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Abstract

In this paper I argue that, despite the criticism of Karl Popper's falsifiability theory for the demarcation between science and non-science, mainly pseudo-science, this criterion is still very useful, and perfectly valid after it was perfected by Popper and his followers. Moreover, even in his original version, considered by Lakatos as "dogmatic", Popper did not assert that this methodology is an absolute demarcation criterion: a single counter-example is not enough to falsify a theory; a theory can legitimately be saved from falsification by introducing an auxiliary hypothesis. Compared to Kuhn's theory of revolutions, which he himself later dissociated from it transforming it into a theory of "micro-revolutions," I consider that Popper's demarcation methodology, along with the subsequent development proposed by him, including the corroboration and the verisimilitude, though imperfect, is not only valid today, but it is still the best demarcation methodology. For argumentation, I used the main works of Popper dealing with this issue, and his main critics and supporters. After a brief presentation of Karl Popper, and an introduction to the demarcation problem and the falsification methodology, I review the main criticisms and the arguments of his supporters, emphasizing the idea that Popper has never put the sign of equality between falsification and rejection. Finally, I present my own conclusions on this issue.

Keywords: Karl Popper, falsifiability, falsification, demarcation problem, pseudo-science

Introduction

For this discussion I have appealed to *Popper Selections*, edited by David Miller, (Miller 1985) Karl Popper's books, *The Logic of Scientific Discovery*, (Karl Raimund Popper 2002b) *Conjectures and Refutations: The Growth of Scientific Knowledge*, (Karl Raimund Popper 2002a) and *Die Zukunft ist offen* (*The Future is Open*) (with Konrad Lorenz), (K. Popper and Lorentz 1985) nd the works of Sven Ove Hansson, « *Science and Pseudo-Science* », (Hansson 2017) Stephen Thornton, « *Karl Popper* », (Thornton 2017) Paul Newall, « *Falsificationism* », (Newall 2005) Imre Lakatos, « *Falsification and Methodology of Scientific Research Programs* », (Imre Lakatos 1970) Brendan Shea, "*Karl Popper: Philosophy of Science Brendan Shea*", (Shea 2017) David Miller, "*Some Hard Questions for Critical Rationalism*", (Miller 2009b) Alan Musgrave și Charles Pigden, « *Imre Lakatos* », (Musgrave and Pigden 2016) Suddhachit Mitra, "*What Constitutes Science: Falsifiability as a Criterion of Demarcation*", (Mitra 2016) Carl G. Hempel, "*Empirical Statements and Falsifiability*", (Hempel 1958) Milos Taliga, "*Against Watkins: From a Popperian point of view*", (Taliga 2004) D. C. Stove, "*Popper on Scientific Statements*", (Stove 1978) A. A. Derksen, "*The Alleged Unity of Popper's Philosophy of Science: Falsifiability as Fake Cement*", (Derksen 1985) Lansana Keita, "*Are Universal Statements Falsifiable? A Critique of Popper's Falsifiability Criterion*", (Keita 1989) and Stephen Toulmin, "*Conceptual Revolutions in Science*" (Toulmin 1967)

After a brief presentation of Popper, relevant in the context of the discussion, I present the main points of view for the demarcation problem in the chapter with the same title. In *Pseudoscience*, I delimit this notion more clearly from non-science, and in the chapter *Falsifiability* I summarize the methodology proposed by Popper. The following chapter, *Falsification and rejection*, is the one in which I am arguing for the clear distinction, also noted by Popper, of the two notions. In *Expansion of falsifiability*, I present the evolution of this concept,

with the improvements proposed by Popper and other researchers. The following two chapters, *Criticisms of falsifiability* and *Supports of falsifiability*, I highlight the pros and cons of the researchers against the falsifiability methodology. After a short chapter on *Current trends* on the problem of the demarcation of science, I present my views in *Conclusions*.

Karl Popper, as a critical rationalist, was an opponent of all forms of skepticism, conventionalism and relativism in science. In 1935 he wrote *Logik der Forschung. Zur Erkenntnistheorie der modernen Naturwissenschaft*, (Karl Raimund Popper 2002b) later translating the book into English and publishing it under the title *The Logic of Scientific Discovery* (1959) considered to be a pioneering work in its field. Many of the arguments in this book are directed against the members of the "Vienna Circle", such as Moritz Schlick, Otto Neurath, Rudolph Carnap, Hans Reichenbach, Carl Hempel and Herbert Feigl. Popper agrees with them on the general aspects of scientific methodology and their mistrust in traditional philosophical methodology, but its solutions have been significantly different. Popper has contributed significantly to the debates on general scientific methodology, the demarcation of pseudoscience, the nature of probability, and the methodology of social sciences.

Popper was deeply impressed by the differences between Freud's and Adler's supposed "scientific" theories and the revolution triggered by Einstein's theory of relativity in physics during the first two decades of the 20th century. While Einstein's theory was extremely "risky" in the sense that it was possible to deduce consequences from it which, if it were proved to be false, would have falsified the whole theory, nothing could, in principle, falsify the psychoanalytic Popper was criticized about his prescriptive approach to science and the focus on the logic of falsifiability. His theory was opposed to Thomas Kuhn's socio-historical approach developed in "*The Structure of Scientific Revolutions*" (1962), (T. S. Kuhn 1996) which, in support, reintroduced

the idea that the change of science is essentially dialectical and depends on the establishment of a consensus within the communities of researchers.

1 The demarcation problem

Karl Popper, as a critical rationalist, was an opponent of all forms of skepticism, conventionalism and relativism in science. In 1935 he wrote *Logik der Forschung. Zur Erkenntnistheorie der modernen Naturwissenschaft*, later translating the book into English and publishing it under the title *The Logic of Scientific Discovery* (Karl Raimund Popper 2002b) considered to be a pioneering work in its field. Many of the arguments in this book are directed against the members of the "Vienna Circle", such as Moritz Schlick, Otto Neurath, Rudolph Carnap, Hans Reichenbach, Carl Hempel and Herbert Feigl. Popper agrees with them on the general aspects of scientific methodology and their mistrust in traditional philosophical methodology, but its solutions have been significantly different. Popper has contributed significantly to the debates on general scientific methodology, the demarcation of pseudoscience, the nature of probability, and the methodology of social sciences.

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idea that the change of science is essentially dialectical and depends on the establishment of a consensus within the communities of researchers.

