

Chapter 21

Logical Foundations of the Unity of Science

Rudolf Carnap

I. What Is Logical Analysis of Science?

The task of analyzing science may be approached from various angles. The analysis of the subject matter of the sciences is carried out by science itself. Biology, for example, analyzes organisms and processes in organisms, and in a similar way every branch of science analyzes its subject matter. Mostly, however, by 'analysis of science' or 'theory of science' is meant an investigation which differs from the branch of science to which it is applied. We may, for instance, think of an investigation of scientific *activity*. We may study the historical development of this activity. Or we may try to find out in which way scientific work depends upon the individual conditions of the men working in science, and upon the status of the society surrounding them. Or we may describe procedures and appliances used in scientific work. These investigations of scientific activity may be called history, psychology, sociology, and methodology of science. The subject matter of such studies is science as a body of actions carried out by certain persons under certain circumstances. Theory of science in this sense will be dealt with at various other places in this *Encyclopedia*; it is certainly an essential part of the foundation of science.

We come to a theory of science in another sense if we study not the actions of scientists but their results, namely, science as a body of ordered knowledge. Here, by 'results' we do not mean beliefs, images, etc., and the behavior influenced by them. That would lead us again to psychology of science. We mean by 'results' certain linguistic expressions, viz., the statements asserted by scientists. The task of the theory of science in this sense will be to analyze such statements, study their kinds and relations, and analyze terms as components of those statements and theories as ordered systems of those statements. A statement is a kind of sequence of spoken sounds, written marks, or the like, produced by human beings for specific purposes. But it is possible to abstract in an analysis of the statements of science from the persons asserting the statements and from the psychological and sociological conditions of such assertions. The analysis of the linguistic expressions of science under such an abstraction is *logic of science*.

Within the logic of science we may distinguish between two chief parts. The investigation may be restricted to the forms of the linguistic expressions involved, i.e., to the way in which they are constructed out of elementary parts (e.g., words) without referring to anything outside of language. Or the investigation goes beyond this boundary and studies linguistic expressions in their relation to objects outside of language. A study restricted in the first-mentioned way is called *formal*; the field of

such formal studies is called formal logic or *logical syntax*. Such a formal or syntactical analysis of the language of science as a whole or in its various branches will lead to results of the following kinds. A certain term (e.g., a word) is defined within a certain theory on the basis of certain other terms, or it is definable in such a way. A certain term, although not definable by certain other terms, is reducible to them (in a sense to be explained later). A certain statement is a logical consequence of (or logically deducible from) certain other statements; and a deduction of it, given within a certain theory, is, or is not, logically correct. A certain statement is incompatible with certain other statements, i.e., its negation is a logical consequence of them. A certain statement is independent of certain other statements, i.e., neither a logical consequence of them nor incompatible with them. A certain theory is inconsistent, i.e., some of its statements are incompatible with the other ones. The last sections of this essay will deal with the question of the unity of science from the logical point of view, studying the logical relations between the terms of the chief branches of science and between the laws stated in these branches; thus it will give an example of a syntactical analysis of the language of science.

In the second part of the logic of science, a given language and the expressions in it are analyzed in another way. Here also, as in logical syntax, abstraction is made from the psychological and sociological side of the language. This investigation, however, is not restricted to formal analysis but takes into consideration one important relation between linguistic expressions and other objects—that of designation. An investigation of this kind is called *semantics*. Results of a semantical analysis of the language of science may, for instance, have the following forms. A certain term designates a certain particular object (e.g., the sun), or a certain property of things (e.g., iron), or a certain relation between things (e.g., fatherhood), or a certain physical function (e.g., temperature); two terms in different branches of science (e.g., '*Homo sapiens*' in biology and 'person' in economics, or, in another way, 'man' in both cases) designate (or: do not designate) the same. What is designated by a certain expression may be called its *designatum*. Two expressions designating the same are called *synonymous*. The term 'true,' as it is used in science and in everyday life, can also be defined within semantics. We see that the chief subject matter of a semantical analysis of the language of science are such properties and relations of expressions, and especially of statements, as are based on the relation of designation. (Where we say 'the designatum of an expression,' the customary phrase is 'the meaning of an expression.' It seems, however, preferable to avoid the word 'meaning' wherever possible because of its ambiguity, i.e., the multiplicity of its designata. Above all, it is important to distinguish between the semantical and the psychological use of the word 'meaning'.)

