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Chapter 3

Logical Positivism and Logical Empiricism: Logic and Meaning

1. Introduction

In the twentieth century, the reluctance to use the terms "empiricism" and "empiricist" evaporated. Those who advocated a privilege status for experience were willing to adopt the terms without apology. We shall see below in Section 2 that the members of Vienna Circle in the 1920s embraced the terms with no sense of the past difficulties. Empiricism became the term for the mainstream of thought that privileged experience. The agenda for early twentieth century empiricism was set by the short-lived Vienna Circle, whose ideas are reviewed in Section 2 here. Two were very influential: that empirical ideas were to be expressed in terms of the meaningfulness of propositions; and that formal, symbolic logic was the appropriate medium for precise analysis of empiricism. These two ideas were distinctive for what came to be known as logical positivism.

Much of the ensuing writing in empiricism took the Vienna Circle's approach as their starting point. They incorporated these ideas and wrote in reaction to them. There was a lot to react to, for the Circle had extreme views. The most extreme was their verifiability criterion of meaning. It allowed proposition to be meaningful only if they directly expressed experiences or were deduced from experiences. At a stroke, vast portions of normal discourse were reduced to meaninglessness, the equivalent of nonsensical babble.

Within a decade, Rudolf Carnap, a key figure in the logical positivist movement, had already retreated from the severe condition that meaning could only be ascribed to propositions deduced from experience. While many other writers sought to correct these excesses, below, in Section 3, I will recount the efforts of Hans Reichenbach. He formulated what came to be known as logical empiricism. It was a milder, prudently tempered version of the logical positivists' extremism. At its core was the assignment of probabilities to propositions. He continued the

logical positivists' focus on meaning. His introduction of a probabilistic version of meaning meant that he could now treat as meaningful propositions in science remote from experience.

A counterpoint to Reichenbach's comfort with inductive inference was an anti-inductivism tempering of empiricism. It manifested in Bertrand Russell's earlier work of the 1910s and, as Section 4 recounts, found its fullest expression in the work of Karl Popper. While he was also working in Vienna at same time as the Vienna circle, Popper developed his distinctive version of deductive empiricism in which all notions of inductive inference were abandoned. He replaced the logical positivists criterion of testability by falsifiability. It was to demarcate not the meaningful, but the scientific. Unlike the ideas of the logical positivists and empiricists, Popper's analysis along with his name retains a strong presence in modern scientific discourse.

Another expression of empiricism in terms of meaningfulness arose independently at the same time as the logical positivist and empiricist movements and also proved to have a longer-lived influence. This is the operationalism of Percy Bridgman, which is reviewed in Section 5. Concepts were, according to the view, only meaningful if we could specify the operations through which the concept is measured; and that specification exhausts the meaning of the concept. A concept, Bridgman insisted, is synonymous with—that is has the same meaning as--the operations that measure it.

2. Logical Positivism[1]

2.1 The Manifesto

The "Vienna Circle," as they named themselves, was an informal discussion group centered in Vienna. Their members included philosophers, scientists and mathematicians. In their manifesto[2] (Hahn, Neurath, Carnap, 1929, p. 318), they listed their members as: Gustav

[1] The secondary literature on logical positivism is enormous. For an entry into the movement overall, see Richardson and Uebel (2022). Of all figures in the Vienna Circle, Carnap has attracted most attention in this literature. For an entry, see Leitgeb and Carus (2022).

[2] The author intended for the manifesto is ambiguous. The forward is signed by Hahn, Neurath and Carnap. However, the typography of the title in the 1929 German edition suggests that the

Bergmann, Rudolf Carnap, Herbert Feigl, Philipp Frank, Kurt Gödel, Hans Hahn, Viktor Kraft, Karl Menger, Marcel Natkin, Otto Neurath, Olga Hahn-Neurath, Theodor Radakovic, Moritz Schlick and Friedrich Waismann. The Circle set out not just to articulate a new empiricist philosophy but to form a movement that would redirect the course of philosophy. While the Circle and its members dissipated within a decade, it succeeded in its goal of influencing profoundly the philosophy of the ensuing years.

There were many views held within this large group. Their manifesto, however, collected the claims common to, or at least assented to, by all. That was essential for the manifesto to serve its purpose of recruiting, aggressively, new thinkers to its movement. The views of the manifesto were unified by what it called empiricism. The term appears repeatedly, favorably, throughout the manifesto, which provides a terse and serviceable definition (Hahn, Neurath, Carnap, 1929, p. 308):

> It is precisely in the rejection of the possibility of synthetic knowledge a priori that the basic thesis of modern empiricism lies. The scientific world-conception knows only empirical statements about things of all kinds, and analytic statements of logic and mathematics.

In still terser terms, this just says that empiricism is founded on a rejection of Kantian and neo-Kantian philosophies. There is no trace here of the reservations about empiricism that still lingered elsewhere.[3] Whereas the Circle rejected Kant's philosophy, it retained Kant's rehabilitated conception of empiricism that, as we saw in the last chapter, had become standard in the German language philosophical literature.

The two core ideas of the Circle were summarized as (Hahn, Neurath, Carnap, 1929, p. 309, emphasis in original):

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work's title is *Wissenschaftliche Weltauffassung* [Scientific World Conception] with the author *Der Wiener Kreis* [The Vienna Circle].

[3] Russell's (1915) work, as we shall see below, acknowledged as an inspiration by the Circle, used a version of Hume's problem of induction to conclude (p. 56): "… it affords a refutation of the older empiricists. They believed that all our knowledge is derived from the senses and dependent upon them."

> We have characterised the *scientific world-conception* essentially by two features. *First* it is *empiricist* and *positivist*: there is knowledge only from experience, which rests on what is immediately given. This sets the limits for the content of legitimate science. *Second*, the scientific world-conception is marked by application of a certain method, namely *logical analysis*.

These two features supply the two components of the label "logical positivism" by which the Circle's conception came to be known. The term does not appear in the manifesto and was not favored by Carnap. He remarked only a few years after the writing of the manifesto (Carnap, 1936/37, p. 422)

> [The position of the Vienna Circle] has sometimes been called Logical Positivism, but I am afraid this name suggests too close a dependence upon the older Positivists, especially Comte and Mach. We have indeed been influenced to a considerable degree by the historical positivism, especially in the earlier stage of our development. But today we would like a more general name for our movement, comprehending the groups in other countries which have developed related views. ... The term "Scientific Empiricism" (proposed by Morris …) is perhaps suitable.

The adjective "scientific" is prominent here and in the manifesto. However, its import is left to the reader to discern. There was an indirect rhetorical element. Science and technology in the 1920s were thriving and use of the adjective suggested a modern, forward-looking orientation to be contrasted with the staid viewpoints of those criticized by the Circle. The more direct meaning, however, appears merely to flag the Circle's goal of using the methods of science. Russell's (1915) monograph was repeatedly reported as an inspiration to the Circle. Its subtitle made plain its allegiance to what would be represented in the text as the scientific method: "*Our Knowledge of the External World: As a Field for Scientific Method in Philosophy.*" The only explicit clue in the manifesto itself is the reported agreement among Circle members over (Hahn, Neurath, Carnap, 1929, p. 304):

> … the specifically scientific attitude: "What can be said at all, can be said clearly" (Wittgenstein); if there are differences of opinion, it is in the end possible to agree, and therefore agreement is demanded.

2.2 Verifiability and the Elimination of Metaphysics

The first of the two core ideas of the Circle, empiricism and positivism, found its strictest expression in the elimination of metaphysics. "The scientific world-conception rejects metaphysical philosophy," they wrote in the manifesto (p. 307). This rejection was not just a dismissal of metaphysics as ungrounded speculation. They intended something more brutal. Metaphysical notions and propositions were equated with nonsensical babble.[4] Their statement was (pp. 306-307):

> Then it appears that there is a sharp boundary between two kinds of statements. To one belong statements as they are made by empirical science; their meaning can be determined by logical analysis or, more precisely, through reduction to the simplest statements about the empirically given. The other statements, to which belong those cited above, reveal themselves as empty of meaning if one takes them in the way that metaphysicians intend.

This is the verifiability criterion of meaning: a proposition is meaningful just in case there is some way to verify it in experience. It was given a terser formulation, first by Friedrich Waismann in his (1930, p. 229):

> A statement describes a state of affairs. The state of affairs either exists or it does not exist. There is no middle ground, and therefore there is no transition between true and false. If it cannot be stated in any way if a sentence is true, then the sentence has no meaning at all; for the meaning of a sentence is the method of its verification. [... denn der Sinn eines Satzes ist die Methode seiner Verifikation.]

It was later reported later by Hans Reichenbach with a lineage claimed tracing back to Wittgenstein (1939, p. 49):

> This is the idea expressed by Wittgenstein in his formula: the meaning of a proposition is the method of its verification.

In a footnote to this summary formula, Reichenbach reports on its use among the Vienna Circle and its attribution to Wittgenstein:

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[4] That is my rendering. The manifesto had a kinder sounding "say nothing but merely express a certain mood and spirit." (p. 307) Nonsensical babble can do that.

> Although this formula is not verbally contained in Wittgenstein's *Tractatus Logico-philosophicus* (London, 1922), it expresses his ideas very adequately and has been used, with this intention, within the "Vienna Circle."

Here Reichenbach repeated the frequent acknowledgment by the Circle of their debt to Wittgenstein. Presumably the idea of the verifiability criterion of meaning is found in Propositions 4.003 of Wittgenstein's *Tractatus* (1922, p. 63):[5]

> Most propositions and questions, that have been written about philosophical matters, are not false, but senseless. We cannot, therefore, answer questions of this kind at all, but only state their senselessness. Most questions and propositions of the philosophers result from the fact that we do not understand the logic of our language.
>
> (They are of the same kind as the question whether the Good is more or less identical than the Beautiful.)

