against there being good prospects for a naturalistic theory of content on the grounds that naturalistic discourse does not have the conceptual resources to build a naturalistic theory that will entail, in an epistemically transparent way, the truths about intentionality. However, as von Eckardt (2001) points out, Horst's conception of naturalization is much stronger than what most current theory of content determination theorists have in mind, *viz.*, strong supervenience or realization (see Supervenience). As a consequence, his arguments that naturalization is implausible given the conceptual resources of naturalistic discourse are seriously misguided.

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See also **Consciousness; Physicalism; Psychology, Philosophy of; Supervenience**

COGNITIVE SIGNIFICANCE

One of the main objectives of logical empiricism was to develop a formal criterion by which cognitively significant statements, which are true or false, could be delineated from meaningless ones, which are neither. The desired criterion would specify, and in some way justify, the logical empiricists' conviction that scientific statements were exemplars of significance and metaphysical ones

were decidedly not (see Logical Empiricism). Finding such a criterion was crucial to logical empiricism. Without it there seemed to be no defensible way to distinguish metaphysics from science and, consequently, no defensible way to exclude metaphysics from subjects that deserved serious philosophical attention (see Demarcation, Problem of). Accordingly, several logical empiricists devoted attention to developing a criterion of cognitive significance, including Carnap, Schlick, Ayer, Hempel, and, to a lesser degree, Reichenbach.

Scientific developments also motivated the project in two related ways. First, physics and biology were demonstrating that a priori metaphysical speculations about empirical matters were usually erroneous and methodologically misguided. Hans Driesch's idea of an essential entelechy was no longer considered scientifically respectable, and the intuitive appeal of the concept of absolute simultaneity was shown to be misleading by Albert Einstein (Feigl 1969). Scientific results demonstrated both the necessity and the fruitfulness of replacing intuitive convictions with precise, empirically testable hypotheses, and logical empiricists thought the same methodology should be applied to philosophy. Formulating a defensible criterion that ensured the privileged epistemological status of science, and revealed the vacuity of metaphysics, was thought crucial to the progress and respectability of philosophy.

Second, many scientific discoveries and emerging research programs, especially in theoretical physics, were considerably removed from everyday observable experience and involved abstract, mathematically sophisticated theories. The logical empiricists felt there was a need for a formal systematization of science that could clarify theoretical concepts, their interrelations, and their connection with observation. The emerging tools of modern mathematical logic made this task seem imminently attainable. With the desire for clarity came the pursuit of a criterion that could sharply distinguish these scientific developments, which provided insights about the world and constituted advances in knowledge, from the obfuscations of metaphysics.

Formulation of a cognitive significance criterion requires an empirical significance criterion to delineate empirical from nonempirical statements and a criterion of analyticity to delineate analytic from synthetic statements (see Analyticity). Most logical empiricists thought analytically true and false statements were meaningful, and most metaphysicians thought their claims were true but not analytically so. In their search for a cognitive significance criterion, as the principal weapon of their antimetaphysical agenda, the logical empiricists focused on empirical significance.

The Verifiability Requirement

The first attempts to develop the antimetaphysical ideas of the logical empiricists into a more rigorous criterion of meaningfulness were based on the verifiability theory of meaning (see Verifiability). Though of auxiliary importance to the rational reconstruction in the *Aufbau*, Carnap (1928a) claimed that a statement was verifiable and thereby meaningful if and only if it could be translated into a constructional system; for instance, by reducing it (at least in principle) to a system about basic physical objects or elementary experiences (§179) (see Carnap, Rudolf). Meaningful questions have verifiable answers; questions that fail this requirement are pseudo-questions devoid of cognitive content (§180).

The first explicit, semiformal criterion originated with Carnap in 1928. With the intention of demonstrating that the realism/idealism debate, and many other philosophical controversies, were devoid of cognitive significance, Carnap (1928b) presented a criterion of factual content:

> If a statement p expresses the content of an experience E, and if the statement q is either the same as p or can be derived from p and prior experiences, either through deductive or inductive arguments, then we say that q is 'supported by' the experience E. . . . A statement p is said to have 'factual content' if experiences which would support p or the contradictory of p are at least conceivable, and if their characteristics can be indicated. (Carnap 1967, 327)

Only statements with factual content are empirically meaningful. Notice that a fairly precise inferential method is specified and that a statement has factual content if there are conceivable experiments that could support it. Thus, the earliest formal significance criterion already emphasized that possible, not necessarily actual, connection to experience made statements meaningful.

