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# HUSSERL'S PHILOSOPHY OF SCIENCE AND THE SEMANTIC APPROACH*

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Husserl's mathematical philosophy of science can be considered an anticipation of the contemporary postpositivistic semantic approach, which regards mathematics and not logic as the appropriate tool for the exact philosophical reconstruction of scientific theories. According to Husserl, an essential part of a theory's reconstruction is the mathematical description of its domain, that is, the world (or the part of the world) the theory intends to talk about. Contrary to the traditional micrological approach favored by the members of the Vienna Circle, Husserl, inspired by modern geometry and set theory, aims at a *macrological* analysis of scientific theories that takes into account the global structures of theories as structured wholes. This is set in the complementary theories of manifolds and theory forms considered by Husserl himself as the culmination of his formal theory of science.

**1. Introduction.** Logical positivism and its offsprings are well known to have a very high esteem for logic, mathematics and the empirical sciences. But they are not the only ones. There are at least two other major nonpositivist philosophical movements in the philosophy of the twentieth century with a similar appraisal of these sciences, considering a proper understanding of them as the essential and central task of philosophy. We are referring to the pragmatism of C. S. Peirce and the phenomenology of E. Husserl.[1] In this paper we wish to draw attention to some rather ignored topics of Husserl's formal philosophy of science which exhibit some striking parallels with contemporary postpositivist developments in modern philosophy of science.

In rough terms the main thesis of this paper is that Husserl's formal philosophy of science can be considered as an anticipation of the contemporary *semantic view of theories* considering *mathematics* and *not logic* to be the appropriate tool for the reconstruction of empirical theories. According to Husserl, an essential part of the reconstruction of an em-

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[1]Recently the relations between logical positivism, exemplified by the philosophy of Carnap, and Peirce's pragmatism have been examined in broad terms by D. Gruender (1982); for an account of the relations between Husserl's phenomenology and Peirce's phenomenology (phaneroscopy), see Spiegelberg (1956–1957). Despite these useful papers, a comprehensive account of the relations of pragmatism, phenomenology and logical positivism is still lacking.

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pirical theory is the mathematical description of its *domain*. For Husserl it is *not* sufficient for a philosophically adequate description of an empirical theory to describe only its linguistic features; what is needed as well is a *mathematical description* of its models or *formal ontology*. Husserl's formal philosophy of sciences takes its inspiration from *Cantor's set theory, Klein's "Erlangen programme"* and *Hilbert's axiomatization of Euclidean geometry*. It aims at the reconstruction of the *global* structure of empirical theories and may therefore be characterized as a *macrological*[2] approach in contrast to the *micrological* one favored by the members of the Vienna Circle in the early decades of the century.

Husserl formulated the essentials of his mathematical, macrological philosophy of science in the last years of the nineteenth century. He published his approach for the first time in *Logische Untersuchungen* in 1900–1901. The liberation of positivist philosophy of science from its logico-linguistic straitjacket began in the fifties with Suppes's claim that philosophy of science should use set theoretical methods instead of metamathematical ones (Suppes 1965).

Thus, Husserl's mathematical philosophy of science anticipates the basic idea of Suppes by more than fifty years. Of course, we do not claim Husserl as the founding father of the semantic view; this would be quite absurd. His mathematical philosophy of science has had virtually no effect on the mainstream of philosophy of science dominated by logical positivism and was almost completely ignored in the phenomenological camp as well, with the rare exceptions of London (1923), Mahnke ([1923] 1977), Becker (1923, 1927), and Cavaillès ([1946] 1970).

Before we go into details, let us remark on the relations between Husserl's phenomenology and logical positivism. Both logical positivism and phenomenology share a common logical and mathematical legacy connected with the work of Leibniz, Bolzano, Cantor, Frege and Hilbert.[3] Other common traits are:

[2]"By the ascent to the systematic theory of theories and manifolds, the *problems of entireties* had been introduced into logic, so far as they can be set as *formal* problems". (Husserl 1969, p. 101, ⟨88⟩/⟨89⟩). And in footnote 1 Husserl adds, "It is a fault of the exposition in the Logical Investigations that this thought was not made central by repeated *emphasis*, despite the fact that it continuously determines the sense of the whole exposition".

[3]It is not the task of this paper to describe precisely the influence that these philosophers and scientists have exerted on Carnap and Husserl. These influences, particularly Frege's, have been well documented (see Mohanty 1982). Carnap, a former student of Frege, respected his teacher as one of the most important figures in modern logic; it seems Husserl has tried to play down Frege's influence on Carnap, despite (or perhaps because of) the similarity of some of their positions, for example, the strict rejection of psychologism in logic (see Mohanty 1982, and Mahnke [1923] 1977). Some remarks on Husserl's mathematical and scientific formation can be found in Heelan (1987, 371) and Mahnke ([1923] 1977, 75f.).

1. a philosophical interest in logic, mathematics and the sciences;
2. the rejection of psychologism in logic;
3. a program of "scientification" of philosophy.

But, in the end, the differences appear to have been more influential:

1. the strong impact of empiricist traditions on the side of logical positivism, versus growing inclinations towards a-priorist metaphysics and "idealism" on the side of Husserl's phenomenology;
2. the rejection of any kind of metaphysics on the part of logical positivism, versus transcendentalism in Husserl's philosophy;
3. the priority of formal logic as the foundational discipline, as against transcendental phenomenology as the ultimate foundation of science and philosophy.

Even if there was some occasional philosophical contact between Husserl and members of the Vienna Circle,[4] one may safely assert that no substantial philosophical debate on the theory of science took place between logical positivism and phenomenology.

To provide a contrasting background for the discussion of Husserl's mathematical philosophy of science, let us recall briefly the essentials of Carnap's *logical* philosophy of science as developed in Carnap ([1934] 1937). This is the clearest and most extreme account of the logical philosophy of science of logical positivism, and, moreover, it is almost contemporary with Husserl's final presentation of his philosophy of science, the "Formale und transzendentale Logik" ([1929] 1974).

