A scientists, whether theorist or experimenter, puts forward statements, or systems of statements, and tests them step by step. In the field of the empirical sciences, more particularly, he constructs hypotheses, or systems of theories, and tests them against experience by observation and experiment.

I suggest that it is the task of the logic of scientific discovery, or the logic of knowledge, to give a logical analysis of this procedure; that is, to analyse the method of the empirical sciences.

But what are these 'methods of the empirical sciences'? And what do we call 'empirical science'?

1. The Problem of Induction.

According to a widely accepted view—to be opposed in this book—the empirical sciences can be characterized by the fact that they use 'inductive methods', as they are called. According to this view, the logic of scientific discovery would be identical with inductive logic, i.e. with the logical analysis of these inductive methods.

It is usual to call an inference 'inductive' if it passes from singular statements (sometimes also called 'particular' statements), such as accounts of the results of observations or experiments, to universal statements, such as hypotheses or theories.

Now it is far from obvious, from a logical point of view, that we are justified in inferring universal statements from singular ones, no matter how numerous; for any conclusion drawn in this way may always turn out to be false: no matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white.
FUNDAMENTAL PROBLEMS

The question whether inductive inferences are justified, or under what conditions, is known as the problem of induction.

The problem of induction may also be formulated as the question of how to establish the truth of universal statements which are based on experience, such as the hypotheses and theoretical systems of the empirical sciences. For many people believe that the truth of these universal statements is ‘known by experience’; yet it is clear that an account of an experience—of an observation or the result of an experiment—in the first place be only a singular statement and not a universal one. Accordingly, people who say of a universal statement that we know its truth from experience usually mean that the truth of this universal statement can somehow be reduced to the truth of singular ones, and that these singular ones are known by experience to be true; which amounts to saying that the universal statement is based on inductive inference. Thus to ask whether there are natural laws known to be true appears to be only another way of asking whether inductive inferences are logically justified.

Yet if we want to find a way of justifying inductive inferences, we must first of all try to establish a principle of induction. A principle of induction would be a statement with the help of which we could put inductive inferences into a logically acceptable form. In the eyes of the upholders of inductive logic, a principle of induction is of supreme importance for scientific method: ‘... this principle’, says Reichenbach, ‘determines the truth of scientific theories. To eliminate it from science would mean nothing less than to deprive science of the power to decide the truth or falsity of its theories. Without it, clearly, science would no longer have the right to distinguish its theories from the fanciful and arbitrary creations of the poet’s mind.’

Now this principle of induction cannot be a purely logical truth like a tautology or an analytic statement. Indeed, if there were such a thing as a purely logical principle of induction, there would be no problem of induction; for in this case, all inductive inferences would have to be regarded as purely logical or tautological transformations, just like inferences in deductive logic. Thus the principle of induction must be a synthetic statement; that is, a statement whose negation is not self-contradictory but logically possible. So the question arises why such a principle should be accepted at all, and how we

I. THE PROBLEM OF INDUCTION

can justify its acceptance on rational grounds.

Some who believe in inductive logic are anxious to point out, with Reichenbach, that ‘the principle of induction is unreservedly accepted by the whole of science and that no man can seriously doubt this principle in everyday life either’. Yet even supposing this were the case—for after all, ‘the whole of science’ might err—I should still contend that a principle of induction is superfluous, and that it must lead to logical inconsistencies.

That inconsistencies may easily arise in connection with the principle of induction should have been clear from the work of Hume; also, that they can be avoided, if at all, only with difficulty. For the principle of induction must be a universal statement in its turn. Thus if we try to regard its truth as known from experience, then the very same problems which occasioned its introduction will arise all over again. To justify it, we should have to employ inductive inferences; and to justify these we should have to assume an inductive principle of a higher order; and so on. Thus the attempt to base the principle of induction on experience breaks down, since it must lead to an infinite regress.

Kant: tried to force his way out of this difficulty by taking the principle of induction (which he formulated as the ‘principle of universal causation’) to be ‘a priori valid’. But I do not think that his ingenious attempt to provide an a priori justification for synthetic statements was successful.

My own view is that the various difficulties of inductive logic here sketched are insurmountable. So also, I fear, are those inherent in the doctrine, so widely current today, that inductive inference, although not ‘strictly valid’, can attain some degree of ‘reliability’ or of ‘probability’. According to this doctrine, inductive inferences are ‘probable inferences’. ‘We have described’, says Reichenbach, ‘the principle of induction as the means whereby science decides upon truth. To be more exact, we should say that it serves to decide upon probability. For it is not given to science to reach either truth or falsity ... but scientific statements can only attain continuous degrees of

1 Reichenbach ibid., p. 67.
2 The decisive passages from Hume are quoted in appendix vii, text to footnotes 5, 6; and 6; see also note 2 to section 81, below.
3 Cf. J. M. Keynes, A Treatise on Probability, 1921; O. Klüpe, Vorlesungen über Logic (ed. by Selz, 1923); Reichenbach (who uses the term ‘probability implications’), Axiomatik der Wahrscheinlichkeitsrechnung, Math. Zeit. 34, 1932; and elsewhere.
probability whose unattainable upper and lower limits are truth and falsity.\footnote{1}`

At this stage I can disregard the fact that the believers in inductive logic entertain an idea of probability that I shall later reject as highly unsuitable for their own purposes (see section 80, below). I can do so because the difficulties mentioned are not even touched by an appeal to probability. For if a certain degree of probability is to be assigned to statements based on inductive inference, then this will have to be justified by invoking a new principle of induction, appropriately modified. And this new principle in its turn will have to be justified, and so on. Nothing is gained, moreover, if the principle of induction, in its turn, is taken not as 'true' but only as 'probable'. In short, like every other form of inductive logic, the logic of probable inference, or 'probability logic', leads either to an infinite regress, or to the doctrine of apriorism.\footnote{2}

The theory to be developed in the following pages stands directly opposed to all attempts to operate with the ideas of inductive logic. It might be described as the theory of the deductive method of testing, or as the view that a hypothesis can only be empirically tested—and only after it has been advanced.

