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The Impact of Religion on Kelvin's Physical Insights. Thermodynamics and the Age of the Earth

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Abstract

Thermodynamics developed as a new branch of physics in the 19th century helping to go beyond a purely mechanistic understanding of nature. Among its founding fathers, it is William Thomson (Lord Kelvin) who offers a most promising perspective in order to highlight the influence of religious views in the improvement of science. In this article, I will focus on the controversy about the age of the Earth—which confronted Kelvin with many geologists and defenders of the theory of evolution—and I will explain the connections between Kelvin's credo and his scientific attack on uniformitarianism. Kelvin's contribution, even if ultimately proven wrong, was right in spirit and served the transition from qualitative to quantitative geology.

Keywords: Influence of religion on science, Kelvin's religious and physical insights, Thermodynamics and the age of the earth, Scientific controversies in 19th century

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1 INTRODUCTION

The history of Thermodynamics is one of the most interesting and dramatic episodes to be found in the history of science. Starting as an investigation on engineering problems, it has become a scientific theory of deep philosophical significance, with consequences inspiring the thoughts of men on many subjects, from economy to cosmology, let alone the sciences of life. Nevertheless, Thermodynamics had to fight throughout its development with former misapprehensions of the nature of heat and of the structure of matter. This new branch of Physics replaced the old conceptions of the caloric theory, vitalism, perpetual motion and affinity theory with the kinetic theory of heat, the laws of conservation of energy and increasing entropy in isolated systems, and the key concept of free energy for understanding chemical reactions.[1]

While there is some debate regarding who must be considered the founding father of Thermodynamics, its most relevant contributors are well recognized. Some of them, like Clausius and Boltzmann, do not possess religious affiliation at all. Others do to some extent: Sadi Carnot had a keen religious sense and considered religion as a benefit for society, provided that it was founded on toleration; James Joule was a sincere Christian who, occasionally, refers to the Almighty in his papers and correspondence; Josiah W. Gibbs was an American Congregationalist of serene piety as shown by his conscientious work and steady churchgoing. But in all these cases, according to the literature, there is no discernible connection between their religious faith and their scientific research.

It is well known that religion had an indirect influence on science in preceding centuries. Religious beliefs could operate within science, providing presupposition and sanction as well as regulating the discussion of method. (Brooke 2014, 110–157, 170, 438) Can we still find any examples of such connection, namely, a religious world-view influencing the scientific work, in the field of Thermodynamics? Undoubtedly, the most promising actors in this regard are three representatives of the Scottish School of Thermodynamics, with its centers both in Edinburgh and Glasgow: James Clerk Maxwell (1831–1879), Peter J. Tait (1831–1901), and

William Thomson (1824–1907), first baron Kelvin—all of whom showed a remarkable interest in the relationship between scientific knowledge and religious questions.

Maxwell was an evangelical Presbyterian who became an Elder of the Church of Scotland. His scientific position was markedly non-positivist and, in his later years, he wrote on the interplay between determinism and free will according to the progress of Physics, as well as on the implications of Thermodynamics regarding the soul's immortality, evolution, morality and consciousness.[2] Tait, assiduous collaborator with Maxwell and Kelvin, was a deeply religious man eventually interested in overthrowing materialism by a purely scientific argument. He also dealt with immortality from a thermodynamic perspective, the heat death of the universe, and the thoughts considered as molecular motions of the brain. (Stewart and Tait 1875) However, even if important links between scientific and religious questions are strongly present in Maxwell and Tait, none of them exemplifies as much as Thomson a true influence of religious knowledge in their scientific research.

As I will try to show in the rest of this article, Lord Kelvin's religious convictions about a created universe—with a beginning and an end—were decisive in the development of the Second Law of Thermodynamics and, more specifically, in changing contemporary geologists' common view regarding the age of the Earth. Of course, the goal of this contribution is not to prejudge the validity of Kelvin's religious and scientific ideas, ultimately proven wrong, but to stress the influence of the former on the latter and the benefit for the progress of geology therein obtained.

2 KELVIN'S CONVICTIONS REGARDING SCIENCE AND RELIGION

William Thomson was an Elder of St Columba's Parish Church (Church of Scotland) in Largs for many years, and remained a devout believer in Christianity throughout his life. It was to that church that his remains were taken after his death in 1907, before final interment at Westminster Abbey, closeby the resting place of Isaac Newton. As Newton, Kelvin was committed throughout his career to natural theology. He did not see any conflict between his mechanical philosophy of nature and his theology, being a firm believer in design but rejecting the "frivolities of teleology." (Roche 2008, 96) However, one of his initial biographers, Silvanus Thomson, judges him as not particularly theistic: "a man who was personally, but not conventionally, religious; a man who would argue for the opening of museums, galleries, and libraries on Sunday, but who would dock his yacht on Sunday morning so that the crew (but not necessarily himself) could attend church. He was equally at home at Presbyterian services in Glasgow, Episcopal services in London, and Free Church services at Largs." (Thompson 1910; Burchfield 1990, 48)

