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Ecological laws of perceiving and acting: In reply to Fodor and Pylyshyn (1981)*

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1. Introduction

This paper is both a reply to Fodor and Pylyshyn (1981) and a systematic explication of one of Gibson's (1979) basic claims, namely, that there are ecological laws relating organisms to the affordances of the environment. Gibson's theory of affordances holds great promise for psychology for a number of reasons: it provides a framework for the precise formulation and testing of hypotheses about behavior and perception (*e.g.* E. J. Gibson, in press; Johnston and Turvey, 1980; Lee, 1980; Shaw and Bransford, 1977); it suggests a way to integrate the phenomenological and mechanistic aspects of psychology without succumbing to either one-sided point of view (Reed, 1980; Runeson, 1977; Shaw *et al.*, in press; Turvey and Shaw, 1979); and it promises to put psychology back on the track of seeking lawful relations—as Gibson (1967, p. 122) once said, in science "You either find causal relations or you do not".

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Fodor and Pylyshyn's (1981) most important argument is that, contrary to Gibson's theory, there cannot be lawful relations between organisms (as epistemic agents) and their environments. Fodor and Pylyshyn do not think *any* psychological theory can be grounded in laws of nature, although they admit as valid Gibson's hypothesis that if affordances were lawfully specified in ambient light, then direct visual perception of affordances would be possible. Because Fodor and Pylyshyn place such a great emphasis on Gibson's claims about ecological laws, and because they evaluate Gibson's claims in the terms of the philosophy of science—terms in which Gibson's claims have neither been criticized nor defended previously—our focus is this aspect of the ecological approach. We will give support to the notion of ecological laws and show how the problems of intension and intentionality are addressed in their context. At bottom line, our claim is that the ecological approach is a scientifically tractable approach to cognition and that what passes as the Establishment's approach, the one championed by Fodor and Pylyshyn, is not. Readers interested in other, less philosophical, aspects of the ecological approach to psychology should refer first to Gibson (1950, 1966, 1979) and Michaels and Carello (1981), and then to references cited in the text.

2. Gibson's ecological approach in overview

It is not obvious that Fodor and Pylyshyn are addressing the same subject matter as Gibson and the proponents of his ecological approach. To the extent that they are not, their arguments against Gibson miss the mark. This section of the paper is addressed to the failure of Fodor and Pylyshyn to make contact with Gibson's approach and, *a fortiori*, their failure to present an accurate account of Gibson's enterprise for those unfamiliar with it.

The ecological approach to perceiving (and acting) was developed by James Gibson, over more than thirty years, as a framework that would do justice to the practical success of an organisms 'everyday' behavior[1]. The per-

[1] This objective is not to be confused with positions that make frequency of occurrence of behavior their primary subject matter. Fodor and Pylyshyn comment that "the goal of psychological theory construction is not to predict most (or even all) of the variance (p. 21)" as a reply to the Gibsonian stress on successful activity. They seem to think that Gibson was the Skinner of perception, as they intimated even more strongly in their Footnote 2. However, they are not Chomsky to Gibson's Skin-
(continued on facing page)

ceiving that this approach is meant to capture is that entailed by organisms' orientations (cf. Jander, 1975) and adjustments of activity to their environments. It is the perceiving required to support running, flying, building, grasping and so forth. Gibson argued that the proper "objects" of perceiving are the same as those of activity. Standing still, walking, and running are all relations between an animal and its supporting surface. Though not always explicitly recognized (Fowler and Turvey, 1978), the supporting surface is just as much an essential constituent of these activities as, for instance, legs; and useful perceiving involved in controlling posture and locomotion must be directed toward the same surface. Thus it would seem that a two-term relation involving the same surface or ground can exist in both cases: an animal *runs* on the ground and an animal *sees* the ground. This much should be common sense. There is no thing *between* the animal and the ground in the relation. This is what Gibson has always meant by direct perception and it is the same as what one would mean by direct action if one were discussing activity.

What begins as common sense does not remain common sense in the light of philosophic and scientific analyses of perception. Conditions of causality and meaningfulness have dictated other types of objects such as retinal images, retinal patterns, or representations. Thinking of perception as *mental* events, divorced from activity, reinforced the theoretical interpretation of such objects as objects of perception, *between* an organism and its environment. It does not take many examples of "illusions" and geometric decompositions of patterns to convince students that they do not see the environment, but some proximal surrogate. Bringing activity back into the story creates a dilemma, however. Organisms do not stand on or fly among images and representations. Images and representations are not the kinds of things that can be objects of "physical" activity. But if this is true, how might perceptual control of activity be accomplished?

Gibson worked to establish a framework that would support both scientific analysis and the direct relation between a perceiving organism and the objects of its perceiving; that is, he sought a framework within which one

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ner. The point of mentioning the frequent practical success of perception is to draw attention to commonplace facts that are so ordinary that they are taken for granted and often ignored in sustained inquiries concerning perception. Just as Chomsky used the regularity and ease of natural language acquisition as a fact to justify treating language as a special subject matter, so Gibson and his followers have argued for the importance of doing justice to natural, effective perception. Thus, if one pursues an analogy to Chomsky's work in linguistics, the proper counterpart to the Gibsonian emphasis on commonplace activities is the selection of natural language as a special subject matter—not frequency of occurrence of types of utterance.

could do justice to the facts of both acting and perceiving without "between-things" (Shaw and Turvey, 1981). How one devises such a framework is not itself obvious. Gibson had to offer a new construal of most of the major sub-problems impinging on perceptual theory, as noted in the five points of his list of theoretical innovations quoted by Fodor and Pylyshyn and as discussed in Mace (1977).

Gibson's ecological approach to perception can be summarized succinctly in terms of a major denial and a major assertion, both implied in the foregoing, *viz*., the denial of mediating objects between an organism and its environment and the assertion of the intentionality of perception.

The claim that perception does not involve inference is a corollary of the denial. Gibson rejected the idea that organisms have to infer the properties of their environments (or even the existence of their environments) from the properties of other, putatively more primary, objects. Emphasizing Gibson's focus on the issue of perceptual objects is critical because "direct" and "indirect" when applied to perception are contrastive terms whose meanings depend heavily on one another, and Gibson's style was one of careful contrast. As Austin (1962) pointed out, the dependence is not fully symmetric. It is "indirect" that "wears the trousers" and "'directly' takes whatever sense it has from the contrast with its opposite" (p. 15). It is clear what Gibson meant by "indirect" and it was in opposition to this that he established his meaning of "direct".

Consonant with Gibson's contrastive style we emphasize a central contrast between the Establishment's characterization of perceiving, as given by Fodor and Pylyshyn, and Gibson's ecological characterization. The Establishment takes its topic to be the fixation of a type of belief: perceptual belief. Thus natural problems for the Establishment would be how one sees a particular shape as a man, as the Lone Ranger, as Tonto's best friend, *etc*. In the ecological approach the latter do not represent a coherent set of examples. Rather, the subject matter is causally constrained by what can be specified in the light (for vision). Fixing the subject matter itself belongs to the scientific realm of argument, subject to empirical test and theoretical progress. Further, because the ecological approach is concerned with the perceiving that goes with acting, the canonical examples are very different from those of the Establishment (as will be evident in the sections that follow). As one writes pages of a manuscript, for instance, the body must be held in a posture that will allow an effective orientation of the head, eyes, arm, hands, and fingers to the desk, pen, and paper to allow writing. Although the writer's primary awareness is directed toward the words needed to express intended ideas, the coordinated posture of the writer's body requires the nested perception of the environment relative to the nested bodily structure. Fodor and Pylyshyn's kind of perception involves clear beginnings and endings. Gibson's kind of perception occurs in nested episodes. Thus one may change some of the details of head and body orientation without disrupting the flow of writing. One might stop, stand up, and walk around the room while preserving the larger orientation of being *in* the room. One might remain oriented vertically to the horizontal ground through the flux of an entire day until one goes to sleep at night. Fodor and Pylyshyn, as Establishment theorists, concentrate on how one *takes* the stimulus environment, appealing to verbal labels of experience to lead the way in delineating subject matter. When the concentration is shifted to perceptual guidance of activity, however, it is clear that most of this continuous, nested perceiving lacks words for referring to it. There are words to talk about the focus of an activity (*e.g.*, writing) but not about the myriad details of perceiving required to control the activity successfully. In sum, Fodor and Pylyshyn's kind of perception (in *percepts*) is whatever eventuates in a perceptual judgment or belief. Gibson's kind of perception, in contrast, is that which eventuates in the "proper" adjustment of oriented (to various levels of the environment) activity.

We now turn to Gibson's major assertion, one which he took very seriously. Gibson never reduced perception to non-intentional activity. "Perceiving," Gibson argues, "is an achievement of the individual, not an appearance in the theater of his consciousness. It is a keeping-in-touch with the world, an experiencing of things, rather than a having of experiences. It involves awareness-of instead of just awareness. It may be awareness of something in the environment or something in the observer or both at once, but there is no content of awareness independent of that of which one is aware. This is close to the act psychology of the nineteenth century except that perception is not a mental act. Neither is it a bodily act. Perceiving is a psychomatic act, not of the mind or of the body, but of a living observer" (1979, pp. 239–40). Fodor and Pylyshyn read Gibson's theory as a theory of mere awareness when it is, in fact, a theory of *awarenesses-of*. The erroneous reading is precipitated, perhaps, by the fact that all previous scientific theories of perception have attempted to reduce perception as an achievement to perception as an awareness, where awareness is not awareness-of, but is merely a relation to a mental content (representation).

The father of Act Psychology, Brentano, had an insight that is often expressed as: "intentionality is the distinctive characteristic of the mental". By this, Brentano meant (among other things) that *directedness towards objects* is a feature of living things. Often this claim is taken to mean something quite obscure, but a clear and scientifically acceptable meaning to Brentano's insight can be given and has been expounded at length by Merleau-Ponty (1962, 1963), Searle (1980) and Gibson (1966, 1979). It might be termed the "ecological concept of intentionality" (for want of a better phrase) because it takes the word "object" in discussions of intentionality much more prosaically than is usually done; it means simply the things that populate an environment.

The intentionality of visual perception can work only by explaining how organisms can "come into psychological contact" with objects with which they are not in physical or, more aptly, mechanical contact. Solving this problem of perceptual "action at a distance" is the function of Gibson's theory of ecological information for perception. As Gibson (1975, p. 310) once wrote in reply to a critic:

> "When Boynton (1975, pp. 300–1) asserts that 'we are not in visual contact with objects, or edges, facets, faces or textures, we are in contact only with photons' this assertion is loaded with epistemology. It is a strictly philosophical conclusion. I disagree with it. There is a misunderstanding of the metaphor of visual contact, one that goes back to Johannes Muller, and it is one that I discussed repeatedly in *The Senses Considered as Perceptual Systems* (1966). It leads to the doctrine that all we can ever *see* (or at least all we can ever see *directly*) is light."

The philosophical assumption underlying virtually all research on vision, and underlying all criticisms of Gibson, is that visual contact must be reduced to a physical or mechanical contact of the sort described above. Thus the intentionality of vision is claimed to be only *apparent*, and is reduced by assumption to causality of an absurdly simply sort. For centuries students of visual perception have been asserting that all that organisms ever see directly is light because (they claim) only light comes into contact with the ocular apparatus of organisms. The fact that critics of Gibson (*e.g.*, Ullman, 1980) repeatedly ask how it is that optimal information gets "into" the organism shows that this simplistic doctrine of physical contact is still being invoked as the material basis of psychological contact. Thomas Reid long ago, and Merleau-Ponty more recently, showed the fallacy underlying this reduction of psychological to physical contact. It is the fallacy of assuming the consequent: if it is assumed that psychological contact must be reduced to *already known cases of physical contact,* then it can be proven that psychological contact is a kind of physical contact. Gibson rejects this philosophical prejudice against the intentionality of psychological contact. If science is to explain how perception is an awareness of objects in the environment then, instead of assuming that it is based on contact between light rays as material things and eyes as material things, science had best *discover* what sorts of material entities could actually give rise to or account for such intentionality.

Light rays do *not* specify the objects with respect to which organisms behave, so the idea that the light is all one organisms can see must be rejected. Perhaps there *is* information *in* light, in the sense of information specifying its source in the environment. This conjecture, dating from around the mid-1950s (see Gibson, 1960), is the origin of the ecological approach to vision. Fodor and Pylyshyn misunderstand Gibson's claims about information and specificity. They have treated his new empirical hypothesis about specificity as some sort of (incorrect) logical claim or argument, based on mere prejudice. But one cannot disprove an empirical hypothesis by *assuming* that it is an incorrect logical claim. The only sound way of testing Gibson's new theory of specificity is to generate hypotheses from it, and to test them. The fundamental hypothesis of the ecological approach to vision, elaborated at great length by Gibson (1966, 1979) is that optical structure specifies its environmental source and that, therefore, mobile organisms with active visual systems that can pick up this information will see their environments and suitably adjust their activity, if and when they detect that information (and only then).

Gibson's view of the organism as active perceiver is characterized by terms like isolating and differentiating, as well as by the metaphors of hunting and clarifying (see Boring, 1967). In a real environment, an organism can choose (within limits) how much and which meaningful details to clarify. There is no definite limit to the possible detail to explore. Fodor and Pylyshyn make a great deal of the fact that organisms (especially people) often draw conclusions about a situation that appear to be more specific than the available optical information about that situation. They ridicule the idea that more sampling of optical structure can clarify a situation on the grounds that this idea introduces an arbitrary, unconstrained move that opens the door to a trivial interpretation of Gibson. But in a natural environment the invariably-present option to sample further is an absolutely essential aspect of the adaptive behavior of organisms and, therefore, of the ecological approach to perceiving and acting. Most assuredly, part of visual perceiving is the ability of an organism to change and select samples according to its current challenges (needs, desires, *etc*). Controlling such changes in an environment requires perceiving changes with appropriate directionality, such as perceiving the prey coming into view or the predator going out of view. It is difficult to understand why Fodor and Pylyshyn think that the opportunity to extend the sampling of optical structure is so arbitrary when it is so integral a part of the daily living of mobile, seeing organisms. Admittedly, there would be a great deal of slop if the problem for the scientist was to predict *when* an organism "decided that" something was an enclosure or a falling-off place.

But if it is an overlapping, nested set of possibilities for activity that is being oriented to in perceiving, orderings on a dimension of levels of clarity can be approached systematically and not arbitrarily. Clarity, we should note, is not tantamount to sharp edges but rather to 'enough' information to pursue the ongoing activities. And the pickup of information, we should note (in reiteration of a point above), does not eventuate in judgment but in the 'proper adjustment of activity'.

In sum, what Gibson's ecological approach wishes to account for is an organism's apprehension of its environment and how it controls its acts with respect to that environment; that is to say, an organism's apprehension of the environment taken in a way that is relevant to the resource requirements of the organism. The issues of what counts as perception, whether or not perception should be construed as judgment, whether perception is direct or indirect, and the place of inference in the scheme are secondary. If it can be assumed that Fodor and Pylyshyn would grant the proponents of the ecological approach that, ideally neutral, statement of a goal[2], then the overarching question takes the form: "can a theory get there from here?". Fodor and Pylyshyn argue that Gibson's ecological approach cannot do the work that it is meant to do because it lacks the necessary resources of inference and representation. They maintain that Gibson tried to get the job done with notions of direct perception, invariant, and information that are so unconstrained that the theory is left open to trivialization.

To counter, we hold that it is the Establishment position that is insufficiently constrained. The main constraint that Fodor and Pylyshyn offer is that direct access to environmental states of affairs is limited to physical outputs of transducers linked to the basic descriptors of an energy type. This gives them *one* clear idea, but it then leaves a burden on inference which we argue (in Sections 3 and 11) inference cannot bear. Our strategy, as proponents of Gibson's ecological approach, is to argue for a conception of natural law that allows meaningful relations between organism and environment to hold. Further, we constrain our use of the term 'perception' (and thus, of course, 'direct perception') to relations governed by such laws. Establishment theorists have a much looser usage of 'perception' which includes perceptual beliefs and judgments (cf. Fodor and Pylyshyn's Footnote 9). We are perfectly willing to admit that inference exists in cognitive life, but we

[2] This is the basic goal of the ecological approach because it is assumed that perception in the service of activity and orientation is the evolutionarily primary kind of perception. Having reached some understanding of this kind of perception, the ecological approach would then address the other varieties of awareness (see Gibson, 1979, p. 255 ff).

wish to keep it separate from perception. We take it that the evaluation of beliefs about environmental states of affairs ordinarily rests on *evidence*. But Fodor and Pylyshyn, like Establishment theorists in general, have no discussion of evidence at all. The issue is dismissed, apparently, as one involving the *justification* of perceptual beliefs rather than the *causation* of perceptual beliefs. This dismissal is very odd given that they argue that "The psychologists' topic is the causation of perceptual beliefs...". Our assumption, on the contrary, is that the evidence of perception most surely plays a role—probably the major role for almost all organisms—in the assessment of belief. The well-motivated need to have a non-inferential source of evidence for belief is one of the reasons proponents of the ecological approach (Shaw *et al.*, in press; Turvey and Shaw, 1979) have argued that perception should be regarded as nonpropositional. This argument—termed "suicidal" by Fodor and Pylyshyn—receives support from other quarters (*e.g.*, Barwise, in press; Dretske, 1969).

