LIMITS OF KNOWLEDGE

THE NINETEENTH-CENTURY EPISTEMOLOGICAL DEBATE AND BEYOND

EDITED BY MICHAEL ANACKER AND NADIA MORO

MIMESIS INTERNATIONAL

PHILOSOPHY

LIMITS OF KNOWLEDGE

The Nineteenth-Century Epistemological Debate and Beyond

Edited by Michael Anacker and Nadia Moro

MIMESIS

www.mimesisinternational.com
e-mail: info@mimesisinternational.com

Isbn: 9788869770135
Book series: *Philosophy*, n. 15

P.I. C.F. 02419370305

CONTENTS

Michael Anacker and Nadia Moro

FOREWORD

Ignorabimus! We will never know! With this peremptory statement, Emil du Bois-Reymond impressed the international audience gathered at the 45th congress of German scientists and physicians in Leipzig in 1872. The exclamation concluded a talk addressing the "Limits of natural knowledge", the contents of which were further elaborated by du Bois-Reymond in 1880. According to du Bois-Reymond, natural science, understood as the mechanical explanation of phenomena, is not able to clear up matter and force as its basic concepts, the origin of motion, the "hyper-mechanical" level of sensation, and freedom of will. Later du Bois-Reymond called these the transcendent limits of knowledge and added further ones: the origin of life, the apparent teleology in nature, and intelligent thinking. Seven world riddles, altogether, which compose "the world problem". Scientific explanation, pursued in terms of mechanical interactions, is confined within such boundaries.

Over the years between du Bois-Reymond's addresses, a fierce controversy – the *Ignorabimus-Streit* – had been stirred up and spread widely beyond German-speaking countries; it concerned the very possibility to set boundaries to knowledge, the development of the sciences, their attainable results, as well as concept formation. The debate, characterized by daring statements such as Haeckel's "*impavidi progrediamur*" grew over decades and its echoes were still to be found in 20th-century epistemological and popular literature.

Recently, a number of relevant publications has been devoted to the *Ignorabimus-Streit*,[1] but the latter has seldom been placed on the agenda

1 For the sake of brevity, we remind of Kurt Bayertz, Myriam Gerhard, and Walter Jaeschke's source-book (*Der Ignorabimus-Streit*, Hamburg 2012) and contributed volume (Hamburg 2007, third volume of the series *Weltanschauung, Philosophie und Naturwissenschaft im 19. Jahrhundert*), as well as Ferdinando Vidoni's monograph *Ignorabimus! Emil du Bois-Reymond e il dibattito sui limiti della conoscenza scientifica nell'Ottocento* (Milano 1988; German edition: Frankfurt

Kästner, Abraham G., Ueber den mathematischen Begriff des Raums, *Philosophisches Magazin*, 4 vols, Halle, 1789–1792, vol. 2, 1790a, 403–19.
Kästner, Abraham G., Was heißt in Euklids Geometrie möglich? *Philosophisches Magazin*, 4 vols, Halle, 1789–1792, vol. 2, 1790b, 391–402.
Koriako, Darius, *Kants Philosophie der Mathematik. Grundlagen – Voraussetzungen – Probleme,* Hamburg, 1999.
Lambert, Johann, *Anlage zur Architectonic*, 2 vols, Riga, 1771.
Parsons, Charles, *Mathematics in Philosophy,* Ithaca, 1983.
Scaravelli, Luigi, Gli incongruenti e la genesi dello spazio kantiano, in: *Scritti kantiani,* Firenze, 1973, 295–335.
Shabel, Lisa, *Mathematics in Kant's Critical Philosophy,* New York, 2003.
Stadler, August, *Kants Theorie der Materie,* Leipzig, 1883.
Trendelenburg, Adolf, *Logische Untersuchungen*, 2 vols, Berlin, ³1870.

Helmut Pulte

EMIL DU BOIS-REYMOND IN CONTEXT
Kantianism and 'Mechanical' Limitations of Knowledge in the Second Half of the 19th Century

0. *Introduction: 'Limits' and Scope of the Paper*[1]

'Du Bois-Reymond in Context': I take it here – at a workshop on 'Limits of Knowledge' – for granted that the content of the famous Ignorabimus-address is known and needs not to be described any more. As it is a multi-layered text, which attracted many and quite diverging comments and interpretations, it seems appropriate to start with some remarks on the 'limits of this paper' especially by indicating what it is *not* about. First, the *physiological background* of Emil du Bois-Reymond's talk, important as it is, lies beyond the scope of this article. Secondly, the paper will not deal with details of du Bois-Reymond's *second limit*, i.e. the debate on consciousness and its possible reduction to physico-chemical laws.[2] Moreover, the important ideological background of the Ignorabimus-discussion is left out here.[3] And finally, although the enormous public attention and dissemination of

1 This paper is a slightly revised and extended version of my talk at the workshop 'Limits of Knowledge. Between Philosophy and the Sciences' (Milano, November 17–18, 2011). I would like to thank Nadia Moro and Renato Pettoello for the organization of and for their excellent hospitality during the workshop. I would also like to thank the DAAD (German Academic Exchange Service) for the financial support of the Milano-Bochum-cooperation within the framework of its 'Vigoni-program'. It seems to me that a common workshop on 'Limits of Knowledge' with a focus on Emil du Bois-Reymond is an ideal subject for a European (and especially a German-Italian) cooperation: His 'Ignorabimus-address' was perceived intensely in Italy and other European countries, and – at the time in question – independent, but similar statements on the limits of scientific knowledge can be found in other countries as well. Cf. e. g. J. Tyndall's 'Scope and Limit of Scientific Materialism' from 1868 (Tyndall 1868) or Th. Huxley's lecture 'On the Physical Basis of Life' (Huxley 1868), delivered in the same year. Du Bois-Reymond in his Ignorabimus-lecture refers to old-established materialists like LaMettrie as his forerunners; cf. Vidoni 1991, 137–156.
2 For this aspect, see Pauen 2007.
3 The ideological background of the debate is analysed in Lübbe 1981 and in Vidoni 1991.

this discussion was a stimulus for my talk, I can deal with this aspect only very briefly, and at the end of my paper.

