24. *Carl G. Hempel on Scientific Theories*

A. *The theoretical language*. The discussion in this section concerns a language *L* which is on the whole similar to the language described in Hempel's essay and in my article [1956-4] on theoretical concepts.[38] The

[38] I shall make use here of my notation of [1956-4], in which "L_O" and "V_O" replace Hempel's "L_B" and "V_B". In contrast to [1956-4], I shall consider all descriptive constants not definable on the basis of V_O as belonging to V_T. Therefore *pure disposition terms will also be taken as theoretical term* (in contradistinction to [1956-4]

class of descriptive (i.e., non-logical) primitive constants of L is divided into two parts: V_O which contains the *observation terms*, and V_T, which contains the *theoretical terms*. The *observation language* L_O is a sublanguage of L; it has a simple logical structure and contains the terms of V_O *but none of* V_T. The *theoretical language* L_T is that sub-language of L which does not contain V_O-terms. The language L, and therefore also L_T, contains a comprehensive system of logic; it also contains, for every constant of V_T, variables for which the constant may be substituted. In contradistinction to the earlier article, I shall also consider that sub-language of L which does not contain any V_T-terms. I shall call this language the *logically extended observation language* L'_O because it may be regarded as being formed from L_O by the addition of the comprehensive logic of L. The two sub-languages L'_O and L_T have this logic in common. But these sub-languages together do not exhaust L, for L also contains *mixed sentences*, i.e., those in which at least one V_O-term and at least one V_T-term occur. Let us assume that logical rules for the language L are given which define the concept of L-truth. A sentence S in L is *L-true in L* (i.e., logically true in the narrower sense) if S is a substitution instance of a logically valid sentence or schema not containing any descriptive constant. I shall write "$\vdash S$" for "S is L-true in L". S_i is said to *L-imply* S_j if and only if $\vdash S_i \supset S_j$; and S_i is said to be L-equivalent to S_j if and only if $\vdash S_i \supset S_j$. (Note that all terms with the prefix "L-" are used in the narrower sense.) The problem of analyticity (logical truth in the wider sense will be discussed later, and a tentative explication will be given in part D.

It is assumed that the terms of V_O designate directly observable properties or relations, and that their meanings are completely understood. In view of the simple logical structure of L_O it is further assumed that all sentences of this language are completely understood. In contrast, the meanings of the theoretical terms of V_T generally go beyond what is directly observable. However, a partial interpretation of the theoretical terms and of the sentences of L containing them is provided by the following two kinds of postulates: the *theoretical postulates* in which only terms of V_T occur, and the *correspondence postulates* which are mixed sentences. We may assume that the number of postulates of these two kinds is finite, since variables of all required kinds are available. Let T be the conjunction of the theoretical postulates, and C the conjunction of the correspondence postulates. These C-postulates are interpretative sentences in the sense of Hempel (§4). However, in distinction to Hempel, I

§§ IX and X); and the *reduction sentences* by which they are introduced will be regarded as C-postulates. (The extended observation language L'_O of [1956-4], which included disposition terms, does not occur in the present discussion; the symbol "L'_O" will now be used in a different sense.)

require that every C-postulate contain at least one V_O-*term* and at least one V_T-term non-vacuously, but I do not require that every term of V_T occur in at least one C-postulate.

We might say that the sentences of L'_O are completely interpreted in a certain sense. These sentences contain as descriptive constants only the completely interpreted terms of V_O. However, it must be admitted that the interpretation of L'_O is not complete in the same strong sense as that of L_O, since L'_O does not satisfy the nominalistic requirement ([1956-4] §II, requirement (3)); sentences of L'_O can be understood only if abstract variables, e.g., variables for classes, for classes of classes, etc., are intelligible.

Hempel discusses (in §5) the following methodological question. Since the purpose of scientific theories is to establish predictive connections between data of experience, is it not possible to avoid the theoretical language and work with observation language alone? In a detailed discussion Hempel gives convincing reasons for the thesis that this is not possible, in other words, that theoretical terms are indispensable for the purposes of science.[39] His main argument is based on the point that a scientific theory has the task of establishing not only deductive relations but also inductive relations among observational data I believe that Hempel was the first to emphasize dearly this important point. However, the question of the exact way in which the inductive relations should be established in a comprehensive language like *L* constitutes a difficult and so far unsolved problem.

