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The Philosophy of Ecology and Sustainability: New Logical and Informational Dimensions

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Abstract: Ecology and sustainability are current narratives about the behavior of humans toward themselves and the environment. Ecology is defined as a science, and a philosophy of ecology has become a recognized domain of the philosophy of science. For some, sustainability is an accepted, important moral goal. In 2013, a *Special Issue* of the journal *Sustainability* dealt with many of the relevant issues. Unfortunately, the economic, ideological, and psychological barriers to ethical behavior and corresponding social action remain great as well as obvious. In this paper, I propose that a new, non-standard and non-propositional logic of real processes, Logic in Reality (LIR) grounded in physics applies to the science and philosophy of these narratives and helps to explicate them. Given the ecological role of organizations and institutions, reference is often made to organizational or institutional logics as guides to ecological practice. This paper suggests that these logics are either too abstract or too informal to have an impact in a conflictual world. Recognition of the suggested new, transdisciplinary logical dimension of ecological processes may provide credibility and support to new initiatives in ecology and its philosophy.

Keywords: common good; contradiction; ecology; ethics; information; logic; philosophy; science; sustainability; transdisciplinarity

1. Introduction

Ecology or ecological science is an approach to a better understanding of the complex interrelationships between humans and their environment. It is a necessary part of any effort to respond to the resistance and barriers to ecological progress and achieve the goal of a sustainable world. Concomitantly, the necessity of managing the explosive expansion of scientific knowledge and the 'infosphere' of communication is apparent. The concept proposed in the 1990s by Capurro and others, of an Informational Ecology as a global ecology of *intellectual* resources, now would include 'natural' ecology and sustainability themselves as domains of knowledge. Further, Zhong and his colleagues in China have recently drawn attention to their version of an Information Ecology that focuses on the ecological characteristics of Information Studies.

In this paper, I propose that what has been missing in these approaches is a rationale for sustainability and ecology in the basic physics of our world. In the mid-20th Century, the Franco-Romanian thinker Stéphane Lupasco proposed a non-propositional logic that can describe the evolution of interactive processes at biological, cognitive, and social levels of human reality. I suggest that the dualism between altruism and selfishness, which is reflected in attitudes toward the environment, can be described by this logic and that this description, as a 'positivity factor' may contribute to predominance of the former.

I start in Section 2 with a summary of relevant recent developments in sustainability and philosophy of ecology. Section 3 introduces the topic of the philosophy of ecology and Section 4 discusses the problem of logic in relation to the realities of ecology and sustainability. Because of its unfamiliarity as well as its significant role in this paper, I provide in Section 5 a minimum overview

of my Logic in Reality (LIR). In Section 6, I refer briefly to the concepts of natural computation and 'infocomputationalism' as alternative rigorous approaches to digital aspects of sustainability. Section 7 reviews some of the prior work on information and information ecology and relates it to LIR. Section 8 looks more in detail, from the LIR perspective, at current work on the Ecology of Information Studies and Section 9 at Sustainability and the Psychology of Moral Responsibility.

Scientific and philosophical debate about the need to preserve the environment has become a matter of survival. The definition of new relevant forms of philosophy and logic that are relevant to this debate requires a delicate balance between use of established forms and the reasoned introduction of new concepts, structures, and definitions. However, when standard current definitions of logic and philosophy are what are being called into question, as in this paper, they cannot themselves be used as criteria for its evaluation. My answers to the valuable comments, negative as well as positive, of the four reviews of the first version of this paper will all be based on this metaphilosophical position (MPP).

Sustainability and the Digital Environment

This paper was stimulated in part by two recent Summit Conferences on Information organized by the International Society for Studies of Information (IS4SI): Response and Responsibility in the Information Sciences, Vienna, 2015 and Digitalization for a Sustainable Society, Gothenburg, 2017. The latter included a panel discussion specifically entitled "Sustainability in the Digital World", moderated by Anna Dubois. Here, Sustainability was understood as comprising social, economic/business, and technical sustainability as well as environmental sustainability, domains of course not totally separated or separable. The hopefully rhetorical question asked was whether the final goal of digitalization was an increase in productivity *per se* or in the *net* benefits to the society of that productivity. Section 7 of this paper addresses some of the relevant issues.

2. Sustainability and Ecology

2.1. What Is 'Ecology'?

In an Editorial in *Science* in 2015 [1], David Inouye, President of the Ecological Society of America, described the new paradigms that have emerged from basic ecological research and the "dramatic growth" of the role of ecology in the society. "With newly developed tools, analytical methods and models to forecast the future of the world's environment, ecologists can inform policy-makers about how to prevent, mitigate or adapt to environmental change." Inouye stated that the science of ecology was about interactions between and relationships among organisms and habitats, on all scales and how they provide information to help understand our world.

I argue here that to understand and support ecology and its role, further understanding is also necessary of the physical nature and operation of such dynamic interactions in nature, including human society. Despite the success of digital tools in offering new scientific and philosophical perspectives here and in other sciences, one must ask what other perspectives might help to understand the *resistance* to implementation of ecological that is, ethical policies in favor of the common good—a sustainable society.

My discussion of the 'foundations of ecology' clarifies one definition at least. In the American Heritage Dictionary, ecology is:

1. the science of the relationships between organisms and their environments;
2. the relationships between organisms and their environments.

As we will see, it is an explicit tenet of Logic in Reality that two such systems or levels of discourse are not separate but interact and inform one another. This clarifies other usages of the 'E-word':

- Categorial use—information ecology, communication ecology

- Adjectival use—ecological context, issue, point, system, questions, quality, dangers, theory, challenge, crisis, etc.
- Adverbial use—ecologically protected, considered (attitude or stance)

In any event, the underlying valence of ecological is positive, referring to a way of functioning for the common good. This sense will underlie the various usages in the remainder of this paper.

2.2. The Science

In the last few years, two related processes affecting human existence have been established with increasing scientific validity: anthropogenic global warming and anthropogenic destruction and unsustainable misuse of natural resources. The resistance of some people to acceptance of a scientific explanation of these processes is an extremely complex phenomenon. It has components of ignorance, greed and political ambition, pretense, and, even perhaps, some *bona fide* religious belief. The major assumption of my analysis of this issue is that the anti-social behavior consequent on this resistance is a scientific fact itself, discussable with reference to individual and collective psychology and its dynamics.

From a political perspective, one argument would be that what has been called the 'late-capitalist' system institutionalizes greed by intensifying the 'closure' of social groups, as the systems and information scientist Wolfgang Hofkirchner has described [2]. The 'solution' proposed by many is to change capitalist society to something more social, but this kind of gratuitous comment is part of the problem. It begs the question of who is to do the changing and if and on what basis it could be successful.

For purposes of discussion, I claim that the polarizations of human beings-in-society—left and right, altruistic and selfish, finally social and anti-social, 'good' and 'evil' in the old terminology are embedded in the genome and, logically, will always be instantiated in society. Two categories of people will always exist, with the balance of power shifting cyclically from one to the other, locally or globally as the case may be. Acceptance of the reality of this dynamic situation, in the framework of the logic I have proposed, may be a step towards appropriate actions to manage it.

Writing three years ago in *Ecological Modeling* [3], the ecologist and philosopher Robert Ulanowicz presented a case against the materialist/mechanist metaphysics of conventional science. I show below how this case and others fit the logical picture I propose for the operation of complex processes.

