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## NETWORK RETHINKING OF NATURE AND SOCIETY

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**ABSTRACT.** In the early eighties, B. Patten and coworkers began to formulate a new ecological approach called environ theory. This theory is grounded on ecological network analysis and general systems theory, and aims to advance the theoretical core of the old ecosystem paradigm. In this paper, we attempt to reconstruct Patten's and his coworkers' ideas, focusing mostly on their fundamental ontological assumptions. Comparing this way of thinking with the one developed, at the same time, by the social-network models, we conclude that ecologists' ideas about nature are analogous to social scientists' ideas about society. Thus, environ theory and Actor-Network Theory (ANT) are not isolated enterprises within science and they can be placed into a more general reconstruction.

**KEY WORDS:** Actor-Network theory, dualisms, ecosystem, environ, network analysis, system ecology.

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### 1. INTRODUCTION

Following a tradition of cosmological thought inspired by Leibniz's monadological ideas and grounded upon Descartes' mechanical, material and reductionist worldview, natural sciences (physics, chemistry, biology etc.) seek for a theoretical organization based on corpuscular theories. This model of science promotes the idea that particles like atoms, molecules, genes, cells, and so forth, defined in an essentialist way, must constitute the theoretical core of the respective scientific fields (Wilden 1997)<sup>1</sup>.

The proven success of the above epistemological model reinforces the power of corpuscular theories and makes natural sciences totally accepted. However, what happens for physics, chemistry and also for the scientific branches of biology like molecular biology, genetics, cellular biology, and the rest, does not stand for ecology. In other words, the science of ecology does not possess its own specific particle to organize its theoretical core according to the model previously described. Given that

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dominant perceptions about science are mostly positivist, the above fact is not devoid of consequences. Many times the epistemological status of ecological theories is disputed, while ecology appears in the evolutionary field as a science which is both theoretically and ontologically redundant (Haila and Taylor 2001). Ecology is then reproached by other powerful disciplines within biology and does not enjoy the social prestige of other natural sciences.

In such an epistemological context, a rather famous ecologist, Bernard Patten, defined in the early eighties the scope of his research: to propose an ecological particle, to indicate what is known about it and determine some directions for learning more (Patten 1982). Although the positivist ideas considering physics as the basic model for the rest of the sciences seem to be central in his enterprise, his methodological reductionism is pragmatic in its essence. In other words, Patten aims to enhance the epistemological status of ecology, instead of acceding to the monadological constructions that are reductionist or rigidly essentialist.

Despite Patten's intentions that refer to the world of ecology in general, the theoretical field in which he is active betrays his deep hopes. As an advocate of General Systems Theory (McIntosh 1985), he tries to bring system ecology back to the scene and to instate the hegemonic role that it played in the interior of ecology during the 60's and 70's (Kwa 1989). In this respect, he attempts to develop the theoretical core of systems' ecology, defining the fundamental ecological "particle" as the entire system of interrelations associated with each natural entity (Patten 1982)<sup>2</sup>. This particle is called "environ" since it surrounds a set of influences localized within a predefined system<sup>3</sup>. Defined as an input-state-output object (Patten 1982), environ finds its origin in the field of system theories; however, it is conceived in a way that emphasizes an advanced version of a system concept: the concept of network<sup>4</sup>.

Actually, Patten's research finds its real identity in the field of network theories and especially in what is called network analysis<sup>5</sup>. Network analysis is a system-oriented methodology that uses mathematical tools, graphs and matrix algebra, in order to reveal all the patterns that organize the connectivity of the system components<sup>6</sup>. Network analysis also started as an environmental application of input-output analysis. The latter was developed by Leontief to analyze the interdependence of industries in an economy.

Hannon (1973) is credited with first applying input-output analysis techniques to ecosystems, investigating the interdependence of organisms<sup>7</sup>. His contributions concerning the development and application of network analysis theory in the ecological field continued the following years, while new and independent lines of research were generated by ecologists such as Levine, Ulanowicz and Herendeen. Patten and sub-

sequent coworkers developed their own approach, introducing General Systems Theory to network analysis and using a formal integration of environment into ecological modeling (Fath and Patten 1999a, 1999b).

It is this last approach that is the focus of our work. In particular, we aim to present environ analysis theory, focusing mostly on matters that pertain to ontology (ontology refers to what exists, i.e., to the object of system ecologists' descriptions). Issues concerning environment and ecological entities are then of primary interest. However, we will not overlook the methodological and epistemological aspects of the theory under study.

We should mention that our presentation of environ theory is not just a detailed narrative. Our work finds its place among other attempts in the field of philosophy of science: it aims not only at describing but also to reconstruct the theory under study. By employing the term 'reconstruction' we do not refer simply to logical reconstructions which clarify scientific discourse by showing deficiencies, contradictions, etc. (Van der Steen 1993). We accept a rather complex version of reconstruction concentrating on the conditions of its scientific practice as well as to its history (Korfiatis and Stamou 1994). It is important to note that under the term 'conditions' we refer to the material, philosophical, social and communicative factors that determine the processes through which the existent scientific knowledge is or has been produced. Within this context, we will focus on system ecologist's implicit or explicit convictions, on the tools they use in order to communicate with the broader scientific community and so forth.

To achieve the above tasks we employed a methodology based on content analysis. It follows then the categorization and classification of the text material in tables of contents. The following categories are columns of these tables: Subject, Text, Narration, Framework, Tools, Vocabulary, Ideas and Worldview. The category "Subject" entitles the studied text material, "Text" includes quotations from authors' papers, while "Narration" contains a reconstruction of the former category and aims at demonstrating the basic scientific idea included in the quotations. "Framework" refers to the general characteristics of system ecologists' framework such as theory structure, the influences that they have received from other scientific fields, the images (analogies, metaphors, etc.) used, and so on. The category "Tools" includes the employed means for the presentation of the text material (diagrams, mathematical equations, etc.), while in "Vocabulary" are included semantic innovations. The category "Ideas" refers to assertions and/or assumptions relating to the way authors deal with philosophical or epistemological concepts (e.g., the concept of wholeness, the concept of causation, the concept of entity, etc.). Both elements of the previous category and scientific knowledge merge in the column "Worldview" so as to provide a coherent idea of how the world is made

up (i.e., mechanistic worldview, monadological worldview, etc.). Quotations included in the category "Text" are horizontally analyzed (separate content analysis is done for each table row). Quotations are ranked in such a way that, taken serially corresponding reconstructions included in the category "Narration" provides a meaningful and coherent text (see table in the appendix).

