Space and Time in Eco-Ontologies

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In this paper, we elaborate on the fundamental characteristics of ecological ontologies, and draw attention to the importance of space and time in the structure of these ontologies. First, we argue that a key to the specification of eco-ontologies is the notion of teleological organization grounded in a notion of recursion. Second, we introduce the notion of roles to characterize the generalized and interactive teleological aspects of ecological systems. Third, we also introduce a preliminary set of temporal and spatial concepts intended to represent ecological space and time in the formalization of eco-ontologies. Fourth, we show how some important epistemological constraints on cognition are fundamentally ecological in nature. This work is informed by Kant's investigations into the foundations of biology, by the hermeneutic investigations of Heidegger and Gadamer, and by mathematical investigations into recursive logic and their application to biology by Spencer-Brown, Maturana, Varela, and Kauffman.

Keywords: ecology, ontology, space, time, epistemology

1. Introduction

This work began as part of a project aimed at enabling communication about ecological systems through the development of computer ontologies especially designed for ecological data. In the course of our investigations, we were led to see the relevance of ecological analysis for the nature of thinking in general. In this paper, we begin by summarizing some of our previously published arguments on the nature of ecological systems. We then proceed to a preliminary account of the formal spatial-temporal character of such systems. Here we attempt to isolate and define some of the fundamental categories of ecological representation. Finally, we show how certain epistemological constraints governing knowing are essentially ecological in nature. Our ecological account thus sheds light on the processes involved in knowing. Our work has been inspired and informed by Kant's seminal investigations into the foundations of biology, by the hermeneutic investigations of Heidegger and Gadamer, and by mathematical investigations into recursive logic and their application to biology by Spencer-Brown, Maturana, Varela, and Kauffman.

In section 2 we argue that a key to the specification of eco-ontologies is the notion of teleological organization grounded in a notion of recursion. We use roles to characterize the generalizable teleological aspect of eco-ontologies. In section 3 we outline aspects of basic units of space and time, working toward a formal account of eco-ontologies. Section 4 develops the relationship between ecological systems and processes of knowing. Both knowing and life participate in self-organizing processes that involve more than simple recursion. Our hypothesis is that basic processes of knowing both inform, and are informed by, fundamental ecological constraints. In this context, we propose a model of self-organizing systems that meets some universal epistemological conditions on knowing. We believe that the incorporation of these conditions provides important clues to the ecological nature of intelligence and, possibly, to the intelligent character of ecological systems. Finally, section 5 presents a focused restatement, and further development of our conclusions.

2. Ecological Ontology: Recursion, Teleology and Roles

The term ecology is derived from the Greek term hoikos that is translated as house, household, or home. As such, ecology is aimed at describing the dimensions of an eco-environment that supports, or provides a home for, or affords success for, various biological species and the biological system as a whole. The environment is conceived as a context that enables, or is a means to, biological life. Moreover, the whole biolog-

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ical system embedded in a physical environment is itself seen as an important aspect of the eco-environment of the species and individuals that compose the biological system. To summarize, ecology deals with environmental systems, both biological and non-biological, as means of species survival. These systems occupy a spatial location during a certain period of time.

2.1. Self-Organizing Systems: From Recursion to Teleology

In this context, we propose to examine the implications of the hypothesis that the fundamental characteristic of ecological ontologies is that they are a kind of self-organizing system, in the sense stipulated by Kant [7] in his Critique of Judgment. In particular, for Kant, a self-organizing system is one in which each of the sub-components of the system are (either directly or indirectly) both means and ends in relation to the whole system and, consequently, to its other sub-components. As an example, symbiotic relations such as those between certain insects and flowering plants are characteristic of self-organizing systems. The bee is a means to (i.e., performs the role of) fertilizing the plant, and the plant is a means to (performs the role of) nourishing the bees. Note that the important notion of roles, discussed above, is a natural characteristic of self-organizing systems as Kant conceived them.

There is an important sense in which things may be said to be purposes of Nature. Kant says, "I should say in a preliminary fashion that a thing exists as a purpose of Nature <u>when it is cause and effect of itself</u>, although in a two-fold sense." Consider the case of a tree. In the first sense when a tree procreates, it produces another like itself. In this case, we see the species of which the tree is a member, in the process of causing itself. In the second sense, we can see the metabolic activities of the tree as involved in the production of the tree itself. Note further, that the whole of the tree is causally dependent on the parts – for example, the leaves – that are in turn causally dependent on the whole. For a more current discussion of recursion and self-causation, see Spencer-Brown [14] and Kauffman and Varela [9].