There have been attempts to demarcate science of non-science since the ancient period: "To be scientific," Aristotle said, "one must deal with causes, one must use logical demonstration, and one must identify the universals which 'inhere' in the particulars of sense." (Laudan 1983)

The demarcation of science by pseudoscience has both theoretical reasons (the problem of delimitation is an illuminating perspective that contributes to the philosophy of science in the same way that error analysis contributes to the study of informal logic and rational reasoning) and practical reasons (the demarcation is important for decision-making both in private and public life). (Mahner 2007)

Logical positivism, through the theory of verifiability of significance (verificationism), considered that only affirmations of factual matters or logical relationships between concepts are significant. (Grayling 2001) But "the verificationist proposals had the aim of solving a distinctly different demarcation problem, namely that between science and metaphysics." (Hansson 2017)

According to Popper, the central issue of the philosophy of science is the demarcation, the distinction between science and what he calls "non-science" (including logic, metaphysics, psychoanalysis, etc.).

> "Any demarcation in my sense must be rough. (This is one of the great differences from any formal meaning criterion of any artificial 'language of science'.) For the transition between metaphysics and science is not a sharp one: what was a metaphysical idea yesterday can become a testable scientific theory tomorrow; and this happens frequently." (Miller 1985)

> "There will be well-testable theories, hardly testable theories, and non-testable theories. Those which are non-testable are of no interest to empirical scientists. They may be described as metaphysical. Here I must again stress a point which has often been misunderstood. Perhaps I can avoid these misunderstandings if I put my point now in this way. Take a square to represent the class of all statements of a language in which we intend to formulate a science; draw a broad horizontal line, dividing it into an upper and lower half; write 'science' and 'testable' into the upper half, and 'metaphysics' and 'non-testable' into the lower: then, I hope, you will realize that I do not propose to draw the line of demarcation

> in such a way that it coincides with the limits of a language, leaving science inside, and banning metaphysics by excluding it from the class of meaningful statements." (Karl Raimund Popper 2002a)

A major argument of Popper is Hume's critique of induction, (Hume 1738) arguing that induction should never be used in science. But he disagrees with the skepticism associated with Hume, nor with the support of Bacon and Newton's pure "observation" as a starting point in the formation of theories, as there are no pure observations that do not imply certain theories. Popper argues that there is no unique methodology for science. It is necessary to solve the problem of demarcation of metaphysics from science. But we should recognize that many metaphysical systems have led to important scientific results. He reminds Democrit's system; and that of Schopenhauer that is very similar to that of Freud. And some, for example, those of Plato or Malebranche or Schopenhauer are wonderful constructions of thought. But at the same time, we should oppose those metaphysical systems that tend to charm and wonder. But obviously, we should do the same with non-metaphysical or anti-metaphysical systems if it displays this dangerous trend. And Popper think we cannot do it in one move. Rather, we must make the effort to analyze the systems in detail; we must show that we understand what the author wants to say, but what he says does not deserve the effort to understand. (Miller 1985)

Instead, Popper proposes falsifiability as a method of scientific investigation. For him, a theory is scientific only if it is falsifiable by a conscious event. Popper's theory of demarcation is based on his perception of the logical asymmetry he has between verification and falsification: it is logically impossible to definitively verify a universal proposition by reference to experience (as Hume says), but a single counter-example refutes definitively the corresponding universal law. In a word, an exception, far from "proving" an exception to the rule, definitively rejects it: (Thornton 2017)

Popper says that they are people of courageous ideas, though very critical of their own ideas, they try to find out if their ideas are correct, trying to find out first whether they are wrong. They operate with courageous conjectures and severe attempts to reject their own conjectures. The criterion of demarcation between science and non-science that he proposes is a simple logical analysis of this image. If it is good or bad, this will be shown by its fertility. Courageous ideas are new and bold hypotheses or conjectures. And severe rejection attempts are critical discussions and severe empirical tests. But when it is a bold conjecture in the sense proposed here, and when not? It is bold if and only if it assumes a great risk of being false - if things were different, and if they seem at that moment to be different. (Miller 1985)

A true scientific theory is restrictive, and can therefore be tested and falsified, but never logically verified. Thus, if a theory has resisted the test, it does not mean it has been verified, it has only a greater degree of corroboration, and can be replaced at any time by a better theory.

Popper uses falsifiability as a demarcation criterion to evaluate theories. The Popper criterion does not exclude from the field of science statements that cannot be falsified, but only theories that contain no falsifiable statement, yet it is not clear what constitutes a "whole theory" and what makes a statement to be "significant".

Verificationism[1] was an essential feature of the logical positivism of the so-called Vienna Circle. Popper noticed that the philosophers of the Vienna Circle mixed up two different issues, the significance and demarcation, and proposed to verify a single solution for both. Popper said that there are significant non-scientific theories, and therefore a significance criterion does not coincide with a delimitation criterion, proposing replacing verifiability with falsifiability as a

[1] Verificationism claims that a statement must, in principle, be empirically checked to be both meaningful and scientific.

delimitation criterion. On the other hand, he strictly opposed the view that statements that are not falsifiable are meaningless or wrong. (Karl Raimund Popper 2002b)

Popper argues that the only logical technique that is integral part of the scientific method is that of deductive testing, the conclusions being deduced from a hypothesis and then compared with each other and other relevant statements to determine whether they falsify or corroborate the hypothesis. Such conclusions are not directly compared to the facts, simply because there are no "pure" facts available; all observations-statements are loaded by theory and are just as much a function of purely subjective factors (interests, expectations, desires, etc.) as they are a function of what is truly objective. (Thornton 2017)

Popper specifies four steps for the deductive procedure[2]:

> "I proposed (though years elapsed before I published this proposal) that the refutability or falsifiability of a theoretical system should be taken as the criterion of its demarcation. According to this view, which I still uphold, a system is to be considered as scientific only if it makes assertions which may clash with observations; and a system is, in fact, tested by attempts to produce such clashes, that is to say by attempts to refute it. Thus testability is the same as refutability, and can therefore likewise be taken as a criterion of demarcation. There are, moreover (as I found later), degrees of testability: some theories expose themselves to possible refutations more boldly than others." (Karl Raimund Popper 2002a)

Popper believes that Hume's philosophy demonstrates that there is an implicit contradiction in traditional empiricism, which claims that all knowledge comes from experience, and that universal sentences (including scientific laws) are verifiable by reference to experience. Contradiction derives from the attempt to show that, despite the openness of the experience, scientific laws can be interpreted as empirical generalizations, which in a way finally confirm a "positive" experience. Popper eliminates the contradiction by rejecting the first of these principles

[2] The steps for the deductive procedure, according to Popper: (1) A test of internal consistency to see possible contradictions; (2) Axiomatization of theory to distinguish between empirical and logical elements; (3) Comparing the new theory with the existing one; (4) Testing the theory by empirically applying the conclusions derived from it to verify whether the theory is corroborated (but not verified). (Karl Raimund Popper 2002b)

and eliminating the imposition of empirical verification into falsifiability in the second principle. He states that scientific theories are not inductively deduced from experience, nor are scientific experiments conducted to verify or establish their truth; all knowledge is provisional, conjectural, hypothetical - we can never prove theories definitively, we can only confirm (temporarily) or refute them. That is why we have to make a choice between theories that explain the set of investigated phenomena, eliminating only those theories that are falsified, and rationally choose between the remaining, unfalsified theories, the one that possesses the highest level of explanatory power and predictive power. Popper emphasizes the importance of the critical spirit of science - critical thinking is the very essence of rationality. (Thornton 2017)

