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LINGUISTICS AS CHEMISTRY: THE SUBSTANCE THEORY OF SEMANTIC PRIMES¹

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1. INTRODUCTION

The aims of this paper are (a) to place theoretical principles in linguistics in a larger conceptual framework, in particular, to note similarities between linguistics and various natural sciences (not only chemistry, but also physics and biology), and (b) to draw a parallel between a particular organizing hypothesis in semantics (the *Substance Theory*) and assumptions of the classical theory of chemical elements, for the purpose of arguing that this parallel is one of structure and that the chemical case can suggest interesting lines of inquiry for the semantic case. I should emphasize at the outset that I am not asserting any *overall* parallel, structural or otherwise, between linguistics and chemistry. In the principal sections of this paper, I am concerned with only one area of chemistry, the theory of substances and elements, and only one area of linguistics, the theory of words and semantic primes.

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Many people have provided useful comments and criticisms. I am especially indebted to Gaberell Drachman, James Heringer, Jerrold Sadock, and Ann Zwicky. The Substance Theory (independent of the chemical analog) was first suggested to me in 1965 by George Boolos. In the intervening years I have had the opportunity to reconsider my initial skepticism toward the idea.

2. TYPES OF PRINCIPLES IN LINGUISTICS

Before we proceed to a treatment of elements, chemical and linguistic, it is necessary to distinguish a number of different types of “theoretical principles” in linguistics. My intent here is first to separate *methodological principles* from *systematic principles*, the latter being my real concern, and then to categorize systematic principles by level, from “descriptive” or “observational” statements to *organizing hypotheses*, central assumptions which, while capable of empirical test, tend to define an area of investigation.

2.1. Methodological Principles

Methodological principles, or “rules of thumb,” are not assumptions capable of verification or falsification in any ordinary sense. Instead, their function is to suggest what the most likely state of affairs is in a given situation, in the absence of evidence of the usual sort. This being the case, the indication given by a methodological principle is always outweighed by pertinent evidence. Methodological principles can therefore be stated in an extreme form. A few linguistic examples will perhaps make these points clearer.

First, there is the Majority Vote Principle in comparative reconstruction, the guideline that says that if the majority of daughter languages agree in having a certain feature, then that feature is to be attributed to the protolanguage. Certainly, no one involved in reconstruction believes this to be valid in general, but when there is no special evidence on the point, the majority will carry the day. If there are other facts that bear on the point, these will prevail, of course.

Second, there is the Contrast Principle in phonology, which says that if segments are in contrast, then they are underlyingly distinct. In the context of structuralist linguistics, the Contrast Principle is an organizing hypothesis rather than a methodological one (see Section 2.2.2). Within the framework of generative phonology, however, it functions as a methodological principle: if there is no contravening evidence, surface contrasts are taken to be underlying contrasts as well.

A third example of a methodological principle is the Surfacist Principle, a syntactic analog of the Contrast Principle. This is the rule that, *ceteris paribus*, the syntactic structure of a sentence is its surface constituent structure. In other words, if you claim that some sentence has a remote syntactic representation, that is, one different from its bracketing into labeled constituents, you have to prove it.

These examples are familiar enough not to require an extended justification of the principles involved. In each case, the methodological principle provides a kind of background assumption, a position taken when no other is especially supported.

Instead of being verified or falsified, methodological principles are judged as useless or useful, and the basis for the judgment is whether the descriptions they recommend are confirmed or not. To defend a methodological principle, one provides numerous illustrations of cases where it chooses a description that turns out to be well supported on other evidence. To refute a methodological principle, one adduces cases where it selects a description that turns out to be unsatisfactory for independent reasons. In either direction, such arguments are not easy. (For the beginning of a negative argument, see Zwicky (1970b) on the Free Ride Principle, a methodological principle opting for longer derivations over shorter ones, other things being equal.)

Examples of methodological principles from other sciences are not hard to find.

In this category are the widespread preferences for round numbers, for equations of degree n over those of degree $n + 1$, and for circles over other conic sections, among many other preferences for “simple” accounts.

2.2. Systematic Principles

In contrast to methodological principles, which are apt to be termed “rules” (in one sense) or “guidelines,” systematic principles are “descriptions,” “observations,” “regularities,” “rules” (in another sense), “laws,” “assumptions,” or “hypotheses,” depending upon their extent and their abstractness. I assume here that the different terms represent differences of degree, especially in view of the observations of many philosophers (for example, Hanson, Kuhn, and Toulmin) that “theoretical” assumptions infect observation in significant ways. That is, I assume that there is a cline from (a) through (e) (and beyond):

- (a) observations that someone said a particular thing on some occasion or made a particular judgment about an utterance on some occasion
- (b) observations that the members of some speech community usually make the same judgment on some point
- (c) claims about the existence of a particular rule in English
- (d) hypotheses about constraints limiting the applicability of rules in a particular language, or universally
- (e) hypotheses about the range of possible rules in natural languages

My concern in the following sections is with the more “theoretical” statements (like (d) and (e)) than with the more “descriptive” ones (like (a) and (b)). But even these “theoretical” assertions range from relatively low-level assumptions, typically capable of precise formulation and usually subject to tests of some standard kind, to much more abstract propositions, often stated rather vaguely and not amenable to straightforward tests and argumentation. The more abstract propositions tend to act as organizing principles defining a field of investigation. Although the deeper principles are in some sense open to empirical verification or falsification, the tests required are quite indirect or involve extremely complex chains of inference in which various fundamental assumptions function. Without intending to claim that the deeper principles are untestable, I have termed the lower-level statements *arguable propositions* and the more abstract ones *organizing hypotheses*.

