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WHAT IS GOOD SCIENCE AND HOW FAR CAN IT GO?

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Does science have the final word? Could it ever have it? On October 2016, the School of Physical Education and Sports of the University of Costa Rica hosted Dr. René van Woudenberg, a philosopher of science from the Free University in Amsterdam. He addressed the audience on the presuppositions of science. In this issue of PENSAR EN MOVIMIENTO we have included both the English and Spanish versions of his manuscript, after it underwent a peer review process. I would like to seize the opportunity to share with our readers a related topic which is seldom discussed among human movement professionals, which is nevertheless fundamental for our scientific endeavors. At the same time, it should serve as an introduction to Dr. van Woudenberg's manuscript.

In this editorial I present a few introductory topics to the philosophy of science, namely, the nature of science, what are its limits, and if and how they should be managed. An attempt is also made to prepare a well-supported list of good scientific research practices. As a researcher who has done most of his work in health and human performance, my focus is on the natural sciences and, more specifically, on human movement science.

Everywhere we look we see numerous health and fitness claims supposedly based on science. The fact that many of these claims contradict each other doesn't seem to bother most people, actually, for many, it is better that way, because each individual can conveniently find "scientific" support for his or her own practices and beliefs. This last element is crucial because science enjoys today a similar status in Western society as religion enjoyed in Europe in the middle ages: it is the final authority that you question at your own peril. I need to ask: just how reliable, how final, how all-encompassing (universally competent) is science as a source of knowledge and a guide for life?

Most scientists agree that a simple theory or explanation is better than a complicated one. Although there seems to be no philosophically sound basis for this presupposition, it is necessary to start somewhere, so I will begin with the most simple view of science which—together with Chalmers (2013, Chapter 1)—I believe is also the most common: we live in a natural world where things are what they are and behave in a particular way; by using the scientific method, a wonderful development that marked the end of the Middle Ages, we humans can collect facts to gain an objective understanding of our natural world and we can predict what will happen under specific conditions. Science has been extremely successful for the past few centuries, and temporary technical limitations alone (e.g. telescopic and microscopic magnifying capacity and image resolution; video sampling frequency; data storage and processing) have limited what can and cannot be answered by it. Anything worth studying should be studied scientifically; science should have the final word on everything. Again, this is a common view of science shared by a large number of people.

Science has indeed been extremely successful, but it turns out that things are slightly more complicated than stated in the previous paragraph, or at least that is what philosophers of science want us practicing scientists to believe. Unfortunately for us, they make a rather strong case. There is no clear-cut definition that enables intellectually honest humans to distinguish science from nonscience, even after major attempts have been made to get there (cf. Moreland, 1989, chapter 1). The scientific method, as a clearly defined series of steps from initial questions to theory development, does not exist. There is no possible way for science to claim that truth has been arrived at, no way to absolutely prove anything. And apparently science cannot even make a solid case for its own credibility without borrowing from other disciplines such as philosophy! In the pages that follow, I will make an attempt at discussing some of those problems and recommending a few good scientific research practices.

Is all knowledge suspect? How about non-scientific knowledge? Is there such a thing as objective truth, or are there multiple ways of understanding the natural world, all equally valid as long as they make one happy and keep the world running? I bring my own presuppositions into these questions: first of all, I believe that it is not possible to deal with any rational discussions without first admitting that we all bring some presuppositions to the table—science certainly does (cf. Moreland, 1989). I believe that there is a natural world that does behave in predictable ways, and that human beings have the ability to perceive that natural world and understand it. With many of the seventeenth century scientists, and many of the current ones, I believe that the natural world was created by a rational, personal being who endowed it with many of his own characteristics: order, rationality, consistency, beauty, and truth. And I believe that science is one broad discipline which can tell us a great deal about our natural world, but it is not the only one that can give us important, reliable knowledge, and it cannot do so in total isolation from other disciplines. Furthermore, honest answers to the most important questions in life are beyond the bounds of science (Lennox, 2009; Medawar, 1984).