2.3. The Tragedy of the Commons—Still

In 1998, thirty years after the appearance of his first paper [4] and now almost twenty years ago, Garrett Hardin wrote an extension [5] restating his basic principle: "The more the population exceeds the carrying capacity of the environment, the more freedoms must be given up". This principle is still true, as is Hardin's challenge that a cardinal task "is to marry the philosopher's literate ethics with the scientist's commitment to numerate analysis" through interdisciplinary work. Already in 1968, Hardin related sustainability of the commons to population density. He did not shy away from the word 'coercion' for necessary control of population growth but does not refer to the role of an economic/fundamentalist ideology that requires or claims to require it.

Part of the problem is that current interdisciplinary and transdisciplinary initiatives in the direction of an increase in the common good are based on outmoded philosophical and logical foundations. Graff has formulated Information Ecology as providing a context for examining the dynamic interdependence between knowledge, scientific epistemologies, and traditional disciplines, that is, interdisciplinarity [6]. However, simply saying that ecology is inter- or transdisciplinary does not provide a methodology for insuring its implementation, with reference to the nature and operation of the relevant interactions at cognitive and social levels of reality. This paper addresses the nature and function of a new logic for this purpose.

The center of preoccupation of this discussion is the human being, his/her environment and his/her behavior. The domains of discourse involved are named differently-sustainability, ecology,

or environmental responsibility. However, they all refer to the essential new and transdisciplinary knowledge necessary for survival and furtherance of the common good, and the methods for and the obstacles to as well as the methods for trying to achieve it. These terms nevertheless focus on somewhat different aspects of the problem. I will return later to the role of transdisciplinarity in relation to sustainability, with special reference to the work of John van Breda in South Africa, which is based on a conception of transdisciplinarity that has the logic referred to in this paper as one of its 'pillars'.

2.4. The New Central Role of Ecology in Science

As well expressed by the philosopher Aaran Gare [7], ecology is becoming central to the evolution of forms of thought—the science, philosophy, and sociology—required to provide the basis for an ecological civilization. In this paper, I take the position that these current developments in the science, psychology, and philosophy of ecology and sustainability on the one hand, and on the other relevant developments in the science and philosophy of information follow a non-standard, non-propositional logic, which I call Logic in Reality (LIR). Recognition of the reality of this natural-logical principle might help to focus debate not only on necessary changes in policy and behavior, but the barriers to their implementation. The target audience for this paper is thus composed of people who feel that their arguments in favor of strategies for the managed, sustainable use of resources would be strengthened by the demonstration of the applicability of a new logic that has a degree of credibility comparable to that of the fundamental physics of our world.

This paper can also be read as a response to the pertinent critique of modern science by Gare and others. Gare says that "Ecological science is a fundamental challenge not only to the core assumptions of modern science, but of industrial civilization. Acceptance of ecology will involve not merely a transformation of science, but a transformation of the relationship between science and other domains of culture, impacting on people's lives, their institutions, and their organizations, and more fundamentally, on their image of the future and of the ultimate ideals and goals worth struggling for. By 'modern' science I mean the form science took with the emergence of industrial civilization, that is, a form of reductionist materialism that denied any purpose to human existence, rendered sentient life unintelligible, created a dualism between body and mind, divided science from and opposed it to the arts and humanities, and yet sustained a vision of the future as the total conquest of nature to serve human purposes, or at least the purposes of the winners in the struggle for survival and dominance."

Gare sees a solution, arguing that "ecology is developing the forms of thinking required to rethink the relationship between humanity and nature and between individuals and their communities, the nature of culture and civilization, and thereby to transform the way people live and organize themselves. It provides the basis for a different vision of the future, with a different kind of ethics and political philosophy than those which have dominated modernity. That is, ecology is developing the forms of thinking required to create an ecological civilization[1]." He calls for new processual forms of ecology, philosophy and complexity for understanding life as ecosystems, that is, as communities of dynamical processes in symbiotic relation, constraining themselves and able to constrain each other directly or indirectly, thereby coordinating their activities to contribute to their common good. "Ecology is thus the science that thus integrates factors in the global ecosystem and thereby transcends the opposition between science and the humanities, giving a place to the narratives and more abstract thought through which humans create themselves and redefine their relation to each other and to the rest of nature." In my view, these positions, fully correct and desirable as goals, still require further scientific underpinning for maximum acceptability that a relevant logical system could provide.

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[1] Gare uses the term 'eco-poiesis' to describe a desired process of 'making homes', the creation of ecological niches in which the inhabitants can exist and develop. The usual meaning is the (hypothetical) artificial creation of a sustainable ecosystem on a lifeless planet.

3. The Philosophy of Ecology

The first article in the *Stanford Encyclopedia of Philosophy (SED)* on ecology, which appeared in 2005 [8], stated that general philosophical conclusions could not yet be drawn about it. Ecology is a central part of biology, but it has an evolutionary context, conceptual structure, and experimental practices and limitations that are unique to it. Typical questions arise due to the indeterminism related to the models used for ecological systems, complexity, ambiguity, and uniqueness, but these will not be discussed further here.

The appearance in 2012 of Philosophy of Ecology as a Volume in the *Handbook of the Philosophy of Science* [9] suggests a certain maturity in the field. Analysis of philosophical aspects of ecological studies could even (it is claimed) provide a bridge between philosophy and current science. Philosophical issues which can be addressed from an ecological perspective include that of diversity-productivity in relation to the common good [2,10], environmental problems, traditional themes within the philosophy of science: contingency, complexity, laws and theories and so on.

The concept of most interest for this paper is the idea that within a philosophy of ecology, an integration of science with ethics may be possible, beyond its standard scientific concerns of population, communities, and ecosystems as such.

3.1. Philosophy of Ecology; Philosophy of Biology

Several recent studies of ecology, biology, and their relation are relevant to this one. The article by James Justus [11] entitled Philosophical Issues in Ecology appears as Chapter 3 in a compendium entitled *The Philosophy of Biology.* Justus constructs his discussion as an ecological perspective underpinning much of evolutionary theory, noting that philosophers of biology have paid relatively little attention to ecology, "largely due to disciplinary inertia". Philosophy enters into the conceptually rich questions ecologists study, offering novel insights into standard topics in the philosophy of science: the history of ecology; 'biodiversity and 'stability in nature; whether there are distinctively ecological laws; reductionism in ecological science; the reality of biological communities; problems of idealization in mathematical modelling; the relations of facts and values; and the management of uncertainty in ecological inference.

I will propose that my non-standard Logic in Reality provides a new approach to these issues, especially the last two. Uncertainty is given an ontological status in a dialectic relationship to 'certainty' in terms of non-standard (non-Kolmogorovian) probabilities. In LIR, there is no topic neutrality; all-logical-properties of living systems have an ethical valence. This point is not 'new' in and of itself; what is new is that the ethical aspect is *logical* in my sense of logic and thus within science.

As we will see, Griffiths' concept of methodology in the philosophy of biology [12] is also very much in the spirit of my logic of real processes applied to science (LIR) and can be applied directly to the philosophy of ecology. "Much work in the philosophy of biology is *self-consciously* (emphasis mine) naturalistic, recognizing no profound discontinuity in either method or content between philosophy and science." LIR grounds this view in its ontological principle of non-separability, thus eliminating the rather defensive implications of 'self-consciousness'. The statement that "there is no clear distinction between the philosophy of biology and theoretical biology" is a *logical* hence scientific concept itself in my system, and the required 'complex chains of argument' are facilitated by seeing the elements in the chains as logical arguments.