Carnap ([1932] 1959) made three significant changes to his proposal. First, building on an earlier example (1928b, §7), he developed in more detail the role of syntax in determining the meaningfulness of words and statements in natural languages. The "elementary" sentence form for a word is the simplest in which it can occur. For Carnap, a word had to have a fixed mode of occurrence in its elementary sentence form to be significant. Besides failing to connect with experience in some way, statements could also be meaningless because they

contained sequences of words that violated the language's syntactic rules, or its "logical syntax." According to Carnap, "Dog boat in of" is meaningless because it violates grammatical syntax, and "Our president is definitely a finite ordinal," is meaningless because it violates logical syntax, 'president' and 'finite ordinal' being members of different logical categories. The focus on syntax led Carnap to contextualize claims of significance to specific languages. Two languages that differ in syntax differ in whether words and word sequences are meaningful.

Second, Carnap ([1932] 1959) no longer required statements to be meaningful by expressing conceivable states of affairs. Rather, statements are meaningful because they exhibit appropriate deducibility relations with protocol statements whose significance was taken as primitive and incorrigible by Carnap at that time (see Protocol Sentences). Third, Carnap did not specify exactly how significant statements must connect to protocol statements, as he had earlier (1928b). In 1932, Carnap would ascertain a word's meaning by considering the elementary sentence in which it occurred and determining what statements entailed and were entailed by it, the truth conditions of the statement, or how it was verified—considerations Carnap then thought were equivalent. The relations were probably left unspecified because Carnap came to appreciate how difficult it was to formalize the significance criterion, and realized that his earlier criterion was seriously flawed, as was shown of Ayer's first formal criterion (see below).

In contrast to antimetaphysical positions that evaluated metaphysical statements as false, Carnap believed his criterion justified a radical elimination of metaphysics as a vacuous enterprise. The defensibility of this claim depended upon the status of the criterion—whether it was an empirical hypothesis that had to be supported by evidence or a definition that had to be justified on other grounds. Carnap ([1932] 1959) did not address this issue, though he labels the criterion as a stipulation. Whether this stipulation was defensible in relation to other possible criteria or whether the statement of the criterion satisfied the criterion itself were questions left unanswered.

In his popularization of the work of Carnap ([1932] 1959) and Schlick ([1932] 1979), Ayer (1934) addressed these questions and stated that a significance criterion should not be taken as an empirical claim about the linguistic habits of the class of people who use the word 'meaning' (see Ayer, Alfred Jules; Schlick, Moritz). Rather, it is a different kind of empirical proposition, which, though conventional, has to satisfy an adequacy condition. The criterion is empirical because, to be adequate, it must classify "propositions which by universal agreement are given as significant" as significant, and propositions that are universally agreed to be nonsignificant as nonsignificant (Ayer 1934, 345).

Ayer developed two formalizations of the criterion. The first edition of *Language, Truth, and Logic* contained the proposal that "a statement is verifiable ... if some observation-statement can be deduced from it in conjunction with certain other premises, without being deducible from those other premises alone," where an observation statement is one that records any actual or possible observation (Ayer 1946, 11).

Following criticisms (see the following section) of his earlier work, a decade later Ayer (1946) proposed a more sophisticated criterion by distinguishing between directly verifiable statements and indirectly verifiable ones. In conjunction with a set of observation statements, *directly* verifiable statements entail at least one observation statement that does not follow from the set alone. *Indirectly* verifiable statements satisfy two requirements: (1) In conjunction with a set of premises, they entail at least one directly verifiable statement that does not follow from the set alone; and (2) the premises can include only statements that are either analytic or directly verifiable or can be indirectly verified on independent grounds. Nonanalytic statements that are directly or indirectly verifiable are meaningful, whereas analytic statements are meaningful but do not assert anything about the world.

Early Criticisms of the Verifiability Criterion

The verifiability criterion faced several criticisms, which took two general forms. The first, already mentioned in the last section, questioned its status—specifically, whether the statement of the criterion satisfies the criterion. The second questioned its adequacy: Does the criterion ensure that obviously meaningful statements, especially scientific ones, are labeled as meaningful and that obviously meaningless statements are labeled as meaningless?

Criticisms of the first form often mistook the point of the criterion, construing it as a simple empirical hypothesis about how the concept of meaning is understood or a dogmatic stipulation about how it should be understood (Stace 1935). As mentioned earlier, Ayer (1934, 1946) clearly recognized that it was not this type of empirical claim, nor was it an arbitrary definition. Rather, as Hempel (1950) later made clear, the criterion was intended to clarify

and explicate the idea of a meaningful statement. As an explication it must accord with intuitions about the meaningfulness of common statements and suggest a framework for understanding how theoretical terms of science are significant (see Explication). The metaphysician can deny the adequacy of this explication but must then develop a more liberal criterion that classifies metaphysical claims as significant while evaluating clearly meaningless assertions as meaningless (Ayer 1934).