The manifesto is short and gives only brief clues to the metaphysics it targets for elimination: "God", "entelechy" (life force) (p. 306) and "scholastic metaphysics and that of the systems of German idealism, but also the hidden metaphysics of Kantian and modern *apriorism*." (p. 308) Presumably the authors of the manifesto expected its readers to be all too familiar with their targets.

A later paper by Carnap gives a more expansive inventory of their metaphysical targets. Words with no meaning are listed here (Carnap, 1931, p. 67):

> Just like the examined examples "principle" and "God," most of the other specifically metaphysical terms are devoid of meaning, e.g. "the Idea," "the Absolute," "the Unconditioned," "the Infinite," "the being of being," "non-being,"

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[5] Perhaps readers will forgive me for expressing my frustration at the needlessly obscurity of the *Tractatus.* It lies not it its ideas but in its opaque presentation. It is a book of solutions without the problems stated. To make sense of the project, readers must search for the problems that Wittgenstein neglected to specify. It is akin to Deep Thought's declaration in Douglas Adam's *Hitchhiker's Guide to the Galaxy* (Pocket Books, 1979, p. 180) that "Forty-two" is the answer to the question of life, the universe and everything. It may be so, but necessary details are missing.

> "thing in itself," "absolute spirit," "objective spirit," "essence," "being-in-itself," "being-in-and-for-itself," "emanation," "manifestation," "articulation," "the Ego," "the non-Ego," etc.

Carnap then proceeded to sentences "from that metaphysical school which at present exerts the strongest influence in Germany." According to his earlier description, they "have no sense, assert nothing, are mere pseudo-statements." They are (Carnap, 1931, p. 69, his emphasis and quote marks):[6]

> "What is to be investigated is being only and—*nothing* else; being alone and further—*nothing*; solely being, and beyond being— *nothing*. *What about this Nothing?* … *Does the Nothing exist only because the Not, i.e. the Negation, exists?* Or is it the other way around? *Does Negation and the Not exist only because the Nothing exists?* … We assert: *the Nothing is prior to the Not and the Negation*. … Where do we seek the Nothing? How do we find the Nothing. … We know the Nothing. … *Anxiety reveals the Nothing*. … That for which and because of which we were anxious, was 'really'—nothing. Indeed: the Nothing itself—as such—was present. … *What about this Nothing?—The Nothing itself nothings.*"

2.3 Anti-metaphysics in Mach and the Vienna Circle

The Vienna Circle made plain its debt to and lineage from the work of Ernst Mach. Moritz Schlick, to whom the manifesto was dedicated, was a guiding spirit; and he held the academic Chair in Vienna previously held by Mach. The manifesto itself was marked as published by the *Verein Ernst Mach*, The Ernst Mach Society, which had also hosted the many discussions of the Circle.

It is easy then to imagine that the antipathy to metaphysics of the Circle and Carnap especially was merely a continuation of Mach's opposition to metaphysics. That is not so. The Circle's version was more severe. Mach disparaged many ordinary conceptions, such as body and ego, as makeshifts (Mach, 1897, p. 11). They might function as rough and ready conveniences of a larger reality composed of elements. Their nature, I noted in the last chapter, is mysterious to me. They cannot be sensations, literally, since there in no foundational distinction in the world between sensors and things sensed.

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[6] Carnap's footnote identifies the sentences as derived from Heidegger's *Was Ist Metaphysik?*

Mach had focused his anti-metaphysical critique on elements of successful, or soon to be successful, science, such as Absolute Space and Time and the notion of atoms. His denunciation of Newton's Absolute Time was quite specific (Mach, 1919, p. 224):

> This absolute time can be measured by comparison with no motion; it has therefore neither a practical nor a scientific value; and no one is justified in saying that he knows aught about it. It is an idle metaphysical conception.

The notion has no place in a careful, positivist analysis. We can know nothing about it. It is idle but nonetheless still a conception. Talk about it is not babble, as was metaphysical talk in the view of the Vienna Circle.

The Circle and especially Carnap had more immediate targets. Their anti-metaphysical fulminations were aimed in great measure at the abstruse proclamations of the German idealists of the era. Carnap's example was Heidegger's 1929 proclamation in his Freiburg inaugural lecture: "*Das Nichts selbst nichtet."—"The Nothing itself nothings."* His was a battle with present enemies over the excesses of obscure philosophy.

2.4 Reduction to the Given

The elimination of metaphysics constituted the negative, destructive component of the new positivist program. The productive part of the program consisted in a massive reduction of the totality of all scientific knowledge to the given, that is, to experience (Hahn, Neurath, Carnap, 1929, pp. 309):

> The aim of scientific effort is to reach the goal, unified science, by applying logical analysis to the empirical material. Since the meaning of every statement of science must be statable by reduction to a statement about the given, likewise the meaning of any concept, whatever branch of science it may belong to, must be statable by step-wise reduction to other concepts, down to the concepts of the lowest level which refer directly to the given. If such an analysis were carried through for all concepts, they would thus be ordered into a reductive system, a 'constitutive system'.

While the description of this ambitious project in the manifesto is brief, there would be little doubt about its more detailed form. For just such a reduction has been attempted in Carnap's (1928) *Aufbau*, The Logical Construction of the World. Here "construction" describes in reverse the same process as the reduction just envisaged in the manifesto. The construction occurs when

we trace back from the given to what was reduced to it. Bertrand Russell's earlier work provided an inspiration. The *Aufbau*'s epigram is (p. 5):[7]

> The supreme maxim in scientific philosophizing is this: Wherever possible, logical constructions are to be substituted for inferred entities. RUSSELL

What results is a system of four levels whose analysis is spread throughout the volume:

- Autopsychological [*eigenpsychischen* = self or proper psychic] loosely, the content of our own minds
- Objects: (Carnap, 1928, p.5) "The word 'object' is here always used in its widest sense, namely, for anything about which a statement can be made."
- Heteropsychological [*fremdpsychischen* = other or foreign psychic] loosely, the content of the minds of others
- Cultural objects [*Die geistigen Gegenstände*] Examples are very broad and include religious ideas.

The first autopsychological level is epistemologically primary and all the rest can be constructed from it. The key relation in this step-by-step construction is reducibility. It is introduced as follows (Carnap, 1928, p.6):

> An object (or concept) is said to be reducible to one or more other objects if all statements about it can be transformed into statements about these other objects.

The ultimate goal of the reduction is replace all the statements of this hierarchy by those that merely use the vocabulary of the first, autopsychological level. It seems that Carnap's intention is for these reduction relations to be deductive; and that makes the aspirations of the reduction especially severe. That this is the intent is, I take it, given in summary form when Carnap (1928 [1961], p. vii], in his introduction to the second edition, conceded that reduction using explicit definitions alone was too severe.

An explicit reason was given repeatedly for reducing everything so severely to the autopsychological, that is, to the content of one's own mind. It is that assertions that go beyond the autopsychological are not factual. In the summary of the Aufbau system in Carnap's Pseudoproblems (1928, p. 339), Carnap gives another reason for the severity of this reduction. It

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[7] The epigram is not an exact quote but a paraphrase of similar remarks in Russell (1915, p. vi) and Russell (1924, p. 34).

is the possibility of error if anything larger is used. More precisely, he is concerned that the reduction not stop at "*b*," which is the heteropsychological level of other minds, for otherwise errors can enter. We must continue to "*a*," the "nucleus of the experience," which turns out to be the autopsychological and the objects constructed from it. In his (translated) words (p. 339):

> … the theoretical content of *b* can rest upon an error even though *a* been correctly recognized.
>
> … For, the scientific justification of the recognition of content *b* always refers to *a*; moreover, on the basis of a we can always be deceived about *b*.

While this possibility is not otherwise mentioned, this fear of error would explain why Carnap was determined to implement such a severe reduction that, he acknowledged repeatedly in his *Aufbau*, has the appearance of a solipsism that he does not endorse.[8] It would also explain why Carnap insisted on the dubious requirement that the reduction relations are deductive, for an inductive logical relation would leave open the possibility of error.

2.5 What is Real

The Vienna Circle sought to use this reduction to the given to bring a close to an old debate in philosophy. In their characterization, the debate was between two views, realism and idealism. Realism asserts that there is a world independent of our sensations. This independent world includes everyday notions such as bodies and the minds of others. Idealism asserts that what we take to be this external world is merely a construction of our sensations. The Circle's resolution was radical. They asserted that *both* positions are untenable, since both involve meaningless propositions, that is, propositions that cannot be reduced to the given. Here is how the assertion appears in the Circle's manifesto (Hahn, Neurath, Carnap, 1929, p. 308; their emphasis):

> In rejecting overt metaphysics and the concealed variety of apriorism, all adherents of the scientific world-conception are at one. Beyond this, the Vienna Circle maintain the view that the statements of (critical) *realism* and *idealism* about the reality or non-reality of the external world and other minds are of a metaphysical

[8] Carnap (1928, p. 101) "The autopsychological basis is also called solipsistic. We do not thereby subscribe to the solipsistic view that only one subject and its experiences are real, while the other subjects are nonreal."

> character, because they are open to the same objections as are the statements of the old metaphysics: they are meaningless, because unverifiable and without content. *For us, something is 'real' through being incorporated into the total structure of experience.*

Essentially the same formulation is found in Carnap's "Testability and Meaning" (1936/37, p. 428-29):

> It is a pseudo-thesis of idealism and older positivism, that a physical object (e.g. the moon) is a construction out of sense-data. Realism on the other hand asserts, that a physical object is not constructed but only cognized by the knowing subject. We—the Vienna Circle—neither affirm nor deny any of these theses, but regard them as pseudo-theses, i.e. as void of cognitive meaning. They arise from the use of the material mode, which speaks about 'the object'; it thereby leads to such pseudo-questions as the "nature of this object", and especially as to whether it is a mere construction or not.