The transdisciplinary complexity of the philosophy of ecology, as that of biology, involves general questions about the nature of science, conceptual problems within ecology, as well as traditional philosophical questions about the ground of existence, plus the more clearly social dimension. As I have indicated elsewhere, complexity theory and its development into systems theory, for example in the work of Edgar Morin [13] lack a necessary grounding in the physics of our world.

Ecology provides a scientific basis for conservation initiatives, pollution reduction and mitigation, and of course sustainability and its rapid development must be seen in the context of progress in philosophy as well as science. Some of the conclusions of the foundational 2000 compendium by

Keller and Golley [14] are still very relevant in general and to the thesis of this paper. Logic in Reality has no problem accepting the "paradoxical" nature of ecological science in going beyond the standard disciplines to the totality of nature, animate and inanimate. LIR can accept the "on-going contradictions" in ecology as a domain that is itself 'unecological and illogical in the standard sense of logic.

3.2. Ethics and Philosophy

Further opinions on the ethical issues involved in sustainability have been available for some time (cf. for example the report by Inge Johansen [15]). In a broader sense, the same issues are treated from the perspective of sustainable development [16]. In order that principles, such as that of environmental justice [17] can be actually implemented, further work is necessary to resolve some of the debates on the source and cultural differences in concepts of individual and collective moral responsibility.

Human beings are animals, and (1) animals do not attack or kill members of their own species unless it is a part of their genetic makeup or in a struggle for mates or dominance; and (2) healthy animals do not intentionally degrade their habitat—to do so would be pathological—and genetically programmed instincts will in general prevent them from doing do by accident. Pierre Jouventin has made this aspect of the natural history of our species the theme of his new book *Man, A Failed Animal* [18]. It makes a necessary critique of standard hyperbole about man as the *summum* of creation. "Our psycho-physiology is closer to that of wolves than that of primates." Despite the more advanced capacities of the human brain for culture, language, and abstract concepts, for example, for anticipatory thinking in relation to the stockpiling of resources, one cannot ignore the negative feedback loops that these capacities also enable.

I claim that the existence of the two general modes of human behavior, developed and primitive, predominantly altruistic or predominantly selfish, are indeed genetically determined, and changes from education and experience supervene on them. However, the grounding of genetic differences is either missing, considered unnecessary or relegated to question-begging concepts of self-organization or spontaneity. Climate change, for example, is not an abstract concept. It is the cumulative result of a great many individual enlightened or unenlightened decisions that do nothing more (or less) than reflect the underlying biases of the individuals making them. Once the principle is accepted that variations in agressivity and altruistic behavior are possible for individuals, understanding their expression in social phenomena such as ecological responsibility and irresponsibility follows naturally. If ecology is to play a major role in knowledge and society, however, its logical foundations must be able to be stated so that the barriers to implementation of sound environmental policies may be more easily overcome. This is the central philosophical theme of this paper which the next Section will begin to address.

4. A Problem of Logic

4.1. Logic and the Global Sustainable Information Society

In everyday speech, the logic of a subject often means no more than the reason why it has occurred, will probably occur or have a certain result, that is, a more or less informal abduction to the best explanation [19]. Magnani has discussed his concept elsewhere, but this reference is of interest because he states that his view of abduction is the basis for of the need for a new *logic* of morality in a technological context. Simple deontic logic fails to include the relation up to and between internal intensions and external structures on which moral worth has been conferred.

The 'logic' in favor of the sustainable use of needed natural resources should be self-explanatory, as an obvious contribution to the common good. At the same time, countervailing forces exist: some humans, as noted, through avoidable ignorance or greed, choose to reject cooperation in favor of wasteful competition and destruction of those resources for private profit. There is here perhaps a logic of another kind, but what is its relation to the first one? One answer requires reference to

the current rapid and profound changes in the society resulting from the information revolution. Hofkirchner's work has been directed toward the achievement of an inclusive Global Sustainable Information Society (GSIS) [2]. Raising the problem-solving capacity of the society, creation of a more efficient collective intelligence in a process of 'Informationalization' are processes necessary for society to cope with the problems resulting from its own development. For Hofkirchner, sustainability, denoting a society's ability to perpetuate its own development in an ethical manner is the most universal value for governing moral behavior. Measures of progress toward the goal proposed by Hofkirchner of a GSIS cannot be made in quantitative terms, for example of the extent of digitalization of the economy, material and intellectual. But how then can one avoid a foundational pessimism?

In my view, many concepts offered to date for understanding, describing and changing behavior, for example, to achieve a GSIS, have been too coarse-grained to be effective. The countervailing forces at work operate with a logic of exclusiveness, with socio-economic relations mediated by essentially criminal castes, gangs, and unscrupulous individual economic actors. Such negative forces are capable of impeding its reworking to put it on a path towards sustainable development. At the level of the academic world which sets the tone for the society, the reason lies in part with the underlying use of logic in its formal sense. Standard logics remain logics of propositions or their mathematical equivalents, incapable of describing complex real processes and thus of providing the necessary theoretical support for them.

4.2. Why Organizational Logic Is Not Enough

The applicability of organizational or institutional logic's sustainable development of an organizational ecology has been discussed, for example by Ren et al. [20]. The problem for me is that the finality of such institutional logics is the maximization of the success of an enterprise, by resolution of conflicts that are internal and external, with 'competitors'. The process of interest in this paper is the maximization of the common good, in conflict with forces that resist or diminish it. Organizational logics have been described that are no more than the process of defining the tasks an organization sets for itself; a set of shared goals, beliefs and concepts of praxis, or a set of algorithms that constitute a basic code under which a company needs to operate. Ren suggests that such organizational logics contribute to the sustainable development of organizational ecology that confers high standards of legitimacy.

Institutional logics have a similar set of descriptors, focusing on how broad belief systems shape the cognition and behavior of the institution's members. These logics are also defined as social patterns of activity and symbolic systems, ways of ordering reality, "rendering experience of time and space meaningful". What such definitions tend to obscure is that the underlying physical reality of the patterns, systems, beliefs, etc. may follow different rules, in particular, ones that do not instantiate the basic truth-functional premises of standard bivalent and multivalent propositional logics. An ideology of algorithms, usually 'simple' ones, to codify complex contradictory and oppositional processes of life, mind and society is counterproductive. Such logics are those, for example, of standard category theory whose requirements of exclusivity and exhaustivity limit their ability to describe the complex interactions in real systems. If, as Ocasio suggests [21], logics can focus the attention of key decision makers on sets of issues and solutions, having an adequate logic becomes essential to any program to further ecology, sustainability, and ethical behavior in general.

In the next Section, I suggest that a missing principle can be imported into the debate from physics that fits the ontology and epistemology of complex processes at biological, cognitive, and social levels of reality. It places the discussion on a sounder scientific basis that was possible for example in the discussion by Boivin and Roch [22] on organizational logics as an *impediment* to collaboration due to conflicts between a "world of inspiration" and standard business practices. I thus build on the informal logics mentioned above by proposing a more rigorous, physically grounded yet still non-propositional, non-truth-functional logic that gives a better picture of real processes in their "states-of-change".

5. Logic in Reality: A Logic of Complex Real Processes

5.1. The Limitations of Standard Logics

Logic is often defined as the theory of correct reasoning, where logic is understood as classical bivalent propositional and predicate logics or their modern multivalent, fuzzy, epistemic, temporal, modal, deontic, or intuitionist versions. Such logics are neither intended to describe nor have the capability of describing reality in nature or society. Application of quantum logics is limited to the quantum domain. Especially in the life sciences and related fields, standard logics based on propositions and equations have been largely absent, due to their inability to reflect the changes and inherent uncertainties and contradictions of the real world. The applicability of logic and its symbolic operators and operations has thus been limited to language and mathematics. This is based on a discretionary metalogical principle introduced by the scholastic followers of Aristotle and maintained in the linguistic turn of the 19th–20th centuries.

