



Whitehead and the British Reception of Einstein's Relativity: An Addendum to Victor Lowe's Whitehead Biography

Ronny Desmet¹

INTRODUCTION

The scope of this biographical essay on Alfred North Whitehead (1861-1947) is very limited. To start with, leaving out his career as a mathematician at Cambridge University (1880-1910) and his career as a philosopher at Harvard University (1924-47), I will focus on his involvement with Albert Einstein's theories of relativity during the London period of his life (1910-24). Furthermore, numerous mathematical, physical, and philosophical influences converge in Whitehead's work on relativity, but I will only touch upon the influence of a restricted number of mathematical physicists and philosophers, and will only treat his friendship with Lord Haldane in more detail, e.g., by taking into account some unpublished letters from Whitehead to Haldane which are part of the Haldane Papers at the National Library of Scotland in Edinburgh.

And yet, despite the limited scope of this essay, it will contain some hints to enrich the part of Victor Lowe's *Alfred North Whitehead: The Man and His Work* dealing with Whitehead's London period.² I will explain in more detail than Lowe³ why Hermann Minkowski and a number of mathematical physicists inspired by Minkowski, and why some of the members of the Aristotelian Society, were important influences when Whitehead developed his views on relativity. Also, I will add a relevant fact, missing in Lowe's biography: Whitehead and Einstein discussed their divergent views on relativity in person on Friday, June 10th, and Saturday, June 11, 1921.

The enrichment of Lowe's account is important, both for philosophers and historians of relativity. The former can learn that Whitehead's philosophy of relativity did not arise out of the blue, but can only be understood properly against the background of the British reception of relativity. The latter can learn that Whitehead's case is a perfect—and hence, unjustly

neglected—example to illustrate a number of the recently acquired insights into the dynamics of the British reception of Einstein's theories.

LOWE'S ACCOUNT

In the summer of 1910 the Whitehead family moved from Cambridge to London in search of a more varied life. During the academic year 1910-11, Whitehead was unemployed, but wrote *An Introduction to Mathematics* (IM). In July 1911 Whitehead joined University College. His first academic year there, he was Lecturer in Applied Mathematics, and the next two years, Reader in Geometry. In 1914 Whitehead was appointed Professor of Applied Mathematics at the Imperial College of Science and Technology. He held that position until he moved to the U.S. in 1924. In 1918 Whitehead was elected Dean of the Faculty of Science of the University of London, and from then on he became actively involved in a host of councils and committees, too many to list. His countless duties, however, did not prevent Whitehead from writing and publishing. In the course of his London years, ten addresses and two essays on education appeared, more than a dozen lectures and articles on science and philosophy, and the three philosophy of physics books which are considered as the main products of his London activities: *An Enquiry Concerning the Principles of Natural Knowledge* (PNK, 1919), *The Concept of Nature* (CN, 1920), and *The Principle of Relativity, with Applications to Physical Science* (R, 1922).

The above paragraph can be considered as a synopsis in a few sentences of Lowe's 130-page account of Whitehead's London years. To this synopsis, I now add some of the details of Lowe's account. Lowe emphasizes that Whitehead's philosophy of physics grew out of his continual effort to complete Volume IV of *Principia Mathematica* on Geometry, a volume intended to give a logical analysis of space. "But quite clearly," Lowe notices, "the whole conception of Geometry as the logical analysis of space required rethinking in the light of the Special Theory of Relativity."⁴ Lowe's remark is confirmed by the Preface of *PNK*, in which Whitehead stresses that the modern theory of relativity, because of its union of space and time, has opened the possibility of a new answer to the question of how the space of physical geometry can be conceived as the logical outcome of generalizations from experience.

Of course, the next point to consider is the question of when and how Whitehead got acquainted with Einstein's Special Theory of Relativity

(STR). To answer the when-part of the question, Lowe looks at two of Whitehead's papers. The first one is "La Théorie Relationniste de l'Espace," a paper Whitehead delivered in April 1914 at the First Congress of Mathematical Philosophy in Paris. Lowe writes: "At this point there is no indication of his plan of an excursion into the philosophy of physics."⁵ And more specifically: "Einstein's special theory of relativity is not mentioned, nor is Minkowski's union of space and time."⁶ The second relevant paper is "Space, Time, and Relativity," a paper Whitehead first read to Section A at the Manchester Meeting of the British Association for the Advancement of Science in 1915, and later, with some commentary added, before the London Aristotelian Society. This paper is the first of Whitehead's writings explicitly discussing the mathematical physics of relativity. Lowe seems to conclude that Whitehead got familiar with STR approximately ten years after Einstein's 1905 *Annalen der Physik* paper, "Zur Elektrodynamik bewegter Körper," and seven years after Minkowski's 1908 Cologne lecture, "Raum und Zeit."

Lowe's conclusion that it took Whitehead quite some years to come across the theories of Einstein and Minkowski is highlighted when recalling one of his conversations with Whitehead: "Talking to me in May 1941, he [Whitehead] said, 'Minkowski's paper was published in 1908, but its influence on me was postponed approximately ten years.' 'Ten' may be an overstatement by one to three years."⁷ A quick calculation—1908 plus 10 minus 3—leads us to 1915 as the earliest possible year of the retarded influence of Minkowski's work on Whitehead.

Lowe's scarce remarks on this issue and the vague chronology that results leave a lot of questions unanswered. For example, it is unclear whether Whitehead learned about Einstein's STR and about Minkowski's work at the same time. Also, Lowe speaks about Einstein's STR, but what about the General Theory of Relativity (GTR)? And more importantly, Lowe tells us nothing on the second part of the question: *how* did Whitehead learn about the theories of relativity?

All this is a bit disappointing, especially since Lowe writes: "Whitehead was greatly affected by the revolution in physics that had taken place in the first decade of the twentieth century,"⁸ and again: "The theory of relativity exercised an enormous influence on Whitehead's thinking."⁹ However, the elucidation of a number of quotes from Whitehead's writings, and of a number of facts in Lowe's biography, against the background of the history of the British reception of Einstein's theories of relativity,

can lead to better conjectures on when and how Whitehead learned about STR and GTR.

ENRICHED ACCOUNT, PART I : THE INFLUENCE OF MATHEMATICAL PHYSICISTS

One of the most relevant Whitehead quotes in this context is from *PNK*. In the Preface of *PNK* Whitehead writes: “In connection with the theory of relativity I have received suggestive stimulus from Dr L. Silberstein’s *Theory of Relativity*, and from an important Memoir (‘The Space-Time Manifold of Relativity,’ *Proc. of the Amer. Acad. of Arts and Sciences*, vol. XLVIII, 1912) by Profs. E.B. Wilson and G.N. Lewis.”¹⁰ One of the most relevant facts in Lowe’s biography is that when Whitehead joined University College in July 1911, he replaced Assistant Professor Ebenezer Cunningham, who accepted a position at Cambridge.¹¹

For one familiar with the recent literature on the history of the reception of Einstein’s theories of relativity, both the memoir of Edwin Bidwell Wilson and Gilbert Newton Lewis¹² and the names of Ebenezer Cunningham¹³ and Ludwik Silberstein¹⁴ ring a bell. Generally speaking, the 1912 memoir of Wilson and Lewis, “The Space-Time Manifold of Relativity,” the 1914 book of Cunningham, *The Principle of Relativity*, and the 1914 book of Silberstein, *The Theory of Relativity*, are important examples to substantiate the claim “that Minkowski’s four-dimensional view of special relativity favored the introduction of Einstein’s theory.”¹⁵ This point, however, has not yet been illustrated by means of Whitehead’s particular case. The given Whitehead quote invites me to do so.

To start with, it is no surprise that Whitehead knew the Wilson and Lewis memoir. In Book VII of his 1898 *Treatise on Universal Algebra with Applications (UA)*, Whitehead forged a vector calculus from Hermann Grassmann’s algebra of extensions, applicable in various branches of physics, especially hydrodynamics and electrodynamics. This was an important first step in Whitehead’s career to make the dream of applied mathematics come true, “that in the future these applications will unify themselves into a mathematical theory of a hypothetical substructure of the universe, uniform under all the diverse phenomena.”¹⁶ Whitehead knew, and referred to, the fact that the approach of Josiah Willard Gibbs at Yale University was similar to his.¹⁷ Gibbs forged a vector calculus of the same kind from William Rowan Hamilton’s algebra of quaternions, and one might say that it belonged to Whitehead’s core business to pay

attention to the development of Gibbs' vector calculus, which must have led him to Wilson and Lewis.

At the age of twenty-two, while being a Yale student of Gibbs, and based on Gibbs' lectures, Wilson wrote "the first full-length book presenting the modern system of vector analysis."¹⁸ The publication of Wilson's 1901 *Vector Analysis* can hardly have escaped Whitehead's attention. At MIT, Wilson began to write on mechanics and relativity. Lewis, who became a famous physical chemist later in life, was one of the first in the US to deal with Einstein's STR, and as early as 1909, at MIT, he and R.G. Tolman published "a highly original exposition of the theory."¹⁹ In his 1910 paper, "On four-dimensional vector analysis, and its application in electrical theory," Lewis employed Gibbs' system of symbolic notation, and transformed Minkowski's approach into a convenient four-dimensional vector analysis.²⁰ It can be considered as a precursor of the Wilson-Lewis memoir,²¹ and its title may have caught Whitehead's attention. In 1911 Wilson and Lewis were promoted to full professors at MIT, and in 1912 they jointly published the 120-page long memoir Whitehead refers to.

Whitehead must have been an enthusiastic reader of the Wilson-Lewis memoir. To start with, the memoir is appealing to all applied mathematicians cherishing the unification-dream, of which Whitehead was one. Its four-dimensional vector calculus, incorporating the geometrical union of space and time, most elegantly unifies (special relativistic) mechanics and (Maxwellian) electrodynamics.

Secondly, the authors—like Whitehead²²—challenged Henri Poincaré's conventionalism, and his choice of Euclidean geometry as the most convenient one. "Indeed," Wilson and Lewis write, "it seemed to Minkowski that . . . a change [of physical geometry] was . . . necessitated by the facts which led to the formulation of the Principle of Relativity."²³ So it is no coincidence that Whitehead's definition of the congruence relation in *PNK* is drawn from "their valuable memoir."²⁴ It was Whitehead's aim with *PNK* and *CN* to overcome Poincaré's conventionalism, and to present the Minkowskian space-time geometry as the logical outcome of our experience, by showing this "particular congruence relation to play a pre-eminent role among the factors posited in sense-awareness."²⁵

Lastly, Whitehead—since his student days at Cambridge interested in the work of Maxwell and his Cambridge-trained followers, especially Whitehead's contemporaries J.H. Poynting, J.J. Thomson, and Joseph

Larmor²⁶—must have welcomed the Minkowskian approach of Wilson and Lewis to elegantly express the electrodynamic equations of moving point charges and their potentials. Whitehead had a strong affinity with Thomson and Larmor’s Electronic Theory of Matter (ETM), and the influence of ETM in the memoir of Wilson and Lewis is clear, for the latter write: “Much of recent progress in the science of electricity has been due to the introduction of the electron theory, in which electricity is regarded not as a continuum but as an assemblage of discrete particles. . . . In our application of our four dimensional geometry to electricity we shall therefore consider first an electric charge as a collection of discrete charges or electrons, each of which is concentrated at a single point.”²⁷ The Minkowskian treatment of the electrodynamic potentials of point charges plays an important role in Whitehead’s theory of gravity, but with this remark I jump from STR over GTR to Whitehead’s 1920s alternative to Einstein’s theory of gravity.