Because science cannot study the natural world in isolation from other disciplines, I will start from a perspective that science must be illuminated by philosophy. In a quote from John Kekes (Kekes, 1980, *Nature of philosophy*, pp. 156-157), Moreland presents a list of important philosophical presuppositions of science:

> Science is committed to several presuppositions: that nature exists, that it has discoverable order, that it is uniform, are existential presuppositions of science; the distinctions between space and time, cause and effect, the observer and the observed, real and apparent, orderly and chaotic, are classificatory presuppositions; while

> intersubjective testability, quantifiability, the public availability of data, are methodological presuppositions; some axiological presuppositions are the honest reporting of results, the worthwhileness of getting the facts right, and scrupulousness in avoiding observational or experimental error. If any one of these presuppositions were abandoned, science, as we know it, could not be done. Yet the acceptance of the presuppositions cannot be a matter of course, for each has been challenged and alternatives are readily available (Moreland, 1989, p. 109).

A major characteristic of science seems to be that because it is practiced or done by human beings, it is not possible to eliminate all possible sources of bias, however shocking that may sound to the naïve scientist. For the positivists and empiricists, it would be ideal if we were able to collect facts free from the constraints of any theories, but this has been shown not to be possible (Chalmers, 2013, Ratzsch, 2000). There is a need for presuppositions, for existing knowledge, to guide our fact-collection efforts in a productive way. Theories are often implicit in the way we measure phenomena, in the choice of measuring instruments, or in our selection of phenomena to be measured. In short, it seems that it is not possible for a scientist to do science independently from his/her own interests and perspective. Not only closely related theories, but even each scientist's worldview will have an impact on his or her science.

According to Ratzsch (2000), this human ingredient of science was somewhat recently rescued by Thomas Kuhn: more than an undesirable but unavoidable element, the application of human values is seen as fundamental to the practice of science. Ratzsch's position is that “contemporary philosophy of science has been searching for some middle ground where reason, observation and objectivity have an appropriate place but where the human factor is at least that—a factor.” (Ratzsch, 2000, Chapter 3, last paragraph).

Now do we, as scientists, search for truth, or do we simply try to find a reasonably good explanation? Plato was cautious on this topic, stating in his Timaeus “...if we can come up with accounts no less likely than any, we ought to be content, keeping in mind that both I, the speaker, and you, the judges, are only human (…) It behooves us not to look for anything beyond this.” (McGrew, Alspector-Kelly, and Allhoff, 2009, p. 27). Apparently, the balance had soon shifted to the side of certainty, as stated by Aristotle in his *Posterior Analytics*. But it swung back again later on: “One critical philosophical development accompanying the scientific revolution was the shift from the Aristotelian conception of science as absolutely certain knowledge derived from first principles to a more modest conception of science as a rational but fallible discipline.” (McGrew et al., 2009, p. 9).

Moses Maimonides expressed a curiously practical view of truth and science in his *Guide of the Perplexed,* stating that the purpose of the astronomer “is not to tell us in which way the spheres truly are, but to posit an astronomical system in which it would be possible for the motions to be circular and uniform and to correspond to what is apprehended through sight, regardless of whether or not things are thus in fact.” (McGrew et al., 2009, p. 84). In other words, it doesn't matter if the model is not true, as long as it fits with observed data. That seems to be the view of many contemporary scientists, who practice a pragmatic instrumentalism even if they don't expressly subscribe to it. I beg to disagree with this position. I concur that science is unable to give us proof that truth has been reached ("Experimental science offers the proof not of the logician but of the lawyer." (Decaen, 2012, p. 26), but I am convinced that truth exists and that we should use our minds to try to grasp it, even if our efforts are like Medawar's asymptote, "for there can be no apodictic certainty in science, no finally conclusive certainty beyond the reach of criticism." (Medawar, 1985, p. 5). We would like to believe that science is making theoretical progress over time and that progress means getting closer to the truth.

The meaning and relevance of truth is only one of many sources of disagreement among philosophers of science, and the details are far beyond the scope of this paper—and much further beyond the expertise of its author. However, from the limited reading I have been able to do in such a vast area, it is apparent that most—if not all—philosophies of science agree on several important points, such as the impossibility to know when truth has been reached mentioned in the previous paragraph. The conviction exists that there should be a constant striving for objectivity, rationality, and empiricality. There is a generalized and necessary belief in the uniformity of nature (van Woudenberg, 2017). And regardless of one's perspective, no philosophy of science can account for each and every case of what has actually happened in the rich history of scientific discovery.

To conclude this section I must add that the mere fact that there is so much debate among different philosophies of science reflects that science is far from perfect and unable to point us in the right direction by itself. Science is limited, even if some scientists don't act as if it were.