Before I can elaborate this view (which might be called 'deducivism', in contrast to 'inducivism'\footnote{1}) I must first make clear the distinction between the psychology of knowledge which deals with empirical facts, and the logic of knowledge which is concerned only with logical relations. For the belief in inductive logic is largely due to a confusion of psychological problems with epistemological ones. It may be worth noticing, by the way, that this confusion spells trouble not only for the logic of knowledge but for its psychology as well.

\footnote{1} Reichenbach, Erkenntnis 1, 1930, p. 186.
\footnote{2} See also chapter 3, below, especially note 2 to section 81, and chapter iv of the Postscript for a fuller statement of this criticism.

\footnote{1} Liebig (in Induction and Deduction, 1863) was probably the first to reject the inductive method from the standpoint of natural science; his attack is directed against Bacon. Duhem (in La theorie physique, son objet et sa structure, 1906; English translation by P. P. Wiener: The Aim and Structure of Physical Theory, Princeton, 1954) held pronounced deducivist views. (But there are also inductivist views to be found in Duhem's book, for example in the third chapter, Part One, where we are told that only experiment, induction, and generalization have produced Descartes's law of refraction; cf. the English translation, p. 34.) See also V. Kraft, Die Grundformen der Wissenschaftlichen Methoden, 1925; and Carnap, Erkenntnis 2, 1932, p. 440.
3. Testing Theories

According to the view that will be put forward here, the method of critically testing theories, and selecting them according to the results of tests, always proceeds on the following lines. From a new idea, put up tentatively, and not yet justified in any way—an anticipation, a hypothesis, a theoretical system, or what you will—conclusions are drawn by means of logical deduction. These conclusions are then compared with one another and with other relevant statements, so as to find what logical relations (such as equivalence, derivability, compatibility, or incompatibility) exist between them.

We may if we like distinguish four different lines along which the testing of a theory could be carried out. First there is the logical comparison of the conclusions among themselves, by which the internal consistency of the system is tested. Secondly, there is the investigation of the logical form of the theory, with the object of determining whether it has the character of an empirical or scientific theory, or whether it is, for example, tautological. Thirdly, there is the com-

1 Address on Max Planck's 60th birthday. The passage quoted begins with the words, 'The supreme task of the physicist is to search for those highly universal laws... etc. (quoted from A. Einstein, Mein Weltbild, 1934, p. 168; English translation by A. Harris: The World as I see It, 1935, p. 125). Similar ideas are found earlier in Liebig, op. cit.; cf. also Mach, Principien der Wärmerechnung, 1860, pp. 444 ff. * The German word 'Einfühlung' is difficult to translate. Harris translates: 'sympathetic understanding of experience'.

parison with other theories, chiefly with the aim of determining whether the theory would constitute a scientific advance should it survive our various tests. And finally, there is the testing of the theory by way of empirical applications of the conclusions which can be derived from it.

The purpose of this last kind of test is to find out how far the new consequences of the theory—whatever may be new in what it asserts—stand up to the demands of practice, whether raised by purely scientific experiments, or by practical technological applications. Here too the procedure of testing turns out to be deductive. With the help of other statements, previously accepted, certain singular statements—which we may call 'predictions'—are deduced from the theory; especially predictions that are easily testable or applicable. From among these statements, those are selected which are not derivable from the current theory, and more especially those which the current theory contradicts. Next we seek a decision as regards these (and other) derived statements by comparing them with the results of practical applications and experiments. If this decision is positive, that is, if the singular conclusions turn out to be acceptable, or verified, then the theory has, for the time being, passed its test: we have found no reason to discard it. But if the decision is negative, or in other words, if the conclusions have been falsified, then their falsification also falsifies the theory from which they were logically deduced.

It should be noticed that a positive decision can only temporarily support the theory, for subsequent negative decisions may always overthrow it. So long as a theory withstands detailed and severe tests and is not superseded by another theory in the course of scientific progress, we may say that it has 'proved its mettle' or that it is 'corroborated' by past experience.

Nothing resembling inductive logic appears in the procedure here outlined. I never assume that we can argue from the truth of singular statements to the truth of theories. I never assume that by force of 'verified' conclusions, theories can be established as 'true', or even as merely 'probable'.

In this book I intend to give a more detailed analysis of the methods of deductive testing. And I shall attempt to show that, within the framework of this analysis, all the problems can be dealt

*1 For this term, see note *1 before section 79, and section 29 of my Postscript.
FUNDAMENTAL PROBLEMS

with that are usually called 'epistemological'. Those problems, more especially, to which inductive logic gives rise, can be eliminated without creating new ones in their place.

4. The Problem of Demarcation.

Of the many objections which are likely to be raised against the view here advanced, the most serious is perhaps the following. In rejecting the method of induction, it may be said, I deprive empirical science of what appears to be its most important characteristic; and this means that I remove the barriers which separate science from metaphysical speculation. My reply to this objection is that my main reason for rejecting inductive logic is precisely that it does not provide a suitable distinguishing mark of the empirical, non-metaphysical, character of a theoretical system; or in other words, that it does not provide a suitable 'criterion of demarcation'.

The problem of finding a criterion which would enable us to distinguish between the empirical sciences on the one hand, and mathematics and logic as well as 'metaphysical' systems on the other, I call the problem of demarcation.1

This problem was known to Hume who attempted to solve it.2 If, following Kant, we call the problem of induction 'Hume's problem', we might call the problem of demarcation 'Kant's problem'.