Hempel points out (especially in §7) that with respect to a language of the kind *L,* which contains theoretical terms, the difficulties of the following three problems are increased considerably. These problems are: first the empirical significance of terms and sentences, second the "experiential import" of sentences, and finally analyticity. In the remainder of this section I shall discuss these three problems.

B. The problem of empirical significance. Let us seek a criterion or explication of empirical meaningfulness for V_T-terms and for sentences containing such terms. Following Hempel, I use the terms "significance" for the explicatum. The explicandum may be informally explained as follows; a sentence is empirically meaningful if its assumption may, under certain conditions, influence the prediction of observable events.

[39] Frank P. Ramsey ("Theories" (1929), in *The Foundations of Mathematics* (1931), ch, IXA) was among the first to emphasize that the terms of a scientific theory cannot be defined explicitly On the basis of observational terms, in contrast to the logical constructionism of Russell and of my [1928-1]. Ramsey's conception Of theories is explained and further developed by Richard S. Braithwaite, *Scientific Explanation* (1953), see ch. III: "The Status of the Theoretical Terms of a Science".

I have discussed this problem of explication in detail and have given a tentative criterion of significance for terms and for sentences in my article [1956-4], especially in sections VI to VIII. These sections may be regarded as an answer to that part of Hempel's essay which deals with the problem of significance. Many points in my article were indeed stimulated by Hempel's essay (I had read its first version of 1954 when I wrote my article) and by conversations and correspondence with Hempel, Feigl, and other members of the Minnesota Center for Philosophy of Science. In the article, I first gave a criterion for the significance of the theoretical *terms* in *L.* Then I proposed to call an expression *E* a *significant sentence* in *L,* if the following two conditions were fulfilled; (a) *E* is a sentence in *L*, i.e., *E* satisfies the rules of formation of *L;* and (b) every theoretical term in *E* is significant according to the first criterion.

In his essay Hempel expresses the view that a criterion of significance can be given only for a whole system, not for isolated sentences. Furthermore, he suspects that any criterion of significance which is not too narrow will be too wide in the following sense; a theory which is dearly meaningful, e.g., a postulate system of physics with suitable correspondence rules, will remain significant according to the criterion when further arbitrary postulates, e.g., cognitively meaningless sentences of a metaphysical pseudo-theory, are added. Hempel's reasoning is that, if a derivation of observable predictions from observation sentences is possible in the first theory this possibility remains after the addition of meaningless postulates. Since my criterion is applicable to single terms and thence to single sentences, it does not lead to this undesirable result, as I have shown in the article mentioned (§VII). It would be interesting to consider whether it might be possible to improve or simplify my criterion of significance with the help of the new method which I shall employ for the definition of analyticity (in D).

C. The problem of experiential import. What we learn from a sentence *S* with respect to possible observable events is called the experiential import of *S*. In contrast, the problem of the significance of *S* is not the question of *what* we learn from *S*, but merely *whether* we learn anything at all about observable events from *S*. Hempel is correct in maintaining that the concept of experiential import, if it can be defined at all, must be taken as relative to the total theory *TC* (Hempel's *T'*), i.e., the conjunction of *T* and *C*. For, if *S* contains only V_T-terms, then obviously we cannot infer from *S* anything about observable events without the help of the postulates. However, it seems to me that this fact by no means makes the concept useless.

Let us define the following concept for a sentence *S* in *L* (analogous definitions can be formulated for a class *K* of sentences).

(1) (a) The *observational content* or O-content of S $=_{Df}$ the class of all non-L-true sentences in L'_O which are implied by *S*.
(b) The *O-content* of *S relative to the theory TC* $=_{Df}$ the O-content of *S* • *TC*.

(2) (a) *S′* is *O-equivalent* (observationally equivalent) to *S* $=_{Df}$ *S′* is a sentence in L'_O, and *S′* has the same O-content as *S*.
(b) *S′* is *O-equivalent* to *S relative to the theory TC* $=_{Df}$ *S′* is a sentence in L'_O, and *S′* has the same O-content relative to *TC* as *S*.