2.2.1. ARGUABLE PROPOSITIONS

Any “natural law” would serve as an example of an arguable proposition. Let us take an illustration from physics—Newton’s Inverse Square Law, which states that the gravitational force between two bodies is inversely proportional to the square of the distance between them (R is the distance between the two bodies and k is a constant associated with the two bodies):

$$F = \frac{k}{R^2}$$

How do we tell that this is an inverse square law, rather than, say, an inverse cube law? A methodological principle chooses squares over cubes so long as the observations on the matter are reasonably consistent with this assumption. Aside from this,

the two positions are indistinguishable so long as (a) the *range* of evidence is narrow, (b) the *accuracy* of the measuring device is low, and (c) *outside effects* cannot be discounted. If we have measurements only over a narrow range for *R*, then we may not be able to distinguish the squares hypothesis from the cubes hypothesis, given the accuracy of our measuring devices and the fact that small perturbations may be random, as a result of experimenter's error or outside effects that were not allowed for. Similarly, very accurate measurements may be worthless if they cannot be made over a sufficient range of values.

The garden-variety arguable propositions of current linguistics are universal hypotheses, most of them *exclusions*, restrictions on the use of certain notational conventions. A typical example is "There are no curly brackets (that is, braces) in syntax," a claim intended to illegitimize references to

$$\text{TENSE} \left(\left\{ \begin{array}{l} \text{M} \\ \text{have} \\ \text{be} \end{array} \right\} \right)$$

and the like in syntactic rules. This particular use of curly brackets, or braces, is criticized first by Ross (1969a); it is treated from a broader perspective by Zwicky (1968) and assimilated to the general exclusion principle by McCawley (1970a). To be effective, the exclusion hypothesis must be supported by observations over the appropriate *range*; these observations must be suitably *accurate*, and there must be some assurance that *outside effects* are not interfering significantly with the evidence. That is, there must be arguments that different phenomena, in different languages, which might have been thought to require the use of curly brackets, do not in fact do so; there must be arguments supporting the general adequacy and completeness of the grammars referred to (for if features of the rules in question were dependent on minor changes in other rules, the evidence from these descriptions would not be worth much), and there must be reason to believe that the supporting evidence is not seriously affected by external facts (difficulty in understanding sentences, for example).

Arguable propositions like Newton's Inverse Square Law or the No Curly Brackets Proposal may also be defended or attacked through arguments of a deeper sort, arguments that refer to general principles of scientific explanation (falsifiability, simplicity, plausibility, for example). Thus, the naturalness argument described in Zwicky (1968) in favor of the No Curly Brackets Proposal is an appeal to theoretical simplicity, as was the argument favoring the elegance of the Copernican heliocentric theory over the complexity of the epicycles in the geocentric theory.

Other examples of arguable propositions from linguistics include the following: (a) a proposal by Chomsky that no transformational rule insert material from one S into a lower S; (b) an unpublished but much discussed suggestion of Kiparsky's that rules effecting absolute neutralizations in phonology be prohibited; (c) the hypothesis that syntactic rules cannot be conditioned by phonological features (the Principle of Phonology-Free Syntax, treated in Zwicky (1969)); (d) the assumption that all the information required for the conditioning of phonological rules is available in superficial syntactic structure (the Principle of Superficial Constraints in Phonology, mentioned in Zwicky (1970a)); (e) a proposal in Zwicky (1970c) for limitations on the use of Greek-letter variables in phonological rules; and (f) a hypothesis, put forward tentatively by Chomsky and Halle (1968), that the phonological cycle is restricted to prosodic phenomena.

The linguistic cases that come first to mind are all exclusive principles, thanks to the emphasis within transformational generative grammar on restricting the range of notational conventions and their uses as a way of specifying as narrowly as possible the notion "possible natural language." Arguable propositions in the natural sciences are customarily stated positively, but they can easily be converted into exclusive principles. Newton's Inverse Square Law, for example, can be interpreted as a ban on physical systems in which the gravitational attraction between bodies is any function of R besides $1/R^2$. The difference, then, between the linguistic examples and the physical example is simply one of degree: physical principles are typically much more specific in their exclusions than are linguistic hypotheses.

There are, however, many sorts of specific, positively stated arguable propositions in linguistics. Putative linguistic universals, such as those treated by various authors in Greenberg (1963), are cases, as are claims that particular rules, phonological or syntactic, are universal in character (as has been argued by Bach (1971), Foley (1970), and Stampe).

2.2.2. ORGANIZING HYPOTHESES

Organizing hypotheses are high-level assumptions, fundamental empirical hypotheses. Various principles of linguistic change have this character—the Neogrammarian hypothesis of the regularity of sound change, for instance, and Kiparsky's (1968) proposal that rules reorder in time so as to reduce markedness. Also of this character are assumptions about the directionality of the relationship between syntactic and semantic representations. The most salient fact about such assumptions is that they are not easily given up, even in the face of apparent counterexamples, which will be treated as manifestations of minor complicating principles or as outright anomalies (see Kuhn (1962)). It is this resistance to disproof that gives organizing hypotheses their "field-defining" nature. They are testable, in some sense, and they can be abandoned after argument, but the tests are not simple nor the arguments straightforward.

As was emphasized earlier, there is no sharp break between arguable propositions and organizing hypotheses. The Principle of Phonology-Free Syntax and the Principle of Superficial Constraints in Phonology, which were mentioned in the preceding section, are fairly high-level assumptions and might be taken to be organizing hypotheses. I have listed them as arguable propositions because that is the way they are viewed in the articles cited, but it would be possible to consider them as being more fundamental, as together asserting a basic "separation of levels" between syntax and phonology.

Before continuing with examples from linguistics, let us look at two celebrated cases of organizing hypotheses in the physical sciences. The first is the Newtonian (originally, Galilean) inertial principle of motion versus the Aristotelian or resistance conception. Toulmin (1963) observes that

Aristotle concentrated his attention on the motion of bodies against appreciable resistance, and on the length of time required for a complete change of position from one place to another. For a variety of reasons, he never really tackled the problem of defining 'velocity' in the case when one considers progressively shorter and shorter periods of time—i.e. instantaneous velocity. Nor was he prepared to pay serious attention to the question how bodies would move if all resisting agencies were effectively or completely removed. As things turned out, his hesitations were unfortunate; yet his reasons for hesitating are understandable, and in their way laudable . . . Leaving aside free fall for the moment as a special case, all the motions we observe going on close around us happen as they do (he saw) through a more-or-less complete balance between

two sets of forces: those tending to maintain the motion and those tending to resist it. In real life, too, a body always takes a definite time to go a definite distance. So the question of instantaneous velocity would have struck him as over-abstract; and he felt the same way about the idea of a completely unresisted motion, which he dismissed as unreal (pp. 50–51).