This rather extreme position depends upon the logical positivists' severe restriction on which propositions are meaningful. Observation propositions about the moon are meaningful, because they are verifiable. Assertions about the moon are only meaningful in so far as they are reducible to such observation propositions. Assertions by realists of the independent existence of the moon as an object are not so reducible. Hence they are meaningless. Since the negation of a meaningless proposition is also meaningless, the denial of the realists' assertion by idealists is correspondingly meaningless.

Carnap's earlier *Aufbau* (1969, p. 333) has a striking example of how this view is applied. It is a parable of a realist and an idealist geographer who map out a mountain somewhere in Africa. They agree on all propositions concerning the observations made during their expedition. Nothing in those observations distinguishes the further realist claim, that the mountain is real, from the idealist claim, that the mountain is merely constructed from their mountain-like sensations. Hence the problem of deciding between them is a pseudoproblem.

2.6 Logical Atomism and Logical Analysis

The second component of logical positivism is the replacing of ordinary language by symbolic logic. Ordinary language, the manifesto insisted, invites misunderstanding (Hahn, Neurath, Carnap, 1929, pp. 307-308):

> Ordinary language for instance uses the same part of speech, the substantive [noun], for things (‘apple’) as well as for qualities (‘hardness’), relations (’friendship’), and processes (‘sleep’); therefore it misleads, one into a ‘thing-like’ conception of functional concepts (hypostasis, substantialization). One can quote countless similar examples of linguistic misleading, that have been equally fatal to philosophers.

There was a solution. The manifesto praised Russell and Wittgenstein for their use of logic in assailing metaphysical excesses. Formal, symbolic logic would be the means to purge our discourse from the misunderstanding induced by ordinary language (Hahn, Neurath, Carnap, 1929, pp. 309):

> Only modern symbolic logic (‘logistic’) succeeds in gaining the required precision of concept definitions and of statements, and in formalizing the intuitive process of inference of ordinary thought, that is to bring it into a rigorous automatically controlled form by means of a symbolic mechanism.

Their praise of Wittgenstein indicates that his *Tractatus Logico-Philosophicus* was an example of the sort of reformulation into a formal, symbolic language that they envisaged. Wittgenstein’s ambitions in his *Tractus* were not just grand but grandiose. In the compact summary provided by Russell’s introduction, the analysis rests on atomic propositions that express the simplest of particular facts, such as “Socrates is wise.” The totality of these atomic propositions exhausts all that is factual in the world. All other propositions can be derived from them by simple, truth functional logic. The goal of the *Tractatus* is to develop sufficient logical apparatus to make this possible. As Russell put it (Wittgenstein, 1922, p. 15):

> Wittgenstein is enabled to assert that propositions are all that follows from the totality of atomic propositions (together with the fact that it is the totality of them); that a proposition is always a truth-function of atomic propositions; and that if p follows from q the meaning of p is contained in the meaning of q, from which of course it results that nothing can be deduced from an atomic proposition.

Carnap’s own implementation of this project came shortly in his “Testability and Meaning” (1936/37). There Carnap laid out the basic elements of a first order predicate logic, which was to be the symbolic logic that would sweep away the misunderstandings. Only a few years had passed since the writing of the manifesto. Yet Carnap had already realized that he must give up

the grandiose vision inherited from Wittgenstein of a full construction of all meaningful propositions by explicit definitions from atomic propositions. Carnap now recognized that the full verification of meaningful propositions allowed by this construction was not achievable. Instead, his system was to be based on the inductive notion of confirmation.[9] Carnap's account of confirmation is rudimentary and little more than a slightly embellished version hypothetico-deductivism. Allowing that Carnap would later be the author of his massive *Logical Foundations of Probability* (1962), his negative appraisal of a probabilistic account of confirmation is striking (1936/37, p. 427):

> It seems to me that at present it is not yet clear whether the concept of degree of confirmation can be defined satisfactorily as a quantitative concept, i.e. a magnitude having numerical values.

In place of the explicit definitions of his earlier construction project, Carnap proposed that dispositional concepts could be introduced with reduction sentences that merely give sufficient conditions for the applicability of the concept or its failure. Their form is (p. 441)

$$Q_1 \supset (Q_2 \supset Q_3)$$

$$Q_4 \supset (Q_5 \supset \sim Q_6)$$

where $\supset$ is merely truth functional, material implication. Loosely, the first tells us that in test condition Q_1 (e.g. this salt is put in water), if Q_2 (the salt dissolves) then Q_3 (the salt is soluble). The second formula is read analogous for the failure of the property to obtain.

In retrospect, the failings of Carnap's project in "Testability and Meaning" are now clear. The problems he sought to understand are difficult and delicate. That his account of confirmation was rudimentary in its fundamental and bound to fail was obscured by the elaborateness of the

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[9] That such a weakening was needed was also apparent to Alfred Ayer, whose 1936 *Language, Truth and Logic* was a widely read, English language introduction to logical positivism. He argued for a "weak" sense of the verifiability principle (Ayer, 1946, p. 37). "[A proposition] is verifiable, in the weak sense, if it is possible for experience to render it probable." Ayer's use of the term "probable" is informal and, loosely speaking, means something akin to "likely." He makes clear (p. 100) that his use of the term is distinct from its use in the mathematical theory of probability.

logical apparatus in which it was formulated. That apparatus introduced enticing but irrelevant technical problems sufficiently rich to distract a generation of theorists.

The essential problem was of a spurious illusion of precision. Unfortunately, it recurs. Each generation in philosophy of science faces delicate and difficult problems. It is enticing to many to expect that they can be solved by some simple formal apparatus. That the formalism is too simple for the task is easy to overlook. Each brings challenging technical problems whose appeal obscures the fundamental inadequacy of the apparatus for the delicacy of problem addressed.

3. Reichenbach's Logical Empiricism[10]

At the same time as logical positivism was being developed, Hans Reichenbach was developing his own version of empiricism. He called it "logistic empiricism" (Reichenbach, 1938, p.v). The view was soon renamed "logical empiricism," as the title of Salmon (1979) indicates. It is natural to group Reichenbach's version of empiricism with logical positivism. The similarities are strong, as Salmon (1977, p.40-41) reports. Reichenbach and Carnap co-edited the new journal, *Erkenntnis*, which was the favored medium of publication for the logical positivists. Reichenbach, like the logical positivists, formulated his empiricism in terms of language. His basic principles determined which propositions are meaningful. Their meaningfulness derives from the appropriate link to experience. Reichenbach, like Carnap, sought to formulate his empiricism in its most precise version using "logistics," or as we now say, symbolic logic.

Once we pass beyond these similarities, we find differences in their approaches that are deep enough for logical empiricism to be not just a variant of logical positivism, but a competitor. Within his development of logical empiricism, Reichenbach criticized logical positivism repeatedly and quite sharply.

On my reading, Reichenbach's critique was well-targeted. It sought to replace the excesses of the logical positivist movement by more modest proposals. Yet his logical empiricism seems to have had less prominence in the later literature. One possibility is that Reichenbach's most explicit formulation of his views, *Experience and Prediction* (1938), is

[10] The secondary literature on Reichenbach's work is extensive and its survey is beyond the reach of this section. For an entry into this literature, see Glymour and Eberhardt (2022).

curiously obscure in its writing. Reichenbach employed a needlessly convoluted and indirect mode of exposition. He did not give his account at the outset but repeatedly took the reader on a prolix and exhausting survey of other accounts. They absorb most of the reader's efforts before Reichenbach finally revealed his view through responses to the views he has rejected. In contrast, Ayer's *Language, Truth and Logic* (1936), a popular exposition of logical positivism, is brightly and directly written and is far more inviting to readers.[11] Google Scholar finds Ayer's work to have roughly two and half as many citations as Reichenbach's.

3.1 Probability Theory of Meaning

The most significant difference from logical positivism is that Reichenbach's logical empiricism is thoroughly probabilistic. Most of the remaining differences derive from this difference. That his account was essentially probabilistic reflected Reichenbach's long-standing engagement with probability theory. His doctoral dissertation at Erlangen (1916) was "The Concept of Probability for the Representation of Reality." The interest developed in later works such as Reichenbach (1932, 1935).

In his *Experience and Prediction*, Reichenbach summarized his probabilistic expansion of the verifiability theory of meaning with two principles (1938, p. 54):

> First principle of the probability theory of meaning: a proposition has meaning if it is possible to determine a weight, i.e., a degree of probability, for the proposition.

This first principle extends the reach of propositions that can be found meaningful. Reichenbach illustrated how this principle could be applied to the proposition that the interior of the sun is ascribed some high temperature. No such temperature can be *deduced* from experience. However, it is well within the capacities of solar physics to provide estimates with some probability. The second principle constrains the reach in a way conformable with empiricism:

> Second principle of the probability theory of meaning: two sentences have the same meaning if they obtain the same weigh, or degree of probability, by every possible observation.

[11] This is from personal experience. I read Ayer's work in my early 20s and found it compelling, even though I had no secure grounding in philosophy sufficient to assess it.

It follows that a difference in the meanings of two propositions must come from a difference in the probabilities of the propositions based on observation. This condition gives observation a controlling role in the meaningfulness of propositions.

These principles allowed Reichenbach to expand the verifiability theory of meaning of the logical positivists (p. 55, his emphasis):

> The probability theory of meaning may be considered as an expansion of the truth theory of physical meaning in which the postulate of verifiability is taken in a wider sense, including the physical possibility of determining either the truth-value or a weight. We shall therefore include both theories under the name *verifiability theory of meaning*. The narrower sense of verification will be expressed by "absolute verification."

