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EDITORIAL

# Water: Molecule, Material and Resource

Biographies come in various forms. Many are hagiographies which sing paens of praise to a famous individual, providing little by way of insight into the lives of the subject. Others are scholarly tomes of formidable size, which deter the average reader from going beyond the prefatory chapter. The best biographies are those in which readers are drawn into the life of the subject, unencumbered by detail, providing a portrait that arouses interest and, on occasion, inspires. Biographical essays are always attractive, short enough to capture a reader's attention, sometimes focusing on relatively obscure and forgotten subjects. Readers are invariably drawn to both the successes and failures of famous individuals. During an idle period of browsing in a bookshop, almost inevitably located in an airport, I was drawn to a volume curiously titled, *$H_2O$: A Biography of Water* (Phillip Ball, Phoenix, Orion Books, London, 2000). Can a molecule, a material and a resource be the subject of a legitimate biography? The author, an accomplished and compelling writer on chemistry and materials, has produced a narrative that breathes life into a subject that must interest both scientists and general readers. As a molecule water epitomizes simplicity; its formula known to almost everyone who has studied science at school. As a material it is encountered constantly in daily life. As a resource it is widely discussed, with doomsday scenarios predicting future wars over water. As I turned the pages, snatching a quick look at paragraphs in random order, my decision to invest in the book was sealed by the title of chapter 2: 'Blood of the Earth. Seas and Rivers of the World'. This section begins with a quote from Leonardo da Vinci's *Notebooks*, which I must reproduce:

'*. . . as man has within him a pool of blood wherein the lungs as he breathes expand and contract, so the body of the earth has its ocean, which also rises and falls every six hours with the breathing of the world. . . .*'

The idea of the Earth as a giant living organism conjures up an image that is remarkably similar to the Gaia hypothesis advanced centuries later by James Lovelock. In a recent book *The Revenge of Gaia* (Penguin, 2006), Lovelock notes that he continues 'to use the metaphor of "the Living Earth" for Gaia; but do not assume that I am thinking of the Earth as alive in a sentient way, or even alive like an animal or bacterium. I think it is time we enlarged the somewhat dogmatic and limited definition of life as something that reproduces and corrects the errors of reproduction by natural selection among the progeny'. Lovelock argues that 'unless we see the Earth as a planet that behaves as if it were alive, at least to the extent of regulating its climate and chemistry, we will lack the will to change our way of life and to understand that we have made it our greatest enemy' (Lovelock, pp. 20–22). Water is of course central to any discussion of 'climate and chemistry'.

I have been drawn in this column to water, by all the recent excitement about the discovery of water on the moon following the Chandrayaan mission. Phillip Ball describes 'lunar prospecting' for water as 'looking for gold in the gutter' (p. 28) adding that 'its discovery elsewhere continues to be greeted with surprise and excitement. Yet planetary scientists and astronomers know better – they know that water pervades the Universe. . . . The issue then is not whether there is water elsewhere, but whether it is liquid – for only in the liquid state does water seem to be capable of providing the matrix of life'. Ball is eloquent when he says: 'A tour through the solar system reveals a rich panoply of watery environments – some irrevocably icy, some steamy, some more barren than the harshest Arctic tundra, some laced with ancient, dried-up waterways. . . and some perhaps, awash with the precious fluid, tempting us to speculate about the life that might be lurking in these celestial oceans' (p. 78). Three recent papers focus renewed interest on lunar water. 'The Moon Mineralogy Mapper ($M^3$)' on the Indian spacecraft Chandrayaan-1 'has now detected absorption features near 2.8 to 3.0 μm on the surface of the Moon' is a succinct statement that summarizes the first report (Pieters, C. M. *et al.*, *Sciencexpress*, 24 September 2009). Two accompanying reports revisit data from earlier fly-by missions; Cassini in 1999 and Deep Impact in June 2009 (Clark, R. N., *Sciencexpress*, 24 September 2009; Sunshine, J. *et al.*, *ibid.*, 24 September 2009). The moon, of course, must have had plenty of water delivered by comets to its surface over eons. Clark cites an estimate of '$10^{13}$ kg of water over 2 billion years, or about 0.5 kg/$m^2$'. Even a cursory reading of these reports suggests that most stories in the popular press of 'moon water' and the possibility of 'human settlements' are wildly exaggerated. The paper

by Pieters *et al.* ends provocatively: 'Perhaps most importantly, harvesting the lunar regiolith for volatiles now becomes a serious option for long-term human activities'. There are ongoing missions that will probe the surface of the Moon, undoubtedly prospecting for water. A Lunar Crater Observation and Sensing Satellite (LCROSS) is due to 'slam into a polar crater' on 9 October, 'with the intention of ploughing up a plume of water ice for many telescopic eyes to see' (Hand, E., *Naturenews*, 18 September 2009). While advocates of plans for manned flights and 'lunar settlements' seem to have been energized by the detection of absorption bands of water, Phillip Ball strikes a contrary note: 'To my mind, if the day comes when we have made our occupation of the Earth so unsustainable that we have to look to so barren a place as the Moon to rescue us, we are in deep trouble. In terms of resources the Moon dosen't have a great deal to offer' (Ball, p. 80). He has an interesting point of view on manned flights: 'Perhaps the most socially important product of these flights was gained by a look backwards – at the blue globe of the world. In comparison with that, it will take more than a few frozen lakes to make the Moon look like an attractive place to live' (p. 81).

