A Default-Oriented Theory of Procedural Semantics

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Procedural Semantics (PS), broadly construed, is the thesis that the meaning of a symbolic expression may be identified with procedures which specify how the expression is to be used, or applied to the world. J.A. Fodor has characterized PS as a wildly implausible form of the verification theory of meaning, and has argued that PS constitutes a plausible semantic theory only for highly simplistic universes, such as "blocks worlds" and databases. Fodor argued further that insofar as PS is defensible, it is "parasitic upon" classical denotational semantics. Fodor's critique of PS provoked various rejoinders. Although these rejoinders were not always in agreement, both Wilks and Woods reasoned that some form of PS must be true if we are to render coherent certain fundamental concepts of model-theoretic semantics (e.g., denotations and truth-conditions). In the present paper these arguments are reviewed and extended. It is argued that not only Tarskian semantics, but other forms of model-theoretic semantics (including possible world and Situation Semantics) may very well ontologically presuppose some form of PS.

In addition, a default-oriented form of PS is presented which avoids the "decision procedure" approach of early PS. The new theory embraces aspects of Quine's pragmatism, and assumes that semantic procedures may return pragmatic (default) truth values which may be revised, if the need arises, by adjudication procedures. On the theory here described, semantic procedures do not constitute the complete meanings of symbolic expressions, but constrain these meanings. It is argued that such constraints must exist if there are to be ontological foundations for such traditional notions as denotations and extensions.

1. INTRODUCTION

J.A. Fodor (1978) presents a critique of a semantic theory which, he argues, has been implicitly adopted, and sometimes explicitly stated, by designers of natural language "comprehension" systems. The theory, known as Proce-
dural Semantics (PS), has received varying formulations. On the version Fodor depicts, the meaning of declarative sentences in natural language may be accurately represented by computational procedures, which can either verify the truth of such sentences or determine their correct application to the universe of discourse. Fodor also identifies PS with the cognate view that the semantics of any natural language may be specified by producing a "compiler," which can translate sentences of the language into computational procedures which represent the meanings of those sentences. Fodor attributes the doctrine of PS to Winograd (1971), Woods (1975), and to Miller and Johnson-Laird (1976).

In section 2, I examine Fodor's criticisms of PS in some detail, and consider the model-theoretic alternative to PS which Fodor advocates. Although he does not describe this alternative semantics in any detail, it is clear that Fodor has in mind some form of classical (denotational) semantics whereby the meanings of referring expressions are fixed (or individuated) by their denotations, and the meanings of complete sentences are given by their truth conditions.

One of Fodor's major conclusions is that insofar as PS is defensible, it is "parasitic upon" classical semantics (CS). This conclusion has been challenged by Woods (1981) and Wilks (1982). In section 3, arguments are reviewed (including some due to Woods and Wilks) which support the opposite of Fodor's conclusion. It is argued that the foundations of CS may well involve some form of PS, not vice versa. In order to present the case most forcefully, I integrate existing arguments with new ones, noting those due to previous authors. In section 3.2, I examine ways in which these arguments may be, and have been, extended to both possible world semantics and Situation Semantics (Barwise & Perry, 1983). Not that I wish to suggest that any of the above model-theoretic approaches are defective for the purpose for which they were intended; rather my contention is that anyone who rejects the very idea of PS (as Fodor does), abandons what may be our best hope for providing model-theory with a firm ontological foundation. In section 3.1, reasons are presented for believing that issues of semantic competence cannot be divorced (as is sometimes supposed) from the foundations of CS. It is argued that procedures (or something closely approximating procedures) form an essential component of semantic competence.

In section 4, background intuitions and motivations are provided for the modified PS described in section 5. Finally, section 5 presents a version of procedural semantics which avoids the principle failings of the form of PS criticized by Fodor. Although this modified version differs from PS in important respects, it shares what is perhaps the primary insight of PS, namely that the mapping between language and the world of experience presupposes that some symbolic expressions (at least) are mapped onto experience by processes which may be closely modeled by computational procedures.
Some of these procedures allow semantically competent agents to form *prima facie* judgements to the effect that a given object falls into a given denotation. On the modified version of PS to be presented, the identity of denotation-sets, and the determinacy of truth-conditions, are not fully *determined* by procedures, but are *constrained* by sets of procedures. Some of these procedures allow an agent to form default-based judgements. Others enable the agent to strengthen some default-based judgements at the expense of other judgements. My contention will be that insofar as declarative sentences have truth conditions, these truth conditions (and hence the meanings of the sentences) are constrained by the kinds of semantic procedures just described.¹

### 2. FODOR’S CRITIQUE

Fodor’s critique (1978) is directed at a form of procedural semantics which is difficult to defend. Nevertheless, it will be useful to examine his objections, because they serve to remind us of the difficulties which a successful modification of procedural semantics must take into account. Fodor’s criticisms center around two claims. (1) The first is that adherents of PS are committed to the view that the meaning of a sentence $S$ is representable by a machine-language procedure into which $S$ is “compiled”. The “compiler” which translates $S$ into machine code constitutes a semantic theory for the natural language in which $S$ occurs. (2) Second, Fodor claims that PS constitutes “an archaic and wildly implausible form of verificationism” (1978, p. 229). Let us consider each of these claims in turn.

#### 2.1 Fodor’s First Claim

Is it true, in the first place, that most advocates of PS would assert that the meaning of a sentence $S$, which is interpreted, say, by an automatic question-answering system, is representable by the machine-language procedure into which $S$ is ultimately translated? Both Johnson-Laird (1978) and Wilks (1982) have challenged this claim, and it is difficult to find computational linguists who even mention machine language in connection with the interpretation of natural language. Certainly, it is possible to find researchers

¹ The theory presented in section 5 adopts an approach which is similar, in spirit, to that presented by Woods (1981, 1986). Important differences exist between the approaches, however. Unlike Woods, I argue that those procedures which govern the use of even such simple predicates as ‘red’ and ‘oval’ are not effective procedures, and may return revisable decisions. Furthermore, the theory presented here does not presume that any sentence has *absolute* truth conditions. Rather, it postulates that the total truth conditions of a sentence are constrained by semantic procedures. Absolute truth conditions will exist only if the constraints converge to a limit.
(Dahl, 1981; Winograd, 1971; Woods, 1981) who have expressed the view that meanings of natural language queries may be represented by canonical procedures into which they are translated, but the examples provided by such researchers are typically Microplanner, Lisp, or Prolog procedures, that is, high-level procedures which contain constants such as 'block,' 'contains,' 'Fred,' 'parent,' 'left-of,' and so forth. Fodor argues, however, that insofar as these high-level procedures have any semantics which a computer could be said to possess, it arises from the fact that such high-level procedures are interpreted or compiled into machine language which is executable on particular machines. And even when a compilation is performed, constants such as 'block,' 'Fred,' 'left-of,' and so forth, are not translated into procedures which are in any sense meaningful to a machine—rather they become meaningless symbolic strings which are stored in arbitrary memory locations. Thus, high-level constants such as 'Fred,' 'left-of,' and so on, only have a semantic interpretation in the mind of the system builder. In other words, the semantics of these high-level expressions is "parasitic upon" the interpretation assigned by the programmer, which Fodor believes to be classical semantics (CS). Furthermore, even when a high-level procedure is ultimately reduced to executable machine code, the semantics of the machine code is again parasitic upon CS, because such code has meaning only when humans attach an interpretation to it, and the interpretation they attach is provided by classical denotational semantics. This, at least, is the line Fodor takes.

Now, the arguments just outlined conflate certain issues, and though I have presented a highly condensed version of Fodor's position, these issues are conflated in Fodor's own presentation. Consider first the conclusion that the semantics of such high-level constants as 'Fred,' 'left-of,' and so forth, must be supplied externally, by the system builder, because such constants are compiled into binary strings which do not intrinsically denote such entities as Fred or relations such as left-of. This conclusion is justified when we are dealing with assertion bases or data bases which contain no procedural mechanisms for relating such binary strings to external objects, properties, or relations. If a given AI system merely answers queries by consulting a data base, and not by consulting the "real world" (the way a robot equipped with sense transducers might), then certainly the system has no way of discerning whether the symbol 'rook' refers to chess pieces, captains, elves, or nothing at all. (Searle makes this point forcefully, 1980.) In this case, the semantics of such expressions is indeed parasitic upon externally supplied interpretations. However, a robot which was programmed to classify rooks, captains, and so forth, by consulting its sensory input, would have very different procedures attached to the words 'rook' and 'captain,' and would have the ability to map these words onto the appropriate objects. Thus, we would have some reason to say that such a robot possessed a semantics for these words.
Fodor eventually considers robots of the type we are considering. When he does so, the focus of his argument shifts from machine language to machine language with transducer capacities, which he refers to as MLT. He claims: (a) that MLT shares the defects of machine language simpliciter, insofar as the referring expressions of MLT operate at the wrong level of abstraction (they refer to things like machine addresses and arithmetic constants, not rooks and captains). He also contends: (b) that the semantics of MLT is still parasitic upon a denotationally based CS. In a rejoinder to Fodor, Johnson-Laird (1978) concedes the existence of this parasitic relationship, but maintains that the parasitic nature of this relationship was not at issue. In section 3, I argue for the opposite conclusion—that the truth of some form of PS is an ontological precondition of CS, not vice versa. However, in what immediately follows, I argue that Fodor's claim that MLT semantics is parasitic upon CS rests upon a mistaken view of the underlying motivation of PS.

