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EDITORIAL

Images and Icons: Chemistry, Physics and the Garden of Mendeleev

Scientific journals are no longer as staid and conservative as they used to be. Brightly illustrated covers, colourful figures and cartoons can be found on their pages. One feature which has always interested me is the practice of having photographs of authors and short, sometimes irreverent biographical sketches. Authors suddenly seem to be made of flesh and blood; a pleasing change for editors, for whom authors are sometimes disembodied and argumentative correspondents. While reading a recent article entitled 'What Einstein meant when he said God does not play dice. . .' (Natarajan, V., *Resonance*, 2008, **13**, 655), I was struck by a sentence in the biographical sketch of the author, which stated that 'a picture of Einstein hangs above his chair'. The author, a young colleague of mine, was clearly proclaiming his commitment to physics and one of the subject's most enduring icons. In the article, the use of the word 'God' is analysed in the context of the author's characterization of Einstein as an atheist. As I read the article it seemed to me that the assessment that Einstein's great contributions stemmed 'from his belief in precise mathematical laws that govern the natural world' summarized in every way the philosophy of physics. Einstein, in some sense, was the prophet of this new religion. For physicists and indeed for almost every educated person, the portrait of Einstein that adorns the walls of many scientific institutions is instantly recognizable; an enduring symbol of the power of physics. Do chemistry and biology have any iconic images that can be proudly flaunted, in order to announce an allegiance to a discipline. Even as I idly thought about chemistry's icons, a book arrived on my table. My task was to find a reviewer, but a quick glance through the book told me that my search for chemistry's iconic image was at an end. The book *The Periodic Table: Its Story and Its Significance* (Scerri, E. R., Oxford University Press, 2007) appeared on the 100th anniversary of the death of Dmitri Mendeleev (1834–1907). In the introduction to the book I found the sentences that I was looking for: 'The periodic table of the elements is one of the most powerful icons in science: A single document that captures the essence of chemistry in an elegant pattern. Indeed, nothing quite like it exists in biology or physics, or any other branch of science, for that matter. One sees periodic tables everywhere: in industrial labs, workshops, academic labs and of course, lecture halls' (p. xiii). Glancing through Scerri's book, I was reminded of the large, colourful and sometimes faded periodic tables that adorned the college classrooms, where I first learnt chemistry many decades ago. They must still be there, hanging disregarded and forlorn, in many chemistry lecture halls across the world. Scerri opens his book with a quotation from *The Elements* by J. Emsley: 'As long as chemistry is studied there will be a periodic table. And even if someday we communicate with another part of the universe, we can be sure that one thing that both cultures will have in common is an ordered system of the elements that will be instantly recognizable by both intelligent life forms'. Scerri's book is scholarly and extremely well documented and, in large measure, fulfills its stated objective of establishing 'that one of the best ways to explore the relationship between chemistry and modern physics is to consider the status of the periodic system' (p. xxii).

The early history of chemistry is set in 18th and 19th century Europe, a continent famous for its wars and the cradle for modern science. Two characters are preeminent in the construction of the periodic table, Julius Lothar Meyer and Dmitri Ivanovich Mendeleev. As often happens, both men converged on the same result; that the known elements could be so arranged as to reveal a periodicity of properties. The controversies for priority were eventually resolved, with the general acceptance of Mendeleev as the main architect of the Periodic Table, as we know it today. Reading Scerri's account of this controversy reminded me that great insights sometimes occur simultaneously; Darwin and Wallace in biology and Schrödinger and Heisenberg in quantum physics. Much of the credit for tirelessly championing the periodic table must go to Mendeleev, who not only defended his creation but also continually worked for its elaboration. His work began around 1865 as an 'attempt to systematize inorganic chemistry'. It reached its climax in 1869 when he produced the first table. Cannizzaro's atomic weights provided his first parameter for classifications, leading to the arrangement of elements in horizontal rows. Scerri notes that February 17, 1869 is 'the date of the famous first table he produced'. Classification and organization were recurrent themes of 18th and 19th century science; biology's most famous names Linnaeus and Darwin were great observers and organizers of the objects they studied. Mendeleev was born in Siberia and did his famous work at the University in St. Petersburg, a city renamed as Leningrad after the success of the Bolshevik Revolution, but restored its original name in more recent times. Pictures of Mendeleev reveal a bearded visage that could only have stepped out from the pages of Tolstoy or Dostoevsky. There is a certain character that is uniquely Russian, fashioned by harsh winters and harsh regimes. Scerri's assessment of Mendeleev is one that must gladden the hearts of chemists: 'His name is invariably and justifiably connected with the periodic system, to the same extent perhaps as Darwin's name is synonymous with the theory of evolution and Einstein's with the theory of relativity'.