Returning to 1914, to the first two British monographs dedicated to STR, I limit myself to mentioning that most of what I said on the impact of the Wilson-Lewis memoir can be repeated for Cunningham’s *Principle of Relativity* and Silberstein’s *Theory of Relativity*.²⁸ Of course, the mere fact that Whitehead’s biography and Cunningham’s intersect in July 1911²⁹ does not imply that Whitehead read Cunningham. However, considering Whitehead’s interest in Larmor’s ETM, the fact that Cunningham first was Larmor’s student and then a major proponent of ETM,³⁰ and finally, the status Cunningham’s 1914 monograph quickly acquired,³¹ it becomes very unlikely that Whitehead missed it—and he certainly did not fail to read Silberstein. Despite the unfortunate lack of references in Whitehead’s writings, he did refer to Silberstein’s 1914 monograph. Furthermore, I can add that his path crossed Silberstein’s on at least three occasions.

Silberstein, trained as a physicist in Poland, student of (among others) Hermann von Helmholtz and Max Plank in Germany, lecturer in mathematical physics in Italy, and author of a 1911 quaternion-formulation of STR, moved to England in 1912, where he obtained a lectureship at University College, London.³² Consequently, Whitehead and Silberstein were University College colleagues during the academic year 1912-13. After joining the Aristotelian Society in 1915, Whitehead became close friends with Thomas Percy Nunn,³³ who was close with Silberstein.³⁴ Finally, on November 6, 1919, Whitehead was present when Silberstein questioned Arthur Eddington at the famous joint meeting of the Royal

Society and the Royal Astronomical Society announcing the results of the May 1919 solar eclipse expedition testing Einstein's GTR.³⁵

The foregoing account on when and how Whitehead first learned about Einstein's STR, as well as Minkowski's work, leads to the conjecture that this happened earlier than suggested by Lowe, thanks to the writings of Wilson, Lewis, Cunningham, and Silberstein. That Whitehead first *wrote* about the STR in 1915 is no counter-argument. It is in line with the slow, but thorough assimilation of ideas which characterizes him. In this he differs from Bertrand Russell, one of the fastest thinkers of his age, to whom Whitehead once wrote: "My ideas and methods grow in a different way to yours and the period of incubation is long and the result attains its intelligible form in the final stage."³⁶ In a maximum count, Whitehead's incubation period to reach full maturity on the subject of relativity stretched from 1912 to 1922—from the earliest possible year to learn about the Wilson-Lewis memoir to the year his involvement with relativity culminated in the publication of *R*. This decade long period is to be compared with the ten years it took Whitehead to write *UA*, and with his ten-year long *Principia Mathematica* involvement.

Turning to the question on when and how Whitehead first learned about Einstein's GTR, it is immediately clear that this must have happened prior to the November 6 meeting in 1919, which launched Einstein's career to superstar-heights. In the April 1919 Preface to his earliest book on the topic, Whitehead already refers to GTR, even though the book mainly deals with STR.³⁷ Furthermore, it is clear that Whitehead had already assimilated GTR prior to the November 6 meeting, for immediately afterwards, on November 15, his first newspaper article on the topic appeared in *The Nation* under the title "A Revolution in Science." Also, he was asked—like philosopher Wildon Carr and physicist Frederick Lindemann—to write a contribution on "Einstein's Theory" for the readers of *The Times Educational Supplement*. Whitehead supplied an article which already contains an introduction to his alternative rendering of GTR, which was the subject of his spring 1920 lecture before the Chemical Society of the students of the Imperial College of Science and Technology³⁸ and of the lectures forming his 1922 *R*. Carr's article was published on January 22, 1920, Lindemann's on January 29, and Whitehead's on February 12.³⁹ The opening of Whitehead's article reads: "The articles on this subject, which appeared on January 22 and 29, summarized the general philosophical theory of relativity and the physical

ideas involved in Einstein's researches. The purpose of the present article is in some respects critical, with the object of suggesting an alternative explanation of Einstein's great achievement."⁴⁰

So, if not in November 1919, when did Whitehead learn about Einstein's GTR? My conjecture is that this happened in 1916, when GTR was introduced in England by Eddington. Indeed, I will now proceed to show that, whereas his urge for unification led him from vector calculus and ETM to STR, the same urge led him—in September 1916—from the STR-problem of gravitation to GTR.

After the unification of mechanics and electrodynamics in terms of Einstein's Lorentz covariant generalizations of Newton's laws of mechanics, the problem of the unification of the forces of gravitation and electromagnetism in terms of a Lorentz covariant generalization of Newton's law of gravitation remained. This is the STR-problem of gravitation. It is addressed by Minkowski in his 1908 paper "Die Grundgleichungen für die elektromagnetischen Vorgänge in bewegten Körpern," and in his famous 1908 Cologne lecture "Raum und Zeit"—the two texts of Minkowski to which Wilson and Lewis, as well as Silberstein, frequently refer.⁴¹

In his Cologne lecture—in translation: "Space and Time"—Minkowski obtains the notion of a world-line in the four-dimensional space-time universe by considering the variation of the space co-ordinates of a material or electrical point due to a variation of its time co-ordinate. Then he writes: "The whole universe is seen to resolve itself into similar world-lines, and . . . in my opinion physical laws might find their most perfect expression as reciprocal relations between these world lines."⁴² And after linking the electrodynamic relations between the world-lines of point-charges to the Maxwell-Lorentz electron theory and the Liénard-Wiechert retarded potentials, Minkowski expresses his belief that the gravitational relations between the world-lines of point-masses should be treated just like the electromagnetic relations in the case of point-charges, and hence, that the resolution of the universe in world-lines can be seen as "the true nucleus of an electromagnetic image of the world."⁴³

Minkowski's belief in the possible unification of gravitation and electromagnetism in terms of a renovated electromagnetic world picture appealed to many mathematical physicists, among whom Arnold Sommerfeld is an interesting example. Indeed, like Whitehead, Sommerfeld did not focus only on the mathematical relevance of Minkowski's work, but "was among the first to champion Minkowskian

relativity for both its physical and mathematical insights.”⁴⁴ Like Whitehead, Sommerfeld held Einstein's STR as “an intermediate step between Lorentz and Minkowski.”⁴⁵ Like Whitehead, Sommerfeld did not consider the electron theory and the retarded potentials as rendered obsolete by STR, but thought that the Minkowskian formulae expressing the retarded potentials “reveal their inner nature in four dimensions, in full simplicity,” and that “it was still possible to pursue the electromagnetic world picture.”⁴⁶ Finally, like Whitehead, Sommerfeld launched a new ether concept by redefining the ether as Minkowski's four-dimensional universe of world-lines, filling, in this way, “the conceptual void created by Einstein's brusque elimination of the ether.”⁴⁷ However, I have no indication that Whitehead read Sommerfeld, and with the Whitehead-Sommerfeld comparison I'm getting ahead of my story again. So, I return to the established Minkowskian influences on Whitehead.

Wilson and Lewis end their 1912 memoir by echoing Minkowski's vision that the searched for formulae expressing the gravitational force and potential must be “completely analogous” to the new formulae expressing the electromagnetic force and potential, and suggest—by analogy—the use of the term “gravito-magnetic” instead of gravitational.⁴⁸ Silberstein—in his 1914 book—mentions Poincaré's 1906 attempt to use the general form of the Lorentz transformations for the treatment of both the dynamics of the electron and universal gravitation, and notices the advantage Minkowski's approach seems to offer for a relativistic theory of gravity.⁴⁹ The most elaborate treatment of the search for a relativistic theory of gravity, however, is given in Cunningham's *Principle of Relativity*.

While dealing with ETM in Minkowskian format, and, more specifically, with the Lorentz covariant four-vector expression of the Liénard-Wiechert potentials for the field due to the motion of a single point-charge, Cunningham refers to “the work founded on that of Poincaré for modifying the law of gravitation to conform to the Principle of Relativity.”⁵⁰ Contrary to Wilson and Lewis, and to Silberstein, however, Cunningham does not leave it at a simple suggestion of the gravitation-electrodynamics analogy. An important part of his Chapter on the dynamics of a particle is devoted to the search for a relativistic theory of gravitation.⁵¹ Moreover, Cunningham does not only refer to the 1906 paper of Poincaré—“*Sur la dynamique de l'électron*”—but also treats the 1911 paper of the Dutch astronomer Willem de Sitter—“On the Bearing of the Principle of Relativity on Gravitational Astronomy”—which has

been called “the most authoritative account in English of the [gravitational and] astronomical importance of the principle of relativity . . . before the appearance of Einstein’s general theory.”⁵²

However, none of the relativistic theories of gravitation Whitehead encountered prior to 1916 was satisfactory. None of the theories which can be found in Poincaré’s 1906 paper, Minkowski’s 1908 papers, De Sitter’s 1911 paper, and Cunningham’s 1914 book, were in accordance with the astronomical observations of the secular motion of the perihelion of Mercury, as De Sitter and Cunningham clearly highlight.⁵³ It seems to have been Minkowski’s opinion that the incorporation of gravitation into relativistic thinking was not a major problem, and he left the more elaborate treatment of this point for a later occasion; but—as Minkowski died on January 12, 1909, at the age of 44 of a sudden and violent attack of appendicitis—he never lived to see how elusive and difficult the task would turn out to be.⁵⁴ Contrary to Minkowski, when Whitehead read his 1915 paper “Space, Time, and Relativity” before the members of the Aristotelian Society, he added the following comment: “We have begun to expect that all physical influences require time for their propagation in space. This generalisation is a long way from being proved. Gravitation stands like a lion in the path.”⁵⁵

Not long after making this comment, however, Whitehead was confronted with Einstein’s GTR, which pretended to have defeated the lion that blocked the road to an empirically adequate relativistic treatment of gravitation. Indeed, this confrontation took place at the Newcastle Meeting of the British Association for the Advancement of Science in September 1916, where Eddington’s address—“Gravity and the Principle of Relativity”—offered many British scientists the opportunity of hearing about Einstein’s GTR for the first time. I now quote Andrew Warwick’s 2003 account of the Eddington-part of this story, and then return to Whitehead:

Einstein published the completed general theory of relativity in late November 1915, but news of his great achievement arrived in Britain only in June 1916 in the form of a letter from de Sitter (working in the neutral Netherlands) to Eddington (then Secretary of the Royal Astronomical Society). The letter . . . gave some account of the astronomical consequences and offered to submit a substantial paper on the subject to the prestigious *Memoirs of the Royal Astronomical Society*. . . . In his reply to de Sitter, Eddington confirmed . . . that he was “immensely interested” to learn more about Einstein’s theory

and suggested that, for the speed of publication, de Sitter submit a paper to the *Monthly Notices* . . . of the Royal Astronomical Society. In the event, de Sitter published a series of three expository papers in the *Monthly Notices* . . . on Einstein's theory of gravitation and its astronomical consequences.⁵⁶

The immediate effect of de Sitter's first letter appears to have been to prompt Eddington to offer a paper on Einstein's work to a session on "Gravitation" to be held at the British Association meeting in Newcastle in early September. At the beginning of July 1916, Eddington informed de Sitter of the meeting and asked if he had any objection to his using the first instalment of the proposed paper . . . as the basis of a presentation. . . . The British Association session on gravitation was introduced by Cunningham, but it was Eddington's subsequent presentation (based on de Sitter's paper) that spelled out the astronomical consequences of the theory. It is a measure of Cunningham and Eddington's ignorance of Einstein's work at this time that the official account of the session . . . made no mention of their presentation, but referred the reader directly to de Sitter's . . . papers in the *Monthly Notices*.⁵⁷

In one of the endnotes added to his 1992 account of the same event, José Sanchez-Ron mentions that among those present at the 86th meeting of the British Association in Newcastle-On-Tyne was "A. N. Whitehead, who presided over Section A (mathematics and physics)."⁵⁸ Whitehead was indeed present at this meeting, and his presidential address, "The Organisation of Thought," is well-known by Whitehead scholars, for it is included in the selection of addresses Whitehead published in 1917 under the same title, *The Organisation of Thought*.⁵⁹ Furthermore, the fact that Whitehead had already studied some Minkowskian generalizations of Newton's law of gravitation, almost excludes the possibility that he did not pay attention to Eddington's introduction of Einstein's GTR, and to the papers by De Sitter which lay at the basis of this introduction.