Of these two problems—the source of nearly all the other problems of the theory of knowledge—the problem of demarcation is, I think, the more fundamental. Indeed, the main reason why epistemologists with empiricist leanings tend to pin their faith to the 'method of induction' seems to be their belief that this method alone can provide a suitable criterion of demarcation. This applies especially to those empiricists who follow the flag of 'positivism'.

The older positivists wished to admit, as scientific or legitimate, only those concepts (or notions or ideas) which were, as they put it, 'derived from experience'; those concepts, that is, which they believed to be logically reducible to elements of sense-experience, such as sensations (or sense-data), impressions, perceptions, visual or auditory

memories, and so forth. Modern positivists are apt to see more clearly that science is not a system of concepts but rather a system of statements.3 Accordingly, they wish to admit, as scientific or legitimate, only those statements which are reducible to elementary (or 'atomic') statements of experience—to 'judgments of perception' or 'atomic propositions' or 'protocol-sentences' or what not.4 It is clear that the implied criterion of demarcation is identical with the demand for an inductive logic.

Since I reject inductive logic I must also reject all these attempts to solve the problem of demarcation. With this rejection, the problem of demarcation gains in importance for the present inquiry. Finding an acceptable criterion of demarcation must be a crucial task for any epistemology which does not accept inductive logic.

Positivists usually interpret the problem of demarcation in a naturalistic way; they interpret it as if it were a problem of natural science. Instead of taking it as their task to propose a suitable convention, they believe they have to discover a difference, existing in the nature of things, as it were, between empirical science on the one hand and metaphysics on the other. They are constantly trying to prove that metaphysics by its very nature is nothing but nonsensical twaddle—'sophistry and illusion', as Hume says, which we should 'commit to the flames'.5

If by the words 'nonsensical' or 'meaningless' we wish to express no more, by definition, than 'not belonging to empirical science', then the characterization of metaphysics as meaningless nonsense would be trivial; for metaphysics has usually been defined as non-empirical. But of course, the positivists believe they can say much more about metaphysics than that some of its statements are non-

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1 With this (and also with sections 1 to 6 and 13 to 24) compare my note in Erkenntnis 3, 1933, p. 426; it is now here reprinted, in translation, in appendix 4.

2 Cf. the last sentence of his Enquiry Concerning Human Understanding. *With the next paragraph (and my allusion to epistemologists) compare for example the quotation from Reichenbach in the text to note 1, section 1.

3 When I wrote this paragraph I overrated the 'modern positivists', as I now see. I should have remembered that in this respect the promising beginning of Wittgenstein's Tractatus—'The world is the totality of facts, not of things'—was cancelled by its end which denounced the man who 'had given no meaning to certain signs in his propositions'. See also my Open Society and its Enemies, chapter 11, section ii, and chapter 4 of my Postscript, especially sections 11 (note 3), 24 (the last five paragraphs), and 25.

4 Nothing depends on names, of course. When I invented the new name 'basic statement' (or 'basic proposition'); see below, sections 7 and 28) I did so only because I needed a term not burdened with the connotation of a perceptual statement. But unfortunately it was soon adopted by others, and used to convey precisely the kind of meaning which I wished to avoid. Cf. also my Postscript, 20.

5 Thus Hume, like Sextus condemned his own Enquiry on its last page; just as later Wittgenstein condemned his own Tractatus on its last page. (See note 2 to section 10.)
FUNDAMENTAL PROBLEMS

The words 'meaningless' or 'nonsensical' convey, and are meant to convey, a derogatory evaluation; and there is no doubt that what the positivists really want to achieve is not so much a successful demarcation as the final overthrow and the annihilation of metaphysics. However this may be, we find that each time the positivists tried to say more clearly what 'meaningful' meant, the attempt led to the same result—to a definition of 'meaningful sentence' (in contradistinction to 'meaningless pseudo-sentence') which simply reiterated the criterion of demarcation of their inductive logic.

This shows itself very clearly in the case of Wittgenstein, according to whom every meaningful proposition must be logically reducible to elementary (or atomic) propositions, which he characterizes as descriptions or 'pictures of reality' (a characterization, by the way, which is to cover all meaningful propositions). We may see from this that Wittgenstein's criterion of meaningfulness coincides with the inductivists' criterion of demarcation, provided we replace their words 'scientific' or 'legitimate' by 'meaningful'. And it is precisely over the problem of induction that this attempt to solve the problem of demarcation comes to grief: positivists, in their anxiety to annihilate metaphysics, annihilate natural science along with it. For scientific laws, too, cannot be logically reduced to elementary statements of experience. If consistently applied, Wittgenstein's criterion of meaningfulness rejects as meaningless those natural laws the search for which, as Einstein says, is 'the supreme task of the physicist': they can never be accepted as genuine or legitimate statements. Wittgenstein's attempt to unmask the problem of induction as an empty pseudo-proposition was formulated by Schlick in the following words:

4. THE PROBLEM OF DEMARCATION

'The problem of induction consists in asking for a logical justification of universal statements about reality . . . We recognize, with Hume, that there is no such logical justification: there can be none, simply because they are not genuine statements.'

This shows how the inductivistic criterion of demarcation fails to draw a dividing line between scientific and metaphysical systems, and why it must accord them equal status; for the verdict of the positivist dogma of meaning is that both are systems of meaningless pseudo-statements. Thus instead of eradicating metaphysics from the empirical sciences, positivism leads to the invasion of metaphysics into the scientific realm.