Having drawn these limits the reader may wonder what this paper is about at all. The short answer is that it will concentrate on what may be regarded as the 'core' of du Bois-Reymond's Ignorabimus-claim with respect to Kantian philosophy of science and epistemology, and the embedding of this issue in the contemporary discussion on mechanism. More specifically, I will try to show that du Bois-Reymond's Kantian commitments, which will be highlighted first (part 1), are not compatible with his argument for his first Ignorabimus. It is shown that his argument rests on a 'classical understanding' of science (also shared by Kant on *other*, i.e. transcendental grounds) which overcharges science with the demand of drawing proper limits of its own undertaking (part 2). The difference between Kant and du Bois-Reymond with respect to atomism is revealing in this respect (part 3). Finally, some consequences of my reconstruction for the Ignorabimus-reception are suggested (part 4).

1. *Kantianism, Mechanism and the 'Gang of Four'*

I will begin with some remarks on Kantianism and mechanism. From the very beginning, du Bois-Reymond located his Ignorabimus-talk at the edge of science and philosophy: Natural science, the "conqueror of the world", as he says, should – at the end of the day – face the challenge to detect and describe the "true limits of its empire".[4] Being one of the 'dukes' of this empire and – at the same time – an investigator of its limits: du Bois-Reymond's *internal* perspective seems to me formative for his whole argument. This is even more the case if we take into account that he had a solid knowledge of history of philosophy, especially of Kant. Du Bois-Reymond refers to Kant's *Metaphysical Foundations of Natural Science* approvingly already at the beginning of his career, and he knows that for Kant both the sound *foundation* and a critical *limitation* of knowledge belong to the most important tasks of theoretical philosophy. Such a philosophical or *external* perspective on the limits of science, however, is explicitly rejected by him in the course of his talk.[5] His guiding conviction is that the discovery of

4 Du Bois-Reymond 1872b, 441. In the following, I quote 'Über die Grenzen des Naturerkennens' and other lectures from his *Reden* (du Bois-Reymond 1912). All translations are mine unless otherwise indicated.

5 When he criticises philosophical reflections on the mind-body problem like those of Descartes or Leibniz as speculations based on arbitrary premises which are not acceptable for the natural scientist, who demands proofs based on firm evidence (du Bois-Reymond 1872b, 455).

true limits of scientific knowledge can only be achieved on the basis of true scientific knowledge of a specific kind.[6] I will later come back to this aspect when I deal with his understanding of mechanism.

The second remark refers to the scientific community of 'Berlin physiology' which was shaped by E. Brücke, C. Ludwig, E. du Bois-Reymond and H. von Helmholtz. It goes without saying that this group was not only familiar with Kant, but also accepted – at least at the beginnings of their research program – the results of Kant's *Metaphysical Foundations* of mechanics. Helmholtz's *Über die Erhaltung der Kraft* from 1847 is only one example of many, but surely the most indicative one.[7] The Berlin group declared mechanical reductionism to be the one and only approach to gain a true understanding of organic matter. Du Bois-Reymond stated in 1848:[8]

> [...] in the end, it must be possible to trace back the events in organic beings to these simple [i.e. mechanical] motions. This reduction would lead to an analytical mechanics of these events. From this it becomes obvious that – if this dissection would not exceed our ability – analytical mechanics would be sufficient up to the problem of personal freedom, which has to be solved by each individual [...].

Typical Kantian features of this kind of mechanism are the commitment to mathematics as an integral part of proper science, to the acceptance of only repulsive and attractive forces which act along the connecting line between two material particles as the unique *causes* of motion, and – as a consequence – to the rejection of a peculiar vital force. These and other similarities make plausible the claim that the Berlin group's foundation of mechanism is strongly shaped by Kant's *Metaphysical Foundations of Natural Science*.[9]

6 It is therefore doubtful that du Bois-Reymond has "merits with respect to the overcoming of materialism" in Germany, as T. Oesterreich states in the revised edition of Ueberweg's canonical *Grundriß* (Ueberweg 1916, 259).

7 Helmholtz, in his early writings, is most explicit with respect to his debts to Kant (see esp. Helmholtz 1847; cf. Heimann 1974). Still 5 years afar from du Bois-Reymond's 'Ignorabimus,' he claimed: "The entire doctrine of sense perceptions [...] is, in a certain sense, the empirical explication of Kant's theoretical discussion about the nature of the intellectual process of the human mind" (Helmholtz 1867, 249). After 1870, Helmholtz successively departed from his early Kantianism for various reasons.

8 Du Bois-Reymond 1848, 9.

9 See Galaty 1974, 302–15, for further evidence.

It would be wrong, however, to declare the 'gang of four' a bridgehead of Kantianism in physiology, as their strong anti-metaphysical tendencies, and sometimes even anti-philosophical, statements show. Especially du Bois-Reymond sometimes evokes the impression to be a 'modern' phenomenalist (like Ernst Mach, for example): "All science", he declares in his early article on 'Lebenskraft,' "has not the aim to reveal the essence of things, but only to apprehend that it [the essence] is not apprehensible".[10] In these contexts, he claims: "To recognize not the causes of motions, but rather its laws seems to us the true task of our striving".[11] One should not push aside this facet of du Bois-Reymond's mechanism, though it is hardly compatible with his overall reductive approach. Quite on the contrary, his strange 'mathematical phenomenalism' will play a central role in what follows.