It is a question of terminological convention whether to use the term 'logic' in the wider sense, including the semantical analysis of the designata of expressions, or in the narrower sense of logical syntax, restricted to formal analysis, abstracting from designation. And accordingly we may distinguish between logic of science in the narrower sense, as the syntax of the language of science, and logic of science in the wider sense, comprehending both syntax and semantics.

II. *The Main Branches of Science*

We use the word 'science' here in its widest sense, including all theoretical knowledge, no matter whether in the field of natural sciences or in the field of the social sciences and the so-called humanities, and no matter whether it is knowledge found by the application of special scientific procedures, or knowledge based on common sense

in everyday life. In the same way the term 'language of science' is meant here to refer to the language which contains all statements (i.e., theoretical sentences as distinguished from emotional expressions, commands, lyrics, etc.) used for scientific purposes or in everyday life. What usually is called science is merely a more systematic continuation of those activities which we carry out in everyday life in order to know something.

The first distinction which we have to make is that between *formal science* and *empirical science*. Formal science consists of the analytic statements established by logic and mathematics; empirical science consists of the synthetic statements established in the different fields of factual knowledge. The relation of formal to empirical science will be dealt with at another place; here we have to do with empirical science, its language, and the problem of its unity.

Let us take 'physics' as a common name for the nonbiological field of science, comprehending both systematic and historical investigations within this field, thus including chemistry, mineralogy, astronomy, geology (which is historical), meteorology, etc. How, then, are we to draw the boundary line between physics and biology? It is obvious that the distinction between these two branches has to be based on the distinction between two kinds of things which we find in nature: organisms and nonorganisms. Let us take this latter distinction as granted; it is the task of biologists to lay down a suitable definition for the term 'organism,' in other words, to tell us the features of a thing which we take as characteristic for its being an organism. How, then, are we to define 'biology' on the basis of 'organism'? We could perhaps think of trying to do it in this way: biology is the branch of science which investigates organisms and the processes occurring in organisms, and physics is the study of nonorganisms. But these definitions would not draw the distinction as it is usually intended. A law stated in physics is intended to be valid universally, without any restriction. For example, the law stating the electrostatic force as a function of electric charges and their distance, or the law determining the pressure of a gas as a function of temperature, or the law determining the angle of refraction as a function of the coefficients of refraction of the two media involved, are intended to apply to the processes in organisms no less than to those in inorganic nature. The biologist has to know these laws of physics in studying the processes in organisms. He needs them for the explanation of these processes. But since they do not suffice, he adds some other laws, not known by the physicist, viz., the specifically biological laws. Biology presupposes physics, but not vice versa.

These reflections lead us to the following definitions. Let us call those terms which we need—in addition to logico-mathematical terms—for the description of processes in inorganic nature *physical terms*, no matter whether, in a given instance, they are applied to such processes or to processes in organisms. That sublanguange of the language of science, which contains—besides logico-mathematical terms—all and only physical terms, may be called *physical language*. The system of those statements which are formulated in the physical language and are acknowledged by a certain group at a certain time is called the physics of that group at that time. Such of these statements as have a specific universal form are called *physical laws*. The physical laws are needed for the explanation of processes in inorganic nature; but, as mentioned before, they apply to processes in organisms also.

The whole of the rest of science may be called *biology (in the wider sense)*. It seems desirable, at least for practical purposes, e.g., for the division of labor in research work, to subdivide this wide field. But it seems questionable whether any distinctions can be found here which, although not of a fundamental nature, are at least clear to about

the same degree as the distinction between physics and biology. At present, it is scarcely possible to predict which subdivisions will be made in the future. The traditional distinction between bodily (or material) and mental (or psychical) processes had its origin in the old magical and later metaphysical mind-body dualism. The distinction as a practical device for the classification of branches of science still plays an important role, even for those scientists who reject that metaphysical dualism; and it will probably continue to do so for some time in the future. But when the aftereffect of such prescientific issues upon science becomes weaker and weaker, it may be that new boundary lines for subdivisions will turn out to be more satisfactory.