In contrast to these anti-metaphysical stratagems—anti-metaphysical in intention, that is—my business, as I see it, is not to bring about the overthrow of metaphysics. It is, rather, to formulate a suitable characterization of empirical science, or to define the concepts 'empirical science' and 'metaphysics' in such a way that we shall be able to say of a given system of statements whether or not its closer study is the concern of empirical science.

My criterion of demarcation will accordingly have to be regarded as a proposal for an agreement or convention. As to the suitability of any such convention opinions may differ; and a reasonable discussion of these questions is only possible between parties having some purpose in common. The choice of that purpose must, of course, be ultimately a matter of decision, going beyond rational argument.

Thus anyone who envisages a system of absolutely certain, irrevocably true statements as the end and purpose of science will certainly reject the proposals I shall make here. And so will those

8 Carnap, Erkenntnis 2, 1932, pp. 219 ff. Earlier Mill had used the word 'meaningless' in a similar way, *no doubt under the influence of Comte; cf. Comte's Early Essays on Social Philosophy, ed. by H. D. Hurton, 1941, p. 223. See also my Open Society, note 51 to chapter 11.

9 Wittgenstein, Tractatus Logico-Philosophicus (1918 and 1922). Proposition 5. *As this was written in 1934, I am dealing here of course only with the Tractatus.

10 Schlick, Naturalwissenschaften 19, 1931, p. 156. (The italics are mine.) Regarding natural laws Schlick writes (p. 155), "It has often been remarked that, strictly, we can never speak of an absolute verification of a law, since we always, so to speak, tacitly make the reservation that it may be modified in the light of further experience. If I may add, by way of parenthesis, Schlick continues, 'a few words on the logical situation, the above-mentioned fact means that a natural law, in principle, does not have the logical character of a statement, but is, rather, a prescription for the formation of statements.' (Formulation' no doubt was meant to include transformation or derivation.) Schlick attributed this theory to a personal communication of Wittgenstein's. See also section 12 of my Postscript.


12 I believe that a reasonable discussion is always possible between parties interested in truth, and ready to pay attention to each other. (Cf. my Open Society, chapter 24.)

13 This is Duhder's view; cf. note 1 to section 19.

36
FUNDAMENTAL PROBLEMS

who see 'the essence of science... in its dignity', which they think resides in its 'wholeness' and its 'real truth and essentiality'.

They will hardly be ready to grant this dignity to modern theoretical physics in which I and others see the most complete realization to date of what I call 'empirical science'.

The aims of science which I have in mind are different. I do not try to justify them, however, by representing them as the true or the essential aims of science. This would only distort the issue, and it would mean a relapse into positivist dogmatism. There is only one way, as far as I can see, of arguing rationally in support of my proposals. This is to analyse their logical consequences: to point out their fertility—their power to elucidate the problems of the theory of knowledge.

Thus I freely admit that in arriving at my proposals I have been guided, in the last analysis, by value judgments and predilections. But I hope that my proposals may be acceptable to those who value not only logical rigour but also freedom from dogmatism; who seek practical applicability, but are even more attracted by the adventure of science, and by discoveries which again and again confront us with new and unexpected questions, challenging us to try out new and hitherto undreamed-of answers.

The fact that value judgments influence my proposals does not mean that I am making the mistake of which I have accused the positivists—that of trying to kill metaphysics by calling it names. I do not even go so far as to assert that metaphysics has no value for empirical science. For it cannot be denied that along with metaphysical ideas which have obstructed the advance of science there have been others—such as speculative atomism—which have aided it. And looking at the matter from the psychological angle, I am inclined to think that scientific discovery is impossible without faith in ideas which are of a purely speculative kind, and sometimes even quite hazy; a faith which is completely unwarranted from the point of view of science, and which, to that extent, is 'metaphysical'.

Yet having issued all these warnings, I still take it to be the first task of the logic of knowledge to put forward a concept of empirical science, in order to make linguistic usage, now somewhat uncertain,

10 This is the view of O. Spann (Kategorienlehre, 1924).
11 Cf. also: Planck, Positivismus und reale Wissenschaft (1931) and Einstein, Die Relativität der Forschung, in Mein Weltbild, 1934, p. 43; English translation by A. Harris: The World as I See It, 1935, pp. 23 ff. *See also section 85, and my Postscript.

5. EXPERIENCE AS A METHOD

as definite as possible, and in order to draw a clear line of demarcation between science and metaphysical ideas—even though these ideas may have furthered the advance of science throughout its history.

5. Experience as a Method.

The task of formulating an acceptable definition of the idea of an 'empirical science' is not without its difficulties. Some of these arise from the fact that there must be many theoretical systems with a logical structure very similar to the one which at any particular time is the accepted system of empirical science. This situation is sometimes described by saying that there is a great number—presumably an infinite number—of 'logically possible worlds'. Yet the system called 'empirical science' is intended to represent only one world: the 'real world' or the 'world of our experience'.

In order to make this idea a little more precise, we may distinguish three requirements which our empirical theoretical system will have to satisfy. First, it must be synthetic, so that it may represent a non-contradictory, a possible world. Secondly, it must satisfy the criterion of demarcation (cf. sections 6 and 21), i.e. it must not be metaphysical, but must represent a world of possible experience. Thirdly, it must be a system distinguished in some way from other such systems as the one which represents our world of experience.

But how is the system that represents our world of experience to be distinguished? The answer is: by the fact that it has been submitted to tests, and has stood up > tests. This means that it is to be distinguished by applying to it that deductive method which it is my aim to analyse, and to describe.

'Experience', on this view, appears as a distinctive method whereby one theoretical system may be distinguished from others; so that empirical science seems to be characterized not only by its logical form but, in addition, by its distinctive method. (This, of course, is also the view of the inductivists, who try to characterize empirical science by its use of the inductive method.)

