Environmental Metaphysics

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We propose the beginnings of a general theory of environments, of the parts or regions of space in which organisms live and move. We draw on two sources: on the one hand on recent work on the ontology of space; and on the other hand on work by ecological scientists on concepts such as territory, habitat, and niche.

1. Environments: Types and Tokens

An environment is in first approximation a volume of space; it is a specific habitat, location, or site that is suitable or adequate for given purposes (of foraging, resting, hunting, breeding, nesting, grooming) in the life of an organism or group of organisms. This spatial notion of environment can be drawn closer to biological and ecological science by taking account of the pertinent physical attributes realized within given spatial regions. Each type of organism is associated with a certain array of environmental conditions, for example: degree of slope, exposure to sunlight, soil fertility, foliage density, size, proximity and type of predators, and so on. Following Hutchinson [6], we can conceive this array of conditions as determining a hypervolume in an abstract many-dimensional space. Every point or region in this hypervolume corresponds to a *niche* in the technical ecological sense: a state of the environment which permits the members of a given species to exist indefinitely.

Biologists, of course, are interested, not in individual organisms and their environments, but rather in statistical laws and regularities, and thus also they are interested in genotypes and phenotypes rather than in genotokens and phenotokens. For the purposes of biological theorizing organisms

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are intersubstitutable: one phenotoken is as good, or as bad, as any other, in reflection of the fact that it is on the level of statistical regularities that adaptation and selection occur. Biologists are interested similarly in niche types and not in niche tokens. It is niche types which are at work for example in such general laws as Grinnell's competitive exclusion principle [4] (which states that, in competition between species that seek the same ecological niche, one species survives while the other expires). And it is niche types which are at work in Hutchinson's distinction between the fundamental and the realized niche, the former being defined as the total multi-dimensional array of environmental conditions under which a given species could live and replace itself, the latter as that portion of this total array which is actually suited for that species at a given time, for example because competition excludes it from other portions.

The ecometaphysician will insist, however, that there is no type without a token, and that tokens, whether of organisms or of environments, are in any case of considerable interest in their own right. In our paper "The Niche" [12], accordingly, we sketched a framework within which token niches (and, more generally, token environments) can be understood as the projections of corresponding niche types into the volumes of space occupied by given organisms. A niche in this token sense is in every case the niche of some organism or group of organisms of some given type, and in our account the relation of fit between a token niche and its tenant is essentially a formal relation—a relation capable of being specified with the aid of basic concepts of mereology, topology, and the theory of location [2]. In the present paper we extend this account by providing more detailed analysis of the internal structures of token niches and of how this determines the causal relations between niches and their surroundings.

2. The Structure of Niches

Consider the bear in its cave (Figure 1). There is manifested here what we might think of as a double hole structure. In the center of this structure is the bear itself, which, by displacing air, at one and the same time creates and occupies a *central hole* in the region of space that it occupies—a hole that is precisely the right size and shape to be occupied by this very bear. (On holes and their fillers see [1].) Surrounding the bear is a *medium*—in this case air—which allows the bear to move and breathe and to leave and enter the cave. Surrounding this medium in whole or in part is an enclosing structure, or what we shall call a *retainer*, which in the present case is constituted by the walls, roof, and floor of the cave. We can accordingly think of the medium as filling a second, larger hole—an *environing hole*—that is exactly as large as the interior of the cave, minus the bear.

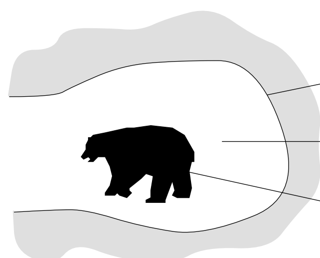

Figure 1. The double hole structure instantiated by the bear in its cave.