The Limits of Science

Even the study of the limits of science is considerably more complicated than one might suppose. In addition to the limits I intend to present more in depth, namely, whether there are areas where science simply cannot provide an answer—Sir Peter Medawar (1984) calls them the first and last things—there are others. Some limits have to do with the self-limitation of growth, with technological capacity or with cognitive inadequacy, and in this line Medawar states that "there is no limit upon the ability of science to answer the kind of questions that science *can* answer" (Medawar, 1984, p.86; the quote sounds unfortunately circular, but the context shows that he meant that all questions *within the domain of science* can be answered and will be answered sooner or later). Some practical limits are due to economic, social, or environmental resources, even if some of those limits can be adjusted by policy. Other practical, external limits have to do with experiments or procedures that science should not embark upon for ethical reasons, a vast and controversial area (here, too, the line is far from set on stone). For the remainder of this paper, I will attempt to focus only on what science, because of its nature, can and cannot tell us about our world. My list, of course, will not be exhaustive regarding the former (an impossible task) or even the latter.

Perhaps the most important limit to science is that it cannot make a case for its own credibility, as stated previously, nor for ruling out other legitimate, rational disciplines like philosophy or theology. Declaring that only science can lead to truth cannot be deducted from science itself, it is a self-refuting statement (Lennox, 2009). So is the claim that "only what can be known by science or quantified and tested empirically is true and rational" (Moreland, 1989, p. 107). The point is that there are many cases in which science is not our source of information, and that does not mean that reason is no longer working and that evidence is no longer relevant (Lennox, 2009); science does not have the monopoly of rational knowledge.

Science, because of its very nature, does not cover all types of rational knowledge. Van Woudenberg (2008) presents examples of what he calls irreducibly extra-scientific knowledge, facts that I know but science played no role in allowing me to know, and cannot even allow me to know, such as my knowledge that lying is wrong, or that I have an obligation to care for my children and my aging parents. The warrant condition for this type of knowledge cannot be satisfied by anything scientific. The study of questions that lie outside science, such as, what is a moral virtue? How do we obtain moral knowledge? is important because, as Moreland wrote, “our culture is so inundated with scientism—roughly, the view that only what science says is true or rational is, in fact, true or rational—and there has been such a pragmatic emphasis on science in education (…) that there is a widespread cultural myth that questions like those above are mere matters of private opinion.” (Moreland, 1989, p. 46). In this sense, a limit to science would be “an explanation or answer to some problem that properly lies outside the boundaries of scientific explanation and is cognitive in nature, that is, it is in principle a rational issue whose solution can be true or approximately true.” (Moreland, 1989, p. 105). Or in van Woudenberg's words, science is limited by irreducibly extra-scientific knowledge, those true beliefs that are warranted but whose warrant condition cannot come from science.

This limit cannot be stressed enough: there are questions that are out of the domain of science. One should always ask: what is the scientific, or at least the rational, justification for believing that science will be able to explain everything? There appears to be none. In their arguments in favor of science and against religion or theology, some contemporary scientists often recur, explicitly or implicitly, to the concept of a “god of the gaps”. This concept was presented by Lucretius in the first century A.D., and has become very popular among atheist and agnostic scientists: as humans are able to explain natural phenomena that were formerly attributed to “the gods”, those gods no longer have a job (McGrew et al., 2009, p. 14). Another way to put it is that the concept of “god” is useful to explain the inexplicable, but because science is explaining more and more, soon the “god did it” explanation would be no longer necessary. There is an automatic, non-warranted extrapolation of this argument to the non-observable world, to the supernatural. This type of reasoning fails to acknowledge that because science decides to limit itself to naturalistic concepts, or to the purely mechanistic or materialistic, it becomes necessary to accept that it will not be competent to handle most questions on values, morality, religion, philosophy, and other areas. According to Ratzsch (2000), most philosophers of science accept these limits, but some of them don't, and in many cases the motivation has an anti-religious flavor. Claiming that the God of Christianity is a god of the gaps is certainly stepping out of science's boundaries, even if the claim has an unfortunate historical basis.

