Poincaré, Indifferent Hypotheses and Metaphysics

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> *. . . the denial of all metaphysics is still metaphysical, and precisely this is what I call modern metaphysics*
>
> (Poincaré [1904, 217], apud During [2001, 87–88])

Abstract The objective of this paper is twofold. First, Poincaré's ideas regarding the role of indifferent hypotheses in physics are described, and the relationship between this particular type of hypothesis and metaphysics is also analyzed. By formulating a relationship between indifferent hypotheses and metaphysics, the author will seek to determine this concept of metaphysics – albeit in an obscure fashion – in the thinking of the French mathematician. This relationship was not presented by Poincaré himself. It is described here in order to suggest that the failure of the French *savant* in developing a coherent epistemology for science is at least partially due to his reluctance to accept that indifferent hypotheses are a constituent part of scientific practice.

Introduction

In this article, I intend to resume a fascinating and controversial topic in the history of science and in the history of the philosophy of science: the relationship between science and metaphysics from the perspective of the scientist. Of course, my goal is not to try to understand such a relationship throughout the whole of its history. That would be an overly ambitious claim, as well as being quite impractical to carry

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out. Moreover, it is certain that over time this relationship has undergone important changes, which have been positive at some moments whilst having been negative at other times. That is, at some (a few) times, scientists have given metaphysics relative importance, while at other times (most often), they have held it in contempt. Even indifference, which is almost always fueled by scientists and not by philosophers, has been present. In the scope of this text, I am interested in the interaction between science and metaphysics as expressed by the considerations developed by the physicist, mathematician and philosopher Henri Poincaré regarding the controversial role played by (according to him) the so-called indifferent hypotheses in physics.

In general, it is considered that metaphysics gradually moved away from the natural sciences during the nineteenth century (Jungnickel and McCormmach 1990). Over the years, mainly as of the 1830s and the rise of positivism, a doctrine that was developed explicitly for the purpose of combating metaphysics, the latter was perceived as not contributing to the development of science and society. Instead, metaphysics would be considered to constitute an obstacle to scientific progress and, as such, should definitely be eradicated. Thus, at the end of the eighteen hundreds, it was not common to find men of science who were interested in, nor concerned with, issues such as the origin of the world or the destiny of human beings. In retrospect, it is now known that this task – i.e., answering such questions – has not been fulfilled nor could it be. Despite the public contempt for metaphysics, little by little, scientists began to be forced to reflect on the relationship between science and metaphysics. In part, this obligation was triggered by the need to describe events that were not visible to the naked eye. Starting out with thermodynamics, and later because of electromagnetism and matters relating to radiation, scientists were led to construct models that made use of causes which are not reducible to structures comparable to human scale. The use of molecules, atoms and electric current in thermodynamics and electromagnetism are examples of such entities, which lead to discussions about what should actually be considered to be an object with a right to exist in the real world. Do these objects (atoms or electric currents) actually exist or are they mere fiction? (Videira 1997).

Respecting an old philosophical tradition, every question involving the issue of existence was routinely classified as belonging to the domain of metaphysics. In the late nineteenth century and the beginning of the next one, metaphysics still stubbornly remained “close” to science, as some scientists and even Poincaré himself, albeit grudgingly, had to take a stand about the reasons for keeping metaphysics alive. Not only Poincaré reflected on this theme; Boltzmann and Maxwell, to keep up with the other two who had been randomly selected, were also concerned about understanding the intrinsic strength of metaphysics (Videira 1992).

