Chapter 6
Carnap's Philosophical Neutrality Between Realism and Instrumentalism

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Carnap's distinctive approach to theoretical terms in empirical science dates from the beginnings of his semantic period in the years following the publication of *The Logical Syntax of Language* (1934). Particularly important, in this context, is his monograph *Foundations of Logic and Mathematics* (1939), where the partial interpretation view of theoretical terms first emerges. This view is further articulated in "The Methodological Character of Theoretical Concepts" (1956b), and it is then connected with Carnap's use of the Ramsey sentence in "Beobachtungssprache und Theoretische Sprache" (1958)— through the mediation, as Stathis Psillos first documented, of Hempel's "The Theoretician's Dilemma" (1958).[1] Carnap continued to work on the Ramsey sentence representation of theories (and the closely related representation using Hilbert's ε-operator) throughout the late 1950s and early 1960s, culminating in *Philosophical Foundations of Physics* in 1966 (based on a typescript of his Fall 1958 seminar at UCLA made by Martin Gardner).

Carnap makes it very clear, beginning in the "Methodological Character" essay, that he intends his approach to dissolve rather than solve the "ontological" dispute between realism and instrumentalism. In line with his general approach to ontological disputes developed in "Empiricism, Semantics, and Ontology" (1950), Carnap regards this dispute—conceived as theoretical rather than practical—as involving a philosophical "pseudo-question" about the "reality" (in an objectionably metaphysical sense) of a certain general kind of entities (in this case theoretical entities), and his strategy (as is typical with him) is rather to argue that both realism and instrumentalism, in so far as they are not entangled with philosophical pseudo-problems, have an important kernel of truth; where they purport to disagree with one another,

[1] See Psillos (2000, pp. 153–154). This chapter includes Carnap's previously unpublished lecture, "Theoretical Concepts in Science," delivered in Santa Barbara on December 29, 1959

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however, we leave the firm ground of science in favor of the confused "inextricable tangle" of traditional philosophy.[2]

Carnap's definitive formulation of what Psillos (1999, chapter 3) has very helpfully called his "neutralism" comes at the very end of the chapter on the Ramsey sentence in the second (1974) edition of *Philosophical Foundations of Physics* (crucially revised with respect to this very issue shortly before his death in 1970) (1974, p. 256): "It is obvious that there is a difference between the meanings of the instrumentalist and the realist ways of speaking. My own view, which I shall not elaborate here, is essentially this. I believe that the question should not be discussed in the form: 'Are theoretical entities real?' but rather in the form: 'Shall we prefer a language of physics (and of science in general) that contains theoretical terms, or a language without such terms?' From this point of view the question becomes one of preference and practical decision.[4]" And the footnote to the last sentence explicitly refers the reader to "Empiricism, Semantics, and Ontology"—which is not cited in either the first edition in 1966 or in the "Methodological Character" essay in 1958.[3]

Carnap's attempt at neutrality has not satisfied either instrumentalists or realists. The leading defender of instrumentalism of our time, Bas van Fraassen, regards logical positivism as perhaps the most important earlier twentieth-century implementation of the empiricist approach he favors; and van Fraassen regards Carnap's "Methodological Character" paper as "in many ways, the culmination of the positivist programme" (1980, 13). Nevertheless, van Fraassen is also very clear and explicit that Carnap's particular implementation, based on formal logic and a fundamentally linguistic or "syntactic" view of theories, is ultimately hopeless (1980, p. 56): "Perhaps the worst consequence of the syntactic approach was the way it focused attention on philosophically irrelevant technical questions. It is hard not to conclude that those discussions of axiomatizability in restricted vocabularies, 'theoretical terms', Craig's theorem, 'reduction sentences', 'empirical languages', Ramsey and Carnap sentences, were one and all off the mark—solutions to purely self-generated problems, and philosophically irrelevant." Thus, despite the fact that Carnap's understanding of the Ramsey sentence leads to a conception of the empirical content of scientific theories which (as we shall see) is virtually identical with van Fraassen's own proposal for what an "agnostic" instrumentalist should assert, van Fraassen has very little patience for Carnap's general approach.

It is striking, by contrast, that Stathis Psillos, who has now mounted the most detailed and insightful defense of scientific realism in the wake of van Fraassen's

[2] Carnap announces the replacement of traditional philosophy by the new discipline of what he calls *Wissenschaftslogik* (the logic of science) in *The Logical Syntax of Language* (§72): "*Wissenschaftslogik takes the place of the inextricable tangle of problems known as philosophy*."

[3] As Martin Gardner explains in his Forward to the second edition (1974, pp. v–vi): "In response to a friendly letter from Grover Maxwell, Carnap agreed (shortly before his death in 1970) that his all-too-brief comments on the conflict between instrumentalism and realism, with respect to the nature of scientific theory, be clarified. With this in mind, he made certain alterations on the two pages [255–256], and added a new footnote referring to a 1950 paper which gives his views in more detail."

work (Psillos, 1999), devotes an entire chapter to the topic of "Carnap's neutralism." He not only has very considerable patience for Carnap's approach, but, in the course of his work, Psillos has also made important contributions to Carnap scholarship (compare note 1 above). With respect to the realism-instrumentalism debate, in particular, Psillos sees important connections between Carnap's use of the Ramsey sentence and contemporary structural realism. In the end, however, Psillos judges that Carnap's neutralism fails—due to a general problem for the Ramsey sentence approach first raised by M.H.A. Newman (1928) in connection with Bertrand Russell's early version of structural realism.[4] The problem, roughly, is that, if the Ramsey sentence is empirically adequate (if all its observational consequences are true), then it is necessarily true as well—true as a matter of (higher-order) logic. So it does not seem, after all, that the Ramsey sentence, as Carnap proposes, can faithfully represent the empirical (or synthetic) content that our original theory is supposed to have. As Psillos himself puts the point (1999, p. 62): "In the end, if no constraints are imposed on the range of the variables of the Ramsey-sentence, it is *a trivial and a priori true assertion* that there are electrons, etc. And this is clearly absurd. For, to say the least, it appears obvious that the [original, un-Ramsified] theory . . . *could* be false, even though it is empirically adequate." Indeed, as Psillos explains several pages later, he takes the Newman problem to undermine *all* forms of structural realism, in so far as it shows that some or another kind of "non-structural information" (about which properties and relations are "natural" or the like) must therefore be added on pain of incoherence.