The parts and the whole are reciprocally dependent upon one another. "In such a product of Nature each part not only exists <u>by means of</u> all the other parts but is also regarded as existing <u>for the sake of</u> the others and of the whole, that is, as an instrument (organ)" [7]. However, this definition is still lacking because the parts of any organized product of human invention (a watch for example) can be considered as being for the sake of the others. But human invention is not a component of Nature in the sense in view in this discussion. Accordingly, Kant additionally stipulates that the parts of a natural self-organizing system can be considered as <u>causally</u> producing one another. Kant concludes that "an organized product of Nature is one in which everything is reciprocally ends and means."

The relation of means to ends embodied in the above description suggests that eco-systems may be conceived as teleological in character. The ecosystem is a means to the life of its constituents and also an end in relation to those constituents. It is very interesting that this sort of analysis introduces, in a natural way, a teleological dimension into the description of an ecological system. Under its guidance, one begins to see an ecological sense in which it is appropriate to ask what something is for, or what its purpose (or, role) might be in the ecological system. Of course, if one ignores the reciprocal means-end analysis Kant pointed to, one might describe the causal antecedents of any number of events but fail to see the ecological system. Such an investigator would fail to identify the ecologically relevant events or relations, or to distinguish them from the indefinitely large set of events and relations that are of minor importance in understanding the ecological system.

For example, in examining the mammalian body, there are many relatively subsidiary questions one might ask about the heart – such as what color it is when viewed on the laboratory dissection table. On the other hand, if one knows that the function, or role, of the heart is to move the blood, and that it is through that function that the heart enables the continued existence of the other organs of the body, and thus its own continued existence as well, then one is directed to ask questions concerning the heart that are relevant to the function of the whole body of which it is a part. Specifically, one is led to ask how the heart moves the blood. The investigator will be led to question the role of a structure or relation in the function of an ecological system as a whole.

Ecological ontologies, then, must be represented in terms that allow us to capture their genuinely self-organizing, ecological nature (i.e., the ecological level of analysis). More formally, such self-organizing systems have the characteristic of recursion in the sense that $A \Rightarrow B \Rightarrow C \Rightarrow A \Rightarrow B$, etc. This description reveals the essentially temporal character of eco-ontologies.

In order to clarify the importance of time in eco-ontologies it is useful to compare them with geo-ontologies [4]. In contrast with the essentially spatial character of geo-ontologies, eco-ontologies are fundamentally temporal in character. The spatial character of geo-ontologies, ontologies for the geographic world, contributes to the hierarchical organization of geo-systems. The temporal character of eco-ontologies on the other hand is a function of the recursive process that is essential to their definition. There is, of course, a possibility of hierarchical relations in eco-ontologies. However, in this case the hierarchies are functional and dynamic in nature. For example, at one level of analysis, the cardiovascular system as a whole may be seen as moving the blood. At a subordinate level of analysis, a variety of interlocking subsystems (e.g., the heart, the arteries, etc.) may be seen as collaborating in moving the blood.

The special importance of time for eco-ontologies derives from the fact that the life course for living beings is structured in terms of time. Today, for a living being, is different from yesterday because living beings change as a function of time. Organisms in an ecological system have a relatively short span of life compared to regular geographic features that can last millions of years. Thus, while for some purposes it may by possible to ignore the temporal dimension in constructing geo-ontologies, the circular causal chains that make for ecological self-causation require that eco-ontologies represent the temporal character of ecological systems.

2.2. From Teleology to Roles

In this paper, our discussion of roles will be focused on their function in eco-ontologies. The notion of roles constitutes a very general category. We are going to limit our discussion to the ecological manifestation of roles. We want to emphasize the way in which the teleological dimension that derives from the notion of recursion is connected with our ideas about ecological roles.

In our view, recursion and the derivative idea of purpose, lead naturally to the notion of roles. Roles are generalized categories of purposive function. Without the category of roles it would be impossible to capture invariant patterns of ecological structure or interrelationship. For example, the idea that there are alternative means to an end makes room for the notion of roles. In cases where several entities or processes fulfill the same purpose, we say that they play the same role with respect to that purpose. The notion of roles enables us to appreciate an invariant in the system when the individuals or processes change. Thus, roles point to a dimension of commonality across differing instantiations. One says for example that Smith and Jones both played the role of Hamlet. In an ecological context, one says that flowers play the role of food source for bees, just as rabbit holes play the role of food source for foxes. So the context for a role involves a narrative which can be instantiated by distinct objects.

