Karl Popper's Philosophical Breakthrough*

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Despite his well-known deductivism, in his early (unpublished) writings, Popper held an inductivist position. Up to 1929 epistemology entered Popper's reflections only as far as the problem was that of the justification of the scientific character of these fields of research. However, in that year, while surveying the history of non-Euclidean geometries, Popper explicitly discussed the cognitive status of geometry without referring to psycho-pedagogical aspects, thus turning from cognitive psychology to the logic and methodology of science. As a consequence of his reflections on the problematic relationship between geometrical-mathematical constructions and physical reality Popper was able to get over a too direct notion of such a relationship, cast doubts on inductive inference and started conceiving in a new (strictly non-inductivist) manner the relationship between theoretical and observational propositions.

> "Let no one ignorant of geometry enter this door."
> —Motto over the main entrance of Plato's Academy

1. Introduction. In the early 1930s Popper's *Logik der Forschung* (1935, actually published in November 1934) came to solve two traditional philosophical problems: the problem of demarcation between science and non-science (by what criterion do we decide which hypothesis is scientific?) and the problem of induction (that has many formulations and variants, among which Popper chose the following: how do we learn from experience?).

The traditional answer to the first question is that all—and only—

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established theories belong to science, while the traditional answer to the second is that experience leads to the adherence to established theories. Popper's answers were different. First, he said that those hypotheses are scientific which are capable of being tested experimentally, where tests of a hypothesis comprise attempts to refute it. Second, he argued that learning from experience is the very act of overthrowing a theory with the help of that experience: we learn from experience by repeatedly positing explanatory hypotheses and refuting them experimentally, thus approximating the truth by stages.

This conclusion took a long elaboration, which I think is very interesting both from the historical and the philosophical point of view. Historically, it is interesting to see *how* Popper came to his original solutions, while philosophically it is interesting to understand *why* he changed his views—and quite radically, as we shall see.

In this paper I explore both paths, albeit very briefly. In order to do that, we will have to consider some of Popper's very first philosophical writings.[1] Of course, *Die beiden Grundprobleme der Erkenntnistheorie* (together with *Logik der Forschung*) is of fundamental importance for an understanding of Popper's philosophy, but if we want to understand its background and get a grasp of the difficult path he had to struggle through in order to conceive and elaborate his ideas, we must consider also his early—and largely still unpublished—German works.[2]

2. Popper's Early Inductivism. "The present work, although highly theoretical in its main parts, has arisen out of practical experiences [with pupils], and has eventually to serve practice again. Its method is therefore essentially inductive" (Popper 1927, 3) Surprising as it may sound, these

1. In particular, I will consider Popper's three theses: the first, submitted in summer 1927, is the final quasi-thesis (*Hausarbeit*) required of all students completing the two-year programme at the Pedagogic Institute, which Popper had to attend in order to qualify as a school teacher; the second is Popper's doctoral dissertation, submitted to the University of Vienna in summer 1928; the third is an additional thesis, qualifying him to teach mathematics and physics in secondary school (*Hauptschule*). See Hacohen 2000, 134–135, 142–144, 156 and 172–173.

2. They are forthcoming as the first volume of Popper's *Gesammelte Werke*: Karl R. Popper, *Frühe Deutsche Schriften (1925–1935)*, edited by Troels E. Hansen. Tübingen: J. C. B. Mohr (Paul Siebeck). All quotations are by permission of the estate of Karl Popper. Together with Wettersten 1985, 1988, and 1992, and Hacohen 1996, 1998, 1999, and 2000, Troels E. Hansen's work will provide us with a new and precious tool for understanding the complex evolution of Popper's thought and for putting it properly into context.

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words appear at the very beginning of a long typescript which constitutes Popper's first philosophical work.[3]

Indeed, in his 1927 thesis, *"Gewohnheit" und "Gesetzerlebnis" in der Erziehung* ("Habit" and "Experience of Law" in Education)[4] Popper clearly holds induction as *the* characteristic feature of empirical science. Contrary to Freud's, Adler's and others' psychological theories, which often go beyond what is factually verifiable, the theories of natural science, he says, only abstract from empirical data, never asserting something beyond the facts (Popper 1927, 19–21).[5] Here Popper is clearly an in-

3. "Die Vorliegende Arbeit, obwohl in ihren Hauptteilen im hohen Grade theoretisch, ist dennoch ganz aus praktischer Erfahrung heraus entstanden und soll letzten Endes wieder der Praxis dienen. Ihre Methode ist daher im Wesentlichen induktiv." In July 1925 the city council merged Vienna's pedagogic and psychological institutes, establishing the Pedagogic Institute. Popper asked for an interview and was admitted. Upon completing his course work, which comprised a two-year teacher-training programme combining academic and practical training, Popper submitted a protothesis (*Hausarbeit*) and took the final qualifying exam. As to his "practical experiences with pupils," it has to be stressed that when Popper describes his methodological stance, in the extensive "Introduction" to the first part of the thesis, and adds a few remarks on the method of observation, his use of the word "observation" is rather peculiar. For, as ter Hark notices, "Instead of relying on his own observations of children during his work in Adler's child guidance clinics, Popper derives his 'observations' from various sorts of literature, ranging from autobiographies to psychological studies, notably Karl Bühler's *Die geistige Entwicklung des Kindes*, Elsa Köhler's *Die Persönlichkeit des dreijährigen Kindes* (1926) and Charlotte Bühler's *Das Seelenleben des Jugendlichen* (1927)" (ter Hark 2002, 96). Committed to his unflinching inductivism, he regards these accounts as "unprejudiced reports," free from theoretical interpretations, "providing a solid and safe basis for an inductive generalization in terms of the notion of *Gesetzerlebnis*" (*ibid.*). Only a few years later he adopts a radically different view: see Popper [1935] 1959, 107 (and fn. *3), together with 59, 106–107, 280, 412–413 and 423; see also Popper [1945] 1966, vol. II, 213–214 and 260–261.