Criticisms of the second form often involved misinterpretations of the details of the criterion, due partially to the ambiguity of what was meant by 'verifiability.' For example, in a criticism of Ayer (1934), Stace (1935) argued that the verifiability criterion made all statements about the past meaningless, since it was in principle impossible to access the past and therefore verify them. His argument involved two misconceptions. First, Stace construed the criterion to require the possibility of conclusive verification, for instance a complete reduction of any statement to (possible) observations that could be directly verified. Ayer (1934) did not address this issue, but Schlick ([1932] 1979), from whose work Ayer drew substantially, emphasized that many meaningful propositions, such as those concerning physical objects, could never be verified conclusively. Accepting Neurath's criticisms in the early 1930s, Carnap accepted that no statement, including no protocol statement, was conclusively verified (see Neurath, Otto). Recall also that Carnap (1928b) classified statements that were "supported by" conceivable experiences—not conclusively verified—as meaningful.

Second, Stace's argument depended on the ambiguity of "possible verification," which made early formulations of the criterion misleadingly unclear (Lewis 1934). The possibility of verification can have three senses: practical possibility, empirical possibility, and logical possibility. Practical possibility was not the intended sense: "There are 10,000-foot mountains on the moon's far side" was meaningful in the 1930s, though its verification was practically impossible (Schlick [1932] 1979).

However, Carnap (1928a, 1928b, [1932] 1959), Schlick ([1932] 1979), and Ayer (1934) were silent on whether empirical or logical possibility divided the verifiable from the unverifiable. Stace thought time travel was empirically impossible. The question was therefore whether statements about past events were meaningful for which no present evidence was available, and no future evidence would be.

In the first detailed analysis of the verifiability criterion, Schlick ([1936] 1979) stated that the logical impossibility of verification renders a statement nonsignificant. Empirical impossibility, which Schlick understood as contradicting the "laws of nature," does not entail non-verifiability. If it did, Schlick argued, the meaningfulness of a putative statement could be established only by empirical inquiry about the laws of nature. For Schlick, this conflated a statement's meaning with its truth. The meaning of a statement is determined ("bestowed") by logical syntax, and only with meaning fixed a priori can its truth or falsity be assessed. Furthermore, since some lawlike generalizations are yet to be identified and lawlike generalizations are never established with absolute certainty, it seems that a sharp boundary between the empirically impossible and possible could never be determined. Hence, there would be no sharp distinction between the verifiable and unverifiable, which Schlick found unacceptable.

For Schlick ([1936] 1979), questions formulated according to the rules of logical grammar are meaningful if and only if it is logically possible to verify their answers. A state of affairs is logically possible for Schlick if the statement that describes it conforms to the logical grammar of language. Hence, meaningful questions may concern states of affairs that contradict well-supported lawlike generalizations. Schlick's position implies that the set of meaningful questions is an extension of the set of questions for which verifiable answers can be imagined. Questions about velocities greater than light are meaningful according to Schlick, but imagining how they could be verified surpasses our mental capabilities.

Schlick's emphasis on logical possibility was problematic because it was unclear that the verification conditions of most metaphysical statements are, or entail, logical impossibilities. In contrast, Carnap ([1936–1937] 1965) and Reichenbach (1938) claimed that metaphysical statements were nonsignificant because no *empirically* possible process of confirmation could be specified for them (see Reichenbach, Hans). Furthermore, if only the *logical* possibility of verification were required for significance, then the nonsignificance of metaphysical statements could no longer be demonstrated by demanding an elucidation of the circumstances in which they could be verified. Metaphysicians can legitimately respond that such circumstances may be difficult or impossible to conceive because they are not empirically possible. Nevertheless, the circumstances may be logically possible, and hence the metaphysical statements may be significant according to Schlick's position.

Faced with the problematic vagueness of the early criteria, a formal specification of the criterion was thought to be crucial. Berlin (1939) pointed out

that the early verifiability criteria were open to objections from metaphysicians because the details of the experiential relevance required of meaningful statements were left unclear: "Relevance is not a precise logical category, and fantastic metaphysical systems may choose to claim that observation data are 'relevant' to their truth" (233).

With formalizations of the criterion, however, came more definitive criticisms. Ayer's (1946, 39) first proposal was seriously flawed because it seemed to make almost all statements verifiable. For any grammatical statement S—for instance "The Absolute is peevish"—any observation statement O, and the conditional $S \rightarrow O$, S and $S \rightarrow O$ jointly entail O, though neither of them alone usually does. According to Ayer's criterion, therefore, S and $S \rightarrow O$ are meaningful except in the rare case that $S \rightarrow O$ entails O (Berlin 1939).