The above conceptual and methodological perception of "reconstruction" appears coherent with all those epistemological processes referring to the term "thorough understanding" (Korfatis and Stamou 1994). Among them, the critical confrontation of any scientific theory with other related scientific or social ideas has an important position. Within this context, it is noticeable that system ecologists' theory concerning nature seems to be in coherence with ideas that Actor-Network Theory states about society<sup>8</sup>. Despite the central network concept, both theories are characterized by turning the concepts that constitute their theoretical core into relatives. This homology indicates that both theories are not isolated enterprises within science but they can be placed into a more general reconstruction. Thus, in the last section, we will try to interweave these different and heterogeneous approaches revealing in each case their homomorphical thought. Proceeding in that way, we hope to enhance an intellectual mood that can lead us to a more complete and critical consideration of the network ecological theory.

## 2. THE CRITICAL APPRAISAL OF NETWORK ENVIRON THEORY

### 2.1. UPGRADING THE CONCEPT OF ENVIRONMENT

Regarding the theoretical treatment of environment, Patten considers Darwin's work as a landmark for contemporary biology. Thereupon he writes (see appendix):

Before Darwin (1859) environment was considered an organic whole. Everything in it made some contribution and had some meaning with respect to everything else. Darwin subscribed to this view, but his emphasis, and that of his followers, on the evolving organism struggling to survive, suppressed the exploration of holistic aspects of the origin of species that might have been developed. After Darwin, the organism came into great focus, first as a comparative anatomical entity, then later with physiological, cellular, molecular, behavioural, and genetic detail. In contrast, the organism's environment blurred through relative inattention into a fuzzy generality (Patten 1982, p. 179).

The logical outcome of the above ideas is the formation of a cognitive context within which biological entities are conceptualized in a discon-

tinuous way. In other words, biological scientists supplant the idea of unification and promote the idea of dualism (figure 1) that Fath and Patten mention (see appendix):

The traditional view reflects years of reductionist science in which objects are studied as entities separated from their natural environment. Even ecology, which is the study of organism-environment relationships, focuses on the impact of environment on discrete biota and vice versa, but less explicitly on the biotic object as an integrated part of a flowing and complete ecosystem. Kareiva (1994) reviewed 1 253 articles published in *Ecology* between 1981 and 1990 and almost 1 000 of these dealt with four or fewer species; this is hardly representative of holistic investigation of the environment and its organisms (Fath and Patten 1999a, pp. 168-169).

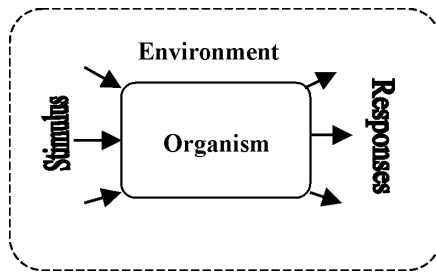


FIGURE 1

Organism-environment dualism (from Fath and Patten 1999a, p. 169).

Organism's alienation from the environment and the sequential internal-external polarization is considered as an essential step for the development of contemporary biology. According to Lewontin (2001), without these distinctions biology would have engaged in an obscurantist holism which consolidates the organic and the inorganic into a vague whole. However, as the above quotation reveals, Patten (like Lewontin and Levins in the field of evolutionary biology, although supporting a different 'paradigm') calls us to revise the old organism-environment dualism in favor of a unified holistic approach.

In particular, Patten and other system ecologists do not accept the traditional biological entity, that is, the organism (Tansley 1935) as an "ecological particle". Patten writes thereupon: "Ecology lacks an elementary particle of its own, with discoverable properties that can clarify the nature of environment and its relationship to life" (Patten 1982, p. 179). It is obvious that instead of the organism they define the environment as the ecological object of study. According to Patten: "Something so universal

and central to existence as environment must deserve better rendering than just external factors determining energy and matter movements across membranes or unspecified selective forces vaguely shaping the course of evolution <sup>10</sup> (Patten 2001, p. 423). This enhanced theoretical treatment of the environment implies a readjustment of ecology's goals and perspectives:

Rather, by recognizing environment as a specific object of study, the goal should be to seek to engage the idealization traditions of physics to uncover the laws pertaining to this object, and have them take their rightful place alongside the other known laws of nature. There must be such laws, for something so universal—the natural complement to all open or non-isolated systems—could hardly be without them. It is not, then, the tedious description of environmental details that should be the concern of future ecology, but rather the discovery of principles that only a shift in perspective from atomism to holism, closeness to openness, and autonomy to non-autonomy can reveal (Patten et al. 1997, p. 258).

The above ideas frame Patten's and his co-workers' enterprise, that is, the introduction into the world of ecology of environ theory. This network ecological theory is mostly grounded on the ideas of the German physiologist and philosopher Von Uexkull. Patten gets both conceptual equipment and theoretical schemata from Von Uexkull's work, which elaborates further according to General Systems Theory prescriptions. In particular, the hard core of environ theory is organized by Von Uexkull's idea that each biological entity has two distinct environments: "world as sensed" and "world-of-action" (Patten 1978, 1990, 2001). Quoting Von Uexkull, Patten writes about these concepts:

World-as-sensed: Every animal is a subject, which in virtue of the structure peculiar to it, selects stimuli from the general influences of the outer world, and to these it responds in a certain way.

World-of-action: These responses, in their turn, consist of certain effects on the outer world, and these again influence the stimuli (Patten 1978, p. 210).

