COLIN A. RUSSELL

Hydrotheology: towards a natural theology for water[1]

This paper is a historical preamble to a fully developed natural theology based on a single substance, water. It origins are traced to a book, Hydrotheologie, by a Hamburg author, J.-A. Fabricius, in 1734. This turns out to be but one of a number of similar specialised works on natural theology in the early eighteenth century. The theme was developed by many others, especially by three of the authors of the Bridgewater Treatises in the next century. Following Darwin, natural theology was transformed but not annihilated. A Harvard chemist, J. P. Cooke, wrote a book Religion and Chemistry which devoted one chapter to water, and other authors dealt with fitness of the environment in general, with water as an important constituent. Its remarkable anomalies have been dealt with most recently by M. J. Denton. To conclude, hydrotheology is placed within the wider context of natural theology as a whole, and its implications for environmental concern are suggested.

Keywords: water, natural theology, hydrotheology, Fabricius, Whewell, Kidd, Prout, Denton, chemistry, hydrogen bond, environment

Introduction

Underlying any quest for a counterfactual chemistry, or any inquiry into the peculiar properties of water in relation to the fitness of the environment for life, lurk two usually unspoken questions: does fitness imply 'design', and does 'design' imply a Designer? We would probably not choose to express it publicly in these terms for, especially in the USA, the phrase 'intelligent design' has overtones and implications that we might wish to avoid. Some would add that such arguments are the last resort of naïve believers confronted with the awesome explicatory power of modern science. They may be a sign of the times, when the gullible and the fanatical enter into an unholy alliance to defend what they perceive to be the essentials of the faith. Nevertheless, any form of argument from scientific data to matters of divinity falls into the category of natural theology, and that is no mere fad of the twentieth or twenty-first centuries. The quest 'from nature up to nature's God' is far from new.

However, a natural theology based on water may seem novel, and is certainly unusual in several respects. First, it is an argument that turns out to be

1 This article is based on a chapter in Lynden-Bell, R.M., Conway Morris, S., Barrow, J.D., Finney, J. L. & Harper, C.L. Jr. (eds.) *Water of Life: Counterfactual Chemistry and Fine-Tuning in Biochemistry*, forthcoming from a major academic press.

essentially chemical, not at all like those from the intricate structures of a living organism or the macro-structure of the cosmos. These topics were to become the standard subjects for natural theologians. Secondly, it focuses on one single, chemically simple substance, so simplicity rather than complexity might seem to be its theme. However, a third characteristic is in strong contrast, for a main preoccupation will not be a study of an object in isolation but rather in its relationships with the rest of the material world. Fourthly, it might become possible to submit the scientific conclusions of this natural theology to rigorous experimental testing. It is hard to see how one could evaluate the testimony of cosmology in this way, and harder still to modify a living organism to see if can still adapt to its surroundings. Attempts have been made in these directions, but they are never easy.

Finally, it is possible to trace the specific trajectory of ideas relating to the natural theology of water over a longer period, and with rather more prospect of success, than in most other cases. The function of this paper is to attempt precisely that. Such an enterprise could of course become merely an exercise in antiquarianism, 'with one damn thing after another' (which is how some people still perceive history). However an attempt will be made to do more than that, and to locate events in a wider context and to enquire whether any patterns of development arise.

1. The beginnings

As far back into antiquity as we can peer there are signs of an unusual fascination with water and its role in the world. This was partly because there was so much of it.

The Egyptian and Babylonian civilisations were well aware of the importance of water for life, whether in the annual irrigation by the Nile or in the welcome rain that followed months of drought and hunger. Mediterranean civilisations were so obviously dependent on water for human survival. The Babylonians gave water a critical role in the creation process, all the lands being sea until the god Marduk intervened to create dry land. Centuries later, around 700 BC, the Milesian philosopher Thales marvelled at the distribution of water between land and sky, perceived the world as afloat like a leaf upon the ocean and concluded that the material world was in fact made of water. His was no natural theology, however, for he produced 'a coherent picture of a number of observed facts *without letting Marduk in*'.[2] So did some of his successors, who maintained the primacy of other 'elements' than water. Over a thousand years later the prophet Mohammed claimed a revelation from God that 'We have made of water everything living.'[3] Even to the religious mind water was

2 Farington, B. *Greek science*, Harmondsworth: Penguin (1953), p. 37 [original italics].
3 *Qur'an*, 21: 30.

at most a constituent of the universe or an instrument in the hand of God. By the twelfth century the same fascination with the role of water in creation was being expressed by Thierry of Chartres. Writing about the third day of the Genesis creation narrative, he noted:

> Observe what happens when the temperature increases in a room with a table in it that has been covered with a uniformly thin plane of water; individual dry spots soon appear on the surface of the table, while in other places the remaining water draws back and collects.[4]

Similar sentiments about the priority of water in nature continue beyond this time, up to 2000 years from Thales. The Brussels chemist Joannes Baptista van Helmont (1579-1644) experimented on the basis that 'all things' were made of water, and so did some of his followers.[5] Robert Boyle wondered whether water had 'a natural temperature',[6] and Richard Bentley spoke of it as 'that vital blood of the Earth which composeth and nourisheth all things'.[7] But in no sense do their writings amount to any kind of natural theology, even at the hands of avowedly Christian writers.

From at least Roman times there was much recourse to spa and other mineral waters. These were generally believed to have been put on the Earth by God in order to cure human ills. Introductions to almost all the books on these topics were couched in terms of a kind of natural theology. In pre-Christian Europe such theology was not necessarily Christian, but, as paganism gave way to Christianity, beliefs about the healing powers of mineral waters were re-interpreted in Christian terms.[8]

With the coming of Christianity the attitude of the early Fathers to water was complex. In addition to sharing the general view of water's importance, they brought a distinctively Christian set of values. On one hand they frequently thought in allegorical terms and saw water as a picture of the cleansing from sin by Christ. This of course was sanctioned by dozens of verses from the New Testament. On the other hand they often thought sacramentally as well, and regarded water that had been set apart by some ecclesiastical process as mysteriously changed in nature, much as they regarded the bread and wine in the communion service. Thus they employed 'holy' water to cleanse from sin, to sanctify vessels washed in it, and especially to bring spiritual benefits at baptism. The sprinkling of congregations at Mass seems to date from the ninth century.

4 Thierry of Chartres, *Tractatus de sex dierum operibus* – 1; cited in Speer, A. 'The discovery of nature: the contribution of the Chartions to the twelfth-century attempts to find a *scientia naturalis', Tradition* (1997) 52, 134-151. My thanks to Prof. Wilson Poon for drawing my attention to this passage.

5 Multhauf, R.P. *Origins of chemistry*, London: Oldbourne (1966).

6 Boyle, R. *A free enquiry into the vulgarly received notion of nature*, London (1686); reproduced, Davis, E.B. & Hunter, M. (eds.), Cambridge: Cambridge University Press (1996), p. 84.