More specifically, in the case of Poincaré, his participation was involuntary in a certain way, and it can be explained not only by the new scientific developments of the era, but it also was a result of the need he felt to respond to the criticisms that were directed at him by the French philosopher Edouard Le Roy, who was one of Henri Bergson’s former students, and by Bergson himself. Accused by Le Roy of being a conventionalist, Poincaré reiterated that scientific laws were creations of

the human spirit, even while he maintained his belief that science would be able to describe external reality. Despite the intrinsic interest of this debate, as shown in the final chapters of *The Value of Science*, this article is not meant to comment on it. Here I will limit myself to comment – with no pretense to be exhaustive – on the reasons given by Poincaré himself to try to deny science of any and all interest in metaphysics. Strictly speaking, I think one cannot make a definitive comment on Poincaré's position as to why metaphysics cannot be excluded from reflections about the nature of science. It seems to me that at the end of his life – *The Value of Science* was published seven years before his death – Poincaré entertained some relevant and serious doubts about the coherence of some of his positions that had been previously divulged. The defense of the realist position made it so that Poincaré approached the gateway to metaphysics, through which he consciously refused to pass. Even so, Poincaré recognized that realism could not be supported only by epistemological reasons; in other words, supported by reasons which took into account the specific nature of scientific knowledge. Contrary to what had been believed for a long time, the type of knowledge that is characterized by science cannot be used to support alone the realist position. Being more than a philosophical position, realism is a decision of metaphysical nature.

According to Ubaldo Sanzo, Poincaré developed epistemological thinking without the participation of ontological or metaphysical considerations (Sanzo 1996). Otherwise, the French *savant* would have refused allowing the establishment of the external world to play a significant role in the process of justifying its own epistemology. However, his refusal cost him a certain price. The price paid was that of never being able to answer the following question: how can we support or justify the certainty of our thoughts? Let me explain. As of the 1890s, when it became clear that there undeniably remained a pluralism in physical theories, Poincaré, who himself was a supporter of pluralism, realized that he probably would be unable to find a solution to the problem of the foundation of an epistemology on any rigorously coherent basis. For him, 'a rigorously coherent basis' meant, for example, that the scientist and epistemologist have no obligation to build a philosophy that is systematic and systemizing.

Since the Enlightenment, natural scientists entertained serious suspicions in relation to the attempts at organization of scientific practice that were proposed by philosophers. The adjective 'systematic' could not be used to understand science, since the latter continually changes, modifying the content of its theories. As of the mid-nineteenth century, it seemed increasingly evident that science would always be subject to evolutionary processes, much like what happens in the world of living organisms. As is known, Poincaré was not the only one to believe in the evolution of science, since Boltzmann and Maxwell, along with Ernst Mach and Wilhelm Ostwald, were also supporters of Charles Darwin's theory of evolution (Engels 1995).

In particular, the evolution of physics forced Poincaré to reflect on the effects of these evolutionary processes. Questions such as 'could the emergence of new theories threaten science regarding its ability to understand nature?' or 'how could one argue that the theories and laws of physics remain true if they themselves

undergo major changes?' came to constitute the agenda of the scientists mentioned above. According to Elie During, Poincaré's position when he faced this agenda can be expressed in the following words:

> On the one hand, [there was the concern] to recognize and draw the consequences from a constant feature of the history of the sciences: the temporary character of theories, with evidence provided by the succession of scientific revolutions. On the other hand, but *at the same time*, [remained the concern] to recognize the objective value of science, and the fact that an effective position had [to be] effectively taken on what was real, not only in the field of technical and applied sciences (...) but even at the level of theories of physics. How can one reconcile these two concerns? And how can one understand this "effective position on what is real", as supposed by science regarding the world? This is what is at stake in *Science and Hypothesis*. A dual strategic concern is echoed: it is about fighting the spontaneous arrogance and dogmatism of scientists, while *at the same* time defending the value of science against the superficial skepticism that was maintained by "common people". (During 2001, 11–12, emphasis in the original)

Let us return to the expression 'a rigorously coherent basis.' A second possibility to understand it, if we accept the ideas of René Thom (1987), is to avoid epistemological audacity, that is, to refuse to want to answer questions concerning the nature of reality. In other words, one must resist metaphysical temptations. Further on in this article, I will show that the apparently inevitable use of characterized hypotheses, which Poincaré called indifferent hypotheses, weakens the ability to resist formulation of considerations regarding reality, and even reality that is investigated by science. In fact, indifferent hypotheses are a legitimate part of physics, and there is no way to avoid the presence of metaphysics in it. Before proceeding, allow me to comment quickly on some observations about the strategy which I will adopt upon trying to reach the goal that I have set.