Patten translates the above concepts in terms of General Systems Theory and replaces them in his work by the equivalent terms "input environment" and "output environment." Thereupon he writes: "World-as-sensed and world-of-action correspond, respectively, to an afferent input environment and efferent output environment" (Patten 2001, p. 431). In regard to the above distinction of the concept of environment, Patten becomes more specific:

The causal model of subject/environment interaction leads to not one, but two equally plausible and useful concepts of environment. The first is input environment H', defined by holon H in the act of receiving energy-matter or perceiving information. Behavioral attributes of the real world that do not

impact H as input during its existence interval cannot influence the state of the object. They go unrecorded by H and consequently are not part of its environment. [...] Reciprocally, the second concept of the environment is that of an output environment H". This begins as a set of potential environments embodied in the states of H. These states are converted to outputs through interaction of H with other objects (Patten 1978, pp. 209-210).

Thus, in network ecological theory environment is a donor and also a receptor; it is both the source of inputs to biological entities and the terminus of their outputs. Considering environment in such a dualistic way, system ecologists counter its ordinary definitions in scientific or social world. Patten et al. mention:

The concept of environment is not well formed in science, or culture. If asked 'What is the environment of A?', the most likely response would be that it is the source of inputs... to A... The popular concept of environment is that of an input-generating structure (Patten et al. 1997, p. 251).

Although system ecologists lead themselves to a dichotomical distinction of the environment, the component parts are joined due to "function circles." Following Von Uexkull's line of thought, Patten mentions: "... 'world-of-action' (output environment) was joined to 'world-as-sensed' (input environment) by 'function circles'. These are cycles of causation that run through the world network and ultimately wrap around to cause outputs to influence inputs" (Patten et al. 1997, p. 251). Thus, environment acquires the characteristics of an entire world in which entities' existence is defined. According to system ecologists, whatever exists beyond such a world is meaningless for the entity itself. Patten, quoting again Von Uexkull's ideas, writes:

The function-circles connect up in the most various ways, and together form the function world of living organisms, within which plants are included. For each individual animal, however, its function-circles constitute a world by themselves, within which it leads its existence in complete isolation (Patten 1978, p. 210).

Through 'function circles', the complex that both entity and environment form, acquires a functional identity. Patten mentions that "function circles in principle confer autonomy upon the entire unit" (Patten 1992, p. 33). Hence, the whole complex may be seen as a distinct, separated and independent unit: "Each organism-environment complex is a distinct unit and each such unit is a partition element of reality" (Patten 2001, p. 429).

## 2.2. ENVIRONS AND ECO-SYSTEMS

In order to turn factual their ideas about environment, system ecologists use innovative terms. Specifically, input and output environments within a system that contains the defining objects or processes as component

parts are respectively called 'input' and 'output environs' (Fath and Patten 1999a; see appendix). The concept of environ applies to the entity-specific environment onto the entity itself, distinguishing it in inputs and outputs (see figure 2). In Patten words: "each object is seen as a partition of two mutually exclusive halves, one comprising the inflow and the other out-flow" (Fath and Patten 1999a, p. 168). Thus, in network environ analysis "each component consists of two system-bounded environs: one acts on the defining component, and the other is acted upon by the component" (Fath and Patten 1999a, p. 169).

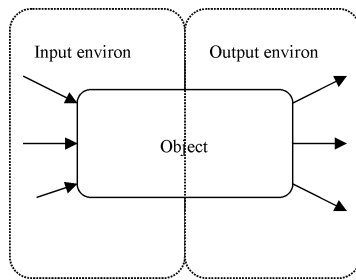


FIGURE 2  
Input-output environ duality (from Fath and Patten 1999a, p.169).

Alternatively, system ecologists use the term 'eco-system' (Jorgensen et al. 1992; Patten et al. 1997). This innovative term is employed to describe the complex formed by the entity and its environment, irrespective of the organizational level (cellular, organismical, etc.). A pictorial representation of the eco-system is given in figure 3.

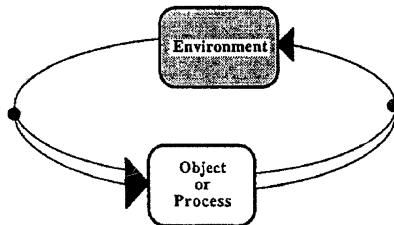


FIGURE 3  
Eco-system, the fundamental unit of ecosystems (from Patten et al. 1997, p. 229).

The reason that Patten adopts a posterior term to environ, i.e., eco-system, has to do with the unification of the network and thermodynamic approaches. These different theories are unified in a series of articles published in the journal *Ecological Modelling* under the general title "Ecosystems emerging." The authors of this uncompleted until now series are Patten who expresses the network perspective, Jorgensen who is active within the field of thermodynamic ecosystem approaches and Straskraba who has a rather immense presence in ecosystem modeling (Jorgensen et al. 1992; Patten et al. 1997; Jorgensen et al. 1999; Straskraba et al. 1999; Jorgensen et al. 2000). We have to emphasize that the above unification is part of a larger one as the authors of this series attempt to unify the entire ecosystem field. Although the idea of pluralism, of the mutual coexistence of different and heterogeneous ecosystem theories organize their enterprise (Jorgensen 1992; Jorgensen et al. 1992), they try to construct a general overarching framework based on universal natural principles like conservation, dissipation, openness, growth and so forth (Patten et al. 1997) <sup>11</sup>. They mention accordingly:

Through eco-systems as a canonical construct we are endeavouring to identify not only a minimal set of relevant principles behind 'ecosystems emerging' but also to understand the specific forms in which these principles are realized in ecosystems and how this contributes to the prediction of ecosystem behaviour (Straskraba et al. 1999, p. 4).

It is important to notice that our reference to the above framework is relevant to the purposes of our article. Although eco-system has a thermodynamic reference, given that it is also defined as an "open... dissipated... [and] dynamical" entity (Patten et al. 1997, p. 267), further investigation reveals that eco-systems and environs are equivalent terms <sup>12</sup>. As system ecologists put it: "Later in this series, eco-systems will become operationalized as 'environs' " (Jorgensen et al. 1992, p. 5). Their equivalence is also evident in the respective pictorial representations. The figure that represents eco-system can be easily transformed to that of the environ if we pull the two founded left and right black cycles, so the component parts of eco-system coincide. It is obvious that the two black cycles represent the input and the output environment or the input and the output environ, respectively.