The notion of probability meaning is eventually (by pp. 62-63) located within a four-part, nested[12] hierarchy of propositions that have

"physical truth meaning,"
"probability meaning,"
"logical meaning" and
"super-empirical meaning."

Propositions have physical truth meaning, as far as I can tell, if their verification is admitted by physical laws. Examples (from p. 38) include propositions about the construction of a bridge across the Atlantic Ocean or a visit to the moon, since they are physically possible even if technologically impractically difficult. An excluded example concerning the construction of a perpetual motion machine, since that its construction is prohibited by the physical law of the conservation of energy.

Propositions have probability meaning if meaning is granted by either of the two principles just quoted.

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[12] A Venn diagram on p. 63 indicates that the nesting is such that each proposition type is contained within the next in the hierarchy. This containment must fail for the super-empirical propositions, which appear to be represented as the all-embracing set. Reichenbach surely did not intend this.

Propositions have logical meaning if they involve no internal, logical contradiction. Propositions concerning perpetual motion machines have logical meaning, but propositions concerning quadrangular circles or railways without rails do not. (Examples from p. 39.)

Super-empirical propositions have the same status in Reichenbach's system as the maligned metaphysical propositions of the logical positivists. Reichenbach, however, was slow to commit to a blanket rejection. He dismissed propositions for which we cannot ascertain truth values as useless as a basis for deciding actions (pp. 64-65). The truth value of some super-empirical proposition can, he allows, still be ascertained. His examples (pp. 65-68) are statements of religious belief. The proposition of the divinity of cats has, in Reichenbach's understanding, the consequence for actions that cats must not be killed. These consequences for actions are, for Reichenbach, the meaning of such super-empirical propositions.

Perhaps most surprising in Reichenbach's development is his treatment of observation propositions. Their identification was a natural starting point for logical positivist analysis, such as given in Hempel (1950, §2). Reichenbach was loath to give them univocal meaning. The complication is that observation requires some sense of possibility and Reichenbach has several of them. This multiplicity confounds the notion of observation sentence (p. 47):

> This term [observation proposition] seems to have a clear meaning; but we find that it depends on the definition of the possibility of observation. To observe the temperature in the interior of the sun, in the same sense as we observe the temperature of our chamber, is logically possible but not physically. So all these categories of sentences have no absolute meaning but vary with the definition of meaning.

3.2 A Probabilistic Logistic

Carnap sought to secure precision in the inferences of philosophy by formalizing them in a first order predicate logic. Reichenbach attempted something similar. He used the same sort of predicate logic as Carnap and merely added one new symbol,[13]

$$\Rightarrow_p$$

[13] As asserted in Reichenbach (1949, p. 45).

Reichenbach called it "probability implication." It corresponds to the more familiar representation of conditional probability. Where we might now write "$P(B|A) = p$", the conditional probability of B given A is p, this relation would be represented in the formalism as "$A \Rightarrow_p B$." Merely adding this symbol profoundly changed the logic, for now Reichenbach needed to provide a serviceable account of probability suitable for his novel idea of probability meaning. He sought to use a relative frequency interpretation of probability. The full analysis provided to be formidable. An informal treatment was provided in a lengthy final Chapter 5 of *Experience and Prediction*. The more technical aspects were already in place with Reichenbach's earlier paper (1932) and his monograph (1935, 1949).

In his "Testability and Meaning," Carnap (1936/37) had mentioned Reichenbach's ideas on probability theory and his 1935 monograph (p. 426), but (as already noted above) Carnap proceeded to dismiss the approach (p. 427):

> It seems to me that at present it is not yet clear whether the concept of degree of confirmation can be defined satisfactorily as a quantitative concept, i.e. a magnitude having numerical values.

Given the depth of Reichenbach's engagement with a probabilistic foundation of his empiricism, Carnap's dismissal must have stung. Carnap and Reichenbach's differences over the meaningfulness of probabilistic propositions had already been aired in discussion in 1929[14]. Reichenbach (1938, pp. 76-77) could now assert with obvious satisfaction that, with his introduction of the notion of "degree of confirmation," Carnap's view and that of the Vienna Circle were moving closer to Reichenbach's own. He then issued a mild rebuke for Carnap in the form of a challenge: "if the interpretation in terms of probability is not accepted by Carnap, he must develop a theory of his own about degrees of confirmation."

[14] As Reichenbach (1938, p. 77, fn. 17) notes, they are reported in *Erkenntnis*, 1(1930), pp. 268-70.

3.3 Fallibilism and Failure of Positivism

Underlying Reichenbach's probabilism was a fallibilism about propositions. We can, in the last analysis, never be absolutely sure of any proposition. That the "positivists," as Reichenbach called them, asserted otherwise was, in his view, a most harmful error.

Reichenbach's assertions of his fallibilism built slowly in the course of his exposition in *Experience and Prediction*. A fairly complete statement of it only emerges roughly half-way through his text. There he finally comes to reject the absolute verifiability of propositions about observation propositions, that is, concrete physical facts; and to reject the absolute verifiability of impression propositions, that is, propositional formulations of our sense experiences. He continued (pp. 187-88):

> We have discovered now that even this is not tenable, that impression propositions also can only be judged by the category of weight. Thus there are left no propositions at all which can be absolutely verified. The predicate of truth-value of a proposition, therefore, is a mere fictive quality; its place is in an ideal world of science only, whereas actual science cannot make use of it. Actual science instead employs throughout the predicate of weight. … So the predicate of weight has entirely superseded the predicate of truth-value and remains our only measure for judging propositions.

This fallibilism was the basis of Reichenbach's repeated reproval of the positivist theory of meaning, which, Reichenbach urged, was based on the failed "principle of retrogression." He formulated the principle in this way (p. 49):[15]

> According to this principle, the meaning of the indirect proposition is obtained by constructing the observation propositions from which the indirect proposition is inferred; the principle of retrogression maintains that this inference is to be interpreted as an equivalence and that the meaning of the conclusion of the inference is the same as the meaning of the premisses of the inference…. This is the idea expressed by Wittgenstein in his formula: the meaning of a proposition is the method of its verification.

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[15] Indirect propositions "are propositions which cannot be directly verified, but which can be reduced in a certain way to other propositions capable of direct verification." (p. 47)

That is, this principle assumes that observation sentences can be absolutely verified and their truth known infallibly. Their absolute verification is then inherited by the indirect propositions whose meaning is given exhaustively by the observations.

To prepare for his reproval, Reichenbach recalled Hume's skeptical contributions to the positivist tradition and their later incorporation into a two-valued logic, that is, one that assigns only values of truth or falsehood to propositions, but not degrees. He then delivered his assessment of the malign influence of infallibilism on the tradition (p. 74):

> Thus resulted the modern positivistic theory, a strange combination of common-sense elements with a doctrinaire radicalism, which contradicted every unbiased view of the intentions of science. The postulate of absolute verifiability, when pronounced within science, has been mitigated by inconsequent application and therefore could do no harm; but in the hands of philosophers it was exaggerated to a radicalism which questioned the legitimacy of the very aim of science—the prevision of the future. Wittgenstein, the most radical mind among modern positivists, writes: "That the sun will rise to-morrow is a hypothesis; and that means that we do not know whether it will rise." [16] He does not realize that there are degrees in the domain of the unknown, such as we have expressed by the predicate of weight. Keeping strictly to the postulate of absolute verifiability, he arrives at the conclusion that nothing can be said about the future.

As his text unfolds, Reichenbach's customarily reserved prose begins to falter and betrays a buried passion. He laments (p. 76) the "too narrow logicism which characterizes this form of positivism, of the unwarranted simplification which does violence to the actual structure of science." This eventually devolves to an *ad hominem* attack on unnamed figures, presumably those advocating logical positivism under the inspiration of Wittgenstein (p. 189):

> But in the hands of pretentious and consistent logicians this schematized conception has produced serious misunderstandings of science and has led to grave distortions in the interpretation of scientific methods.

The distortions are then summarized (p. 189):

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16 Reichenbach's footnote cited Proposition 6.36311 of Wittgenstein's *Tractatus* (1922, p. 181).

> This procedure [of identifying the unverifiable with the meaningless] is carried through with more or less consistency; but none of its representatives has as yet had the courage to carry his principle through to its ultimate consequence and to admit that there are no meaningful sentences at all left in science.

3.4 Realism

We saw above that the Vienna Circle found both realism and idealism to be meaningless: neither can be verified in experience. To fill the void left by their elimination, the Circle offered their conception of what it is to be real: "For us, something is 'real' through being incorporated into the total structure of experience." This notion of reality would appear to be solipsistic, especially given that propositions asserting the existence of other minds are meaningless. Or perhaps it is a redefinition of the very notion of "real."

The Circle justified their treatment of the real by their view that factual propositions can only be meaningful if they are deduced from experience. Reichenbach did not ascribe to this strict binary division of propositions into the meaningful and the meaningless. His notion of probability meaning allowed for propositions well beyond those of observation to be meaningful. The attribution of a temperature to the interior of the sun was one of his examples. While observation propositions retained a privileged status in Reichenbach's logical empiricism, they too only had a probability meaning. They did not enjoy the infallibility accorded to them by the logical positivists. Thus, Reichenbach could assign different probability weights to a wide range of propositions that spanned from ordinary observational propositions through to propositions of the theoretical sciences and even to some super-empirical propositions that the Circle would denounce as meaningless. Here is his example of propositions concerning the sun (p. 131):

> The statement, "The sun is a ball of glowing gases of high temperature," is not equivalent to any set of statements about physical facts outside the sun, even if the set is infinite and even if it comprehends all points of a surface surrounding the sun; we get by these observations a set of elements from which we may with probability infer the sun's existence and qualities, but which is by no means of equivalent meaning.