7 Bentley, R. *A confutation of atheism from the origin and frame of the world*, London (1692).

8 Personal communication from Dr N. G. Coley.

In such circumstances the 'natural' properties of water were of much less interest. However there was a further tradition that called upon all things created to praise their Maker, and water was one of those things. It is exemplified by the ancient canticle sung until recently in many Anglican churches, the *Benedicite*.[9] This song enjoins all creation, especially the aquatic parts, to 'praise Him and magnify Him for ever', including 'waters that be above the firmament', 'showers and dews', 'dews and frosts', 'ice and snow', 'seas and floods', and even 'ye wells'. The later hymn of Francis of Assisi similarly urges: 'thou flowing water pure and clear, make music for thy Lord to hear, Alleluia'. Water in this context was not invested with special properties but was just one part of the created order. Following the Renaissance and Reformation, however, matters were to take quite a new turn.

2. The coming of physicotheology

This phenomenon was a response to the rapid rise of a scientific world-view often referred to as the 'Scientific revolution' that was essentially mechanical in character. The whole of creation was seen by many as a vast interlocking mechanism which routinely excluded forces that could be deemed as occult or magical. This raised problems about the role of divine Providence, though these were addressed by many writers and did not, in the end, prove to be destructive of faith. But in the short term the challenge was to use the very complexity of the world as a signpost to its Creator. Science was therefore seen not as an adversary, but as an ally, for faith. At this time, when Isaac Newton was still a young man, physicotheology, or as we might prefer, a distinctive brand of natural theology, was born.

The marvels of the mechanical universe were interpreted mathematically, rather than in terms of allegory as had been the mediaeval tradition. They were seen as a wonderful antidote to the atheism that threatened the church at that time. In that spirit Robert Boyle endowed his famous Lectures,[10] whose purpose was to prove Christian religion against its enemies, and thus in effect to justify the ways of God to man. This prospect was made even more attractive by discoveries through the microscope, and, in 1691, John Ray's *Wisdom of God manifested in the works of Creation* extended the argument to the world of biology.[11]

The first specific attempt to focus strongly on water may perhaps be located in 1734. In that year a book appeared in Hamburg mysteriously entitled *Hydrotheologie*.[12] However its subtitle tells all:

9 The book of *The song of the three* in the Apocrypha.

10 These Lectures, after an absence of well over a century, have recently been revived in the Church of St-Mary-le-Bow, in the City of London.

11 Ray, J. *The wisdom of God manifested in the works of creation*, London (1691).

12 Fabricius, J.A. *Hydrotheologie*, Hamburg: König and Richter (1734).

Hydrotheologie

Or an attempt

through observing the properties, distribution and movement of

Water,

to encourage human beings to love and admire

the benevolence of the powerful Creator

The author of this curiously named book was Johann-Alberto Fabricius (1668-1736), Professor at the Hamburg Gymnasium, a copious fact-collector, classical scholar and author of over a dozen books on bibliography, theology and history.[13] Now he was to produce a volume of about 450 pages devoted to a topic rarely discussed in theology but frequently in science – or what passed for science in those days. Within the volume were three 'Books' that dealt with, respectively, the properties, distribution and movement of water. The last two concerned the vast amounts of this fluid on earth and were mainly about geography. The first was still obsessed by water *en masse*, but nevertheless did touch on some matters of chemical interest. These included the viscosity of water, its 'wetness and ability to make other bodies wet', its power as a solvent and its ability to extinguish fires, soften, cleanse and erode. He concluded that these properties demonstrate 'the wisdom and goodness of the great Creator', both separately and together.

It was the integration of water within one vast mechanical universe that so moved Fabricius. Writing of 'all parts of nature' he says:

> There is none which does not give us reasons to wonder at the magnitude of the works of the Lord… But nothing else might move us more in this way than the combined consideration of all the properties of water… and of its beneficial relation to the other creatures.[14]

Here, then, was an early attempt to use water in the service of natural theology. Some historians have consigned it to a footnote with ill-concealed contempt,[15] but it is important not to consider this in isolation. In the early eighteenth century, F. C. Lesser (1692-1754),[16] produced works on the theology of

13 *Neue Deutsche Biographie*, Berlin (1960).
14 Fabricius, J.A. *op. cit.*, (12), I, 30.
15 e.g. Dillenberger, J. *Protestant thought and natural science*, London: Collins (1961), p.150.
16 *Neue Deutsche Biographie*, Berlin (1960).

stones,[17] insects[18] and even one on shells.[19] Far from being an eccentric crank Lesser was a German naturalist well-respected by his scientific community, and probably the greatest bibliographer of the eighteenth century. All these works went through several editions and/or translations and their influence must have been considerable. Before Fabricius wrote his treatise on water he had also produced *Pyrotheologie*,[20] an analogous volume on fire. Yet a further field was pharmacotheology, where numerous workers, including the famous chemist from Halle, F. Hoffmann (1660-1742), argued from natural theology to justify the therapeutic use of herbs and other naturally occurring products.[21] So Fabricius was far from being the isolated figure of fun as it was once common to regard him.

At this stage there was little understanding of the unique properties of water: it was capable of many uses, there was a great deal of it and that was about all that could be said. It was just 'there'. When William Paley wrote his epochal *Natural Theology*, in 1802, water was one still commonly regarded as of the four elements, remarkable for its ability to support the life of fish, animals and plants, and for its absence of taste, which enables us to continue drinking it without boredom. But, with Fabricius, Paley is chiefly impressed by its movement and 'incessant circulation'.

3. Fine tuning the arguments: macro-scale

These sentiments were still being expressed as late as 1819,[22] though by now chemists and others had learned a great deal more about water. From about 1800 it was widely agreed that water was a compound of hydrogen and oxygen.[23] Latent and specific heats were recognised by now, and those for water had been measured.[24] The remarkable expansion of water as it cooled just above its freezing temperature had been known for over a century, and in 1806 the temperature where this starts was established as 39.5˚F [4˚C] by the Scottish chemist Thomas Charles Hope.[25]

In the early nineteenth century another legacy (from the Earl of Bridgewater) led to publication of a further series of books on natural theology, eight in all, the Bridgewater Treatises[26] first published between 1833 and 1836 and intended to show 'the power, wisdom and goodness of God as manifested in the

17 Lesser, F.C. *Lithotheologie*, Hamburg (1735).
18 Lesser, F.C. *Insecto-Theologie*, Frankfort (1738).
19 Lesser, F.C. *Testaceotheologie*, Leipzig (1756).
20 Fabricius, J.A. *Pyrotheologie*, Hamburg (1732).
21 Krafft, F. *Pharmazie* (1996) 51, 422-426.
22 Paley, W. *Natural Theology*, 18th edn., (1819), pp. 310-311.
23 Partington, J.R. *A history of chemistry*, vol. iii, London: Macmillan (1962).
24 McKie, D. & Heathcote, N. H. de V. *The discovery of specific and latent heats*, London (1935).
25 Hope, T.C. *Trans. Roy. Soc. Edinburgh* (1805) 5, 379.
26 Topham, J. 'Science and popular education in the 1830s: the role of the Bridgewater Treatises', *Brit. J. Hist. Sci*. (1992) 25, 397-430.

