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Chapter 6

The Twentieth Century Ascendance of "Empirical Science"

1. Introduction

In Chapter 2, we saw how empiricism slowly shed its negative associations with medical quackery in the course of the nineteenth century, even if it still was accorded a lesser status in scientific methodology. This chapter traces a different strand in the history. Its concern is not empiric*ism*, the general doctrine. It is concerned with the emergence of the notion of "empirical science" among scientists. The two may seem so close that one might wonder if they can be separated. The difference is that the term empiricism designates a well-developed philosophy concerning how we learn of the world and its nature. "Empirical science," as it emerges in the course of the twentieth century in the writing of scientists, is a much looser view that arose as an application of some version of empiricism. It offers a general picture of science, done well, as deriving its content from experience. It generally lacks the skepticism of Big-E Empiricism. Empirical science, as understood in ordinary scientific discourse, is an optimistic view that allows experience to inform us of contingent propositions in science that extend well beyond experience. The term, or the idea behind it, has become common and even ubiquitous in the writings of practicing scientists.

Scientists and philosophers of science treat the notion of "empirical science" differently. For practicing scientists, the notion is almost universally accepted as a default fact about good science. It is beyond serious challenges. When proposals in science seem to threaten it, the empirical character of good science is to be defended energetically. That is so, even if most practicing scientists could not give a well-articulated account of precisely what the term means, once they have gone beyond the idea that it requires science to be grounded in observation and experiment.

For the philosophers of science, it was a term of art that required careful dissection in accord with their specific version of empiricism. Just how might we bridge the gap between experience and results deeper in the science? How are we to think of these deeper results?

Philosopher of science gave different answers. Reichenbach allowed probabilistic relations to bridge the gap and for results in science to enjoy probabilistic security. Popper insisted that no such inductive link is possible and that the propositions of a science enjoy only a provisional status as well tested, but not yet refuted. Van Fraassen argued that we should resist assigning truth to any claims beyond those of direct experience.

This chapter will review how the scientists' conception of empirical science evolved out of work by philosophers to identify and eventually elevate the place of the empirical in science. Section 2 will review how the first steps towards the notion of empirical science came in the nineteenth century with the idea of an "empirical law" in the philosophical literature. The notion was freed from a connection with medical quackery, but it was still a lesser form of science. For the scientists in the course of the nineteenth century, empirical laws became important and, even though they recognized that they were not entirely secure inductively, they grew to be a respected and important component of the sciences.

Section 3 identifies a clear indication that the fortunes of the idea of the empirical changed, starting in the 1930s and accelerating in the 1950s. An "ngram" plot of terms in which the adjective "empirical" appears shows its sudden rise in popularity. At about the same time, we shall see in Section 4, that philosophers of science now treated the notion of empirical science as an unproblematic default conception for science. Karl Popper's formulations of the empirical character of science proved to be especially influential among scientists and will be recounted in Section 5.

The remaining sections will review how the conception of empirical science migrated into common scientific thinking. That it was a migration and not an independent proposal is already clear from its close association with the term "empirical." It is a term of art of philosophers that originally denoted a disparaged medical tradition. Section 6 will give a characterization of the conception of empirical science as it appears to be used commonly in science. It is:

> *Scientists' conception of empirical science*. Science consists of observational and experimental reports and further results inferred from them. The observational and experimental reports are the empirical evidence indispensable for science.

It is uncommon for scientists to specify just what is intended by their frequent use of the term "empirical." That is a task left for philosophers of science. However, when scientists perceive a threat to empirical science, we can read their conception of empirical science from their responses, for these responses often include a specification of what counts as acceptable empirical science. Sections 7, 8 and 9 will review how such threats arose in forensic science, evolutionary biology and fundamental physics and cosmology; and how the scientists used their conception of empirical science to deflect them.

2. Empirical Laws in the Nineteenth Century

The first step towards the modern notion of "empirical science" came with the nineteenth century recognition of "empirical laws" in science. They have the character of simple generalizations in restricted domains and, it followed, could not be extended securely to universally applicable foundational laws.

What is easily overlooked but notable is the mere fact that the term "empirical" is used at all. These results could have been given many other labels: "observed regularities," "simple inductive laws," and many variants. That "empirical" was used reflects that it had lost its negative connotations and retained only the idea of a strong connection to experience.

The idea of an empirical law appears throughout the writing of methodologists of the nineteenth century. William Whewell, for example, reproduced one of his essays from 1834 in an appendix to his *Philosophy of the Inductive Sciences*. In it, he juxtaposed merely empirical laws with laws of demonstrable necessity. It is a juxtaposition that is common in nineteenth century writing. He described them as follows: (1834, p. 573, his emphasis)

> "What is the kind and degree of cogency of the best proofs of the laws of motion, or of the fundamental principles of mechanics, exprest [*sic*] in any other way?" Are these laws, philosophically considered, *necessary*, and capable of demonstration by means of self-evident axioms, like the truths of geometry; or are they *empirical*, and only known to be true by trial and observation, like such general rules as we obtain in natural history.

