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The Task of the Logic of Science (1987)

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1. THE LOGIC OF SCIENCE

The works of the Vienna Circle and related groups have as their object to investigate science either as a whole or in its individual branches: they analyse the concepts, sentences, proofs, and theories that appear different scientific fields, and they do this not so much from the point of view of the historical development of science as from the logical point of view. This field of work, for which there exists as yet no commonly recognized general term, may perhaps be called the theory of science and more precisely the *logic of science*. By "science" is to be understood here the totality of accepted sentences; and this includes not only assertions of the scientists but also those of everyday life; for there is no sharp boundary between these two fields.

Some refer to this field of work as part of philosophy. But since the term "philosophy" frequently carries the connotation of a field different from the "ordinary" sciences, such an appellation can easily cause confusion. If we look at the historical development of our field of work, we must indeed admit that it has developed out of philosophy. But this is also true of some other scientific fields. Thus the natural sciences and mathematics issued originally from the womb of philosophy, but even in antiquity cut themselves loose and assumed the character of independent scientific fields. In spite of its philosophical origin, physics is certainly no longer thought of as a philosophical field by anyone. And those sociologists who do scientific work, i.e., those who investigate social processes and their connections according to empirical methods without the admixture of metaphysical pseudo-theses, nowadays no longer regard their field of work as part of philosophy. Finally, psychologists too, as far as they do empirical and not metaphysical work, are gradually coming to see that their field of work is part of empirical science and not of philosophy. Likewise our own discipline, logic or the logic of science, is in the process of cutting itself loose from philosophy and of becoming a properly scientific field, where all work is done according to strict scientific methods and not by means of "higher" or "deeper" insights. This field is, it seems to me, the last scientific field to split off from philosophy. What still remains behind is the kind of problems that metaphysicians are wont to raise, e.g., "What is the first cause of the world?", "What is the nature of nothingness?", "Why is there something rather than nothing?" But these are pseudo-problems without any scientific content.

While metaphysics pretends to deal with the "hidden causes" and the "true nature" of things, the logic of science does not refer to things at all. For everything that can be said about things is said by science, or more specifically, by the special branch of science that deals with the corresponding domain of things. There is nothing else, nothing "higher" to be said about things than what science says about them. Rather, the object of the logic of science is science itself as an ordered complex of sentences. Everything that can be said about organisms and organic processes has to be said by biology as an empirical science; there are not, in addition, philosophical sentences about these processes, sentences of "natural philosophy" about "life". But it is perfectly possible to conduct a logical investigation into the concepts, hypotheses, and theories of biology, and this is part of the logic of science.

The logic of science includes questions of the following kind (our formulation here is not a precise one). Is the law of the constancy of the velocity of light in relativity theory a stipulation or a factual sentence? Does general relativity theory contain a logical contradiction? In what way can the macro-concepts of physics (e.g., temperature, density, velocity of sound, etc.) be defined in terms of micro-concepts (electromagnetic field, gravitational field, electrons, etc.)? Is such and such a theory, t_2, compatible or incompatible with a theory t_1? If compatible, is t_2 contained in the sense of t_1, or does the content of t_2 go beyond that of t_1? In the latter case, what part of the content of t_2 goes beyond t_1? Is the concept c_{n} reducible to the concepts c_1, $\ldots c_{\mathrm{m}}$? Do the two concepts c_1 and c_2 (which differ in their definitions) have the same meaning? Or at least, can the one always be substituted for the other on the basis of the laws of nature? Do the two sentences p_1 and p_2 (which differ in their wordings) have the same sense or not? Does p_2 follow from p_1 with logical necessity? Or at least with the necessity of the laws of nature? Does the content of a law go beyond the content of those observation sentences that led to the setting up of the law? What is the sense of sentences expressing probability? Is the concept "probability" synonymous with "relative frequency"?

When we ask here for the "sense" of a sentence and the "meaning" of a concept, this is not meant in the psychological sense. We are not asking what images and ideas we associate with this or that sentence or with this or that concept; this would be a psychological question calling for an empirical answer, which could not be answered at all in general, but only in different ways according to the experimental subject and the particular circumstances of the moment. Rather, we are asking for "sense" and "meaning" in the *logical* sense. But what is meant by this? Are we not in danger of falling back into philosophical speculation in appealing here to the point of view of "logic", as distinct from that of psychology? For what kind of sentence do we use in answering these and similar questions of the logic of science? We take the view, expressed already by Hume, that besides logico-mathematical tautologies (analytic sentences) science contains only the empirical sentences of the factual sciences (cf. n. 1). Some of our opponents have seized on this and really touched a sensitive spot in our overall view; they have objected that if a sentence is senseless unless it belongs to either mathematics or the factual sciences, then all the sentences in our own works are also senseless! Moreover, the view that the sentences of the logic of science are just as senseless as those of metaphysics has been held not only by our opponents, but even by some who, like us, reject metaphysics and work in this field (cf. n. 6). Against all of them we shall here take the view that *the sentences of the logic of science are sentences of the logical syntax of language.* These sentences therefore lie inside the boundary drawn by Hume; for logical syntax is—as we shall see—nothing but the mathematics of language.