My main concern here, however, is to point out that du Bois-Reymond's mechanism is compatible with the findings of Kant's *Metaphysical Foundations* and that its shaping was influenced by Kant's approach. Thus, the message of this short overview on Kantianism and mechanism is twofold: First, du Bois-Reymond shares Kant's view that there are certain barriers to scientific knowledge which have to be determined, whatever these barriers are. However, he rejects and inverts Kant's claim that this is a task of *philosophy* and not of *science* itself. Second, he shares, by and large, the content of Kant's mechanism, though he does not adopt Kant's specific philosophical foundation.

2. *'Laplace's Intellect', du Bois-Reymond's 'Ignorabimus' and Mechanical Euclideanism*

In a second step, I would like to take a closer look at du Bois-Reymond's understanding of science. I would like to stress, above all, the *epistemological status* he attributes to the basic laws of mechanics on which, according to his reductive approach, natural science is based. In his famous address from 1872 he states: "The propositions of mechanics are representable in mathematical form, and they bear the same apodictic certainty as the propositions of mathematics".[12]

10 Du Bois-Reymond 1848, 15.

11 Du Bois-Reymond 1848, 15.

12 Du Bois-Reymond 1872b, 442. This position is hardly backed by his methodology: Though his writings are pretty unprofitable with respect to scientific method, there can be no doubt that for him *induction* is the 'silver bullet' to scientific knowledge in general and to basic laws of nature in particular (cf. Malter 1981, 52f., 60). In this respect, he is closer to the British tradition than to many of his German predecessors and leading figures of the day in the tradition of mechanism, especially mathematical physicists like Riemann, Neumann, or later Boltzmann.

This understanding of laws and principles of mechanics makes du Bois-Reymond a late exponent of a tradition I call 'mechanical Euclideanism'. This label indicates that Euclid's *Elements* with its seemingly evident and unshakable axioms and its deductive structure served as an ideal for theoretical mechanics. Mechanical Euclideanism strives for certain, infallible foundations of mechanics. Most of its representatives held the view that – by and large – Newton's laws and the principles of analytical mechanics already achieved this ideal. Truth, evidence and certainty are the basic features of its axioms or first principles. Mechanical Euclideanism is – to pick up an observation from Lakatos' – 'epistemologically neutral,' meaning that it is compatible with empirical, rationalistic or even transcendental foundations of its first principles. From Newton to Euler, Lagrange, Laplace well into the 19th century, this view of mechanics was absolutely dominating in mathematical physics and its respective philosophies.[13]

Du Bois-Reymond's Ignorabimus-address is a late but paradigmatic example of mechanical Euclideanism: His leading model of scientific understanding – the intellect of Laplace – is constitutive for his whole argument and, at the same time, a perfect expression of the concept of science at stake here.[14] According to du Bois-Reymond, Laplace's intellect is similar to our human intellect to the extent that it has a complete *nomic* knowledge of nature, i.e. both intellects know all the mechanical laws necessary in order to describe the behavior of all atoms of the universe. Laplace's intellect is superior to the human intellect only to the degree that it can also store all the details of the distribution of matter, i.e. the places and velocities of the atoms at one moment. Du Bois-Reymond's whole argument about the limits of scientific knowledge rests on the premise of complete and certain nomic knowledge of nature. In so far he is an adherent of traditional mechanical Euclideanism, though he nowhere gives an epistemological justification for why he sticks to this position. In fact, he argues for *limits* of scientific knowledge on the basis of an *ideal* of complete and infallible scientific knowledge.

13 And it was, if you take a glance at the *Metaphysical Foundations*, also Kant's ideal of mechanics as a science built up on synthetic principles a priori. In du Bois-Reymond's periphery it can be detected, for example, in the writings of young Helmholtz, or in Wilhelm Wundt's early writings, for example in his book *Die physikalischen Axiome und ihre Beziehung zum Kausalprinzip* from 1866 (Wundt 1866; cf. Pulte 2005, 405f.).

14 "Der von Laplace gedachte Geist" (du Bois-Reymond 1872b, 443). Only later this intellect turned into a 'demon'. Cf. Pulte 2005, 59–66, for details about this transformation and for 'Laplace's intellect' as an expression of mechanical Euclideanism.

As for the reception of du Bois-Reymond's argument, it is important to note that mechanical Euclideanism as an ideal of science became problematic and increasingly unpopular precisely at the time he gave his Ignorabimus-address. I would just like to refer to a few examples in order to illustrate this development, which starts with Jacobi, the mathematician in the late 1840ies, but was communicated only two decades later.[15] Jacobi's starting point is a criticism of analytical mechanics in the tradition of Lagrange, which du Bois-Reymond regards as the hallmark of scientific perfection. Jacobi, however, confronted mechanics with a sharp dichotomy of mathematical knowledge, based on logic, and empirical knowledge, which can never obtain the epistemological status claimed by mechanical Euclideanism:[16]

> Everything is reduced to mathematical operation [...]. Nature is totally ignored [in] the constitution of bodies [...]. Analytical mechanics here clearly lacks any justification; it even abandons the idea of justification in order to remain a purely mathematical science.

This criticism was advanced by Bernhard Riemann in his famous inaugural talk from 1854 and later by Carl Neumann. Both these investigations and Jacobi's point of view were published in 1867 and 1869 respectively. While Jacobi downgraded mechanical axioms to mere *conventions*,[17] Riemann and Neumann labelled them *hypotheses*, which are revisable in the course of empirical investigation and which are, to a certain extent, "arbitrary and incomprehensible", as Neumann put it.[18] Both combined their radicalisation of Jacobi's view with a critical analysis of matter and force, especially of atomism.