Alternatively, the notion of role is often linked with change in time, or perspective, in relation to the same entity. An individual may have a unique identity but can play different roles (sometimes simultaneously) during its lifetime. For example, a person may play the roles of a student, a parent, and a member of a club. Similarly, a lake can play the role of habitat for a species of fish, of water supply for a nearby town, a center for recreation for people wishing to swim or boat, and a food source for people who live by fishing. In this way, roles also help to express different points of view of the same phenomenon. The same object may instantiate differing roles. Fonseca [2] has pointed out that it is this capacity of an object to play different roles that makes intelligible the interaction and integration of different ontologies (ecological or otherwise).

In this respect our analysis differs from that of Guarino [6]. Fonseca uses a more unrestrained definition of roles than Guarino [6], who argues that roles should have their own hierarchy and can only subsume or be subsumed by another role. Guarino emphasizes only the role-determined structure of ontologies. On the other hand we also wish to point to the rich insights that are available when it is recognized that the same object can play a variety of roles in interlocking ecological systems. For Fonseca, concepts in one ontology may play roles that are concepts in a second ontology. A more rigid specification would require, for instance, a habitat to be a subclass of a geographical region. As a consequence, in a biologist's ontology, a habitat would not be a concept but only a potential role. By using a more flexible specification of role, a habitat may play a role in ontology 1 while being a concept in ontology 2. In this second ontology a habitat has an identity and all the attributes that characterize a concept as being distinct from other concepts. In short, Fonseca [2] considers that a concept in an ontology plays roles that may be concepts in other ontologies.

2.3. Narratives

The notion of narrative, or story, is important for our discussion of roles for several reasons. First, narratives are the most general form of discourse we possess. This means that they are extremely flexible, so we will not have to go beyond them to a higher level of analysis in the future. Second, they are realized in both space and time. Third, narratives can provide the meaning required for recognizing and defining roles. In the above example, we could tell 'the story of bees' and 'the story of foxes' – two narratives with some important similarities, including the fact that they both require a search for food in well defined spaces. So, we find that those well defined spaces can be viewed as playing similar roles in the two space/time narratives.

Because of the generality entailed by roles, it is possible to specify role relations common to differing ecological systems. For example: *Foxes : Rabbit Holes :: Bees : Flowers*. What this says is that the relation (R_1) which defines the common role, i.e., 'place to find food,' obtains between *Foxes* and *Rabbit Holes*, and between *Bees* and *Flowers*. That is, at an appropriate level of analysis, the same relation obtains between *Foxes* and *Rabbit Holes* as obtains between *Bees* and *Flowers*. This relation, R_1, would be diagrammed as within the two time-space narrative domains.

We can also say that the corresponding *Foxes : Bees :: Rabbit Holes : Flowers* holds, insofar as there is a degree of similarity between the story of foxes and the story of bees. In fact, if it did not hold, then neither would it make any sense to notice that the first set of relations holds. This relation, R_2, would be diagrammed as between the two time/space narrative domains. Both R_1 and R_2 are necessary for the notion of common role to obtain. So this relation, R_2, appears essential for defining similarities across narratives.

We think that narratives can be the foundation of a hermeneutic ontology editor. In another paper [3], we discussed some principles that can be used in such an ontology editor. Perhaps the key point is to see that an ontology editor is distinct from ontologies. We conceive the editor to be a 'place' where persons assuming different conceptual schemas may come to learn from one another through interaction with each other and with their texts. This would involve a back and forth process which includes dimensions of understanding, interpretation, and application.

The hermeneutic ontology editor builds ontologies from narratives. All the concepts and relationships are first laid down in a narrative. Later on, the narrative is mined, and concepts and relationships are transferred to an ontology. In a first step this process is to be performed by ontology engineers, but studies to automate the transfer will also be carried out. The process of creating an ontology is a hermeneutic enterprise. Therefore, it is necessary to have a space for interaction. The interaction is achieved through the use of questions. Once a version of the narrative is released, potential users of the ontology go through the narrative and ask questions for clarification. The replies to the questions come as changes in the narrative. These changes will in their turn lead to changes in the concepts and relationships in the ontology.