2. LOGICAL SYNTAX

By the *logical syntax* of a language we understand the theory of the forms of the sentences and other linguistic units of this language. This theory deals with *forms*, that is, it does not ask for the sense of a sentence or the meaning of the words that occur in it; but it divides the words of the language into syntactic kinds and only asks for the kinds of words that occur in it and their sequence. Logical syntax is nothing more than the development of analytic consequences from the syntactic rules of the language in question. These rules are of two kinds. The *formation rules* of the language determine how sentences can be formed out of words (or other signs). Such rules are usually given in the grammar of a language; the only difference between the usual rules of grammar, as drawn up in linguistics, and the formation rules drawn up in logical syntax is that the latter are strictly formal, whereas the former often make reference to the meanings of words (e.g., "If a noun designates a female person, a country, or a ship . . ."). The second kind of syntactic rules are the *transformation rules* of the language. These stipulate that a sentence can be inferred from one or more other sentences if those sentences satisfy certain formal conditions, i.e., conditions which refer only to the form of the sentence. Thus transformation rules correspond more or less to what are called rules of inference in logic, except that they do not refer to judgements conceived either as acts of consciousness or as the contents of such acts, as rules of inference do for some (psychological) logicians, but to sentences conceived as linguistic structures. The transformation rules must also be strictly formal, a requirement which is not always satisfied in traditional logic, though the historical development of logic shows more and more clearly a tendency towards strict formality, towards the elimination of any reference to meaning. The symbolic method of modern logic, formed in imitation of mathematics, first made it possible to draw up strictly formal rules.

If we wanted to represent the complete syntax of a natural language like English for example, and hence, to set up the complete system of the formation and transformation rules tacitly underlying English linguistic usage and to develop its consequences, we would find that this system of rules is very complicated, considerably more complicated than might appear at first sight. Let us try to get clear about this by using some examples. In logical syntax words are divided into *species* in such a way that two words belong to the same species if and only if they behave in the same way with respect to the formation rules, and hence with respect to sentence construction; or in other words: if a sentence containing the first word remains a sentence when the second word is substituted for the first (no regard being paid to the truth or falsity of the sentences). After the words have thus been divided into species, we no longer need to mention certain words in formulating the formation rules, but can simply mention word species. Into how many different species do the words of the English language divide? After a casual glance at a grammar of the English language, it might be thought that there are a few dozen word species: general nouns, proper nouns . . ., verbs taking a direct object . . . However, closer inspection shows that we must distinguish several hundred, perhaps even several thousand different word species in the English language. First of all, it is clear that the different inflected forms of a word belong to different species ("give", "gives", "gave", "given"). Further, even general nouns in the singular and in subject position do not all belong to the same species, e.g., "pencil" and "courage". "My pencil weighs ten pounds" is a sentence, even though a false one; "My courage weighs ten pounds" is not (as might be thought) a false sentence, but not a sentence at all, since we cannot ascribe weight to a property of a person even if we want to. We must therefore divide the nouns of the kinds mentioned into subspecies: into names of things, designations of properties, names of numbers, etc. But even these subdivisions are not always sufficient to determine a species. Many words even form a species by themselves (we then call them "isolated"). E.g., there would seem to be only a few other words, if any at all, which can take the place of the word "cognisance" ("I take ___ of this", "It falls within my ___ ", etc.). This shows that for the English language a complete system of formation rules alone would be enormous in scope. The great complexity of the system of rules for natural languages is the reason why in the practice of logical analysis we either analyse only certain turns of phrase and modes of expression of a natural language or, if we want to set up the complete system of the rules of a language, we take up a constructed symbolic language of the kind developed in modern logic (cf. n. 4). In what follows we shall speak simply of "syntax" instead of "logical syntax"; and we shall do so wherever there is no danger of confusion with "syntax" in the linguistic sense, the difference being that linguistics does not formulate the formation rules formally and does not include the transformation rules along with them.

If a sentence can be obtained from certain other sentences by (sometimes repeated) application of the transformation rules, we call it a *consequence* of those other sentences. Since the transformation rules are formulated without reference to meaning, the concept "consequence" is also a formal one. With the help of this concept we can set up further syntactic definitions. Let us cite some examples of such concepts which are frequently employed in the logical analysis of scientific sentences. We call a sentence *analytic* (or tautological) if it is the consequence of any sentence, and hence, if it is true unconditionally, whatever else may be the case. A sentence is called *contradictory* if every sentence of the language in question is a consequence of it. A sentence is *synthetic* if it is neither analytic nor contradictory. For example, in the English language, "Horses are horses", "A horse is either healthy or sick", and "2 + 2 = 4" are analytic; the sentences "There are horses which are not horses", "There is a horse which is both healthy and sick", and "2 + 2 = 5" are contradictory, and the sentences "This horse is sick" and "I have four pencils" are synthetic. Synthetic sentences are what are usually called "statements about reality". The sentences of the factual sciences—both general laws and concrete sentences about certain particular objects and processes are synthetic. In a certain sense, these synthetic sentences form the core of science. The sentences of logic and mathematics are analytic. Considered from the practical point of view, they only serve the purpose of making it easier for scientists to operate with synthetic sentences. It would be possible to construct a language of science in such a way that there would be nothing but synthetic sentences in it; there would then be no logical and mathematical sentences; but the whole of the factual sciences could be expressed in it in an unabbreviated way. It is only for reasons of technical simplification that scientists do not in reality proceed in this way, but employ a language comprising, besides synthetic sentences, the analytic sentences of logic and mathematics, e.g., the ones mentioned above, but also less trivial ones which cannot at first glance be recognized as analytic. Incidentally, mathematics is as it were an excerpt from logic; it consists of those logical sentences that contain numerals, numerical variables, and similar expressions (e.g., "$2 + 2 = 4$"); but there is no sharp line demarcating mathematics from the rest of logic. While analytic sentences have a different syntactic character from synthetic ones, they do not (as might be thought) lie on a different level. Both kinds of sentences are employed together, tied together into compound sentences (by "and", "or", "if", and the like), and subjected to the same kinds of transformations.