Here we have a sympathetic exposition of an organizing hypothesis formulated by Aristotle. In Aristotle's commonsensical view, bodies move only while they are impelled. A wagon on a country road, not a freely falling ball, is the paradigm for dynamics. The position is, ultimately, empirical. However, it is easier to imagine tests of Newton's Inverse Square Law (given that there is *some* attractive force between bodies) than to construct experiments bearing on the Aristotelian Resistance Hypothesis. In time, Aristotle's hypothesis was abandoned in favor of a different organizing hypothesis, namely, Newton's First Law, which holds that every particle continues in a state of rest, or in motion with constant speed in a straight line, unless acted upon by an outside force. Both hypotheses are difficult to formulate precisely, and the change from one to the other was accompanied by changes in other fundamental assumptions and was supported by arguments of many different types, including experimental evidence bearing indirectly upon the question and general considerations of adequacy of explanation.

The second example comes from astronomy—Kepler's First Law that the orbit of each planet about the sun is elliptical, with the sun at one of the foci of the ellipse. This organizing hypothesis replaced the theory that the orbits are circular, a proposition that seems to many (as it seemed to Aristotle) so self-evident that it scarcely would require support. The example is especially interesting because it illustrates a change from an organizing hypothesis that asserts circular motion to the present state of affairs, a methodological principle which prefers circles to ellipses, other things being equal. The same evolution from organizing hypothesis to methodological principle can be seen in the history of the Contrast Principle in phonology (mentioned briefly in Section 2.1). The reverse development, from methodological principle to organizing hypothesis, is not unknown either; I shall suggest an example shortly.

The history of Kepler's First Law illustrates another sort of evolution as well—a change from an organizing hypothesis to an arguable proposition of the ordinary sort. Clearly, when first put forth, Kepler's First Law was a fundamental thesis about astronomy, revolutionary in its content. Once accurate instruments of the required type had been developed, however, the difference between circular and elliptic motion could be detected by normal methods, and soon it became possible to derive Kepler's laws of planetary motion from Newton's laws, so that Kepler's First Law became a relatively low-level hypothesis in a network of assumptions.

Now let us return to examples of organizing hypotheses in linguistics. First we examine the "requirement that transformations preserve meaning," as Partee (1971) phrases it. I shall refer to this hypothesis as the *Post Office Principle*, on the grounds that it treats syntax as an elaborate delivery system, a system designed to get messages to an addressee without changing their content. As Partee notes, the Post Office Principle is viewed as a methodological principle by Katz and Postal (1964), who stress that the principle is "not . . . a statement in linguistic theory, but rather . . . a rule of thumb based on the general character of linguistic descriptions" (p. 157). But, in case after case, the Post Office Principle seemed to recommend analyses that were later confirmed by independent evidence, and it was thus elevated from a methodological principle to an organizing hypothesis. As Partee puts it, the principle "gained support very quickly, to the point where it was widely accepted as one of the

more solidly established generalizations in linguistic theory and used as a criterion for transformational rules" (p. 2).

As is typically the case with organizing hypotheses, it is difficult to formulate the Post Office Principle precisely: as Partee points out, it involves in an essential way the difficult but fundamental notion of "synonymy," just as Newton's First Law involves in an essential way the difficult but fundamental notions of "motion" and "force." As is also typical of organizing hypotheses, it is hard to adduce convincing evidence for or against the Post Office Principle. The problem is that it is almost always possible to fix up a description so that it will conform to the principle. Accordingly, whether or not he believes in the Post Office Principle.

The final example of an organizing hypothesis that I will give is the one referred to in the title of this article, namely, the Substance Theory of Semantic Primes. In the form I shall use in the remainder of this paper, the hypothesis is: *every semantic prime is realizable as a lexical unit (root, inflection, or derivational affix) in some natural language*. A stronger version might be suggested: in any language, most semantic primes are realized as lexical units. The strongest form of the hypothesis—in any language, all semantic primes are realized as lexical units—seems clearly too much to hope for. I shall be content to defend the weak, or simple existential, form of the hypothesis in the sections to follow.

The idea behind the name "Substance Theory of Semantic Primes" is that every semantic prime is a real substance (a root, inflection, or derivational affix), not merely a principle manifested by real substances. The analogy here is with chemical elements, which, on the modern view, are assumed to be realizable as substances, as opposed to the ancient "elements" fire, air, earth, and water, or the alchemical "elements" salt, sulphur, and mercury, which were "not substances at all, but metaphysical abstractions of properties, typifying the natures of bodies" (Partington (1948, p. 113)).

Clearly, the Substance Theory is an organizing hypothesis rather than a methodological principle or an arguable proposition of the usual sort. It is difficult to see how one could construct a straightforward argument for or against the idea. And the reference to "realization" in the statement of the hypothesis makes its precise formulation a formidable task.

3. THE SUBSTANCE THEORY

In the remaining part of this paper, I review briefly the (very sparse) literature on semantic primes, preparatory to considering uses of the Substance Theory in discussions of semantics. Next, I take up the analogy with chemistry and argue that the analogy is material, to use Hesse's (1966) term. Finally, I supply a more general discussion of metaphor and analogy in linguistics, with additional examples of material analogies.