I suggested above that, despite his lack of patience with Carnap's approach, van Fraassen's view of what a scientific theory should properly assert is virtually identical with Carnap's conception of the Ramsey sentence representation of a theory's synthetic or empirical content.[5] Van Fraassen thinks that we should only assert that the observational phenomena are *embeddable into* an abstract model for the theory, and the Ramsey sentence, on Carnap's account, says precisely the same—that there is some abstract (mathematical) model of the theory such that all observable phenomena behave in the way that the theory requires (1966/1974, pp. 254–255): "Some physicists are content to think about such terms as 'electron' in the Ramsey way. They evade the question about existence by stating that there are certain observable events, in bubble chambers and so on, that can be described by certain mathematical functions, within the framework of a certain theoretical system. Beyond that they will assert nothing." Nevertheless, it is equally true, as Psillos has argued, that Carnap's view also has much in common with contemporary structural realism. Indeed, the last sentence of *Philosophical Foundations of Physics* expresses Carnap's fervent hope "that science will continue to make great progress and lead us to ever deeper insights into the structure of the world" (1966/1974, p. 292).[6]

[4] For discussion, see Demopoulos and Friedman (1985). The problem has recently been rigorously generalized by Demopoulos (2003, 2007) to apply directly to Carnap's use of the Ramsey sentence.

[5] This point is first emphasized in Demopoulos (2003, § 5).

[6] The connection between this remark and contemporary structural realism will become clearer below: see note 23 below, together with the paragraph to which it is appended.

That Carnap has this much in common with both van Fraassen's instrumentalism and contemporary structural realism suggests, at least to me, that Carnap's attempt at neutrality may have succeeded after all. He may in fact have articulated a version of structuralism that recognizes the strengths of both instrumentalism and realism while simultaneously avoiding the philosophical "pseudo-questions" on which they appear substantively to differ.

Carnap's serious discussion of what is now called the problem of theoretical terms begins, as I have suggested, with *Foundations of Logic and Mathematics* in 1939. There, however, he does not in fact use the concept of a "theoretical" term, nor does he engage with the debate between realism and instrumentalism. Carnap instead distinguishes between "elementary" and "abstract" terms—where the latter are introduced as terms that occur later in a more-or-less continuous series beginning with very simple ordinary language predicates of observable things ("bright", "dark", "red", "blue") and ending with the most abstruse terms of contemporary mathematical physics ("electric field", "electric potential", "wave function"). We can, Carnap says, state standard semantical rules (such as "the term 'te' designates temperature") for any of these terms. "But," he continues (§ 24, 204), "suppose we have in mind the following purpose for our syntactical and semantical description of the system of physics: the description of the system shall teach a layman to understand it, i.e., to enable him to apply it to his observations in order to arrive at explanations and predictions." We cannot presuppose that the layman already understands the more abstract terms in question, so we cannot introduce them in the semantical metalanguage via standard rules of designation. The alternative is to give no direct semantic interpretation at all for the abstract terms; view them as having only *implicit* definitions within the total language of physics; and then use the semantic interpretations (rules of designation) we can legitimately give for the more concrete or elementary terms to anchor the whole system on "the solid ground of the observable facts" (§ 24, 207).

Carnap calls this kind of interpretation of the abstract terms an "indirect interpretation"—which, as he points out, is, in an important sense, "incomplete" (ibid.); and this is clearly the same idea as what he will later, in the "Methodological Character" essay, call a *partial* interpretation (of the theoretical terms). In 1939, however, Carnap is primarily addressing a problem about *meaning* or *understanding* (rather than an "ontological" problem), and he makes it very clear, in particular, that this perspective on "abstract" (theoretical) terms takes its starting point from the increasing use of the abstract (Hilbertian) axiomatic method in modern mathematical physics (§ 25, 209): "The development of physics in recent centuries, and especially in the past few decades, has more and more led to that method in the construction, testing, and application of physical theories which we call *formalization*, i.e., the construction of a calculus supplemented by [a partial or incomplete—MF] interpretation. It was the progress of knowledge and the particular structure of the subject matter that suggested and made practically possible this increasing formalization. In consequence it became more and more possible to forego an 'intuitive understanding' of the abstract terms and axioms and theorems formulated with their help." Carnap sees the theories of relativity and quantum mechanics as the

culmination of this development—where the use of highly abstract terms introduced by something like Hilbertian implicit definitions (terms such as "electron", "electromagnetic field", "metric-tensor", and "psi-function") has become a pervasive and essential feature of physical practice.[7]

According to Carnap's account in the "Methodological Character" essay, only the observational terms of a scientific theory are semantically interpreted (by specifying observable properties and relations as their designata). The theoretical terms, by contrast, are semantically uninterpreted, and are only implicitly defined, in the sense of Hilbert, by the axioms and postulates of the relevant theory (e.g., Maxwell's equations for the electromagnetic field). Among these axioms and postulates, however, are mixed sentences or *correspondence rules*, which describe (lawlike) relationships among theoretical and observational entities, and, in this way, the theoretical terms and sentences receive a *partial* interpretation in terms of the connections they induce among observables. For example, Maxwell's equations, in the presence of suitable correspondence rules relating values of the electromagnetic field to actual measurements (of electric and magnetic intensities, and the like), generate observable predictions and thus have empirical content.

Are we thereby "ontologically committed" to the existence of a mysterious unobservable entity corresponding to our term for the electromagnetic field? Here, unlike in 1939, Carnap explicitly considers this question and devotes considerable effort towards trying to defuse it. He stipulates, first of all, that the values of the variables of his theoretical language L_T range over a domain of entities including a denumerable sequence isomorphic to the natural numbers and closed over the formation of relations and classes. The domain therefore contains natural numbers, real numbers, sets of real numbers, and so on. "Now," Carnap (1956b, p. 43) continues, "we proceed to physics." We conceive space-time points as quadruples of real numbers which thereby belong to the (purely mathematical) domain D we have already constructed. Moreover, physical magnitudes (such as the electromagnetic field) are functions whose arguments are space-time points and values are real numbers or systems of real numbers (such as vectors, tensors, and so on). Thus, all the entities needed for values of our variables have already been constructed within our purely mathematical domain D. And the same holds, Carnap adds, for the entities of biology, psychology, and the social sciences.

[7] For the case of quantum mechanics, in particular, see Carnap (§ 25, 210–211): "If we demand from the modern physicist an answer to the question what he means by the symbol 'ψ' of his calculus, and are astonished that he cannot give an answer, we ought to realize that the situation was already essentially the same in classical physics. There the physicist could not tell us what he meant by the symbol 'E' in Maxwell's equations. [. . .] An 'intuitive understanding' or a direct translation of 'E' into terms referring to observable properties is neither necessary nor possible. The situation of the modern physicist is not essentially different. He knows how to use the symbol 'ψ' in the calculus in order to derive predictions which we can test by observations. (If they have the form of probability statements, they are tested by statistical results of observations.) Thus the physicist, although he cannot give us a translation into everyday language, understands the symbol 'ψ' and the laws of quantum mechanics. He possesses that kind of understanding which alone is essential in the field of knowledge and science."

