Entropic Creation

Religious Contexts of Thermodynamics and Cosmology

Helge S. Kragh

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Chapter 1

Introduction

The present work is a contribution to two different but related areas of intellectual history. First, it belongs to the history of science in so far that it offers a novel perspective on the history of cosmological thought, focusing on the period 1850-1920 and with an emphasis on religious, philosophical and ideological aspects. Second, it belongs to the history of ideas in so far that it is a case study on the relationship between science and religion from the perspective of early physical cosmology. The work is essentially about the interactions between cosmology, physics, religion and ideology in the latter half of the nineteenth century and the first years of the twentieth century. The key concept under consideration is the entropy function introduced by Rudolf Clausius in 1865, the basis of one formulation (out of several) of the second law of thermodynamics. Much has been written on the history of this fundamental law – whether expressed in terms of entropy or not – but surprisingly few authors have dealt seriously with the cosmological, cultural and religious implications of the law as perceived by the historical actors. The best known of these implications is the so-called heat death, the gloomy prediction that the world will eventually and inevitably 'melt away', come to a final end where all energy is transformed into the form of mechanically useless heat.[1]

Although I deal in some detail with the infamous hypothesis of the thermal end of the world, and provide some new information on the subject, my study is mainly focused on what was held, in some quarters, to be a corollary of the heat death hypothesis, namely that the universe must have had a beginning in time. To put it briefly, given that we do not live in a high-entropic world, and assuming that the entropy law is valid for the universe at large, entropy can only have increased for a finite period of time. If this is the case, the universe must have had a beginning of a sort – and if it had a beginning it presumably originated in a creative act. This is the essence of the 'entropic creation argument', which is the central theme of my investigation. Thus, thermodynamics leads to predictions concerning not only the end of the world, but also its beginning, and for this reason it enters domains that traditionally belong to religion. No wonder, then, that the second law of thermodynamics became a major battlefield in the heated ideological discussions of the late nineteenth century. In the chapters that follow, I examine in detail this discussion and the views on the heat death and the entropic argument that were

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1 The heat death and other cultural and ideological aspects of nineteenth-century thermodynamics is among the subjects of Stephen Brush's fascinating *The Temperature of History* (Brush 1978) and is also covered in Brush 1967. Other works which deal with the topic include Hiebert 1966, Jaki 1974, Myers 1986, Clarke 2001 and Neswald 2006. Others again are mentioned in the notes to the text.

discussed in the period under consideration. While it is understandable that the second law became involved in the cultural struggle in a general sense, it is much less obvious why it came to be considered a *theoria non grata* by some thinkers of a materialistic or socialist inclination.

Given how large a role the entropic argument played in science, ideology and theology from about 1870 to 1910 it is surprising that the topic has never – with one exception – received serious attention from intellectual historians. From time to time it has been mentioned in the literature, but mostly *en passant* and as an appendix to the heat death. If it is mentioned, its significance is not always appreciated. Thus John Davis writes, quite erroneously, that 'It was not widely recognised in the nineteenth century, but the Second Law implied a finite age for the universe: if the available energy was indeed running down, it could not have been running down forever'.[2] As is amply documented by the present study, the entropic argument for a finite-age universe was in truth widely recognized.

In *Matter and Spirit in the Universe*, a book published by Imperial College Press in 2004, I examined the subject in connection with a broader investigation of the relationship between cosmology and Christian religion.[3] The present work relies to some extent on this book and also on other of my publications, but it goes much further and deeper. It was only when I had written the main part of my manuscript that I became aware of Elizabeth Neswald's *Thermodynamik als kultureller Kampfplatz*, a comprehensive work on popular and ideological aspects of the 'fascination history' of entropy from 1850 to 1915.[4] Neswald's detailed account includes a chapter on 'Der entropologische Gottesbeweis' and in general covers much of the same ground as I do. There are, however, considerable differences between the two works, both in approach and coverage. Although I have made use of material presented in *Thermodynamik als kultureller Kampfplatz*, Neswald's book has not influenced mine to any appreciable extent.

The lack of scholarly interest in the debate concerning the cosmological implications of the entropy law is all the more surprising in light of the fact that it attracted a large number of scientists, intellectuals and social critics. Many of them had only a perfunctory knowledge of thermodynamics, and some not even that, but lack of knowledge did not always deter them from offering their view on the nature and consequences of the law of entropy increase, and doing so with amazing self-confidence. Some of the participants in the discussion over the cosmological significance of the theory of heat may best be described as crackpots or pseudo-scientists (or, as Pierre Duhem expressed it, 'village scholars and café physicists'.) When I have nonetheless included these dubious figures, it is obviously not because of the intrinsic merit of their works. It is because of their pertinence within the

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2 Davis 1999, p. 16.

3 Kragh 2004. I have also dealt with aspects of the entropic-cosmological argument in Kragh 2006b and Kragh 2007a.

4 Neswald 2006. Stanley Jaki is one of the very few historians of science who previously called attention to the entropic creation argument (Jaki 1966, pp. 441-6). The theoretical physicist Peter Landsberg reviewed the argument in 1991, but it took more than a decade until his work attracted any attention (Landsberg 1991).

historical context. People such as J.G. Vogt, O. Caspari and H. Sonnenschmidt were completely and deservedly ignored by the scientific elite, but their works influenced other actors whose views – scientifically respectable or not – reflected important attitudes of the age.

Although many of the participants in the debate are today forgotten, and some were obscure figures even in their own time, others were prominent scientists and men of culture. To name but a few of those who will appear in the subsequent chapters, consider this list: James Clerk Maxwell, William Thomson, Hermann von Helmholtz, Ernst Mach, Pierre Duhem, Ludwig Boltzmann, Ernst Haeckel, Svante Arrhenius, Herbert Spencer, Friedrich Engels, Friedrich Nietzsche, Charles Sanders Peirce, Franz Brentano, William Stanley Jevons and Henri Bergson. Incomplete as the list is, it does indicate the diverse backgrounds of the discussants and also that the problem of entropy appealed to some of the great minds of the late nineteenth century. Remarkably, only very few of these great minds were astronomers or had expert knowledge of astronomy. The entropic argument does not belong exclusively to the history of astronomy, but it certainly was an important part of astronomy in a wider sense. After all, astronomy has a large share in cosmology. Yet, for reasons unknown to me the topic has been almost totally ignored by historians of nineteenth-century astronomy.[5] Nor does it figure in the voluminous literature dealing with the interaction of science and religion in the period, which is much dominated by the debate over Darwinism.

I have organized the book in seven chapters, some of which are more important than others. The core chapters are 4 and 5, where the reader will find a detailed account of the heat death and the entropic creation argument from about 1860 to 1920, including a discussion of how these topics related to religious issues. Most of my references are to literature from Germany, France and Great Britain, and to a lesser extent the United States. I have no doubt that the topic was also discussed in other countries, such as Italy, Belgium and Austria-Hungary, but I have made no effort to cover the entire literature, which would be nearly impossible and possibly also rather pointless. As will become clear, the central issues in the thermodynamics-religion debate rarely turned up in the scientific literature but were mostly discussed in other contexts and often appeared in journals and booklets of a somewhat obscure kind.

Although thermodynamics only dates from the mid-nineteenth century, one can find structurally similar arguments relating to the beginning and end of the world much earlier. They can be found early in antiquity, and from the time of Newton they can be followed until the nineteenth century. Chapter 2 mentions some of these arguments as an introduction to the later discussion. The history of thermodynamics, starting about 1840 with the law of energy or 'force' conservation, has been thoroughly covered by historians of science, and there is no need to cover the same ground. Yet, to make my study more self-contained I start Chapter 3 with a condensed account

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[5] History of astronomy and cosmology in the second part of the nineteenth century has received relatively little attention. The main works are Hoskin 1982, Crowe 1994, Merleau-Ponty 1983 and North 1990. None of these works includes as much as a reference to the entropic creation argument.

of the early development of the mechanical theory of heat and its cosmological significance. Naturally, I pay more attention to the second law than the first, but my comments on the development of the second law of thermodynamics should merely be seen as an introduction to what follows. The focal theme of Chapter 3 is the idea of the heat death, such as it emerged in the 1850s and 1860s.

I suggest distinguishing between a 'restricted' and 'wide' form of the entropic argument, depending on whether it is seen as a proof of the universe being of finite age or a proof of God's creation of the world. From a theological point of view there is no simple connection between the two versions, but if divine creation is supposed to have taken place in the past (and only at a singular moment in the past) there is indeed a connection. The argument, in both versions, was introduced in the late 1860s, such as described in Chapter 4. This chapter deals in particular with the attempts to turn the argument into a scientifically based proof of God's existence, something which was mostly discussed by Catholic scholars and theologians, although it can also be found in the literature of non-Catholic countries, including Great Britain. In the first section of Chapter 4 I depart from the historical account in order to discuss more systematically the meaning and contexts of the entropic creation argument. Precisely because of the claimed connection to Christian dogmas the second law of thermodynamics, or rather the application of this law to the universe as a whole, became highly controversial and entered the *Kulturkampf* of the late nineteenth century. I take up this ideological debate in Chapter 5, which offers a fairly complete account of the high points of the debate in France, Britain and, not least, Germany. For reasons that will become clear, it was mostly in the new German empire that the debate evolved to such a level that it also included important political and ideological aspects.

One of the more striking features of the debate was that it was shunned by most professional astronomers, the very group of scientists whose expertise would seem to be relevant. But of course astronomical issues could not be ignored, and in fact they were not. Chapter 5 includes a description of the astronomers' universe, in particular with respect to the central question of whether the universe is spatially and materially finite or infinite. This question, which was widely seen as related to the temporal course of the universe, was hotly debated by German men of science and culture, including Mach, Haeckel and Engels. Although the question could not be decided observationally, astronomical arguments such as Olbers's paradox and the gravitational paradox did enter the debate. The possibility of a finite yet limitless universe was occasionally mentioned, but it was only with the advent of general relativity theory that it was taken seriously and developed into a cosmological model. Entropy was a multi-faceted concept, intrinsically related to a probabilistic interpretation of natural processes. Chapter 5 includes an account of Ludwig Boltzmann's and others' probabilistic interpretation of the second law and how this development influenced the cosmological debate. I also include a brief account of the cosmological thoughts of heterodox thinkers such as Chauncey Wright, Charles Sanders Peirce and Henri Bergson. My prime concern is not their cosmologies as such, but rather how they related the law of entropy increase to their cosmological views.

It should be noted that I use the words 'world', 'cosmos' and 'universe' largely synonymously. During the period under consideration there was no consensus of how to use the words, but in some cases scientists and philosophers tended to describe planetary systems as 'worlds' while they reserved 'universe' for the much larger, perhaps infinitely large system of stars and nebulae. It is not always clear what authors in the late nineteenth century had in mind when they wrote about the 'world', but to avoid confusion I have tried to reconstruct the meaning from the context of their works.

About the time of World War I the formerly intense interest in the relations between thermodynamics, cosmology and religion petered out. I could justifiably have stopped my work with Joseph Schnippenkötter's dissertation of 1920, *Das Entropiegesetz*, which I refer to as the swan song of the entropic creation argument. However, although the argument no longer played a significant role after 1920, it did not vanish, and I have decided to include a brief chapter in which I follow what remained of it in the two interwar decades. I cover, if not in detail, the early development of relativistic cosmology and also some of the alternative cosmologies that followed in the wake of the discovery of the expansion of the universe. Georges Lemaître's proposal of a 'primeval atom' universe in 1931 marks in many ways a revolutionary change in cosmological thought and can reasonably be seen as the origin of the Big-Bang universe. Although the original proposal did not explicitly refer to the entropic creation argument, I suggest that this idea was part of Lemaître's reasons to propose his hypothesis.

To my knowledge, Edmund Whittaker's *Space and Spirit* from 1946 marks the last serious attempt to prove from thermodynamics the existence of God. This is not to say that the heat death and ideas of entropic creation have disappeared totally from the scene, or that their shadows cannot be found in the post-World War II era. As I indicate in the final chapter, the story that I tell principally in Chapters 4 and 5 continues up to the present. But I have not attempted to cover the post-1920 period in nearly the same details as the earlier period. Among the themes that I pay attention to in Chapter 5 is the hostile attitude to the law of entropy increase that characterized Friedrich Engels and a few others of the early communist thinkers. This theme I follow up in Chapter 7 by outlining the sad story of how cosmological thought was restricted in the Soviet Union because certain views of the structure and development of the cosmos were thought to be ideologically dangerous.

The central theme of my study, the relationship between thermodynamics and religion in pre-Einsteinian cosmology, is focused around the concepts of decay and origin. These concepts, broad and rather vague as they are, can be followed through most of intellectual history where they have played an important role not only in scientific thinking but also in philosophical, social, economical and religious contexts. Of course, the continuity one can find – or construct – does not mean that entropy considerations in any real sense were part of intellectual history before the middle of the nineteenth century.[6] At any rate, my purpose is not to unfold the

[6] Sambursky (1963, p. 200) argues that one can find the notion of the heat death in ancient Greek science.

'entropic theme' as a unit-idea in history, but to examine it in a specific historical period and context.

According to the 'invariance thesis', as propounded by Arthur Lovejoy and others, certain ideas or themes have a life of their own and can be found in almost any branch of thinking and at any time. As Lovejoy contends, 'the same idea often appears, sometimes considerably disguised, in the most diverse regions of the intellectual world.'[7] It may be tempting to see the discussion of the heat death in the late nineteenth century as an instance of the more general theme 'decay' and, in the same manner, the entropic creation idea as an instance of the theme of 'origin'. In the language of Gerald Holton, decay and origin would count as opposing pairs of *themata*. The themata considered by Holton typically appear as pairs of thesis-antithesis, including evolution/devolution, plenum/vacuum, symmetry/asymmetry and hierarchy/unity.[8]

Some of the attempts to describe longer spans of history in terms of concepts such as themata or invariant unit-ideas are bold and fascinating; but the genre is also problematical, especially if it is not realized that concepts and ideas are rarely quite the same over long periods of time. The physicists who discussed the heat death in the Victorian era were indeed discussing decay, but they did it in a specific context based on the second law of thermodynamics and restrained by inadequate knowledge of the structure of the cosmos. It would clearly be anachronistic to consider earlier discussions of decay as anticipations of the entropic heat death. There were structural similarities and some measure of continuity, but the scientific concept of entropy provided discussions of decay with a whole new perspective.

Associated with the decay/origin pair of themes is the pair of contrasting cosmogonies in the shape of cyclic or steady-state world pictures versus evolutionary or creation world pictures. The two opposite conceptions of the universe were closely connected with the entropy debate in the late nineteenth century, but they can be found much earlier and make up an important guiding theme in the history of cosmological thought.[9] Holton emphasizes – perhaps over-emphasizes – the persuasiveness and invariance of themata. Questions concerning themata are not of the kind that get solved and disposed of. Contrary to scientific theories they are not proved or disproved. 'Rather, they rise and fall and rise again with the tides of contemporaneous usefulness or intellectual fashion. And occasionally a great theme develops and struggles to establish itself – at least for a time.'[10] As to cosmology Holton noted the apparently final triumph of the Big-Bang creation cosmogony over the rival view based on continuous existence, but he also prophesied that 'this theme will come in again through the back door'. Indeed, this is what has happened during the last few years, when cyclic and other eternal-universe cosmological theories have made a surprising comeback.[11] While cosmologists a decade or two ago would

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[7] Lovejoy 1976, p. 15.

[8] Holton 1988 and Holton 1978, pp. 3-24.

[9] Jaki 1974 is organized along this theme.

[10] Holton 1988, p. 46.

[11] During the last two decades a dozen or more models of the eternal universe have been proposed. Although the finite-age standard model continues to dominate cosmology, a few of

have confidently affirmed that the universe is of finite age, and while this is still the consensus view, today they are not quite as certain.

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the alternatives have attracted much attention and are considered to be possible rivals to the consensus view. For an overview, see Kragh 2008.

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Chapter 2

Some Early Ideas on Decay and Creation

Has the world always existed? Will it ever come to an end? Grand questions like these, often connected with questions concerning the spatial finitude of the universe, have been discussed since antiquity. More often than not this occurred in religious contexts and related to theological arguments in favour of – or sometimes in opposition to – a divinely created world. Centuries before the emergence of thermodynamics it was argued that the world is in a state of steady decay and that this implies that it was created a finite time ago. Some of these early arguments for a finite-age universe have a structural similarity with the nineteenth-century arguments based on thermodynamical reasoning that will be examined in the following chapters. It is outside the scope of the present work to discuss systematically pre-nineteenth-century thoughts on the beginning and end of the universe, nor is this necessary in order to follow the main story. Yet, as a prelude to the entropic-cosmological arguments of the second half of the nineteenth century it may be useful to refer to some related cases of an earlier origin.

Examples from the Ancient World

According to the conception of the universe favoured by the Greek school of atomism, there was no room for design, purpose or divine agency. All that existed were material atoms moving randomly in a void. This is not to say that the atomists inspired by Leucippus and Democritus denied the existence of the gods, but they did deny that the gods were responsible for or interfered with natural processes. Their aim was to explain the cosmos naturalistically, without relying on either pre-established design, divine agency or miracles. Their universe was mechanical, but it was made and operated without the need of a master mechanic. The atomists explained the origin and subsequent differentiation of the cosmos by random collisions of atoms, leading to aggregations which tended to preserve themselves in dynamical but stable systems. The overall scheme was from disorder to order – a development governed by a kind of evolutionary or counterentropic principle.[1]

[1] Classical scholars have noted the contrast to the law of increase of entropy. For example, Graham (2006, p. 275) writes that ‘atomism builds order out of disorder by a reverse entropy process’. According to Martin Barnett, Greek natural philosophy was opposed to the notion of irreversible change, and ‘The notion of the “dissipation” of substance, entailing a “running down” of the world, was therefore completely foreign to Greek philosophy.’ Barnett 1958, p. 329. However, although there was not, of course, any second law of thermodynamics in ancient Greece, this is to go too far.

In his famous poem *De rerum natura*, composed about 50 BC, the Roman poet Titus Lucretius Carus presented his own version of atomism, one which derived in equal measures from Democritus and Epicurus. In the first book he denied creation by asserting the permanence of matter, and he did so in a way that would greatly appeal to materialist thinkers nearly two thousand years later: 'Nothing is ever divinely generated from nothing … Nothing can be produced from nothing … [from which principles] we shall understand whence each individual thing is generated, and how all things are done without the agency of gods.'[2] After having affirmed that the universe is spatially infinite ('All that exists … is bounded in no direction') Lucretius proceeded with arguing for an infinity of inhabited worlds, of 'other orbs of Earth in other regions of space, and various races of men and generations of beasts'. He further explained that although the cosmos is infinite in space, it is of finite age and 'there will be an end to the heaven and the Earth.' He based his argument on the shortness of human history, which he found to be inexplicable if the world had always existed:

> If there was no origin of the heavens and Earth from generation, and if they existed from all eternity, how is it that other poets, before the time of the Theban war, and the destruction of Troy, have not also sung of other exploits of the inhabitants of Earth? How have the actions of so many men thus from time to time fallen into oblivion? How is it that they no where survive in remembrance, and are no where stamped on everlasting monuments of fame? But, as I am of opinion, the whole of the world is of comparatively modern date, and recent in its origin; and had its beginning but a short time ago.[3]

To Lucretius the world commenced with man, and he dated the origin from the time that poets first sang upon Earth. Not only did the universe have a beginning, it was also decaying, on its way to an end. Lucretius spoke of a cosmic deterioration, a theme which can be followed throughout the history of cosmological thought. 'The walls of the great world, being assailed around, shall suffer decay, and fall into mouldering ruins. … It is vain to believe that this frame of the world will last for ever; for neither do its veins, so to speak, submit to receive what is sufficient for its maintenance, nor does nature minister as much aliment as is needed.'[4]

Although Lucretius thus argued that the world is in a state of decay and has existed only in a finite span of time, he did not connect the two arguments by deriving the latter from the former. His view of a universe of finite age contradicted established cosmological thoughts based on the philosophical systems of Plato and Aristotle. In his dialogue *Phaedo*, Plato has Socrates discussing whether nature proceeds unidirectionally or circularly ('going round, as it were in a circle'). Socrates has

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[2] Lucretius 1997, p. 10, a reprint of a translation by John S. Watson from 1904. The phrase 'nothing can be produced from nothing' (*nil posse creari de nihilo*) was not used by ancient Latin writers in the later Christian sense of *creatio ex nihilo*, but rather meant that one thing could not be produced from another, quite different thing. Nonetheless, many materialists and scientific naturalists in the second half of the nineteenth century approvingly quoted Lucretius in support of their claim of an eternal universe.

[3] Ibid., pp. 45, 93 and 205.

[4] Ibid., p. 96.

no sympathy for the first case, and he asks, rhetorically, ‘if all things that have life should die, and, when they had died, the dead should remain in that condition, is it not inevitable that at last all things would be dead and nothing alive? For if the living were generated from any other things than from the dead, and the living were to die, is there any escape from the final result that all things would be swallowed up in death?’[5]

Aristotle’s very successful cosmological system, as he presented it in his *De caelo* and elsewhere, built upon the notion that the universe as a whole must be finite in extent but infinite in duration, ungenerated as well as indestructible: ‘That the heaven as a whole neither came into being nor admits of destruction, as some assert, but is one and eternal, with no end or beginning of its total duration, containing and embracing in itself the infinity of time, we may convince ourselves.’ The world was ultimately the creation of God, and ‘The activity of God is immortality, i.e. eternal life. Therefore the movement of God must be eternal.’[6] A spatially infinite world was impossible, for by its very nature the world revolves in a circle, and Aristotle argued that such motion was impossible for an infinite body as it would imply the nonsensical notion of an infinite velocity. Although Aristotle’s assumptions about a finite and eternal cosmos were highly influential, they were not accepted by all ancient philosophers. For example, they were opposed by the Stoics and Epicureans, who not only returned to pre-Socratic ideas of cosmic evolution but also operated with versions of an infinite or indeterminably large universe.

The problem of the eternity of the world (or the Earth) remained a matter of dispute especially among Stoic philosophers who objected to Aristotle’s thesis with empirical arguments based on the observed surface of the Earth. They reasoned that erosion is a unidirectional process and if it had been at work since an infinite time, all mountains and valleys would by now have been planed down. They clearly are not, and hence the Earth can have existed only in a limited span of time. This argument against the eternity of the world was developed by the Stoic philosopher Zeno of Citium around 320 BC and reported by Theophrastus as follows:

> If the Earth had no beginning in which it came into being, no part of it would still be seen to be elevated above the rest. The mountains would now all be quite low, the hills all on a level with the plain, for with the great rains pouring down from everlasting each year, objects elevated to a height would naturally in some cases have been broken off by winter storms, in others would have subsided into a loose condition and would all of them have been completely planed down. As it is, the constant unevenness and the great multitude of mountains with their vast heights soaring to heaven are indications that the Earth is not from everlasting.[7]

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5 *Phaedo*, 72 a 11-20, in Plato 1966, p. 251. Couprie 1998 suggests that this passage may have inspired Nietzsche to his thoughts about a non-teleological, recurrent universe. Plato’s *Timaios* includes a famous and much discussed creation story, but today it is generally agreed that it should be read metaphorically and not as a claim that the universe has a beginning in time.

6 *De caelo*, II 1, 283 b 26-30, and II 3, 286 a 8-10, in Aristotle 1984, pp. 470-2.

7 Quoted in Freudenthal 1991, p. 50.

This is possibly the first time we meet a theme that would come to occupy a prominent position in cosmological thinking more than two thousand years later: there exist in nature unidirectional processes – whether given by erosion, frictional forces, radioactivity or entropy increase – that speak against an eternal world. Faced with the Stoics' argument, proponents of Aristotelian physics postulated that corruptive geological processes were counteracted by generative processes, but they were unable to provide a satisfactory account, based on Aristotle's matter theory, of how these compensating processes operated.

In *De aeternitate mundi contra Proclum* and a lost treatise entitled *De aeternitate mundi contra Aristotelem*, John Philoponus, a Christian neo-Platonist philosopher from Alexandria who lived in the sixth century, criticized Aristotle's natural philosophy and sought to replace it with a system in harmony with monotheism. Thus, he attacked the traditional doctrine of the eternity of the world as well as the postulate of an essential difference between the terrestrial and heavenly parts of the world.[8] Since God had created the world out of nothing, it must have a finite age, contrary to what Aristotle had taught. Philoponus did not rest content with basing his conclusion on the authority of the Bible, but proved (to his own satisfaction) by means of *reductio ad absurdum* arguments that an eternal universe would lead to absurdities. Offering a whole battery of arguments against pagan infinitism, his main point was the asymmetry between future and past events: whereas future events are possibilities (potential), past events have happened and are therefore certain (actual).

One of Philoponus' arguments for the origin of the universe rested on the claim that it can only contain a finite amount of force or power. For example, the heavens are manifestly composite, but whatever is composite contains the grounds of its dissolution; therefore it cannot contain infinite power. Another of his arguments was based on the impossibility of eternal motion. For example, if the universe had existed in an eternity, there must have been in the past an infinite number of motions that is continually being increased. But, he claimed, an actual infinite quantity cannot be increased. If the universe had traversed an actual infinity of years, how many days would it have traversed? Another variant related to the revolutions of the celestial bodies, which were known to move with different periods, Saturn more slowly than Jupiter and much more slowly than the fixed stars. Now, if Saturn had revolved an infinity of times, Jupiter would have performed three times as many revolutions and the stars more than 10,000 times an infinite number of revolutions! This Philoponus thought was an impossible notion, 'Thus necessarily the revolution of the heavenly bodies must have a beginning.'[9] Nearly fourteen centuries later Eugen Dühring in

[8] Sorabji 1987, especially pp. 164-78. Although Philoponus' cosmological treatise against Aristotle is no longer extant, its content is known from the discussion of Simplicius and other authors (Philoponus 1987).

[9] Sambursky 1973, p. 135. See also Sambursky 1987, pp. 154-63. Islamic theologian-philosophers such as Abu Yusuf al-Kindi and Abu Hamīd al-Ghāzāli knew of Philoponus' works which provided inspiration for their version of the cosmological proof of God, the so-called *kalām* argument, so named after the Arabic name of 'word' which referred to philosophical theology (Craig 1979, pp. 8-9). Modernized versions of Philoponus' argument have continued to attract interest (Whitrow 1978).

Germany would come up with a somewhat similar argument against the past eternity of the world (Chapter 5).

The logic of Philoponus' argument, and many other arguments in the same tradition, was that the assumption of an infinitely old world leads to absurd conclusions. Such arguments were much discussed later in the Middle Ages, and in *De aeternitate mundi* Thomas Aquinas mentioned as an example what he called 'the argument from the infinity of souls': if the world had always existed, there would necessarily be an infinite number of souls (given that the soul is immortal). However, Aquinas found the argument to be inadequate. As he pointed out, God could have introduced beings with souls in a world with an infinite past, so they had only existed for a finite period of time, or he could have chosen to have made the world without such creatures at all.

Cosmic Deterioration

During most of the Scientific Revolution, from Copernicus to Newton, it was generally believed that nature is slowly but irrevocably decaying. The belief can be seen as an aspect of theories of 'cosmic fall' that were popular in the sixteenth century and were as much about the moral fall of man as of the physical deterioration of the Earth and cosmos. Martin Luther claimed that 'The world degenerates and grows worse and worse every day,' and added that the present trees and fruits 'are but miserable remnants … of those former riches which the Earth produced when first created.' He was sure that 'the world will perish shortly.'[10] The idea of nature's decay comprehended two aspects of which the most discussed was the supposed inferiority of modern man's mental and moral qualities as compared to those of the admired ancients. Humans, it was often said, had dwindled from giants to dwarfs. The other aspect related to the physical universe, or parts of it. It was not considered as quite as important as the fall of man, but this is the aspect which is of relevance in the present context and with which we shall be concerned.

The decay of nature manifested itself in particular in the rugged surface of the Earth, so obvious to any observer. God had of course created the Earth, and most philosophers thought that his creation was originally perfect in shape and had since deteriorated to its present form, marked by irregularities such as mountains, valleys and rivers. The belief could be supported by references to scripture, such as Isaiah 24:4 and Psalms 102:26, which provided it with additional authority. As Godfrey Goodman, later bishop of Gloucester, expressed it in his *The Fall of Man* of 1616: 'Now since the fruitfulnesse, or barrennesse of the earth, proceedes from the influence and disposition of the heauens; in the last place I dare accuse the materiall heauens, as being guiltie, conspiring, and together ioyntly tending to corruption; Scripture shall warrant me, *the heauens shall waxe old as doth a garment*, Psalme 102, vers. 26.'[11]

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10 Luther, *Commentary on the Book of Genesis* (1545), as quoted in Hepburn 1973-74, p. 506.

11 Quoted in Jones 1965, p. 28. The full title of Goodman's book was *The Fall of Man, or the Corruption of Nature, Proved by the Light of our Naturall Reason*. As we shall see, the

One of the first advocates of the theory of decay was the English divine Francis Shakelton, who in a treatise of 1580, *A Blazyng Starre*, confidently stated that ‘this worlde shall perishe and passe awaie, if we doe but consider the partes whereof it doeth consist, for doe we not see the yearth to be changed and corrupted?’ Shakelton found evidence of nature’s decay all over, in mountains, earthquakes and floods, even in ‘the constitution of the celestiall worlde, [which] is not the same that it hath been in tymes paste, for so much as the Sunne, is not so farre distant from vs now, as it hath been heretofore.’ The world was surely approaching its end:

> Let this therefore be a forcible argument to proue, that the world shall haue an ende: for so muche as it doeth waxe old, and euery part thereof doeth feele some debilitie and weaknesse. For there is lesse vertue in Plantes hearbes than euer before. And more feeble strength in euery liuing creature than euer was before. And less age in men than euer was before. It remaineth therefore (of necessitie) that shortly there shall be an ende and consumation of the Worlde, because it is (as it were) subiecte to olde age, and therefore feeble in euery parte.[12]

A century later we find what is essentially the same theme displayed in Thomas Burnet’s cosmogonical scenario as laid out in *Telluris theoria sacra*, published in 1681. According to Burnet, the primeval Earth was created as a perfect sphere corresponding to a state of paradise; only after long phases of decay would it return to a new smooth-surfaced globe.[13] Presently the Earth is a ‘hideous ruin’, much different from its original splendour. Burnet stressed that the decay was a powerful argument against the pagan Aristotelian notion of a changeless or cyclic eternity. Erosion is a one-way process and to Burnet it was clear evidence that the duration of the Earth was finite. He phrased his insight in counterfactual terms: ‘If this present state and form of the earth had been from eternity, it would long ere this destroyed itself … the mountains sinking by degrees into the valleys, and into the sea, and the waters rising above the earth … .’[14] Yet, the history of the Earth did not end with its destruction, for a new heaven and a new paradisiac Earth would follow the global conflagration. Just as the phase of decay could be justified by means of citations from the Bible, so was it the case with the hypothesis of this future phase of restoration – ‘There was the hope that creation itself would one day be set free from its slavery to decay and would share the glorious freedom of the children of God. For we know that up to the present time all of creation groans with pain, like the pain of childbirth.’[15]

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quoted passage from the Bible continued to be quoted in scientific-religious contexts well into the second half of the nineteenth century.

12 Quotations from Jones 1965, pp. 23-4.

13 English translation, *The Sacred Theory of the Earth* (1684; reprint edition, London 1965). On the concept of the decaying Earth in the seventeenth century, see Jones 1965, pp. 22-40, Davies 1966, and Russell 1994, pp. 21-7. On Burnet’s work, see also Gould 1987.

14 Burnet 1691, p. 44.

15 Romans 8: 21-22, and see also Rev. 21: 1.

Burnet's contemporary, the great natural philosopher Robert Hooke, was convinced that nature is evolving and in a state of universal, not merely terrestrial decay. In a lecture of 1689, only published posthumously, he said:

> … we find nothing in Holy Writ that seems to argue such a constancy of Nature; but on the contrary many Expressions that denote a continual decay, and a tendency to a final Dissolution; and this not only of Terrestrial Beings, but of Celestial, even of the Sun, Moon and Stars and of the Heavens themselves. Nor have I hitherto met with any Doctrine among the Philosophers, that is repugnant to this Doctrine, but many that agree with it, and suppose the like States to happen to all the Celestial Bodies, that is, to the Stars and Planets that happen to the Individuals of any Species.[16]

However, at that time the idea of denudation and decay had begun to fall in disfavour, primarily because the idea did not agree with the teleological turn in theological thinking. With respect to cosmic decay, the Bible was far from unequivocal. There were indeed several passages which supported decay and corruption, but there were also passages to the opposite effect. After all, if 'The heavens declare the glory of God', how can they be in a state of decay? In addition, the vitality and progress of the sciences were increasingly seen as conflicting with the claim of a general decay, whether moral or physical. The world might be approaching an end, but it would not be an imminent one, such as millenarian reformers had traditionally believed. Natural philosophers came to see their divinely inspired experiments and devices as an improvement on the original creation, and it was an improvement still in the making. Surely, there was plenty of room for further progress, all to God's delight. If God had created the best of all possible worlds, and had created it for the benefit of man, it was hard to believe that it was degenerating. As early as 1627 George Hakewill published a work in which he argued by means of a wealth of examples that nature is virile and in a process of constant restoration.[17] The heavens were not decaying, nor was the Earth less fertile than in ancient time.

The changed approach can be witnessed in the erudite theologian and philologist Richard Bentley's *Confutation of Atheism* of 1693, a work written under the influence of Newton's new mechanical physics. Bentley considered the argument that the rugged surface of the Earth 'rather carries the face of a Ruin or a rude and indigested Lump of Atoms that casually convened so, than a Work of Divine Artifice', but only to refute it. He concluded that the irregular mountains and valleys are really 'another Argument of the Divine Wisdom & Goodness … a new and invincible Argument, that the present Frame of the World has not existed from Eternity'.[18] Bentley did not infer from a finite future to a finite past. On the contrary, using a version of Philoponus' argument he reasoned that whereas the past is closed with

[16] Hooke, *Discourse of Earthquakes and Subterraneous Eruptions* (1667-94), as transcribed in Drake 1996, p. 319.

[17] Jones 1965, pp. 29-37. See also Hepburn 1955. The title of Hakewill's work was *An Apologie of the Power and Providence of God in the Government of the World*.

[18] Bentley, *Confutation of Atheism* (1693), as reprinted in Cohen 1978, pp. 384, 392-3. On the transition of British cosmogonies after the 1680s, see Porter 1979.

respect to actual events, the future can be conceived to be open. Considering the present revolution of the Earth, he wrote:

> God almighty, if he so pleaseth, may continue this motion to perpetuity in infinite revolutions to come; because futurity is inexhaustible, and can never be spent or run out by past and present events. But then, if we look backwards from this present revolution, we may apprehend the impossibility of infinite revolutions on that side; because all are already past, and so were once actually present and consequently are finite ... For surely we cannot conceive a preter-iteness (if I might say so) still backwards *in infinitum*, that never was present, as we can an endless futurity that never will be present.[19]

By far, most of the doomsday scenarios proposed over the last two millennia have been transformations, not annihilations. The general expectation among theologians and philosophers was that the universe would be drastically transformed from its present state, yet somehow the new universe would still include the information of the old. There have, however, also been proposals that the present universe will disappear completely after the Last Judgment, an idea which was popular in Lutheran theology in parts of the seventeenth century. According to this kind of eschatology, the original *creatio ex nihilo* would be followed by a final *reductio ad nihilum*, a change from being to non-being. (For biblical support, see 2 Peter 3: 10 and Revelation 20: 11.) The latter kind of cosmic end has its modern analogy in relativistic Big-Bang models of the closed type, where the universe will eventually contract and disappear in a 'big crunch'. But scientifically based ideas of annihilation of matter, space and time belong to the post-1920 era. Before that time, the end of the world, as suggested by the second law of thermodynamics or other processes of decay, meant the end of life and activity in the universe, its irreversible transformation into an equilibrium state rather than its annihilation into nothingness.

A World of Finite Age

As Bentley was well aware, the theory of decay could be used apologetically, as an argument for God's creation of the world a finite time ago. He was not the first to recognize that if the present world – Earth or universe, the difference was not really important – is in a state of progressing degeneration, it might be argued that there was a time, following the creation, when the decay started. The world could not have existed for ever – not, at least, in a form similar to the one we observe – for if so the decay would now be total, which it is not. This is how the learned judge Sir Matthew Hale interpreted the situation in a book published in 1677:

> That if the World were eternal, by the continual fall and wearing of Waters all the protuberances of the Earth would infinite Ages since have been levelled, and the Superficies of the Earth rendred plain, no Mountains, no Vallies, no inequalities would be therein, but the Superficies thereof would have been as level as the Superficies of the water.[20]

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19 *Confutation of Atheism*, sixth sermon, as quoted in Whitrow 1990, p. 29.

20 Quoted in Davies 1966, p. 278.

The question of the temporal extension of the world also turned up in the correspondence between Leibniz and Samuel Clarke, the latter serving as Newton's mouthpiece in the famous philosophical controversy. Leibniz disagreed with Newton on a number of issues, including the nature of space and time, but he shared his belief in a materially infinite universe, which he found to be 'more agreeable' to God's wisdom. While there could be no spatial bounds, he admitted the possibility of a temporal bound, a beginning of the universe. Yet Clarke maintained that parity between spatial and temporal infinity followed from Leibniz's philosophy. In order to protect his position, Leibniz pointed out that on the assumption that the world is uniformly increasing in perfection it follows that its age must be finite, for otherwise its perfection would be infinite now: 'If it is the nature of things in the whole, to grow uniformly in perfection; the universe of creatures must have had a beginning. And therefore, there will be reasons to limit the duration of things, even though there were none to limit their extension.'[21]

Leibniz may not have felt his argument to be quite convincing, for he added that, according to 'some famous divines', even if the world had existed in an eternity it would still depend upon God, hence be created. He undoubtedly had in mind the idea of *creatio continuans* such as expounded by Thomas Aquinas, who in *De aeternitate mundi* from about 1270 had argued that there is no contradiction in claiming that a divinely created universe has always existed.[22] In general, Leibniz was unwilling to commit himself on the problem of a beginning of time. He believed that there were possible worlds both with a beginning in time and with a past infinity. Which world had God chosen to actualize? He reasoned that, if nature is 'always perfect … it is more probable that it had no beginning'.[23] On the other hand, if nature decreases in perfection as we go backward in time, and if we reach a state of minimum perfection, then it is more probable that time had a beginning.

Although the concept of decay or denudation fell into disfavour in eighteenth-century geological thinking, a version of it survived in astronomy. Newton was not much concerned with the surface of the Earth, but he came to believe that the celestial bodies' friction in the ether and their mutual gravitational perturbations would slowly cause nature to decay. He had originally pictured nature as a perpetual worker, but at the time of the publication of *Principia* he tended to see the cosmos as a machine that was running down. 'A continual miracle is needed to keep the Sun and the fixed stars from rushing together through gravity,' he told the Scottish mathematician David Gregory in a conversation of 1694.[24] In 1706 Newton mentioned explicitly

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[21] Alexander 1956, p. 80. See also Vailati 1997, pp. 167-8.

[22] On the important concept of *creatio continuans*, see Carroll 1998 and also Copan and Craig 2004, pp. 147-57. Several biblical texts speak of creation through natural processes, for example Ps. 104: 14, 30. Bonaventure, the Franciscan theologian and contemporary of Thomas Aquinas, argued that the eternity of the world was not only false but also philosophically absurd: if the universe had no beginning, an infinite number of revolutions must have taken place in the heavens, and therefore the present could not have been reached. Aquinas disagreed with Bonaventure and maintained that creation can be understood in the sense of preservation and dependence.

[23] Leibniz 1970, p. 664.

[24] Memoranda by Gregory, in Newton 1961, p. 336.

the universal tendency of motion to diminish: 'By reason of the tenacity of fluids, motion is more apt to be lost than got, and is always upon the decay. … Seeing therefore the variety of motion which we find in the world is always decreasing, there is a necessity of conserving and recruiting it by active principles.' As to the active, regenerating principles, he wrote: 'If it were not for these Principles, the Bodies of the Earth, Planets, Comets, Sun, and all things in them, would grow cold and freeze, and become inactive Masses; and all Putrefaction, Generation, Vegetation and Life would cease, and the Planets and Comets would not remain in their Orbits.'[25]

In his correspondence with Bentley, Newton mentioned the possibility 'that there might be other Systems of Worlds before the present ones, and others before those, and so on to all past Eternity.'[26] Although he found 'the growth of new Systems out of old ones' to be absurd, he granted that such a process might be accomplished by the will of a divine power. Newton realized that a non-decaying universe could be used by atheists to argue against a created universe, which was one reason for his emphasis on God's providence and responsibility for the continuing existence of the world. Conversely, a decaying universe could be seen as 'a very strong philosophical argument against the eternity', such as Henry Pemberton, a medical doctor and mathematician, argued in 1728: 'It is thus, that these inequalities [in the motions of the planets] must continually increase by slow degree, till they render at length the present frame of nature unfit for the purposes it now serves. And a more convincing proof cannot be desired against the present constitutions having existed from eternity than this, that a certain number of years will bring it to an end.'[27]

The same theme was discussed by William Whiston, the author of the *New Theory of the Earth* (1696) and a friend of Newton until he was expelled from Cambridge because of heretical religious views. In his *Astronomical Principles of Religion*, Whiston stated that, 'it follows, that the several Systems, with their several Fixed Stars and Suns, do naturally and constantly, unless Miraculous Power interposes to hinder it, approach nearer and nearer to the Common Center of all their Gravity'. However, since we have not actually observed any decay, the world must have existed in a limited span of time, in agreement with the words of the Bible. It followed from Newton's system that 'the World has not been from all Eternity', but was created by God, whom Whiston at one place described as 'the only Author of the Power of Gravity'.[28] In papers read before the Royal Society 1691-93, Edmond Halley attempted to prove that the motion of the Earth and the other planets would be progressively retarded by their passage through the ether; if so, the world would come to an end. Speaking of the Sun and the Moon, he argued that 'how long soever

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25 Newton 1952, pp. 399-402. See also Kubrin 1967, reprinted in Russell 1973, pp. 147-69.

26 Kubrin 1967 (Russell 1973, p. 154).

27 Quoted in Kubrin 1967 (Russell 1973, p. 151).

28 Whiston, *Astronomical Principles of Religion, Natural and Reveal'd* (London, 1717), pp. 88-9 and p. 123. Whiston succeeded Newton as Lucasian Professor of Mathematics at the University of Cambridge. He was expelled as an Arian in 1710 and subsequently moved to London.

these Globes may last they cannot be Aeternal ... hence will necessarily follow the necessity of that Act of Creation'.[29]

Similar lines of argument appeared in some texts on Newtonian astronomy in the age of Enlightenment, including a book published by James Ferguson in 1757. Ferguson wanted to bring home the point that the universe had been created, and hence must be of a finite age. This he did by developing an old argument of Newton's – that if gravity remained unchanged the planets would eventually collide with the Sun. Or, more generally, if the world shows signs of gradual decay it cannot have existed forever (in that case it would already be in a state of total dissolution). His argument was as follows:

> For, had it [the world] existed from eternity, and been left by the Deity to be governed by the combined actions of the above [Newtonian] forces or powers, generally called Laws, it had been at an end long ago …. But we may be certain that it will last as long as was intended by its Author, who ought no more to be found fault with for framing so perishable a world, than for making men mortal.[30]

Here we have a general argument for the temporal finiteness of the universe, based upon a universal law that is supposed to vary monotonically with time. Ferguson's argument (or the earlier ones of Hale, Bentley, Hooke and Pemberton) depended on a tendency of decay in the mechanical laws that proved unwarranted. Newton's laws of motion do not depend on history, they are time-symmetric. Indeed, in works from the 1780s Pierre-Simon Laplace proved that the 'world' (in the restricted sense of the solar system) was a mechanically stable system and that there was no reason to fear that perturbations or frictional forces would one day cause the system to disrupt, such as Newton had believed.[31] The 'Newton of France' disseminated the optimistic message to a broader audience in his influential *Exposition du système du monde*, published in 1796. It is in this work that we find the high point of philosophical determinism, sometimes known as Laplace's demon or intelligence, an entity that may look like the all-knowing God but was rather intended to be a substitute for him:

> We must therefore envisage the present state of the universe as the effect of its anterior state and as the cause of its future state. An intelligence that knew, for a given instant, all the forces acting in nature and the respective situations of the beings that made it up, if it were in addition vast enough to submit these data to analysis, would embrace in a single formula the motions of the largest bodies of the universe and those of the smallest

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29 See Schaffer 1977, p. 32. Halley's attitude was ambiguous as he did not consider his arguments in favour of a cosmic beginning and end to be convincing. Some of his contemporaries suspected that he believed in the eternity of the world.

30 Ferguson 1778, p. 84.

31 Laplace, whose early education had been religious and oriented towards priesthood, became an atheist or an agnostic. He was puzzled over Newton's assertive comments about God's role in the universe and unable to imagine how a scientist as brilliant as Newton could be genuinely committed to religious beliefs and, moreover, let them interfere with his scientific work. See Hahn 2005, pp. 201-2.

> atom: nothing would be uncertain for it and the future like the past would be present to its eyes.[32]

It was only with the second law of thermodynamics that a fundamental law of nature was discovered that distinguishes past from present (the real blow against Laplace's vision came with quantum mechanics). What is here to note is that the structure of Ferguson's argument did not differ essentially from the arguments of a finite-age universe that were proposed in the nineteenth century on the basis of the laws of thermodynamics.

Even with Laplace's stable and deterministic world, and with thermodynamics still in the future, it was possible to find unidirectional processes in nature that indicated a world in decay. The general idea of irreversible and dissipative processes in nature appeared in natural philosophy many years before the second law of thermodynamics, especially in connection with geology and geophysics. During the last decades of the eighteenth century it became common to conceive the Sun as a huge chemical machine which had once given rise to the Earth and the other planets, originally in a molten state and since then decreasing in temperature. If the Earth had been cooling for many thousands of years, such as the comte du Buffon (Georges Louis Leclerc) controversially argued in his *Epoques de la nature* from 1778, perhaps the Sun, too, was gradually cooling. Buffon started developing his naturalistic cosmogony in 1749, much to the dismay of the church. Two years later he barely escaped censure by the Paris theologians. Buffon's great insight was that the Earth – or nature – has a history which can be understood by basically the same means that are used in ordinary history:

> Just as in civil history we consult warrants, study medallions, and decipher ancient inscriptions, in order to determine the epochs of the human revolutions and fix the dates of moral events, so in natural history one must dig through the archives of the world, extract ancient relics from the bowels of the Earth, gather together their fragments, and assemble again in a single body of proofs all those indications of the physical changes which can carry us back to the different Ages of Nature. … Natural history … embraces in its scope all regions of space and all periods equally, and has no limits other than those of the universe.[33]

In this way Buffon was led to the conclusion that the Earth was hotter in the past and much older than believed according to tradition. The further step to the conjecture that other celestial bodies faced a destiny similar to that of the Earth was first taken by the French astronomer and pioneer historian of astronomy Jean-Sylvain Bailly. In a paper of 1777 he predicted that all planetary bodies must eventually reach a final state of equilibrium in which all motion ceases.[34] The kind of thermal death that

[32] Quoted in Morando 1995, p. 149.

[33] Buffon, *Epoques de la nature*, as quoted in Toulmin and Goodfield 1965, p. 144.

[34] On Bailly and his work, see Smith 1954. According to Brush (1986, p. 552), 'Thus the modern concept of the "heat death" of the universe, usually attributed to the 19th-century thermodynamic speculations of Thomson, Clausius, and Helmholtz, was actually published as early as 1777.'

Bailly predicted was however based on a special hypothesis of internal heat, and was not, as in the later thermodynamical heat death, founded on a general law of nature.

Scenarios of the kind envisaged by Buffon and Bailly were not uncommon at the turn of the century, decades before they could be justified by the laws of the conservation and degradation of energy. The idea turned up, for example, in William Paley's famous and hugely successful *Natural Theology*, the period's most influential attempt to prove God's existence from the design of nature. The prestige of Newton's work tended to accord theological prominence to astronomically rather than biologically based arguments, but by the end of the eighteenth century the trend changed. Paley focused on the living world and stated that 'My opinion of Astronomy has always been that it is *not* the best medium through which to prove the agency of an intelligent Creator.' Nonetheless, following the tradition of Newton, Bentley and William Derham, he did include astronomy among his arguments and conceded that, once the existence of God had been established, astronomy 'shows beyond all other sciences, the magnificence of his operation'.[35] If the Sun was gradually cooling, as he believed, not only would it lead to a lifeless, frozen Earth in the future, it also meant that the solar system was of finite age: 'The sun also himself must be in his progress towards growing cold; which puts an end to the possibility of his having existed, as he is, from eternity.'[36] Paley did not conclude that the Sun must therefore have been created by a divine power, possibly because he found the inference to be obvious.

Degenerative and dissipative processes were known by natural philosophers many years before the discovery of the second law of thermodynamics. They were known, more or less intuitively, from the earth and planetary sciences, and also from plain observations of the decay occurring on the surface of the Earth. The influential Scottish theologian Thomas Chalmers, author of the *Astronomical Discourses* (1817), stressed the transitory nature of the phenomenal world, a view he supported by references to the Bible. While God was eternal and enduring, 'nature contains within itself the rudiments of decay ... unless renewed by the hand of the Almighty, the earth ... must disappear in the mighty roll of ages and of centuries'.[37]

In his last work, the melancholic *Consolations in Travel*, the great chemist and natural philosopher Humphry Davy reflected in the form of a series of dialogues on the nature of time and decay: 'I said, ... we refer the changes, the destruction of material forms, to *time*, but there must be physical laws in nature by which they are produced.' Davy wrote that 'science has discovered the principle of decay of things' and suggested that 'every thing belonging to the earth, whether in its primitive state, or modified by human hands, is submitted to certain and immutable laws of destruction, as permanent and universal as those which produce the planetary motions.' As to the

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35 Paley 1805 (9th edn), p. 412. On the changes in British natural theology, including the change from astronomy to natural history, see Gascoigne 1988.

36 Paley 1805, p. 417. Paley's book included many arguments to the effect that the world is designed in details to allow the existence of human beings, which makes it a classic of early anthropic reasoning (see Barrow and Tipler 1986, pp. 77-82).

37 From an essay on 'The non-eternity of the present order of things', quoted in Smith 1979, p. 65.

agent of destruction, he thought that it was gravitational attraction which 'tends, as it were, to produce rest, a sort of eternal sleep in nature'.[38] The physical law of destruction that Davy vaguely anticipated was not gravitation, though. It was related to the theory of heat, or what came to be known as thermodynamics. And it is to the early history of this science that we shall now proceed.

[38] Davy 1840, pp. 368-70. *Consolations in Travel, or the Last Days of a Philosopher* was first published posthumously in 1830.

Chapter 3

Thermodynamics and the Heat Death

Until the middle of the nineteenth century, the only link between cosmology and fundamental physics had been by way of Newton's law of gravitation. Like this law, the new laws of thermodynamics that emerged in the years around 1850 were assumed to be valid for all parts of the entire universe, and hence potentially of cosmological significance. From a rather early date thermodynamical reasoning was applied to the universe at large, not only leading to the notorious heat death but also to more or less scientifically based arguments concerning the origin of the universe. This chapter is meant as an introduction to and preparation for these developments. It briefly outlines how thermodynamics emerged as a science, a topic which has attracted much scholarly attention and about which there exists an extensive literature.

From Caloric to Energy

According to the highly successful caloric theory, dating from the 1730s, heat was an imponderable and self-repulsive fluid – sometimes called *caloric* – that could be transferred from hotter to colder bodies. Although the fluid could move from one place to another, in a closed system it was assumed to be a conserved quantity. The caloric theory was not only a cornerstone of chemistry, it also served as the foundation of two of the pioneering works of what came to be known as thermodynamics, Jean Baptiste Joseph Fourier's celebrated *Théorie analytique de la chaleur* of 1822 and Sadi Carnot's no less celebrated *Réflexions sur la puissance motrice du feu* published two years later.

In his general theory of heat engines Carnot stressed that in the ideal case these were reversible machines, and he used the idea of reversibility to introduce and calculate the maximum efficiency for such a machine. Modelling his theory of caloric power on hydrodynamics, he showed that the ratio of the work done by a reversible engine to the heat taken from the source is a function of the temperatures of the source and condenser only. When the temperature difference is nearly zero, the ratio depends only on the temperature of the source. His entire argument in *Réflexions* rested on the generally accepted assumption that the subtle heat substance was conserved as it moved around in the heat engine. That is, his theory was based on the assumption of heat being conserved in the production of work and, also, that work is being produced by the transformation of heat from a higher to a lower temperature.[1] Another basic assumption, here made explicit for the first time, was

[1] A few years after the publication of *Réflexions*, Carnot abandoned the caloric theory in favour of a dynamical conception of heat. However, his revised ideas did not influence the

the impossibility of perpetual motion, which is to say that it is impossible to have 'motive power being created in unlimited quantities without the consumption of caloric or of any other agent'.[2] In a footnote Carnot speculated that the principle was cosmologically valid. He wrote, rather cryptically, that a perpetual motion machine 'would even possess the force necessary to move the entire universe and to sustain and constantly accelerate its motion'.

In spite of its innovative insights Carnot's treatise was largely ignored for a decade or more. It became known only from about 1834, when Emile Clapeyron published an important paper, 'Mémoire sur la puissance motrice de la chaleur', in which he clarified and greatly extended Carnot's arguments. It was in this paper that a graphical representation of the Carnot cycle (relating pressure to volume) first appeared. Like Carnot, Clapeyron accepted the caloric theory based on heat conservation.

The route that led from caloric to the doctrine of energy conservation is complex, but its main stages are now well understood.[3] It is generally accepted that the first to introduce the notion of an indestructible 'force' (more or less in the sense of energy) was the German physician Julius Robert Mayer, who in 1842 gave a first account of his idea of force conservation. According to Mayer, there exists a quantity, soon to be called energy,[4] which is always conserved although it can be converted from one form to another. From some rather inaccurate experiments he calculated the mechanical equivalent of heat, meaning the conversion factor between mechanical work and heat energy. In modern units, Mayer gave the factor as 1 cal = 3.65 J, while the correct quantity is 4.184 cal/J (Joule's best value was 4.236 cal/J). In later works from the 1840s he extended his theory to cover not only energy transformations on Earth but also phenomena in the solar system, including a clever theory of solar heat based on the mechanism of meteoric collisions with the Sun. The significance of Mayer's work went at first unnoticed and was only recognized in the 1860s, not without dispute.[5]

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development of thermodynamics as he kept them privately. His manuscript notes remained unknown until 1878 and were published only a century later. See Carnot 1986.

2 Carnot 1986, p. 69. The impossibility of a *perpetuum mobile* was at the time generally recognized, but only for purely mechanical processes.

3 See, for example, Elkana 1974 and Cardwell 1971. For a spirited account of the early history of thermodynamics, see also Gillispie 1973, pp. 352-405.

4 The term 'energy' derives from the Greek word *energeia* invented by Aristotle in the *Nicomachean Ethics* and with a connotation quite different from the current one. Aristotle's term is usually translated as 'activity' or sometimes 'actuality' or 'being at work'. The word was first used in something like its modern meaning by Thomas Young in a lecture of 1807, although he used it in the more restricted sense of the Leibnizian *vis viva*, corresponding to kinetic energy except for a factor of one half. As a term of physics 'energy' only came in general use from about 1860. The name 'thermodynamics' was coined by William Thomson in 1854.

5 Caneva 1993. For decades, the history of thermodynamics was characterized by acrimonious controversies of priority, especially between Germans and Britons concerning the discovery of the law of energy conservation. Although an important part of the history of

The Manchester brewer and natural philosopher James Prescott Joule came to energy conservation independently and slightly later, by following an approach which focused on the interconversion of various forms of energy, such as electrical, mechanical and thermal. In a paper published in the *Philosophical Magazine* in 1845, dealing with the rarefaction and condensation of air, he reported experimental evidence in favour of energy as a conserved quantity which can exist in different forms. He used the occasion to criticize the theory of Clapeyron (and thereby also Carnot's theory) for contradicting 'recognized principles of philosophy' because it led to a destruction of energy that contradicted the new doctrine of energy conservation. Like his contemporaries, Joule spoke of 'force' rather than 'energy', but in the present context the name and precise meaning of the concept is less important.[6] According to Clapeyron's view, force (*vis viva*) would be lost with the passage of heat in a steam engine, but this Joule denied with a reference to theology rather than physics: 'Believing that the power to destroy belongs to the Creator alone, I entirely coincide with Roget and Faraday in the opinion that any theory which, when carried out, demands the annihilation of force, is necessarily erroneous.'[7] Joule suggested that order in the universe was maintained by means of conversions of 'forces' and that the constancy of these expressed nature's self-sufficiency, ultimately to be traced back to God.

Joule's works did not arouse much immediate attention. The situation changed only after 1847 when young Hermann von Helmholtz in Germany published his important memoir *Ueber die Erhaltung der Kraft*, a privately printed work that marks the effective beginning of the law of energy conservation, if not of thermodynamics in the wider meaning.[8] (The editors of *Annalen der Physik* turned it down because of its lack of experimental content.) Helmholtz first considered thermal problems in a paper of 1846 where he sought to correlate animal heat with heat phenomena known from physics and chemistry; he found that the quantity of heat generated by animals was equal to the heat produced by burning their food in a calorimeter. The following year, still unaware of the works of Mayer, he used the impossibility of perpetual motion to justify a general correlation principle. His memoir of 1847 not only provided a mathematical formulation of the principle of energy conservation, it also demonstrated the unifying role of energy in all areas of natural philosophy. Helmholtz stressed that the principle was neither a tautology nor an axiomatic statement. Rather it should be understood as a hypothesis of physics totally divorced from philosophical considerations. But in this respect Helmholtz did not represent

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the reception of thermodynamics, the controversy played no significant role with respect to the theme considered here, the cosmological implications of the second law.

[6] 'Energy' was very little used in the 1840s. All that the 1842 edition of the *Encyclopaedia Britannica* had to say about the word was this: 'ENERGY, a term of Greek origin, signifying the power, virtue, or efficacy of a thing. It is also used figuratively, to denote emphasis of speech.'

[7] Joule 1963, p. 189. The reference is to Peter Mark Roget, a British natural philosopher and longtime secretary of the Royal Society who about 1830 investigated Voltaic electricity. Faraday needs no introduction.

[8] For a detailed analysis of Helmholtz's pioneering work, see Bevilacqua 1993.

the majority view. To most of his contemporaries, the law of energy conservation was inextricably connected with problems of a philosophical nature.

By 1847 caloric was about to disappear from physics, on its way to be replaced by heat as a mode of motion and a manifestation of the much more general concept of energy. It is not too much to say that the general concept of energy was invented as a result of the events in the 1840s. Although 'energy' quickly became something of a catchword and applied to a variety of physical problems, the concept was often misunderstood by non-experts, whether scientists or laymen. As late as 1864-65 the eminent astronomer and natural philosopher John Herschel criticized the principle of energy conservation in terms revealing that he did not understand its true meaning. Herschel complained that the principle was a mere verbal truism, whereas in reality it is an empirical generalization.[9]

Perspectives on Early Energy Physics

The thermodynamical theory that emerged in the mid-nineteenth century almost immediately became of cosmological importance, although in a way that astronomers at first paid little attention to, and which was mostly discussed outside the astronomical community. The cosmic significance of thermal phenomena was occasionally discussed before the formulation of energy conservation. Thus, in a paper of 1819 the French experimental physicists Nicolas Clément and Charles-Bernard Desormes envisaged what a universe devoid of heat would look like: 'Not only would there be no more life in this dismal universe … but also movement of every kind would have ceased on Earth. There would no longer be an atmosphere, no rivers, no seas; motionlessness and death would be everywhere.'[10] This may look like an anticipation of the doctrine of the heat death, but it was not: the prediction of the heat death is based on an empirically confirmed law of nature, whereas the statement by Clément and Desormes was merely a counterfactual scenario.

Fourier mentioned in the introduction to *Théorie analytique* that his theory of heat conduction was applicable also to the Earth and the solar system, and he emphasized that 'the action of heat is always present, it penetrates all bodies and spaces, it … occurs in all the phenomena of the universe'.[11] Likewise, in Carnot's *Réflexions* one finds a similar rhetoric and a few passages referring to the meteorological and geological effects of heat, such as the fall of rain and volcanic eruptions. Based on such evidence Donald Cardwell has suggested that a 'new cosmology of heat' appeared in the 1820s.[12] However, this is an acceptable claim only if 'cosmology' is understood in a highly restricted meaning and not in the standard sense that relates

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[9] James 1985; Smith 1998, p. 6.

[10] Clément and Desormes 1819, p. 322.

[11] Fourier 1878, p. 14. In a paper of 1824, Fourier suggested that heat radiation from the stars caused the temperature of interplanetary space to differ from absolute zero, thereby having a major effect on the Earth's climate (Herivel 1975, p. 202).

[12] Cardwell 1971, pp. 118-9. See also Merleau-Ponty 1983, pp. 212-25, who gives a valuable review of the cosmo-energetic views of the pioneers of thermodynamics. As Merleau-Ponty points out, the idea to consider heat (or fire) as a cosmological agent was well known to

to the universe at large. Fourier, Carnot and a few others of their generation realized that heat is a universal phenomenon, on par with gravitation, and in this sense is of cosmological significance. They used the theory of heat in attempts to understand the physics of the Earth and the Sun, but (with the exception of Clément and Desormes) they did not go beyond the solar system and nor did they speak of the universe as a whole. For this reason it seems to me that 'the new cosmology of heat' is not really part of the history of cosmology. A kind of heat cosmology did eventually emerge, but only with the second law of thermodynamics.

Spiritual and religious reflections based on the new thermodynamics relied on the second law in particular, but in some cases the law of energy conservation was enough to serve as an argument for a divine creator. A case in point is the Danish engineer and physicist Ludvig August Colding, who in 1843 suggested his own version of the conservation and correlation of 'forces'. Colding, who was a pupil of Hans Christian Ørsted, believed that spiritual activity was a higher form of energy and that the law of energy conservation proved not only the immortality of the soul but also that God had created the world out of nothing. 'It was the religious philosophy of life which led me to the concept of the imperishability of forces,' he admitted in an essay of 1856. Influenced by German *Naturphilosophie*, Colding was convinced that the forces were independent entities, detached from matter and spiritual in nature. The forces of nature, he wrote, 'are not even bound by the Earth, but in fact, traverse the universe without cessation and bring light and clearness to every globe in the endless void, so that it may be clear to all that the goal of existence is the evolution of an ever more perfect spiritual and harmonious rational whole'.[13]

As mentioned, Joule believed that the conservation of matter and forces was a sure sign of the universe being created by God to the benefit of man. In a lecture of 1847, delivered in the reading room of St Ann's Church in Manchester, he elaborated on the connection: 'Thus it is that order is maintained in the universe – nothing is deranged, nothing ever lost, but the entire machinery, complicated as it is, works smoothly and harmoniously … the whole being governed by the sovereign will of God.'[14] Four years later William Thomson wrote in a manuscript that 'although no destruction of energy can take place in the material world without an act of power possessed only by the supreme ruler yet transformations take place'.[15]

The English lawyer, chemist and physicist William Grove was equally convinced of the religious implications of the correlation between different kinds of forces or energies. He spelled out the message in the concluding remarks of his widely read book, *Correlation of Physical Forces*, first published in 1846. Can we conceive of force without antecedent force? Grove could not, 'without calling for the interposition of created power, any more than I can conceive the sudden appearance

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eighteenth-century natural philosophers such as Johann Heinrich Lambert, Pierre Prévost and William Herschel.

13 The essay, 'Scientific reflections on the relationship between the activity of spiritual life and the general forces of nature', was published in Danish. An English translation by Per Dahl appears in Colding 1972, pp. 105-28. See also Caneva 1997.

14 Joule 1963, p. 273.

15 Quoted in Smith 1976, p. 281.

of a mass of matter come from nowhere, and formed from nothing'. He concluded from the interconnectedness of the forces of nature that 'neither matter nor space can be created or annihilated, and that an essential cause is unattainable – Causation is the will, Creation the act, of God.'[16] Robert Mayer emphasized the net conservation of forces rather than their correlation. Although he was reluctant to link his scientific work directly to religion and metaphysics, he considered energy conservation to be a weapon against materialism and atheism. He believed, like Colding, that the existence and immortality of the soul followed from the new science of heat. In 1867 he wrote about the principle of energy conservation that it was 'diametrically opposed to the principles and consequences of the materialistic viewpoint'.[17]

Also the Alsatian Gustave-Adolphe Hirn, a Protestant scientist who did important work in applied thermodynamics, believed that the new science of heat was linked to metaphysics and religion. It was, he argued, an antidote to materialistic blindness, and as such it supported the notion of a divinely created world.[18] Finally, the British physiologist William Benjamin Carpenter was yet another Christian contributor to the correlation of forces, which to him meant the correlation between vital and physical forces in particular. He was convinced that ultimately the forces of the second kind (such as electricity, heat, light and mechanical motion) derived from the same agency, 'the creative and sustaining will of the Deity'.[19]

After the concept of energy and the law stating its conservation had been firmly established, a considerable literature appeared in which the first law of thermodynamics was seen as indicating a shift in world view from materialism to idealism or spiritualism. In several cases the idea of energy conservation was presented apologetically, say as an argument for the connection between the human mind and that of God, not unlike what Colding and Grove had stated in the 1840s. To mention but one example, the American writer and science promoter Edward Youmans published in 1865 a compilation of essays, *The Correlation and Conservation of Forces*, in which he wrote: 'It has been shown that a pure principle forms the immaterial foundation of the universe. From the baldest materiality we rise at last to a truth of the spiritual world, of so exalted an order that it has been said "to connect the mind of man with the Spirit of God".' Youmans saw the same tendency in all branches of science, namely that 'material ideas are giving place to dynamical ideas'.[20] Ironically, at about the same time materialists began to see in energy conservation a scientific justification for their godless ideas. As argued at length by the Jesuit scholar Karl Alois Kneller, most of the historical actors

16 Quoted from the fourth edition, as reprinted in Youmans 1865, on p. 195 and p. 199. On Grove, see Cantor 1976.

17 See Caneva 1993, p. 44.

18 Hirn 1885-86. Hirn published his early ideas about science, metaphysics and the Christian world view in a series of articles 1850-51 in *Revue d'Alsace*. See Papanelopoulou 2006.

19 Carpenter 1850, p. 730. Carpenter's role in the history of the first law of thermodynamics is detailed in Hall 1979. See also Brooke and Cantor 1998, pp. 262-8.

20 Youmans 1865, p. xii. See also Hiebert 1966, who gives other examples.

responsible for the law of energy conservation were sincere Christians and opposed to the new trend of materialism.[21]

The Second Law of Thermodynamics

Experts in the theory of heat, notably Rudolf Clausius in Germany and William Thomson in Scotland, realized that the theories of Carnot and Joule were not easily reconcilable, but they responded somewhat differently to the perceived difficulty. The result of their considerations was a new and fundamental principle of nature, the second law of thermodynamics.

Clausius concluded that the basic principle of Carnot's theory, properly understood, could after all be reconciled with Joule's works. In 1850, in a paper entitled 'Über die bewegende Kraft der Wärme', he formulated a synthetic theory that rested on two fundamental principles of what soon came to be known as thermodynamics. The first was energy conservation, or the equivalence of heat and work, and the second was the statement that it is impossible for a self-acting cyclic machine to convey heat from a body of lower temperature to another at a higher temperature.

Thomson said about the same in a paper of 1851, and the following year, after having read Helmholtz's memoir, he formulated the second law as an inbuilt tendency in nature towards dissipation of energy; or, in another version, that it is impossible to gain work by cooling matter below the temperature of the coldest of its surroundings. In a draft version written in early 1851 he formulated his insight in semi-religious language: '*We may ... regard it as certain that, neither by natural agencies of inanimate matter, nor by the operations arbitrarily effected by animated Creatures, can there be any change produced in the amount of mechanical energy in the Universe*; and the belief that Creative Power alone can either call into existence or annihilate mechanical energy, enters the mind with perfect conviction.'[22] In the published version, Thomson similarly included a reference to the 'Creative Power'. He formulated his important insight as follows:

> 1. There is at present in the material world a universal tendency to the dissipation of mechanical energy. 2. Any *restoration* of mechanical energy, without more than an equivalent of dissipation, is impossible in inanimate material processes, and is probably never effected by means of organized matter, either endowed with vegetable life or subjected to the will of an animated creature.[23]

Notice that Thomson was, at this stage, uncertain if his law of energy dissipation was valid also for life processes.

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[21] Kneller 1912, first published 1903 as a special issue of the Catholic periodical *Stimmen aus Maria-Laach*. An English translation appeared in 1911 as *Christianity and the Leaders of Modern Science* (London: Herder).

[22] Quoted in Smith 1998, p. 139. For Thomson's route to thermodynamics, see also Smith 1976.

[23] Thomson, 'On a universal tendency in nature to the dissipation of mechanical energy', *Philosophical Magazine* 4 (1852), 304-6. This paper, and other of Thomson's early works on thermodynamics, can be found in Thomson 1882 (quotation from p. 514).

Clausius continued to reformulate and generalize the second law, the first fruit of his efforts being a paper of 1854 in which he proved that for any cyclical process, the quantity dQ/T integrated over the whole process is less than zero for an irreversible process or equal to zero for a reversible one. The symbol dQ denotes an infinitesimal amount of heat absorbed by the system, and T is the absolute temperature. This may be seen as a first step towards introducing the entropy function, but Clausius only took the final step in 1865, when he coined the word *entropy* for what he initially had referred to as *Verwandlungsinhalt*, content of transformation. He derived the name from the Greek word for transformation, stating that he liked the word because it was universal in character and similar to the word energy. Clausius defined the entropy difference between two states A and B, $\Delta S = S_B - S_A$, as the integral of dQ/T, where the path of integration corresponds to a reversible transformation from A to B. Since the value of the integral is zero around a cycle, for any reversible transformation it is independent of the path, depending only on the initial and final states. Clausius could now state the laws of thermodynamics in a definitive formulation:

> If for the entire universe we conceive the same magnitude to be determined, consistently and with due regard to all circumstances, which for a single body I have called *entropy*, and if at the same time we introduce the other and simpler conception of energy, we may express in the following manner the fundamental laws of the universe which correspond to the two fundamental theorems of the mechanical theory of heat. 1. *The energy of the universe is constant*. 2. *The entropy of the universe tends to a maximum*.[24]

It is important to realize that the law of entropy increase is only valid for an isolated physical system as a whole and that entropy can decrease locally within the system. For example, when an amount of hot water is mixed with an amount of cold water, the entropy of the first decreases and the entropy of the latter increases; but the two changes do not cancel. An additional amount of entropy is created in the process of mixing hot and cold water. As the example illustrates, the entropy of parts of an isolated system may decrease and that of other parts may increase, only the increase is always greater than the decrease. There is no corresponding law for a non-isolated system, where the entropy may either increase or decrease, depending on whether heat is added to or removed from the system or whether irreversible processes occur in it.

Entropy is a most useful quantity, equally applicable to stars and refrigerators, but it is not a necessary ingredient of thermodynamics. Clausius paid relatively little importance to the concept he had invented, uncertain as he was about its true meaning and significance. The concept of entropy was for a long time considered abstract and difficult, and for this reason it only permeated slowly into physical theory, and even more slowly into neighbouring disciplines such as chemistry, geology and biology – not to mention philosophy. Still in the early years of the twentieth century it was rare to find the concept mentioned in textbooks on physical chemistry and chemical thermodynamics.[25] Adding to its lack of popularity was that Clausius's famous

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[24] Clausius 1867, p. 365. Clausius's early papers on thermodynamics are collected in Clausius 1867.

[25] See the survey in Kragh and Weininger 1996.

formulation of 1865 was a spirited speculation rather than a rigorous proof. Indeed, it was only with Max Planck's reformulation of thermodynamics in the late 1870s that the second law was put in an entirely satisfactory form.[26] Planck, more than Clausius, stressed that the essence of the law is entropy increase ($\Delta S \geq 0$), and that it prohibits any process in which the entropy of an isolated system decreases.

Rather than making direct use of the entropy function one may use the concept of 'free energy' introduced by Helmholtz in 1882. If E is the total energy of a system, Helmholtz's free energy F is defined as $F = E - TS$, where $TS = E - F$ is what Helmholtz called the 'bound energy'. For an isothermal process, an increase in entropy corresponds to a decrease in free energy. According to Helmholtz, 'processes spontaneously originating and proceeding without the help of any external force, when the system is at rest and maintained at a constant uniform temperature, can take place only in such a direction as to cause diminution of free energy.'[27]

The other pioneer of the second law of thermodynamics, Thomson (the later Lord Kelvin), never used the concept of entropy and only rarely referred to it; he preferred to speak of dissipation of heat or energy, a concept he found more easy to use and visualize.[28] His dissipation referred to a situation in which two bodies at different temperatures placed in contact transfer heat from the warmer to the colder without work being done. Although the energy is conserved, it has become dissipated in the sense that the system's capacity to perform mechanical or other work has diminished. Contrary to what Thomson believed, the dissipation of heat does not exactly correspond to a change in entropy, and in general the dissipation theorem is weaker than the entropy theorem in explaining why some processes occur spontaneously and some do not. As Maxwell cautioned in his classic *The Theory of Heat*, 'the doctrine of the dissipation of energy is closely connected with that of the growth of entropy, but by no means identical with it'.[29]

Whatever its version, by the late 1850s thermodynamics was practically complete and its significance widely recognized. In his presidential address of 1863 to the British Association for the Advancement of Science, William Armstrong characterized the dynamical theory of heat as 'probably the most important discovery of the present century'.[30] By that time, the theory had already entered more popular literature. *Cyclopædia of the Physical Sciences*, an encyclopedia first published in 1857 and edited by the Glasgow astronomer John Nichol, included an extensive

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[26] Kuhn 1978, pp. 11-18; Kim 1983. At about the same time as Planck, the American Josiah Willard Gibbs did very important work in thermodynamics and the understanding of entropy, not least in the area of chemical processes. The modern understanding of thermodynamics rests essentially on the works of Boltzmann, Gibbs and Planck.

[27] Helmholtz 1882, p. 23. On Helmholtz's contributions to thermodynamics, see Kragh 1993.

[28] Whitworth 1998, pp. 47-8, discusses the various meanings of the word 'dissipation' and suggests that Thomson's use of it reflects his social thoughts.

[29] Maxwell 1875 (first published 1871), p. 192. For the contemporary discussion about the relationship between entropy and dissipation, see Daub 1970a. As far as the discussion of the cosmological implications of the second law is concerned, the difference between the two concepts is unimportant.

[30] Armstrong 1864, p. lx.

article on the mechanical theory of heat by the Scottish engineer William Macquorn Rankine, one of the pioneers of the new science. Rankine introduced in 1854 a state function corresponding to the later entropy function, but he considered it a purely calculational quantity and only discussed it in connection with reversible processes. He never formulated something like the entropy law, which was in fact foreign to him.[31] According to Rankine's article in *Cyclopædia*, 'The first and second laws virtually comprise the whole theory of Thermo-dynamics.'

Although physicists recognized the importance of the second law at an early date, it took some time until it became known to other groups of scientists, not to mention the general public. In a letter to Peter G. Tait of 1873, Maxwell pointed out that 'to speak familiarly of a 2nd Law as of a thing known for some years, to men of culture who have never even heard of a 1st Law, may arouse sentiments unfavourable to patient attention.'[32] And two years later Lord Rayleigh complained that 'The second law of thermodynamics, and the theory of dissipation founded upon it, ... has not hitherto received full recognition from engineers and chemists, nor from the scientific public.'[33] Entropy was widely perceived to be a less intelligible quantity than energy, to be abstract and enigmatic. The Czech physical chemist František Wald was one among several scientists who tried to reformulate thermodynamics in a more understandable version. Entropy appeared as a mathematical ghost, he wrote, 'as a necessary evil, a mysterious truth, which does not quite fit the human brain'.[34] According to Wald, entropy was characterized by being the 'efficiency' of energy; and the second law was to be understood as a necessary consequence of the law of causality, which meant that it was a postulate of reason rather than a result of experiments.

Since about 1860, then, scientists were in possession of two great laws of thermodynamics, one dealing with *conservation*, the other with *evolution*. The first law says that *if* something happens, the total energy of the system remains unchanged; but as to the question if something will in fact happen under certain circumstances, it has nothing to say. This is where the second law enters. The two laws were in theory complementary but in practice they often appeared as rivals, with the first dominating the second. Are not the notions of conservation and evolution contradictory? Whereas energy or force had quickly become assimilated by the nineteenth-century's mind, entropy remained an abstract and elusive concept. Although the laws are not reducible one to the other, the second law was to a large extent absorbed by the first, or at least overshadowed by it.