One possibility of dividing biology in the wider sense into two fields is such that the first corresponds roughly to what is usually called biology, and the second comprehends among other parts those which usually are called psychology and social science. The second field deals with the behavior of individual organisms and groups of organisms within their environment, with the dispositions to such behavior, with such features of processes in organisms as are relevant to the behavior, and with certain features of the environment which are characteristic of and relevant to the behavior, e.g., objects observed and work done by organisms.

The first of the two fields of biology in the wider sense may be called biology in the narrower sense, or, for the following discussions, simply *biology*. This use of the term 'biology' seems justified by the fact that, in terms of the customary classification, this part contains most of what is usually called biology, namely, general biology, botany, and the greater part of zoology. The terms which are used in this field in addition to logico-mathematical and physical terms may be called biological terms in the narrower sense, or simply *biological terms*. Since many statements of biology contain physical terms besides biological ones, the *biological language* cannot be restricted to biological terms; it contains the physical language as a sublanguage and, in addition, the biological terms. Statements and laws belonging to this language but not to physical language will be called *biological statements* and *biological laws*.

The distinction between the two fields of biology in the wider sense has been indicated only in a very vague way. At the present time it is not yet clear as to how the boundary line may best be drawn. Which processes in an organism are to be assigned to the second field? Perhaps the connection of a process with the processes in the nervous system might be taken as characteristic, or, to restrict it more, the connection with speaking activities, or, more generally, with activities involving signs. Another way of characterization might come from the other direction, from outside, namely, selecting the processes in an organism from the point of view of their relevance to achievements in the environment (see Brunswik and Ness). There is no name in common use for this second field. (The term 'mental sciences' suggests too narrow a field and is connected too closely with the metaphysical dualism mentioned before.) The term 'behavioristics' has been proposed. If it is used, it must be made clear that the word 'behavior' has here a greater extension than it had with the earlier behaviorists. Here it is intended to designate not only the overt behavior which can be observed from outside but also internal behavior (i.e., processes within the organism); further, dispositions to behavior which may not be manifest in a special case; and, finally certain effects upon the environment. Within this second field we may distinguish roughly between two parts dealing with individual organisms and with groups of organisms. But it seems doubtful whether any sharp line can be drawn between these two parts. Compared with the customary classification of science, the first part would include chiefly psychology, but also some parts of physiology and the humanities. The second part would chiefly include social science and, further, the greater part of the

humanities and history, but it has not only to deal with groups of human beings but also to deal with groups of other organisms. For the following discussion, the terms 'psychology' and 'social science' will be used as names of the two parts because of lack of better terms. It is clear that both the question of boundary lines and the question of suitable terms for the sections is still in need of much more discussion.

III. Reducibility

The question of the unity of science is meant here as a problem of the logic of science, not of ontology. We do not ask: "Is the world one?" "Are all events fundamentally of one kind?" "Are the so-called mental processes really physical processes or not?" "Are the so-called physical processes really spiritual or not?" It seems doubtful whether we can find any theoretical content in such philosophical questions as discussed by monism, dualism, and pluralism. In any case, when we ask whether there is a unity in science, we mean this as a question of logic, concerning the logical relationships between the terms and the laws of the various branches of science. Since it belongs to the logic of science, the question concerns scientists and logicians alike.

Let us first deal with the question of terms. (Instead of the word 'term' the word 'concept' could be taken, which is more frequently used by logicians. But the word 'term' is more clear, since it shows that we mean signs, e.g., words, expressions consisting of words, artificial symbols, etc., of course with the meaning they have in the language in question. We do not mean 'concept' in its psychological sense, i.e., images or thoughts somehow connected with a word; that would not belong to logic.) We know the meaning (designatum) of a term if we know under what conditions we are permitted to apply it in a concrete case and under what conditions not. Such a knowledge of the conditions of application can be of two different kinds. In some cases we may have a merely practical knowledge, i.e., we are able to use the term in question correctly without giving a theoretical account of the rules for its use. In other cases we may be able to give an explicit formulation of the conditions for the application of the term. If now a certain term x is such that the conditions for its application (as used in the language of science) can be formulated with the help of the terms y, z , etc., we call such a formulation a *reduction statement* for x in terms of y, z , etc., and we call x *reducible* to y, z , etc. There may be several sets of conditions for the application of x ; hence x may be reducible to y, z , etc., and also to u, v , etc., and perhaps to other sets. There may even be cases of mutual reducibility, e.g., each term of the set x_1, x_2 , etc., is reducible to y_1, y_2 , etc.; and, on the other hand, each term of the set y_1, y_2 , etc., is reducible to x_1, x_2 , etc.