Sanchez-Ron warns us to avoid the temptation of reducing the British introduction of Einstein's GTR to the role De Sitter and Eddington played,⁶⁰ and he himself includes, among others, Lindemann and Silberstein. Lindemann published a paper, together with his father, on "Daylight Photography of Stars as a Means of Testing the Equivalence Postulate in the Theory of Relativity" in the December issue of *The Monthly Notices*.⁶¹ "Silberstein was one of the most prolific physicists to publish papers or

books dealing with general relativity in British journals and publishing houses,” and “could be considered as ‘the second’ after Eddington.”⁶²

Lindemann, who later in life became Winston Churchill’s “counsellor, confidant and closest companion,” spent the most important years of his education in Germany, and achieved international recognition as a physicist in Berlin.⁶³ Given the brilliance of his work, Walter Nernst arranged for Lindemann to be one of the secretaries at the first Solvay Conference in Brussels, and at that conference, in November 1911, amid the greatest scientists in the world, Lindemann’s lifelong friendship with Einstein began.⁶⁴ However: “At the onset of the war in 1914 he returned to England, where he contributed remarkably to the development of aeronautics and, through experiments in which he calmly put his own life at risk, discovered the scientific method of escaping from aeroplane spin.”⁶⁵

Given this biographical interlude on Lindemann, it is clear that Whitehead did not need Eddington’s 1916 address, nor De Sitter’s 1916-17 papers, to learn about Einstein’s GTR. Lindemann had his own contacts, including Einstein himself, to receive Einstein’s papers on the subject. In Silberstein’s case—even though the influence of De Sitter on his writings is considerable—a similar statement can be made. In fact, Einstein wrote to his friend Michele Besso on May 7, 1917: “*Lieber Michele! Ich sende Dir einige Abhandlungen mit der Bitte, Sie an Herrn Dr. L. Silberstein . . . weiterzusenden, der mich darum gebeten hat.*”⁶⁶ But does the fact that both Lindemann and Silberstein had De Sitter and Eddington-independent access to Einstein imply that Whitehead also learned about GTR thanks to them, and not only thanks to the famous Dutch astronomer (De Sitter), and to his former Cambridge student (Eddington)?⁶⁷ I know of no Lindemann-Whitehead connection and, hence, exclude any assertion that Lindemann co-introduced Whitehead to Einstein’s GTR. And even though I did—to some extent—establish a Silberstein-Whitehead connection, it does not allow me to answer the question with regard to Silberstein.

However, what I do know is that the paper the Lindemanns wrote in 1916 was not likely to catch Whitehead’s attention, as it was about a particular experimental set-up to test GTR, whereas some of Silberstein’s papers on Einstein’s GTR were almost certainly read by Whitehead, because he knew Silberstein from his STR-work, because they were fundamental as well as critical, and because Whitehead’s own alternative theory of gravity shows a number of striking similarities with them,

especially with Silberstein's 1918 paper "General Relativity without the Equivalence Hypothesis."

Silberstein, who had a kind of love-hate relationship with Einstein's GTR—willing to accept it wholeheartedly, and yet, relentlessly criticizing it—has been called Einstein's "*advocatus diaboli*,"⁶⁸ as well as "Einstein's antagonist."⁶⁹ This might suggest that Whitehead derived his critical attitude in GTR-context from Silberstein, but this suggestion is only partially true. Whitehead's critique of Einstein's approach has many more sources, too many to list here. Some date from his Cambridge period, others from his London period. Some are to be found in the domain of mathematical physics, others in the domain of philosophy. And finally, one must not forget that, from its introduction in England, Einstein's GTR was exposed to critique.

An example of an early source of Whitehead's critique of Einstein's GTR is Poincaré. Poincaré's critique of the Helmholtzian idea that the metric of space can be determined by the mechanics of rigid rods is closely related to Whitehead's critique of the Einsteinian idea that the metric of space-time can be determined by the physics of the distribution of matter (embodied in the energy-momentum tensor). The notions of rigidity and of distribution seem to presuppose the metric they are meant to define, and in order to avoid circularity, it is best "to maintain the old division between physics and geometry,"⁷⁰ and to reject Einstein's identification of the physics of gravitation with the geometry of space-time, even while granting his GTR the status of an empirically successful theory.

An example of a philosophical source of Whitehead is James Ward. Whitehead "saw a good deal" of Ward while still in Cambridge,⁷¹ and he lists Ward in the Preface of *PNK* as one of the philosophers to whom he has "heavy obligations to acknowledge,"⁷² without, however, telling us why. Fortunately, in two recent papers, Pierfrancesco Basile has convincingly analysed the impact of Ward on Whitehead. To give just one example, "the mistake of 'hardening' abstractions into concrete facts denounced by Ward in *Naturalism and Agnosticism* is a clear antecedent of what Whitehead calls 'the fallacy of misplaced concreteness.'"⁷³ As Whitehead holds space-time to be an abstraction from the concrete network of interrelated events constituting reality, he can only take Einstein's identification of space-time with concrete physical reality as an instance of the fallacy of misplaced concreteness.

And finally, the 1916-17 papers of De Sitter reflect an, at that time, ongoing Einstein-De Sitter exchange about Einstein's Machian explanation of inertia, and about the priority of matter over space-time—initially leading Einstein to the postulation of unobservable distant masses at the boundary of the universe in order to explain inertia, and to the rejection of De Sitter's cosmological model for an empty universe, without matter.⁷⁴ So there never was a “pure” or “uncritical” transmission of Einstein's GTR from the Continent to Britain to start with. When Whitehead learned about it, GTR was already wrapped in De Sitter's critique, elements of which became part of Whitehead's own critique of Einstein's GTR. Indeed, Whitehead repeatedly attacks the Machian explanation of inertia in his writings on relativity, and he replaced the ontological model in which matter has priority over space-time, and space-time over the relatedness of events, with a model in which these priorities are reversed.

It is impossible, because of the enormous multiplicity of its sources, to properly explain Whitehead's critique of Einstein's GTR solely in terms of the influence of Silberstein, or even in terms of all Minkowskians together. However, it is *not* impossible to give a fair account of Whitehead's alternative theory of gravity in those terms. It is with a non-mathematical synopsis of such an account that I want to close this section.

Whitehead's alternative theory of gravity starts with Minkowski. In “Einstein's Theory” in *The Times Educational Supplement* of February 12, 1920, Whitehead included the following tribute to Minkowski: “Before passing on to Einstein's later work a tribute should be paid to the genius of Minkowski. It was he who stated in its full generality the conception of a four-dimensional world embracing space and time, in which the ultimate elements, or points, are the infinitesimal occurrences in the life of each particle. He built on Einstein's foundations and his work forms an essential factor in the evolution of relativistic theory.”⁷⁵

It is important to notice that Whitehead trades in a substance ontology for a process ontology. So Minkowski's universe of electrical and material points, each of which has an “everlasting career,”⁷⁶ got translated into Whitehead's passage of nature, a flux of perishing occurrences or events, each of which (if we limit the discussion to physics) can be characterized by a definite charge and mass; and Minkowski's world-lines got translated into Whitehead's historical routes of events, characterized by a permanent charge and mass. But Minkowski and Whitehead share

the same unification-dream. Expressed in Whitehead's terminology: it is possible to invent a physics of the reciprocal relations of historical routes of events, accounting both for electromagnetism and gravitation. Their leading idea is the same: in both the charge-case and the mass-case the causal interrelation between infinitesimal occurrences of historical routes has to be described in terms of Lorentz covariant retarded potentials which satisfy the wave equation.

Becoming a bit more technical, and looking at the gravitational part of his unified theory, Whitehead associates with each infinitesimal occurrence of an historical route, not only the definite mass shared by all infinitesimal occurrences constituting that particular route, but also the infinitesimal length of that particular occurrence. For all occurrences, the length can be expressed in terms of the Minkowskian metric, which thus becomes the uniform background-metric of Whitehead's theory. Next, Whitehead expresses the gravitational influence of an infinitesimal occurrence (of an historical route on the infinitesimal occurrence of another historical route) as a Lorentz covariant retarded gravitational potential which satisfies the wave equation, in fact, an identical twin of the Lorentz covariant Liénard-Wiechert retarded electrodynamic potential as expressed in Cunningham's 1914 monograph.

Leaving it at this, Whitehead's theory would not be an empirical improvement compared to the other Minkowskian theories of gravity. Whitehead, however, does not only learn from the Minkowskians, but also from Einstein. So the tribute to Minkowski quoted above has to be completed, which is exactly what Whitehead does in his 1922 book: "My whole course of thought presupposes the magnificent stroke of genius by which Einstein and Minkowski assimilated time and space. It also presupposes the general method of seeking tensor . . . relations as general expressions for the laws of the physical field, a method due to Einstein. But the worst homage we can pay to genius is to accept uncritically formulations of truths which we owe to it."⁷⁷

The success of Whitehead's theory of gravity depends on the way he incorporates the Minkowskian elements to describe space-time and gravitation into Einsteinian tensor expressions, and its divergence from Einstein's theory of gravity depends on the fact that he does not throw all the elements in a unique tensor. I start with the latter point: whereas Einstein's law of gravitation is expressed in terms of one fundamental tensor embodying both space-time geometry and gravitational physics,

Whitehead maintains the old division between physics and geometry. His law of gravitation is expressed in terms of two tensors, a space-time tensor and a gravitational field tensor. I proceed by specifying the Minkowskian ingredients of these tensors: The first tensor (also called the Galilean tensor) expresses the uniform relatedness of events. It incorporates the Minkowskian space-time metric. This first tensor enables the calculation of lengths. The second tensor (also called the potential mass impetus tensor) expresses the causal relatedness of events. It incorporates the masses, the lengths (calculated by means of the first tensor), and the Lorentz covariant retarded potentials, associated with the relevant infinitesimal occurrences (those which are taken into account). This second tensor enables us to calculate how routes are affected by a gravitational field.

It is important to notice that when splitting Einstein's one fundamental tensor in two, and when incorporating retarded potentials in the second one, Whitehead's method is similar to the method Silberstein followed in his 1918 paper, "General Relativity without the Equivalence Hypothesis," but Whitehead's result is superior to the result Silberstein attained. In fact, the second tensor is so intelligently assembled in terms of Minkowskian elements that the route of Mercury, calculated by means of it, is in accordance with the astronomical observations of the secular motion of Mercury's perihelion. Moreover, it has been shown that Whitehead's and Einstein's equations share the Schwarzschild-solution⁷⁸ and the Kerr-solution.⁷⁹ These solutions describe almost all the routes which have been under investigation by physicists dealing with GTR, including, of course, Mercury's route, and that other paradigmatic case, the route of a ray of light passing the Sun. Hence, Whitehead's and Einstein's theories of gravity are to a large extent empirically equivalent.

To summarize: Whitehead's ultimate motivation is best characterized as an urge for unification. He has turned Minkowski's belief in the possibility to unify the electrodynamics of point-charges and the gravitation of point-masses in terms of reciprocal relations of world-lines and retarded potentials, into a fully fledged theory of causally efficient historical routes of events characterized by definite charges and masses. The causal efficacy in Whitehead's theory is described by means of field tensors involving retarded potentials, and also against the uniform background of a space-time tensor involving the Minkowskian metric. Whitehead succeeded in turning Minkowski's belief into an empirically successful theory because he stood on the shoulders of Wilson and Lewis, Cunningham, Silberstein,

and—of course—Einstein, but also because of his original combination of some of the elements in their writings.

