Notre Dame Journal of Formal Logic
Volume VI, Number 2, April 1965

REMARKS ON THE LINGUISTIC FOUNDATIONS OF PHYSICS

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In this paper, we present a linguistic theory of physics taken as the representative of that older group of sciences generically referred to as the physical sciences. These extend from what is acknowledged to be 'pure physics' to the rigorous parts of biology such as bio-physics, bio-chemistry and genetics. We wish to exclude such disciplines as descriptive biology, all purely descriptive sciences, as well as the behavioural sciences which, from the point of view adopted here, are either proto- or pseudo-sciences, depending on the particulars of the case.

This is by no means the first time that physics has been looked upon as a language, as is well-known. We have simply attempted to bring together some of the salient results of modern research into the foundations of science and philosophical linguistics. Of the many views which have been advanced on these questions, we are reacting most 'to' (not 'against') L. Wittgenstein so far as philosophical linguistics is concerned, and K. R. Popper so far as the logic of physics is involved. It will be quite evident that they would not assent to many of the things which are said herein. Our heritage however, is of the spirit, not of the letter, and we owe much where we have learnt much.

By 'language' we shall understand 'a system of symbols, syntactical rules and definitions which is developed and organized so as to give meaning to certain aspects or features of the field of human experience'.

The main function of language so understood is consequently epistemological. The otherwise important problem of the communicability of the meaning thus expressed will not be entered into here. We shall simply assume that the language is 'public' in the sense that the definitions are either operational in the case of the semantical terms, or are nominal in the case of theoretical terms, and that furthermore all such terms are univocal.

It is desirable at this point to define a few important terms which are used in senses that are somewhat at variance with the prevalent usages of philosophers of language and logicians. This divergence in the use of terms is not practiced here for the sake of originality, but because of the necessity inherent in the linguistic approach to the foundations of physics.

Received January 5, 1964

"'To be the case' is simply to be an isolate of human experience. The totality of 'what is the case' will be referred to, if need be, as 'the real $\mathcal{E}$'. The real so envisaged is the ensemble of the discrete isolates obtained from the continuum of human experience **E**. An element of the real is therefore singled out from the continuous background of which it is an integral part. A spectral line taken independently of the spectrum, e.g. simply as a blackening of the film, is an example of such an element. They are contrasted with their background, but are not interpreted, that is, endowed with meaning. Seen in this way, an element of the real is a non-linguistic entity, an isolate whose existence in space-time is independent of any and all linguistic systems. As such, it cannot be described in itself, it can only be named or otherwise symbolised. This means that, from the linguistic point of view 'what is the case' is, by itself and in itself, meaningless. It is neither 'this' nor 'that', it simply is.

A 'State of affairs σ' is an ordered set of elements of the real. As such, it is describable from a given point of view, by means of appropriate experiential modes or techniques. It is characterized by a dual aspect: the given isolates that are the material elements of the set, and the ordering principle which gives it a formal structure. In point of fact, it is the perspective within which $\mathcal{E}$ is viewed that truly defines the state of affairs, determining both its formal aspect and the kinds of elements that enter into it. For this reason, we shall call such a perspective 'noetic'. Because the elements of $\mathcal{E}$ individually considered are simply the case, a state of affairs is non-linguistic. On the other hand, because of the formal arrangement of the specified elements within the set, it is susceptible of description by means of a suitable terminology[1]. For this reason, a state of affairs may be taken to be pre-linguistic. It is well to point out also that a state of affairs, by exhibiting a given relationship between certain specified isolates provides them with a de facto-interpretation which, as we saw above, is absent when these same isolates are considered only as members of $\mathcal{E}$.

All states of affairs may be grouped together into a universal referential Σ_u which encompasses the totality of human experience, and consequently forms the only concrete reality that is semantically meaningful.

Any subset of Σ_u will be called a 'linguistic referential $\Sigma_{\mathcal{L}}$', and any given member of $\Sigma_{\mathcal{L}}$ a 'linguistic referent'. Furthermore, a referential $\Sigma_{\mathcal{L}}$ whose members are all describable within the same perspective is said to be 'homogeneous with respect to that perspective'. In this sense, it is possible to conform to the usage common to ordinary language speakers and talk meaningfully of 'physical reality', 'biological reality', etc. denoting in each case the ensemble of all states of affairs definable within these noetic perspectives.