Furthermore, system ecologists use both terms in a similar way. The eco-system is a partition unit of the ecosystem to which momentarily belongs: "[s]uch partitions are in terms of subenvironments of the total instantaneous within-system 'environment' which is the ecosystem" (Jorgensen et al. 1992, p. 5). The same is valid for environs:

All transactional input environs of all the components within a system form one partition of the system's internal network, and all the transactional output environs form another... Thus, the entire network of transactional bonds within systems can be decomposed into separate, non-overlapping (in the sense of not sharing any exchange media-markers, avatars) sub-networks (environments) associated with their components (Patten et al. 1997, p. 253).

In general, the terms 'eco-system' and 'environ' become perceptible in the context of the General Systems Theory. Besides the system connotations of environ, system ecologists referring to eco-systems mention that:

[W]e are dealing with a class of systems we call 'eco-systems' These are not ecosystems in the usual sense, but un-isolated (permeable to energy) or open (energy matter permeable) entities at any level of organization which interact by exchange of energy or matter with their abiotic and biotic surroundings (Straskraba et al. 1999, p. 4).

As a class of systems, eco-systems or environs refer to both physico-chemical and biological systems. We reached this conclusion from the fact that the eco-system's component entity (Patten et al. 1997; Jorgensen et al. 1999), or the environs' defining entity (Patten 1982), could be either object or subject. In respect to these terms, Patten et al. mention:

Some systems (physical and chemical) seem always to respond exactly in accordance with the environment they experience. Others (biological) are often more inclined to a certain spontaneity and lack of predictability. The former we will call objects, and the latter subjects. Our conjecture is: All non-living entities are objects, whereas all living ones are subjects. This divides the stuff of the universe into two behavioural distinct categories. One is utterly and absolutely enslaved to physical law within the meaning of 'determinacy' as we have defined this; behaviour is non-autonomous, un-spontaneous, and strictly reactive. The other has latitude not to repeal but to interpret reality, and respond to the interpretation. To that extent, this group possesses autonomy, spontaneity, and a proactive capacity to engage its physical surroundings (Patten et al. 1997, p. 242).

It is noticeable that the distinction between subjects and objects or living and non-living matter is exhaustive and universal. In other words, there are no entities in the universe that should not be enlisted in this dualistic scheme. Therefore, human naturalization as a fact is unavoidable. Thereupon, system ecologists mention:

We are no longer the masters of the universe we once thought we were, but like other creatures must take our place as an integrated member of the biosphere. New phenomena of nature have appeared in our works, but no

basic laws have had to be set aside. Even in planetary dominion, man is still only part of a larger whole (Jorgensen et al. 1992, pp. 7-8).

Nevertheless, non-living entities are conceptualized as eco-systems (or environs) only in the case that they exchange both energy and matter with their surroundings. On the contrary, system ecologists apply the term eco-system (or environ) to all subjects since the latter are defined as open entities (Jorgensen et al. 1999).

### 2.3. THEORETICAL IMPLICATIONS OF SYSTEM ECOLOGISTS' ONTOLOGICAL COMMITMENTS

The representation of subjects and objects as eco-systems promotes a relativistic perception of entities. Both eco-system definition and its pictorial representation denote that entities, irrespective of the biological level, are ecologically meaningful only when they are connected with their environment. Thus, traditional biological entities such as cell, organism etc., can be conceived only within their context of reference. Patten and his co-workers mention: "the same organism in two different ecosystems cannot be the same eco-system. Environment becomes integral in such a concept of the organism" (Jorgensen et al. 1992, p. 5).

The reinforcement of environment and mostly the symmetry that eco-system's figure manifests imply that relativism is not confined in the domain of traditional entities, it is also extended to the concept of environment. One should have already noticed this kind of relativism in the quotations, where system ecologists formalize the concepts of input and output environment. The relevant terminology denotes that environment has not an ontological hypostasis independent of the entity that it surrounds. Patten expresses this opinion explicitly when he writes: "Environment, in other words, is relativistic-entity defined and generated <sup>13</sup>" (Patten 2001, p. 429). It is noticeable that contrary to Von Uexkull, environment's relativism is universal. In other words, it also applies to the domain of non-biological entities. Thus, Patten stresses that environment is "entity-specific, defined by some object or subject, each with a finite existence interval (like the lifetime of an organism)" (Patten et al. 1997, p. 252).

On the basis of the above relativistic ideas, system ecologists conceive entities as relations. This becomes obvious in the pictorial representation of environ. In figure 2, the entity (object or subject) consists of two mutually exclusive halves, one of which represents input environment (or input environ) and the other represents output environment (or output environ). Evidently, the emphasis is given to processes instead of entities. As system ecologists sustain: "Flow takes priority over the objects, and reality is a flowing, changing process" (Fath and Patten 1999b, p. 195).

Besides, in such a relationist framework, environment is not considered as an absolute property of geophysical space; it is determined within processes: entity's activities. A rather novel philosophical viewpoint then emerges: system ecologists "envisage a material reality in which the very processes that take place constitute spontaneously the space-time coordinates in which they take place" (Haila and Taylor 2001, p. 97).

It is noticeable that this perspective stays close to systems thinking: the ecosystem appears less as an entity with a concrete spatial position and more as a complex of interacting dynamical processes. Moreover, in regard to ecosystem studies, what the consideration of ecosystem as a flowing object really implies is the promotion of the traditional system categories of inputs and outputs. At this point, someone could infer why the term eco-system becomes operationalized as environ. The latter has a principal role in ecosystem network modeling, shaping new methodological directions<sup>14</sup>. This novel methodology is in contrast with traditional ecosystem studies as exemplified by the International Biological Programme launched some decades ago. System ecologists do not study nutrient concentrations and biomasses; instead, they focus on individual processes leading to intercompartmental energy-matter flows (Straskraba et al. 1999).