A *definition* is the simplest form of a reduction statement. For the formulation of examples, let us use ' \equiv ' (called the symbol of equivalence) as abbreviation for 'if and only if.' Example of a definition for 'ox': ' x is an ox \equiv x is a quadruped and horned and cloven-footed and ruminant, etc.' This is also a reduction statement because it states the conditions for the application of the term 'ox,' saying that this term can be applied to a thing if and only if that thing is a quadruped and horned, etc. By that definition the term 'ox' is shown to be reducible to—moreover definable by—the set of terms 'quadruped,' 'horned,' etc.

A reduction statement sometimes cannot be formulated in the simple form of a definition, i.e., of an equivalence statement, ' $\dots \equiv \dots$,' but only in the somewhat more complex form 'If \dots , then: $\dots \equiv \dots$.' Thus a reduction statement is either a simple (i.e., explicit) definition or, so to speak, a conditional definition. (The term

'reduction statement' is generally used in the narrower sense, referring to the second, conditional form.) For instance, the following statement is a reduction statement for the term 'electric charge' (taken here for the sake of simplicity as a nonquantitative term), i.e., for the statement form 'the body x has an electric charge at the time t ': 'If a light body y is placed near x at t , then: x has an electric charge at $t \equiv y$ is attracted by x at t .' A general way of procedure which enables us to find out whether or not a certain term can be applied in concrete cases may be called a *method of determination* for the term in question. The method of determination for a quantitative term (e.g., 'temperature') is the method of measurement for that term. Whenever we know an experimental method of determination for a term, we are in a position to formulate a reduction statement for it. To know an experimental method of determination for a term, say ' Q_3 ,' means to know two things. First, we must know an experimental situation which we have to create, say the state Q_1 , e.g., the arrangement of measuring apparatuses and of suitable conditions for their use. Second, we must know the possible experimental result, say Q_2 , which, if it occurs, will confirm the presence of the property Q_3 . In the simplest case—let us leave aside the more complex cases— Q_2 is also such that its nonoccurrence shows that the thing in question does not have the property Q_3 . Then a reduction statement for ' Q_3 ,' i.e., for the statement form 'the thing (or space-time-point) x is Q_3 (i.e., has the property Q_3) at the time t ,' can be formulated in this way: 'If x is Q_1 (i.e., x and the surroundings of x are in the state Q_1) at time t , then: x is Q_3 at $t \equiv x$ is Q_2 at t .' On the basis of this reduction statement, the term ' Q_3 ' is reducible to ' Q_1 ,' ' Q_2 ,' and spatio-temporal terms. Whenever a term ' Q_3 ' expresses the disposition of a thing to behave in a certain way (Q_2) to certain conditions (Q_1), we have a reduction statement of the form given above. If there is a connection of such a kind between Q_1 , Q_2 , and Q_3 , then in biology and psychology in certain cases the following terminology is applied: 'To the stimulus Q_1 we find the reaction Q_2 as a symptom for Q_3 .' But the situation is not essentially different from the analogous one in physics, where we usually do not apply that terminology.

Sometimes we know several methods of determination for a certain term. For example, we can determine the presence of an electric current by observing either the heat produced in the conductor, or the deviation of a magnetic needle, or the quantity of a substance separated from an electrolyte, etc. Thus the term 'electric current' is reducible to each of many sets of other terms. Since not only can an electric current be measured by measuring a temperature but also, conversely, a temperature can be measured by measuring the electric current produced by a thermo-electric element, there is mutual reducibility between the terms of the theory of electricity, on the one hand, and those of the theory of heat, on the other. The same holds for the terms of the theory of electricity and those of the theory of magnetism.