If we ask for the content or *sense* of a certain sentence s from the logical (as distinct from the psychological) point of view, our question can only mean this: what do we learn from s? Or: what sentences are consequences of s, without being consequences of any sentence whatsoever and hence saying nothing? We therefore define: by the content of a sentence s we understand the class of those consequences of s that are not analytic.

The concept "content" is one of the most important syntactic concepts. The contents of sentences are characteristic of their logical relationships to one another and of their role in the system of science. The content of an analytic sentence is empty; the content of a contradictory sentence is the total content, i.e., the class of all non-analytic sentences of the language in question. The content of a synthetic sentence is a (proper) part of the total content. Further, the content of a sentence is contained in that of another if and only if the first sentence is a consequence of the second. Sentences having the same content say the same thing, no matter how different their forms may be.

As the sameness of sense of two *sentences* is formally defined as "sameness of content", so we can also formally define the sameness of meaning of two expressions (e.g., words). This concept will then apply to two expressions if interchanging them never changes the sense and hence the content of the sentence. We therefore define: two expressions are called *synonymous*, first, if they are of the same category, so that if the first word is replaced by the second in a sentence, the result is always another sentence, and secondly, if the sentence resulting from such a replacement always has the same content as the original sentence.

The syntactic structure of a language consists essentially of a series of definitions of syntactic concepts. Syntactic rules too are definitions. This is because formation rules are nothing but the definition of the concept "sentence", and transformation rules form the definition of the concept "immediate consequence". The definitions of further syntactic concepts (e.g., "existential sentence", "consequence", "analytic", "content", etc.) can be linked to these two initial definitions. The entire syntax of any language consists of sentences, namely of definitions and other analytic sentences that rest on definitions. The sentences of the syntax of a language must again be formulated in a language. We call this language the syntactic language, while the language whose syntax is represented we call object language. Syntax deals with the forms of linguistic structures and hence with certain combinations of certain elements, namely linguistic signs; and it can carry out its task with the aid of mathematical concepts developed in combinatorial analysis or arithmetic. *Syntax* is nothing but the *mathematics of linguistic forms.*

Object language and syntactic language are in general two different languages; this is the case if we formulate, e.g., the syntax of the French language in definitions and other sentences belonging to the English language. But object language and syntactic language can also coincide; or more precisely, the syntactic language may be part of the object language. This is the case if we formulate, e.g., the syntax of the French language in the French language itself. And it can also happen that a syntactic sentence says something, not only about other sentences of the same language, but even about itself, without giving rise to contradictions (cf. n. 5).

3. THE LOGIC OF SCIENCE AS THE LOGICAL SYNTAX OF THE LANGUAGE OF SCIENCE

We have raised above the question of the character of the sentences of the logic of science. We now want to show that they are sentences of syntax in the sense elucidated, that of a formal theory of linguistic forms. Such an interpretation is obvious for those sentences, considerations, and problems of the logic of science that deal with the sentences and concepts of some scientific field or other and their logical relations. But there are many sentences and questions of the logic of science which in their usual formulation appear to deal with things entirely different from linguistic structures, such as numbers, properties of numbers, mathematical functions, space and time, the causal relation between two processes, the relation between things and sense experiences, the relation between a "mental process" and the simultaneous brain process, certain physical micro-processes (e.g., inside an atom) and their knowability and indeterminacy, the possibility or impossibility of some states or others, the necessary or accidental character of certain processes, and the like. However, closer observation shows that such sentences only seem to refer to extralinguistic objects: they can be translated into sentences that simply talk about the formal properties of linguistic structures;

i.e., into syntactic sentences. Further, we often encounter sentences in the logic of science which, while dealing with linguistic structures, do not seem to deal with their formal properties, but instead with the meaning of the words or with the sense of the sentences; we shall see that such sentences, too, can be translated into formal syntactic sentences.

Let us distinguish three kinds of sentences:

1. *Genuine object sentences.* (These not only seem to be, but really are about extralinguistic objects.) Example: "The rose is red".

2. *Pseudo-object-sentences* or sentences of the *material mode of speech.* (These only seem to be about extralinguistic objects, e.g., about a rose, but in reality they are about the linguistic designation for that object, e.g., about the word "rose".) Example: "A rose is a thing".

3. *Syntactic sentences* or sentences of the *formal mode of speech.* (These are about linguistic structures.) Example: "The word 'rose' is a designation for a thing".