The limitation of logic to the epistemological domain is well illustrated by the papers given at a 2009 conference suggestively entitled "Logic of Change, Change of Logic" [23]. One stated objective of the Conference was the understanding of human behavior. Human behavior was defined by the attributes of attitudes, beliefs, intentions, and change in those attributes. But what is the status of human actions *as* change? Are these to be placed forever outside any logical framework?

5.2. A Dynamic Logic of/in Reality

In the middle of the last century, the Franco-Romanian philosopher Stéphane Lupasco (Bucharest, 1900–Paris, 1988) challenged the monolithic propositional, truth-functional character of logic and proposed an extension of logic to real process phenomena, based on the perceived dualities of matter-energy. I have updated and extended this work as Logic in Reality (LIR) [24]. Grounded a particle/field view of the universe, the axioms and rules of LIR provide a framework for analyzing and explaining real world entities and processes at biological, cognitive, and social levels of reality or complexity, including information, environmental phenomena, and the dynamics of their evolution.

Details of Lupasco's original work and LIR are provided elsewhere ([24,25]). Briefly, the most important concepts of LIR are: (1) every real complex process is accompanied, logically and functionally, by its opposite or contradiction, but only in the sense that when one element is (predominantly) present or actualized, the other is (predominantly) absent or potentialized, alternately and reciprocally, without either ever going to zero (the Axioms of Conditional Contradiction and Asymptoticity); (2) the emergence of a new entity at a higher level of reality or complexity can take place at the point of equilibrium or maximum interaction or "counter-action" between the two (the Axiom of the *Included* Middle). Together, these contradictional relations will be referred to as the Principle of Dynamic Opposition (PDO) of LIR.

A major component of LIR is its categorial ontology in which the sole material category is Energy, and the most important formal category is Dynamic Opposition. From the LIR metaphysical standpoint, for real systems or phenomena or processes in which real dualities are instantiated, their terms are *not* separated or separable. Real complex phenomena display a contradictory relation to or interaction between themselves and their opposites. On the other hand, there are many phenomena in which such interactions are not present, and they, and the simple changes in which they are involved can be described by classical, binary logic or its modern versions. Examples of such phenomena can be found in all sciences, but the most well-known in ecology is the Lotka–Volterra model of coupled differential equations for predator–prey population cycles. This kind of analysis tells us nothing new about the (fatal) interaction between predator and prey.

LIR approaches in a new way the unavoidable cognitive problems that emerge from the classical philosophical dichotomies, such as appearance and reality. It offers alternative concepts of space and time and final and effective causes as categories with non-separable categorial features. Non-Separability underlies many metaphysical and phenomenal dualities of reality, such

as determinism and indeterminism, subject and object, continuity and discreteness, internal and external, and simultaneity and succession. This is a 'vital' concept: to consider process elements that are contradictorily linked as separable is a form of a category error. The claim is that Non-Separability exists on the macroscopic and on the quantum levels, providing a principle of organization or structure in macroscopic phenomena that has been neglected in science and philosophy.

Unfortunately, there are few serious discussions of physical opposition or antagonism as logical hence scientific properties of nature. The Argentine logician Florencio Asenjo proposed [26] a "logic of opposition as an instrument with which to place antinomicity in its most general setting". His new kind of antinomicity was a horizontal one, not involving negation but depending on objects seen in real, physical opposition. However, Asenjo's 'objects' were not macroscopic processes, but complex numerical models for representing contradictory observations in quantum mechanics. His theory is thus of interest here only by its implication of the conceptual importance of opposition.

5.3. A Metalogical Rejunction

There is a further reason for including the Lupasco approach in this paper on ecology: Lupasco effected a return of logic to its original sense of a global science of nature, which one might call a metalogical "rejunction" [27]. No diminishing of the value of standard logic in its appropriate domain of evaluation of statements about reality was intended or implied. However, Lupasco's logical theory [24] and LIR are at the same time scientific theories and, to the extent that their physical postulates or underpinnings could be disproved, they could meet Popper's criterion of falsifiability. In another sense, they are metatheories that propose analyzing the extent to which other theories adequately represent the non-separable properties of real phenomena.

LIR logical operators of implication, conjunction, and disjunction themselves must be considered as processes, subject to the same logical rules, fundamental postulates, and formalisms as other real and hence, natural processes constituted by series of series of series, etc., of alternating actualizations and potentializations. These series are not finite, however, in reality, processes do stop, and they are thus not infinite. Following Lupasco, we use the term transfinite for these series or chains, which are called ortho-or para-dialectics. The reader is referred to [24] for details of this applicable non-standard calculus. The operators of Logic in Reality, natural operators in the classification of Burgin and myself [28] are extremely complex, being both symbolic, material, and mental, but also in part symbolized, naturalized and social, since implication, conjunction, and disjunction obviously also function within social systems. As a final remark, the same picture applied to conjunction and disjunction as opposites provides the basis for a non-classical set theory, in which there is no absolute separation between sets and their members.

A corollary of LIR is the necessary logical existence hence the scientific nature of irrational, non- or anti-scientific and anti-ecological positions, as well as their opposites. Such positions are supported by a great deal of energy and obviously correspond to certain fundamental human structures and needs. They can, however, be assimilated into the LIR framework. LIR itself assumes the existence of an 'anti-LIR'.

To summarize this Section, we may say that it is the inherent inability of standard logics to handle change that disqualifies them as a basis for understanding the world. LIR attempts to take the world as it is, in all its complexities and contradictions or better countervalences as the basis for understanding it. This concept led one reviewer to ask, however, if both ecological and anti-ecological positions exist, and both alternate between being predominantly actual and potential, why one should prefer one to the other. This is not a question in which LIR takes sides, but of real people acting in consequence of their genetic and educational makeup. What is characteristic of selfish (anti-) positions is that they refuse a relationship to others. Altruistic individuals see others as an inseparable part of themselves, resulting in a self-interest argument for altruistic, ethical behavior.

References to a logic are indeed made in perspectives on ecology and sustainability. It is in general clear, however, that one is not dealing with 1st Order Predicate Logic or any mathematical

equivalent of it, let alone something like LIR. The sense is still generic or anecdotal, simply reflecting the perception of a certain order, without any explanation of why it should exist. Thus, 'logic' may refer to the set of prior assumptions used in sustainability studies, as for example in [29]. Weiss and Buchanan state [30] that the logic of the processes of change from cells to organisms is a logic of *patterning*. It is the interaction of the entities that it is the process and not the entities themselves. From the LIR perspective, including its categorial feature of non-separability, a complete conceptual separation between entities and their interactions is neither necessary nor correct.

6. Natural Computation and LIR

The increasing role of digital computation in ecological studies should not obscure the possibility of including computational systems involving *analog* computation and in general non-numeric and non-algorithmic information processing as equally important to the understanding of ecological processes. The reader is urged to consult, in this connection, the major work of Gordana Dodig-Crnkovic on natural computation [31]. This work functions as a conceptual bridge between new computational approaches and the view I expressed in [32] which focused on LIR as describing *non-computable processes.*

The detailed understanding of how natural processes operate is essential to choosing appropriate strategies to try to protect them. Dodig-Crnkovic has enriched the field of computation beyond standard algorithmic Turing machine models by including agent-based models that cover the entire range of interactive phenomena from physics to cognition. In her terms, interaction is communication of computing processes with each other and with the environment. Based on the essential role of information in natural processes, she argues for an 'infocomputationalism (ICON) as a new philosophy of nature" as a basis for unification of disparate phenomena, based on a natural computational interpretation of their informational dynamics. Dodig-Crnkovic has related ICON to Floridi's program for the Philosophy of Information [33] by contrasting it with the pan-computational stance, that of Zuse, Lloyd, and others, which takes the universe to be a digital, Turing-like computer that in fact computes using some digital algorithm, operating on bits as the fundamental 'stuff of the universe' (It-from-Bit).