John Stuart Mill, in his influential nineteenth century *System*, gave "empirical laws" a similar lesser place in science: (1882, p. 366, his emphasis)

> Scientific inquirers give the name of Empirical Laws to those uniformities which observation or experiment has shown to exist, but on which they hesitate to rely in

> cases varying much from those which have been actually observed, for want of seeing any reason *why* such a law should exist.

He soon summarized their limitations (pp. 368-69):

> Empirical laws, therefore, can only be received as true within the limits of time and place in which they have been found true by observation ; and not merely the limits of time and place, but of time, place, and circumstance for, since it is the very meaning of an empirical law that we do not know the ultimate laws of causation on which it is dependent, we can not foresee, without actual trial, in what manner or to what extent the introduction of any new circumstance may affect it.

It hard not to see a begrudging tone in Mill's treatment of empirical laws. That they have a place in science is undeniable, so he has to fit them into his narrative.

This tension is all the more evident in W. Stanley Jevons' expansive review in his *Principles of Science* of the place of empirical laws in science. In his discussion of the vapor pressure of water (1874, p. 126), he noted that no formula contained in an empirical law would match exactly with the results of experiments. He lamented that this fact "illustrate[s] the feeble powers of empirical inquiry." This lament reflected his reservations elsewhere about empirically derived results. He noted: (1888, p.xxx)

> However useful may be empirical knowledge, it, is yet of slight importance compared with the well-connected and perfectly explained body of knowledge which constitutes an advanced and deductive science.

What is striking, however, in Jevons' narrative in *Principles of Science* is the vastness of the reach of empirical laws in science. Chemistry is a repeated example. He noted (p. 160) "The science of chemistry, however much its theory may have progressed, still presents us with a vast body of empirical knowledge." And then (p.161) "There are whole branches of chemical knowledge which are as yet mere aggregates of disconnected facts." Jevons further recounted (p. 166) the importance of laws first discovered empirically but which are then shown to have a sound basis in a law of nature. Kepler's empirical discovery of regularities in planetary motions (p. 222) is an instance of this discovery process. In reporting how novel experiences can overturn older science, Jevons recorded the still further reach of empirical laws (p. 335): "… the natural sciences of Botany, Zoology, Geology, &c., the laws of which are almost wholly empirical."

Jevons' inventory of empirical laws omitted treatment of empirical psychology. German interest in "*Empirische Psychologie*" had become so well developed that a French commentator, Théodule-Armand Ribot (1879) wrote a synoptic summary entitled *La Psychologie Allemande Contemporaine (École expérimentale)* that reported its empirical character. In a reflection of its importance, an English translation elevated "empirical" into the subtitle (Ribot, 1899), *German Psychology of Today: The Empirical School.*

A notable development in the strand of history traced here is that the term "empirical science" appears in an 1898 cataloguing of conceptions of science. It is not the first use of the term in the later nineteenth century, but it is illuminating for its care in identifying the scope of empirical science. In his *Sphere of Science*, Hoffmann (1898, p. 255) gave a three-part division of science:

> We thus see that there are three kinds of science and only three : the sciences that begin with single facts and arrange them into systems under more general facts, which we will call empirical sciences, because all their data are derived from direct observation and experiment; the sciences that begin with principles and arrange the facts under them, which we will call normative sciences, because they take a principle or norm of reason as their starting-point; and finally the science that seeks to explain all the other sciences and bring them into unity, which is philosophy properly so called.

Hoffmann then gave a tabular representation of the different sorts of sciences, rendered here as Table 1.

	Empirical sciences	*Normative Sciences*	
Physical	Astronomy, Geology, Physics, Chemistry, Biology	Logic, Mathematics, Aethetics, Ethics, Economics Politics	Philosophy
Psychical	Psychology, Sociology, Descriptive Theology		

Table 1. Hoffman's table of sciences

The list of empirical sciences coincides near enough with those we might now designate as empirical sciences. Hoffman's conception of the nature of these sciences did not match our later view. Empirical sciences, in his understanding, were epistemically weaker and apparently amounted to little more than a repository of empirical laws. He described their limitations as follows (pp. 256-57):

> No fact or collection of facts can ever become a principle, but a few facts even cannot be examined with any care without revealing principles. It is for this reason that no scientific mind can ever stop content with empirical science. It must ask, How are the facts related to the principles? What meaning do they have in the light of the principles and how are they to be scientifically arranged under them?