Carnap then cautions the reader (1956b, pp. 44–45): "We have considered some of the kinds of entities referred to in mathematics, physics, psychology, and the social sciences and have indicated that they belong to the [purely mathematical] domain *D*. However, I wish to emphasize here that this talk about the admission of this or that kind of entity as values of variables in L_T is only a way of speaking intended to make the use of L_T, and especially the use of quantified variables in L_T, more easily understandable. Therefore the explanations just given must not be understood as implying that those who accept and use a language of the kind here described are thereby committed to certain 'ontological' doctrines in the traditional metaphysical sense. The usual ontological questions about the '*reality*' (in an alleged metaphysical sense) of numbers, classes, space-time points, bodies, minds, etc., are pseudo-questions without cognitive content." By contrast, questions about the reality of entities as asked and answered *within* science—a question, for example, about the reality of the electromagnetic field—can be given a "good scientific meaning" (1956b, p. 45) if, for example, "we agree to understand the acceptance of the reality, say, of the electromagnetic field in the classical sense as the acceptance of a language L_T and in it a term, say '*E*', and a set of postulates *T* which includes the classical laws of the electromagnetic field (say, the Maxwell equations) as postulates for '*E*'. For an observer *X* to 'accept' the postulates of *T*, means here not simply to take *T* as an uninterpreted calculus, but to use *T* together with specified rules of correspondence *C* for guiding his expectations by deriving predictions about future observable events from observed events with the help of *T* and *C*."

The circumstance that Carnap proposes a purely mathematical interpretation of the values of the theoretical variables indicates that he is already envisioning a kind of structuralist view—which, as noted above, has much in common with his later use of the Ramsey sentence. However, Carnap does not appeal to the Ramsey sentence here (in 1956b), and, as noted above, he only comes to appreciate the relationship between his developing view of theoretical terms and Ramsey's work after reading Hempel's "Theoretician's Dilemma" in 1958 (see again note 1 above). The main point of Hempel's paper is to consider two methods for avoiding or eliminating theoretical terms: re-axiomatization based on Craig's theorem and the Ramsey sentence. The main problem with the first method, according to Hempel, is that it fails to capture the *inductive* systematization of the observational data effected by theories with theoretical terms. In particular, an object may exhibit observable behavior which then gives *inductive* (but not *deductive*) support for the satisfaction of some theoretical predicate (as, e.g., we can inductively infer that a given object is magnetized from the observable behavior of attracted iron filings). We are then in a position, via the theory, *deductively* to infer that some other observable behavior will follow (e.g., the motion of a magnetized object may then induce a current in a wire). And, as a result, we have now established an *inductive* connection between the first observable behavior and the second—one which could certainly not be established in any version of the theory (such as the Craig re-axiomatization) that dispenses with theoretical structure entirely.[8]

[8] For discussion of Hempel's treatment of the Ramsey sentence and the Craig re-axiomatization, see Friedman (2008), Demopoulos (2008).

The Ramsey sentence, Hempel appears to suggest, does not suffer from this defect (or at least not to the same degree), because it retains logical variables referring to the original theoretical entities in place of the original (constant) theoretical terms.[9] The problem now, however, is that, for precisely this reason, the Ramsey sentence continues to have the very same existential commitments as the original theory (1958, p. 81): "[T]he Ramsey-sentence associated with an interpreted theory T′ avoids reference to hypothetical entities only in letter . . . rather than in spirit. For it still asserts the existence of certain entities of the kind postulated by T′, without guaranteeing any more than does T′ that those entities are observable or at least fully characterizable in terms of observables. Hence, Ramsey-sentences provide no satisfactory way of avoiding theoretical concepts."

Carnap's reply to Hempel in the Carnap Schilpp volume (published in 1963, but likely written in the late 1950s) is especially interesting. For, in the first place, Carnap warmly refers to Hempel (1958) as providing "a thorough and illuminating investigation of the many logical and methodological question connected with theoretical concepts" (1963, p. 962), and Carnap here singles out Hempel's distinction between *inductive* and *deductive* systematization (ibid.): Hempel explains that, whereas "the *O*-content of a sentence *S* [the set of observational sentences implied by *S*] . . . may serve in certain respects as a substitute for *S*, namely as far as *deductive* relations among the sentences of [the extended observation language] are concerned, . . . the same does not hold for the equally important *inductive* relations, and . . . therefore the concept of *O*-content does not furnish a suitable method for dispensing with theoretical terms. In this view I agree with Hempel." Indeed, Carnap's remarks in 1956b about how correspondence rules *C* generate a partial interpretation of an abstract theory *T* (e.g., Maxwell's equations for the electromagnetic field) furnish a perfect example of this. When we "derive" predictions about future observable events from (prior) observed events we establish precisely an *inductive* relation between observables in Hempel's sense (as in the example of the magnetized object).

Moreover, in the second place, Carnap also replies to Hempel's (1958) critical remarks on the existential commitments of the Ramsey sentence (1963, p. 963): "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 language which I have chosen in [Carnap 1956b §VII]) purely logical-mathematical entities, e.g., natural numbers, classes of such, classes of classes, etc. Nevertheless [the Ramsey sentence of *T*] 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." So two points are now clear. First, Carnap takes

[9] Demopoulos (2008, note 17, pp. 374–375) points out that Hempel is far from suggesting this explicitly. So perhaps it is better to say that Hempel's discussion appears to suggest *to Carnap* that the Ramsey sentence is inductively superior to the Craig re-axiomatization (see the discussion below).

the Ramsey sentence (unlike the Craig re-axiomatization) to provide not only a deductive but also an inductive systematization of the observable phenomena (concerned with both deductive and inductive "relations" between "observable events"). Second, Carnap takes the Ramsey sentence to have synthetic or factual content simply because it thereby constrains the observable phenomena in definite ways. Carnap is not supposing, therefore, that an abstract theory has any synthetic or factual content *beyond* its empirical adequacy (both deductive and inductive), and, in this respect, he (as I have suggested) is in agreement with van Fraassen but not with contemporary scientific realists like Psillos. The Newman problem is no objection to Carnap.[10]

This should not be surprising if we keep firmly in mind the fact that theoretical terms, for Carnap, are semantically uninterpreted. We assign no designata to them in our semantical meta-language, and so Tarskian semantics (as Carnap understands it) does not assign truth-values to purely theoretical sentences. Yet it does assign truth values to the corresponding Ramsey sentence; and the Ramsey sentence, as we have just seen, establishes very significant inductive connections between (fully interpreted) observational sentences—connections that can by no means be recovered in a reformulation (like the Craig re-axiomatization) that simply dispenses with theoretical structure entirely. It is precisely this, in the end, that is secured by a *partial* interpretation of the theoretical terms via correspondence rules.