4. Later, Popper (1957, 50) translates the title as *On Habit and Belief in Laws*, omitting the last two words of the original title; however, *"Habit" and "Experience of Law" in Education* seems a more appropriate translation: see also Hacohen 2000, 133 fn. 5, and ter Hark 2002, 101. As Michel ter Hark rightly observes, *"Gewohnheit" und "Gesetzerlebnis" in der Erziehung* "is not just a thesis in pedagogy, as the title seems to convey; it is also, indeed more so, a psychological study firmly rooted in the tradition of German child psychology and the *Denkpsychologie*" (ter Hark 2002, 83). It is, as Popper himself describes it, an "empirical-psychological investigation" ("empirisch-psychologische Untersuchung", Popper 1927, 127), "conceived as a Kantian critique of the limits of scientific pedagogy" (Hacohen 2000, 142). For a detailed analysis of Popper's first thesis, see Hacohen 2000, 142–149, and ter Hark 2002.

5. On 32 we read: "As far as [a psychological theory] affirms the existence of causal connections between *real experiences*, its value can be put on the same level of the theories (and hypotheses) of natural sciences, since these connections are verifiable" ("Soweit sie kausale Zusammenhänge *von realen Erlebnissen* behauptet, kann sie an Wert den Theorien (und Hypothesen) der naturwissenschaften gleichgesetzt werden,

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ductivist (in the style of Ernst Mach[6])—something which, in his later accounts of the early development of his own thought, is totally absent and even implicitly denied. In fact, contrary to what he later reports (Popper [1935] 1959, 311–312; see also Popper 1957, [1974a] 1976, 31–44), he did not arrive at his criticism of induction in the years between 1926 and 1928, nor did he formulate his famous criterion of demarcation in those years. "Instead of being involved in abstract epistemological and methodological problems, Popper in this period attempted to find his way in the different fields of psychology" (ter Hark 2002, 80; 1993).[7]

In order to be empirical, a theory "may only be formed inductively, through abstraction from empirical facts, and may never be projected into them" (Popper 1927, 20).[8] The inductive process follows three steps:

a. an "unprejudiced description (phenomenology) of empirical facts"[9] (no reference to Husserl), that is, a comprehensive description of the psychology of lawfulness among children (Popper 1927, 20);
b. an "attempt at abstraction" (1927, 20);[10]
c. an "ordered representation (from a theoretical perspective)" (1927, 20),[11] so as to offer an explanation of the phenomena taken into consideration (19).

Interestingly, Popper also points out an intrinsic danger in the inductive method, which threatens particularly psychoanalysis. The first (phenomenological) stage will always receive a feedback from the third (theoretical) one, so that the facts are selected to fill certain gaps in the theory: "As

denn diese Zusammenhänge sind verifizierbar"). It is worth noticing that Popper's term for "experiences" (*Erlebnisse*) is the same term Carnap and other logical empiricists use to refer to sensations.

6. See Popper [1935] 1959, 75, where he expresses bewilderment and dissent at Mach's calling "Fourier's theory of heat conduction a 'model theory of physics' for the curious reason that 'this theory is founded not on a *hypothesis* but on an *observable fact*'."

7. Far from being an abstract treatment of the problem of induction, Popper's 1927 thesis is "a psychological attempt to answer some urgent practical pedagogical questions" (ter Hark 2002, 81): it concerns philosophy of education rather than philosophy of science. It is in no way involved with what Popper would later call "the problem of induction." "Indeed, it is clear from the first sentences of the Preface that induction is not a topic of (critical) discussion at all" (ter Hark 2002, 81).

8. "Entscheidend für den Charakter einer ernst zu nehmenden empirischen Wissenschaft ist aber jedenfalls, dass eine Theorie nur induktiv, durch Abstraktion aus empirischen Sachverhalten, gebildet werden darf, niemals aber in die Sachverhalt hineigedeutet sein darf."

9. "Unvoreingenommene Beschreibung (Phänomenologie) der empirischen Sachverhalte."

10. "Abstraktionversuch."

11. "Geordnete Darstellung (aus theoretischen Gesichtspunkten)."

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time goes by, systematics penetrates deeper and deeper into phenomenology; this entails the danger that phenomenology, the description, which must be purely empirical and unprejudiced, gets influenced by the theory itself. As a consequence, it [phenomenology] presupposes the theory for which it should provide the inductively based empirical evidence in the first place; this would clearly be a so-called circular reasoning, a *petitio principii*" (1927, 20).[12] Clearly, Popper is very far from his later and well known deductive view that there is no observation that is not theory-laden.[13]

Consider also the following passages:[14]

> Free thinking . . . is critical thinking—dogmatic thinking is not free: under free thought one can only understand thinking "without prejudices", that is, thinking which *judges* states of affairs, without presupposing the result (the judgement) of judging; critical thinking is also thinking with foundations; it is active, spontaneous and autonomous thinking, in contrast with dogmatic thinking, which does not touch the accepted (adopted) "judgement". (Popper 1927, 10)[15]
>
> We shall use the terms "dogmatic" and "critical" in a more liberal sense than is often usual: by *"dogmatic thinking"* we wish to mean a type of thinking that is characterized by the mere acceptance of and sticking to certain principles. These principles are *adopted*,