This 'internal' dissolution of 'top down-Euclideanism' has been received neither in contemporary science nor in later historical investigations. Other impacts which led to the same end eventually gained some importance and prominence. However, these later developments were rather 'bottom up-processes', brought about by the incapability of mechanics to capture adequately certain empirical phenomena like those of electrodynamics. They had to succeed the 'top down-dissolution' of mechanical Euclideanism, and both processes led to what I call '*modern* mathematical philosophy of nature,' which considers even the basic principles of science

15 Cf. Pulte 2005, 359–431.

16 Jacobi 1847/48, 29.

17 Exactly 50 years before H. Poincaré did; cf. Pulte 1994 for more details.

18 Neumann 1870, 13; cf. Riemann 1853, 525. For an analysis of Neumann's background, see Pulte 2009.

as revisable hypothesis.[19] In 1872 du Bois-Reymond must have had at least partial knowledge of these writings by Riemann and others.[20] However, he adhered to the *classical* ideal in his address, and this seems to me important for its reception (cf. part 4). Here, I would like to stress two aspects: First, du Bois-Reymond's adherence to mechanical Euclideanism implies that proper scientific knowledge is extremely demanding in epistemological respects – it is 'crystal clear' – quantitative, mathematical knowledge of a certain type. Therefore, atoms have to be conceived first and foremost as mathematical entities, furnished with *quantitative* properties like extension, mass and form. Therefore, the addition of *qualitative* properties in order to explain certain seemingly non-mechanical phenomena of the outside world or *qualitative* perceptions, sensations and feelings of our inner consciousness as phenomena become insurmountable obstacles for, or limits of our intellect. It is important to note that du Bois-Reymond's 'limits of knowledge' depends on his extremely high epistemological standard, which quickly lost its plausibility. Second, du Bois-Reymond's adherence to mechanical Euclideanism is justified – from his point of view – because science at least partly meets this high epistemological standard, especially in the field of celestial mechanics. That is why he labels knowledge gained by the Laplacian intellect "astronomical knowledge".[21] The empire

19 I already mentioned young Wilhelm Wundt as one of the chief witnesses of mechanical Euclideanism at the time of the Ignorabimus-talk (cf. note 12). Later, in the second edition of his *Prinzipien*, he summed up the dramatic change of the common attitude towards the foundations of mechanics in these words: "What had been accepted as an axiom in former times was now labelled as 'hypothesis', thereby expressing that also alternative systems of premises – perhaps deviating essentially from the established system – can be chosen, as long as they serve the purpose of linking the phenomena which have to be described" (Wundt 1910, 2; cf. Pulte 2005, 405).

20 For example, we learn from his talk 'Leibnizsche Gedanken in der neueren Naturwissenschaft' from 1870 that he had studied Riemann's inaugural lecture; cf. du Bois-Reymond 1870, 385.

21 Du Bois-Reymond 1872b, 455. The definition of this term reveals du Bois-Reymond's mechanical Euclideanism quite well and deserves a full quotation of the original: "Ich nenne astronomische Kenntnis eines materiellen Systems solche Kenntnis aller seiner Teile, ihrer gegenseitigen Lage und Bewegung, daß ihre Lage und Bewegung zu irgend einer vergangenen und zukünftigen Zeit mit derselben Sicherheit berechnet werden kann, wie Lage und Bewegung der Himmelskörper bei vorausgesetzter unbedingter Schärfe der Beobachtungen und Vollendung der Theorie. Dazu gehört, daß man kenne 1. die Gesetze, nach welchen die zwischen den Teilen des Systemes wirksamen Kräfte sich mit der Entfernung ändern; 2. die Lage der Teile des Systemes in zwei durch ein Zeitdifferential getrennten Augenblicken [...]. Astronomische Kenntnis eines materiellen

of 'crystal clear' scientific knowledge may be small at the moment, but it can expand until it reaches certain limits which are insurmountable forever.

This is the reason why du Bois-Reymond asks, against Kant, for a determination of limits of knowledge by *science itself*: In order to determine limits of science one has to dispose of positive and unshakable scientific knowledge and appropriate methods to gain such knowledge, which disqualifies philosophy for such a task. He claims:[22]

> We believe that philosophy can sometimes take advantage of the method of natural science. However, vice versa natural science can take no advantage from the method of philosophy. For science, its aim and the way towards it are defined with clarity and certainty beyond any doubt: Knowledge of the physical world and its changes and mechanical explanation of the latter by observation, experiment and calculation. [...] How powerless philosophical thinking remains even in the hands of eminent thinkers – when the task is to guess the laws of the physical world – will be shown clearly in the following [...].

And in the following, he criticises (among others) Kant for not appreciating Leibniz's law of the conservation of *vis viva* in his *Metaphysical Foundations of Natural Science*. This ancillary criticism is meant to illustrate du Bois-Reymond's main point: Philosophical reflection about the physical world cannot reveal its basic laws, and without these basic laws no clear definition of the limits of science is possible.

3. *Du Bois-Reymond's Atomism and the Kantian Response*

The previous remarks have shown that Kant is an ambiguous figure for du Bois-Reymond – a philosopher who was unusually well-informed about *science*, but also an inconvenient and somehow proprietorial thinker with *respect to science*. According to Kant's philosophy of science, the definition of limits of scientific knowledge is just the other side of the coin of a philosophical foundation of science. This view is unacceptable for du Bois-Reymond, and this seems to be the main reason why he rejected later, in his

Systems ist bei unserer Unfähigkeit, Materie und Kraft zu begreifen, die vollkommenste Kenntnis, die wir von dem System erlangen können. Es ist die, wobei unser Kausalitätstrieb sich zu beruhigen gewohnt ist, und welche der *Laplacesche* Geist selber bei gehörigem Gebrauche seiner Weltformel von dem System besitzen würde" (du Bois-Reymond 1872b, 455–56).