We have already noted that early advocates of PS were not explicitly concerned with machine language. However, a defensible PS stance towards MLT would be to concede that the semantics of MLT primitives is radically different from the semantics of higher-level primitives. Nothing in the PS position entails that a direct translation can be established between the two sets of primitives. A more reasonable claim, from the PS standpoint, would be that MLT provides executable mappings from symbolic strings onto the world itself. Moreover, because MLT procedures are executable, it is plausible to suppose that high-level programs (which are supported by MLT) should also be able to provide a mapping from strings of natural language onto the external world. Fodor seems to believe that this mapping relationship is somehow parasitic upon our describing in some CS-oriented metalanguage what the mapping is. But this ignores the fact that a computer does not execute programs by consulting the denotational semantics that we attach to its MLT primitives, but by being wired in such a way that a suitable MLT program causes it to map strings onto the world.

Now, to be sure, Fodor objects that it is naive to suppose that MLT programs could map strings onto a world as subtle and varied as the one we occupy. However, this objection arises from independent misgivings which we address below. If we grant, for the moment, that MLT programs could effectively map sentences onto appropriate situations, then any robot which possessed these programs would, in a tacit sense, “know the semantics” of those sentences. (Whether such a robot could be said to “understand” the natural language in the conscious way that Searle explores, is a separate issue, and will not be addressed here.) Furthermore, since a robot need not interpret its machine code (in the denotational sense) in order to execute that code, Fodor's claim that the semantics of MLT is parasitic upon CS is not well founded. For a machine to possess (or tacitly know) the semantics of its machine language in the sense required by PS, is just for the machine to stand in the right causal relationship to that machine language.
2.2 Fodor's Second Claim

Fodor's case does not rest entirely upon his claims about machine language. His strongest arguments concern the identification of PS with a "wildly implausible form of verificationism." He would, for example, deny that a robot could be constructed which possessed procedures capable of verifying the truth of most declarative sentences in, say, English. The arguments Fodor employs are essentially those philosophers have employed against early forms of the verification theory of meaning (cf. Hempel, 1950). These arguments are weighty and resulted in substantial revisions to the verification theory. It is not clear, however, that such arguments undermine the underlying idea that procedures (or something akin to procedures) are required to establish the connection between symbols and the world they symbolize.

The recurring theme of Fodor's antiverificationist arguments is that empirical assertions such as "Some birds are blue" are not conclusively verifiable, because there are no procedures which could fully establish whether, for example, something is a bird. Even if there were foolproof methods for testing such simple properties as 'blue,' and 'soft,' more complex (natural kind) concepts such as 'bird,' and scientific concepts such as 'gravitational force' are not decomposable into a checklist of simple properties whose presence can be straightforwardly verified. To support this claim Fodor cites the failure of 250 years of British Empiricism, reaching back to Locke and Hume, to produce any plausible instances where the atomistic reduction of physical objects to "bundles of sensations" is actually carried out. In addition, Fodor appeals to the Quinean thesis (Quine, 1953) that any empirical belief, which has received some confirmation from experience, may be retracted in order to preserve the consistency or credibility of some larger network of beliefs. This network may be a scientific theory, or may simply be our total set of beliefs about the world. Correlative with this thesis is the doctrine that the meaning of any empirical sentence is inextricably interwoven with the meanings of an entire network of commonly accepted beliefs.

Most contemporary philosophers of science adhere to some version of the Quinean thesis, especially as it applies to theoretical entities such as mass and force, or electrons. It is often noted that no finite number of sense observations could exhaust the total set of potential observations implied by the assertion that electrons exist. Consequently, no finite set of observations could entirely verify the claim that electrons exist. Quine maintains that no clear distinction exists between the theoretical entities of science and commonplace entities such as birds and desks, although the latter are conceded to be closer to "the periphery of experience" than theoretical entites are. (That is, the latter have meanings which are more nearly expressible in sensation-oriented language). Still, on Quine's view, even the assertion that "This is red" carries some theoretical import, and might be rejected to preserve a given theory.
In section 5, we examine Quine's view in more detail. For the present we should note that, although not all linguists and philosophers accept Quine's claim that every observational term carries theoretical presuppositions, there seems to be a general consensus that effective verification procedures do not exist either for natural kind terms or for the more theoretical terms of science. In light of this it appears that PS, in the form described by Fodor, should be abandoned. However, in the following section, I offer reasons for supposing that some alternative form of PS must be defensible if adequate foundations are to be provided for classical (Tarskian), possible world, and Situation Semantics.

3. FOUNDATIONS OF MODEL-THEORETIC SEMANTICS

If we were to list the current contenders for the "favorite semantic theory of cognitive researchers," it is probable that situation-based and possible world semantics would appear at the top of the list, followed perhaps by some variation of classical Tarskian semantics. What these theories share is that they attempt to specify the meaning of each declarative sentence in terms of set-theoretic objects and truth values. In each case the meaning of some sentence is specified in isolation from one's total network of beliefs. In the case of Situation Semantics, meanings are fixed by reference to sets of abstract situations which could support the truth of a sentence. Possible world semantics specifies the meaning of a sentence in terms of the composition of extensionally defined functions, which provide mappings from possible worlds to extensions and truth values. By contrast, Tarskian semantics determines the meaning of referring expressions in terms of their extensions in the actual world, and fixes the meaning of entire sentences in terms of set membership and inclusion relations which hold between the extensions of constituent expressions in the sentences.

Each of the foregoing model-theoretic systems presupposes that certain sets of comparatively large or infinite cardinality can be individuated with precision sufficient to fix the meanings of individual sentences in a language. The actual processes by which language users individuate the members of these large sets are commonly relegated to the realm of semantic competence, and are not taken to belong to the province of semantic theory per se. Model-theorists frequently adopt the metaphysics of realism, according to which abstract sets and their members are assumed to exist quite apart from anyone's ability to individuate these objects. Not surprisingly, realism is controversial among philosophers and mathematical intuitionists. I shall not address that controversy here, but it is worth noting that the view that semantics proper is entirely separate from epistemic concerns becomes less plausible when realism is rejected. However, in what follows I shall assume

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2 Additional difficulties with verificationism may be found in Hempel (1950).
the correctness of realism. Thus, we assume that individuals, sets, sets of sets, and so on, have an existence entirely independent of our ability to distinguish these objects. What shall concern us here is the manner in which particular individuals and sets (namely, those denoted by the primitive expressions in a language) become tied to their symbolic counterparts (e.g., n-ary predicates). For, although model-theory does not explicitly address the question how primitive expressions come to denote (or refer to) particular objects or sets, it is clear that model-theoretic semantics is only possible because the relevant denotation (or naming) relations do get established. If it can be shown that denotation relations can only be established if language users have certain cognitive abilities, then any semantic theory which presupposes the existence of denotation relations will be ontologically dependent upon whatever renders those cognitive abilities possible.

In what follows, it will be argued that the establishment of denotation relations does in fact require the existence of special cognitive abilities, and that these abilities, in turn, presuppose the existence of something very like computational procedures. Not surprisingly, the abilities in question include the ability to notice resemblances between physical objects, and to judge that different objects fall into the same class. Clearly, these abilities are important preconditions of semantic competence. I shall argue further that semantic competence is not something wholly parasitic upon semantics, but that semantic competence and semantics proper both presuppose the existence of processes which may be viewed as procedural in an extended sense. Before proceeding, it would be best to clarify this sense.

Within computer science, procedural processes are commonly identified with formal symbol manipulations (symbolic computations). By contrast, I will take procedural processes to include not only symbolic computations, but also the kinds of analog processes exemplified in connectionist (PDP) nets and sense transducers. That is, if a mechanism consistently "computes a function" (or does so to a high degree of approximation) it will, for our purposes, be taken to "execute a procedure." No doubt, this usage is somewhat nonstandard, but I believe it captures one of the senses of 'procedure' to be found in earlier treatments of PS. Moreover, the concept of a procedure seems to be our nearest analogue for describing the class of processes with which we shall be concerned.

