Lett Mat Int (2014) 1:179–184
DOI 10.1007/s40329-014-0031-7

Falsifications and scientific progress: Popper as sceptical optimist

Carlo Veronesi

Published online: 30 January 2014

Abstract A scientific theory must be falsifiable, and scientific knowledge is always tentative, or conjectural. These are the main ideas of Popper's *Logic of Scientific Discovery*. Since 1960 his writings contain some essential developments of these views and make some steps towards epistemological optimism. Although we cannot justify any claim that a scientific theory is true, the aim of science is the search of truth and we have no reason to be sceptical about the notion of getting nearer to the truth. Our knowledge can grow, and science can progress. Nevertheless, Popper's theory of approximation to the truth is problematic and is still the subject of studies and discussions.

Keywords Karl Popper · Alfred Tarski · Philosophy of science · Logic · Truthlikeness

1 References to two fundamental problems of knowledge

Popper's philosophy of science takes as a starting point two fundamental problems of knowledge theory: the problem of induction, which Popper calls 'Hume's problem', and the problem of demarcation, which is called 'Kant's problem'.

The problem of demarcation consists in the search for a criterion that makes it possible to distinguish empirical science from metaphysical speculation, philosophical systems and other forms of human knowledge. One answer to this problem is widely agreed upon: science is based on facts and is distinguished by its inductive method, which derives universal laws by generalising the results of observations and experiments. Thus, to demarcate science recourse is made to a 'principle of induction', which can be expressed as follows: if an observable property is valid for a certain number of members of a class, then it is valid for all members of the class. Popper, like Hume, declares himself contrary to induction and, like Kant, maintains that science begins with hypotheses and not with the gathering of experimental data, but all the same he thinks that it is possible to provide a criterion of demarcation. Hume maintained that induction, as a method of formulating laws or habits, was an irrational procedure, and according to Popper as well, it is not legitimate to go from particular cases to a universal law, that is, one that is valid for a potentially infinite set of cases; it is only permissible to go, in the presence of contrasting observations, to the falsification of the law. Using an example that is by now well known, Popper argues that, no matter how many white swans are observed, no one can be certain that the law 'All swans are white' will always be valid in all regions of space and time: a single observation of a black swan can render it false. It is precisely the possibility of falsification that characterises the empirical sciences and which, according to Popper, draws the line of demarcation between the theories of science and the doctrines of metaphysics or pseudoscience.

Elsewhere [15] we remarked that a young Popper arrived to this idea under the impression of the great upheaval in physics wrought by Einstein's theory of relativity. Newton's theory of gravitation, based on action at a distance of masses, had carried the day for more than two centuries but was replaced, at the beginning of the twentieth century, by relativistic physics. In 1919 the English astronomer Arthur Eddington organised two scientific

C. Veronesi (✉)
Via Fiori Chiari, 5, 46040 Rodigo (Mantua), Italy
e-mail: veronesicarlo@alice.it

expeditions to measure, during an eclipse of the sun in the southern hemisphere, an effect of general relativity which, in a normal day of sunshine, would have been impossible to observe. It was during this expedition that confirmation arrived that the trajectory of the luminous rays of the stars, even though these are without mass in the classic sense of the term, are curved when they pass near the sun. This result, predicted by Einstein and unforeseeable according to Newton's theory, led to the global triumph of the new relativistic physics, even appearing on the front page of the *New York Times*. In that same year—1919—young Popper was able to attend a lecture given by Einstein in Vienna, remaining impressed by the fact that the physics of Newton, which appeared indisputable, could be replaced by a better theory, especially because Einstein himself had explained that in its turn the theory of relativity could also be confuted. Popper became convinced that we can never be sure in science that the truth has been reached, nor could even the most thoroughly tested theories escape the risk of falsification.

The falsifiability of scientific theories, which for Popper was suggested by logic and by the history of science, could also appear to be a rule of common sense. No theory should be taken into account if it evades all checks and if it cannot be contradicted by any observable fact. The predictions of soothsayers and astrologers, often so vague and imprecise as to be suitable for any kind of situation, are neither reliable nor scientific. Thus, science cannot reasonably include theories that render the search for counter-examples impractical, even though this means excluding theories that enjoy greater consideration than astrology.

