the science of complexity.

Levels of reality are studied in ontology in the framework of category theory. For those of you who are not familiar with this discipline, a working definition is that category theory involves the collection, organization and analysis of empirical *prima facie* information about the world and the adequacy of its formalisms. It provides a decomposition and formal description of reality into categories of types of entities including processes and events as well as things.

Reality can also be divided formally into a sequence of physical levels, starting with that of basic quantum physics and characterized by increasing complexity and studied in the corresponding fields of chemistry, biology, psychology and the social sciences and humanities, and cosmology.

To repeat, transdisciplinarity is not a new discipline, but as you will have noted, the number of important individual disciplines that it is necessary to take into account in order to arrive at a more or less complete initial picture of reality is very large. Transdisciplinarity thus has, among other things, the task of seeing what all disciplines have in common, as well as what lies through and beyond them. What they have in common is a basis for "making sense" of the totality of human knowledge and hopefully providing a path to a unified understanding of it. In this task, the logic of the included middle, due to its grounding in physics and exemplification of the principle of dynamic opposition, has an essential role, as we will see, in tying together the various aspects of transdisciplinarity. In my opinion, it is *the* logic of reality (LOR), and I will so refer to it in the remainder of this talk. Further, our discussion of the pillars of transdisciplinarity must, as far as is possible for non-specialists, meet the standards of rigor and coherence that characterize the disciplines themselves.

In this talk, I will focus on the relations between my logic and levels of reality and complexity, as well as between the other two of the pillars of transdisciplinarity, complexity and levels of reality. I will also discuss the process of emergence, in which all three pillars are critically involved. I will begin with a few additional details about levels of reality from the physical standpoint.

2. Levels of Reality

To a physical scientist like myself, the description of the world in terms of discontinuous levels of reality seems natural and rigorous. At the human level, one has no direct contact with the world of quanta, or even cells, but one visualizes the "inside" of a proton, observes the fantastic variety of biological life, and is conscious of the existence of consciousness itself. This picture supports a view of reality as constituted by levels that are in some essential respect separated. That different scientific laws apply to the phenomena at these different levels also seems natural. Most people would also agree that another kind of illogical or a-logical "rules" apply in the areas of affectivity, love and religious faith.

A concept of levels of reality, however, in *all* of which at least *some* of the same basic principles are instantiated, suggests a possible isomorphism of the underlying laws of nature. For now, I will take the view that there are six such major levels of reality, as follows:

• Macrophysical	Classical Physics
• Biological	Biology
• Microphysical	Quantum Mechanics
• Psychological	Psychology; Cognitive Science
• Social	Sociology
• Cosmological	Cosmology

[4] Lowe, E. J., *A Survey of Metaphysics*. Oxford: Oxford University Press, 2002

Such a division is an idealization, and reality is a coherent whole. Thus, independently of the properties that are proposed as the basis for the location of the cuts between levels, an additional principle seems necessary, namely, to explain the basis of transition from one level to the next. This is, in other words, the problem of emergence, and I will suggest a concept of emergence that "emerges" naturally from the logic of reality, the logic of the included middle.

3. Logic and Contradiction

Transdisciplinarity is about man, man and the reality of which he is a part. Transdisciplinarity is thus about human successes - progress and creativity, but also failures and regression, or virtue and vice in the traditional expression. In a word, it must account for contradictions and inconsistencies, as well as the appearance of new forms and entities. Classical logic, the binary logic of Aristotle, does not allow contradiction. Designed for propositions, it cannot in principle apply to complex aspects of the real world. However, if all or part of reality does in fact instantiate contradiction, by this definition, reality cannot be logical. Despite this potential inadequacy as a picture of reality, logic has been maintained as a quasi-monolithic doctrine since antiquity. Intuitions that other logical principles may govern existence can be found in both Western and Eastern thought. However, it was not until the development of quantum mechanics in the 20th Century, in particular by Planck, Pauli and Heisenberg, that the failure of classical logic to apply to or describe specific physical systems became evident,[5] potentially facilitating the re-evaluation of logic in general.