Interlude

In order to move toward my goal of showing one of the main philosophical tensions experienced by Poincaré, which, despite his explicit unwillingness, he yielded to the provocations created by metaphysics, I believe it is important to point out the way (i.e., the strategy) that I will accomplish the goal of showing that the French scientist revised his position on 'first philosophy'. I begin by describing what I will not do in this work. For example, I do not intend to go through all the philosophical works of Poincaré. Thus, I recognize that is not my intention to reconstruct his arguments about the nature, purpose and methods of science thoroughly. The perspective I adopt, which is consciously daring or even bold, portrays Poincaré as an ambivalent scientist-philosopher in regards to the relationship between science and metaphysics. In a few instances in his philosophical texts, Poincaré appears to be someone who believes in his own ability to give certainty to scientific propositions. In others, he displays his suspicions about an epistemology which is deliberately constructed without resorting to metaphysical elements.

However, the search for coherence carried out by Poincaré leads me to make but a single comment on the totality of his epistemological production. Upon looking closely at the set of his reflections, it becomes possible for us to see that it was organized so that he could defend his positions without feeling the need to provide detailed arguments. Poincaré's writings, as already mentioned by some commentators (During 2001), were published to express views and opinions – his and those of others – and not to analyze opposing arguments, as currently occurs in the field of philosophy of science. Poincaré seems wary of long and detailed arguments as if their size and complexity could raise doubts in the mind of his reader:

> Behind the elegant prose of articles and prefaces that supply the article in *Science and Hypothesis*, [there is] no concern for the "popularization" of science, and [there is] no desire for systematic exposition. Poincaré did not spend much time with the preparation of his texts and he rarely returned to them. He conceived them as interventions. Rather than to consolidate a philosophical position, his concepts and arguments served him as support, as temporary setups for [the realization] of circumstantial operations. (During 2001, 7)

The above quotation leads us in a direction different from that which is usually followed by the interpreters of his thinking, according to whom Poincaré had developed a clear, well established philosophical position. That does not seem to us to be During's position, and it certainly is not ours. The clarity, candor and accuracy of Poincaré's claims hide the lack of precise, detailed arguments. However, although it is not difficult to verify the presence of these features, it is far from me to conclude that his theses are incomprehensible, because they are simple.

Poincaré Faced with Worldly Issues

Since I do not intend to construct a comprehensive analysis of Poincaré's philosophical thinking, allow me to defend my opinion by resorting to a single text of the French savant. The article, which I have chosen to discuss in favor of my interpretation of Poincaré and metaphysics, does not openly and explicitly discuss the presence of the latter. In the text 'New Concepts of Matter' (Poincaré 1933), the title of his contribution to the volume devoted to materialism, published in 1913, and therefore after his death, Poincaré avoided making a pronouncement about burning issues such as: the meaning of human existence, even if they did figure into the agenda of themes of the book in which his work came out. However, when it comes to metaphysics, only voluntarism is not enough to stop it. An indication of the weakness of voluntarism, which is not to be confused with will power, in which Poincaré is great, is the frequency of the expression "form of thinking" that appears in his text.

If it seems unquestionable that after the First World War people widely discussed the role of visions of the world, it is certain that at the time of the publication of the book about materialism, a year before the war which was scheduled by European powers and which was meant to be the war to end all wars, people also commented

about the characteristics by which, for example, human cultures and societies differed from each other. It is not uncommon to find references to the term 'vision of the world', linking it to philosophical positions close to relativism and culturalism, since that would serve to embody our understanding of what the world is.

Attempts at explanation – even scientific one – would occur inside the visions of the world. It starts with a distinction, which is unsurpassable for many, between the world and the way we understand it. There would be no possibility of understanding the world without resorting to a vision or image, i.e., without resorting to elements, which are often freely chosen by the scientists themselves or even by lay people, that is, by common people, that prove necessary to make science itself real and effective. One example is the regularity of behavior attributed to natural phenomena. As with other publications by Poincaré, in his text on the conception of matter, we found no reflection on causality, determinism and unity of nature, which are traditional, metaphysical issues that could be analyzed in the light of science.