3.1. Semantic Primes

The statement of the Substance Theory in Section 2.2.2 refers specifically to "semantic primes" and therefore locates the hypothesis within the broad framework of generative semantics. This restriction is unnecessary, however, for the hypothesis is equally appropriate within theories that assume that the semantic readings of lexical units are constructs of primes called "features," "markers," "specifications," or the like. That

is, I intend my remarks to apply not only to systems like those of McCawley (1968) and Lakoff (1970), in which semantic structures are of the same type as syntactic structures, but also to standard Katz-Fodor semantics (as presented in Katz (1966), for example), in which semantic representations of lexical units are sets of markers, as well as to various intermediate positions in which semantic representations of lexical units are more or less complex structures containing markers (as in such extensions of, variants of, or alternatives to the Katz-Fodor position as Gruber (1965), Weinreich (1966), Leech (1969), and Chafe (1970)).

Within none of these frameworks has there been any extended discussion of the character of the atomic units that appear in semantic descriptions. The following remarks by Katz (1966) are representative:

Just as the meaning of a word is not atomic, a sense of a word is not an undifferentiated whole, but, rather, has a complex conceptual structure. The reading which represents a sense provides an analysis of the structure of that sense which decomposes it into conceptual elements and their interrelations. Semantic markers represent the conceptual elements into which a reading decomposes a sense. They thus provide the theoretical constructs needed to reconstruct the interrelations holding between such conceptual elements in the structure of a sense.

. . . Just as syntactic markers enable us to formulate empirical generalizations about the syntactic structure of linguistic constructions, so semantic markers enable us to construct empirical generalizations about the meaning of linguistic constructions. For example, the English words 'bachelor', 'man', 'priest', 'bull', 'uncle', 'boy', etc., have a semantic feature in common which is not part of the meaning of any of the words 'child', 'mole', 'mother', 'classmate', 'nuts', 'bolts', 'cow', etc. The first set of words, but not the second, are similar in meaning in that the meaning of each member contains the concept of maleness. If we include the semantic marker (Male) in the lexical readings for each of the words in the first set and exclude it from the lexical entries for each of the words in the second, we thereby express this empirical generalization. Thus, semantic markers make it possible to formulate such generalizations by providing us with the elements in terms of which these generalizations can be stated (pp. 155-157).

In practice, primes are set up within some narrow area that is of interest to the investigator, as a way of giving an account of the semantic relationships he perceives in that area (see, for example, Fillmore (1969)). There is virtually no attempt to argue for one system of primes over various possible alternatives. The only areas which have been "mapped" well in this way are inflectional categories and a few fields that are of interest to anthropologists as well as linguists—folk taxonomies, kinship systems, and color terms. Otherwise, these investigations are in their infancy. And surely the most-quoted words on the subject are those of Bendix (1966, p. 17): "a rough road into the empirical semantic wilderness is preferable to a well-paved one timidly skirting the borders."

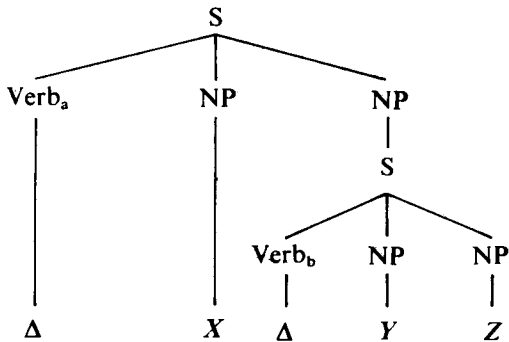
For my purposes here, the most notable gap in existing treatments of semantic primes is the absence of assertions of formal or substantive universals involving them.² There are the same few exceptions as before, kinship and color terms especially.

² Chomsky's (1965) references to semantic universals are quite brief: "A theory of substantive universals might hold, for example, that certain designative functions must be carried out in a specified way in each language. Thus it might assert that each language will contain terms that designate persons or lexical items referring to specific kinds of objects, feelings, behavior, and so on" (p. 28); as formal universals, he suggests "the assumption that proper names, in any language, must designate objects meeting a condition of spatiotemporal contiguity [a footnote here illustrates the hypothesis], and that the same is true of other terms designating objects; or the condition that the color words of any language must subdivide the color spectrum into continuous segments; or the condition that artifacts are defined in terms of certain human goals, needs, and functions instead of solely in terms of physical qualities" (p. 29). In the same vein, James Heringer has suggested to me the hypothesis that words in natural (as opposed to technical) languages never refer to absolute measurements.

Given the lack of such assertions, we must try to infer general principles from whatever practices there have been.

First, however, a few words are necessary about the differences between words and semantic primes. There is a reasonably clear illustration of the distinction in Postal (1970):

I have claimed that the underlying structure of *remind* clauses is of the form:



where $Verb_a$ is an element like *strike*, $Verb_b$ an element with the properties of a Similarity Predicate. In the context of the discussion of Generative Semantics, it is clear that there is no suggestion that these underlying verbals are *lexical items*, in particular none that they are the lexical *strike*, *resemble*, etc. The idea is that the underlying elements are *semantic verbs*, that is, predicates. Consequently, the claim is only that the underlying elements of *remind* clauses are those predicates which are lawfully connected to the various regularities documented for *strike* and Similarity Predicates. In particular, I would like to emphasize that it is not excluded that the actual lexical verb *strike* may have certain special properties not associated with the underlying predicate or predicate complex which shows up as the Surface Verb *remind*. Just so, the particular predicate of similarity which underlies *remind* may lack some ad hoc features of any or all of the verbals *similar*, *resemble*, *like*. In short, I have not intended to claim that *remind* is in any sense derived from underlying structures which contain the lexical verbs *strike*, or *resemble/similar/like*. Rather, I have argued that the derivation must be from elements whose properties are *included* in these lexical elements (pp. 113–114).