creation'. They offered an unprecedented opportunity for fine-tuning the old arguments in the light of fresh discoveries about water. One of these was delivered by the mathematician and philosopher William Whewell, later to become Master of Trinity College, Cambridge. His brief was 'Astronomy and general physics considered with reference to natural theology.' He uses the newly discovered 'laws of heat with respect to water',[27] though it is only in those terms that he may be said to have given 'the first systematic argument for the fitness of water.'[28] Some of the 'offices' of this fluid he pronounced to be:

1. Heat is communicated by 'internal circulation' [= convection]. This helps to moderate differences between hot and cold parts of the earth.
2. Expansion near freezing temperature (from 40° to 32°F), though causing burst pipes in winter, also ensures that ice floats and can therefore be melted in summer, and additionally helps to pulverise the soil. This property is evidently 'selected with a beneficent design'.
3. Water readily evaporates into the air, a process essential to plant life.
4. Water as clouds helps to modify the fervour of the sun.
5. Water as clouds gives rain to the earth.
6. Snow and ice are bad conductors of heat and thus protect bulbs and roots in the ground.
7. The high latent heat of water avoids quick changes of state.
8. Water supplies springs.

Of these eight functions only some – 2, 6 and 7 – reflect the rare if not unique physical properties of water. The rest could apply to other liquids, but only water is present in such large amounts as to demonstrate them.

As with earlier writers, Whewell is profoundly impressed by water circulation. He quotes John Dalton to the effect that, of the 36 inches of water that fall annually on Britain (or perhaps Manchester!), 13 inches come by evaporation of the sea and the remaining 23 inches from the ground. And so there is a continual circulation. Whewell cites Howard's *Climate of London*,[29] writing about the frequent introduction of rain by a south-east wind:

> Vapour brought to us by such a wind must have been generated in countries to the south and east of our island. It is therefore, probably, in the extensive valleys watered by the Meuse, the Moselle and the Rhine, if not from the more distant Elbe, with the Oder and the Weser, that the water rises, in the

27 Whewell, W. *Astronomy and general physics considered with reference to natural theology*, 4th edn., London: Pickering (1834), pp. 80-95.
28 Denton, M.J. *Nature's destiny*, New York: The Free Press (1998), p. 22.
29 Howard, L. *The climate of London*, London (1818-20), vol. ii, pp. 216-217.

> midst of sunshine, which is soon afterwards to form *our* clouds, and pour down *our* thunder-showers.[30]

It is impossible to avoid the conclusion that the chief fascination of water for those natural theologians was still in connection with the weather.

This impression is strengthened by another Bridgewater Treatise, that written by William Prout, whose title could hardly be more specific, dealing with chemistry, meteorology and digestion.[31] He observes that air is hardly ever saturated with water, so condensation when it rises does not inevitably lead to cloud formation. Thus, 'by the benevolent arrangement we enjoy' permanent mist is prevented.[32] He has much to say about snow, commenting on its whiteness which reflects rays and thus prevents rapid melting;[33] its low conducting properties and its lightness (shielding vegetation below); and the ability of snow-water to contain much oxygen and to be thus 'particularly favourable to vegetation'.[34] All of which leads him to infer from the 'great designs' incontrovertible evidence for 'the great Author of nature'.[35] But when he develops his third promised theme, the important role of water in digestion rather strangely receives little attention.

A third Bridgewater Treatise was written by John Kidd, Regius Professor of Medicine at Oxford, his theme being 'The adaptation of external nature to the physical condition of man'. Unlike his colleagues, Kidd plies an argument that was entirely anthropocentric – as his title suggests. Amongst the general uses for water he mentions its necessity for life and stresses the consequences of long-term deprivation. It is also used in the manufacture of garments, utensils, and so forth, and in the preparation of medicines. He revels in the delights of drinking tea and coffee and (at great length) of taking a bath! Scientific issues are addressed in a section on 'the fluidity of water'. Its fluid properties enable it to be used to generate power, both by water wheels and by steam engines. Its high specific and latent heats are referred to (though not in those terms) and again the consequences of its anomalous freezing behaviour are discussed. Most interestingly he observes:

> With reference to the constitution of nature, we may more forcibly be impressed with the conviction of its general harmony and subserviency to our wants, by the supposition of its being different from what it is, than by the direct contemplation of its natural state.[36]

30 Whewell, W. *op. cit.*, (27), p. 95.
31 Prout, W. *Chemistry, meteorology and the function of digestion, considered with reference to natural theology*, 3rd edn., London: Churchill (1845).
32 *ibid.*, p. 269.
33 *ibid.*, p. 23.
34 *ibid.*, p. 289.
35 *ibid.*, pp. 315-316.
36 Kidd, J. *On the adaptation of external nature to the physical condition of man*, London: Bohn (1852), p. 108.

This is near as a Bridgewater author gets to contemplating a counterfactual science.

It would be a great mistake to write off the Bridgewater Treatises as merely 'worthy' documents, a response to the last will and testament of the Earl, and of no significance thereafter. In fact they had a large circulation, again with several editions for most of them, and many camp-followers whose dependence on them was obvious. Just one can be mentioned, Henry Duncan (1774-1846), a church minister in Scotland, whose many admirers ranged from Andrew Carnegie to Rudyard Kipling. He wrote a highly acclaimed work, the *Sacred philosophy of the seasons*.[37] The Treatises of both Whewell and William Buckland are cited, and much play is made of the role of water in the climatic cycles. The conclusion to his section on rain is entirely Whewellian:

> We see tremendous and destructive forces controlled and regulated with consummate skill, so as to harmonize with the other powers and conditions of the physical world, while these, again, equally harmonize with the circumstances of the moral world, – thus forming one amazing but mysterious whole.[38]

4. Hydrotheology after Darwin

It is often said that the coming of Darwinian evolution was the death knell for natural theology. Design was to be replaced by chance. The universe was recognised to be far older than was once thought and there was time for all kinds of evolutionary processes to produce life forms that could adapt to their environment. Thus it would seem that the appearance of 'design' was a chimera, an illusion and no self-respecting scientist would subscribe again to natural theology.