Science is, therefore, limited in its scope because there is rational knowledge which is not scientific. Another perspective on this issue is the type of questions that need to be answered. Science asks and attempts to answer a wide range of questions but, as briefly mentioned above, **it simply cannot answer the ultimate questions**, such as: Why do we exist? How did everything begin? Do humans possess freedom? It has been proposed that those questions are irrelevant, but then, why do they keep coming up? As van Woudenberg states, “all the while two facts remain: first, ultimate questions continue to seem meaningful to us as well as of utter importance, and second, science

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doesn't have a handle on them" (2008, p. 17).

Not only can science not answer the ultimate questions, but it cannot answer questions about the brute facts either. This refers to ultimate or final explanations based on universal laws, which do not explain why those laws apply and not others. One example of this category of brute facts is the gravitational constant: we know how to apply it and it is extremely helpful when calculating human movement or space travel, but science cannot explain what gravity *is*. **Brute facts constitute a limit of natural science** (van Woudenberg, 2008).

Another broad category of limits of science has already been hinted at twice, but will now be described in slightly more detail: **the existence of presuppositions of science**. Science cannot exist, it cannot be practiced unless some basic presuppositions, which cannot be arrived at scientifically, are in place. Precisely because this has been a discussion topic among philosophers of science, I invited Dr. René van Woudenberg to share his perspective with our journal (available in this issue in both English and Spanish). Interested readers may find a more profound, more detailed presentation of the topic in that manuscript.

Perhaps the best example is the uniformity principle (that because A and B procedures under C and D circumstances have resulted in S innumerable times, it will continue to be so), which cannot be proven by any means available to humans; this was originally called the problem of induction, by David Hume. The extreme weaknesses of this presupposition are well captured by Dell Ratzsch: "So uniformity makes no predictions, is untestable, is not at empirical risk, can be bent to accommodate anything, is preferentially protected and rests ultimately upon philosophical considerations. Yet the uniformity principle is not only legitimately scientific, it is utterly essential to science." (Ratzsch, 2000, Methodological Naturalism, Par. 10.). Apparently, other disciplines tend to be judged more rigorously... Another key presupposition is that we can rely on our cognitive abilities such as perception, reason, and memory. But in order to test their reliability, we need to first trust them, what William Alston has called *epistemic circularity* (van Woudenberg, 2008, p. 13). It is then not possible to scientifically support the reliability of those human cognitive abilities essential for the scientific endeavour.

The last category of limits I would like to address has to do with the norms of theory choice. There is a wide variety of norms to assist in choosing between two or more competing theories, but no agreement on their relative importance or even on which should be included. **Science itself cannot tell us how to choose among theories** without resorting to philosophy and all kinds of extra-scientific convictions and beliefs. Some examples of norms for theory choice are presented in the next section on *good science*, a particularly relevant topic for scientific journal editors, as it sheds light on the decision to accept or reject manuscripts for publication.

Accepting that the limits do exist, I would like to briefly present how they should be managed. There are at least two fronts. To begin with, scientists must reflect on their discipline and honestly seek to either respect its boundaries, or complement it with the tools, principles and experts from other disciplines. Then, to the extent that individuals fail to respect the limits, be it because of radically different perspectives about science or because of the natural tendency to carelessly push one's claims and convictions as far as one is allowed, it will fall on the shoulders of the scientific community to exercise its refereeing responsibility, the same way that journal editors and reviewers referee the quality of publications. There are many examples of scientists and philosophers who, without an

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element of censorship sometimes present in scientific journals, are playing a very important role in the management of the limits of science by keeping these issues on the table and contributing their well-supported arguments to the discussion.

What is good science?

The three desirable characteristics of science or of its theories, as stated by Ratzsch (2000), are objectivity, rationality and empiricality. These have already been mentioned, but not defined. Well-known philosophers of science have devoted countless pages to the clarification of these terms; for our current purposes, and not without realizing the risk of oversimplification, *rationality* will be the expectation of order, that the world is regular, uniform, and shows patterns that are understandable to the scientist. *Empiricality* has to do with the observability of facts, that is, the possibility of verification by measurement or experimentation. Finally, *objectivity* means that the interpretation of those facts or measurements should not vary widely from scientist to scientist.