22 Du Bois-Reymond 1872a, 438.

Sieben Welträtsel from 1880, the interpretation that his 'Ignorabimus' was an appeal to *Erkenntniskritik* in the spirit of Kant.[23]

It is worthwhile to examine the Kantian context a bit closer in order to uncover some misunderstandings in the whole discussion, especially with respect to du Bois-Reymond's claim that the investigation of limits of science ought to be a task of science itself and not of philosophy. I will confine myself to only *one* aspect, i.e. the conceptual consistency of atomism, which is exemplary for the difference between Kant and du Bois-Reymond.

Du Bois-Reymond starts his analysis of atomism from the epistemologically privileged point of view of Laplace's intellect: From the beginning, he presupposes that the basic laws of mechanics are true and that *therefore* the basic concepts underlying these laws, i.e. Newtonian space and time, point masses and central forces represent elements of reality. This means that in his Ignorabimus-lecture he shares a standard argument of scientific realism with respect to the key concepts of successful theories. We are always driven, as he says, by our "need for causality" and end up with conceptions of "smallest particles" and "central forces".[24] Though he declares these to be mere "surrogates of an explanation", his whole argument rests on matter and force as physical entities and *therefore* results in his well-known contradictory claim with respect to atomism.[25] This position is based on a conceptual distinction between passive particles of matter and active central forces. The former are bearers of forces and properties like inertia, which are not reducible to other properties. Now, two possibilities can be discerned: *First*, if we divide matter in smaller parts subsequently, atomism implies the existence of a final point, i.e. the atoms, which are coordinated to the point masses of mechanical theory. Their continual *existence* demands that they occupy space and that they exert repulsive forces of arbitrarily large magnitudes if one tries to continue the division process. Otherwise they would be divided by sufficiently large forces and could not

23 Cf. du Bois-Reymond 1880, 66. Here, Kant's "reform of philosophy" is even interpreted as a turning point of philosophy to the worse: Philosophy after Kant became "esoteric" and unlearned the "language of common sense"; moreover, it developed a hostile attitude towards science which is the "new world power growing next to her".

24 Du Bois-Reymond 1872b, 447.

25 Cf. du Bois-Reymond 1872b, 447–49. His argument is only shortly described here. A more detailed analysis, including du Bois-Reymond's distinction of 'physical' and 'philosophical atoms', can be found in Vidoni 1991, 121–125 and Wilholt 2008, 3–5. Partly, du Bois-Reymond's argument repeats points of criticism raised against atomism in the early debate about Newton's physics in the 18th century; cf. Scott 1970.

be *atoms* in the literal sense at all. This first possibility, however, contradicts the conceptual distinction of matter and force, which leaves matter as a *passive* bearer of active forces. *Second*, if the atoms are conceived alternatively as a *mere point* without extension, i.e. as mere centres of forces, the relation of matter and force would become totally obscure. Moreover, in this case we could not understand at all that matter bears physical properties like, for example, *inertia*. This dilemma leads du Bois-Reymond to the defeatist conclusion that we face a "transcendent barrier"[26] and will never understand the 'essence' of matter and force.

I would like to contrast, respectively, two aspects of du Bois-Reymond's argument: *First*, it obviously rests on the absolute validity claims of his mechanism, which articulates a certain type of scientific realism: The basic laws of mechanics are known to us and their truth is guaranteed. But is there anything more to gain in science? Du Bois-Reymond's answer is 'yes'[27] – and this is a *remarkable contrast* to his more 'phenomenological' approach to scientific laws mentioned earlier: According to du Bois-Reymond, the concepts of true laws have to be spelled out *realistically*: Humans' insatiable thirst for causal explanation transcends the best scientific knowledge available. Du Bois-Reymond's loose talk of 'essence of matter' and 'essence of force' is revealing in this respect: At the end of the argument, the *scientist* turns out to be a *true metaphysician*.

Second, there is a striking contrast between du Bois-Reymond's and Kant's approach to atomism: In various writings, Kant strongly opposes a natural philosophy based on atoms and void,[28] though he "asserts that it is not possible to rule out [...] an atomistic philosophy a priori".[29] In the second antinomy of pure reason he points out that the only use of atomism for natural science can be a *methodological* one. Kant here – in the *antithesis* of this antinomy – leaves no doubt that he rejects atomism precisely in the sense as it is later applied by du Bois-Reymond.[30] One might be even tempted to think that there exists a 'pre-established harmony' between Kant and

26 "Niemand, der etwas tiefer nachgedacht hat, verkennt die transzendente Natur des Hindernisses, das hier sich uns entgegenstellt" (du Bois-Reymond 1872b, 449). 'Transzendente' in this quotation should not be read as 'transcendental' (but cf. Wilholt 2008, 4).