With the universe represented as a network of computing processes at different scales or levels of granularity, ICON sees information as a consequence of (natural) computation. Adopting Floridi's Informational Structural Realism, which argues for the entire existing physical universe being an informational structure, natural computation can be seen as a process governing the dynamics of information. Dodig-Crnkovic replaces the emphasis where it belongs, namely on understanding that part of natural phenomena which may be subsumed under the concept of computation. It is to these ideas that the term natural computation, that is, information processing by natural systems, can be usefully applied. As she points out, computationalism is not the world; it is a modeling framework that is acceptable within certain domains and does not exhaust our possibilities to relate to the world.

The approach of Dodig-Crnkovic is thus complementary to that of Logic in Reality: the latter provides the logico-philosophical description of the evolution of natural processes described above. Both are theories of interactive processes in nature—one as the evolution of logical elements and the other of the processes as computations (which of these two perspectives is perceived as stronger is a matter of personal preference, provided both are accepted as valid). These processes operate at all levels of reality, biological, cognitive, and social—according to a set of isomorphic laws governing the essential interactions of the elements of the processes at each level. These laws are termed isomorphic because they all involve movement from actual to potential and vice versa but obviously operate on different substrates. Both theories also connect the properties of information and energy, enabling new ways of formulating a science of information. Like LIR, ICON is concerned with the *logic* used to relate an agent, in the broadest sense of the term, with its real world. Again, real means here physical entities, not models, signs, or algorithms of them.

Let us now see how my logical approach is relevant to the major developments in sustainability and ecology in the context of the parallel major developments in the science and philosophy of information.

7. New Informational Narratives: Relation to Ecology

7.1. The Science and (Meta-) Philosophy of Information

A proper description of information as a complex emergent phenomenon at the intersection of technology, science, and philosophy is now a major field of study. The relevance of the first two disciplines have been accepted for some time, but only in the last twenty years has the pioneering work of Luciano Floridi in the West [33] begun to receive proper attention and that of Wu Kun in China on Information Philosophy become accessible [34].

In a series of recent papers in English, some of them in collaboration with myself [34,35], Wu Kun has demonstrated not only the relevance of a philosophical perspective based on considerations of the unique and ubiquitous properties of information, better information processes, but the convergence of philosophy and science in general as a consequence.

Wu has characterized his Philosophy of Information as a Metaphilosophy since it discusses ways in which all theories are constituted and operate in an evolving informational world. Following his outline for information, one may construct an "informational" model of knowledge that includes as its proper parts Information Science and its data. In the framework of Logic in Reality, the essential point is to recognize what brings together, rather than what differentiates or separates, the epistemological and ontological elements of information. In my view, this is not informational-theoretic jargon but essential aspects of Information Science and of the core role of LIR in the philosophy of ecology.

The origins and evolution of both humans and human society are cooperative processes of biologically inherited information patterns, psychological patterns of informational activity and informationally defined patterns of behavior. As Wu puts it, "A man is a multidimensional unification of natural and social existence, psychology, biology and behavior." The open-ended character of this multi-dimensional existence implies for human existence that, as postulated in Logic in Reality, it instantiates both determinism and indeterminism, with one predominating at the expense of the other, alternately and reciprocally, according to the Principle of Dynamic Opposition. Finally, here, the understanding of the role of the informational world makes possible a new discussion of the value of information, and consequently of a new philosophy of value and a philosophy of ecology as the highest value. The theory of the dual existence and dual evolution of matter-energy and information has the effect that their value is formed in their synchronous and diachronous interaction. As is discussed among other places in the field of Relational Quantum Mechanics, it is the interactions that are the primary existential mode, and "things", without their various interior and exterior interactions, do not exist.

Summarizing, following Wu, one should refer to the Philosophy of Information as a Metaphilosophy, the concept of information as a basic category of philosophy, defining the central role of information and information science in all relevant disciplines such as ontology and epistemology as well as in science [36]. This is a metaphilosophical principle, since it has to do with the content of philosophy itself. Justification for Wu's calling his Philosophy of Information a Metaphilosophy, "a highest philosophy", to be distinguished from all others, is its unique and universal character, its new worldview, as an informational conception of history, society, values, knowledge, science, and technology. In the framework of this analysis of the domains of sustainability and ecology, one can show that the imbrication of scientific, (in the usual sense), ethical and social considerations follow the same logic of processes.

7.2. Information as a Resource

Since the advent of the information revolution seen by Floridi [37] and the continued rapid expansion of knowledge, information has become a resource which, like physical natural resources can be used responsibly and sustainably. Capurro had in fact defined [38] Informational Ecology as an ecology of *intellectual* resources, (which today would include 'natural' ecology and sustainability themselves as domains of knowledge). This concept goes beyond the limitations of information as a commodity. Capurro proposed the following contours of a theory of Information Ecology and some suggestions for practical action. Summarizing rapidly, his essential points were (1) the preservation of the social, linguistic, and historical dimensions of information as natural rights and (2) the avoidance of informational pollution. For Capurro, the key ecological issue concerning the production, storage, accessibility, selection and use of all kinds of knowledge was the preservation and increase of its social character as a common good.

Consequently, another ecological issue for a global information ecology was to criticize and seek to reduce the gap between the 'information-rich' and 'information-poor', those who lack access to cyberspace and the educational tools to use it. From a functional standpoint, recognition of the ecological nature of the crisis, material and ideological, in the information culture is the first step in trying to surmount it. A final remark by Capurro still seems very pertinent: "We should try to think more specifically on the question to which Information Ecology could be an answer." Some candidates for this question may occur to the reader from the remainder of this paper.

7.3. The Common Developmental Goal

As I discussed in a forthcoming *Special Issue of Progress in Biophysics and Molecular Biology*, a convergence and collaboration between the West and China is taking place in the field of ecology [39]. A manuscript submitted to the National Science Review (of China) by Zhongmin Xu, the Western ecologist Robert Ulanowicz, and their colleagues is most aptly entitled The Common Developmental Road [40]. Elsewhere, Ulanowicz has expressed the inability of Newtonian and Darwinian approaches and proposed a *new set of 'process-based' axioms* for the description of complex living systems [41]. The Common Developmental Road document is constituted by studies of the extensive writings of Ulanowicz, available in Chinese.

Western thought since the Enlightenment has been predominantly linear in scope, while Eastern philosophy has focused mostly on the cyclical since its origins. Recent advances in complex systems, however, have highlighted the importance of cycles in nature, thereby opening an avenue for new common endeavors. The analysis centers on the role of autocatalytic loops and addresses the evolutionary relationship between competition and cooperation. It posits an evolutionary chain running from individual competition, to individual cooperation, to collective competition, to deep cooperation. The resulting developmental narrative could become a useful tool for facilitating approaches to ecology in a context of communication between Eastern and Western cultures.