It is evident, in short, that both the Establishment and the ecological approach recognize that both natural law and inference (of some sort) play a role in the "cognitive" life of at least some organisms. The two positions differ on where to draw the line. Ecological theorists seek to extend the application of natural law as far as possible, in part because that strategy promises a method of tight constraint (see Kugler *et al.*, 1980, in press) and in part because we can hope, thereby, to explain the lawful evolution of inference in a scientifically principled way. Establishment theorists, on the other hand, apparently want to extend cognition or intelligence as far as possible, choosing to limit the role of natural law. Regularities, then, must be accounted for by mental rules and representation—which are themselves constrained by very little except unsystematic intuitions and by whatever data a theorist chooses to model. The following Section highlights the logical shortcomings that infirm the Establishment's position on perception.

3. The infeasibility of the Establishment view

The Establishment view is grounded in the following two assertions:

Assertion 1: An animal by virtue of its physical makeup is linked nomologically to the conventional physical properties of light, sound, molecular distributions in the air, *etc.*

Assertion 2: An animal by virtue of its intellectual makeup is linked *non*-nomologically to the behaviorally significant properties of the surrounding surfaces and substances.

These two assertions underly the Establishment theory that perception should be described as an inferential process from evidence statements (couched in the restricted vocabulary of predicates referring to putatively basic energy variables) to belief statements (couched in the indefinitely large vocabulary of predicates referring to activity-relevant properties of the environment).

On the Establishment view there are two sides to the evolution of perceptual capacity (in accord with the above assertions): evolution must (a) produce living things that are selectively sensitive to the basic descriptors of one energy form or of several energy forms and (b) provide living things with the conceptual basis needed to make correct inferences from the basic energy descriptors to the survival relevant properties of their environments. The conceptual basis must include concepts that stand for environmental properties and concepts that stand for how those properties structure energy distributions in media (Turvey and Shaw, 1979). As Fodor and Pylyshyn express it, how an animal gets from properties of the light to properties of the environment is to "infer the latter from the former on the basis of (usually implicit) knowledge of the correlations that connect them". They should have added "and on the basis of (usually implicit) knowledge of the kinds of things that populate the environment".

Presumably how evolution meets the challenge of Assertion 1 would be addressed by physical theory. After all, a biological transducer of an energy variable is an aggregate of physical entities—molecules—rendered as a single functional unit by a constraint that, initially low in selectivity and imprecise in function, gradually sharpens up to high specificity and narrow precise function. Obviously the requisite physical theory would have to subsume an answer to the question of how constraints arise spontaneously—how definite structures or regularities arise in physical systems that are initially homogeneous or, more generally, how it is possible for new dynamic restraints to originate in a physical system where the system's present state variables and dynamical equations completely determine the system's future state variables (Pattee, 1971, 1972, 1973). A careful analysis of thermal processes under boundary conditions of the sort that can be met terrestrially reveals that the tendency for molecules to organize is a very general property of a certain class of physical systems and is not indigenous to living systems. Molecular organization is not uniquely biological; rather it is a general feature of all energy flow systems (Iberall, 1977; Morowitz, 1968, 1978; Prigogine and Nicolis, 1971). Molecular organization of the kind found in transducing elements is not a property of biological systems but rather is a property of the environmental matrix in which biological systems can arise and be maintained. Energy flux (from a high potential energy source to a low potential energy sink through an intermediary collection of matter) is a self-organizing principle that is at the core of the major physical theories currently addressing the basics of biological organization as thermodynamic phenomena, namely, Homeokinetic Theory and Dissipative Structure Theory.

Insights such as these about self-organizing systems coming from non-equilibrium thermodynamics vindicate the widespread applicability of physical principles throughout the evolving cosmos. Although there are laws of nature that apply only to a biological scale this does not mean that there is any fundamental dichotomy between biology and physics (Reed, in press *b*). The principles are common to both scales (Iberall, 1977; Morowitz, 1968; Yates, 1980 *a*). A quarter of a century ago, such a separation of biology from physics was being promulgated authoritatively (Elsasser, 1958). In recent years, the centuries-old dualism of psychology and physics has been revived, and two of the more vociferous proponents of this dualistic view are Fodor (1975, 1980) and Pylyshyn (1980). As will become apparent, Assertion 2 of the Establishment view entails a dualistic approach to psychology. We will argue that these recent endorsements of dualism reduce, if not destroy, the scientific credibility of psychology and that the dualistic position is based, in no small part, on a mistaken conception of what counts as a lawful relation.

It is important to underscore the relation between a physical theory of evolution in non-equilibrium, non-conservative systems and the theory of evolution synthesized from Darwin and the results accumulated in molecular biology. The latter theory presupposes, at a minimum, self-reproduction, self-maintenance, selective irritability to significant energy dimensions and directable motility (Prigogine *et al.*, 1972; Reed, in press *a*). Therefore the explanation of the *basic* properties of living things must be sought in non-equilibrium physics (*e.g.*, Eigen, 1971; Prigogine *et al.*, 1972). Countenancing this fact the entrenched view of perception must turn to physical processes for the genesis of selective sensitivity to the basic descriptors of energy.

But to what processes must the entrenched view turn for the genesis of knowledge that enables inferences to go through from energy-referential predicates to beliefs about the environment? It cannot be thermodynamic processes or any future elaboration of them. To turn to lawful processes would be tantamount to denying Assertion 2. Hence, the answer that the Establishment view must endorse, if it takes Assertion 2 seriously, is that the conceptual knowledge originates in a process of justifying inferences against the backdrop of the synthetic theory of evolution. It is a relatively simple matter to show that this answer is fallacious.

All forms of non-demonstrative inference proposed by inductive logicians —enumerative inference, eliminative inference, and abductive inference— can be expressed as a confirmatory relation between evidence and hypothesis. The conditions of adequacy for confirmation vary among the forms of inference (see Smokler, 1968) but this is immaterial to the points we wish to make, *viz.*, that the very notion of inference requires the ability to project relevant hypotheses, the concurrent availability of predicates in which to frame evidence statements and in which to frame hypotheses and a conceptual commensurability between the predicates in which evidence and hypotheses are couched. To clarify, the notion of a basic set of hypotheses is explicit in eliminative and abductive inference and implied in enumerative inference. For example, one version of abduction (Hanson, 1958, p. 72) goes as follows:

Some surprising phenomenon P is observed.
P would be explicable as a matter of course if H were true.
Hence there is reason to think that H is true.

If the requisite knowledge implicated in Assertion 2 were derived from inference then it would have to be supposed that appropriate hypotheses, that is, hypotheses that were generalizations about environmental states of affairs, were already at the disposal of the animal. What is their origin? Surely the answer cannot be "inference" for that would precipitate a vicious regress. But if the answer is not "inference" then the only option left to the Establishment view is that the origin of the hypothesis is extra-physical and extra-conceptual. These are mutually exclusive categories unless, of course, one's theory countenances a benevolent creator.

The same conclusion follows from the point about the concurrent availability of predicates. The predicates in the evidence statements stand for energy variables and by argument have their origin in physical processes. But for any form of inference there must be available, concurrently, predicates in which to couch both evidence and hypothesis, which means for the Establishment view that there must be predicates that stand for environmental properties (like an obstacle to locomotion). The origin of these environment-referential predicates cannot be inferential (infinite regress) and it cannot be physical for the reasons already given.

The general conclusion to be drawn is that in Assertion 2 the Establishment view takes out a loan on intelligence that *science* can never repay: The Establishment view is not a scientifically tractable view and *a fortiori* a view of perception that science would be ill-advised to pursue.

Let us proceed to radically alter the Establishment view so as to dilute the problem of concurrently available predicates. Let us allow that animals can see objects (rather than just the light) in the non-epistemic sense of seeing that Dretske (1969) has isolated in the ordinary language use of the verb "see". That is, let us allow that seeing things is an emergent property of distributed physical processes, that there is a kind of seeing of objects that is fundamental and truly a physical state of affairs. There will then be objects to which interpreted predicates can be assigned in the Establishment scheme of things. Now what we wish to show is that even allowing for this radical modification in the Establishment view it is still scientifically intractable. The source of intractability will be identified as the semantic theory under which the Establishment view labors.

Consider the marsh periwinkle, a snail that is found where vegetation is present in the upper intertidal zone. The snail ascends plant stems just prior to the inundation by the advancing tide of the substrate on which it moves. The evidence is that the snails when contacted by the advancing tide move under visual guidance to the nearest plant stem (Hamilton, 1977). When the tide is out the snails move about in the vicinity of the plants, milling around the bases of the stems and steering their way between them. There are two characteristics of plant stems to which the marsh periwinkle's behavior is referred, *viz*., something that can be climbed up and something that impedes forward locomotion. Let us see how the marsh periwinkle/plant stem situation is analyzed under the Establishment view.

Let us say that for a thing to be a barrier it must have the properties p, q, r. That is, (p,q,r) is the intension *b* of "barrier". And let us say that for a thing to be a climb-upable thing it must have the properties s, t, u, v. That is, (s,t,u,v,) is the intension *c* of "climbable". The extension of *b* (in the intertidal zone) is the plant stems and other snails. The extension of *c* (in the intertidal zone) is the plant stems (other snails being unwilling and too short to comply). Thus *c* is coextensive with *b*. Our liberalization of the Establishment view allows that the marsh periwinkle can see (non-inferentially) things such as plant stems and snails but this ability, in and of itself, will not help the marsh periwinkle behave adaptively. This is because, under the Establishment view, what is seen are the individuals that possess the property *b* and the property *c*, that is, members of the extensions, but not the properties *b* and *c*, that is, the intensions. To paraphrase Fodor and Pylyshyn (their Section 7.1), the ability to see individuals in the extension of a property does not imply the ability to see the property. How than are we to account for the specific directedness of the behavior of marsh periwinkles toward plant stems, *viz*., their seeing them as things to climb on the occasion of the incoming tide? How can the marsh periwinkle's behavior be referential of the intension *c* when its seeing is restricted to the (ambiguous) extensions? The answer from the Establishment view goes as follows. "Sees a climbable thing" is an illegitimate construction for the marsh periwinkle. Rather the construction should be "believes that a plant stem is the thing now seen possessing the property *c*". This construction requires (i) imputing to the marsh periwinkle an internal symbol system that can represent the intension *c* and (ii) the notion of the marsh periwinkle as being related to that representation, and to others. Neither of these requirements unduly strains Assertion 2 above; indeed, they are implicitly contained within it.

Let us see where all of this takes us. We modified the Establishment view so as to give it a modicum of protection against arguments that infirm the view, arguments having to do with the origin of the inferential apparatus that is the hallmark of the Establishment position. To reiterate, we allowed that seeing objects was non-epistemic and simply (*sic*) a matter of physics. In the Establishment view, however, this physical state of affairs cannot be intensional--it can only be extensional. Put another way, the property *c* ascribed to plant stems is not by virtue of a physical description under which snails and plant stems fall but by virtue of a conception that the marsh periwinkle has: the intension *c* is a mental representation, a concept. Herein lies an atavistic notion with which the Establishment view unabashedly concurs —a category, that is, individuals subsumed under a property, is a mental imposition on an objective world. This notion is a biased Kantianism which must always be arbitrary and relative to the current state of physics. The properties studied by contemporary physics are taken by the Establishment to be real (by and large) rather than mental, whereas the environmental properties of significance to the activities of organisms which are not studied by contemporary physics are taken by the Establishment to be mental rather than real. More generally, this notion tacitly assumes that relatively simplistic physical taxonomies (properties of objects) and relatively simplistic biological taxonomies ("plant stems") are sufficient for the analysis of perception and action, an assumption that is readily refuted by behavioral observation. Consider, for example, the South African limpets (genus *Patella*) that are preyed upon by both the starfish *Mathasterias glacialis* and the gastropod *Thais dubia*. The limpets react to their predators by either fleeing or agressing. Whether a limpet perceives a predator to be attackable or not depends on the size of the limpet relative to the size of the predator. Limpets above a certain size will attack the small gastropod and flee the larger starfish. Limpets above a certain, larger size will perceive both predatory species as attackable (Branch, 1979). Obviously for the limpets, the property 'attackable enemy' is not coextensive with the biological taxonomy of 'predators of limpet genus *Patella*'. Equally obviously, the property that distinguishes predator to be attacked from predator to be fled will not be found in any current physical taxonomy of properties (cf. Mackie, 1970). Finally, this notion is nominalistic: to dispense with properties by reducing everything to bare individuals, their names and collections of such. Under the semantic doctrine of extensionalism, the ontic correlate of a property is its extension. It follows that if a number of individuals are collected under a rule, an intension, then that rule, that intension, must be subjective—of mental origin not physical origin.

Proponents of the Establishment position thus hold the view that only propertyless individuals are seen and that intensions are concepts; therefore, they are forced to assume that intensions are inferred from collections of individuals. Inference always involves both evidence statements and hypotheses, as noted above. For a marsh periwinkle to have the intension *c* it must have inferred the intension. Which means that it or an ancestor must have been able to project a hypothesis of the form "plant stems have *c*" which means that its or an ancestor's internal symbol system must have been able to represent the property *c*. We are on the slippery slide of an infinite regress and the reason for it is commonly understood (Fodor, 1975). Any system whose present competence is defined by a logic of a certain representational power cannot progress through formal logical operations to a higher degree of competence. That is to say, it cannot come to represent more states of affairs than it can currently represent although it can come to mark off those states of affairs that do in fact obtain from those that do not. In short, the representational medium must exhibit preadaptive foresight, being able to represent all relevant states of affairs be they extant or future (see Kugler *et al.*, in press). But there is no sensible scientific story to be told about such foresight.

There is something most improper about the nominalism inherent in the Establishment view of perception, given that it is meant to be a view about *living* things. To force intensions into mental representations is to regard organism–environment systems as non-evolving, closed systems. As just noted, the conceptual interpretation of intension assumes a fixedness of basic intensions, given *a priori*, to which all systemic states of affairs, present and future, are reducible. But organism–environment systems are open to fluxes of energy and matter and open to various forms of competition. In consequence, organism–environment systems graduate from states of less structure to states of more structure through successions of stabilities and instabilities. Their systemic properties are *a posteriori* facts not *a priori* prescriptions (see Kugler *et al.*, 1980, in press). For evolving, open systems neither nominalism nor the conventional interpretation of its counterpart, property realism, will do. Both take intensions as given at the outset. What is needed is an understanding of the properties of organism–environment systems as *a posteriori*, but nevertheless real (Ghiselin, in press; Shaw *et al.*, in press; Reed, in press *b*).

To return to the main point. Even by radically liberalizing the Establishment view of perception we reach the conclusion stated above—that the Establishment view has taken a loan out on intelligence that science cannot possibly repay. Several hints as to the reasons for this excessive borrowing have been noted and two of them will be taken up in earnest below, *viz.*, the denial that intensions are physically specifiable and, relatedly, the claim that intensional description mandates conceptual ascription. Let us conclude this section with one further criticism of the viability of the Established view of perception.

There would seem to be *prima facie* evidence that this view is on the right track. The "seeing machines" of artificial intelligence takes a mosaic of shades of grey projected from an arrangement of opaque objects and map the mosaic to a description of the arrangement with which human observers would be in very reasonable agreement. Roughly speaking the machines work by constructing successive representations of the original mosaic where the predicates in these successive representations are successively more like those that capture the properties of the physical arrangement responsible for the mosaic. Many seeing machines (*e.g.*, Falk, 1972) but not all (*e.g.*, Waltz, 1975) use a variant of abductive inference, usually inference to the best explanation (see Harman, 1965, 1968). As such they are susceptible to the above origin argument, which will come as no surprise to anybody. There is a more subtle criticism of seeing machines that we wish to focus on and it is based, in part, on the requirement alluded to above that for an inference to go through, the predicates in the evidence statements and those in the hypotheses must be conceptually close, if not identical.

At the core of machine instantiations of the Establishment view are the notions of representation and matching. To the representational power of the first-order predicate calculus is added the computational power of serial pattern matching procedures that successively test alternative interpretations of a thing by matching evidence statements to hypotheses in the form of general pattern templates. But any time some such matching procedure is proposed there is the possibility that no algorithmic solution exists that can achieve the match in less time than some exponential function of the number of details to be compared in the template and the primitive stimulus description as given by encoding (Lewis and Papadimitriou, 1978). Supposedly, the biological uselessness of matching as a computational process can be circumvented by strategies that reduce the complexity of the evidence statement to-hypothesis comparison. It is of singular importance that in machine instantiations the most obvious and most prominent strategy is to increase the grain size of description; that is, to couch the evidence statements and the hypotheses in terms of relatively few, higher-order predicates (Hayes-Roth, 1977). Generally speaking, in order for there to be a successful match (inference to the best explanation) it is not only necessary that the evidence predicates be rich, few in number and at the same grain size as the hypothesis predicates but it is also necessary that the evidence predicates be members of *precisely* the same set as (or directly comparable to) the hypothesis predicates. Given this claim we should then ask both *why and how any given thing comes to be described in just those predicates that are consonant with the hypothesis mediating its interpretation.* This question is the unsung part of the Establishment's central problem of mapping a stimulus to its apposite representation(s) in memory; for the Establishment the so-called Höffding function is reduced to how contact is achieved between an appropriate *internal* description of the stimulus and the knowledge structures relevant to its interpretation. How the appropriate description of the stimulus is arrived at is rarely at issue. And it is not difficult to see why.