The crucial notion in discussions of primes and words is that of “realization,” or “correspondence to”: English *and*, in one of its senses, realizes the prime AND³ because, aside from any syntactic or stylistic peculiarities associated with this sense of English *and*, its properties are those of an entity which bears certain specific relations to other entities (for example, OR, NOT, IF, ONE) which, taken together, form the basis for a semantic description of English. Among the relations in question is the duality of AND and OR—that AND is equivalent to NOT-OR-NOT and, conversely, that OR is equivalent to NOT-AND-NOT, or, stated precisely, that R AND S is equivalent to NOT ((NOT R) OR (NOT S)) and that R OR S is equivalent to NOT ((NOT R) AND (NOT S)). Just as one sense of *and* corresponds to AND, so one sense of *similar* corresponds to (realizes) LIKE, *become* and *-en* correspond to INCHOATIVE, and *say* corresponds to ASSERT.

3.1.1. THE SUBSTANCE THEORY IN THE LITERATURE

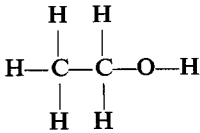
A run through semantic descriptions in the literature has turned up no primes which strike me as being incapable of realization in a word or affix; in nearly every case, in fact, there is an obvious English lexical item corresponding to the prime. In addition, it

³ I shall follow the custom of using small capital letters for primes, as contrasted with italics for words or other lexical units.

is undoubtedly significant (as James Heringer has pointed out to me) that the factors governing selectional restrictions in English seem always to have easy "English translations"—(*concrete*) *object, feminine, human, activity*, to cite a few. If there is not necessarily a lexical unit corresponding to each prime, then we should expect to come across "inexpressible" selectional restrictions, which would require the invention of new technical terms for the purposes of linguistic description.

Although there are no examples now available of semantic primes that are not realizable in a word or affix, both Katz and Lakoff have taken pains *not* to subscribe to the Substance Theory. Both assume that the set of semantic primes, like the set of phonological features, is universal, but neither is willing to assert more than that the set of primes together is sufficient to provide an adequate account of the internal meaning relationships in the lexicon of any language. Katz (1966) even supplies the chemical analog:

It is important to stress that, although the semantic markers are given in the orthography of a natural language, they cannot be identified with the words or expressions of the language used to provide them with suggestive labels. Rather, they are to be regarded as constructs of a linguistic theory, just as terms such as 'force' are regarded as labels for constructs in natural science. There is an analogy between the formula for a chemical compound and a reading (which may be thought of as a formula for a semantic compound). The formula for the chemical compound ethyl alcohol,



represents the structure of an alcohol molecule in a way analogous to that in which a reading for 'bachelor' represents the conceptual structure of one of its senses. Both representations exhibit the elements out of which the compound is formed and the relations that form it. In the former case, the formula employs the chemical constructs 'Hydrogen molecule', 'Chemical bond', 'Oxygen molecule', etc., while in the latter the formula employs the linguistic concepts '(Physical Object)', '(Male)', '(Selection Restriction)', etc. (p. 156).

Lakoff (1970) finds himself asking whether there are two semantic primes WURF and GLIP with certain specified properties; he concludes:

In an arbitrary system, one could always make up such predicates, but that is beside the point. The question here is an empirical one. Is there any evidence that such atomic predicates actually exist in the logical forms of sentences of natural language? This does not necessarily mean that there must actually be in some language single lexical items directly corresponding to these predicates. However, it is required, at the very least, that such predicates appear elsewhere. For example, there might be a number of other verbs which can be decomposed in terms of one or the other of these predicates (p. 351).

Lakoff does not claim that the Substance Theory is invalid; he merely withholds judgment on the matter and proposes a weaker condition on the universality of primes. The only thing that his condition rules out is the positing of a prime on the basis of properties of one lexical item in one language—surely a minimal constraint on the content of semantic theory.

In one instance, Lakoff (1970) uses the existence of a word corresponding to a putative prime as evidence for the prime's existence. In connection with the proposed decomposition of one sense of *persuade* into CAUSE-INCHOATIVE-INTEND, he writes:

Aside from the rule of predicate-lifting, all of the rules used in this derivation and in similar derivations are needed anyway in English grammar. Moreover, structures like [the one proposed for *persuade*] are also needed independently in English grammar. That is, there must be a verb “cause” which is a two-place predicate, a verb “come about” which is a one-place predicate, and a verb “intend” which is a two-place predicate (p. 342).

If there were no reason to suppose that primes were realized as words, then the existence of a verb *cause* in English would be irrelevant to the analysis of *persuade* as containing the prime CAUSE.

Since Katz and Lakoff do not suggest any analyses that violate the Substance Theory, we must turn to others for examples. As it happens, some relevant work has been done by logicians.

3.1.2. LOGICALLY ADEQUATE BUT LINGUISTICALLY UNNATURAL SYSTEMS

It has been the goal of logic to construct precise and satisfying accounts of a few areas of form and meaning that are of independent philosophical or mathematical interest. One of the criteria for satisfaction is systematic elegance—parsimony in primitive symbols or concepts, in sets of axioms, and so on. Logicians have been extremely ingenious in their parsimony. And their systems are often quite unnatural linguistically. Linguistic judgments of unnaturalness, in combination with predictions made by the Substance Theory, allow us to conclude that the logician’s primes cannot be linguistic primes. I provide two cases here.

First, we consider the example of the Sheffer stroke.⁴ A classic result of symbolic logic is that the logical connectives \sim ‘not’, $\&$ ‘and’, \vee ‘or’, \supset ‘implies’, and \equiv ‘if and only if’ can all be defined from one connective (either one of two different connectives, in fact). This is the Sheffer stroke $|$ ‘not both . . . and . . .’. The remaining connectives are definable in several ways, for instance:

$$\begin{aligned} \sim P & \text{ defined as } P | P \\ P \vee Q & \text{ defined as } \sim P | \sim Q \\ P \supset Q & \text{ defined as } \sim P \vee Q \\ P \& Q & \text{ defined as } \sim (\sim P \vee \sim Q) \\ P \equiv Q & \text{ defined as } (P \supset Q) \& (Q \supset P) \end{aligned}$$

What is linguistically interesting about this logician’s strategy is that no language seems to have a conjunctive root *nub*, with the property that $A \text{ nub } B$ means ‘not both A and B’, and I would view with considerable suspicion any report of a language with such a conjunction. If no language has a lexical unit *nub*, then according to the Substance Theory, the Sheffer stroke cannot represent a semantic prime for linguistic, as opposed to logical, purposes.