The juxtaposition of two ways of proceeding in science also entered the methodological discussion of major works of science. Walther Nernst's authoritative *Theoretische Chemie* includes with it in his introductory chapter (1898, p. 2, 1904, p. 2)

> The history of the exact sciences teaches us that we may discover new laws of nature in two essentially different ways, one of which may be designated as the empirical, the other as the theoretical. Thus in one way by suitable observations, one collects abundant material, capable wherever possible of mathematical expression, concerning the phenomena between which he suspects a connection; and then by a repeated and purely empirical grouping of the data so obtained, he seeks to approach the desired goal: in this way, for example, were found certain relations between the properties of the elements and their atomic weights. The

> second way, on the other hand, leads from suggested conceptions regarding the nature of certain phenomena, through pure speculation to new information, the correctness of which must be determined by subsequent research; thus by kinetic considerations of the combination and dissociation of substances reacting on each other, the law of chemical mass action was discovered.

The hesitation expressed by methodologists writing in generalities is no longer evident in Nernst's formulation. His example of empirical laws are the laws of thermodynamics, which were empirically derived and proved to have remarkably resilient, universal application. He noted: (1898, p. 2, 1904, p.2)

> … what is unquestionably the most brilliant example of a law of nature empirically proven, viz. the doctrines of thermodynamics, these are applicable to every occurrence which we see transpiring in nature, and therefore demand natural attention in the scientific investigation of every particular phenomenon.

It might perhaps overstate matters if we see a trend here. Those writing in the abstract continue to associate the term "empirical" with a weaker methodology. Yet, in the practice of science, the empirical is becoming essential to scientific inquiry and is eclipsing deductive methods in their fecundity.

3. The Twentieth Century Rise of "Empirical"

The fortunes of the adjective "empirical" changed for the better in the course of the early to mid-twentieth century. An oblique indication of the change is provided by Google's "ngram viewer." It plots the frequency of occurrence of terms in percentages in English language books published in the US for the time period indicated. Figure 1 shows the ngram plot for 1800 to 2000 for a selection of terms using the adjective "empirical."

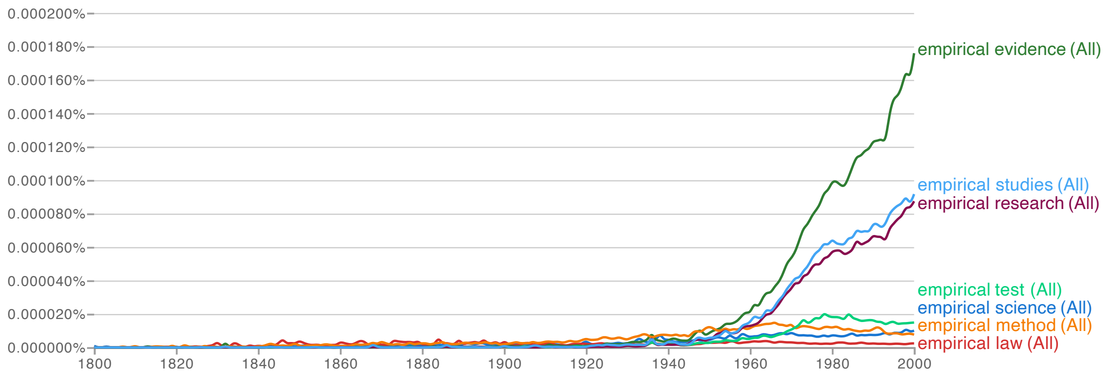

Figure 1. ngram plot of frequency of terms containing "empirical"

The plot shows a small increase in usage roughly around 1930 and then growing quickly starting around 1950. Interpreting the plot is not so straightforward. It might just indicate that this period enjoyed a rise in the publication of science books overall. Since other ngram plots (not shown) indicate no corresponding rise in terms like "science," "evidence" and "experiment," I read the plots of showing an increase in the usage of the adjective "empirical" specifically.

In any case, even if the overall plot is confounded by a rise in scientific publication, that confounding cannot be responsible for the difference between the rise in usage of the term "empirical evidence" compared to other terms containing the adjective "empirical." Its usage in "empirical evidence" increases the most.[1] This increase indicates that evidence derived from experience—empirically—was losing the lesser status afforded to it by nineteenth century writers and becoming more respectable as a foundation for science.

4. Philosophers of Science on Empirical Science

A part of the favorable rise of the adjective "empirical" is the description of science, properly done, as "empirical science." This description became routine among mainstreams of philosophy of science in the earlier twentieth century. An affirmation of the currency of this conception is given by Russell (1927) in the opening line of the chapter "What is an empirical Science?" He wrote: (p. 169)

[1] That it increases the most of terms with the adjective "empirical" is affirmed by an ngram plot (not shown) of "empirical *" that uses the wildcard symbol "*" to match any other word.

> It would be generally agreed that physics is an empirical science, as contrasted with logic and pure mathematics.

The multivolume *International Encyclopedia of Unified Science* codified the ideas of new movements in philosophy of science that were enlivened by the logical positivists of the Vienna Circle. With its first publication in 1938, the two parts of Volume 1 embodied the new empirical conception of science. It was "empirical science," founded on a thorough-going empiricism. The adjective "empirical" appears 201 times in Volume 1, Part 1 (Neurath et al., 1955a) with 94 of these occurrences in "empirical science"; and "empirical" appears 208 times in Volume 1, Part 2 (Neurath et al., 1955b), with 62 of them in "empirical science."