Let us suppose that the persons of a certain group have a certain set of terms in common, either on account of a merely practical agreement about the conditions of their application or with an explicit stipulation of such conditions for a part of the terms. Then a reduction statement reducing a new term to the terms of that original set may be used as a way of introducing the new term into the language of the group. This way of introduction assures conformity as to the use of the new term. If a certain language (e.g., a sublanguage of the language of science, covering a certain branch of science) is such that every term of it is reducible to a certain set of terms, then this language can be constructed on the basis of that set by introducing one new term after the other by reduction statements. In this case we call the basic set of terms a *sufficient reduction basis* for that language.

IV. *The Unity of the Language of Science*

Now we will analyze the logical relations among the terms of different parts of the language of science with respect to reducibility. We have indicated a division of the whole language of science into some parts. Now we may make another division cutting across the first, by distinguishing in a rough way, without any claims to exactness, between those terms which we use on a prescientific level in our everyday language, and for whose application no scientific procedure is necessary, and scientific terms in the narrower sense. That sublanguagc which is the common part of this prescientific language and the physical language may be called physical thing-language or briefly *thing-language*. It is this language that we use in speaking about the properties of the observable (inorganic) things surrounding us. Terms like 'hot' and 'cold' may be regarded as belonging to the thing-language, but not 'temperature' because its determination requires the application of a technical instrument; further, 'heavy' and 'light' (but not 'weight'); 'red,' 'blue,' etc.; 'large,' 'small,' 'thick,' 'thin,' etc.

The terms so far mentioned designate what we may call observable properties, i.e., such as can be determined by a direct observation. We will call them *observable thing-predicates*. Besides such terms the thing-language contains other ones, e.g., those expressing the disposition of a thing to a certain behavior under certain conditions, e.g., 'elastic,' 'soluble,' 'flexible,' 'transparent,' 'fragile,' 'plastic,' etc. These terms—they might be called disposition-predicates—are reducible to observable thing-predicates because we can describe the experimental conditions and the reactions characteristic of such disposition-predicates in terms of observable thing-predicates. Example of a reduction statement for 'elastic': 'If the body x is stretched and then released at the time t , then: x is elastic at the time $t \equiv x$ contracts at t ,' where the terms 'stretched,' 'released,' and 'contracting' can be defined by observable thing-predicates. If these predicates are taken as a basis, we can moreover introduce, by iterated application of definition and (conditional) reduction, every other term of the *thing-language*, e.g., designations of substances, e.g., 'stone,' 'water,' 'sugar,' or of processes, e.g., 'rain,' 'fire,' etc. For every term of that language is such that we can apply it either on the basis of direct observation or with the help of an experiment for which we know the conditions and the possible result determining the application of the term in question.

Now we can easily see that every term of the *physical language* is reducible to those of the thing-language and hence finally to observable thing-predicates. On the scientific level, we have the quantitative coefficient of elasticity instead of the qualitative term 'elastic' of the thing-language; we have the quantitative term 'temperature' instead of the qualitative ones 'hot' and 'cold'; and we have all the terms by means of which physicists describe the temporary or permanent states of things or processes. For any such term the physicist knows at least one method of determination. Physicists would not admit into their language any term for which no method of determination by observations were given. The formulation of such a method, i.e., the description of the experimental arrangement to be carried out and of the possible result determining the application of the term in question, is a reduction statement for that term. Sometimes the term will not be directly reduced by the reduction statement to thing-predicates, but first to other scientific terms, and these by their reduction statements again to other scientific terms, etc.; but such a reduction chain must in any case finally lead to predicates of the thing-language and, moreover, to observable thing-predicates because otherwise there would be no way of determining whether or not the physical term in question can be applied in special cases, on the basis of given observation statements.

If we come to *biology* (this term now always understood in the narrower sense), we find again the same situation. For any biological term the biologist who introduces or uses it must know empirical criteria for its application. This applies, of course, only to biological terms in the sense explained before, including all terms used in scientific biology proper, but not to certain terms used sometimes in the philosophy of biology—'a whole,' 'entelechy,' etc. It may happen that for the description of the criterion, i.e., the method of determination of a term, other biological terms are needed. In this case the term in question is first reducible to them. But at least indirectly it must be reducible to terms of the thing-language and finally to observable thing-predicates, because the determination of the term in question in a concrete case must finally be based upon observations of concrete things, i.e., upon observation statements formulated in the thing-language.