System ecologists' thinking is quite relational, meaning that it is more concentrated on links and associations rather than disjunctions. In each case, distinctions, like entity-environment, input environment-output environment, and so forth, which take a superficial dualism status, seem to be dominated by the idea of unity. Obviously, the whole discussion is organized around holistic principles: entities are wholes composed of mutually defined, interdependent and complementary parts. Thus, networks or systems rather than isolated parts are of primary concern.

This holistic perspective is based on the activation of "function circles." The idea of "function circles" refers to "feedback loops," an idea posterior to Von Uexkull's era. It must be acknowledged that system ecologists continue to view feedback as a mechanism that determines the emergence of properties or behaviors that are not characteristic of the elements taken separately (Bergandi 2000). According with the hallmarks of the traditional system ecology (especially the work of Howard Odum), cybernetics logic keeps up with holism. Nevertheless, feedback loops are detected at all eco-systems, irrespective of the biological level. On that account, Patten and his co-workers seem to apply holistic thoughts, which previously referred almost exclusively to the ecosystem level, to the entire biological world. This is also the reason that the terms eco-system and ecosystem have identical signifiers<sup>15</sup>.

Moreover, it is known that the idea of feedback loops is used broadly in ecosystem studies, in ecosystem cybernetics, in order to depict inte-

grated processes. Its importance then may be found in the fact that system ecologists could use it as a criterion to individualize ecological entities, that is, eco-systems (or environs). This idea is in accordance with the extract presented below, where system ecologists quoting Von Uexkull, make reference to “function circles”: “If this circle is interrupted at any point whatsoever, the existence of the animal is imperiled. Continuity of the complete whole must never be lost sight of (Uexkull 1926: 129)” (Patten 2001, p. 431). Therefore, through “function circles” or “feedback loops,” the entity-environment complex (or the input environ-output environ complex) behaves as an indivisible unit. The whole unit has ontological primacy upon its parts; features such as integrity, connectedness and feedback-regulation are pivotal. These features are depicted in the pictorial representation of eco-system through the notion of cycle, and as we have already seen, they attribute to the whole unit autonomy. Hence, the above complex satisfies all those presuppositions that are necessary in order for system ecologists to construct the world in a monadological way that is also holistic.

The above monadological construction of the world differs from the already known ones. Focusing on environment as a system, or better as a structured network, system ecologists give emphasis to processes and shift their perspective from atomism, closeness and autonomy to holism, openness and non-autonomy, respectively. The dominant idea that organizes their thought and differentiates their enterprise from the previous monadological constructions is the holistic idea of entities’ continuity, the fact that the entity-environment complex and not the entity itself, forms an integrated and autonomous unit. It also seems that system ecologists adopt the line of Leibniz’s monadological thought, which argues for the non-completeness of wholes, as these are included into other wholes (Law 2004). This implication is unavoidable, provided that there is a resemblance between non-completeness and the eco-systems’ property that our authors call “openness” (Jorgensen et al. 1999). Without expanding further, we should mention that according to system ecologists, eco-systems are embedded into larger eco-systems, which are included into even larger ones, and so on. Based on this view not only the organism-environment complex, but also the organism itself constitutes a network. The latter is constructed of processes and relations that lower level entities, such as cells, configure in conjunction with their environments; in turn, these entities, thought as eco-systems, are also networks, and so forth.

World’s monadological construction based on eco-systems (or environs) does not confine itself to a pure biological domain. As a class of systems, eco-systems (or environs) do not belong exclusively in the category of physico-chemical or biological systems. On the contrary, they form a common methodological unit for both categories of entities. Proceeding

with such a monadological construction, system ecologists attempt to respond to a fixed request of system ecology and a holistic worldview in general. This attempt corresponds to the overstepping of the traditional distinction existing in the field of ecology between autoecology and synecology. In other words, it aims at unifying two theoretical domains, the biological and the physico-chemical, which in modern science are comprehensible as distinct (McIntosh 1980, 1985). However, in defining eco-system (or treating environ methodologically) in physico-chemical terms, it seems that they give to the whole approach a unified but reductionist character. Then, in order to avoid the reduction of living matter into the inorganic one, they incorporate to their theory an innovative ontological condition: a living eco-system such as a cell or an organism is also a 'model-making' entity (Patten et al. 1997, p. 267). Under this condition, biological entities are conceptualized as subjects who interpret the reality and respond to this interpretation. Thus, contrary to non living entities (objects), which are just passive responders to physics and chemistry, "[l]iving things act as agencies, with self-interest as the basis for their environmental relations" (Patten et al. 1997, p. 233).

Obviously, the theoretical treatment of biological entities as free agents with cognitive-like capacities promotes a profound turn in the world of ecosystem ecology. Ecological processes other than the materialistic ones, meaning other than ecosystem energetics, should be acknowledged now as important. We refer to communicative processes like information, exchanging and semiotic phenomena emphasizing semantic aspects of information, like transmission and interpretation of signals. It is worthy mentioned that system ecologists recognize ecosystems as semiotic systems; they accept the existence of communicative processes between ecosystem parts (Patten et al. 1997). However, they do not proceed within a biosemiotic framework<sup>16</sup>. In other words, they do not follow a research program that attempts to investigate ecosystem behavior through the thorough understanding of semiotic relations, the organisms' ethology. Neither do they accept subjectivist or constructivist ideas associated to the above framework. Instead, they insist that materialistic and physical processes, based on flows of energy and matter, have priority over communication or semiosis (Patten 2001).