Rudolf Carnap's chapter, "Logical Foundations of the Unity of Science," repeats Russell's characterization. He wrote: (Neurath et al, 1955a, p. 45, Carnap's emphasis)

> The first distinction which we have to make is that between *formal science* and *empirical science*. Formal science consists of the analytic statements established by logic and mathematics; empirical science consists of the synthetic statements established in the different fields of factual knowledge.

This characterization, which might well appear quite benign to modern readers, includes a significant transition in the conception of science. In the nineteenth century, this division was roughly the one emphasized in Kant's work of rationalism versus empiricism. We saw above that nineteenth century writers inclined towards some version of the rationalist approach as the proper basis of secure science. Empirically based science was only admitted begrudgingly as an expedient with the hope that it would be replaced by a principled science more aligned with a rationalist approach.

In his chapter, "Scientific Empiricism," Charles Morris acknowledged the transition. He first recalled the older conception: (Neurath et al, 1955a, p. 64)

> Previously they had functioned as rival methods: mathematics as one way to get knowledge of nature, and experimental observation as another. Those scientists who advocated the former were one species of "rationalists," and the advocates of the latter were one species of "empiricists"— even the philosophical opposition of rationalism and empiricism was at bottom a reflection of what were to be taken as different scientific methods for knowing nature.

After reflecting briefly on the transition, Morris summarized its result: (p. 64)

> The important result was a double shift from a metaphysical to a methodological rationalism, and from a loose-jointed empiricism to an empiricism which utilized the techniques and the form of mathematics. Rationalism and empiricism in this way ceased to be rival methods for knowing nature and became complementary components of experimental science with its one observational-hypothetical-deductive-experimental method.

5. The Influence of Karl Popper

Karl Popper was a philosopher of science who worked in the same community as the logical positivists, while insisting that he was not one of them. He too, freely, wrote of "empirical science" in his writings. His most influential work was his 1935 *Logik der Forschung*, which came to prominence in the English language literature through its first English translation of 1959, *Logic of Scientific Discovery*. The first chapter begins with synoptic statements in which the term "empirical sciences" (German "*Die empirischen Wissenschaften*") appears four times: (Popper, 2005, p.3, my emphasis)

> A scientist, whether theorist or experimenter, puts forward statements, or systems of statements, and tests them step by step. In the field of the *empirical sciences*, more particularly, he constructs hypotheses, or systems of theories, and tests them against experience by observation and experiment.
>
> I suggest that it is the task of the logic of scientific discovery, or the logic of knowledge, to give a logical analysis of this procedure; that is, to analyse the method of the *empirical sciences*.
>
> But what are these 'methods of the *empirical sciences*'? And what do we call '*empirical science*'?

Popper's answer to this last question included two notable themes. One was a complete repudiation of inductive inference. Sciences, he held, are not supported inductively by empirical evidence. They can only be tested by empirical evidence and refuted by it. The other was his demarcation criterion. It offered falsifiability as the criterion that demarcated empirical science. It served, Popper noted (p. 11): "… to distinguish between the empirical sciences on the one hand, and mathematics and logic as well as 'metaphysical' systems on the other.."

Popper's writings are pertinent here. Of all the philosophers of science writing in the mid twentieth century, his name is most recognizable by scientists in the twenty-first century. His authority is cited repeatedly for his demarcation criterion. It has proven to be a valuable rhetorical instrument for scientists seeking to deflect heterodox approaches. However, scientists who draw on Popper's authority are quite selective in drawing only on his demarcation criterion. The practice of modern science is ineliminably inductive. Norton (manuscript) elaborates the complete failure of Popper's anti-inductivism in the present practice of science and the weaknesses and dangers of his oversimplified demarcation criterion.

6. The Scientists' Empirical Science

The idea that science is empirical is well-established in the mainstream of science. The adjective "empirical," such as in "empirical evidence," or the adverb "empirically," such as in "tested empirically," is quite commonplace. There can be little doubt that the term has been drawn from the philosophical discussion. To see this, we need only reflect on what would otherwise be the complete oddity of this widespread use of the term "empirical." Its origin lies in the description of an ancient medical sect and its conception of medical practice was, for a long time, derided as quackery. Why would scientists embrace a term long associated with quackery so willingly? The answer is obvious. Later philosophical analysis exonerated the term and gave it the meaning the scientists have adopted.

The conception of empirical science that is widespread in science is a subset of the variety of commitments assigned to the notion in the philosophical literature. A rough approximation of this more popular conception is:

> *Scientists' conception of empirical science*. Science consists of observational and experimental reports and further results inferred from them. The observational and experimental reports are the empirical evidence indispensable for science.