It is important to emphasize, however, that Carnap does not propose to replace the original theory T containing constant theoretical terms with a Ramsey sentence replacing these terms with existentially quantified variables. Carnap rather proposes to view the original theory T as the conjunction of the Ramsey sentence and the Carnap sentence, where the latter is the conditional with the Ramsey sentence as antecedent and T itself as consequence. (The conjunction of the Carnap sentence with the Ramsey sentence, is therefore logically equivalent to T, and the Carnap sentence gives us a particular existential instantiation, in terms of the original constant theoretical terms of T, of the existentially generalized Ramsey sentence.) Thus, immediately after his reply to Hempel on the existential commitments of the Ramsey sentence, Carnap says (1963, p. 963): "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 $L_O{}'$ [the extended observation language]. Their function is to serve in the explication

[10] Demopoulos (2007) provides an outstanding discussion of the motivations for Carnap's view of theoretical terms and its relationship, in particular, with the Hilbertian axiomatic method. In the course of his discussion, however, Demopoulos criticizes Carnap's use of the Ramsey sentence for requiring only the existence of an appropriate mathematical structure—which, as Demopoulos shows, is "almost analytic" in so far as it logically follows from the totality of the observational consequences of the theory together with a cardinality assumption (a version of the Newman problem: see note 4 above). Carnap's own view, however, is that the synthetic content of a theory does not exceed its empirical content, and he aims to defend this view, moreover, against the metaphysical excesses of both realism and instrumentalism. Demopoulos, from this point of view, appears to be relying on a fundamentally realist intuition about what the (synthetic) content of a scientific theory should be taken to be.

of experiential import and, more importantly, in the explication of analyticity." And the way Carnap now explicates analyticity, of course, is by viewing the Ramsey sentence as representing the synthetic part of *T* while the Carnap sentence represents its analytic part.

I shall return to the question of analyticity in a moment. But I first want to observe that Carnap's preference for his reformulation of *T* over the Ramsey sentence of *T* corresponds to his own way of understanding the choice between "the instrumentalist and the realist ways of speaking." For recall that, at the end of the second edition of the chapter on the Ramsey sentence in *Philosophical Foundations of Physics*, Carnap states that the decision between realism and instrumentalism should be discussed in the form (1974, p. 256): "Shall we prefer a language of physics (and of science in general) that contains theoretical terms, or a language without such terms?" Carnap's preference, as very clearly stated in the reply to Hempel, is to adopt the former alternative, and so his choice, as he now understands the issue, is to adopt precisely the language of *realism*. This does not mean, however, that Carnap is now committed to a realist epistemology and metaphysics (of the kind defended by Psillos, for example), which aims to "explain" the success of science by appealing to pre-existing objective natural kinds in the world, a theory of "factual reference" linking theoretical terms to such objective natural kinds, and an epistemological defense of the "no miracles" argument against the "pessimistic meta-induction." Carnap's whole point is to *replace* the question "are theoretical entities real?" with the question which form of language we should prefer—and prefer for purely pragmatic or practical rather than theoretical reasons.

But what then are these reasons? Why is Carnap dissatisfied with the Ramsey sentence itself as a formulation of our scientific theory? Well, suppose we were to attempt directly to make deductions from the Ramsey sentence of the axiomatic theory *T*. We would need to proceed by an instantiation of all the existentially quantified variables, followed by ordinary logico-mathematical reasoning on the basis of this existential instantiation, and concluding with an existential generalization whereby all the existential quantifiers are then reintroduced at the end. This procedure is very complex and cumbersome, and, most importantly, it does not correspond to the way in which we in fact make deductions from axioms in scientific practice—where, in effect, we treat the axioms of *T* as an Hilbertian implicit definition of the *constant* theoretical terms of *T*, and we then proceed to engage in ordinary logico-mathematical reasoning from these axioms without worrying about existential instantiation and generalization.[11] It is much more convenient, then, to add the Carnap sentence to the Ramsey sentence—where the Carnap sentence takes over

[11] Carnap makes this clear in *Philosophical Foundations of Physics* (1966/1974, pp. 253–254): "Ramsey certainly did not mean—and no one has suggested—that physicists should abandon theoretical terms in their speech and writing. To do so would require enormously complicated statements. For example, it is easy to say in the customary [realistic] language that a certain object has a mass of five grams. . . . [But] the translation of even this brief sentence into the Ramsey language demands an immensely long sentence, which contains the formulas corresponding to all the theoretical postulates, all the correspondence postulates, and their existential quantifiers. . . . It is

the role of existential instantiation from the Ramsey sentence, and thereby allows us to proceed with ordinary mathematical reasoning in the style of Hilbert without worrying about cumbersome restrictions on existential variables in natural deduction. Whereas existential instantiation is of course not a logically valid inference, the Carnap sentence, taken as a *non-logical* axiom of *T*, is now seen, nonetheless, as an *analytic* postulate (a meaning postulate)—a conventional choice of (constant) names arbitrarily given to a sequence of values of the existential variables which, by the Ramsey sentence, must (synthetically) exist.[12]

We must therefore modify our earlier claim (arising on Carnap's original version of the partial interpretation conception) that theoretical sentences are assigned no truth values. While it is still the case that no semantical rules of designation in the usual sense (of the form "the term 'te' designates temperature") are provided for theoretical constants, they are now (arbitrarily) assigned a sequence of semantical values that make the theory come out true from among the values ranged over by the theoretical variables (certain sets, functions, and so on).[13] If the Ramsey sentence is true then such a sequence must (synthetically) exist, and so there can be no gap, on Carnap's conception, between the empirical adequacy of a partially interpreted theory (the truth of its Ramsey sentence) and the full (semantical) truth of the theory (the conjunction of the Ramsey sentence and the Carnap sentence).[14]

In this way, in particular, Carnap's use of the Ramsey sentence (as representing the empirical or synthetic content of the original theory using constant theoretical terms) serves a profoundly different purpose than van Fraassen's defense of instrumentalism on the basis of a fundamental epistemological distinction between "acceptance" and "belief." To "accept" a theory, for van Fraassen, is to assert that the

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evident that it would be inconvenient to substitute the Ramsey way of speaking for the ordinary discourse of physics in which theoretical terms are used [, ... so that] physicists find it vastly more convenient to talk in the shorthand language that includes theoretical terms, such as 'proton', 'electron', and 'neutron'."