12. "Es dringt also mit der Zeit die Systematik immer mehr in die Phänomenologie ein; das bringt die Gefahr hervor, dass die Phänomenologie, die Beschreibung, die rein empirisch, unvoreingenommen sein soll, sich von der Theorie selbst beeinflussen lässt, was zur Folge hätte, dass sie die Theorie vorauusetzt, für die sie die induktiven Beweisgrundlagen erst liefern sollte; das wäre also das, was man einen Zirkelschluss, eine petitio principii nennt." "This", Popper adds, "is precisely the mistake into which have fallen, for instance, the psychoanalytic movements (Freud, Adler)" ("In eben dieser Fehler sind z. B. die psychoanalytischen Richtungen (Freud, Adler) verfallen", 1927, 21). The issue is raised also in ter Hark 2002, 89.

13. See references in fn. 3.

14. These passages are also quoted in ter Hark 2002, 85 and 93, but with a different translation.

15. "Freies denken aber ist kritisches Denken — dogmatisches Denken ist unfrei: Unter freiem Denken kann man nur jenes Denken verstehen, das 'vor-urteilsfrei' ist, das heisst Sachverhalts *beuirteilt*, ohne das Ergebnis (Urteil) der Beurteilung vorauszusetzen; kritisches Denken ist also Denken mit Gründen; es ist aktiv und spontan, Selbst-denken, im Gegensatz zum dogmatischen Denken, das an dem angenommenen (übernommenen) 'Urteil' nicht rührt." Critical thinking is identified with revision of a framework in response to conflicting experiences. In later years, Popper considers the interchange between dogmatic and critical thinking as a trial and error process, vital to the growth of knowledge. In 1927, dogmatic thinking is just an obstacle to the learning process, not a necessary stage: it remains confined to psychology, never crossing the boundary into logic, the realm of critical thinking.

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> "blindly" taken for true, without even recognizing the possibility of their falsehood; that is, they are in particular not investigated as to their correctness through experience; one *sticks to them*; that is, one applies them stubbornly wherever they seem to be applicable . . .. (Popper 1927, 15–16)[16]
>
> *Critical thinking*, by contrast, can be characterized by such questions as "is it really true?" (or "correct"?), "does it really have to be that way?"; also in the field of ethics: "is it really good and right?", etc. Critical thought attempts to question the principles that are usually at first blindly received and dogmatically maintained, in order to accept and apply them first after *verification*, particularly by means of experience, but also through reflection. (Popper 1927, 17)[17]

In 1927, then, Popper feels the necessity to justify the scientific character of psychology comparing it to natural sciences, which are founded (as Popper himself thinks in those years) on induction. At this stage, thus, there is no such a thing as a "problem of induction": *induction is to Popper no problem at all*— without any qualms, it is taken to be *the* criterion for empirical science.

3. The Problem of Demarcation. In his first thesis Popper states some "general methodological presuppositions" (1927, 18)[18] about the problem of the scientific character of pedagogy, defending its scientific status against the sceptics on the basis of the "objective-scientific *decidability* of

16. "Wir gebrauchen dabei die Worte 'dogmatisch' und 'kritisch' in etwas weiterem Sinne, als dies häufig üblich ist: Unter '*dogmatischem Denken*' wollen wir eine Art des Denkens verstehen, die charakterisiert ist durch blosses Hinnehmen und Festhalten gewisser Grundsätze: Die Grundsätze werden *hingenommen*, d.h. 'blind' für wahr gehalten, ohne die Möglichkeit überhaupt zu sehen, dass sie falsch sein können; also im besonderen nicht erst durch Erfahrungen auf ihre Richtigkeit geprüft; sie werden *festgehalten* d.h., sie werden hartnäckig angewendet, wo sie nur anwendbar zu sein scheinen." In this and in the following passage Popper describes something very close to Kuhn's "normal science" activity: there can be no critical phase without a preceding dogmatic phase. However, for Popper in such a phase an expectation is formed so that error elimination can begin to work on it.

17. "Versuchen wir nun das *'kritische' Denken* zu charakterisieren; mit Fragen wie: Ist das auch wirklich wahr? (oder richtig?); muss das wirklich so sein? Auf ethischem Gebiet auch: Ist das auch wirklich gut und recht? u.s.w. versucht es, die gewöhnlich erst dogmatisch aufgestellten und festgehaltenen Grundsätze 'in Frage zu ziehen', um sie erst nach *Bewährung*, vor allem durch die Erfahrung, aber auch durch Nachdenken, anzunehmen und anzuwenden."

18. "Allgemeine methodologische Voraussetzungen." Over a third of the thesis is devoted to methodological and theoretical introductions, descriptions of the pedagogical and psychological problem situation, and a definition of its task.

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pedagogical problems properly put" (7):[19] these remarks, as ter Hark also notices (2002, 88), are Popper's first steps in methodology, or the philosophy of science. Such a treatment should deal primarily with the "*delimitation* of the empirical part of pedagogy from its non-empirical part" (7, my emphasis)[20] since Popper holds it to be true that "pedagogy as a modern science must first be purely empirical" (7).[21] Complementarily, it is more important "to delimit the rational, speculative part" (7).[22] These first methodological remarks do not show any sign of Popper's deductive method of trial and error: Popper's stance is thoroughly traditional, that is, inductive (see ter Hark 2002, 88).