To summarize our discussion of roles, in an established ecosystem every component can be viewed as having a role. In our example of the bee and of the flower, the bee plays the role of helper in the flower reproduction process, and the flower plays the role of a feeder. A species may be a feeder at one level and it may be food at a different level. In an ecological system, every relevant component has a role and all the roles are tied so that removing one will interfere with others. Moreover, as individuals change, through birth and death, for example, the system continues because there are new individuals who take up and play the roles previously played by other individuals.

It follows that the self-causation manifest in ecological systems can only be seen if one is considering a level of analysis that includes roles. Accordingly, an ecosystem is defined as a structure of interlocking roles. The notion of roles thus allows us to understand the continuity of form in ecological systems. On the other hand, insofar as the same entity can play different roles, the notion of roles also enables us to appreciate the complex ways in which differing ecological sub-systems can interact.

We conclude that the notion of roles, in both of its dual aspects, is an essential component of an ecological account. Eco-systems and their interactions are characterized in terms of roles. Each role is a function of time and space, and each entity construable as a component of an ecological system may be said to be playing a role.

3. Operations on Ecological Space and Time

Whether we believe that theories are created before we collect data or that data are the foundation for the development of theories, we agree that data are linked to theories in some way. Therefore how data are collected and linked to theories is a matter of interest here. We believe that ontologies include theories of how the world works and that we use data to support or falsify our theories. The discussion carried out here is a step in enabling linkages between data and complex concepts in ontologies.

From the whole universe of possibilities of phenomena that can be measured, the researcher chooses a few to observe and to collect related data. In ecology, data are collected mostly based on points in space and instants in time. Later on, these points and instants are aggregated and transformed in many ways to turn out more complex structures. Therefore, we need to define basic units of space and time. Then we can specify the operations that can be applied on them in order to create more complex structures. Finally, we argue that the notion of an ecological system is so bound up with the notions of time and space that the latter notions must be adapted to the ecological context to which they are relevant. Hence, we propose to speak of ecological time and space. In this connection, we point to some fundamental ideas of Spencer-Brown, Varela, and Kauffman which we take as a point of departure for developing a more formal account of the notion of self-organizing ecological systems presented in this paper. We do not undertake a full formalization here, but wish to make our readers aware of the very provocative and rigorous notions that have inspired and encouraged our work. We are currently preparing a more formal account of our own development of these ideas in the spirit of the above mentioned authors.

3.1. Elements

A basic unit of space, *p*, is the point. A point is an ordered pair in the coordinate plane. The set of all points is called P.

The basic unit of time, *t*, is the instant. An instant is a point in any kind of time framework. Instants are linked to facts that happen along a timeline. The set of all instants is called T.

We are interested in the points and instants that an ecologist chooses to collect. The collected points belong to a set $P_{collected}, P_{collected} \subset P$. Collected instants belong to a set $T_{collected}, T_{collected} \subset T$. In being so, collected instants are ordered: a fact that happened at t_i comes before a fact that happened at another instant t_{i+1}. This can be represented as a *sequence* [1], a function whose domain is the set positive integers less than or equal a positive integer, called *collected*, which represents the number of measurements made by an ecologist.

Once we have the data collected as units, the next question is how we can transform these units into more complex structures such as ecological niches, trajectories, and lifetimes. The transformations of basic units of space and time into more complex concepts may be used later in the formalization of eco-ontologies.

3.2. Basic Operations

We consider two types of operations, *grouping* and *extension*. Extension can be further subdivided into weak and strong extension. Grouping is the gathering of units in a way that the individual units are still preserved. The result is a set that would conform to set theory. The result of the extension operation is a more elaborate structure. The results are ordered sets. If in the resulting structure the individual components can still be identified we call it *weak extension*. If it is impossible to identify the basic units in the result, we call it *strong extension*.

Consider, for instance, that an ecologist has a database with information about the whereabouts of a certain group of polar bears. The detailed information contains points with x,y coordinates and timestamps collected with a certain periodicity. In this case, examples of the operations would be:

- applying the *grouping* operation to space units would give a point set, P_g. From the set of collected points the ecologist could select some according to a classification criteria such that $P_g \subset P_{collected}$. Consider, for instance, that the ecologist needs all the points where a specific bear was during the morning.
- applying the *weak extension* operation to a point set would give an ordered point set that can be represented as a line. A line is also a *sequence*, i.e., each element in the point set is associated to an element in the set of positive integers less than or equal a positive integer representing the number of measurements. Here the ecologist might need the points travelled by a certain bear in a specific period of time. The ecologist needs the points in a certain order so that he/she can trace a line with the trajectory of the bear in this specific period.
- the result of a *strong extension* operation could correspond, for instance, to buffer areas created around a point *p*. Different functions applied to the point will lead to spaces of different shapes. Here the ecologist applies a function on all the points of all the bears to create a region that will correspond to the habitat of the polar bears.