Most token niches, we submit, exhibit a double hole structure of this sort. The medium of a niche is what results when a given spatial region (of given altitude, orientation, exposure, etc.) comprehends air or water molecules or some other stuff which instantiate environmental properties (of temperature, pressure, viscosity, etc.) which fall within the threshold values determined for the organisms of the corresponding type. And the retainer contributes a physical demarcation between the medium and the outer world, blocking or channeling different types of causal flows and thereby bringing it about that a certain niche type is instantiated in the relevant region of space.

3. The Medium for Life

The medium is that into which the tenant fits—it is that which occupies the environing hole of the niche. Media are, in our technical sense, necessarily such that they exist only within the context of niches. Indeed, a body of air or water constitutes a medium in this technical sense only relative to a given type of niche, and thus only relative to a given type of organism. It is the type of organism which fixes the relevant hypervolume of environmental properties which the medium exemplifies.

Consider, now, what happens when a tenant leaves its niche. It seems to be a characteristic feature of such cases that the gap left by the tenant, or by any other object that is removed from the niche, is filled immediately by the surrounding medium. Modulo the elasticity of the retainer (consider the kangaroo joey leaving the pouch of its mother), this is an operational test for being a niche medium. If Luigi is buried in a hole filled with concrete, the latter is not a medium, because it does not pass our operational test. Luigi, accordingly, is not in a niche. If, as we are arguing, every niche has a medium of the appropriate sort, then there are for this reason no niches in cases where inanimate bodies of dense matter are housed within immediately surrounding bodies of dense matter (as Michelangelo's *David*, for example, was once housed inside a solid block of stone). The operational test is, on the other hand, complied with in the case of, say, a valve in a piston or a jewel in a jewel box. In such cases we are still able to apply the basic niche concept even though the pertinent tenant is not alive.

Typical examples of media are air, smoke (and gases in general), water (and liquids in general). Water—in contrast to air—may serve in some circumstances as medium and in other circumstances as (partial) retainer, for example as the horizontal underlying support for the niches of small flies above the surface of a lake. Rarely, however, will the medium of a niche be constituted in homogeneous fashion of a single stuff. Rather, terrestrial token niches will standardly involve *mixed* media, sometimes hugely diverse combinations of air plus water plus other nutrients and impurities, including radioactive impurities, as well as vitamins, amino acids, salts, and sugars in which organisms of different sorts, from protozoa to large mammals, live.

Every medium is in fact a mixed medium in the sense that every medium involves, in addition to particles of matter, some intervening empty space. A medium is constituted out of space and matter in such a way that the tenant may move freely within it. And we shall suppose that the same medium may be constituted out of different matter at different times (as with every material body, there may be a turnover of particles). Note that we speak here of 'constitution' rather than of 'identity'. This allows us to remain neutral with regard to the question whether the medium is to be identified with the relevant portion of space and matter or whether the same space and matter may constitute two or more distinct media which would then share the same location. (Compare the essays collected in [10].) Consider a small island which supports simultaneously two populations of seed-eating and insect-eating birds. Or consider a mud-dwelling bacterium which shares a location with a sea-bottom-dwelling fish such as a sculpin. The bacteria are sensitive primarily to the viscosity and turbulence of the surrounding medium and are affected hardly at all by the force of gravity. For the sculpin, in contrast, gravity is more important than viscosity and turbulence. If the relation of material constitution is nothing but identity, then we would have to account for cases such as this by conceiving different types of niche as being instantiated by the same token. If, on the other hand, constitution is not identity, then different niche types would have different niche tokens which would be, as it were, superimposed one upon the other.

4. Retainers and Fiat Boundaries

Given any niche token, then, it is its mixed medium that is at any time the carrier of the properties represented in the corresponding niche type. The job of the retainer is to protect or demarcate the medium and to ensure that it satisfies those properties. In this sense the retainer of a niche functions as a causal barrier, in a way analogous to the skin or hide or an organism. The very geometry of the retainer-medium-tenant configuration is determined by this causal function: the medium surrounds the tenant, and the retainer surrounds the medium demarcating it from the outer world.