Nevertheless, Kelvin remained a devout believer in Christianity throughout his life and, seemingly, attendance at chapel was part of his daily routine by the end of his life. But more than his personal commitment to a specific church, our main interest in this section tackles his overall viewpoint of the relationship between science and religion. We can summarize his understanding in three general assertions illustrated by some personal quotations:

(1) Kelvin was a scientist, far from any kind of fundamentalism and creationism:[3] "If a probable solution [to any scientific problem], consistent with the ordinary course of nature can be found, we must not invoke an abnormal act of creative power." (Thomson 1871/2011) His belief in the evidence of design in nature did not entail any belief in a continuous interference in the mechanism of the universe, or even in an occasional miracle. It was only in the creation of life that Kelvin believed that a divine alteration in the laws of nature was either necessary or probable. (Burchfield 1990, 48)

(2) Kelvin was a realist in his understanding of the laws of nature as the work of a creative intelligence, who governs the universe according to his own design: "I believe that the more thoroughly science is studied, the further does it take us from anything comparable to atheism." (Thompson 1910, 1103) According to his view, the laws of the universe were not merely formulated by scientists but discovered by science through investigation and proper reasoning. Even though his interpretation of the relationship between natural law and divine order was neither novel nor profound, this point was fundamental to his belief in science, and yet his own concern, and that of science in general as he defined it, was with the discovery and application of natural laws, not with their origin. The task of science, therefore, was to discover the immediate natural cause for any phenomenon without undue concern for its ultimate cause. And in the case of the age of the Earth—as we shall see in the rest of the article—he was convinced that this procedure led inexorably to the conclusion that time was of finite and relatively limited duration. (Burchfield 1990, 49)

(3) Kelvin saw his Christian faith as supporting and informing his scientific work: "Do not be afraid of being free thinkers. If you think strongly enough you will be forced by science to the belief in God, which is the foundation of all religion. You will find science not antagonistic but helpful to religion." (Thompson 1910, 1099) The more thoroughly he conducted scien-

tific research, the more he believed that science excludes atheism. This last viewpoint will become more evident in his address to the annual meeting of the Christian Evidence Society, on 23rd May 1889, which will be presented more in detail in section 5.

These three convictions help to understand why his postulate on the dissipation of energy led him into conflict with the defenders of the theory of evolution by natural selection. Moreover, he believed that geology and evolutionary biology were weak subjects when placed against the rigor of mathematically based natural philosophy. However, before entering such controversy, we must address his contribution to developing the Second Law of Thermodynamics, arguing that the key issue was the explanation of irreversible processes.

3 THE DEVELOPMENT OF THE SECOND LAW OF THERMODYNAMICS

In 1851, after Sadi Carnot and James Joule's seminal work in Thermodynamics with the discovery of the mechanical equivalent of heat and the conservation of energy, and independently of Clausius, Kelvin set out to formulate the principle of dissipation of energy which would eventually give rise to the Second Law. How to reconcile Carnot and Joule? In Carnot's theory, lost heat was absolutely lost but Kelvin surmised that it was "lost to man irrecoverably; but not lost in the material world." The concept of "irreversible process" then proved to be key for establishing the new paradigm. After some hesitations, he was able to deliver a paper that Joule was able to read carefully, sending back comments and suggestions. This was the beginning of a fruitful collaboration between the two men, which lasted from 1852 to 1856 and included, e.g., the discovery of the so-called Kelvin-Joule effect.

In what measure was Kelvin's religious background relevant for the statement of the Second Law? From his epoch of student in Glasgow, he was taught and strongly believed that solely God was the eternal creator, being unthinkable that human beings could create or destroy by themselves. It was a call for conservation and stability in nature, being knowable by Physics, and Kelvin agreed with Joule in believing that the power to annihilate mechanical work only belonged to God. Nonetheless, Kelvin's beliefs had been challenged by the discovery in 1833 that Encke's comet was slowing down, as Whitaker has pointed out: "This indicated the presence of a resistive medium in the universe, which would ultimately destroy the motion of all celestial objects, and thus bring the universe together, of course, with all life on it, to a halt. To Kelvin this too came to seem an obvious and accepted truth. As early as 1841, for example, he discussed how the production of tides would retard the Moon. He came to see such decay, which he was to call 'irreversibility' or 'dissipation' as a central and universal feature of physical systems: mountains are eroded, humans and animals die." (Whitaker 2008, 294).

Little by little, Kelvin's own thoughts became clarified in this respect, "I believe the tendency in the material world is for motion to become diffused, and that as a whole the reverse of concentration is gradually going on—I believe that no physical action can ever restore the heat emitted from the Sun, and that this source is not inexhaustible; also that the motions of the Earth and other planets are losing vis viva which is converted into heat; and that although some vis viva may be restored for instance to the Earth by heat received from the sun, or by other means, that the loss cannot be precisely compensated and I think it probable that it is under compensated." (Sharlin 1979, 112).