The elucidations in parentheses have not been formulated with precision. The more precise definition reads: a sentence ascribing a property P_1 to an object belongs to the material mode of speech if and only if there is a different syntactic property P_2 parallel to it; and saying that a syntactic property P_2 is parallel to a property P_1 here means that P_2 belongs to the designation of an object if and only if P_1 belongs to the object. In the examples cited, "(being) a designation for a thing" is a syntactic property parallel to the property "(being) a thing" because a designation for something is a designation for a thing if and only if that something is a thing. The sentence "A rose is a thing" belongs therefore to the material mode of speech. It can be translated into the parallel sentence "'Rose' is a designation for a thing" belonging to the formal mode of speech. On the other hand, there is no syntactic property which would be parallel to the property "red" and which would therefore belong to all designations of red things and only to them; for we cannot tell by looking at the designation for a thing (e.g., "rose", "moon") whether the thing is red or not. The sentence "The rose is red" does not therefore belong to the material mode of speech, but is a genuine object sentence.

Let us give a few more examples of sentences in the material mode of speech and their translation into the formal mode.

Material Mode of Speech	*Formal Mode of Speech*
la. The case where A is older than B while B is older than A is impossible	1b. The sentence "A is older than B and B is older than A" is contradictory.

la belongs to the material mode of speech because there is a syntactic property "contradictory" parallel to the property "(logically) impossible". For a sentence that states a case is contradictory if and only if the case it states is impossible. Unlike la, the following is a genuine object sentence: "The case where a husband is 30 years older than his wife occurs rarely"; for there is no syntactic property parallel to the property of occurring rarely.

Like the concept "impossible", the other so-called modal concepts, "possible", "necessary", and "contingent", belong to the material mode of speech.

2a. The fact that the body *a* is now expanding follows with natural necessity from the fact that *a* is being heated.	2b. The sentence "*a* is expanding" is a consequence of the sentence "*a* is being heated" and the laws of physics (those that are accepted at the present time.)
3a. There is no beginning and no end of time.	3b. There is no smallest and no greatest temporal coordinate.
4a. 5 is a number.	4b. '5' is a numeral.

Like sentence 4a, a sentence also belongs to the material mode of speech if it states of something that it is a thing, a property, a relation, a place, a point of time, or the like; the parallel sentence of the formal mode of speech then says that the corresponding designation is a thing designation, a property designation, etc. Unlike sentence 4a, the sentence "5 is a prime number" is a genuine (and in particular a mathematical) object sentence; for there is no syntactic predicate parallel to the predicate "prime number".

The sentences of the material mode of speech create the illusion of a reference to objects where no such reference is made. Hence they lead easily to unclarities and pseudo-problems, even to contradictions. It is therefore advisable to avoid the material mode of speech as much as possible, at least at the decisive points, and to employ instead the formal mode of speech. This enables us to avoid some philosophical pseudo- problems. E.g., we are easily misled by sentences like 4a into asking the pseudo-question "What exactly are *numbers*?", whereas the only question it makes sense to ask is "What syntactic rules hold for *numerals*?" The same applies to the pseudo-questions about the nature of "time", "space", "things", and "contents of experience"; they are replaced by questions about the syntactic character of the corresponding designations: of temporal coordinates, etc.

A further advantage of the formal mode of speech is that it prevents us from overlooking the important fact that *the theses of the logic of science are relative to a language*. Such absolutist theses as "A thing is . . . ", "A number is . . . ", and "There are properties of properties" (or: "There are not"), are here replaced by such theses as "A thing designation . . . " "A number designation . . . ", and "There are second-order predicates" (or: "There are not"). By their obvious reference to language, these theses call our attention to the fact that they are still in need of being supplemented by specifying *to what language* they are supposed to refer. The theses of the logic of science can then be meant either *as assertions* concerning a certain language, which may be given historically or else specified by its rules, or *as proposals* concerning a language to be established (cf. the example of the finitist thesis in n. 7 below).

While the following sentences, 5a and 6a, deal with linguistic expressions, they deal with them materially since they make reference to meaning and sense. It is possible to translate them into the formal mode of speech with the aid of the syntactic concepts defined earlier.

5a. The expressions "mustang" and "wild horse" have the same meaning.

5b. The expressions "mustang" and "wild horse" are synonymous.

6a. The sentences "A is bigger than B" and "B is smaller than A" have the same content (sense.) They say the same thing. They describe the same state of affairs.

6b. The sentences "A is bigger than B" and "B is smaller than B" are equivalent.

4. SCIENCE AS AN INSTRUMENT OF UNIFIED SCIENCE

In the field of the logic of science, different complexes of problems are being worked on at the present time. And it is becoming more and more clear that all questions in this field are syntactic questions. Many current investigations are concerned with the so-called *problem of the foundations of mathematics* and hence with syntactic questions concerning the logico-mathematical part of the language of science (cf. n. 7). Others are concerned with logico-scientific problems of *physics*, that is, with questions concerning the syntactic character of the concepts and laws of physics (cf. n. 8).

Among the most important questions that are being attacked at the present time in the logic of science are questions about the *syntactic relations between the different languages that form part of the language of unified science*. This is the formal way of stating those problems that are usually called, in traditional formulation, problems of the relations between different domains of objects (or even more philosophically, between different modes of being). The main issue here is how to bridge the gap between physics on the one hand and biology, psychology, and sociology on the other.