We have seen that, being a *découpage* operated on the totality of what is the case when viewed in a certain light, a state of affairs is endowed with a

1. By 'terminology' we mean an 'algorithm'—e.g. tensor analysis, differential equations, etc.—and a set of definitions linking some algorithmic symbols to non-linguistic entities of a theoretical nature.

meaning characteristic of the determining point of view. It is therefore to that extent describable by means of an appropriate semantical molecular term or 's-term'. If we represent the descriptive function of the language by 'L', we will have

$$s = \mathsf{L}(\sigma) \tag{1}$$

If the s-terms describing the elements of a given referential $\Sigma_{\mathcal{L}}$ were to be grouped together, we would obtain a set $S_{\mathcal{L}}$ which could be interpreted as a sort of linguistic image of $\Sigma_{\mathcal{L}}$. At any rate, according to the definitions previously given, $S_{\mathcal{L}}$ is the class of all statements of facts (in Carnap's sense), the members of which are, by definition, semantically verified.

However, in the case of languages such as physics, such a set, though very important, plays a limited role in the overall problem of verification. Of greater importance are the 'generalized s-terms' or 's-cells'. An s-cell is obtained from an s-term by a process of algorithmic generalization, whereby syntactical constants and variables are substituted for the partieular values that these may have in the description of a given state of affairs. To illustrate what is meant here, we may take a very simple example familiar to everyone[2]. The free fall of a particular object (denoted by the subscript 'j') at a given time and place may be described by the following s-terms:

$$r_j = r_{o,j} + \dot{r}_{o,j}\, t + k_j\, t^2 \qquad (k_j = -g_j/2) \tag{2}$$

The semantical cell, on the other hand, is characterized by the sentential schema:[3]

$$r = r_o + \dot{r}_o\, t + k\, t^2 \qquad (k = -g/2) \tag{3}$$

It is apparent that both equations exhibit the same sentential form and that they differ only in certain values of the algorithm; in particular, that we have:

2. Although, quite evidently, one could supply similar examples from the more "modern" developments of physics, such as the wave function for a free particle. However, relatively few philosophers of science are sufficiently conversant with modern physics for such examples to be appropriately illustrative, more philosophers being in touch with the behavioral than with the physical sciences. On the other hand, all educated persons may be supposed to be tolerably familiar with the so-called 'free fall' and the classical theory of gravitation. This is why we do not heed N. R. Hanson's otherwise reasonable admonition in a paper of this type which is not concerned with the logic of discovery. Cf. N. R. Hanson's: "Patterns of Discovery", Cambridge 1958.
3. In this paper, we distinguish between 'propositions', 'statements' and 'sentences'. By 'sentence', we mean the 'algorithmic structure of a (well-formed) molecular term'; by 'proposition' we mean a molecular term which is 'L-determined' in Carnap's sense; and by a 'statement,' we mean a molecular term which is 'L-undetermined', or 'factual' in Carnap's sense'. Cf. R. Carnap: Meaning and Necessity. Chicago 1947.

$$r_{o,j} \in r_o$$
$$\dot{r}_{o,j} \in \mathring{r}_o \qquad (4)$$
$$k_j \in k$$

This is an instance of the process of algorithmic generalization from descriptions of actual states of affairs such as (2) which is carried out most simply by leaving the constants and variables unspecified, except for their types -e.g. a length, a velocity, an acceleration, as in the above example.

Furthermore, it should be noted that the process we have just described has no inverse. What is observed at the experimental level are individual states of affairs, not classes of them. While an s-term always describes an actual state of affairs, an s-cell is a general term which has no concrete referent, it simply denotes a class of particular terms referring to individual concrete instances. Consequently, an *s*-cell can't be obtained except by generalization of an *s*-term, and an *s*-term may be obtained only from a corresponding state of affairs. For this reason, an *s*-cell is not to be considered a 'statement' but rather a 'pseudo-statement'.