Logical considerations, in my expanded sense of logic, enter into other work by Ulanowicz relevant to ecology. The advantages of a logical stance, based on Logic in Reality, toward the complex phenomena of life is that it enables the maintenance of opposing elements in the proper dynamic relationship without 'either-or'. All environmental action involves trade-offs and compromises, but there is a close relationship to the dynamics of the opposing elements in the evolution of natural processes, and more meaningful descriptions of those dynamics are desirable and possible. In Ulanowicz' terms, [41] they can be designated as apophatic, the absence or not (yet) existence of constraints and the constraints themselves due to the inherent, existing organization in an ecological (or other natural) system. A proper picture of the ecological world could be seen metaphorically as a 'dialectic' between the buildup of constraints and the decay of that organization. Networks in natural processes are apophatic to the extent that marginal or neglected secondary flows may make a large contribution to their evolution. This is close to the position taken by Lupasco of the valorization of

elements generally given lower ontological status: diversities, vagueness, minorities, contradictions, women, the other, etc.

One can also see a connection with the use by Lupasco of the Pauli Exclusion Principle as the determinant of diversity, through the existence of something that is not possible (electrons with the same spin in the same shell); what is potential as discussed above as part of Logic in Reality; and Deacon's recent discussion [42] of what is absent or missing as a causal factor in change and the nature of information. Salthe has proposed [43] an approach to complexity, in its synchronic and diachronic aspects, through an extension of natural philosophy to an ecology of developing systems. For Salthe, the 2nd Law of Thermodynamics is the primary final cause in ecology, consequent system development and evolution. In the logico-philosophical view presented here, processes in nature require the joint operation of the 2nd Law and the capacity for diversity offered by the Pauli Exclusion Principle as the basis for the emergence of new complex forms.

A further connection between LIR and Ulanowicz' work can be seen in his suggestion of the need to move from a simplistic positivist notion of a scientific basis for ethics to one that incorporates apophatic (in my language potentialized) elements as well as didactic ones—absolute proscriptions. In this context, one can understand Ulanowicz' statement that: "preoccupation with physics as a chimera has led us astray of ecological reality", where 'physics' includes conventional dynamic systems theory and mechanistic reductionism. His approach to the evolution of ecosystems would lead to "a more encompassing quantification of reality". I thus agree with Ulanowicz' conclusions, citing Patten: (1) ecological dynamics are the result of the interaction between opposing sets of contingencies; (2) the reversible laws of physics guide but never of themselves determine ecological dynamics; (3) reductionism is incapable of supporting and explicating desired normative attitudes toward the environment. The outcome he suggests, however, of a more encompassing *quantification* of reality, seems unnecessarily limited. By expanding the *interpretation* of the laws of physics, without going outside them, to include dynamic relationships between exactly what Ulanowicz describes, namely the 'non-existent' and existent, in the logic of reality the potential and the actual, one can explicate rigorous *qualifications* of reality which lead, also directly, to normative ethical positions.

With this conception in mind of a functional role for logic in ecology, let us look at a further recent interpretation of an Informational Ecology.

8. A Methodology of Information Ecology

In Section 7, I referred to the pioneering work of Wu Kun in Xi'an, China in the field of Information Philosophy in the 1980's. In this same period, working in Beijing, Yixin Zhong, one of the pioneers in China in Artificial Intelligence, made a major contribution to the definition of Information Science [44,45]. For a summary in English of these very recent developments, the reader is encouraged to look at an article by another major Chinese information scientist, Xueshan Yan [46]. As discussed by both Zhong and Wu, the establishment and development of Information Science as a separate discipline is thus a new development in science itself. It derives from, as often repeated, the work of Turing, Shannon, and von Neumann but adds a new logical dimension that I am trying to call attention to here. Relevant to this dimension is the definition by Deacon [47] of 'Boltzmann' and 'Darwin' information to obtain a better dynamic explanation of information as a natural process by relating its properties to high-order theories of thermodynamic entropy and natural selection. The feature, correctly considered by Deacon as common, is that of absence, what is not or not yet present or, in LIR terms, actual.

Information Science is not a single or cross-disciplinary subject, but an inter- or transdisciplinary subject system consisting of many levels and disciplines. We see the practice of Information Science, involving the attention paid to the complex interactions between fields, as taking on a wider causal role in the transformation of the essential forms and functions of the sciences in general. This transformation can be considered as part of a new scientific or knowledge paradigm in which information theory and science are the dominant modes of knowledge acquisition.

In the last four years, Zhong has had a leading role in two further major developments: he has participated in the extension of concepts of intelligence from Artificial Intelligence to a new Intelligence Science and has further integrated his scheme of the ascent from data to knowledge to intelligence into an Information Ecology, IE. At the 2017 Summit Conference on Information in Gothenburg, a sub-Conference was held on the methodology, philosophy, ethics, and thinking of IE, with a focus on Information Studies.

Zhong derives his concept of an Information Ecology [48] from the information involved in the survival conditions for human subjects (and by implication other animals). From the viewpoint of the subject–object interaction, information alone is not a complete information process including higher level products, knowledge and intelligence, constituting an information system. All information systems together with their environments constitute in turn an information ecosystem, whose finality is the optimization of the processes and the interactive relationships with other subjects, in other words, an ecology. As defined by Zhong, the principles of Logic in Reality outlined above are pertinent to this Information Ecology in several ways, but the most important is that there need be no separation between this concept of IE and the more familiar one of Capurro. Both depend on the underlying evolution of science and philosophy under the influence of information.

The emphasis in the Information Ecology of Zhong, however, is on its function as a holistic *methodology* that can be applied for example to Intelligence Science but also to ecology. In Zhong's words [49], "The common feature of ecology and information ecology, the core of ecological methodology, is the concern with the interrelations among all the elements of an ecosystem and the ecosystem as a whole." As I have shown elsewhere, my Logic in Reality extends the categorial feature of non-separability to mereology, a new view of part–whole interactions of which Zhong gives a clear example here.

The additional dimension which Zhong and his colleagues have given to their Information Ecology is its application to Information Studies, studies themselves being considered as ecological systems. Zhong's Information Ecology is thus closely related and applies to the advances in the Philosophy and Metaphilosophy of Information of Wu Kun mentioned above. In addition to Information Philosophy, Information Science, Technology, Management, the Information Economy, and so on can be viewed as together forming a large-scale information ecosystem.

Zhong's 'manifesto' for replacing reductionist methodology in information studies with an ecological methodology should thus be seen, in my opinion, as a contribution to the extension of the role of ecology in both science and philosophy discussed here. For individual examples of the application of this version of IE, the interested reader is referred to the *Proceedings* of The First International Forum on Ecological Methodology in Information Studies (IFEIS, [50]).

According to Burgin [51], the Information Ecology of Zhong is part of general ecology standpoint which studies information ecosystems either as physical, mental, or structural ecosystems with natural, technological, and social components. It is a holistic approach to the existence and functioning of information processing systems, as well as for better understanding of information processes in all spheres of reality. If ecology of plants studies structures and processes in systems of plants, information ecology studies structures and processes in organizations of information processing systems and formations.

At the Conference, Wang and Wang [52] stated that the concept of Information Ecology should be relative to intelligent agents. "The basic difference between Information Ecology and Natural Ecology is that the former is naturally formed and the latter basically intelligent agent-made." In agreeing with this formulation, I simply suggest that we are dealing here, nonetheless with an ontological concept: if reciprocity is the radical characteristic of Information Ecology as well as of information, the logical rules governing its evolution must be at least in part isomorphic with the rules governing reciprocity in other physical contexts. I have discussed elsewhere reciprocity as a dynamic process following the rules of Logic in Reality.