An example of a somewhat different type is provided by Prior (1960), whose object is to assail the notion that the meaning of the word *and* is completely given by an account of the role it plays in deductions (that from P and Q we can infer P , that from P and Q we can infer Q , and that from P and Q we can infer P and Q). He affects to claim that any statement Y can be inferred from any other, X , by citing an inference of the form:

$$\begin{aligned} X \\ X \text{ tonk } Y \\ \therefore Y \end{aligned}$$

⁴ Almost every standard logic text treats this subject; see, for example, Copi (1967, p. 201).

Prior adds:

There may well be readers who have not previously encountered the conjunction 'tonk', it being a comparatively recent addition to the language; but it is the simplest matter in the world to explain what it means. Its meaning is completely given by the rules that (i) from any statement P we can infer any statement formed by joining P to any statement Q by 'tonk' . . . and that (ii) from any 'contonktive' statement P-tonk-Q we can infer the contained statement Q.

Not only is *tonk* not a "comparatively recent addition to the language," it is not part of *any* language. Consequently, according to the Substance Theory, whatever it might be, it is no semantic prime. Belnap (1962) has observed that the definition of *tonk* is inconsistent, thereby providing an explanation for its unnaturalness.

The point of cases like the two just considered is that the Substance Theory can link with observations about what sort of lexical items occur in the world's languages to yield predictions about possible semantic primes. Without the mediation of the Substance Theory, there is no reason for there to be a relation between the kinds of lexical units that occur in languages and the semantic primes that are proposed for them.

3.2. The Analogy with Chemistry

The Substance Theory of Semantic Primes, as I have already pointed out, is analogous to Boyle's requirement, in the "Sceptical Chymist" of 1661, that chemical elements be isolable substances and not abstract principles. We have also seen, in Section 3.1.1, Katz's comparison of semantic structure to chemical structure. In this section I will press this analogy further, with the intention of using the chemical case to suggest useful lines of inquiry in the linguistic case. That is, I will be claiming that the parallels between chemical structure and semantic structure are deep ones. This is not to say, of course, that the two subfields of the different disciplines are isomorphic in every detail. I do not anticipate the discovery of a set of deep principles from which the properties of chemical structure and those of semantic structure will both be derivable. Indeed, there are aspects of each subfield which are without obvious analogs in the other; for instance, there is nothing in the chemical case that is a natural correspondent of the phonological identity that unites the two senses of *persuade* (CAUSE-INCHOATIVE-INTEND and CAUSE-INCHOATIVE-BELIEVE) or the distinct senses (each a separate lexical unit) of many other words.

The initial analogy is of language to matter. The strategy of the disciplines, linguistics and chemistry, respectively, is to analyze heterogeneous physical material (speech, materials) into its parts (words, substances) and then to treat these parts as either elemental substances (semantic primes, elements) or compounds of such elemental substances. These analytic preliminaries require the identification and removal of various kinds of intrusive factors.

The central part of the analogy, then, is an occurrence of a semantic prime in some language, on the one hand, and an atom of some chemical element, on the other. Corresponding to lexical entries are molecules.⁵ Certain molecules, hydrogen molecules for instance, are composed of only one sort of atom. In the same way, certain lexical entries, the entry for *cause* for instance, are composed of only one sort of prime.

⁵ This much of the parallel is echoed by Postal (1970, pp. 100–101), who speaks of "semantic atoms" and "semantic molecules" but does not take the terms to be more than simple metaphors.

Other molecules, the sulfuric acid molecule for one, possess an internal structure in which more than one sort of atom (hydrogen, sulfur, oxygen) occurs. Just so, some lexical entries, the entry for *kill* among them, possess an internal structure with more than one sort of prime (CAUSE, INCHOATIVE, NOT, ALIVE).

In both linguistics and chemistry, the great majority of the known substances (or words) are complex. In each field, the number of actually occurring substances is quite large, and the number of possible substances is infinite in principle, though limited in fact by external factors (the physical instability of the molecules, the psychological complexity of the words).

Also, in both linguistics and chemistry, there are molecular properties which are "emergent," in the sense that they are not predictable by known principles from the character of the constituents of the molecule. Broad (1925) writes of a familiar chemical example:

Oxygen has certain properties and Hydrogen has certain other properties. They combine to form water, and the proportions in which they do this are fixed. Nothing that we know about Oxygen itself or in combination with anything but Hydrogen could give us the least reason to suppose that it could combine with Hydrogen at all . . . And most of the chemical and physical properties of water have no known connexion, either quantitative or qualitative, with those of Oxygen and Hydrogen. Here we have a clear instance where, so far as we can tell, the properties of a whole composed of two constituents could not have been predicted from a knowledge of these properties taken separately, or from this combined with a knowledge of the properties of other wholes which contain these constituents (pp. 62-63).

The linguistic analog is the apparent impossibility of predicting the full range of syntactic properties of a lexical item given its decomposition into primes. From what semantic analysis of the verb *question* could one predict that it can be used performatively when its direct object is a simple NP (as in *I question that statement*) or a *whether*-clause (as in *I question whether we should do this*) but not when it is any other sort of *wh*-clause (**I question where he lives*) or a *that*-clause (**I question that he was responsible*) or an *if*-clause (**I question if we should do this*)?

In the quantitative atomic theory proposed by Dalton, it is assumed that the atoms of the same element are identical, in the sense that they have identical masses, and that atoms of different elements have different masses. The corresponding assumptions in semantics are that instances of the same semantic prime are associated with the same cognitive meaning (that is, that the cognitive meaning of a semantic prime is invariant across languages) and that different semantic primes have different meanings.