In his book, Carnap describes the realm of philosophy in general and of philosophy of science in particular, and the relations of these disciplines to logic. He says that philosophy, having been purged of all non-scientific ingredients, is nothing but *logic of science*. *All philosophical*

[4]They are not very profound and sometimes are rather polemical: In Carnap (1969) we find some quite friendly remarks concerning the role of the phenomenological method of "bracketing" for the development of Carnap's "constructional systems"; in his (1937), two phenomenological examples are mentioned in passing with the intention to show that phenomenology is a philosophy that lacks clarity.

The relations between Husserl and Schlick are of a more intensive but sometimes rather polemical kind. In his *Habilitationsschrift* "Das Wesen der Wahrheit nach der modernen Logik" (1910–1911), Schlick criticizes Husserl's truth theory of the *Logische Untersuchungen 1* ([1913] 1975). In *Allgemeine Erkenntnislehre* (1922), Schlick polemizes against Husserl's conception of phenomenology as the founding discipline of logic as well as psychology. In the second edition of the *Logische Untersuchungen* Husserl strikes back very harshly ([1913] 1975, vi). Schlick reacted to Husserl's criticism by recanting some of his statements in the second edition (1925) of *Allgemeine Erkenntnislehre*. However, there is another more indirect connection between Husserl and the Vienna Circle. He seems to have influenced markedly some Polish philosophers like Lesniewki and Lukasiewicz who have been considered by the members of the Circle as close allies (see Beth 1968, 353).

*questions are logical questions concerning the logical analysis of science,* its propositions, concepts and theories. The logic of science is searching for theorems that are syntactic in character. This implies that all meaningful philosophical problems are problems about the logical syntax of scientific language. The logical syntax of a language is the formal theory of the expressions of that language: the systematic specification of the formal rules in the language and the development of the consequences flowing from these rules.

In sum, we can formulate the following fundamental equation as the basis of Carnap's early philosophy of science put forward in his *Logical Syntax of Language*:

PHILOSOPHY = PHILOSOPHY OF SCIENCE

= LOGIC OF SCIENCE

= SYNTAX OF SCIENTIFIC LANGUAGE

A discussion of the history of this equation is not the task of this paper. It goes without saying that today it has very few adherents; but perhaps it should be mentioned that even now, for Quine, "philosophy of science is philosophy enough". From it has evolved a concept of an empirical theory, later to be called the "received view", well-known for its successes as well as for its shortcomings (see Suppe 1974, 12).

In the next section we recall the essentials of the *semantic* approach to scientific theories. This sets the stage for the presentation of Husserl's philosophy of science in sections 3 and 4. In particular, we discuss in section 4 some aspects of London's *set theoretic philosophy of science* which can be considered as a concretization of Husserl's approach. In section 5 we sketch a comparison of the phenomenological and the semantic philosophy of science, discussing their affinities and differences with respect to the topic of foundations, meaning, and the progress of science. We end with some concluding remarks in section 6.

**2. The Semantic Approach.** Carnap's account of logical philosophy of science has been definitively *refuted*. By the end of the sixties at the latest, philosophers came to the conclusion that something was fundamentally wrong with the traditional approach: what was needed were not further refinements and epicycles but a radically new start.

Up to the present no universally accepted paradigm has evolved out of the crisis of the classical logical positivist philosophy of science (see Suppe 1974). Some philosophers like Toulmin, Hanson and Feyerabend were led to the conclusion that a *logical* or more generally a *formal philosophy of science* does not make much sense after all: the evolution and dynamics of science, according to them, are too manifold and changing to be caught in the simplistic formalism of crude logic. Others did not react so pessimistically. Instead of denying *tout court* the possibility of any adequate formal reconstruction of empirical theories and their evolution, these philosophers tackled the task of supplanting the traditional formal account by a better one. Following common usage, this approach—favored by Suppes (1965, 1969), Sneed (1979), van Fraassen (1980), among many others—may be called the *semantic view of theories*. As this is not a monolithic research program, it is somewhat misleading to talk of "*the* semantic approach". Rather, there exists a *whole family* of semantic approaches living on more or less friendly terms with each other. However, ignoring their differences, all members of the family can be characterized in general terms by *two basic assumptions*. According to the semantic view:

1. scientific theories are to be conceived primarily *not* as linguistic entities (sets of statements) but as certain nonlinguistic conceptual *structures* called, for example, (partial or potential) models, state spaces, or configuration spaces;
2. the appropriate tool for the formal description of scientific theories is *not* logic but *mathematics,* (see Suppe 1974, Stegmüller 1979, van Fraassen 1987).

Thus, as we shall see, the basic assumptions of *contemporary* formal philosophy of science match quite well with the *Husserlian* philosophy of science of some sixty years ago.

To make possible a sensible comparison of semantic and Husserlian formal philosophy of science, it is convenient to recall the essentials of the semantic approach in somewhat greater detail. At the basis of all versions of the semantic view we find Suppes's simple but far-reaching insight that an empirical theory should be characterized directly by its *models,* whereas its linguistic formulation is of secondary importance. It has turned out that in most cases set theory is a convenient tool for the description of the theory's models. Thus, as a first approximation, an empirical theory **T** can be identified with its class of models **M(T)**, the models being *structured sets*. So the first task of philosophy of science, according to the semantic approach, is to describe in set theoretic or mathematical terms the models of a theory. Then, the class of models **M(T)** of an empirical theory **T** is used to express "the empirical claim" (Sneed 1979) or the "theoretical hypothesis" (van Fraassen 1987) of **T**, to wit the assertion that a certain class **I(T)** of real (or "empirical") systems is a subclass of **M(T)** or, in more refined versions of the semantic view, that the elements of **I(T)** can be extended in a certain way to elements of **M(T)**. This is only a rough outline of the semantic view of empirical theories; for a sophisticated and comprehensive up-to-date account see

Balzer, Moulines, Sneed (1987); for a more intuitive account, see van Fraassen (1987). We will further address the semantic approach in section 5. But already from our sketchy description we may take note of the following important feature:

> The logical reconstruction of an empirical theory based on the formal description of its class of models is primarily carried out with the aid of *mathematics,* be it set theory, topology, geometry, systems theory or something else. Logic in the traditional sense is not excluded as an auxiliary discipline but it is just one among many (see van Benthem 1982, Note 4, 467). Contemporary formal philosophy of science does not care much about the boundaries between different formal sciences; it will draw on any that seem useful.