Even the psychoanalysis of Freud, according to Popper, is closer to metaphysics than to science, because no kind of human behaviour can be either predicted or excluded on the basis of this theory. Instead, Popper's position on Marxism is rather more detailed: in his opinion Marx's doctrine was born as a falsifiable theory, with historically verifiable predictions, but then the followers of Marxism fitted it out with a battery of auxiliary hypotheses to prevent its being clearly contradicted by the facts. In this way they often managed to reinterpret theories and facts so as to make them agree, but in saving the theory, they sacrificed its scientificity.

2 The optimistic turn of Popper's thinking

In his important 1935 *Logik der Forschung* [translated into English as *The Logic of Scientific Discovery* (1959)], Popper, in order to give credence to the thesis that verifications of theories (no matter how numerous) are in any case insufficient, took care to clear the field from another idea of an inductivist or verificationist nature, that is, that evidence in favour, even if unable to lead to the truth, can in any case increase the probability of theories (obviously in the absence of counter-examples). According to him, the probability of a universal law turns out to be equal to zero because the number of favourable cases, necessarily finite, must be seen in reference to the infinity totality of possible cases. Hence the results in favour can in no way increase the probability of a theory; they can only increase the degree of 'corroboration'. Popper uses the term 'corroboration' to provide an indication of how well a theory has stood up to the attempts to confute it, as well as its provisional acceptability. To this end, the number of examples in favour does not count. Banal evidence, such as that which might derive from the repetition of the same experiment, does not increase the corroboration. A theory can be said to be corroborated only if it passes rigorous tests of risky predictions, that is, those at high risk of falsification. More precisely, Popper connects the degree of corroboration of a theory to the success in the prediction of events that are unexpected, surprising and considered improbably in light of previous knowledge. The prediction that the distance between two fixed stars, measured during the day, would be different from that measured at night, would have been unthinkable without Einstein's theory of gravitation (which predicts that light must be attracted to the sun in exactly the same way that heavy bodies are). Thus, confirmation of this prediction by the British expeditions during the 1919 eclipse provided extraordinary corroboration of Einstein's theory. However, the corroboration of a theory is a temporal account of its past successes, which provides no guarantee of its ability to pass future tests. Newton's physics, over the course of two centuries, had registered a series of confirmations as well as of corroborating successes, culminating in the discovery of Neptune. This planet, whose existence has been postulated to explain the anomaly of the orbit of Uranus, was discovered in 1846 by the German astronomer Johann Gottfried Galle in exactly the region of space in which the earlier calculations (based on Newton's celestial mechanics) by John Couch Adams and Urbain Le Verrier had situated it. The sensational success of this prediction provided a huge amount of support for the Newtonian theory, but did not prevents its later refutation.

For the reasons we have just given, in the final pages of *The Logic of Scientific Discovery* (which is still a youthful work, published when the author was just over 30), Popper observes that corroboration is not a value of truth, and that in his logic of science it was possible to avoid the use of concepts of 'true' and 'false' [7: pp. 273–274]. In this order of ideas, he spoke of progress only as the elimination of erroneous theories in favour of others that were more comprehensive, or as the discovery of new problems that were deeper and more general [7: p. 281], almost as if, as

Imre Lakatos noted, scientific progress consisted in 'an increased awareness of ignorance rather than a growth of knowledge' [2: p. 155]. However, after the publication of *Logic*, Popper came into contact with Alfred Tarski's theory of truth, which led him to change the tone of his own philosophy and integrate the logic of discovery, in which it only seemed possible to reveal the error, with the theory of verisimilitude and the approximation to truth.

The Polish logician Tarski—explains Popper—had rehabilitated a theory of truth as a 'correspondence to the facts', which is another common sense idea of the truth. Following Tarski it is possible to write that 'the sentence "snow is white" is true if and only if snow is white' [13: p. 64].