[12] Demopoulos (2008, § 5) defends Carnap's attribution of analyticity to the Carnap sentence—making use of Winnie (1970)—by arguing that the Carnap sentence of *T* (but not in general *T* itself) can be viewed as an implicit definition of the theoretical terms that is *non-creative* in the sense of generating no observational consequences not already implied by the Ramsey sentence. My own aim, however, is not to defend this attribution (which is intuitively very plausible in any case), but to investigate what follows from it, on Carnap's understanding, for the realism/instrumentalism dispute.

[13] From this point of view, the theoretical constants are really term-forming operators rather than primitive non-logical constants, and it is precisely this that is then made completely explicit in the ε-operator variant. For the ε-operator, applied to any open sentence, selects an arbitrary object from the domain that satisfies this open sentence. For details see Carnap (1961), Psillos (2000).

[14] However, there are models of the Craig re-axiomatization of a theory in which the Ramsey sentence of the theory is not true. So the truth of the observational consequences alone does not imply the truth of the theory. But if we understand empirical adequacy (as Carnap appears to do) to include both deductive and inductive systematization of the phenomena, then the point in the text holds. For a detailed discussion of the technical issues surrounding this point, and of its history in the logical literature, see Demopoulos (2011).

observational phenomena are embeddable into some abstract model of the theory—and this, as we pointed out, is precisely what the Ramsey sentence says. But to "believe" the theory, in van Fraassen's terms, is to go much further and assert that the theory itself is true—and van Fraassen therefore agrees with contemporary scientific realists that the truth of the theory is quite distinct from the truth of its Ramsey sentence. For Carnap, by contrast, no such gap between empirical adequacy and truth makes logical (semantical) sense: there is no room remaining for van Fraassen's instrumentalist to "accept" the theory without being simultaneously committed to its truth.[15] This is how, from Carnap's point of view, he entirely *dissolves* the purely philosophical debate between realism and instrumentalism while also preserving what he takes to be the genuinely important insights of both positions.[16]

For Carnap, the only "ontological" question that now matters concerns the existence of an appropriate mathematical structure into which the observable phenomena are to be embedded—and this question, in turn, is answered within the ongoing practice of modern mathematical physics itself. For the great advances of modern mathematical physics, from Carnap's point of view, consist precisely in the discovery of appropriate systems of abstract axioms (and correspondence rules) characterizing the mathematical structures in question. Indeed, this fundamental feature of modern physics provided Carnap with the initial motivations for his distinctive approach to theoretical terms when he first seriously considered this topic in 1939. For, as already noted, Carnap then took the new theories of relativity and quantum mechanics to represent the triumph of the Hilbertian axiomatic method—including Hilbertian implicit definitions—within empirical science.

Carnap discusses the axiomatic foundations of quantum mechanics, in particular, in the final chapter of *Philosophical Foundations of Physics*. It is not yet clear, he says, how the language of physics must change in response to the fundamentally non-classical character of quantum probabilities, but Carnap is sure, nonetheless, that the modern axiomatic method represents our best hope for future progress:

[15] Demopoulos (2003, § 5) makes a closely related point (without referring to Carnap) by arguing that the conjunction of van Fraassen's constructive empiricism and the semantic view of theories is an unstable philosophical position. My argument is that Carnap's own position is not at all unstable in this way and, moreover, is thereby stably neutral between realism and instrumentalism.

[16] See especially the conclusion of the chapter on the Ramsey sentence in the first edition of *Philosophical Foundations of Physics* (1966, p. 256): "It is obvious that there is a difference between the meanings of the instrumentalist and the realist ways of speaking. My own view, which I shall not elaborate here, is that the conflict between the two approaches is essentially linguistic. It is a question of which way of speaking is to be preferred under a given set of circumstances. To say that a theory is a reliable instrument—that is, that the predictions of observable events that it yields will be confirmed—is essentially the same as saying that the theory is true and that the theoretical, unobservable entities it speaks about exist. Thus, there is no incompatibility between the thesis of the instrumentalist and that of the realist. At least, there is no incompatibility so long as the former avoids such negative assertions as, '. . . but the theory does not consist of sentences which are either true or false, and the atoms, electrons, and the like do not really exist'." Van Fraassen's agnosticism, by contrast, needs to make room for precisely the assertion that the theory is empirically adequate but its postulated theoretical entities do *not* exist.

> [. . .] I am convinced that two tendencies, which have led to great improvements in the language of mathematics during the last half century, will prove equally effective in sharpening and clarifying the language of physics: the application of modern logic and set theory, and the adoption of the axiomatic method in its modern form, which presupposes a formalized language system. In present-day physics, in which not only the content of theories but also the entire conceptual structure of physics is under discussion, both those methods could be of enormous help.
>
> Here is an exciting challenge, which calls for close cooperation between physicists and logicians—better still, for the work of younger men who have studied both physics and logic. The application of modern logic and the axiomatic method to physics will, I believe, do much more than just improve communication among physicists and between physicists and other scientists. It will accomplish something of far greater importance: it will make it easier to create new concepts, to formulate fresh assumptions. An enormous amount of new experimental results has been collected in recent years, much of it due to the great improvement of experimental instruments, such as the big atom smashers. On the basis of these results, great progress has been made in the development of quantum mechanics. Unfortunately, efforts to rebuild the theory, in such a way that all the new data fit into it, have not been successful. Some surprising puzzles and bewildering quandaries have appeared. Their solution is an urgent, but most difficult, task. It seems a fair assumption that the use of new conceptual tools could here be of essential help. (1966/1974, 291)[17]

The very last paragraph of both the chapter and the book immediately follows these words (1966/1974, pp. 291–292): "Some physicists believe that there is a good chance for a new breakthrough [in our understanding of quantum mechanics] in the near future. Whether it will be soon or later, we may trust—provided the world's leading statesman refrain from the ultimate folly of nuclear war and permit humanity to survive—that science will continue to make great progress and lead us to ever deeper insights into the structure of the world."