Establishment theorists working on a given problem typically deal with an optimal set of predicates, bypassing the question of how just *those* predicates would be chosen on a given occasion if there were a choice (as there must be), and focusing attention on the supposedly more important issue of how the match is effected. The theorist can refer to the determination of the requisite stimulus descriptors on a given occasion as (simply) a matter of encoding and leave the problem of how it is done to another time or to other theorists.

Where the strategy just noted seeks only to implement matching, another strategy seeks to implement both matching and encoding. Again, however, the sought after implementation is with respect to a single class of objects (for example, a set of stick figures, a set of opaque polyhedra). As with the first strategy noted, the choice of predicates and representational format will be determined by the nature of the object class. A successful implementation of the encoding stage is equated with a procedure that successfully maps the selected objects onto the chosen set of predicates. The encoding problem gets defined as follows: Given that the set of predicates S is the proprietary set, by what means can a member of the set of objects be described reliably in terms of S? This second strategy is deceptive because it appears to resolve the issues raised by the Höffding function. In actuality, by the restriction to a single class of objects it avoids the thorny aspects of the Höffding function with which we are presently concerned, namely, *given a stimulus to be de-*

scribed preparatory to matching, what set of predicates should be applied and in what way should they be related? The Establishment view holds that inference mediates evidence statements and hypotheses and recognizes the computational impotency that is potentially incident to numerically large predicate sets. But what mediates stimuli and evidence statements? And how fares the tractability of the computational task if the proposed mediator is inference?

In sum, and as anticipated in Section 2, the Establishment talks a great deal about how to make the right inferences and talks very little about how to get the right premises. Our suspicion, once again, is that in order to explain how the right premises are arrived at, the Establishment will have to take out a very large loan on intelligence in the form of foreknowledge—one that is not repayable.

How does the ecological approach to perception distinguish from the traditional? A simple answer is that it eliminates Assertion 2 of the Establishment view and beefs up Assertion 1 to bring in the properties that Assertion 2 was advanced to accommodate. It holds that an adequate theory of perception requires not more psychology but more physics of the kind appropriate to living things and their environments. Perception is not in the province of mental states or formal languages of representation and computation but in the province of physical principles at the scale of ecology.

A core claim of the ecological approach is that an organism (as an epistemic agent) and its environment (as the support for its acts) are bound together as a synergistic system *by laws*. Some of these laws may repeat in many organism--environment synergies, others will be unique in the kinds of properties that they link. These laws that epistemically bind an organism and its environment are termed 'ecological laws' and it is the existence of such laws that is denied by Fodor and Pylyshyn. In Sections 4 and 5 we evaluate the grounds for this denial.

4. The argument from the philosophy of science

Fodor and Pylyshyn's argument against ecological laws is constructed with the aid of four notions—natural kind, projectible predicate, natural law and counterfactual entailment. Thus, for example, we are told (in their Section 4) that among the scientific decisions which go together to converge on directly detectable properties there is the decision to determine whether a property is projectible, the decision as to whether a generalization which involves that property is lawlike, and a decision as to whether the generalization is counterfactual-supporting. It is painfully obvious, however, that no substantive argument can be built from the notions of kinds, projectibles, laws and counterfactuals given the current state of the art. In the philosophy of science these notions are notoriously opaque and notoriously uneven in their usage and are commonly recognized as such without undue embarrassment.

Our main intent in this paper is to make a constructive argument for ecological laws, not to engage a diatribe. However, insofar as Fodor and Pylyshyn have chosen to ground their argument in the philosophy of science, we feel it incumbent upon us to show that that foundation is porous—lest philosophical wool be pulled over the eyes of the unwary non-philosopher. The philosophy of science provides no algorithms, nor even consistently reliable rules of thumb, for making the decisions that Fodor and Pylyshyn say will converge on directly detectable properties.

Natural kind terms are said by Fodor and Pylyshyn to be the terms embodied in a statement of law. And when this claim is first introduced (Section 2.2) there is a strong intimation that natural kind terms are relative to the domain to which the law refers. If one translation of "domain" is "scale of magnitudes" then it is to be expected that theoretically significant terms, natural kinds, will vary with domain to be consistent with the understanding that the laws of nature must have a definite scale (Feynmann *et al.*, 1972). Fodor and Pylyshyn give us 'mammals' and 'hearts' as examples of natural kinds (and 'being born before 1982' as a non-example) and a true universal conditional relating extensions is forwarded as an example of a generalization of law, *viz.*, 'All mammals have hearts'. There is much controversy about biological terms such as 'mammals'. A growing sentiment is that taxon names merely name individuals and do not pick out natural kinds. If laws subsume only natural kinds, then taxon names cannot enter into natural laws (Ghiselin, 1974; Hull, 1976, 1978). The sentiment can be responded to by arguing that a species, for example, can be defined intensionally, can pick out a natural kind, but need not occur in any law (Kitts and Kitts, 1979); or by arguing that the names of taxa refer to either an individual or a kind depending on context and with either status can enter into a law (*e.g.*, Van Valen, 1976). Freeing the conception of natural kind from the requirement of inclusion in a natural law is the tack taken by Putnam (1970 *a, b*); a natural kind term merely serves to draw attention to commonalities among things that are superficially different; it is a scientific convenience and an intentionally temporary one at that. Bunge's (1977) tack is different again —a natural kind is determined by a set of lawfully related properties.

These various considerations indicating the uncertain usage of 'natural kind' could easily be expanded (see Schwartz, 1977). But a brief summarizing comment must suffice. For the notion of natural kind to serve in the premises of an argument requires that there be a criterion for distinguishing (natural) kinds from non (natural) kinds and an analysis of what it means for something to be a kind, paralleling Quine's (1960) requirements for the use of the analytical/synthetic distinction. Fodor and Pylyshyn give us no hints as to how these requirements are to be met. But then they are not alone (cf. Wilder, 1972).

The equivocal status of natural kinds leads Fodor and Pylyshyn to argue according to the fallacy of equivocation. In Section 4 of their paper natural kind status is conferred on nothing but the properties identified by the physical sciences in contradiction to the intimation in Section 2.2 that natural kinds are *relative* to the domain of inquiry. This conferral leads them in Section 4 to limit the honorific 'law' to relations among conventional physical magnitudes. This latter move produces even further equivocality in their argument because now the intimation is that a law relates intensions (properties or magnitudes) rather than extensions (domains of propertyless individuals), but it is the extensional view of laws that Fodor and Pylyshyn introduce at the outset of their argument and it is the extensional view of laws that is doing the donkey work in the Fodor and Pylyshyn criticism of the ecological approach. There is a recently initiated debate that promises to be hotly contested about whether laws are properly construed as embodying extensions (the orthodox view) or intensions (see Dretske, 1978, 1979; Niiniluoto, 1978). Indeed, it will prove to be the case that the resolution of this debate on the structure of law bears significantly on the outcome of the argument between the Established view of perception and the ecological view. To reiterate, what is doing a good deal of the work for Fodor and Pylyshyn in their denial of the optical specification of ecological properties is the orthodox view of law. In anticipation, under the heterodox view of law, the Fodor and Pylyshyn argument loses much of its sting.

The notions of natural kinds and projectible predicates are misleadingly equated by Fodor and Pylyshyn. This equation is tenuous and largely absent in the literature. The theory of projection (of projectible predicates) is said to hold promise for determining natural kinds by its orginator Goodman (1965). Quine (1970), on the other hand, sees the determination of a projectible predicate following from a scientific understanding of the notion of natural kind (see Wilder, 1972). And Putnam holds the two notions distinct in that the determination of natural kinds is a matter for physics (Putnam, 1970 *a*) but that the determination of projectible predicates is a matter for psychology (Putnam, 1970 *b*).

The problem of projectible predicates is generally expressed in Goodman's (1965) classic argument involving the predicates green and grue. Grue applies to a thing if and only if it has been observed and is green or it has not been observed and is blue. For some fixed number of observations of green emeralds the sentences "All emeralds are green" and "All emeralds are grue" express legitimate generalizations but only the former is a generalization of law. Goodman's query is: Why should the present evidence favor the hypothesis that all emeralds are green rather than the contrary hypothesis that all emeralds are grue? Why is 'green' projected and 'grue' not? Goodman's own solution is that a predicate is projectible if it is projected sufficiently often. A kindly reading of this solution is that it seems to relocate the problem from the logic of enumerative induction to the logic of abduction (*e.g.*, Fain, 1970; Moreland, 1976). Why, at the very outset, should some predicates be preferred for projection over others? A less kindly reading of Goodman's solution is that given by Putnam (1970*b*) and noted above, namely, that it defines the problem as psychology's and not philosophy's. Passing the buck to psychology is a regressive move if all the relevant psychology, of perception, action and cognition, is as the establishment view says it is: a matter of non-demonstrative inference. In sum, Fodor and Pylyshyn give the impression (and fire their argument with the impression) that deciding on projectibles is a routine matter rather than a matter of considerable perplexity that doggedly rebuffs the philosophy of science (*e.g.*, Moreland, 1976; Priest, 1976; Quine, 1970; Vickers, 1967). As with natural kinds, to employ the notion of projectible predicate in the premises of an argument requires that we have at our disposal criteria for distinguishing projectible from non-projectible predicates and an analysis of what it means for a predicate to be projectible. Fodor and Pylyshyn provide us with neither because nobody has the slightest idea how they can be provided.

Finally, let us turn to counterfactuals. In the standard view of laws, generalizations of law are contrasted with generalizations of fact in that the former are said to support or sustain contrary-to-fact conditionals, conditionals that are of the form 'if A had been an S it would have been P'. Thus, Galileo's law is said to sustain the counterfactual 'if this (supported) body were unsupported it would fall with uniform acceleration'. The generalization of fact that 'All the authors of this paper are Gibsonians' does not sustain the counterfactual 'If Jerry Fodor were an author of this paper he would be a Gibsonian'. There has been much puzzlement over why it is possible to advance counterfactual conditionals through the combining of laws with unfulfilled suppositions that modify the extension of the law's subject. This putative capacity of laws is attributed by some to a kind of nomic necessity (Johnson, 1925) that laws express between occurrences over and above a merely factual uniformity. Laws express that which occurs of necessity (it is said) while accidental generalizations do not. Unfortunately, a closer look at this claim that laws are counterfactually entailing reveals that it is neither so clear nor so secure as to warrant the status as a distinguishing criterion (Ayer, 1970). Indeed, rather than shedding any light, counterfactuals are vague and in need of clarification (Lewis, 1973).

For example, there are cases in which it is fair to say that a counterfactual *is* sustained by a generalization of fact. In some of these cases the reason lies primarily in the form of the counterfactual, in other cases it lies in the assumptive context in which the counterfactual is employed, in yet other cases it lies in the causal backdrop for the regularities expressed in the generalization of fact.

Exemplary of cases of the first kind is the counterfactual 'If Jerry Fodor were identical with one of the authors of this paper then he would be a Gibsonian' which is sustained by the generalization 'All the authors of this paper are Gibsonians'. With regard to cases of the second kind, consider the following scenario. Suppose that there is a Weightwatcher's convention and that one room at the convention center is a meeting place only for people who used to weigh more than 200 lb and currently weigh less than 150 lb. Let us call this group, to which one applied for membership after reducing from above 200 lb to below 150 lb. 'The supra 200 to sub 150 club' and formulate a generalization of fact: 'All the people in this room are members of the club and currently weigh less than 150 lb'. Now under the assumption that Mary is a member of the club and does not necessarily keep her weight below 150 lb then the generalization just given would support the counterfactual 'If Mary were in this room she would weigh less than 150 lb'. It would not do so, however, if it were assumed that Mary has kept her weight below 150 lb and is not a member of the club.

An example appropriated from Mackie (1973) clarifies cases of the third kind. Given a box containing some stones, we assert that none of the stones are radioactive because a nearby Geiger counter has remained quiescent. By itself the universal conditional 'All the stones in this box are non-radioactive' does not support the counterfactual that 'If that other stone were in this box it would not be radioactive'. If it were known to be the case, however, that this box were the left hand box of a pair linked to a device that collects and sorts stones, casting the radioactive one into the right hand box, then the generalization would sustain the counterfactual.

The uncertainty touched upon, *i.e.*, which types of counterfactuals are implied in the claim that laws entail counterfactuals, can be extended (after Achinstein, 1971). Are acceptable counterfactuals to be couched in a general form 'Anything is such that if it were ...' or a specific form 'If such and such an item were ...'. And if it is the general form, which general form? With reference to Galileo's law, for example, should the counterfactual read 'Any body is such that if it were unsupported it would fall with uniform acceleration', or should it read 'Anything is such that if it were a body that is unsupported it would fall with uniform acceleration'?

Moreover, the issue of the dependency of counterfactual entailment on assumptive context that was identified for so-called accidental generalization can be extended to generalization of law (Achinstein, 1971). Consider Boyle's law 'All gases satisfy the relationship $pV = RT$'. Does it sustain the counterfactual 'If the substance in that jar, which happens to be lead, were an ideal gas it would satisfy the relation $pV = RT$'? If it is assumed that the lead in the jar takes on the properties of an ideal gas, the answer is "yes". If it is assumed that there has just been a shift in the way the label 'ideal gas' is applied, the answer is "no".

Finally, it should be noted that there is uncertainty about whether the claim is that laws imply counterfactuals or whether it is, more simply, that laws can be *appealed to* to defend counterfactuals. If 'imply' is what is intended, then Dretske (1977) for one is not aware of any familiar use of imply that fits the bill. Being told that 'All Ss are P' is not to be told that 'If this A were an S it would be P'. If laws are as the orthodox view says they are, *viz.*, an intensional relation between extensions (that is, of the form of a universal conditional that is true), then Dretske argues that it cannot be the law as such that endorses the counterfactual but more properly the knowledge that one brings to the law. Mackie (1973) argues that the entailment of counterfactuals is not an index of some special property, such as nomic necessity, that distinguishes universal conditionals supportive of counterfactuals from those that are not supportive. It is just that some logically formulable counterfactuals are more acceptable than others and the genuine problem, argues Mackie (1973), is to explain why. The reason that 'If Jerry Fodor were an author of this paper he would be a Gibsonian' is not acceptable is because the sole ground for believing the universal 'All authors of this paper are Gibsonians' is an enumerative check and this ground dissolves when another individual is added to the list of authors. And the reason why the above counterfactual concerning non-radioactive stones is accepted the second time through is because the universal generalization that is the inductive ground for the counterfactual has been reinforced.

So much for the (non-pellucid) notion of counterfactuals and so much for the security of an argument grounded in the uncertain notions of counterfactual entailment, natural kinds, projectible predicates and lawlike statements. Let us move on to more positive matters.

5. The specification of intension: affordances and ecological laws

Let us ecological realists put our major ontological cards on the table: (i) There are no bare particulars (individuals) *and* there are no pure forms. The nominalist claim that universals are collections of individuals is denied as is the Platonist claim that individuals in themselves are clusters of universals (Bunge, 1977). There are no universals in themselves but there are properties that are invariant across a given collection of evolving individuals. (ii) Some properties are intrinsic to a thing (invariant across all relations instantiated throughout that thing's existence) and some properties of a thing are mutual, invariant only in its relations to other specified things, but both kinds of property are real, and neither is more real than the other. (iii) Things may be regarded as individuals or classes (concrete collections of things) depending on the context and the interests of the observer; however, while *any* collection may be considered *a class by interpretation* (Russell, 1903), only real historically existing things can be shown to be propertied individuals. (iv) There are no things that do not change and no changes that take place independently of things. (v) Categories of kind may be distinguished, such as event, substance, place and relation (see Ghiselin, in press): (a) *events* as kinds are individuated as species of transformations yielding at least one effective change across a variety of persistences (*e.g.*, "aging" works for many things, leaving identity persistent (Shaw and Pittenger, 1977)); (b) *substances* as kinds (of evolved thing) are individuated as species of persistences resulting from one or more effective changes across a variety of changes (*e.g.*, a biological species is the biogeographically largest invariant under the transformation of reproductive competition (Ghiselin, 1974; Reed, 1979*b*)); (c) *places* as kinds are individuated as the minimal regions persistent over various types of animate activity, such as standing, running, climbing, *etc.* (Gibson, 1979, pp. 34, 36, 43); (d) *relations* are individuated as higher order kinds (persistence–change pairs) such as a place at which an event occurred. (vi) All things, therefore, have both persistent and transient properties, both of which are real and neither of which is more real than the other (Bunge, 1977; Gibson, 1979, p.12f). (vii) Properties are not a separate category of individual, for *there are only propertied things* (Bunge, 1977). (viii) Succinctly, properties are *inclusion relations* among things; hence we can now state (ix) *The ecological principle of nesting* (Gibson, 1979, p. 9): all things are more or less complexly nested. This nesting has no limit either in scale or grain—those relations (v,d) among things nested within a thing, and those relations into which a thing is nested, constitute a thing's properties, intrinsic and dispositional.