We shall have the opportunity in section 5 to compare these ideas on the existence of irreversible processes with the use he made of St Peter's Epistle at his religious address to the Christian Evidence Society. Suffice to say by now that Kelvin helped to develop the Second Law of Thermodynamics arguing that the key issue in its interpretation was the explanation of such processes. As is presently well known by physicists, if entropy always increases in a closed system like the universe, the latter would ultimately reach a state of uniform temperature and maximum entropy from which it would be impossible to extract any work. Kelvin famously christened this final possibility as the Heat Death of the Universe. Therefore, his Thermodynamics relied on the dominance of the energy concept, which he believed underlies all physics, with the First and Second Law expressing the indestructibility and the dissipation of energy. When, in 1852, he announced the discovery of the Second Law, he turned immediately to its implications for the age of the Earth (Burchfield 1990, 22).

4 THE CONTROVERSY ABOUT THE AGE OF THE EARTH

4.1 The situation

In the middle of the 19th century, it was widely assumed that the Earth was much older than literal reading of biblical texts and pseudoscientific methodologies suggested. Practitioners of Geology—which had emerged as a new discipline in the early 1800s—had realized that the Earth was very ancient. But how much? In fact, by the 1840s most geologists had accepted the ideas of Charles Lyell (1797–1875) on the uniformitarian nature of the Earth's history, and adhered to the view that the Earth's history was practically infinite. (Wyse Jackson 2008, 160–161) Lyell's doctrine had forerunners. James Hutton (1726–1797) had published in 1795 a *Theory of the Earth* that enjoyed notoriety for a cyclic view of the Earth's history that promised no vestige of a beginning, nor prospect of an end. (Brooke 2014, 292) However, no geological argumentation was given until Lyell affirmed that the Earth existed in a state of dynamic balance: except for occasional, purely local variations, the forces acting on its surface should have remained constant both in kind and degree, through interminable ages. (Burchfield 1990, 9)

Obviously, the topic was relevant for the understanding of the fossil record and the fledging field of natural evolution of living organisms. Both Jean-Baptiste Lamarck (1744–1829) and Georges Cuvier (1769–1832) had agreed that the succession of forms revealed by the paleontological record required far more time than the chronologies of Genesis would allow. (Burchfield 1990, 6) In arguing for organic transformation, Lamarck disregarded any restriction on the Earth's age. Time, he insisted, "was never a difficulty for nature." Given enough of it, transformation could occur without the drawback of extinction. (Brooke 2014, 327) An indefinite age of the Earth in geological terms—as long as one needed for all practical purposes—released biological hypotheses from time constrictions. However—as often is the case in the emergence of a new interdisciplinary framework—"it would have been an oversimplification to claim either that immensity of time was directly deducible from 'facts' or that it was merely an assumption imposed on the data. It was rather that the assumption and the interpretation of the data stood in a symbiotic relationship, which permitted a coherent and plausible account of causal sequences." (Brooke 2014, 338)

Nevertheless, there had also been some previous attempts at estimating the age of the Earth with scientific methods. Georges-Louis Leclerc, Comte de Buffon (1707–1788), dealing with the cooling rate of spheres of different size and materials, determined that the Earth was nearly 75,000 years old, a figure considerably higher than that thought correct by the bulk of his contemporaries, (Wyse Jackson 2008, 163; Brooke 2014, 320) but still very unrealistic. A century later, the development of Thermodynamics and the newly stated Second Law provided the context in which Kelvin held the center-stage in the debate about the Earth's age for almost four decades. "His domination of this subject began in the 1860s and lasted largely unchallenged until the close of that century, and he was pivotal in promoting the viewpoint of the physicists that often ran contrary to the opinions held by the geologists." (Wyse Jackson 2008, 160)

4.2 Kelvin's position

From the very beginning—with the writing of *On the Secular Cooling of the Earth* (Thomson 1864)—Kelvin set out to show that geologists, especially uniformitarian geologists, had neglected the principles of Thermodynamics in their speculations. He was convinced that the uniformitarianism espoused by Lyell and his followers should be wrong. Even if Kelvin's interest on the thermal history of the Earth had already begun in 1844, while he was still a Cambridge undergraduate, now, with the establishment of the First and, especially, the Second Law of Thermodynamics, he counted on a more fundamental approach to the problem of the Earth's age: "Belief in the universal validity of natural laws was implicit in every step in Kelvin's reasoning (…). He believed that the proper application of Thermodynamics would provide valuable insights into many basic geological problems." (Burchfield 1990, 51)

From a physicist's viewpoint, it was simply untenable not to tackle the issue of the Earth's dynamics and our planet's timespan in keeping with the activity of the sun. In spite of the uncertainties in his calculations, Thomson believed that they presented adequate refutation for any theories of the Earth's age that required immeasurably vast times. (Burchfield 1990, 31–32) He did want to defend and promote good science, and believed that geology and evolutionary biology were weak subjects when placed against the exactness of mathematically based physics. Indeed, many contemporary physicists did not even believe that geology and biology were sciences at all. (McCartney 2003, 122)

Moreover, since the laws of Thermodynamics had to have been operating from the birth of the universe, the Earth's conditions for the emergence of life could not be constant since the indefinite past. The Earth had once been unable to support life. Of course, Kelvin was not concerned with defending a literal interpretation of the Genesis narratives and he was happy to even speculate that life came to Earth via a meteor, but, soon after his criticisms, people began to wonder how these universal laws of physics related to or contrasted with the universal law of biological evolution as established by Charles Darwin (1809–1882) in his 1859 *Origin of Species*. Kelvin repeatedly returned to this topic, which led him into conflict with other scientists such as John Tyndall (1820–1893), Thomas Huxley (1825–1895), and Darwin himself.