Empirical evidence is the central idea. It is both sufficient and necessary for the support of these further results. What is notable is what is missing. Formulations of Big-E Empiricism go to pains to restrict what can be factually learned beyond the experience itself. Whether there is a such a limit to experience only is left open in the scientists' conception. It is a detail to be filled in by individual scientists who have embraced the idea of empirical science. My sense is that, tacitly, the overwhelming proportion of scientists are optimistic. For them, the inferential reach of evidence extends to facts far beyond those of experience itself.

Whereas I do believe this optimism is dominant, there are so many scientists and such a diversity of sciences that we should not expect a univocal agreement on this optimism. The pressing difficulties of individual sciences may incline a scientist to some form of pessimism. The notable example is quantum mechanics, whose enduring foundational difficulties try even the most patient. A retraction to instrumentalism over theoretical terms is a common reaction. Kemble's (1937) textbook of quantum mechanics talks of the "empirical" throughout, using such terms as "empirical basis," "empirical results" and "empirical facts." However, he adopted an instrumental interpretation of the central theoretical term in quantum mechanics. He wrote (p. 328): "… the wave function is merely a subjective computational tool and not in any sense a description of objective reality."

It is not so easy to find explicit formulations of this scientists' conception in general science writing. The conception is so pervasive that an insistence on the need for empirical evidence requires no further justification in general scientific writing. The idea is so fundamental to modern science that challenges to it are met with fierce responses. In them, at last, we find scientists articulating the centrality of empirical evidence in their conception of science. The sections that follow give several examples.

7. Empirical Science in Forensic Science

The admission of testimony by scientific experts in the courtroom has required the legal community to grapple with foundational problems of science. There is no shortage of consultants ready to inform a court on the authority of their scientific expertise. The difficulty for a court is to determine whether that expertise is based on a reliable science and whether that science provides the level of certainty claimed. These difficulties led to a synoptic response in September 2016 when "PCAST," the US President's Council of Advisors on Science and Technology, presented their report to the President, *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature Comparison Methods* (PCAST, 2016).

The report examined the various forensic methods that, ostensibly, are scientifically well-founded. These methods seek to determine whether various physical properties of physical evidence at a crime scene could be associated with a particular suspect. To do so, different methods attempt to match the evidence with the suspect using DNA samples, bitemarks, latent fingerprints, firearm marks, footwear and hair. The Council's goal was to determine whether these methods addressed in the report were, as the report title indicates, "scientifically valid."

This determination required the Council to specify just what constitutes scientific validity. To this end, the first concept they introduced was "foundational validity." It was defined as: (PCAST, p. 4, their emphasis)

> *Foundational validity* for a forensic-science method requires that it be shown, based on empirical studies, to be *repeatable, reproducible, and accurate*, at levels that have been measured and are appropriate to the intended application.

This concept *requires* that evidence establishes the fitness for purpose of the method considered. The evidence is to come from "empirical studies." That is, empirical evidence is asserted as *necessary*. The sufficiency of empirical evidence is implicit in so far as no other evidential requirement is stated; and that assertions of effectiveness of a method not so supported are to be discounted. That is, the report goes on to state: (p. 6, their emphasis)

> Once a method has been established as foundationally valid based on appropriate empirical studies, claims about the method's accuracy and the probative value of proposed identifications, in order to be valid, must be based on such empirical studies. *Statements claiming or implying greater certainty than demonstrated by empirical evidence are scientifically invalid.*

A large number of experts and authorities are associated by name with the report. There are the Chairs (2), Vice-Chairs (2) and members of the Council (6); staff (3); Senior Advisors (14); and the Working group itself: members (6), staff (2) and a writer (1). This group of people was drawn broadly from universities, industry, commerce and the law. What is most striking is that, in all this large number, there are *no* philosophers or philosophers of science. Since the issue addressed is a core topic in philosophy of science, something has failed. Perhaps the Council has been parochial or negligent in its search for relevant experts; or perhaps the profession of philosophy of science has failed to display its expertise and show its utility.[2]

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[2] In my pessimistic moments, I fear the latter. Too many philosophers of science, in an exercise of misplaced cleverness, have convinced themselves of the underdetermination thesis. In its strongest form, it asserts that no body evidence, no matter how extensive can ever determine a

This omission is to our present advantage, since is assures us that the views expressed in the report are drawn from communities outside philosophy of science.

The PCAST report notes (p.1, 22) that it was in part responding to a report by the National Research Council (NRC, 2009) that found disturbing weaknesses in the scientific foundations of forensic methods. This earlier report also needed to specify what counts as good science, so that deviations from it could be identified. That specification was given in summary in an epigraph at the head of Chapter 4: *The Principles of Science and Interpreting Data.* A naïve reading is that the text is a quote from somewhere in Isaac Newton's named masterpiece. It reads: (p. 111)

> Scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning.
>
> Isaac Newton (1687, 1713, 1726)
> "Rules for the study of natural philosophy,"
> *Philosophiae Naturalis Principia Mathematica*

The epigraph conforms with the modern idea that good science is based on empirical evidence. As any competent historian and philosopher of science will no doubt recognize instantly, the formulation and even vocabulary are modern and not to be found in Newton's *Principia*. This epigraph, however, tells us that the authors of this 2009 report were eager to establish the historical pedigree of their characterization of science. It is, they are suggesting, not a momentary infatuation, but a long-established standard, already found in our greatest of scientific heroes, Isaac Newton.