The fact that information processes can be said to have an ecology at all is critical. In the broadest sense of the set of relations and interactions that is *desired* as the optimum mode of operation of those processes, the term is acceptable. However, it will always require further discussion of what those processes are in reality.

Zhong's position has been echoed by his colleague Ouyang Kang [53]. From a perspective of science, information ecology involves the expansion and application of the principles and methods of ecology in information science research. From the perspective of practice, the real problems that information ecology encounters are the irrationality and injustice in information processing and information sharing, information overload, information pollution, information harassment, and information crime. He calls for fairness but also cognitive justice in operating in an informational world. In addition to systematicity and objectivity, standard principles in all research, the methodological principles of subjectivity and justice should be developed to insure respect for all private and public actors.

Two Forms of Information Ecology

From the work of Capurro and Zhong, two forms of Informational Ecology can be discerned, characterized by their primary focus on the epistemological or ontological domain. Two different non-standard logics apply, that of the former, focused on Information Studies, is the recently introduced Transconsistent Logic of Zheng Jincheng [54]. This is a new logical approach, within the conception of Universal Logic of He Huacan, who has described it as "a revolution in mathematics, logic and foundations of computer science". It points to the errors and contradictions inherent in standard linguistic logics but remains a logic of propositions or their mathematical equivalents.

Many of the papers presented in the Gothenburg Conference, in which the concept of a logic was used in the 'generic' sense, could be said to be using it transconsistently. The logic of the ontological domain is the non-linguistic, non-truth-functional logic of real processes, Logic in Reality, I have described above. Both logical-philosophical approaches provide conceptual bridges to related developments in standard ecology, ethics and social action.

9. Sustainability: Logic and the Psychology of Moral Responsibility

9.1. The Logic of Sustainability Is–What?

The concepts of ecology and sustainability help to naturalize the transdisciplinary attitudes of rigor, tolerance, openness and, authenticity. As one moves into a field such as ecology in which ethics has an important role, the situation becomes similar to that described by the Swiss philosopher and mathematician Ferdinand Gonseth [55] as requiring a new dialectical synthesis. The subject—we—construct a reality in which intuition and experience, theory and experiment have a new and dynamic, changing significance. Such a reality should have some 'logic' to it, and I have suggested Logic in Reality as a framework for discussing these complex links between science and philosophy.

As Gaspar has pointed out [56], most of environmental education and behavior change projects and models regarding environmental behavior are still biased by a positivity fallacy, i.e., the belief that as long as people have something we can designate admittedly non-rigorously as the right attitudes, intentions, skills, information, etc., the right pro-ecological behavior should follow. However, the social sciences literature shows that there is an inconsistency between attitudes and behaviors in this regard and that the difficulty in changing behaviors is being underestimated. One reason for this might be that the role of dispositional and situational characteristics in inducing an inhibitive/constraining effect over pro-ecological behavior is being underestimated. Consequently, the barriers and constraints are not being analyzed and dealt with.

In order to fill this gap, a process view of psychosocial barriers and constraints is required which allows a better understanding of: (1) the interaction between dispositional and situational

characteristics that might inhibit/constrain the implementation and maintenance of pro-ecological behaviors; and (2) the role of unconscious factors in this. Hardin's example of intended and unintended communication aimed at persuading people to act pro-ecologically, mirrors what can be found in projects and actions that aim to promote pro-ecological behaviors. On one hand, communication in these focuses on persuading people to achieve one or more pro-ecological behavioral goals i.e., goal(s) to act pro-ecologically. While this can promote or strengthen existent pro-ecological goals, on the other hand, it can also induce a conflict with existent anti-ecological goals.

It is interesting that Gaspar also cites Hardin's point that the messages received regarding the environment consciously and unconsciously may be *contradictory.* Supporting the desired pro-ecological behavior becomes a question of understanding and managing contradiction. Logic in Reality accepts this challenge, while other logics tend to be eliminativist about contradiction by giving it only a linguistic connotation. Preferable terms are counteraction and countervalence.

If one searches specifically for a logic of sustainability on the Internet, one is confronted by a mass of references to a *business* logic of sustainability, sustainable ways of doing business. I will not attempt to evaluate here how successful these enterprises are from an ethical standpoint, but I think that the issues of a logic of sustainability are broader. Mohrman and Shani support this view [57]. "Most of the global economy and the knowledge upon which it is predicated carry a logic of resource abundance even in the face of increasing competition for scarce resources, and a singular focus on economic outcomes. We argue that the development of new capabilities to address triple bottom line sustainability requires a change in that logic and requires new rules of interaction, new organizational and inter-organizational designs, and new ways of learning."

In 2008, Bosselmann [58] circumscribed the problem in a few words: "The appetite of states to exploit the global environment is greater than their interest to preserve it. This logic is increasingly becoming a 'logic of self-determination' not just of states, but of humanity at large. Ecological sustainability is the only principle that could reverse the current logic."

As discussed above in relation to ecology, the position I take in this paper is that understanding perceived regularities in behavior toward the environment as a logic is done in the context of an outdated and inapplicable concept of logic in general. Let us now look further at what might be accomplished with a logic of processes such as LIR.

9.2. Strategies for Avoiding Tragedies of the Commons

As a way of looking at the dynamics of social, economic, and political processes, the major work of Castells referred to above [17] has proven extremely prescient. He sees society as a complex system of networks that are a consequence of the new information and communication technologies. The LIR logical approach, applied to an analysis of the properties of the networks and their nodes, as well as to the segments of the society that are disfavored or excluded completely, complements Castells' informal reference to a "logic" of the network society and its dynamics. In his Chapter on the environmental movement, he distinguishes between environmentalism as ecology in practice, and ecology as environmentalism in theory and writes:

> "By environmentalism I refer to all forms of collective behavior that, in their discourse and their practice, aim at correcting destructive forms of relationship between human action and its natural environment, in opposition to the prevailing structural and institutional *logic* (emphasis mine)."

However, if environmentalism involves individual or collective moral responsibility to the environment and to other human beings, the question of the origin of this responsibility cannot be avoided. The operation of the principles of dynamic opposition in LIR, namely, that any complex process is accompanied by its more or less potentialized contradiction or "counteraction", is exemplified in the tragedy of the commons. Socially valid institutions put into place to solve instances of the tragedy of the commons often cause tragedy of another sort. In LIR terms, a tendency toward

rigidity in an institution, viewed as a process, not a static entity, is a tendency toward an identity of non-contradiction. Rigid institutions, which Daniels called "tragic" [59], have an excess of stability (*vs.* what would be equally bad, absence of sufficient stability or anti-stability) involving both benefits and costs. My argument is that if this tendency is *anticipated*, programs to build responsiveness as an emergent property can be planned for. Delays that might otherwise significantly increase the costs of reform might accordingly be avoided.

9.3. Selfishness and Altruism

In this brief survey of attitudes toward ecology and sustainability, I can only touch on the vast literature on the origins and operation of altruism vs. egoism or selfishness in human behavior. Several review articles can be found in the Stanford Encyclopedia of Philosophy, for example [60], although they lack direct reference to the issues addressed in this paper. A few general remarks may suggest areas for further work. In an analysis of the psychology of environmental responsibility [61], I related the existence of the two tendencies primarily toward one form of behavior rather than the other to the existence, at the highest human cognitive levels, of expressions of the primary oppositions in the world discussed above.