Here, as noted above, Carnap appears to ally himself with contemporary structural realism. Yet no committed defender of scientific realism—whether structural or not—would be satisfied at this point, and would surely press the question of how, on Carnap's approach, we are really gaining insights into the structure of reality. Have I not emphasized repeatedly that the variables representing theoretical terms,

[17] As we saw in note 7 above, the case of quantum mechanics was an especially important part of Carnap's motivations for originally proposing the partial interpretation view of theoretical terms in 1939. To see what conceptual problems Carnap might have in mind here (in *Philosophical Foundations of Physics*), compare Carnap's earlier discussion of the importance of the analytic/synthetic distinction in modern physics (1966/1974, pp. 257–258): "In my opinion, a sharp analytic-synthetic distinction is of supreme importance for the philosophy of science. The theory of relativity, for example, could not have been developed if Einstein had not realized that the structure of physical space and time cannot be determined without physical tests. He saw clearly the sharp dividing line that must always be kept in mind between pure mathematics, with its many types of logically consistent geometries, and physics, in which only experiment and observation can determine which geometries can be applied most usefully to the physical world. This distinction between analytic truth (which includes logical and mathematical truth) and factual truth is equally important today in quantum theory, as physicists explore the nature of elementary particles and search for a field theory that will bind quantum mechanics to relativity." So it appears that Carnap may now have particularly in mind the problem of developing a consistent axiomatic approach to relativistic quantum field theory.

for Carnap, range only over purely *mathematical* entities (numbers, sets, and so on)? Did I not just say, in particular, that the only "ontological" question that now matters, for Carnap, concerns the existence of an appropriate (purely) mathematical structure into which the observable phenomena are to be embedded? And what does this last question have to do, in any case, with the structure of the *physical* world?

In order properly to answer these questions, we need to appreciate what Carnap himself understands by "the physical world." It turns out that Carnap has a remarkably consistent understanding, beginning with his first major philosophical work, *Der logische Aufbau der Welt* (1928). The title of this work is standardly translated as *The Logical Structure of the World*, which already indicates its relevance for the questions we are here attempting to address. However, even if one has doubts about this translation ("the logical *construction* of the world" would perhaps be more appropriate), there is no doubt that an emphasis on the mathematical structures employed in modern physics plays an absolutely central role. In § 16 of the *Aufbau*, for example, Carnap argues that "*all scientific statements are structure statements*," on the grounds that "science wants to speak of that which is objective; and all that does not belong to structure but to the material—everything that can be pointed to concretely—is ultimately subjective." Carnap continues (ibid.): "We easily notice this desubjectivization in *physics*, which has already transformed almost all physical concepts into purely structural concepts." And he then illustrates the transformation in question by the abstract mathematical concepts employed in the general theory of relativity.[18]

Carnap devotes § 136 to a more detailed discussion of what he calls *the physical world* (the world of physics).[19] This world is constructed on the basis of the already constructed *perceptual world* (§ 135), whose construction itself begins, in turn, with *the space-time world* (§ 125). The latter consists of the *world-points* (ibid.): "the points of n-dimensional real number space, and thus n-tuples of [real] numbers," to which colors (and then other sensory qualities) are assigned from the point of view of some or another given perceiver at some or another position in space. This assignment, when subject to various methodological directives (§ 126), eventually results in a set of *perceptual things* (sensed by the given perceiver) (§ 134), which, when completed or extended by analogy (to include things not sensed by the given perceiver), then results in the (now) *four*-dimensional *perceptual world* (§ 135). The immediately following § 136 begins by distinguishing the latter from the *physical world*, where "mere numbers, the '*physical state-magnitudes*'," are now "assigned to the points of the four-dimensional [real] number space."

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[18] The illustration, set off in small type, is as follows (ibid.): "First, all mathematical concepts are reducible to those of the theory of relations; four-dimensional tensor or vector fields are structural schemata; the network of world-lines with the relations of coincidence and proper time is a structural schema where only one or two relations are still named—which (relations), moreover, are already uniquely determined by the character of the schema."

[19] The German is "*die physikalische Welt*," and Carnap thereby trades on the distinction between "*physisch*" (corporeal or material as opposed to psychological or mental ["*psychisch*"]) and "*physikalisch*" (pertaining to the science of physics).

Both the four-dimensional space-time world with which Carnap begins his construction of the physical world and the assignment of physical state-magnitudes that completes this construction are purely mathematical objects: quadruples of real numbers and functions from these to various systems of real numbers (vectors, tensors, and so on). Nevertheless, the latter construction essentially involves the intervening perceptual world, by means of what Carnap calls (§ 136) the "*physical-qualitative coordination*." This results, in particular, in the coordination of specific numerical values of various physical state-magnitudes (e.g., values of the electromagnetic field) to the various sensory qualities (e.g., colors) already assigned to the space-time points of the perceptual world, and the resulting distribution of these specific numerical values just *is* what Carnap calls the physical world (the world of physics).[20] The only element of Carnap's construction that is not purely mathematical is therefore the distribution of sensory qualities constituting the perceptual world—*now seen as embedded within a larger, purely mathematical* (purely numerical) *structure*. Hence, Carnap's general view of the science of physics in the *Aufbau* is essentially the same as that found in his mature philosophy of science of the 1950s and 1960s.

In *The Logical Syntax of Language* (1934), Carnap discusses what he calls "the language of physics [*die Sprache der Physik*]" (§ 40) or, equivalently, "the physical language [*die physikalische Sprache*]" (§ 82). This language results from adding certain primitive descriptive functions, representing "physical state magnitudes," to the purely mathematical Language II: a version of the simple theory of types over the natural numbers taken as individuals. Here, in particular, we can represent the real numbers (as certain sets of natural numbers) and then introduce space-time points as quadruples of real numbers. In the case of a function representing a physical state magnitude (§ 40), "the argument-expression contains four real number expressions, namely, the space-time coordinates; the value-expression contains one or more real number expressions (e.g., for a scalar one, for an ordinary vector three)." According to § 82: "The logic of science [*Wissenschaftslogik*] of physics is the syntax of the physical language. All the so-called epistemological problems concerning physics (in so far as we are not dealing with metaphysical pseudo-problems) are partly

[20] Carnap further characterizes the physical-qualitative coordination as follows (ibid.): "[There] subsists a one-many coordination between qualities and state-magnitudes of such a kind that, if an assignment of physical state-magnitudes from some or another (purely numerical) structure holds at a physical point and its neighborhood, then to the coordinated world-point of the perceptual world the quality coordinated to this structure is always assigned, or at least can always be consistently assigned. But the coordination is not univocal in the converse direction: the assignment of a quality to a world-point of the perceptual world does not determine which particular state-magnitude structure is assigned to the neighborhood of the coordinated physical world-point; only a class is [thereby] determined to which this structure must belong. The physical-qualitative coordination can certainly not be free of the imprecision that attaches to the perceptual world in general." This lack of determinacy in the coordination from the qualitative to the physical realm reflects the circumstance, already noted, that any inference from the former to the latter (e.g., from the observable behavior of iron filings to the structure of the electromagnetic fields in their neighborhood) is inductive rather than deductive (compare the paragraph to which note 8 above is appended).