In the text that was chosen, Poincaré does not seem interested in taking a stand on whether science is materialistic or not, nor whether it would necessarily lead us to accept materialism. His concern is to show how science evolves. Therefore, he does not answer the question of whether science is materialistic or not since he believed that this does not have a precise meaning, which prevents the formulation of a satisfactory response. Poincaré's problem seems to lie in his inability to understand the meaning of the word 'materialism'. This is a misleading concept. Nonetheless, and as if not to disappoint his readers, most of which were probably religious practitioners, Poincaré said that not all scientists are materialists, since science does not control their lives, at least not the totality of their lives (Rollet 1996). In other words, science does not reach the level of values that are responsible for decisions regarding how one should live.

As previously stated, the article 'New Concepts of Matter' is intended to provide arguments in favor of a certain conception of the evolution of science, particularly physics. Throughout the nineteenth century, and having as motivation the most important transformations which occurred in the scientific disciplines, there was a widespread need to show that science, even as it was going through processes of improvement and replacement of theories and models, could continue to supply the goal of understanding reality. In Poincaré's viewpoint, this claim can be expressed as if he did not want to deny the effective possibility of attributing truth value to scientific laws and theories. He seems to hold that visions of the world are the basis upon which science builds theories about objects and phenomena, which in turn are known to exist in relationships that are found in theories. Those relationships are more important than the actual objects and phenomena that supposedly exist in nature, and in fact, the 'true object' that is recognizable by science is formed by these relationships. Poincaré's position is sometimes understood as being in favor of realism of a structural type (During 2001).

In the article of 1913, Poincaré states that history moves like a pendulum. On certain occasions, history nears the atomistic position, while after a period of time, and whether it is short or long does not matter, it approaches the opposite position, advocated by supporters of continuity. Without telling us why, at this moment

Poincaré takes a bold step by asserting that this pendulum cannot be avoided, "... science is doomed to oscillate constantly between atomism and continuity, between the mechanism and dynamism and, conversely, [even] these oscillations will never stop" (Poincaré 1933).

The impossibility of imposing an end to these oscillations is explained by the French mathematician as follows:

> This struggle [between the antagonistic positions mentioned above] will last as long as science does, since it is due to the opposition of two irreconcilable needs of the human spirit, of which the latter could not break away without ceasing to exist. [These irreconcilable requirements are:] that of understanding, and we can only comprehend that which is finite, and that of to seeing and we can only see extension, which is infinite. (Poincaré 1933, 50)

The characterization given by Poincaré to the process of development of human knowledge suggests that the need for resorting to visions of the world – which is also inevitable and permanent – stems from a characteristic of the latter, namely, its weakness, that is, in its inherent inability to comprehend totality. In that which concerns him, weakness is not only permanent, but it is also constitutive, originating from the fact that the human spirit observes objects from a viewpoint that is external to him. There is always an insuperable distance between the spirit (or the subject) and the object. In other words, it is never possible to reach a situation whereby it would be feasible to have a metaphysical stillness achieved through the determination of a bridge built between the spirit and the object; the spirit and the object must never be confused or fusioned. Furthermore, for Poincaré, dualism, which is one of the hallmarks of Modern Thought, is inevitable.

Realism According to Poincaré

Realism, a philosophical position that Poincaré does not forego, is directly connected to the objectivity of science. One might even think that realism and objectivity may blend into one. It seems to me that it may still be possible to show the presence of continuity between the different branches of science. Poincaré never forgot a lesson he learned in his own time: that science, with a considerable and seemingly unpredictable frequency, can be revised. In spite of constantly undergoing revisions, science does not need to open up to its capacity to describe reality. Therefore, Poincaré saw himself as being obliged to show how these revisions do not prevent the recognition, expressed through theories and laws, that reality is intelligible and understandable. How then can one reconcile these two apparently irreconcilable demands between the 'fact' that science has a (very busy) history and its objective value as perceived in its ability to say things about reality? The key to answering this question lies in the belief, which was never abandoned by the French scientist, that reality is displayed in the invariable relationships that science formulates from observations of natural phenomena. Whether in physics, or in geometry, the 'real' objects of science are constituted by relationships, which remain

invariable in a certain group of transformations. For Poincaré, this invariability is the most faithful characteristic of scientific objectivity (Zahar 2001).