That statement is in fact a caricature of the true situation, and for several reasons. First, large numbers of leading scientists would have echoed the words of Lord Kelvin who described Paley's *magnum opus* as 'that excellent old book'; many prominent physical scientists were far from convinced by Darwin. Secondly, many people readily accepted both design *and* evolution, which was conceived to be God's method for accomplishing His design (this happened to be especially true of Christians with evangelical leanings).[39] Others, like Clerk Maxwell, regarded molecules as outside the sphere of natural selection, for their properties were fixed for all time; a clear distinction therefore existed

37 Duncan, H. *Sacred philosophy of the seasons: illustrating the perfections of God in the phenomena of the year*, 3rd edn., Edinburgh: Oliphant (1838).
38 *ibid*., p. 34.
39 Livingstone, D.N. *Darwin's Forgotten Defenders: the Encounter between Evangelical Theology and Evolutionary Thought*, Scottish Academic Press (1987); Livingstone, D.N., Hart, D.G. & Noll, M.A. (eds.), *Evangelicals and Science in Historical Perspective*, New York: Oxford University Press (1999).

between Darwin's notions and molecular events or properties that 'happened' to support life. Thirdly, the notion of a permanent 'conflict' between science and religion has been shown to be largely an artifice devised by a few militant agnostics (notably T. H. Huxley) as a means of social control. If people believed that Darwin had really routed the religious establishment they would be more likely to support British science in its quest for both autonomy and government support.[40]

In the light of this it could be argued that the need for natural theology was greater, not less, than before. Various works appeared on this subject, some more influential than others. Much of it was clearly derivative, probably from a variety of sources. Thus the very popular *Theology in science*,[41] by the ubiquitous Dr Brewer, first appeared in 1860 but was still thriving thirty years later. He expounds the large scale phenomena of evaporation and circulation of water and draws the usual conclusions. His book also has a specific section on 'Deviations from general laws in the case of water'.[42] Brewer deals with two: the expansion on cooling, and the phenomena that arise from a high specific heat ('water can receive or lose heat without showing it'). They offer him 'proof of design, beyond the possibility of a doubt'.[43] Still in the spirit of Fabricius, he has a further section on 'The circulation of water (as evidence of divine wisdom and goodness)'. His conclusion on the watering of England from 'the Meuse, the Rhine and the Moselle' comes straight from the pages of Whewell or of his source Luke Howard.

Clearly water was a good topic for these apologists, for evolutionary dogma hardly applied to that (chemical evolution was still far in the future, in the late twentieth century). One major effort was by a chemist, Josiah Cooke (1827-1894), professor of chemistry at Harvard, though his book covered the whole of chemistry, and not just water.[44] It was based on lectures delivered in 1861:

> At the time when the lectures were written, Mr Darwin's book on the Origin of Species, then recently published, was exciting great attention, and was thought by many to have an injurious bearing on the argument for design. It was, therefore, made the chief aim of these lectures to show that there is abundant evidence of design in the properties of the chemical elements alone, and hence that the great argument of Natural Theology rests upon a basis which no theories of organic development can shake.[45]

40 Russell, C.A. 'The conflict metaphor and its social origins', *Science & Christian Belief* (1989) 1, 3-26.
41 Brewer, E.C. *Theology in science; or the testimony of science to the wisdom and goodness of God*, 7th edn., London: Jarrold (c.1890).
42 *ibid*., pp.236-240.
43 *ibid*., p. 240.
44 Cooke, J.P. *Religion and Chemistry*, New York: Little (1864).
45 *ibid*., Preface to the First Edition, reproduced in rev. edn., London: Macmillan (1881), pp. vii-viii.

One of Cooke's ten chapters is devoted to water. He begins with its role in meteorology, and after discussing the mechanisms producing rain concludes that 'science, by discovering these evidences of skilful adaptation' can only fall back on the answers given to Job:[46]

> Does the rain have a father? Who fathers the drops of dew? [Job 38:28]
>
> How great is God – beyond our understanding! The number of his years is past finding out. He draws up the drops of water, which distil as rain to the streams. [Job 36: 26-27.]

Having written at some length about circulation of water in general he continues:

> Let us consider some of the qualities of water; but at the same time, let us not forget that the strength of our argument lies not so much in the fact that each property has been skilfully adjusted to some special end, as it does in the harmonious working of all the separate details… In these very facts lies the whole force of the argument from design, and it is only the limitations of our knowledge and faculties which weaken the impression on our minds.[47]

This explicitly emphasises the world as a *system*, in which water plays an important, if not decisive, part. So he announces 'a familiar fact, that water is an essential condition of human life', constituting 'the greatest part of all organized beings'.[48] The distribution of this vital fluid is afforded by condensation on the mountains which are amongst 'the most beneficent means in the Divine Providence by which the earth had been fertilized and rendered a fit abode for man'.[49] Condensation by other means is also mentioned, most notably formation of dew absorbed by leaves which also have other important functions. 'If this can result from chance, under its modern name of natural selection, then chance is but a counterfeit name of God.'[50] Water 'is the great cleansing agent of the world'.[51] Spurred on by this confidence (and possibly by his own rhetoric) Cooke waxes eloquent over the aesthetic advantages of water (murmuring brooks, roaring torrents, bubbling springs etc.), marvelling again that 'The grand result is an harmonious system.'[52]

All this may well be very interesting, but it is not chemistry, nor does it address the question as to *why* water should be so necessary. He begins to repair this omission when he goes on to speak of human uses for steam. Steam heating is possible because steam is 'peculiarly fitted for this work'. Though it

46 *ibid.*, pp. 125-126.
47 *ibid.*, pp. 127-128.
48 *ibid.*, p. 129.
49 *ibid.*, p. 130.
50 *ibid.*, p. 135.
51 *ibid.*, p. 137.
52 *ibid.*, p. 138.

'merely acts the part of a common carrier' steam is capable of 'holding so large a quantity of heat'.[53] He does not specify latent or specific heats but does claim that 'when water is heated through a given number of degrees it absorbs twice as much heat as any other substance' (with one or two exceptions).[54] Then, once more, we are launched on to a geographical excursus (particularly about the Gulf Stream) from which we return at last to specific reference to the anomalous density of water just above its freezing temperature. Its familiar effects on lakes, fishes and vegetation are mentioned, and there follows a surprising caution not to make too much of this one anomaly since other fluids may in the future be found to behave in a similar manner. It is the whole interlocking system of effects that so impresses Cooke.

His final point is truly chemical: that 'water is the most universal solvent known'.[55] The consequences of this are sketched for life and for inorganic nature, notably the hydrates, rocks and other constituents of our earth. He concludes:

> Of all the materials of our globe, water bears most conspicuously the stamp of the Great Designer, and as in the Book of Nature, it teaches the most impressive lesson of His wisdom and power, so in the Book of Grace it has been made a token of God's eternal covenant with man, and still reflects His never-fading promise from the painted bow.[56]

Water featured prominently in several other essays that appeared in the middle and late nineteenth century. One remarkable one was a lecture delivered in 1877 to the Nottingham Literary and Philosophical Society by James M. Wilson, then a mathematics master at Rugby School. Ordained in 1879, he became headmaster of Clifton College and (from 1890) Archdeacon of Manchester. He supported Darwinism but still saw a role for natural theology.

His lecture was entitled 'Water: some properties and peculiarities of it; a chapter in natural theology'; it later appeared as the first chapter of his volume *Essays and Addresses*.[57] Like all his predecessors he was deeply impressed by the atmospheric and meteorological effects of water circulation. But unlike them he tried to focus more strongly on the *anomalous* properties of water. Thus, after referring to climatic consequences of the expansion of water by heat, he strongly asserts that 'in one property of expansion, water is unique, absolutely unique'.[58] This is its expansion on cooling below 4°C. The consequences of ice floating on water for marine life and the structures of rocks and soil are clearly displayed.