3.3. Derived Concepts

Now, using our operations in space and time we can further classify facts. Then regarding spatial location, we can call a point *p*

- *internal* to a place;
- *external* to a place;

and regarding spatial range, we can call a point *p*

- *local* to a place;
- *global* to a place;

and regarding time, we can call an instant *t*

- *ephemeral* in an age;
- *permanent* in an age.

3.4. Connections in Space and Time

We can consider space and time as two important dimensions to describe the interactions between an ecological environment and its surroundings.

	Ephemeral	**Permanent**
Internal	Sickness	Symbiosis
External	Distraction	Structural Coupling

Table 1
Interactions in Space and Time

Regarding where the interaction occurs we can have (Table 1):

- the interaction happens in the system. The new element crossed the system boundary and it is now inside the system in a definite way.
- the interaction is external to the system. It acts on the system but without penetrating it, at least in a permanent character;

Regarding the duration of the interaction we can have:

- some interactions can be of an ephemeral character;
- some interactions have a permanent character or a recursive one.

When the interaction is ephemeral and internal the tendency of an ecological system is to absorb locally the disturbance without propagating the instability to the whole system. When the interaction occurs externally to the system and it is ephemeral we can consider it only a distraction without any consequences.

The permanent interaction causes structural changes in the system. When they are internal to the systems, the two systems learn how to live with each other and the relationship is beneficial to both of them. This process is called symbiosis [10].

The second type of permanent interaction is between a system and an external agent. Since its character is permanent, or at least of a recurrent character, the system needs to learn how to live with it. What happens then is what Maturana and Varela [11] call *structural coupling*. Structural coupling is the resulting change in the structure of each of the two interacting living systems. The structures in each system change as a result of the presence of the other system. As Maturana and Varela stress the change is not made by the other system being instead started by it.

3.5. Relations of Ecological Time and Space

In this section we point briefly to the ideas introduced by Spencer-Brown [14]and subsequently developed by Kauffman and Varela [9] concerning recursive, imaginary logics. We believe these logics provide fundamental insights into relationships between time and space in a way that sheds light on oscillatory (i.e., recursive) biological phenomena. We hope in this way to develop an integrated formal approach to the ecological ideas previously introduced in this section (e.g., habitat, structural coupling, symbiosis, etc.).

In the course of a reformulation of some aspects of the foundations of logic, as presented in Principia Mathematica, by Russell and Whitehead, Spencer-Brown was led to consider imaginary logical forms. These forms are analogous to the imaginary numbers in arithmetic which arise when one is faced with equations like $x^2 = -1$. Such equations are not solvable (without inconsistency) if one is limited to the real numbers. Their consistent solution requires extending the range of possible values to the imaginary realm, the complex plane.

Spencer-Brown showed that the logical equations he was considering could not be solved consistently without recourse to an imaginary dimension which he identified as time. The introduction of time allowed for the separation of inconsistent spaces, and thus allowed for the equations to be handled in a consistent fashion. Moreover, and relevant to our discussion of the recursive nature of self-organizing systems, the equations in question could be interpreted as self-indicating. That is, they were self-referential and thus entailed an infinitely recurring oscillation back and forth between a variety of inconsistent spaces. More recently, Varela [15], Maturana and Varela [12], Kauffman and Varela

[9], and Kauffman [8], intrigued by the self-indicating and consequent oscillatory nature of these mathematical systems, have taken the Spencer-Brown's insights as a point of departure for examining self-organizing (i.e., self-causing) biological systems.

Toward a formalization of eco-ontologies, we are exploring ecological space and time, and space-time relationships. With respect to time, we hold that an ecologically relevant notion of that dimension must focus on ecological recursions as fundamental measures and constituents of ecological time. Similarly, spatiality, in an ecologically relevant sense, must be construed as embedded within the various phases of the temporal sequence of recursions – as places where various purposes and roles are played out.

As we have shown, the ability to see an ecological system, as such, depends on the observer taking a teleological perspective – one capable of discerning means and ends. Since the demise of Aristotelian physics, natural scientists have assumed realms of space and time that are unaffected by teleological considerations. Fruitful as this modern view has been, we believe that the examination of ecological systems requires exploration of a complementary ecological space-time one grounded in the notions of self-organization and purpose.