The discussion seems rather trivial, but what Tarski made evident—and this is the decisive element of his discovery—was that to speak about the correspondence of a sentence with the facts we need an 'object language' and a 'metalanguage'. The object language is used to speak about facts, things and properties of the world, such as snow and its colour. Metalanguage is used to speak about both statements in object language, such as the statement in quotation marks 'snow is white', and about the facts of the world to which the statement refer.[1] In his comment Popper goes on to say that once the need for this metalanguage has been understood, it is not difficult to see how a statement can correspond to the facts, and it is also possible to explain the traps of everyday language, such as the classic 'antinomy of the liar', according to which the statement 'I am lying' is self-contradictory (the contradiction deriving from the fact that in everyday language no distinction is made between the levels of language and metalanguage).

Encouraged by Tarski's results, Popper began to think that it might be possible to speak of objective truth, that is, of truth as correspondence to facts, without fear of falling into paradoxes, and that hence there was no longer any reason to abstain from speaking of the truth of science. One scientific theory could correspond to the facts better than another, that is, it could be closer to the truth. It would be rather unreasonable to think that Einstein's physics, which had been successful in risky predictions, with precise measurements of phenomena not predicted by previous theories, did not contain something of the truth, or that it was no closer to the truth than all the rival theories that had preceded it [11: pp. 1192–1193]. Popper became convinced that theories could come close to reality, and that it was also possible to recognise progress made towards the truth. If a theory had passed the tests that had been failed by a previous theory, then we have reason to believe that it is more verisimilar: we can therefore think that a highly corroborated theory is closer to the truth than one with a lower degree of corroboration.

Popper developed these concepts in the writings of his later years, and it is rather peculiar that his philosophy is known above all for its falsificationist methodology and much less known for these more articulated positions, in spite of these having been illustrated in lectures, talks and articles over the course of several decades. In one essay that joins two lectures given in the years 1960 and 1961, Popper himself wrote that, after having become aware of Tarski's ideas on truth and becoming convinced that the idea of truth was not so 'dangerously vague and metaphysical' [8: p. 314], he was able to contribute 'essential further developments' [8: p. 291] to the ideas expressed in his *Logic of Scientific Discovery*.[2] According to this new outlook, science is something more than an incessant discovery of failures, and is not limited to revealing error and replacing erroneous theories. Scientific progress is not made only by means of conjectures and refutations; it is progress by means of conjectures, refutations and corroborations. Thus, corroborations, which were initially the point of departure for ulterior attempts at refutation [7: Appendix IX, p. 419], became signs of progress and steps forward towards the truth, because a corroborated scientific theory, even if it can still be refuted, can be in the running as an approximately true theory and in any case contain a part of the truth. In this way Popper can also explain the possible paradox of false theories, such as Newtonian physics, which in any case function for centuries and continue to be used even after they have been falsified; this without taking refuge in pragmatism or instrumentalism, concepts according to which scientific theories are only convenient instruments for working without any pretext of aiding our understanding of the world. To the contrary, Popper states that the aim of science is precisely to search for the truth and that, in spite of difficulties and limited successes, it even manages to approach it.

3 Truth and approximation of truth

A further difficulty of the concept of truth derives from the conviction that a satisfying theory of truth must comprehend a criterion for believing in it in a way that is established and rational. According to Popper, this idea confuses what is true with what we know to be true, and does not take account of the fact that a theory can be true even if no

[1] On the concept of truth as conformity with (or correspondence to) reality or as conformity with the "existing state of affairs", see [13].

[2] Among the essays of Popper's optimistic phase, Imre Lakatos particularly remarks the 'Addendum' to *The Open Society and its Enemies* [10], even while reproaching Popper for not having 'fully exploited the possibilities opened up by his Tarskian turn' [2: p. 159].

one believes it. Popper maintains that truth must be separated from subjective experience of believing in it, and that the concepts of truth and certainty must not be confused. The aim of science cannot be to search for certainty, because all knowledge is fallible and thus uncertain, but the search for truth nevertheless remains. The theory of objective truth supported by Popper makes it possible to say that we search for the truth even if, as the ancient Greek philosopher Xenophanes (c.570–c.475 BCE) pointed out, we might not ever reach it, or recognise it when we do reach it. Using a famous metaphor, Popper compares the status of truth to a mountaintop wrapped in clouds. A climber might not only have trouble reaching it, but recognising it when he does: up in the clouds he might not be able to distinguish the main peak from the smaller peaks surrounding it. However, he can understand when he has not reached it, as when, for instance, he discerns one even higher, and he can consequently decide to continue on in that direction. As a rule we do not have a criterion of truth, that is, a procedure for recognising it, but we do have criteria for moving towards it.