Certainly, these characteristics cannot be taken for granted, since there are all kinds of threats to each one of them. There are, however, many ways to foster them. In that sense, it should be possible to distinguish poor science from stronger science. After all, scientists need to know how to do better science, journal editors must be able to weed out weaker communication pieces of science, funding agencies should base their decisions on scientific quality besides policy, and even the educated public needs to be able to recognize stronger science. Therefore, while a checklist of sufficient and necessary requirements cannot be prepared, some guidelines, organized here in table form, should help distinguish stronger from weaker science. They are classified as relating to the quality of a theory, or the quality of specific experiments or pieces of evidence (in Stephen Wykstra's terms, cited by van Woudenberg (2008), *theoretical* and *methodological*). Within each category, an attempt has been made to present them in ascending order of sophistication, where more sophisticated qualities tend not to be as widely accepted. The table also attempts to identify whether each quality would naturally reinforce objectivity, rationality, or empiricality.

It must be pointed out that these are not empirical factors as defined by conventionalists and pragmatists. They are more in the line of some of Kuhn's values in science: empirical accuracy, consistency, breadth of scope, simplicity, and fruitfulness (Ratzsch, 2000, Rationality, par. 8), or in the line of generally accepted desiderata for theories: empirical adequacy, simplicity, good fit with other theories, giving rise to unexpected discoveries, fruitfulness, observational nesting, track record, smoothness, internal consistency, and compatibility with well-grounded metaphysical beliefs (Ratzsch, 2000, Confirmation, paragraph 17). They are related to Artigas' five criteria for assessing theories in normal scientific research: explanatory power, predictive power, accuracy of explanations and predictions, convergence of varied and independent proofs, and mutual support.

In the context of the Theory of Scientific Rationality, Van Woudenberg (2008) calls them norms for theory choice. As explained in the last limit of science presented in the previous section, there is less than clear agreement on these norms and, when forced to choose between two apparently equivalent theories, scientists don't have absolute or definitive scientific criteria for making the choice, attaching different weight or importance to each of the qualities presented below, to the extreme of discarding some of them.

Table 1

Guidelines for the assessment of science quality according to theoretical aspects

Quality or characteristic	Stronger science	Weaker science
01 Simplicity Rationality (we consider it simple because it can be understood by the human mind)	A simpler theory that accounts for all observed phenomena is typically preferred to a complex one.	A theory that becomes complicated in order to accommodate a few discrepancies in the evidence.
02 Association and succession Rationality	When two or more phenomena occur together (**conjunction** or **contigüity**). Considered a basic first step, but never sufficient to establish causality. The case becomes a bit stronger if the phenomena always occur in the same order (**succession**).	The association has only been observed once or a few times.
03 Freedom from impossibilities Rationality	Not a strong quality by itself.	When the description of some phenomenon is free from impossibilites (proposed by Aristotle in *Meteorology*, as presented by McMullin, 2013, p. 153).
04 Coherence or consistency Rationality and Empiricality	All of many available observations (Buridan's *apparentia*) are in harmony with the explanation. Significantly stronger if several unsuccessful attempts have been made at falsifying the theory or explanation. Chalmers calls this the process of testing the claims against the evidence.	Only a few observations are available, even though they are consistent with the explanation. OR one or more available observations are not consistent with the explanation, but are qualified *ad hoc* to achieve consistency. Instead of testing the claims against the evidence, the former are accommodated to the latter.
05 Falsifiability Empiricality and objectivity	Related with the previous one. The theory or hypothesis should be highly at risk of being falsified. Recognizes the fallibility of science.	A theory without informative content, which then cannot be falsified.
06 Predictive ability Rationality and Empiricality	The theory is able to predict new, unknown or even unexpected results (McMullin, 2013, p. 180; Medawar, 1985, p. 4). Predictions or explanations have a high degree of accuracy.	Predictions are conservative, highly unlikely to fail.