In investigating the syntactic relations between the languages of biology and physics, we must distinguish two different questions, depending on whether we are dealing with a relation between concepts or with a relation between sentences, especially if we are dealing with a relation between spatio-temporally general sentences, the so- called laws. The first question reads: Can the concepts of the language of biology be incorporated into the language of physics? This question is to be answered in the affirmative. For biological concepts refer to states and processes in bodies and hence to regions of space-time; in particular, these concepts are connected by means of laws with physical concepts and hence with observational concepts. Every sentence of the language of biology can be subjected to empirical verification because from it, together with other sentences already recognized by science, we can derive sentences of the form of observation sentences which we can then confront with the observation sentences we actually have at hand. The second question reads: Are biological *laws* of the same form as the laws of physics? By giving an affirmative answer to the first question, we have also answered the second question in the affirmative. This question must be carefully distinguished from a third question: Are biological laws *derivable* from the laws of physics in the narrower sense, i.e., from those laws that are required for explaining processes in inorganic bodies? This question cannot be answered given the present state of biological research; numerous experimental investigations are still required before it can be decided. The thesis of *vitalism*, even in its modern form ("neovitalism"), contains pseudo-concepts. If we remove them in an effort to lay bare the scientific kernel of the vitalist thesis, we get a negative answer to the third question above. The justifications usually given for this answer, though supposedly conclusive, are in fact wholly inadequate and very far from sufficient for really deciding the question.

As for the *problem of how to bridge the gap between the languages of psychology and physics*, we can ask analogous questions to the ones we asked about the language of biology. The first question is: Can the *concepts* of the language of psychology be incorporated into the language of physics? The thesis of *physicalism* which we are advocating (cf. bibliographical indications below) answers this question in the affirmative. The justification is analogous to the one we gave in the case of biological concepts. For if there were a psychological concept which could not be connected by any laws with the concepts of physics, then a sentence stating something about a person with the aid of this concept could not be verified by another person and would therefore have no scientific application. This answer also yields an affirmative answer to the second question: Can psychological laws be incorporated into the language of physics, and hence, do they have the same character as the laws of physics in the narrower sense? This question must not be confused with the third question: Can psychological laws be *derived* from the laws of physics or at least from the laws of biology? This question is still open today. At the present time we are still far from being able to carry out this kind of derivation. But on the other hand, it also cannot be proved, nor can it even be made the least bit plausible, that such a derivation can never be carried out or that it is in principle excluded.

Physicalism shows in an analogous way that the concepts and sentences of the *language of sociology* can be incorporated into the language of physics. Here, too, the question remains open whether we shall succeed in deriving sociological laws from physical ones in the narrower sense, or at least from biological ones, or even just from psychological ones.

One of the most important tasks for further work in the logic of science will be to carry out the operations that physicalism declares to be possible and to exhibit the syntactic rules for incorporating the different biological, psychological, and sociological concepts into the language of physics. By such an analysis of these concepts we are creating a *unified language* out of these languages. We are thus healing the split that has divided science till now. This split goes back to a mythological origin, and its after-effects can still be felt among present-day scholars. The nuclear concepts involved in the splitting-up of the field of science are surrounded even today by a mysterious halo; the concepts "life", "soul" (or in more careful writers, "mental processes", "mind", "consciousness"), and "objective spirit" (or in more careful writers, "norms" and "national spirit") look as if they belonged to a "higher sphere", as opposed to the "lower sphere" of what is "merely material". The origins of this conception evidently go back to a time when "divine knowledge" was still distinguished from "human knowledge", and things "celestial" from things "terrestrial". If we leave aside the accompanying mythological feelings and look at things from a purely scientific point of view, we see that we are dealing simply with certain empirical differences. In the first case ("life") we are dealing simply with the difference between inorganic and organic processes, where the latter are distinguished from the former by certain empirically ascertainable characteristics, but without there being a sharp boundary between the two; if we like, we can call the processes and bodies of the latter kind "animate" ones, as long as we understand no more by this than the empirical characteristics indicated. In the second case ("soul") we are dealing simply with a way of distinguishing a special class of organic processes; the boundary of this class is not unequivocally fixed and is often drawn in very different ways—and this itself argues against the fundamental significance of the boundary. Given the most comprehensive way of marking out this class, it includes all those processes in an organic body that stand in an especially close relation, on the one hand to processes in the sense organs, and on the other to processes in the motor organs (so that nearly all organic processes are included in this class). Given a narrower demarcation, this class includes only those organic processes that take place in a nervous system or in close connection with one. Given the narrowest demarcation (the so-called "conscious" processes in the narrower sense), this class includes only those processes in an organism (or more precisely, in a nervous system) for which there exists an easily activated disposition to verbal responses. Here, too, there would be no objection to distinguishing a special class of processes marked out in one of these ways and making it the subject of a special investigation. But just as in the case where some physical processes, such as the processes of heat conduction, are marked out and specially investigated, we are dealing only with a boundary drawn for some practical purpose such as division of labour. And the only objection to designating processes of this kind by a special term such as "mental" or "psychic" would be that these and other customary terms are too heavily charged with inappropriate accompanying images and feelings owing to their mythological origins, as indicated above. And finally, what is distinguished in the third case ("spirit") are those processes in organisms and especially in human beings that are involved in group behaviour, whether in the relations within the group or in the relations between one group and another, this group behaviour being conditioned by stimulus-response connections between the individuals of the group. It is easily seen that in all three cases the boundaries are far less sharp than any of the boundaries in physics, like the one between gravitation and electromagnetism. The only reason why such enormous importance has been attached to those differences, why the biggest philosophical problems have been connected with them since antiquity, and why even the special sciences take their basic orientation from them, is that there are great differences in emotional attitudes present in these cases, whereas there are none in the case of the intraphysical boundaries. This is to say nothing about the desirable or undesirable consequences which these emotional reactions have in our practical lives. It is only to call attention to the effect they have of slowing down scientific progress by delaying the insight into the uniform character of scientific concepts. Once this obstacle has been overcome by physicalism, the *logico-scientific analysis of the concepts* of the different branches of science will be able to display with increasing clarity the kinship and the interdependence of these concepts and thus form a *tool for the construction of a unified science* (cf. n. 9).