The theory of knowledge, whose task is the analysis of the method or procedure peculiar to empirical science, may accordingly be described as a theory of the empirical method—a theory of what is usually called 'experience'.

* Cf. appendix x.

39
6. **Falsifiability as a Criterion of Demarcation.**

The criterion of demarcation inherent in inductive logic—that is, the positivistic dogma of meaning—is equivalent to the requirement that all the statements of empirical science (or all 'meaningful' statements) must be capable of being finally decided, with respect to their truth and falsity; we shall say that they must be 'conclusively decidable'. This means that their form must be such that to verify them and to falsify them must both be logically possible. Thus Schlick says: '... a genuine statement must be capable of conclusively verification', and Waismann says still more clearly: 'If there is no possible way to determine whether a statement is true then that statement has no meaning whatsoever. For the meaning of a statement is the method of its verification.'

Now in my view there is no such thing as induction. Thus inference to theories, from singular statements which are 'verified by experience' (whatever that may mean), is logically inadmissible. Theories are, therefore, never empirically verifiable. If we wish to avoid the positivist's mistake of eliminating, by our criterion of demarcation, the theoretical systems of natural science, then we must choose a criterion which allows us to admit to the domain of empirical science even statements which cannot be verified.

But I shall certainly admit a system as empirical or scientific only if it is capable of being tested by experience. These considerations suggest that not the verifiability but the falsifiability of a system is to be taken as a criterion of demarcation. In other words: I shall not

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**6. Falsifiability and Demarcation**

require of a scientific system that it shall be capable of being singled out, once and for all, in a positive sense; but I shall require that its logical form shall be such that it can be singled out, by means of empirical tests, in a negative sense: it must be possible for an empirical scientific system to be refuted by experience.

(Thus the statement, 'It will rain or not rain here tomorrow' will not be regarded as empirical, simply because it cannot be refuted; whereas the statement, 'It will rain here tomorrow' will be regarded as empirical.)

Various objections might be raised against the criterion of demarcation here proposed. In the first place, it may well seem somewhat wrong-headed to suggest that science, which is supposed to give us positive information, should be characterized as satisfying a negative requirement such as refutability. However, I shall show, in sections 31 to 46, that this objection has little weight, since the amount of positive information about the world which is conveyed by a scientific statement is the greater the more likely it is to clash, because of its logical character, with possible singular statements. (Not for nothing do we call the laws of nature 'laws': the more they prohibit the more they say.)

Again, the attempt might be made to turn against me my own criticism of the inductivist criterion of demarcation; for it might seem that objections can be raised against falsifiability as a criterion of demarcation similar to those which I myself raised against verifiability.

This attack would not disturb me. My proposal is based upon an asymmetry between verifiability and falsifiability; an asymmetry which results from the logical form of universal statements. For these are never derivable from singular statements, but can be contradicted by singular statements. Consequently it is possible by means of purely deductive inferences (with the help of the *modus tollens* of classical logic) to argue from the truth of singular statements to the falsity of universal statements. Such an argument to the falsity of universal statements is the only strictly deductive kind of inference that proceeds, as it were, in the 'inductive direction'; that is, from singular to universal statements.

A third objection may seem more serious. It might be said that

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1 Schlick, *Naturwissenschaften* 19, 1931, p. 150.


3 I am not, of course, here considering so-called 'mathematical induction'. What I am denying is that there is such a thing as induction in the so-called 'inductive sciences': that there are either 'inductive procedures' or 'inductive inferences'.

4 In his *Logical Syntax* (1937, pp. 321 f.) Carnap admitted that this was a mistake (with a reference to my criticism); and he did so even more fully in *Testability and Meaning*, recognizing the fact that universal laws are not only 'convenient' for science but even 'essential' (Philosophy of Science 4, 1937, p. 77). But in his inductivist *Logical Foundations of Probability* (1950), he returns to a position very like the one here criticized: finding that universal laws have zero probability (p. 51), he is compelled to say (p. 575) that though they need not be expelled from science, science can very well do without them.

5 Note that I suggest falsifiability as a criterion of demarcation, but not of meaning.

Note, moreover, that I have already (section 4) sharply criticized the use of the idea of meaning as a criterion of demarcation, and that I attack the dogma of meaning again, even more sharply, in section 9. It is therefore a sheer myth (though any number of repetitions of my theory have been based upon this myth) that I ever proposed falsifiability as a criterion of meaning. Falsifiability separates two kinds of perfectly meaningful statements: the falsifiable and the non-falsifiable. It draws a line inside meaningful language, not around it. See also appendix 1, and chapter 1 of my *Postscript*, especially sections 17 and 19.

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**40**
even if the asymmetry is admitted, it is still impossible, for various reasons, that any theoretical system should ever be conclusively falsified. For it is always possible to find some way of evading falsification, for example by introducing *ad hoc* an auxiliary hypothesis, or by changing *ad hoc* a definition. It is even possible without logical inconsistency to adopt the position of simply refusing to acknowledge any falsifying experience whatsoever. Admittedly, scientists do not usually proceed in this way, but logically such procedure is possible; and this fact, it might be claimed, makes the logical value of my proposed criterion of demarcation dubious, to say the least.

I must admit the justice of this criticism; but I need not therefore withdraw my proposal to adopt falsifiability as a criterion of demarcation. For I am going to propose (in sections 20–f.) that the *empirical method* shall be characterized as a method that excludes precisely those ways of evading falsification which, as my imaginary critic rightly insists, are logically possible. According to my proposal, what characterizes the empirical method is its manner of exposing to falsification, in every conceivable way, the system to be tested. Its aim is not to save the lives of untenable systems but, on the contrary, to select the one which is by comparison the fittest, by exposing them all to the fiercest struggle for survival.