Let us take as an example the term 'muscle.' Certainly biologists know the conditions for a part of an organism to be a muscle; otherwise the term could not be used in concrete cases. The problem is: Which other terms are needed for the formulation of those conditions? It will be necessary to describe the functions within the organism which are characteristic of muscles, in other words, to formulate certain laws connecting the processes in muscles with those in their environment, or, again in still other words, to describe the reactions to certain stimuli characteristic of muscles. Both the processes in the environment and those in the muscle (in the customary terminology: stimuli and reactions) must be described in such a way that we can determine them by observations. Hence the term 'muscle,' although not definable in terms of the thing-language, is reducible to them. Similar considerations easily show the reducibility of any other biological term—whether it be a designation of a kind of organism, or of a kind of part of organisms, or of a kind of process in organisms.

The result found so far may be formulated in this way: The terms of the thing-language, and even the narrower class of the observable thing-predicates, supply a sufficient basis for the languages both of physics and of biology. (There are, by the way, many reduction bases for these languages, each of which is much more restricted than the classes mentioned.) Now the question may be raised whether a basis of the kind mentioned is sufficient even for the whole language of science. The affirmative answer to this question is sometimes called *physicalism* (because it was first formulated not with respect to the thing-language but to the wider physical language as a sufficient basis). If the thesis of physicalism is applied to biology only, it scarcely meets any serious objections. The situation is somewhat changed, however, when it is applied to psychology and social science (individual and social behavioristics). Since many of the objections raised against it are based on misinterpretations, it is necessary to make clear what the thesis is intended to assert and what not.

The question of the reducibility of the terms of psychology to those of the biological language and thereby to those of the thing-language is closely connected with the problem of the various methods used in psychology. As chief examples of methods used in this field in its present state, the physiological, the behavioristic, and the introspective methods may be considered. The *physiological approach* consists in an investigation of the functions of certain organs in the organism, above all, of the nervous system. Here, the terms used are either those of biology or those so closely related to them that there will scarcely be any doubt with respect to their reducibility to the terms of the biological language and the thing-language. For the *behavioristic approach* different ways are possible. The investigation may be restricted to the external behavior of an organism, i.e., to such movements, sounds, etc., as can be observed by other organisms in the neighborhood of the first. Or processes within the organism

may also be taken into account so that this approach overlaps with the physiological one. Or, finally, objects in the environment of the organism, either observed or worked on or produced by it, may also be studied. Now it is easy to see that a term for whose determination a behavioristic method—of one of the kinds mentioned or of a related kind—is known, is reducible to the terms of the biological language, including the thing-language. As we have seen before, the formulation of the method of determination for a term is a reduction statement for that term, either in the form of a simple definition or in the conditional form. By that statement the term is shown to be reducible to the terms applied in describing the method, namely, the experimental arrangement and the characteristic result. Now, conditions and results consist in the behavioristic method either of physiological processes in the organism or of observable processes in the organism and in its environment. Hence they can be described in terms of the biological language. If we have to do with a behavioristic approach in its pure form, i.e., leaving aside physiological investigations, then the description of the conditions and results characteristic for a term can in most cases be given directly in terms of the thing-language. Hence the behavioristic reduction of psychological terms is often simpler than the physiological reduction of the same term.

Let us take as an example the term 'angry.' If for anger we knew a sufficient and necessary criterion to be found by a physiological analysis of the nervous system or other organs, then we could define 'angry' in terms of the biological language. The same holds if we knew such a criterion to be determined by the observation of the overt, external behavior. But a physiological criterion is not yet known. And the peripheral symptoms known are presumably not necessary criteria because it might be that a person of strong self-control is able to suppress these symptoms. If this is the case, the term 'angry' is, at least at the present time, not definable in terms of the biological language. But, nevertheless, it is reducible to such terms. It is sufficient for the formulation of a reduction sentence to know a behavioristic procedure which enables us—if not always, at least under suitable circumstances—to determine whether the organism in question is angry or not. And we know indeed such procedures; otherwise we should never be able to apply the term 'angry' to another person on the basis of our observations of his behavior, as we constantly do in everyday life and in scientific investigation. A reduction of the term 'angry' or similar terms by the formulation of such procedures is indeed less useful than a definition would be, because a definition supplies a complete (i.e., unconditional) criterion for the term in question, while a reduction statement of the conditional form gives only an incomplete one. But a criterion, conditional or not, is all we need for ascertaining reducibility. Thus the result is the following: If for any psychological term we know either a physiological or a behavioristic method of determination, then that term is reducible to those terms of the thing-language.