Not every niche, however, involves a complete demarcation of this sort. Consider once again the niche depicted in Figure 1. Inspection reveals that the environing hole in fact has two sorts of boundary: a solid physical boundary, corresponding to the retainer, on the one hand; and what we have elsewhere [13] called a *fiat* boundary (illustrated by the broken line in Figure 2), on the other. The latter is a boundary which corresponds to no physical discontinuity in the underlying material of the niche in question and to no qualitative heterogeneity in its surroundings. Fiat boundaries of this sort are similar to those which delineate connected body parts (such as your hand and your arm) or geographic features (such as bays within their surrounding seas or seas within surrounding oceans) [11]. In our present case, the fiat boundary at the mouth of the cave supplements an associated retainer in such a way as to form a complete surrounding boundary that is analogous—topologically—to a sphere.

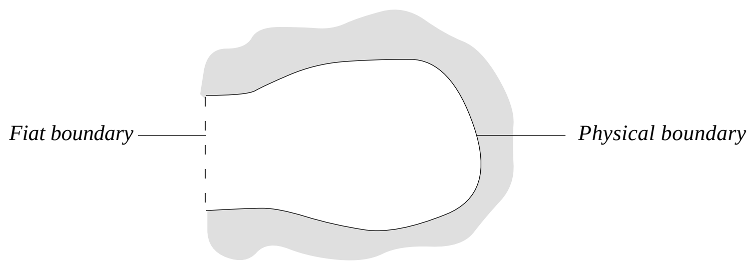

Figure 2. Two types of boundary.

Most developed niches (a cave, a shell, a nest, a house) are bound partly by a physical retaining boundary and partly by a fiat boundary of this sort. When the bear leaves its cave or the squirrel leaves its dray, however, then it enters a niche whose physical retainer is a much more heterogeneous structure involving the surfaces of the relevant trees, leaves, meadows, rivers, ice floes, and so forth. There are also cases where the boundary of the medium is entirely of the fiat sort. Consider, for example, a skylark flying high in the sky, or an open ocean fish. Here, too, in certain circumstances we may speak of the bird or the fish as being in a niche, and here, too, we can recognize a double hole structure. However, in such cases the environing hole appears not to be determined or supplemented by solid physical boundaries at all, for there is no relevant solid retaining object. We should rather think of the boundary around the medium of the bird or of the fish as a fiat boundary delineating a bubble-like (often cylindrical) zone or volume of space in which, at any given time, the bird or fish is housed.

Such fiat boundaries are indirect by-products of the behavior patterns of the organisms involved. This means, inter alia, that they are affected by the phenomenon of vagueness. While it may be determinately true of certain regions that they fall within the interior of the niche for the fish, and determinately true of certain other regions that they fall within its exterior, there will standardly be no sharp line which constitutes a single (fiat) boundary of the niche in question. Rather, it may be that we have to deal with whole families of bubble-like nested regions which form dense concentric clusters, each of which might at any given time qualify (perhaps to variable degrees) as the location of the relevant token niche.

5. Security vs. Freedom of Movement

Organisms of different types and at different stages of their development will embrace different strategies in regard to the demands of security and freedom of movement in their interaction with the outside world. Common plants, for example, enjoy a maximum of protection in the earliest post-germination phases of their existence (when they are underground) and a minimum thereafter, combined with a negligible freedom of (self-moved) movement at every stage. Snails build their own protection in the form of a shell around themselves. And barnacles gain further protection by bonding themselves to a solid surface, thereby sacrificing freedom of movement almost entirely.

This suggests a classification of niches according to the type of their exterior boundary and thus according to the degree to which their media are protected by the isolating power of solid niche retainers. We distinguish four main classes, as follows (see Figure 3).