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31 On the relationship between Clausius's and Rankine's functions, see Hutchison 1973.

32 Maxwell 1990-2002, vol. 2, p. 833. There is a nice parallel to C.P. Snow's famous remark, made eighty-six years later: 'Once or twice I have been provoked and I have asked the company [of men of culture] how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of: Have you read a work of Shakespeare's?' Snow 1993, p. 15.

33 Rayleigh 1875.

34 Wald 1889, p. 4.

Even experts in thermodynamics disagreed as to the meaning and domain of applicability of the entropy law. For instance, Robert Kirchhoff wanted to restrict entropy to be valid only for equilibrium states, a view which was later adopted by Wilhelm Ostwald; Planck, on the other hand, maintained that the very essence of entropy growth was the irreversibility of transitory processes. A similar disagreement did not extend to the uncontroversial law of energy conservation. The unique position of the second law was underlined by the difficulties of formulating thermodynamics in terms of variational or minimum principles. Although Helmholtz did use the technique of variational principles in his work on chemical thermodynamics, this was only possible by presupposing thermal processes to be reversible or 'quasi-reversible'. By the turn of the century it was generally agreed that irreversible thermodynamics, alone among the fundamental theories of physics, cannot be described by means of variational principles.[35]

The difficulty of the concept of entropy is illustrated by an extended controversy in the journal *The Electrician* in 1902-03 in which British physicists and electrical engineers – including James Swinburne, Oliver Lodge, John Perry, and Oliver Heaviside – discussed the meaning and proper use of the concept.[36] The controversy attracted interest also from abroad and made Poincaré and Planck intervene in attempts to clarify the subject. A decade later, the discussion was renewed by Hugh Callendar, a professor at Imperial College, London, and a specialist in the thermodynamical properties of steam. Callendar noted that according to the kinetic theory, entropy has no physical existence but is just an abstract mathematical function relating to the distribution of energy. He suggested to endow entropy with materiality, to imagine it to consist of some indestructible form of matter, perhaps made up of 'molecules of caloric'. In front of the physics section of the British Association, he said, 'I cannot help feeling that we have everything to gain by attaching a material conception to a quantity of caloric [entropy] as the natural measure of a quantity of heat as opposed to a quantity of heat energy.'[37] Nothing useful came out of Callendar's suggestion, although the interpretation of Carnot's caloric as entropy was later taken up by several scientists.[38]

Discussions about the foundational features of the theory of thermodynamics continued, but rarely was its validity questioned. Experts recognized from an early date that the two laws constituted fundamental features of nature, with the same supreme epistemic authority as the laws of mechanics. The laws of thermodynamics have been called 'perhaps the most general statements that have ever been made about the universe as a whole'.[39] Albert Einstein in general denied that there were final or eternal theories of physics, but he was willing to exclude thermodynamics

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[35] Yourgrau and Mandelstam 1955, pp. 93-95.

[36] *The Electrician* 50 (1902-03).

[37] Callendar 1912, p. 27, an untitled presidential address on modern theories of heat given to the 1912 meeting of the British Association. The address received wide attention. It was reprinted in *Science* 36 (1912), 321-36 and appeared in German translation as 'Die Natur der Wärme', *Naturwissenschaftliche Rundschau* 27 (1912), 545-7, 561-3.

[38] Elkana 1974, pp. 89-91.

[39] Raman 1970, p. 333.

from the rule because of the theory's simplicity and high degree of generality. As he wrote in his autobiographical notes: 'It is the only physical theory of a universal content which I am convinced that within the framework of the applicability of its basic concepts, it will never be overthrown.'[40]

The Heat Death Scenario

As became clear in the 1850s, the second law of thermodynamics, if applied to the entire universe, leads to the grim prediction that in the far future all work processes will cease, a prediction known as the heat death. Although Carnot's theory was based on the conservation of caloric, and thus contradicted the first law of thermodynamics, it included (or can be reconstructed to include) an embryonic form of the second law. It has consequently been suggested that the idea of a perpetual degradation of energy in the universe, which is the essence of the heat death, should be attributed to Carnot.[41] However, Carnot did not actually relate to such a scenario, nor did he spell out the cosmic consequences of a continual transformation of work into heat. These consequences were first stated by Thomson and Helmholtz in the early 1850s.

In a draft to his 1851 paper 'On the dynamical theory of heat' Thomson connected his still immature ideas of energy dissipation with his Christian faith. Destruction of energy, he wrote, could only occur on the command of 'the supreme ruler', and the new science of thermodynamics forbade that the material world would ever return to any previous state. Moreover:

> 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; ... 'The earth shall wax old &c'. The permanence of the present forms & circumstances of the physical world is limited.[42]

Not only was it God alone who could create and annihilate energy, it was also only He who could reverse the transformations of energy in nature. In the printed version of the memoir, Thomson chose not to include these cosmological speculations.

At the Liverpool meeting of the British Association in 1854, Thomson went a step further and gave a sweeping survey of his cosmo-energetic ideas. Since the

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40 Einstein et al. 1949, p. 33. Young Einstein was a specialist in thermodynamics and statistical mechanics, including calculations of entropy. He was aware of the cosmological use of the second law, but seems not to have taken any interest in the topic.

41 Bailyn 1985, who argues that Carnot's theory was 'an inspired insight into the nature of the Second Law, an insight that penetrated the caloric fog' (p. 1095). According to Callendar 1912, p. 23, 'entropy was simply Carnot's caloric under another name'. For the contrary view, that Carnot was not a precursor of thermodynamics and the concept of entropy, see Kuhn 1955.

42 Quoted in Smith 1998, p. 111. For 'The earth shall wax old &c', see Psalms 102 and Isaiah 51: 6. The draft is transcribed in Smith 1976. See also Wilson 1974. On Thomson and the irreversible cosmos, see further the account in Smith and Wise 1989, pp. 497-523, 615-21.

dissipation of energy means a universal change from potential to kinetic and thermal energy, 'we find that a time must have been when the earth, with no sun to illuminate it, the other bodies known to us as planets, and the other countless smaller planetary masses … must have been indefinitely remote from one another and from all other solids in space.' As to the far future: 'The end of this world as a habitation for man, or for any living creature or plant existing in it, is *mechanically inevitable*.' And there was more. Inviting his audience to trace backwards in time the actions of the laws of physics, he came to a limit, a beginning 'beyond which mechanical speculations cannot lead us' and to which 'science can point no antecedent except the Will of a Creator.' Whereas thermodynamics and mechanics allowed one to extrapolate into the endless future, 'we can be stopped by no barrier of past time, without ascertaining at some finite epoch a state of matter derivable from no antecedent by natural laws'. However, such an origin of matter and motion, mechanically inexplicable and different from any known process, contradicted his sense of both causality and methodological uniformitarianism.

> Although we can conceive of such a state of all matter, or of the matter within any limited space, ... yet we have no indications whatever of natural instances of it, and in the present state of science we may look for mechanical antecedents to every natural state of matter which we either know or can conceive at any past epoch however remote.[43]

Thomson ended his address with suggesting as an initial scenario that, 'the potential energy of gravitation may be in reality the ultimate created antecedent of all the motion, heat, and light at present in the universe.' Here we have, for the first time, the second law of thermodynamics used, not to predict the far future but a singular state in the distant past. Apparently Thomson came to this idea as early as 1842, when he, inspired by his study of Fourier's theory of heat conduction, realized that the heat equation would have no meaningful solutions for negative values of the time parameter. He found that an arbitrary initial distribution cannot in general be produced by some previous possible distribution. His biographer Silvanus P. Thompson recollected that Thomson once told him, 'It was this argument from Fourier that made me think there must have been a beginning … Trace back the past, and one comes to a beginning – to a time zero, beyond which the values are impossible.'[44]

Thomson's ideas were appraised by François Moigno, a French abbé, mathematician and astronomer, in his journal *Cosmos*. As Moigno pointed out, Thomson's view of the origin of the solar system differed drastically from the Laplacian hypothesis generally accepted in France. According to the school of Laplace, the solar system was in a state of harmonious mechanical stability; there was no reason to fear for an end of the world, except that the Sun would gradually become colder. If there was an end, it would be a cold death. Thomson, on the other hand, confidently asserted that the end of the world was 'mechanically inevitable', a different and much stronger prediction. He believed that gravitation was the original form of all the energy in

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43 Thomson 1884, pp. 37-8. A French translation of the paper appeared in *Comptes Rendus* 49 (1855), 1197-1202.

44 Thompson 1910, vol. 1, pp. 111-2.

the universe. The world, meaning the planetary system, would experience a heat death caused by gravitational collapse into the Sun. Although critical to Thomson's theory, Moigno was pleased to note how it agreed with the Revelation of Peter: 'The heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the Earth also and the works that are therein shall be burned up.'[45]

In his earlier paper of 1852, Thomson considered from a thermodynamical perspective the energy radiated from the Sun. He concluded that the Sun, a finite body, could only shine for a limited span of time; because sunlight was essential to life on Earth it followed that life could not be expected to continue indefinitely. According to thermodynamics, 'within a finite period of time past the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be performed, which are impossible under the laws to which the known operations going on at present in the material world are subject.'[46] This comes close to the heat death, but in 1852 Thomson restricted his scenario to the solar system and did not extend it to the universe at large. The first to suggest such an extension was Helmholtz, in a popular lecture on the interaction of natural forces that he delivered in Königsberg in early 1854:

> If the universe be delivered over to the undisturbed action of its physical processes, all force will finally pass into the form of heat, and all heat will come into a state of equilibrium. Then all possibility of a further change would be at an end, and the complete cessation of all natural processes must set in. The life of men, animals, and plants could not of course continue if the sun had lost his high temperature, and with it his light, – if all the components of the earth's surface had closed those combinations which their affinities demand. In short, the universe from that time onward would be condemned to a state of eternal rest.[47]

Helmholtz recognized the parallel of the scenario to that of 'the Mosaic tradition', which he illustrated by quoting lines from Genesis. But he was careful not to make too much out of the analogy. At the end of his lecture he stated that the second law 'radiates light into the distant nights of the beginning and of the end of the history of the universe. To our own race it permits a long but not an endless existence; it threatens with a day of judgment, the dawn of which is still happily obscured.'[48] The cosmos did not evolve teleologically, but rather dysteleologically.

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45 Moigno 1855, as quoted in Smith and Wise 1989, pp. 522-3. Moigno collaborated with and inspired the French physicist and engineer Marc Séguin, one of the contributors to the discovery of the equivalence of heat and mechanical force. Several of Séguin's papers, published in *Cosmos* and elsewhere, contained references to the creative power of God.

46 Thomson 1882, p. 514. See also James 1982.

47 Helmholtz 1995, p. 30.

48 Ibid., p. 43. See also Koenigsberger 1902-03, vol. 1, pp. 211-8. An English translation appeared as 'On the interaction of natural forces', *Philosophical Magazine* 11 (1856), 489-518. Helmholtz's reference to the second law of thermodynamics as throwing light on 'the beginning and …the end of the history of the universe' may indicate that he realized how the law could be used as an argument for the finite age of the universe. However, he did not elaborate, nor did he later refer to the entropic argument of cosmic origin.

Helmholtz's address was well received, but there were also voices which disapproved of the pessimistic message of a dying world. One of those voices belonged to the German philosopher Karl Rosenkranz, who in 1856 argued that the world developed progressively and teleologically, towards the perfection of humanity. From his point of view Helmholtz's scenario was absurd, and he suggested as an alternative an organic and cyclic world picture in which there was room for endless progressive development.[49] The reference to the Bible was noticed by Helmholtz's stern father, the *Gymnasium* teacher Ferdinand Helmholtz, who disapproved of it. As he wrote to his son: 'The only thing I do not like in your lecture, though I quite appreciate your motive, is the introduction of the Mosaic creation. That is fundamentally untrue, and a weak concession of science which we should not make to our opponents … .'[50] There were indeed scientists who found material in Helmholtz's lecture for apologetic use. The physiologist Carl Ludwig, who was a close friend of Helmholtz, wrote in 1854 a letter to the Prussian minister of education in which he pointed out that science ought not to be confused with religious principles. With reference to Helmholtz's lecture he mentioned Alfred Volkmann, a professor of physiology and anatomy at Halle, whom he described as 'not only a staunch Christian, but he has lately been busying himself in the attempt to deduce a proof for the personal God from this very lecture of Helmholtz.'[51]

Thomson's version of the heat death came in 1862, in a paper dealing with the origin and duration of the Sun's emission of heat radiation. The result of energy dissipation, he wrote, 'would inevitably be a state of universal rest and death'. However, Thomson qualified his statement by noting that the heat death would only occur 'if the universe were finite and left to obey existing laws', and he did not accept the first of the premises:

> But it is impossible to conceive a limit to the extent of matter in the universe, and therefore science points rather to an endless progress, through an endless space, of action involving the transformation of potential energy into palpable motion and thence into heat, than to a single finite mechanism, running down like a clock, and stopping for ever.[52]

For Thomson, the optimistic Victorian progressivist, the universal heat death was not real as he did not accept that the laws of thermodynamics were valid for an infinitely extended universe. He concluded that, 'no conclusions of dynamical science regarding the future condition of the earth can be held to give dispiriting views as to the destiny of the race of intelligent beings by which it is at present inhabited.'[53] In the discussions of the heat death that took place over the next half century, Thomson was often seen as an advocate of the hypothesis. Few of the authors realized that he did not, in fact, believe in the thermal end of the universe.

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[49] On Rosenkranz's response to Helmholtz, see Neswald 2006, pp. 227-8.

[50] Koenigsberger 1902-03, vol. 1, p. 212. Ferdinand Helmholtz had abandoned theological studies and changed to classical languages, in part from conscientious motives.

[51] Ibid., p. 217. The nature of Volkmann's intended proof is unknown.

[52] Thomson 1891, pp. 356-7.

[53] Ibid., p. 374.

Together with his close friend Peter Guthrie Tait, professor of natural philosophy at Edinburgh, Thomson presented the same year a remarkable popular account of his cosmological views in *Good Words*, a popular Presbyterian magazine. The two authors explained that the original energy of the universe was gravitational and that this form of energy would gradually turn into heat, the result being 'an arrangement of matter possessing no realizable potential energy, but uniformly hot ... chaos and darkness as "*in the beginning*".' The reference to Genesis was by no means accidental, for Thomson and Tait explicitly pointed out the agreement between their scientific scenario and the words of the Bible:

> We have the sober scientific certainty that heavens and earth shall 'wax old as doth a garment'; and that this slow progress must gradually, by natural agencies which we see going on under fixed laws, bring about circumstances in which 'the elements shall melt with fervent heat.' With such views forced upon us ..., dark indeed would be the prospects of the human race if unilluminated by that light which reveals 'new heavens and a new earth'.[54]

It should be noted that Thomson and Tait, in speaking of a cosmic end, mainly referred to the destiny of the Earth and its inhabitants. They did not address the question of the extension to the universe at large or if the heat death applied to an infinite world. These questions would soon come to be much discussed, if more in Continental Europe than in Great Britain.

It did not take many years for the heat death scenario to disseminate from the world of physics to the general cultural arena.[55] The prospect of a dying Earth and Sun was a theme that appealed to several poets of the Victorian age, among them Algernon Charles Swinburne whose 'The Garden of Proserpine' appeared in 1866. In the last verse of the poem, he expressed the consequence of the second law of thermodynamics as follows:

> Then star nor sun shall waken,
>   Nor any change of light:
> Nor sound of waters shaken,
>   Nor any sound or sight:
> Nor wintry leaves nor vernal,
> Nor days nor things diurnal.
> Only the sleep eternal
>   In an eternal night.[56]

As mentioned, Thomson, Tait and Helmholtz largely limited their heat death scenarios to the solar system. In the far future, planets and other celestial matter would coalesce with the dying Sun, eventually leaving only a giant lump of cold,

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[54] Quoted in Smith and Wise 1989, p. 535. 'New heavens and a new earth' is a reference to 2 Peter 3: 13.

[55] On nineteenth-century literary and artistic responses to thermodynamics, see Myers 1986 and Beer 1989.

[56] Swinburne, who was accused of championing libertinism and atheism, was a controversial figure in British cultural life. Among his few advocates was William K. Clifford

motionless matter surrounded by empty but perhaps ether-filled space. In their textbook *Treatise on Natural Philosophy*, first published 1867, Thomson and Tait wrote about the ultimate fate of our solar system: 'That result is the falling together of all into one mass, which, although rotating for a time, must in the end come to rest relatively to the surrounding medium.'[57] If the Sun were a typical star, and the nebulae stars in the making, it was but a small step to extrapolate the scenario to the universe as a whole. This is what Eardley Maitland – who described himself as 'an amateur' – did in 1870:

> Thus, in the course of time, nebulæ would form suns, suns would grow cold, or, while yet glowing, would come into contact and combine with other suns, till gradually space would be peopled with suns, larger and larger, but less and less thickly strewn. Pursuing the idea, we arrive at a period when all the stars of each galaxy shall become agglomerated into one mighty globe – nay, when all these vast galactic suns shall come together and form one solitary orb, in which all the matter once scattered through space shall be collected, accomplishing its successive fates as a sun without a system – a world without a sun – a cold and naked ball.[58]

In spite of his formulation of the laws of thermodynamics in terms of *die Welt*, Clausius seems not to have been much concerned with the cosmological implications of the second law, and even less with the ideological and theological debate related to the issue. In the third edition of his comprehensive text on thermodynamics, a work of more than 1,000 pages, one looks in vain for references to cosmological or extra-scientific aspects of the second law.[59] Yet, in 1864, before he had explicitly introduced the notion of entropy, he offered his cosmological version of the heat death scenario, and this without Thomson's provisos. There is, Clausius wrote, a general tendency in nature towards unidirectional change:

> If one applies this to the universe in total, one reaches a remarkable conclusion. … Namely, if, in the universe, heat always shows the endeavour to change its distribution in such a way that existing temperature differences are thereby smoothened, then the universe must continually get closer and closer to the state, where the forces cannot produce any new motions, and no further differences exist.[60]

Three years later, now employing the new entropy concept, Clausius reformulated the heat death statement as follows: '*The entropy of the universe tends toward a maximum*. The more the universe approaches this limiting condition in which the entropy is a maximum, the more do the occasions of further change diminish; and

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who included a passage from Swinburne's poem in his 1875 review of Stewart and Tait's *The Unseen Universe* (see Chapter 4). On Clifford and Swinburne, see Dawson 2004, p. 265.

57 Thomson and Tait 1890, p. 258.

58 Maitland 1870, p. 212.

59 Clausius 1879-91. It is unknown if Clausius had any religious convictions. If he had, he kept them to himself.

60 Clausius 1864, pp. 1-2.

supposing this condition to be at last completely attained, no further change could evermore take place, and the universe would be in a state of unchanging death.'[61]

Clausius further emphasized that the second law contradicted the generally held view that the overall state of the world remains the same, with transformations in one direction at particular places and times being counterbalanced by reverse transformations at other places and times. In other words, it conflicted with the notion of a cyclic universe, the popular view that 'the same conditions constantly recur, and in the long run the state of the world remains unchanged.'[62] Clausius ended his lecture by pointing out that the present state of the universe is very far from equilibrium and that the march towards the heat death is exceedingly slow. Yet the important thing was that a law of nature had been discovered which 'allows us to conclude with certainty that everything in the universe does not occur in cycles, but that it changes its condition continually in a certain direction, and thus tends towards a limiting condition.' Not only for Clausius, but even more so for Thomson and his circle of Christian scientists, was it an appealing feature of the second law that it countered what they considered the materialistic and un-Christian notion of a cyclic world. It should be noted that Clausius did not bother to explain what he meant by the 'universe' or 'world'. Neither he nor Thomson related their views to astronomical knowledge, but used the terms in a vague and general sense that their readers could interpret in pretty much the way they preferred. In some contrast to Thomson, Clausius never connected his view of thermodynamics with religious or other extra-scientific attitudes. He preferred to stay on the safe ground of physics.[63]

Rankine and Helmholtz on the Heat Death

The claim of the heat death did not go uncontested, neither within scientific circles nor outside them. Many scientists as well as non-scientists felt it unbearable that life in the universe shall one day cease to exist, and they came up with a variety of suggestions to avoid the heat death. As the French chemist and philosopher Emile Meyerson put it, 'A sort of secret repugnance was felt to the idea of a continual change of the universe in the same direction.'[64] The German physicist Felix Auerbach, professor at the University of Jena, described energy as the 'world mistress' (*Weltherrin*), but one that casts dark and ill-fated shadows which tend to destroy the beauty and greatness of the energy – 'we call this evil demon the entropy.' He asked: 'Of what good is the energy in the long run, if its shadow becomes longer and longer as the world proceeds and as it increasingly becomes evening.'[65] We shall look at some of the attempts to

[61] Clausius 1868, p. 419. This was an English translation of a lecture delivered before the German Association of Natural Scientists and Physicians in Frankfurt am Main on 23 September 1867.

[62] Ibid., p. 417.

[63] Very little is known about Clausius's personal life and practically nothing about his view of religion. Ronge 1955 provides important information of his life from about 1855 to 1868, but has nothing to say about his attitude to religion.

[64] Meyerson 1930, p. 268. Translation of French original of 1908.

[65] Auerbach 1902, p. 1.

avoid the heat death in the following chapters, and here mainly call attention to the first one, suggested by Rankine as early as 1852, before the hypothesis of the heat death had been clearly formulated.

Rankine suggested that radiant heat energy might under certain circumstances allow a reconcentration of energy and thereby physical activity to go on endlessly. He admitted that for other energy forms, 'there will be an end to all physical phenomena', but believed radiant heat was an exception. Rankine conjectured that radiant heat was conducted by a bounded interstellar medium – an ether of some sort that contained the entire sidereal universe – and that outside this medium there was nothing but empty space. His idea of an ethereal medium was uncontroversial, but he further suggested – quite speculatively – that it was unable to absorb heat and possess a definite temperature: 'There must exist between the atmospheres of the heavenly bodies a material medium capable of transmitting light and heat; and it may be regarded as almost certain that this interstellar medium is perfectly transparent and … incapable of converting heat, or light (which is a species of heat), from the radiant into the fixed or conductible form.' In that case, when the radiant heat reached the boundary of the ether it would be reflected and eventually reconcentrate in one or more focal points (in the language of optics). If one further imagined one of the extinct celestial bodies to pass such a focal point, 'it will be vaporised and resolved into its elements', and part of the radiant heat would be converted into chemical energy and wake the body alive. It was thus conceivable, Rankine wrote, that

> although, from what we can see of the known world, its condition seems to tend continually towards the equable diffusion, in the form of radiant heat, of all physical energy, the extinction of the stars, and the cessation of all phenomena, yet the world, as now created, may possibly be provided within itself with the means of reconcentrating its physical energies, and renewing its activity and life.[66]

Dissipative and constructive processes might eternally go on together, and 'some of the luminous objects which we see in distant regions of space may be, not stars, but foci in the interstellar ether.' Rankine's point was that the structure of the universe determined whether there would be a heat death or not. Since so little was known about this structure, it might well be that what appeared to be irreversible processes were in reality reversible.

During the following decades many speculations within the same spirit – attempts to devise counterentropic processes – were suggested, but few of them attracted serious attention, and none were generally accepted. Some of these speculations referred specifically to biological growth, a phenomenon which, on the face of it, may seem to defy the message of decay that characterizes the second law.[67] Rankine's 'ingenious, though, perhaps, fanciful hypothesis' received critical comments from

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[66] 'On the reconcentration of the mechanical energy of the universe', in Rankine 1881, pp. 200-202. The paper was read to the 1852 meeting of the British Association in Belfast. A German translation of Rankine's paper appeared in *Sirius: Zeitschrift für populäre Astronomie* 11 (1883), 13-15.

[67] Thomson suggested that organic life might be an exception to the second law, and also Helmholtz envisaged the possibility of biological processes being associated with entropy

the mathematician and geophysicist William Hopkins in his presidential address to the 1853 meeting of the British Association. Hopkins argued that the hypothesis led to consequences inconsistent with the actual order of nature and that it failed to refute Thomson's conclusion of a material universe progressing towards an end state. 'My own convictions entirely coincide with those of Prof. Thomson', he said.[68]

Neither did Clausius accept Rankine's conjecture, which he found was flatly contradicted by the second law, as he understood it. In 1864 he answered Rankine's challenge in a long and detailed paper in which he made use of Gustav Kirchhoff's recent work on ideal heat or blackbody radiation. 'If this view [Rankine's] were correct, the theorem that I have taken to be a fundamental principle – that the heat cannot by itself pass from a colder to a warmer body – must be wrong; and then we would have to reject ... the second law of the mechanical theory of heat.'[69] Clausius's conclusion, based on lengthy calculations, was unambiguous: radiant heat was no exception to the second law and nor could it provide a means of escaping the heat death. According to Clausius, the dire prospect of the heat death was an inescapable consequence of the second law of thermodynamics, a law which governed the entire universe.

In his influential popular lectures Helmholtz often spoke of the first law of thermodynamics, whereas his references to the second law and its cosmic implications were much less frequent. In a lecture of 1869 delivered at the meeting of German scientists and physicians (Versammlung deutscher Naturforscher und Ärzte) in Innsbruck, he briefly called attention to 'Carnot's law of the mechanical theory of heat, as modified by Clausius'. He did not use the term entropy. The Carnot-Clausius law, he said, leads us to 'see with the mind's eye the original condition of things in which the matter composing the celestial bodies was still cold, and probably distributed as chaotic vapour or dust through space; we see that it must have developed heat when it collected together under the influence of gravity.'[70] That is, he used the second law to suggest a picture of the origin of the universe in accordance with Kant's nebular cosmogony, a cosmogonical hypothesis which greatly appealed to him and to which he had first called attention in his 1854 Königsberg lecture.

Helmholtz returned to Kant's cosmogony, or what he called the Kant-Laplace nebular hypothesis,[71] in a public lecture in Heidelberg two years later that principally dealt with the origin of the planetary system and the Sun's heat. Without specifically

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decrease. Later, several biologists proposed vitalistic, counterentropic principles, such as Hans Driesch in 1908 ('entelechy') and Felix Auerbach in 1910 ('ectropy').

68 Hopkins 1853, p. liv. William Hopkins was a famous Cambridge coach with whom young Thomson had studied. In a paper of 1852 he had argued that the principle of energy dissipation would lead to a freezing Earth, contrary to the belief of uniformitarian geology. Hopkins 1852.

69 Clausius 1864, p. 4.

70 Helmholtz 1995, p. 215.

71 Helmholtz was in part responsible for the unfortunate term 'Kant-Laplace hypothesis' as he, both in 1854 and 1871, failed to distinguish properly between Kant's nebular cosmogony of 1755 and Laplace's hypothesis of 1796 of the formation of the planetary system. In reality the two theories have little in common, amongst other reasons because Kant suggested a speculative theory of the entire universe, and Laplace's theory, based on much more scientific

mentioning the second law, he noted, as Thomson and others had, that the Sun would burn out at some time in the future, a thought 'which we only reluctantly admit' and which 'seems to us an insult to the beneficent Creative Power'. Helmholtz's attitude in his 1871 lecture was somewhat ambiguous, an ambiguity which was presumably deliberate. Although he argued for a lifeless universe in the future, he also seems to have held a door open for endless life. On the one hand, the message of the new physics was this:

> We are but as dust on Earth; which again is but a speck of dust in the immensity of space; and the previous duration of our race ... is but an instant compared with the primeval times of our planet; ... and far more does the duration of our race sink into insignificance compared with the enormous periods during which worlds have been in process of formation, and will still continue to form when our Sun is extinguished, and our Earth is either solidified in cold or is united with the ignited central body of our system.[72]

Yet, on the other hand and under the impact of Darwin's new theory of biological evolution (which he admired), Helmholtz vaguely suggested that life-processes might go on on 'new worlds', perhaps disseminated from the solar system by means of meteors or comets. As I read him, he appealed to the first law of thermodynamics as a possible argument against the heat death predicted by the second law:

> The flame even, ... may become extinct, but the heat which it produces continues to exist – indestructible, imperishable, as an invisible motion, now agitating the molecules of ponderable matter, and then radiating into boundless space as the vibration of an ether. Even there it retains the characteristic peculiarities of its origin, and it reveals its history to the inquirer who questions it by the spectroscope. United afresh, these rays may ignite a new flame, and thus, as it were, acquire a new bodily existence.[73]

But Helmholtz knew that there was no scientific basis for his speculation and that neither radiant heat nor the law of energy conservation can be used to erode the stern authority of the second law. One should of course read Helmholtz's statements in the context of a popular lecture. It is my impression that he phrased his lecture in such a way that it would appeal to his audience, while at the same time expressing himself so vaguely that it could not be accused of including direct errors. Also one should be aware that Helmholtz, like most other scientists of his day, confined his comments on life-processes to the solar system and had almost nothing to say about the heat death in its wider cosmological meaning. When he spoke of possible 'new worlds', he meant new planetary systems.

Apart from Rankine's very early objection against the heat death, opposition and alternatives began to mount in the late 1860s, at about the same time as the entropy law was first used as an argument in favour of a created universe. The opposition

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reasoning, was concerned only with the origin of the planetary system. For a clear distinction between the two theories, see Stanley Jaki's introduction to Kant 1981.

72 Helmholtz 1995, p. 275. In 1882 Helmholtz expressed uncertainty about whether the second law applies to 'the fine structures of the organic living tissues'. Helmholtz 1883, p. 972.

73 Helmholtz 1995, p. 275.

was strongest in Germany, where the hypothesis of an end of the world became part of the cultural and ideological struggle. Although the heat death met opposition in Great Britain too, in this country it was not considered a controversial claim to quite the same extent as it was in Germany. Many of the anti-heat-death proposals of the 1860s and 1870s appealed to one or two mechanisms to avoid the conclusion drawn by the thermodynamicists: one was the assumption of collisions between the stars or other celestial bodies; the other was speculations of the world ether as an active thermal agent that could absorb and re-emit heat. In addition, even if none of these mechanisms worked satisfactorily, one could always fall back on the assumption of an infinite universe in which the second law of thermodynamics presumably held no authority. More about this in what follows.

Among the early contributors to the law of energy conservation, J.R. Mayer and C.F. Mohr denied Clausius's global prediction from the second law. Mayer believed that the mechanical theory of heat was valid for all kinds of terrestrial energy economy, but not for the universe, and he consequently refrained from applying the theory to the universe at large. At the 1869 meeting in Innsbruck of the German Association of Natural Scientists and Physicians, he made it quite clear that he was opposed to the view associated with 'the so-called entropy', namely that 'the entire machine of creation must eventually come to a standstill.'[74] Contrary to many other opponents of the heat death, Mayer's opposition did not reflect a materialistic *Weltanschauung*. On the contrary, he rejected materialism and ended his address with the words, 'a true philosophy must be, and cannot be other than, a propaedeutic for Christian religion.'

During a stay in England, Mayer had met Edward William Brayley, a London professor of physical geography, who had suggested that the Earth and other planets were formed by collision and coalescence of meteors originally produced by solar matter. As Mayer understood him, his theory led to the consequence that the heat death could be avoided if stellar collisions were taken into account.[75] Mayer was a friend of Carl Gustav Reuschle, who taught mathematics and geography at a Stuttgart *Gymnasium* and wrote widely on subjects in philosophy, physics and mathematics. He, Reuschle, was among the first to oppose in public the heat death hypothesis of Clausius and Thomson. In a letter to Reuschle, Mayer wrote: 'What pleases me particularly in your essay is what you say against the view of Thomson, who speaks of the final rest of the world; I could never myself subscribe to this view. My reason is ... that a few years ago Brayley in London said that if two stars of the size of the Sun collide all condensed mass must be dissolved and the molecules be dissipated

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[74] Mayer, 'Ueber nothwendige Consequenzen und Inconsequenzen der Wärmemechanik' (1869), in Mayer 1978, pp. 341-9. See also the translated extract in Mayer 1870.

[75] Brayley 1865. In this paper, based on a series of lectures on 'astronomical physics', Brayley speculated that the Sun consisted of an ethereal substance out of which ponderable matter was produced. While he dealt with collisions of meteors, he did not refer to either stellar collisions or the heat death.

throughout the universe.'[76] In his reply, Reuschle mentioned that Mohr should also be counted to the group of German anti-heat-death scientists.

In articles of 1869 and 1872, Reuschle criticized the heat death hypothesis, which he found could be countered by collisions between cold celestial bodies which presumably would regenerate run-down areas of the universe. Even without this counterentropic mechanism, it would take an infinity of time to approach the heat death asymptotically, and 'What will happen in the infinite future, will never happen.'[77] Reuschle was willing to accept the validity of the entropy law for limited parts of the material world, but not for the universe as a whole, which he assumed was infinite. As he wrote in 1874: 'All individual parts, including the most finite complexes, that is, even the celestial bodies, solar systems and stellar systems, have come into being and will disappear; and that in such a way that the origin and disappearance of the individual parts of the universe form an eternal cycle.'[78] Like several other opponents of the heat death, Reuschle thought of the universe in organistic terms. As an additional argument against the heat death scenario he pointed out that although Thomson and Clausius agreed that there would come a final state, they disagreed about the nature of the state: according to Thomson it would be a collection of dead stars, according to Clausius a rarefied, uniform gas of particles. How seriously could one take a theory that led to such contradictory scenarios?

Carl Friedrich Mohr, best known as an analytical chemist, counts as one of the precursors of the law of energy conservation, a distinction based on an essay of 1837 in which he vaguely suggested 'force' to be a conserved and convertible quantity. In the 1860s Mohr turned to thermodynamics, which he however understood (or rather misunderstood) in his own qualitative and somewhat amateurish way. Impressed by the cyclic motions of matter and heat on Earth, as evidenced by geochemistry, meteorology and climatology, he thought that the universe too was in a state of equilibrium that would remain for ever. 'There is no reason at all to take into account Clausius's feared entropy of the world, or the equalization of all motion into uniform heat', he wrote. On the contrary, 'one can claim with certainty that the maximum entropy already has been reached an infinity of time ago.'[79] Mohr did not argue from the supposed absence of a heat death to an eternally existing world, but rather the other way around: 'Thus, it is evident that the assumption that the world has existed without a beginning rules out the feared entropy or return to an equilibrium state. ... Since the entropy has not set in, it cannot occur in the future.'[80]

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76 Letter of 21 July 1869, in Mayer 1893, pp. 300-301. See also Caspari 1874, p. 28. The reference is to Reuschle 1869. Reuschle published in 1868 a long article on Kant's contributions to science, including a glorifying evaluation of his cosmological theory (Reuschle 1868).

77 Reuschle 1872, p. 340. On Reuschle and his relationship with Mayer, see Mayer 1893, pp. 286-7. Although Reuschle agreed with Mayer on most points, he did not share his Christian conviction (ibid., p. 304).

78 Quoted in Neswald 2006, p. 256. See also Reuschle 1869, p. 261.

79 Mohr 1869, p. 43.

80 Ibid., p. 44. A similar argument appeared in Caspari 1874. It makes no sense to say about the entropy that it is 'ruled out' or does not 'set in'. Mohr, who apparently did not quite

As a preparation for the following chapter it should be noted that when scientists from the 1850s to the 1920s spoke of the beginning of the universe they usually had in mind a scenario something like the one outlined in Kant's *Allgemeine Naturgeschichte und Theorie des Himmels*. Originally the universe was a formless mist, a gas-like chaos of primordial particles or perhaps a dilute ethereal substance, whether corpuscular or continuous in structure. That is, the starting point was a pre-existing universe as far as matter and space was concerned, only did time and organization still not exist in the primeval chaos. The picture bore in qualitative terms resemblance to the scenarios of Babylonian and other ancient cosmogonies, such as Helmholtz noted in his 1854 address. The 'beginning' meant the original formation of condensations under the force of gravity, a differentiation between areas of space with more matter and areas with less matter, and also the beginning of unidirectional processes such as the degradation of energy. Or, to put it crudely: the beginning of the universe marked the first unwinding of the cosmic clock, not the creation of the clock.

As to where the clock – the matter and motion of the original universe – had come from, this question was considered outside science. If it was considered a meaningful question at all, the answer would have to be found in religion, not science. As James Jeans picturesquely expressed it in 1928, shortly before the discovery of the expanding universe, 'we may think of the finger of God agitating the ether.'[81] To claim that the universe was of finite age was not to state that before a certain time in the past there was 'nothing'. The claim involved that time, motion, order and processes were only introduced in the pre-universe a finite period of time ago.

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understand the second law, spoke of entropy as if it were the same as the heat death. The same lack of understanding can be found in Reuschle's articles of 1869 and 1872, and also in some other German writers (such as Meyer 1906).

[81] Jeans 1928b, p. 699. Jeans did not mean the memorable phrase in an apologetic sense. On his views about science and religion, see Kragh 2004, pp. 95-103.

Chapter 4

The Entropic Creation Argument

From about 1870, the second law of thermodynamics was occasionally used apologetically, usually by arguing that it necessitated a world with a beginning in time. If the universe comes to an end, it must have had a beginning. In this chapter I look at how the argument was introduced and discussed by scientists and other authors in Britain, Germany and France. It was mainly among Catholic circles in Germany that the law of entropy increase attracted serious attention as a theological argument, and for this reason – and because this episode in the history of science and religion is so little known – I deal in some detail with the German-Catholic discussion in the period from about 1880 to 1920. Other aspects of the discussion, including ideological and philosophical perspectives, will be dealt with in the following chapter. But first it may be helpful to present a more systematic outline of the entropic creation argument.

A New Proof of the Existence of God

Assuming that the law of entropy increase is valid for the universe as a whole, it is but a small step to conclude that the universe cannot have existed eternally. If so, it has presumably come into existence some finite time in the past, an event that many people would not hesitate to identify with a creative act. The claim that thermodynamics leads to a finite-age, created universe has been called the entropological or *entropic argument* for creation, whether or not formulated in terms of entropy (and, in fact, many arguments of the kind in the late nineteenth century avoided reference to the difficult and abstract notion of entropy).

According to the second law of thermodynamics, an isolated system will eventually reach internal thermal equilibrium, after which time only random fluctuations about the state of equilibrium can take place. The system can never return to its former non-equilibrium state. Now the present universe is far from being in equilibrium, which is a simple statement of observation; consequently it cannot be of infinite age but must have had a beginning, been born in a state of minimum entropy or maximum free energy. (The minimum entropy does not need to be minimal in an absolute sense, but only smaller than any later quantity of entropy.) The argument so far can be formulated syllogistically:

I. The entropy of the world increases continually.
II. Our present world is not in a state of very high entropy.
III. Hence the world must be of finite age.

In this argument, premise I is Clausius's version of the second law. Stated as a law governing the history of the universe it is assumed to be permanent, to be valid throughout cosmic history; this is in principle a problem, but one that it shares with other laws of nature, and the assumption seems to have been taken for granted in the nineteenth century. Whereas the second law can be taken to be a fact of science, Clausius's global formulation presupposes that the law can be applied to the universe at large, and this is *not* a fact (see further below). Premise II merely expresses an empirical fact, as a world of very high or maximum entropy would look entirely different from the one we live in. There is order, structure, life and available energy in the universe, all of which contradicts that entropy could have increased indefinitely. (The existence of human beings is incompatible with a maximum-entropy scenario, which indicates a relation between entropic and anthropic reasonings.) Whereas the argument stated so far is relatively straightforward, it becomes more problematic when extended to a theistic argument, which can proceed as follows:

IV. If the world had a beginning, it must have been created.
V. If created, there must be a creator, that is, God must exist.

We are here on slippery ground, for other reasons because 'finite age' and 'beginning' cannot be simply identified with 'creation'.[1] A temporal origin may be considered to be just a limit imposed on the extrapolation into the past of the laws of physics. Whether such a limit is regarded as a cosmic creation is a question that cannot be answered by science; if meaningful, it belongs to metaphysics or theology. Moreover, does it necessarily follow that a created entity, or rather a created world, requires a creator? One might prefer a more cautious version of statement V, for example to break it down into three steps:

V.a. If created, there must have been a creative act.
V.b. There must have been a cause for this act.
V.c. Only God (who is transcendent) can be the cause for the creation of the world.

But this does not really change much.

The classical proofs for the existence of God are usually classified in three groups, the ontological, the teleological or physico-theological, and the cosmological (to which some others may be added, such as the axiological, the moral and the pragmatic proof, but these are of no relevance here).[2] The first one, which is independent of experience, is intended to prove the existence of the most perfect conceivable being:

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[1] Indeed, finite age need not imply a cosmic beginning. The much discussed Hartle-Hawking model of 1983 has a finite past but is uncreated and with no beginning in time.

[2] Of course, many religious believers, both then and now, did not care about scientific or philosophical proofs which they tended to see as a sterile academic game. Søren Kierkegaard remarked: 'Whoever therefore attempts to demonstrate the existence of God ... [is] an excellent subject for a comedy of the higher lunacy!' (Kierkegaard 1936, chapter 3, p. 34). However, in

for example, God is by definition the most perfect being, and that alone implies that he must exist, for a non-existent being cannot possibly be perfect. The teleological argument, on the other hand, is empirically based. It aims at proving the existence of an all-good designer and creator of the universe on the ground that nature is ordered and purposeful. The world is a cosmos, not a chaos. The cosmological argument is intended to prove the existence of a necessary being, an *ens per se*, who is the prime mover or cause of the universe. It exists in several versions, some of them relating to a 'first mover' or 'first cause'. But the argument does not need to refer to causes or beginnings. For example, the argument from contingence assumes that contingent objects or events presuppose a necessary being; since there are such contingent objects and events a necessary being must exist. Another version claims that if all natural phenomena are governed by laws (such as they seem to be, at least on a fundamental level), there must exist a being who has produced the laws, a divine legislator. Incidentally, this version may as well be taken to belong to the class of physico-theological proofs.[3]

Yet another version of the cosmological proof or argument is based on the claim that the universe has only existed for a finite period of time, and this is evidently where the entropic argument enters. The entropic argument can be considered a variant of the classical cosmological proof for the existence of God that dates back to Islamic philosophers and theologians in the Middle Ages. The cosmological proof depends on the fact (or rather the assumption) that everything in the universe is contingent and therefore must have a cause, a reason for its existence.[4] To avoid an infinite regress one arrives at a necessary being, namely God. The cosmological argument exists in many versions, one of which can be boiled down to the syllogism:[5]

1. Everything that begins to exist has a cause of its existence.
2. The universe began to exist.
3. Therefore the universe has a cause of its existence.

Here, statement 2 can be argued either logically or empirically, and it is as a scientific argument in support of this statement that the entropy law plays a role. The alternative is to argue for statement 2 by proving from a logical and mathematical basis that an everlasting universe is impossible, for instance by referring to the impossibility of an actual infinity. Although the entropic argument is part of a logical-philosophical line of reasoning, it rests on an empirically confirmed law of nature and is in this respect closer to proofs of God relating to natural theology than to the standard cosmological

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the *Kulturkampf* of the late nineteenth century, scientifically based arguments for or against God were widely seen as important.

3 For an entertaining, if indecisive discussion of proofs of God's existence, see the debate between Bertrand Russell and the Jesuit philosopher Frederick Copleston, as reprinted in Russell 1967, pp. 138-59. For a more systematic discussion, see Flew 1966.

4 Philosophers have discussed the possibility of uncaused beginnings of things. See Smith 1988.

5 This is William Craig's brief formulation of the argument (Craig 1979). In this version it is limited to a temporally finite universe, but it can also be adopted for an eternal universe (see Rowe 1975).

proof. At any rate, if the argument is accepted, it seems to follow that, to avoid an infinite regress or some uncaused natural beginning, an ultimate and supernatural cause must exist in the form of a necessary and transcendent being. What should this being be if not God?

The entropic-theistic argument shares with other forms of the cosmological argument (and arguments based on natural theology as well) that the best it can do is to provide evidence for a creative divine being. It cannot be an argument for the Christian God, at least not without additional arguments, but can just as well be an argument for Allah or Yahweh. In fact, it is not even a monotheistic argument, for there could be any number of gods involved in the cosmic creation process. The entropic proof was an attempt to demonstrate the existence of God from positive scientific knowledge, in this case the second law of thermodynamics. In this respect it differs from arguments of God-of-the-gaps type where divine action is inferred from the impotence of science to account for certain natural phenomena.

It is worth pointing out that the Christian doctrine of creation is complex as well as controversial, and that it is not really comprehensible from the more limited perspective of scientific thinking.[6] It is generally agreed – and was so agreed in the late nineteenth century – that God created the world *along with* time rather than *in* time. Cosmic creation is primarily about the ontological dependence of the world on God, and not so much about beginning in the conventional temporal sense. Nor is God's absolute eternity to be understood as endless temporal duration, but as a qualitatively different form of changelessness. Now, so the scientific mind will query, how can an eternal and non-temporal divine being act upon the manifestly temporal and non-eternal world? There are many other problems, but these are the business of theologians and philosophers of religion.[7] These kinds of questions did not directly enter the context of problems here discussed, and consequently we can afford the luxury of ignoring them.

Although the cosmological consequences of the second law were often stated in terms such as 'beginning' and 'end', let me repeat that this should not be understood literally, in the meaning of cosmic creation and annihilation in the strong sense. Such a meaning – where the space, time, energy and matter of the universe appears from nothing and disappears into nothing – made sense within the framework of relativistic Big-Bang models in the 1930s and later on, but it was outside the mental framework of scientists in the Victorian era. The most the entropic argument can do is to lead to a beginning of changes and processes in the universe, just as the heat death is an end of changes and processes, not of the universe itself. When the universe had reached its end, it would still exist, but in a frozen or dead form where time had no longer a meaning because there were no processes by means of which it could be measured. Many authors in the late nineteenth century spoke loosely of the end of the world, without fully recognizing that it meant the end of world processes. Josef Schnippenkötter, who in 1920 wrote a comprehensive dissertation on the entropic creation argument, expressed it as follows: 'The end of the world is the stagnation of what happens in the world, the cold death or the heat death. In

[6] See Hyers 1984 and the concise discussion in Hepburn 1967.

[7] Some of the problems of the cosmological argument are considered in Dupré 1972.

the sense of the entropy law the "end of the world" does not mean annihilation of the world matter or the end of the existence of the cosmic clock. The "dead" world exists, as was it a corpse.'[8]

The entropic argument is not, and was never used as, a proof of God's creation of the world out of nothing. After all, nothingness cannot be assigned a value of entropy, or any other physical quantity. The logic was rather that if it is accepted that physical processes cannot arise spontaneously out of inert matter, a transcendent agent must have breathed life into the matter, must have wound up the cosmic clock. Most of the procreation discussants in the late nineteenth century accepted a kind of dead precreation universe, which they typically conceived as a chaotic, gaseous state of matter. However, to some theologians and philosophers, it was an un-Christian thought that the world had existed eternally in a chaotic state of hibernation and then, at a given date, was shaped by God into a living cosmos. As Alexander Bruce, a Scottish theologian, pointed out in 1892, it was really a pagan tradition of thinking of God merely as the shaper of chaos into a world of order.[9] And yet this was all the entropic argument could offer.

Early Ideas of a Cosmic Beginning

The entropic argument can be dated to the late 1860s, although, as noted above, traces of it can be found earlier in Thomson's paper of 1854 and perhaps also in Helmholtz's Königsberg address from the same year. Given the elementary nature of the argument, it is likely that several scientists realized at an early date that the second law could be used as evidence for a world of finite age, but I know of no clear public statements on the matter until 1868-70, when the argument was given voice by authors in France, Germany and Great Britain.

Elme Marie Caro was a French philosopher who from 1864 to his death in 1887 served as professor of philosophy in Paris. In several of his publications he was concerned with defending Christian values against the new trend of positivism and related anti-spiritual and anti-metaphysical tendencies in science. His first and most successful book in this area was *Le matérialisme et la science* which appeared in its first two editions in 1868. The primary aim of Caro's book was to show that natural science can neither replace nor suppress metaphysics and theistic philosophy. He attacked in particular Ludwig Büchner, the controversial author of *Kraft und Stoff*, and among his other targets were Auguste Comte, Herbert Spencer and the Dutch materialist physiologist Jacob Moleschott. According to Caro's line of argument, materialistic science was by its very nature unable to say anything about origins, whether related to life, matter, energy or order in nature. Moreover, the new experimental schools of physics, chemistry and physiology did not offer the

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[8] Schnippenkötter 1920, p. 63. Rudolf Falb was one of the few writers who clearly distinguished between an end of the world, in the sense of a transformation of matter and energy, and an annihilation of the world, in the sense of a 'disappearance without a trace of the universe' (Falb 1875, p. 199).

[9] Bruce 1892, pp. 65-6.

slightest support of positivism and materialism; on the contrary, he claimed that they contradicted the dogma of scientific materialism.

Caro's arguments in favour of a spiritual world view in harmony with Christian tradition were essentially philosophical, but he also made use of recent advances in the sciences, including thermodynamics. As he saw it, the works of Clausius and others 'absolutely contradict the eternity so recklessly [claimed to be] affirmed by the movements in their present forms, and also the pretended necessity of a circular course of life'.[10] The universe, he argued, must have had a beginning and this alone showed that it was not governed by what he called the materialistic law of determinism.

As far as thermodynamics was concerned, Caro relied on the works of Athanase Dupré, dean of the Faculty of Science at the Collège Royal in Rennes and a recognized expert in the new mechanical theory of heat.[11] In 1866 Dupré had pointed out that although the first law of thermodynamics might seem to lead to an indefinite duration of the present order of nature, this was not the case if the second law was taken into account. 'Thus, *in the future*, the present order cannot, except for certain modifications, continue for ever. *In the past*, it is certain that there has been a beginning ... .'[12] Dupré argued that the second law can have operated only in a finite span of time, and Caro adopted his argument. Neither Dupré nor Caro concluded that the world must therefore have been created by God, but it is clear from Caro's exposition that he considered the entropic argument as a welcome support for a divinely created universe.

Caro's book attracted some attention also outside France and was positively reviewed in the British *Saturday Review*, among other places. The anonymous reviewer expressed satisfaction with Caro's anti-positivism in general and reported the author's view that not only did the second law lead to a heat death, it also made it 'infinitely probable that the laws which now regulate the world had been arranged by an intelligent Cause'.[13] The review was noticed by Maxwell, for whom the argument was neither new nor unwelcome. He referred to the review in a letter of April 1868 to the editor of *Saturday Review*, Mark Pattison, rector of Lincoln College in Oxford. In this letter he explained his own position and related to some of the ideological extrapolations drawn from the sciences of mechanics and heat.

Maxwell was a committed Evangelical in whose thinking science was never far from religion. For example, in his inaugural lecture at Aberdeen in 1856 he confirmed his belief that natural theology was an integral part of the study of science. 'But as Physical Science advances we see more and more that the laws of nature are *not* mere arbitrary and unconnected decisions of Omnipresence, but that they are essential parts

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10 Caro 1868, p. 293.

11 On Dupré, see the entry in *Dictionary of Scientific Biography* by Robert Fox. Dupré's most important work, published in 1869 as *Théorie mécanique de la chaleur*, summarized several earlier papers on the subject and was used as an advanced textbook.

12 Quotation from the lengthy extract that appeared in Caro 1868 (p. 290). Compare also with Bertin 1867: 'M. Dupré also shows that, in the past, they [motions in the world] must have started off by the action of a supernatural cause' (p. 81).

13 'Science and positivism', *Saturday Review* 25 (1868), 455-6. See also Maxwell 1990-2002, vol. 2, p. 359 and Garber, Brush and Everitt 1995, pp. 185-94.

of one universal system in which infinite Power serves only to reveal unsearchable Wisdom and external Truth.'[14] His Evangelicalism led him to a position that has been described as anti-deist, anti-utilitarian and anti-positivist.[15] Maxwell was fully aware of the danger of using science apologetically, a temptation he resisted. He believed that science should be kept separate from religion and warned against using the most recent advances in science to change the interpretation of the Holy Book. On the other hand, he admitted that certain conclusions from science might legitimately enhance the religious sensibility.[16]

In his letter of 1868 to Pattison, Maxwell criticized what he interchangeably called positivists and materialists. According to the strict materialist, 'everything depends on the motion of matter'. He – the materialist – is therefore forced to admit perfect reversibility (since the laws of mechanics are time-symmetric), from which follows that, 'if every motion great & small were accurately reversed, and the world left to itself again, everything would happen backwards … Of course all living things would regrede from the grave to the cradle and we should have a memory of the future but not of the past.' However, given the fundamental nature of the second law of thermodynamics this was a grave mistake. On the contrary, the arrow of time associated with this law 'leads to the doctrine of a beginning & an end instead of cyclical progression for ever'. Maxwell was aware that the questions he discussed might be accused of being metaphysical, but if so he had no regret: 'I happen to be interested in speculations standing on experimental and mathematical data and reaching beyond the sphere of the senses without passing into that of words and nothing more.'[17]

Having received a letter of reply from the editor of *Saturday Review*, Maxwell responded by offering a long and popular account of the essence of the mechanical theory of heat. His response included the following comment: 'I think you are right in thinking that we are likely to arrive at physical indications of a beginning & an end. That end is not destruction of matter or of energy but such a distribution of energy that no further change is possible without an intervention of an agent who need not create either matter or energy but only direct the energy into new channels.'[18] He did not have to explain the nature of the intervening agent. The notion of the world in decay had long been adopted by Christian thinking, and in the decades after 1860 it

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[14] Jones 1973, p. 77. The mathematician and philosopher Karl Pearson recalled an examination by Maxwell in which he, Pearson, had come to speak disrespectfully of Noah's flood: 'Clerk Maxwell was instantly aroused to the highest pitch of anger, reproving me for want of faith in the Bible. I had no idea at the time that he had retained the rigid faith of his childhood, and was, if possible, a firmer believer than Gladstone in the accuracy of Genesis.' Porter 1986, p. 200.

[15] Theerman 1977. On Maxwell's religious views, see also Harman 1998 and McNatt 2004.

[16] See the letter to the theologian Charles J. Ellicott in Maxwell 1990-2002, vol. 3, pp. 416-8. Ellicott agreed with Maxwell and replied that 'Theologians are a great deal too fond of using the latest scientific hypotheses they can get hold of.'

[17] Maxwell 1990-2002, vol. 2, pp. 360-361. Maxwell was at the time occupied with developing his statistical interpretation of the second law.

[18] Ibid., p. 361. Garber, Brush and Everitt 1995, p. 193.

reappeared in a modernized form as the heat death. The association between world and decay was close enough that a Catholic writer could propose the term *cosmodysy* – derived from the Greek 'decay of the world' – for hypotheses concerning the far future of the universe.[19]

Not only was the heat death an integral part of the anti-materialistic, thermodynamic world view; so was the beginning of the world. Thomson had indicated as much in 1854, and in an address to the Liverpool meeting of the British Association in 1870 Maxwell stated in public his version of the cosmic consequences of the second law. If we trace the history of the universe backwards in time, we

> arrive at the conception of a state of things which cannot be conceived as the result of a previous state of things, and we find that this critical condition actually existed at an epoch not in the utmost depths of a past eternity, but separated from the present time by a finite interval. This idea of a beginning is one which the physical researches of recent times have brought home to us, more than any observer of the course of scientific thought in former times would have reason to expect.[20]

The following year Maxwell conveyed the same message in his textbook *The Theory of Heat*. Basing his argument on Fourier's theory of heat conduction, he mentioned (as Thomson had done earlier) that the theory broke down for $t \leq 0$, meaning that the present world cannot be deduced from any distribution of temperatures occurring earlier than the magic moment $t = 0$. 'This is only one of the cases', he noted, 'in which a consideration of the dissipation of energy leads to the determination of a superior limit to the antiquity of the observed order of things.'[21] Maxwell thus used thermodynamics to argue that the world has not always existed; but he stopped short of stating explicitly that it must therefore have been created by a supernatural creator, God. Heat conduction and the second law were not the only parts of the physical sciences Maxwell could draw upon in order to present arguments for a divine creation. He also appealed to the permanence of atoms and molecules, as will be discussed below.

Thomson and Maxwell agreed that there was no conflict between science and Christian faith, and also that the principle of continuity prevented science from dealing with origins. Their view was in general accordance with ideas of natural theology such as espoused by, for example, William Whewell in his influential *Philosophy of the Inductive Sciences*. Whewell stated that, 'in the sciences which trace the progress of natural occurrences, we can in no case go back to an origin, but in every instance appear to find ourselves separated from it by a state of things, and an order of events, of a kind altogether different from those which come under our experience'.[22] Thomson concluded as much in 1854, and Maxwell brought home the same message in 1870. Although science pointed to a beginning, it had no power to investigate it. It marked a line of demarcation between science and religion. This view was generally accepted by Christian scientists, not only in the nineteenth

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19 Herbermann 1907-22, p. 186. The name did not catch on.

20 Maxwell 1965, part 2, pp. 215-29. See also Harmann 1998, p. 205.

21 Maxwell 1875, p. 265 (the same sentence appeared in the first edition of 1871).

22 Whewell 1996, vol. 2, p. 145 (reprint of original of 1840).

century but also in later periods. For example, the belief was spelled out in detail by the British astronomer Edward Walter Maunder, a sincere Christian and the author of a book on the astronomy of the Bible. In 1908 he expressed himself along the same line as had previously Maxwell and Thomson. According to Maunder, science could only study the universe as a machine in operation, not how the machine was originally constructed:

> Science … cannot go back to the absolute beginnings of things, or forward to the absolute ends of things. … Men therefore cannot find out for themselves how the worlds were originally made, or how the spirit of man was first formed within him; and this, not merely because these beginnings of things were of necessity outside his experience, but also because beginnings, as such, must lie outside the law by which he reasons. By no process of research, therefore, could man find out for himself the facts that are stated in the first chapter of Genesis. They must have been revealed.[23]

The Würzburg Connection: Fick and Brentano

In German-speaking Europe the entropic creation argument was first discussed in 1868-69, independently by two professors at the University of Würzburg, Adolf Fick and Franz (von) Brentano. Fick, a student of Carl Ludwig and Emil du Bois-Reymond, was a distinguished physiologist who also did important work on the borderline between medicine and physics, and he is today particularly known for the two laws of diffusion named after him. After having worked in Zurich 1852-68 he became professor at Würzburg, a position he held until two years before his death in 1901. The versatile Fick used the 'thermodynamic method' in physiology, primarily by using the law of energy conservation to understand physiological processes, a subject which was of great interest also to Helmholtz.[24]

Right after his move to Würzburg, Fick gave a series of six popular lectures which in 1869 was published as *Die Naturkraefte in Ihrer Wechselbeziehung*. Clausius had moved from Zurich to Würzburg the same year, 1868, and for a brief period – he left for Bonn in 1869 – he and Fick were thus colleagues. Although there is no documentation for an interaction between the two professors, one may assume that Fick benefited from discussions with Clausius. At any rate, Fick dedicated *Die Naturkraefte* to Clausius, whose global formulation of the thermodynamical laws he adopted. According to the first law, the energy 'of the entire world is a constant

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23 Maunder 1908, pp. 18-19. Maunder is best known for his studies of the Sun and the variation of the frequency of sunspots. He was also actively involved in the controversy over the canals on Mars, arguing that they did not exist. After his retirement in 1913, he served for a time as secretary for the Victoria Institute, a society devoted to reconcile science and religion. He contributed with a section on astronomy to *The International Standard Bible Encyclopaedia* (Chicago, 1915).

24 See the article on Fick in *Dictionary of Scientific Biography* by K.E. Rothschuh. On Fick and his use of thermodynamics in physiological processes, see Kremer 1990. Fick was raised in the Protestant faith and known as a pious person, but he had no formal church affiliation.

quantity unchangeable in all eternity, for an intervention from *outside the world* is inconceivable'. He formulated Clausius's second law as the lesson of the heat death, that the universe develops as had it a purpose – namely to die. As Fick formulated it: 'In the end all forces in the universe must take the form of heat and all temperature differences in the world must be equalized.' Again following Clausius, he pointed out that the second law precluded any idea of an eternally cyclic universe. As Fick explained, although the heat death concerned the state of the universe in a far future it also led to consequences for the distant past:

> This final state ... must be reached after a finite time has elapsed, counted from any arbitrarily chosen initial state which does not include infinite speeds or an infinite scattering of matter in space – that is, counted from any initial state that can be conceived at all. To put it the other way around, if the world had existed in an eternity the final state would already have been reached.[25]

We have here a clear statement of the entropic creation argument in its limited version, that is, without speaking of a divinely created world. However, Fick did not unequivocally conclude that the world once had a beginning in time, only that this was a possibility favoured by current scientific knowledge. The only escape he could see was that there was something seriously wrong with the second law, this 'highest, most general and most fundamental abstraction of science', and this he doubted. If the law were universally valid, then 'the world cannot have existed from eternity, it must have come into existence at a time not infinitely far from the present in an event which cannot be comprehended as [belonging] to the chain of natural causes, that is, in a creative act [*Schöpfungsakt*].'[26] Fick did not elaborate, nor did he mention the connection to religious ideas of a created universe.

A few years later, after having studied Clausius's and Boltzmann's attempts to base the second law on the laws of mechanics, Fick became more cautious. He found the attempts to be satisfactory, but pointed out that they led to a probabilistic understanding of the law of entropy increase. Therefore, 'the law of energy dissipation cannot be assigned certainty, only a measure of probability'. It is possible, if highly unlikely, that a temperature difference will arise spontaneously in a gas. In the spirit of Maxwell and Boltzmann, Fick asked his readers to imagine a column of a gas at a certain temperature and pressure. For how long a time need we observe the gas until we are willing to make a bet, at odds of 100 to 1, that for a period of 1 second the temperature of the upper part of the gas column will be 100 degrees higher than the lower part? His point was that the answer can be given by a finite period of time. 'It does not matter, in the present context, if the solution to this problem is given by a number of years which, printed in small writing, is a mile long, or as long as the distance to Sirius; for it concerns a principle which should be valid for eternity.' Fick concluded:

> I believe that one now has to admit that the law of dissipation of energy is not an inviolable law of nature, but a rule which, although of very general validity, allows exceptions. …

25 Fick 1869, p. 34. Reprinted in Fick 1903, pp. 296-361.

26 Ibid., pp. 69-70.

> In any case, the principle of energy dissipation cannot be used to justify far-reaching conclusions concerning the universe as a whole.[27]

That is, he retreated from his position five years earlier. Although he did not say so, it is clear from his address that in 1874 he no longer believed in a universe of a finite age.

While Fick kept silent about the theological implications of the second law, Brentano, his younger colleague in Würzburg, did not. The Austrian-German philosopher Franz Brentano is best known for his contributions to psychology and epistemology, and also for his important contributions to Aristotelian scholarship. He was ordained a Catholic priest in 1864, but nine years later he left the church. His break with the church was in part rooted in dissatisfaction with the new doctrine of papal infallibility, promulgated at the first Vatican Council in 1870, but also because he found some of the basic teachings of the church to be contradictory. However, he remained a theist of Christian inclination, and was convinced that the existence of God followed from scientific and philosophical principles. Contrary to most other Catholics, the young Brentano was much inspired by Comte's positivism with which he to some extent sympathized. In an article of 1869, he called Comte 'one of the foremost thinkers of which our century can boast'.[28] In 1874 he left Würzburg to take up a position as professor of philosophy in Vienna, where he worked until 1894, after which he retired to Italy. He was followed in the philosophy chair by Ernst Mach, whose position became professor of the history and theory of the inductive sciences, the first university chair of its kind. Brentano was a charismatic teacher who during his twenty years in Vienna influenced many of his students, including later notabilities such as Edmund Husserl and Sigmund Freud.

An enthusiast of what he considered to be the scientific method, Brentano wanted to use positive science to establish a new form of natural theology.[29] He first discussed the theological implications of the laws of thermodynamics in a lecture series on 'The Law of Entropy and its Significance for Metaphysics' which he gave in Würzburg in the winter semester of 1868-69, that is, simultaneously with Fick's lectures. He later reported: 'Shortly thereafter, when I went to England, it appeared that there the famous physicist, Tait, had drawn the same conclusion, a sure sign of how obvious it is and how perfectly inevitably it forces itself upon us.'[30] He subsequently dealt with the theme in several lectures at the universities of Würzburg and Vienna, and he also discussed it with his friend Boltzmann.[31] However, his apologetic arguments were not well known at the time as they were only published posthumously.

Brentano developed systematically four proofs of God: the teleological proof, the proof from motion, the proof from contingency, and what he called the psychological

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[27] Fick, 'Ueber das Prinzip der "Zerstreuung der Energie"', published 1874 in the proceedings of the Würzburg Academy of Science. Here from Fick 1903, pp. 362-5.

[28] Quoted in Burgess 1974, p. 80. On Brentano's life and work, see McAlister 1976.

[29] Löffler 1995.

[30] Brentano 1987, p. 279, a translation of *Vom Dasein Gottes* (Leipzig, 1929). The lectures were given 1868-91 but the individual parts are not provided with dates.

[31] On the relationship between Brentano and Boltzmann, and the letters exchanged between them 1903-06, see Blackmore 1995.

proof. Of these, the last one was the most original, but in the present context it is his proof from motion that merits attention. This proof was basically the classical argument of a first mover, revised and extended by recent discoveries of physics. With these discoveries 'it is possible to show', Brentano wrote, 'that in contrast to the Aristotelian doctrine of the eternity of motion, all the alteration that we observe in the world must have had a beginning.'[32] He was referring, of course, to the laws of energy conservation and entropy increase (contrary to the materialists, he did not see the first law as a problem for a world of finite age). First he discussed the heat death and some of the attempts to escape it, concluding that no such route of escape existed.

Brentano was aware of the standard objection that in a universe infinite in matter and space the degradation of energy will never come to an end and consequently the heat death will never occur. He countered with the not very convincing argument that such a universe was ruled out by the laws of mechanics because it could possess no centre of gravity – and 'the fundamental laws of mechanics require a centre of gravity for every system of moving masses'. At any rate, having convinced himself of the inevitability of the heat death he turned around the arrow of time: 'If our inference to the final state was necessary, then ... the development of the world, in as much as it leads to an end, must also once have had a beginning.'[33] Or, more forcefully expressed:

> Thus the development of the universe had a beginning just as surely as it will have an end, and at one time the energy supply of the universe did not exist at all. If we now ask whence nature has since acquired the energy which it once did not possess, there is only *one* answer to that: It certainly did not get it from itself. For according to the law of the conservation of energy, nature left to itself can no more gain than lose the smallest part of energy. So we are absolutely forced to assume that the quantity of energy the universe has at its disposal, with which it erected the starry vault and wove the delicate figures of plant and animal life and all the charm of human loveliness ... this energy was lent to the universe a finite period of time ago by an ultramundane principle. Its activity is the Alpha and Omega of the whole history of the universe.[34]

Here we see how Brentano managed to turn the first law of thermodynamics into an ally of the theistic argument.

In his advocacy of the entropic proof of God, Brentano argued against the famous German psychologist and philosopher Wilhelm Wundt, who in 1877 had suggested that the heat death would never occur in a universe which was infinite in space but finite in matter.[35] In such a universe the second law would still be valid, but the continual increase of entropy would never result in a state of perfect equilibrium. Wundt believed that the universe must necessarily be eternal in order not to contradict the principle of causality, but Brentano found his objections to be unconvincing and paradoxical, indeed 'utterly impossible'. In a later manuscript,

32 Brentano 1987, p. 270
33 Ibid., p. 278
34 Ibid., p. 280.
35 Wundt 1877. See also Chapter 5.

written before 1902, Brentano resumed his attack on Wundt. He admitted that the ideas of the psychologist-philosopher regarding time and world development were ingenious, but also found them to be nonsensical and unable to save the world from the heat death.[36]

Having carefully considered various possible loopholes in the entropic argument, Brentano concluded that it was compelling. Scientific reason clearly told that the energy of the universe had come into existence a finite period of time ago, supplied by 'an ultramundane principle'. He further argued that the transcendent principle must be good and have the properties of a creator or an intelligence:

> The creative principle whose existence we have proved is creator of everything that belongs to the universe, or has or could have an influence on it. For only in this case ... can it have knowledge of the universe ... And the creative intelligence is to be regarded, not only as the creator of everything that belongs to the universe, but also its sole, first cause.[37]

Finally Brentano concluded that the creative principle must also be an omnipotent and infinite being – 'Therefore it is infinite existence, absolutely perfect, not merely infinitely more perfect than we are. Therefore it is God.'

Brentano continued to value the entropic proof and, contrary to Fick, did not believe that Boltzmann's probabilistic interpretation of the entropy law undermined it. In a letter of 1909 he wrote that the applicability of the law to the universe had not diminished because of recent advances in physics. He had confronted Boltzmann on the issue: 'When Boltzmann visited me in Florence, right away I reduced him to the greatest embarrassment over the means of avoiding the thermal death of the universe, which he'd prided himself on having discovered. And in keeping with his noble, upright character, he did not deny it.'[38] It is not clear what Brentano's argument against Boltzmann's view was.

Fick and Brentano were not alone in realizing the symmetry between end and beginning within the context of the second law. The same year, 1869, Carl Reuschle called attention to the possibility that entropy increase might lead to cosmic creation, if only to dismiss it unceremoniously. 'We must abandon either the consequences of W. Thomson and Clausius, or the infinity of the universe', he stated. For Reuschle the decision was easy. There can be no doubt, he wrote, 'as to which of the two horns of the dilemma we have to drop, for we have no intention to return from the mechanics of heat to the dogma of creation'.[39]

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[36] Brentano 1988, p. 69.

[37] Brentano 1987, p. 305.

[38] Ibid., p. 9. Boltzmann visited Brentano in 1905. On Boltzmann's probabilistic interpretation of the entropy of the universe, see Chapter 5.

[39] Reuschle 1869, p. 247.

Entropy in the Service of Faith?

The Scotsman Robert Chambers caused a scandal when he anonymously published *Vestiges of the Natural History of Creation* in 1844. The main reason was that he argued that the world and its inhabitants had developed from earlier, more primitive forms over long spans of time, a process that he pictured naturalistically and as governed by one grand principle of evolution covering both organic and inorganic realms. This is not to say that God was not part of the evolutionary picture, for Chambers considered his work to be a contribution to natural theology. 'We have seen powerful evidence', he wrote, 'that the construction of this globe and its associates, and inferentially that of all the other globes of space, was the result, not of any immediate or personal exertion of the part of the Deity, but of natural laws which are expressions of his will.'[40] Many readers in early Victorian Britain found *Vestiges* controversial because of the withdrawn role of the divine creator. It could be seen as a deistic tract or, even worse, as an atheistic argument masquerading as natural theology. The furor caused by *Vestiges* was only a prelude to what happened in the second part of the century, when thermodynamics and evolutionary biology threatened the harmony between reason and faith.

During the 1860s, the decade following the publication of Darwin's *Origin of Species*, the relationship between science and religion in Britain began to be strained. Worried about signs of an increasing dissociation, a group of London scientists issued in 1865 a declaration in which they attempted to establish, or reestablish, a harmonious alliance between science and religion. 'We conceive that it is impossible for the Word of God, as written in the book of nature, and God's Word written in Holy Scripture, to contradict one another, however much they may appear to differ', they declared. 'We confidently believe, that a time will come when the two records will be seen to agree in every particular.'[41]

But not all agreed that science revealed divine truths or that it would ultimately lead to the same lofty goal as religion – or that this goal was worth pursuing. Several prominent British men of science, including William K. Clifford, John Tyndall, Thomas Huxley and Francis Galton, argued that explanation in terms of matter and motion was the ultimate goal of science, whereas moral and spiritual issues were irrelevant. Nature, they claimed, was nothing but a complex system of atoms and energy.[42] As seen from their perspective, natural science reigned supreme when it came to descriptions and explanations of the natural world. The British scientific naturalists did not necessarily believe that science and religion were antagonistic, but they did believe that science and theology were. Some of them, including Huxley, Tyndall and Spencer, were members of the so-called X-Club, an influential social

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[40] Chambers 1969, pp. 153-4, a reprint of the 1844 edition. The authorship of the book was first acknowledged in the twelfth edition of 1884, after Chamber's death. Much has been written on the context and influence of Chamber's *Vestiges*. The most detailed work, and possibly the definitive work on the subject, is Secord 2000.

[41] Brock and Macleod 1976, p. 41.

[42] On British scientific naturalism, see Turner 1974 and Lightman 2001. The religious discussion in Victorian Britain, as provoked in part by the attitude of the scientific naturalists, is treated in Livingston 2007.

club whose members supported naturalism, Darwinian evolutionism, Anglican liberalism and the professionalisation of science.[43]

The strategy of their opponents, such as the psychologist James Ward and the statesman Arthur Balfour, was to disengage 'science' and 'naturalism', to deny that naturalism had any scientific authority. Naturalism was incompatible with the scientific outlook, Balfour claimed.[44] Another strategy was to suggest that the false views of the materialists and scientific naturalists were due to their lack of understanding of the true nature of science. In a paper of 1888 Tait insisted that no genuine scientific men would dream of considering science and religion as incompatible. He even claimed that, 'The so-called incompatibility of religion and science is proclaimed solely from the ranks of those whose subject has not yet reached the scientific stage, and from the ranks of pseudo-science. ... The present outcry is the work of a small minority only, and has no countenance from those who really know science.'[45] The Cambridge physicist Gabriel Stokes agreed that there was no opposition between science and Christian religion, if for no other reason because they were so different. Statements to the contrary were 'wild scientific conjectures put forward by some, chiefly those whose science is only at secondhand, as if they were well-established scientific conclusions'.[46]

Although few of the scientific naturalists were atheists, their position was widely seen as a provocative challenge to Christian faith and the established social order. The challenge appeared even greater as it coincided with the debate over Darwinian evolution and the publication of *The Descent of Man* in 1871.

Among the much discussed provocations was Tyndall's presidential address to the 1874 meeting of the British Association in Belfast, where he, in conclusion of a long account of the triumphant march of science through history, said: 'The impregnable position of science may be described in a few words. We claim, and we shall wrest, from theology the entire domain of cosmological theory.'[47] In the polarized debate of the 1870s Tyndall's rejection of Christian theism made headlines and gave him a reputation as a materialist and an atheist. In the popular press he was portrayed as 'an aggressive, dishonest, devious, and distinctly un-British materialist'.[48] Shortly after having delivered the address, he wrote to a friend: 'You can form no notion of the religious agitation. Every pulpit in Belfast thundered at me. Even the Roman Catholics who are usually wise enough to let such things alone came down upon

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43 The X-Club was formed in 1864 and its activities continued until the 1890s. See MacLeod 1970 and Barton 1998.

44 The prominent conservative politician Arthur Balfour (Prime Minister 1902-05) published in 1895 *The Foundations of Belief* (London: Longmans) in which he objected to the claims of naturalism and defended a theistic cosmology. See Jacyna 1980. James Ward attacked the scientific naturalists in Ward 1899.

45 Article on 'Religion and science' from *The Scots Observer* 1888, reproduced in Knott 1911, pp. 293-5.

46 Letter to A.H. Tabrum of 16 January 1895, in Stokes 1907, vol. 1, p. 77.

47 Tyndall 1874, p. xcv. Barton 1987 provides a close analysis of Tyndall's Belfast address. See also Lightman 2004.

48 Lightman 2004, p. 202.

me.'[49] A materialist of a kind he was, but in a sense very different from, say, Büchner and Dühring in Germany. Tyndall's particular form of materialism – or realism, which may be a more appropriate term – was qualified, and it included a strong dose of romantic idealism. Nor was Comtean positivism, with its claim of having established a secular alternative to orthodox religion, very popular among British scientific naturalists. Huxley charged that French positivist philosophy was no more scientific than 'ultramontane Catholicism' and he characterized positivism with the memorable phrase 'Catholicism *minus* Christianity'.[50]

For Thomson, Tait, Stewart, Maxwell and other British physicists who were opposed to materialism or scientific naturalism, reversibility was associated with mechanism and materialism (and, implicitly, atheism) while such views were contradicted by the irreversibility as expressed by the second law of thermodynamics. To put it briefly, from an ideological point of view the first law was associated with materialism and positivism, the second with more idealistic or spiritual lines of thought. It may not be an accident that Tyndall dealt at length with energy conservation in his popular book *Heat, a Mode of Motion*, but found no place within the book's 570 pages to mention energy dissipation. He sought to chase away the ghost of entropy by ignoring it and focusing one-sidedly on the first law. 'The law of conservation [of energy] rigidly excludes both creation and annihilation', he wrote.[51] Tyndall, the scientific naturalist, did not find it worth mentioning that the law of energy conservation only constituted half the truth of the new thermodynamics.