In psychology, as we find it today, there is, besides the physiological and the behavioristic approach, the so-called *introspective method*. The questions as to its validity, limits, and necessity are still more unclear and in need of further discussion than the analogous questions with respect to the two other methods. Much of what has been said about it, especially by philosophers, may be looked at with some suspicion. But the facts themselves to which the term 'introspection' is meant to refer will scarcely be denied by anybody, e.g., the fact that a person sometimes knows that he is angry without applying any of those procedures which another person would have to apply, i.e., without looking with the help of a physiological instrument at his nervous system or looking at the play of his facial muscles. The problems of the practical reliability and theoretical validity of the introspective method may here be

left aside. For the discussion of reducibility an answer to these problems is not needed. It will suffice to show that in every case, no matter whether the introspective method is applicable or not, the behavioristic method can be applied at any rate. But we must be careful in the interpretation of this assertion. It is not meant as saying: 'Every psychological process can be ascertained by the behavioristic method.' Here we have to do not with the single processes themselves (e.g., Peter's anger yesterday morning) but with kinds of processes (e.g., anger). If Robinson Crusoe is angry and then dies before anybody comes to his island, nobody except himself ever knows of this single occurrence of anger. But anger of the same kind, occurring with other persons, may be studied and ascertained by a behavioristic method, if circumstances are favorable. (Analogy: if an electrically charged raindrop falls into the ocean without an observer or suitable recording instrument in the neighborhood, nobody will ever know of that charge. But a charge of the same kind can be found out under suitable circumstances by certain observations.) Further, in order to come to a correct formulation of the thesis, we have to apply it not to the kinds of processes (e.g., anger) but rather to the terms designating such kinds of processes (e.g., 'anger'). The difference might seem trivial but is, in fact, essential. We do not at all enter a discussion about the question whether or not there are kinds of events which can never have any behavioristic symptoms, and hence are knowable only by introspection. We have to do with psychological terms not with kinds of events. For any such term, say, 'Q,' the psychological language contains a statement form applying that term, e.g., 'The person. . . is at the time. . . in the state Q.' Then the utterance by speaking or writing of the statement 'I am now (or: I was yesterday) in the state Q,' is (under suitable circumstances, e.g., as to reliability, etc.) an observable symptom for the state Q. Hence there cannot be a term in the psychological language, taken as an intersubjective language for mutual communication, which designates a kind of state or event without any behavioristic symptom. Therefore, there is a behavioristic method of determination for any term of the psychological language. Hence every such term is reducible to those of the thing-language.

The logical nature of the psychological terms becomes clear by an analogy with those physical terms which are introduced by reduction statements of the conditional form. Terms of both kinds designate a state characterized by the disposition to certain reactions. In both cases the state is not the same as those reactions. Anger is not the same as the movements by which an angry organism reacts to the conditions in his environment, just as the state of being electrically charged is not the same as the process of attracting other bodies. In both cases that state sometimes occurs without these events which are observable from outside; they are consequences of the state according to certain laws and may therefore under suitable circumstances be taken as symptoms for it; but they are not identical with it.

The last field to be dealt with is *social science* (in the wide sense indicated before; also called social behavioristics). Here we need no detailed analysis because it is easy to see that every term of this field is reducible to terms of the other fields. The result of any investigation of a group of men or other organisms can be described in terms of the members, their relations to one another and to their environment. Therefore, the conditions for the application of any term can be formulated in terms of psychology, biology, and physics, including the thing-language. Many terms can even be defined on that basis, and the rest is certainly reducible to it.