We must also notice that the term *Abgrenzung* (which we might translate with "delimitation") does have a different meaning from the standard one, usually translated with "demarcation." In fact, it is crucial that in 1927 Popper is not relying on a deductive method (falsifiability) as a criterion of demarcation: as we have seen, he takes inductive method for granted. In 1927 Popper's problem is actually to *verify* the point to which general theoretical assertions are supported by empirical facts, and are consequently valid: he is simply delimiting the science which intends to relate to reality (logic and mathematics excluded, then) through the integral and concrete support of empirical evidence. Only empirical theories—that is, theories whose assertions are covered by empirical facts—share the true scientific method (that is, of course, induction). Moreover, this early discussion of *Abgrenzung* is a discussion within the field of psychology, while Popper's later discussion of the demarcation problem is framed in terms of a sharp distinction between scientific disciplines (such as physics) and non-scientific ones (such as psychoanalysis and Marxism):[23] in 1927 Popper speaks only of the boundary between Adler's theory and empirical psychology (Külpe's and Bühler's *Denkpsychologie*). This does not mean that Popper's *Hausarbeit* is to be regarded as an early attempt to solve a problem of demarcation between science and non-science:[24] in fact, Popper has by no means in mind the concept of demarcation (or the solution to the problem of demarcation) as we know it from his published works (see Popper [1935] 1959, 34–35; and [1979] 1994, XXVII and 3–5). In his

19. ". . . eine wissenschaftlich- objektive *Entscheidbarkeit* von richtig gestellen pädagogischen Problemen."

20. "*Abgrenzung* des empirischen Teils der Pädagogik vom nicht-empirischen erfassen."

21. ". . . die Pädagogik als moderne Wissenschaft in erster Linie rein-empirisch sein muss."

22. ". . . umso wichtiger ist die Abgrenzung des rationalen, spekulativen Teils."

23. See also, on the same point, ter Hark 2002, 91.

24. Troels E. Hansen thinks differently: see his 2004.

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1927 thesis the problem of demarcation is as absent as the problem of induction.[25]

In his 1928 doctoral dissertation, *Zur Methodenfrage der Denkpsychologie* (The Problem of Method in Cognitive Psychology)[26] Popper holds an inductivist position and works on the theory, rather than on the psychology, of knowledge. For in his second thesis Popper discusses scientific method in psychology, taking as his starting point Schlick's *Allgemeine Erkenntnislehre* and Bühler's *Die Krise der Psychologie*.[27] Bühler defends a "pluralism of aspects"(Popper 1928, 5)[28] in psychology and establishes his methodology as a prerequisite for a theory of language. Psychology is possible if and only if the aspects of experience, of behaviour and of ideas in the objective sense ("Gebilde des objektiven Geistes") find an equal place. Popper applies this pluralistic methodology first to the mind-body problem and next to cognitive psychology (*Denkpsychologie*). He aims first at defending Bühler's pluralistic methodology against the objections of physicalism,[29] and then at showing that Bühler's pluralistic methodology "will display itself also as *inevitable* in cognitive psychology" (Popper 1928, 5).[30] As to Schlick, Popper discusses, in particular, the setting out of the psychophysical analogy, according to which the series of psychical and physical phenomena of the nervous system run in parallel, with none being the cause or the effect of the other. Schlick regards such a parallelism as a hypothesis which we have to accept in order to remedy several problems faced by the theory of the reciprocal action of mind and

25. This analysis also sheds light on the profound relationship between the problem of demarcation and the problem of induction. Albeit there is no discussion on the priority of the former—at least in its "qualified" form—over the latter (which, to repeat, is no problem at all in 1927), both the early and the later solution to the problem of demarcation depend on the method employed: the former solution depends on an inductive method, while the latter on a deductive one. The two problems are intrinsically interwoven, actually constituting two faces of the same conundrum (see below, fn. 37).

26. "The purpose of this thesis, stated Popper, was to outline some of the methodological preconditions for scientific practice in cognitive psychology. In *Die Krise der Psychologie* (The Crisis in Psychology) Bühler established his methodology as a prerequisite for a theory of language. Popper intended to show that the same methodology was equally necessary for cognitive psychology" (Hacohen 2000, 156). For a description and contextualization of this thesis, see Hacohen 2000, 156–163.

27. See Schlick [1918] 1925 and Bühler 1927. "The purpose of the thesis . . . is to outline some of the methodological preconditions for scientific practice in cognitive psychology" (Hacohen 2000, 156).

28. "Pluralismus der Aspekte."

29. Actually, Popper presents Schlick's *Allgemeine Erkenntnislehre* as a countermodel to Bühler's *Die Krise der Psychologie*; see Hacohen 2000, 158–159.

30. ". . . sich auch in der *Denkpsychologie als unvermeidbar* erweist."

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body. He therefore accepts the parallelism as a necessary postulate if we want to explain reality. But postulates such as these *remain outside empirical science*, and the same holds for the reciprocal causality which "neovitalists" require (see Popper 1928, 42). Popper objects to both physicalism and the psychophysical parallelism. He concedes that the choice between Bühler's pluralism (which recognizes the interaction of body and mind) and Schlick's physicalism can not be logically decided. However, he argues, a methodological separation between physics and psychology is essential. Schlick's physicalism offers no working hypothesis for psychology. The positivist ideal of the methodological unity of the sciences is logically problematic and methodologically not viable. Scientific procedures are logical and autonomous: the task of epistemology is to determine them. In contrast, pre-scientific thinking reflects psychological experience. Epistemological and psychological issues must be kept separated (see Hacohen 2000, 158–161).