And yet, Whitehead failed to impact the course of physics, because—as Eddington once remarked⁸⁰—his theory of gravity had come out of season for the physicist. In a sense, Whitehead deconstructed Einstein's GTR with Silbersteinian tools, and he went “back in time” to complete the Poincaré-Minkowski-De Sitter-Cunningham program of finding a Lorentz covariant theory of gravity with the bits and pieces he thought valuable. Compare Whitehead's ad hoc work on gravity, published in 1920 and 1922, with Eddington's innovative work in the same time-frame (1920-22): Eddington took the second step (Hermann Weyl the first) in broadening the geometry of GTR to better include electromagnetism next to gravitation (contrary to Whitehead's theory, Einstein's was no unified theory); and he contributed to the research on the propagation of gravitational waves. No surprise that Whitehead's backtracking physics—no matter his innovation of the conceptual foundations of physics—did not receive the same attention from the community of physicists as Eddington's forefront work.

ENRICHED ACCOUNT, PART II : THE INFLUENCE OF PHILOSOPHERS

I opened the last section with some quotes from Whitehead's writings and from Lowe's biography in order to identify the mathematical physicists whose influence I wanted to include in my account. I will now proceed in the same manner to identify the philosophers that will play a major role in my completion of Lowe's account of Whitehead's involvement with relativity.

In his “Autobiographical Notes” Whitehead writes: “My philosophical writings started in London, at the latter end of the war. The London Aristotelian Society was a pleasant centre of discussion, and close friendships were formed.”⁸¹ Lowe adds that when Whitehead joined the Aristotelian Society in 1915, the active members during Whitehead's time included Samuel Alexander, Charles Dunbar Broad, Herbert Wildon Carr, Lord Haldane, Lloyd Morgan, Thomas Percy Nunn, Norman Kemp Smith, and D'Arcy Thompson. I will not treat Morgan, Smith, and Thompson here, and have already drawn attention to Nunn and his 1923 *Relativity and Gravitation* when discussing Silberstein in the previous section. So I will limit myself to Alexander, Broad, Carr, and Haldane. Alexander, Broad, and Carr function, so to speak, as the ABC of my treatment of the philosophical influences

on Whitehead, and my account on Haldane in this section functions as an introduction to my account of the 1921 encounter of Whitehead and Einstein in the last section, “Long Scientific Discussion.”

In the April 1920 Preface of *CN*, Whitehead holds that his conceptual reorganization of physics, in which the assimilation of space and time plays a dominant role, can claim the independent support of Minkowski from the side of science, and of Alexander from the side of philosophy.⁸² Given the major importance of Minkowski in Whitehead’s conceptual reorganization of physics (*cf.* previous section), Whitehead’s reference to Alexander is an invitation to study the impact of the *opus magnum* of this Australian-born British philosopher on Whitehead’s thought. I am referring, of course, to *Space, Time and Deity*, developed from the Gifford Lectures Alexander delivered at the University of Glasgow in the sessions 1916-18, and published in two volumes in 1920.

In the same Preface, Whitehead indeed refers to Alexander’s Gifford lectures, adding that they are “delivered some few years ago but [are] not yet published,” and he informs his readers that Alexander “also summarized his conclusions [on the issue of the assimilation of space and time] in a lecture to the Aristotelian Society in the July of 1918.”⁸³ The importance of *Space, Time and Deity* for his thinking is reemphasized in Whitehead’s June 1925 Preface to *Science and the Modern World (SMW)*. This time he writes: “There has been no occasion in the text to make detailed reference to Lloyd Morgan’s *Emergent Evolution* or to Alexander’s *Space, Time and Deity*. It will be obvious for the readers that I have found them very suggestive. I am especially indebted to Alexander’s great work.”⁸⁴

In between 1920 and 1925, George Temple—a mathematician who had taken his first degree as an evening student, and was working in 1923 as a research assistant at Birkbeck College, London—gave a lecture on “A Generalization of Professor Whitehead’s Theory of Relativity” at the Physical Society of London. In the paper he read, Temple treats Silberstein as a scientific precursor of Whitehead (as I did in the previous section), and Alexander as a philosophical precursor. According to Temple, compared to the course of reasoning which led Whitehead to his alternative law of gravitation, “a similar course of reasoning is put forward by Prof. Samuel Alexander [in *Space, Time and Deity*].”⁸⁵ The interesting thing is that Whitehead was present, that he responded to Temple’s paper, and that his response is registered in the Proceedings of the Physical Society of London.

“Prof. A. N. Whitehead congratulated the Society on publishing the first Paper on this subject from the pen of a young scientist whose work augurs a very distinguished career. The mathematics in the Paper was handled in a way that showed the author to be the master and not the slave of his symbols.”⁸⁶ That Whitehead’s praise was sincere is proven by the fact that he was the main reason for Temple’s move from Birkbeck College to Imperial College. Temple became Demonstrator in Mathematics at Imperial College in 1924, the year Whitehead moved from London University to Harvard University.

“Prof. Whitehead then proceeded to indicate some respects in which his own presentation of Relativity differs from that of what may be called the orthodox school. The latter recognises only one field of natural relations, . . . wholly contingent. . . . Prof. Whitehead, on the other hand, puts forward a more conservative view—and in this he is supported on philosophical grounds by Prof. Alexander—and postulates two fields of natural relations [the geometrical field of uniform, spatio-temporal relations, and the physical field of contingent, causal relations, RD].”⁸⁷ In other words, Whitehead agreed with Temple to treat Alexander as one of his philosophical precursors, and reconfirmed in 1923 what he wrote in 1920 about the support of Alexander.

I limit myself to a mere hint at the importance of Alexander for Whitehead’s treatment of relativity, without going into further detail. I close the topic with a quote from Alexander justifying Whitehead’s use of the adjective *independent* when claiming Alexander’s support. In the February 1920 Preface to the first edition of *Space, Time and Deity* Alexander writes: “The first volume and the first two chapters of the second were in pages before the summer of last year, and accordingly I have made no reference to Mr. A. N. Whitehead’s work on *The Principles of Natural Knowledge*, nor to Mr. Einstein’s generalised form of the Theory of Relativity . . . which has lately become generally known in this country through Mr. Eddington and other exponents.”⁸⁸

In contemporary philosophical attempts to clarify the concept of “emergence,” next to Morgan’s *Emergent Evolution* and Alexander’s *Space, Time and Deity*, Broad’s *The Mind and its Place in Nature* is often considered as a necessary touchstone.⁸⁹ Apart from the interesting question of what happened with Morgan, Alexander, and Broad’s notion of emergence in Whitehead’s writings, I similarly hold that all accounts to

clarify Whitehead's mature concept of relativity need to include Broad, next to Morgan and Alexander.

In the Preface of *CN*, Whitehead writes: "Since the publication of *An Essay concerning the Principles of Natural Knowledge* I have had the advantage of reading Mr C. D. Broad's *Perception, Physics, and Reality* . . . This valuable book has assisted me in my discussion in Chapter II, though I am unaware as to how far Mr Broad would assent to any of my arguments as they stand."⁹⁰ *Perception, Physics, and Reality* actually was Broad's Cambridge dissertation, written under the influence of Russell and G.E. Moore, and published in 1914. Whitehead read the first book of this promising young philosopher—who first studied physics and chemistry, but was to become a leading contributor to analytic philosophy—after the publication of *PNK* in 1919, but before the appearance of Broad's *Scientific Thought* in 1923, and *The Mind and its Place in Nature* in 1925.⁹¹ Whitehead links the dissertation of Broad to Chapter II of *CN*. This chapter is about Whitehead's critique of the bifurcation of nature into the real and objective world of mathematical physics, and the apparent and subjective world of human perception. Einstein's treatment of relativity can be interpreted as an instance of deepening the gap between these two worlds, whereas Whitehead's treatment is an attempt to bridge the gap. The fact that Whitehead refers to Broad and his *Perception, Physics, and Reality*, is an incentive to study the influence of Broad and his writings on Whitehead's diagnostic and relativistic remedy of the bifurcation of nature.

Moreover, notice the link between the bifurcation of nature arising in my discussion of Broad, and the fallacy of misplaced concreteness arising in my discussion of Ward in the previous section: the first can be seen as resulting from the second. Taking the abstract world of science as concrete, and reifying abstractions such as "matter" and "space-time" to the extent of conceiving them as more real than the concrete perceived and perceptual events, entails the bifurcation of nature. This Ward-Broad link is important in the sense that, no matter how different they might be, according to Whitehead, like most other British philosophers they share the rejection of the error of bifurcating nature, which is why he writes that the British philosophers to whom he has heavy obligations to acknowledge, "amid their divergences of opinion, are united in the candid zeal of their quest for the truth."⁹²

Whitehead lived in a time when, and at a place where, the major philosophical dualisms—objective/subjective, real/apparent, primary/

secondary, mental/material, etc.—were heavily debated and fought by philosophers of the realist, the idealist, and the pragmatist brands. Whitehead knew most of the key debaters and fighters of each brand personally,⁹³ and one might argue that it is their shared fight against dualisms and bifurcations which most influenced Whitehead. However, and again, I will not enter into any detail, and postpone the tasks of highlighting affinities and divergences between Whitehead and Broad, and of showing how the shared fight of British philosophy transformed into Whitehead's fight against the bifurcation of nature and against misplaced concreteness. So I close my discussion on Broad, but not without telling an anecdote.

In the previous section I have emphasized that Whitehead transformed Minkowski's world-lines of substantial points into historical routes of events, a key notion in his alternative to GTR. In 1922, when defining the notion of historical route in *R*, Whitehead added in a footnote: "I borrow the term 'historical' from Prof. C.D. Broad."⁹⁴ In April 1923, a critical review of *R* appeared in *Mind*, and its author correctly observed that Whitehead's alternative law of gravitation appears as an equation involving historical routes, and that "this is perhaps the most original and philosophically interesting feature of his theory."⁹⁵ The critical review was signed by . . . C.D. Broad.

The next philosopher and key-member of the Aristotelian Society on my list is Wildon Carr. He already appeared in the previous section, and he will reappear in the last section. No wonder he is also on Whitehead's *PNK*-list of philosophers to acknowledge. In 1931, in his "In Memoriam" of Carr for *Mind*, F.C.S. Schiller—the primary English representative of pragmatism—focuses on two services Carr was able to render to philosophy. Schiller writes:

He [Carr] realized that Philosophy could not stand aloof from the development of the sciences, and pertinaciously urged upon his fellow philosophers the immense importance of the new physics of Relativity from which he drew a new argument in favour of idealism. Opinions differ, and will probably continue to differ, as to whether this argument is valid; but there can be little doubt that Philosophy must take scientific discoveries into account and reflect on them, if it does not desire to condemn itself to stagnation in a backwater of antiquated opinion.

Another and even greater service Carr was able to render to Philosophy was a consequence of his business ability, conciliatory personality, and great powers of organisation. He was a great organiser, who was able to overcome the extreme and almost pathological individualism of philosophers, and, *mirabile dictu*, to persuade them to co-operate for the common good of their subject. By these qualities he could make a success of any organisation with which he was connected. He belonged for over fifty years to the Aristotelian Society, and . . . it was Carr who was really responsible for raising it to its present rank as a national institution.⁹⁶

What Schiller wrote on Carr, could just as well have been written by Whitehead. Even though Whitehead wrote that “the necessary association of the physical theory of relativity with any form of idealistic philosophy is not at all evident to me,”⁹⁷ he agreed with Carr on its immense importance for philosophy, and he actively participated in the symposia and discussions Carr organised on the subject. Examples of such Aristotelian Society symposia and discussions to which both Whitehead and Carr contributed are: the 1919 symposium on “Time, space, and material: Are they, and if so, in what sense, the ultimate data of science?” (with Sir Oliver Lodge as one of the other participants), the 1922 discussion on “The idealistic interpretation of Einstein’s theory” (with Nunn and Dorothy Winch among the other participants), and the 1923 symposium on “The problem of simultaneity.”⁹⁸

For the third time, I must say that I will not go into further detail. I close my discussion on Carr with one small addition, paving the way to my treatment of Lord Haldane. Carr’s interest in the principle of relativity grew into his 1920 monograph on the subject, *The General Principle of Relativity, in its philosophical and historical aspect*.⁹⁹ The main thesis of the book was already spelled out in the first and the last sentence of his January 22nd 1919 article on “Einstein’s Theory,” which I mentioned in the previous section: “The principle on which Einstein’s general theory of relativity is based is not new to philosophy. . . . The new principle of relativity is the triumph of an old principle of philosophy.”

