Ernest Nagel (New York), The Logic of Reduction in the Sciences:

Scientific theories are frequently employed as evidence either for a superior "reality" to which the objects of crude, daily experience are "reduced"; or for discrediting science because, in the light of such alleged reductions, it makes unintelligible well-tested practices and beliefs of every-day life. While those contemporary thinkers in whom the leaven of traditional idealisms is still at work have been the most conspicuous players of this game of shuttle-cock and battle-dore, careful study of the nature of "reduction" in the sciences has not been made even by those whose exclusive preoccupation is the logic of science. I think, for example, that the "physicalism" associated with the theory known in America as logical-positivism has been formulated until very recently with sufficient ambiguity to make understandable its precipitate rejection by many as an inadequate, "crude" behaviorism.

Now logical-positivism is a living movement, and some of its apparently "basic" tenets have been subsequently suppressed as unessential. It is therefore difficult to define categorically one's position with respect to it. But I think it is fundamental to logical positivism to hold that the meaning of terms is to be ascertained by examining them in the contexts wherein they are used, and in no other fashion; and to maintain that in the clarification of meanings by such proceedural analysis lies the task of philosophy. I know that these tenets do not uniquely define the logical- positivists, and that many different tendencies in philosophy may be characterized in this fashion. But this situation only helps to explain why so many thinkers can gladly march side by side with members of the positivist group, without feeling obliged to display the official uniform of the *Wiener Kreis.*

The following study of the use of the term "reduction", brief and inadequate though it is, is intended to exemplify the clarification which may be won by the type of analysis referred to. The application however, of the distinctions drawn to the further question as to what sciences are "autonomous" with respect to one another, is not considered here.

I

The nature of reduction in the sciences is closely associated with the nature of scientific explanation. The type of explanation particularly relevant to our inquiry can be stated roughly as follows:

An entity is exhibited as a complex of constituents, whereby some phases of its behavior can be shown to be related in terms of their relation to phases of the behavior of its constituents. Thus, the pressure of a gas may be explained by regarding the gas as a complex of molecules subject to the laws of dynamics, finding expressions for the pressure, temperature and volume of the gas as functions of certain dynamical properties of the molecules and material constants, and finally obtaining the relation between pressure, temperature and volume *via* these functions.

In general, an entity E is analyzed as a complex Γ of entities $a_1 \ldots a_n$. These latter are defined by means of laws g which connect phases α_1, α_2, etc. of their behavior in context Σ. Phases $\emptyset_i$ of E's behavior in Σ, are connected by functions h_i to the phases α_1, α_2 etc. when the entities $a_1, \ldots a_n$ occur in complex Γ; the functions h thus state the conditions for the occurrence of the $\emptyset$'s in terms of the occurrence of the α's. Finally, functions f_i will be found connecting the $\emptyset$'s with each other, and will thus state the conditions for the occurrence of a $\emptyset$ in terms of the occurrence of other phases of E.

Some obvious but essential points must be noted:

a) Every explanation will give an account of only *some* phase of the *total* behavior of an entity. The equations of motion do not explain the color, temperature, or biological behavior of a body.

b) The phase of behavior studied is correlated in certain ways with other selected traits of a body, because these traits and modes of correlation are alone relevant for determining the occurrence of that phase, for reasons usually regarded as sufficient. The discovery and isolation of the relevant traits has been a long and difficult process historically, however obvious the relevance may seem to-day.

c) The occurrence of every phase of behavior explained by certain laws is referred to a definite field or context which is isolated from "disturbing" elements. For there is no behavior apart from *some* context. If the "nature" of an entity consists in the set of its relational traits which are invariant in some *determinate* context, that context enters constitutively into that entity as having that nature.

d) The invariant relational traits of an entity can be employed to define implicitly the entity within some context, and so to identify the science whose subject matter it is. Thus, if every body exhibits in every context the properties called mechanical, mechanics

studies those traits of bodies which remain invariant under the most general transformations. If, however, the nature of an entity is defined in terms of the invariants of its behavior in an indefinite aggregate of contexts, that nature is never completely known as long as its invariants in *every* context are not known. Consequently, it is an empirical question whether the invariants of the behavior of an entity in one context are inferrable from its invariants in another.