However, it is only with his third, 1929 thesis, *Axiome, Definitionen und Postulate der Geometrie*,[31] that Popper sets himself on the path towards a satisfactory solution of the problem of demarcation. Indeed, here Popper follows three steps (see Hansen 2004):

1. he shifts the focus of his work from the psychology of knowledge to the theory of knowledge (Popper 1929, 25–36): he is no longer interested in the "experience of law" (*Gesetzerlebnis*), but in the *logical status* of natural laws: indeed, he speaks of such things as the "validity of foundations" ("Geltung der Grundsätze", 25);
2. he distinguishes between strictly universal statements and numerical universal statements (or, what is the same, between strictly universal statements and singular statements);
3. he solves the problem of induction—a problem that "can not even be formulated" without the distinction between strictly universal statements and singular statements.[32]

31. The thesis is divided into three parts. The first part introduces mathematical-logical problems and scientific-theoretical ones. The former are axiomatic and can be resolved with no reference to reality; the latter are methodological and involve epistemological issues, raising the foundation problem. The second part discusses the historical development of both group of problems. Popper particularly focuses on the parallel postulate, outlining the rise of non-Euclidean geometries and analyzing their space conceptions. In the third part, which develops the problems systematically, Popper explores the grounds of geometrical validity, the applicability of geometry to reality and the methodological rules governing space in physics. This final part is the most original and contains important methodological observations. For a fuller discussion of Popper's third thesis, see Hacohen 2000, 171–178.

32. "[Das Induktionsproblem] läßt sicht ohne diese Unterscheidung gar nicht formulieren": see Popper [1979] 1994, 227.

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These three steps take Popper to his philosophical breakthrough, allowing his revolutionary solution to the problem of rationality. Let me put this into context.

4. Popper's Philosophical Breakthrough. At the very beginning of his philosophical development, Popper was an inductivist; then he radically changed his mind. The break that marks Popper's philosophical development dates, I suggest, to 1929 (ten years after the year Popper identifies as crucial for his views).[33]

As I see him, Popper is the philosopher of revolution. He said that we learn from experience by the very act of overthrowing a theory with the help of that experience. We learn from experience, that is, by repeatedly positing explanatory hypotheses and refuting them experimentally, thus approximating the truth by stages. In other words, we gain theoretical knowledge when and only when revolutions occur.

And I think that one of the most important lessons we could learn from him resides precisely in the revolutions Popper's thought went through in his early and most creative years. The first revolution was political: in his youth he was a communist and then a socialist, but eventually renounced both these ideas since he found them mistaken. The second revolution was epistemological: Popper was a committed inductivist and then became a deductivist. While the first revolution took place in 1919, as Popper himself says in his autobiography ([1974a] 1976, 31–38), it is 1929 that marks the turn in Popper's philosophy.[34] For, I suggest, in *Axiome, Definitionen und Postulate der Geometrie* we notice a significant break (maybe due to very practical reasons, given Popper's new job as a teacher of mathematics and physics) from the subjects he had been studying and which had a pedagogic-psychological character. Up to 1929 epistemology enters as far as the problem is that of the justification of

33. I do not mean to say that Popper lied about this: 1919 proved indeed crucial for him (and not only for him). But I think the insights Popper had then took ten years to crystallize first in a criticism of induction, and then in a consistent solution of the problem of demarcation—as the argument of *Die beiden Grundprobleme der Erkenntnistheorie* testifies.

34. As Hacohen rightly notices, "A reader of Popper's 1928 dissertation would not identify the writer as Popper. A reader of *Die beiden Grundprobleme der Erkenntnistheorie* . . . could make no mistake" (Hacohen 2000, 171). The 1927 and 1928 theses are not concerned with questions related to epistemology and the logic of science. Popper's philosophical breakthrough originates from his sharply separating logic and psychology. (A crucial aspect of Popper's philosophy is its roots in the philosophy, psychology and pedagogy of the Würzburg school; see the detailed account provided by John Wettersten in his 1992, chapter 8). The 1929 thesis, shifting Popper's inquiry from psychology to the philosophy of science, bridges the gap between *Zur Methodenfrage der Denkpsychologie* and *Die beiden Grundprobleme der Erkenntnistheorie*.

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the scientific character of these fields of research. In 1929 Popper explicitly discusses the cognitive status of geometry without referring to psychopedagogical aspects. This thesis first formulates the problem of scientific rationality, enabling Popper's future philosophical progress. It reflects Popper's turn from cognitive psychology to the logic and methodology of science.