There have been various demarcation proposals: this should refer to a research program, (I. Lakatos 1974) an epistemic domain or a cognitive discipline, representing common goals of knowledge and practice (Bunge 1982) (Mahner 2007) a theory (K. Popper 1963), a practice, (Lugg 1992) (Morris 1987) a problem or a scientific inquiry (Siitonen 1984) and a specific investigation. (T. Kuhn 1970) (Mayo 1996) The difficulty is to select the demarcation method. Derksen (Derksen 1993) places emphasis on demoting the pseudoscience man (the person who promotes pseudoscience), in the idea that pseudoscience has scientific claims and such claims are associated with a person, not a theory.

2 Pseudoscience

The delimitation between science and pseudoscience is part of the more general task of determining which beliefs are epistemologically justified.

Science can be described as partly descriptive, partly normative. A definition of science can focus on descriptive content and specify how the term is used, or it can focus on the normative

element and clarify the more fundamental meaning of the term[3]. The earliest use of this name is considered to belong to the French physiologist François Magendie, (Magendie 1843) who is considered one of the pioneers of experimental physiology. There is a divergence between the philosophers of science and some members of the scientific community about the possibility of an objective distinction between "pseudoscience" and "science."

Professor Paul DeHart Hurd believes that a great deal of scientists can distinguish between science and various pseudoscience (Hurd 1998) such as astrology, (Sfetcu 2015, 257) charlatanism, occultism (Sfetcu 2015, 229) or superstition. Pseudoscience is any subject that appears to be scientific at first glance, or whose supporters claim to be scientific, but which contravenes test conditions or deviates from other fundamental aspects of scientific methods.

Standards for demarcation may vary by domain, but several basic principles are universally accepted. All the experimental results should be reproducible, the scientific method can be applied everywhere, the prejudices can be controlled or eliminated, the experiments are correct, the studies can be objective, etc. Data to be documented for reproduction and for further studies. Statistical quantification of importance, trust, and error are also important tools for the scientific method. (Sfetcu 2015, 2)

The conflict between science and pseudoscience is found, on the one hand, in the community of disciplines of knowledge that includes natural and social sciences and humanities, and on the other hand in a wide variety of movements and doctrines such as creationism (Sfetcu 2015, 112) astrology, homeopathy and holocaust denialism, in conflict with generally accepted results and methods in the knowledge community.

[3] Pseudoscience is a methodology, belief, or practice considered by its supporters to be scientific, or which seems to be scientific, but does not adhere to an appropriate scientific methodology, lacking its supportive evidence or plausible character, or confirmed scientific status.

Not all non-sciences are pseudoscience, like metaphysics or religion. Mahner proposed the term "para-science" for non-scientific practices that are not pseudoscience. (Mahner 2007)

"Un-scientific" is a narrower concept than "non-scientific" because the first term implies a certain form of contradiction or conflict with science, and "pseudo-scientific" is more restricted than "non-scientific" because it implies an intentionality. Many authors assume that in order to be pseudoscientific, an activity or a teaching must satisfy two criteria: (Hansson 1996) (1) not being scientific and its main supporters attempt to create the impression that it is scientific.

However, there are phenomena that meet both criteria, but are not pseudoscientific, such as fraud in science. Some forms of pseudoscience have as objective the struggle against a scientific theory (scientific denialism), such as the denial of the Nazi Holocaust (Gleberzon 1984) or the denial of climate change. (Williams 2005) Also, the theory of "intelligent design" (Sfetcu 2015, 103) supports a fundamentalist interpretation of genesis denying evolution.

Grove included among the pseudoscientific doctrines those who "intend to provide alternative explanations to those in science, or to pretend to explain what science cannot explain." (Grove 1985) In a wider sense, it is assumed that pseudoscience includes not only doctrines contrary to science proclaimed to be scientific but also doctrines contrary to science in court, whether or not presented in the name of science. (Hansson 1996)

3 Falsifiability

Karl Popper proposed falsifiability as an important criterion in distinguishing between science and pseudoscience. He argues that verification and confirmation can play no role in formulating a satisfactory criterion of demarcation. Instead, it proposes that scientific theories be distinguished from non-scientific theories by testable claims that future observations might reveal

to be false. Popper draws attention to the fact that scientific theories are characterized by the existence of potential counterfeiters - statements that might be found to be false.

Popper is a realist who argues that scientific theories follow the truth; he does not believe that empirical evidence can ever give us reason to believe that a theory is true or can be true. In this sense, Popper is a fallibilist, stating that it is impossible to justify the belief that a certain scientific theory is true. Where others see the progress of science by confirming the truth of private claims, Popper describes science as progressing on an evolutionary model, the observations selecting against inappropriate theories by falsifying them. (Shea 2017) Thus, the term *falsifiability* is synonymous with *testability*.

> "My proposal is based upon an asymmetry between verifiability and falsifiability; an asymmetry which results from the logical form of universal statements. For these are never derivable from singular statements but can be contradicted by singular statements. Consequently, it is possible by means of purely deductive inferences (with the help of the modus tollens of classical logic) to argue from the truth of singular statements to the falsity of universal statements. Such an argument to the falsity of universal statements is the only strictly deductive kind of inference that proceeds, as it were, in the 'inductive direction'; that is, from singular to universal statements."
>
> Karl Popper, The Logic of Scientific Discovery (Karl Raimund Popper 2002b)

Popper pointed out that non-falsifiable claims are important in science. Contrary to intuition, non-falsifiable assertions can be incorporated into - and deductively generated by - falsifiable theories. Popper invented the notion of metaphysical research programs to name such non-falsifiable ideas. Unlike positivism, which considered statements to be meaningless if they cannot be verified or falsified, Popper argued that falsifiability is only a special case of the more general notion of criticality, even though he admitted that empirical rejection is one of the most effective methods by which theories can be criticized. Criticality, unlike falsifiability and therefore rationality, can be comprehensive (without logical boundaries), although this statement is controversial, even among the supporters of Popper's philosophy and rationalism.