4.3 The controversy with Darwin

Whereas it is still unclear Kelvin's influence on Darwinism, which fell short of being mainstream among biologists until the 1930s, it is far from any doubt that Darwin was troubled with Kelvin's calculations. In *The Origin of Species*, the English naturalist had "argued that the topography of the Weald in southeast England had taken 306 million years to form. His theory of evolution had initially many skeptics because it seemed that there was not enough time available for biological evolution to have taken place, yet through his Wealden example Darwin had provided enough time. (Wyse Jackson 2008, 161)

Despite Morus' claim that Kelvin regarded Thermodynamics as a powerful weapon with which to counter Darwinian evolution, (Morus 2005, 141–142) Kelvin did not actually oppose the basic principles of an evolutionary naturalism. He was not averse to the idea that once life had started, all subsequent creatures might have proceeded by orderly evolution from some such origin.[4] The (alleged) conflict between the law of evolution by natural selection and the increase of entropy in closed systems was only apparent, since the latter does not preclude states of low internal entropy in living beings—which always need some kind of energy transfer with the environment. Even if it is difficult to avoid the suspicion that *The Origin of Species* stimulated Kelvin's interest in the Earth's age, his interest in the problem predates Darwin's work. (Burchfield 1990, 32)[5]

The controversy, however, arose from the relatively short habitable age of the Earth—according to Thomson's estimates—which threatened to contradict Darwin's gradualist explanation counting on slow natural selection to bring about biological diversity. Kelvin set out to prove the actual Earth's age through the application of the laws of physics—as we shall see in the next section— and discussed the validity of Darwin's ideas with John Phillips (1800–1874), successively professor of Geology in London, Dublin, and Oxford. The latter's examination in 1861 of the deposition rate of sediments and the rock succession gave an estimate of 54 million year, very wide of the mark of Darwin's estimate based on the denudation of the Weald. (Wyse Jackson 2008, 161–162)

For the following decades, Kelvin championed the idea of a definite Earth's age, which could be calculated and which put a limit to the available biological times for evolution. By 1868 it had become obvious that Kelvin's attack struck not only at uniformitarianism but at Charles Darwin's theory of natural selection as well. (Burchfield 1990, 2) Kelvin's timescales could be questioned, but the problem still stood. Nonetheless, as

Thomas Huxley implied in his 1869 Presidential address to the Geological Society of London, for the biologists Thomson's timescale did not necessarily cause them problems, as they, the biologists, simply used the geologists timescale in the absence of having one for themselves. But, for the years to come, the biologists were concerned that Thomson's age limits were too short for biological evolution. Even politicians as Salisbury referred to Kelvin in attacking the basis of Darwin's theory of natural selection, saying that there was not enough time for natural selection to have taken place. (Wyse Jackson 2008, 169–171) How were Kelvin's calculations made?

4.4 Kelvin's calculations

Convinced by the principle of the dissipation of energy (the Second Law) that geological uniformity could not be a law of nature, Thomson saw in the principle of the conservation of energy (the First Law) the means by which to determine the limits of the Earth's—and the sun's—age. (Burchfield 1990, 13) He dealt with such calculation "in three ways: the first was in relation to the Sun, and he attempted to estimate how long it had been shining and used this as a corollary for the age of the Earth. Secondly, Thomson investigated the effect that friction caused by tides might have had on the shape of the Earth. The third method took the secular cooling rate of the Earth, and it is for this work that Thomson is chiefly remembered in the geochronological field." (Wyse Jackson 2008, 162)

According to the first method, Kelvin reached the conclusion that the sun had been shining for as much as 100 million years, with a higher threshold of 500 million years. But he was more confident in an operational range between 20 and 60 million years, and would defend the lower limit towards the end of his life. Regarding the second method, "he realised that if one took the present rotation rate of the Earth, and used this to calculate what the shape of the globe would have been if this had been the primordial spinning rate, one would expect a spheroidially flattened globe of a particular shape. This expected shape he found was appreciably no different from the actual shape of the globe, and so he deduced that very little time had elapsed since the formation of our planet. He acknowledged that there were difficulties of actually determining accurately the parameters that fed into this methodology, but was confident that the Earth was no more than 1,000 million years old, and that 100 million years old was the more plausible figure." (Wyse Jackson 2008, 165)[6]

Nonetheless, the third method proved to be the most reliable throughout the years, apparently because of the possibility to better controlling empirical parameters. In addition, it counted on a long tradition of research. Thermal gradients of the Earth's bulk had already been investigated through temperature readings from various depths in mines or from boreholes, but not very accurately until the invention in the 1830s of specialized thermometers designed for the task. As late as the 1860s the results were still poor; the temperature at the center of the Earth was deemed to be roughly 2,000 Celsius degrees—about a half of the currently estimated real temperature. In April 1862, Thomson read his *On the Secular Cooling of the Earth*—published two years later in the *Transactions of the Royal Society of Edinburgh* and summarized in *The Times*—and began a sharp attack on uniformitarianism and its allegedly extended or indefinite history of the Earth. (Wyse Jackson 2008, 166) Kelvin's mind was pressed by the conviction that geologists have overlooked the essential principles of Thermodynamics.