Thomson and Maxwell were not the only British scientists who referred to the possibility of demonstrating the existence of a creative God from the second law of thermodynamics. So did their colleague and friend Tait, who in 1871 delivered an address to the British Association at its meeting in Edinburgh. The law of energy dissipation, he regretted to say, was still not well known, yet this law was 'far the most promising and fertile portion of Natural Philosophy'. It had applications in all branches of science, including geology and cosmology:

> It leads ... by sure steps of deductive reasoning, to the necessary future of the universe – necessary, that is, if physical laws for ever remain unchanged – so it enables us distinctly to say that the present order of things has *not* been evolved through infinite past time by the agency of laws now at work, but must have had a distinctive beginning, a state beyond

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49 Tyndall to Thomas Archer Hirst, 26 August 1874, as quoted in Neswald 2006, p. 262. James Wilson, who started his career as a mathematician and astronomer before he changed to the service of the church, was acquainted with Tyndall and his circle in the 1870s. In 1919, while being Canon of Worcester, he reminisced that Tyndall and some of his friends 'were out to sweep the Christian faith away'. Wilson 1919, p. 202.

50 Eisen 1964, p. 341. See also Huxley's attack on Comtean positivism in 'The scientific aspects of positivism', published in the *Fortnightly Review* in 1869 and reprinted in Huxley 1880, pp. 147-73. According to Huxley, Comte had 'but the most superficial, and merely second-hand, knowledge of most branches of what is usually understood by science' (p. 149).

51 Tyndall 1870 (4th edn), p. 467.

> which we are totally unable to penetrate, a state, in fact, which must have been produced by other than now acting causes.[52]

Few if any of the audience in Edinburgh would fail to identifiy Tait's other agency with God.

Tait's colleague Balfour Stewart, professor of natural philosophy at Owens College, Manchester, also accepted the entropic creation argument. In a popular article of 1870 on the dissipation of energy he characterized heat as 'the dreary waste heap of the universe ... [which] is always continuing to increase'. He pointed out that 'The principle of degradation would appear to hold throughout, and if we regard not mere matter but useful energy, we are driven to contemplate the death of the universe.'[53] But Stewart did not consider the prospect a tragedy, for eternal life was not to be desired. In an elementary textbook of energy physics he imagined the universe as a cosmic candle. If the candle is not lit, then perhaps it makes sense to regard it as having existed forever, but we know the universe-candle to be lit, and hence we can be certain that it has not been burning from eternity, and that one day it will cease to burn. 'We are led to look to a beginning in which the particles of matter were in a diffuse chaotic state, ... and we are led to look to an end in which the whole universe will be one equally heated inert mass, and from which everything like life or motion or beauty will have utterly gone away.'[54]

The energy-based arguments of Tait and Stewart can also be found, if in a different version, in *The Unseen Universe*, an important and controversial book they published anonymously in 1875 and by 1888 had appeared in fourteen editions.[55] It was a major aim of the book to refute extreme philosophies of materialism, and to do so on scientific rather than metaphysical grounds. Science, they claimed, was the best weapon against 'the horrors and blasphemies of Materialism'.[56] Far from being in conflict, science and religion were in such intimate harmony that they 'tell us the same tale.' Stewart and Tait wanted to base their Christian belief in the immortality of the soul on a scientific basis, and for this purpose they introduced a kind of parallel universe, a spiritual heaven connected by bonds of energy or ether to the material universe. They believed that the visible universe was finite, although they admitted that it was a hypothesis they could not prove. On the other hand, they claimed that a spatially infinite universe must necessarily be eternal, and since scientific evidence indicated a beginning of the universe they found it reasonable to conclude that it could not be infinite in size. 'No doubt, if scientific principle imperatively demanded the eternity of the present visible universe, we should be compelled to acknowledge

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52 Tait 1871, p. 6. The same message occurred in Tait 1876, p. 26, where he wrote that energy dissipation points 'to a beginning, to a state of things incapable of being derived by present laws of tangible matter and its energy from any conceivable previous arrangement'.

53 Stewart 1870.

54 Stewart 1873, p. 153.

55 Stewart and Tait 1901, a reprint of the third edition of 1876 (facsimile reproduction by Elibron Classics 2005). For analysis, see Heimann 1972. See also Schweber 1982 and Gooday 2004. The first three editions were anonymous, but informed readers were aware of the book's authorship.

56 Stewart and Tait 1901, p. 21.

its infinity as a consequence; but we shall see presently that scientific principle leads quite in the opposite direction.'[57]

After a lengthy exposition of the laws of thermodynamics, Stewart and Tait summarized the second law by announcing heat to be 'the communist of our universe'. The kinetic energy of the planets and other celestial bodies would slowly diminish and convert into heat, with the result that the stars would swallow up the planets and coalesce into ever greater masses. Rather than referring to difficult concepts such as entropy or dissipation they stated the counterfactual creation argument as follows: 'The very fact ... that the large masses of the visible universe are of finite size, is sufficient to assure us that the process cannot have been going on for ever; or, in other words, that the visible universe must have had its origin in time, and we may conclude that if the visible universe be finite in mass the process will ultimately come to an end.'[58]

Although Stewart and Tait rated the second law highly, they emphasized that it was merely a generalisation derived from experience. Moreover, in 1867 Maxwell had introduced in a letter to Tait a thought experiment with an intelligent being who could direct molecular flows molecule by molecule, thereby violating the second law.[59] Because of Maxwell's 'demon' – the name was coined by Thomson in 1874 – Stewart and Tait considered the law to be less fundamental than the laws of energy and mass conservation and also less fundamental than 'the law of Biogenesis', that is, the impossibility of life being produced from lifeless matter. Although the visible universe must come to an end, and immortality in this universe thus was impossible, they suggested the existence of an eternal and ethereal 'unseen universe' which was the seat of spiritual forces and in contact with its material counterpart. They asserted that energy conservation was applicable to the total system and argued that immortality was thereby saved. By what they claimed was scientific logic, they were led to the conclusion that 'the visible universe [has been] brought about by an intelligent agency residing in the unseen.'[60]

Tait and Stewart believed that recent physical science supported the notion of a creative God, but not that divine action had any legitimate role in scientific reasoning. On the contrary, it was 'the bounden duty of the man of science to put back the direct interference of the Great First Cause – the unconditioned – as far back as he possibly can in time.' Such a first abrupt manifestation of the universe, or just parts of it such as atoms, would however contradict the 'principle of unbroken continuity', which Tait and Stewart held to be sacrosanct. This principle was essentially the law of causality, that every effect must be the result of an antecedent cause, but in a wider sense it also referred to the uniformity and comprehensibility of the universe as a whole. Fortunately the contradiction could be avoided by appealing to the eternal unseen universe as a kind of source for the material one. 'We conceive it to be the

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57 Ibid., p. 213.

58 Ibid., pp. 166-7.

59 Daub 1970b and Leff and Rex 1990, which includes reprints of primary and secondary sources. On Maxwell's demon, see also Chapter 5.

60 Stewart and Tait 1901, p. 218.

duty of the man of science to treat the original production of the visible universe just in the same way as he would any other phenomenon.'[61]

Because of the connection to the unseen universe, the two physicists did not have to face the impossible problem of accounting scientifically for the creation of the material world *ex nihilo*. They looked for an explanation in scientific terms and therefore did not consider creation by a transcendent being. Their 'intelligent Agent' operated in the universe, in agreement with the Christian doctrine of a God who is not only transcendent but also immanent:

> We are led to a scientific conception of it [the universe] which is, we have seen, strikingly analogous to the system which is presented to us in the Christian religion. For not only are the nebulous beginning and fiery termination of the present visible universe indicated in the Christian records, but a constitution and power are therein assigned to the Unseen Universe strikingly analogous to those at which we arrive by a legitimate scientific process.[62]

Stewart and Tait ended their book by emphasizing the intimate harmony between science and faith. Science, they wrote, 'instead of appearing antagonistic to the claims of Christianity, is in reality its most efficient supporter'. And, should the reader have failed to absorb the message: 'The truth is, that science and religion neither are nor can be two fields of knowledge with no possible communication between them. Such a hypothesis is simply absurd.'[63]

Some of the ideas of *The Unseen Universe* can be found in two popular articles of 1868 that Stewart wrote jointly with the astronomer Norman Lockyer and in which they cautiously presented recent findings in spectroscopy as arguments against materialism and social disorder. Having introduced Thomson's principle of energy dissipation (and noted the 'striking analogy between the social and the physical world'), they formulated the hypothesis of the heat death. According to Thomson's principle, 'There is, in fact, a tendency abroad to change all kinds of energy into low-temperature heat equally spread about, – a thing that is of no possible use to anyone. ... As far as we are able to judge, the life of the universe will come to an end not less certainly, but only more slowly, than the life of him who pens these lines or of those who read them.' As far as the conditions of life were concerned, the two authors contrasted materialism with the hypothesis of a vital principle independent of matter. 'We suppose', they wrote, 'that a Supreme Intelligence, without interfering with the ordinary laws of matter, pervades the universe, exercising a directive energy capable of comparison with that which is exercised by a living being.'[64] However,

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[61] Ibid, p. 95.

[62] Ibid., p. 271.

[63] Ibid., pp. 271-2.

[64] Stewart and Lockyer, 'The place of life in a universe of energy', *Macmillan's Magazine* 20 (September 1868), 319-27, reprinted in Lockyer 1874, pp. 85-103 (on p. 94 and p. 102). Stewart and Lockyer relied in part on what they called 'the principle of delicacy', namely that an exceedingly small primordial impulse 'from without' can produce great effects in the construction of the material world. This principle was introduced in a preceding article, Stewart and Lockyer, 'The Sun as a type of material universe', *Macmillan's Magazine* 20

they admitted that the hypothesis, although possible, could not be justified from a scientific point of view.

In an article in the *Princeton Review*, Stewart further elaborated on some of the same topics, including the theological significance of the unseen universe. He summarized: 'We are thus led to regard the production of the visible universe as an event which had antecedents capable of being intellectually perceived, arising, in fact, out of a previous universe of some sort, but yet very different from the ether as we understand it.'[65]

Meant to be a Christian argument against the scientific naturalists and their materialistic metaphysics, *The Unseen Universe* caused much debate. Stewart and Tait had suggested that energy might be transferred from the visible to the invisible universe, and that energy might therefore not be conserved in the universe known to science. In an extensive and critical review in *Nature*, the anonymous reviewer dismissed the suggestion as being nothing but a useless 'theological dogma'. As to the possible objection that energy dissipation would be valid also to the unseen universe, Stewart and Tait had replied that it was assumedly of infinite size; therefore there was no reason to believe in strict energy dissipation in the universe in its totality. The reviewer found this answer to be wholly unsatisfactory, for why not regard the visible universe to be infinite?

> The moment that it is so regarded the arguments on which its end and its beginning are inferred seem to vanish into air. An infinite universe will have an infinite store of energy, and there is no need to suppose that its store is ever exhausted, or that in any finite time it has become practically degraded and unavailable. The whole elaborate machinery of the invisible universe, piled one on the top of the other, seems to us to fall like a house of cards, if we can accept the eternal duration of an infinite by-sense-perceptible universe.[66]

Some of the opponents of *The Unseen Universe* criticized it for being a return to an outdated natural theology. For example, in a highly critical review the mathematician William Kingdon Clifford charged that Tait and Stewart had made inappropriate extrapolations from known physics. After all, how do we know that the laws of physics apply to an entirely different realm such as the unseen universe? Clifford dismissed the arguments of Tait and Stewart as ideological, as nothing but an attempt to refashion supernatural marvels. He ridiculed their belief in 'spiritual bodies, replete with energy, angels, archangels, incarnation, molecular demons, miracles and "universal gehenna"'.[67] Not all religious readers of *The Unseen Universe* sympathized

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(August 1868), 257-66, reprinted in Lockyer 1874, pp. 63-84. See also Gooday 2004 and Myers 1986.

65 Stewart 1878-79, p. 545. As late as 1884 he asked whether the visible universe had its origin in physical or spiritual forces (Stewart 1884).

66 *Nature* 12 (1875), 41-3, on p. 43. Stewart and Tait responded anonymously in *Nature* 12 (1875), 66, maintaining that they had introduced no new dogma. They repeated as their belief that the visible universe was finite but claimed that their argument against past eternity would be valid even in the case of an infinite visible universe.

67 Clifford 1879, vol. 1, pp. 237-45, originally published in the *Fortnightly Review* 23 (1875), 776-93. The introductory passage was suppressed in the posthumously published *Lectures and Addresses*.

with its message, but many considered the book to be effective ammunition in the war against materialism. An American Presbyterian journal appraised it as follows: 'This book is one of the products of the reaction against the views of the quasi-scientists, who, for some time past, have managed to maintain almost exclusive control of the ways of access to the ear of the non-scientific public. This reaction is one of the reassuring signs of the times. True science is beginning to speak out against science "falsely so called".'[68]

George Gabriel Stokes, the eminent physicist and Lucasian professor of mathematics at Cambridge, might have agreed. He believed that science and religion occupied separate realms with no conflict and that materialism was not only inadequate, but antithetical to the true spirit of science. Contrary to scientists in favour of positivism and scientism, such as Haeckel and Ostwald in Germany, he emphasized that the domain of science was limited: 'Science cannot explain the feeling we have of right and wrong. Science does not cover the whole of man's complex nature.'[69] For example, the resurrection of Jesus Christ from the dead did not contradict scientific knowledge, for it was a supernatural event outside science altogether. As an outspoken member of the religious establishment, Stokes was convinced that God intervened in the course of nature, either acting by fiat or through the laws of nature. In 1891 he delivered the Gifford Lectures, which were published 1891-93 as *Natural Theology* in two volumes. At least at one occasion, in a paper in the *Journal of the Transactions of the Victoria Institute*, he concluded that the law of energy dissipation implied that God had created the universe.[70]

As to the doctrine of conservation of energy, Stokes noted that it 'has, I think, given needless alarm to some who have the cause of religion at heart'; but he assured his audience that such alarm was groundless. Moving on from the first to the second law of thermodynamics, he pointed out that the principle of energy dissipation contradicted eternalist and uniformitarian doctrines. 'We are bound to face the problem of the existence of the state of things we see around us as something that had a beginning, or, at any rate, something that was preceded by a state entirely different.' If the heat death was taken to be a true scenario for the future, 'the present order of things ought to be capable of being deduced in like manner from what existed at any anterior time, however remote.'[71] In a letter of much later date, Stokes returned to the claim that the world is eternal in both the past and the future. He believed that such views 'fly in the face of the best, I might almost say universal, scientific opinion'. He was referring to the heat death as caused by the continual degradation of energy:

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[68] Anonymous review in *The Presbytarian Quarterly and Princeton Review* 6 (1877), 183-8, on p. 183.

[69] Stokes 1907, vol. 1, p. 80. From 1895 to 1901 Stokes kept a correspondence on science and religion with Arthur H. Tabrum, an official of the London Post Office.

[70] See Wilson 1984. From 1886 until his death in 1903 Stokes served as an active president of the Victoria Institute. Although he took the Bible most seriously (he preferred to read it in Greek), he also objected to the 'Bibliolatry' and 'slavish literalism' of some religious people. See Stokes 1907, vol. 1, p. 84.

[71] Stokes 1880, p. 230 and p. 233.

> For the sun, just as for our steam-engines, we are living upon capital; in the latter case we are drawing upon our bank deposit, we are exhausting our coal-fields. At the present day there is a tolerable agreement among scientific men to regard nebulae as suns in process of formation, while among the stars there are a few smaller ones which are blood red. These are generally looked upon as effete stars; stars in process of extinction. …As regards the main question, those who say that the present order of things has gone on from a past eternity, and is calculated to go on for an eternity to come, only, in my opinion, thereby display their own scientific ignorance.[72]

The Victoria Institute or Philosophical Society of Great Britain was founded in 1865 to combat the influence of materialistic tendencies in science and culture, such as Darwinian evolutionism. As stated in the first issue of its journal (1866-67), the primary object of the Victoria Institute was 'To investigate fully and impartially the most important questions of Philosophy and Science, but more especially those that bear upon the great truths revealed in Holy Scripture, with the view of defending these truths against the oppositions of Science, falsely so called.' The early Victoria Institute was a rather militant and conservative organization which favoured a Biblical literalism far from the views of many Christian scientists. For example, when Maxwell was invited to join the institute, he declined, in part because he disagreed with its narrow and somewhat simplistic theology.[73]

In 1880 Henry Cotterill, Bishop of Edinburgh, published a paper in the Victoria Institute's journal in which he surveyed the relations between science and religion, concluding that the unity and order of the physical world could only be explained on the assumption of a transcendent and omnipotent deity. Among the sciences he referred to was thermodynamics. As to the scientists' confidence in the absolute validity of the conservation of energy, he suggested that it corresponded to what, religiously expressed, was the belief that the universe subsists in God. Cotterill further argued that the second law strengthened the connection between science and Christian religion:

> Were it not for this second law, which indicates that the present visible universe has had a beginning and must have an end, the scientific principle of continuity might seem to mean that the universe is eternal, and subsists in God, in the Pantheistic sense, as belonging to His Infinite and Eternal Being. But we learn, not only that the permanence which it has in its Creator is consistent with its being subject to cyclical changes, but that its order and its causations, if left to themselves, must terminate; which is the strongest conceivable proof that the origin of these is not in Nature itself. In fact, this law of dissipation is the very interpretation of the law of conservation that Religion as a whole requires.[74]

Among British authors, the most detailed and explicit version of the entropic creation thesis was perhaps due to Joseph John Murphy, an Irish religious author and close collaborator of James Thomson, William's elder brother who was an engineer and himself a contributor of some importance to the new science of heat. In 1869

72 Letter of 25 July 1900, in Stokes 1907, vol. 1, pp. 81-2.

73 See McNatt 2004. The Victoria Institute and its journal still exists, now as a creationist organization. On its early history, see Titterington 1950.

74 Cotterill 1880-81, pp. 31-2. See also www.creationism.org/victoria/.

Murphy published a large work, *Habit and Intelligence*, in which he dealt with just about everything, from physics and geology to morality and political institutions. In his chapter on 'The Motive Powers of the Universe' he examined the heat death scenario, cautiously pointing out that lack of knowledge of the size of the universe prevented any firm conclusion to be drawn. If the universe was infinite, which could not be ruled out, it would also be immortal. However, 'though the universe may be destined for a future without end, it cannot have existed through a past without beginning.' Basing his reasoning on the nebular hypothesis, he wrote: 'At the beginning, so far as we can judge, there was no aggregation, but all matter existed in a diffused state, as it appears to exist in the nebulae now. Physical reasonings will bring us no farther back than this: "the things which are seen were not made of things which do appear".'[75] Murphy did not comment on the religious implications, something he would do four years later in another work, *The Scientific Bases of Faith*. At about the same time Stanley Gibson, rector of Sandon College, Essex, drew attention to the entropic argument, which he stated as follows:

> The Universe cannot have existed from eternity under its present code of laws... Hence we must assume an epoch at which these laws had a beginning. Metaphysically speaking, such a beginning is not identical with a creation, because this latter word is generally understood to mean the calling into existence of the substance of matter. But still such a beginning of the present order of nature does suggest origination in a divine will.[76]

Gibson was careful to point out that the argument related to the entire universe, not merely the solar system, and that it was possibly invalid if the material universe was infinite. He was fully aware of the danger of basing the claim of a first cause on holes in the current state of scientific knowledge, for might it not be that these holes would be filled out? 'Because we do not know the natural cause of any phenomenon ... is it safe at once to pronounce it supernatural?'[77] Gibson therefore cautioned that the argument from the second law of thermodynamics did not *prove* either a beginning of the world or a divine creator. Yet he found the argument to be suggestive and provide evidence that the world had indeed been created by a supernatural being.

In some contrast to the cautious Gibson, Murphy's use of thermodynamics was explicitly apologetical, if by no means uncritically so. Like many of his contemporaries, he associated the energy concept with mind and spirit and saw in the new science a proof of the spiritual world view, even that 'matter can only be conceived of as spiritual'. Energy physics, he claimed, had refuted the godless materialism that some scientists mistakenly took to be the hallmark of modern science:

> Simple naked materialistic atheism – that is to say the system which would resolve all into the laws of mere matter – is thus shown to be scientifically false; and this from data

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[75] Murphy 1869, vol. 1, p. 63. See also Seeger 1969. The reference ('the things which are...') is to Hebrews 11: 3.

[76] Gibson 1875, p. 69.

[77] Ibid., p. 79.

> afforded by the sciences of matter alone, without referring to those of life and mind. The ultimate unity must be spiritual, in the sense at least of not being material.[78]

The nebular hypothesis was controversial because of its naturalistic explanation of cosmic evolution. It might seem to leave little room for divine agency except that God had assumedly created the primordial system and the laws that governed its further development. Didn't it reduce God's position to that of an absentee legislator? The Scottish physicist David Brewster came to dislike the hypothesis which he suspected was 'incompatible with religious truth and dishonouring to the great Author of the material universe'.[79] However, there was no unanimity concerning the question. Murphy considered the evolutionary world view and the nebular hypothesis as arguments in favour of religion, not against it, but stressed that the conclusion of a finite-age universe did not depend on the truth of the nebular hypothesis. From the law of energy dissipation followed that the universe must have had a beginning in time, which 'is a truth of purely physical science, deduced from the laws of thermodynamics'. From this followed again that the world was created by God, for 'the only way in which we can conceive that origin is that it is due to the determination of a Will, guided, as our own will is, by Intelligence towards a purpose.'[80] Murphy professed that he had no wish of harmonizing scripture with science and admitted that the argument from energy dissipation did not qualify as an absolute proof of God's existence. He nonetheless believed that the only admissible conclusion to draw from thermodynamics was 'that the powers of matter and of mind alike are the result and expression of a Living Will ... then also an Intelligent Will; and if an Intelligent Will, then also a Holy Will.'[81]

Apologetic use of the second law, such as can be found in Murphy, Brentano, Gutberlet and some other authors, was never common. Only relatively few of those who accepted the entropic argument for a beginning of the universe concluded that it was created by God or otherwise related thermodynamics to theology. Among the few who did make such a connection was a group of Catholic scholars in Germany, to be considered below, and also Arthur Erich Haas, an Austrian physicist and pioneer historian of science.[82] A Catholic with a strong interest in philosophy, Haas sought as a young man to connect his faith with the scientific world view. In an article of 1907 he reasoned in accordance with the entropic argument that the universe can have existed only for a finite period of time. Recognizing that the size of the universe is unknown, he wanted to separate the question of the beginning of processes from

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[78] Murphy 1873, p. 47.

[79] Brewster, *More Worlds than One* (London, 1867), as quoted in Gascoigne 1988, p. 239. For the nebular world view and its relation to religion, see Brush 1987 and Numbers 1977.

[80] Murphy 1873, p. 198 and p. 200.

[81] Ibid., p. 51.

[82] Haas is best known for his contributions to early atomic theory, which included the first introduction of quantum theory in the architecture of atoms. After 1935, when he emigrated to the United States, he focused on problems of cosmology in the style of Eddington. For an appreciation of his work and attitude to the relationship between science and religion, see Kragh 2004, pp. 189-93.

the question of the finitude of the universe. This he did by introducing a quantity – essentially a form of energy density – which has the property that it remains finite even in the case of an indefinitely large universe. He argued that this property, the 'specific supply of events', was analogous to the entropy, which he saw as an indication that the law of entropy increase might be valid also for an infinitely large universe.

Haas was aware of the many attempts that Ernst Haeckel and other thinkers of a materialistic or positivistic inclination had made in order to retain the eternity of the universe (see Chapter 5), but these he rejected as pseudo-scientific. They were, he said, based on 'artificial hypotheses' and 'dogma of philosophical faith'. He concluded that an eternal world was inconsistent with the laws of physics, and also that a world with a beginning in time cannot be accounted for purely in terms of physics. His argument was essentially of the God-of-the-gaps type:

> The monistic-materialistic conception of the world is therefore unable to explain the world picture. … With the recognition of its inability it follows that physics has reached the limit of its capacity with respect to philosophy. But the importance of this apparently negative result is that *it demands the assumption of a being whose actions are not subjugated to the general laws of nature [and] who is independent of nature, transcends it and rules over it*.[83]

According to Haas, physics had no power to suggest how this necessary being – which he identified with God – acts on nature. It may be through an initial act of cosmic creation or by continual creative intervention throughout eternity. The physicist just cannot tell and must leave the question to the theologian. 'Physics itself leaves the choice open between theism, deism and cosmic pantheism', Haas asserted. 'Only with atheism is it absolutely inconsistent, in so far the meaning of physics is not restricted to the so often misunderstood laws of conservation of 'force and matter' and leaves out all other laws.'[84] Haas seems to have soon abandoned this kind of entropic-theological reasoning, and been content to point out the general congruence between Christian belief and the world view of modern physics.

In a much later article, published while he was a professor at the Catholic University of Notre Dame, Indiana, Haas argued that the physical universe defied an exhaustive scientific explanation and that it was meaningless to consider the origin of the universe in terms of physics.[85] He believed that the new developments in physics, such as quantum mechanics and relativity theory, had strengthened religious sentiments and made science-based or scientistic atheism a much less plausible position. Thus, the temporal asymmetry implied by the second law of thermodynamics stood in 'complete opposition to the atheistic theory', he maintained. Like several other Christian writers, Haas emphasized that according to the atheistic world view it was a fundamental dogma that the universe is infinite in space and time. But, fortunately for the believer, this dogma was undermined by modern cosmological knowledge. 'Theoretical physicists believe in the finite extension of the universe', he

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83 Haas 1907, p. 524.

84 Ibid., p. 525.

85 Haas 1938.

exaggerated.[86] Not only did modern science lead to a spatially finite universe – thus making it impossible to see in the universe a substitute for the infinite deity – it also pointed to a universe of finite duration. As Haas noted, 'this scientific conclusion is in very interesting agreement with the religious idea of creation.' He did not elaborate. Among the arguments in favour of a temporally finite universe he mentioned the law of entropy increase and also the presence of radioactive minerals in the crust of the Earth (see further in Chapter 5).

In the early years of the twentieth century the entropic creation argument was well known, if rarely accepted as sufficient evidence for divine creation.[87] The extent to which the entropic argument had become disseminated may be illustrated by the fact that it appeared even in ordinary dictionaries. For example, it was mentioned in the article on 'Entropy' in the German *Meyers Konversationslexikon* of 1895, and the Danish 25-volume dictionary *Salmonsens Konversationsleksikon* included in its edition of 1918 an article on 'Energy' which gave a precise account of the heat death and the entropic argument for a beginning of the universe.[88] But, of course, because the argument was well known it does not follow that it was generally accepted. In most cases, the heat death and its inference to cosmic creation were only mentioned indirectly. To quote but one example, in a popular work on *The Forces of Nature*, the Danish physicist and meteorologist Adam Paulsen included a chapter on the degradation of energy. He expressed the consequences as follows:

> While the world, then, proceeds towards its destruction, it must also once have had a beginning. … If we go farther and farther back in the evolutionary course of the solar system, we must finally come to a state, where everything is motion and no motion has yet been transformed into heat. But such a state cannot be caused by some antecedent order without violating what we know empirically about the laws of energy transformations. The acting cause that has produced it stands outside the laws that govern matter and energy.[89]

Paulsen carefully avoided problematic terms such as 'creation' and 'beginning of the universe', and he ventured no idea of what the acting cause could have been. His neutral stance was characteristic for a great deal of the literature at the end of the nineteenth century.

The Austrian physicist Friedrich Hasenöhrl, Boltzmann's successor in Vienna, referred to the entropic 'proof of God' in a review article of 1915, but only to reject

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[86] Although some of the cosmological models based on general relativity were spatially closed (with the curvature of space being positive), there were also models with a flat, infinite space. There was no agreement among physicists and astronomers in the 1930s about the spatial extension of the universe, nor were there any means to determine the question unambiguously by observations.

[87] Schnippenkötter 1920, a doctoral dissertation presented at the University of Würzburg, discusses the extensive literature and refers to more than 200 books and papers on the subject. For a modern survey, see Neswald 2006, pp. 281-94.

[88] *Meyers Konversationslexikon*, vol. 5 (Leipzig, 1895), pp. 820-821; *Salmonsens Konversationsleksikon,* vol. 7 (Copenhagen, 1918), p. 192.

[89] Paulsen 1874-79, vol. 3, pp. 396-7.

it as an unwarranted speculation.[90] At about the same time the subject was taken up by Bernhard Bavink, a German philosopher of Protestant faith and teacher of physics who had a deep interest in the relationship between religion and the physical sciences.[91] Bavink first examined the entropic argument for the existence of God in a paper of 1907, only to conclude that it was invalid and that no theological consequences followed from thermodynamics.[92] Seven years later he elaborated his arguments in *Ergebnisse und Probleme der Naturwissenschaften*, a masterly exposition of philosophy of science which over the years appeared in at least ten editions.

Bavink argued that the entire discussion of the theological relevance of the entropy law was meaningless. Not only did the discussion rely on arbitrary assumptions about the spatial extension of the world, it also rested on a basic misunderstanding of the theistic concept of God. 'From the standpoint of theism, God is not the creator of the world because it once began, but because without him there would be no world in universal time at all.'[93] That is, whether or not the world had a beginning in time was not of great importance; the world could have existed in an eternity and still be God's creation. The apologetic inference from temporal finitude to the existence of God was therefore a fallacy. Bavink returned to the theme in a later book, written after the theory of relativity had changed the notions of space and time. His conclusion was the same: 'The question of whether the world is *causa sui* or the work of God in the sense of Christianity has absolutely nothing to do with the question of its course in time – which itself belongs to the world. It remains the same irrespective of whether t runs from $-\infty$ to ∞ or whether the time must be thought of as running back into itself (in the sense of relativity theory). It is in no way a question of existence of such, but of the meaning of what exists.'[94]

Although not particularly controversial, Bavink's objection was not generally accepted, neither by theologians nor physical scientists. Does divine creation require a cosmic beginning, a universe of finite age? According to Bruce's *Apologetics*, Christians were divided on the issue. He suggested that although an eternal universe might not be contrary to Christian theism as long as the eternity was God's will, still 'it must be admitted that a creation implying a historical beginning most effectually guards the supremacy of God, and the dependence of the world upon Him.' If the material world was conceived as eternal, it was difficult to escape the heretic notion

[90] Hasenöhrl 1915, p. 690.

[91] On Bavink, see Hentschel 1993.

[92] Bavink 1907.

[93] Bavink 1914, p. 125.

[94] Bavink 1952, pp. 100-102. Much the same point was made in connection with the controversy between Big-Bang models and the steady-state model of the universe. As the British priest and philosopher Erich Mascall wrote in 1956, 'The whole question whether the world had a beginning or not is, in the last resort, profoundly unimportant for theology.' Mascall 1956, p. 155. The Protestant theologian Conrad Hyers has expressed a similar view: 'Divine creativity is not restricted to a finite stretch of time, or to the past, but is a continuing activity, as theologians from Augustine to Luther and Calvin to the present have argued. Creation is not just a matter of beginnings.' Hyers 1984, p. 67.

of a necessary coexistence of God and the world, the consequence being either 'Manichæan dualism or pantheism'.[95]

German Catholics on the Entropic Argument

The critical-scientific activity of German Catholics in the last quarter of the nineteenth century should be seen on the background of, on the one hand, the rise of neo-scholasticism, and, on the other, the anti-Catholicism of the new united German empire. In the 1870s Bismarck and his minister of culture, Adalbert Falk, carried out a campaign to keep out Catholics from public life and culture, especially in Prussia. In 1872 and the years that followed Jesuits were expelled, displomatic relations with the Vatican came to a halt, and laws were passed that forbade Catholic orders and congregations; education, including training of the clergy, was brought under state control.[96] The result of these anti-Catholic measures, an important part of what is known as the *Kulturkampf*, was a strengthening of Catholic self-consciousness, particularly in Bavaria and the Rhineland. Scientific and intellectual activity within the context of neo-scholasticism was one of the ways the new self-consciousness found expression. Whether for this reason or not, scientists of Catholic creed contributed very significantly to scientific research, quantitatively as well as qualitatively.[97]

In the second half of the nineteenth century the Catholic church was seriously disturbed by what came to be known as the 'modernist crisis', a confrontation between traditional church dogmas and modern ideas coming from the humanities as well as the natural sciences. During the long pontificate of Pope Pius IX (1846-78) the church did what it could to fight the dangerous modernists. Although the Vatican Council (the twentieth ecumenical council, 1869-70) declared that faith and reason can never be opposed to one another, reality was different. It became a dogma within the Catholic church that, since truth cannot contradict truth, there can be no conflict between genuine science and genuine religion: 'Even though faith is above reason, there can never be any real disagreement between faith and reason, since it is the same God who reveals the mysteries and infuses faith who has endowed the human mind with the light of reason. God cannot deny himself, nor can truth ever be in opposition to truth.' Yet, the pious Thomist rhetoric could not hide the fact that religion and science, genuine or not, did not always evolve harmoniously. The Vatican Council admitted as much, for why else should it declare that 'all faithful

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[95] Bruce 1892, p. 65. 'Manichæan dualism' refers to the dualistic world view of Manichaeism, a gnostic religion established in Persia in the third century.

[96] A detailed account of the *Kulturkampf* from 1871 to 1890 is given in Schmidt-Volkmar 1962.

[97] For evidence, see the account of Christian scientists in Kneller 1912. The explicit purpose of the book was to bring home the point that there is no conflict between Christian faith and scientific research, such as claimed by materialists and monists. In spite of its partisanship and one-sidedness, this is a valuable and generally overlooked historical source. A similar catalogue of Christian scientists was drawn up by a French Jesuit about 1890, again with the purpose of demonstrating that science and belief were not antithetical (Antonin Eymieu, *La part des croyants dans les progrès de la science*, mentioned in Paul 1972, p. 201).

Christians are forbidden to defend as the legitimate conclusions of science those opinions which are known to be contrary to the doctrine of faith, particularly if they have been condemned by the Church.'[98]

In 1864 the Pope declared that reconciliation between the church and modern society was impossible, and he called on Catholic intellectuals to assist him in the fight against modernity. In the encyclical *Quanta Cura* and an associated 'syllabus of errors' the pontiff condemned a number of opinions as heretical, including that 'all action of God upon man is to be denied'. Another of the erroneous propositions was the belief that 'human reason, without any reference whatever to God, is the sole arbiter of truth and falsehood, and of good and evil.'[99] Six years later, the Vatican Council declared: 'If anyone is so bold as to assert that there exists nothing besides matter: let him be anathema.' Moreover: 'If anyone does not confess that the world and all the things which are contained in it, both spiritual and material, were produced, according to their whole substance, out of nothing by God; … or denies that the world was created for the glory of God: let him be anathema.'[100]

But the actions taken by Pius IX were a loser's fight, politically as well as intellectually. In the eyes of many scientists and liberal thinkers they did nothing but confirm the bad reputation of the Roman Catholic church. Or they reaffirmed prejudices, as in the case of John William Draper, the English-American chemist, astronomer and writer of cultural history. Draper, who served as professor of chemistry and natural philosophy at the University of the City of New York since 1839, was a pioneer of astrophotography – in 1840 he produced the first Daguerreotype of the Moon and two years later of the Sun. More to the point, apart from his scientific achievements he was radically opposed to the Catholic church.[101] His widely read *History of the Conflict between Religion and Science*, published in 1874, was not anti-Christian but it most certainly was anti-Catholic. Here is what Draper concluded about the conflict between Catholicism and enlightened thought:

> An impassable and hourly-widening gulf intervenes between Catholicism and the spirit of the age. Catholicism insists that blind faith is superior to reason; that mysteries are of more importance than facts. She claims to be the sole interpreter of Nature and revelation, the supreme arbiter of knowledge. … Then has it in truth come to this, that Roman Christianity and Science are recognized by their respective adherents as being absolutely incompatible; they cannot exist together; one must yield to the other; mankind must make a choice – it cannot have both.

As to Protestantism, his verdict was much more favourable: 'For Catholicism to reconcile itself to Science, there are formidable, perhaps insuperable obstacles in the way. For Protestantism to achieve that great result there are not. In the one case there is a bitter, a mortal animosity to be overcome; in the other, a friendship, that

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98 First Vatican Council, 'Dogmatic constitution on the Catholic faith', quoted from www.ewtn.com/library/COUNCILS/V1.HTM.

99 The syllabus of errors condemned by Pius IX. See www.papalencyclicals.net.

100 From www.ewtn.com/library/COUNCILS/V1.HTM.

101 On Draper, see Fleming 1972 (first published 1950). His important contributions to astrophotography are dealt with in Hentschel 2002.

misunderstandings have alienated, to be restored.'[102] Whatever Draper's diatribe, the new Pope, Leo XIII (1879-1904), realized that some kind of reconciliation was needed. It was during his pontificate that Bismarck resumed full diplomatic relations with the Vatican and repealed a number of anti-Catholic laws. In 1887 the Pope declared that the *Kulturkampf* was over. As an important part of his strategy, Leo XIII actively encouraged scholars to engage in the world of science and to show that Catholic thought and modern science were not, after all, irreconcilable.[103]

However, the professed aim of Leo XIII was not to modernize Christianity, but rather to Christianize modernity. The attempted reconciliation was given a particular twist because of the Pope's insistence that it had to respect neo-scholastic or neo-Thomistic natural philosophy. He claimed that a true understanding of nature could only be obtained if scientific facts were interpreted in the light of scholastic philosophy. Contrary to what is often thought, neo-scholasticism was not (and is not) apologetic in the sense of being explicitly concerned with a defense of Catholicism as a religion. Although there was no consensus on the matter, in the years around the turn of the century many leading Catholic philosophers and theologians agreed that neo-scholasticism should be considered a philosophy in its own right. Maurice de Wulf, a Catholic philosopher and historian of ideas, expressed it in this way: 'It is clear that there can be no such thing as a *Catholic philosophy* any more than there can be a *Catholic science*. ... Modern scholasticism will progress and develop without meddling in any way with matters of religion; it would be a fatal blunder to confound it with apologetics.'[104] Nevertheless, although neo-scholasticism might not be the servant of Catholic faith, the two were certainly intimately connected.

During the period 1885-1915 there was a great deal of interest in the entropic argument among theologians and Christian laymen. The interest was largely limited to Catholic communities, whereas few Protestants and Evangelicals were aroused by natural theology based on the laws of thermodynamics. The large Protestant dictionary *Die Religion in Geschichte und Gegenwart* (1909-13) included an extensive article on 'Energy and energetics' which referred to the entropy law and the heat death, but without mentioning the entropic creation argument or other possible theological consequences of thermodynamics.[105] Nor did the dictionary's entry on 'Proofs of God', which discussed eight classes of proofs, have anything to say about the entropic argument. The subject was discussed mainly by German Catholics, and to a lesser extent also by their brothers of faith in France and Belgium. This chapter in the history of the relationship between science and religion is today nearly forgotten, and even at the time its visibility was limited. Very few scientists of

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102 Draper 1874, p. 348 and p. 363. Although Draper's views no longer enjoy acceptance they do illustrate the tension between Catholicism and science as perceived by some scientific naturalists in the period.

103 A concise account of the cultural and political role of Leo XIII is given in Hayes 1941, pp. 141-8. See also Chadwick 1998, pp. 273-331 for details on his successful efforts to end the *Kulturkampf*.

104 Wulf 1956, p. 198 (translation of French original of 1907).

105 Titius 1910. The neglect of natural theology by Protestant divines during the nineteenth century is implicitly documented in Barth 1972, which on its more than 650 pages includes almost no references to science or natural theology.

importance contributed to the subject which was mainly discussed in rather obscure publications, either booklets or journals associated with Catholic organizations. In Germany the entropic argument made its appearance in journals such as *Apologetische Rundschau*, *Natur und Offenbarung*, *Stimmen aus Maria-Laach* and *Monatsblätter für den katholischen Religionsunterricht*, hardly sources familiar to most physicists and astronomers.

One might believe that the Catholic authors were happy to accept thermodynamics as an ally in their campaign for the theistic argument, but this was not generally the case. They were not primarily interested in supporting theism with scientific authority, for the belief in God was after all a dogma independent of such support. If a satisfactory proof of God's existence could be constructed on the basis of thermodynamics, so much the better; on the other hand, if the proof failed, no theological implications followed. Although some of the authors involved in the discussion did accept the entropic proof, others did their best to demonstrate that no valid proof of God could be built on the law of entropy increase.

The interest in the subject reflected Pope Leo XIII's attempt to engage faithful scientists and scholars in the study of Christian philosophy and to show that science and neo-Thomism could benefit from one another. Science was not a born enemy of faith; on the contrary, supplied with the right metaphysical foundation it could be used to defend the faith, such as Leo XIII urged in his encyclical *Aeterni Patris* issued in 1879. Moreover, the sacred philosophy would provide the physical sciences with a deeper and more satisfactory perspective. For, 'the investigation of facts and the contemplation of nature is not alone sufficient for their profitable exercise and advance; but, when facts have been established, it is necessary ... to inquire into the laws which govern them and the principles whence their order and varied unity and mutual attraction in diversity arise.'[106] According to the *Corpus juris canonici* of 1917, all teaching in the Catholic seminaries should be based on the principles and thoughts of Thomas Aquinas, lovingly known as the 'angelic doctor'.

Neo-scholastic philosophers occupied themselves with both of the thermodynamic laws. As to the first law, they denied that it included the soul or the human mind, but not that mind and matter were entirely separate.[107] On the contrary, within the Thomist framework of the Aristotelian categories 'matter' and 'mind' they argued that the soul must be able to act on matter. They were careful, though, not to represent the soul in physical terms, as some kind of energy. First of all, they denied that the laws of conservation of matter and energy implied an eternal universe. The amount of energy in the universe had always been the same, but it had nonetheless come into existence, namely by a supernatural act. Catholic thinkers did not try to explain the act in terms of physics, they accepted it as a matter of faith.

As an example of German-Catholic contributions to the entropic-apologetic literature we shall first consider an article of 1912 in which G. Schrader used the entropy law to infer God's existence. The second law, he wrote, 'refers to a beginning

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[106] Papal encyclical *Aeterni Patris* of 1879, paragraph 29, online version on www.papalencyclicals.net

[107] De Munnynck 1897.

of the world-development and hence provides support for a proof of God'.[108] Schrader carefully pointed out that the two thermodynamical laws only applied to the universe if it was a closed, finite system with a finite number of celestial bodies. To support this presupposition he made use of various logical arguments and also drew upon the authority of astronomers, who, he claimed, now agreed on the finiteness of the universe.[109] Apparently he was unacquainted with the possibility of space being curved, which he did not mention. At any rate, 'From the entropy law we make the important deduction that the world-development will come to an end and once had a beginning.' Surely, the original energy and its differentiation in intensity could not have been produced spontaneously. 'It could only have come from a cause external to the material world. There has never been a clock which could wind itself up and start to tick. Neither has a building ever built itself, a painting ever painted itself, or a poem ever composed itself.' After having discussed the entropic creation argument in various versions, Schrader concluded that the world process could only have been initiated by a transcendent cause or author. 'So there exists an intelligent and powerful author of the world development. Who is this powerful and intelligent author? It is he who is spoken of in the first chapter of Genesis.'[110] It goes without saying that Schrader's 'proof' was incomplete and unimpressive from a theological point of view. Thus he did not provide any argument why the transcendent creator should have the properties of the biblical God.

Carl Braun, a Jesuit theologian and amateur astronomer, had studied under Pietro Secchi in Rome and taught physics at Catholic schools until 1878, when he became director of an observatory in Kalócsa in Hungary. In 1887 he published *Über Kosmogonie vom Standpunkte christlicher Wissenschaft*, which appeared in a second edition in 1896 and a third in 1905. The book was composed of a series of essays first published in *Natur und Offenbarung* 1885-86.[111] Braun based his apologetical arguments on a broad range of astronomical, mathematical and physical data, including the second law. Because all energy is not transformed into heat in our present world, 'it is impossible that this [entropy-increasing] process can have gone on in an infinite time.' From the scientifically based prediction that the universe once will come to an end it follows that it cannot be necessary. The universe is contingent, hence there must be a reason for its existence which cannot belong to the universe itself. Braun concluded: 'There exists a sublime being who has created

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108 Schrader 1912, p. 25. The book appeared in the *Leuchtturm* series, published by a Catholic lay organization. I have not been able to establish even the first name of Schrader, who is not listed in *Poggendorff's biographisch-literarisches Handwörterbuch* or other standard biographical sources.

109 In fact, there was no such consensus. Schrader may have had in mind contemporary world models of Hugo von Seeliger, Cornelius Kapteyn and Karl Schwarzschild. However, these were models of the distribution of stars in the Milky Way and only qualified as cosmological models if the Milky Way was identified with the material universe. Astronomers disagreed if this assumption was warranted.

110 Schrader 1912, p. 42 and pp. 50-1.

111 The book received an extensive review by Mary Clerke in *Nature*. Although a Catholic like Braun, Clerke focused on its scientific aspects, especially Braun's explanation of the solar system. Clerke 1887.

this world. And this truth is no longer a theological or philosophical doctrine, but a consequence of science itself.'[112] Notice that this is a somewhat different kind of creation argument, since it does not rely on a universe of finite age but only on one limited in the future. Arguments of this type, which may be called arguments of contingency, were popular among Catholic scholars.

The theistic significance of the second law was also defended by Rudolf Schweitzer, a German organic chemist and entropic apologist. In a booklet of 1902 he wrote: 'As Clausius correctly has recognized, in the far future the entropy will reach a maximum; but it must likewise have had a minimum in the distant past. This entropic minimum must have been the starting point for all cosmic evolution.'[113] Although the title of Schweitzer's work referred to the entropic *Schöpferbeweis*, in fact he did not consider it to be a satisfactory proof. He did believe that the second law agreed fully with Christian faith, and that it contradicted the 'unscientific', 'implausible' and 'fantastic' notion of eternal cycles, but not that it qualified as a valid proof of God. All scientific knowledge is empirically grounded, he pointed out, and for this reason only more or less probable; not even the laws of physics are absolute truths that can serve as infallible axioms in a proof. 'It will probably never be possible to derive a rigorous proof of the existence of a creator from considerations of a purely scientific nature,' he admitted. Less could do, though, and Schweitzer was convinced that thermodynamics contradicted the claim that scientific knowledge supports the atheistic belief in an eternal universe. He concluded that the entropy law was, after all, a valuable ally of theism. In general the lesson was this: 'I am pleased to agree with nearly all apologists that the sciences have the role of confirming religious truths and, in cases that are theologically unclear, to speak out decisively for one view or other. It is certain that the atheism can best be combated if it is attacked on its own ground.'[114]

Jesuits seem to have taken the topic more seriously than most, such as indicated by two theological works from the 1890s. Joseph Hontheim, who after theological studies entered the order of *Societas Jesu* in 1882, was particularly interested in natural theology on which subject he published *Institutiones theodicaeae sive theologiae naturalis* in 1893. It was with this work that the name *argumentum entropologicum* was introduced in the theological literature, and it was also used in a dissertation of Bernhard Boeder in 1895. Both Hontheim and Boeder used the entropy law apologetically, to construct a complete proof of God's existence on the basis of thermodynamics. They realized, however, that the entropic proof was merely a new way of arguing for the beginning of the universe and that it could be seen as related to the old argument based on a first mover, the *argumentum cinesiologicum*.[115]

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112 Braun 1889 (reprint of 1887 edition), p. 198 and p. 246. The book was often cited by Catholic scholars as an authoritative exposition of cosmology. Constantin Gutberlet praised 'the famous astronomer and physicist C. Braun' for his 'genius' and 'exact mathematical, and solid philosophical' reasoning (Gutberlet 1908, p. 190). In fact, Braun was a minor figure in astronomical circles and his professional competence limited to astronomical instruments.

113 Schweitzer 1902, p. 52.

114 Ibid., pp. 57-8.

115 The two dissertations were written in Latin. I rely on the discussion in Schnippenkötter 1920, pp. 82-4 and Neswald 2006, p. 284.

Hontheim reasoned that a beginning of the world process might be understood in three different ways. First, matter might have come into existence simultaneously with the process, in which case there must exist a creator of the material universe. Second, matter might originally have existed in an inert state, to be activated with energy in such a way that the world process was initially in a state far from equilibrium, corresponding to minimum entropy; in that case, there must exist a creator of energy in the universe. According to Hontheim's third scenario, the original supply of energy would have left the universe in a state of complete equilibrium (maximum entropy) had it not been for some transcendent power who separated the energy in free and bound states, that is, who provided the tensional, low-entropy state necessary for future development. In this third case, there must have been a supernatural power capable of reversing the entropy law instantly and on the largest possible scale – a kind of incomprehensible Maxwellian demon who could only be God. Hontheim's two last cases could be seen as consonant with the Kant-Laplace scenario, while the first one could not.

Although many German Jesuits found the entropic creation argument attractive, not all of them accepted it as a valid proof of God or a necessary part of natural theology. Gerhard Esser, a Bonn theologian and religious author, was impressed by the law of entropy, which he considered to be a powerful weapon against the eternal-cyclical cosmologies favoured by materialists and positivists: 'The second law of energetics launches a mortal blow against the materialistic dogma of the eternal duration of the world processes,' he wrote.[116] In spite of his confidence in the law of entropy, he denied that it could serve as an independent proof of God. The law was helpful in combating the materialist enemy, but not theologically necessary. When it came to proofs of God, Esser preferred the traditional proofs based on the contingency of the world and the causality of natural processes. He believed that only such proofs were truly compelling. The causality argument rested on the belief that the law of causality was either *a priori* valid or could only be denied in theory, but not in practice – quantum mechanics was still to come. According to the Danish astronomer and mathematician Thorvald Thiele, director of the Copenhagen observatory: 'If the law of causality is acknowledged to be an assumption which always holds good, then every observation gives us a revelation which, when correctly appraised and compared with others, teaches us the laws by which God rules the world.'[117]

If the second law was an empirical generalization – and this was the opinion of most physicists – the entropic argument could not have the same persuasive power as purely logical deductions from some undisputable fact. After all, how could one justify a generalization from the laboratory, or even the solar system, to the entire universe? The philosopher Erich Becher cautioned that the global heat death, as well as the inference from heat death to cosmic beginning, rested on certain assumptions that might well be questioned. 'It is possible that the cosmos began a finite time ago, and that it tends toward the heat death. But it is also possible that there is no one

116 Esser 1907, p. 206. See also Hegglin 1883, another Jesuit who accepted the entropic beginning and end of the world but without finding the argument compelling.

117 Thiele 1903, p. 1.

direction of processes in nature, but that it changes in the whole or in parts of the world.'[118]

Several authors believed that the spatial and temporal finitude of the universe could be proved logically, without recourse to observations, and in that case there really was no reason to give priority to the entropy law. After all, logic is supposed to be a stronger argument than inference from empirical data. The Jesuit Tillman Pesch argued that the notion of the universe being finite in time rested on 'a much more solid basis' than the empirical entropy law, which consequently could merely add physical support to a truth theologians had arrived at from philosophical analysis. 'It would be foolhardy to base, at the present moment in time, a certain conception of the future state of the world's rest on scientific data. While some experts speak of a terrifying cooling, others refer to a "world fire" ... For the time being it will be wise not to pay attention to the scientific value of such predictions.'[119]

Pesch's sceptical attitude was shared by Désiré Nys, a professor at the Catholic University in Louvain and a leading philosopher in the neo-scholastic tradition who in his youth had studied chemistry under Ostwald in Leipzig. He taught courses in chemistry and cosmology at the Institut Supérieur de Philosophie, an autonomous school associated with the university which had been conceived by Leo XIII. Organized by the Belgian cardinal Désiré Joseph Mercier, the institute became as a stronghold of neo-Thomism soon after its inauguration in 1891. Among other activities, the institute published *Revue Néo-Scholastique* with Mercier as its editor. Mercier emphasized that the aim of the new institute should be 'to form, in greater numbers, men who will devote themselves to science *for itself*, without any aim that is professional or directly apologetic'.[120] In Nys' audience was young Georges Lemaître, the later cosmologist, who in this way became acquainted with philosophical cosmology.[121]

In one of the volumes of his *Cours de philosophie*, Nys examined in detail the claim that the second law implied a beginning of the world. He concluded that the law could not be assigned absolute certainty, and for this and other reasons he dismissed its apologetic use and retreated to the safe haven of faith. 'Did the world have a beginning? Only faith permits us to respond to this question with complete certainty.'[122] According to Nys, human reason – limited as it was – was unable to provide a definite proof against the possibility of an eternal world. It is a characteristic feature of the Catholic debate that although thermodynamics was found interesting and relevant, it (and science in general) was not given the same kind of epistemic priority that doctrines of logic and faith were.

118 Becher 1915, p. 275, who referred to Boltzmann's statistical interpretation of the second law.

119 Pesch, *Die grossen Welträtsel* (Freiburg, 1892), as quoted in Schnippenkötter 1920, p. 89.

120 Address of 1891, quoted in Wulf 1956, p. 270.

121 Lemaître started his studies in philosophy shortly before World War I, see Lambert 2000, p. 30.

122 Nys 1913, p. 193.

As one might expect, the view of Nys was in complete agreement with neo-scholastic philosophy such as expounded in the authoritative *Manual of Modern Scholastic Philosophy*, written by Cardinal Mercier and several of the professors at the Louvain institute. Cosmology, we are told, comprises three parts, namely, (i) the origin of the inorganic world, meaning its first efficient cause; (ii) its intrinsic constitution or ultimate constitutive causes; and (iii) its destiny or final cause.[123] It should be clear that cosmology in the neo-scholastic philosophical tradition constituted a much broader subject than the current meaning of the term with its emphasis on physics and astronomy. It was 'natural philosophy' rather than 'the science of the universe'. As to the origin of the world as a proof of the existence of God, Mercier and his coauthors wrote: 'If the world had a beginning in time, there must evidently exist an eternal self-subsisting Being to have caused it: for out of complete nothingness nothing could have come.' However, they were careful not to accept the argument as a proof of God's existence:

> But even if science could demonstrate that the actual state of this world as we find it had a commencement; if geological data, etc., could trace the history of the past and show that at a certain stage of the cosmic evolutions life was impossible, if the law of entropy could establish as a fact that the forces of the world have had an origin in far-off ages, reason alone could never be sure that this state was not endlessly preceded by some other state of which science is entirely ignorant. In any case it is imprudent, seeing the difficulty of the question and the state of uncertainty of the best philosophers with regard to these matters, to identify the question of the existence of God with that of the commencement of the world.[124]

Scientific considerations concerning the beginning of the universe were valuable, but they could not stand alone as they needed to be supported by metaphysical arguments. It should be of no surprise that the views of Nys and Mercier were little more than repetitions of what Thomas Aquinas had said more than 300 years earlier. In his main theological work *Summa theologiae* he wrote: 'Hence that the world began to exist is an object of faith, but not of demonstration or science' (Question 46, Article 2).

But not all Catholic scholars shared the sceptical attitude expressed by Pesch, Nys and Mercier. Drawing on the authority of the Hamburg physicist Johannes Classen, F. Nothen declared that 'the universe degrades to the heat death with mathematical certainty' and that the second law therefore provided a safe route to God.[125] Among those who found the entropic argument to be convincing were Ludwig Dressel and Constantin Gutberlet in Germany. Dressel, a physics teacher and Jesuit, summarized the argument as follows:

> If the natural processes come to an end, they must have had a beginning. Without natural processes the world cannot have existed at an earlier time, and so the world itself must have had a beginning; therefore, it was created, and there exists an omnipotent Creator.

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[123] Mercier et al. 1917, vol. 1, p. 47. The work was based on manuscripts written in 1905. See also Baschab 1923, p. 7.

[124] Mercier et al. 1917, vol. 2, p. 42.

[125] Nothen 1915, p. 118.

> … It is this omnipotent and omniscient Creator of whom there is written in Genesis: *In principio creavit Deus coelum et terram*.[126]

Dressel's reasoning was unsophisticated, especially when it came to the obligatory defense of the materially finite universe. (He considered space to be merely a mental construction and therefore left it out of consideration.) Not only did he claim that the idea of an infinity of celestial bodies was absurd, he also insisted that true infinity is an attribute that belongs to God only and therefore cannot be ascribed to the physical universe.

According to Dressel, energy possessed a 'natural desire' to change into heat, a desire which was greater the more distant the past. 'At the beginning of natural processes, when the entropy was zero, ... this desire was at its maximum, and with all its strength it opened up for the changes of the world. For this reason, there can have been no world before this [first] event.'[127] However, entropy is not defined in absolute measure but only in terms of differences between entropy states. It makes no sense to speak of a zero-entropy state a finite time ago, only of a state of the world that had lower entropy than all later states. By 1909, when Dressel wrote his essay, Walther Nernst had recently formulated his heat theorem or third law of thermodynamics. In its later formulation this law amounts to a method of calculating not only entropy changes but also absolute entropies: the entropy becomes zero at zero absolute temperature. It is unlikely that Dressel was familiar with Nernst's new heat theorem. Moreover, Nernst understood the law in a way that was entirely different from the modern interpretation, which was first suggested by Planck in 1910 (but generally accepted only much later). Nernst maintained that entropy is a matter of differences, not absolute values.[128]

Constantin Gutberlet, a Catholic philosopher and theologian, was a central figure in German neo-scholasticism.[129] He had studied at the Collegio Romano 1856-62, where he was ordained as a priest, and subsequently taught natural science at the seminary in Fulda. In 1888 he founded the review journal *Philosophisches Jahrbuch der Görres-Gesellschaft*, which included among its articles reviews of the entropic argument from the perspective of neo-scholastic thought. When the Prussian anti-Catholic laws forced him to resign from his position in Fulda, he moved to the friendlier environment in Würzburg, where he spent the years 1875-86. After the end of the *Kulturkampf* he returned to Fulda, where he stayed until his death in 1928.

Although Gutberlet offered more cogent and precise arguments than Dressel, his ended up with the same conclusion. In writings between 1882 and 1908 he analyzed the problem systematically, concluding that there were no convincing reasons to reject the thermodynamical creation argument. Like Dressel and most other authors

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126 Dressel 1909, p. 150 and p. 160.

127 Ibid., p. 158. This was not Dressel's only problematic statement. Given that he was a physics teacher and the author of an elementary textbook in physics (Dressel 1895), it is surprising that he stated on p. 155 that entropy is measured in the same unit as energy. Entropy, as defined by Clausius, is energy per temperature and its modern unit is Joule/Kelvin.

128 On Nernst's heat theorem and its relation to entropy, see Barkan 1999 and Cropper 1987.

129 On Gutberlet's life and work, see his autobiographical account in Gutberlet 1923.

engaged in the discussion, he believed that the argument presupposed a finite universe and therefore paid particular attention to this issue: 'Is the universe necessary and uncreated, or is it contingent and originated? To the scientist, this question depends on the solution of this great, in recent time so much discussed problem of the entropy, the rest state of the world processes. Without knowledge of the finitude of the world mass one cannot claim a limited supply of forces and therefore also not a creation.'[130] He admitted that it was difficult to prove *a priori* that the universe is finite, but thought that a proof by analogy with the temporal extension might be satisfactory: 'Since it can be clearly demonstrated that eternal motion is impossible, it is beyond doubt that for analogous reasons infinite space cannot be filled throughout.'[131]

To prove that the universe is indeed materially finite he appealed to a variety of arguments, some of them of an astronomical nature (including Olbers's and Seeliger's paradoxes) and others of a logical-mathematical nature. As he wrote in a theological work of 1888, 'It is absolutely impossible that the number of celestial bodies or atoms can be infinite, or altogether that the existing matter can have an infinite extension.'[132] *Numerus infinitus repugnat* had for centuries been part of scholastic philosophy, and Gutberlet fully accepted the doctrine. Even though finitude was essential to the entropy argument, Gutberlet argued that an infinite universe must also have its cause in a transcendent creator; for only an infinite, transcendent power would be able to supply matter with an infinite amount of moving force. It should be pointed out that most neo-scholastic philosophers operated with an Aristotelian concept of space according to which space and place, and therefore space and matter, were inseparably connected. From this point of view there was no difference between the spatial extension of the universe and its material extension. To speak of an infinite void outside the material world, as some astronomers did, made no sense within the framework of scholastic thought.

One of the standard arguments against the heat death was that the closer the entropy of the world approached its maximum, the slower would it increase and therefore never actually reach the maximum. Gutberlet admitted that the entropy might increase asymptotically but believed that even in this case the heat death would occur. For the amount of free energy will eventually become 'so small that it is able to sustain only the weakest life processes; the existence of humans, with their large consumption of energy, will not be possible'.[133] In his *Lehrbuch der Apologetik* he discussed several proofs of God and included a new entropy-based argument against an eternally recurrent universe. He claimed that even though one might imagine a few periods of evolution and decline, an infinite number was ruled out. Because: 'By each decline the amount of free energy [*zurückverwandelbare Wärme*]

130 Gutberlet 1908, p. 23. See also Gutberlet 1900, pp. 80-8.

131 Gutberlet 1908, p. 99.

132 Gutberlet, *Lehrbuch der Apologetik* (Münster, 1888), p. 147, as quoted in Isenkrahe 1920, vol. 1, p. 220. On the paradoxes of Olbers and Seeliger, see Chapter 5.

133 Gutberlet 1908, p. 94. In fact, the second law does not lead to a general function $S = S(t)$. All that the law says is that the function increases monotonically. J.A. McWilliams, a later Jesuit philosopher, agreed with Gutberlet. He pointed out that although absolute equilibrium will never be established, a point will eventually be reached at which the presently known world process can no longer be carried on. McWilliams 1939, p. 44.

will decrease, and the amount of bound energy will increase, so that in the end no revolution would any longer be possible.'[134] That is, by claiming that the entropy in the series of cosmic cycles increases, Gutberlet reinstated the heat death, if not in our world cycle then in some future cycle.[135]

In *Kosmos*, a book published in 1908, Gutberlet offered a comprehensive account of the evolution of the universe as seen from the perspective of neo-scholastic philosophy. He carefully reviewed the entropic creation argument and also the recent astronomical literature, which, he believed, indicated a limited Milky Way universe where the stellar system was surrounded by an endless void space. However, although he found these empirically based arguments to add valuable support for a material universe of finite size and age, his main argument was philosophical rather than scientific. Does the universe exist by itself and by necessity? Or is its existence contingent and therefore in demand of an explanation in terms of some primary cause? Philosophers of a materialist or positivist inclination opted for the first alternative. They claimed that it was meaningless to ask for any reason for the existence of the world, which necessarily must be uncreated and imperishable. The universe is its own cause, what in scholastic language was termed *causa sui*. But according to Gutberlet and other neo-scholastic thinkers, the universe did not exist *a se*. The only absolute and uncaused being is God, who is truly *ens a se*. Gutberlet therefore devoted a great deal of effort to prove that the universe is contingent. For example, he argued from the second law of thermodynamics that the world is perishable and thus cannot exist by its own reason. In this respect, his argument was similar to the one Braun had discussed in 1889.

Gutberlet further argued that the transcendent cause of the universe must be a being with qualities like those of the Christian God. The creator of the universe must be omnipotent and therefore also a personal God with knowledge and will (because, if he did not possess knowledge and will, he would not be omnipotent). According to Gutberlet, God's freedom of will manifested itself in the finite age of the universe. The universe could have come into being at any time, corresponding to an infinity of possible ages. 'The world could not itself determine its beginning … A transcendent cause must have *chosen* the time of the beginning among an infinity of possibilities. The cause of the world therefore possesses freedom; and also will and knowledge, without which freedom of will is not possible.'[136] Gutberlet apparently imagined a kind of divine or absolute time which existed before the creation of the world, although he did not explicitly defend such an unorthodox view. At any rate, to say that God determined the time of the creation of the world, such as Gutberlet said, seems to involve a concept of time separated from processes in the physical world. It is generally agreed that such a concept is problematic.

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[134] On p. 203. For a critical analysis of Gutberlet's various proofs of God, see Rahnberg 1978.

[135] Gutberlet's speculation has a curious similarity with entropy calculations based on modern cosmology. Quentin Smith summarizes: 'If an infinite number of previous cycles had elapsed, each with increasing entropy, then the present cycle would be in a state of maximum entropy – but in fact it is in a state of relatively low entropy.' Craig and Smith 1995, p. 113.

[136] Gutberlet 1908, p. 138.

The argument of Gutberlet and others that the physical universe cannot exist by itself or have come into existence by itself was a standard ingredient in neo-scholastic apologetics. It was advanced in many versions, some of them philosophically sophisticated and others of a quite primitive kind. Jakob Schmitz, a Catholic writer, assumed the Kant-Laplace scenario of an initial gaseous state of the universe. But why a gas? Why not a fluid or solid state? Apparently there was nothing in the nature of matter that dictated its beginning in the form of a gas. And why are the abundance of the chemical elements distributed in a certain way rather than in some other way? The properties of matter are contingent, for they could have been different, and therefore they cannot be used as an ultimate explanation. 'The only satisfactory solution to this problem is the following: the primordial matter is the product of an omniscient and omnipotent being who voluntarily created this world, although he could also have chosen and created another one.'[137]

The physicist Caspar Isenkrahe, a most active participant in the German debate over entropy and theology, was not convinced by the reasonings offered by fellow-Catholics such as Braun, Dressel and Gutberlet.[138] Although today forgotten, Isenkrahe was well known in his own days. He corresponded with renowned mathematicians and physicists such as Felix Klein, Heinrich Hertz and Helmholtz, and was known in particular for a mechanical theory of gravitation proposed in *Der Rätsel von der Schwerkraft* from 1879. In this work he explained gravitation in terms of collisions between ether particles and matter.[139] Isenkrahe, who from 1870 to his retirement in 1911 worked as a physics professor at *Gymnasium* schools in Krefeld, Bonn and Trier, was a Catholic with a strong interest in apologetics. In many books and articles he examined the relationship between physics and Christianity, and in particular the possibility of proving scientifically the existence of God. In a book of 1915 he offered a detailed and systematic account of the cosmological proof of God, but without supporting the entropic argument. He argued that the cosmological proof, as usually stated, rested on contradictions and erroneous reasoning, from which he concluded that it was in need of an improved, more exact formulation.[140] In general, he was sceptical about proofs of God and argued that Christian faith had

[137] Schmitz 1912, p. 17. The argument from contingency was also given priority in Baschab 1923.

[138] Miller 1927 gives a complete bibliography of Isenkrahe's works as well as a biographical sketch.

[139] Isenkrahe 1879. Isenkrahe's theory of gravitation was a modernized version of the theory proposed by the Geneva natural philosopher George-Louis Lesage in 1782. It attracted considerable attention in Germany and was prominently included in Ferdinand Rosenberger's history of physics published 1886-90 (Rosenberger 1965, vol. 3, pp. 595-607). As late as 1915 Isenkrahe returned to his old idea, which he discussed in relation to the cosmological entropy problem and Seeliger's gravitation paradox (Isenkrahe 1915a). Shortly before his death in 1921 Isenkrahe joined the anti-relativistic literature with a work directed against Einstein's theory, which, he argued, rested on a shaky conceptual foundation (Isenkrahe 1921).

[140] Isenkrahe 1915b. In Kragh 2004, p. 53, I stated that Isenkrahe accepted the entropic argument as a proof of God's existence. The statement is quite wrong and I use the occasion to regret and correct it.

to be based differently, preferably in revelation. In works on 'experimental theology' he examined claims of miracles from a scientific point of view.

In *Energie, Entropie, Weltanfang, Weltende*, a small book published in 1910, Isenkrahe presented a systematical and critical investigation of the entropic argument in order to clarify precisely on which preconditions the argument rested. Even if one should find it legitimate to infer from the second law to a beginning of the world process – and Isenkrahe did not – the inference did not imply a beginning of the existence of the world, even less so its creation: 'The further inference, from the beginning of the world process to the beginning of the world [*Weltdasein*] and from there to the creation of the world, is outside the domain of science.'[141] Playing the devil's advocate, Isenkrahe listed a number of assumptions on which the entropic argument rested. The most important of these were: (i) Clausius's law is valid for at least some natural processes. (ii) There are no natural processes in which the entropy decreases. (iii) The material world is finite in the sense that it consists of a denumerable number of particles. (iv) The increase of entropy does not approach the maximum value asymptotically, but actually reaches the maximum. (v) Before the beginning of world entropy, either there were no processes at all or these had only existed in a denumerable amount of time units.

Isenkrahe argued that not all of these assumptions could be justified. Thus, referring to phenomena such as radioactivity, life processes, diffusion of gaseous particles and radiation pressure, he concluded that there was reason to doubt the correctness of (ii). He found the finitude arguments of Dressel and Gutberlet unconvincing and therefore saw no good reason to accept (iii). As to (iv), the asymptotic behaviour of the entropy function had been considered by Duhem in 1905 and also by Gutberlet, who concluded that it did not save us from the heat death. Isenkrahe disagreed and suggested that life might go on, perhaps indefinitely, even in a very high-entropic environment: 'An end of human descendants does in no way imply the end of life, and it is still an open question if there is a limit to the adaptability of life to changed external conditions.'[142] Having discussed the various possibilities of entropy growth, Isenkrahe concluded that only two of these were logically and physically acceptable. In both of the scenarios the entropy approached its maximum value asymptotically, whereas they differed in their behaviour near the state of minimum entropy. In one of the scenarios, the entropy started in $S = S_{min}$ at $t = 0$, in the other it evolved asymptotically from the minimum state and proceeded like a logistic curve, $S \rightarrow S_{min}$ for $t \rightarrow -\infty$ and $S \rightarrow S_{max}$ for $t \rightarrow \infty$. The latter case may be represented by $S(t) = S^*[1 + \exp(-kt)]^{-1}$ in which the rate of change of S is always positive, in agreement with the second law. Only if this kind of case could be ruled out would the entropic creation argument be supported, and Isenkrahe concluded that an asymptotic behaviour in the past could not, in fact, be ruled out.

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141 Isenkrahe 1910, p. 79.

142 Ibid., p. 45. The same argument for everlasting life was made in Rademacher 1909. Isenkrahe and Rademacher may be seen as precursors of the much later tradition of 'physical eschatology' which is usually traced back to a paper by Freeman Dyson of 1979. In his bibliographical review of physical eschatology, Ćirković seems unaware of these pre-World War I speculations (Ćirković 2003b).

The whole point of Isenkrahe's polemic, directed primarily against Dressel and Gutberlet, was to raise doubts about the cosmological significance of the law of entropy increase. He thought that he had found an ally in Thomson, who in an amendment to his 1851 article introduced what he called 'the total intrinsic energy' of a body. According to Thomson, 'in our present state of ignorance regarding perfect cold and the nature of molecular forces, we cannot determine this total mechanical energy for any portion of matter, not even can we be sure that it is not infinitely great for a finite portion of matter.'[143] Isenkrahe seized upon Thomson's remark in order to weaken the heat death argument. If the energy of finite parts of the world is infinite, so presumably is the entropy, and how can an infinite quantity increase towards a maximum?

In a later work Isenkrahe suggested related reasons why the heat death may never occur. The heat death hypothesis was based on the assumption that heat is the ultimately degraded form of energy, but was this assumption in agreement with modern physics? Isenkrahe referred to the aurora borealis and to new physical experiments on 'radiating matter' (cathode rays and similar discharge phenomena) which indicated the existence of intra-atomic vibrations that do not manifest themselves as heat.[144] Recent developments in physics, he suggested, contradicted the idea that all forms of energy would ultimately degrade to heat. So, all things considered, from Isenkrahe's perspective the entropic creation argument rested on a rather weak foundation and consequently it should not be used apologetically. 'No one should use weapons which he does not master or only master insufficiently; it is for this reason that the use of scientific arguments (often claimed to be particularly compelling) is a precarious and dangerous matter for the apologist.'[145]

It may appear strange that Isenkrahe polemicized with such fervour against Dressel, Gutberlet and other fellow-Catholics, rather than aiming to contradict the atheist cosmology defended by materialists and positivists. This did in no way indicate any sympathy for the cause of materialism, only that he found it pointless to engage in a rational discussion with convinced atheists. As far as he was concerned, they were beyond pedagogical reach.

Isenkrahe's position, that the second law did not necessarily lead to a beginning and an end of the universe, was shared by Aloys Müller, a Catholic physicist at the University of Bonn. In an investigation of 1913, Müller first assumed that (1) the universe is finite in size, and (2) the second law is strictly valid. He argued that even in this case, the most favourable one from an apologetic point of view, it is possible to construct entropy functions $S(t)$ that do not have the property that after a

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143 Thomson 1882, p. 292; Isenkrahe 1910, p. 41.

144 Isenkrahe 1920, vol. 3, pp. 90-91. This kind of argument can be found much earlier. For example, in a textbook of 1877 the Danish physicist Ludvig Lorenz pointed out that it followed from the second law of thermodynamics that the mechanically available energy of the universe tends to disappear. However, the mechanical theory of gases suggested that molecules were composed of atoms in motion. Lorenz argued that if such internal motion really existed it would mean that the second law could not be absolutely valid. Lorenz 1877, p. 190.

145 Isenkrahe 1920, vol. 3, p. 96, extract of letter from Isenkrahe to Franz Sawicki of 15 December 1914.

finite time $S = S_{max}$ and a finite time ago $S = S_{min}$. Although this was not an original observation, Müller used it to stress that since we do not know $S(t)$ for the universe, we can draw no certain cosmological consequences from thermodynamics: 'Let us assume that the universe is finite and also that the entropy law has absolute validity; even then it is quite impossible to decide if the world system tends towards the so-called physical death in a finite or an infinite time.'[146]

Müller next dropped the assumption (1), that is, he considered the possibility of an infinitely large universe. Contrary to 'the philosophers who uncritically use the entropy law for apologetic purposes', he did not find it acceptable to dismiss a materially infinite universe on the ground that it contains an actual infinity of objects. After all, he pointed out, with Georg Cantor's set theory a certain kind of infinities, transfinite numbers, had become well-defined mathematical quantities. Not only was it unknown whether the universe is finite or not, physicists also disagreed about the precise meaning of the second law. 'In spite of the services that the second law has done, it is still a law that is far from perfectly transparent', Müller wrote. 'The second law is less a result of physics than a problem for physics. It is inadmissible to draw wide-ranging inferences from it which rest on a foundation that is wholly unproven.'[147] He finally questioned the assumption (2), which he did by appealing to Boltzmann's probabilistic interpretation of the entropy function. If entropy only increases in a statistical sense, the second law is not absolutely valid, which to Müller was one more reason why it cannot be applied to the far future and the distant past of the cosmos. Although Müller and Isenkrahe quarelled about technicalities in the pages of the *Monatsblättern*, they agreed about the essential message: The second law of thermodynamics is unable to give a definite answer to questions concerning the beginning and end of the universe. It followed that the law could not be used apologetically.

At about the time of World War I it seems that most Catholic theologians were prepared to abandon the entropic proof. So much ink had been spilled on the subject, with so little return. Part of the discussion had taken place in the *Monatsblättern für den katholischen Religionsunterricht für höheren Lehranstalten*, where the entropic argument had been discussed in considerable detail by Isenkrahe, Müller and others, but in 1915 the editors decided to terminate the discussion.[148] The decline of theological interest in the argument may further be illustrated by Franz Sawicki, a Polish-German Catholic philosopher of religion who in his *Die Wahrheit des Christentums* of 1911 fully endorsed the entropic argument: 'Even if the world and its supply of energy were infinitely large, still the world process would not proceed endlessly. … When it is established that the world process had a beginning, then it is no longer possible to evade the assumption of a first transcendent mover.'[149]

[146] Müller 1913, pp. 164-5. Müller's paper was a slightly extended version of a paper of 1910 he had published in *Natur und Offenbarung*. While Müller supported the views of Isenkrahe and Chwolson, he used the opportunity to polemicize against A. Konrad, an Austrian who had defended the entropic proof in *Entropie, Weltanfang, Gott* (Graz, 1912).

[147] Müller 1913, p. 200.

[148] Neswald 2006, pp. 286-7.

[149] Sawicki 1911, p. 56.

Sawicki was aware of Isenkrahe's critical attitude and from 1914 they engaged in a correspondence concerning the issue. In the second edition of *Die Wahrheit*, published in 1913, Sawicki admitted that the proof was less satisfactory than he originally thought, yet he still found it theologically valuable. With the third edition of 1918 he had become convinced of Isenkrahe's objections and now concluded that 'the so-called entropic proof can no longer be maintained'.[150] Not only could the law not claim absolute validity, the argument also rested on the assumption of a finite universe for which there was no certain evidence.

Other theologians pointed out that the entropic argument failed on theological grounds in so far as the heat death of Thomson and Clausius did not really agree with the Bible. The two eschatological scenarios are quite different: according to thermodynamics, the world will slowly come to a peaceful end where all temperature differences have disappeared, whereas some biblical passages speak of a sudden and most violent catastrophe that will occur in the near future. 'The heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the Earth also and the works that are therein shall be burned up.'[151]

The cautious attitude of the Catholic church with regard to the heat death and entropic creation in the 1910s is characteristically illustrated by the authoritative multi-volume *Catholic Encyclopedia* published 1907-22. Although the work includes no entry on either of the subjects, they do appear in several of the articles, if in a rather uncommitted way. For example, the article on 'Creation' states that the material world is not eternal, for the world-substance must be conceived either as possessing eternal motion or not. If the primeval matter was not endowed with activity, evolution could not have begun. 'If eternally active it would have passed through an infinite number of changes, which is self-contradictory.' Moreover, 'the evolutionary process would long since have come to an end, i.e. to a static equilibrium of forces according to the law of entropy.' So, the universe had an origin in time and has since developed into its present state, but how this has happened and how it will evolve in the future, 'science will never tell'.[152]

Entropic arguments also entered the article on 'Energy' in which Spencer was taken as a representative of the materialistic-mechanical view claimed to be justified by the law of energy conservation. The view of the world as an eternally working machine was of course repudiated, not least on the ground that 'the second law

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150 Quoted in Isenkrahe 1920, vol. 3, p. v. See also Schnippenkötter 1920, p. 91, who quotes several other theologians who argued against the entropic proof.