Initial (naive, dogmatic, or naturalist) deduction of statements is made through *modus tollens*, through an observation. The logic of *naive falsifiability* is valid but limited, due to possible "compensatory adjustments". Popper acknowledged these limitations (Karl Raimund Popper 2002b) in response to Pierre Duhem's criticism. W. V. Quine called this the argument of *confirmation holism*. To falsify logically a universal, one can find a single true falsifiable statement, but it is always possible to change the universal statement or the existential statement so that it does not falsify. Thus, naive falsification does not allow scientists to present a definitive falsification of universal statements.

Popper denied having imagined such naive theory of falsifiability. He contests that he has ever developed a naive theory of falsifiability. From the very beginning he emphasized in his work published in 1933, and especially in 1934, that you can avoid any refutation, but that it is very important to try to build your theory in such a way that it can be denied. One may try - and he has said it explicitly in *The Logic of Scientific Discovery* - to save the theory by means of assumptions or other means. (K. Popper and Lorentz 1985)

To overcome these problems, Popper imagined that science progresses by successively rejecting falsified theories by keeping those with more explanatory power, rather than by falsified statements.

The second form of falsifiability considered was the *methodological* one. The falsificationist makes the same basic assumptions as in dogmatic falsification, but they are called *tentatives*, a set of supposedly assumptions to falsify the theories. Methodological falsifiability supports risky decisions. Although the choice we make might be wrong, the methodological falsificationist sees this as a problem of the least two evils. Paul Newall states that it is hard to criticize methodological falsification for the simple reason that it is unfalsifiable. (Newall 2005)

To reduce conventionalism from methodological falsification, Popper designed a *sophisticated* version of falsifiability based on imposed conditions, that is, the new theory to have excessive empirical content, to explain everything that was explained before, and some of these new predictions to be confirmed by experiment. A theory must not be rejected as false until a better one develops. This leads us to a notion of growth or development of theories instead of dogmatic falsifiability that accepts or rejects them in single cases and no experiment can be crucial if it is not interpreted as such after the event in the light of a new theory for which it offers corroboration. Finally, the idea of proliferation of theories (pluralism) is important for sophisticated falsifiability, unlike the dogmatic version. (Newall 2005) The conflict in science is not so between theories and experiments, but always between rival theories.

> "Whilst I do not demand any final certainty from science (and consequently do not get it), the conventionalist seeks in science 'a system of knowledge based upon ultimate grounds', to use a phrase of Dingler." (Karl Raimund Popper 2002b)

Lakatos states that sophisticated falsification is different from the naive both in the rules of acceptance (or the "demarcation criterion") and in its rules of falsification or rejection. There is no falsification before the occurrence of a better theory. But then the negative distinctive character of naive falsification disappears; criticism becomes more difficult and also positive, constructive. (Imre Lakatos 1970)

The problem of sophisticated falsifiability is precisely the multitude of theories considered. In the case of two incompatible theories, we have to go back to the conventional aspects of methodological falsifiability or the incontestable hypotheses of dogmatic falsifiability to make a choice. Calling on new corroborated facts involves a clear delimitation between observational and theoretical terms, with conventional decisions on what constitutes "basic" knowledge. For naive falsifiability, science develops through the successive experimental rejection of theories; steady proliferation of theories is optional but not mandatory. For sophisticated falsifiability, proliferation

of theories cannot wait until accepted theories are "rejected." While naive falsifiability emphasizes the "urgency of replacing a falsified hypothesis with a better one," sophisticated falsifiability underscores the urgency of replacing any of the best assumptions. (Imre Lakatos 1970)

Popper says that

"The system of basic statements, as I use the term, is to include, rather, all self-consistent singular statements of a certain logical form—all conceivable singular statements of fact, as it were. Thus, the system of all basic statements will contain many statements which are mutually incompatible. "

"A theory is to be called 'empirical' or 'falsifiable' if it divides the class of all possible basic statements unambiguously into the following two nonempty subclasses. First, the class of all those basic statements with which it is inconsistent (or which it rules out or prohibits): we call this the class of the potential falsifiers of the theory; and secondly, the class of those basic statements which it does not contradict (or which it 'permits'). We can put this more briefly by saying: a theory is falsifiable if the class of its potential falsifiers is not empty." (Karl Raimund Popper 2002b)

4 Falsification and refutation

Dogmatic falsifiability refers to scientific statements considered individually. These can be falsified and, depending on the outcome, scientific theories can be considered falsifiable and accepted, refuted, or can be maintained by adding *ad-hoc* hypotheses:

” There is one important method of avoiding or evading refutations: it is the method of auxiliary hypotheses or *ad hoc* hypotheses. If any of our conjectures goes wrong - if, for example, the planet Uranus does not move exactly as Newton's theory demands - *then we have to change the theory*. But there are in the main two kinds of changes; *conservative* and *revolutionary*. And among the more conservative changes there are again two: *ad hoc hypotheses* and *auxiliary hypotheses*... I call a conjecture '*ad hoc*' if it is introduced (like this one) to explain a particular difficulty, but if (in contrast to this one) *it cannot be tested independently*.” (K. Popper 1974)

” not to pronounce too severe an edict against *ad hoc* hypotheses: they may become testable after all, as may also happen to a metaphysical hypothesis. But in general, our criterion of testability warns us against *ad hoc* hypotheses... *Ad hoc* hypotheses - that is, at the time untestable auxiliary hypotheses - can save almost any theory from any *particular* refutation. But this does not mean that we go on with an *ad hoc* hypothesis as long as we like. It may become testable; and a negative test may force us either to give it up or to introduce a new secondary *ad hoc* hypothesis, and so on, *ad infinitum*. This, in fact, is a thing we almost always avoid. (I say 'almost' because methodological rules are not hard and fast.) Moreover, the possibility of making things up with ad hoc hypotheses must not

> be exaggerated: there are many refutations which cannot be evaded in this way, even though some kind of immunizing tactic such as ignoring the refutation is always possible." (K. Popper 1974)

Popper admits that in practice only one counter-example is not enough to falsify a theory; therefore, scientific theories are retained in many cases despite abnormal evidence. (Mitra 2016)

" We say that a theory is falsified only if we have accepted basic statements which contradict it. This condition is necessary, but not sufficient; for we have seen that non-reproducible single occurrences are of no significance to science. Thus a few stray basic statements contradicting a theory will hardly induce us to reject it as falsified. We shall take it as falsified only if we discover a reproducible effect which refutes the theory. In other words, we only accept the falsification if a low-level empirical hypothesis which describes such an effect is proposed and corroborated." (Karl Raimund Popper 2002b, 66)

A scientific theory, according to Popper, can be legitimately saved from falsification by introducing an auxiliary hypothesis to generate new, falsifiable predictions. Also, if there are suspicions of bias or error, the researchers might introduce an auxiliary falsifiable hypothesis that would allow testing. But this technique cannot solve the problem in general, because any auxiliary hypothesis can be challenged in the same way, *ad infinitum*. To solve this regression, Popper introduces the idea of a basic statement, an empirical statement that can be used both to determine whether a given theory is falsifiable and, if necessary, to corroborate falsification assumptions. Basic statements must be both singular and existential (formal requirement) and be testable through inter-subjective observation (material requirement). (Shea 2017) He points out that basic knowledge is not knowledge for meaningful determination; they can be challenged at any time, especially if they are suspected that their non-critical acceptance may be responsible for the difficulties encountered later. To avoid regression, Popper appeals to the role played by the convention and basic statements:

" Every test of a theory, whether resulting in its collaboration or falsification, must stop at some basic statement or other which we decide to accept. If we do not come to any decision, and do not accept some basic statement or other, then the test will have led nowhere… This procedure has no natural end. Thus if the test is to lead us anywhere, nothing remains but

> to stop at some point or other and say that we are satisfied, for the time being. (Karl R. Popper 1959, 86)

In this case, Popper considers that the consensus of the relevant scientific community is necessary.