#### THE CASE OF ACTOR-NETWORK THEORY

The former ecological perception of the world shows several similarities to enterprises in the field of social sciences, especially to Actor-Network Theory (ANT). This theory is a useful way of thinking about how spatial relations come to be wrapped up into complex networks (Murdoch 1998). ANT adherents argue against the Euclidean definition of space as some-

thing fixed, absolute and external, supporting instead a notion of space that is “plastic” and defined in terms of processes. Similar observations could be made in relation to time. A social geographer, David Harvey (1997), provides an especially clear analysis of this subject arguing that space like time are structures of relations or a set of ordering systems inherent to human practices and activities. Differently stated, space and time are not “independent realities, but relations derived from processes and events” (Harvey 1997, p. 256). For instance, what until now is defined as geographical proximity “is the result of a science, geography, of a profession, geographers, of a practice, mapping system, measuring, triangulating” (Latour 1997, p. 2). Beyond the involvement of scientific processes that require further analysis, ANT claims that space-time definition relates to interactions, processes and events of ordinary social life. This could mean that the distance separating two cities is a time-space feature that is linked to processes such as technology development, media of transportation, travelers’ socio-economic position, and others. Thus, it must be assessed from within such processes.

Therefore, in correspondence to the way in which system ecologists conceive environment, ANT advocates treat the notions of space and time through a relativistic perspective. This perspective is also expanded to the entities’ (or actors’ or agents’) perception. Thereupon, Law sustains:

Is an agent an agent primarily because he or she inhabits a body that carries knowledge, skills, values and all the rest? Or is an agent an agent because he or she inhabits a set of elements (including, of course a body) that stretches out into the network of materials, somatic and otherwise, that surrounds each body? Actor-network theory doesn’t deny that human beings usually have to do with bodies. Neither does it deny that human beings have an inner life. But it insists that social agents are never located in bodies and bodies alone, but rather an actor is a patterned network of heterogeneous relations, or an effect produced by such a network (Law 2001, pp. 3- 4).

Thus, similar to the case of organism, the image of actors as networks implies that human actors cannot be conceived out of their context of reference, that is, the same human in two different networks cannot be the same actor-network. Action arises from collective endeavor and the collectives are made up of actors or agents<sup>17</sup>, whose identities are determined in relation to one another (Murdoch 1997a). In network ecology, alike, this type of thinking focuses on networks and associations (Murdoch 1997a, 1997b). The entities become perceptible as relations and the emphasis is given to processes that sustain networks, to processes of translation. All these ideas denote that ANT is a “relational and process-oriented sociology,” which treats social structure better as a verb than as a noun (Law 2001).

Following this relationist perspective, ANT joints diverse sections of social life (science, religion, politics, economy, and the like) into heterogeneous wholes. Nevertheless, it is the idea of symmetry, the symmetrical treatment of natural and social entities, which differentiates this theory in the area of social sciences and offers its uniqueness (Murdoch, 2001) <sup>18</sup>. Following this idea, ANT adherents attribute the capacity of agency to entities that are not only enlisted in the social domain (Callon and Latour 1992). At this point, ANT advocates adopt a conceptual distinction in regard to entities, which is based upon the same terminology that system ecologists use. In particular, they argue that agents or actors, within configured networks, could be subjects or objects. The first category includes social entities like humans, families, social organizations, and others; while the second one is comprised of natural and human-made material entities like animals, plants, machines, artifacts, and so forth.

Proceeding further with the homomorphism in regard to entities perception, we observe that ANT advocates talk about hybrids or "quasi objects" (Latour 1993). Thus, similar to eco-systems, which represent a class of systems that is neither completely physico-chemical nor completely biological; the hybrid entities of ANT mix the social and the natural world. As a paradigm, we would mention the diagrams that a natural scientist employs, in the scientific laboratory, in order to describe the causal relation between grazing and nutrient concentration in the soil. Their hybrid character comes about from the fact that they enclose relations among a plenty of heterogeneous entities belonging to both nature: paper, ink, grazing animals, plants, soil, chemical substances, etc., and culture: stock breeders, scientists who will validate or not the results, financial supporters, etc. Through hybrids, ANT brings nature and society onto the same level and then studies social (as traditionally occurs in the field of sociology) as well as natural entities as actors or agents within a structured network. Hence, in respect to the previous paradigm, ANT advocates consider that the actor could be the natural scientist. According to John Law, this actor is a "heterogeneous engineer," someone who fits together bits and pieces from the social, the technical, the conceptual and the textual and brings them into patterned and robust network configurations in order to achieve his/her goals (Law 1987). In this context, the laboratory is perceived as an activity space that involves communication and persuasion.

Anyhow, what is most important in the previous paradigm is the consideration of natural agents as actors. For instance, according to ANT theoreticians, the material part of the diagrams (paper, ink, etc.) allows some kind of representations precluding others, while the properties of soil nutrients shape the methodology that natural scientist will apply. The laboratory, then, besides being a human space of communication and

persuasion, includes diverse material activities and practices mediated by networks of objects. Among the latter, all those mechanisms that convert material objects into written documents, referred as “inscription devices,” possess an important role (Latour and Woolgar 1986). Such a device, would be, in the previous paradigm regarding grazing, the electronic scale. Again, this is an entity that is neither natural nor social in an absolute sense, but rather an entity that encloses a network of heterogeneous others in its making, such as materials, scientists, technicians, and so forth.

The principle of symmetry stems from the belief that there is no rule suggesting which network elements are really agents and which simply transfer the action of others. Thus, an electronic scale may participate as an actor in the experiments executed by the natural scientist, “representing” or “translating” (through marking weights) all those agents, the nutrients, techniques referring to the extraction and isolation of soil nutrients, and the rest, with which it forms an experimental network. However, the same device could function as an “intermediary”: the natural scientist could use it as an object that mediates communication among scientists, so as to argue for the plausibility of his/her enterprise. Therefore, the symmetry principle impels ANT theorists to uncover how associations and networks are built and maintained without showing any a priori preference on what will be linked to what and on how the linkages will be forged. In Murdoch’s words: “Action can come from humans and non-humans alike— it all depends on the links within networks. The role of analyst is, therefore, to follow the actor-networks as they stretch through space and time” (Murdoch 1997b, p. 334).