151 2 Peter 3: 10-13; also Revelation 21: 1-4. The argument was made in Rademacher 1909. More than eighty years later the distinguished Evangelical theologian Wolfhart Pannenberg noted the same discrepancy between thermodynamics and the Bible, which he characterized as 'one of the most obvious conflicts between a worldview based on modern science and the Christian faith'. Pannenberg 1981, p. 14. The contrast between the thermal end of the universe and its end according to the Bible is further underlined by the optimistic message of the latter. The Revelation of John speaks of 'a new heaven and a new Earth', whereas the heat death is irreversible. As Arthur Peacocke has emphasized, there is a world of difference between scientific futurology and proper eschatology. Peacocke 2004, p. 332.

152 Herbermann 1907-22, articles on 'Creation' (vol. 4, pp. 470-475) and 'Universe' (vol. 15, pp. 183-8), on p. 472 and p. 186.

of thermodynamics and its consequences – present us with the materials for a very powerful argument against that theory.' According to the law of Clausius and Thomson, the physical world 'much more closely resembles a clock which has been put together and wound up at some definite date in the past and will run down to a point at which it will stop dead in the future.'[153] Finally, the ambivalent attitude to the apologetic use of thermodynamics is exemplified by the *Catholic Encyclopedia*'s account of proofs of God's existence, which does not include specific reference to the entropic creation argument. Nonetheless, the argument is there. Referring to 'physical theories commonly accepted by present-day scientists' the author of the article on 'God' (P.J. Toner) said that the universe had an origin in time. 'If it be true that the goal towards which physical evolution is tending is the uniform distribution of heat and other forms of energy, it would follow clearly that the existing process has not been going on from eternity; else the goal would have been reached long ago.'[154] Notice the hypothetical formulation, which I believe is not an accident.

The swan song of the theological entropic argument was sung by the Jesuit physics teacher Josef Schnippenkötter in his dissertation of 1920, based on a review of more than 200 works relating to the argument. Schnippenkötter, who had studied philosophy, physics and mathematics in Munich and Göttingen, agreed with Isenkrahe's criticism and concluded that the argument failed to deliver a valid proof of God's existence. The so-called entropic proof of God, as advocated by Dressel, Braun, Gutberlet, Schweitzer and others, carried no force. He admitted that there were no compelling reasons to adopt the materialistic alternative of an ever-existing universe, for which he had no sympathy at all, but then 'there also is no scientifically certain proof that the end and the beginning of the world, and then the existence of God, can be derived from the entropy law.'[155]

It should not be assumed that all theologians considered the question of a beginning of the universe to be of great importance. This was not the case among Catholics, and it was even less so among Protestants and Anglicans. Many theologians could easily accept a universe with no beginning and still believe in God as the creator of the world in an absolute sense. As one example, consider Hastings Rashdall, a Cambridge theologian who in 1908 – at a time when the entropic argument was hotly debated by German Catholics – gave a series of lectures on philosophy and religion. Rashdall was an idealist, meaning that he thought that the ultimate reality was spiritual and that the physical universe only existed because of the mind of God (or perhaps in the mind of God). He referred to Thomson's argument from energy dissipation, but did not find it particularly important:

> There is no difficulty in supposing this particular series of phenomena which constitutes our physical Universe may have had a beginning in time. On the other hand there is no positive evidence, for those who cannot regard the early chapters of Genesis as representing on such a matter anything but a primitive legend edited by a later Jewish thinker, that it had such a beginning. … The question, therefore, whether there was a beginning of the

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153 Ibid., article on 'Energy' (vol. 5, pp. 422-8), on p. 426.

154 Ibid., article on 'God' (vol. 6, pp. 608-21), on p. 610.

155 Schnippenkötter 1920, p. 95, who based many of his arguments on Isenkrahe's works.

> series of events which constitute the history of our physical world must (so far as I can see) be left an open one.[156]

One reason why Rashdall was not impressed by arguments for a finite-age universe was that they did not touch the essence of creation in a religious sense as he saw it: 'For religious purposes it seems enough to believe that each member of the time-series … is caused by God. The more reflecting Theologians have generally admitted that the act of divine Conservation is essentially the same as that of Creation. A God who can be represented as "upholding all things by the power of his word" is a creative Deity whether the act of creation be in time, or eternally continuous.'[157] The same argument was stated by Bavink, and of course it was not foreign to Catholic theologians either. In scholastic philosophy the term 'first cause' was often used in an abstract and extended way that referred to an ontological rather than a chronological primacy. With such a notion it made sense to claim that even an infinite series of secondary causes requires a first or ultimate cause. P.G. Toner, in his article in the *Catholic Encyclopedia*, maintained that the philosophical version of the cosmological argument was conclusive even if it be granted that the world may have existed from eternity. Infinite or indefinite duration 'is altogether different from the eternity we attribute to God. Hence to admit that the world might possibly be eternal in this sense implies no denial of the essentially finite and contingent character of its existence.'[158]

Arguments from science to God could take many routes, and cosmic creation in the temporal sense was only one of them. For example, it might be argued that the very order and comprehensibility of the universe – that reality seems to be adapted to our mathematics and mental constitution – is a sure sign of a divine consciousness. Faith in God follows from faith in the objective value of science. This was essentially how the Italian philosopher Antonio Aliotta argued in 1912, although of course he was not the first to do so. The scientist, he wrote, 'is the unconscious priest of an undying religion, of that faith whose temple is the universe, and whose inexhaustible revelation will be found in the inmost depths of the mind'. From this point of view, beginning and end were unimportant; what mattered was the beauty of life and creative spontaneity we witness in nature: 'The lot of the theistic conception is not undissolubly bound up with that of a beginning of the cosmic process in time, since it is possible to reach the Personal God even if we concede the eternity of the world.'[159] Aliotta welcomed the idealistic reaction against the materialistic and scientistic philosophy often associated with science because it paved the way for perspectives of a more theistic orientation. But he also realized, and regretted, that the anti-materialistic reaction had opened up for all sorts of irrationalism and anti-intellectualism (such as 'Theosophy, the speculations of the

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156 Rashdall 1931 (first published 1909), p. 89. On Rashdall's theological views, see Livingston 2007, pp. 93-5.

157 Rashdall 1931, p. 92.

158 Herbermann 1907-22, p. 611. And similarly in Baschab 1923, p. 70: 'Even if matter were eternal, we should still lack an explanation of its existence.'

159 Aliotta 1914 (translation of Italian original of 1912), p. 465 and p. 479.

Kabala, occultism, magic, spiritualism, all the ravings of the neo-Platonists and neo-Pythagoreans…'[160]).

A Mathematical Digression

The question of the material finitude of the universe occupied a central position in the debate concerning the entropic creation argument. It was commonly claimed that the notion of an infinity of objects was 'absurd', but the claims rarely went beyond the rhetorical level. Since the time of Aristotle, the majority of mathematicians, philosophers and theologians had taken for granted that so-called realized or actual infinities (as distinct from potential infinities) cannot exist. Whereas the actual infinite is a determinate totality, the potential infinite is not. As Johannes Kepler, a committed finitist, wrote in his *Epitome astronomiae Copernicanae* (1618-21), 'all number of things is actually finite for the very reason that it is a number.'[161] Even Descartes, who was a pioneer infinitist, insisted that God alone is actually infinite, so that physical space must be described as merely indefinite rather than truly infinite. If the actual infinite were allowed, not only would it lead to a number of logical paradoxes, it would also cause theological problems. For example, according to Augustin Cauchy, the brilliant mathematician and a passionate Catholic, infinity and eternity were divine attributes not to be found elsewhere. 'God alone is infinite, outside him everything is finite', he wrote. 'Spiritual beings and corporeal beings are given by finite numbers, and the world has its limits in space as well as in time.' His younger friend abbé Moigno completely agreed and suggested that the impossibility of an actual infinity indicated the truth of theism.[162]

However, in the early 1880s the German mathematician Georg Cantor developed a new theory of what he called transfinite numbers, an extension of finite numbers and no less real than these. Cantor was not the first to argue that actual infinities could be understood in a mathematically consistent way – Bernhard Bolzano had done so in 1821 – but it was only his work that provided a whole new perspective on the problem of the infinite. For the actual or true infinite Cantor assigned the Phoenician symbol $\aleph_0$(aleph zero). This first transfinite number he took to represent the totality of natural numbers (1, 2, 3, …) as a completed unity. To put it briefly, Cantor concluded that the actual infinite exists in the same meaning that finite numbers exist, namely, that the concept is logically consistent and operationally useful. Moreover, he showed that there exists a hierarchy of infinities and that some infinities are greater than others. For our purpose, what matters is that according to Cantor's analysis even infinite sets can be understood mathematically and

160 Ibid., p. xv.

161 Quoted in Koyré 1968, p. 86.

162 Cauchy 1868, p. 27, a series of lectures on natural philosophy given in Turin in 1833. Moigno, who edited the volume, added an appendix of his own, 'Impossibilité du nombre actuellement infini'. On Cauchy as a Christian mathematician, see Grattan-Guinness 2000, pp. 481-3. Carl Braun, the Jesuit author of the Christian cosmogony, claimed that it followed from the impossibility of an actual infinity that matter must have been created by a transcendent being (Braun 1889, p. 193).

characterized by a new kind of definite numbers.[163] Whereas Cantor was convinced of the reality of infinitely large numbers, he was strongly (and curiously) opposed to the notion of infinitely small numbers.

Cantor's innovative work might seem to be of interest to mathematicians and logicians only, but in fact it related significantly to problems of philosophy, metaphysics and theology – and, indirectly, cosmology. The deeply religious Cantor was convinced that with the discovery of the *Transfinitum*, the collection of all transfinite numbers, he had come closer to the mind of God.[164] Through his studies of mathematics and the history of Christian thought he came to see himself as God's messenger and ambassador. Although baptized as a Lutheran and nominally remaining one throughout his life, Cantor developed a particular strong interest in Catholic theology and can in some respects be counted as belonging to the German neo-scholastic intellectual community. He corresponded with several Catholic philosophers and theologians, and even addressed one letter to Pope Leo XIII.[165] Among his correspondents were Tillman Pesch, Aloys von Schmid, Joseph Hontheim and Constantin Gutberlet, all of whom were involved in the discussion concerning thermodynamics and cosmology.

One reason why Cantor's defence of the actual infinite could be seen as theologically problematical was its potential connection to pantheism. If actually infinite, transfinite numbers really existed, as claimed by Cantor, it might seem to endow nature with the quality of infinity, a quality which according to theologians' thinking belonged exclusively to God. Eager to distance himself from pantheism and other heresies, Cantor argued that his theory of transfinite numbers posed no threat to religion. The *Transfinitum* really existed, but it was a reality that characterized God's infinity more than the nature he had created. Cantor suggested that Thomas Aquinas' rejection of the actual infinite should not be understood in an absolute sense, as was it impossible, but only in the sense that it was an improbable concept. His correspondent Gutberlet, who expressed concern about the theological significance of the transfinite numbers, accepted Cantor's argument and so did the Austrian-born cardinal Johannes Franzelin, a leading Jesuit philosopher and theologian whom Cantor consulted.[166] According to Gutberlet, the actual infinite existed in the absolute mind of God, but only in this ideal or non-physical sense (Cantor maintained that the transfinite also existed *in concreto*). As mentioned, Gutberlet categorically denied that the number of objects in the physical universe could be infinite. His arguments

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163 On Cantor and his theory, and the difficulties it faced in the mathematical community, see Dauben 1979. His first major work, *Grundlagen einer allgemeinen Mannigfaltigkeitslehre*, appeared in 1883, when he was professor in Halle.

164 For details on Cantor's theological use of his transfinite set theory, see Thiele 2005, Dauben 1977 and Dauben 1979, pp. 140-48. Other aspects are dealt with in Ferreirós 2004. Cantor was not the only late-nineteenth-century mathematician who found pure mathematics to be of apologetic value. For British mathematicians and their attempts to connect their science with theology, see Cohen 2007.

165 The letter of 1896, written in Latin, is reproduced in Purkert and Ilgauds 1987, pp. 198-9.

166 For the correspondance between Cantor and Franzelin, see Cantor 1887.

were criticized by Isenkrahe, who found them to be unconvincing and objected to his theological use of infinite quantities.[167]

The crucial question is whether an actual infinite can be instantiated in the real world. This, of course, depends on the meaning of reality. To Cantor, who was basically a Platonist or objective idealist, numbers and other mathematical ideas had a permanent existence and they were more real than the ephemeral sense perceptions. He always maintained that he had discovered the transfinite numbers, not constructed them. Although the question may have appeared as misguided to Cantor, to the large majority of non-Platonists it was not. If, to speak with David Hilbert, Cantor's paradise exists only in the ideal world invented by the mathematicians, the infinite has no place in physical reality. Cantor was convinced that the existence of actual transfinite numbers *in concreto* could be proved from philosophical as well as empirical arguments. He believed they were scientifically necessary because a complete explanation of natural phenomena would be impossible if it rested only on finite assumptions.

As one might expect, Cantor was hostile to the materialistic and atheistic tendencies that spread in German scientific circles. As he saw it, mechanical physics was 'the real cause of present-day materialism and positivism, which has developed into a sort of monster and flaunts in the shiny garment of science'.[168] In another letter, to the French mathematician Charles Hermite, he wrote that the higher aim of his work was 'to dispose of the rampant delusions of scepticism, atheism, materialism, positivism, pantheism etc., and gradually bring [people] back to the only rational system – to theism'.[169] Cantor's anti-mechanicism made him oppose the atomic theory, although from reasons very different from those of Mach, Duhem, Ostwald and their allies. He rejected atomism in its Daltonian version but accepted a dynamical form of point-atoms. Moreover, he distinguished between two kinds of point-atoms, one describing material atoms and the other ether atoms. His sketch of a theory of the constitution of matter was speculative and out of step with contemporary developments in physics and chemistry.[170] He thought his innovations in set theory might help create an alternative physics, what he called an 'organic explanation of nature', but never developed his sketchy ideas.

In a letter of December 1893 to Joseph Hontheim, whose *Institutiones theodicaeae* he had read shortly after its appearance, he stressed that there was no contradiction between his theory of the transfinite and the dogma of St Thomas. On the contrary, 'in a not so distant future my theory will prove to be literally a weapon of destruction against all pantheism, positivism and materialism!' In the same letter, he referred to the creation of the world: 'Not only do I accept with all Christian philosophers the temporal origin of the creation, I also share your view that this truth can be proved by rational means. ... It does not follow from the establishment of actual infinities or,

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167 Gutberlet 1886; Gutberlet 1908, pp. 27-37. Isenkrahe 1920, vol. 1, includes a long letter from Cantor to Gutberlet concerning a thought experiment on infinities (pp. 177-81).

168 Letter to C.A. Valson, probably of 1886, as quoted in Ferreirós 2004, p. 71.

169 Letter of 1894, quoted in Purkert and Ilgauds 1987, p. 117.

170 See his letter to the Swedish mathematician Gösta Mittag-Leffler of 16 November 1884, reproduced in Purkert and Ilgauds 1987, pp. 204-5.

as I call them, transfinite numbers, that one has to renounce the rational proof of the world's beginning in time.'[171]

A more elaborate account can be found in an earlier letter to Aloys von Schmid, a Munich professor of apologetics and dogmatics. It can be shown, Cantor wrote, that

> innumerably many of the sick phenomena of the recent period and its science are connected with the monstrous nonsense of an infinitely flown time or, as it is usually if wrongly expressed, the eternity of the world, respectively its matter. On the other hand, I appreciate and respect the many attempts of a purely demonstrative nature that have been made by Christian philosophers to prove the finitude of past time and thus the beginning of the world a finite time from the present.

Cantor rejected all arguments against an eternal world based on the impossibility of actual or definite infinite numbers, and in general denounced attempts to use such arguments in the service of Christian faith. But he also stressed that 'This does not preclude that the temporal finitude of creation can be demonstrated rationally in other ways, if not purely mathematically.'[172] At any rate, textbooks in Catholic philosophy continued to consider the claimed impossibility of the actual infinite an argument in favour of a spatially and temporally finite world. For example: 'An absolutely infinite quantity, whether discrete or continuous, is an impossibility. It is thus clear that since a universe which was actually infinite in extent would involve the actuality of both these infinities, it is therefore impossible.'[173]

Cantor was aware of the discussion of the heat death and the thermodynamically based argument for a beginning of the world, but apparently he did not refer to it in his published writings. That he was neither indifferent nor uninformed is shown by a letter to Gutberlet of 1 May 1888 in which he offered critical comments on the speculative use of thermodynamics. He had serious reservations with respect to 'the unjustified extension and application of the law of energy conservation to the entire world, such as fancied by Thomson, Helmholtz, Clausius and their friends.' Probably referring to the heat death, he dismissed 'the fantastic speculations' associated with thermodynamics as 'quite worthless'.[174] Unfortunately he did not elaborate.

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171 Ternus 1929, pp. 566-7.

172 Letter to Schmid of 5 August 1887, in Meschkowski and Nilson 1991, p. 298. In a paper of 1886 Cantor offered a comprehensive critique of the attitude of philosophers and scientists with respect to actual infinities (Cantor 1962, pp. 370-376).

173 Phillips 1934, vol. 2, p. 69. Arguments for the existence of God based on the impossibility of an actual infinite continue to attract interest. William Lane Craig finds the following syllogism a convincing argument that the universe began to exist: (i) an actual infinite cannot exist; (ii) an infinite temporal regress of events is an actual infinite; (iii) therefore an infinite temporal regress of events cannot exist. The proposition that the universe began to exist is an important premise in his proof of God's existence. See Craig and Smith 1995, pp. 9-30.

174 Meschkowski and Nilson 1991, p. 314. It is more than a little confusing that Cantor seems to have associated the heat death with the first, rather than the second law of thermodynamics.

Another Kind of Creation Argument

In his book of 1914, Bavink criticized the tendency to look for God only in cosmic processes, for, as he said, if God had created the world, atoms were his creations no less than galaxies and the universe as a whole. To think differently would be 'half theism, half atheism'.[175] Indeed, there was at that time a long tradition for considering the permanence of the building blocks of matter as an argument for God, who alone had the power to create them or make them disappear. It was important for Gassendi, Boyle, Newton and other seventeenth-century atomists to refute the old accusation against atomism that it was associated with materialism and atheism. In Query 31 of his *Optics*, Newton famously suggested that 'God in the Beginning form'd Matter in solid, massy, hard, impenetrable, moveable Particles, ... so hard, as never to wear or break in pieces; no ordinary Power being able to divide what God himself made one in the first Creation.'[176] When Newtonian atomism was turned into the immensely useful chemical atomic theory by John Dalton, in his *New System of Chemical Philosophy*, the divine permanence of atoms remained. 'We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen,' Dalton wrote.[177]

Maxwell was impressed by the fact, as had recently been revealed by the spectroscope, that atoms and molecules of the same chemical species were all alike and had not changed the slightest 'since the time when Nature began'. In his earlier mentioned address to the British Association in Liverpool in 1870, he ascertained that 'no power in nature can now alter in the least either the mass or the period of any one of them [atoms or molecules].' And this made him reflect:

> When we find that here, and in the starry heavens, there are innumerable multitudes of little bodies of exactly the same mass, so many, and no more, to the grain, and vibrating in exactly the same time, so many times, and no more, in a second, … we seem to have advanced along the path of natural knowledge to one of those points at which we must accept the guidance of that faith by which we understand that 'that which is seen was not made of things which do appear'.[178]

Three years later, at the meeting in Bradford, he confirmed the limitation of natural knowledge by referring to the striking uniformity and permanence of atoms and molecules. This strongly indicated that the smallest particles of matter were divinely created, although Maxwell was careful not to extend his argument to a scientific proof of God's existence. While some of Maxwell's contemporaries favoured ideas of 'inorganic Darwinism', this was a notion he firmly resisted: 'No theory of evolution

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175 Bavink 1914, p. 144.

176 Newton 1952, p. 400. Newton also appealed to the uniformity of nature as indicated by the identity of sunlight and starlight. In *Principia* he noted that 'the light of the fixed stars is of the same nature as the light of the sun', which he saw as evidence that the universe had been designed by 'an intelligent and powerful being'. Newton 1999, p. 940.

177 Dalton 1808, p. 212.

178 Maxwell 1965, part 2, p. 225. The reference is to Hebrews 11: 3, the same quotation that Murphy used the previous year.

can be formed to account for the similarity of molecules, for evolution necessarily implies continuous change, and the molecule is incapable of growth or decay, of generation or destruction.' Alluding to natural theology and borrowing an expression from John Herschel, he famously referred to the molecule as a 'manufactured article' (manufactured, of course, by God):

> We have been led, along a strictly scientific path, very near to the point at which Science must stop. Not that Science is debarred from studying the internal mechanism of a molecule which she cannot take to pieces, any more than from investigating an organism which she cannot put together. But in tracing back the history of matter Science is arrested when she assures, on the one hand, that the molecule has been made, and on the other, that it has not been made by any of the processes we call natural. Science is incompetent to reason upon the creation itself out of nothing. We have reached the utmost limit of our thinking faculties when we have admitted that because matter cannot be eternal and self-existent it must have been created.[179]

Maxwell underlined the religious basis of his considerations by his closing remark, that molecules 'continue this day as they were created – perfect in number and measure and weight ... they are essential constituents of the image of Him who in the beginning created, not only the heaven and the earth, but the materials of which heaven and earth consist.' Few of his listeners would have missed the reference to the Wisdom of Solomon (11: 20).

James Challis, professor of astronomy at Cambridge University, developed a unified cosmological system based on two fundamental entities, ether and atoms. He, too, was convinced that 'they came into existence, and are such as they are, by the immediate will and power of the Creator of all things'.[180] Although he considered the ether to be a spiritual agency of a kind not unlike the ether of *The Unseen Universe*, he criticized Stewart and Tait for their unwillingness to draw direct theological consequences from the ether-based world view. Challis, who had no such reservations, even suggested that the laws of the ether revealed the existence of angels in accordance with scripture.

The atoms of the 1870s were no longer Newton's or Dalton's massive, hard and impenetrable particles, which were not only conceptually troublesome but also unable to explain elastic collisions, specific heats and the spectral lines emitted by heated bodies. According to William Thomson's theory of vortex atoms, dating from 1867, all atomic particles were vortical structures in a perfect fluid, the ether.[181] The vortex atomic hypothesis was considered attractive by many British scientists, in

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179 Maxwell 1965, part 2, p. 376. See also Harman 1998, pp. 187, 199 and 205. 'Manufactured articles' were introduced in Herschel 1831, p. 38. Maxwell repeated and amplified his arguments in his article on 'Atom' for the 1875 edition of *Encyclopedia Britannica*, see Maxwell 1965, part 2, pp. 483-4. Clifford criticized Maxwell's argument and suggested that even if molecules were exactly alike (which he doubted) they might well be the product of natural evolution. Clifford 1879, vol. 1, pp. 217-9.

180 Challis 1873, p. 20. On Challis and his attempt to unify cosmology and theology, see Scheuer 1997, pp. 257-85.

181 A full account of the development of the theory of vortex atoms is given in Kragh 2002.

part because of its congruence with their religious feelings. Thomson had proved mathematically that, once formed, vortex atoms would be absolutely permanent, a result which to him implied that they could only have come into existence through 'an act of creative power', that is, they must have been divinely created. The same point was made by Tait, who pointed out that the theory 'implies the *absolute necessity* of an intervention of Creative Power to form or destroy one atom even of dead matter'.[182] The vortex atom was entirely different from the hard Daltonian atom, as it was not connected with the materialism that since the days of Democritus had been associated with atomism. For this reason, Thomson's atomic theory did not agree well with the agenda of scientific naturalists such as John Tyndall and William Clifford. Not only did the vortex atom abolish the traditional association between atomism and materialism, it also founded atomic theory upon the ether, this non- or quasimaterial medium that was so dear to Victorian scientists.[183]

The argument of Maxwell and others that the identity and permanence of atoms implied that they were created, hence suggesting a divine origin, entered some of the theological works of the period. In Germany, Gutberlet argued that atoms cannot exist by virtue of their own nature. He claimed that if this were the case they would not only be materially alike but also exist in the same state of motion, which they do not. Consequently, a force from outside the universe must have been responsible for the distribution of motion among atoms.[184] Murphy, who commented on Maxwell's line of reasoning in *The Scientific Bases of Faith*, was somewhat sceptical, mainly because he was not convinced that the chemical elements were not different states of one universal element or atom. There were indications from both experiment and speculative theory of a deep-lying unity of all matter, an idea typically associated with William Prout's hypothesis of 1815 according to which hydrogen was the primary element, the *protyle*. In fact, Prout's hypothesis did not make Maxwell's argument less convincing, as the hydrogen atom would still count as a manufactured particle. As Murphy admitted, 'It would still be demonstrably impossible that any merely physical theory should ever penetrate to the unity which is behind all diversity.'[185]

Gibson, who cited a long passage from Maxwell's Bradford address, considered it 'an argument for an intelligent and moral first cause'. On the other hand, he shared Murphy's sceptical attitude and warned against jumping to the conclusion that atoms were the result of immediate divine action. For, as he noted, 'this referring of inexplicable facts to such action has been shown to be mistaken innumerable times'. The alternative would seem to be the evolutionary theory of matter – some form of inorganic Darwinism – but even in this case there would remain the question of how to account for the primordial atoms.[186] As late as 1900 Stokes referred to Maxwell's

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[182] Tait 1871, p. 6.

[183] For the ideological use of the ether, including vortex atoms, see Wynne 1979. On Lodge and the theological significance of the ether, see Wilson 1971 and Noakes 2005.

[184] Gutberlet 1878, p. 134.

[185] Murphy 1873, p. 196. On Prout's hypothesis and its role in nineteenth-century physics and chemistry, see Brock 1985.

[186] Gibson 1875, pp. 75-80. The general idea that atoms were complex structures formed in an evolutionary process was favoured by several British scientists, including William Crookes and Norman Lockyer. Crookes suggested in 1886 that the atoms of a particular

argument as a response to those who believed in the eternity of matter. 'In matter of a given kind, say the gas hydrogen, the molecules are all just like one another … in that respect resembling manufactured articles', he wrote to a correspondent. 'This leads us to the idea that hydrogen, for instance, did not exist just as it is from past eternity, but was in some way made. But there science comes to the end of her tether; how it was made she cannot inform us.'[187]

The line of reasoning here dealt with was mostly discussed among British scientists but can be found also on the Continent. The eminent French chemist Charles-Adolphe Wurtz, professor at the Ecole de Médicine and a pioneer of organic chemistry, gave in 1874 the opening address at the Meeting of the French Association for the Progress of Science. On this occasion he related to some of the same themes as Maxwell. Contrary to many other French chemists at the time, Wurtz was a staunch supporter of the atomic theory and spoke out against the positivism and anti-clericalism that was widespread in the young Third Republic and represented by the powerful chemist and politician Marcelin Berthelot in particular.[188] To Wurtz, who was of Lutheran faith, the new atomic theory had little in common with the old and materialistic atomism; on the contrary, it entered as an important part of a revised natural theology. After having recounted how spectroscopy had revealed that atoms are everywhere the same in the universe, he concluded:

> Through the corner of the veil we have been permitted to raise, she [nature] enables us to see both the harmony and the profundity of the plan of the universe. Then we enter on another domain which the human spirit will be always impelled to enter and explore. It is thus, and you cannot change it. It is in vain that science has revealed to it the structure of the world and the order of all the phenomena; it wishes to mount higher, and in the conviction that things have not in themselves their own *raison d'être*, their support and their origin, it is led to subject them to a first cause – unique, universal God.[189]

A related argument was enunciated by Pietro Angelo Secchi, the Italian Jesuit astronomer who did pioneering work in solar physics and stellar spectroscopy.

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element are not identical, but differ in atomic weight. The evolution hypothesis received some credibility from astrospectroscopy and experiments with cathode rays, and later from radioactivity. Of course, developments in twentieth-century physics and cosmology have vindicated the speculation.

187 Stokes 1907, vol. 1, p. 83. Like Maxwell, Stokes was cautious not use the argument as a proof of God's creation of matter.

188 On Wurtz and his controversy with Berthelot concerning the atomic theory, see Rocke 2001. Berthelot was a permanent member of the Senate and served for brief periods as minister of education (1886-87) and foreign minister (1895-96). He did not accept the reality of atoms and was reluctant to adopt atomic models and conventions. Among his important contributions to chemistry was the formulation of the 'principle of maximum work' according to which the heat evolved by a chemical reaction was its driving force. This thermochemical principle was severely criticized by Duhem, among others, who pointed out that it did not agree with the second law of thermodynamics.

189 Wurtz 1874, p. 350. The address appeared originally as 'La théorie des atomes dans la conception générale du monde', *Comptes Rendus de l'Association Française pour l'Avancement des Sciences* (1874), 7-23.

Secchi, who spent most of his career at the Collegio Romano, was a specialist in solar physics and stellar spectra but also published on planets, comets and gaseous nebulae. He was convinced that science had led to the recognition of an active and sublime being responsible for nature's wonderful structure, and he cited as evidence that the same elements, subject to the same laws, had been found in the laboratory and in the atmospheres of the stars. Not only was such uniformity to be expected if the world was created, it also indicated that intelligent life was plentiful in the universe.

In 1876-77 Secchi gave two lectures on 'la grandezza del Creato' which subsequently were translated into German as *Die Grösse der Schöpfung*. He used the entropic argument to conclude that 'the world was created at a definite time and thus is not eternal, as the materialists claim.'[190] One might believe that Secchi was therefore forced to accept the heat death as well, but apparently he did not. Somehow he convinced himself that the degradation of energy was not inevitable on a cosmological scale, as it might vary periodically in time and space. The heat death was merely 'like the sleep of the vegetable kingdom under the winter's icy breath of air', and it would be followed by 'a merry awakening to new life'.[191] Whatever the prediction of the second law, this might be the way the Creator had chosen to organize nature.

Secchi believed that the universe was of finite age and that it was also finite in the sense of including only a finite number of stars and nebulae. Not only did he find a materially infinite universe to be conceptually impossible, he also referred to Olbers's paradox as an argument against infinity: 'If it [the world] was infinite and populated with innumerable stars, the celestial vault should appear to us as brilliant as the whole surface of the sun. ... We are therefore stopped by the fact of a finite physical world. And in spite of its finiteness it is already too inconceivable for us; there is therefore no use in aspiring at what we simply cannot comprehend.'[192]

Although the permanence of elementary matter might be used as an argument for creation, and hence theism, the general view was that the law of mass conservation rather spoke in favour of matter being eternal – uncreated and indestructable. Indeed, from about 1870 the eternity of matter became a hallmark of materialism and atheism, and consequently something to be resisted by most Christians. However, the doctrine of the eternity of matter was not always or necessarily seen as contradictory to theism. An interesting example is provided by the cosmological views of the Mormons, or the members of the Church of Jesus Christ of Latter-Day Saints. Mormon cosmologists had no problem with presenting matter as uncreated – as uncreated and eternal as God himself. Joseph Smith, the founder and prophet of the Mormon religion (established as a church in 1830), emphasized that there never had been a creation *ex nihilo* but only a creation of the world out of eternally existing elements. Mormon theology differed in several aspects drastically from the theology

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190 Secchi 1882, p. 14. On Secchi's science, faith and career, see Pohle 1904 and the entry in *Dictionary of Scientific Biography* (vol. 12, pp. 266-70) written by Giorgio Abetti.

191 Secchi 1872, vol. 2, pp. 608-9. In his presentation of the entropic creation argument, Secchi referred to Fick's work of 1869.

192 Secchi 1878, pp. 330-331.

of orthodox Christianity, not least in depicting God as material and personal. Not only did it downplay the transcendent aspects of God, it simply denied them. Also contrary to the orthodox versions of Christianity, the Mormons had no problem with naturalism, for although God had created nature and its laws, he ruled passively and only indirectly, limited by and through the laws of nature.

Orson Pratt, a Mormon apostle and self-taught astronomer, was the first and most important of the early scientists of Mormonism. Starting in the early 1840s, he published on a variety of subjects in science and theology, and in a book of 1877, entitled *Key to the Universe*, he presented a cosmology in accordance with Mormon thought. According to Pratt, the divinely dependent universe had always existed:

> As the elements of all worlds were not created, but are eternal, and as they have always been the tabernacle or dwelling place of God, they must have eternally been acted upon by His spirit; consequently must have passed through endless series of operations without beginning. Instead of seeking to trace out evidences of a beginning to the elements, we shall at once pronounce them eternal, from the fact that we have no account of their creation from nothing, for God himself must be an eternal substance: and it is just as reasonable to believe that all the other elements which are His tabernacle, are eternal, as to admit, as we are compelled to do, the eternity of His substance.[193]

Erase the terms 'God', 'spirit' and 'tabernacle', and we have a prime example of materialist cosmology! Pratt's cosmology and cosmogony was entirely qualitative, at places indeed naïve, and he has been justly ignored by most historians of astronomy. His *Key to the Universe* did not mention either entropic creation or the heat death, concepts that he may not have been acquainted with.

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[193] Quoted in Skabelund 1965, p. 202. For a full account of Mormon cosmology, see Paul 1992, who treats Pratt on pp. 131-42.

Chapter 5

Concepts of the Universe

Introduction

During the period from about 1860 to 1910, science progressed greatly and became a major intellectual and political force, constantly engaged in battles with traditional values derived from religion and idealistic philosophy. The debate took different forms in the major European countries, with the relationship between science and religion being invariably on the agenda. In Germany, an opposition grew up against idealism, clericalism and what was left of the *Naturphilosophie* of the romantic era, epitomized by Ludwig Büchner's widely read *Kraft und Stoff*, a materialistic manifesto first published in 1855. Some of the themes found in Germany appeared in the British debate on science and religion as well, but in different shapes and intensities. British advocates of a scientific world view were rarely militant atheists of the kind known from Germany. As evidenced by Charles Bradlaugh, an uncompromising atheist and advocate of materialism, such people were not unknown in Britain; but Bradlaugh and his fellow secularists had little interest in science and even less influence.[1]

In France, the situation was not only marked by the successful trend of positivism but also by the Third Republic's sustained anti-Catholicism and anti-clericalism. In 1880 Jesuits and other unauthorized congregations were disbanded by law, and the measure was followed by a general offensive against faith and church. The campaign reached its climax shortly after the turn of the century when Catholic schools were closed and thousands of monks and nuns expelled. Finally, in 1905 the Republic broke totally with the church and ceased to recognize any form of religion. Only some years later did state and church establish a fragile *modus vivendi*. Priests and Catholic thinkers responded in a variety of ways to the difficult situation, one of them being a more active participation in scientific, social and philosophical debates. Part of the Catholic intellectual counteroffensive was directed against the attempts to use science as a weapon against religion.[2] According to French Catholics this was all wrong, for science, truly understood, was in deep harmony with Catholic thought.

Among the scientific ideas that fueled the cultural struggle, Darwin's theory of the evolution of species was by far the most important. But the more arcane science of thermodynamics also had its share, especially by way of its cosmological implications. The debate concerning the heat death and its corollary, the entropic creation argument, involved a fairly large number of philosophers, social critics and

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1 Bradlaugh edited for many years *The National Reformer*, a periodical for freethinking, republicanism, women's rights and social reforms. In 1866 he founded the still existing National Secular Society and served as its first president.

2 See Paul 1972 and Paul 1979.

writers with a theological background. Of course scientists participated too, but they were rarely of the first rank and often their understanding of thermodynamics was deficient. As indicated by the participants and the literary sources in which the debate took place, it was popular and ideological rather than scientific. Cyclic cosmologies were particularly popular and more often than not defended by non-scientists who nevertheless presented their favoured models as solidly founded on science, contrary to the creation cosmologies supposed to be theological dogmas in scientific disguise. Of course, those in favour of a universe of finite age did their best to avoid references to religion and held that the debate was between good science and bad science.

Given that the controversy was of a cosmological nature it is remarkable that the specialists in the structure of the universe – the astronomers – kept a low profile. Only very few professional astronomers showed an interest in cosmological questions, and even fewer referred to the implications of thermodynamics, a science which somehow failed to attract astronomical interest.[3] Secchi was one of the few nineteenth-century astronomers who did refer to the entropic creation argument. As another of the rare examples one may mention Charles Augustus Young, a Princeton astronomer and well known author of astronomical texts. As a young man he had studied at a theological seminary in order to become a missionary, and he retained a strong religious conviction. In a textbook of 1893, *General Astronomy*, Young included a brief section on the cosmological consequences of the law of energy dissipation. In spite of all uncertainty about the universe, he considered it a fact 'that the present system of stars and worlds is not an eternal one'. Because of the continual dissipation of energy the universe would tend toward a dead state of absolute stagnation. 'If we carry our imagination backwards we reach at last a "beginning of things", which has no intelligible antecedent: if forwards, an end of things in stagnation. That by some process or other this end of things will result in "new heavens and a new earth" we can hardly doubt, but science has as yet no word of explanation.'[4]

As we have noted several times, the whole issue of the temporal development of the universe was closely related to discussions concerning the spatial extension of the universe. Although not necessarily with good reason, it was generally assumed that spatial infinity went with temporal infinity, spatial finitude with temporal finitude. Somehow it seemed natural that an infinitely great universe must have existed in an infinity of time; or that a universe finite in space must also be finite in time. The space-time connection was expressed by John Draper, who wrote: 'If there be a multiplicity of worlds in infinite space, there is also a succession of worlds in infinite time. As one cloud replaces another cloud in the skies, so this starry system, the universe, is the successor of countless others that have preceded it – the predecessor

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3 Among the few exceptions should be mentioned the Swiss-German astrophysicist Robert Emden, who in an important work of 1907 applied thermodynamics to the study of stellar atmospheres (Emden 1907).

4 Young 1893, pp. 524-5. He reflected on the philosophical and theological implications of contemporary astronomy in Young 1882, concluding that the scientific world view was in harmony with Christian belief.

of countless others that will follow. There is an unceasing metamorphosis of events, without beginning or end.'[5]

Moreover, this division often went hand in hand with religious and ideological attitudes, typically in the sense that finitism was associated with theism and infinitism with atheism or materialism. This was clearly the rule, but there were exceptions. There might be many reasons for preferring either a finite or an infinite universe, and not all of them had ideological or religious roots. For example, in a prescient work of 1900 the German astronomer Karl Schwarzschild investigated the possibility of space being curved either positively or negatively. Should space have a constant positive curvature, he estimated from astronomical data that the radius must be larger than about 1600 light years. For philosophical reasons he found it 'satisfying to reason' if 'we could conceive of space as being closed and finite, and filled, more or less completely, by this stellar system. If this were the case, then a time will come when space will have been investigated like the surface of the Earth, where macroscopic investigations are complete and only the microscopic ones need continue.'[6] As far as I know, Schwarzschild's epistemic preference for a closed, finite space was independent of religious or ideological motivations.

Pictures from the British Scene

Herbert Spencer, the influential philosopher of evolution *par excellence*, was not a scientist but he was considered to belong to the group of British scientific naturalists. In *First Principles*, a work that appeared in 1862 and was subsequently published in many editions and impressions, he engaged in questions of cosmology which he related to the science of heat.[7] He first discussed what may be meant by the origin of the universe, basing his entire discussion on what is conceivable and what is not (a dangerous kind of reasoning, one may add). The atheistic hypothesis of eternal self-existence was not an answer as it failed to offer an explanation of the universe; moreover, infinite past time was ruled out as 'absolutely unthinkable'. Spencer went on to exclude the pantheistic hypothesis of self-creation which involved the, to him, impossible notion of a change without a cause. What was left was the theistic hypothesis of creation by a supernatural agency outside the material universe, but neither was this possibility found to be acceptable. Not only was the creation of matter out of nothing a 'real mystery', the creation of space itself was even more mysterious. The theistic hypothesis inevitably leads to the notion of a first cause which must be infinite and absolute, and Spencer found that the argument in favour

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[5] Draper 1874, p. 243.

[6] Schwarzschild's paper exists in an English translation as Schwarzschild 1998, where the quotation is on p. 2542. The original source is *Vierteljahrschrift der Astronomischen Gesellschaft* 25 (1900), 337-47.

[7] Spencer 1911, pp. 22-9. Spencer classified his discussion of the origin of the universe under the heading 'Ultimate Religious Ideas'.

of such a cause had only 'nominal value'.[8] He characterized the Christian belief in creation with terms such as 'superstition' and 'faith in magic'.

Like many of his contemporaries, Spencer was fascinated by the principle of energy conservation, which he tended to elevate to a status as the ultimate law of nature and all its manifestations. 'Though Space, Time, Matter, and motion, are apparently all necessary data of intelligence, yet a psychological analysis … shows us that these are either built up, or abstracted from, experiences of Force.' Anticipating the later school of energetics, he argued that experience is always concerned with energy, and therefore the foundation of all science is rooted in the concept of energy: 'The sole truth which transcends experience by underlying it, is thus the Persistence of Force. This being the basis of experience, must be the basis of any scientific organisation of experiences.'[9] To Spencer, the concept of energy was not limited to the world of physics, for it applied equally well to phenomena of life ('vital force') and to social and mental phenomena ('social force' and 'nervous force').

Spencer did not directly refer to either the second law of thermodynamics or the entropic creation argument, but later in *First Principles* he discussed a kind of heat death and its implications for cosmic evolution. This was not the first time he had thought of the heat death, but for a while he seems to have misunderstood it completely, such as indicated by a letter to Tyndall of 1858. 'I fully recognize, and have all along recognized, the tendency to ultimate equilibrium. ... Thus you see that my views commit me most fully to the doctrine of ultimate equilibration', he wrote. It was only after having been enlightened by Tyndall that he understood, to his horror, the true meaning of the equilibrium. 'Regarding as I had done, equilibration as the ultimate and *highest* state of society, I had assumed it to be not only the ultimate but also the highest state of the universe. And your assertion that when equilibrium was reached life must cease, staggered me. Indeed not seeing my way out of the conclusion, I remember being out of spirits for some days afterwards. I still feel unsettled about the matter ...'[10]

As Spencer was forced to realize, much to his regret, progressive evolution seemed incompatible with the second law of thermodynamics. The evolutionary philosopher considered the heat death to be unacceptable and he consequently found a way out of the dilemma by the vague suggestion that 'certain of the great facts which science has established imply potential renewals of life, now in one region now in another; followed, possibly, at a period unimaginably remote by a more general removal'. He further referred to speculations in the style of Rankine, that motion associated with

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8 Ibid., pp. 27-8. Unacquainted with Riemannian geometry, Spencer argued for the impossibility of a finite first cause by claiming that if something is finite, it must be bounded, and 'to conceive a thing as bounded without assuming a region surrounding its boundaries is impossible.'

9 Ibid., p. 169 and p. 192.

10 Quoted in Clarke 2001, p. 67. Without mentioning Spencer by name, Tyndall later recalled the incident as follows: 'Some years ago I found myself in discussion with a friend who entertained the notion that the general tendency of things in this world is towards equilibrium, the result of which would be peace and blessedness to the human race. My notion was that equilibrium meant not peace and blessedness, but death.' Tyndall 1897, p. 10, from a lecture delivered in 1880.

radiant heat might not be lost but reradiated from boundaries in ether-filled space. Spencer, an advocate of and believer in endless rhythms in nature on all levels, recognized that he was on speculative ground, but he nonetheless concluded in an optimistic note: 'It is not inferable from the general progress towards equilibrium that a state of universal quiescence or death will be reached; ... if a process of reasoning ends in that conclusion, a further process of reasoning points to renewals of activity and life.'[11] This was more wishful thinking than a rational argument, but apparently it satisfied him.

Spencer's somewhat desperate attempt to make the law of energy dissipation comply with the general idea of progressive evolution did not find much acceptance among British scientists.[12] On the other hand, he was not the only one who was alarmed by the implications of the second law and sought means to avoid them. Samuel Tolver Preston, a telegraph engineer, self-taught physicist and prolific writer on subjects of natural philosophy, concluded that it was the duty of the scientific mind to find a way to avoid not only the 'so apparently purposeless' heat death but also 'the necessity for assuming in past time a violation of physical principles at present recognized to exist'.[13] This Preston did in several papers, one of his ways being to assume indefinite local fluctuations of temperature and matter in the endless universe, an assumption he justified in terms of the kinetic theory of gases. He believed that the diffusion of gases might constitute an exception to the irreversibility of the second law, a line of reasoning which was followed also by a few other scientists. For example, the German meteorologist Carl August Schmidt suggested in 1894 that gravity's influence on atmospheric particles might cause heat emitted from the Earth and other heavenly bodies to be reconcentrated.[14] If this was the case, the law of entropy increase would not be absolutely valid and the heat death might be avoided.

In a paper of 1877 Preston suggested that the second law might be violated in the process of mixing and diffusion of gases, a proposal related to Maxwell's famous demon.[15] Boltzmann responded to the claim in a lengthy paper in which he pointed out that the contradiction was apparent only and rested on an incomplete understanding of Clausius's law.[16] Undeterred by such criticism Preston maintained that it was plainly intolerable – against the spirit of science – to accept the heat death and a beginning of the universe:

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11 Spencer 1911, p. 431.

12 Smyth 1872 claimed that the two theories are indeed contradictory, a claim that would later be repeated by Haeckel and Arrhenius.

13 Preston 1879a, p. 152. See also Preston 1879b and Preston 1880. William Muir criticized Preston 1879b for being 'full of confusion of reasoning and of unsoundness' (Muir 1879). Nor was Maxwell impressed by Preston: 'He is by no means a paradoxer, though a fierce speculator, and what is rare among such folks he improves and amends his errors.' Letter to Tait of 12 December 1877, reproduced in Garber, Brush and Everitt 1995, p. 272.

14 Schmidt 1894; Gutberlet 1908, p. 76.

15 Preston 1877. On Maxwell's demon, see below.

16 Boltzmann 1968, vol. 2, pp. 289-317 (originally published 1878).

> Those who are inclined to view the physical causation of the past in the light of the physical causation of the present, or who look upon the principle of the conservation of energy as a truth as necessary in the past as in the present (or who are disposed to regard physical truths as independent of time), are bound to believe that some process of recurrence must exist, whereby useful change and activity are continued in the universe, and the purposeless end of a changeless chaos prevented – and that we should seek for the explanation of this, not so much with the view to prove the fact hereby, but rather as a satisfaction or confirmation of a fact we already had logical reasons for believing to exist.[17]

As we shall soon see, Preston was not alone in feeling this way. To give but one example, Pliny Earle Chase, an American professor of mathematics and a Quaker graduate of Harvard University, came up with a hypothesis of light-matter conversion to counter the 'common fallacy' of the universal heat death. Whatever his reasons, they were scarcely anti-religious. Chase speculated that the velocity of planetary bodies might be related to the velocity of light, from which he concluded that there was 'a profound scientific truth in the doctrine that the first act of creation was the divine command, "Let there be light"'.[18]

Spencer was perhaps the earliest of the evolutionary thinkers who found the physicists' heat death to be disturbing and incompatible with progressive evolution, but he was far from being the only one. The father of modern evolutionary biology, Charles Darwin, was worried because the second law challenged his optimistic belief in greater perfection obtained through the slow evolutionary process. In his autobiography, begun in 1876 but only published posthumously, he referred to 'the view now held by most physicists, namely, that the sun with all the planets will in time grow too cold for life, unless indeed some great body dashes into the sun and thus gives it fresh life.' It is, he continued, 'an intolerable thought that he [man] and all other sentient beings are doomed to complete annihilation after such long-continued slow progress.' Darwin admitted that to those who had a strong faith in the immortality of the human soul, such a prospect might not appear so dreadful. Alas, he also had to admit that he did not himself belong to that company: 'I cannot pretend to throw the least light on such abstruse problems [as the immortality of the soul and the existence of God]. The mystery of the beginning of all things is insoluble by us, and I for one must be content to remain an Agnostic.'[19]

As mentioned, in the ideological debate in the late nineteenth century finitism was usually associated with political conservatism and Christian belief, whereas socialists and materialists adhered to the doctrine of an infinite and eternal universe. But there were exceptions to the rule. William Thomson was not only a pioneer of thermodynamics, he was also a devout Christian; yet he had no doubt that the universe

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17 Preston 1879a, pp. 158-9.

18 Chase 1875, p. 253. Chase published extensively on cosmophysics and the nebular hypothesis, more often than not guided by numerological considerations. See, e.g., Chase 1876.

19 Darwin 1958, pp. 66-7. Darwin ended up as either an agnostic or an atheist. Much has been written on his views on religion, a topic which is still somewhat controversial. See the comprehensive study by Brown 1986.

is spatially infinite. His argument was not based in either religion or astronomy, but in a common-sense consideration which perhaps carried – or should have carried – a limited force of conviction. 'I say *finitude* is incomprehensible, the infinite in the universe *is* comprehensible,' he said in a popular lecture of 1884. 'What would you think of a universe in which you could travel one, ten or a thousand miles, or even to California, and then find it come to an end? Can you suppose an end to matter or an end of space? The idea is incomprehensible.'[20] On the other hand, he did not find it incomprehensible that the universe had a beginning in time.

During the last three decades of the nineteenth century Thomson was engaged in an extensive controversy with geologists and natural historians concerning the age of the Earth. Although this famous controversy was limited to the solar system, and thus not cosmological in nature, it included some of the same elements that figured in the debate over the end of the world. In a lecture of 1869 Huxley attacked the physicists' 'favourite dogma' that the Sun was on its way to extinction and, consequently, life on Earth would eventually cease to exist. In his response to Thomson's challenge of geological uniformitarianism he called upon the authority of the law of energy conservation, which he thought contradicted the prediction of a dying Sun. But Thomson pointed out that Huxley's arguments were 'directly opposed to the general principle of the dissipation of energy' and 'very inconsistent with our special knowledge of the conduction and radiation of heat, of thermo-electric currents, of chemical action, and of physical astronomy'.[21] Huxley had appealed to Kant's speculations of a recurrent universe where decay was endlessly balanced by reproductive processes. Thomson was not impressed. He suggested that had Kant known about the second law of thermodynamics he would not have come up with the chimera of a phoenix universe.

Many Victorians were both horrified and fascinated by the prospect that the Sun and the current order of the universe might not last forever. The concept of an absolute end was as unwelcome as the concept of an absolute beginning. Richard Proctor, a respected amateur astronomer and prolific science writer, was willing to admit that the Earth might become inhabitable because of the continual degradation of energy, but he could not imagine a dead universe. In an essay of 1874 he reassured his readers of the continuity of the past and the future: 'No one can indeed doubt that that progression in space is of its very nature limitless. But this is equally true, though not less inconceivable, of time. Progression implies only relative beginning and relative ending; but that there should be an absolute beginning or an absolute end is not merely inconceivable, like absolute eternity, but is inconsistent with the necessary conditions of the progression of time as presented to us by our conceptions.'[22] Proctor was at the time a Catholic, but in 1875 he left the church,

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20 'The wave theory of light', pp. 307-55 in Thomson 1891. Quotation on p. 322.

21 Address 'On geological dynamics' presented to the Geological Society of Glasgow in 1869. Reproduced in Thomson 1894, pp. 73-131 (quotation on p. 119). On the age of the Earth debate, see Burchfield 1975.

22 Proctor 1874, p. 91. See also Beer 1989, pp. 169-70. On Proctor's important role in the debate over pluralism, see Crowe 1999, pp. 367-77.

possibly because he found his strong belief in extraterrestrial life to disagree with Catholic doctrines.

An illuminating perspective on the British debate can be obtained through William Stanley Jevons's celebrated book *Principles of Science*. Jevons, who is best known for his important works in logic and economics, was also a philosopher of science of some importance, and in the final part of his massive work he discussed topics of a cosmological nature. Although he wanted to keep theology out of the book, he did not hide his dissatisfaction with materialists and positivists of the Comtean school. 'My purpose', he wrote, is 'showing that atheism and materialism are no necessary results of scientific method … [and that] we cannot disprove the possibility of Divine interference in the course of nature.'[23] Referring to Tait and Maxwell, Jevons stated the entropic creation argument, although he referred to the dissipation of energy rather than entropy. However, he saw it as a problem rather than a solution, as a created universe could not be explained on scientific grounds:

> Now the theory of heat places us in a dilemma either of believing in Creation at an assignable date in the past, or else of supposing that some inexplicable change in the working of natural laws then took place. Physical science gives no countenance to the notion of infinite duration of matter in one continuous course of existence. And if in time past there has been a discontinuity of law, why may there not be a similar event awaiting the world in the future? Infinite ingenuity could have implanted some agency in matter so that it might never yet have made its tremendous powers manifest. We have a very good theory of the conservation of energy, but the foremost physicists do not deny that there may possibly be forms of energy, neither kinetic nor potential, and therefore of unknown nature.[24]

Elsewhere he extended the dilemma to a trilemma, adding the equally unacceptable possibility that 'We must … deny that anything exists', which he dismissed as absurd. He even considered that the present order of things might be but 'a part of one single pulsation in the existence of the universe', and considered Rankine's speculation of 1852 as a possible solution. 'But if the material universe consist of a finite collection of heated matter situated in a finite portion of an infinite adamantine medium, then either this universe must have existed for a finite time, or else it must have cooled down during the infinity of past time indefinitely near to the absolute zero of temperature.'[25] Jevons did not endorse the cyclical universe any more than uniform eternal existence or creation in a finite past. It was only after having been criticized by Clifford that he felt forced to admit, if only reluctantly, that 'the known laws of nature do not enable us to assign a "beginning". Science leads us backwards into infinite past duration.'[26]

However, Jevons's attitude was ambiguous. He could not think of the universe without thinking of God, and who could confidently say that he knew God's thoughts? 'No single law of nature can warrant us in making an absolute prediction,' he wrote.

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23 Jevons 1877 (1st edn 1874), p. 766.
24 Ibid., p. 744-5.
25 Ibid., p. 752.
26 Ibid., p. xxxii.

And he continued: ‘To assume, then, that scientific method can take everything within its cold embrace of uniformity, is to imply that the Creator cannot outstrip the intelligence of his creatures, and that the existing Universe is not infinite in extent and complexity, an assumption for which I see no logical basis whatever.’[27]

In a lecture of 1872 Clifford distinguished between exactness in a practical or approximative meaning and in a theoretical or absolute meaning. He insisted that we have no right to assume that the laws of nature are theoretically exact. We do not know for sure that the laws are exactly true, nor can we ever know. Scientific truth, he said, is ‘not that which we can ideally contemplate without error, but that which we may act upon without fear’. The assumption of the absolute immutability of the laws of nature is nothing but a postulate from which no universal conclusions about past or future can justifiably be drawn. ‘A law would be theoretically universal if it were true of all cases whatever; and this is what we do not know of any law at all.’[28] Although Clifford did not refer to the cosmological consequences of thermodynamics, it followed from his philosophy that they could not be assigned status as scientific knowledge. Two years later, in a lecture on ‘The first and last catastrophe’, he launched an attack on all attempts to find out of beginnings and ends from the present state of nature. Such endeavours, which he found in Maxwell, Tait, Jevons, Murphy and others, were unwarranted extrapolations from thermodynamics to cosmic history. It is a fallacy, he said, to conclude

> that if we consider the case of the whole universe we should be able, supposing we had paper and ink enough, to write down an equation which would enable us to make out the history of the world forward, as far forward as we liked to go; but if we attempted to calculate the history of the world backward, we should come to a point where the equation would begin to talk nonsense – we should come to a state of things which could not have been produced from any previous state of things by any known natural laws.[29]

According to Clifford, such reasoning was based on illegitimate extrapolation. Thermodynamics could be used to find the time that the Earth passed from a liquid to a solid state, as Thomson had done, but not to find ‘the time of the commencement of the universe’. He denied that there was any evidence of a catastrophe implying the beginning of the laws of nature, and concluded that we know nothing, and cannot know anything, of either the beginning or end of the world. If we trace the history of the universe back in time, ‘We do not come to something of which we cannot make any further calculation; we find that however far we like to go back, we approximate to a certain state of things, but never actually get to it.’ Clifford’s position was seemingly agnostic, but in reality he argued that the world is uncreated and infinitely old.

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27 Ibid., p. 739.

28 Clifford 1947, p. 12. Address ‘On the aims and instruments of scientific thought’ delivered before the British Association in August 1872.

29 Clifford 1879, vol. 1, p. 221. The lecture was originally published in *Fortnightly Review* 1875. Clifford’s essays were dampened down to reduce the polemic when they were published by his widow. See Dawson 2004.

The general position that the universe at large does not belong to the domain of science was widespread, in Britain as elsewhere. In a biographical account of Lord Kelvin (William Thomson), the Glasgow physicist Andrew Gray emphasized that Clausius's formulation of the laws of thermodynamics was really a misstatement. The energy of the universe might be constant 'if the universe is finite; [but] if the universe is infinite in extent the statement has no meaning'. He continued: 'In any case, we know nothing about the universe as a whole, and therefore make no statements regarding it.'[30]

By and large, this seems also to have been the opinion of John Henry Poynting, professor of physics at the University of Birmingham, who in a popular paper of 1902 commented on 'the melancholy picture of the ultimate fate of Nature, ... when each kind of energy has sunk to one level, when all matter is at one temperature, and the universe is a system of dark, worn-out suns and frozen planets hung in a calm, lifeless sea of energy.' According to Poynting, the picture presupposed that our fragmentary knowledge of the finite applied to the universe, which he assumed was infinite. Nonetheless, if the law of dissipation of energy was applied to the countless stars, it seemed to lead to the result that 'we may be merely at one stage of a gradual drawing together of matter into larger and larger masses with successive conversions of position-energy into heat at centres more and more remote and at epochs further and further apart.' Rather than using the heat death scenario to infer an end of the world, Poynting suggested that the dissipative processes might have taken place since eternity and would continue in an indefinite future: 'This is no doubt wild speculation, but at least it will serve to show that as we know of no beginning of the activity of nature so we need not picture any end.'[31]

Much of the discussion concerning the entropic end of the world was concerned with the solar system rather than the universe at large. For example, in a paper in the *Proceedings of the Royal Society* of 1882 the engineer, inventor and industrialist William Siemens devised a model of the Sun in which the energy was regenerated rather than wasted into space. This he conceived to be effected by means of rarefied matter diffused throughout space in such a way that it received the radiated energy and returned it to the Sun in another form. The cyclic process involved no degradation of energy and thus violated the second law of thermodynamics. Siemens had long had the conviction 'that the prodigious and seemingly wanton dissipation of solar heat is unnecessary to satisfy accepted principles regarding the conservation of energy, but that this heat apparently expended without producing any effect whatever may be effectively arrested and returned over and over again to the Sun'.[32] His theory of conservation of solar energy aroused considerable attention and received critical comments by several scientists in Britain and France. Siemens did not develop his

[30] Gray 1908, p. 140.

[31] Poynting, 'The transformation and dissipation of energy', *The Inquirer* (1902), 627-8, reproduced in Poynting 1920, pp. 658-63 (on p. 663).

[32] Siemens 1882, p. 397. Together with other contributions to the debate, a revised version of this paper is reproduced in Siemens 1883, pp. 1-22. Clerke 1886, pp. 353-5, found the theory to be ingenious but wrong because it violated the 'inexorable law of nature that there is no work without waste'. On Siemens's solar model, see also Schaffer 1995.

ideas into a cosmological theory, but assuming the material universe to consist of stars the step from the solar system to the universe was but small.

A Believer's Sceptical Cosmology

Pierre Duhem – French chemist, physicist, philosopher and historian of science – responded to the heat death scenario in a way that had similarities with Clifford's, namely by being sceptical and methodologically grounded. But that is where the similarity ends. While a professor in Bordeaux, he forcefully reflected on the relation between the laws of thermodynamics and religion in an article of 1905 entitled 'Physique de croyant' in the *Annales de Philosophie Chrétienne*, a Catholic journal founded in the 1830s. The article received much wider attention when it was included as an appendix in the second edition (1914) of Duhem's important work on the philosophy of the physical sciences, *La théorie physique*. However, this was not the first time he commented on the cosmological significance of thermodynamical laws. Duhem was a leading expert in chemical thermodynamics and instrumental in the process that led from classical thermochemistry, as developed by Berthelot, to the new theory of chemical potentials. In a textbook of 1897 he expressed his disapproval of Clausius's cosmological formulations of the two laws, which he found to be foreign to physics.[33] He repeated his criticism in a later textbook in which he argued that energy and entropy cannot be uniquely defined for the universe as a whole, irrespective of whether it is infinite or limited in space. He therefore concluded that there was no logical justification for Clausius's cosmological formulation. More generally:

> All the philosophical consequences that one believes to be able to derive from an extension of the principle of energy conservation and the principle of entropy increase to the universe prove to be an idea that is completely erroneous with respect to the nature and range of thermodynamics and, in general, the science of physics.[34]

Duhem's paper of 1905 was a response to a lengthy article by the young philosopher Abel Rey, who had concluded that 'Duhem's scientific philosophy is that of a believer' (note that Rey referred to Duhem's philosophy of science, not his science).[35] Although he was indeed a believer, a sincere and devout Catholic, Duhem was eager to point out that his works in physics and chemistry should be considered on their own merits, independent of his religion. They were not examples of 'Catholic science', nor even coloured by his Catholic faith. It followed from his positivistic, anti-metaphysical methodology of science that there could not be any impact from

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33 Duhem 1897, p. 83. Duhem wrote that Clausius had applied the laws of thermodynamics to the universe, 'which he assimilates to a system of bodies of limited extension and isolated in an absolutely void space'. As far as I know, Clausius never mentioned either this or any other cosmological model.

34 Duhem 1910, p. 94.

35 Rey 1904. Duhem's article is translated in Duhem 1974, pp. 273-311. See also Hiebert 1966, pp. 1070-3 and particularly Paul 1979, pp. 137-78, who offers a detailed analysis of the article in the context of the French science-religion discussion in the Third Republic.

religion to science, nor from science to religion (whereas he accepted an impact from science to metaphysics). He refuted that arguments from physics, or science in general, could validly serve as objections against religion, and also, conversely, that such arguments could support the religious cause. Although the order of nature was ultimately the work of the creator, he denied any direct connections between science and religion based on natural theology. According to his friend abbé Bernies, Duhem held the view that 'science properly spoken was neither Christian nor anti-Christian, once it kept itself within its limits. It was simply science. Science and Revelation have one domain, but absolutely different methods.'[36] In short, Pierre Duhem was an ardent advocate of the independence thesis.[37]

In order to illustrate his view on the relationship between physics and theology, Duhem referred to the case of thermodynamics. 'Is the principle of the conservation of energy compatible with free will?' he asked, only to conclude that the answer was neither a yes nor a no.[38] There is no answer, for the question is scientifically meaningless. Duhem then turned to the entropic argument for creation and decay. One might believe that the believer Duhem happily accepted it as support of Christian doctrines, but this was far from the case. Concerning Clausius's cosmological version of the second law, he wrote:

> From this theorem many a philosopher maintained the conclusion of the impossibility of a world in which physical and chemical changes would go on being produced forever; it pleased them to think that these changes had had a beginning and would have an end; creation in time, if not of matter, at least of its aptitude for change, and the establishment in a more or less remote future of a state of absolute rest and universal death were for these thinkers inevitable consequences of the principles of thermodynamics.[39]

However, Duhem did not accept these conclusions which were 'marred in more than one place by fallacies'. The argument 'implicitly assumes the assimilation of the universe to a finite collection of bodies isolated in a space absolutely void of matter', he wrote, repeating what he had said in 1897, and providing his statement with no further clarification. Whatever he meant with it, he found no reason to accept the assumption. Moreover, he argued that the entropy law merely says that the entropy of the world increases endlessly, not that it has any lower or upper limit.

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36 Commemoration article of 1917, quoted in Jaki 1984, p. 233.

37 According to a typology suggested by Ian Barbour, attitudes to how science and religion relate (or should relate?) can be roughly summarized in four positions: The integration thesis; the independence thesis; the dialogue thesis; and the conflict thesis. See Barbour 1990. Several other typologies have been proposed, some of them much more complex and fine-grained. For a historically based criticism of Barbour's fourfold typology, see Cantor and Kenny 2001.

38 Duhem's example was not purely hypothetical. It was an issue that had been discussed by several authors, including Maxwell. See also Croll 1872 and Croll 1891, which according to one reader offered an understanding of energy which was 'an effective reply to mechanical atheism'. Letter to *Nature* 44 (1891), 320 by T.T. Sherlock.

39 Duhem 1974, p. 288.

> It is true that the entropy of the universe has to increase endlessly, but it does not impose any lower or upper limit on this entropy; nothing then would stop this magnitude from varying from $-\infty$ to $+\infty$ while the time itself varied from $-\infty$ to $+\infty$; then the allegedly demonstrated impossibilities regarding an eternal life for the universe would vanish.[40]

It may be objected that this view does not agree with the understanding of entropy as a measure of molecular disorder, for according to Boltzmann's ideas a time must come when the disorder of a system is at its maximum. It cannot increase endlessly. However, Duhem was an orthodox anti-atomist who did not accept the statistical-mechanical interpretation of entropy, and it was presumably for this reason that he saw no problem in an ever-increasing entropy and not merely entropy increasing towards an asymptotic value.

Duhem's aim was certainly not to argue against a universe of finite age, but to warn that physical theory does not justify long-term predictions of such a kind. In this respect he was, like Clifford before him, an agnostic. 'It is absurd', he wrote, 'to question this theory [thermodynamics] for information concerning events which might have happened in an extremely remote past, and absurd to demand of it predictions of events a very long way off.' It would be a gross misconception of the scope and nature of science to believe that one could claim for it 'the proof of a dogma affirmed by our faith'. In agreement with his general philosophy of science Duhem pointed out that it would be perfectly possible (if not perhaps reasonable) to construct a new thermodynamics which was in agreement with experimental data and gave the same predictions as the old thermodynamics for ten thousand years; and yet, the new theory could be constructed in such a way that it 'might tell us that the entropy of the universe after increasing for a period of 100 million years will decrease over a new period of 100 million years in order to increase again in an eternal cycle'.[41] He definitely did not subscribe to such a perverse world view, but wanted to bring home the point that science is incapable of making trustworthy predictions about either the beginning or end of the world, or its perpetual activity.

Concerning the more general relationship between cosmology and physics, Duhem claimed that the two fields are so different that physical theory cannot be meaningfully applied to cosmology. He did not deny that knowledge of physics can be useful, and even indispensable, for the cosmologist, but nonetheless argued that 'physical theory can never demonstrate or contradict an assertion of cosmology, for the propositions constituting one of these doctrines can never bear on the same terms which the propositions forming the other do, and between two propositions not bearing on the same terms there can be neither agreement nor contradiction.'[42] The only connection of cosmology with theoretical physics was by means of analogy. Duhem's denial of the possibility of physical cosmology may appear surprising, but one should be aware that he mostly spoke of 'cosmology' in a philosophical, neo-scholastic sense of the word. He believed that the cosmology of Aristotelian physics was 'unmistakably analogous' to the generalized thermodynamics that he so much admired.

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40 Ibid.

41 Ibid., p. 290.

42 Ibid., p. 301.

The *fin de siècle* ideology in France was in part coloured by a growing revolt against positivism, scientism and the agnostic-materialistic ideas that the scientific world view was accused of fostering. In early 1895 the French literary critic and orthodox Catholic Ferdinand Brunetière published an article in which he attacked positivistic science and argued that it had failed to answer, or even address, the greater questions of matter and life. In the heated debate that followed, some critics of science proclaimed 'the bankruptcy of science' (Brunetière did not use the phrase, but only spoke of the failure of science).[43] Nor was it only in France that science was charged with being morally bankrupt. The Victorian feminist Frances Power Cobbe wrote in 1888 that a man bred to science 'will view his mother's tears not as expressions of her sorrow, but as solutions of muriates and carbonates of soda, and of phosphates of lime; and he will reflect that they were caused not by his selfishness, but [by] cerebral pressure on her lachrymal glands'.[44] Contrary to what preachers of the scientific gospel claimed, positivistic science was widely held to be inferior to religion because it provided no insight into the supreme mysteries of the universe, or into the mysteries of the meaning of love, life and death. In this intellectual climate, French Catholics eyed an opportunity to come back on the scene, not only as critics of scientistic tendencies but also as interpreters of and contributors to science.

Duhem was very much his own. His ideas, whether scientific, political or religious, conflicted sharply with those held by the cultural and scientific elite of France. Not only was he an orthodox Catholic, he was also politically conservative and strongly anti-Republican. Nor can he be taken as a representative of Catholic scientists, most of whom had no problems with arguing apologetically, to the effect that science supported Christian theology. For example, in 1905 the Catholic geologist Albert de Lapparent gave a series of lectures which was published as *Science et apologétique* and whose message was that recent developments in science were fully congruent with Christian faith. Contrary to Duhem, Lapparent believed that the idea of a beginning and an end of the universe could be given scientific support: 'The [Christian] idea of origin and end applied to the entire creation seems to find a remarkable confirmation in the fundamental law of this energetics in which all the sciences of matter tend more and more to meet.'[45] While Duhem emphatically denied using science apologetically, he saw his research in the history of medieval science in a different light. The study of the history of science would show, he wrote, that 'during those very ages when men cared above all for the kingdom of God and of its justice, God accorded to them as a bonus the most profound and fertile thoughts concerning matters down here.'[46] According to Duhem, the controversy between Catholic thought and modern science was essentially a misunderstanding based in

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[43] On the bankruptcy of science debate, see Paul 1968 and MacLeod 1982. For a broader and more philosophical perspective on the tensions between science and anti-intellectualism about the turn of the century, see Fouillée 1896 and Aliotta 1914. Lightman 2004 (p. 228) suggests that a similar anti-scientific attitude can be found in Britain in the second half of the 1870s, in part a reaction to Tyndall's Belfast address.

[44] Quoted in Heilbron 1982, p. 58. The source is Cobbe, 'The scientific spirit of the age', *Contemporary Review* 54 (1888), 126-39.

[45] Quoted in Paul 1979, p. 128.

[46] Pierre-Duhem 1936, p. 168.

a failure to appreciate the separate domains of the two fields. He had nothing but disdain for the many words wasted on the subject:

> It has been fashionable for some time to oppose the great theories of physics to the fundamental doctrines on which spiritualistic philosophy and the Catholic faith rest; these doctrines are really expected to be seen crumbling under the ramming blows of scientific systems. Of course, these struggles of science against faith impassion those who are very poorly acquainted with the teachings of science and who are not at all acquainted with the dogmas of faith; but at times they preoccupy and disturb men whose intelligence and conscience are far above those of village scholars and café physicists.[47]

Duhem's views were controversial, both within the state university system and within the Catholic church. As an indiscreet Catholic, his career was deeply affected by the hostility of anticlerical governments toward Catholicism.[48] As an independent mind, his insistence on a sharp separation between science and faith made him a target from some Catholics, who suspected him of philosophical scepticism and 'fideism', the heretical belief that faith rests on faith and nothing else. Not only was his view concerning science and religion problematical, so was his philosophy of science, primarily because it was radically anti-metaphysical and seemed to undermine natural theology.[49] Bernard Brunhes, a professor of physics and director of the Observatory at Puy-de-Dôme, had a high regard of Duhem and his philosophy of physics. In 1908 he published an excellent and comprehensive review of the second law of thermodynamics, entitled *La dégradation de l'énergie*, but chose not to include the wider cosmological and religious aspects. The Catholic Brunhes was not foreign to these aspects, but like Duhem he wanted to keep them separate from the scientific aspects.[50]

Duhem's assertion that the laws of thermodynamics cannot be applied to the universe at large, and for this reason alone carry no religious relevance, can be found in other contemporary thinkers as well, irrespective of their religious affiliations. Bavink, who was a Protestant, agreed that only 'a pure act of faith' could justify entropic-cosmological conclusions. He further agreed with Duhem (without mentioning him[51]) that although entropy increases in time it does not need ever to reach a maximum. It could, for example, increase toward some state asymptotically, approaching it indefinitely without ever reaching it.[52] As Bavink pointed out, the law of entropy increase has not itself anything to say of *how* the entropy increases.

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47 Duhem 1974, p. 283.

48 On Duhem's troubles with the political system, see Paul 1972 and Jaki 1984.

49 The leading Catholic philosopher and neo-Thomist Jacques Maritain were among those who objected to Duhem's philosophy of science. On the dissonance between Duhem's ideas and Catholic orthodoxy, see Paul 1979 and Martin 1991.

50 Brunhes 1908; Brunhes 1905-06. On his Catholic faith, see *Cosmos* 62 (1910), 593.

51 *La thórie de physique* appeared in German in 1908, entitled *Ziel und Struktur der physikalischen Theorie*, translated by Friedrich Adler and with a sympathetic forword by Mach, but the translation did not include the appendix on the physics of a believer in which Duhem referred to the heat death.

52 Bavink 1914, pp. 129-31. The first to have suggested that the second law does not necessarily lead to a maximum entropy, even if plenty of time is available, may have been

German Materialists, Monists and Positivists

'Take any three natural scientists, and two will be atheists and materialists every time.'[53] Thus read a maxim from mid-nineteenth century Germany, indicating the rise of scientific materialism in the wake of the uprisings 1848-49. Signs of a turning tide already appeared in the 1830s when the young theologian and philosopher David Friedrich Strauss published the controversial *Das Leben Jesu* (1835-36) in which he argued in great detail that the New Testament was largely a collection of myths. At the time an idealist of the Hegelian school, Strauss moved towards a positivistic and materialistic position, for which reason he came to be seen as an ally by many materialists and monists later in the century. For example, Haeckel praised Strauss in his *Welträtsel*. On the other hand, his ideas were anathema among most German theologians interested in the relationship between science and religion. Otto Zöckler, a Lutheran professor of theology in Greifswald, was a prolific writer on apologetics and natural theology. In *Schöpfungsgeschichte und Naturwissenschaft* (1869) and many other works he argued for an integration of science and biblical faith. However, where such integration was judged impossible, as in the case of Darwinian evolution, he stayed on the ground of the Bible.[54] Zöckler and Strauss belonged to opposite camps in German intellectual life.

In 1872, with the publication of *Der alte und der neue Glaube*, Strauss moved even farther away from Christian religion. Although he remained deeply religious, he considered Christianity to be nothing but a mythology that belonged to the past. It had to be replaced by a new religion, based on science or even identified with science. According to the new 'natural religion' there was no personal God and no life after death – all that existed was the substance immanent in the physical cosmos. In this connection he pointed out that theologians had traditionally claimed the universe to be spatially finite, because true infinity belongs to God. On the other hand, according to the 'independent philosophy' the universe was infinite. The world picture Strauss advocated in 1872 was inspired by Kant's cosmogony and, he believed, supported by the principle of force conservation. Like Kant he thought of the universe as an infinite collection of 'worlds' that are constantly in flux, with life disappearing in one world only to reappear in another. Whereas the individual worlds, including our own solar system, were limited in time, this was not the case with the universe at large. 'If we contemplate the universe as a whole, there never has been a time when it did not exist. ... The universe [is] an infinite collection of worlds in all states of

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Arthur J. von Oettingen, a physicist from the university of Dorpat (now Tartu in Estonia). In a critical paper of 1876 Oettingen argued that Clausius' version of the second law was wrong: 'If a heat exchange needs long time, then the end of this process will only happen in long time, that is, it will *never* happen. An long continual increase will not result in a maximum, for this is only possible in a finite time.' Oettingen 1876, p. 132.

53 Gregory 1977, p. 29, which gives a full analysis of the rise of German scientific materialism. For a general evaluation of the many shades of materialism in the three last decades of the nineteenth century, see Hayes 1941, pp. 123-64.

54 Zöckler founded in 1865 the apologetical periodical *Der Beweis des Glauben* which he edited until his death in 1906. His strong interest in natural theology was not shared by the majority of German Protestant theologians. See Gregory 1992, pp. 112-59.

formation and decay, and even in this eternal cycle of change it preserves itself in an absolute vitality which is ever the same.'[55] This was a view in full agreement with that of the majority of positivists and materialists. Strauss's thoughts on religion and philosophy, and especially his exposition in *Der alte und der neue Glaube*, had a great impact on Haeckel and helped to shape his monistic world picture.