Evolution and transformation should not prevent the formulation of a unified conception of science; hence Poincaré's concern about finding a solution to the above question can ensure continuity between theories. This continuity between two theories is not the result of the analysis of objects of a certain type, nor of the particular nature of a process that exists in nature, but rather of the logical forms of the structures that underlie their physical content. The analysis of natural objects and processes does not absolutely supply us with what theories talk about, which nonetheless does not prevent them from being considered true.

It can be stated that Poincaré was a skeptic with regard to the physical content of theories; but regarding structures, he was a realist. When he was led to try to determine his position, Poincaré was content to say that a scientific theory is, at best, likely to correctly represent certain structures of reality, without ever being able to say what these structures are. Thus, at the epistemological level, he took a pessimistic position.

Poincaré maintained that there were no hypotheses about nature – here he refers to essences – of things, but only about the relationships between these things. With regard to the ontologies retained by mechanical models, and the nature of the entities and processes postulated by both of them (ontology and nature), they are topics to be decided on conventional levels. They are called indifferent hypotheses that are related to entities and processes, of which one cannot have direct experience. The concept of Poincaré's theory of physics can be understood as being structural. His physics was structural physics. According to him, structures are linked to the notion of a group, and the latter is characterized by a set of operations governed by general properties of combination (associativity, reversibility, etc.). In short, Poincaré's realism is supported by the existence of mathematical relations, which remain unchanged even if the phenomena described may differ amongst themselves.

Dangerous, but Necessary Hypotheses

Poincaré distinguished at least three types of hypotheses in physics (Poincaré 1933). However, as noted above, his attention was particularly focused on indifferent hypotheses, since they generally consisted of assertions concerning the structure of matter. The adjective 'indifferent' which is used by Poincaré to underline this kind of hypotheses, although it may be comfortable regarding the construction and understanding of a specific theory, exerts no influence on the scientific value of this same theory, whose laws are based on differential equations, which are responsible for its structure (Poincaré 1933).

If at several times Poincaré is direct and very economical in the use of the words used to express his thoughts, situations arise in which he is obliged to pursue the discursive formulations necessary to avoid the presence of metaphysics. The latter means, in the case which interests us here, the formulation of speculative

thoughts and theories about reality, its structure and its modes of operation and organization. Even while believing it is almost impossible to end metaphysical discussions, Poincaré believed it would be useful to discuss the nature and function of the constituent elements of any theory of physics, and even more so when those elements could be used as a gateway for metaphysics to be mixed with science . In particular, Poincaré believed that the most favorable elements for the existence of such a mixture would be hypotheses. His distrust should not be seen as meaning the acceptance of the positivist attitude in science. Indeed, Poincaré tried to avoid "ontological boldness": "... Poincaré's epistemology is, in fact, a persistent and persevering reduction of scientific hypotheses to pure and simple conventions" (Daston and Galison 2007).

Like virtually all scientists after Kant, Poincaré thought that science could never know things as they are, that is, it is within the domain of essences they would be found, once and for all, forbidden to scientific practice. In the case of science, the support given to the Kantian thesis can be explained by a deliberate attempt to avoid metaphysical speculation. Metaphysics would not be helpful in seeking out solutions to scientific problems. On the contrary, any attempt to resort to metaphysics would imply the emergence of new problems for which no one could provide solutions (Giedymin 1982).