It is true that some terms which are used in psychology are such that they designate a certain behavior (or disposition to behavior) within a group of a certain kind or a certain attitude toward a group, e.g., 'desirous of ruling,' 'shy,' and others. It may be

that for the definition or reduction of a term of this kind some terms of social science describing the group involved are needed. This shows that there is not a clear-cut line between psychology and social science and that in some cases it is not clear whether a term is better assigned to one or to the other field. But such terms are also certainly reducible to those of the thing-language because every term referring to a group of organisms is reducible to terms referring to individual organisms.

The result of our analysis is that the class of observable thing-predicates is a sufficient reduction basis for the whole of the language of science, including the cognitive part of the everyday language.

V. *The Problem of the Unity of Laws*

The relations between the terms of the various branches of science have been considered. There remains the task of analyzing the relations between the laws. According to our previous consideration, a biological law contains only terms which are reducible to physical terms. Hence there is a common language to which both the biological and the physical laws belong so that they can be logically compared and connected. We can ask whether or not a certain biological law is compatible with the system of physical laws, and whether or not it is derivable from them. But the answer to these questions cannot be inferred from the reducibility of the terms. At the present state of the development of science, it is certainly not possible to derive the biological laws from the physical ones. Some philosophers believe that such a derivation is forever impossible because of the very nature of the two fields. But the proofs attempted so far for this thesis are certainly insufficient. This question is, it seems, the scientific kernel of the problem of vitalism; some recent discussions of this problem are, however, entangled with rather questionable metaphysical issues. The question of derivability itself is, of course, a very serious scientific problem. But it will scarcely be possible to find a solution for it before many more results of experimental investigation are available than we have today. In the meantime the efforts toward derivation of more and more biological laws from physical laws—in the customary formulation: explanation of more and more processes in organisms with the help of physics and chemistry—will be, as it has been, a very fruitful tendency in biological research.

As we have seen before, the fields of psychology and social science are very closely connected with each other. A clear division of the laws of these fields is perhaps still less possible than a division of the terms. If the laws are classified in some way or other, it will be seen that sometimes a psychological law is derivable from those of social science, and sometimes a law of social science from those of psychology. (An example of the first kind is the explanation of the behavior of adults—e.g., in the theories of A. Adler and Freud—by their position within the family or a larger group during childhood; an example of the second kind is the obvious explanation of an increase of the price of a commodity by the reactions of buyers and sellers in the case of a diminished supply.) It is obvious that, at the present time, laws of psychology and social science cannot be derived from those of biology and physics. On the other hand, no scientific reason is known for the assumption that such a derivation should be in principle and forever impossible.

Thus there is at present *no unity of laws*. The construction of one homogeneous system of laws for the whole of science is an aim for the future development of science. This aim cannot be shown to be unattainable. But we do not, of course, know whether it will ever be reached.

On the other hand, there is a *unity of language* in science, viz., a common reduction basis for the terms of all branches of science, this basis consisting of a very narrow and homogeneous class of terms of the physical thing-language. This unity of terms is indeed less far-reaching and effective than the unity of laws would be, but it is a necessary preliminary condition for the unity of laws. We can endeavor to develop science more and more in the direction of a unified system of laws only because we have already at present a unified language. And, in addition, the fact that we have this unity of language is of the greatest practical importance. The practical use of laws consists in making predictions with their help. The important fact is that very often a prediction cannot be based on our knowledge of only one branch of science. For instance, the construction of automobiles will be influenced by a prediction of the presumable number of sales. This number depends upon the satisfaction of the buyers and the economic situation. Hence we have to combine knowledge about the function of the motor, the effect of gases and vibration on the human organism, the ability of persons to learn a certain technique, their willingness to spend so much money for so much service, the development of the general economic situation, etc. This knowledge concerns particular facts and general laws belonging to all the four branches, partly scientific and partly commonsense knowledge. For very many decisions, both in individual and in social life, we need such a prediction based upon a combined knowledge of concrete facts and general laws belonging to different branches of science. If now the terms of different branches had no logical connection between one another, such as is supplied by the homogeneous reduction basis, but were of fundamentally different character, as some philosophers believe, then it would not be possible to connect singular statements and laws of different fields in such a way as to derive predictions from them. Therefore, the unity of the language of science is the basis for the practical application of theoretical knowledge.

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