empirical questions, most of which belong to psychology, and partly logical questions that belong to syntax." The most important epistemological problem capable of a purely logical or syntactic treatment is that of empirically testing theoretical claims involving the primitive physical magnitudes (such as the electromagnetic field), and it is solved simply by stipulating syntactic rules concerning "what forms the *protocol-sentences*, by means of which the results of observations are expressed, may have." The empirical testing of any theoretical sentence in the language of physics then proceeds by logically deriving protocol sentences on the basis of the transformation rules of the language.[21]

However, since there is as yet no notion of (semantical) interpretation in *Logical Syntax*, there is here no conception of a "partial" (or "indirect" or "incomplete") interpretation of the fundamental theoretical terms in virtue of the logical relationships established by the theoretical axioms (including correspondence rules) between these terms and the (fully interpreted) observational terms. This conception, as we have seen, first emerges in *Foundations of Logic and Mathematics* (1939), and, as we have also seen, it is further developed in "The Methodological Character of Theoretical Concepts" (1956b). Carnap now stipulates that the domain of interpretation over which the variables of the theoretical language are taken to range consists of the iterative hierarchy of sets defined over the natural numbers, and, once again, conceives physical magnitudes as functions from space-time points (n-tuples of real numbers) to various system of real numbers (scalars, vectors, tensors, and so on).[22] When Carnap connects this picture with the Ramsey sentence

[21] This process of testing is described in an extremely open-ended way (§ 82): "A sentence of physics, whether it is a P-fundamental sentence [i.e., a physical axiom—MF] or an otherwise valid sentence or an indeterminate assumption (i.e., a premise whose consequences are investigated), is *tested*, in that consequences are deduced from it on the basis of the transformation rules of the language until one finally arrives at propositions of the form of protocol-sentences. These are compared with the protocol-sentences actually accepted and either confirmed or disconfirmed by then. If a sentence that is an L-consequence of certain P-fundamental sentences contradicts a proposition accepted as a protocol-sentence, then some alteration must be undertaken in the system. . . . There are no established rules for the kind of alteration that must be made."

[22] The same idea occurs in "Empiricism, Semantics, and Ontology," in Carnap's discussion of the linguistic framework described as "*The spatio-temporal coordinate system for physics*" (1956a, p. 212): "The new entities are the space-time points. Each is an ordered quadruple of four real numbers, called its coordinates, consisting of three spatial and one temporal coordinates. The physical state of a spatio-temporal point or region is described either with the help of qualitative predicates (e.g., 'hot') or by ascribing numbers as values of a physical magnitude (e.g., mass, temperature, and the like)." Carnap's comments on the distinction between internal and external questions relevant to this framework are especially interesting and instructive (213): "Internal questions are here, in general, empirical questions to be answered by empirical investigations. On the other hand, the external questions of the reality of physical space and physical time are pseudo-questions. A question like 'Are there (really) space-time points?' is ambiguous. It may be meant as an internal question; then the affirmative answer is, of course, analytic and trivial. Or it may be meant in the external sense: 'Shall we introduce such and such forms into our language?'; in this case it is not a theoretical but a practical question, a matter of decision rather than assertion, and hence the proposed formulation would be misleading. Or finally, it may be meant in the following sense: 'Are our experiences such that the use of the linguistic forms in question will be expedient and fruitful?'

view of theories beginning in 1958, the existentially quantified theoretical variables in the Ramsey sentence are interpreted as ranging over precisely the same domain—which therefore supplies (arbitrarily chosen) denotations for the constant theoretical terms in the Carnap-sentence as well.

Thus Carnap's resolution of the "ontological" dispute between realism and instrumentalism in *Philosophical Foundations of Physics*—in terms of the idea that theoretical terms such as "electron", "electromagnetic field", "metric-tensor", and "psi-function" can be taken to refer to purely mathematical entities—is by no means a desperate or ad hoc maneuver. On the contrary, it represents the culmination of a general view of the science of physics that he had held, virtually continuously, throughout his entire intellectual career. The view in question, moreover, was always deeply rooted, for Carnap, in the development of the Hilbertian axiomatic method, now successfully applied to the new physical theories of relativity and quantum mechanics. On this view, the properly empirical (synthetic or non-analytic) subject matter of physics is given by its observable or perceptual content, and the goal of physics is then to systematize this content (both deductively and inductively) within a formal axiomatic system employing the characteristically abstract resources of modern mathematics. To construct such an axiomatization is to define what counts as the physical world—the world of physics—at some particular given stage of our evolving empirical knowledge.

Once again, however, the committed scientific realist will raise a fundamental objection at this point. There is a crucial distinction, surely, between our conception of the physical world at some given stage of inquiry and the structure of this world itself. Indeed, the very mention of evolving stages of inquiry appears clearly to presuppose such a distinction, in so far as physicists are always open to revising their conception of the physical world in the light of new empirical evidence. The world of physics—the *real* world of physics—is precisely that which we are attempting to learn more and more about as empirical inquiry progresses, and it is not necessarily identical, therefore, with what we happen to take this world to be at any given stage. This fundamental objection is as powerful as it is intuitive, and so it is well worth noting, finally, that Carnap attempts to incorporate such a realist intuition within his conception as well.

I have already observed that Carnap appears to ally himself with contemporary structural realism at the conclusion of *Philosophical Foundations of Physics*, where he speaks of the progress of science "lead[ing] us to ever deeper insights into the structure of the world" (1966/1974, p. 292). At the end of his earlier chapter on the Ramsey sentence, Carnap describes what he calls "the 'descriptive' or 'realist' view of theories" as follows (1966/1974, pp. 255–256): "Advocates of this approach find it both convenient and psychologically comforting to think of electrons, magnetic fields, and gravitational waves as actual entities about which science is steadily learning more. . . . The changing view about the structure of electrons,

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This is a theoretical question of a factual, empirical nature. But it concerns a matter of degree; therefore the formulation in the form 'real or not?' would be inadequate."

genes, and other [unobservable] things does not mean that there is not something 'there', behind each observable phenomenon; it merely indicates that more and more is being learned about the structure of those entities." And Carnap continues in this vein in the following paragraph (1966/1974, p. 256): "Today, little is known about [the electron's] structure; tomorrow a great deal may be known. It is as correct, say the advocates of the descriptive approach, to speak of an electron as an existing thing as it is to speak of apples and tables and galaxies as existing things."[23]