Hempel gives in a recent article[40] a thorough and illuminating investigation of many logical and methodological questions connected with theoretical concepts. He explains (in a different terminology) that either the O-content of a sentence *S* or, more simply, a sentence *S′* which is O-equivalent to *S*, may serve in certain respects as a substitute for *S*, namely as far as *deductive* relations among the sentences of L'_O are concerned. But he remarks correctly that the same does not hold for the equally important *inductive* relations, and that therefore the concept of O-content does not furnish a suitable method for dispensing with theoretical terms. In this view I agree with Hempel. However, it seems to me that, although it cannot replace *S* completely, the O-content of *S* relative to a given theory *TC* may still be taken as an explicatum for the experiential import (or, if one prefers, the deductive experiential import) of *S*.

Furthermore, Hempel explains the method proposed by Ramsey for the effective transformation of any sentence *S* into a certain O-equivalent sentence. The latter sentence is called by Hempel the *Ramsey-sentence* associated with *S*; I shall denote it by "^{R}S". This sentence ^{R}S is obtained from *S* by replacing the *n* theoretical terms occurring in *S* by *n* distinct variables not occurring in *S*, and then prefixing *n* existential quantifiers with these variables. It is easy to show that, for a given theory *TC*, the Ramsey-sentence ^{R}TC is O-equivalent to *TC*; and for any sentence *S*, the Ramsey-sentence $^{R}(S \bullet TC)$ is O-equivalent to *S* relative to *TC*. Ramsey proposes to represent a theory in the form ^{R}TC rather than in the customary form *TC*. In this way the theoretical terms and sentences, which are only incompletely interpreted, would be avoided. Hempel warns that the Ramsey-sentence ^{R}TC "avoids reference to hypothetical entities only in letter-replacing ... constants by ... variables-, rather than in spirit. For it still asserts the existence of certain entities of the kind postulated by *TC*, without guaranteeing any more than does *TC* that those entities are observable or at least fully characterizable in terms

[40] Carl G. Hempel, "The Theoretician's Dilemma: A Study in the Logic of Theory Construction", in vol. II of *Minnesota Studies in Philosophy of Science* (1958). The Ramsey method is described in § 9.

of observables. Hence, Ramsey-sentences provide no satisfactory way of avoiding theoretical concepts. And indeed, Ramsey himself makes no such claim". I agree with Hempel that the Ramsey-sentence does indeed refer to theoretical entities by the use of abstract variables. However, it should be noted that these entities are not unobservable physical objects like atoms, electrons, etc., but rather (at least in the form of the theoretical language which I have chosen in [1956-4] §VII) purely logicomathematical entities, e.g., natural numbers, classes of such, classes of classes, etc.[41] Nevertheless, ^{R}TC is obviously a factual sentence. It says that the observable events in the world are such that there are numbers, classes of such, etc., which are correlated with the events in a prescribed way and which have among themselves certain relations; and this assertion is clearly a factual statement about the world.

I do not propose to abandon the theoretical terms and postulates, as Ramsey suggests, but rather to preserve them in L_T and simultaneously to give an important function to the Ramsey-sentences in L'_O. Their function is to serve in the explication of experiential import and, more importantly, in the explication of analyticity.

For any sentence *S* L-implied by *TC*, including any postulate of *TC*, the Ramsey-sentence relative to *TC*, $^{R}(S \bullet TC)$, is always L-equivalent to ^{R}TC. But this does not make it impossible to analyze any one of the postulates separately (for instance, for the purpose of deciding to omit or replace it). We simply have to investigate the postulate on the basis of the conjunction of the other postulates of *TC*.