Water, as a molecule, made its first appearance at the beginning of the 19th century when John Dalton began to wonder about 'the union of atoms into compounds'. Ball describes this early history noting that 'the picture of a water molecule as a union of two atoms of hydrogen with one of oxygen is a long way from Democritus' idea of an element comprised of rounded, slippery, indivisible particles. And yet this is just our starting point. For there is no clue here as to why water is so special, why it is the quintessential liquid and solvent, the stuff of snowflakes and glaciers and the essence of life on Earth' (p. 139). Students of science learn about water's anomalous properties quite early in their careers. Water is such a familiar substance that most people find it difficult to believe that much about water is still shrouded in mystery. Ball quotes Felix Franks who many years ago summarized the view of experts: 'Of all the known liquids, water is probably the most studied and least understood'. Ball is an outstanding expositor of science. In discussing water's anomalous properties he draws attention to the fact that 'water's large heat capacity means that warm ocean currents can carry a phenomenal amount of heat. The Gulf Stream which ultimately keeps Northern Europe warmer than Labrador (at the same latitude) by carrying heat from tropical South America northwards across the Atlantic Ocean, bears with it every day twice as much heat as would be produced by burning all of the coal mined globally in a year'. I learnt about the Gulf Stream in high school geography decades ago but I am sure that we were never told that 'the effect of ocean circulation on global climate depends on . . . water's most pronounced anomalies'. Water and its properties were heatedly discussed in chemistry departments in the late 1960s and early 1970s, when 'polywater' was 'discovered'. This form of water was produced in thin capillaries by Russian scientists and quickly became enmeshed in controversy. The Cold War as Ball notes produced 'a cloak of paranoia between East and West that has not been matched since'. J. Desmond Bernal, one of the earliest to propose a structure for liquid water, allowed ideology to cloud his judgement when he hastily pronounced his verdict, that 'this (polywater) is the most important physico-chemical discovery of the century'. Ball's account of the polywater saga, as controversy turned into a debacle, is gripping; there must be a tinge of regret that genuine errors of technique and judgement might have blighted otherwise commendable careers in science. For Indian readers there are nuggets. Ball recalls the episode in the mid-1990s when 'an Indian chemist named Ramar Pillai claimed to have found a way to turn water into "petrol" – a yellow inflammable liquid – by brewing it with a local herb'. I can almost hear the murmurs of protest at the description of the protagonist as 'an Indian chemist'. Water has been central to some of science's most hotly debated controversies in recent times. The 'cold fusion' story of Martin Fleischmann and Stanley Pons was based on the electrolysis of water. The aim of producing energy from water can be seductive and Ball describes the rise and fall of cold fusion in compelling terms. The 'memory effect' exhibited by water in the infamous paper published in *Nature* by Jacques Benveniste was based on experiments that 'claimed that infinitely diluted reagents retain their biological effectiveness'. The aftermath left both the authors and *Nature* bruised. Ball recalls that his 'Ph D supervisor, a physicist, widely respected for his work on the liquid state' remarking with a grin 'So you are going to work for a journal that believes water has a memory'. The Benveniste experiments appeared to provide a basis for the apparent efficacy of homeopathy, water serving as the 'vehicle for information'. Why is water the subject of continuing study? In Ball's words: 'Water is inspirational. It infuses us with spirit. It quickens the heart to watch a clear, gurgling brook or the pounding of wild surf. The rhythmic lap of the waves on a beach soothes and reassures. So we bring to the study of water an emotional response that does not accompany the investigation of, say, bismuth.'

The epilogue of Ball's book treats water as a resource – blue gold. He reminds us of Coleridge's *Ancient Mariner*: 'Water, water, everywhere, nor any drop to drink'. Even as Andhra Pradesh and Karnataka reel under unprecedented floods, as rivers rage and dam gates must be opened, the problems of water as a resource are both pressing and difficult. The technologies of desalination are not yet readily accessible to address shortages. The management of both drought and floods is constantly discussed, with solutions being elusive. Water is essential for life but water, as Ball notes, can also be a destroyer. He quotes the Book of Job:

'*If he holds back the waters, there is drought*
*If he lets them loose, they devastate the land.*'

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