Church (1949) presented a decisive criticism of Ayer's (1946, 13) second proposal. Consider three logically independent observation statements O_1, O_2, and O_3 and any statement S. The disjunction $(\neg O_1 \wedge O_2) \vee (\neg S \wedge O_3)$ is directly verifiable, since in conjunction with O_1 it entails O_3. Also, $(\neg O_1 \wedge O_2) \vee (\neg S \wedge O_3)$ and S together entail O_2. Hence, by Ayer's criterion, S is indirectly verifiable, unless $(\neg O_1 \wedge O_2) \vee (\neg S \wedge O_3)$ alone entails O_2, which implies $\neg S$ and O_3 entail O_2 so that $\neg S$ is directly verifiable. Thus, according to Ayer's criterion, any statement is indirectly verifiable, and therefore significant, or its negation is directly verifiable, and thereby meaningful.

Nidditch (1961) pointed out that Ayer's (1946) proposal could be amended to avoid Church's (1949) criticism by specifying that the premises could only be analytic, directly verifiable, or indirectly verifiable on independent grounds *and* could only be composed of such statements. Thus that $(\neg O_1 \wedge O_2) \vee (\neg S \wedge O_3)$ and S together entail O_2 does not show that S is indirectly verifiable because $(\neg O_1 \wedge O_2) \vee (\neg S \wedge O_3)$ contains a statement (S) that has not been shown to be analytic, directly verifiable, or independently verifiable on independent grounds. Unfortunately, Scheffler (1963) pointed out that according to Nidditch's (1961) revised criterion, an argument similar to Church's (1949) with the disjunction $\neg O_2 \vee (S \wedge O_1)$ shows that any statement S is significant, unless it is a logical consequence of an observation statement. Scheffler (1963) also pointed out that Ayer's second proposal makes any statement of the form $S \wedge (O_1 \rightarrow O_2)$ significant, where O_1, O_2 are logically independent observation sentences and S is any statement. $S \wedge (O_1 \rightarrow O_2)$ entails $O_2$when conjoined with O_1 and neither the conjunction nor O_1 entails O_2 alone.

Beyond Verifiability: Carnap and Hempel

While Ayer first attempted to formalize the verifiability criterion, Carnap ([1936–7] 1965) recognized the obvious weaknesses of verifiability-based significance criteria. At roughly the same time, in the light of Tarski's rigorous semantic account of truth, Carnap was coming to accept that a systematic (that is, nonpragmatic) account might be possible for other concepts, such as 'confirmation.' He subsequently refocused the question of cognitive significance away from verifiability, which seemed to connote the possibility of definitive establishment of truth, to confirmability—the possibility of obtaining evidence, however partial, for a statement. In particular, Carnap thought a justifiable significance criterion could be formulated if an adequate account of the confirmation of theory by observation were available. A better understanding of the latter would provide a clearer grasp of how scientific terms are significant due to their connection to observation and prediction and how metaphysical concepts are not, because they lack this connection. Yet, insights into the nature of confirmation of theory by observation do not alone determine the form of an adequate significance criterion. Rather, these insights were important because Carnap ([1936–7] 1965) radically changed the nature of the debate over cognitive significance.

Carnap reemphasized (from his work in 1932) that what expressions are cognitively significant depends upon the structure of language, and hence a criterion could be proposed relative to only a specific language. He distinguished two kinds of questions about cognitive significance: those concerning "historically given language system[s]" and those concerning constructible ones (Carnap [1932] 1959, 237). Answers to the two kinds of questions are evaluated by different standards. To be meaningful in the first case, an expression E must be a sentence of L, which is determined by the language's syntax, and it must "fulfill the empiricist criterion of meaning" (167) for L. Carnap does not disclose the exact form of the criterion—verifiability, testability, or confirmability—for a particular language, such as English.

The reason for Carnap's silence, however, was his belief that the second type of question posed a more fruitful direction for the debate. The second type of question is practical, and the answers are proposals, not assertions. Carnap ([1936–7] 1965) remarked that he was no longer concerned with arguing directly that metaphysical statements are not cognitively significant (236). Rather, his strategy was to construct a language L in which every

nonanalytic statement was confirmable by some experimental procedure. Given its designed structure, L will clearly indicate how theoretical statements can be confirmed by observational ones, and it will not permit the construction of metaphysical statements. If a language such as L can be constructed that accords with intuitions about the significance of common statements and is sufficient for the purposes of science, then the onus is on the metaphysician to show why metaphysical statements are significant in anything but an emotive or attitude-expressing way.

In a review paper more than a decade later, Hempel (1950) construed Carnap's ([1936–1937] 1965) position as proposing a translatability criterion—a sentence is cognitively significant if and only if it is translatable into an empiricist language (see Hempel, Carl). The vocabulary of an empiricist language L contains observational predicates, the customary logical constants, and any expression constructible from these; the sentence formation rules of L are those of *Principia Mathematica*. The problem Carnap ([1936–1937] 1965) attempted to rectify was that many theoretical terms of science cannot be defined in L.