The medical doctor and science popularizer Ludwig Büchner was among the most influential of the new cast of materialists and freethinkers, a result mainly of his widely read *Kraft und Stoff* from 1855, sometimes referred to as the gospel of materialism.[56] In the wake of the 1848 revolution *Kraft und Stoff* was considered dangerous by the clergy and conservative groups, and as a result Büchner was forced to resign his lectureship at the University of Tübingen. Subtitled *Empirisch-naturphilosophische Studien*, the book went through twelve editions in seventeen years and was translated into seventeen languages. It was a real hit.[57] The central message in Büchner's philosophy was the inseparability between force and matter: no force without matter, and no matter without force. Force had often been conceived as an independent and primary entity, such as the *Naturphilosophen* did, and in this capacity it had been exploited for theological and spiritual purposes. With the materialistic conception of force as bound to inert matter, Büchner wanted to make such exploitation impossible.

Although the conservation of force was an important theme in *Kraft und Stoff*, Büchner did not clearly understand the concept as energy conservation and he did not refer to any of the fathers of thermodynamics. In 1855 he may have been unaware of the law of energy conservation; if he was not, he did not understand it. Force was for him an 'expression for the cause of a possible or an actual movement', a formulation few physicists would have accepted. Not only was force conserved, so was matter, and since the world was made up of force and matter it followed that it must be uncreated and eternal. Whereas Maxwell saw divine creation behind the permanence of atoms, Büchner saw the immortality of atoms as proof that they had always existed. 'It is impossible that the world can have been created. ... How could something have been created which cannot be annihilated!'[58] He challenged the belief in a divine designer by pointing out that the Sun and stars had shone on the Earth for untold ages before there was any life. Moreover, the solar system 'must perish in time, and with it all that is great, all that man has ever accomplished or ever done on Earth, must subside again into the chaos of eternal oblivion'. According to Büchner, a finite collection of stars would suffer from gravitational collapse, from which he concluded that the universe was infinite in space as well as time. He summarized his cyclic or rhythmic world view, a doctrine common to the majority of materialists,

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[55] Strauss 1873 (4th edn), p. 152-3. The book included a chapter on the Kant-Laplace cosmogony, but did not refer to the heat death or other aspects of thermodynamics.

[56] This is the expression of John Theodore Merz in his comprehensive survey of nineteenth-century intellectual history (Merz 1965, vol. 2, p. 561; first published 1904). On Büchner, see Gregory 1977, pp. 100-121. See also Lange 1887, pp. 443-53, 643-5.

[57] Among the readers of *Kraft und Stoff* was young Albert Einstein at the impressionable age of 12 or so. One may imagine that Büchner's book contributed to the 'positively fanatic orgy of freethinking' that Einstein for a time immersed himself in (Einstein et al. 1949, p. 5).

[58] Büchner 1872 (12th edn), p. 13.

as follows: 'The "cycle of matter" stands on the side of the "cycle of force" as a necessary correlate; it tells us that nothing is created and nothing disappears, and that the secret of nature is founded on an eternal, by itself carried cycle in such a way that cause and effect are connected without a beginning and without an end.'[59]

Although Büchner did not refer to the founding fathers of energy conservation in *Kraft und Stoff*, he did so in a piece of 1857 with the title *Die Unsterblichkeit der Kraft*, and in *Licht und Leben* (1882) he took up the second law and some of its cosmological consequences. Inspired by Helmholtz and Hirn, he discussed the fate of the Sun and the prediction that eventually it would die the heat death. However, he refused to believe that the *Wärmetod* was the end of the universe. How could he, convinced as he was that the universe is necessarily everlasting? He admitted that the Sun and other individual star systems would suffer the heat death but claimed, like several of his contemporaries, that the prediction of the second law was only locally valid. If our world died, surely other worlds would be born, so that on the whole the universe would continue its existence. And he convinced himself that our solar system, after the Sun had become extinguished, would re-emerge in all its splendour. Our world was a phoenix universe which 'must and will ... celebrate its resurrection some day'.[60] In the end, the scientific materialist Büchner had an almost religious faith in the eternity of life.

Another of the German scientific materialists, the Königsberg physician and philosophical author Heinrich Czolbe, defended in *Neue Darstellung des Sensualismus* (1855) his own philosophical system of materialism, what he called 'sensualism'. Like Büchner, he denied that the universe would ever end in an irreversible state of heat death, but he went much farther in claiming stability to be eternal and absolute. Any beginning or end was ruled out, for 'a limit of time, or its end somewhere in either the past or the future, is as unthinkable … as a limit of space'.[61] Czolbe denied consistently any notion of creation or origin whatever, not only of the universe but also of the solar system; this implied that he rejected the nebular hypothesis, otherwise so popular among materialists. His view of nature was strictly atemporal and ahistorical: not only had the Earth always existed, so had organic life forms. To believe otherwise would be to admit the mysterious concept of creation a place in scientific philosophy, and this Czolbe would have nothing of. Darwin was still a few years in the future. The only variations from strict stability he would admit were minor oscillations. In effect, Czolbe denied the evolutionary world view, which was untypical among materialists. On the other hand, he was not the only philosopher of his generation who was radically opposed to directions of progress or decay in nature. Another example is provided by the American Chauncey Wright, who rejected all theories based on unidirectional development (see the end of this Chapter).

Hermann Sonnenschmidt, the author of a book titled *Kosmologie*, should presumably be counted as a materialist, but little is known of him except from what

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59 Ibid., p. 24.

60 Quoted in Gregory 1977, p. 163.

61 Czolbe 1855, p. 183. On Czolbe's philosophical system, see Gregory 1977, pp. 122-41, and Lange 1887, pp. 459-68.

can be derived from his book. His cosmological system was essentially home-made and speculative, although based on some astronomical knowledge and the nebular hypothesis of Kant and Laplace in particular. In Sonnenschmidt's universe, time had always existed and would remain for ever, and space was infinite, continuously filled with matter: 'Time has neither beginning nor end. ... Space is positively infinite. ... Matter can neither be created nor annihilated; it rather exists for ever. We thus stand in contradiction to the learned theists but in agreement with all insightful people, in particular those knowledgeable about nature.'[62] Although he accepted that the entropy law led to the decay of individual parts of the universe, such as stars and nebulae, he followed Büchner in denying the cosmic heat death and arguing for a cyclic universe. Parts of Sonnenschmidt's book were explicitly directed against the Christian tradition and its view of nature. He found the ideas of 'the Christian philosophers' to be unreasonable as well as ridiculous, especially when it came to the divine creation of the world. Since God was supposedly eternal and omniscient, he 'must have known for quintillions of years, and even longer, when and how he would create the world'.[63] Who, in an age of positive science, could seriously believe in such nonsense?

Many of the themes that can be found in Büchner, Czolbe and Sonnenschmidt also appeared in *Die Kraft*, a book published in 1878 by Johannes Gustav Vogt, a 35-year-old professor of philosophy in Leipzig. Vogt presented a speculative, dilettantish and highly ambitious world system in the German tradition of materialistic natural philosophy, a system that was purely mechanical and based on atoms, force and ether. Vogt's mechanicism was however of the dynamical kind, as he assumed that space was continuously filled with force rather than matter. Much like Sonnenschmidt he stressed that truly creative acts had no place in science and that the universe must necessarily be infinite and eternal. Even though parts of the universe may be running down, there will always be other parts in which constructive processes take over, the result being a regenerating universe with no heat death. Contrary to some other advocates of eternalism, Vogt argued for an eternal succession of worlds rather than an endless repetition of the same world: 'An eternal circular course, an eternal coming and going of worlds and, with them, of feeling, thinking and knowing beings.'[64]

Vogt considered the eternal cyclic world to be true by necessity and therefore dismissed physical theories that contradicted it. One of these theories was Clausius's heat death based on the steady increase of entropy. Vogt wrote that the advocates of the entropy law

> quite forget to deliver the proof why this limit state [of maximum entropy] has not been reached a long time ago if the world should be temporally infinite, or ... if all temperature differences in the world should finally be completely equalized, to demonstrate how the necessary factors, which condition the present inequality in heat distribution and the

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[62] Sonnenschmidt 1880, pp. 12-13.

[63] Ibid., p. 9. According to theistic thinking, such premonition is consistent with the power of God. As mentioned in Chapter 4, Gutberlet argued that the definite age of the universe was a sign of divine creation, because it demonstrated God's total freedom.

[64] Vogt 1878, p. 655.

> phenomena of motion, have come into the world and how they can again disappear from it?[65]

That is, rather than use the law of entropy increase to infer a beginning of the world, Vogt used what he considered to be the absurdity of a finite-age world to infer the fallacy of the entropy law ('an empirical speculation', he called it).

In a book of 1891 Vogt developed a speculative theory in which all matter was said to consist of a plenum of force-particles (*Pyknatome*) that pulsated about centres of condensation.[66] He claimed immodestly that all phenomena of inorganic nature could be explained on this basis. Vogt's strange theory of pulsating atoms of matter, as well as other of Vogt's unorthodox ideas, were ignored by the physicists; but they influenced Nietzsche (see below) and also attracted the attention of the famous Jena zoologist and evolutionist Ernst Haeckel.[67] Being a materialist of a kind, Haeckel's philosophy of nature differed considerably from the classical mechanistic materialism of, say, Büchner and Czolbe. In *Natürliche Schöpfungs-Geschichte* (1868) and other works he presented what he called his 'monistic' world view, claimed to be a consequence of the general theory of evolution. His ambition was to turn Darwin's theory into an evolutionary *Weltanschauung*, and he realized that this brought him into conflict with the entropy law and its message that nature is governed by a tendency towards decay. Haeckel claimed a fundamental unity of organic and inorganic nature which he worshipped in a way that had unmistakable traits of pantheism. Indeed, the religious but anti-Christian Haeckel sometimes spoke of pantheism as the religious expression of monism. He believed that he had exorcised the personal God and as a substitute established a new religion founded on monistic philosophy.[68]

Haeckel gave a systematic exposition of his monism in *Die Welträthsel* from 1899, a work which was staggering in its scope, such as indicated by the contents of its four parts, dealing with anthropology, psychology, cosmology and theology – all weaved together in a single world system. Haeckel's book was greatly successful[69] but also greatly controversial, not least because of its sweeping generalizations and aggressive attitude to Christian dogmas in general and Catholic faith in particular; his criticism included rejection of theism, free will and the immortality of the soul. If Duhem supported the independence thesis, Haeckel was an uncompromising

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[65] Ibid., p. 90.

[66] Vogt 1891, which in its expanded edition of 1901 was entitled *Entstehen und Vergehen der Welt als kosmischer Kreisprozess*.

[67] Haeckel 1901, chapter 12, who found Vogt's ideas to be 'sinnreiche'. Karl Pearson was more perceptive, realizing that Vogt was a pseudo-scientist (Pearson 1911, vol. 1, p. 90).

[68] For an in-depth analysis of Haeckel's monistic religion, see Holt 1971. See also the account in Di Gregorio 2005.

[69] *Die Welträthsel* was the spelling of the original edition, whereas later editions were entitled *Die Welträtsel*. By 1919 the book had been translated into 24 languages and the German editions alone had been printed in 340,000 copies. The English edition appeared in 1900 as *The Riddle of the Universe*, translated by Joseph McCabe. According to an anonymous and critical review in *Nature*, the work illustrated 'the sad fact that a great investigator may not be convincing as a philosopher' (vol. 63, 1901, pp. 320-321).

advocate of the conflict thesis. Following Draper and other critics of Catholicism, he repeatedly stressed that the world views of modern science and Christianity were necessarily in contradiction:

> Either the Church wins, and then are … our universities no better than gaols, and our colleges become cloistral schools; or else the modern rational State proves victorious – then, in the twentieth century, human culture, freedom and prosperity will continue their progressive development until they far surpass even the height of the nineteenth century.[70]

He joined with enthusiasm Bismarck's attack on the Catholic church and expressed his support of the *Kulturkampf* as being necessary and justified. Yet he also maintained that monism was not opposed to religion *per se*. In 1906 he founded the Deutschen Monistenbundes (German Association of Monism) as a forum for his version of monism, scientism and anti-Christianity. The organization was located at Haeckel's institute of zoology at Jena University and Haeckel became its honorary president.[71]

Haeckel had a reputation of being a radical or even a revolutionary, but in reality he was a conservative reformer who concealed his liberal-conservative agenda under a smog of aggressive rhetoric.[72] Yet, although he was by no means a Marxist or socialist, *Die Welträtsel* contributed importantly to the ideological debate in Germany and monism was often seen as associated with socialist and other radical ideas. Engels was much influenced by Haeckel's writings, including his *Natürliche Schöpfungs-Geschichte* and *Anthropogenie*. As is evident from Engels's *Dialektik der Natur*, Haeckel served as an important source for his views of Darwinian biology and that in spite of the fact that Haeckel presented Darwinism as contrary to socialism. Many years later, in his *Materialism and Empirio-Criticism* of 1909, Lenin referred approvingly to Haeckel as a potential ally in the class struggle. Whereas he fiercely attacked Ernst Mach, he praised Haeckel for having shown 'the partisanship of philosophy in current society, and the true social significance of the struggle of materialism against idealism and agnosticism.' Haeckel's book, so Lenin wrote, 'became a weapon in the class struggle. The professors of philosophy and theology in every country of the world set about denouncing and annihilating Haeckel in every possible way.'[73]

Haeckel categorically rejected 'cosmological creationism', that is, the divine creation of the world, which he believed was incompatible with the laws of mass and

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[70] Haeckel 1901, p. 457. He referred several times approvingly to Draper 1874.

[71] As a response to the Monistenbund, the biologist Eberhard Dennert established in 1907 the Keplerbund (Kepler Association) for scientists oriented towards a Christian-Evangelical world view.

[72] Di Gregorio 2005, p. 497.

[73] Lenin 1927, p. 358. Although Lenin thought that Haeckel might be used in the class struggle, he realized that Haeckelian monism had almost nothing in common with the scientific world view founded on the philosophy of dialectical materialism. Ironically, some authors have associated Haeckel not with socialism but with fascism (Di Gregorio 2005, pp. 569-71).

force conservation. These two laws he grouped together in what he called 'the law of substance', claimed to be the primary and most fundamental law of all natural, social and spiritual phenomena. In an essay of 1895 he wrote about this 'supreme basic law of the cosmos' as had it the status of either an *a priori* truth or a religious dogma: 'As "matter and energy" are inseparably combined in every thing, so also these two basic "conservation laws" hang together in one law of substance. For the religion of reason of the science of today this law of substance is just as much the immovable foundation stone as the dogma of the "infallibility of the pope" is for the Catholic church of today – the rudest slap in the face for reason.'[74]

Some of the ideas discussed in *Die Welträtsel* can be found much earlier in Haeckel's writings, before he was aware of the second law of thermodynamics. Thus, in the *Natürliche Schöpfungs-Geschichte* he referred enthusiastically to Kant's cosmogony such as expounded in his *Allgemeine Naturgeschichte*. Whereas Kant had been careful not to present his 'cosmological gas theory' (as Haeckel called it) as a purely naturalistic theory, to Haeckel it deserved praise precisely because it was 'purely mechanical and monistic, … and completely rules out any supernatural process, any purposeful and conscious action of a personal Creator'.[75] Yet, in spite of all his praise, Haeckel criticized Kant for having proposed a cosmological scenario which necessitated a first event, namely, the inexplicable initial collision between gas particles that caused the original rotatory motions. Kant had admitted that this first event was of divine origin, a suggestion that Haeckel contemptuously rejected. His creed was this:

> The world is unlimited in space and time, and it is immeasurable. It is eternal and infinite. … The great principles of the conservation of force and conservation of matter, which form the basis of our entire view of nature, allow no other conception. The world, in so far as it is accessible to the capacity of human knowledge, appears as an unbroken chain of material phenomena of motion which causes a continual change in the forms … [but] the matter and its inseparable force remains eternal and indestructable.[76]

Haeckel similarly criticized the distinguished physiologist Emil du Bois-Reymond for having accepted in a lecture of 1894 divine creation an indefinite time ago and thereby, according to Haeckel, having betrayed monistic thinking.[77] This had not always been the opinion of du Bois-Reymond. In 1872 he gave a famous lecture in

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[74] Haeckel 1895, p. 199, as translated in Hiebert 1966, p. 1057. See also Haeckel 1906, p. 40: 'God is the supreme law of nature, the law of substance, and we have thus arrived at the highest pantheistic conception of the idea of God.' Haeckel thought that his grand law of substance was true *a priori*, as it was a necessary consequence of the principle of causality.

[75] Haeckel 1872 (3rd edn), p. 287. Whereas Kant, the cosmogonist, had been ignored in Germany for most of a century, from the 1860s onwards he was turned into a scientific hero. His theory of the universe was praised in particular by materialists and monists, who were pleased to point out that it excluded any direct action on the part of a personal creator. Apart from Haeckel, also Reuschle, Engels, Strauss, Spencer and Huxley sang the praise of Kant's cosmogonical scenario.

[76] Ibid., pp. 288-9.

[77] Haeckel 1901, p. 274. Du Bois-Reymond, 'Über Neo-Vitalismus', reprinted in du Bois-Reymond 1912, vol. 2, pp. 492-515.

Leipzig, 'Über die Grenzen des Naturerkennens', in which he assumed the universe to be spatially and temporally infinite, although containing only a finite amount of matter. Eight years later, in Berlin, he discussed the limits of scientific knowledge and what he called the 'seven world riddles'. As one of the world riddles (*Welträtsel*) he singled out the origin of matter and motion, a problem he took to be transcendent and therefore beyond scientific solution. At that time du Bois-Reymond held that the origin of the universe, if there was one, must be placed infinitely back in time. The only solution he could think of was to introduce a supernatural agent or to assume that matter had always been in motion, and he rejected both possibilities.[78]

As for Haeckel, he saw no reason to introduce a creator, divine or not, for according to true monism motion was an immanent and primary quality in all matter, a claim he believed was confirmed by recent findings in astrospectroscopy. Among the fundamental insights that progress in physics and astronomy had led to, he mentioned that (i) space is infinite and unbounded, throughout filled with an all-pervading 'substance'; (ii) cosmological time is likewise infinite and unbounded, that is, eternal; (iii) the pattern of the cosmic motion of matter in space is an eternal cycle; and (iv) the eternal periodical changes in the world are followed by changes in the condensation state of the world-substance, its composition in ponderable and imponderable (or ethereal) matter. These were Haeckel's assertions, and they should not be confounded with what physicists and astronomers had learned from studying the heavens with their telescopes and spectroscopes. In fact, none of the theses mentioned by Haeckel enjoyed the support of the astrophysicists.

Although machines or other finite things cannot move perpetually, Haeckel believed that 'the entire universe is itself an all-encompassing *perpetuum mobile* … an everlasting "cosmic machine" which keeps itself going in eternal and uninterrupted motion.' It followed that 'the theory of the entropy is refuted.'[79] In an earlier book, *Der Monismus* of 1892, he had stressed that although mortality was an attribute of almost all objects in the universe, the universe itself was immortal. Moreover, he claimed that the conservation laws of matter and energy implied eternity on a fundamental level: 'The cosmos as a whole is immortal. It is just as inconceivable that any of the atoms of our brain or of the energies of our spirit should vanish out of the world, as that any other particle of matter or energy could do so. At our death there disappears only the individual form on which the nerve-substance was fashioned, and the personal "soul" which represented the work performed by this.'[80] A few years later radioactivity and Einsteinian mass-energy transformation proved that matter and energy can in fact 'vanish out of the world'. But Haeckel ignored the revolution in physics that occurred during the decade following the publication of *Die Welträtsel*.

Haeckel was neither the first nor the last to conceive the universe as analogous to a *perpetuum mobile* machine. So did Otto Caspari in the 1870s and Walther Nernst as late as in the 1930s. Everybody agreed that it was impossible to construct a finite

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[78] 'Die sieben Welträthsel' in du Bois-Reymond 1912, vol. 1, pp. 65-98. The impact of du Bois-Reymond's lectures on the limits of science is discussed in Vidoni 1991.

[79] Haeckel 1901, p. 285.

[80] Haeckel 1892, as quoted in Di Gregorio 2005, p. 491.

machine working eternally, but advocates of the cyclic universe maintained that the impossibility enshrined in the first law of thermodynamics could not be transferred to the universe at large. 'We can in no way agree with the views of our famous physicists', wrote the author Carus Sterne in 1876. 'If inferences to the past of the world are already difficult, those directed at the future are even worse. What is impossible in the laboratory, need not be so in the universe.'[81] According to Oswald Köhler, a German amateur astronomer, the universe was indeed 'the true and unique *perpetuum mobile*'. It was, Köhler wrote, 'like a clock that was never wound, that has run for all eternity and will run for all eternity'.[82] Although parts of the cosmic machinery would continually break down here and there, at other places it would be repaired with the same speed, leaving the universe as a whole in an eternal state of equilibrium. Köhler believed that the infinite universe was in a steady state and that this was a necessary consequence of the indestructability of matter and the eternity of time.

To return to Haeckel, he concluded that the two laws of thermodynamics were contradictory, and since energy conservation was beyond doubt – it was a central part of the grand law of substance – the law of entropy must be wrong. His argument was that the first law led necessarily to an eternal world, whereas the second law led to both a beginning and an end of the world:

> If the theory of entropy were true, the mentioned 'end of the world' should also correspond to a 'beginning' of the world, a [state of] *minimum entropy* in which the temperature differences between the separate parts of the world were maximally large. Both notions are equally untenable according to our monistic and strictly consistent conception of the eternal cosmogonical processes; both of them contradict the concept of the substance. There is no beginning of the world, just as there is no end. Just as the universe is infinite, so it remains in eternal motion; living force is continually transformed into tensional force and vice versa, and the sum of the actual and potential energy remains constant. … The second law of the mechanical theory of heat contradicts the first law and must be abandoned.[83]

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[81] Sterne 1876, p. 465. Carus Sterne (a pseudonym for Ernst Krause) was a materialist writer and early supporter of Darwinian evolutionism. After having received a doctorate in botany, he founded in 1877 the journal *Kosmos*, co-edited by Otto Caspari and Gustav Jäger. The subtitle of the first issue referred specifically to the two gurus of evolutionism: *Zeitschrift für einheitliche Weltanschauung auf Grund der Entwicklungslehre in Verbindung mit Charles Darwin und Ernst Haeckel*. The journal became a vehicle of Haeckel's 'scientific Darwinism' and other parts of the monistic-materialistic world view, including anti-clericalism and anti-Christianity.

[82] Köhler 1895 (3rd edn), p. 380. Köhler relied in part on Klein 1870, another exposition of a materialistic cosmology, although one that focused on the natural history of the solar system, the Earth and its living species ('organogenesis' in Klein's terminology). As a counterargument against Köhler and Haeckel, J.A. McWilliams (1939, p. 41) contended that even though the universe might be a perpetual motion machine, this would only prove that it was supernaturally created.

[83] Haeckel 1901, p. 286.

As late as 1914, in a booklet with the characteristic title *Gott-Natur*, the 80-year-old Haeckel portrayed the universe as a 'perpetual cosmic cycle'.[84]

A cyclic and eternal universe was also the theme of Köhler's *Weltschöpfung und Weltuntergang*, a book that appeared in four editions between 1887 and 1896. Köhler was a materialist who believed that the matter of the universe could not possibly have been created, but contrary to other materialists and monists he seems to have accepted the global consequences of the second law of thermodynamics, including the entropic beginning. But how can a beginning of the universe be made to agree with eternally existing matter? According to Köhler the answer was eternal recurrence. The world began its evolution in a gaseous state and would approach a cold and dark end state, but 'before the gaseous state the matter of the universe existed in another state, and after the dissipation of heat and cooling of the hot celestial bodies yet another state will arrive.'[85] There would be an end of the world, a state of very high entropy, yet it would only be a prelude to a new world; and the beginning of the present evolution was preceded by the end of an earlier world. The heat death was not absolute or irreversible, it was no real death but rather a state of suspended animation.

Köhler speculated that collisions between stars, or between entire nebulae, might produce the free energy necessary to revive the apparently dead universe:

> The universe is guaranteed an eternal course due to the distances of its masses from one another and their mutual lack of connection, [and] to its infinite extension and the laws that ultimately permit that motion is turned into new heat and new dissemination of matter. The best proof of the eternal, immortal life of the universe is however to be found in the fact that the world has not yet suffered the heat death of the physicist Clausius.[86]

As Köhler saw it, the recurrent universe was the only escape from the unacceptable assumption of a divinely created world. 'The question of the cosmic thermo-physical cycles is closely connected with the question of the existence of God,' he wrote. And God was nothing but 'a product of humans' imagination'.[87] Cyclic or eternal cosmologies appealed to many materialists not only because of their godlessness but also because they nourished the hope of everlasting life and progress. Köhler, on the other hand, flatly denied that the universe had any purpose or that human life was of any particular significance in the evolution of the cosmos. Our world would come to an end, and with it all civilizations; a new world would be born from the ashes, and new civilizations eventually evolve. But there would be no connection between the two, no awareness of previous civilizations. For this reason, in Köhler's cosmology progress was limited to a particular world cycle.

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84 Haeckel 1914.
85 Köhler 1895, p. 372.
86 Ibid., p. 380.
87 Ibid., p. 442 and p. 50.

Neo-Romanticism

The materialistic movement in Germany and elsewhere was to some extent a revolt against romanticism and the influence of spiritual, idealistic and religious thinking in science. But the movement evolved in diverse and strange ways, so that, by the end of the century, some versions appeared in decidedly anti-materialistic philosophies. Haeckel's monism belonged to this category. As David Knight, Stephen Brush and others have pointed out, positivism and *Naturphilosophie* were really not too remote from one another.[88] What materialism, positivism and monism had in common was not a mechanistic or materialistic world view, but rather scientism and opposition towards established religion. Whether justified or not, many contemporary observers saw a connection between the materialists and the later schools of positivism and monism. As mentioned in Chapter 4, Maxwell sometimes spoke about materialism and positivism as were they the same. Johannes Reinke, a professor of botany at the University of Kiel, noted that 'even though monism may in theory resist materialism, in practice it is a continuation of it.'[89]

The romantic or neo-romantic features of positivism appeared clearly in the energetics movement which under the leadership of Wilhelm Ostwald and Georg Helm became an important part of German scientific and cultural life at the end of the century. Although primarily German, its influence extended to other countries, including France, Italy, Sweden and the United States. Not only was the movement opposed to mechanicism and atomism, it was also anti-materialistic, such as epitomized by Ostwald's address at the Lübeck meeting of the German Association of Natural Scientists and Physicians in 1895, where he engaged in a famous controversy with Boltzmann over the existence of atoms and the foundation of thermodynamics.[90] The title of Ostwald's programmatic address was 'Die Überwindung des wissenschaftlichen Materialismus'. The ambitious aim of Ostwald and his allies was to rid science of visualizable hypotheses and analogies with mechanics, to construct an alternative *hypothesenfreie Wissenschaft*.[91] In this process, thermodynamics was perceived to be particularly important, as it functioned as a paradigm of a theory which was neutral as to the constitution of matter – indeed which did not rely on the concept of matter. Like the *Naturphilosophen* of earlier generations, the energetics movement stressed the notion of unity in science, in this case based on energy rather than the vague concept of 'force'. Ostwald even founded a journal which he, with an evident allusion to the romantic era, called *Annalen der Naturphilosophie*.

Ostwald's conception of the second law differed substantially from the one held by Planck and Boltzmann. He considered it to be a law of reversible processes only,

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88 Knight 1967; Brush 1978, pp. 92-6; Barton 1987, pp. 122-4. See also Holt 1971 who objects to the common view that Haeckel's monism was basically materialistic. On the contrary, 'German materialism was transformed by Haeckel into an idealistic and semi-vitalistic system quite opposite its origins' (p. 267).

89 Reinke 1899, p. 449. The message of Reinke's book was that modern science leads to theism, whereas atheists are unable to fully understand nature.

90 Hiebert 1971. See also Loria 1918.

91 Ostwald 1902, a work dedicated to Mach.

and its main function to tell whether something happens or not. It was 'das allgemeine Gesetz des Geschehens'.[92] According to Ostwald, the law of entropy increase, or the dissipation of energy, had nothing to do with the second law of thermodynamics (a claim that surely will puzzle a modern physicist). Although Ostwald and Haeckel had much in common, there were also differences between the systems of energetics and monism. As Haeckel pointed out, the supreme law of substance combined matter and force, whereas Ostwald's 'dynamicism' one-sidedly gave priority to force over matter. In this respect, Ostwald was closer to the *Naturphilosophen* than Haeckel was.

Whereas Ostwald showed no interest in cosmology and was not involved in the entropic-cosmological debate, in his *Die Philosophie der Werte* from 1913 he did comment on the 'icy death' that threatened life in the future. He found the prospect threatening but also fascinating, as it would constitute a 'spiritual and moral revolution' of the same magnitude as the one initiated by Copernicus. The coming revolution in thought was opposed to religion, for according to Ostwald the heat death showed that 'the final goal of the sum of all human work is to be found in man himself.'[93] Although Ostwald was anti-religious, he considered science in the elevated form of energetics or monism to be a legitimate *Ersatzreligion* which one day would replace Christianity and other theistic religions. Indeed, in 1913 he wrote that the principal task of monism was to free science 'from the hitherto existing influence of the priesthood, and to establish in place of the traditional ethics dependent on revelation a rational scientific ethics, based on facts.'[94] No wonder that Catholic theologians were eager to counter the influence of energetics and to maintain the superiority of the neo-scholastic world view.[95]

Energetics, monism and positivism were related ideologies of science that exerted strong influence in German and French scientific life. British physicists and chemists, on the other hand, had little sympathy for the abstract, anti-metaphysical and fact-oriented view of science championed in different ways by Mach, Duhem and Ostwald. Nor had they any sympathy for the anti-religious tendencies found in Germany. In a critical comment on Ostwald's energetics programme, the Irish physicist George Francis FitzGerald distinguished between the metaphysically receptive British style and the unphilosophical German style: 'The view of science which he [Ostwald] puts forward – a sort of well arranged catalogue of facts without any hypotheses – is worthy of a German who plods by habit and instinct. A Briton wants emotion – something to raise enthusiasm, something with a human interest. He is not content with dry catalogues, he must have a *theory* of gravitation,

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92 'Die philosophische Bedeutung des zweiten Hauptsatzes', pp. 64-80 in Ostwald 1912, on p. 70. See also Leegwater 1986. On the differences between the views of Ostwald and Planck, see Niedersen 1986; and on Helm's conception of the second law, which roughly agreed with Ostwald's, see Deltete 2005.

93 Ostwald 1913, p. 98.

94 Quoted in Hiebert 1966, p. 1062. On Ostwald's scientism and quasi-religious monism, see Hakfoort 1992.

95 On the relationship between energetics and neo-scholasticism, as perceived by a leading Catholic philosopher, see Nys 1911-12.

a *hypothesis* of natural selection.'[96] The battle-cry for emotions and actions was repeated by French neo-romanticists, who also contrasted their style with that of the supposedly unimaginative Germans. At the same time, they objected to the British style in physics, which they found too mechanistic and lacking in *esprit*.

By the turn of the century, the ideological aspects of natural philosophy and foundational science had changed considerably from what they were twenty years earlier.[97] Anti-materialism was as popular as ever, but now a strong rival to energetics had appeared in the form of the electromagnetic or etherial world view. The essence of this view of nature was the belief that the electromagnetic ether was the ultimate reality of the world; it was the stuff out of which electrons and material atoms were formed and to which they would eventually return.[98] The way in which Ostwald and his energeticist allies spoke of 'matter as subordinate to energy' was strikingly similar to the rhetoric of the electrodynamicists who wanted to reduce matter to ether and electricity. In both cases materialism was discarded and matter declared an epiphenomenon.

Oliver Lodge, physicist and spiritualist, was the best known of the British popular advocates of the electromagnetic ether, but I shall here call attention to the less well known Georg Wilhelm de Tunzelmann, a London physicist and engineer. In a book of 1910, Tunzelmann argued that an eternal, self-maintaining universe was irreconcilable with the law of entropy; moreover, he suggested that this law was a consequence of the molecular constitution of matter, and hence practically a certainty:

> The hypothesis of a universe without intelligent formative or directive power therefore leads of necessity to the conclusion that it has a beginning in time, and that it must come to an end in what we may call physical death. This state will be attained when all its organised, or available, energy has been transformed into a uniform distribution of unorganised energy, when physical change of every kind must cease. The advocates of this hypothesis are then confronted with the problem of the creation of a universe in the absence of creative intelligence.[99]

Although the argument may look like the traditional theistic creation argument, Tunzelmann did not conclude that a transcendent and omnipresent God had to be introduced. He preferred to speak of an all-pervading, universal *mind* which he likened to a refined and even more fundamental entity than the ether. This universal

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96 FitzGerald 1896, p. 442.

97 On *fin de siècle* attitudes in and to the physical sciences, see Heilbron 1982 who notes the presence of 'thermodynamic eschatology' as an element in the period's world view (p. 60).

98 The ether-based electromagnetic world view existed in several versions. For an introduction to its wider implications, including references to the literature, see Kragh 1997 and Kragh 1999, pp. 105-19. Although thermodynamics and the new electron theory were generally seen as belonging to different realms of science, some physicists suggested links between them. H.L. Callendar (1912) thought that entropy might be understood as a kind of matter made up of positive and negative electrons in union, a picture that Nernst and others had suggested for the ethereal medium.

99 Tunzelmann 1910, p. 451.

mind he considered as an extension of the human mind, and for this reason without the power of creating or destroying energy. Therefore, Tunzelmann's argument did not provide a proof of the creation of the universe, 'but only of its formation, or building up, from the material available, the total energy-content'.[100] In this respect, his argument did not differ from the entropic creation argument, which, as we have seen, also started from a pre-existing universe of matter and energy.

As an example from Germany, consider the Berlin physicist Bernhard Weinstein who in 1911 published a book on the foundations of physics. Weinstein felt attracted to monism, but not in Ostwald's energeticist form of 'materialistic-mechanical monism'. He preferred the alternative of what he called psychical or spiritual monism, a view which he associated with Spinozist pantheism and according to which the mind was the basis of all phenomena. Among the subjects that Weinstein dealt with was the heat death, which 'has frightened so many people – what kind of world would it be without the wonderful light from the heavens!'[101] After having reviewed the possibilities that the heat death may not occur, he concluded that there is nothing to prevent the finite, material universe from the entropic end. He speculated that perhaps the end of the material world would result in a complete transformation of matter into a uniform sea of ether; and perhaps, by means of an as yet unknown mechanism, the ether might subsequently re-condense into particles of matter. However, he was enough of a physicist to realize that the speculation had no basis in science.

'All of life is a fight against the entropic death', Weinstein declared, and it was a fight that life, in so far as it is a manifestation of matter, was doomed to lose. However, as seen from Weinstein's monistic-spiritual point of view, the end of organic life might not be the end of the living universe. He suggested that 'psychical energy' was even more primary than heat and ether, and that a maximum-entropy world would ultimately consist of such energy. 'That would correspond to the Indians' thoughts of Brahma and Buddha's nirvana. Would we call such an end in an absolutely spiritual being death? Certainly not death, but probably a dreamless sleep from which there is no awakening.'[102] Weinstein further reasoned that if the world comes to an end, it must have a beginning. His argument differed from the standard entropic argument still discussed in German Catholic circles:

> The world cannot emerge by itself from the entropic death. If the world, understood as matter, substance or energy, is finite, ... the entropic death must occur within a finite time. But then the world, and its processes in particular, must also have begun a finite time ago. This cannot have happened by itself, ... [and] a supernatural cause must consequently have been active. If one is forced to admit such a cause in the beginning, one can also let it govern the end, so that a beginning follows the end, and so on in all eternity.[103]

That is, if God is called into action to create the world, or to start the entropic clock, why not let him perform his cosmic miracle more than once? Why not an infinite

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100 Ibid., p. 497.
101 Weinstein 1911, p. 243.
102 Ibid., p. 272.
103 Ibid., p. 248.

number of times? Weinstein did not accept the theistic version of the entropic argument, but he did agree that the beginning of the universe was no less a problem of science than the end of it. ‘As far as I can see, only Spinozist pantheism, among all philosophies, can lead to a satisfactory solution’, he wrote.

Degeneration, either in a biological or psychological sense, was an important theme in *fin de siècle* ideology and much discussed in cultural, literary and artistic circles. Some writers suggested that degeneration and decadence were related to the period’s neo-romantic style in art and science. Occasionally inorganic decay as expressed in the law of entropy increase was associated with the general feeling of degeneration. ‘The second law of thermodynamics was the most powerful figuration of degeneration that the nineteenth century proposed’, says a modern commentator.[104] However, although one can find proposals that social decline and racial degeneration were connected with entropic decay, such ideas were rare. Entropy may have been a ‘powerful figuration of degeneration’, but its real role in the degeneration ideology was limited.

Socialists and Speculators

Energy and entropy considerations were not only part of the philosophical and religious battlefield in Bismarck’s new Germany, they also played a role in political ideology, if only indirectly. Eugen Karl Dühring, an amateur physicist, economist and philosopher in the materialist tradition, practised law in Berlin until he lost his eyesight and then became *Privatdozent* at the university of Berlin. However, his position was terminated because of a quarrel with the professoriate and in 1877 he was forced to retire. After that time he worked as lecturer at a *Gymnasium* and subsequently as a private scholar. Dühring published in 1872 a valuable work on the historical development of mechanical physics which also covered the history of the mechanical theory of heat. In this work he stated that ideas of infinite space and mass were contradictory and therefore must be excluded from physics.[105] His philosophy of nature and reality was a mixture of Kantianism, materialism and positivism, and in spite of the primacy he gave to matter it included idealistic and teleological elements as well. While admitting that the future development of the world was probably beyond human knowledge, Dühring thought that with the passage of time the motion of matter would give rise to genuinely new forms. However, since he believed that the number of possible changes is finite, there must be either an eternal recurrence of the world process or an end to it.

In 1875 Dühring turned to socialism and started developing his own radical and non-Marxist version of a socialist world view, natural philosophy included. Although an uncompromising atheist – religion was a pathological state, ‘a cradle of delusions’ – he argued in a book published the same year, *Cursus der Philosophie*, that the universe might well have had an origin in time, at least of a kind. According

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[104] Chamberlin 1985, p. 272. On degeneration as a theme in *fin de siècle* thinking, see Brush 1978, pp. 103-20.

[105] Dühring 1877 (2nd edn), p. 469. For a contemporary analysis of Dühring’s philosophy, see Vaihinger 1876.

to Dühring's 'law of definite numbers' no reality could be ascribed to infinitely large quantities. The universe can only contain a finite number of objects, he stated, and the real, matter-filled space must be limited. Dühring believed that a completed or actual infinity was an inadmissible contradiction, whereas a potential or incompleted infinity was not. In this way he introduced an asymmetry between past and future durations: the world was finite in past time, but infinite in future time.

> The number of the Earth's revolutions round the Sun up to the present time must be a finite number, even though it cannot be stated. … It follows with undeniable necessity from the law of the definite numbers that all periodical processes of nature must have had some beginning, and that all differentiation, in so far as it succeeds in producing a series of different realities, points back to a first term for every species. All the multifariousness of nature which appears in succession must have its roots in one self-equal state.[106]

This was a most unusual view for a materialist and socialist. As to the original or self-equal state of the world (*einem sich selbst gleichen Zustand*), Dühring explained that it was 'an unchanging existence of matter which comprised no accumulation of changes in time'.[107] The original world-state was timeless but contained within it the potentiality of transforming into a rhythmical series of processes. Dühring's arguments were not very clear. He was careful not to speak of a creative act, and in fact denied that the world had an actual beginning. But he also maintained the world's finitude in past time and said that the self-equal state could not be in complete equilibrium, since such an equilibrium state could not by itself give way to an active world. Although he admitted the possibility that the world might return to a self-equal state in the far future, he did not endorse the idea of such an end and in fact denied that a world catastrophe would ever occur. In his book of 1875 he dealt with the cosmic consequences of the first law of thermodynamics, but had nothing to say about the second law.

Apparently Dühring was unwilling to ascribe physical reality to space itself and he rejected the 'wild ideas of the spatially infinite reality' that he found in Spinoza and some other thinkers. Whereas the abstract empty space might be unlimited and infinite, his *Wirklichkeitsphilosophie* told him that the same was not the case with the material universe. He was aware of the contemporary discussion of non-Euclidean geometries, but scornfully dismissed these ideas as 'mathematical mysticism', even 'religious stupidity'. Gauss, in particular, raised his anger. He attacked the great mathematician – this 'son of a bricklayer' – for having seriously proposed that the curvature of space might be detected by means of geodetic measurements. This, he thought, was 'either a bad joke or a sign of madness'.[108]

Eugen Dühring would probably have remained an unwritten chapter in the history of ideas had Friedrich Engels not devoted an entire book to refute his views of science, history and society. Marx and Engels, who had at first ignored Dühring, came to the conclusion that his views were too popular in radical circles to remain unchallenged. Within the Social Democratic party Dühring enjoyed a certain popularity and his

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106 Dühring 1875, pp. 64-5; Engels 1975, p. 62. See also Small 2001, pp. 22-6.

107 Dühring 1875, p. 79; Engels 1975, p. 69.

108 Dühring 1875, p. 67. Gauss died in 1855.

views were much discussed at the socialist congress in Gotha in May 1877. A series of articles on Dühring and his ideas that appeared in the *Berliner Freie Presse* in the fall of 1876 convinced Marx and Engels that they had to take action.[109] The job of exposing Dühring's erroneous ideas, including his 'bumptious pseudo-science', was left to Engels whose *Anti-Dühring* appeared in 1878.[110] Of interest in the present context is Engels's sharp rejection of Dühring's suggestion of a primordial self-equal state with a suspicious similarity to a cosmic beginning. To Engels and most other socialist thinkers, this was an unacceptable view because it left the door open for this most un-socialist of beings, the creative God:

> If the world had ever been in a state in which no change whatever was taking place, how could it pass from this state to alteration? The absolutely unchanging, especially when it has been in this state from eternity, cannot possibly get out of such a state by itself and pass over into a state of motion and change. An initial impulse must therefore have come from outside, from outside the universe, an impulse which set it in motion. But as everyone knows, the 'initial impulse' is only another expression for God. God and the beyond, which in his world schematism Herr Dühring pretended to have so beautifully unrigged, are both introduced again by him here, sharpened and deepened, into natural philosophy.[111]

Together with *Dialektik der Natur*, a collection of fragmentary notes written in the period 1872-82 but only published in 1927, *Anti-Dühring* became the foundation of the dialectical natural philosophy that came to serve as an important part of the communist world view. It was a central doctrine of Engels's philosophical system that matter was uncreatable as well as indestructible. Since he also believed that matter was necessarily coupled with motion (understood in a general sense), it followed that motion could neither be created nor destroyed. Engels, who had a broad if somewhat superficial knowledge of science, was early on acquainted with the new mechanical conception of heat which he knew from Grove's *Correlation of the Physical Forces*. He had read Helmholtz's *Ueber die Erhaltung der Kraft* and *Populäre wissenschaftlicher Vorträge* and also Ernst Mach's work of 1872 on the history of the principle of energy conservation. From about 1868 he was aware of Clausius's formulation of the laws of thermodynamics, including the alarming heat death scenario. He had also read, if not necessarily understood, Clausius's *Über den zweiten Hauptsatz der mechanischen Wärmetheorie* (1867) as well as some

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[109] Liedman 1977, vol. 2, pp. 198-220. Although Dühring did not consider himself a socialist, but rather an independent social and economic reformer, he was widely seen as belonging to the socialist camp. For a brief period his views were considered a serious alternative to Marxism.

[110] Engels 1975, p. 11, who complained that Dühring 'speaks of all possible things and some others as well' (ibid., p. 389). The book originally appeared in serialized form in the Social Democratic newspaper *Vorwärts*. For historical background on Engels's works in philosophy of science, see Sheehan 1993 and Robert Cohen's entry in *Dictionary of Scientific Biography* (supplement volume). See also www.marxists.org/archive/marx/index.htm.

[111] Engels 1975, p. 68. Unsurprisingly, Lenin fully agreed with Engels. According to Lenin, Dühring's embarrassing acceptance of a cosmic beginning was rooted in his failure to recognize the objectivity of space and time. Lenin 1927, p. 169.

other works on thermodynamics. These included Maxwell's *Theory of Heat* and Fick's *Die Naturkraefte*, the work in which the entropic creation argument was first formulated.[112]

In a letter to Marx of 21 March 1869 Engels expressed his intense dislike of the idea of an ever-increasing entropy and its long-term consequences. The letter is worth quoting at some length. Without explicitly referring to Clausius's entropy, Engels started with his own version of the heat death:

> In Germany the conversion of the natural forces, for instance, heat into mechanical energy, etc., has given rise to a very absurd theory, which incidentally follows with a certain inevitability from Laplace's old hypothesis, but is now displayed, *as it were*, with mathematical proofs: that the world is becoming steadily colder, that the *temperature* in the universe is levelling down and that, in the end, a moment will come when all life will be impossible and the entire world will consist of frozen spheres rotating round one another.

This new rage in German intellectual life was not only scientifically ridiculous, it was also ideologically dangerous:

> I am simply waiting for the moment when the clerics *seize upon* this theory as the last word in materialism. It is impossible to imagine anything more stupid. Since, according to this theory, in the existing world, more heat must always be converted into other energy than can be obtained by converting other energy into heat, so the original *hot state*, out of which things have cooled, is obviously inexplicable, *even contradictory*, and thus presumes a God. Newton's first impulse is thus converted into a first heating. Nevertheless, the theory is regarded as the finest and highest perfection of materialism; these gentlemen prefer to construct a world that begins in nonsense and ends in nonsense, instead of regarding these nonsensical consequences as proof that what they call natural law is, to date, only half-known to them.[113]

As the socialist Engels saw it, irreversibility was incompatible with dialectical materialism, a philosophy that required eternal recurrence as a fundamental pattern of nature. 'The eternally repeated succession of worlds in infinite time is only the logical complement to the co-existence of innumerable worlds in infinite space', he wrote in *Dialektik der Natur*.[114]

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112 For an extensive discussion of Engels's readings and the roots of his dialectical philosophy of nature, see Liedman 1977. See also Reiprich 1969 and Gemkow et al. 1970, pp. 430-52.

113 *Marx-Engels Collected Works*, vol. 43, p. 245. Here quoted from the website www.marxists.org/archive/marx/index.htm. It would seem that Engels had not yet grasped the true meaning of the second law and the heat death. Also his association between the heat death and materialism is surprising.

114 Engels 1940, p. 24. Engels referred to Draper, who in the *History of the Intellectual Development of Europe* (1864) had written, 'The multiplicity of worlds in infinite space leads to the conception of a succession of worlds in infinite time' (vol. 2, p. 325, as quoted by Engels). As mentioned, a similar passage appeared in Draper's *History of the Conflict between Religion and Science*.

Engels considered the law of entropy increase to be ideologically dangerous because of its association with creation, miracles and theism. 'Clausius – if correct – proves that the universe has been created, *ergo* that matter is creatable, *ergo* that it is destructible, *ergo* that also force, or motion, is creatable and destructible, *ergo* that the whole theory of the "conservation of force" is nonsense, *ergo* that all its consequences are also nonsense.'[115] Contrary to many other critics of the second law and its cosmological implications, by 1880 Engels had a fair understanding of the qualitative meaning of the law. But he concluded that it must be wrong because of its absurd consequences:

> Clausius' second law, etc., however it may be formulated, shows energy is lost, qualitatively if not quantitatively. *Entropy cannot be destroyed by natural means but it can certainly be created*. The world clock has to be wound up, then it goes on running until it arrives at a state of equilibrium from which only a miracle can set it going again. The energy expended in winding has disappeared, at least qualitatively, and can only be restored by an *impulse from outside*. Hence, an impulse from outside was necessary at the beginning also, hence, the quantity of motion, or energy, existing in the universe was not always the same, hence, energy has been artificially created, i.e. it must be creatable and therefore destructible. *Ad absurdum*![116]

Whereas Clausius and Thomson had rejected eternal recurrence as incompatible with the second law of thermodynamics, Engels was deeply committed to the idea. He believed that in the future science would demonstrate that 'the heat radiated into space must be able to become transformed into another form of motion, in which it can once more be stored up and rendered active.'[117] As others had done before him, he speculated that dead stars would sooner or later collide with one another and produce an enormous heat energy that locally would lower the entropy and restart evolutionary processes. The Sun would eventually complete its life history and die, and the same would happen for the other stars, yet the universe would remain alive for ever:

> It is an eternal cycle in which matter moves, ... a cycle in which every finite mode of existence of matter, whether it be sun or nebular vapour, single animal or genus of animals, chemical combination or dissociation, is equally transient, and wherein nothing is eternal but eternally changing, eternally moving matter and the laws according to which it moves and changes. But however often, and however relentlessly, this cycle is completed in time and space; however many millions of suns and earths may arise and pass away, …we have the certainty that matter remains eternally the same in all its transformations, that none of its attributes can ever be lost, and therefore, also, that with the same iron necessity that it

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115 Engels 1940, p. 205. On Engels and the second law, see also Treder 1971. Writing in the happy days of the German Democratic Republic, Treder praised Engels's 'enormous intellectual capacities' and claimed that he had arrived at the correct, statistical conception of the second law many years before it was accepted by the physicists.

116 Engels 1940, p. 216.

117 Ibid., p. 23.

> will exterminate on the earth its highest creation, the thinking mind, it must somewhere else and at another time again produce it.[118]

His belief that the universe *in toto* was a *perpetuum mobile* was no less firm than Haeckel's, and no less lacking in scientific justification. The second law of thermodynamics was apparent only, it was a paradox in need of a solution. Although the problem of 'the apparently lost heat' had not yet been solved, 'it will be solved, just as surely as it is certain that there are no miracles in nature and that the original heat of the nebular ball is not communicated to it miraculously from outside the universe'.[119]

Engels' rejection of the heat death and the finite universe was closely connected with his militant atheism and anti-clericalism. He subscribed uncritically to the conflict thesis and regarded Christianity as an enemy of science to no less an extent than John Draper did in his contemporary *History of the Conflict between Religion and Science*. He was convinced, though, that materialistic science was on its way to winning the struggle:

> God is no where treated worse than by the natural scientists who believe in him. … Newton still allowed him the 'first impulse,' but forbade him any further interference in his solar system … Secchi only allows him a creative act as regards the primordial nebula. … And finally Tyndall totally forbids him any entry into nature and relegates him to the world of emotional processes. … What a distance to the old God – the creator of heaven and earth, the maintainer of things – without whom not a hair can fall from the head.[120]

In *Ludwig Feuerbach*, a book published in 1886, he reflected on the relation of thinking and being, or what he called the relation of spirit to nature, and he expressed the central problem as follows: 'The question: which is primary, spirit or nature – that question, in relation to the Church was sharpened into this: Did god create the world or has the world been in existence eternally?'[121] Engels's view on the second law and the structure of the universe was more than just a curious episode in the history of nineteenth-century science. It became part of the doctrines of dialectical materialism and thereby incorporated in the official philosophy of nature that dominated much thinking in the Soviet Union and other communist countries through a good deal of the twentieth century. The view cast long shadows, such as I shall return to in Chapter 7.

Dühring and Engels were not the only early socialist thinkers who occupied themselves with questions of speculative cosmology. So did Louis-Auguste Blanqui, the French revolutionary activist and utopian communist. Blanqui spent the years

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118 Ibid., p. 25. In his notes to the English edition of *Dialectics of Nature*, published 1940, the English biologist and Marxist John B.S. Haldane suggested that Engels would have welcomed the cosmological theory developed in the 1930s by Edward Arthur Milne. Given that Milne's cosmology was of the Big-Bang type and Milne explicitly used it in support of his Christian belief, Haldane's suggestion is unconvincing. On Haldane's and Milne's cosmological views, see Kragh 2004.

119 Engels 1940, p. 202.

120 Ibid., p. 200.

121 As quoted in Wetter 1953, p. 281.

1871-79 in prison, and during his first year of imprisonment he wrote a small book entitled *L'éternité par les astres* which appeared in print 1872.[122] Unsurprising for a socialist and atheist, Blanqui was a committed infinitist. As he wrote in the very beginning of his work: 'The universe is infinite in time and space, eternal, unborn and indivisible. … The universe is a sphere with its centre everywhere and its surface nowhere. … Surely, the infinite universe is incomprehensible, but the limited universe is absurd.'[123] Blanqui not only defended an eternal cyclical universe, he also claimed that it was recurrent in the strong sense that every single event in history would endlessly repeat itself; in fact, at any given moment in time there would be exact replicas of any number of human individuals elsewhere in the infinite universe, all of them performing the same actions and thinking the same thoughts. His cosmic scenario, based on speculations rather than science, was this:

> The universe is at the same time life and death, destruction and creation, change and stability, tumult and rest. It comes about and dissolves without end, it is always the same, with all beings forever rejuvenated. In spite of its perennial becoming it is cast in bronze, and prints incessantly the very same page. Both in its details and entirety, it is transformation and immanence for eternity.

It is to be noted that Blanqui advocated a universe which was spatially and materially infinite as well as eternally recurrent. These two properties are not easily reconcilable, for how can an infinity of atoms reconfigure within a cycle of finite period?[124]

Blanqui apparently based his belief in strict recurrence on the fact that there is only a limited number of ultimate building blocks in the form of the atoms of the sixty-four chemical elements known at the time. Inevitably, in a materially homogeneous and infinite universe atoms must combine in identical structures, and they must do so an infinite number of times. Matter, he stated, 'does not issue out of nothing, nor can it return there. Matter is eternal, imperishable. Although on a perpetual course of transformations, it cannot diminish or increase by as much as an atom.'[125] Blanqui was clearly a dilettante in matters of science, yet he claimed immodestly that his cosmic speculations were strictly scientific, 'a simple deduction from spectral analysis and from Laplace's cosmology'. Although he did not mention the second law of thermodynamics, he did refer, if somewhat obscurely, to the tendency of energy dissipation and its unacceptable implications. Somehow the energy must be reconcentrated, and he claimed that this was possible by means of

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[122] Blanqui 1872. For comments, see Jaki 1974, pp. 314-9. As Jaki points out, it is something of a puzzle why Blanqui wrote the book, which seems unconnected with – and in some respects even contradictory to – his political philosophy.

[123] I quote from the unpaginated online version www.marxists.org/francais/blanqui/1872/astres.htm.

[124] As Delevsky emphasizes: 'The idea of eternal recurrence is essentially based on the consideration that the number of possible combinations is finite and exhaustive, or that the duration of their getting together is finite.' In spite of this insight, he claims that Blanqui's speculation was characterized by 'an impeccable logic'. Delevsky 1946, p. 401 and p. 396.

[125] As we have seen, Maxwell, Wurtz and Secchi saw in the identity and permanence of atoms a sign of divine creation. Blanqui, and later some other materialist thinkers, interpreted the same phenomenon as proof of an eternal, godless universe.

the gravitational energy involved in the collision of dead stars. If Blanqui was aware of the entropic creation argument, which is doubtful, he did not mention it. At any rate, he took it as an axiom that the universe could not possibly have come into existence a finite time ago.

In the same period when Engels wrote down his notes for a dialectics of nature, another German thinker, Friedrich Nietzsche, took up an interest in the sciences, primarily physics and evolutionary biology.[126] Nietzsche was particularly interested in the cosmological consequences of the laws of thermodynamics, which he had read about in works of Vogt, Caspari and Zöllner. Having read Vogt's *Die Kraft*, he summarized the work in the message that the only alternative to the cyclic universe was the belief in God.[127] By 1882 he had perused Mayer's *Die Mechanik der Wärme*, which he did not appreciate, suspecting Mayer to be a materialist *and* a theist. As he wrote in a letter: 'Ultimately even Mayer has a second force in the background, the *primum mobile*, God – besides motion itself. And he certainly needs God!'[128]

Nietzsche was also familiar with Dühring's writings, including his *Cursus der Philosophie* which he thoroughly disliked (he seems to have been unaware of Engels's *Anti-Dühring*). While he accepted Dühring's claim of a materially finite world he denied the finitude of past time, in part because of its association with the 'absurd' notion of a created world. Concerning the beginning of the world, he wrote: 'I have come across this idea in earlier thinkers: every time it was determined by other ulterior considerations (mostly theological), in favour of the *creator spiritus*.'[129] Nietzsche had read the astrophysicist K.F. Zöllner's *Über die Natur der Cometen*, a work that influenced his thinking about a final state of the universe. In a note he wrote in 1882, this influence is particularly clear: 'Only with the false assumption of an infinite space, in which force evaporates, so to speak, is the final state an unproductive dead one.'[130] Three years later he formulated his argument against a closed future in the following way: 'If the world had a goal, it would have been reached. If there was an unintended final state, it would similarly have been reached.'[131] The circular argument presupposes that the world is infinitely old, such as Nietzsche believed, but it does not lead to his favoured cyclic universe any more than it leads to a linear future.

Otto Caspari, a Heidelberg philosopher of a Leibnizian orientation, published in 1874 a booklet in which he gave a critical account of what he called Thomson's hypothesis of the heat death.[132] He did not accept the hypothesis and seems to

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126 Much, perhaps too much, has been written about Nietzsche and the sciences of his day. On this subject, and his fascination of eternal-recurrence cosmology, see Small 2001, D'Iorio 1995, and Moore and Brobjer 2004. See also Brush 1978, pp. 72-5 and Rey 1927, pp. 309-13.

127 On Nietzsche's reading of *Die Kraft*, see Bauer 1984.

128 Letter to P. Gast of 20 March 1882, as quoted in Pearson 2000, p. 27.

129 *The Will to Power*, section 1066 (Small 2001, p. 26).

130 Small 2001, p. 66. Nietzsche borrowed Zöllner's book four times 1872-74 and later bought his own copy of it. On Zöllner, see below.

131 See the discussion in Couprie 1998, who suggests that Nietzsche's use of the argument was inspired by ancient Greek philosophers such as Anaximander and Plato.

132 Caspari 1874.

have been ignorant of Thomson's denial of the heat death as a reality of the future universe. In fact, the booklet on *Die Thomson'sche Hypothese* was more about his own speculations than about Thomson's works on the subject. Like several other German writers in the period, Caspari thought of the universe as a living organism and distanced himself from the vulgar Britons who modelled the universe after the mechanical theory of the steam engine. His own alternative was based on a vaguely formulated hypothesis of 'macroscopic organicism'. Caspari had no doubt that the world, contrary to the steam engine, is eternal, with motion and heat energy being endlessly recycled, and therefore postulated counter-entropic processes that would reactivate the apparently burnt-out universe. As to the mechanisms for such regeneration, he introduced the world ether as a thermal agent and also suggested that heat was a wave phenomenon in analogy with light. If so, it followed that interference between heat sources over cosmic distances could produce cold and hot zones in the universe. Since such zones will continually arise, temperature differences between different parts of the universe will always remain. Few physicists would have accepted his reasoning, speculative and obscure as it was, but here it is:

> Heat directed against heat does not without exception produce further heat, but in particular circumstances, and apart from other sources of heat and heat processes going on in the surrounding environment, gives rise to indifferent static heat, i.e. a lack of temperature compared with the environment, or the creation of cold.[133]

Nietzsche apparently found some inspiration in Caspari's speculations of heat interference. Thus, in a notebook he wrote that, 'Darkness arises out of light against light, cold out of heat against heat.'[134] Caspari concluded that the heat death, which he mistakenly associated with mechanical materialism as found particularly in industrialized Britain, need not occur. In fact, this was the very starting point of his argument: since the world has existed for an eternity, and the final equalization of temperature has not occurred, the mechanical theory of heat must be wrong in a cosmological context.[135] This kind of logic was accepted also by other late-nineteenth century thinkers, including F. Mohr, O. Köhler and, as mentioned, Nietzsche.

The German neo-Kantian philosopher Hans Vaihinger served as professor in Halle from 1884 to 1906. In his mature philosophy, as expounded in *Die Philosophie des Als-Ob* (1911), he defended the general idea that something can work 'as if' true, even though false and recognized to be false. Vaihinger held that the goal of scientific and other theories was to establish useful 'fictions'. Thus, he believed that the atom was fictional, a self-contradictory concept, but that it was nonetheless necessary in order to deal with reality as experienced in scientific experiments. At the age of

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133 Ibid., p. 39. Caspari did not invent the wave theory of heat, which for a period was considered an alternative to the caloric theory until it was replaced by the mechanical conception of heat. However, after 1850 the wave theory disappeared, and at the time of Caspari it had long been forgotten. On the wave theory of heat, see Brush 1986, pp. 303-34 (where Caspari's speculation is not mentioned). The idea of interference between heat rays would later be examined scientifically by Max von Laue (Laue 1906).

134 Small 2001, p. 144.

135 Caspari 1874, pp. 26-7.

twenty-three he wrote a paper on the cosmological problem in which he analyzed from a philosophical point of view various theories of the universe, including the idea of irreversible evolution based on thermodynamics. This work can be seen as a prologue to his later philosophy, as he suggested that the universe is a fiction because it entails contradictory concepts, pictures based on both mechanicism and organicism.

In his account of the cosmological theory based on the entropy law, Vaihinger recognized that it included not only an end of the universe but also that it led to 'an origin in time and a future annihilation of the present structure of the solar system and also the universe'.[136] Like Caspari, he tended to associate the thermodynamic theory of the universe with the picture of a mechanical or thermal machine – indeed, he spoke of the theory as the highest triumph of mechanical cosmology. Because of the inbuilt mechanical necessity there would be no room for either an 'extramundane principle' or an immanent purposefulness of the cosmos. This view differed from what the pioneers of the second law of thermodynamics thought, but apparently Vaihinger was as ignorant of this as Caspari was. Vaihinger did not endorse the irreversible entropic cosmos any more than he endorsed the organistic alternative of an eternal-cyclical universe. He seems to have believed that both of the pictures, although contradictory (or, perhaps better: complementary), were necessary. As to Caspari's organistic view – 'not only the most recent, but also the clearest ... exposition of the organic-teleological cosmology'[137] – he criticized it over several pages. On the other hand, he apparently agreed with some of Caspari's objections to the running-down universe. For example, Vaihinger stated that, 'although there is no finite *perpetuum mobile*, the infinite universe may be such one.'[138]

Although Nietzsche scornfully rejected what he called 'macrocosmic organicism', his own attempt to avoid the heat death had features in common with Caspari's and also with Vogt's. His answer, which he came upon in the summer of 1881, was eternal recurrence – 'the *most scientific* of all possible hypotheses'. This was not in itself an original answer except that Nietzsche was not satisfied with accepting it as a philosophical doctrine but believed it followed from the laws of physics.[139] He presented his cosmological thoughts in the book *Der Wille zur Macht*, written during the years 1884-88 but only published posthumously in 1901. The idea of eternal recurrence can also be found, in a dramatic form, in his famous work *Also sprach Zarathustra*. Nietzsche believed that the universe had always existed and consequently rejected ideas of a cosmic beginning as quasi-religious superstition. Likewise, there could be no final state or goal: 'If the motion of the world had a final state, that state would have been reached. The sole fundamental fact, however,

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136 Vaihinger 1875, p. 200. The paper included comments on German writers such as Fick, Caspari, Reuschle, Zöllner, Czolbe, Dühring, Mohr and Mayer. Vaihinger criticized Dühring for his finitism (see also Vaihinger 1876, pp. 92-3).

137 Vaihinger 1875, p. 206.

138 Ibid., p. 202.

139 Brush calls Nietzsche's argument 'not at all nonsense' and 'one of the clearest and most persuasive statements of the "recurrence paradox" by anyone in the nineteenth century' (Brush 1978, pp. 74-6). Stanley Jaki is much less impressed by 'Nietzsche's wholly unscientific way of thinking' (1974, p. 324).

is that it does not have a final state; and every philosophy or scientific hypothesis (e.g. mechanism) in which such a state becomes necessary is *refuted* by this fact alone.'[140]

While Nietzsche's universe had neither beginning nor end, eternal recurrence demanded that it was finite with respect to matter, space and energy. Astronomical evidence, such as Olbers's paradox, did not enter his reasoning.[141] Nietzsche conceived the universe as 'a definite quantity of energy, as a definite number of centres of energy', but did not bother to define what he meant by the term energy. At any rate, he thought that the belief followed from the laws of conservation of matter and energy. From this rather materialistic starting point he claimed that 'it follows therefrom that the universe must go through a calculable number of combinations in the great game of chance which constitutes its existence.' He went on:

> In infinity, at some moment or other, every possible combination must once have been realized; not only this, but it must have been realized an infinite number of times. And inasmuch as between every one of these combinations and its next recurrence every other possible combination would necessarily have been undergone, and since every one of these combinations would determine the whole series in the same order, a circular movement of absolutely identical series is thus demonstrated: the universe is thus shown to be a circular movement which has already repeated itself an infinite number of times, and which plays its game for all eternity.[142]

It seems that Nietzsche first encountered the idea of eternal recurrence from a somewhat unlikely source, namely the great poet Heinrich Heine, whom he much admired. In one of his works, Heine wrote as follows:

> Time is infinite, but the things in time, the concrete bodies, are finite. They ... have their determinate number, and the number of configurations which, all of themselves, are formed out of them is also determinate. Now, however long a time may pass, according to the eternal laws governing the combinations of this eternal play of repetition, all configurations which have previously existed on this Earth must yet meet, attract, repulse, kiss, and corrupt each other again. ... And thus it will happen one day that a man will be born again, just like me, and a woman will be born, just like Mary ...[143]

Nietzsche shared Caspari's misconception that the heat death was an expression of materialism, and was therefore led to conclude that his cosmological theory constituted a blow against the materialistic or mechanistic world view. 'Owing to the fact that the universe has not reached this final state, materialism shows itself to be but an

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140 *The Will to Power*, section 144 (Small 2001, p. 144).

141 He was, however, aware of the paradox. In a notebook of 1884 he wrote: 'According to Fr Secchi space cannot be unbounded, because … an infinite firmament populated by innumerable stars would appear as bright as the Sun across its entire extent.' Small 2001, p. 78.

142 As quoted in Brush 1978, p. 75.

143 Quoted in Den Ouden 1982, p. 107. The source was a draft chapter of Heine's *Reise von München nach Genoa*, included in *Letzte Gedichte und Gedenken von H. Heine* (Hamburg, 1869).

imperfect and provisional hypothesis', he wrote. In another entry he made the same point by referring to Thomson: 'If e.g. mechanism cannot avoid the consequence of a final state which Thomson has drawn for it, then mechanism is refuted.'[144] As we have seen, there was in fact a connection between materialism and the heat death, but it was opposite to the one claimed by Caspari and Nietzsche: the heat death, and irreversibility in general, was seen as a sign of anti-materialism, whereas eternal recurrence was considered to be in harmony with, or even a consequence of, the doctrines of reversible mechanicism and materialism. Contrary to what Nietzsche thought, thermodynamics precludes the kind of recurrent universe he favoured.[145]

In this respect, the intuition of Oswald Spengler, the author of the highly influential *Untergang des Abendlandes*, was more sound. Spengler referred to entropy as a powerful symbol of decline and stated that the entropy theory was unique in introducing irreversibility into the domain of mechanical physics. The theory, he said, marked 'the beginning of the destruction of that masterpiece of Western intelligence, the old dynamic physics'. It heralded an end to the world, as in the non-scientific world views of ancient cultures: 'What the myth of *Götterdämmerung* signified of old, the irreligious form of it, the theory of Entropy, signifies to-day – world's end as completion of an inwardly necessary evolution.'[146]

Is Thermodynamics Cosmologically Meaningful?

Many of those who criticized, or otherwise commented on, the cosmological use of the second law did it from reasons related to ideological or religious views. They took their starting point in such views and preferences and then evaluated the second law and its domain accordingly. But of course there were also scientists and philosophers who discussed the heat death and the hypothesis of entropic creation from more scientific and methodological points of view. They may have been biased for or against these cosmological implications – have *wanted* them to be true or not – but if so they were careful to present their arguments in a way that did not reflect such bias. Duhem believed as a Christian that God had created the world, yet he argued, strictly on a scientific and methodological basis, that the entropic creation argument was fallacious. The period from about 1880 to 1910 witnessed an interesting discussion that was principally concerned with the domain of applicability of the entropy law. The discussion is highly instructive because it involved considerations based on both physics, cosmology and philosophy, and also because it reflects contemporary positions in the philosophy of science.

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144 *The Will to Power*, section 1066 (Small 2001, p. 93).

145 According to the neo-Kantian philosopher and author Friedrich Lange, materialists had always taught that the world undergoes phases of destruction and creation, but as a whole is eternal and infinite in space (Lange 1887, pp. 557-8). Walther Löb, a physical chemist at the University of Bonn, was the first to point out that Nietzsche's claim lacks scientific basis (Löb 1908).

146 Spengler 1980, pp. 420-424. *Der Untergang des Abendlandes* was first published 1918-22. On its influence on German scientific and cultural life in the 1920s, see Forman 1971.

The famous Austrian positivist physicist and philosopher Ernst Mach advocated a view of science that was anti-metaphysical, but not materialistic. Indeed, Lenin attacked him fiercely (and rather unfairly) as a reactionary advocate of relativism, subjective idealism and solipsism. He even accused him of having betrayed science for the cause of fideism – 'the philosophy of the scientist Mach relates to natural science as the kiss of the Christian Judas does to Christ'.[147] Whatever the reasonableness of Lenin's characterization, within communist circles 'machism' would soon become a term of abuse.

Mach was nominally a Catholic, but in reality he was an atheist and strongly opposed to Christian doctrines.[148] In his influential *Die Mechanik in ihrer Entwicklung*, published in 1883, he wrote that 'the physical philosophy of theology is a fruitless achievement, a reversion to a lower state of scientific culture.'[149] Yet, as a pioneer historian of science he had enough historical sense to warn his readers against considering science and religion to be constantly involved in warfare: 'It would be a great mistake to suppose that the phrase "warfare of science" is a correct description of its general attitude toward religion, that the only repression of intellectual development has come from priests, and that if their hands had been held off, growing science would have shot up with stupendous velocity.' Referring to the development of mechanics before 1800, he spoke insightfully of 'the thoroughness with which theological thought thus permeated scientific inquiry'.[150]

Under the influence of Gustav Fechner's psycho-physics, Mach arrived in the early 1870s at the conclusion that scientific knowledge is basically a matter of sensation. As to the laws of nature, he regarded them as man-made generalizations of empirical facts, not something objectively existing. The laws of thermodynamics, for example, were nothing but generalized summary expressions of a large number of observed facts. According to Mach, theories of physics were built on underlying entities that merely served as aids to prediction, and theories therefore had no truly explanatory power but were tools to organize sense data in the most economic and effective ways. *Denkökonomie* was at the heart of all scientific theories. Although he did not in any way oppose the laws of thermodynamics, he did oppose the attempts of Clausius, Maxwell, Boltzmann and others to understand them as mechanical theories in terms of the atoms and molecules of gas theory.[151] He denied that such atoms and

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[147] Lenin 1927, p. 356.

[148] For Mach's hostility against Christian religion, and against Catholicism in particular, see Blackmore 1972, p. 235 and pp. 290-292.

[149] Mach 1960, p. 557. The ninth edition of *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt* appeared in an English translation in 1942 (*The Science of Mechanics*), reprinted in 1960.

[150] Ibid., pp. 541-2 and p. 546. The reference to 'warfare of science' was undoubtedly to White 1876.

[151] Although Mach had an extensive knowledge of the theory of heat, his understanding of modern thermodynamics was limited. At least Planck thought so, as he wrote in a letter to Ostwald of 1901: 'As far as Mach is concerned, I must say that although I otherwise much appreciate the independence and sharpness of his judgment, I do not think him competent as far as the second law is concerned.' Quoted in Heilbron 1986, p. 45. On Planck's low appreciation of Mach as a thermodynamicist, see also Blackmore 1972, p. 219 and p. 225.

molecules were really existing entities. What is here of greater relevance, he also opposed extrapolations of the laws to the entire universe. His overall objective was to rid science of concepts that have no parallel in sense experience, and he believed the universe was one such concept.

In 1871, while professor of physics at the University of Prague, Mach gave a lecture on the history of the principle of energy conservation in which he criticized the concepts of the heat death and the beginning of the world by arguing that they were scientifically meaningless. It is 'completely illusory', he wrote, to apply the second law to the entire universe. This was not because of any problem with Clausius's law in particular but because of the subject, the universe, to which no meaningful statements could be attached. What does it mean to say that some object in the universe suffers a change after the passage of a certain time? Mach argued that, for the statement to be meaningful, we must consider the object separate from another part of the universe, which acts as a clock. But this is not possible for the universe itself, since there is nothing left that can serve as a clock. '*The world* is like a machine in which the motion of certain parts is determined by the motion of other parts, only *nothing* is determined about the motion of the machine as a whole. ... For the universe there is no [measure of] time.' Concerning Clausius's formulations of the laws of thermodynamics, he barked: 'Scientific theorems of this kind appear to me worse than the worst philosophical theorems.'[152] The same message was brought home in a later reworking of the essay:

> Expressions such as 'the energy of the world' and 'the entropy of the world' are somewhat scholastic in nature. Energy and entropy are concepts of measure. What meaning can it have to apply these concepts to a case where they are *not even applicable*, in which their values are indeterminate? *If* the entropy of the world could be determined, it would be an absolute measure of time and it would be, at best, nothing but a tautology to say that the entropy of *the world* increases with *time*. Time, and the fact that certain changes take place in a definite sense, are one and the same thing. [153]

Mach's point was that the universe does not have the status of an object, it is not a thing, but the collection of all things; the whole cannot be treated in the same way as the parts of which it consists. The last sentence in the quotation refers to the fact that the second law, alone of all the fundamental laws of physics, refers to time and distinguishes between the past and the future. According to the entropic theory of time, the entropy is an objective measure of time. But then, to say that the entropy increases with time, is that not the same as saying that time increases with time?

The German-American positivist philosopher Johann (or John) Stallo shared and admired much of Mach's thinking, and the admiration was mutual.[154] In his

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[152] Mach 1909, pp. 36-7. Engels, who owned a copy of Mach's book, underlined the polemical passage. Reiprich 1969, p. 37.

[153] Mach 1923, pp. 209-10, originally published as Mach 1894-95. Mach included essentially the same passage in a textbook on thermal physics from 1896. See footnote on p. 338 in Mach 1919.

[154] Thiele 1969. Mach dedicated his *Principien der Wärmelehre*, published in 1896, to Stallo. On Stallo and his *Concepts and Theories of Modern Physics*, see Moyer 1983, pp. 3-

main work *The Concepts and Theories of Modern Physics* of 1882, Stallo severely criticized the theory of atoms as a foundation of dynamical physics. In addition, in the last chapter of the book he commented on the problems of relating thermodynamics to cosmology, his view on the matter fully agreeing with Mach. He asserted that any proper cosmogony, such as based on the second law of thermodynamics, must presume 'that the universe is finite in past time at least, for it is a theory respecting the origin or *beginning* of the universe'.[155] Stallo's objections were essentially a repetition of Mach's, except that he stressed the infinite extension of the universe: 'We can not deal with the Infinite as with a physically real thing, because definite physical reality is coextensive with action and reaction; and physical laws can not be applied to it, because they are determinations of the modes of interaction between distinct, finite bodies. The universe, so called, is not a distinct body, and there are no bodies without it with which it could interact.' Arguing that even finite forms related to the infinite, he concluded as follows:

> The Infinite is simply the expression of the essential relativity of all material things and their properties. ... And in this sense, and in this sense only, the universe is necessarily infinite in mass as well as in space and in time. It follows that all cosmogonies which purport to be theories of the origin of the universe as an absolute whole, in the light of physical and dynamical laws, are fundamentally absurd.[156]

Georg Helm, the German physicist and leader of the school of energetics, agreed with his kindred spirits Mach and Stallo. The energeticists stressed that the laws of thermodynamics were nothing but empirical relations between measurable quantities, and from this point of view Helm found it easy to criticize Clausius's global formulation of the two laws as both unnecessary and lacking in precision. The formulation of the first law as a statement of the energy of the world was just 'an empty saying', and the same was the case with Clausius's version of the second law, which was 'nothing more than a metaphysical aberration.'[157] Moreover, Helm argued that Clausius's law merely states that when a system passes from one equilibrium state to another, the entropy change cannot have decreased. One cannot tell from the law itself if the entropy has increased or remained constant. Neither Stallo nor Helm mentioned explicitly the religious aspects associated with cosmo-thermodynamics.

The Russian physicist Orest Danilovich Chwolson, professor of physics at the University of St. Petersburg, has long ago sunk into oblivion, but in the early years of the twentieth century he was a well known figure in international physics. Having studied in Leipzig as a young man he had good connections to the German physics community and followed closely the discussion in Germany concerning science, philosophy, religion and society. In 1896 he wrote the first book in Russian on the

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155 Stallo 1882, p. 271.

156 Ibid., p. 276. Stallo was aware of the possibility of space being positively curved, and hence of finite volume, but he seems to have considered it as nothing but a mathematical curiosity.