On the latter point, Whitehead certainly disagreed with Carr. For him, the principle of relativity implied a new philosophy of relatedness which drew a lot from *all* philosophical movements, but could not be captured under any of the existing philosophical labels, be it “idealist,” Carr’s label, or “realist,” the New Realists’ label. For him the idealism/realism opposition was one of the dualisms to be fought, and the occasional association of

Whitehead's thought with the New Realism of Russell, Moore, Alexander, Broad, and Nunn, is as inaccurate as its occasional association with the neo-Hegelianism of F.H. Bradley, McTaggart, and Lord Haldane.¹⁰⁰ True, a book can be written on the influence of New Realism on Whitehead, starting with the intellectual cross-fertilization of Whitehead and Russell. Also true: a book can be written on the influence of neo-Hegelianism on Whitehead, starting with the following Whitehead-quote: "I have never read a page of Hegel. That is not true. I remember when I was staying with Haldane at Cloan I read one page of Hegel. But it is true that I was influenced by Hegel. I was an intimate friend of McTaggart almost from the very first day he came to the University, and saw him for a few minutes almost daily, and I had many a chat with Lord Haldane about his Hegelian point of view, and I have read books about Hegel. But lack of first-hand acquaintance is a very good reason for not endeavouring in print to display any knowledge of Hegel."¹⁰¹ To characterize Whitehead's philosophy as realist, or as idealist, however, would be a mistake.

This brings us smoothly to the Whitehead-Haldane connection. What can be the connection between a mathematician creating a new philosophy of relatedness beyond the realism/idealism divide, and a politician who wrote on July 24, 1921: "I think I remain in the main an Hegelian, with Hegel interpreted *de novo*"?¹⁰² Apart from the fact that they were both philosophers, and members of the Aristotelian Society who developed a more intimate relation, frequently visiting each other and talking deep,¹⁰³ Whitehead and Haldane shared a passion for relativity, which culminated in their writings on Einstein's GTR, and in their encounter with Einstein himself. In order to be able to discuss the mutual Whitehead-Haldane influence (in this section), and to give an account of the Whitehead-Einstein encounter (in the final section), I must first give a quick summary of Haldane's biography.

Richard Burdon Sanderson Haldane was born in Edinburgh on July 30, 1856. His brother was the physiologist John Scott Haldane, and his sister was the author Elizabeth Haldane. Haldane studied in Edinburgh, in Göttingen, and in London. He often returned to Göttingen to renew his friendships in the town. "Haldane had close links with the German nation and was a great admirer of the country's cultural heritage and scientific prowess."¹⁰⁴

In 1885 Haldane was elected a Liberal Member of Parliament; in 1905 he was appointed Secretary of State for War; in 1911 he was given

a peerage, becoming the Viscount Haldane; and in 1912 Haldane succeeded Lord Loreburn as Lord Chancellor. But in 1915 he was forced to resign: “[Haldane] had been sent by the British government on an abortive mission to Germany in 1912 and had subsequently, almost on the outbreak of war, been unwise enough to speak of Germany as his ‘spiritual home.’ Not unexpectedly, he [was] hounded from office in 1915 after a propaganda campaign which alleged, among other things, that he was an illegitimate brother of the Kaiser, had a German wife—he was in fact a lifelong bachelor—and had delayed the mobilization of the British Expeditionary Force in 1914.”¹⁰⁵

Haldane was not only a politician, he was a philosopher as well. Prior to becoming Secretary of State for War in 1905, he had already published *Life of Adam Smith* in 1887, and *The Pathway to Reality*, his Gifford lectures delivered at the University of St. Andrews in the sessions 1902-04. During the period 1905-15, Haldane became a huge admirer of Einstein and his work, and after his resignation as Lord Chancellor in 1915, Haldane meditated on writing a book on the philosophy of relativity. It became his most important philosophical work, published as *The Reign of Relativity* in May 1921.

In 1922 Haldane published *The Philosophy of Humanism*, based on his Donaldson lectures at Trinity College in Dublin earlier that year, and to be considered as a continuation of *The Reign of Relativity*; in 1924 he became Lord Chancellor again; and later that same year he was chosen to be Leader of the House of Lords. Haldane died on August 19, 1928. Upon Haldane’s death, in a letter to his sister Elizabeth, Whitehead wrote: “Richard Haldane lived his life on a great scale, inspired by great motives, and effective in determining the great issues in action and in thought. It was impossible not to love him. In his presence one seemed to forget his greatness in one’s affection for him.”¹⁰⁶ And Haldane’s death prompted Einstein to write to Elizabeth: “He was one of the warmest and most harmonic people I had the opportunity of meeting in my life.”¹⁰⁷

Of course, the first element to consider in Haldane’s biography in order to understand the mutual Whitehead-Haldane influence is *The Reign of Relativity*. In *Haldane: The Life of Viscount Haldane of Cloan*, Haldane’s biographer, Frederick Maurice, reflects on the success of *The Reign of Relativity*: “Much of his success was, of course, due to the wide interest which Einstein’s statement of his theories had aroused, but the book had its origin not in Einstein, but in the development of Haldane’s philo-

sophical thought. It was a natural progression from the second volume of *The Pathway to Reality*. He had begun to meditate on this progression as soon as he left office in 1915 and *The Reign of Relativity* was the result of years of thought and of much reading and research. Einstein had acted as a spur to what was already moving in his mind. In the earlier work he had maintained the principle of degrees in knowledge and reality alike. From this it was but a step to the relativity of knowledge, the main thesis of *The Reign of Relativity*.¹⁰⁸

Carr would certainly summarize Maurice's comment on *The Reign of Relativity* by saying that the principle of relativity was not new to Haldane's philosophy. This summary invites us to oppose Whitehead and Haldane, for Whitehead considered Einstein and Minkowski's relativity as a radically new element in the history of philosophy. But, of course, this is not the whole story. Whitehead may not have shared Carr and Haldane's incorporation of the theory of relativity in an existing philosophy of the idealist brand, but that did not prevent him from helping Haldane with the mathematics of Einstein's theory,¹⁰⁹ and from drawing some important philosophical lessons from Haldane's humanism (the topic I will end this section with). On the other hand, it did not prevent Haldane from devoting twenty pages of his book to Whitehead's *PNK* and *CN*.

Haldane's extensive treatment of *PNK* and *CN* starts as follows: "It is interesting that an explanation has been insisted on in England of the whole doctrine of relativity which . . . is more thorough in the logical treatment of relativity than anything I have so far become acquainted with in the works of either Einstein himself or of his disciples in Germany. The author of this explanation is Professor A.N. Whitehead, who has set it forth in detail in two recent books, *The Principles of Natural Knowledge* and *The Concept of Nature*."¹¹⁰ Apparently Haldane's admiration for Whitehead equalled, or even surpassed, his admiration for Einstein and his German disciples. This impression is confirmed by three more quotes from *The Reign of Relativity*.

Haldane writes: "Bold leaders, like Einstein and Whitehead, are beckoning [the sciences of mathematics and physics] forward, from ground which is treacherous into territory which may or may not prove secure."¹¹¹ And: "Only one equipped as is Professor Whitehead with both mathematical and logical science of the highest order could have explored hitherto unfamiliar ground with the originality and the thoroughness which he has shown to us."¹¹² And once more: "Professor Whitehead seems to me

to have brought out [the character of space and time] in his treatment of relativity more thoroughly than Einstein or even Minkowski himself has done."¹¹³

This kind of treatment is certainly reason enough to make one blush, and after receiving Haldane's book by mail, Whitehead wrote to him on May 26, 1921: "This afternoon also brought me the copy of your book which you have been good enough to send me. In looking over its pages I have felt overwhelmed by your generous treatment of my work. I can only tell you—and it is the only thanks worth rendering—that it is an immense encouragement and the most solid honours which I can hope to attain."¹¹⁴ Haldane's book was an immense encouragement for Whitehead, as must have been a letter from Haldane in September or October 1921, to which Whitehead replied: "Your letter came as the greatest encouragement possible. After all, one writes for one or two people and the rest must take its distance. I do not believe in the disconnection between science and philosophy, though often it embodies a sound practical counsel in the particular circumstances of a short life, or of a special occasion. The complementarity of things impresses itself on one. I am distrusting ruthless simplifications, neglecting half the plain facts of existence. It is intolerable arrogance to assume that what we cannot immediately fit into our petty systems must be non-existent."¹¹⁵

Since Whitehead's fame has grown, it is difficult to picture him as in need of encouragement, but his letters to Haldane reveal that in the 1921-24 timeframe he was certainly not the victim of an army of enthusiastic admirers. Apart from a very limited number, most scientists and philosophers took their distance from his work. They felt uncomfortable with Whitehead's interdisciplinary approach, necessitated by his ultimate urge to think things together instead of thinking things away which do not seem to fit in one's limited scientific or philosophical worldview. This reminds me of the anecdote Whitehead tells in Chapter I of *R* about the "two distinguished persons" to whom he had explained the scheme of *R*: "The philosopher advised me to omit the mathematics, and the mathematician urged the cutting out of the philosophy. At the moment I was persuaded: it certainly is a nuisance for philosophers to be worried with applied mathematics, and for mathematicians to be saddled with philosophy. But further reflection has made me retain my original plan."¹¹⁶

One should not underestimate the isolating effect on Whitehead of trying to think together things that are as far apart in most minds as

science and philosophy. And consequently, one should not underestimate the important role people like Haldane played in stimulating Whitehead to keep on going. Another example of Haldane's encouragement can be found in Whitehead's response upon receiving Haldane's comment on *R*, following its 1922 publication: "You encourage me by your comment on my new book, even though I must suppose that—in the phraseology of the Romans—it is written 'with your own kindness.'"¹¹⁷ No wonder Whitehead looked forward to his evening gatherings with Haldane, and was disappointed when he could not make it. For example, in Whitehead's letter to Haldane of November 13, 1922, we read: "I look forward to the vivid pleasure of another evening with you."¹¹⁸ And in a letter Whitehead wrote to Haldane on June 27, 1922, he says: "To my very great regret I find that I am engaged on Friday night. It is a severe disappointment."¹¹⁹

Apart from the encouragement of a friend, Whitehead also benefited from some valuable philosophical lessons thanks to his friendship with Haldane, and thanks to his reading of Haldane's books. So let us turn to Haldane's *Reign of Relativity* again, and to his *Philosophy of Humanism*.

In *The Reign of Relativity* Haldane extends his treatment of relativity from the domain of physics to the domain of knowledge, and from the domain of knowledge to the domain of ethics. He extends Einstein's theory of relativity to a relativistic epistemology, and goes beyond epistemology when, at the end of his book, he asks: "Assuming the principle of relativity to mean all that has been said, what guidance does it offer for the conduct of our individual lives?"¹²⁰ Haldane does not think this question is difficult to answer. According to him, the relativity of all knowledge clearly implies an ethics of tolerance, and he writes that when we are fully aware of this relativity, there may come to us, "contentment of spirit, and a peace which passes our everyday understanding. We grow in tolerance, for we see that we are all of us more, even in moments of deep depression, than we appear to ourselves to be, and that humanity extends beyond the limits that are assigned even by itself to itself."¹²¹

This important lesson of Haldane's 1921 book did not escape its reviewers in the British newspapers. In *The Times* of May 27, 1921, a correspondent wrote: "Lord Haldane's volume, *The Reign of Relativity* . . . published today, gives us fresh hope. . . . As a warning against a disastrous dogmatism the principle of relativity, in this sense, although hardly original, cannot be enunciated too frequently."¹²² In *The Sunday Times* of May 29, 1921, Wildon Carr wrote in his review of the book: "Perhaps the most

interesting pages are near the end . . . Apparently, the chief practical lesson that the ex-Chancellor has learnt from life is toleration.”¹²³

The same warning against dogmatism, and the same promotion of tolerance, are important messages of Haldane’s 1922 book, *The Philosophy of Humanism*. The issue of the unavoidable limitation of all knowledge, implied by the overall relativity of things and thoughts, is treated in *The Philosophy of Humanism* as the issue that knowledge cannot be but an abstraction from concreteness. So Haldane’s 1921 warning that the real always extends beyond the boundaries of our knowledge, is translated in his 1922 warning that the real is always more concrete, even in its general principles, than our abstract knowledge of it.