In the thesis Popper presents a scholarly survey of the problems connected to geometrical axioms, postulates and definitions in Euclidean geometry. As is well known, Euclid's fifth postulate (the parallel postulate) proved very problematic: the dissatisfaction with it stemmed from its complicated and somewhat contrived nature, when compared with other postulates; it was considered true, but not sufficiently self-evident to justify its status as a postulate.[35] Since its appearance, then, non-trivial attempts were made to prove it from the other axioms. Failures to do this culminated in the various non-Euclidean geometries first devised by Gauss, Bolyai, Lobatchevskij and Riemann, who gave up the parallels postulate and developed a geometry independent of it. Non-Euclidean geometries were purely conceptual. They were not grounded in experience or perception, and thus epistemology was irrelevant to them (see Popper 1929, 61).[36]

For the first time, theoretical physics faced a choice among competing geometries: all of them were internally consistent, offered alternative space-conceptions and were always unconditionally true. There arose the problem of their application to reality. Logic (as well as mathematics) is never involved in questions of conformity to reality, since the relationships it establishes among objects are conceptual, not real: the only thing at

35. The fifth postulate is stated in Book I of Euclid's *Elements*: "if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles" (Euclid 1951, 443). This postulate has various formulations, all of which are proved to be equivalent to Euclid's original statement.

36. In hindsight we should observe that the status of these attempts was unclear. In particular, the difference between any geometry interpreted as purely conceptual and the same geometry interpreted as synthetic was nebulous. Thus, when Gauss formulated his own geometry he claimed to have refuted Kant's transcendental proof. He was wrong, since he never produced an interpretation of his geometry as a description of real space. Russell's dissertation (1897) still faced similar difficulties. Until Hilbert made pure geometry purely formal, that is purely analytic, and Einstein made the first tenable interpretation of real space as non-Euclidean, i.e. of geometry as purely synthetic, conflating pure geometry and its synthetic interpretations was a common practice. Thus, the relationship between epistemology and pure geometry was unclear.

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issue is its internal consistency.[37] The same holds for pure geometry: all geometric theorems are analytic, derived from axioms. As long as the axioms are accepted, the theorems are valid *a priori.* Applied geometry, however, is different: it establishes *real*, not conceptual, relationships among objects. Its theorems are, at least in part, synthetic and valid *a posteriori.* Their proof requires observational verification. Therefore, *applied geometry involves scientific procedure and raises epistemological as well as methodological issues* (see Hacohen 2000, 176–177).

The most striking applications of geometry are in the field of theoretical physics, where divergent concepts of geometrical-physical space compete. Popper agrees with Poincaré (against Helmholtz): our choice of geometry for physical space is free and physical theories can always be reinterpreted in the light of geometry—but such reinterpretation often requires introducing too many ad hoc hypotheses. Therefore, Popper adopts the methodological proposal that scientific theories require the greatest economy in the use of hypotheses (see Popper [1935] 1959, 82–83). Our choice among competing geometrical metrics to describe our space can be *methodologically* decided. It is Popper's first statement on the methodology of natural science. The methodological path he sets himself to take is clear; while accepting a strong conventionalist component in methodology, Popper chooses to make tests express the final verdict upon our decisions (Hacohen 2000, 177–178). For sure, the acceptance of these results is conventional, but our decision bears an *epistemic* value. Together with the idea of simplicity, the metaphysical assumption of realism paves a new way, rigorously deductive, far both from Poincaré's conventionalism and Helmholtz's inductivism.

Thus, *applied geometry sets the context for Popper's discussion of scientific rationality*. In the following years, he will be applying the hypothetico-deductive model to all natural sciences (which, unlike geometry, are not axiomatic): "whenever we are doubtful whether or not our statements deal with the real world, we can decide it by asking ourselves whether or

37. Incidentally, this constitutes the core of Popper's later solution of the problem of induction, based upon deductive method. As Mark Notturno argues (2000, chapter 5), since their conclusions do not follow from their premises, not only inductive arguments are unable to provide adequate justifications but they prove to be of no value for critical thinking: they can never force us to question our premises, that is to reexamine our beliefs—let alone to choose between them. However, despite logic can not compel our beliefs, it can force us to choose: rationality is not a property of knowledge, but a task for researchers. *It is not the content of a theory which is rational, but the way we hold it:* this is the core of Popper's critical rationalism. Being rational means nothing but being willing to appeal only to reason and arguments to resolve our disputes. Rationality requires no foundation, no grounding upon expert opinion or consensus. It needs only critical dialogue. See also Gattei 2004.

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not we are ready to accept an empirical refutation. If we are determined, on principle, to defend our statements in the face of refutations . . ., we are not speaking about reality. Only if we are ready to accept refutations do we speak about reality" (Popper 1946, 212).

Consider the closing paragraph of the 1929 thesis:

> Only now, after having surveyed the different species of pure and applied geometries . . . it is possible to formulate a conclusive judgement about their kind of validity: are they valid *a priori* or *a posteriori*, in a rigorous or in an approximate way? It is necessary to clarify that the opposition between validity *a priori* and *a posteriori* opens an insurmountable abyss between two sciences. For the propositions of an *a priori* science hold exactly, as purely conceptual constructions, while all the propositions of an *a posteriori* science can be regarded as *approximately valid* only on the basis of ascertainment by observation and experiment, on the basis of "empirical verification".[38] *Only* pure geometries are valid *a priori*, as it was proved. *Pure geometry* and the various kinds of *applications* of geometry are therefore *completely different* sciences. (Popper 1929, 142–143)[39]

To sum up, then, it is the problematic relationship between geometrical-mathematical constructions and physical reality which triggers Popper's philosophical revolution. As a consequence, he gets over a too direct notion of such relationship, casting doubts on inductive inference, and starts conceiving in a new (non-inductivist) manner the problem of the relationship between axiomatized theories and reality, between theoretical and observational propositions. It is only in 1929 that Popper sees induction as a problem—and, given its close interdependence with the solution of the demarcation problem, 1929 marks the first step towards such a solution. Here lies Popper's philosophical breakthrough, the insight that

38. Actually, this still seems to have an inductivistic flavour. That is why I tend to think that this is only the first step towards the rejection of inductivism in favour of deductivism.