157 Helm 2000, p. 175-6 (German original of 1898). On energetics as a world view, see Hiebert 1971, Hakfoort 1992 and Robert Deltete's introduction to Helm 2000 (pp. 4-52).

sensational X-rays discovered by Röntgen. Without ever having sympathy for the cause of socialism, in the difficult years after the October Revolution he taught science courses for workers at the Communist University. He was active in maintaining scientific relations between the Soviet Union and the young Weimar Germany, for which reason he was appointed honorary member of the German Physical Society.

Chwolson did experimental research in electricity, heat and optics, and was known in particular as an author of textbooks. His *Lehrbuch der Physik*, a translation from Russian, appeared in five massive volumes 1903-13. Chwolson presented here the two laws of thermodynamics as being absolutely valid and of fundamental nature, but he objected to Clausius's cosmological formulation: 'Such a generalization is not, however, admissible as it goes beyond the limits of what we can know about nature.'[158] A much more elaborate critique followed in publications from 1906 and 1910. Chwolson had no objections at all against the second law, only against the extension of its domain to the universe as a whole. In fact, rarely has this law been praised with such enthusiasm and eloquence:

> I claim that the discovery of this law is the highest that the human spirit has until now achieved in all areas of knowledge; that the thoughts and philosophical depth that are at the basis of this law have a universal importance for the knowledge of what exists, … and that no science has demonstrated a result or thought which can be compared in magnificence to the entropy law. Humankind can be as proud of this law – which expresses the beautiful temple of absolute truths – as of all other [laws] that it has achieved and fought for, for almost all of these are either subjects of controversy or only approximately true. Among the few real truths that humankind has been able to fight its way to, the entropy law stands above.[159]

Chwolson believed of course that the celebrated laws of conservation of mass and energy were true, but only in the sense that they were highly probable. He was unwilling to grant them quite the same divine status as the second law of thermodynamics, which he at one place referred to as 'infallible'.[160] In 1906 he came dangerously close to describing the second law as *a priori* and axiomatically true, and that in spite of his generally empiricist view of science which permeated his textbook and also his discussion of 1910. His admiration for the law of entropy increase was unbound: 'We value above all the philosophical and cosmological significance of this law. It governs all events that occur in the world, and as a law of tendency it is the law of the evolution of the world; it teaches us that the world is an organism that evolves in a certain, strictly defined direction.'[161]

The quoted lines are from a booklet of 1906 in which Chwolson mercilessly attacked Haeckel's *Die Welträtsel* and used the occasion to offer his own opinion of the laws of thermodynamics and their significance for the scientific world view. Chwolson, who obviously was not a friend of monism, castigated Haeckel's views

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158 Chwolson 1905, p. 515.

159 Chwolson 1908 (2nd edn), p. 63. 'Das zwölfte Gebot' was Chwolson's demand that 'one should not write about things that one does not understand.'

160 Ibid., p. 83.

161 Chwolson 1908, p. 68.

and exposed in details the zoology professor's embarrassing lack of knowledge of even elementary physics.[162] He dismissed the 'law of substance' as a pseudo-law and ridiculed Haeckel's uncritical adoption of Vogt's 'pyknotic' theory of matter and ether. It was not difficult for Chwolson to illustrate that 'Haeckel has no idea of the content of the energy law' and that he used the law incorrectly when arguing, for example, that the universe is a *perpetuum mobile*. Even worse, Haeckel's glaring misconception of thermodynamics had led him to conclude that the two basic laws were incompatible, and hence that the second law must be wrong. According to Chwolson, when it came to physics Haeckel was a dilettante whose irresponsible claims were based on gross misunderstandings and revealed 'a scarcely believable lack of knowledge of the most elementary questions.' It is hard to disagree with Chwolson's verdict.

As expected, Chwolson also criticized Haeckel for his claim that the universe is infinite, although the reason was not that he considered the claim to be wrong. The problem was that it was not even wrong. Like Mach, Chwolson thought that the question was scientifically meaningless. To speak of a finite and bounded world was 'obviously nonsense', yet its opposite, the infinite world, was no better as it was nothing but 'a meaningless combination of empty words'.[163] In his 1906 anti-Haeckel tract and also in an article of 1910 in the Italian periodical *Scientia* he suggested distinguishing between what he called the observable 'world' and the much larger 'universe', the totality of everything that exists. The world was known from astronomical observations to be essentially homogeneous, to consist of the same forms of matter and to be governed by the same laws of physics. But what about the universe at large? The empiricist Chwolson insisted that this was not a scientific question, as it could never be determined observationally, not even in principle. The domain of the scientists, *qua* scientists, was strictly the world, or what were parts of the world. Therefore:

> *Physics has nothing to do with the universe*; it is not an object of scientific research as it is not accessible to any observation. World-laws are laws that are valid in all parts of the world, i.e. the physicists' world. There may be universal laws, and perhaps the world-laws are just special cases of the universal laws. When the physicist speaks of the 'world' he means his limited [and observable] world. … To identify this world with the

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[162] Chwolson was not the only scientist to point out Haeckel's lack of understanding of physics. According to Tunzelmann, the famous German biologist did not have 'even the elementary knowledge of physics which a first-year student is expected to possess' (Tunzelmann 1910, p. 617). Understandably, Catholic authors quoted Chwolson against Haeckel with delight and emphasized that Haeckel was an ignorant in matters of thermodynamics (for example, Gutberlet 1908, p. 61 and Schrader 1912, p. 45).

[163] Chwolson considered a third possibility, that space might be finite yet unbounded, but rejected it as a 'nebulous fantasy' because he thought it would involve a fourth dimension that space was curved in (Chwolson 1910, p. 46). Given that the idea of curved Riemannian space was well known in the early years of the twentieth century Chwolson's rejection is surprising.

> universe is a proof of either thoughtlessness or madness, and in any case lack of scientific understanding.[164]

Chwolson found it illegitimate to extrapolate from the 'world' to the 'universe', for such extrapolation he considered to be nothing but 'a generalized anthropomorphism'. After all, it was possible – if not likely – that in faraway parts of the universe the law of gravitation would be different, say be represented by a repulsive force instead of an attractive force. The same might be the case with the sublime entropy law. It would seem to follow that the notion of a universal heat death lost its status as a necessary consequence, but for Chwolson it was more important that the heat death prediction remained valid for the limited 'world'. Whereas he did not comment on the entropic creation argument, he argued against those who sought to eliminate the heat death by invoking counter-entropic processes in the cosmos. Although Chwolson had sympathy for the cause of religion, in his attack on Haeckel he wisely avoided references to religious arguments.

Haeckel promptly responded to Chwolson's attack in a brochure entitled *Monismus und Naturgesetz* in which he offered further comments on the cosmological use of thermodynamics. More clearly than in *Die Welträtsel*, he identified the law of entropy increase with the beginning and end of the world – the latter was held to be a 'necessary consequence' of the former. The heat death 'must correspond to an original "beginning of the world", a minimum entropy. In this way we arrive happily at a "miracle", at the "creation of the world from nothing"!'[165] In his angry polemic directed against the Russian physicist ('a narrow-minded specialist') Haeckel misrepresented Chwolson's views which he sought to discredit by associating them with Christian theism. He claimed, wrongly, that Chwolson accepted the heat death and the entropic creation argument in its wider sense, that is, including the inference to a divinely created world. In fact Chwolson did nothing of the kind, which Haeckel must have known. As far as Chwolson is concerned, his attack on Haeckel should be seen as continuation of his opposition to Russian philosophical and scientific materialists, whom he criticized for eroding morality and religious belief. In popular lectures and writings he spoke out for the intellectual limitation of science and the value of religion.[166]

Clifford, Mach, Stallo and Chwolson argued in different ways that the laws of thermodynamics were not applicable to the universe as a whole, or that the concepts

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164 Chwolson 1908, p. 43, and similarly in Chwolson 1910. For critique of Chwolson's view, see Schnippenkötter 1920, pp. 29-31, 49-52.

165 Haeckel 1906, p. 23. Di Gregorio 2005, a detailed biography of Haeckel, does not mention either the controversy with Chwolson or Haeckel's concern with the law of entropy increase.

166 Vucinich 1970, pp. 373-4. Known in Russia as a supporter of 'idealistic physics', Chwolson's views were welcomed by theological writers. According to Sheehan 1993, p. 159, he sought to reconcile physics with religious belief and was in the early years of the Soviet Union known as 'an exponent of a fideist interpretation of the new trends in physics'. Lenin had studied Chwolson's anti-Haeckel tract to which he referred in *Materialism and Empirio-Criticism*, presenting it as a quasi-theological and 'arch-reactionary pamphlet against Haeckel'. Lenin 1927, p. 358.

of energy and entropy could not be meaningfully defined in a truly cosmological context. Other authors tended to give, in a sense, thermodynamics higher status than cosmology, meaning that they accepted *a priori* the laws to be absolutely valid and from this presupposition they drew an appropriate cosmological picture.

The influential and versatile German philosopher Eduard von Hartmann had an almost unlimited faith in the second law.[167] Contrary to Chwolson he had no problem with a finite material universe, which he conceived as a finite collection of matter and energy in space, something like the astronomers' Milky Way universe. Hartmann was a finitist in the sense that he was convinced that all numbers and physical quantities must necessarily be finite, whether referring to atoms, celestial bodies, periods of time or the divisibility of matter. In 1902 he published *Die Weltanschauung der modernen Physik*, an impressive work on the philosophy of foundational physics with detailed chapters on thermodynamics. Hartmann followed the consensus view that the two laws had no meaning for an infinite material universe, and from this he concluded – somewhat surprisingly – that the universe must be finite:

> For the case of a finite material universe ... [it follows] that both laws must be absolutely valid. ... The finiteness of the world is thus an indispensable consequence of the supposition that both of the energetic laws are absolutely valid, and not only approximately so, that they are theoretical truths in the meaning of exact science. In any case, physics has no reason to doubt the finiteness of the universe.[168]

But how could Hartmann know that the laws of thermodynamics are absolutely true? As Bavink pointed out, his argument was flawed: 'Anyone who agrees with von Hartmann in concluding that the world must be finite in order that the law of entropy may hold, can equally well conclude that friction cannot exist in order that Galileo's law of falling bodies may be true.'[169] According to Bavink, Hartmann's reasoning was nothing but a 'pure sophism', and Schnippenkötter later called it 'a perfect *petitio principii*'.[170] Nonetheless, it was adopted by some entropic apologists. Thus, Gerhard Esser was impressed by Chwolson's and Hartmann's confidence in the absolute validity of the second law, which he accepted as a justification of the finite universe. The laws of thermodynamics are valid only if the universe is finite, he wrote, and then went on: 'But if the laws of energetics are exact truths, ... then the spatial finitude of the world is an undeniable consequence.'[171]

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[167] Although generally known as a 'pessimistic philosopher' and follower of Schopenhauer, Hartmann combined his interest in speculative idealism with knowledge of and respect for the natural sciences. He adopted a teleological view of nature and rejected materialism in whatever of its many forms. Being a Christian of a kind, he believed that pessimism was the natural foundation for the ethical-religious system of the future.

[168] Hartmann 1902, pp. 30-1. Hartmann presented his inference as a 'simple syllogism', which it is not. For criticism of Hartmann, see Bavink 1914, pp. 128-39 and Isenkrahe 1920, vol. 1.

[169] Bavink 1914, p. 128.

[170] Schnippenkötter 1920, p. 86.

[171] Esser 1907, p. 174.

Hartmann, who apparently did not recognize the weakness of his argument, drew temporal consequences from the absolute validity of the second law: 'If the world is finite it follows from the second law ... that *it began a finite time ago*, for otherwise it would already have been brought into an equilibrium state.' Or expressed differently: 'The second law proves ... that the infinite duration of world processes is untenable.'[172] He thus accepted the entropic creation argument in its restricted version. Although Hartmann did not use it as a proof of theism, he did note that it agreed with religious ideas and contradicted the views of scientific materialism. Materialists and monists from Büchner to Haeckel had used the law of energy conservation to justify the atheistic conception of an eternal world, but they had failed to take into account the thermodynamical evolution law. 'The second law shows how rash these inferences are and demonstrates the dogma of the eternity of world processes to be a false prejudice.'[173] Of course, a finite universe had its own problems, conceptually as well as astronomically, but these were problems that Hartmann shared with many others.

In the years around the turn of the century, Max Planck was probably the greatest scientific authority on the second law of thermodynamics, a law which significantly shaped his ideas of blackbody radiation and thus the early theory of energy quantization. Planck had no interest in speculative cosmology and did not, in spite of being a devout Christian, feel tempted to use the entropy law apologetically or otherwise relate physics to religion in any direct way.[174] Yet in his important textbook of thermodynamics he commented critically on Clausius' cosmological formulations of the laws of thermodynamics. Like Mach had done earlier, Planck concluded that 'The energy and the entropy of the world have no meaning, because such quantities admit of no accurate definition.'[175] However, he also argued that the more comprehensive the system, the more justified is it to speak of the laws as universally valid. In this approximate sense, he said, one can speak of the energy and

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172 Hartmann 1902, p. 33 and p. vi. Hartmann criticized Clausius's concept of entropy which he thought was not suited to represent the true meaning of the second law. He consequently did not speak of entropy increase or entropic beginning, but preferred to refer to the free energy.

173 Ibid., p. 34. Hartmann's authority was sometimes called in support by German authors with an apologetic interest in connecting the finite-age universe with Christian creation. See Schnippenkötter 1920, pp. 53, 85-6.

174 On Planck as a believer and his view on the relations between science and religion, see Planck 1950, which ends with the words: 'Religion and natural science are fighting a joint battle in an incessant, never relaxing crusade against scepticism and against dogmatism, against disbelief and against superstition, and the rallying cry in this crusade has always been, and always will be: "*On to God*!"' The chapter was based on an address given in Leipzig 1937. Near the end of his life, Planck abandoned his belief in the Christian God (Herneck 1960).

175 Planck 1911 (3rd edn), p. 104. Contrary to empiricists such as Mach and Helm, Planck tended to see the second law as *a priori* valid: 'The gist of the second law has nothing to do with experiment. ... Presumably the time will come when the principle of the increase of the entropy will be presented without any connection with human experiments.' Ibid., pp. 105-6.

entropy of the world. Yet, and with no attempt of clarification, 'There can be no talk of a definite maximum of the entropy of the world in any physical meaning.'[176] As to the first law, he suggested to replace Clausius's version with the more satisfactory formulation that $(1/E)(dE/dT \rightarrow 0$ for $A \rightarrow \infty$, where T is the absolute temperature and E denotes the energy of a large space of area A.

In a lecture delivered 1908 at the University of Leiden Planck dealt at length with the second law, including some of the recent attempts to contradict it. In a work of 1906 the theoretical physicist Max von Laue had showed that interference of two coherent heat rays of equal intensity (or temperature) might result in two other rays of different intensities, one higher and one lower.[177] This would amount to a contradiction of the second law, at least under the standard assumption that entropy is an additive property. In his 1908 lecture Planck took up Laue's work and used it to comment on the heat death, 'which has made [the second law] unpopular among many physicists and philosophers'. Admitting that he gave free reign to fantasy, he speculated that there might exist systems of celestial bodies coherent with ours elsewhere in the universe. The two systems would behave normally so long as they were isolated from one another, but if brought into contact they would apparently violate the second law of thermodynamics by producing a system with lower entropy, and hence deliver an escape from the heat death. Planck further noted that even without this artificial mechanism the heat death might not be inevitable. Perhaps there was no reason for pessimism, he suggested, for the unlimited extension of the observable world would make whatever worry one might have to be unfounded. He may have meant that the law of entropy increase is not valid for an infinite universe, but did not clearly say.[178]

The Astronomers' Universe

Although astrophysics prominently entered astronomy in the second half of the nineteenth century, cosmology remained a foreign element that the majority of astronomers either ignored or relegated to popular expositions. Sharing an empiricist attitude, they tended to confine their research to what could be measured with their telescopes and spectroscopic equipment. As a typical example, consider the French astronomer Hervé Faye, professor at the Ecole Polytechnique, who in 1884 published a book with the inviting title *Sur l'origine du monde*.[179] Was he concerned with the origin of the universe? Not at all, he considered the term *monde* (world or universe) in the restricted sense of the ensemble of celestial bodies that astronomers could observe. His universe consisted of millions of 'worlds', gravitationally bound systems such as planetary systems, star clusters and nebulae. It was such worlds, and

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176 Ibid., p. 104. This sentence was left out in later editions and does not appear in the English translation *Treatise on Thermodynamics* (New York: Dover Publications, 1945).

177 Laue 1906. Arrhenius and a few others used Laue's result to question the heat death.

178 Planck 1969, p. 45.

179 Faye 1884, with an introductory chapter on 'La science et l'idée de Dieu'. As a Catholic, Faye believed that astronomical studies led to a recognition of the almighty God.

the solar system in particular, that Faye and most other astronomers focused on. His colleague Charles Wolf, an astronomer at the Paris Observatory, published in 1886 another book on cosmogony, like Faye basing his discussion of the formation of the solar system on the Kant-Laplace picture.[180] Although Wolf included a chapter on *La fin des mondes*, it only dealt with mechanical instability and the possibility that the Sun would run out of energy. Neither Faye nor Wolf considered the second law of thermodynamics.

Faye's attitude to astronomy and cosmology, shared by most of his colleagues, conformed in a general way with the spirit of positivism that permeated so much of the period's science, in France as elsewhere. Anti-atomism was one result, anti-cosmology another.[181] In his *Cours de philosophie positive* (1830-42) and other works Auguste Comte stressed that astronomy was an observational and empirical science, and he even questioned the legitimacy of sidereal astronomy. Comte was no astronomical ignorant, for he had studied for two years at the Ecole Polytechnique and taken courses in astronomy from the famous astronomer Jean-Baptiste Delambre. But he held an overly narrow view of the astronomical sciences, which he essentially identified with celestial mechanics in the style of Laplace.[182] Concerning the stars he wrote: 'We conceive the possibility of determining their forms, their distances, their magnitudes, and their movements, but we can never by any means investigate their chemical composition or mineralogical structure, still less the nature of the organic beings that live on their surface, etc.' It followed that cosmology could not possibly attain the status of a positive science. It is necessary, Comte wrote, 'that we separate more completely than is commonly done the solar from the universal point of view, the idea of the world from that of the universe: the first is the highest we can actually attain, and it is also the only one that truly interests us.'[183] According to Comte, any branch of knowledge progressed through three different stages, from the theological over the metaphysical to the positive. It followed that religion and science must necessarily be in a state of conflict.

The author and philosopher Emile Littré, a friend and follower of Comte, distinguished explicitly between 'the world' (*le monde*) and 'the universe', where the

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180 Wolf 1886. Wolf included in his book his own French translation of Kant's *Allgemeine Naturgeschichte und Theorie des Himmels*. The *de facto* identification of 'world' or 'cosmos' with the solar system was far from restricted to French authors. To mention but one German example, Klein's *Entwickelungsgeschichte des Kosmos* (1870) was restricted to the planets and the Earth in particular.

181 Whereas the anti-atomism associated with positivism has been widely discussed by historians of science, anti-cosmology has scarcely received any attention (but see Merleau-Ponty 1983).

182 In 1844 Comte published the elementary *Traité philosophique d'astronomie populaire*, based on a series of public lectures in Paris. On Comte and astronomy, see Merleau-Ponty 1983, pp. 282-9.

183 Comte, *Cours de philosophie positive*, vol. 2, quoted from the translation in Crowe 1994, pp. 147-8. Comte carried his notorious critique of stellar astronomy and cosmology further in his *Système de politique positive* (1851), where he excoriated those who still considered astronomy to be allied with religion. According to Comte, the opposite was the case: all true science was in radical opposition to religion.

first term referred to the solar system and the second to the immense space populated with stars accessible to the best telescopes. As for cosmology in the even wider sense, the study of everything physical (whether observable or not), he dismissed it as 'a chimera'. According to Littré, the aim of evolutionary cosmogony was to find earlier states of the universe by means of traces left from the past. He believed that this research programme implied that any notion of an origin was ruled out, as such a primeval state could not possibly have been caused by an antecedent state. 'From the point of view of modern cosmology, an earlier state is always preceded by a still earlier state which ... remains inaccessible.'[184]

In 1890, in an oft-quoted passage, the Irish astronomer and historian of astronomy Agnes Mary Clerke made clear that the nebulae were parts of the Milky Way, not separate galactic systems. And what about the universe beyond the Milky Way? Clerke raised the question only to dismiss it: 'With the infinite possibilities beyond, science has no concern.'[185] In a later book, the massive *Problems of Astrophysics*, she likewise refrained from going beyond what she poetically called 'the equatorial girdle of a sphere containing stars and nebulae'. For, as she wrote:

> The whole material creation is, to our apprehension, enclosed within this sphere. We know nothing of what may lie beyond. Thought may wander into the void, but observation cannot follow. And where its faithful escort halts, positive science comes to a standstill. Fully recognising the illimitable possibilities of omnipotence, we have no choice but to confine our researches within the bounds of the visible world.[186]

There were many voices like Clerke's. The great American astronomer Simon Newcomb, professor of mathematics and astronomy at Johns Hopkins University, was not afraid of speculation, but with regard to cosmology he preferred a cautious attitude. In an essay on unsolved problems in astronomy he asked if the universe was populated with stars all over, or if they were largely contained in the system of the Milky Way, itself floating in infinite empty space. The question, he wrote, 'must always remain unanswered by us mortals. … Far outside of *what we call the universe* might still exist *other universes* which we can never see.' For all practical purposes, the Milky Way 'seems to form the base on which the universe is built and to bind all the stars into a system'.[187] In an age of positivism, the general attitude was that theories and hypotheses were put forward in order to explain facts, and hence 'when there are no facts to be explained, no theory is required. As there are no observed facts as to what exists beyond the farthest stars, the mind of the astronomer

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184 Littré 1873, p. 524.

185 Clerke 1890, p. 368. Clerke was a devout Catholic who often referred to themes of natural theology in her works. However, she never entertained the idea of a finite-age universe from a scientific point of view. In a book of 1886 she briefly considered 'the inevitable final bankruptcy', but only in relation to the solar system. Without mentioning the laws of thermodynamics, she expressed doubts with respect to hypotheses of regeneration of energy, stating that 'It is, however, an inexorable law of nature that there is no work without waste' (Clerke 1886, p. 354). On Clerke, see Brück 2002.

186 Clerke 1903, p. 538.

187 Newcomb 1906, pp. 5-6. Emphasis added.

is a complete blank on the subject. Popular imagination can fill up the blank as it pleases.'[188]

The agnostic attitude of Clerke and Newcomb was common at the turn of the century. For example, it was given expression by the physicist and astronomer George Darwin (a son of Charles Darwin) in his presidential address to the British Association in 1905. Does it not seem as futile to imagine that man 'can discover the origin and tendency of the universe as to expect a housefly to instruct us as to the theory of the motions of the planets?' Although Darwin admitted the great progress that had occurred in the sciences, he concluded that 'the advance towards an explanation of the universe remains miserably slight.' His prediction of future knowledge was as pessimistic as it was wrong: 'We may indeed be amazed at all that man has been able to find out, but the immeasurable magnitude of the undiscovered will throughout all time remain to humble his pride. Our children's children will still be gazing and marvelling at the starry heavens, but the riddle will never be read.'[189]

Did the Milky Way make up the entire material universe? Or were stars and star systems to be found indefinitely in infinite space, as suggested by Newton and Kant in different versions? Due to the absence of reliable distance measurements, the size of the Milky Way remained a matter of educated guesswork, and so did the distances to the nebulae (of course, the two problems were intimately related). Although by 1900 the consensus view was that practically the entire material universe was concentrated in the Milky Way, such as concluded by Clerke, the view was not universally accepted and it had no firm foundation in either theory or observational fact. Is there a finite or infinite number of shining objects in the universe? Again, nobody really knew. Arguments of mechanical stability accruing back to Newton (in his correspondence with Bentley) seemed to require an infinite universe populated with an infinite number of stars, but neither was this view without problems.

One of the problems was the famous Olbers's paradox, named after the German astronomer Wilhelm Olbers, who in 1823 restated what had been known since the days of Newton – namely, that an infinity of uniformly distributed stars would cause the night sky to be shiningly bright.[190] There were various ways to cope with the problem, which in the nineteenth century was not really seen as much of a paradox. Among the possible saving operations were:

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[188] Newcomb, *The Observatory* 30 (1907), 362, an anonymous review essay of Gore 1907.

[189] Darwin 1905, p. 32. G.H. Darwin died in 1912 and thus did not live to experience the revolution that relativistic cosmology brought with it.

[190] The history of Olbers's paradox is exhaustively described in Jaki 1969 and Harrison 1987. The paradox was briefly noted by Kepler as early as 1610 and it received thorough consideration by the Swiss astronomer Jean-Philippe Loys de Chéseaux in 1744. For this reason, it is sometimes referred to as the Chéseaux-Olbers paradox.

(a) Interstellar absorption of light.
(b) A hierarchical stellar universe, i.e. non-uniform distribution of stars.
(c) Only a finite number of luminating bodies (in infinite space).
(d) Space is finite, but unbounded, and filled uniformly with stars.
(e) The stellar universe is of finite age.

To these may be added (f): the universe is expanding. However, the idea of an expanding universe was unknown in pre-1920 science and can therefore be left out. Among the other possibilities, (a) was generally accepted until the early part of the twentieth century when observational evidence indicated that space was much more transparent than assumed. The two last possibilities remained marginal for a long time, but are those that relate to the temporal aspects of the universe. Option (e) provided a solution to Olbers's paradox and an argument for a created universe independent of the entropic argument; and because option (d) assumed a finite sidereal universe it could be counted as support of the heat death and entropic creation scenarios.

Surprisingly, the first to point out that Olbers's paradox might be defused if the universe had not always existed – if the oldest stars were not infinitely old – seems to have been the American poet and novelist Edgar Allan Poe in a lecture 'On the Cosmogony of the Universe' of February 1848. Poe developed his cosmic vision in the prose poem *Eureka* of the same year, a remarkable work that described the origin and development of the universe in a way that anticipated the much later Big-Bang scenario.[191] His universe took its start with a divinely created primordial particle, in a state of 'absolute extreme of Simplicity … absolutely unique, individual, undivided'. The primordial particle exploded in 'one instantaneous flash' from which matter was radiated outwards in space. 'This Oneness is in principle abundantly sufficient to account for the constitution, the existing phaenomena and their plainly inevitable annihilation of at least the material Universe.' Because the universe had existed only in a finite time, he could assume that the distance to the stars most far away was so immense that no light rays from them had *yet* been able to reach the Earth. This argument referred to a static and infinite universe, but in fact Poe believed that the universe consisted of only a finite number of stars populating an infinite space. That is, he adopted (c) as well as (e) as solutions to Olbers's paradox. Poe also described a kind of final annihilation, an end of the universe, but suggested that it would be followed by the birth of a new universe. Whatever the originality of Poe's spirited essay, it failed to attract the interest of the astronomers, and perhaps understandably so. After all, it was a contribution to speculative and quasi-theological cosmogony rather than to the astronomical sciences.

Another case of a finite-age universe turned up in the astronomical literature in 1858, when the German astronomer Johann Mädler, in his book *Der Fixsternhimmel*, discussed Olbers's paradox. Mädler was at that time director of the Dorpat Observatory, one of the most prestigious positions in the astronomical community. Not knowing of Poe's essay, he wrote that one argument had been overlooked, namely:

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[191] Poe 1848. On Poe's cosmological vision, see Cappi 1994 and Tipler 1988.

> The world is created, and hence is not eternal. Thus no motion in the universe can have lasted for infinite time; in particular, this applies to a beam of light. In the finite amount of time it could travel before it reached our eye, a light beam could pass through only a finite space no matter how large the speed of light. If we knew the moment of creation, we would be able to calculate its boundary.[192]

Three years later, in a popular book entitled *Der Wunderbau des Weltalls*, Mädler repeated the suggestion which also appeared in his widely read *Geschichte der Himmelskunde*. Because of the finite velocity of light, 'a star at an infinite distance will only be visible to us if it had existed for an eternity, that is, if it were not created.'[193] Mädler saw no reason to accept eternal heavenly objects and suggested that questions of actual infinities should be left to the metaphysicians. An argument quite similar to Mädler's was included in a popular book on astronomy published by the Leiden astronomer Frederik Kaiser in 1860.[194] Kaiser, who saw the study of astronomy as a road to God, believed the universe was infinite and uniformly filled with stars and nebulae. Whereas some thinkers found such a universe contrary to Christian ideas, for Kaiser it counted as a tribute to God's omnipotence. The idea of a finite-age universe, as propounded by Mädler and Kaiser, must have been well known, but it failed to attract serious attention among the astronomers. On the other hand, it did attract the attention of Engels, who in his notes for the *Dialektik der Natur* quoted Mädler's argument of 1861 and approvingly called it 'a *beautiful argument* against the so-called absorption of light'.[195] Engels's appreciation is ironic, as Mädler argued in favour of a created universe, a notion that Engels definitely did not support.

Although Mädler did not relate his finite-age idea to theology, he most likely was inspired by his colleague at the University of Dorpat, the Lutheran theologian and church historian Johann Heinrich Kurtz. In a book on the relationship between astronomy and theology, *Die Astronomie und die Bibel*, Kurtz argued that our solar system was unique and located near the centre of the stellar universe. The book included a detailed examination of astronomy in the Old Testament and also reflections on the reconcilability of Christianity with the modern picture of the cosmos. Kurtz, who was well read in astronomy, argued the cause of anti-pluralism, that 'the like of our planetary system is nowhere to be found in all the known universe'. What is of more interest, he also discussed Olbers's paradox and suggested that astronomers should attempt to decide 'whether the primeval matter

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[192] Mädler 1858, p. 87. See also Tipler 1988. Mädler was a Christian and opposed to materialism, but he believed that faith and science should be kept separate (Kneller 1912, p. 143).

[193] Mädler 1873, vol. 2, pp. 223-4.

[194] Kaiser's *De Sterrenhemel* (3rd edn 1860) was translated into Danish in 1867 by Mathilde Ørsted, the daughter of H.C. Ørsted. 'If the universe is created; if it has not existed eternally, and if the number of stars is infinite, then the light rays from the stars very far away could not have reached our eye, and therefore the stars would not occupy the heaven with a glowing sunlight.' Kaiser 1867, p. 146.

[195] Engels 1940, p. 221. Engels suggested a non-absorption solution of Olbers's paradox, but his proposal was quite wrong.

and forces concerned in the production of these [stellar] bodies existed from eternity, or were created in time'.[196]

Mädler was in opposition to 'Büchner and his kindred spirits' who illegitimately used science to justify their ideas of materialism and atheism. He thought that this unhealthy trend could only be countered by means of scientific arguments, whereas theological and philosophical arguments would fail to make an impression. Mädler was a theist, but he denied that the deity played a role in the physical cosmos or could be used as a hypothesis in science. 'The universe is a clockwork', he wrote, 'but not of the kind that needs the help of the maker when it does not function well. Our God thrones beyond time and eternity, and his home is changeless; the deeper we investigate his work, the more we are confirmed in this view.'[197] His God was closer to Leibniz's than to Newton's.

Olbers's paradox could be avoided even if the stars were assumed to be distributed uniformly in transparent space, namely by postulating that cosmic space itself was finite (and hence that the number of stars was finite). Not only was this hard to imagine in the nineteenth century, it was impossible so long as space was taken to be Euclidean. But it was no longer impossible if one adopted Bernhard Riemann's idea of a positively curved space, such as he had outlined in 1853 in a famous lecture on the connection between geometry and physics. 'If we … ascribe to space constant curvature, it must necessarily be finite provided this curvature has ever so small a positive value.'[198] Probably the first scientist who seriously applied the notions of non-Euclidean geometry to astronomy, and indeed to cosmology, was the German Karl Friedrich Zöllner, a brilliant but also eccentric and polemical astrophysicist at Leipzig. Zöllner not only adopted Riemann's spherical space as representing physical space, he also argued that the fundamental laws of physics were determined by the geometrical structure of the cosmos. In this sense, he anticipated some of the features in Einstein's theory of general relativity.[199]

Zöllner's use of non-Euclidean geometry dates back to 1872, when he published an essay on the 'Finiteness of matter in endless space' in his remarkable work *Über die Natur der Cometen*. The book did deal with the nature of comets, but the main part of it was a strange mixture of philosophy and history of science and wild, chauvinistic charges of plagiarism. Zöllner was among the first scientists to praise Kant's *Allgemeine Naturgeschichte*, which he did by including extensive excerpts and also, characteristically, by accusing Laplace of having plagiarized the great philosopher-scientist from Königsberg. His main targets were British scientists, though, including Thomson, Tait and Darwin, and he also attacked Helmholtz and du Bois-Reymond, two of the most powerful men in German science. No wonder

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[196] Kurtz's book was translated into English as *The Bible and Astronomy* (Kurtz 1857), a translation of the third German edition of 1852. Quotations from p. 423 and p. 433. For a later examination of the astronomy of the Bible, see Maunder 1908.

[197] Mädler, 'Ueber Himmelskunde als Lehrobjekt in Unterrichtsanstalten', written in 1864 and published pp. 298-337 in Mädler 1870.

[198] Riemann 1873, an English translation made by William K. Clifford. For background on non-Euclidean geometries and the early attempts to connect them to problems of physics and astronomy, see Gray 1979 and Kragh 2006a, pp. 125-30.

[199] See Leihkauf 1983.

that the book aroused a storm of controversy. Zöllner, who embraced the romantic-idealistic thoughts of Schopenhauer, believed that knowledge of nature flowed from the mind rather than the laboratory, a view diametrically opposite to Helmholtz's philosophy of science.[200]

Zöllner argued that a finite quantity of matter in the universe would dissolve to zero density in an infinite Euclidean space in an infinite time. To account for the fact that the matter density is not zero, he subjected the assumptions on which the conclusion rested to close analysis. He found it would not do to introduce an infinite quantity of matter, because it would result in an infinite pressure anywhere in the universe. He therefore focused on the assumptions of infinite time and space. As to the first assumption, he realized that a universe of finite age would solve the problem of the vanishing matter density. One could imagine, he wrote,

> an act of creation in which had begun, at a time in the *finite* past, a certain finite initial state of the world, which now continues in a way that is imperceptible to our senses and periods of time [and which] approaches the several times mentioned end state in which, after an infinite time, the elements of matter are to be found in infinitely large distances. From a physical point of view, such a process would be equivalent with a gradual dissolution of the world into nothing or with the annihilation of the world.[201]

However, Zöllner was unwilling to accept a limitation of time 'either in the past, in the form of a definite beginning, or in the future, in the form of a definite end of all material changes'. Not only would a beginning limit the causal chain arbitrarily, it would also, he thought, contradict the Leibnizian principle of sufficient reason: there can be given no reason why the universe came into being a certain time ago rather than at any other time. He therefore decided to drop the assumption of the infinite Euclidean space and adopt a Riemannian space. 'It seems to me', he wrote, that

> any contradictions will disappear … if we ascribe to the constant curvature of space not the value zero but a positive value, however small. … The assumption of a positive value of the spatial curvature measure involves us in no way in contradictions with the phenomena of the experiences world if only its value is taken to be sufficiently small.[202]

In this way he made Olbers's paradox disappear without having to assume a limitation of either cosmic time or space. Zöllner thought that in a positively curved space all physical processes would occur cyclically, indeed that the universe itself would be cyclic, so that time would go on forever. 'Parts of a finite quantity of matter moving apart with a finite speed ... would converge again, and in this way transform kinetic

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[200] The vituperative remarks in *Über die Natur der Cometen* caused Helmholtz to reply to the attack and publicly distance himself from Zöllner's ideas of science, society and philosophy. Zöllner turned to spiritualism in 1875, and in 1881 he published a highly speculative and unorthodox attempt to integrate theology and spiritualism with natural science, a work entitled *Naturwissenschaft und Christliche Offenbarung*. His 'transcendent physics' appeared as volume three of Zöllner 1878-81. His speculations in this area involved psychical forces and the fourth dimension, but not phenomena as mundane as thermodynamics.

[201] Zöllner 1872, p. 306. See also Jaki 1969, pp. 158-62.

[202] Zöllner 1872, p. 308.

energy to potential energy, and by separation from potential to kinetic energy, as periodical as a pendulum.' He noted with satisfaction that energy conservation would be applicable to his finite material universe, whereas he did not comment on the apparent irreconcilability between a cyclic universe and the irreversibility inherent in the second law of thermodynamics. In 1872, the same year as Zöllner's essay appeared, Clifford pointed out that within the framework of Riemannian geometry there was no need to associate boundedness with finite extent, or unboundedness with infinity. He emphasized that the geometrical structure of space was a question of empirical fact, not of metaphysics.[203]

Zöllner's cosmological ideas were subjected to lengthy and critical commentary by the experimental psychologist Wilhelm Wundt, whose attitude to science was influenced by the ideas of Ernst Heinrich Weber, Gustav Theodor Fechner and Helmholtz. However, he mistakenly took Zöllner's proposal to imply finite cosmic time as well.[204] Among Wundt's arguments against Zöllner was that his curved-space universe would be subject to the heat death, something Zöllner had not taken into consideration. In his article of 1877 Wundt examined clearly and systematically the various possibilities of a finite universe – whether with respect to time, space or matter – and then repeated the exercise with regard to infinite universe models. His discussion can be seen as an updated version of what Kant had done in his *Kritik der reinen Vernunft*, only with a different outcome.[205]

Like most scientific materialists, Wundt favoured an infinite and eternal universe. But instead of having matter distributed uniformly, he argued that the amount of matter was finite, that it was largely concentrated in our neighbourhood, and that its density approached zero at infinity. He thought that with this world model he could escape the unwanted consequences of the second law, as the model, so he claimed, allowed dissipated heat energy to retransform into mechanically useful energy. But such an anti-entropic mechanism was not really necessary, for the important point was that in a spatially infinite universe entropy would never reach its maximum state: 'In an infinite space, equilibrium will only occur in an infinite time. … In the case of a spatially infinite world the law that the entropy of the world strives toward a maximum must be modified with the additional statement that this entropic maximum can never be reached in reality.'[206]

Wundt realized that the heat death could be used to argue for a beginning of the world, and hence for divine creation, something he found was characteristic of British

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203 Clifford 1947, p. 11.

204 Wundt 1877. For another critical discussion, see Budde 1872.

205 Briefly put, Kant proved (to his own satisfaction) that the world 'has a beginning in time, and is limited also with regard to space', but also that it 'has no beginning and no limits in space.' Kant 1966, pp. 306-7. Since the concept of the world is thus contradictory, he inferred that it cannot cover a physical reality but is rather a regulative principle of heuristic value. Although Kantianism was strong in Germany in the second half of the nineteenth century, Kant's philosophy of the universe played almost no role at all in the debate concerning entropy and cosmology.

206 Wundt 1877, pp. 126-7. Wundt thought that this conclusion was independent of the amount of matter. His reasons for preferring a finite-matter universe were primarily astronomically based.

physicists who tended 'to bring exact scientific considerations into a certain harmony with theological views'. But it was a harmony that betrayed the very foundation of science: 'The beginning and end of the world requires an act of creation and a renewal of the world which disagree with the causal description of nature. Every world view can ultimately be traced back to something unrecognizable, but in this case this transcendent feature is transferred to the finite context of phenomena. … In this way the miracle has become part of the course of nature.'[207] Gutberlet too objected to Zöllner's conclusion, if for reasons very different from Wundt's. He was familiar with non-Euclidean geometry, which he had examined from a philosophical point of view as early as 1882, but flatly denied that physical space could be curved. Its Euclidean nature was self-evident, he claimed, a necessary fact that 'no rational person can deny'.[208] As far as Gutberlet was concerned, Zöllner had gone all wrong in dismissing the possibility of a world of finite age. He argued that it was illegitimate to base the eternity of the world on the principle of sufficient reason, as this principle presupposed that that world is necessary rather than contingent. From a Christian point of view this was a serious error.

The German periodical *Sirius*, a journal of popular astronomy founded in 1880, was mainly concerned with observations of comets, planets and variable stars, but its content also reflected the contemporary debate over cosmology. Its first editor was the Austrian Rudolf Falb, who after theological studies in Vienna was ordained as a Catholic priest in 1864, only to leave the church four years later. At the time when he founded *Sirius*, he had replaced theology with studies in mathematics, astronomy and geology. The apostate Falb published several papers in astronomy and vulcanology, in part based on a journey he made to Chile and Peru in 1877. In 1880 he was succeeded as editor by Hermann Joseph Klein, a respected amateur astronomer who possessed a private observatory in Cologne. Klein was a prolific writer of articles and books on astronomy, geology and meteorology.[209]

In two articles in *Sirius*, Falb examined the questions of the spatial, material and temporal finitude of the universe. As to the extension in space, he argued that the very concept of space had only meaning in connection with matter: 'Where there is no material body, no space can exist.'[210] From this premise followed the possibility of limited space, as the question of what is beyond the end of space was deemed illegitimate; for according to Falb there was no way to define 'beyond'. While the consensus view was that temporal finitude followed spatial finitude, this was not the opinion of Falb. On the contrary, he was convinced that the universe must be as eternal as matter. A universe consisting of a limited number of stars and nebulae would eventually contract gravitationally to a giant sun, but this sun would

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207 Ibid., p. 99.

208 Gutberlet 1908, pp. 53-6. On his analysis of non-Euclidean geometry, see Gutberlet 1882. Mach, too, dismissed ideas of non-Euclidean space, which he found to be 'grotesque fictions'. Blackmore 1972, p. 260.

209 On Falb and Klein, see *Poggendorff's biographisch-literarisches Handwörterbuch*, vol. 3 (Leipzig: J. A. Barth, 1898). I am not aware of Falb's reasons for breaking with the Catholic church.

210 Falb 1876, p. 5.

immediately evaporate and form an expanding gas, a nebulous body of the same kind as the one that had originally given rise to the celestial bodies. Falb contended that the process would continue indefinitely: 'The life of the world is to be conceived as a recurrence of expansion and contraction, like the breaths of a monstrous colossus. In this way the eternity of processes becomes understandable, that is, the infinite duration of the universe. ... The end of the world is at the same time the beginning of the world.'[211]

Klein, too, was an advocate of the recurrent universe. Contrary to Falb, he confronted the eternity of the world with the second law of thermodynamics and the heat death that followed from it. He considered the entropic end of the world to be 'undeniable', a strict deduction from the mechanical theory of heat. According to this theory, he wrote, 'An eternal circuit of nature – an eternal and recurrent formation and dissolution of celestial bodies, of planets and solar systems – is strictly precluded.' Nonetheless, he found such a conclusion to be intellectually unsatisfactory because it led to the unpalatable notion of a beginning of the universe. The only way out of the dilemma was to assume that Clausius's law was inapplicable to the universe, that 'there exists an unknown circumstance which makes the entire universe a reversible machine.'[212] Contrary to most of his kindred spirits, Klein emphasized that the existence of a cosmic counterentropic mechanism was wholly hypothetical and had no basis in physics.

Eternal Life in an Infinite Universe

The question of the spatial extension of the universe was also discussed in connection with another of cosmology's classical problems, the so-called gravitation paradox. Since this problem related only indirectly to the world's extension in time, we need not go into detail.[213] The German astronomer Hugo von Seeliger, a former student of Zöllner and from 1882 to his death in 1924 director of the Munich Observatory, was one of the few astronomers about the turn of the century who can reasonably be called a 'cosmologist'. Not only did he combine astronomical observations and advanced mathematical analysis, he also had a keen interest in philosophical problems. In 1895 he proved that an infinite Euclidean universe with a roughly uniform mass distribution cannot be brought into agreement with Newton's law of gravitation, as the gravitational force exerted on a body by integration over all the masses in the infinite universe does not lead to a unique result (the integral diverges).[214] Seeliger's concern was not really to save Newton's infinite stellar system, for at the time he rejected the notion of an actual infinity and tended to believe that the material universe must be finite.

The following year Seeliger framed the gravitation paradox differently by showing that the Newtonian universe allows motions that start with finite speed and accelerate to infinitely great speeds in finite time. In a popular presentation he

211 Falb 1875, p. 202.
212 Klein 1897, p. 217 and p. 250.
213 For these details, see Jaki 1979, North 1990, pp. 30-49 and Norton 1999.
214 Seeliger 1895.

summarized that whatever the mass distribution in the universe, there must occur infinitely great accelerations in it. From this follows 'motions which, starting from finite velocities, would lead within a finite time, to infinite velocities'.[215] Such a behaviour is obviously unacceptable. Seeliger therefore suggested to modify Newton's inverse-square law at very large distances. According to Newton's immensely successful law, the gravitational force between two masses m and M can be expressed as $F(r) = GMm/r^2$, where G is a constant and r the distance between the two bodies. His suggestion was to replace the law with $F^*(r) = F(r)\exp(-\Lambda r)$, where Λ is a cosmological constant so small that its effects will be unnoticeable except for exceedingly large distances.[216] The modified force law was essentially *ad hoc* and also arbitrary, since many other modifications might resolve the gravitation paradox in a similar way. The idea of modifying Newton's inverse-square law was not, by itself, very original, for many such modifications had been proposed during the nineteenth century. However, what was original in Seeliger's approach was that he used it in a genuinely cosmological context and not, as in most other proposals, to solve problems of planetary astronomy. As Gutberlet criticized Zöllner for having introduced curved space, so he criticized Seeliger for introducing a modification of Newton's law of gravitation, which he considered to be 'very fantastic and unjustified'.[217] For Gutberlet, the Catholic philosopher, Seeliger's analysis proved the impossibility of an infinite, material universe.

In a paper of 1909 Seeliger argued that Olbers's paradox might be resolved if it was assumed that there existed in the universe a large number of non-luminating 'dark stars', an idea that held considerable credibility at the time.[218] What is of more relevance, he considered the cosmological significance of the laws of thermodynamics, concluding that in the case of an infinite universe they either became meaningless or lost their validity. Seeliger insisted that the meaning of the second law was restricted to the statement that the entropy of an isolated system would increase in time; if the system became very large, the law would still be valid, but there was no way in which this process could be extrapolated to an infinitely large system. 'Quite apart from purely physical objections, the entropy law itself is not consistent with an indefinite extension of its domain of applicability.'[219] Thus, Seeliger's position roughly corresponded to the views held by, for example, Stallo and Chwolson.

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215 Seeliger 1897-98, p. 546. See also Norton 1999.

216 Seeliger's cosmological constant was taken over by Einstein in his general-relativistic cosmological model of 1917, where it signified the average density of matter in the universe. However, Einstein was not originally inspired by Seeliger's constant, which he did not know of until later in 1917.

217 Gutberlet 1908, p. 51. Gutberlet noticed that Seeliger's hypothesis corresponded to an absorption of gravitation, which he found to be 'fantastic and undetectable'. In fact, at the time several researchers had tried to detect gravitational absorption and at least one positive result was reported. For a history of this problem, see Martins 1999.

218 Seeliger 1909. The same suggestion had been proposed in 1883 by the German physicist Eilhardt Wiedemann in a paper in the popular French journal *L'Astronomie* (see *Beiblätter zu den Annalen der Physik und Chemie* 7, 1883, 216).

219 Seeliger 1909, p. 22.

As Fick had done many years earlier, Seeliger concluded that Boltzmann's probabilistic interpretation of the second law had changed its character by robbing it of its absolute validity. 'From our point of view', he argued, 'the law of entropy has definitely not the character of a general law, but it is an empirical law subject to certain preconditions.' Whereas Boltzmann and most other physicists did not consider the probabilistic interpretation to constitute a radical break with the former understanding of the law, Seeliger believed it changed the entire discussion of the irreversibility of natural processes. He denied that the development of the universe was determined by a general tendency of nature towards ever more unordered states. 'The contrary can just as well be supposed, and perhaps with more right. If so, ... there will be more and more ordered states in nature as time goes on and the entropy law will therefore become increasingly invalid. I believe that this presumption has more in its favour than its opposite.'[220]

Whereas Thomson argued that the universe is spatially infinite and temporally finite, the Swedish astronomer Carl Charlier, professor at the University of Lund, favoured the opposite combination. Unusually for a professional astronomer at the time, Charlier transcended the divide between scientific astronomy and philosophical reflections on the more speculative aspects of cosmology. In a paper of 1896 in *Archiv für systematische Philosophie* he concluded, after having criticized the arguments of Kant and Spencer, that 'A finite time is a contradiction, ... An infinite time may be difficult to conceive, but it is not contradictory.'[221] In order to support this conclusion with scientific arguments he referred to what he somewhat ambiguously called the law of conservation of matter, the old doctrine that *ex nihilo nihil fit*. Although this law could not be verified, it was scientifically based in so far as it was a generalization of empirical knowledge. Charlier thought that the law implied that the universe was temporally limitless, his argument being as follows: if there is a lower limit to cosmic time, matter must have come into existence; if there is an upper limit, matter must disappear. In either of the cases the principle of 'matter conservation' would be violated. As to the spatial extension of the universe Charlier argued from Olbers's and Seeliger's paradoxes that it must be finite, a solution he preferred to Seeliger's modification of Newton's law of gravitation. He summarized: 'The world is infinite in time, which follows from the principle of the indestructability of matter; it has no beginning in time, and will have no end.'[222]

Although Charlier did not relate his argument for an eternal universe to the second law of thermodynamics, he did refer to the law and the possibility of a heat death. If the world was finite in size, as he tended to believe, the heat death would occur, indeed would have occurred. This did not make Charlier doubt the eternity of the world, but it did make him wonder if the world were really finite in size. Because, 'Just as a universe infinitely extended in space is a necessary condition

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220 Seeliger 1909, p. 21. On the probabilistic interpretation of entropy, see below.

221 Charlier 1896, p. 481. On Charlier, see Holmberg 1999, pp. 53-89.

222 Charlier 1896, p. 493. 'Matter conservation' is obviously an ambiguous term; in Charlier's case it should presumably be understood as mass conservation. Charlier spoke of a spatially rather than materially finite universe, but he may not have distinguished between the two as he did not refer to the possibility of a closed space.

for a development that goes on indefinitely, so, it seems to me, is it a necessary condition for a consistent mechanical world view.'[223] Charlier, who was in favour of such a world view, obviously considered it a dilemma that astronomical observations did not fit with it. As a possible resolution of the dilemma he pointed out that it rested on the assumption of uniformly distributed stars, which assumption might be questioned. He vaguely suggested that if the density distribution of stars diminished with the distance from Earth in some appropriate manner, the problem did not need to arise. What in 1896 was merely a speculation became twelve years later 'Charlier's universe', a cosmological model of a fractal and hierarchical universe built up in a particular way of spherically arranged nebulae and clusters of nebulae.[224] With this model, clever but also somewhat artificial, he was able to retain the infinite Newtonian universe and yet avoid Seeliger's gravitational paradox and also the optical paradox of Olbers.

In his paper of 1896 Charlier had noticed 'the religious interest in the questions concerning the size of the universe', but without elaborating. He had an interest in religion, such as shown by a booklet he published on the subject and which was based on a lecture of 1894 presented to a Swedish society of 'Students and Workers'.[225] This interest did not imply that he was religious in any traditional sense. Far from it, he criticized Christianity and other theistic religions both for their intolerance and for being based on superstition. What was needed, he argued, was a kind of secular and scientifically based world view not unlike the one promoted by monists and positivists in Germany. One may see his hierarchical, infinite universe of 1908 not only as consonant with his political ideology, but developed with the purpose of adding scientific support to a preconceived ideological view. In the introduction to his paper of 1908 he said as much, namely that 'from a philosophical point of view, the infinity of the world (its matter) appeared to me almost to be an axiom.'[226] In a series of lectures given at the University of California in 1924, Charlier recapitulated his hierarchic model of the infinite universe and reflected on the choice 'between the materialistic and the theological solutions of the world-problem'. His own sympathy was clearly for the materialistic solution. He admitted that the heat death was a problem for a finite universe, 'but it has no meaning for an infinitely extended world.'[227]

Charlier's compatriot, the versatile chemist and physicist Svante Arrhenius, a Nobel laureate of 1903, is best known as the inventor of the theory of ionic dissociation of electrolytes. At the time he received the Nobel Prize, he had moved on to other areas

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[223] Ibid., p. 494.

[224] Charlier 1908. An extended version in English appeared in 1922. On Charlier's hierarchical universe, see Jaki 1969, pp. 198-204.

[225] The booklet, published 1895, carried the title *Kan Religion Finnas utan Gudomlig Uppenbarelse?*, that is, 'Can there be Religion without Divine Revelation?' According to Holmberg 1999, p. 57, Charlier was regarded as 'something of a radical person'.

[226] Charlier 1908, p. 1.

[227] Charlier 1925, p. 58 and p. 182. Charlier used the occasion to express his low opinion of Kant's cosmogony. He found the *Allgemeine Naturgeschichte*, which he had studied carefully, to be 'a rather feeble product' and 'scientifically, of very small value' (p. 60 and p. 63).

of science. He had a strong interest in 'cosmic physics', an area attempting to integrate astrophysics, meteorology, atmospheric science and climatology. Although cosmic physics did not include cosmology as ordinarily understood, Arrhenius's voluminous *Lehrbuch der kosmischen Physik* of 1903 contained what became a leading theme of his cosmological system, namely long-term stability. By postulating an exchange of matter between stars and nebulae he believed to have found a mechanism that would stabilize the universe and keep the heat death in check. The idea of a finite-age universe 'is hard to bring into agreement with the indestructability of energy and matter', he said; but by invoking assumptions of collisions between stars and nebulae he thought it was possible to keep the world system going for an indefinite period of time.[228] This was also the opinion of Ulrich Dühring, a German physical chemist who in 1897 criticized the heat death hypothesis.[229] As he argued, there were undoubtedly many energetic processes in the universe that were still unknown, and some of these might well be entropy-consuming. Although he did not refer to particular processes, he found the extrapolation from the laboratory to the universe to be unwarranted.

Arrhenius's idea of stellar collisions as a counterentropic mechanism was not new. A similar idea had been suggested by Brayley in 1865 and a few years later it was adopted by Mayer and Reuschle (see Chapter 3). Moreover, it featured prominently in a cosmogonical theory proposed in 1889 by James Croll, a Scottish amateur scientist. Croll's cosmogony differed from the standard Kant-Laplace picture by starting with a large number of cold dark bodies moving with high velocities. He argued that it was just as possible for the universe to have started with a given amount of kinetic energy as with a given amount of matter. 'If the masses were created, they may as likely have been created in motion as in rest; and if they were eternal, they may as likely have been eternally in motion as eternally at rest.'[230] Croll developed an impact theory according to which stellar masses produced heat by collision in such a way that a final dissipation of energy would not occur. The sidereal universe could go on forever, he maintained, the deathly equilibrium being constantly broken by collisions between celestial bodies. It is unknown to what extent, if any, Arrhenius drew upon the ideas of Croll and other early researchers.

For Arrhenius it was an emotional and intellectual necessity to establish a cosmology that secured eternal cosmic evolution in an infinite, self-perpetuating universe. Only such a universe would be scientifically comprehensible and make supernatural causes unnecessary, he claimed. In a paper of 1909 he argued for a kind of cosmological principle – that the infinite universe is uniformly populated

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[228] Arrhenius 1903, vol. 1, pp. 221-33. For other examples of the collision hypothesis, see Delevsky 1946. On Arrhenius as a cosmologist and popularizer of cosmological ideas, see Lundmark 1927 and Amelin 1993. Arrhenius benefited from discussions with his friend and collaborator Nils Ekholm, who about 1900 had suggested a way to transform heat into mechanical energy by means of radiation pressure. At that time, Ekholm expressed doubts as to the validity of the law of entropy increase. See Ekholm 1902 and Amelin 1993, p. 51.

[229] Dühring 1897 (exstract by W. Ostwald). Arrhenius, who was on the editorial board of *Zeitschrift für physikalische Chemie*, was presumably acquainted with Dühring's paper.

[230] Croll 1889, p. 3. Croll is best known for his astronomical theory of the ice ages, published in 1875 as *Climate and Time*.

throughout with stars and nebulae. He based his belief on a philosophical principle of a somewhat dubious validity: 'It is an axiom that when we cannot prove something to be true, we must assume that qualitatively it is of the same kind as what is accessible to our senses. … So, there is in essence no weighty reason why the universe should not be uniformly populated with stars.'[231] Although Chwolson did not mention Arrhenius by name, his paper of 1910, published in the same journal (*Scientia*), may well have been a response to the Swedish Nobel laureate. Chwolson flatly rejected Arrhenius's views, which he branded as pseudo-scientific and antropomorphic.

In works between 1903 and 1913 Arrhenius developed his ideas into a qualitative cosmological theory that agreed with the views of many positivists and monists. In this period he was strongly influenced by Haeckel's monistic philosophy and published in monist periodicals such as the American journal *The Monist* and the German *Das monistische Jahrhundert*. Together with the German-American physiologist Jacques Loeb, he took part in the first International Monist Congress held in Hamburg in 1911 with Ostwald in the chair. Arrhenius used his popular works to advocate the monistic world view and defend what he called 'the cause of humanity'. One aspect of the new humanism, distinguishing it from the older conservative ideology, was that it allowed a universe with eternal life.

In his paper of 1909, Arrhenius addressed the problem of an infinite universe that had been pointed out by Seeliger, but only to deny that there was a problem. He wrongly asserted that in the case of a uniform and infinite universe the gravitational potential would be a finite quantity. Arrhenius simply failed to understand Seeliger's mathematics and claimed from simple symmetry arguments that the attractive forces on a body would cancel and thereby leave it in a state of stable equilibrium. In essence, he repeated the error that Bentley had made in his correspondence with Newton in the 1690s.[232] Like most other scientists of a positivistic or materialistic inclination, Arrhenius denied that the world could possibly have an origin in time, an idea he found was non-scientific and grossly inconsistent as it was impossible to comprehend creation of matter and energy.[233]

Not all advocates of cosmic physics agreed with Arrhenius. The Austrian meteorologist and geophysicist Wilhelm Trabert worked in the same area as his Swedish colleague, yet his version of cosmic physics was quite different. In a textbook of 1911, carrying the same title as Arrhenius's earlier book, he suggested that there was only a limited amount of matter in the universe. Contrary to Arrhenius, Trabert saw no problem in either a materially finite universe or the universal validity of the law of entropy increase: 'The world at large develops in a definite manner, as

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231 Arrhenius 1909, p. 218 and p. 226. The paper appeared in English translation as 'Infinity of the universe', *The Monist* 21 (1911), 161-73.

232 Bentley suggested that the infinite gravitational force caused by matter on one side of a body would cancel the infinite force from matter on the other side, thereby leaving the body in a state of stable equilibrium. Newton objected that it was illegitimate to conclude in this way that $\infty - \infty = 0$. In his *Confutation of Atheism*, Bentley admitted that, had it not been for divine interference, 'the Fixt Starrs could not be fixed, but would naturally convene together, and confound System with System'. Cohen 1978, p. 351.

233 Arrhenius 1907, pp. 163-9. German translation as *Die Vorstellung vom Weltgebäude im Wandel der Zeiten* (Leipzig: Akademische Verlagsgesellschaft, 1911).

in accordance with a certain tendency toward a goal. ... We know of no force which counters these unidirectional processes ... [The tendency toward maximum entropy] is the driving agent of the development of the world, and also, as far as we know, its goal.'[234]

In the preface to his best-selling *Worlds in the Making*, Arrhenius wrote that his guiding principle had been 'the conviction that the Universe in its essence has always been what it is now. Matter, energy, and life have only varied as to shape and position in space.'[235] His dismissal of a created world and its end in a heat death was a premise, not a conclusion, which may explain why he so easily accepted Haeckel's and Engels's claim of a contradiction between the two laws of thermodynamics:

> If Clausius were right, however, this heat-death, we may object, should already have occurred in the infinitely long space of time that the universe has been in existence. Or we may argue that the world has not yet been in existence sufficiently long, but that, anyhow, it had a beginning. That would contradict the first part of the law of Clausius, that the energy of the universe is constant; for in that case all the energy would have originated in the moment of creation. That is quite inconceivable, and we must hence look for conditions for which the entropy law of Clausius does not hold.[236]

Unlike Haeckel, Arrhenius had a sound knowledge of the science of thermodynamics and was able to follow the arguments of Clausius and Thomson. He nonetheless objected to Clausius's theory of entropy increase, which he found was untenable in its standard formulation, and concluded that on a cosmic scale entropy-increasing processes would be balanced by entropy-decreasing processes. Among the solutions he came up with was a mechanism based on dust particles that would allow nebulae to absorb light and yet remain cool. This mechanism he combined with a hypothesis of radiation pressure. As he wrote in 1909: 'It seems perfectly reasonable that the nebulae are able to absorb the energy radiating from the stars. The nebulae also possess the ability to check the dust particles driven away from the sun by the light-pressure, so that these cold bodies may be considered as storage houses for the quantities of matter and energy that radiate from the hot suns.'[237] In *Worlds in the Making* he concluded that the proposed mechanisms would allow that 'the evolution of the world can continue in an eternal cycle, in which there is neither beginning nor end, and in which life may exist and continue forever and undiminished.'[238] Arrhenius's universe was a vast thermal machine operating with two heat reservoirs, the hot stars and the much cooler nebulae; although entropy would increase in the first reservoir, it would be compensated by the decrease in the second. His picture

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[234] Trabert 1911, p. 645.

[235] Arrhenius 1908, p. ix, a translation of *Världernas Utveckling* (Stockholm: Gebers, 1906).

[236] Arrhenius 1908, p. 193. Emile Meyerson noticed that Haeckel's and Arrhenius's dismissal of the general validity of the second law was not empirically based, but of an *a priori* nature, rooted in a conviction anterior and superior to all experience (Meyerson 1930, p. 269).

[237] Arrhenius 1909, p. 223.

[238] Arrhenius 1908, p. 211.

of the regenerating world had some similarity with the one proposed by Kant about 150 years earlier, except that Arrhenius had no need for God as the cause of the universe.[239]

The suggestion of the Swedish chemist-turned-cosmologist was widely discussed and attracted much popular interest, but it failed to win scientific approval. It attracted the attention of Henri Poincaré, who in his late work *Hypothèse cosmogonique* showed that 'Arrhenius' demon' was unable to counter the second law of thermodynamics. It might retard the universal heat death, perhaps for an exceedingly long time, but it could not cancel it. 'We have to renounce the dream of the "eternal recurrence" and the perpetual rebirth of worlds', Poincaré concluded. 'It appears that Arrhenius' solution is insufficient.'[240] Poincaré did not support either a finite or an infinite universe, but he did point out the well-known problems facing an infinite universe populated uniformly with stars and galaxies (Olbers's optical paradox and Seeliger's gravitational paradox). He also referred, if only uncommittedly, to the possibility that the geometry of the universe might be Riemannian, thus allowing a finite yet unbounded space. However, faithful to his conventionalist philosophy, Poincaré denied that the geometry of space was something that could be determined objectively. It was a matter of convention, to be determined by the principle of simplicity, and on this account he saw no reason to depart from Euclidean geometry.[241]

Arrhenius seems to have accepted Poincaré's criticism, at least in part, but this only made him look for additional processes that could prevent the cosmic armageddon. In later editions of *Worlds in the Making* he argued that collisions between rapidly moving nebulae would release large quantities of energy and reduce entropy, thereby preventing the heat death eternally. In spite of this rescuing manoeuvre, after Poincaré's detailed and damaging criticism, little more was heard of Arrhenius' cosmology. Yet, as late as 1927 Abel Rey brought new attention to Arrhenius's proposal and general idea of an eternally cyclic universe. Rey's programmatic *Le retour éternel et la philosophie de la physique* pictured eternal recurrence as the supreme embodiment of scientific objectivity and rationality, whereas he associated irreversibility with subjectivism. The rationalist Rey shared the Laplacian view of the universe as a perfect machine, a *perpetuum mobile* or 'a blind machine constructed in such a manner that it might pass through the same states in an infinite number of times'. He called the idea of eternal recurrence 'one of the most profound, the least discussed, and the most fertile' of scientific hypotheses.[242]

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[239] Arrhenius 1907 dealt in some detail with Kant's cosmogony, but stressed that his own theory was different. According to some critics, his cosmological theory was essentially a modernized version of Kant's (Weinstein 1913, p. 110).

[240] Poincaré 1911, p. lxix. See also pp. 240-65. Arrhenius's unconventional understanding of the second law was also criticized by Johannes Wilhelm Classen, a Hamburg physicist. According to Classen, who defended the heat death and the cosmic beginning, Arrhenius's ideas 'cannot be justified by physics' (Classen 1910, p. 24, a publication of the Keplerbund).

[241] Poincaré's view was shared by Seeliger, who believed that space had no existence apart from a means of spatial coordination of objects. He denied that the geometry of space could be determined by astronomical or physical methods. See Seeliger 1913.

[242] Rey 1927, p. 44 and p. 267. See also Delevsky 1946 and Jaki 1974, pp. 343-5.

Recurring or cyclic conceptions of the universe were indeed popular in the years around the turn of the century. Whether they were profound and fertile, as held by Rey, is more debatable. The Swiss-born physicist Ludwig Zehnder, professor in Freiburg and later at the Berlin Technical University, assumed in a book of 1897 that all celestial bodies were confined within a gigantic, possibly infinite sphere of ether. Like several other scientists at the time, he conceived the ether as a kind of rarefied gas consisting of tiny atoms endowed with mass and other physical properties.[243] According to Zehnder, electricity was to be understood in terms of the motion of ether atoms. A sidereal universe including a limited number of stars – a picture favoured by Olbers's paradox – would be subject to gravitational collapse, with all the stars rushing towards a 'central sun'. However, this would not be the end of the world, for according to Zehnder the cooling of the central sun would lead to an increase of the kinetic energy of the ether atoms and consequently to an increased electrical repulsion between atoms of matter. The result would be an expansion of the material universe, eventually to be followed by new contraction when the gravitational attraction came to dominate the electrical repulsion. In this way Zehnder believed he had constructed on a scientific basis an eternal and cyclic universe. In a book of 1914, inspired by Arrhenius's ideas of colliding nebulae, he presented his world picture in an updated and more popular version.[244] Although Zehnder's material universe was limited, his aim was the same as Arrhenius's, namely, to argue that the universe was eternal and not subject to any heat death.

Rey's compatriot, Camille Flammarion, was one of the few astronomers who commented on the thermal future of the world, although he did so in popular texts and novels and not in his scientific works. In his best-selling *La fin du monde* from 1894, a science-fiction novel mixed with popular science, he wrote of how humankind would eventually disappear from Earth because of changed thermal conditions. Although his vision has often been used to illustrate the heat death, in fact the mechanism he invoked for the deterioration of the Earth's habitability was cooling caused by lack of water vapour in the atmosphere, not the depletion of the Sun's energy nor the general increase of entropy in the universe.[245] Flammarion was well aware of the heat death scenario: 'It is certainly incontestable that, whereas energy is indestructible, there is a general tendency towards its dissipation, which will result in a state of universal rest and death, and the mathematical argument [for this] is impeccable.' However, he immediately went on to deny that such a state would ever occur: 'Why? Because the universe is not a finite quantity.' Flammarion neither believed in a cosmic beginning nor an end, such as he clearly spelled out in

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[243] Zehnder 1897, extensively reviewed in Klein 1897. The idea of a corpuscular ether was defended by Dmitri Mendeleev, Caspar Isenkrahe, Robert Grassmann and Carl von Nägeli, among others. On late-nineteenth-century ether theories, see Kragh 1989 and Cantor and Hodge 1981.

[244] Zehnder 1914. His theory of a pulsating and materially finite universe had some similarity to the picture outlined in Falb 1875.

[245] On Flammarion's novel, see Clarke 2001, pp. 35-41, 52-8. However, Clarke mistakenly believes that Flammarion's prophecy of the end of life on Earth was related to the thermodynamical heat death. For a correction of this and similar mistakes, see Kleinert 1992.

the final lines of *La fin du monde*: 'And infinite space rests for ever populated with worlds [nebulae] and stars, spirits and suns; and eternity endures for ever. For it can have no end, and no beginning.'[246]

Flammarion subscribed to a mystical, cosmical religion of a pantheistic kind that had little to do with traditional Christianity, and he was convinced that the universe was full of intelligent life, indeed that the cosmos itself was alive. As a prophetic positivist and a social optimist he believed that life and spirit would go on endlessly, if not on Earth then elsewhere. Consequently he was bound to deny the heat death and to ignore the entropic creation argument. His elementary objection, that the second law was only valid for a finite system and not for the supposedly infinite universe, was stated in the context of a futuristic novel. As we have seen, this was a standard argument at the time, stated also in scientific contexts.

To the generation of scientists to which Arrhenius and Flammarion belonged, the notion of the beginning of the universe was weird, nearly incomprehensible. As the Cambridge professor of mathematics Ernest Hobson confirmed in his Gifford Lectures of 1921-22, 'Of absolute origins, Science knows nothing, and we can form no conception.' With respect to the primordial state of the universe, such as postulated in the nebular hypothesis, he said that it 'presents a problem which we do not attempt to solve'. Hobson was aware of the many attempts to apply the second law of thermodynamics to the cosmos, but warned that they rested on a speculative foundation, principally because the law lost any definite meaning if extrapolated from a finite system to an infinite universe. 'This theory', he said, 'is open to the very serious criticism applicable to all statements made about the physical universe as a whole.'[247] Hobson did little more than repeat what many critics of the finite-age universe had argued in the nineteenth century. However, his attitude to the problem was rooted in a philosophy that had nothing in common with the one held by either positivists or materialists: He argued that knowledge about ultimate realities, such as met in cosmology, belonged to the domains of religion and idealistic philosophy.

Most scientists were unconvinced of the entropic argument, which they either ignored or presented as a dilemma rather than a solution. One more example is the British geophysicist Arthur Holmes, a pioneer of radioactive dating methods and one of the first scientists to estimate the age of the Earth by means of such methods. It was uncontroversial to ascribe a finite age to the Earth, and only mildly controversial that the age was as high as the order of one billion years, but to ascribe a finite age to the universe was an entirely different matter. In *The Age of the Earth*, a classic of 1913, Holmes formulated the entropic creation paradox in a way strikingly similar to how Jevons and his contemporaries had discussed it in the 1870s:

> Gravitational energy alone affords no escape from the ultimate *Wärmetod*, the thermal extinction towards which the universe would appear to be tending. If the development of the universe be everywhere towards equalization of temperature implied by the laws of thermodynamics, the question arises – Why, in the abundance of time past, has this

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[246] Flammarion 1894, pp. 377-85. See also Flammarion 1891. The question of the actual infinite was discussed by French philosophers involved in the *fin de siècle* debate concerning the value and meaning of science (Fouillée 1896, pp. 173-80).

[247] Hobson 1923, p. 315 and p. 238.

> melancholy state not already overtaken us? Either we must believe in a definite beginning, in the creation of a universe furiously ablaze with energy, or else we must assume that the phenomena which we have studied simply reflect our limited experience.[248]

Holmes, like most others, tended towards the latter alternative. Modern as he was in his use of radioactivity in geochronology, in matters of cosmology he was a traditionalist. Like Arrhenius, he suggested that there must exist some external force that replenish the Sun and the stars, for 'in the universe nothing is lost ... In its cyclic development we may find the secret of its eternity.'[249] Notice, once again, how the eternity of the universe is taken for granted, not something that is in need of proof or evidence.

The Irish geologist John Joly shared Holmes's instinctive dislike of a definite beginning of the universe. In 1892 he published a popular article entitled 'A speculation as to the prematerial condition of the universe' in which he attempted to reconcile the eternity of the universe with the idea that progressive change can only have gone on for a limited period of time.[250] Joly's problem was the origin of progressive or uniform changes in the universe, which he stated in very general terms: 'Consider the legitimate *reductio ad absurdum* of an ember raked from a fire 1000 years ago. Is it not yet cooled down to the constant temperature of its surroundings? And we may evidently increase the time a million-fold if we please. It appears as if we must regard eternity as outliving every progressive change.'[251] He may have had the entropy law in mind, but in fact he mentioned neither it nor other aspects of thermodynamics. Joly believed that an absolute beginning of the universe was 'unthinkable': matter and motion must always have existed, at least in the form of 'an active but unprogressive eternity'. Although 'there is no beginning or ending to the activity of the universe', there is a beginning and an end to the presently observed progressive activity. To account for this beginning he made the drastic suggestion that gravitation was absent in the primordial, static universe and that somehow and at some time matter became endowed with the force of gravity. He does not seem to have recognized that a sudden beginning of gravitation would be no less miraculous than the sudden beginning of motion.

Arrhenius's popular expositions, coloured as they were by monism and a vague form of pantheism, caused some debate, especially in Scandinavia and Germany. His views were critically discussed by the Swedish cultural commentator and cleric Samuel Andreas Fries, whereas they were received sympathetically by Hjalmar Tallqvist, a professor of physics at Helsinki University, Finland. In a popular book on energy and entropy, Tallqvist described the heat death scenario and briefly mentioned the unlikely possibility of an entropic beginning. Why has the heat death not already occurred, given that 'the universe as a whole can only be conceived as eternal'?[252] Referring to the hypotheses of Arrhenius and Nernst, Tallqvist suggested

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[248] Holmes 1913, pp. 120-121.

[249] Ibid., p. 121. Holmes referred to Spencer's 'profound insight'.

[250] *Scientific Proceedings of the Royal Dublin Society* 7 (1892), 563-73. Reprinted in Joly 1915, pp. 288-302.

[251] Joly 1915, p. 290.

[252] Tallqvist 1924, p. 147.

that 'the not particularly pleasant' heat death might not be an inevitable consequence of thermodynamics.

In Denmark, Arrhenius's views met opposition from Hans Martensen-Larsen, an author and priest. Martensen-Larsen was convinced that the universe was finite and that only such a universe was in accordance with Christian belief. 'If the sidereal universe in which we live is finite, we stand in a peculiar way before God. ... [We feel] that there must be something infinite outside and above it. ... If the universe is finite in mass, we are led towards the idea of a beginning and a creation.' Whereas Arrhenius had dismissed the idea of a positively curved space, Martensen-Larsen found it an interesting possibility that supported his religiously motivated belief in a finite universe. He further welcomed the heat death scenario based on thermodynamics and criticized the attempts of Arrhenius, Haeckel and others to escape the consequences of the second law. Arrhenius's arguments, he said, were based on 'a postulate of faith, fashioned like it was science.'[253] The Catholic philosopher Constantin Gutberlet, a veteran in the entropic-apologetic debate, found Arrhenius' views worrying enough to merit an extensive refutation. According to Gutberlet, the universal validity of Newton's law of gravitation was beyond question. From this, and the paradoxes of Olbers and Seeliger, he concluded that Arrhenius's claim of an infinite universe was refuted.[254]

Arrhenius's use of radiant heat and its associated pressure was neither the first nor the last attempt to use starlight to question the validity of the second law of thermodynamics. The American astronomer and physicist Henry Turner Eddy, a professor at the University of Cincinnati, argued in a thought experiment of 1882 that radiant heat was an exception to the second law. Eddy did not accept the axiomatic nature of Clausius's law, but considered it to be merely an empirical law that might well be subject to exceptions, and he interpreted his thought experiment as providing support for the Maxwell-Boltzmann hypothesis of the law being probabilistic in nature. As did several other authors in the period, he saw this idea as an escape from the pessimistic prediction of a universal heat death.[255] Since a large part of the heat exchange in the universe takes place in radiant form, then 'I must regard it as still an open question as to whether, on the whole, the available energy of the universe is being dissipated and its entropy increased or not.'[256] Eddy's ingenious thought experiment received wide notice and comments from luminaries such as Boltzmann, Gibbs and George F. FitzGerald. The discussion concerning radiant heat was of a technical and conceptual nature, and did not involve ideological or cosmological issues, at least not explicitly.

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253 Martensen-Larsen 1915, p. 159 and p. 175.

254 Gutberlet 1915.

255 It was commonly believed that the statistical nature of the second law somehow makes it valid only for average values, not for fluctuations. However, as Leo Szilard demonstrated in 1925, the belief is unfounded. Boltzmann's formulation does not imply that the second law is merely approximately valid or has lost its 'dogmatically strict character'. Szilard 1925.

256 Eddy 1882-83. For context and analysis of the thought experiment, see Carazza and Kragh 1989. Eddy referred to Rankine's old paper of 1852, suggesting that Clausius's objections to radiant heat as an exception to the second law were not compelling.

Radioactivity as a Cosmic Clock

The cosmological significance of the law of entropy is a consequence of entropy growth being irreversible. Should there be other irreversible phenomena in nature of a similarly general kind, other universal arrows of time, these might perhaps be used in the same way as the entropic creation argument, namely to suggest that the universe had an origin in time. After 1930 the expansion of the universe came to function in this manner, as a cosmic clock, but the concept of the expanding universe was an unknown concept until then.