Specifically, he carried out experiments to determine the conductivity of various rock types, taking up 3,900 Celsius degrees as the temperature of fusion for the rocks. Knowing the thermal conductivities of rocks near Edinburgh and Greenwich, and assuming they were typical values for the Earth's interior, he was able to calculate the rate of heat loss and so determine the duration of the process. (Brooke 2014, 388–389) He consequently argued, in keeping with his own calculations based on Fourier's analysis of heat conduction, that consolidation of the surface would have taken place 98 million years ago—a necessary fact, apparently, for the emergence of life. The lower and higher limits of his estimate were, respectively, 20 and 400 million years. (Wyse Jackson 2008, 167–168) For Kelvin, the state of things in the Earth, its geological history, and its capability to generate life had to be limited within such period of past time.

In 1868, "Thomson revisited the subject of the Earth's antiquity when he addressed the members of the Geological Society of Glasgow. He used the occasion to try to bring the geologists around to his viewpoint, and gave the assembled company a synopsis of the methods and results used in both the tidal friction and secular cooling schemes to age the Earth. He concluded that the Earth was no more than 100 million years old." (Wyse Jackson 2008, 168) In 1876, this figure had shrunk to 50 million years (Brooke 2014, 388–389) and in a short letter to *Nature* in 1897 he established a range of 20 to 40 million years, with 24 million years as the most likely number. (Wyse Jackson 2008, 170) His different ways of determining the Earth's age eventually came up with the same figures, in orders of magnitude, which meant strong support for believing in the correctness of the estimates. Even physicists that were aware of the imperfections in the available data—and the vagueness of

Kelvin's figures—still accepted the truth of his reasoning and the validity of his fundamental results. Moreover, it was in his emphasis that the laws of Thermodynamics must apply to any physical system, including the universe as a whole, that Kelvin made his unique contribution to the problem of geochronology. (Burchfield 1990, 47)

4.5 Kelvin's legacy

As is well known, Thomson's scientific contribution was ultimately proven wrong. On the one hand, his speculative assumptions were established concepts of mechanical analogy, classical dynamics, energy conversion, and the nebular hypothesis, which could be considered among the overall postulates available to science. The conservation of energy made it possible to calculate the magnitudes of the probable energy conversions within the system and to speculate reasonably about the probable effects of both past and present energy transformations. Kelvin's aim was to extend the limits of this speculation until he could locate, define, and date the original condition of the Earth. However, his knowledge of geology was rudimentary and, despite the accelerated growth of science in the nineteenth century, every determination of the Earth's age still involved key parameters that defied measurement. (Burchfield 1990, 51–52, 215–217) On the other hand, and more importantly for the third method of determination, Kelvin had "made four assumptions about the conditions of the Earth. First, it was solid; secondly it began at the same temperature throughout; thirdly, that it must be homogeneous and have an identical conductivity throughout; and finally, no internal heat source was present. Subsequently all of these assumptions were challenged and found to be untenable and incorrect." (Wyse Jackson 2008, 168)

It was this last hypothesis, i.e., that no internal energy source was present, what mainly derailed Kelvin's calculations. But one can hardly blame him for it. With the discovery of radioactivity by Antoine Henri Becquerel (1852–1908) in 1896, it was soon recognized that disintegration of radioactive elements provided an internal heat source for the Earth. (Wyse Jackson 2008, 168) Such energy source could power the sun for the long timespan required by the theory of evolution. Ernest Rutherford (1871–1937) finally made the argument in a lecture attended by Kelvin that radioactive decay provided the unknown energy source Kelvin had alluded to in 1862, but the estimate was not overturned until the development in 1907 of radiometric dating of rocks. "In public Thomson remained defiant to the end of his life. None of the criticisms of his methods thrown at him by geologists or the biologists made him moderate or alter his views substantially, and he continued to hold that the Earth was rather young", (Wyse Jackson 2008, 174) but in private he admitted his quantitative defeat, even though no better estimate for the Earth's age was provided.

It must be stressed, though, that once Kelvin's change of framework is accepted, vagueness about the Earth's timescales cannot be permitted. Even if the discovery of radioactivity enormously increased the limits of the Earth's age, geological times were finite, definite, and could be estimated. For more than four decades, Kelvin's chronology and hypotheses regarding the Earth's structure and internal dynamics had been among the most potent influences shaping the development of geophysical theory. (Burchfield 1990, 212) He changed the geologists' view and somehow provoked the transition from qualitative to quantitative geology.

Remarkably, the question of the Earth's age was never entirely free from some degree of tension between physics and geology. This stand-off continued until the mid-1920s when the latter were arguing that the Earth was older than the age suggested by the former for the universe. (Wyse Jackson 2008, 162) "But if the tensions thus generated sometimes produced more heat than light, their effects were by no means always negative. Both physics and geology were stimulated by the interaction of ideas and methods, and both ultimately profited from the exchange." (Burchfield 1990, 217) Eventually, it was only when thermonuclear fusion was acknowledged in the 1930s that tensions receded and Thomson's age paradox was truly resolved.