53 *ibid.*, p. 141.
54 *ibid.*, p. 143.
55 *ibid.*, p. 155.
56 *ibid.*, p. 162.
57 Wilson, J.M. *Essays and addresses: an attempt to treat some religious questions in a scientific spirit*, London: Macmillan (1887), pp. 1-30.
58 *ibid.*, p. 4.

Wilson goes on to admire the liquidity of water, noting that its existence in that state depends on many parameters and that 'these elements are adjusted to one another in such a manner as to produce the actual result we see'.[59] These, rather than anything specific about water, are the cause for wonder. However he goes on immediately to record that

> Water is once more unique. Its specific heat, as this property is called, is far greater than that of all other bodies, solid or liquid.[60]

The very high specific heat is used to account for the large-scale transference of heat in the oceans, as in the Gulf Stream.

The high latent heat of fusion of ice prevents too rapid a thaw with vast flooding in consequence. When it comes to converting liquid water to vapour by the expenditure of heat no other liquid 'approaches water in the quantity it requires.'[61] And this 'extraordinary latent heat of vapour' means that vast stores of heat are transferable across the globe, to be discharged when most needed.

One remarkable property of water, anomalous but not uniquely so, is the power of absorption of radiant heat, explored by John Tyndall, namely its ability to trap heat:

> Aqueous vapour will not let heat radiated from the earth pass through. It absorbs it; it serves as a covering, as a light but warm blanket to the earth at night… this singular and beautiful property of water.[62]

This must be one of the earliest descriptions of what we now call the 'greenhouse effect' of water vapour. It is in fact at least as significant as that of CO_2.

Wilson's final point of anomaly is the solvent ability of water. 'Its powers of dissolving salts, and of fertilising the soil, are perhaps the most extraordinary,'[63] though he had little time to develop the theme. Sadly, he left unexplored the whole range of the reactions of water. The conclusion of the scientific part of his address related to molecules of water, though at that time he had no way of connecting their existence with the phenomena he had described. The conclusion is a lengthy philosophical musing on natural theology in general. While accepting that biological evolution may have led natural theology to change its emphasis, he is adamant that this does not apply to the physical realm. He acknowledges that conclusions about the mutability of organic forms had to change:

> But this can never be the case with inorganic nature. We cannot conceive of a revolution in Science which would overthrow our belief in the permanence

59 *ibid.*, p. 6.
60 *ibid.*, p. 7.
61 *ibid.*, p. 9.
62 *ibid.*, p. 11.
63 *ibid.*, p. 12.

> of the chemical and physical properties of inorganic elements. And hence the basis of Natural Theology that I am considering this evening is not transient.[64]

A new development came at the very end of the century with a book by the Rev. Joseph Morris from Durham, offering *A new natural theology*, but this time 'based upon the doctrine of evolution'.[65] Dealing specifically with Wilson's *Address* on water, he admits the arguments are 'ingenious to a degree' but focuses on Wilson's admission that all anomalies probably depend upon a single property of water (which we do not yet know). These must result either from design or from an evolutionary growth. Morris argues that his opponent 'sees only the evolution of life, and is blind to the evolution of matter'.[66] This was indeed the case, but Morris' ideas on this topic were exceedingly vague, and we should certainly not read into them anything like the modern theories of chemical evolution. Nevertheless, his book offers further proof that, contrary to popular opinion, evolution did not kill natural theology, even though it may have transformed it.

One last essay in this genre, concerned to evaluate the impact of evolution on teleology, and thus natural theology, appeared in America just before World War I. This was a book, *The fitness of the environment*, whose sub-title defined it as 'an inquiry into the biological significance of the properties of matter'.[67] Its author, Lawrence Henderson, was a professor of biological chemistry at Harvard, and his intention was made clear in his opening words:

> Darwinian fitness is compounded of a mutual relationship between the organism and the environment. Of this, fitness of environment is quite as essential a component as the fitness which arises in the process of organic evolution; and in fundamental characteristics the actual environment is the fittest possible abode for life.[68]

Apart from offering an early example of the use of the word 'environment' in a book title, Henderson's volume proposes 'deep design laws' but draws back from a natural theology in any traditional sense. It is not theistic, though certainly not atheistic. The third of his eight chapters is devoted to water. He refers to the Bridgewater Treatises and also to another chemist at Harvard, J. P. Cooke. He does not appear to have been aware of Wilson's essay. He deals with the anomalous properties of water in a more systematic manner than any of his predecessors.

64 *ibid.*, p. 27.
65 Morris, J. *A new natural theology, based upon the doctrine of evolution*, London: Walter Scott (1905).
66 *ibid.*, pp. 28-29.
67 Henderson, L.J. *The fitness of the environment: an inquiry into the biological significance of the properties of matter*, New York: Macmillan (1913).
68 *ibid.*, p. v.

First he emphasises specific heat, showing how it may be derived and enumerating some of the consequences of the unusually high specific heat for water. The effects include a relatively constant temperature in streams, lakes and oceans, and also a moderation of the summer and winter temperatures on earth. Marine organisms are able to move about, and animals like man maintain constancy of body temperature without too much difficulty since water is a high proportion of their bodies. Moving on to the high latent heat of water, Henderson observes that the large amount of heat required to melt ice ensures the temperature of the underlying water is fairly constant. He continues:

> In view of the other favourable qualities of water it is perhaps not surprising to find that its latent heat of evaporation is by far the highest known. So great, in truth, is this quantity and so important the process that the latent heat of evaporation is one of the most important regulatory factors at present known to meteorologists.[69]

The threefold inheritance of this property can be summarised:

> First, it operates powerfully to equalise and to moderate the temperature of the earth; secondly, it makes possible very effective regulation of the temperature of the living organism; and thirdly, it favours the meteorological cycle. All of these effects are true maxima, for no other substance can in this respect compare with water.[70]

After brief reference to the unusually high thermal conductivity of water, Henderson turns to the anomalous expansion on cooling below 4°C. Without it, life on earth would have been 'very greatly restricted', though he believes Prout overstated the importance of this anomaly.[71]

Henderson then becomes much more chemical than Cooke, reflecting no doubt the advances in chemistry in the previous half-century. In referring to the great solvent powers of water, as exemplified by its action on rocks and so forth, he depicts it as 'a chemically inert solvent', whereas most of his examples arise from chemical action prior to any act of solution. This is curious, as the facts were very familiar even in Victorian times. He triumphantly vindicates his position by listing over fifty individual substances known to be present in urine. The fact that water can promote ionisation to a unique degree was interpreted in terms of the ideas of Arrhenius and Loeb. At that time almost nothing was known of reactions in other polar solvents as liquid ammonia and liquid hydrogen fluoride. Finally, the great surface tension of water leads to its rise in capillary systems and to complex phenomena of adsorption, important for its passage through soil and the processes of chemical physiology.

Henderson concludes that

69 *ibid.*, p. 98.
70 *ibid.*, p. 105.
71 *ibid.*, pp. 107-108.