Since the prohibition of the use of hypotheses had been formulated by Newton, they were seen – mainly by positivists, empiricists and inductivists – as suspicious and dangerous, which however was not enough to keep them from being used. Hypotheses seemed to be indispensable, and their presence a necessity. Yet Poincaré believed it to be possible to control the use of hypotheses if the reason for their need was understood. An intermediate step, to be carried out so that the understanding of the necessity of using hypotheses could be achieved, was the recognition of different types of hypotheses that were frequent in physics. Some hypotheses could be subjected to empirical testing. In this case, they were called conceptive truths. A second type performed the function of fixing one's thinking, clearing up the logical schema of a theory, just like its internal structure. Here, the role played by hypotheses is didactic. Finally, a third type of hypotheses is called apparent hypotheses. They are apparent because they can be reduced to definitions or to conventions in disguise. The strength of such hypotheses is due to their ability to accurately check mathematics and science by employing the latter. In Poincaré's thinking, these hypotheses play a key role, since they are freely created by the human spirit (Sanzo 1996). It must be noted that such conventions are imposed on science but not on nature. Any attempt to impose them on nature is to be seen as a remark in favor of metaphysics, and this is done by the imposition that natural phenomena may follow the rules of human thinking.

However, stating that these hypotheses are conventions does not mean that they are arbitrary, at least not totally and absolutely. Experiments can serve to formulate such hypotheses, since it is useful to show us the easy way in its formulation. Although it may sound ambiguous, and perhaps even contradictory, the rigor of the sciences is due to the presence of apparent hypotheses that are created by scientists, which makes the conscious effort of scientists responsible for accuracy.

Being aware, accuracy is the result of a decision, making the spirit of the scientist more acute during the formulation of scientific theories.

As it is the result of a decision, the control of hypotheses comes to be associated with voluntarism. How can one ensure that voluntarism is enough to prevent the proliferation of hypotheses, thus jeopardizing the accuracy of scientific theories? That is, how can one trust the common sense of scientists? It became important to formulate a regulator criterion to prevent the proliferation of hypotheses, and it should ideally be economical and easy to use it. Poincaré was concerned with the formulation of a criterion that would meet this need. His criterion was mainly quantitative, and his preference tended to be for those theories that used the fewest possible assumptions. For example, Poincaré preferred energetism over atomic theory, because the former no longer required the use of atoms, even as fiction.

At the end of the nineteenth century, the issue regarding the reality of atoms was not an issue that really worried Poincaré. His attention was focused on knowing whether the atomic hypothesis had an unavoidable role in the construction of theories of physics such as thermodynamics. The answer to this problem would be found through experiments, since they are the only source of truth for science.

Stating that hypotheses are conventions does not mean they all are admissible. Once again, use and excessive belief in the "powers" of the hypotheses are sources of serious problems for scientists. To avoid excessive liberality, Poincaré sought to assess the degree of admissibility of a hypothesis by means of the resources of fecundity and simplicity.

As shown in the discussion with E. Le Roy, Poincaré did not accept easily the conventionalist label, although that qualification is not so unbefitting for him (Sanzo 1996). His discomfort was not so much due to the label, but rather to the confusion that was often established between conventionalism, nominalism, and skepticism. Being comfortable is not the same as being arbitrary. In order to establish this distinction between convenience and arbitrariness, Poincaré analyzed the nature of truth in physics and the truth found in mathematics. They are two types of criterion of truth. Mathematics can tell us nothing about reality. Its role in physics arises during the work of organizing the theories and laws of the latter.

In order to clarify his viewpoints about the differences between physics and mathematics, Poincaré compared the first to a library. The collections of books that are classified and organized in the halls of libraries are substitutes for the laws and theories of physics, i.e., collections of books and magazines are substitutes for the latter. Experimental physics is the only field of science that can enrich and enhance a library's catalog, as it discovers new natural facts. On the other hand, the goal of mathematical physics is to organize the library's catalog, it is up to mathematical physics to organize the facts "collected" by experimental physics. This arrangement, or organization, provides no new information to librarians. The library does not become richer or more complete if its catalog is better designed. No collection is found in it as though it resulted from a donation provided by mathematical physics. The latter can help the reader to find more easily the book he seeks. By pointing things out for librarians and indicating gaps in their collections, mathematical physics suggests the performing of new experiments, which may eventually increase

the knowledge of phenomena that occur in nature. In other words, we can say that mathematical physics contributes to the spread of scientific laws in order to increase and improve the efficiency of science.