Haldane writes: “The real is never abstract. It is always concrete, even in its general principles. This is a plain and obvious truth. We fall in love with persons, not with qualities. It is just you, here and now, that we turn to, not to any abstract construction out of general principles.”¹²⁴ But he adds that our knowledge of the real is never concrete; it is always abstract, even in its most concrete bits and pieces. So the unreachable aim of human knowledge, whether in science or philosophy, in art or religion, must be the point where the abstract general principles of knowledge meet the concrete general principles of reality. According to Haldane, trying to capture the general principles while bypassing the concrete, is falling “into the sin of the abstract mind,” whereas trying to capture the concrete while bypassing the general principles, is falling “into the disorderliness of those who build on shifting sand.” And he adds: “The well-balanced intelligence takes full account of both aspects, refusing to be plunged into abstractions, on the one hand, or to live from hand to mouth, on the other. The mind of genius reaches a yet higher level, for it does justice to the claims of both by bringing them into larger wholes in which the two aspects are transcended and so reconciled in a fuller entirety. This is the secret of genius alike in poetry and in science.”¹²⁵ In conclusion, Haldane urges his readers “to direct [their] attention to the fullness and richness of life, and to interpret these from a really comprehensive outlook.”¹²⁶

In the *Daily News* of June 22, 1922—the day *The Philosophy of Humanism* was published—Evelyn Underhill asked: “What is the contribution of humanism as Haldane defines it?” And she replied: “I think the answer must be this: it releases us from the tyranny of abstractions.”¹²⁷

Underhill’s review must have pleased Haldane, but even more so, Whitehead’s assessment of Haldane’s 1922 book. In a letter written to

Haldane on June 27, 1922, Whitehead thanks Haldane for sending his book, and he adds: "I was delighted to find that you start from the concrete fact—our 'enjoyment' of life—and postpone to the latter half of your lectures the abstractions of science. This procedure is consonant with your philosophical outlook, and is also one of the ways in which a philosopher who is also a statesman may correct philosophers who are also professors. I am more and more convinced that a thoroughgoing examination of abstractions and relatedness should be the starting-point of philosophy. If I construe rightly your attitude, you are a pioneer in enforcing this doctrine."¹²⁸

It is clear that Whitehead—a top mathematician who actually helped Haldane with the math needed to write the second part of his 1922 book, dealing with mathematical physics—did not turn to Haldane to learn about the physics of relativity. But it is also clear that Haldane's humanism was consonant with Whitehead's developing philosophical outlook, and even guided it to a certain extent. When Whitehead writes that "a thoroughgoing examination of abstractions and relatedness should be the starting-point of philosophy," we can add that it is exactly this examination of the paradoxical interplay of the concrete and the abstract, and of the relatedness of all events, started in his London period, which led to the philosophical masterpieces he wrote later in life. The secret of Whitehead's success, to a large extent, coincides with the secret of genius Haldane wrote about.

I cannot conclude my discussion of the Whitehead-Haldane friendship, and on their mutual influence, without quoting the touching words Whitehead wrote to Haldane on July 24, 1924, prior to leaving England for the US: "Beyond your kindness, which I have loved, and the interest of the great affairs which you have controlled, there is something that lies so much deeper that I cannot put it in the short phrases of a note: It is the example of your faith which has cheered me so much. I mean your unshaken belief that the philosophic impulse is not a minor curiosity, but a search for the solid basis of reason on which human faith can rest."¹²⁹

THE LONG SCIENTIFIC DISCUSSION WHICH SENT EINSTEIN TO BED

The one item I announced, but have not yet treated, is the fact that Whitehead and Einstein met in June 1921, thanks to the friendship and mutual admiration of Haldane and Whitehead. In *Einstein und Whitehead*, Joachim Stolz holds that this Whitehead-Einstein encounter, of

which he only read in Phillip Frank's Einstein biography, "is not in any way confirmed."¹³⁰ So I will not simply state the fact, but also prove it. A first element of my demonstration is Whitehead's May 26, 1921, letter to Haldane. In this letter Whitehead writes: "It will give me very great pleasure to accept your kind invitation to dinner on June 10th, and to have the honour of meeting Prof. Einstein."¹³¹

The point is that Haldane, who was a great admirer of Einstein (*cf.* previous section), had managed to convince Einstein to come to London and to stay at his home from June the 10th to June the 15th. The occasion was Einstein's first trip to the US, and the opportunity this offered to visit the UK upon his return. Of course, Haldane and his sister Elizabeth were thrilled that Einstein had accepted their offer. Both unmarried, they lived together, and wrote a letter to their mother almost every day.¹³² When the stay of Einstein and his wife Elsa's at Haldane's was finally settled, Haldane wrote to his mother: "The Einsteins are to stay here," and Elizabeth wrote: "The Einsteins are staying, which is no joke," adding that she had also been engaging a room for Einstein's friend, Dr. Freundlich.¹³³ The German astronomer Erwin Finlay Freundlich, whose mother was British, accompanied Einstein during his 1921 U.S.-U.K. trip, because he was familiar with both the English language, and with Einstein's relativity. In other words, he was perfect to act as Einstein's interpreter. As Elizabeth wrote to her mother on June 11, during the Einstein-visit: "Mrs. Einstein . . . speaks English quite well. . . . Prof. Freundlich is half Scotch so he speaks English too. Prof. Einstein can speak French, not English."¹³⁴

For Haldane, Einstein's visit was the perfect opportunity to invite some of his friends to come and meet Einstein, and to discuss relativity. Of course he invited Whitehead, whom he considered as Einstein's equal (*cf.* previous section). But, evidently, he also invited a number of other friends—politicians, religious leaders, scientists, philosophers, artists—to have dinner on June 10th with Einstein, or to join the reception afterwards. Given Haldane's status, and Einstein's fame, this high society event did not escape the attention of the British newspapers, and so one can consult *The Times* of June 11, 1921, and *The Jewish Chronicle* of June 17, 1921, to see that, next to Whitehead, Arthur Eddington and Wildon Carr were also invited, and met Einstein on June 10, 1921.¹³⁵

Actually, the Einsteins arrived on June 8 with the White Star liner *Celtic* in Liverpool, and on June 9, at the University of Manchester, Einstein addressed the Jewish Student Society, gave the Adamson lecture

on relativity, and was made *doctor honoris causa*. But on June 10, indeed, the Einsteins travelled to London. Haldane met them at two o'clock, and first took his visitors to Burlington House, where the famous November 6, 1919, meeting had taken place, and where they were welcomed by Eddington. Then Haldane took the Einsteins to his London home at Queen Ann's Gate "where a dinner party of quite exceptional nature was to be held for them that evening."¹³⁶

This exceptional dinner party is mentioned by many Einstein biographers. Unfortunately, only one incident receives their attention. Here is Ronald Clark's version of it: "Choosing his moment carefully, [Randall] Davidson [the Archbishop of Canterbury] turned to Einstein and queried: 'Lord Haldane tells us that your theory ought to make a great difference to our morale.' But Einstein merely replied: 'Do not believe a word of it. It makes no difference. It is purely abstract—science.'"¹³⁷ Given what I have already written on Haldane's philosophy, one can imagine the unease Einstein's remark must have caused.¹³⁸ "I can well understand Einstein hastily shearing off the subject," Eddington later noted of the incident, "in those days one had to become an expert in dodging persons who mixed up the fourth dimension with spiritualism. But surely the answer need not be preserved as though it were one of Einstein's more perspicacious utterances."¹³⁹

Next to this Davidson-Einstein exchange, however, Einstein's GTR was also on the menu of Haldane's dinner party on Friday June 10. Proof of this can be found in the letter Eddington sent to Einstein (at Haldane's) on June 12. Eddington writes: "Here is the paper we were speaking about on Friday night. Later on I shall be interested in our conversations about it."¹⁴⁰ The paper was his innovative 1921 paper, "A Generalization of Weyl's Theory of the Electromagnetic and Gravitational Fields" (*cf.* "Scientific Account, Part 1"), and Eddington informs Einstein that his work "is an *extension*, but is not in the slightest degree an *emendation*, of yours."¹⁴¹ Einstein's initial response was negative—he thought it was "beautiful but physically meaningless."¹⁴² But his opinion was to change, and by July 3, 1922, he wrote to Haldane: "Eddington's extension of Weyl's theory is truly based on a deep thought. I am trying hard, but in vain, to complete the course of thought, in order for it to acquire the character of a well-rounded theory."¹⁴³

So what about Whitehead? Did he also discuss relativity with Einstein that evening? The answer is yes. And I will demonstrate this in two steps: yes they had a discussion, yes it was about relativity. As a first step, I offer

a quote from *Life Cycles: Reflections of an Evolutionary Biologist*, an autobiographical memoir written by John Tyler Bonner. In his account of a meeting he had with Einstein at Princeton, Bonner writes the following:

I told him [Einstein] that I knew philosopher Alfred North Whitehead and had once asked him if he had ever met Einstein. Whitehead replied that indeed he had—under the most embarrassing circumstances. Lord Haldane, a very forceful man, had invited both of them to dinner. After dinner he escorted them to his study and left them there alone, saying they must have so much to say to each other. He told me, ‘Both Professor Einstein and I are very shy men, and we had an excruciating time—neither of us could think of what to say.’ I asked Professor Einstein if his memory of the event was the same. He gave me a warm smile and said it certainly was—it was a painful evening indeed. ‘You see,’ he said, ‘I was never able to understand anything Whitehead had written, so what could I say?’¹⁴⁴

It is highly unlikely that Haldane separated Whitehead and Einstein from his other guests on the evening of June 10 and, even though their shyness may have prevented them from talking smoothly, neither could have had trouble talking on the subject of relativity. It is also unlikely that Freundlich was not present, because Einstein did not speak English, Whitehead’s French was poor, and maybe his German was insufficient too, which may have been the reason for Freundlich’s presence when Whitehead and Einstein discussed relativity again the next day, on June 11. Anyway, what Bonner’s account does show is that they did have a talk. And that Whitehead was shy is confirmed by the fact that contrary to most people who met Einstein, including Haldane during Einstein’s stay, he most probably did not organize to have pictures taken of him and Einstein, for I am unable to trace one.

The second step in my demonstration that Whitehead and Einstein discussed relativity is what Phillip Frank writes in his Einstein biography. According to Frank: “Whitehead had long discussions with Einstein and repeatedly attempted to convince him that on metaphysical grounds the attempt must be made to get along without the assumption of a curvature of space. Einstein, however, was not inclined to give up a theory, against which neither logical nor experimental reasons could be cited, nor considerations of simplicity and beauty. Whitehead’s metaphysics did not seem quite plausible to him.”¹⁴⁵ Frank’s account seems much more plausible to me than Bonner’s. It is indeed very likely that Whitehead tried to convince Einstein to give up his identification of the geometry of space-time and

the physics of gravitation, which implied a non-uniform curvature of space-time by the inhomogeneous spread of matter, hence contradicting Whitehead's metaphysical view of the spatio-temporal uniformity of the network of all events.