However, the search for truth might also reveal itself to be a secondary ideal if it is limited to the trivial aspects of reality, because in science we seek something more than simple truth. Much in the same way as in mathematics, where we are not content with saying that two plus two equals four, in science as well we desire truths that are interesting and difficult to attain. We thus prefer a bold conjecture, even if it should turn out to be false, to a series of assertions that are true but uninteresting. From failure we can learn much about the truth; we can, eliminating our errors, come closer to it. Popper adds—and this is the new element—that to approach truth it is generally not sufficient to correct the errors of a previous theory. Certainly what is needed is a new theory that solves the difficulties of the earlier one, but this theory must also make it possible to predict facts never before observed, and to pass some of the tests regarding these new predictions. 'An unbroken sequence of refuted theories would soon leave us bewildered and helpless' [8: p 330]: we need success and empirical corroboration in order to understand if we are on the right path, and also to appreciate the meaning of successful refutations.

All of these considerations take off from an intuitive base: the idea that scientific progress is made by means of a sequence of false (or presumably so) theories, ever closer to the truth, and that these can arise both by means of the correction of the aspects that are gradually falsified as well as by means of the support of new consequences or verified predictions. To explain precisely what he means, Popper considers two theories, A and B, both of which are false (A can be considered an earlier theory and B a later one that replaced it) and states that B is closer to the truth than A if in the passage from A to B the set of false consequences is reduced without impairing the set of true consequences, or the set of true consequences is reinforced without incrementing at the same time the set of false consequences. This definition appears well posed logically: while a true theory has only true consequences, affirmations both true and false can follow from false premises. Moreover, common sense seems to agree with the idea that one false theory can contain fewer errors than another given the same amount of true information, or a greater amount of true information given equal false information. Unfortunately, a few years later some critics [5, 14] showed that none of the conditions established by Popper for approaching truth can be verified, because the true consequences and false consequences of a theory increase and decrease together.

Given the importance of this negative result, which opened a new line of epistemological research, we want to expound on it in some detail. To this end, given the two false theories A and B, let A_T indicate the truth-content (=the set of true logical consequences) of theory A, and A_F its falsity-content (=the set of consequences of A that do not belong to A_T). Analogously, B_T and B_F are respectively the truth-content and falsity-content of theory B. Using these symbols, Popper's comparative definition of verisimilitude or truthlikeness can be rewritten as follows: theory B is closer to the truth than theory A if and only if ($A_T \subset B_T$ and $B_F \subseteq A_F$) or ($B_F \subset A_F$ and $A_T \subseteq B_T$). Now let us show, following Tichý and Miller, that these two conditions cannot be satisfied if the theories are false and thus *no false theory B can be closer to the truth than a false theory A* on the basis of Popper's criterion.

Let us first suppose that $A_T \subset B_T$ and that b is a true consequence of B but not of A (in the passage from A to B the truth-content is incremented, by example with the proposition b). Since B is false, B_F is not empty: I can thus consider a false consequence f of B and form the conjunction $b\&f$. This conjunction is false (it would be true if and only if both b and f were true) and is a consequence of B (because $b\&f$ is a consequence of the propositions b and f, and moreover both b and f are consequences of B): it therefore belongs to the falsity-content of B. The conjunction $b\&f$ cannot also belong to the falsity-content of A, because in that case both b and f would have to be consequences of A, contrary to our assumption that b is not. Therefore, if $A_T \subset B_T$, there exists a proposition, $b\&f$, which belongs to B_F and not to A_F, and there cannot be $B_F \subseteq A_F$ as required by Popper's case 1. If the truth-content of the new theory B exceeds the truth-content of A, contemporarily the falsity-content of B also exceeds that of A.