4. Self-Organization and Knowing

In this section, we take up the relationship between self-organizing ecological systems and intelligence. This seems especially appropriate in that a fair number of the discussions of self-organizing systems in the $20^{th.}$ century have been as much directed to questions concerning intelligence, as to biology per se [16]. It is our thesis is that self-organizing ecological systems, as we have sketched them above, are capable of exhibiting characteristics of intelligence not manifested in many of the models of intelligence current in the cognitive science literature. Moreover, we argue that these characteristics of intelligence are not only important, but are essential to all intelligent activity, not just human reasoning. In particular, intelligent systems are subject to certain epistemic conditions which may be naturally met by properly configured ecological systems. In this context, we are led to the hypothesis that intelligence is a property of self-organizing ecological activity.

We offer the outlines of an epistemologically oriented theory of ecological systems. As we will show, epistemic competence is a manifestation of principles of self-organization. Thus, our project in this section is to show some of the rich connections between an ecological interpretation of living systems and the intelligence that is naturally associated with them. Accordingly, one aspect of our approach to the topic of this issue of AI Communications is to show how certain fundamental conditions on knowing arise from the temporal-spatial situation of self-organizing systems. Answers to questions about the nature of reasoning about space and time – spatio-temporal ontologies, for example – inevitably depend upon a prior understanding of the relations of space and time to reason itself.

4.1. An Epistemic Conundrum: Forests and Trees

We begin our discussion with a description of an epistemic problem familiar, in one version or another, to everyone – the problem of knowing forests. Suppose one wished to know a forest, then, at first glance, it would seem that there would be no better way than to go into the forest. However, when standing in the middle of the forest, one's vision of the forest is unfortunately obscured by the trees. So, one might decide to leave the forest in order to know it. But having done so, one would discover that one no longer had access to the trees that constitute the forest. This is a conundrum.

In more general terms, the moral we wish to draw from the above parable is that there is an epistemic difficulty at the very center of the process of knowing. The difficulty is as follows: If one wishes to know an object, it would seem that one must enter into a connection with it. This would seem to be a condition of access to the object. On the other hand, having entered into a connection with the object, one would find that the object had slipped away, for in order to know an object, one must have an independent standpoint or perspective from which to view it. In response to this difficulty, one might then take up a position apart from the object of interest. Having done so, however, would not solve the problem. Now our would-be-knower would have lost the access required to know established by his first move.

4.2. The Circularity of the Process of Knowing

Our epistemic conundrum has been often discussed in a variety of contexts. It is generally recognized that neither horn of the dilemma represents an adequate account of the situation of the competent knower. This is demonstrated by the fact that we are faced with a dilemma that entails the impossibility of knowing. Instead, it has often been suggested that the process of understanding involves a kind circular negotiation between whole and parts, forests and trees. For example, already in the $19^{th.}$ century, Schleiermacher had described the hermeneutic process through which we understand texts as circular. According to Gadamer [5], "Even in the case of a contemporary text with whose language or content we are unfamiliar, the meaning is revealed only in ... the oscillating movement between whole and part," p.191.

Moreover, it has become a commonplace among anthropologists that knowing an unfamiliar culture requires negotiating a related difficulty. If one is, in some sense, too close to the culture, one loses the independence of perspective required for seeing what is essential. On the other hand, without closeness to the details of the culture, one cannot hope to know it. Winch describes the negotiation of the problem in terms of a tacking back and forth between 'experience near' and 'experience distant' elements of the analysis (see Bernstein's, 1983, account of Winch's discussion of this problem).

Similar arguments have arisen in historical studies where it is sometimes argued that one cannot really understand a historical event because it lies in the irretrievable past. On the other hand, it is argued that insofar as the historian is part of the tradition in which the event has been significant, he or she cannot possess the independence required for appreciating it. Clearly, the hermeneutic problems of reading and understanding texts are also connected with these issues. It is largely for this reason that Gadamer [5] has held that a hermeneutic analysis is required for categories of events where the knower is historically conditioned.

At the deepest level, one thinks of Heidegger's notion of thrownness. Human beings find themselves 'thrown' in a world by which they are therefore conditioned. At the same time, it is precisely that world by which they are conditioned that they aim to understand. How is this possible? Heidegger suggests that understanding may be approached via a 'hermeneutic circle,' in which there is a continual tacking back and forth, not only between general and specific aspects of experience, but also between the assumptive context of experience and what is new. Here the hermeneutic circle involves a dialogue between the tradition that frames experience and the novelties that emerge in the context of that tradition.