Popper rejects the idea of selecting a more probable theory from two equally strong theories. He believes that theories with high informative content must be preferred, they have high predictive power and are more testable. But it may seem paradoxical, Popper argues that the less probable the theory, the better form scientific point of view, being more falsifiable. (Shea 2017)

In *Conjectures and Refutations*, (Karl Raimund Popper 2002a) Popper integrated concepts of truth and content to construct the metalogical concept of "truthlikeness" or "verisimilitude". (Thornton 2017) He explained this concept by referring to the logical consequences of theories, "the content of truth" and "the content of falsity".

Popper proposes a list of "six types of case in which we should be inclined to say of a theory t 1 that it is superseded by t 2 in the sense that t 2 seems--as far as we know--to correspond better to the facts than t 1, in some sense or other." (Karl Raimund Popper 2002a, 232)

Verisimilitude allowed Popper to attenuate what many saws as the pessimism of an anti-inductivist philosophy of science, (Thornton 2017) who argued that most, if not all, scientific theories were false. Thus, scientific progress could now be represented as progress to truth, and experimental corroboration could be an indicator of verisimilitude.

Although Popper consistently rejects the idea that science-based and well-corroborated theories with high content of informative content can be considered true or likely to be true, his concept of verisimilitude explores the idea that such theories are closer to truth than falsified theories who have replaced them:

"the idea of verisimilitude is most important in cases where we know that we have to work with theories which are *at best* approximations—that is to say, theories of which we know that they cannot be true." (Karl Raimund Popper 2002a, 235)

In his response to Lakatos, Popper insisted on a clear distinction between falsification and refutation. (K. Popper 1974) The purpose of empirical testing is not only to falsify individual assumptions but also to discriminate against competing hypotheses; to falsify the implicit judgment that they are as close to the truth. He has repeatedly stressed that verisimilitude judgments are inevitably comparative. But what he did not explicitly was to connect the verisimilitude or to approximate the truth with the results (both positive and negative) of the empirical tests:

"I do not suggest that the explicit introduction of the idea of verisimilitude will lead to any changes in the theory of method. On the contrary, I think that my theory of testability or corroboration by empirical tests is the proper methodological counterpart to this new metalogical idea. The only improvement is one of clarification." (Karl Raimund Popper 2002a, 235)

In the context of the debate on quantum mechanics, Popper argues that probabilities are objective claims to an external mind-independent world, and ”proposes the propensity theory as a variant of the relative frequency theories of probability defended by logical positivists such as Richard von Mises and Hans Reichenbach”. (Shea 2017) Popper argues that logical or subjective theories misinterpret the scientific assertions about probability, proposing that probabilities be treated as propensities in experimental settings to produce certain results, rather than being derived from the reference class of the results obtained by running these experiments. (Shea 2017) The results of the experiments are important because they allow us to test hypotheses on the values of certain probabilities; however, the results are not themselves a part of the probability itself.

Popper's final position was to recognize the impossibility of discriminate non-science science solely based on falsifiability of scientific claims; he acknowledges that scientific theories

are predictive and consequently prohibitive only when taken together with auxiliary assumptions, and that readjustment or modification is an integral part of scientific practice. (Thornton 2017)

5 Extension of falsifiability

Popper's delimitation criterion refers to the logical structure of theories. Imre Lakatos said that if a theory is scientific or non-scientific, it can be determined independently of the facts. (Imre Lakatos 1973, 117) He proposed a modification of Popper's criterion, which he called "sophisticated (methodological) falsification", where the delimitation criterion should not apply to a hypothesis or isolated theory but to a whole research program. At Lakatos there appears a "hard core" of central thesis, that is resilient, constituting a research program. Thus, a research program is progressive if new theories make surprising predictions that are confirmed. Progress in science is only possible if each new theory developed in the program has empirically greater content than its predecessor. Otherwise, the program is pseudoscientific. Good science is progressive, bad science is degenerative, and if a research program does not predict anything new or involves new predictions that never happen, then such degeneration could have turned into a pseudoscience. (Hansson 2017)

Lakatos' methodology was an attempt to reconcile Popper's falsification with Thomas Kuhn's paradigms. Lakatos proposed a middle way in which Kuhn's socio-psychological approaches were replaced by logical-methodological ones.

Paul Thagard believes that a theory is pseudo-scientific if it fails to progress and "the community of practitioners makes little attempt to develop the theory towards solutions of the problems, shows no concern for attempts to evaluate the theory in relation to others, and is selective in considering confirmations and disconfirmations." (Thagard 1978, 228) He proposed another set of principles to try to overcome these difficulties and considers it important for society to find a

way to do so[4]. Thagard states that sometimes theories will spend some time only as "unpromising" before they really deserve the title of pseudoscience.

Daniel Rothbart sets eligibility criteria according to which the theory should include the rigor's explanatory success and gain testable implications that are incompatible with those of the rival. (Rothbart 1990)

George Reisch proposed that the demarcation be based on the integration of theory properly in other sciences. In general, according to Reisch, an epistemic domain is pseudo-scientific if it cannot be incorporated into the existing set of established sciences. (Reisch 1998)

Sociologist Robert K. Merton (Merton 1973) proposed demarcation criteria based on the value of science, characterized by a spirit that can be summed up as four sets of institutional imperatives: universalism (affirmations must be subject to predetermined impersonal criteria), communism (the findings are products of social collaboration), disinterestedness (institutional control to reduce the effects of personal or ideological motives), and organized skepticism (detached examination of beliefs). (Hansson 2017)

Many other authors have proposed demarcation criteria to identify pseudoscience science. These typically include faith in authority, unrepeatable experiments, selected examples, unwillingness to test, non-compliance with rejection information, embedded subterfuges, abandoned explanations without replacement. (Hansson 2017)