Let us now suppose that $B_F \subset A_F$ and that g is a false consequence of A but not of B (in the passage from A to B the falsity-content is deprived of proposition g). Let us consider a false proposition f of B to form the implication $f \rightarrow g$. This

implication is true (it would be false only for true f and false g) and it is a consequence of A (because the implication $f \rightarrow g$ is a consequence of proposition g, and proposition g is a consequence of A): it thus belongs to the truth-content of A. The statement $f \rightarrow g$ cannot also belong to the truth-content of B because in that case both f and g would have to be consequences of B, contrary to our assumption that g is not. Therefore, in the case where $B_F \subset A_F$, there exists a statement, $f \rightarrow g$, which belongs to A_T and not to B_T and there cannot be $A_T \subseteq B_T$ as required by case 2 of Popper's definition. In the passage from A to B the falsity-content cannot diminish without at the same time also diminishing the truth-content.

This negative result, according to which two false scientific theories cannot be compared, might appear to be a mere logical artifice. Looking at the history of science, it seems reasonable to think that theories that are gradually falsified can still be considered increasingly better approximations to an unknown truth. The astronomical system of Copernicus has come to be considered better with respect to that of Ptolemy, and the theories of Newton and Einstein are considered even better. We might also cite trivial examples of false statements that we judge to be closer to the truth than others: the statement 'There are ten planets in the solar system' seems to be less false and thus closer to the truth than the statement 'There are ten thousand planets in the solar system'.

In any case, even if the results of Tichý and Miller seem rather counter-intuitive, Popper acknowledged his logical error and attempted to correct the initial definitions of verisimilitude, and so did some of his students and other scholars in the years that followed. One idea might be that of placing a few restrictions on the classes of logical consequences that might work for or against the verisimilitude of theories, for example, comparing only the truth contents or privileging atomic or elementary propositions. This search for an approach to truth can be conducted, as Popper suggested, 'in a kind of metrical or at least topological space' [8: p. 314] but, in spite of a great plethora of approaches, the search has not produced results that are unanimously shared. Thus the intuitive idea of a progressive approach to truth is not easily captured by formal definitions and the problem of verisimilitude remains an open one.[3]

4 Concluding observations and a glance at ulterior problems

In an autobiographical note about his youthful interests, Popper wrote that in the autumn of 1919, when he tackled his first problem of the philosophy of science, he was not worried about the truth of theories: 'My problem was different: I wished to distinguish between science and pseudo-science, knowing very well that science often errs and that pseudo-science may happen to stumble on the truth' [9: p. 44]. Be that as it may, already at the origin of all of Popper's discourse, and his efforts to distinguish science from other forms of knowledge, it is possible to recognise an undeclared assumption: the basic idea that the requirement of falsifiability in any case renders science superior to metaphysics and pseudo-science. Imprecise theories, such as astrology and psychoanalysis, or theories that resort to continual correction to render them immune from failure, such as Marxism, can add nothing to our knowledge: if the search for counter-examples is not practical, then neither can we have any clue as to their provisional reliability. Further, even if one metaphysical theory or another should by some chance speak the truth, it would in any case be a truth that was static and without progress. To the contrary, it is the falsifiable aspects of theories, the refutations and successes in resisting the attempts at refutation, that are capable of contributing to progress towards the truth. These ideas, not yet clarified in Popper's youthful work, would be elaborated, as we have seen, in the later development of his thinking.

Pavel Tichý, one of the logicians who criticised the Popperian definitions of verisimiltude, defines Popper's mature conception as 'optimistic scepticism' [14: p. 155]: the scepticism comes from the statement that we can never prove the truth of a scientific theory; the optimism derives from another of his statements, that our theories, presumably false, can be improved by approaching the truth. It was Popper himself who empowered these definitions of Tichý's, speaking of his position as halfway between a pessimistic and an optimistic conception of scientific knowledge [12: pp. 3–10], tending to be closer to optimism than to sceptical pessimism. This is because, while we might be sceptical about our capability to recognise the truth, we have no reason to be so towards the notion of approaching the truth and the fact that our science can grow and progress.