Freed of these strictures of logical positivism, Reichenbach could offer a more expansive view on what is real. Once again, his development was labored and indirect. The primary vehicle for the development was a parable, somewhat reminiscent of Plato's cave. Reichenbach

(§13) asked us to image the shadows cast by birds under various lighting condition. He eventually sketched an elaborate "cubical world" (§14). Observers are within a cube of translucent material. They can see the shadows cast by the birds outside the cube, but not the birds themselves. A system of mirrors ensures that the shadows are duplicated on two sides of the cube.

The important datum for observers within the cube is that the shadows on the two walls are strongly correlated in their form and behavior. Reichenbach's reasoning (pp. 119-122) seems to proceed as follows. A strict positivist would only admit as meaningful a proposition asserting the correlation among the shadows. The further proposition that the shadows are multiple projections of fewer birds is meaningful only in so far as it asserts the original correlation among the shadows. Reichenbach's logical empiricist cannot assert absolutely that the shadows are cast by birds external to the cube. However, this logical empiricist can infer from the correlations that there is an increased probability of the existence of these external birds.[17] Thus the proposition asserting their existence has a probability meaning distinct from that of propositions concerning the shadows.

There are two statements here. The first merely asserts a correlation among the shadows. The second asserts the existence, external to the cube, of the birds. Of them, Reichenbach writes (p.121):

> The positivistic conception demands that two statements have the same meaning if they are equally determined as true or false by all possible facts; the probability conception demands the same meaning only if the statements obtain the same weight by all possible facts. It is to be admitted that the observable facts do not furnish a difference as to absolute truth or absolute falsehood of the two theories in question; but the weight conferred on them by the facts observable within the cube is different. Whereas the positivistic definition of meaning must therefore consider the two theories in question as having the same meaning, the probability definition of meaning furnishes a different meaning for both theories-although the domain of

[17] Readers of Reichenbach's later writings will have no trouble identifying this inference as an application of what Reichenbach later called the "principle of the common cause" (Reichenbach, 1956, §19).

observable facts is the same, and although only the postulate of physical possibility is employed in the definition of meaning.

The bird shadows and the cubical world are parables. The shadows are the analogs of our impressions or sense experiences; and the birds are the analogs of the external world that produces these impressions. Positivists limit meaning to propositions about the shadows, that is, to impressions. Logical empiricists, however, can attribute what Reichenbach calls surplus meaning to the external reality of the birds, that is, to the contents of the external world that produce the impressions by a process of projection. This for Reichenbach is an expression of realism or, as he called it, the "realistic conception of the world" (p. 129):

> By analogy with the example of the cubical world our contention reads: Impressions are only effects produced within our body by physical things, in the same sense as the shadows are effects of the birds. Thus impressions are only external elements relative to the physical things; these things are projected to our impressions but not reduced to our impressions. The "external world" therefore has an existence of its own, independent of our impressions.
>
> This is the so-called realistic conception of the world.

An earlier statement is comparable in its import (p. 111):

> …there is no equivalence between propositions concerning external things and propositions concerning impressions; there is only a probability connection. This relation is thus a projection and not a reduction; the existence of the external things is not reducible to the existence of impressions. The external things have an independent existence.

This approach led Reichenbach to decide in favor of Boltzmann and against Mach's skepticism in the venerable debate over the existence of atoms (pp. 212-13):

> The atoms have been discovered by the physicists in a way analogous to the discovery of the birds in the cubical world. Certain observed relations between macroscopic bodies—such as expressed in Dalton's law of multiple proportions—made it very probable that all bodies are built up of very small particles, though these particles could not be directly observed; this was the first substantiation given by the physicists to the theory of atoms.

3.5 Reichenbach's Conventionalism in Theories of Space and Time

Reichenbach's realism is defined in its opposition to the Vienna Circle's view. It resides in an insistence that propositions about the external world have a meaning that goes beyond our sense impressions.

Here I have gone into some detail in specifying the character of Reichenbach's realism because his writings elsewhere have a non-realist import. Most famously, his field-defining monograph in the philosophy of space and time (1928/1958) defended a conventionality for the geometry of space and for the simultaneity of spatially-separated events in special relativity. In more recent years, this has led to many casual remarks in discussions that characterize Reichenbach as an antirealist. The sense of realism used in these remarks is different. It relates to the later version of scientific realism that we shall see below as the foil for van Fraassen's constructive empiricism.

I still today have a vivid recollection of what would happen when such remarks were made in the presence of Wes Salmon, Reichenbach's accomplished student. He would command the attention of the room and, with the full authority befitting a most senior member of the profession, he would declare "Reichenbach was a realist!"

Reichenbach's own answer is found in *Experience and Prediction* (pp. 127-29). There he discusses his interpretation of Einstein's 1905 analysis of the simultaneity of two spatially separated events in a single inertial frame of reference. Many such relations are possible. There are no facts in the background capable of giving even a probability meaning to the preference for one such relation over many others. In this sense, the choice of a simultaneity relation must be made conventionally. This is an antirealist thesis, but it is very limited in its scope and is not part of a general antirealism.

3.6 Logic not Psychology

Reichenbach was also quite explicit in renouncing the attachment of empiricist thinking to the mental life of cognizers. This attachment had become prominent through the work of Hobbes and Locke and had found an extreme expression in Machian sensationalism. It is understandable that Hobbes and Locke should engage in analyses that, in later terms, merged logic and psychology. For in their time there was no distinct psychology as a science. They were part of its historical initiation. After psychology had become identifiable as an independent science, conflating it with logical analysis in epistemology ceased to be excusable.

Thus, it was fitting that, in spite of their reverence for Mach, the logical positivists had begun to move their epistemology away from a theory of mental life. Their emphasis became the meaning of propositions and the project of construction of the world by logical means. Nonetheless, Carnap's *Aufbau* was still quite dependent on psychological ideas. His construction was concerned with the autopsychological and the heteropsychological. His epistemology was still entangled, even if only in name, in the mental life of cognizers.

The traces of a move away from psychology do appear in Carnap's writings as a consequence of Carnap's emphasis on logic. To allow his logical analyses to incorporate experience, it entered as sentences, a basic unit of logical analysis. More specifically, it entered as the "protocol sentences." Then, whether experience verified some result was removed from a matter of psychology to one of logical relations among sentences. Carnap (1934, p. 42) defined "protocol sentences" that formed a "protocol language" as:

> Verification is based upon "protocal [sic] statements," a term whose meaning will be made clearer in the course of fu[r]ther discussion. This term is understood to include statements belonging to the basic protocol or direct record of a scientist's (say a physicist's or psychologist's) experience.

This text is a liberal translation with typographical errors of the German (Carnap, 1931a, p. 437)"

> Die Nachprüfung geschieht an Hand der 'Protokollsätze.' Hierunter sind die Sätze verstanden, die das ursprüngliche Protokoll etwa eines Physikers oder Psychologen enthält.

It is notable that the translator, Max Black, felt the need to explain the German term "Protokoll." At that time and still today, in English, "protocol" has a narrower meaning, commonly associated with formal documents in diplomacy.[18]

Where Carnap's account made no clear separation from psychology, it was otherwise with Reichenbach. He was eager to purge psychology from epistemology and emphasized, quite correctly in my view, that the two are distinct. He wrote (1938, p. 5):

> There is a great difference between the system of logical interconnections of thought and the actual way in which thinking processes are performed. The psychological operations of thinking are rather vague and fluctuating processes;

[18] Or so I find in the 1911 edition of the *Concise Oxford English Dictionary.*

> they almost never keep to the ways prescribed by logic and may even skip whole groups of operations which would be needed for a complete exposition of the subject in question. … It would be, therefore, a vain attempt to construct a theory of knowledge which is at the same time logically complete and in strict correspondence with the psychological processes of thought.

He continued to emphasize that the real subject of epistemology is a normative logic. It is not how we *do* think, but the standard that determines ideally how we *ought* to think:

> The only way to escape this difficulty is to distinguish carefully the task of epistemology from that of psychology. Epistemology does not regard the processes of thinking in their actual occurrence; this task is entirely left to psychology. What epistemology intends is to construct thinking processes in a way in which they ought to occur if they are to be ranged in a consistent system; or to construct justifiable sets of operations which can be intercalated between the starting-point and the issue of thought-processes, replacing the real intermediate links. Epistemology thus considers a logical substitute rather than real processes.

Drawing explicitly on an expression from Carnap's *Aufbau*, Reichenbach called the process of arriving at this logical substitute "rational reconstruction" [*rationelle Nachkonstruktion*]

4. Russell and Popper's Anti-inductivism

Inductive inferences from experience had a stable if unremarkable role in logical positivism. It rose to a central position in Reichenbach's logical empiricism because of the constitutive role of probability theory in the probability theory of meaning. Inductive inference did not fare so well in the work of other philosophers, who we might expect otherwise to be sympathetic to empiricism. One of the reasons was the revival of Hume's problem of induction in the early part of the twentieth century, after it had all but disappeared from the philosophical literature in the nineteenth century.[19]

[19] For an account of the revival of the problem of induction in the early twentieth century, see Norton (2024, Ch. 6, §6-8).

4.1 Russell's Reluctance

The problem of induction was revived in a prominent place in Chapter VI of Russell's (1912) widely accessible *Problems of Philosophy*. Russell soon outlined the threat it posed to empiricism in his 1915, *Our Knowledge of the External World*. Russell approached the problem (1915, pp. 34-37) from several perspectives. He determined that some sort of principle is needed if induction by simple enumeration is to be "valid," as he called it. One formulation was (p. 37):

> … every instance of a proposition … being true increases the probability of its being true in a fresh instance, and that a sufficient number of favourable instances will, in the absence of instances to the contrary, make the probability of the truth of a fresh instance approach indefinitely near to certainty.