Despite recent developments in paraconsistent and intuitionist logics, the logic underlying work in all scientific fields, with the possible exception of quantum mechanics, continues to be based on classical or neo-classical notions of truth and/or non-contradiction. This is also true for discussions of ethics or morality and high-level human phenomena such as art and creativity. To the extent that logic is considered at all, it is thought to be in some way in opposition to the essential components of spontaneity, imagination and emotion in normal behavior. Although people value "being logical" as a necessary criterion for socio-economic survival and success, formal logic is considered dry and uninteresting, as well as being essentially inaccessible to the average person - a necessary evil. Logic and epistemology, the philosophy of knowledge, share unfortunately well-deserved reputations for using examples and references that are far removed from daily life and its problems.

Stéphane Lupasco, who deserves a major, still unrecognized place in the history of Western thought,[6] provided a theoretical basis for the quasi-universal rejection of contradiction and the maintenance of absolute separation between classical pairs of opposites, especially part and whole, simultaneity and succession, subject and object. Lupasco was able to show that such abstract, idealized concepts are still present in most of current cosmology that is based on Einstein's ideas of general and special relativity. The weaknesses of this system are beginning to be recognized, one hundred years after its basic formulation, due to recent advances in quantum non-locality or non-separability. However, these developments have not yet received adequate attention from logicians.

4. Logic of Reality – Logic of Energy

The purpose of the next part of my talk will be to show in more detail in what the logic of the included middle consists, in particular its grounding in physics and the extension of its physical-metaphysical principles to logic.

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 one another. Information has been shown to be equivalent to energy, and even the vacuum carries energy, albeit in a way that is still not

[5] For reasons that are themselves explicable in my approach, attempts are still being made to save classical principles in quantum theory and probability theory, among others.

[6] Nicolescu, Basarab, "*Le tiers inclus. De la physique quantique à l'ontologie*" in Badescu, Horia and Nicolescu, Basarab (eds.), *Stéphane Lupasco. L'homme et l'œuvre.* Paris: Editions du Rocher, 1999

well understood. The logic of the included middle is a logic of reality as energy (LOR) based on its dialectical characteristics, that is, that it instantiates a number of fundamental dualities.

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.

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.

- 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 (two other dualities I discuss 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 third 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 principle of antagonism in energy is 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 in a chemical reaction. The significance of the T-state for more complex processes will become apparent later.

5. Dynamic Opposition. The Fundamental Postulate

The fundamental postulate of this 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*[7]:

> “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. Therefore, an Aristotelian logic, in which one tries to eliminate or avoid contradiction, is not adequate to describe real systems, all of which are derived from energy.

I should pay tribute here to the great Brazilian logician Newton da Costa, one of the pioneers of paraconsistent logic and one of the first to see the necessity of modifying the classical structure of logic. I have had the privilege of meeting two of his students and collaborators, Jean-Yves Béziau of the University of Neuchâtel in Switzerland, and Walter Carnielli of the University of Campinas here in Brazil. Another name to be mentioned in connection with paraconsistent logic is that of Graham Priest of the University of Melbourne in Australia, who went even farther in the direction of seeing real contradictions in the world, which he calls dialetheias.

Unfortunately, all of these logicians, whether or not they have made any ontological commitment, that is, any statement about the applicability of their logic to the real world, fall short of a description of the actual energetic changes in it. Current paraconsistent logics, which permit true contradictions as noted, but retain idealized, abstract concepts of truth and falsity, fail to give an adequate picture of the emergence of complex, real-world phenomena. The schools of both Priest and da Costa seek, as far as possible, to make their logics be as close as possible to classical logic, in order to benefit from its advantages as a description of the everyday world and in standard syllogistic proof, that is, demonstration of the truth of propositions. Carnielli, who does not make the ontological commitment of Priest, believes that his logic “supports” a metaphysical notion of essence, but it is still semantic/linguistic, and the “truth” of reality is not addressed. In paraconsistent concepts 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. I have therefore designated this logic as *transconsistent.*

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[7] Lupasco, Stéphane, *Le principe d’antagonisme et la logique de l’énergie.* Paris : Editions Hermann, 1951, re-edited Paris: Editions du Rocher, 1987

These considerations 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 non-e in such a fashion that e or non-e can only be but potentialized by the actualization of non-e or e, but not disappear such that 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. As discussed later, 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.