It is quite clear from what precedes that the description of a given state of affairs, as indeed the state of affairs itself, reflect a certain way of looking at the world of experience (Cf. N. R. Hanson: *Patterns of Discovery*, Cambridge U. P. 1958). It is worth emphasizing again that states of affairs, as defined here, do not in any conceivable sense 'suggest' themselves, and especially not in the sense that their meaning is implicit in the spatio-temporal distribution of their elements, although, psychologically speaking, such a distribution may suggest a relation which becomes meaningful when viewed in a particular light. This however, belongs to the domain of the so-called "logic of discovery" and not to be foundations of physics proper.[4]

We are now in a better position to describe, in a formal and explicit way, what the semantical structure of a formal object language such as physics is[5].

The Semantical Structure

Let E stand for the continuum of experience. Looking at this continuum through a given noetic structure -i.e. the theory-certain of its features stand out, the ensemble of which we called 'the real $\mathcal{E}$':

4. A "Baconian" mind conceived as a faithful and untarnished mirror in which the 'real world' may be reflected must be relegated to an appropriate limbo so far as the physical sciences are concerned (we are not confusing here 'science' and 'applied science'). Fundamentally, one sees only what one is looking for, provided that certain non-linguistic conditions are satisfied. The 'grid' of relations does not stand by itself in the 'real world', but must be supplied by the theory. Cf. K. R. Popper: "The Logic of Scientific Discovery". N. Y. 1959.
5. For classification of languages, cf. infra pp. 120-121.

$$\mathcal{E} = \{\epsilon_1, \epsilon_2, \ldots, \epsilon_n\} \qquad (n \text{ infinitely large}) \tag{5}$$

The elements of $\mathcal{E}$, being givens of experience, are embedded in time and distributed in space, i.e. each one is unique.

Next, an ordering principle or relational grid, previously defined by the noetic structure -i.e., the theory- is super-imposed on $\mathcal{E}$, thereby establishing a characteristic relationship among some specified elements, provided that such elements are the case. In practice, the relational grid is imposed on $\mathcal{E}$ by means of a suitable experimental apparatus. The result of this determining process is what we called a state of affairs σ. If λ^μ denotes the generating function characteristic of the apparatus for a given state of affairs σ_J^μ, we will have:

$$\sigma_J^\mu = \lambda^\mu [\mathcal{E}]_J \tag{6}$$

with the Greek superscript characterizing the Lambda generating function i.e. the 'type' of state of affairs that is obtained, and the Latin subscript 'j' denoting a particular instance of the state of affairs generated by the particular Lambda out of individual elements of $\mathcal{E}$.

The ensemble of all such states of affairs of all kinds is the referential $\Sigma_{\mathcal{L}}$ of the language $\mathcal{L}$. Thus:

$$\Sigma_{\mathcal{L}} = \left\{\sigma_1^1, \sigma_2^1, \ldots, \sigma_n^1;\ \sigma_1^2, \sigma_2^2, \sigma_3^2, \ldots;\ \ldots;\ \sigma_1^\nu \sigma_2^\nu, \ldots, \sigma_n^\nu\right\} \begin{matrix} \text{'}\nu\text{' finite} \\ \text{'}n\text{' potentially infinite} \end{matrix} \tag{7}$$

Every observed state of affairs is describable in principle by means of a suitable terminology, i.e. by means of a suitably interpreted algorithm. Let '$\mathsf{L}_{\mathcal{L}}$' be the semantical function generating the appropriate s-terms corresponding to each observed state of affairs. Then, we will have:

$$S_J^\mu = \mathsf{L}_{\mathcal{L}}(\sigma_J^\mu) \tag{8}$$

Furthermore, in an object language such as physics, the criteria of operationism require that

$$\mathsf{L}^{-1}(S_J^\mu) = \mathsf{L}^{-1}\mathsf{L}(\sigma_J^\mu) = \sigma_J^\mu \tag{9}$$

so that the L-function must satisfy the relation of semantical convertibility[6]

$$\mathsf{L}^{-1}\mathsf{L} = \mathsf{I} \tag{10}$$

However, as was indicated earlier (p. 112) what is of great significance for the problem of verification is not so much the description of a large number of individual states of affairs of one kind as the determination of appropriate semantical cells.