Mendeleev's ideas of periodicity acquired widespread, albeit slow, acceptance in the years following his original proposal. In 1889, Mendeleev reviewed the status of the Periodic Table, while delivering the Faraday Lecture at the Royal Institution. By then the believers outnumbered the critics. His words introducing his own work are an eloquent statement of the importance of incontrovertible facts and generalizations in advancing science. Indeed two of the most celebrated advances of the 19th century, Darwin's evolutionary synthesis and Mendeleev's periodic table symbolize the critical importance of organizing a vast body of known facts, as an essential prerequisite for a major conceptual advance. Mendeleev uses a biological metaphor: 'But as the shade of the leaves and roots of living plants, together with the relics of a decayed vegetation, favour the growth of the seedling and serve to promote its luxurious development, in like manner sound generalizations – together with the relics of those which have proved to be untenable – promote scientific productivity, and ensure the luxurious growth of science. . . (*J. Chem. Soc.*, 1889, **55**, 634). He recognizes that critics abound but provides a stout defence: 'We still may hear the voices of its opponents; they enjoy perfect freedom, but vainly will their voices rise so long as they do not use the language of demonstrated facts'. Over a century after Mendeleev's death, chemistry and indeed all of science has grown in a manner that the very vastness of available facts intimidates new entrants to any field, who may have a talent for empirical generalizations.

In thinking about the virtues of empiricism, I was pleasantly surprised to receive an article entitled 'The End of Theory: The Data Deluge Makes the Scientific Method Obsolete' (Anderson, C., *The Wired Magazine*, 23 June 2008). This brief editorial essay begins in a provocative fashion with a quote: 'All models are wrong, but some are useful'; tempting readers to go further. The summary of the computer revolution is compelling: 'Sixty years ago, digital computers made information readable. Twenty years ago, the Internet made it reachable. Ten years ago, the first search engine crawlers made it a single database. Now Google and like-minded companies are sifting through the most measured age in history, treating this massive corpus as a laboratory of the human condition. They are the children of the Petabyte Age'. Anderson's conclusion merits some reflections: 'Correlation supersedes causation and science can advance even without coherent models, unified theories, or really any mechanistic explanation at all'. Confronted with the extraordinary power of modern approaches to data gathering, organization, retrieval and interpretation, I was left with the uneasy feeling that the Age of Darwin and Mendeleev has long passed into the pages of history, never to return again to science as practiced in the brave new world.

Mendeleev died in 1907, by which time six Nobel prizes had been awarded. He was twice considered seriously by the award committee but passed over, ostensibly on the ground that his seminal work had been done decades earlier. Mendeleev and Oswald Avery, who established DNA as the genetic material, are always cited as the most famous examples of Nobel omissions. The closest that Mendeleev came to getting the prize was in 1906, when Henri Moissan the discoverer of fluorine, an element that ironically appeared inevitable as a result of the periodic principle, was preferred (Hargittai, B. and Hargittai, I., *Struct. Chem.*, 2007, **18**, 253). A search of the Nobel website for references to Mendeleev yielded a dozen hits, including presentation speeches for Frederick Soddy (1921) and Edwin McMillan and Glenn Seaborg (1951). Curiously, there was no mention of Mendeleev in the presentation speeches for William Ramsay (1904) who discovered the rare gases or Moissan (1906).

In remembering Mendeleev we celebrate the diversity of chemistry as revealed by the elements and the materials they form. There is unity in this diversity. There is no paean to chemistry that is more enthusiastic than Oliver Sacks' wonderful book *Uncle Tungsten: Memories of a Chemical Boyhood* (Vintage Books, New York, 2001). Sacks' book will delight all those who relish chemistry and good prose. Sacks, a neurologist and writer of uncommon distinction, describes a photograph of Mendeleev: 'He looked like a cross between Fagin and Svengali, with a huge mass of hair and beard and piercing hypnotic eyes. A wild extravagant barbaric figure – but as romantic, in his way, as the Byronic Humphry Davy. He notes that he 'spent hours now, enchanted, totally absorbed, wandering, making discoveries, in the enchanted garden of Mendeleev'. Sacks also quotes C. P. Snow, whose first reaction to the Periodic Table was very similar: 'All the jumbles and recipes and the hotchpotch of the inorganic chemistry of my boyhood seemed to fit themselves into the scheme before my eyes – as though one were standing beside a jungle and it suddenly transformed itself into a Dutch garden. The periodicity that Mendeleev recognized is taught today as the inevitable consequence of atomic structure theory, one of the great constructs of 20th century physics. Is there more to be learnt from the Mendeleev classification? Spending some time in Mendeleev's garden may still be instructive and entertaining for a future generation of chemists.

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