6. The Axioms of the Logic of Reality

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 non-A (not (A and non-A)).
3. Excluded Middle: there exists no third term T that is at the same time A and non-A.

This logic, in various forms, 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 better describes the world. The separation of terms that classical logic supports shows up in, for example, discussions of universals and particulars, appearance *vs.* reality and in an absolute difference required between internal and external processes.

Logic in reality (LOR), as we have seen, is an extension of classical logic to real-world phenomena. 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 so that they 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, non-A is potential, reciprocally, proportionally 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.

To my knowledge, the theory developed here is the only one in which all three axioms of classical logic are modified at once. To put it another way, standard logics, (classical or non-classical) consist of axioms and a set of rules of inference for determining the truth of propositions and linguistic formulations of beliefs, etc. My logic consists of axioms and a set of rules for determining the dynamic state of the contradictory elements involved in a phenomenon.

[js1] Comentário: Which? Highlight the principles, putting them in italics

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 will be provided for them. LOR can also account for a broad and deep range of other kinds of intuition related to real-world situations, such as the intuition often ascribed to women.

One should be careful, however, not to conflate LOR and intuitionist logic. L.E.J. Brouwer[8] and his followers developed intuitionist logic as a basis for mathematical reasoning about infinite sets. Brouwer then went on to claim that the law of the excluded middle cannot apply in mathematics, "once it has been recognized to be an autonomous interior constructional activity which, although it can be applied to an exterior world, neither in its origin nor in its methods depends on an exterior world". He thus 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 this work of a basis (or need) for applying such principles outside mathematics. He did not, apparently, formulate or show the necessity of a law of the included middle, and his formulations contain many idealized distinctions and processes which apply only within mathematics, and not to the real world.

The concept of an energetic state of phenomena, the T-state, being not only an element of a *logic* but one that overturns, in certain areas, an axiom of commonsense logic, the law of the excluded middle, is the crucial innovation of this logic of and in reality. It is thus important to first make clear what a T-state is *not*: it is not an average of two or more elements, a static, scalar result of an arithmetical operation. It is not the result of a physical mixture or fusion; gray is also an "average" of black and white, but this result is inert, without the capacity of change or development. Similarly, a T-state is not the static equilibrium that results from the neutralization of two elements, such as equal quantities of acid and alkali. At a microscopic level, some regions of such materials may depart from equilibrium, but the fluctuations are only statistical in nature.

At a single level of reality, the second and third axioms of classical logic are essentially equivalent: there are no contradictions in the same time and place. In my extension of logic, a T-state resolves a contradiction at another level of reality. The "classical" example is the unification in the quanton (T) of the apparently contradictory elements of particle (A) and wave (non-A). What is involved at the single, "lower" level of reality are more or less mutually exclusive, antagonistic pairs that can be seen as resulting from the projection of a T-state on it. The T-state is an "included" middle or third term in that it is located in the model at an intermediate point in a complex configuration space. In contrast to the Hegelian triad, the three elements here coexist at the same moment of time. It should be re-emphasized that "A and non-A at the same time" does not mean that both are fully actual. One element is more or less actual, and the other is, correspondingly, more or less potential. It should be stated here that "at the same time" does not imply an instant of standard clock-time.

The logic of the included middle is capable of describing a coherent transition between levels of reality. A given T-state (which effects the unification of A and non-A) is associated with another couple of contradictory elements at its higher level (A^1, non-A^1), which are in turn resolved at another level by T^1. The application of the logic of the included middle implies an open, incomplete structure of the set of all possible levels of reality, similar to that defined by Gödel for formal systems.[9] Concatenations of systems and dialectics never have a third term in the sense of a Hegelian or Marxist synthesis. The T-state is not a term, but a state, and emergent T-states, at a higher level of reality, can also enter as elements into contradictory relations.

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[8] Brouwer, L.E.J., *Cambridge Lectures on Intuitionism* (1951), quoted at http://home.mira.net/~gaffcam/phil/brouwer.htm

[9] As Priest has shown, the paradox at the heart of Gödel's theorem is also paraconsistent.