Reading the final sentence of *Philosophical Foundations of Physics* against the background of these passages, it appears (despite the seemingly condescending use of "psychologically comforting" in the first passage) that Carnap has considerable sympathy for the realist intuition that we are learning more and more about the "same" entities (or at least about the "same" world). At the end of his 1959 Santa Barbara Lecture, published in Psillos (2000), Carnap attempts to incorporate this intuition directly into his logical framework. He is here considering the circumstance that (explicitly) defining theoretical terms by means of Hilbert's ε-operator results in an "indeterminate" meaning for them, since it assigns objects as their designata that are arbitrarily selected from a larger class of equally suitable objects (see note 13 above). Since *any* of the objects in the class in question can equally well satisfy the corresponding existential quantification, there is simply no answer to the question whether the denotation of the theoretical terms is one particular member of the class or some other. The meaning of the theoretical term, in this respect, is still left unspecified, and this, Carnap remarks, is exactly what we want (Psillos 2000, pp. 171–172): "So this definition [via the ε-operator] {gives} just so much specification as we can give, and not more. We do not want to give more, because the meaning should be left unspecified in some respect, because otherwise the physicist could not—as he wants to—add tomorrow more and more postulates, and even more and more correspondence postulates, and thereby make the meaning of the same term more specific than {it is} today. So, it seems to me that the ε-operator is just exactly the tailor-made tool that we needed, in order to give an explicit definition, that, in spite of being explicit, does not determine the meaning completely, but just to that extent that it is needed."

Although these brief remarks do not address the question of what happens when the physicist radically revises some of the postulates of a theory (and does not simply add new postulates without rejecting any old ones), they confirm that Carnap intends to accommodate the intuition that physicists increase their knowledge of the "same" physical world as empirical inquiry proceeds.[24] In particular, although

[23] The structural realist conception of theoretical terms was introduced by John Worrall (1989) as a way of preserving referential continuity over time while accommodating such cases as the non-existence of an electromagnetic aether as originally conceived. Such cases are to be accommodated precisely by maintaining that *mathematical structure* is nonetheless preserved in the transition (for example) between the earlier aether theories of electromagnetism of Green and Stokes and Maxwell's theory of the electromagnetic field. For discussion, see Psillos (1999, chapters 6 and 7).

[24] Carnap makes some interesting—but also tantalizingly brief—remarks on "revolutionary" scientific changes in his reply to Quine in Schilpp (1963, p. 921).

Carnap's representation of a scientific theory as the conjunction of the Ramsey sentence and the Carnap sentence—or, equivalently, the ε-operator representation—characterizes the designation of a theoretical term as in general "incomplete" or not fully specified, he is open to increasingly narrow specifications of this same ("indeterminate") designation as our knowledge of the "structure" of the entity being characterized increases. Carnap appears to be thereby open, in principle, to the possibility that we could (ideally) specify the designation uniquely by adding enough structural information in the postulates of the theory so that there remains exactly one object in the relevant class of objects that can (truly) instantiate the corresponding variable in the Ramsey sentence. In such an ideal situation, of course, no "indeterminacy" would remain, and we could replace the ε-operator (or the corresponding existential quantifier) with a definite description operator.[25]

David Lewis (1970) proposes a general method for explicitly defining theoretical terms by replacing the existential quantifiers in the Ramsey sentence of a theory by definite descriptions.[26] Lewis is not happy with Carnap's conception of the observation language, and he explicitly conceives his project as a defense of scientific realism. Lewis does agree, however, that a theoretical term is precisely one that is implicitly defined by the postulates of a given axiomatic theory, relative to antecedently understood terms whose meanings are already fully specified. The crucial difference between him and Carnap, in this context, is that Lewis sees no reason to suppose that the theoretical terms of such a theory are in general multiply realized in the sense that there is more than one sequence of values of the variables in the theory's Ramsey sentence that satisfies it. Lewis claims, on the contrary (1970, p. 433), "that it is reasonable to hope that a good theory will not in fact be multiply realized." For Lewis, Carnap's partial interpretation conception, according to which a single sequence of values is (in general) arbitrarily chosen from among a class of equally good such sequences (1970, p. 432), "concedes too much to the instrumentalist view of a theory as a mere formal abacus" and does not do "justice to our naïve

[25] Carnap's above remarks concerning the ε-operator, recorded in (Psillos 2000, p. 171), might be taken to imply that some "indeterminacy" always will (and indeed always should) remain, so that a unique specification of the designation is never possible. It appears to me, however, that a weaker reading is also available, according to which Carnap is only saying that, if we begin with a situation where we do not have a unique specification (as in the example Carnap uses), then the ε-operator is exactly what we want—for it can then adequately represent *both* non-unique and unique specifications. In the *Aufbau*, Carnap was aiming for "purely structural concepts" in science, defined by "structural definite descriptions" (§ 15), and the illustration from relativistic space-time theory provided in the following section (§ 16; see note 18 above) takes the two primitive relations of the theory to be "already uniquely determined by the [purely formal] character of the [structural] schema." In the *Aufbau*, however, Carnap takes the relations over which the variables of the theoretical language range to be explicitly definable from an observational (and indeed autopsychological) basis—which is certainly not the case in the later period now under consideration. This raises delicate logical issues about the general formal possibility of unique specifications for the theoretical terms that are closely related to the Newman problem: for further discussion, see again Demopoulos and Friedman (1985), Demopoulos (2003).

[26] Lewis worked closely with Carnap at UCLA and is fully cognizant of (and indeed directly inspired by) Carnap's work on the Ramsey sentence (1970, note 4, p. 431).

impression that we [fully—MF] understand the theoretical terms of a true theory . . . without making any arbitrary choice among realizations."[27]

Although Carnap appears to be open in principle to the possibility of uniquely realized theories, he also takes the view that theoretical terms are precisely those that are axiomatically introduced by Hilbertian implicit definitions (relative to observational terms whose meanings are already fully understood) to be most faithfully captured by his partial interpretation conception. For it is this conception, in Carnap's eyes, that best represents—within the context of the implicit definition view—the realist intuition that we are always learning more about the "same" theoretical entities.

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[27] Lewis (1970) does not directly consider the logical issues related to the Newman problem concerning the general formal possibility of unique realizations (note 25 above), although he does consider an allied logical problem raised in Winnie (1967). Lewis (1984, note 9, p. 224) does consider the Newman problem (as an anticipation of Hilary Putnam's "model-theoretic argument"), and he replies by appealing to an "inegalitarian" view of physical properties restricted to those that "carve nature at the joints." At this point, however, his opposition to Putnam's "descriptivism" appears far removed from the implicit definition conception of theoretical terms, and, in any case, his emphasis on "objective joints in nature" introduces exactly the kind of metaphysics Carnap is most concerned to avoid. Demopoulos (2003) discusses Carnap on theoretical terms, the Newman problem, Winnie (1967), and Lewis (1970) (as well as Putnam's argument). Against this background, I hope more fully to discuss, from a Carnapian perspective, the relationship between Lewis (1970) and Lewis (1984) in future work.

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