The proposed criterion of demarcation also leads us to a solution of Hume’s problem of induction—of the problem of the validity of natural laws. The root of this problem is the apparent contradiction between what may be called ‘the fundamental thesis of empiricism’—the thesis that experience alone can decide upon the truth or falsity of scientific statements—and Hume’s realization of the inadmissibility of inductive arguments. This contradiction arises only if it is assumed that all empirical scientific statements must be ‘conclusively decidable’, i.e. that their verification and their falsification must both in principle be possible. If we renounce this requirement and admit as empirical also statements which are decidable in one sense only—unilaterally decidable and, more especially, falsifiable—and which may be tested by systematic attempts to falsify them, the contradiction disappears: the method of falsification presupposes no inductive inference, but only the tautological transformations of deductive logic whose validity is not in dispute.\(^4\)

\(^4\) For this see also my paper mentioned in note 1 to section 4, now here reprinted in appendix *a*; and my Postscript, esp. section *a*.

7. The Problem of the 'Empirical Basis'.

If falsifiability is to be at all applicable as a criterion of demarcation, then singular statements must be available which can serve as premises in falsifying inferences. Our criterion therefore appears only to shift the problem—to lead us back from the question of the empirical character of theories to the question of the empirical character of singular statements.

Yet even so, something has been gained. For in the practice of scientific research, demarcation is sometimes of immediate urgency in connection with theoretical systems, whereas in connection with singular statements, doubt as to their empirical character rarely arises. It is true that errors of observation occur and that they give rise to false singular statements, but the scientist scarcely ever has occasion to describe a singular statement as non-empirical or metaphysical.

Problems of the empirical basis—that is, problems concerning the empirical character of singular statements, and how they are tested—thus play a part within the logic of science that differs somewhat from that played by most of the other problems which will concern us. For most of these stand in close relation to the *practice* of research, whilst the problem of the empirical basis belongs almost exclusively to the *theory* of knowledge. I shall have to deal with them, however, since they have given rise to many obscurities. This is especially true of the relation between perceptual experiences and *basic statements*. (What I call a ‘basic statement’ or a ‘basic proposition’ is a statement which can serve as a premise in an empirical falsification; in brief, a statement of a singular fact.)

Perceptual experiences have often been regarded as providing a kind of justification for basic statements. It was held that these statements are ‘based upon’ these experiences; that their truth becomes *manifest by inspection* through these experiences, or that it is made ‘evident’ by these experiences, etc. All these expressions exhibit the perfectly sound tendency to emphasize the close connection between basic statements and our perceptual experiences. Yet it was also rightly felt that statements can be logically justified only by statements. Thus the connection between the perceptions and the statements remained obscure, and was described by correspondingly obscure expressions which elucidated nothing, but slurred over the difficulties or, at best, adumbrated them through metaphors.
8. Scientific Objectivity and Subjective Conviction.

The words 'objective' and 'subjective' are philosophical terms heavily burdened with a heritage of contradictory usages and of inconclusive and interminable discussions.

My use of the terms 'objective' and 'subjective' is not unlike Kant's. He uses the word 'objective' to indicate that scientific knowledge should be justifiable, independently of anybody's whim: a justification is 'objective' if in principle it can be tested and understood by anybody. 'If something is valid', he writes, 'for anybody in possession of his reason, then its grounds are objective and sufficient.'

Now I hold that scientific theories are never fully justifiable or verifiable, but that they are nevertheless testable. I shall therefore say that the objectivity of scientific statements lies in the fact that they can be inter-subjectively tested.

The word 'subjective' is applied by Kant to our feelings of conviction (of varying degrees). To examine how these come about


2 I have since generalized this formulation; for inter-subjective testing is merely a very important aspect of the more general idea of inter-subjective criticism, or in other words, of the idea of mutual rational control by critical discussion. This more general idea, discussed at some length in *Open Society and Its Enemies*, chapters 23 and 24, and in my *Poverty of Historicism*, section 32, is also discussed in my *Postscript*, especially in chapters i, ii, and vi.

8. Scientific Objectivity

is the business of psychology. They may arise, for example, 'in accordance with the laws of association.' Objective reasons too may serve as 'subjective causes of judging,' in so far as we may reflect upon these reasons, and become convinced of their cogency.

Kant was perhaps the first to realize that the objectivity of scientific statements is closely connected with the construction of theories—with the use of hypotheses and universal statements. Only when certain events recur in accordance with rules or regularities, as is the case with repeatable experiments, can our observations be tested—in principle—by anyone. We do not take even our own observations quite seriously, or accept them as scientific observations, until we have repeated and tested them. Only by such repetitions can we convince ourselves that we are not dealing with a mere isolated 'coincidence', but with events which, on account of their regularity and reproducibility, are in principle inter-subjectively testable.

Every experimental physicist knows those surprising and inexplicable apparent 'effects' which in his laboratory can perhaps even be reproduced for some time, but which finally disappear without trace. Of course, no physicist would say in such a case that he had made a scientific discovery (though he might try to rearrange his experiments so as to make the effect reproducible). Indeed the scientifically significant physical effect may be defined as that which can be regularly reproduced by anyone who carries out the appropriate experiment in the way prescribed. No serious physicist would offer for publication, as a scientific discovery, any such 'occult effect', as I propose to call it—one for whose reproduction he could give no instructions. The 'discovery' would be only too soon rejected as chimerical, simply because attempts to test it would lead to negative


* Kant realized that from the required objectivity of scientific statements it follows that they must be at any time inter-subjectively testable, and that they must therefore have the form of universal laws or theories. He formulated this discovery somewhat obscurely by his 'principle of temporal succession according to the law of causality' (which principle he believed that he could prove a priori by employing the reasoning here indicated). I do not postulate any such principle (if, section 12); but I agree that scientific statements, since they must be inter-subjectively testable, must always have the character of universal hypotheses. * See also note * i to section 22.
FUNDAMENTAL PROBLEMS

8. SCIENTIFIC OBJECTIVITY

results. (It follows that any controversy over the question whether events which are in principle unrepeatable and unique ever do occur cannot be decided by science: it would be a metaphysical controversy.)