There are so many experts and authorities involved in the NRC report that the full list requires four pages in the report. There is the Committee on Identifying the Needs of the Forensic Science Community (17) and their staff (15); and the Committee on Science, Technology and Law (26) and their staff (2). The list includes no philosophers, philosophers of

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scientific theory, in stark contradiction with the routine successes of the sciences. Why would the Council want the opinion of such figures who hold that, as matter of principle, none of the methods under consideration or any other can work?

science or historians of science who could have alerted the report writers to the spurious character of the epigraph.[3]

8. Empirical Science in Evolutionary Biology

So called "creation science" and "intelligent design" movements have presented enduring challenges to evolutionary biology. The diversity of biological species, this movement asserts, did not arise as evolutionary biology asserts through the slow accumulation of inherited adaptations. Rather they arose in a single, creative act. The US National Academy of Science has taken on the task of providing a unified response that defends evolutionary biology. A central theme of their response is that creation science fails to meet the standards of empirical science. To support this response, the Academy literature provided a characterization of what constitutes empirical science. One synoptic formulation was appealing enough to the Academy for it to be given twice in Academy publications: (National Academy of Sciences, 1998, p. 27; 1999, p.1)

> Science is a particular way of knowing about the world. In science, explanations are restricted to those that can be inferred from confirmable data—the results obtained through observations and experiments that can be substantiated by other scientists. Anything that can be observed or measured is amenable to scientific investigation. Explanations that cannot be based on empirical evidence are not a part of science.

The last sentence emphasizes that supporting empirical evidence is necessary for results to count as scientific. The import of this characterization is then applied to creation science: (National Academy of Sciences, 1999, pp.1-2)

> …the claims of creation science lack empirical support and cannot be meaningfully tested. These observations lead to two fundamental conclusions: the teaching of evolution should be an integral part of science instruction, and creation science is in fact not science and should not be presented as such in science classes.

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[3] Here again, in my pessimistic moments, I fear that no historian of science was consulted because too many historians of science, in an excess of misplaced sophistication, have convinced themselves of the untenable view that all science is "situated" to such an extent that it fails to make objective discoveries.

A later Academy publication develops similar themes: (Institute of Medicine, 2008, p. 12, their emphasis)

> Science is not the only way of knowing and understanding. *But science is a way of knowing that differs from other ways in its dependence on empirical evidence and testable explanations.*

This insistence on empirical evidence is targeted at the religious motivations apparent in the proponents of creation science. Science, but not religion, is responsible to empirical evidence. For example, the report notes: (Institute of Medicine, 2008, p. 12, their emphasis)

> Science and religion are based on different aspects of human experience. In science, explanations *must* be based on evidence drawn from examining the natural world. Scientifically based observations or experiments that conflict with an explanation eventually *must* lead to modification or even abandonment of that explanation. Religious faith, in contrast, does not depend only on empirical evidence, is not necessarily modified in the face of conflicting evidence, and typically involves supernatural forces or entities. Because they are not a part of nature, supernatural entities cannot be investigated by science. In this sense, science and religion are separate and address aspects of human understanding in different ways. Attempts to pit science and religion against each other create controversy where none needs to exist.

Once again, empirical evidence is declared necessary.

The synoptic characterization of science given by the National Academy of Science in 1998 and 1999 proved popular in treatments of creation science and evolutionary biology. In 2005, parents of students in the Dover Area School District in York County, Pennsylvania, sued in US federal court over the school board's plans to introduce intelligent design, a form of creation science, into ninth-grade science classes. Among its findings adverse to the proponents of intelligent design, the court concluded that intelligent design is not science. This judgment required a characterization of science. In his ruling, Judge John E. Jones III reproduced the Academy's synoptic characterization of science (Jones, 2005, p. 66).

In the discussion prior the reproduction of this characterization, Jones (p. 65) rejected supernatural explanations as part of science and noted:

> This self-imposed convention of science, which limits inquiry to testable, natural explanations about the natural world, is referred to by philosophers as "methodological naturalism" and is sometimes known as the scientific method. … Methodological naturalism is a "ground rule" of science today which requires scientists to seek explanations in the world around us based upon what we can observe, test, replicate, and verify.

The notion of explanation plays a distinctive role in these defenses of the scientific status of evolutionary biology for a reason that is specific to evolutionary biology. It is a historical science, whose subject consists almost entirely of past events. That means that the bulk of the evidential support for evolutionary biology does not come from novel prediction, but from its explanatory successes in accounting for these past events.