D. The problem of analyticity. Let us consider the task of finding an explication for the concept of *analytic sentence* for the language *L.* I shall use "A-true" as the term for the explicatum. The class of the sentences which are analytic (or logically true in the wider sense) is more comprehensive than that of the L-true sentences. It comprises all those sentences whose truth is based, not on contingent facts, but merely on the meanings of the descriptive and logical constants occurring. For the sentences of L_O the problem of explication can be solved with the help of meaning postulates, which I shall call here "*A-postulates*". Whenever either a logical relation holds among the meanings of the primitive predicates in L_O (e.g., incompatibility between "blue" and "red") or a certain structural property characterizes a two- or more-place primitive predicate of L_O in virtue of its meaning (e.g., the relation "Warmer" is asymmetric and transitive), then these relations and properties are expressed in A-postulates. Let A_O be the conjunction of the A-postulates for O-terms. A_O is formulated in L'_O (it can usually be formulated even in L_O). Let A_T be the conjunction of the A-postulates for theoretical terms;

[41]This is explained in greater detail in [1959-2] § 3.

later I shall explain how these postulates are constructed. Let A be the conjunction of A_O and A_T. For analyticity as the explicandum, I propose the following explication:

(3) S is *A-true* in $L =_{Df} S$ is a sentence in L, and S is L-implied by A ($\vdash A \supset S$).

I have explained the general role of the A-postulates in greater detail in the paper [1952-5]. The explanation given there is, however, directly applicable only to descriptive constants whose meanings are completely known, thus in language L only to the O-terms. When we introduce new primitive constants by postulates in such a way that the terms are interpreted only incompletely, the situation is entirely different. Hempel has pointed out correctly that the problem of the explication of analyticity is in this case more difficult, because the postulates then have simultaneously two different functions. They serve both for the stipulation of logical meaning relations (relations among the meanings of the new terms and relations between these meanings and the meanings of the old terms) and for the assertion of factual relations. Hempel regarded these difficulties as so great that the concept of analyticity for sentences with theoretical terms appeared to him as quite elusive. During my work on the article (1956-4) and subsequently, I long searched in vain for a solution to this problem; more specifically, for a general method for analyzing the total postulate set *TC* into two components: analytic meaning postulates A_T for the theoretical terms, and synthetic *P-postulates P* which represent the factual content of the theory *TC*. I believe now to have found a solution for this problem.

Before I describe the general method, I will mention a solution for a special case which I had found earlier. (It is indicated in [1952-5] at the end of §3, and explained by Hempel in his essay §7.) This solution applies when *TC* is the conjunction of a set of reduction sentences for a new primitive predicate "Q_3" (compare [1936-10] §10):

(4) (a) "$(x)[Q_1x \supset Q_2x \supset (Q_3x)]$",
(b) "$(x)[Q_4x \supset (Q_5x \supset {\sim}Q_3x)]$",
(c) "$(x)[Q_1x \supset (Q'_2x \supset Q_3x)]$",
(d) "$(x)[Q_4x \supset (Q_5'x \supset {\sim}Q_3x)]$",
etc.

We take "Q_3" as a theoretical term and the other predicates as observation terms. Thus *TC* is here simply *C*, since it consists of mixed sentences, i.e., C-postulates, but contains no T-postulates. Writing "$Q_{1,2}x$" for "$(Q_1x \bullet Q_2x) \vee (Q'_1x \bullet Q'_2x) \vee \ldots$", and "$Q_{4,5}x$" for "$(Q_4x \bullet Q_5x) \vee (Q'_4x \bullet Q'_5x) \vee \ldots$", the conjunction of the reduction sentences (4) is L-equivalent to:

(4′) "$(x)(Q_{1,2}x \supset Q_3x) \bullet (x)(Q_{4.5}x \supset {\sim}Q_3x)$".

My earlier solution consisted in separating (4′), hence *C*, into two comportents S' and $S' \supset C$, where S' is the sentence "$(x) \sim(Q_{1,2}x \bullet Q_{4,5}x)$". C is clearly L-equivalent to the conjunction of S' and $S' \supset C$. I proposed to take the second component $S' \supset C$ as a meaning postulate. In [1936-10] I called the sentence S' the "representative sentence" of the set of given reduction sentences for "Q_3", because it "represents, so to speak, the factual content of the set". S' is a sentence in L_O, and is in general factual. But if the conjunction C of the reduction sentences consists of just one bilateral reduction sentence, then S' is L-true[42] and C itself may be taken as the meaning postulate.[43]

In analogy to the method just described for a simple special case, we can now easily specify a general method applicable to any TC. We decompose TC into two components, the first being the Ramsey-sentence ${}^{R}TC$ and the second the conditional sentence ${}^{R}TC \supset TC$. The method then consists in taking the first component as a P-postulate, and the second as an A-postulate for the theoretical terms in TC, hence as an A_T- postulate. The two components satisfy the following conditions (5):

(5) (a) The two components together are L-equivalent to TC.
(b) The first component is O-equivalent to TC.
(c) The second component contains theoretical terms; but its O-content is null, since its Ramsey-sentence is L-true in L'_O.