An interesting aspect of Frank's account is the fact that he does not write "a long discussion," but "long discussions," and that he claims that Whitehead *repeatedly* attempted to convince Einstein. This aspect of Frank's account can also be confirmed. Indeed, in the overview to her mother of what happened during Einstein's stay on June 11, the day after the dinner-party, Elizabeth Haldane writes "Whitehead, the mathematician, had a long and useful talk," and she adds that "afterwards . . . the Einsteins rested."¹⁴⁶ Moreover, the fact that Whitehead and Einstein also had a long discussion on Saturday July 11, is confirmed by a special correspondent of *The Times*—most likely J.W.N. Sullivan—and by a Spanish journalist of *El Sol*, Ricardo Baeza, who was based in London and Dublin in 1920-21. The strikingly similar accounts of the joint interview the *Times* correspondent and Baeza had with Einstein—assisted by Freundlich—on July 11, appeared in *The Times* of June 13, 1921, and in *El Sol* on July 4, 1921.

A servant ushered the two journalists into Lord Haldane's library, and they were told that Einstein had just risen from bed, having been tired out by a long scientific discussion just before their visit (which, by the way, corresponds nicely with what Elizabeth writes on Einstein resting after his talk with Whitehead). During the interview, at a certain point, the *Times* journalist mentioned Whitehead and his alternative theory of relativity. Here is what he writes on what happened then: "Both Einstein and his disciple [Freundlich] became more animated at this point, and informed me that they had just spent two hours in discussing his theory with Professor Whitehead and that they did not yet fully understand it. I remembered the 'long scientific discussion' which, I had been told, had sent Einstein to bed, and I did not press the matter."

What more proof does one need? In the absence of proof, Scholz could write that Frank's account on the Whitehead-Einstein discussions was not in any way confirmed. But as of now, no Whitehead scholar should ever question Frank's account again. However, every Whitehead scholar can still be a bit sad, as I am, that no details on these private discussions have been saved. Whitehead may have taken notes, since Haldane's letter to his mother of June 17, contains the sentence: "Last night, Prof. Whitehead,

the mathematician, dined with me alone, to compare notes.”¹⁴⁷ However, maybe I should not take this too literally, since it may be that Haldane and Whitehead just exchanged their impressions on the Einstein visit. These—by the way—must also have included impressions of the famous talk Einstein gave at King’s College on June 13, a talk Haldane introduced to the audience, and which Whitehead attended—and not as just one among the audience, like his student Herbert Dingle, but as Dean of the Faculty of Science of the University of London, next to other prominent people, such as Professor Lindemann, with whom Einstein spent a whole day in Oxford on June 14. On the other hand, if I take Haldane’s remark on having dinner with Whitehead on June 16 to compare notes literally, and they both made notes, then the sad thing is that Haldane’s notes are not among his papers in the National Library of Scotland, and Whitehead’s private papers were destroyed after his death.

Let us end this paper not on a sad note, but with an expression of hope. I hope the material it contains is sufficient to persuade philosophers and historians of science not to exclude Whitehead from their relativity-accounts in the future, as has been the rule in the past. I hope, e.g., that if Thomas Ryckman ever publishes an enlarged edition of his marvelous *The Reign of Relativity: Philosophy in Physics 1915-1925*, he will not again limit himself to just giving a Haldane quote at the start of his introduction, and mentioning that Haldane wrote *The Reign of Relativity* in a hidden endnote. Haldane and—above all—his friend Whitehead deserve better.

ACKNOWLEDGEMENT

I sincerely thank the following persons for their support and encouragement: John Cobb, Hilmar Duerbeck, Tim Eastman, Peter Farleigh, Thomas Glick, Isabelle Stengers, Jean Paul Van Bendegem, and Michel Weber.

NOTES

1. Research Assistant at the Center for Logic and Philosophy of Science, Brussels University, <http://www.vub.ac.be/CLWF/members/ronny/index.shtml>.
2. Volume II, Chapters I to VI.
3. Actually, one should henceforth read “Lowe and McHenry” each time I write “Lowe,” for Leemon McHenry, while being Lowe’s research assistant, was in fact the principal author of Chapters V and VI.

4. Lowe 1990: 94.

5. Ibid.

6. Ibid., 15.

7. Ibid. Notice that Minkowski's "Raum und Zeit" was not published in 1908, but in 1909. However, his "Die Grundgleichungen für die elektromagnetischen Vorgänge in bewegten Körpern" was published in 1908, so Whitehead may have referred to that paper.

8. Lowe 1990: 94.

9. Ibid., 123.

10. *PNK* vii.

11. Lowe 1990: 7.

12. See, e.g., Walter 1999: 115-17.

13. See, e.g., Goldberg 1970: 113-17, Sanchez-Ron 1987: 39-41 and 49-53, Warwick 2003: 399-442.

14. See, e.g., Sanchez-Ron 1987: 49-53, and 1992: 59-72; Havas 1993: 88-125; McCausland 1999: 278-83; and Duerbeck and Flin 2005: 186-209 and 2006: 1087-94.

15. Sanchez-Ron 1987: 53.

16. *ESP* 285.

17. *UA* 573.

18. Crowe 1967: 229.

19. Goldberg 1970: 98. Goldberg refers to G.N. Lewis and R.G. Tolman, "The Principle of Relativity and Non-Newtonian Mechanics." *Phil. Mag.* 18: 281-93.

20. Walter 1999a: 103 and 115. Lewis' 1910 paper can be found in *Proceedings of the American Academy of Arts and Science* 46: 165-81.

21. However, Walter stresses that, in his collaboration with Wilson, Lewis kept the same symbolic notation as before, but adopted the non-Euclidean style. Cf. Walter 1999a: 115. In fact, Walter's 1999a paper is all about "The non-Euclidean style of Minkowkian relativity."

22. See, e.g., *MCMW* 11, *ESP* 260 and 265, *ADG* 41, and *CN* 121-24.

23. Lewis & Wilson 1912: 389.

24. *PNK* 141.

25. *CN* 123.

26. See Lowe 1985: 92-109, and Warwick 2003: 333-98.
27. Wilson and Lewis 1912: 473.
28. The exception is what I said on the Wilson-Lewis definition of congruence.
29. Their biographies also intersect at other occasions, e.g., at the Newcastle Meeting of the British Association for the Advancement of Science in September 1916 (Sanchez-Ron 1992: 6 and Warwick 2003: 462).
30. Warwick 2003: 399-442.
31. E.g., by 1918, Arthur Eddington wrote in the Preface to his Report on the Relativity Theory of Gravitation: "The older theory of relativity . . . is fully treated in the well-known text-books of L. Silberstein . . . and E. Cunningham" (vii).
32. Duerbeck and Flin 2006: 1087-89.
33. Lowe 1990: 161 and 240.
34. Nunn read the proofs of Silberstein's 1914 book (Silberstein 1924: v). On July 8, 1922, in a letter to Lord Haldane, Nunn writes: "I am not a mathematician, but I am an amateur of the subject and have mixed a good deal with men (like L. Silberstein) who are keen followers and even developpers of the theory of relativity when it first came among us" (National Library of Scotland, Haldane Papers, manuscript 5915, folio 192). No wonder that in April 1923, in the Preface to his *Relativity and Gravitation*, Nunn refers to Silberstein's writings for a fuller treatment of the subject (Nunn 1923: 6).
35. Whitehead's *UA* had led to his election to the Royal Society (Lowe 1962: 137), and his account of the November 1919 meeting is one of the most-quoted parts of his writings (*SMW* 10).
36. Russell 1968: 78.
37. *PNK* vi.
38. This lecture is included as Chapter VIII of Whitehead's 1920 *CN*.
39. Whitehead's "Einstein's Theory" is reprinted in *ESP* (332-42) and in *IS* (125-35).
40. *ESP* 332 and *IS* 125.
41. E.g., Wilson and Lewis 1912: 391 and 495; and Silberstein 1924: 125, 127-28, 141, 266, and 282.
42. Minkowski 1908: 76.
43. *Ibid.*, 1908: 91.
44. Walter 1999b: 69.

45. *Ibid.*, 71.
46. *Ibid.*, 71-72.
47. *Ibid.*, 72.
48. Wilson and Lewis 1912: 495-96.
49. Silberstein 1924: 86, 241.
50. Cunningham 1914: 109.
51. *Ibid.*, 1914: 171-80.
52. Warwick 2003: 453.
53. Cunningham 1914: 180.
54. Corry 2004: 192, 227.
55. *ESP* 225.
56. Warwick 2003: 457-58; for similar accounts of this 1916 De Sitter-Eddington exchange, see Stachel 2002: 456 and Crelinsten 2006: 94-98.
57. Warwick 2003: 462-63.
58. Sanchez-Ron 1992: 76.
59. *OT* 105-33.
60. Sanchez-Ron 1992: 59.
61. *Ibid.*, 60-61.
62. *Ibid.*, 71-72.
63. Fort 2003: 1-2.
64. *Ibid.*, 30-32.
65. *Ibid.*, 1.
66. "Dear Michele! I'm sending you some reprints, asking you to forward them to Dr. L. Silberstein . . . who has requested them." The German quote in the main text is a quote from Document 335 in *The Collected Papers of Albert Einstein*, Volume 8, Part A, p. 446. For the English translation, and more details on the Silberstein-Einstein correspondence, cf. Duerbeck and Flin 2006: 1089.
67. For the Whitehead-Eddington professor-student relationship, see Douglas 1957: 10.
68. Pais 1983: 305.
69. Duerbeck and Flin 2005: 186.
70. *R v.*

71. Lowe 1985: 118.
72. *PNK* viii.
73. Quote from Pierfrancesco Basile's "James Ward (1843-1925)," to be published.
74. For an account of the 1916-17 Einstein-De Sitter dialogue, see Janssen 1998: 351-57 (also <<http://www.tc.umn.edu/~janss011/>>) and Crelinsten 2006: 103-08 and Matteo Realdi's 2007 lecture "The Universe of Willem de Sitter" (also <http://www.phil-inst.hu/~szekely/PIRT_BUDAPEST/>).
75. *ESP* 334-35 and *IS* 128.
76. Minkowski 1908: 76.
77. *R* 88.
78. This has been shown by Eddington in 1924.
79. This has been shown by Robert Russell and Christoff Wasserman in 1987.
80. Cf. Lowe 1990: 127.
81. *ESP* 14.
82. *CN* vii-viii.
83. *Ibid.*, viii.
84. *SMW* viii.
85. Temple 1923: 177.
86. *Ibid.*, 192.
87. *Ibid.*, 193.
88. Alexander 1920: xli.
89. See, e.g., Clayton 2006: 1-37.
90. *CN* viii.
91. Van Cleve 2005: 57.
92. *PNK* viii.
93. To give an example for each brand, not discussed in this essay: Bertrand Russell, J.M.E. McTaggart, and F.C. Schiller (all three are mentioned by Whitehead in *PNK* viii).
94. *R* 30.
95. Broad 1923: 219.
96. Schiller 1931: 535.

97. *IS* 145.

98. For these symposia and discussions, see the *Proceedings* of the Aristotelian Society, and for a reprint of Whitehead's contributions, respectively, *IS* 56-68, 145-48, and 149-56.

99. In the Preface to his 1920 book, Carr gives an interesting summary of how his interest in the principle of relativity developed.

100. Cf. Lowe 1990: 109.

101. *ESP* 116.

102. National Library of Scotland, Haldane Papers, ms. 5915, folio 82.

103. Lowe 1990: 82.

104. White and Gribbin 1993: 158.

105. Clark 1971: 272.

106. National Library of Scotland, Haldane Papers, ms. 6034, folio 22.

107. *Ibid.*, ms. 6034, folio 92 (my translation).

108. Maurice 1938: 98.

109. Lowe 1990:82 and Haldane 1922: v.

110. Haldane 1921: 63.

111. *Ibid.*, 75.

112. *Ibid.*, 81.

113. *Ibid.*, 110.

114. National Library of Scotland, Haldane Papers, ms. 5915, folio 17.

115. *Ibid.*, ms, 5915, folios 97-101.

116. *R* 4.

117. National Library of Scotland, Haldane Papers, ms. 5915, folio 223.

118. *Ibid.*, ms. 5915, folio 223.