Table 1.

Affordance	Effectivity	Activity
grabable thing	grabber thing	grabbing
climb-upable thing	climber thing	climbing
dig-intoable thing	digger thing	digging
copulate-withable thing	copulater thing	copulating
crawl-intoable thing	crawler thing	crawling
leap-overable thing	leaper thing	leaping
alight-onable thing	alighter thing	alighting

Roughly defined, ecological science is the study of the inclusion relations, *i.e.*, properties, of evolved things. Two such properties are affordances and effectivities. The notion of an affordance can be schematized as follows:

A propertied thing X (*e.g.*, a crevice) affords an activity Y (*e.g.*, crawling into) for a propertied thing Z (*e.g.*, a lizard) if and only if certain properties of X (*e.g.*, the spatial extent of the crevice in the horizontal dimension) are dually complemented by certain properties of Z (*e.g.*, the substantial width of the lizard in the horizontal dimension), where dual complementation of properties translates approximately as properties that are related by a symmetrical transformation or duality T such that: $T(P_1) \rightarrow P_2$ and $T(P_2) \rightarrow P_1$ (McClane and Birkhoff, 1967; Shaw and Turvey, 1981).

The complementary notion of an effectivity (roughly, a goal-directed act) can be schematized in like manner:

A propertied thing Z (an organism) can effect activity Y with respect to a propertied thing X (an environmental situation) if and only if certain properties of Z are dually complemented by certain properties of X.

In other words, affordances and effectivities are dispositional properties of things referring to a thing's potentialities—to what can happen. As such they are to be distinguished from occurrent properties, the properties that a thing is currently exhibiting be they discernible by naked observation or aided observation (say, through a microscope) (see Goodman, 1965; Levi and Morgenbesser, 1964).

Table 1 gives a sample of affordances and effectivities together with the activity that they complicate. Notice that in Table 1 a term such as "shoe" —a favorite of Fodor and Pylyshyn's—does not appear. The term "shoe" does not pick out an affordance. Rather it designates a thing that would appear in the extension of a variety of affordances.

The distinction between occurrent properties and dispositional properties is of considerable significance. We shall see that the problem of dispositionals as we face it in the ecological approach is in no small part the problem of assigning a disposition to a thing solely on the basis of occurrent non-dispositional properties of the thing that relate invariantly to the disposition within well defined boundary conditions. This distinction between disposition and occurrence, between possibility and actuality, should not be construed, however, as countenancing a reading of affordances and effectivities as non-real things. One gets the impression that an inability to construe 'possibility' as anything but an epistemological category is basic to modern psychology whose theorists focus only on conceptual possibility. For three conturies we have been told that possibilities for action are not among the kinds of things that can be seen or heard or smelt, *etc.*, rather these possibilities have been claimed to be the epistemic consequences of inference. In contrast, the ecological approach, with its commitment to realism (Shaw *et al.*, in press), focuses on real possibility; for it takes possibility to be an ontological category (cf., Bunge, 1977; Harré, 1970), Possibilities for action or, more precisely, things with possibilities for action, are among the kinds of things that populate an animal's niche and are, therefore, things to be seen or heard or smelt, *etc.*

It is characteristic of dispositionals that they occur (minimally) in pairs (a characteristic which is expressed in the affordance–effectivity pairings of Table 1). Thus the display of a dispositional property commonly involves an interaction between two or more things: salt dissolves in water, clay is molded with the hands, copper corrodes in nitric acid. Although a disposition is frequently ascribed to only one of the interacting things, it must be remembered that what is called a disposition and what is called its complement is a matter of convention. It is because water has the disposition to dissolve salt that salt is water-solvent. Moreover, it shall be underscored that actual dissolution is a systemic property (the system being solute-and-solvent) while the solute and solvent properties are properties of the system's (dually complementing) components. Thus, it is redundant to say, as Fodor and Pylyshyn do, that an affordance is a dispositional *and* a relational property as if dispositionals were definable independently of their complements.

It is also characteristic of dispositionals, though less apparently so, that they are of different orders (Broad, 1925). Magnetizable objects have a disposition to become magnetic when certain operations are performed on them. And magnetism is a disposition, for example, to attract and repel iron filings and to induce electricity in electric coils. Magnetizability, therefore, is a higher order disposition than magnetism.

The notion of dispositional order coupled with the notion of dispositional complementation enables a distinction between dispositions in an organism-free world that should continue to be termed 'dispositions', and dispositions in an organism-populated world that are to be termed 'affordances' and 'effectivities'. In an organism-free world dispositions and their complements are general properties referring to a certain set of entities. For example, mass or inertia is a dispositional property in general, as are viscosity and flexibility. No particular individuals are identified as possessing the properties and no particular values are identified to bound the properties. In an organism-populated world, in contrast, dispositional properties and their complements are properties of the nesting relationships of individuals—where individual might translate as complex individual (Suppe, 1974) or individual class (Van Valen, 1976) in concert with (iii) above; they refer to relations among particular things and, therefore, to a certain scale of magnitude. Thus the dispositions of an organism-free world and the dispositions of an organism-populated world, *viz.*, affordances, are not of the same order. The latter are ontologically condensed out of the former, so to speak, by the presence of living things. As such, dispositional properties exist whether there are living things or not; but affordances exist only in their mutuality with living things.

Passing beyond these preliminaries, let us ask what it means to ascribe a disposition to something; for example, to ascribe climbable to a plant stem. It is to assert, claims Harré (1970), (a) a specific behavior hypothetical together with (b) a non-specific categorical referring to the nature of the thing. With respect to a plant stem (in the niche of the marsh periwinkle) it is to claim (a) that "the plant stem will support climbing" and (b) that climbable, although a property that is expressed discontinuously or even never at all, is due to some properties of the plant stem that are (relatively) continuously present. The latter properties are the causal grounding for climbable and are said to be in the nature of the plant stem (cf. Armstrong, 1961; Broad, 1925). Of the two phases of the ascription process identified by Harré (1970), it is the second phase that invokes the most discussion. At issue is whether the causal grounding of a disposition is itself dispositional (Armstrong, 1961; Harré, 1970; Levi and Morgenbesser, 1964; Popper, 1965). We go with Mackie's (1973) view of what seems the most plausible, namely this: Dispositions have occurrent grounding in properties that are not themselves peculiarly dispositional, even though they sometimes have to be introduced and talked about in dispositional terms.

However, for the marsh periwinkle to perceive the possibility for climbing does not amount to the task of discovering the categorical basis for the possibility. We shall argue that an affordance has to be anchored in two distinct ways (cf., Goosens, 1977; Mackie, 1973), corresponding to whether it constitutes a natural kind for ecological science or a natural kind for an animal, where 'natural kind' is given Putnam's (1970*a*) interpretation. The anchoring required for (ecological) science is to the dually complementing properties of X and Z that causally account for the activity Y by which the affordance is manifested. A climb-upable thing must possess a certain rigidity, a certain surface area, a certain height, a certain textual quality, *etc.*, to support the climbing of the snail and the snail must be of a certain mass, its mucous of a certain viscosity, its ventral surface of a certain flexibility, *etc.*, to effect the climbing. This way of anchoring an affordance—when pursued thoroughly—is continuous with the ontological anchoring of dispositionals in general. Consider solubility. The property of salts is that they are lattices of electrically charged ions held together by the electrical attraction between opposite charges. The property of water and other solvents is that they are liquids with high dielectric constants which reduce the electrical attraction of the ions down to a small fraction of its original value. The categorical bases of the complementary dispositions of salt and water are occurrent properties but they are not obvious properties—they are not observable without the aid of instruments and experimental analysis.

Construed as natural kinds for animals, affordances do not require a grounding in occurrent properties that satisfy the explanatory strictures of science but in occurrent properties that satisfy the pragmatic criteria of successful activity in a restricted universe of possibilities, *viz.*, an ecological world. The occurrent property that defines an affordance for an animal is a non-dispositional property or conjunction of non-dispositional properties that is invariant over the extension of the affordance and over the perspectives that the animal would take naturally on the individuals in the extension. As a natural kind for an animal, an affordance is definable both intensionally and extensionally but it will be the intensional definition that will do the work in providing a lawful grounding for the direct perception of affordances.

The analysis of an affordance as a natural kind for an animal is two stage. The first stage is very much a matter of ecological physics: to isolate occurrent physical properties that are invariant over the extension and the perspectives and which are non-accidentally related to the extension of the affordance. The tricky term is 'non-accidental'. The case of the marsh periwinkle, for example, requires the determination of a lawful relation between an occurrent property *o* of plant stems and the affordance *c* (climb-upable) of plant stems so that (for the ecological world of the marsh periwinkle) the concommitance of the intensions *o* and *c* is nomically necessary rather than accidental. Taking the proper construal of natural laws to be an extensional relation of intensions (rather than an intensional relation of extensions, a point to be discussed in some detail below) we would thus have the law '*o*-ness → *c*-ness'. What might constitute *o* in the case of the marsh periwinkle/plant stem situation? An educated guess (considering Lee, 1980; Hamilton, 1977; Strong and Ray, 1975) is that *o* is a vertically aligned opaque surface of some minimal height occupying no less and no more than so many degrees of azimuth, where the magnitudes are in the scale of the snail.

At this juncture one expects to hear from the Establishment theorist *qua* nominalist calls for a principle of property individuation. The predilection for extensionalism is sustained, one is told, by the failure to provide a criterion by which two properties, two intensions, can be judged the same—the criterion of synomymy (in the very broad sense of analytically equivalent to) being regarded with suspicion (Quine, 1960). Two properties are the same, extensionalists (*e.g.*, Wilson, 1955) might argue, when their extensions are identical. But this criterion of identity is captious for it equates cointension with coextension. And it is also contrary to the way science does business. Properties are used to individuate individuals, not conversely. So we ask: Is a principle for individuating properties a genuine quest when one's ontology denies properties divorced from individuals and *vice versa*?

It seems to us that the task of ecological science is not the principled individuation of properties but rather the empirical delineation of affordances. Any such delineation requires combining ecological physics with evolutionary ecology, and surely no simple algorithm of delineation can be given. But just as surely affordances can be delineated, for ecologists do so all the time. Schall and Pianka (1980) express our ecological realist sentiments precisely. They argue that their affordance-based taxonomy of the evasive behaviors of lizards reflects "biological reality" and that, no matter how these categories of evasive behavior are described in words, "lizards grouped into one category behaved differently than those grouped in another". To give a different expression to a major point of Section 3, if current logical language and current taxonomies in physics and biology cannot accommodate the richness of ecological reality, so much the worse for our inadequate logic and taxonomies.

The second stage in analyzing an affordance for an animal is very much a matter (for visually detected affordances) of mathematical optics: to describe the light patterned by an affordance-specific occurrent property and to characterize that patterning in terms of an optical variable, an optical property, that stands in strict correspondence to the occurrent property.

Again for the case of the marsh periwinkle, the assumption is of a nomically necessary relation between a property *e* of the optic array and the occurrent property *o*, that is, a law of the form '*e*-ness → *o*-ness'. Paradigmatic of the kind of optical property *e* that we have in mind is Lee's (1976, 1980) time-to-contact variable, $\tau(t)$. What is significant about $\tau(t)$ is that it is (a) a dimensionless magnitude non-eliminable in favor of putatively more basic, micro-optical properties, and (b) an emergent magnitude unique to the event of a point of observation moving in a transparent medium at uniform or non-uniform velocity toward a substantial surface.

Thus we have two laws relating properties: '*o*-ness → *c*-ness' (between occurrent property and affordance) and '*e*-ness → *o*-ness' (between optical property and occurrent environmental property). By transitivity we have: '*e*-ness → *c*-ness'. That is, there is a *lawful* specification of an affordance by an optical property. In sum, there is a legitimate construal of dispositions and of natural law that, in principle, allows affordances to be optically specified, thus denying (on grounds separate from those identified in Section 4) Fodor and Pylyshyn their argument against the direct perception of ecologically-significant properties. Recall that Fodor and Pylyshyn admit quite cheerfully in the conclusion of their Section 4 that if there were laws about ecological kinds then there could be direct detection of ecological kinds.

There are, however, several steps to be taken to shore up the foregoing argument. Before proceeding to take these steps let us conclude the present Section with certain points with which we take the argument so far to be consistent.

First, the requisite occurrent, non-dispositional property generally, if not always, will be an abstraction away from the variety of individuals that lie in the affordance's extension. To successfully isolate the occurrent properties that intensionally define an affordance as a natural kind for an animal will be, in most instances, as challenging to science as the general problem of determining the categorical basis of dispositions (such as solvency). It has been remarked (Fodor, 1980, comments on commentaries) that collecting stamps is preferable to picking up this particular gauntlet. What can we say? Science is hard and the temperament of some people is much more suited to stamp collecting than to science.

Second, to stress a point of Quine (1970), the occurrent property need not necessarily have to capture any "ultimate" similarity among members of a kind, only such as is relevant to the domain of inquiry. The occurrent property that rationalizes membership in the natural kind 'water-solvent' could be analyzed further into sub-atomic constituents, but it isn't.

Third, to stress a related point of Levi and Morgenbesser (1964), not every disposition need have a microstructural basis. Generally speaking, the ground of a disposition is the cluster of properties which theory and observation have shown can be substituted for the disposition. In short, the basis of a disposition is relative to the set of properties to which a scale or domain of inquiry is committed. A well-respected example of a non-microstructural ground for a disposition is one in which the force exerted on a body is given in terms of relations between that body and properties of its surroundings by means of force functions.

Fourth, to stress a point of Goodman (1965), if there are good reasons to be confident in a given occurrent property, then there is no need to await an explication of the connection between it and the primary occurrent property (in the case of soluble, 'dissolves', and in the case of climbable, 'climbs'); it is legitimate to proceed to use the occurrent property as the definition of the dispositional property.

Fifth, to stress a point of Greene (1975), the non-ultimacy of the requisite non-dispositional occurrent properties is consistent with the view that evolution engaged in a good deal of practical engineering, making use *ad hoc* of regularities in the animal's world and settling for specialized success (Frazzetta, 1975). It is therefore ill-advised to attempt an understanding of perception from a general theory that specializes to particular cases and eventually orients to actual-world complexities. A better starting point is a thoroughgoing description of ecological worlds as restricted universes of possibilities for action; special purpose solutions to actual-world complexities might then suggest themselves (Runeson, 1977; Turvey and Remez, 1979; Warren and Todd, in press).

Sixth, and finally, the foregoing argument, based as it is on defining the dispositional in terms of the occurrent, is Gibson's. We quote:

> "I have described the environment as the surfaces that separate substances from the medium in which the animals live. But I have also described what the environment *affords* animals, mentioning the terrain, shelters, water, fire, objects, tools, other animals and human displays. How do we go from surfaces to affordances? And if there is information in light for the perception of surfaces, is there information for the perception of what they afford? Perhaps the composition and layout of surfaces constitute what they afford. If so, to perceive them is to perceive what they afford". (Gibson, 1979, p. 127).

6. The intensional view of law

In Section 3 we gave an analysis of the marsh periwinkle/plant stem situation in the extensionalist semantics of the Establishment view. We will give that analysis again in a more explicit form in order to (1) highlight precisely why it *denies* the possibility of the specification of affordances and (2) clarify the

Table 2. *The marsh periwinkle/plant stem situation*

The Establishment/extensional analysis	The ecological/intensional analysis
1. E is the set of things that are climb-upable.	1. *c* is the intension that defines climb-upable.
2. L is the set of light patterns associated with E.	2. *e* is an optical property that corresponds uniquely to *c*.
3. F is the set of things that impede forward locomotion, *i.e.*, collide-withable things.	3. *b* is the intension that defines collide-withable.
4. The set of climb-upable things is included in the set of collide-withable things, $E \subseteq F$.	4. *f* is an optical property that corresponds uniquely to *b*.
5. G is the set of things that are climb-upable and collide-withable, *i.e.*, $G = E \cap F$.	5. *e* is specific to *c* and *f* is specific to *b*.
6. $G = E$.	6. Generally, the optic array is specific to environmental properties, *e.g.*, *affordances*, for any environmental property that can modulate light there is a corresponding and unique optical property.
7. L is the set of light patterns associated with G.	
8. Therefore L is not specific to climb-upable.	
9. Generally, the optic array is not specific to environmental properties, *e.g.*, affordances; for any environmental property that can modulate light there is a correlated and ambiguous set of light patterns.	

contrast between it and the analysis given in Section 5 which *confirms* the possibility of the specification of affordances. The two analyses are given in Table 2.