In a notorious passage, Popper suggested that "`[although] the degree of corroboration of a theory cannot be interpreted simply as a measure of its verisimilitude, it can be taken as an

[4] According to Thagard's method, (Thagard 1978) a theory is not scientific if it fulfills two conditions: 1) It is less progressive than alternative theories over a long period of time and faces many unresolved problems; and ... 2) The community of practitioners is making little attempts or none to develop to solve the problems, is not interested in the evaluation of the theory and is selective in terms of confirmations and disagreements.

indication of how its verisimilitude appears at the time." (Karl R. Popper 1979) After all, Miller states, (Miller 2009b) the degree of corroboration of any falsified theory gives no indication, however small, either about the verisimilitude of the theory or how well the Truth is approximated. Popper thought that a hypothesis that failed in some tests, but did not fail very badly, will give rise to a hypothesis with some predictions tested with certainty beyond the limits of experimental errors, but not too wrong, will be closer to the truth than to a failed radical rival one, even if both are falsified. (Miller 2009b) But the lack of a solution to this difficulty is not an excuse for a retreat into instrumentalism, inductivism or irrationality, and should not prevent us from seeking a more modest answer to the incontestable fact that "not all cases of falsification are the same." (Kvasz 2004, 263)

6 Criticism of falsifiability

Thomas Kuhn criticized falsifiability because it characterized "the entire scientific enterprise in terms that apply only to its occasional revolutionary parts," (T. Kuhn 1970) and it cannot be generalized. In Kuhn's view, a delimitation criterion must refer to the functioning of normal science. (T. Kuhn 1970, 802) But Kuhn ignored Popper's sophisticated falsification and his extended theory.

Kuhn objects to Popper's entire theory and excludes any possibility of rational reconstruction of the development of science. In Kuhn's view, "there can be no logic, but only psychology of discovery". (Imre Lakatos 1978, 90)

In a brief comparison of Hume, Carnap and Popper, Watkins points out that the development of science is inductive and irrational according to Hume, inductive and rational according to Carnap, non-inductive and rational according to Popper. (J. W. N. Watkins 1968)

Extending this comparison, it can be added that the development of science is non-inductive and irrational, according to Kuhn. (Imre Lakatos 1978, 90)

Popper criticized Kuhn's demarcation criterion, claiming that Kuhn's criterion leads to a "major disaster…[the] replacement of a rational criterion of science by a sociological one." (K. Popper 1974, 1146–1147)

Stephen Toulmin asserts that Kuhn has practically exposed three successive theories of scientific change, departing from the original theory of "scientific revolutions." Kuhn interprets the contrast between "normal" and "revolutionary" change in two alternative ways: sometimes as a philosophical analysis, sometimes as a sociological hypothesis, so that the "paradigm" is duly ambiguous. (Toulmin 1967)

Paul Feyerabend, argued that it is neither possible nor desirable to distinguish between science and non-science. (Feyerabend 2010) He also rejected Lakatos's argument for ad-hoc hypotheses, arguing that science would not have progressed without using all available methods to support new theories. For Feyerabend, a special status of science can derive only from the social and physical value of its results, and not from its method.

Imre Lakatos states that by falsifiability Popper has made a disconnect between science's play (falsifiability) and the purpose of science (the development of true theories). To restore the link between the game and its goal, Lakatos states that Popper has introduced a "whiff of "inductivism."[5]" (Imre Lakatos 1978, 160)

Note that Lakatos's criticism of Popper is equally valid against himself. (Musgrave and Pigden 2016)

[5] "An inductive principle that correlates realistic metaphysics with methodological appraisals, verisimilitude with corroboration, which reinterprets the rules of" scientific play "as a conjectural theory of the signs of knowledge increase, that is, the signs of increasing verisimilitude of our scientific theories." (Champion 1985, 156)

Popper's falsification has been criticized for both the exclusion of legitimate science (Hansson 2006) as well as for granting of scientific status to several pseudo-sciences. (Agassi 1991) (Mahner 2007, 518–19) Larry Laudan states that it "has the untoward consequence of countenancing as ‘scientific’ every crank claim which makes ascertainably false assertions." (Laudan 1983, 121)

W. Bartley, in 1976, argued that Popper had destroyed the dialogue. "he gulfs between Popper's way of doing philosophy and that of the bulk of contemporary professional philosophers is as great as that between astronomy and astrology." (Bartley 1976) Rafe Champion states that "his theory of conjectural knowledge does not even pretend to provide positively justified foundations of belief." (Champion 1985)

Putnam argues that the initial acceptance of Newtonian mechanics had little or nothing to do with falsifiable predictions, because scientists have accepted the success of theory in explaining the previously established phenomena. (Putnam, Gasper, and Trout 1974)

Hacking states that many aspects of scientific practice, including experiments, cannot be interpreted as attempts to falsify or corroborate. (Hacking 1983)

Physicists Alan Sokal and Jean Bricmont have criticized the falsifiability of not accurately describing the way science works, and that falsifiability cannot distinguish between astrology and astronomy. (Sokal and Bricmont 1999)

Some economists, like those of the Austrian school, believe that macroeconomics is empirically unfalsifiable. (Heath 2015) (von Mises 2014)

Many philosophers also assert that mathematics is not experimentally falsifiable, and therefore is not a science in accordance with Karl Popper's definition. (Shasha and Lazere 1998)

Some criticize Popper that his theory does not offer a legitimate alternative to the inductivist proposals he criticizes. Jeffrey argues that Bayesianism, with the emphasis on the extent to which empirical evidence supports a hypothesis, is much closer to scientific practice than Popper's falsifiability. (Jeffrey 1975)

One of the great challenges of falsifiability is the Duhem-Quine thesis. (Quine 1953) With regard to Newton's first law of inertia, it is assumed that a body is neither at rest nor in a uniform motion in a straight line and apparently not driven by an external force. This observation seems to reject Newton's law, but it's not this way. The planet's orbits are driven by gravitational forces: "The physicist can never subject an isolated hypothesis to experimental test, but only a whole group of hypotheses; when the experiment is in disagreement with his predictions, what he learns is that at least one of the hypotheses constituting this group is unacceptable and ought to be modified; but the experiment does not designate which one should be changed." (Ariew 2014) Because the first law is used along with many assumptions, it is not possible to reject the law if what the law provides is not accomplished, for supposing assumptions or additional assumptions may be to blame. Therefore, Newton's first law is unfalsifiable. (Mitra 2016)

D.C. Stove considers Popper's theory of scientific (non-statistical) and non-scientific statements to be simple denials or simple claims of existence or local existence. (Stove 1978) What Stove regards as "mere assertions of local existence", Popper calls them mere assertions of existence." In fact, he says, Popper's falsifiability criterion requires that a statement, in order to be empirical, be inconsistent with a certain basic statement in the sense stated by Stove. And a "mere denial of local existence," Popper calls it a "singular non-existence statement," which, when empirical, is an "instantial statements." According to Stove, a non-statistical law or theory of science empirical may be inconsistent with another, but Popper's philosophy of scientific

statements is incompatible with this obvious fact, because Popper identifies laws or theories with simple denials of existence, and mere denial of existence cannot be inconsistent with another. Stove asserts that Popper's falsifiability criterion excludes from empirical science all those statements that, according to Popper himself, constitute the basis for observing science.