APPENDIX

Supplementary Remarks and Bibliographical References (the numbers in parentheses following the authors' names refer to the bibliography, pp. 283ff.)

1. THE ELIMINATION OF METAPHYSICS

The view that only mathematical and factual sentences have sense and that the sentences of metaphysics are senseless was already expressed by Hume in its classical form (*An Enquiry into the Human Understanding*, ch. XII, pt. 3): "It seems to me, that the only objects of the abstract science or of demonstration are quantity and number . . . All other inquiries of men regard only matter of fact and existence; and these are evidently incapable of demonstration . . . When we run over libraries, persuaded of these principles, what havoc must we make! If we take in our hand any volume; of divinity or school metaphysics, for instance; let us ask: *Does it contain any abstract reasoning concerning quantity or number*? No. *Does it contain any experimental reasoning concerning matter of fact or existence*? No. Commit it then to the flames; for it can contain nothing but sophistry and illusion."

The elimination of metaphysics and the insight that works on the theory of science are logical, logico-scientific works can be traced back historically to two different lines of development. The first line derives mainly from the anti-idealistic attitude of empiricists, materialists, and positivists; the names to be mentioned here include Hume, the French philosophers of the Enlightenment, the French and German materialists, Mach, Ostwald, Poincaré and Russell. The other line derives from the development of modern logic (see under 3 below); Wittgenstein demonstrated the senselessness of metaphysics by a logical analysis of language; cf. also Carnap (6), Neurath (3), and Hahn (2).

2. CONTEMPORARY LOGIC OF SCIENCE

In order to characterize the field of the logic of science, let us name some researchers working in this field. There is, first, the Vienna Circle (see the bibliographies in Neurath (2) and in *Erkenntnis* **1**, p. 315) whose members outside Vienna include Carnap (Prague), Feigl (Iowa), Frank (Prague), and Neurath (The Hague); related views are held in Vienna by Kraft, Menger, Popper, Ziller, et al.; in Berlin by Dubislaw, Grelling, Hempel, et al.; in the Scandinavian countries by Jørgensen, Kaila, et al.; in Poland by Ajdukiewicz, Chwistek, Kolarbinski, Lesniewski, Lukasiewicz, Tarski, et al. (see the bibliography in *Erkenntnis* **1**, p. 335); in Istanbul by v. Mises and Reichenbach; in Paris by Langevin, Abel Rey, Rougier, et al.; in England by Russell, Stebbing, et al.; and in America by Bridgman, Langford, Lewis, Morris, et al. The following collections belong to the logic of science: *Schriften zur wissenschaftlichen Weltauffassung*, edited by Schlick and Frank (and published by J. Springer, Vienna), *Veröffentlichungen des Vereines Ernst Mach* (published by Arthur Wolf, Vienna), and the present collection, *Einheitswissenschaft.* Further, most of the contributions to the following journals belong to the logic of science: *Erkenntnis* (Leipzig, F. Meiner, since 1930), *Philosophy of Science* (Baltimore, William and Wilkins, since 1934; not always free from metaphysics), *Analysis* (Oxford, Blackwell's, since 1933), and *Studia philosophica* (Lemberg 1934). The "Conferences on the Epistemology of the Exact Sciences" were also devoted to the logic of science: the first in Prague in 1929 (report with bibliography in *Erkenntnis* **1**, 1930), the second in Königsberg in 1930 (report with bibliography in *Erkenntnis* **2**, 1931).

Unfortunately, there is as yet no book that could serve as a first introduction to the whole field of the logic of science; a short survey intelligible to the general reader is given by Neurath (2), (with Carnap and Hahn). For the literature on particular areas of the logic of science, see bibliographical indications below.

3. THE DEVELOPMENT OF LOGICAL SYNTAX

The strictly formal point of view of logical syntax could not be developed before there was a symbolic logic. Modern symbolic logic or *logistics* realizes Leibniz's ideas. Its development began around 1850. The first comprehensive, but now outdated system was created by Frege in 1893. Following him, Russell, Whitehead, and Hilbert made major contributions to the further development of logistics. At the present time, Russell (1) represents the standard work from which all further work begins, whether it tries to continue it or to improve it. A detailed account of the historical development of logistics is given in Jørgensen (1).

Frege was the first and for a long time the only one to carry out a strictly formal treatment, as required by logical syntax. But it was only later that the task of logical syntax as a theory of language was explicitly formulated and that a start was made to carry out this task, this being due mainly to Hilbert ("metamathematics") and the Warsaw logicians ("metalogic"). An exact method was created and applied by Gödel (1). Carnap (11) contains a systematic account of logical syntax and a demonstration showing that the syntax of a language can be formulated without contradiction in the language itself.