In the remainder of section 3, we examine three varieties of denotation-based semantics. In each case we consider arguments to the effect that the denotation relations posited by the semantics ontologically presuppose the existence of special kinds of procedures. We shall focus primarily upon the denotations of primitive n-ary predicates, since the foundational issues which concern these predicates are central (and essentially the same) for each of the semantic systems we consider.
3.1 Tarskian Semantics
Let us first consider Tarskian semantics, which corresponds well with Fodor's description of classical semantics, CS. As widely understood, Tarskian semantics individuates the meanings of n-ary predicates solely in terms of the extensions of the expressions. This has the obvious drawback that it renders all co-referential predicates synonymous (e.g., 'unicorn' and 'pixie' would be synonymous). We will ignore this difficulty, however, since it can be substantially diminished by moving from actual to possible denotations. Rather, we focus upon certain foundational problems which arise for either formulation. The first of these problems is ontological, the second concerns semantic competence. Aspects of these problems are discussed by Putnam (1980), Wilks (1982), and Woods (1981). In the following section, I attempt to crystalize certain issues underlying the genesis of denotation relations. In section 3.1.2, the relationship of denotation relations to semantic competence is examined.

3.1.1 The Genesis Problem. The genesis problem concerns the establishment of denotation relations for primitive predicates, for example, for common nouns and simple transitive verbs. Because the creation of denotation relations in most applications of Tarskian semantics (to proof theory or computational linguistics) occurs in the context of an assumed metalanguage, the genesis problem is rarely confronted in its general form. Nevertheless, the problem raises deep questions both in cognitive theory and the philosophy of language. Consider, for example, the relationship which holds between the noun, 'cat,' and its extension. Why is it correct to say, in English, that 'cat' denotes this set, but that 'zog' does not? Clearly, the set of cats is a possible extension for 'zog.' Moreover, from a set-theoretic standpoint, there is some function which maps 'zog' onto this set. So, it seems hopeless to attempt to explain the fact that 'cat' actually denotes a certain set by appealing solely to the existence of an abstract function which maps 'cat' onto a particular set of objects. It is widely conceded that if we wish to explain how 'cat' (and not 'zog') denotes the set of cats, we must somehow address the fact that 'cat' has a particular conventional usage, while 'zog' does not. If we reject (as it seems we must) the simplistic verificationist claim that usage conventions for predicates like 'cat' are determined by effective procedures, we are left wondering how 'cat' does become tied to its

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1 Some would maintain that Tarskian semantics identifies the meanings of predicates with properties, rather than extensions. However, with respect to the issues which concern us, this interpretation does not distinguish Tarskian semantics from Situation Semantics. Since we consider Situation Semantics in section 3.2, we shall defer discussion of the 'property' interpretation.
denotation. Below, I argue that, in the absence of decision procedures, the creation of the denotation relation must at least involve something like procedures which establish a strong prima facie case that something is a 'cat.' Since this argument proceeds by the elimination of alternative explanations, we now consider these alternatives.

In the case of most common nouns and relation names found in natural language, we may readily dismiss the possibility that a denotation relationship is established by first explicitly displaying the entire extension of the intended denotation class, and then "baptising" the class with a symbolic label. Not only is it manifestly false that this happens, but given the resource limitations of language users, such an explicit enumeration is impossible for all but unusually small extensions.

A superficially more promising alternative than the above is to suppose that a predicate, say 'cat,' acquires its denotation by being associated with a description (or symbol) in some antecedently understood fragment of language. This fragment may occur either in a separate metalanguage, or in the same language as the predicate in question (provided the fragment does not contain the definiendum itself). Now, while it may be true that some words acquire their denotations through the method just sketched, this can scarcely be a general account of the origins of denotation relations. For this method is clearly parasitic upon the semantics of the antecedently understood language fragment, which contains its own denoting expressions whose denotations must somehow be established. Even if we suppose that predicates in our public (shared) language acquire meaning by association with symbols in some innate language of thought, at least some expressions in this internal language must have denotations of their own. If we are to avoid an infinite regress, some of these denotations must be acquired without resort to yet another representation language. (Lewis, 1976, makes a similar point.)

The method of assigning denotations just outlined, fails as a general method, because it fails to address the fact that some symbols (at least) must be "grounded" or anchored to the world itself (rather than to other bits of language). There is an alternative account which fails for a similar reason. According to this account, the existence of denotation relations is somehow explained by the fact that there exist natural groupings of objects in the world, and that objects within a natural group all share the same property. In instances where the objects may plausibly be regarded as belonging to the

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4 It is important to recall that the translation of predicates into a procedural language, such as MLT, does not lead to any similar regress in the assignment of denotations to referring expressions, because MLT acquires its semantics by virtue of being directly executable on particular machines. From the machine's standpoint, languages such as MLT do not even contain denoting expressions, and should not be regarded so much as languages as causal mechanisms which enable machines to process information, and create associations between symbols and sensory input. Moreover, a machine may follow procedures, in the technical sense previously explained, without any programming language being present in the machine.
same natural kind (e.g., cats), it is often suggested that this shared property is an *essence*, which may or may not be discoverable by scientific means. Now, natural kind theory (essentialism) has its controversial aspects, but for present purposes we will ignore the controversy. Let us suppose that natural kinds, and even essences, do exist. Let us further suppose that objects which fall into nonnatural classes (tables, radios, etc.), all possess simple or complex properties in virtue of which they fall into their respective classes. We may even assume that the boundaries among all these classes (whether natural or nonnatural) are as sharp and distinct as we could hope for. None of these assumptions, taken separately or jointly, explains how the (grounding) connection between a denoting term and its extension becomes established. At best, they establish the possibility that a symbol or expression could come to have a clearly individuated set as its denotation.

We have previously noted that primitive predicates in our public languages (e.g., 'cat') do not intrinsically denote anything whatsoever. Moreover, it seems clear that they could never come to denote anything unless they are actually used in some systematic way. This systematic use must include the application of the predicate to objects which at least appear to belong to the intended denotation set (appear, that is, by virtue of resemblances which language users ostensibly notice). Now, it may be that part of the process which guides an agent's application of a term to the world includes a translation of the external symbol into some expression in an internal language of thought (cf. Fodor, 1975). However, even if this is so, there must exist other processes which enable the agent to connect the internal symbol with an external object or situation. For, if there are no processes by which the internal symbol becomes associated with putative members of the intended denotation set, then the internal language remains ungrounded.

In light of the foregoing, it seems safe to conclude that denotation relations for primitive denoting expressions can only be established if there exist processes (at least) which guide agents in the application of symbols to *prima facie* candidates for membership in the intended denotation. The question we now consider is whether these processes are merely causal, or whether they are something more restricted than that, for example, procedural processes. We will take it as a constraint on an acceptable answer that the processes in question provide at least some basis for the notion of correct usage. For, if the processes which govern the application of a symbol to the world do not provide even a partial basis for correctness, it is difficult to see what else could possibly play that role.

Let us begin by assuming that the processes under consideration are not procedural (in our extended sense), but merely causal. Now, if these causal processes are to provide a foundation for correct usage, then explanations of these processes must eventually appeal to notions such as 'standard causal chains' or 'standard background conditions.' For a given object may provoke a given symbolic response, for example, 'cat,' but do so via the wrong
mechanism, for example, because the subject's judgement has been affected by hallucinogenic drugs. In such a case there may well be a causal relationship between an external object and the subject, but the relationship is not of the correct kind. Any causal account of denotation must somehow distinguish the occasions when a symbol is linked by acceptable causal chains to its denotation, from those when it is linked to an appropriate object by an unacceptable causal chain, or to an entirely inappropriate object.

We may summarize the preceding by observing that a denoting symbol is correctly used only if its application proceeds via standardized (acceptable) causal chains. These standardized chains must be such that the same stimulus always leads to the same (or very nearly the same) internal response. Moreover, the causal chains must have the property that a variety of distinct objects (those which at least appear to belong to the same extension) can provoke the same internal state. In effect, these causal chains must ensure (or closely approximate) a many-to-one functional mapping from external stimuli to the same inner state.