Hempel's interpretation, however, slightly misconstrued Carnap's intention. Carnap ([1936–7] 1965) did not try to demonstrate how theoretical terms could be connected to observational ones in order to *assert* translatability as a criterion of cognitive significance. Rather, in accord with the *principle of tolerance* (Carnap 1934) Carnap's project in 1936–1937 was to construct an alternative to metaphysically infused language. The features of the language are then evaluated with respect to the purposes of the language user on pragmatic grounds. Although it seems to conflict with his position in 1932, Carnap (1963) clarified that a "neutral attitude toward various forms of language based on the principle that everyone is free to use the language most suited to his purposes, has remained the same throughout my life" (18–19). Carnap ([1936–1937] 1965) tried to formulate a replacement for metaphysics, rather than directly repudiate it on empiricist grounds.

Three definitions were important in this regard. The forms presented here are slightly modified from those given by Carnap ([1936–1937] 1965):

1. The confirmation of a sentence S is completely reducible to the confirmation of a class of sentences C if S is a consequence of a finite subclass of C.
2. The confirmation of S directly incompletely reduces to the confirmation of C if (a) the confirmation of S is not completely reducible to C and (b) there is an infinite subclass C' of mutually independent sentences of C such that S entails, by substitution alone, each member of C'.
3. The confirmation of a predicate P reduces to the confirmation of a class of predicates Q if the confirmation of every full sentence of P with a particular argument (e.g., $P(a)$, in which a is a constant of the language) is reducible to the confirmation of a consistent set of predicates of Q with the same argument, together with their negations.

With these definitions Carnap ([1936–1937] 1965) showed how dispositional predicates (for instance, "is soluble in water") S could be introduced into an empiricist language by means of reduction postulates or finite chains of them. These postulates could take the simple form of a reduction pair:

$$(\forall x)(Wx \rightarrow (Dx \rightarrow Sx));$$
$$(\forall x)(Fx \rightarrow (Rx \rightarrow \neg Sx));$$

in which W, D, F, and R designate observational terms and S is a dispositional predicate. (In the solubility example, Sx = "x is soluble in water"; Dx = "x dissolves in water"; Wx = "x is placed in water"; and R and F are other observational terms.) If $(Vx)\,(Dx \leftrightarrow \neg Rx)$ and $(Vx)\,(Wx \leftrightarrow Fx)$, then the reduction pair is a bilateral reduction sentence:

$$(\forall x)(Wx \rightarrow (Dx \leftrightarrow Sx)).$$

The reduction postulates introduce, but do not explicitly define, terms by specifying their logical relations with observational terms. They also provide confirmation relations between the two types of terms. For instance, the above reduction pair entails that the confirmation of S reduces to that of the confirmation of the set $\{W, D, F, R\}$. Carnap ([1936–1937] 1965) defined a sentence or a predicate to be confirmable (following definitions 1–3 above) if its confirmation reduces to that of a class of observable predicates (156–157). Reduction postulates provide such a reduction for disposition terms such as S. The reduction pair does not define S in terms of observational terms. If $\neg Wx$ and $\neg Fx$, then Sx is undetermined. However, the conditions in which S or its negation hold can be extended by adding other reduction postulates to the language. Carnap thought that supplementing an empiricist language to include terms that could be introduced by means of reduction postulates or chains of them (for example, if Wx is introduced by a reduction pair) would adequately translate all theoretical terms of scientific theories.

Although it set a more rigorous standard for the debate, Carnap's ([1936–1937] 1965) proposal encountered difficulties. Carnap believed that bilateral reduction sentences were analytic, since all the consequences of individual reduction sentences that contained only observation terms were tautologies. Yet, Hempel (1951) pointed out that two bilateral reduction sentences together sometimes entailed synthetic statements that contained only observation terms. Since the idea that the conjunction of two analytic sentences could entail synthetic statements was counterintuitive, Hempel made the important suggestion that analyticity and cognitive significance must be relativized to a specific language *and* a particular theoretical context. A bilateral reduction sentence could be analytic in one context but synthetic in a different context that contained other reduction postulates.

Hempel (1950) also argued that many theoretical terms, for instance "gravitational potential" or "electric field," could not be translated into an empiricist language with reduction postulates or chains of them. Introducing a term with reduction postulates provides some sufficient and necessary observation conditions for the term, but Hempel claimed that this was possible only in simple cases, such as electric fields of a simple kind. Introducing a theoretical term with reduction sentences also unduly restricted theoretical concepts to observation conditions. The concept of length could not be constructed to describe unobservable intervals, for instance 1×10^{-100} m, and the principles of calculus would not be constructible in such a language (Hempel 1951). Carnap's ([1936–1937] 1965) proposal could not accommodate most of scientific theorizing.