With Henri Becquerel's discovery of radioactivity in 1896, and the subsequent investigations of Marie and Pierre Curie that led to the discovery of radium and polonium, a new irreversible phenomenon came to light. After several years of confusion it was established that radioactivity is a property associated with the atoms of the chemical elements and that the decay rate, as given by the half-life, is a constant that depends only on the atomic species. It is not influenced at all by external changes, such as pressure, temperature or chemical reactions. The long-lived radioactive elements, such as uranium and thorium, decayed spontaneously and irreversibly; most likely, they were never formed by fusion of lighter elements nor by the decay of hypothetical transuranic elements. In the early years of the twentieth century it was occasionally suggested that there might be opposite processes in nature whereby the parent elements themselves were built up, but the speculation was eventually abandoned because of lack of evidence. If the decay rates were independent of external physical conditions, such as indicated by experiments, how was it that radioactive bodies were still present in the Earth's crust? Somehow they must have been part of the original condensation process out of which the Earth was supposedly formed, but the original nebulous material must itself have existed in a limited time, for otherwise its content of radioactivity would have vanished.[257]

Arguments of this kind would seem to indicate not only that the Earth was of finite age, but that this was also the case with the universe. Although radioactivity was studied as a terrestrial phenomenon, it was generally agreed that the material composition of the Earth was largely representative of the cosmos. In addition, spectrographic investigations of the Sun and the stars seemed to show that radioactive elements were not confined to the Earth (for a brief while it was contemplated that the core of the Sun might consist of uranium or radium). The argument received further credibility from the assumption, generally accepted in the period from about 1902 to 1913, that all or most chemical elements are radioactive, only that most of them have exceedingly long half-lives.[258] Altogether, it seemed that radioactivity did not agree easily with the material universe being eternal.

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[257] The role of radioactivity in astronomy and cosmology from about 1900 to 1930 is examined in Kragh 2007b.

[258] As Rutherford expressed it: 'It is a matter of general experience that every physical property discovered for one element has been found to be shared by others in varying degrees. … It might thus be expected on general principles that the property of radioactivity which is so marked in a substance like radium would be shown by other substances. ' Rutherford 1906, p. 216.

In fact, arguments of this kind were not common and, as far as I know, can only be met after 1910. In his previously mentioned lecture of 1911, Arthur Haas not only referred to the entropic argument in support of a finite-age universe, he also introduced the argument based on radioactive decay. Haas pointed out that if uranium was to be explained as a decay product of a heavier, hypothetical element, then this element would again have to be the product of a still heavier mother substance, and so on *ad infinitum*. Under the assumption of an eternal universe this would lead to the impossible conclusion of an element of infinite atomic weight! Moreover, the disintegration of an infinite series of radioactive elements would give rise to an infinite amount of heat which, when distributed in the spatially finite universe, would make the temperature of the present universe infinitely high! Therefore: 'The phenomenon of atomic decay, which probably governs not only radium and uranium but all matter, constitutes an important new objection against the assumption of an eternal world process.'[259]

Haas thought that the radioactive argument was weaker than the one derived from the second law of thermodynamics because radioactivity was still poorly understood. One could not claim with absolute confidence that it was impossible 'that there occur in nature processes opposite to the atomic disintegration; namely, that complex atoms may be formed from simpler ones by consumption of strong heat'. Yet Haas found the radioactive argument to be a valuable supplement to the argument based on the entropy law. His suggestion that radioactive bodies might indicate a universe of finite age did not fall on deaf ears. It was taken up by the Belgian neo-Thomistic philosopher Desiré Nys, who gave it a sympathetic review in his textbook in philosophy.[260] Like Haas, Nys found radioactivity to be an argument in favour of the finitude of time, but not a compelling one.

In a book of 1915 Erich Becher, a professor of philosophy at the University of Münster, reached a conclusion similar to Haas's, based on radioactivity as an unwinding clock in analogy with the degradation of energy. 'Why have the continually decaying radioactive substances not already been used up? ... It again appears that it [the material world] exhibits a unidirectional, irreversible course; that it is oriented towards an end and indicates a beginning.'[261] Martensen-Larsen agreed and noted with satisfaction that the phenomenon was yet another indication of a created world – 'that the world process must have had a beginning and strives towards an end'.[262] While Haas, Becher and Martensen-Larsen used radioactivity to support the idea of a universe with an origin in time, neither of them used the argument directly apologetically, as a proof of God's existence. They probably realized that, if taken alone, it was not an argument of great force.

The cosmological significance of radioactive decay was occasionally discussed, but it occupied but a small place in the scientific work physicists and chemists

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259 Haas 1912, pp. 183-4.

260 Nys 1913, pp. 190-3.

261 Becher 1915, pp. 279-81.

262 Martensen-Larsen 1915, p. 172. Curiously, while Maxwell, Secchi and Wurtz used the stability of atoms as an argument for creation in the 1870s, Haas, Becher and Martensen-Larsen used in the 1910s their instability for the same purpose.

did on radioactivity (astronomers seem to have ignored the subject). Two of the period's foremost experts in radioactivity, the Austrians Stefan Meyer and Egon von Schweidler, mentioned specifically the parallel between entropy increase and radioactive decay in a survey article of 1915. If only decay processes occurred in nature, then 'the second law of the mechanical theory of heat has a counterpart: just as in the transformation of energy, in the case of matter there is a preferred direction.' On the other hand, should radioactive processes turn out to be reversible, matter would be transformed not only destructively but also constructively, making possible a material state of equilibrium. The two Viennese physicists were impressed by the perspectives of the young science of radioactivity which seemed able to provide an empirically based answer to 'the age-old, never solved and yet never silenced question of origin and end, of the finitude or eternity of the cosmos'.[263]

The German physical chemist Walther Nernst was among the first to comment on the connection between radioactive decay and the second law of thermodynamics. In an address of 1912 he considered the cosmic heat death, this 'most fatal consequence' of the second law. Nernst was strongly opposed to the heat death, but contrary to some other opponents he admitted that it followed strictly from thermodynamics, and he dismissed all standard attempts to avoid the conclusion. But what about non-standard attempts, such as based on radioactivity? Nernst noted that radioactive decay was as irreversible as the degradation of energy, which might seem to indicate that 'the prospects of a Götterdämmerung of the universe have only doubled'. Yet, this was not his final conclusion, for he speculated that radioactive decay might ultimately result in an energy-enriched ether out of which new atoms might be recreated. If so, 'the end of all events need not follow unconditionally from our present view of nature.'[264] Nernst realized that his idea was nothing but an interesting speculation, but after 1920 he returned to it and developed it into a cosmological theory of a stationary and eternal universe with continual creation of matter (see Chapter 6).

In the early days of radioactivity it was sometimes suggested that the enigmatic phenomenon violated not only the first law of thermodynamics but also the the second. William Crookes said as much in 1898, when he argued that the energy might be taken from the surrounding air by the collision of light molecules with the heavy atoms of radioactive elements acting as a kind of Maxwellian demon.[265] In a public conference of 1900 Marie Curie suggested the possibility in more explicit terms: 'If the source of energy cannot be found ... we are forced to admit that Carnot's principle is not absolutely general [and] ... that the radioactive substances are able to transform heat from the ambient environment into work.'[266] However, nothing came out of this or similar speculations. Progress in the science of radioactivity soon proved that it did not contradict either of the thermodynamical principles, although the first law would have to be generalized to a combined matter and energy conservation law (by means of $E = mc^2$) to accomodate subatomic transformations.

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263 Meyer and von Schweidler 1915, pp. 512-3. A similar exposition appeared in Becher 1915, pp. 280-281.

264 Nernst 1912, pp. 105-6.

265 Crookes 1898, pp. 26-7.

266 Curie 1954, p. 105. See also Brunhes 1908, pp. 207-8.

Brownian motion – the irregular fluctuations that small particles exhibit in gases and fluids – was occasionally used to argue against the absolute validity of the second law. In a few cases the phenomenon entered the cosmological arguments against a heat death. The application of classical thermodynamics to some system presupposes that the system may be treated as approximately continuous, that is, that its molecular constitution is not dominant. Fluctuations, as in Brownian motion in a column of air, cause microscopically visible particles to rise against gravity now and then; in this way heat energy is turned into gravitational potential energy, which has lower entropy. The suggestion that Brownian motion violates Clausius's law was first enunciated by the French physicist Léon Gouy in 1888, and it received further attention by remarks made by Poincaré in the early twentieth century. As Poincaré expressed it in 1904, if Gouy's idea was correct, then 'to see the world return backward, we no longer have need of the infinitely subtle eye of Maxwell's demon; our microscope suffices us'.[267] However, Poincaré did not actually endorse the idea. That Brownian motion may be seen as a kind of Maxwellian demon was clearly recognized by Einstein in his theory of 1905 in which he analyzed the phenomenon. If it can actually be observed, Einstein wrote, 'then classical thermodynamics can no longer be looked upon as applicable with precision to bodies even of dimensions distinguishable in a microscope'.[268]

Although radioactivity, considered in a cosmological context, might provide an additional argument for a beginning of the world, it might also be taken as support for a cyclic world view. This is what Hermann Scheffler, a German author and amateur scientist, did in a booklet of 1906 in which he claimed that everything in the world derived from a 'universal energy' of radioactive origin.[269] But it is of more interest to consider the early works of Soddy, recipient of the 1921 Nobel Prize in chemistry. Soddy was a pioneer in radiochemical research and had in 1902, in collaboration with Rutherford, proposed the exponential law of radioactive decay, the foundational law governing all elementary processes of radioactivity. As early as 1904 Soddy suggested, purely speculatively and addressed to a general readership, a connection between radioactivity and cosmology. He wrote of 'a sudden beginning of the universe – the time when present laws began to operate' and found it necessary to suppose that 'the universe as a thing in being had its origin in some initial creative act, in which a certain amount of energy was conferred upon it, sufficient to keep it in being for some period of years.'[270] This could be read as an anticipation of the Big-Bang scenario, or a scientific version of the biblical creation story, but it was neither of these things. Soddy was not religious, and his taste was for a cyclic world view of the kind advocated by Arrhenius at about the same time. He was raised in a Calvinist home, but as a young man he renounced his parents' religion and turned away from any kind of religious doctrine.

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267 Quoted in Brush 1986, p. 671. On Brownian motion as a possible realization of Maxwell's demon, see also Houllevigue 1913, pp. 55-7.

268 Einstein 1965, p. 2.

269 Scheffler 1906.

270 Soddy 1904, p. 188.

Soddy gave a fuller and clearer exposition of his cosmic views in *The Interpretation of Radium*, a book based on a series of public lectures delivered at the University of Glasgow in 1908. In the final chapter he speculated that subatomic energy played a role not only in radioactive processes, but also cosmologically:

> The idea which arises in one's mind as the most attractive and consistent explanation of the universe in light of present knowledge, is perhaps that matter is breaking down and its energy being evolved and degraded in one part of a cycle of evolution, and in another part still unknown to us, the matter is being built up with the utilisation of waste energy. The consequences would be that, in spite of the incessant changes, an equilibrium condition would result, and continue indefinitely.[271]

The universe that Soddy imagined to keep going by means of atom-destructive and complementary atom-constructive processes (and corresponding increase and decrease in entropy), was 'a conservative system, limited with reference neither to the future nor the past, and demanding neither an initial creative act to start it nor a final state of exhaustion as its necessary termination'.[272] Soddy was from an early date captivated by Ouroboros, the tail-devouring serpent which for the alchemists served as a symbol for eternity and immortality, and in his book of 1909 he used it to symbolize cyclic and ever-regenerative cosmological processes.

The radioactivity-cosmology connection never was a strong one, but it continued to receive mention also in the post-World War I period. Thus, in a lecture of 1922, dealing with borderline problems between astronomy and geology, Arthur Eddington said: 'In radioactivity we see a mechanism running down which must at some time have been wound up. Without entering into any details, it would seem clear that the winding-up process must have occurred under physical conditions vastly different from those in which we now observe only a running-down.' However, Eddington did not identify these vastly different physical conditions with a primeval state of the universe, but with 'the general brewing of material which occurs under the intense heat in the interior of the stars'.[273] Eight years later, Eddington's former research student Georges Lemaître would propose the first cosmological Big-Bang model ever, and in his thinking the radioactive creation argument served as an important inspiration.[274]

Entropy and Probability

The beginning of statistical considerations in physics was closely connected with the kinetic theory of gases and the second law of thermodynamics, such as discussed by

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[271] Soddy 1909, pp. 241-2.

[272] Ibid., p. 189. On Soddy and his lifelong fascination by cyclic processes, see Sclove 1989.

[273] Eddington 1923, p. 19. The strongly religious Eddington never accepted a universe of a definite age. On his view of the science-religion relationship, see Stanley 2007.

[274] See Kragh 1996, p. 48, with further details in Kragh and Lambert 2007. Lemaître proposed that the primeval universe was a superdense and super-radioactive 'atom' whose explosive decay constituted what later became known as the Big Bang.

Clausius, Maxwell and a few others in the 1860s. Maxwell was keenly aware that the statistical approach led to results that differed from those of ordinary mechanics, first of all that they were not symmetric in time. In other branches of physics the sign of the time parameter did not matter, but not so in statistical physics and thermodynamics: 'It makes all the difference in the world whether we suppose the inquiry to be historical or prophetical – whether our object is to deduce the past state or the future state of things from the known present state. In astronomy, the two problems differ only in the sign of *t*, the time; in the theory of the diffusion of matter, heat, or motion, the prophetical problem is always capable of solution; but the historical one, except in singular cases, is insoluble.'[275]

To Maxwell and some of his contemporaries, statistical physics was not only a new approach to understanding nature, it was also associated with the problem of free will, and hence part of the debate over scientific naturalism and materialism. Maxwell invented his famous demon in 1867, in a letter to Tait, and four years later it appeared in his *Theory of Heat*. The essence of the thought experiment is a vessel which contains two gases, one cold and one hot, separated by a diaphragm in which there is a hole or a valve. Maxwell now imagined a 'finite being' who could open and close the hole and was able to observe the motions of the individual gas molecules. By letting fast moving molecules pass from the cold to the hot gas the being would take heat from the colder body and transfer it to the hotter, thereby violating the second law. 'The hot system has got hotter and the cold colder and yet no work has been done, only the intelligence of a very observant and neat-fingered being has been employed.'[276]

Together with his demon, Maxwell introduced the possibility that the second law, and perhaps other laws of physics as well, was not really an attribute of nature herself but perhaps a result of human perception being incomplete and uncertain. In an article of 1877 he argued that the principle of energy dissipation might be looked upon as an expression of subjectivity rather than objectivity:

> The idea of the dissipation of energy depends on the extent of our knowledge. Available energy is energy which we can direct into any desired channel. Dissipated energy is energy which we cannot lay hold of and direct at pleasure, such as the energy of the confused agitation of molecules which we call heat. Now confusion, like the correlative term order, is not a property of material things in themselves, but only in relation to the mind which perceives them. … The notion of dissipated energy could not occur to a being who could not turn any of the energies of nature to his account, or to one who could trace the motion of every molecule and seize it at the right moment. It is only to a being in the intermediate stage, who can lay hold of some forms of energy while others elude his grasp, that energy appears to be passing from the available to the dissipated state.[277]

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[275] Unpublished paper of 1873 entitled 'Does the progress of physical science tend to give any advantage to the opinion of necessity (or determinism) over that of the contingency of events and the freedom of the will?' In Maxwell 1990-2002, vol. 2, pp. 814-23, p. 819. Also reproduced in Campbell and Garnett 1969, pp. 434-44 (originally published 1882).

[276] Letter to Tait of 11 December 1867, in Garber, Brush and Everitt 1995, p. 177.

[277] Article on 'Diffusion' in *Encyclopædia Britannica*, see Maxwell 1965, Part 2, p. 646.

Then, if the entropy of a system depends on the perceiving mind, how real can the heat death be? Maxwell suggested that the second law was merely highly probable, not mechanically inevitable. This he regarded as a positive feature as it could be used as an argument against materialism and for human freedom. He suggested that atomism, thermodynamics and statistics could be understood as evidence for the possibility of free will.[278] In his 1880 address to the Victoria Institute, Stokes related Maxwell's demon to natural theology, namely, as a possible means to avoid the heat death. Although he admitted that Maxwell's thought experiment was speculative, he found that it offered a picture of 'how the natural tendency of a natural law may be averted without any disturbance of the law itself, provided, and only provided, we superadd the idea of will guided by design'.[279]

According to the mathematician and biometrician Karl Pearson, who was to some extent inspired by Mach, laws of nature were not independent of humans but, on the contrary, conditioned by our mental and perceptive qualities. They were fundamentally anthropomorphic. 'There is more meaning in the statement that man gives laws to Nature that in its converse that Nature gives laws to man,' he wrote in *The Grammar of Science*, first published 1892.[280] As an example of this philosophy he referred to Maxwell's demon, which he suggested was an excellent illustration of how natural law was relative to the physiological constitution of humans. It followed from Pearson's point of view – or Maxwell's, if taken to its extreme – that the heat death was an artifact produced by the perceptive faculty of human beings. From the perspective of ants or worms there presumably would be no running-down of the universe.

Starting in 1872, Ludwig Boltzmann developed and generalized Maxwell's kinetic theory of gases which built on the assumption of collisions between gas molecules. As a result of this work he was led to introduce a certain distribution function which attained its minimum value for the Maxwell equilibrium state. Boltzmann originally designated the function by the symbol E, but in the 1890s it changed to H. According to Boltzmann's 'H-theorem' a gas in a non-equilibrium state will spontaneously change in such a way that H decreases, which pointed to a molecular-dynamical understanding of the second law of thermodynamics. This line of work culminated in 1877 with Boltzmann's celebrated statistical theory, in which entropy was defined in terms of a probabilistic measure. In modern notation, he derived the famous expression $S = k \log W$, where k denotes Boltzmann's constant and W is proportional to the number of microstates corresponding to a certain macrostate.[281]

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278 On the connection between statistical physics and human freedom, as perceived in the second half of the nineteenth century, see Porter 1986, pp. 151-219. The connection was also seen as important by Catholic scientists in their efforts to harmonize modern science with religious issues (see Nye 1976).

279 Stokes 1880, p. 238.

280 Pearson 1911, vol. 1, p. 87. In a note added on p. 394 Pearson claimed that the irreversibility of natural processes was purely relative to the motion of the events and their observer. All processes and all history would be reversed for an observer moving away from Earth with superluminal velocity. This is a surprising claim, given that Pearson was aware of the theory of relativity which forbids such motion.

281 The equation $S = k \log W$ was first formulated by Planck, not by Boltzmann.

According to Boltzmann, the essence of the second law was that a system, starting in an improbable state, moves spontaneously through a series of states that are ever more probable and finally ends in a maximum-probable state, meaning maximum entropy. The lower the value of W, the higher the degree of ordering, and the law can therefore be said to be a statement about increase of disorder. For example, in a maximally ordered system, such as a perfect crystal at absolute zero temperature, $W = 1$ and therefore $S = 0$; if the crystal is left to itself (and kept isolated from its surroundings) it will spontaneously move into a less ordered state, corresponding to an increased entropy.

The development of the understanding of the second law constitutes a complex history,[282] most of which is of little relevance in the present context, and for this reason I shall suffice to mention some of the results that were of cosmological significance. Boltzmann showed that the H-function had the property that in a closed system $dH/dt \leq 0$, with equality holding only if the velocities of the gas particles were distributed in accordance with the Maxwell-Boltzmann distribution law. In the case of a gas occupying a volume V, the H-function relates to the entropy by the simple expression $H = -S/kV$. Since the entropy of a gas could thus be expressed by $-H$, he claimed to have provided a mechanical reduction of the second law. According to Boltzmann's formulation of 1872, the H-function would always decrease, or the entropy always increase, and five years later he realized that the second law of thermodynamics could be formulated in probabilistic terms.But how can this law, the very expression of nature's irreversibility, be derived from a theory which is manifestly reversible?

This question was addressed independently by physicists in Britain, Germany and Austria. In a paper of 1875 on the dissipation of energy, Thomson noted the contrast between the reversible mechanics and the irreversible heat phenomena, and he argued that a violation of the second law was only impossible in a statistical sense. Considering a bar of iron, he noted that there is a non-zero probability that at some time the one half of it will spontaneously become one degree warmer than the other half. But this presupposes the bar to be perfectly isolated, which Thomson considered to be a non-physical idealization: 'Do away with this impossible ideal, and believe the number of molecules in the universe to be infinite; then we may say one-half of the bar will never become warmer than the other, except by the agency of external sources of heat and cold. This one instance suffices to explain the philosophy of the foundation on which the theory of the dissipation of energy rests.'[283]

Thomson's paper was not much noticed in the German-speaking countries, where most of the subsequent discussion took place. Boltzmann's colleague in Vienna, the physical chemist Joseph Loschmidt, believed that the irreversibility problem or paradox proved that the second law cannot be absolutely valid. In 1869 he devised a thought experiment in which, he argued, it was possible to bring a gas from a lower to a higher temperature without the expenditure of work, thus contradicting Clausius's

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282 For this history, see the survey in Brush 1986 and, for more details, Brush 1974.

283 'The kinetic theory of the dissipation of energy', pp. 11-20 in Thomson 1911, on p. 16. Reprinted in Brush 1966, vol. 2, pp. 176-87. It was in this paper that Maxwell's 'intelligent demons' first appeared in print.

law. From this he drew the conclusion that Clausius was wrong and that the only foundation of the second law was to be found in analytical mechanics. However, the microscopic laws of mechanics are invariant under time reversal, and a time-reversed evolution contradicts the second law – hence the 'reversibility paradox'.

Loschmidt seems to have been motivated in part by a desire to avoid the heat death of the universe, a scenario he abhorred. In 1876, when presenting his paradox with greater clarity, he discussed it in a cosmological context. He was worried about the 'surprising conclusion' of Clausius and Thomson that 'the whole universe at some definite period, however remote, would infallibly come to an end. ... This state of general death will then last eternally.'[284] This was unacceptable to Loschmidt, who maintained that in the case of the solar system the equalization of temperature would not be of eternal duration. He suggested instead that the Sun and the other stars would evolve cyclically over long periods of time, never to become permanently extinct. Because of gravitational actions they would continually change between being hot and cold, and bright and dark. As evidence for his speculation he pointed to dark stars and novae which he thought represented two phases in the eternal life cycle of the stars. Loschmidt was pleased to have found that the consequences of the second law could be avoided:

> Thereby the terrifying *nimbus* of the second law, by which it was made to appear as a principle annihilating the total life of the universe, would also be destroyed; and mankind could take comfort in the disclosure that humanity was not solely dependent upon coal or the Sun in order to transform heat into work, but would have an inexhaustible supply of transformable heat at hand in all ages.[285]

Understandably, Loschmidt's work was welcomed by those in favour of an eternal, cyclic universe. Its cause had mostly been fought by philosophers and other amateurs, and so they were pleased to include among their allies a distinguished physical scientist.[286]

Loschmidt's objection inspired Boltzmann to further develop his theory into a genuinely probabilistic theory of molecular disorder. In 1877 he commented that a consequence of Loschmidt's reversibility theorem would be that 'if we follow the states of the universe to the infinitely far past, then we are, in fact, equally justified to consider it most probable that we will arrive at a state in which finally all temperature differences have ceased, as if we follow the states of the universe to the most distant future.'[287]

Another problem, known as the recurrence paradox, was raised by the German mathematician Ernst Zermelo, who in 1896 claimed that the second law disagreed

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[284] Loschmidt 1878, p. 184, an English abstract of his treatise presented to the Vienna Academy of Science (Loschmidt 1876).

[285] As translated in Daub 1970b, p. 221.

[286] Hermann Klein, the editor of the popular-astronomical journal *Sirius* and a supporter of cyclic cosmologies, included in his journal parts of Loschmidt's treatise to the Vienna Academy. See *Sirius* 6 (1878), 17-21 and Neswald 2006, p. 254.

[287] Boltzmann 1968, vol. 2, p. 122. The three volumes of the *Wissenschaftliche Abhandlungen* were first published in Leipzig in 1909.

with Newtonian mechanics because of the theorem, proved by Poincaré in 1890, that an isolated mechanical system will at some stage in its development return to its initial stage (or arbitrarily close to it). This could be seen as a problem for the second law, but Zermelo instead concluded that it was a problem for the mechanical world view. He believed that the second law is an absolute truth, and thus that any theory inconsistent with it must be false. This would be the case not only for the kinetic theory of gases but for any theory based on the assumption that matter is composed of discrete particles moving in accordance with the laws of mechanics.[288]

Unknown to Zermelo and Boltzmann, Poincaré had noted the same paradox three years earlier (and Nietzsche had privately dealt with it in a qualitative manner in the mid-1880s). According to Poincaré, when the world has reached the equilibrium state corresponding to the heat death, it follows from the recurrence theorem that it will *not* remain there for ever.

> It merely stays there for an enormously long time, a time which is longer the more numerous are the molecules. This state will not be the final death of the universe, but a sort of slumber, from which it will awake after millions of millions of centuries. According to this theory, to see heat pass from a cold body to a warm one, it will not be necessary to have the acute vision, the intelligence, and the dexterity of Maxwell's demon; it will suffice to have a little patience.

Poincaré expressed the hope that 'some day the telescope will show us a world in the process of waking up, where the laws of thermodynamics are reversed'.[289] As far as Poincaré was concerned, this was little more than an academic exercise. His proof of the mechanical recurrence theorem required physical space, and the number of particles in it, to be finite, and he saw no reason why the real universe should match these conditions. Poincaré's confidence in the absolute validity of the second law remained unshaken, and he regarded the prediction of a cyclic, recurring universe to have no relevance for the real world. In early 1903 he expressed his view as follows: 'If the universe is regarded as an isolated system, it can never come back to its original state; for its entropy is always growing, and this entropy being a function of the co-ordinates, would come back to its original value if the universe came back to its original state.'[290]

Boltzmann was a Catholic, but was careful to keep his science separate from his religious convictions. He denied that his scientific world view was, or could possibly be, contrary to Christian religion. 'I should be the last to put forward the views here mentioned, if they harboured any danger for religion', he said in 1900, referring to comments on aesthetics and values that might appear as reductionistic. 'Yet I know that the time will come when all will own that they are as irrelevant to religion as the question whether the Earth is at rest or moving around the Sun.'[291] He had no doubt

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[288] On the Zermelo-Boltzmann discussion, see Steckline 1983 and Brush 1986, pp. 632-5.

[289] Poincaré 1893. The quotation is from the translation in Brush 1966, vol. 2, pp. 203-7.

[290] Poincaré 1902-03, p. 689.

[291] Boltzmann 1905, p. 324.

about the existence of God – 'the highest concept which encompasses everything' – and believed that the schism between believers and non-believers was to a large extent rooted in different conceptions of what the term 'God' meant.[292]

Boltzmann shared, at least for a period, Poincaré's conviction that the heat death was an unavoidable consequence of the second law. In a popular lecture of 1886 he made it clear that all attempts to save the universe from the heat death had been unsuccessful and would remain futile.[293] Although entropy may on occasions decrease, the probability is so small that it can be ignored in almost all cases. As an illustration, Boltzmann considered a gas of volume 1 cm^3, containing about 10^{19} molecules. He calculated that it would take 10^{109} years (!) until the gas molecules had returned to their initial state. Boltzmann continued to think about the problem, and in the 1890s he addressed some of the metaphysical and cosmological problems of the statistical theory of entropy. This theory enabled him to come up with a new answer to the old problem of why we have not already suffered the heat death. In 1895 he developed a remarkable scenario of anti-entropic pockets in a universe which as a whole is in thermal equilibrium:

> If we assume the universe great enough we can make the probability of one relatively small part being in any given state (however far from the state of thermal equilibrium) as great as we please. We can also make the probability great that, though the whole universe is in thermal equilibrium, our world is in its present state. But can we imagine, on the other side, how small a part of the whole universe this world is? Assuming the universe great enough, the probability that such a small part of it as our present world be in its present state, is no longer small. If this assumption were correct, our world would return more and more to thermal equilibrium; but because the whole universe is so great, it might be probable that at some future time some other world might deviate as far from thermal equilibrium as our world does at present.[294]

It is to be noted that Boltzmann assumed in this passage the universe as a whole to be in thermal equilibrium, and thus implicitly that it has existed eternally or for an exceedingly long time. He did not consider the possibility of a beginning in time. In general he suggested a many-worlds picture, although the worlds were apparently taken to be just different parts of the universe – perhaps he thought of different nebulae – and not (as in later many-world theories) causally separated regions.

In one of his replies to Zermelo, Boltzmann stated that his mechanical explanation of the second law depended on the ('of course unprovable') assumption that the universe started from a very improbable, low-entropic state and is still in a relatively improbable state far from the heat death – after all, life exists. He offered two ways to understand the assumption. According to the first scenario, our world is a representative sample of the entire, low-entropy universe. The other was a scenario

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[292] Lecture of 1897, in Boltzmann 1905, p. 187. Cercignani 1998 sees Boltzmann's remarks as 'an explicit declaration of pantheism' (p. 183), which I find difficult to accept.

[293] Boltzmann 1905, p. 33.

[294] Boltzmann 1895, p. 415. For more than a century, Boltzmann's argument – which he ascribed to 'my old assistant, Dr Schuetz' – has attracted the interest of physicists and philosophers. For a recent review, see Ćirković 2003.

of entropy fluctuations in an otherwise high-entropic universe. 'There must be then in the universe, which is in thermal equilibrium as a whole and therefore dead, here and there relatively small regions of the size of our galaxy (which we call worlds), which during the relatively short time of aeons deviate significantly from thermal equilibrium.' Boltzmann preferred the second viewpoint because it promised an understanding of 'the second law and the heat death of each individual world without invoking a unidirectional change of the entire universe from a definite initial state to a final state'.[295]

It appears that Boltzmann had mixed feelings with regard to this kind of cosmological speculation, which he found was of little scientific value. As he stated in a reply to Zermelo of 1897, whatever one's taste, such hypothetical discussions on the nature of the universe could not upset the mechanical view of nature. In the second volume of his great textbook on gas theory, published in 1898, he included a section in which he repeated and amplified his ideas of many worlds, entropy fluctuations and time reversal. He was of course fully aware that these cosmological considerations were highly speculative, but found them to be consistent and also useful because they opened up new perspectives.[296]

Boltzmann's statistical theory of entropy continued to play some role in the discussion of the heat death in the early part of the twentieth century. Jean Perrin, the French physicist and future Nobel laureate, cautioned in a book of 1903 that the principle of entropy increase might not be applicable to the universe. And if it were nevertheless applied, the result did not need to be the heat death. In agreement with Boltzmann he asserted that even if the universe is finite, some perturbation might spontaneously disrupt the equilibrium and bring the universe back to life. He also pointed out that atoms and molecules were no longer conceived as *êtres morts*, but appeared to be complex structures of subatomic particles in motion, and that the new picture of matter made it unlikely that the universe would ever come to an end.[297]

Erich Becher's *Weltgebaüde, Weltgesetze, Weltentwicklung* provided an up-to-date account of the philosophical consequences of modern physics and astronomy, including the state of cosmology shortly before general relativity changed the picture. The author discussed the two rival views of the universe – the limited Milky Way model versus the unlimited island universe theory – but realized that observations failed to settle the issue. Although he was aware of the possibility of a closed Riemannian space, he preferred an uncommitted attitude because of the lack of observational evidence. Becher dealt in some detail with the cosmological implications of the second law of thermodynamics: 'From the fact that the heat death has not been reached, it seems to follow that the world has not existed in an eternity. So, is nature not eternal? Has the course of nature not only an end, but also a beginning

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295 Brush 1966, vol. 2, pp. 238-45, on p. 242. Boltzmann distinguished between the entire universe (*Universum*) and individual worlds (*Einzelwelten*).

296 Boltzmann 1898, pp. 256-9. For a critical assessment of Boltzmann's view of entropy and time, see Weizsäcker 1939.

297 Perrin 1903, pp. 179-80. See also Nye 1972, p. 78. Perrin was himself an early contributor to models of complex atoms. He received the 1926 Nobel Prize in physics, in part for his investigations of Brownian motion.

in time?' Appealing to Boltzmann's interpretation, Becher expressed doubts that the growth of entropy would result in a final state even though the universe might be finite. According to this interpretation, in the course of aeons there is a non-zero probability that entropy decreases: 'The future after the heat death has occurred covers infinite eternities. Although it is highly improbable that nature will return to a more ordered state, in the course of infinite time even the most improbable event is to be expected.'[298] Becher admitted that such a scenario of alternating periods of cosmic death and life was hypothetical, but comforted himself that the final heat death was no less hypothetical.

Beyond Orthodoxy: Wright, Peirce and Bergson

Chauncey Wright, an American philosopher who worked as a mathematician ('computer') for the *Nautical Almanac*, is best known as one of the founders of pragmatism and is sometimes mentioned as a precursor of some of the ideas of C.S. Peirce and William James.[299] He was strongly, nearly fanatically, opposed to the popular nebular hypothesis and other theories that represented nature as in a state of development from some beginning to some end. Impressed by the law of energy conservation he attacked such theories in writings from the 1860s in which he characterized evolutionary cosmologies as unscientific prejudices. A truly scientific cosmology had to be based on what he called 'the principle of counter-movements', according to which 'there is no action in nature to which there is not some counter-action, and no production in nature by which in infinite ages there can result an infinite product.' For philosophical reasons Wright much preferred a recurrent, cyclical universe to the evolutionary universe with its irreversible change toward either perfection or decay. 'The order of nature is almost universally regarded as a progression from a determinate beginning to a determinate conclusion', he complained. 'The dynamical theory of heat lengthens out the process better, perhaps, than the nebular hypothesis alone; but both leave the universe at length in a hopeless chaos of huge, dark masses, – ruined suns wandering in eternal night.'[300]

As Wright saw it, it was the task of the philosophical cosmologist to devise a theory of the stellar universe in which there was an endless series of constructive and destructive processes. 'How do we … avoid the ultimate catastrophe which we regard as the *reductio ad absurdum* of a scientific theory? How do we … constitute that cycle of movements which we regard as characteristic of all natural phenomena?'[301] The cosmological theory he proposed in 1864 was founded on the principle of counter-movements and built in particular on the use of gravity and heat as opposing forces. In a lengthy and critical review of 1865 of Spencer's philosophy, Wright reconsidered the role of heat in cosmological processes. He recognized that his idea of a steady-state universe violated the second law of thermodynamics, but claimed that the law 'so far from suggesting a dramatic *dénouement*, such as the

[298] Becher 1915, p. 265 and p. 268.
[299] See Ryan and Madden 2000. Wright is not well known outside the United States.
[300] Wright 1864, p. 9 and p. 22.
[301] Ibid., p. 22.

ultimate death of nature, only propounds new problems'.[302] He saw no reason to accept the law of energy dissipation as eternally and absolutely valid. If it conflicted with an everlasting, cyclical universe, so much the worse for the law. Contrary to most German proponents of an eternal universe, Wright was neither a materialist nor a monist, and he did not present his cosmological views as contrary to Christian religion. In spite of his opposition to evolutionary cosmologies, he was an advocate of Darwinism and in 1872 he visited Darwin in his home in England.

Although today best known as a pragmatic philosopher and the founder of semiotics, Charles Sanders Peirce devoted most of his professional life to physics, mathematics and astronomy; he was employed for over thirty years by the U.S. Coast and Geodetic Survey as a physicist. Peirce's philosophy involved centrally the concept of *tychism*, with which he meant that there is absolute chance in the universe and its fundamental laws are probabilistic and inexact, although in such a way that they develop over time and become increasingly rigid. It followed that the universe must be in a state of evolution, its variety and diversity being caused by spontaneous changes. Peirce's cosmology was not restricted to the universe made up of inorganic matter, for he considered matter to be closely associated with mind.

Largely independent of the discussion in Europe, Peirce developed about 1890 a cosmological system in which chance and disorder played a central role, if in a sense very different from the one of the Maxwell-Boltzmann tradition. Peirce, who was familiar with the works of Clausius and Maxwell, published his ideas in a series of papers 1891-93 in the American journal *The Monist*. Although he did not refer to Boltzmann by name, he was aware of the statistical theory of entropy, to which he alluded in an article of 1892, where he wrote that 'by the principles of probabilities there must occasionally happen to be concentrations of heat in the gases contrary to the second law of thermodynamics'.[303] His system – half science, half metaphysics – was thoroughly indeterministic and assumed that even the laws of nature were only statistically valid. Moreover, he suggested that the laws might share the evolutionary feature of the material world, that is, that they varied in time. The laws of thermodynamics were no exception. Peirce's understanding of the second law was unorthodox, and his cosmology no less so. In 1891 he described his hypothesis as follows:

> The state of things in the infinite past is chaos … the nothingness of which consists in the total absence of regularity. The state of things in the infinite future is death, the nothingness of which consists in the complete triumph of law and absence of all spontaneity. Between these, we have on our side a state of things in which there is some absolute spontaneity counter to all law, and some degree of conformity to law, … .[304]

This picture, starting from chaos and ending in an ordered and symmetrical system, turns the ordinary interpretation of the second law on its head. Some years earlier, in a 1884 lecture on 'Design and Chance', he declared that the heat death – in which 'there shall be no force but heat and the temperature everywhere the same' – was

302 Wright 1865, pp. 466-7.

303 *The Monist* (1892), in Peirce 1966, p. 171.

304 Quoted in Reynolds 1996, p. 405. See also the collection of articles in Peirce 1966.

unavoidable. Confusingly, the next year he rejected the global heat death scenario, retracting to a position similar to that of many other evolutionary progressivists of the Victorian era: 'But, on the other hand, we may take it as certain that other intellectual races exist on other planets, – if not of our solar system, then of others; and also that innumerable new intellectual races have yet to be developed; so that on the whole, it may be regarded as most certain that intellectual life in the universe will never finally cease.'[305] Perhaps he thought, such as he said in his 'Design and Chance' lecture, that the living universe would be saved by what he called 'chance', an influence he considered to be opposite to dissipative forces, or what some later authors referred to as 'ectropy'.

Peirce's vague suggestion of time-varying laws of nature might have served as a solution to the entropic paradox. After all, if laws are allowed to change in time, why not assume that the growth of entropy is a relatively recent phenomenon, restricted to, say, the last 100,000 years? In fact, no one proposed a solution of this kind, and Peirce did not refer to the entropy law as possibly changing in time, nor did he mention other concrete examples.[306] He only discussed the subject in a very general way. It was generally taken for granted that laws of nature are permanent. For example, in an address of 1911 Poincaré discussed the idea, but only to dismiss the hypothesis of time-varying laws as inconsistent with the very meaning of natural law. According to Poincaré, law-based knowledge about the past, as in geology and astronomy, necessitated immutable laws that link past and present: 'If ... the immutability of the laws plays a part in the premises of all our reasoning process, it is bound to occur in our conclusions.'[307] That is, he held that invariable natural laws are a necessary condition for any scientific knowledge. The consensus view among scientists was in agreement with Poincaré's belief, not with Peirce's. It would take several decades until the idea of time-varying laws of nature was seriously discussed in fundamental physics.

Peirce's iconoclastic cosmology cannot be accused of being overly lucid or even coherent, and perhaps it was not meant to be so.[308] He seems to have believed that the universe evolves towards greater complexity and less spontaneity; and he also believed that there was an ultimate state governed by law and regularity from which no departure is possible. That is, he accepted large-scale irreversibility and denied the notion of eternal recurrence, but his picture of cosmic evolution disagreed with

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[305] Reynolds 1996, p. 423.

[306] In his address of 1871 to the British Association, Tait was careful to note that the heat death prediction depended on the assumption that 'physical laws for ever remain unchanged.' Tait 1871, p. 97.

[307] Poincaré 1913, p. 51. For a philosophical perspective, see Balashov 1992. Only from the 1930s did the idea of varying laws of nature (meaning varying constants of nature) gain some foothold in physics. Since then, there have been many proposals of, for example, a varying constant of gravitation or velocity of light. So far, none of these theories have received convincing experimental support.

[308] Reynolds 1996 says about Peirce's cosmological system that its 'coherence [is] open to doubt' (p. 418), and Porter 1986 notes that it 'was by no means in conformity with the common sense either of his own day or of ours' (p. 225). From what I know about it, I can only agree.

the second law of thermodynamics as understood by authorities such as Thomson, Boltzmann and Planck. The question of the finitude of space was a standard ingredient in the discussions of the late nineteenth century, but apparently it played no major role in Peirce's evolutionary cosmology. On the other hand, he was well aware of the possibility of space being curved and as the only scientist of his time he maintained that this *must* be the case. In writings between 1891 and 1902 he argued from rather obscure philosophical reasons that physical space was either positively or negatively curved, with the latter possibility being the most likely. Whereas his main arguments were philosophical, he also employed data from astronomical observations. In an unpublished address to the American Mathematical Society from 1894 he concluded that there was astronomical evidence for a negatively curved space, and he returned to the same conclusion in an address of 1901: 'The proper motions of the stars show very strong indications that our space is really hyperbolic.'[309] However, he did not draw any connection between cosmic entropy and the geometry of space.

If Peirce's views on cosmology and thermodynamics were unorthodox, so were those of Henri Bergson in France. Indeed, there are some similarities between the two thinkers apart from their lack of orthodoxy and privately constructed vocabularies. In his main work *L'Evolution créatrice* from 1906 Bergson referred to the second law of thermodynamics as 'the most metaphysical of the laws of physics' because of its inbuilt irreversibility and apparent indication of a beginning of the world order – 'it points out without interposed symbols, without artificial devices of measurements, the direction in which the world is going'. He was well aware of the heat death, which he expressed as 'a world like our solar system is seen to be ever exhausting something of the mutability it contains. In the beginning it had the maximum of possible utilization of energy; this mutability has gone on diminishing unceasingly.'[310]

With regard to the initial state of 'maximum mutability' Bergson considered various contemporary proposals, but without endorsing any of them. He did not accept the materialistic theory of everlasting recurrence, such as was revived by Arrhenius and other authors of a materialistic inclination, and also he did not accept the many-worlds scenario, which he ascribed to Boltzmann. These ideas relied on the assumption of an infinite universe, and Bergson's sympathy was definitely for finitism, the view that the universe is finite in both its spatial and temporal dimensions. Moreover, he held an asymmetrical view of time, that the future is open and the past determined. According to Bergson, given enough time entropic processes might in principle occur in reverse order, but this would imply reversibility of concrete durations, something which he considered to be impossible.

Bergson's finitism might seem to lead him to the idea of a finite-age, created universe, and there were indeed Catholic thinkers who interpreted his views as being in accordance with theism. However, Bergson insisted that 'the universe endures', although he qualified his statement with the remark that the duration was characterized by the creation of novelty, 'the continual elaboration of the absolutely new'. Milič Čapek has cogently argued that Bergson did not admit the simple dichotomy between

[309] Dipert 1977, p. 411. See also Beichler 1988, p. 209.

[310] Bergson 1965, p. 265.

an eternal universe and one created instantaneously in the past. Bergson wrote: 'The mystery that spreads over the existence of the universe comes in great part from this, that we want the genesis of it to have been accomplished at one stroke or the whole matter to be eternal.' This was however a 'prejudice' common to materialists and their opponents, the theists. 'Once this prejudice is eradicated, the idea of creation becomes more clear, for it is merged in that of growth. But it is no longer then of the universe in its totality that we must speak.'[311]

Even though Bergson denied that the universe had existed eternally, he did not hold that it was created instantaneously, whether *ex nihilo* or from some primordial state. At least, he played down the importance of absolute or initial beginning and, as an alternative, he offered a process account of the beginning of the universe in which creativity and duration went hand in hand. While some scholars have emphasized Bergson's creationism, as linked to the idea of a finite past, others have emphasized his eternalism.[312] Precisely how to understand Bergson's thoughts, I dare not say. It is possible, perhaps even tempting, to read into Bergson's vaguely formulated thoughts many of the ideas of later scientific cosmology. But I do not consider such an interpretation to be reasonable.[313]

Although Bergson supported some version of the second law, at least as being valid for the solar system, he also believed that life-phenomena were exceptions governed by 'ectropy', a kind of anti-entropy or chaos-to-order principle.[314] He refrained from accepting a truly universal heat death, as predicted from an extension of the second law to the entire universe. In Bergson's view, nature was a kind of organic whole driven by a non-physical, indeterministic life force, an *élan vital*. 'The universe is not made, it is being made continually.'[315] This formula may be seen to be in harmony with the theological concept of *creatio continuans*, but Bergson refrained from making a connection. He was aware of the contrast between his

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311 Čapek 1971, p. 375. Čapek points out certain similarities between Bergson's cosmogonical ideas and the expanding model of the universe that Lemaître proposed in 1931. I do not agree that Lemaître's model is close to that sketched by Bergson, either in essence or in motivation.

312 For a discussion, see Goodman 1992.

313 Gunter 1971 finds close resemblances between Bergson's ideas and those of later cosmological models. Not only did *L'Evolution créatrice* anticipate 'the course of scientific cosmology by more than a decade', it must also 'be interpreted as proposing an "expanding universe"'. Gunter's attempt to present Bergson as a precursor of modern cosmology is unconvincing.

314 The name 'ectropy' goes back to 1900, when it was introduced by Georg Hirth in the context of biological systems (Hirth 1900). It became widely known through Felix Auerbach's *Ektropismus oder die physikalische Lehre des Lebens* (Leipzig, 1910). The mistaken view that the evolution of life forms contradicts the second law continued to play a role during the twentieth century, since the 1960s often in the context of the new creationism. Local processes, such as the building up of complicated molecules from simpler ones, can occur even though they involve a decrease in entropy. Because the energy diminishes in such a way that the free energy is lower for the product, they are in full accord with the second law of thermodynamics. For an overview, see Patterson 1983.

315 Bergson 1965, p. 255. On Bergson's view on cosmology, thermodynamics and religion, see also Howe 1993.

vitalistic view and the second law, but suggested that life, in a generalized sense, must have priority over thermodynamics. Even if organic, carbon-based life was extinguished, there would still be events with a minimum of psychic activity. For Bergson, the preeminent philosopher of 'becoming', it was impossible to accept an ultimate death of life in the universe.

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Chapter 6

Post-1920 Developments

After World War I the discussions of the cosmic role of entropy took a new turn. The topic was no longer seen as very important in the ideological debate, and it largely disappeared as a theological issue. On the other hand, it began to play some role in the new scientific cosmology based on Einstein's relativistic theory, where thermodynamic considerations made their entry in the mid-1920s. While little more was heard of the entropic creation argument, whether in its restricted or extended form, in the interwar period the heat death was a matter of concern to several scientists who opposed relativity theory and the expanding universe. Like in the earlier period, the debate carried with it ideological issues, but not in quite the same way, or with quite the same intensity, as before the war. The lack of visibility of the entropic argument for a world of finite age may be illustrated by a survey article that J. Delevsky wrote in 1946 on the opposing cosmologies based on, respectively, eternally repeated cycles and irreversible development. Although Delevsky dealt extensively with the heat death, he had nothing to say of how the law of entropy might be used as an argument for a beginning of the universe.[1]

Relativity and Entropy

A new and fruitful chapter in the annals of cosmology started in 1917, when Einstein applied his recently formulated theory of general relativity to the universe at large. Confronted by the classical boundary problem, Einstein circumvented it by conceiving the universe to be spatially closed in accordance with Riemannian geometry. He introduced in his cosmological field equations a so-called cosmological constant which physically acts as a cosmic repulsion proportional to the distance and thereby counteracts the gravitational attraction. Moreover, he deduced that the new constant was proportionally related to the average density of matter in the universe and could be expressed by the constant radius of curvature.

Einstein's original model was static and spatially closed, and the same was the case with the alternative model which the Dutch astronomer Willem de Sitter suggested later in 1917. The main difference was that whereas Einstein's solution corresponded to a matter-filled universe, in the case considered by de Sitter the universe was empty. Einstein was puzzled that an empty universe could be positively curved, but grudgingly had to admit that de Sitter's solution followed from the field equations. Also the expanding model proposed by Georges Lemaître in 1927 was spatially closed. Indeed, it was often (if wrongly) assumed that general relativity

1 Delevsky 1946.

implied a Riemannian space of finite size. But, as first shown by the Russian physicist Alexander Friedmann in papers of 1922 and 1924, the general theory of relativity does not uniquely prescribe the metrical properties of space. Its curvature may be positive, zero or negative, corresponding to a closed (Riemannian), flat (Euclidean) or hyperbolical (Lobachevskian) space; the kind of metric depends on the values of the density of mass in the universe and the cosmological constant.

If the universe was spherically or elliptically closed, as generally believed, it presumably meant that the standard way of avoiding the heat death – namely by arguing that the second law was not applicable to an infinite universe – was no longer feasible. To those who for theological or other reasons believed that the universe must be finite, Einstein's model was a gift from heaven; on the other hand, it was bad news for the materialists in favour of an infinite universe. From this point of view it is rather perplexing to read what the philosopher and physicist Moritz Schlick, a coming leader of the Vienna school of logical positivism, wrote on the subject in a book of 1920. Schlick asserted that the closed Einstein universe was saved from the heat death, because 'no energy and no matter can escape from it to infinity, as space is not infinite'.[2]

Einstein never referred explicitly to the heat death, nor to the low-entropic beginning of the cosmos, but on one occasion he did mention it implicitly. In a semipopular book on the theory of relativity, published in 1917, he referred to the classical conception of the universe (the Milky Way system) as consisting of 'a finite [stellar] island in the infinite ocean of space'. In this kind of universe, as favoured by Seeliger, Kapteyn and several other astronomers, starlight would disappear in space, never to return or interact with other celestial bodies. 'Such a finite material universe would be destined to become gradually but systematically impoverished', Einstein commented.[3] Although not referring directly to the law of entropy increase, this is clearly a statement of the heat death. Einstein apparently subscribed to the view that it would only occur in a materially finite universe.

One of the first to point out the trans-scientific importance of the Einstein universe was the Norwegian theologian Kristian Schjelderup, who in a dissertation of 1921 examined the truth of Christian belief as seen from the perspective of the new, relativistic world view. He argued that Einstein's theory made it necessary to revise some religious dogmas, such as the immortality of man. Schjelderup found the closed and spherical universe to be of great theological interest because it made possible the eternity of the world, a conclusion contrary to the one held by most finitists. 'According to the theory of relativity, the energy remains within the closed spherical world system; it is not dissipated into a void and infinite space. ... Any conception of a true *creation of the world* ceases to be valid,' he wrote. 'The world simply exists as a demonstrative fact. The idea of creation can only be maintained in so far that use is made of the concept of time.'[4] He also considered the Thomistic concept of 'eternal creation' (*creatio continuans*), but dismissed it as a mere 'play

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[2] Schlick 1920, p. 76. Schlick did not directly refer to the heat death, but to 'destruction' (*Verödung*). Yet it is hard to see what he had in mind if not the cosmic heat death.

[3] Einstein 1917, p. 72. Reprinted in Einstein 1996, pp. 420-538.

[4] Schjelderup 1921, pp. 84-5.

with words'. Whereas some theologians found that the theory of relativity opened up new vistas in religious thought, and therefore was to be welcomed, others believed that it constituted a threat against religion. The Archbishop of Boston, cardinal William O'Connell, advised in 1929 his fellow-Catholics to shun Einstein's theory because it was 'a befogged speculation producing universal doubt about God and his Creation … cloaking the ghastly apparition of atheism'.[5]

The question of whether the universe is spatially finite or infinite continued for some time to arouse philosophical discussion. Herbert Wildon Carr, a British professor of philosophy, claimed in 1921 that 'Einstein's space-time is the death-knell of materialism, ... If space is not endless, but finite (and this is the essential principle of the Riemannian geometry), and if time is not in its existence independent of space, ... then the very foundation of the materialistic concept is undermined.'[6] Precisely because the question of the extension of space could not be answered observationally, it appealed to cosmologists' philosophical attitudes and desires. A case in point is Lemaître, who was epistemically committed to finitude and deliberately constructed his models of 1927 and 1931 in such a way that they were finite. His commitment reflected an epistemic attitude probably rooted in theology: educated in neo-Thomistic philosophy, he shared Catholic thinkers' rejection of the actual infinite. In a conversation with the American physicist Richard Chase Tolman in the early 1930s he said that the finite model was 'optimistic', since only in this case could the universe in its totality be regarded as comprehensible to the human mind.[7] Some twenty years later he spoke of 'the nightmare of infinite space' and declared as his credo that the universe 'is like Eden, the garden which had been placed at the disposal of man so that he could cultivate it and explore it'. According to Lemaître's philosophy, 'The universe is not too large for man; it exceeds neither the possibilities of man nor the capacity of the human spirit.'[8]

The relativistic models of the universe were intially considered in a geometrical perspective, whereas the content of matter and radiation played no role. The thermodynamics of the Einstein universe was first examined in 1925-26, and a few years later Tolman greatly developed the study of the thermodynamical properties of model universes. In 1931, shortly after the expansion of the universe had been generally accepted, he re-examined the cosmic entropy problems in the case of a non-static universe filled with radiation. The first of the classical problems was, why has the entropy of the universe not already reached its maximum value? Tolman was aware that one common answer to this problem was 'to assume that the universe was indeed created at a finite time in the past with sufficient available energy so that the entropy has not yet reached its maximum value'.[9] But this he considered an *ad*

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5 *New York Times*, 25 April 1929, as quoted in Jammer 1999, p. 48.

6 Carr 1921, who referred to the mathematician Hermann Weyl's *Raum, Zeit, Materie* (Berlin, 1918) as strong support of his view. It was countered by Hugh Elliot, a materialist and secularist, in *Nature* 108 (1921), 432.

7 Tolman 1934, p. 484. Lemaître's epistemic preference for a closed universe corresponded to the one expressed by Schwarzschild in 1900.

8 Lambert 2000, p. 313.

9 Tolman 1931, p. 1642.

hoc solution, and for this reason unsatisfactory and scientifically uninteresting. The other problem concerned the heat death as the ultimate fate of the universe. Tolman's calculations, based on relativistic thermodynamics, showed that for this particular model universe, the entropy would *not* reach a maximum state. However, he was uncertain if the result could be generalized to the real, matter-filled and expanding universe. 'It would seem wisest', he wrote, 'if we no longer dogmatically assert that the principles of thermodynamics necessarily require a universe which was created at a finite time in the past and which fated for stagnation and death in the future.'[10]

But there were other scientists who spoke in a different voice about the relationship between the law of entropy increase and the expanding universe. The two phenomena were sometimes seen as either complementary or alternative. Eddington may have been the first to introduce what effectively was the 'cosmological arrow of time', in so far as he recognized that the expansion of the universe can function as a measure of time and, in this respect, is analogous to the growth of entropy. The analogy included the beginning of time. In *The Expansion of the Universe*, a popular book published in 1933, he wrote: 'The continual expansion of the world raises the same kind of question of an ultimate beginning as has been raised by the continual increase of entropy in the world.'[11]

Relativistic cosmology was a small field which for a decade or so remained isolated from observational astronomy. The majority of astronomers felt no obligation to take the relativistic models of the universe seriously or just be acquainted with them. For example, in his careful review of 1925 of the structure of the universe, Charlier ignored the cosmological theories based on Einsteinian relativity. He briefly referred to 'speculative men in our time' who entertained the idea of curved space, but dismissed such speculations as belonging to either mathematics or philosophy.[12] Charlier's attitude was not atypical among astronomers.

If relativistic cosmology was isolated from mainstream astronomy, so it was isolated from mainstream physics.[13] Percy W. Bridgman, a specialist in thermodynamics and high-pressure physics (and a Nobel laureate of 1946), developed in the 1920s and 1930s an operationalist philosophy of science, the key message of which was that the meaning of a concept is given by the operations that can be applied to specify and understand the concept. Not surprisingly, cosmology did not fit well within such an operationalist framework. In two papers of 1932 Bridgman addressed cosmological questions, including the cosmic heat death. He was highly critical of the possibility of scientific cosmology, which he found was nothing but a 'metaphysical conviction', and he doubted if the second law of thermodynamics could be validly applied to the universe. 'By what logical right can the argument be

10 Tolman 1934, p. 444.

11 Eddington 1933, p. 55. Eddington did not believe in a Big-Bang beginning of the world. One page later he stated that, 'it has seemed to me that the most satisfactory theory would be one which made the beginning *not too unaesthetically abrupt*.'

12 Charlier 1925, p. 182.

13 Eisenstaedt 1989.

extended to the entire universe?' he asked.[14] Bridgman thought there was no such right, even though he mistakenly believed that the infinite universe was ruled out by Einstein's theory ('relativity theory seems to demand that the universe is finite'). As to the heat death he suggested that if it was ever to come, it would be as a result of the first law of thermodynamics, not the second.

Gilbert Lewis, the eminent American physical chemist and specialist in chemical thermodynamics, agreed that it was rash to extrapolate laboratory experiences to the entire universe. He considered the second law to be 'a source of uneasiness' and suggested in 1930 an anti-Eddington time-symmetric theory where irreversibility was only apparent. The assumption of a running-down universe has 'no support from thermodynamics', he wrote, for 'Gain in entropy always means loss of information, and nothing else.'[15] According to Lewis, entropy was to be understood as a measure of our ignorance of the actual distribution of a system of particles, and therefore as a purely subjective concept. He believed that it followed from Boltzmann's statistical interpretation of thermodynamics that if the universe is finite, then the present state of the universe has occurred in the past and will recur in the future. His claim that the law of increase of entropy is merely a statement about the information we have about a physical system has since been elaborated by a large number of researchers and forms an important part of modern information theory.

The views of Lewis, Tolman, Bridgman and Lemaître were known also outside the world of the physical sciences. At least they were known to John Elof Boodin, an American philosopher of religion who in a book of 1934 referred to Lemaître's new hypothesis of the primeval-atom universe. He was however unable to accept scientific accounts of the origin of the universe, and pointed out that even Lemaître's daring hypothesis presupposed a material proto-universe. 'A mechanistic hypothesis, molded upon inorganic matter, cannot be a sufficient explanation of the universe. ... The mechanistic hypothesis, if taken as a philosophy, lands us in intellectual bankruptcy. It requires a miracle in order to start the world and holds out no promise for the future except universal death.'[16] He was of course referring to the law of entropy increase. Describing entropy as 'the *bête noir* of mechanistic cosmology' he reasoned that the second law did not preclude the existence of some synthetic and constructive principle in the universe, something complementary to the ever-increasing, destructive entropy.

According to Boodin, there was no reason to look outside the universe for a *deus ex machina*, for the principle might be immanent and of spiritual nature. 'If we require a creative genius to start the universe, why not assume that this creative

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[14] Bridgman 1955, p. 263. See also Kragh 2004, pp. 154-6. Bridgman's two papers were 'Statistical mechanics and the second law of thermodynamics', *Bulletin of the American Mathematical Society* (April 1932) and 'The time scale', *The Scientific Monthly* (August 1932), reprinted in Bridgman 1955, pp. 236-68 and 269-77.

[15] Lewis 1930, p. 573. A detailed historical account of Lewis' theory of the symmetry of time is given in Stuewer 1975. See also Whitrow 1990, pp. 7-9. Lewis first stated his heterodox opinion in his Silliman Lectures of 1926 where he concluded that there is 'not even a shred of truth left in the statement that an isolated system moves toward a state of equilibrium' (Lewis 1926, p. 153).

[16] Boodin 1934, p. 108.

genius is eternally involved in the nature of the cosmos? In that case we do not need to postulate a miracle in some finite past – some billions of years ago.' The only alternative to magic was to accept an eternal cosmos full of life and mind: 'A workable cosmological theory must be in some sense animistic.'[17] Although neither a scientist nor a Christian theologian, Boodin found his idealistic world view to be consonant with both science and Christianity.

A full-blown rationalistic cosmology consonant with theism was developed by the British astrophysicist Edward Arthur Milne in the period from 1933 until his death in 1950. I have examined Milne's theory elsewhere and shall therefore call attention only to some of its aspects that are relevant in the present context.[18] Milne did not accept general relativity, but by means of what he called 'kinematic relativity' he succeeded to explain the expansion of the universe on the basis of a kind of Big-Bang theory. By explicitly referring to God's creative power he argued that the universe must have started in a point-singularity, and he further suggested that a divinely created universe must necessarily be infinite in extent: 'It requires a more powerful God to create an infinite universe than a finite universe; it requires a greater God to leave room for an infinity of opportunities for the play of evolution than to wind up a mechanism, once and for all. We rescue the idea of God from the littleness that a pessimistic science has in the past placed upon him.'[19]

Milne offered a full exposition of his cosmo-apologetics in his Cadbury Lectures for 1950, which were posthumously published two years later as *Modern Cosmology and the Christian Idea of God*. In this remarkable work he examined the hypothesis of the heat death, which 'has been given wide publicity … and has been largely accepted as the considered verdict of physics and astronomy.' However, Milne disagreed: 'I believe this conclusion to be mistaken; it is not an inevitable consequence of the second law of thermodynamics as applied to the universe as a whole, and I do not believe it to be true of the universe as it is.'[20] He argued that it was impossible to make valid propositions about the entropy (or other properties) of all the bodies in an infinite universe, but his argument was not restricted to this case. He contended that the notion of entropy increase is not applicable to the universe, whether finite or infinite, because changes in entropy requires the system to be closed, to have something outside it. And, *ex hypothesi*, there is nothing external to the universe.

Since Milne did not believe in the increase of entropy on a cosmic scale, naturally he could not subscribe to the entropic proof of God. In fact, he considered the thermal end of the universe to be in conflict with the creative deity: 'There has always seemed to me something derogating from the omnipotence of the Creator, if the totality of things created had to be subject to the humiliation of a "heat death".'[21] In his biography of Jeans, he took his distinguished colleague to task for

17 Ibid., pp. 111-2. In a later work Boodin made the daring (and unjustified) suggestion that the entropy had its source in the cosmological constant appearing in Einstein's general-relativistic field equations (Boodin 1943).

18 Kragh 2004, pp. 200-229, where further references can be found.

19 Milne 1948, p. 233.

20 Milne 1952a, p. 146.

21 Milne 1948, p. 12.

his unshakable belief in what he called 'astronomical eschatology'. Noting that the process of entropy increase was often compared to the running down of a clock, he wrote: 'It invites the obvious comment that for a clock to run down, it must first have been wound up; if so, who wound it up, and cannot the great Winder-up of the universe wind it up again if it runs down?'[22]

It is noteworthy that Milne explicitly presented his cosmological system as a theistic theory, or one consonant with theism; and yet it disagreed with the cosmological assumptions which in the late nineteenth century were commonly associated with a divinely created universe. For one thing, there was no heat death or other end of Milne's universe. For another thing, it was infinite in extent, a property that was traditionally taken to be a feature associated with atheism and materialism. Milne's apologetic cosmology was no less heterodox from a theological point of view than it was scientifically. Understandably, it was not welcomed in theological circles.

The Nernst-MacMillan Alternative

As outlined above, during the period from about 1860 to 1910 many scientists as well as non-scientists were unwilling to accept a unidirectional universe whose fate would be the cessation of all physical processes, including life. From Rankine in the 1850s to Arrhenius and Soddy in the first decade of the twentieth century, they suggested ways to avoid the heat death, for example by postulating processes that might balance the steady dissipation of energy and then result in an eternal, if dynamical universe.

The tradition continued after World War I, when several scientists suggested cosmic pictures in the same spirit, modernizing the view by taking into account some of the recent advances in physics.[23] Although these theories were ignored by most astronomers and physicists – with the result that they are rarely mentioned in historical works on cosmology – their advocates included respected scientists such as Emil Wiechert, William MacMillan, Robert Millikan and Walther Nernst, of whom the latter two were recipients of the Nobel Prize (in physics and chemistry, respectively). With the acceptance of the relativistic expanding universe, theories based on an eternal universe largely disappeared from scientific cosmology, but not completely so. The later steady-state theory, proposed in 1948 by Fred Hoyle, Thomas Gold and Hermann Bondi, was developed independently of the older tradition of recycling universes but nonetheless had some similarity with it.

The physical chemist Walther Nernst became interested in astro- and cosmophysics shortly before World War I, most likely inspired by his colleague Arrhenius. Although an expert in chemical thermodynamics, he never used the concept of entropy, but preferred to formulate the second law in terms of Carnot cycles. He found entropy unnecessary and regarded it with suspicion, associated as it was with Clausius's cosmological formulation. Ever since 1886, when he studied under Boltzmann and

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22 Milne 1952b, p. 164.

23 See Kragh 2004, pp. 84-95, of which the present account is a reworking.

had first become acquainted with the gloomy prediction of the heat death, he had denied believing in this alleged consequence of the second law of thermodynamics. Nernst was strongly and emotionally opposed to any *Götterdämmerung des Weltalls*, and his work in astrophysics was, as he admitted, wholly motivated by his desire to find an alternative.[24]

Nernst first thought of a mechanism for maintaining energy equilibrium in the universe in a lecture of 1912 and nine years later he developed the idea into a cosmic world picture, now justifying it by the new quantum theory. A believer in the ether, he suggested that the ethereal medium was a huge energy reservoir, with its energy being stored in the form of the zero-point energy known from quantum theory. This kind of energy at zero absolute temperature had been introduced by Planck in 1911, and Nernst immediately applied the concept to cosmic physics.[25] In his 1921 booklet *Das Weltgebäude im Lichte der Neueren Forschung* he speculated that the hidden energy of the ether would occasionally form configurations out of which radioactive atoms would be created. Eternal recycling of radioactivity would prevent the heat death, and secure the stationary universe to which Nernst was so clearly committed metaphysically. As he wrote: 'Our eyes need not, in the far future, have to look at the world as a horrible graveyard, but at a continual abundance of brightly shining stars which come into existence and disappear.'[26] According to Nernst, the universe was in a state of eternal equilibrium, with radioactive degradation of stellar matter being balanced by the formation of new matter out of the energy-enriched ether.

The principle of stationarity was an 'intellectual necessity', an *a priori* hypothesis which could not be subjected to experimental tests and whose acceptance was, in the end, subjective. Nernst admitted that his scenario was speculative and out of tune with contemporary physics, but he saw no other way to maintain the eternal universe which for him had priority over the known laws of physics. It is clear from his writings that he felt the stationary universe to be not only an intellectual but also an emotional necessity (he did not indicate any connections to religious views). In 1938 the aging Nernst had a discussion with young Carl Friedrich von Weizsäcker, the nuclear physicist who was also a pioneer of Big-Bang cosmology. According to Weizsäcker's recollections, Nernst flatly and passionately denied that a finite-age universe could be part of science. Weizsäcker felt that, in Nernst's mind, 'the everlasting universe had taken the place both of the eternal God and of the immortal soul ... and it was blasphemy to deny it God's attributes'.[27]

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24 Nernst 1921, p. 2, and Nernst 1935, p. 528. For a contemporary survey of Nernst's early thoughts on astrophysics and cosmology, see Günther 1924. On his non-use of entropy in chemical thermodynamics, see Kragh and Weininger 1996, pp. 103-4.

25 In the original quantum theory, the energy of an oscillator of frequency ω was given by $E = nh\omega$, where h is Planck's constant and $n = 1,2,3,\ldots$. According to Planck's theory of 1911, the expression was $E = (n+\frac{1}{2})h\omega$, meaning that even in the ground state $n = 0$ there would be a 'zero-point energy' of $\frac{1}{2}h\omega$. With the advent of quantum mechanics, the zero-point energy was given a proper physical justification.

26 Nernst 1921, p. 37.

27 Weizsäcker 1964, p. 153. Weizsäcker's indication that Nernst's cosmological views were based in pantheism, or otherwise religiously motivated, lacks support. Nernst never expressed interest in religion.

The recognized German physicist Emil Wiechert, a professor at Göttingen, was an expert in electron and ether theory and also one of the founders of modern geophysics. He stuck throughout his life to the ether, which he claimed constituted a cure against the 'materialism' of Einsteinian relativity. In works of 1921 he speculated, much like Nernst, that ether-matter transmutations might continually take place in the depths of space and in this way provide a cosmic cycle that made the heat death avoidable. He saw his ether-driven perpetual universe as part of a general fight against materialism, and he suggested that the ether was not merely a physical quantity, but was also connected with the human spirit.[28] This was also the belief of Oliver Lodge in England, who was no less devoted to the ether than Wiechert. The ether, he wrote, 'is the primary instrument of Mind, the vehicle of Soul, the habitation of Spirit. Truly it may be called the living garment of God'.[29] Lodge found the heat death to be intolerable, and around 1920 he vaguely suggested 'that light-pressure may afford an escape from some popular eschatological conclusions based on the doctrine of the dissipation of energy'.[30] As late as 1931, at a meeting of the British Association devoted to the evolving universe, the 81-year-old physicist claimed that too much attention had been paid to the second law of thermodynamics, and that 'the final and inevitable increase of entropy to a maximum is a bug-bear, an idol, to which philosophers should not bow the knee.'[31]

Ideas of a recreative universe broadly similar to those of Nernst and Wiechert were independently developed by William Duncan MacMillan, professor of astronomy at the University of Chicago. He first expounded his hypothesis of a regenerating, eternal universe with an equilibrium between organization and dissipation processes in 1918, and in subsequent papers he developed the idea. Like Nernst, he effectively formulated what in the later steady-state theory became known as the perfect cosmological principle, the claim that the universe is homogeneous in space as well as time (and therefore can have no temporal boundaries). Although MacMillan avoided referring to religious issues in his writings on cosmogony and astrophysics, it is quite clear that there was more at stake for him than simply coming up with a scientifically adequate theory of the universe. He just did not *want* a running-down universe. His eternal, ever-creative universe was not derived from either theory of observation, but rather a picture designed to lend support to a cosmic optimism that he felt was threatened by the world view of modern physics. 'The forbidden picture of the galaxy as a dismal, dreary graveyard of dead stars fades away from our sight', he wrote in 1920, referring to his own theory; 'in its stead we see an indefinite

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28 Wiechert 1921. Irreversible heat death cosmology was obviously antithetical to the strong trend of *Lebensphilosophie* that permeated so much of science and intellectual life in the young Weimar Republic, such as detailed by Paul Forman (Forman 1971). On the other hand, the views of Nernst and Wiechert cannot be fully explained as reflections of the Weimar Zeitgeist, as very similar views were held by scientists in the United States and elsewhere.

29 Lodge 1925, p. 179.

30 Lodge 1920. According to Lodge, the idea was suggested by his assistant Edward E. Robinson.

31 *Nature* 128 (1931), 722.

continuation of our present active, living universe with its never-ending ebb and flow of energy.'[32]

MacMillan's unorthodox theory found a receptive ear in the physicist Robert Millikan, whose studies of the cosmic rays led him to cosmological speculations consonant with MacMillan's. Both of the American scientists resisted a universe without some kind of continual creation and associated it with a mechanistic, atheistic and materialistic world view which modern science had made obsolete. Referring to the great financial depression, on the last day of 1930 the *New York Times* praised Millikan's view and called attention to 'the cosmic optimism of the science that ... has faith in a continuing creation and that cooperates with "a Creator continually on the job"'.[33]

Millikan believed that with his hypothesis of cosmic building-up processes it was possible 'to regard the universe as in a steady state' and also 'to banish forever the nihilistic doctrine of its ultimate "heat death"', as he wrote in 1928. The same year he and his research student G. Harvey Cameron ended a major scientific paper by pointing out that their theory of cosmic rays included 'a violation of the Second Law of Thermodynamics as applied to the universe', that is, it provided an escape from the heat death. Concerning the heat death hypothesis, they wrote:

> Before the advent of Einstein it was a necessary consequence of the Second Law *provided the universe were treated as a closed system*. Scientists, however, have always objected that such treatment represents an extravagant and illegitimate extrapolation from our very limited mundane experience, and modern philosophers and theologians have also objected on the ground that it overthrows the doctrine of Immanence and requires a return to the middle-age assumption of a Deus ex machina.[34]

The reference to Einstein may seem puzzling, but it should be read as a reference to Einsteinian mass-energy equivalence (as given by $E = mc^2$) and not to the closed cosmological model. It was the energy released from disappearing mass that made regeneration of particles possible throughout Millikan's universe.

Millikan was a Christian who believed that his religion was in perfect harmony with science, which furnished 'a sublime conception of God, ... wholly consonant with the highest ideals of religion'.[35] As he saw it, an irreversible universe governed by the entropy law was non-Christian. By the mid-1930s experimental investigations of the cosmic rays had undermined Millikan's building-up hypothesis, and he

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32 MacMillan 1920, p. 73.

33 'Cosmic optimism', *New York Times*, 31 December 1930, p. 16. In the interwar period entropy was sometimes associated with nihilism, chaos and political unrest. Joachim Schumacher, a German communist, wrote in 1936 ironically that 'The "entropy law" is … throughout suspicious as Jewish-communist egalitarianism and dissolution.' Schumacher 1972, p. 114.

34 Millikan and Cameron 1928, p. 556. In another paper of 1928, Millikan stated that he was now able 'to banish forever the nihilistic doctrine of its [the universe's] ultimate "heat death"'. Millikan 1928, p. 283.

35 Millikan 1951, p. 311. From a statement on the role of science in relation to religion, published in *Science* in 1931 and signed by a distinguished group of American scientists, church leaders and businessmen.

grudgingly admitted that questions concerning the end of the universe 'must be left to the philosopher and metaphysician'.[36] Yet the metaphysical foundation on which he had originally based his theory, an evolving universe revealing the creator's continual activity, remained essential to his spiritual outlook and view of science. Millikan had no doubt that the world was created by God, and he believed that his own version of steady-state theory, or something close to it, was consonant with Christian belief. The question was not whether the world was created or not, but rather whether it was created once and for all or if creation took place continually. He continued to defend the eternal universe and oppose the hypothesis of the heat death, which he likened to 'the worst form of ecclesiastical dogma'. Like Bridgman and Lewis he denied that the second law held any authority for the universe as a whole: 'The dogma of the heat death rests squarely on the assumption that we infinitesimal mites on a speck of a world know all about how the universe behaves in all its parts, ... even though that is the sort of sweeping generalization that has led physicists into error half a dozen times during the last thirty years.'[37]

More Views on the Heat Death

The popular views of a regenerating universe were countered by two of Britain's leading astronomers and popularizers of science, James Jeans and Arthur Eddington. Jeans was convinced that cosmic processes occurred unidirectionally, in accordance with the second law, and that life and activity were therefore bound to disappear. 'What we are witnessing is less the rising of the curtain before the play than the burning out of the candle-ends on an empty stage on which the drama is already over,' as he expressed it in a 1928 lecture before the Royal Society of Arts.[38] In another lecture the same year he repeated the grim message, emphasizing that there was no escape from the heat death: 'The fabric of the universe weathers, crumbles, and dissolves with age, and no restoration or reconstruction is possible. The second law of thermodynamics compels the natural universe to move ever in the same direction along the same road, a road which ends only in death and annihilation.'[39]

Although Jeans dismissed the notion of a cyclic or perpetual universe as scientifically unfounded, he realized that for emotional reasons it appealed to many people and was probably more popular than the idea of a unidirectional birth-to-death universe. An imperishable universe was a metaphysical hope as ingrained as the wish for immortality, but it was wrong nonetheless as it had no foundation in physics. Jeans's conception collided head-on with the view of MacMillan, Millikan and others who favoured a constructive and eternal universe. Not only did the latter view violate the second law, it was also based on what he thought were fanciful building-up hypotheses with no justification in physics. 'With universes as with mortals, the only life is progress to the grave,' he solemnly declared in *The Universe*

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36 Millikan 1935, p. 454-5.

37 Ibid., p. 456.

38 Jeans 1928a, p. 470.

39 Jeans 1928b, p. 698.

Around Us from 1929.[40] Although Eddington disagreed with Jeans on a number of points – including the relationship between science and religion – with respect to the cosmic consequences of thermodynamics they spoke with one voice. Eddington denied that Clausius's prediction of a running-down universe was pessimistic and contrary to religion. After all, 'Since when has the teaching that "heaven and earth shall pass away" become ecclesiastically un-orthodox?'[41] He felt no sympathy at all for recurrent universe models such as proposed by Nernst and Millikan:

> I am no Phoenix worshipper. … I would feel more content that the Universe should accomplish some great scheme of evolution and, having achieved whatever may be achieved, lapse back into chaotic changelessness, than that its purpose should be banalized by continual repetition. I am an Evolutionist, not a Multiplicationist. It seems rather stupid to keep doing the same thing over and over again.[42]

Jeans and Eddington were of course aware of the often discussed connection between the heat death and cosmic creation, but they responded somewhat differently to it. Jeans argued from the second law that evolution could not be traced indefinitely back in time and that the atoms found today must thus have begun to exist, perhaps formed from a primeval gas of high-energy photons. As what he admitted was a crude imagery he proposed that one might think of 'the finger of God agitating the ether'.[43] According to Jeans, the matter of the universe could not have existed forever, for if this was the case it would have transformed completely into radiation. In 1930 he stated his version of the entropic creation argument as follows: 'The entropy of the universe must for ever increase to its final maximum value. It has not yet reached this: we should not be thinking about it if it had. It is still increasing rapidly, and so must have had a beginning; there must have been what we may describe as a "creation" at a time not infinitely remote.'[44]

Although Jeans flirted with God and religious language, and although some of his writings were within the time-honoured tradition of natural theology, he refrained from using entropy increase to infer a divine creation of the world. Neither did Eddington, who recognized that 'Travelling backwards into the past we find a world with more and more organisation … [which] is something which could not occur fortuitously.' The entropic argument, he went on, 'has been quoted as scientific proof of the intervention of the Creator at a time not infinitely remote from to-day'. However, Eddington dismissed the alleged proof as 'incredible' as well as a 'naïve theological doctrine'. This doctrine, he exaggerated, 'is at present to be found in

40 Jeans 1930a, p. 330.

41 Eddington 1935, p. 59. On Eddington's view on religion and science, see Kragh 2004, pp. 103-12 and Batten 1994. A full discussion has recently been provided by Matthew Stanley, who also deals in detail with the debate over Eddington's view in Great Britain (Stanley 2007).