The concept of level of reality, developed above, requires further discussion in this context. Levels of reality have been defined in terms of application of a different set of laws of nature. It is easy to see the differences in the applicable laws between the macrophysical and biological, or microphysical and mental levels, but what constitutes the minimum requirement for the establishment of a new level? Nicolescu[10] assumed that the laws of nature are *isomorphic* throughout the levels of reality, due to the operation of the fundamental postulate at all of them. If this is accepted, then than one can define sub-levels within the major levels which differ by at least one additional law or rule. Higher conceptual levels of reality, for example as different levels of meaning corresponding to artistic or poetic levels of perception can be described by such a picture. Another example is the French expression of the "degree" at which a statement (or artistic performance) is to be understood – "*au premier degré, au deuxième degré, etc.*"

Patrick Paul[11] has made some additional hypotheses that relate the concepts of dynamic opposition and levels of reality in a highly original way. They assist in answering questions about the relative probability of emergence of T-states (included middles) that will be useful in the discussion of emergence later. Paul observes that the macrophysical level is composed of objects that display little internal dynamics *qua* objects, and proposes that the primary principle of organization is in fact that of hierarchies. At the next major level of reality, that of life and neuro-psychic phenomena, dynamic opposition is the primary principle of organization, although hierarchies are still found as discussed above. At the level of reality of quanta and of higher levels of human consciousness, hierarchies and dynamic opposition are still found, but the major principle of organization, in place of an opposition of energy in one or another form (including information), is what he calls "complementarity". (This use of the term should not be confused with that of Bohr that, as discussed, is now seen to be inadequate for quantum phenomena). By complementarity, Paul emphasizes a form of dynamic opposition which differs from that of the lower levels in that the actualization of one element, A or non-A, would not, if the actualization were complete, result in the destruction of the contradictory term. Paul finds support for this concept in various religious traditions whose objective is to describe the transcendental nature of the individual human being. At this level of reality, one is dealing with real, but non-physical relations. Paul in fact sees the trend to complementarity as an ontogenesis. All of these considerations are consistent with the logic of reality as the applicable logical system.

7. Complexity and Emergence

The third pillar of transdisciplinarity proposed by Nicolescu – complexity – receives a natural explication when related to levels of reality. The key point is that complexity is not a smooth function of levels of reality. It goes from large values at the quantum level, through a minimum at the macrophysical level, increasing again at the biological level and reaching the largest values at the human mental and social level. Complexity is thus a function of the relative degree to which heterogeneity, diversity and contradiction (or opposition, antagonism) are the prevailing tendencies as opposed to homogeneity and identity. Domains exist throughout reality that are the consequence of what I might call emergent simplicity, and it is no more than commonsense to say that binary logic applies to them.

Energetic exchanges are thus a necessary but not sufficient condition for complexity. In a game of billiards, the cue stick and balls exchange energy, but the location of the complex processes of interest are in the mind of the player (intentionality, frustration, etc.). What is necessary is that the system embody some form of internal representation of the processes being actualized.

Any discussion of such issues at a reasonable level immediately results in a need for a new, Lupascian interpretation of causality, cause and effect, which need to be contradictorially related, that is, as one is actualized, the other is potentialized and *vice versa*, reciprocally and alternately, but never completely. Phenomena in LOR do not *have* causes and effects; they are causes and effects or rather cause/effects. The world instantiates aspects that are both *relatively* closed, static and rational and open, dynamic and irrational. The world is then full of emergent phenomena - T-states - that are the

[10] Nicolescu, Basarab, "Le tiers inclus. De la physique quantique à l'ontologie", in H. Badescu and B. Nicolescu (eds.), *Stéphane Lupasco ; L'homme et l'œuvre.* Paris: Editions du Rocher, p. 129

[11] Paul, Patrick, private communication, 2003, re his Thesis

consequence of these two tendencies being of equal force. There are no accidents or indeterminacies that are not, also, in part determined. Chance and necessity do not exist independently of one another; in a very real sense, they are partners.

One must be careful, again, not to reject the simple concepts of truth and causality. They have been too important in the history of thought and are too useful in everyday life to be discarded. Rather, a clear delimitation of the domains where these interpretations apply must be established, for example, in computational models of reasoning. It is in the domain of complex phenomena in which the new and dynamic interpretations of truth, causality and determinism, the consequences of the principle of dynamic opposition, most clearly apply.