27 This point is already stressed in Malter 1981, 53.

28 See, for example, Kant's argument in the second anticipation of perception (Kant 1787, B 215–16; AA III, 156–57).

29 Friedman 1992, 217.

30 "No composite thing in the world is made up of simple parts, and there nowhere exists in the world anything simple" (Kant 1787, B 463; transl. Kant 1933, 402). A composite physical thing cannot be decomposed in simple, non-composite parts, because these parts would have to occupy space, and – as space is made up of spaces – therefore could be divided further, contrary to the assumption.

du Bois-Reymond in so far as the very meaning of Kant's antinomies of pure reason, too, is to uncover *certain* limitations of knowledge – barriers[31] which are passed over only at the expense of hopeless contradictions or fruitless speculations. This bias is certainly present in Neokantian interpretations of du Bois-Reymond's first 'Ignorabimus'. Nevertheless, it does not do justice to the point at stake here and is quite odd and misleading from an epistemological perspective: Kant's and du Bois-Reymond's attitudes towards atomism reveal just how *fundamental* the difference between both approaches is: du Bois-Reymond admits of 'simple constituents' of matter as a corner-stone of his mechanism, the basic laws of which are true. He adheres to the *first* thesis of Kant's second antinomy, according to which every substance consists of simple parts. It is this premise which du Bois-Reymond tries to extend as far as possible in order to define his 'empire' of true scientific knowledge in full size. Eventually, his limits are conceptual inconsistencies which are *self-refuting* with respect to his mechanism because they undermine its whole conceptual framework.[32]

Kant, on the other hand, has a quite different understanding of how to determine limits of knowledge by means of his antinomies. To start with, he argues that both the *thesis* and the *antithesis* of the second antinomy are *false*. This is because we can perceive the world neither as an infinite nor as a finite whole but only as a succession of empirical phenomena which are arranged and ordered according to rules of understanding and intuition. The 'regression' of appearances is *no* process ending in something that is an 'absolutely unconditioned' (ein 'Schlechthinunbedingtes;' like du Bois-Reymond's atom). We may introduce atoms as 'working fictions' if this facilitates the regress in the series of phenomena, but they can never be the final step of our conceptual ordering of the appearances: This would mean to introduce a *constitutive concept* without any foundation in our understanding. Of course, according to Kant understanding and intuition determine, how scientific knowledge looks like. But *stricto sensu*, they do not define *limits* which separate inside and outside of our knowledge: *There is no epistemic outside*. Here, in the context of the antinomies, we have to do

31 For the difference of 'limits' and 'barriers' in Kant's epistemology cf. part 4, esp. n. 35.

32 Kant describes, in the 'Transcendental Dialectics,' the 'realist' in this manner: "The realist in the transcendental meaning of this term, treats these modifications of our sensibility as self-subsisting things, that is, treats *mere representations* as things in themselves" (Kant 1787, B 519; transl. Kant 1933, 439).

with a regulative and not with a constitutive 'principle of reason,' as Kant points out:[33]

> [This] principle of reason is thus properly only a *rule*, prescribing a regress in the series of conditions of given appearances, and forbidding it to bring the regress to a close by treating anything at which it may arrive as absolutely unconditioned. It is not a principle of the possibility of experience, and of empirical knowledge of objects of the senses, and therefore not a principle of the understanding; for every experience, in conformity with the given [forms of] intuition, is enclosed within limits. Nor is it a *constitutive* principle of reason, enabling us to extend our concept of the sensible world beyond all possible experience. It is rather a principle of the greatest possible continuation and extension of experience, allowing no empirical limit to hold as absolute. Thus it is a principle of reason which serves as a *rule*, postulating what we ought to do in the regress, but *not anticipating* what is present *in the object as it is in itself, prior to all regress*. Accordingly I entitle it a *regulative principle of reason* [...].

This statement leaves no doubt about the fundamental difference between Kant and du Bois-Reymond with respect to atomism and their philosophies of science in general: According to Kant, du Bois-Reymond's approach to introduce atoms as 'absolutely unconditioned' entities means to establish unjustified *empirical* limits of scientific knowledge, or – to put it in Kant's own terminology – to try to establish a constitutive principle where no constitution of scientific knowledge *can* take place. Instead, he votes for a continuing process of *empirical* research. By its very nature it is excluded (in his words) "to bring the regress to a close by treating anything at which it may arrive as absolutely unconditioned". His analysis in a way anticipates and rejects du Bois-Reymond's first limit of knowledge: There is and there can be no unsolvable riddle of atomism for science, unless science itself overstrains its own capacities and degenerates into traditional, pre-critical metaphysics.

4. *Conclusion: A Glimpse at the Ignorabimus-Reception*

Nicholas Rescher was quite right when he ascribed to Kant what he called the 'principle of augmentation of questions' in science: The more scientific knowledge we acquire, the more questions can be raised.[34] This is the reason why Kant, in his *Prolegomena*, distinguishes between 'limits' and 'barriers' of science: 'Limits' imply the idea of a space – here a cognitive space – which is divided; 'barrier' merely implies the negation of something beyond. Human reason in Kant's sense has *barriers* – it cannot grasp the 'thing in itself' – but it has *no limits*, and therefore mathematics and natural science are not limited either, as he states emphatically.[35] They are *unlimited* ventures of human reason.

33 Kant 1787, B 537; transl. Kant 1933, 450.
34 Rescher 1985, 87–88.

I do *not* think, however, that Nicholas Rescher was right when he ascribed the attitude that science is an open and infinite process *to du Bois-Reymond*.[36] According to the reconstruction presented here, his understanding of science rather allows and demands that it *can* come to an end. That is why his epistemological attitude was sometimes described as *agnostic*.[37] But it has to be kept in mind that du Bois-Reymond's agnosticism is *relative* to his ideal of crystal clear knowledge based on his type of mechanism, i.e. it is an agnosticism with respect to the question how far exactly this crystal clear knowledge can be extended. In this immanent and very restricted sense, du Bois-Reymond was right to postulate limits of knowledge, though the later course of science and philosophy of science made highly visible that they are much narrower than he himself ever would have expected.