9. Non-Empirical Physics

Developments in physics and cosmology over the last few decades have led some scientists to affirm and delineate the empirical character of science as they conceive it. These affirmations arise from repeated concerns that two general lines of research have strayed too far from sound empirical physics into poorly grounded speculation. One line is string theory in particle physics. It has the lofty ambition to be the "theory of everything." The other is inflationary cosmology. It posits an early era of extremely rapid cosmic expansion just after the big bank and is closely association with the idea of a multiverse, which is the proposal for the existence, loosely speaking, many parallel universes.

In work leading up to and in his 2013, *String Theory and the Scientific Method*, Richard Dawid sought to support string theory by introducing the notion of "non-empirical theory assessment" and "non-empirical evidence." (Dawid, 2013, *passim*) The work triggered a coalescence of then growing concerns about the speculative character of string theory and notions of inflation and the multiverse. Dawid's notion of non-empirical theory assessment as a means to support string theory was too provocative to resist. Critics of string theory and multiverse theories understood it to endorse unreliable speculation without empirical foundations as serviceable science.[4]

These concerns were aired in a workshop, "Why Trust a Theory? Reconsidering Scientific Methodology in Light of Modern Physics," held in Munich in December, 2015. It was followed by a collection of papers in Dardashti et al. (2019). In the volume, in his "The Dangers of Non-Empirical Confirmation," Carlo Rovelli reacted to the expression "non-empirical confirmation" used by Dawid in his 2015 coauthored paper (Dawid, et al. 2015). In response, Rovelli stressed the unique status of empirical evidence in confirming science. He wrote: (2019, p. 22, his emphasis)

> The reason only *empirical* evidence can grant "confirmation", in the common sense of the word, is crucial and important: We all tend to be blinded by our beliefs. We pile up non-empirical arguments in support these. The historical success of science is grounded in the readiness to give up beloved beliefs when empirical evidence is against them. We create theories with our intelligence, use non-empirical arguments to grow confidence in them, but then *ask nature* if they are right or wrong. They are often wrong. Witness the recent surprise of many theorists in not finding the low-energy super-symmetric particles they expected.

Rovelli then recalled the successes of modern medicine and that: (p. 122, his emphasis) "…This feat has been achieved by simply *not* trusting non-empirical arguments." He then reaffirmed the unique status of empirical evidence: (p. 122, his emphasis) "…The problem with Dawid is that he fails to say that, for this process, only *empirical* evidence is convincing." The analysis then turned to string theory: (p. 123) "String theory is a living proof of the dangers of excessive reliance on nonempirical arguments." Here we should recall that Rovelli is one of the founders of loop quantum gravity, a prominent competitor of string theory.

In his contribution to the same volume, cosmologist and commentator Sean Carroll sought to protect multiverse theories from the objection that they are not falsifiable. Carroll's

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[4] On my reading, on the contrary, Dawid's proposal is likely an endorsement of the strength and reach of empirical evidence in science. It is that we *already* have enough empirical evidence in cases such as string theory so that *further* empirical evidence is not needed. See Chapter 12 for further discussion.

proposal was to dispense with the criterion of falsifiability and replace it with two requirements. He wrote (2019, p. 303, his emphasis in boldface)

> Falsifiability gets at two of the (potentially many) important aspects of science:
>
> • **Definiteness**. A good scientific theory says something specific and inflexible about how nature works. It shouldn't be possible to take any conceivable set of facts and claim that they are compatible with the theory.
>
> • **Empiricism**. The ultimate purpose of a theory is to account for what we observe. No theory should be judged to be correct solely on the basis of its beauty or reasonableness or other qualities that can be established without getting out of our armchairs and looking at the world.

The second aspect provides a characterization of empiricism in science. It affirms the necessity of empirical evidence, but not that it has an exclusive role in the support for scientific theories. These conditions serve to sustain the primary goal of Carroll's chapter, as he gave it: (p. 301)

> In this chapter, I stake out a judicious middle position. Multiverse models are scientific in an utterly conventional sense; they describe definite physical situations, and they are ultimately judged on their ability to provide an explanation for data collected in observations and experiments. But they are perfectly ordinary science, so the ways in which we evaluate the multiverse as a scientific hypothesis are precisely the ways in which hypotheses have always been judged …

Carroll was writing in support of multiverse theory. George Ellis and Joe Silk wrote as critics of the theory and their *Nature* commentary (Ellis and Silk, 2014) reacted to Carroll's analysis as given in an earlier formulation (Carroll, 2014). They wrote: (p. 322)

> Earlier this year, championing the multiverse and the many-worlds hypothesis, Carroll dismissed Popper's falsifiability criterion as a "blunt instrument" …. He offered two other requirements: a scientific theory should be "definite" and "empirical". By definite, Carroll means that the theory says "something clear and unambiguous about how reality functions". By empirical, he agrees with the customary definition that a theory should be judged a success or failure by its ability to explain the data.