We may now return to a point made in the previous section: to my thesis that a subjective experience, or a feeling of conviction, can never justify a scientific statement, and that within science it can play no part except that of an object of an empirical (a psychological) inquiry. No matter how intense a feeling of conviction it may be, it can never justify a statement. Thus I may be utterly convinced of the truth of a statement; certain of the evidence of my perceptions; overwhelmed by the intensity of my experience: every doubt may seem to me absurd. But does this afford the slightest reason for science to accept my statement? Can any statement be justified by the fact that K. R. P. is utterly convinced of its truth? The answer is, 'No'; and any other answer would be incompatible with the idea of scientific objectivity. Even the fact, for me so firmly established, that I am experiencing this feeling of conviction, cannot appear within the field of objective science except in the form of a psychological hypothesis which, of course, calls for inter-subjective testing; from the conjecture that I have this feeling of conviction the psychologist may deduce, with the help of psychological and other theories, certain predictions about my behaviour; and these may be confirmed or refuted in the course of experimental tests. But from the epistemological point of view, it is quite irrelevant whether my feeling of conviction was strong or weak; whether it came from a strong or even irresistible impression of indubitable certainty (or 'self-evidence'), or merely from a doubtfully surmise. None of this has any bearing on the question of how scientific statements can be justified.

Considerations like these do not of course provide an answer to the problem of the empirical basis. But at least they help us to see its main difficulty. In demanding objectivity for basic statements as well as for other scientific statements, we deprive ourselves of any logical means by which we might have hoped to reduce the truth of scientific statements to our experiences. Moreover we debar ourselves from granting any favoured status to statements which describe experiences, such as those statements which describe our perceptions (and which are sometimes called 'protocol sentences'). They can occur in science only as psychological statements; and this means, as hypotheses of a kind whose standards of inter-subjective testing (considering the present state of psychology) are certainly not very high.

Whatever may be our eventual answer to the question of the empirical basis, one thing must be clear: if we adhere to our demand that scientific statements must be objective, then those statements which belong to the empirical basis of science must also be objective, i.e. inter-subjectively testable. Yet inter-subjective testability always implies that, from the statements which are to be tested, other testable statements can be deduced. Thus if the basic statements in their turn are to be inter-subjectively testable, there can be no ultimate statements in science: there can be no statements in science which cannot be tested, and therefore none which cannot in principle be refuted, by falsifying some of the conclusions which can be deduced from them.

We thus arrive at the following view. Systems of theories are tested by deducing from them statements of a lesser level of universality. These statements in their turn, since they are to be inter-subjectively testable, must be testable in like manner—and so ad infinitum.

It might be thought that this view leads to an infinite regress, and that it is therefore untenable. In section 1, when criticizing induction, I raised the objection that it may lead to an infinite regress; and it might well appeal to the reader now that the very same objection can be urged against that procedure of deductive testing which I myself advocate. However, this is not so. The deductive method of testing cannot establish or justify the statements which are being tested; nor is it intended to do so. Thus there is no danger of an infinite regress. But it must be admitted that the situation to which I have drawn attention—testability ad infinitum and the absence of ultimate statements which are not in need of tests—does create a problem. For, clearly, tests cannot in fact be carried on ad infinitum: sooner or later we have to stop. Without discussing this problem here in detail, I only wish to point out that the fact that the tests cannot go on for ever does not clash with my demand that every
scientific statement must be testable. For I do not demand that every scientific statement must have in fact been tested before it is accepted. I only demand that every such statement must be capable of being tested; or in other words, I refuse to accept the view that there are statements in science which we have, resignedly, to accept as true merely because it does not seem possible, for logical reasons, to test them.

CHAPTER III

THEORIES

The empirical sciences are systems of theories. The logic of scientific knowledge can therefore be described as a theory of theories.

Scientific theories are universal statements. Like all linguistic representations they are systems of signs or symbols. Thus I do not think it helpful to express the difference between universal theories and singular statements by saying that the latter are 'concrete' whereas theories are merely symbolic formulæ or symbolic schemata; for exactly the same may be said of even the most 'concrete' statements.

Theories are nets cast to catch what we call 'the world': to rationalize, to explain, and to master it. We endeavour to make the mesh ever finer and finer.


To give a causal explanation of an event means to deduce a statement which describes it, using as premises of the deduction one or more universal laws, together with certain singular statements, the initial conditions. For example, we can say that we have given a causal

*81 This is a critical allusion to a view which I later described as 'instrumentalism' and which was represented in Vienna by Mach, Wittgenstein, and Schlick (cf. notes *4 and 7 to section 4, and note 3 to section 27). It is the view that a theory is nothing but a tool or an instrument for prediction. I have analysed and criticized it in my papers 'A Note on Berkeley as a Precursor of Mach', Brit. Journ. Philos. Science 6, 1933, pp. 26 ff.; 'Three Views Concerning Human Knowledge', in Contemporary British Philosophy in, 1956, edited by H. D. Lewis, pp. 355 ff.; and more fully in my Postscript, sections *11 to *15 and *19 to *26. My point of view is, briefly, that our ordinary language is full of theories; that observation is always observation in the light of theories; that it is only the inductivist prejudice which leads people to think that the evidence for a phenomenal language, free of theories, and distinguishable from a 'theoretical language', and lastly, that the theorist is interested in explanation as such, that is to say, in testable explanatory theories: applications and predictions interest him only for theoretical reasons—because they may be used as tests of theories. See also the new appendix *8.
Theories

explanation of the breaking of a certain piece of thread if we have found that the thread has a tensile strength of 1 lb. and that a weight of 2 lbs. was put on it. If we analyse this causal explanation we shall find several constituent parts. On the one hand there is the hypothesis: 'Whenever a thread is loaded with a weight exceeding that which characterizes the tensile strength of the thread, then it will break'; a statement which has the character of a universal law of nature. On the other hand we have singular statements (in this case two) which apply only to the specific event in question: 'The weight characteristic for this thread is 1 lb.', and 'The weight put on this thread was 2 lbs.'