It is significant to our concerns that the kinds of causal chains we have been considering can only exist against a background of standard conditions. In the context of standard conditions, such causal chains are repeatable processes which behave as mapping functions. As such, they accord very well with our notion of a procedural process. Indeed, given our usage of 'procedure,' the causal chains clearly instantiate procedures. However, in light of the fact that we are assigning a technical sense to 'procedure,' we should not attach undue importance to the label. What is significant is that the causal processes in question are of a special, functional kind, which can be modeled by computational procedures more readily than (unrestricted) causal chains in general can be. The belief that these functional processes are presupposed by the existence of primitive denotation relations seems to have been an underlying contention of earlier advocates of PS. I do not claim to have proven that their belief is correct, but I hope to have rendered it a reasonable conclusion. For it is difficult to see how denotation relations could ever be established in the absence of standardized processes (procedures) which at least constrain correct usage.

3.2.2 Semantic Competence. Hopefully, it has by now emerged that important aspects of semantic competence are inseparable from certain preconditions of denotation relations. For, it is very natural to suppose that many of the cognitive procedures which enable the creation of denotation relationships are among the procedures (standardized processes) which enable one to identify prima facie instances of physical-object concepts. The processes that allow one to identify something as a cat, say, certainly seem to include at least some of the processes involved in establishing the usage of 'cat' in English. No doubt, the establishment of conventional usage involves other processes as well (patterns of usage must be established in the
linguistic community at large), but in light of the foregoing, it is difficult to accept the view that semantic competence is entirely parasitic upon an ontologically prior, pure semantics. Rather, it seems that semantic competence and semantics proper are both ontologically dependent upon some of the same cognitive procedures.

3.2 Possible Worlds and Situation-Based Semantics

In section 3.1.1 reasons were presented for believing that primitive denotation relations are only possible in the context of usage procedures which link primitive predicates to putative members of a symbol’s extension. I shall now argue that both Montague-style (possible worlds) semantics, and Situation Semantics are similarly dependent upon the existence of usage procedures. Consider first Montague semantics. In Montague’s system (and in kindred systems such as Lewis, 1976), the intension of a declarative sentence is formed through the composition of intensions which belong to the primitive parts of the sentence. Common nouns belong to this category of primitives, and the intension of a common noun N is taken to be an extensional function F from each possible world Wi to the extension of N in Wi. Thus, the intension of N is simply a set of ordered pairs of the form (W,E), where W names a possible world, and E names an extensional-set in that world.

Now, the problems associated with individuating possible worlds are well known, but they shall not concern us here. Rather, we are again concerned with the relationship between a symbol (in this case, N) and a set (in this case, the function F). In particular, we wish to consider how the symbol N comes to have the particular function F as its intension. Now, given that the number of possible worlds is at least intractably large (if not infinite), and given that a noun’s extension in a given possible world is often intractably large, we may dismiss the possibility that the function F becomes associated with N via a baptism involving an enumeration of each pair (Wi, Ei) in F. Moreover, for reasons analogous to those presented in 3.1, we cannot suppose that, for all instances of F and N, F becomes associated with N via some metalinguistic description or definition, for this supposition would lead either to an infinite regress or to circularity. It seems clear, in fact, that in the general case, we can only explain the connection between F and N by considering the processes which establish Ei as the extension of N in at least some possible worlds.

Now, if we were to suppose for the moment that there exists, for each primitive common noun N, a general decision procedure, which ascertains whether a given object falls into Ei for each Wi, and if we further supposed that our actual usage of N is guided by this procedure, then our problem would be greatly simplified. For the function F would be logically determined by this procedure, and the association of F with N would be established by the presumed fact that we would have, over some period of time, (tacitly) adopted the decision procedure as our convention for using N. We
know, however, that decision procedures of the required type do not exist. In the absence of such procedures, we must consider what could establish a connection between N and its extension in each possible world.

In section 3.1, we presented reasons for believing that the denotation relation between N and Ei in our world could only be established via pragmatic usage procedures, which could at least determine an object's prima facie membership in an extension. Since our earlier arguments did not depend upon details peculiar to our possible world, it seems reasonable to suppose that usage procedures would be required to establish denotation relations in many possible worlds. It is even plausible that the very same procedures which guide our usage of N in the actual world, should determine usage in other possible worlds, since it is in the actual world that we determine what an element of N's extension must be like. Presumably, elements of N's extension in other possible worlds must strongly resemble those in our world. In any case, it seems clear that function F could not be the intension of N, unless a denotation relation is at least established between N and its extension in our possible world. In light of this (and our arguments in 3.1), it is reasonable to conclude that possible world semantics is every bit as dependent upon the existence of pragmatic usage procedures as Tarskian semantics.

It is not difficult to see that a similar conclusion holds for the Situation Semantics of Barwise and Perry (1983). This becomes apparent once we reflect that situation-types are an essential component of the Barwise and Perry theory, and that, on the theory, situation-types are functions which take individuals and relations as arguments. Relations are taken to include properties (unary relations), as well as relations of higher arity. Barwise and Perry take relations, including properties, to be primitive aspects of reality. For example, the property cat is simply that primitive quality which all objects in the extension of 'cat' share. As Winograd (1985) has observed, Barwise and Perry say very little about the nature of primitive relations (including properties), or about how they are individuated, and so on. At the moment, however, we are concerned with a different, though related question, namely, how does the relationship between a property name (unary predicate) and the property itself become established? Clearly, this question is not essentially different from our earlier question about the relationship between a predicate and the essences postulated by natural kind theory. As before, we are again confronted with the fact that the existence of "objective" natural groupings in the external world does not by itself suffice to explain how denotation relations become established. The members of a natural group may all share a single property, and this property may be as simple as we like to suppose, but unless there exist at least fallible processes by which we can recognize this property, no denotation relationship can be established. We have already presented reasons for viewing these processes as procedural.
Now, it is entirely possible that Barwise and Perry would agree that procedures are ultimately required to provide the foundation for their approach, for they remark (1981, p. 388) that: "The domain A of individuals and the domain R of relations are parallel products of conceptual activity, that of individuation" (my italics). On the view we have been presenting, the processes by which properties (and relations) are individuated would be a subset of the processes which permit the creation of denotation relations.

3.4 Indeterminacy of Extensions

Before leaving this discussion of model-theoretic systems, I wish to emphasize that we have so far been concerned with foundational issues. Nothing said thus far challenges the correctness of the semantic systems we have considered. Rather, we have been concerned with the preconditions of these theories. My contention (which harks back to previous advocates of PS) is that any model-theory we favor will need to be grounded by a deeper, process-based semantics. The theory outlined in the remainder of this paper is an attempt to characterize this deeper semantics.

Now, there are some (e.g., Soames, 1984) who readily concede that in some sense model-theories must be grounded, but they deny that the processes which ground the primitives of model-theory have any bearing upon semantics. Rather, they take these processes to be relevant to concerns about competence, and knowledge. By contrast, our view is that such processes should be considered part of semantics, because they enter into the mapping relationship between symbols and the world symbolized. Commonly, these mappings are described abstractly as functions, and these functions are taken to be an essential part of semantics. However, if it should turn out that these functions are idealized (or even imaginary) relations, then we may need to fall back upon processes and procedures if we are to understand the reality of these mapping relationships.

Moreover, there are reasons to believe that the alleged mapping functions are indeed idealizations. For, given that we do not possess effective procedures for selecting the extensions of predicates (or, for selecting the properties associated with predicates), serious doubts arise about the adequacy of constraints on the boundaries of extensions. If the boundaries of extensions are underconstrained, it follows that the identity of the functions at issue are also underconstrained. (Analogous remarks apply to the mapping between a predicate and a property.) We have argued that defeasible procedures of some kind are required to establish at least some constraints on these boundaries. We have conjectured that these procedures provide the basis for pragmatic, fallible judgements about membership in extensions. Such fallible judgements may need to be revised in the light of future evidence. Moreover, the fallibility of these judgements does not merely have epistemic implications. For, unless it can be shown that there exist objective constraints suffi-
cient to determine uniquely the membership of a predicate’s extension, we should be prepared to accept that the only real constraints are ones that arise as a consequence of the fallible procedures we follow, and the way the world is. In section 5, we describe additional constraints on the membership of extensions, over and above those we have so far considered. But these additional constraints do not suffice to ensure a unique membership for any external, physical object extension.