Symbolically, the relation between the sentential schema characteristic of a semantical cell and the s-term from which it is obtained may be ex-

6. The semantical convertibility rule (10) is not necessarily commutative, in the sense that there is not a unique s^ν_k corresponding to a given σ_k^ν. The same state of affairs is generally describable in several ways, depending on the purpose for which it is described.

pressed by a function of generalization $G_{\mathcal{L}}$ characteristic of the algorithm used. Thus:

$$S^{\nu} = G_{\mathcal{L}}(S_k^{\nu}) \tag{11}$$

The ensemble of all such semantical cells forms what will be called the 'semantical universe of discourse (of the language $\mathcal{L}$) U_s':

$$U_s = \{s^1, s^2, s^3, \ldots\ldots, s^{\nu}, \ldots.\} \qquad (\nu \text{ finite}) \tag{12}$$

It should be noted that the semantical universe of discourse is devoid of any intrinsic ordering principle. It is simply a collection of unrelated semantical cells obtained by generalization of descriptions of many kinds of actual states of affairs. Whatever relations may obtain between different members of U_s come from elsewhere. In point of fact, the s-cells are ultimately defined and correlated in an indirect way by means of a relational structure which incorporates the noetic perspective itself, namely the theory. The development and description of such structures is the 'theoretical or noetic' function of the language, just as the definition and description of states of affairs is its semantical function. It is now time to turn our attention to it.

The theoretical structure. There is more to an object language such as physics than simply the capability of describing actual states of affairs by means of a convenient terminology. It is also possible to form molecular terms independently of any semantical rule. Such linguistic terms will be referred to here as 'propositions' or 'molecular $\mathcal{L}$-terms'. A proposition is said to be 'well-formed' whenever it satisfies certain canons usually expressed in terms of algorithmic rules, which, taken collectively, are characteristic of the language considered. For example, these canons, among others enable one to determine that a given proposition is of geometry, while another is of chemistry, and still another of quantum mechanics. The canonical aspect however is not the most important one from the point of view we have adopted here, and consequently we shall not dwell upon it any further. Of far greater significance is the validation of the propositions in the language. This sort of validation is not at all like semantical verifiability, which is topological in nature. Rather, it is a purely linguistic process, such as is provided by syntactical derivation from axioms or propositions recognized as true or valid and which, taken collectively, define the language itself by determining its type and its structure. It is characteristic that, in the case of physics which occupies us at present, the theory may in principle be formulated axiomatically, although this is not always done in practice, the formalization of a given theory being primarily a metalinguistic requirement, and consequently of relatively minor interest to the practitioner of the discipline, except in so far as it does isolate the primitive assumptions of the theory.

The formal system obtained by axiomatizing the theory must evidently satisfy, as far as possible, the normal conditions of consistency, completeness, and independence that are the metalinguistic *desiderata* of all formal languages. However, the necessity to refer to the semantical universe of discourse imposes additional conditions on the formalized language which, collectively considered, will be called the 'principle of linguistic adequation'. This principle is of the greatest importance since on it is based the entire problem of linguistic verifiability; the remainder of this paper will accordingly be devoted to it and to connected questions.

Linguistic adequation. Seen as a formal system, the theoretical structure appears as an ordered set of propositions, some primitive, others derived by means of an appropriate algorithm embodying the syntactical rules of derivation. As was alluded to above, the primitive propositions determine the characteristic properties of the theoretical structure, and consequently, of the language itself. For example, the axioms will determine whether the theory is to be conservative or not, a field-type conceptual structure or some other, etc. Simply put, the axiomatic set $\mathfrak{a}_{\mathcal{L}}$ defines an angle of view, a perspective within which certain features of the real are going to stand out from among the rest as constituents of recognizable patterns. It is as if the axiomatic set ultimately defined linguistic grids of ordering principles for certain pre-determined types of possible concrete occurrences which, should they happen to be the case, would automatically appear to the trained and expectant mind as actual 'states of affairs'. The ability of the set $\mathfrak{a}_{\mathcal{L}}$ of primitive propositions to define grids of relations which will yield actual states of affairs is one of the necessary criteria for its justification, as we shall see.