e) The constituents into which an entity is analyzed are frequently incapable of direct observation. Only certain selected traits of observable bodies, like mass and motion, are ascribed to the constituents in the interest of logical economy, because these alone are found to be relevant. But every analysis takes its point of departure from the objects of gross experience — it is *their* behavior which must be explained. Consequently, if some theory of microscopic constituents fails to account for certain traits of gross behavior, the existence of such traits is not thereby brought into dispute.

f) Every science is identified by the phases of behavior it studies, and so indirectly by the laws it employs to explain those phases. Mechanics, for example, studies the motion of bodies; its explanations are in terms of equations with prescribed mathematical form which relate positions, times, masses, etc. In discussing the "reducibility" of one science to another, it is essential to state the identifying characteristics of the science *at the time* for which reduction is to be effected. Although chemistry may in some sense be reducible to contemporary physics, it is not the case that it is reducible to the physics of the early nineteenth century. There is always the possibility that in order to reduce one science to another the characteristic traits of the first may be explicitly included in the identifying traits of the second. Unless the respective sciences are each first identified by a specific set of phases and laws, discussions of reducibility degenerate into a quarrel about words or expressions of hope and despair. Charles Peirce's remarks about the classification of sciences apply with equal force to their reducibility: "If classifications are to be restricted to sciences actually existing at the time the classifications are made, the classifications certainly ought to differ from age to age. If Plato's classification was satisfactory in his day, it cannot be good today; and if it be good now, the inference will be that it was bad when he proposed it".

II

Several distinct senses of "reduction" can now be enumerated:

1) Every inquiry into the behavior of entities must isolate certain phases of behavior and neglect others. The total behavior of the entity will then be subordinated, for the purposes of the inquiry, to the selected phases. Proceeding in this manner, it is possible to discover common invariants in the behavior of billiard-balls and in the behavior of a suicide hurling himself from a high tower. Such subordinations of total behavior to selected phases of behavior will be called *selective reduction.* By applying selective reduction differently, the same entity may become the subject matter for different sciences.

2) An entity E may be analyzable in stated ways as a complex Γ of certain entities $a_1, \ldots a_n$. If every entity similar to E is also analyzable as the complex Γ of entities similar to the a's, and so that the occurrence of a complex Γ of the latter is the condition for the occurrence of an entity similar to E, E will be said to be *constitutively reduced.* The constituents are usually defined in terms of traits which they possess in contexts other than the one in which they occur as constituting E. In that case, the possibility of a constitutive reduction of E does *not* entail that the occurrence of some phase of its behavior is theoretically deducible from the defining properties of its constituents and the fact that they occur in the complex. The evidence from contemporary science supports the thesis that constitutive reduction is possible for bodies, and indeed in such a way that the ultimate constituents of all bodies are of like kind. But it is not an essential condition for constitutive reduction that it terminates in this way. There may be degrees or levels of constitutive reduction: a building may be reduced to bricks and mortar in certain relations, while the reduction of an organic body may terminate in a complex arrangement of cells.

3) An entity E may be constitutively reduced in such a way that the occurrence of a phase $\varnothing$ in context Σ may be theoretically inferrable from the defining properties of its constituents and the fact that they occur in a complex Γ. This will be called *characteristic reduction.* Many phases of bodies are capable of such reduction, but not all: the occurrence of qualities like color and temperature cannot be inferred from the occurrence of the microscopic constituents of bodies, when these latter are defined in contexts without reference to the occurrence of these qualities. What often

seems like a reduction depends upon the implicit introduction of an *ad hoc* function correlating the quality with certain constellations of constituents. This does not mean that the constituents no longer satisfy the laws defining them; it *does* mean that the context in which the constituents occur when they are in the arrangement Γ, enters constitutively into the natures they now possess.

4) The phases $\varnothing_1$ and $\varnothing_2$ of the two entities E_1 and E_2 occuring in context Σ may be related by a function f. E_1 and E_2 may be characteristically reducible with respect to these phases in such a manner that f is theoretically deducible from the laws of the constituents and the fact that they occur in certain complexes. This will be called *complete reduction.* Thus the laws of the digestive behavior of the stomach acting upon certain salts seem capable of this kind of reduction. On the other hand, it is possible that while certain phases of organs in living bodies may be characteristically reducible, the laws of their conjoint behavior within the context of living bodies may not be deducible from the laws of the constituents. However, disbelief in the complete or even the characterstic reducibility of organic behavior does not commit one to vitalism in any form. For such disbelief may be based on the possibility that the context of organization which constitutes the living body requires a redefinition of the organs composing it.