He then impugned this principle by replicating Hume's celebrated critique, although Hume himself is not named (Russell's emphasis):

> But this brings us to our other question, namely, how is our principle known to be true? Obviously, since it is required to justify induction, it cannot be proved by induction; since it goes beyond the empirical data, it cannot be proved by them alone; since it is required to justify all inferences from empirical data to what goes beyond them, it cannot itself be even rendered in any degree probable by such data. Hence, *if* it is known, it is not known by experience, but independently of experience. I do not say that any such principle is known: I only say that it is required to justify the inferences from experience which empiricists allow, and that it cannot itself be justified empirically.

The negative consequences for empiricism then followed (p. 37):

> Thus logical knowledge is not derivable from experience alone, and the empiricist's philosophy can therefore not be accepted in its entirety, in spite of its excellence in many matters which lie outside logic.

Russell expanded on the problem, later in the text (p. 56, Russell's emphasis):

> Thus general truths cannot be inferred from particular truths alone, but must, if they are to be known, be either self-evident, or inferred from premisses of which at least one is a general truth. But all *empirical* evidence is of *particular* truths. Hence, if there is any knowledge of general truths at all, there must be *some* knowledge of

> general truths which is independent of empirical evidence, *i.e.* does not depend upon the data of sense.

The restriction on empiricism now followed:

> The above conclusion, of which we had an instance in the case of the inductive principle, is important, since it affords a refutation of the older empiricists. They believed that all our knowledge is derived from the senses and dependent upon them.

It is striking that the formulation of the complaint against empiricism offered by Russell parallels closely that given earlier by Henry Sidgwick and reported in the last chapter. It is quite likely that something more than mere coincidence is at work. Sidgwick held a professorship at Cambridge during Russell's time there. Russell later recalled Sidgwick as an influence on him that was exceptional in not being directed towards German idealism. He recalled, perhaps ruefully (Russell, 1959, p. 27):

> At the time, I, in common with other young people, did not give him nearly as much respect as he deserved. We called him 'Old Sidg' and regarded him merely as out of date.

4.2 Popper's Falsificationism

Perhaps I am overstepping in sensing a begrudging reluctance in Russell's pessimistic appraisal of empiricism. However, I find no such reluctance in Popper's anti-inductivism. The first chapter of his *Objective Knowledge* (1979, p.1) begins with a boast, clothed in feigned modesty:

> Of course, I may be mistaken; but I think I have solved a major philosophical problem: the problem of induction.

Popper's solution was published in his *Logik der Forschung* (1935) and its expanded translation, *Logic of Scientific Discovery* (2005). The solution was severe. It allowed that the problem rendered inductive inference unsalvageable by any means. Unlike Sidgwick, Russell and Reichenbach, Popper concluded that inductive inference was to be abandoned entirely. He wrote (2005, pp. 6-7, Popper's emphasis):

> 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*, …

This method, the now widely-known method of conjectures and refutations, consists of a cycle of operations. We can enter the cycle at the point at which a scientist conjectures a new theory and, to test it, makes predictions with it that are not predictions of the existing theory. Popper's narrative (2005, p. 10, Popper's emphasis) continues:

> 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 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.

The key property of this procedure is that it is independent of inductive inferences (p. 10):

> 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'.

Popper then developed one of his most popular theses: the condition of falsifiability as the criterion for distinguishing or demarcating science from other systems (p. 18, Popper's emphasis):

> … 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 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*. …

Although this proposal differs from that of other empiricists of his time, Popper can be categorized as an empiricist for his agreement with a fundamental tenet of empiricism: the privileging of experience, but now for its decisive role in the method he delineated. He wrote of it (2005, p. 17, Popper's emphasis):

> '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. …
>
> 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'*.

Although it may now appear benign to us to label Popper as an "empiricist," he explicitly adopted the label only in early writings. In drafts written in the years 1930 to 1933 and subsequently published as Popper (2009), he wrote (pp. 78-79, Popper's emphasis):

> The position advanced here is *empiricist* by virtue of its fundamental principle (the *fundamental thesis of empiricism*) that only *experience* can decide the truth or falsity of an empirical statement.
>
> According to the *deductivist-empiricist* view advocated here, there is only *one* relationship between natural laws, theories and *universal* empirical statements, on the one hand, and s*ingular empirical statements* (the "empirical basis"…) on the other, namely that of logical deduction. With the help of theories, *predictions* are deduced and tested by experience.

Whereas Popper emphasized the differences between his falsificationism and the views of the logical positivists, they are very close in their overall framing. One way to see this is to note that core propositions of each can be interconverted merely by the substitution of two words. The logical positivists asserted that:

> A proposition is *meaningful* just if it can be *tested* by experience.

Popper asserted that:

> A proposition is *scientific* just if it can be *falsified* by experience.

The substitutions do change the meaning of the assertions in important ways. Its mere possibility, however, show how close they are in their overall conceptions of their projects. Logical relations with experience are to be used to distinguish a meritorious property in systems of propositions.

In spite of their mutual affinity, Popper's relationship with the logical positivists was combative. He was irked that they paid scant attention to his ideas, complained that they misunderstood them and sought to establish temporal priority for the discovery of his ideas. What made this last claim awkward was that Popper's publication of his ideas came after the early published work of the Vienna Circle. The earliest of Popper's publications was a 1933 letter to the logical positivists' journal, *Erkenntnis*,[20] as Popper acknowledged in *Objective Knowledge* (1979, p. 2). Presumably to repair this lacuna, Popper wrote heroic, autobiographical recollections that included his preferred chronology of discovery, such as the first essay "Science: Conjectures and Refutations" in his Popper (1962, Ch. 1).

4.3 An Appraisal of Popper's Falsificationism[21]

Popper's empiricism is distinctive among those reviewed in this chapter. For, unlike these other accounts, his empiricism and a recognition of his name maintain a strong presence even today in discussions of the foundation of science in the larger public sphere, outside the narrower confines of philosophy of science. For this reason, I include here an appraisal of Popper's account.

First, I emphasize the real strengths of Popper's account. In the later part of the twentieth century, there was a shift towards excessively skeptical appraisals of science. It became fashionable to doubt that science had achieved its goal of objective knowledge of the world and to argue that the methods of science were too flawed ever to achieve these goals. Popper's account persisted as a visible counterbalance to this skepticism. It defended the core rationality of science and the privileged status of scientific knowledge.

Many, like me, were alarmed at the readiness of the literature to accept shoddy argumentation if it supported some form of skepticism. That alarm should not blind us to the inherent weaknesses in Popper's account. We should know what they are so that we can seek

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[20] The 1933 letter is published in translation in the 1959 edition of *Logic of Scientific Discovery*, along with a synopsis of Popper's grievances with the logical positivists.

[21] For a more extensive version of this appraisal, see Norton (manuscript).

better ways of identifying and defending the rationality of science. To this end, I provide a brief synopsis of the weaknesses of Popper's account.

The principal weakness lies at the foundation of Popper's account and is ultimately responsible for the others that follow. Science is an inductive enterprise and effective scientists seek empirical evidence that inductively supports its theories. Once Popper renounces all recourse to inductive inference, he has set himself an insoluble problem. He must find some replacement for inductive inference that both secures the rationality of science and conforms with the activities of scientists. His efforts fall short and inevitably so.

What privileges the major results of our mature science is that they are supported strongly by the empirical evidence. Those inductive relations of support can be displayed for us to examine in a way that is independent of the particular pathways followed by the scientists to establish them. The evidence for, say, big bang cosmology and the evolutionary origin of biological species can be inspected and assessed without a need to consider whether the scientists arrived at these relations of support laudably, by painstaking, critical investigations, or, less laudably, by haphazard adventures.

Popper's account admits no such static assessment. To affirm the privilege of some result in science, we must ask for the process that the scientists followed to arrive at the result; and it must confirm with the method Popper prescribed. A clear case of the difficulties that follow is the Popperian deprecation of *ad hoc* hypotheses; that is, hypotheses that are contrived to protect some theory from falsification. Such hypotheses are inadmissible, in Popper's (1962, p. 37) account, because of the history of their formulation. The one hypothesis, introduced by different scientists in different processes, might be appraised either as admissible or not. Inductivists face no such difficulties. The hypothesis stands or falls on the evidence that supports it inductively, independently of how it came to be proposed.

Where an inductivist would assess some theory as well supported inductively, Popper's surrogate is that it is well corroborated. That is, the hypothesis has survived "serious but unsuccessful attempt to falsify the theory." (Popper, 1962, p. 36) The definitive critique of the replacement of confirmation by corroboration is Salmon (1981): that some theory is well corroborated provides no basis for us to use it to make predictions. Corroboration is merely a statement about the past.

There are further problems. For a theory to be well corroborated, it must be subjected to severe testing. At its simplest, such testing presumes the testing scientists are genuinely (above: "seriously") trying to falsify the theory. That is, corroboration depends on our ability to affirm that the scientists were virtuous in this sense. We may try to circumvent the difficult question of detecting this virtue in the scientists by identifying what counts as a serious test. Popper (1962, p. 36, Popper's emphasis) gave this summary:

> [Corroborations] should count only if they are the result of *risky* predictions; that is to say, if, unenlightened by the theory in question, we should have expected an event which was incompatible with the theory--an event which would have refuted the theory.

This formulation does not sit well with Popper's abandoning of inductive inference. That we should have expected this event in the future requires a prediction that would rest on inductive notions abandoned by Popper.

More generally, successful corroboration is quite limited in its resources. They are roughly comparable to those of simple hypothetico-deductive confirmation. We know that something has gone well when a prediction of a theory is verified by experience. The weakness is that we do not know what in the theory is responsible for the success. Newton's mechanics enjoyed prodigious predictive success, although his absolute state of rest played no role in those successes. For an inductivist the superfluity of the absolute state of rest is revealed by the fact that we have no evidence specifically for it.