The Establishment/extensional analysis goes through on the following assumptions: (i) that the generalization of law or of fact is in the form of a syntactic universal. Thus, 'All plant stems as climb-upable things are L' is the conditional that expresses Step 2 in the analysis; (ii) the substitutivity of coextensive predicates. Thus, given Steps 3–6, 'All plant stems as collide-withable things are L' is the conditional that expresses Step 7 in the analysis; (iii) light patterns, or any patterned energy distributions, are correlated statistically with their sources in the sense that this set of individual patterns more or less goes with this set of individual sources. Remember that it is ambient energy (*e.g.*, reflected light) that is being referred to not radiant energy (*e.g.*, emitted light) and, therefore, 'sources' means, *e.g.*, surface layouts. Assumptions (i) and (ii) follow from the traditional conception of law. They are both rejected in the view of law advanced by Dretske (1977), a view which sustains the ecological/intensional analysis. As promised above, the two conceptions of law will be compared.

The standard construal starts with the claim that a law is expressed by a lawlike sentence that is true (Goodman, 1947). Every law must therefore be a lawlike sentence, but the converse does not hold. What is a lawlike sentence? A necessary but insufficient requirement, it is claimed, is that a lawlike sentence be in the form of a universal conditional, (x)Sx → Px; for example, "All metals conduct electricity", "All planets in the solar system move in elliptical orbits", "All ravens are black". A little thought reveals where the insufficiency lies. The number of universal conditionals that are true is likely to be indefinitely large, considerably larger, we should suppose, than the number of universal conditionals that can qualify as lawlike sentences and thus be legitimate candidates for natural law. Consider the following sentence (adapted from Hempel and Oppenheim, 1948) which is syntactically universal and true:

(S1) All apples in basket *b* at time *t* are red.

And contrast it with another syntactically universal and true sentence such as

(S2) All metals conduct electricity

Both universal conditionals identify objective regularities, but they are not of like kind. The latter sentence (S2) is commonly said to express a generalization of law. The former sentence (S1), in contrast, is commonly said to express merely a generalization of fact or an 'accidental' generalization—one would probably not find reference to (S1) a compelling explanation of why a particular apple randomly selected from the basket was in fact red. It is the case, however, that both generalizations are accommodated by the formula (x) Sx → Px and that both are perfect: in both there is nothing characterizable as S that is not coordinately characterizable as P.

There is, therefore, a problem of distinguishing those universal truths that express lawlike generalizations from those that do not. Presumably there ought to be auxiliary characteristics that pick out the lawlike universal conditionals suggesting an equation of the form: law = universal conditional + A, where A identifies the distinguishing characteristics or special uses that qualify a universal truth as a law. Roughly, the traditional claim is that the adding of A, or some significant subset of A (Niiniluoto, 1978), transforms a universal truth into a law. It is precisely this claim that Dretske (1977, 1978) denies. The universal conditional does not have the requisite structure to function in the special way that laws function and no amount of using universal conditionals in the way that laws are used can effect this metamorphosis. It is like supposing, argues Dretske (1978), that one could make thumb tacks into garden hoses by using them to water flowers.

Dretske's (1977) main argument is a very powerful one: "The class of laws, *i.e.*, of law sentences, is not closed under the same operation as is the class of universal statements" (p. 250). Specifically, the operation of coextensive predicate substitution is an operation under which the class of law sentences is *not* closed, but under which the class of universal statements *is* closed. Dretske gives the following example: "Diamonds have a refractive index of 2.419", which is a law of nature. Now "are mined in Kimberlite" is coextensive with "diamonds", so by coextensive predicate substitution one gets "All things mined in Kimberlite have a refractive index of 2.419", which is a universal statement, but not a law of nature. Dretske suggests that only where the predicate substitution is itself based on a law sentence will coextensive predicate substitution in a law statement produce a law statement. (Although he offers no proof for this, intuitively it seems correct.)

From the above argument Dretske concludes that there is a sort of "opacity" in law sentences. (This is not quite the same sort of opacity as found in intensional contexts.) It is not that the truth-values of law statements are perturbed by coextensive predicate substitution, but merely that their status *as laws* is disrupted. To account for this "opacity" Dretske argues that law statements such as "All Fs are Gs" are not universal statements about "F" or "G" but particular statements relating the properties uniquely pertaining to Fs or Gs. That is, an appropriate schema for law statements is "F-ness → G-ness" (*i.e.*, a relation between two properties).

The explanatory practices implicit in Dretske's theory of law sentences differ from the more or less standard theory in several ways. The traditional explanatory use of law statements emphasizes both that these statements have *classes* as their subjects and that the statements hold for all (particular) instantiations of those classes. Dretske (1977) queries whether universal statements can be put to such explanatory uses:

> "You cannot make a silk purse out of a sow's ear, not even a very good sow's ear; and you cannot *make* a generalization, not even a purely universal generalization, explain its instances. The fact that *every* F is G fails to explain why *any* F is G … . The fact that all men are mortal does not explain why you and I are mortal; it *says* (in the sense of implies) that we are mortal, but it does not even suggest *why* this might be so … . Subsuming an instance under a generalization has exactly as much explanatory power as deriving Q from P·Q. None". (p. 262).

Although universal statement *imply* singular statements, they do not explain or justify those singular statements.

The traditional view that a law statement is an intensional relation between extensions gives primacy to the ontological question "What is the ontological status of this sort of intensional relation?" There have been three main answers to this question approximately of the form "objective existents", "mental entities", and "merely ways of talking". The genuineness of this question and of the answers given to it are undermined when the Dretskean view of law is assumed, *viz.*, an extensional relation between intensions. The pressing ontological questions now become: What sort of status have the various (intensional) relata of natural laws? What status have the various (extensional) relations of natural laws? (Reed, 1979*a*, in press *a*).

Let us return the discussion to the sorts of laws we have been referring to as ecological laws, roughly, laws that inform the relation of things perceived to actions performed. As noted, Fodor and Pylyshyn's argument comes down to a denial of such laws and we suspect (as remarked in Section 3) that they have in mind, more generally, the notion that physical science is not quite up to the task of explaining 'mental events' as a class (see Pylyshyn, 1980). An argument of this latter kind can be made rather convincingly (*e.g.*, Davidson, 1970) but the soundness of the argument is of no avail if it is the case that law statements are not attempts to explain intensional relations among classes. This is to say, arguments that rule out generalizations of the sort (x) (Fx → Gx) where either F is physical and G is psychological (or *vice versa*) or, more aptly for our current purposes, where F is environment-referential and G is organism-referential (or *vice versa*), do not infirm the notion of ecological law because ecological laws do not make this form (Reed, 1979*a*, in press *a*). Here is another example of such a law.

Organisms which have true eyes (not merely single photoreceptors) and which can locomote (in any way: *e.g.*, flying, swimming, gliding, walking) are able to take advantage of a law relating the physical structuring of light in the environment to the movements produced in locomoting (Gibson, 1979; Turvey and Remez, 1979; Turvey, 1979). At a stationary (physical) point of view (whether or not an eye is present) there is a dense projection of light. Each edge of a surface and each surface in the environment projects a unique and specific pattern of optical discontinuities in a visual solid angle to each point of view. The smallest simply connected regions within this solid angle are called optical texture elements. When an organism moves forward there is a global transformation of the solid angle that produces a vectorial movement of each optical texture element. These vectors are so arranged that it is a law that the focus of optical expansion (*i.e.*, the texture element with the smallest vector, and around which there is a systematic gradient of increase in the size of the vectors) is the projective "point at infinity" along the line of sight (see Lee, 1976, 1980). This law of optical expansion gives a basis for goal-directed movement: "To start moving, make the optic array flow. To stop, cancel the flow. To go back, make the flow reverse". (Gibson, 1979).

People walking *forward* in a room that is so arranged as to produce the optical pattern that specifies *backward* locomotion will report that they are moving backward, as the law implies (Lishman and Lee, 1973). Doves and pigeons move their heads rhythmically when they walk forward, but only if the walking forward changes their body coordinates with reference to a local inertial frame. Rhythmic head movements are absent if the forward locomotion is not accompanied by optical expansion (Friedman, 1975; Frost, 1978), as the law implies. In the Dretskean view: There exists a definite relation between an expansion pattern of "optical flow" (F) and locomotion directed towards a point (Lp) such that (Lp ↔ E).

In conclusion, the view of law statements as extensional relations among intensions suggests ontological questions and answers different from those of the traditional view. The traditional view of law sentences as universal generalizations has caused philosophers to ask about the ontological status of the implied universal classes of things, and the implied intensional relations among particular things. Dretske's view of law sentences offers two alternative questions: First, what is the ontological status of the properties that are the relata of laws? For example, what is the ontological status of 'optical expansion pattern' and 'locomoting toward a point' that are the relata of the above ecological law? Second, what is the ontological status of the lawful relations found among properties? For example, how are "optical expansion pattern" and "directed locomotion" related? It is to these sorts of ontological questions, inspired by the intensional view of laws of nature, that the ecological approach is directed.

The points made about the intensional view of law bear on the third assumption sustaining the Establishment analysis given in Table 2—an object is correlated with a class of light patterns—an assumption that is grounded in history as well as the semantic theory of extensionalism.

The classical problems of the constancies are surely problems of formulation, not of fact. They are bound to arise if one describes the unvarying perception in the face of varying perspectives as follows: For thing X and organism Z, every perspective that Z takes on X will be associated with a different light pattern. There are, therefore, potentially infinite tokens of light patterns of type L, *viz.*, those that X produces, so how can X be consistently perceived on the basis of the light patterns that X produces? That the tokens of L are correlated with X, in the limp sense of 'go together', can be *of itself* no help whatsoever in consistently perceiving X as X. Thus, we have the classical problem of the constancies. And, thus, we have a motivation for the standard and shopworn claim that there must be, at the disposal of the organism, knowledge structures and inferential capabilities that allow it to quite rightly believe that the tokens of L, infinite as they may be, index the same unchanging source.

Many years ago, Gibson (1950) took a bold step and denied the limp correlational view that sustains the classical formulation of the constancies. Perceptual constancy, he argued, was based on the fact that for any given environmental property there is a corresponding property of ambient energy, however complex, and that the design of living things is compatible with such regularities. For Gibson, there is no problem of constancies where 'problem' means something an animal must solve in the capacity of perceiver. For Gibson, there is a problem of constancies where 'problem' refers to the physical and mathematical construal of the structuring of energy distributions by environmental properties that reveals in what way energy distributions are specific to the properties that structure them. Of course, *this* problem is a problem for science (Mace, 1977).

Another prominent example of Gibson's rejection of the limp correlational or extensional interpretation of the relation of light patterns to circumstances is in the treatment of vision as proprioceptive. Light patterns at the eyes are coextensive with two general properties: the surface layout and the orientation of the organism to that surface layout. Faced with this coextension traditional vision theory was unable to accommodate the naturalness of the ordinary language claim that one "sees where one is going". The traditional analysis delimited cues in a light pattern that were meant to sustain inferences about the surface layout, that is, exteroception; these cues, however, were unable to sustain inferences about one's position with respect to that layout, that is, proprioception. Gibson salvaged ordinary language usage by showing that for each kind of change of the body with respect to the surroundings (*e.g.*, turning one's head, descending, hopping backwards) there is a corresponding, unique global transformation of the light to the eyes (see Gibson, 1968; and see Section 4); and, moreover, that it is reasonable to suppose that there are properties of optical structure that remain invariant over these transformations and which correspond with the persisting properties of the surroundings.

Given Gibson's unrelenting insistence on a lawful correspondence of environmental and optical properties and his outright denial of a limp view of correlated individuals, it is hard to understand how Fodor and Pylyshyn can ascribe that view to him. But they do make the ascription, and repeatedly.

7. The scope of laws

Ecological laws will seem strange when contrasted with philosophy textbook examples of laws. This is because, prior to Dretske's (1977) work, philosophers were confused about the claim that laws are unlimited in scope. For those brought up to believe that "law statements" must fit the schema (x) (Fx → Gx) (*e.g.*, "All ravens are black") it will come as a shock to see the following put forward as a law (after Gibson, 1979, p. 133): "A rigid object with a sharp dihedral angle, an edge, affords cutting and scraping; it is a *knife...*". Surely knives are things with which nearly everybody is familiar; must we try to state laws concerning such obvious things? We would claim that, indeed, psychologists are required to attempt to describe the lawful regularities of the environment if they wish to produce a scientific explanation of the origin, function and causation of behavior.

Because the traditional view of laws of nature is based on the unwarranted assumption that laws must be expressed as universally quantified statements about extensions (*e.g.*, the set of all ravens and the set of black things) it implies to many that the scope of any true law is universal. For example, Popper (1965) distinguishes numerically universal from strictly universal statements, the former being cases where "All X's" is a denumerable quantity. Strict universality means not only true of a non-denumerable quantity of things, but unrestricted as to time or place. Ravens, after all, will everywhere and everywhen have black feathers—or so the traditional story goes.

The extensionalist account of laws as strictly universal statements simply will not do any longer; it cannot even account for laws in physics, much less in biology (*e.g.*, natural selection) or psychology. If modern cosmology is to be believed at all, physical laws *cannot* be indifferent to place and time; such basic properties of the universe as the four forces are absent in a black hole (Wheeler, 1974). The universal scope of laws of nature should not be taken to mean that the same laws apply everywhere and everywhen, for laws can only apply where they are instantiated. The laws governing electron orbits are universal, but no one expects them to operate in the solar nucleus, where atoms are deprived of their electron shells by the intense play of other forces. Following Dretske, we take laws to be particular statements about *properties* that are *more or less* widely distributed in space–time. Electrons as propertied things are wider-spread than knives, but laws about the latter are every bit as universal as those about the former: laws relating the properties of knives (or electrons) to other properties (*e.g.*, viscosity of surfaces or electron orbits) are applicable to each and every case where those properties are instantiated. Where those properties are not instantiated, the laws do not apply. The scope of a law, therefore, is determined by the relative ambiguity in the evolving cosmos of the properties related by that law. There is an emerging orthodoxy, even among those who adhere to the extensionalist view of law, that complete generality or non-limited scope is not a condition *sine qua non* for laws (Achinstein, 1971; Earman, 1978; Kitts and Kitts, 1979; Schlick, 1949; Van Valen, 1976; Wilson, 1979).

Given the conclusion on which the arguments contained in Sections 5, 6 and 7 converge, namely, that the notion of ecological laws is a viable one, let us proceed to apply that conclusion to the phenomena termed 'misperceptions'.

8. Misperception misconstrued

There is perhaps no topic more representative of the superficiality of established thinking about perception as the topic of error. The much-worked claim that "illusions" and "failures of perception" are instances of failed inference (*e.g.*, Fodor and Pylyshyn, Section 2.5) has about as much intellectual force as a cough in the night.

A straight stick partially immersed in water appears bent. Is this appearance to be termed a perceptual error? From the play of light at the eyes, did the nervous system draw the wrong inference, *viz.*, that the stick was bent when in fact the stick was straight? And is it the case that this error clearly denies direct perception because if perception were direct then the stick should have been seen as straight, which it is, and not as bent, which it is not? These questions, of course, are fatuous, for how ought a straight stick to appear immersed in water if it is really a straight stick? If it appeared straight then it is adamantly clear that perception is a source of deception and error because perception would be letting the straight stick appear as it ought not appear. The situation of straight-stick-immersed-in-water must structure the light in a way that is physically sincere. The differential in refractive indices between the media of air and water cannot be compromised. Therefore, ***there is no intelligible sense in which it can be claimed that the stick ought to appear straight if perception were free of error and if perception were direct*** (Woodbridge, 1913).

A human visually detects that he or she is changing coordinates relative to the inertial frame given by the surrounding layout of surfaces. Recall from Section 6 that global optical outflow is invariant with forward locomotion and global optical inflow is invariant with backward locomotion. If you are walking forward on a motionless floor in a room where the walls and ceiling are moving as a unit in the same direction as you but faster then it appears to you that you are moving backward (Lishman and Lee, 1973). Now there is no intelligible sense in which it can be claimed that if your perception were truly free of error, if your perception of your relation to the surroundings was truly direct, then you should appear to be moving forward. Moreover to predicate of you the walker (a) 'detects global optical outflow' and (b) 'takes to be moving backward' is not to pick out two distinct states of affairs that require an inferential step for their connection. Rather (a) and (b) refer to a single state of affairs. There is a physical law at the scale of ecology that nomically relates (a) and (b)—as was noted in Section 6—and by that law *homo sapiens* (gratefully) abides.

The appearance of a straight stick bent in water and the appearance of moving backward when walking forward in a room that is moving with you in the same direction but faster has nothing to do with inference, propositions, knowledge, representation, *etc*. States of affairs appear to organisms as they ought to appear, and it is because they do that successful acting and knowing are possible (Shaw *et al.*, in press). It is the very fact that appearances are taken as being what they ought to be and not something else that invites, sustains and gives closure to inquiry. The stick is grasped, retrieved from the water, held up in the air and returned to the water. Its appearance changes from bent to straight to bent, with these appearances linked by a transformation that takes the stick from one medium (water) to another (air) and back again.

At this juncture it might be advanced that if there is any error involved, it is not because things appear to organisms as they ought not to appear; rather, it is because organisms behave with regard to things as they ought not to behave. The ecological approach, however, resists the logical decoupling of perceiving and acting on which such an argument is based. Perception and action, affordance and effectivity, are bound as dual complements; acting must be as felicitous as perceiving is veridical (Michaels and Carello, 1981; Shaw and Turvey, 1981; Shaw *et al.*, in press). Consider the following examples.