Obviously, for both Heidegger and Gadamer, the tradition becomes an object of reflection as well as the objects that arise for consideration in its light. Equally obviously, both the framework and the elements of experience are necessary means for seeing the other. Each is a ground against which the other stands out as figure. This is the hermeneutic circle in its most fundamental level of analysis.

4.3. A Hermeneutic Solution to the Conundrum of Knowing Forests and Trees

What is at stake in the hermeneutic examples provided above is an oscillation between two dimensions of connectedness and disconnectedness. Knowing requires connectedness to the parts (trees) and also to the whole (forest). No account of intelligence which fails to explicate these facts is epistemologically adequate. The recognition of these constraints, however, is only necessary but not sufficient for an adequate theory of intelligence. The theorist's problem derives from the fact that the two kinds of connectedness we are considering seem incompatible – hence the conundrum.

In this context, we have followed the medieval dictum: When faced with a contradiction, draw a distinction. The important point to be remembered here is that the source of the conundrum lies in the requirement of an apparent inconsistency between the two apparently necessary dimensions of connectedness of the to-be-known world with the would-be-knower, discussed above. Our proposal is that this duality need not entail contradiction if we allow for a distinction in the application of the conditions it embodies. By allowing for a distinction of perspective, or time, between the two kinds of connectedness, we are able to avoid the contradiction.

4.3.1. The Phenomenology of Figure-Ground and Right-Left Hands

Such a distinction of perspective is drawn by every child who holds a block firmly in the left hand, while exploring it with the right hand. This two-handed approach to knowing seems to overcome the dilemma raised above.

To the extent that the block is held firmly, so that the correlation between the left hand and the block is perfect, the child receives no information through his left hand, and all the information that he receives comes through the right hand, which is moving over the block and thus not correlated with it. The amount of information received by either hand is precisely complementary, in Heisenberg's sense [13]. The same holds for a blind person's cane. If the cane is held firmly, the user will receive information about the object the cane is touching, but nothing about the cane itself. If, alternatively, the user's grip on the cane is loosened, the user will gather more information about the cane, but proportionally less about the object the cane touches. This latter example is due to Niels Bohr.

The phenomenology of this duality in perceptual experience has been described by Heidegger as the distinction between the ready-to-hand and the present-at-hand. To give an often-cited example, in the act of hammering, the hammer is not the object of focus, but there is no doubt that the hammerer has a kind of access to the hammer. This access is tacit inasmuch as the object of explicit attention is the nail. In this case, the hammer is said to be ready-to-hand. In this ready-to-hand mode, the hammer is not cognized as an object with a certain set of properties, but it is simply integrated into the skilled action patterns of the user. It is a part of the tacit context of the activity of driving the nail.

In Heideggerian terms, the block in the previous example is said to be 'ready-to-hand' to the left hand, and 'present-at-hand' to the right hand. The firmly gripped cane is ready-to-hand to the blind person crossing the street, while the curb he/she inspects through the cane is present-at-hand. The left hand's correlation with the block constitutes necessary background against which the right hand explores the object. Likewise, the correlation between the hand and the firmly held cane is a part of the background that is required if the user is to perceive the curb. The parallel between this background horizon and what Gestalt psychologists called the perceptual 'ground', on the one hand, and between the thing observed (the block, or curb) and what Gestaltists called the 'figure,' should be noticed. The universal figure-ground structure of perception is the result of the differences in information flow described above.

Interestingly enough, although one cannot <u>see</u> the forest for the trees, one must <u>know</u> the forest in the sense of having a tacit access to (correlation with) it. Explicit knowledge of the forest and trees may alternate in time. But the epistemic connectedness (through, say, the right hand) involved in explicit knowledge of the figure must be complemented with a tacit connectedness with the perceptual ground (the alternative, in this case, left hand). Accordingly, the knower is simultaneously both connected and not connected with the object of inquiry. Interior to the knower is the capacity to break the correlation between his or her two hands. So the child is both correlated (left hand) and not correlated (right hand) with the to-be-known object. This is the child's way beyond the dilemma with which we began this discussion. We, too, are capable of avoiding it because we are capable of breaking the correlation between one aspect of our being and another. This first distinction is drawn by us and within us, and is responsible for the universality of the figure-ground phenomenological structuring of experience.