In spite of his shortcomings, Kelvin's legacy stimulated inquiry of fundamental problems in geology, which no longer could neglect physics and its estimates of geological timespans. Interdisciplinarity matters when dealing with big questions, even though occasionally spawns quarrels. 19th century Thermodynamics showed the non-uniform character of actual physical processes and pointed to one beginning and one end for each of them. The geological processes giving rise to our planet could not be an exception to the rule and, thanks to William Thomson's insistence, biologists and geologists came to understand what the Second Law meant for their respective disciplines: Physical time is a relevant variable for both biology and geology that cannot simply be assumed to be infinite or much bigger than the evolution's relevant time scales.

5 WERE THERE RELIGIOUS MOTIVATIONS IN KELVIN'S CRITIQUES?

Even if general agreement exists among historians of science regarding Kelvin's influence in the birth of modern geology, it is less clear the influence of Kelvin's religious motivations in his scientific argumentation. According to Burchfield, the question of natural selection provided an additional spur to Kelvin's activity. He was not opposed to evolution as such, but rejected natural selection because it left no place for the operation of design or divine order in the evolution of life. For him, design was as much a principle of nature as were the laws of Thermodynamics; design made science possible by lending intelligibility to nature. But, even though he attacked uniformitarianism directly, his broader aim was to insure that the results of geological speculation be made physically and philosophically sound. This was a purely scientific goal, and any return to supernatural catastrophes would be as repugnant as a continuation of radical uniformity. (Burchfield 1990, 33, 37)

This last statement is important. It shows that Kelvin was not looking for some sort of "special divine action" in nature. How religious-driven world views influence science may become a subtler matter. All in all, the specific question I wish to address here is whether Kelvin's criticisms of uniformitarianism, right or wrong, can be traced back to religious motivations. This fact can be difficult to assess, since the influence of religious motivations is not a matter of black or white. However, it is worthwhile listening to Kelvin in his 1889 address to the Christian Evidence Society (Thomson 1889/1902)[7]:

> I have long felt that there was a general impression in the non-scientific world, that the scientific world believes Science has discovered ways of explaining all the facts of Nature without adopting any definite belief in a Creator. I have never doubted that that impression was utterly groundless. It seems to me that when a scientific man says—as it has been said from time to time—that there is no God, he does not express his own ideas clearly. He is, perhaps, struggling with difficulties; but when he says he does not believe in a creative power, I am convinced he does not faithfully express what is in his own mind, He does not fully express his own ideas. He is out of his depth.
>
> We are all out of our depth when we approach the subject of life. The scientific man, in looking at a piece of dead matter, thinking over the results of certain combinations which he can impose upon it, is himself a living miracle, proving that there is something beyond that mass of dead matter of which he is thinking. His very thought is in itself a contradiction to the idea that there is nothing in existence but dead matter. Science can do little positively towards the objects of this society. But it can do something, and

> that something is vital and fundamental. It is to show that what we see in the world of dead matter and of life around us is not a result of the fortuitous concourse of atoms.
>
> I may refer to that old, but never uninteresting subject of the miracles of geology. Physical science does something for us here. *St. Peter speaks of scoffers who said that 'all things continue as they were from the beginning of the creation'; but the apostle affirms himself that 'all these things shall be dissolved'. It seems to me that even physical science absolutely demonstrates the scientific truth of these words.* We feel that there is no possibility of things going on for ever as they have done for the last six thousand years. In science, as in morals and politics, there is absolutely no periodicity. One thing we may prophesy of the future for certain—it will be unlike the past. Everything is in a state of evolution and progress. The science of dead matter, which has been the principal subject of my thoughts during my life, is, I may say, strenuous on this point, that the age of the Earth is definite. We do not say whether it is twenty million years or more, or less, but let me say it is not indefinite. And we can say very definitely that it is not an inconceivably great number of millions of years. Here, then, we are brought face to face with the most wonderful of all miracles, the commencement of life on this earth. This earth, certainly a moderate number of millions of years ago, was a red-hot globe; all scientific men of the present day agree that life came upon this earth somehow. If some form or some part of the life at present existing came to this earth, carried on some moss-grown stone perhaps broken away from mountains in other worlds; even if some part of the life had come in that way—for there is nothing too far-fetched in the idea, and probably some such action as that did take place, since meteors do come every day to the earth from other parts of the universe;—still, that does not in the slightest degree diminish the wonder, the tremendous miracle, we have in the commencement of life in this world.

In this speech, even if the Biblical quote does not obviously commit to any specific theory, it leads to a line of critique that permeates all of Kelvin's attacks upon Darwinian evolution as well as the earlier uniformitarian-catastrophist controversy. This specific religious view is different from his prevalent belief in the evidence of design in the universe, in keeping with Paley's Natural Theology. (Burchfield 1990, 48) Actually, it departs from the idea of a perfect universe which evolves according to well-defined timeless cycles. Nature's dynamicity goes beyond perfect regularities. As Burchfield himself acknowledges, "In the finite system composed of the sun, the Earth, and the solar system, the amount of available useful energy must be finite; it must be constantly dissipated according to the second law of Thermodynamics; and the system must be running down. The past activities of both the Earth and sun must have been greater than those going on at present, and they cannot have been repeated in an indefinite succession of cycles. In other words, Kelvin believed that complete uniformity of action in geology violated the second law of Thermodynamics and thus could not itself be a law of nature." (Burchfield 1990, 52) Hard to deny that Kelvin's reading of 2 *Peter* 3:4.10 inspired his understanding of a universe running downhill with a preferred arrow of time.