O'Hear believes that Popper's epistemology leads to unacceptable skepticism and cannot avoid a commitment to inductive procedures. (O'Hear 1996) Similarly, W. Salmon argues that Popper's idea of corroborating theory involves referring to inductive procedures. (Salmon and Hitchcock 2017)

Many other researchers, such as Miller, Tichý and Grünbaum, have argued defects in the official definitions of Popper's theory. Thus, it is believed that verisimilitude is important in Popper's system because of its application to the theories that are known to be false. In this sense, Popper wrote:

> "Ultimately, the idea of verisimilitude is most important in cases where we know that we have to work with theories which are at best approximations—that is to say, theories of which we know that they cannot be true. (This is often the case in the social sciences). In these cases, we can still speak of better or worse approximations to the truth (and we therefore do not need to interpret these cases in an instrumentalist sense)." (Karl Raimund Popper 2002a, 235)

Thornton argues that the problems of Popper's formal definitions were considered important because they have been linked to the verisimilitude of false theories. Miller and Tichý demonstrated that Popper's verisimilitude conditions for comparing the truths and falsity of content can be met only when theories are true. In the case of false theories, Popper's definitions are wrong. (Thornton 2017) Therefore, Popper's conditions to compare levels of veracity can never be met.

Following the failure of Popper's definitions in 1974, some critics believed that the entire theory of falsifiability has been undermined. Popper acknowledged the deficiencies, (Karl R. Popper 1979, 371) but argued that "I do think that we should not conclude from the failure of

my attempts to solve the problem [of defining verisimilitude] that the problem cannot be solved." (Karl R. Popper 1979, 372) He lower the importance of the concept in his philosophy, stating that he never intended to point out that degrees of verisimilitude cannot be determined, excepting certain limited cases, and arguing instead that the main value of the concept is heuristic and intuitive, and the absence of a formal appropriate definition is not so important in the evaluation of theories relative to issues in which we have an interest. (Thornton 2017)

7 Support of falsifiability

Popper's supporters argued that most criticism is based on an incomprehensible interpretation of his ideas. They argue that Popper should not be interpreted as meaning that falsifiability is a sufficient condition for the demarcation of science. Some passages seem to suggest that he considers it is only a necessary condition. (Feleppa 1990, 142) Other passages would suggest that for a theory to be scientific, Popper requires (besides falsifiability) other tests, and that negative test results are accepted. (Cioffi 1985, 14–16) A demarcation criterion based on falsifiability that includes these elements will avoid the most obvious counter-arguments of a criterion based on falsifiability alone. (Hansson 2017)

David Miller believes that the demarcation problem and the problem of induction at Popper are sometimes " lamentably misunderstood... The problem of demarcation is solved much as Popper solved it." (Miller 2009b) Many critics misunderstand Popper's philosophy in the demarcation problem. His task is not to "distinguish scientific and non-scientific matters in a way which exhibits a surer epistemic warrant or evidential ground for science than for non-science," according to Laudan, (Laudan 1983, 118) nor "to explicate the paradigmatic usages of scientific". (Laudan 1983, 122) The issue is not about safety, mandate, and reasons for those living with the fear that they may not be "entitled to believe any scientific theories," (Papineau 2006, 63) only

accidentally concerned with the ratification of the non-scientific status. (Grünbaum 1989) The main problem of the theory of knowledge, at least for an empiricist, is quite different in nature: Popper has described the main problem of the theory of knowledge as "the critical analysis of the appeal to the authority of experience" (K. Popper 1934, chap. 10) The philosophy of Popper strongly opposes. It expresses, as Miller states, all these trends in fashion and all views science as "a body of knowledge":

> "In the present context, it hardly matters whether or not I am right concerning the irrefutability of any of these three theories [those of Freud, Adler, and Marx]: here they serve merely as examples, as illustrations. For my purpose is to show that my `problem of demarcation' was from the beginning the practical problem of assessing theories, and of judging their claims. It certainly was not a problem of classifying or distinguishing some subject matters called `science' and `metaphysics'. It was, rather, an urgent practical problem: under what conditions is a critical appeal to experience possible | one that could bear some fruit?" (Karl Raimund Popper 1983)

The clear philosophical, and even logical, problem that emerges here is: Under what circumstances is an empirical investigation worthwhile to engage? with the clear solution: "Since the formulation of a hypothesis, its acceptance as a candidate for the truth, must precede its consideration, the task of an empirical investigation cannot be to promote hypotheses, but only to demote them. Empiricism demands that a hypothesis be retained unless it clashes in an appropriate way with experience. An accepted hypothesis therefore remains accepted until it is rejected. No further action is needed." (Miller 2009a)

Miller believes that the problem of induction is also solved in the way Popper did it.

Milos Taliga, in *Against Watkins: From a Popperian Point of View*, (Taliga 2004) argues against John Watkins' critique (John W. N. Watkins 1997) which argues that Popper's verisimilitude theory (along with his theory of corroboration) introduces justifying and inductivist elements. In short, Watkins argues that Popper's statement that "we can know, or at least have reason to believe, that we are making progress with respect to truth'" (Karl Raimund Popper 1983,

chap. 16) is certainly a justification, and the assertion that "if two competing theories have been criticized and tested as thoroughly as we could manage, with the result that the degree of corroboration of one of them is greater than that of the other, we will, in general, have reason to believe that the first is a better approximation to the truth than the second" (Karl Raimund Popper 1983, 58) is sufficient for Watkins to come to the conclusion that "in short, corroboration-appraisals provide some justification for the corresponding verisimilitude-appraisals ... It seems clear that an inductive element has been let in here". (John W. N. Watkins 1997, chaps. 16–17) After describing Watkins's argument in detail, Taliga analyzes it and ultimately concludes that the essence of criticism is

"the question 'Why the best corroborated theory is the best theory?' Watkins thinks that Popper's answer would be: 'Because it is more truthlike than all the others considered and *we can know* it, or at least have *positive reasons* to believe in it'. But the truth is that Popper *always* emphasized that our verisimilitude-appraisal of competing hypotheses is *only a guess*. He also insisted that we *can defend* it by the help of corroboration-appraisals and other *critical reasons*. But we *cannot justify* it by them." (Taliga 2004, 154)

Watkins transforms Popper's critical reasons (offered to defend but not to justify) in positive reasons (offered to justify).