4.3.2. Play: The Self-Organizing Unfolding of an Experienced World in Time

We require but one more step to complete our resolution of the difficulty with which we began. As we have seen, differing aspects of the object of inquiry are accessible from differing perspectives. Each perspective is defined by a figure-ground relationship. But we have recognized that the trees and the forest, because each is the ground and context for seeing the other, cannot be seen simultaneously. The non-contradictory integration of those two perspectives into a unified experience requires time. The spatiality of the complementary and contradictory perspectives may be brought together in a temporally integrated experience of the whole and the parts involving movement back and forth between the two logically incompatible perspectives.

Similarly, let us reconsider the child playing with a block. The movement back and forth, as the child plays with a block, is an alternative figure/ground oscillation as the block moves from one hand to the other. It is in this play that the block is known. Gadamer invokes the notion of play to characterize the to and fro movement involved in understanding a text. He tells us that play is a mode of being in the world whenever interpretation or understanding are at stake. Following Gadamer's brilliant discussion, we argue that the conundrum of the forest and the trees is overcome in the oscillation of play. Thus play represents a third position, beyond the either/or of correlation with the object, or lack of correlation with the object.

We now suggest that play, which is the form of understanding discussed in this section, is also the form of the self-organizing processes described in relation to eco-ontologies in previous sections. Consider the following remarks of Gadamer on play, "The movement of playing has no goal that brings it to an end; rather, it renews itself in constant repetition. The movement backward and forward is obviously so central to the definition of play that it makes no difference who or what performs this movement," p.103. Note two points in this connection. First, Gadamer is pointing out that play has a form that transcends the individuals involved in it. We saw this characteristic in our proposed role-structure of self-organizing systems. Second, Gadamer states that play "renews itself in constant repetition." This is precisely the form of recursive self-organization we have been concerned to describe in ecological systems. Knowing is a manifestation of life and thus participates in its self-organizing form.

5. The "Two-Handed" Form of Ecological Self-Organization

We are suggesting the hypothesis that hermeneutic self-organization and ecological self-organization possess the same underlying form. However, to say that they both involve some sort of recursion would be fairly trivial. In this section we propose a further specification of the form of self-organization that takes us beyond simple recursion. In particular, we have seen that hermeneutic play requires a necessary duality at the heart of the activity of knowing. At any given moment, the knower both is and is not distinguished from the object of knowledge. Furthermore, epistemic connectedness (information flow) is associated with lack of correlation, while the presence of correlation is associated with epistemic disconnection (lack of information flow).

So, the structure of self-organization involves at least two modes of connectedness with its environment. In our discussion above, we have exemplified this duality in terms the left and right handed modes of connection. The detection of information (figure) through one channel requires a contemporaneous correlation with the background (ground) via another channel. If one is to measure the ground, one must at the same time establish a correlation with another ground, and so on. As already mentioned, Bohr has suggested that in such situations the potential for relative information flow between the two channels would be complementary. The back and forth movement of self-organization involves more than a simple oscillation between epistemic connectedness and disconnectedness. It always includes a dual and complementary oscillation of correlation and uncorrelation between the self-organizing system and the relevant environmental object.

One further point is worth mentioning in this connection. The moments of correlation and uncorrelation are not, in and of themselves, sufficient to constitute self-organizing phenomena. Rather, as our previous discussion would indicate, self-organizing phenomena are essentially temporal as well as spatial. They involve the process of oscillatory movement <u>between</u> moments of correlation and uncorrelation.

We identify three functions which we believe characterize mental as well as biological life – first, a movement from lack of correlation toward correlation, and second, a movement from correlation to lack of correlation, and third, a dynamic play between the first two functions. Returning to our example of a child moving a block back and forth between the two hands, each hand oscillates between movement from uncorrelation toward correlation and movement away from correlation toward uncorrelation. Moreover, in the case under discussion, when one hand performs one function the other hand performs the alternative function. The two functions are understood as requiring one another. Taken together, they constitute the play of self-organization.

In undertaking this description, we have attempted to show that the nature of self-organization involves more than simple recursion. Instead, it involves a peculiar duality of relationship with the environment through which the self-organizing system simultaneously distinguishes, and does not distinguish, itself from its environment. We take this to be a contribution to the understanding of intelligent systems, and, we hypothesize, of self-organizing ecological systems in general. We believe that future attempts toward a formal theory of self-organizing systems and their ontologies must take this into account. If the hypothesis that ecological systems participate in the self-organizing form embodied in intelligence is correct, then ecological systems in general are "two-handed." The complementary processes of moving toward, and away from, correlation with the environment may be a characteristic of life itself.

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