4. BACKGROUND FOR MODIFIED PROCEDURAL SEMANTICS

In order to provide an intuitive sense of the semantic theory which follows, it may help to consider Putnam's essentialism (1970), which is a form of natural kind theory. In Putnam’s theory the members of a natural kind, for example, lemons, all share some unique essential structure, which, though not immediately observable, is discoverable by scientific means. In order to account for the fact that speakers of the language manage to use natural kind terms when they are unable to observe the alleged essence in particular cases, (or when they lack knowledge of the essence), Putnam postulates that speakers know a set of “core facts,” involving observable properties, which characterize a stereotypical instance of the natural kind in question. The core facts for lemons, for example, include being yellow, being sour, being oval, and so forth. Putnam argues, and it is widely conceded, that no single core fact is true of every instance of a natural kind. He argues further (1973) that we can imagine circumstances in which an object exhibits all the core facts typically associated with a given kind, but which lacks the crucial essence, and thus fails to qualify as an instance of the kind. The example he cites involves an imaginary “Twin Earth,” which possesses a substance having all the appearances and behavioral characteristics of water (it boils and freezes at the right temperatures, etc.) but which has a chemical structure quite different from H2O. Putnam maintains that, were we to visit this planet, we would refer to this substance as water only until we discovered its different chemical structure. Once we learned that it lacked the essential structure of “earth water,” we would cease to call it water.

Now, Putnam’s example is controversial because it seems entirely possible that speakers of English would simply allow that “Twin Earth water” and “earth water” are different kinds of water. On the face of it there is no reason why water should not be treated as a generic class which contains different kinds. If we adopt this approach, we might still maintain that water is

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1 It would seem to be incumbent upon those who maintain that—the processes by which denotation relations are established are irrelevant to the identity of denotation relations—to demonstrate just what does constrain the identity of extensions. Of crucial relevance here is the fact that set theory may determine the space of possible extensions, but cannot determine which of these possibilities is selected as the actual extension. If the selection processes under-constrain the extension, what could fully constrain its membership?
necessarily present when all the core facts associated with water are present. However, since Putnam’s view is supported by the general Quinean doctrine that any given belief might be abandoned in order to preserve some alternative body of beliefs, and since I wish to show that PS can be modified to accommodate even this Quinean doctrine, I will proceed as though Putnam’s conclusion was uncontroversial. Let us consider, therefore, how Putnam’s general thesis about the meanings of natural kind terms might be reconciled with a procedural approach to semantics.

4.1 Core Properties Versus Deeply Embedded Beliefs

For convenience, we assume that \{p_1, p_2, \ldots, p_n\} constitutes the set (CORE) of core properties typical of those instances of a natural kind K, which we normally encounter, at present. We assume that any given \(p_i\) may be absent from any given instance of K, and that some object may possess all elements of CORE while failing to be in K. These assumptions are consistent with the premise that possessing any of certain specifiable subsets of the CORE set is a default condition for being in K. For example, the default condition might be that a candidate \(X\) exhibit a subset of CORE properties which has, by induction, been associated with natural kind K. This default condition can be overridden by the presence or absence of a scientifically “certified” essence for kind K, but even assertions of the form “E is the essence for kind K” are subject to revision, in light of future changes in the prevailing theory. We can integrate these observations in the following way.

Let us conjecture that the meaning of each natural kind term K is largely (though not wholly) determined by what Quine calls a deeply embedded belief. We might regard each such belief as a meaning axiom, because such a belief is so central to the meaning of the particular K it contains, that it cannot be rejected without substantially altering the meaning of K. A schematic example of such a meaning axiom is given below.

\[\text{A1: An object } O \text{ is in kind } K \text{ at time } t, \text{ if } O \text{ possesses at time } t \text{ a feature } X, \text{ and } X \text{ is the only typical cause, under the prevailing conditions of observation, of the occurrence of a set of properties CORE.}\]

Note that the above axiom presupposes that a unique feature (essence) typically causes the occurrence of the CORE set. This presupposition can be

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4 It is possible to construe PDP (connectionist) nets as devices which induce concepts consisting of weighted subsets of core properties. Unlike the artificially precise concepts induced by algorithms such as Michalski’s “star” procedure (1983), concepts in PDP nets are not explicitly represented by formulas, but are implicit in the distribution of weights over various connection links. An object which is recognized by a PDP net as instantiating a particular concept will possess a salient subset of the properties in the CORE set.

7 Meaning axioms, in the present sense, are to be distinguished from the purely analytic “meaning postulates” posited by some verificationists. The latter were taken to have no empirical content and may be construed as “rewrite procedures.” Thus, “a brother is a male sibling” might qualify as a meaning postulate.
used to explain the plausible contention that, were we to discover someday that two separate essences each commonly cause the CORE properties which we now use to identify water, we could say that we were mistaken in thinking that 'water' denotes a natural kind. In such a case we might plausibly claim that we had falsely presupposed that we were dealing with one natural kind, when in fact two natural kinds were present. If we thereafter adopted the convention that 'water' denotes the subclass associated with one of the two essences, and not the other, then we should be rejecting A1, and altering the meaning of K. A1 may be an axiom to which we are strongly committed, but once particular "essences" are known, we may tie natural kind terms directly to the individual essences, and relinquish our commitment to A1.

4.2 Meaning Axioms and Goal-Driven Procedures
Let us now consider what role A1 might play within the framework of PS. Suppose that A1, and similar axioms, become encoded in some logic-based programming language, which permits axioms of significant complexity to be represented, and which contains built-in inference mechanisms permitting both deductive and default inferences to be made. We may regard Prolog as an impoverished example of the kind of programming language suggested here. Now, an axiom such as A1 may be viewed as a top-level, goal-oriented procedure which can be used to show that an object is in kind K. However, some of the subgoal procedures, which are required to establish the top-level goal in question, may be defined only by a large network of other axioms. For example, it seems reasonable to suppose that meanings of predicates such as 'cause-of' can be represented by sets of axioms, but that these axioms, construed as procedures, may engender searches which converge upon answers only in the limit (if indeed they ever converge). A possible axiom for the 'cause-of' relation might be:

A2: cause-of(A, B) if according to some correct scientific theory, B is predicted to occur after any occurrence of A, provided certain background conditions c1 . . . cn obtain.

Axiom A2 may, in turn, lead us in search of a correct scientific theory, which may lead us to an axiom such as:

A3: correct-theory(X) if X is a theory and X explains our total set of observations at least as well as any alternative theory, and X will never be rejected in favor of a theory which can explain more observations than X.

Now, we will never be in a position to establish the last subgoal in the above conditional, but since we often need to form judgements about correctness, we allow ourselves to pretend (or assume) that the last subgoal is satisfied, so that we may derive the default conclusion that X is a correct theory. For example, we do not know with total certainty that the theory, which holds that the observable properties associated with water are caused
by the chemical structure $\text{H}_2\text{O}$, will never be overturned by a better theory, but we allow ourselves the default conclusion that this theory is correct. This default conclusion, combined with an appropriate instantiation of A1, allows us to derive many more default conclusions to the effect that particular samples, having an $\text{H}_2\text{O}$ structure, belong to the kind *water*.

Now, it should be stressed that, on the semantic theory we are considering, A1, A2, and A3, are not themselves default axioms. Rather, I suggest that we possess pragmatically oriented procedures which *permit us to derive* default conclusions from such axioms when we either have strong reasons for assuming the subgoals are satisfied, or we are strongly motivated to satisfy the top-level goal, but lack the resources to satisfy *all* the subgoals. In cases where a particular default conclusion is repeatedly obtained from the same set of initial assumptions, a new default rule may be "compiled." For example, after repeatedly deriving the conclusion "This is water" from the premises "This is $\text{H}_2\text{O}$" and "$\text{H}_2\text{O}$ is postulated to be the essence of water by the best available theory," we compile the *pragmatic meaning rule*, "water(x) if consists-of-$\text{H}_2\text{O}(x)$."

We are now in a position to understand how meaning axioms, such as A1, A2 and A3, can serve to constrain truth conditions at a very abstract level, and yet act as major premises in default reasoning processes which terminate in pragmatic (revisable) judgements. We have seen several places at which default assumptions are required to enable the satisfaction of subgoals in the *process* of satisfying a top-level goal like "This substance belongs to the kind, WATER." Moreover, even the axioms A1 and A2, jointly ensure that we might discover an instance of water, say, which possessed the essence belonging to that kind, but which lacked some typical CORE properties. For A2 reminds us that a cause (in this case an essence) can be expected to produce all its usual effects only when a standard set of background conditions obtain. Considerations such as these, together with the default techniques we have glimpsed, serve to ensure both that we can formulate descriptions of concrete objects in our experience, and that these descriptions can be retracted if the need arises. On the other hand, axioms like A1 and A2 provide the high-level constraints which enable us to say that "This is a water" has truth conditions. If some such constraints did not exist, it would be difficult to make sense of the claim that "This is water" has any truth conditions whatsoever.