The existence of complex triadic relations throughout nature but especially at the quantum and highest levels of reality is not arbitrary but a consequence of the fact that all phenomena are energetic and carry the potentialities, as well as the actualities, of energy from the lowest to the highest levels. It is in this sense that Nicolescu's distinction between: "Objective Nature," "Subjective Nature" and "Trans-Nature," and that between levels of reality, levels of perception and the term or element of interaction between them should be understood. This does not exclude the applicability of binary relations *within* levels. For example, an enormous of *complicated* binary logics can be computer generated by cellular automata. Most of these logics have meaning outside and even inside the system only as abstract curiosities, with no theoretical or practical applications.

To repeat, I suggest that where the principles of the logic of reality apply and a T-state emerges from the dynamic opposition of two elements, it can be at another level either of reality or of complexity. The latter can be a hierarchical level within the same level of reality (e.g., socio-political), provided the contradictory terms are in a dynamic, interactive relation of conjunction or disjunction. As Nicolescu says[12], "the logic of the included middle is a logic of complexity" that permits crossing between different domains of knowledge. Nicolescu focuses here on higher, ontological levels of reality where the "complementarity" of Patrick Paul can be the organizing principle, rather than contradiction in the sense of counter-action as noted earlier. However, at all levels, those involving complex mental phenomena, in which macrophysical and biological components are (almost) absent, and those in which the latter are predominant, the operation of an included middle always enables the downward causal connection between adjacent levels.

8. LOR and Science

The question of the logic underlying the methodology and application of the natural and social sciences is not generally included in discussions of them. In addition, scientists are themselves largely unaware of the logical assumptions underlying their work, assumptions which are equivalent to the elimination of themselves as subjects or actors in it. They tend to resist, like the majority of non-scientists, any new paradigm in which a principle of contradiction is accepted, which might imply threats to their security or identity. The apparent general nature of the problem suggests that a cultural shift is needed to understand the critical role of the logic of contradiction underlying behavior, and that on-going failure to do so and establish a proper, transdisciplinary world-view will have far-reaching negative consequences.

In my opinion, one can only have confidence in the value and relevance of the principles of transdisciplinarity by making regular comparisons with the best current work in science, philosophy and logic. The consequence is that one can start to see how the principle of dynamic opposition can be used or applied. I will take two examples from the recent scientific literature, but ones that literally affect all of us, since one is about the brain and the other about the universe.

As you know, brains consist primarily of two types of cells: neurons and glial cells. Neuro-anatomists have always focused on neurons, which are easily identifiable entities or identities with apparently clear-cut functional roles. The possible role of glial cells, other than that of mechanical support, which accompany neurons and are of three main types, and so are diverse and diffuse (the term comes from the Greek word for glue or slime), has been largely ignored to date. People who worked on them got little credit and were accused of being "glia-centric". It now appears that glial cells have very important roles to play in pain, depression and other central nervous system

[12] *SLHO*, p. 130

phenomena. The logic of reality, which teaches that identity and diversity are always linked functionally, could have predicted this new result. At present, the LOR approach would suggest looking for new functional relations and interactions between neurons and glia.

In cosmology, the latest theory has arrived at a conception of the source of the current expansion of the universe in terms of a dark energy, currently constituting 73% of the mass of the universe *vs*. only 23% of cold dark matter and even less, about 4% of the ordinary matter/energy with which we are familiar. The nature of dark energy and matter is not known, but it does appear that in the past, the situation was reversed, and ordinary and dark matter predominated at the expense of dark, "negative" energy. This theory has been challenged recently by a proposal that the expansion of the universe is a by-product of enormous ripples in the fabric of space-time. These ripples, caused by rapid inflation after the "Big Bang", allegedly mimic the properties of dark energy. In the second theory, one has recourse to a series of hypothetical constructions that are separate identities - the "ripples", the "Big Bang" and "the fabric of space-time" - all of which embody concepts of time, space and cause from classical logic. Despite their theoretical and mathematical complications, they are static conceptual entities, the idealized products of processes in which they do not participate. Accordingly, I will hazard the prediction that based on the principles I have been talking about, the first of these theories, in which one can see the operation of a dynamic opposition, an alternating actualization and potentialization, is closer to being correct.