39. "Erst jetzt, nachdem die verschiedenen Arten der reinen und . . . der angewandten Geometrien klar überblickt werden können, ist ein abschliessendes Urteil über die Art ihrer Geltung möglich: Gelten sie a priori oder a posteriori, streng oder nur annäherungsweise? Man muss sich darüber klar sein, dass der Gegensatz zwischen aprioriischer und aposteriorischer Geltung eine unüberbrückbare Kluft zwischen zwei Wissenschaften aufreisst. Denn die Sätze der apriorischen Wissenschaft gelten als rein begriffliche Konstruktionen genau, während alle Sätze einer aposteriorischen Wissenschaft erst auf Grund von Bestätigungen durch Beobachtung und Experiment, auf Grund 'empirischer Verifikation' als *annäherungweise gültig* betrachtet werden dürfen. Von rein apriorischer Geltung sind nun, wie sich gezeigt hat, *nur* die reinen Geometrien. Die *reine Geometrie* und die verschiedenen Arten der *Anwendungen* der Geometrie sind daher ganz *verschiedene Wissenschaften.*"

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might allow us to bridge the gap in our reconstruction of the decisive developments of his thought, from the early inductivist position to the one he adopts in *Die beiden Grundprobleme der Erkenntnistheorie*.

5. Popper's Later Fall Back into Inductivism. In *Logik der Forschung* Popper proposes that a theory is scientific if and only if it can be overthrown with the help of experience, and that we gain theoretical knowledge from experience when and only when revolutions occur. There is nothing explicit about corroboration, namely about the failure to refute hypotheses.[40] Therefore, Popper tried to solve the problem of induction *not* by his theory of corroboration, which came later,[41] but by his theory of gradual approximation to the truth by repeatedly making explanatory hypotheses and refuting them experimentally. It is important to stress how Popper's *original* solution of the problem of induction, as stated in the early 1930s, offers a model of the progress of science and of the growth of knowledge by a never-ending process of conjectures and refutations—of bold scientific hypotheses which we must do our best to criticize and refute.

In *Logik der Forschung* Popper declares learning from experience to be not by positive evidence but by negative evidence. For, if we search for positive evidence, the evidence will not be scientific, the only way to find positive evidence recognizable by science is by looking for negative evidence.[42] If we look for negative evidence, says Popper, we may find it, or else we will find positive evidence; but if we look for positive evidence we will find only positive evidence, which is of no scientific value (see Agassi 1961, 1968).

40. Popper's criterion of demarcation does not distinguish between refuted and corroborated hypotheses. By Popper's criterion even hypotheses which were amply refuted by experience are fully entitled to the honorary status of scientific hypotheses.

41. In his 1963b, which Popper describes as a paper containing "some essential further developments of the ideas of my *Logic of Scientific Discovery*" (215). Indeed, there he says that science without positive evidence is impossible, and that his theory of science as conjectures and refutations should be replaced with a theory of science as conjectures, corroborations and refutations. The empirical support a theory gains from experience is *only* a measure of its having stood up severe tests—but no degree of corroboration of a hypothesis can secure that it will not be refuted in the next test; no degree of corroboration of a hypothesis makes it even slightly more probable that it will be refuted in the next test. Corroboration implies neither verification nor any increase of probability.

42. ". . . the whole importance of the refutation of received opinion, or of the best scientific opinion or idea or proposal, is just this: refutation opens the road to innovation. Nothing is a more potent heuristic than refutation. Nothing is more conducive to progress than criticism of the current situation, nothing more likely to herald the new than discontent with the old. Criticism is liberation. The positive power of negative thinking" (Agassi 1988, 497–498).

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Science, then, is to Popper a special case of Socratic dialogue, with experiments and observations offering new arguments, or new empirical criticisms. And when an attempt at empirical criticism misfires the result is positive evidence. Whatever role positive evidence may play, it can not play any role *qua* positive evidence. It may stimulate the invention of a conjecture and it may be not only a positive support of one conjecture, but also a refutation of another. This, and *no more*: the corroboration of a theory is enlightening, though less enlightening than its refutation—but it is not really necessary.

However, in his later works Popper claimed that corroboration *is* important, and not only enlightening as discovery and increasing of explanatory power of a hypothesis. Corroboration became even *essential* to science, since it constitutes an encouragement to our research: a good theory should be not only capable of being refuted, but also it should not be refuted too soon. We want positive evidence before we get negative evidence, so as to be assured that knowledge grows. With that, Popper changed his view of science from a theory of conjectures and refutations to a theory of conjectures, corroborations and refutations. Indeed, in 1963 Popper introduced a "third requirement" to be satisfied by a new scientific theory for it to be a major advance on its predecessors. His first two requirements were: (1) "The new theory should proceed from some *simple, new, and powerful, unifying idea* about some connection or relation . . . between hitherto unconnected things . . . or facts . . . or new 'theoretical entities' . . ."; and (2) "the new theory should be *independently testable*" (Popper 1963b, 241; see also 240–248). The third was: "the theory should pass some new, and severe, tests" (Popper 1963b, 242). It may be divided into two parts: "first we require of a good theory that it should be successful in some of its new predictions; secondly we require that it is not refuted too soon—that is, before it has been strikingly successful" (Popper 1963b, 247; see also Watkins 1984, 288–304).[43]