Carl Hempel, in *Empirical Statements and Falsifiability* (Hempel 1958) also criticizes Watkins' statements against Popper. Watkins tends to conceal the nature of the problem at hand by arguing that the falsifiability criterion of empirical statements is itself a qualifying statement as true or false, giving Popper "an attempt to falsify his falsifiability criterion of science." (John W. N. Watkins 1997, 122) But Popper, far from considering his falsifiability criterion as a falsifiable statement, is very explicit in characterizing his proposal as a "proposal for a stipulation" that must be judged by its suitability to purpose its theoretical.

8 The current trend

After the falsifiability concept was overthrown, the issue of the method of demarcation between science and pseudoscience was again raised: to choose the most probable theory for educational purposes, the best-correlated theory for the sake of truth, or the most informative and explanatory theory to get closer the most of reality? It may be that the most informative and explanatory theories are not the riskiest estimate, or not likely to have the highest probability before the test, so it would not necessarily give you the greatest chance of learning. A theory that would correspond to somewhat falsifiability would be the most probable theory, having the best chance of learning from its own mistakes. (Derksen 1985) But there is also a need for corroboration.

Promoting methodological pluralism would be a solution that can ease the difficult choice between the most probable theory and the best corroborated theory, but choosing the most well-correlated theory puts at risk the empirical character and the rationality of science, and by choosing the most probable we risk losing the best approximation of truth.

In 1978, Paul Thagard proposed that pseudoscience be distinguished from science first of all because it would be less progressive than alternative theories over a long period of time, and its supporters fail to recognize or solve problems with the theory. (Thagard 1978) In 1983, Mario Bunge suggested the categories of "faith areas" and "research areas" to help distinguish between pseudoscience and science, where the former is primarily personal and subjective, and the second involves a certain systematic approach. (Bunge 1982)

The importance of demarcation seems to have decreased after Laudan (Laudan 1983) argued that there was no chance of finding a necessary and sufficient criterion for something as heterogeneous as scientific methodology. The delimitation criteria would have historically been used as "war machines" in polemical disputes between "scientists" and "pseudoscientists." In his view, the demarcation between science and non-science was a pseudo-problem, more importantly

focusing on the distinction between reliable and unreliable knowledge. (Laudan 1983) Sebastian Lutz, on the other hand, argues that demarcation must not be the only necessary and sufficient condition; there must be a necessary criterion and a sufficiently different criterion. (Lutz 2011) Other critics have supported multiple demarcation criteria specific to each major branch of science.

The demarcation issue was compared by Michael LeVine with the issue of distinguishing false news from real news, which became prominent in the US presidential election in 2016. (LeVine 2016)

Conclusions

Although highly criticized, Popper's contributions to the philosophy of science are immense. The approach of his scientific methodology, based on falsifiability, though not widely accepted, played a vital role in the development of the philosophy of science and influenced all philosophers who later addressed the issue of the demarcation between science and non-science, including Kuhn, Lakatos and Feyerabend. The popularity of falsifiability theory has played an important role in strengthening the image of science as an empirical activity, including in justice. Popper's work in the philosophy of science, including verisimilitude, quantum mechanics, probability theory and methodological individualism, continues to influence researchers today.

Popper made a clear distinction between the logic of falsifiability and the applied methodology. From a logical point of view, a law can be falsifiable, even if it is not conclusively verifiable. Methodologically, no observation is exempt from the possibility of error. Thus, Popper explicitly acknowledges that, in practice, a single conflicting or counter-example situation is never methodological enough to falsify a theory, and that scientific theories are often retained even though much of the available evidence conflicts with theories. (Thornton 2017) The way in which a theory is formulated has no consequence in terms of the philosophy of science. Popper points

out that there is no unique method for scientific theory, agreeing with Einstein that there is "no logical way leading to these laws of science; it is only the intuition that rests on an empathic understanding of experience". (Einstein 1918)

Popper did not consider that a theory that is not scientific is not necessarily explanatory, nor meaningless; a theory that is not scientific (because it is not understood) at any given time can become falsifiable and thus scientific, with the development of technology or the further development of the theory. (Thornton 2017) A falsified observation theory can be revised, rejected, or maintained as it is by changing ancillary assumptions, provided new falsified predictions are produced. Popper admits that scientists can keep theories even if predictions fail, when there is no better predictive theory. Instead, theories that are permanently immunized against falsifiability by introducing non-verifiable ad-hoc hypotheses can no longer be classified as scientific. (Shea 2017)

> ”we can always adopt evasive tactics in the face of refutations. I called these tactics (for historical reasons) 'conventionalist stratagems [or twists]', but my friend Professor Hans Albert has found a much better term for them. He calls them *'immunizing tactics or stratagems':* we can always immunize a theory against refutation. There are many such evasive immunizing tactics; and if nothing better occurs to us, we can always deny the objectivity - or even the existence - of the refuting observation.” (Karl Raimund Popper 2002b)

> ”There is a legitimate place for dogmatism, though a very limited place. He who gives up his theory too easily in the face of apparent refutations will never discover the possibilities inherent in his theory. There is room in science for debate: for attack and therefore also for defence. Only if we try to defend them can we learn all the different possibilities inherent in our theories. As always, science is conjecture. You have to conjecture when to stop defending a favourite theory, and when to try a new one." (K. Popper 1974)

In social sciences, Popper's falsification remains a powerful criterion, with value-added assumptions.

Although many contemporary scholars find it difficult to compare the empirical content, the content of the truth and the content of falsehood of different theories, they agree with Popper that there must be a way to do this using an intuitive approach. In this respect, A. A. Derksen states

that it is not necessary that the best corroborated theory be the most falsifiable for more severe testing. (Derksen 1985) In Popper's opinion, lowering the severity of a test explains "why an often-repeated test will no longer be considered as significant or as severe: there is something like a law of diminishing returns from repeated tests." (Karl Raimund Popper 2002a, 240)

Popper asserts that "“what we attempt in science is to describe (and so far as possible) explain reality". (Karl R. Popper 1979, 40) Although Popper argues that realism is an undeniable metaphysical vision of nature, he believes, however, that we have good reasons to accept realism and to reject unrealistic ideas, such as idealism or instrumentalism. Scientific theories should be interpreted as attempts to describe an independent reality of mind.

In recent years, however, Popper's falsifiability theory has been revitalized. Its supporters affirm that the concept can be clarified by other means than the necessary and sufficient criteria, (Pigliucci 2013) (Mahner 2013) or that such a definition is indeed possible, although it must be supplemented with discipline-specific criteria to become fully operational. (Hansson 1996)

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