> Water is fit… with a fitness no less marvelous and varied than that fitness of the organism which has been won by the process of adaptation in the course of organic evolution.

He acknowledges that the present situation of science differs from that of Whewell 'only in the better definition of the issue'. However, he claims for himself and his contemporaries 'our modern freedom from metaphysical and theological associations',[72] apparently oblivious to the fact that he was no freer from metaphysical assumptions than those before him, and that upon those assumptions depend the role (if any) for theology. As the old proverb has it, 'you see what you want to see', and (of course) fail to see what your metaphysics denies.[73]

5: Modern hydrotheology: fine tuning on the micro-scale

All of the arguments so far have been extensively concerned with large-scale physical phenomena particularly those of meteorology and geology. In the 1930s, the emphasis began to change. Once more the role of water in biological processes was discussed. In 1934 a book appeared with the provocative title *The great design*.[74] It contained one chemical chapter, from that master of polemics H. E. Armstrong.[75] Writing on 'the chemical romance of the green leaf', he stressed the importance of water (and commended Moses for placing it first in creation). It is, as he said 'a material of intense activity, provided it has the proper companionship'. All vital changes take place when the water decomposes into hydrogen and hydroxyl. That is the very beginning of the processes leading to formation of sugar and other organic molecules. Moreover, water has another function, already recognised by Wilson: 'it is the buffer to receive the shock of the impinging light waves and transmit to us our share of solar energy'.[76] His conclusion is not so much theological as mystical, calling for a new chemistry, for the old has 'no romance in it, no religion'.[77] He had of course for many years been demanding a revolution in chemistry teaching and these arguments are probably part of that crusade.

The biological theme was taken further in 1938 by a medical writer, W. O. Greenwood, in a book *Biology and Christian belief*.[78] In his final chapter, 'On purpose', he chooses water as one of many examples refuting 'the hypothesis of a blind chance'. Dealing yet again with the 4°C anomaly and its consequences, he considers the presence of water in each living cell and concludes that 'of all

72 *ibid*., p. 131.
73 A further, more philosophical, discussion by the same author may be found in Henderson, L.J. *The Order of Nature*, London: Harvard University Press (1917).
74 Mason, F. (ed.), *The great design: order and progress in nature*, London: Duckworth (1934).
75 *ibid*., pp. 187-206.
76 *ibid*., pp. 204-205.
77 *ibid*., p.194.
78 Greenwood, W.O. *Biology and Christian belief*, London: SCM Press (1938), p.180.

the thousands of possible liquids other than water, there is not one that would have the faintest possibility of supporting life'. Stressing also the critical importance of carbon to life he argued that these two bodies, water and carbon, present 'a clear case of purpose – a thought-out plan'.[79] In the case of carbon, adaptation cannot 'touch the fringe of an approach to explanation' for the very construction of complex molecules depends upon the carbon atom being there. As for water's behaviour between 0° and 4°C, he remarks:

> Why this unparalleled exception in the case of water? If built on a mechanistic plan, a fortuitous method, is there any one single reason why water should not behave in this physical respect exactly as other liquids do?[80]

It is obvious that these two illustrations with biological themes related to *origins* of life, not its subsequent development. Moreover, they do not address the problem as to how these beneficial properties may change at very high pressures. This is a complex issue and includes phenomena of bacteria able to withstand quite remarkable extremes of heat as well as pressure.

At this point it is necessary to point briefly to three developments in recent science that place the earliest arguments in a wider context, though by no means destroy their value.

First, there has been a spectacular growth in cosmology, and with it a new understanding of how the elements in our universe have been formed. That includes carbon, hydrogen and oxygen. Natural theologians like Cooke and Wilson recoiled from the notion of evolution of inert matter, but that was hardly relevant to the fitness of water for life processes, if only on grounds of the different time-scales. Interestingly, if a resonance level in the carbon nucleus had differed from its actual value by a very small percentage, carbon would have been a rare element, and organic chemistry and life a mere dream. It is reported that Fred Hoyle found nothing that could shake his atheism as much as this discovery.[81]

However modern cosmology has also shown something of the vastness of the universe, and therefore of the probability of millions of planets on which something like life as we know it could have developed. In an Introduction to a late edition of Henderson's book *The fitness of the environment*, the biochemist George Wald commented in 1958 that 'we now believe that life, being part of the order of nature, must arise inevitably wherever it can, given enough time.'[82] However it may be observed that scale has nothing to do with teleology, and that the repeated formation of life elsewhere is no more (and no less) wonderful than a one-off appearance on earth. Yet this is a point that many scientists find hard to grasp.

79 *ibid.*, p. 181.
80 *ibid.*, p. 179.
81 Gingerich, O. in Templeton, J.M. (ed.), *Evidence of purpose*, New York: Continuum (1994), p.24.
82 Wald, G. in Henderson *op. cit.*, (73), p. xxiii.

Secondly, discoveries with polar non-aqueous solvents have shown that many of the chemical properties of water are not unique. This began with the pioneer work on liquid ammonia by Franklin and others at the end of the nineteenth century. Some have gone so far as to claim that the prolific availability of water has had a bad effect, having inhibited the development of inorganic chemistry![83] It has certainly opened our eyes to the general importance of non-aqueous polar solvents, and the possibility – however apparently remote – that one or more of them might serve as an alternative basis for life.

Then, thirdly, there is now a gradual realisation that 'the remarkable behaviour of water is due largely to the structure of the water molecule, its dipole character, its small volume, and properties related thereto'.[84] These in turn have been at least partially explained in terms of the hydrogen bond developed by Huggins and others in the 1920s, originally in connection with organic tautomerism.[85] Wald wrote that most of the properties described by Henderson in fact arise from a single cause, the hydrogen bond.[86] We now know that without this hydrogen bond water would boil at 200˚K rather than 373˚K, the DNA helix would not exist and life as we know it would be totally impossible.[87] It must again be said that to know a physical cause of a group of phenomena is only problematic to a philosophy of God-in-the-gaps. One could well write a natural theology of the hydrogen bond itself.[88]

These and other developments in contemporary science do not invalidate a form of hydrotheology, though they may greatly modify it. So it cannot be surprising that modern authors have written about water as providing evidence of design. They range from short popular treatments[89] to more detailed scholarly examinations of water in the light of modern science, evolution included. One of these is an account in Barrow and Tipler's *Anthropic Cosmological Principle*,[90] and another is in a recent book by Michael Denton[91] that devotes a whole chapter to the subject, one of the most comprehensive statements available today.

83 Addison, C.C. *Use of non-aqueous solvents in inorganic chemistry*, London: Royal Institute of Chemistry (1960).

84 Jander, J. *Die Chemie in Wasserähnlichen Lösungsmitteln*, Berlin: Springer Verlag (1949) [cited in Addison *op. cit.*, (83)].