119. *Ibid.*, ms. 5915, folio 183.

120. Haldane 1921:425.

121. *Ibid.*, 426.

122. National Library of Scotland, Haldane Papers, ms. 6105. page 114, folio 142.

123. *Ibid.*, ms. 6105, page 115, folio 143.

124. Haldane 1922: 87-88.

125. Ibid., 92.
126. Ibid., 99.
127. National Library of Scotland, Haldane Papers, ms. 6105, page 133, folio 163.
128. Ibid., ms. 5915, folio 183.
129. Ibid., ms. 5916, folio 129.
130. Stolz 1995: 30.
- 131 National Library of Scotland, Haldane Papers, ms. 5915, folio 17.
132. At the end of his visit, Einstein wrote to Haldane's mother: "For the first time in my life I have heard of a prominent man who converses by letter every day with his mother." Ibid., folio 132, my translation.
133. Ibid., manuscript 6004, folios 104-105 & ms. 6056, folios 120-21.
134. Ibid., ms. 6056, folios 124-25.
135. Eddington, like Whitehead, was invited for dinner; Carr only for the reception held afterwards. Ibid., ms. 6105, page 121, folio 150.
136. Clark 1971: 274.
137. Ibid., 1971: 275.
138. Maybe that is the reason why Elizabeth wrote to her mother the next day that "the atmosphere was tense." National Library of Scotland, Haldane Papers, ms. 6056, folios 124-25.
139. Quoted by Clark 1971: 276.
140. Quoted by Ryckman 2005: 285.
141. Quoted by Ryckman 2005: 221.
142. Quoted by Stachel 2002: 467.
143. National Library of Scotland, Haldane Papers, ms. 5915, folio 188.
144. Bonner 1993: 66-67.
145. Frank 1947: 189.
146. National Library of Scotland, Haldane Papers, ms. 6056, folios 126-27.
147. Ibid., ms. 6004, folio 113.

WORKS CITED

- Alexander, Samuel. *Space, Time and Deity. Volume I.* 1927 Impression of 1920 First Edition. Kessinger Publishing's Rare Reprints.

- Basile, Pierfrancesco. "Rethinking Leibniz: Whitehead, Ward, and the Idealist Legacy." *Process Studies* 35 (2006): 207-29.
- _____. "James Ward (1843-1925)." Forthcoming.
- Bonner, John Tyler. *Life Cycles: Reflections of an Evolutionary Biologist*. Princeton UP, 1993.
- Broad, Charles Dunbar. "Review: *The Principle of Relativity, with Applications to Physical Science*." *Mind* 32 (1923): 211-19.
- Carr, Herbert Wildon. "Einstein's Theory." *The Times, Educational Supplement* of January 22, 1920: 47.
- _____. *The General Principle of Relativity, in Its Philosophical and Historical Aspect*. London: MacMillan, 1920.
- Clark, Ronald. *Einstein: A Life*. New York: John Wiley, 1971.
- Clayton, Philip. *Mind & Emergence: From Quantum to Consciousness*. Oxford UP, 2006.
- Corry, Leo. *David Hilbert and the Axiomatization of Physics (1898-1918)*. Dordrecht/Boston/London: Kluwer Academic Press, 2004.
- Crelinsten, Jeffrey. *Einstein's Jury: The Race to Test Relativity*. Princeton UP, 2006.
- Crowe, Michael. *A History of Vector Analysis*. Notre Dame and London: U of Notre Dame P, 1967.
- Cunningham, Ebenezer. *The Principle of Relativity*. Cambridge at the University Press, 1914.
- Douglas, Alice Vibert. *Arthur Stanley Eddington*. Toronto and New York: Thomas Nelson, 1957.
- Duerbeck, Hilmar W., and Piotr Flin. "Ludwik Silberstein—Einstein's Antagonist." *Einstein's Kosmos*. Ed. Hilmar W. Duerbeck and Wolfgang R. Dick, Frankfurt am Main: Verlag Harri Deutch, 2005: 186-209.
- _____. "Silberstein, General Relativity and Cosmology." *Albert Einstein Century International Conference*. Ed. J.-M. Alimi and A. Füzfa. American Institute of Physics, 2006: 1087-94.
- Eddington, Arthur. *Report on the Relativity Theory of Gravitation*. 1918. New York: Dover Phoenix Editions, 2006.
- _____. "Comparison of Whitehead's and Einstein's Formulae." *Nature* 113 (1924): 192.
- Einstein, Albert. *The Collected Papers of Albert Einstein. Volume 8. The Berlin Years: Correspondence, 1914-1918, Part A: 1914-1917*. Ed. Schulmann, Kox, Janssen, and Illy. Princeton UP, 1998.
- Fort, Adrian. *PROF: The Life of Frederick Lindemann*. London: Jonathan Cape, 2003.
- Frank, Phillip. *Einstein: His Life and Times*. New York: Knopf, 1947.

- Goldberg, Stanley. "In Defense of Ether: The British Response to Einstein's Special Theory of Relativity." *Historical Studies in the Physical Sciences*. Ed. Russell McCormmach. Philadelphia: U of Pennsylvania P, 1970: 89-125.
- Haldane, Richard. *The Reign of Relativity*. New Haven: Yale UP, 1921.
- _____. *The Philosophy of Humanism*. London: John Murray, 1922.
- _____. *An Autobiography*. London: Hodder and Stoughton, 1931.
- Havas, Peter. "The General-Relativistic Two-Body Problem and the Einstein-Silberstein Controversy." *The Attraction of Gravitation: New Studies in the History of General Relativity*. Ed. John Earman, Michel Janssen, and John Norton. Boston/Basel/Berlin: Birkhäuser, 1993: 88-125.
- Janssen, Michel. "The Einstein-De Sitter-Weyl-Klein Debate." See Einstein 1998: 351-57.
- Lewis, Gilbert Newton. "On Four-Dimensional Vector Analysis and Its Applications in Electrical Theory." *Proceedings of the American Academy of Arts and Sciences* 46 (1910): 165-81.
- Lindemann, Frederick. "Einstein's Theory: A Revolution in Thought." *The Times, Educational Supplement* of January 29, 1920: 59.
- Lowe, Victor. *Understanding Whitehead*. Baltimore: John Hopkins, 1966.
- _____. *Alfred North Whitehead: The Man and His Work; Volume I: 1861-1910*. Baltimore and London: John Hopkins, 1985.
- _____. *Alfred North Whitehead: The Man and His Work; Volume II: 1910-1947*. Ed. J. B. Schneewind. Baltimore and London: John Hopkins, 1990.
- Maurice, Frederick. *Haldane: The Life of Viscount Haldane of Cloan*. London: Faber and Faber, 1938.
- McCausland, Ian. "Anomalies in the History of Relativity." *Journal of Scientific Explorations* 13 (1999): 271-90.
- Minkowski, Hermann. "Space and Time." 1918. *The Principle of Relativity*. Ed. Arnold Sommerfeld. New York: Dover, 1923.
- Nunn, T. Percy. *Relativity and Gravitation*. London: U of London P, 1923.
- Pais, Abraham. 'Subtle is the Lord . . .' *The Science and Life of Albert Einstein*. Oxford UP, 1982.
- Russell, Bertrand. *The Autobiography of Bertrand Russell. Vol. 2 (1914-1944)*. London: George Allen & Unwin, 1968.
- Realdi, Matteo. "The Universe of Willem de Sitter." 2007 <http://www.phil-inst.hu/~szekely/PIRT_BUDAPEST>.
- Russell, Robert, and Christoff Wasserman. "Kerr solution of Whitehead's theory of gravity." *Bulletin of the American Physical Society* 32 (1987): 90.
- Ryckman, Thomas. *The Reign of Relativity: Philosophy in Physics 1915-1925*. Oxford UP, 2005.

- Sanchez-Ron, José M. "The Reception of Special Relativity in Great-Britain." *The Comparative Reception of Relativity*. Ed. Thomas F. Glick. Dordrecht: D. Reidel, 1987: 27-58.
- _____. "The Reception of General Relativity Among British Physicists and Mathematicians (1915-1930)." *Studies in the History of General Relativity*. Ed. Jean Eisenstaedt and A.J. Kox. Boston-Basel-Berlin: Birkhäuser, 1992: 57-88.
- Schiller, F.C.S. "In Memoriam: Herbert Wildon Carr, Jan. 1, 1857-July 8, 1931." *Mind, New Series* 40.160 (1931): 535-36.
- Silberstein, Ludwik. "General Relativity without the Equivalence Hypothesis." *Philosophical Magazine*. 36 (1918): 94-128.
- _____. *The Theory of Relativity: Second Edition, Enlarged*. London: Macmillan, 1924.
- Stachel, John. *Einstein from 'B' to 'Z'*. Boston/Basel/Berlin: Birkhäuser, 2002.
- Stolz, Joachim. *Whitehead und Einstein*. Frankfurt am Main: Peter Lang, 1995.
- Temple, George. "A Generalisation of Professor Whitehead's Theory of Relativity." *Proceedings of the Physical Society of London*. 36 (1923): 176-93.
- Van Cleve, James. "C.D. Broad (1887-1971)." *A Companion to Analytical Philosophy*. Ed. Martinich and Sosa. Oxford: Blackwell, 2005: 57-67.
- Walter, Scott. "The non-Euclidean style of Minkowskian relativity." 1999a. *The Symbolic Universe: Geometry and Physics 1890-1930*. Ed. Jeremy Gray. Oxford UP, 1999: 91-127.
- _____. "Minkowski, Mathematicians, and the Mathematical Theory of Relativity." 1999b. *The Expanding Worlds of General Relativity*. Ed. Groenner, Renn, Ritter, Sauer. Boston/Basel: Birkhäuser, 1999.
- Warwick, Andrew. *Masters of Theory: Cambridge and the Rise of Mathematical Physics*. Chicago-London: U of Chicago P, 2003.
- White, Michael & Gribbin, John. *Einstein: A Life in Science*. London and New York: Simon & Schuster, 1993.
- Wilson, Edwin Bidwell, and Lewis Gilbert Newton. "The Space-Time Manifold of Relativity." *Proceedings of the American Academy of Arts and Sciences*. 48.11 (1912): 389-507.

WHITEHEAD, ALFRED NORTH. IN CHRONOLOGICAL ORDER:

- UA. *A Treatise on Universal Algebra, with Applications*. 1898. New York: Hafner, 1960.
- MCMW. "On Mathematical Concepts of the Material World." 1905/1906. *Alfred North Whitehead: An Anthology*. Ed. Northrop and Mason. New York: MacMillan, 1961: 7-82.

- ADG. *The Axioms of Descriptive Geometry*. 1907. New York: Dover Phoenix Editions, 2005.
- PM. *Principia Mathematica to *56*. 1910. Cambridge at the UP, 1970.
- IM. *An Introduction to Mathematics*. 1911. Oxford UP, 1958.
- TRE. "La Théorie Relationniste de l'Espace." 1914. *Revue de Métaphysique et de Morale* 23.3 (1916): 423-51.
- OT. *The Organisation of Thought*. 1917. Westport Connecticut: Greenwood Press, 1974.
- PNK. *An Enquiry Concerning the Principles of Natural Knowledge*. 1919. New York: Dover Publications, 1982.
- RS. "A Revolution of Science." *The Nation* of November 15, 1919: 232-33.
- CN. *Concept of Nature, The*. 1920. Cambridge UP, 1986.
- R. *The Principle of Relativity with applications to Physical Science*. Cambridge at the UP, 1922.
- SMW. *Science and the Modern World*. 1925. New York: Free Press, 1967.
- PR. *Process and Reality*. 1929. Revised. Ed. Donald Sherburne and David Ray Griffin. New York: MacMillan Company, 1979.
- ESP. *Essays in Science and Philosophy*. 1947. Westport Connecticut: Greenwood, 1968.
- IS. *Interpretation of Science: Selected Essays*. Ed. A. H. Johnson. New York: Bobbs-Merril, 1961.