For an introduction to logistics, see Hilbert (1) and Carnap (4) (the former is easier to understand, the latter goes in more detail into applications) and further Russell (3) and Behmann (1). The writings cited must also serve provisionally as an introduction to logical syntax, although they were not written from this point of view; an account of syntax intelligible to the general reader is not yet available.

4. EXAMPLES OF THE SYMBOLIC METHOD OF LOGISTICS

Let us, by means of a few hints, give an insight into the methods of logistics. Instead of the words of ordinary language, logistics, like mathematics, employs letters and symbols. Let 'a', 'b', 'c' . . . designate the individual objects of a certain domain of objects. Let 'P', 'Q' . . . designate the properties of those objects. That object a has the property P is usually expressed by the sentence '$P(a)$', and that a does not have the property P by '$\sim P(a)$'. A sentence of the form 'A v B', where 'A' and 'B' stand for any sentences, shall be true if and only if one or both of the two sentences 'A and 'B' are true; the sign 'v' thus corresponds roughly to the English word "or". The sentence '$(x)[P(x)]$' shall be true if and only if the sentences '$P(a)$','P(b)','$P(c)$', etc. are all true; that sentence therefore corresponds to the sentence "Every object has the property P" of the English word language. The sentence '$(Ex)[P(x)]$' shall be true if and only if at least one sentence of the series '$P(a)$', '$P(b)$', etc. is true; that sentence can therefore be translated into this sentence of the English word language: "At least one object has the property P" or: " There is (at least) one object with the property P".

From the meanings of the signs as specified above we can infer the validity of the following *transformation rules*:

1. If we are given two sentences of the form 'A v B' and '$\sim A$', then a sentence of the form 'B' follows from them.

2. From a sentence of the form '$(x)[P(x)]$' we can derive any sentence of the form 'P(—)', where the stroke is replaced by the name of any object; the same holds true if 'P' is replaced by the designation of any other property, provided it is the same one in both sentences.

3. From a sentence of the form 'P(—)', where the stroke is replaced by the designation of any object, there follows (i.e., we can derive) the sentence '$(Ex)[P(x)]$'; likewise for designations of other properties.

Example of a derivation. Let the following two sentences be given as premises: '$(x)[P(x)$ v $Q(x)]$' (1) and '$\sim P(a)$' (2). From (1) follows according to the second rule: '$P(a)$ v $Q(a)'$(3), and from (3) and (2) according to the first rule: '$Q(a)'$. This shows that '$Q(a)'$ is a *consequence* of those two initial sentences. It can be seen that the derivation proceeds in a purely formal way, i.e., we are not concerned with the meanings of the signs, but manipulate the signs by following the rules as it were mechanically and as if we were calculating.

In many cases, the easiest way to carry out the *logical analysis of an expression of a word language* is by comparison with a symbolic language. This is true especially for logical words (as for example "there is", "every", "all", "no", "nothing", "not", "or", "if", "other", "there", "without", "also", and similar words). If we are to give a logical characterization of the English language, we can say, e.g.: the concept of existence, in the sense in which it is symbolized in the symbolic language indicated above by '*(Ex)*' and defined by the third rule given above among other rules, is expressed in the English language by phrases like "There is a . . . ", "There exists a . . . ", or simply by "A . . . " (e.g., in the sentence "I have a pencil" or symbolically: "*(Ex)* [I have x and x is a pencil]"). Such a comparison with a symbolic language with exact rules enables us to give a far sharper characterization of the expressions of the English language than would be possible with the aid of the usual grammatical categories or by translation into another word language.

5. THE CONTRADICTIONS

The Greeks already racked their brains over the problem contained in the liar's sentence, who says: "I am lying" or in other words: "This sentence is false". If this sentence is true, then what it says must be true; and the sentence is therefore false; and conversely, it it is false, it is true. It was thought till now that the contradiction arose from the fact that the sentence talked about itself; to avoid contradictions of this kind, we would have to exclude such self-referring sentences. But this would also be to exclude the possibility of formulating the syntax of a language in the language itself. However, after more exact investigations it was learnt that unrestricted operations with the concepts "true" and "false" also lead to contradictions even if no sentences that talk about themselves are used. The error in the liar's sentence is not therefore its self-reference, but an inadmissible operation with the concepts "true" and "false", which can only be used with special precautions (cf. Carnap (12)). Accordingly, the syntax of the language L can be formulated in the language L itself without the danger of any contradictions arising, and the extent to which it can be formulated depends on how rich the language L is in means of expression, and in particular, on how rich it is in mathematical concepts.

6. THE LOGIC OF SCIENCE AS SYNTAX

Wittgenstein (1) in particular has pointed out the close connection between the logic of science ("philosophy") and syntax, but without regarding the two as identical, as we do. The main difference between our view and Wittgenstein's is the following: Wittgenstein believes that neither syntax nor the logic of science can be formulated in correct sentences. "Philosophy is not a body of doctrine but an activity. A philosophical work consists essentially of elucidations. Philosophy does not result in 'philosophical propositions', but rather in the clarification of propositions" (4.112). "My propositions serve as elucidations in the following way: anyone who understands me eventually recognizes them as nonsensical, when he has used them—as steps—to climb up beyond them" (6.54). Neurath in particular has objected to the necessity of such senseless "elucidations" in (7), pp. 395 ff., and (9), p. 29. Carnap (11) has shown that the logic of science is syntax and can therefore be formulated as exactly as syntax; in the same place, he has given a detailed account of the dangers of the material mode of speech.