42 Eddington 1928, p. 86.

43 Jeans 1928b, p. 699.

44 Jeans 1930b, p. 182.

every textbook of thermodynamics, namely that some billions of years ago God wound up the material universe and has left it to chance ever since'.[45]

Eddington stated frankly that he was unwilling to believe in a beginning of the universe and even more unwilling to introduce God as a cause of the cosmic discontinuity. The conception of God that the entropic argument could offer was deistic, and this was not a God in accordance with his conviction as a Quaker: 'Even those who would welcome a proof of the intervention of a Creator will probably consider that a single winding-up at some remote epoch is not really the kind of relation between God and his world that brings satisfaction to the mind.'[46] He was, as he admitted, caught in a dilemma from which he could see no escape. Whereas the deeply religious Eddington dismissed the notion of an origin of the universe, Bertrand Russell found in the heat death confirmation of his atheism, and yet he considered entropic reasoning to be quite a strong argument for a created world.

> We must, I think, admit that there is far more to be said for the view that the universe had a beginning in time at some not infinitely remote period, than there is for any of the other theological conclusions which scientists have recently been urging us to admit. The argument does not have demonstrative certainty. The second law of thermodynamics may not hold at all times and places, or we may be mistaken in thinking the universe is spatially finite; but as arguments of this nature go, it is a good one, and I think we ought provisionally to accept the hypothesis that the world had a beginning at some definite, though unknown, date.[47]

So, in this remarkable statement the atheist Russell accepted the entropic argument for a beginning of the universe. Did he also infer that the world was therefore made by a divine creator? Of course not:

> reason whatever why the universe should not have begun spontaneously, except that it seems odd that it should do so; but there is no law of nature to the effect that things which seem odd to us must not happen. To infer a Creator is to infer a cause, and causal inferences are only admissible in science when they proceed from observed causal laws. There is, therefore, no better reason to suppose that the world was caused by a Creator than to suppose that it was uncaused; either equally contradicts the causal laws that we can observe.[48]

Most philosophers in the interwar period ignored cosmology, and consequently also the cosmological implications of thermodynamics. Russell was an exception, and so was Susan Stebbing, a logician and professor of philosophy at the University of London who in 1937 subjected the philosophical views of Jeans, Eddington and

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45 Eddington 1928, p. 85. Even though Eddington referred to the creation doctrine in a 'suitably disguised' version, he must have known that he was wrong: very few textbooks of thermodynamics in the 1920s included references to the heat death, and almost none to entropic creation.

46 Eddington 1935, p. 59.

47 Russell 1931, pp. 117-8. *The Scientific Outlook* was a highly critical response to Eddington's philosophy of science. See Stanley 2007, pp. 215-20.

48 Russell 1931, p. 118.

others to critical scrutiny. The general aim of *Philosophy and the Physicists* was to show that modern physical theory did not warrant any form of either idealism or metaphysical materialism. Since materialism was decidedly unpopular among British physicists in the 1930s, Stebbing focused on idealism, particular in the forms she found in the widely read works of Jeans and Eddington. With regard to entropic creation, she much favoured Eddington's view over that held by Jeans. The problem, as she saw it, was that creation out of nothing was not a legitimate part of science, and 'the inference to a First Cause is not scientifically permissible, since the notion of an uncaused cause is not in conformity with the way in which a scientist makes use of causal laws.'[49] Stebbing summarized her view as follows:

> In my opinion no arguments favourable to Christian beliefs can be drawn from the law of entropy, either with regard to the beginning of the world or with regard to its gradual and final degeneration into a condition of thermodynamical equilibrium. That a God such as a Christian could worship originally created this world is surely not to be inferred from the laws of physical phenomena. … It is a sign of the dominance of the scientists in our thinking to-day that many Christian apologists seem more concerned either to refute the second law of thermodynamics or to show that it is compatible with the teaching of Christ than to consider what kind of world it is in which we – common readers and scientists alike – are living to-day.[50]

Eddington returned to the theme of a possible origin of the world, as indicated by the entropic argument, in an address of January 1931, at a time when he had accepted the expanding universe but shortly before Lemaître proposed his hypothesis of an explosive beginning of the world. After having stressed the entropy as the arrow of time, he repeated that 'Philosophically, the notion of a beginning of the present order of Nature is repugnant to me.'[51] He never changed his mind and continued to resist Big-Bang models of the universe until his death in 1944.

It was Eddington's remark that provoked his former research student Lemaître to publish his brief note in *Nature* of 9 May in which he proposed, purely qualitatively, that the world had started in the radioactive explosion of a superdense 'unique atom' (he would later change his metaphor to 'an isotope of the neutron'). Lemaître did not mention explicitly the entropic creation argument, but he did refer to 'thermodynamical principles from the point of view of quantum theory'. As he argued more clearly in a paper later the same year, the principle of the growth of entropy adopted to electromagnetic radiation implies a 'pulverization of energy', namely that the number of energy particles (photons) steadily increases. For a blackbody-distributed photon gas at temperature T, the entropy per volume is given by $S = aT^3$ and the number of photons per volume by $N = bT^3$ where a and b are constants; hence it follows from $dS/dt \geq 0$ that $dN/dt \geq 0$. More generally, Lemaître claimed that the number of particles sharing a certain amount of energy is constantly increasing, corresponding to a multiplication of particles arising from the initial explosion of the

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49 Stebbing 1937, p. 259.

50 Ibid., pp. 259-60. Stebbing's observation would have been more correct had it referred to the 1890s rather than the 1930s.

51 Eddington 1931, p. 450.

hypothetical *atome primitif*. 'If we go back in the course of time we must find fewer and fewer quanta, until we find all energy of the universe packed in a few or even in a unique quantum.'[52] Although Lemaître's argument was far from satisfying, and although he did not refer specifically to entropy in his 1931 note to *Nature*, he did in fact make use of a form of the entropic creation argument.[53]

Whereas Lemaître appears to have accepted the entropic argument for a beginning, Tolman did not. In his major work of 1934, *Relativity, Thermodynamics and Cosmology*, he warned cosmologists against philosophical preferences and what he called 'the evils of autistic and wishfulfilling thinking'. Among such prejudices he included the belief that the universe was created in the past: 'We must be specially careful to keep our judgments uninfected by the demands of theology and unswerved by human hopes and fears. The discovery of models, which start expansion from a singular state of zero volume, must not be confused with a proof that the actual universe was created at a finite time in the past.'[54] The creation of the world was a radical concept which was difficult to comprehend and to which scientists had to accustom themselves. During the 1930s, Tolman's cautious attitude was the rule rather than the exception.

Entropic Creation's Last Stand

Although the entropic creation argument in its wider sense was not highly regarded after World War I, in a few cases it was taken up for discussion by theologians and Christian scientists. Ernest William Barnes, Bishop of Birmingham, belonged to the liberal wing of the Church of England. He had started his career as a Cambridge mathematician, and in his *Scientific Theory and Religion* of 1933 he discussed in impressive technical details the relationship between religion and the new physical world view, including cosmology.[55] Much like Lemaître, Barnes was emotionally committed to the universe being finite. 'Infinite space is simply a scandal to human thought,' he declared in 1931. 'In Riemannian spherical space we can have a finite and uniform distribution of universes [galaxies], inasmuch as such space is

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52 Lemaître 1931a and Lemaître 1931b. Existing sources do not allow a precise reconstruction of Lemaître's path to the primeval atom hypothesis, but at least three factors acted as motivations: (1) entropic considerations relating to number of particles; (2) the existence of long-lived radioactive isotopes; (3) the so-called Birkhoff theorem in the theory of general relativity. Although the hypothesis was strictly scientific, religious motivations, too, played a role. For details, see Lambert 1997 and Kragh and Lambert 2007.

53 See also Lemaître's address of 1945 to the Swiss Scientific Society, as reprinted in Lemaître 1946, pp. 147-76. Surprisingly, Lemaître's argument (1931b) was flawed, for other reasons because one cannot infer from the entropy of photons to the entropy of material particles. Moreover, Lemaître failed to take into account the expansion of the universe and the fact that the temperature decreases with the expansion. This serious discrepancy is discussed in Kragh and Lambert 2007.

54 Tolman 1934, p. 486.

55 On Barnes and his views on science and religion, see Bowler 2001, pp. 260-77, and Valente 2005.

unbounded.'[56] In *Scientific Theory and Religion* he put to task those who tolerated 'the absurd idea that space can possibly be infinite'. His rejection of an infinite universe was subjective, and perhaps epistemic, but not explicitly rooted in religious arguments.

In his discussion of the cosmological consequences of thermodynamics Barnes stated that 'We are thus driven to the belief that God lies behind [the] phenomena.' But later in the book he made it clear that he did not accept such a proof of God resting on the classical notion that 'there was a time when God wound up the clock and a time will come when it will stop if He does not wind it up again.'[57] Not that he had any strong arguments against the picture – it just went against his 'instinct' and 'general outlook' which told him that God was no transcendent watchmaker. Barnes knew that the heat death prediction rested on certain assumptions that could well be questioned, and that there were alternative cosmological theories in which the heat death would not occur. Among these was the McMillan-Millikan theory of the recurrent universe, which he mentioned as a possibility but without endorsing it. In a 1931 address to the British Association he considered 'a never-ending sequence of alternate periods of world-building and world-destruction, the rise and fall of universes without end'. However, this was merely a 'not very satisfying' possibility.[58]

William Ralph Inge, Dean at St Paul's 1911-34 and a well known cultural commentator, had no scientific training, but he felt it his duty to keep up with developments in the sciences. For, as he expressed it in an essay from 1925: 'A religion which does not touch science, and a science which does not touch religion, are mutilated and barren. Not that religion can ever be a science, or science a religion; but we may hope for a time when the science of a religious man will be scientific, and when the religion of a scientific man religious.'[59] Inge's most important work, from our perspective, was his book *God and the Astronomers* from 1934 in which he considered, among other subjects, the heat death. As a Christian he saw no reason to be disturbed, and as evidence he quoted, as Thomson had done more than eighty years earlier, the 102nd Psalm. 'The idea of the end of the world is intolerable only to modernist philosophy, which finds in the idea of unending progress a pitiful substitute for the blessed hope of everlasting life', whereas 'the philosophy of the Great Tradition may view the prospect of "the new *Götterdämmerung*" without deep concern, just because the fate of its own God is not involved.'[60]

Just like Barnes, Inge did not endorse the entropic argument for a beginning of the universe or relate it to divine creation. True, the argument seemed to agree nicely with the traditional Christian belief of the universe being created *ex nihilo*, but Inge objected to this 'naive deistic doctrine' which did not even have unambiguous support

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56 Barnes 1931, p. 598.

57 Barnes 1933, p. 240 and p. 595.

58 Barnes 1931, p. 600.

59 Untitled essay in Needham 1925, pp. 343-89, on p. 348.

60 Inge 1934, p. 27 and p. 69. See also the essay review by F.C.S. Schiller in *Mind* 43 (1934), 382-9.

in Genesis.[61] Commenting on Eddington, Inge wrote that although the hypothesis that the order of things 'started off with a bang' was not really incredible, 'it is so unlikely what we observe of the divine working that most of us would be unwilling to believe it'. At any rate, he could see no obligation why Christians should trace back in time the cosmic movie until they found a discontinuity to be explained in terms of a first mover. 'What we assert is the absolute *dependence* of the creation on the Creator', he wrote, a notion for which a bang, big or small, was irrelevant.[62]

The emphasis on atemporal creation in the form of continual dependence may explain Inge's at first sight surprising sympathy for models of the recurrent or recycling universe. 'This idea has long attracted me', he admitted, for 'in that case the universe may be perpetual as its Creator is eternal; and there must be some hitherto unknown agency which counterbalances entropy.' As to possible entropy-reducing processes he mentioned Arrhenius's ideas and also Millikan's more recent and 'very attractive' theory, although he was aware that it had little support among scientists. 'Are we sure that there is no creation (say) of hydrogen atoms out of radiation?' he asked.

> A discovery of such a balance between creation and destruction would be extremely welcome to most of us. It would end the necessity for believing in the creation of the universe in Time. It would satisfy our very natural feeling that a perpetual continuance of the universe would be more in accordance with what we may imagine to be the will of God than its temporary existence and final annihilation.[63]

The point to note is that we have here a church leader and distinguished theologian endorsing a recurrent, eternal universe in order to *avoid* a creation of the world at a definite time in the past. Traditionally this kind of universe had been taken to support the cause of atheism and materialism, but evidently Inge did not see it this way (nor did Millikan). Although Inge maintained that the fate of the material universe was not a vital question for religion, he found the prospects of the second law to be disturbing: 'Our astronomers have got themselves into a philosophical impasse by trying to fit real Time, and Entropy, which presupposes real Time, into a purely mathematical universe. The Second Law leaves them with an ultimate acosmism and pan-nihilism.'[64]

To many religious people, whether laypersons or theologians, the new scientific world view of relativity, quantum mechanics and evolutionary biology seemed confusing and hostile to higher values. Walter R. Matthews, Inge's successor as Dean of St Paul's, was among the many who gave voice to the worries. Without giving reasons he assumed the expanding universe was merely a speculation, but

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61 *Creatio ex nihilo* is not mentioned explicitly in the Bible and was only introduced as a Christian dogma in the second century. It was made an official doctrine of the Catholic church at the Fourth Lateran Council in 1215. Experts are divided on the question of whether the notion of cosmic creation out of nothing is implied by Genesis or other parts of the Bible. For opposing views, see May 1994 and Copan and Craig 2004.

62 Inge 1934, p. 244 and p. 234.

63 Ibid., pp. 64-5. Other quotations from pp. 27, 69, 101, 244, 234.

64 Ibid., p. 70.

nonetheless he complained in a book of 1935 that it 'add[s] to our bewilderment and our sense of homelessness'. The heat death, such as confidently predicted by Jeans and Eddington, might be taken to agree with the apocalyptical passages in the Bible and the increase of entropy might even indicate a created universe. But Matthews found it of little comfort to the theologian. 'The impression grows upon us that we are in a world which is alien to our values, indifferent to our hopes, and, if purposive at all, is directed towards ends for which we are irrelevant.'[65]

Cosmological entropy considerations also entered theological literature in *Cosmology*, a textbook written by J.A. McWilliams, a Jesuit scholar at St Louis University. McWilliams had to face the traditional objection that the heat death would only occur on the supposition that the world is finite in extent. His answer was two-pronged. First he adopted the traditional scholastic argument that an infinite universe is ruled out because it involves the possibility of an actual infinite number: 'The expression, "a world of actually infinite extent", is a congeries of words for which no justification can be found either in fact or in concept.'[66] But McWilliams also appealed to the uniformity assumption known as the cosmological principle, that is, the generally held assumption that the universe is homogeneous and isotropic on a very large scale. Whereas somewhat speculative versions of this principle can be found in pre-1900 cosmology, with the emergence of relativistic cosmology it received strong observational and theoretical support. Since our part of the universe is governed by the second law of thermodynamics, 'therefore the same should be true of the entire universe', whether finite or infinite.

McWilliams presented the heat death as if it were fully congruent with Catholic faith, whereas he criticized the hypotheses of Nernst, MacMillan and Millikan, not only because they lacked scientific support but also because he found them problematical from a theological perspective – they were 'altogether mechanical'. Millikan and other advocates of a recurrent universe directly or indirectly identified it with an eternal universe, but as McWilliams pointed out, 'even granted the world will never come to a stop, that does not mean that it never *started*. Hence it would not mean that the world was eternal, much less uncreated.'[67] Moreover, as a good Thomist he reminded his readers about what had been known since the Middle Ages, that beginning cannot be identified with creation:

> Even supposing such [an eternal] world to exist, that fact would not exclude the need of its being created. Creation does not directly refer to the duration of the world, but to the reason for its existence; and it means that the reason for the world's existence is not within itself but in Another. Creation means that the world is *ab alio*. Granted an omnipotent

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[65] Matthews 1935, pp. 98-9.

[66] McWilliams 1939, p. 43 (1st edn 1928). McWilliams further suggested that the recently discovered expansion of the universe indicated that it was finite ('it means that the size, since it is increasing, is actually finite', on p. 9). The argument is wrong, as the expansion is independent of the curvature of space and merely denotes that cosmological distances are increasing in time.

[67] Ibid., p. 45.

> God, then He can produce anything that is not a contradiction. Therefore, if an 'eternal' world is not a contradiction, God could produce such a world.[68]

The universe might be finite in time or be eternal; in either case it was created and in accordance with Christian thought. The same point was made in another textbook from the same period, *Modern Thomistic Philosophy*, which also included a brief discussion of the entropic creation argument. However, following the older Catholic literature the author concluded that it was 'not absolutely demonstrative'. For one thing, it was founded on a physical theory which, as any theory belonging to science, could be wrong; for another thing, it failed to show that the notion of an infinitely old universe involves a contradiction.[69] The Catholic philosopher Charles Baschab preferred to do without the entropic argument at all. Like several other authors in the neo-scholastic tradition, he gave priority to the argument from contingency which does not depend crucially on a universe of finite age: matter is subject to change and therefore contingent; even if it is supposed to be eternal, it does not explain its own existence and is therefore in need of an explanation based on a necessary being.[70]

The most explicit use of the entropic creation argument as a proof of God was due to Edmund Taylor Whittaker, a distinguished mathematician and theoretical physicist who served as professor at the University of Edinburgh. The erudite Whittaker converted to Catholicism in 1930, was in 1936 appointed a member of the Pontifical Academy of Sciences[71] and until his death in 1956 he remained active within British Catholic life. Contrary to the large majority of scientists in the twentieth century, Whittaker used modern science apologetically and maintained that physics and cosmology led to conclusions that strongly supported Christian belief. He first took on his apologetic role in *The Beginning and End of the World*, in which he argued that the old entropic argument was a valid proof for God's existence. The second law of thermodynamics did not merely indicate a beginning of the universe, it led to the inevitable conclusion that there had been 'a *creation*, when the total entropy of the universe was less than it has ever been subsequently'. Whittaker went on along the theological trajectory: 'The knowledge that the world has been created in time, and will ultimately die, is of primary importance for metaphysics and theology; for it implies that God is not Nature, and Nature is not God ... For if God were bound up with the world, it would be necessary for God to be born and to perish.'[72]

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68 Ibid.

69 Phillips 1934, vol. 1, pp. 170-171.

70 Baschab 1923, pp. 70-74.

71 The *Pontificia Accademia delle Scienze* was formed in 1936, on the basis of the former *Pontificia Accademia dei Nuovi Lincei*, an institution founded by Pius IX in 1847 and which claimed to have roots in the *Linceorum Academia* of 1603. According to the charter of the academy, its membership is independent of nationality and creeds, and its goal is 'to honour pure science wherever it is found, assure its freedom and promote its researches.'

72 Whittaker 1942, p. 40. The book was reviewed by Jeans in *Nature* 150 (1942), 671. Jeans thought that cosmology had disappointingly little to say on religion: 'The two never make real contact, still less come to grips – how could they? … Science can speak with philosophy, and philosophy with religion, but attempts to short-circuit philosophy have

According to the world model favoured by Eddington, the universe had always existed and the expansion set in asymptotically only at some time in the past. Even Lemaître's Big-Bang model presupposed a kind of physical beginning, an original state of the world in which time had no meaning because physical processes had not yet begun. However, Whittaker denied that the initial state of the world was a pre-existing universe, inert but with physical attributes. He may have believed that such a notion was un-Christian, although Lemaître obviously did not think so. Whittaker seems to have rejected not only Jeans's finger but also Lemaître's acausal mechanism of the origin of the universe:

> There is no ground for supposing that matter ... existed before this in an inert condition, and was in some sense galvanized into activity at a certain instant: for what could have determined this instant rather than all of the other instants of the past eternity? It is simpler to postulate creation *ex nihilo*, an operation of Divine Will to constitute Nature from nothingness.[73]

In his works between 1942 and 1946, Whittaker emphasized with great religious feeling the significance of modern cosmology to the philosopher and theologian. Although he was careful not to claim that a universe of finite age constituted a proof of God's existence in any direct sense, he did his best to demonstrate the consonance of modern cosmological theory with the doctrines of Christian natural theology. He stated as a matter of fact that cosmology had shown that 'there must have been a Creation'. No wonder that Pope Pius XII in his notorious 1951 address *Un Ora* drew on Whittaker's authority in his attempt to show that modern physics and astronomy pointed to the existence of a transcendent creator.[74]

Whittaker's most sustained attempt at cosmo-theology appeared in a series of lectures he delivered in Trinity College, Dublin, in 1946 and which appeared as a book the same year. The message of *Space and Spirit* was that the world view of modern physical science offered strong arguments in favour of a universe created by an almighty and omniscient God. 'The deeper understanding of the nature of the material universe, which has been achieved by scientific discovery, has opened up new prospects and possibilities to the advocate of belief in God.' Whereas Lemaître refrained from speaking of the origin of the universe as a creation, Whittaker had no such reservations. Not only did he find God confirmed in the finite age of the universe, he also found the divine creator in the lawfulness of the universe, the fact that the universe is a cosmos and not a chaos:

> Mathematical law is a concept of the mind; and from the existence of mathematical law it is not unreasonable to infer that there is a mind, analogous to our minds, in or behind material Nature: the order which exists is meant to exist; ... When we reflect on the unity of the cosmos – its coherence and interconnectedness, the adaption and co-ordination of

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usually failed, and perhaps must always fail; the universe does not carry its secrets written on its sleeves.'

73 Whittaker 1942, p. 63.

74 Whittaker 1943, p. 460. For the Pope's address, see Chapter 7.

> its parts – we are led to consider that it exists for some intelligent end. In a world that was not the expression of intelligence, science would never have come into being.[75]

Moreover, since the mathematical laws are universally valid, the same throughout the universe, they must reflect the will of a single mind, which he considered to be an argument for monotheism such as Christianity. The argument was not new, having previously been used to demonstrate that there cannot be many gods.[76] Having thus argued for monotheism, Whittaker was faced with the age-old problem of identifying the universal mind with the transcendent God of the Bible. So far the argument might as well point to an immanent mind, to a form of pantheism. But according to Whittaker, modern cosmology and thermodynamics came to the rescue:

> If we have the knowledge that the universe cannot have existed for an infinite time in the past under the operation of our present laws of nature – in other words, that there must have been a Creation – and moreover that there must come a time when for physical reasons life will be impossible, then these are facts which make it incredible to suppose that God is bound and conditioned by a world which has its appointed times of birth and death. If we have in any way arrived at the conviction that God exists, modern cosmology points to the further conclusion that He must be, in one aspect at least, extramundane.[77]

Whittaker's views differed in important respects from those of his fellow-Catholic Lemaître, yet the two agreed that although the history of the universe can be traced far backward in time, its true origin will forever be beyond the possibility of scientific explanation. In Whittaker's words, 'The Creation itself being a unique event is of course outside science altogether.'

Summary and Overview

Let me now outline in a summary fashion the most important themes and arguments that have been presented in the previous sections and which are all concerned with aspects of the relationship between cosmology, thermodynamics and religion.

The mechanical theory of heat was part of the ideological debate from the very beginning, that is, from the 1840s onwards. We have seen how the conservation of energy or 'force' was interpreted as a sign of God's sovereignty and in support of a spiritual world view, opposed to materialism, by pioneers such as Joule, Colding, Grove, Mayer and Hirn. From this perspective it is remarkable that within a few decades the law of energy conservation became the darling of the materialist opposition. Büchner and many others considered the law to be proof that the universe is eternal, and in some cases (such as Haeckel and Arrhenius) they used its authority against the predictions of the second law of thermodynamics.

The second law was often seen as associated with anti-mechanicism and, more vaguely, spiritual interpretations of science. Bergson called it the most metaphysical

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75 Whittaker 1946, pp. 129-35.

76 For example: 'Scientific observations cannot be reconciled with polytheism, for scientific observations demand the assumption of one universal law.' Maunder 1908, p. 15.

77 Whittaker 1946, p. 131.

of the laws of physics, to Boodin it was the *bête noir* of mechanistic cosmology, and according to Aliotta it dealt 'the heaviest blow to the mechanical theory'.[78] The association might cover theism as well. Not only did Clausius's law lead to a heat death, which could be interpreted as a scientific version of the apocalypse, it was also used to infer a creation of the world in agreement with Genesis. The apocalyptic theme was developed at an early date – by Thomson, Tait and Helmholtz – but most theologians and Christian scientists realized that the similarity was at best superficial and perhaps only symbolical. Indeed, there were those who saw the slow, dull and inevitable march toward the heat death as conflicting with Christian faith and the notion of the Day of Judgment, a view which may first have been clearly stated by Johann Rademacher in 1909.

All the same, the heat death scenario was generally seen as being in agreement with Christian values and in conflict with the ideas of materialism and positivism. But it also appeared to be in conflict with the ideal of endless progress accepted by the large majority of scientists and scholars whatever their views on religion. If scientists of a Christian faith saw this as a problem, they could comfort themselves that the heat death would only become a reality in an indeterminately far future, or they could deny that it would ever occur. Thus, Thomson did not accept the heat death as something that would really happen; and many years later Millikan argued against the ultimate end of the universe, which to him was a materialistic and basically non-Christian notion. Millikan was not the only one who 'misunderstood' the ideological connotation of the heat death. Caspari and Nietzsche both denied its reality and argued in favour of an endless cyclic universe, which they saw as opposed to mechanicism and materialism. Also Vaihinger tended to associate the irreversible, thermodynamical universe with mechanicism.

The second law of thermodynamics was controversial, and a major reason was that it, when applied to the universe as a whole, seemed to imply an absolute beginning. Such a beginning in a minimum-entropy state does not necessarily indicate a divinely created world, but the connection was generally assumed and often stated to follow rigorously from fundamental physics. It was, Murphy claimed in 1873, 'a truth of purely physical science'; and according to Carl Braun's Christian cosmogony of 1889, the divine creation of the world was 'a consequence of science itself'. The entropic creation argument was highly controversial and became part of the cultural struggle of the late nineteenth century. Most of the discussants placed their bets on one of two views, either for or against entropic creation, but there were also a few who suggested from either a theological or a philosophical perspective that the entire debate was pointless. Bavink in 1907 and Rashdall in 1908 argued that the apologetic inference from a finite cosmic past to the existence of God was a fallacy: even an eternal world is 'created' in the sense that it is in need of God to preserve its existence. Whatever the temporal extension of the world, it must be caused by a transcendent creator.

Starting in the late 1860s, with Caro in France, Maxwell and Tait in Britain, and Fick and Brentano in Germany, many authors adopted the entropic creation argument in either its restricted or wide version. As to the restricted version, which

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78 Aliotta 1914, p. 348.

did not refer explicitly to God as the creator of the universe, there was little variation in the arguments except that some were more detailed than others. I am aware of only one physical scientist of the first rank who publicly defended the strong version, that is, used the second law to infer the existence of God. This was Edmund Whittaker, and his defence came as late as 1946, some thirty years after the entropic creation argument had stopped attracting attention. In the period from about 1870 to 1915, when the argument was widely discussed, its extended form was advocated by Brentano, Murphy, Braun, Schrader, Dressel, Haas, Gutberlet and Sawicki. Of these, Haas was the only physicist, and his advocacy was restricted to a single paper written in his youth. Only in a few cases, as in Brentano, Dressel and Gutberlet, was the argument developed in something like a complete proof of the existence of God. It was, of course, possible to argue for a divinely created world without accepting the heat death, as did Secchi.

The apologetic use of the second law was usually based on the entropic creation argument, but it was also possible to use the heat death directly, without any reference to cosmic creation. Braun and Gutberlet were among those who stressed that the heat death of the future proved the contingent nature of the universe. The prediction that the universe will perish implied that it must be caused and therefore cannot exist *a se*. They argued that the uncaused cause of the universe must be God. According to this version, the world could have existed in an infinity of time; what mattered was that it would not continue to exist, at least not necessarily so.

Most of the entropic apologists were cautious and well aware of the many problems of using a law of physics for theological purposes. Although they may have found entropy increase a useful argument for a created world, they recognized that it did not have the certainty that allowed it to function as a really satisfactory proof of God. This was the conclusion of Nys and Isenkrahe, and it was also what Sawicki came to accept. It is important to realize that most of the Catholic scholars who engaged in the debate did *not* embrace the entropic creation argument enthusiastically. They reviewed it critically and often with the same arguments as their opponents in the materialistic-atheistic camp. Isenkrahe, in particular, spent great efforts to demonstrate that the second law cannot work as a satisfactory proof of God's existence. At about the same time, Aloys Müller reached the same conclusion. Maxwell warned in the 1860s against the hasty use of scientific theories in support of religious views, and his warning was generally accepted. Nearly one hundred years later, the Anglican theologian M. Davidson mentioned as an instructive example, 'the law of the increase of entropy on which some Christian apologists have been disposed to build an imposing edifice'.[79]

Whether or not the entropy law was considered useful as an argument *for* Christian faith, almost all believers found that it served a purpose as an argument *against* the eternal and cyclic universe that was so clearly associated with the cause of anti-religious materialism. This theme was visible among pioneer thermodynamicists such as Thomson, Clausius and Maxwell, and it continued to be part of the apologetically coloured literature well into the twentieth century. But recall that not all Christian authors considered the eternally recurrent universe to be materialistic and un-

[79] Davidson 1955, p. 168.

Christian: Inge had sympathy for the idea and Millikan saw it as a bulwark against godless materialism. It was quite possible to draw diametrically opposite views in the realm of theology from the same scientific law, the principle of entropy increase. According to one view, the one associated with pessimism, the law had nothing to offer except the thermal destruction of all life and activity in the world. This gloomy prospect was disturbing to some, but with others it served an apologetic purpose. Not only could it be used as an argument for cosmic creation, the destruction of the world could be seen as a confirmation of its contingent nature and hence its dependence on God's will.

It was a dogma among materialists, positivists and monists that the universe is infinite in extension, which was usually taken to imply spatial as well as material infinitude; the opposite position, finitism, was no less of a dogma among their Christian antagonists. When it came to infinitism, the problematic issue was usually the number of things in the universe, not the spatial extension. It was relatively easy to conceive space as infinite, such as Thomson did, but much harder to conceive it as uniformly filled with matter, for in this case one was faced with the problem of an actual infinity of numbers of objects or processes. The space-only infinitism depended on one's conception of space. If space was merely thought of as a container of matter and physical phenomena, as was typically the picture of the Milky Way universe, problems did not necessarily arise. On the other hand, the situation was different if space was thought to be filled up with ether, especially if the ether was conceived to be endowed with energy or otherwise being substantial in nature.

There was little unity in the ideas of the eternal and cyclic universe favoured by scientists and writers of a materialist inclination except that they were all qualitative and more or less speculative. Most of the models pictured the universe as regenerating in space as well as time, meaning that evolution occurred all over in the infinite universe at any given time. This was the kind of cyclic universe presented by Strauss, Spencer, Büchner, Nietzsche, Arrhenius and many others. Cyclic models in the modern sense, where the size of the universe varies periodically in time, were incompatible with the notion of an infinite universe. However, a few writers suggested pulsating models of this type (although without the singularities of the later relativistic models). The first clearly presented case of a pulsating universe may have been the one suggested by Falb in 1875, and in 1897 Zehnder proposed a more elaborate model along the same lines. Both Falb and Zehnder argued that the universe is finite in space but infinite in time.

It is not obvious why the question of the size of the universe, and the number of its objects, should be correlated with belief in such a way, but one theological argument was that true infinitude is reserved for God: to claim that the physical universe is infinite would obscure a crucial difference between God and nature, and then to open up for pantheism and like heresies. This view has been common ever since Augustine, and yet there have always been dissenting voices among theologians and Christian scientists. Although infinitism was definitely correlated with atheism in the second part of the nineteenth century, and finitism with theism, the correlation was not perfect. Christian scientist as he was, Thomson nonetheless concluded that a spatially finite universe was impossible. The Dutch astronomer Frederik Kaiser believed that the infinite universe reflected God's omnipotence, a conviction that

Milne shared and stated nearly a century later. On the other side of the spectrum the arch-materialist Dühring argued that there cannot be an infinite number of objects in the universe. The positions of Thomson and Dühring were exceptions, though, and in general one can be fairly confident that an author who in a philosophical or ideological context advocated a finite universe was a Christian; and that one who advocated an infinite universe was a materialist of some sort. I think this empirical correlation holds reasonably well 1860-1915, that it is neither generally valid nor rationally justified.

Indeed, a look further back in time demonstrates that there is nothing 'natural' in the correlation between theism and spatial (or even temporal) finitism. Cardinal Nicholas of Cusa believed that the universe is infinite, and his arguments were primarily theological. He thought that a limited universe, whether in space or time, would imply a limitation of the creator himself. Nor did Descartes, Newton, Bentley and Leibniz see any grave problem in a divinely created, infinite universe.[80] Quite the contrary, such a universe would be 'more agreeable' to God's wisdom, as Leibniz expressed it. The Cambridge Platonist philosopher Henry More restated the argument that the universe must be infinite because God's omnipotence requires it:

> It had been far more splendid, glorious and magnificent for God to have made the universe commensurate with his own immensity, … than to have confined his omnipotence to work only in one little spot of an infinite inane capacity, and to begin to act but t'other day. Thus the late creation, and finiteness, of the world seem to conflict with the undoubted oracle of truth.[81]

More's defense of an infinite universe concerned its size, not its duration. During the seventeenth century belief in the eternity of the world was definitely seen as heretical, but the attitude changed somewhat in the following century.

Leibniz, and also the influential German philosopher Christian Wolff, emphasized that the active force (the *vis viva* given by mv^2) was the ultimate physical reality and that it was absolutely conserved. To many Leibnizians and Wolffians in the eighteenth century the conserved *vis viva* was God's way of keeping the world machine alive eternally. As they saw it, a divinely created, yet eternal world was not a contradiction in terms. The German polymath Johann Heinrich Lambert argued in his *Cosmologische Briefe* of 1761 that the universe is infinite in time but finite in space. Neither did it occur to Kant that his cosmology, founded as it was on an infinite and ever-creative universe, should be opposed to Christian belief. The Christian astronomer Olbers was much inspired by Kant and he shared his belief in an infinite universe, yet one created by 'a creative omnipotence'. Also John Herschel, definitely neither an atheist nor a materialist, favoured an infinite and hierarchical universe in the style of Kant. More examples could be mentioned, but the point should be clear: prior to the use of thermodynamics in cosmology people did not associate

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[80] Descartes and other seventeenth-century infinitists believed that the universe is infinite only in the sense that it is impossible to conceive any limits to it or to imagine an even greater universe. They often preferred to speak of an indefinite or limitless world rather than an infinite world.

[81] More, *Lux orientales* (1682), as quoted in Lovejoy 1976, p. 126.

finitism with theism, or infinitism with atheism. In other words, the correlation was historically contingent.

It would be wrong to believe that belief in a finite universe was always religiously motivated, or that belief in infinitude was invariably a sign of a materialistic or atheistic view. Astronomers often preferred an agnostic attitude, typically suggesting that the size of the universe would for ever be beyond human knowledge, so why care to discuss the question? If they spoke out in favour of either finitism or infinitism, they referred to observations or sometimes to philosophical considerations. As far as I can tell, religious or ideological motives played no role in Schwarzschild's preference for a closed and finite universe, which was grounded in epistemological rather than religious considerations.

With Einstein's theory of 1917 a finite universe appeared much more plausible, even to be a necessary consequence of general relativity. Although the Einstein model was in some cases taken as support for theism, in general it was not. Theoretical cosmology in the 1920s, which essentially meant the rival world models of Einstein and de Sitter, rarely aroused public debate and was ignored by most philosophers and theologians. In the 1930s, Barnes found infinite space to be a 'scandal to human thought' and Lemaître considered it a 'nightmare', but this shared view did not reflect their Christian belief, at least not in any direct sense. The case of Carl Charlier is more tricky. His argument of 1896 that the universe is spatially finite was based on astronomical reasoning, namely the paradoxes of Olbers and Seeliger. Twelve years later he constructed a model of the infinite Newtonian universe that avoided the paradoxes and he consequently changed to spatial infinitism. On the face of it, religious (or anti-religious) motives played no role in either 1896 or in 1908, but a closer view reveals that such motives did enter Charlier's considerations, although it is hard to tell exactly how and to what extent.

The primary aim of the advocates of an everlasting, regenerative universe was to show that the heat death and the entropic beginning were hypotheses that could be reasonably doubted. This could be done either by denying the absolute validity of the second law or by arguing that it has no cosmological validity. A few critics simply dismissed the law, typically with the argument that since it led to an absurd conclusion, it must be wrong. From a logical point of view it is permissible to infer the falseness of a premise from the falseness of the consequence, but of course the claim that the conclusion is absurd or wrong was far from immune to criticism. At any rate, this was the way Büchner argued, and he was followed by Vogt and Haeckel. Another argument of a somewhat curious nature was that the universe could not possibly have an end state; for in that case it would have been reached long ago. Nietzsche, Köhler and Arrhenius were among those who presupposed an eternal universe and drew consequences from the presupposition. As far as they were concerned, the eternity of the universe was an *explanans*, not an *explanandum*. A similar kind of doubtful inference was made by Hartmann when he deduced from the absolute validity of the law of entropy that the universe must be finite.

By far the most common strategy against the heat death was to claim that the laws of thermodynamics were not applicable to the universe as a whole. The denial came in two versions. According to Mach, Stallo, Chwolson and others it was illegitimate to extrapolate from laboratory or terrestrial experiences to the universe at large, a concept which is unique and for which no scientific laws hold. There are no laws *of* the universe, only laws for what is *in* the universe.[82] This methodological argument was held to be valid for the universe *qua* universe, irrespective of whether it is finite or not (and this question was held to be metaphysical). The other version, adopted by most materialists, relied specifically on the assumption that the universe is infinite in space and matter. If so, the amount of energy would be infinite too, and it would presumably take an eternity to degrade it to bound heat energy.

Although most critics of the heat death considered infinitism to be a perfectly good argument, they would also appeal to a variety of other arguments to weaken the force of the entropy law. A few, such as Haeckel and Arrhenius, claimed that the two laws of thermodynamics were contradictory, from which they concluded that the absolute validity of the second law had to be abandoned. Other materialists, including Tyndall and Spencer, responded to the assumed inconsistency by concentrating on the first law and ignoring the second. Yet another argument against the strict validity of the law of entropy, this time of a sociological nature, was to refer to the lack of consensus among specialists with respect to the precise meaning of the law. If the authorities did not agree, there seemed to be no reason to accept the universal validity of the principle of entropy increase.

Apart from these general objections, the critics introduced local mechanisms supposed to show that entropy does not always increase. Such counterentropic mechanisms might or might not go hand in hand with the objection based on an infinite universe. The earliest proposal of a counterentropic phenomenon was Rankine's 1852 speculation of reconcentration of radiant heat energy, a proposal that was cited by many critics of the entropy law for a surprisingly long period of time. A solution to the running-down universe along these lines was suggested by the astronomy writer John Gore, who thought that the mechanism might be able 'to raise the general temperature of the ether, and preserve the great principle of the conservation of energy'.[83] However, it was only one mechanism among many. Others included collisions between celestial bodies, interference between heat waves, energy stored in the world ether, diffusion of gases, radiation pressure and intra-atomic energy. The argument that available energy can be restored by stellar collisions was particularly long-lived, but it was rarely considered a serious objection against the global rise of entropy. After 1911 a few critics argued that the zero-point energy associated with quantum theory constituted a major problem for the depletion of free energy.[84] If space (or the ether) possessed an energy even in its ground state, it might seem that the general argument for the heat death failed.

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[82] The question of whether the concept of law is valid for the universe played some role during the cosmological controversy in the 1950s, when Hermann Bondi and William McCrea argued that this is not the case. See Kragh 1996, p. 241 and p. 249, and Bondi 1966. The question is still a matter of discussion among philosophers of science. See also Toulmin 1982 as discussed in Chapter 7.

[83] Gore 1888, p. 238.

[84] Schnippenkötter 1920, p. 18. As mentioned, Nernst used the zero-point energy of the ether to argue for an eternal universe.

In addition, there were more general arguments that led to the same conclusion – that the entropy law has only limited validity – but without relying on specific mechanisms. On a very general level it was pointed out that the law of entropy increase is an empirical law and for this reason its truth can never be known with absolute certainty. Indeed, with Boltzmann's probabilistic interpretation it seemed that the second law was only statistically valid and hence that the new interpretation furnished a loophole to avoid the universal heat death. When Fick decided that it was unwarranted to draw cosmological conclusions from the second law, he appealed to Boltzmann's formulation, and Müller and Seeliger later used the same argument. According to some scientists, the probabilistic interpretation profoundly altered the status of the second law. It could be argued that all that the law really said was that entropy increases except when it does not. Is this an authoritative law of physics on which cosmology can be safely founded? On a less general level came interpretations of the second law that denied that the world would ever reach a state of maximum entropy. According to Duhem there was no maximum entropy, only a continual increase in entropy; and Bavink, Isenkrahe and others argued that although the limit might be approached asymptotically, it would never actually be reached. Likewise, there was no compelling reason why the universe should have begun a finite time ago in a minimum-entropy state, only in a low-entropy state.

The debate over the heat death and the beginning of the world in some unlikely state of minimum entropy was allegedly scientific, in the sense that it was kept in scientific terms and drew on arguments of a scientific nature; but in reality ideology, metaphysical and religious presuppositions, not to mention sheer wishful thinking, was no less important than the purportedly scientific arguments. This may have been a main reason why so few professional physical scientists found it worthwhile to engage in the debate. Although physicists, chemists and astronomers did participate, they were relatively few in number and rarely of the first rank. Moreover, they were generally careful not to include philosophical or religious views about the universe in their research publications. It is a characteristic feature of the controversy over entropic beginning and end that it was nearly invisible in the pages of *Astronomische Nachrichten*, *Philosophical Magazine*, *Comptes Rendus*, *Annalen der Physik* and other high-ranking scientific journals. A perusal of abstract journals such as *Science Abstracts*, *Astronomischer Jahresbericht* and *Beiblätter zu den Annalen der Physik und Chemie* confirms the invisibility. The absence of the debate in professional scientific literature is probably one reason why the controversy has been neglected by most historians of science and ideas.

Chapter 7

Shadows from the Past

The present study focuses on the period from the 1850s to about 1920, and includes a brief chapter on the two decades between the two world wars. Although I do not intend to cover the subsequent period it will not be out of place to offer a few additional remarks on the subject of cosmology and entropy, including how it has developed since the end of World War II. My comments relate to, and aim to perspectivize, the earlier development by calling further attention to some of the themes that were discussed in the late nineteenth century. One of the themes is the surprising – and depressing – relationship between socialist or communist thought and cosmology, while the other is the role of the entropy law in the modern understanding of the universe.

Cosmology, Entropy and Socialism

As shown in Chapter 5, the running-down universe associated with the law of entropy increase was a source of worry to Friedrich Engels, who considered it anti-materialistic and opposed to the socialist world view. The question continued to play a role in the decades after World War I, both in Western socialist circles and in the new Soviet Union founded upon the political philosophy of Marx, Engels and Lenin. Although there was no consensus of how cosmology and thermodynamics related to socialist ideology, many Marxists tended to agree with Engels. As Joseph Needham, British socialist and eminent biochemist, wrote about the second law:

> It has been a godsend to theologians filled with pessimism about human affairs, and delighted to find scientific backing for their despite of nature – 'the heavens shall perish ... they shall all wax old as doth a garment'. ... Another reason for which theologians or theologically-minded scientists extol the second law is that it is tempting to identify the 'winding-up' process, whatever it was, which started our galaxy off in its course with a maximum of free energy, with the act of creation by a personal deity.[1]

However, contrary to Engels, Needham was not an atheist, and he struggled hard to link together his religious faith and his political principles, which he did basically by considering science and religion as occupying separate domains. As science had nothing to say about human values and ultimate purposes, so religion had nothing to say about the fabric of the physical universe. Needham speculated that free energy might somehow be continually formed, so that we should see our world always running down but never reaching the end of the process. 'For those who like

[1] Needham 1943, p. 218.

theological speculation, this might be regarded as a modern form of the "General Concourse" in which God must ever uphold the universe which he created.'[2]

Another of Britain's socialist scientists, the evolutionary biologist John B.S. Haldane, followed with keen interest the development in cosmology, including its more speculative aspects. Thus, in an essay of 1927 he suggested that although life on Earth was doomed to disappear, on other planets biological evolution would go on. In a response to Jeans's pessimistic view of the heat death, he speculated that Boltzmann's idea of low-entropy pockets in the universe implied that life might after all continue endlessly. The present universe might melt away in heat radiation, yet 'in the course of eternity any event with a finite probability will occur'. Based on this comforting thought, Haldane argued that, 'there is no need to assume a break in the order of Nature to account for the beginning of the present universe'.[3]

British socialists seem to have been both fascinated and frightened by the entropy law. *The New Age*, a periodical subtitled 'A Socialist Review of Religion, Science, and Art', included in 1921 an article that extolled the law as nothing less than 'the greatest natural discovery of all times'. As the anonymous author explained, as time goes on,

> More and more energy deteriorates, and becomes imprisoned as heat; the Entropic factor grows incessantly, until all energy becomes inactive, deteriorated, dead, frozen; until all physical happenings end. ... Like a clock-work which runs down is nature to us, but we can never discover how the clock is wound up. ... The nature that we experience is a constant falling into ruins; Nature *ends*; is enclosed in Beginning and End.[4]

It is unclear why the author described the heat death with such sympathy and exuberance, and also unclear what it had to do with New Age socialism. Nor is it clear why the young Marxist writer Christopher Caudwell, in his posthumously published *The Crisis in Physics*, praised the entropy law as fundamental to any understanding of reality and, apparently, as congruent with the socialist world view. Caudwell recognized that the law could be taken to imply a beginning of the universe, but he strove hard, by means of Hegelian dialectics, to prove that this was not the case after all. The running-down universe, he concluded, 'is also the Universe evolving, and the dialectic generation of new domains and new complexities. The fully wound-up Universe is also purer Being – the Universe fully run down.'[5] In this way he was able to convince himself that the law of entropy increase was compatible with the dialectical laws of Hegel, Marx and Lenin.

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[2] Ibid., p. 219. Needham summarized his thoughts on the relationship between Christianity and socialism in Spengler's aphorism, 'Christian theology is the grandmother of bolshevism' (ibid., p. 72). He realized, earlier and more clearly than most, that although communism was strongly anti-religious, it could itself be considered a secular religion.

[3] Haldane 1928. On Haldane as a cosmologist, see Kragh 2004, pp. 220-225. And on his quasi-scientific eschatology, Adams 2000.

[4] 'The end of a dispensation', *The New Age* 29, no. 17 (1921), 195-7.

[5] Caudwell 1939, p. 197 and p. 208. On Caudwell, who was killed in the Spanish Civil War, see Thompson 1995.

In the attempts to establish an ideologically acceptable view of science, the new physics became a matter of considerable controversy in the young Soviet Union. Physicists and party philosophers discussed the problematic relationship of relativity theory and quantum mechanics to Marxist-Leninist philosophy.[6] However, it was not only the new physical theories that might seem to be opposed to Leninist thought, the same might be the case with parts of classical physics, such as the second law of thermodynamics. The law of entropy, including its cosmological implications, became a matter of dispute in the Soviet Union, where it was discussed in a variety of ways, not all of them relating to physics. To some revolutionary minds, entropy seemed opposed to revolution.

Although the Russian author Yevgeny Zamyatin came to disagree with the Communist Party, before 1917 he was a committed Bolshevik and in his novels he continued to praise the revolutionary spirit. In an essay of 1923, entitled 'On literature, revolution, entropy, and other matters', the engineer-trained Zamyatin described the revolution in Russia in the language of thermodynamics. To him, the law of entropy was conformist and anti-revolutionary because it promised a dull equilibrium state from which no new revolution could ever emerge. 'The law of revolution is red, fiery, deadly; but this death means the birth of new life, a new star. And the law of entropy is cold, ice blue, like the icy interplanetary infinities. ... The Sun ages into a planet, ... if the planet is to be kindled into youth again, it must be set on fire, it must be thrown off the smooth highway of evolution.'[7] Like some nineteenth-century scientists in the materialist tradition, he appealed to stellar collisions as a means of countering the consequences of increasing entropy and thereby catalyzing new revolutions: 'Two dead, dark stars collide with an inaudible, deafening crash and light a new star: this is revolution.'[8] But this was not to happen, neither in the stellar nor in the social world. Stalin's Soviet Union was meant to be the beginning of the end stage of society, not the catalyst of further revolutions that Zamyatin had hoped for.

In part because of Engels's opposition to finite space and time, and because of the long tradition of associating these concepts with idealism, clericalism and bourgeois thought, infinite space and time became incorporated in twentieth-century dialectical materialism and in this way obtained status as official doctrines in communist thinking. According to the ideology of Soviet communism, as it was formulated in the late 1930s, cosmological models with a heat death, and hence a finite upper time scale, had to be rejected because of their theistic implications. Of course, models with a finite lower time scale were even worse. V. Shafirkin, a communist party philosopher and cosmologist of the 1930s, were among those who firmly rejected the heat death as a bourgeois myth. The universe was surely in eternal flux, as Engels had so brilliantly realized. Shafirkin's means to avoid the heat death were unoriginal: first, it had never been proved that there are no counter-entropic processes in the universe; second, the entropy law can only be applied to finite systems, not to the

6 See Vucinich 1980 and Graham 1972.
7 Zamyatin 1970, p. 108. See also Clarke 2001, pp. 78-81, 136-51.
8 Zamyatin 1970, p. 107.

infinite universe.[9] The doctrine of the eternity of matter, an axiom in Soviet dialectical materialism, was taken to imply a world view closely similar to the one advocated by Engels and other nineteenth-century materialists. On the other hand, while some materialists had supported cyclic or recurrent cosmologies, these were rejected by most Soviet philosophers.

Although the political and ideological aspects of cosmology were also discussed before World War II, it was only during the period of the Stalin cult that the communist party took an official interest in the matter. Andrei Zhdanov, Stalin's notorious chief ideologue, said in a speech of 1947 that Lemaître and his kindred spirits were 'Falsifiers of science [who] want to revive the fairy tale of the origin of the world from nothing … Another failure of the 'theory' in question consists in the fact that it brings us to the idealistic attitude of assuming the world to be finite.'[10] In another address of the same year, he attacked Eddington, Milne and 'many of Einstein's supporters'.[11] At a meeting in Leningrad (St Petersburg) the following year, Soviet astronomers confirmed in a resolution the need to fight against the 'reactionary-idealistic "theory" of a finite widening of the universe ... [and] to expose tirelessly this astronomical idealism, which helps clericalism'.[12]

The communist dogma of an infinite material universe even became enshrined in the officially approved definition of cosmology. One such definition from the early 1950s reads: 'Cosmology is the study of an *infinite* universe as a coherent, single whole and of the whole region embraced by observation as a part of the universe.'[13] Although there was no official ban on cosmology – it was not needed – the field was widely seen as politically suspect, with the result that it practically ceased to exist in the Soviet Union until the early 1960s when ideological constraints loosened.

Many of the charges against Western-style cosmology had roots back in the cultural struggle of the nineteenth century. It was not only that particular models and concepts of cosmology were attacked – including Big-Bang models, the finite universe, the heat death and even the steady-state model – the very application of physical theories to the universe as a whole was regarded as suspect and unmarxist. Soviet authorities and party philosophers claimed that it was unscientific and against the spirit of dialectical materialism to extrapolate local laws of physics, such as relativity theory and the second law of thermodynamics, to the entire universe. Whether or not there were political motives behind, Soviet physicists and astronomers conformed to the dogma of the communist party either by abandoning cosmology altogether or adapting to the party line.

Several Soviet authors sought to refute the idealistic hypothesis of the heat death, either by arguing that it was illegitimate to extrapolate the second law to the entire

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9 Haley 1980, pp. 75-81. See also Wetter 1953, pp. 323-6.

10 Quoted in Kragh 1996, p. 260, which includes a brief account of cosmology in the Soviet Union. See also Mikulak 1955 and, for a full discussion of Soviet dialectical materialism, Wetter 1953.

11 A German translation of Zhdanov's address is included in Wetter 1953, pp. 594-616.

12 Kragh 1996, p. 262.

13 Haley 1980, p. 151. Emphasis added.

universe or by claiming that there existed anti-entropic processes counteracting the decay processes described by the entropy law.[14] As we have seen, both strategies can be traced back to the nineteenth century. The physicist J.R. Plotkin argued in 1950 that the law of entropy increase was invalid for an infinite universe, irrespective of its concrete structure. 'Hence a state of equilibrium for the whole universe not only is impossible, but does not make any sense at all. … Attempts at applying to the whole universe the conclusions of the second law of thermodynamics have no scientific foundation.'[15] In their important textbook on statistical physics, the two eminent Soviet theorists Lev Landau and Evgeny Lifschitz reached a somewhat similar conclusion, if based on strictly scientific arguments: 'The Universe as a whole must be regarded not as a closed system but as a system in a variable gravitational field. Consequently the application of the law of increase of entropy does not prove that equilibrium must necessarily exist.'[16]

It was not only in the Soviet Union that the ideology of Marx and Engels coloured cosmological views. Evry Schatzmann, a French astrophysicist and communist, wrote in 1957 a book in which he emphatically denied the heat death and the finitude of the universe. 'Any attempt to apply the second law of thermodynamics to the universe is without foundation', he argued; 'There is … no reason for considering as well-founded the theory of the "heat death" of the universe.' Quoting Engels in support, Schatzmann criticized the 'extraordinary confusion between the finite and the infinite, which consists in attributing properties of a finite system to the infinite universe'.[17]

During the Kruschev era a few philosophers and scientists suggested that spatially finite models did not necessarily conflict with dialectical materialism as espoused by Lenin. This was a minority view, though, and temporal finitude continued to be anathema. Following Engels's original warning against the entropy law, many Soviet scholars claimed that it, and the heat death in particular, was in effect a theological plot. Much like their materialist comrades in the nineteenth century, they claimed that the universe is characterized by an equilibrium between forces of order and disorder. Only about 1964 did the traditional party line meet substantial opposition from scientists and philosophers, some of whom argued that finite world models were neither more nor less materialistic than infinite models. Within a few years, Soviet cosmologists, lead by Yakov Zel'dovich, were hard at work investigating and improving Big-Bang models.

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[14] See titles (in Russian) in Graham 1972, p. 500.

[15] J.R. Plotkin, 'Increase of entropy in an infinite universe', *Journal of Experimental and Theoretical Physics* 20 (1950), 1051-4 (in Russian). Quoted from the abstract in *Physics Abstract* 54 (1951), 1101.

[16] Landau and Lifschitz 1968, p. 30. Landau was awarded the Nobel Prize in 1962, for his important contributions to the quantum theory of condensed matter. During the Stalin era he was accused by Marxist critics for idealistic interpretations of modern physics, which involved not only quantum mechanics and relativity but also the second law of thermodynamics. According to one critic, he supported the myth of the heat death, thereby ignoring that Engels had dealt it a mortal blow many years ago (Vucinich 2001, p. 113).

[17] Schatzmann 1966, p. 272 and p. 203 (French original 1957).

Still, outside of a small group of physicists and astronomers orthodoxy remained. Millions of innocent young people in the Soviet Union and Eastern Europe were brought up with the doctrines of historical and dialectical materialism, including that 'The universe has no beginning in time, and no end, and matter exists eternally.' Since space and time only exist in connection with matter, and matter is uncreatable, then 'also space and time must be uncreatable'.[18] In this way dialectical materialism purportedly showed that the theory of the universe having a beginning in time must be false.

Among the early Soviet contributors to Big-Bang cosmology was Andrei Sakharov, the later so famous political dissident, who in a prescient work of 1967 suggested that the baryon number (essentially the number of protons and neutrons) might not be conserved exactly and that this might have important cosmological implications. Sakharov continued to work on cosmological problems after he was exciled to Gorky in 1980. His interest reflected a belief in a cyclic universe which was not so much grounded in scientific data as related to metaphysical and emotional desires. When he was awarded the Nobel peace prize of 1975, he included (*in absentia*) in his lecture a reference to physics and cosmology that revealed those desires:

> I support the cosmological hypothesis that states that the development of the universe is repeated in its basic characteristics an infinite number of times. Further, other civilizations, including more 'successful' ones, should exist an infinite number of times on the 'preceding' and the 'subsequent' pages of the book of the universe. Nevertheless, this weltanschauung cannot in the least devalue our sacred inspirations in this world, into which, like a gleam in the darkness, we have appeared in the darkness for an instant from the black nothingness of the ever-conscious matter, in order to make good the demands of reason and create a life worthy of ourselves and of the goal we only dimly perceive.[19]

What is interesting about this passage is that Sakharov, an anti-communist and political dissident, defends a regenerating cosmos much like the one favoured by the early generations of materialists and socialists. Although Sakharov was not a Christian, neither was he an atheist. He fought for religious freedom as well as freedom from religion. Yet he described himself as 'religious' in the sense that he believed in some non-physical, spiritual principle behind and above the world of matter and energy.[20]

Sadly, while Soviet science was gradually depoliticized, the *de facto* ban on cosmology went unchallenged in communist China throughout the 1960s and most of the 1970s. The ideological interference with cosmological theory took a new turn during the Cultural Revolution in Mao Zedong's empire, when relativistic cosmology for a while was declared a reactionary, anti-socialist pseudo-science. Fang Lizhi, a Chinese physicist, got caught up in the frenzy of the Cultural Revolution when in

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18 Fromm et al. 1974, p. 137, an East-German textbook in historical and dialectical materialism aimed at schoolchildren 16-17 years of age.

19 Quoted in Drell and Okun 1990, p. 32. Sakharov was not allowed to go to Stockholm to accept his Nobel Prize, which was instead received by his wife, Elena Bonnor.

20 Sakharov 1990, p. 4.

1972 he published a theoretical paper on Big-Bang cosmology, the first of its kind in the People's Republic. Enraged radical Marxists rallied against Fang's heresy and its obvious betrayal of the true spirit of proletarian science. During the next couple of years, some thirty papers were published against the anti-socialist Big-Bang theory. As late as 1976, the journal *Acta Physica Sinica* carried an article that warned against 'the schools of physics promoting a finite universe [which] are linked up with all sorts of idealist philosophy, including theology'. Moreover:

> Materialism asserts that the universe is infinite, while idealism advocates finitude. At every stage in the history of physics, these two philosophical lines have engaged in fierce struggle … with every new advance in science the idealists distort and take advantage of the latest results to 'prove' with varying sleights of hand that the universe is finite, serving the reactionary rule of the moribund exploiting classes … We must ferret out and combat every kind of reactionary philosophical viewpoint in the domain of scientific research, using Marxism to establish our position in the natural sciences.[21]

The party line was to deny cosmology scientific legitimacy, much like materialists and positivists had argued in the nineteenth century. Questions of the universe at large could not be answered scientifically, only on the basis of the 'profound philosophical synthesis' of Marxism-Leninism:

> The dialectical-materialist conception of the universe tells us that the natural world is infinite, and it exists indefinitely. The world is infinite. Both space and time are boundless and infinite. The universe in both its macroscopic and microscopic aspects is infinite. Matter is infinitely divisible.[22]

Only with the fall of the Gang of Four in 1978 did it become possible to do cosmological research in China. Fang's troubles with the political authorities were not over, though.[23]

Views from the Recent Past

During the second half of the twentieth century the role of the principle of entropy increase in cosmology was no longer considered a very central issue either by physicists or theologians. The heat death continued to be discussed, if only sporadically and rarely in its former role as an indication of the beginning of the universe. Of the many review articles that have been written on entropy, including those published on the occasion of the centenary in 1965, only very few mention the cosmological aspects.

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[21] Lizhi 1991, pp. 309-13. The author of the article was Liu Bowen. See also Williams 1999, p. 75.

[22] Lizhi 1991, p. 311.

[23] Fang Lizhi developed into China's most prominent political dissident, the country's parallel to Sakharov in the Soviet Union. In 1987 he was expelled from the Chinese Communist Party for the second time, and in the turmoil following the Tiananmen Square massacre of June 1989 he took refuge in the US Embassy in Beijing to avoid being arrested as a traitor and class enemy.

In the earlier period several works of a theological orientation included treatment of cosmological questions, among these the consequences to be drawn from the second law of thermodynamics. This tradition continued after World War II, but in a different form that reflected the increasing lack of relevance of the entropic creation argument. One example is *Weltschöpfung und Weltende* from 1952, a work by the Protestant theologian Karl Heim, professor of dogmatics at Tübingen University.[24] Given that the author was born in 1874, the book included an impressively competent review of modern evolutionary cosmology. Careful not to use cosmological theory apologetically, Heim pointed out that although the ideas of Lemaître and George Gamow were generally consonant with Genesis, the biblical creation story goes beyond scientific cosmology: it is a true creation story in the strong *ex nihilo* sense, whereas scientific cosmology must start with some initial state and cannot explain the creation itself at $t = 0$. Heim dealt in some detail with the thermodynamical heat death, which he accepted as overwhelmingly probable, but he chose to ignore the entropic argument for a creation of the universe.

The attitude seems to have been shared by the Catholic church. In Pope Pius XII's controversial address *Un Ora*, delivered on 22 November 1951 to the Pontifical Academy of Sciences, he dealt at some length with 'the mutability of things', whether macroscopic or microscopic, which he saw as evidence of a divinely created universe. The scientifically demonstrated mutability of the cosmos at all levels supported the classical proof of an unmoved mover, he suggested. On the other hand, the Pope associated the old idea of eternally stable chemical atoms with atheism and the 'fantastic monistic philosophy' of Haeckel. Moving from the realm of atoms and molecules to that of stars and galaxies, he referred to the new Big-Bang theory as support of Christian theism – cosmology, he concluded, 'has confirmed the contingency of the universe and also the well-founded deduction as to the epoch when the cosmos came forth from the hands of the Creator'. Although he did not mention explicitly the beginning of entropy increase, he came close: 'The farther back we go, the more matter presents itself as always more enriched with free energy... . Thus everything seems to indicate that the material universe had in finite times a mighty beginning.'[25]

The Pope was undoubtedly aware of the entropic argument, but he may have found the heat death sufficient for his purpose. At any rate, in an associated discourse he made it clear that he considered the heat death an additional argument for a universe subordinated to the will of God. The Pope's comment reflected the century-long development of the interaction between thermodynamics, cosmology and religion:

> While a hundred years ago, especially after the discovery of the law of constants, it was thought that the natural processes were reversible and therefore, according to the principles of strict causality – or, rather, determination – an ever-recurring renewal and rejuvenation of the cosmos was considered possible. With the law of entropy, discovered by Rudolf Clausius, it became known that the spontaneous processes of nature are always

[24] Heim 1952. The book was the last volume in the six-volume series *Der evangelische Glaube und das Denken der Gegenwart*.

[25] On the Pope's 1951 address, see Kragh 1996, pp. 256-9. An English translation appears in McLaughlin 1957, pp. 137-47, and on www.papalencyclicals.net.

> related to a diminution of the free and utilizable energy, which in a closed material system must finally lead to a cessation of the processes on the macroscopic scale. This fatal destiny, which only hypotheses, sometimes far too gratuitous ones such as the continuous renewal of creation, forcibly try to deny, but which instead comes from positive scientific experience, postulates eloquently the existence of a Necessary Being.[26]

Clearly, to the Catholic church the past was not merely past. What prompted Pius XII to take up the discussion and warn against 'hypotheses ... [of] the continuous renewal of creation' was probably the emergence on the cosmological arena of the steady-state theory. Although he did not mention the theory, its presence can be read between the lines.

In a discussion of ethical values in science, the American physicist Robert Bruce Lindsay defended in 1959 the unorthodox view that scientific theories are not independent of value judgments. The second law of thermodynamics presents a pessimistic picture of the future and tends to reduce the value of life and dignity of man. Lindsay therefore suggested what he called 'the thermodynamic imperative', namely, that people should fight the law as vigorously as possible 'to increase the degree of order in their environment so as to combat the natural tendency for order in the universe to be transformed into disorder'. He realized of course that humans cannot change a law of nature, yet he felt that 'the remorseless natural increase in entropy of the universe' threatened the very meaning of life.[27] His paper in *Science* provoked several responses, one of which offered a Christian perspective of the same type that was so common in the late nineteenth century. Perhaps, the author suggested, the general pessimism could be combated by taking into account the message

> … that there is a Creator of the universe (and the second law of thermodynamics) who is able to 'wind it up' again. Perhaps this is suggested in the Bible (II Peter 3:13) where it is stated that there will be 'new heavens and a new earth' subsequent to judgment and dissolution of the present system.[28]

With progress in cosmology and the emergence in the 1960s of the Big-Bang standard model the problem of a finite-age universe could be discussed scientifically without invoking the entropy law. Most cosmologists agreed that the cosmic expansion, the abundance of light elements, the distribution of quasars and the microwave background radiation constituted convincing evidence for a universe starting in a Big Bang, which meant that the law of entropy increase became unnecessary as an argument for a beginning of the universe. But of course one can still find the entropic argument, if typically elsewhere than in the scientific literature.

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26 Discourse at the plenary session of the Pontifical Academy, 22 November 1951. See [Vatican 1986] pp. 73-84 and www.ewtn.com/library/PAPALDOC/P12MCRSE.HTM.

27 Lindsay 1959, p. 378 and p. 385. Lindsay was apparently unaware that he had been foreshadowed by Ostwald, who many years earlier promoted what he called the 'energetic imperative', a subject to which he devoted an entire book. The principal message of Ostwald's energetic imperative was, 'Waste no energy; turn it all to account!' See Ostwald 1912, p. 13 and Hakfoort 1992.

28 Robert A. Erb, *Science* 47 (1959), 330A.

In *God and the New Physics*, the physicist Paul Davies states: 'The universe cannot have existed for ever, otherwise it would have reached its equilibrium end state an infinite time ago. Conclusion: the universe did not always exist.'[29] Davies did not use the argument apologetically, something which is rarely done. According to the theologian Ted Peters, 'the second law suggests a finite history for the cosmos', but characteristically he adds that this is only if combined with evidence from Big-Bang cosmology.[30]

If one wants to prove the existence of God from the notion that the universe had a beginning, there are better ways than relying on the entropic creation argument. Perhaps it is symptomatic that this time-honoured argument is today relegated to communications from fundamentalist and creationist circles. One of the websites of the Institute for Creation Research, a leading institution of scientific creationism, explains as follows:

> ... it is obvious that ultimately *all* energy in the universe will be unavailable energy, if present processes go on long enough. ... No more work can be done and the universe will reach what the physicists call its ultimate 'heat death.' Thus, the Second Law proves, *as certainly as science can prove anything whatever*, that the universe had a beginning. Similarly, the First Law shows that the universe could not have begun itself. ... Since energy could not create itself, the most scientific and logical conclusion to which we could possibly come is that: 'In the beginning, God created the heaven and the earth.'[31]

Although a shadow of the past, this is quite a nice formulation of the extended entropic creation argument.

In the current discussion concerning the theological significance of modern cosmology, entropy considerations play but a minor role. It enters in William Lane Craig's detailed works on the cosmological proof, but his arguments in favour of a divine origin of the world do not depend critically on the entropy law. What is important for him is that the universe had an origin in time, and here thermodynamics merely enters as one empirical argument among several others. Given the long discussion of the applicability of the second law to the universe as a whole, it is interesting to note that for Craig this is not a problem: 'For by definition the universe is a closed system, since it is all there is.' He therefore has no doubts either about the heat death, or that the universe will die. 'But if this is so, then why, if the universe

[29] Davies 1983, p. 11.

[30] Peters 1999, p. 273. Peters assumes the second law to be valid for the universe as a whole, because it is a closed system that does not exchange energy with an external source. 'If there were such an energy source, our notion of the universe would expand to include it, and then we would be right back where we started' (ibid.). Compare with Delevsky's claim: 'An infinite system is not an isolated system in the sense that is presumed in the theory of the degradation of energy. An infinite universe must be a non-isolated system.' Delevsky 1946, p. 395.

[31] http://icr.cybrhost.com/pubs/imp/imp-003.htm, based on Henry M. Morris, 'Evolution, thermodynamics, and entropy', *Impact* no. 3 (1973). On scientific creationists and their use of the law of entropy increase, see Numbers 2006.

has always existed, has it not reached a state of maximum entropy? ... In short, the present state of disequilibrium points to a beginning of the universe.'[32]

Several philosophers have argued that it is illegitimate to extrapolate the thermodynamical laws to the entire universe, an objection that was well known in the nineteenth century, when it was first raised by Mach. The distinguished British philosopher and historian of ideas Stephen Toulmin pointed out that to say about a law, such as the entropy principle, that it holds universally is not the same as to say that it holds for the universe. He seriously doubts that any meaning can be ascribed to Clausius's version of the second law, and therefore also dismisses the heat death prediction as meaningless. 'Suppose it is completely established that the Second Law can be applied to all physical systems thermally isolated from the rest of the universe, does it necessarily apply also to the universe taken as a whole?' Toulmin thinks that it does not, which leads him to conclude: 'The running-down universe is a myth, and we shall discover about the Apocalypse from physics only what we read into the subject.'[33] I have quoted Toulmin, not because I find his remarks to be particularly original or valuable, but rather to illustrate how little they differ from the critical ideas discussed more than a century ago.

From a physical point of view, the whole question of the entropy of the universe has changed very considerably since the days it was discussed by Tolman, and of course even more considerably since the days of Duhem and Isenkrahe. Not only does gravity have to be taken into account – and that means general relativity – so does a variety of physical processes from stellar nucleosynthesis to the formation of black holes. For example, the steady-state theory proposed in 1948 by Hoyle, Bondi and Gold was based on the 'perfect cosmological principle' according to which the universe is homogeneous in both its spatial and temporal dimensions. The principle obviously is incompatible with the heat death, and therefore apparently also with the second law of thermodynamics, but the problem was taken care of by the hypothesis of matter creation which counteracts entropy increase. According to Bondi, 'the creation process, together with the expansion of the universe, prevents the approach of the heat death, the state of thermodynamic equilibrium in which no evolution can take place and in which the passage of time has no significance'.[34] Although the entropy increases locally, the total entropy within the observable universe remains approximately constant and does not increase with time. Since the steady-state theory turned out to be wrong, this is of historical interest only, yet it does illustrate how physical processes in the cosmos may affect the law of entropy increase.

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[32] Craig 1979, pp. 131-2. Like Peters, Craig believes that the universe is necessarily an isolated system in the sense of thermodynamics, meaning that there is no other system with which the universe can exchange energy or information.

[33] Toulmin 1982, p. 40 and p. 49.

[34] Bondi 1952, p. 144. Neither the steady-state theory nor the associated hypothesis of continual creation of matter was proposed in order to avoid the heat death. The heat death played only a very limited role in the controversy between this theory and the class of relativistic evolution cosmologies. However, a few scientists felt attracted to the steady-state theory because, in Hoyle's words, 'The possibilities of physical evolution, and perhaps even of life, may well be without limit.' See Kragh 1996, p. 189.

Modern cosmology does not operate with continual creation of matter, but there are many other entropy-consuming sources which play the same role and complicate the picture. Generally speaking, cosmologists in the post-World War II era had a more relaxed attitude to the heat death than the earlier generation characterized by figures such as Jeans and Eddington. As mentioned, Milne reached the conclusion that 'an unconditional prediction of the heat-death of the universe is an over-statement'. The British relativist cosmologist William Bonnor similarly thought that 'the second law is not now taken so seriously in cosmology', because 'It has never been shown to apply to the universe as a whole, especially to an infinite universe.'[35] Neither Milne nor Bonnor denied the general validity of the second law, but they questioned if it was applicable to the universe as a whole.

In an investigation of 1982 Steven Frautschi, an American physicist, concluded that there is no basis for the classical heat death, an equilibrium end state of the universe in which all temperature differences have vanished. 'Far from approaching equilibrium, the expanding universe … falls further and further behind achieving equilibrium', he concludes.[36] Nevertheless, there are other reasons why the universe will ultimately die. Indeed, there has recently been much interest in the state of the universe in the far future, a branch of speculative science sometimes known as 'physical eschatology'.[37] Entropy may not be quite the villain it was assumed to be, but it is generally accepted that life and activity in the universe *will* come to an end. In spite of the revolution in the world picture that has occurred in the twentieth century, the pessimistic inference about the future that nineteenth-century physicists drew from thermodynamics is not far wrong. According to some writers, the new scientific eschatologies (if they are scientific) are theologically relevant, and they are not contradicting Christian faith.[38]

As the heat death has occasionally attracted theological attention, so has the possible finitude of the universe, once thought to be a precondition for the heat death. We have seen how the finite universe has traditionally been associated with theism, and alternatively how the infinite universe was part of the materialistic-atheistic world view. This view is still alive, such as we are reminded by Stanley Jaki, a learned Benedictine priest and historian of cosmology. An infinite universe, he says, is 'a scientific cover-up for atheism'.[39] However, on this topic there really is no unanimity among theologians and Christian scientists. One might believe that progress in scientific cosmology has made such ideological associations redundant – that the question has been reduced to a technical one, say to determine the curvature of cosmic space – but this is not quite the case. Actual infinities, as in the case of a

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[35] Milne 1952b, p. 166; Bonnor 1960, p. 174.

[36] Frautschi 1982, p. 595. According to Frautschi, there will always be a thermodynamical arrow of time, but the number and intensity of processes will decrease without limit. This is in general agreement with Pierre Duhem's intuition of 1905, that the increase of entropy of the universe does not lead to a maximum value.

[37] Ćirković 2003b. See also contributions in Ellis 2002.

[38] Davis 1999, who writes: 'Despite the revolutionary new scientific discoveries that have occurred since the nineteenth century … the fundamental scientific outlook is still the same; thermodynamic pessimism finally prevails' (p. 25).

[39] Quoted in Lerner 1991, p. 386.

universe filled with an infinite number of objects, almost always create conceptual problems.[40] They may 'threaten to enter if God had to keep track not only of the items of knowledge, but also of God's own knowledge'. The cosmologist George Ellis, like Eddington a Quaker, therefore suggests 'that to make the overall view coherent, we must assume *there is a finite number of particles, and beings, in the universe*'.[41]

I am not, of course, concluding that there is nothing new under the Sun; but I am suggesting that some of the discussions in the late nineteenth century are still relevant and most likely will remain so in the future. It is probably fair to say that more recent developments in physics and cosmology have *not* led to a clarification of the question of the entropy of the universe. It is still believed that the entropy of the present universe is low because it started in an even lower entropy state and has not had time to reach a higher value. In this sense, the entropic argument for a finite-age universe is still with us and it is valid especially for an open universe, such as is favoured by current observations. The problem is what is meant by the entropy of the universe, or if the notion is at all scientifically meaningful – a question first asked by Mach in the early 1870s. It is far from clear how to apply thermodynamics to a universe governed by classical general relativity or if the notion of the entropy of the entire universe is well defined. A modern text in cosmology states: 'It is still not known exactly how to define the entropy associated with the gravitational field in general relativity.' And according to Robert Wald, an expert in cosmology and thermodynamics, there is 'no reason to expect that there will be a meaningful notion of the "total entropy of the universe"'.[42]

This is highly interesting from a scientific point of view, but not so much so from a historical point of view. After all, the modern understanding of thermodynamics and cosmology is largely irrelevant when it comes to appreciate the historical situation from about 1860 to 1920, the period that forms the focus of the present study.

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[40] Richard Schlegel argued in 1962 that the space of the steady-state theory contained a denumerable infinity of particles, and that this made it contradictory (see Kragh 1996, p. 236). Pamela Huby concluded that actual infinities cannot occur in nature and, therefore, the universe must be finite in space as well as time (Huby 1971). See also Whitrow 1978.

[41] Ellis 1993, p. 394. See also Ellis and Brundrit 1979, where it is argued that a low-density, infinite and uniform universe leads to highly bizarre consequences, such as an infinite number of genetically identical beings in the universe at any time.

[42] Coles 2001, p. 210; Wald 2006, p. 396.

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