5) It may happen that when certain laws of one science are symbolized in appropriate ways, they have a formal structure identical with the laws of another science, which may deal with completely different phases of behavior. Thus the laws of mutual action between electrical currents can be expressed in equations which have the same form as Lagrange's equations for the dynamics of mechanical systems. Such an exhibition of an identical formal pattern will be called *formal reduction.* Formal reduction does not entail either complete or characteristic reduction, although it may sometimes offer a clue how these latter may be effected.

6) Theories in every science must be capable of translation into statements about the content of possible sensuous experience. For the possible material of sense is the ultimate starting point and the culmination of every inquiry in the natural sciences, since in that material is to be found the meaning as well as the evidence for the truth of all material propositions. The analysis of propositions so as to exhibit their reference to the qualitative continuum will be called *epistemic reduction.* What material of sense is employed for

this type of reduction depends both on the phase of behavior studied and on the degree of sophistication achieved by the science. In the interest of precision and certainty, specially selected empirical qualities and events may be employed as the ultimate data for verification. Thus, physics uses spatial coincidences as its ultimate data, and it may be possible to employ similar data in all the sciences. In that case, every science would be epistemically reduced to physics.

It will thus be clear that one science may be reducible to another in some of the above senses, without being reducible in all senses. In any case, expert familiarity with the details of the sciences under discussion is required to decide whether reduction in any sense can be effected.

Ernest Nagel (New York), **Die Logik der „Reduktion" in den Wiſſenſchaften (Inhaltsangabe):**

Der vorſtehende Aufſatz iſt der Bedeutungsklärung des wiſſenſchaftslogiſchen Begriffes „Reduktion" gewidmet; er ſoll zugleich am Beiſpiel einer bisher nicht genügend präziſierten Begriffsbildung die Forſchungsmethoden des logiſchen Poſitivismus erläutern, nach deſſen Hauptthese die Bedeutung eines Begriffes ausſchließlich durch eine Analyſe ſeiner Verwendung in wiſſenſchaftlichen Satzzuſammenhängen beſtimmt werden könne. Der Aufſatz beſchäftigt ſich demgemäß mit den verſchiedenen Anwendungsweiſen des Begriffes „Reduktion".

Die Eigenart mancher Reduktionsmethoden ergibt ſich aus dem Charakter der wiſſenſchaftlichen Erklärung, über die deshalb in Teil I einige Bemerkungen vorausgeſchickt werden. „Erklärungen" in dem hier gemeinten Sinne beziehen ſich auf das Auftreten beſtimmter „Phaſen" des „Verhaltens" von „Gebilden" („entities") in gewiſſen „Zuſammenhängen". Die hervorgehobenen Ausdrücke, die in dem kurzen Aufſatz nicht definiert ſind, können etwa wie folgt erläutert werden: „Gebilde" ſind beliebige Gegenſtände der empiriſchen Forſchung, z. B. Atome, Billardkugeln, Gaſe, Organismen; „Phaſen (des Verhaltens)" ſind mögliche Eigenſchaften ſolcher Gebilde, z. B. Maſſe, Druck, Temperatur, Farbe; das „Verhalten" eines Gebildes iſt die Geſamtheit der Zuſtände, die es durchläuft; der „Zuſammenhang", in dem ſich ein Gebilde befindet, iſt durch den Zuſtand ſeiner Umgebung beſtimmmt.

Der vom Verfaſſer ins Auge gefaßte Typ wiſſenſchaftlicher Erklärungen iſt nun ſo zu charakteriſieren: Ein Gebilde (z. B. ein Gas) wird als ein Komplex von „Konſtituenten" (z. B. von Molekülen) dargeſtellt, und es wird aus den Beziehungen zwiſchen gewiſſen Phaſen der Konſtituenten (z. B. zwiſchen den dynamiſchen Eigenſchaften der Moleküle) eine Beziehung zwiſchen den entſprechenden Phaſen des Gebildes (z. B. Druck, Temperatur und Volumen des Gaſes) hergeleitet; auf Grund dieſer Beziehung läßt ſich eine der betrachteten Phaſen durch die anderen „erklären" (z. B. Wert des Druckes aus denen der Temperatur und des Volumens beſtimmen).