Elaborating further this symmetrical framework, ANT advocates incorporate in their theory the worldview of Leibniz (Law 2004). Similar to system ecologists, they argue that each whole as a network is qualitatively distinct and unique. As a result, they limit themselves to describing exhaustively the processes of translation and the relations that agents of the network in question form (Castree 2002). Advocates of ANT also claim that network agents, alike eco-systems, are both points and structured networks, or both individuals and collectives (Bingham 1996; Murdoch 1998). The inscription devices could serve as a paradigm. We saw that they constitute a network of heterogeneous entities and relations. At the same time, this network is a rather stabilized unit, a point (another resemblance with system ecologists, who consider eco-systems as cybernetic machines). As a point, this network could enter into new-formed networks constructed by innovative research programs, involving novel experiments, laboratory equipment and agents. However, within ANT there is a full application of Leibniz’s ideas (Law 2004). Actor-network theoreticians accept the idea that wholes as networks are included into other networks; even though they do not accept the hierarchical connotations, the as-

sumption of a hierarchy theory where wholes of lower levels are included into larger ones.

In general, ANT advocates organize their thought about entities in a similar way to system ecologists. They consider social and natural agents in a common framework and simultaneously adopt a conceptual distinction based unavoidably on the assumption that between objects and subjects or natural and social agents, there is a difference. Nevertheless, the two network theories conceive the above “difference” divergently. According to system ecologists, the distinction living-non living has the status of an ontological dualism and leads to methodological differentiations, although all eco-systems obey to the same set of natural principles (Patten et al. 1997). On the contrary, ANT advocates argue that every distinction generated between nature and culture is not ontological; nature-culture dualism does not exist a priori but it is produced ex post. The latter means that the classification of entities into the social or the natural domain results from co-constructionist processes occurring in networks, where objects or subjects act. In other words, “networks are sets of relations which give rise to the objects and dualisms that make up our world: ‘machines, people, social institutions, the nature world, the divine—all are effects or products’ (Law and Mol 1995: 277)” (Murdoch 1997a, p. 743). Thus, regarding again the paradigm of grazing, the natural scientist and the soil chemical materials do not preexist. They are associated, mutually modified and co-constructed during scientific practices that take place in the laboratory. As Latour puts it, natural and social agents “mutually exchange and enhance their properties” (Latour 1999, p. 125).

What the symmetrical treatment of natural and social entities really implies is raising non-human entities to the human level and degrading human entities to the non-human one (Laurier and Philo 1999). At this point, the first objections to ANT emerge. Among them the most important ones are those claiming that the framework of symmetry is actually inequitable (Hacking 1997; Hacking 1999). The reason for this inequitable-ness is found within the above-mentioned process of exchange properties: non-human agents gain more than human network agents lose. For instance, inscription devices would play an activate role in networks engaging scientists, but they will never incorporate the psychological characteristics of human action. Therefore, contrary to the hard versions of ANT, a modest version—appeared recently—argue that the theory must take into account the specific properties of human action that differentiate humans from objects<sup>19</sup>.

In that fashion, the conceptual distinction of entities takes the status of an ontological dualism. This dualism is grounded on criteria used also by system ecologists. Thus, similar to network ecology, the feature that

distinguishes human from non-human entities is found in the cognitive domain; this feature is intentionality (Pickering 1993). In other words, humans have the capacity to accept or not their classification into standardized behaviors, to reinvent themselves and renegotiate their position in network configurations, resulting in unforeseeable actions (Murdoch 1998). Therefore, contrary to non-human entities that can “act utterly indifferently,” humans can modify both themselves and the networks in which they are engaged (Haraway 1997).

In spite of the above distinction, it is important to note that the adherents to the modest versions of ANT concede the central tenets of ANT. Ecologizing ‘sociology’, that is, treating natural and social entities within a common framework is one of their primary interests. Apart from that, they also accept a co-constructionist mode of analysis that remains agnostic about any actual prevailing state of natural and social affairs, although in a moderate fashion (Murdoch 2001).

#### CONCLUSION

According to the above discussion, all network theoreticians declare for a unified theoretical treatment of entities that until now were classified into different and opposing ontological domains. Thus, a new type of thinking emerges: new theoretical categories and methodological tools are developed “focusing on how things are stitched together across divisions and distinctions” (Murdoch 1997b, p. 322). Network theories in other words are mostly relationist theories. They shift our attention away from entities toward collectives and complex ecologies (Murdoch 2001).

Despite the common relationist framework that network theories share, there are differences. On the one side, network ecological theory responds to a traditional objective in regard to ecosystem field: resistance to scientific reductionism. Dualisms such as organism-environment, living-non living matter, etc., are considered problematic because they deny too much of the intrinsic unity of world (Patten 2001). System ecologists organize their theory around the idea of holism and elaborate a relationist framework in order to confront the riddle of wholeness. Moreover, this holistic perspective is compatible with the idea of realism: an objective and unified world including humans exists unconditionally and with independence from any observer. Within this epistemological context, true knowledge is feasible, provided that scientists will follow positivistic and naturalistic practices. Indeed, system ecologists believe that they will uncover the implicit unity of the world as long as they organize their theory around natural principles, give priority to physical materialistic processes, and apply a quantitative scientific method that respects the relationist viewpoint.

On the other side, Actor-Network Theory concentrates on yielding a unified theoretical perspective that overcomes mostly the deficiencies of dualistic thinking. According to ANT adherents, “[d]ualistic thinking is problematic in social theory because it tends to cleave theoretical perspectives into two distinct and incommensurable parts, thereby polarizing whole fields of concepts and leading to a fractured view of the world (Sayer 1991)” (Murdoch 1997b, p. 322). Thus, the preferential position that holism possesses in regard to the organization of network ecological theory is taken in ANT agenda by another critical principle, named “symmetry.” Although symmetrical thinking concentrates on networks and associations, it stands in the middle of dualisms; it takes an ‘in-between’ rather than an external position, seeking for how these dualisms emerge. In other words, although all networks theorists proclaim the end of the ‘here’ and ‘there’, system ecologists accept that dualisms preexist forming networks or wholes, while ANT advocates claim that dualisms are network effects. The latter implies that the focus of ANT “is upon neither nature nor society, for these categories emerge from the relations established within the networks themselves” (Murdoch 1997a, p. 743). Obviously, ANT advocates work within a different epistemological framework. Their relationist viewpoint, based on a mixture of relativistic ideas and co-constructionist processes referring mostly to a complex series of negotiations, is incommensurable with essentialist or realistic ideas. In Demeritt’s words, “Latour proposes a radical metaphysics of ‘relative existence’ in which determinations of epistemological truth and ontological reality are contingent and depend on the strength of heterogeneously assembled actor networks of human and non-human entities” (Demeritt 2002, p. 775). Therefore, comparing environ network theory and ANT we conclude that even though they share a common corpus of ideas that is network thinking in general, they can not be aligned; the same seemingly ideas are colored differently in different contexts.