Although ultimately untenable, adequacy conditions for a significance criterion were included in Carnap's ([1936–1937] 1965) papers, generalized by Hempel (1951) as: If N is a nonsignificant sentence, then all truth-functional compound sentences that nonvacuously contain N must be nonsignificant. It follows that the denial of a nonsignificant sentence is nonsignificant and that a disjunction, conjunction, or conditional containing a nonsignificant component sentence is also nonsignificant. Yet Hempel (1951) was pessimistic that any adequate criterion satisfying this condition and yielding a sharp dichotomy between significance and nonsignificance could be found. Instead, he thought that cognitive significance was a matter of degree:

> Significant systems range from those whose entire extralogical vocabulary consists of observational terms, through theories whose formulation relies heavily on theoretical constructs, on to systems with hardly any bearing on potential empirical findings. (74).

Hempel suggested that it may be more fruitful to compare theoretical systems according to other characteristics, such as clarity, predictive and explanatory power, and simplicity. On these bases, the failings of metaphysical systems would be more clearly manifested.

Of all the logical empiricists' criteria, Carnap's (1956) criterion was the most sophisticated. It attempted to rectify the deficiencies of his 1936–7 work and thereby avoid Hempel's pessimistic conclusions. Scientific languages were divided into two parts, a theoretical language L_T and an observation language L_O. Let V_O be the class of descriptive constants of L_O, and V_T be the class of *primitive* descriptive constants of L_T. Members of V_O designate observable properties and relations such as 'hard,' 'white,' and 'in physical contact with.' The logical structure of L_O contains only an elementary logic, such as a simple first-order predicate calculus.

The descriptive constants of L_T, called theoretical terms, designate unobservable properties and relations such as 'electron' or 'magnetic field.' L_T contains the mathematics required by science along with the "entities" referred to in scientific physical, psychological, and social theories, though Carnap stressed that this way of speaking does not entail any ontological theses. A theory was construed as a finite set of postulates within L_T and represented by the conjunction of its members T. A finite set of correspondence rules, represented by the conjunction of its members C, connects terms of V_T and V_O.

Within this framework Carnap (1956) presented three definitions, reformulated as:

D1. A theoretical term M is *significant relative* to a class K with respect to L_T, L_O, T, and $C =_{df}$ if (i) $K \subset V_T$, (ii) $M \notin K$, and (iii) there are three sentences S_M, $S_K \in L_T$, and $S_O \in L_O$ such that:
   (a) S_M contains M as the only descriptive term.
   (b) The descriptive terms in S_K belong to K.
   (c) $(S_M \wedge S_K \wedge T \wedge C)$ is consistent.
   (d) $(S_M \wedge S_K \wedge T \wedge C)$ logically implies S_O.
   (e) $\neg[(S_K \wedge T \wedge C)$ logically implies $S_O]$.

D2. A theoretical term M_n is *significant* with respect to L_T, L_O, T, and $C =_{df}$ if there is a sequence of theoretical constants $<M_1, \ldots M_n>$ $(M_i \in V_T)$ such that every M_i is significant relative to $\{M_1, \ldots M_{i-1}\}$ with respect to L_T, L_O, T, and C.

D3. An expression A of L_T is a significant sentence of $L_T =_{df}$ if (i) A satisfies the rules of

formation of L_T and (ii) every descriptive term in A is significant, as in D2.

These definitions, especially D1 (d) and (e), are intended to explicate the idea that a significant term must make a predictive difference. Carnap was aware that observation statements can often be deduced only from theoretical statements containing several theoretical terms. With D2 Carnap implicitly distinguishes between theoretical terms whose significance depends on other theoretical terms and those that acquire significance independently of others. In contrast to his work in 1936–7, and in accord with Hempel's (1951) relativization of analyticity and cognitive significance, Carnap (1956) specified that the significance of theoretical terms is relativized to a particular language *and* a particular theory T.

With the adequacy of his proposal in mind, Carnap (1956, 54–6) proved an interesting result. Consider a language in which V_T is divided into empirically meaningful terms V_1 and empirically meaningless terms V_2. Assume that C does not permit any implication relation between those sentences that contain only V_1 or V_O terms and those sentences that contain only V_2 terms. For a given theory T that can be resolved into a class of statements T_1 that contain only terms from V_1, and T_2 that contain only terms of V_2, then a simple but adequate significance criterion can be given. Any theoretical term that occurs only in isolated sentences, which can be omitted from T without affecting the class of sentences of L_O that it entails in conjunction with C, is meaningless.