All propositions which are not primitive in the sense defined above are derived from these according to appropriate syntactical rules which determine their 'pedigrees' or derivations and, through the chosen algorithm, insures that they are 'well-formed'. The propositions collectively considered describe in an explicit manner the properties of the theoretical model implicitly contained in the axiomatic set $\mathfrak{a}_{\mathcal{L}}$. Therefore, the propositional referential is itself a conceptual or ideal structure, and not a concrete situation however rearranged, much less what is the case. In general, this ideal structure is some sort of abstract hyperspace -e.g. a phase space, a imosphere in Hilbert space, a space-time continuum, etc.- endowed with characteristic properties which enable us to give meaning to dynamical equations expressed in terms of them. The properties of such models are related in characteristic ways to $\mathcal{L}$-cells and, through them, to s-cells as we shall see later.

Among propositions, some are of particular interest to us in the present context. These are the $\mathcal{L}$-terms which are formulated uniquely by means of atomic terms which are themselves susceptible of a semantical -i.e. experimental- interpretation or definition. Length, mass, time, velocity, scattering angle, half-width, etc. are examples of such atomic terms. These propositions, which may be algorithmically similar to s-cells, will be referred to as '$\mathcal{L}$-cells', and denoted by 'ℓ'. Furthermore, the ensemble of all $\mathcal{L}$-cells which have a pedigree within a given language $\mathcal{L}$ will be called the 'linguistic (or theoretical) universe of discourse $U_{\mathcal{L}}$'. Thus, if ℓ^{ν} denotes a linguistic cell, and if $\mathfrak{a}_{\mathcal{L}}$ denotes the set of axioms characteristic of the language $\mathcal{L}$, we shall find, in accordance with what precedes:

$$\vdash \ulcorner a_{\mathcal{L}} \supset \ell^{\nu} \urcorner \tag{13}$$

and

$$U_{\mathcal{L}} = \{\ell^1, \ell^2, \ldots, \ell^{\nu}, \ldots\} \ (\nu \text{ finite}) \tag{14}$$

Furthermore, the theoretical universe of discourse $U_{\mathcal{L}}$, in contrast to U_s, possesses an intrinsic order in the sense that the theoretical structure is an organic whole and, therefore, an ordered one.

So far, we have seen that a formal object language is characterized by two distinct functions, semantical and theoretical. The question now before us is, how are these functions coordinated? This leads naturally to a consideration of the two universes of discourse in which these linguistic functions are manifested. The simplest way to approach this problem is undoubtedly to study how $U_{\mathcal{L}}$ and U_s are related. If the theoretical dimension of the languate -i.e. the theory- is to be at all relevant to its semantical dimension, the two universes of discourse must overlap, so that $U_{\mathcal{L}} \cap U_s$ is not empty, i.e. there are elements in both sets that are formally identical despite the fact that they are different types of terms. $U_{\mathcal{L}} \cap U_s$ will be referred to as the 'domain of adequation' of the language.

Whenever two sets overlap, at least three subsets are defined, namely $\widetilde{U}_{\mathcal{L}} \cap U_s$, $U_{\mathcal{L}} \cap \widetilde{U}_s$ and $U_{\mathcal{L}} \cap U_s$[7]. The last mentioned is particularly important, since it is a measure of the degree to which the language achieves the correlation and linguistic justification of the states of affairs that it defines.

As we saw earlier, all s-terms are descriptions of individual states of affairs, while $\mathcal{L}$-terms are descriptions of properties of some abstract structure, and are therefore general. Under these conditions, is it possible to have members in $U_{\mathcal{L}} \cap U_s$? In point of fact, it is evident that the answer must be yes. Let us see how this is done.