Example 1

Sharks electrically detect things to eat and things that impede locomotion (Kalmijn, 1974). An edible living thing such as a flatfish differs in ionic composition from the surrounding water, producing a bioelectric field partially modulated in the rhythm of the living thing's respiratory movements. A flatfish that has buried itself in the sand will be detectable by a shark swimming just above it. Reproducing the bioelectric field of the flatfish artificially, by passing a current between two electrodes buried in the sand, invites the same predatory behavior. The shark digs tenaciously at the source of the field departing from the site when the act fails to reveal an edible thing (Kalmijn, 1971). Now there is no intelligible sense in which it can be claimed that the source ought to have appeared *inedible* if the shark's perception were free of error and if the shark's perception of affordances were direct. In the niche of the shark 'an edible thing' and 'electric field of, say, type F' are nomically related. To predicate of the shark (a) 'detects electric field of type F' and (b) 'takes to be an edible thing' is not to refer to two different states of affairs, one (*viz.* (b)) that is reached from the other (*viz.* (a)) by an inference. Rather, it is to make reference in two ways to a single state of affairs of the shark–niche system. The linking of (a) and (b) is not something that goes on in the "mind" of the shark, as the Establishment would have it. The linking of (a) and (b) is in the physics of an ecological world, namely, that system given by the complementation of the shark and its niche.

But what of the shark's actions? Should we not classify them as being in error, as being wrong? After all, the source of the electric field proved not to be an edible thing. Given the nomic relation between 'electric field of type F' and 'edible' there is no intelligible sense in which it can be said that the shark's act of investigating the source of the field was wrong. The wrong action for the shark, given its niche and its appetite, would be *not* investigating the source of the field.

Example 2

Trichogramma is a parasitic wasp that lays its eggs in the eggs of other insects. An important distinction for *Trichogramma* is that between propertied things in which eggs might be laid and propertied things in which they might not. The present, though limited, understanding is that the occurrent properties of an egg-lay-inable thing are very roughly the conjunction of the following properties: a thing of minimal volume and diameter in proportion to the size of the wasp, can be walked on by the wasp, a minimal degree of exposed surface (not overly buried) and motionless (Evans, 1978). Let us term this conjunction the occurrent property *w*. It is the case that, although insect eggs naturally fit the bill (that is, exhibit *w*), mercury globules, glass rods, lobelia seeds, calcium carbonate crystals and sand grains can be substituted for them (Evans, 1978). With its ovipositor (egg-laying tube), the wasp will try to penetrate these things exhibiting *w* and will fail to do so. Now there is no intelligible sense in which it can be claimed that these various things ought to have appeared as *non egg-lay-inable* things if the wasp's perception were free of error and if the wasp's perception of affordances were direct. In the niche of this tiny parasitic wasp, 'an egg-lay-inable thing' and '*w*' are nomically related. And we can repeat the argument voiced twice above, beginning with the claim that to predicate of *Trichogramma* (a) 'detects *w*' and (b) 'takes to be an egg-lay-inable thing' is not to refer to two distinct states of affairs linked by inference. Moreover, there is no intelligible sense in which it can be claimed that the wasp acted wrongly in trying to pierce mercury globules, lobelia seeds, *etc.* To the contrary, the wrong action would have been *not* to try to penetrate these things exhibiting *w*.

Example 3

Monstera gigantea is an arboreal vine whose seeds germinate on the ground subsequent to falling from the parent plant. Soon after germinating, the seedling grows in the direction of the nearest tree, contacts the tree and ascends, losing its roots in the process. The seedling is skototropic and, in fact, always grows in the direction of the darkest sector of the horizon that comprises more than a few degrees of the horizon (Strong and Ray, 1975). The seedling can be said to perceive a climb-upable thing. In the niche of the plant, dark sectors of the horizon that are of a minimal extent relate invariantly to climb-upable things (that is, trees) and the darkest sector of minimal extent relates invariantly to that climb-upable thing that can be reached with a minimum of horizontal growth. If a dark cul-de-sac, a box with three sides and a top, is placed on the ground in the vicinity of seedlings, they will grow toward it and inside it. Being inside the dark box impedes the photosynthesis process crucial to the vine's maintenance. Now, there is no intelligible sense in which it can be claimed that the box should have appeared *non climb-upable* if the vine's perception were free of error and if the vine's perception of affordances were direct. In the niche of *Monstera gigantea*, 'darkest sector of a minimal extent' and 'a climb-upable thing' are nomically related Again, to predicate of *Monstera gigantea* (a) 'detects darkest sector of a minimal extent' and (b) 'takes it to be a climb-upable thing' is not to identify two states of affairs mediated by inference. In the physical design of the system comprised of the vine and its niche, (a) and (b) refer to a single state of affairs.

Insofar as growing into the box is detrimental to photosynthesis, should we not attribute "wrong action" to the vine that grows toward and eventually into the box? As with the other examples, it makes absolutely no sense to do so. For *Monstera gigantea*, on the detection of a dark sector of the horizon, the wrong action would be *not* growing toward it.

Let us return to the immersed stick. Any difficulties there might have been with 'stick appears bent' are removed by the physical theory of refraction. Clarifying the physical grounds for the appearance (rather than clarifying the non-demonstrative inferential grounds) does the trick. We pursue this moral with regard to geometric illusions, those in which lines that physical measurement reveals as equal in length, straight, parallel or intersecting may be seen as unequal in length (Müller–Lyer illusion), curved (Wundt–Herring illusion), non-parallel (Zollner illusion) or non-intersecting (Poggendorf illusion).

For example, the Müller–Lyer illusion is interpreted traditionally as exemplifying a measurement error. The perceiver sees difference in length between two lines that are equal to some standard of measure, say, a ruler. This observation holds for humans and for flies. The Establishment is tempted to say that the perceiver, human or fly, falsely infers from the play of light at the eyes that the two lines are of different lengths when, in fact, they are of the same length.

What must be assumed to give legitimacy to this claim for perceptual error? The following come quickly to mind: (1) Whatever the proper basis of measurement for describing the figure is, it is one and the same as the basis of the measurement device by which the figure is described. (2) The perceiver as measurement device quantifies over the same basis as that of the measurement device by which the figure is described. (To not assume this is to assume something like a mismatch between the measurement of oranges in candela/m^2 by a photometer and the measurement of oranges in kilograms by a balance. Nobody would ascribe error to the photometer because its readings did not confirm those of the balance). And (3) of the two measuring systems, the non-biological and the biological, it is the former that is privileged with regard to reality status, otherwise the inclination would be to refer to the Müller–Lyer illusion as a physical error rather than a perceptual error.

Remarkably, these assumptions go unchallenged in the absence of any independently argued grounds of support. And they do so because of their consistency with an assumption that is much deeper and at the core of the Establishment view, *viz.*, that the organism and its environment are logically independent. Among other things, this latter assumption gives license to the selection of a basis of measurement that is organism-*non*-referential.

As argued above, there is no intelligible sense in which the straight stick in water could appear other than bent given the physical grounds for this natural phenomenon. Similarly, we shall suppose (and construct an argument accordingly) that there is no intelligible sense in which line segments of equal length in the context of attached angles of different degrees could appear other than unequal in length once the physical grounds for this natural phenomenon are known. The proper construal of the task for science with regard to the stick in water was to explain a *difference in appearance, not an error in perception*. The task reduces to the question: What physical principles are responsible for the different appearances of a straight stick (completely) in air and a straight stick (partially) in water? We assume, therefore, that the Müller–Lyer figure is appearing to human and to fly as it ought to appear (that is, without the benefit of any epistemic intervention), and that the task is explaining why two lines should appear equal in some contexts and unequal in others. To assume that the figure is appearing as it ought to appear is to deny the assumptions that legalize the claim of perceptual error. In reference to the first assumption, the ecological approach could not commit itself uncritically to a conventional and convenient standard of measure and, relatedly, in reference to the third assumption it could not invest reality disproportionately in an objective, organism-non-referential physics (nor conversely, in a subjective, environment-non-referential psychology). *The ecological approach is committed to the empirical discovery of a basis of measurement common to both environment and organism* (Shaw and Cutting, 1980). This commitment follows from the assumption of organism–environment synergy or mutuality (Gibson, 1979; Michaels and Carello, 1981; Shaw and Turvey, 1981; Turvey and Shaw, 1979).

Measurement of extent presupposes the determination of "chords", that is, the differences in distance between pairs of points lying on a figure. A geometry which defines figures in terms of such differential lengths is called a *chord* geometry, say, as opposed to a *point* geometry. Since chords may be ordered in terms of length, natural numbers may be used to index the various lengths. In this way a point geometry is but a special case of a geometry whose chords approach zero length at limit. Hence, the natural number-based chord geometry can approach, at limit, the precision of measurement provided by a real number-based point geometry. However, there is one important difference between the two types of geometries: whereas measurements carried out in point geometry by necessity are infinitesimally precise, those carried out in chord geometry are no more precise than the tolerance provided by their shortest chord.

This feature of chord geometry is very convenient for expressing the limited resolving power of natural measuring devices such as the human and fly visual systems. Moreover, this feature also permits a principled continuity to be defined between systems which conduct measurements at micro-levels of precision, say those limited only by quantum uncertainty, and those systems that function at more macro-levels of precision, such as the human and fly visual systems, whose tolerances are set by the dioptrics of the eye and the angular separation of the receptors. Interestingly and importantly, there is a simple first-order relationship between visual resolution and body height, Resolution = k/H degrees, where k is a constant of proportionality and H is height (Kirschfield, 1976). This points to the fact that, although the lens eyes of large animals and the compound eyes of small animals differ in absolute resolution, they do not differ in practical resolution. A human of approximately 2 m height looking at a fly 5 m away resolves the fly into the same number of points as a fly of approximately 2 mm height looking at another fly 5 mm away. In short, within some distance that is a constant proportion of the scale of the animal, visual resolution is roughly equal for the large and the small species. This is consistent with the observation that large animals act with respect to things at greater absolute distance than do small animals. And it is important in that it gives sustenance to the thesis that the Müller–Lyer figure ought to appear in the same way to human and to fly.

Suppose, for the sake of argument, that endpoints of line segments, vertices, and intersections are located by natural number chord-coordinates as the centers of iso-extent, chord distributions. In asymmetrically dense regions of high geometric complexity these centers will often be shifted away from the locations given by real number, Euclidean point-coordinates. For instance, in the Müller–Lyer figure, angles that open outwardly have chord distributions with centers further out, approximated where the physical vertices are, for the same reason.

It is important to note that chord density information is intrinsic in nature; it is a function of the overall structure of a pattern. A measurement (*e.g.*, perceptual sample) carried out on one region of the structure is dependent upon what measurements might reveal in all other regions. By contrast, more conventional physical measurements are *extrinsic* in nature; they are insensitive to overall structure and depend only on local circumstances. Moreover, the standard of measurement in chord geometries is intrinsic, being dictated by the organization of the pattern to be measured (its chord distribution). The standard of measurement in Euclidean-based (physical) geometries is extrinsic, being selected for convenience from extraneous sources (the Bureau of Standards).

The importance of intrinsic metrics is well known among ecologists. For example, one of the most fundamental issues in evolutionary ecology is the extent and result of competition among allied species whose geographical ranges overlap. Studying such a situation requires measuring organismic characters to evaluate the amount of divergence between individuals of competing species. In the best studied cases, that of length of body and length of beak among avian competitors for food, it is well known that extrinsic metrics produce spurious significance. Based on his own and Schoener's (1965) data, Eckhardt (1979, p. 145) recently concluded that "statistically significant morphological differences as based on extrinsic metrics do not necessarily imply ecologically significant differences". We suspect that the data of a large body of psychological research are similarly spurious, because ecologically relevant measures are consistently eschewed by psychologists in favor of extrinsic—and therefore uninterpretable—measures. Our complaint with those who study illusions, or who use ecologically uninteresting or unrepresentative displays, is not that they cannot, in principle, help us to understand the "mechanism" of perception, as Fodor and Pylyshyn (their Section 2.5) put it. Rather, it is that only when the ecologically relevant measurement principles are developed will we ever be able to comprehend what went on in these sorts of studies in the first place.

In conclusion, if the proprietary system of measurement is taken to be based on intrinsic measures of structure (perhaps, chord geometry) rather than extrinsic (conventional physical) measures, then in principle the two fundamental perplexities of the geometric illusions are soluable: First, measurement by a biological system can sometimes be at odds with measurement by a non-biological system because the two systems of measuring do not share common bases. Second, a structure embedded in one context (Müller–Lyer figure with angles open inwardly) may appear to be different in magnitude from the same structure embedded in another context (Müller–Lyer figure with angles open outwardly). We take this conclusion, favoring intrinsic measures, to be in the spirit of Gibson's (1966, p. 313) admonition that the information for length of line is not simply length of line.

9. Direct perception: the one and only gambit

With the help of the arguments given in Sections 5 through 8 we can now make precise the claim of Section 2 that the ecological approach places tight constraints on the use of the term 'perception'. The overarching constraint is that the term 'perception' must be reserved for designating *only* actual states of affairs of an organism–environment system that include states of affairs involving properties of the environment taken with reference to capabilities of the organism, thereby vindicating perception as the incorrigible basis for an organism knowing its environment.

Consider the statement 'Z perceives X-having-*a*', where, as before, Z stands or organism, X for a thing and *a* for a property of that thing (recalling that in the realist ontology of Section 5, neither properties nor things are independently real). The use of the term 'perceives' in the context of this statement is legitimate *if and only if* the statement identifies an actual state of affairs of the organism–environment system. The following is a tentative formulation of what that evaluation entails.

The perceiving of X-having-*a* by Z presupposes a law, L:

an ambient energy property *e* is nomically related to *a* in that it is unique and specific to *a* in Z's niche.

Given L, 'Z perceives X-having-*a*' designates an actual state of affairs if:

(i) X-having-*a* is present,

(ii) the *e* resulting from (i) and L is available to Z,

(iii) Z detects the *e* defined in (ii).

Several factors contribute to the tentativeness of the foregoing. For example, the proper *ecological* definitions of the terms "present" (in (i)) and "available" (in (ii)) have yet to be given satisfactorily. The goal of such definitions is clear, however: both terms must be tied systematically to the effectivities of Z and to the occasions on which the affordances of a thing are actualized with respect to Z (see Section 11; and see Shaw *et al.*, in press, for a pass at this problem).

Although the above conditions are not expressed in precisely the form demanded by the ecological approach, they are expressed, nevertheless, in a form sufficient for our current purposes. They illustrate the one and only gambit open to the ecological approach with regard to defining perception. Recognizing the caveats, we claim that the necessary and sufficient condition for legitimately using the term 'perceives' is met only when L and conditions (i), (ii) and (iii) hold. *The incorrigible basis for an organism knowing its environment lies in the satisfaction of L and the three conditions.* Moreover, *the satisfaction of L and the three conditions defines 'directly perceives'*, although, strictly speaking, in the ecological approach 'directly' is redundant. There can be no other sense of 'perceives'.

If a current state of affairs of an organism–environment system can be described truly as 'Z *knows* X-having-*a*' (by virtue of the fact, say, that Z directs its behavior to X in a certain way) and L does not hold, then it is incorrect to describe this state of affairs alternatively as 'Z *perceives* X-having-*a*'. The term 'perceives' must enter legally into some statements, describing some states of affairs involving Z and X, that are the necessary support for the statement 'Z knows X-having-*a*'. But in the absence of a law '*a*-ness → *e*-ness' it cannot be said legally that 'Z perceives X-having-*a*'. More properly it should be said that 'Z infers X-having-*a*', 'Z judges X-having-*a*', *etc.*

If condition (iii) does not hold when L and the other two conditions do hold, then we may speak of a 'lack of perceiving' (see Gibson, 1966; 1979; Michaels and Carello, 1981). Similarly, we can speak of a 'lack of perceiving' if condition (ii) (and, by implication, (iii)) does not hold when L and condition (i) do hold. However, it would be an abuse of the term 'perceives', as here defined, to speak of a situation of the foregoing type as an 'error in perceiving' or even as a 'failure to perceive'. The statement 'Z perceives X-having-*a*' identifies a *property* of the organism–environment system, a property that is emergent on the fulfilling of L and the three conditions. A property can be present or not present, existing or not existing, but a property cannot be right or wrong. Thus terms like 'right' and 'wrong' cannot be conjuncted with 'perceives'. If condition (i) does not hold and L and the other two conditions do hold then we have the circumstance captured by the examples of the preceding Section. For such circumstances the proper description of the organism–environment state of affairs is roughly '(To) Z appears X'-having-*a*'. X' is introduced because, while it is the case that X is not present (in Example 3 of Section 8 a tree was not present), *some* thing is present (there was a box). Again, the realist ontology given in Section 5 does not allow thingless properties. Now the important point to be made about a statement of the kind '(To) Z appears X'-having-*a*'—the point repeatedly underscored in Section 8—is that it identifies a property of the organism–environment system that emerges *lawfully* from the satisfaction of *just* L and the conditions (ii) and (iii). Given that it is a property one can talk about it as "present" or "not present", but not as "right" or "wrong". And given that it is a nomologically based property it would be superfluous and ill-advised to refer to its etiology in the terms of inference, propositions, representation, *etc.*

In the Section that follows we analyze the strategy of building a description of one thing from the predicates used to describe another thing. The conclusions reached in the following Section dovetail with the points expressed in the present Section.