Wittgenstein's views have acted in more than one respect as a strong stimulus on the Vienna Circle. The historical lines leading up to his views have been little clarified up to now, because he himself does not cite any sources (except for Frege and Russell). Oskar Kraus (*Wege und Abwege der Philosophie*, Prague 1934, ch. II on B. Russell's *Analysis of Mind*, reprinted from *Archive der gesamten Psychologie* 1930) thinks he can detect a significant influence on Wittgenstein in Brentano's and his pupils', especially Marty's, works in the philosophy of language. On the other hand, one can also recognize the influence of Weyl, who takes the position of intuitionism and who is in turn influenced by Husserl (cf. Carnap (1l), p. 139).

7. THE LOGIC OF SCIENCE OF MATHEMATICS

Questions of the logic of science concerning mathematics, or as they are often called, questions about the "foundations of mathematics", are questions of the syntax of the logico-mathematical part of the language of science. The main distinction to be drawn here is whether we arc dealing with *assertions* about a given mathematical system, e.g., that of classical mathematics, or with *proposals* to set up the language of mathematics in such and such a way. Thus the problem of real numbers for example does not concern some "ideal objects" of a mysterious nature called "real numbers", but simply the syntax of expressions for real numbers either in an already existing mathematical language or in one newly to be set up. The discussion of such problems gains much in clarity if the question is translated from the usual material mode of speech into the formal mode. Let us consider, e.g., thesis la of finitism or intuitionism and its antithesis 2a:

Material Mode of Speech	*Formal Mode of Speech*
1a. Existence always refers to a finite, restricted domain.	1b. There are no unrestricted existential sentences (in such and such a language).
2a. Existence can also refer to an unrestricted domain.	2b. There are also unrestricted existential sentences (in such and such a language).

The material formulation la or 2a is absolutist; it leads one into the error of thinking that the present problem can be considered by itself, without reference to a certain linguistic system. And this gives rise to endless philosophical disputes about "existence". On the other hand, if the two theses are translated into the formal mode of speech, 1b and 2b, one sees at once that they are incomplete and that one must add a specification of a language. The decision between the two theses depends then on this addition. E.g., with reference to the language of classical mathematics, 1b is false and 2b true; with respect to the language of intuitionist mathematics, it is the other way round. If theses lb and 2b are not meant as assertions but as proposals, the dispute vanishes: one sets up two different languages. True, there arise further questions about the syntactic character of these two languages. But these questions are no longer the kind of bottomless philosophical questions associated with the material mode of speech, but rather questions which rest on the firm ground of syntax, which are located within a precisely defined problematic situation, which can be formulated by means of sharp concepts, and which can he treated according to exact methods. The same applies, e.g., to the dispute about the justification of indefinite and especially non-predicative concepts. The question to be asked here is not "Are these concepts meaningful?" but rather formally: "Do we want to incorporate such concepts into our language or not?" Some logicians (especially the intuitionists) reject such concepts; other logicians want to employ them because without them classical mathematics cannot be constructed to its full extent. If the question is displaced onto the level of syntax, one is no longer concerned with "meaningful" and "meaningless", but with the consequences of the introduction or elimination of those concepts, and especially, with securing freedom from contradiction in their employment.

8. THE LOGIC OF SCIENCE OF PHYSICS

One question belonging to the logic of science of physics is whether we are to lay down statistical or deterministic laws in physics; another question is whether in laying down statistical laws we must presuppose that there are deterministic micro-laws underlying the statistical laws. At the present time, one of the most hotly debated problems is one concerning the concept of probability; the question raised concerns the sense of sentences expressing probability and the method of their verification. To formulate this as a formal, syntactic question: given a sentence expressing probability (e.g., "The probability of throwing 5 with the present die is 1/6"), by what rules can we derive other sentences from it? How does this derivation lead to observation sentences (e.g., "I see that the number thrown with the present die is now 5")? What conditions must be satisfied by given observation sentences if we are to be justified in saying that the corresponding sentence expressing a probability has been confirmed by them? Further, the question has been raised whether, as a consequence of Heisenberg's indeterminacy relation, it is not meaningless to speak at the same time of the location and the velocity of a particle; or to formulate it syntactically, whether it does not seem appropriate to change the formation rules of the language of physics in such a way that sentences of a certain form will no longer be admitted.

9. BRIDGE PROBLEMS

It would be profitable to conduct historical investigations to determine at what times and in what circles the *connections between different sciences were emphasized*, and hence, who contributed when to the development of a *unified science*. Neurath in particular has for a long time been stressing the importance of such "bridge problems" and is presently urging our Circle to work on them. The problems in question call for empirical investigations on the one hand and for logical ones on the other. Among the empirical investigations that serve to fill the gaps between adjoining fields of knowledge belong, e.g., physical investigations of biological processes, e.g., of electrical processes inside living cells, and further, physiological investigations of processes in the central nervous system and behaviouristic investigations of certain defects in perception and speech processes etc. Neurath is trying to sum up the results or this research, which was conducted in different places, and by looking at the results from a unified point of view, to fit them into a unified science. Further, he wants to promote the investigation of logical "bridge problems" connected with those empirical findings. Here he is dealing with syntactic questions about the relations between the different languages, and the treatment of these questions has as its goal the construction of a unified physicalistic language of science.