The ample *reception* of du Bois-Reymond's 'Ignorabimus' is beyond the scope of this paper. However, I would like to conclude with some remarks in order to adumbrate some consequences for it in the light of the reconstruction presented here: *First*, I fully agree with Friedrich Albert Lange, who stated that theologians and traditional metaphysicians were *completely wrong* when they celebrated du Bois-Reymond as a scientist who hands over the epistemological authority of science back to them.[38] *Second*, I also think that representatives of a somehow *naïve* scientism and materialism like Ernst Haeckel were *completely wrong* when they accused du Bois-Reymond of giving up science as an epistemic authority – this needs no comment either. *Third*, it seems to me that Lange and other Neokantians were mainly wrong when they tried to incorporate du Bois-Reymond in

35 "As long as the cognition of reason is uniform, it is not possible to think about definite limits [of knowledge]. In mathematics and in natural science human reason detects barriers ["Schranken"], but not limits ["Grenzen"], viz, that something lies outside to it and is unreachable forever, but not [in the sense] that it will find completion anywhere in its internal proceeding. The enlarging of insights in mathematics, and the possibility of continual new inventions are infinite; likewise the discovery of new properties of nature, of new forces and laws, by continued experience and its unification by reason. However, barriers cannot to be mistaken here [...]" (Kant 1783, §57; AA IV, 352).
36 Cf. Rescher 1985, 208.
37 Cf., for example, Vidoni 1991, esp. 113–35.
38 Lange 1873 II, 604–05.

the Neokantian project of *Erkenntniskritik*. Unlike other projects that aim at a modern, up to date-version of Kantianism, du Bois-Reymond's first 'Ignorabimus' did not serve this purpose: Its project is not *Erkenntniskritik* in Kant's sense, but *Erkenntnisbeschränkung* in a dogmatic (i.e. scientistic) manner. *Fourth*, I think that later representatives of science as well as some partisans of logical empiricism[39] were wrong in accusing du Bois-Reymond of epistemologically degrading science in relation to philosophy: They simply did not realize his ambitious epistemological standards of science, partly because they stuck to the same traditional ideal. David Hilbert is a typical example of this strand of reception.[40]

Finally, I think that du Bois-Reymond was partly right when he later labeled his own 'Ignorabimus' a *schibboleth*, i.e. a catchword that at least allows separating enemies and friends within the debate. This dichotomy is not least a result of dogmatic epistemological claims which are immanent to a *classical* understanding of science. *Modern* science and philosophy of science, on the other hand, do not confront but rather negotiate the epistemic and non-epistemic aims and virtues of science. They are not in need of such a 'schibboleth' any longer. Therefore, if anything the slogan of modern science and its philosophy is: 'No *Ignoramus,* and no *Ignorabimus*!'

References

Bayertz, Kurt & Gerhard, Myriam & Jaeschke, Walter (Hgg.), *Weltanschauung, Philosophie und Naturwissenschaft*, Bd. 3: *Der Ignorabimus-Streit*, Hamburg, 2007.

du Bois-Reymond, Emil, Über die Lebenskraft. Aus der Vorrede zu den 'Untersuchungen über tierische Elektrizität' vom März 1848, in: du Bois-Reymond 1912 I, 1848, 1–26.

du-Bois-Reymond, Emil, Leibnizsche Gedanken in der neueren Naturwissenschaft. In der Leibniz-Sitzung der Akademie der Wissenschaften am 7. Juli 1870 gehaltene Rede, in: du Bois-Reymond, 1912 I, 1870, 370–92.

du Bois-Reymond, Emil, Über Geschichte der Wissenschaft. In der Leibniz-Sitzung der Akademie der Wissenschaften am 4. Juli 1872 gehaltene Rede, in: du Bois-Reymond 1912 I, 1872a, 431–40.

du Bois-Reymond, Emil, Über die Grenzen des Naturerkennens. In der zweiten allgemeinen Sitzung der 45. Versammlung Deutscher Naturforscher und Ärzte zu Leipzig am 14. August 1872 gehaltener Vortrag, in: du Bois-Reymond 1912 I, 1872b, 441–73.

du Bois-Reymond, Emil, Die sieben Welträtsel. In der Leibniz-Sitzung der Akademie der Wissenschaften am 8. Juli 1880 gehaltene Rede, in: du Bois-Reymond 1912 II, 1880, 65–98.

du Bois-Reymond, Emil, *Reden in zwei Bänden*. 2. Aufl, Leipzig, 1912.

Friedman, Michael, *Kant and the Exact Sciences*, Cambridge (Mass.)/ London, 1992.

Galaty, David H., The Philosophical Basis of Mid-Nineteenth Century German Reductionism, *Journal of the History of Medicine and Allied Sciences* 29, 1974, 259–316.

Heimann, Peter M., Helmholtz and Kant: The Metaphysical Foundations of 'Ueber die Erhaltung der Kraft', *Studies in History and Philosophy of Science* 5, 1974, 205-38.

Helmholtz, Hermann von, Ueber die Erhaltung der Kraft: Eine physikalische Abhandlung, vorgetragen in der Sitzung der physikalischen Gesellschaft zu Berlin am 23. Juli 1847, in: Helmholtz 1892–95 I, 1847, 12–68.

Helmholtz, Hermann von, *Handbuch der physiologischen Optik*, Hg. von Karsten, Gustav, Leipzig, 1867.

Helmholtz, Hermann von, *Wissenschaftliche Abhandlungen*. 3 Bde, Leipzig, 1882–95.

Huxley, Thomas H., On the Physical Basis of Life, in: Huxley, Thomas H., *Collected Essays (1893–1894)*, Vol. 1, *Method and Results*, Hildesheim/ New York, 1970, 1868.

Jacobi, Carl G. J., *Vorlesungen über analytische Mechanik. Berlin 1847/48*. Nach einer Mitschrift von Wilhelm Scheibner hg. von Pulte, Helmut. Braunschweig [u.a.] 1996, 1847/48.