Like Husserl's account, the modern semantic view is based on a liberal methodology taking logic and mathematics as a *connected spectrum* of formal foundational disciplines.

**3. Husserl's Mathematical Philosophy of Science.** The basic ideas of Husserl's mathematical philosophy of science are already present in his "Logische Untersuchungen 1" (LU) ([1913] 1975, §62–72) of 1900, partly written as early as 1896. They are elaborated further in "Einleitung in die Logik und Erkenntnistheorie" (*Vorlesungen 1906/07*) (ELE) (1984) and reach their final form in "Formale und transzendentale Logik" (FTL) ([1929] 1974). During this long period, more than thirty years, the essentials of Husserl's philosophy of science remain largely intact, especially his core, "theory of manifolds and the corresponding theory forms". Thus we can concentrate our discussion on FTL taking notice of ELE and LU only casually and thereby neglecting to some extent the internal evolution of Husserl's thought.[5]

In sharp contrast to Carnap's reductionist interpretation of the progress of logic in the nineteenth and early twentieth century, Husserl conceptualizes this progress as an *extension* of the original *logical domain*: The starting point of Husserl's conception of logic as philosophy of science

[5]In the following we will deal mainly with Husserl's *formal logic of science* touching upon its *transcendental foundation* only occasionally. Our main interest lies in the investigation of possible points of direct contact of Husserlian and postpositivist analytical formal philosophy of science and not, as it were, in a faithful and complete reconstruction of phenomenological philosophy of science. Of course, this restriction is not to be interpreted as the assertion that Husserl's transcendental logic could not possibly be of interest to analytical philosophers of science. In particular, Husserl's phenomenological analysis of the correlation between apophantic and ontological aspects of formal logic could be helpful to elucidate philosophically the corresponding relation between syntax and semantics.

is the traditional definition of logic as the art of thinking. This rough and preliminary definition of logic is refined by observing that logic is not concerned with all kinds of thinking but only with those which may be called *rational* or *reasonable thinking* that aims at reasons and arguments for an assertion. This kind of thinking is best realized in the sciences. Thus, more precisely, *logic* is the art and/or *theory* of *scientific thinking*. In this sense logic is oriented towards science. Science offers the logical *kat' exochaen* (Husserl 1984, 4). Further, science is science qua its logical character. *All sciences have essential properties in common that can be characterized as logical properties*. This being the case, there must be a science of the sciences *as* sciences. This is logic. *Logic is the science of science*.

After these generalities, we have to elucidate what Husserl meant by the logical character of science; up to now we have not said anything concrete about it. He asserts that the unification of logic and mathematics originating in the work of Bolzano, Boole, de Morgan, Schröder and others, has paved the way for a proper understanding of the *two-sided character of classical formal logics*: formal apophantics and formal ontology. Apophantic logic is the domain of judgement; it uses linguistic categories (*Bedeutungskategorien*) such as judgement, proposition, syllogism, subject, and predicate. On the other hand, formal ontology is the domain of formal objects; it uses "object categories" (*Gegenstandskategorien*) such as object, unity, plurality, relation, and state of affair (see Husserl [1929] 1974, §27, ⟨77, 78⟩; also Sokolowski 1973, 309–310).

Contrary to logicism's reductionist interpretation according to which mathematics is a branch of logic, Husserl maintains for mathematics an independent position. According to him, the relationship between mathematics and logic is not simple sub- or superordination but is of a quite subtle dialectical nature.

From a formal point of view, mathematics can be characterized as *set theory*, but this, according to Husserl, is not philosophically satisfying. According to him, the unifying sense-giving idea of formal mathematics is the idea of *formal ontology*:

> . . . one recognizes that the theory of sets and the theory of cardinal numbers relate to the empty universe, *any object whatever* or *anything whatever*, with a formal universality that, on principle, leaves out of consideration every material determination of objects. . . . This gives rise to the idea of an all-embracing science, a *formal mathematics in the fully comprehensive sense* . . . it is natural to view this whole mathematics as an *ontology* (an apriori theory of objects), though a *formal* one, relating to the pure modes of anything whatever. (1969, §24, ⟨68⟩)

*Formal ontology* as a *Wissenschaft vom Seienden überhaupt* can be characterized further as a *science of the possible*:[6]

> A science of anything whatever in formal generality is a science of the possibly being, science not of the factual and the factually determined but of that kind of being which can be thought to exist, i.e. the possible. Knowledge of possibilities precedes knowledge of the actual. (Husserl, FTL, supplementary text 7, 419, my translation)

Husserl's formal ontology and formal apophantics constrain the formal structure of possible scientific theories in two complementary ways. No theory can possess a domain whose formal structure is at odds with the constraints that are laid upon it by the laws of formal ontology. The domain of a real theory, being real, must be possible and for this reason has to conform with the laws of formal ontology as the science of the possible. On the other hand, the judgements and the arguments of a science must conform to the standards of apophantic logic, since in the sphere of judgements and arguments it is apophantics that determines what is to be considered as scientific and what is not.

In modern terms, the roles of formal ontology and formal apophantics in Husserl's scenario are *the semantic* and *the syntactic part of a theory's logical reconstruction*. In the semantic part, we are engaged in the description of the theory's *models,* that is, those entities that satisfy (at least approximately) the laws of the theory. For the description of the models we may use a formal theory like a convenient set theory, for example, classical set theory or fuzzy set theory. Of course, today we are more cautious than Husserl; we would not assert that each scientific theory *must* conform to the reconstructional standards of a certain fixed formal theory. If it transpired that the models of a certain empirical theory could not be reconstructed in, say, ordinary set theory, we would not immediately disqualify the theory as being unscientific; we could also blame set theory itself for insufficient expressive power. But such modern relativizations do not call for a fundamental revision of Husserl's approach. In the syntactic part of the logical reconstruction of a theory we are concerned with linguistic and grammatical questions; more precisely, we aim at a logical reconstruction of the theory's language, its vocabulary and its grammar.