85 Huggins, M.C. '50 years of hydrogen bond theory', *Angew. Chem. Int. Ed.* (1971) 10, 147.

86 Wald, G. in Henderson *op. cit*., (73), p. xxi.

87 Pimentel, G.C. & McClennan, A.L. *The hydrogen bond*, San Francisco: Freeman (1960).

88 It is of course true that hydrogen bonds are also found elsewhere, as in the ferociously reactive hydrogen fluoride and in liquid ammonia (though that substance is a gas at ordinary temperatures and pressures). Other compounds having an -O-H bond also exhibit hydrogen bonding but to nothing like the extent of water. Nor do they possess most of its other highly unusual properties.

89 e.g., Russell, C.A. in Pearman, R., Fergus, M. & Alexander, P. (eds.) *Wonders of creation*, Berkhamsted: Lion (1975), pp. 77-81.

90 Barrow, J.D. & Tipler, F.J. *The Anthropic Cosmological Principle*; New York: Oxford University Press (new edn. 1988), pp. 524-541.

91 Denton, M.J. *Nature's destiny: how the laws of biology reveal purpose in the universe*, New York: The Free Press (1998), pp. 19-46.

Denton begins his argument by stating that 'the properties of water in themselves provide as much evidence as physics and cosmology in support of the proposition that the laws of nature are specifically arranged for carbon-based life'.[92] He dates the first significant consideration of water's fitness to the early nineteenth century, following Lavoisier's experiments on the nature of water (though Lavoisier most certainly did not show 'that it was made up of two hydrogen atoms combined with one oxygen atom'!). Denton starts with Whewell in 1832, thirty years after 'scientific knowledge had rapidly increased' (he does not say how). He also cites Henderson, but goes on to add further characteristics of water that Henderson did not mention. One was its exceptionally low viscosity which seems to be at the right level for supporting life-processes, not least those depending on diffusion. Another was proton conductance, highly important in photosynthesis and oxidative phosphorylation. He piles 'coincidence upon coincidence' by listing three sets of properties having beneficial consequences. The lists below are his (though the table is mine). The first column contains properties which affect its action on rocks such as weathering and dissolution; the second those which help to keep water in the liquid state; and the third those which work to maintain low body temperatures in animals.

Properties of water which enhance weathering	**Properties of water which together tend to preserve it in the liquid state**	**Properties of water involved in temperature regulation**
High surface tension Expansion of freezing Solvation power Viscosity of ice * Low viscosity of water Chemical reactivity of water	High thermal capacity Conductivity of water Expansion of water on freezing Expansion of water below 4˚C. Low heat conductivity of ice High latent heat of freezing Relatively high viscosity of ice*	Low viscosity High thermal capacity Heat conductivity Latent heat of evaporation

* By 'viscosity of ice' Denton appears to mean its ability to 'creep' or slowly 'flow' over rocks as in glaciers. The 'high viscosity' in column 2 is however replaced by 'low viscosity' in the text. It refers to the sliding of high level ice down to warmer seas where it melts and becomes liquid again. Presumably the 'viscosity' is a function of the friction set up between ice and underlying rocks.

92 *ibid*., p. 19.

Denton's conclusion is surely beyond doubt:

> There is indeed no other candidate fluid which is remotely competitive with water as the medium for carbon-based life. If water did not exist, it would have to be invented. Without the long chain of vital coincidences in the physical and chemical properties of water, carbon-based life could not exist in any form remotely comparable with that which exists on earth. And we, as intelligent carbon-based life forms, would almost certainly not be here to wonder at the life-giving properties of this vital fluid.[93]

If Fabricius had been a chemist, he would have been delighted!

Although the author did not set out to develop an argument from design he confesses that, at the end, it had become 'in effect an essay in natural theology in the spirit and tradition of William Paley's *Natural Theology* or the Bridgewater Treatises'.[94] Yet in fact Denton's seems to be a rather isolated voice, though his book has been welcomed by advocates of a modern natural theology as John Polkinghorne.

One final, extraordinary function of water has recently emerged though (so far as I am aware) without comment relating to natural theology. It concerns the role of water vapour as a permanent greenhouse gas in our atmosphere. From the beginning of emergent life it has helped to absorb some of the earth's radiation as a black body causing most of the sun's incident rays to be reflected back. This would have prevented a total freeze-up and kept the planet just warm enough for life. Carbon dioxide also assisted this process, but only in our own day has the 'enhanced greenhouse effect' been strong enough to cause concern. Now, if water vapour did not possess this remarkable 'greenhouse' property the mean temperature on our globe would be -18° not +15°C.[95] It is interesting to note this in view of the priority of water vapour, or 'mist' in the account of creation in Genesis 1.

Despite the occasional allusions to Natural theology in the context of the properties of water, taken as a whole Natural theology has taken some hard knocks since World War II, not least from those theologians who, following Karl Barth, say 'Nein!' to the whole enterprise. For them, revealed theology is rather less threatening and far more important than natural theology. The latter can only take us so far, leading us to, at best, a limited theism. Christianity, however, has always depended upon the biblical revelation of God in Christ who is presented as Lord and Saviour of the world. Partly for this reason, the initiative for the modern revival of natural theology has come more from scientists than from theologians. The Baconian 'book of God's works' must always be read in conjunction with the 'book of God's Word'.

93 *ibid.*, p. 46.
94 *ibid.*, p. xii.
95 As summarised in Lloyd, R. 'Global warming; the physical chemistry', Royal Society of Chemistry *Environmental Chemistry Group Bulletin*, July, 2005, 5-7.

There have also been reactions to what has been seen to be the crude and naïve arguments of some writers in the nineteenth century, who ignored the philosophical caveats of Hume and others. More recently, the resumption of natural theology by the proponents of Intelligent Design has actually weakened the support for the arguments from design in general. This is because, especially in the USA, the ID movement is seen as 'creationist' (in the American sense) and anti-evolution in its approach. There is no necessary reason for intelligent design *not* to be perceived by those who see Genesis in other than literal terms. It seems that 'guilt by association' is too readily conferred and natural theology should be evaluated on its own merits, not by asking whether some of its supporters are approved or not.

A second reason may be identified for the low profile for hydrotheology. When natural theology itself is frowned upon for whatever reasons, it is hardly likely that its application to a single chemical substance would enthuse many supporters. There is the sheer technical difficulty in understanding the detailed arguments relating to water chemistry. Even Denton's lucid account would make hard reading for a non-scientist, whether theologian or not. One may go further, and stress that this is a rare example of arguments coming not from cosmology, or even biology, but from chemistry. Apart from Josiah Cooke virtually no writer till now has derived a natural theology from that science. If so, hydrotheology is genuinely breaking new ground.

Thirdly, it seems that other, more pressing agendas constrain the scientific and theological communities to place their emphases elsewhere. These are too many, and too obvious, to be listed here (though one is touched upon in the conclusion).

Fourthly, the favourable reception of the Anthropic Principle has been seen as a threat to natural theology in anything like its classical sense. There is an inevitability about the universe that precludes an argument from intelligent design. Denton's conclusion (above) is perfectly acceptable provided it is not theocratised. Moreover, a chemistry that explores alternatives to water in the generation and support of life may well be counterfactual, but it need not be counterfeit. And if such chemistry succeeds, where does it leave the proponents of hydrotheology?