Although $\mathcal{L}$-terms do not describe actual states of affairs, they may describe classes of possible ones, provided that the atomic constituents of the $\mathcal{L}$-terms are susceptible of receiving a semantical interpretation and furthermore, provided that the syntactical form of the propositions correspond to one that is characteristic of a semantical cell. For if we say that "all planetary orbits are conics" on the strength of the gravitational field theory, we thereby describe a class of possille states of affairs only if we can define semantically what we mean by 'planetary orbit' and by 'conic'.

In order to illustrate the principle of linguistic adequation, let us consider the familiar example of planetary motion alluded to above. The generality of the process is not dependent in any way on the particulars of the case, and appropriate examples could easily be chosen from the more modern developments of physics (Cf. n 2).

Semantically, we have astronomical observations which give the position of individual planets—Mars for example--at different times. Following

7. We neglect here both $\widetilde{U}_{\mathcal{L}} \cap \widetilde{U}_s$ which is the set of all terms which do not belong to the language, since it is clearly irrelevent, and the union of $U_{\mathcal{L}}$ and U_s which is not particularly significant in this paper.

Kepler's work on the results of Tycho Brahe, one may rearrange the mass of data in such a way that one obtains a molecular s-term describing the particular orbit of Mars as an ellipse with the Sun at one focus. This statement of fact may be put in the following form:

$$1/r_m = \mathbf{C}_m [1 + \epsilon_m \cos(\theta - \theta_0)] \qquad (15\text{-a})$$

with:

- $\mathbf{C}_m$ constant factor characteristic of Mars
- ϵ_m excentricity of Mars' orbit. In this case, $\epsilon_m < 1$ and the orbit is an ellipse
- θ_0 turning point for Mars
- r_m radius vector of Mars

What is important is that r_m, $\mathbf{C}_m$ and ϵ_m are semantically determined, along with the angles. (15-a) is an s-term in as much as it describes an actual state of affairs, the elliptic orbit of Mars. The corresponding s-cell is given immediately by algorithmic generalization and we obtain

$$1/r = \mathbf{C}[1 + \epsilon \cos(\theta - \theta_0)] \qquad (15\text{-b})$$

with $0 < \epsilon < 1$

We now proceed to the determination of the corresponding $\mathcal{L}$-cell. Linguistically, assuming a field theoretical framework, we shall proceed as follows. We can represent the properties of space in the neighborhood of a large mass M_c by a proposition, such as

$$\vec{\mathbf{G}} = \gamma \frac{M_c}{r^2} \vec{\epsilon_r} \qquad (15\text{-c})$$

- M_c 'causal' mass setting up the field
- r distance between the 'causal' mass and any point in the field
- γ algorithmic constant
- ϵ_r unit radial vector

Furthermore, we assume that any particle with the necessary characteristics (i.e. having a gravitational 'charge' m) immersed in the field will interact with it and that this interaction will become manifest as a force acting on the particle:

$$\vec{\mathbf{F}} = m\vec{\mathbf{G}} \qquad (15\text{-d})$$

The behaviour of the particle will be affected in a way that may be expressed as

$$\vec{\mathbf{F}} = \dot{\vec{p}} \qquad \text{(dynamical equation)} \qquad (15\text{-e})$$

Next, we make a fundamental assumption which is characteristic of the noetic model (i.e. it is a primitive proposition) and assert that '$\mathbf{F}$' in (15-d) is really the same thing as '$\mathbf{F}$' in (15-e). From this it follows that

$$m\vec{\mathbf{G}} = \dot{\vec{p}} = m\, d\vec{v}/dt \quad \text{(non-relativistic case)} \qquad (15\text{-f})$$

which, by virtue of the principle of equivalence (another fundamental noetic assumption) yields

$$\vec{G} = d\vec{v}/dt \tag{15-g}$$

Transforming this last proposition algorithmically, so as to obtain a geometrical (i.e. time independent) expression, we get

$$r^{-1} = C[1 + \epsilon \cos(\theta - \theta_0)] \tag{15-h}$$

which is clearly the equation of a conic. This last expression is evidently a general proposition: it describes the linguistic behaviour of the model. Furthermore, it is easy to see that it exhibits the same sentential structure as (15-b); consequently these two expressions should belong to the domain of adequation of the language (here, the language of the gravitational field theory)[8]. However, in spite of their algorithmic identity, the two expressions are not homogeneous, having a different genesis and a different mode of verification. Consequently, they will be said to be 'homomorphic'.