**4. On the Theories of Manifolds[7] and Theory Forms.** Thus far the perspective of Husserlian formal philosophy of science can be characterized as strictly *local*. We have been concerned exclusively with those

[6]A similar conception of mathematics as the science of the possible or the hypothetical has been put forward by Peirce (1931, 1935, 4:189ff.).

[7]The English translation of *Mannigfaltigkeitslehre* changes between "theory of manifolds" and "theory of multiplicities", the latter in Cairns's translation of the "Formale und

things that appear *inside* the frame of one single possible theory. For example, in formal apophantics we have dealt with forms of judgements, arguments and their elements; in formal ontology, correspondingly with objects-as-such, and relations-of-sets-as-such. This conception of logic, familiar from Carnap (1937) as well, may (following Stegmüller) conveniently be dubbed "micrological analysis". It dominated the theory of science of logical empiricism for decades without a serious rival. Only recently it has been called into doubt whether the micrological analysis really tells us all we want to know about the structure of empirical theories. Several authors have brought forward the thesis that the micrological perspective is incomplete and should be replaced or at least be supplemented by an approach, which may be called *macrological analysis,* that takes into account the *global structures of empirical theories as structured wholes*. This is exactly the aim of Husserl's *theory of manifolds* and his *theory of possible* theory forms or theory of deductive systems.

The case of modern geometry provided Husserl with the decisive inspiration for his macrological theory of science. According to Riemann and his followers, especially Klein, geometry is no longer to be considered as the theory of the structure of physical space but rather as the *science of possible space forms* regardless of their being of physical space or of certain of its parts.

Mathematically, a space form is just a set of unspecified elements (often called "points") together with certain relations defined on it. Paradigmatic for this approach is Hilbert's axiomatization of Euclidean geometry. Thus, in a first approximation, modern mathematics may be described as an ensemble of "geometries" and "arithmetics". This picture of modern mathematics as an ensemble of generalized geometries and arithmetics is not totally false but surely rather naive. A more adequate account must realize that the first aim of extended formal mathematics is not to explore, as it were, one manifold after another, but rather to do a kind of *meta-research*; that is, for example, to investigate the class of manifolds generally, to classify them, to find connections and interrelations between different types. In other words, extended formal mathematics is a *theory of possible theories* rather than a mere ensemble of theories. As is well known, this informal description of the structure of modern mathematics can be made precise in different frameworks, for example, in the struc-

transzendentale Logik". Cairns's translation is fortunate: Husserl parallels his philosophical *Mannigfaltigkeitslehre* with Riemann's geometrical theory of the same name. But in the realm of geometry, *Mannigfaltigkeit* is rendered into "manifold" throughout and there is no reason to think that the philosopher's vocabulary should deviate from the mathematician's in this case, since this would cut off Husserl's philosophical concept from its proper mathematical source. Thus, in this paper *Mannigfaltigkeit* is rendered "manifold" throughout.

turalist reconstruction of Bourbaki or in the category theory of MacLane and Eilenberg (see MacLane 1971). It is this conception of modern mathematics as a theory of possible theories which serves Husserl as a guideline for his own macrological philosophy of sciences:

> The most universal idea of a theory of manifolds is the idea of a science that develops in a determinate manner the essential types of possible theories (and correlative provinces) and explores the manners in which those types are interrelated conformably to laws. All actual theories, then are specializations or singularizations of corresponding theory forms; just as all theoretically treated provinces of cognition are single manifolds. If the relevant formal theory has been actually developed within the theory of manifolds, then all the deductive theoretical work necessary to the building of all actual theories with the same form has been done. (1969, §28 ⟨80⟩)

The distinction of the apophantic and the ontological aspects of formal logic made on the micrological level extends to a corresponding distinction on the macrological level. Thus, in macrological analysis we distinguish an ontological component, *the theory of manifolds,* dealing with the structure of domains of possible theories, and an apophantic component, *the theory of possible theory forms* or *theory of deductive systems* concerned with the investigation of the global apophantic aspects of possible theories.

London's paper (1923) can be considered as a set theoretic concretization of Husserl's largely programmatic account of a *macrological* philosophy of science. From the very beginning London favors a definitively macrological approach in contrast to the traditional micrological approach (1923, 337). According to his paper, the adequate tool for the description of the global structures of scientific theories is *informal set theory*. More than thirty years before Suppes we find the proposal that *set theory* and not micrological logic is the appropriate tool of philosophy of science to elucidate the formal and conceptual structures of (empirical) theories. In order to characterize a specific manifold, it is necessary to specify its defining relations. For this purpose London uses a kind of "relational calculus" in which the main tools are *products of relations* and *concatenation laws* that define new relations from old ones. London's relational calculus can be characterized in modern terms: starting from sets $X$, $Y$, . . . new objects are constructed with the aid of relational constructions like Cartesian products and pullbacks (MacLane 1971). In this way a manifold in the sense London describes may be compactly denoted by $\langle X; R_1, \ldots, R_s \rangle$. It is evident that this set theoretic characterization of the domains of possible theories is essentially the same as the modern structuralist characterization of the set of (possible or partial) models of a theory, or Ludwig's species-of-structures approach (Ludwig 1978).

On the side of global apophantic logic, that is, the theory of possible theory forms, London's approach can be considered an informal predecessor of some of the work of Tarski and other Polish logicians. Given a set $A$ of propositions, London introduces the notion of the "power of $A$", (1923, 361, §12) which in modern terms is essentially the set of all consequences of $A$, or $A$'s content. He goes on to consider how to compare the content of competing theories (theory forms), thereby touching on similar problems as Popper some forty years later when he tried to define an adequate measure of verisimilitude (London 1923, 369f §16).