5. MODIFIED PROCEDURAL SEMANTICS

The reader will recall that, in section 2, all of Fodor's criticisms were rejected, except the argument that PS embodies a naive form of verificationism. We saw that Fodor's rejection of verificationism was founded upon his appeal to Quine's doctrine of the interconnectedness and revisability of empirical meanings and beliefs. For the sake of argument, and in order to
demonstrate the flexibility of the underlying themes of PS, I will assume that Quine's doctrine is correct, and present a form of PS which is consistent with this doctrine in nearly all respects. Since Quine's theory is generally thought to represent the extreme end of a spectrum, which has classical PS as its other extreme, it is plausible to suppose that, if PS can be modified to accommodate Quine's epistemology, it can also be rendered compatible with less extreme theories.

5.1 Testable Predicates

The modified PS which follows requires the notion of a "testable" predicate, and this notion, which is used here in a technical sense, requires some explanation. We might think of a testable predicate as one which comes about as close to expressing an objectively verifiable property as we ever get. For example, 'red', 'cat', '3 mm long', and 'house' are good candidates for testable predicates. Relational predicates may also be testable. 'Touches,' 'left-of,' and 'colder than' are good candidates for testable relational predicates. The meanings of testable predicates are typically learned by having, among other things, appropriate kinds of sense experiences, and the application of such predicates to the world is typically justified, in part, by processing sensory information.

In calling such predicates "testable," it is not implied that we possess infallible procedures for applying these predicates to the world. As the critics of verificationism have repeatedly argued, no finite number of observations can conclusively establish that something is yellow. On the other hand, it is certain that we do manage to form prima facie judgements about instances of colors, shapes, sizes, and so forth. I wish to suggest that our meaning rules for testable predicates may involve some calls to subprocedures which directly test available sensory information, and calls to other subprocedures which could involve us in an infinite search, if they were all executed. Normally, however, we do not attempt to execute the latter subprocedures. Instead, we make the default assumption that they return success. For example, when we confront an object which appears to be producing sensory information appropriate to a yellow object (this is determined by a complex set of procedures which terminate), we normally make the default assumption that our sense organs are performing well, that the conditions of observation are standard, and so forth. We may possess fallible procedures for investigating whether these background conditions obtain, but these fallible procedures presuppose the correctness of other sensory observations, which in turn raise new questions about different sets of background conditions, and so on ad infinitum. An initial default assumption, to the effect that background conditions are standard, bypasses this infinite regress and permits an empirical judgement (e.g., This is yellow) to be made.
Now, because empirical judgements, even judgements as intimately linked to experience as color judgements, are founded upon default assumptions of the kind we have been considering, the revisability of experiential reports is assured. Furthermore, the existence of such default components seems to be a necessary precondition for the termination of empirical judgements. However, an equally essential precondition is the existence of terminating procedures which can process and classify sensory information as being "apple-like," "sweet-tasting," and so forth. There is no need to suppose that such procedures return clear answers for all possible inputs (i.e., the procedures can be partial functions), but the procedures which classify sensory input must contain terminating, non-default components if the gap between symbols and sensations is ever to be bridged. For the gap (or the mapping process) cannot be bridged by a retreat into an endless succession of further procedure calls, nor can it be bridged by simply assuming that all sensory information has been detected by default processes. If all our procedures returned only default values, we would not be making genuine contact with experience.

In light of the above, I offer the hypothesis that the use of a testable predicate, T, may be modeled by open-ended rules such as the following:

\[ \text{R1: has}(x, T) \text{ if appears-to-have}(x, T) \land p2 \land p3 \land p4. \]

We may view R1 as a Prolog-like procedure which tells us that, to determine whether \( x \) has the property \( T \), we must first determine that \( x \) appears to have property \( T \). In R1, the predicate 'appears-to-have' is assumed to name a procedure, which processes sensory input and returns a value for the parameter \( T \), say 'apple.' Procedures such as appears-to-have might be implemented by means of a PDP net. There is increasing evidence that connectionist mechanisms cope well with the problem of recognizing instances of family resemblance concepts. However, the theory I propose is not committed to connectionism. It may be that more conventional approaches to object recognition will ultimately prove more successful than the connectionist approach. In that case, the appears-to-have procedure might well be implemented by means of more conventional procedures.

Returning now to R1, the terms \( p2, p3, p4 \), are intended to denote background-checking procedures. For example, 'p2' may represent a procedure which ascertains that an agent's sense organs are performing well, while 'p3' represents a procedure which checks that external conditions of observation

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* If a value for 'T' is supplied to the appears-to-have procedure, then that value is compared with the value returned. If a match is found, the next subgoal, \( p2 \) will be tested. Otherwise, failure is returned for the top-level goal is(x, T).
are standard. These background procedures are typically not invoked, but are assumed by default to return 'true.'* When invoked, they check background conditions by invoking other rules which involve other testable predicates. However, it should not be supposed that \( p_2 \ldots p_4 \) are effective procedures. Rather, they may be regarded as collections of (tacitly held) heuristics, which guide the processes of background checking in a somewhat haphazard fashion (as the axioms in a Prolog procedure would guide a search process if the axioms were stored in haphazard order). We might even suppose that not all of \( p_2 \ldots p_4 \) are presently defined. For example, \( p_4 \) may be left undefined until future scientific discoveries are made. Since \( p_4 \) is allowed to "succeed by default," this indeterminacy need not prevent the open-ended rule \( R_1 \) from being used in our present state of incomplete knowledge.

5.2 A Principle of Empirical Meaning

Now, given the concept of a testable predicate as described above, we may introduce the notion of a testable sentence, which, in turn, forms the key-stone of the definition of an empirically meaningful sentence, which we propose below. We define 'testable sentence' as follows. A testable sentence, \( Y \), must satisfy (a), (b), or (c) below, where \( T \) is a testable predicate, and \( c_1 \ldots c_n \) are constants denoting identifiable individuals:

a) \( Y \) has the form ‘\( c_1 \) is \( T \),’ as in ‘\( c_1 \) is red’,

b) \( Y \) has the form ‘\( c_1 \ldots c_n \) satisfy the relation \( T \),’ as in ‘\( c_1 \) and \( c_2 \) satisfy the relation is left-of’.

c) \( Y \) is the negation of a testable sentence.

Given the above recursive definition, I propose the following recursive definition of an empirically meaningful sentence \( S \). This definition assumes that a sentence may derive its meaning, in part, from a background network of sentences (or a background theory) \( TH \).

\[
(P) \ S \text{ is empirically meaningful if one of the following conditions holds: (i) } S \text{ is a testable sentence. (ii) } S \text{ is truth-functionally molecular and all of its sentential components are empirically meaningful. (iii) } S \text{ is not truth-functionally molecular, and there is a set of sentences } R, \text{ such that } R \subseteq TH, \text{ } S \in R, \text{ some testable sentences are derivable from } R \text{ (by deductive or default reasoning pro-}
\]

* It should be noted that 'appears-to-have(\( x, T \))' is a terminating procedure which returns judgements which are not revisable in the way in which judgements such as 'has(\( x, T \))' are revisable. Since the 'appears-to-have' procedure makes no default assumptions, and merely processes sensory input, my claim is that if the procedure is correctly executed, the judgement it returns is correct. This does not entail that I am committed to the positivistic doctrine that all sense-data reports are infallible, for it is always possible that we have incorrectly executed an effective procedure. The problem here is epistemological rather than ontological. We can never be totally certain that we have correctly executed a procedure, though we may suppose that there is a truth of the matter. In this respect I depart from Quine's relativistic ontology.
cesses), and if any member of \( R \) were deleted, the testable ramifications of \( R \) would be diminished.

The principle just proposed bears some resemblance to the verification principle proposed by Ayer (1952). However, important differences exist. For example, condition (ii) in (P) ensures that difficulties raised by Hempel (1950), concerning molecular sentences, are avoided. Furthermore, Ayer's verification principle involves the concept of completely verifiable observation statements, whereas (P) appeals to the notion of testable sentences which are not susceptible to conclusive verification. Also, among other things, condition (iii) provides for the possibility that testable sentences may be inferred through default reasoning rather than deductive reasoning.