Evolutionary biology gives reasons to believe that there are systematic species-wide universals, circumscribed ways in which the sexes differ, and random quantitative variation among individuals, but few if any differences among races and ethnic groups. Heritable behavioral traits, rather than a shared family environment, are determinants for violence and temperaments and thus, if not for the political party to which one belongs, at least partly whether one is predominantly liberal or conservative.

Logic in Reality postulates that this differentiation, which is not and does not need to be total, ultimately has the same dynamic origin in the oppositions in the physical and the biological substrates of which we are composed. This dialectic approach is not the one which Stephen Pinker correctly criticizes of "holistic interactionism" [62], which assigns equivalent values to possibly interacting environmental factors that may not interact at all. On the other hand, once it is agreed that human nature is *not* indefinitely modifiable by experience, as Pinker suggests, genuine social progress may be achieved by addressing aspects of it such as a minimum sense of sympathy and empathy with others.

The corollary of my theory is, however, that resistance to and refusal of the other (seeing him or her as *totally* external) is *also* part of the human genetic endowment. No purely neural network theory of morality, in which the mind is trained by experience, can completely override this basis of behavior, although parental environment can obviously change the degree to which social or anti-social behavior is expressed. This conclusion may be considered overly pessimistic, but it has the merit of being realistic and, perhaps, helping to avoid wasted efforts in inhospitable territory.

According to my logic, there should thus be a positive correlation *today* between environmental concern and psychological factors such as knowledge and the general acceptance of responsibility. My view that universal human characteristics determine attitudes and actions *vis à vis* the environment is supported by the studies of the biologist E. O. Wilson. His model of social evolution [63], based on insect, animal, and human data accounts in its current form for most of the dynamics of individual and group selection. Most importantly for this study, it describes the origin and relative evolutionary success of altruism or groups in which altruistic individual predominate. His theory clearly acknowledges the dialectic character of the situation in his dictum: "Selfishness beats altruism within groups. Altruistic groups beat selfish groups. Everything else is commentary".

9.4. Free Will Is Not Required for Moral Responsibility

The logic of/in reality offers a basis for a culturally independent individual and collective moral responsibility that does not require that human intentionality or agency be "free" in some absolute sense. My view is that free will exists, but only as an appearance in the conscious mind of an individual in opposition to and because of her predominantly unconscious knowledge of her lack

of total 'freedom', that is, isolation from other individuals. The philosophical issue of compatibility (compatibilism) with a deterministic universe is therefore a false problem; individual responsibility for one's actions *does* exist, but its source does not lie in free will, or the absence of it. There is a reciprocal mutual instantiation of appearance and reality that corresponds to the contradictory LIR interpretation: appearance and reality can never both be fully actualized at the same time. The idea of a completely free agent is a (particularly strong) intuition that is not unrelated to ultra-conservative libertarian ideology.

In the framework of Logic in Reality, I cut through the debate about the relation between self and other by suggesting that they, also, are not totally separate or disjunct. From here, it is not a big jump to assuming that people who take an altruistic attitude to other human beings will do so to the environment and will behave to further ecological and sustainable practices and the common good [10] in general.

The task, and it is such a difficult one that it is rarely explicitly discussed, is how to make altruistic behavior attractive enough to egoistic people for them to change their own. My only answer, and I am aware that it is unsatisfactory, is to multiply transdisciplinary initiatives like this one so that they occupy a larger portion of the available (cyber-) space.

9.5. Sustainability and Transdisciplinarity in South Africa

Swilling and Annecke [64] have specifically proposed sustainability as an alternative to an on-going tragedy of the commons. They propose a "just transition" that reconciles the sustainable use of natural resources with a pervasive commitment to sufficiency, the (hypothetical?) situation where over-consumers are satisfied with less so that under-consumers can secure a minimum. Reference is made to the "perplexing logics" of the different literatures on the subject and the "compelling logics" of climate science. I am afraid, however, that the 'implacable logic of the market' may still be the one dominates. One can at least hope that new communities in South Africa and elsewhere may try to instantiate sustainability on a small scale.

Working at the University of Stellenbosch, one of the first to offer a PhD. in Transdisciplinarity, John van Breda has placed sustainability and ecology in a transdisciplinary, hermeneutic framework in a major monograph, *Exploring Sustainability Science: A Southern African Perspective* [65]. Van Breda's key point in the context of this study is that we are dealing with complex social-ecological systems problems that simply cannot be approached from *within* the confines of the single disciplines or sub-disciplines only. Given the fragmentation of both the world and our knowledge-systems, van Breda's central argument is that the overcoming of disciplinary boundaries is a necessary prerequisite for finding sustainable solutions to complex planetary problems. However, we cannot merely assume that a trans-disciplinary dialogue will emerge when the different disciplines come together to look for solutions. What is essential is to see *how* such a trans-disciplinary dialogue between the different disciplines can be achieved. "It is then in this sense of a dynamic interplay between theory and praxis that the hermeneutics of a trans-disciplinary dialogue between the different disciplines should be seen as a *sine qua non* for the conceptualization of a 'sustainability science'". Without understanding *how* the different disciplines are to communicate and develop a shared understanding of the complex world and it remains highly improbable, if not impossible, to imagine the meaning and establishment of a 'sustainability science'. This means that overcoming the disciplinary divide is not only of theoretical interest but is a necessary prerequisite in our search for sustainable solutions to today's problems.

The approach that van Breda suggests is that of Transdisciplinarity in the acceptation of the theoretical physicist Basarab Nicolescu [66], defined as what lies within, between, and beyond individual disciplines, including those of science and philosophy. The 'pillars' of this Transdisciplinarity are a concept of levels of reality, complexity and the logic of Stéphane Lupasco, the logic of the included middle discussed above as Logic in Reality. As required by van Breda, transdisciplinarity in this interpretation provides a new way of understanding the non-separability of subject–object relation as a dynamic unity, an emergent property of the recursive, dynamic

interplay between the subject and object. Sustainability thus becomes the new field in which the age-old philosophical questions receive new functional answers directly relevant to the functioning of the society.

10. Conclusions and Outlook. Sustainabilization

New insights from the science, philosophy, and logic of information have been applied to the theoretical foundations of ecology and sustainability. A non-propositional logic of processes, Logic in Reality (LIR), is proposed here as a logic of ecology—an *eco*-logic—that also defines a basis for moral responsibility. It formalizes the not incorrect but incomplete references to logics in the literature. Both Informational Ecology and the Ecology of Information Studies, which emphasize the phenomena and the studies of these phenomena respectively, follow this logic.

I hope that this paper may be considered a contribution to *sustainabilization*, defined by Hofkirchner in [3] as "the process of putting society in a position to avoid anthropogenic breakdown and safeguard a stable path of development below the threshold of endangering the maintenance of society." Wu Kun sees the philosophy of information as the cause of a revolution in philosophy [67]; Hofkirchner sees the information revolution as contributing to sustainabilism—the result of the process of sustainabilization—needed for the advent of a Global Sustainable Information Society (GSIS), mentioned in Section 3.1 above. The goals of Hofkirchner of a GSIS, of ecological and sustainable practices in society receive further justification and support from grounding in LIR as well as science. The same can be said for the Ecological Civilization of Gare.

By seeing the logical relationships between the human and non-human domains of nature, better strategies for influencing the society to move in an environmentally responsible manner may be possible. I realize that I am adding yet another domain of discourse to the vast array in place. However, my hope is that recognition of the validity of this logic grounded in physics and exemplified in information science and systems science may suggest new strategies for to the transdisciplinary problems of society, facilitating the application of ecological and ethical principles.

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