Apparently this interesting piece of Husserlian formal philosophy of science has been completely neglected by analytical philosophers of science and phenomenologists alike. Seen from a contemporary point of view, Husserl and London's confidence in the power of mathematics and a priori reasoning lead them astray when they touch the central question of completeness of a theory and its underlying manifold. Inspired by the "Euclidean ideal" Husserl asserts the following:

> If the *Euclidean ideal* were actualized, then the whole infinite system of space geometry could be derived from the irreducible finite system of axioms by purely syllogistic deduction (that is to say, according to the principles of the lower level logic); and thus the *apriori essence of space could become fully disclosed in a theory*. The transition to form then yields the form-idea of any manifold that, conceived as subject to an axiom-system by formalization, could be *completely explained nomologically,* in a deductive theory that would be (as I usually expressed it in my Göttingen lectures) "equiform" with geometry. (1969, §31, ⟨83⟩)

Expressed in modern terms, Husserl poses the problem whether a theory, for example, Euclidean geometry or elementary arithmetics, is *complete*.[8] If it is, he calls the theory's domain—its manifold—*definite* and

[8]Today there are several distinct concepts of completeness in use (see van Dalen 1983, 48f.; also Rosado Haddock 1973, 78).

$C_1$: = A set $S$ (of propositions) is maximally consistent iff

(i) $S$ is consistent;

(ii) $S \subset S'$ and $S'$ consistent $\Rightarrow S' = S$.

In other words, $S$ is complete in the sense of $C_1$, iff $S$ has no consistent extension. This concept of completeness is called by Bachelard (1968, 58) *syntactical completeness*.

$C_2$: = A set $S$ is complete (sometimes called simply complete) if for each $s$

either $S \vdash s$ or $S \vdash$ not $s$.

the corresponding system of axioms complete. He gives the following explicit definition of these terms:

> The axiom-system formally defining such a manifold is distinguished by the circumstance that any proposition (proposition form naturally) that can be constructed, in accordance with the grammar of pure logic, out of concepts (concepts-forms) occurring in that system, is either "true"—that is to say: an analytic (purely deducible) consequence of the axioms—or "false"—that is to say: an analytic contradiction—; *tertium non datur.* Naturally this raises extremely significant problems. How can one know a priori that a province is a nomological province . . . ? . . . how can one know, how can one prove, that a system of axioms is definite, is a "complete" system? (1969, §31, ⟨84⟩)

Husserl uses the completeness of a system as a criterion for the logical classification of the sciences. When the above-stated question can be answered affirmatively for a science, Husserl calls this science "deductive" or "theoretically explanatory". After explicating the notion of completeness in such a precise and succinct way, Husserl commits a fundamental mistake when he simply states that for *a priori reasons* (whatever this means) all deductive sciences, in particular all theories of formal mathematics, are *complete,* whereas sciences like psychology, phenomenology or history are *not complete.* In a similar vein, London asserts that the possibility of characterizing the domain of a theory *relationally* is a sufficient condition for the completeness of the corresponding theory. However, in 1931, Gödel proved that already the elementary arithmetic of the integers is incomplete. Thus, Husserl's reliance on a priori reasons is not sound. In particular, most mathematical and physical theories are, contrary to Husserl's claim, not "deductive" or nomologically explanatory

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If $\vdash$ satisfies the deduction theorem we get $C_1 \Leftrightarrow C_2$, (see van Dalen 1983, 49).

$C_3$: = A set $S$ is complete with respect to a model $m$ if all true propositions of $m$ can be deduced from $S$:

$${}_m\vDash s \Rightarrow S \vdash s$$

This concept of completeness is called by Bachelard (1968, 58) *semantical completeness.*

Apparently Husserl identifies these three concepts of completeness. But there are systems of propositional logic that are *not* complete in the sense of $C_1$ and $C_2$ while they are complete in the sense of $C_3$. Thus *semantical completeness* does not imply *syntactical completeness.* That Husserl has overlooked this possibility leads Bachelard to claim, ". . . not only here but elsewhere, despite his distinction of the two correlates *theory* and *multiplicity,* [Husserl] never came to distinguish the *syntactical* and the *semantical*" (1968, 58). In my opinion this verdict is totally unwarranted. For a detailed and fair interpretation of Husserl's theory of logic in the light of contemporary logics, see Rosado Haddock (1973).

theories. They also belong, ***horribile dictu*** for a classical rationalist, to the same class of sciences as psychology and history, and "we can understand the principle of *unity* in such sciences *only by going beyond the analytico-logical form*" (1969, 102 ⟨90⟩). Husserl has not shown how we can "go beyond", since in his theory of science he was interested only in genuinely scientific, that is, "deductive" (complete) theories. The modern semantic approach has dealt with this problem, proposing to characterize an empirical theory **T** by its class of models **M(T)** (conceptual structure) *plus* a loosely specified but not totally undetermined domain **I(T)** of intended applications that is to capture the *empirical* realm the theory intends to talk about. In other words, the semantic approach takes into account that (generally) the meaning of empirical theories cannot be exhausted by purely formal means (see Sneed 1979 and Balzer, Moulines, and Sneed 1987). From a somewhat different point of view we will have more to say on the "empirization" of Husserl's "rationalist" account by the semantic approach in the next section.