Wie der Verfaſſer hervorhebt, bezieht ſich jede einzelne ſolche Erklärung ſtets nur auf *einige* Phaſen eines Gebildes; jede wiſſenſchaftliche Diſziplin kann

durch die Phaſen beſtimmt werden, die ſie unterſucht, und indirekt alſo durch die zu ihrer Erklärung angewandten Geſetze.

Teil II des Aufſatzes dient der Aufweiſung und terminologiſchen Unterſcheidung von ſechs verſchiedenen Bedeutungen des Begriffes „Reduktion"; ſie ſeien hier kurz erläutert:

1. Eine *ſelektive Reduktion* liegt vor, wenn gewiſſe Verhaltensphaſen des unterſuchten Gebildes iſolierend (gegenüber den übrigen Phaſen) herausgehoben und in Beziehung zueinander geſetzt werden. (Beiſpiel: Die Erklärung der Bewegung eines Organismus mittels der Geſetze der Mechanik.)

2. Eine *konſtitutive Reduktion* liegt vor, wenn ein Gebilde E derart in Konſtituenten zerlegt wird, daß ein Gebilde E' dann und nur dann „ähnlich" zu E iſt, wenn es in Konſtituenten zerlegbar iſt, die denen von E „ähnlich" ſind. (Beiſpiel: die konſtitutive Reduktion der phyſiſchen Körper auf die Elementarbauſteine der Materie.)

3. Eine konſtitutive Reduktion heißt *charakteriſtiſch*, wenn das Auftreten gewiſſer Phaſen eines Gebildes aus den definierenden Eigenſchaften der Konſtituenten ableitbar iſt.

4. Eine charakteriſtiſche Reduktion zweier Gebilde heißt *vollſtändig*, wenn gewiſſe Phaſen der beiden Gebilde durch einen Funktionalzuſammenhang geſetzlich verknüpft ſind, der aus den für ihre Konſtituenten gültigen Geſetzen ableitbar iſt. — Die Unterſcheidung zwiſchen charakteriſtiſcher und vollſtändiger Reduktion iſt z. B. für die Formulierung und Unterſuchung des Vitalismusproblems wichtig.

5. Der Nachweis der ſtrukturellen Übereinſtimmung zweier empiriſcher Geſetze (etwa des klaſſiſchen Gravitationsgeſetzes mit dem Coulombſchen Geſetz) heißt *formale Reduktion.*

6. Die Rückführung des Gehalts eines empiriſchen Satzes auf Angaben über mögliche Sinneserfahrungen wird als *epiſtemiſche Reduktion* bezeichnet. (Beiſpiel: Reduktion eines Satzes der Phyſik auf Ausſagen über beobachtbare Koinzidenzen zwiſchen Zeigern und Skalenſtrichen.)

Der Verfaſſer betont die Notwendigkeit einer Unterſcheidung dieſer verſchiedenen Begriffe, z. B. auch bei der Diskuſſion der phyſikaliſtiſchen Theſe von der Reduzierbarkeit aller Sätze der empiriſchen Wiſſenſchaft auf ſolche der Phyſik.

C. G. Hempel.

Moritz Schlick (Wien), Über den Begriff der Ganzheit:

Das Wort „Ganzheit" gehört zu den am meiſten mißbrauchten in der gegenwärtigen Philoſophie. Mit ſeiner Hilfe werden biologiſche, ſoziologiſche und pſychologiſche Grundfragen ſcheinbar philoſophiſch aufgeklärt — aber eben nur ſcheinbar, denn genauere Betrachtung der vorgeſchlagenen Löſungen lehrt, daß in keiner von ihnen das Wort „Ganzheit" in ſo präziſer Weiſe gebraucht wird, daß die Sätze, in denen es vorkommt, einen klaren Sinn ergeben.