Popper's demarcation criterion is superficially appealing for its simplicity. For this reason, it has been taken up by many scientists. It is an easy and apparently damning critique of an opposing theory, if the critic can argue that the targeted theory is unfalsifiable. Although being unfalsifiable is a warning that something is amiss, making it the entirety of the criterion comes at an unsustainable cost. The simple criterion enables any fringe theory to claim cheaply the distinction of being scientific. It merely needs to interweave something falsifiable into the tangle of its claims. At the other extreme, an otherwise quite responsible science can fail to be falsifiable by novel predictions if all pertinent evidence has been collected and is known. Here we might imagine the excavation of an archaeological site, in which everything that can be known about it has been collected and catalogued.

The criterion and the cycle of conjectures and refutations promotes a historically unrealistic image of scientists as self-effacing and modest, all too eager to accept refutation of their pet theories and abandon their ideas. Science has not worked that way. New theories rarely emerge so perfectly formed that they are trouble-free. They require proponents to endure setbacks tenaciously so that their theories can survive long enough for an eventual vindication, in the rarer cases when it is to come.

If we are to seek a logical positivist response to Popper's work, we can look to Hempel's (1950, pp. 47-48) critique of Popper's criterion. It is mildly stated but devastating. Hempel, whose primary expertise and orientation was in logic, noted that the property of propositions being scientific under Popper's criterion behaves badly under simple logical operations such as "not," "and" and "or." If a proposition *S* is judged scientific, then its negation may not be so judged. If we conjoin—represented by "&"—a non-scientific, unfalsifiable proposition *N* to *S*, we arrive at something falsifiable and thus scientific, *S&N*. If we disjoin—represented by—"v"—an unfalsifiable *N* to a scientific *S*, we arrive at an unscientific, unfalsifiable *S*v*N*.[22]

When the problem is expressed in such simple terms, it is easy to dismiss them as nuisances of a logician's pedantry. Who would be troubled by such transparent contaminations of scientific propositions? The difficulty is that the contaminations need not be so transparent. The first arises when a physicist is adjudicating between:

All electrons are spin one half.

and its negation

There are electrons that are not spin one half.

The decision is between the first, a scientific proposition, and the second, an unscientific one. The adjudication, we are to believe, poses a question that lies outside science.

The second case is that of conjunction conferring the status of being scientific too easily. It is the logic that underwrites the example above of a fringe theory cheaply acquiring the status of science. The third example of disjunction is, in the general case, that being scientific need not be preserved under deductive inference, for *S* deductively entails *S*v*N*. A scientist may start with a scientific theory and deduce some apparently innocuous conclusion from it that turns out to be unscientific. For example, a falsifiable proposition in gravitational astronomy is:

[22] This last case is not in Hempel's paper, but an obvious extension of his critique.

The planet Vulcan, with its suitably computed mass and orbit, allows Newtonian theory to account for the anomalous motion of Mercury.

It is falsifiable. The supposed planet Vulcan was not observed in the computed positions and the proposition was falsified. We can deduce another proposition from this scientific proposition:

There are ways that Newtonian theory can account for the anomalous motion of Mercury.

Since the scope of the "ways" indicated is unlimited, this second proposition is unfalsifiable and thus unscientific. After that small deductive step, we are no longer practicing science.

In contrast, inductivists have no need for a special criterion of demarcation to distinguish what is science. What matters for the inductivist is whether a hypothesis or a theory is well supported inductively by the empirical evidence. The expectation is that a mature science is well supported inductively. A theory or hypothesis falls short if it fails to be well supported inductively by empirical evidence. There is no need for further conditions to distinguish the merit of some system of propositions.

A final difficulty for Popper's account is that its abandoning of inductive inference is motivated by Popper's conviction that the problem of induction is insoluble. There is no great shame in this last conviction. Some of the most astute of his contemporaries, Bertrand Russell and Hans Reichenbach,[23] agreed. However, we now know that induction eludes the problem of induction if we reconceive induction materially; or so I have argued in my Norton (2024, Ch.6). Philosophers of science can endorse the use of inductive inference in science with clear consciences.

5. Operationalism

5.1 Turmoil in Physics

The Nobel Prize winning physicist, Percy Bridgman, outlined what he called the "operational point of view"[24] in his 1927 *Logical Foundations of Physics*. He wrote at a time of

[23] Reichenbach formulated his pragmatic solution to excuse his allegiance to inductive inference. See Norton (2024, Ch.6) for details.

[24] For example in (1927, pp. 9, 25, 31 and elsewhere). The term "operationalism" does not appear in his volume (1927). Bridgman (1938, p. 114) later affirmed that "he had never talked of

great turmoil in physics. Einstein's two theories of relativity had overturned the prior certainties of physics and the emerging quantum theory promised still greater disruptions. Bridgman's diagnosis was that a defect in our concepts left us prone to the disruptions. He wrote of Einstein's two theories of relativity (1927, p. 1):

> Reflection on the situation after the event shows that it should not have needed the new experimental facts which led to relativity to convince us of the inadequacy of our previous concepts, but that a sufficiently shrewd analysis should have prepared us for at least the possibility of what Einstein did.

The older attitude introduced concepts through their properties. Newton had introduced his Absolute Time by specifying its properties (1927, p. 4). This, Bridgman determined, was the core of the trouble that eventually ensued.

5.2 Bridgman's Remedy

In place of this approach, as a remedy, Bridgman urged that we define a concept exhaustively by the operations used to measure it. He took the concepts of length in special relativity as his illustrative example (1927, pp. 5, 9-23). We measure the length of an object at rest by a simple procedure of comparison with a measuring rod. If the object is moving, we must employ a different set of operations. It will require the identification of the location of the ends of the moving object *at the same moment of time*. Thus, operations informed by simultaneity are required, where these were not required for operations measuring the length of the resting object. Suitably configured clocks, for example, might be required to introduce simultaneity into the measuring operation.

The different conditions of the object—rest or motion—require different measuring operations for length. Further differences require still more, distinct operations to determine lengths. To illustrate this need, Bridgman considered length measurements over a wide range of scales. He considered larger distance measures on terrestrial, solar and stellar scales; and shorter measures over microscopic and molecular distances. All required different operations. He summarized the outcome and his overall operational conception as follows (1927, p. 5, his emphasis):

'operationalism' or 'operationism." He feared such "grandiloquent words" would mislead in suggesting "a profound new theory of the of knowledge or of meaning."

> The concept of length is therefore fixed when the operations by which length is measured are fixed: that is, the concept of length involves as much as and nothing more than the set of operations by which length is determined. In general, we mean by any concept nothing more than a set of operations; *the concept is synonymous with the corresponding set of operations*.

The essential point is that a different set of operations defines a different concept. It is through this feature that our conceptual system will always be ready for new discoveries. We will not be taken unawares again by the novelty of such discoveries as relativity theory and the quantum theory. Memorably, he avers, we may "hope to render unnecessary the services of the unborn Einsteins." (1927, p. 24)

Here, as Bridgman recalled (pp.7-9), he is taking his cue directly from Einstein. For the starting point of Einstein's special theory of relativity was the recognition that judgments of the simultaneity of events differ according to the state of motion of the inertial reference frame in which they are made. There is no single concept of simultaneity, but one for each inertial frame of reference. Einstein revealed this through a celebrated operational analysis that used light signals to determine the simultaneity of spatial separated events. It showed that events judged simultaneous in one inertial frame of reference may not be judged so in another. Had we employed Einstein's operational conceptions from the start, our conceptual systems would have been prepared for the discovery of these differing judgments.

Correspondingly, this operational approach would have protected us from Newton's failed notion of Absolute Time, for there are no operations that measure it. "Therefore," Bridgman concluded (p. 6), "the previous statement that absolute time does not exist is replaced by the statement that absolute time is meaningless."

5.3 Mental Operations

The operationalist point of view is most commonly recalled in terms of physical measurement operations. It should have been evident from the start that purely physical measurement operations would be insufficient to define fully all the concepts then used in physics. This inadequacy was likely evident to Bridgman at the outset. Presumably for this reason, Bridgman allowed in his essay (1927, pp. 6-7) what he called "mental" operations. His example (1927, p. 6) is "mathematical continuity… those [operations] by which we determine whether a given aggregate of magnitudes is continuous." The concept requires something beyond

physical operations. A property of a continuous magnitudes is density: between any two values we can always find a third. Iteration leads to a regress of infinitely many, arbitrarily close magnitudes whose full existence cannot be demonstrated by the physical operations available to us. However, we readily conceive of the continuity by mentally picturing an intervening magnitude between any two others. Perhaps we might even imagine what Bridgman later called a "paper and pencil" operation: the intermediate value is calculated arithmetically by averaging the two bounding values.

The difficulty with allowing mental operations is that they have creative powers that far outstrip the requirements of a modest empiricism. They can conjure up the many universes of multiverse cosmology and the enormous number of alternative particle theories of the string theory landscape. In 1927, Bridgman was loath to restrict their range and import. Instead, he obscured the difference between physical and mental operations and diminished the importance of the distinction (pp. 6-7):

> It is not intended to imply that there is a hard and fast division between physical and mental concepts, or that one kind of concept does not always contain an element of the other; this classification of concept is not important for our future considerations.