The tasks of chemistry are partly analytical (to devise methods for isolating and identifying substances), partly descriptive (to say what sorts of substances occur and what their properties are), and partly explanatory (to give an account of chemical structure from which the observed phenomena could be predicted). The analytical and descriptive aspects of elemental theory are summarized well in Weeks (1968), from which I conclude that semantics is a few hundred years behind chemistry simply in the matter of listing elements, not to mention explaining their properties. It is as if we were really sure of only a dozen or so chemical elements. Semantics has had no Mendelev to organize the elements in a periodic table according to their salient common properties; and the linguistic analog of the Bohr atom, from which the groupings in the periodic table could be predicted, is scarcely imaginable.

If the structural analogy between chemistry and semantics is deep, what sorts of developments can we expect in semantics? Three, at least: the discovery of isotopes,

a theory of valence, and the hypothesis of subatomic structure. I believe that there are indications that all three of these expectations are met.

First, there is the matter of isotopes. The discovery of different atoms of the "same" element with different masses (and even of atoms of "different" elements with the same mass) is an obvious embarrassment for a theory which takes an invariant mass to be criterial for a given element. The existence of isotopes, especially those which (like light and heavy hydrogen) have quite distinct properties, makes the study of subatomic structure inevitable. What are the semantic analogs of isotopes? They are occurrences of the "same" semantic prime with different meanings. Just this sort of situation is exhibited by lexical items which are "denotatively" distinct but do not differ in any independently motivated semantic feature; these are terms for correlative species, for example *rose*, *chrysanthemum*, and *pansy*, or *snap*, *crackle*, *thud*, and *rumble*. (The latter set of cases is from the discussion in Leech (1969, pp. 85–89).) It is natural to say that these two sets of items represent only two semantic primes—(SPECIFIC) FLOWER and MAKE A (SPECIFIC) NOISE—and that the individual lexical items differ subatomically.

Next, we turn to a theory of valence, a set of combinatory principles for semantic primes. Among these principles in semantics are conditions stating that a certain predicate "takes" so many arguments, of such and such a type; these conditions have been much studied by Fillmore ((1970), for example), among others. Also relevant here are conditions governing the embedding of one S in another—the deep structure constraints of Perlmutter (1971), restrictions on the occurrence of special classes of predicates, such as the stative and activity predicates, constraints against certain predicates embedding themselves (*TRY to TRY, *INTEND to INTEND), and the like.

Finally, there is subatomic structure. This is already called for by the isotope cases and might serve to explain the valence phenomena. It could also provide an account of the way in which primes fall into subclasses having properties in common (a set of connectives, like AND and OR, a set of modal elements, like NECESSARY and POSSIBLE, and so on). There are in addition a number of relationships among primes that might be accounted for by means of subatomic structure—the duality relation of NECESSARY-POSSIBLE, REQUIRE-PERMIT, AND-OR, and SOME-EVERY, for instance, or the relation between nonepistemic BE FREE TO and epistemic POSSIBLE (both realized as English *can*) and between nonepistemic HAVE TO and epistemic NECESSARY (both realized as English *must*). In his treatment of semantic primes, Grosu (1970) adopts a theory of subatomic structure without comment by deciding "to represent them as bundles of semantic and syntactic properties" (p. 41); he includes (pp. 84–89) a tentative list of such properties (or types already mentioned) for seven putative primes—CAUSE, INCHOATIVE, TRY, INTEND, BE ABLE TO, BE FREE TO, and HAVE TO.

In his discussion of the sort of emergence illustrated earlier in this section, Nagel (1961, pp. 366–374) observes that emergence is relative to a particular theory, so that as theories change, it may become possible to predict properties that were inexplicable within a previous theory. He notes that a change of this sort has occurred in chemistry, where properties of substances which were formerly thought to be emergent now can be predicted from an electronic theory of atomic composition. It is even possible to imagine that all properties of interest to chemists and still considered emergent might be predictable. The rather breathtaking linguistic analog is that there might turn out to be no syntactic exceptions, that the behavior of every lexical item with respect to syntactic rules and constraints might be predictable in some way from its semantic structure.⁶

⁶ Exactly this hypothesis has been made to me by Georgia Green in conversation.

3.3. Analogy and Metaphor

I have claimed that the parallel between chemical structure and semantic structure is systematic enough to merit study, hence, that it is like the parallel between water waves and electromagnetic phenomena, which is treated at length by Hesse (1966) in her very interesting work on models and analogies. She draws a distinction between metaphors, which are suggestive but not productive, and material analogies, which function to provide models for inquiry.

Merely metaphoric are such names as the “Post Office Principle” and the “Free Ride Principle,” as well as Ross’s “tree-pruning” (1969b) and “Pied Piping” (1967, Section 4.3). More information about the way the post office operates is not likely to further the study of the requirement that transformations preserve meaning,⁷ and arboricultural research will not elucidate problems of derived constituent structure.

To round out this discussion, I will contrast some instance of merely metaphorical writing with examples of more illuminating analogies, choosing now nontransformational illustrations.

For the unsatisfying cases, I have selected ideas of two of the most original and inspiring traditional grammarians, Noreen and Jespersen. Lotz (1966) summarizes Noreen’s theory of the structure of grammar as follows:

Thus, grammar should have three branches, each of which should view the entire speech phenomenon from a special angle: *phonology*, which should treat the articulated sound; *semology*, which should deal with the linguistically formed psychological content; and *morphology*, which should account for the way in which the sound material is formed to express the semantic content. He attempted to elucidate these distinctions by analogies, e.g., a certain object can be regarded as a piece of bone (material), having the shape of a cube (content), and serving as a dice (form); or, as a building composed of bricks (material), in Moorish style (content), and serving as a café (form). But these analogies are rather far-fetched and not very illuminating (pp. 58–59).

And McCawley (1970b) attacks Jespersen’s poetic attempts in *Analytic Syntax* (1969, pp. 120–121) to distinguish the notions “nexus” and “junction”:

In *AS*, his characterizations of nexus and junction rest heavily on analogies which I find unenlightening (p. 447).