It becomes possible now to see more clearly what is meant by 'adequation': we have linguistic adequation whenever it is possible to establish a one-to-one homomorphic correspondence between $\mathcal{L}$- and s-cells. Thus, the domain of adequation is the subset $U_s \cap U_{\mathcal{L}}$ in which pairs of sentences may be found such that

$$|\ell^\nu| = |S^\nu| \tag{16}$$

the vertical strokes of either side of the terms indicating that it is neither the proposition nor the pseudo-statement that are being considered, but their algorithmic structures. It should be remarked at this point that the mapping which is characteristic of adequation is effected between cells and not between members of cells, nor between members and cells. Once it has been established beyond reasonable doubt that there is a non-empty semantical cell, the corresponding linguistic cell is considered to be adequate or 'verified'. There is no need—and one might add, no desire—to expand further effort and energy similarly to 'verify' other 'members' of the s-cell and even less all such members, since each s-cell has, in principle, infinitely many members. One well observed and well recorded state of affairs is sufficient to define a semantical cell. Linguistic verification is not a matter of probability or 'degree of confirmation' but one of homomorphic mapping of a propositional set onto a semantical one. This analysis also shows why it is that there is a fundamental asymmetry between 'verifiabil-

8. Sometimes, the $\mathcal{L}$-cell itself is structured, in the sense that it possesses proper subsets, each described by an appropriate $\mathcal{L}$-term obtained from the $\mathcal{L}$-term characteristic of the $\mathcal{L}$-cell by means of propositional particularisation. This process is purely algorithmic, and results from the application of such things as boundary conditions. In the example taken here, particularisation will result from the application of boundary conditions to the energy of the system, which will determine in which case we are—i.e. hyperbolic, parabolic, elliptic or circular paths.

ity' and 'falsifiability' when these are taken as empirical criteria of testability[9]. Verifiability applies properly speaking only to statements. A statement is verified to the extend that $s_j^\nu = \mathsf{L}_{\mathcal{L}}(\sigma_j^\nu)$, i.e. to the extent that '$\mathsf{L}_{\mathcal{L}}$' includes proper operational definitions. Falsifiability on the other hand applies to propositions only. In particular, it applies to $\mathcal{L}$-cells which are said to be 'falsified' if it is not possible to find a non-empty s-cell homomorphically corresponding to them. Propositions are said to be verified in as much as they have a 'pedigree' or derivation on the theory, i.e. if they are '$\mathcal{L}$-determined' in Carnap's sense, which is of course in no way empirical.

$\widetilde{U}_{\mathcal{L}} \cap U_s$ is the set of all descriptions of actual states of affairs which have no algorithmic counterpart in the theory. It indicates the degree to which the language is 'semantically incomplete'. In the ideal case, i.e. in the semantically complete language, this subset should be empty. In principle therefore, a language should be able to account for all the states of affairs that it defines. It may fail to do so in essentially two ways. First, it may be the case that the states of affairs defined by the experimental apparatus do not possess the proper relational structure, i.e. the operating λ-function is not the same as that defined by the theory of the apparatus, that is that determined by the appropriate $\mathcal{L}$-cell. This type of failing is often serious, for it implies that the semantical referential generated is no longer the one that the language is supposed to describe. [A celebrated example of this—among many others--is the experimental law for 'black-body' radiation, compared to the laws characteristic of the Wien and the Raleigh-Jeans 'classical' expectations.] In the second case, although the state of affairs generated by the apparatus has the correct type of relational structure, it does not yield the right one exactly. This usually reflects a flaw in the language which need not be fatal, but which may very well be [Cf. e.g. the 'discrepancy' in the precession of the perihelion of Mercury].