We have thus two different kinds of statement, both of which are necessary ingredients of a complete causal explanation. They are (i) universal statements, i.e. hypotheses of the character of natural laws, and (2) singular statements, which apply to the specific event in question and which I shall call 'initial conditions'. It is from universal statements in conjunction with initial conditions that we deduce the singular statement, 'This thread will break'. We call this statement a specific or singular prediction.

The initial conditions describe what is usually called the 'cause' of the event in question. (The fact that a load of 2 lbs. was put on a thread with a tensile strength of 1 lb. was the 'cause' of its breaking.) And the prediction describes what is usually called the 'effect'. Both these terms I shall avoid. In physics the use of the expression 'causal explanation' is restricted as a rule to the special case in which the universal laws have the form of laws of 'action by contact'; or more precisely, of action at a vanishing distance, expressed by differential equations. This restriction will not be assumed here. Furthermore, I shall not make any general assertion as to the universal applicability of this deductive method of theoretical explanation. Thus I shall not assert any 'principle of causality' (or 'principle of universal causation').

1 The idea of regarding the principle of causality as the expression of a rule or of a decision is due to H. Gomperz, Das Problem der Willensfreiheit, 1907. Cf. Schlick, Die Kausalität in der gegenwärtigen Physik, Naturwissenschaften, 1931, p. 154.

2 I feel that I should say here more explicitly that the decision to search for causal explanation is that by which the theoretician adopts his aim—or the aim of theoretical science. His aim is to find explanatory theories (if possible, true explanatory theories); that is to say, theories which describe certain structural properties of the world, and which permit us to deduce, with the help of initial conditions, the effects to be explained. It was the purpose of the present section to explain, if only very briefly, what we mean by causal explanation. A somewhat fuller statement will be found in appendix 5, and in my Postscript, section 12. My explanation of explanation has been adopted in the text of the present work. The reader will find in it an attempt to explain it in a way as there that explanatory theories are nothing but premises for deducing predictions. I therefore wish to make it quite clear that I consider the theorist's interest in explanation—that is, in discovering explanatory theories—as irreducible to the practical technological interest in the deduction of predictions. The theorist's interest in predictions, on the other hand, is explicable as due to his interest in the problem whether his theories are true; or in other words, as due to his interest in testing his theories—in trying to find out whether they cannot be shown to be false. See also appendix 9, note 4 and text.
now established that within one field at least it is pointless to seek any longer for laws, is not accepted here. This matter will be discussed in section 78.\textsuperscript{24}


Scientific theories are perpetually changing. This is not due to mere chance but might well be expected, according to our characterization of empirical science.

Perhaps this is why, as a rule, only branches of science—and these only temporarily—ever acquire the form of an elaborate and logically well-constructed system of theories. In spite of this, a tentative system can usually be quite well surveyed as a whole, with all its important consequences. This is very necessary; for a severe test of a system presupposes that it is at the time sufficiently definite and final in form to make it impossible for new assumptions to be smuggled in. In other words, the system must be formulated sufficiently clearly and definitely to make every new assumption easily recognizable for what it is: a modification and therefore a revision of the system.

This, I believe, is the reason why the form of a rigorous system is aimed at. It is the form of a so-called 'axiomatized system'—the form which Hilbert, for example, was able to give to certain branches of theoretical physics. The attempt is made to collect all the assumptions which are needed, but no more, to form the apex of the system. They are usually called the 'axioms' (or 'postulates', or 'primitive propositions'; no claim to truth is implied in the term 'axiom' as here used). The axioms are chosen in such a way that all the other statements belonging to the theoretical system can be derived from the axioms by purely logical or mathematical transformations.

A theoretical system may be said to be axiomatized if a set of statements, the axioms, has been formulated which satisfies the following four fundamental requirements. (a) The system of axioms must be free from contradiction (whether self-contradiction or mutual contradiction). This is equivalent to the demand that not every arbitrarily chosen statement is deducible from it.\textsuperscript{1} (b) The system must be independent, i.e. it must not contain any axiom deducible from the remaining axioms. (In other words, a statement is to be called an axiom only if it is not deducible within the rest of the system.) These two conditions concern the axiom system as such; as regards the relation of the axiom system to the bulk of the theory, the axioms should be (c) sufficient for the deduction of all statements belonging

\textsuperscript{1} Cf. section 24.
THEORIES

to the theory which is to be axiomatized, and (d) necessary, for the same purpose; which means that they should contain no superfluous assumptions.²

In a theory thus axiomatized it is possible to investigate the mutual dependence of various parts of the system. For example, we may investigate whether a certain part of the theory is derivable from some part of the axioms. Investigations of this kind (of which more will be said in sections 63 and 64, and 75 to 77) have an important bearing on the problem of falsifiability. They make it clear why the falsification of a logically deduced statement may sometimes not affect the whole system but only some part of it, which may then be regarded as falsified. This is possible because, although the theories of physics are in general not completely axiomatized, the connections between its various parts may yet be sufficiently clear to enable us to decide which of its sub-systems are affected by some particular falsifying observation.³