One example of the application in science of the principles of LOR is from John Symons' discussion of the "tangled interplay of natural science and metaphysics"[13]: he argues that metaphysical inquiry in the philosophy of mind concerns the same phenomena that our sciences investigate. The logic of reality gives a metaphysical and physical picture of mental phenomena that is at the boundary between science and philosophy and explicates both the disciplines and the sense of "interplay". In my interpretation, interplay implies a shift of attention, according to the actual-potential scheme, between the physical and the metaphysical aspects of natural phenomena. In my view, only a logic of reality is capable of providing an adequate framework for the discussion of such issues.

9. A Role for LOR in Philosophical Debate

I would like now to try to convey to you, very briefly, an idea of the debates that are going on *within* some of the major philosophical disciplines. In these debates, one can see, without *too* much projection, how arguments based on the principles of classical logic no longer even start to resolve essential questions. In other words, among the transdisciplinary aspects of disciplines, one must include common sources of error and confusion.

It should be clear that I am not suggesting that theories cannot be changed and new ones proposed nor that philosophical positions cannot be modified. What I am criticizing is that the structure, the form of the arguments in the debates is always the same – a replica of the form of argument in classical logic that amounts to tautology. When people take and present a position of any kind – scientific, political or interpersonal – there are only two ways in which this is done: the majority defend their positions as being exclusively correct, or else a small minority accepts that an opposing position may be right part of the time. The problem is that even in the second case, no explanation is given of *how and why* such opposing positions can exist at the same time to describe the same phenomenon.

One area of formal philosophical debate in which a positive trend can be discerned is that of the theory of explanation, the explaining of explanation itself. The key questions are "What is an explanation?" and "What are explanations of?" Answers to these questions developed over the last half-century tended to focus on linguistic aspects of explanation, explanation as a logical proposition of some kind. More recently, the necessity of relating explanation to an underlying theory of real phenomena has been recognized, but attempts are still made to restrict this to a purely formal operation of inference or deduction, dependent only on the classic structures of a classical first-order, consistent logic. Only in the last few years has it become apparent that such an approach provides no insight into what really constitutes an explanation, and that something like a logic of reality is required, that includes the antagonistic or contradictory aspects of the phenomenon under study.

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[13] Symons, John, "Functionalism as Metaphysics, Functionalism as Science", paper for publication, 2004

A similar situation obtains with regard to theories of realism. People who try to answer the age-old question of "What is Real?" are apparently irrevocably split into two camps: the realist who believe that reality exists independently of our ideas, theories, etc. about it, and anti-realists who believe the contrary. The first group requires a classical notion of bivalence, that is, statements are true or false and we can tell which is correct; the second that a statement is either true or false, but we cannot tell which. The former uses classical logic, the latter intuitionist. From the point of view of LOR, both miss the point, even at the semantic level, because of the inability to accept the partial validity of the opposite view, in certain circumstances. In the LOR formulation, the world is robustly realist, but the description of its functioning is freed from the reliance on classical logic.

Conclusion

In conclusion, I would hope that we could agree on (at least) one thing, namely, how to look at the process I have used in this talk. I have said that the Lupasco-Nicolescu system has a high level of validity as a framework for understanding complex problems in both science and philosophy. Serious workers in these disciplines should, accordingly, take it into account. At the same time, I have said that modern science supports the Lupasco logic of reality. From the standpoint of this logic itself, the existence and interaction of these two perspectives, which we can all have, is another expression, at a high level of human knowledge, of the generally applicable principle of dynamic opposition. In it, the two aspects, that the logic of reality offers an alternate interpretation of science, and that science supports the logic of reality, alternately and reciprocally actualized and potentialized, illuminate and explicate one another. There is, truly, a contradiction here, or better a complementarity, and it is one from which new transdisciplinary understanding can emerge.

The three pillars of transdisciplinarity should thus be seen not only as solid "supports" of wisdom, as in the original metaphor of T. E. Lawrence, but also as dynamic systems of points of view capable of evolution and change. One output of this Congress could be, therefore, new interpretations and applications of the pillars themselves.

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