It became apparent over subsequent decades of Bridgman's writing that this treatment of mental operations was hasty. They play an important role in physical theorizing. A variety of them, "paper and pencil operations," appear over a hundred times by name in Bridgman's 1941 treatise on thermodynamics.[25] Writing decades later, Bridgman recognized that he had been hasty in his 1927 treatment of mental operations. He reported (1959, p. 522):

> If I were writing again I would try to emphasize more the importance of the mental or "paper-and-pencil" operations. Among the very most important of the "mental" operations are the verbal operations. These play a much greater role than I realized

[25] They appear almost always as vague allusions to incompletely specified calculations in the surrounding text. I found just two more precise instances. The density of a matter flux is calculated in a paper and pencil operation by dividing the flux by the velocity (1941, p. 39). The measured electric and magnetic field strengths E and H are combined in a paper and pencil operation for the electromagnetic field energy density $(E^2 + H^2)/8\pi$ (p. 91).

> at the time, and I have tried to emphasize this in my later writings, particularly in *The Way Things Are*.

By this time, Bridgman made explicit what was already becoming implicit in his earlier writings: that mental operations could serve only as an intermediate in analyses that should eventually rely only on physical operations. This is, I believe, the import of his synopsis in his 1959 *The Way Things Are*. He wrote (1959a, p. 153):[26]

> In discussing operations, we have repeatedly emphasized that if our operations are to be of significance in a scientific context they must be capable of emerging eventually onto the instrumental level, and not remain indefinitely on the verbal level. The fact that here we have not been able to give complete instrumental meaning to the concepts of field or of action at a distance leads me to suspect that in any theoretical correlation of instrumental results we will never be able to make the instrumental emergence complete, but there always will remain some verbal or "paper-and-pencil" component.

5.4 Bridgman's Empiricism and Antirealism

Underlying his analysis, Bridgman reported, is a commitment to empiricism. "Thus the fundamental attitude of this essay is empiricism…," he wrote (1927, p. vi). More fully (p. 3):

> The attitude of the physicist must therefore be one of pure empiricism. He recognizes no *a priori* principles which determine or limit the possibilities of new experience.

This disavowal of the *a priori* conformed with the comparable doctrines of the logical positivists and logical empiricists. Bridgman was correspondingly scornful of metaphysics. He lamented "… the utter unintelligibility to the physicist of many metaphysical speculations and the sterility of such speculations in yielding physical results." (p. vii) Correspondingly, he refused to ascribe reality to anything not directly accessible to operational measurement. The refusal was severe.

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[26] He also wrote in (1951, p. 260) "…such operations must be capable of eventually, although perhaps indirectly, making connection with instrumental operations. Only in this way can the physicist keep his feet on the ground or achieve a satisfactory degree of precision; instrumental contact affords the only 'reality' which he accepts as pertinent for him." There are similar remarks in Bridgman (1938, p. 124).

While an electric field strength can be ascertained operationally at any point in space, that operational fact is insufficient to accord reality to the electric field itself (p.57):

> I believe that a critical examination will show that the ascription of physical reality to the electric field is entirely without justification. I cannot find a single physical phenomenon or a single physical operation by which evidence of the existence of the field may be obtained independent of the operations which entered the definition.

Here we see an alignment with many of the views of the logical positivists. Yet his views were likely not derived from them. As the early publication date of his essay (1927) suggests, Bridgman's views seem to have developed independently of those of the Vienna Circle. Their members make no appearance in his essay. He there reported (p. v) reading only Clifford, Stallo,[27] Mach and Poincaré, but denied (p. vi) any conscious debt even to them. A later autobiographical report emphasized the independence of the thinking that led to his 1927 essay. He recalled (1938, p. 115) that it came "only after at least ten years of more or less continuous pondering." Bridgman later wrote on Carnap and logical positivism, but only to disavow allegiance to their views (1959, p. 522):

> However, the fact that I appreciate the importance of the verbal operations does not mean that I now ascribe the exclusive significance to a linguistic sentential analysis that many of the logical positivists do, as exemplified for example by Carnap. It has always seemed to me that linguistic analysis of this sort is capable of giving only a partial and distorted picture of the whole situation.

5.5 Meaning

The identification of meaning is the principal vehicle used by Bridgman to protect physics from spurious ideas. The celebrated formulation of operationalism in the 1927 essay was quoted above: "we mean by any concept nothing more than a set of operations" and "*the concept is synonymous with the corresponding set of operations*." Here "synonymous" is just "has the same meaning." Troublesome concepts, such as Newton's Absolute Time, are dispatched as

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[27] Stallo, presented himself as a reformed Hegelian (1884, p. 11) and lamented "the metaphysical malady which seems to be one of the unavoidable disorders of intellectual infancy."

meaningless. Bridgman devoted several pages (1927, pp. 28-31) to discussion of "Meaningless Questions." These are questions whose answers would require operations that do not exist. A simple example is the question of whether a star is at rest. Presumably Bridgman intended that no operation can distinguish its rest in special relativity from its inertial motion.[28]

That Bridgman is prepared to attribute meaning to a question indicates that he is more a physicist than a philosopher. For philosophers with a grounding in logic attribute meaning to terms and propositions, not to questions. Bridgman's meaningless questions correspond to the logical positivists' "pseudo-questions." We may wonder just what the term "Logic" in the title of Bridgman's 1927 essay designates. It presumably designates some aspect of the informal inferential practices of physics.

Bridgman's later synopsis gives a more succinct statement of the centrality of meaning in his analysis (1951, p. 257):

> The fundamental idea back of an operational analysis is simple enough; namely that we do not know the meaning of a concept unless we can specify the operations which were used by us or our neighbour in applying the concept in any concrete situation.

Bridgman then added a puzzling qualification: a specification of the operations is necessary for meaning, without assuring sufficiency. That is, he wrote (1951, pp. 257-58) "In making an operational analysis we are dealing with necessary, as distinguished from sufficient, conditions."

This qualification seems to contradict the above 1927 formula "*the concept is synonymous with the corresponding set of operations.*" For synonymy makes the operations both necessary and sufficient for the meaning of the concept. Perhaps Bridgman's intent here was to allow for other looser meanings that concepts may have. He noted elsewhere (1959, p. 523):

> … in every-day usage "meaning" has much wider connotations. For some sort of "meaning" can be ascribed to any expression whatever, and in fact it is always possible to give an operational analysis of any such meaning, provided only that the accepted operations are selected from a sufficiently extensive repertory.

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[28] The example fails in the FLRW spacetimes of modern cosmology. The motion of a star with respect to the cosmic rest frame can be determined by measuring the Doppler shift in the cosmic background radiation within the rest frame of the star.

Specifying operations would be necessary if the concept is to have a meaning suitable for scientific applications. How their specification would not provide the wider connotations of meaning in every-day life.

5.6 Influence

While the work of the logical positivists and logical empiricists exercised a controlling influence in some sectors of philosophy for a few decades, their influence came to be largely negative. New schools of thought defined themselves through their opposition to logical positivism and empiricism, even while often only having a thin grasp of the views opposed. Such was not the fate of Bridgman's operationalism. The utility of seeking operational definitions has persisted as a convenient tool of analysis, while commonly used without a commitment to a larger operationist orientation. The identification of an operational definition of a concept or the realization that such a definition is lacking can advance a foundational analysis. It can secure an empirical foundation for the concept or suggest the lack of it. Here the imprecision of Bridgman's writing may have been helpful. It leaves room for later authors to mold operational thinking to their liking.

Behaviorism in 20th century psychology was based on the explicit adoption of an operationalist orientation. The term "operationism" (as opposed to "operationALism") was coined within the behaviorist literature.[29] In present day philosophy of science, the last stronghold of operationalist thinking lies in the interpretation of subjective probabilities. Agents are understood to harbor probabilistically weighted beliefs only in so far as those probabilities are expressible as actions. These actions may be the range of wagers the agents are willing to undertake when engaging with a bookie at a racetrack or, more generally, the agents' preferences in contexts requiring decisions.

Hempel's (1966, pp. 91-96) analysis is generally recognized as the most telling criticism of operationalism in the philosophical literature. The concern is that a strict adherence to operationalism renders science unworkable. Even the slightest change in a measuring operation introduces a new conception. A flood of conceptions is triggered that will overwhelm our cognitive powers. To illustrate his point, Hempel considered numerous operations for measuring lengths and temperatures. There can be no default supposition that each new conception agrees

[29] For details see Chang (2021, §1.4).

with the prior conceptions. Determining agreement or lack of it expands the analytic burden massively and would make the science unworkable. That they may not agree is precisely the motivation for Bridgman's introduction of operational definitions. We might read Bridgman's (1938, pp. 121-22) remarks as an earlier recognition and response to Hempel's objection. The concern is granted, but Bridgman insists that it is never "safe" to make the default assumption of agreement among different operations.

6. Conclusion

Earlier empiricisms, including that of the logical positivists and operationalists, harbored a severe form of skepticism. They recognized that propositions venturing beyond experience were less secure. However, they had no means with which to accord them a lesser, but still respectable status. It was all or nothing. Propositions were to be celebrated or discounted; and only expressions of experience were to be celebrated. In the most extreme version, the logical positivists had reduced anything that strayed beyond experience to meaningless babble.

Reichenbach's corrections to the excesses of logical positivism afforded the means of avoiding this skepticism and provides, in my view, the best expression of empiricism of the approaches reviewed in this chapter. Although the meaningfulness of propositions was still central to Reichenbach's analysis, the use probabilistic analysis allowed a wide range of propositions to be meaningful. Its use of probabilistic analysis avoided the insoluble problems created for Popper by his renunciation of inductive inference. The result was a fallibilist empiricism in which propositions that ventured beyond direct experience could still be treated as meaningful. Their probabilistic weight assured us of how seriously they should be taken, while at the same time preserving empiricism since those weights were controlled by experience. Hence Reichenbach could advocate his version of realism concerning the external world. Propositions about immediate experience and about states of affairs remote from experience were meaningful up to the probabilities assigned to them. This fortunate accommodation of empiricism and realism would not last.

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