It leaves them precisely where they were. Those who used the natural theology of water to 'prove' the existence of God as a logical necessity would be still struggling (despite Aquinas). However, those who *for other reasons* had embraced the Christian faith and found in nature facts that were entirely congruent with that faith, would have nothing to fear from any counterfactual chemistry. If, as they believe, the whole universe is God's creation then He will be the cause of all phenomena, including those we cannot yet understand. Such a God would not be limited by our circumscribed view of what constitutes a necessary condition of life or anything else.

Meanwhile it seems the time is right not to wind up hydrotheology but to extend it and indeed to proclaim the wonders it discloses. Today, natural theology may have been transformed, but its arguments still possess great force, and its appeal continues. As Polkinghorne wrote in 1988, 'Natural theology is currently undergoing a revival, not so much at the hand of the theologians (whose nerve, with some honourable exceptions, has not yet returned) but at the hand of the scientists.'[96] Since then he has written with even greater confidence.[97] Surely the time has come for chemists to take it seriously, and never more effectively than in the study of that utterly extraordinary liquid, water.

In working towards a natural theology for water, however, we are treating the arguments of natural theology in a rather new way. Traditionally, the great aim was to demonstrate the universality of the laws of nature which pointed to a Lawmaker of incredible power and ingenuity. Even Paley did this, as did Fabricius when he discussed the hydrological and geological cycles. But the later, more chemical, aspects of hydrotheology are at the opposite methodological extreme. One single kind of molecule is brought into focus, in perhaps the ultimate case of fine-tuning. The question here is even simpler than that posed by Paley's watch. Without design how can one single substance have such an amazing array of anomalous properties, be so well-suited for biological, meteorological and geological functions and at the same time be so abundant on earth? To a non-believer this may have no more, or no less, an apologetic constraint than (say) Newton's inverse square law of gravity. But to those who already hold a theistic position it can exert a powerful stimulus to marvel and worship. And unlike other arguments it confirms the concerns of God for the smallest as well as the largest objects in his universe. But then we already knew that from Jesus.

Conclusion

If one function of a natural theology of water is to stress design and teleology, there is one other that has not yet been addressed and which must merit even a brief discussion here. Many of the earlier natural theologians had more than one agenda. While many – probably most – of them genuinely wanted to defend Christianity, some were clearly using their arguments for other purposes. There has been endless debate as to how far 'social control' was in the minds of those who wished to show that everything in nature was for the best, so we had better conform to the mores of the establishment which thus was a mirror to nature.[98] A study of hydrotheology cannot fail to underline the importance of water in our world, and from there it is but one step to the problems of its uneven availability.

96 Polkinghorne, J. *Science and creation*, London: SPCK (1988), p. 15.
97 Polkinghorne, J. 'Where is natural theology today?', *Science & Christian Belief* (2006) 18, 169-179.
98 To give but one example, Cleobury, F.H. in *A return to natural theology*, London: Clarke (1967), p. 233, argues for birth control and control of immigration.

Here is one area of contemporary concern to the communities of science and theology. Here they have a common interest and it is one of extreme urgency. This concerns the environment, affected at all points by science and technology, and yet also a matter for deep theological reflection. The environmental crises of pollution, climate change, extinction of species and rape of the earth must be faced in our own generation. There are obviously reasons of self-interest in such action. The fate of our great-grand-children hangs in the balance, and possibly ours too. Yet it seems that these reasons are not sufficient for politicians and public opinion to move fast enough. An additional spur to action could be provided by the Christian church, though first it has to recognise the many biblical injunctions to responsible care of a world that belongs not to us but to its Creator. If, as Old and New Testaments proclaim, the universe is God's handiwork and we humans have a stewardship to exercise over it, then we need to exercise our responsibilities at once. Never was this truer than in the case of water.

Although water is freely available over the globe, drinkable water is scarce in many lands and millions in Africa and elsewhere are literally dying from thirst. And in other places excess of water poses immense threats of flooding and devastation. Human compassion by itself may spur some of us to take action, but it is rarely enough. It is here that natural theology surprisingly comes in. According to Moltmann, natural theology has three functions. It can be *educative*, prompting basic questions about God; it can be *hermeneutical*, helping people to understand their faith; and it can be *eschatological*, anticipating a knowledge of God in glory.[99] As we have seen, the natural theology of water has consistently pointed to that substance as a marvellous creation, and eminently suited to many of our needs on earth. Add to that the commands from revealed theology to love our neighbours as ourselves and we have an additional motive for action. How can we deny to our fellow citizens their 'divine inheritance… in air and water undefiled'?[100] How can we sit idly by when millions in Bangladesh are likely to be rendered homeless by rising water due to global warming? How can we contemplate this amazing product of creation and do nothing about it when millions more need wells, water-purifiers and a whole new water technology?

If those in the West who profess to follow Christ spring to action and share their privileged knowledge with the dying or threatened multitudes, if they bring the 'water of life' in a physical as well as a spiritual sense, the natural theologians will not have written in vain. The additional incentive might just be sufficient to supplement action undertaken for other reasons. If so, humanity will gain at every level as the prospects of imminent disaster recede. And

99 Moltmann, J. *God in creation: an ecological doctrine of creation*, London: SCM Press (1985), p. 58.
100 The surprising sentiment of a Victorian chemical manufacturer: Morrison, J. *Trans. Tyne Chem. Soc.* (1878), 167.

then may come to pass the words of the ancient prophecy:

> The earth shall be filled with the knowledge of the glory of the Lord,
> as the waters cover the sea.[101]

Colin Russell is Emeritus Professor and formerly Head of the Department of History of Science and Technology at the Open University, UK.

101 Habakkuk 2:14.

CHRISTIANS·IN·SCIENCE

Co-sponsors of Science and Christian Belief

CiS is an international network of those concerned with the relationship between science and Christian faith, open to scientists, teachers, students and all those with an interest in this dialogue.

We have hundreds of members in the UK and worldwide, seeking to integrate their faith and their work or studies in science.

- Developing and promoting biblical Christian views on the nature, scope and limitations of science, and on the changing interactions between science & faith.
- Bringing Biblical Christian thought on scientific issues into the public arena.
- Encouraging Christians who are engaged in scientific work to maintain an active faith and to apply it in their professional lives.
- Communicating the Christian gospel within the scientific community.
- Stimulating responsible Christian attitudes and action towards care for the environment.
- Helping Christians who are science students to integrate their religious beliefs and their scientific studies.

Literature & resources
Science and Christian Belief and a quarterly newsletter are sent to all members.

Conferences
Day conferences are held annually in London and other UK locations.

Fellowship and support
Our members have been involved in organising lecture series, study groups, discussion forums, departmental prayer groups, and more.

www.cis.org.uk

Contact: CiS Secretary, Dr Caroline Berry, 4 Sackville Close, Sevenoaks, TN13 3QD.
Tel: 01732 451907, E-mail: secretary@cis.org.uk.