Compare the corresponding analogies in Jespersen (1924):

Comparisons, of course, are always to some extent inadequate, still as these things are very hard to express in a completely logical or scientific way, we may be allowed to say that the way in which the adjunct is joined to its primary is like the way in which the nose and the ears are fixed on the head, while an adnex rests on its primary as the head on the trunk or a door on the wall. A junction is here like a picture, a nexus like a process or drama (p. 116).

In the same work, Jespersen strives to account for the relationships of modifiers by means of an analogy less striking than he had hoped it would be:

... it is really most natural that a less special term is used in order further to specialize what is already to some extent special: the method of attaining a high degree of specialization is analogous to that of reaching the roof of a building by means of ladders: if one ladder will not do, you first take the tallest ladder you have and tie the second tallest to the top of it, and if that is not enough, you tie on the next in length, etc. In the same way,

⁷ Although I cannot resist pointing out that structures in violation of derivational constraints are the analogs of pieces of mail returned to the sender.

if *widow* is not special enough, you add *poor*, which is less special than *widow*, and yet, if it is added, enables you to reach farther in specialization; if that does not suffice, you add the subjunct *very*, which in itself is much more general than *poor* (p. 108).

For an instance of a more productive analogy, consider the parallel between replacement of vocabulary items in a language over time and the decay of radioactive elements, a parallel first emphasized by Swadesh and discussed clearly by Lees (1953):

The members of the chosen subset may be likened to the (indistinguishable) atoms in a given mass of a radioactive element. Since the rate of disintegration is predictable at any time during observation of the sample, the mass (or number of remaining atoms) of the element remaining among the decay products at any time in the sample is a measure of how long the sample has been decaying. The analysis of decay products in mineral samples permits the calculation of the age of the earth's crust. Similarly, analyses of morpheme decay products should provide an absolute chronology for lexical history (pp. 113–114).

This analogy turns out to have several faults: morpheme decay probably does not proceed at a constant rate, and, even if it did, the resulting estimates of absolute chronologies would normally not be exact enough for ordinary linguistic purposes. Nevertheless, the analogy is close enough to have inspired some important research, and in special cases glottochronological methods are still useful.

Analogies of many kinds were a fancy of nineteenth-century writers on language. In the following passage, Whitney (1867) spoke more truly than he could have known:⁸

There is a yet closer parallelism between the life of language and that of the animal kingdom in general. The speech of each person is, as it were, an individual of a species, with its general inherited conformity to the specific type, but also with its individual peculiarities, its tendency to variation and the formation of a new species. The dialects, languages, groups, families, stocks, set up by the linguistic student, correspond with the varieties, species, genera, and so on, of the zoölogist. And the questions which the students of nature are so excitedly discussing at the present day—the nature of specific distinctions, the derivation of species by individual variation and natural selection, the unity of origin of animal life—all are closely akin with those which the linguistic student has constant occasion to treat. We need not here dwell further upon the comparison: it is so naturally suggested, and so fruitful of interesting and instructive analogies, that it has been repeatedly drawn out and employed, by students both of nature and of language (pp. 46–47).

Whitney cites Lyell and Schleicher as additional proponents of the proportion
species : variety = language : dialect

and of the related parallels between genetic classification in linguistics and biological taxonomy, although Whitney nevertheless castigates Schleicher for attempting “to prove by [this proportion’s] aid the truth of the Darwinian theory, overlooking the fact that the relation between the two classes of phenomena is one of analogy only, not of essential agreement” (p. 47).

In fact, the analogy is a deep one. There is a population of individuals, who vary in a number of characteristics (linguistic or morphological). The individuals form themselves into a number of groups on the basis of their similarities. There is also an ability for certain pairs of individuals to interact in a special way, if they are brought

⁸ The passage is sandwiched between an analogy relating linguistic history and organic growth and decay and one associating earlier stages of a language with geological strata.

together. (Their speech is mutually intelligible, in the linguistic case, or they can (inter)breed, in the biological case.) The interactive ability is then used scientifically as a necessary and sufficient test for determining groups within the population. (In the linguistic case, mutual intelligibility is used as a stringent criterion for a *language*, and in the biological case, ability to interbreed is used as a stringent criterion for a *species*.)

Several developments of these notions can be predicted. First, it will frequently not be possible to bring together the appropriate pairs in order to test relationships. Thus, biological specimens may be dead, or geographically separated, or ecologically separated; languages may be defunct or far-flung. In both fields, the consequence is the development of an independent notion of relationship, one based solely on the characteristics. In the case of biology, this is the "morphological" species, as opposed to the "biological" species (see, *inter alia*, Cain (1954)). In the case of linguistics, this is the Stammbaum principle of genetic classification, as opposed to a sociolinguistic classification. The new, or "strict," theory is easily seen to be unsatisfactory because the characteristics will show a considerable degree of independence, hence, a Wellentheorie in linguistics and a theory of diffusion of characters through gene pools in biology.

Another, less predictable characteristic of the systems we are considering is that the stringent criterion turns out not to characterize a transitive relation. That is, evidence will arise indicating that the criterion is not necessary but merely sufficient. In the case of biology, we have animal chains in which each animal can breed with the animals in the adjoining territory, although the animals at the extremes cannot interbreed (a readable exposition occurs in Dobzhansky (1955, Chapter 8)); in the case of a "species" of gulls surrounding the North Pole, the extremes happen to occur in the same area and cannot interbreed. The linguistic analogies are well-known cases where groups of speakers find their dialect mutually intelligible with their neighbors' but the extreme dialects are not mutually intelligible. Indeed, knowing the case of the gulls, we might have been able to predict the existence of problematical dialect chains.

The analogy between linguistic and biological classification is a systematic one: in most respects, there is a point-to-point correspondence between the two fields. The claim made in this paper is that the correspondence between semantic and chemical structure is of the same sort.

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