Quality or characteristic	Stronger science	Weaker science
07 Alternative explanations Empiricality, rationality	There are several alternative explanations but the proposed one shows reasonably good evidence and is coherent	The only strength of the proposed theory is the insufficiency of all alternative explanations
08 Scope of application Objectivity and rationality	A broader scope is preferred to an extremely limited scope	Two problematic extremes are possible. First, an extremely limited scope. But second, a scope that is too broad: application extends beyond warranted limits (unwarranted extrapolation) or as Mayo's partitioning of theories puts it, the theories generalize to a greater degree than is warranted by the evidence.
09 Fruitfulness in guiding new research Empiricality	A theory may be judged stronger to a rival if it points more clearly to new areas of research, if it fosters progress.	The theory or a particular experiment is sterile, reaches a dead end.
10 Verification of the rules of correspondence Rationality	Confirmation of the rules of correspondence is not possible, but a very good approximation is, when distinct correspondence rules connected with the same theoretical matters are available, or when existing theories in entirely different areas can be linked theoretically (Ratzsch, 2000). There is convergence of varied and independent proofs: when different phenomena that can be tested independently can be explained and predicted by the same theory (Artigas, 2001, p. 200).	No independent confirmation of the rules of correspondence can even be attempted.
11 Consistency with extra-scientific knowledge Rationality	Theories are consistent with generally-accepted, extra-scientific knowledge. Theories are compatible with well-grounded metaphysical beliefs (Ratzsch, 2000, referring to Newton-Smith's *Rationality of Science,* 1981).	Theories are in conflict with generally accepted, extra-scientific knowledge.

Table 2

Guidelines for the assessment of science quality according to methodological aspects

Quality or characteristic	Stronger science	Weaker science
01 The phenomenon under study is observable (quantifiable, measurable) and verifiable Empiricality and objectivity	The claim may be subjected to empirical scrutiny, it is "observable" (quantifiable) by different methods and different people.	The claim is only observable by a particular instrument and the instrument's functionality is based on a theory associated with the phenomenon under study.
02 Range and variety of evidence. Coincidence (Chalmers, 2013) All three	A wide range of phenomena, as described by qualitatively different genuine tests, coincide in supporting the theory (Chalmers, 2013, chapter 17)	The tests supporting the theory are very limited in type or number.
03 Good inductive process Rationality and empiricality	Not only follows appropriate inductive procedures, but attempts to exclude other relevant causal factors and tests the invariability of any purported correlation, as recommended by Francis Bacon.	Limited to following appropriate inductive procedures.
04 Reproducibility Objectivity and empiricality	The reproduction of an experiment by other researchers is highly desirable and generally considered a necessary characteristic of science.	Strict reproducibility may not be possible. Even if possible, funding agencies will often reject an experiment unless it adds a new perspective; the results from new experiments may need to be argued into being a reproduction of prior results.
05 Quality of the experiment Rationality	Results from experiments that were adequately performed but in addition are relevant and significant (cf. Chalmers, 2013).	Experimental results that are adequately performed but may not be relevant because they add nothing to the state of the art.

Quality or characteristic	Stronger science	Weaker science
06 Handling of unique or atypical results Objectivity and empiricality	In a study reporting atypical results, greater care is necessary: experimental design should be strong and results should be later reproduced by a separate group. Any necessary auxiliaries are subjected to tests independently of the theory that is being argued for (Chalmers, 2013, ch. 17). The authors provide references or examples supporting or testing the auxiliaries independently.	Atypical results turn out not to be reproducible or are likely to arise from a weak methodology. Auxiliaries are introduced but not tested independently. Rather, they simply accommodate the theory to the evidence.
07 Compliance with accepted criteria in the context of specific disciplines Rationality, objectivity	In addition to all the qualities listed above, which apply to all natural sciences, there those currently-accepted, discipline-specific criteria. The methods used in research comply with specific criteria preferred by the scientific community in that specific field, e.g., in exercise science, studies with humans are double-blind.	If methods do not comply with the commonly accepted ones, and the experiment or theory is not strong in other aspects.

To summarize, in this editorial I have briefly discussed three main ideas which are relevant to scientific work. First, I explained that the popular concept of *science* is often too simplistic, almost childish, as it does not take into consideration major discussions among philosophers who have taken this topic seriously. I specifically proposed that there is no clear definition that will allow honest, thinking humans to distinguish between science and non-science; that there is no consensus on the scientific method, as a clearly defined series of steps taking us from the initial questions to theory development; that there is no possible way for science to claim that truth has been arrived at (although I believe that truth exists), no way to absolutely prove anything; that the scientific endeavor is impossible without starting from non-scientific presuppositions. Second, I have proposed that science has limits which scientists must know and respect if we want to be intellectually honest. And last, I submitted that although there is no consensus among scientists to establish a frontier between science and non-science, there are indeed theoretical and methodological criteria or qualities that enable us to tell stronger science apart from weaker science.

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