## NOTES

- 1 Essentialist definitions are based on the idea that entities are those which form relations and not relations those which form entities.
- 2 The quotation marks emphasize the fact that Patten does not perceive the concept of 'particle' similar to other known monadological theories. Although we will discuss this theme in the following section, we have to pinpoint that Patten wants to define an ecological unit of organization characterized by a relational and not a traditional corpuscular structure. The reason that he insists to call this unit as particle is not as we previously saw without meaning.
- 3 In later articles, Patten and his co-workers, also use an alternative to environment term, namely 'eco-system'. We will refer to these terms in the next sections.
- 4 Latour (1993), emphasizes that network concept is more flexible than system concept, more historical than structure concept and more empirical than the concept of complexity.
- 5 On network analysis, see Fath and Patten 1999a; Fath and Patten, 1999b; Fath 2004.
- 6 Viewing ecosystems as graphs and networks does not exhaust modern ecosystem theory (Nielsen and Ulanowicz 2000). Within the contemporary ecosystem field, someone could also find novel thermodynamic approaches, which study ecosystems as dissipative structures. The term 'dissipative', coined by the Nobel-awarded chemist Prigogine, is used to denote self-organizing systems that expend or degrade high quality energy for the maintenance of their organization (Jorgensen et al. 1999). In this alternative case, system ecologists examine thermodynamic efficiencies using methods for optimized ecosystem functioning (Nielsen and Ulanowicz 2000). Recently, Patten and Fath have engaged in this framework. In particular they have tried to codify and unify, through a network perspective, different optimization criteria about ecosystems' development (Fath et al. 2001).
- 7 In the relevant article, titled "The structure of ecosystems," Hannon attempts mostly to determine the total energy flows that directly and indirectly link organisms to their ecosystem.
- 8 Actor-Network Theory has been developed within sociological studies of science by Michel Callon, Bruno Latour and John Law at about the same period with network ecological theory (Murdoch 1997b). Although ANT focuses mostly on science, it has extended to other fields, including organization theory and social geography.
- 9 In a posterior scientific article, Patten (1990), accepts organism as an ecological entity and specifically, as an elementary unit for microecology. In that way, he constrains his heuristic for the field of macroecology. However, his real intentions become clear later, when the proposed particle (environment or ecosystem) is considered as a general ecological entity (Jorgensen et al. 1992; Patten et al. 1997).
- 10 If we take into account that Patten becomes more specific, defining ecological subject as the relationship of environment to life, we would suppose that ecology could study the environment of biological entities, irrespective of the biological level.
- 11 This new unified theory responds to the general objectives, which we have already seen in the beginning of this section. We have to note that these objectives are rather positivist. Thus, in the series "Ecosystems Emerging,"

- system ecologists study environment seeking for universal natural principles and construct their theory in such a way that fits the deductive structure of physics. The latter is evident in this quotation: "The theory will be presented in a series of papers, each dealing with a primary proposition. Secondary propositions will follow from the primary ones" (Jorgensen et al. 1992, p. 23).
- 12 This is the reason why we use these articles as text material in our attempt to reconstruct network ecological theory.
- 13 A similar view about environment is found in the work of Lewontin (2001). He argues that environment is something that surrounds and it can only exist when there is something in the center that is surrounded. Thus, environment is the set of external conditions, which are relative to organism's existence because organism interacts with the elements of the external world.
- 14 Apart from methodological aspects, the environ concept facilitates system ecologists to construct a causal and formalistic theory, fitting to General System Theory's patterns. The reason is simple. Based on the system categories of inputs and outputs, environ reflects explicitly the distinction between stimulus and response or cause and effect, in behavior and causal domain, respectively.
- 15 We should notice that the application of a homomorphical way of thought to the entire biological world is also evident in the case of environs. In this case, both the components parts of the ecosystem (horizontal homomorphism) and the ecosystem itself (vertical homomorphism) could be represented as input and output environs.
- 16 On biosemiotics as a new paradigm in the world of biology, see Hofmeyer 1997; Kull 1998; Sharov 2001.
- 17 Actor is any element which bends space around itself, make other elements dependent upon itself and "translate" their will into the language of its own (Callon and Latour 1981). Actor attempts to convince other elements so as to align their interests with its own interests. When this persuasive process is accomplished, an actor-network is created. In the terminology of ANT these phenomena are represented by the term "translation" (Murdoch 1997a; Sidorova and Sarker 2000). Translation includes three stages: problematization, interessement and enrolment. Problematization is the first stage during which an actor defines identities and interests of other elements that are consistent with its own interests, acclaiming also itself as a necessary representative of them. Interessement is the second stage during which the process of convincing other elements to accept the definition of the actor occurs. Enrolment is the last stage involving the alignment of elements' interests with actor's ones.
- 18 Symmetry principle, although in a different version, is fundamental in most social studies of science (introduced by Bloor 1973). According to this principle: "Sociologists of scientific knowledge should treat correct science and false science equally; they should analyze what are taken by most scientists to be true claims about the natural world and what are treated by most as mistaken claims the same way" (Collins and Yearley 1992, p. 302).
- 19 On the modest versions of ANT see Murdoch 1998. See also Castree 2002.







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