**5. Phenomenological and Semantic Philosophy of Science: Affinities and Differences.** In the preceding sections we have shown that there exist some remarkable similarities between Husserl's mathematical philosophy of science and the semantic approach. This might tempt one to consider the whole of Husserlian philosophy of science as a kind of anticipation of the semantic approach. However, such a view would be wrong. The Husserlian and the semantic approach are offsprings of rather different philosophical attitudes; Husserl's philosophy throughout bears strong rationalist and apriorist traits while the semantic approach proclaims its empiricist origins. A succinct comparison between both is rendered more difficult by the fact that their styles are rather different. While Husserl presents his account in a very general and programmatic form, the exponents of the semantic approach are more cautious with respect to general claims; they stress the detailed analysis of concrete scientific concepts and theories. Moreover, the semantic approach is hardly a homogeneous conception, but rather a family of rival approaches whose advocates hold opposing views in many areas, for example, in the ongoing debate on matters of realism and empiricism (see Churchland and Hooker 1985). However, in the following we will ignore all family quarrels and pretend that there exists a kind of "optimal synthesis" of the different versions of the semantic approach.[9] It goes without saying that the following remarks do not cover the whole scope of possible relations between the

[9]This may be a rather bold conjecture since the communication between the structuralist and the state-space version of the semantic approach leaves much to be desired. I know of only one paper, Pérez Ransanz (1985), that deals with an explicit comparison of both approaches.

Husserlian and the semantic philosophy of science. We confine ourselves to three central points at which the differences as well as the affinities can be presented concisely, namely the *foundation,* the *meaning,* and the *progress* of scientific theories.

Beginning with the "Logical Investigations", a main motive of Husserl's philosophizing is to make clear the true meaning of science and to explicate it in theoretical clarity. According to Husserl, explication means grounding by an ultimate foundational science, that is, by his transcendental phenomenology. This preoccupation with an ultimate foundation for all (scientific) knowledge Husserl shares with authors like Russell and the early Carnap, philosophers who are in almost all other respects quite alien to him. He is even more radical: while logicism and early logical positivism consider formal logic as the *fundamentum inconcussum* of science and philosophy, Husserl puts logic itself in question:

> . . . in our progressive criticisms [logic] is continuously and very seriously called in question. These criticisms lead us, *from logic as theory, back to logical reason* and the new field pertaining to it. . . . *How is a theory of logical reason possible? . . . Such a theory is radically possible as the phenomenology of logical reason, within the frame of transcendental phenomenology as a whole.* (1969, pp. 265–266)

In contradistinction to the rationalist and foundationalist approaches of Russell, Carnap, and Husserl, the semantic approach considers itself as a decidedly *empirical, nonfoundationalist* theory of science:

> Roughly, I maintain that there is an empirical, descriptive (but not *merely* descriptive) 'science of science'. Philosophy of science-in-general, in my view, deals with problems of providing a clear, coherent conceptual framework for formulating the empirical claims of specific theories of science.
>
> The 'science of science' I have in mind is a social science. Its primary objects are, very roughly, groups of people—'scientific communiaties'—engaged in a cooperative activity which produces, among other things, scientific theories'. (Sneed 1976, 116)

Remembering Husserl's lifelong struggle against naturalism and psychologism, it seems evident that he would have opposed this kind of empirical philosophy of science. Thus it appears plausible to draw the conclusion, as Rorty does (1979), that Husserl's phenomenological philosophy of science belongs to a quite different metaphilosophical category than the semantic approach. However, this does not exclude the possibility that there exist interesting relations between the two approaches. As Rorty has pointed out, many of the modern philosophical currents may be conceived as "heretic" offsprings of classical "orthodox" traditions and indeed we may consider the semantic approach as a kind of empiricist heresy of Husserl's phenomenological philosophy of science. In order to substantiate this claim, we have to take a closer look at the basic philosophical intentions of both conceptions.

Up to now we characterized the phenomenological theory of science as an eidetic science which for every scientific discipline provides insight into the essential basic structure (regional ontology) that it presupposes. Conceiving phenomenology in this way is not wrong but incomplete: phenomenology as radical philosophy cannot simply accept the facticity of these essences; it has to understand them as meaning structures that are ultimately constituted by transcendental subjectivity. Mohanty describes this basic task of *transcendental* phenomenology (in contradistinction to a merely *eidetic* one) in the following way:

> Phenomenology is now no longer a morphological science of essences, but a radical attempt to clarify meanings, to trace higher order meaning-formations to more basic layers of meanings and to the appropriate acts constituting such formations.
>
> . . . .
>
> This is the sort of philosophical enterprise that more and more brought the concepts of life world and transcendental subjectivity to the forefront in Husserl's thought. (1978, 310)

The important role of meanings in Husserl's philosophy of science has also been observed by Gutting.[10] The concern with meanings brings transcendental phenomenology closer to the semantic approach as we shall now explain.

According to van Fraassen, one of the strengths of the semantic approach is its capacity to deal with meanings in a much more satisfying way than the traditional account of logical empiricism, thereby yielding a promising empiricist theory of meaning:[11]

> Our view, to state it succinctly, is that in natural and scientific language, there are meaning relations among the terms which are not merely relations of extensions. . . . And this meaning structure has

[10]"Husserl is, I believe, correct in emphasizing the fundamental concern of scientists with essential meanings as opposed to mere facts. Contemporary philosophy of science has come to question more and more the sharp positivistic distinction between analytic truths of meaning and synthetic truths of fact and, as a result, to admit that a basic concern of science is evaluating the conceptual frameworks through which we interpret facts" (Gutting 1978–1979, 48).

[11]For an application of the structuralist approach at the elucidation of a Hegelian theory of conceptual development, see Thagard (1982).

> a representation in terms of a *model* (always a mathematical structure, and most usually some mathematical space). (1970, 327)

Van Fraassen explains his conception by the following example that already has been treated by Husserl and Wittgenstein.[12] Suppose we observe somebody who, under normal circumstances, utters sentences like:

> *X* is green, *X* is not red, *Y* is green
>
> Nothing that is green can be red.