Kant, Immanuel (AA), *Gesammelte Schriften*. Hg. von der (Königlich) Preußischen Akademie der Wissenschaften bzw. der (Deutschen) Akademie der Wissenschaften (der DDR). 29 Bde, Berlin (und Leipzig), 1910–1983.

Kant, Immanuel, *Prolegomena zu einer jeden künftigen Metaphysik, die als Wissenschaft wird auftreten können*, Riga, in: AA IV, 1783, 253–383.

Kant, Immanuel, *Kritik der reinen Vernunft*, 2. Aufl., Riga, in: AA III, 1787.

Kant, Immanuel, *Critique of Pure Reason*, transl. by Smith, Norman K. London, 1933.

Lange, Friedrich A., *Geschichte des Materialismus und Kritik seiner Bedeutung in der Gegenwart*, 2 Bde, 2. Aufl., Leipzig; Neudruck Frankfurt a. M. 1974, 1873.

Lübbe, Hermann, Wissenschaft und Weltanschauung. Ideenpolitische

39 See Vidoni 1991, 179–94 and Stöltzner 2007.

40 For Hilbert's response to du Bois-Reymond's 'Ignorabimus' see McCarty 2005.

Fronten im Streit um Emil Du Bois-Reymond, in: Mann 1981, 129–48.
Malter, R., 'Kausalitätstrieb' und Erkenntnisschranke. Zur philosophischen Grundposition Emil Du Bois-Reymonds, in: Mann 1981, 45–77.
McCarty, David C., Problems and Riddles: Hilbert and the Du Bois-Reymonds, *Synthese* 147, 2005, 63–79.
Mann, Gunter (Hg.), *Naturwissen und Erkenntnis im 19. Jahrhundert: Emil Du Bois-Reymond*, Hildesheim, 1981.
Metze, Erich, *Emil Du Bois-Reymond. Sein Wirken und seine Weltanschauung*, Bielefeld, 1918.
Neumann, Carl, *Ueber die Principien der Galilei-Newton'schen Theorie. Akademische Antrittsrede gehalten in der Aula der Universität Leipzig am 3. November 1869*, Leipzig, 1870.
Pauen, Michael, Die Grenzen des Erkennens. Von Du Bois-Reymond zur aktuellen Philosophie des Geistes, in: Bayertz & Gerhard & Jaeschke 2007, 151–82.
Pulte, Helmut, C.G.J. Jacobis Vermächtnis einer 'konventionalen' analytischen Mechanik. Vorgeschichte, Nachschriften und Inhalt seiner letzten Mechanik-Vorlesung, *Annals of Science* 51, 1994, 487–517.
Pulte, Helmut, *Axiomatik und Empirie. Eine wissenschaftstheoriegeschichtliche Untersuchung zum Verhältnis von Axiomatik und Empirie von Newton bis Neumann*, Darmstadt, 2005.
Pulte, Helmut, From Axioms to Conventions and Hypotheses: The Foundation of Mechanics and the Roots of Carl Neumann's 'Principles of the Galilean-Newtonian Theory', in: *The Significance of the Hypothetical in the Natural Sciences*, ed. by Heidelberger, Michael & Schiemann, Gregor, Berlin/New York, 2009, 71–92.
Rescher, Nicholas, *Die Grenzen der Wissenschaft*, Stuttgart, 1985.
Riemann, Georg Friedrich Bernhard, *Gesammelte mathematische Werke und wissenschaftlicher Nachlaß*, Hg. unter Mitwirkung von Dedekind, Richard und Weber, Heinrich, 2. Aufl., Leipzig, 1892.
Riemann, Georg Friedrich Bernhard, Neue mathematische Principien der Naturphilosophie, in: Riemann 1892, 1853, 528–32.
Riemann, Georg Friedrich B., Ueber die Hypothesen, welche der Geometrie zu Grunde liegen. Habilitationsvortrag vom 10. Juni 1854, in: Riemann 1892, 1854, 272–86.
Scott, Wilson L., *The Conflict between Atomism and Conservation Theory 1644 to 1860*, London, 1970.
Stöltzner, Michael, "Das 'Ignorabimus' ist sinnlos". Der Wiener Kreis und die Rückkehr eines alten Problems in der Quantenmechanik, in: Bayertz & Gerhard & Jaeschke 2007, 132–49.

Tyndall, John, Scope and Limit of Scientific Materialism, in: *Fragments of Science. A Series of Detached Essays, Addresses, and Reviews*, vol. 2. 6th ed., London 1898, 1868, 75–89.
Ueberweg, Friedrich, *Grundriss der Geschichte der Philosophie*. Vierter Teil: *Das neunzehnte Jahrhundert und die Gegenwart*, Neu bearbeitet und hg. von Oesterreich, Konstantin, 11th ed. Aufl., Berlin, 1916.
Vidoni, Ferdinando, *Ignorabimus! Emil Du Bois-Reymond und die Debatte über die Grenzen wissenschaftlicher Erkenntnis im 19. Jahrhundert*, Frankfurt a. M./Bern/New York/Paris, 1991.
Wilholt, Torsten, When realism made a difference: The constitution of matter and its conceptual enigmas in late 19th century physics, *Studies in History and Philosophy of Modern Physics* 39, 2008, 1–16.
Wundt, Wilhelm, *Die physikalischen Axiome und ihre Beziehung zum Kausalprinzip*, Heidelberg, 1866.
Wundt, Wilhelm, *Die Prinzipien der mechanischen Naturlehre. Ein Kapitel aus einer Philosophie der Naturwissenschaften*, Stuttgart, 1910.