These results show, in my opinion, that this method supplies an adequate explication for the distinction between those postulates which represent factual relations between completely given meanings, and those which merely represent meaning relations.

It may be that we wish to establish still further sentences as A_T-postulates in addition to those formed from a theory TC in the way described. But we shall admit as A_T-postulates only sentences whose conjunction satisfies the condition (5c). It then follows that a sentence in L_O is L-implied by $A_O \bullet A_T$ if and only if it is L-implied by A_O alone. Thus:

(6) A sentence S in L'_O is A-true in L if and only if $\vdash A_O \supset S$.

As P-postulates we shall admit only sentences in L'_O. Let P be their conjunction. We define:

(7) S is *P-true* in $L =_{Df} S$ is a sentence in L such that $\vdash A \bullet P \supset S$.

The P-postulates are intended to have factual content. Therefore a sen-

[42] This is what I mane by the sentence [1936-10] p. 452. lines 20-22. Hempel (in his footnote 32) and Pap (§ 2) are right that my formulation was incorrect.

[43] I wish to make an incidental remark on the formula

$$(R)\ (x)\ (t)[Q_1xt \supset (Q_3xt \equiv Q_2xt)],$$

which I gave in [1936-10] p. 440 as the reduction sentence for the *permanent* disposition "x is soluble in water". R is not a genuine bilateral reduction sentence. Its Ramsey-sentence is L-equivalent to the synthetic sentence

$$\text{“}(x)[(\exists t)(Q_1xt \bullet Q_2xt) \supset (t)(Q_1xt \supset Q_2xt)]\text{”.}$$

R can be changed into a bilateral reduction sentence for the *instantaneous* disposition "x is soluble in water at the time t" by writing "Q_3xt" instead of "Q_3x".

tence which is known to be A-true will not be taken as a P-postulate. (However, I do not make non-A-truth a requirement for P-postulates, because there is in general no decision procedure for A-truth.)

In the special case when ^{R}TC is found to be A-true or even L-true, we drop the first component and take *TC* itself instead of the conditional sentence as an A_T-postulate.

Let us look back at the earlier mentioned case where *TC* is a conjunction of reduction sentences for "Q_3", as represented by the formulas (4′). In this case ^{R}TC is as follows:

(8) "$(\exists F)[(x)(Q_{1,2}x \supset Fx) \bullet (x)(Q_{4,5}x \supset {\sim}Fx)]$".

This is L-equivalent to "$(x)(Q_{1,2}x \supset {\sim}Q_{4,5}x)$" and therefore to "$(x) {\sim}(Q_{1,2}x \bullet Q_{4,5}x)$" which was the representative sentence *S*′. Thus we see that the method for the analysis of a given set of reduction sentences into an A-postulate and a P-postulate, which I proposed in [1952-5], is just a special case of the general method described above which is based on Ramsey's device.

Within the framework of the new method a scientific theory is represented by P-postulates and A_T-postulates. Within this framework, those sentences which in the original method appeared as T-postulates and C-postulates are not taken as postulates but are theorems derived from *P* and A_T; they are P-true according to definition (7). Since the original terminology, which applies the label "postulates" only to the T-postulates and the C-postulates, may be more customary, it may often seem preferable to keep this terminology and not to use the terms "A_T-postulates" and "P-postulates". If so, we may continue to represent scientific theories by T-postulates and C-postulates and take for "A-true" and "P-true" the following definitions, which take the place of definitions (3) and (7) of the new method and are equivalent to them:

(9) *S* is *A-true* in $L =_{\text{Df}}$ *S* is a sentence in *L* such that $\vdash A_O \bullet (^{R}TC \supset TC) \supset S$.

(10) *S* is *P-true* in $L =_{\text{Df}}$ *S* is a sentence in *L* such that $\vdash A_O \bullet TC \supset S$.