Then we can explain his linguistic behavior by assuming that he is guided by a "color theory" which is encapsulated in the abstract structure of the color spectrum and can be thought of as a line segment or an interval of the real numbers (representing the wavelengths). Thus the colors "red" and "green" are localized at different regions of the line and it is logically impossible that one and the same object is red and green (all over) at the same time. In this way the meanings of his utterances are controlled (and explained) by reference to a mathematical model. This, in a nutshell, is the meaning theory of the semantic approach. Two important traits of this meaning bestowal via models should be mentioned explicitly:

1. The models guiding the meaning structure of scientific theories may contain a good deal of structure which corresponds to no elements of reality. Thus the link between language and reality mediated by mathematical models may be a very incomplete one, even for our best theories (see van Fraassen 1987, 122).
2. To say that somebody, or even a whole group of persons, is guided by a mathematical model structure does not mean that it is known completely and can be expressed adequately by those who are using this model-guided language. Thus the meaning theory of the semantic approach allows a kind of tacit knowledge even at a very high conceptual level of theorizing. Of course, if the model is made conscious it is possible to control the use and development of the theory more directly, for example, Lagrangean (or Hamiltonian) frameworks are used in a quite deliberate and reflexive manner (see Born 1983, 328 and Bunge 1977, 81).

Since the models have their origin in the conceptual structures proposed by the scientific community, all "objective" meaning is constituted by something "subjective". We cannot separate "the empirical" from "the

[12]As has been pointed out by Hintikka and Hintikka (1986, chapter 6, section 7), a remarkable similarity obtains between Husserl and Wittgenstein's points of view on problems of meaning, at least in the earlier periods of the latter. According to McGuinness (1979, 67–68), Wittgenstein, Schlick, and Waismann debated this topic and explicitly mentioned Husserl. For some time Wittgenstein even characterized his philosophy as "phenomenology" (see Spiegelberg 1981, 1982).

conceptual" in a neat way, and empirical meanings are inextricably intertwined with the conceptual structure of the models. If we could identify the scientific community with some kind of transcendental subjectivity—a move that certainly would need arguing and that an orthodox Husserlian surely would not accept—van Fraassen's sketch of an empiricist theory of meaning would match quite well with Husserl's own characterization of transcendental philosophy:

> [Transcendental philosophy is] a philosophy, that against the prescientific and scientific objectivism goes back to the knowing subjectivity as the primary place of all objective meaning formation and validation of being. It takes it upon itself to understand the existing world as a product of meaning and validation and in this way to initiate an essentially new kind of understanding of the scientific character of the sciences and of philosophy. (Husserl [1935] 1954, 110, my translation)

Of course, for Husserl the domain in which the meanings of science are constituted is not such a mundane entity as the scientific community but rather a transcendental one; more precisely it is transcendental subjectivity that constitutes all meanings, that of the prescientific life world as well as the "objective" world of science. However, the meaning constitutions of the life world and the scientific world are not independent; Husserl claims that the meanings of science are higher order meanings that are founded in the meanings of the life world. In order to understand this claim at least roughly, we have to sketch the role of the concepts of *life world* and *foundation* somewhat more precisely. The topic "life world and science" has been discussed extensively in the phenomenological literature; for example, see the contributions in Ströker (1979). We do not aim to deal with this topic exhaustively; for our purposes it will be sufficient to recall some of the essentials, as can be found in Heelan's recent account (1987).

The life world is the intuitive surrounding world of life, pregiven for all in common. It is neither an object nor a conceptual framework that could be replaced by another. It is the ultimate pregiven horizon of all perceptible objects and practical goals. The life world is always contemporary. It is the point of departure for all science, both historically and for each new student. Our life world—in contradistinction to the life world, say, of the Homo sapiens of the Cromagnon era—is full of scientific artifacts and technologies; it is formed by the scientific praxis to a great extent, even for those who understand nothing of science as a theory. For example, even if we know nothing about the scientific theory of thermodynamics we can use a thermometer as a device to measure the directly experienced ("life world") quality "warmth" as "temperature". Common sense takes this correspondence for granted. For it, the possibility of a "translation" of life world experience into the language of the mathematical natural sciences is a matter of course since our life world already is formed by artifacts that make use precisely of this possibility. But philosophically, the above-mentioned correspondence is not at all trivial. It lies at the heart of modern "Galilean" natural science, and expresses its basic idea, namely that:

> . . . all in the specific sensible qualities that reveals itself as real must have a *mathematical index* and that from this fact results an indirect mathematization. . . . The whole infinite nature as a concrete universe of causality—that was the content of this astonishing conception—became a peculiar kind of applied mathematics. (Husserl [1935] 1954, 38, my translation)

The presence of scientific artifacts in our life world demonstrates the more general fact that a life world is always a product of past cultural traditions that are sedimented within it and influence its present praxes. Performing the transcendental reduction (epoché or bracketing) of objective science, transcendental phenomenology explicates this sedimented structure of the life world in order to understand how the life world provides the soil or foundation of all scientific theory. It reveals, according to Husserl, that all scientific terms and constructions gain their full meaning from original praxes of the life world. More precisely, the genesis of their meaning is to be understood as a superposition of more or less idealized evidences, each of which finally presupposes a primary evidence that is not idealized and belongs to the experience of the *Lebenswelt*. For Husserl the correspondence between sensible and scientific qualities indicates a strong parallelism between the structure of the life world and the scientific world. This is a rather strong thesis that stands in marked contrast to van Fraassen's cautious claim that the link between the conceptual models and observable reality may only be incomplete and partial even in our best scientific theories. Husserl's thesis seems to be wrong: as Heelan convincingly points out (1983 and 1987). Our intuitive space experiences may not be related to their scientific counterparts in a one-to-one manner; rather they are determined by a very complex context of human interests and competences. Thus, the meaning structure of scientific theory arises in a more complicated way from the meaning structure of life world experiences than Husserl's rationalist and apriorist approach is prepared to concede; conceptualizing the emergence of scientific meaning as an inductive extrapolation of life world meaning with the aid of mathematical idealization in general will not do. More generally the constitution of scientific meaning in the course of the conceptual development of science cannot be understood as a continuous and cumulative progress, as Husserl seems to assure. Rather, one of the main problems of contemporary philosophy of science is how to conceptualize the structure of scientific progress. This problem cannot be tackled satisfactorily by an apriorist approach. It has to be investigated empirically, taking into account the actual history of science, rather than a transcendentally purified version of an "intentional history" of occidental science as a whole. Thus we cannot but agree with the following statement of Mohanty:

> A transcendental subjectivity that is to serve as the domain within which all meanings have to have their genesis needs to be, in the first place, a *concrete* field of experience. . . . It also needs to be *historical,* for meanings are constituted on the foundation of other historically sedimented structures. (1978, 320, Mohanty's emphasis)

In a way, Mohanty's statement is in line with the natural evolution of Husserl's own thinking, since the emergence of the concept of life world can be understood as a self-critical development in which Husserl attacks indirectly his own ahistoricism (see Carr 1987, 163). One way of concretizing transcendental subjectivity is to construe the transcendental domain as the historical communicative situation of the scientific community, as has been proposed by Apel (1973, see in particular "Transformation der Transzendentalphilosophie"). Such a move could bring transcendental phenomenology into the neighborhood of the semantic approach which focussed its explication of the meaning structure of science on the "rational reconstruction" of its conceptual history. Kuhn, certainly not a wholehearted supporter of every kind of formal theory of science, takes a quite favorable view of the structuralist version of the semantic approach in this respect.[13] Even the assessment of such an ardent antiformalist as Feyerabend (1977) is not totally unfavorable. It is not the place here to evaluate these judgements further, but we may say at least that the semantic approach is sufficiently rich and flexible to assimilate suggestions and insights of many nonpositivistic, sociologically and historically oriented currents within philosophy of science. It provides a good testing ground for clarifying and exploring ideas, thereby paving the way for a comprehensive *and* exact philosophy of science that can cope with the problems of foundation, meaning, and progress of science in a satisfactory manner.

[13]"To a far greater extent and also far more naturally than any previous mode of formalization, Sneed's lends itself to the reconstruction of theory dynamics, the process by which theories change and grow" (Kuhn 1976, 184). Moreover, he expresses the hope, "If only simpler and more palatable ways of representing the essentials of Sneed's position can be found, philosophers, practitioners, and historians of science may, for the first time in years, find fruitful channels for interdisciplinary communication" (1976, 181).

**6. Concluding Remarks.** In the course of their development both the semantic approach as well as Husserl's phenomenological philosophy of science have come to realize that the meaning structure of science inextricably depends on preformational, not completely fathomable, cultural and historical contingencies. Husserl explicates this via a highly stylized "intentional history" of Galilean science and its foundation in the *Lebenswelt*. The semantic approach does the same via detailed "rational reconstructions" of the dynamics of "middle sized" empirical theories, up to now avoiding explicit statements concerning a possibly ultimate basis for all this theorizing. At least at first sight these two approaches do not seem totally incompatible. Husserl's sweeping claim that transcendental phenomenology provides the ultimate foundations of science with apodictic certainty, however, is not acceptable for the semantic approach (nor for any other nondogmatic contemporary philosophy of science). The alleged superiority of the phenomenological methods over all other naturalistic or empirical methods of inquiry does not seem tenable. In particular, the disdain for formal methods sometimes revealed from certain quarters of the phenomenological camp seems to be inadequate; some injection of mathematical and logical rigor would do no harm to contemporary phenomenology. Whatever its strengths, logical philosophy of science is not one.[14] So quite recently J. J. Compton can assert, "To speak of phenomenology in the same breath in which one speaks of the philosophy of science, and in particular of the philosophy of the natural sciences, sounds suspiciously like a bad joke. For 'we all know' that the two are philosophical worlds apart and express incompatible tendencies of thought" (1988, 99). Compton himself does not subscribe to such a view but the general attitude he describes seems to be quite popular. It is amusing to contrast Compton's statement with Mahnke's characterization of phenomenology stated some sixty years ago, ". . . phenomenology stands in con-

[14]The *logical* traits of phenomenological philosophy of science have been withering away in the writings of later phenomenological authors; for example, in Gurwitsch's *Phenomenology and the Theory of Science* (1974) we do not find a single reference to the theory of manifolds—considered by Husserl himself as the culmination point of his formal philosophy of science—nor any mention of logicians and philosophers like Bolzano, Frege, and Tarski, and all the more no member of the Vienna Circle and its cognates is mentioned. Perhaps they have nothing relevant to say on matters of philosophy of science, but such a presumption is itself a philosophical stand that is, to put it mildly, subject to discussion.

The global assertion that post-Husserlian phenomenology has totally neglected the legacy of Husserl's mathematical philosophy of science should perhaps be qualified: this assertion is true only for the "Heidegger-dominated" phenomenology of the German-speaking countries (and some other countries as well, for example, the Netherlands). In France, the situation has been different: French philosophers of science like Gaston Bachelard, Cavaillès, and Suzanne Bachelard are influenced by Husserl's mathematical philosophy of science to quite a considerable extent. However, their work has exerted no influence on the mainstream of Anglo-Saxon philosophy of science.

trast to many modern philosophies of intuition and experience which arouse in the mathematician or natural scientist the rightful suspicion that they are unscientific. Unlike them, phenomenology finds it so essential to recognize the fundamental importance of the eternally valid systematic structure of formal mathematics as the ideal storeroom of the forms of theories of all exact sciences that it places 'with clear consciousness, for the first time since Leibniz, at the entrance to the unified theory of science'" ([1923] 1977, 75). It is hard to believe that Compton and Mahnke are referring to one and the same subject matter and one wonders how such a shift of meaning has been possible.

Considering the common traits and interests, the segregation of the phenomenological and the semantic approaches is a bad state of affairs; today, the gap between (Anglo-Saxon) empiricist and (Continental) phenomenological philosophy of science does not appear as unbridgeable as fifty years ago when, on the one hand, any kind of metaphysics was considered as pure evil to be banned from the domain of serious scientific philosophy without mercy, and, on the other hand, philosophy in the style of logical empiricism was dismissed as a mere "philosophical puerility" (1969, Introduction, ⟨12⟩). For some recent attempts to overcome these obsolete borderlines see Apel (1973), Rorty (1979), Heelan (1983), or Margolis (1987).

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