The problem is that this criterion cannot be utilized for a theory T' equivalent to T that cannot be similarly divided. Carnap (1956), however, showed by indirect proof that his criterion led to the desired conclusion that the terms of V_2 were not significant relative to T' (L_O, L_T, and C) and that therefore the criterion was not too liberal.

The Supposed Failure of Carnap

Kaplan (1975) raised two objections to Carnap's (1956) criterion that were designed to show that it was too liberal and too restrictive. Kaplan's first objection utilized the "deoccamization" of $T \wedge C$. The label is appropriate, since the transformation of $T \wedge C$ into its deoccamization $T' \wedge C'$ involves replacing all instances of some theoretical terms with disjunctions or conjunctions of new terms of the same type: an Occam-unfriendly multiplication of theoretical terms. Kaplan proved that any deductive systematization of L_O by $T \wedge C$ is also established by any of its deoccamizations. This motivates his intuition that deoccamization should preserve the empirical content of a theory and, therefore, not change the significance of its theoretical terms.

The objection is as follows: If any members of V_T are significant with respect to T, C, L_T, and L_O, then there must be at least one M_1 that is significant relative to an empty K (D2). Yet, if $T \wedge C$ is deoccamized such that M_1 is resolved into two new terms M_{11} and M_{12} that are never found apart, then the original argument that satisfied D1 can no longer be used, since $T' \wedge C'$ do not provide similar logical relationships for M_{11} and M_{12} individually. Hence, the sequence of theoretical terms required by D2 will have no first member. Subsequently, no chain of implications that establishes the significance of successive theoretical terms exists. Although deoccamization preserves the deductive systematization of L_O, according to Carnap's criterion it may render every theoretical term of $T' \wedge C'$ meaningless and therefore render $T' \wedge C'$ devoid of empirical content.

Creath (1976) vindicated the core of Carnap's (1956) criterion by generalizing it to accommodate *sets* of terms, reformulated as:

D1′. A theoretical term M is *significant relative* to a class K with respect to L_T, L_O, T, and $C =_{df}$ if (i) $K \subset V_T$, (ii) $M \notin K$, (iii) there is a class J such that $J \subset V_T$, $M \in J$, but J and K do not share any members, and (iv) there are sentences S_J, $S_K \in L_T$, and $S_O \in L_O$ such that:

- (a) S_J contains members of J as the only descriptive terms.
- (b) The descriptive terms in S_K belong to K.
- (c) $(S_J \wedge S_K \wedge T \wedge C)$ *is* consistent.
- (d) $(S_J \wedge S_K \wedge T \wedge C)$ logically implies S_O.
- (e) $\neg$[$(S_K \wedge T \wedge C)$ logically implies S_O].
- (f) It is not the case that $(\exists J')(J' \subset J)$ and sentences $S_{J'}$, $S_{K'} \in L_T$, and $S_{O'} \in L_O$ such that:
  - (f1) $S_{J'}$ contains only terms of J' as its descriptive terms.
  - (f2) The descriptive terms of $S_{K'}$ belong to K.
  - (f3) $(S_{J'} \wedge S_{K'} \wedge T \wedge C)$ is consistent.
  - (f4) $(S_{J'} \wedge S_{K'} \wedge T \wedge C)$ logically implies $S_{O'}$.
  - (f5) $\neg$[$(S_{K'} \wedge T \wedge C)$ logically implies $S_{O'}$].

D2′. A theoretical term M_n is *significant* with respect to L_T, L_O, T and $C =_{df}$ if there is a sequence of sets $\langle J_1, \ldots J_n \rangle$ ($M_n \in J_n$ and $J_i \subset V_T$) such that every member of every set J_i is significant relative to the union of

J_1 through J_{i-1} with respect to L_T, L_O, T and C.

Condition (f) ensures that each member of J is required for the significance of the entire set. Creath (1976) points out that any term made significant by D1 and D2 of Carnap (1956) is made significant by D1′ and D2′ and that according to the generalized criterion, Kaplan's (1975) deoccamization criticism no longer holds.

Kaplan (1975) and Rozeboom (1960) revealed an apparent second flaw in Carnap's (1956) proposal: As postulates (definitions for Kaplan's criticism) are added to $T \wedge C$, the theoretical terms it contains may change from cognitively significant to nonsignificant or vice versa. Consider an example from Kaplan (1975) in which $V_O = \{J_O, P_O, R_O\}$; L_O is the class of all sentences of first-order logic with identity that contain no descriptive constants or only those from V_O; $V_T = \{B_T, F_T, G_T, H_T, M_T, N_T\}$; and L_T is the class of all sentences of first-order logic with identity that contain theoretical terms from V_T. Let T be:

$$(T)[(\forall x)(H_T x \rightarrow F_T x)] \wedge [(\forall x)(H_T x \rightarrow (B_T x \vee \neg G_T x))] \wedge [(\forall x)(M_T x \leftrightarrow N_T x)];$$

and let C be:

$$(C)[(\forall x)(R_O x \rightarrow H_T x)] \wedge [(\forall x)(F_T x \rightarrow J_O x)] \wedge [(\forall x)(G_T x \rightarrow P_O x)].$$

G_T, F_T, and H_T are significant with respect to $T \wedge C$ relative to the empty set (see Carnap [1956] D1) and, hence, significant with respect to L_O, L_T, T, and C (see Carnap [1956] D2). R_O is significant relative to $K = \{G_T\}$; M_T and N_T are not significant.