The motivation behind (P) is that we want to require that each empirically meaningful sentence has some testable consequences, at least when that sentence is combined with other empirical sentences, and default inferences are permitted. Given both (P) and the prevailing body of scientific belief concerning electrons, it is not difficult to show that 'Electrons exist' is empirically meaningful. For there is certainly a subset of existing sub-atomic theory which taken together with background beliefs physicists commonly hold, will enable us to derive testable consequences from 'Electrons exist.' Even the sentence 'God exists,' often cited as a counter example to the verification theory of meaning, turns out to be empirically meaningful according to (P). At least this is so, given the beliefs people typically hold about God. Of course, the meaning will vary according to the background beliefs people hold, but in most theological systems, God is taken to be the ultimate cause of all physical reality. In such systems, God functions as a theoretical entity which plays a role in explaining the world we experience. Moreover, experiences which are described as 'mystical' do exist, whether or not we agree that they are really mystical. The hypothesis that God exists, if accepted, would help to explain the existence of some mystical reports, at least against a background of religious belief. Whether explanations of this type are correct is not the issue here.

5.3 Pragmatic and Complete Meaning

Let us now consider how (P) bears upon the question, "What constitutes the meaning of a given sentence?" For, (P) may tell us whether a sentence has empirical meaning, but not tell us what constitutes that meaning. Furthermore, how does (P) illuminate the meanings of nonempirical (a priori or analytic) sentences? Let us consider these questions in reverse order. Recall that, for methodological reasons, we are assuming the correctness of Quine's general theory. And, on that theory, all meaningful sentences are empirical to some degree, because every such sentence could enter into one's network of beliefs in a way which affects the testable ramifications of that network. Thus, on Quine’s theory, nonempirical sentences do not present a problem for principle (P) for the simple reason that they do not exist. Of course, if
one rejects Quine’s theory, some other account of analytic sentences is required. A non-Quinean account is given in (Hadley, 1973) which is compatible with the general thrust of verificationism.

We return now to consider how (P) bears upon the meanings of individual sentences. Let us suppose that a given sentence S is empirically meaningful according to (P). This still does not tell us what the meaning of S is. To deal with this problem, we propose to distinguish between S’s pragmatic meaning, which governs the use of S in everyday situations, and S’s complete meaning, which constitutes the set of empirical conditions relevant to the truth of S.

A sentence’s pragmatic meaning may be regarded as a procedure, Q, (or a set of procedures) which determine the sentence’s prima facie truth value in any possible world. We may conjecture that Q is a procedure which is determined through the composition of more elementary pragmatic procedures, which are in turn attached to the primitive components of the sentence (cf. Hadley, 1988). The compositional process which determines the pragmatic meaning Q may be understood by analogy with the compositional process which determines the intension of a sentence within the Montague-Lewis framework. Unlike Montague and Lewis, however, we regard sentential intensions not only as functions in the set-theoretic sense, but as abstract procedures which might be implemented in a variety of ways. Furthermore, we suppose that the intensions of referring expressions (including common nouns) are not functions which return exact extensions for each possible world, but abstract procedures which identify prima facie members of an extension, given a circumstance in a possible world. In section 4, we considered examples of pragmatic rules which comprise the abstract meaning procedures for natural kind terms, for example, ‘water.’ I argued that some of these procedures may be “compiled,” once repeated chains of default inferences are noted. For example, ‘water(x) if consists-of-HH2O(x)’ may be such a compiled pragmatic procedure. It may be, however, that pragmatic meaning procedures are more likely to be the source of our beliefs about what properties are typical of a class, than they are to be “compiled” from such beliefs. That is, it seems plausible from an epistemic standpoint that we first acquire procedures for identifying instances of a class, and later, upon reflection, we formulate particular beliefs about the class, based upon our pragmatic procedures. However, speculation about the origin of pragmatic meaning procedures is somewhat beside the point here. Of crucial concern to us is the hypothesis that pragmatic meaning procedures exist, and that they always involve either the immediate evaluation of testable predicates, or the invocation of other pragmatic procedures which eventually “bottom out” in testable predicates. Any judgement returned by a

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1 The precise sense in which these procedures are abstract, and the relationship of these procedures to Montague’s intensions, is described in detail in (Hadley, 1988).
pragmatic meaning procedure is revisable, in principle, since the judgement is justified, in part, by the evaluation of testable predicates, which in turn involves default reasoning. Furthermore, even when decisions returned by subprocedures are not called into question, pragmatic meaning procedures are assumed only to provide prima facie evidence for membership in natural classes.

We turn now from pragmatic meanings to complete meanings. The complete meaning of a sentence differs from its pragmatic meaning in important respects. For example, a typical language user will know the pragmatic meaning of a sentence, but not its complete meaning. This is because, unlike complete meaning, a sentence's pragmatic meaning can be known in relative isolation from the total set of testable consequences which the sentence entails (deductively or by default) when embedded in a larger network of beliefs. It is this total set of testable consequences which determine what conditions in the world are relevant to the sentence's truth. Let 'Ts' denote the set of testable consequences of a sentence S. In general, Ts includes those testable sentences which are both derivable from the larger theory (network) in which S is embedded, and which also have S in their set of support. In addition, set Ts includes conditionals which state that if certain testable sentences are true, than certain other testable sentences are also true. The motivation for including these conditionals is that many testable sentences are derivable from scientific laws only when testable antecedent conditions obtain.

Given this definition of 'testable consequence,' we may define the complete meaning of an atomic sentence as the set of conditions which would have to obtain in order to satisfy each testable sentence in the set Ts which exists for that sentence. The sentences in Ts may collectively be regarded as a description of the empirical conditions relevant to the truth of the given sentence. The complete meaning of a truth-functionally molecular sentence is formed through a compositional process which takes the complete meanings of atomic sentences as arguments. It is important to bear in mind that for a given sentence S, the membership of set Ts may change (and hence the complete meaning of S may change) when the background theory in which S is embedded is modified. Thus, we obtain the Quinean result that the complete meaning of any empirical sentence may be inseparable from the larger network of assertions (or beliefs) in which it is embedded. We should also note that, since a given Ts will contain both deductively valid and default consequences of S, the sentences in Ts should not be regarded as collectively describing the absolute truth conditions of S. One or more default consequences in Ts may fail to obtain without entailing the falsity of S. However, since the default consequences of S (and indeed all other elements of Ts) are

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11 Conceivably, not every sentence has a pragmatic meaning. In particular, theoretical sentences may lack prima facie procedures determining their use, because they contain primitive referring expressions, (e.g. 'meson') which may lack pragmatic meaning procedures.
relevant to the truth of $S$, any judgement concerning the truth of $S$ must be based upon weighing those elements of $T_S$ which do obtain, against those which do not. The judgement is made by (admittedly) incomplete, heuristically driven adjudication procedures\(^{12}\) which consult pragmatic meaning procedures wherever possible, and which attempt to minimize revisions to the current theory.

It is tempting to suppose that, though the elements to $T_S$ do not jointly describe the necessary conditions of $S$'s truth, they may still describe sufficient conditions for its truth. For, if all the testable consequences of $S$ actually obtain in the world (this could not be ascertained by finite methods, of course), then we may sensibly ask, what more could be required for the truth of $S$? The answer, for nearly all practical purposes, is nothing more is required. However, if we accept the general tenets of Quine's theory, and of prevailing philosophy of science, then we must reply that, for $S$ to be true in anything even approaching an absolute sense, $S$ would have to occur in a network (or theory) which not only accords with our experience of the world, but which could not be supplanted by a theory of equal or greater simplicity, possessing greater explanatory power than the theory which contains $S$ (given the world we actually inhabit).

Now, we may not wish to judge the truth of a sentence within the context of all possible theories, but rather within the limited context of our current conceptual framework. In this case, the set $T_S$ may be regarded as a description of sufficient conditions for $S$'s truth. But even in this case we must recall that $T_S$ contains testable sentences which cannot be conclusively verified by finite methods. Thus, while the set $T_S$ constrains our assignment of a truth value to $S$ at a given time, we are never logically in a position to assign $S$ an absolute truth value.