1. At one extreme we find niches that are fully bounded by a retainer. A niche of this class is an ideal niche from the perspective of protection—a perfect *cavity*, physically protected in each direction and in relation to each pertinent family of intruders or impurities. Examples are: a closed oyster shell, a submarine, a car, a nuclear clean room facility, an incubating tent. We may include here also niches such as a fine-mesh cage, whose surrounding physical structure, though incomplete in some degree, is sufficiently dense to supply a protective retainer which fully circumscribes the relevant niche. Class 1 niches can be subdivided into those whose retainers offer full protection without access points (a full passive defense, such as that provided by a larval cocoon) and those with defended access points (such as an oyster shell, which must actively keep its shell closed to prevent predators from prying it open). The degree of protection, in turn, will depend on the physical properties of the retainer: the walls of the crocodile's egg, for example, have a higher protective value than the thin membrane which is the *zona pellucida* of the mammalian zygote.

2. Most niches are, like the bear's cave, not fully bounded, but rather bounded only to a certain degree. Examples are: a kangaroo-pouch, a nest, a hive, a cabriolet. All of these are niches which, geometrically, do not involve closed cavities but rather natural or artificial *hollows* within their respective environments, with a fiat boundary marking (more or less vaguely) the

opening. Nevertheless they are for a range of different reasons fairly robust from the perspective of protection. Trenches (in battlefields) are of this kind. We may further include in this category niches with multiple openings—*tunnel* niches—such as a person's stomach (which can be a niche for a parasite) or a path cleared in the jungle (which can be a niche for hunters).

3. Some niches are bounded by a partial retainer which offers no or a very low degree of protection—by a floor, for example, or by a single wall. This is the case of the niche around two people chatting on the sidewalk (bounded by the pavement) or the niche of the oxpecker removing ticks from the back of an African rhinoceros (bounded by a part of the rhinoceros's hide). We may include in this category also niches which are bounded on two sides: consider a pedestrian with an umbrella.

4. Finally, at the other extreme of the continuum between bound and free we find niches which lack a retainer altogether. Such niches are bubble-like zones in the relevant region of space, as in the case of the niche of the open ocean fish. This class of niche, too, may manifest a range of different topologies. When a falcon is flying in the sky circling above the area where its prey is to be found, the niche of the falcon is its orbit, a torus-shaped region that is bordered, again, by boundaries of the fiat sort.

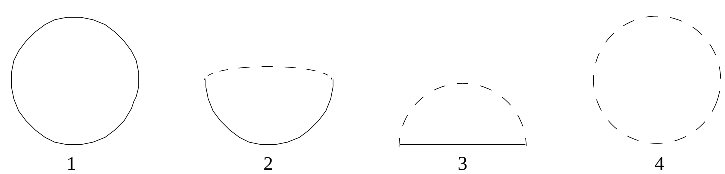

Figure 3. The four basic niche classes (seen from the side). A solid line indicates a physical retainer; dotted lines indicate fiat boundaries.

As will be clear from the examples considered, our classification is a simplification of the range of cases actually realized in the three-dimensional world. It is simplified not least in that it does not do justice to the ways in which the physical boundaries of niches—particularly of higher organisms—may involve *mixed* retainers, which is to say retainers blocking or channeling causal flows of different types. Thus for example both walls and windows may be part of a single retainer. Often, a niche of class 2 can be transformed into a niche of class 1 by adding a plug- or door-like structure or by augmenting the surroundings in such a way as to replace all fiat boundaries by boundaries of the physical sort. More generally, one can move along the continuum by adding or removing portions of the relevant retainer. Thus, niches of classes 2 and 3 are topologically equivalent, but they differ from the perspective of protection. As we saw, the freer the niche, the easier it is for the tenant to move out of it (for example when fleeing from predators).

We may further subclassify niches of classes 1 through 3 into those which are stationary (a larval chamber; a rabbit hole; a meadow) and those which are mobile (a womb; a snail's shell; the back of a rhinoceros). It seems however that class 4 niches can only be stationary: in the absence of a retainer there is no mechanism whereby the medium would follow the tenant (so that the niche would be as it were dragged along with the tenant) as the latter moves from place to place. Hence with each step the organism must reconstitute a new medium for itself in a process which will standardly occur spontaneously, as in the case of the fish in the ocean or the bird in the sky.