In my opinion, the best articulation of the influence of Kelvin's religious ideas on the First and the Second Law is offered by Peter Bowler's account of the similarities of thought with his brother James: "Like many nineteenth-century scientists, both brothers saw their investigations of nature as a means of understanding the divine creation. The motivation underlying their work on Thermodynamics was both practical and religious (…). [T]he brothers' worldview focused on the source of energy which drove all natural processes. The ultimate source of energy was God—He had created just so much energy in the beginning, and the laws of nature He had instituted led to an inevitable decline in the amount of energy that was left available for useful work in natural processes. This was a universe with a built-in trend toward what would later be known as the 'heat death', the point at which all matter was at a uniform temperature. At this point the total amount of energy was still the same as at the creation, but none was available to make anything happen, because useful work can only be obtained if there is a difference of temperature between the source of the energy (such as the steam engine's boiler) and the sink (the environment into which the waste steam and water is exhausted). Small wonder that with a worldview in which the dissipation of useful energy was an inevitable part of the divine plan, the two brothers were driven by a desire to minimize the amount of unnecessary waste in any machine. Throughout their careers, they strove to design machines which extracted as much of the useable energy as possible, losing only what the laws of nature made inevitable." (Bowler 2008, 57–58)

The abovementioned reference to the Bible as support in Kelvin's attack to any form of vagueness regarding geological times is not unique. He had also quoted the words of *Isaiah* 51:6, "for the heavens shall vanish away like smoke, and the earth shall wax old like a garment," in a draft of his famous 1851 paper (Thomson 1851/1882). To sum up, then, "this deep belief in a decaying creation as opposed to a timeless creator was as much theological as his belief in conservation and stability (…). The two beliefs, equally strongly based, seemed in conflict, and hence his intense inner struggles, before he eventually came to an original and creative combination of the two in the laws of Thermodynamics." (Whitaker 2008, 294–295)

6 CONCLUSIONS

Among scientists of different disciplines it is not uncommon to regard physicists with some suspicion, as people imbued in their own narrow understanding of nature who care little about other scientific achievements. Such view, even if exaggerated, might well fit into the view that William Thomson enjoyed during his life time. Understandable as such an image could be, it fails to recognize two main determinative issues in Lord Kelvin's intellectual life:

(1) The influence of a religious world-view on his scientific understanding of nature is subtler than generally assumed to be the case throughout the history of the science-religion dialogue. Kelvin was neither a fundamentalist reader of the Bible nor a mere believer who avoided any surreptitious influence of his credo in his scientific work. The idea of a Creator and a created world inspired him as something that should provide information regarding the functioning of the universe. Finally, as I have tried to show, he envisaged a deep unity between a world with a beginning and an end and the consequences of the laws of Thermodynamics discovered by him and some of his friends.

(2) Even though his specific estimates regarding the Earth's age were proven wrong, they were right in spirit, providing an enormous thrust for the advance of geology as a quantitative science. Thermodynamics was not a physical discipline that could be put aside when discussing big questions about our world. It does not mean to despise other scientific enterprises, but to give them the possibility of becoming more and more realistic by incorporating their methods and results into a more integrated scientific framework. The role of Thermodynamics for scientific inspiration is still present, e.g., in relation with the explanation of the arrow of time. And Kelvin must be credited for it.

Last but not least, Kelvin's own understanding of Thermodynamics teaches us that the religious perspective of the world should not be considered as something totally strange to science, especially when dealing with problems of the latter's foundations. As Morus rightly points out, "[T]hermodynamics was far more than just a physical theory as far as Thomson was concerned. It was an expression of the way in which he saw his world. Thermodynamics, or so it seemed to many of its promoters, embodied a particular set of values in its operations. It revealed a universe where economy, efficiency, thrift, and the avoidance of waste were built into the very fabric of things. It also revealed a universe ruled by God. The principle of conservation—for William Thomson as for Joule—was a theological as much as a physical imperative. Matter and energy were conserved because, being created by God, they could not be destroyed by any other agency. It was also a universe that had a sense of direction, forever running down towards its ultimate dissolution. If the dominant metaphor of eighteenth-century natural philosophy was of a balance, with nature's forces forever working to restore equilibrium, the metaphor for Thermodynamics was the steam engine continually propelling nature forwards. Like the industry it encapsulated, Thomson's Thermodynamics was also ambitiously expansionist. Thomson and his fellows regarded it as the ultimate science and therefore as the ultimate arbiter over nature. Other sciences, like biology or geology, would have to pay due obeisance. Thomson's triumph was to produce a new physics that not only explained how to build better steam engines, but accounted for the age of the universe and foresaw its end at the same time." (Morus 2008, 138–139)

REFERENCES

Bowler, P. 2008. "James Thomson and the Culture of a Victorian Engineer." In *Kelvin: Life, Labours, and Legacy*, edited by R. Flood, M. McCartney, and A. Whitaker, 56–63. New York: Oxford University Press.