10. Intensional description and conceptual ascription

In our various examples we have cast the marsh periwinkle and *Monstera gigantea* as perceiving things that are climb-upable, the shark as perceiving things that are edible, and the parasitic wasp *Trichogramma* as perceiving things in which it can deposit its eggs. In these roles we are assigning to the marsh periwinkle and tropical vine the description 'can perceive climb-upable things', to the shark the description 'can perceive edible things' and to the wasp the description 'can perceive egg-lay-inable things'. These descriptions involve a borrowing of properties of the environment to predicate a property of the organism. Thus 'can perceive climb-upable things' borrows a property of a kind of thing, namely, plant stems, and applies it in the construction of a property of another kind of thing, namely, marsh periwinkle or tropical vine. Thus, we have the notion of a property (climb-upable) of a perceivable thing (plant stem) and the property of a perceiver thing (marsh periwinkle) that makes it suitable to perceiving that property (climb-upable). In embedding the property 'climb-upable' in the property 'can perceive climb-upable things' we have concocted what is sometimes referred to as an intensional context. The Establishment attitude with regard to intensional contexts was expressed in Section 3. It is that *to give an intensional description to an organism is to ascribe the concept of the embedded property or properties to the organism*. To construct the intensional context 'can perceive climb-upable things' is, in the Establishment tradition, to ascribe the *concept* 'climb-upable thing' to the organism and to claim that 'perceives a climb-upable thing' is a relation of the organism to this concept. The significance of this equation of intensional description and conceptual ascription should not be underestimated. More than anything else it is the hallmark of the Establishment view and it is the target of the criticism from a consideration of origin: in order for an organism to perceive property x, it must have the concept of property x. This mistaken equation has led to the Sisyphean struggle from the nadir of nativism to the pinnacle of empiricism, and back again down the slippery slopes of conceptualism. If "inputs" require concepts to be meaningful, then concepts must precede "inputs" as in nativism; but if concepts (to be at all useful in the real world) require "input" for their content, then "inputs" must precede concepts, as in empiricism (either of the ontogenetic or the phylogenetic variety). Despite centuries of widespread and unjustified optimism, this dilemma (that the mistaken equation of intension and conception gives rise to) has resisted resolution and will continue to do so (Kant notwithstanding). The problem is with the doctrine of intractable non-specificity (Turvey and Shaw, 1979); that is, in the Establishment's terms, the doctrine of meaningless "inputs" which requires that "inputs" be associated with meaningful concepts. Gibson repeatedly urged psychologists to reject this doctrine that shackles them to a futile oscillation from innate to acquired, and back again.

What did we actually do when we constructed the property 'can perceive a climb-upable thing'? Quite uncomplicatedly, we took the concept of one sort of property of one sort of thing to build a concept of another sort of property of another sort of thing. This procedure must always lead to intensionality. What we wish to explore is what this procedure has to do with ascribing concepts. Does this procedure of creating intensional contexts mandate—as the Establishment might seem to demand—the ascribing of concepts?

Consider a balance that does not tip for objects less than 4 oz but does tip for objects greater than 4 oz. We observe the balance and say "only objects of 4 oz or more tip the balance". We describe the balance's behavior through the use of the concept of weighing 4 oz or more and we proceed to construct the property 'sensitive to 4 oz or more'. Surely in this case no one would wish to claim that the balance possesses the concept of '4 oz or more'. Rather, the claim would be that there is a law of nature that subsumes some property *x* of the balance and the property of weight to explain the balance's behavior given the initial conditions. Strictly speaking the intensional context 'sensitive to 4 oz or more' is just a way of indirectly referring to the property *x* and the law. And it is to be expected that, generally speaking, *describing a thing in terms of the properties of other things to which it is sensitive does not mandate ascribing the concept of such properties of the thing.*

Take another example of building intensional descriptions. To construct the property 'fish cakes are nauseating' is to describe fish cakes with a property borrowed from humans, namely, the property of making humans vomit. It is not, of course, to ascribe a concept of this human property to fish cakes. To repeat, borrowing the property of one thing to describe another thing always leads to intensional descriptions but it obviously has nothing to do directly or remotely with ascribing concepts. So we will have to dig more deeply to uncover the conditions that apparently countenance the Establishment's equation of intensional description and conceptual ascription when the intensional description is of the kind exemplified by 'perceives (or registers, or senses, or detects) a climb-upable thing'.

Suppose we predicate of a thing 'sensitivity to light'. The thing in question might be a piece of cloth that is bleached by bright sunlight. Or it might be a photocell in a camera. Or it might be a human. To describe these things—cloth, photocell, human—in this way, however, would not warrant the ascription of the *concept* of light to them and the property of 'senses light' would not be interpreted as a relation of a thing to the concept 'light'. Presumably the equation of intensional description and conceptual ascription does not hold for 'sensitivity to light' because (i) energy media and the variables that conventionally describe them are not the sort of stuff that concepts are about, at least not the concepts that an organism is said to be in epistemic relation to in the Establishment interpretation of intensional contexts; and (ii) 'sensitivity to light' is in the physical nature of cloth, photocell and human. It has something to do with their physical design relative to that of photons. And with respect to the human, the Establishment would suppose that predicating the property 'sensitivity to light' falls out of Assertion 1 of the Establishment position.

Groups of beans absorbing water in closely adjacent vessels are mutually sensitive to each other's rates of absorption as expressed in the negative correlation of their respective uptakes. This is so even when the vessels in which they are housed eliminate effects of the geomagnetic field and of static biomagnetic fields, revealing that the interaction between the groups of beans is through oscillating biomagnetic fields (Brown, 1979). It is legitimate, therefore, to predicate of the beans: (a) 'sensitivity to the water content or absorptive state of neighboring beans' and (b) 'sensitivity to a magnetic cycle'. Of course, (a) and (b) do not pick out two different properties of the beans, they just pick out the same property in two different ways. 'Water content or absorptive state of neighboring beans' and 'magnetic cycle' is a lawful, not coincidental, concommitance of properties in the ecological world of beans. Moreover, although (a) and (b) were built up from the properties 'water content or absorptive state' and 'magnetic cycle', we would be reluctant to ascribe the concepts of these properties to the beans and, obviously, reluctant to claim that 'sensing water content or absorptive state' or 'sensing magnetic cycle' are to be interpreted as relations the beans take to the conceptual representation of these properties. More simply, it is just assumed that the behavior of the beans has something to do with the mutuality of their physical design (or the physical design of ensembles of them) and magnetic fields of a certain form.

But what precisely is the reason for the reluctance to ascribe these concepts to the beans? It is probably because a magnetic field is like light in the previous example—not the sort of stuff that the Establishment is willing to let into the class of things that get conceptually transcribed in an internal medium of representation. On the other hand, one has the niggling feeling that 'water content or absorptive state' is close to, if not in fact, a kind of thing that is in the class of conceptually representable. At extremes of the cycle we could predicate of the beans 'sensed that their neighbors were saturated', 'sensed that their neighbors were unsaturated'. To predicate of a person 'sensed that the child sitting next to her was full' or 'sensed that the child sitting next to her was still hungry' would be interpreted by the Establishment as the person being related to an internal representation (that is, concept) of hunger *qua* food content. This surely would have to be the case for the Establishment, given that sated or unsated are coextensive properties (the extension being the child).

We can entertain the following question: If only (a) could be predicated of the beans, that is 'sensitivity to the water content or absorptive state of neighboring beans', because of ignorance of a law that relates the specifics of the varying water content to the specifics of a varying magnetic field, would there then be justification, in the Establishment view, to ascribe to the beans the *concept* of 'water content or absorptive state'? One suspects that the answer would have to be "yes" and that what prohibits this answer *is* the nomic relation of water content to magnetic field. That relation means that any reason to ascribe the concept of absorptive state to the beans is also reason to ascribe the concept of magnetic field, but a property like 'magnetic field' is not the sort of property that the Establishment willingly allows into the representational medium.

The situation of the shark and edible things is the same sort of situation as that of the beans and absorptive states of neighboring beans. We can construct these two intensional descriptions of the shark: (p) 'can perceive edible things' and (q) 'can detect magnetic field of type F'. Because the properties 'edible' and 'magnetic field' are lawful, not coincidental, concommitants in the ecological world of the shark, (p) and (q) pick out not two different properties of the shark but the same property; they just happen to do so in two different ways. Moreover, although (p) and (q) were built from the properties 'edible' and 'magnetic field of type F', we ought to be as reluctant in the case of the shark as we are in the case of the beans to ascribe the concepts of these properties to the shark. And by the same token, we ought to be reluctant to claim that 'perceiving an edible thing' or detecting a magnetic field of type F' are to be interpreted as a relation of the shark to the internal representation of these properties. In short, we should assume, just as we did for the beans (and for the cloth, photocell and human with respect to light) that what (p) and (q) do is indirectly refer to a mutuality of the physical design of the shark and a property of its environment.

Obviously, this conclusion about the shark and the property edible is not the Establishment's and it is roughly apparent that the Establishment reading of the shark predicate 'perceives an edible thing', *viz.*, a relation of the shark to the internal representation of edible, follows in part from the Establishment view of law. Let us reconsider the observations that led to the non-Establishment conclusion about the shark. Observation 1: It is common procedure to build a property of one kind of thing through the borrowing of properties of another kind of thing. Where Z is a kind of organism and X is a kind of thing in its environment, one builds a property of Z by borrowing a property of X. Observation 2: This way of building a property of a thing Z by borrowing a property of a thing X is just that and nothing more. Of itself, it has no implications for ascribing to Z the concept of the borrowed property of X. Observation 3: The Establishment traditionally treats this way of building properties or intensional contexts as license to ascribe to Z a concept of the borrowed property of X. Observation 4: Given that Observations 2 and 3 do not concur it must be assumed that the Establishment believes that the content of Observation 3 follows from Observation 2 under certain conditions. That is to say, under certain conditions the intensional description of Z using a borrowed property mandates the ascription of the concept of the borrowed property to Z. Observation 5: If for the borrowed property there is a corresponding property *e* in the structured energy medium in which Z is immersed then there is no need to ascribe a concept of the borrowed property to Z. Observation 6: In conclusion, the Establishment draws the equation of internal description and conceptual ascription on the assumption that an energy medium is not structured by the borrowed property of X in a way that is specific to the borrowed property. That is to say. the equation rests on an extensional view of the relation of environmental things to energy distributions.

What else might bolster the Establishment's equating of intensional description with conceptual ascription? Take a fairly standard approach to semantics in which a predicate, *e.g.*, 'is edible' is seen to have two interesting features: an extension and a meaning. Borrowing predicates to build new predicates produces predicates, such as 'can perceive edibility', which similarly have an extension and a meaning. The extension of a new predicate can be a function of either the extension or the meaning of the borrowed predicate. The extension of the new predicate 'bites an edible thing' would seem to be, quite straightforwardly, a function of the extension of 'edible thing'. Thus, if we predicate of shark 'bites an edible thing', then the shark bites a flatfish or it bites a whiting or it bites ..., *etc., etc.*, and we are simply ascribing to the propertied thing shark a relation to another propertied thing. On the other hand, the extension of the new predicate 'wants an edible thing' is not a function of the extension of 'edible thing' but plausibly it is a function of the *meaning* of 'edible thing'. To predicate of the shark 'wants an edible thing' is, therefore, to ascribe to the propertied thing shark a relation to a meaning or concept and not to a propertied thing. We have converged once again on the Establishment thesis: an intensional description of an organism, such as 'can perceive edibility' is to be construed as a relation of the organism to a concept. And perhaps we should recognize at this juncture that intensional descriptions of the kind 'wants an edible thing', 'can perceive an edible thing', are commonly termed intentional in order to underscore that, for example, on the occasion on which these descriptions are predicated of the shark, the concept 'edible thing' need have no extension.

It thus seems that the Establishment predilection to read an intensional description of an organism as license to ascribe concepts to the organism is bolstered by a prevailing semantic theory that uses only extensions and meanings. One suspects that this license would be abrogated by a more richly endowed semantic theory.

Let us explore briefly the implications of the arguments of Section 5 and distinguish among the meaning, interpretation (or designation), and extension of a property. The meaning of 'edible' in the ecological world of the shark is given in the dual complementation of certain properties of the propertied thing shark and certain properties of certain kinds of things that, in juxtaposition with shark, actualize eating, felicitous metabolizing, *etc.* The meaning of 'edible', therefore, is in the province of the physical analysis of edibility as an affordance for the species *Scyliorhinus*; the *meaning* of 'edible' is not in the province of the shark. But the *designation* of 'edible' can be. In the province of the shark, it is the property 'electric field of type F' (among other properties suited to detection by vision and olfaction). And in that same province, the *extension* of 'edible' is the various forms of marine life that exhibit that property. In this semantics, which takes properties seriously, the extension of a predicate built from a borrowed predicate, such as 'can perceive an edible thing', would be a function of the extension of the borrowed property. In short, this constructed predicate ascribes a relation between a property of one propertied thing, *viz.*, shark, and a property of another propertied thing, *viz.*, magnetic field, that is based on the nomic relation between 'edible thing' and 'magnetic field of type F'. As with the case of the balance referred to above, and 'can perceive things greater than 4 oz', the constructed predicate for the shark of 'sensitivity to an edible thing' is simply a way of referring *indirectly* to a lawful relation between properties.

But how are we to construe the lawful relations of properties that are *indirectly* referred to by the foregoing intensional contexts? Generally speaking, laws of nature in their technical form neither explicitly invoke the notion of cause and effect nor allow differentiation between cause and effect (Yates, 1980*b*). For example, those laws that involve conservation are reversible, or time-isotropic. The intended meanings of "cause" and "effect" are given more adequate expression by technical terms such as boundary condition, initial and final state (Margenau, 1960). We underscore this feature of natural laws in order to inhibit the temptation to blindly interpret intensional contexts involving sensing, detecting, *etc.*, as including *two* properties, one of X and one of Z, such that the property of X causes the property of Z or that the property of X causes a change in the property of Z. It could be said that the intensional context (M): 'marsh periwinkle perceives a climb-upable thing', picks out a lawful relation between 'climb-upable' as that property of X which is sensed and a 'climb-upable-thing detector' as that property of Z which does the sensing. This reading of the intensional context is in the spirit of promoting "grandmother detectors", a strategy to which Fodor and Pylyshyn, among others (*e.g.*, Ullman, 1980), appeal when giving an interpretation of direct perception (see their Section 4). Under this construal the property 'climb-upable' causes an effect in the 'climb-upable' detector. But we have just given reason for not being bound to a cause–effect interpretation of the lawful connection picked out indirectly by the intensional context (M); and we have given ample reason for rejecting (M) as licensing the ascription of a facsimile of the thing detected to the thing doing the detecting. The "grandmother detector" reading of (M) is formally no different from the one with which we began; that is, 'a climb-upable-thing detector belonging to the marsh periwinkle perceives a climb-upable thing' is a kin of 'marsh periwinkle detects a climb-upable thing' and heir to the same analysis. Returning to the balance and to the beans, it makes no more sense to ascribe to them, respectively, a detector for 'thing 4 oz or more' and a detector for 'absorptive states of neighbors' than to ascribe to them the concepts of these properties. The intensional contexts of above, taking balance and beans as their respective subjects, resist sensible interpretation in terms of concepts *and* detectors. And there is no reason to argue the contrary for those intensional contexts taking marsh periwinkle, shark, parasitic wasp and tropical vine as their subjects.

The moral of this Section should be repeated. Though simple its implications are far reaching: When we borrow a property of X to construct a description of Z we should not then give to Z a concept of that property. Contravening this standard is the rampant tendency to ascribe to Z neural devices such as detectors or formal devices such as structural descriptions (see Section 3) that essentially represent the very property that is sensed. This tendency is the Establishment's: For Z to see, detect, register, perceive, or whatever, property *x* of X, Z must *have* property *x in some sense*, neurophysiologically or conceptually. (This tendency to proliferate properties by unwarranted duplication has been referred to as the *first-order isomorphism fallacy* (see Summerfield *et al.*, 1981, for a discussion).)

To rephrase the question with which we began this particular line of argument: How should an intensional context that involves a term such as 'perceiving' be construed? The answer given by the ecological approach eschews rules (of computation) in favor of natural laws, representations in favor of occurrent properties, and concepts in favor of affordances. Thus, the answer we propose makes perception a function of an ecosystem rather than of an organism (Turvey and Shaw, 1979), and looks like this: Intensional contexts, such as (M), index an *emergent* property of highly distributed physical processes of a dynamic system, precisely the system given in the dual complement of an organism (*e.g.*, marsh periwinkle) and its niche (cf., Kugler *et al.*, in press; Prindle *et al.*, 1980; Shaw and Turvey, 1981; Shaw and Todd, 1980). Very roughly, whereas the Establishment has tried to give a mechanism for perception, that is, an account of intensional contexts like (M), on the basis of getting the borrowed property *x* of X into the organism, the ecological approach tries to give a mechanism for perception on the basis of keeping the borrowed property *x* where it belongs, *viz.*, with X. To do so, however, requires the ecological approach to provide a richer semantic context in which to interpret perception; one that allows natural laws, relating occurrent properties to both animal and environment dispositions, to replace cognitive rules, relating concepts and representations.