The middle road between scepticism and optimism sought by Popper seems problematical in any case: from the technical point of view there remains the problem of an acceptable formalization of the notion of verisimilitude; from the epistemological point of view Popper had to recognise that in order to justify his rediscovered optimism he needs a 'whiff' of inductivism [11: p. 1193] to be able to state (taking the history of science as his point of departure) that the theories best corroborated are those closest to the truth. We can see that in this way Popper, after having kicked induction out the door, lets it back in through the window, and further that his inductive argument, weak

[3] For a survey of the studies on verosimiltude, see [6].

nevertheless, needs notions that do not seem objective in the strict sense. Popper says that science progresses by means of risky predictions and results that are unexpected, surprising and sometimes spectacular; he also tells us that science seeks truths that are difficult and interesting. In either case, it appears that (aside from Popper's intentions) other elements, of a subjective, psychological or perhaps aesthetic nature, must be introduced into the scientific enterprise. Recently some scholars of the problem of verisimilitude have begun to consider, albeit with a great deal of caution, the possibility of introducing a principle of aesthetic induction into the evaluation of scientific theories.[4] But this is another story.

Translated from the Italian by Kim Williams.

References

1. Kuipers, T.A.F.: Beauty, a Road to The Truth? Synthese **131**(3), 291–328 (2002)
2. Lakatos, I.: Popper on demarcation and induction. In: Worrall, J., Currie, G. (eds.) The methodology of scientific research programmes: philosophical papers, vol. I. Cambridge University Press, Cambridge (1978)
3. McAllister, J.W.: Beauty and Revolution in Science. Cornell University Press, Ithaca (1996)
4. Miller, D.: Beauty: a road to the truth? In: Out of Error. Further Essays on Critical Rationalism, pp. 183–196. Ashgate, Aldershot (2006)
5. Miller, D.: Popper's qualitative theory of verisimilitude. Br. J. Philos. Sci. **25**, 166–177 (1974)
6. Oddie, G.: Truthlikeness. In: Edward N. Zalta (ed.) The Stanford Encyclopedia of Philosophy (Fall 2008 Edition). http://plato.stanford.edu/archives/fall2008/entries/truthlikeness/ (2008). Accessed 3 December 2013
7. Popper, K.R.: The Logic of Scientific Discovery. Hutchinson, London (1959)
8. Popper, K. R.: Truth, rationality, and the growth of scientific knowledge. Chap. 10. In: Conjectures and Refutations, 7th ed. (2002). Routledge, London (1963a)
9. Popper, K. R.: Science: conjectures and refutations, Chap. 1. In: Conjectures and Refutations, 7th edn. (2002). Routledge, London (1963b)
10. Popper, K. R.: Facts, standards and truth: a further criticism of relativism, addendum. In: The Open Society and its Enemies, vol. 2, p. 369. Routledge, London (1966)
11. Popper, K.R.: Replies to my critics. In: Schilpp, P.A. (ed.) The Philosophy of Karl Popper, pp. 961–1197. Open Court, La Salle (1974)
12. Popper, K. R.: Optimist, pessimist and pragmatist views of scientific knowledge (1963), Part 1: introduction. In: After The Open Society. Routledge, London (2008)
13. Tarski, A.: Truth and Proof. *Sci. Am.* 63–70, 75–77 (1969)
14. Tichý, P.: On Popper's definitions of verisimilitude. Br. J. Philos. Sci. **25**, 155–160 (1974)
15. Veronesi, C.: Problemi del falsificazionismo di Popper. Lettera Matematica PRISTEM **77**, 42–49 (2011)

Carlo Veronesi taught mathematics and physics in upper secondary schools. He also taught history and epistemology of mathematics in specialization courses for teachers at the University of Pavia and the University of Parma. His interests are focused on Popper's epistemology and on the foundations of mathematics. His publications include *Popper filosofo della matematica* (PRISTEM, 2007). He is currently expert of logic and philosophy of science at the Department of Philosophy, Education and Psychology of the University of Verona.

[4] The discussion on aesthetic induction is introduced in [3]. On the relationship between aesthetic induction and truth, see [1] and [4].