

rather than around a diverse set of practical lessons borne from experience, the authors have limited this book's contribution to an alternative view of how decision-makers might confront complex and contested environmental and science policies. ■

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Mind over matter?

The Ingredients: A Guided Tour of the Elements

by Philip Ball

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Another book on the chemical elements? It is daunting to write about such a familiar topic but Philip Ball has the credentials to do so. A consultant editor for *Nature*, he has written extensively about science in addition to broadcasting on television and radio.

The main hurdle to writing about the elements is that chemistry is all about molecules and not elements, just as a song is about tunes and not notes and a sentence is about words and not letters. There are those who feel that even molecules do not provide a full understanding of chemistry, and that molecular assemblies, rather than individual molecules, are the irreducible leitmotifs of function in both materials science and biology. In such a scenario, the 120 or so chemical elements belong more to physics than to chemistry and, in their austerity, remind us of a time when chemistry was closer to atomic physics than to functional biology.

So are the elements relevant today? Ball has deflected this question in two ways in this provocative book, which is surely worth a read by both general readers and chemists. He has been quite subjective in his choice of elements, and the book is clearly a 'guided' tour. Secondly, he has taken poetic licence in defining the term 'element'.

The first of these two approaches cannot be questioned. So much has been written about the elements that a new book need not be just descriptive or comprehensive. To a physicist, the formation of any of the known elements is merely a reaffirmation of the rules of quantum mechanics. Yet the distribution of the 92 elements found naturally on the surface of our planet is quite skewed. No more than 30 are of widespread occurrence in the mineral world. The entry of an element into the 'biological club' is even more stringent, being largely restricted to around six members of moderate temperament that have low atomic



Golden touch: the tale of King Midas highlights the allure of gold for human societies.

number and a prime location in the middle of the periodic table. These attributes lead readily to covalency, which in turn favours specificity and reversibility in the reactions in which the corresponding molecules can participate. Carbon, cerium and californium are not equal partners, and Ball has done well in not treating them in the same way.

The elements that the author has chosen to highlight are excellent selections. Gold and oxygen would have been my choices, too. Gold has always fascinated humans and will always continue to do so. Ball's account of this "most useless of metals" is arresting as it brings together alchemy, chemistry, physics, metallurgy, a little biology, history, geography, economics, sociology and culture, in what is truly the best chapter of the book. The author reiterates that it is metals, rather than any of the other elements, that have so definitively encouraged or limited the scope of human activity. Coinage metals fascinated man long ago, then in the twentieth century the focus shifted to metals such as chromium, tungsten and the platinum group. Today, geopolitical strategy is driven by the availability or accessibility of titanium, zirconium and thorium. Clearly, nature has bestowed her favours unequally in her distribution of the metallic elements, and we can expect that humans will continue to be as unprincipled, as ruthless and in the end as silly as they always have been in their quest to gain access and control of metals.

But if gold is the sovereign of the periodic table, oxygen is surely the prime minister. Ball's account of this element is mostly historical, however, and much of what he says about the scientific interactions or otherwise between Antoine Lavoisier, Joseph Priestley and Carl Scheele, for example, has been described elsewhere. The role of oxygen in maintaining the various biochemical cycles

is also well known. I would have liked to have seen more in this chapter. Oxygen is too pivotal an element to be treated lightly and needs to have been addressed from a modern viewpoint. It is the only element, apart from fluorine, that can react with so many others. Unlike fluorine, however, it is not so reactive as to become exotic, and it is more flexible than fluorine in the kinds of bonds it forms. Oxygen can, in effect, feel the pulse of the rest of the elements quite accurately, and it does this in increasingly subtle ways, such as by participating in hydrogen bonds.

The organization of the elements into the periodic table is treated competently, as is the synthesis of new elements in the 'atom factories' in Berkeley and Dubna, and these chapters contain a lot of information. Ball's description of isotopes is particularly good, and I do not believe that I have seen such an imaginative handling of this usually stodgy topic. His breezy journey through the landscape of some technologically important elements (iron, silicon, palladium, the lanthanides and the noble gases) provides a lively end to the guided tour.

It is in the second of his stratagems that Ball becomes more controversial. When he states that "the story of the elements is not simply a tale of a hundred or so different types of atoms... it is a story about our cultural interactions with the nature and composition of matter", he moves beyond what is strictly scientific towards a looser and softer mode of thought. The holistic approach of Aristotle led to the quartet of earth, fire, air and water. Add a fifth — ether — and we obtain the 'panchabhoota', or five elements, of the Hindu canon; the Absolute is worshipped in these manifestations to this day.

Ball refers to Plato, Galen, Leonardo, Shakespeare and T. S. Eliot to illustrate that these holistic concepts have satisfied humankind's needs over time. But it is an absolute fact that these interpretations are scientifically wrong, just as Dmitry Mendeleev, Lothar Meyer and the scientists who preceded them for a hundred or so years were scientifically correct about the nature of the elements. The periodic table is one of the grandest intellectual accomplishments of the scientific world, and in trying to make the story of the elements more inclusive by interpreting a scientific subject from the viewpoint of the humanities, Ball is treading on unexplored and possibly treacherous ground. Conversely, critics of physics and chemistry maintain that all of the important problems in these subjects are essentially solved. Is this book then an implicit recognition of this fact? ■

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Stories of the Invisible: A Guided Tour of Molecules (Oxford University Press, £7.99), also by Philip Ball, is now published in paperback.