$U_{\mathcal{L}} \cap \widetilde{U}_s$ is the set of all $\mathcal{L}$-cells for which there are no corresponding semantical cells in U_s. As such, it may be called the set of theoretical hypotheses. It is a mark of a semantical limitation of the language in as much as it is unable to give a concrete dimension to well defined possible states of affairs. Such limitations may be due either to the inadequacy of the language or to that of existing experimental techniques. However, this is seldom fatal, and this subset is usually well populated in 'living' languages, that is in all sciences which are not a 'closed chapter', such as classical particle mechanics is to-day.

Before we conclude, it may be worthwhile to attempt a classification of the different types of languages that are recognizable within the epistemological framework that has characterized this paper.

All languages which give us the means to order the concrete isolates of human experience are commonly referred to as 'object languages'. These are fundamentally of two types, depending on the nature of the referential. If the referential $\Sigma_{\mathcal{L}}$ is homogeneous with respect to a noetic perspective

9. Cf. for example: K. R. Popper: *The Logic of Scientific Discovery*, N. Y. 1959.

—i.e. if all the states of affairs are describable by means of that perspective the corresponding object languagesis said to be 'formal', because all such known languages are formalizable. If the referential is heterogeneous, the language is said to be 'natural' or 'ordinary'. English, French, German are examples of natural object languages, since their referentials encompass the totality of human experience, and therefore the totality of principles ordering the elements of the 'real'. On the other hand, Physics, Ethics, etc., are examples of formal object languages, since each is characterized by a given theory which manifests itself in a homogeneous semantical universe of discourse[10].

A language which has no semantical dimension will be called a 'formal abstract language'. Its sole function is to generate and explicate linguistic structures which embody certain conceptions, for example some abstract manifold. The various branches of mathematics are instances of such languages. It is quite evident that abstract languages do not, in any way, refer to the 'real', and that they are consequently devoid of a domain of adequation. Their sole 'referential' is theoretical.

Finally, there are also pseudo-linguistic structures which may be formalized but which do not, in any sense of the term, describe properties of models. Such pseudo-languages will be called 'linguistic matrices' in as much as they form the mold or skeleton upon which meaningful languages may be constructed. The different types of logic are examples of such matrices. So is any abstract language used as an algorithm or calculus in another formal language (tensor calculus as used in relativity for example), since in such cases the original theoretical interpretation of the abstract language is abandoned in order to be replaced by that of the formal object language which it helps to formulate.

Quite evidently, this short paper cannot pretend to present a complete picture of a linguistic theory of physics. Most of the points made or alluded to deserve a fuller treatment which goes beyond the more modest aim set here, which was to outline such a theory.

We shall now conclude with a few summary remarks. In the case of a formal object language such as physics, linguistic verification implies the ability of the language to generate correctly states of affairs, the descriptions of which are homomorphic with members of the theoretical universe of discourse. Correlatively, a language--and therefore a theory—becomes inadequate when it loses its structural ability to generate its supporting evidence. This assertion is not quite as paradoxical as it appears to be at first, particularly if we remember that the states of affairs are formally determined by means of a linguistic principle. For example, one does not go about designing an experimental apparatus just to see what will happen

10. Actually, this is somewhat of an oversimplification. 'Physics' is not so much a language as a family of languages. If we let $\mathcal{L}_\phi$ stand for physics, and let $\mathcal{L}_1$ stand for mechanics, $\mathcal{L}_2$ for electro-magnetic theory, $\mathcal{L}_3$ for thermodynamics, etc., then we shall have

$$\mathcal{L}_\phi = \bigcup_k \mathcal{L}_k$$

when it is plugged in, one usually knows exactly what the equipment is for, and what will come out of it. What is tested experimentally is not the form of the state of affairs, but rather whether there exist experimental elements of the right kind, such that they may be put into the relationship which is characteristic of the state of affairs. What is looked for is the concrete existence of a state of affairs, not its formal structure which is generally known before hand. This is not a form of solipsism either, since the linguistic existence of a state of affairs cannot compel its non-linguistic (i.e. concrete) existence. Human languages simply do not have this power. To think that they do is to indulge in a form of the 'ontological fallacy'. The whole justification of experimentation is precisely that it determines whether the physical world is such that it is susceptible of being re-ordered in a specified way. It is not a test for meaning, but simply for 'non-linguistic existence' of meaningful relations.

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