Brooke, J.H. 2014. *Science and Religion. Some Historical Perspectives.* Cambridge: Cambridge University Press.

Burchfield, J.D. 1990. *Lord Kelvin and the Age of the Earth.* Chicago: University of Chicago Press.

Mahon, B. 2004. *The Man Who Changed Everything. The Life of James Clerk Maxwell.* Chichester: John Wiley and Sons.

McCartney, M. 2003. "William Thomson, Lord Kelvin 1824–1907." In *Physicists of Ireland. Passion and Precision*, edited by M. McCartney and A. Whitaker, 116–125. Bristol and Philadelphia: Institute of Physics Publishing.

Morus, I.R. 2005. *When Physics Became King*. Chicago: University of Chicago Press.

Morus, I.R. 2008. "A Dynamical Form of Mechanical Effect': Thomson's Thermodynamics." In *Kelvin: Life, Labours, and Legacy*, edited by R. Flood, M. McCartney, and A. Whitaker, 122–139. New York: Oxford University Press.

Müller, I. 2007. *A History of Thermodynamics. The Doctrine of Energy and Entropy*. Berlin – Heidelberg: Springer.

Roche, J. 2008. "Concepts and Models of the Magnetic Field." In *Kelvin: Life,* *Labours, and Legacy*, edited by R. Flood, M. McCartney, and A. Whitaker, 94–121. New York: Oxford University Press.

Sharlin, H.I. 1979. *Lord Kelvin: The Dynamic Victorian.* University Park: Pennsylvania State University Press.

Stewart, B., and Tait, P.G. 1875. *The Unseen Universe or Physical Speculations on a Future State*. London: Macmillan.

Thompson, S.P. 1910. *The Life of William Thomson, Baron Kelvin of Largs* (2 vols.) London: Macmillan.

Thomson, W. 1851/1882. "On the dynamical theory of heat, with numerical results deduced from Mr. Joule's equivalent of a thermal unit, and Mr. Regnault's observations on steam." *Proceedings of the Royal Society of Edinburgh* 3:48–52; reprinted in *Mathematical and Physical Papers*, vol. 1, 174–210. Cambridge: Cambridge University Press.

Thomson, W. 1864. "On the Secular Cooling of the Earth." *Transactions of the Royal Society of Edinburgh* 23:167–169. (Read in April 28, 1862.)

Thomson, W. 1871/2011. "Presidential Address to the British Association, Edinburgh." *Geology and General Physics. Popular Lectures and Addresses*, vol. 2, 132–205. Cambridge: Cambridge University Press.

Thomson, W. 1889/1902. "Address to the Christian Evidence Society" (Lord Kelvin's address as the Chairman of the Christian Evidence Society, in London, at its nineteenth anniversary, May 23, 1889)." In *A Cloud of Witnesses. The greatest men in the world for Christ and the book*, edited by Stephen A. Northrop, 460–461. Kansas City: The Christian Evidence Publishing Co.

Whitaker, A. 2008. "Kelvin—The Legacy." In *Kelvin: Life, Labours, and Legacy*, edited by R. Flood, M. McCartney, and A. Whitaker, 278–306. New York: Oxford University Press.

Wood, A. 2008. "Fifty-Eight Years of Friendship: Kelvin and Stokes." In *Kelvin: Life, Labours, and Legacy*, edited by R. Flood, M. McCartney, and A. Whitaker, 64–85. New York: Oxford University Press.

Wyse Jackson, P.N. 2008. "William Thomson's Determinations of the Age of the Earth." In *Kelvin: Life, Labours, and Legacy*, edited by R. Flood, M. McCartney, and A. Whitaker, 160–174. New York: Oxford University Press.

NOTES

1. For a recent general history of Thermodynamics, see (Müller 2007).
2. A very good presentation of Maxwell's life and works can be found in (Mahon 2004).

3. "Stokes and Thomson were firmly in the creation camp, although for different reasons, and were certainly not as fundamentalist in their beliefs as the physicists Faraday and Maxwell. Neither Stokes nor Thomson went so far as to take literally the time periods in the Genesis account of creation." (Wood 2008, 83).
4. "In his 1871 address to the British Association, he specifically warned against invoking an 'abnormal act of Creative Power' if a solution to the origin and diffusion of life could be found 'consistent with the ordinary course of nature'." (Brooke 2014, 389) See also section 2, paragraph (1) of this article.
5. "As Stephen Brush put it in 1982, the rationale that the argument between Thomson and the geologists and Darwin was about evolution was, and continues to be, overstated. Thomson's main bone of contention with Darwin's logic was that it didn't follow the laws of physics. That lay at the root of the debate between the physicists and the geologists. He didn't take a stance against biological evolution." (Wyse Jackson 2008, 162)
6. For a detailed account of each of these approaches, see (Wyse Jackson 2008, 163–170).
7. As far as I know, this speech is only accessible via secondary sources. I have directly addressed the Christian Evidence Society in order to obtain the original version, but the attempt has not been successful.