6. Niche Construction

The history of evolution is, in part, a history of the passage from organisms with very simple (often to a significant degree fiat) niches, which arise automatically in virtue of the actions of the organisms in question, to organisms with complex, physically walled niches which reflect the hard work of construction of materially dense retainers of appropriate types. Niches of the latter sort have the advantage that they can survive for longer or shorter periods even in the absence of a tenant. Moreover, their greater survival-capacity, sometimes extending across generations, can justify the investment of ever greater quantities of energy and resources for the purposes of niche-embellishment.

Niches thus arise in many cases as a result of symbiosis between organisms and the tracts of the environment which they occupy. This is especially true in the case of niches of classes 1 and 2, that is, niches with a physically protecting retainer. In such cases, the building of a niche (what some call "ecosystem engineering" [8]) is a complex process that typically involves activities and metabolic processes through which an organism or population modifies the environment. This process involves changing properties of the surrounding environment—as for example when animals build houses and nests. They may then work hard to improve or repair their niches, in relation both to media (as when you turn up the heating in your tent) and retainers (as when you mend the roof of your house). We can in this light then distinguish intuitively between felicitous niches, within which organisms flourish, and critical niches, within which organisms fail to flourish, sometimes catastrophically. A niche is felicitous if, and only if, for every dimension of the relevant hypervolume the relevant variables are within the threshold values.

Constructing a niche typically involves the building of artefacts, as when a bird builds a nest or people build houses. In many cases, however, the niche is not an artefact—not a new, positive object in its own right, but rather merely the modification of a pre-existing habitat, as when a worm creates a wormhole or an insect chooses a water-filled cavity as site for oviposition [7]. The case of plants is somewhat intermediate between these two. The niche of a plant is the result of a continuous process which changes relevant environmental factors such as exposure to sunlight and the chemical composition of the soil, while at the same time taking advantage of the solid and enduring retaining structure which this soil provides [3, 5].

The theory of the construction and maintenance of niches is of more than merely philosophical significance; it is important also for evolutionary theory. Recent work suggests that niche construction may result in selective processes that outweigh other sources of selection, sometimes to the point of generating novel or unusual evolutionary outcomes. Some ant and termite species, for instance, have developed the habit of plugging the entrances to their nests at night in order to regulate temperature. It has also been argued that niche construction may influence the genetic variation in a population. Adaptation, under such conditions, ceases to be a one-way process determined by environmentally imposed problems and becomes a two-way process of natural selection and concomitant environmental modification [9].

7. From Ecometaphysics to Environmental Ethics

The theory outlined above is designed, not as a substitute for biological science, but rather as a contribution to its ontological foundations. It might be conceived as analogous to set theory as a theory of the ways in which mathematical structures—above all structures designed for use in physics—

relate to concrete objects in reality. Thus the theory is not concerned with the task of formulating laws or regularities of a biological sort, for example via averaging or other quantitative techniques. Rather, it deals in ontological principles to the effect that, for example, there is no niche without a medium, there is no medium without a tenant, and so on. Thus also it deals with aspects of the environments in which organisms live which are so fundamental (or so trivial) that biological science has tended to ignore them. Such a treatment of the ontology of environments may be of importance in many different areas. Theories in ethics, for example, have in many cases rested on some developed ontological conception of the bearers of ethical significance, for example in the form of a metaphysics of persons or communities, or of a theory of actions or motives. Current developments in the realm of environmental ethics are we believe in need of a similar metaphysical explication of the central category of environment and of the associated organism–environment relationship. Only then, we would argue, will philosophers in this field be in a position where they can raise questions concerning the ethical significance of such formations in a correspondingly systematic framework.

Acknowledgments

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