Now, it may be objected that the above theory of complete meaning contains a serious flaw insofar as it seems not to require sentences to have complete truth conditions. It may be argued that unless sentences have both necessary and sufficient truth conditions, we cannot define entailment relations between sentences, and logic becomes impossible. To reply, we should note that our theory does not require that we disallow the completeness of truth conditions. It is merely compatible with the assumption that our entire network of beliefs, together with our deductive and default reasoning mechanisms, underdetermine the truth conditions of a sentence. It is possible

\(^{12}\) In human cognition, such procedures appear to take the form of heuristics, which are applied in a somewhat haphazard fashion. One goal of these heuristics is to preserve the global consistency of a belief system, while maximizing the degree of agreement between beliefs in general and particular judgements based upon prima facie evidence. Another goal is to minimize the complexity of and the number of revisions required by our theory. To a substantial degree these two goals conflict, and no principled strategy appears to exist for resolving these conflicts. Nevertheless, in practice we do make the pragmatic decisions required to resolve these conflicts, and it is reasonable to suppose that this process can be explained procedurally.
that, in the very long run, adjudication procedures which weigh *prima facie* evidence would converge upon a fixed truth value for a given sentence embedded in a belief network. If so, it might make sense to speak of the absolute truth conditions for the sentence. However, if convergence does not, or could not occur, we may need to relinquish the ideal of absolute truth conditions, and its correlative notion, absolute denotations. For, unless it can be shown (contrary to our previous arguments) that denotation relations are fully constrained and determinate, it is difficult to accept the thesis that fully determinate truth conditions exist. Of course, we may wish to ignore complications about indeterminacy for the purpose of defining logical notions such as ‘valid consequence,’ ‘true under all interpretations,’ etc. In ignoring these complications we make idealizing assumptions, for example, that it is sensible to speak of fully determinate denotations. It is interesting to note that our *idealized, pre-theoretic* intuitions about the determinacy of denotations and truth conditions could be explained by the supposition that (pre-theoretically) we are naive verificationists, that is, we tacitly assume the existence of effective verification procedures for applying symbols to the world.

5.4 Discussion
Let us briefly review the reasons which have been given for saying that the semantic theory presented here constitutes a kind of procedural semantics. First, I have argued that denotations and truth conditions of empirical sentences exist only if terminating procedures occur as *part* of the meaning of at least some words (i.e., testable predicates). (Admittedly, these are procedures in an *extended* sense, but as we have noted, this extended sense played a part in prior theories of PS.) The terminating procedures in question may not possess simple names, but we may refer to them via such artifices as: ‘the procedure which determines whether something looks yellow, or whether something tastes the particular way spinach tastes.’ Terminating procedures such as these directly provide the means by which testable predicates are anchored to experience, and indirectly provide the means by which all empirical sentences are tied to experience. Without procedures such as these there could be no semantics.

Second, I have theorized that natural kind terms, numerous referring expressions, and derivatively, many empirical sentences possess pragmatic meaning procedures capable of determining *prima facie* denotations and truth values. It is because such pragmatic procedures exist that we are able to use language freely, without considering the infinity of ramifications a sentence may have, and without engaging in exceedingly complex chains of inference. While knowledge of such procedures is a precondition of semantic competence, the pragmatic procedures are themselves the source of many beliefs which serve to constrain the complete meaning of sentences.
Third, even a highly theoretical sentence (which may lack a pragmatic meaning procedure) may be regarded as an axiom embedded in a large network of axioms. The entire axiomatic network, together with background deductive and default inference mechanisms, may be viewed as an intricate high-level procedure which constrains the conditions under which declarative sentences may be applied to the world. Any attempt to confirm the truth of a highly theoretical sentence in this network must engender a chain of inference which terminates in the evaluation of testable sentences. Such sentences, in turn, presuppose the existence of terminating procedures. Positive confirmation of any proper subset of the testable consequences of a theoretical sentence cannot, of course, entirely confirm the sentence itself (for, among other things, this would involve the fallacy of affirming the consequent). But, insofar as it is possible to confirm a theoretical sentence to some degree, we must possess procedures for deriving testable consequences from the theory which contains that sentence. This fact alone may not provide a strong case for calling our semantic theory procedural. However, when combined with the reasons presented in the preceding two paragraphs, it seems not unnatural to call our theory procedural semantics.

Before closing, I wish to address a question which might arise from the domain of set theory. The question is whether the modified PS proposed here is able to account for the meaning of mathematical expressions which denote non-denumerable sets. For example, since the expression (E) ‘power set of the natural numbers’ denotes a non-denumerable set, it is scarcely plausible to identify E’s meaning with some pragmatic (defeasible) meaning procedure, capable of identifying members of this set. After all, some members of that power set are themselves infinite sets. On the other hand, it would also seem implausible to suppose that E derives its meaning by virtue of denoting a theoretical entity, postulated by a scientific theory. For, E seems not to derive its meaning primarily from any role it plays in an empirically testable theory. How then can we account for the meaning of this and similar mathematical expressions?

Before venturing an answer to this question, it should be acknowledged that among mathematicians the existence of non-denumerable sets is controversial. Many intuitionists do not concede the existence of such sets. However, for argument’s sake we grant the existence of such sets, and the meaningfulness of expressions which denote these sets. We may go further, and grant the meaningfulness of an infinity of other arbitrarily complex mathematical expressions. The thesis I wish to advocate is that complex mathematical expressions derive their meaning through the composition of primitive expressions which do have computational meaning. That is, the complex expressions in question are ultimately decomposable into expressions which are computable, at least in the limit, and at least for certain ranges of arguments.
For example, let us suppose that 'power set of the natural numbers' is formally represented as 'F(G),' where 'F' denotes the power set function, and 'G' denotes the natural numbers. Note that the power set function, F, is computable when restricted to finite arguments, and that G is a recursive set — one whose characteristic function is computable. When we compose F with G we obtain the noncomputable result, F(G). Now, it is arguable that whatever confidence we have in the existence of this set, and whatever meaning we can assign to 'F(G),' derives from our understanding of a restricted form of F, in which F is a computable function for deriving the power set of a finite set, and from our understanding of a recursive process for enumerating the members of G. (Would we really think there was an infinity of natural numbers if we did not know a rule for generating the numerals?) In other words our understanding of 'F(G)' may very well be parasitic upon our understanding of computational processes associated with 'F' and 'G.' Thus, if we wish to side with non-intuitionistic mathematicians, and maintain that 'F(G)' denotes a non-denumerable set, PS provides an explanation of how we are able to form some sense of the membership of this set. This is not to suggest that the existence of the set is in any way parasitic upon the compositional processes which engender our understanding, but rather that the denotation relationship which holds between the expression and the set it denotes is indeed parasitic upon the composition of the procedures associated with F and G. When we reflect that, in general, the primitives of set theory all have computational meaning in finite domains, and that (within mathematics) nonprimitives are explicitly decomposable into primitives, it becomes plausible that arbitrarily complex mathematical expressions derive meaning via compositional processes analogous to that just described.

CONCLUSION

In the foregoing it has been argued that a modified form of PS is both defensible and ontologically presupposed by three major model-theoretic semantic systems. In section 2, we examined Fodor's critique of PS and found that it rested upon two separate arguments. We rejected the first of these arguments for two reasons: (a) it required the dubious assumption that any advocate of PS holds that the meaning of a sentence is given by a machine language procedure, and (b) it also required the dubious premise that a machine possesses the semantics of its machine language only if it assigns a Tarskian interpretation to that language. The second of Fodor's arguments—to the effect that PS is simply a naive form of verificationism appropriate to "toy" universes—is not easy to dismiss. Indeed, the argument underscores the need for a revision of PS which takes account of the complexity of the mapping relationship between symbols and the world.
In section 3, we considered three distinct approaches to model theoretic semantics, and argued that each approach ontologically presupposes usage procedures of some kind. The first approach considered was Tarskian semantics, which accords with Fodor's conception of classical semantics. We argued that denotation relations, and thus denotational semantics, can arise only if there exist semantic procedures which permit agents to identify prima facie members of some denotations. Furthermore, if denotational semantics is to avoid a vicious retreat into metalanguages, it must assume that we individuate at least some denotations by methods which at least include the use of operationally understood procedures, that is, procedures which do not have to be interpreted to be executed.

We found that similar arguments apply to possible world and situation-based semantics. Unless the intensional functions of possible world semantics are at least constrained by procedures for determining (or approximately determining) extensions in possible worlds, the existence of such functions becomes doubtful. Virtually the same difficulty arises for situation semantics, when the mapping of symbols onto properties and other relations is addressed.

In sections 4 and 5, a modified form of procedural semantics was presented, which addresses the complexities which must be faced by any theory which seeks to explain the mapping relation between symbolic strings and the world they describe. It was argued that PS can be modified to avoid the pitfalls of naive verificationism, by permitting meaning procedures to return default truth values, and by integrating default reasoning into the process by which agents decide the applicability of predicates to sense-experience. Both Putnam's theory of natural kind terms and Quine's doctrine of the revisability of empirical judgements were seen to be compatible with the view that many referring expressions possess pragmatic meaning procedures.

The modified procedural semantics presented herein still requires further development. It is hoped, however, that the salient outlines of the theory are clear, and that the need for a procedural approach to semantics has been demonstrated. No doubt, alternative approaches to procedural semantics, which come to terms with the pragmatic issues we have considered, are possible. My overriding concern has been to demonstrate that some form of procedural semantics is required to provide foundations for model-theories. Procedures alone may not tell the whole story about semantics, but they are a necessary part of the story.

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REFERENCES