They expand with their concerns by affirming Sabine Hossenfelder's (2014) reaction to Dawid's proposal of non-empirical theory assessment, which she derided as "post-empirical science" and "post-empirical physics."[5] Ellis and Silk (2014, pp. 322-23) wrote:

> We agree with theoretical physicist Sabine Hossenfelder: post-empirical science is an oxymoron … Theories such as quantum mechanics and relativity turned out well because they made predictions that survived testing. Yet numerous historical examples point to how, in the absence of adequate data, elegant and compelling ideas led researchers in the wrong direction, from Ptolemy's geocentric theories of the cosmos to Lord Kelvin's 'vortex theory' of the atom and Fred Hoyle's perpetual steady-state Universe.

What matters for present purposes is not which is correct: Carroll's positive assessment of multiverse theory or Ellis and Silk's negative assessment. It is where they agree. Ellis and Silk above affirm that Carroll's use of "empirical" "agrees with the customary definition" and with Hossenfelder that "post-empirical science" is an oxymoron, a contradiction in terms.

10. Conclusion

This chapter has tracked the emergence of the concept of empirical science in the nineteenth and twentieth century. The concept is distinct from the doctrine of empiricism, even if closely connected with it. It is readily understood as an application of empiricism. It answers the question: according to the doctrine, what is the appropriate conception of science? The difficulty with this question is that there is no single doctrine of empiricism. Different versions of empiricism will deliver answers that may differ considerably in their details.

This chapter has tried to show, however, that, in their importing of the conception from philosophy to science, practicing scientists have suppressed these many possible differences. They have adopted a much reduced and simplified conception of empirical science. It amounts to a requirement that a science, properly developed, simply consists of reports of observation and

[5] Hossenfelder (2014) concluded: "In summary, there's no such thing as post-empirical physics. If it doesn't describe nature, if it has nothing to say about any observation, if it doesn't even aspire to this, it's not physics."

experiment and what can be inferred from them. That is, empirical science depends exclusively on empirical evidence for support of its content.

Philosophers of science—*we* philosophers of science, since I am one—tend to complicated formulations of our ideas. Our empiricisms and our conceptions of the right sort of science have many interconnected parts. My exposition of small-e empiricism requires several chapters just to specify what the doctrine takes experience to be. The value for the present project of delineating the scientists' conception is that it identifies which part of the philosopher's conceptions matters to scientists, when they need a conception of practical utility in their work. That is a useful service. We should follow their lead and assign a central importance to the notion of empirical evidence in formulation an empiricism well adapted to science.

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Encyclopedia of Unified Science "Empirical science" is a term appearing huge numbers of times, throughout.

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C Rovelli "The dangers of non-empirical confirmation" 2016

"The reason only empirical evidence can grant "confirmation" in the common sense of the word, is crucial and important: we all tend to be blinded by our beliefs. We pile up non-empirical arguments in support these. The historical success of science is grounded in the readiness to give up beloved beliefs when empirical evidence is against them. We create theories with our intelligence, use non-empirical arguments to grow confidence in them, but then ask nature if they are right or wrong. They are often wrong. Witness –if more was need– the recent surprise of many theorists in not finding the low-energy super-symmetric particles they expected."

*****Modern****

Carlo Rovelli, “Dangers of non-empirical confirmation” arXiv
“The reason only empirical evidence can grant “confirmation” in the common sense of the word, is crucial and important: we all tend to be blinded by our beliefs. We pile up non-empirical arguments in support these. The historical success of science is grounded in the readiness to give up beloved beliefs when empirical evidence is against them. We create theories with our intelligence, use non-empirical arguments to grow confidence in them, but then ask nature if they are right or wrong. They are often wrong. Witness –if more was need– the recent surprise of many theorists in not finding the low-energy super-symmetric particles they expected.”
“The problem with Dawid is that he fails to say that, for this, only empirical evidence is convincing.”

Ijjas, Steinhardt 2017 doubts “nonempirical science”

Baggott, “But is it Science” Aeon
“This is ‘post-empirical’ science, where truth no longer matters, and it is potentially very dangerous.”
“For example, in the so-called Many-Worlds interpretation of quantum mechanics, there are universes containing our parallel selves, identical to us but for their different experiences of quantum physics. !ese theories are attractive to some few theoretical physicists and philosophers, but there is absolutely no empirical evidence for them.”
“Welcome to the oxymoron that is post-empirical science.”
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Evidence based medicine

“During the past 300 years, demands that the practice of medicine be founded on scientifically trustworthy empirical evidence have become increasingly vocal.”

Djulbegovic, “Progress in evidence-based medicine: a quarter century on,” The Lancet, 2017. p. 415

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Places to look for scientific empiricism: creationism/evolution debate. Debate over climate change. Debate over Dawid’s non-empirical science. Evidence based medicine.

Much talk of “empirical methods” in finance and software development.