Consider a definitional extension T' of T in an extended vocabulary V_T' and language L_T'. After adding two definitions to T:

$$(\text{DEF1})(\forall x)(D1_T x \leftrightarrow (M_T x \wedge (\exists x) F_T x))$$

and

$$(\text{DEF2})(\forall x)(D2_T x \leftrightarrow (M_T x \rightarrow (\exists x) G_T x)),$$

$D1_T$ is significant relative to the empty set and therefore significant with respect to T', C, L_O, and L_T' (D2). $D2_T$ is significant relative to $K = \{D1_T\}$, and therefore significant with respect to T', C, L_O, and L_T' (D2). M_T, which failed to be significant with respect to T, C, L_O, and L_T, is now significant with respect to T', C, L_O, and L_T'. A similar procedure makes N_T significant. Kaplan thought this showed that Carnap's (1956) criterion was too liberal. The procedure seems able to make any theoretical term significant with respect to some extended language and definition-extended theory, but "definitional extensions are ordinarily thought of as having no more empirical content than the original theory" (Kaplan 1975, 90).

Using the same basic strategy, Rozeboom (1960) demonstrated that extending $T \wedge C$ can transform an empirically significant term into an insignificant one. Consider a term M that is significant with respect to T, C, L_T, and L_O. Rozeboom showed that if postulates (not necessarily definitions) are added to T or to C to form T' or C', in some cases D1(e) will no longer be satisfied, and no other sentences S_M', S_K', S_O' exist by which M could be independently shown to be significant. Furthermore, if $T \wedge C$ is maximally L_O consistent, no theoretical term of L_T is significant, since D1(e) is never satisfied; for any S_O, if $T \wedge C$ is maximally L_O consistent then it alone implies S_O. Rozeboom (1960) took the strength of his criticism to depend upon the claim that for a criterion to be "intuitively acceptable," theoretical terms must retain significance if T or C is extended.

Carnap (1956) can be defended in at least two ways. First, as Kaplan (1975) notes, the criterion was restricted to primitive, nondefined theoretical terms. It was explicitly formulated to avoid criticisms derived from definitional extensions. Defined terms often play an important role in scientific theories, and it could be objected that any adequate criterion should apply directly to theories that contain them. Yet the amendment that any theoretical term within the definiens of a significant defined term must be antecedently shown significant quells these worries (Creath 1976).

Second, Carnap (1956) insisted that terms are significant only *within a particular language* and *for a particular T and C*. He did not intend to formulate a criterion of cognitive significance that held under theory or language change. If Carnap's (1956) work on a significance criterion was an explication of the idea of meaningfulness (Hempel 1950), the explicandum was the idea of a meaningful statement of a particular language in a particular theoretical context, not meaningfulness per se. Hence, Kaplan and Rozeboom's objections, which rely on questionable intuitions about the invariance of significance as $T \wedge C$ changes, are not appropriately directed at Carnap (1956). The fact that Carnap did not attempt such an account is not merely the result of a realization that so many problems would thwart the project. Rather, it is a consequence of the external/internal framework that he believed was the most fruitful approach to the philosophical questions (Carnap 1947).

Furthermore, Rozeboom's acceptability condition is especially counterintuitive, since changes in

T or C designate changes in the connections between theoretical terms themselves or theoretical terms and observation terms. Additional postulates that specify new connections, or changes in the connections, between these terms can obviously change the significance of a theoretical term. Scientific advances are sometimes made when empirical or theoretical discoveries render a theoretical term nonsignificant.

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See also **Analyticity; Ayer, Alfred Jules; Carnap, Rudolf; Corroboration; Demarcation, Problem of; Explication; Feigel, Herbert; Hempel, Carl; Logical Empiricism; Neurath, Otto; Popper, Karl; Rational Reconstruction; Reichenbach, Hans; Schlick, Moritz; Verifiability; Vienna Circle**

COMPLEMENTARITY

The existence of indivisible interaction quanta is a crucial point that implies the *impossibility of any sharp separation between the behavior of atomic objects and the interaction with the measuring instruments that serve to define the conditions under which the phenomena appear*. In fact, the individuality