43. However, as Joseph Agassi rightly argued, this is not only a change of the rules during the game, but actually a step back into inductivism and justificationism—an unnecessary and too generous concession to Logical Positivism: see Agassi 1968, 26–27. In his 1974 reply to Alfred J. Ayer in the Schilpp volumes Popper somehow admits it: "there might be a 'whiff' of inductivism here. It enters with the vague realist assumption that reality, though unknown, is in some respects similar to what science tells us or, in other words, with the assumption that science can progress towards greater verisimilitude" (Popper 1974b, 1193). And again, in a lecture written in 1960: "I admit that there may be a whiff of verificationism here; but this seems to me a case where we have to put up with it, if we do not want a whiff of some form of instrumentalism that takes theories to be mere instruments of exploration" (Popper 1963b, 248). These passages have been differently understood. Of the first, William Newton Smith says that "it is just false to say that there is a whiff of inductivism here—there is a full-blown storm" (Newton-Smith 1981, 68). Of the second, David Miller says that

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But if our aim is to learn from experience all this is redundant. We learn from experience by repeatedly positing explanatory hypotheses and refuting them experimentally, thus approximating the truth by stages. From this point of view corroborations are entirely irrelevant. On the contrary, testing matters, and it has an undeniable epistemological significance. "Testing is important because it is only by subjecting our theories to tests that we have any opportunity of eliminating those that are false; and the more severe the test, the more generous the opportunity" (Miller 1994, 120).[44] Corroborations are needed if science is to exist, but they make no contribution to the progress of science or to the growth of knowledge.

How do we learn, then? Popper's answer is: by criticizing our errors. The idea that anything we say can be subjected to critical examination is the core of Popper's philosophical attitude, his solution to the problem of rationality. Popper takes the critical attitude as fundamental: corroboration is just one sort of happening in the history of science which results from this attitude and to which, in turn, this very attitude should be applied.[45] Practically all rational philosophers have stressed the value of criticism, yet they almost all viewed criticism—that is, the elimination of error—as a preliminary to the positive advancement of the understanding. Popper almost alone, and alone in the twentieth century, claimed that criticism constitutes the very engine of the advancement of our understanding of the world and of our place in it.[46]

Rationality is critical debate, said Popper. As Joseph Agassi remarked,

"Popper's famous third requirement has to be seen as embodying not a 'whiff of verificationism' . . ., but what might be called a whiff of verisimilitudinism" (Miller 1994, 120–121). By contrast, Joseph Agassi states that "either Popper assigns no value to positive evidence *qua* positive evidence, or he is in the same boat as the inductive philosophers who cannot bring positive evidence to support their theories of positive evidence" (Agassi 1968, 27); see also Agassi 1993, 201–204.

44. "We might put it this way. When a theory fails a test, we learn something but end up knowing nothing (since what we knew, our theory, has been eliminated). But when a theory passes a test (when, that is to say, it is corroborated), we learn nothing (since we already knew what the result of the test was going to be) but we continue to know something" (Miller 1994, 120).

45. We should take notice of well-corroborated theories and try to explain the fact that they were corroborated. And since a variety of explanations may be available, we would have to examine critically each of them.

46. "We can criticize science by attempting to empirically refute its doctrines; we can criticize pseudo-science by exposing its pretense; we can criticize metaphysics by showing its poverty; we can criticize a research program by finding and criticizing the comprehensive system—the metaphysics—behind it. And criticism opens the way to the introduction of an alternative to whatever was criticized, and vice versa" (Agassi 1988, 498).

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"rationality is not any critical debate, but only that which is oriented towards a specific goal as well as might be reasonably expected" (Agassi 1968, 34). And this goal, I suggest, must be truth (see also Gattei 2002a, 249–252, and 2002b, 449–451). The appropriate standards of criticism are not those that appeal to justification, but those that appeal to truth. While traditional philosophy regarded the justification of beliefs as the goal, and the critical method a way of reaching it, for Popper the goal is truth, and it is the method of investigation itself that is rational.[47] This is the core of the revolution Popper marked in twentieth century philosophy of science—rationality requires no foundation, only critical dialogue: it is the end of foundationist philosophy.

From the philosophical point of view, the twentieth century was characterized by the crisis of foundationalism. Philosophers were confronted with the problem of how to respond to it. Some have concluded that scientific knowledge is unjustified and hence irrational after all. Others—indeed, the majority—have opted for retaining the idea that scientific knowledge is justified belief, while weakening either the idea that truth is correspondence with reality or the idea that justification shows that a statement is true. Each of these responses retains the foundationalist theory of rationality, according to which it is irrational to accept a belief that has not been justified and obligatory to accept one that has. But the failure of foundationalism has no implication whatsoever for truth. It does not belittle the truth, and it does not reduce it to solidarity and consensus (Wittgenstein, Kuhn). It only shows that—as Socrates beautifully said—we are living in the twilight zone between knowledge and ignorance, where the views that we hold may be true, but where we are unable to know that they are. The failure of foundationalism does not drag epistemology with it. The twilight zone between knowledge and ignorance is an ideal well worth holding on to.

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47. See also above, fn. 37. Truth (i.e. correspondence) is an ideal, a regulative idea, always sought and never sure to have been obtained: indeed, we may well obtain truth, but not justified certainty that we have obtained it. The linguistic turn no longer threatens realist metaphysics and objective science.

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