Every generalization is a hypothesis. This is enough to show the relevance that hypotheses have for science. Every hypothesis goes further than that; it states more than what is found in the experiments that were performed. Strictly speaking, a hypothesis cannot avoid going beyond them, because from its constitution a statement is to be made, for which today – or even forever – empirical evidence is not yet available. In order to avoid the "excesses" present in hypotheses, it is necessary and compulsory to submit them to the demands of empirical verification. The abandonment of hypotheses, which are not sustained by facts, prevents speculation and dogmatism, as it helps create a barrier against metaphysics.

Mathematical physics plays an important role in the exact formulation of hypotheses, which in a considerable number of situations, are tacit and unconscious. The requirement of conceptual precision, which is to be obeyed in the formulation of hypotheses, obligates scientists to formulate the exact content of their hypothetical statements. But why does generalization usually take a mathematical form? This is due to the fact that an observable phenomenon consists of the superposition of a large number of elementary phenomena, which are similar to each other. Mathematics allows scientists to combine something similar with something else that is similar. Their goal is to find the result of a combination, taken as a whole, without having to rebuild it part by part.

The mathematical physicist recognizes the homogeneity of a physical object because it has an admirable degree of symmetry. Indeed, mathematical symmetry enables physicists to conceptualize perceived analogies between different phenomena; this was the case of Maxwell, who, according to Poincaré, had a deep intuition to find symmetries. The Scottish physicist, according to his continental colleague, always used his intuition to find the mathematical analogies between optics, magnetism and electricity to formulate his own version of electromagnetic theory. The requirement of symmetry between the fields of physics allowed Maxwell to create and to find physical analogies. The hypotheses imposed by symmetry are the common basis of all theories of mathematical physics. This should make it possible to have knowledge of the hidden harmony of things, or to find the symmetries that lie behind phenomena.

Indifferent hypotheses receive this designation because they do not change anything in a theory. One of Poincaré's examples was mathematical analysis, which can be stated hypothetically, at the very beginning, that matter is continuous or discrete. Regardless of the position adopted, it does not change the method of application of infinitesimal calculus. These indifferent hypotheses would not be dangerous, as long as it were possible to know explicitly that they are present. They may even be useful, whether as an artifice of calculation or to support understanding through the use of concrete images. There is therefore no reason to suspect indifferent hypothesis before proceeding to analyze their content and wording. In short, the recognition of their hypothetical character is not enough to ban them from the scientific scene.

Conclusion

According to Poincaré, one cannot obtain information about an interesting experiment if it does not go through a process of generalization. Bits of information that are not connected to each other have no interest whatsoever. The element that puts the information together is a hypothesis which, like the bricks that form a house, constitutes the whole of the experiment. Hypotheses are indispensable to science. The verification provided by experiments is insufficient to allow for safe and definitive control over the hypotheses; yet control is necessary to prevent or decrease speculation in science. Actually, it is impossible to reduce to zero the level of speculation in science, even if it is due to the unavoidable presence of tacit and unconscious hypotheses in science. These often are not even recognized as hypotheses, which make them particularly dangerous. Critical analysis, mathematical physics and experiments can help ward off metaphysics, but not enough to make it disappear once and for all.

Against expectations, and fueled mainly by empiricists and positivists, generalization and unity in science are not obtained by means of empirical facts or ideas that are empirically verified, whether by generalization or by unity, both are based on hypotheses that are freely formulated by scientists. These hypotheses can be modified in a process that is infinite and endless.

It is an odd conclusion, since the pace of science therefore seemed to be dictated by metaphysics and not by experiments or theory. However, one thing seems certain, and even though this conclusion has been obtained from an analysis of Poincaré's own thinking, he himself would never accept it. Accepting it, according to him, would mean denying the possibility of practicing science.

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