11. Toward a natural basis for intentionality

There are two major conclusions to the deliberations of Section 10:

1. To describe one propertied thing Z in terms of the properties of another propertied thing X to which it is sensitive is not to ascribe the concepts of these properties to Z.

2. An intensional context of the kind 'Z can perceive property *x* of X' or 'Z perceives property *x* of X and acts accordingly' is merely an indirect way of referring to a lawful relation of properties. Taken together, these two conclusions inform us that when the expression 'organism Z perceives the affordance *a* of thing X' designates an actual state of affairs, it *does not* mean that Z has a concept of *a* that mediates the perception of *a* and *does* mean that there is a nomological basis to the perception of *a* by Z. And that, in a nutshell, is the thesis of direct perception defined more explicitly in Section 9. Let us bring this thesis to bear on the problem of intentionality.

A gannet swoops upwards and then dives down to the water, neatly spearing a fish in its beak on its way back up to the surface. To succeed in this act of fundamental importance to its survival, the bird must anticipate when it will make contact with the water: for if it pulls its wings back a fraction of a second too late, their lightweight hollow bones will shatter with the impact. Yet the bird cannot pull up and slow down to ease its impact, else it will lose its prey. This example (drawn from Lee, 1980) illustrates the problem posed by intentional activity for psychology. It is tempting to say that the "cause" of the bird's wing retraction is imminent collision, but how can a future event (one that might not occur) "cause" a present action? How can a collision at a later time "cause" a movement at an earlier time.

While it is acceptable to say that imminent collision *appears* to "cause" wing retraction it is not acceptable to claim that imminent collision actually "causes" that behavior. "Causes" should not come *after* "effects", and causes should definitely not be merely possible states of affairs when their effects are actual facts. Clearly, whatever is the actual "cause" of the wing retraction must *exist* (and not merely as a possibility) *prior* to the retraction.

Gibson's (1979) conception of information, the one that we have defended in detail in this paper, is roughly the claim that real possibilities are specified by current states of affairs. In the flowing optic array at the eyes of the diving gannet there currently exists information specific to a future encounter, *viz.*, contact with the water. There is an optical property (the inverse of the rate of dilation of the optic array structured by fish-in-water) that is lawfully related to the property 'time-to-contact' and a felicitious entry into the water follows if wing folding is initiated when this optical property, $\tau(t)$, assumes a certain margin value (Lee, 1980).

There is an important promissory note attached to the Gibsonian conception of information: Cutting the Gordian knot of intentionality. Recall L and the three conditions in Section 9 whose satisfaction defines the legitimate use of the term 'perceives'. We wish to consider the status of condition (i), *viz.*, X-having-*a* is present, in an account of intentional activity, that is, activity directed toward an object (see Section 2). There are two extreme positions that can be taken on condition (i)'s involvement in intentional activity: to rabidly deny it or to rabidly assert it. Condition (i) might be denied outright on the nominalist ontological grounds that only bare individuals exist and, therefore, X-having-*a* is a non-existent environmental state of affairs. Or it might be denied on the lesser grounds that the "objects" to which behavior is directed often have no extension. To emphasize the denial of condition (i)'s involvement is likely to lead to representationalism and thence—as we note below—to solipsism. In contrast, a rabid assertion of condition (i)'s involvement runs into problems when intentional activity is clearly manifest (such as a shark digging tenaciously at the site of a biomagnet field of type F) in the absence of 'X-having-*a*' (an edible thing). The three-fold moral of Section 8 inculcated into the definition of perception in Section 9 is that (a) information about X-having-*a* *must* be present for perceiving X-having-*a*; (b) extra-niche circumstances can be created such that the ambient energy property *e* that is nomologically linked to *a* is present in the absence of X-having-*a*; and (c) when (b) is the case it *must* appear to Z that *some* thing-having-*a* is present. Here then is the way to cut the Gordian knot of intentionality.

The *pick up of information* involves two relata that must both exist—a propertied thing Z (an organism) and a property of a propertied thing E (ambient energy)—and therefore *is relational*; the *specificity of information* involves two relata, one that must exist and one that in extraordinary circumstances may not exist—a property of a propertied thing E and a property of a propertied thing X (a piece of the environment)—and therefore *is intentional.*

How would the Establishment address the intentional activity of the gannet? To begin with, the gannet's wing retraction is not caused by any future state of affairs, nor even by the possible fact of collision. The apparent "action at a distance" of the water's surface on the bird's wings is discounted (see Section 2). The "intentional inexistence" (to use Brentano's phrase) of the imminent collision is replaced with the actual existence of a mental representation of the collision. The retraction of the wings is not in regard to the possible future collision but rather is in respect to an actual mental representation (in the internal language) of the counter-factual case ("If I keep falling at this rate I will crash"). The Establishment scheme of things reduces the intentionality (directedness towards a goal) of the gannet to a *self-description* (in the internal language) involving counter-factuals, and we are on another slippery slide of the scientifically unwelcome kind that we met in Section 3: Any reduction of intentional directedness (a quasi-relation, with one of the relata allowed to be absent on some extraordinary occasions) to self-representation (a true relation, both relata necessarily existing) must lead to solipsism (see Aquila, 1977; Fodor, 1980).

In the Establishment view the gannet's "direct" transduction of the conventional variables of light leads to one "state of mind" (see Fodor and Pylyshyn, Section 5). By inference the gannet can move from this first state of mind to a second state of mind, *viz.*, "perceiving that the layout is such-and-so". In concert with Assertions 1 and 2 of the Establishment position, the gannet is directly aware of the effects of light energy on its body but not of the propertied things that constitute its environment. Nor, according to the Establishment story, can the gannet be aware directly of the propertied thing that is *itself*, either as body or as agent. All it can be aware of are the effects of signals from proprioceptive transducers on central processes and these do not specify a body or its actions—in short, the gannet has to infer itself and what it is doing from its proprioceptor signals. The solipsism that marks this story is suitably expressed by Dennett's (1978) image of a person controlling a robot: The person is in a cockpit, aware only of banks of lights and switches; the trick is to pull the appropriate switches in association with given patterns of lights, leading to adaptive behavior in the environment (which is, unfortunately, unavailable for inspection). Surely, the foregoing cannot be an account of the design principles governing *any* species of organism and the burden of proof must be put squarely on the Establishment's shoulders: To show how it can avoid a solipsistic account of an intentional activity such as the gannet's diving for food, a solipsism that follows, as the night the day, the reduction of intentionality to representation.

Reducing intentionality to representation falls prey to other criticisms of the kind highlighted in Section 3. How did the gannet come by its counterfactual representation? If birds that experience non-felicitous collisions all die, then how could the content of a living bird's mental representations involve imminent collision? If the gannet only infers that it is falling and that contact is imminent then how did it come by such accurate and precise inferences as it surely has? An appeal to theories of induction, such as Goodman's (1965) with its analysis of projectible properties, is vacuous (as shown in Section 4) because they provide only *post hoc* procedures for determining which few of a limitless number of properties are projectible and hence no way of insuring the viability of any given induction. The suitability of trial and error as an *ex post facto* analysis for philosophers does not carry over to evolving creatures like the gannet; use of this method would eliminate not edify. To reiterate the thesis of Section 3 the Establishment must assume lawful processes playing out at the ecological scale which fashion organism–niche systems so designed that the activity-relevant properties of the niche—the projectible properties—are detected directly by the organism. If not, then the Establishment must appeal to a pre-established harmony between, say, the gannet's internal representations and the actual environmental states of affairs with respect to which it lives its life.

We cannot be too demure, however, about the above, ecological account of the gannet's diving. That account does give the proper ordering of initial conditions and final conditions, and it does so without recourse to the contrived and scientifically unwelcome measures that mark the Establishment's interpretation. But it brings new challenges that must be met if the account is to be fully satisfactory. Notably, there is the question of the marginal values of $\tau(t)$: How are they selected within the system defined by the complementation of the gannet and its niche? In addressing this question we catch a glimpse of how the relation between intentions and ecological laws might be defined.

No law functions in isolation. Rather, the interpretation and application of any law requires a context of constraints, what might be termed the law's *nomic context*. These constraints are the initial conditions and final conditions, comprising the law's domain and co-domain respectively, together with boundary conditions, symmetry conditions and scale factors. Collectively, these constraints define the law and its relationship to other laws, more precisely, to other nomic contexts of broader and narrower scope. In concert with the ecological principle of nesting (Section 5), laws will stand in superordinate and subordinate relation to other laws (Feynman, 1965).

Patently, laws relate the event of placing salt into water to the event of salt dissolving in water; the event of placing an acorn into fertile soil to the event of an oak tree growing in the soil; and, perhaps, the seeing of a prey by a hungry predator to the chasing of the prey. But exactly when the salt dissolves, or when the healthy tree matures, or when the successful predator makes the capture, is not given by the respective laws alone. There is an additional requirement, *viz.*, that the values of the initial conditions be given: How much salt; how warm the water? How fertile the soil; how much rain? How fast the predator; how near the prey? The specific values or restricted ranges of values within which the consequent event falls are the *marginal values* of the final condition of the law. The specific values required to fix the parameters of the antecedent event are the marginal values of the initial condition of the law. Clearly, fixing either set of marginal values fixes, within the accuracy of the law, the other set of marginal values. This fact is important. It suggests the place of entry of intention into the nomic context of an ecological law. Roughly, an intention can be regarded as a convention, based on a criterion, by which marginal values of the final conditions of a law might be selected so as to constrain the marginal values that its initial conditions can assume.

To illustrate, assume a law of predation, the nomic context of which is the context of the dual subordinate laws—the laws of capture and escape. If we, as scientists, wished to selectively study, say, cases of predation which focus on the goals of predators rather than on the goals of prey, then we would require a convention or decision rule. The convention would involve some criterion for distinguishing cases of one kind of predation from cases of the other. What form might such a criterion take? If velocity vectors, V_1 and V_2, are assigned to two organisms, O_1 and O_2, respectively, who are engaged in prey–predator competition, then the fixing of appropriate initial conditions (such as the distance d separating the pair and the duration t of their chase) necessarily eventuates in three final conditions:

(1) where $V_1 - V_2 = k$, $V_1 > V_2$ (over some suitable marginal values of d and t), the prey *escapes* the predator;

(2) where $V_1 - V_2 = -k$, $V_1 < V_2$ (over some suitable marginal values of d and t), the predator *captures* the prey;

(3) where $V_1 - V_2 = 0$, $V_1 = V_2$ (over some suitable marginal values of d and t), the prey and predator are engaged in a 'no-win' *chase*.

To elect to study the intention of capture is to select, from among all cases of predation, only those where the vector sum has a negative value, $-k$. Here $-k$ is the *criterion*, and our *convention* (as students of capture) is a decision rule (*e.g.*, a Kronecker delta function) that uses $-k$ to select the appropriate cases. That is, those cases for which particular marginal values of d and t hold. In short, to adopt the criterion-based convention is to constrain the marginal values that the initial conditions of the law of predation can assume. It is to be emphasized that there is nothing arbitrary about the criterion. The three final conditions of the law of predation that the criteria designate, comprise three nonlinear *phases* of predation behavior arising from the continuous linear variation of the initial conditions of the law.

Returning to the gannet, the intentions 'dive for a fish' and 'alight on the water' are expressed in the nomic context of a law that relates a property of the optical flow field to the time at which a substantial surface (here, that of a body of water) will be contacted. The time-to-contact law is nested within other laws such as a law of search and a law of predation. A law of search is strongly implicated. All motile organisms from bacteria to man search for resources rectilinearly—continuously and erratically turning between straight stretches (Jander, 1975). Rectilinear search is efficient given that the distribution of resources is patchy (MacArthur and Pianka, 1966).

The intention 'to dive...' entails that the contact with the water be head-first and vigorous, with the wings retracted at some time prior to contact. The intention 'to alight...' entails that the contact with the water be feet-first and gentle, with the wings spread at some time prior to contact. Presumably, the times relative to contact, at which the behaviors of retracting and spreading the wings are initiated, respectively, are not identical. That is to say, the two behaviors are initiated at different marginal values of the same optical variable, $\tau(t)$. The intentions 'to alight...' and 'to dive...' are thus playing systematic roles in the nomic context of the time-to-contact law. The intention 'to dive...' is synonymous with the selection of a criterion k specific to the final condition of interest (head-first, vigorous contact) and thereby to fixing, within the nomic context of the time-to-contact law, just those marginal values of the initial condition (the variable $\tau(t)$) requisite to yield k. The gannet's intention, therefore, is tantamount to a convention that relates a categorical state (vigorous contact), associated with the final conditions of the law, to values of the initial conditions of the law.

How is such a convention to be interpreted? The more or less standard answer from the Establishment is that it is a rule that the gannet possesses of the form "when in a state of hunger and diving for food, use the set y of $\tau(t)$ values". In sharp contrast, the ecological approach would treat the convention as a challenge for science expressed as follows: How does the occasion of being hungry bring the gannet under the aegis of one nested collection of laws rather than another and how are the nomic contexts of these laws so coordinated as to nomologically select the initial values of the subordinate time-to-contact law on the occasion of diving for food?

It is only fitting that this discussion of intentionality concludes with the marsh periwinkle. A plant stem for the marsh periwinkle can be something to be climbed up and it can be something that impedes forward locomotion. On the occasion of contact with the incoming tide the marsh periwinkle perceives a plant stem as climb-upable. The following statements cover the situation:

c = plant stem is climb-upable,

b = plant stem is collide-withable,

and, on the occasion of the incoming tide,

I = marsh periwinkle perceives c.

I is a typical intentional statement. Its truth evaluation depends on the marsh periwinkle Z, the statement c and the occasion O. In brief, I = P(Z,c,O) where P stands for perceives. In the more general formulation P could stand for other pragmatic functions such as knows, believes, *etc*.

Recall from Sections 3 and 7 that in the Establishment view Z can behave differently to two coextensive properties on two different occasions if and only if Z can represent these properties to itself differently. Given that c and b are coextensive, the Establishment reads the parenthesized symbols of I as follows: On the occasion O, Z represents to itself c. In the Establishment view the occasion of contact with the incoming tide plays the role of a "cue" that *selects* (in the sense of *retrieves*) a *representation*. What reading does the ecological approach give to (Z,c,O)? By argument, c is specified by e and b is specified by f (see Table 2) and it follows from the thesis of direct perception that the requested reading is: On the occasion O, Z relates to e. In the ecological view the occasion of contact with the incoming tide plays the role of a state of affairs that *selects* (in the sense of *attunes*) a marsh periwinkle/niche *relation*.

The marsh periwinkle/plant stem situation expresses a central problem for the theory of intentionality: how an organism can take the same propertied thing to afford different acts on different occasions (cf. Shaw, *et al.*, in press). The person who takes a bottle to be a throwable thing on the occasion of a bar-room brawl and a put-intoable thing on the occasion of needing to put out a cigarette exemplifies the problem, as does the hermit crab who takes a sea anemone to be a portable protective thing on the occasion of losing the actinians on its shell and an edible thing on the occasion of being hungry (von Uexkull, 1957). For both the Establishment and the ecological approach the problem is one of selective constraint. For a given thing X and an organism Z, an occasion constrains Z to one of several or many acts that X makes possible for Z. Occasions individuate affordances.

To conclude, the Establishment treatment of the intentionality problem under analysis conjures up the image of an organism on the occasion of being hungry (such as the hermit crab) moving about with a concept of food in mind and looking for something in the environment that will match this concept; or an organism on the occasion of impending danger from the approaching tide (such as the marsh periwinkle) moving about with a concept of a thing that can be climbed up in mind and looking for some thing in the environment that will match that concept. The ecological approach's treatment of the problem conjures up a very different image, *viz.*, of an organism, on a given occasion, moving in the context of one set of (nested) laws rather than another The latter image expresses belief in a natural basis to intentionality whereas the former image, that of the Establishment, does not.

12. Postscript

The current controversy between the Establishment view as defended by Fodor and Pylyshyn and the ecological view as defended by ourselves is continuous with a larger issue that has been debated endlessly by philosophers and scientists alike: Are the uniformities observed in nature expressions of an underlying coherent framework of laws, or are such uniformities but the insidious inventions of the human mind, applied to nature by one faculty and interpreted by another faculty. Kant ascribed all the apparent order in nature to formulations of pure reason. "The understanding", he argued, "does not draw its laws from nature but prescribes them to nature". With respect to the uniformities of perceiving and acting, the Establishment is similarly inclined to prescribe to nature.

The physicist Sommerfield expressed the sceptical attitude of all scientists who stubbornly pursue a nomological view of natural order—that there is an intolerable arrogance in the premise of "prescribing to nature" (Guilleman, 1968). It is a sentiment with which James Gibson would concur, and it is a sentiment with which we concur as members of that "substantial minority" who believe that Gibson's ecological approach to the knowings of organisms is both revolutionary and correct.

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